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Observatoire royal de Belgique

Royal Observatory of Belgium

Mensen voor Aarde en Ruimte, Aarde en Ruimte voor Mensen
Des hommes et des femmes pour la Terre et l'Espace, La Terre et l'Espace pour l'Homme

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Deel 1: Wetenschappelijke activiteiten

Partie 1: Activités Scientifiques

Part 1: Scientific Activities

Summary

Abbreviations

AAM	Atmospheric Angular Momentum
AGU	American Geophysical Union
BC	BepiColombo
BELA	BEpicolombo Laser Altimetry experiment
BELSPO	BELgian Science POlicy
BERNESE	GNSS analysis software developed at University of Bern
BIPM	Bureau International des Poids et Mesures
CATREF	Combination and Analysis of Terrestrial REference Frames
CB	Central Bureau
CCTF	Comité Consultatif pour le Temps et les Fréquences
CETP	Centre d'Etude des Environnements Terrestre et Planétaires
CGGTTS	CCTF Group on GNSS Time Transfer Standards
CMB	Core-Mantle Boundary
CNBA	Comité National Belge d'Astronomie
CNBGG	Comité National Belge de Géodésie et Géophysique
CNES	Centre National d'Etude Spatiale
Co-I	Co-Investigator
COST	European CO-operation in the field of Scientific and Technological research
CSL	Centre Spatial de Liège
DGPS	Differential GPS
DLR	Deutsche zentrum für Luft- und Raumfahrt
DSN	Deep Space Network
DYNAMO	DYNAMique des Orbites
EGNOS	European Geostationary Navigation Overlay Service
EGU	European Geophysical Union
E-GVAP	EUMETNET GPS Water Vapor Program
ENIC	Ecole Nouvelle d'Ingénieurs en Communication
ENSG	Ecole Nationale de Sciences Géographiques
EOP	Earth Orientation Parameters
EPN	EUREF Permanent GNSS Network
EPN CB	EUREF Permanent GNSS Network Central Bureau
ESA	European Space Agency
ESAC	Earth Science Advisory Committee
ESOC	European Space Operations Centre
ESTAG	Exploration, Science and Technology Advisory Group
ESTEC	European Space Research and Technology Centre
ETRF	European Terrestrial Reference Frame
ETRS89	European Terrestrial Reference System
EU	European Union
EUREF	EUropean REference Frame
EUROPLANET	EUROpean PLAnetary NETwork
FCN	Free Core Nutation
FICN	Free Inner Core Nutation
FNRS	Fonds National de la Recherche Scientifique
FRFC	Fonds de la Recherche Fondamentale Collective

FRIA	Fonds pour la formation à la Recherche dans l'Industrie et dans l'Agriculture
FUNDP	Facultés Universitaires Notre-Dame de la Paix
GALILEO	European global satellite navigation system
GCM	General Circulation Model
GEP	Geophysical and Environmental Package
GEPID	GEP Interface Document
GGOS	Global Geodetic Observing System
GGSP	Galileo Geodetic Service Provider
GINS	Géodésie par Intégrations Numériques Simultanées
GLONASS	Russian GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRGS	Groupe de Recherche de Géodésie Spatiale
GSFC	Goddard Space Flight Center
GTRF	Galileo Terrestrial Reference Frame
HCS	Haut Conseil Scientifique
HQ	Head Quarter
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICD	Interface Control Document
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IERS	International Earth Rotation and Reference Systems Service
IGN	Institut Géographique National
IGS	International GNSS Service
IGS05	IGS Realization of the ITRF2005
IIP	Instrument Information Package
IMCCE	Institut de Mécanique Céleste et de Calculs des Ephémérides
INSU	Institut National des Sciences de l'Univers
IPGP	Institut de Physique de Globe de Paris
ISSI	International Space Science Institute
ITRF2005	International Terrestrial Reference Frame (latest realization)
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service
JPL	Jet Propulsion Laboratory
JSR	Journées Système de Référence
LaRa	Lander Radioscience experiment
LAREG	LAboratoire de REcherche en Géodésie
LMD	Laboratoire de Météorologie Dynamique
LOD	Length-Of-Day
LPG	Laboratoire de Planétologie et Géodynamique
µas	microarcsecond
MaRS	Mars express Radio Science experiment
MEMO	Mars Escape and Magnetic Orbiter
MER	Mars Exploration Rover
MEX	Mars Express
MGS	Mars Global Surveyor

MHB	Mathews Herring and Buffett nutation model adopted by the IAU
MINT	Mars INTerior
MOLA	Mars Orbiter Laser Altimeter
MORE	Mercury Orbiter Radioscience Experiment
MPO	Mercury Planetary Orbiter
MRA	Mutual Recognition Agreement
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NNO	New Norcia ESA ground station
NTP	Network Time Protocol
ODF	Orbit Data Files
ODY	Mars Odyssey
OMP	Observatoire Midi-Pyrénées/Orban Microwave Products
PDR	Preliminary Design Review
PI	Principal Investigator
PPP	Precise Point Positioning
PRODEX	PROgramme for the Development of scientific EXperiments
PTB	Physikalisch-Technische Bundesanstalt
ROB	Royal Observatory of Belgium
RTK	Real Time Kinematic
S/C	Spacecraft
SIMBIO-SYS	Spectrometers and Imagers for MPO Bepicolombo Integrated Observatory SYStem
SF2A	Société Française d'Astronomie et d'Astrophysique
SLIM	Second-generation Louvain-la-neuve Ice-ocean Model
SONYR	Spin-Orbit N-bodY Relativistic model
STCE	Solar and Terrestrial Center of Excellence
STD	Science Definition Team
SW	Space Weather
TAI	International Atomic Time
TEC	Total Electron Content
TID	Travelling Ionospheric Disturbance
TNF	Tracking and Navigation Files
TWSTFT	Two-Way Satellite Time and Frequency Transfer
UCL	Université Catholique de Louvain
UCLA	University of California Los Angeles
ULB	Université Libre de Bruxelles
ULg	Université de Liège
USNO	US Naval Observatory
UTC	Universal Time Coordinate
UTC(ORB)	UTC of Royal Observatory of Belgium
VeRa	Venus Express Radioscience experiment
VEX	Venus Express
VLBI	Very Long Baseline Interferometry
VUB	Vrije Universiteit Brussel
WG	Working Group
ZTD	Zenith Total Delay

DEPARTMENT 1: Reference Systems and Geodynamics

SECTION 1: Time, Earth Rotation, and Space Geodesy

Introduction:

Mission and objectives

The mission of the Section 1 “Time, Earth Rotation, and Space Geodesy” is to contribute to the elaboration of reference systems (terrestrial and celestial) and timescales, theoretically as well as observationally, to integrate Belgium in the international reference frames (concerning space geodesy and time), and to obtain information on the Earth’s interior, rotation, dynamics, and crustal deformation, at local, regional, and global levels. The ultimate goals are the understanding of the dynamics of the Earth’s interior and surface deformation.

Additionally to the planet Earth, these objectives have been extended to the other terrestrial planets, Mars, Venus, and Mercury, and to the large moons of the solar system planets. These missions are included in a long-term vision, closely related to the international activities and opportunities, and to the activities described in the statute of the Royal Observatory of Belgium (ROB) as well as in the strategic plan of our Director.

The activities of Section 1 are grouped into three general themes: (1) Time and timescales, (2) Space geodesy with GNSS, and (3) Rotation and internal structure of the Earth and the other planets that are mentioned in the strategic plan of the ROB. In total they are divided into four different scientific projects (research and/or operational projects). Here we describe the present objectives of the projects and we give important milestones reached this year for each of them. A further description is also provided in the introduction of some projects.

(a) Project 1 ‘TIME – TIME TRANSFER’ (Operational and research project)

The scientists involved in this project have the responsibilities to establish the Belgian time scale (UTC (ORB)) and to participate in international timescales by incorporating Belgium in these timescales. We maintain presently six high-quality clocks for participation in two international timescales: the International Atomic Time (TAI) and the International GNSS Service Timescale (IGST). The present requirement for the clock precision and stability is at the level of the nanosecond over one day, which can only be achieved with high-quality clocks, when located in temperature-controlled environment. Our six clocks are located in such an environment and their performances are continuously monitored by inter-comparison between themselves and also with atomic clocks of other laboratories participating to TAI. In order to perform these comparisons, as well as to transfer time at the centres where the computations for the international timescale are performed, we need methods which insure a time-transfer precision matching the required precision of the timescales. These comparisons are usually performed using code measurements of GPS satellites in common view. The scientists involved in the project mainly work on the improvement of the time transfer by using both code and phase measurements of geodetic receivers, in order to enhance its precision and accuracy. This requires the establishment of new analysis strategies, new error modelling, and new computer codes, and the installation and adaptation of the procedures to new equipments. The scientists of this project also take care of the legal issues related to the legal time. An additional important part of the work is related to the quality control and maintenance of the clocks, as our involvement in the definition of international timescale impose us a quasi perfect reliability.

<u>Milestones reached this year:</u> (1) We have pursued the development of the tool "Atomium" dedicated to time transfer at the picosecond level and based on the GPS Precise Point Positioning (PPP) approach (1.1) by incorporating better weighting, (1.2) by implementing an optional Kalman filter allowing a continuous operation across midnight using only small matrices and an evolution through near-real time applications, (1.3) by extending the tool developed for GPS time and frequency transfer to GLONASS; (2) we have developed a new analysis of GPS carrier phases in order to remove the day boundary discontinuities, which are due to the code noise, and hence to provide a continuous solution for the clocks; (3) we have developed a combined least square analysis of the GPS and the data from the Two-Way Satellite Time and Frequency Transfer (TWSTFT) in order to get a combined solution of time transfer which takes advantage of the good calibration of the TWSTFT and the good stability of the GPS phase analysis.

(b) Project 2 'GNSS' (Operational and research project)

The year 2007 has seen the departure of René Warnant (Project 'Effect of the Earth atmosphere in Space Geodesy') and an important part of his team (S. Lejeune, J. Spits, and M. Bavier) to the Royal Meteorological Institute. The procedure for replacing R. Warnant in the permanent staff is in place but the selection procedure has not yet started. This departure triggered a reflection on the structure of the GNSS-related projects and it was decided to merge the projects 'Effect of the Earth atmosphere in Space Geodesy' and 'GNSS-based Geodesy and Geodynamics' to form a new project 'GNSS'. The new project reflects the natural symbiosis between the GNSS-based atmospheric monitoring and GNSS-based geodesy as both are using the same data and both have the potential to improve each other through a mutual process of validation.

The objective of the 'GNSS' project is to integrate Belgium in international terrestrial coordinate reference systems through the integration of a number of continuous observing GNSS reference stations in international GNSS observation networks. Within that frame, the 'GNSS' project contributes actively to the European and global development of GNSS observation networks, their products and applications since more than ten years. This has resulted in a number of responsibilities within the EUREF Permanent GNSS Network (EPN) and the International GNSS Service (IGS). The continuation of these responsibilities, and the services associated with them, is one of the main objectives of this project. In addition, as it was the case in several European Agencies simultaneously involved in the EPN data analysis and performing tropospheric research, these activities found a natural synergy and led to the involvement in the EUMETNET E-GVAP project as one of its near real-time GNSS analysis centres. Also the E-GVAP service will be continued in the future.

The "Space Weather" (SW) service for the GNSS surveyors previously operated by the project 'Effect of the Earth atmosphere in Space Geodesy' is continuing under the SIDC website and is managed at the Meteorological institute. The SW activities of the new 'GNSS' project are now targeting the high-end GNSS user community and scientific applications. In addition, it will take advantage of the GNSS data available in the international services to which the project is contributing.

The service activities described above are based on a solid dose of research that also guarantees that the services are of the highest level. The research concerns the modelling, mitigation and understanding of the GNSS error sources affecting the services mentioned above. Examples are the investigation of the influence of the reference frame, the GNSS antenna calibration, the troposphere and the ionosphere on GNSS-based positioning and deformation monitoring.

At the moment, a part of the services is already based on multiple GNSS, more specifically on GPS and GLONASS (Russian equivalent of GPS) observations. With the upcoming GALILEO positioning system, the scientists involved in this project will also work on the incorporation, treatment, and enhancement of GALILEO precise positioning in the research and the services they maintain.

- *<u>Milestones reached this year:</u> (1) Our permanent GPS station in Uccle has been selected by the consortium responsible for the development of the prototype Galileo Geodetic Service Provider (GGSP)* *as candidate for the future Galileo Terrestrial Reference Frame (GTRF) network. (2) 16 new GNSS stations were integrated in the EPN tracking network (3) we have set up new additional short-latency coordinate estimation (available within 1 day delay after the observations). This solution is sent daily to the EUREF combinations centre. (3) We demonstrated that it is impossible to determine for each GNSS antenna type a universal value indicating the difference between coordinates obtained with relative and absolute calibrations. In fact, the coordinate difference is strongly dependent on the processed method, the processed network, and the way the reference frame is defined. (4) We have shown that several regional GNSS-based coordinate solutions have biases with respect to each other and that it is necessary to add global GPS stations to a regional GPS network in order compute reliable coordinates.*

(c) Project 3 'EARTH ROTATION' (Research project)

The objectives of the project 'Earth rotation' are to better understand and model the Earth rotation and orientation variations, and to study physical properties of the Earth's interior and the interaction between the solid Earth and the geophysical fluids. The work is based on theoretical developments as well as on the analysis of data from Earth rotation monitoring and general circulation models of the atmosphere, ocean, and hydrosphere. The scientists involved in this project work on the improvement of Very Long Baseline Interferometry (VLBI) observations as well as of analytical and numerical Earth rotation models. They study the angular momentum budget of the complex system composed of the solid Earth, the core, the atmosphere, the ocean, the cryosphere, and the hydrosphere at all timescales. This allows them to better understand the dynamics of all the components of the Earth rotation, as Length-of-day variation (LOD), polar motion (PM), and precession/nutation, as well as to improve their knowledge and understanding of the system, from the external fluid layers to the Earth deep interior.

Milestones reached this year: *(1) in our theoretical work, we have established an analytical method to compute the topographic coupling at the core-mantle boundary and its effects on nutations; (2) in our analysis of Very Long Baseline Interferometry (VLBI) data, we have studied the contamination of the analysis strategy to Earth Orientation Parameters (EOP) determination and shown that this can be at a couple of tens of microarcsecond on the nutation amplitudes and at the level of a few tenths of day (100 days) on the FCN (FICN respectively); FCN and FICN stand for Free Core Nutation and Free Inner Core Nutation respectively; (3) concerning the FCN free mode, we have estimated its time variable amplitude from VLBI data and our model has been proposed for the International Earth rotation and Reference frame Service (IERS) conventions and shown that the atmosphere could globally excite the FCN but the atmospheric data (in the current state-of-the-art) could not reproduce the exact time variability of the observed FCN amplitude; (4) using a Bayesian approach we have estimated from the analysis of VLBI data in time domain the boundaries within which the geophysical parameters may be expected to change, and in particular, to which extend the inner core parameters and precession may vary; we have shown that, in particular for the inner core parameters, the error on the adopted parameter values, were underestimated; (5) we have also estimated the FCN free mode with this approach and shown that both results are coherent.*

(d) Project 4 'GEODESY AND GEOPHYSICS OF TERRESTRIAL PLANETS' (Research project)

The project aims at a better understanding of the gravity field, the rotation and orientation variations (polar motion, precession, nutations, and librations), and the tides of the terrestrial planets and large natural satellites in order to gain insight into their interior structure and composition. Geodetic data on the gravity field and rotation of a planet can be obtained from landers or/and orbiting spacecraft. In our project, radio science data from Mars Global Surveyor (MGS), Mars Odyssey, Mars Express (MEX), and Venus Express (VEX) are the principal source of information. Radio science data from the future ExoMars mission to Mars and from the BepiColombo mission to Mercury will be treated in the future. For the analysis of the data, and for simulations of future experiments, large and complex computer programs are used and developed, such as GINS/DYNAMO, which is one of only a few codes in the world that can compute accurate orbits of spacecrafts from radio science data. Besides the data-analysis, the project has a strong theoretical research component, which is oriented towards the construction of detailed mineralogical models for the interior of the planets and the dynamical response of these models to both internal and external forcing. The time-variable gravitational interaction with the other planets, moons, and the Sun is particularly important for changes in the gravity field and rotation. Therefore, the orbital motion of the large bodies of our Solar System is also investigated, both theoretically and observationally.

<u>Milestones reached this year:</u> *(1) The Lander Radio-science experiment, LaRa, has been officially selected as part of the 'Humboldt' payload on the lander platform of the ExoMars mission and the industrial partner has started the development; (2) A theory for the deflection of a spherical thin shell with varying rigidity has been developed and published in order to better understand the structure of the crust and lithosphere of terrestrial planets; (3) An extended invited review paper on the rotation of the terrestrial planets has been written and published in the Elsevier reference work 'Treatise on Geophysics'; (4) A model has been developed for the electrical conductivity of iron-rich minerals in view of the interpretation of electromagnetic data from space missions; (5) From an analysis of eight years of MGS/Odyssey tracking data, we have obtained the time variations of gravity coefficients induced by the seasonal changes in the atmosphere and ice caps, as well as a degree-two Love number k_2 of about 0.12, which implies that the core of Mars is liquid; (6) The determinations of the mass and ephemeris of Phobos have been improved by using MEX radio-tracking data; (7) Several papers on the libration of Mercury have been published; in particular, we have shown that planetary perturbations lead to forced librations in longitude with periods on the order of several years and amplitudes of several tens of arcseconds; (8) Observation strategies have been developed for the determination of Mercury's libration from camera images; (9) The orbital evolution of the Galilean satellites and the tidal energy dissipation in Jupiter and Io have been determined from an extensive set of astrometric observations; (10) We have shown that libration observations of the Galilean moon Europa can be used to determine the existence of a sub-surface ocean and to estimate the thickness of the icy shell.*

Links between the different projects of Section 1

The four projects within Section 1 all fit in the themes (1) Time and timescales, (2) Space geodesy with GNSS, and (3) Rotation and internal structure of the Earth and the other planets. They have multiple mutual links. The project 'Time and Time-transfer' uses in Brussels the same GPS receivers as the 'GNSS' project; the interaction with the GNSS project concerns choice, installation, and optimum use of the receivers, as well as data analysis strategies. The year 2007 has seen the kickoff of the STCE project (Solar and Terrestrial Center of Excellence) aiming at a better understanding of Space Weather (variations in the Sun-Earth environment, mainly originating from solar activity) and its effects on Earth and in particular on GPS. This topic is deeply addressed by the projects 'GNSS' and 'Time and Time-transfer'. The Earth rotation variations and Earth orientation changes, studied by the scientists of the project 'Earth Rotation', are deduced from global measurements of Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR and LLR), and also GPS data, to which the GNSS project contributes. The project 'Geodesy and Geophysics of other planets' extends the geodesy research performed in the project 'Earth rotation' to the rocky planets and satellites of our solar system. As such, the methodologies are common between these two projects. Moreover, the limited amount of planetary data is a strong stimulus for developing methods utilizing synergies between different experiments. Such methods have also been applied to Earth with unprecedented results.

A. Research Theme “Time and Time Transfer”

A.1. Operational and Research project “Time and Time Transfer”

A.1.1. Objectives

- To maintain high-quality clocks for participation in the international timescales (mainly TAI and IGS), and for the realization of a local high-quality timescale UTC(ORB) close to UTC;
- To develop strategies and tools for GNSS time transfer in order to improve the precisions of remote clock comparisons, and to perform high-performance analyses of the data gathered at ROB;
- To maintain the official Belgian time called UTC(ORB) within one hundred of nanosecond with respect to TAI;
- To define a legal Belgian time and to include ROB in the international Mutual Recognition Agreement (MRA);
- To provide UTC to Belgian users via NTP.

A.1.2. Progress and results

The Time Laboratory of the Royal Observatory of Belgium is one of the 50 time laboratories over the world in which are distributed the 300 atomic clocks used by the BIPM (Bureau International des Poids et Mesures, Paris) for the realization of the International Atomic Time (TAI).

A.1.2.1. Service

- During the year 2007, we maintained our 3 cesium atomic clocks and 3 hydrogen masers in operation and continued the near-real time monitoring of our clocks by comparison with the other laboratories’ UTC(k) with a one day delay, at the nanosecond level accuracy. The plot for each clock is available in near-real time on private web-pages as well as the comparison between our realization of UTC and the true UTC, as presented in the picture here below; to problems with the H-maser used for the generation of UTC(ORB), our time scale was less stable than during previous years, but still remained in a 150 nanosecond range.

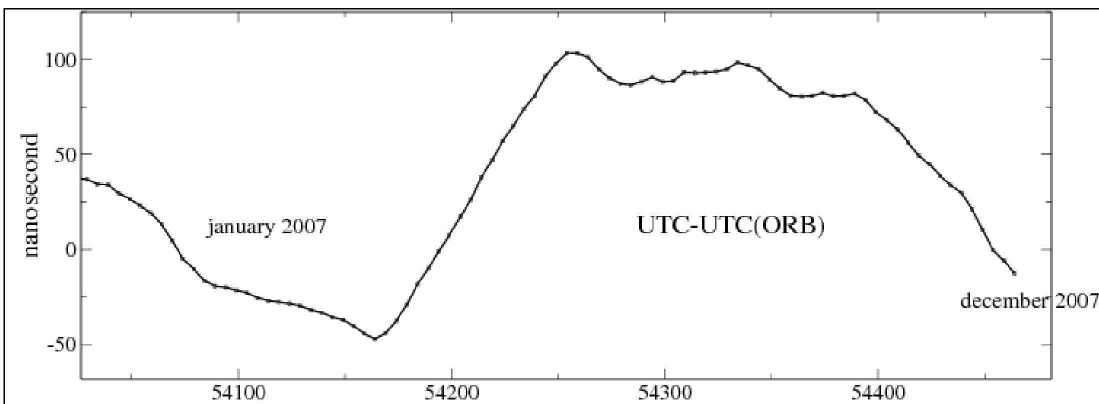

Figure 1. Evolution of UTC-UTC(ORB) over the year 2007.

- We have performed the management of the clock signals needed for GNSS receivers BRUS, ZTBR, PLB2 and BRUX;
- The NTP servers are now fully operational for the diffusion of UTC(ORB) via internet, and are continuously monitored. All the servers and PCs of the 3 institutes (ROB, RMI, BISA), as well as a huge number of external anonymous clients, use these time sources (about 25 requests per minute);

- We have continued the procedure to get UTC(ORB), or equivalent realizations of UTC, as legal time for Belgium;
- We have negotiated with the Metrology Service for collaboration in the frame of the Mutual Recognition Agreements (MRA) in the frame of the realization of a precise timescale in Belgium;
- We have prepared a JD for the next IAU General Assemble (2009): set up of the SOC, invited talk, rationale and draft program;
- We have participated in the calibration campaign of the Ashtech Z-XII3T receivers and Septentrio receivers for time applications, organized by the BIPM and aiming at obtaining the hardware time delay of the clock, the needed periphery, and the associated cables;
- We have prepared the part 5 (Time scales and Time transfer) of the EFTF 2008 as chair of that part.

A.1.2.2. Results

- We modernized the software R2CGGTTS (getting the CGGTTS[1] files using geodetic receivers, and the ionospheric free code P3[2]) used by the BIPM (project TAIP3: using GPS links based on R2CGGTTS for the realization of TAI) in order to include a more precise correction for tropospheric delays.
- We have developed and improved the tool "Atomium" dedicated to precise time transfer only, in the Precise Point Positioning (PPP)[3] mode, using more appropriate weighting; the objective of that work is to transfer time from one single station to another one at a few hundreds of picoseconds or better.
- We have implemented the Kalman filtering in GPS carrier-phase and code analysis for time transfer with Atomium; this implementation aims at an evolution towards quasi-real time applications;
- We have extended the tool Atomium developed for GPS time and frequency transfer to GLONASS and to the combined analysis GPS+GLONASS; we have shown that the present GLONASS constellation, when added to the GPS one, does not allow to improve the quality of the time and frequency transfer based on GNSS, compared to GPS only; it prepares us however for the future treatment of combined GPS+GALILEO future data.

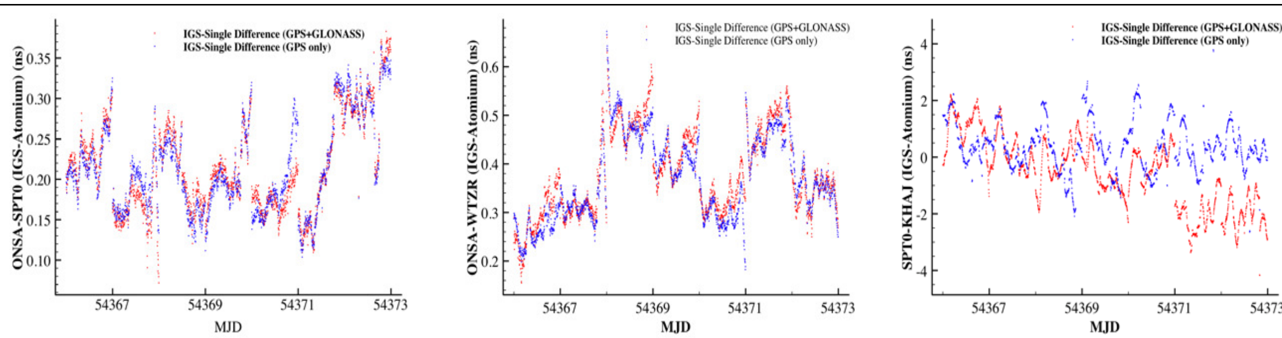

Figure 2. Differences between the IGS solution and GPS (in blue) and GPS+GLONASS (in red) time transfer in single differences for the links ONSA–SPT0 (short link), ONSA-WTZR (long link) and SPT0-KHAJ (very long link).

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[1] Format compiled by the CCTF Group on GNSS Time Transfer Standards (CGGTTS). CCTF stands for Consultative Committee for Time and Frequency.

[2] P3 is software recently developed at ROB for time transfer using geodesic receivers and worldwide used.

[3] Precise Point Positioning (PPP) is a method that performs precise position determination as well as receiver clock solution using a single GPS receiver. This positioning approach arose from the advent of widely available precise GPS orbit and clock data products and has accuracy at the centimetre level.

- We developed software to provide simulated orbits and clocks for GALILEO satellites in the standard format used by the IGS (sp3) in order to prepare our future work on adding GALILEO in the treatment of time transfer and to investigate the impact and improvements.
- We have developed a new analysis of GPS carrier phases in order to get a continuous solution for the clocks; we have shown the high sensitivity of the method to particular parameters, the necessity to use compatible station positions and satellite orbits at the sub-cm level, and the necessity to use IGS rapid rather than final satellite orbits and clocks; the improvement is shown in Figure 3. where the "phase-only solution" (black curve) corresponds to our new treatment; the results are compared with those of IGS and the present PPP solution; small jumps still appear in the solutions due to the satellite orbits discontinuities (see the passage at day 54116) but the improvement is already very good.

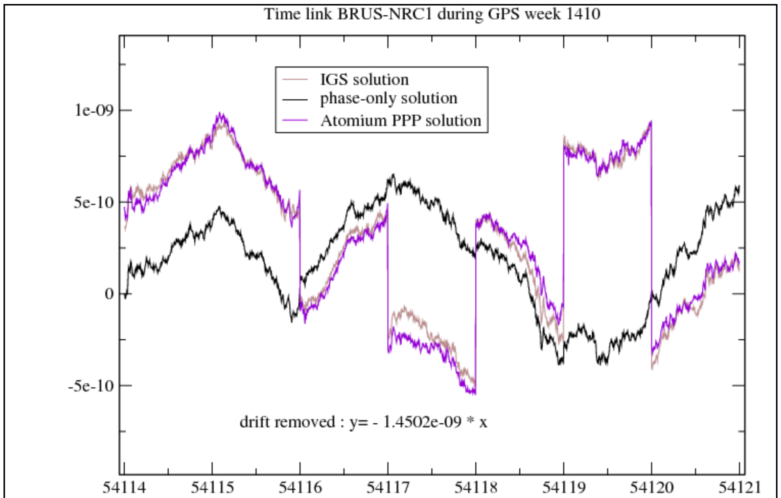

Figure 3. Frequency transfer with GPS phase-only analysis provides a continuous solution (black curve), which is not the case in classical PPP or IGS solutions, based on a combined analysis of code and carrier phase data.

- We have developed a combined least square analysis of the GPS-based time transfer data and the data from the Two-Way Satellite Time and Frequency Transfer (TWSTFT) in order to get a combined solution of time transfer which takes advantage of the good calibration of the TWSTFT and the good stability of the GPS phase analysis; we have shown a large improvement in medium baseline (1000 km) for which the day boundary jumps of the GPS-only solution are reduced in the combined GPS+TW solution; there are still some imperfections in the inter-continental baselines to be solved in the future.

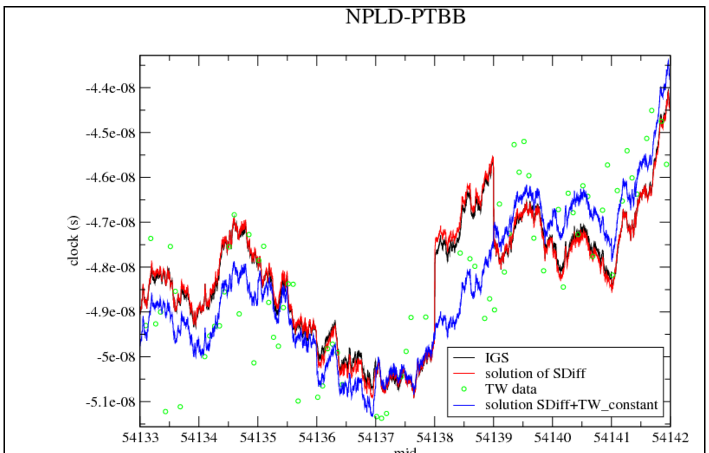

Figure 4. Comparison between the time links obtained with GPS (IGS or SDiff) and with the combination of GPS and TW (in blue).

- We have shown that residual ionospheric effects can be observed in the L3 (phase), P3 (code) ionospheric-free combination used by *Atomium* during strong ionospheric perturbations. This can be assessed by observing the presence of jumps in the sigmas of the station clock synchronization errors, in particular by observing that the sigmas are substantially higher on that GPS day compared with quiet days.

A.1.3. Perspective for next years

- To continue the development of the GPS time and frequency transfer analysis tool "Atomium"; to perform comparisons between the different techniques of time transfer and the different software available in the scientific community;

- To investigate the impact of adding GALILEO and enhanced GPS on time transfer;
- To continue the investigation of the impact of adding GLONASS on time transfer;
- To continue the procedure to propose UTC(ORB) as basis for legal time in Belgium;
- To prepare the Quality Criteria for the Time laboratory (norm ISO17025 for calibration certification), necessary for the key comparisons of the MRA;
- To continue the development of the tool for continuous frequency transfer based on phase-only analysis;
- In collaboration with the BIPM, to study the effect of combining the results of GPS phase-only analysis and two-way (TWSTFT) links in the TAI computation;
- To use ionospheric maps in Atomium to improve ionospheric corrections, either using IONEX files provided by IGS, or local Total Electron Content (TEC) maps provided by SWACI (N. Jakowski), or any other "on-the-market" maps;
- To implement higher order ionospheric corrections in Atomium.

A.1.4. Personnel involved

Scientific staff: P. Defraigne, C. Bruyninx, F. Roosbeek, Q. Baire, S. Pireaux

Technical staff: F. Coutereel, E. Driegelinck

A.1.5. Partnerships

Without grants

- BIPM (Bureau International des Poids et Mesures: G. Petit, F. Arias) (scientific exchange in the construction of TAI, see 8th perspective)
- NRL (US Naval Research Laboratory: K. Senior)
- DLR (Institute of Communications and Navigation, German Aerospace Center: A. Moudrak)
- National collaboration: Septentrio (J.-M. Sleewaegen) (preparation of GALILEO receiver data analysis)
- INRIM (Italian Institute for Metrology, Turin)
- NRCan (F. Lahaye)
- CNES (J. Delporte)
- Jean-Pierre Barriot (Laboratoire Terre-Océan, Observatoire Géodésique de Tahiti)
- Norbert Jakowski (DLR) (exchange of information on ionospheric maps)

Visitors

- 12 March 2007: Pasquale Nardone, ULB, preparation of the expo "Jeunesses Scentifiques"
- 30 May 2007 to December 3, 2007: Mari-Carmen Martinez from Univ. of Alicante.
- Graduating student: L. Tollet (UCL)

Grants/Projects used for this research/service

- Quentin Baire got a "supplementary researcher" contract from BELSPO.
- Sophie Pireaux got a contract within the Solar-Terrestrial Center of Excellence.

A.1.6. Publications

A.1.6.1. Publications with peer system

[1] **Defraigne P., Bruyninx C.**
On the link between GPS pseudorange noise and day-boundary discontinuities in geodetic time transfer solutions,

GPS solutions, 11(4), pp. 239-249

[2] **Defraigne P.,** Banerjee P., Lewandowski W.
Time transfer through GPS,
Indian Journal of Radio and Space Physics, 36, pp. 303-312

[3] Le Poncin-Lafitte C., **Lambert S.B.**
Numerical study of relativistic frequency shift for cold-atom clock experiments in space
Class. Quantum Grav. 24, 801

A.1.6.2. Publications without peer system

[4] **P. Defraigne, C. Bruyninx**
Multipath mitigation in GPS-based time and frequency transfer,
Proc. EFTF 2006, March 2006 (CD-rom)

[5] **Roosbeek F., Defraigne P.**
Long Term Study of the H-Maser Clocks at the Royal Observatory of Belgium,
Proc. EFTF 2006, March 2006 (CD-rom)

[6] Petit G., **Defraigne P.**, Warrington B., Uhrich P.,
Calibration of dual frequency GPS receivers for TAI,
Proc. EFTF 2006, March 2006 (CD-rom)

[7] **Defraigne P., Baire Q., Guyennon N.**
Time and Frequency Transfer from PPP using GLONASS and GPS data,
Proc 27th EFTF, Geneva, May 2007 (CD-rom)

[8] Jiang Z., Petit G., **Defraigne P.**
Combination of GPS Carrier Phase Solution with a Calibrated Time Transfer Link,
Proc 27th EFTF, Geneva, May 2007 (CD-rom)

[9] **Defraigne P., Guyennon N., Bruyninx C.**
PPP and Phase-only GPS time and frequency transfer;
Proc 27th EFTF, Geneva, May 2007 (CD-rom)

[10] **Defraigne P., Bruyninx C.**
On the impact of multipath in GPS-based time and frequency transfer,
Proc. IGS Workshop, May 2006, Darmstadt, Germany (CD-rom)

A.1.6.3. Publications in press

[11] **Defraigne P., Guyennon N., Bruyninx C**.
GPS Time and Frequency Transfer: PPP and Phase-only analysis,
Submitted to Intern. Journ. of Navigation and Observation, 2007.

[12] Petiteau A., Auger G., Halloin H., Jeannin O., **Pireaux S.**, Plagnol E., Regimbau T., Vinet J-Y.
LISACode: A scientific simulator of LISA
Physical Review D, accepted in November 2007

[13] **Pireaux S.,** Chauvineau B.
Relativistic versus Newtonian orbitography: RMI software, illustration with the LISA mission
Submitted to Gravitation

A.1.6.4. Reports, thesis, etc.

[14] Altamimi Z., Barruol G., Barriot J.P., Biancale R., Bonnefond P., Cazenave A., Cretaux J.F., F. Deleflie, Exertier P., Francou G., Gambis D., Gontier A.-M., Kasser M., Lalancette M.F., Marty

J.-C., Metris G., Perosanz F., Pierron F., Remy F., **Pireaux S.**, Samain E., Souchay J., Willis P., Woppelmann G.
GRGS - Rapport d'Activité 2003 – 2006. Avril 2007. Présenté par Nicole CAPITAINE, Présidente du Conseil Scientifique et Michel KASSER, Directeur Exécutif.
www.oca.eu/heberges/grgs/publications/index.html

[15] **Tollet L.**
Utilisation du filtre de Kalman pour les comparaisons d'horloges à distance par GPS,
Mémoire UCL

A.1.7. Scientific outreach

A.1.7.1. Meeting presentations

[1] Jiang Z., Petit G., **Defraigne P.**
Combination of GPS Carrier Phase Solution with a Calibrated Time Transfer Link
27th EFTF, Geneva, May 2007.

[2] **Defraigne P., Guyennon N., Bruyninx C.**
PPP and Phase-only GPS time and frequency transfer
27th EFTF, Geneva, (poster), May 2007.

[3] **Defraigne P., Baire Q., Guyennon N.**
Time and Frequency Transfer from PPP using GLONASS and GPS data
27th EFTF, Geneva, (poster), May 2007.

A.1.8. Missions

Research missions (assemblies, symposia, workshops, etc): 5

B. Research Theme "Space Geodesy with GNSS"

The research theme "Space Geodesy with GNSS" concerns the application of GNSS, like GPS, GLONASS and later Galileo, to the observation and monitoring of Earth systems, as well as the modelling, mitigation and understanding of the GNSS error sources affecting these various applications.

B.1. Operational and research project "GNSS"

B.1.1. Objectives

The goal of the 'GNSS' project is to maintain the integration of Belgium in international coordinate reference frames through operational, service and research activities.

On the operational level, the project maintains a number of continuous observing GPS reference stations distributed over the Belgian territory and integrates them in international GNSS observation networks.

The project has been contributing to the European and global development of GNSS observation networks, their products and applications since more than ten years. This has resulted in a number of responsibilities within the International GNSS Service (IGS) and especially the EUREF Permanent GNSS Network (EPN). The continuation of these, internationally recognized, responsibilities and services is an important part of this project for example the management of the EUREF Central Bureau and the activities related to our EPN GNSS data analysis centre. In addition, as it was the case in several European Agencies simultaneously involved in the EPN data analysis and performing tropospheric research, these activities found a natural synergy and led to the involvement in the E-GVAP project as one of its near real-time GNSS analysis centres. E-GVAP is a EUMETNET project in which specialized GNSS analysis centres (like we at ROB) tropospheric Zenith Path Delays computed using near-real time GNSS data to the European meteorological institutes which are testing their assimilation for the improvement of their numerical weather models.

The service activities described above are based on a solid dose of research that also guarantees that the services are of the highest level. The research concerns the modelling, mitigation and understanding of the GNSS error sources affecting these applications. Examples of such error sources are the reference frame, the troposphere and the ionosphere.

B.1.2. Progress and results

B.1.2.1. Maintenance of GPS Observation Network (operational activities)

The daily maintenance of the ROB network of permanent GPS stations has been continued (Figure 5). The data are integrated in international observation networks (IGS and EPN) and are distributed to the user community (surveyors, scientists, other ROB projects) using the Internet. Two GPS stations have been upgraded with a new Septentrio receiver (WARE & BREE).

In 2007, our permanent GPS station in Uccle has been selected by the consortium responsible for the development of the prototype Galileo Geodetic Service Provider (GGSP) as candidate for the future Galileo Terrestrial Reference Frame (GTRF) network.

Figure 5. Network of continuous operating GPS reference stations

B.1.2.2. EUREF Permanent Network Central Bureau (service activities)

The project hosts the EPN Central Bureau (CB) and performs the daily management of the EPN, the European network of continuous observing GNSS reference stations serving multi-disciplinary applications and covering 38 European countries, see [3], [5], [17], [18], [19], and [23]. We act as the liaison between EPN station operators and analysis centres and ensure that the datasets meet the requirements of the analysis by performing daily checks of the GNSS data flow and data quality. A large part of the work is dedicated to the maintenance and continuously updating of the EPN CB web site (http://epncb.oma.be/).

- In 2007, 16 new GNSS stations were integrated in the EPN tracking network and 5 were decommissioned, bringing the total of EPN stations to 205 (see Figure 6 and Figure 7).
- The real-time GNSS data transfers in the EPN have been declared as an official part of the routine EPN operations and the procedures for checking the latency and meta-data of these real-time GNSS data transfers have been put in operation.
- As a growing number of EPN stations are observing GLONASS as well as GPS satellites, our GNSS data quality check software has been updated to also check the quality of GLONASS observations.
- A new rapid coordinate solution is now generated at the EPN CB in order to allow a quick monitoring of the EPN station coordinates.

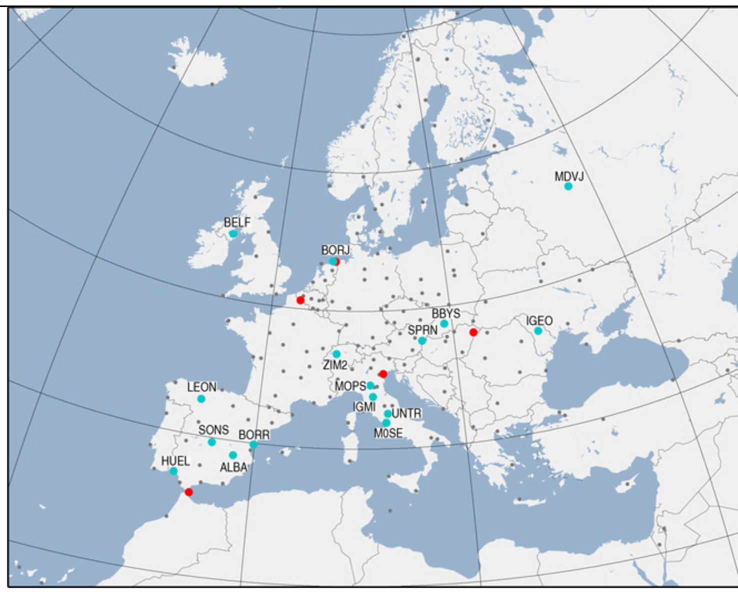

Figure 6. Network of EPN stations. Stations indicated in blue have been added to the EPN in 2007; those in red have been decommissioned.

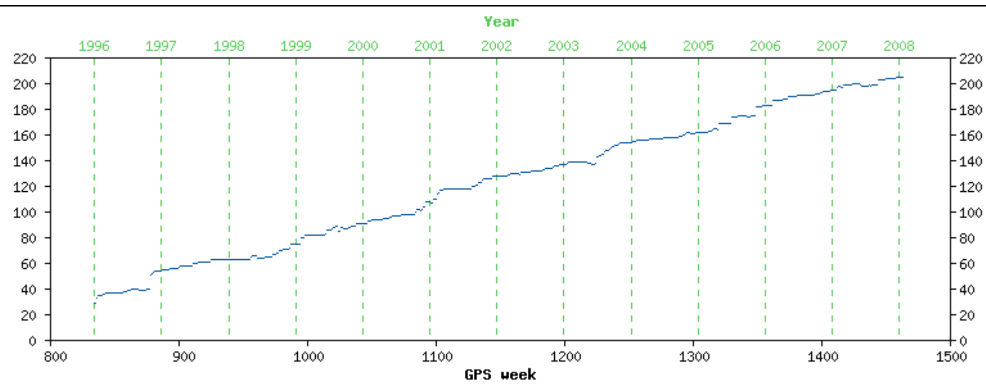

Figure 7. Number of EPN stations since 1996

B.1.2.3. GNSS Analysis Centre contributing to international services (service activities)

- Since 1996, the project is operating a GNSS analysis centre providing weekly coordinate estimates to EUREF for a network of GNSS stations in and around Belgium in order to maintain the European Coordinate Reference System (ETRS89), see [1], [4], and [14]. In 2007, we have set up new additional short-latency coordinate estimation (available with a 1-day delay after the observations) which is submitted to EUREF.

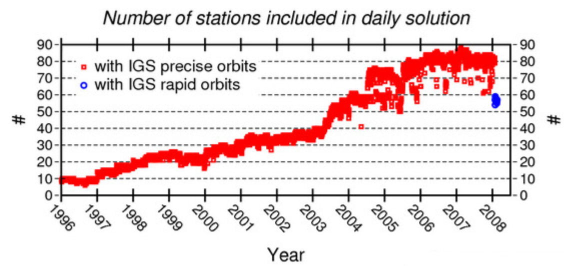

Figure 8. Number of GNSS stations included in the weekly (red) and daily (blue) EUREF positioning service since 1996.

Figure 9. GNSS stations included in near real-time E-GVAP service

- In 2007, our EUMETNET E-GVAP solution (see Figure 9) was revisited in order to adhere to new standards, such as the new IGS05 reference frame, the introduction of the new absolute phase centre models, and the inclusion of GLONASS data. Presently, the new solution has been running successfully since one month for validation purposes.
  Since 2007, ROB's contribution to E-GVAP is performed within the frame the Solar Terrestrial Centre of Excellence collaboration between the ROB, the Royal Meteorological Institute and the Belgian Institute for Space Aeronomy).

B.1.2.4. Determination of deformations of the Earth's crust using GNSS (research activities)

Deformations of the Earth's crust are determined by computing regularly the positioning of permanent GPS stations and then by combining these positions together to obtain their time evolution, and, if possible, their linear velocities.

- In 2007, a new re-processing of recent and historical GNSS data (covering 11 years) of the ROB and EPN permanent GPS stations in and around Belgium has been performed using the most recent modelling schemes used by the Bernese 5.0 software, significantly reducing the noise on the resulting coordinate time series (see Figure 10 and [16]). Based on these results also the velocities of our geophysical stations located at Bree and Meeuwen have been re-estimated (collaboration with seismology section) indicating that no significant deformations occur across the Feldbiss fault zone in Northern Limburg.

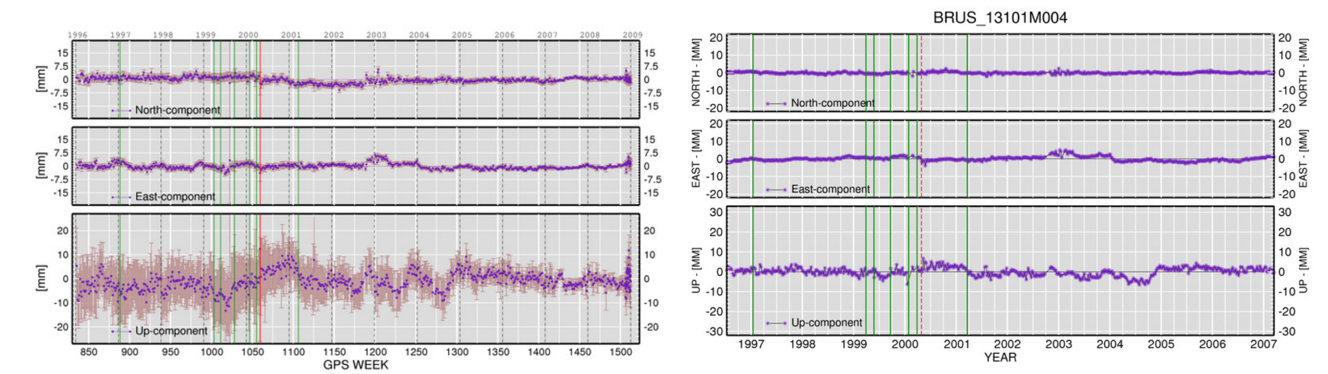

Figure 10. Left: old coordinate time series of BRUS. Right: new reprocessed coordinate time series of BRUS.

- A GPS station has been installed in Nov and Dec, 2007 near the future Belgian Antarctic Base with the goal to test the GPS equipment that will be installed in 2008 within the frame of the GIANT project (collaboration with RMA and NGI). GIANT is a program of collocated geophysical measurements in the Belgian Antarctic Base (collaboration with seismology section of ROB).

B.1.2.5. Influence of the different error sources on GNSS positioning (research activities)

- The influence of recently published new GNSS antenna calibration models on the European coordinate reference frame (ETRS89) has been evaluated for 23 different antenna/radome combinations. The results demonstrate that it is impossible to determine for each antenna/radome type a universal value for the difference between the coordinates obtained with new and old calibrations. In general the height component is mostly affected by the change of the calibration model and the agreement between results obtained for different stations with the same antenna/radome combination is mostly at the 5–10 mm level [21]. For stations located in central Europe, the change of calibration model causes mean coordinate differences mostly below 1 cm for the vertical and below 2 mm for the horizontal components. But, for stations located at the border of Europe, the coordinate differences reach up to 3 cm for the height component and 5 mm for the horizontal components.

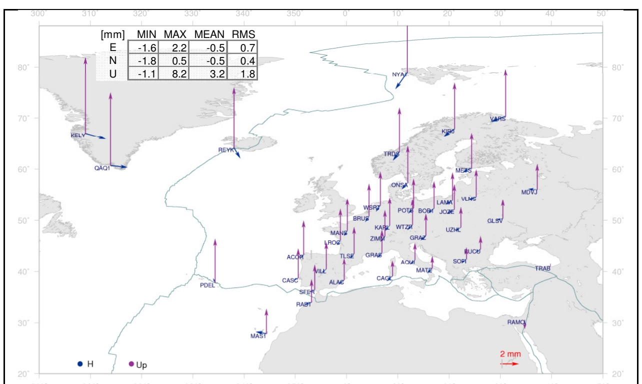

Figure 11. Position differences between the regional cumulative solution in IGS05 and the regional cumulative solution in ITRF2005.

- The influence of the reference frame on GNSS-based station coordinates has been evaluated. The comparison of the coordinate differences (Figure 11) between two regional networks where one is tied to the IGS05 and the other to the ITRF2005, showed coordinate differences reaching up to 1 cm in the vertical, a tilt and a bias of about 3 mm. These differences are caused by the regional (European) difference between IGS05 and ITRF2005 reference frames. In addition, we showed that several regional solutions have biases with respect to each other and that it is necessary to add global GPS stations to a regional GPS network to compute reliable coordinates.
- The study of the influence of the ionospheric activity on GNSS-based deformation monitoring using kinematic positioning was started late 2007. First results, obtained with GNSS data gathered during an ionospheric (super)storm in Oct. 2003, show a significant degradation of the positioning results for stations located in Northern Europe and less degradation for Central Europe (see Figure 12).

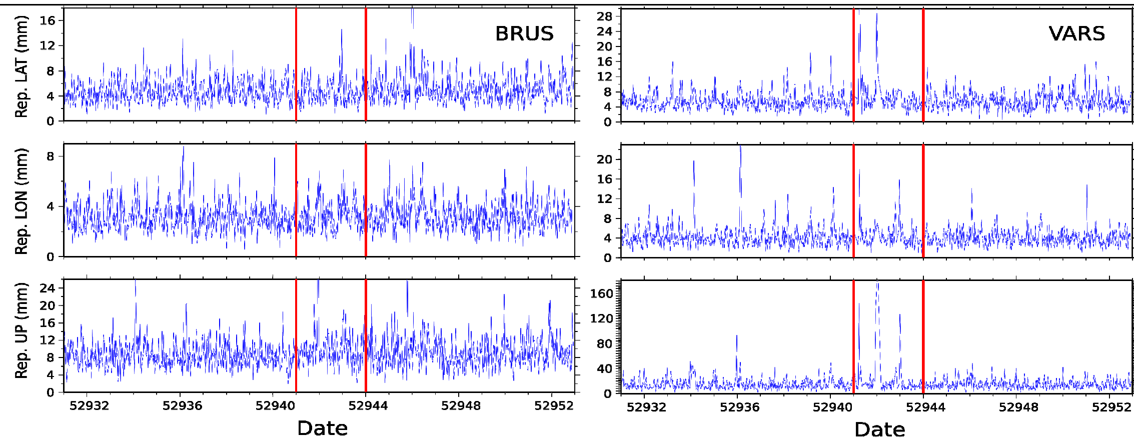

Figure 12. 1-hour position repeatability for station BRUS (left) and VARS (right) for Up, East and North components. The red lines delimitate the ionospheric storm. The date is modified Julian date.

B.1.3. Perspective for next years

- Continue the maintenance of the ROB GPS network, the EPN service activities (EPN Central Bureau, EPN Data Centre, EPN Analysis Centre)
- Continue the replacements of the old GPS receivers used for the ROB GPS stations by new ones and replace the ISDN lines by ADSL lines
- Continue to contribute to E-GVAP as real-time GNSS analysis centre
- Continue to improve the GPS data modelling and the reprocessing of historical GNSS data, and the estimation of site coordinates and velocities
- Continue to investigate the potential of the Precise Point Positioning (PPP) technique
- Continue to investigate the optimal way of fixing the reference frame of a regional GPS network
- Continue to investigate the influence of ionospheric activity on GNSS-based deformation monitoring
- Investigate the sensibility of the tropospheric zenith path delay estimation to the parameterization of the GNSS data analysis
- Contribute to GIANT project with installation of a GPS station at Belgian Antarctic Base and analysis of the GPS data.

B.1.4. Personnel involved

Scientific staff: C. Bruyninx, N. Bergeot, F. Coutereel, O. Khoda, J. Legrand, M. Moins, E. Pottiaux, F. Roosbeek

Technical staff: D. Mesmaker, A. Moyaert, R. Laurent

B.1.5. Partnerships

List of national partners without grant

- P. Voet, Nationaal Geografisch Instituut (NGI)
- A. Muls, Royal Military Academy (RMA)

List of international partners without grant

- A. Kenyeres, FOMI Satellite Observatory, Hungary
- C. Volksen, Bayerische Kommission fuer die Internationale Erdmessung (BEK), Germany
- G. Stangl, Institute of Space Research, Austria
- H. Habrich, G. Weber, W. Sohne, Bundesamt für Kartographie und Geodäsie (BKG), Germany

- Z. Altamimi, X. Collilieux, IGN/LAREG, France
- H. Van der Marel, TU Delft, Netherlands
- M. Diament, V. Ballu, Institut de Physique du Globe de Paris
- M. Bouin, Laboratoire de Recherche en Géodésie
- M. Régnier, Bernard Pelletier, Stéphane Calmant, Institut de Recherche pour le Développement

Grants/Projects used for this research/service

- BELSPO Action 1, MO/33/12, "Study of the impact of using combined GALILEO and modernized GPS measurements for high accuracy positioning and timing applications", Jan. 2005 – March 2007, M. Moins
- BELSPO Action 1, MO/33/19, "European ground deformations obtained from GNSS observation networks", Jan. 2007 – Dec. 2008, J. Legrand
- BELSPO fellowship for non-EU post-doc researchers, "Influence of the absolute GNSS antenna phase centre models on the European Reference Frame", March 2007- Feb. 2008: O. Khoda
- Solar Terrestrial Center of Excellence: N. Bergeot, F. Coutereel, E. Pottiaux

B.1.6. Publications

B.1.6.1. Publications with peer review

[1] **Bruyninx C**.
Comparing GPS-only with GPS+GLONASS Positioning in a Regional Permanent GNSS Network
GPS Solutions, 11(3), pp. 97-106

[2] Altamimi, Z., X. Collilieux, **J. Legrand**, B. Garayt, and C. Boucher (2007)
ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters
J. Geophys. Res., 112, B09401, DOI: 10.1029/2007JB004949

B.1.6.2. Publications without peer review

[3] **Bruyninx C**.
Status of the EUREF Permanent Network
Mitteilungen des BKG, Band 38, EUREF Publication No. 15, Ed. BKG, Frankfurt am Main, pp. 47-54

[4] **Bruyninx C**.
Introducing GLONASS in the EUREF Permanent Network: First Results
Proc. IGS Workshop, May 2006, Darmstadt, Germany

[5] **Bruyninx C., Carpentier G., Defraigne P**.
Analysis of the Coordinate Differences caused by Different Methods to align the Combined EUREF Solution to the ITRF
Mitteilungen des BKG, Band 38, EUREF Publication No. 15, Ed. BKG, Frankfurt am Main, pp. 330-338

[6] **Bruyninx C., Carpentier G, Lejeune S., Pottiaux E., Roosbeek F.,** Voet P., Warnant R.
National report of Belgium
Mitteilungen des BKG, Band 38, EUREF Publication No. 15, Ed. BKG, Frankfurt am Main, pp. 216-217

[7] Daghay S., **M. Moins**, **C. Bruyninx**, Y. Rolain, **F. Roosbeek**
Impact of the Combined GPS+Galileo Satellite Geometry on Positioning Precision

Mitteilungen des BKG, Band 38, EUREF Publication No. 15, Ed. BKG, Frankfurt am Main, pp. 342-348

[8] Moore A., **Bruyninx C**., Noll C., Scharber M.
IGS Network & Data Center Position Paper
Proc. IGS Workshop, May 2006, Darmstadt, Germany (on CD)

[9] Noll C., Moore A., **Bruyninx C**., Scharber M.
IGS Data Flow – Today and Proposal for the Future
Proc. IGS Workshop, May 2006, Darmstadt, Germany (on CD)

[10] Weber R., **Bruyninx C**.
IGS GNSS WG / Inter-Commission Study Group 1.2 – Use of GNSS for Reference Frames: Report for the Period 2003-2007
International Association of Geodesy, IAG Commission 1- Reference Frames, Bulletin No. 20, ed. H. Drewes, H. Hornik, pp 65-66

[11] Weber R., **Bruyninx C**.
The GNSS Working Group of the IGS – Challenges of the GNSS Modernization Programs
Proc. IGS Workshop, May 2006, Darmstadt, Germany

B.1.6.3. Publications in press, submitted

[12] Bavier M., **Bruyninx C**., S. Lejeune, **M. Moins, E. Pottiaux, F. Roosbeek**, P. Voet, R. Warnant
National report of Belgium
Proc. EUREF symposium, June 2006, Riga, in press

[13] **Bergeot,** Bouin, Diament, Pelletier, Régnier, Calmant, Ballu
Interseismic velocity field in the central Vanuatu locked subduction zone context from GPS measurements
Submitted to Journal of Geophysical Research

[14] **Bruyninx C**.
GPS and GLONASS Data Analysis using Stations from the EUREF Permanent Network
Proc. EUREF symposium, June 2006, Riga, in press

[15] **Bruyninx C**., Z. Altamimi , C. Boucher, E. Brockmann, A. Caporali, W. Gurtner, H. Habrich, H. Hornik, J. Ihde, A. Kenyeres, J. Mäkinen, G. Stangl, H. van der Marel, J. Simek, W. Söhne, J.A. Torres, G. Weber
The European Reference Frame: Maintenance and Products
IAG Proceedings, GRF, Springer, in press

[16] **Bruyninx C**., De Vidts B., **Roosbeek F.**, Voet P.
National Report of Belgium
Proc. EUREF symposium, June 2007, London, in press

[17] **Bruyninx C., Roosbeek F**.
The EUREF Permanent Network: Recent Achievements
Proc. EUREF symposium, June 2006, Riga, in press

[18] **Bruyninx C., Roosbeek F**.
EPN Status and New Developments
Proc. EUREF symposium, June 2007, London, in press

[19] **Bruyninx C., Carpentier G., Roosbeek F**.
The EUREF Permanent Network: Monitoring and On-line Resources

IAG Proceedings, GRF, Springer, in press

[20] Kenyeres A., **Bruyninx C**.
Noise and Periodic Terms in the EPN Time Series
IAG Proceedings, GRF, Springer, in press

[21] **Khoda O., Bruyninx C**.
Switching from Relative to Absolute Antenna Phase Center Variations in a Regional Network: Stability of the Coordinates Differences
Proc. EUREF symposium, June 2007, London, in press

[22] **Moins M., Bruyninx C**.
Relative Positioning in Europe: Influence of the GPS+Galileo Satellite Geometry
Proc. EUREF symposium, June 2006, Riga, in press

[23] Torres J.A., Z. Altamimi, C. Boucher, E. Brockmann, **C. Bruyninx**, A. Caporali, W. Gurtner, H. Habrich, H. Hornik, J. Ihde, A. Kenyeres, J. Mäkinen, H. v. d. Marel, H. Seeger, J. Simek, G. Stangl, G. Weber
Status of the European Reference Frame (EUREF)
Submitted to IAG Proceedings, IUGG Perugia

B.1.6.4. Reports, thesis, etc

[24] Bastos L., **Bruyninx C**., Becker M., B. Ambrosius, M. Davilla, HJ. Euler, JM. Nocquet, R. Fernandes, C. Prati, W. Spakman, G. Stangl, H. Wilmes, Zerbini S.
PLEGG: Platform for European GNSS based GeoProducts - Database and Solutions
Reply to FP7-INFRASTRUCTURES-2007-1 call, 146 pages

[25] **Bergeot N**.
Etude du cycle sismique du Vanuatu par GPS
PhD Thesis, the Institut de Physique du Globe de Paris

[26] **Legrand J**.
Champ de Vitesses de l'ITRF, Propriétés Cinématiques de la Croûte Terrestre et Condition de Non Rotation Globale
PhD Thesis, Observatoire de Paris

B.1.7. Scientific outreach

Meeting presentations

[1] **Camelbeeck T., Vanneste K., Alexandre P., Bruyninx C. and Van Camp M**.
Relevance of geodetic, seismicity and active faulting studies to assess lithospheric deformation and long term earthquake activity in intraplate Northwest Europe (poster)
EGU 2007 General Assembly, April 15-20, 2006, Vienna, **Austria**

[2] **Legrand J.,** Altamimi Z. and Jamet O.
Explicit application of the No-Net-Rotation Condition over an interpolated ITRF2005 velocity field using least squares collocation method
EGU 2007 General Assembly, 15-20 April 2007, Vienna, Austria

[3] **Vanneste K., Verbeeck K., Bruyninx C. and Camelbeeck T**.
Paleoseismic re-interpretation of a trench across the Geleen fault near Born (The Netherlands), Lower Rhine Graben area (poster)
EGU 2007 General Assembly, April 15-20, 2006, Vienna, Austria

[4] **Khoda O., Bruyninx C**.

Switching from Relative to Absolute Antenna Phase Center Variations in a Regional Network: Stability of the Coordinates Differences (poster)
EUREF 2007, June 4-6, 2007, London, UK

[5] **Bruyninx C., Roosbeek F**.
EPN Status and New Developments (invited)
EUREF 2007, June 4-6, 2007, London, UK

[6] **Bruyninx C**., De Vidts B., **Roosbeek F.**, Voet P.
National Report of Belgium
EUREF 2007, June 4-6, 2007, London, UK

[7] Weber R., **Bruyninx C**.
The Use of GNSS for Reference Frames Report of IAG SG 1.2 and the IGS GNSS Working Group (poster)
IUGG General Assembly, July 2-13, 2007, Perugia, Italy

[8] Torres J., Altamimi Z., Boucher C., Brockmann E., **Bruyninx C**., Caporali A., Gurtner W., Hornik H., Kenyeres A., Makinen J., V. D. Marel H., Simek J., Ihde J., Habrich H., Stangl G., Seeger H., Weber G.
Status of the European Reference Frame (EUREF)
IUGG General Assembly, July 2-13, 2007, Perugia, Italy

[9] Ihde J., Altmamimi Z., **Bruyninx C**., Torres J.A., Weber G.
EUREF- the continental ITRF and IGS densification in Europe
International Committee on Global Navigation Satellite Systems (ICG), Sept. 4-7, Bangalore

[10] **Bruyninx C., Legrand J**.
Sensibility of the reference frame definition in a regional network (poster)
AGU Fall Meeting 2007, December 10-14, 2007, San Francisco, US

[11] **Legrand J**., Altamimi Z. and Jamet O.
Explicit Application of the No-Net-Rotation Condition Using ITRF2005 Velocity Field
AGU Fall Meeting 12007, December 10-14, 2007, San Francisco, US

Websites

- The EPN CB website http://epncb.oma.be/ has been improved: all web pages are now fully dynamical reducing the number of web pages by 50%. Also the first interactive plots have been introduced. Each month, more than 3000 unique visitors access the EPN CB web site.
- The web-site http://www.gps.oma.be/ has received during 2007 a monthly average of 2500 unique visitors.
- A new web site http://www.epncb.oma.be/EUREF2008 was created in preparation of the EUREF 2008 symposium which will be organized by ROB, NGI and RMA in Brussels in June 2008.

B.1.8. Missions

Assemblies, symposia (number):	C. Bruyninx (1), N. Bergeot (1), J. Legrand (4), E. Pottiaux (1), F. Roosbeek (1)
Commissions, working groups (days):	C. Bruyninx (5)
Research visits (days):	C. Bruyninx (6), J. Legrand (4)
Field missions (days):	D. Mesmaker (1), A. Moyaert (3), F. Roosbeek (2)

C. Research Theme "Rotation and internal structure of the Earth and the other planets"

The research aims at better understanding the rotation of the Earth and of the other terrestrial planets or satellites, their interior, and the relation between their rotation and their interior.

C.1. Research project "Earth Rotation"

C.1.1. Objectives

Long-term objectives: to understand and model the Earth rotation changes and orientation variations i.e. length-of-day, precession, nutations, librations, and polar motion; to understand the associated physics of the Earth interior and the interaction between the solid Earth and the geophysical fluids.

C.1.2. Progress and results

C.1.2.1. Analysis of VLBI data

- Very Long Baseline Interferometry (VLBI) measures differential arrival time of radio signals from distant radio sources (e.g., quasars) on antennas located quite uniformly on the continents. Although very distant, these radio sources are not point-like and are not observed on a regular basis. A global data reduction to determine astrometric positions of all radio sources can lead to an unstable celestial reference frame. By unstable, we mean rotating and with axes randomly moving. The goals of the study performed during the year 2007 were (i) to quantify the effect of the celestial frame instability propagated in the Earth Orientation Parameters (EOP) determinations, and (ii) to quantify the propagation of the effect from EOP to the most sensitive geophysical parameters (e.g., resonant frequencies of the outer and inner cores, or Free Core Nutation (FCN) and Free Inner Core Nutation (FICN), that are commonly adjusted on the observed nutation amplitudes). In practice we generated several VLBI global solutions, analyzing VLBI delays accumulated from 1984 to 2007, and using different constraints on the radio source positions, to obtain nutation offset time series. Then we analyzed the nutation time series obtained from each global solution, from which we extracted some prominent spectral components reflecting non rigid Earth's response to the external tidal potential. Finally we deduced values of the outer and inner core resonant frequencies from each solution. We showed that the error propagated in VLBI analysis due to instability in the celestial reference frame can produce an additional error in the estimates of nutation spectral components of 15 μas for the 18.6-yr term, and decreasing for shorter periods. This led to an uncertainty of a few tenths of day on the FCN period and of less than 200 on its quality factor, and an uncertainty of roughly 100 days on the FICN period and of 100 on its quality factor. The values yielded for the outer and inner core resonant frequencies are nevertheless close to the MHB values within the error bars. See papers published [2, 4, 16, 17] and in press [19, 23].
- From VLBI nutation series, one can derive information on the fluid core, such as the resonant frequency associated with the retrograde FCN. This frequency has been determined, along with other parameters, in recent literature. The values are not always the same and we have thus tried to understand the reason for that. We have looked at the sensitivity of the FCN frequency with respect to three factors not considered before: the state-of-the-art VLBI analysis strategy, the effect of possible changes with time, and the atmospheric contribution. For that purpose, we have used several geodetic VLBI nutation data sets, we have estimated the amplitudes of various forced nutations, from which we have deduced the resonant FCN frequency (see Figure 13 for the period and quality factor of the FCN); time stability has been checked using a sliding window. We have shown that the resonant period is stable within half a day from one VLBI data set to another. Atmospheric

contribution has been assessed using the 6-hr NCEP/NCAR Reanalysis data and we have found important effects on the amplitude of the nutation and even an impact on the geophysical parameters determined from nutation. This work has been published [2].

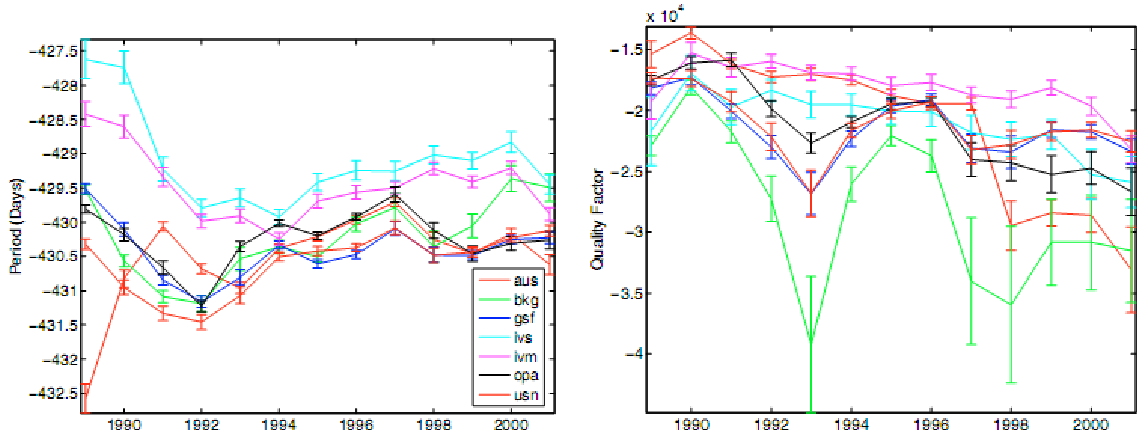

Figure 13. Time variation of the estimates of the period and quality factor the FCN from VLBI residuals for different VLBI nutation series.

- We have estimated the Earth interior parameters from precession and nutation observations in the time domain, in collaboration with O. de Viron (IPGP, France). We have studied how well the parameters can be retrieved from two approaches:

  (1) The Earth interior parameters are estimated from the nutation amplitudes which are determined from the VLBI data time series.

  (2) The Earth interior parameters are estimated directly from the nutation data time series. We use a probabilistic (Bayesian) inversion method as it does not require the model to be linear and allows for an easy incorporation of the model uncertainties. This allows to use all the available information of the data time series and to take into account the time variable error on the data.
- We have compared the estimation of the parameters and determined realistic error bars that can be derived from the a priori knowledge of the data uncertainties. We have shown that, in particular for the inner core parameters, the error on the adopted parameter values, were underestimated (see Figure 14).
- In addition to the forced nutation due to the gravitational torque, a free oscillation due to the excitation of the free FCN (Free Core Nutation) mode by the geophysical fluids can be observed in the data. We have estimated the time-dependent amplitude of this oscillation by means of the least-squares method on a sliding window. Our estimation of the time-dependent amplitude of the free mode is in agreement with that performed by Herring et al. (2002) and with the values obtained above.
- See Papers [18, 21, 24].

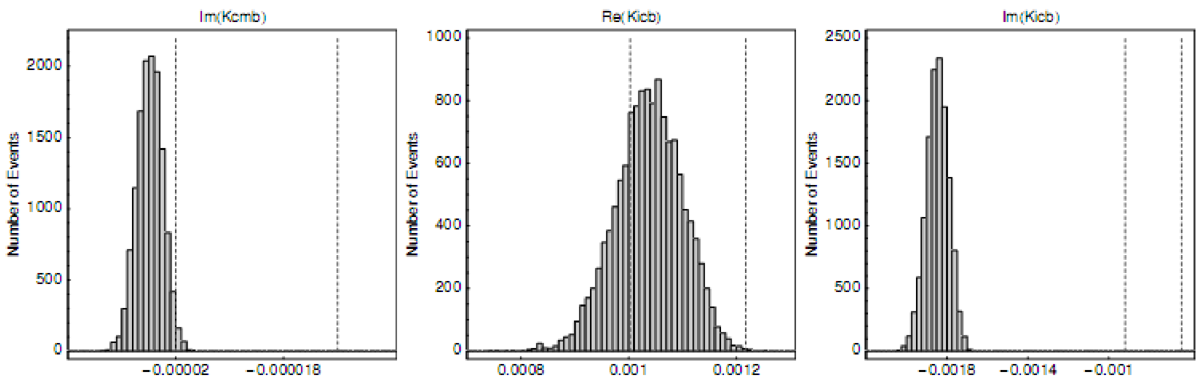

Figure 14. Empirical marginal posterior distributions for the coupling constants, obtained from the Bayesian inversion of the nutation data. The dashed vertical lines represent the 3-σ range of values obtained by Mathews et al. (2002).

C.1.2.2. Theory of nutation

- The tidal potential generated by bodies in the solar system contains Poisson terms, i.e., periodic terms with linearly time-dependent amplitudes. The influence of these terms in the Earth's rotation, although expected to be small, is of interest for high accuracy modeling, and has thus has been computed. Starting from Liouville's equations (conservation of angular momentum), and following an analytical treatment, we have obtained the relations accounting for Poisson terms in the forcing and providing the solution for the wobble. We have shown that the transfer function for nutations must be supplemented by additional terms proportional to the amplitude of the Poisson term of the potential. The highest contribution to the nutation is at the level of several microseconds. A contribution to the obliquity rate at the level of 88 µas/cy is found as well. This work has been done in collaboration with Marta Folgueira. Paper published [1] and in press [22].
- A new nutation model and a new evaluation from observation of the geophysical parameters have been presented by G. Krasinski (Institute of Applied Astronomy, Saint Petersburg, Russia). In collaboration with N. Capitaine (Observatoire de Paris) and S. Mathews (Madras University, India), we have carefully examined and found important errors and misunderstanding in this new theory. We have commented this in a paper available on ArXiv (astro-ph). Paper [9].
- We have worked with M. Folgueira (Univ. Complutense de Madrid, Spain) on the topographic coupling at the core mantle boundary and we have developed an analytical approach to compute the effects on the FCN and on the nutation. Paper in press [20].
- We have continued our work in collaboration with C. Huang (Shanghai Observatory, China) on the electromagnetic coupling at the CMB and its effects on nutation. Paper published [15].

C.1.2.3. Numerical integration for nutation

- Second order/non-linear effects on nutation have been studied by using a numerical integration of a simple non-linear Earth rotation model. The inertial and visco-magnetic couplings have been introduced in the numerical model in order to obtain a more complete response of the Earth to the forcing including the planetary interactions. We have analyzed the nutation amplitude in the time domain for the solid Earth and the core in continuation of the work done last year. Nutations of the whole Earth from this numerical integration method have been obtained. The results of this fully non-linear method for nutation in the time domain, which includes inertial and visco-magnetic core-mantle boundary couplings, have been compared with the precise analytical solutions. A paper is in preparation and another is accepted [25].

- We have analyzed the impact of plate tectonics on the CMB flattening and therewith on the FCN period and examined the range of possible FCN period values. We have computed the resonance effects on the nutation in the time domain. A paper is in preparation.
- We have analyzed the impact of Earth rotation changes and coupling mechanisms at the CMB (in particular the electromagnetic coupling) on the FCN resonance and we have examined the changes in the amplitude of the Earth response to planetary forcing, i.e. the changes in the nutation amplitudes, induced by this resonance in the Earth history. We have found that the increase of nutations due to the resonance is very small below 50 milliarcseconds. A paper is in preparation.

C.1.2.4. Book and review paper on nutation

- We have worked in collaboration with S. Mathews (Madras Univ., India) on an invited paper for the Treatise of Geophysics. This paper has been revised and published. Paper published [3].
- We have advanced in the preparation of the final version of the book on 'Precession, Nutation, and Wobble of the Earth' (in collaboration with S. Mathews, Madras Univ., India).

C.1.3. Perspective for next years

C.1.3.1. Analysis of VLBI data

- In collaboration with Observatoire de Paris, we shall examine in full detail the observed nutation series for a better determination of their amplitudes. We shall work in particular on the first step in a combination between GNSS data and VLBI data.
- We shall finish and publish the work on the estimation of the Earth interior parameters from a time domain approach applied on the VLBI precession and nutation observations, in collaboration with O. de Viron (IPGP, France).
- We shall finish and publish the work on the estimation of the amplitude of the free FCN mode jointly with the geophysical parameters, in the Bayesian framework already developed, in collaboration with O. de Viron (IPGP, France).
- From the Bayesian inversion of the VLBI data, we shall estimate the "compliances" describing the ability of the Earth and fluid core to deform under several forcings. We plan to interpret these estimated compliances in terms of Earth interior properties such that, for example, anelastic properties of the mantle.
- We shall work on the computation of the atmospheric contribution to nutations in order to be able to better correct prior to our VLBI-based geophysical parameter determinations, in collaboration with O. de Viron (IPGP, France).

C.1.3.2. Theory of nutation

- We shall finish the work with M. Folgueira (Univ. Complutense de Madrid, Spain) on the topographic coupling at the core mantle boundary and we have developed an analytical approach to compute the effects on the FCN and on the nutation.
- A paper on the influence of electromagnetic core-mantle coupling on the rotation of the Earth will be finished (in collaboration with ChengLi Huang).
- We shall begin the computation of nutation (and libration) for a triaxial planet. A numerical method to calculate rotation variations of a planet with a bi-axial ellipsoidal form will be extended to include tri-axial planets. This method will serve to determine a more accurate theoretical nutation series for the Earth and to study accurately the librations of Mercury and the large synchronously-rotating natural satellites (see part research on planets).
- We shall finish the book on Nutation with S. Mathews (Univ. Madras, India).

C.1.3.3. Theory of long term Earth rotation

- We shall finish the work on the electromagnetic coupling at the core mantle boundary and its effect on the Earth history in collaboration with Nicolas Rambaux (IMCCE, Observatoire de Paris).

C.1.4. Personnel involved

Scientific staff: V. Dehant, S. Lambert, L. Koot, T. Van Hoolst

Technical staff: R. Laurent, L. Van Camp

C.1.5. Partnerships

List of international partners without grant

- P.M. Mathews, Department of Theoretical Physics, Univ. of Madras, India
- M. Folgueira-Lopez, Universidad Complutense de Madrid, Spain
- S. Lambert, N. Rambaux, and N. Capitaine, Observatoire de Paris, France
- O. de Viron, IPGP, France

Grants/Projects used for this research/service

- BELSPO-Action 1, 1-MO/33/013, Interaction planète-couches fluides : Effet sur la rotation planétaire, S. Lambert
- FNRS Aspirant, L. Koot
- EU, Descartes Prize 2003, M. Folgueira (visits), N. Rambaux (6 months)

Visitors:

- O. de Viron, IPGP, France, 2-3 January
- M. Folgueira-Lopez, Universidad Complutense de Madrid, Spain, 1 March-31 March, 16-20 July

C.1.6. Publications

C.1.6.1. Publications with peer review

[1] **Folgueira M., Dehant V., Lambert S.B., Rambaux N**.
Impact of tidal Poisson terms to non-rigid Earth rotation,
Astron. Astrophys., 469(3), pp. 1197-1202, DOI: 10.1051/0004-6361:20066822.

[2] **Lambert S.B., Dehant V**.
The Earth's core parameters as seen by the VLBI,
Astron. Astrophys., 469, pp. 777-781, DOI: 10.1051/0004-6361:20077392.

[3] **Dehant V.,** Mathews M.P.
Earth Rotation Variations,
In: Treatise of Geophysics, invited paper, Elsevier Publ., Vol. 3 'Geodesy', eds. T. Herring and J. Schubert, pp. 295-349.

[4] Souchay J., **Lambert S.B.**, Le Poncin-Lafitte C.
A comparative study of rigid Earth, non rigid Earth nutation theories and observational data,
Astron. Astrophys., 472, pp. 681-689, DOI: 10.1051/0004-6361:20077065.

[5] Le Poncin-Lafitte C., **Lambert, S.B.**
Numerical study of relativistic frequency shift for cold-atom clock experiments in space,
Class. Quantum Grav., 24(4), pp. 801-808, DOI: 10.1088/0264-9381/24/4/003.

C.1.6.2. Publications without peer review

[6] Capitaine C., Andrei A.H., Calabretta M., **Dehant V.**, Fukushima T., Guinot B., Hohenkerk C., Klioner S., Kovalevsky J., Kumkova I., Ma C., McCarthy D.D., Seidelmann P.K., Wallace P.
Report of Division I Working Group on 'Nomenclature for Fundamental Astronomy' (NFA),
In: IAU Transactions, Vol. 26A, Reports on Astronomy 2002-2005, Ed. O. Engvold, Cambridge University Press, pp. 59-62, DOI: 10.1017/S1743921306004340.

[7] **Dehant V.**, Brzezinski A., Capitaine N., Dickey J., Fukushima T., Gambis D., Gross R., Hefty J., Huang C., Ma C., Malkin Z., Poma A., Ray J., Richter B., Ron C., Rothacher M., Sidorenkov N., Soffel M., Vondrak J.
Report of Commission 19 on Earth Rotation and Reference System,
In: IAU Transactions, Vol. 26A, Reports on Astronomy 2002-2005, Ed. O. Engvold, Cambridge University Press, pp. 29-50, DOI: 10.1017/S1743921306004315.

[8] Fukushima T., Vondrak J., Capitaine N., **Dehant V.**, Krasinsky G., Matsakis D., Milani A., Platais I.
Report of Division I: Fundamental Astronomy,
In: IAU Transactions, Vol. 26A, Reports on Astronomy 2002-2005, Ed. O. Engvold, Cambridge University Press, pp. 1-1, DOI: 10.1017/S174392130700107X.

[9] Mathews P. M., Capitaine N., **Dehant V.**
Comments on the ERA-2005 numerical theory of Earth rotation,
Reprint arXiv:0710.0166, 12 p., DOI: 2007arXiv0710.0166M.

[10] Rummel R., Beutler G., **Dehant V.,** Gross R., Ilk K.H., Plag H.-P., Poli P., Rothacher M., Stein S., Thomas R., Woodworth P.L., Zerbini S., Zlotnicki V.
Understanding a dynamic planet: Earth science requirements for gravimetry,
In: The Global Geodetic Observing System: Meeting the requirements of a global society on a changing planet in 2020, the Reference Document GGOS-2020, May 2007, pp. 54-61.

[11] Zumberge J.F., Border J.S., **Dehant V.,** Folkner W.M., Jones D.L., Martin-Mur T., Oberst J., Williams J.G., Wu X.
Geodesy: foundation for exploring the planets, the solar system and beyond,
In: The Global Geodetic Observing System: Meeting the requirements of a global society on a changing planet in 2020, the Reference Document GGOS-2020, May 2007, pp. 95-100.

[12] **Dehant V**.
Report of Commission 3 on Earth Rotation and Geodynamics,
Geodesist's Handbook, J. Geodesy, 78(9-12), Part Commission reports, Commission 3, 10 p; also in: IAG Travaux, publication on the web, Part Commission reports, Commission 3, 17 p.

[13] **Dehant V.**, de Viron O., Capitaine N.
The 3D representation of the new transformation from the terrestrial to the celestial system,
In: Proc. JD 16, IAU XXVI General Assembly, Prague, 14-25 August, 2006, Highlights of Astronomy, Vol. 14, Cambridge University Press, pp. 486-486, DOI: 10.1017/S174392130701160X.

[14] Capitaine N., Andrei A., Calabretta M., **Dehant V.,** Fukushima T., Guinot B., Hohenkerk C., Kaplan G.H., Klioner S.A., Kovalevski J., Kumkova I.I., Ma, C., McCarthy D.D., Seidelmann K.P., Wallace P.T.
Proposed terminology in fundamental astronomy based on IAU 2000 resolutions,
In: Proc. JD 16, IAU XXVI General Assembly, Prague, 14-25 August, 2006, Highlights of Astronomy, Vol. 14, Cambridge University Press, pp. 474-475, DOI: 10.1017/S1743921307011490.

[15] Huang C.-L., **Dehant V.**, Liao X.-H., de Viron O., **Van Hoolst T.**
Does The Magnetic Field In The Fluid Core Contribute A Lot To Earth Nutation?
In: Proc. JD 16, IAU XXVI General Assembly, Prague, 14-25 August, 2006, Highlights of Astronomy, Vol. 14, Cambridge University Press, pp. 483-483, DOI: 10.1017/S174392130701157X.

[16] **Lambert S.B.,** Bizouard C., **Dehant V.**
The winter dance of the Earth's pole,
In: Proc. SF2A 2006, Eds. D. Barret, F. Casoli, T. Contini, G. Lagache, A. Lecavelier, and L. Pagani, extended abstract, pp. 31-32.

[17] **Lambert S.B., Gontier A.-M., Dehant, V**.
Some issues about the Earth's core and inner core through VLBI
In: J. Boehm et al. (Eds.), Proc. 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universitaet Wien, 206-208.

C.1.6.3. Publications in press, submitted

[18] **Dehant V**., **Lambert S.B., Rambaux N**., Folgueira M., **Koot L.**
Recent advances in modeling precession-nutation,
In: Proc. Journées Systèmes de Références Spatio-temporels, Paris, France September 2007, Ed. N. Capitaine, in press.

[19] **Lambert S.B., Dehant V.,** Gontier A.-M.
Some issues in the Earth's interior exploration with VLBI
In: Proc. Journées Systèmes de Références Spatio-temporels, Paris, France September 2007, Ed. N. Capitaine, in press.

[20] Folgueira M., **Dehant V.**
Estimation of the topographic torque at the core-mantle boundary on the nutation,
In: Proc. Journées Systèmes de Références Spatio-temporels, Paris, France September 2007, Ed. N. Capitaine, in press.

[21] **Koot L., Rivoldini A.**, de Viron O., **Dehant V.**
Estimation of Earth interior parameters from a Bayesian inversion of nutation time series
Proceedings des Journées Systèmes de Référence spatio-temporels 2007, in press.

[22] **Dehant V.**, Folgueira M., **Rambaux N., Lambert S.B.**
Contributions of tidal Poisson terms in the theory of the nutation of a nonrigid Earth,
In: IUGG proceedings Perugia, Italy, in press.

[23] **Lambert S.B., Dehant V.,** Gontier A.-M.
Celestial frame instability in VLBI analysis and its impact on geophysics,
Astron. Astrophys., in press.

[24] **Koot L., Rivoldini A., de Viron O., Dehant V**.
Estimation of Earth interior parameters from a Bayesian inversion of VLBI nutation time series,
J. Geophys. Res., accepted.

[25] **Rambaux N**.
Centrifugal librations of Earth's rotation,
Astron. Astrophys., accepted.

C.1.7. Scientific outreach

Meeting presentations

[1] **Lambert S.B.,** Gontier A.-M., **Dehant V**.
Some issues about the Earth's core and inner core through VLBI
18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, Vienna, Austria, April 12-13, 2007.

[2] **Dehant V., Lambert S**.
Physics of the Earth outer core and inner core from VLBI,
AGU Spring Meeting, Invited oral presentation, Acapulco, Mexico, May 2007.

[3] **Dehant V**.
Report of activities of Commission 3 on Geodynamics and Earth Rotation,
IUGG General Assembly, Perugia, Italy, July 2-14, 2007.

[4] Folgueira M., **Rambaux N., Lambert S., Dehant V**.
Second order Poisson terms in the non-rigid Earth nutation theory,
IUGG General Assembly, Perugia, Italy, July 2-14, 2007.

[5] **Dehant V., Lambert S.B.,** Gontier A.-M.
VLBI analysis strategy and geophysical parameters,
IUGG General Assembly, Perugia, Italy, 2-14 July, 2007.

[6] **Dehant V**.
Contribution to theory from Commission 3 on Geodynamics and Earth Rotation,
IUGG General Assembly, Perugia, Italy, July 2-14, 2007.

[7] **Dehant V**.
Report of the convener of Session GS003 on Geodynamics and Earth Rotation,
IUGG General Assembly, IAG Closing Ceremony, Perugia, Italy, July 2-14, 2007.

[8] **Koot L., Rivoldini A.,** de Viron O., **Dehant V**.
Estimation of Earth interior parameters from a Bayesian inversion of nutation data in the time domain,
Journées Systèmes de Référence Spatio-temporels, Paris, France, September 17-19, 2007.

[9] **Dehant V.,** de Viron O.
Necessary improvements of ocean models to meet the needs of geodesy,
SLIM annual meeting, October 5, 2007.

[10] **Koot L., Rivoldini A.,** de Viron O**., Dehant V**.
Les nutations et la structure interne de la Terre,
Colloque du Groupement de Recherche G2, Grenoble, France, November 21-23, 2007.

Websites

- Updating of website on Earth rotation
- T. Van Hoolst: Responsible for the SBC website

C.1.8. Missions

Assemblies, symposia (number):	V. Dehant (4), L. Koot (1), T. Van Hoolst (1), S. Lambert (2)
Commissions, working groups (days):	S. Lambert (1)
Research visits (days):	V. Dehant (2), L. Koot (2)
Field missions (days):	V. Dehant (7)

C.2. Research project: “Geodesy and Geophysics of Terrestrial Planets”

C.2.1. Introduction

Although it is generally accepted that the interior of the four terrestrial planets is similar to that of the Earth, even basic questions on the global interior structure and composition of Mercury, Venus, and Mars remain unanswered. The Earth’s interior structure has been successfully investigated through the analysis of the propagation of seismic waves in the Earth’s solid and liquid internal layers. For lack of seismometers on the other planets – though they are planned for Mars and some seismic data on the Moon has been obtained by the Apollo missions – planetary geodesy is one of the primary means for probing the interior structure of planets. At ROB, Section 1 is involved in studies of the gravity field and rotation of terrestrial planets and large natural satellites.

The gravity field of planetary bodies can best be studied through the precise monitoring of the trajectory of passing or orbiting spacecrafts. Because the gravity field of a planet is determined by the planet’s internal mass distribution, spatial and temporal variations in the gravity field can be used to determine physical properties of the planet. Since the beginning of the space age, the large-scale structure of the gravity field of planets and moons has been successfully used to determine the moment of inertia, which is a measure of the radial density distribution. The moment of inertia is considered as one of the major constraints on the interior structure of planets and large moons. Constraints on planetary interiors can also be obtained from rotation variations. Three broad classes of rotation variations are usually considered: rotation rate variations, orientation changes with respect to inertial space (precession and nutation), and orientation changes with respect to the rotation axis (polar motion). They are due to both internal (angular momentum changes between solid and liquid layers) and external (gravitational torques) causes. By studying rotational variations of a terrestrial planet, more can be learnt about the excitation processes. Moreover, as the rotational response depends on the planet’s structure and composition, also insight into the planetary interior can be obtained. This is particularly so for the rotational variations due to well-known external gravitational causes, such as for example for the nutations of Mars and the libration of Mercury.

The geophysical interest of these studies is to improve our knowledge of the interior, atmosphere, and dynamics of rocky planets and large natural satellites. For that purpose, we investigate the relation of rotation variations, gravity field, and tidal variations with interior and atmosphere properties and orbital motion characteristics. These studies rely on theoretical developments as well as on analyses of radio tracking data of spacecrafts in orbit around or landed on these planets or satellites.

C.2.2. Objectives

ESA’s Mars Express mission to Mars has started its science phase in January 2004, and we are involved in its radio-science experiment MaRS (at Co-I level). Our main objectives are to determine accurate gravity maps of selected areas on Mars for a better understanding of properties of the crust and lithosphere and to obtain the time-variable part of the low-degree gravity field for studies of Mars’ interior.

BepiColombo is an ESA mission to Mercury scheduled for launch in 2013. Our group is involved at Co-I level in the radio science, the altimeter, and the camera teams. The radio-science experiment will measure Doppler shifts of radio links between the Earth and the lower of two Mercury orbiters (MPO) of the BepiColombo project. From the three experiments, the rotation variations (called librations) and gravity field of Mercury will be determined. The results will be used to determine the interior structure and dynamics of the innermost planet of our solar system. A point of main interest is the determination of the physical state (liquid or solid) and size of Mercury’s core, which will have large implications for our knowledge of the formation and evolution of terrestrial planets. In 2007, we have focused on theoretical studies of the rotation, interior and gravitational field of Mercury, and have performed numerical simulations of the mission. We have also extended theses studies to large satellites of the Solar System.

For the interpretation of gravity and rotation data in terms of interior properties, models of the interior structure and composition of terrestrial planets and large moons are an essential requirement. A major objective therefore is the development of interior structure models of terrestrial planets. For that purpose, we use recent data on material properties at high pressure and temperature.

We have continued preparations for the radio-science experiment LaRa of the future ExoMars mission to Mars. In particular, technical studies for the development of an X-band transponder and antenna have started in collaboration with the Belgian company OMP and with CSL.

C.2.3. Progress and results

C.2.3.1. Mars: General space mission results

- A review of the Mars Express Orbiter Radio Science (MaRS) Experiment, in which we collaborate at Co-I level, has been published [29].
- We are involved at Co-I level in a proposal for a future mission to Mars called MEMO (Mars Escape and Magnetic Orbiter), which has been retained as a NEXT mission for the AURORA program of ESA [19, 25, 37, 38, 45].
- We are involved in the Science Definition Team (SDT) of the MarsTwin mission proposal, which has been retained as a NEXT mission for the AURORA program of ESA [44]. MarsTwin is a network of landers equipped with geophysical and geodetic instruments, and includes a radio-science experiment. The mission has been combined with MEMO and has been selected by ESA for Phase A study.

C.2.3.2. Mars: MEX data processing

- Our Mars data base consists of radio tracking data of several space missions and their associated ancillary data. About 300 shell and fortran codes have been developed over time to manage and process them. In 2007, the codes for processing Venus Express (VEX), Mars Global Surveyor (MGS), and Mars Reconnaissance orbiter (MRO) data have been written. Several tools for automatic data handling have been developed (see [58]).
- For the analysis of the data we use the GINS/DYNAMO orbitography codes (developed by GRGS/CNES and being continuously adapted to planetary applications at ROB), which allows obtaining the orbit of the spacecraft, the global gravity field, and its time variations.
- All MEX tracking data until the end of 2007 have been collected, archived and processed for inclusion in the GINS/DYNAMO codes.

C.2.3.3. Mars: LaRa

- The lander platform of the ExoMars mission will house a radio-science experiment called LaRa (Lander Radioscience). The official selection of LaRa as part of the ‘Humboldt’ payload on the lander platform has been decided in 2007. LaRa has been designed to transpond an X-band signal transmitted from the Earth ground stations back to the Earth. The relative radial velocity between the Martian lander and the Earth is inferred from Doppler effects measured at the Earth ground stations and will be used to determine accurately the rotation of Mars. First versions of the “LaRa Interface Document” and the “LaRa Instrument Requirements” have been sent out to ESA to outline the interfaces with the platform and the generic performances desired. In close collaboration with CSL, a statement of work has been established for the industrial partner responsible for developing LaRa. The proposal contract (phase B) and associated planning have been defined including all activities needed to reach the PDR (Preliminary Design Review) milestone. A detailed project structure and documents have been drafted to improve the communication between the different partners of the consortium and to manage efficiently the current critical issues (see [46-57]).

- We have studied in detail the link budget of LaRa. The main objective of this link budget analysis is to identify and include all the significant contributions to the radio link. The required factors include the performance of LaRa itself, the configuration and performance of the uplink and downlink Earth
- ground stations (DSN 70m/34m) and the impact of the propagation medium in the frequency band of interest (X-band).
- We have performed preliminary numerical simulations of the Doppler measurements in order to quantify the precision that can be obtained on the orientation of Mars. Therefore, GINS software routines have been developed and implemented for a direct-to-Earth radio link by (1) modelling the direct-to-Earth Doppler measurements between a Martian lander and the tracking stations on the Earth, (2) implementing this model in the software, (3) coding and validating the partial derivatives of the Doppler data with respect to the lander position and the Mars orientation parameters.

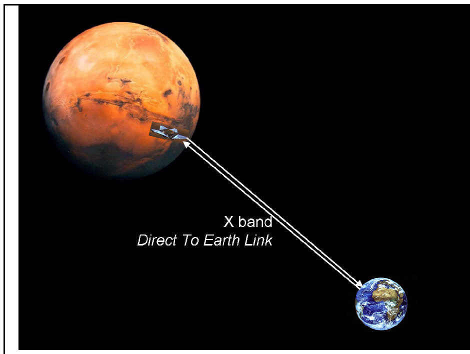

Figure 15. X-band radio link between the lander at the surface of Mars and the ground stations on Earth.

- With the same codes developed, we have started processing the direct-to-Earth data from the Mars Pathfinder and Viking lander missions.

C.2.3.4. Mars: crust and lithosphere

- The investigation of the internal structure of the Martian crust and lithosphere is conducted by performing gravity observations during the pericenter passage of the Mars Express spacecraft in its orbit around Mars. In 2007, there was no new pass above the Tharsis area, which is the focus of our work on Mars, and we have treated a series of more than 100 unofficial MEX gravity passes, dating between 2004 and 2006. These data are widely dispersed on Mars and are generally not of sufficient quality to influence the estimates of geophysical parameters. Targeted gravity data on Venus remains scarce, with only two successful passes in 2006 and none in 2007.
- New tools for the use of gravity data in the investigation of the lithospheric structure of telluric planets have been developed. Part of the theoretical progress has been published in a paper [26] on the theory of the deflection of a spherical thin shell with varying rigidity. A numerical code for the solution of the flexure equations derived in the above paper has been optimized and extended to include lateral loading, which cannot be neglected when computing stress fields.
- Preliminary stress and strain maps for various types of loading and compensating mechanisms have been generated.

C.2.3.5. Mars: interior structure, rotation and tides

- An extended invited review paper on the rotation of the terrestrial planets has been written and published in the Elsevier reference work 'Treatise on Geophysics' [17].
- A brief overview of the use of rotation variations for the determination of properties of the interior and atmosphere of Mars has been published [11].
- A paper on the modelling of the electrical conductivity of iron-rich minerals has been published [1].
- In collaboration with Christophe Monnier and Pierre Vacher (Nantes University), a procedure has been developed to compute the oxide composition of crustal rocks, which are produced as partial melts of the mantle.
- Two papers on the physics of bodily tides in terrestrial planets have been published [8, 10].
- The interior structure models of Mars have been updated to incorporate the most recent data on thermoelastic properties of liquid metal alloys and their melting properties. Our model results show

that the published geodetic data on Mars imply an entirely liquid core with radius of about (1720±50) km.

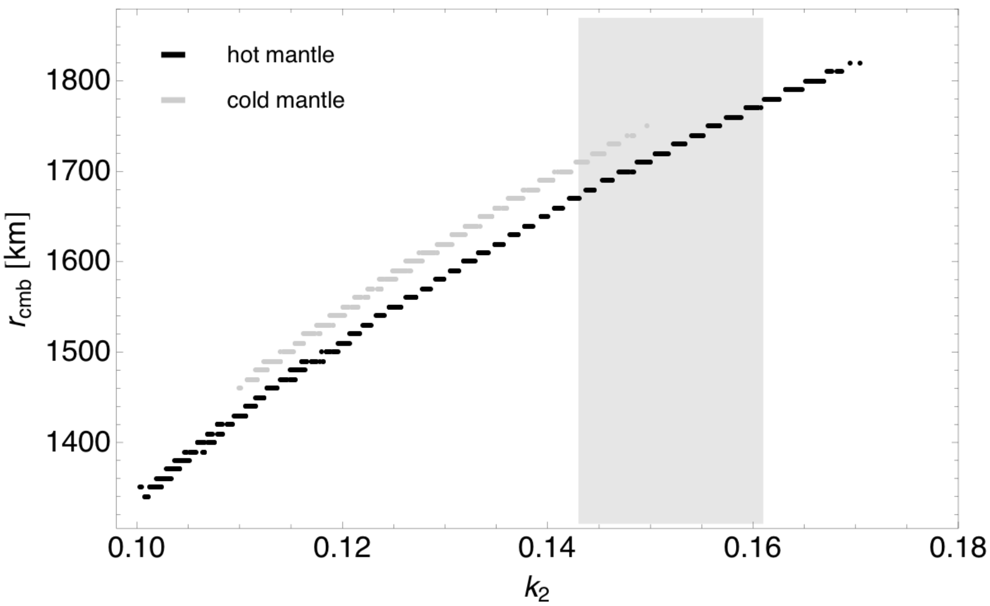

Figure 16. Core radius as a function of the k2 Love number for hot (black) and cold (grey) mantles, for different crust densities and thicknesses, for different core sulfur fractions, and for the two mantle mineralogies. The horizontal dimension of the grey shaded area corresponds to the uncertainty on the k2 value of Konopliv et al. (2006). An increase of that precision as expected with LaRa will further constrain the core radius.

- We have shown that the new interior models lead to significantly larger nutation amplitudes than did previous basic interior models, which had a smaller core.
- From an analysis of eight years of MGS/Odyssey tracking data, we have obtained a degree-two Love number k_2 of about 0.12, which is lower than recent American estimates of about 0.15. This value indicates that Mars has a liquid core. The difference between the estimates reflects that the Love number cannot be accurately determined yet because of its small effect on spacecraft dynamics. A similar study on MGS tracking data has been published [3, see also 65].
- Our model for the joint inversion of geodetic, seismic, and electromagnetic data in terms of mantle temperature and composition has been extended to allow for uncertainties on thermoelastic properties of mantle minerals. We have found that most of the estimated parameter values, with the exception of the temperature values in the lowest part of the mantle and the global volume fraction of the mineral olivine, are quite robust with respect to the introduced uncertainties on the mineral data.
- A study has been finished and submitted for publication on the use of the MOLA altimeter onboard the MGS spacecraft to determine Mars' rotation variations [39]. It has been shown that altimeter data at ground track crossing points can be used to detect the nutations of Mars. Information on the Martian core, which is contained in the nutations, is difficult to retrieve because the core contribution to nutations is at the level of the accuracy of the method. Simulations also demonstrate that the observational determination of the libration amplitude and obliquity of Mercury can be improved by using the BELA laser altimeter of the BepiColombo mission to Mercury.

C.2.3.6. Mars: atmosphere and polar caps

- A paper has been published on the atmospheric escape and habitability with particular emphasis on the effect of the magnetic field evolution on the Martian climate [7, see also 22].

- In a semi-analytical approach, the effect of impacts on the atmospheric evolution of Mars has been studied. Meteorite impacts cause atmospheric erosion but also deliver material and volatiles to the planet. We have shown that meteorite impacts alone cannot explain the possible existence of a denser atmosphere on the early Mars [43].
- Participation in a review paper on the habitability of Mars in collaboration with E. Javaux (ULg) [42].
- The variations in the seasonal and long-term (over the last 500 kyr) CO_2 and H_2O surface loadings have been calculated by using a Martian General Circulation Model (GCM) and the long-term insolation variations. These data were used to investigate the effect of the Martian interior on surface deformation and rotation variations of Mars. Only surface displacements can be used to infer estimates of the mantle viscosity of Mars with the present observational precision [35].
- A paper has been published on the effect of the internal structure of Mars on seasonal deformations due to loading [27].
- In a continuing study of the time-variable, low-degree gravity field of Mars, analysis of 8 years of MGS and ODY tracking data has resulted in a slightly smaller variation of the degree-three zonal gravity coefficient than published values using 6 years of tracking data. These gravity variations are geophysically interesting because they are linked with the CO_2 sublimation and condensation cycle of Mars' atmosphere. A similar study on a reduced set of MGS tracking data has been published [3, see also 65].

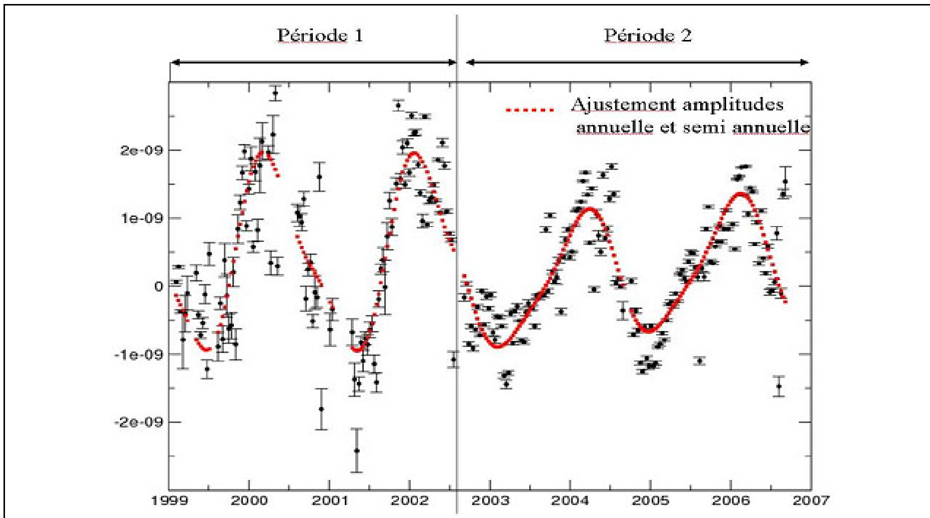

Figure 17. Determination of the δC_{30} from MGS and Mars Odyssey spacecraft.

- By using numerical simulations, we have shown that radio-tracking of an orbiter with orbital inclination of about 77 or 50 degrees in addition to the nearly polar orbiters would result in a 10 times better determination of the time-variable, low-degree gravity field of Mars than currently possible. This would allow accurately measuring the seasonal CO_2 mass exchange between the atmosphere and the polar caps.

C.2.3.7. Mars: moons

- A paper on the ephemerides of the Martian moons has been published [4].
- With M. Efroimsky (USNO, USA) and P. Gurfil (Technion, Israel) a paper has been published on the long-term evolution of orbits about a precessing oblate planet [5].
- We have shown on synthetic data that the main features of the interior density distribution in Phobos can be inferred from its mass and principal moments of inertia as the only data by using a numerical method with a discretization of the volume in 3D cuboids. This study prepares the analysis of future MEX radio-science data during close flybys of Phobos. See [63].

By improving the precision of the reconstructed MEX orbits around Mars by a factor of at least 2 with respect to the navigation orbit provided by the European Space Operation Center (ESOC), the mass of the largest of the two Martian moons Phobos has been determined with a better uncertainty than recently published by an American team using the Mars Global Surveyor (MGS) and Mars Odyssey (ODY) spacecraft. MEX is well-suited for these kinds of studies since it can pass closer to the moons than the other spacecraft on account of its far more elliptical orbit and it therefore is more sensitive to the gravitational attraction of the mass of the Martian moons. A paper on the Phobos mass and the improvement of the Phobos ephemeris has been submitted and accepted for publication [34, see also 32].

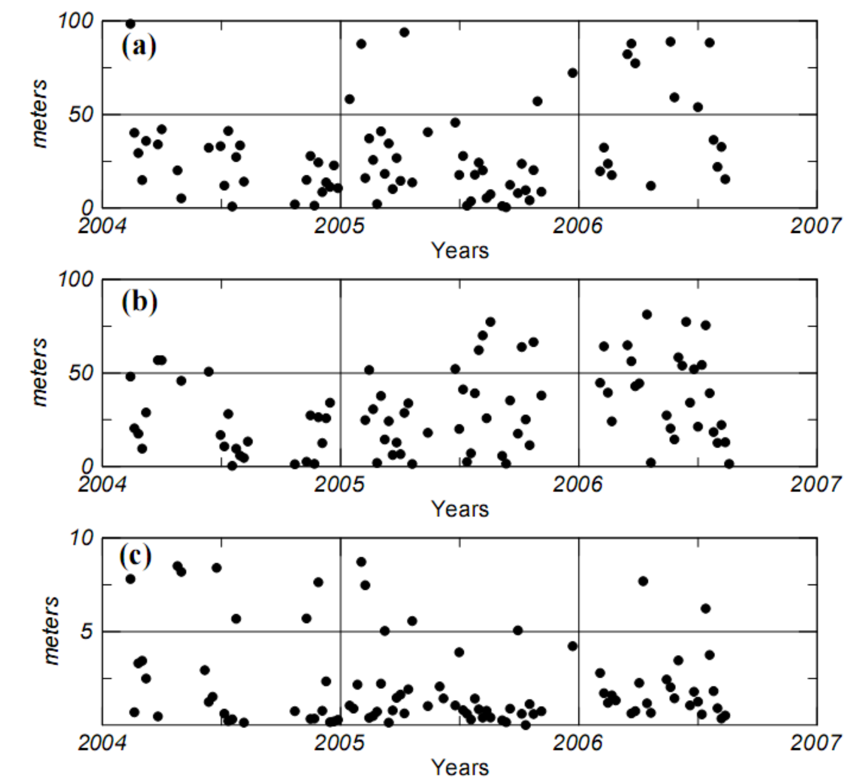

Figure 18. Rms value of the overlap differences. They correspond to the rms of the MEX position differences between successive 7 days data-arcs over overlap duration of 21 hours.
(a) along-track direction, (b) normal to the orbit plane, and (c) radial direction.

C.2.3.8. Mercury: interior structure

- An invited review paper on the interior structure, rotation, and tides of Mercury has been published [16].
- Mantle and crust mineralogies have been calculated from published geochemical models for Mercury. In collaboration with Pascal Tarits (Institut Universitaire Européen de la Mer, France), we have shown that, due to the very different oxide/silicate ratios, the geochemical models have very different electromagnetic signatures. As a result, future measurements with the magnetometers onboard the forthcoming MESSENGER and BepiColombo missions to Mercury will help differentiating between the models and will shed light on Mercury's formation.
- We have continued our efforts to develop state-of-the-art interior structure models of Mercury. The models are based on the mass and radius of Mercury and on assumptions on the core composition and mantle mineralogy, and incorporate the most recent data on thermoelastic properties of liquid metal alloys and their melting properties. The sensitivity of future geodetic observations of the rotation and tides of Mercury to key parameters of the interior (such as core size and composition) has been studied. This study will serve to specify required observational precisions for the BepiColombo mission to Mercury and to determine the interior structure of Mercury when rotation and tide results become available.
- The simulation of flow circulation in the core of Mercury has

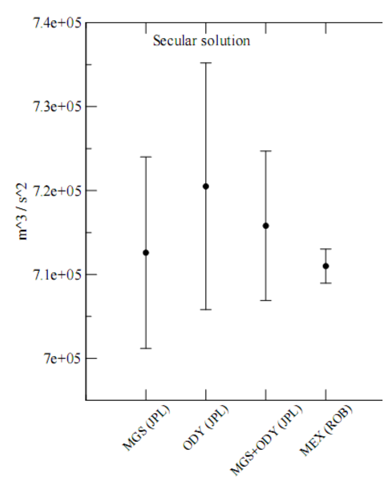

Figure 19. Our Phobos GM value (MEX(ROB)) compared with other published values.

been initiated with colleagues of ULB.

- We have computed the effects of tides on altimetry measurements from a spacecraft orbiting around a planet, and we have evaluated the possibility to deduce information on the interior of the planet from these measurements. The altimetry range measurement from an orbiting spacecraft has been expressed analytically as a function of the topography of the planet, its tidal radial deformations and the gravitational pull of the tidally distorted planet on the spacecraft position. Altimetric range measurements were simulated around Mars, Mercury and Europa, and the contribution of the tides was estimated at 1 m, 35 m and 30 m, respectively. Mission strategies were determined that maximize the tidal content of the data, which can be used to deduce information on the interior of the planet [64].
- We are involved at Co-I level in the laser altimeter experiment of BepiColombo (BELA), see [6]

C.2.3.9. Mercury: libration

- In collaboration with S. Peale (UCLA Santa Barbara) and J.-L. Margot (Cornell University), we have shown that planetary perturbations lead to forced librations in longitude with periods on the order of several years and amplitudes of several tens of arcseconds. We further showed that the measurement of the 88-day libration amplitude for the purposes of determining Mercury's core properties is not compromised by the additional librations, because of the latter's small amplitude and long period. The results have been published in Icarus [9].
- A study has been initiated to investigate the possible excitation of the free libration of Mercury. Although the free libration is expected to be damped on a relatively short time scale, recent observations by Margot et al. (2007) of Mercury's rotation suggest it to have a non-negligible amplitude. Preliminary results show that a resonant excitation of the libration would be possible if the period of the free libration is close to the orbital period of Jupiter (11.85 years).
- Papers on Mercury's libration [2, 24, 40], on Mercury's obliquity [13], and on the spin-orbit resonance and precession of Mercury have been published [14].

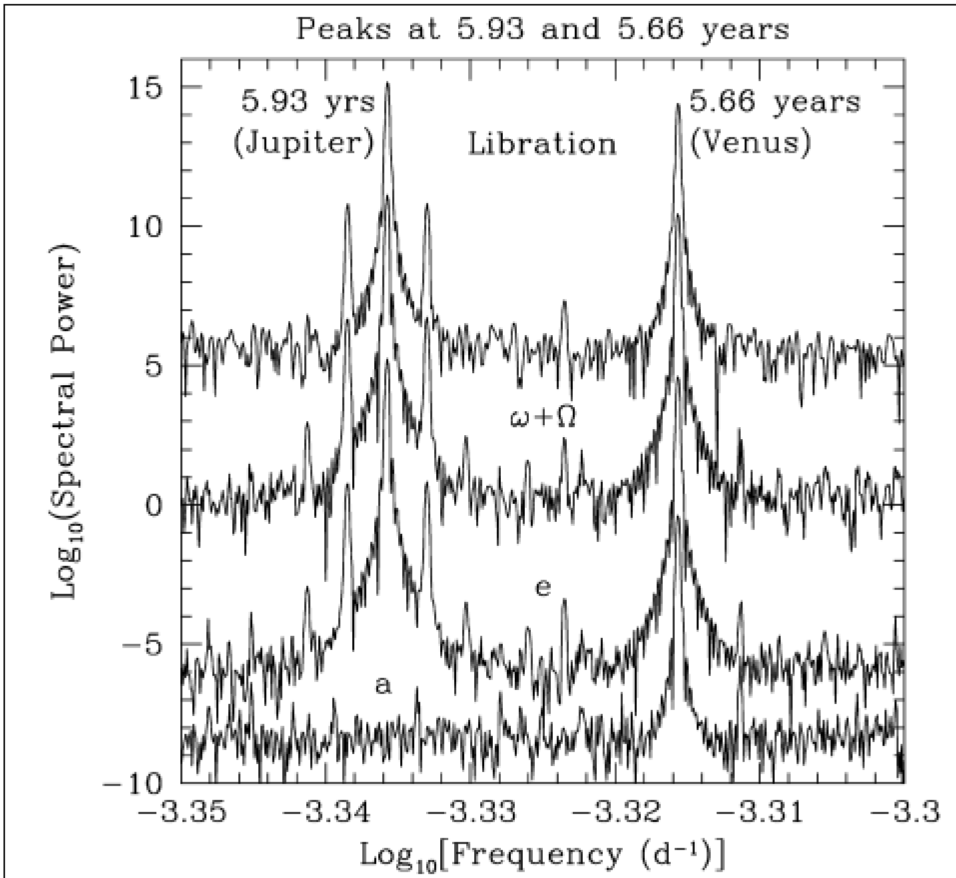

Figure 20. Power spectral densities of the libration, semi-major axis, eccentricity and longitude of perihelion.

- Repeated photographic measurements of selected target positions on the surface of Mercury are central to the BepiColombo strategy to determine the obliquity and libration in longitude of Mercury. We simulated these measurements in order to estimate the expected libration accuracy as a function of the number of measurements, the number of different targets and their locations on the surface of the planet, and the spacecraft initial conditions. Observation strategies (timing and position of surface positions to be measured) are developed as a function of spacecraft orbit initial conditions that will optimize the scientific results. The numerical code has been extended to allow similar analyses of other solar system bodies, and first results for the libration of the Galilean satellite Europa have been obtained. See [61].

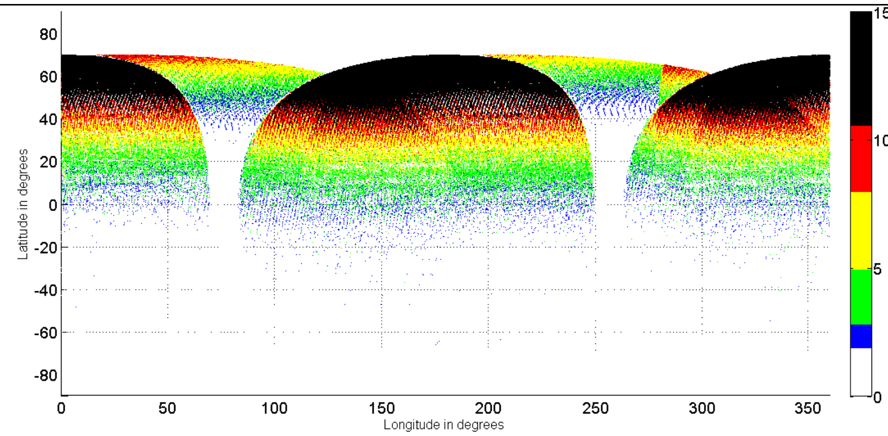

Figure 21. Possible number of camera images for the BepiColombo MPO orbiter.

C.2.3.10. Earth

- Joint inversions of PREM densities, PREM acoustic speeds and electromagnetic apparent resistivities have been studied to determine the thermal state and mineralogy of the lower mantle [36]. Our results on synthetic data show that the mineralogy and iron content are well recovered but that the determination of the temperature from inversions is problematic due to sparse and inaccurate data on apparent resistivities.
- The previously devised lower mantle model which allows for the computation of density, acoustic wave velocity, and electromagnetic surface impedance in terms of temperature and composition has been extended to include the electrical conductivity of the upper mantle. Inversion of the extended model is ongoing.

C.2.3.11. Venus

- Our involvement at Co-I level in VeRa has implied participation in several publications [15, 20, 21].
- In order to study the circulation of the atmosphere of Venus and its effects on the rotation and gravity field, a GCM has been installed at ROB.

C.2.3.12. Natural satellites

- We participated in defining and writing the proposal for the LAPLACE Jupiter-Europa mission submitted to ESA's Cosmic Vision programme [59].
- In collaboration with Antoine Mocquet (Nantes University), a new method based on a Monte-Carlo approach has been developed to invert seismic wave arrival times measured by the Apollo seismometers on the Moon. The originality of the method is that there is no need for an a priori assumption on the nature of the waves or for the localization and time of the Moonquakes to be known, conditions which have limited the scientific use of the seismic Moon data.
- A comparison of analytical and numerical methods for the study of the rotation of the Galilean satellites has been published [12].
- The orbital evolution of the Galilean satellites and the tidal energy dissipation in Jupiter and Io have been determined from an extensive set of astrometric observations and by using an accurate numerical

model for the orbital evolution of natural satellites developed at ROB. The rate of tidal energy dissipation in Io is in close agreement with the observed heat flux suggesting that Io is close to thermal equilibrium.

- We have extended the classical Radau equation for the calculation of the moment of inertia from the observed flattening of a rotating planet to satellites that rotate synchronously with their orbital motion and are flattened by rotation and tides [28].
- Several lines of evidence suggest that large icy satellites have a subsurface ocean beneath an icy shell. The Galilean moon Europa is thought to have a thin icy shell, but its thickness is not well constrained. A new method has been developed to determine the thickness of the icy shell by means of librations (rotation variations). We have shown that the internal gravitational coupling between the icy shell and the solid interior is the dominant coupling relevant for libration and we have derived an analytical expression for it. By using the mass, radius, and mean moment of inertia as constraints, we have calculated interior structure models of Europa and we have shown that the libration amplitude differs by about 10% between models with a thin and thick shell. A paper is in press in Icarus [28, see also 31].

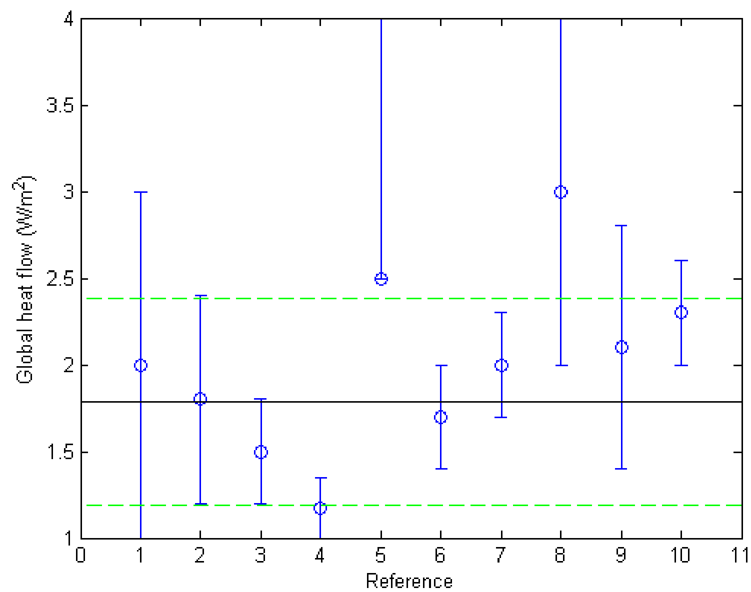

Figure 22. Energy dissipation rate (solid horizontal line) compared to estimates of the global heat flux at the surface of Io

- We have shown that a free libration of Europa can have a period equal to the period of the forced libration for shell thicknesses of about 1 km. Therefore, the forced libration of Europa can be resonantly enhanced when the icy shell is very thin.
- A review paper on the rotation of Europa has been written [41].
- We have investigated whether Europa's internal tidal dissipation can be measured through its effect on the orbital motion of the Galilean satellites such as we have recently done for Io's tidal dissipation. It turned out that the estimation of the dissipation rate in Europa is strongly correlated with the estimation of Io's dissipation rate and that it is not possible to correctly estimate both dissipation rates given the errors on the current ephemerides of the Galilean satellites [23].

- For length-of-day (LOD) variations of the Earth on longer time scales than several days, the core is known to exhibit torsional oscillations in which cylindrical annuli coaxial with the rotation axis rotate as rigid bodies. We used a similar approach to study the effect of motion in the ocean of Europa on the libration in longitude of Europa. First results show that the libration depends on the ocean viscosity but that the effect of the ocean dynamics is very small for realistic viscosity values.

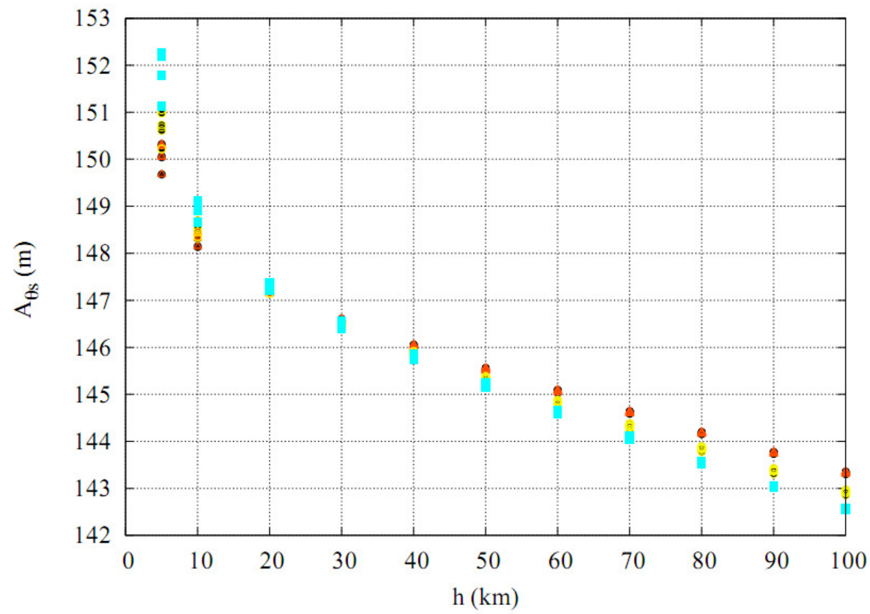

Figure 23. Amplitude of the shell libration as a function of the thickness h of the icy shell of Europa. Colors correspond to different shell densities.

C.2.3.13. Varia

Participation in the Response to the Call for Tender for an Apophis Explorer [60].

C.2.4. Perspective for next years

In the next few years, our current research projects will be continued but also extended in both applications and methodologies. Mars Express, MGS and ODY tracking data will be further analyzed in order to constrain (1) the interior structure and mineralogy of Mars, (2) properties of the crust and lithosphere at selected targets, and (3) the CO_2 condensation and sublimation cycle of the atmosphere and polar caps. Additional radio-tracking data to the American MER rovers will be taken into account. Moreover, MOLA altimeter data at ground track crossings will be interpreted in terms of rotation variations of Mars. A similar study for simulated data will be performed for Mercury. Analysis of Venus Express radio science (VeRa) data will be started. We will further develop and refine our models of the interior structure of terrestrial planets and large natural satellites, with particular emphasis on the mineralogical composition and temperature. Theoretical and simulation studies to constrain the interior structure of terrestrial planets by rotational, tidal, gravitational, and orbital data will be continued and the effects of dissipation will be included. Our synergetic approach to probe the interior of terrestrial planets by joint geodetic, seismic, and electromagnetic means will also be further pursued and will be applied to the Earth, Mars, and the Moon. Lithospheric stress and strain fields will be modeled and compared with observed tectonic features on Mars. In view of the upcoming Mercury missions, the 3:2 resonance and libration of Mercury will be modeled in more detail. Strategies and numerical tools will be developed to determine the interior of Mercury from obliquity and libration measurements. Further attention will be devoted to changes in the atmosphere of Mars and Venus, both on short (seasonal) and long time scales, and to their effects on planetary rotation. Our studies on the interior structure, rotation and tides of terrestrial planets will be extended to the large and intermediate-size rocky and icy natural satellites of the Solar System. We will further develop our Martian climate model in order to assess the habitability of Mars and to understand the atmosphere evolution of Mars. We will continue the scientific and technical preparations for the radio-science experiment LaRa of the ExoMars lander and will participate in the development of new missions to the planets and satellites.

C.2.5. Personnel involved

Scientific staff: R.-M. Baland, M. Beuthe, V. Dehant, J. Duron, Ö. Karatekin, S. Le Maistre, M. Mitrovic, G. Pfyffer, L.B.S. Pham, S. Rosat, P. Rosenblatt, N. Rambaux, A. Rivoldini, A. Trinh, T. Van Hoolst, O. Verhoeven, M. Yseboodt

Technical staff: S. Raynal, L. Van Camp

C.2.6. Partnerships

List of international partners without grant

- O. de Viron and M. Greff-Lefftz (IPGP, France)
- V. Lainey, V. Robert, A. Vienne, J.-E. Arlot, and W. Thuillot (IMCCE, Paris, France)
- M. Menvielle (CETP, Paris, France)
- A. Mocquet, G. Choblet, P. Vacher, and B. Langlais (LPG, University of Nantes, France)
- J.-P. Barriot (Univ. Polynésie Française, Tahiti)
- J.-Ch. Marty, R. Biancale, and G. Balmino (OMP, Toulouse, France)
- P. Tarits (Institut Universitaire Européen de la Mer, Plouzane, France)
- E. Bois (Observatoire de la Côte d'Azur, France)
- M. Pätzold and S. Tellmann (University of Cologne, Germany)
- B. Häusler (Universität der Bundeswehr Institut für Raumfahrttechnik Munich, Germany)
- S. Rosat (Institut de Physique du Globe de Strasbourg, Strasbourg, France)
- D. Breuer, F. Sohl, J. Oberst, and T. Spohn (DLR, Berlin)
- A. Milani (Univ. Pise, Italy)
- W. Folkner, S. Asmar, and A. Konopliv (JPL, USA)
- G. Neumann (GSFC, USA)
- All the MEX MaRS team, the VEX VeRa team, the BC MORE team, the BC BELA team, the NEXT team, the MEMO team, and the LaRa team.

List of national partners without grant

- A. Lemaître, S. d'Hoedt, and J. Henrard (FUNDP)
- E. Javaux (ULg)
- D. Orban, L. Thomassen, and S. Burger (OMP)
- E. Renotte and L. Rossi (CSL)
- J.-P. De Cuyper and L. Winter (ROB).

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- BELSPO-Action 2: Contract W1/33/D01 for J. Duron
- EuroPlaNet: EU, Coordination Action, Call: FP6-2202-Infra structures-1, 001637, Contract: 001637
- PRODEX 8: Contract: C90182 (1114100 € for 2005-2008), Planet Interior
- FRIA: PhD, G. Pfyffer (2004-2008) and R.M. Baland (2007-2011)
- FNRS, Chargé de recherches, M. Yseboodt, October 2006-September 2007
- FNRS Aspirant: L.B.S. Pham (2007-2011) and A. Trinh (2007-2011)
- Tournesol-MINT, T04/060, Communauté française, 2004-2007, about 3 missions of maximum 21 days to France

- FNRS/FRFC 2008 : 12000 €, "Networking in the frame of internal structure of the terrestrial planet"

Visitors:

- A. Mocquet, Nantes Univ., France, 20 January-18 February
- Short visits: 18 persons

C.2.7. Publications

C.2.7.1. Publications with peer review

[1] Vacher P., **Verhoeven O.**
Modelling the electrical conductivity of iron-rich minerals for planetary applications
Planet. Space Sci., 55, DOI: 10.1016/j.pss.2006.10.003, 2007

[2] **Rambaux N., Van Hoolst T., Dehant V**., Bois E.
Inertial core-mantle coupling and libration of Mercury,
Astron. Astrophys., 468(2), pp. 711-719, DOI: 10.1051/0004-6361:20053974

[3] Balmino G., **Duron J.,** Marty J. C., **Karatekin Ö.**
Mars long wavelength gravity field time variations. A new solution from MGS tracking data
In: Dynamic Planet: Monitoring and understanding a dynamic planet with geodetic and oceanographic tools, Editors: P. Tregoning, C. Rizos, Berlin Heiderberg New York, Springer, 130, 895-903

[4] Lainey V., **Dehant V**., Pätzold M.
First numerical ephemerides of the two Martian moons,
Astron. Astrophys., 465(3), pp. 1075-1084, DOI: 10.1051/0004-6361:20065466

[5] Gurfil P., **Lainey V**., Efroimsky M.
Long-term evolution of orbits about a precessing oblate planet: 3. A semianalytical and a purely numerical approach
Celestial Mechanics and Dynamical Astronomy, Volume 99, Issue 4, pp.261-292, DOI: 10.1007/s10569-007-9099-0

[6] Thomas N., Spohn T., Barriot J.-P., Benz W., Beutler G., Christensen U., **Dehant V.**, Fallnich C., Giardini D., Groussin O., Gunderson K., Hauber E., Hilchenbach M., Iess L., Jorda L., Lamy P., Lara L.-M., Lognonné P., Lopez-Moreno J.J., Michaelis H., Oberst J., Resendes D., Rodrigo R., Sasaki S., Seiferlin K., Wieczorek M., Whitby J.
The BepiColombo Laser Altimeter (BELA): concept and baseline design,
Planet. Space Sci., 55, pp. 1398-1413, DOI: 10.1016/j.pss.2007.03.003.

[7] **Dehant V**., Lammer H., Kulikov Yu. N., Grießmeier J.-M., Breuer D., **Verhoeven O., Karatekin Ö**., **Van Hoolst T**., Korablev O., Lognonné P.
The Planetary Magnetic Dynamo Effect on Atmospheric Protection of Early Earth and Mars
Space Science Reviews 129(1-3), pp. 279-300, DOI: 10.1007/s11214-007-9163-9

[8] Efroimsky M., **Lainey V**.,
Physics of bodily tides in terrestrial planets and the appropriate scales of dynamical evolution
Journal of Geophysical Research, Volume 112, Issue E12, DOI: 10.1029/2007JE002908

[9] Peale S.J., **Yseboodt M**., Margot J.L.
Long Period Forcing of Mercury's Libration in Longitude
Icarus, 187, pp. 365–373, DOI:10.1016/j.icarus.2006.10.028

[10] Efroimsky M., **Lainey** V.

On the theory of bodily tides
In: Proc. New Trends in Astrodynamics and Applications III - An International Conference, August 16-18, 2006, AIP Conference Proceedings, 886, pp. 131-138 (2007), DOI:10.1063/1.2710050

[11] **Dehant V., Van Hoolst T**.
Information on interior structure of the terrestrial planets from their rotation
In: Proc. Workshop organized in honor of Prof. J. Henrard at the occasion of his retirement, 'Rotation of celestial bodies', Namur, 1st and 2d of December 2005, pp. 1-7

[12] **Rambaux N.**, Henrard J.
The rotation of Galilean satellites
In: Proc. Workshop organized in honor of Prof. J. Henrard at the occasion of his retirement, 'Rotation of celestial bodies', Namur, 1st and 2d of December 2005, pp. 95-102

[13] Bois E., **Rambaux N**.
On the oscillations in Mercury's obliquity
Icarus 192(2), 308-317

[14] **Rambaux N**., Lemaître A., D'Hoedt S.
Coupled rotational motion of Mercury
Astronomy & Astrophysics 470, 741-747

[15] Pätzold M., Häusler B., Simpson R.A., Tellmann S., Mattei R., Asmar S.W., Bird M.K., **Dehant V.**, Eidel W., Imamura T., Tyler G.L.
Venus Express Radio Science: Sounding of the Venus surface, atmosphere, and ionosphere,
Nature, Letters, 450, pp. 657-660, DOI: 10.1038/nature06239

[16] **Van Hoolst T**., Sohl F., Holin I, **Verhoeven O., Dehant V.,** Spohn T
Mercury's interior structure, rotation, and tides
Space Science Reviews 132 (2-4), 203-227, DOI: 10.1007/s11214-007-9202-6

[17] **Van Hoolst T**.
The rotation of the terrestrial planets
Treatise on Geophysics, Vol.10: Planets and Moons, pp. 123-164, DOI: 10.1007/s11214-007-9202-6

C.2.7.2. Publications without peer review

[18] Barriot J.P., **Karatekin Ö., Dehant V**.
Mars time-variable gravity field: a possible cumulative effect on a family of equatorial orbits
Seventh International Conference on Mars, held July 9-13, 2007 in Pasadena, California, LPI Contribution No. 1353, p. 3091 (2 pages)

[19] Leblanc F., Langlais B., Chassefière E., Sotin C., Barabash S., **Dehant V.**, Dougherty M., Lammer H., Mandea M., Vennerstrøm S.
MEMO: Mars Escape and Magnetic Orbiter,
In: Proc. 38th Lunar and Planetary Science Conference, (Lunar and Planetary Science XXXVIII) (LPSC), League City, Texas, USA, March 12-16, 2007, extended abstract, LPI Contribution No. 1338, p. 1581 (2 pages).

[20] Mattei R., Häusler B., Pätzold M., Remus S., Eidel W., Tellmann S., Andert T., Selle J., Bird M.K., Simpson R.A., Tyler G.L., **Dehant V.**, Asmar S., Barriot J.-P., Imamura T.
The radio science experiment VeRa onboard ESA´s Venus Express spacecraft
In: Proc. German National Aerospace Conference (CEAS), Berlin, Germany, 10 p.

[21] Häusler B., Pätzold M., Tyler G.L., Barriot J.-P., Bird M.K., **Dehant V.**, Hinson D.P., Simpson R.A., Treumann R.A., Eidel W., Mattei R., **Rosenblatt P**., Remus S., Selle J., Tellmann S.
Venus Atmospheric, Ionospheric, Surface and Interplanetary Radio-Wave Propagation Studies with the VeRa Radio-Science Experiment
ESA Publication, SP-1295, 30 p.

[22] Lammer H., **Dehant V.**, Korablev O., Lundin R.
Planetary-Sun interactions
In: 'Geology and Habitability of Terrestrial Planets', Eds. K. Fishbaugh, P. Lognonné, F. Raulin, D. Des Marais, O. Korablev, Space Science Series of ISSI, Vol. 24, reprinted from Space Science Reviews, Springer, Dordrecht, The Netherlands, Space Science Reviews, 129(1-3), pp. 205-206, DOI: 10.1007/s11214-007-9190-6

[23] Berthier J., Lainey V., Bell J., **Dehant V.**
Astrometric reduction of the Mars Exploration Rover night-time observations
In: Proc. SF2A 2006, Eds. D. Barret, F. Casoli, T. Contini, G. Lagache, A. Lecavelier, and L. Pagani, extended abstract, pp. 379-380

[24] Bois E., **Rambaux N.**, **Dehant V.**, **Van Hoolst T**., Greff-Lefftz M., Mocquet A., Legros H.
Etude des couplages rotation-noyau des planètes telluriques
In: Proc. Programme National de Planétologie de l'INSU, 11-13 September 2006, Nancy, France, extended abstract, 2 p., on CD-ROM.

[25] Leblanc F., Langlais B., Chassefière E., Sotin C., Barabash S., **Dehant V.**, Dougherty M., Lammer H., Mandea M., Vennerstrøm S.
MEMO: Mars Escape and Magnetic Orbiter
In: Proc. LPSC, Houston, USA, March 12-16, 2007, extended abstract, #1581, publication on the web, 2 p.

C.2.7.3. Publications in press, submitted

[26] **Beuthe M**.
Thin elastic shells with variable thickness for lithospheric flexure of one-plate planets
Geophysical Journal International, 172 (2), 817-841 (2008), DOI: 10.1111/j.1365-246X.2007.03671.x

[27] **Métivier L., Karatekin Ö., Dehant V**.
The effect of the internal structure of Mars on its seasonal loading deformations
Icarus, DOI: 10.1016/j.icarus.2007.12.001, published online, in press

[28] **Van Hoolst T., Rambaux N., Karatekin Ö., Dehant V., Rivoldini A**.
The librations, shape, and icy shell of Europa
Icarus, DOI:10.1016/j.icarus.2007.12.011, published online, in press

[29] Pätzold M., Tellmann S., Andert T., Carone L., Fels M., Schaa R., Stanzel C., Audenrieth-Kersten I., Gahr A., Müller A.-L., Stracke B., Stupar D., Walter C., Häusler B., Remus S., Selle J., Griebel H., Eidel W., Asmar S., Goltz G., Kahan D., Barriot J.-P., **Dehant V.**, **Beuthe M., Rosenblatt P., Karatekin O., Lainey V.**, Tyler G.L., Hinson D., Simpson R., Twicken J.
The Observations of the Mars Express Orbiter Radio Science (MaRS) Experiment after One Year in Orbit,
ESA Scientific Publication, ESA-SP, in press

[30] Viré A., Detandt Y., **Karatekin Ö**., Degrez G.
Numerical Simulations of Unsteady Flow around an Entry Capsule
Proc. 4th International Planetary Probe Workshop, JPL, Pasadena, USA, ESA Scientific Publication, ESA-SP, in press

[31] **Rambaux N., Karatekin Ö., Van Hoolst T**.
Europa's librations and ice shell thickness
In: Proc. Société Française d'Astronomie et d'Astrohysique (SF2A), Grenoble, France, in press

[32] **Rosenblatt P., Lainey V., Le Maistre S.,** Marty J.C., **Dehant V.,** Pätzold M., Häusler B., **Van Hoolst T**.
Accurate Mars Express orbit determination to improve Martian Moon ephemerides
Proc. Société Française d'Astronomie et d'Astrophysique (SF2A), Grenoble, France, 2-7 July 2007, in press.

[33] Barriot J.P., **Dehant V., Yseboodt M., Karatekin Ö**.
Monitoring Mars Length-of-Day variations from a high altitude circular equatorial orbit
Celestial Mechanics and Dynamical Astron., submitted

[34] **Rosenblatt P., Lainey V., Le Maistre S**., Marty J.C., **Dehant V.,** Pätzold M., **Van Hoolst T.**, Häusler B.
Accurate Mars Express orbit to improve the determination of the mass and ephemeris of the Martian moons,
Planet. Space Sci., submitted

[35] Hagedoorn J.M., **Karatekin Ö., Van Hoolst T., Dehant V.**
Ice age cycles and climate change on Mars: possible influence on the rotation and gravity
Icarus, submitted

[36] **Verhoeven O**., Vacher P., **Rivoldini A**., Menvielle M., Arrial P-A., Mocquet A., Choblet G., Tarits P., **Dehant V.**, **Van Hoolst T.**
Constraints on thermal state and composition of the Earth's lower mantle from electromagnetic impedances and seismic data
J. Geophys. Res., submitted

[37] Leblanc F., Langlais B., Fouchet T., Barabash S., Breuer D., Chassefière E., Coates A., **Dehant V.**, Forget F., Lammer H., Lewis S., Lopez-Valverde M., Mandea M., Menvielle M., A. Pais, Pätzold M., Read P., Sotin C., Tarits P., Vennerstrøm S.
Mars Environment and Magnetic Orbiter, science and measurement objectives
Astrobiology, submitted

[38] Langlais B., Leblanc F., Fouchet T., Barabash S., Breuer D., Chassefière E., Coates A., **Dehant V.**, Forget F., Lammer H., Lewis S., Lopez-Valverde M., Mandea M., Menvielle M., A. Pais, Pätzold M., Read P., Sotin C., Tarits P., Vennerstrøm S., Branduardi-Raymont G., Cremonese G., Merayo J.G.M., Ott T., Rème H., Trotignon J.G., Walhund J.E.
Mars Environment and Magnetic Orbiter model payload
Cosmic Vision 2007 special issue of Astronomical Journal, submitted

[39] **Rosat S., Rosenblatt P., Trinh A., Dehant V**.
Mars and Mercury rotation variations from altimetry crossover data: Feasibility study
J. Geophys. Res. Planets, submitted

[40] Dufey J., Lemaître A., **Rambaux N.**
Planetary perturbations on Mercury's libration in longitude
Celestial Mechanics and Dynamical Astronomy, submitted

[41] Bills B. G., Nimmo F., **Karatekin Ö.**, **Van Hoolst T., Rambaux N.**, Levrard B., Laskar J.
Rotational dynamics of Europa
University of Arizona Press Space Science Series, submitted

[42] Javaux E., **Dehant V.**
Habitability: from stars to cells

Astron. Astrophys. Rev., submitted

[43] **Pham L.B.S., Karatekin Ö., Dehant V**.
Effect of meteorite impacts on the atmospheric evolution of Mars
Submitted to Astrobiology.

C.2.7.4. Reports, thesis, etc

[44] **Dehant V.,** Lognonné P.
MarsTwin: Answer to the ESA Exploration Program Call on the NEXT mission in the frame of the preparation of the Mars Sample Return
Pdf file

[45] Leblanc M. and the MEMO Team including **Dehant V.**
MEMO: Mars Environment and Magnetic Orbiter
Pdf file

[46] **Dehant V.,** Folkner W., **Le Maistre S.,** Orban D., and the LaRa Team
LaRa to GEP Interface Control Document (GEPID)
50 pages

[47] **Dehant V.,** Folkner W., **Le Maistre S**., Orban D., and the LaRa Team
LaRa Requirements
3 pages

[48] **Dehant V.,** Folkner W., **Le Maistre S**., Orban D., and the LaRa Team
LaRa Team answers to RIDs
22 pages

[49] **Dehant V., Le Maistre S**.
Statement of Work: Transponder design and breadboard; Contract 1 ROB-OMP
10 pages

[50] **Dehant V., Le Maistre S**.
Statement of Work: Transponder design and breadboard; Contract 2 ROB-OMP
7 pages

[51] **Dehant V., Mitrovic M**.
Statement of Work: Transponder design and breadboard; Contract 3 ROB-OMP
7 pages

[52] **Dehant V., Mitrovic M**., Renotte E., Rossi L.
Statement of Work for the ExoMars LaRa instrument; Contract to industry for Phase C-D,
25 pages

[53] **Dehant V.,** Folkner W., Renotte E., Orban D., and the LaRa Team
LaRa Quarterly Instrument Report for period
22 pages

[54] **Dehant V.,** Folkner W., Renotte E., Orban D., and the LaRa Team
LaRa Instrument Report for first ExoMars meeting
Ppt file, 14 pages

[55] **Dehant V.,** Folkner W., Renotte E., Orban D., and the LaRa Team
LaRa Quarterly Instrument Report for period Apr.-Jun. 2007
Ppt file, 14 pages

[56] **Dehant V.,** Folkner W., Renotte E., Orban D., and the LaRa Team

LaRa Quarterly Instrument Report for period Jul.-Sep. 2007
Ppt file, 12 pages

[57] **Dehant V.,** Folkner W., Renotte E., Orban D., and the LaRa Team
LaRa Quarterly Instrument Report for period Oct.-Dec. 2007
Ppt file, 18 pages

[58] **Le Maistre S**.
Guide de gestion et d'utilisation de la base de données et des softwares
Internal report

[59] Blanc M. and the LAPLACE consortium (including **V. Dehant** and **T. Van Hoolst**)
LAPLACE. A mission to Europa and the Jupiter System for ESA's Cosmic Vision Programme
38 pages

[60] Arrigo P., Allouis E., Barraclough S., Carusi A., **Dehant V.,** Kemble S., **Karatekin Ö.,** Pätzold M., Parkinson R., Perkinson M.-C., Perozzi E., Povoleri A., Sembely X., Trenkel C., Watt M., Wolters S.
APEX, Apophis Explorer
Proposal for the Apophis design completion, EADS Astrium TP1717

[61] **Pfyffer G**.
Rapport Annuel F.R.I.A 2007
August 2007

[62] **Baland R.M**.
Structure interne d'Europe à partir des mesures de poursuite Doppler d'un orbiteur
Graduate thesis, Université Catholique de Louvain, Louvain-La-Neuve, Belgium, 2007

[63] **Cao N.-T**.
Etude de la structure interne de Phobos
Post-graduate thesis, Université de Nantes, France, 2007

[64] **Trinh A**.
Effet des marées de Mercure sur les mesures altimétriques de la mission spatiale BepiColombo
Mémoire de licence, Université Libre de Bruxelles, May 2007

[65] **Duron J**.
Analyse des perturbations orbitales d'un satellite autour de Mars
PhD thesis, Université Catholique de Louvain, Belgium, June 2007

C.2.8. Scientific outreach

Meeting presentations

[1] **Dehant V.** and the ROB team
Work on Mars at ROB
Meeting of the MEX Radioscience, Cologne, Germany, January 4, 2007

[2] **Dehant V.** and the LaRa Team
Lander Radioscience in GEP
Meeting of the GEP Consortium, Berlin, Germany, 21st February 2007

[3] **Dehant V., Van Hoolst T**., Lemaître A.
Rotation, libration, and gravitational field of Mercury
MORE Science Meeting, Roma, Italy, 26-27 February 2007

[4] Leblanc F., Langlais B., Chassefière E., Sotin C., Barabash S., **Dehant V.**, Dougherty M., Lammer H., Mandea M., Vennerstrøm S.
MEMO: Mars Escape and Magnetic Orbiter
Lunar Planetary Science Conference (LPSC), Houston, USA, March 12-16, 2007

[5] **Yseboodt M**.
The librations of Mercury
FNRS Contact Group Astronomie & Astrophysique, Brussels, March 16, 2007

[6] **Dehant V**.
Report of ROB in the frame of MaRS
MaRS Team Meeting, Munich, Germany, April 12-13, 2007

[7] **Le Maistre S., Beuthe M., Dehant V**.
MaRSian Gravity on Targets: Data Status
MaRS Team Meeting, Munich, Germany, April 12-13, 2007

[8] **Beuthe M., Dehant V**.
Lithosphere with variable thickness: the case of a one-plate planet
EGU Meeting, Vienna, Austria, April 16-20, 2007

[9] **Rosat S., Rosenblatt P., Trinh A., Dehant V**., Neumann G.
Improvement of the Mars rotation parameters using the a priori information embedded in MOLA altimeter crossover data
EGU Meeting, Vienna, Austria, April 16-20, 2007

[10] **Van Hoolst T., Rivoldini A., Verhoeven O**., Vacher P., Mocquet A., **Dehant V**.
Mercury's Interior Structure
EGU Meeting, Vienna, Austria, April 16-20, 2007

[11] **Dehant V.**, **Van Hoolst T**., Mocquet A., Menvielle M., Lognonne P., Spohn T.
Mars rotation and deformation as seen from a lander or a spacecraft orbiting a planet
EGU Meeting, Vienna, Austria, April 16-20, 2007

[12] **Rambaux N., Karatekin Ö., Van Hoolst T**.
Librations and ice shell thickness of Europa
EGU 2007, Vienna, April 16-20

[13] **Dehant V.**, Folkner W., **Le Maistre S**., Orban D., and the LaRa Team: Asmar S., Benoist J., Biancale R., Biele J., Budnik F., de Viron O., Häusler B., Lognonné P., Menvielle M., Schubert G., Spohn T., Tortora P., **Van Hoolst T.**, Witasse O.
ExoMars/GEP Lander Radioscience LaRa
EGU Meeting, Vienna, Austria, April 16-20, 2007

[14] **Karatekin Ö., Pham L.B.S., Dehant V**., Lammer H.
Toward a climatological model for early Mars
EGU 2007, Vienna, April 16-20

[15] **Baland R.-M., Lainey V., Rosenblatt P., Dehant V**.
Consideration of Europa's icy shell thickness from the observation of its orbital motion
EGU Meeting, poster, Vienna, Austria, April 16-20, 2007

[16] Toubeau J., Deleersnijder E., de Viron O., **Karatekin Ö**., Remacle J.-F., **Van Hoolst T**., **Dehant V.**
Non-equilibrium tide of Europa
EGU 2007, Vienna, April 16-20, 2007

[17] **Yseboodt M., Van Hoolst T., Dehant V**.

The rotation and interior of Mercury with the BepiColombo spacecraft
38th annual AAS meeting of the Division on Dynamical Astronomy, Ann Arbor, Michigan, USA, May 6-10, 2007

[18] **Dehant V**.
Rotation et structure de l'intérieur des planètes par observation spatiale
Ecole doctorale de l'EOGS (Ecole et Observatoire de Géophysique de Strasbourg), June 7-8, 2007

[19] **Dehant V**.
Présentation du travail de l'équipe de l'Observatoire Royal de Belgique
Meeting CNES/GRGS-ROB, Brussels, June 11, 2007

[20] Javaux E., **Dehant V.**
Astrobiology and habitability
Meeting of the FNRS Contact Group on 'Astrobiology', Brussels, June 12, 2007

[21] **Karatekin Ö., Pham L.B.S., Dehant V**., Lammer, H.
Toward a climatological model for early Mars
1st workshop of the FNRS Astrobiology contact group, Brussels, June 12

[22] **Beuthe M**.
Etude de la lithosphère par analyse en cohérence et admittance au moyen d'ondelettes
Journées Gravimétrie du CNES: GOCE – Applications et Outils pour la Terre Solide, Paris, France, 19 June 2007

[23] **Le Maistre S**.
GINS development in PhD frame
Journée GINS, Toulouse, France, June 2007

[24] **Rosenblatt P**.
Planetary geodesy at ROB
ROB-CNES meeting, Brussels, Belgium, June 2007

[25] **Dehant V.,** Biancale R.
Work at ROB (Royal Observatory of Belgium) and at CNES/OMP (Observatoire Midi-Pyrénées
First European Workshop on Solar System Dynamics and Ephemerides, ESA/ESOC, Darmstadt, Germany, June 21-22, 2007

[26] Marty J.C., Balmino G., **Duron J., Rosenblatt P**., Biancale R., **Dehant V.**
Precise orbit and planetary gravity field determination using GINS software
First European Workshop on Solar System Dynamics and Ephemerides, ESA/ESOC, Darmstadt, Germany, June 21-22, 2007

[27] **Rosenblatt P., Lainey V., Le Maistre S**., Marty J.C., **Dehant V**., Pätzold M., Häusler B., **Van Hoolst T**.
Accurate Mars Express orbit determination to improve Martian Moons ephemerides
First European Workshop on Solar System Dynamics and Ephemerides, ESA/ESOC, Darmstadt, Germany, June 21-22, 2007

[28] **Rosenblatt P., Lainey V., Le Maistre S**., Marty J.-C., **Dehant V.**, Pätzold M., Häusler B., **Van Hoolst T**.
Accurate Mars Express orbit determination to improve Martian moon ephemerides
Journées GINS, Toulouse, France, June 26, 2007

[29] **Duron J.**, Balmino G., Marty J.-C., **Rosenblatt P., Dehant V., Van Hoolst T**.
Mars gravity field and its temporal variations

Journées GINS, Toulouse, France, June 26, 2007

[30] **Rambaux N**., Bois E., **Van Hoolst T., Dehant V.**
Libration of Mercury and signature of its interior
Theory and Applications of Dynamical Systems, a meeting in honor of Claude Froeschle, Spoleto, Italy, 24-28 June, 2007

[31] **Rosenblatt P., Lainey V., Le Maistre S., Dehant V**., Pätzold M., Marty J.-C.
Using Phobos images for testing and quantifying the real accuracy of the orbit of Mars Express
Société Francaise d'Astronomie et d'Astrohysique (SF2A), Grenoble, France, July 2-7, 2007

[32] **Rambaux N., Karatekin Ö., Van Hoolst T**.
Europa's librations and ice shell thickness
Société Française d'Astronomie et d'Astrohysique (SF2A), Grenoble, France, July 2-7, 2007

[33] **Dehant V.** and the LaRa team
LaRa
4th WG ExoMars/GEP, ESTEC, Darmstadt, The Netherlands, July 4, 2007

[34] Barriot J.P., **Karatekin Ö., Dehant V**.
Mars time-variable gravity field: a possible cumulative effect on a family of equatorial orbits
7th International Mars Conference, Caltech, Pasadena, California, USA, July 9-13, 2007

[35] **Karatekin Ö., Wautier J., Van Hoolst T**.
Length-of-day variations of Mars
7th International Mars Conference, Caltech, Pasadena, California, USA, July 9-13, 2007

[36] **Dehant V.**, Folkner W., **Le Maistre S**., Orban D., Renotte E., and the LaRa Team
ExoMars/GEP Lander Radioscience LaRa, a Space Geodesy Experiment to Mar
IUGG General Assembly, Session JAS001 'Planetary cores: physics, chemistry and dynamics', Perugia, Italy, July 2-14, 2007

[37] **Dehant V**.
Surveying the planets and the Solar System
IUGG General Assembly, Workshop on 'Trend in Science and Space Technology in Earth and Planetary Survey', Perugia, Italy, July 7th, 2007

[38] **Rivoldini A., Verhoeven O**., Mocquet A., **Van Hoolst T., Dehant V**.
Recent progress in models of planetary interiors
IUGG 2007, Session JAS001 'Planetary cores: physics, chemistry and dynamics', Perugia, Italy, July 2-14, 2007

[39] **Karatekin Ö., Rambaux N., Van Hoolst T**.
Librations of outer solar system satellites
4th Annual Meeting of AOGS, Asia Oceania Geosciences Society (AOGS), Bangkok, 30 July-4 August 2007

[40] **Le Maistre S., Dehant V**.
MaRSian Gravity on Targets: Data Status
MaRS team Meeting, Brussels, Belgium, August 2007

[41] **Beuthe M., Dehant V**.
Lithospheric flexure on one-plate planets with non-uniform rigidity
Second European Planetary Science Congress, Potsdam, Germany, August 19-24, 2007

[42] **Dehant V., Van Hoolst T., Le Maistre S., Trinh A., Rosenblatt P., Rosat S**.
Radioscience on terrestrial planet in order to measure tides and rotation
Second European Planetary Science Congress, Potsdam, Germany, August 19-24, 2007

[43] **Pfyffer G., Rambaux N., Van Hoolst T., Dehant V**.
Libration of Mercury from the BepiColombo radio science and camera experiments
Second European Planetary Science Congress, Potsdam, Germany, August 19-24, 2007

[44] **Rosenblatt P., Le Maistre S.**, Marty J.C., **Duron J., Dehant V**.
Taking advantage of the MEMO orbiter to improve the determination of Mars' gravity field
Second European Planetary Science Congress, Potsdam, Germany, August 19-24, 2007

[45] Mattei R., Häusler B., Pätzold M., Remus S., Eidel W., Tellmann S., Andert T., Selle J., Bird M.K., Simpson R.A., Tyler G.L., **Dehant V.**, Asmar S., Barriot J.-P., Imamura T.
The radio science experiment VeRa onboard ESA´s Venus Express spacecraft
German National Aerospace Conference (CEAS), Berlin, Germany, September 10-13, 2007

[46] **Dehant V.** and the LaRa team
LaRa
ExoMars/GEP, ESTEC, Darmstadt, The Netherlands, 8-9 October, 2007

[47] **Pham L.B.S**.
Toward a climatological model for Mars
MeteoClim PhD Symposium 2007, October 10, 2007

[48] **Rambaux N., Van Hoolst T**., Lemaître A., Bois E., D'Hoedt S., **Dehant V.**
Mercury's rotation and sulfur concentration in the core
39th DPS (Division for Planetary Sciences of the American Astronomical Society) meeting, Orlando, Florida, October 7-12, 2007

[49] Lognonné P., and the SEIS team including **Dehant V.**
The SEISmic experiment onboard ExoMars Descend Module
European Mars Science and Exploration Conference: Mars Express and ExoMars, ESA-ESTEC, Noordwijk, The Netherlands, November 12-16, 2007

[50] Leblanc F. and the MEMO Steering Committee including **Dehant V.**
The Mars Escape and Magnetic Orbiter: a cosmic vision proposal
European Mars Science and Exploration Conference: Mars Express and ExoMars, ESA/ESTEC, Noordwijk, The Netherlands, November 12-16, 2007

[51] **Rosenblatt P., Le Maistre S.**, Marty J.C., **Dehant V., Van Hoolst T.**
A geodetic orbital experiment for ExoMars
European Mars Science and Exploration Conference: Mars Express and ExoMars, ESA-ESTEC, Noordwijk, The Netherlands, November 12-16, 2007

[52] **Dehant V.**, **Le Maistre S**., Folkner W., Renotte E., Orban D., **Mitrovic M**. and the LaRa team
The geodesy experiment LaRa onboard ExoMars
European Mars Science and Exploration Conference: Mars Express and ExoMars, ESA-ESTEC, Noordwijk, The Netherlands, November 12-16, 2007

[53] **Rosenblatt P.**, Lainey V., **Le Maistre S**., Marty J.C., **Dehant V.**, Pätzold M., Häusler B., **Van Hoolst T.**
Improvement of the ephemerides and masses of the Martian moons from MEX accurate orbit determination
Mars meeting, Stanford, USA, December 2007

[54] **Rosenblatt P., Lainey V., Le Maistre S.,** Marty J.C., **Dehant V**., Pätzold M., **Van Hoolst T**., Häusler B.
Improvement of the ephemerides and masses of the Martian moons from MEX precise orbit determination
AGU Fall meeting 2007, San Francisco, December 10-14, 2007

[55] **Duron J.,** Marty J.C., Balmino G., **Rosenblatt P., Le Maistre S., Dehant V**.
Martian Gravity Field Mean Model and its Time Variations from Mars Global Surveyor and Odyssey data
AGU Fall meeting 2007, San Francisco, December 10-14, 2007

[56] Lognonné P., Regnier P., and the MoonTwin Science (including **Dehant V.**) and industrial Team
Moon geophysics and Lunar risk monitoring: Apollo data reprocessing and perspectives with the MoonTwin project
AGU Fall meeting 2007, San Francisco, December 10-14, 2007

[57] **Van Hoolst T., Rambaux N., Karatekin Ö**.
The hydrostatic shape of Europa and implications for the satellite's libration
AGU Fall meeting 2007, San Francisco, December 10-14, 2007

[58] Lainey V., Desmars J., Arlot J., **Karatekin Ö.**, Noyelles B., Vienne A.
First Steps toward an Accurate Quantification of the Saturnian Tidal Dissipation
AGU Fall meeting, San Francisco, December 10-14, 2007

National and international responsibilities

- V. Dehant: PI (Principal Investigator) of the Lander Radioscience experiment (LaRa) in the frame of the AURORA/ExoMars mission to Mars
- V. Dehant: Co-I (co-Investigator) of the Seismology experiment (SEIS) in the frame of the AURORA/ExoMars mission to Mars
- V. Dehant: Co-I of Mercury Orbiter Radio-science Experiment (MORE) in the frame of the ESA BepiColombo mission to Mercury
- V. Dehant: Co-I of BepiColombo Laser Altimeter (BELA) in the frame of the ESA BepiColombo mission to Mercury
- V. Dehant: Co-I of the VenusExpress Radio science experiment (VeRa) in the frame of the ESA VenusExpress mission
- V. Dehant: Co-I of the MarsExpress Radio Science experiment (MaRS) in the frame of the ESA MarsExpress mission
- T. Van Hoolst: Co-I of SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem), the camera experiment of ESA's BepiColombo mission to Mercury

C.2.9. Missions

Assemblies, symposia (number): M. Beuthe (3), V. Dehant (5), Ö. Karatekin (4), S. Le Maistre (3), G. Pfyffer (1), P. Rosenblatt (4), A. Rivoldini (1), S. Rosat (1), T. Van Hoolst (3), O. Verhoeven (1). M. Yseboodt (1)

Commissions, working groups (days): M. Beuthe (1), V. Dehant (42), S. Le Maistre (7), P. Rosenblatt (4), T. Van Hoolst (19), M. Yseboodt (2)

Research visits (days): V. Dehant (4), J. Duron (288), Ö. Karatekin (10), M. Mitrovic (1), T. Van Hoolst (1), O. Verhoeven (55), M. Yseboodt (4)

SECTION 2 & 3: Seismology and Gravimetry

Introduction:

Within the interiors of continent, large earthquakes are rare and why, where and when these earthquakes occur is poorly understood. New ideas about these questions have begun to emerge from studies within continental interiors, including central and eastern North America, Northwest Europe, China and Australia. Due to their complex geological history, continents contain many fossil weak zones accumulated over billion of years, such as ancient rifts and faults, including those along continental margin. At any given time, only a few are seismically active. On short timescales seismicity continues on presently active structures, in part because many events are aftershocks of larger past events. On longer timescales, part of the seismicity migrates to other structures, which are often unknown. Therefore, the seismic hazard is diffuse and complicated in both space and time. The present earthquake history can bias views of hazard and recurrence by giving attention on recently active features and focusing earthquake prevention in some areas of past seismicity where large earthquakes will not occur for a very long time, while it is neglected in apparently less active areas that are in fact more hazardous.

Based on these new ideas, we focus a part of the scientific activities (research topic: seismic activity – methodologies and regional studies) of the section on the methodologies to better understand the seismic activity and the potential for large earthquakes in northwest continental intraplate Europe. Evaluating the recurrence behaviour of large earthquakes along active faults, when they have been identified, and understanding the irregularity of the seismic cycle are important in the development of new methodologies for seismic hazard assessment. Our section is conducting such specific studies along the North- and East-Anatolian faults in Turkey to try to understand the mechanical interaction between fault segments. Slow active faults are studied in northwest Europe and the central Thracian depression in Bulgaria.

We are considering also evaluating correctly our vulnerability to such earthquakes, which is essential to adopt adequate prevention measures (research topic: seismic hazards and risks).

Other scientific activities of the section are devoted to conduct gravity measurements at the Earth surface with the purpose of studying geodynamical processes. The normal Earth gravity field is defined at the surface of an international referenced ellipsoid (World Geodetic System 84). It reflects the effect of the attraction due to the Earth mass and the centrifugial force due to the Earth diurnal rotation. The reference equipotential surface of the gravity field, the geoïd, does not correspond to the ellipsoïd. The main reasons of this difference are that the density distribution inside the Earth is not homegeneous and that geodynamics phenomena prevent some regions from the isostatic equilibrium. Therefore, gravity measurements are important to evidence geographical heterogeneities in the underground and to study geodynamical processes and their time evolution.

An important part of this scientific work (research topic: present-day deformation of the lithosphere) is devoted to evaluate deformation of the lithosphere using its imprint on the gravity signal. For this purpose, the section is in charge of the scientific and technical follow-up of the superconducting gravimeter installed in the Membach station, of an absolute gravimeter and several field relative gravimeters.

In this context, the Royal Observatory of Belgium (ROB) is also sheltering up to the end of 2007 the International Center for Earth Tides (ICET), which in turn is responsible of the database of the Global Geodynamics Project (GGP), a network of more than 20 stations equipped with superconducting gravimeters (research topic: Earth tides and gravimetry).

In order to support its scientific research, its scientific expertise and to provide pertinent information to the public and the authorities, the section develops different operational projects with the purpose of:

- Monitoring the seismic activity in Belgium and surrounding regions by analysing the data from the Belgian seismic and accelerometric stations, developing and maintaining these networks;
- Developing the ways to provide fast and reliable information to the authorities and the public when an earthquake is felt or occurred in Belgium;

- Providing our measured seismic phases for worldwide seismic events and waveform data from specific well-calibrated stations to the seismological international centers;
- Providing the scientists in other institutions, the public, the administration and the private companies in Belgium with a scientific and technical expertise in earthquake seismology.

A. Research Theme "Seismic Activity – Methodologies and Regional Studies"

To characterize the seismic activity in a region, it is necessary to collect and analyse reliable information on the active seismogenic zones and faults, and their respective earthquake activity.

The Royal Observatory of Belgium is conducting different research activities on the seismic activity in northwest Europe (project: seismicity in northwest Europe).The data collected by the Belgian seismic network allow us to evaluate precisely the location, the magnitude and the focal mechanism of present earthquakes in northwest Europe. The earthquakes recorded by this modern network, progressively implanted since 1985, form a list of events covering a very short time period compared to the duration of the mechanical processes generating large earthquakes on active faults. Thus, to have a correct image of the seismic activity, it is necessary to enlarge our information as far as possible in time and hence to investigate historical documents to retrieve earthquakes of the past. The known earthquake history of our regions begins around 700 AD. Until the XIVth century, the rare historical sources allow the establishment of a list of the strongest earthquakes, but few can be reliably assessed in terms of magnitude and location. Since the XIVth century, the number of different sources (chronicles, annotations, parish registers, account registers,…) has increased significantly. These give more details on local effects and allow more reliable estimation of damage and felt areas of the earthquakes. It is possible to determine their probable epicentral area and also to estimate their magnitude by comparison with recent earthquakes for which the magnitude was instrumentally determined.

As most large earthquakes provoke visible surface deformation, it is possible to retrieve the traces of past large earthquakes by their fingerprint in the morphology and the geologic records. This is the objective of paleoseismology. In continental intraplate Europe, active faults remain largely unidentified and the potential for large earthquakes unknown. To evaluate this potential (project: paleoseismology and active faults in continental intraplate regions), the problems to solve are different from those encountered in seismically active zones. Identifying active faults is a difficult problem mainly because their morphological expression is often not clear due to the low level of deformation, the climatic regime and the strong anthropic activity. On the other hand, the interpretation of deformations and their dating are very complex due to the long duration of the seismic cycle which produces overlap between tectonic and climatic events. The experience of our team in this domain is now used in different other projects elsewhere in the world.

One of these studies, supported by a CEE Marie Curie project, concerns a specific study along the North- and East-Anatolian faults in Turkey to try to understand the mechanical interaction between fault segments (project: understanding the irregularity of the seismic cycle: a case study in Turkey).

A.1. Research Project “seismicity of northwest Europe”

A.1.1. Objectives

The main objectives of the project are to conduct seismotectonic analysis of the seismic activity in northwest Europe and to provide a reliable catalogue of earthquakes in Belgium and the surrounding regions. As instrumental earthquake data are available only since ~1900, they are not sufficient to obtain a realistic picture of the long-term seismic activity in northwestern Europe. Historical seismicity studies are thus essential to complement instrumental studies.

We investigate also the structure of the lithosphere which is important in the understanding of the seismic activity, but also to provide reliable crustal models for earthquake location.

A.1.2. Progress and results

A.1.2.1. Instrumental seismicity

- In cooperation with S. Stein (Northwestern University), we began an investigation to compare the seismic activity in intraplate northwest Europe and central and eastern North America. Its main objective is to define a methodological framework to evaluate long term seismic activity in stable continental region, and to provide clues on where and when the next large destructive earthquake should occur.

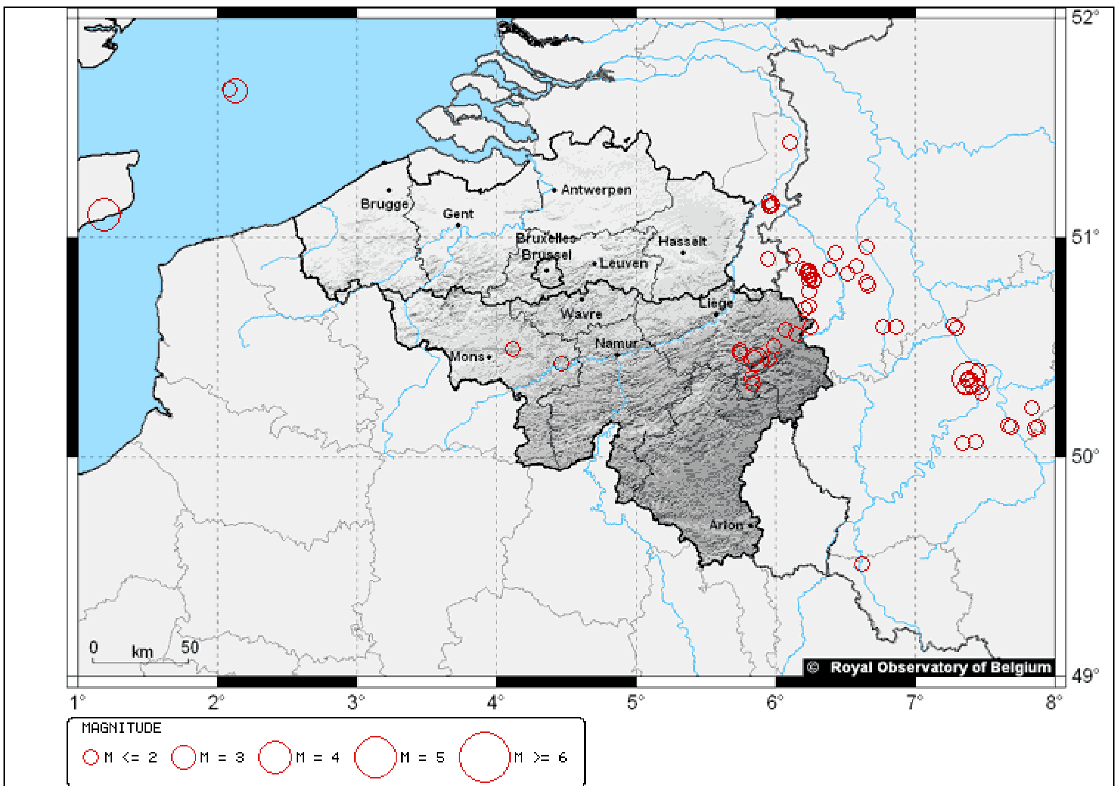

Figure 24. Seismic activity in Belgium and the surrounding regions in 2007.

- During the first year of his Phd-program, Thomas Lecocq completed and homogenized the Belgian earthquake catalogue (1985-2007) and began to study of the spatial distribution of hypocenters in the Ardenne-Eifel region. Using relocation techniques, we improved the relative location between events. To achieve this, we installed and made some improvements to the COMPLOC package. The improvements were made at different levels, mainly to allow us to control how and how well the program works. To have a control of the quality of the relocation process, we compared two absolute locations using our program HYPO2000: one before starting the relocation, with the raw data from the database and the second with the same data, corrected for the station terms COMPLOC computed. The first few tests confirm the location quality improvement.

- In 2007, 60 earthquakes occurred in the part of northwest Europe monitored by the Royal Observatory of Belgium (Figure 24). They range from M_L 0.1 to 4.3.The strongest of magnitude 4.3 occurred in Folkestone in England on April 28 and caused minor damages in the epicentral area. In Belgium, the strongest earthquake occurred near La Gleize on November 25 at 3h10m. Even if it was only of magnitude $M_L = 3.1$ and located at a depth of 15 km, it was strongly felt in Spa and Theux.

A.1.2.2. Historical seismicity

- *New research on the 18 September 1692 earthquake*: In the northwest of Europe the strongest known seismic event occurred on 18 September 1692. This earthquake produced significant destructions in the northern part of the Belgian Ardenne and caused widespread damage from Kent to the Rhineland in Germany and to Champagne. The traditional catalogues and compilations of historical seismicity give an overview of this earthquake from a limited number of sources contemporary of the event. Moreover, in these catalogues the difference between an original document and a later copy is not clearly specified. This lack of the rules of historical criticism was the cause of many mistakes. Previous studies gave wrong epicentre locations for the 1692 earthquake: for instance the area between Brussels and Antwerp or Eastern Brabant (Tienen). The first one who called the Brabant epicentre into question is the Alsatian scientist Jean Vogt (1984). The new study of Alexandre and al. (in press) confirms the Vogt's hypothesis about the location in the Verviers region and leads to draw a new map of the macroseismic area (Figure 25). New discoveries in different libraries and archives, for instance in a very useful source, the "*Unglücks-Chronica*", provide additional information on the effects of the 18 September 1692 earthquake, mainly for localities in the epicentral area and in Germany. In the northern part of the Belgian Ardenne, substantial to heavy damage and sometimes complete destruction of houses and large buildings (castles and churches) is described, suggesting intensity values on the EMS-98 macroseismic scale ranging from VII to VIII. German records allowed also to improve the assessment of the intensities in large cities like Köln, Mainz, Trier and Frankfurt and thus allowed to better delimitate the isoseismals of intensities V and VI towards the East. Based on the intensity evaluation for the 220 localities for which contemporary information is available, the magnitude of the earthquake has been evaluated to range between 6 and 6 ¼. A new list of the known aftershocks of the 18 September 1692 earthquake is presented together with maps indicating the localities in which these have been reported.
- *New research on past seismic events from periodical press (XVIIth-XXth centuries):* Historical data from old newspapers are very useful for the study of the past earthquakes. "Gazettes" from the second half of the XVIIth century until the end of the XVIIIth century, modern newspapers of the XIXth and XXth century contain many data from local correspondents, which ensure the determination of local intensities of the telluric events. The data gathered by Pierre Alexandre, Thierry Camelbeeck and David Kusman (ULB) led to the drawing of new macroseismic maps for the seismic crisis of the years 1755-1762, with epicentres in the Lower Rhine Embayment, and for the earthquakes of 23 February 1828 (epicentre in Hesbaye), 30 May and 6 September 1911 (epicentre in Verviers area), and 11 June 1938 (epicentre in Oudenaarde area).
- *New research on the effects in Hesbaye of the 1828 earthquake*: In cooperation with A.-M. Barszez (FPMons) and A. Sabbe (FPMons), A. Philipront and T. Camelbeeck collected original information on the effects of the 23 February 1828 earthquake in the villages of Hesbaye. We developed a methodology to study the earthquake impact in architectural inheritage, mainly for historical earthquakes.
- *Historical earthquake Database of the Royal Observatory of Belgium*: With the cooperation of J. Barthelemy, P. Alexandre and T. Camelbeeck continued to verify the historical data that have been

introduced in the earthquake database of the ROB by students as holiday job. The data concerning earthquakes that occurred during the XXth century should be soon available on our web site.

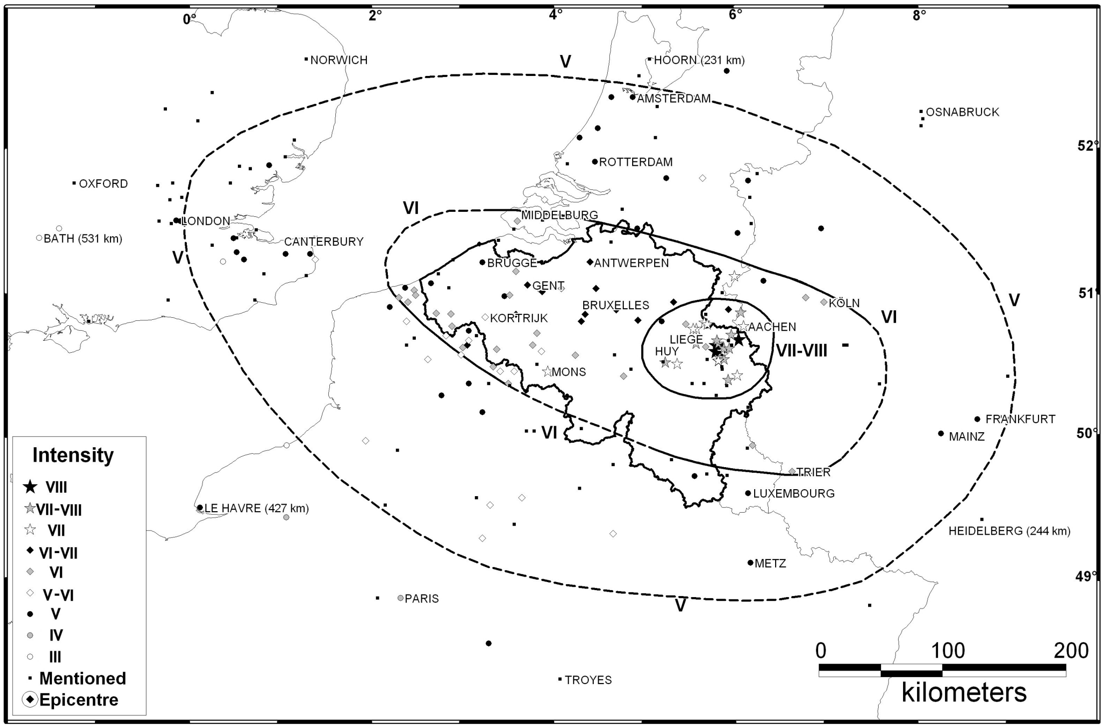

Figure 25. Macroseismic area of the 18 September 1692 earthquake (Alexandre et al., in press).

A.1.2.3. Compilation study “Seismicity of Flanders” for the Flemish Government

In May 2007, the Department “Leefmilieu, Natuur en Energie” of the Flemish Government issued a call for a scientific compilation study concerning the seismicity of Flanders, consisting of two main tasks:

- Study of seismic hazard, including time-independent factors (geologic conditions, soil stability, ...) and time-dependent factors (earthquake probabilities), which should lead to the drafting of a seismic hazard map;
- Study of the earthquake history of Flanders and surrounding areas, and its situation in the current tectonic context.

Considering the multidisciplinary aspect of such a study, we submitted a project proposal together with three other partners: the Belgian Geological Survey, the Department Civil Engineering of the University of Leuven, and the Laboratory for Soil Mechanics of the University of Gent. Our proposal was accepted, but a number of administrative and juridical (structure with subcontracts) difficulties have delayed the start of the project, but all issues have been solved now. The project will be launched in March 2008, and will last one year.

A.1.2.4. Structure of the lithosphere

In the framework of her Phd-thesis, Els Sichien finalized the determination of the Moho depth underneath Belgium (Figure 26) using wide-angle PmP and SmS waves reflected on the Moho generated by local earthquakes and induced and man-made events recoded by the stations of the Belgian seismic network. To enlarge our determination underneath the Brabant Massif, we installed two temporary stations in Ronse and Markegem, so that we could register more PmP-waves from North Sea explosions.

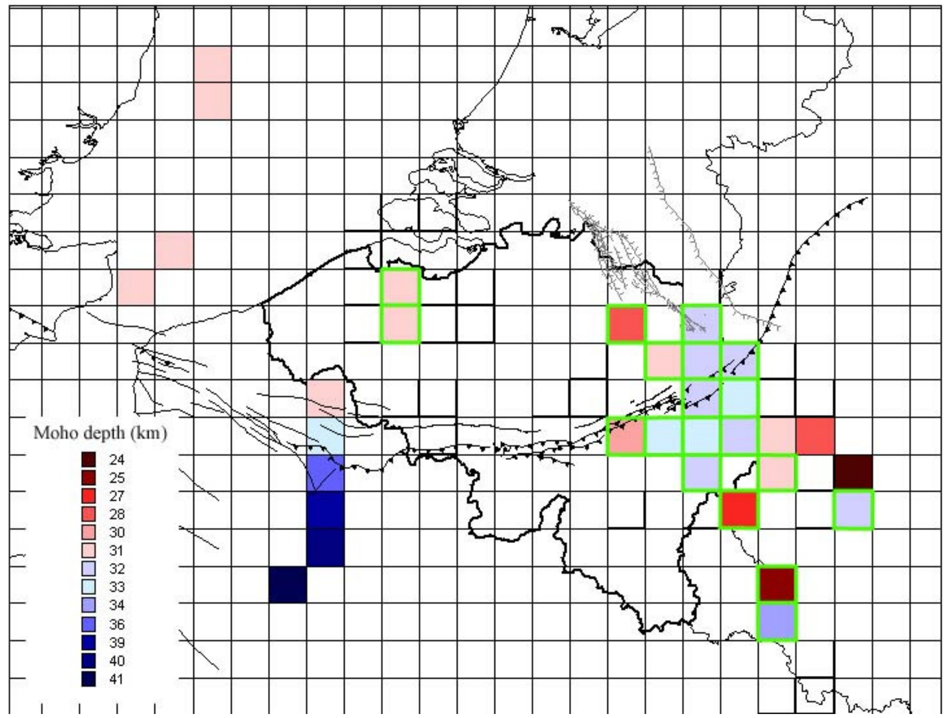

Figure 26. The Moho depth underneath Belgium by using arrival times of PmP-waves

We also started the local seismic tomography over Belgium. At first, we controled the data set and determine the well-located earthquakes to be used in the inversion. In a second phase, we tested the program SIMULPS and determined the parameters needed to perform a good tomography. We started testing the program INVER3D, developed by Fabienne Collin at the Royal Observatory of Belgium. This program has never been used for a three-dimensionnal tomography of this size. After a few test, several parameters had to be changed to make the program working for a tomography with a spatial scale of several tens of km.

A.1.3. Perspective for next years

A.1.3.1. Instrumental seismicity

The comparison of the earthquake activity in central US and northwestern Europe will be continued.

The quality of the relocation process of earthquakes in our region since 1985 will be determined using our new control tools. Once we will be sure that the relocation is good, we will focus on the results, trying to identify active structures by looking at alignments and groups of events. These structures will then be compared to known geological boundaries (on geological maps, if available), and we will try to identify them on field. We will use aerial photographs to have a first look at the geomorphology. We also plan to use satellite images for the same purpose.

We will reinstall programs written by T. Camelbeeck to determine fault plane solutions using the P and S-wave complete signals and write scripts to create their input from our database, so they can be as easy to use as FPSOL on POSEIDON. Once we will have the tools, scripts and database available, we will determine as many fault plane solutions as we can, starting with the Ardenne-Eifel region and expanding to the whole catalog once done.

A.1.3.2. Historical seismicity

A part of the important documentation of historical seismicity gathered from 1985 by Pierre Alexandre has not yet been exploited, that's to say it should subject these documents to the rules of historical criticism, publish the original texts and insert the reliable data in the databank of the ROB. It would be useful that this work was accomplished before the retirement of P. Alexandre.

New investigations in archives and libraries to look for documents on past seismicity are necessary to complete the already gathered documentation on the past seismicity of our regions; particularly the earthquakes of 4 April 1640, 20 January 1760, 23 February 1828 and 2 September 1896 need new studies of their area perceptibility and their effects and damage on the buildings of the concerned area.

Many data already inserted in the ROB seismicity databank of the Belgian area must be checked to be presented according the rules of sources criticism.

To lend one's support to this ROB databank, it would be necessary that the ROB publish in the next years the basis documentation of the historical seismicity of the Belgian area, that's to say the original texts from contemporaneous witnesses of the events, going with a catalogue of the worthless data from previous compilations. Moreover Th. Camelbeeck and P. Alexandre are working on a popularization book concerning the seismicity of the Belgium area from the VIIIth century.

A.1.3.3. Structure of the lithosphere

The local tomography over Belgium should be ended and the results interpreted in terms of geological structure. We will also publish the results of the Moho depth determination.

A.1.4. Personnel involved

Scientific staff: Alexandre Pierre (leader of the historical seismicity studies)
Camelbeeck Thierry (coordinator of the whole project and routine seismic monitoring)
Collin Fabienne (routine seismic monitoring)
Lecocq Thomas (FRIA-FC76908)
Philipront Amélie (investigations on the 1828 earthquake)
Sichien Els (IWT-43205, study on the crustal structure)
Vanneste Kris (coordinator of the project: Compilation study "Seismicity of Flanders")

Technical staff: Castelein Stefaan, Martin Henri, Vandeputte William, Driegelinck Eddy

A.1.5. Partnerships

List of international partners without grant

- Seismic section at the KNMI in De Bilt (The Netherlands)
- European Center for Geodynamics and Seismology and University of Luxemburg (GD Luxemburg)
- Seismic station Bensberg of the Cologne University (Germany)
- Bureau Central Séismologique Français (EOPG Strasbourg)
- Seth Stein (Northwestern University, Chicago)
- Massimiliano Stucchi, Istituto di Ricerca sul Rischio Sismico, Milano
- Jérôme Lambert, Bureau de Recherches Géologiques et Minières, Orléans
- Gottfried Grünthal, GeoForschungsZentrum, Potsdam

List of national partners without grant

- Alain Sabbe and Anne-Marie Barszez (FP Mons)
- Claude de Moreau de Gerbehaye, Head of Department, Archives Générales du Royaume/Rijksarchief
- Christian Dury, Archivist, Archives de l'Évêché de Liège

- David Kusman (ULB)

Grants/Projects used for this research/service

- PhD grant n° 43205 of the Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT-Vlaanderen).
- PhD grant n°FC76908 of the Fonds de la Recherche pour l'Industrie et l'Agriculture (FRIA)

A.1.6. Missions

Commissions, working groups (days):	Alexandre Pierre (2)
Research visits (days):	Camelbeeck Thierry (4)
Field missions (days):	Camelbeeck Thierry (2), Alexandre Pierre (7), Lecocq Thomas (6)

A.2. Research Project "Paleoseismology and active faults in continental intraplate regions"

A.2.1. Objectives

The research project "Paleoseismology and active faults" aims to develop and apply methodologies to identify active faults and to search for evidence of paleoearthquakes in the geologic record. These studies use a multidisciplinary approach combining investigations of the ground morphology, subsurface geophysical and geological investigations. For this purpose, the section seismology possesses a geodetic total station, the material to study aerial photos and the instruments to conduct resistivity, induced-polarisation and ground-penetrating radar measurements, and also the equipment to realize up to 6 m deep hand-borings.

These investigations extend our knowledge of the seismic cycle of active faults in intracontinental contexts but also plate boundaries, and thus contribute to a better assessment of seismic hazard. Investigations are focused on Belgium and neighboring areas, but also on other intraplate continental regions of the world, Bulgaria and Tanzania.

A.2.2. Progress and results

A.2.2.1. Fault activity in NW Europe and its relationship to seismic activity

We continued our search for active faults in Northern France. At two sites we did geophysical measurements, H/V-seismic-noise and electrical resistivity profiling, to locate possible faults. The sites we investigated where located south of Saint-Amand-Les-Eaux and at Wallers. The indications for faults on these two sites came from boreholes several hundreds of meters apart and we centered our profiles on breaks in the morphology that might represent fault scarps but that could also be created by other processes. The result of these measurements is that along the distance of our profiles there is no (long lasting) active fault. On both profiles we can interpret a small displacement of some meters, but the displaced layers are cretaceous deposits and thus too old for such a tiny displacement. We also did a one-day field exploration of the Bailleul fault between Bailleul and Hondeghem. Jean-Pierre Colbeaux guided us to several sites where the available borehole or vertical electrical sounding (VES) data suggested that the correlated layers of Cretaceous where vertically displaced, south down by the supposed Bailleul Fault. This possible fault is located at the southern margins of the EW oriented line of hills Kemmelberg, Rodeberg, Zwarteberg, Mont des Cats, Mont des Recollets and Mont Cassel. The observed topography at the sites we visited was however not convincing that this is an active fault. We decided to concentrate our future efforts in the Artois region on the zone of faults between (Folkestone, GB) Sangatte and Cambrai, for which we have more indicators of their recent activity.

A.2.2.2. Active faults and past large earthquakes in the Upper Thracian Depression, Bulgaria

During the visit of our colleagues from the Bulgarian Academy of Sciences in September we finalized the interpretation of the paleoseismic trenches in Kopanite and Popovitsa, and started writing a manuscript that now has to be completed by our Bulgarian colleagues.

In the month of November we conducted a geophysical reconnaissance survey in the Upper Thracian Depression. Seven electric resistivity profiles were collected at three different sites:

- Tatarevo site on Popovitsa fault: This site was selected by our Bulgarian colleagues as a candidate for future trenching. The passage of the fault at this site was inferred from hand-auger holes. We recorded three profiles across the suspected fault trace with different recording parameters. All three profiles show clear evidence vertically displaced stratigraphic layers, confirming the presence of the fault at this site (Figure 27).
- Site north of the Maritsa River: Contemporary sources describe surface faulting across the river in the 1928 earthquake, but so far we have not been able to determine the position of the fault close to the river. We recorded a long profile parallel to the northern bank of the river, but again we did not find any clear indication of a normal fault. Either the fault is located further northeast, or its vertical slip component is strongly reduced.
- Choba escarpment: This is a topographic escarpment ca. 10 km north of, and parallel to the Chirpan fault which we studied earlier. It has a similar geomorphic expression as Chirpan fault, and would therefore be a good candidate to extend our paleoseismic research. We recorded three profiles at three different sites. The westernmost profile shows a clear fault signature, but the two other profiles are more ambiguous. Further geomorphic research will be necessary to distinguish between faulting and fluvial incision at these sites.

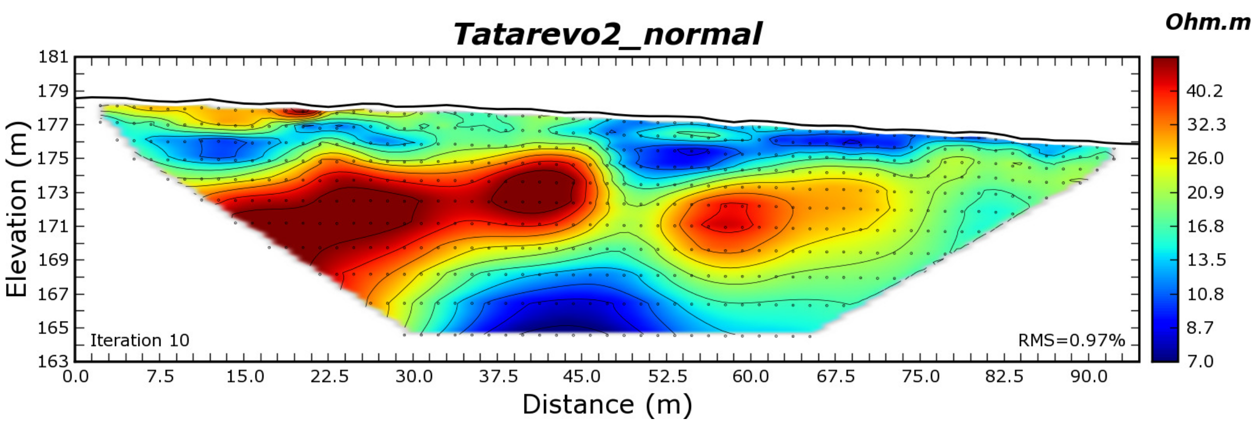

Figure 27. Electric resistivity profile across Popovitsa fault at Tatarevo: the fault is clearly evidenced by vertical displacement of high-resistivity layer, and juxtaposition against low-resistivity layer in the downthrown block.

A.2.3. Perspective for next years

In 2008, we intend to write a publication with the final conclusions from the paleoseismic investigation of the Geleen fault in the Belgian Maas valley. We will also cooperate with our Bulgarian colleagues to submit a paper with our findings from Kopanite and Popovitsa trenches. A new trench at the Tatarevo site in Bulgaria is scheduled for September. We will conduct targeted geophysical reconnaissance at one or two of the most promising sites in the Boulonnais-Artois region in northern France. For the Boulonnais-Artois region in northern France, we decided to focus our future efforts on the Sangatte fault and the Marqueffles fault, for which indications of recent activity are relatively strong. We will conduct a gravity profile across the Sangatte fault, to better pinpoint this structure, and if time permits, carry out an electric resistivity survey at one or more sites on the Marqueffles fault.

In the framework of the Phd-thesis of Thomas Lecocq, we will begin investigations to identify active faults in the Ardenne, by using the methodologies developed by our section during the last 10 years.

A.2.4. Personnel involved

Scientific staff: Camelbeeck Thierry, Petermans Toon, Vanneste Kris, Verbeeck Koen

Technical staff: Castelein Stefaan

A.2.5. Partnerships

List of international partners without grant

- Michel Sébrier et Françoise Bergerat (Université Paris VI, Paris)
- Jean-Pierre Colbeaux (Conseil scientifique des parcs régionaux Nord de la France)
- Alexander Radulov, Geological Institute and Marlena Yaneva, Geological Institute, Bulgarian Academy of Sciences

List of national partners without grant

- Sara Vandycke (Faculté Polytechnique de Mons)
- Dimitri Vandenberghe, Luminescene Laboratory, University of Gent
- Florias Mees, Laboratory of Mineralogy and Petrology, University of Gent
- Etienne Paulissen, Physical and Regional Geography Research Group, Katholieke Universiteit LeuvenPerson, Institute

Visitors:

- Alexander Radulov, Marlena Yaneva & Stefan Shanov, Geological Institute, Bulgarian Academy of Sciences, 11-16/09/2007

A.2.6. Missions

Field missions (days): Camelbeeck Thierry (2), Vanneste Kris (27), Verbeeck Koen (28), Petermans Toon (1)

A.3. Research Project "Seismic Cycles - Understanding the irregularity of seismic cycles: A case study in Turkey"

A.3.1. Objectives

This project is conducted in the framework of a CEE Marie Curie Excellence support. It is seeking to obtain a most extensive chronology of past events along both the North and the East Anatolian Faults. For that purpose, we use a diverse array of complementary techniques, involving trenching across the fault combined with subsurface geophysics, dating of displaced geomorphic features and drilling of lake sediments along the fault trace. The objective of the project is to get an extensive chronology of past earthquakes along the Anatolia Fault system in Turkey.

A.3.2. Progress and results

We have made significant progress toward the establishment of an accurate earthquake chronology along the North Anatolian Fault System combining main different techniques: trenching across the fault with subsurface geophysics and coring of lake sediments along the fault trace.

Regarding the earthquake record obtained by paleoseismic trenching, the analysis of a first trench has revealed six major earthquakes in the last 3000 years, the first one being the known M=8 1668 historical earthquakes. The Destek trench site was located on the eastern part of the central segment of the North Anatolian Fault, that ruptured during the M=7.4 1943 earthquake. The earthquake chronology should be tightly constrained as we collected about 150 dating material, mostly charcoals that show very little contamination. We are expecting further radiocarbon dating from our collaborator, Dr. Jeff Pigati (USGS Arizona) to accurately constrain the timing of individual events. We would thus obtain the longest paleoseismic record of earthquakes on the North Anatolian Fault.

Collaboration with Dr. Jeff Pigati, a specialist in geochronology, was very successful unabling us to assess in depth (1) the reliability of our dating material, charcoal, looking for possible contaminations and (2) the usefulness of other dating materials like gastropod as chronometer in Turkey. The sharing of its expertise also provided a good training for our team in radiocarbon dating.

Finally, we also developed a new promising technique the mapping of physical properties, like the magnetic susceptibility, directly measured on trench walls. Point measurements of the magnetic susceptibility done on trench walls in summer 2006, with a regular spacing vertically and horizontally, did provide a physical property map of the sediments in the trench. The latter was used to access sediment provenance independently of the trench log and helped identifying sediments related to earthquakes. The success of this technique has encouraged us to investigate the usefulness of other physical/geochemical properties mappable in the field on the trench walls for tracking sedimentary deposits related to earthquakes.

The dissemination of the first results of this research occurred through the active participation to workshops and conferences (European Geophysical Union), and we are waiting for the final readiocarbon dating results to write the first papers on that subject.

During summer 2007, we have opened a new successful trench 150 km east of the previous site, where 4-6 events could potentially be identified. The site is located on the eastern fault segment that ruptured in 1939 during an M=7.9 earthquake. The site study also included a complete geophysical survey (electrical tomography, ground penetrating radar) to clearly identify the different fault segments. On that trench walls we measured the magnetic susceptibility and the elemental composition of the sediments using an XRF scanner. We also collected dating material (charcoal and gastropod) and sediment samples for further laboratory analyses (grain size, Total Organic Carbon). Finally we also performed a geomorphic study of the area particularly focusing on the set of terraces associated with the Kelkit River.

Regarding the use of sedimentary cores to extract an earthquake chronology, we analyzed short cores collected during summer 2006 to characterize the signature in the sediments of the recent sequence of M>7 earthquakes that occurred in 1939-1942-1943-1944 on the North Anatolian Fault. We focus on six different shallow lakes mostly located near paleoseismic trenching sites and ran a range of analysis (geochemical with an ITRAX X-ray core scanner, geophysical with a Geotek core scanner, bulk mineralogy, grain size, organic matter, d13C, Cesium and Lead dating ...) on selected short cores for each lake. The earthquake signature of the most recent large earthquakes that occurred at the sites under study will then be used to identify on long (3–6 meters) cores the other major past earthquakes of the last few thousand years.

Because of the lack of laboratory facilities for sedimentological studies at the Royal Observatory of Belgium, we developed intensive collaborations with Prof. Fagel, U. of Liège, for storage, basic sedimentary analysis (grain-size, mineralogy, etc), TOC, ^{13}C; Prof. Cagatay, Eastern Mediterranean Center for Oceanography and Limnology (EMCOL), Istanbul Technical U., for storage, ITRAX X-Ray core scanner; Prof. Moran and Prof. King, U. of Rhodes Island, USA, for Geotek, CCD imaging, Cesium and Lead dating.

The first results of this research were advertised through the active participation to workshops and conferences (European Geosciences Union, International Limnogeology Congress – ILIC), but we are still waiting for Cesium and Lead dating results to firmly interpret the results obtained and write the first papers on that subject.

During the summer of 2007, long cores from 5 shallow lakes along the North Anatolian Fault have been successfully obtained using coring material from EMCOL, Istanbul Technical U. We also acquired high resolution seismic reflection profiles in each lake using the rented EMCOL material. Seismic surveys were necessary to select the best coring sites, to define the sediment architecture and to model the sites response to earthquakes.

On the East Anatolian Fault, we focus our study on the Lake Hazar, which is a 20 km long, 5 km wide and 210 m deep active pull-apart basin. The lake, its sediments and its fault related structure have never been studied before (no reliable bathymetric maps, no geophysical survey, no limnological survey in the deep part of the lake, no coring), even if it is a major active structure capable of producing earthquakes of magnitude greater than 7 and is located within 100 km of at least three dams on the Euphrates-Tigris river system. Two known historical earthquakes of magnitude 6.7 and greater than 7.1 occurred in that area in 1874 and 1875, but possible associated fault ruptures are unknown.

We did collect short cores in the shallow part of the lake during summer 2006 that were successfully analyzed in the same ways as the cores from lakes along the North Anatolian Fault.

The lack of existing scientific data and the high scientific interest of that tectonic lake lead us to set up an interdisciplinary study of the lake. The main project goal is still to understand the sedimentary lake record, the lake structure and extract the first earthquake chronology on the East Anatolian Fault. Most of data acquisition occurred during summer 2007, where we conducted:

- a limnological/biological study in collaboration with Turkish biologists: Dr. Naime Arslan Eskisehir Osmangazi University; Dr. Elif Neyran Soylu and Dr. Faruk Maraslioglu, Samsum Ondokuz Mayis University.
- a complete seismic survey in collaboration with Prof. Marc de Batist, Ghent U. and Prof. Namik Cagatay, PhD student Emre Damci, EMCOL, Istanbul Technical U. The later was required to select the appropriate deep coring site, and was necessary to understand the fault segmentation and the occurrence of the two historical earthquakes.
- a coring campaign to extract 5 m long sedimentary cores from two sites selected using the seismic survey. The chronology of past earthquakes on the East Anatolian Fault will be obtained mainly using these long cores. Coring was done in collaboration with Prof. Namik Cagatay, EMCOL, Istanbul Technical U. We had many technical problems with the platform and coring system built by EMCOL–ITU.
- Unsuccessful paleoseismological trenching across the East Anatolian fault (trenches without any recent sediment able to record the occurrence of earthquakes). The dryness and the erosiveness of environment are not favorable to the preservation of young sediments capable of recording earthquakes near the main fault trace.
- more than 12 excavations on the major alluvial fan at the south-western extremity of the Hazar Lake that is bounded to the south by the East Anatolian Fault. We logged (conventional logging plus magnetic susceptibility measurements) all exposures looking for sedimentary disturbed structures, namely seismites, and sampled all the exposures. Our goal was to correlate the alluvial fan sedimentary record with the lake sediment record.

The Hazar lake area has been the focus of two earthquakes of magnitude greater than 5.5 in the last 4 years. Our Turkisk collegues, Prof. Cagatay, Prof. Gorur from Istanbul Technical University and the project leader, Dr. Aurelia Hubert-Ferrari, gave regional and national TV interviews in which the project was advertised as well as the significant earthquake hazard related to the East Anatolian Fault in that area.

A.3.3. Perspective for next years

Spring 2008

- Paleoseismological trench studies:

  a) Dating of charcoal samples from the Resadiye trench to constrain the earthquake.

b) Local geomorphic map of the trench site will be produced.

c) Writing paper about frist trench site in Destek.

- Sedimentological lake studies:
  - Cores along the North Anatolian Fault (Ulas Avsar's thesis)
    - Analyses (water content, LOI, mineralogy, Isotopes) in Liege of short cores collected in summer 2007
    - Geotek –Geophysical- core scanning analysis in U. of Aachen of short and long cores collected during summer 2007
    - ITRAX –Geochemical- core scanning analysis in U of Stockholm of short and long cores collected during summer 2007
    - Anisotropy of the magnetic susceptibility in U. of Utrech of short and long cores collected during summer 2007.
    - Selection of dating material, and sending it to Jeff Pigati.

  The analysis will continue until the fall.

  - Cores along the East Anatolian Fault- Hazar area (Xavier Boes's Thesis)
    - Geotek core scanning analysis in Rhodes Island U. of short and long cores collected in summer 2007
    - ITRAX –Geochemical- core scanning analysis of short and long cores collected during summer 2007
    - Cesium and lead dating in Rhodes Island U.

    Selection of dating material, and sending it to Jeff Pigati.

Summer 2008

- Paleoseismological trench studies – Golova Site

Paleoseismic trenchs are planned on the Golova site (Figure 24) selected during summer 2007 during field work. The site is located near Asagitepecik lake, also studied in that project. At this site, we aim to get a good chronology of earthquakes using classical paleoseismological trenches, where past earthquakes can be identify because they disrupt the stratigraphy near the fault trace. The fault segment studied ruptured in 1939 during a M=7.9 earthquake, and was associated with up to 8 m of right-lateral displacement. No paleoseismological data exist on that fault segment. Kris Vanneste, Koen Verbeeck and David Garcia will help with the paleoseismological trench studies.

- Other Paleoseismological trench site study

We plan to try to find another site for Paleoseimological trenching along the NAF, and open a trench.

- Lake studies – Compilation of Information about Lake level changes, paleoclimate, additional short cores taken on some key lakes

Ulas Avsar plan to compile information about Lake level changes, past climate at the site under study. He may also take additional short cores needed for paleomagnetic study.

- Fall 2008 – Paleoseismological trench studies:

  - Most of our time will be devoted to the analyses of material collected in the field: paleoseismological trench logs, and soil samples.

  - Participation to AGU Fall meeting

- Fall 2008 – Sedimentological trench studies:

  - Analysis of sedimentary cores if not finished during spring time

  - Writing papers

- Participation to AGU Fall meeting

A.3.4. Personel involved

Scientific staff: Hubert-Ferrari Aurélia (project leader), Boës Xavier, Fraser Jeffrey, Avsar Ulas, Garcia Moreno, Vanneste Kris (paleoseismic work), Verbeeck Koen (paleoseismic work), Lecocq Thomas (geophysical investigation)

A.3.5. Partnerships

List of international partners without grant

- Erhan Altunel, Hatice Kutluk, Eskisehir Osmangazi University, Turkey
- Naime Arslan, Eskisehir Osmangazi University, Turkey
- Moran Bradley, University of Rhode Island, Narragansett, USA
- Namik Cagatay, Istanbul Technical University
- Emin Demirbag, Istanbul Technical University
- James Dolan, U. Southern California, USA
- Neyran Soylu Elif, Samsum Ondokuz Mayis University, Turkey
- Chip Heil, University of Rhode Island, Narragansett, USA
- King John, University of Rhode Island, Narragansett, USA
- Jarg Pettinga, University of Canterbury, New Zealand
- Jeff Pigati, USGS Arizona, USA
- Andy Nicol, Institute of Geological and Nuclear Sciences, New Zealand
- Ludvig Löwemark, Stockholm University, Sweden

List of national partners without grant

- Nathalie Fagel, U. of Liège
- Marc de Batist, Ghent University
- Nadine Matielli, ULB
- Philippe Claeys, VUB

Grants/Projects used for this research/service

- Marie Curie Excellence Grant MEXT-CT-2005-02

Research visits (days): Avsar Ulas (65), Boës Xavier (100), Garcia Moreno David (65), Hubert-Ferrari Aurélia (15), Fraser Jeffrey (2)

Field missions (days): Avsar Ulas (110), Boës Xavier (45), Garcia Moreno David (64), Hubert-Ferrari Aurélia (32), Fraser Jeffrey (57)

B. Research theme “Present-day deformation of the lithosphere”

B.1. Research Project “Deformations of the lithosphere in northwest Europe caused by climatic loading and tectonic strains – geophysical instrumentation”

B.1.1. Objectives

In northwest Europe, modelling of the present day movements and deformations of the lithosphere are controlled by the glacial isostatic adjustment (GIA). These movements are in apparent contradiction with those inferred from the study of the seismic activity, in-situ stress, the geologic and geomorphic quaternary investigations. Therefore, it is paramount to investigate the relative contributions of the tectonic forces and of the climatic loading.

Our goals in this project are:

1. To interpret the present-day deformations by including the WALCORS and FLEPOS GPS networks in the European network, in collaboration with Section 1 of ROB;
2. To perform absolute gravity measurements along a profile in the Ardenne and Germany. Comparison of these measurements with the GPS data will allow us to determine a stable reference, which is paramount to ensure reliable long-term measurements;
3. To better understand the relationship between present-day deformations and the observed ones in the karst morphology in the Walloon caves. For that purpose strain measurements in the Rochefort cave are essential to understand the local deformation rates and to relate them with the regional scale;
4. To model and correct the hydrological effects on geodetic and geophysics measurements.

These investigations are favoured by the development of geophysical instrumentation for the Rochefort laboratory, but also for the monitoring of the water levels in Uccle and for the Lanzarote Geodynamical Laboratories of Cuerva de los Verdes, Jameos del Agua and Timanfaya. The long time series of these instruments are analysed using the HiCum software developed at the ROB. This program allows detecting very weak stationary signals.

B.1.2. Progress and results

B.1.2.1. Absolute gravity measurements

To better assess the present-day crustal deformations, absolute gravity measurements using the FG5-202 gravimeter have been conducted along a profile twice a year since September 1999. This 140 km long profile includes 8 stations across the Belgian Ardenne and the Roer Graben. During the profile, the FG5-202 calibration is controlled at the Membach reference station. We also perform AG measurements in Ostend yearly. Presently we observe an average gravity rate of change of +3.0±5.0 nm/s²/yr, which is equivalent to a subsidence rate of -1.5±2.5 mm/yr (1nm/s² ⇔ 0.5 mm). The observed rate provides an upper limit on the possible uplift of the Ardennes and does not contradict the subsidence predicted by GIA models and GPS measurements (-1.2±0.6 mm/yr according to Nocquet et al., 2005). This is paramount to evaluate the future impact of sea level rise. Three stations worth of note are Jülich, Ostend and Membach:

- In Jülich, a gravity rate of change of 37.0±5.9 nm s^{-2}/year equivalent to 18.3±3.0 mm/yr is due to anthropogenic subsidence. These measurements complement other geodetic measurements around the brown coal mining region. This will allow us to get an insight into mass redistribution phenomena related to gradual surface subsidence. The Jülich experience demonstrates that anthropogenic subsidence can reduce or eliminate the possibility of monitoring tectonic deformation in the Graben.

- In Ostend, the AG measurements agree with tide gauge data, mean sea level and CGPS measurements.
- In Membach, differences in the rates observed since 1996 and 1999 and comparison with global hydrological models indicate that long term environmental effects may influence the inferred trend.

Our study indicates that, even in difficult conditions, AG measurements repeated once a year can resolve vertical land movements at the mm level, which is appropriate to monitor GIA effects, present-day ice mass changes, deformations at plate boundaries or subsidence in river deltas, provided the instruments are carefully maintained. The seasonal variations do not influence the trend significantly if campaigns are repeated during the same season, but can provide insights into ongoing hydrological processes. This study also confirms the need to measure for decades, using accurate and stable geodetic techniques like AG, for investigating slow deformation processes in intraplate context.

The slow crustal deformations are also monitored using CGPS in Bree and Meeuwen. At Membach station the CGPS measurements in Membach were interrupted in 2003; a new station is operational in Jalhay since 2006.

To monitor the stability of the Black Forest Observatory, where a superconducting gravimeter should be installed in 2008 or 2009, we were invited to perform absolute gravity measurements in November. This allowed us to initiate new projects in low-frequency seismology (BFO is a leading observatory in that field) and to bring our experience in superconducting gravimetry and hydrological effects on gravity.

B.1.2.2. Strain measurements in the Rochefort cave

Very recent fault activity has been observed in different caves of the Belgian Ardennes. To quantify these movements and to understand their possible causes, specific investigations have been conducted in the karstic network of the Rochefort cave where the morphological evidence of this activity is well visible. A geophysical laboratory was installed in the cave in 1997 to monitor the movements along some of the faults in parallel with environmental parameters such temperature, atmospheric pressure and water flow from stalactites. Specific instrumental devices have been developed to be able to measure very slow fault movements. During the ten years of measurements at the fault “Fontaine-Bagdad”, which presents the most significant displacement in the karstic morphology of the order of 0.3 m, a continuous relative movement of 0.03 mm/year is evidenced in the direction parallel to the observed slickensides. It suggests that the total displacement could have occurred since the end of the last glacial period and that this type of surface deformation is one of the expressions of the deformations of the lithosphere caused by the climatic cycles of loading and unloading of the large ice sheet. In relationship to gravity measurements, a pluviometric station has also been developped and will complement the environmental measurements inside the Rochefort site.

B.1.2.3. Hydrological and other environmental effects

Membach:

We were the first to establish a reliable model to correct hydrological effects on SG measurements. This model is based on comprehensive local hydrogeological investigations (Van Camp et al., JGR, 2006). Remaining variations are partly due to atmospheric influences that are not completely corrected using the 1D model based on the local barometric data. Using the corrected time series, together with the University of Hanover, a 3D atmospheric model was applied on the corrected Membach time series. The variance of the remaining gravity residuals was then decreased by 16%. Such a work was already done by different authors but the improvements were mostly masked by the uncorrected prevailing hydrological effects. Because we are able to correct hydrological effects efficiently, 3D atmospheric models can be validated accurately at the Membach station. This is part of the PhD thesis work of O. Gitlein (U. Hanover).

For the first time we had also the opportunity to apply our hydrological model to improve the signal from a storm surge in the North Sea, which caused ocean loading deformations on the north-west European shelf. This event was generated by winds over the northern North Sea and the surge travelled southwards as a Kelvin wave along the east coast of the UK, taking about 9 hours to travel, with increasing amplitude, from Scotland to the Thames estuary and then to Belgium, the Netherlands and Germany. In the Fratrepietro et al paper (GRL, 2006) we presented the influence of such a storm surge on gravity at the Membach station in 2000. However, while the surge tends to increase the gravity, on the other hand, because storms are accompanied by rainfalls, hydrological effects tend to decrease gravity at the Membach station, partly masking the loading effect of the surge. In 2000 no hydrological data were available to correct the rainfall effect, making difficult its detection. This was not more the case during the large event of November 9, 2007.

Jülich:

At the Jülich site the seasonal variations are mostly caused by changes in the shallow unconfined aquifer. We took the data from wells recording around the station, modeled the gravity effect, and evaluated the porosity that best reduces the seasonal variations. We found a value of 22%. The seasonal variations, as well as a step-like function in fall 2003, are smoothed out.

Rochefort:

In karst aquifers, the void spaces consist of caves and conduits, smaller fissures, and a porous matrix. From a drainage point of view, they are structured in two types of subsystems: the drains with low retention capacity and high permeability, and the annex systems with high capacity but weak connectivity to the drain. The degree of interconnection or the permeability of the different subsystems can vary over several orders of magnitude. Because of the heterogeneity of such aquifers, it is not possible to know the spatial distribution of the different subsystems. When the system is flooded, the rise of the water table depends on the characteristics of the subsystems. The drains are distinguished from the annex subsystems by very short residence time of water. This dynamic is essentially nonlinear and does not permit reliable predictions.

The main inputs of the Rochefort cave are swallow holes of the Lomme River. The river is canalized; however, in strong flood conditions, the water spills over the dyke and sinks into the Nou Maulin swallow hole, connecting suddenly the cave network. This induces very fast rises of the water table in the caves, causing fast gravitational effects that can be investigated using precise gravimetric methods. The absolute gravimeter FG5-202 was installed on the ground surface above the cave during the winters 2005-2006 and 2006-2007 and monitored transient increase in gravity of about 100 nm/s² during the floods. This moderate gravity variation suggests either a weaker porosity or that only the filling of the cave and conduits was responsible for the observed gravitational effect. The role of the unsaturated zone above the cave ("epikarst") is questionable and should be investigated soon.

B.1.2.4. Geophysical instrumentation and analysis of very weak signals

We continued to design the loggers DigitROB which is a new low-power acquisition system consuming about 10 µA which could continuously work over one year with 2 AA ion batteries. We reached a resolution of the order of 10^{-5} in the measurement of the variability of the oscillation periods of a vertical pendulum. We also adapted in cooperation with Ramon Ortiz (MNCN, Madrid) our picoDAS data logger (most recent development of EDAS) for the seismic monitoring of volcanoes. It requires a clocking accuracy of 1/100$^{\text{th}}$ of second in absolute.

We start to develop the prototype of a new sea tides and tsunami monitoring sensor, including a ZIGBEE wireless data transfer system compatible with the communication networks of EDAS.

We continued to optimize the procedure of spring gravimeters calibration with our inertial forces platform (Figure 28). A new microprocessor controls the step motor to produce maximum smooth vertical motion of the platform. We set up the system equipped with two L&C Gravimeters.

Figure 28. Calibration of a spring gravimeter with the oscillating platform developed at the ROB.

We continued the experiments in Uccle and Lanzarote with the specific instrumentation developed at the ROB. In Uccle, we are monitoring the water levels since more than 20 years, whereas in Lanzarote, three different sites are equipped since a long time period with 40 instruments dedicated to monitor ground movements and environmental parameters.

A Phd thesis has been undertaken by Zhu Ping to identify very weak stationnary signals (VWS project) in geophysical recordings. During the first year, Zhu Ping developed part of the software, based on the HiCum method, and already applied it to continuous recordings collected during specific ROB projects: the barometric pressure influence on tidal gravity variations in Membach – sea level recordings in a lava tube in Lanzarote – the monitoring of strain, pressure and temperature in the Rochefort cave – ground water levels in the three upper aquifers in Uccle. Using this approach, we also studied the possible tidal triggering of earthquakes and applied it to the Vrancea seismic zone in Roumania.

B.1.3. Perspective for next years

In collaboration with Olivier de Viron (IPG Paris), we intend to analyse the terrestrial gravity data from northwest Europe (ROB database) to evaluate large scale mechanical properties of the lithosphere and to discriminate the origin of the gravity anomalies in southern and northern Belgium.

In collaboration with S.D.P. Williams (POL) and N. Penna (U. Newcastle) we will investigate the gravitational influence of the November 2007 storm surge in the North Sea.

In collaboration with the Nordic Geodetic Commission, we will continue to collaborate in order to share the AG data for better constraining GIA models.

The AG profile is a long-term project. We plan to continue the profile once a year; after 14-20 years, we should be able to constrain any possible long-term trend with accuracy better than 1 nm/s²/yr.

Different experimental development will be done in the geophysical laboratory. A specific attention will be given to the clock synchronisation with GPS and to the wireless transfer of data. A full digital PID feedback will be designed for the gravitational balance and the LCR spring gravimeter. The lift platform to calibrate spring gravimeter will be reinstalled in the gravimetric room of the ROB. We will also continue our investigations on the tidal triggering of earthquakes.

A FRFC project has been introduced to complement the AG measurements by 6 more stations in northern France and Belgium, but also to further investigate hydrological effects on geodetic measurements in Membach, Rochefort and Jülich and to include the analysis of GPS data from the WALCORS and FLEPOS networks, in collaboration with Section 1.

B.1.4. Personnel involved

Scientific staff: Camelbeeck T. (responsible for the investigations in Rochefort)
Van Camp M. (responsible of superconducting and absolute gravimeters)
Van Ruymbeke M. (responsible of the laboratory of geophysical instrumentation)
Ping Zhu (action 2 Phd-thesis)

Technical staff: Bukasa B., Castelein S., Hendrickx M., Noël J.-P., Rapagnani G., Renders F.

Volunteers: de Kerchove E., Tuts G.

B.1.5. Partnerships

List of international partners without grant

- Prof. H.-G. Scherneck (Onsala Space Observatory), Dr. G. Strykowski (The Danish National Space Center), and the Working Group for Geodynamics of the Nordic Geodetic Commission;
- Prof. K.-G. Hinzen (U. of Cologne);
- Dr E. Pomplun, Dr. E. Kümmerle and M. Möllmann-Coers (Forschungszentrum Jülich);
- Prof. O. Francis, Dr T. van Dam (U. of Luxembourg);
- Dr. S.D.P. Williams (Proudman Oceanographic Laboratory, UK);
- Dr. Nigel Penna (U. of Newcastle);
- Dr L. Timmen, O. Gitlein (U. Hanover);
- Dr O. de Viron (IPGP, Paris) ;
- Prof. B. Meurers (U. of Vienna);
- Dr. W. Zürn, Dr. T. Forbrigger, Dr. R. Widmer (BFO, U. Karlsruhe, U. Stuttgart).
- Prof. J.-P. Barriot (U. Polynésie Française, Tahiti).
- Pr Ricardo Vieira & E.Veles, Univ.Comput.Madrid
- Pr R.Ortiz, Museo Nacional de Ciencias Naturales, Madrid
- Pr P.Bernard & Fr. Beauducel, IPGParis
- Pr D. Zugravescu, Institute of Geodynamics of Romanian Academy, Bucharest, Romania
- Pr Cai Wei Xin, BES-CEA (China)
- Dr. F. Greco, Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania
- Mr. S. Panepinto, Dipartimento di Chimica e Fisica della Tierra, Universita di Palermo

List of national partners without grant

- Prof. A. Dassargues (ULg/KUL);
- Prof. M. Vanclooster (UCL);
- Prof. V. Hallet (FNDP, Namur);
- Prof. Y. Quinif, Dr O. Kaufman (FPMS Mons);
- Dr. P. Meus (DGRNE, Division de l'Eau, MET);
- Ir J. Verstraeten (Afdeling Waterwegen Kust, Ostende);

Grants/Projects used for this research/service

- Ph. D. action 2 grant WI/33/G02.

B.1.6. Missions

Commissions, working groups (days): Camelbeeck T. (7)

Field missions (days): Camelbeeck T. (1), Castelein Stefaan (29), Noël J.-P. (1), Van Ruymbeke (18), Van Camp M. (45)

B.2. Metrology

B.2.1. Objectives

Gravimetry is a domain strongly related to metrology because *g* enters in the determination of standards derived from the kilogram (electrical intensity, pressure, force) and is to play an essential role in the new realization of the kilogram. *g* is also a key value to determine the geoid, the dynamic surface of the Earth.

The Royal Observatory of Belgium possesses an absolute gravimeter and as such participated to the "key comparisons" of AGs at the Bureau International des Poids et Mesure in Paris. The process is still ongoing to designate the Observatory as responsible for gravity in Belgium. In particular, the SPF Economy is waiting for a new law allowing this designation, which is necessary to be allowed to participate in future "key comparisons". Independently of these official comparisons in Paris, our absolute gravimeter participates in numerous intercomparison campaigns and in calibrating and controlling relative gravimeters.

Since Cavendish first measured Newton's Gravitational constant 200 years ago, "Big G" remains one of the most elusive constants in physics. As an alternative to the classical torsion balance experiments, we are developing at the ROB a static vertical pendulum in feed-back loop control to determine G.

B.2.2. Progress and results

As high accuracy reference instrument, the Belgian FG5-202 AG also participates in numerous international comparisons. In 2007 the FG5-202 was compared in Membach to the Luxemburg FG5-216 on 3-4 May and successfully participated to the International Comparison of Absolute Gravimeters in Walferdange, 11-14 November.

A meeting was organized at the SPF Economie (Métrologie, 24 September 2007) and the process is still ongoing to designate the Observatory as responsible for gravity in Belgium. In particular, the SPF Economie is waiting for a new law allowing this designation, which is necessary to be allowed to participate in future "key comparisons" of AGs at the BIPM.

Experiments have been done in order to validate our apparatus to determine G and to improve its signal to noise ratio.

B.2.3. Perspective for next year

As the absolute determination of the gravity is essential in geophysics and metrology, new intercomparison campaigns will take place in Luxemburg and possibly at other stations.

The next years will be devoted to the installation of the "G"-experiment in the gravimetry room of the ROB in complement to the one installed in the underground laboratory in Walferdange

B.2.4. Personnel involved

Scientific staff: Naslin S. ("G" experiment)
Van Camp M. (responsible of superconducting and absolute gravimeters)
Van Ruymbeke M. (responsible of the laboratory of geophysical instrumentation)

Technical staff: Castelein S., Noël J.-P., Renders F.

B.3. Projects "GIANT: Geodesy for Ice in ANTarctica" and "LISSA: Lithospheric and Intraplate Structure and Seismicity in Antarctica"

B.3.1. Objectives

GIANT: The University of Luxemburg and the ROB proposed an experiment to utilize contemporary geodetic techniques to provide information on the ice mass balance of the Antarctic Ice sheet, in the vicinity of the future Belgian station in Antarctica. This experiment will provide information which can be used to convert the satellite altimetric data into mass balance information.

We proposed to install two continuously operating GPS stations at a bedrock site (which is quite exceptional in inland Antarctica) at the proposed Belgian Antarctic Observatory. In order to derive reliable surface deformations, the GPS data will be analysed in a dedicated manner taking into account the location of the BAB and the extreme ionospheric conditions. In addition, the proposed GPS observations will be supported with annual observations of absolute gravity at the Belgian base itself. Given the noise on the absolute gravity and the GPS-based surface deformation results, we expect to be able to extract useful information on the mass balance of the region (an area of 500 km) within 7 years.

LISSA: The ROB will also install a seismic broadband station in the Belgian base. That station will allow to monitor the seismic activity in Antarctica, in the framework of international seismological cooperation, and to study the properties of the lithosphere at proximity of the base.

B.3.2. Progress and results

We participated in different meeting with the Belgian Science Policy and the International Polar Funcation in order to design the laboratory where the geophysical measurements will take place. This laboratory should be build during the austral summer 2008-2009.

B.3.3. Perspective for next years

If the construction works are on schedule, seismic measurements and possibly GPS and gravity measurements may start in early 2009. Otherwise it is hoped to start in late 2009.

During the spring 2008 tests will be performed at the Membach station in order to check that the air pump that will be installed by the Royal Meteorological Institute will not disturb the seismometer in Antarctica

B.3.4. Personnel involved

Scientific staff: Camelbeeck T. (responsible of the whole project)
Van Camp M. (ROB responsible for GIANT)

B.3.5. Missions

Commissions, working groups (days): Camelbeeck T. (4), Van Camp M. (2)

B.3.6. Partnerships

List of international partners without grant

- Prof. O. Francis, Dr T. van Dam (U. of Luxembourg)

C. Research theme “seismic hazards and risks”

To provide the decision makers (engineers, urban planners…) with usable information to prevent the worst consequences of future earthquakes, scientists introduced the concept of seismic hazard of a region or a site. It defines the characteristics of the strong ground motions to consider in the design of buildings, taking into account their lifetime and their societal importance (private house, public administration, hospital, school, power plant…).
Adequate preventive action requires studying the vulnerability of the buildings. It defines their sensitivity to the strong ground motions caused by earthquakes. The vulnerability concept includes the importance of the buildings in terms of costs, but also in terms of unsubstantial value or threat to human lives. The seismic risk, linked to the impact on buildings, defines the damage costs of a future earthquake in a given construction. The stakes concern also the impact in terms of human lives, number of injuries, economical costs due to the activity interruption or perturbation, social costs of homeless…

During the recent years, we developed methodologies to evaluate local seismic hazard in Belgium, basically by introducing site effects evaluation by the combination of experimental techniques with 1-D numerical modeling. In cooperation with the Department of Architecture of the Polytechnic Faculty of Mons, we began vulnerability and seismic risk studies.

C.1. Project: site effects – seismic hazard

C.1.1. Objectives

Many studies demonstrate that the seismic response of a site is largely dependent on the local geological conditions. The purpose of this project is to develop and integrate different methodologies, which allow estimating site effects from ambient noise records and numerical simulation. It aims to develop techniques to be specifically used in urban areas. By integrating the procedures into databases, it will improve strongly the seismic hazard studies conducted at the ROB and the expertise of the ROB for the increasing external requests in the field of seismic hazard assessment.

C.1.2. Progress and results

In 2007, we integrated deterministic seismic scenario calculations and a probabilistic seismic hazard study (partly done by Edouard Foriers at the ROB in 2006) for the Brussels Capital Region. All these results can be found in the final report of the project Belspo-Action 1 M0/33/016.

The Probabilistic assessment has been done using the CRISIS software. We calculated the Peak Ground Acceleration for a 10% probability of exceedance for the next 50 years, corresponding to a returen period of 475 years. The overall average result for Brussels resulting from 162 calculations including all the uncertainties using a logic tree approach is 0.05 g.

In the deterministic approach, we considered four seismic scenarios:

- The first one is a modelling of the 1938 Oudenaarde earthquake (Ms 5.0), which cause damages in Brussels;
- We modeled also a M 6.2 earthquake with an epicentre along the Bree fault scarp (part of the Feldbiss fault system in the Roer Graben);
- We also considered a M 4.8 earthquake in Hoeilaart (at 10 km of the centre of Brussels);
- To provide response spectra usable in building design, we considered also real strong motion records on the bedrock of the Campano Lucano of November 1980 in Italy (Ms = 6.9), that we rescaled to a PGA of 0.5 m/s²

We introduced the influence of site-effects by convolving the simulated earthquake signals obtained by the FINSIM software with the transfer functions (Figure 29) of five distinct places in Brussels (Heysel, city centre, Louisa, ROB and Lot in the south of Brussels). These transfer functions were calculated in one of the first phases of the project. In general, the results of the deterministic approach lie in the expectations of the probabilistic approach with calculated PGA values varying between 0.01 g (simulated Oudenaarde event at Heysel location) to 0.173 g (Campano Lucano rescaled 0.05 g event at Lot). However, the ground accelerations and associated ground response vary strongly with the sediment thickness and thus site-effects play an important role. In this sense, the calculated PGA at the surface can be up to 3 times more in Lot in the south of Brussels, compared with the other places, which is explained by the higher resonance frequency of the transfer function in Lot.

In 2007, ONDRAF/NIRAS asked the expertise of the ROB to conduct investigations to validate the choice of the Peak Ground Acceleration (PGA) to take into account in the design of the building for the storage of the short-lived and moderately active radioactive waste, located in Dessel. The regulation authorities (AFCN/FANC) recommended first providing an evaluation of the strong ground motions of possible large earthquakes occurring along the Rauw fault even if their probability of occurrence is very low. For this purpose, we evaluated the possible strong ground motions for the Dessel site in a deterministic approach in terms of expected peak ground accelerations (PGA) and ground response spectra. We did calculations for different scenarios, i.e. large earthquakes that are generated at nearby supposed active Quaternary faults as the Rauw fault at 10 km and the Geleen fault at 40 km. In these calculations, we considered also the site-effects by integrating the soil profile and its geotechnical characteristics (e.g. damping and shear wave velocity). The calculations of the seismic scenarios were executed with different software so that we could compare the linear strong ground motions modelling with the non-linear strong ground motion modelling. In the non-linear modelling, the soil profile will dissipate by greater input accelerations more seismic energy so that the resulting ground response will be more attenuated than by linear modelling. In order to validate our soil model, we conducted four ambient noise measurements to know the resonance frequency of the soil. The calculated soil model fitted well these measurements. All the results of these calculations are written in a confidential report for ONDRAF/NIRAS.

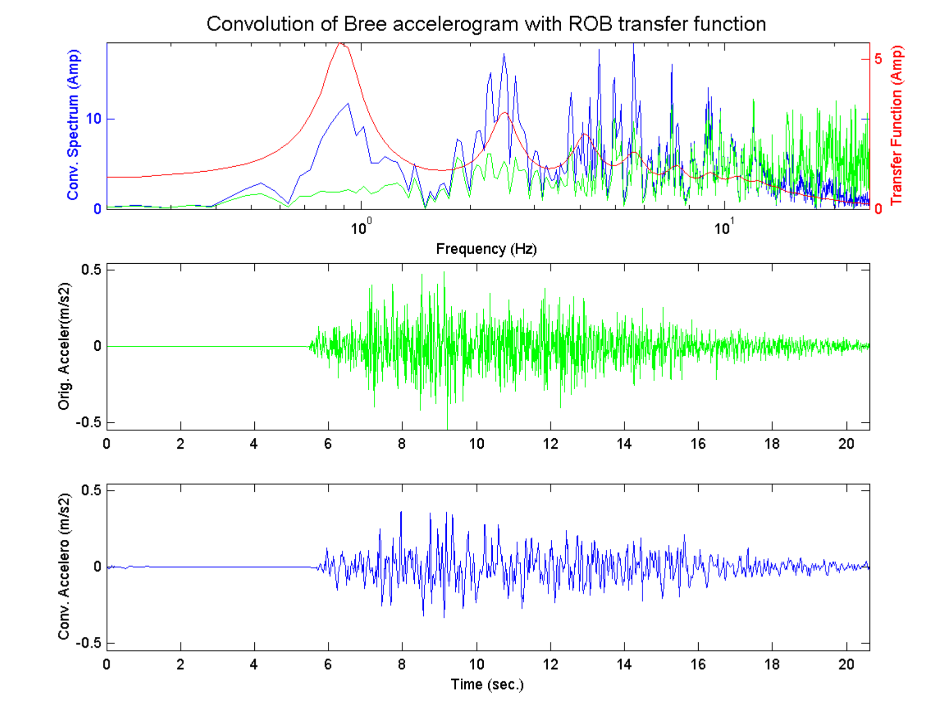

Figure 29. Seismic scenario of a M_0 6.2 earthquake along the Bree fault scarp for the site of the ROB in Uccle/Ukkel. The convolved signal and frequency spectrum is in blue colour, the originals in green and the transfer function in red.

C.1.3. Perspective for next years

For the ONDRAF/NIRAS project, four seismometers will be installed in the beginning of 2008 around the nuclear sites of Mol-Dessel. Two will be installed at the grounds of Smet Boringen in Dessel, one in a borehole at 600 meters depth and one at the surface. The two others will be installed at the grounds of the SCK in Mol, one in the Hades underground laboratory at 200 meters depth and one at the surface. This will improve our knowledge of the soil geotechnical parameters and real transfer functions can be obtained in case of earthquakes.

In 2008, a probabilistic seismic hazard study will be conducted for the Dessel nuclear site. In order to discuss and verify proposed methods, seismic parameters and results, a working group was constituted with people from the ROB, NIRAS/ONDAF, KULeuven, Tractebel and the Belgian Geological Survey.

We have been invited to participate to the proposal SHARE in the framework on the European Commission 7th program dedicated to the homogeneization of seismic hazard in Europe.

C.1.4. Personnel involved

Scientific staff: Camelbeeck Thierry (responsible for the ONDRAF/NIRAS project)
Petermans Toon

Technical staff: Castelein Stefaan

C.1.5. Partnerships

List of national partners without grant

- Wim Cool and Laurent Wouters - ONDRAF/NIRAS
- Alain Van Cotthem and Viviane Warnotte – Tractebel
- Noël Vandenberghe - KU Leuven
- Michiel Dusar - Belgian Geological Survey

Grants/Projects used for this research/service

- Belspo-Action 1 “Seismic hazard – strong ground motions: evaluation of site effects and lo-cal seismic hazard in Belgium”: M0/33/016
- ONDRAF/NIRAS Convention CCHO 2007-4177/00/00

C.1.6. Missions

Commissions, working groups (days): Camelbeeck Thierry (2)
Research visits (days): Camelbeeck Thierry (6), Petermans Toon (3)
Field missions (days): Castelein Stefaan (3). Petermans Toon (3)

C.2. Research Project “earthquake risks in Belgium”

C.2.1. Objectives

This project concerns the development of methodologies to evaluate seismic risks in Belgium. The project is done in cooperation with the Department of Architecture of the Polytechnic Faculty of Mons. Three different topics are considered: (1) the development of strategies to evaluate the seismic vulnerability of buildings in Belgium; (2) the evaluation of the repairing costs for the earthquakes that occurred since 1932 in Belgium, on the basis of the available information (macroseismic inquiry at the ROB, archives of the Disaster Fund …) and; (3) the elaboration of a methodology for the identification of seismic pathologies on architectural heritage and its application in Belgium.

C.2.2. Progress and results

We established an inventory of pathologies of churches in the epicentral area of the 23rd February 1828 earthquake by their observation in the field (Figure 30). Practical worksheets have been elaborated using the rules of the methodology and they were applied to several of the studied churches in Hesbaye. We extended also our investigation to the churches damaged by the earthquake of 11 June 1938, including search in the archives, inventory of churches touched by the earthquake, direct observations...

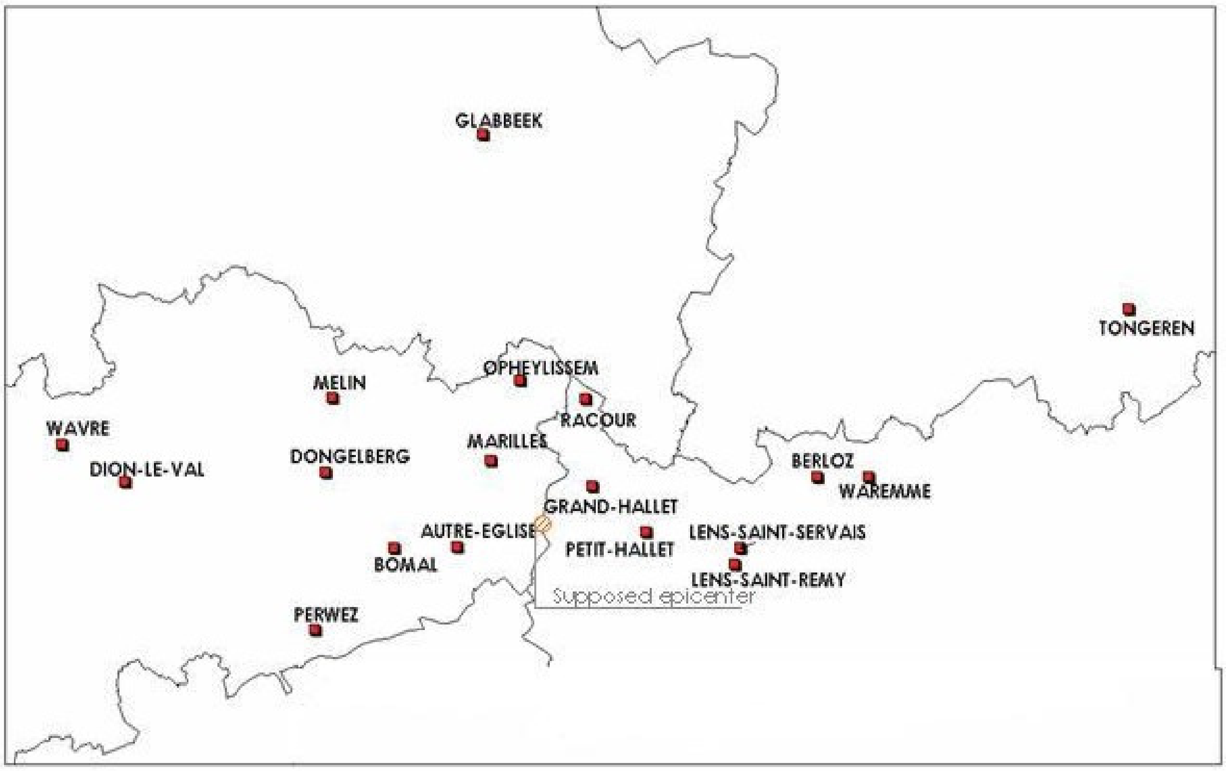

Figure 30. Location of churches for which historical sources mentioned damage caused by the 23 February 1828 earthquake.

Using the methodology developed by Anne-Marie Barszez (see annual report of 2006), we begun to analyse the repairing costs of the known damages (from the ROB databank) during the 11 June 1938 earthquake.

C.2.3. Perspective for next years

We forecast to prepare publications on the different methodologies developed to study the seismic pathologies in the churches of Belgium and on the repairing costs of damages caused by earthquakes as a tool to evaluate seismic risks.

C.2.4. Personnel involved

Scientific staff: Camelbeeck Thierry, Petermans Toon, Philipront Amélie

Technical staff: Castelein Stefaan

C.2.5. Partnerships

List of national partners without grant

- Anne-Marie Barszez, Alain Sabbe and Hugues Wilquin (Faculté Polytechnique de Mons).
- André Plumier et Hervé Degéé (Université de Liège)

C.2.6. Missions

Commissions, working groups (days):	Camelbeeck Thierry (4), Philipront Amélie (3)
Field missions (days):	Camelbeeck Thierry (3), Philipront Amélie (10)

D. Research Theme “Earth Tides”

D.1. Research Project “Global and Regional Earth Tides Studies”

Earth Tidal research is performed in a widely international context, as the Royal Observatory of Belgium (ROB) is sheltering the International Center for Earth Tides (ICET), which in turn is responsible of the database of the Global Geodynamics Project (GGP), a network of more than 20 stations equipped with superconducting gravimeters. These instruments are characterized by a very high sensitivity (10^{-11}g) and a very low instrumental drift, a few parts in 10^{-9}g, and provide new possibilities in tidal gravity studies. Many foreign scientists are thus collaborating with us not only in the framework of GGP but also for studies related to tidal phenomena in general.

D.1.1. Objectives

Interpretation of global earth tides observations with emphasis on the fine spectrum of the tidal waves, the determination of the liquid core resonance effect (NDFW) in the diurnal spectrum and the detection of the effect of the polar motion on gravity. For that purpose we use principally the global network of superconducting gravimeters (SG), known as Global Geodynamics Project (GGP).

Gravimeters, clinometers and strain meters are also used to monitor interactions between ground deformation, tidal signals and meteorological parameters.

D.1.2. Progress and results

Until July, we prepared actively several workshops and meetings. At the “First Asia Workshop on Superconducting Gravimetry, Hsinchu, Taiwan, March 12-16” we presented 3 communications. Two communications were dedicated to the study of the GGP network observations with emphasis on the free core nutation (FCN) on one side and the detection of the tiny forth-diurnal waves generated by the indirect effect of the ocean tides. With S. Rosat we focused on the European GGP stations for the study of the FCN. European GGP stations are indeed a very suitable for that purpose as the ocean tidal loading is very low in the diurnal band. New results have been presented at the EGU meeting in Vienna and at the IUGG General Assembly in Perugia. Considering the tidal parameters of 16 European stations (including 7 GGP stations) corrected for the ocean tidal loading, the mean tidal parameters for O1 and M2 agree within 0.1% with the DDW99 and the MAT01 models for an inelastic Earth. Moreover the GGP stations recover very well the FCN parameters. For that purpose the generalized least squares and Bayesian approaches give compatible results, provided that a non-negative Q-value condition is imposed on the least squares. During the stay of A. P. Venedikov we analysed very long records of ocean tides data to determine MSL variations, focusing on the detection of discontinuities in the records. The results were presented in Perugia.

During the second half of the year we made a re-analysis of the Oostend tide gauge data based on a 60 years (1945-2006) series. Beside the accurate determination of tidal constituents, including non-linear tides, the main goal was the determination of the MSL variations at Oostend. This work has been performed with the collaboration of A. P. Venedikov and Hans Poppe (Vlaamse hydrografie - Agentschap Maritieme Dienstverlening en Kust). With the help of J. C. Zhou we recomputed and evaluated global tidal gravity parameters on a 0.5°x0.5° grid based on recent ocean tides models.

The final version of the paper summarizing the results obtained during the project “Earth Tidal Observations in Siberia” sponsored by the S&T bilateral cooperation agreement between Belgium and Russia (convention BL/33/R09) has been published. The collaboration with the “Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania” has been finalized by the submission of a paper.

D.1.3. Perspective for next year

After his retirement, B. Ducarme will finalize the study of the 60 years of tide gauge records and publish the results.

D.1.4. Personnel involved

Scientific staff: Ducarme B.

Technical staff: Vandercoilden L.

D.1.5. Partnerships

List of international partners without grant

- Prof. A.P. Venedikov, Institute of Geophysics, Bulgarian Academy of Sciences
- Dr. V.Y. Timofeev, Trofimuk Institute of Petroleum Geology and Geophysics SB RAS, Novosibirsk
- Dr. H.P. Sun, Dr. X.G. Hu, Mr. Chen X.D., Mr.Zhou J. C. Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan
- Dr. F. Greco, Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania
- Mr. S. Panepinto, Dipartimento di Chimica e Fisica della Tierra, Universita di Palermo

List of national partners without grant

- Dr. Séverine Rosat, Royal Observatory of Belgium
- Ing. Guido Dumon and Hans Poppe, Vlaamse hydrografie - Agentschap Maritieme Dienstverlening en Kust

D.2. Operational Project “International Center for Earth Tides (ICET)”

D.2.1. Objectives

The terms of reference of the International Center for Earth Tides (ICET) are:

- To collect all available measurements on Earth tides as World Data Center C;
- To evaluate these data by convenient methods of analysis in order to reduce the very large amount of measurements to a limited number of parameters which should contain all the desired and needed geophysical information;
- To compare the data from different instruments and different stations distributed all over the world, evaluate their precision and accuracy from the point of view of internal errors as well as external errors;
- To build a data bank allowing immediate and easy comparison of earth tides parameters with different Earth models and other geodetic and geophysical parameters;
- To ensure a broad diffusion of the results and information to all interested laboratories and individual scientists.

D.2.2. Progress and results

Since 1997 ICET is the scientific responsible of the "Global Geodynamics Project-Information System and Data Centre" (GGP-ISDC, http://ggp.gfz-potsdam.de/). The data owners can upload themselves the original minute sampled data. The data are carefully preprocessed at ICET using a standard procedure, to correct for tares and spikes. The data are then decimated to one hour and analyzed. The analysis results are directly communicated to the data owners. This follow up is required to detect quickly the anomalies that could affect the data. Each year CD-ROM's are edited with the raw and corrected minute data as well as the log files and the auxiliary data, when available. In 2007 we edited the CD-ROM's ETGGP#9 and ETGGP#9a with the data from July 2005 till June 2006.

The "Bulletin d'Information des Marées Terrestres" (BIM) n° 143 was printed in 300 copies. Some 275 copies are sent to libraries and individual scientists all over the world. It is devoted to scientific papers concerning tidal research.

The complete collection of BIM has been scanned and will become available on the ICET WEB site in 2008.

Global tidal gravity parameters have been computed on a 0.5°x0.5° grid using the NAO99 ocean tide model for 9 waves (Mf, Q1, O1, P1, K1, N2, M2, S2, K2). Interpolation software is proposed on the ICET WEB site to provide an input compatible with the most common tidal prediction software.

The ICET WEB site (http://www.astro.oma.be/ICET/) has been updated and developed. Besides general information including historical aspect and last ICET reports, it proposes to the visitors an access to:

- The general bibliography on Earth Tides from 1870-1997 either by alphabetical order of the first author or following a decimal classification;
- The table of content of all the BIM issues, and starting from BIM 133 an electronic version of the papers;
- Various tidal analysis and preprocessing software available directly or on request from ICET;
- Ocean tides loading computations and the predicted tidal gravity parameters for all the tidal gravity stations.
- Interpolation software for predicted tidal gravity parameters at any continental location in the world.

D.2.3. Perspective for next year

ICET will move to the University of French Polynesia (Tahiti) under the responsibility of its new director Prof. Jean-Pierre Barriot. During the first half of 2008 the ROB will continue to provide a limited support for the GGP data reduction and analysis, including the edition of CD-ROM's ETGGP#10 and ETGGP#10a with the data from July 2006 till June 2007.

D.2.4. Personnel involved

Scientific staff: Ducarme B.

Technical staff: Vandercoilden L.

D.2.5. Partnerships

List of International partners without grant

- D. Crossley, J. Hinderer: Global Geodynamics Project (GGP)
- B. Rittschel: GeoForschungsZentrum Potsdam (D)
- J. Bogusz: Warsaw University of Technology, Institute of Geodesy and Geodetic Astronomy
- Jean-Pierre Barriot, Laboratoire des Sciences de la Terre, Université de Polynésie Française à Tahiti

Grants used for this research

- Federation of Astronomical and Geophysical Services

E. Operational projects for scientific research and expertise

In order to support its scientific research, its scientific expertise and to provide pertinent information to the public and the authorities, the section of seismology develops and maintains different tools. Their good working state is fundamental for the continuity of the different activities of the section.

E.1. Operational Project "seismic and accelerometric networks – gravity measurements – international data exchange"

E.1.1. Objectives

The section of seismology installed, is maintaining and analysing the data from the seismic and accelerometric Belgian networks and is continuing the long tradition of the ROB in gravity measurements.

The Belgian seismic network, with 24 permanent stations, is mainly dedicated to the monitoring and the scientific study of the seismic activity in Belgium. The ROB is managing 3 stations in Grand-Duchy of Luxemburg (in cooperation with the European Center for Geodynamics and Seismology) and one station in The Netherlands (in cooperation with the Netherlands Meteorological Institute). Earthquakes worldwide with magnitude greater than 4.5 – 5.0 are recorded by the Belgian seismic network. The measurements on these recordings are sent in routine to the International Centres (EMSC and ISC) where the data from the stations worldwide are analyzed to furnish a global catalogue of earthquakes and phase arrival time models. We provide also real-time seismic signals from some Belgian stations to the ORFEUS and IRIS centres. In November 2006 the IRIS Board of Directors authorized admission of the Royal Observatory of Belgium as "Foreign affiliate".

The accelerometric network was installed to complement the seismic network by furnishing reliable data when strong ground motions saturate traditional seismometers. It is an important tool for the professionals in the field of earthquake engineering and engineering seismology.

The section maintains and analyses the data from the AG absolute gravimeter FG5 and the SG superconducting gravimeter in Membach and by conducting gravimetric measurements with spring gravimeters. Since 2004, we are conducting gravity and magnetic measurements in the Upper Thracian Depression in Bulgaria to investigate the upper crustal structure of these regions where two large earthquakes occurred in 1928. This study is done in parallel with our investigation on the active faults that generated these two events. A convention has been signed in 2006 with the Walloon Region to include the sites of the WALCORS GPS network in the Belgian Gravimetric Base Network BLGBN98. The WALCORS network includes 23 GPS stations, most equipped with special concrete pillars providing good conditions for gravity measurements. For Geodetic purposes this new network will insure the collocation of two complementary techniques. Moreover the integrity of these sites is guaranteed. The interest for the Walloon Region is that, in case of anomalous behavior of the GPS antennas, it will be possible, by repeated gravity measurements, to check if this behavior is associated with gravity changes and thus corresponds most probably with real vertical displacements of the antenna. Several campaigns, performed in spring and in autumn, are scheduled to include the WALCORS points in BLGBN98 and detect eventual seasonal variations. The convention concerns 4 campaigns from September 2006 to April 2008. Reiteration of the network is planned after 5 years.

Since 1997 the SG of Membach participates in the Global Geodynamics Project SG data base and since 2005, in the IRIS seismic data base to promote SGs among seismologists.

E.1.2. Progress and results

E.1.2.1. "Seismic network and instrumentation"

<u>Status of the seismic network – management in 2007</u>

The control of the good working of the Belgian seismic network is done on a daily basis. The first step in this routine work is the visual inspection by the homemade program SAVEDATA of the 720 files of two minutes data of the previous day from the stations of Membach, Sart Tilman, Dourbes and Seneffe, and of the 360 files of four minutes data from Uccle. All the files with seismic events are automatically transferred to the directory dedicated for the daily measurements and a list of these events is created. Each night, this list is used to recall the event data in the other permanent seismic stations. The second step is the control of the data that have been sent by the different stations to our main server. If some data are lacking, an inspection of the origin of the problem is done, and an adequate solution is provided to solve it. Table 1 furnishes the information concerning the status of the different seismic stations in the course of 2007. The violet color indicates the stations that have a continous link with the seismic center in Uccle. The signals from these stations are also visible on the web site of the seismology section with a delay of 10 minutes. The green cells correspond to periods for which data are available (the monthly number of available files are indicated) in the different stations, the red cells to periods during which the stations were not working and the orange cells inform of some failures in the station during the corresponding month. Blue cells at the end of the year 2007 indicate that all the data have not yet been transferred from the corresponding stations (BRQ, CTH, LES and MRD are the only stations that are not linked to Uccle by a telemetry link).

Table 1: status of the Belgian seismic network 2007.

2007	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
BOU	416	705	895	1030	752	736	881	994	190	915	862	633
BRQ	remplacement du sismo dans le forage L4-C			110	754	737	883	1020	918	935	863	87
CLA	390	686	870	1026	727	610	852	966	867	891	833	612
CTH	402	708	897	1038	666	738	869	996	921	937	863	505
DOU	398	691	869	1028	729	714	852	971	869	891	837	612
EBN	401	689	869	1028	728	712	852	969	869	893	426	609
GES	407	701	894	1027	752	736	880	992	889	915	862	632
HRK	418	705	896	1028	751	733	881	995	893	912	862	633
KLB	415	704	896	1027	751	735	881	995	894	914	858	632
LCH	418	705	896	1030	751	736	880	647	894	915	862	633
LES	152	676	570	193	755	595			646	828	314	1
MEMH								418	621	626	617	472
MEMS	400	690	869	1024	727	682	852	938	866	888	832	602
MRD	422	708	897	1038	736	738	883	996	921	937	863	243
OPT			792	1028	751	582	882	993	863	914	862	631
RCH	459	705	894	1158	909	861	709	1307	917	914	849	632
ROB	417	705	896	1025	751	731	714	995	575	travaux	508	632
RQR	418	705	894	1030	752	736	881	995	894	915	862	632
SKQ	422	705	896	1030	752	736	881	995	894	915	862	632
SNF	401	691	870	968	vandalisme			16	583	678	599	423
STI	418	708	896	1027	751	735	881	995	894	913	862	632
UCCS	343	575	726	824	623	622	713	763	731	754	697	524
UCCH	343	581	723	824	623	614	711	767	731	750	695	524
VIA	418	704	896	1025	750	735	880	994	894	913	856	632
WLF	400	687	869	1025	729	713	845	971	869	892	838	612
ZEV	422	705	895	1029	717	556	747	995	894	916	602	142

The inspection of the table indicates that we lost relatively few data. Therefore, the management of the Belgian seismic network working seems relatively adequate.

During 2007, we have to solve temporary or more permanent problems in some of the seismic stations. In Bracquegnies (BRQ) we equipped the borehole with a L4-C seismometer. We did the same operation at the Couthuin (CTH) station. In Lessines (LES), the old PC was replaced by a new Linux PC with a removable hard disk. At Opitter (OPT), we decided to install a surface seismometer in the expectation of a new borehole seismometer asked for in a LOTTO-proposal. The station in Seneffe (SNF), which is one of the six stations for which the phase measurements are sent to the international centres, has been out of work due to vandalism. It takes a few months to install a sufficiently safe infrastructure to reinstall the equipments.

The most important part of the daily routine is the measurement of seismic phases, amplitude and sense of motions for the earthquakes and other seismic events recorded by our seismic stations. There are two different procedures, one to analyse the local and regional seismic events and one to analyse teleseismic events. For teleseismic events, a database of events (external catalogue) is based by the on-line analysis of the daily or alert E-mails send automatically by the USGS (Unites States Geological Survey), the LDG (Liaison et Détection Géophysique, Commissariat à l'Energie Atomique, France) and the EMSC (Euromediterranean Seismological Center). This catalogue can be considered as complete with a delay of around 10 days. Therefore, the different measurements are conducted with a minimum delay of 10 days. During the year 2007, 12 monthly messages of phases picking and 15 alarm messages for local earthquakes were sent to CSEM and ING (Madrid). After developing the new procedures, we were also able to send our data to the ISC (International Seismic Center).

Local and regional earthquakes are analysed with a maximum delay of one day during the week and three days after the week-end. Nevertheless, a particular attention is given to local earthquakes, even during the week-end, by a regular look on the real-time seismic traces on the web site of the section. Therefore, when a local earthquake is clearly identified during the week-end, it is also often analysed. After the measurements of local earthquakes have been done, they are introduced in the database. The procedure allows to locate them and to determine their local magnitude. When this is done, the events are automatically implemented in the internal catalogue.

New infrastructures in seismic stations

To improve our capacity of providing as fast as possible reliable information to the Centre de crise in case of an earthquake in or near Belgium and to increase our capability in the international exchange of real time seismic data, we developed our infrastructure in the stations of Rochefort and Eben-Emael. To improve the quality of detection and location of seismic events in southern North Sea and near the Belgian coast, we began also the project to install a new seismic station in Oostende.

Rochefort (RCH)

On the Rochefort site, the 16 bits acquisition system will soon be replaced by a new 24 bits Quanterra Q330 acquisition system. This decision was taken following the good results we have had with such equipment in Membach and the troubleshooting of problems due to the instability of the Quanterra self-calibration we have achieved this year. The installation of new equipments in addition to the already installed equipments has rosen the interest for a permanent internet connection to this site. An internet connection will be installed with a fiber optic cable linking the cave to the surface building. This solution will give a very good immunity to lightning issues. Moreover the quality of the seismic data acquired on this site make it, with the possibility to get the data in real time, a good station for conducting automatic events detection and localization, and also to provide real time data to the international centers ORFEUS and IRIS.

Eben-Emael (EBN)

Concerning the remote access to measured data, we have established a permanent internet connection with our seismic station in Eben-Emael (EBN). In order to lower the transition costs from ISDN to ADSL, a preliminary study was conducted and an affordable technical solution was identified and implemented with success.

Oostende

Following our contacts with the scientific education private centre "Earth Explorer" in Oostende, to install a seismometer at bedrock level, the Department "Leefmilieu, Natuur en Energie" of the Flemish

Government agreed to fund the drilling of a borehole down to bedrock. As part of the agreement, we needed to draft a detailed specifications report describing technical requirements for the borehole. These specifications have been revised a number of times in agreement with all involved partners (Flemish Government, Earth Explorer, Belgian Geological Survey, and the ONDRAF/NIRAS), and were finally approved. The Flemish Government assigned the contract to Smet Boringen, and drilling of the borehole will start in March 2008. We also asked for a financial support from the LOTTO to buy the borehole seismometer for that station, but also to buy a new borehole seismometer for the station in Opitter.

New developments for an improved seismic alert system

The development of new infrastructures for the seismic stations is strongly related to our development of a reliable alert system, with an automatic detection, location and magnitude determination of seismic events. For this purpose, a first stage will be to receive continuously data from a maximum of seismic stations and to develop the methodologies and software to do the work.

Hence, after the installation of an internet connection in Eben-Emael, it is planned to install internet connections in other stations.

As part of this project for an automatic detection and location system of seismic events, we have attended two meetings, each presenting the possibilities offered by software designed for this purpose. The first meeting, in Bucharest (Romania), showed the possibilities of the «SeisComP» software developed by the GeoForschungsZentrum Potsdam (Deutschland). The second meeting demonstrated in Rome (Italy) the capability of «Earthworm» software maintained by the American company ISTI. We have first planned to test the «SeisComP» software. We have then started the writing of the middleware required to make our own seismic station able to communicate with «SeisComP» in order to run the first tests.

Mobile stations

The modernisation of our seismic measuring infrastructure has gone on with the completion of a 24 bits mobile station prototype. The added features with respect to the previous model are: a resolution of 24 bits instead of 16 bits, the possible choice between GPS and DCF for time synchronization and the support of the TCP/IP protocol for the remote access to the acquired data. Moreover, their low power consumption make it possible to power supply them with solar panels.

Seismometer calibration

Concerning the calibration of our sensors, the process for calibrating L4-C and L4-3D seismometers has been improved thanks to the development of automation scripts. The length of time required for processing the data of calibration has been shortened and the whole process is less tedious.

E.1.2.2. "Accelerometric network"

The network is working correctly and checked thoroughly at the ORB once a week (Mol is checked twice a week). The accelerometer of Membach ("MEMA") broke down and was sent back to the manufacturer for repair.

The stations of La Reid (THEA) and Sart-Tilman (STIA) succesfuly recorded the 25 November 2007 La Gleize M_L=3.1 earthquake (Figure 31). This earthquake was too small to trigger the other accelerometers.

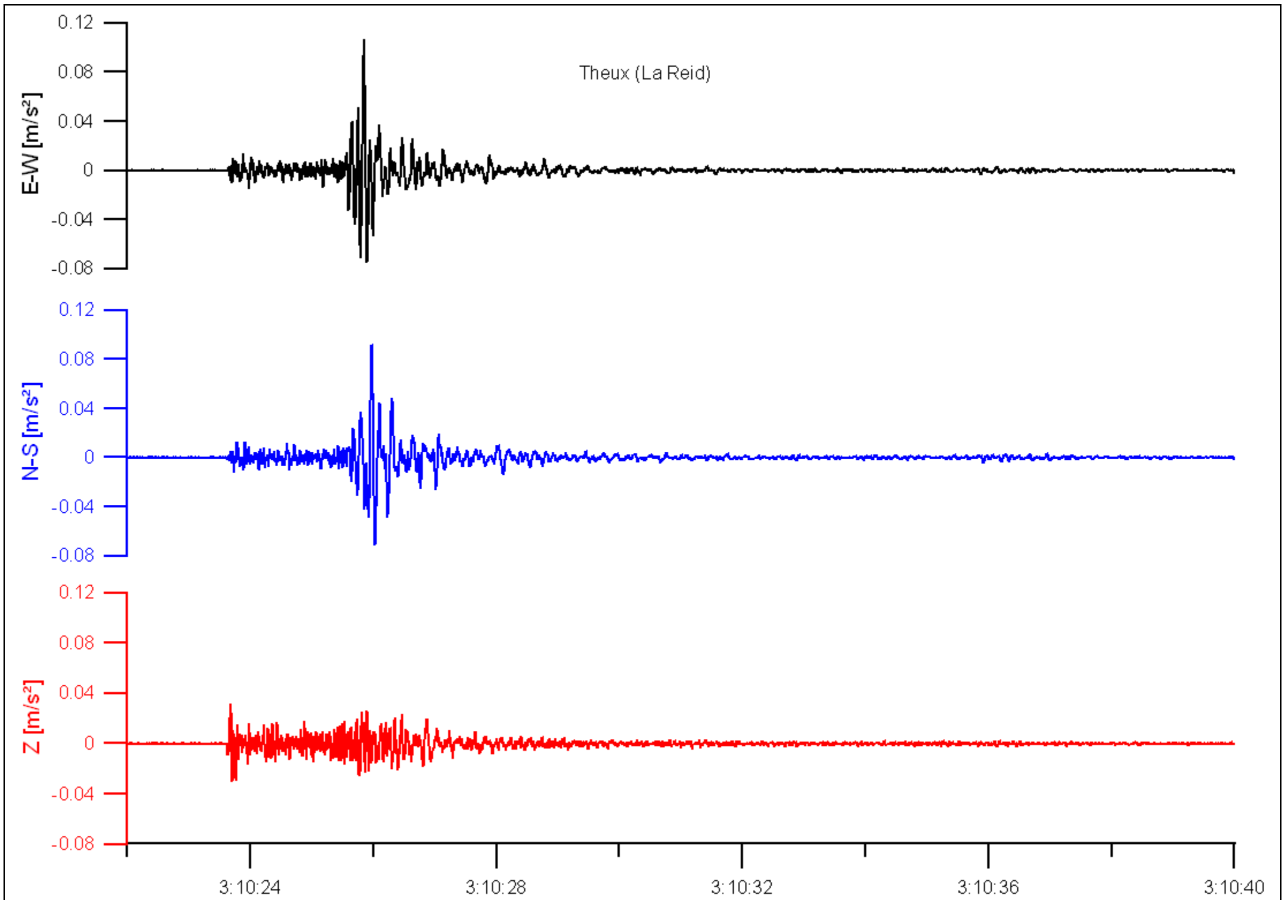

Figure 31. Accelerometric recordings at the station THEA for the La Gleize earthquake of 25 November 2007

E.1.2.3. "Gravity measurements"

Gravity measurements in Membach

Below 1.5 mHz the superconducting gravimeters (SGs) are competitive with the best spring gravimeters and seismometers, and can achieve the lowest noise level at frequencies lower than ~1.0 mHz. SGs can therefore make a significant contribution to the illumination of long-wavelength density heterogeneities in the Earth's mantle.

Since 1997, most of the SGs data are collected under the framework of the GGP (Global Geodynamics Project) global network that presently includes about 25 instruments. Up to now the data are being gathered in a specific database for geodesists, using a specific format. In order to promote the SG data among the seismic community, in 2004, contacts with IRIS encouraged us to provide the IRIS database with on-line data. Due to the complexity of the SEED format, but also to test a standard seismic data logger on a SG and to provide data from the Güralp CMG-3ESP Broadband seismometer, a Q330 data logger was installed in 2005 at the Membach Geodynamic station.

Connecting the Q330 on a SG was not easy. First, due to different technical problems we had to perform a standard exchange during the winter 2006-2007. After installing a new Q330 in March 2007, we performed different technical operations to both the SG and the Q330 (e.g. removing parasitic ground loops) to ensure a reliable DC level and a stable calibration factor (at the 0.1% level). This took time, because one needs several weeks after each operation to check the stability of the system.

Today, in the tidal and the seismic free oscillation frequency bands, the Q330 behaves as good as the usual voltmeters. For longer periods, in the next years it will be interesting to see if the DC level of the

Q330 remains stable: indeed, the Q330 performs a self-calibration to adjust the dynamic response to maximize waveform integrity; the DC absolute calibration is deliberately sacrificed and therefore, the long-term stability could be compromised. This is in contrast to the voltmeters that emphasize DC accuracy at the expense of frequency response, phase purity, and related issues that affect waveform integrity.

Project WALCORS

The spring 2007 campaign met several difficulties. One of the two gravimeters involved in the measurements was not working properly and one of the absolute reference stations was not accessible. Therefore, during the autumn campaign, the faulty instrument was replaced by a top quality SCINTREX CG5 gravimeter and an additional absolute station was included in the network to strengthen it in the South of Belgium. The following conclusions can be drawn on the basis of the already conducted three campaigns. Three instruments have been used on the WALCORS network: LCRD32 (NGI, B), LCR G402 (ROB), Scintrex CG5 (ECGS, L). The precision of the adjustment of the scale factor of one individual gravimeter using several reference stations is limited to 10^{-5}. The resulting bias on the 180mgal gravity difference of the WALCORS network could thus reach 18 µgal. However the use of two instruments on a single campaign or the global adjustment of two different campaigns of the same instrument reduces the bias to less than 10 µgal. The scale of the CG5 instrument fits perfectly the set absolute reference stations. The scale of D32 is 1.0015 and the scale of G402 1.0010, in agreement with previous determinations on the BLGBN98 gravity network. The adjustment error on one individual point ranges between 5µgal and 10µgal. The difference between the adjusted and the initial value at the reference stations is generally lower than 5µgal.

Comparison of different campaigns shows some discrepancies larger than 20µgal. It is sometimes due to bad local conditions or to insufficient connections to the neighboring stations. Unfortunately the only spring campaign met some difficulties, so that no firm conclusion can be drawn concerning possible seasonal effects. However large unexplained gravity differences seem to exist in the area of the province of Luxemburg between spring and autumn. These conclusions should be confirmed by the next spring campaign.

Gravity and magnetic measurements in Bulgaria

In 2007, 35 new gravity points have been measured on a total of 205 points. The limits of the Thracian depression have been well imaged by the Bouguer anomaly.

Interpretation of Chinese potential field data

We used the methodologies developed at the ROB to interpret in terms of structural geology gravimetric and magnetic data from the Sishuan region.

E.1.3. Perspective for next years

E.1.3.1. "Seismic network"

We will develop progressively the infrastructure and the methodologies to realize automatic event detection, location and magnitude estimation.

Borehole seismometers should be installed in Oostende, Dessel and Opitter. A Quanterra acquisition system should be installed at the Rochefort station allowing us to transmit in real time the data from the station to IRIS and ORFEUS.

E.1.3.2. "Accelerometric network"

The accelerometers must be visited on regular basis for maintenance and/or repair. In 2008 all the stations will be controlled in situ by S. Castelein and batteries replaced.

E.1.3.3. "Gravity measurements"

The superconducting gravimeter in Membach suffers from numerous interruptions of the power supply, partly due to the Company "Intermosane". We plan to install a reliable uninterruptible power supply to prevent for at least 36 hours the feedback circuit from shuting down. This is paramount to avoid steps in the SG time series as this circuit controls the levitation of the superconducting sphere. These last months we also have had serious problems with the reception of the DCF77 signal, which ensures accurate timing of the data acquisition systems. Interferences from the Intermosane network are suspected (correlation between occurrence of the interferences and power cuts). This should be solved in 2008 too.

Together with J. Steim we will continue investigating the efficiency of the Q330 datalogger on the S.G., and together with IRIS and GFZ Potsdam, working on the implementation of SG's data on the IRIS database.

A last campaign of the Walcors project is scheduled in spring 2008. The organization of this campaign will be very similar to the last 2007 campaign. A general compensation of the 4 campaigns will provide an overall stability assessment of the WALCORS gravity stations at the end of the convention.

We intend to conduct magnetic measurements in Bulgaria and provide a complete interpretation of the gravimetric and magnetic data collected since 2004.

E.1.4. Personnel involved

Scientific staff: Camelbeeck T. (responsible for the management of the project)
Collin F. (control of the good-working of the seismic network and of the daily measurements)
Ducarme B. (participation to the Walcors project)
Everaerts M. (participation to the Walcors project, project in Bulgaria and China)
Van Camp M. (responsible for the gravity measurements)
Vanneste K. (charged of the contacts with the Flamish Government)

Technical staff: Rapagnani G. (developments for the seismic alert and the seismic stations)
Bukasa B. (maintenance of the seismic stations)
Castelein S. (maintenance and control of the accelerometric stations)
Driegelinck E. (daily routine measurements)
Hendrickx M. (maintenance and control of the SG in Membach)
Martin H. (control of the seismic network and of the IT infrastructure)
Vandeputte W. (daily routine measurements)

E.1.5. Partnerships

List of international partners without grant

- Dr Tim Ahern, R. Benson (IRIS, USA);
- B. Ritscheld (GFZ Potsdam);
- Dr. J. Steim (Quanterra, USA);
- Kinemetrics, USA;
- Micro-g-LaCoste, USA;
- GWR instruments, USA;
- Prof. O. Francis (U. Luxembourg (GD Luxembourg));
- Bureau International des Poids et Mesures, France;
- Dr. Philippe Richard (METAS, Switzerland);
- Dr. S. Williams (Proudman Oceanographic Laboratory, UK);
- V.Y. Timofeev, Institute of Petroleum Geology and Geophysics SB RAS, Novosibirsk
- Dimitar Dimitrov Central Laboratory of Geodesy Bulgarian Academy of Science
- Pascal Sailac, EOST Strasbourg

- P Keating Geological Survey of Canada
- Junxian Chen Tongji University
- R. Barzaghi – Director, International Geoid Service, Polytecnico Milano
- H Duquenne Lareg IGN France
- H. Denker – Institut fur Erdmessung, Univ. Hannover
- S. Bonvalot – Director, Bureau Gravimetrique International, CNES, Toulouse

List of national partners without grant

- Laurent Wouters - ONDRAF/NIRAS
- Michiel Dusar - Belgian Geological Survey
- P. Lambot and C. Verteneuil, National Geographic Institute
- A. Demoulin, University of Liège
- J. Yans, FUNDP in Namur

Grants/Projects used for this research/service

- Convention de prestation de services concernant la calibration gravimétrique du réseau Walcors, passée entre la Région wallonne et l'Observatoire Royal de Belgique (ORB)
- Bilateral cooperation between Belgium and Bulgaria

E.1.6. Missions

Commissions, working groups (days): Camelbeeck Thierry (4), Ducarme B. (2), Everaerts M. (2), Rapagnani G. (6), Vanneste K. (2)

Research visits (days): Everaerts M. (8)

Field missions (days): Bukasa B. (31), Everaerts M. (36), Rapagnani G. (17), Martin H. (15), Castelein S. (11)

E.2. Operational project "IT infrastructure - seismological database – web site"

E.2.1. Progress and results

Different investigations have been conducted to improve our IT infrastructure and our web site.

- Studying the market for buying and configuring a new application server (seissrv3) ;
- Studying the market for buying and configuring a specific web server for te section seismology (end of 2007) ;
- Analyzing the functions performed by the old application and file server Terra. Gradually implementing them on the application server Poseidon and the file server Gaia. Data from the stations are gradually managed by these two servers in order to replace the old one ;
- Installation of an agenda for the section seismology on intranet (seisweb.oma.be/calendar) ;
- Installation of a 'Wiki' for the section seismology on intranet (seisweb.oma.be/seismowiki) ;
- Retrieving seismic measurement files (hypo71) and inserting them into the databank (development and implementation of the needed software) ;
- Integrating epicenter calculations into the program that manages phase measurements ;
- Adding information about the events and their characteristics to the seismic traces on the website.

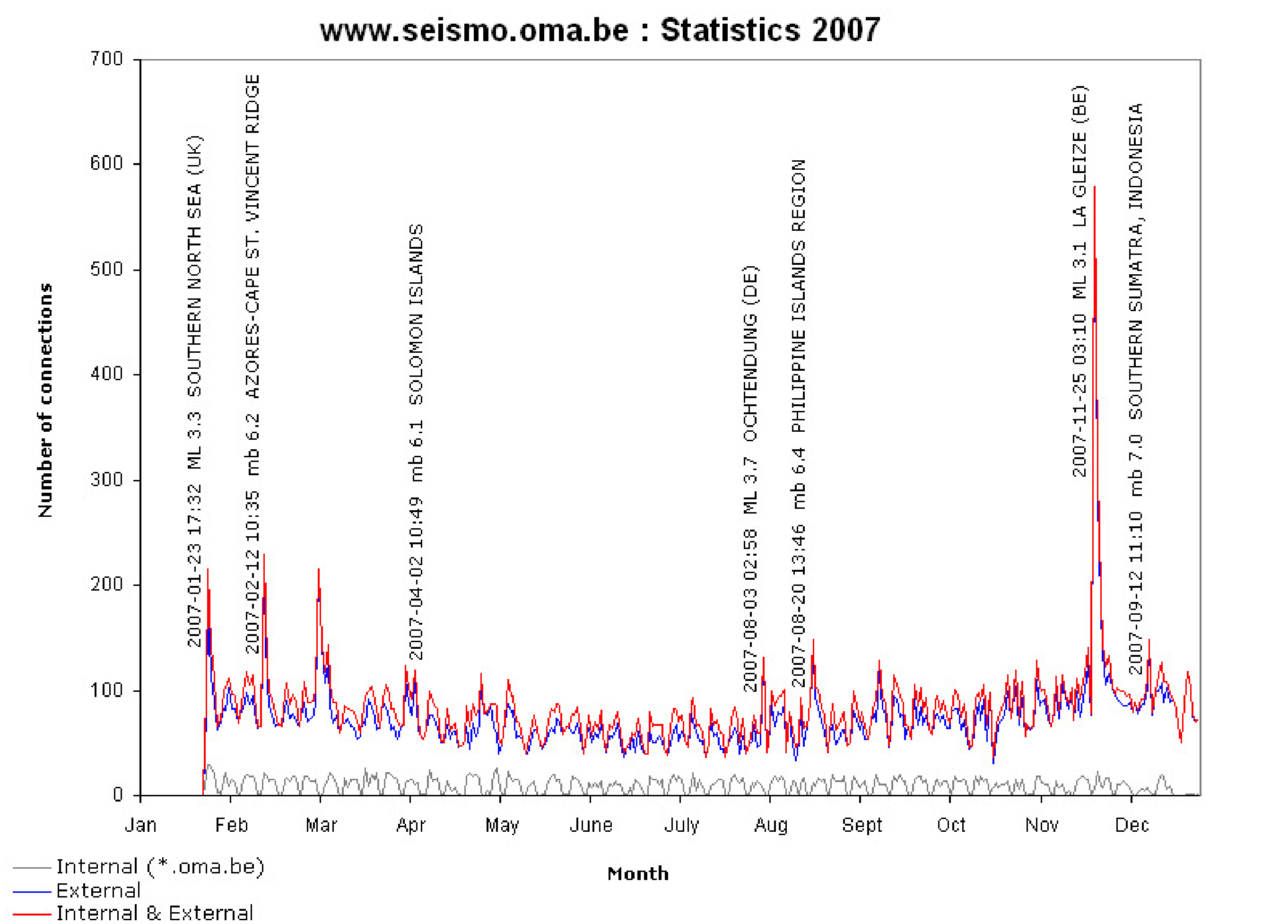

Figure 32. Daily connections to the seismology section web site during 2007

The statistics of the daily connections to the web site of the section seismology is presented on Figure 32. Some peaks occurred the days of the occurrence of specific earthquakes. More than 500 connections have been done on 25 November, after the occurrence of theM_L=3.1 La Gleize earthquake, strongly felt in the region of Spa and Theux (60 answers to our on-line inquiry, Figure 33)

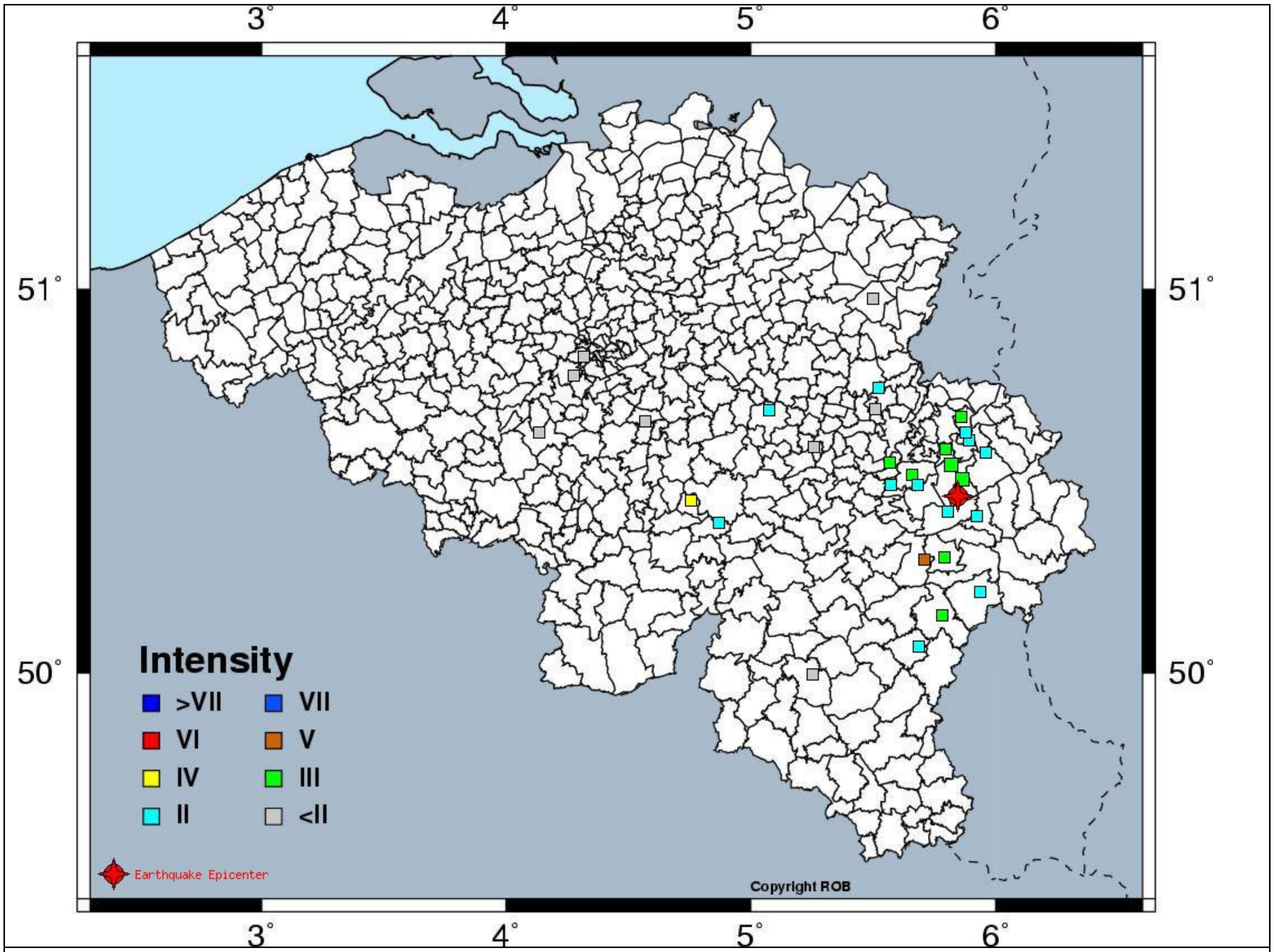

Figure 33. Results of the on-line web inquiry about the La Gleize earthquake on 25 November 2007. Intensity values are only indicative.

E.2.2. Perspective for following years

- Installing and configuring the section seismology web server (Extranet), including a site for content version management ;
- Testing and implementing effective operation of the new application server designed to replace the application server Poseidon ;
- Replacement of the application/file server Terra and application server Poseidon by the new application server. The biggest problem remains the replacement of our data analysis program "dp" ;
- Setting up of a regular backup process on the new application and file servers (poseidon replacement server and Gaia).

E.2.3. Personnel involved

Scientific staff: Camelbeeck T., Vanneste K.

Technical staff: Rapagnani G. (software and hardware developments)
Devos F. (development of the web-site)
Hendrickx M. (maintenance and control of the SG in Membach)
Martin H. (control of the seismic network and of the IT infrastructure)

F. Publications

F.1. Publications with peer review

[1] Cadicheanu N., **van Ruymbeke M., Zhu P**.
Tidal triggering evidence of intermediate depth earthquakes in the Vrancea zone (Romania)
Natural Hazards Earth Syst. Sci., 7, 733-740, 2007.

[2] **Camelbeeck T., Vanneste K., Alexandre P., Verbeeck K., Petermans T**., Rosset P., **Everaerts M.,** Warnant R., **Van Camp M**.
Relevance of active faulting and seismicity studies to assess long term earthquake activity in Northwest Europe, Continental Intraplate Earthquakes: Science, Hazard, and Policy Issues
Geological Society of America, S. Stein and S. Mazzotti (eds.) Special Paper 425, 193-224, 2007

[3] Demoulin A., **Ducarme B., Everaerts M**.
Seasonal height change influence in GPS and gravimetric campaign data
Journal of Geodynamics, 2007, 43, 308-319

[4] **Ducarme B.,** Timofeev V.Y., **Everaerts M**., Gornov P.Y., Parovishnii V.A., **van Ruymbeke M.**
A Trans Siberian tidal gravity profile (TSP) for the validation of tidal gravity loading corrections
J. of Geodynamics, 2008, 45, 78-82, (DOI: 10.1016/j.jog.2007.07.001)

[5] **Ducarme B.,** Sun H. P., Xu J. Q., Sun H. P.
Determination of the free core nutation period from tidal gravity observations of the GGP superconducting gravimeter network
Journal of Geodesy, 2007, 81, 179-187 (DOI: 10.1007/s00190-006-0098-9)

[6] Hu X. -G., Liu L.T., **Ducarme B.,** Hsu H.T., Sun H.P.
Wavelet filter analysis of local atmospheric pressure effects in the long period tidal Bands
Physics of the Earth and Planet. Int., 2006, 159, 59-70, (DOI:10.1016/j.pepi.2006.06.001)

[7] Hu X. G., Liu L. T., **Ducarme B**., Xu H. J., Sun H. P.
Estimation of the pole tide gravimetric factor at the chandler period through Wavelet filtering
Geoph. J. Int., 2007, 169, 821-829 (DOI: 10.1111/j.1365-246X.2007.03330.x)

[8] Meurers B., **Van Camp M., and Petermans T**.
Correcting gravity time series using rain fall modeling at the Vienna and Membach stations and application to Earth tide analysis
Journal of Geodesy, doi: 10.1007/s00190-007-0137-1, 2007.

[9] Prokopenko A.A., Khursevich G.K., Bezrukova E.V., Kuzmin M.I., **Boës X.,** Williams D.F., Fedenya S.A., Kulagina N.V., Letunova P.P., Abzaeva A.A.
Paleoenvironmental proxy records from Lake Hovsgol, Mongolia, and a synthesis of Holocene climate change in the Lake Baikal watershed
Quaternary Research, 68, 2007, Issue 1, 2-17.

[10] **Vanneste K., Verbeeck K., Petermans T**.
Pseudo-3D imaging a low-sliprate, active normal fault using shallow geophysical methods: The Geleen fault in the Belgian Maas River valley
Geophysics, 73(1): B1-B9, 2008.

[11] **van Ruymbeke M., Zhu P**., Cadicheanu N., **Naslin S.**

Very Weak Signals (VWS) detected by stacking method according to different astronomical periodicities (HiCum)
Natural Hazards Earth Syst. Sci., 7, 651-656, 2007.

F.2. Publications without peer review

[12] **Alexandre P**., Kusman D, **Camelbeeck T**.
La presse périodique, une source pour l'histoire des tremblements de terre dans l'espace belge
M. D'Hoore, D. Luyten and Th. Delplancq (eds), Le journal dans tous ses états – Het rijk van de krant, special issue of Archives et Bibliothèques de Belgique – Archief- en Bibliotheekwezen in België, vol. 78, fasc. 1-4, 2007, p. 257-278

[13] Chen X. D., **Ducarme B.**, Sun H. P.
Influence of the equilibrium ocean pole tide on the gravity field
Bull. Inf. Marées Terrestres, 2007, 143, 11443-11450

[14] **Ducarme B.,** Zhou J. C., Sun H. P.
Evaluation of M4 ocean tide loading inside the GGP network.
Bull. Inf. Marées Terrestres, 2007, 143, 11473-11488

[15] El Wahabi A., **van Ruymbeke M., Ducarme B**.
Precursory signals of the last eruption of Mount Etna detected by continuous gravity observations
Bull. Inf. Marées Terrestres, 2007, 143, 11499-11506

[16] **Petermans, T.,** Rosset P., **Camelbeeck T.**
Combining ambient noise Measurement with 1D numerical ground Modelling to constrain Site Effects in the Brussels-Capital Region, Belgium.
In: Proceedings of the EGU Congress, Vienna, Austria, 16-20 April 2007, Abstract 06546.

[17] Timofeev V.Yu, **Ducarme B, Van Ruymbeke M**, Gornov P.Yu, **Everaerts M**.,Gribanova E.I., Parovishnii V.A, Semibalamut V.M, Woppelmann G, Ardyukov D.G.
Transcontinental Tidal profile: Atlantic coast of Europe south of Siberia-Pacific coast of Russia
Fizica Zemli (earth physics) in Russian

[18] Venedikov A.P., **Ducarme B.**
Localization and estimation of jumps, hidden frequencies and other perturbations in Earth Tides residues
Bull. Inf. Marées Terrestres, 2007, 143, 11507-11517

[19] Zhou J. C., Sun H. P., **Ducarme B.**
Validating the synthetic tidal gravity parameters with superconducting gravimeter observations
Bull. Inf. Marées Terrestres, 2007, 143, 11489-11497

F.3. Publications in press, submitted

[20] **Alexandre P**., Lambert J.
Les séismes de 1373 (Ribagorza) ressentis à Saint-Affrique
Submitted to Revue du Rouergue, 2008

[21] **Alexandre P.,** Kusman D**., Petermans T., Camelbeeck T.**
The 18 September 1692 Earthquake in the Belgian Ardenne and its aftershocks
In press in J. Fréchet, M. Meghraoui and M. Stucchi (eds.), Modern Approach in Historical Seismology: Interdisciplinary studies of past and recent earthquakes, Springer, Series: Modern Approaches in Solid Earth Sciences

[22] **Boës X.**
Ce que les sédiments des lacs nous apprennent sur les changements du climat et de l'envirronement.
Ciel et Terre, 123, 2, pp. 34-41.

[23] **Boës X., Avsar U**., King J., Moran B., Ranger M., Cagatay N., **Hubert Ferrari A**.
Assessment of Lake Sediment Sensitivity to Earthquakes and Climate Cycles along the North Anatolian Fault
11e Congrès de Sédimentologie, Caen, 23-25 Octobre 2007. Publ. ASF, 57, 30.

[24] **Boës X.,** Piotrowska N., Fagel N.
High resolution geochemical record of Lake Baikal silicocalstic sediments over the Termination I.
11e Congrès de Sédimentologie, Caen, 23-25 Octobre 2007. Publ. ASF, 57, 32.

[25] **Boës X.,** Loutre M.F., Fagel N.
Tracking El Nino Cycles in Southern America from annually laminated lake sediments
11e Congrès de Sédimentologie, Caen, 23-25 Octobre 2007. Publ. ASF, 57, 31.

[26] **Boës X., Avsar U**., Doner L., Heil C., King J., Moran B., Ranger M., Cagatay N., **Hubert Ferrari A**.
Assessment of Lake Sediment Sensitivity to Earthquakes and Climate Cycles along the North Anatolian Fault
4th International Limnogeology Congress Barcelona, July 11-14th 2007, pp. xx.

[27] **Camelbeeck T., Alexandre P**., Kusman D.
Les séismes en Belgique et leurs effets sur le bâti, le patrimoine architectural et l'environnement
In "Evaluation et prevention du risqué sismique en Région wallonne", Aménagement et urbanisme, 87-99.

[28] De Vleeschouwer F., Van Vliët-Lanoé B., Fagel N., Richter T., **Boës X.**
High resolution petrography on resin impregnated Holocene peat columns containing tephras. Principle, applications and perspectives
Quaternary International, Special issue on Tephrostratigraphy. *In press*

[29] **Ducarme B., Rosat S.,** Xu J. Q., **Vandercoilden L**., Sun H. P.
European tidal gravity observations: Comparison with Earth Tides models and estimation of the Free Core Nutation (FCN) parameters
Accepted for publication in IAG Proc., Symp. GS003 "Earth Rotation and Geodynamics", XXIV IUGG General Assembly, Perugia, I.

[30] Fagel N., **Boës X.**
High Resolution clay mineral record in Lake Baikal sediments: the Holocene and Late Glacial transition
Paleo 3. In press.

[31] **Hubert-Ferrari A**., G. King, Van Der Woerd J., Villa I., Altunel E. , Armijo R.
Long-term evolution of the North Anatolian fault: New constraints on its eastern termination
In Geodynamics of Collision and Collapse at the Africa-Arabia-Eurasia Subduction Zone, Editor R. Govers, Geological Society of London Special, accepted.

[32] Panepinto S., Greco F., Dario L., **Ducarme B.**
Tidal gravity observations at Mt. Etna and Stromboli: results concerning the modeled and observed tidal factors
Submitted to Annals of Geophysics

[33] Rosset P., **Petermans T., Camelbeeck T**.
L'aléa sismique local en Belgique
In "Evaluation et prevention du risqué sismique en Région wallonne", Aménagement et urbanisme, 9-23.

[34] Sabbe A., **Camelbeeck T., Barszez A.-M., Philipront A**.
Comment déceler l'origine sismique de certains désordres affectant le patrimoine architectural et comment y remédier
Les cahiers de l'urbanisme.

[35] **Sichien E.**, Monfret T., Pardo M., Vera E., Gaffet S., Vallée M.
Three-dimensional attenuation structure of Central Chile (30°-32°S) using local earthquakes: evidences of a fluid and fractured medium related to the 1997 Punitaqui (Mw = 7.2) intraslab event
Submitted to Geophysical journal international

[36] Vandenberghe D., **Vanneste K., Verbeeck K.,** Paulissen E., Buylaert J.-P., De Corte F., Van den haute P.
Late Weichselian and Holocene earthquake events along the Geleen fault in NE Belgium: OSL age constraints
In press in Quaternary International, doi: 10.1016/j.quaint.2007.11.017.

[37] **Vanneste K.**, Mees F., **Verbeeck K**.
Application of thin-section analysis to identify paleoearthquakes on the "slow", active Geleen fault, Roer Valley graben
In press in Tectonophysics Special Issue "Earthquake Geology: methods and applications", doi: 10.1016/j.tecto.2007.10.011.

F.4. Reports, thesis, etc

[38] **Avsar U.**
MEXT-CT-2005-025617: Seismic Cycles-Scientific Progress Report October2005-October2007
European Commission, Research Directorate General, Human Resources and Mobility; Marie Curie Actions.

[39] **Boës X.**
Seismic cycles EU-Project, the lakes sediments study 2006-2007.
Document de Synthèse de la mission de carottage du projet Marie Curie "*Understanding the irregularity of Seismic cycles: A case Study in Turkey*".Communauté européenne, *Marie Curie actions* 60 p.

[40] **Ducarme B**., **Vandercoilden L**.
Global Geodynamics Project: CD-ROM ETGGP #9
International Center for Earth Tides

[41] **Ducarme B., Vandercoilden L**.
Global Geodynamics Project: CD-ROM ETGGP #9A
International Center for Earth Tides

[42] **Lecocq T**.
Relocalisation de tremblements de terre en Ardenne (Belgique), Méthode d'analyse et identification de structures actives
Mémoire de DEA, ULB, June 2007, 22pp, *in French.*

[43] **Lecocq T**.
FRIA - Rapport d'activités 2006-2007

Report in order for the financial support to continue for 2007-2008, August 2007, 8pp, *in French*.

[44] **Petermans T., Camelbeeck T**.
Evaluation of the strong ground motions at the Dessel-site generated by large earthquakes on the Rauw and Feldbiss faults
Report for ONDRAF/NIRAS. Convention: CCHO: 2007-4177/00/00, pp 29.

[45] **Petermans T., Camelbeeck T**.
Note on the Belgium seismic catalogue of the Royal Observatory of Belgium
Report for ONDRAF/NIRAS. Convention: CCHO: 2007-4177/00/00, pp 3.

[46] **Petermans T., Camelbeeck T**.
The Spectral Ratio Slope method (SRS): Application at the Uccle seismic stations
Report for ONDRAF/NIRAS. Convention: CCHO: 2007-4177/00/00, pp 6.

[47] **Petermans T**., Rosset P., and **Camelbeeck T**.
Evaluation of site-effects and local seismic hazard in Belgium
Final report - Research project MO/33/016 for the Belgian Science Policy, 72 pp.

[48] **Sichien E.,** Henriet J.-P., **Camelbeeck T**.
Een studie van de structuur van de Belgische korst door locale seismische tomografie.
Voortgangsrapport 3de jaar.

G. Scientific outreach

Meeting presentations

[1] **Avsar U., Boes X., Hubert-Ferrari A.,** Fagel N.
Potential of Shallow Lake Systems to Trace Environmental Changes Caused by Earthquakes.
European Geosciences Union Meeting, Vienna, April 15-20, 2007.

[2] **Barszez A.-M., Philipront A**.
Pérennité du patrimoine bâti et risque sismique en Belgique
Symposium, « De la bonne idée à la réalisation pratique… » CSTC, 28/11/07, Bruxelles, abstract and poster.

[3] **Barszez A.-M., Philipront A**.
Seismic Risk in Belgium through Post-Seismic Costs Assessment
Mercea 08", Italie, 7-11th July 2008, abstract.

[4] **Boës X., Avsar U.,** Doner L., Heil C., King J., **Moran B., Ranger M., Cagatay N., Hubert-Ferrari A**
Assessment of Lake Sediment Sensitivity to Earthquakes and Climate Cycles along the North Anatolian Fault.
4th International Limnogeology Congress - ILIC July 11-14th 2007, Barcelona.

[5] **Boës X., Avsar U**., King J, Bradley M., Cagatay N., **Hubert-Ferrari A.**
Assessment of Lake Sediment Sensitivity along the North Anatolian Fault
11e Congres français de sédimentologie, Caen, 2007 (23-25 oct.), Livre des résumés.

[6] **Boës X., Avsar U**., King J, Cagatay N., **Hubert-Ferrari A.**
Assessment of Lake Sediment Sensitivity to Earthquakes and Climate Cycles along the North Anatolian Fault
European Geosciences Union Meeting, Vienna, April 15-20, 2007.

[7] Cadicheanu N., **van Ruymbeke M**.

Research of tidal periodicities in the seismic hazards of the Vrancea zone, Romania, (poster)
European geosciences union meeting, Vienna, Apr, 2007

[8] **Camelbeeck T., Vanneste K., Alexandre P., Bruyninx C., Van Camp, M**.
Relevance of geodetic, seismicity and active faulting studies to assess lithospheric deformation and long-term earthquake activity in intraplate Northwest Europe
EGU meeting, Vienna, April 15-20, 2007

[9] Delvaux D., Macheyeki A.S., Kervyn F., **Petermans T., Verbeeck K**., Temu E.B.
Earthquake geology of the Kanda fault system (Tanganyika-Rukwa rift, SW highlands of Tanzania)
EGU General Assembly 2007, Vienna, 15-20 April 2007 (Poster presentation)

[10] de Viron O., Panet I., Mikhailov V., **Van Camp M.,** Diament M.
Retrieving Earthquake Signature in GRACE Data
AGU Fall meeting, San Francisco, USA, December 10-14, 2007.

[11] **Ducarme B., Vandercoilden L**.
GGP network: internal and external consistency and applications to the determination of the FCN parameters
First Asia Workshop on Superconducting Gravimetry, Hsinchu, Taiwan, March 12-16, 2007

[12] **Ducarme B.**, Venedikov A. P.
Localization and estimation of jumps and other perturbations in the tidal records
First Asia Workshop on Superconducting Gravimetry, Hsinchu, Taiwan, March 12-16, 2007

[13] **Ducarme B.,** Zhou J. C., Sun H. P.
Detection of M4 ocean tide loading inside the GGP network
First Asia Workshop on Superconducting Gravimetry, Hsinchu, Taiwan, March 12-16, 2007

[14] **Ducarme B.,** Venedikov A. P., Vieira R., Dimitrov D.
Study of the mean sea level and its time variations
Symp. JGS002 "Global Sea Level Change", XXIV IUGG General Assembly, Perugia, I.

[15] **Ducarme B**., Xu J. Q., **Vandercoilden L.,** Sun H. P.
European tidal gravity observations: Comparison with Earth Tides models and estimation of the Free Core Nutation (FCN) period
Symp. GS003 "Earth Rotation and Geodynamics", XXIV IUGG General Assembly, Perugia, I.

[16] **Everaerts M.**
Oral presentation: Progress report on seasonal gravity campaign carried out on permanent GPS stations in Walloon region
Conference, etc 94 Journées Luxembourgeoise de Géodynamique Gonderange Grand Duchy of Luxemburg 12-14 november 2007

[17] **Fraser J.**, Pigati J., **Hubert-Ferrari A., Vanneste K., Boës X., Avsar U.,** Altinok S.
Development of paleoseismic trench logging and dating techniques: a case study on the Central North Anatolian Fault
EGU General Assembly 2007, Vienna, 15-20 April 2007 (Poster presentation)

[18] Francis O., **Van Camp M**., Williams S.D.P.
On the drift of a Superconducting Gravimeter and the Noise of an Absolute Gravimeter
International Symposium on Terrestrial Gravimetry: Static and Mobile Measurements, St Petersburg, August 20-23, 2007.

[19] Gitlein O., Timmen L., **Van Camp M**.

Atmosphere Reduction for Terrestrial Absolute Gravimetry in the Fennoscandian Land Uplift Network
Geodätische Woche, Leipzig, 25-27 September 2007

[20] **Hubert-Ferrari A., Boës X., Fraser J., Avsar U., Vanneste K.,** Catagay N., De Batist M., Fagel N.
A Marie Curie Excellence Team Project at the Royal Observatory of Belgium: Understanding the irregularity of seismic cycles: A case study in Turkey
BELQUA Workshop 2007, Brussel, 12 March 2007 (Oral presentation by A. Hubert-Ferrari)

[21] **Hubert-Ferrari A., Boës X., Fraser J., Avsar U., Vanneste K**., Catagay N, Altunel E.,de Batist M., Fagel N.
Understanding the irregularity of Seismic cycles: A Case study in Turkey-A Marie Curie Excellence Team Project
European Geosciences Union Meeting, Vienne, April 15-20, 2007.

[22] **Lecocq T., Petermans T., Alexandre P. Camelbeeck T**.
Seismicity of the Ardenne (Belgium): spatial distribution and implications in terms of active tectonics
EGU General Assembly (poster), Vienna, Austria, April 15-20, 2007.

[23] **Lecocq T**.
Relocalisation de tremblements de terre en Ardenne
PhD seminar, ULB, Brussels, Belgium, June 21, 2007.

[24] **Lecocq T., Petermans T., Alexandre P., Camelbeeck T.**
Earthquake relocation in the Ardenne (Belgium): identification of active structures in Intraplate context.
Geologica Belgica Doctoral Seminar, Brussels, Belgium, October, 19 2007.

[25] **Lecocq T., Petermans T., Alexandre, P., Camelbeeck T.,**
Earthquake relocation in the Ardenne (Belgium): identification of active structures in Intraplate contex
AGU Fall Meeting (*poster)*, San Francisco, USA, December, 6-15 2007.

[26] Macheyeki A.S., Delvaux D., Kervyn F., **Petermans T., Verbeeck K**., Temu E.B.
Occurrence of large paleo-earthquakes along the major Kanda fault system (Tanganyika-Rukwa rift, SW highlands of Tanzania)
EGU General Assembly 2007, Vienna, 15-20 April 2007 (Poster presentation)

[27] Minguely B, Averbusch O, **Everaerts M,** Mansy J-L, Hanot F.
Oral presentation the geometry of northern Variscan Trust front in the Artois area (northern France) Insight from sismique imaging and 2.5 D gravity modeling
Mechanic of Variscan Orogeny: A modern view on orogenic research Orleans France 13-15 septembre 2007

[28] **Naslin S., van Ruymbeke M**
Application of earth tides instrumentation in the measurement of the universal constant of gravitation G, description of the specificities of our experiment (Oral)
European Geosciences Union (EGU) General Assembly, Vienna, Austria (16/04/07)

[29] **Naslin S.**
Thesis report (Oral), University of Luxembourg (04/07/07)

[30] **Petermans, T., Rosset P., Camelbeeck T.**
Combining ambient noise Measurement with 1D numerical ground Modelling to constrain Site Effects in the Brussels-Capital Region, Belgium.

Poster presentation at the EGU general assembly, Vienna, Austria on 15-20 April 2007.

[31] **Philipront A.**
Which are the effects of great earthquakes on the architectural heritage in our areas? Application to the churches of Hesbaye, inventory, methodology and prospects.
BeSeiG, Belgian Seismic Group, meeting of 11th of September 2007, KUL, Leuven.

[32] **Rosat S.,** Florsch N., **Ducarme B.,** Hinderer J., Llubes M.
Analysis of the FCN resonance in Superconducting Gravimeters data of the European GGP sub-network using a Bayesian approach
EGU General Assembly, Vienna, Austria, 15 – 20 April 2007

[33] **Sichien E.,** Henriet J.-P., **Camelbeeck T.**
Estimating crustal thickness in Belgium using Moho-reflected waves itle of the presentation
Poster presentation at the EGU general assembly, Vienna, Austria on 15-20 april 2007

[34] **Sichien E., Camelbeeck T.** and Henriet J .P.
Estimating crustal thickness in Belgium using Moho-reflected waves and the three-dimensional velocity structure of the Belgian crust
Oral presentation at the Geologica Belgica doctoral seminar, Brussels, Belgium on 19 October 2007

[35] Sun H. P., Xu J. Q., **Ducarme B.**
Experimental Earth Tidal Models Based on Global Observations of the Superconducting Gravimeters in Considering Earth's Nearly Diurnal Free Wobble of the Liquid Core
Symp. GS003 "Earth Rotation and Geodynamics", XXIV IUGG General Assembly, Perugia, I.

[36] **Van Camp M.,** van Dam T., Vanclooster M., Dassargues A., Gitlein O.
Are superconducting gravimeters expensive soil moisture probes?
94th Journées Luxembourgeoises de Géodynamique, Gonderange, Grand Duchy of Luxemburg, November 12-14, 2007.

[37] **Van Camp M.,** Williams S.D.P., Hinzen K.-G., **Camelbeeck T.**
Intraplate Vertical Land Movements Constrained by Absolute Gravity Measurements
AGU Fall meeting (*poster*), San Francisco, USA, December 10-14, 2007

[38] van Dam T., **Van Camp M.**, Vanclooster M., Dassargues A.
Are superconducting gravimeters expensive soil moisture probes?
AGU Fall meeting, San Francisco, USA, December 10-14, 2007.

[39] **Vanneste K., Verbeeck K., Petermans T**., Yaneva M., Nikolov G., Béatse H.
New evidence for prehistoric co-seismic surface rupturing in the Lower Rhine graben area
EGU General Assembly 2007, Vienna, 15-20 April 2007 (Poster presentation)

[40] **Vanneste K., Verbeeck K., Bruyninx C., Camelbeeck T.**
Paleoseismic re-interpretation of a trench across the Geleen fault near Born (The Netherlands), Lower Rhine graben area
EGU General Assembly 2007, Vienna, 15-20 April 2007 (Poster presentation)

[41] **van Ruymbeke M.,** Beauducel Fr., Somerhausen A., Howard R., **Naslin S**., Cadicheanu N., **Zhu P**.
Description of the HiCum method dedicated to periodical signals analysis (poster)
EGU General Assembly 2007, Vienna, 15-20 April 2007

[42] **van Ruymbeke M.,** Beauducel Fr., Somerhausen A., Howard R., **Naslin S.,** Cadicheanu N., **Zhu P.**
Evaluation of the level of detection of very weak geodynamics signals with the HiCum (poster)

EGU General Assembly 2007, Vienna, 15-20 April 2007

[43] **Verbeeck K**., Radulov A., **Vanneste K.,** Yaneva M., **Petermans T., Camelbeeck T.,** Shanov S.
Paleoseismologic investigation of two well-documented historical large earthquakes in the Upper Thracian Depression, southern Bulgaria
EGU General Assembly 2007, Vienna, 15-20 April 2007

[44] **Zhu P., van Ruymbeke M.**
Solid earth-tide influence on the earthquakes triggering and on wave velocity variations (oral report)
EGU General Assembly 2007, Vienna, 15-20 April 2007

Expertise, Audit

- Camelbeeck Thierry: expertise at the meeting concerning the applicability of Eurocode 8 code for masonry building, organized by Wienerberger in Leuven (28 February 2007) - Presentation of the seismic risk in Belgium to the “Belgian Seveso Committee”, Brussels (27 November 2007)

Meeting organization

- Van Camp Michel: Chair of the G15 session, AGU Fall Meeting, San Francisco, December 10-14, 2007 - Member of the jury of the “Geodesy Best Student Paper”, AGU Fall meeting, 2007.

Educational responsibilities (Seminars, students …)

- Boës Xavier: (1) séminaire Evaluation des cycles climatiques et des tremblements de terre dans les carottes sédimentaires laminées par des techniques à haute résolution RX, Geotek, XRF et polymérisation.Laboratoire EPOC, Bordeaux, France, 1er Octobre 2007 ; (2) encadrement de la thèse de doctorat de Avsar Ulas.
- Camelbeeck Thierry: (1) Member of the jury of the thesis of agregation of Sara Vandycke: Déformations cassantes du nord-ouest européen, Faculté Polytechnique de Mons (29 January and 14 February 2007) – (2) Member of the jury of the thesis of Mattias Schevenels: The impact of uncertain dynamic soil characteristics on the prediction of ground vibrations, Katholieke Universiteit Leuven (30 May 2007) – (3) Co-promotor of the MSc-thesis of Amélie Philipront: Quels sont les effets sur le patrimoine architectural des séismes importants de nos régions? Application aux églises de Hesbaye – Inventaire, méthodologies et perspectives, Faculté Polytechnique de Mons (23 June 2007) – (4-7) Director of thesis of Thomas Lecocq and Jeff Fraser (Université Libre de Bruxelles), Els Sichien (Gent Universiteit) and Valérie Calbini (Ecole et Observatoire des Sciences de la Terre de Strasbourg) – (8) Responsible of the 1 month stage at the ROB of Samia Shamakh, student of the Faculté Polytechnique de Mons – (9) Presentation of a seminar Le risque sismique est-il une réalité dans nos regions? In the framework of the « Séminaires d’urbanisme » of the Institut Supérieur d’Urbanisme et de Rénovation Urbaine, Brussels (28 March 2007) – (10) Presentation of a seminar on the seismic risks for students in engineering at the Université Libre de Bruxelles (30 March 2007).
- Everaerts M.: training in gravimetry for students of ULB and Gent University (1 day each) – co-promotor of one Phd-thesis at the FUNDP in Namur.
- Lecocq Thomas: La tomographie électrique et la prospection radar, travaux pratiques pour étudiants de l’ULB, February, 13 & 19, 2007.
- Hubert-Ferrari Aurélia: Responsible of the PhD thesis of Ulas Avsar and Jeff Fraser, and of master thesis of David Garcia
- Van Camp, M: séminaire « Apports de la gravimétrie en métrologie et en géophysique à l’Observatoire Royal de Belgique », UCL, Louvain-la-Neuve, 2007-11-08 - Member of the jury of the thesis of Gwendoline Pajot : Caractérisation, analyse et interprétation des données de gradiométrie en gravimétrie, IPGP (France), 2007-09-27.

Websites

- Aurélia Hubert-Ferrari: Creation of the present web site for the Seismic Cycle project
- B. Ducarme, L. Vandercoilden: Website of the International Centre for Earth Tides
- Devos F.: website of the section seismology

Visitors

Thierry Camelbeeck welcomed:

- David Kusman (Université Libre de Bruxelles) on 9 March 2007.
- Alain Bernard (Université Libre de Bruxelles) on 2 May 2007.
- Frédéric Nguyen (Université de Liège) on 4 June 2007.
- Michiel Dusar (Belgian Geological Survey) on 15 June 2007.
- Rebecca Harrington (University of Los-Angeles) on 10 July 2007.
- Stefan Shanov and Alexander Radulov (Bulgarian Academy of Sciences) from 10 to 14 September 2007.
- De Vuyst (journalist of "Athéna") on 11 October 2007.
- Y. Yilmaz (Instanbul Institute of Geophysics) on 25 October 2007.
- Hans Havenith (Université de Liège) on 26 October 2007.
- Seth Stein (Northwestern University, Chicago) from 2 to 5 December 2007.
- Michel Sébrier (Université Paris VI) on 19 December 2007.

B. Ducarme welcomed :

- Angel Petkov Venedikov, Geophysical Institute and Central Laboratory of Geophysics, Bulgarian Academy of Sciences, Sofia, 1 month (1-29 June)
- Jean-Pierre Barriot, Laboratoire des Sciences de la Terre, Université de Polynésie Française, Tahiti, 1 week (2-7 December)

M. Van Camp welcomed:

- F. Dupont (BRGM, France) at the Sohier station, to measure the vertical gravity gradient and to link the French Gravity Network to a reference absolute gravity station (2007-01-26).
- Olivier Francis (U. Luxembourg) at the Membach station, to compare his FG5-216 absolute gravimeter with our FG5-202 one (2007-05-03 and 2007-05-04).
- Students from secondary school (2007-03-14 and 2007-04-15).
- Seth Stein (Northwestern University, Chicago); Klaus Hinzen, Sharon Reamer and Claus Fleisher (U. of Cologne) at the Membach station (2007-12-03).

K. Vanneste welcomed:

- Stefan Shanov, Alexander Radulov and Marlena Yaneva, Geological Institute of the Bulgarian Academy of Sciences, 11-16 September

K. Verbeeck welcomed:

- Stefan Shanov, Alexander Radulov and Marlena Yaneva, Geological Institute of the Bulgarian Academy of Sciences, 11-16 September

M. Van Ruymbeke welcomed:

- Cadicheanu, N, Institute of Geodynamics of Romanian Academy, Bucharest, Romania (60days)
- Short visits: number of persons 16

H. Missions not specified in the projects

Assemblies, symposia:

- Camelbeeck Thierry: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Ducarme Bernard: XXIV IUGG General Assembly, Perugia, Italy, July 2-13, 2007 - First Asia Workshop on Superconducting Gravimetry, Hsinchu, Taiwan, March 12-16, 2007
- Fraser Jeffrey: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Hubert-Ferrari Aurélia: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Everaerts M.: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Lecocq Thomas: European Gosciences Union General Assembly, Vienna, Austria, April, 15-20 2007 and American Geophysical Union Fall meeting, San Francisco, USA, December, 10-14 2007
- Naslin Sébastien: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Petermans Toon: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007.
- Philipront Amélie: "Journée Risque Sismique", présentation de résultats de recherches LCPC, Laboratoire Central des Ponts et Chaussées, 28/09/2007, Paris - « De la bonne idée à la réalisation pratique… » CSTC, 28/11/2007, Bruxelles
- Sichien Els: 15-20 april 2007 : EGU general assembly, Vienna Austria and 19 October 2007 : Geologica Belgica doctoral seminar, Brussels, Belgium
- Vanneste Kris: 15-21/04/2007: EGU General Assembly 2007, Vienna, Austria.
- Van Camp Michel: (a) NKG Working Group for Geodynamics, Tallinn, Estonia, 27-29 March 2007; (b) 10 Jahre Seismik-AG, St Michael Gymnasium, Monschau, Germany, 5 May 2007; (c) "Subduction zone geodynamics", Montpellier, France, 5-7 June 2007; (d) Journées Luxembourgeoises de Geodynamique, Luxemburg, 12-14 November 2007; (e) AGU Fall meeting, San Francisco, USA, 10-14 December 2007.
- Van Ruymbeke Michel: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 20072007 - Symposium of Earth Tides, Jena, 31 August – 5 September 2007.
- Verbeeck Koen: 15-21/04/2007: EGU General Assembly 2007, Vienna, Austria.
- Zhu Ping: European Geosciences Union General Assemby, Vienne, Austria, April 15-20 2007 - Symposium of Earth Tides, Jena, 31 August – 5 September 2007.

Commissions, working groups:

- Camelbeeck Thierry: (a) « Rhine-Maas Seismologists » meetings, U. Cologne (Bensberg), 1 march 2007 and De Bilt, KNMI, 5 September 2007 – (b) « Belgian Seismic Group » meeting, ROB, 28 February 2007, Liège, 5 June 2007, ROB, 29 August 2007, Leuven, 11 September 2007 and ROB, 17 October 2007.
- Lecocq Thomas: « Rhine-Maas Seismologists » meetings, Bensberg, Universität zu Köln, 2007-03-01. and De Bilt, KNMI, 2007-09-05.
- Philipront Amélie: BeSeiG, Belgian Seismic Group, meetings of 11th of September 2007, KUL, Leuven and 20th of December 2007, Crisis Center, Bruxelles
- Van Camp Michel: « RMS » meetings in U. Cologne (Bensberg), 2007-03-01 and De Bilt, KNMI, 2007-09-05.
- Vanneste Kris: 03/01/2007: Meeting of the Rhine-Meuse Seismologists, Bensberg, Germany.

Research visits:

- Camelbeeck Thierry: EOPG Strasbourg, collaborative work on site effects in the Upper Rhine graben with Valérie Calbini (Phd student) and Michel Granet (9-14 December 2007).
- Everaerts M.: Tongji University in China from 7 to 17 December 2007.
- Lecocq Thomas: (a) MTMF seismic station inauguration, "Seismo at school project", Monthermé, France, 2007-10-12 – (b) COULOMB course, USGS Menlo Park University, California, USA, 2007-12-08.
- Sichien Els: 5-9 November 2007: Geosciences azur, university of Nice, Sophia Atipolis, France
- Van Camp Michel: (a) IPGP, Paris, 2007-03-26 (discussion of the ERC Sumatra project with M. Diament); (b) University of Montpellier, 2007-06-04 (discussion about the gravity measurements in karstic areas: comparison of the Rochefort and Larzac cases); (c) Black Forest Observatory, 14-16 November 2007 (discussions on future projects in low frequency seismology and gravimetry).

DEPARTMENT 2: Astrometry and Dynamics of Celestial Bodies

SECTION 4: Astrometry of Solar System Bodies

Introduction

The Royal Observatory of Belgium has a long tradition in excellent astrometry of asteroids and comets. In the last years, worldwide asteroid astrometry got a new impetus thanks to several developments. First, there was the extension of the asteroid population with new groups, such as the Transneptunian objects. More influence came from the realisation that asteroids may pose a threat to civilisation if one would collide with the Earth. The Royal Observatory of Belgium continues to provide excellent astrometry of asteroids thanks to the RUSTICCA project, and participates when possible to international projects. The activities within this project are described in the project "RUSTICCA".

Recently the section got involved, together with other sections of the Royal Observatory, in the data reduction of the astrometric satellite Gaia, in the Coordination Unit dealing with solar system objects. The activities within this project are described in a separate chapter.

The long-lasting activity of photographing the sky in the department produced an important collection of astrophotographic plates, most of them under the management of the section. In order to keep the data accessible for modern research, they have to be digitised. Since several years digitisation projects have been started at the Royal Observatory. These activities are described in the Theme "Digitisation".

Finally the section is responsible for producing the Yearbook of the Royal Observatory.

Some members of the section are also active in projects which are not directly related to the nominal activities of the section, such as asteroseismology. These activities are described in the reports of the sections in which these activities best fit.

A. Research Theme “Asteroids”

A.1. Project “RUSTICCA”

A.1.1. Objectives

The Project "RUSTICCA", standing for "Revalorising the Ukkel Schmidt Telescope by Installing a CCD Camera", started in 1993 and consists in the installation of a CCD camera on the Ukkel Schmidt Telescope and modernising the telescope. The main objective of this camera is to continue the long-lasting tradition of excellent astrometric observations of minor planets performed at Ukkel, but also other types of observations have been performed: photometry of cataclysmic variables (discontinued since people interested in this subject have left the Observatory), photometry of the mutual phenomena of the satellites of Jupiter and observations of possible occultations of stars by minor planets. Recently we observed occultations and eclipses of an asteroid by its satellite and we tried to observe mutual phenomena of the satellites of Uranus.

A.1.2. Progress and results

A.1.2.1. Observations in 2007

In 2007 observations have been performed on 40 nights by 5 observers. They include H. Debehogne (4 nights, 108 frames), P. De Cat (11 nights, 455 frames), E. Elst (7 nights, 188 frames), T. Pauwels (25 nights, 2044 frames) and P. Vingerhoets (9 nights, 467 frames).

These observations concerned:

- Astrometry of minor planets: 31 nights (5 of which failed to produce anything due to clouds or technical problems) covering 87 fields by 1068 images, producing 1500 astrometric positions. Out of these, 7 fields with 87 images produced 31 positions of objects of the Near-Earth Objects confirmation page. Observers: H. Debehogne, P. De Cat, E. Elst, T. Pauwels.
- Occultations of stars by minor planets, the so-called Planoccult phenomena: 10 events attempted on 9 nights, with 70 images and films, producing 10 light curves. Observers: P. De Cat, T. Pauwels, P. Vingerhoets. None of these gave a positive occultation, meaning that in none of these cases Ukkel turned out to be in the shadow path of the asteroid.
- Mutual phenomena (eclipses and occultations) of an asteroid and its satellite: 5 events attempted on 6 nights (1 of which failed due to clouds), with 1505 images, producing 5 light curves. Observers: P. De Cat, T. Pauwels, P. Vingerhoets.
- Mutual phenomena (eclipses and occultations) of satellites of Uranus, the so-called PHEURA phenomena: 2 nights attempting 2 phenomena, 1 of which failed due to technical problems, while the other gave no useful result due to haze. In spite of 9 images and films, no light curve could be produced. Observers: P. De Cat, T. Pauwels, P. Vingerhoets.
- Images for public outreach: 2 nights producing beautiful images of comet Holmes (35 images without scientific purpose). Observers: E. Elst, T. Pauwels.

Together they produced 2687 images and films.

A.1.2.2. Other activities

Apart from the observations themselves, a lot of work was put routinely in the preparation of the observations (setting up the list of objects to observe in the coming night, many times just in case the weather might clear up), the reductions of the observations (running the automatic processes, searching asteroids, measuring them and identifying them), and finally computing ephemerides for newly found objects.

In collaboration with the time service (C. Bruyninx) the exact coordinates (longitude and latitude) of the dome of the telescope were determined in the GPS system. This is also useful to publish in the Yearbook.

We prepared everything to observe the mutual events of the satellites of Uranus that could be observable from Ukkel. Such events occur only during short seasons around the equinoxes of Uranus, once every 44 years. All potentially observable events from Ukkel were in the period July 24, 2007 -- January 7, 2008. Unfortunately, all failed due to bad weather conditions. This is too bad because the next opportunity to observe such events will be no earlier than 2050.

The reduction software had only minor modifications in 2007.

The maintenance of the telescope also took a lot of attention. See the technical report in the individual report of T. Pauwels.

Finally, all raw data has been archived on CD-ROM, along with the necessary documentation to interpret the observations in the future, adding another 31 CD-ROMs to the archive, containing 2789 images and films.

A.1.2.3. Summary of the results obtained since 1996

From 1996 to 2007 a total of 19 429 astrometric positions of minor planets and 73 astrometric positions of comets have been published in the Minor Planet Circulars. The number of 1400 published positions in 2007 is rather low compared to the top years 2003-2005, with around 3000 positions per year. This can partly be explained by the weather, but also partly by a lack of staff. Apart from a few volunteers, there was only 1.5 staff members available for the permanence at the telescope, and thus it is inevitable that some clear nights were lost.

Excluding the Daily Orbit Updates, 265 positions of minor planets (NEOs) and comets have been published in the Minor Planet Electronic Circulars.

The total number of preliminary designations of minor planets attributed to observations of the RUSTICCA project amounts to 293. With only 3 new designations attributed in 2007, all of them in mid-December (until mid-December it looked as if we would finish the year without any new designation!), 2007 has been the least productive year since the start of the project.

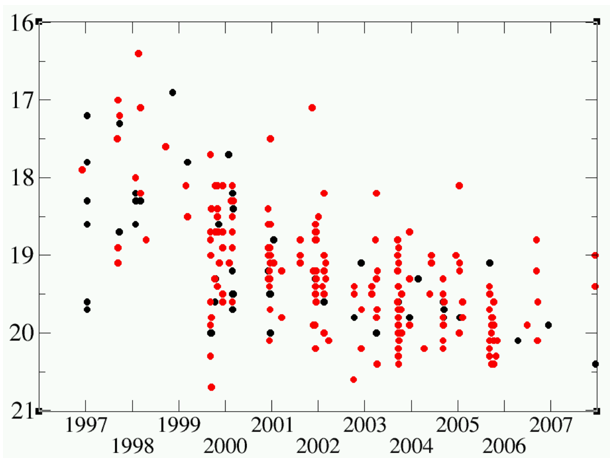

Figure 34. Magnitude of minor planets discovered with RUSTICCA versus date of discovery.

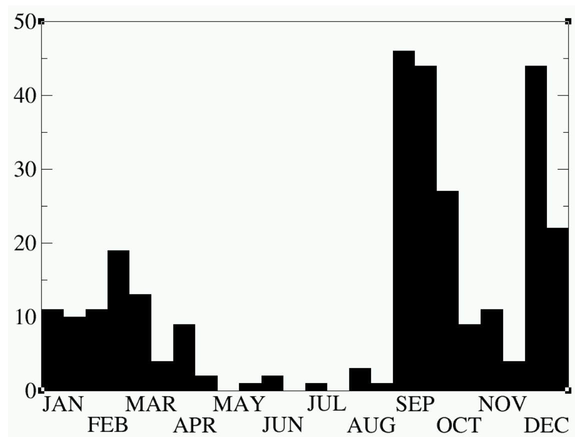

Figure 35. Number of minor planet discoveries per month

Figure 34 analyses in how far this is due to the fact that potential discoveries are getting exhausted. It shows for each assigned preliminary designation in abscissa the date of discovery and in ordinate the magnitude at the time of discovery. Dots are lying inside a triangle. The lower limit corresponds to the limit magnitude of the telescope. In spite of the effort to push the images to fainter objects (total exposure times per field were typically 15 minutes in 1997, while they are around 50 minutes nowadays), this lower limit does not show a clear departure from horizontality, and the limit magnitude remains around 20.5. This could, however, be due to a different photometric reduction. On the other side, the upper limit is clearly diagonal. It represents the magnitude of the brightest object that can still be discovered. In 1996 there were still undiscovered asteroids of magnitude 16.5, nowadays the brightest undiscovered asteroids are around magnitude 19. A brute extrapolation of this plot would put the last discovery from Ukkel with the current means around 2014.

Figure 35 shows the distribution of assigned preliminary designations per half month slot, irrespective of the year. The dip between May and August is due to holidays, the short nights and the fact that the ecliptic (and the asteroids) is low in the sky around that time. The fact that January to April contains many less designations than September to December is easily explained by the fact that in fall the ecliptic is high in the sky in the second half of the night, i.e. when you can expect new objects to appear, while that part of the ecliptic is low in the sky in winter. But the strange feature is the very deep dip in the second half of October and November. There is no explanation for that, except if it would turn out that in November there would be systematically less clear nights than in September or December.

171 of these minor planets with preliminary designation attributed to Ukkel are currently multiple opposition objects, and 93 have been permanently numbered, with the discovery attributed to a RUSTICCA observation. The discoverers with the number of discovered minor planets are: H. Boffin (6 minor planets), P. De Cat (4 minor planets), E. Elst (7 minor planets), E. Elst and H. Debehogne (7 minor planets), E. Elst and S. Ipatov (4 minor planets), E. Elst and D. Taeymans (1 minor planet), T. Pauwels (60 minor planets),

T. Pauwels and H. Boffin (1 minor planet), T. Pauwels and P. De Cat (1 minor planet), T. Pauwels and S. Ipatov (2 minor planets).

A total of 43 light curves of cataclysmic variables could be established (1999-2003), 19 light curves of mutual phenomena of the Galilean satellites of Jupiter (1997 and 2003), and 8 light curves of mutual phenomena of an asteroid and its satellite (2006 and 2007).

The team observed 43 potential occultations of stars by minor planets in the period 2003-2007. 11 of these gave no results to due clouds, 2 others because the target star turned out to be too faint, and 2 phenomena failed because of technical problems. 26 other phenomena gave a negative result, meaning that we could deduce from the observations that the shadow of the minor planet missed Ukkel. 2 phenomena, both in 2005, gave a positive occultation, where precise timings of the beginning and end of the occultation could be derived. Given the uncertainty in the predictions of the occultation paths, 2 positive occultations out of 43 attempted is a good result.

The archive now consists of 336 CD-ROMs with a total of 25 293 images and films.

A.1.3. Perspective for next years

Astrometric observations of minor planets are still expected to be useful for a few years. At the current rate of world-wide observations, this could be for another 10 years. However, big survey programmes are planned for the near future, which could accelerate the rate of discoveries of faint objects. At the moment when all objects in the reach of the telescope will be well-known or routinely observed elsewhere, new observation programmes will have to be defined. An interesting programme may be the mutual phenomena of asteroids and their satellites, of which a few have already been observed in 2006 and 2007. In 2009, there is again a season of mutual phenomena of the satellites of Jupiter, which we plan to observe.

A.1.4. Personnel involved

Scientific staff: T. Pauwels, P. De Cat

A.1.5. Partnerships

List of international partners without grant

- Minor Planet Center, Cambridge, MA, USA for the identification and publication of asteroid positions.
- EAON (European Asteroidal Occultation Network) for the preparation and reduction of PLANOCCULT observations.
- IMCCE, Paris, for the reduction of PHEMU and PHEURA observations.

List of national partners without grant

- Eric W. Elst
- Henri Debehogne
- Pierre Vingerhoets

Grants/Projects used for this research/service

- Lotto grant for the purchase of the camera.

Visitors:

- Short visits: 3

A.1.6. Publications

A.1.6.1. Publications with peer review

[1] Herald, D., et al. (1520 (!) authors, including **De Cat, P., Pauwels, T., Vingerhoets, P.**)
Geocentric Occultation Observations
Minor Planet Circulars 60649--60651.

[2] **De Cat P.,** et al.
12 positions of minor planets
Minor Planet Electronic Circulars 2007-B36, 2007-F80.

[3] **De Cat P.**, et al.
7 positions of comets
Minor Planet Electronic Circular 2007-B39.

[4] Boffin, H.
4 positions of minor planets
MPS 198 109, 199 449.

[5] **De Cat P.**
7 positions of comets
Minor Planet Circular 58753.

[6] **De Cat, P.**
435 positions of minor planets
MPS 196 956, 197 035, 197 037, 197 063, 197 163, 197 360, 197 475, 197 538, 197 624, 197 752, 197 846, 197 852, 197 863, 197 891, 199 537, 202 354, 205 621, 205 647, 205 874, 215 341, 215 657, 215 971, 216 042, 216 049, 216 138, 216 146, 216 172, 216 180, 216 265, 216 274, 216 474, 216 479, 216 548, 216 590, 216 734, 216 931, 216 978, 217 038, 217 081, 217 190, 217 443, 217 480, 220 852, 223 345, 223 374, 223 382, 223 462, 223 488, 223 521, 223 575, 223 596, 223 608, 223 654, 223 884, 223 973, 224 228, 224 229, 224 382, 224 409, 224 415, 224 506, 231 277, 231 288, 231 294, 231 297, 231 316, 231 318, 231 320, 231 323, 231 332, 231 336, 231 390, 231 425, 231 430, 231 442, 231 503, 231 514, 231 534, 231 538, 231 548, 231 550, 231 551, 231 575, 231 585, 231 590, 231 605, 231 610, 231 633, 231 635, 231 666, 231 853, 231 901, 231 904.

[7] **Elst, E.**
161 positions of minor planets
MPS 196 346, 202 871, 202 915, 203 003, 203 004, 203 169, 203 199, 203 315, 203 389, 203 395, 203 413, 203 426, 203 427, 203 433, 203 434, 203 435, 203 463, 203 482, 203 529, 203 540, 203 550, 203 568, 203 590, 203 655, 203 672, 203 692, 203 741, 203 768, 203 775, 203 807, 203 810, 203 939, 204 002, 204 003, 204 044, 204 095, 204 156, 204 158, 204 223, 204 245, 204 278, 204 409, 204 427, 204 680, 206 256, 207 103, 207 246, 207 419, 207 437, 207 469, 207 503, 207 767, 207 915, 210 164, 210 462, 231 717, 231 722, 231 761, 231 765, 231 766, 231 853, 231 869, 231 876, 231 901, 231 904, 231 931, 231 991, 231 996, 232 013, 232 053, 232 066, 232 090, 232 092, 232 110, 232 131, 232 141, 232 156, 232 207, 232 225, 232 261, 232 262, 232 269, 232 291, 232 295, 232 331, 232 352, 232 365, 232 393, 232 394, 232 411, 232 458, 232 466, 232 469, 232 494, 232 507, 232 524.

[8] **Elst, E., Debehogne, H.**
295 positions of minor planets
MPS 202 871, 202 915, 203 003, 203 004, 203 169, 203 199, 203 315, 203 389, 203 395, 203 413, 203 426, 203 427, 203 433, 203 434, 203 435, 203 463, 203 482, 203 529, 203 540, 203 550, 203 568, 203 590, 203 655, 203 672, 203 692, 203 741, 203 768, 203 775, 203 807, 203

810, 203 939, 204 002, 204 003, 204 044, 204 095, 204 156, 204 158, 204 223, 204 245, 204 278, 204 409, 204 427, 207 103, 207 246, 207 419, 207 437, 207 469, 207 503, 207 767, 207 915, 210 462.

[9] **Elst, E.**, Ipatov, S.
2 positions of minor planets
MPS 210 164.

[10] **Elst, E.**, Taeymans, D.
8 positions of minor planets
MPS 196 346, 204 680.

[11] **Pauwels, T.**
692 positions of minor planets
MPS 192 158, 192 326, 192 557, 192 672, 192 689, 193 262, 193 435, 193 982, 195 336, 195 766, 195 906, 196 035, 196 247, 197 136, 197 280, 197 289, 197 396, 197 442, 199 449, 201 567, 206 187, 209 015, 209 034, 212 275, 212 672, 214 375, 214 950, 215 086, 215 423, 215 441, 215 640, 215 728, 215 754, 216 140, 216 165, 216 265, 216 474, 216 479, 217 081, 217 341, 217 443, 217 657, 218 723, 220 259, 220 366, 220 411, 220 418, 220 488, 220 623, 220 677, 220 777, 221 130, 221 131, 221 356, 221 775, 221 881, 222 128, 222 278, 222 605, 222 611, 222 632, 223 152, 223 374, 223 428, 223 462, 223 596, 223 608, 223 654, 223 727, 224 300, 224 506, 228 961, 229 192, 229 750, 229 922, 231 695, 231 717, 231 755, 231 758, 231 761, 231 765, 231 781, 231 802, 231 853, 231 869, 231 876, 231 901, 231 904, 231 907, 231 972, 231 991, 232 092, 232 093, 232 131, 232 148, 232 207, 232 225, 232 226, 232 246, 232 269, 232 291, 232 306, 232 327, 232 335, 232 338, 232 361, 232 372, 232 383, 232 386, 232 393, 232 394, 232 411, 232 433, 232 448, 232 452, 232 466, 232 507, 232 519, 232 524.

[12] **Pauwels, T.**, Boffin, H.
3 positions of minor planets
MPS 199 449.

[13] **Pauwels, T., De Cat, P.**
7 positions of minor planets
MPS 223 462.

Notes:

- There is some debate about whether the MPCs are considered as reviewed or not. B. Marsden (former director) insisted on the fact that the MPCs are a "refereed journal" (though the refereeing process is almost entirely automated nowadays).
- We have grouped positions according to the author list. ADS groups them per month, irrespective of authors. This way the count of publications is totally different (basically one per month). For an objective count, one should count positions rather than publications.

A.1.6.2. Publications without peer review

[14] Berthier, J., et al. (19 authors including **De Cat, P., Pauwels, T., Vingerhoets, P.**)
An Observing Campaign of the Mutual Events within (617) Patroclus-Menoetius Binary Trojan System
American Astronomical Society, DPS meeting #39, #35.05.

A.1.6.3. Publications in press, submitted

[15] **Pauwels, T., Vingerhoets, P., Cuypers, J.**
A problem with the reduction of the observations of the PHEMU97 and PHEMU03 events with the Ukkel Schmidt Telescope

To be published in: Proceedings of the MEOTUS workshop.

[16] **Pauwels, T., De Cat, P., Vingerhoets, P.**
The possibility to observe PHEURA events with the Ukkel Schmidt Telescope
To be published in: Proceedings of the MEOTUS workshop.

B. Research Theme "Digitisation"

B.1. Project "Digitisation of the Heritage of the Federal Scientific Institutes"

B.1.1. Objectives

The Belgian Federal Science Policy Office has recognised the importance of preserving and making available the heritage of the Federal Scientific Institutes (FSI). The means is to digitise the collections of these institutes, and put them on the web.

After a study of the cost of such a digitisation, the government took the principal decision to implement the basic scenario in the course of ten years. By the end of 2005, Belspo had initiated some ten smaller scale operational projects. We joined project No. 7 (which we call "007") "digitisation of photographic glass plates", involving the Royal Museum of Central Africa, the Royal Institute for the Study and Conservation of Belgium's Artistic Heritage (interim coordinator), the Belgian Institute for Space Aeronomy and the Royal Observatory of Belgium, with the aim of digitising our astrophotographic plates on a high-resolution digitiser that should have been built in the course of the "D4A" project (see reports 2002-2005), but which could not be finalised in due time because of events beyond our control. First aim of the 007 project is to make the digitiser operational, and then start to digitise our collections. In parallel we want to set up a detailed catalogue with thumbnails of our plate collection. In collaboration with the experts in digitising astronomical plates at the US Naval Observatory in Washington DC (USNO), the experts in aerial photography at the National Geographic Institute (NGI) and AGFA-Gevaert, a world-leader in photographic matters, the goal is to acquire the necessary know-how, hardware and software for digitising the information contained in the photographic images, as well as the associated metadata. The project aim is to offer the results to the public and to make them directly usable for scientific research through the modern techniques of the information society.

Since these first projects come to an end by the end of 2008, Belspo has started to search actively for financing digitising projects beyond 2008. Two committees are supporting this activity. The aim is to set up a public-private partnership.

B.1.2. Progress and results

In autumn 2007 the DAMIAN digitiser has been finally installed in a temperature and humidity stabilised clean room with adjacent archive room. The ROB is financing this with a Lotto grant that became available in March 2003 and through the ROB's own resources.

B.1.2.1. Management

There were meetings of the Vast Bureau of project 007 on January 16 and November 29. The meeting of November 29 was in conjunction with a visit to the digitising facility.

There were progress meetings at the Observatory level on March 26, September 11, November 26 and December 4.

On December 20, there was a meeting together with potential users of our digitiser from the IMCCE (Institut de Mécanique Céleste et de Calcul des Ephémérides, Paris). They want to digitise plates with Galilean Satellites of Jupiter.

In order to investigate the possibility of a public-private partnership, Belspo set up two working groups: "call to tender" and "juridical aspects". T. Pauwels was member of the former one to represent the Observatory. There were meetings on May 7 and June 13. The main objective in 2007 was to do a critical review of a proposal of call to tender set up by Altran (private company).

B.1.2.2. Preparing the environment

The works in the basement of the Telescope building, including the clean room for the digitiser and the archives room, executed under the supervision of the Regie der Gebouwen, were finished in May 2007. The same holds for the re-installation of the electric system and the hot water supply for the climatisation.

Next, the works on the climatisation, which had been started in December 2004, could be resumed by Becker Reinraumtechnik. Preliminary acceptance tests of the stability of the temperature and humidity in the clean room, as foreseen by the contract, were started (see also section "software").

Several digital temperature sensors were tested on stability and appropriateness for measuring the temperature in the clean room. Part of these sensors were calibrated with a precision of 0.02 K. In order to achieve this, a method was designed and applied to compare sensors with different response times. The testing of the temperature and relative humidity stability for the final provisional delivery of the climatisation installation was done in June and July 2007. The clean room temperature is kept at 18°C within 0.1°C and the relative humidity at 50% within 1%.

B.1.2.3. Building the digitiser

The DAMIAN digitiser is based on an ABL3600 air bearing XY-table from Aerotech, with as add-ons:

- an automatic film roll transport and plate holder system,
- a plate exchanger and loader system with a turntable and plate-tray magazine.

In agreement with Aerotech the design was extended for making the plate-tray magazine part of a removable device with a capacity of 31 plate trays. The production of the machine was finished in July 2007. J.-P. De Cuyper, Lars Winter and Georges de Decker did the partial provisional delivery of the ABL3600 XY-table in July 2007 at the premises of Aerotech in Pittsburgh, Pennsylvania, US. The static and dynamic repeatability tests were performed, using the benchmark software and the 250mm x 250mm geogrid (geometric grid of chromium dots on a glass plate every 0.5mm in X and Y direction with diameters ranging from 50µm to 300µm, made by BVM Maskshop in Germany).

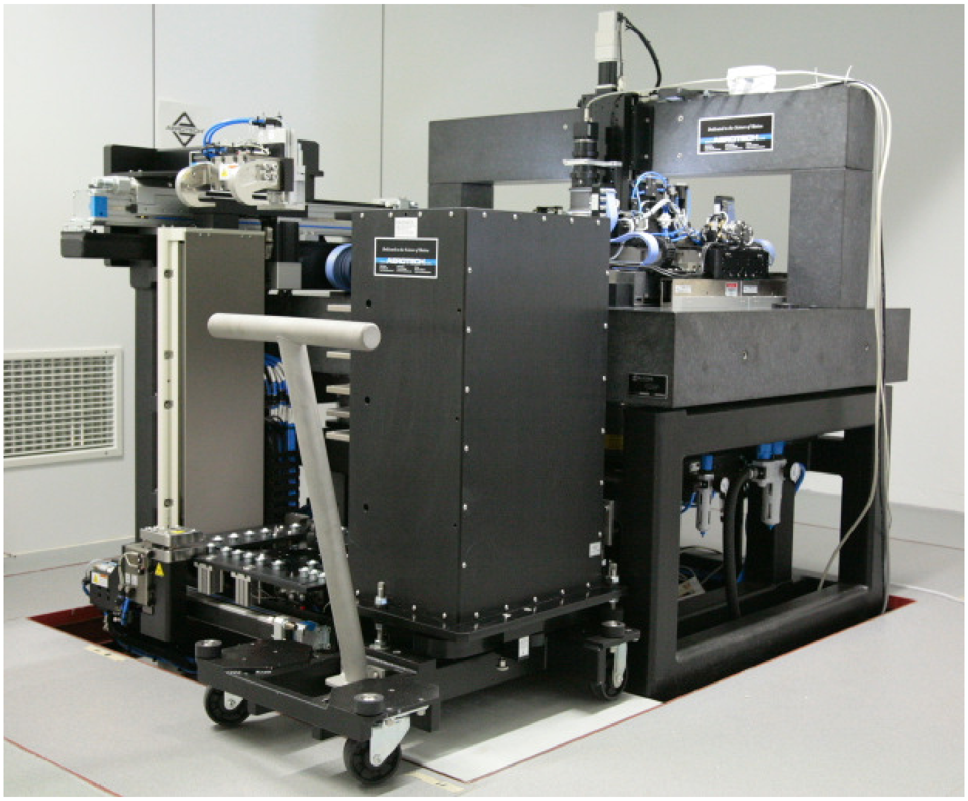

Figure 36. DAMIAN digitiser with automatic plate loader and removable plate tray magazine.

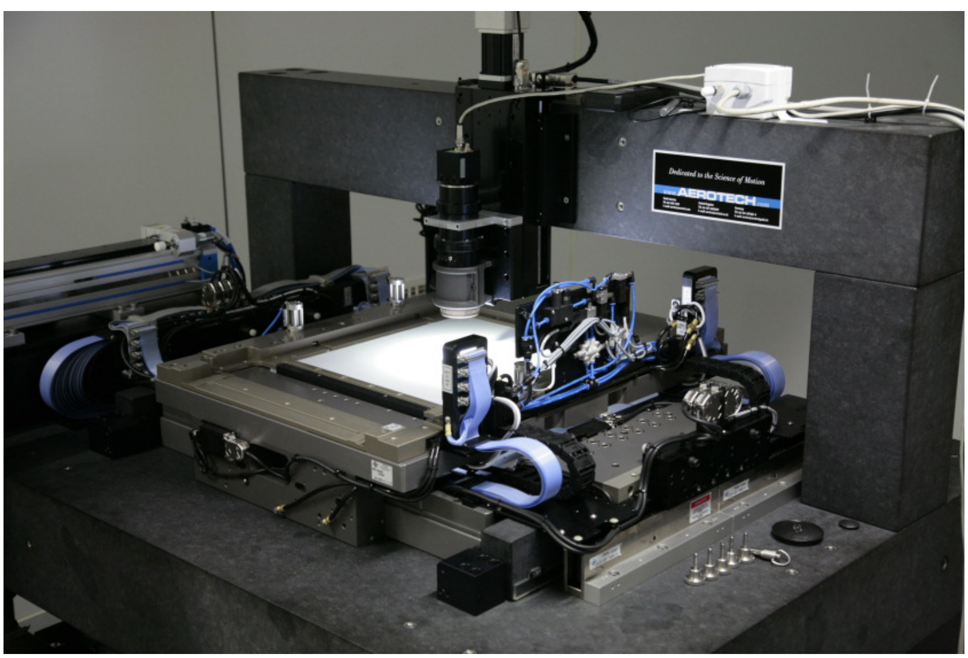

Figure 37. DAMIAN digitiser, detail of air bearing XY-table and granite bridge with Z-axis, telecentric objective and CMOS camera.

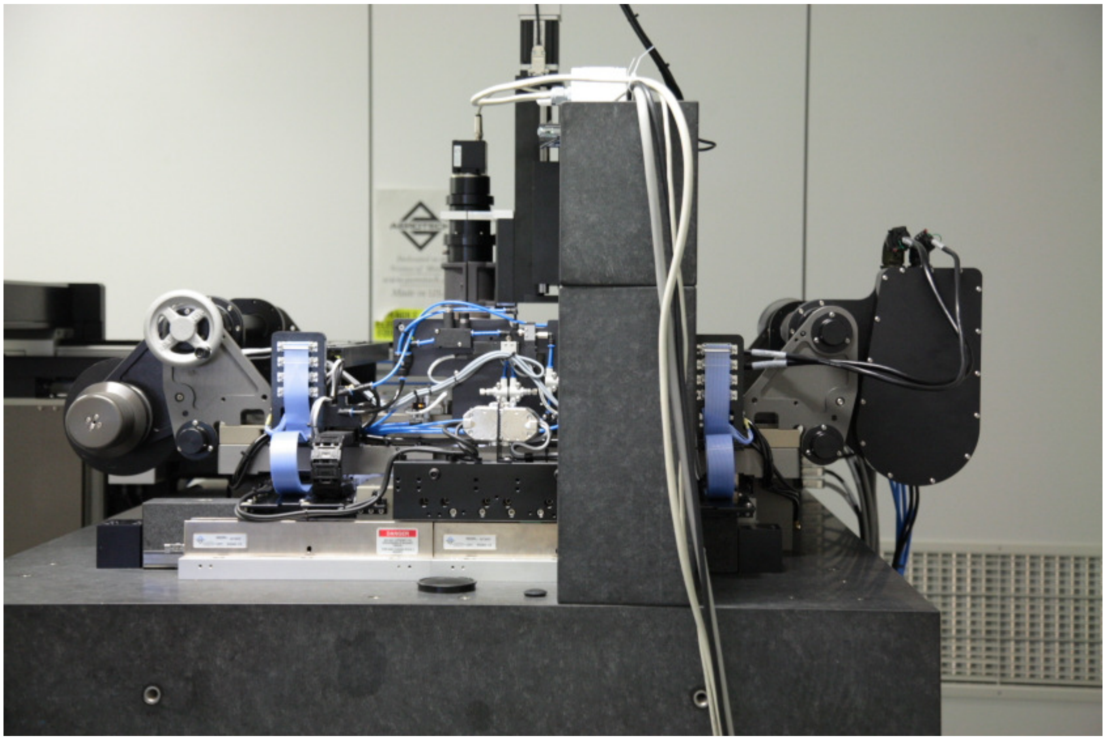

Figure 38. DAMIAN digitiser with automatic filmroll transport system.

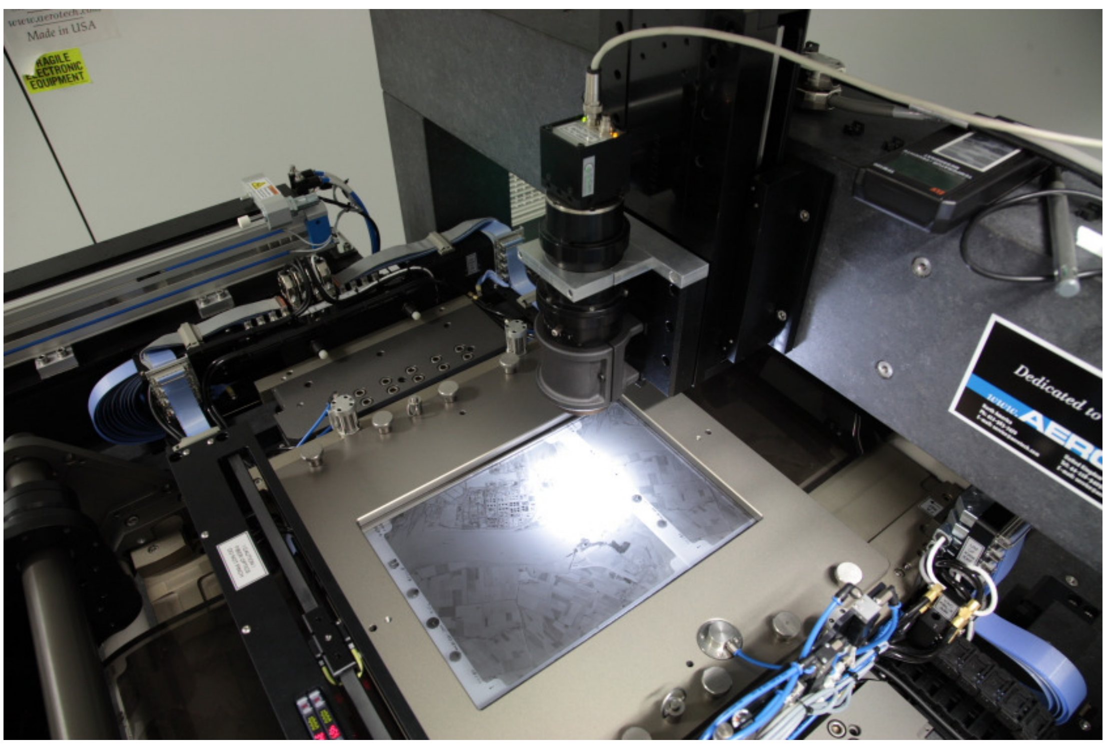

Figure 39. DAMIAN digitiser, detail of counter pressure plate with vacuum suction, the CMOS camera and telecentric objective with alignment plate and the diffuse illumination.

In September 2007 the XY-table and the add-ons were shipped to the ROB and moved into the basement of the Telescope building. The granite base with the XY-table was put on top of its iron weldment table on one of the mechanically isolated foundation blocks in the measurement clean room. At the same time the frequency-regulated air compressor from Ateliers François (AF) was delivered and installed. In October, Aerotech did the final build-up and alignment. The accuracy, precision and repeatability of the XY-table were tested using a laser interferometer. Aerotech also demonstrated the functionality of the automatic film roll transport system and of the automatic plate exchanger and turntable. The total provisional delivery was done based on the results of the static and dynamic benchmark tests, using the 350mm x 350mm geogrid. The positioning error of less than 10 nanometer measured by Aerotech was confirmed.

We continued the development of the solid state diffuse illumination system using very bright LED's. A total diffuse illumination was found to give an optimal reduction of the background plate noise in the digital images. For operating a dynamic illumination while acquiring digital images at a rate of less than 0.3 seconds per image file, a separate microprocessor is needed in order to relieve the CPU of the control PC. We also started the design of a new illumination control unit and the testing of the usability of some microprocessors. This new concept is necessary in order to be able to adapt the illumination in less than 10 ms without compromising the 16 bit stability and the precision of the light intensity. A high precision computer regulated DC power supply needed for the illumination system was designed and constructed. The BCi4 CMOS camera was tested with its new software driver of Vector International. A new CMOS BCi4 production camera, with DC power supply over the USB cable, was delivered mid December 2007.

In November and December 2007 the construction of the DAMIAN digitiser was continued. After aligning the digital camera with the axes of the XY-table, the moving dot procedure was used to determine the distortion model of the field of view. The “distortion free” field of view of the Schneider Xenoplan 1:1 two-sided telecentric objective was found to have a diameter of 7mm. This limits the size of the sub-images for recomposing the (aerial) photographs to 5mm x 5mm. A first calibration of the XY-table was done with the benchmark tests using the 350mm x 350mm geogrid. The testing of the automatic film roll transport system was started for the digitisation of (aerial) photographs on film rolls, in close collaboration with the NGI and AFGA-Gevaert.

The development of a new two-sided telecentric objective with a distortion free field of view diameter of at least 22mm was started. This will allow to reduce the stepping time of the XY-table by a factor of 10 and to make the DAMIAN digitiser at least 8 times faster.

The DAMIAN digitiser can digitise photographic images up to 342mm wide on glass plates, film sheets and film rolls. A cast aluminium counter pressure plate and plate trays with a central opening corresponding to the actual image size are needed. By the end of 2007 counter pressure plates and plate trays were available for digitising film rolls of 240mm and 254mm wide (with images sizes up to respectively 230mm and 240mm wide), film sheets of 240mm wide (with an image up to 230mm x 230mm) and glass plates of 250mm x 250mm x 5mm and 350mm x 350mm x 5mm (with images sizes up to respectively 240mm x 240mm and 342mm x 342mm).

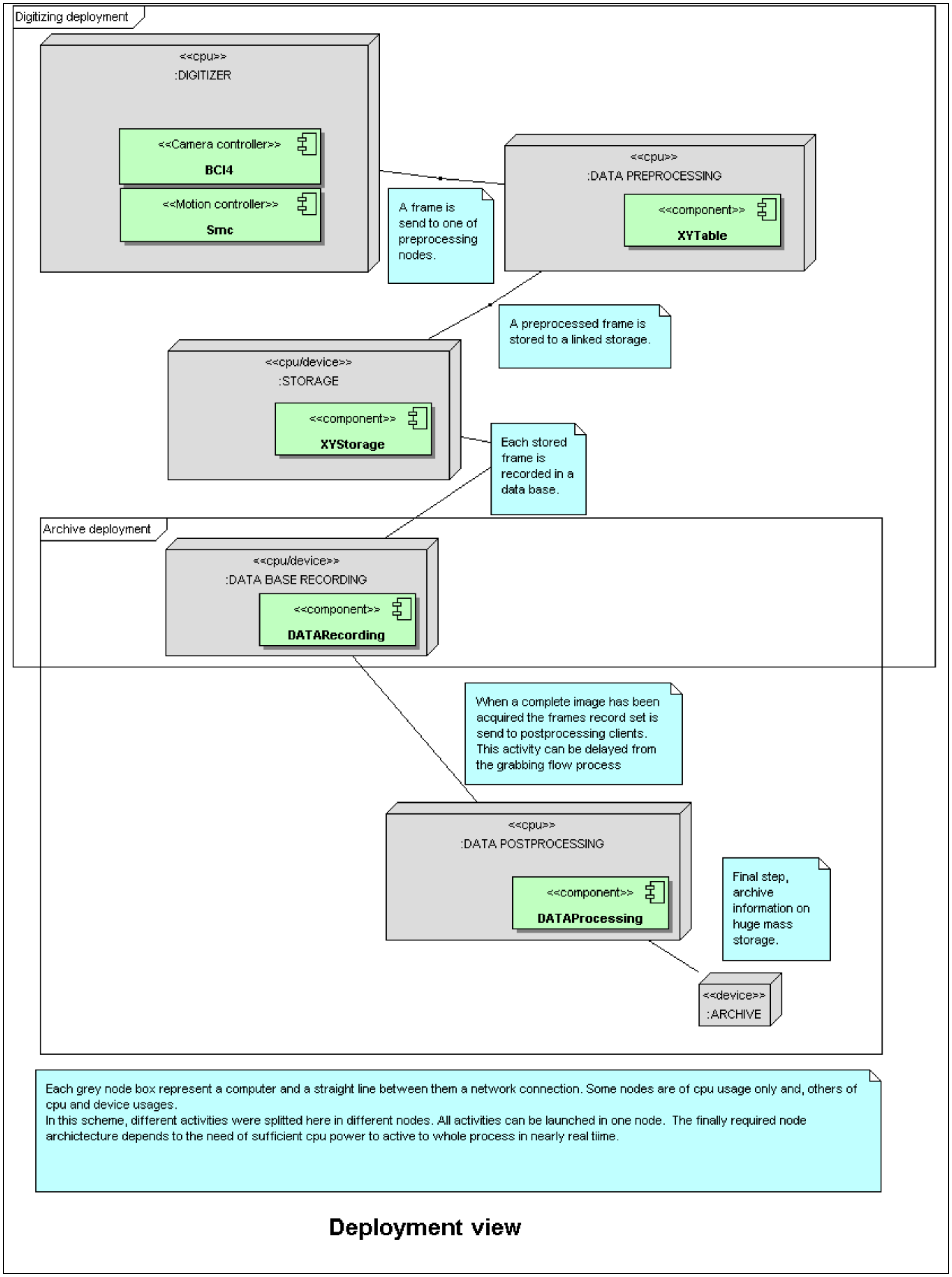

Figure 40. Schematic representation of the software for the control of the XY-table and the digital camera.

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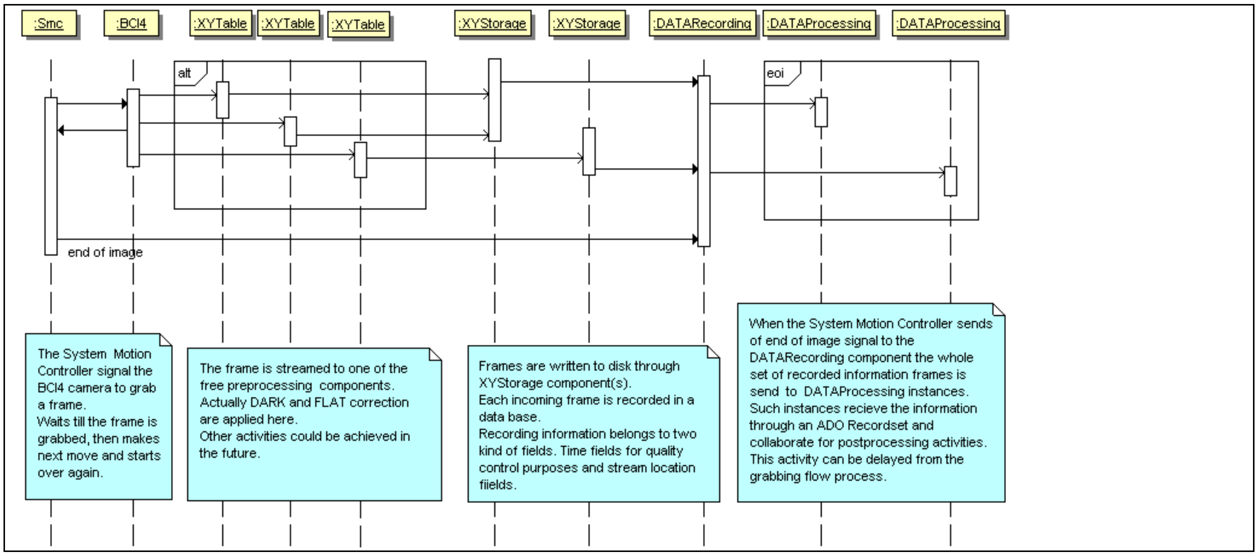

Figure 41. Flow chart of the digitisation process of a photographic image.

B.1.2.4. Software development for controlling the digitiser

A first version was developed of the software for a distributed image capture and storage, in order to be able to handle the huge data stream generated by the CMOS camera during the digitisation process. The concept of the software for the control of the XY-table and the digital camera and the further storage and treatment of the digital images is represented schematically with overview diagrams.

The first diagram (Figure 40), using a deployment view, shows the two main activities:

- the digitising activity, ranging from producing a digital image to storing the digital image together with the corresponding meta data and environment parameters,
- the archiving activity, collecting the subimages of an analogue photograph and converting them to a standard format such as .fits or .tiff.

The second diagram (Figure 41), using a sequence diagram, shows a flow chart of the digitisation process of a photographic image, in which the capture of a digital image is determined by the stepwise motion of the XY-table.

The third diagram (Figure 42), the User Application Framework (UAF), shows a digital image, with a GUI window in front for the control of the digital camera and the histogram of the recorded image. Each PC participating to the digitisation process has a service application which remains active in the background. The UAF communicates with these service applications to start objects, to communicate with them, to select methods and to set parameter values.

This application allows controlling the BCi4 CMOS camera in a direct, interactive and user-friendly way:

- loading and disactivating the camera firmware;
- setting the values of the offset, the pre-charge, the integration time, etc.;
- setting the size of the Window of Interest (WOI, the region recorded).

The UAF also allows choosing dynamically the PC's for starting up the objects participating in the data pre-processing and those for providing the storage of the digital image files. The selection of the participating PC's and storage directories is done by means of identifiers.

In the "Data post processing - Frame conversion" field at the bottom, two selection buttons, "PMI" and "BMP", allow to start up DATAProcessing objects for the conversion of the digital images to the desired image format.

The OneSix field allows controlling and recording the ambient temperature in the measuring room.

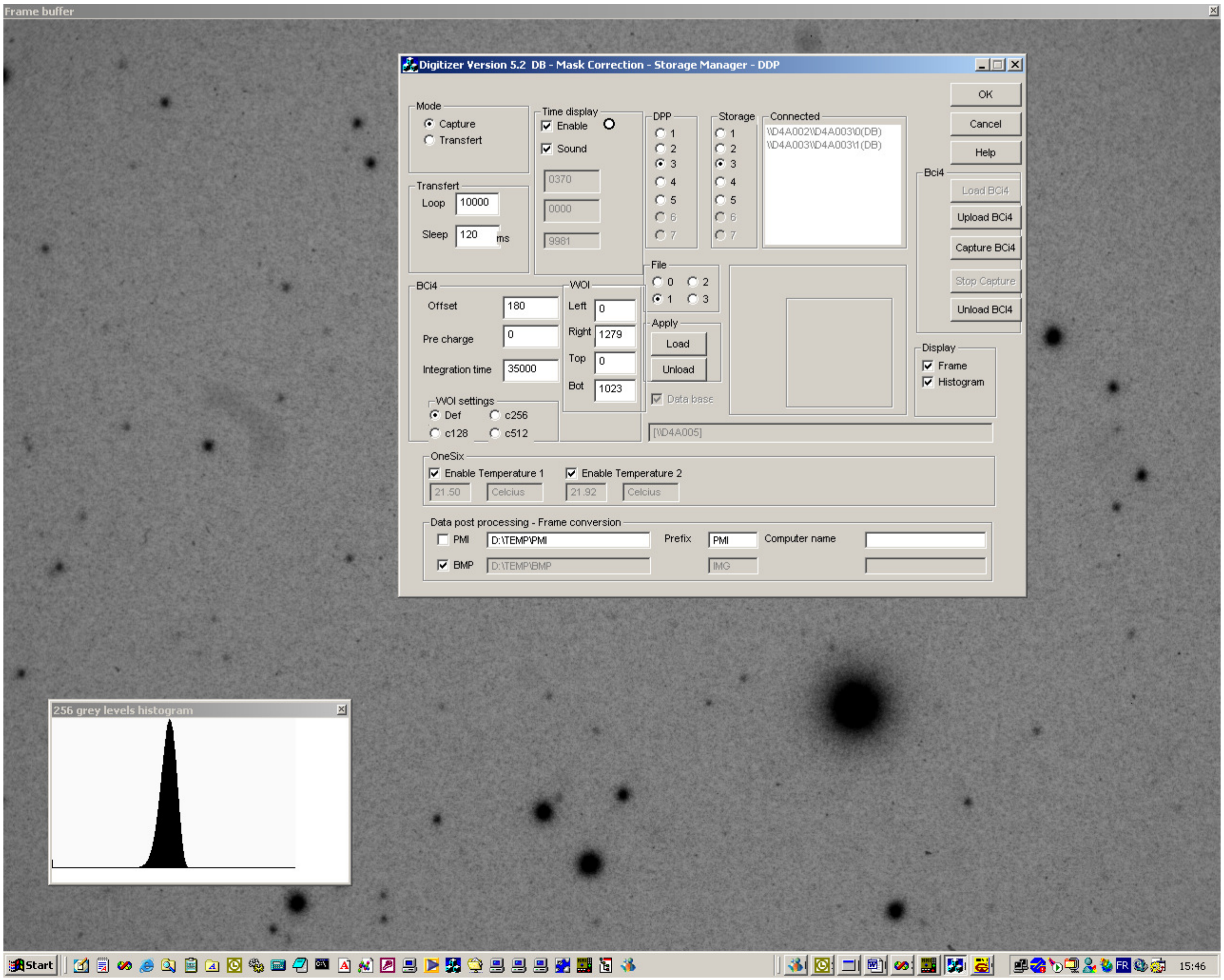

Figure 42. The User Application Framework (UAF), showing a digital image with a GUI window in front for the control of the digital camera.

Figure 43 shows a screen shot of Aerotech's graphical application, which forms the interface between the motion of the XY-table and the recording of the digital images, using G-code commands. The link between the real-time OS used by Aerotech and the MS Windows OS is realised by a DLL interface.

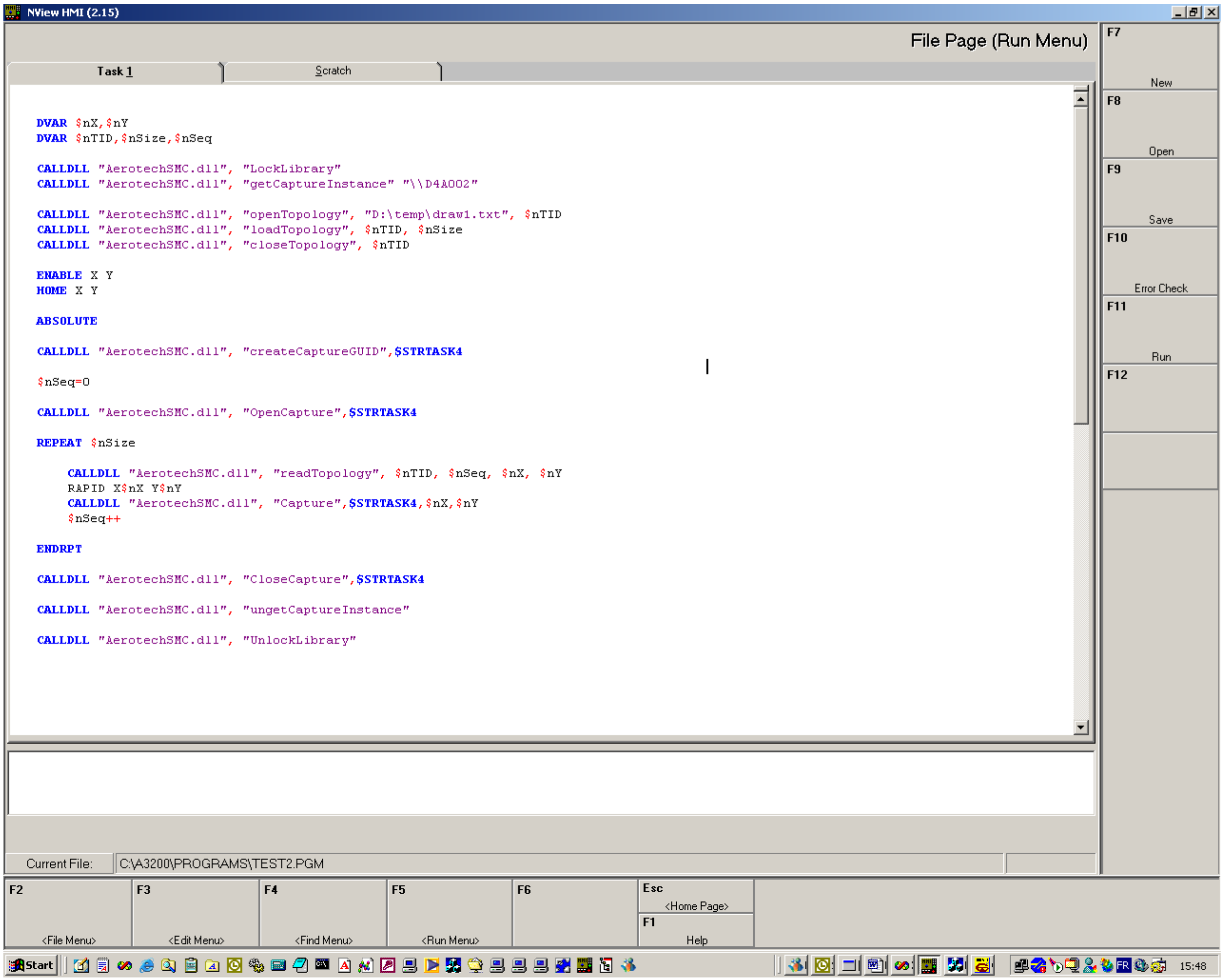

Figure 43. A screen shot of Aerotech's graphical application NVIEW HMI - Digital automation platform.

B.1.2.5. Software for controlling the climatisation

The climatisation device of Becker-Reinraumtechnik is controlled by a SAIA controller dependent on a number of environment parameters, which are recorded in real time. A software interface with the SAIA controller was developed that allows reading these environment parameters and storing them in an Excel table. This software has two functions:

- To check the quality and stability of the air temperature and relative humidity produced by the climatisation device in the measuring room. The acceptance criteria are that in the clean room the temperature should stay within 0.1 degree of the nominal temperature of 18 degrees, and the relative humidity within 1% of the nominal 50%.
- As an interface between the environment parameters and the digitisation metadata table. At the time of capture of a digital image, the values of the environment parameters (temperature, relative humidity, overpressure, etc.) are recorded in a metadata table and written to the header of the corresponding image file.

For the DT80000 digital temperature sensor a software interface was developed to read in real time the voltage, and convert it to calibrated temperature in the Celsius scale. Together with the relative humidity sensor, this gives an independent and calibrated control measurement for the acceptance tests of the values measured and used by the SAIA controller of the climatisation device.

The geometric and radiometric benchmark software for the digitiser was improved and fully tested in view of the provisional deliveries, as well as a first version of the data reduction software needed to analyse the test results. These software packages, together with the Automation3200 control software of Aerotech were installed on a portable Shuttle mini-PC and tested. This Shuttle PC was used for the provisional deliveries of the XY-table in July and October 2007.

Optimisation and tests were performed of the moving dot software for the alignment of the BCi4 camera with the axes of the XY-table and of the software for fitting a correct distortion model to the field of view of the camera.

In November the observed instability in the geometry of the field of view of the BCi4 CMOS testcamera when taking a series of images after each other was found to be due to the occurrence in idle mode of an internal short circuit in the electronics, causing extra heating of the camera. After discussing this with Vector International, they adapted their firmware to avoid this problem.

The step and stare motion control software of the XY-table was extended to be able to adapt the stepping to the actual pixel size determined with the distortion model. This makes it possible to reassemble the subimages of a digitised (aerial) photograph back into one single image with minimal geometric distortion.

B.1.2.6. Cataloguing the collections

The work on the digital catalogue and the pre-scanning of the photographic plates archived at the ROB was continued.. For the prescanning the AFGA DuoScan HiD A4 flatbed scanner at the ROB was used for the smaller plates and the AGFA XY-15 Plus A3+ graphical flatbed scanner at the NGI for the larger ones and for scanning the paper maps of the CdC Atlas. At the end of 2007 the digital photographic plates catalogue contained metadata of 21136 direct images of the sky and of 2258 spectra (mostly multiple exposures on one photographic glass plate) and prescans 10845 of photographic plates.

The ODBC compliant relational catalogue contains already a description of:

- the (complete) collection of the Carte du Ciel (CdC): 659 exposures (659 prescans) of the glass plates and 571 scans of the atlas maps published by the ROB;
- the collection of the Double Astrograph (DAG): 10462 exposures (5431 prescans);
- the oldest collection (1924 - 1939) of the Zeiss Triplet (TRP): 1846 exposures (1032 prescans);
- the collection of the ESO Grand Prism Objective (ESO-GPO): 7181exposures (3723 prescans) and
- another 1078 exposures (462 prescans) taken at telescopes elsewhere (Boyden, Cordoba, ESO Schmidt, Schmidt Rozen, GPO Haute Provence, Hoherlist, etc.).

Concerning the spectra the digital catalogue contains information of:

- the more recent collection (1948 – 1967) of the TRP: 476 spectra;
- the collection of the 1.50m at the Observatoire de Haute Provence (OHP150): 557 spectra;
- the collection of the ESO 1.52m (ESO152): 1198 spectra and
- the collection of the ESO 3.60m (ESO360): 27 spectra.

B.1.3. Perspective for next years

B.1.3.1. Hardware

In 2008 the automatic plate loader and film roll transport system of the DAMIAN digitiser will be made operational. The necessary counter pressure plates and plate trays will be milled for digitising different sized photographic images on glass plates, film sheets and film rolls.

A cooled BCi4 production camera will be purpose-built by Vector International and installed. We foresse the development and installation of a computer controlled solid state diffuse illumination system using very bright LED's and a microprocessor control unit allowing to adapt the illumination in less than 10ms without compromising the 16 bit stability and the precision of the light intensity.

We will continue the optical and mechanical design of a two-sided telecentric objective with a distortion free field of view diameter of at least 22mm. This will allow to reduce the stepping time of the XY-table by a factor of 10 and to make the DAMIAN digitiser at least 8 times faster.

Digitisation of photographic images on film roll and glass plates will commence in fully automatic mode.

B.1.3.2. Software

Development of the operation mode control software for the automatic plate loader and the film roll transport system of the DAMIAN digitiser will continue. Development of the necessary step and stare software for digitising different sized photographic images on glass plates, film sheets and film rolls is likewise foreseen.

We will develop further the software package for the digitisation of (aerial) photographs using a dynamic exposure time and illumination intensity and the reassembling of the 12bit subimages into one 16bit tiled fit image file. We will develop and test a new software interface for the cooled BCi4 camera.

B.1.3.3. Digital catalogue

Further development of the digital photographic plates catalogue of the direct images of the sky and the spectra, in the form of an ODBC compliant relational database. Extension and cross-checking of the metadata with information available in complementary sources. The production of pre-scans images will be continued and used for creating thumbnails for linking to the catalogue. The digital catalogue will be made available on intranet and internet.

B.1.3.4. Digitisation

Routine digitisation of our collection should start on the scanning time allocated to the ROB. The funding of the project "007" is foreseen till the end of 2008. To extend the project beyond 2008, two options appear to exist. On the one hand a public-private partnership could be established. On the other hand, in the coming years the UDAPAC project is supposed to start (see project UDAPAC). Since it will use the same facilities, we expect that there will be some interaction between the digitisation of our collections and UDAPAC.

B.1.4. Personnel involved

Scientific staff: R. Van der Linden, T. Pauwels, J.-P. De Cuyper, L. Winter

Technical staff: G. De Decker, D. Duval, G. Peeters

B.1.5. Partnerships

List of international partners without grant

- The US Naval Observatory, Washington DC, US
- Uwe Laux, Thüringer Landessternwarte Tautenburg, Germany

List of national partners with grant

- Royal Museum of Central Africa
- Royal Institute for the study and Conservation of Belgium's Artistic Heritage

List of national partners without grant

- Belgian Institute for Space Aeronomy
- National Geopgraphical Institute
- AGFA-Gevaert NV, Mortsel

Grants/Projects used for this research/service

- *Digitaliseringsplan van de FWI's* of Belspo
- Lotto-grant for the purchase of the digitiser

Visitors

- Lars Winter
- Al Ciez, Eric Schmidt & Clive Lewin, Aerotech Inc, 21-27 October 2007

B.1.6. Publications

B.1.6.1. Publications in press, submitted

[1] N. Zacharias, **L. Winter**, E. R. Holdenried**, J.-P. De Cuyper,** G. L. Wyco , G. Wieder
The StarScan plate measuring machine: overview and calibrations
Submitted to PASP

B.1.7. Scientific outreach

Meeting presentations

[1] **J.-P. De Cuyper**
The DAMIAN Facility
Information event on e-Infrastructures, FP7, Cordis, EU Research Infrastructure, Brussels, 06 February 2007

[2] **J.-P. De Cuyper**
The DAMIAN Facility
Presentation at the US Naval Observatory, Washington DC, US, 13 July 2007

[3] **J.-P. De Cuyper**
The DAMIAN Digitiser
Poster, Astronomical Data Analysis Software and Systems – ADASS XVII Conference, London, UK, 23-26 September 2007

[4] **J.-P. De Cuyper**
The DAMIAN Facility
Aerial Photography meeting, AGFA-Gevaert, Mortsel, 28 November 2007

B.1.8. Missions

Assemblies, symposia (days): J.-P. De Cuyper (6)

Commissions, working groups (days): T. Pauwels (2)

Research visits (days): J.-P. De Cuyper (30), L. Winter (11), G. de Decker (8)

B.2. Project UDAPAC

B.2.1. Objectives

The UDAPAC project was initiated in 2000. In this project the Royal Observatory would serve as a host for the European collections of the direct astrophotographic plates for which the owners have no more means, interest or know-how to keep them. In the long run, parallel with the other digitisation projects, these plates could be digitised. Until now no concrete action has been undertaken. In 2005 there were some discussions on the opportunity to start the raising of funds for UDAPAC. However, some people had the feeling that it would be better to wait till the DAMIAN digitiser would be operational (see the previous project) and could have demonstrated its utility, so that applications for funding would be stronger.

B.2.2. Progress and results

The activities in 2007 were limited to looking for potential financial resources. We have been searching in the direction of an FP7 project, but no concrete decision has been taken yet.

B.2.3. Perspective for next years

In the next years, once the archives room and the digitiser have been realised in the 007 project (see the previous project), routine operations in UDAPAC should start. But before that a funding source will be searched.

B.2.4. Personnel involved

Scientific staff: R. Van der Linden, T. Pauwels

B.2.5. Partnerships

List of international partners without grant

- Elizabeth Griffin
- Other partners still to be determined

B.2.6. Missions

Research visits:

- T. Pauwels (2 days)

SECTION 5: Astrometry and Dynamics of Stellar Systems

Introduction:

Our research field pertains to the domain of stellar physics and stellar evolution since we study the physical processes occurring in the atmospheres of early- to mid-type main-sequence stars. Among the many different processes, we focus on stellar pulsation, rotation and the influence of an environment with varying metallicity of B/Be-type stars and on multiplicity, stellar pulsation and chemical composition of A/F-type stars. Since the vast majority of all stars is a member of double and multiple stellar systems, we also perform detailed investigations of such systems, ranging from visually resolved (wide) pairs to very close binaries (e.g. spectroscopic and photometric stellar systems) using a variety of techniques.

A. Research Theme “Binaries”

Stellar formation and evolution cannot be really understood without a good knowledge of the properties of binary and multiple systems, because 50 to 70% of all stars belong to such a system. **Binary and multiple stars** with well-characterized components are attractive targets to study different phenomena of high astrophysical relevance including their own formation and history. Astrometry helps in the full characterization of the components in a powerful way as it allows determining the orbital motions and, derived from these, the stellar masses - a fundamental property of stars - in a straightforward manner. **Wide binaries**, especially if the components have different spectral types, are used to calibrate the luminosities and temperatures of single stars and to confront evolutionary tracks and models. They represent the high angular momentum class. In contrast, **close binaries** offer excellent opportunities for the combination of data obtained with different techniques resulting in great progress for understanding the impact of binarity on the stellar atmospheres or close binary evolution.

A.1. Project “Visual Binaries and Multiple Stars”

A.1.1. Objectives

Visual binaries allow a direct calibration of the mass-luminosity relation on the lower main sequence via the study of their orbital motions. Differential magnitudes and colours are collected along with accurate relative positions with the purpose to investigate the physical status, to improve the knowledge of their orbits and to derive the associated properties such as photometrically derived mass ratios. One of our aims is to investigate a volume-limited sample of visual binary and multiple stars in the solar neighbourhood.

A.1.2. Progress and results

- In the framework of a first Belgo-Bulgarian project, we acquired accurate relative astrometry and differential multi-colour (BVRI) photometry for the components of **71 visual systems** of which 6 are orbital binaries, 27 are nearby and 30 are multiple systems. Two new visual double stars of intermediate separation were also found. The estimated accuracies in position angle and angular separation are 0.04° and 0.01" respectively, while those in differential photometry are of the order of 0.01-0.02 mag. We assessed the physical nature of the association for 55 systems. New basic binary properties were derived for 20 bound systems. The component colours and masses were obtained for two orbital systems **[1].**
- In the light of obtaining accurate fundamental data for binary and multiple stars with interesting properties, we selected the bright binary system **θ^2 Tau** for a detailed study because both components are among the more massive stars of the Hyades located in the turnoff region of its colour-magnitude diagram and because the evolutionary status of the components is still under debate. We determined a new orbit solution to derive the fundamental properties of both components to a high accuracy. We significantly improved the knowledge of the orbital parameters and associated fundamental proper-

ties. The component masses and luminosities thus derived are found to be compatible with current stellar evolution models adopting the Hyades metallicity **[3].**

- Using the Wilson-Devinney code, we derived new geometric and photometric elements from the RI light curves of two Algol-type eclipsing binary systems: **RW CrB and VZ Leo**. The geometry of both systems is that of a semi-detached binary where the secondary component fills its Roche lobe while the primary component is well inside. In the case of RW CrB, we fitted a binary model with a cool spot. Investigation of the orbital period evolution of both systems indicated a period decrease which can only be explained by a loss (non-conservation) of angular momentum. Finally, we interpreted these results by comparing with other similar systems **[4]**. In addition, new times of minima of various other eclipsing binary systems with eccentric orbits were reported **[2].**

A.1.3. Perspective for next years

The acquisition and exploitation of component colours for various nearby visual binaries will be pursued.

In 2006, we derived the component masses of the Hyades binary system θ^2 Tau by application of the code KOREL and simultaneous fitting of the radial velocities and the interferometric data. Future work will consist in confirming this first direct measurement of the radial velocity of the "hidden" component through a careful analysis of the behaviour and reliability of the adopted disentangling technique as well as in using the disentangled component spectra to perform a detailed chemical analysis, in order to determine as accurately as possible the physical properties and the evolutionary status. This will eventually allow to test whether or not convective overshooting is needed in the models.

For a few systems of high astrophysical relevance for which we would need very high-angular resolution astrometric data, we will submit applications for interferometric observations provided they satisfy the criteria for eligibility (e.g. ESO for the Southern and CHARA (US) for the Northern objects).

A.1.4. Personnel involved

Scientific staff: Y. Frémat, P. De Cat, P. Lampens, H. Hensberge

Technical staff: D. Duval

A.1.5. Partnerships

List of international partners without grant

- R. Argyle, Cambridge, UK
- P.G. Niarchos, Department of Astrophysics, Astronomy and Mechanics, Univ of Athens, Greece
- J.L. Prieur, Toulouse, France
- M. Scardia, Brera, Italy
- P. Škoda, Astronomical Institute of the Academy of Sciences, Ondřejov, Czech Republic
- A. Strigachev, Institute of Astronomy of the Academy of Sciences, Sofia, Bulgaria
- G. Torres, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA
- B. Ulas, Onsekiz Mart University of Canakkale, Dept. of Physics, Canakkale, Turkey

Grants used for this research

- Belgo-Bulgarian bilateral project "Photometric and Spectroscopic Follow-up Studies of Binary Systems of Special Interest"(BL/33/011ext)
- Action-1 "Pulsation, chemical composition and multiplicity in main-sequence A- and F-type stars" of the Federal Science Policy (MO/33/018)
- "Modern Aspects of Theoretical and Observational Astrophysics", Federal Science Policy

Visitors:

- A. Strigachev, Institute of Astronomy, Sofia, Bulgaria: 4.5 weeks

A.1.6. Publications

A.1.6.1. Publications with peer review

[1] **Lampens, P**., Strigachev, A., **Duval, D.**
Multicolour CCD Measurements of Visual Double and Multiple Stars. III
A&A 464, 641

A.1.6.2. Publications without peer review

[2] Biro, I.B., Borkovits, T., Hegedűs, T., Kiss, Z.T., Kovacs, T., **Lampens, P.,** Regaly, Zs., Robertson, C.W., Van Cauteren, P.
New Times of Minima of Eclipsing Binary Systems
IBVS, 5753, 1

[3] **Lampens, P., Frémat, Y., De Cat, P., Hensberge, H**.
Spectral disentangling and combined orbital solution for the Hyades binary θ^2 Tau
In: Proceedings of IAU Symp. 240 "Binary Stars as Critical Tools & Tests in Contemporary Astrophysics", eds. W. I. Hartkopf, P. Harmanec and E. F. Guinan, 22-25 August 2006, Prague, Czech Republic, 213

A.1.6.3. Publications in press, submitted

[4] B. Ulas, P. G. Niarchos, **P. Lampens**, A. Liakos,
RI photometry and light-curve analysis of the Algol-type eclipsing binaries RW CrB and VZ Leo
New Astronomy (submitted)

[5] **Lampens, P., Frémat, Y., Hensberge, H.,** Tamazian, V., Docobo, J. A., Balega, Y.
DG Leo: A Triple System with a Surprising Variety of Physical Phenomena
In: Multiple Stars Across the H-R Diagram, ESO Astrophysics Symposia, Springer-Verlag Berlin Heidelberg, 2008, 59

A.1.6.4. Reports

[6] Hartkopf, W. I., Allen, C., Davis, J. A., Fekel, F. C., **Lampens, P**., Ling, J. F., Oblak, E., Oswalt, T. D., Scarfe, C.
Commission 26: Double and Multiple Stars
In: IAU Transactions, Vol. 26A, Reports on Astronomy 2002-2005, ed. O. Engvold, Cambridge University Press, 2007, 193-202

B. Research Theme “Asteroseismology”

The overall objective of **asteroseismology** is to probe the internal structure of pulsating stars. To this aim we observe and study the light and the spectral variations of main-sequence pulsating stars of spectral type B(e)-A-F over a time-scale of several seasons or years.

B.1. Asteroseismology of single, binary or multiple stars

B.1.1. Objectives

Special attention is given to the study of B-A-F **pulsating components of binary or multiple stars** with the goals to improve knowledge of pulsation physics through constraints on the physical parameters of the variable component derived from the binary or multiple nature of the system and to study the interaction between pulsation and binarity. Since more than 50% of all stars are expected to be binaries, understanding the effects of binarity on the pulsation characteristics is a matter of prime importance. We focus our efforts unto those binaries which are also promising targets for the application of the technique of spectral disentangling.

B.1.2. Progress and results

B.1.2.1. Main-sequence A-F stars (γ Dor = γ Doradus star; δ Sct = δ Scuti star)

- The region in the H-R diagram where the main sequence interferes with the Cepheid Instability Strip hosts A- and F-type stars which are affected by a rich variety of internal physical processes (including pulsation, diffusion, convection and magnetism). Main-sequence A-type stars are among the best cases to study the complex interplay between all these processes. We are presently exploring a large sample of A-F stars which are suspected of binarity, using both high-resolution spectroscopy and differential CCD photometry. The goal is to perform detailed chemical abundance analyses and to search at the same time for oscillations, binarity and/or chemical peculiarity. Of the 32 investigated targets, 8 are spectroscopic binaries and 3 have been identified as **δ Scuti pulsators** with rapid line-profile variations (LPVs). We derived their atmospheric stellar parameters by fitting the observed spectra with synthetic ones. This work also led to the detailed analysis of the light variations of **HD 217860** revealing interesting multiperiodic photometric and spectroscopic variations of type δ Scuti, with up to 8 frequencies common to two large photometric data sets **[7].** The data were collected through a collaboration with professional as well as amateur astronomers**.**
- In a similar context, Dr. S. Hekker, who is finishing the work on solar-like oscillations in (sub)giant stars, has been learning how to use the codes developed by Dr. Y. Frémat for the interpretation of the observed spectra (cf. project "Pulsation, chemical composition and multiplicity in main-sequence A- and F-type stars"). A summer sample consisting of suspected A-F type binaries was defined for which new high-resolution observations were requested at the Observatoire de Haute-Provence (France) (3 nights granted) **[28].** For some new binaries, a long-term monitoring in radial velocity is being pursued at the National Astrophysical Observatory (NAO), Rozhen. A photometric campaign was launched during the winter 2007-2008 for the newly detected δ Scuti *and* peculiar binary star **HD 68725** (also in collab. with amateur astronomers) as a complement to the recent radial velocities.
- Due to bad weather, the ELODIE data already collected for the Ap star **HD 98088** could not be used to detect rapid LPVs in the chemically peculiar (CP) component, whereas LPVs were possibly found in the chemically *normal* star. We re-observed the binary with the spectrograph SOPHIE of the Observatoire de Haute-Provence (France). Thanks to the higher efficiency, a high-cadence and high-resolution time series of spectra with a good signal-to-noise ratio was obtained. The spectra show

relatively large line residuals for the CP component at some phases. We will apply for additional observations in order to carry out an in-depth study of this magnetic A-type binary.

- The primary component of **CT Her** is a δ Scuti pulsator with a period of about ~28 min and a full amplitude of at most 0.03 mag. High-precision light curves of this oscillating eclipsing binary were collected in the framework of a long multi-site campaign (2004-2007) set up with the purpose to study pulsation in a short-period binary which is undergoing mass transfer. Using approximate photometric and absolute elements to describe the system, we performed a modelling of the V- and B-light curves using the Wilson-Devinney method. After subtraction of an improved semi-detached binary model, the residual data revealed five significant pulsation frequencies all located in the range 45-53 c/d with semi-amplitudes of 1-4 mmag **[20, 37, 38].** We wrote two applications to acquire inexistent radial velocity data in order to obtain a consistent and accurate determination of the absolute parameters of this very interesting Algol-type binary and a few objects of the same class. Two other oscillating eclipsing systems and one potential candidate were also studied **[10,39]**.
- **BL Cam** is an extreme metal-deficient high-amplitude pulsator of **type SX Phe**, a class of pulsators related to the type δ Scuti. An extensive study based on 283 hr of CCD photometric observations obtained during a multi-site campaign carried out in 2005-2006 was performed. The frequency analysis revealed a very rich and dense pulsational content consisting of 25 significant peaks, 22 of which correspond to independent modes. This represents the most complex spectrum ever detected in this class of pulsators **[9].**
- We finalized the detailed abundance analysis for the slow rotators within a sample of 37 southern (candidate) **γ Dors** for which CORALIE spectra were obtained from 1998 to 2003 (La Silla, Chile). We find that the abundance pattern of these γ Dors is not distinct from the constant A- and F-type stars that were also analysed **[17]**.

B.1.3. Progress and results

B.1.3.1. Main-sequence O-B stars (SPB = slowly pulsating B star; β Cep = β Cephei star)

- **β Cru** is a bright southern β Cep. It is a spectroscopic binary with an orbital period of about 5 years. We applied for guaranteed time with AMBER to enable an accurare mass determination by combining the spectroscopic and visual orbit based on these optical interferometric observations (six hours allocated) **[26,27**
- We continued to search for **magnetic fields** in SPBs and β Ceps. We now have at least one magnetic field measurement for all the confirmed southern SPBs. We determined the stellar parameters based on the available Geneva data of all the 46 stars that have been observed. An extensive literature search was performed for the 16 objects for which a magnetic field has been detected at 3σ-level **[16, 18]**. We will continue to apply for additional observations. **θ Car** is a peculiar B0.2V star with enhanced nitrogen and carbon deficiency. It is known as a binary system, but it is not clear yet whether the chemical anomalies can be explained by mass transfer between the components. Using 69 CORALIE spectra, we studied the orbital motion, which lead to a slightly eccentric obit of about 2.2 days. However, it does not seem to be possible to combine all published radial velocity variations in a single orbit. In the magnetic field measurements, we found evidence for variations with a period of about 8 minutes **[19]**. Additional spectra are being collected in Argentina to resolve the orbit-problem.
- We continued with the **mode identification** for 6 SPBs which are multiperiodic in spectroscopy. The results of the Fourier Parameter Fit method were summarized. For each star, the 5 best moment solutions that are compatible with the results of the photometric identification were determined and the corresponding line profile variations were calculated. **HD 21071** is a multiperiodic SPB for which both Geneva and Strömgren photometry is available. Combining both types of data revealed up to 8 frequencies. From a comparison between the observed frequencies and the theoretical eigenfrequen-

cies, a model was found that fits all the observed values including a rotationally split *l*=1 mode. A new spectroscopic multi-site campaign will be needed to confirm this result **[24]**. **V2104 Cyg** is a new Be star. For this late B-type star, 3 independent SPB-like frequencies with amplitudes below 0.01 mag were detected. Due to the fast rotation, it was impossible to draw any conclusion on the degree *l* of the modes **[12]**.

- Rotating hot stars still pose many asteroseismic key questions such as the **influence of rotation** on mode selection, mixing of elements, and stellar evolution. We therefore organized a spectroscopic multi-site campaign for the bright β Cep star **ε Cen** resulting in 17 nights with HERCULES (Mount-John, New Zealand), 7 nights with GIRAFFE (Sutherland, South-Africa), and 14 nights with CORALIE (La Silla, Chile) in 2008 **[25]**.

B.1.3.2. Rotation and pulsation in main-sequence gravity mode pulsators

- A successful asteroseismic study requires a sufficient number of identified pulsation modes per star. This stage has not yet been reached for **SPBs** and **γ Dors** because the observed g-modes are generally not fully characterized. The current spectroscopic methods of mode identification have not yet been verified as usable for the growing number of g-modes observed. A new project (Action-1) was defined with the aims (1) to examine and improve these procedures, specifically with regard to g-mode pulsators, and (2) to investigate whether there is any correlation between the amplitude and/or type of the excited modes and the projected rotational velocity of the pulsating star **[22]**.
- The possibility of using AMBER for optical interferometric observations of **γ Dor and SPBs** in multiple systems to enable an accurare mass determination by combining the spectroscopic and visual orbit was explored in detail. An extensive literature search for the currently known (candidate) γ Dor and SPBs in such systems however showed that the possible targets are too faint in the K-band to ensure a good feasibility.
- We applied for telescope time in La Palma and France to obtain high-quality, high-resolution spectra for a sample of (candidate) γ Dors and SPBs in order (1) to determine their *v*sin*i*, (2) to classify their variability, and (3) to derive their chemical composition. All these proposals were just below the cut-off line. However, spectra are being taken with HERCULES (Mount-John, New Zealand), and occasionally with FIES at the Nordic Optical Telescope (La Palma, Spain). We started the organization of spectroscopic multi-site campaigns for northern and southern γ Dors and SPBs and submitted 5 proposals for telescope time in Chile **[23]**, China **[24]**, and South-Africa (23 nights in total allocated). Additional runs in 2008 will also be scheduled with HERCULES (Mount-John, New Zealand).

B.1.4. Perspective for next years

We will carry out a detailed chemical abundance analysis for all the A-F type stars of our sample. To achieve this goal, an automated procedure based on the simultaneous application of a simplex minimization procedure and the code SYNSPEC (Hubeny 1987) will be developed. Finally, we intend to study the interactions between the different observed phenomena in the full sample.

With respect to the oEA stars, the next step will consist in incorporating the light curves acquired in 2007 with the aim to improve the determination of the detected pulsation frequencies of CT Her. Since the binary parameters are currently not uniquely determined, we will collect more data to complement the primary minima as well as radial velocities.

The multi-site campaigns of the g-mode pulsators of type γ Dors and SPBs will be pursued and their long-term analysis, mode identification and interpretation will be continued.

We will apply for new high-cadence observations of the magnetic binary HD 98088, with the aim to detect the rapid (P~5-20 min) LPVs which are predicted by the theory of rapidly oscillating Ap stars.

B.1.5. Personnel

Scientific staff: P. De Cat, Y. Frémat, S. Hekker, P. Lampens, J. Cuypers

B.1.6. Partnerships

List of international partners without grant

- M. Cunha, Centro de Astrofisica da Universidade do Porto, Portugal
- Z. Kraicheva, D. Dimitrov, Institute of Astronomy, Bulgarian Academy of Sciences, Sofia, Bulgaria
- S. Kleidis, Zagori Observatory, Athens, Greece
- D. Kurtz, University of Central Lancashire, Preston, UK
- D. E. Mkrtichian, Sejong University, Seoul, Korea
- C. Neiner, Observatoire de Meudon, France
- P. G. Niarchos, K. Gazeas, University of Athens, Greece
- C. W. Robertson, SETEC Observatory, USA
- E. Rodríguez, M.J. López-González, Instituto de Astrofísica de Andalucía, Granada, Spain
- J. Vidal-Saínz, J.M. Gómez-Forellad, Grup d'Estudis Astronomics (GEA), Barcelona, Spain
- J. Zorec, Institut d'Astrophysique, France
- H. Bruntt, University of Sydney, Australia
- J.N. Fu, Beijing Normal University, China
- S. Hubrig et al., European Southern Observatory, Chile
- P. Mathias, S. Jankov, Observatoire de Côte d'Azur, Nice, France
- J. Telting, Nordic Optical Telescope, La Palma, Spain
- K. Uytterhoeven, INAF-Osservatorio Astronomico di Brera, Merate, Italy
- K. Pollard et al.,University of Canterbury, Christchurch, New Zealand
- K. Yakut, University of Ege, Turkey

List of national partners without grant

- C. Aerts et al., Katholieke Universiteit Leuven & BAG, Belgium
- A. Noels et al., Université de Liège & BAG, Belgium
- P. Van Cauteren, Beersel Hills Observatory, Belgium

Grants used for this research

- Belgo-Bulgarian bilateral project "Photometric and Spectroscopic Follow-up Studies of Binary Systems of Special Interest"(BL/33/011-ext)
- Action-1 "Pulsation, chemical composition and multiplicity in main-sequence A- and F-type stars" of the Federal Science Policy (MO/33/018)
- "Modern Aspects of Theoretical and Observational Astrophysics", Federal Science Policy(IAP P5/36)
- Project G.0178.02 of the Fund for Scientific Research (FWO) - Flanders (Belgium)

Visitors:

- S. Hekker, Leiden university: Sep-Nov (2 days)

B.1.7. Publications

B.1.7.1. Publications with peer review

[1] Briquet M., Hubrig S., **De Cat P.**, Aerts C., North P., Schöller M.
On the co-existence of chemically peculiar Bp stars, slowly pulsating B stars and constant B stars in the same part of the H-R diagram
Astronomy & Astrophysics 466 (2007), 269-276

[2] Briquet M., Hubrig S., **De Cat P.**, Aerts C., North P., Schöller M.
A comparative study of B-type pulsators and non-pulsating chemically peculiar Bp stars

Communications in Asteroseismology 150 (2007), 187-188

[3] Briquet M., Hubrig S., Schöller M., **De Cat P.**
Discovery of magnetic fields in three He variable Bp stars with He and Si spots
Astronomische Nachrichten 328 (2007), 41-45

[4] **De Cat P.**, Briquet M., Aerts C., Goossens K., Saesen S., **Cuypers J.**, Yakut K., Scuflaire S., Dupret M.-A., Uytterhoeven K., Van Winckel H., Raskin G., Davignon G., Le Guillou L., Van Malderen R., Reyniers M., Acke B., De Meester W., Vanautgaerden J., Vandenbussche B., Verhoelst T., Waelkens C., Deroo P., Reyniers K., Ausseloos M., Broeders E., Daszyńska-Daskiewicz J., Debosscher J., De Ruyter S., Lefever K., Decin G., Kolenberg K., Mazumdar A., Van Kerckhoven C., De Ridder J., Drummond R., Barban C., Vanhollebeke E., Maas T., Decin L.
Long term photometric monitoring with the Mercator telescope: Frequencies and mode identification of variable O-B stars
Astronomy & Astrophysics 463 (2007), 243-249

[5] **De Cat P.**
Observational asteroseismology of SPB stars
Communications in Asteroseismology 150 (2007), 167-174

[6] Desmet M., Briquet M., **De Cat P.**, Aerts C., Handler G., Krzesinski J., Lehmann H., Masuda S., Mathias P., Mkrtichian D.E., Telting J., Uytterhoeven K., Yang S.L.S.
A spectroscopic study of the β Cephei star 12 (DD) Lacertae
Communications in Asteroseismology 150 (2007), 195-196

[7] **Frémat, Y., Lampens, P.,** Van Cauteren, P., Kleidis, S., Gazeas, K., Niarchos, P.G., Neiner, C., Dimitrov, D., **Cuypers, J.,** Montalbán, J., **De Cat, P.,** Robertson, C.W.
Search for pulsation among suspected A-type binaries and the new multiperiodic δ Scuti star HD 217860
A&A 471, 675 (2007)

[8] Groenewegen M.A.T., Decin L., Salaris M., **De Cat P.**
The Pleiades eclipsing binary HD 23642 revisited
Astronomy & Astrophysics 463 (2007), 579-588

[9] Rodríguez, E., Fauvaud, S., Farrell, J.A., Zhou, A.-Y., Sareyan, J.-P., López-González, M.J., Dupret, M.-A., Grigahcène, A., De Ridder, J., Klingenberg, G., Wolf, M., Van Cauteren, P., **Lampens, P.**, Martínez, D. & 36 co-authors
The field high-amplitude SX Phoenicis variable BL Camelopardalis: results from a multisite photometric campaign. I. Pulsation
A&A 471, 255 (2007)

[10] Rodríguez, E., García, J. M., Costa, V., Van Cauteren, P., **Lampens, P.,** Olson, E. C., Amado, P. J., López-González, M. J., Rolland, A., López de Coca, P., Turcu, V., Kim, S.-L., Zhou, A.-Y., Wood, M. A.,Hintz, E., Pop, A., Moldovan, D., Etzel, P. B., Lee, D.-J., Handler, G., Mkrtichian, D. E.
δ Sct stars in eclipsing binaries: the case of Y Cam
Communications in Astroseismology 150, 63 (2007)

[11] Saesen S., Briquet M., **Cuypers J.**, **De Cat P.**, Goossens K.
Asteroseismology of the β Cephei star KP Per
Communications in Asteroseismology 150 (2007), 197-198

[12] Uytterhoeven K., Poretti E., Rodríguez E., **De Cat P.**, Mathias P., Telting J.H., Costa V., Miglio A.

Multiperiodicity in the newly discovered mid-late Be star V2104 Cygni
Astronomy and Astrophysics 470 (2007), 1051-1057

[13] Zima W., **De Cat P.**, Aerts C.
Mode identification of multi-periodic Slowly Pulsating B-stars: results and problems
Communications in Asteroseismology 150 (2007), 189-190

B.1.7.2. Publications without peer review

[14] Bedding T.R., Brun A.S., Christensen-Dalsgaard J., et al. (including **De Cat P.**)
Joint Discussion 17 "Highlights of recent progress in the seismology of the Sun and Sun-like stars"
Highlights of Astronomy 14 (2007), 491

[15] Hubrig S., Briquet M., Schöller M., **De Cat P.**, Mathys G., Neiner C.
Discovery of Magnetic Fields in Slowly Pulsating B Stars
ASP Conference Series 361 (2007), 434

[16] Hubrig S., Schöller M., Briquet M., Pogodin M.A., Yudin R.V., Gonzalez J.F., Morel T., **De Cat P.**, Ignace R., North P., Mathys G., Peters G.J.
Magnetic fields in massive stars
Contrib. Astron. Obs. Skalnaté Pleso 35 (2007), 1

B.1.7.3. Publications in press, submitted

[17] Bruntt H., **De Cat P.,** Aerts C.
A spectroscopic study of southern (candidate) γ Doradus stars. II. Detailed abundance analysis and fundamental parameters
Astronomy & Astrophysics, in press

[18] Hubrig S., Briquet M., Schöller M., **De Cat P.**
New measurements of magnetic fields in SPB and β Cephei stars
Proceedings of the IAU Symposium 250, in press

[19] Hubrig S., Briquet M., Morel T., **De Cat P.**, Schöller M.
A study of the peculiar B0 star θ Carinae
Proceedings of the IAU Symposium 250, in press

[20] **Lampens, P.**, A. Strigachev, S.-L. Kim, E. Rodríguez, M.J. López-González, J. Vidal-Saínz, D. Mkrtichian, D. Litvinenko, P. Van Cauteren, P. Wils, J.M. Gómez-Forellad
Study of the oscillating Algol-type binary CT Her
Communications in Asteroseismology (submitted)

B.1.7.4. Reports, thesis, proposals.

[21] Carrier F., **De Cat P.**, Miglio A., Montalbán J.
Search for solar-like oscillations in the γ Doradus star HD167858
ESO telescope time application for HARPS observations in period 81 (9 nights allocated)

[22] De Cat P., Lampens P., Cuypers J., Hensberge H., Frémat Y.
Rotation and pulsation in main-sequence gravity mode pulsators
Action-1 proposal for 2008-2009 (granted)

[23] **De Cat P.**, Wright D.J., Pollard K.R., Cottrell P.L., Zima W., **Frémat Y.**, **Lampens P.**
Towards asteroseismology of main-sequence g-mode pulsators: a spectroscopic multi-site campaign for the γ Doradus stars HD 147787 and HD 189631
ESO telescope time application for HARPS observations in period 81 (7 nights allocated)

[24] **De Cat P.**, Briquet M., Frémat Y., Fu J.N., Mathias P., Wright D.J., Zima W.
Towards asteroseismology of main-sequence g-mode pulsators : a spectroscopic multi-site campaign for the slowly pulsating B stars HD 21071 and HD 25558, and the γ Doradus star HD 218396
Xinglong telescope time application for observations with the 2.16-m telescope (7 nights allocated)

[25] **De Cat P.**, Telting J., Zima W., Briquet M., Pollard K.
Pulsational characterization of the rotating β Cephei star ε Centauri
South-African Astronomical Observatory telescope time application for GIRAFFE observations in quarter 2 of 2008 (7 nights allocated)

[26] Desmet M., Aerts C., Acke B., **De Cat P.**, **Cuypers J.**, Briquet M., Mathias P., Bonneau D.
High-precision mass determination of the components of the binary star β Crucis
ESO telescope time application for guaranteed time with AMBER in period 80 (3h allocated)

[27] Desmet M., Aerts C., Acke B., **De Cat P.**, **Cuypers J.**, Briquet M., Mathias P., Bonneau D.
High-precision mass determination of the components of the binary star β Crucis
ESO telescope time application for guaranteed time with AMBER in period 81 (3h allocated)

[28] **Lampens P., Frémat Y., Hekker S., De Cat P.**
Search for pulsation and chemical peculiarity among suspected A- and F-type binaries
Observatoire de Haute Provence time application for SOPHIE observations in the first semester of 2008 (3 nights allocated)

[29] **Lampens, P.,** Kraicheva, Z.,
First report of the project "Photometric and Spectroscopic Follow-up Studies of Binaries of Special Interest"
Document for the Federal Science Policy, May 2007

[30] **Lampens, P.**
First report of the project "Pulsation, chemical composition and multiplicity in main-sequence A- and F-type stars" (Ref. MO/33/018)
Document for the Federal Science Policy, Jan 2007

[31] **Lampens, P.**
Report on "The Launch Event for 7th European Framework Programme", Jan 30
Document for the Director, Jan 2007

[32] **Lampens, P.**
Minutes of the meeting of the BNEC Working Group on Instrumentation, July 9
Document for the President, Jul 2007

B.1.8. Scientific outreach

Meeting presentations

[1] **De Cat P.**
Photometric monitoring with Mercator (P7): application to variable O-B stars
Talk presented during the Mercator day (Leuven, Belgium), November 8, 2007

[2] Desmet M., Briquet M., **De Cat P.**, Zima W., Handler G., Krzeninski J., Lehmann H., Masuda S., Mathias P., Mkrtichian D.E., Telting J., Uytterhoever K., Yang S.L.S., Aerts C.
Spectroscopic mode identification for the β Cephei star 12 Lacertae

Contributed talk presented during the 2nd HELAS International Conference on “Helioseismology, asteroseismology and MHD connections” (Göttingen, Germany, August 20-24, 2007), August 20, 2007

[3] Hubrig S., Briquet M., Schöller M., **De Cat P.**
New measurements of magnetic fields in SPB and β Cephei stars
Poster presented during the IAU Symposium 250 on “Massive Stars as Cosmic Engines” (Grand Hyatt, Hawaii, December 10-14, 2007)

[4] Hubrig S., Briquet M., Morel T., **De Cat P.**, Schöller M.
A study of the peculiar B0 star θ Carinae
Poster presented during the IAU Symposium 250 on “Massive Stars as Cosmic Engines” (Grand Hyatt, Hawaii, December 10-14, 2007)

[5] **P. Lampens**, A. Strigachev, S.-L. Kim, E. Rodríguez, M.J. López-González, J. Vidal-Saínz, D. Mkrtichian, D. Litvinenko, P. Van Cauteren, P. Wils, J.M. Gómez-Forellad
Study of the oscillating Algol-type binary CT Her
BAG Meeting “Celebration of COROT”, 13 Jun 2007, Liège, Belgium

[6] **Lampens, P.**, A. Strigachev, S.-L. Kim, E. Rodríguez, M.J. López-González, J. Vidal-Saínz, D. Mkrtichian, D. Litvinenko, P. Van Cauteren, P. Wils, J.M. Gómez-Forellad
Study of the oscillating Algol-type binary CT Her
Joint European and National Astronomy Meeting 2007, EAS S2 “Stellar Evolution and Asteroseismology”, 20-25 Aug 2007, Yerevan, Armenia

[7] B. Ulaş, P. Niarchos, **P. Lampens,** V. Manimanis, P. Van Cauteren
The Algol-type binary VV UMa: New VRI photometry and search for pulsation
Joint European and National Astronomy Meeting 2007, EAS S2 “Stellar Evolution and Asteroseismology”, 20-25 Aug 2007, Yerevan, Armenia

Educational responsibilities:

- P. De Cat: member of the scientific committee for the PhD guidance of M. Desmet (K.U.Leuven)

B.1.9. Missions

Assemblies, symposia (number):	P. De Cat (1), P. Lampens (1)
Commissions, working groups (days):	P. De Cat (4), P. Lampens (2)
Research visits (days):	P. De Cat (22), P. Lampens (1)
Field missions (days):	Lampens (64)

B.2. Stellar Characterization

B.2.1. Objectives

Be stars define a class of very intriguing main-sequence massive stars that show emission in their spectra. They are surrounded by an equatorial disk or flattened envelope and are generally considered to be fast rotators. The true origin of the Be phenomenon in intermediate mass stars is still a matter of debate. There are currently two main scenarii. In the first one, Be stars are the components of non-resolved binaries, in the second one, rapid though non-critical rotation combines its effects with one or more other physical processes to provoke matter ejection and, consequently, the formation of a circumstellar equatorial disk.

Since, Be stars occupy the same hydrodynamically instable region in the H-R diagram as the pulsating β Cep and SPB stars, one of these additional phenomena is presently suspected to be related to the beating of different pulsation modes. This is, however, only confirmed for μ Cen.

The behaviour of **B-type stars** is dependent of the metallicity in the environment: B-type stars have less-efficient stellar winds at low metallicity (typically in the Large and the Small Magellanic Clouds) than at high metallicity. Thus, B-type stars rotate faster at low than at high metallicity. It is therefore expected that more Be stars would be detected at low-metallicity regimes.

B.2.2. Progress and results

B.2.2.1. He strong stars

The **He strong stars** are fast rotating B-type magnetic stars that show line emission which have a lot in common with the Be stars. In order to study their properties and the effects of He overabundance on the determination of stellar parameters, we modelled their spectra in the vicinity of the Balmer discontinuity assuming NLTE. We showed that the spectrophotometric method of Barbier-Chalonge-Divan that is often applied to derive the effective temperature and the surface gravity in Be and *normal* B-type stars can be adapted to study stars that show He abundance peculiarities Error! Reference source not found.. We further studied the impact of a low metallicity regime on the evolution of the internal angular momentum and the stellar evolution of B(e)-type stars of the Small Magellanic Cloud (SMC) Error! Reference source not found..

B.2.2.2. Metallicity and pulsations

Theory did not foresee pulsations in B-type stars at low metallicity due to the lack of metallic elements. Using the sample of **B(e) stars** observed in the SMC with the VLT-GIRAFFE, we cross-matched the stellar positions with the light curves of the MACHO data base **[8]** to verify this observationally. The first short-term multiperiodic Be stars were found **[10].** The study was next refined and another ~30 Be stars with 2, 3 or 4 short-term periods as well as 9 B-type stars with 1 or 2 short-term periods were discovered Error! Reference source not found.. We also found that the instability domain is shifted towards higher temperatures in the SMC than in the Milky Way, implying that fast rotation favours the pulsations. This first outcome was recently confirmed by a new theoretical study. The results further imply the need for new opacities Error! Reference source not found..

B.2.2.3. Nature of emission line stars

Young open clusters which contain emission line stars (ELS) are ideal test cases for understanding the occurrence and evolution of **Be stars** as a function of the mass, metallicity, and rotational velocity. The goal is to determine the nature of the ELS: are they classical Be stars or pre-main sequence stars (PMS)? We explored NGC 6611 and M16 (the Eagle nebula) using our observations made with the VLT-GIRAFFE and the Wide Field Imager in slitless spectroscopic mode (WFI). NGC 6611 was previously known to host a lot of Be stars. However, we showed that only a small fraction are true ELS whereas the other candidates are B-type stars with nebular emission lines. We also claim that the majority of the ELS are in the pre-main-sequence phase. The classical Be stars found confirm the evolutionary status scenario in the Milky Way Error! Reference source not found..

B.2.2.4. WFI-Hα survey

Using the WFI, we collected 8 million spectra in open clusters and fields of the LMC & SMC in order to detect ELS in Hα. By cross-correlating with photometric catalogues, we were able to classify the stars. Preliminary results as well as the codes developed for analysing the spectra were presented at the ESO colloquium about instrumentation (2007).

B.2.3. Perspective for next years

The study of B(e) stars at different metallicity regimes will be pursued in an effort to improve the current understanding of the Be phenomenon. A first article about the frequency of Be stars in the SMC is in preparation. We will extend our study of B(e) stars to the intermediate-metallicity regime of the LMC. The comparison between observations and existing models for pulsating stars at the metallicity of the LMC will be most interesting. The study of the nature of emission line stars will be extended to other open clusters in the Milky Way as well, and a proposal for observing ELS in young open clusters in the SMC with VLT-FLAMES will be submitted for testing the scenarii of evolution and occurrence of Be stars. A study of the effects of rotation on the chemical composition of fast rotating main-sequence B-type stars is also foreseen.

B.2.4. Personnel

Scientific staff: Y. Frémat, C. Martayan

B.2.5. Partnerships

List of international partners without grant

- D. Baade, ESO Garching, GERMANY
- P. Diago, Observatori Astronomic, Universidad de Valencia, SPAIN
- M. Floquet, A.-H. Hubert, C. Martayan, M. Mekkas, C.Neiner, GEPI-Observatoire de Paris-Meudon (France)
- J. Fabregat, J. Gutiérrez-Soto, Observatori Astronomic, Universidad de Valencia (Spain)
- J. Zorec, Institut d'Astrophysique de Paris (France)

Grants/Projects used for this research/service

- EARA grant obtained for a research mission at the Institut d'Astrophysique de Paris

Visitors:

- J. Zorec, Institut d'Astrophysique de Paris, 5 days

B.2.6. Publications

B.2.6.1. Publications with peer review

[1] Cidale, L. S.; Arias, M. L.; Torres, A. F.; Zorec, J**.; Frémat, Y**.; Cruzado, A.
Fundamental parameters of He-weak and He-strong stars
2007, A&A, 468, 263

[2] Gutiérrez-Soto, J.; Fabregat, J.; Suso, J.; Suárez, J. C.; Moya, A.; Garrido, R.; Hubert, A.-M.; Floquet, M.; Neiner, C.; **Frémat, Y**.
Multiperiodic pulsations in the Be stars NW Serpentis and V1446 Aquilae
2007, A&A, 472, 565

[3] **Martayan, C.; Frémat, Y.;** Hubert, A.-M.; Floquet, M.; Zorec, J.; Neiner, C.
Effects of metallicity, star-formation conditions, and evolution in B and Be stars. II. Small Magellanic Cloud, field of NGC330
2007, A&A, 462, 683

B.2.6.2. Publications without peer review

[4] Arias, M. L.; Zorec, J.; **Frémat, Y.**
Circumstellar Rings, Flat and Flaring Disks
2007, ASPC, 361, 419

[5] Gutiérrez-Soto, J.; Fabregat, J.; Suso, J.; Suárez, J. C.; Moya, A.; Garrido, R.; Hubert, A.; Floquet, M.; Neiner, C.; **Frémat, Y.**
Multiperiodic Pulsations in the Be Stars NWSer and V1446Aql
2007, ASPC, 361, 84

[6] Levenhagen, R. S.; Leister, N. V.; Zorec, J.; **Frémat, Y**.
Metallicity vs. Be Phenomenon Relation in the Solar Neighborhood
2007, ASPC, 361, 457

[7] **Martayan C.**, Floquet M., Hubert .A-M., Neiner C., **Frémat Y.**, Baade D., Fabregat J.
On the nature of early-type emission line objects in NGC 6611
SF2A2007, astroph 0709.2823

[8] **Martayan, C., Frémat Y.,** Hubert A.-M., Floquet M., Neiner C., Zorec J., Baade D., Guttiérez-Soto J., Fabregat J., Mekkas M.
On the behaviour of B and Be stars at low metallicity
SF2A2007, astroph 0709.2820

[9] **Martayan C., Frémat Y.**, Hubert A.-M., Floquet M., Neiner C., Zorec J.
Be stars and stellar evolution
IAUS250, Hawaii USA, 9-14/12/2007, proceedings F. Bresolin, Crowther P. A. & Puls J. Eds.

[10] **Martayan, C**.; Hubert, A.-M.; Floquet, M.; Neiner, C.; **Frémat, Y**.; Zorec, J.
Effects of Metallicity, Star Formation Conditions and Evolution of B & Be stars
2007, ASPC, 361, 356

[11] Meynet G., Walborn N., Hunter I, **Martayan C.**, Van Marle A. J., Marchenko S. V., Vink J. S., Limongi M., Levesque E. M., Modjaz M.
Evolution of massive stars at low metallicity
IAUS250, Hawaii USA, 9-14/12/2007, proceedings F. Bresolin, Crowther P. A. & Puls J. Eds.

[12] Zorec, J.; **Frémat, Y**.; **Martayan, C.;** Cidale, L. S.; Torres, A. F.
Rotation in the ZAMS: Be and Bn stars
2007, ASPC, 361, 539

[13] Zorec, J.; **Frémat, Y**.; Domiciano de Souza, A.
Differential Rotation in Early-Type Stars
2007, ASPC, 361, 542

B.2.6.3. Publications in press, submitted

[14] Diago P. D., Gutiérrez-Soto J., Fabregat J., **Martayan C.**
Pulsating B and Be stars in the Small Magellanic Cloud
2008, A&A, in press, astroph 0709.4573

[15] **Martayan C.**, Floquet M., Hubert .A-M., Neiner C., **Frémat Y.**, Baade D., Fabregat J.
On the nature of early-type stars in NGC 6611 and M16
2008, A&A, submitted

B.2.7. Scientific outreach

Meeting presentations

[1] **Martayan C.**, Floquet M., Hubert .A-M., Neiner C., **Frémat Y.**, Baade D., Fabregat J.
On the nature of early-type emission line objects in NGC 6611
SF2A conference, Grenoble, France, poster

[2] **Martayan C.**

On the behaviour of B and Be stars at low metallicity
SF2A conference, Grenoble, France, talk

[3] **Martayan C.**
The low metallicity effects on B and Be stars
IAUS250, Hawaii USA, 9-14/12/2007, talk (special session about the evolution of massive stars)

[4] **Martayan C., Frémat Y.**, Hubert A.-M., Floquet M., Neiner C., Zorec J.
Be stars and stellar evolution
IAUS250, Hawaii USA, 9-14/12/2007, poster

B.2.8. Missions

Assemblies, symposia (number):	C. Martayan (1), Y. Frémat (1)
Research visits (days):	Y. Frémat (9)
Field missions (days):	Y. Frémat (14)

B.3. Asteroseismology from space missions: CoRoT, Kepler

We are involved in the asteroseismic space missions **CoRoT** (CNES-CNRS-ESA-Brazil) and **KEPLER** (NASA). CoRoT (successfully launched in December 2006) will probe the inner structure of the stars, as well as detect many extrasolar planets, by observing the periodic micro-eclipses occurring when these bodies transit in front of their parent star. Due to the high photometric performances and the long observing runs covering five months without interruption, the experiment will be a pioneer mission in both domains. KEPLER (launch foreseen in 2009) will observe fixed fields and continuously monitor over 100.000 stars for at least 4 years, with a slow cadence, and additionally 512 stars with a rapid cadence. The mission is designed to search for extra-solar planetary systems using the transit technique, particularly Earth-like planets in the habital zone. Both missions will provide a huge amount of extremely high-quality data useful for refined asteroseismic studies. It is thus also relevant to invest time in some of the preparatory aspects of these missions.

B.3.1. Objectives

The very first and preliminary **CoRoT** light curves have just been distributed (end of 2007). More and improved light curves from the exoplanetary and asteroseismic CoRoT fields will be made available during 2008. Concerning **KEPLER**, we plan to contribute to the gathering of complementary ground-based observations needed to select the most interesting asteroseismic targets from the KEPLER Input Catalogue (KIC).

B.3.2. Progress and results

- We have started to analyse the light curve of a Be star observed by CoRoT using the technique of Fourier analysis. This first analysis provided more than 30 frequencies, several of which are harmonic and combination frequencies. This result may prove interesting in the context of the search of an additional phenomenon combined to the fast rotation to understand the mechanism of mass ejection in Be stars. With the new observations, we hope to identify new cases related to the beating of different pulsation modes.
- We collaborate with the CoRoT Binary Thematic Team with the aim to exploit the CoRoT data concerning pulsating components of newly identified eclipsing binary systems. The experience with the study of the oEA star CT Her will be most useful in this respect. At this stage it is however not yet clear which data will be available.

- Various team members are part of the Kepler Asteroseismic Science Consortium (KASC). The Consortium will prepare the asteroseismic programme and will contribute to the analysis of the huge data sets. Two proposals for Work Packages were submitted. In one, we proposed to provide complemanetary ground-based information for a limited number of potential asteroseismic targets of spectral type B(e), A or F in the Kepler field-of-view which are on/near the main-sequence evolutionary phase [1]. A list with the coordinates and the spectroscopic parameters of newly identified (main-sequence) variable stars of type B(e)AF in the Kepler field-of-view based on data from the KIC was requested. We would need such information to write meaningful applications in order to obtain high signal-to-noise spectra of the potential targets with a (large) telescope. A list of already identified variable stars of different classes located in the Kepler field-of-view was produced [2].

B.3.3. Perspective for next years

B.3.3.1. CoRot

Data on various kinds of variable stars observed by CoRoT will soon be analysed. This will concern B-type and Be stars, A- and F-type stars as well as pulsating components of newly detected eclipsing binary systems. The CoRoT data on Be stars will be studied in collaboration with the CoRoT Be team in order to obtain an improved understanding of the origin of Be stars.

B.3.3.2. Kepler

Assuming that telescope time is granted, we will perform the complementary observations with the goal to provide an atmospheric characterization for a limited number of asteroseismic targets from ground-based spectroscopy based on a semi-automatic parameter determination from spectra fitting and synthesis.

B.3.4. Personnel

Scientific staff: P. De Cat, Y. Frémat, S. Hekker, P. Lampens, C. Martayan

B.3.5. Partnerships

- A.-M. Hubert, M. Floquet, C. Neiner, J. Guttiérez-Soto, GEPI-Observatoire de Paris, FRANCE
- B. Leroy, LESIA-Observatoire de Paris, FRANCE

B.3.6. Publications

B.3.6.1. Reports, thesis, etc

[1] **Lampens P., De Cat P., Frémat Y., Hekker S., Martayan C.**
WP TASK1-ROB

[2] **Lampens, P.**
1 report for KASC Working Group on A-F type stars in the Kepler field,
1 report for KASC Working Group on Open Clusters in the Kepler field, WP TASK2-ROB
Documents for the Kepler Asteroseismology Science Consortium, Dec 2007

B.3.7. Missions

Assemblies, symposia (number): P. Lampens (1), S. Hekker (1), C. Martayan (1)

Research visits (days): C. Martayan (1)

C. Instrumentation

The design and development of (new) instrumentation is the mandatory path to better understand the universe and the stars. By participating to this task, we contribute to a service for the scientific community while ensuring ourselves at the same time a deep knowledge of the instrument and of its possibilities.

C.1. The HERMES echelle spectrograph

HERMES is the acronym for High Efficiency and Resolution Mercator Echelle Spectrograph, an echelle spectrograph built for the Mercator telescope of the Instituut voor Sterrenkunde at the Roque de los Muchachos Observatory (La Palma). The instrument is expected to be operational in 2008. The Royal Observatory of Belgium carries the responsibility to provide the data reduction and instrument control software in order to provide a differential reduction procedure in contrast to the existing pipelines. The respective contributions are described in the **interdepartemental report**.

C.2. Project "Humain Observatory for Astrophysics of Coeval Stars"

C.2.1. Objectives

The radio-astronomical station of Humain which is a part of the Royal Observatory of Belgium, is still a privileged site in Belgium with respect to location and environmental light pollution. It is is therefore a suitable site for the construction of a small optical observatory. The aim is to operate a small but well-equipped optical observatory which will be dedicated to a few very specific observational programmes. The project "HOACS" was launched with the goal to perform CCD photometric observations of (intrinsic as well as extrinsic) variable stars under sky conditions which are better than those in the region of Brussels, in support of the ongoing astronomical research projects of the Observatory.

C.2.2. Progress and results

Progress has been extremely slow. The construction of the building which should protect the telescopes and the instruments is not finished yet, although a completely new roof was put in place after the first one failed to give satisfaction. The illustrations below show the status of the works during the two major visits with the concerned parties, respectively in February (Figure 44) and in November 2007 (Figure 45). A justicial procedure is ongoing which currently blocks the finalisation of the building and its exploitation.

Figure 44. Status Humain optical observatory on 26/02/2007

Figure 45. Status Humain optical observatory on 28/11/2007

C.2.3. Perspective for next years

Hopefully, we will be able to set up the telescopes with their instruments (called HULC1 and HULC2) in 2008 and the first nightly observations at the Humain observatory will be performed during the spring season.

C.2.4. Personnel involved

Scientific staff: P. Lampens (project coordinator)

Technical staff: Ir. V. Rogge (Technical supervision)
Dhr. Janssens

C.2.5. Missions

- Visits to the radio-observatory of Humain and discussion with all concerned parties on the construction of a small optical facility at Humain (26/02, 28/11)

DEPARTMENT 3: Astrophysics

SECTIONS 6 & 7: Astrophysics of galactic and extragalactic objects & Physics of stellar atmospheres

Introduction:

Stars evolve, process chemical species into different ones and re-cycle part of the material in the galaxy and a new cycle of star formation. Stellar structure, stellar evolution and galaxy evolution are closely linked. Many physical processes intervene in this cycle. The research in department 3 concerns several, but evidently only a small part, of the building blocks contributing to the general picture and encompass projects giving insight in very different stages of the star's life, from young objects to very evolved ones. We have grouped them in two research themes: stellar winds and circumstellar structures playing their major role in evolved evolutionary phases; binaries and asteroseismology as tools to study fundamental stellar parameters and interior structure; and studies concentrating on cataclysmic stellar events. Many of the projects emphasize participation in observational astronomy and analysis techniques, as expected from the Observatory. The department is now also involved in an operational project that will provide in a few years an echelle spectrograph at the Mercator telescope (La Palma, Spain). Theoretical aspects are more strongly emphasized in C.1 and A.1. Several of the projects rely significantly on external grants and personnel on temporary contracts. There exist strong connections with research projects of department 2, a cooperation that will develop further with the involvement in the aforementioned echelle spectrograph HERMES and the preparations for the GAIA mission.

A. Research Theme "Stellar Winds and Circumstellar Structures"

The theme around stellar winds and circumstellar material splits again in two poles of interest (other themes are discussed further on in the report): the strong radiatively driven winds from the most massive, short-lived stars and the strong winds in late evolutionary stages of intermediate-mass stars that give rise to planetary nebulae. Multi-wavelength studies of the winds of massive stars show that they are structured and contain shocked gas; if this is not taken into account, predicted mass loss rates may be significantly in error and valuable indicators of stellar duplicity may be overlooked. The project A.1 concentrates on the understanding of the hydrodynamics producing the structure by confronting theory and observations.

The mass loss in the final steps of evolution of initial intermediate mass stars is a complex process with repercussions on the internal evolution of the star itself. The complex interplay among various physical processes is not yet understood, but the structure of the circumstellar material must clearly reflect the history of the mass loss events. The project A.2 uses a multitude of observing techniques and a radiative transfer code developed by one of its members to gain insight in the late evolution stages of these stars.

A.1. Hot stars

A.1.1. Objectives

Hot stars have radiatively driven stellar winds. Considerable observational evidence exists that these winds are not smooth, but structured. This project tries to elucidate the nature of this structure, by studying these stars both observationally (at various wavelengths) and theoretically (by constructing models for the hydrodynamics and radiative transfer).

A.1.2. Progress and results

Work continued on the modelling of large-scale structure (so-called Co-rotating Interaction Regions - CIRs) in the winds of massive stars. This was done through the combined use of the Zeus code to calculate the hydrodynamics and the Wind3D code to do the radiative transfer.

A. Lobel developed the Wind3D code that solves the problem of the transport of radiation in three geometric dimensions in the scattering winds of massive stars. The time-independent transfer equation is solved following Adam's numerical scheme. Wind3D is currently implemented as a fully parallelized (exact) accelerated lambda iteration scheme with a two-level atom formulation. It runs on several 64-bit multi-CPU compute servers at the ROB. Wind3D has carefully been load balanced for parallel processing utilizing the OpenMP programming strategy, and shows excellent scaling properties for multi-threading. The code accepts arbitrary 3-D velocity fields (in Cartesian geometry) without assumptions of axial symmetry.

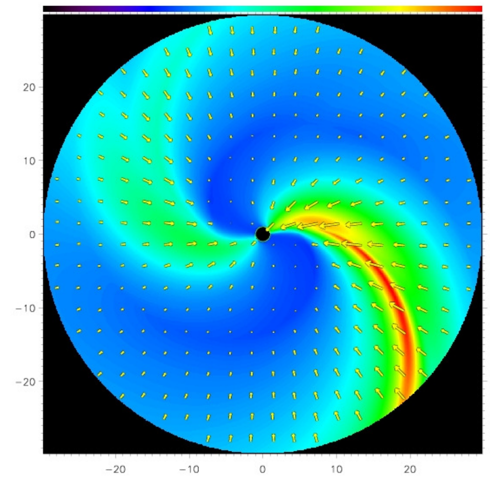

Figure 46: Hydrodynamical simulation of two unequal Co-rotating Interaction Regions in the equatorial plane of a hot-star wind.

Our modelling of the radiatively driven stellar wind starts with the assumption that there are spots on the stellar surface. Calculations with the Zeus code show that these spots result in CIRs. These are spiral-shaped density and velocity perturbations that move through the wind. These CIRs therefore also perturb those spectral lines that are largely formed in the wind (such as the Si IV λλ1394 doublet). The Zeus hydrodynamical models were used as input to the Wind3D code, which then calculated the time-evolution of the Si IV P Cygni profile. Models were made for the early B-type Ib supergiant HD 64760 for which a good time-coverage of this spectral line exists. By exploring the parameter space, we arrived at the best-fit solution for the observed time evolution of the Si IV line. From this we could derive that the spots causing the large-scale structure in the wind are not fixed on the stellar surface. This very much suggests that they are due to an interference pattern between different non-radial pulsation modes. The additional amount of matter brought into the wind by these structures is quite small (less than 1 %). It remains intriguing that these structures are not destroyed by the instability of the radiatively driven wind. The best-fit hydrodynamical result is shown here in Figure 46. The colour scale shows the density enhancement (compared to a smooth wind). Two unequal CIRs are visible (the “spiral arms”); these are responsible for the variability in the spectral lines. Figure 47 shows the effect of these CIRs on the Si IV P Cygni profiles. The result of this work will be published in **[5]** and presented at conferences **[4,9,10,12]**. An Observatory webpage was set up to show animations of the hydrodynamical models[4].

[4] http://www.astro.oma.be/HOTSTAR/CIR/CIR.html

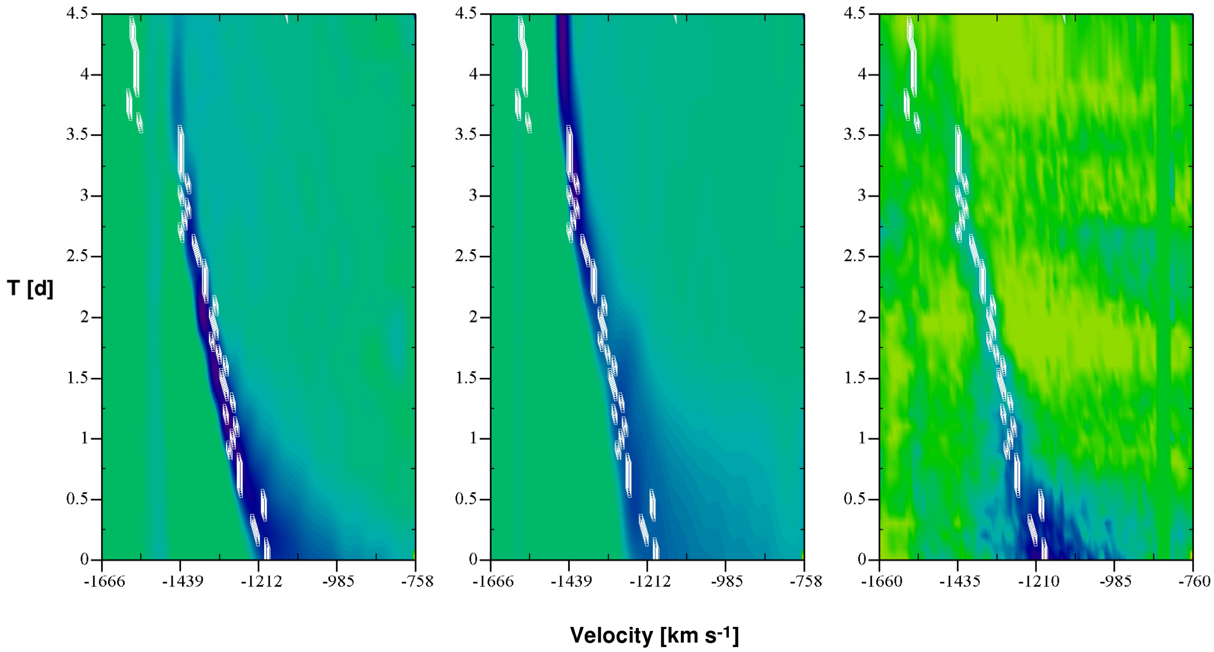

Figure 47. Right-hand panel: the dynamic spectrum of the Si IV λ1394 line observed in HD 64760 reveals a Discrete Absorption Component (DAC) that shifts toward larger velocities over time (going upward on the y-axis). Left-hand and middle panels: theoretical mode

On the observational side, we continued our work on non-thermal radio emitters. The large amount of data available for Cyg OB2 No. 9 was reduced with the help of Joan Vandekerckhove. The resulting radio light curve clearly has a 2.35-yr period, which shows that Cyg OB2 No. 9 must be a binary. It is quite exceptional that binarity has been detected from a radio light curve instead of the more classical indicators, such as an optical light curve or optical spectra. The reduction of radio data on other non-thermal radio emitters (Cyg OB2 Nos. 5 and 8A) is continuing. The results of our previous research on HD 167971 have now been published **[1]** and those on Cyg OB2 No. 9 have been submitted for publication.

To interpret the data of both thermal and non-thermal radio emitters, we started exploring models of porosity on the expected radio fluxes of these stars. Preliminary results show that porosity might explain why we can detect non-thermal emission from close binaries, contrary to expection (as the emission should be completely absorbed in the stellar wind). General overviews of our work on radio emitters (both thermal and non-thermal) have been presented at conferences **[2,6,7]**.

We obtained 60 and 160 µm images of five hot stars with the Japanese infrared satellite Akari. A pipeline reduction of all these data has been made and we have clear detections at 60 µm for all stars and for two at 160 µm. These data still need to be modeled using a theoretical spectrum synthesis code (CMFGEN) to derive the amount of clumping in the wind. In addition, we also detected two rings around HD 80077 on the Akari images. These are highly relevant as they provide the best evidence yet that HD 80077 is a Luminous Blue Variable. The rings are very similar to those seen around SN 1987A, and they are therefore also important in understanding the progenitor of this supernova.

A.1.3. Perspective for next years

We will apply the Zeus hydrodynamics code and the Wind3D radiative transfer code to a large number of stars and more spectral lines in order to continue modelling large-scale structure in the stellar wind. The reduction of existing and new radio data on thermal and non-thermal radio emitters will continue. Publications on Cyg OB2 No. 8A and 9 Sgr have a high priority. For the thermal emitters, CMGEN models will be constructed and compared to the observations. Optical spectra of the triple system HD 167971 will be obtained in 2008; these will be reduced and interpreted.

A.1.4. Personnel involved

Scientific staff: R. Blomme, A. Lobel

Technical staff: J. Vandekerckhove

A.1.5. Partnerships

List of international partners without grant

- R. K. Prinja, University College London, UK
- S. Van Loo, University of Leeds, UK
- S. M. Dougherty, DRAO, Canada

List of national partners without grant

- M. De Becker, G. Rauw, Université de Liège

Grants/Projects used for this research/service

- Belgian Federal Science Policy Office: Terugkeermandaten: Dec 2005-2007 (A. Lobel)

A.1.6. Publications

A.1.6.1. Publications with peer review

[1] **R. Blomme,** M. De Becker, M.C. Runacres, S. Van Loo, D.Y.A. Setia Gunawan
Non-thermal radio emission from O-type stars. II. HD 167971
Astron. Astrophys., 464, 701

A.1.6.2. Publications without peer review

[2] **R. Blomme**
Structure in the Winds of OB Stars: Radio and Millimetre Observations
Proceedings "Active OB stars" conference, Eds. S. Stefl, S. Owocki & A. Okazaki, ASP Conf. Proc., 361, 186

[3] **A. Lobel**
SpectroWeb: An Interactive Graphical Database of Digital Stellar Spectral Atlases
in "The Ultraviolet Universe: Stars from Birth to Death", 26th meeting of the International Astronomical Union, Joint Discussion 4, 16-17 Aug. 2006, Prague, ed. A. Gomez de Castro and M. Barstow (Madrid: Editorial Complutense Univ. of Madrid) pp 167

[4] **A. Lobel, R. Blomme**
Three Dimensional Radiative Transfer in Winds of Massive Stars: Wind3D
in "The Ultraviolet Universe: Stars from Birth to Death", 26th meeting of the International Astronomical Union, Joint Discussion 4, 16-17 August 2006, Prague, ed. A. Gomez de Castro and M. Barstow (Madrid: Editorial Complutense Univ. of Madrid) pp 119

A.1.6.3. Publications in press, submitted

[5] **A. Lobel, R. Blomme**
Modeling Ultraviolet Wind Line Variability in Massive Hot Stars
The Astrophysical Journal, 677, April 2008, Main Journal, *in press*

[6] **R. Blomme**
Radio observations of mass loss in OB stars
Proceedings of "Mass loss from stars and the evolution of stellar clusters", Eds. A. de Koter, L. Smith and R. Waters, *in press*

[7] **R. Blomme**, S. Van Loo, M. De Becker, G. Rauw, S.M. Dougherty, M.C. Runacres
Non-thermal radio emission from the colliding winds of O-star binaries
Proceedings of "Massive Stars: Fundamental Parameters and Circumstellar Interactions", Eds. P. Benaglia, G. Bosch and C.E. Cappa, *in press*

[8] M. De Becker, G. Rauw, J.M. Pittard, **R. Blomme**, G.E. Romero, H. Sana, I.R. Stevens
The investigation of particle acceleration in colliding-wind massive binaries with SIMBOL-X
Proceedings workshop "Simbol-X: the hard X-ray universe in focus", in press

[9] **R. Blomme**
Corotating Interaction Regions and clumping
in "Clumping in Hot Star Winds", Eds. W.-R. Hamann, A. Feldmeier & L. Oskinova, Potsdam: Univ.-Verl., in press

[10] **R. Blomme, A. Lobel**
Modelling ultraviolet wind line variability in massive hot stars
Poster paper IAU Symposium 250, "Massive stars as cosmic engines", in press

[11] **A. Lobel**
SpectroWeb: Oscillator Strength Measurements of Atomic Absorption Lines in the Sun and Procyon
in Proc. of the 9th Int. Coll. on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas at Lund, Sweden, August 7-10, 2007. The Journal of Physics: Conf. Series (JPCS), (The Institute of Physics Publ., UK), in press

[12] **A. Lobel**
Modeling DACs in UV Lines of Massive Hot Stars
in "Clumping in Hot Star Winds", Eds. W.-R. Hamann, A. Feldmeier & L. Oskinova, Potsdam: Univ.-Verlag, in press

A.1.7. Scientific outreach

Meeting presentations

[1] **R. Blomme**
Corotating Interaction Regions and clumping
Workshop "Clumping in Hot Star Winds", Potsdam, Germany, 18-22 June 2007, contributed talk

[2] **R. Blomme, A. Lobel**
Modelling ultraviolet wind line variability in massive hot stars
IAU Symposium 250, "Massive stars as cosmic engines", Kauai, USA, poster presentation

[3] **A. Lobel**
Modeling UV Wind Line Variability in Massive Hot Stars,
Workshop "Clumping in Hot Star Winds", Potsdam, Germany, 18-22 June 2007, contributed talk

[4] **A. Lobel**
SpectroWeb: an Online Astrophysical Database of Spectral Atlases,
Poster Presentation at the 9th Int. Coll. on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas, Aug 7-10 2007, Lund Univ., Sweden

[5] **A. Lobel**
Modeling UV Wind Line Variability in Massive Hot Stars,

Oral Presentation at the Royal Observatory of Belgium, Inst. Colloquium, Sep 11 2007, ROB Meridian Room, Brussels

Websites

- R. Blomme: Responsible for contents of the website of "Hot Star Group" of the Observatory (webmaster = Joan Vandekerckhove)
- R. Blomme: Website on "Co-rotating Interaction Regions" (part of website of "Hot Star Group").
- Lobel: SpectroWeb: The Interactive Graphical Database of Digital Stellar Spectral Atlases at spectra.freeshell.org. Line data & references update of Jul 2007 for ASOS 9 meeting, Lund

A.1.8. Missions

Assemblies, symposia (number):	R. Blomme (2), A. Lobel (2)
Research visits (days):	R. Blomme (3)

A.2. Post AGB stars and Planetary Nebulae

A.2.1. Objectives

We have been studying the final stages of evolution of intermediate mass stars, i.e. the evolution from the asymptotic giant branch (AGB) through the planetary nebula phases. This evolution is still poorly understood mainly because of a complex interplay among various physical processes between the central star and its circumstellar nebula (created through mass loss, which also influences the internal evolution of the central star). Hence, these objects provide excellent laboratories for astrophysical processes.

A.2.2. Progress and results

A.2.2.1. Sakurai's Object

When intermediate mass stars reach the final stages of their evolution, they experience thermal pulses. These are semi-periodic helium shell flashes that occur mostly at the tip of the AGB. It is theorized that about 25% of all objects will experience one additional (very) late thermal pulse (VLTP) after they have left the AGB. Despite this high percentage, this process is only very rarely observed. The discovery of Sakurai's star in 1996 provided the first opportunity in modern times to observe a very late thermal pulse. This object has baffled the scientific community with its very fast evolution. To reproduce this evolution we have proposed a new theoretical model which suppresses convective mixing under the influence of flash burning. A strong prediction of this model is that the star will evolve back to a temperature of 80,000K within the next 5 to 10 years. In an international collaboration we are monitoring this evolution. Progress reports of this campaign were presented in [9]-[13]. We have obtained new radio observations (VLA) and optical spectra (FORS1/2, VISIR on the VLT) in 2007. This year the reduction of all available VLA and optical data has been completed. During a work visit to the Observatory in Cape Town the interpretation of these observations was reassessed. The radio flux shows a marked increase starting somewhere between 2005 and 2006, while the optical data show a steady exponential decline in flux as well as excitation level compared to the 2001 spectrum. Taken at face value these results seem contradictory. Our interpretation is that in the optical we see the spectrum of a shock which occurred around 1998 and which is currently dissipating. The radio flux observed in 2004 and 2005 probably also originated in that shock. The marked increase in radio flux in 2006 and 2007 is ascribed to an increase in temperature of the central star, now starting to photo-ionize carbon. The central star temperature must be lower than hitherto thought: around 12,000K in 2006. These results were published in [3].

A.2.2.2. CK Vul

CK Vul was discovered in 1670 and was long thought to be a nova. Modern observations made this classification very unlikely and one of the proposed theories is that this is one of a handful of known post-VLTP objects. Based on radio data and optical (Hα+[N II]) images we performed an in-depth analysis of the nebula surrounding this object. By comparing our image obtained in 2004 with a similar image from 1991, we could clearly determine that the nebula is expanding. By studying the rate of expansion we found that the nebula originated in the 1670 explosion. We also detected for the first time a very faint and large (70 arcsec) bipolar emission nebula which also is centered on the 1670 explosion. Furthermore we discovered a very compact radio source which coincides with the center of expansion of the nebula. It has no optical counterpart. We believe that this is the central star which had not previously been detected. The radio emission is consistent with free-free emission, and we believe this to originate from a circumstellar or circumbinary disk. These results were published in [1] and presented at meetings in [5] and [8].

A.2.2.3. Abundance Analysis of post-AGB Stars

The thermal pulses that occur at the end of the AGB evolution mix chemically enriched material from the helium burning shell to the surface of the star. This process will alter the chemical composition of the stellar photosphere leading to the enrichment of certain elements. This allows us to test the theory of nuclear burning. One of the puzzling findings in the study of the chemical evolution of (post-)AGB stars is why very similar stars (in terms of metallicity, spectral type, infrared properties, etc.) show a very different photospheric composition. We aim at extending the still limited sample of s-process enriched post-AGB stars, in order to obtain a statistically large enough sample that allows us to formulate conclusions concerning the 3rd dredge-up occurrence. We continued the collaboration with Van Winckel and Reyniers at the KU Leuven to do such an analysis for two post-AGB stars that are strongly enriched in s-process elements (IRAS08281-4850 and IRAS14325-6428). We selected these two post-AGB stars on the basis of IR colours indicative of a past history of heavy mass loss. They are cool sources in the locus of the Planetary Nebulae (PNe) in the IRAS colour-colour diagram. Abundances of both objects were derived for the first time on the basis of high-quality UVES and EMMI spectra, using a critically compiled line list with accurate log(gf) values, together with the latest Kurucz model atmospheres. Both objects have very similar spectroscopically defined effective temperatures of 7750 - 8000 K. They are strongly carbon and s-process enriched, with a C/O ratio of 1.9 and 1.6, and an [ls/Fe] of +1.7 and +1.2, for IRAS 08281-4850 and IRAS 14325-6428 respectively. Moreover, the spectral energy distributions (SEDs) point to heavy mass-loss during the preceding AGB phase. IRAS 08281-4850 and IRAS 14325-6428 are prototypical post-AGB objects in the sense that they show strong post 3rd dredge-up chemical enrichments. The neutron irradiation has been extremely efficient, despite the only mild sub-solar metallicity. This is not conforming to the recent chemical models. The existence of very similar post-AGB stars without any enrichment emphasizes our poor knowledge of the details of the AGB nucleosynthesis and dredge-up phenomena. We call for a very systematic chemical study of all cool sources in the PN region of the IRAS colour-colour diagram. During 2007 we published the results of the abundance analysis [2].

A.2.2.4. Modeling UVES spectra of post-AGB stars

In 2006 we started modeling UVES spectra of four emission line post-AGB stars. This project was continued in 2007. The objects in our sample show P-Cygni type Hα profiles, formed by self-absorption in the wind which is indicative of strong mass loss. This implies that such line profiles are ideally suited to derive information about wind parameters and mass loss rate. Because these parameters are crucial in the study of post-AGB evolution, we have tried to derive them. We employed Darko Jevremović on a non-EU research fellowship to produce non-LTE wind-blanketed stellar atmosphere models using the Phoenix code in order to match the observed spectra. These models will be needed to analyze the observed spectra. We built and discussed grids of NLTE models with an appropriate temperature range, with different characteristics of the stellar wind for IRAS 14488-5405, one of the objects in our sample. We ran into major difficulties to match the particular Balmer line profiles of this object. We have tried to construct a new mass-loss law. In the process several bugs in the Phoenix code were discovered. After correction, and the recalculation of models, a best matching model was selected. Darko Jevremović left and we are waiting for him to continue with the fine-tuning of the model and the determination of the abundances.

A.2.2.5. NGC 7027

NGC 7027 is the brightest planetary nebula at radio wavelengths. Its spectral energy distribution is a classical case of free-free emission: optically thick below 2GHz, optically thin above 5 GHz, and the turnover range in between. The well-understood radio SED and the bright, compact nebula makes NGC 7027 a valuable calibrator at a wide range of frequencies. It also allows us to tie together the high frequency calibrators (planets) and the low frequency ones (radio galaxies). We have data from a 25-year monitoring program with the VLA showing a clear evolution in the radio flux: an increase of the optically thick flux and the decrease of the optically thin flux. The former is the result of the expansion of the nebula leading to an increase of the $\tau = \frac{2}{3}$ radius, while the latter is the result of the evolution of the central star. Using the rate of flux increase at optically thick frequencies we could derive an expansion distance of 980±100 pc. By comparing the decline in flux at optically thin frequencies with theoretical models by Blöcker we could determine the mass of the central star to be 0.65±0.01 $M_{\odot}$. Based on this analysis we could also determine that the central star is heating up at a rate of 155 K/yr, while the luminosity is decreasing at a rate of 0.07 %/yr. These results were presented in paper [7].

A.2.2.6. IRAS12316-6401 – a new symbiotic Mira?

We discovered IRAS12316-6401 in our search for obscured PNe from the IRAS catalogue. The evolutionary status of this object is still under debate. From IRAS and MSX photometry it is clear it has an extended circumstellar envelope containing cool dust, which is typical for PNe. However, the high-resolution optical emission line spectrum obtained with EMMI shows very broad emission lines with velocities up to at least 600 km/s. This is not normally observed in regular PNe, but is typical for symbiotic binaries. The emission line spectrum shows high excitation lines from [Fe VII] and possibly also [Fe VI], which is also unusual for PNe since iron is strongly depleted into refractory grains. The broad emission lines must therefore be formed in gas where grains never were formed, or where they have been fully destroyed. The information in the spectroscopic image suggests that this system is driving a powerful jet which is aimed almost directly at us. This jet is ionized by a hot white dwarf. It seems very plausible that a binary companion is feeding the material for the jet. However, to date no direct evidence for the existence of such a companion exists. No stellar continuum has been detected in the spectrum, possibly due to extinction by dust. The evidence we have gathered so far is pointing toward the fact that this is an extended symbiotic Mira, but the proof is not yet conclusive. If this is confirmed by future observations, IRAS12316-6401 would only be the 9th object in the elusive class which may be important to better understand the formation of bipolar PNe. These results were presented at meetings in [4] and [15].

A.2.2.7. Morphology and kinematics of the bipolar post-AGB star IRAS 16594-4656

The spectrum of IRAS 16594-4656 shows shock excited H2 emission and collisionally excited emission lines such as [O I], [C I], and [Fe II]. The goal is to determine the location of the H2 and [Fe II] shock emission, to determine the shock velocities, and constrain the physical properties in the shock. High resolution spectra of the H2 1-0 S(1), H2 2-1 S(1), [Fe II], and Paβ emission lines were obtained with the near infrared spectrograph Phoenix on Gemini South. A high resolution UVES spectrum was obtained via the collaboration with M. Reyniers (K.U.Leuven). The position-velocity diagrams of H2 1-0 S(1), H2 2-1 S(1), and [Fe II] show that this emission is spatially extended. The collisionally excited [O I] and [C I] optical emission lines have a similar double peaked profile compared to the extracted H2 profile and appear to be produced in the same shock. They all indicate an expansion velocity of ~8 km/s and the presence of a neutral, very high density region with ne around 3 x 106 to 5 x107 cm-3. The [Fe II] emission however is single peaked. It has a gaussian FWHM of 30 km/s and a total width of 62 km/s at 1% of the peak. The Paβ profile is even wider with a gaussian FWHM of 48 km/s and a total width of 75 km/s at 1%

of the peak. The H2 emission is excited in a slow 5 to 20 km/s shock into dense material at the edge of the lobes, caused by the interaction of the AGB ejecta and the post-AGB wind. The 3D representation made by A. Ginsburg of the H2 data shows a hollow structure with less H2 emission in the equatorial region. The [Fe II] emission is not present in the lobes, but originates close to the central star in fast shocks in the post-AGB wind or in a disk. The Paβ emission also appears to originate close to the star. These results have been published in [6] and presented at a meeting in [14].

A.2.2.8. HST snapshot survey of post-AGB stars and proto-planetary nebulae

Within this international collaboration we show the results from a Hubble Space Telescope (HST) snapshot survey of post-AGB objects. The aim of the survey is to complement existing HST images of PPN and to connect various types of nebulosities with physical and chemical properties of their central stars. Nebulosities are detected in 15 of 33 sources. Images and photometric and geometric measurements are presented. For sources with nebulosities we see a morphological bifurcation into two groups, DUPLEX and SOLE, as previous studies have found. We find further support to the previous results suggesting that this dichotomy is caused by a difference in optical thickness of the dust shell. The remaining 18 sources are classified as stellar post-AGB objects, because our observations indicate a lack of nebulosity. We show that some stellar sources may in fact be DUPLEX or SOLE based on their infrared colors. The cause of the differences among the groups is investigated. We discuss some evidence suggesting that high progenitor-mass AGB stars tend to become DUPLEX post-AGB objects. Intermediate progenitor-mass AGB stars tend to be SOLE post-AGB objects. Most of the stellar sources probably have low mass progenitors and do not seem to develop nebulosities during the post-AGB phase and therefore do not become planetary nebulae. The referee's comments were incorporated and the article was accepted for publication [16].

A.2.3. Perspective for next years

The main emphasis of the research during the coming years will be threefold. One part will be monitoring the spectral evolution of Sakurai's object. To this end optical spectra (using FORS and VISIR on the VLT) and radio observations (using the VLA) will be obtained on a yearly basis. These data will be analyzed and modeled using the photoionization code Cloudy to derive the evolution of the central star temperature as a function of time. These data will be used to test the new theory proposed by Falk Herwig. Another part of the research will be modeling high resolution spectra of post-AGB stars obtained with UVES on the VLT and EMMI on the NTT with the aim of deriving the mass-loss rate and the chemical composition of these stars. Non-LTE model atmospheres will be used for this work. Darko Jevremović will need to produce these models. In support of both lines of research, van Hoof will continue to develop the modeling code Cloudy, as well as his web-based Atomic Line List (see sections B.2 and B.3).

We will also work on interferometry data obtained at ESO with the VLTI. We will also receive interferometric data with VISA in the framework of Belgian GTO time. As this is a completely new field this will require major study and modeling work.

A.2.4. Personnel involved

Scientific staff: G.C. Van de Steene, P.A.M. Van Hoof, D. Jevremovic

A.2.5. Partnerships

List of international partners without grant

- Albert A. Zijlstra, University of Manchester
- Marcin Hajduk, Centrum Astronomii, Torun
- Nye Evans, School of Chemistry and Physics, Keele
- Steward P.S. Eyres, Centre for Astrophysics, Preston
- Stefan Kimeswenger, Institut für Astrophysik, Innsbruck

- Falk Herwig, School of Chemistry and Physics, Keele
- Krzysztof Gesicki, Centrum Astronomii, Torun
- Rick A. Perley, NRAO, Socorro
- T. Ueta, Dept. of Astronomy and Astrophysics University of Denver, USA
- A. Ginsburg, Dept. of Astronomy and Astrophysics University of Denver, USA
- N. Siódmiak, Space Telescope Science Institute, USA
- M. Meixner, Space Telescope Science Institute, USA
- Sugerman, Goucher College, USA
- R. Szczerba, N. Copernicus Astronomical Center, Poland

List of national partners without grant

- Hans Van Winckel, K.U. Leuven
- Maarten Reyniers, K.U. Leuven

Grants/Projects used for this research/service

- Belspo-Action 1 MO/33/017
- Research Fellowship for non-EU postdocs

Visitors

- Short visits: 1

A.2.6. Publications

A.2.6.1. Publications with peer review

[1] Hajduk M., Zijlstra A.A., **van Hoof P.A.M.,** Lopéz J.A., Drew J.E., Evans A., Eyres S.P.S., Gesicki K., Greimel R., Kerber F., Kimeswenger S., Richer M.
The enigma of CK Vul: the central star and nebula of the oldest nova
MNRAS, 378, 1298

[2] Reyniers M., Van de Steene G.C., van Hoof P.A.M., Van Winckel H.
IRAS 14325-6428 and IRAS 08281-4850: two A-type post-AGB stars with s-process enrichment
A&A, 471, 247

[3] **van Hoof P.A.M**., Hajduk M., Zijlstra A.A., Herwig F., Evans A., **Van de Steene G.C**., Kimeswenger S., Kerber F., Eyres S.P.S.
The onset of photoionization in Sakurai's Object (V4334 Sgr)
A&A, 471, L9

A.2.6.2. Publications without peer review

[4] **van Hoof P.A.M., Van de Steene G.C**.
IRAS12316-6401: A New Symbiotic Mira?
Proceedings of the meeting `evolution and chemistry of symbiotic stars, binary post-AGB and related objects', eds. Mikolajewska J., Szczerba R., Baltic Astronomy, 16, 59

[5] Hajduk M., Zijlstra A.A., Evans A., Kerber F., **van Hoof P.A.M.,** Pollacco D.L., Eyres S.P.S., Ki-meswenger S., Gesicki K.
Nova 1670 Vul
Proceedings of the workshop `Why Galaxies Care About AGB Stars', eds. Kerschbaum C., Charbon-nel C., Wing R.F., ASP Conference Series, Vol. 378, p. 301

A.2.6.3. Publications in press, submitted

[6] **Van de Steene G.C.,** Ueta T., **van Hoof P.A.M**., Reyniers M., Ginsburg A.G.

Kinematics and H2 morphology of the multipolar post-AGB star IRAS 16594-4656
A&A, in press

[7] Zijlstra A.A., **van Hoof P.A.M.,** Perley R.
The evolution of NGC 7027 at radio frequencies – A new determination of the distance and core mass
ApJ, submitted

[8] Hajduk M., Zijlstra A.A., **van Hoof P.A.M.,** Lopéz J.A., Drew J.E., Evans A., Eyres S.P.S., Gesicki K., Greimel R., Kerber F., Kimeswenger S.
On the evolved nature of CK Vul
Proceedings of the Hydrogen Deficient Stars conference, eds. Werner K., Rauch T., ASP Conference Series, in press

[9] Hajduk M., Gesicki K., **van Hoof P.A.M**., Lopéz J.A., Zijlstra A.A.
Studying the old planetary nebula of V4334 Sgr
Proceedings of the Hydrogen Deficient Stars conference, eds. Werner K., Rauch T., ASP Conference Series, in press

[10] Kimeswenger S., Zijlstra A.A., **van Hoof P.A.M**., Hajduk M., Herwig F., Lechner M.F.M., Eyres S.P.S., **Van de Steene G.C.**
Morphologies of the nebulae around "born again" central stars of planetary nebulae
Proceedings of the Hydrogen Deficient Stars conference, eds. Werner K., Rauch T., ASP Conference Series, in press

[11] **van Hoof P.A.M**., Hajduk M., Zijlstra A.A., Herwig F., **Van de Steene G.C**., Kimeswenger S., Evans A.
Recent observations of V4334 Sgr and V605 Aql
Proceedings of the Hydrogen Deficient Stars conference, eds. Werner K., Rauch T., ASP Conference Series, in press

[12] Kimeswenger S., Zijlstra A.A., **van Hoof P.A.M**., Hajduk M., Lechner M.F.M., **Van de Steene G.C**., Gesicki K.
Symmetry and asymmetry in "born again" planetary nebulae
Proceedings of the Asymmetric Planetary Nebulae IV conference, eds. Corradi R.L.M., Manchado A., Soker N., in press

[13] **van Hoof P.A.M**., Hajduk M., Zijlstra A.A., Herwig F., Evans A., **Van de Steene G.C**., Kimeswenger S., Kerber F., Eyres S.P.S.
Recent observations of Sakurai's object
Proceedings of the Asymmetric Planetary Nebulae IV conference, eds. Corradi R.L.M., Manchado A., Soker N., in press

[14] **Van de Steene G.C**., Ueta T., **van Hoof P.A.M**., Reyniers M., Ginsburg A.G.
Morphology and kinematics of the bipolar post-AGB star IRAS 16594-4656
Proceedings of the Asymmetric Planetary Nebulae IV conference, eds. Corradi R.L.M., Manchado A., Soker N., in press

[15] **van Hoof P.A.M., Van de Steene G.C.**
IRAS12316-6401: A New Symbiotic Mira?
Proceedings of the Asymmetric Planetary Nebulae IV conference, eds. Corradi R.L.M., Manchado A., Soker N., in press

[16] Siodmiak, N., Meixner, M., Ueta, T., Sugerman, B. E. K., **Van de Steene, G.C**., Szczerba, R.
HST snapshot survey of post-AGB objects
ApJ, in press

A.2.7. Scientific outreach

Meeting presentations

[1] **van Hoof P.A.M.**, Hajduk M., Zijlstra A.A., Herwig F., **Van de Steene G.C.**, Kimeswenger S., Evans A.
Recent observations of V4334 Sgr and V605 Aql
Oral presentation at the Hydrogen Deficient Stars conference, 17 -21 September, Tübingen

[2] **van Hoof P.A.M.**, Hajduk M., Zijlstra A.A., Herwig F., Evans A., **Van de Steene G.C.**, Kimeswenger S., Kerber F., Eyres S.P.S.
Recent observations of Sakurai's object
Oral presentation at the Asymmetric Planetary Nebulae IV conference, 18 – 22 June, La Palma

[3] **van Hoof P.A.M., Van de Steene G.C.**
IRAS12316-6401: A New Symbiotic Mira?
Poster presentation at the Asymmetric Planetary Nebulae IV conference, 18 – 22 June, La Palma

[4] **Van de Steene, G. C.**, Ueta, T., **van Hoof, P. A.M.**, Reyniers, M., Ginsburg, A.G.
Shock emission in the multipolar post-AGB star IRAS 16594-4656
Poster presentation at the Assymetrical Planetary Nebulae conference, 18 – 22 June, La Palma

A.2.8. Missions

Assemblies, symposia (number): G.C. van de Steene (3), P.A.M. Van Hoof (3)

Research visits (days): P.A.M. Van Hoof (13)

A.3. The Photoionization Code Cloudy

A.3.1. Objectives

Cloudy is a code designed to model the interstellar medium in the widest possible sense. It can treat a wide range of physical conditions, ranging from gamma-ray and X-ray photoionized plasmas to photodissociation regions (PDR) and molecular clouds. As such it can model many types of objects, including (but not limited to) active galactic nuclei, star forming regions, planetary nebulae, and post-AGB stars. It was the first code that could produce a fully self-consistent model of a photo-ionized region including the PDR and molecular regions surrounding it. The code is being developed continually with the aim of improving the modeling results and to widen its scope. The code is publicly available and is widely used. Currently around 120 papers per year cite the use of Cloudy.

A.3.2. Progress and results

The photoionization code Cloudy plays a crucial role in the research of van Hoof. He is a member of the international development team of this code. Most importantly he is the primary author of the grain model in Cloudy. Grains play an important role in many environments (including post-AGB stars and PNe) because of extinction, photoelectric heating, their influence on the charge and ionization balance of the gas, as catalysts for grain-surface chemical reactions (e.g. H2 formation), and as seeds for freeze-out of molecules. It is therefore important to keep the grain model in Cloudy up-to-date. To this end van Hoof continued his work on implementing the new X-ray treatment of grains as well as improved opacity functions for polycyclic aromatic hydrocarbons (PAHs), both of which are important for modeling PNe and post-AGB stars. The new X-ray treatment will be part of the upcoming release in 2008. Van Hoof advised on several group publications discussing new features of the code and its application to various astrophysical objects (refs [17]-[22] below). Van Hoof fixed several bugs in the code and assisted in updating the documentation of the parts of the code that he is responsible for. He also assisted in the release of version c07.02.00 of the code in February 2007 as well as the bug-fix roll-up later on that year. Furthermore he assisted in the preparations for the upcoming release of Cloudy which is scheduled for February of 2008. He assisted in maintaining and updating the Cloudy web sites as listed in section A.2.6. Van Hoof also organized the Cloudy Development Summit held in February 2007 at the ROB. This workshop brought Cloudy developers together to discuss the development of the code.

A.3.3. Perspective for next years

The development of Cloudy will continue for many years to come. This will first and foremost be aimed at implementing new physics and improving/updating the physics that is already included in the code. Some effort will also be directed towards fixing deficiencies in the code and improving the documentation (either on the web or in the manual called Hazy). In the next year the efforts of van Hoof will be mainly aimed at finishing the improved opacity functions for polycyclic aromatic hydrocarbons (PAHs). This development will have consequences for modeling many types of environments, including planetary nebulae and post-AGB stars.

A.3.4. Partnerships

List of international partners without grant

- Gary J. Ferland, University of Kentucky
- Ryan Porter, University of Kentucky
- Robin J.R. Williams, AWE, United Kingdom
- William J Henney, UNAM, Morelia
- Joe C. Weingartner, George Mason University, Fairfax
- Nick P. Abel, University of Cincinnatti
- Gargi Shaw, University of Kentucky
- Roderick Johnstone, Institute of Astronomy, Cambridge

Grants/Projects used for this research/service

- Belspo-Action 1

Visitors

- Short visits: 3

A.3.5. Publications

A.3.5.1. Publications with peer review

[1] Röllig M., Abel N.P., Bell T., Bensch F., Black J., Ferland G.J., Jonkheid B., Kamp I., Kaufman M.J., Le Bourlot J., Le Petit F., Meijerink R., Morata Chirivella O., Ossenkopf V., Roueff E., Shaw G., Spaans M., Sternberg A., Stutzki J., Thi W.-F., van Dishoeck E.F., **van Hoof P.A.M.**, Viti S., Wolfire M.G.
A PDR-code comparison study
A&A, 467, 187

A.3.5.2. Publications without peer review

[2] Ferland G.J., Fabian A.C., Hatch N.A., Johnstone R.M., Porter R.L., **van Hoof P.A.M.**, Williams R.J.R.
Molecular emission from filaments in cooling flows
Proceedings of the 211th AAS meeting, #54.08, BAAS, Vol. 39

A.3.5.3. Publications in press, submitted

[3] Shaw G., Ferland G.J., Srianand R., Abel N.P., **van Hoof P.A.M.**
On the enhanced cosmic ray ionization rate in the diffuse cloud towards ζ Persei
ApJ, in press

[4] Ferland G.J., Fabian A.C., Hatch N.A., Johnstone R.M., Porter R.L., **van Hoof P.A.M.**, Williams R.J.R.
The origin of molecular hydrogen emission in cooling-flow filaments
MNRAS pink pages, in press

[5] Abel N.P., **van Hoof P.A.M.**, Shaw G., Elwert T., Ferland G.J.
Sensitivity of PDR Calculations to Microphysical Detail
ApJ, submitted

[6] **van Hoof P.A.M.**, Abel N.P., Williams R.J.R., Porter R.L., Ferland G.J.
Modeling X-ray ionization of grains with Cloudy
Proceedings of the Far-Infrared 2007 workshop, ed. Kramer C., EAS Publication Series, in press

A.3.6. Scientific outreach

Meeting presentations

[1] **van Hoof P.A.M.**, Abel N.P., Williams R.J.R., Porter R.L., Ferland G.J.
Modeling X-ray ionization of grains with Cloudy
Poster presentation at the Far-Infrared 2007 workshop

Meeting organization

- Organizer of the Cloudy Development Summit held 12 – 15 February 2007 at the ROB.

Scientific Software

- Cloudy is an open-source code and is distributed under a BSD-style license. It can be freely obtained from http://www.nublado.org or from the Subversion repository listed below.

Websites

- Assisted in answering user questions on the discussion forum:
- http://tech.groups.yahoo.com/group/cloudy_simulations
- Assisted in maintaining the Subversion repository for the photoionization code Cloudy: https://cloud9.pa.uky.edu/svn/cloudy
- Maintained the ViewVC repository browser for Cloudy: https://cloud9.pa.uky.edu/cgi-bin/view.cgi
- Assisted in maintaining the Cloudy Wiki: https://cloud9.pa.uky.edu/trac/cloudy

A.3.7. Missions

Assemblies, symposia (number): P.A.M. Van Hoof (1)

A.4. The Atomic Line List

A.4.1. Objectives

The atomic line list is a web-based compilation of approximately 1.41 million allowed, intercombination and forbidden atomic transitions with wavelengths in the range from 0.06 nm to 1000 μm. It is publicly available and its primary aim is to assist spectroscopists in the identification of absorption or emission lines in astrophysical or laboratory spectra. It is complete for all elements up to and including zinc. It is widely used in the astronomical and physical community and beyond and serves more than 10,000 users per year.

A.4.2. Progress and results

The selection rules have been improved to include more intercombination and forbidden lines. This solves the longstanding problem that some observed lines were missing in the line list.

A.4.3. Perspective for next years

The upgrade to v2.05 which will include lines for elements gallium through krypton, update the data for several other ions, fix several problems, and will feature many improvements to the web interface is nearly ready and planned for release in 2008. Once that is completed, van Hoof will start adding data for 5th and 6th row elements, most notably s-process elements.

A.4.4. Scientific outreach

Websites

- Maintains the Atomic Line List: http://www.pa.uky.edu/~peter/atomic

B. Research Theme "Variable Stars, Asteroseismology and Binaries"

B.1. Variable Stars and Asteroseismology

B.1.1. Objectives

Research on variables stars leads to a better knowledge of stellar structure and evolution. Asteroseismology in particular, refers to the study of the internal structure of pulsating stars through the interpretation of their frequency spectra. In order to achieve this goal, observation and detection of the variability of the stars and a precise analysis of the observed periodicities is necessary. The emphasis of the research carried out here, is on detection of multiple periods in pulsating variable stars in general and on B-type and γ Doradus stars in particular.

B.1.2. Progress and results

Earlier developed methods to improve the detection of periods in variable stars were tested further and applied to a large number of data sets of variable stars. The algorithms were adapted to the (new) future needs: a few data sets with a huge number of observations per star, as will be the case for the satellite COROT or a huge number of data sets with only few observations per star as for the satellite Gaia (launch foreseen for 2011).

The comparative study of different methods of period analysis was continued. The whole dataset of epoch photometry available from the Hipparcos satellite had already been re-analyzed in 2006, but now a more detailed investigation of the results was initiated. In some case multiples or integer fractions of the real period were found and now this is taken into account for the statistics. Results were presented at the Gaia meeting in Bologna (see further).

The work on automatic classification of variable stars was continued and resulted in a paper in A&A. To Jonas Debosscher (Institute of Astronomy, Department of Physics and Astronomy, KULeuven) and Luis Sarro (Madrid), further input was given on characteristics of variable stars in general and on periods and period search methods in particular. This information has been implemented in the tools developed for the classification of the variable stars that will be detected by the satellite CoRoT. CoRoT (Convection Rotation and planetary Transits) is a space mission led by the French Space Agency (CNES) in conjunction with ESA and other international partners. The primary objective of CoRoT will be to search for exoplanets. Since CoRoT can detect very small luminosity variations a lot of variable stars will be detected and these have to be classified. The classification methods are now also being adapted for the satellite Gaia.

The in-depth analysis of the observations of the Mercator telescope operated at La Palma by the Institute of Astronomy of the KULeuven went on. Our new methods and classical methods of period analysis were further applied to these data in search for variable stars and periodicities. This work has been done in collaboration with Peter De Cat (Dep. II) and collaborators of the Institute of Astronomy.

The study of the γ Doradus stars photometrically observed with the Mercator telescope and SAAO (South Africa) in the frame of an earlier international collaboration continued. The data were combined with earlier observations by the satellite Hipparcos or by ground-based observatories in order to improve the accuracy of the periods, phases and amplitudes. This work is not finished yet, since, as stated before, not all cases have consistent results from the first analysis.

Assistance was given to a detailed period analysis of the δ Scuti star HD 217860 that revealed interesting multiperiodic photometric and spectroscopic variations. Up to eight frequencies common to two large photometric data sets were found. More details of this research can be found in the report of Yves Frémat and Patricia Lampens, the main authors of the article on this subject as it appeared in A&A.

A large number of high-resolution spectra of B[e] and L(uminous)B(lue)V(ariable) stars was reduced (92 spectra of 42 different objects), and some of them were used in on-going analyses with M. Kraus (Ondrejov, Czechia) concerning B[e] supergiants in the Magellanic Clouds, especially LHA-115 S23 in the Small MC. It appears that the star has become cooler over the last 20 years as judged from the disappearance of photospheric He I lines and photometry. The final revision of a paper on the unclassified B[e] star CD-42.11721 was made when M. Borges was starting his fellowship.

B.1.3. Perspective for next years

The analysis of the periodic variables observed by the Mercator telescope will be continued in collaboration with the Institute of Astronomy of the KULeuven.

The analysis of the observations of γ Doradus stars will go on.

Data on variable stars observed with the satellite COROT will be analysed.

Some internal meetings and discussions on asteroseismological applications of the Kepler satellite were already attended. The launch of the Kepler satellite is foreseen for 2009. Its main mission is to detect (earth-like) exoplanets, but variable stars will be observed as well.

Period analyses of stars of different type will be continued and methods will be evaluated and adapted in view of the new or expected data. Attempts will be made to optimize the algorithms to analyze huge amounts of stars simultaneously.

B.1.4. Personnel involved

Scientific staff: J. Cuypers, P. De Cat, Y. Frémat, P. Lampens, M. Borges

B.1.5. Partnerships

List of international partners

- Laurent Eyer, Observatoire de Genève, Switzerland
- Luis Sarro, Artificial Intelligence Department, UNED & Virtual Observatory, Spain
- Michaela Kraus, Ondrejov Astronomical Institute, Czechia & F. X. de Araújo, Observatorio Nacional, RJ, Brasil

List of national partners

- Institute of Astronomy (Conny Aerts, Jonas DeBosscher and others), Department of Physics and As-tronomy, K.U.Leuven

Grants/Projects used for this research

- FWO-project G.0332.06 "Observationele bepaling van nauwkeurige interne en circumstellaire structuurmodellen van sterren", Promotor: Prof. Dr. Conny Aerts, partners: K.U.Leuven, UGent, V.U.Brussel, KSB
- Post-doc Fellowship non-EU researchers (one year, M. Borges, ON, Rio de Janeiro)
- Koninklijke Vlaamse Academie van Belgie: support for visit of M. Kraus to ROB (in cooperation with Czech Academy of Sciences)
- Research grant of M. Kraus, Czechia: support for work visit of M. Borges to Ondrejov Astronomical Institute

Visitors

- M. Kraus, Ondrejov Astronomical Institute, Czechia: April 15-28 (KVAB), September 17-29

B.1.6. Publications

B.1.6.1. Publications with peer review

[1] **De Cat, P.**, Briquet, M., Aerts, C., Goossens, K., Saesen, S., **Cuypers, J.,** Yakut, K., Scuflaire, R., Dupret, M.-A., Uytterhoeven, K., van Winckel, H., Raskin, G., Davignon, G., Le Guillou, L., van Malderen, R., Reyniers, M., Acke, B., de Meester, W., Vanautgaerden, J., Vandenbussche, B., Ver-hoelst, T., Waelkens, C., Deroo, P., Reyniers, K., Ausseloos, M., Broeders, E., Daszyńska-Daszkiewicz, J., Debosscher, J., de Ruyter, S., Lefever, K., Decin, G., Kolenberg, K., Mazumdar, A., van Kerckhoven, C., de Ridder, J., Drummond, R., Barban, C., Vanhollebeke, E., Maas, T., Decin, L.
Long term photometric monitoring with the Mercator telescope - Frequencies and mode identifica-tion of variable O-B stars
Astron. Astrophys., 463, 243-249

[2] Saesen, S., Briquet, M., **Cuypers, J., De Cat, P.,** Goossens, K.
Asteroseismology of the β Cephei star KP Per
Communications in Asteroseismology, 150, 197

[3] **Frémat, Y., Lampens, P.,** van Cauteren, P., Kleidis, S., Gazeas, K., Niarchos, P., Neiner, C., Dimi-trov, D., **Cuypers, J.,** Montalbán, J., **De Cat, P.,** Robertson, C. W.,
Search for pulsation among suspected A-type binaries and the new multiperiodic δ Scuti star HD 217860,
Astron. Astrophys. 471, 675-686

[4] Debosscher, J., Sarro, L. M., Aerts, C., **Cuypers, J.,** Vandenbussche, B., Garrido, R., Solano, E.
Automated supervised classification of variable stars. I. Methodology,
Astron. Astrophys. 475, 1159-1183

B.1.6.2. Reports

[5] Borges Fernandes M.
Report of the fellowship for non-EU researchers "High-Precision Echelle Spectroscopy of Emission-Line Stellar Sources" (13 p.)

B.1.7. Scientific Outreach

Meeting presentations

[1] Borges Fernandes M.
Stars with the B[e] phenomenon: the evolutionary stage of some curious objects
Ondrejov Astronomical Institute, May 29 and ROB seminars, May 15

B.1.8. Missions

Assemblies, symposia (number): Cuypers, J. (3), Borges M. (6)

Research visits (days): Cuypers, J. (26), Borges M. (23)

B.2. Binary Stars

B.2.1. Objectives

Binaries are an important source of precise fundamental stellar parameters and hence provide empirical constraints on stellar evolution. In stellar groups, they provide anchor points for the interpretation of the whole stellar population. Main goals: characterize the binary population in young stellar groups (Sco-Cen, NGC 2244) and perform a detailed analysis of the most interesting close binaries (mostly, but not exclusively, in these groups) using the novel spectral disentangling technique.

B.2.2. Progress and results

The reconstruction of intrinsic star spectra from binary and higher-multiplicity stellar systems, of which the components remain spectroscopically unresolved, is based on a set of spectra taken at varying orbital phases and exploit the varying differential Doppler shifts of the spectral lines of the components. The detailed analysis of the methods to separate the spectra of multiple systems was continued in cooperation with S. Ilijić and resulted in a submitted paper [8] (meanwhile accepted). It discusses the reasons for indeterminacies in the low-frequency components of the reconstructed spectra, and when and how they can be reduced or avoided, either during the observation process or during the analysis. It discusses also the progression of bias in the input data to the reconstructed spectra and shows how to remove or avoid it, with emphasis on the proper use of eclipse spectra. In 2007, the analytical computations on the singular values for low-multiplicity systems were extended and improved, with a generalization to multi-component systems for certain aspects. A number of tests, done on real data, support now our conclusions on the improvement in robustness that may be obtained from assigning a proper weight to spectra taken in eclipse; not (only) based on the random noise in such spectra, but also taking into account the beneficial effect of the change in the dilution of the lines of the components on the position of the true continuum level in the reconstructed spectra.This work is part of the PhD thesis of K. B. Torres, that she will defend on April 16, 2008.

A paper [1] in MNRAS discusses in detail the photometry of two binaries in Scorpius-Centaurus, V883 Cen and η Muscae, based on work described in the annual report of 2006. Cooperation with a research group at the University of Cannakale in Turkey is set-up, to combine our spectroscopic data-sets on η Muscae in a search for a third spectroscopic component. Hopefully, V. Bakis will obtain a fellowship granted by Turkey to come for two months as a young post-doc to the ROB. η Muscae consists, except for this suspected component, of a massive close-binary and a light pre-main-sequence star as visual component (see Figure 48).

In the framework of the search for binary stars in Sco-Cen, with M. David (UA) and C. Nitschelm (pre-vious UA, now professor at UCN, Antofagasta) the feasibility of using the photometry from the ASAS project (All-Sky Automated Survey) to detect ellipsoidal variables and eclipsing binaries for Sco-Cen stars fainter than visual magnitude 7 was investigated, and, more demanding, for stars up to 14th magnitude in the open cluster NGC 2244. The photometry was shown to be useful to improve the orbital period of the 9th magnitude β Lyrae-type eclipsing variable HP Lupi in the field of the Sco-Cen associations, to derive the rotation period of the 9th magnitude magnetic (foreground) star NGC2244-#381, and to document the apsidal motion in the 8.5th magnitude eclipsing binary NGC2244-#200. It fails for most stars in NGC2244 because of the large pixel size in combination with the high star density in an open cluster, though iso-lated stars in NGC2244 gave rms scatter below 0.01 mag till magnitude 11, and an rms of 0.005 for brighter stars, till images saturate. Therefore, a systematic application to the fainter members on our Sco-Cen program is envisaged for the next year(s). Finally, as far as Sco-Cen is concerned, the move of C. Nitschelm allows us to have from the second half of 2008 on a broader access to Chilean telescopes, and several observing proposals are being prepared.

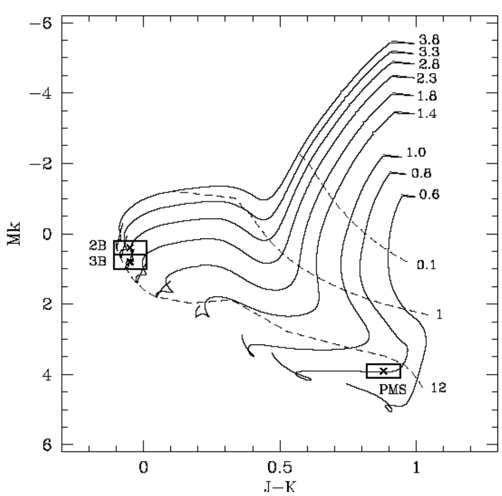

Figure 48. Colour-colour diagram with the close binary eta Muscae and its pre-main sequence companion superposed on PMS evolutionary tracks (labeled with mass)

At the end of the year, during a two-week visit of P. Koubsky (Ondrejov, Czechia), the standard data reduction of spectra of the triple system HD208905 obtained by S. Daflon (ON, Rio de Janeiro, Brazil) was improved, since the standard data reduction turned out to be insufficient for spectra disentangling purposes. This work will be continued during a next visit of P. Koubsky to ROB early in 2008, and a participation in the disentangling process is also foreseen.

B.2.3. Perspective for next years

Identification of binaries in Sco-Cen, with emphasis on the Hipparcos-selected subsample of stars in Sco-Cen. Analyse and interprete the spectroscopic data of the binary-search program in Sco-Cen, and study the usefulness of different observing techniques (e.g. interferometry) to improve the completeness of the binary sample. Further, detailed analyses on other specific binary systems. Priority in 2008 goes to the analysis of RV Crateris (paper on absolute dimensions of components) and η Muscae.

B.2.4. Personnel involved

Scientific staff: H. Hensberge, K.B.V. Torres

B.2.5. Partnerships

List of international partners without grant

- L.P. Vaz, K.B.V. Torres, UFMG, Belo Horizonte, Brazil (promoter, PhD student) : RV Crt & spectra disentangling
- N. Landin, UFMG, Belo Horizonte: computation pre-main-sequence tracks
- K. Pavlovski, University of Zagreb, Croatia: NGC2244
- S. Ilijić, University of Zagreb, Croatia: numerical codes & theory of spectra disentangling
- P. Koubsky, Ondrejov, Czechia & S. Daflon, ON, Rio de Janeiro, Brazil: HD208905
- C. Nitschelm, UCN, Antofagasta, Chile: Scorpius-Centaurus

List of national partners without grant

- M. David, UA: Scorpius-Centaurus

Grants/Projects used for this research

- PhD fellowship, CNPq, Brazil

Visitors

- P. Koubsky, Ondrejov Astronomical Institute, Czechia: Dec. 4 - 14

B.2.6. Publications

B.2.6.1. Publications with peer review

[1] **Hensberge H., Nitschelm C.,** Olsen E.H., Sterken C., David M., **Freyhammer L.M.,** Landin N.R., Bouzid M.Y., **Papadaki C.,** Pritchard J.D., Clausen J.V., Vaz L.P.R.
The eclipsing double-lined binaries V883 Cen and η Mus
MNRAS 379, 349

B.2.6.2. Publications without peer review

[2] **Hensberge H.,** Vaz L.P. R., Torres K.B. V., Armond T.
Spectral disentangling applied to triple systems: RV Crt
In: Multiple Stars across the H-R Diagram, ESO Astrophysics Symposia, S. Hubrig, M. Petr-Gotzens and A. Tokovinin (eds.), 47

[3] **Lampens P., Frémat Y., Hensberge H.,** Tamazian V., Docobo J.A., Balega Y.
DG Leo: a triple system with a surprising variety of physical phenomena
In: Multiple Stars across the H-R Diagram, ESO Astrophysics Symposia, S. Hubrig, M. Petr-Gotzens and A. Tokovinin (eds.), 59

[4] **Hensberge H.**
Instrumental signatures in echelle spectra
In: The future of photometric, spectrophotometric and polarimetric polarization (ed. C. Sterken), ASPC, 364, 275

[5] **Hensberge H.,** Pavlovski, K.
Modern analysis techniques for spectroscopic binaries
In: Modern Binaries, W.I. Hartkopf, E. Guinan, P. Harmanec (eds), IAUS 240, 136 (invited talk)

[6] **Torres K.B.V.,** Vaz L.P.R., **Hensberge H.**
Comparison of different spectral disentangling techniques applied to a triple system
In: Modern Binaries, W.I. Hartkopf, E. Guinan, P. Harmanec (eds), IAUS 240, 210 (poster)

[7] **Lampens P., Frémat Y., De Cat P., Hensberge H.**
Spectral Disentangling and combined orbital solution for the Hyades binary θ2 Tau
In: Modern Binaries, W.I. Hartkopf, E. Guinan, P. Harmanec (eds), IAUS 240, 213 (poster)

[8] Nitschelm C., **Hensberge H.,** David M.
Study of the duplicity and the multiplicity in the Sco-Cen complex (Sco OB2)
VI Reunion Annual SOCHIAS, 39

B.2.6.3. Publications in press, submitted

[9] **Hensberge H**., Ilijić S., **Torres K.B.V**.
On the separation of component spectra in binary and higher-multiplicity stellar systems: bias pro-gression and spurious patterns
A&A, in press

B.2.7. Scientific outreach

Meeting presentations

[1] **Hensberge H**.
Modern analysis techniques for spectroscopic binaries
ROB seminars, May 29

[2] **Torres, K.B.V., Hensberge, H.,** Vaz, L.P.R.
Methods of spectral separation: spurious patterns and bias in the reconstructed spectra of multiple systems
Annual meeting of the Sociedade de Astronomia do Brasil, September 7

Educational responsibilities

- Hensberge H: co-promoter of PhD thesis of K.B.V. Torres at UFMG, Belo Horizonte, Brazil

B.2.8. Missions

Research visits (days): H. Hensberge (21), K.B.V. Torres (6)

B.3. Solar Abundances and relevant Spectroscopic Data

B.3.1. Objectives

The determination of accurate abundances in the solar photosphere (adopting the best spectroscopic data and the most representative solar models) remains very important in solar and stellar physics.

B.3.2. Progress and results

A full revision of the solar abundance of a large number of elements has been carried out. Special attention has been paid to the selection of our atomic lines (i.e. unblended solar lines with very accurate transition probabilities). This new determination has been based on new intensity measurements from the best solar spectra adopting the most representative 1D and 3D solar models.

A solar-calibrated atomic and molecular data bank in the infrared is in progress and will include about 110.000 lines in the spectral region from 250 to 10.000 cm-1 [lambda 1.000 – 40.000 nm]. It enables to reproduce rather well the observed solar spectrum and should also be useful for the calculation of synthetic spectra of cool (solar-type) stars. Part of this data bank (about 70.000 lines from 600 to 5.600 cm-1) is complete and will be soon available on the ROB website.

B.3.3. Perspective for next years

Two main works in 2008: the review paper on solar abundances for ARAA (with N. Grevesse and M. Asplund) and the completion of the new IR spectroscopic data base.

B.3.4. Personnel involved

Scientific staff: J. Sauval (ROB)

List of international partners without grant

- Martin Asplund, Max Planck Institut für Astrophysik, Garching
- Pat Scott, Department of Physics, Stockholm University

List of national partners without grant

- Nicolas Grevesse, Institut d'astrophysique, Université de Liège

B.3.5. Publications

B.3.5.1. Publications with peer review

[1] Grevesse N., Asplund M**., Sauval A.J**.
The solar chemical composition
Space Science Reviews 130, pp. 105-114, 2007

C. Comet C/2004 Q2 (Machholz)

C.1. Rotation period of Comet C/2004 Q2 (Machholz)

C.1.1. Objectives

Rotation periods of cometary nuclei are scarce, though important to study the nature and origin of these objects. In a test project with the Mercator telescope CCD images of comet C/2004 Q2 (Machholz) the feasibility of deriving a rotation period from this kind of observations was studied. It was part of the Master thesis of Pieter De Groote of the Astronomical Institute of the KULeuven. Promotor was Maarten Reyniers, co-promotors were D. Bodewits (Groningen & Goddard Space Center) and Jan Cuypers.

C.1.2. Progress and results

C/2004 Q2 (Machholz) was monitored using the Merope CCD camera on the Mercator telescope at La Palma, in January 2005, during its closest approach to Earth, implying a high spatial resolution (50 km per pixel). 170 Images were recorded in three different photometric broadband filters, two blue ones (Geneva U and B) and one red (Cousins I). Magnitudes for the comet's optocenter were derived with very small apertures to isolate the contribution of the nucleus to the bright coma, including correction for the seeing. The CCD photometry also allowed studying the coma profile of the inner coma in the different bands. A rotation period for the nucleus of P=9.1h was derived. The period is on the short side compared to published periods of other comets, but still shorter periods are known. Nevertheless, comparing our results with images obtained in the narrowband CN filter, the possibility that our method sampled P/2 instead of P cannot be excluded. A paper on these results and on the derived comet coma profiles has been submitted to A&A.

Other results could be derived from these observations as well. A letter paper on “Folding ion rays in comet C/2004 Q2 (Machholz) and the connection with the solar wind” by P. Degroote, D. Bodewits and M. Reyniers was accepted for A&A (2008, 477, L41-44).

C.1.3. Perspective for next years

More observations of comets have been or will be done with the Merope CCD camera on the Mercator telescope. Of the bright comet 17P/Holmes not enough observations were available, to come to conclusions. In the future other comets will be observed from La Palma.

C.1.4. Personnel involved

Scientific staff: J. Cuypers

C.1.5. Partnerships

List of national partners without grant

- Institute of Astronomy (Maarten Reyniers, Pieter De Groote), Department of Physics and Astronomy, K.U.Leuven

List of international partners without grant

- Dennis Bodewits (KVI Atomic Physics, Groningen & Goddard Space Center)

C.1.6. Publications

C.1.6.1. Publications in press, submitted

[2] Degroote, P., Bodewits, D., **Cuypers, J.,** Waelkens, C.
The rotation and coma profiles of comet C/2004 Q2 (Machholz),
Astron. Astrophys. Submitted

Educational responsibilities

- Jan Cuypers: co-promotor at the KULeuven of master student Pieter De Groote.

C.1.7. Missions

Research visit (days): J. Cuypers (5)

DEPARTMENT 4: Solar Physics

SECTION 8: Structure and Dynamics of the Solar Atmosphere

SECTION 9: Solar Activity

The Department of Solar Physics is in principle divided in two sections: Structure and Dynamics of the Solar Atmopshere (section 8) and Solar Activity (section 9). This historical division is however of no more relevance and consequently omitted in what follows.

The Solar Physics Department of the Royal Observatory of Belgium is internationally known as the 'Solar Influences Data analysis Center' and will be referered to as SIDC in the remaining of this report.

Introduction

The year 2007 has been another vibrant time for the SIDC, and we trust that the following sections of this report account for our exciting scientific production in this period. The investigations carried out by team members have led to more than 20 refereed publications in 2007, including an article in the journal Science (Reale, Parenti, Reeves et al, Science 2007). More than 70 oral and poster presentations were given in 2007 conferences by team members. Our involvement in instrumental developments, whether ground- or space-based, has further matured, and the SIDC services have been praised by their users.

During 2007, Judith de Patoul, Gisèle Evrard, Matthieu Kretzschmar, and Gareth Lawrence left the SIDC, while Matthijs Krijger, Olivier Lemaître, Erik Pylyser, Andrew Stanger, Stéphane Vanraes, and Andrea Verdini entered the team.

Judith de Patoul started a PhD in solar physics at MPS in Germany. Gisèle Evrard retired in February 2007 leaving behind a vacant ICT position, and above all, many years of good services. Matthieu Kretzschmar obtained a permanent academic position at the Orléans University in France.

Andrew Stanger has been hired from January 16 on a PRODEX SWAP position. Matthijs Krijger took on August 1 the SIDC scientific staff position that he had obtained in 2006. On August 17, Andrea Verdini started to work on Solar Orbiter science supported by the SIDC Data Exploitation project. In October and November 2007, Stéphane Vanraes and Olivier Lemaître were hired on permanent positions. Finally, just before the end of the year Erik Pylyser started to work on the Solar Orbiter EUI project that was being actively prepared at that time. Additionally the organization of the SOHO20 conference benefitted from the temporary support of Tatiana Willems, Eric Pottiaux, and Marjolein Duran.

In June 2007, Jean-François Hochedez took Department headship after David Berghmans had resigned.

On 27 Feb 2007, Eva Robbrecht held very succesfully her PhD defence.

A big disappointment in 2007 was the delay of the PROBA2 launch date from May 2008, by about a year. In order to ensure the launch date, a firm agreement with the launch authorities should have been in place by the end of 2007. The absence of such an agreement motivated the SWAP and LYRA PIs to contact the General Director of ESA J. Dordain and express our worries. His answer re-assured us that ESA is doing all it can to get PROBA2 launched as soon as possible. Unfortunately, as a consequence of the unconfirmed launch date, the support to SWAP and LYRA by the ESA Science Directorate (through the Nationally Led Mission program) remained not implemented. Nevertheless useful and interesting work has been carried out and is reported in the corresponding sections below.

In 2007, the emergence of STCE activities has, amongst other things, allowed starting the refurbishment of the Humain radio station.

R. Van der Linden, ROB General Director, but still active within the SIDC, remained member of the NASA Prediction Panel of cycle 24 (SC24PP), who published its first conclusions during the annual Boulder Space Weather Workshop.

The involvement of SIDC as an international actor in Space Weather research and services has been highly visible during the fourth European Space Weather Week (ESWW4) organized by the SIDC with for the first time STCE support in November 2007 at the Royal Library in Brussels.

Earlier in the year, in late August, the very successful SOHO20 conference was organised in Ghent, Belgium by the SIDC as the twentieth occurrence of the high-status series of SOHO conference. It has been a great success due to the high quality of the contributed and invited presentations and the impeccable organisation.

The last few months of 2007 have been very demanding as the EUI consortium, led by J.-F. Hochedez, Principal Investigator, and strongly supported by the SIDC EUI team, made headway toward the ESA called proposal, successfully submitted on 15 January 2008. Athough the instrument selection is not known at the time of this writing, the preliminary feedbacks from the Agency are positive.

The SIDC team looks forward to further stimulating research and projects in 2008 and beyond.

A. Research Theme "Solar eruptions investigations"

The intrinsic dynamic nature of the Sun has its most visible expression in the form of eruptive events. Their study is of high relevance for the SIDC, and has a two-fold interest. The first interest is related to space weather in the near-Earth environment, which is driven by the Sun and most directly by the solar wind and the transient solar events carried along with it. The second interest, related to the first, relies on the importance of understanding the fundamental science leading to the origin and development of solar transients. Among them, we can name Coronal Mass Ejections (CMEs), Corotating Interaction Regions (CIRs), flares and EIT waves as the important manifestations of the ever-changing solar atmosphere.

A.1. Flares studies

A.1.1. Objectives

Solar flares represent a major type of solar transients and are interrelated to other manifestations of solar activity such as Coronal Mass Ejections (CMEs) and Active Regions (ARs). Flares are defined by a localized and sudden increase of solar radiance. They play a significant role in the generation of Solar Energetic Particles (SEPs) and in the variability of the Earth ionosphere. Their geo-effects are thus quasi-immediate (they are different from CMEs in this respect), while the prediction of their timing, location and magnitude is still in its infancy. Investigations on their precursors are therefore required. Various imaging instruments observe indicators of the accumulation of magnetic energy. EUV imagers such as SOHO-EIT, STEREO-EUVI and soon PROBA2-SWAP and SDO-AIA can offer pertinent information, but flares are also the main short-term features in radiometers time-series. Their physics will progress thanks to instruments such as PROBA2-LYRA and SDO-EVE. New approaches such as quantitative statistical studies are called in order to improve flare prediction.

A.1.2. Progress and results

Delouille et al **[1]** presented an algorithmic method that identifies and characterizes flares. It reliably detects flares in sequences of EUV images and catalogs their properties (location, intensity, size). Using data from EIT, we have compared the extracted EUV parameters with X-ray flares detected by GOES. A first analysis on STEREO-EUVI image series has been carried out.

During a flare, the emission at various wavelengths increases with diverse strength at different times corresponding to several physical processes. The respective contribution of various wavelengths to the TSI, as well as their timing, is not well known. Kretzschmar et al **[3]** have shown that -on average- a flare produces an increase of the TSI of a few ppm (and up to 30 ppm), for flares ranging from C to X levels. About the same increase is observed in the optical and near infrared (NIR) as measured by SPM. White light flares are also shown to be a systematic feature of flares. The 0.1-50 nm range amounts to only 40% of the observed increase in the TSI. Hence, the GOES classification does not necessarily reproduce the importance of a flare at all wavelengths.

A.1.3. Perspective for next years

PROBA2-LYRA and SDO-EVE data are expected to generate interesting flare studies, but imaging observations such as PROBA2-SWAP and SDO-AIA too. Although Catherine Timmermans had to decline the BELSPO "Action 2" **[6]** grant that was approved for her, the collaboration with her and the Institute of Statistics will go on. In this frame, the confidence for various precursors will be estimated on the basis of Functional Data Analysis (FDA), which is able to take time series instead of scalars as input to forecasting schemes. The HPKB (HelioPhysics Knowledge Base) initiated by the SDO team in LMSAL goes obviously in the direction required to identify hidden correlations **[2]**. HPKB and this project will mutually support each other.

A.1.4. Personnel involved

Scientific staff: V. Delouille, M. Kretzschmar, J. de Patoul, B. Nicula, J.-F. Hochedez

A.1.5. Partnerships

List of international partners without grant

- T. Dudok de Wit, M. Kretzschmar, LPCE, Orléans, France
- W. Schmutz, PMOD-WRC, Davos, CH
- K. Schrijver, LMSAL, Palo Alto, Ca, USA

List of national partners without grant

- S. Dewitte, S. Mekaoui, RMI, Brussels
- C. Timmermans (PhD student), R. von Sachs, Statistics Institute, UCL, LLN

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- LYRA Preparation to Exploitation PEA

A.1.6. Publications

A.1.6.1. Publications with peer review

[1] Lilensten, J.; Dudok de Wit, T.; Amblard, P.-O.; Aboudarham, J.; Auchère, F.; **Kretzschmar, M.**
Recommendation for a set of solar EUV lines to be monitored for aeronomy applications
Annales Geophysicae, Volume 25, Issue 6, 2007, pp.1299-1310, 2007

A.1.6.2. Publications in press, submitted

[2] Dudok de Wit, T.; **Kretzschmar, M.;** Aboudarham, J.; Amblard, P.-O.; Auchère, F.; Lilensten, J.
Which solar EUV indices are best for reconstructing the solar EUV irradiance?
Advances in Space Research, Volume 42, Issue 5, p. 903-911, 2008

[3] Lilensten, J.; Dudok de Wit, T.; **Kretzschmar, M.;** Amblard, P.-O.; Moussaoui, S.; Aboudarham, J.; Auchère, F.

Review on the solar spectral variability in the EUV for space weather purposes
Annales Geophysicae, Volume 26, Issue 2, 2008, pp.269-279

A.1.6.3. Reports, thesis, etc

[4] **Delouille V., Hochedez, J.-F.**
Report on flare detection performance
Local report, 15 Jan 2007

[5] Timmermans, **Delouille, Hochedez**
Analyse de données fonctionnelles appliquées à la physique solaire et à l'étude des relations Terre-Soleil
FNRS proposal, 1 Feb 2007

[6] Timmermans, **Delouille, Hochedez**
Statistical exploration of solar activity and solar-terrestrial relationships
Action 2 proposal, 15 Feb 2007 [successful]

[7] **Delouille, Hochedez**
Report on flare forecasting possibilities
Local report, 30 Mar 2007

A.1.7. Scientific outreach

Meeting presentations

[1] **V. Delouille, J. de Patoul, B. Nicula, J.-F. Hochedez**
Flare recognition in Solar EUV Images (contributed talk given by VD)
5th SECCHI Consortium Meeting, 5-8 March 2007

[2] Schrijver, Carolus J.; Hurlburt, N. E.; Cheung, M. C.; Title, A. M.; **Delouille, V.; Hochedez, J.-F.; Berghmans, D.**
Helio-informatics: Preparing For The Future Of Heliophysics Research (contrib. talk given by KS)
American Astronomical Society Meeting 210, #25.14

[3] **M. Kretzschmar** ; T. Dudok de Wit ; S. Mekaoui ; W. Schmutz ; **J.F. Hochedez;** S. Dewitte
The response of total solar irradiance to flares (contributed talk given by MK)
SOHO 20, Ghent, Belgium, 27-31 August 2007

National and international responsibilities

- J-F Hochedez: PI of the LYRA instrument on the ESA PROBA2 mission
- V. Delouile and M. Kretzschmar: Co-I of the LYRA instrument on the ESA PROBA2 mission
- J-F Hochedez: Associate Investigator of the AIA instrument on the NASA SDO mission

Meeting organization

- D. Berghmans, J.-F. Hochedez: SOC & LOC members of the HPKB mtg (30 people), ROB, 20-22 June 2007
- J.-F. Hochedez: SOC member of the SMESE workshop, IAS, Orsay, Mar 2008

Educational responsibilities

- V. Delouille: Co-promoter of Catherine Timmermans' PhD

A.1.8. Missions

Assemblies, symposia (number): V. Delouille (1)

A.2. CME studies

A.2.1. Objectives

Coronal Mass Ejections (CMEs) represent the other major type of solar transients. A CME is a bubble of plasma threaded with magnetic field lines that is ejected from the Sun over several hours and may hit the Earth after a few days. It can then deeply affect the near-Earth environment. CMEs are conventionally defined as such only when observed by coronagraphs. Lower down, one studies their on-disc precursors and signatures. Further out in the heliosphere, one speaks of interplanetary CMEs (ICMEs), detected in-situ mainly by plasma and magnetic field measurements. The CME/ICME structure is believed to maintain its identity all along during is propagation through the heliosphere. Questions regarding their origin, internal structure and dynamics are unanswered.

An impressive fleet of spacecraft providing remote solar observations (SOHO, TRACE, STEREO, and HINODE) and in-situ data (ACE, Wind, Ulysses, SOHO, STEREO) operating in 2007 have offered great opportunities for the investigation of solar eruptive events and their influences on space weather. SOHO-LASCO is the first space coronagraph that has detected CMEs routinely over a solar cycle, complemented at present by the COR instruments onboard STEREO. On-disc signatures of CMEs are observed by EUV imagers such as SOHO-EIT and now by SECCHI-EUVI from both STEREO spacecrafts. HINODE and TRACE provide high resolution images of the solar atmosphere, helping to understand the elusive processes leading to solar eruptions. Of special importance for space weather are ACE (located at the L1 point between the Earth and the Sun) and Wind (located in the near-Earth space as well), and together with Ulysses their contribution to ICME studies is highly valuable.

The idea of the present research is to provide a link between the different aspects of the CME phenomenon, including attempts at reconstructing their geometry in 3D from STEREO data, studies of outstanding global events (eruptions affecting a large fraction of the corona), investigations of their rate and statistical distributions over SOHO years, and analysis of in-situ multi-spacecraft data relevant to their cruise through the heliosphere.

A.2.2. Progress and results

A.2.2.1. Stereoscopic 3D reconstruction of STEREO – EUVI data and study of the origin of CMEs

The STEREO (Solar TErrestrial RElations Observatory) mission provides an unprecedented perspective on the Sun. STEREO comprises two identical spacecraft located at different positions along the Earth's orbit. The images obtained from the STEREO – SECCHI (Sun Earth Connection Coronal and Heliospheric Investigation) instrument suite, onboard both spacecrafts, can be combined to obtain information on the 3D structure of solar features by means of stereoscopic and 3D reconstruction techniques. L. Rodriguez and S. Gissot have used SECCHI – EUVI (Extreme Ultraviolet Imager) data from both spacecraft. Special hardware is used to display the observations in a stereoscopic manner. A stereoscopic image couple is presented to the left and right eyes of the viewer, and the human brain produces a feeling of depth. The second approach to obtain quantitative results is a tie-point technique based partially on tools in the SolarSoftware package. Manual association of features in both images delivers their altitude. The method is straightforward but limited by possible ambiguities in the definition of the tie-points. It is moreover time-consuming. The third method consists in having the association done automatically via local correlation tracking (1D or 2D LCT). A complete automated procedure was developped. It allows us to perform the calculation of the altitude of every pixel in the images without any kind of user interaction. The 2D LCT method delivers higher quality estimations than its 1D predecessor, but still needs further testing and refinement before its results become scientifically useful **[8][9][10][11]**. Finally, the fourth method is based on optical flow, and reported by Gissot et al in **[7]**.

A.2.2.2. Study of outstanding global CME events

A new type of CMEs – global CMEs – was first described by A. Zhukov **[1]**. Observations of the low solar corona in the extreme ultraviolet and in soft X-rays evidence a close relationship between coronal dimmings and CMEs. Dimmings are usually interpreted as places of plasma evacuation during the CME eruption. A. Zhukov characterized a CME by the apparent angular extent of associated dimmings above the solar limb and defined a global CME as a CME with the total apparent extent of limb dimmings of more than 180 degrees. Several examples of global CMEs were discussed. All the global CMEs identified up to now are fast full halo CMEs associated with X-class flares (if they originate on the front side of the Sun). It was demonstrated that global CMEs involve an eruption of several magnetic flux systems distributed on a large spatial scale comparable to one-half of the solar disk (true angular width around 180 degrees). Possible interpretations of the global CME phenomenon and challenges it presents to CME modeling were discussed. These results suggest a nonlocal nature of the CME eruption mechanism **[1]**.

During his visit to the Mullard Space Science Laboratory (UK), A. Zhukov has investigated properties of coronal dimmings associated with CMEs and their recovery. It was found that, contrary to some previous results, dimmings recover not only by shrinking their outer boundaries but also by internal brightening. It was also demonstrated that the ICME connectivity to the Sun is maintained even after the complete recovery of corresponding coronal dimmings. This fact can be explained in terms of interchange reconnection of open manetic field lines in dimmings with surrounding closed fields of the quiet Sun, which merely disperses the open field lines while maintaining their open configuration. A paper describing these results is in preparation.

A.2.2.3. Statistical and Cycle investigation using CACTUS (Computer Aided CME Tracking)

The CACTus software package is designed to automatically detect coronal mass ejections (CMEs) in coronagraphic images from LASCO onboard SOHO. The detection of a CME is done in two steps from running difference images: (1) detection of bright features moving radially outward and (2) clustering those detections into "CACTus CMEs".

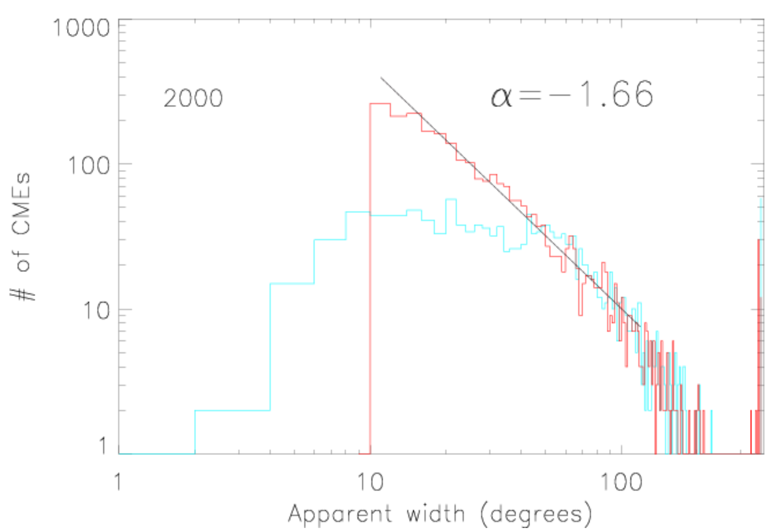

Figure 49. Log-log plot of the apparent CME width distribution for year 2000, it is representative for all other years. The CDAW CME widths (blue) are log-normally distributed, broadly peaked around 30◦ while the CACTus CME widths (red) display a power law behavior, meaning the CME widths θ are distributed according N (θ) = N_0 θ^α with power α ≈ −1.66, where N (θ) is the number of events with angular extent θ and N_0 a constant.

In 2007, the CACTus CME catalog has been exploited. E. Robbrecht has extended the previous catalog, which now runs from September 1997 to March 2007 i.e. over quasi all solar cycle 23. She has thereafter performed a rigorous statistical analysis on the whole catalog. She studied the evolution of the CME characteristics over the solar cycle and compared them with similar results obtained by manual detection. Not only this proved that automated CME detection is possible, but also that significant differences exist between the CME parameters deduced from CACTus and the ones that had been registered in the manually assembled CDAW catalog. We stress that these are not just a consequence of differently measuring the CME parameters, but mainly due to the consideration by CACTus of many small events, which are discarded by human observers. This has lead to a discussion on the very definition of the CME phenomenon. Automated detection not only serves operational applications but it also challenges scientific understanding. In **Figure 49**, we plot the CME width distributions from both catalogs. The CACTus distribution is in red while the CDAW is in blue. A remarkable difference in CME widths between the two catalogs is seen. Contrarily to CDAW, the CACTus CME widths seem to be power-law distributed, which could indicate that eruptions and restructuring of the coronal magnetic field is a scale invariant process **[4]**: there is no typical size of a CME. Such behaviour is well known for e.g. flares, but it is an important new result for CMEs.

A.2.2.4. Multi-spacecraft studies directed towards the understanding of the CME evolution

When CMEs are detected in the interplanetary space by means of in-situ data they are termed interplanetary CMEs (ICMEs). They are identified by a set of signatures in magnetic field and plasma data **[3]**. The study of ICMEs is normally hampered by the fact that the in-situ data used represent only a 1D cut through the full 3D structure. To increase the amount of information available, one has to use data from several spacecraft. Currently L. Rodriguez and A. Zhukov are using data from ACE, Ulysses and SOHO **[6]**. Multi-spacecraft studies are best suited to help unveiling open questions regarding the evolution and internal structure of CMEs. Furthermore, the use of Ulysses data gives a different perspective due to its orbit, which provides us with the opportunity to study ICMEs at high latitudes in the heliosphere **[2][6]**. When the source region is clearly discernable, EUV and white light data can be used in order to correlate characteristics seen during eruption with those measured later in-situ **[6]**.

A magnetic cloud (MC) is a special kind of ICME in which the magnetic field vector presents a smooth rotation, the plasma temperature is low and the magnetic field intensity is high with a low variance. It is believed that magnetic clouds are the interplanetary manifestation of flux ropes expelled from the Sun during a CME. Thus, a flux rope model can be applied to those ICMEs which present a cloud structure, using data from the different satellites, in order to get a better approximation of what the global structure of magnetic clouds may look like **[6]**.

At high energies, the elemental composition of energetic particles (~1 MeV/nuc) was studied in relation to MCs. Statistically, using a dataset of 40 MCs, we found that the relative abundances of the particles inside magnetic clouds are consistent with those found for gradual solar energetic particle events (SEPs), which correspond to particles accelerated at shocks driven by CMEs. However, there are isolated cases in which flare particles are detected. They represent a signature of impulsive solar energetic particle acceleration. In this respect, we have investigated one MC observed by Ulysses in 2001 for which there are imprints of flare acceleration seen in the composition of energetic particles, and as well in the charge state distributions of solar wind ions **[5]**.

A.2.2.5. Technical works in view of the exploitation of the STEREO mission

Following the STEREO launch in late 2006, the SECCHI data (EUVI, COR, and HI) became available in early 2007. A local archive has been set up and routinely populated with the SECCHI data.

The Solar Weather Browser and the CACTus software were adapted to the SECCHI data by D. Berghmans, G. Lawrence, C. Marqué, and E. Robbrecht. An example of a CACTus CME detection in STEREO data is shown in Figure 50. D. Berghmans wrote IDL routines for the production of XML event files by CACTus. These event files will eventually be used for a Solar Event Database (SED) and for the Heliospheric Knowledge Base (HPKB, SDO). E. Robbrecht made CACTus results available online via www.sidc.be/cactus.

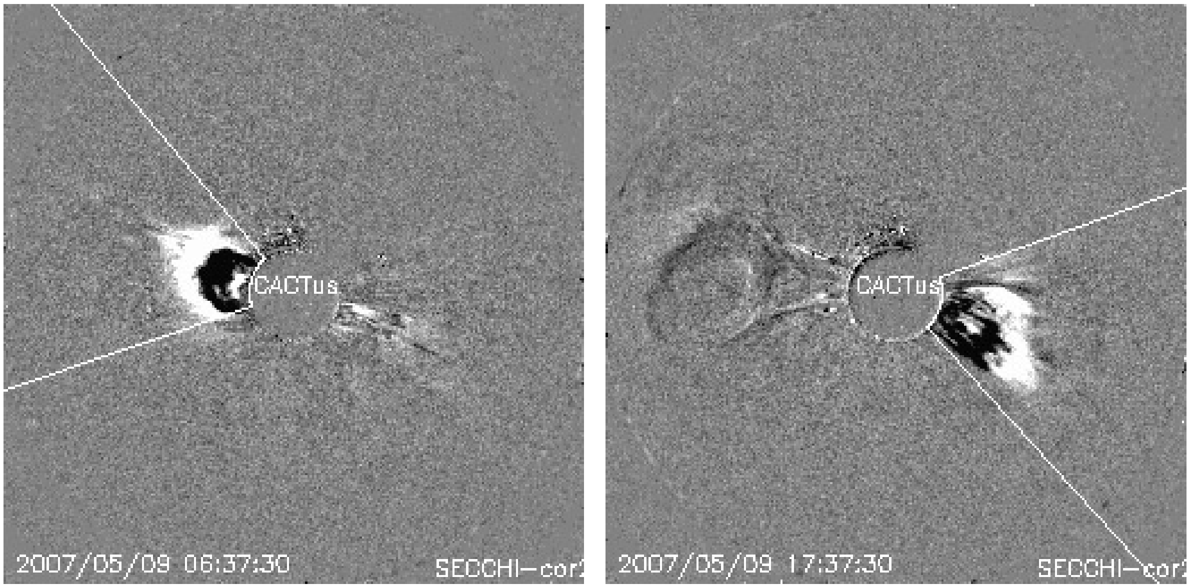

Figure 50: Two examples of a CACTus CME detection in running difference STEREO/COR2 images. Bright material resembles ejected coronal mass. The white lines indicate the edges of the detected CMEs. The field-of-view for COR2 goes from 2 to 15 Rsun.

We have further rewritten the CACTus software such that we will soon be able to update the version in the SolarSoftWare[5].

A.2.3. Perspective for next years

CME investigations will continue as they are essential to the SIDC research as well as to its space weather application. The STEREO-SECCHI data will be recorded and analysed in various ways. As the angular separation of the spacecraft increases, new studies become possible. While it becomes more difficult to carry out stereoscopic inversion, due to the increasingly different points of view of the two spacecraft, the possibility of studying the same CME from a side- and a frontal-view can bring interesting new results. Additionally, the advent of the new solar cycle should provide many more STEREO observations of CMEs, with a potential of outstanding events. A preliminary list of interesting events was already compiled. Several Sun – Earth connection events well observed by STEREO were identified. These events will be investigated by the SIDC team members and the STEREO community.

The proposal for a 1 year visit of a non-EU research fellow (Marilena Mierla) was selected. She will work on low coronal aspects of CMEs.

A prospect group for an ISSI proposal is being put together and should address the different stages of the Sun-Earth connection.

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[5] The SolarSoftWare (SSW) system is a set of integrated software libraries, databases, and system utilities which provides a common programming and data analysis environment for solar physics. The SSW system is built from Yohkoh, SOHO, SDAC and Astronomy libraries and draws upon contributions from many members of those projects. It is primarily an IDL-based system, although some instrument teams integrate executables written in other languages. The SSW environment provides a consistent look and feel at widely distributed co-investigator institutions to facilitate data exchange and to stimulate coordinated analysis.

A.2.4. Personnel involved

Scientific staff: A. Zhukov, L. Rodriguez, E. Robbrecht, G. Lawrence, S. Gissot, C. Marqué, D. Berghmans

A.2.5. Partnerships

List of international partners without grant

- STEREO – SECCHI consortium
- STEREO team, Max-Planck Institute for Solar System Research, Germany.
- Solar Physics group at the Department of Applied Maths, University of Cambridge, U.K.
- I. S. Veselovsky, Skobeltsyn Institute of Nuclear Physics, Moscw State University, Russia
- G. Attrill, Mullard Space Science Laboratory, University College of London, UK
- L. Trichtchenko, Geomagnetic Laboratory, Natural Resources Canada
- J. Zhang, George Mason University, USA

List of national partners without grant

- S. Poedts, CPA, KUL

Grants/Projects used for this research/service

- Preparation to the exploitation of STEREO PEA
- Solar Drivers of Space Weather PEA
- SIDC Data Exploitation PEA
- Preparation to the exploitation of SWAP PEA

A.2.6. Publications

A.2.6.1. Publications with peer review

[1] **A. N. Zhukov** and I. S. Veselovsky
Global Coronal Mass Ejections
The Astrophysical Journal, 664, L131–L134, 2007

[2] Gazis P. R., Balogh A., Dalla S., Decker R., Heber B., Horbury T., Kilchenmann A., Kota J., Kucharek J., Kunow H., Lario D., Potgieter M. S., Richardson J. D., Riley P., **Rodriguez L.**, Siscoe G., von Steiger R.
Interplanetary coronal mass ejections in the outer heliosphere and at high latitude
Space Science Reviews, Vol. 123/1-4, 2007.

[3] Wimmer-Schweingruber R. F., Crooker N., Balogh A., Bothmer V., Forsyth R. J., Gazis P. R., Gosling J. T., Horbury T., Kilchenmann A., Richardson I. G., Richardson J. D., Riley P., **Rodriguez L.**, von Steiger R., Wurz P., Zurbuchen T. H.
In-situ Solar Wind and Field Signatures of Interplanetary Coronal Mass Ejections
Space Science Reviews, Vol. 123/1-4, 2007.

A.2.6.2. Publications in press, submitted

[4] **Robbrecht, E., Berghmans, D., Van der Linden R.A.M**.
CME rate during solar cycle 23 and the scale invariance of CMEs
Accepted in ApJ Letters, 2008

[5] **Rodriguez L.**, Krupp N., Woch J., Fraenz M.
Elemental abundances of energetic particles within magnetic clouds detected by Ulysses
The Astrophysical Journal, in press, 2007.

[6] **Rodriguez L.**, **Zhukov A. N.**, Dasso S, Mandrini C. H., Cremades H., Cid C., Cerrato Y., Saiz E., Aran A., Menvielle M., Poedts S., Schmieder B.
Magnetic Clouds seen at different locations in the Heliosphere
Annales Geophysicae, Volume 26, Issue 2, 2008, pp.213-229

[7] **S.F. Gissot, J.-F. Hochedez**, P. Chainais, J.-P. Antoine
3D Reconstruction from SECCHI-EUVI Images Using an Optical-Flow Algorithm: Method Description and Observation of an Erupting Filament
Solar Physics, Volume 252, Issue 2, pp.397-408, 2008

A.2.6.3. Reports, thesis, etc

[8] **A. N. Zhukov**
STEREO-SECCHI: Preparation to Exploitation and Exploitation
PRODEX Project Performance report, 2007

[9] **Robbrecht, E**.
New Techniques for the Characterisation of Dynamical Phenomena in Solar Coronal Images
PhD Thesis, defence on 28 February 2007 at the KULeuven

A.2.7. Scientific outreach

Meeting presentations

[1] **Gissot, S. F.; Hochedez, J.-F.**
3D with EUVI images using optical flow (contributed talk)
5th SECCHI Consortium Meeting, Orsay, France, 5-8 March 2007

[2] **Robbrecht, E., Berghmans, D., Van der Linden R.A.M**.
The statistical importance of narrow CMEs: Open questions to be addressed by SECCHI (talk)
5th SECCHI Consortium Meeting, Orsay, France, 5-8 March 2007

[3] **Robbrecht, E., Berghmans, D., Van der Linden R.A.M.**
New perspectives on CME rates and their distributions (invited talk)
SOHO20 conference, August 2007, Gent, Belgium

[4] **Robbrecht, E., Berghmans, D., Van der Linden R.A.M.**
New perspectives on CME rates and their distributions (talk)
Seminar at George Mason University, October 2007, Washngton DC, USA

[5] **Robbrecht, E., Berghmans, D., Van der Linden R.A.M.**
New perspectives on CME rates and their distributions (talk)
ILWS meeting, September 2007, Boulder, USA

[6] **A. N. Zhukov**
Nouvelles observations de la couronne solaire et la physique des CMEs
Workshop « Nouveaux utiles pour la compréhension de la couronne solaire », June 19 – 20, 2007, Meudon, France

[7] **A. N. Zhukov**, I. S. Veselovsky
Global Coronal Mass Ejections
SOHO-20 Conference “Solar Transients”, August 27 – 31, 2007, Ghent, Belgium

[8] **Rodriguez L**.
Data from STEREO, an overview and introduction to stereoscopy
Seminar of the Astrophysics group in the Department of Applied Maths, Cambridge, England, February 2007

[9] **Rodriguez L., Zhukov A. N., Marqué C.**
Study of CME related phenomena using STEREO/EUVI data
American Geophysical Union 2007 Joint Assembly, Acapulco, México, May 2007

[10] **Rodriguez L., Zhukov A. N., Gissot S., Marqué C.**
3D Reconstruction of CME-related Phenomena Using STEREO/SECCHI/EUVI Data
IUGG XXIV General Assembly, July 2 – 13, 2007, Perugia, Italy

[11] **Rodriguez L., Zhukov A. N., Gissot S., Marqué C**.
The use of combined STEREO-A/B EUVI data in CME related studies,
SOHO 20 – Transient Events on the Sun and in the Heliosphere, Ghent, Belgium, August 2007.

[12] **Rodriguez L.**, **Zhukov A. N.**, Cid C., Cremades H., Dasso S., Aran A., Cerrato Y., Mandrini C., Menvielle M., Poedts S., Saiz E., Schmieder B.
On the Geoeffectiveness of Frontside Full Halo CMEs
ESWW 4, Brussels, Belgium, November 2007.

National and international responsibilities

- D. Berghmans, F. Clette, J.-F. Hochedez, O. Podladchikova, E. Robbrecht, A. Zhukov: STEREO-SECCHI Co-Investigators

Websites

- http://sidc.be/cactus

A.2.8. Missions

Assemblies, symposia (number):	D. Berghmans (1), J.-F. Hochedez (1), G. Lawrence (1), O. Podladchikova (4), E. Robbrecht (1), L. Rodriguez (3), A. Zhukov (4), S. Gissot (1)
Commissions, working groups (days):	A. Zhukov (1), O. Podladchikova (4)
Research visits (days):	E. Robbrecht (15), L. Rodriguez (1), A. Zhukov (5), O. Podladchikova (6)

A.3. EIT waves

A.3.1. Objectives

EIT waves (also known as coronal shock waves) came into focus in 1997, when a propagating disturbance on a large area of the solar disc was discovered in EIT data. The process underlying and relating EIT and Moreton waves are still under discussion, and this is the objective of this research project to confirm or falsify some of them. Are EIT waves fast MHD waves, or not?

A.3.2. Progress and results

In 2007, we have further developed the topological approach introduced by C. Delannée, in which the phenomenon would proceed from plasma compression and Joule heating instead of the classical fast-magnetosonic wave mode. Delanneé, Hochedez and Aulanier **[1]** reported on a halo CME that was observed on May 2, 1998. It was related to an EIT wave, a Moreton wave, an X class flare, radio emission sources, and dimmings. We studied this event to find the relationship between all these structures. We have co-aligned multi-wavelength observations and the online potential field source surface (PFSS) model. The observed EIT and Moreton waves present brightenings that remain at the same location, and we have related them to the connectivity of the coronal potential magnetic field. The stationary brightenings occur where the field exhibits drastic jumps of connectivity. EIT and Moreton waves may involve Joule heating resulting from electric currents in the neighboring area of these jumps, while the magnetic field lines are opening during a CME.

In a follow-up paper **[2]** (and talk **[4]**), we compared quantitatively two alternative interpretations for EIT waves: fast-mode magnetosonic waves versus the direct signature of the gradual opening of magnetic field lines during a CME (cf. **[1]**). Using independent 3D MHD codes, we performed dimensionless numerical simulations of a slowly rotating magnetic bipole. They generate progressively a twisted magnetic flux tube and then its fast expansion. We analyse the origins, the development, and the observability in EUV of the narrow electric currents sheets that appear in the simulations, and confront it with well-known SOHO-EIT observations of EIT waves (7 April and 12 May 1997). The timing, orientation, and location of observed patches are remarkably well reproduced, and we conjecture that propagating EIT waves can be the observational signature of Joule heating in electric current shells that separate expanding flux tubes from their surrounding fields during CMEs or plasma compression inside this current shell. We also propose that the bright edges of halo CMEs correspond to plasma compression in current shells.

A.3.3. Perspective for next years

The study of EIT wave is a core topic of the SIDC and will be pursued. Future progress will depend on the observations by PROBA2-SWAP and SDO-AIA from 2009 on.

In 2007, an "Action 1" proposal was submitted and granted by C. Marqué and D. Berghmans to study coronal shock wave signatures related to flares and coronal mass ejections. The idea is to gather a sample of very well observed events, using the scientific opportunity brought by new generation instruments (STEREO, SWAP…) and the current solar cyle period (minimum) where such events propagate relatively far from the eruptive site due to the simplicity of the global solar magnetic field. We plan to extract from these individual studies a set of generic properties in order to understand the physical nature of these phenomena. These properties will be collected both by direct data analysis and by forward modeling of these events. Dr. J. Magdalenic has been selected in Feb 2008 to work on that project.

The objective of the ICARUS project (Belgium Italy travel grant) is to determine the properties of the coronal plasma in solar dynamics events, exploiting the experience in the data analysis of the ROB and the heritage in numerical simulations of the Department of Astronomy and Space Science of Florence. Numerical simulations are also foreseen, consisting of a 2D representation of the solar surface in which the magnetic flux emergence disturbs the initial equilibrium state. The modeling will be an attempt to verify a scenario, in which an avalanche of reconnection events produces the observed EIT waves. If this is the case, particle acceleration is also achieved when reconnection occurs. Estimates of the energy and spectra of accelerated particles can be given, so that a comparison with observations could be made.

A.3.4. Personnel involved

Scientific staff: J.-F. Hochedez C. Marqué, A. Verdini, A. Zhukov, O. Podladchikova , D. Berghmans

A.3.5. Partnerships

List of international partners without grant

- G. Aulanier, LESIA, Meudon observatory, Meudon, France.
- T. Török, MSSL, UK
- J. Burkpile, S. Gibson & G. de Toma, HAO, Boulder, Colorado
- K.-L. Klein, Observatoire de Paris, Meudon, France
- V Krasnoselskikh & Thierry Dudok de Wit, LPCE, Orléans, France
- V. Yurchyshyn, Big Bear Solar Observatory, Big Bear City, California
- M. Velli, JPL, Pasadena, California

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- "Global waves and shocks in the corona: origin, nature, inverse & forward modeling" Action 1
- ICARUS – FW/AD/I/ad/4293 Commisariat général aux Relations internationales de la Communauté française de Belgique. Project Leader: J.F. Hochedez (Belgium), M. Velli (Italy)

Visitors:

- C. Delannée, 27 June 2007, and 27-29 August 2007

A.3.6. Publications

A.3.6.1. Publications with peer review

[1] Delannée, C.; **Hochedez, J.-F.;** Aulanier, G.
Stationary parts of an EIT and Moreton wave: a topological model
Astronomy and Astrophysics, Volume 465, Issue 2, April II 2007, pp.603-612

A.3.6.2. Publications in press, submitted

[2] Delannée, C.; Török, T.; Aulanier, G.; **Hochedez, J.-F.**
A New Model for Propagating Parts of EIT Waves: A Current Shell in a CME
Solar Physics, Volume 247, Issue 1, pp.123-150, 2008

A.3.6.3. Reports, thesis, etc

[3] **Marqué, C.; Berghmans, D.**
Global waves and shocks in the corona: origin, nature, inverse & forward modeling
Action 1 proposal

A.3.7. Scientific outreach

Meeting presentations

[4] C. Delannée, T. Török, G. Aulanier, **J.-F. Hochedez**
A non wave model for coronal waves (invited talk given by C. Delannée, 28 Aug.)
SOHO 20, Ghent, Belgium, 27-31 August 2007

A.4. Solar and interplanetary disturbances causing severe geomagnetic storms

A.4.1. Objectives

The objective of the project is to study the sources (in the corona and in the inner heliosphere) of the strongest geoeffective disturbances that occurred during the solar cycle 23.

A.4.2. Progress and results

A. Zhukov has published a review paper **[1]** about forecasting of geomagnetic storms using the observations of CMEs. The respective roles of photospheric, low corona EUV and coronagraphic observations in the process of geomagnetic storm forecasting were discussed. In most of the cases, EIT and LASCO are capable of identifying the eruption of an Earth-directed CME, and provide us with a good estimate of the arrival time. Some indications of the resulting ICME's magnetic configuration can be obtained. It was demonstrated, however, that predicting CMEs before they actually occur is still a challenge. The profile of the interplanetary magnetic field north – south component is difficult to predict. Additionally, false alarms (e.g. from partial halo CMEs) or missed events (when solar signatures are inconclusive) can occur. Forecasting may also be difficult if the geometry of a CME is not clear or in complicated cases of multiple (interacting) CMEs. To monitor and forecast ICME propagation more precisely, CMEs should be tracked from a vantage point out of the Sun–Earth line, as will be provided by the STEREO mission when the angular separation is sufficient.

A. Zhukov participated in the international study of the November 2004 geomagnetic storm events, one of the largest space weather events of the solar cycle 23. The real-time monitoring and forecasting of the events during this period (which was one of the most difficult periods to forecast) was discussed. A. Zhukov identified nine halo CMEs, interacting on their way through the interplanetary medium and forming two geoeffective interplanetary structures that produced this complex event. Forecast of the CME propagation was critically analyzed and warnings issued by regional warning centers revealed certain deficiencies in predictions of interplanetary characteristics of ICMEs **[2]**.

A. Zhukov has also actively participated in an international collaboration **[3]** studying solar and interplanetary sources of major geomagnetic storms (minimum Dst < –100 nT) occurred in 1996–2005. On the basis of careful examination of the complete array of solar and in situ solar wind observations, the overall solar and interplanetary sources were identified and characterized for each major geomagnetic storm. The storm-driving component, which possesses a prolonged and enhanced southward magnetic field, may be an ICME, the sheath of shocked plasma upstream of an ICME, a corotating interaction region (CIR), or a combination of these structures. Solar and interplanetary sources were classified into three broad types: (1) S-type, in which the storm is associated with a single ICME and a single CME at the Sun; (2) M-type, in which the storm is associated with a complex solar wind flow produced by multiple interacting ICMEs arising from multiple halo CMEs launched from the Sun in a short period; (3) C-type, in which the storm is associated with a CIR formed at the leading edge of a high-speed stream originating from a solar coronal hole. For the 88 major storms, the S-type, M-type, and C-type events number 53 (60%), 24 (27%), and 11 (13%), respectively. For the 85 events for which the surface source regions could be investigated, 54 (63%) of the storms originated in solar active regions, 11 (13%) in quiet Sun regions associated with quiescent filaments or filament channels, and 11 (13%) were associated with coronal holes. Remarkably, nine (11%) CME-driven events showed no sign of eruptive features on the surface or in the low corona (e.g., no flare, no coronal dimming, no post-eruption arcade, etc.), even though all the available solar observations in a suitable time period were carefully examined. Thus while it is generally true that a major geomagnetic storm is more likely to be driven by a frontside fast halo CME associated with a major flare, the results of the study indicate a broad distribution of source properties. The results of the study are important for space weather forecasting **[1]**.

A.4.3. Perspective for next years

The project was finished in 2007. The collaboration with the teams that participated in the project will be continued.

A.4.4. Partnerships

List of international partners without grant

- Max-Planck-Institut für Sonnesystemforschung, Lindau, Germany
- Skobeltsyn Institute of Nuclear Physics, Russia
- IZMIRAN, Russia
- Astronomical Institute, Czech Republic

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- ESA INTAS grant 03-51-6206

A.4.5. Personnel involved

Scientific staff: A. Zhukov, R. Van der Linden

A.4.6. Publications

A.4.6.1. Publications with peer review

[1] **A. N. Zhukov**
Using CME Observations for Geomagnetic Storm Forecasting
In: J. Lilensten (ed.), Space Weather – Research towards Applications in Europe, Astrophysics and Space Science Library, volume 344, 5–13, 2007, Springer

[2] L. Trichtchenko, **A. Zhukov**, **R. Van der Linden**, S. M. Stankov, N. Jakowski, I. Stanisławska, G. Juchnikowski, P. Wilkinson, G. Patterson, A. W. P. Thomson
November 2004 space weather events: Real-time observations and forecasts
Space Weather, vol. 5, S06001, doi:10.1029/2006SW000281, 2007

[3] J. Zhang, I. G. Richardson, D. F. Webb, N. Gopalswamy, E. Huttunen, J. C. Kasper, N. V. Nitta, W. Poomvises, B. J. Thompson, C.-C. Wu, S. Yashiro, **A. N. Zhukov**
Solar and interplanetary sources of major geomagnetic storms (Dst <= –100 nT) during 1996–2005
Journal of Geophysical Research, vol. 112, A10102, doi:10.1029/2007JA012321, 2007

[4] Consolini, Giuseppe; **Kretzschmar, Matthieu**
Thermodynamics of rare events and impulsive relaxation events in the magnetospheric sub-storm dynamics
Planetary and Space Science, Volume 55, Issue 15, p. 2244-2250, 2007

A.4.7. Scientific outreach

Meeting presentations

[1] V. Bothmer, **A. Zhukov**
STEREO – Answering Space Weather Science Challenges (invited talk)
Fourth European Space Weather Week, November 5 – 10, 2007, Brussels, Belgium

A.4.8. Missions

Assemblies, symposia (number): A. Zhukov (1)
Research visits (days): A. Zhukov (4 days)

B. Investigations of the quiescent solar atmosphere and of the solar wind

The quiescent solar atmosphere and the solar wind express a physics that takes place at small spatial and short temporal scales. Fortunately, there exist now a range of observational and theroretical diagnostics, which allow developing knowledge around abstract concepts such as turbulence, reconnection, and nanoflares, believed to explain coronal heating and solar wind acceleration. Whether they build upon forward modeling, spectroscopic analysis, or coronal sesimlogy, most projects reported under the present theme link macroscopic observations with fundamental yet hidden phenomena. The last three projects however address on the contrary the large-scale regions and structures in the solar atmosphere, or the long time scale of the solar cycle.

B.1. Turbulent coronal heating and solar wind acceleration in coronal holes

B.1.1. Objectives

This project intends to provide a theoretical background for exploitation and interpretation of observations from current and future space mission (HINODE, STEREO, HELEX). The longstanding problem of how the solar corona can be heated and the solar wind accelerated in coronal holes appears crucial considering the turbulent state of the plasma in these regions, and the fact that both the solar wind and the solar atmosphere are permeated by Alfvén waves, as confirmed by recent observations from Hinode and CoMP. We aim at understanding the origin of the turbulent spectrum in the solar wind and the ability of Alfvén waves to trigger nonlinear dynamics that can ultimately heat the solar corona through turbulent dissipation. The connection to the data is made through the comparison of small and large scale properties of the turbulent solar wind accelerated by this mechanism, namely: bulk flow, temperature and density of the solar wind, the evolution of the turbulent spectrum, and rms values for the velocity field fluctuation in the corona.

B.1.2. Progress and results

Recent spectropolarimetric analysis of the fluctuations in the low corona demonstrates that with current and future observation techniques the detection of Alfvén waves is becoming a possibility rather than a hope, foreseeing stronger constraints on the input parameters for any solar wind model. Some of these techniques have been developed for indirect detection of Alfvén waves based on observations of structures in coronal holes, such as plumes, jets and spicules that highlight the disturbances propagating along the magnetic field. Refinement of these methods is necessary to establish an unambiguous detection and involves a proper modeling of wave propagation in the chromosphere and transition region.

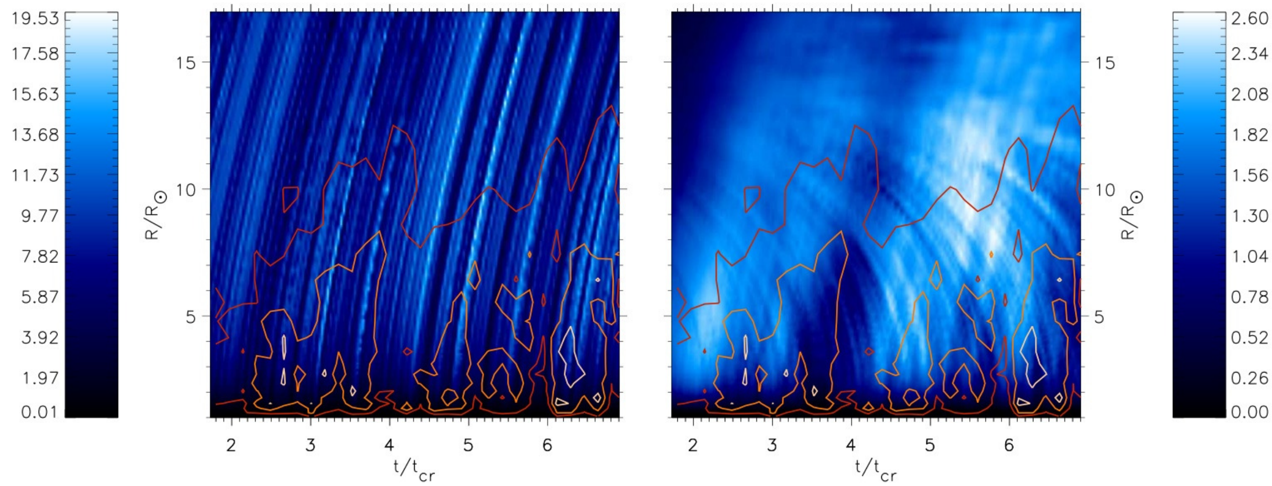


Figure 51. Contour of the outgoing and reflected Alfvén waves (left and right panel respectively) as a function of time and distance. On the right, one can distinguish two paths of the reflected waves, having the characteristic phase speed of the outgoing component and the ingoing one (speed=wind speed ± Alfvén speed respectively). Overplotted in red contour is the heating per unit mass. The dissipation follows the outgoing path and it is enhanced one crossing time after the outgoing and reflected waves overlap, triggering the turbulent cascade. It is expected that in the chromosphere and transition region, where reflection is stronger, the stratification becomes a fundamental element to trace the path of Alfvén waves, which are a mixing of outgoing and ingoing propagating disturbances, subject to strong nonlinear interactions.

B.1.3. Perspective for next years

The idea is hence to adapt the theoretical studies developed so far (an example is given in Figure 51) as a tool for detection of Alfvén waves in the Hinode observation of spicules. It is expected that the STEREO data, suffering form line of sight integration problems in less extent, will be more suitable for this kind of analysis, avoiding the statistical treatment necessary for Hinode data. Further developments on the theoretical side involve the inclusion of the solar wind dynamics (back reaction) in the model and of compressible effects. However, before such implementations can be made a detailed study on boundary conditions, such as the input spectra at the coronal base or at the photospheric level, must be performed. In fact the attained level of turbulence depends on the frequency of the waves and on the way they are injected (i.e. by velocity field fluctuations, as photospheric large scale motions, or by direct injection of Alfvén waves).

B.1.4. Personnel involved

Scientific staff: A. Verdini

B.1.5. Partnerships

List of international partners without grant

- M. Velli, University of Florence, Italy; and JPL-Pasadena, Ca, USA
- E. Buchlin, IAS-Paris, France.
- W. Matthaeus, Bartol Research Institute, University of Delaware, Newark, USA
- P. Dmitruk, Instituto de Astronomia y Fisica del Espacio, Buenos Aires, Argentina
- S. Oughton, Dep. of Mathematics, University of Waikato, New Zeeland

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA

B.1.6. Scientific outreach

Meeting presentations

[1] **Verdini A.**, Velli M., Matthaeus W., Buchlin E.
Alfvén waves and MHD turbulence in coronal heating and solar wind
IPAM reunion conference (UCLA), Lake Arrowed, CA, US, 7/12/07-12/12/07

B.1.7. Missions

Assemblies, symposia (number): A. Verdini (1)
Research visits (days): A. Verdini (2 days)

B.2. Coronal heating by turbulent dynamo driving

B.2.1. Objectives

The production of magnetic field by convective motions of the plasma is fundamental to explain the origin of solar magnetic fields and is the topic of MHD dynamo theory (Moffatt, 1978; Zeldovich *et al.*, 1983). Dynamo can also appear in the evolution of magnetic fields and is thus an important but still unobserved effect. Important progresses in the understanding of solar and terrestrial dynamos were made by Parker (Parker, 1955) and Steenbeck, Krause and Radler (Steenbeck *et al.*, 1966), when they introduced a mechanism known as the α-effect.

The α-effect belongs to kinematic dynamos, where the velocity V is imposed (the other type of dynamo, the MHD dynamo, takes into account the coupling between the velocity and the magnetic field). It is therefore a linear problem, which goal is to show the large scale growth of an initial "seed" of magnetic field.

Thus the question arises of how the small-scale α-effect participates in the larger-scale observable phenomena, and how the information about these small scales can be extracted from observations. This problem is treated in the framework of a numerical model, which allows one to switch between various parameters of the α-effect as diffusion coefficient and few magnetic field dissipative processes in the solar corona.

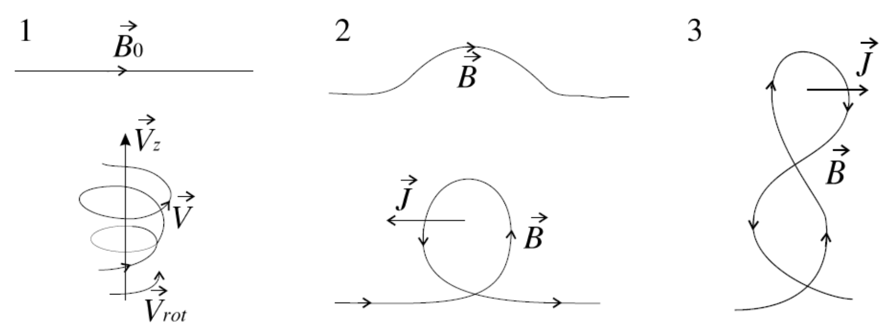
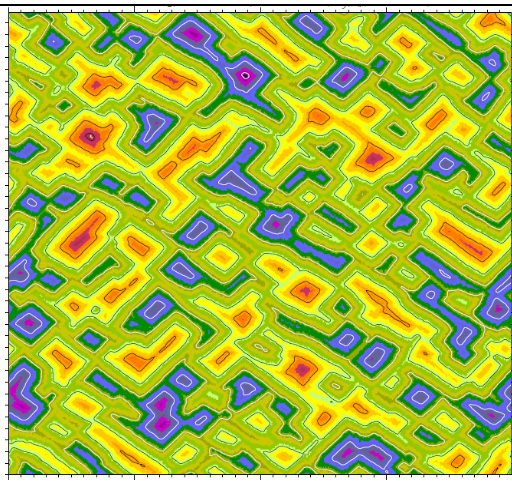
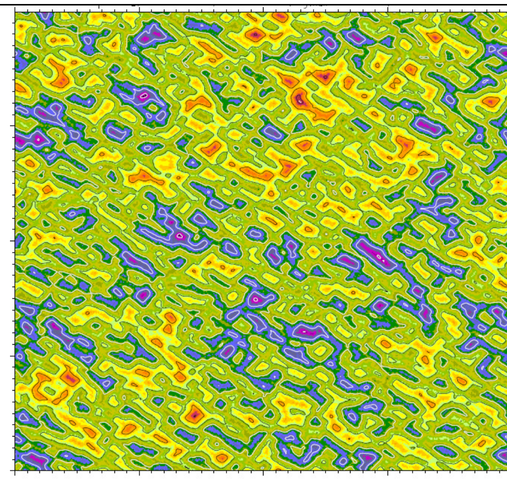


Figure 52. Helicity and principle of the α-effect. A rising vortex (1) forms a "bump" with magnetic field lines (2) twists them, thereby increasing magnetic energy.

B.2.2. Progress and results



a. α-effect vortices development broken-up by magnetic field dissipation only.



b. α-effect magnetic vortices development broken-up by magnetic field dissipation and diffusion.

Figure 53. Simulated magnetic field Bz, 1000x1000 km. Photospheric cross-section of Bz created by α-effect magnetic vortices

Our main result of 2007 is the development of the stable code. It is the first code able to investigate this kind of processes. The first results of code exploitation are demonstrated in Figure 53

It is impossible to observe the driving (photospheric magnetic field) or dissipating (EUV corona) effects because the structures which will correspond to the α-effect are broken up by the dissipative processes (magnetic field diffusion and dissipation) before the structures achieve the observational resolution.

B.2.3. Perspective for next years

- To exploit the code and to publish a series of papers.
- To find the method to uncover from experimental EUV and magnetic field data the underlying participation of the α-effect in the solar corona formation.

B.2.4. Personnel involved

Scientific staff: Elena Podladchikova, Ronald Van der Linden

B.2.5. Partnerships

List of international partners without grant

- V. Krasnosselskikh, LPCE/CNRS, Universite d'Orleans
- B. Lefebvre, Imperial College, London, UK
- T. Horbury, Imperial College, London, UK
- N. Vilmer, Paris Meudon, France
- R. Lin , UCB, Berkeley, USA

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA

B.2.6. Scientific outreach

[1] **O. Podladchikova**, B. Lefebvre, V. Krasnoselkikh, N. Vilmer, R. Lin
A new model of coronal heating (Invited Talk)

IAGA general Asssembly, Perugia, Italy, July 2007

B.2.7. Missions

Assemblies, symposia (number):	O. Podladchikova (1)
Research visits (days):	O. Podladchikova (2 days)

B.3. Sub-pixel analysis of solar images

B.3.1. Objectives

The solar UV observations made by imaging telescopes are limited by their spatial resolution and cadence. In this project, we aim at providing access to sub-pixel (and sub-exposure-time) information by:

- analysing the so-called spatial noise that stems from sub-pixel solar structures,
- simulating Quiet Sun images using stochastic processes,
- applying super-resolution method to enhance the spatial resolution.

B.3.2. Progress and results

B.3.2.1. Spatial and temporal noise in solar EUV observations

Solar telescope will probably never be able to resolve the smallest events at their intrinsic physical scales. The pixels of current and future EUV imagers thus contain a so-called “spatial noise” because their signal is the average of solar intensities having subpixel scales. We showed in **[3]** that it is possible to recover some information about subpixel spatial and temporal variability. If solar rotation induces a displacement of less than one pixel between two consecutive images, moments computed on sufficiently short time-windows give insight about sub-pixel spatial statistics as well as about temporal variability. It is then possible to discriminate sub-pixel behaviors between small structures and more uniform areas.

B.3.2.2. Multifractal analysis and synthesis of Quiet Sun EUV images

The High Resolution Imagers (HRI) onboard Solar Orbiter will have an unprecedented spatial pixel size of 80 km at the Sun during perihelion. But it is necessary to assess whether the expected radiance and the needed cadence can provide a sufficient signal-to-noise ratio. In **[4],** we first analyzed a set of 1997 Quiet Sun EIT images and showed evidence for scale-invariance (self-similarity). Our aim has then been to emulate the increase in resolution that takes place with (1) a resolution comparable to TRACE or SDO-AIA instead of EIT, and (2) a closer distance to the Sun. Our aim is to estimate the expected loss in SNR when going from a low to a high resolution. The low resolution was simulated by an appropriate coarsening of EIT images. The simulated loss in SNR is less than if it were a uniform source. Indeed, the Quiet Sun exhibits an irregular behavior, and we further quantify this property by estimating the multifractal spectrum of these images. We have designed tools to simulate Quiet Sun images having the same multifractal spectrum as the original images. We show that Compound Poisson Cascades **[1]** provide synthetic Quiet Sun images that mimic their statistical properties.

B.3.2.3. Enhanced resolution of solar images

It is possible to increase the resolution of EUV solar images using ‘super-resolution’ algorithms. They allow us e.g. to separate coronal loops better, or to resolve small events. Several algorithms have been proposed in the literature, and we chose for our application the inverse problem formulation proposed by Daubechies, Defrise and Demol (2004). Its solution is based on registration and L1-penalization, and assumes sparsity of the high-resolution image in an appropriate wavelet basis. We developed further the work performed by A. Eudes at SIDC in 2006. We generalized the method used for estimating the shift between the images by adopting an optical flow method. We applied the method on a set of STEREO-

SECCHI-EUVI images obtained with small scale artificial offpoints. Subpixel resolution can be achieved on a regular basis provided that small scale offpoints spread and known appropriately are available **[2]**.

B.3.3. Perspective for next years

Our near future goal relates mainly to §B.3.2.2 in view of the Solar Orbiter mission **[3]**. The aim is to simulate images at HRI resolution at perihelion, that is, at ~5 times better resolution than TRACE. In addition to preserving the singularity spectrum of the original images, the model should also maintain the histogram. This additional constraint increases the difficulty of finding an appropriate stochastic model.

V. Delouille and J.-F. Hochedez were awarded for the Tournesol project titled 'COSSMIC: Couronne Solaire, Segmentation et Modélisation d'Images par des Cascades' (Projet Tournesol 2007, scientific collaboration with Université de Clermont Ferrand and Université catholique de Louvain)

B.3.4. Personnel involved

Scientific staff: V. Delouille, J.-F. Hochedez

B.3.5. Partnerships

List of international partners without grant

- Pierre Chainais, Professor, Université Blaise Pascal Clermont II
- Vincent Barra, Professor, Université Blaise Pascal Clermont II
- Etienne Bordès, Student, Université Blaise Pascal Clermont II
- Frédéric Auchère, CNRS, Institut d'Astrophysique Spatiale
- Angelos Vourlidas, NRL, Washington, DC, USA
- Jean-Pierre Wuelser, LMSAL, Palo Alto, Ca, USA

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- CoSSMIC Tournesol project

Visitors:

- Pierre Chainais, Professor, Université Blaise Pascal Clermont II, 28 May-1 Jun 2007

B.3.6. Publications

B.3.6.1. Publications without peer review

[1] P. Chainais, **V. Delouille, J.-F. Hochedez**
Modeling images of the Quiet Sun in the extreme ultra-violet
Wavelets XII, Proceedings of the SPIE, Volume 6701, pp. 670111 (2007)

[2] P. Chainais, **V. Delouille, J.-F. Hochedez**
Modelisation des images de Soleil calme dans l'extreme ultra-violet
Actes de colloques du GRETSI

B.3.6.2. Publications in press, submitted

[3] **V.Delouille**, P.Chainais, **J.-F. Hochedez**
Spatial and Temporal Noise in Solar EUV Observations
Solar Physics, Volume 248, Issue 2, pp.441-455

[4] **V.Delouille**, P.Chainais**, J.-F. Hochedez**
Quantifying and containing the curse of high resolution coronal imaging
Ann. Geophys., Volume 26, Number 10, 2008, Page(s) 3169-3184

B.3.6.3. Reports, thesis, etc

[5] **V.Delouille, J.-F. Hochedez**
Analyse de l'aliasing spatial par une approche directe
Local report, 15 Mar 2007

B.3.7. Scientific outreach

Meeting presentations

[1] **V. Delouille**, P. Chainais, **J.-F. Hochedez**, V. Barra
Quantifying and containing the curse on high resolution coronal imaging (poster)
SOHO 20 Conference, Ghent, Belgium, 27-31 August 2007

[2] E. Bordes, **V. Delouille**, A. Eudes, **J.-F. Hochedez**
Super-resolution of EUV images using small scale offpoints (poster)
SOHO 20 Conference, Ghent, Belgium, 27-31August 2007

[3] **V. Delouille**, P. Chainais, **J.-F. Hochedez**
Quantifying and containing the curse on high resolution coronal imaging (oral)
EUI Consortium meeting, 17-19 October 2007

B.3.8. Missions

Assemblies, symposia (number): V. Delouille (1)

B.4. Coronal heating in Active Regions

B.4.1. Objectives

According to several theories, coronal heating processes would be mostly impulsive. Some consider that such heating occurs in *nanoflares* events of unresolved scales (Parker, 1988). The objective of this project is to test the nanoflare hypothesis in active regions, studying the problem from both the theoretical and the observational points of view.

B.4.2. Progress and results

ROB leads an international working group funded by ISSI which addresses the above objectives. In this frame, the following international investigations are in progress:

B.4.2.1. Thermal structure of active regions

The thermal structure of active regions (AR) is studied observationally with particular attention to small scales. The XRT high resolution (1") X-ray telescope onboard HINODE has appeared very adequate for this purpose. 2007 has been devoted to the development of a new method for plasma diagnostics, which exploits the nine broad-band channels of XRT, collectively sensitive to the 2-10 MK temperature range.

We called this technique *Combined Improved Filter Ratio* (CIFR). It is able to reveal for the first time a fine thermal structure at the limit of the instrumental resolution (~ 2") in ARs at T° > 2 MK. However, the CIFR technique has still some limitation when estimating the temperature with broadband instruments. Current work therefore addresses ways to reduce the uncertainties. The first results applying this technique on a quiescent active region were published in *Science* **[1]**. While testing the CIFR limits, the work has been extended towards flare and post-flare data.

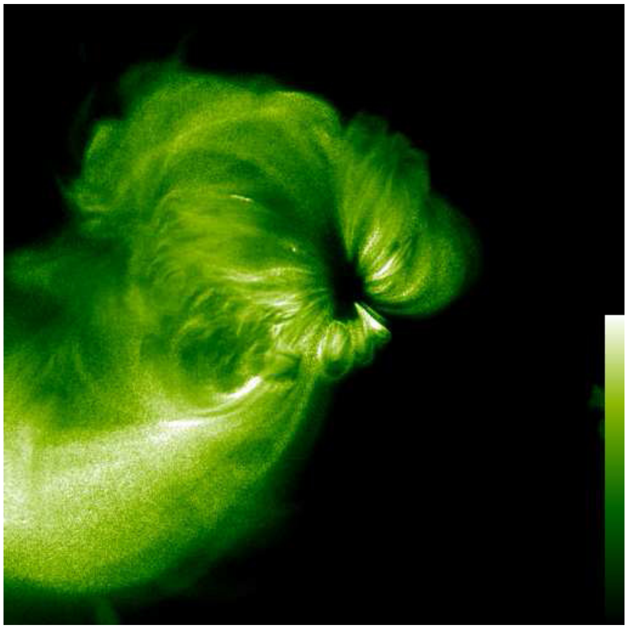


Figure 54. Temperature map of an active region produced by our new technique (the improved combined filter ratio, CIFR). From Reale et al. (2007).

B.4.2.2. Radiative signature of nanoflares

Nanoflares may originate from turbulent phenomena. In this case, their energy distribution must have a power-law behaviour and such an energy distribution is indeed verified at observed scales. To test the turbulent origin of nanoflares, it would be necessary to find their signature in the radiative emission of the heated plasma. Parenti et al. (2006) studied the conditions under which turbulent signatures in some coronal emission lines could be identified. They used a forward modeling of a coronal loop. In 2007, this work has been further extended to test the diagnostics capabilities of the lithium-like iso-electronic EUV lines. A work comparing the above theoretical results with observations is also in progress.

B.4.3. Perspective for next years

The CIFR technique needs to be further developed to improve the absolute calibration in temperature. The plan is also to extract the emission measure (EM) maps and compare the results with those from spectroscopic data. The final purpose is disentangling ambiguities present when analysing data from broadband instruments.

B.4.4. Personnel involved

Scientific staff: S. Parenti

B.4.5. Partnerships

List of international partners without grant

- Twelve people participating to the ISSI project that S. Parenti is leading
- F. Reale, University of Palermo-INAF, IT
- K. K. Reeves, Harvard-Smithsonian Center for Astrophysics, USA
- P. Young, Naval Research Laboratory, USA

Grants/Projects used for this research/service

- Chercheur Supplémentaire
- SIDC Data Exploitation PEA
- LYRA preparation to exploitation PEA

Visitors:

- Fabio Reale, University of Palermo-INAF, IT, Dec 2007

B.4.6. Publications

B.4.6.1. Publications with peer review

[1] Reale F., **Parenti S.**, Reeves K., Weber M., Bobra M G., Barbera M., Kano R., Narukage N., Shimojo M, Sakao T., DeLuca E.E., Peres G., Golub L.
Fine thermal structure of coronal active regions from Hinode/XRT

Science, 318, 1583, 2007

[2] Reale, F., **Parenti S.**, K. Reeves, Weber M., Bobra M G., Barbera M., Kano R., Narukage N., Shimojo M, Sakao T., DeLuca E.E., Peres G., Golub L.,
Magnetic activity and the solar corona: first results from the Hinode satellite
MnSAI, 78, 591, 2007

B.4.6.2. Publications in press, submitted

[3] **Parenti, S**., Reale, F., Reeves K.
Fine thermal structure of a flare with Hinode/XRT
2008, Proceedings for the 6th Hinode workshop, in press

[4] K. Reeves, **Parenti S.**, Reale, F, Weber M
Methods of Analyzing Temperatures in Post-Flare Loops using the XRT on Hinode
American Geophysical Union, Fall Meeting 2007, in press

B.4.7. Scientific outreach

Meeting presentations

[1] **S. Parenti**, E. Buchlin, P. Cargill, S. Galtier, P. Young, J.-C. Vial
Looking for signatures of coronal heating in the radiative emission of a coronal loop
3rd Coronal Loop workshop, June 2007 (oral presentation)

[2] **Parenti, S**., Reale, F., Reeves K.
Fine thermal structure of a flare with Hinode/XRT (poster)
6th Hinode workshop, 2008

National and international responsibilities

- S. Parenti: Lead of a working group funded by ISSI entitled "The role of spectroscopic and imaging data in understanding the coronal heating.": ***http://www.issibern.ch/teams/Spectdata***
- S. Parenti: Response to the ESA AO for European membership in the Hinode Science Working Team.

Educational responsibilities (Seminars, students …)

- S. Parenti **:** *Looking for signatures of coronal heating in the radiative emission of a coronal loop*, Palermo Astrophysics Observatory, 28-5-2007

B.4.8. Missions

Assemblies, symposia (number):	S. Parenti (3)
Commissions, working groups (days):	S. Parenti (4 days)
Research visits (days):	S. Parenti (5 days)

B.5. Plasma flows studied from spectroscopic ultraviolet observations

B.5.1. Objectives

Spectroscopic UV observations such as the ones allowed by SOHO-SUMER are highly suited to study flows of mass and energy, their velocities, and thereby, important coronal heating signatures.

B.5.2. Progress and results

In 2007, we have investigated spectroscopically the footpoints of AR loops and chromospheric spicules at chromospheric and TR (Transition Region) temperatures.

SUMER (the Solar Ultraviolet Measurements of Emitted Radiation instrument) is a telescope and spectrometer on SOHO (the Solar and Heliospheric Observatory spacecraft of ESA and NASA, launched in December 1995).

B.5.2.1. Plasma flow in active regions

Impulsive heating of coronal loops induces plasma flow from the lower layers of the solar athmosphere. This theory requires that both chromospheric evaporation and coronal condensation are present. In 2007, we have investigated Doppler shifts in active region loops. Marked and steady downflows were registered by SOHO-SUMER in both footpoints of loops in TR lines and at low corona temperatures. Those results were presented in a poster contribution at the SOHO20 conference **[1]**, and subsequently in a refereed publication for the conference proceedings **[1]**.

B.5.2.2. Solar chromospheric limb spicules

After a visit to J. Pasachoff's institute (Williams College), data reduction methods were introduced to his team **[2]**, and a series of SUMER spicule studies (performed together with TRACE and SST in 2004) were analysed.

B.5.3. Perspective for next years

The AR footpoint observations are compatible with the nanoflare picture, but the work needs to be extended to a wider range of temperatures (viz. coronal lines).

A common publication on spicules with J. Pasachoff and members of his team is possible. One of his students currently writes a thesis on this subject. Further co-operation regarding SUMER data involving other ROB-SIDC scientists is desired.

B.5.4. Personnel involved

Scientific staff: I. Dammasch, S. Parenti

B.5.5. Partnerships

List of international partners without grant

- W. Curdt, MPS, Lindau, Germany
- B. N. Dwivedi, BHU, India, and MPS, Germany
- U. Feldman, NRL, DC, USA
- J. Pasachoff, Hopkins Observatory, Williams College, Williamstown, MA, USA

Grants/Projects used for this research/service

- Travel costs for July 2007 visit granted by Williams College
- ISSI Coronal Heating team
- SIDC Data Exploitation PEA
- LYRA Preparation to Exploitation PEA

B.5.6. Publications

B.5.6.1. Publications in press, submitted

[1] **I. E. Dammasch**, W. Curdt, B. N. Dwivedi, **S. Parenti**
The Redshifted Footpoints of Coronal Loops
Ann. Geophys., Volume 26, Number 10, 2008, Page(s) 2955-2959

B.5.7. Scientific outreach

Meeting presentations

[1] **I. E. Dammasch**, W. Curdt, B. N. Dwivedi, **S. Parenti**
The Redshifted Footpoints of Coronal Loops (poster)
SOHO20 Conference, Ghent, Aug 2007

[2] **Ingolf E. Dammasch**
Solar UV Spectroscopy with SUMER on SOHO (seminar)
Colloquium, Williams College, 10 Jul 2007

[3] **Ingolf E. Dammasch**
Solar UV Spectroscopy with SUMER on SOHO (extended seminar)
SIDC Seminar, ROB, 11 Oct 2007

B.5.8. Missions

Assemblies, symposia (number):	I. Dammasch (1)
Research visits (days):	I. Dammasch (9 days)

B.6. Dynamic behavior of the chromosphere and Transition Region

B.6.1. Objectives

The objectives of this research project are to improve the understanding of the dynamics of the upper solar atmosphere, through studying the coupling between the different upper layers, employing space- and ground based observations in multiple wavelengths as well as physical modeling.

B.6.2. Progress and results

In recent years many different kind of oscillations have been observed in the solar chromosphere and transition region. However the question remains to which extent all oscillations in different lines and continua correlate in space and time. The degree of such correlations constrains the models of propagation and dissipation of waves in the chromosphere and higher layers.

In 2007 this research was continued, showing little correlation between lower chromosphere and lower transition region when observing different Lyman lines, UV continua and Ca II K. A publication has been submitted to present these results.

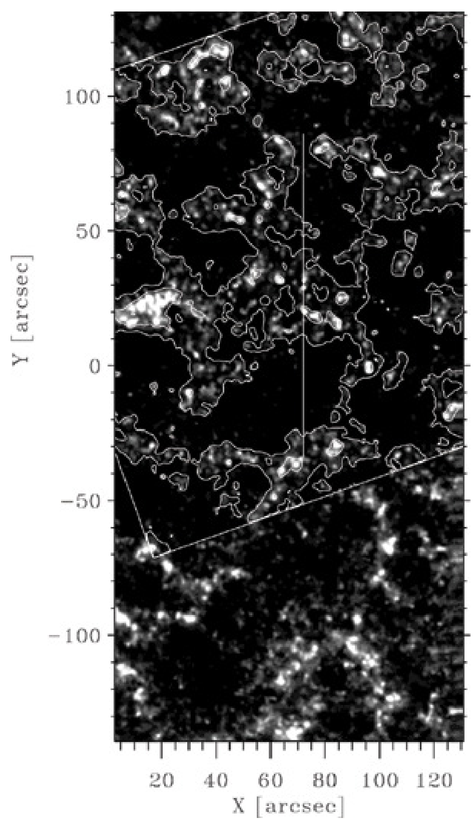


Figure 55. TRACE 160.0 nm image overlaid with contours of Ca II K from VTT and SUMER slit position (solid central line).

B.6.3. Perspective for next years

Cooperation is being prepared with the Centre for Plasma Astrophysics of the Catholic University of Leuven to combine magnetic non linear force free field modelling with chromospheric observations and study the magnetic connection between the different solar atmospheric layers.

B.6.4. Personnel involved

Scientific staff: J. M. Krijger

B.6.5. Partnerships

List of international partners without grant

- P. Heinzel, Astronomical Institute, Academy of Sciences of the Czech Republic, Ondrejov, Czech Republic
- W. Curdt, Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany
- W. Schmidt, Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany
- R. Rutten, Astronomical Institute, University Utrecht, Utrecht, Netherlands

B.6.6. Publications

B.6.6.1. Publications in press, submitted

[1] **J.M. Krijger**, P. Heinzel, W. Curdt, W. Schmidt
Dynamic behaviour of the upper solar atmosphere:II. SUMER/SOHO, TRACE and VTT observations
Astronomy&Astrophysics

B.6.7. Missions

Assemblies, symposia (number): J. M. Krijger (1)
Research visits (days): J. M. Krijger (1)

B.7. Coronal seismology

B.7.1. Objectives

The corona exhibits a large variety of oscillations, standing waves and propagating disturbances. They permit the determination of plasma physical parameters, and are essential processes. But on top of these interesting motions, movies of the solar atmosphere reveal as well modifications in brightness that can be due to density or temperature variations. Our aim in this project is to estimate simultaneously and to disentangle the apparent plane-of-the-sky velocity vector and the brightness variation (BV) from successive images.

B.7.2. Progress and results

The present work analyses solar extreme-ultraviolet images, as recorded by the Extreme-ultraviolet Imaging Telescope (EIT) on board the Solar and Heliospheric Observatory (SoHO) or by the Transition Region and Coronal Explorer (TRACE). In 2007, the fundamental elements of our Optical Flow algorithm (Velociraptor) have been published **[1]**, and applied to coronal seismology **[2]**. Movies of the solar corona in extreme ultraviolet (EUV) bandpasses exhibit complex patterns of magnetically structured plasma features surrounding the solar surface. Among the various phenomena observed, coronal oscillations are seen. Velociraptor is used to explore and analyse the oscillating motions of coronal loops. Velocity fields are estimated and selected features are tracked to form trajectories. The oscillating features are extracted via a Morlet wavelet analysis, which provides parameters such as the instantaneous period, the amplitude, or the phase anywhere along the loop.

B.7.3. Perspective for next years

Velociraptor represents an important pre-processing in the SDO-AIA pipeline, and must be ported to accomodate such data volume. Additional efforts also need to be devoted to make it available online to the community.

B.7.4. Personnel involved

Scientific staff: S. Gissot, J.-F. Hochedez

B.7.5. Partnerships

List of international partners without grant

- Vincent Barra, Pierre Chainais, ISIMA, Université de Clermont-Ferrand, France

List of national partners without grant

- Jean-Pierre Antoine, UCL, LLN

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- Tournesol project 'COSSMIC: Couronne Solaire, segmentation et modelisation d'images par des cascades'

Visitors:

- Short visits: E. Koenig

B.7.6. Publications

B.7.6.1. Publications with peer review

[1] **Gissot, S. F.; Hochedez, J.-F.**
Multiscale optical flow probing of dynamics in solar EUV images: algorithm, calibration, and first results
Astronomy and Astrophysics, Volume 464, Issue 3, March IV 2007, pp.1107-1118

B.7.6.2. Publications in press, submitted

[2] **Gissot, S. F.; Hochedez, J.-F.**
Oscillation analysis using optical flow: Application to an EUV movie of the solar corona
Statistical Methodology, Volume 5, Issue 4, p. 340-349, 2008

B.7.7. Scientific outreach

Meeting presentations

[1] **Gissot, S. F**.
Motion Analysis and multiscale algorithms. Application to EUV images of the solar corona
Université catholique de Louvain, Louvain-La-Neuve, "Semaine ondelettes", 27/04/2007.

Meeting organization

- Jean-François Hochedez: SOC member of the ADA5 workshop, May 2008

Websites

- http://sidc.be/velociraptor/

B.7.8. Missions

Assemblies, symposia (number):	S. Gissot (1)
Research visits (days):	S. Gissot (2 days)

B.8. Prominences and filaments

B.8.1. Objectives

The evolution and eventual eruption of prominences is not well understood. Spectroscopic observations of the chromospheric plasma as well as of the filament channel provide us with insights. Inside the cavity, the knowledge of physical parameters (electron density and temperature distribution) can give us the information about magnetic structure sustaining the filament.

B.8.2. Progress and results

B.8.2.1. Prominences

Parenti at al. 2005 built a FUV spectra atlas of a quiescent prominence. Using it, we derived the Differential Emission Measure **[3]**, the pressure, and the non-thermal velocities (NTV) in the prominence, which were then used to investigate the energy balance. If the NTV are interpreted as signature of waves, they cannot play an important role in balancing the energy losses by radiation. **[1].** Spectroscopic observations of prominences at the limb were also performed and their absorption and/or volume blocking interpreted **[2].**

B.8.2.2. Filament channels & cavities

A formal collaboration was set up with Dr. Sarah Gibson (HAO, Boulder) to study filament cavities at different wavelengths. She gathered a working group on that topic, in order to make coordinated observations (JOP) and coordinated data analysis. Work started with coordinated observations in August 2007. Data from various instruments, including radio data from Nançay radioheliograph have been processed.

B.8.3. Perspective for next years

We plan to expand the first investigatioin towards activated prominences. A new JOP led by S. Parenti has been approved: "*Eruptive and quiescent prominences with SOHO and Hinode",* it is to be held in April 2008. Its aim is to extend the existing atlas of quiescent prominences over a larger range of temperatures and to build a similar atlas for an activated prominence. It will allow quantifying and modeling the H I and He I continuum absorption and lines (the Doppler shift of the lines will be plotted as a function of tenperature), constraining the Prominence Corona Transition Region (PCTR) and studying its dynamics (Doppler shift, NTV, dimmings), and finally comparing these plasma properties between quiet and activated prominences

In the framework of S. Gibson's collaboration, more data analysis will be performed as well as a new JOP campaign in April 2008 too. The final goal is writing a review paper about filament cavities.

B.8.4. Personnel involved

Scientific staff: S. Parenti, C.Marqué, I. Dammasch

B.8.5. Partnerships

List of international partners without grant

- Sarah Gibson & Giuliana de Toma, High Altitude Observatory, Boulder, Colorado

- Durgesh Tripati, DAMTP, Cambridge, UK
- Therese Kucera, Goddard Space Flight Center, Greenbelt, Maryland
- Kathy Reeves, Center for Astrophysics, Cambridge, Massachussetts
- Jean-Claude Vial, Institut d'Astophysique Spatiale (Fr)
- Nicolas Labrosse, University of Glasgow (UK)

Grants/Projects used for this research/service

- ISSI team on prominences
- SIDC Data Exploitation PEA
- LYRA preparation to exploitation PEA
- Solar Drivers of space weather PEA

B.8.6. Publications

B.8.6.1. Publications with peer review

[1] **Parenti S.**, J.C. Vial
Prominence and Quiet-Sun plasma parameters derived from FUV spectral emission
Volume 469, Issue 3, July III 2007, pp.1109, A&A

[2] Heinzel, P.; Fárník, F.; Anzer, U.; **Dammasch, I.**
Limb Prominences Seen in UV, EUV and SXR
New Solar Physics with Solar-B Mission ASP Conference Series, Vol. 369, proceedings of the conference held 8-11 November, 2005 at The Kyoto International Community House, Kyoto, Japan. Edited by Kazunari Shibata, Shin'ichi Nagata, Takashi Sakurai. San Francisco: Astronomical Society of the Pacific, 2007, p.279

B.8.6.2. Publications in press, submitted

[3] **Parenti, S**., Vial, J.-C., and Lemaire, P.
Solar prominence properties derived from the UV-EUV SUMER spectral atlas
2008, Adv. Space Res., 41, 144.

B.8.7. Scientific outreach

Meeting presentations

[1] **S. Parenti,** J.-C. Vial
Prominence plasma investigations with SOHO/SUMER spectra (solicited talk)
IUGG XXIV

National and international responsibilities

- Leader of a JOP to be held in April 2008
- S. Parenti is partner of an international working group funded by ISSI. The project title is "Spectroscopy and Imaging of Quiescent and Eruptive Prominences from Space" (December 2007)

B.8.8. Missions

Assemblies, symposia (number): S. Parenti (1)

B.9. Forward modeling of the corona

B.9.1. Objectives

This project aims at modeling the electron density and temperature distribution of the quiet solar corona, which can then produce modeled coronal EUV images and modeled spectral irradiance time series. Potential extrapolations of the photospheric magnetic field (PFSS) are used to build the geometry of magnetic field lines that support the electron distributions **[1]**. The idea is to build a realistic yet easy to compute coronal model which could ultimately be used as a generic tool for the interpretation of observational data. The model has so far been applied to radio observations from the Nançay Radioheliograph **[1]**, and more recently to the EUV images from the SOHO-EIT instrument.

B.9.2. Progress and results

Some new ideas were initiated and tested in 2007. The extension of the modeling to the EUV spectrum has revealed the limitations of a single model to account for a wide range of temperatures and densities. This is illustrated in the figures below taken from a poster presented in meetings in Boulder and Brussels ([1] and [2]). The figures show that a given model can only fit one wavelength with a better accuracy than the other, both in terms of structures and overall irradiance. Figure 56 shows the observed corona (top) compared with the simulated one (bottom). Both simulated images were obtained with a model adjusted to fit the 28.4 nm spectroheliogram (on the right, in yellow). In Figure 57, the same model - adjusted to 28.4 nm and one given day - reproduces the integrated flux at 28.4 nm (bottom curves) over one year with fairly good accuracy. It reproduces the 19.5 nm variations (top) only in a relative way.

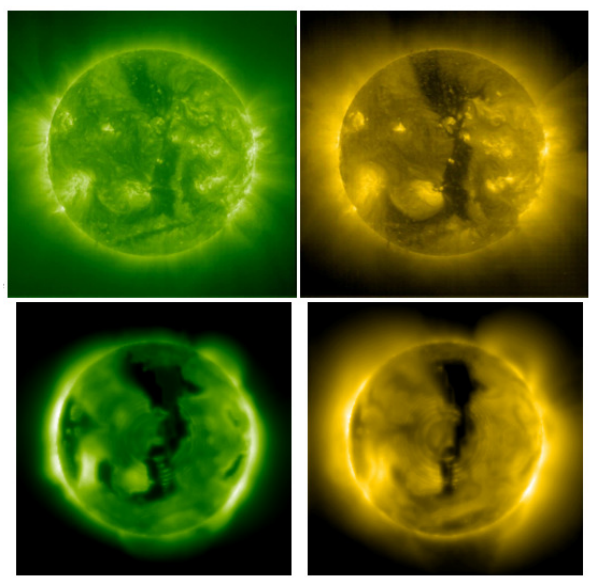


Figure 56: Comparison of observed (top) and simulated (bottom) EIT images at 19.5 nm (left in green) and 28.4 nm (right in yellow)

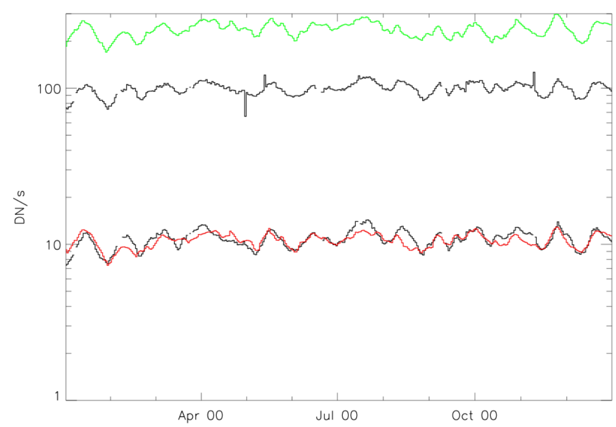


Figure 57: Evolution over one year of the integrated flux at 19.5 nm (top) and 28.4 nm (bottom). The green and red curves are the simulated flux at the same corresponding wavelengths

B.9.3. Perspective for next years

We want to finalize the publications related to the EUV and radio modeling. Our goal is also to extend this work to the modeling of the EUV and radio irradiance, at least in the range reachable by the model (coronal lines for EUV, and meter wave for the radio). It will thus become applicable to LYRA data exploitation.

B.9.4. Personnel involved

Scientific staff: C.Marqué, M. Kretzschmar

B.9.5. Partnerships

List of international partners without grant

- Dr. Y.-M. Wang & A. Thernisien, Naval Reasearch Laboratory, Washington DC, USA
- Dr. M. Kretzschmar, LPCE, Orléans, France (after leaving ROB)

Grants/Project used for this research/service

- Solar Drivers of space weather PEA
- LYRA Preparation to Exploitation PEA

B.9.6. Publications

B.9.6.1. Publications submitted

[1] **C. Marqué**, Y.-M. Wang, P. Reiser, A. F. Thernisien
Modeling of the metric radio emission of the quiet solar corona using potential field extrapolations
Submitted to the Astrophysical Journal

B.9.7. Scientific outreach

Meeting presentation

[1] **C. Marqué, M. Kretzschmar**
Forward modeling of the electron density and temperature distribution in the corona using EUV and Radio observations [poster]
Living with a Star Workshop, Boulder, USA, September 2007

[2] **C. Marqué, M. Kretzschmar**
Forward modeling of the electron density and temperature distribution in the corona using EUV and Radio observations [poster]
4th European Space Weather Week, Brussels, Belgium, November 2007

B.9.8. Missions

Assemblies, symposia (number): C. Marqué (2)

B.10. Segmentation of EUV solar images

B.10.1. Objectives

This project develops methods for segmenting EUV images into Coronal Holes (CH), Quiet Sun (QS) and Active Regions (AR). Segmentation has several applications: It allows determining automatically the location of Coronal Holes that are the source of the fast solar wind. Second, when the segmentation process is done on long series of images (using e.g. the SOHO-EIT archives), it produces time series of areas and mean intensities for the separate AR, QS, and CH structures, allowing for solar cycle studies. Thirdly, it permits to focus time-consuming post-processing on e.g. AR only. Moreover, this approach paves the way to bridging observations between imaging data and time series (from radiometers). Time series resulting form the segmentation of EUV coronal images can provide interesting information to reconstruct the solar spectrum.

B.10.2. Progress and results

Together with Vincent Barra (Université Clermont-Ferrand II), we have developed a multi-channel Spatial Possibilistic Clustering Algorithm (SPoCA). SPoCA is an unsupervised spatially-constrained fuzzy clustering algorithm that automatically segments EUV solar images into 3 classes: Coronal Holes, Quiet Sun and Active Regions **[2].** It manages the arbitrariness consecutive to the various noises present in the images and to the imprecision in the definition and borders of the above regions. We applied the algorithm to SoHO-EIT images taken from January 1997 till May 2005, viz. along almost a full solar cycle. Two EIT bandpasses (around 19.5nm and 17.1nm) were simultaneous input to SPoCA. We built three types of time series: for the areas, the mean intensities, and the integrated intensities of the three classes. They all exhibit various periodicities. To estimate precisely their characteristic frequencies, we performed a Morlet wavelet analysis, which can address non stationary oscillations. As expected, we measure a faster solar rotation period for AR than for CH. The other extracted frequencies are at 1-year and 1.6-year for CH on one hand, and at 2-year for both QS and AR on the other hand.

In the other work **[1],** we combined images from several passbands in a different way: we used a fuzzy clustering on each channel separately, and next we fused the membership maps using a fusion operator. Finally, we segment by assigning pixels to the class for which the fused membership is the highest. We also applied this second algorithm on the 8-year dataset, and obtained similar results as in **[2]**. Both segmentations are internally stabilized over the whole data set, but they show a contamination of the QS by the surroundings of an AR.

We then improved SPoCA by two means. First, we propose a correction for the limb brightening, which allows considering the solar corona up to 1.1 solar radii. Second, we reduce the contamination of the Quiet Sun by AR by over-segmenting images using more than the three desired classes (typically 6), and by aggregating them back into QS, AR, and CH.

B.10.3. Perspective for next years

We plan to further exploit SPOCA. For example, the present algorithm confuses coronal holes and filaments. We will also study the connection between time series obtained through segmentations and irradiance time series recorded by radiometers.

B.10.4. Personnel involved

Scientific staff: V. Delouille, J.-F. Hochedez, M. Kretzschmar

B.10.5. Partnerships

List of international partners without grant

- Vincent Barra, Université Blaise Pascal Clermont II
- Matthieu Kretzschmar, Université d'Orléans (previously ROB)

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- LYRA Preparation to Exploitation PEA
- CoSSMIC Tournesol project

Visitors:

- Vincent Barra, Professor, Université Blaise Pascal Clermont II, 19-22 Jun 2007

B.10.6. Publications

B.10.6.1. Publications with peer review

[1] V. Barra, **V. Delouille, J.F. Hochedez**
Segmentation of Extreme Ultraviolet Solar Images using a Multispectral Data Fusion Process
Proceedings of the IEEE International Conference on Fuzzy Systems (2007), London

B.10.6.2. Publications in press, submitted

[2] V.Barra, **V. Delouille, J.-F. Hochedez**
Segmentation of Extreme Ultraviolet Solar Images via Multichannel Fuzzy Clustering
Advances in Space Research, Volume 42, Issue 5, p. 917-925. (2008)

B.10.7. Scientific outreach

Meeting presentations

[1] **V. Delouille**, V. Barra, **J.-F. Hochedez**
Segmentation of EUV images (oral presentation given by VD)
1st Heliophysics Knowledge Base Workshop, Brussels, 20-22 June 2007

B.10.8. Missions

Research visits (days): V. Delouille (4 days)

B.11. Solar rotation and solar cycle investigations

B.11.1. Objectives

The general objective of this project is to advance the knowledge, phenomenology, and prediction of long-term evolutions of the Sun, and especially of the solar cycle. The assets of this project are the various archives of the SIDC, such as the International Sunspot Number archive (for which SIDC is the World Data Center) as well as the SOHO-EIT observations. In the last years, the specific objective of this project has been to relate solar activity with the solar (differential) rotation, and to accurately characterize the latter by tracing individual Bright Points in SOHO EIT images taken at 28.4 nm. Additionally, once traced, individual and global evolutions of BPs can be studied for their own sake.

B.11.2. Progress and results

A secular deceleration of the mean solar rotation in the 20th century was found in **[1]** by tracing sunspot groups. This variation also shows a finer modulation indicating a connection with the phase of the 11-year solar cycle. In the years 1902 and 1913 we have found possible rotational signatures of two weak solar activity cycles (Gleissberg minimum). The rotation velocity residual increased in these years for about 0.4°/day. This is in a qualitative and quantitative agreement with a similar rotational behaviour during the Maunder minimum. A qualitatively similar behaviour was also found on a shorter time scale for the period 1998–2000. As solar activity was increasing, the equatorial rotation velocity determined by tracing coronal bright points was decreasing (in this part of analysis monthly values were used). A dependence of the solar rotation velocity measured by magnetic tracers and solar activity and interplanetary magnetic field was found. Interplay between the Reynolds and the Maxwell stresses is proposed for the interpretation. As stated by Rüdiger & Hollerbach (2004), the more magnetic the Sun is, more rigid is its rotation.

In June 2007, F. Clette undertook a study of small high-latitude magnetic dipoles in EIT images. It showed that such spotless dipoles started to appear only in 2007 and that most of them had the magnetic polarity of the next solar cycle. So, these are potential early precursors of the new cycle, well before the first sunspots of the new cycle are observed.

B.11.3. Perspective for next years

The NASA SDO mission and its long lifetime open new perspectives for interesting long-term coronal phenomenology studies. Special attention could be given to potential long term evolutions of parameters associated to short-lived events such as bright points or flares. Their correlation with white light proxies could give new insights via the exploitation of the historical SIDC archive of white-light observation of sunspots. Another perspective is the application of our Optical Flow technique to EIT and AIA data. It can seamlessly and accurately monitor rotational parameters across large data sets.

B.11.4. Personnel involved

Scientific staff: J.-F. Hochedez, S. Gissot, F. Clette

B.11.5. Partnerships

List of international partners without grant

- Roman Brajsa, Hvar Observatory, University of Zagreb, Zagreb, Croatia
- Hubertus Wöhl, Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA

B.11.6. Publications

B.11.6.1. Publications with peer review

[1] Brajša, R.; Wöhl, H.; Ruždjak, D.; Vršnak, B.; Verbanac, G.; Svalgaard, L.; **Hochedez, J.-F.**
On the solar rotation and activity
Astronomische Nachrichten, Vol.328, Issue 10, p.1013, 2007

[2] Mulec, M.; Brajša, R.; Wöhl, H.; Hanslmeier, A.; Vršnak, B.; Ruždjak, V.; **Hochedez, J.-F.;** Engler, J.
Solar Rotation Velocity Determined by Coronal Bright Points - New Data and Analysis
Central European Astrophysical Bulletin, 31, (2007), 1, 1-10, Proc. 2nd Central European Solar Physics Meeting

B.11.6.2. Publications in press, submitted

[3] Brajša, R.; Mulec, M.; Hanslmeier, A.; Wöhl, H.; Ruždjak, V.; **Hochedez, J.-F.**
Coronal bright points as tracers for solar rotation in October-November 1999
Accepted in Central European Astrophysical Bulletin, Proc. 3rd Central European Solar Physics Meeting, Bairisch Koelldorf, Austria, 10-12 October 2007

B.11.7. Missions

Assemblies, symposia (number): F. Clette (1)

B.12. Large-scale structure of the quiescent solar corona

B.12.1. Objectives

The SOHO and the STEREO missions present a rich variety of opportunities for investigating the large-scale structure of the quiescent solar corona. We concentrate on the investigation of the properties of the coronal streamer belt on the base of coronagraphic and EUV image data.

B.12.2. Progress and results

A study of the three-dimensional structure of the streamer belt has been performed, in collaboration with the Laboratoire d'Astrophysique de Marseille (LAM). A model developed at LAM permits to simulate the quasi-stationary configuration of the streamer belt starting from the National Solar Observatory photospheric magnetograms and using the potential field source surface (PFSS) model. The synoptic maps of the streamer belt obtained with SOHO/LASCO C2 coronagraph and the simulated synoptic maps constructed from the model of the warped plasma sheet have been compared. The epoch of solar cycle maximum was addressed and the origin of polar streamers was investigated. A key conjecture is that polar streamers are "classical" streamers (loops with the current sheet above them) associated with polar crown photospheric neutral line. The position of the current sheet was found comparing the position of streamers, loops observed by EIT and of neutral lines of the photospheric magnetic field. To determine the position of the neutral lines, the synoptic maps produced by HelioSynoptics (Dr. P. McIntosh) were used. The method turned out to work surprisingly well and the positions of polar streamers were succesfully described. Such a description permits us to determine correctly the polarity of the heliospheric magnetic field during Ulysses polar pass in 2000 (in collaboration with L. Rodriguez) – a feature that has up to now escaped theoretical interpretation. The conclusion of the work is that during the solar cycle maximum the streamer belt has a configuration drastically different from the one given by the potential field source surface model. A paper describing these results has been submitted [1].

A study of the solar corona pressure scale height was continued. EIT images in all four bandpasses are taken and the profiles of radial decrease of the coronal brightness have been extracted from different position angles around the Sun. The profiles are fitted with isothermal curves using a more reliable method than in prevous studies and the properties of fits are being investigated.

B.12.3. Perspective for next years

The investigation of the streamer belt will be continued. The model will be applied to the STEREO/SECCHI data taking into account multiple viewpoints. The understanding of the quiet corona magnetic configuration will allow us to get an insight into the 3D structure of CMEs, using the observations of low corona CME counterparts (e.g. coronal dimmings). Investigation of the variation of the coronal pressure scale height with the solar cycle will be finalized with a goal to get an insight into the change of the coronal structure on a long temporal scale.

B.12.4. Personnel involved

Scientific staff: A. Zhukov, J. De Patoul

B.12.5. Partnerships

List of international partners without grant

- P. Lamy, A. Llebaria, F. Saez, Laboratoire d'Astrophysique de Marseille, France
- S. Koutchmy, Institut d'Astrophysique de Paris, France
- G. Stenborg, NASA Goddard Space Flight Center, USA

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- SIDC Telescience PEA

B.12.6. Publications

B.12.6.1. Publications in press, submitted

[1] **Zhukov A. N.**, Saez F., Lamy P., Llebaria A., Stenborg G.

The Origin of Polar Streamers in the Solar Corona
The Astrophysical Journal, Volume 680, Issue 2, pp. 1532-1541., 2008

B.12.7. Missions

Research visits (days): A. Zhukov (4 days)

C. Development and operations of solar instruments

The development of future solar instruments permits to maximize the design of experiments that will bring new observations and hence deeper investigations. Reciprocally, the data analysis of past observations drives the knowledge and therefore the content of the proposals in which SIDC participates. The same is true with science operations of existing space and ground based instruments. In 2007, SIDC has contributed to various developments and operations of both old and emerging projects.

C.1. Operations of solar optical observations at ROB

C.1.1. Objectives

The optical USET (Uccle Solar Equatorial Table) instruments are providing visual and CCD observations in support to the SIDC sunspot index determination, as one of the reference stations in the worldwide network. Long-term observations offer a continuous characterization of the solar activity and of the sources of irradiance variations. The introduction of white-light and Hα CCD imagers, now in routine use, marks also an ongoing effort to improve and better understand existing solar activity indices and to study new quantitative ground-based solar indices with modern electronic imaging techniques. The USET activities thus follow two main axes:

1/ Optical observations of the Sun and characterisation of its activity:

- Visual observations of sunspot, digitization and exploitation of drawings
- Digital imaging in white-light (photosphere) for synoptic observations
- Digital imaging in the H-alpha line (chromosphere) for real-time flare patrol observations.
- Digital imaging in the CaII-K line (chromosphere) for UV chromospheric flux indices (proxies).

2/ Digitization and processing of the visual sunspot observations of the Uccle station, and publication in the SIDC Bulletin of additional indices for this reference station:

- Total, hemispheric and central zone sunspot number (raw and normalized)
- PPSI index
- Classification (type, sunspot count, heliographic coordinates) and history of individual sunspot groups
- Dates of possible return of well developed sunspot groups (Zürich types E & F)

C.1.2. Progress and results

C.1.2.1. Observations and operational duties

- CCD synoptic images were acquired on a daily basis and automatically transferred to a dedicated archive and the latest images were uploaded to the SIDC servers and were displayed in the "Latest Solar Data" pages, together with imagery from other observatories and spacecrafts, for worldwide access.
- Uccle sunspot drawings were scanned immediately after the observations and included in near-real time in the "Latest Solar Data" web page of the SIDC, together with drawings from the Catania, Locarno and Crimea observatories. At the end of each month, all digitized drawings were processed to deliver the Uccle sunpot indices and sunspot group evolution data for the SIDC “Sunspot bulletin” (page 4).

- **2007 statistics for the sunspot observations** (table below):
  - Overall, there were less observing days than in 2006, which was a rather favorable year (-21 days). The total is similar to the one of 2005. The number of drawings is sigiificantly higher because a second drawing was made on many days, in an effort to take advantage of the best sky quality.
  - 11 observers contributed to the observations in 2007, with again the bulk of the observations done by two main observers and occasional support from voluntary scientists.

Observer	Duty days	Days with no observations	Days with observations	1 drawing	2 drawings	Total nb. Of drawings
Ben Moussa	1	0	1	1	0	1
Berghmans	20	6	14	4	10	24
Boulvin	137	57.5	79	15	90	195
Ergen	136	23.5	112	64	48	150
Clette	18	4	14	8	5	18
Laurence	1	1	0	0	0	0
Rodriguez	25	12	13	10	3	16
Theissen	12	3	9	1	8	17
Lemaître	9	3	6	2	4	10
Vanraes	5	3	2	0	2	4
Zhukov	1	1	0	0	0	0
Total	**365**	**114**	**250**	**105**	**170**	**435**

- **2007 statistics for the CCD observations**: less images were produced in 2007 than in 2006, again because of a lower number of usable clear days.

Camera	Nb. Days	Nb. Images
Photosphere	234	974
Chromosphere	234	950
Total	**234**	**1924**

C.1.2.2. Maintenance of the telescope and existing CCD camera system

No major failure took place on the telescope in 2007. The aging DALSA cameras worked almost flawlessly in 2007, except for the dead bit on the H-alpha camera: raw images are strongly degraded but can be recovered by software (like in 2006, there was not time to develop the correction software).

The new regular maintenance schedule was executed by A. Ergen and J-L Dufond. The telescope optics were cleaned on Feb.13. 2007 while the cameras were cleaned on March 28, and June 1st 2007. As no action was taken the Régie des Bâtiments to do repairs, the solar dome still suffered from water leaks on rainy days. In February, a study was undertaken regarding the possibility of reusing mechanical parts from the largely unused Triplet dome for replacing worn out parts of the solar dome: the components turned out to be slightly different and incompatible. Therefore, no quick improvement is thus possible to improve the worrying mechanical wear of the solar dome.

C.1.2.3. New camera systems (LOTTO funding)

- In June 2007, new cameras for the white-light, H-alpha and CaII-K telescopes were selected and ordered. We chose the KAF-4021 interline CCD array because of its high quantum efficiency in the near ultraviolet (40%) well adapted for CaII-K observations and because the interline readout is optimal for shutterless operations. Among the various cameras based on this sensor, the final choice came to the QImaging Retiga 4000R camera that provided the best signal-to-noise ratio at a reasonable price (Peltier cooled sensor) and also uses a simple standard Firewire data connection, much more flexible than on earlier DALSA cameras. 3 identical cameras were ordered in order to streamline system development and maintenance work and allow hot-swapping in case of malfunction of one of the cameras. The cameras were delivered Aug. 2007 and then went through a first laboratory evaluation.

- Software development: The camera software development and testing had to await the arrival of our new programmer in October 2007. Entirely new custom control software was developed. A first working version was tested at the end of the year.
- Extended Firewire connexion: in parallel, we investigated possible solutions for extending the Firewire bus in order to allow placing the control PC in the control room downstairs from the dome (fiber optics cables or multiple repeaters with standard copper cables). The necessary components for the latter cheaper option were order but were not yet delivered by the end of the year.

C.1.2.4. New H-alpha and CaII-K optics

- From February to June 2007, a focal reducer was designed to mate one old DALSA camera on the new H-alpha optics. Because of the long delays at the ROB mechanical workshop, in June 2007, the focus was shifted to the installation of the newly delivered cameras.
- In September 2007, the design and manufacturing of an adjustable optical mount for the new H-alpha optics and camera was initiated.
- In preparation of the new CaII-K telescope, a set of two identical interference filters (2 Å bandpass) were ordered in June 2007, based on the specification of the PSPT network (Osservatorio di Roma). Those custom-made filters were delivered on October 24, 2007. These are the most specialized ele-ments of the optical system that will be prepared in 2008.
- The new cameras were installed for a first end-to-end test run late in December 2007. Those tests demonstrated that the cameras performed very well in monochromatic light and provided a decisive improvement of image quality and resolution compared to the old system. However, the test revealed some defects that will be investigated early in 2008: presence of dust specks inside the camera optics and fogging of internal lenses due to outgassing from the heated Fabry-Pérot monochromator.

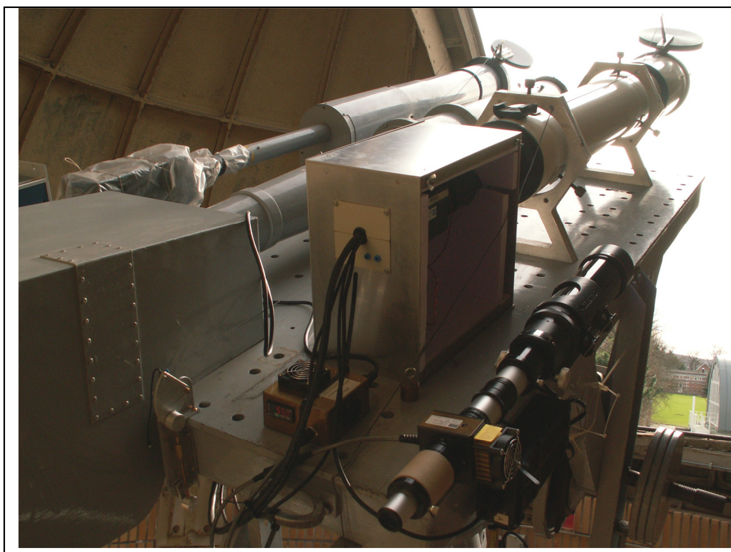


Figure 58. View of the new compact H-alpha telescope and Fabry-Pérot monochromator installed in a test configuration on the USET in February 2007 (black optical tube on the lower right). The white-light and old H-alpha CCD telescopes in operation since 2002 can be seen on its left. The large enclosure in the center harbours the white-light CCD camera.

C.1.2.5. USET data exploitation and distribution

- **Development of a new Web user interface and data browser:** In the context of a training work (Garyp Ramani, Bachelor in Computer science, ESI), new Web data access pages to the USET image archive were developed in order to improve the visualization and selection of USET images and increase their visibility on the SIDC site. The new USET data interface includes several new visualizations of the images (whole–rotation navigators using mosaics and movies) and a new data query interface including pre-visualization thumbnail images giving access to the existing SQL database (L. Wauters).

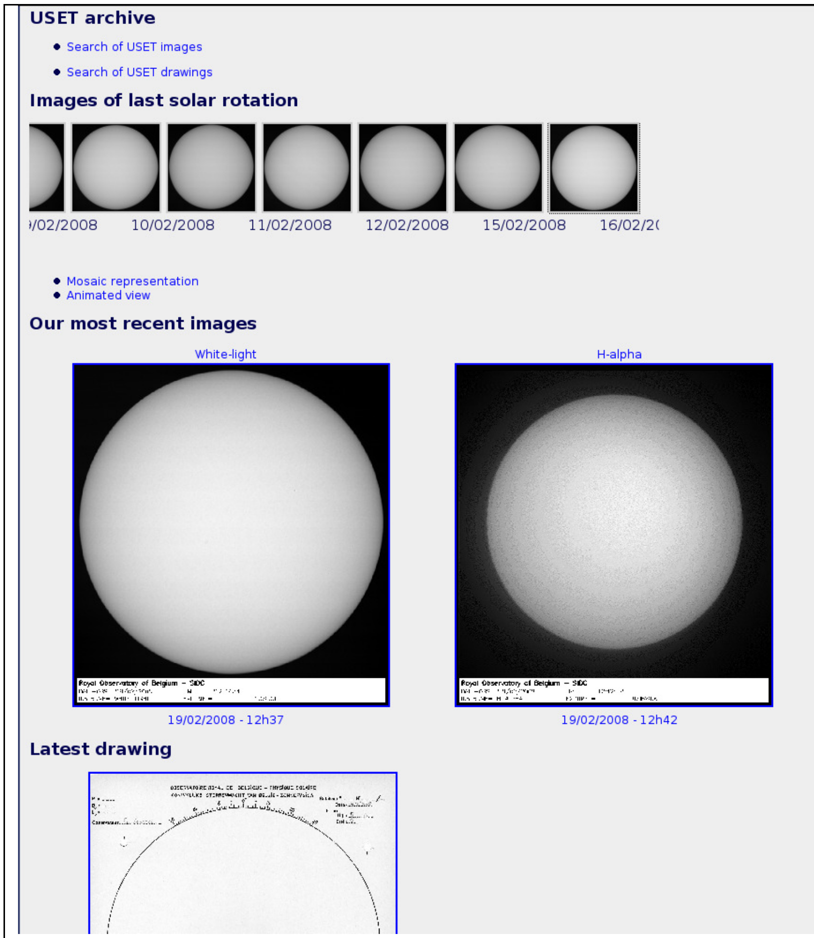


Figure 59. Section of the main USET data query Web interface, displaying the latest images in each channel and latest Uccle sunspot drawing, as well as an interactive panorama of the last 28 days (1 Carrington rotation). On top of the page, two links lead to query forms allowing to search and select datasets from the archive of past images and digitized drawings. NB: The blank solar disks are representative of the very low level of activity prevailing since early 2007.

- **Processing software for USET solar drawings**: the improvement of some of the processing routines was continued (heliographic coordinate, Julian date calculation based on new yearbook calculations, improved backup programs). Some bugs fixes proved necessary in the old SOLKOP program used for the tracking of individual sunspot groups, due to impropred handling of empty solar rotations (period of minimum of solar activity). By lack of time, the global rewriting of this huge program could not be undertaken in 2007.
- **Drawing digitization**: The new DIGISUN program developed in 2006 by an ESI trainee has been used routinely in 2007. With the arrival of our new programmer, it will become possible to fix some residual bugs that were identified and to expand further this application in order to use it for global digitization of large drawing collections. In this context, next to the SOTERIA project (see below), an informal collaboration was established in Dec. 2007 with Jan Rybak and the solar team of the Astronomical Institute in Tatranska Lomnica in order to prepare a coordinated digitization of the Uccle and Skalnate Pleso solar drawing collections. A similar collaboration was initiated with the Specola Solare Ticinense (M. Bianda, S. Cortesi) to study the possibility of digitizing the Zürich-Locarno drawing collection, which forms the base of the International Sunspot Index. This is the longest homogenous collection available. It spans the last 160 years and includes the original Wolf drawings.

C.1.2.6. Participation to the SOTERIA project (SOLar-TERrestrial Investigations and Archives)

This project proposal was submitted to the European 7th Framework Program (FP7 scheme: Collaborative project, Topic: SPA.2007.2.1.01, Space Science) in June 2007, under the Coordination of Giovanni Lapenta (KUL). We strongly contributed to the preparation of the Work Package 2 and 3 sections (Photosphere and Chromosphere). The proposal was selected by the EU at the end of 2007. The main contribution relevant to our solar optical instruments is the production of whole-disk CCD images in white-light, H-alpha and CaII-K to support studies of the chromospheric flares and waves (WP3) and of proxies of solar spectral irradiance (WP5).

This project will probably start by mid-2008 in phase with the instruments and tools developed in previous years for the USET and that are about to become operational.

C.1.2.7. Design and construction of a solar pointer for the USET

The development and testing of a solar pointer undertaken in 2005 by J-L Dufond and A.Ergen was continued. This pointer will improve the accuracy of sunspot drawings and allow an accurate and controlled centering of the CCD camera system (mechanical drift correction, atmospheric image motion, controlled off-pointing for flat-field sequences). In 2007, test campaigns were conducted to characteristize the photometric signal (sensitivity to depointing, signal-to-noise ratio, gain setting and angular sensitivity, etc.). By the end of the year, this characterization was completed, leaving as next step the implementation of a control software and hardware interface. This was proposed as a training project for an ESI graduate student in the academic year 2007-2008. A student, Pierre Charlier, chose the project and will be working on that topic in Feb.-June 2008.

C.1.3. Perspective for next years

Thanks to the arrival of one replacement programmer and operator in 2007, a lot of projects that had been postponed for years will become possible. However, given the amount of tasks that were backlogged, those tasks will have to be prioritized and spread over time. In particular, another ICT position has become vacant in 2007 and the largest needs are precisely in the domain of software upgrades, maintenance and development.

Next to the continuation of the USET solar activity monitoring observations and data dissemination, the key steps for next year will be:

- Instrument development:
  - Installation and final commissioning of the new H-alpha and white-light imaging systems.
  - Design and construction of the CaII-K telescope and optics
  - Completion of the solar pointer: this will involve a study phase in order to optimize the system to the actual properties of image turbulence at the Uccle site. This work will be partly carried out in the context of a training period (cf. ESI below)
- Trainees: over the 2007-2008 academic year, one computer graduate student (ESI; Pierre Charlier) will contribute to the development of a new micro-controller-based system for the operation of the solar telescope and dome. This new hardware and software will replace the aging system in use since the late 1980 and will open the way towards the inclusion of a solar pointer and larger automation of the USET.
- Software development, partly in the context of the SOTERIA project:
  - Development of new software tools for sunspot drawing digitization in view of the bulk digitization of the Uccle drawing collection.
  - Development of a new program for the group tracking, in replacement of the existing SOLKOP program. The latter will require an extensive study in order to document it and recover the base algorithms that it contains and that were applied over the last 25 years to generate the published Uccle tables.

- o Development of new programs for the selection and pre-processing of high-cadence images from the 3 new camera systems.
- o Implementation of systematic procedures for the determination of the camera dark level and flat-field, which will be used in the routine observations of the new cameras.
- o Upgrade and reorganization of the USET web pages.

C.1.4. Personnel involved

Scientific staff: F. Clette, M. Krijger, L. Wauters, D. Berghmans, L. Rodriguez, G. Lawrence, A.Zhukov, S.Gissot

Technical staff: J.-L. Dufond, A. Ergen, O. Boulvin, O. Lemaître, S. Vanraes

C.1.5. Partnerships

List of international partners without grant

- Dr I. Ermolli, Ossevatorio Astronomico di Roma, Italy

Grants/Projects used for this research/service

- LOTTO equipment grant (attributed in November 2006)
- SIDC Telescience PEA

Visitors:

- Short visits: 1 person, 1 group

C.1.6. Publications

C.1.6.1. Reports, thesis, etc

[1] **The SIDC team**
Uccle-USET sunspot numbers, sunspot group table, returning group list
SIDC sunspot bulletin (12 monthly issues)

[2] **F. Clette**
Belgian report to JOSO: 2004-2006
JOSO Report

C.1.7. Scientific outreach

Websites

- Real-time web distribution of CCD camera images
- Real-time web distribution of scanned solar drawings
- Development of a new USET Web data access page featuring visual data query tool (preview thumbnail images) and a whole-rotation navigator (mosaic, movie, sliding strip). Via an SQL database, it gives access to the whole USET archive of white-light and H-alpha CCD images as well as the scans of USET drawings. (URL: www.sidc.be/USET)

C.1.8. Missions

Commissions, working groups: Clette, Frédéric (1 day)

C.2. Science operations of the SOHO-EIT shutterless program

C.2.1. Objectives

In the context of solar activity monitoring, SIDC is leading the so called “EIT shutterless” program. It is a small scale / high cadence observational program originally based on a specific mode of the SOHO-EIT instrument. It was initiated by ROB in 2000 and it runs since then every three months.This program have generally run in coordination with other instruments on board SOHO, CORONAS, and TRACE, but the new missions STEREO and Hinode now participate too.

C.2.2. Progress and results

In 2007, the EIT shutterless program occurred four times:

Campaign label	Dates	Targets	EIT	Other in-struments	Note	Lead
29	11 and 17 Oct 2007	N pole CH ; QS	195 -171	MDI, TRACE (171, 1600; 171), EUVI, CDS	polar jet	S. Parenti
28	2 and 9 Aug 2007	N-E promi-nence; N pole CH	304 -171	TRACE (171;171), SECCHI 304	absorption feature at the pole	S. Parenti
27	9 and 15 May 2007	ARs 953 ; 954	304 -195	TRACE (171, C IV). CDS. Hinode-STEREO	flare	S. Parenti
26	16 and 24 Jan 2007	S pole CH ; ARs 10939 -10938	304 -195	TRACE (171;171,C IV, 1600, 1700 & WL). CDS, MDI	Macrospicule / polar jet	S. Parenti

C.2.3. Perspective for next years

We intend to keep on running the EIT shutterless as long as SOHO-EIT is alive. Interesting investigations will be enabled by PROBA2-SWAP and SDO-AIA data. A summary paper will be written in due time.

C.2.4. Personnel involved

Scientific staff: S. Parenti, J.-F. Hochedez, D. Berghmans, F. Clette

C.2.5. Partnerships

List of international partners without grant

- Goddard Space Flight Center, NASA, Md, USA
- Naval Research Labaoratory, Washington, DC, USA
- Institut d’Astrophysique Spatiale, Orsay, France
- STEREO, HINODE, CDS, MDI, TRACE operators and science consortia

Grants/Projects used for this research/service

- SIDC data exploitation PEA

C.2.6. Scientific outreach

National and international responsibilities

- S. Parenti: Responsible person of the SOHO high cadence synoptic observational 'shutterless' program

Websites

- Webpages of the EIT synoptic program (Shutterless). http://www.sidc.be/EIT/High-cadence

C.3. Science development of solar radioelectric observations in Belgium

C.3.1. Objectives

The radiotelescopes of the Humain station were installed to provide radioelectric observations of the Sun for flare monitoring and long-term recording of the solar radio flux in the upper-chromosphere and low corona. In particular, a 13-m decimetric radiometer was previously dedicated to the continuous recording of the 600MHz radio flux, which produced one of the longest existing flux series (absolute solar index, unique station worldwide). By lack of staff replacement, the radio observations were stopped in July 2005. A modernization and redeployment project submitted in 2004 has become part of Work Package 2 of the Solar-Terrestrial Center of Excellence (STCE). It is called HUMSOLAR, for HUmain Multi-frequency SOLar Array for Radio monitoring. Its implementation started at the very end of 2007 and will bring the following new capabilities:

- Integrated absolute radio flux at 600 MHz, and future extension to other frequencies, including 2,8Ghz (10.7 cm flux).
- Possible future addition of radio spectrograms in the 30MHz-3GHz range (CALLISTO), for flare monitoring and diagnostics
- Near-real time transmission and processing of the Humain data in support to the SIDC solar flare monitoring.

C.3.2. Progress and results

As the radio instruments have been put out of operation since mid-2005, there was no work at the station in 2007. The activities were thus limited to the present and future preservation of the site and to the preparation of the implementation of the STCE "Ground-based Observations" work package.

C.3.2.1. CALLISTO collaboration

In 2007, given the absence of approved STCE funding, no progress took place regarding the installation of a CALLISTO receiver at Humain. Occasional contacts were maintained with C. Monstein, Chief Engineer at the ETH Zürich.

C.3.2.2. Implementation of WP2 of the Solar-terrestrial Center of Excellence (STCE)

The STCE proposal was finally approved in the fall of 2007. This allowed initiating the recruiting of the first scientific staff position: a radioastronomer. The recruiting procedure took place from September to mid-December 2007 and led to the selection of a candidate, Christophe Marqué, who will start working for the STCE in January 2008.

C.3.2.3. Preservation of the site quality and protection of the radioelectric spectrum

- BIPT:
    - Several frequency allocation requests from the BIPT were processed (7/3, 6/9/07)
    - A representative from the Solar Physics team took part in a preparatory meeting convened by the BIPT in view of the World Radiocommunication Conference-2007 (March 9) for the Belgian

participation to international negotiations of radio regulations. He provided support to the continued protection of radioastronomy bands by the Belgian BIPT delegation.

- Lhoist Industries: new negotiations took place with the local and General Directors of the Lhoist Company concerning the future extension of the quarry located near the Humain station. A new site was proposed by Lhoist in July 2007. This site is located on the plateau du Gerny a few hundred meters from the current station.
  - On Sept. 21, a first evaluation of the site was conducted. With help from Koen Verbeeck (Section Seismology), we made measurements of the actual horizon and of the topology of the terrain. I also identified transmitter masts and other potential sources of radio interferences.
  - The requirements and possibilities for implementing a systematic survey of the quality of the radiospectrum at the new site were evaluated. For such a specialized campaign, we concluded that the ROB team itself will have to carry out this specialized campaign. In November 2007, a financial plan for implementing this site survey was submitted to Mrs. Laurence Indri and Mr Geoffroy Fiévet, Lhoist Director.
- CRAF: F. Clette took part more actively to the CRAF activities as Belgian representative (European-level radioastronomy frequency protection). At the fall meeting of the CRAF (ESTEC), he presented the status and plans for the Humain solar radiotelescopes and established personal contacts with other teams in view of possible technical collaborations.
- URSI: As member of the URSI Commission J (radioastronomy), F. Clette continued to act as URSI representative to the FAGS Council, which emphasizes the current connection between solar radioastronomy and operational space-weather services.

C.3.3. Perspective for next years

In the framework of the STCE, new staff members will form a new team around the radio instruments in 2008. The main tasks for 2008 will be:

- Coordination of the redeployment work of new radiotelescopes and recruiting of new staff (technician, operator).
- Installation of a first CALLISTO spectrograph, with support from the ETH radio scientists. In order to quickly get an operational instrument, a log-periodic antenna will be installed in parallel with the operational 6-m antenna and the data transmission through ADSL will be implemented. This will require the repair or replacement of the main telephone line connecting the station to the network.
- Design and implementation of a site survey station and execution of a multi-month measuring campaign on the new site proposed by Lhoist.
- Repair and commissioning of the antenna pointing system of the 6-m parabola (destroyed by a lightning stroke in 2005) and development and replication of identical control systems for other antennas. This will also include the re-cabling of a subset of the 4-m parabolas formerly belonging to the radio interferometers.
- Design of a new receiver at 600MHz to restart the calibrated flux measurements started at the Humain station more than 50 years ago and interrupted in 2005 by lack of staff. Different bilateral collaborations will be pursued in this context, probably implying a few short stays at other observatories (Ottawa/Penticton, Zürich, Bologna).
- Meetings: oral presentations highlighting the new developments at the Humain station were submitted and will be presented at the URSI Benelux Forum (May 2008) and at the URSI General Assembly (Aug. 2008).

C.3.4. Personnel involved

Scientific staff: F. Clette

Technical staff: J.-L. Dufond, A. Ergen, P. Janssens

C.3.5. Partnerships

List of international partners without grant

- Dr Arnold Benz, Eng. Christian Monstein, Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland.
- Dr Kenneth Tapping, Dominion Radio Astrophysical Observatory, Penticton (Ottawa), Canada.
- Dr Roberto Ambrosini, Instituto de Radioastronomia, Bologna, Italia
- Dr Mauro Messerotti, Osservatorio Astronomico di Trieste, Italy

Grants/Projects used for this research/service

- STCE: work package 2 "Ground-based Observations" (end of 2007)

Visitors:

- Short visits: 2 persons

C.3.6. Scientific outreach

Meeting presentations

F. Clette, "Status of the Humain Station", 45th CRAF meeting, ESTEC, Noordwijk, 26-27/11/2007.

C.3.7. Missions

Commissions, working groups (days): Clette, Frédéric (3)
Field missions (days): Clette, Frédéric (1), Dufond, Jean-Luc (1), Ergen, Aydin (1)

C.4. Science development of the SWAP EUV telescope on ESA PROBA2

C.4.1. Objectives

SWAP is a solar extreme ultraviolet (EUV) imager designed for scientific studies of space weather events in the solar corona and for daily monitoring of the solar corona. The instrument is built under the project management of the Centre Spatial de Liège (CSL). After launch on the PROBA2 satellite, the Royal Observatory of Belgium will be the principal investigator institute for the exploitation of the data.

C.4.2. Progress and results

We outline the progress in 2007 over various tasks foreseen in the SWAP project proposal (PRODEX 2005-2006-2007):

C.4.2.1. Scientific Support during SWAP development

While the launch date slips, the instrument developments continued as planned. By June 2007, all SWAP hardware was delivered and nearly all SWAP work-packages of CSL were completed. As a consequence, ROB has become de-facto the main contact point for the remaining preparatory SWAP activities (see below). SWAP was integrated with the platform during the second half of the year.

C.4.2.2. SWAP onboard software

The first System Validation test 5 (SVT5) was conducted on December 18, 2007 at the Verhaert premises (Kruibeke) with the PROBA2 flight model, including the SWAP flight model. In this end-to-end test, the SWAP instrument operations, as commanded by the SWAP PI-team, were tested through the PROBA2 ground segment and spacecraft systems. The analysis of the resulting SWAP science telemetry and ancillary data brought up a number of serious issues in the SWAP onboard software. The required software adaptions are at the moment under discussion.

C.4.2.3. SWAP calibration

An end-to-end calibration of the SWAP flight model was conducted at the PTB facilities of the BESSY synchrotron in Berlin on February 27 and 28, 2007. An overview of the activities and a first few results are presented in PR-CSL-SWP-07076. A full pre-flight SWAP calibration paper is in preparation. However during the analysis of the calibration data we discovered an unforeseen effect of the CMOS-APS detector, called image lag, when operated in destructive read-out. This effect is due to the soft-reset of the detector and is essentially undesired. However the effect can be bypassed, if wanted, by running the detector in non-destructive read-out. In addition, the effect itself could enhance the observation of fast, relatively dark eruptions and could thus possibly be a new mode to operate EUV imagers. These results are discussed in a recently accepted publication (De Groof et al, 2008).

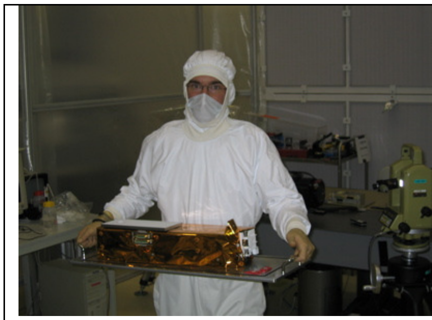


Fig. 60: Project Manager J.P. Halain showing the SWAP FM

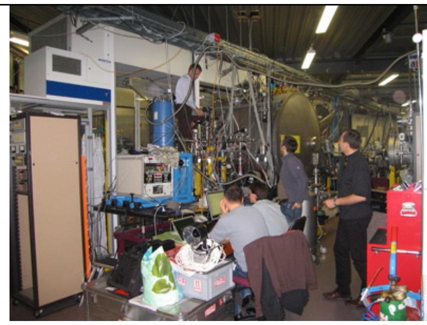


Fig. 61: Scene at BESSY/PTB during the SWAP final calibration

Fig. 62: Scene at BESSY/PTB during the SWAP final calibration

C.4.2.4. Preparation to SWAP operations

The PROBA2 Science Center (P2SC) was further developed. First versions of the main components specified in the Interface Control Document (SPB-PB2GS-TN-642) are now in place. These include

- a web-based interface (PHP) to generate instrument operations sheets (IOS) to command the SWAP instrument. These IOSs are validated through an XML schema.
- a tool that reads in the ancillary data files and inserts the content of these in a SQLite database
- a web-based interface that allows to browse the content of the database containg ancillary data
- software that reads the telemetry image files and reformats these into an image + metadata.

The System Validation test 5 (Dec 18) and the subsequent analysis of the resulting data has been an ideal test case to the above P2SC components.

C.4.2.5. Data analysis support and Space Weather products

In synergy with other SIDC projects, a solar image browser was developed, the so-called "Solar Weather Browser" (SWB). The SWB will be ideal to browse SWAP images and combine it with metadata overlays. This development resulted in a publication in Solar Physics (Bogdan et al, see below).

C.4.2.6. Independent research and scientific community building

In this pre-launch phase of the SWAP project, we concentrated on capacity building activities.

C.4.3. Perspective for next years

We await the final determination of the launch date and the release of the "Nationaly Led Mission" resources. The PROBA2 science center will be finalised, concentrating on the integration of the existing components. The SWAP pre-flight calibration paper will be written and submitted.

With SWAP scheduled for launch in December 2008 the coming months will see the completion of the ground segment software. Analysis of the Systems Validation Testing results is ongoing and is expected to be complete by the end of the first quarter of 2008. Delivery and integration of the flight MCPM is scheduled by mid-2008. Following a succesful launch the nominal mission will be 2 years, and a mission extension will be proposed in due course.

C.4.4. Personnel involved

Scientific staff: D. Berghmans, B. Nicula, G. Lawrence, A. Stanger

C.4.5. Partnerships

List of international partners without grant

- The partners of the SCSL team (see http://proba2.sidc.be/SCSL/)

List of national partners without grant

- Centre Spatial de Liège, Ulg
- Center for Plasma Astrophysics (CPA), KULeuven
- Verhaert NV
- Spacebel

Grants/Projects used for this research/service

- SWAP Preparation to Exploitation PEA
- ESA-ISSI contract 19260/05/NL/JA/na – Preparation of the exploitation of SWAP and LYRA on PROBA2
- SIDC Telescience PEA

Visitors:

- The SWAP project requires intensive collaborations with the Belgian partners (see above). We estimate that 10 visits for meetings occurred over the year

C.4.6. Publications

C.4.6.1. Publications without peer review

[1] J.M. Defise, J.P. Halain, **D. Berghmans**, F. Denis, E. Mazy, P. Rochus, T. Thibert, **B. Nicula**, A. De Groof, **J.F. Hochedez**, U. Schuehle, M.F. Ravet, F. Delmotte
SWAP, a novel EUV telescope for Space Weather
Proceedings of SPIE, 6689, pp.66890S, 2007

C.4.6.2. Publications in press, submitted

[2] **B. Nicula, C. Marqué, D. Berghmans**
Visualization of distribututed solar data and metadata with the Solar Weather Browser
Solar Physics, Volume 248, Issue 2, pp.225-232, 2008

[3] A. De Groof, **D. Berghmans, B. Nicula,** J.P. Halain, J.M. Defise, T. Thibert, U. Schuehle
CMOS-APS detectors for solar physics. Lessons learned during the SWAP pre-flight calibrations
Solar Physics, Volume 249, Issue 1, pp.147-163, 2008

C.4.6.3. Reports, thesis, etc

[4] Thibert, T., De Groof, A., **Berghmans, D.**, Halain, J.P., Defise, J.M.
SWAP FM calibration Report

Internal Report March 29, 2007, RP-CSL-SWP-0707076_I01R01.pdf

[5] De Groof, A., Nicula, B., Stanger, A., Berghmans, D.
Analysis report of SWAP data and associated housekeeping and ancillary data during the PROBA2 System Validation Test 5
Internal Report Jan 19, 2008, RP_ROB_SWAP_SVT5.doc Issue 01 Rev 00

C.4.7. Scientific outreach

As PI-team of the SWAP instrument it is part of our commitment to stimulate the use of SWAP data and to maximize its scientific return. At the same time we want to build research capacity in our group, through interaction with external people, to be ready to make the best possible use of the SWAP data when they arrive. These goals are achieved by setting up international projects and networks in which SWAP data is of primary importance:

- "Tournesol" project (travel money from the Vlaamse Gemeenschap) with the Observatoire de Paris and the University of Orléans.
- Science Consortium for SWAP and LYRA (see below under *Meeting Organization*)
- SOTERIA, a pan-European project selected for FP7-funding in which SWAP and LYRA data have a crucial role.

In addition, during the 2007 International Heliosphysical Year, an open door was organized at ROB where a PROBA2 maquette was on public display and the SWAP team members gave explanations to the visitors.

Meeting presentations

[1] **D. Berghmans, J.-F. Hochedez,** J.-M. Defise and the SWAP and LYRA instruments teams
Monitoring the Sun with the ESA PROBA2 mission (poster presentation)
Living With a Star Science Workshop, Boulder (US), 10-13 September 2007

[2] **D. Berghmans**, J.-M. Defise, S. Poedts, **O. Podladchikova**, A. De Groof, **B. Nicula, J.-F. Hochedez**
The PROBA2 satellite on the hunt for solar eruptions. A Belgian contribution to IHY (invited talk)
General Scientific Meeting 2007 - Belgian Physical Society, May 30 2007, UIA Antwerp

[3] **D. Berghmans, B. Nicula, G. Lawrence, A. Stanger, J.-F. Hochedez**, J.-P. Halain, J.-M. Defise
SWAP a Third Eye for STEREO (invited talk)
5th SECCHI consortium, IAS Orsay, F, 5-8 March 2007

[4] **D. Berghmans,** J.-M. Defise, **J.-F. Hochedez**
The PROBA2 satellite (invited talk)
ILWS meeting, Sweden, June 12, 2007

[5] **Lawrence, G., Berghmans, D., Hochedez, J.-F.**, and the PROBA2 instrument consortium teams
Space Weather with Small Satellites (invited talk)
Second IHY European Assembly, Jun 18-22 2007, Torino, Italy

[6] **Berghmans, and the SWAP and LYRA ROB teams**
Progress report on LYRA-SWAP ground segment (oral presentation)
Project meeting presentation

Meeting organization

- The Third meeting of the *Science Consortium for SWAP and LYRA* was organized in Bern (ISSI) on April 18 and April 19, 2007.
- A "PROBA2 science meeting" of the *Science Consortium for SWAP and LYRA* was organized on Novembre 5, 2007, in conjunction with the 4th European Space Weather Week. Special invited guests included Dirk Bernaerts (ESA), Kristof Gantois (Verhaert).

Websites

- http://swap.sidc.be/
- http://proba2.sidc.be/SCSL/

C.4.8. Missions

Assemblies, symposia (number):	D. Berghmans (2), A. Stanger (3)
Commissions, working groups (days):	D. Berghmans (1)
Research visits (days):	D. Berghmans (2), G. Lawrence (1)
Field missions (days):	D. Berghmans (3), A. Stanger (3)

C.5. Science development of the LYRA VUV radiometer on ESA PROBA2

C.5.1. Objectives

LYRA is a solar XUV and VUV radiometer that will embark in 2009 on the ESA PROBA2 mission. Its purpose is to monitor the solar irradiance in four passbands relevant to Solar Physics, Space Weather, and Aeronomy. LYRA also assesses the interest of new solar-blind diamond detectors and the degradation properties of UV filters. It was built by a Belgian–Swiss–German consortium with additional international collaborations (Japan, USA, Russia, France). Jean-François Hochedez is LYRA's Principal Investigator, Y. Stockman (CSL) is its Project Manager, and Werner Schmutz (PMOD) is its Swiss Lead co-I. As PI institute, our objective is to make LYRA a success in every respect. In 2007, this translated into the management and the understanding of its calibration campaigns, and into the preparation of its future flight operations.

C.5.2. Progress and results

LYRA successfully passed ESA DRB on June 15. Jean-François Hochedez gave an invited seminar **[4]** about LYRA and SWAP on Oct. 10 at the Lebedev Physical Institute (FIAN) and talks **[1][2][5][6][7]** have been given about LYRA during the two 2007 editions of the SCSL.

C.5.2.1. Calibration and their analysis

During 5-8 Feb, LYRA was recalibrated at PTB, Berlin in order to record missing measurements and to assess potential in-air degradations. A. BenMoussa coordinated this 3rd and last LYRA calibration campaign **[7]**, carried out in the normal incidence beamline of the Physkalisch-Technische Bundesanstalt (PTB) at the electron storage ring BESSY II. The objectives were to measure instrument properties (diamond detectors, UV LEDs) and to determine any potential degradation in the radiometric responsivity before integration and alignement onboard PROBA2. The figures show LYRA at PTB, and then in Verhaert, before and after integration.

Figure 63. LYRA inside the vacuum chamber at PTB

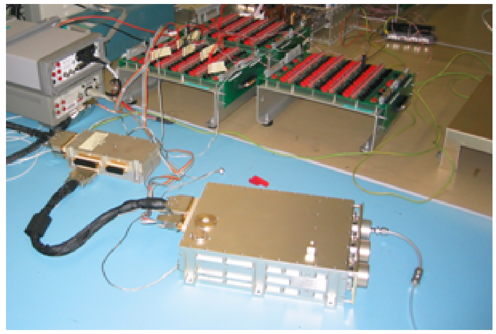


Figure 64. LYRA at Verhaert (Belgium) before integration.

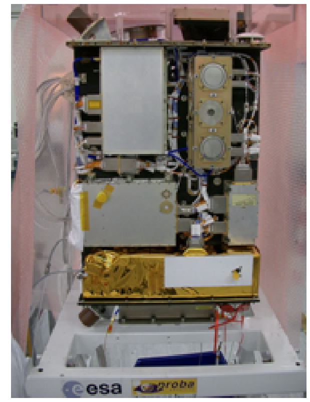


Figure 65. LYRA and SWAP onboard PROBA2

Future scientific analysis requires an in-depth understanding of the instrument response, its filters, sensors, etc. Internal reports were contributed on the following subjects: **[8]** considers using pulsed LED as an additional calibration source. This influenced the last ground test procedures; results will also be used during the commissioning phase and later during in-flight calibration. **[9]** is about the comparison of sensor flatfields, as measured in two campaigns 2005 and 2006, at the calibration source BESSY. It was subsequently updated with the results from the third calibration campaign in 2007 and will influence the calibration software. **[10]** is the analysis of the instrument output using various integration times from 10 s to 10 ms. This will have consequences for the selection of integration times. The deadtime correction which was found to be needed will be part of the calibration software. **[11]** is about the analysis of detector tests within the above-mentioned calibration campaign. This influenced the final selection of the spectral responsivity curves. **[12]** compares various tests involving internal calibration sources (LED). This forms the basis to evaluate the last on-ground tests as well as the instrument performance during commissioning phase and later during in-flight calibration. Finally **[13]** is about the conversion of the instrument output into physical units. This was started in 2006 and revised with the help of additional solar sample spectra.

C.5.2.2. Preparation to operations

A meeting was held at BELSPO (Jan 9) to discuss the P2SC (Proba2 Science Centre) operations. Version V1R3 of the LYRA User Manual (LUM) **[4]** was realeased on Jan 18. The LYRA first light procedure has been detailed in **[6]**. The LYRA depacketizer was programmed in C++ by M. Dominique. She also specified the needed HK and ancillary data. The SVT5 end-to-end test (meant to validate the on-board SW, and the ground segment) occurred in December. It was globally successful.

C.5.2.3. Preparation to scientific exploitation

ROSES **[5]**, an algorithmic and instrumental concept enhancing LYRA was (unsuccesfully) submitted to the French ANR on Feb 23. M. Dominique has developed a method capable of retrieving the extinction coefficient distribution as a function of altitude from LYRA data acquired in occultation **[2]**. This method was implemented and tested under some simplifying hypothesis (spectral average of the absorption cross-sections over each LYRA channel, uniformity of the solar emission) on simulated noisy data.

C.5.2.4. PICARD-PREMOS

In 2007, the Belgian hardware contribution to the Picard-Premos had to be canceled due to the bad performance of the detectors delivered by IMOMEC. ROB remains nevertheless co-I.

C.5.3. Perspective for next years

The LYRA radiometric model is finished, but subtle properties of the instrument related to e.g. inconsistencies among measurements, interpolations where no data is available, or pulsing LED behaviours still need to be investigated. The scientific paper reporting these results is in preparation, and expected to be submitted in 2008. Progress should be made also in understanding how radiation affects the performance of LYRA. In collaboration with SCK-CEN (Belgian Nuclear Research Center) and the University of Brussels (cyclotron of VUB), gamma doses (0.1Gy/h up to 50kGy/h) and charged particle beams (protons and alpha up to 40MeV) can be used to study our diamond detectors rad-hardness.

The calibration results will be incorporated in the data pipeline: The radiometric model will be recalculated using the most recent responsivities, which - together with the additional solar sample spectra – will eventually lead to the numerical values necessary for a procedure that transforms LYRA counts into solar irradiance values. Information about long-term behaviour, off-pointing effects etc. will be added to the already existing concept. In 2009, PROBA2 will be launched, embarking LYRA. The crucial phase of commissioning will follow, before entering science operations. We then anticipate the return of all past investments in instrument development and in operations preparation.

During commissioning, the instrument's performance will be evaluated. Afterwards, we will be responsible for daily commanding of the instrument, of monitoring the results and instrument health. While keeping track of other missions that can supplement the interpretation of LYRA data for the purpose of cross-calibration, the correction software will have to be continually updated and distributed via a data analysis support website. Eventually, LYRA has a high potential for engineering and scientific publications in international journals. Parts of the software to do this already exist, but the whole chain has to be automated. We will also keep on preparing exploitation of the LYRA data in view of irradiance and occultation studies.

The LYRA website is available at lyra.oma.be. It is quite update regarding instrumental and publication aspects, but has to be updated with respect to the operational aspects.

C.5.4. Personnel involved

Scientific staff: J.-F. Hochedez (LYRA Principal Investigator)
M. Dominique (Science exploitation and operations preparation)
I. E. Dammasch (Ground calibration analysis)
A. BenMoussa (Calibrations management and analysis)
B. Giordanengo (Operations preparation)
M. Kretzschmar

C.5.5. Partnerships

List of international partners without grant

- SCSL, the Science Committee of SWAP and LYRA, a team of ~20 members representing the interest of the international community for the 2 instruments, see proba2.sidc.be/SCSL/
- Werner Schmutz, Silvio Kohler, Tanja Egorova, Hansjörg Roth, Eugene Rozanov, Christoph Wehrli, PMOD, Davos, CH
- ISSI insititute, Bern, CH
- Hilde Schroeven-Deceuninck, PRODEX office, ESA, NL
- Udo Kroth, Christian Laubis, Matthias Richter, Franck Scholze, PTB, BESSY, Berlin, Germany
- Udo Schühle, MPS, Lindau, Germany

List of national partners without grant

- Yvan Stockman, JP Halain, JM Defise, CSL, Liège
- Ken Haenen, IMO/IMOMEC, Diepenbeck

- Didier Gillotay, Didier Fussen, Filip Vanhellemont, BISA

Grants/Projects used for this research/service

- The LYRA preparation for exploitation PEA
- The BOLD GSTP project
- ESA-ISSI contract 19260/05/NL/JA/na – Preparation of the exploitation of SWAP and LYRA on PROBA2

C.5.6. Publications

C.5.6.1. Publications without peer review

[1] Theissen, A.; **Benmoussa, A.;** Schühle, U.; **Hochedez, J.-F.;** Schmutz, W.
LYRA - a solar UV radiometer using diamond detectors
Modern solar facilities - advanced solar science, Proceedings of a Workshop held on 27-29 September 2006 at Göttingen, 2007

C.5.6.2. Publications in press, submitted

[2] **M. Dominique,** D. Gillotay, D. Fussen, F. Vanhellemont, **J.-F. Hochedez,** W. Schmutz
Retrieval of O, O2, O3 and N2 mesospheric and thermospheric distributions from PROBA2 LYRA occultation data
Accepted in Proc. for the 3rd meeting on Occultations for Probing Atmosphere and Climate

[3] T. Egorova, E. Rozanov, **J.-F. Hochedez**, and W. Schmutz
Reconstruction of the solar spectral UV irradiance for nowcasting of the middle atmosphere state on the basis of LYRA measurements
Atmos. Chem. Phys. Discuss., 8, 4099-4116 (2008)

C.5.6.3. Reports, thesis, etc

[4] **Dominique, Hochedez, and the LYRA team**
The LYRA User Manual (V1 R3)
Project document

[5] Dudok de Wit, and the ROSES team
The ROSES proposal
ANR proposal

[6] **Dominique, Hochedez, and the LYRA team**
LYRA First Light Procedure
Project document

[7] **A. BenMoussa**
Lyra NI extra Calibration Plan
Project document

[8] **Dammasch, I**
LYRA Pulsed LED Tests: Data Analysis
Project document

[9] **Dammasch, I**
LYRA Detectors: Positions, Flatfields, Consequences
Project document

[10] **Dammasch, I**
LYRA Noise Distribution: Report

Project document

[11] **Dammasch, I**
LYRA Responsivity Measurements: BESSY NI March 2007 Updates
Project document

[12] **Dammasch, I**
LYRA Dark Current and LED Measurements
Project document

[13] **Dammasch, I**
LYRA Calibration Software
Project document

C.5.7. Scientific outreach

Meeting presentations

[1] **M. Dominique**
Lyra commissioning plan (oral)
3rd meeting of the Science Consortium of Swap and Lyra, ISSI, Berne, 18-19/04/2007

[2] **Ingolf E. Dammasch**
LYRA Calibration: Ongoing Efforts and Problems (oral)
SCSL3, Bern, Apr 2007

[3] **M. Dominique**, D. Gillotay, D. Fussen, F. Vanhellemont, **J. F. Hochedez** and W. Schmutz
Retrieval of O, O2, O3 and N2 mesospheric and thermospheric distributions from PROBA2 LYRA occultation data (poster presentation with a short oral introduction)
OPAC-3: 3rd meeting on Occultations for Probing Atmosphere and Climate (Graz, Autriche), 17-21/09/2007

[4] **Hochedez**, and the SWAP and LYRA teams
LYRA and SWAP heralding future solar UV observations (invited oral)
Invited Lebedev Physical Institute (FIAN, Moscow) seminar, 10 Oct. 2007

[5] **Hochedez, and the LYRA team**
LYRA status (oral)
SCSL4 seminar

[6] **Ingolf E. Dammasch**
Current Developments in LYRA Calibration
SCSL4, Brussels, Nov 2007

[7] **M. Dominique**
Lyra operations (oral presentation)
4th meeting of the Science Consortium of Swap and Lyra, ISSI, Brussels, 05/11/2007

Websites

- Updates on http://lyra.sidc.be

C.5.8. Missions

Assemblies, symposia (number):	M. Dominique (3)
Commissions, working groups (days):	J.-F. Hochedez (4), M. Dominique (8), I. Dammasch (4), A. BenMoussa (2)
Field missions (days):	A. BenMoussa (3)

C.6. International developments of solar UV space technologies

C.6.1. Objectives

Building up on their heritage, collaborations, and knowledge of both the needs and opportunities, members of the SIDC initiate and contribute to the development of critical optical components for improved UV solar observations. The selected technologies are currently imaging and non-imaging wide bandgap UV detectors and porous diffractive filters. In 2006-2009, the purpose of the BOLD project (Blind to Optical Light Detectors) is to demonstrate the feasibility of wide-bandgap nitride-based detectors for EUV/VUV imaging in space. A GSTP project has been set up by BELSPO and ESA, involving IMEC, ROB, and CRHEA (F). Its goal is the manufacturing and testing of an AlN hybridized 2D APS of 512x512 format and 10µm pixel pitch. It will be characterized from the EUV to the visible ranges. Porous filters are highly complementary to BOLD sensors; and are also investigated.

C.6.2. Progress and results

C.6.2.1. BOLD – wide bandgap imaging UV detectors - support to development

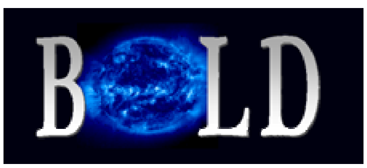


Figure 66. BOLD logo

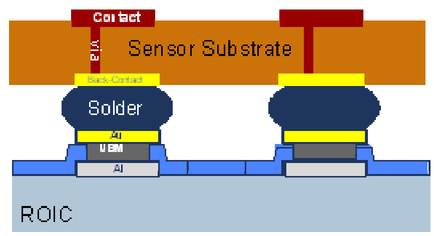


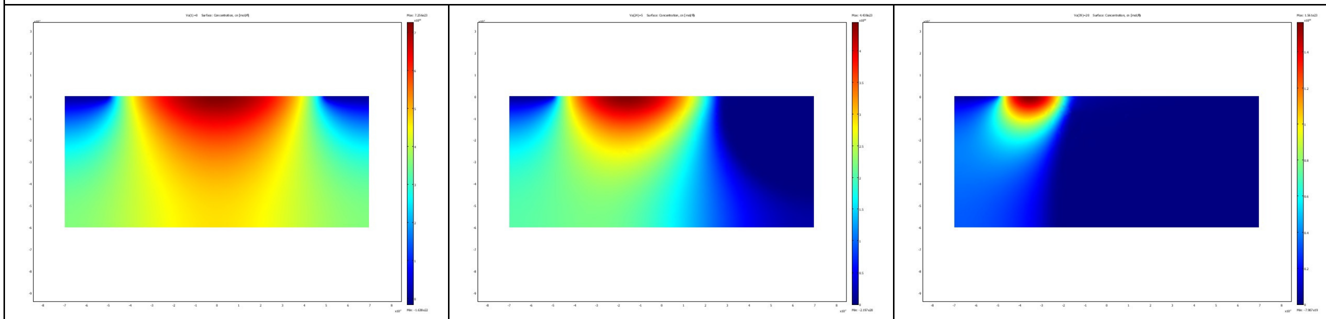
Figure 67. Interconnection between the nitride active layer and the CMOS ROIC using indium bumps technology

A GSTP BOLD project started in June 2006 for a period of 26 months (*viz.* until September 2008) **[3]**. ROB is responsible for the conceptual pixel design study (WP-1100) and for the UV tests (WP-5200), performed at BISA, IMO, and PTB. Since Jan. 07, when the COMSOL Multiphysics PDE solver was ordered, B. Giordanengo, A. BenMoussa and JF Hochedez are developing a physics model of the photo-electronics processes in the BOLD pixel. As to WP-5200, samples were selected (BOLD-Prototypes-Selection-ROB-20070221.pdf), and a test plan was written (BOLD_Calibration_Plan_V1.2-20070226-ABM.doc) in Feb. 07. A BOLD test campaign occurred at PTB/Bessy2 (March 1) and at ROB/BISA (March 5-6). Results are in BOLD-PTB-Test-ROB-20070309.pdf and BOLD _Phone call april 2007executive summary-20070426-JFH.doc. An analysis of the effects of and solutions against photo-emission is in **[16]**. In May 2007, another test campaign was prepared **[15]** and performed at BISA (May 4) and PTB (May 7-11). Its aim was to evaluate various pixel designs by estimating their performance as EUV detectors. 15 device samples had been pre-selected. They had different photosensitive material (AlN→GaN) and surface area. They were characterized on the Grazing Incidence (GI) beamline [5-20nm] and on the Normal Incidence (NI) beamline [40-80 and 115-225nm]. In 2007, the progresses of the BOLD project were reviewed during project meetings on 2 Feb, 19 Jun, 8 Nov, and 26-27 Nov.

C.6.2.2. BOLD – Physical modeling

The electronic properties of AlGaN photodetectors and photodiodes (MSM and Schottky) are simulated using the commercial Comsol Multiphysics® software. This software is able to solve system of linear or non-linear partial differential equations (PED) using finite element method (FEM).

Figure 68. Electronic density simulation of AlN photodiode at λ = 190 nm (Gap = 200 nm)



V = 0V | V = -5V | V= -20V

The first version of the model that describes the electronic properties of a photodiode or photodetector was composed of Poisson equation plus electron conservation equation. The Schottky barrier was poorly modelised.

To better simulate the real photodetectors, the model has been improved:

- To take into account hole contribution, Poison equation has been modified and the hole conservation equation has been added to the system of PEDs
- The Schottky barrier model has been completely reviewed and modified. Now Schottky barrier is based on thermoionic model.
- A realistic simulation of photodetectors needs to take into account light, i.e. generation and recombination of pair of electron/hole. This term is now integrated in the model.

C.6.2.3. Development of single-pixel wide bandgap UV detectors

A LYRA diamond MSM detector was reprocessed (ROB design, IEMN-IMOMEC manufacturers) and fully characterized at the PTB-Bessy II synchrotron facility. Results are published **[6]**. Signifiant improvements were achieved thanks to the smaller electrode gap. The reprocessed device exhibits a better stability as compared to the LYRA FM MSM sensors. Unfortunately, LYRA could not profit of it due to an early integration of the instrument. New reprocessed diamond devices were lent to the University of Munster (Germany) for research in the field of laser applications. In parallel, ROB prepares future solar instrument and missions with the development of new solar blind detectors based on the AlN **[4]** and cBN **[5]** materials in collaboration with the 'Institut d'Electronique et de Microélectronique et de Nanotechnologie' (IEMN, France), the City University of Hong Kong, and the Department of Physics of Kansas State University.

C.6.2.4. Filters

The development of porous filters happens in the frame of collaboration with LPI/FIAN, which started during early phases of the LYRA project. Due to other commitments, the redaction of the article on porous diffractive filters **[7]** progressed slowly in 2007. Yet, it received a boost during our visit to LPI/FIAN, Moscow and to JINR, Dubna in October.

C.6.3. Perspective for next years

It is believed that the BOLD technology would benefit to the Solar Orbiter mission. A continuation program must be prepared to pursue the current contract in case the feasibility is shown. It is hoped that improved single pixel detectors could be proposed in the frame of a successor to LYRA or to other UV radiometers, but optimization of the manufacturing process is required. Several ideas on porous filters still need to be experimented.

Although these new devices proved their general suitability for space applications, further improvements of their performance characteristics are still needed. Different approaches to improve the responsivity of MSM photodetectors are investigated: size reduction towards submicron finger contacts, semi-transparent electrodes and/or asymmetric electrodes. All these solutions provide better detector characteristics in terms of dark current, UV/visible contrast, linearity and enhancement in the VUV responsivity.

C.6.4. Personnel involved

Scientific staff: A. BenMoussa (Lead single pixel sensor development and lead measurements)
B. Giordanengo (Lead imaging sensor development [BOLD] and lead modeling)
M. Dominique (Lead filters development)
J.-F. Hochedez (science management)

C.6.5. Partnerships

List of international partners without grant

- J.-Y. Duboz, CRHEA, Valbonne, France
- A. Soltani, Institut d'Electronique de Microélectronique et de Nanotechnologie, Lille, France
- W. Zhang, Department of Physics and Materials Science, Hong Kong
- H.X Jiang, Department of Physics, Kansas State University
- J. Morse, European Synchrotron Radiation Facility, Grenoble, France
- T. Saito, NMIJ : National metrology Insitute of Japan, Tsukuba, Japan
- A. Mitrofanov, LPI/FIAN, Moscow, Russia

List of national partners without grant

- D. Gillotay, D. Bolsee, BISA, Brussels
- K. Haenen, V. Mortet, IMO, Diepenbeek
- J. John, M. Germain, J. Roggen, IMEC, Leuven

Grants/Projects used for this research/service

- BOLD ESA-GSTP
- LYRA preparation to exploitation PEA

Visitors:

- IMEC and CRHEA partners, 2 Feb. 2007 (BOLD mtg)
- Ali Soltani (IEMN) and Brahim Benbakhti (IEMN/CRHEA), 12 Jul. 2007

C.6.6. Publications

C.6.6.1. Publications with peer review

[1] A. Soltani, **A. BenMoussa**, S. Touati, V. Hoël, J-C. De Jaeger, J. Laureyns, Y.Cordier, C. Marhic, M.A. Djouadi and C. Dua
Development and analysis of low resistance ohmic contact to n-AlGaN/GaN HEMT
Diamond and Related Materials 16 (2007) 262-26

C.6.6.2. Publications without peer review

[2] J. John, P. Malinowski, P. Alparicio, G. Hellings, M. Germain, F. Semond, J-Y Duboz, **J.-F. Hochedez, A. BenMoussa**
AlGaN Extrem-UV detectors for space applications
WOCSDICE 2007, May 20-23, 2007, Venice , Italy, 31st workshop on Compound Semiconductor Devices and Integrated Circuits.

[3] John, J.; Malinowski, P.; Aparicio, P.; Hellings, G.; Lorenz, A.; Germain, M.; Semond, F.; Duboz, J.-Y.; **BenMoussa, A.; Hochedez, J.-F.;** Kroth, U.; Richter, M.
$Al_xGa_{1-x}N$ focal plane arrays for imaging applications in the extreme ultraviolet (EUV) wavelength range
Optical Sensing Technology and Applications. Edited by Baldini, Francesco; Homola, Jiri; Lieberman, Robert A.; Miler, Miroslav. Proceedings of the SPIE, Volume 6585, pp. 658505 (2007)

C.6.6.3. Publications in press, submitted

[4] **Benmoussa, A.; Hochedez, J. F.;** Dahal, R.; Li, J.; Lin, J. Y.; Jiang, H. X.; Soltani, A.; de Jaeger, J.-C.; Kroth, U.; Richter, M.
Characterization of AlN metal-semiconductor-metal diodes in the spectral range of 44-360 nm: Photoemission assessments
Applied Physics Letters, Volume 92, Issue 2, id. 022108 (2008)

[5] A. Soltani, H.A. Barkad, M. Mattalah, B. Benbakhti, J.-C. De Jaeger, Y. M. Chong, Y. S. Zou, W. J. Zhang, S.T. Lee, **A. BenMoussa, B. Giordanengo, J.-F. Hochedez**
193 nm deep-ultraviolet solar-blind cubic boron nitride based photodetectors
Applied Physics Letters, Volume 92, Issue 5, id. 053501 (2008)

[6] **A. BenMoussa**, A. Soltani, K. Haenen, U. Kroth, V. Mortet, H.A. Barkad, D. Bolsee, C. Hermans, M. Richter, J.C. De Jaeger , **J.-F. Hochedez**
New developments on diamond photodetector for VUV Solar Observations
Semiconductor Science and Technology 23, 035026 (2008)

[7] **M. Dominique**, A. Mitrofanov, **J.-F. Hochedez**
Development of new porous filters for solar observation
Accepted in Applied Optics (2008)

C.6.6.4. Reports, thesis, etc

[8] **A. BenMoussa**
Monthly BOLD progress report Feb 2007
Technical Report, Monthly Progress Report

[9] **A. BenMoussa**
Monthly BOLD progress report March-April-May 2007
Technical Report, Monthly Progress Report

[10] **A. BenMoussa**
BOLD prototype selection I – Preliminary report
Technical Report, 20 Feb 2007

[11] **A. BenMoussa**
BOLD prototype selection II -TESTS
Technical Report, 7 March 2007

[12] **A. BenMoussa**
BOLD prototype selection III – ROB TESTS
Technical Report, 20 April 2007

[13] **A. BenMoussa**
BOLD prototype selection IV -TESTS
Technical Report, 21 May 2007

[14] **Benmoussa, A.; Hochedez, J. F.**
BOLD Progress report for the period October to December 2006

Project report, 4 Jan. 2007

[15] J. John, M. Germain, **A. BenMoussa and J-F Hochedez**
Measurement plan for the PTB/Bessy VUV/EUV campaign may 7-10, 2007
Project document, April 2007

[16] **A. BenMoussa and J-F Hochedez**
Photoemission contribution in the VUV: Measurement and possible solutions
Project document, 2 May 2007

[17] **A. BenMoussa, B. Giordanengo and J-F Hochedez**
Tests and their analysis V1.0 to 1.5
Project document, April-July 2007

C.6.7. Scientific outreach

Meeting presentations

[1] **J.-F. Hochedez**
Solar Orbiter –driven requirements for BOLD specifications
BOLD meeting at ROB, Feb 2, 2007

[2] **J.-F. Hochedez**
HELEX–driven requirements for BOLD specifications
BOLD meeting at IMEC, June 19, 2007

[3] **J.-F. Hochedez**
Update on the context of the BOLD project (oral presentation given by JFH)t
BOLD meeting at ESTEC, Nov 27, 2007

[4] Mitrofanov A.V., **Dominique M.,** Apel P.Yu., **Hochedez J.-F.**
Ion irradiated polymers as nanoscale optical materials for X-ray optics and solar astronomy
REI (Radiation Effetcs in Insulators), Caen, Aug. 28th – Sept. 1st 2007

[5] **M. Dominique, A. BenMoussa, J.-F. Hochedez**, A. Mitrofanov
Development of new technologies for solar observation (poster presentation)
SOHO 20, Ghent, Belgium, 27-31 August 2007

Meeting organization

- J.-F. Hochedez: organizer of the 2 Feb. 2007 BOLD ESA progress meeting at ROB

Websites

- In 2007, the BOLD website (http://bold.oma.be) has been entirely restructured and updated by A. BenMoussa and B. Giordanengo, using the "SPIP" Content Management System.

C.6.8. Missions

Assemblies, symposia (number):	M. Dominique (1), A. BenMoussa (1), B. Giordanengo (1)
Commissions, working groups (days):	J.-F. Hochedez (4), A. BenMoussa (4)
Research visits (days):	M. Dominique (5), J.-F. Hochedez (5), B. Giordanengo (10)
Field missions (days):	A. BenMoussa (14), B. Giordanengo (6)

C.7. Solar Orbiter and the Extreme Ultraviolet Imager (EUI)

C.7.1. Objectives

Solar Orbiter (S.O.) is going to be the major solar and heliophysics ESA space mission after SOHO. It is planned for launch in 2017. Thanks to several attributes of its orbit, it will offer unique new observations. Its highly eccentic orbit with perihelion at 0.22AU will eventually be elevated out of the ecliptic plane by up to 30 degrees. From those exclusive vantage points its payload of remote sensing and in-situ instruments will take advantage of proximity, high resolution and co-rotation to return data detailing previously unexplored regions of the Sun in unprecedented detail. SIDC has developed special interest for EUI, the suite of UV telescopes, in line with our heritage and expertise. Stimulated by the will to shape a key undertaking, and encouraged by BESLPO, Jean-François Hochedez has again invested in 2007 in order to involve himself and the SIDC at the highest possible level, namely in view of EUI PI-ship.

C.7.2. Progress and results

Three types of activities occurred in 2007, more or less sequentially. The first two months corresponded to TIUD studies, as follow-ups of the LOI (letter of intent) submission of September 2006. We have reviewed the successive versions of the TIUD-B (TIUD-B_EUI_Draft1-V2tc-20070201-JFH.doc). Then, as member of the NASA-ESA HELEX Joint Science and Technology Definition Team, J.-F. Hochedez participated and contributed to its three meetings (March, May and September 2007). Finally, the last five months of the year have been devoted to a very large extent to leading and preparing the EUI proposal, due Jan. 15, 2008. A comprehensive document of more than 300 pages was compiled in final draft format by December 14th, with Red Team comments pending. The proposal outlines the science case for the chosen passbands and the technical requirements for ensuring optimal data return while detailing how the Solar Orbiter mission's primary science goals would be best met with this design. I can be noted that E. Podladchikoval is co-I for the RPW proposal, and S. Parenti is Co-I for one of the S.O.-spectrometer (EUS) proposals.

C.7.2.1. HELEX activities

In the frame of the JSTDT meetings, HELEX has emerged as a synergetic concept gathering Solar Orbiter and the four Inner Heliosphere Sentinels into one programmatic frame. J.-F. Hochedez was an active member of the JSTDT and contributed with several discussion elements, oral presentations **[1][2]** and documents **[3][4]**.

C.7.2.2. EUI proposal activities

In view of the nearing proposing phase, the PI visited the British and German partners in July 2007, and set up a scheme of regular (quasi-weekly) teleconferences from August on; see their minutes: **[5][6][7][8][9][10][11][12][13][14][15][16]**. G. Lawrence has been responsible for taking notes and distributing their minutes. For their organization, SIDC registered to a dedicated communication service (powwownow). Following the expression of interest of two US groups (NRL and SAO), a series of letter exchanges occurred during the summer time until early October **[17]**. JF Hochedez gave an invited talk on EUI at the LPI **[3]**. He triggered the 6th Consortium meeting, held at ROB (17–19 Oct), where all EUI-related issues were discussed **[21][4]**, coinciding with the issue by ESA of the S.O. payload AO. SIDC had largely contributed to documents on EUI design trade-offs **[18]**, on the benefits of APS detectors **[19]**, on the possibility of having several HRIs sharing a unique focal plane **[20]**, about on-board data management, etc. The group in charge of writing the Science Rationale section of the proposal was structured by the PI and co-led by A. Zhukov. A. Verdini contributed to the section related to particle acceleration in the solar atmosphere. The PI initiated and maintained a list of all EUI action items that neded to be monitored for the achievement of the proposal **[22]**. A difficult issue arose on the choice on the "hot" (> 3MK) passband among 133 Å and 335 Å. A. Zhukov and S. Parenti performed one of the two competitive studies; as a result, it appeared that the best compromise (at proposal level) was to actually go for a passband centered 195 Å. A. BenMoussa and J.-F. Hochedez reviewed the specifications for EUI detectors **[23]**, including suggestions on the pixel layouts **[24]**. In November, a set of questions were sent to ESA **[25]**. There has been a science EUI meeting at SIDC on Nov 30 to prepare the restricted consortium meeting to be held on Dec 3 at CSL. A dedicated private FTP site (eui@ftp.sidc.be) was created. The concept of a filter "noria" was proposed on (EUI-noria-20071206-JFH.ppt) in order to provide redundancy for the thin filters at the cost of a simple yet robust mechanism. J.M. Krijger computed orbit parameters and induced their effect on operations. The rest of December 2007 (including the "holidays") was heavily oriented toward proposal reviewing and writing, with special responsibility on the cover letter, the executive summary, part I, part VI (the financial plan), and emphasis on the following sections: Detectors (§342 of part I & §2.3.2 of part III), functional operating modes (§3.7 of part I), data management (§4.5 of part I), in-flight calibration (§5.4 of part I), flight operation concepts (§7 of part I), Data reduction, scientific analysis and archival support (§8 of part I), descoping (§2.4 of part III, with GL), flight operations (§5.3 of part II, EID-B), the whole part V (the management plan), and … the EUI logo. The people listed in the personnel sub-section have provided very essential contributions to those.

C.7.2.3. EUI website (http://eui.sidc.be)

A first version was released internally by A. Verdini and S. Parenti, with two main objectives:

[1] Provide a tool for the consortium members where information and documentation and is gathered so as to enhance communication.

[2] Provide a starting point for outreach where general information about the consortium, the mission, and the instrument is available.

C. Marqué, J.M. Krijger, B. Nicula, and F. Auchère (IAS, F) created a scientific movie, which vizualizes EUI-FSI observations over the S.O. mission lifetime

C.7.2.4. Compression studies

The telemetry limitations of EUI conflict with its scientific requirements and impose efficient and high-quality compression methods. The solar physics assessment of the compression quality controls the selection of the needed algorithm. The functions of the latter include denoising and recoding.

In 2007, we have analysed the performance the JPEG2000 compression scheme on solar EUV images of the corona according to various quality measures. We observed that at a given compression rate, low-intensity regions such as the Quiet Sun and Coronal Holes are more degraded than high-intensity active regions, and consequently require a lower compression rate at a given quality level.

We plan to continue the work on an optimal compression algorithm and the best possible hardware implementation for the Solar Orbiter mission design. This work is part of the software development work-package, and further developments will be carried out in 2008, including a poster presentation at the ADA5 conference expected in May 2008.

C.7.3. Perspective for next years

The official selection is due in 2008. Beyond that date, the EUI development should be in line with the ISRR conclusions and have a very fast pace.

C.7.4. Personnel involved

Scientific staff: J.-F. Hochedez, J. M. Krijger, S. Parenti, A. Zhukov, A. Benmoussa, D. Berghmans, V. Delouille, B. Giordanengo, S. Gissot, M. Kretzschmar, G. Lawrence, C. Marqué, B. Nicula, O. Podladchikova, L. Rodriguez , A. Verdini

C.7.5. Partnerships

List of international partners without grant

- Louise Harra, Sarah Matthews, Lidia Van Driel, and MSSL EUI team members, Mullard Space Sceinces Laboratory, University College of London, UK
- Thierry Appourchaux, Frédéric Auchère, Jean-Claude Vial, and IAS EUI team members, Institut d'Astrophysique Spatiale, France
- Institut d'Optique (France)
- Udo Schühle, Luca Teriaca, Werner Curdt, Sami Solanki, Eckart Marsch, and MPS EUI team members, Max-Planck Institute für Sonnensystemforschung, Germany
- Leon Golub, Ed DeLuca, and SAO GI-HRI team members
- Richard Marsden, Philippe Kletzkine, ESA
- JSTDT scientific and NASA/ESA members

List of national partners without grant

- Pierre Rochus, Jean-Marc Defise, Jean-Philippe Halain, and EUI team members, CSL, Liège
- François-Olivier Devaux, Antonin Descampe, Université catholique de Louvain and IntoPIX
- Benoît Macq, Professor, Université catholique de Louvain

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA
- Support frome most SIDC projects

C.7.6. Publications

C.7.6.1. Publications without peer review

[1] **Hochedez J.-F.**, Appourchaux T., Defise J.-M., Harra L. K., Schühle U., Auchère F., Curdt W., Hancock B., **Kretzschmar M.**, **Lawrence G.**, Leclech J.-C., Marsch E., Mercier R., **Parenti S.**, **Podladchikova E.**, Ravet M.-F., Rochus P., **Rodriguez L.**, Rouesnel F., Solanki S., Teriaca L., Van Driel L., Vial J. C., Winter B., **Zhukov A.**
The Ultraviolet Imaging Telescopes of Solar Orbiter,
The SecondSolar Orbiter Workshop, 16-20 October 2006, Athens, Greece (edited by E. Marsch, K. Tsinganos, R. Marsden, and L. Conroy), ESA SP-641, ESA Publ. Div., Noordwijk, 2007.

C.7.6.2. Publications in press, submitted

[2] **Hochedez** et al
EUI proposal
Submitted to ESA on January 15, 2008, in response to the ESA AO for S.O. scientific payload

C.7.6.3. Reports, thesis, etc

[3] **Hochedez, J.-F**.
The case for XUV-VUV imaging on Solar Orbiter and Sentinels
JSTDT project document

[4] **J.-F. Hochedez, A. Zhukov, M. Dominique**

Visibility of density structures to be sensed by the heliospheric imager(s) considered for Solar Orbiter
JSTDT project document

[5] **Berghmans, Krijger, Hochedez**
MoT of the EUI teleconference held on 20070817
EUI project document

[6] **S. Parenti and V. Delouille, J.-F. Hochedez,** U. Schühle, S. Matthews
MoT of the EUI teleconference held on 20070914
EUI project document

[7] Harra, **Hochedez**, Schühle
MoT of the EUI teleconference held on 20070928
EUI project document

[8] **D. Berghmans, A. Zhukov**, U. Schühle, **JF Hochedez**
MoT of the EUI teleconference held on 20071004
EUI project document

[9] Halain, **Hochedez**
MoT of the EUI teleconference held on 20071024
EUI project document

[10] **V. Delouille, J.-F Hochedez,** J.-P. Halain, P. Rochus
MoT of the EUI teleconference held on 20071031
EUI project document

[11] W. Curdt, **JF Hochedez**
MoT of the EUI teleconference held on 20071107
EUI project document

[12] **G. Lawrence, JF Hochedez**
MoT of the EUI teleconference held on 20071114
EUI project document

[13] **G. Lawrence, JF Hochedez,** JP Halain
MoT of the EUI teleconference held on 20071121
EUI project document

[14] **G. Lawrence, JF Hochedez**
MoT of the EUI teleconference held on 20071128
EUI project document

[15] **G. Lawrence, M. Krijger, JF Hochedez**
MoT of the EUI teleconference held on 20071205
EUI project document

[16] **G. Lawrence, M. Krijger, JF Hochedez**
MoT of the EUI teleconference held on 20071212
EUI project document

[17] **Hochedez, J.-F.,** for the EUI consortium
Formal letters with US groups discussing their involvement in EUI
EUI project documents

[18] Auchère, F; **Hochedez, J.-F.**
EUI design trade-offs as of 24 Sept 2007

EUI project document

[19] **Hochedez, J.-F.; Nicula, B; Berghmans, D.**
Potential benefits of CMOS-APS to the Solar Orbiter EUI
EUI project document

[20] **Hochedez, J.-F.; Parenti, S.**
GIHRI and EUV HRI sharing a common focal plane
EUI project document

[21] **Hochedez, J.-F**.
6th Consortium meeting – purpose and agenda
EUI project document

[22] **Hochedez, J.-F**.
Action Item list for the EUI proposal
EUI project document

[23] **A. BenMoussa, J-F Hochedez**, and the DWG
EUI detectors specifications V1.0 to 2.2 (8 doc)
EUI project document

[24] **J-F Hochedez**
Suggestions on pixel layouts for HRI and FSI
EUI project document

[25] **J-F Hochedez,** for the EUI Consortium
EUI questions to ESA about the AO
EUI project document

C.7.7. Scientific outreach

Meeting presentations

[1] **Hochedez, J.-F.**
UV imagers on the Inner Heliospheric Sentinels (oral)
JSTDT meeting #2, Washington D.C., USA, 7–10 May 2007

[2] **Hochedez, J.-F.**
Visibility of density structures to be sensed by S.O-GHI (oral)
JSTDT meeting #3, London, 4–6 Sep 2007

[3] **Hochedez, J.-F.,** and the EUI Consortium
EUI - Above the dormant (?) volcano (invited oral)
Invited Lebedev Physical Institute (FIAN, Moscow) seminar, 10 Oct. 2007

[4] **Hochedez, J.-F.**
Discussion on augmented and Descope solutions for EUI
EUI project document

National and international responsibilities

- J.-F. Hochedez: Member of the Joint ESA NASA Science and Technology Definition Team (JSTDT) for HELEX (S.O. and Sentinels)
- J.-F. Hochedez: S.O.-EUI Principal Investigator
- A. Zhukov, S. Parenti, J. M. Krijger: Co-Investigators of the EUI instrument onboard Solar Orbiter
- J-F Hochedez: GI-HRI (proposing) co-Investigator (Leon Golub, SAO, being PI)
- S. Parenti: Co-I for the Solar Orbiter/ EUS spectrometer.

- O. Podladchikova: Co-I for the Solar Orbiter RPW instrument

Meeting organization

- EUI Consortium meeting, ROB, 17-19 Oct.

Websites

- eui.sidc.be

C.7.8. Missions

Commissions, working groups (days):	J.-F. Hochedez (6), O. Podladchikova (1)
Research visits (days):	J.-F. Hochedez (5), A. BenMoussa (4), S. Gissot (1), G. Lawrence (5), O. Podladchikova (2), L. Rodriguez (2), A. Zhukov (2)

C.8. Further solar instruments proposing activities

C.8.1. Objectives

Motivated by past commitment, or triggered by special opportunities, SIDC participates to other instruments proposals than the ones mentioned above. 2007 has especially been the year when ESA released its "Cosmic Vision" (CV) AO. SIDC members contributed to the four solar-related proposals.

C.8.2. Progress and results

C.8.2.1. KUAFU-ELATE

Kuafu is a Chinese space mission dedicated to synoptic observations for the science of Space Weather. It emerged very rapidly few years ago. J.-F. Hochedez has been anticipated to become the science PI for its ELATE (EUV and Lyman-alpha Telecope). However, 2007 has been a year of relatively low activity for Kuafu in China. This has possibly been a result of Solar Orbiter re-surfacing in Europe. Nevertheless a poster was presented **[1]**, and a science rationale written up for EDI/ELATE **[2]**.

C.8.2.2. COMPASS Cosmic Vision proposals to ESA

COMPASS was a CV proposal for a space mission addressing the magnetism in the solar atmosphere. The proposal was not pre-selected as part of the CV process. S. Parenti participated as Co-I to the writing of the COMPASS proposal

C.8.2.3. Solar Probe and PHOIBOS Cosmic Vision proposals to ESA

PHOIBOS (Probing Heliospheric Origins with an Inner Boundary Observing Spacecraft) was a CV proposal for a space mission, which intended, like Solar Probe, to explore the inner frontier of the solar system. It was designed to understand how the solar corona forms and how the solar wind accelerates. The proposal was not pre-selected as part of the CV process. E. Podladchikova participated as Co-I to the writing of the PHOIBOS proposal.

C.8.2.4. DYNAMICCS Cosmic Vision proposals to ESA

DYNAMICCS was a CV proposal that aimed at unifying heliosismology, coronal physics, and space weather. An advanced successor of LYRA was foreseen as part of the scientific payload. The proposal was not pre-selected as part of the CV process. JF Hochedez participated as Co-I to the writing of the DynaMICCS proposal Error! Reference source not found.**[3][2]**.

C.8.2.5. HIRISE Cosmic Vision proposals to ESA

HIRISE is a CV proposal that aims at high resolution coronal physics. JF Hochedez participated as Co-I to the writing of the HIRISE proposal **[4]**. HIRISE was shortlisted by the CV selection process, and its PI receives an ESA TRP support.

C.8.2.6. PROBA3 - ASPIICS

The PROBA3 mission could form a giant externally occulted coronagraph by using a two-spacecraft orbiting in formation: one telescope and one occulter separated by about 150m. This unprecedented technology-demonstration instrument would provide the first high-resolution images of the inner corona from space (1.1 to 3 solar radii). The SIDC goal is to participate in the science operations and exploitation of the observations: topology and connectivity of magnetic fields between the solar surface and the outer corona and heliosphere, initial acceleration of the solar wind, onset and source identification of CMEs. 2007 was a transition year between the industrial study of the coronagraph (ASPIICs, Laboratoire d'Astrophysique Spatiale de Marseilles) and Phase A. We provided a Statement of interest to BELSPO (April-May 2007) describing our possible involvement. Various contacts took place with potential partners of a future science consortium that will be in charge of the design and construction of this instrument. As members of this consortium, our role will be limited to science participation and will start effectively in the last few months before launch (scheduled in 2013). Based on our PROBA2 experience, we might take a more prominent role.

C.8.2.7. SMESE - LYOT, RAISE

In 2007, J.-F. Hochedez was invited to join the SOC of the SMESE workshop to be held in March 2008, and to become Co-I of the RAISE rocket experiment (PI D. Hassler of SWRI, USA).

C.8.3. Perspective for next years

The involvement of SIDC in emerging missions is expected to depend on the fate of Solar Orbiter.

C.8.4. Personnel involved

Scientific staff: J.-F. Hochedez, L. Rodriguez, S. Parenti, E. Podladchikova, A. Verdini, F. Clette, D. Berghmans, R. Van der Linden

C.8.5. Partnerships

List of international partners without grant

- C.Y.Tu, PKU, China
- E. Marsch, MPS, Germany
- D. Hassler, SWRI, USA
- J.-C. Vial, IAS, CNRS, France
- L. Damé, SA, CNRS, France
- S. Turck-Chièze, CEN-Saclay, France
- D. Mc.Comas (Solar Probe- PI), USA
- M. Velli (PHOIBOS, PI, Solar Probe scientist leader), JPL, USA
- M. Maksimovic (PHOIBOS PI, Solar Probe co-I), Lesia , France
- P. Lamy, Laboratoire d'Astrophysique Spatiale, Marseilles, France
- A. Vourlidas, Dennis Socker, Naval research Laboratory, Washington DC, USA

Grants/Projects used for this research/service

- SIDC Data Exploitation PEA

Visitors:

- Dr. Marco Velli visited ROB in July 2007 to discuss Solar Probe NASA Proposal.

C.8.6. Publications

C.8.6.1. Publications in press, submitted

[1] Turck-Chièze, S.; Lamy, P.; Carr, C.; Carton, P. H.; Chevalier, A.; Dandouras, I.; Defise, J. M.; Dewitte, S.; Dudok de Wit, T.; Halain, J. P.; Hasan, S.; **Hochedez, J. F**.; Horbury, T.; Levacher, P.; Meissonier,M.; Murphy, N.; Rochus, P; Ruzmaikin, A.;Schmutz, W.; Thuillier, G.; Vivès, S.
The DynaMICCS perspective
Experimental Astronomy, Online First, 2008

C.8.6.2. Reports, thesis, etc

[2] **Rodriguez, L; Hochedez, J.-F.**
Science rationale for Kuafu A – ELATE
KUAFU project document

[3] Turck-Chièze, S.; et al
DynaMICCS proposal
Proposal document in response to ESA's Cosmic Vision AO

[4] Damé, L.; et al
Hirise Proposal
Proposal document in response to ESA's Cosmic Vision AO

[5] Fineschi, S.; Solanki, S..; et al
Compass Proposal
Proposal document in response to ESA's Cosmic Vision AO

[6] Maksimovic, M.; Velli, M.; et al
Phoibos Proposal
Proposal document in response to ESA's Cosmic Vision AO

C.8.7. Scientific outreach

Meeting presentations

[1] Rochus, Defise, **Hochedez,** Schuehle
UV solar disc imagers of Kuafu-A (poster)
Kuafu meeting

[2] **JF Hochedez,** T. Dudok de Wit, M. Kretzschmar, W. Schmutz, and the LYRA Team
LYRA onboard DynaMICCS (oral)
DynaMICCS meeting, CEN Saclay, 6 Feb. 2007

[3] **D. Berghmans and JF Hochedez**
Solar Imaging Science Fiction - Lessons learned and not learned with the PROBA2 experiment
SOHO 20, Ghent, Belgium, 27-31 August 2007

C.8.8. Missions

Research visits (days): J.-F. Hochedez (2), F. Clette (1), R. Van der Linden (1)

D. SIDC internal and external services

The SIDC has continued to gain international recognition for its expertise and operational services in the domain of solar activity and space weather. These activities are obviously driven by the scientific studies and developments reported in the previous sections of this report, but some studies were also performed specifically in the context of the monitoring and forecasting of the solar activity cycle.

D.1. World Data Centre for the Sunspot Index

As the World Data Center for the Sunspot Index and a data analyses service of the FAGS, the SIDC is in charge of the determination, archival and mid-term prediction of the International Sunspot Number, the most fundamental solar activity index. Given its unequalled time coverage of three centuries, it is used as a reference index in innumerable studies and publications. Most other indices, introduced more recently, are calibrated on the sunspot number in order to define long-term irradiance models for backwards and forward extrapolations. Along that axis, the solar physics team has developed internally new researches in the domain of solar indices to extend the base sunspot reference.

D.1.1. Objectives

The main duty of the WDC of SIDC consists in the computation, publication and diffusion of the International Sunspot Number and additional indices, based on visual observations from a worldwide network of about 85 stations. Obviously, we aim to do this in the most objective way and include verifications of the quality of the data. At the same time, we need to be involved in the international efforts to better quantify (the evolution of) solar activity by studying other types of indices, by investigating the cross-correlation between the various indices and by researching the physical conditions involved in the solar variability. Understanding these physical conditions can lead to new methods to forecast the future evolution of these indices. By contrast to the ‘classical’ methods, that are largely statistical in nature, the new techniques should be physics-based and hence more reliable.

D.1.2. Progress and results

D.1.2.1. Regular service

The routine operations of the SIDC as World Data Centre for the Sunspot Index were performed as planned. These include:

- Data processing:
  - On a daily basis: automated production of the Estimated International Sunspot Number (EISN), distributed through the ursigrams of the RWC service.
  - On a monthly basis, determination of the provisional sunspot number (total and normalized hemispheric north & south counts) and distribution of these by fax, email and website. This task is executed every 1st of the month, in principle before 11UT.
  - Computation of the definitive sunspot number (total & hemispheric) based on the entire network (70-75 stations). These are published on a quarterly basis.
  - Mid-term prediction using the Waldmeier classical method and the Combined Method.
- Archive:
  - Maintenance of the archive: yearly, monthly, monthly smoothed and daily sunspot numbers.
  - The archive is publicly accessible through the SIDC Web and FTP site (ASCII data files and plots)

- Sunspot Bulletin (monthly publication):
  - Provisional sunspot data
  - 24-month predictions of the monthly Sunspot Number
  - Summary of the URSIGRAMS, with additional indices (PPSI, 600MHz flux, 2800MHz (10cm) flux, Terre Adélie cosmic ray counts, solar flare index, X-flare index, Wingst Ak geomagnetic index).
  - Uccle daily provisional relative and normalized sunspot numbers derived from the digitized USET drawings.
  - Table of major sunspot groups observed at Uccle and probable return of major groups derived from Uccle sunspot group classification.
  - Quarterly SIDC-News issue: SIDC definitive international and Hemispheric Sunspot Numbers for 3 months.

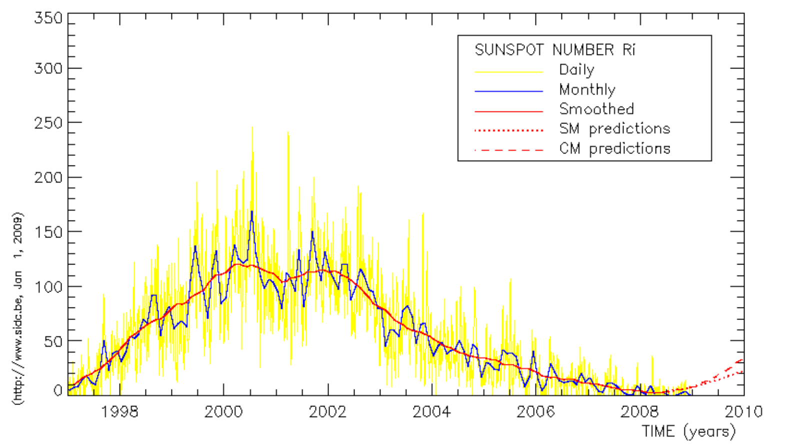


Figure 69. Plot of the daily, monthly and smoothed monthly sunspot index over the last 12 years. Dashed red lines indicate the predicted index over the next 12 months based on two methods. 2007 marked the final decline of cycle #23, with a minimum of activity probably reached in early 2008.

D.1.2.2. Work context in 2007

In 2007, with the additional retirement of G. Evrard (Feb. 2007), we had to continue working with a minimal staff. However, the recruiting of a replacement programmer and a new operator in Oct. and Nov. 2007 opened the perspective for future improvements of the situation.

D.1.2.3. Global review about the past, present and future determination of the sunspot index

Following the review presented in September 2006 at the 2nd International Symposium on Solar Climate, over the first half of 2007, F.Clette brought the final minor corrections to a review paper for Advances in Space Research. The paper was published in Sept. 2007 and led to various positive reactions and requests from readers by the end of 2007.

D.1.2.4. Solar cycle modeling and prediction

Further work and improvements were carried out on a paper authored by A. Baranovski, following advices from the referees. This paper, initiated in 2006 while Dr. Baranovski was working at the ROB, was accepted on Aug. 20, 2007. It presents the long-term analysis of the sunspot time series using the mathematical approach of non-linear dynamical systems.

A second independent approach was followed in collaboration with T. Podladchikova, a PhD. Student at Kiev Technical Observatory. In this technique, it is assumed that the first signs of a solar cycle are already visible in the descending phase of the previous cycle, and integral parameters are defined that have predictive capacity for the amplitude of the next solar cycle. A paper based on this analysis was published in 2007.

Both techniques can be used to generate forecasts for the amplitude of solar cycle 24 and were thus submitted to the Solar Cycle 24 Prediction Panel (SC24PP). This Panel was set up in 2006 by NASA, NOAA and ISES with the important task to try to obtain a consensus forecast for the timing and amplitude of the next solar maximum. This has for example large relevance for satellite operators, since the amplitude of the solar cycle has – through the variation of the ionizing EUV radiation – a substantial influence on the atmospheric drag experienced by satellites in Low-Earth Orbit.

As mentioned in last year's report, the SIDC director was invited as member of the SC24PP, which met for a second workshop in March 2007. The panel's findings were released during Boulder Space Weather Workshop in April 2007. Simultaneously, a press release was issued in the US, followed a little later by similar press releases in other countries. Also the SIDC issued a press release about the subject, which can still be consulted in the news items on the SIDC website: http://sidc.be/news/094/welcome.html. The (late) start of the new solar cycle has been source of a number of several other communications issued by the SIDC. One of these was related to the appearance of the first signs of the next solar cycle in December 2007: a reversed magnetic polarity region at high latitude on the solar surface (see Figure 70).

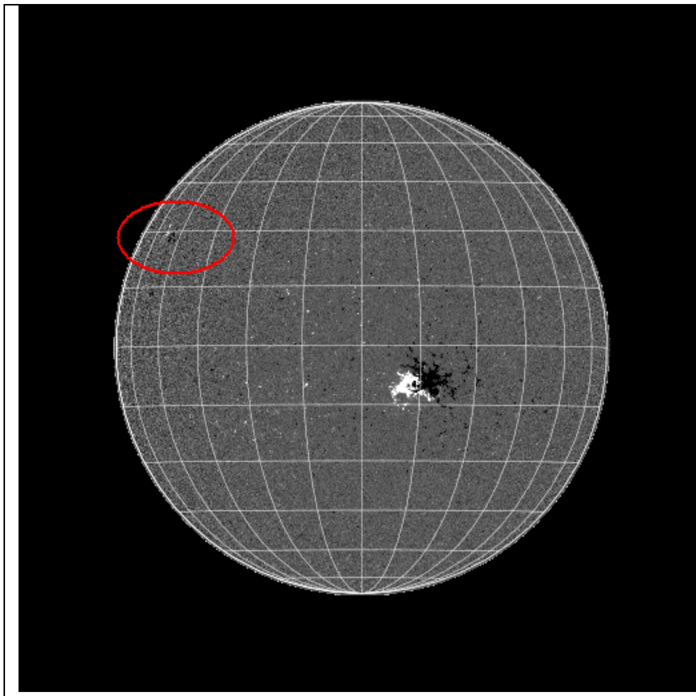


Figure 70. A magnetogram of the sun on December 13, 2007. The area in the red circle has reversed magnetic polarity. Although there was no sunspot observed, it can be regarded as one of the first manifestations of the next solar cycle.

D.1.2.5.Modernisation of data input and manipulation

The SIDC has further progressed with the effort to modernise, facilitate and speed up the data ingestion. In particular, we have been trying to convince all remaining observers contributing to the monthly sunspot data processing to use the web-based interface. There are now only a few observers left that do not yet do so. Since the web interface allows daily data transmission, we now use typically a large set of observations to calculate the daily Estimated International Sunspot Number (EISN) that is transmitted through the daily ursigrams sent out by the SIDC as RWC Belgium. We calculate and distribute this EISN each day at 12:30UT for the day itself and the day before.

The increased facility to provide data through the web interface and the continuous efforts of the SIDC collaborators to increase the visibility of our activities, amongst other things by several public presentations, have led to an increase of observers contributing to the network.

Work is in progress to automate to a larger extent the calculation of the Sunspot Index, using scripts operating directly on the online database generated through the web interface. This new software would also make it easier to change aspects of the calculations and for example experiment with the choice of pilot station. This facility will be exploited to study the consistency of the normalization of the sunspot index.

D.1.2.6.Pilot study of multi-station sunspot group tracking

In Oct. 2007, a pilot study was undertaken using the USSPS messages collected routinely by the SIDC-RWC. The goal was to experiment with the extraction of the parameters of each active region as recorded by several stations, in particular to identify high-latitude sunspot groups. This should allow sorting out active regions belonging to successive sunspot cycles in the current minimum phase of the solar cycle. Initial statistics were derived concerning the reliability of the values coming from those different data sources.

D.1.2.7. Collaboration with the Locarno pilot station

F.Clette was invited as SIDC representative by Dr. M. Bianda, Director of the IRSOL, to present a keynote lecture at the occasion of a local workshop dedicated to S. Cortesi, main observer of the Locarno pilot station of the SIDC network for the last 50 years. As S. Cortesi was victim of an unexpected accident, this meeting was postponed to January 2008.

D.1.2.8. Project proposal "Air density models derived from multi-satellite drag observations,", "ADM-Wind" Atmospheric Density Models-Wind

In June 2007, we were invited to take part in this Technical proposal in response to ESA ITT call ESA/AO/1-5394/07/NL/HE. Our role was to contribute solar activity indices as input to models of the thermosphere based on CHAMP & GRACE data and meant for predicting atmospheric drag on artificial satellites. The project was finally not selected but might be submitted again in the future for a different call.

D.1.2.9. SOTERIA project (SOlar-TERrestrial Investigations and Archives)

This project proposal was submitted to the European 7th Framework Program (FP7 scheme: Collaborative project, Topic: SPA.2007.2.1.01, Space Science) in June 2007, under the Coordination of Giovanni Lapenta (KUL). We took part in the preparation of the Work Packages 2 and 3 (Photosphere and Chromosphere). The proposal was selected by the EU at the end of 2007. Two main tasks are relevant to the SIDC-WDC:

- The digitization of the full collection of the Uccle sunspot drawings and the production of a 60-year long active region database (starting in 1940)
- The definition and study of new solar activity indices based on photographic and CCD images of the photosphere.

This project will probably start by mid-2008 in phase with the instruments and tools developed in previous years for the USET and that are about to become operational.

D.1.2.10. Reshaping the future: ICSU concultation on the future of FAGS (Federation of Astronomical and Geophysical Services) and the World Data Centre System

The International Council of Scientific Unions (ICSU) started in 2005 a process of reorganization and redefinition of its interdisciplinary bodies, to which belong both the FAGS and the WDC System. In response, both organizations organized a consultation amongst their members and commenced mutual discussions about the possibility to merge the two systems.

As URSI representative to the FAGS council, F.Clette contributed to the preparation of the FAGS White-Paper that will define the future reorganization of that body in the context of ICSU and in connection with the parallel structure of World Data Services. This process may lead to a refinancing of the FAGS services by the ICSU. The WDC-sunspot is directly involved, as it is at the same time one of the 12 FAGS services. As key contribution, F.Clette developed a FAGS/WDC cross study.

The FAGS white paper was discussed at the annual FAGS meeting. The WDC Panel held its first general assembly in many years to develop a common response. R. Van der Linden was asked to represent the FAGS Council at this meeting.

D.1.3. Perspective for next years

- In the context of the SOTERIA project (mid-2008?), continuation of the investigations regarding:
  - the retroactive constitution of hemispheric and per-cycle sunspot time series;
  - the study of the potential of photospheric imaging as a replacement of visual observations for the extension of the historical Ri time series.

- A study will be performed on the consistency of the scaling procedure used for the normalisation of the individual observations to the global Sunspot Index (k-factors). There is evidence for a solar-cycle dependency that will be further investigated. The possibility of long-term drifts will equally be studied.
- On the longer term, continuation of the software upgrade and modernization work will continue. This will lead to the publication of a comprehensive description of the statistical method and principles used in the past for deriving the International Sunspot Number (and probably ideas on how to improve it)
- Further encouragement and optimization of the import/export of data with the WOLF interface, which is a reliable and automated import of observing reports. This will be further developed to update the data processing for the Sunspot Index calculations.
- Because of the departure of A.Baranovski, the dynamical analysis of the sunspot time series cannot be pursued and must thus be abandoned, at least for some time.
- ICSU: continuation of our participation to the FAGS & WDC redefinition process.
- The collaboration with T. Podladchikova will be continued. She will probably visit the ROB during 2008 to continue this work and to commence another activity related to the short-term forecasting of the Sunspot Index.

D.1.4. Personnel involved

Scientific staff: Van der Linden, Ronald (WDC Director, science supervision)
Clette, Frédéric (science supervision, software and research)
Berghmans, David (science supervision, observer and user management)
Vanlommel, Petra (EISN production, Sunspot Bulletin)
Wauters, Laurence (Observation database development, statistical data analysis)
Willems, Sarah (observer and user management, IT support)

Technical staff: Boulvin, Olivier (operator)
Ergen, Aydin (backup operator)
Olivier Lemaitre (backup operator)

D.1.5. Partnerships

List of international partners without grant

- Worldwide network of 85 observing stations in 29 countries
- V. Nollau & A. Baranovski (Dresden University of Technology)
- Consortium CLS, CNES, AIUB/University of Bern, University of Prague, LPG/CNRS Grenoble, SIDC/ROB led by Jean-Jacques Valette, CLS, Collecte Localisation Satellites, Ramonville, France. Joint proposal was not selected. The collaboration might be continued outside of this proposal.
- T. Podladchikova, Kiev Technical University.

Grants/Projects used for this research/service

- FAGS/ICSU funding
- ESA/PRODEX Contract C90192 "SIDC Telescience".
- ESA/PRODEX Contract C90205 "SIDC Data Exploitation".
- Remnants of ESA contract 16913/03/NL/LvH. (SWENET support)

D.1.6. Publications

D.1.6.1. Publications with peer review

[1] **Clette, F., Berghmans, D., Vanlommel, P., Van der Linden, R.,** Koeckelenbergh, A., **Wauters, L**.

From the Wolf Number to the International Sunspot Index: 25 years of SIDC (Review paper)
Advances in Space research, 40, Issue 7, 919 – 928, 2007

[2] **Baranovski, A.L., Clette, F**., Nollau, V.
Nonlinear solar cycle forecasting: theory and perspectives
Annales Geophysicae, 25, 1 – 11

D.1.6.2. Publications without peer review

[3] **Van der Linden, R., Vanlommel P. and the SIDC-team**
SIDC Monthly Bulletin of Solar and Geomagnetic Activity, 12 issues
The Sunspot Bulletin

[4] **R. Van der Linden and the SIDC Team**
SIDC News
4 issues

[5] **Vanlommel, P.**
Het Solar Influences Data analyses Center van de Koninklijke Sterrenwacht van België
Space Connection Vol. 61, 3-7

D.1.6.3. Publications in press, submitted

[6] T. Podladchikova, B. Lefebvre, **R.A.M. Van der Linden**
Integral activity of the declining phase of sunspot cycles as precursor of the next cycle
Journal of Atmospheric and Solar-Terrestrial Physics, in press.

D.1.6.4. Reports, thesis, etc

[7] D. Biesecker, M. Dikpati, K. Dowdy, D. Hathaway, T. Hoeksema, E. Kihn, H. Lundstedt, D. Pesnell, M. Rast, L. Svalgaard, R. Thompson, **R. Van der Linden**, J. Kunches, O.C. St. Cyr
Consensus Statement of the Solar Cycle 24 Prediction Panel
Press release, March 20, 2007.

[8] **The SIDC Team**
Solar Cycle 24: Belgian Expertise in International Panel
Press release, April 25, 2007.

D.1.7. Scientific outreach

Meeting presentations

[1] **F. Clette, R. Van der Linden, P. Vanlommel**, A. Koeckelenbergh
25 years of sunspot activity index at the SIDC (oral presentation).
General Scientific Meeting 2007 of the Belgian Physical Society meeting, Univ. Antwerpen, 30/5/07

[2] **Berghmans, D., F. Clette, R. Van der Linden**
History of the Sunspot index
BAA meeting, London, 24 Nov 2007

[3] D. Biesecker, M. Dikpati, K. Dowdy, D. Hathaway, T. Hoeksema, E. Kihn, H. Lundstedt, D. Pesnell, M. Rast, L. Svalgaard, R. Thompson, **R. Van der Linden**, J. Kunches, O.C. St. Cyr
The Solar Cycle 24 Consensus Prediction
SEC Space Weather Workshop, Boulder, USA, April 24-27, 2007.

[4] **R. Van der Linden**, N. Capitaine
The Federation of Astrophysical and Geophysical data analysis Services

Oral presentation at the World Data Centres Conference, Bremen, 7-9 May 2007.

[5] **P. Vanlommel, R.A.M. Van der Linden**
The SIDC: WDC for the sunspot index and RWC for space weather services in Belgium
poster at the World Data Centres Conference, Bremen, 7-9 May 2007.

[6] **P. Vanlommel, R.A.M. Van der Linden**
The SIDC: data and data management of the WDC for the sunspot index
poster at the World Data Centres Conference, Bremen, 7-9 May 2007.

Websites

- Sunspot data is continuously updated on http://sidc.be
- http://sidc.be/WOLF/wolf_sunspot_index/

D.1.8. Missions

Assemblies, symposia:	F. Clette (1), R. Van der Linden (1), P. Vanlommel (1)
Commissions, working groups:	F. Clette (2), R. Van der Linden (7), A. Zhukov (1)

D.2. The operational activities as RWC Belgium

D.2.1. Objectives

RWC Belgium is a permanent service center specializing in solar monitoring and solar activity forecasting. It is run by the SIDC under the auspices of the ISES network. Its solid base is the solar physics research undertaken at the SIDC and our involvement in solar observations from space and ground, giving access to a large volume of solar and heliospheric data that can collectively span operational requirements. Building on insights derived from our scientific studies, the SIDC provides expert and timely information on and assessment of solar dynamics and its likely relevance for human technology.

D.2.2. Progress and results

D.2.2.1.Routine operations

For the RWC activities, a continuous data stream from ground-based and spacecraft instruments has to be analysed and interpreted. The daily routine of RWC activities includes different tasks:

- *Data distribution*. The RWC acts as a hub for further distribution of solar and geophysical data, mostly in the form of ISES encoded messages.
- *Monitoring solar activity and space weather*. To maintain a high standard in our activities as an RWC, we develop and use software that autonomously detects space weather events. This service is timely and assists the forecaster on duty in his monitoring and alerting task. Examples are CACTus (CME detector), B2X (flare detector), and NEMO (EIT-wave detector). These monitoring activities result in an alert service. Most of the warnings are sent out automatically in several alert-type messages, though some alerts need human intervention.
- *Forecasting solar activity and space weather*. Reports and forecasts of solar activity and space weather conditions are distributed every day (including weekends and holidays) at approximately 12:30 UT in the 'ursigram' messages. Weekly summaries are sent out in principle on Mondays, while more extensive monthly summaries of solar and geomagnetic activity are included in the Sunspot Bulletin of the SIDC. The latter also includes medium-term forecasts of the evolution of the sunspot cycle.

On the technical level, the monitoring, alerting and forecasting services of the RWC contain three main aspects: client database management, production of data/messages and delivery of data/messages. These activities are managed in a semi-autonomous way by the software package *PreviMaster*, which handles the solar data, the forecasts and alerts in conjunction with a database. The interface between the human operator and the *PreviMaster* package to receive the daily forecasts, manually triggered alerts and other subsidiary information is a secured web-based tool called called *PreviWeb*. Continuous maintenance and upgrade of these two packages, and the SIDC website itself, is an important never-ending task.

D.2.2.2.New Developments

In 2007, the new **GPS (RTK) daily, weekly, monthly products** became fully operational. Users were able to register for these products that provide information on the ionospheric variability over Belgium. RTK is a technique which allows a mobile user to measure its position with a cm-level precision in real-time by making use of differential corrections broadcast by a reference station. The positioning error is mainly affected by the small-scale gradients in the ionosphere. Through the website, the SIDC project provides information concerning the effects of small-scale gradients in the ionosphere on RTK precision for 6 European countries (Belgium, The Netherlands, Germany, Switzerland, Italy, UK) using a system of colours (see Figure 71).

A **MySQL database** contains information related to different aspects of the RWC. The database links products and users, keeps track of the daily forecast and measurements like flares, 10cm flux, and geo-magnetic disturbances described by the A- and K-index. During 2007, the database has been incorporated more strongly into the daily RWC processes on different levels: the public website, the private website used for the forecast, this is previweb, and PreviMaster. The information directly linked to the forecast itself, is easy to retrieve through the previweb interface in the form of data or a graph. The figures below show graphs over the timespan of one year, but it is also possible to make a short term analysis of recent forecast right on the spot.

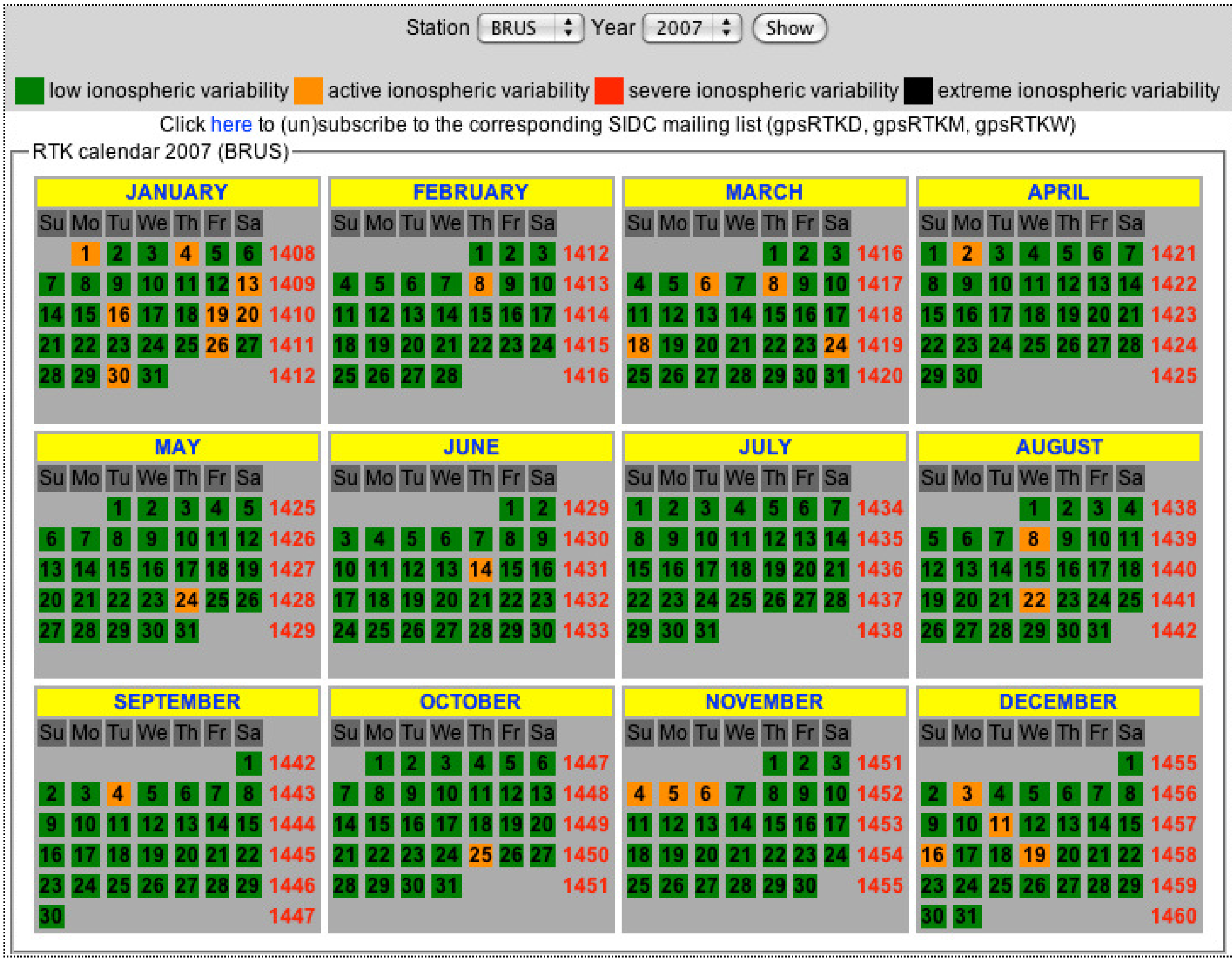


Figure 71. *An overview of the daily ionospheric variability (IV) of the ionosphere measured by the station located in Brussels for the full year 2007.*

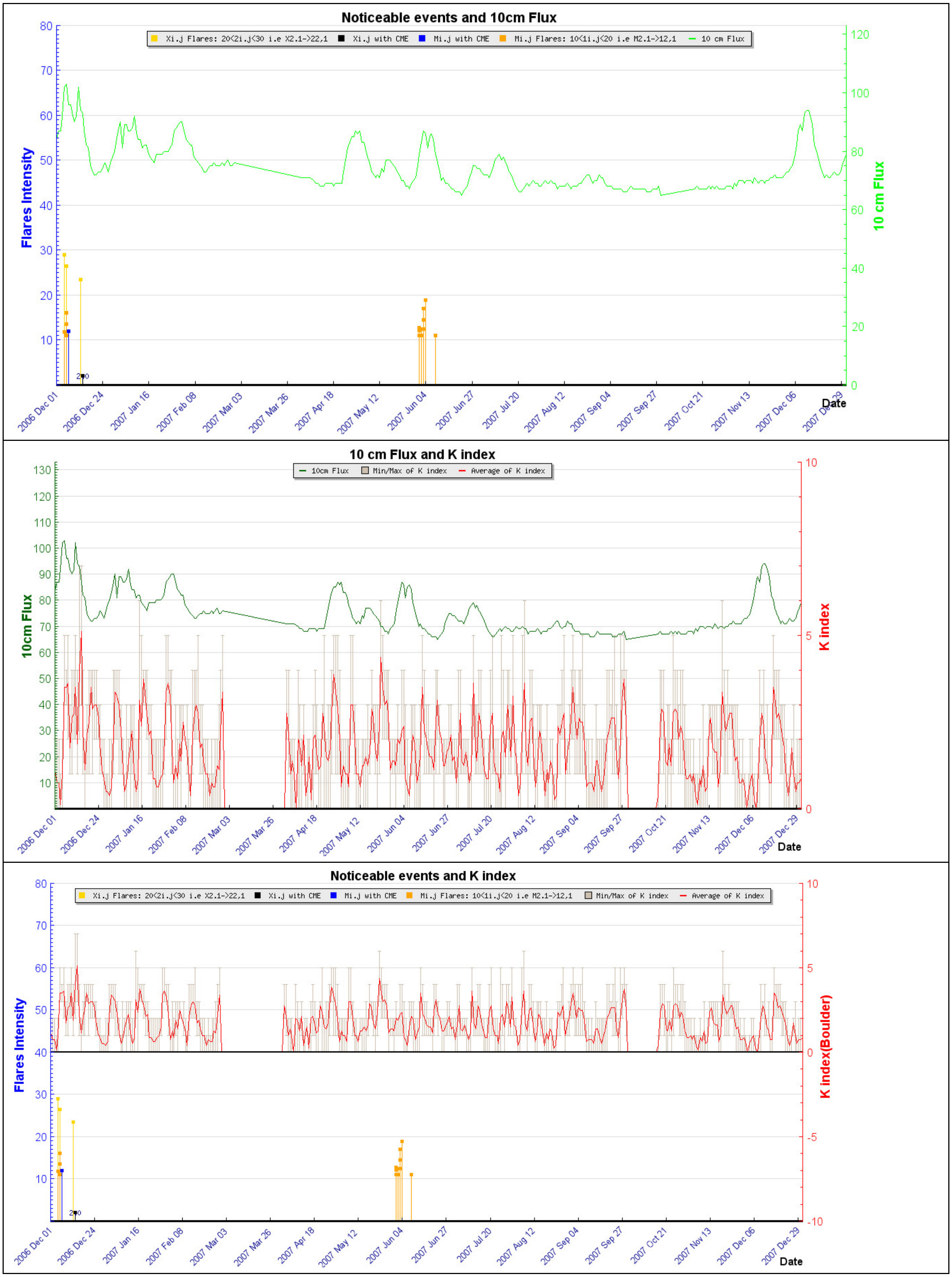


Figure 72. *Graphs such as these can be retrieved by a simple procedure available on PreviWeb. The start and end date can be choosen. These particular graphs give a comparison between the number of C, M or X flares and the K-index, the K-index and the 10cm flux and the number of flares and the K index for the period between end 2006 and the beginning of 2008.*

NEMO (Novel EIT wave Machine Observing), a new software package for detection of EIT waves forms one block of the Space Weather software package together with CACTus (the CME detector which works with coronograph data). NEMO consists of a series of high level image processing techniques especially developed to extract eruptive features from the EUV solar disk. This technique is based on the general statistical properties and underlying physics of eruptive on-disk events. Such events are tell-tale signs of coronal mass ejections that are not always seen by coronographs.

NEMO runs since 2007 automatically on a daily basis. The real time results are made available online: http://sidc.be/nemo. If the CME is associated with a flare, the profile of the X-ray flux curve gives an indication of the fact that an eruptive plasma event occurred. The type of radio outburst is another way to identify CMEs. NEMO gives also a clear indication of the strength of the event. NEMO runs on EIT and STEREO data (see Figure 73 for a typical event).

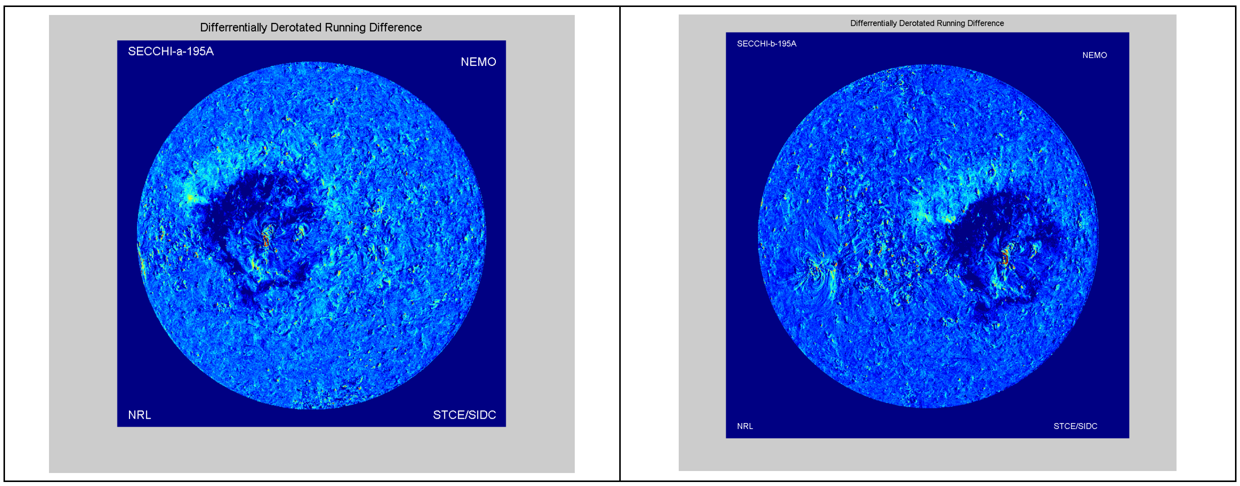


Figure 73. ***Simultaneous detection of EIT wave by SECCHI a (left) and SECCHI b (right) onboard STEREO***

The **Solar Weather Browser**, hereafter SWB, is a tool that allows to easily display solar images from different observatories together with solar metadata, and to combine them on the fly on a simple desktop or laptop computer, without the need of data processing. On the server side, most of the work has been devoted to the inclusion of new data sets, namely the data from the SECCHI-STEREO instruments.

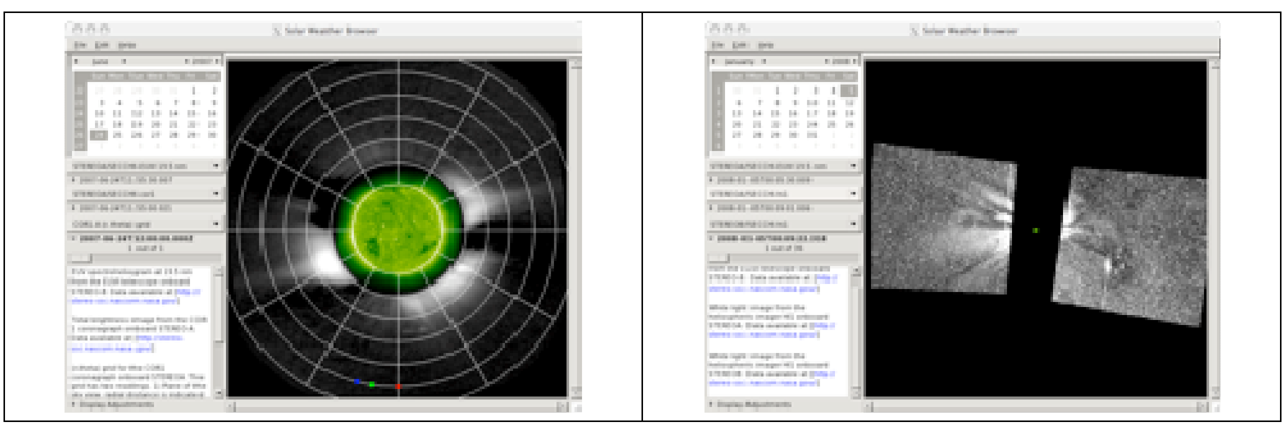


Figure 74. ***Some snapshots of the SWB interface. On the left: combination of EUVI, COR1, and position grid showing the Earth & s/c positions (colored dots); on the right: Panoramic view of the heliosphere, with EUVI (green dots), and HI1 instruments***

Data from the HAO instruments (white-light & Hα coronagraphs, Hα and HeI spectroheliograms) were also included into SWB. For the forecast team, the SWB offers an easy tool to browse through solar data while performing the forecast and solar monitoring.

During 2007, a number of products that were in test phase were opened for registration, some at the explicit request of users. These relate mainly to geomagnetic forecasting and monitoring. For a full list of products currently available from RWC Belgium, see http://sidc.be/registration/registration_main.php.

D.2.2.3. Organisation of Meetings, Events and Public Outreach

On May 10, the **Space Weather Working Team** (SWWT) meeting was organized at the ROB. The SWWT is a European discussion forum on space weather, set up by ESA. There were about 20 participants.

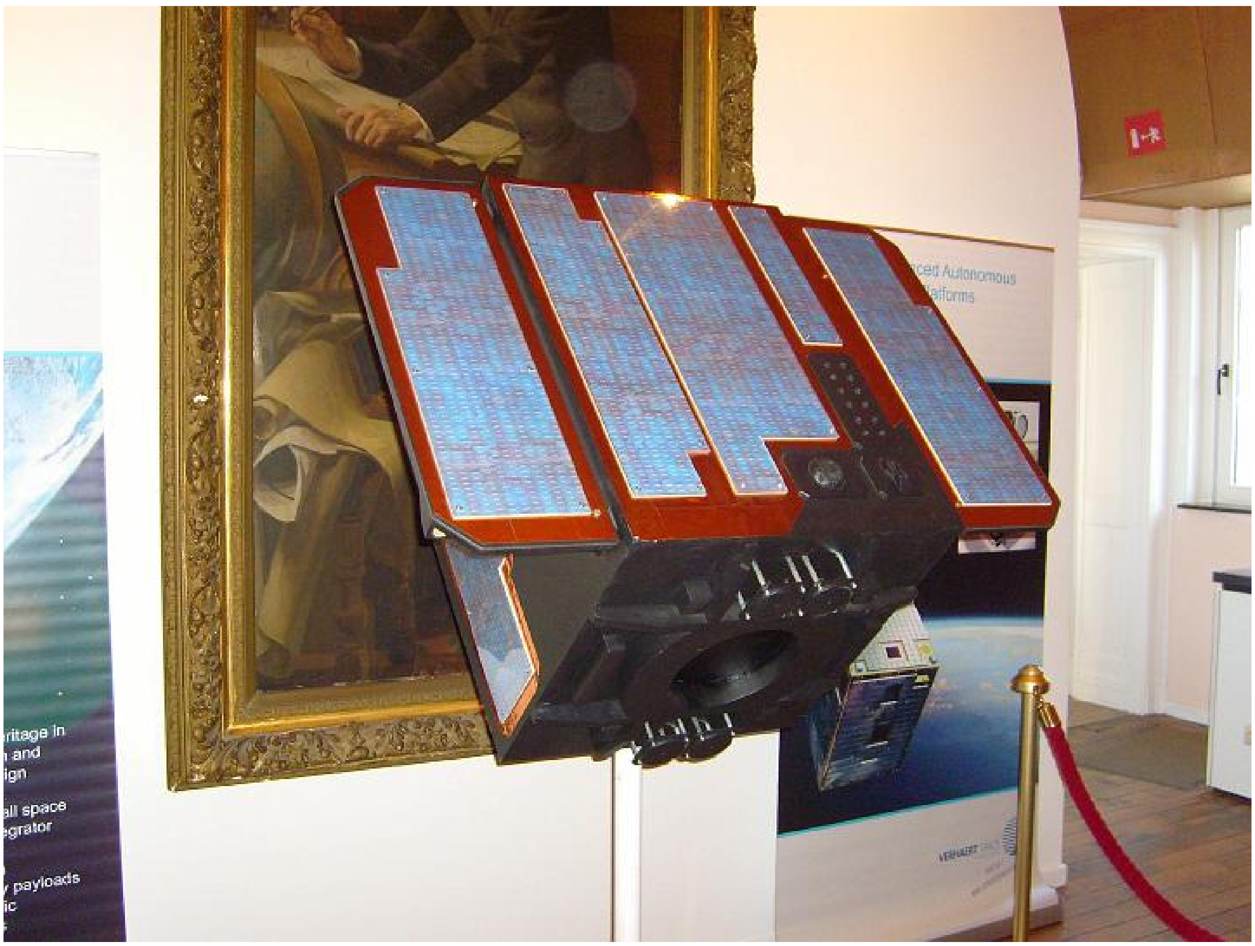


Figure 75. ***The maquette of the PROBA2 satellite*.**

The RWC concerns the involvement of the scientific space weather community, commercial and amateur organizations and the general public. Special attention is given to the users. This human aspect triggers the necessicity of *space weather education* and awareness of society. In view of this, the RWC pays special attention to publicity and promotion of space weather and related activities. Our **website** is the ultimate window to the space weather community and the public on which for example on a regular basis 'News Items' are posted. Several people from the general public reacted on our items about the delayed start of solar cycle 24. Space weather presentations were given and press releases made. The **Open Door Weekend** of the three institutes at the Space Pole in Uccle in October 2007 was organized in the frame of the **International Heliospherical Year**. At this occasion, an exhibition about space weather and space missions was set up. Maquettes of SOHO, SWAP, Lyra and PROBA 2 were shown (see Figure 75). Spectacular movies from the STEREO and HINODE space missions were displayed to the public.

In parallel with the exhibition, information sessions on space weather and our ground based solar observatory were given near the solar dome.

Also in the context of the IHY, a **temporary exhibition** (in two parts) was set up around this theme **in the Planetarium**. This exhibition will stay until 2008, and is to be followed by the construction of a new Planetarium show with Space Weather as main topic.

D.2.2.4.The fourth European Space Weather Week

From Nov 05-09, 2007, the Fourth European Space Weather Week (ESWW4) was jointly organized by the SIDC, ESA, the Space Weather Working Team (SWWT) and the COST 724 community. This event was built on the advances made during the first three European Space Weather Weeks held at ESA/ESTEC in 2004 and 2005 and in Brussels in 2006. The workshop adopted the central aim of bringing together diverse communities working on all elements of space weather. Hot topics and recent advances in both scientific and applications based domains were discussed. The flow of information between new scientific results and space weather services is one of the keynotes towards the creation of a sustainable space weather activity in Europe.

The conference, with 169 attendees from 31 different countries, was held at the Royal Library of Belgium. The expertise of the SIDC as a science and services center and our deep involvement in space missions like SOHO, STEREO, PROBA2 made of us one of the keyrole players of space weather activities in Europe and worldwide. Through the organization of this series of succesful European space weather weeks, we strengthened our position and visibility in the space weather community.

During ESWW4, a press conference was organized (see http://sidc.be/news/098/welcome.html), to which 4 journalists attended.

At the welcome reception of ESWW4, IHY Gold Club medals were awarded to three retired Belgian scientists.

D.2.2.5.Startup of the Solar-Terrestrial Center of Excellence

During the year 2007, work further progressed on laying the foundation of the Solar-Terrestrial Center of Excellence, in execution of the decision of the Belgian Federal Ministerial Council of March 22, 2006. Following the introduction of the detailed workplan and a cost-benefit analysis at the end of 2006, a final clearance was given early 2007. In consequence, a convention was drawn up between the three institutes and the Belgian Science Policy Office in order to work out the practical details of the implementation. The first funding was not received until late in 2007, so that most of the STCE activities could not really start up yet in 2007. The first recrutements were however started after the summer, so that 2008 will see the first full operation for at least some of the workplans.

The Solar-Terrestrial Center of Excellence is a scientific project that aims at the creation of an international expert center and at an improved valorization of solar and solar-terrestrial research and services. The STCE clusters the know-how of 3 Belgian Federal institutes, the Royal Observatory of Belgium (ROB), the Royal Meteorological Institute of Belgium (RMIB) and the Belgian Institute of Space Aeronomy (BISA). Top-class scientists, technicians and ITpeople were or will be attracted and hired. The scientific research performed in all three institutes is done independently but at the same time in a highly complementary way. This joint expert center brings together the contributing solar-terrestrial activities.

The STCE will build upon existing experience present in the 3 institutes related to Solar-Terrestrial physics. These include among others:

- SPENVIS, the Space Environment Information System (BISA), http://www.spenvis.oma.be
- The World Data Center for the Sunspot Index (ROB/SIDC), http://sidc.be

- Principal Investigator of the telescope VIRGO-DIARAD onboard of the international satellite SOHO (RMI), http://remotesensing.oma.be/solarconstant/virgo/virgo.html
- Lead of the PICARD, i.e. French microsatellite, mission center (BIRA), http://www.busoc.be/picard.en.htm
- SOVAP instrument for solar constant measurements onboard of PICARD (RMI)
- SOVIM-DIARAD instrument for solar constant measurements for the International Space Station (RMI)
- Dourbes geomagnetic station (RMI)
- Regional Warning Center for ISES concerning space weather services (ROB/SIDC), http://www.sidc.be
- Co-Investigator of SWENET (BISA), http://esaspaceweather.net/swenet/index.html
- Investigation of the ionosphere by the Ionosonde (RMI)
- Principal Investigator of the innovating instruments SWAP & LYRA onboard of the European micro-satellite PROBA2 (ROB/SIDC), http://lyra.oma.be and http://swap.oma.be

The STCE will operate in a strong collaborative spirit within the international environment: we expect strong benefits from joint work within the networks created by ESA (SWWT, SWENET), EU (COST, FP7) and others (e.g. ISSI)

D.2.3. Perspective for following years

It is our task to continue developing products, ameliorating existing products with the requests and wishes of the scientific, technological and amateur community in our mind. At the same time, we have to keep the structure and scripts that are at the base of the RWC transparent and efficient. We act on both sides: the programmatic level, which forms a platform on which the RWC can exist as a purely technical entity and the other side, which is user-related.

Some of the daily processes are complicated and detours on the programmatic level are made in the communication between databases and previweb/previmaster. This has to be simplified and made more transparent. Several steps in this direction were already performed. This process continues.

The SIDC as RWC should define a vision on different aspects: management level, outreach, and internal communication. The RWC offers an ideal platform for scientists to look further then only science and to strengthen the link between business/applications and science.

The MsQL data base is especially valuable for performing complex tasks like data mixing. This is a procedure in which different sorts of data are linked: X-ray flare duration, flare frequency, sunspot configuration, noticeable events, … Scientific research will be performed through this data mixing in 2008.

Within the STCE, there are plans to redevelop the radio observatory in Humain and amongst other things start to perform a local measurement of the 10cm Flux in Humain, Belgium. A specific receiver is needed. Collaboration with the Canadian team Penticton measuring this index since 1947 is established. An existing antenna on the site of Humain will be refurbished. The idea is to cover the 12 hours gap of Penticton. Monitoring of the solar activity will be provided with radiospectrogram giving the possibility to alert for flare and CME-events in real time. This is an advantage compared with space-based missions.

The involvement of the SIDC in the creation of the permanent planetarium show will increase again as it comes to the specific content of the show. A visit of a professional scenarist to the Regional Warning Center was planned for March 2008.

D.2.3.1. The Solar-Terrestrial Centre of Excellence, STCE

In 2008, the SIDC has to be integrated in the STCE. The STCE is initiated in 2007 with the announcing, selection and hiring of a number of people. This included the Education and Public Outreach people, the

General Coordinator. A radio astronomer and 2 senior researchers working at the SIDC work in the frame of the STCE.

D.2.3.2.The Fifth European Space Weather Week

The ESWW5 will be held on Nov 17-23, 2008 at the Royal Observatory of Belgium. R.A.M. Van der Linden and P. Vanlommel are members of the program committee. This committee gives the direction of the content of the ESWW5 and has the task to put up the scientific program. New ideas are brought in to innovate the concept of the space weather week. Special attention is given to the communication between users and scientists and to applications. A user/application fair is one of the innovations.

D.2.3.3.The Space Situational Awareness Programme and Other Initiatives

In the course of 2007, discussions started on a new optional program of the European Space Agency, called Space Situational Awareness. This programme is intended to have also a strong Space Weather component. The SIDC will strive towards a prominent role in this programme.

At the same time, several other initiatives are ongoing relating Space Weather to another international context: World Meteorological Organisation, EUMETSAT, UN Commission on the Peaceful Uses of Outer Space,… Also in these the SIDC will need to take an active role.

D.2.4. Personnel involved

Scientific staff:	Ronald Van der Linden, D. Berghmans, F. Clette, G. Lawrence, C. Marqué, B. Nicula, E. Podladchikova, E. Robbrecht, L. Rodriguez, P. Vanlommel, L. Wauters, A. Zhukov.
Technical staff:	O. Boulvin, S. Willems

D.2.5. Partnerships

List of national and international partners

- RWC Belgium is one of the nodes in the International Space Environment Service (ISES, see http://www.ises-spaceweather.org/).
- ROB Planetarium
- RMIB and BISA
- The SIDC continues to contribute to SWENET, see http://esa-spaceweather.net/swenet/index.html.
- The COST 724 community
- Naval Research Laboratory, Washington DC, USA
- High Altitude Observatory, Boulder CO, USA
- Observatoire de Paris, Meudon, France

Grants used for this activity:

ESA/PRODEX Contract C90192 "SIDC Telescience".
ESA/PRODEX Contract C90205 "SIDC Data Exploitation".
ESA/PRODEX Contract C90204 "Solar Drivers of space weather"

Various financial contributions and registration fees for the ESWW4 conference.

D.2.6. Publications

D.2.6.1.Publications with peer review

[1] L. Trichtchenko, **A. Zhukov**, **R. Van der Linden**, S. M. Stankov, N. Jakowski, I. Stanisławska, G. Juchnikowski, P. Wilkinson, G. Patterson, A. W. P. Thomson

November 2004 space weather events: Real-time observations and forecasts
Space Weather, vol. 5, S06001, doi:10.1029/2006SW000281, 2007

[2] **A. N. Zhukov** and I. S. Veselovsky
Global Coronal Mass Ejections
The Astrophysical Journal, 664, L131–L134, 2007

[3] J. Zhang, I. G. Richardson, D. F. Webb, N. Gopalswamy, E. Huttunen, J. C. Kasper, N. V. Nitta, W. Poomvises, B. J. Thompson, C.-C. Wu, S. Yashiro, **A. N. Zhukov**
Solar and interplanetary sources of major geomagnetic storms (Dst <= –100 nT) during 1996–2005
Journal of Geophysical Research, vol. 112, A10102, doi:10.1029/2007JA012321, 2007

[4] **A. N. Zhukov**
Using CME Observations for Geomagnetic Storm Forecasting
In: J. Lilensten (ed.), Space Weather – Research towards Applications in Europe, Astrophysics and Space Science Library, volume 344, 5–13, 2007, Springer

D.2.6.2.Publications without peer review

[5] **Vanlommel, P.**
Het Solar Influences Data analyses Center van de Koninklijke Sterrenwacht van België
Space Connection Vol. 61, 3-7

[6] **Vanlommel, P. and the SIDC-team**
Solar cycle 24, Belgian expertise in international panel
Press release April 25, 2007

[7] **Vanlommel, P. and the SIDC-team,**
The Fourth European Space Weather Week, Space Weather: a threat? The tempers of the sun.
Press release November 5, 2007

[8] **Vanlommel, P. and the SIDC-team,**
The Solar-Terrestrial Center of Excellence, Belgian know-how of a comprehensive space weather service
Press release November 5, 2007

D.2.6.3.Publications in press, submitted

[9] **B. Nicula, C. Marqué, D. Berghmans**
Visualization of distribututed solar data and metadata with the Solar Weather Browser
Sol. Phys.

[10] **Vanlommel, P.**
De aarde in de greep van de zon
Zenit

D.2.6.4.Reports, thesis, etc

[11] **R.A.M. Van der Linden and the SIDC team**.
Annual report 2007 to the International Space Environment Service.
ISES Annual Report

[12] **The SIDC team**
Outgoing messages from RWC Belgium: e.g. 365 daily ursigrams, 52 weekly bulletins, 4 quarterly bulletins, 12 Monthly Ri Reports, 12 Monthly Ri_hemispheric Reports, all-quiet-alerts,

presto alerts, halo CME alerts, GOES X-ray flare detection alert, reduced GPS accuracy alert, advance alert: enhanced geomagnetic activity warning.
E-mail distribution.The alerts are sent when needed, the other bulletins are sent on a regular basis.

D.2.7. Scientific outreach

Meeting presentations

[1] **O. Podladchikova, D. Berghmans**
EIT wave Automatic Detection
MSSL/USL, UK, January, 2007 (Invited Seminar)

[2] **O. Podladchikova, D. Berghmans**
NEMO/STEREO
5th SECCHI Consortium Meeting, Paris, France, March 2007 (Talk)

[3] **O. Podladchikova, D. Berghmans**
EIT wave catalog by NEMO
LPCE/CNRS, Orlenas University, March 2007 (Seminar)

[4] C. **Marqué, B. Nicula, A. Stanger, D. Berghmans**
The Solar Weather Browser: a quick look solar data browser [talk]
5th SECCHI Consortium Meeting, Orsay, France, March 2007

[5] **O. Podladchikova, D. Berghmans**
Preparation to Blast wave study with SECCHI
European Geophysical Union, EGU General Assembly, April 2007 (Invited talk)

[6] **O. Podladchikova, D. Berghmans**
Coronal Shock waves observation by NEMO techniques
Imperial College, London, UK, April 2007 (Invited seminar)

[7] **O. Podladchikova**
NEMO trial version for HINODE data
Institute European Geophysical Union, EGU General Assembly, April 2007 (Invited talk)

[8] **O. Podladchikova**, M. Pick
The joint study of NEMO EIT waves in EUV and Radio
Observatoire de Paris, Meudon, May 2007 (Invited seminar)

[9] **P. Vanlommel, R.A.M. Van der Linden**
The SIDC: WDC for the sunspot index and RWC for space weather services in Belgium
poster at the WDC conference, Bremen, May 2007

[10] **P. Vanlommel, R.A.M. Van der Linden**
The SIDC: data and data mamagement of the WDC for the sunspot index
poster at the WDC conference, Bremen, May 2007

[11] **Lawrence, G**., Rochus, P., Tu, C. **Berghmans, D., Hochedez, J.-F.**
The Kua-Fu Mission
Second IHY European Assembly, June 2007, Torino, Italy

[12] **O. Podladchikova, D. Berghmans**
NEMO for SDO
1ste Heliophysics Knowledge Base Workshop, ROB Brussels, Belgium, June 2007 (talk)

[13] **C. Marqué, B. Nicula, D. Berghmans**

The Solar Weather Browser [talk]
CESRA Meeting, Ioannina, Greece, June 2007

[14] **C. Marqué, B. Nicula, D. Berghmans**
The Solar Weather Browser [talk]
1st Heliophysics Knowledge Base Workshop, R.O.B, June 2007

[15] **O. Podladchikova, D. Berghmans**
Software to analyse EIT waves with STEREO
IAGA general Assembly, Perugia, Italy, July 2007 (Invited talk)

[16] **O. Podladchikova**
The identification of the EIT wave nature. Theory versus simulations. Historical aspects
SHINE meeting (American Science Foundation), July 2007 (Invited Review)

[17] **O. Podladchikova**
MHD waves in the Solar Corona
Summer School "Advances in Physics", Ukraine, August 2007 (Invited Tutorial)

[18] **C. Marqué, B. Nicula, A. Stanger, D. Berghmans**
The Solar Weather Browser [poster]
Living with a Star Workshop, Boulder, USA, September 2007

National and international responsibilities

- R. Van der Linden: Representation in ISES Board.
- R. Van der Linden: member of the scientific organizing committee of the fourth European Space Weather Week.
- R. Van der Linden: member of the Space Situational Awareness Users Group

Websites

- The SIDC website http://sidc.be (http://sidc.be/nemo)
- Creation and maintenance of the website of the European Space Weather Week: http://sidc.be/esww4

D.2.8. Missions

- P. Vanlommel, OFO course: Writing press releases, May 2007
- R. Van der Linden: SWWT meeting, Paris, 1 day
- R. Van der Linden & D. Berghmans: SSA meeting, Paris, 1 day
- A. Stanger, HAO, 4 days

D.3. Organisation of the SOHO20 Conference

D.3.1. Objectives

SIDC organized the 20th edition of the conferences associated to the SOHO ESA/NASA deep space mission. The meeting was held from 27 to 31 August 2007 at 'Het Pand' in Gent, Belgium, on the topic "Transient Events on the Sun and in the Heliosphere". Over 130 participants from 20 countries contributed to the success of "SOHO 20", which was organized around 4 scientific sessions: (1) Transients and dynamics in the lower solar atmosphere, (2) CMEs: Why and how do they erupt? (3) Heliospheric transients, and (4) Solar and heliospheric science in the next decade and beyond. The 4th session also included a panel discussion on "The next twenty years in solar physics". J.-F. Hochedez was the Chair of the SOC, with B. Fleck and J. Gurman as co-Chairs, and of the LOC, with E. Robbrecht as co-Chair.

D.3.2. Progress and results

In late 2006 and early 2007, JF Hochedez formed the SOC of SOHO20 by personal invitation. In Jan 2007, E. Robbrecht and JF Hochedez estimated the costs. In this period, JFH collected ideas to optimize the scope of the sessions. In February, the poster announcing the conference was designed (ER and JFH with www.vanlooveren-gobert.be), as well as the http://soho20.org/ website (B. Giordanengo, S. Willems, V. Delouille, ER, JFH). In March, Anne Vandersyppe and Tatiana Willems prepared a checklist for all necessary actions. An immense quantity of actions had subsequently to be triggered and monitored. They cannot be all accounted here. BG, ER and JFH set up a contract with Ogone and Europabank for the participants to be able to pay their fees online. Invited speakers were selected in intense collaboration with the SOC during May. Successive announcements have been released. Many abstract for contributed talks and posters were thus received. Another SOC-collaborative effort in June and July led to the list of the selected abstracts. The time table was optimized from July 13 to mid-August. The meeting was a great success, with a very international participation from all branches of solar physics. Presentations were of high quality. Both oral and poster sessions were well attended and awards were given for the best posters at the conference dinner.

D.3.3. Perspective for next years

The proceedings papers are being refereed and will be gathered into a special issue of Annales of Geophysics to appear in 2008. SIDC has widely developed its collaboration potentials at the occasion of SOHO20, and gained in international reputation.

D.3.4. Personnel involved

Scientific staff:	J.-F. Hochedez (SOC & LOC chair), E. Robbrecht (co-Chair of the LOC, Guest Editor of the SOHO20 special issue of Annales Geophysicae), B. Giordanengo (Conception, creation, and administration of the SOHO20 website, i.e. CMS system setup, participants and abstracts registration management, online payment, automatic mailing for the deadlines, invitation letters, etc), E. Pottiaux, D. Berghmans, I. Dammasch, V. Delouille, M. Kretzschmar, G. Lawrence, C. Marqué. S. Parenti, E. Podladchikova, L. Rodriguez, A. Zhukov
Technical staff:	A. Vandersyppe, S. Willems, T. Willems

D.3.5. Partnerships

List of international partners without grant

SOC members (See also the list at http://soho20.org/-SOC-LOC-.htm)

- Ayumi Asai, Nobeyama Solar Radio Observatory, Japan
- Dipankar Banerjee , Indian Institute of Astrophysics, India
- Volker Bothmer, Göttingen Universität, Germany
- Christina Cohen, California Institute of Technology, USA
- Thierry Dudok de Wit, LPCE/CNRS, Université d'Orléans, France
- Bernhard Fleck (SOC co-chair), ESA RSS Dept., NASA/GSFC, USA
- Lyndsay Fletcher, University of Glasgow, UK

- Toni Galvin, University of New Hampshire, Durham, USA
- Sarah Gibson, HAO/NCAR, Boulder, USA
- Victor Grechnev, Inst. of Solar Terrestrial Physics, Irkutsk, Russia
- Joe Gurman (SOC co-chair), NASA/GSFC, USA
- Don Hassler, Southwest Research Institute, Boulder, USA
- Jean-François Hochedez (SOC & LOC chair), Royal Observatory of Belgium, Belgium
- Stefaan Poedts, Katholieke Universiteit Leuven, Belgium
- Daniele Spadaro, Osservatorio Astrofisico di Catania, Italy
- Marco Velli, Università di Firenze, Italy
- Angelos Vourlidas, Naval Research Laboratory; USA
- Jingxiu Wang Beijing, Astronomical Observatory, China

List of national partners without grant

SOC/LOC members:

- Anik De Groof, Katholieke Universiteit Leuven, Belgium
- Pierre Rochus, Université de Liège, Belgium

Grants/Projects used for this research/service

- BELSPO (SIDC Data Exploitation PEA)
- ESA HQ grant
- ESA SOHO project
- FWO grant
- ROB support
- NASA LWS support
- Ghent University support

D.3.6. Publications

D.3.6.1. Publications in press, submitted

[1] **Robbrecht, E.; Hochedez, J.-F.;** Fleck, B.; Gurman, J.; Forsyth, R.
Preface: SOHO 20 - Transient events on the Sun and in the heliosphere
Annales Geophysicae, Volume 26, Issue 10, 2008, pp.2953-2953

D.3.7. Scientific outreach

Editorial responsibilities

- E. Robbrecht: Guest Editor of the Proceedings of the SOHO20 meeting, , with title: "SOHO20 - Transient events on the Sun and in the heliosphere"
- JF Hochedez: Guest Editor of the Proceedings of the SOHO20 meeting, , with title: "SOHO20 - Transient events on the Sun and in the heliosphere"

Meeting organization

- J.-F. Hochedez: SOC & LOC Chair of the SOHO 20 conference
- E. Robbrecht: LOC co-Chair of the SOHO 20 conference

Websites

- http://soho20.org

D.3.8. Missions

Field missions (days): J.-F. Hochedez (2), E. Robbrecht (4), A. Vandersyppe (4), T. Willems (2)

INTERDEPARTEMENTAL ACTIVITIES

A. Solar System Dynamics

A.1. Ephemerides of the Galilean Moons of Jupiter

A.1.1. Objectives

The aim is to determine very accurate ephemerides of the four Galilean moons of Jupiter from the collection of photographic plates of the Galilean moons of Jupiter taken by Dan Pascu at USNO over a period of more than 30 years. In collaboration with the IMCCE, Observatoire de Paris, France and the US Naval Observatory (USNO), Washington DC, US, the positions of the Galilean moons and the stars on the plates are to be extracted from the digital subimages produced by the DAMIAN digitiser and corrected for systematic errors caused by the distortion of the field of view during the digitisation. These corrected positions on the glass plates are then to be converted to celestial coordinates on sky taking into account all systematic effects at the time of the exposure. From these celestial positions very accurate orbital parameters will be calculated at different epochs as well as their evolution in time.

A.1.2. Progress and results

The work started in 2006 was continued and extended. The scientific and technical details of the extraction of the positions of the Galilean moons and the stars from digitised images were discussed with the partners at the IMCCE and USNO. Tests were done with digital images obtained with the MAMA digitiser at the Observatoire de Paris.

A.1.3. Perspective for next year

In 2008 a first series of selected plates will be digitised with the DAMIAN facility. The positions of the Galilean moons and of the stars will be extracted and corrected for systematic errors and the results analysed and published. A comparison with previous results and with those obtained with the MAMA machine will be made.

A.1.4. Personnel involved

Scientific Staff: J.-P. De Cuyper, L. Winter, V. Dehant, T. Van Hoolst

Technical Staff: G. de Decker

A.1.5. Partnerships

List of international partners

- Jean-Eudes Arlot, Valéry Laigney & Vincent Robert, IMCCE, Observatoire de Paris, France
- Dan Pascu & Norbert Zacharias, US Naval Observatory, Washington DC, US

Visitors:

- Jean-Eudes Arlot, Valéry Laigney & Vincent Robert; IMCCE, Observatoire de Paris, 23 May, 28 November and 20 December 2007

A.1.6. Missions

J.-P. De Cuyper (5 days), L. Winter (5 days), G. De Decker (3 days)

B. HERMES echelle spectrograph

In 2004, financial support was obtained by IvS KU Leuven (FWO and KU Leuven), ULB (FNRS) and ROB (Lotto) to build an echelle spectrograph for the Mercator telescope of the IvS at the Roque de los Muchachos Observatory on La Palma. Meanwhile, additional partners entered into the project (Thüringer Landessternwarte Tautenburg and Observatoire de Genève). The spectrograph is expected to be operational in the second half of 2008. HERMES is the acronym for High Efficiency and Resolution Mercator Echelle Spectrograph.

B.1. Data reduction package for the HERMES echelle spectrograph

B.1.1. Objectives

The Royal Observatory of Belgium has the responsability to provide in due time the data reduction and instrument control software (work package WP900). The objective is to provide, in contrast to the existing pipelines, a differential data-reduction system. The WP900 working group involves personnel from the department 2 and 3, as well as colleagues from the other partners in the HERMES project.

B.1.2. Progress and results

In 2007, a large part of the data reduction pipeline up to the extraction of the spectral orders was developed (see Figure 76) with programming contributions of Louis Dumortier, a new full-time programmer in the project, Yves Frémat and Herman Hensberge (and J. De Ridder, KULeuven and S. Van Eck, ULB). C. Siopis (ULB) kindly gave some lectures on the Python programming language, new to the ROB and ULB contributors. The learning curve of the language has been steeper than anticipated, resulting in less progress than hoped for at the start of the project.

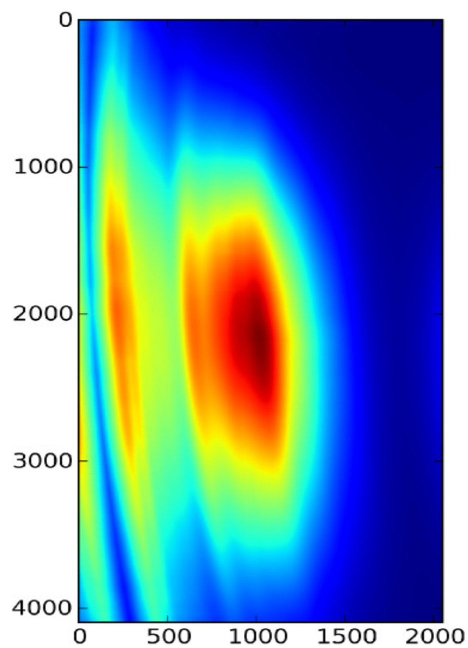


Figure 76: Background algorithm applied to a flat-field image taken by the FEROS echelle spectrograph

Tests on FEROS data obtained in 2004 as part of the project on Sco-Cen were analysed to evaluate the chances to implement a good merging and normalization of the spectral orders by the use of reference star spectra, by checking whether that instrument is sufficiently stable to rely on non-simultaneous observa-tions to model changes in the imaging. A minor part of the FEROS observations still suffers from erratic inconsistencies presumably due to lack of repetitivity in the shutter actions. The choice of reference stars is in preparation with the aid of P. Lampens and D. Duval, who made a first selection of candidate-reference stars.

With M. Borges having a one-year fellowship at ROB, FEROS spectra of much lower signal-to-noise ratio than previously treated by us were analysed and reduced, with the aim to test some procedures developed for higher signal-to-noise applications in a broader context. In this context, we developed also the option (in our personal FEROS pipeline based on ESO-MIDAS) to rebin the data piecewise in constant wavelength steps, such that for a set of subsequent orders the rebinned data always have a bin size within 10% of the size of the pixels on the CCD detector and such that subsequent sets have sufficient wavelength overlap. M. Borges was asked also to take the lead in the manual group and organise the meetings of this group, including P. Lampens, G. Van de Steene, S. Van Eck (ULB) and M. Reyniers (KULeuven, left the project during 2007).

B.1.3. Perspective for next years

The full pipeline will be developed before the end of the year, with aspects depending on the commissioning of the spectrograph depending on the availability of the instrument at the Mercator telescope. During commissioning time in late 2008 and/or early 2009, the instrument model must be developed and minor changes to the pipeline, mostly related with the choice of empirical fit functions, needs to be implemented. The final software for the construction of the instrument model in python language will need development efforts afterwards. The commissioning-time instrument model construction may depend partly on other software environments.

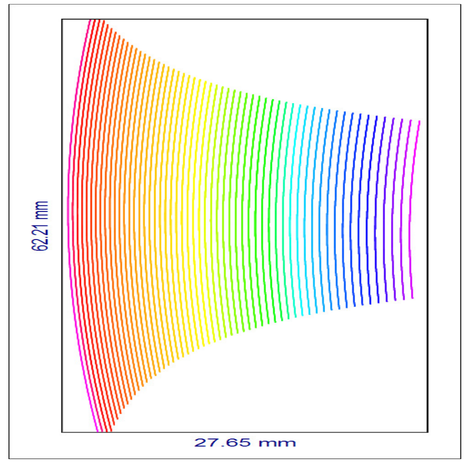


Figure 77. Echelle format of the HERMES spectrograph, projected on the CCD detector

B.1.4. Personnel involved

Scientific staff: M. Borges, Y. Frémat, H. Hensberge, P. Lampens, G. C. Van de Steene

Technical staff: L. Dumortier, D. Duval

B.1.5. Partnerships

Grants/Projects used for this research/service

- Financement by Lotto (2004) 'Onderdelen voor de opbouw van een hoge resolutie echelle spectrograaf voor de 1.2m MERCATOR telescoop'. H. Hensberge is promoter for ROB in the HERMES project of KULeuven – ULB – ROB.
- Post-doc fellowship to non-EU researchers (Belgian Science Policy)

List of national partners without grant

- J. De Ridder, KULeuven (software structure), H. Van Winckel (HERMES project leader)
- S. Van Eck, A. Jorissen, C. Siopis, ULB (module programming & introduction to python)

B.1.6. Scientific outreach

Meeting organization

Work Package 900 (data reduction software) progress meetings at ROB (24/01, 07/03, 09/05, 25/06) and KULeuven (20/11) with 10-13 participants, manual group meetings (24/04, 11/06, 24/07) with 5 - 6 participants

B.1.7. Missions

Research visits (days): Dumortier, L. (8), Frémat, Y. (2), Hensberge H. (8)

B.2. Procurement of optical components for the HERMES echelle spectrograph

B.2.1. Objectives

The Royal Observatory of Belgium contributes with the Lotto grant to the procurement of optical components for the HERMES echelle spectrograph. For information on the lay-out of the instrument, see http://hermes.ster.kuleuven.ac.be.

B.2.2. Progress and results

The ROB, in cooperation with the HERMES consortium, assigned the construction of the optical parts of the HERMES spectrograph financed by their Lotto grant to SESO, and followed up the progress in the construction process. Two doublets for the guiding telescope were delivered at the end of 2007.

B.2.3. Perspective for next years

The provisional delivery of the components is foreseen early in 2008. ROB will participate in the evaluation of the quality of the components, before acceptance.

B.2.4. Personnel involved

Scientific staff: J.-P. De Cuyper, H. Hensberge

B.2.5. Partnerships

List of international partners without grant

- U. Laux, H. Lehmann, H. Winkler (Thüringer Landessternwarte Tautenburg, Germany)
- Observatoire de Genève (Switzerland)

List of national partners without grant

- H. Van Winckel, J. De Ridder, M. Reyniers (KULeuven)
- A. Jorissen, S. Van Eck (ULB)

Grants/Projects used for this research/service

- Financement by Lotto (2004) 'Onderdelen voor de opbouw van een hoge resolutie echelle spectrograaf voor de 1.2m MERCATOR telescoop'

B.2.6. Publications

B.2.6.1. Publications without peer review

[2] **De Cuyper J.-P., Hensberge H.,** Raskin G, Van Winckel H, Lehmann H., Winkler, J., Laux U.
HERMES, a High-Resolution, Fiber-Fed Spectrograph for the Mercator Telescope
In: Astronomical Data Analysis Software and Systems XVI (eds. Richard A. Shaw, Frank Hill, David J. Bell), ASPC 376, 653

B.2.7. Missions

Commissions, working groups (days): J.-P. De Cuyper (3)

C. Gaia data reduction

Gaia is a cornerstone mission of the ESA Space Program, scheduled for launch in 2011. The satellite is aimed to repeatedly survey the whole sky to obtain positions, parallaxes and proper motions to micro-arcsec precision for all of the 10^9 objects brighter than V = 20. Compared to the previous Hipparcos mission (Figure 78), Gaia will achieve a substantial improvement in terms of astrometric accuracy and number of studied objects: parallax and proper-motion accuracy will be 100 times better and the number of stars is increased by a factor 10000. It is therefore considered as an ambitious astrometric mission that will significantly improve our understanding of the formation and evolution of the Milky Way Galaxy.

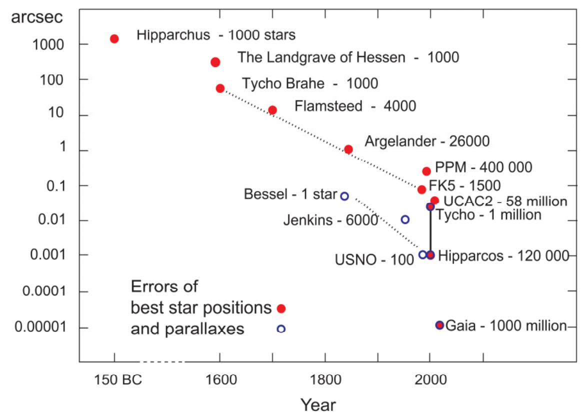


Figure 78: Evolution of the parallax and star position accuracy. Gaia is a real breakthrough that will provide parallaxes 100 times better than Hipparcos for a number of stars increased by a factor of 10000. (Credit: ESA)

The main weakness of the HIPPARCOS satellite was to not have any instrument dedicated to radial velocity determination and object/stellar classification. The strength of Gaia follows from the onboard dispersed photometric instrument that will cover the whole optical wavelength range (330–1050 nm) and the medium resolution spectrograph (RVS or Radial Velocity Spectrograph: 847–874 nm). These instruments will enable: the accurate simultaneous measurement of radial velocities (RVs), the variability characterization, as well as the determination of the astrophysical parameters (APs) down to magnitude 17 and the classification of all the targets down to magnitude 20.

The Gaia data processing represents a huge challenge due to both the sheer volume of data and the technical complexity of the processing. Such an effort has been compared to the mapping of the human genome for the impact that it will have on Galactic astrophysics. The European scientific community has been given the responsibility for all aspects of the data treatment and thus the Gaia **DPAC** (**D**ata **P**rocessing and **A**nalysis **C**onsortium) was set up in 2006. The DPAC involves more than 300 scientists in 15 countries spread over 8 **C**oordination **U**nits (**CU**s).

At the Observatory, we are 7 to be involved in the DPAC and in the development of the Gaia reduction software, 2 of us being funded by a dedicated PRODEX program. We are contributing to the software development of four different CUs: CU4 (Object Processing), CU6 (Spectroscopic Processing), CU7 (Variability Processing), CU8 (Astrophysical Parameters).

The software development made for Gaia takes place in 6-months development cycles, each cycle aiming to improve the previous software deliveries. The present report describes the work carried out during cycles 2 and 3.

C.1. Astrometric Reduction of Small Solar System Objects (CU4)

C.1.1. Objectives

The Pauwels-De Cat team (section 4 of the ROB) has been assigned the task of developing the software for **DU**454 "Astrometric reduction of small solar system objects", which is one of the **D**eveloping **U**nits of CU4. Its task will be to receive pixel coordinates of moving objects from DU453 (CCD processing) and to combine it with attitude and calibration data of the satellite as derived by IDT and/or AGIS (CU3), to produce positions (right ascension and declination) in the ICRS reference system.

C.1.2. Progress and results

Time was invested to learn the Java programming language and the framework for code development established by CU1 (Gaia System Architecture). A non-negligible time was also devoted to go through the numerous documents issued by the GAIA community, describing the work of DUs that will interact with DU454 or describing the framework to use. At CU4 meeting 2 (November 2006), DU454 was selected as one of the prototype DUs to give an extensive progress review at the next meeting. By having a few DUs in advance of the other DUs, potential problems can be detected more easily, and the prototype DUs can serve as an example for the other DUs. On a one-day meeting (February 16) in Paris of the prototype DUs of the Solar System part, the work was planned for the coming months.

The first action was to produce the software requirement specification document (SRS, [1]) listing also in detail the input/output (I/O) of the DU. Next, we made a skeleton of the programming code. This code contained only a dummy algorithm, but at this stage it was only the intention to have something that compiled and could run with dummy data, but inside the framework defined by CU1. Finally, we started extensive discussions with other DUs of the Solar System group, in order to get all DUs aligned about I/O. We have set up a detailed list of items at input and output.

There were two regular CU4 meetings in 2007, each marking the end of one of the six-month cycles in which the work is organised. The first one, CU4 meeting 3, at the end of cycle 2, was held in Nice, May 10-11. At that meeting we presented our SRS document [1]. The second one, CU4 meeting 4, at the end of cycle 3, was held in Paris, November 12-13. At that meeting we presented the skeleton of our code [2].

C.1.3. Perspectives for next years

Software developing will continue over the next four years. Parallel, the corresponding documents will be produced and adapted to the evolving software. This will be done in 10 six-month cycles, of which the first three cycles already ended. By 2011, the final software should be ready.

C.1.4. Personnel involved

Scientific staff: T. Pauwels, P. De Cat

Technical staff: A. Jonckheere

C.1.5. Partnerships

List of international partners without grant

- J.-E. Arlot and team, IMCCE, Paris, France
- All CU4 members

Grants/Projects used for this research/service

- PRODEX, Gaia-DPAC: Binaries, Extreme Stars and Solar System Objects, D. Pourbaix (BPI, ULB), Y. Frémat (Bco-I, ROB) , E. Gosset (Bco-I, Liège), T. Pauwels (Bco-I, ROB) 2007 – 2009

C.1.6. Publications

D.3.8.1.Reports, thesis, etc

[1] T. Pauwels
Software Requirements Specification for DU454 Astrometric Reduction
Gaia report no. GAIA-C4-SP-ROB-TP-001-01.

C.1.7. Scientific outreach

Meeting presentations

[1] **T. Pauwels**
Review for DU454 "Astrometric reduction for SSO"
10 – 11 May 2007, Progress report presented at CU4 meeting 3, OCA, Nice, France

[2] **T. Pauwels**
DU 454
12 – 13 November 2007, Progress report presented at CU4 meeting 4, Paris, France

Websites

- Update of the DU454 GaiaWiki page.

C.1.8. Missions

Commissions, working groups (days): P. De Cat (2), A. Jonckheere (2), T. Pauwels (5)

C.2. Single transit analysis (CU6)

C.2.1. Objectives

Radial and rotational velocity measurements will be an important part of the final output catalog of the mission. The Single Transit Analysis (STA) development unit (DU650: managed by Y.Viala, Paris-Meudon) has the responsability to develop different techniques that will allow to measure the radial and rotational velocity. Our objectives and duties in DU650 are to implement a minimum distance method and to implement Fourier transform techniques to derive the radial velocity and rotational velocity of single lined stars.

C.2.2. Progress and results

Our algorithms were implemented in the Java programming language. This implementation was done following the Gaia Software Engineering Guidelines and by using the Gaia and CU6 datamodel. Two versions of our codes were delivered to the CNES. Various documents were also delivered [1]-[3], describing the algorithm implementation (Software Requirements Specification, Design Document, Release Note, Users Manual, Test and Performance Verification Report). Java Unit tests were developed to provide technical tests of the code. To scientifically validate the code, it was applied to a large number of simulated data. A systematic bias was found that is due to the observations and templates not being normalized. The results also suggest that sharper templates provide better results. Intrinsic errors were determined and compared to those from Monte-Carlo simulations: agreement was not as good as it should be. These developments and first results were presented at the different CU meetings [1]-[6]. They are promising but show that the software still needs to be improved in different aspects (e.g. better error bar computation, normalization, noise filtering etc …).

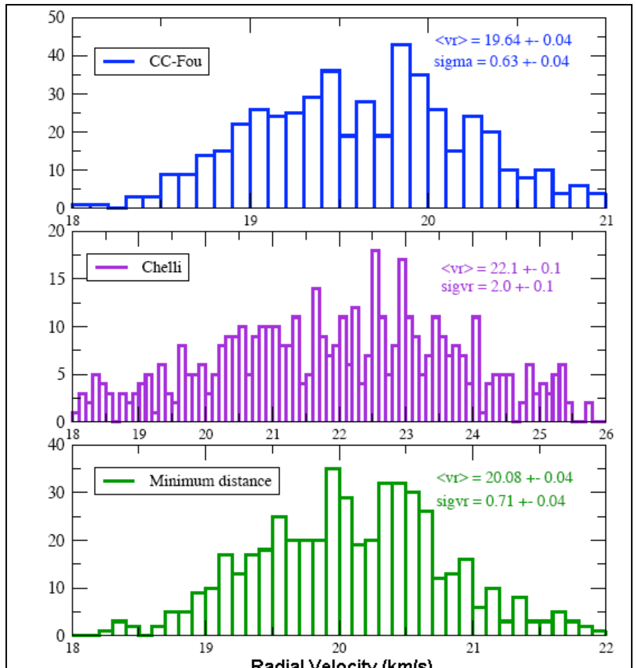


Figure 79: Monte Carlo simulations to estimate the current accuracy of the radial velocity determinations carried out adopting the 3 procedures implemented at ROB. The true radial velocity of the simulations is 20 km/s for a solar-like star. At this stage, the Fourier approaches (CC-Fou and Chelli) seems to be more sensitive to the template and source spectrum slope.

C.2.3. Perspective for next years

The algorithms will be extended to also determine the rotational velocity. It will be integrated with other software modules (e.g. those that normalize spectra). Various ways will be explored to optimize the code. Tests for the scientific validation of the code will continue. Additional important responsibilities such as the integration of all the STA algorithms (by R. Blomme) are also foreseen.

C.2.4. Personnel involved

Scientific staff: R. Blomme, Y. Frémat, C. Martayan

Technical staff: A. Jonckheere

C.2.5. Partnerships

List of international partners without grant

- D. Katz, Y. Viala, C. Delle Luche, Observatoire de Paris-Meudon, France
- C. Martayan, Observatoire de Paris/Meudon, France (at ROB since September 2007)
- All CU6 members

List of national partners without grant

- Y. Damerdji, Université de Liège

Grants/Projects used for this research/service

- PRODEX, Gaia-DPAC: Binaries, Extreme Stars and Solar System Objects, D. Pourbaix (BPI, ULB), Y. Frémat (Bco-I, ROB), E. Gosset (Bco-I, Liège), T. Pauwels (Bco-I, ROB) 2007-2009

Visitors:

- Y. Viala, C. Delle Luche (Observatoire de Paris-Meudon, France), E. Gosset, (Université de Liège), 11 May 2007, discussion Single-Transit Analysis

C.2.6. Publications

D.3.8.2. Reports, thesis, etc

[1] Y. Viala, **R. Blomme**, C. Delle Luche, J.-M. Désert, **Y. Frémat**, E. Gosset, D. Katz , **C. Martayan**
Single Transit Analysis (DU650) Software Requirements Specification
Gaia report no. GAIA-C6-SP-OPM-YV-001-3

[2] Y. Viala, **R. Blomme**, C. Delle Luche, J.-M. Désert, **Y. Frémat**, E. Gosset, D. Katz, **C. Martayan**
Software Design Document for Single Transit Analysis
Gaia report no. GAIA-C6-SP-OPM-YV-002-1

[3] Y. Viala, **R. Blomme**, M. David, C. Delle-Luche, **Y. Frémat**, E. Gosset
Software Test Plan and Verification Report for Single Transit Analysis -DU650 (Cycle 2)
Gaia report no. GAIA-C6-SP-OPM-YV-003-1

C.2.7. Scientific outreach

Meeting presentations

[1] **R. Blomme**
Radial and rotational velocity determination by minimum distance method
22 May 2007, CU6 workshop 3, MSSL, UK

[2] **Y. Frémat**, **A. Lobel**,
Radial velocity of single lined spectra by cross-correlation in Fourier space
22 May 2007, CU6 workshop 3, MSSL, UK

[3] **C. Martayan**,
Coarse characterization of source
7 December 2007, CU6 workshop 4, Toulouse, France

[4] **A. Jonckheere**,
Differences and similarities for software development in CU4, CU6, CU7, CU8
7 December 2007, CU6 workshop 4, Toulouse, France

[5] **R. Blomme**
Radial and rotational velocity determination by minimum distance method
7 December 2007, CU6 workshop 4, Toulouse, France

[6] **Y. Frémat**,
Radial velocity of singled lined spectra by cross-correlation in Fourier space, cycle 3 overview
7 December 2007, CU6 workshop 4, CNES, Toulouse, France

National and international responsibilities

- R. Blomme is manager of the package "Determination of radial velocity by minimum distance method"
- Y. Frémat is manager of the package "Determination of radial velocity by cross correlation in Fourier space"
- C. Martayan is manager of the package "Coarse characterization of sources".

Websites

- Creation and update of related GaiaWiki pages.

Meeting organization:

- May 2007. Organization of a 1-day STA radial velocity discussion meeting (invited people were: Y. Viala, C. Delle Luche, E. Gosset).

C.2.8. Missions

Commissions, working groups (days): R. Blomme (8), Y. Frémat (13), A. Jonckheere (3) C. Martayan (3)

C.3. Variability Characterization (CU7)

C.3.1. Objectives

The tasks of the people involved at the Observatory are the supervision of the general work package Variability characterization and the concrete realization of the subworkpackage Period Search. The latter includes the coding (in Java) of that part of the variability pipeline that will deal with (possible) periodicity in the data. In the final reduction only a limited number of methods for period search will be used, but it is necessary to evaluate the behaviour, the efficiency and the computational feasibility of different methods.

We are responsible for a few other minor work packages as well, but the work to be done there is postponed to next year.

C.3.2. Progress and results

In 2006 already started the definition of the requirements necessary for the processing of variable data. This resulted in 2007 in a lot of Software Requirement Specification Documents (SRS) to describe the needs [1]-[8], as well at the top level (Characterization, general pipeline) as at a lower level. Also a few SRS were written for the test algorithms, although it is very likely that not all the methods will be used in the final reduction. But this was done for comparison reasons.

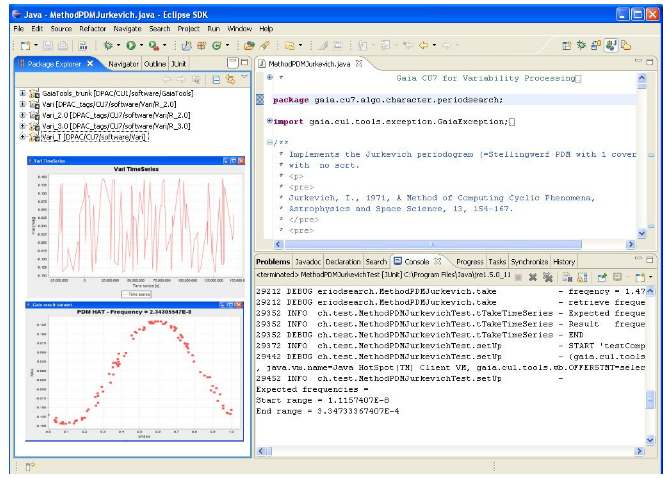


Figure 80: Implementation of the phase dispersion minimization method for period search (Jurkevich 1971).

To compare the different methods (Figure 80) the application of the methods to Hipparcos data of known periodic variables as done in 2006 was studied in more detail now. The Fourier method known as Lomb-Scargle algorithm has the highest rate of success in finding (known) periods (89%) and is also one of the fasted methods. It is still to be seen what percentage of success other methods could add to this and if there are groups of specific variable stars where the periods are not easily found by this method but can be discovered by other methods. This is still under investigation.

Results of the comparison of different methods for period search were presented at the 4th CU7 meeting in Bologna (March 2007) [1]-[2]. Also the first worked out guidelines for the general processing were presented there and later at the 5th CU7 meeting in Lisbon [3]-[4].

A first (limited) version of the characterization following these guidelines was coded and integrated.

As agreed in CU7 each member of CU7 was also reviewer of other SRS documents. Jan Cuypers reviewed and commented on the Top Level SRS document (GAIA-C7-SP-GEN-PD-006-01) and the Global Variability SRS documents (Catalogue visualization, GAIA-C7-SP-SVO-LSB-008, and Survey Quality assessment, GAIA-C7-SP-SVO-LSB-008).

C.3.3. Perspective for next years

A more elaborated pipeline for the characterization of the variability will be coded and implemented. A selection of the methods for Period Search will be made based on the results of data series of known and simulated variables. The methods will have to be implemented with their statistical properties. The influence of a long term trend on the period search and further modeling of the data will have to be studied.

C.3.4. Personnel involved

Scientific staff: J. Cuypers, P. De Cat

Technical staff: A. Jonckheere

C.3.5. Partnerships

List of international partners

- L. Eyer, Observatoire de Genève, Switzerland
- L. Sarro, Artificial Intelligence Department, UNED & Virtual Observatory, Spain
- A. Lanzafame, Department of Physics and Astronomy, University of Catania, Italy
- All CU7 members

List of national partners

- Institute of Astronomy (C. Aerts, J. De Ridder, J. Blomme, …), Department of Physics and Astronomy, K.U.Leuven

Grants/Projects used for this research

- PRODEX, Gaia-DPAC: Variability, C. Aerts (BPI, KULeuven), J. Cuypers (Bco-I, ROB), 2007-2009
- FWO-project G.0332.06 "Observationele bepaling van nauwkeurige interne en circumstellaire structuurmodellen van sterren", Promotor: Prof. Dr. Conny Aerts, partners: K.U.Leuven, UGent, V.U.Brussel, ROB (J. Cuypers)

C.3.6. Publications

C.3.6.1. Reports, thesis, etc

Gaia Software Requirement Specification (SRS) documents (so far only internal reports):

[1] **J. Cuypers,**
Variability Characterization SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-007

[2] **J. Cuypers,**
Period Search SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-002

[3] **P. De Cat,**
PeriodSearch: Jurkevich Method SRS,
Gaia report no. GAIA-C7-SP-ROB-PDC-001

[4] **J. Cuypers,**
Period Search: Deeming Method SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-001

[5] **J. Cuypers,**
Period Search: HLSQS Method SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-004

[6] **J. Cuypers,**
Period Search: Lomb-Scargle Method, SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-005

[7] **J. Cuypers,**
Period Search: String Length Method, SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-006

[8] **J. Cuypers,**
Variability Characterization End Test, SRS,
Gaia report no. GAIA-C7-SP-ROB-JCU-003

C.3.7. Scientific outreach

Meeting presentations

[1] **J. Cuypers,**
Variability Characterization: Period Search: Current SRS Ideas
23 – 24 March 2007, 4th Gaia CU7 meeting, Bologna, Italy

[2] **J. Cuypers,**
Variability Characterization: Current SRS Ideas

23 – 24 March 2007, 4th Gaia CU7 meeting, Bologna, Italy

[3] **J. Cuypers,**
Period Search Methods
30 – 31 October 2007, 5th Gaia CU7 meeting, Lisbon, Portugal

[4] **A. Jonckheere, J. Cuypers,**
SDD example walk through,
30 – 31 October 2007, 5th Gaia CU7 meeting, Lisbon, Portugal

National and international responsibilities

- J. Cuypers is the manager of the Variability characterization and period search top level work-package

C.3.8. Missions

Commissions, working groups (days): J. Cuypers (10), A. Jonckheere (2)

C.4. Extended Stellar Parametrizer (CU8)

C.4.1. Objectives

The extended stellar parametrizer is one of the CU8 top level workpackages. Its goal is to take care of the subsample of "extreme" but important stars which may not be well treated by "standard" grids and thus by GSP-phot (Generalised Stellar Parametrizer). ESP also reconsiders combinations and specific use of the Gaia data. It is composed of 5 workpackages having the responsibility to study "Cool stars", "Ultra Cool stars", "Anomalous Abundance Stars", "Hot Stars" and "Emission Line stars". Hot and emission line stars are under the responsibility of the ROB, while the other packages are managed by Spanish, Swedish and Italian teams.

C.4.2. Progress and results

Since the implementation of the Gaia software has to be performed in JAVA, a few weeks were devoted in the beginning of 2007 to learn the coding language and guidelines. Six-month development cycles were adopted by CNES. We had therefore two software delivery deadlines in 2007 [2]-[8]. In April and October two versions of the "Extended Stellar Parametrizer" have been delivered to CNES. At the present time, the algorithms is mainly treating the RVS spectral range of Gaia in order to derive the astrophysical parameters (effective temperature, surface gravity) of hot stars and characterize the spectral line emission observed in emission line stars. Several tests have been carried out to estimate the efficiency of the software using a Montecarlo technique (Figure 81) and the available Gaia simulated data. In spite the fact that the RVS spectral range is dominated by broad Hydrogen lines, these tests showed us that to increase the accuracy of our determinations we had to take into account rotation broadening. It showed also that to study stars fainter

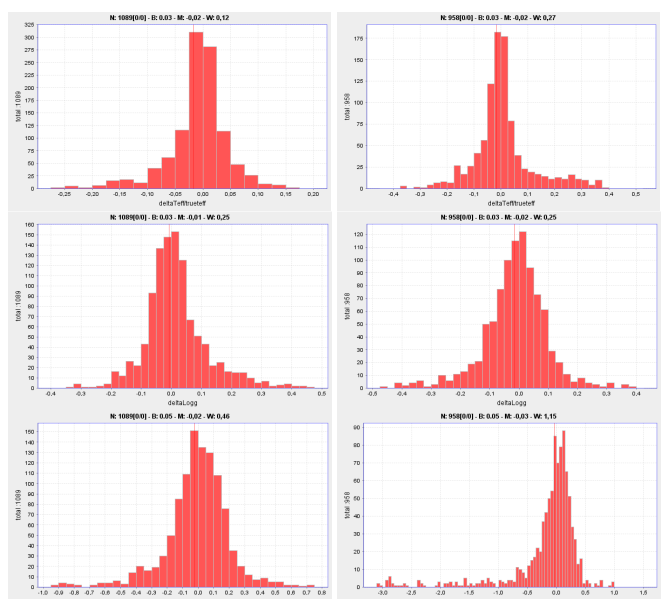


Figure 81: Montecarlo simulations we carried out for B (left) and O (right) type stars. Effective temperature (upper), surface gravity (middle) and apparent rotation velocity (lower) deviations have been estimated.

than magnitude 12 the use of noise filtering techniques should be tried.

Another goal of the ESP is to test in some cases different approaches to model [1] the stellar atmospheres and spectra, and to provide grids of synthetic spectra that will be used, after processing by CU2, to test the different algorithms (mainly of CU6 and CU8). In this framework, experiments were done with the CMFGEN stellar atmosphere code to calculate spectra for hot stars. Preliminary results suggest that the effect of mass loss might be detectable for the hottest stars.

Parallel to the development of the ESP, we also contributed in the first draft of the functional analysis of CU8 [5] and to the first overview of its Software Requirements Specifications [9].

C.4.3. Perspective for next years

Software will be delivered that determines the stellar parameters of hot stars, based on a grid of template spectra. The possibility of extracting information about the mass-loss rate from the Hα line will be explored. We will further continue to develop our algorithms for the classification of emission line stars. Using the server (gaiasrv) that we bought at the end of 2007, we will further also provide CU2 with synthetic spectra computed for O, WR, and Be stars.

C.4.4. Personnel involved

Scientific staff: R. Blomme, Y. Frémat, C. Martayan

Technical staff: A. Jonckheere

C.4.5. Partnerships

List of international partners without grant

- A. Lanzafame, Italy
- O. Kochukov, Uppsala, Sweden
- C. Martayan, Observatoire de Paris/Meudon, France (at ROB since September 2007)
- D. Barrado, Spain
- All CU8 members

Grants/Projects used for this research

- PRODEX, Gaia-DPAC: Binaries, Extreme Stars and Solar System Objects, D. Pourbaix (BPI, ULB), Y. Frémat (Bco-I, ROB) , E. Gosset (Bco-I, Liège), T. Pauwels (Bco-I, ROB) 2007 – 2009

Visitors:

- A. Miroshnichenko, University of North Carolina, 20 – 23 June 2007 (**PRODEX C90290**)

C.4.6. Publications

C.4.6.1. Publications in press, submitted

[1] J.-C. Bouret, T. Lanz, **Y. Frémat,** F. Martins, K. Lefever, **R. Blomme**, **C. Martayan**, C. Neiner, P. Quinet, J. Zorec
The spectra of massive stars with Gaia
Proceedings of "Massive Stars: Fundamental Parameters and Circumstellar Interactions", Eds. P. Benaglia, G. Bosch and C.E. Cappa, *in press*

C.4.6.2. Reports, thesis, etc

[2] **Y. Frémat,** A. Lanzafame, B. Leroy, C. Martayan, C. Neiner

Cycle 2 - Extended Stellar Parametrizer – Software Requirements Specification, Software Design, Software Users Manual
Gaia report no. GAIA-C8-SP-ROB-YF-002-01

[3] B. Leroy**, Y. Frémat**, A. Lanzafame, C. Martayan, C. Neiner
Cycle 2 - ESP – Software Test Plan and Verification Report
Gaia report no. GAIA-C8-SP-OPM-BL-001-01

[4] A. Lanzafame, **Y. Frémat,** B. Leroy, C. Martayan, C. Neiner
Extended Stellar Parametrizer, Cycle 2 Software Release Note
Gaia report no. GAIA-C8-SP-UNCT-AL-002-1

[5] F. Thévenin, C.A.L. Bailer-Jones, **Y. Frémat**, A.M. Janotto
Functional Analysis of CU8
Gaia report no. GAIA-C8-TN-OCA-FT-001-1

[6] **Y. Frémat**, D. Barrado, **A. Jonckheere,** A. Lanzafame, **C. Martayan**, C. Neiner, L. Sarro, V. Straizys
Cycle 3 - Extended Stellar Parametrizer – Software Requirements Specification, Software Design, Software Users Manual
Gaia report no. GAIA-C8-SP-ROB-YF-002-03

[7] **Y. Frémat,** D. Barrado, L. Barro, **A. Jonckheere,** A. Lanzafame, **C. Martayan,** C. Neiner, L. Sarro, V. Straizys
Cycle 3 - ESP – Software Test Plan and Verification Report
Gaia report no. GAIA-C8-SP-OPM-BL-001-03

[8] A. Lanzafame, **Y. Frémat,** D. Barrado, L. Barro, **A. Jonckheere,** C. Neiner, **C. Martayan,** V. Straizys
Extended Stellar Parametrizer, Cycle 3 Software Release Note
Gaia report no. GAIA-C8-SP-UNCT-AL-002-2

[9] C.A.L. Bailer-Jones, A.-M. Janotto, F. Thévenin, **Y. Frémat**
CU8 Software Requirements Specification
Gaia report no. GAIA-C8-SP-MPIA-CBJ-032-01

C.4.7. Scientific outreach

Meeting presentations

[1] **Y. Frémat**
Selected stars for ESP
8 – 9 March 2007, GBOG Meeting 02, Paris, France

[2] **Y. Frémat,** D. Barrado, A. Lanzafame, C. Martayan, C. Neiner, V. Straizys
Extended Stellar Parametrizer, Report on Cycle 2 work
14 – 15 June 2007, CU8 Meeting 3, Uppsala, Sweden

[3] **Y. Frémat, R. Blomme, A. Jonckheere, C. Martayan,** B. deBatz, A.-M. Hubert, M. Floquet, B. Leroy, C. Neiner
Classification of Hot and Emission Line Stars
13 – 14 December 2007, CU8 Meeting 4, Athens, Greece

[4] **A. Jonckheere**,
Differences and similarities for software development in CU4, CU6, CU7, CU8
6 – 7 November 2007, GHOST meeting 3, Meudon, France

[5] **Y. Frémat**

ESP/Hot stars overview of cycle 3
6 – 7 November 2007, GHOST meeting 3, Meudon, France

National and international responsibilities

- R. Blomme is Manager of the Hot Stars work package
- Y. Frémat is manager of the Extended Stellar Parametrizer top level work package
- Y. Frémat is CU8 representative for the **GBOG** (**G**aia **G**round **B**ased **O**bservations)
- C. Martayan is Manager of the Emission Line Stars work package

Websites

- Creation and update of related GaiaWiki pages.

C.4.8. Missions

Commissions, working groups (days): R. Blomme (2), Y. Frémat (10), A. Jonckheere (3), C. Martayan (2)

Research visits (days): Y. Frémat (5)

GENERAL SCIENTIFIC ACTIVITIES

Representations at national level

- V. Dehant: President of the Belgian National Comittee of Geodesy and Geophysics;
- V. Dehant, T. Van Hoolst, R. Van der Linden: members of the Belgian National Comittee of Astronomy;
- C. Bruyninx, Th Camelbeeck, K. Vanneste: Member of the Belgian National Comittee of Geodesy and Geophysics;
- F. Roosbeek, T. Van Hoolst, M. Everaerts, M/ Van Camp: Associate member of the Belgian National Comittee of Geodesy and Geophysics;
- V. Dehant, C. Bruyninx, F. Roosbeek, T. Van Hoolst: Associated Member of the Belgian National Committee of Space Research
- S. Lambert: Member of the Comité National Français de Géodésie et Géophysique (CNFGG);
- P. Lampens: ROB representative in the Belgian national ESO Committee (BNEC)
- P. De Cat, Y. Frémat, P. Lampens: Members of the HERMES consortium
- Y. Frémat: Member of the Société Française d'Astrophysique
- Griet Van de Steene: member of BNEC
- Griet Van de Steene: member of VISA time allocation committee
- Camelbeeck Thierry, M. Van Camp: Member of BESEIG
- Camelbeeck Thierry: Associate member of the Royal Academy for Overseas sciences
- Camelbeeck Thierry: President of the Société Royale Belge d'Astronomie, de météorologie et de physique du globe.
- Camelbeeck Thierry: Member of the "Belgian committee for the Quaternary" – BELQUA
- Lecocq Thomas: Member of Geologica Belgica
- Lecocq Thomas: Member of Société Géologique du Nord, France.

Representations at international level

- V. Dehant: Belgian representative in the IUGG Council;
- V. Dehant: Belgian representative in IAG;
- P. Defraigne: Belgian representative at the Consultative Committee for Time and Frequency, BIPM (Bureau International des Poids et Mesures);
- Th. Camelbeeck: Belgian representative at the International Association of Seismology and Physics of the Earth;
- K. Vanneste: Belgian representative in the European Seismological Commission (ESC) for the period 2006–2010;
- F. Collin, Belgian representative at the Euro-Mediterranean Seismological Center;
- G. Van de Steene: Belgian representative in the ESO User's committee;
- M. Van Camp: Belgian representative for the working group "Global Earthquake Risk Map Initiative", Global Science Forum, OECD;
- G. Van de Steene: ROB representative Herschell PACS mission guaranteed time project on evolved stars;
- F.Clette: Belgian representative in the CRAF (Committee for RadioAstronomy Frequencies);
- F.Clette: Belgian representative to the JOSO Board (Joint Organisation for Solar Observations).

Memberships of international scientific committees:

- C. Bruyninx: Member of the International Global Navigation Systems Society;
- V. Dehant: President of the Panel 'Earth Science' for the evaluation of the Descartes Research Prize;
- Th. Camelbeeck: referee for internal report of the French CEA;
- A. Hubert-Ferrari: referee for the National Sciences Foundation - Tectonic Section;

- M. Van Camp: referee for CNRS project;
- M. Van Camp: representative of the Observatory as IRIS foreign affiliate;
- M. Van Camp: Member of the ‘Working group on Gravimetry’, Consultative Committee for Mass and Related Quantities, Bureau International des Poids et Mesures (BIPM, Sèvres, France);
- M. Van Camp: Member of GGP;
- P. De Cat, Y. Frémat: Member of the Gaia Hot Star Team (GHOST);
- P. De Cat, T. Pauwels: Members of Gaia DPAC Coordination Unit 4 “Astrometric processing” (CU4);
- P. De Cat, R. Blomme, Y. Frémat, A. Jonckheere and C. Martayan are Members of the Gaia DPAC Coordination Unit 6 “Spectroscopic processing” (CU6);
- J. Cuypers, P. De Cat and A. Jonckheere are Members of the GAIA-DPAC Coordination Unit 7 “Variability processing” (CU7);
- R. Blomme, Y. Frémat, A. Jonckheere and C. Martayan are Members of the GAIA-DPAC Coordination Unit 8 “Astrophysical parameters” (CU8);
- T. Pauwels: Deputy of Gaia DPAC DU454;
- Y. Frémat: Member of the CoRoT Be stars workgroup;
- P. De Cat: Member of the CoRoT Gamma Doradus Working Group;
- P. Lampens: Member of the CoRoT Binary Thematic Team;
- R. Van der Linden: Member of the Solar Cycle 24 Prediction Panel (NASA/ISES);
- D. Berghmans: member of the Solar System Working Group (SSWG, ESA Advisory Committee);
- D. Berghmans, R. Van der Linden: member of the Space Weather Working Team (SWWT);
- D. Berghmans: member of the Working Group of the International Living with a Star (ILWS);
- D. Berghmans: member of the Belgian national committee for the *International Heliophysical Year;*
- F. Clette: URSI Commission J (Radioastronomy);
- F. Clette: URSI representative to the FAGS Committee (Federation of Astronomical and Geophysical Data Analysis Services) since 2006;
- E. Podladchikova, A. Ben Moussa: Referee for space call of FP7 projects;
- A. Verdini: NASA peer review on “Heliophysics Theory Program”, Washington D.C., 1/10/07-5/10/07;
- A. BenMoussa: Evaluator for the French PNANO/ANR programme (Nanosciences and nanotechnologies);
- B. Giordanengo: Evaluator for the French PNANO/ANR programme

IAU (International Astronomical Union)

- V. Dehant: Member (as Past-President) of Commission 19 “Earth Rotation” Advisory Board;
- P. Defraigne: Member of Commission 19 “Earth Rotation” Advisory Board;
- P. Defraigne: Member of the Organizing Committee of Division I “Fundamental Astronomy”;
- P. Defraigne: President of Commission 31 “Time”;
- T. Pauwels: Member of IAU Task Force on the Preservation and Digitization of Photographic Plates (PDPP);
- T. Pauwels: Member of IAU Working Group on the Astrographic Catalogue and Carte du Ciel Plates;
- T. Pauwels: Member of IAU Working Group "Astrometry by small ground-based telescopes";
- T. Pauwels: Member of IAU Commission 7 "Celestial Mechanics & Dynamical Astronomy";
- T. Pauwels: Member of IAU Commission 8 "Astrometry";
- C. Bruyninx, P. Defraigne, V. Dehant, F. Roosbeek, T. Van Hoolst: Members of IAU Commission 19 “Earth Rotation”;

- T. Pauwels, P. De Cat: Member of IAU Commission 20 "Positions & Motions of Minor Planets, Comets & Satellites";
- Herman Hensberge: Member of IAU Commission 25 “Stellar Photometry and Polarimetry”;
- P. De Cat, P. Lampens: Member of IAU commission 26;
- T. Van Hoolst, P. De Cat, P. Lampens: Member of IAU Commission 27 “Variable Stars”;
- C. Bruyninx, P. Defraigne, V. Dehant: Members of IAU Commission 31 “Time”;
- Ronny Blomme: Member of IAU Commission 36 “Theory of Stellar Atmospheres”

IAG (International Association of Geodesy)

- V. Dehant: President of IAG Commission 3 “Earth Rotation and Geodynamics”;
- C. Bruyninx: Network Coordinator of the EUREF Permanent GPS Network (EPN);
- C. Bruyninx: Head of Central Bureau of the EUREF Permanent GPS Network (EPN);
- C. Bruyninx: Chair of the “EUREF Technical Working Group”, governing board of the “sub-commission for Europe” SC1.3.a: of IAG Commission 1 “Reference Frames”;
- C. Bruyninx: Chair of the IAG Working Group SC1.3 “Regional Dense Velocity Fields”;
- F. Roosbeek: Member of Central Bureau of the EUREF Permanent GPS Network (EPN);
- C. Bruyninx: Member of the EPN Special Project “Time Series Monitoring”;
- C. Bruyninx: Head of EPN Analysis Center;
- C. Bruyninx: Head of EPN Data Center;
- C. Bruyninx: Co-chair of the Inter-Commission Study Group IC-SG1.2 “Use of GNSS for Reference Frames” (joint between IAG Commission 1 “Reference Frames”, Commission 4 “Positioning and Applications”, and IGS International GNSS Service);
- C. Bruyninx: Member of the IAG Inter-Commission Project 1.2 on “Vertical Reference Frames”;
- C. Bruyninx: Member of the Working Group “European Combined Geodetic Network (ECGN)” of the EUREF sub-commission”;
- T. Van Hoolst: Member of the IAG Commission 3 Advisory Board representing the Inter-commission on “Theory”;
- Ö. Karatekin: Member of the IAG Commission 3 Advisory Board representing the Inter-commission on “Planetary Geodesy”;
- C. Bruyninx: Member of the Governing Board of “Wegener”, an IAG Inter-commission project;
- Ö. Karatekin: Member of steering committee of the Inter-commission on “Planetary Geodesy”;
- T. Van Hoolst: Member of steering committee of the IAG Inter-commission on “Theory”;
- C. Bruyninx, F. Roosbeek: Members of IAG Commission 1;
- M. Van Camp: Member of IAG Commission 2
- C. Bruyninx, P. Defraigne, V. Dehant, Ö. Karatekin, F. Roosbeek, T. Van Hoolst: Members of IAG Commission 3;
- C. Bruyninx, F. Roosbeek: Members of IAG Commission 4;
- C. Bruyninx: Member of IAG Commission 19;
- T. Van Hoolst: Effective member of IAG Sub-Commission 3.3 “Geophysical Fluids” of the IAG commission 3 “Geodynamics and Earth Rotation”;
- B. Ducarme: Member of Working Group “Precise Tidal Predictions”, of the Earth Tides Sub-commission;
- M. Van Camp: member of the Study Group 2.1.1 on Comparisons of Absolute Gravimeter SGCAG of sub-commission 2.1 (Gravity and Gravity Networks) of IAG Commission 2 (Gravity Field).

IERS (International Earth rotation and Reference systems Service)

- T. Van Hoolst: Head of the IERS Special Bureau for the Core
- P. Defraigne, V. Dehant: Members of IERS Special Bureau for the Core
- V. Dehant: Member of the IERS Conventions Editorial Board;

- S. Lambert: Member of the IERS Working Group on “Prediction”;
- T. Van Hoolst: IERS Associate Member

IGS (International GNSS Service)

- C. Bruyninx: Associate Member of the IGS
- C. Bruyninx: Member of Real-time IGS Pilot Project Committee
- C. Bruyninx: Co-chair of the IGS Working Group on GNSS
- P. Defraigne: Member of the WG 'Clock Products WG' of the IGS

IVS (International VLBI Service)

- S. Lambert: Associate Member of IVS (International VLBI Service for Astronomy and Geodesy);
- S. Lambert: Member of the WG “Second Realization of the ICRF” of IAU/IERS/IVS.

AGU (American Geophysical Union)

- V. Dehant: Member of the Selection Committee for the Bowie Medal of AGU;
- Th. Camelbeeck, T. Lecocq, M. Van Camp: Members of AGU

EGU (European Geophysical Union)

- V. Dehant: Member of the Selection Committee for the Veining Meinesz Medal of EGU (European Geophysical Union).

ESA (European Space Agency)

- T. Van Hoolst: Chairman of the WG on “Jovian Satellites” of the LAPLACE Mission to Europa and the Jovian System;
- V. Dehant: Member of the WG on “Jovian Satellites” of the LAPLACE Mission to Europa and the Jovian System;
- V. Dehant, Ö. Karatekin, N. Rambaux, T. Van Hoolst. O. Verhoeven: Members of the WG on “Europa” within the Initiative for a Future Mission to Europa and the Jovian System;
- V. Dehant: Member of the Review Team for the Cassini-Huygens Archive;
- V. Dehant, T. Van Hoolst, O. Verhoeven, A. Rivoldini: Member of the Working Group MINT "Mars INTerior synergy".

Editorial responsibilities

- C. Bruyninx: Member of the Advisory Editorial Board of GPS Solutions;
- V. Dehant: Editor of IAG Proceedings Meeting 2007 for the Session GS003;
- B. Ducarme: Editor of “Bulletin d’Information des Marées Terrestres”;
- J. Cuypers: editor of a special issue of Space Connection (part of Science Connection) on Heliophysical Research in Belgium on the occasion of the International Heliophysical Year 2007-2008.

Journal refereeing

- P. Defraigne: referee for *IEEE Transaction on Ultrason., Ferroel. and Freq. Control*
- P. Defraigne: referee for *Metrologia*
- C. Bruyninx: referee for *GPS Solutions*
- N. Bergeot, C. Bruyninx: referee for *IAG Symposia Series*
- C. Bruyninx: referee for *Journal of Geodesy*
- T. Van Hoolst: referee for *Journal of Geophysical Research*
- T. Van Hoolst: referee for *Geophysical Journal International*
- T. Van Hoolst: referee for *Icarus*
- T. Van Hoolst: referee for *Treatise on Geophysics*

- O. Verhoeven: referee for *Journal of Geophysical Research*
- P. Alexandre: referee for a paper in J. Fréchet, M. Meghraoui and M. Stucchi (eds.), *Modern Approach in Historical Seismology: Interdisciplinary studies of past and recent earthquakes*, Springer, Series: Modern Approaches in Solid Earth Sciences
- P. Alexandre: referee for the *Bulletin de la Société Géographique de Liège*
- Th. Camelbeeck: referee for *Tectonophysics*
- B. Ducarme: referee for *Journal of Geodesy*
- B. Ducarme: referee for *Geophysical Journal International*
- B. Ducarme: referee for *Journal of Geodynamics*
- M. Everaerts: referee for *Journal of African Geology*
- A. Hubert-Ferrari: referee for *Journal of Geophysical Research*
- A. Hubert-Ferrari: referee for *Geophysical Journal International*
- A. Hubert-Ferrari: referee for *Tectonophysics*
- A. Hubert-Ferrari: referee for *Turkish Journal of Earth Sciences*
- A. Hubert-Ferrari: referee for *Earth and Planetary Sciences Letters*
- M. Van Camp: Referee for *Geophysisical Research Letters*
- M. Van Camp: Referee for *Hydrogeology J.*
- M. Van Camp: Referee for *J. Geophysical Research* (2x)
- M. Van Camp: Referee for *Metrologia*
- J. Sauval: Referee for *Astronomy and Astrophysics*
- E. Robbrecht: referee for *Solar Physics*
- J.-F. Hochedez: referee for *Solar Physics*
- L. Rodriguez: referee for *Annales Geophysicae*
- L. Rodriguez: referee for the *Journal of Atmospheric and Solar-Terrestrial Physics*
- L. Rodriguez: referee for *Geofísica Internacional*
- V. Delouille: referee for *Solar Physics*
- V. Delouille: referee for *Annales of Geophysicae*
- V. Delouille: referee for *International Journal of Wavelet, Multiresolution and Information Processing.*
- J.-F. Hochedez: referee for *Statistical Methodology*
- C. Marqué: referee for *The Astrophysical Journal*
- S. Parenti: referee for *Space Sci. Rev.*
- S. Parenti: referee for *Astronomy and Astrophysics*
- E. Podladchikova: referee for *The Astrophysical Journal*
- E. Podladchikova: referee for *Astronomy and Astrophysics*
- E. Podladchikova: referee for the *Journal of Atmospheric and Solar-Terrestrial Physics*
- A. Zhukov: referee for *Annales Geophysicae*
- A. Zhukov: referee for *The Astrophysical Journal Letters*
- R. Van der Linden: referee for *Solar Physics*

Teaching at universities

- V. Dehant: Lecturer at the UCL, Title "Géophysique Interne" (PHYS2140), 15h, until June 2007
- V. Dehant: Lecturer at the UCL, Title "Questions Spéciales de Géophysique Interne" (PHYS3233), 8h, until June 2007
- V. Dehant: Lecturer at the UCL, Title " Géophysique Interne" (PHYS2160), 25h, from June 2007
- V. Dehant: Lecturer at the UCL, Title "Astronomie et Géodésie" (PHYS1120), 7.5h
- V. Dehant: Lecturer at the Nantes University, "Géophysique des planets telluriques", 10h
- L. Koot : exercises of the lecture on "Astronomie et Géophysique" at the UCL
- T. Van Hoolst: lecturer of the course "Theoretical seismology" at the Katholieke Universiteit Leuven, 36h (every two years)

- T. Van Hoolst: lecturer of the course “Physics of Planets” at the Katholieke Universiteit Leuven, 36h (every two years)
- O. Verhoeven: Chargé d'enseignement, Nantes University, Planétologie: structure interne des planètes telluriques, 8h
- P. Defraigne: lecturer of the course ‘Astronomie Mathématique’, lecture PHYS2131, Professeur à temps partiel at Université Catholique de Louvain, 15h (+7h30 of exercices), co-titularity with J.P. van Ypersele de Strihou and M.F. Loutre;
- Alexandre P.: Chargé de cours à l'ULg, “Géographie historique", 30h; "Eléments de critique historique à l'usage des géographes", 30h.
- Everaerts M.: Lecturer at the Liège University « Gravimétrie, magnétisme et leurs applications géologiques »
- F. Clette: lecturer of the course "Le Soleil: structure, activité et impact sur l'environnement terrestre ", Université de Liège, DEA "Astrophysique et Sciences Spatiales", 20h (15/2-19/6/2007).

Expertise, Audit

- V. Dehant: President of the Panel ‘Earth Science’ for the evaluation of the Descartes Research Prize;
- V. Dehant: Member of the Review Team for the ESA Cassini-Huygens mission archive;
- V. Dehant: Member of “Earth Science Advisory Committee (ESAC)” of ESA;
- V. Dehant: Member of “Exploration, Science and Technology Advisory Group (ESTAG)” of ESA;
- P. Defraigne: Member of the FNRS commission Astronomie et Géophysique;
- V. Dehant: Member of the High Scientific Council (HCS) of the Observatoire de Paris;
- C. Bruyninx: Member of the Scientific Council of RENAG (Réseau National Géodesique de France);
- V. Dehant: Member of the Scientific Council of the Institut de Physique du Globe de Paris
- V. Dehant: Member of the Audit Committee of the Physics and Geography Department of VUB

Running or Finalized Theses (summary)

- 9 PhD students in Section 1 at ROB**:** R.M. Baland (UCL), J. Duron (UCL), L. Koot (UCL), S. Le Maistre (UCL), L.B.S. Pham (UCL), G. Pfyffer (UCL), E. Pottiaux (UCL), A. Rivoldini (UCL), A. Trinh (UCL)
- 1 PhD student related to Section 1 outside ROB (ROB staff is co-promoter): V. Robert (Observatoire de Paris)
- 6 Master students in Section 1: Rose-Marie Baland (UCL), Samuel Goossens (UCL), Le Binh San Pham (UCL), John Wautier (UCL), Laetitia Tollet (UCL), Antony Trinh (ULB)
- 3 Master students in Department 4
- F.Clette: Maître de stage, ESI (Ecole Supérieure d'Informatique), Garyp Ramani, 13/2-2/6/2007.
- E. Podladchikova, promoter of 3 master students at Ukrainian Polytechnic High school.

Meeting organization

- C. Bruyninx: Organisation of EUREF Technical Working Group Meeting, Brussels, 2 days, March 2006;
- V. Dehant: Astrobiology Contact Group meeting, Brussels, 12 June;
- V. Dehant: Organizer of Session GS003 'Geodynamics and Earth Rotation', at IUGG General Assembly, Perugia, Italy.
- V. Dehant: MaRS and VeRa Team Meeting in Brussels, 16-17 August.
- Jacques Sauval: Co-organizer of the 8th meeting of the Contact group “Astronomie et Astrophysique” (March 14) at the ROB Planetarium (as secretary)
- Space Weather Working Team (SWWT, May 10, 2007 at ROB), about 20 participants
- Heliospheric Knowledge Base meeting (SDO, June 19-22 2007 at ROB), about 30 participants

- Fourth European Space Weather Week (ESWW4, November 5-9 2007 Brussels), about 150 participants
- 20th SOHO Workshop (SOHO20, Aug 27-31, 2007, Gent) about 200 participants.
- 4th Consortium meeting for SWAP and LYRA (SCSL4, Nov 5 2007, KSB) about 10 participants

Awards

- V. Dehant: elected AGU Fellow
- Van Camp Michel: 2006 Editors' Citation for Excellence in Refereeing for Geophysical Research Letters (American Geophysical Union).
- H. Debehogne: assigned as discoverer of 3 minor planets.
- H. Debehogne, E. Elst: assigned as discoverers of 2 minor planets.
- P. De Cat: assigned as discoverer of 3 minor planets.
- E. Elst: assigned as discoverer of 99 minor planets.
- E. Elst, H. Debehogne: assigned as discoverers of 4 minor planets.
- E. Elst, S. Ipatov: assigned as discoverer of 1 minor planet.
- T. Pauwels: assigned as discoverer of 5 minor planets.
- T. Pauwels, P. De Cat: assigned as discoverers of 1 minor planet.
- D. Berghmans and the EIT consortium: A proposal for an EU Descartes award for the "EIT consortium" was submitted and later defended for the Descartes Grand Jury and the EU commission.

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D. PLANETARIUM

D.1. Activités

D.1.1. Visiteurs

- En 2007, le Planétarium a accueilli **28.588 visiteurs** hors événements spéciaux (Nuit des Chercheurs, Erfgoeddag, Family Day, etc.), chiffre en diminution (-1764 visiteurs / -5.8 %) par rapport à l'année précédente. Cette baisse peut être attribuée à l'absence de nouveau spectacle programmé en 2007 qui prive le Planétarium d'une couverture médiatique souvent efficace auprès du grand public.
- La part du **public scolaire** (19.947 élèves) s'élève à 69.8 % du nombre total de visiteurs, chiffre en légère hausse. Le public familial (mercredis après-midi, dimanches, congés scolaires) atteint le nombre de 8.641 visiteurs (-1448 personnes).
- La répartition entre public néerlandophone (14.838 visiteurs / 51.9 %) et public francophone (13.750 visiteurs / 48.1 %) est **équilibrée**.
- La formule des **ateliers** (workshops) permettant aux écoles venues assister à un programme ou un cours de prolonger leur visite au Planétarium en effectuant des activités pédagogiques (fabrication d'une carte du ciel, d'un déclinateur solaire, calcul des échelles du système solaire, etc.) sous la direction des animateurs ou des enseignants détachés au Planétarium continue de connaître un succès croissant : 3.917 élèves (+11%) y ont participé au cours de l'année 2007.

D.1.2. Spectacles

- Le Planétarium n'a pas inauguré de nouveau spectacle en 2007, mais il est engagé dans la création de plusieurs productions sur la **météo solaire** (diffusion courant 2008 – production interne) et sur le **projet ALMA** (diffusion fin 2008/début 2009 – co-production APLF/ESO).

- Des représentations des spectacles **« Planètes en Vue »** et **« Origins of Life »** en vidéo plein voûte (technologie du *Full-Dome*) ont été offertes au public le 28 septembre à l'occasion de la troisième « *European Researcher's Night* » financée par le département Recherche de la Commission Européenne. ; en parallèle, était proposé dans l'auditoire le spectacle théâtral **« Fusion Road Show »** (expériences interactives sur la fusion nucléaire) dans l'auditoire ; plus de 600 personnes ont été accueillies lors de cette soirée.

Figure 1. Le 'Fusion Road Show' en cours

- Lors de l'inauguration le 4 octobre de l'exposition « Spoutnik : le début de l'ère spatiale » (cf. ci-dessous) a été projeté le spectacle *Full-Dome* **« Dawn of the Space Age ».**

D.1.3. Expositions

- L'**exposition permanente** permet aux visiteurs de découvrir les thèmes de recherche et les missions de service public menés par les scientifiques des Instituts du Pôle Espace.
- Dans le cadre de l'Année Héliophysique Internationale, le Planétarium a présenté une nouvelle exposition temporaire intitulée **« Soleil : ami ou ennemi ? »**, réalisée en collaboration étroite avec les chercheurs du Département de Physique Solaire de l'Observatoire : panneaux didactiques, helioquiz, maquette du Soleil, et séquences vidéo composent cette exposition prévue pour couvrir l'année scolaire 2007-2008.

Figure 2, Maquette et panneaux de l'exposition "Soleil: ami ou ennemi?"

- Une **exposition photographique** (portraits de scientifiques des Etablissements Scientifiques Fédéraux) installée initialement lors de la Nuit des Chercheurs 2006 a complété l'offre scénographique du Planétarium jusqu'en septembre.

- Le 4 octobre a été inaugurée en présence de l'Ambassadeur de Russie une exposition photographique intitulée **« Spoutnik : le début de l'ère spatiale »** consacrée au satellite Spoutnik dont on fêtait le 50ème anniversaire du lancement ; cette exposition est le fait de l'agence de presse russe RIA Novosti.

Figure3. Ouverture de l'expo Spoutnik

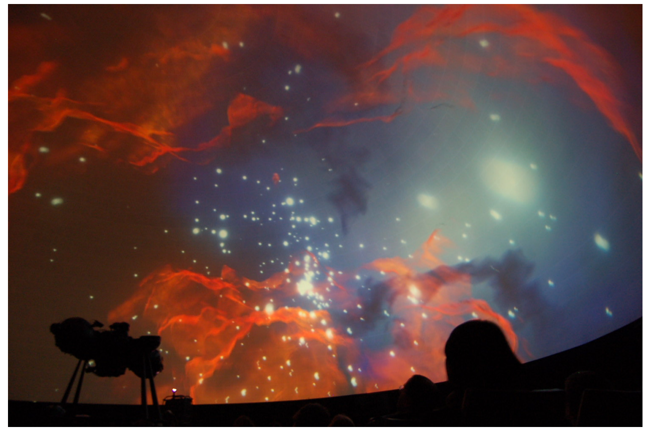

Figure 4. Projection "full-dome" à l'occasion de "Researchers Night"

D.1.4. Conférences, colloques, séances spéciales

- Plusieurs **réunions** ont été tenues dans les locaux du Planétarium : réunion du Comité de Direction de la Politique scientifique fédérale (13 mars) ; réunion du Groupe de Contact Astrophysique FNRS & ROB Astronomy Day (16 mars) ; réunions du Comité de Pilotage IYA2009 (18 juin et 5 décembre).
- Des séances spéciales ont été organisées pour : la **réception de nouvel-an** du Haut-Représentant belge pour la politique spatiale (23 janvier) ; le **projet PI** initié par la VUB et soutenu par la Communauté flamande (19 février) ; le **Erfgoeddag** (22 avril) ; les participants de **l'Expo-Sciences** (Jeunesses Scientifiques de Belgique – 3 et 4 mai) ; le **Printemps des Musées** (20 mai) ; le **Family Day de La Poste** (23 septembre) ; la **Nuit des Chercheurs** (28 septembre) ; le **personnel de l'Observatoire** (30 septembre – démonstration de la technologie *Full-Dome*) ; les **Nocturnes des Musées Bruxellois** (8 et 29 novembre).
- Une **démonstration d'ateliers** ayant pour thème la mission « Vénus Express » a été proposée aux enseignants du secondaire tant néerlandophones que francophones (en collaboration avec Norma Crosby de l'IASB).
- Le Planétarium a loué ses locaux à des firmes à différentes reprises (**13 locations**) dans l'année ; l'on peut notamment citer : **concert** BOZAR de musique indienne (17 janvier) ; conférence de presse organisée par la RTBF présentant l'action **« Planète Nature »** (20 mars) ; conférence de presse Union Europénne /Belspo présentant la **« Nuit des Chercheurs »** (26 septembre).
- L'équipe du Planétarium a eu l'honneur d'accueillir le **Prince Philippe** et ses enfants en visite privée à l'occasion d'une projection de spectacle.

D.1.5. Brochures

- Deux **dépliants/posters** (une version néerlandophone et une version francophone) ont été réalisés en 2007. Ces publications s'adressent aux enseignants et décrivent au recto les programmes, les cours et les nouvelles activités pédagogiques du Planétarium, alors qu'au verso est présenté le système Terre-Soleil (dans le cadre de l'Année Héliophysique Internationale) ; les dépliants/posters ont été envoyés à l'ensemble des écoles du Royaume au moment de la rentrée scolaire.

- Fin 2007 a été préparée la **brochure destinée au grand public** : elle présente les différents programmes et contient diverses informations pratiques ; elle couvre l'année 2008.
- Le **site Internet** du Planétarium est continuellement mis à jour. On peut y trouver l'actualité du moment. Une nouvelle mouture du site est prévue pour l'année 2008.

D.1.6. Collaborations

- La collaboration avec la **Mini-Europe** (mise en place d'un ticket combiné pour les groupes) s'est poursuivie avec succès, ainsi que celle avec le **Volksterrenwacht Mira** (Grimbergen).
- Une nouvelle collaboration a été établie avec **Living Tomorrow** (Vilvoorde) : un ticket combiné est disponible pour les groupes.
- Le Planétarium a participé en 2007 à l'« **Expo-Sciences** » organisée par les Jeunesses Scientifiques de Belgique au Palais des Expositions du Heysel en mai (notamment : participation au jury de sélection).
- Une collaboration centrée sur les **PassPole** a été établie avec les Jeunesses Scientifiques de Belgique dans le cadre de l'Année Polaire Internationale 2007.
- L'équipe pédagogique du Planétarium a participé aux journées **Portes Ouvertes** de l'Observatoire royal de Belgique des 6 et 7 octobre en animant un atelier utilisant le déclinateur solaire ; l'exposition temporaire consacrée au Soleil a été installée à l'Observatoire pour l'occasion.

Figure 5. Demonstration du déclinateur solaire aux Portes Ouvertes à Uccle.

- Le Planétarium a été l'un des participants des différentes réunions organisées par le « **Forum Espace & Enseignement** ». Ce Forum, soutenu par le Fonds Prince Philippe, est destiné à promouvoir les carrières scientifiques auprès des acteurs de l'enseignement belge.
- Des réunions régulières de la **Cellule Communication du Pôle Espace** ont eu lieu au cours de l'année.
- Le Planétarium est membre du Comité de Pilotage de **l'Année Héliophysique Internationale 2007**, et a participé à ce titre aux différentes réunions de travail.
- L'**Observatoire des Musées** (Belspo) a réalisé entre mai 2006 et mars 2007 une enquête concernant les habitudes des visites des enseignants dans les musées fédéraux ; une partie de l'enquête est dédiée au Planétarium.
- Une offre spéciale a été proposée aux **OCMW/CPAS** dans le cadre de la brochure « Dix lieux à découvrir) édités par de la vzw « Kunst en Democratie ».
- Le Planétarium est membre des **associations touristiques** suivantes : « Toeristische Attracties », « Attractions & Tourisme », « Brusselse Museumraad », « Office de Promotion du Tourisme Wallonie-Bruxelles ».
    - Il a à ce titre participé aux **Nocturnes des Musées** et à l'action « Explore les Musées avec **Tom & Charlotte** (jeu-parcours pour les enfants) organisées par le « Brusselse Museumraad »
- Le Planétarium est membre des **associations de planétariums** suivantes : « International Planetarium Society (IPS) », « Vereniging van Nederlandstalige Planetaria (PLANed) », « Association des Planétariums de langue Française (APLF) », « Arbeitsgemeinschaft deutschsprachiger Planetarien (ADP)».

- o Des réunions de travail de **PLANed**, l'association des planétariums de langue néerlandophone née sous l'impulsion du Planétarium de l'ORB, se sont déroulées à Hove (dans les locaux d'Urania, 3 avril) et aux Planétarium Artis (Amsterdam, 12 juin) et Europlanetarium (Genk, 10 décembre).
- o Le Planétarium a également été présent lors du **colloque annuel APLF** ayant eu lieu à Marseille (France) et lors du **colloque annuel ADP** à Schwaz (Autriche).

D.1.7. Projet ESERO

- Le 1er octobre 2006, l'Agence Spatiale Européenne (ESA) signait avec l'Observatoire royal de Belgique un contrat permettant au Planétarium d'établir dans ces locaux un « **European Space Education Resource Office** » (ESERO). Le but de ce projet pilote (d'une durée totale de deux années) est de favoriser la promotion des matières et carrières scientifiques en général, et celles liées au domaine du spatial en particulier, via des contacts étroits avec, notamment mais pas exclusivement, le milieu éducatif.
- Suite à un appel à candidatures fort suivi, l'Observatoire royal de Belgique a recruté en février 2007 **deux Office Managers** (rôle néerlandophone et rôle francophone) chargés de mener à bien les différentes tâches liées au projet ESERO.
- D'importants **travaux d'infrastructure** (aménagement complet de deux pièces de l'ancienne conciergerie, du patio et du couloir menant à la salle de réunion) ont été menés par une société et le personnel technique de l'Observatoire et du Planétarium.
- L'**ouverture officielle** du bureau ESERO Belgium s'est déroulée le 27 avril en présence des autorités de tutelle et des représentants de l'ESA.
- Les Office Managers ont remis à l'ESA le 31 juillet un « ***Consolidated Study Report*** » décrivant la place réservée en Belgique à la promotion du spatial au sein du milieu éducatif tant formel qu'informel. La qualité et l'exhaustivité de ce rapport ont été spécialement saluées par les représentants de l'ESA.
- Sur base de cette étude, les Office Managers ont remis à l'ESA le 31 octobre un « ***Operational strategy and action plan*** » établissant les opérations prioritaires à mener pour accentuer la promotion du spatial au sein des différentes milieux éducatifs.
- La **phase opérationnelle** a débuté le 1er novembre 2007, notamment par la préparation de plusieurs événements (projets de classes-pilotes, création de fiches pédagogiques, organisation de portes ouvertes, participation à des salons) prévus pour l'année 2008.

Figure 6. Ouverture du bureau ESERO

D.1.8. International Year of Astronomy 2009

- Le Planétarium a été choisi par le BNCA (*Belgian National Committee for Astronomy*) pour agir en tant que « ***Special Point of Contact*** » auprès de *l'International Astronomical Union* pour la coordination et la promotion des activités à planifier et réaliser en Belgique durant l'année 2009 dans le cadre de l'Année Internationale de l'Astronomie.
- Un **Comité de Pilotage** regroupant des astronomes professionnels et amateurs et des acteurs du domaine de la promotion des sciences a été mis en place ; ce Comité s'est réuni à trois reprises en 2007 (18 juin, 12 septembre, 5 décembre).
- Plusieurs **projets d'activités** (pièces de théâtre sur Galilée, olympiade d'astronomie, édition spéciale de timbre, etc.) ont été définis au cours de ces réunions ; des groupes de travail spécifiques sont en charge de leur réalisation concrète.
- Une présentation orale des activités belges a été effectuée lors du colloque « ***Communicating Astronomy with the Public*** » ayant eu lieu à Athènes en octobre.

D.2. Moyens mis en oeuvre

D.2.1. Personnel

- Au 31 décembre 2007, le personnel du Planétarium se composait de **17 membres** :
  - R. Alvarez, chef de travaux, statutaire - responsable
  - V. Bastin, experte technique, contractuelle – animatrice scientifique
  - G. Champagne, attaché scientifique, contractuel - R&D
  - S. Consiglio, administratief medewerker, contractueel – accueil
  - H. De Rycke, gedetacheerd leraar – cours
  - D. De Winter, administratief deskundige, contractueel – accueil
  - B. Froidure, attachée classe 1, contractuelle – Office manager ESERO
  - T. Goethals, attaché klasse 1, contractueel – Office manager ESERO
  - A. Ipuz-Mendez, collaborateur nettoyage, contractuelle - entretien
  - J-C. Jacques, assistant technique, statutaire – opérateur
  - A-L. Kochuyt, attaché klasse 1, statutaire – relations publiques
  - N. Lubkowski, collaborateur technicien, contractuel - technique
  - A. Milis, industrieel ingenieur, statutaire - responsable technique
  - R. Mostaert, enseignant sous contrat - cours
  - A. Sayer, collaborateur nettoyage, contractuelle - entretien
  - G. Smet, technisch assistent, contractueel – animateur scientifique
  - W. Vander Putten, technisch deskundige, contractueel - infographisme

D.2.2. Equipement

- Au cours de l'année 2007 a été menée à bien toute la procédure de sélection relative à deux **appels d'offre d'achat** (subsides obtenus auprès du Lotto pour l'achat d'équipement scientifique) diffusés dans le cadre de deux procédures négociées sans publicité.
  - Ces appels d'offre concernaient d'une part la livraison et l'installation d'un **serveur de média et d'un système de contrôle**, et d'autre part la livraison et l'installation de deux **projecteurs vidéo** haute-technologie.
  - Les appels ont été publiés en novembre 2006, les offres ont été reçues en février 2007, une première pré-sélection a été effectuée en avril, suivie par une période de négociation qui a abouti en juillet à la **sélection des offres retenues** (sociétés RSA Cosmos et Barco).
- Le Planétarium a bénéficié d'un subside accordé dans le cadre de la **Dotation spécifique** 2007 pour financer l'exposition temporaire et le spectacle de planétarium consacrés au Soleil.

D.3. Projets en cours et à venir

D.3.1. Projet ESERO

- La phase opérationnelle du projet ESERO, débutée au 1^{e} novembre 2007, se poursuivra jusqu'au 31 octobre 2008. Le projet, actuellement dans sa phase pilote, sera alors évalué dans sa globalité avant une éventuelle reconduction du contrat liant l'Observatoire à l'ESA.

D.3.2. International Year of Astronomy 2009

- L'année 2008 constituera une année cruciale pour finaliser le calendrier des activités placées sous le sigle de l'Année Internationale de l'Astronomie 2009. Le Comité de Pilotage et les différents groupes de travail se réuniront à plusieurs reprises pour mener à bien cette tâche.

D.3.3. Vers un planétarium numérique

- Les systèmes de contrôle, serveur média et projecteurs vidéo haute-technologie acquis dans le cadre des **appels d'offre** conclus en 2007 seront installés au début de l'année 2008.
- Cet équipement marque la première phase d'un projet global en plusieurs étapes menant à terme vers un système de « **planétarium numérique** » (couverture vidéo complète du dôme : système *Full-Dome*)

E. BIBLIOTHEQUE

E.1. Situation du personnel de la bibliothèque commune à l'ORB et à l'IRM

Personnel scientifique:	Pierre Alexandre (Chef de travaux)
Personnel administratif:	Jean-Marie Danloy (Technicien de la recherche, statutaire) Myriam Vandercoilden (Technicienne de la recherche, contractuelle) Luc Vanhassel (Adjunct-Technicus der vorsing, statutair BIPT)

E.2. Activités de la bibliothèque

E.2.1. Activités générales

Pour les livres et les périodiques de l'ORB, le personnel de la Bibliothèque à assuré la centralisation des propositions d'achat, l'achat des titres sélectionnés, le catalogage de ceux-ci, le "bulletinage" des numéros de périodiques, le classement des ouvrages, l'accueil des visiteurs, le prêt aux lecteurs et le prêt inter-bibliothèques. Les mêmes services ont été effectués pour les livres et les périodiques de l'IRM, à l'exception des achats, des propositions d'achats et du "bulletinage" des périodiques, opérations directement effectuées à l'IRM.

E.2.2. Abonnements, échanges et achats

La bibliothèque a bénéficié en 2007 de 155 abonnements à des périodiques en version sur papier (80 pour l'IRM, 75 pour l'ORB) ; en outre, environ 170 publications périodiques ont été reçues soit par dons soit par échanges avec d'autres institutions. Les collections se sont enrichies par ailleurs de 50 livres acquis par achat (11 pour l'IRM, 39 pour l'ORB) et d'environ une quarantaine d'autres ouvrages reçus par dons ou par échanges.

E.2.3. Périodiques électroniques

L'abonnement aux versions électroniques de certains périodiques, en sus des versions sur papier, a pris de l'extension en 2007: trente abonnements ont été pris en 2007 par les deux instituts (dix-sept pour l'ORB, douze pour l'IRM, et un abonnement commun à l'ORB, l'IRM et l'IAS pour les cinq parties du *Journal of Geophysical Research*).

Par ailleurs, l'accès au réseau électronique SwetsWise, auquel l'ORB et l'IRM sont affiliés, a permis d'accéder gratuitement à la version électronique de certains périodiques pour lesquels les deux instituts ont souscrit un abonnement à la version sur papier (la version électronique pour l'année en cours étant offerte en sus par l'éditeur). Au stade actuel, le nombre de ces périodiques gratuits du réseau SwetsWise est de 48 pour les trois instituts d'Uccle, étant donné que grâce à SwetsWise le personnel de chaque institut, ORB, IRM ou IAS, peut avoir aussi accès (du moins pour l'année en cours) aux versions électroniques gratuites des revues dont la version papier est achetée par un des deux autres instituts.

E.2.4. Classement des collections

Quelque 127 collections de périodiques peu ou pas consultés (collections en double, revues écrites en cyrillique, collections devenues obsolètes) ont été transférés de la bibliothèque vers un local de reserve, ce qui a permis de faire face à l'extension annuelle des périodiques courants, et de réaménager la totalité de la collection des périodiques de géophysique, ainsi qu'une partie de la collection des périodiques d'astronomie.

Par ailleurs, le récolement général des collections de livres antérieurs au XXe siècle a été poursuivi. A l'occasion de l'informatisation progressive de la bibliothèque, des ouvrages enregistrés séparément ont été rattachés aux grandes collections dont ils faisaient éventuellement partie. La reliure de 140 volumes de périodiques a également été effectuée.

E.2.5. Informatisation de la bibliothèque

Pour rappel, l'informatisation de la bibliothèque de l'ORB – IRM au moyen du système de gestion VU-BIS comporte trois opérations distinctes:

- Catalogage des données bibliographiques (en ce compris les mots-clefs) relatives aux titres de périodiques, aux collections de livres et aux livres (ceux-ci étant soit enregistrés isolément soit reliés à une collection de livres).
- "Bulletinage" des périodiques, soit des numéros de l'année en cours, soit des tomes entiers après reliure.
- Attribution aux divers volumes (livres ou périodiques) de numéros de "codes-barres" permettant le prêt informatisé.

En 2007, les activités d'informatisation de la Bibliothèque ont été les suivantes:

- Catalogage et "bulletinage" systématique, avec attribution de "codes-barres", de tous les livres et numéros de périodiques acquis en 2007 (opération effectuée depuis l'année 1996).
- Relevé systématique, en vue de leur informatisation future, des dates de clôture des collections de périodiques qui ont cessé de paraître (jusqu'ici, seules les dates de départ de ces collections avaient été relevées).
- Vérification et correction des données bibliographiques encodées avant 1996 au moyen d'un autre système de gestion informatique, et attribution de "codes-barres", pour les livres entrés à la bibliothèque entre 1951 et 1996 (le catalogage proprement dit de ces livres ayant déjà été effectué auparavant).

Dans l'accomplissement de ces travaux, la Bibliothèque a bénéficié de l'aide de Mme Christine Roberti, pour le bulletinage des numéros de périodiques de l'année 2007 acquis par l'IRM.

Un arrêté ministériel du Service Public Fédéral de Programmation Politique Scientifique a confié aux Etablissements scientifiques fédéraux la charge de réaliser des "catalogues informatisés des bibliothèques des Etablissements scientifiques fédéraux", s'inscrivant dans le cadre de la mise en œuvre du "Plan de digitalisation du patrimoine culturel et scientifique des Etablissements scientifiques fédéraux relevant du Ministre de la Politique scientifique". Ce travail se déroule du 1er novembre 2005 au 31 décembre 2008. L'arrêté attribue une somme totale de 19.078 Euro pour les deux institutions (ORB et IRM), et ce pour des frais de personnel permettant l'engagement, pendant neuf mois environ, d'un agent de niveau C chargé d'encoder les données des livres et brochures antérieures à la date de 1951. Pour éviter toute solution de continuité dans le contrat de cet agent, il a été prévu de reporter les sommes allouées en 2005-2006 et 2007 à l'année 2008. Les épreuves de selection de cet agent ont eu lieu le 14 novembre 2007 à l'ORB, et la candidature retenue a été celle d'Ana Maria Hernando, dont le contrat prendra cours en février 2008.

E.2.6. Participation à des expositions

La bibliothèque de l'ORB-IRM a participé à l'exposition "British Vision. Observatie en verbeelding in de British kunst, 1750-1950" (Gent, 6 oktober 2007 – 13 januari 2008), en y exposant l'ouvrage précieux illustré de Thomas Forster, *Researches about atmospheric phenomena* (1823).

F. DIENST INLICHTINGEN – SERVICE DE RENSEIGNEMENTS – INFORMATION SERVICE

F.1. Activities

The activities related to the information services consist of several tasks: answering questions and inquiries from public and press, assisting in all kind of outreach activities, giving general information on ROB and astronomy and astronomy related subjects, advising the planetarium, organize the visits to the ROB, including the organization and coordination of open doors days and related activities, all kind of assistance for exhibitions and public relations activities (press communications, press conferences etc.) and preparing of texts for printing or for the web site.

This report describes mostly activities of the persons directly related to the information services. Activities of a few other services are included, especially if those are meant for a general public. If activities are directly related to a particular research domain or theme, they will be found in the section on the PUBLIC OUTREACH of the SCIENTIFIC DEPARTMENTS.

F.2. Information given to the media

F.2.1. Interviews

Many interviews on different subjects were given by members of the Observatory, including:

- VTM (Open Doors, 6/10)
- RTBf (Open Doors, 6/10)
- RTBf (on daylight saving time, summer and winter, March and October)
- Radio Contact (26/3, on meteors and meteorites)
- Bel-RTL radio (meteors, 8/6)
- VRT-Radio 1 (29/11 on the time zone change of Venezuela)

F.2.2. Information given to the media

On many occasions information (without interview) was was also supplied to the media by telephone or email, mostly to newspaper and magazine journalists but also to television and radio (VRT TV1, RTL, RTBF-radio …).

F.2.3. Assistance with TV and film recordings

Assistance was given to TV and film recordings on the site in Ukkel (RTBF, Woestijnvis, student projects …)

F.3. Exhibitions

- The information service contributed to the exhibition on the Sun (in the Planetarium and at the open doors) with ideas and help for the design, writing and translations of texts, and search for illustrations.
- Material and texts were supplied for exhibitions on astronomy and related sciences (e.g. Evere, February).

Figure 7. ROB telescopes on display at an exhibition in Evere.

F.4. Questions from the public

In 2007 about 480 questions by email, 600 by telephone and 200 by letter or fax were answered by the information services directly. Amongst the subjects of the questions (not directly related to research activities): sunset, sunrise, equinoxes and solstitia, horizontal coordinates of sun and moon, the amount of shadow, moon phases, fireballs, meteors, satellite re-entries, eclipses in 2007 and other years, all sort of calendar topics, time keeping, time zones, tides, star maps and visibility of constellations over the world, comets now and in history (including ***Comet 17P/Holmes***), Mars, Venus and other planets in the sky, information about historical scientific instruments, the profession of astronomer, external influences (sun, planets, universe, …) on climate change, distances in the universe, structure of the universe, Hubble Space Telescope and other satellites and space missions, candidate meteorites, photographs and images of the Observatory, history of the observatory, evolution of the solar system, the planets and the moon, atmospheric halos, visibility of objects on the moon, goniometry, giving and/or registering of stars names, buying stars or land on planets etc.

In order to supply the answers to some of the questions, programs had to be (re-)written. Subroutines created by T. Pauwels (Dep. II) were gratefully used.

F.5. Digital photographs, illustrations and movies

A second set of (digital) photographs of all aspects of the ROB were made. Pictures of the instruments of the museum, of some of the buildings and the domes and of the meridian line at the main entrance were made. Old pictures and/or text were scanned and archived. A few were sent out for a variety of purposes, including for foreign journals or seminars abroad.

The work on the digital photo archive continued.

F.6. Website

- The content of webpages with the answers to frequently asked questions was regularly updated. For 2007 the pages on sunrise and sunset, on moon phases and moonrise and moonset, on daylight savings time, on the calendar in general and on the Islamic calendar (Ramadan) had at least one update or revision.
- A webpage was created for the open doors days.
- Pages on the celestial phenomena of the month were put on the web on a regular basis.
- French translations of the web pages of Frequently Asked Questions were created.
- First drafts of a German version of the Frequently Asked Questions were supplied.

- Websites for the planets Mars, Venus, Mercury, and for the Icy Satellites with information for a general public were created.

F.7. Visits

A large number of individual visitors and groups visited the ROB this year. The individual visitors were mainly journalists and other media-related persons, amateur astronomers with a specific demand and/or students. Groups were, in general, received on every first Monday of the month.

In total about 50 individual visits and 10 groups were guided, including a numerous group of the amateur astronomers association VVS (Vereniging voor Sterrenkunde) on November 10.

F.8. Meetings and missions

A large number of meetings, internal as well as external, were attended. This year most meetings were related to the activities in the frame of the International Heliophysical Year 2007-2008 and the Open Door Days of the institutes in Uccle. We had a few meetings with the communication responsibles of the Federal Institutes on topics of general interest, common activities and the journal Science Connection. The regular meetings of the cell communication of the Space Pole were attended.

In 2007 the first meetings on the International Year of Astronomy 2009 were organized (18/06, Planetarium; 12/09 ROB and 05/12 Planetarium).

F.9. Publications and related tasks

- The editing of a special issue of Space Connection (part of Science Connection) on Heliophysical Research in Belgium on the occasion of the International Heliophysical Year 2007-2008 was done at the Observatory. The research related to the Sun and to the influence of the solar activity on the Earth as studied in Belgian institutes was highlighted in this publication. The Solar Physics department supplied a lot of text and illustrations, the astrophysics department provided texts on the Sun as a star. The search for and selection of most of the illustrations for the publication and the homogenization of the parts of the different institutes (ROB, BISA, RMI and Centre for plasma-astrophysics (KULeuven)) was done at the ROB, as well as supervison of the translation and the final layout. The publication was printed at 20000 copies for Science Connection and 14000 were added to be distributed during the Open Doors Days at the Space Pole and at the Planetarium during the exhibition on the Sun.
- For the Helioquiz, the educational tool on PC as presented by the Space Pole (BISA) in special displays, many questions related to the stars and the sun were prepared and/or translated (Dutch, French, English). The tool is now on several displays and can be put on other PCs as well. Displays were put at the Open Doors days of the Space Pole, in the planetarium and at exhibitions.
- Translations, corrections and proofreading of articles for the journal Science Connection.
- Translation of press conference texts and for the exhibition on the Sun (Planetarium)
- The computer presentations describing the history and the activities of the ROB were updated on a regular basis and used on several occasions, but mainly as the introductory part during group visits.

F.10. Personnel

- **J. Cuypers**, (Dep III, information services), werkleider
- **Y. Coene**, technisch expert (Dep I, information services)
- **H. Langenaken**, technisch expert (Dep. III).
- Many other members of the ROB gave information to the public, some occasionally, others as a part of their daily work as in the sections Seismology, GPS, Solar Physics etc.

F.11. Open doors days: 6-7 October 2007

In the weekend of 6-7 October open doors days were held at the Observatory and the other institutes of the Space Pole. The main theme was the Sun and its interaction with the Earth in the framework of the International Heliophysical Year (IHY).

Internal meetings with representatives from the different departments and/or research groups of the Observatory were organised. The main topics of the meetings were the general flow of the visitors, the places to visit, the location of presentations, exhibitions, instruments …Most of the preparation was done in collaboration with the IHY steering committee. The press and the media were contacted in different ways (email, direct contact…). Good media coverage of the event was the result of these actions. During Saturday, interviews to the media were given and the event was an item in the main news of all major national television chains.

In the main building almost all sections and research groups of the ROB showed there results. In the meridian room not only the old instruments were presented, but some models of solar research satellites, kindly provided by ESA and the Centre Spatial de Liège (CSL), could be admired as well. The sun in 3D was very popular here. The bus of the European project SWEETS (Space Weather and Europe - an Educational Tool with the Sun) with the space weather poster exhibition, an interactive exhibition including video presentations on space weather and a small solar telescope were a success as well. The assistance of the personnel of the Centre for Plasma Astrophysics of the K.U.Leuven, guests at the Open Doors days in the context of IHY 2007, was highly appreciated. The workshop for young and old organized by the personnel of the Planetarium had a large audience.

The dome of the Schmidt telescope was open to the public. There was a display with explanation of the observations with the telescope, an example image displayed in the control room and regular demonstrations of the motion of the telescope. Visitors could freely walk through the dome. There were no organised oral presentations, but staff of the Observatory was present to answer questions, which turned out to be a full-time job for two staff members on Sunday afternoon. Transit of the visitors through the dome went quite smooth, thanks to the entrance at the front, and exit at the back (through the Midas room), except on Sunday afternoon, where there was a bottleneck at the entrance, due to the high interest.

A total of about 10000 persons visited the site in Uccle during the weekend. According to the results of a questionnaire done by the "Observatory of the Public" all visitors were extremely satisfied.

About 70 members of the personnel participated at different levels during one or two days. Even more helped with the general preparations, and/or the posters or exhibition stands.

Figure 8. Some images taken during the open doors weekend.

G. PUBLIC OUTREACH of the SCIENTIFIC DEPARTMENTS

G.1. Scientific and technical expertise to the authorities and the industry

- Th. Camelbeeck participated to the workgroup for the application of the European directive INSPIRE (16 January 2007, 8 May 2007)
- Th. Camelbeeck participated to the expert review panel for the projects TOPO-EUROPE of the Council of Europe, Strasbourg 21-22 June 2007 and 6-7 December 2007.

G.2. Information given to the public

- F. Collin and K. Vanneste answered to written requests for information concerning earthquakes or seismic hazard by the public.
- E. Robbrecht gave interview for students of the "Hogeschool Brussel" for film project work.
- E. Robbrecht presented the CACTus program to PhD students of the IPI at the University of Gent.

G.3. Information given to the media

Press interviews

- P. Defraigne was interviewed by Radio Nostalgie ('le journal') related to "summer time".
- P. Defraigne was interviewd by RTBF-la Première for the program 'Matin Première' on 26/10 related to "winter time".
- R. Van der Linden was interviewed by Radio Brussel FM related to "summer time".
- P. Alexandre participated in the RTBF TV Programme: "Planète Nature – La Station Princess Elisabeth, témoin du changement climatique" on 5 September 2007.
- P. Alexandre was interviewed by Paul Vaute for an article "Un réchauffement au coeur du Moyen Age" in La Libre Belgique on 23 February 2007.
- Th. Camelbeeck was interviewed on the seismic hazard in Belgium for "Athena", the newspaper of the Walloon Region.
- Th. Camelbeeck gave a series of interviews after the earthquake near La Gleize of 25 November 2007.
- M. Van Camp Michel met with 4 journalists at the Belgian Science Policy Office to present the scientific projects at the Princess Elisabeth station (2007-13-09)
- M. Van Camp was interviewed by RTL-TVI about an F16 breaking the sound barrier above Brussels, 2007-10-31)
- M. Van Camp visited the Membach station with journalist Yves Bastin, who published a one page article in the "La Meuse" newspaper (2007-11-28). He reported quite nicely the work performed at the Membach station.
- P. Vanlommel and R. Van der Linden were interviewed by several journalists related to the organisation of the 4th European Space Weather Week.

Press releases

Four press releases were issued (in Dutch, French and English):

- The STEREO space mission and the role of the ROB therein.
- The Solar-Terrestrial Center of Excellence.
- The 4th European Space Weather Week.
- Solar cycle 24 prediction.

These releases appeared widely in the Belgian media.

G.4. Publications in popular journals

[1] Cuypers, J.
De Melkweg
in Zomerschool Sterrenkunde Syllabus, VVS, 2007, 58-63

[2] Cuypers, J.
Practicum: Periodeanalyse van Variabele Sterren
in Zomerschool Sterrenkunde Syllabus, VVS, 2007, 100-102

[3] Cuypers, J.
Geboorte, leven en dood van sterren,(from 'De Sterren', Cuypers, J. VVS, 2001)
in Zomerschool Sterrenkunde Syllabus, VVS, 2007, 27-43

[4] Clette, F.
Le rôle des amateurs en physique solaire
OBAFJKM (CAB), N° 80, avril-juin 2007, pp. 1-14.

G.5. Public conferences

- V. Dehant, "Mars Express radioscience experiment to understand the interior of Mars", Mol, 23/02.
- T. Van Hoolst, "De inwendige structuur en samenstelling van aardse planeten, deel 1", Volkssterrenwacht Urania, Hove, 27/02.
- T. Van Hoolst, "De inwendige structuur en samenstelling van aardse planeten, deel 2", Volkssterrenwacht Urania, Hove, 07/03.
- P. Defraigne, "La mesure du temps hier et aujourd'hui", Ecole Notre Dame, Rhodes Saint Genèse, 19/10.
- P. Defraigne, "La mesure du temps hier et aujourd'hui", Ecole Saint-Joseph, Ixelles, 04/12.
- X. Boës, "Ce que les sédiments des lacs nous apprennent sur les changements du climat et de l'environnement", Société Royale Belge d'Astronomie, de Météorologie et de physique du globe, Bruxelles, 17/01.
- Th. Camelbeeck, "L'activité séismique en Belgique" in the conference cycle of the Société Royale Belge d'Astronomie, de Météorologie et de Physique du Globe, 15/12.
- J. Cuypers, Zomerschool sterrenkunde, organised by Vereniging voor Sterrenkunde (VVS), Leuven, 29/08:
  - Lecture on "The Milky Way";
  - Seminar, practical course: "Period Analysis of Variable Stars on Computer".
- J. Cuypers, "COROT: exoplanets and stellar oscillations", Helios-VVS, Ramsel-Herselt, 21/01.
- H. Hensberge: "De sterren van het zwarte doek", Vriendenkring VUB, 16/02.
- F. Clette, "Du nombre de Wolf à l'indices international des taches solaires: les 25 ans du SIDC", Cercle Astronomique de Bruxelles, Brussels, 18/01.
- F. Clette, "Les nouveaux outils de la physique solaire", Cercle Astronomique de Bruxelles, Brussels, 21/06.
- F. Clette, "Le Soleil aujourd'hui: dans l'intimité d'une étoile" Association Olympus Mons, Université de Mons-Hainaut, 21/11.

G.6. Visits

- Visit to ROB of 'Limburgse Zonnewaarnemers' (May 5, 2007)

G.7. Web-sites

- Updating of the Earth Rotation website
  - http://www.astro.oma.be/D1/EARTH_ROT/index.php
  - http://www.astro.oma.be/D1/EARTH_ROT/FR/start_fr.php
- Updating and creation websites for the planets Mars, Venus, Mercury, and for the Icy Satellites
  - http://www.astro.oma.be/D1/PLANET/MERCURY/home_mercury.php
  - http://www.astro.oma.be/D1/PLANET/VENUS/home_venus.php
  - http://www.astro.oma.be/D1/PLANET/MARS/home_mars.php
  - http://www.astro.oma.be/D1/PLANET/ISY/home_icy.php
- Updating of the didactic (film) website
  - http://www.astro.oma.be/D1/DIDAC/index.php
- Jacques Sauval: Updating the ROB website for the Contact group Astronomie & Astrophysique
- Griet Van de Steene: practical organization of ROB seminars, announcements, and website
- Updating of the website of the Solar Influences data Analysis Service (SIDC):
  - http://www.sidc.be

H. THE YEARBOOK

H.1.1. Objectives

Every year the Royal Observatory of Belgium publishes a Yearbook with ephemerides, the most important astronomical phenomena and their visibility in Ukkel and in Belgium.

H.1.2. Progress and results

In 2007 the Yearbook for 2008 was published. It was produced by C. Bruyninx (Coordinates), F. Clette (The Sun, Tables), J. Cuypers (Calendars, Comets, Meteors), T. Pauwels (Title, Preamble, Constants, Planetary and Satellite Data, Planetary Phenomena, Visibility and ephemerides of the planets, Minor planets, Eclipses, Transits, Occultations, Satellites of Jupiter), F. Roosbeek (The Moon, Tables) and J. Sauval (Comets, Meteors), with the technical assistance of G. Evrard and D. Mesmaker. The preparation (choosing the value of Delta_t to apply) was done by T. Pauwels. Translations were made by R. Alvarez and T. Pauwels. The general coordination, lay-out, final editing and contact with the publisher was done by T. Pauwels.

In 2007 the Yearbook had to be adapted to the demotion of Pluto to dwarf planet.

The chapter "Coordinates" was also rewritten to be adapted to the extensive use of GPS nowadays. The revised version includes the coordinates of our IGS permanent GPS station and the coordinates of the Schmidt telescope. For that purpose the coordinates of the Schmidt telescope have been computed from GPS measurements.

T. Pauwels programmed the computation of the PHEMU phenomena (mutual eclipses and occultations of the Galilean Satellites), with the intention of including them in the Yearbook 2008. However, there are no such events visible from Ukkel in 2008, so they will appear for the first time in the Yearbook 2009.

F. Clette finalised the process of completely rewriting the totally outdated software to compute the chapters related to the Sun and the Tables. This was done in collaboration with T. Pauwels, in order to make advantageous use of existing software.

H.1.3. Perspective for next years

In 2009 we shall introduce a new chapter with mutual phenomena of the satellites of Jupiter.

H.1.4. Publications

[1] **Pauwels, T., Bruyninx, C., Clette, F., Cuypers, J., Roosbeek, F., Sauval, J.**
Annuaire de l'Observatoire royal de Belgique - Jaarboek van de Koninklijke Sterrenwacht van België 2008

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A. ADMINISTRATIE / ADMINISTRATION

A.1. HUMAN RESOURCES

A.1.1. Personeel / Personnel

Algemeen directeur: Van der Linden Ronald

A.1.1.1. Vastbenoemd personeel / Personnel statutaire

Wetenschappelijk personeel / Personnel scientifique

Name/Nom	Functie/Fonction	
Alexandre Pierre	Chef de travaux	80 %
Alvarez Rodrigo	Chef de travaux	
Berghmans David	Werkleider	
Blomme Ronny	Werkleider	
Bruyninx Carine	Werkleider	
Camelbeeck Thierry	Chef de section ff.	
Clette Frédéric	Chef de travaux	
Collin Fabienne	Chef de travaux	80 %
Cuypers Jan	Werkleider	
De Cat Peter	Werkleider	
Defraigne Pascale	Chef de travaux	80 %
Dehant Véronique	Chef de section	
Frémat Yves	Assistant	
Hensberge Herman	Departementshoofd a.i.	
Hochedez Jean-François	Chef de travaux	
Krijger Johannes Matthys	Assistent (vanaf 01/08/2007)	
Lampens Patricia	Departementshoofd	
Pauwels Thierry	Afdelingshoofd	
Roosbeek Fabian	Chef de travaux	
Van Camp Michel	Chef de travaux	
Van De Steene Griet	Werkleider	
Van Hoolst Tim	Werkleider-geaggregeerde	
Van Ruymbeke Michel	Chef de travaux	
Vanneste Kris	Werkleider	
Verbeiren Roland	Departementshoofd (tot 30/04/2007)	
Yseboodt Marie	Assistant (à partir du 01/10/2007)	

Technisch en administratief personeel / Personnel technique et administratif

Name/Nom	Functie/Fonction
Vander Putten Eric	Adviseur (tot 31/08/2007)
De Knijf Marc	Attaché A1
Kochuyt Anne-Lize	Attaché A1
Milis Andre	Attaché A2
Dufond Jean-Luc	Attaché A2
Rezabek Oleg	Attaché A1
Rogge Vincent	Attaché A1
Asselberghs Somnina	Technisch deskundige

Bukasa Baudouin	Expert technique	
Castelein Stefaan	Technisch deskundige	
Coene Yves	Expert technique	
Driegelinck Eddy	Expert technique	
Dumortier Louis	Expert ICT	
Duval David	Expert technique	
Ergen Aydin	Expert technique	
Hendrickx Marc	Expert technique	80%
Kesteloot Gisèle	Expert technique (jusqu'au 31/01/2007)	
Langenaken Hilde	Technisch deskundige	80%
Martin Henri	Expert technique	80%
Mesmaker Dominique	Expert technique	
Moyaert Ann	ICT deskundige	80%
Olivier Jean-Pierre	Expert technique (jusqu'au 31/07/2007)	
Peeters Georges	Technisch deskundige	80%
Peeters Roger	Technisch deskundige	
Renders Francis	Technisch deskundige	
Somerhausen André	Expert ICT	
Strubbe Marc	Technisch deskundige	
Van Camp Lydia	Technisch deskundige	80%
Van Damme Daniel	Technisch deskundige	
Van De Putte William	Technisch deskundige	
Van Der Gucht Ignace	Technisch deskundige	
Vandekerckhove Joan	Technisch deskundige	
Vandercoilden Leslie	Expert technique	
Vanraes Stéphane	ICT deskundige (vanaf 08/10/2007)	
Verbeemen Christiane	Expert technique	50%
Vermeiren Katinka	ICT deskundige	80%
Barthélémy Julie	Chef technicien de la recherche	50%
Brebant Christian	Assistant administratif	
Bruyninckx Martine	Administratief assistent	
Danloy Jean-Marie	Assistant administratif	
Depasse Béatrice	Assistant administratif	
De Wachter Rudi	Technisch assistent	
Jacques Jean-Claude	Assistant technique	
Janssens Paul	Assistant technique	
Laurent Robert	Technisch assistent	
Lemaitre Olivier	Assistant technique (à partir du 15/11/2007)	
Mortier Carine	Administratief assistent	
Mues Christian	Assistant technique (jusqu'au 31/10/2007)	
Van Den Brande Theophilis	Technisch assistent	
Vanden Elshout Ronny	Assistant technique	
Verbeeren Anja	Administratief assistent (vanaf 01/06/2007)	
Consiglio Sylvia	Administratief medewerker (vanaf 01/07/2007)	
De Ridder Christiane	Administratief medewerker	

A.1.1.2. Personeel met externe beurzen / Personnel sur bourses externes

Name/Nom	Functie/Fonction
Baland Rose-Marie	Boursier FRIA (à partir du 01/12/2007)
Koot Laurence	Boursier FNRS
Lecocq Thomas	Boursier FRIA

Pfyffer Gregor	Boursier FRIA
Pham Le Binh San	Boursier FNRS (à partir du 01/10/2007)
Sichien Els	Beursstudent IWT
Trinh Antony	Boursier FNRS (à partir du 01/10/2007)
Yseboodt Marie	Boursier FNRS (jusqu'au 30/09/2007)
Khoda Oleg	Boursier Non-EU (à partir du 01/03/2007)
Jevremovic Darko	Boursier Non-EU (jusqu'au 31/12/2007)
Borges Fernandes Marcello	Boursier Non-EU (jusqu'au 31/12/2007)

A.1.1.3. Contractueel personeel beheerd door de POD Wetenschapsbeleid / Personnel contractual géré par le SPP Politique Scientifique

Name/Nom	Functie/Fonction	
Bizerimana Philippe	Collaborateur technique	
Boulvin Olivier	Expert technique	
Consiglio Sylvia	Administratief medewerker (tot 30/06/2007)	
De Vos Frédéric	Expert ICT	
De Winter Davy	Technisch deskundige	
Lubkowski Noël	Collaborateur technique	
Motte Philippe	Collaborateur technique	
Mouling Ilse	Administratief assistent	80 %
Rapagnani Giovanni	Attaché A1	
Sayer Amina	Collaborateur technique	50 %
Vandersyppe Anne	Administratief expert	
Vanlommel Petra	W/S Assistent (tot 15/12/2007)	80 %
Winter Lars	W/S Assistent (01/11/2007 t/m 31/12/2007)	

A.1.1.4. Contractueel personeel / Personnel contractuel

Wetenschappelijk personeel / Personnel scientifique

Naam/Nom	Functie/Fonction	Contract
Avşar Ulaş	Attaché	EU Marie Curie
Baire Quentin	Attaché	Chercheur supp
Baland Rose-Marie	Attaché (du 01/09/2007 au 30/11/2007)	Action 1
Benmoussa Ali	Chef de travaux	PRODEX
Bergeot Nicolas	Assistant	STCE
Beuthe Mikael	Assistant	PRODEX
Boës Xavier	Attaché	EU Marie Curie
Champagne Georges	Attaché	Service contract / Cherch. Sppl.
Coutereel Frank	Attaché (vanaf 01/12/2007)	STCE
Dammasch Ingolf	Attaché	PRODEX
De Cuyper Jean-Pierre	Werkleider	DIGITALISATION
Delouille Véronique	Assistant	PRODEX
De Patoul Judith	Attaché (jusqu'au 01/10/2007)	PRODEX
Dominique Marie (25%)	Assistant	PRODEX
Duron Julien	Attaché (jusqu'au 01/10/2007)	Action 2
Everaerts Michel	Chef de travaux	Action 1
Fraser Jeffrey	Attaché	EU Marie Curie
Garcia Moreno David	Attaché (à partir du 16/09/2007)	EU Marie Curie
Giordanengo Boris	Assistant	PRODEX
Gissot Samuel	Assistant	PRODEX

Hekker Saskia	Assistent (vanaf 16/11/2007)	Action 2
Hochedez Jean-François	Chef de travaux (jusqu'au 30/04/2007)	PRODEX
Hubert-Ferrari Aurelia	Chef de département	EU Marie Curie
Joukov Andrei	Assistant	PRODEX
Karatekin Ozgur	Assistant	PRODEX
Kretschmar Matthieu	Assistant (jusqu'au 31/08/2007)	PRODEX
Lambert Sébastien	Assistant (jusqu'au 31/08/2007)	PRODEX
Lawrence Gareth	Assistent (jusqu'au 31/12/2007	PRODEX
LeMaistre Sébastien	Attaché	PRODEX
Legrand Juliette	Assistant (à partir du 01/04/2007)	Action 1
Lejeune Sandrine	Attaché (jusqu'au 31/01/2007)	PRODEX
Lobel Alex	Werkleider (tot 30/11/2007)	Terugkeermandaat
Marqué Christophe	Assistant	PRODEX
Martayan Christophe	Assistant	PRODEX
Moins Michael	Attaché (jusqu'au 28/02/2007)	Action 1
Mitrovic Michel	Assistant (à partir du 01/11/2007)	PRODEX
Nicula Bogdan	Assistant	PRODEX
Parenti Suzanna	Assistant	Chercheur supp
Petermans Toon	Attaché	Action 1
Philipront Amélie	Attaché (à partir du 01/09/2007)	refinanc. ESF
Pireaux Sophie	Assistant (à partir du 15/09/2007)	STCE
Podladchikova Olena	Assistant (jusqu'au 31/10/2007)	PRODEX
	Chef de travaux (à partir du 01/11/2007)	PRODEX
Pottiaux Eric	Attaché	PRODEX
Pylyser Eric	Assistant (vanaf 16/12/2007)	PRODEX
Rivoldini Attilio	Attaché	Action 1
Robbrecht Eva	Attaché	PRODEX
Rodriguez Luciano	Assistant	PRODEX
Rosat Séverine	Assistant	PRODEX
Rosenblatt Pascal	Assistant	PRODEX
Stanger Andrew	Attaché	PRODEX
Van Hoof Peter	Assistent	IUAP / Actie 1
Vanlommel Petra	Werkleider (vanaf 16/12/2007)	STCE
Verbeeck Koen	Attaché	Action 1
Verdini Andrea	Assistant (à partir du 17/08/2007)	PRODEX
Verhoeven Olivier	Assistant	PRODEX
Wauters Laurence (80%)	Assistant	PRODEX
Willems Tatiana (50%)	Attaché (du 16/04/2007 au 30/09/2007)	SOHO20
Zhu Ping	Attaché	Action 2

Technisch en administratief personeel / personnel technique et administratif

Naam/Nom	Functie/Fonction	Contract
Goethals Thomas	Attaché A1	ESERO
Jonckheere Anthony	Adviseur A3	PRODEX
Mostaert Régis	Attaché A1	Dotation
Naslin Sébastien	Attaché A1 (jusqu'au 31/08/2007)	Mécénat
Van Elder Sophie (50%)	Attaché A1	PRODEX
Wellens Véronique	Attaché A1	Dotation
De Decker Georges	Attaché A2	Digitalisation
Willems Sarah	Attaché A2	PRODEX
Herreman David	Expert ICT	Dotation

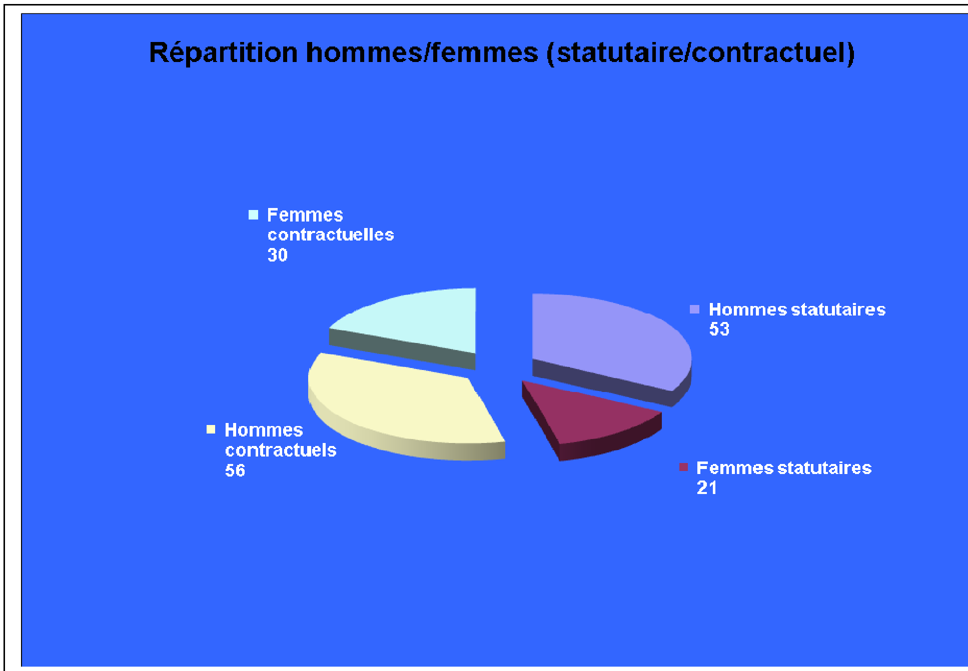
Bastin Véronique	Expert technique	Dotation
Vander Putten Wim	Technisch expert	Dotatie
Vandercoilden Myriam	Assistant administratif	Dotation Pole
Smet Gert	Technisch assistent	Dotatie
Trocmet Cécile	Assistant administratif (à p. du 1/07/07)	Dotation
Wijns Erik	Technisch medewerker	Dotatie
El Amrani Malika (50%)	Collaborateur technique	Dotation
Gonzales Sanchez Bénédicte (50%)	Collaborateur technique	Dotation
Herman Viviane (10%)	Collaborateur technique	Dotation
Ipuz Mendez Adriana (50%)	Collaborateur technique	Dotation
Sayer Amina (50%)	Collaborateur technique	Dotation
Vermeylen Jacqueline (50%)	Collaborateur technique	Dotation

A.1.1.5. Gedetacheerd personeel / Personnel détaché

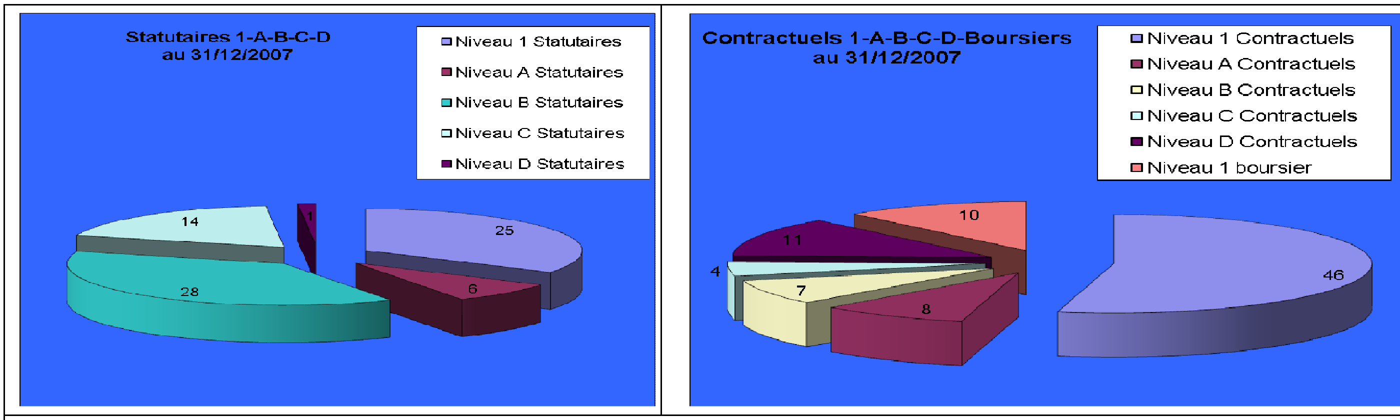
Naam/Nom	Functie/Fonction	Contract
Ducarme Bernard	Chercheur qualifié	FNRS
Vanhassel Luc	Adjunct technicus	BIPT
Van Schandevyl Pascale	Lerares (tot 31/08/2007)	Onderwijs Vlaamse Gemeenschap
De Rijcke Hendrick	Leraar (vanaf 01/09/2007)	Onderwijs Vlaamse Gemeenschap

A.1.2. Statistieken / Statistiques

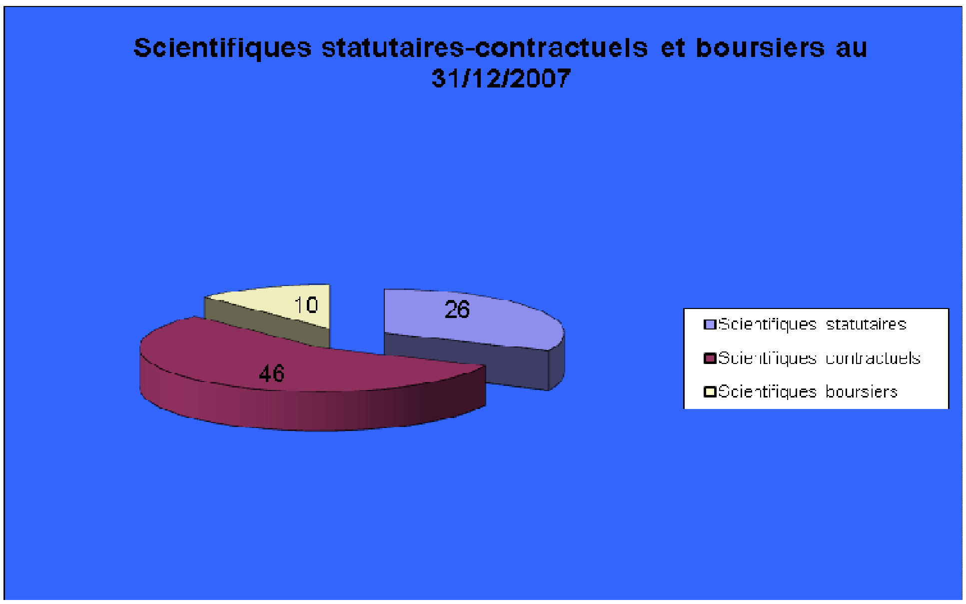
In dit onderdeel wordt de statistische informative over de verdeling van de personeelsklassen grafisch voorgesteld.



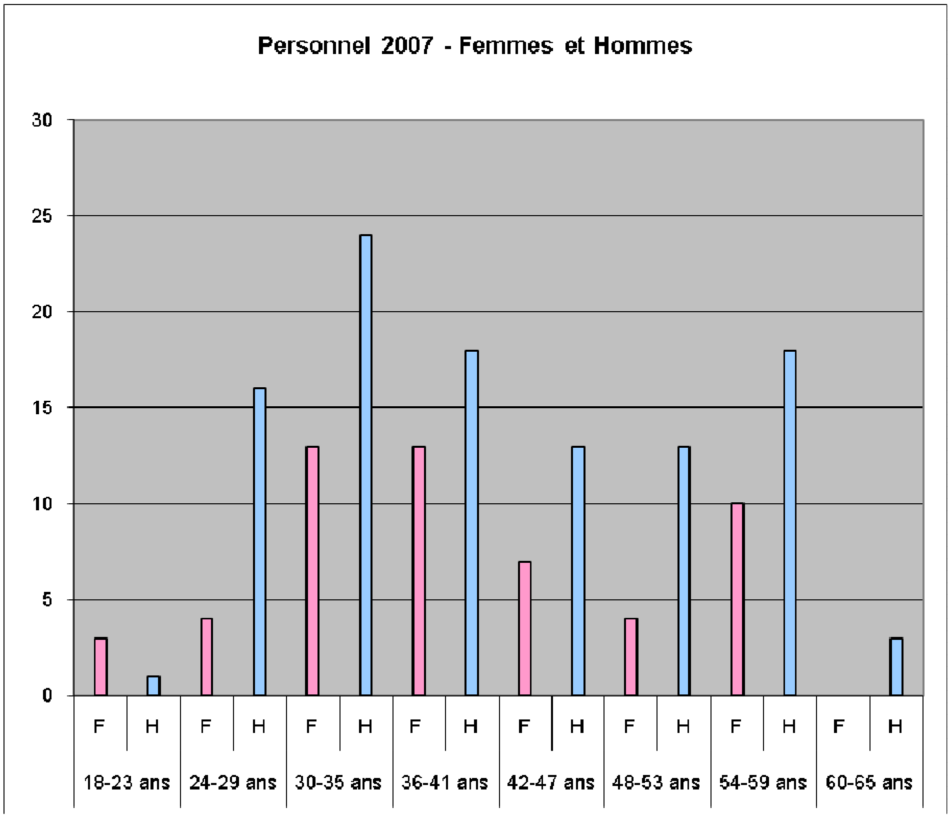
Figuur/Figure 1. Verdeling van het personeel volgens statuut en geslacht / Répartition du personnel selon statut et sexe.



Figuur/Figure 2. Verdeling over niveaus / Distribution selon niveau.



Figuur/Figure 3. Verdeling wetenschappelijk personeel volgens statuut / Distribution personnel scientifique selon statut



Figuur / Figure 4. Leeftijdsverdeling / Distribution selon l'âge

A.1.3. Betrokken personeel / Personnel concerné

Wellens Véronique	Assistante du Directeur /Resources humaines
De Ridder Christiane	Directiesecretariaat
Mortier Carine	Personeelsbeheer/Directiesecretariaat
Trocmet Cécile	Resources humaines/Sécretariat de Direction
Verbeemen Christiane	Resources humaines/Sécretariat de Direction
Verbeeren Anja	Personeelsbeheer/Directiesecretariaat

A.2. FINANCIELE DIENST / SERVICE FINANCIERE

A.2.1. Situation générale

Les moyens de fonctionnement de l'Observatoire sont présentés selon leur origine.

A.2.1.1. Enveloppe du personnel

L'enveloppe du personnel est utilisée pour les salaires du personnel statutaire. L'enveloppe disponible en 2007 etait de l'ordre de 4.6 millions d'euros.

A.2.1.2. Moyens propres de l'ORB

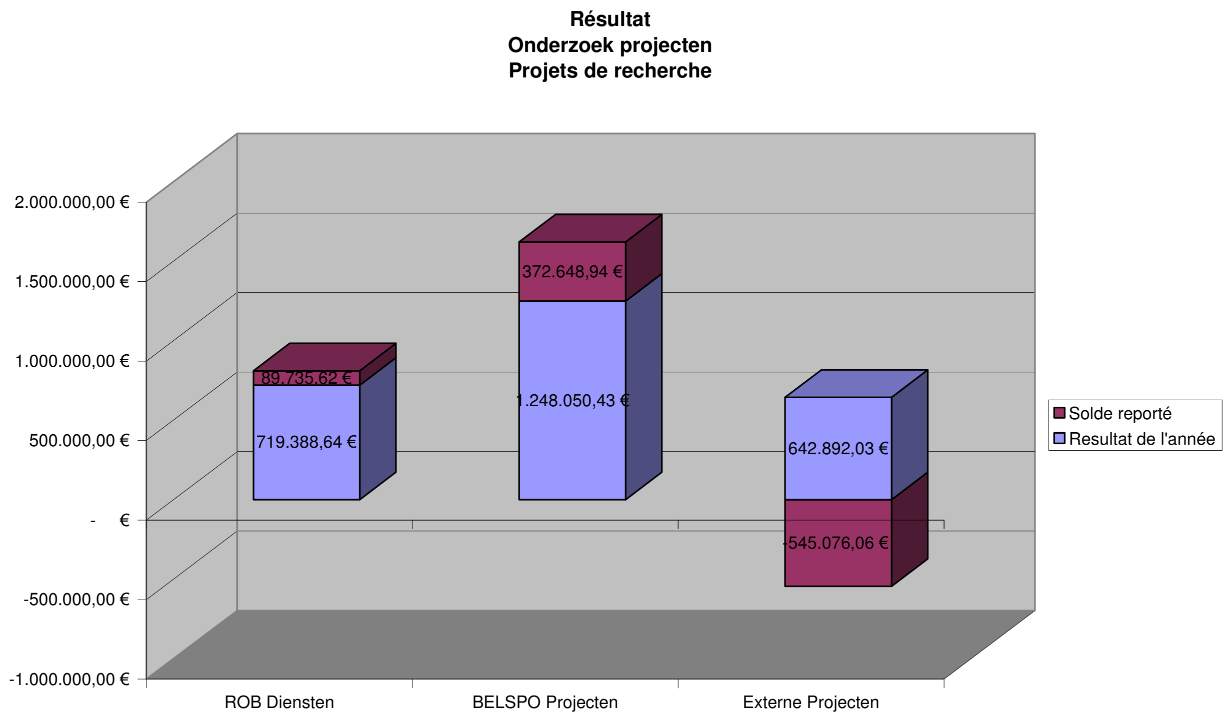
L'ORB répartit les revenus propres de l'administration en quatre postes différents :

- La dotation qui doit financer le fonctionnement et l'équipement de base de l'institution
- Les services aux tiers
- Les projets et les programmes de recherche financés par l'état belge
- Les projets et les programmes de recherche financés par des tiers

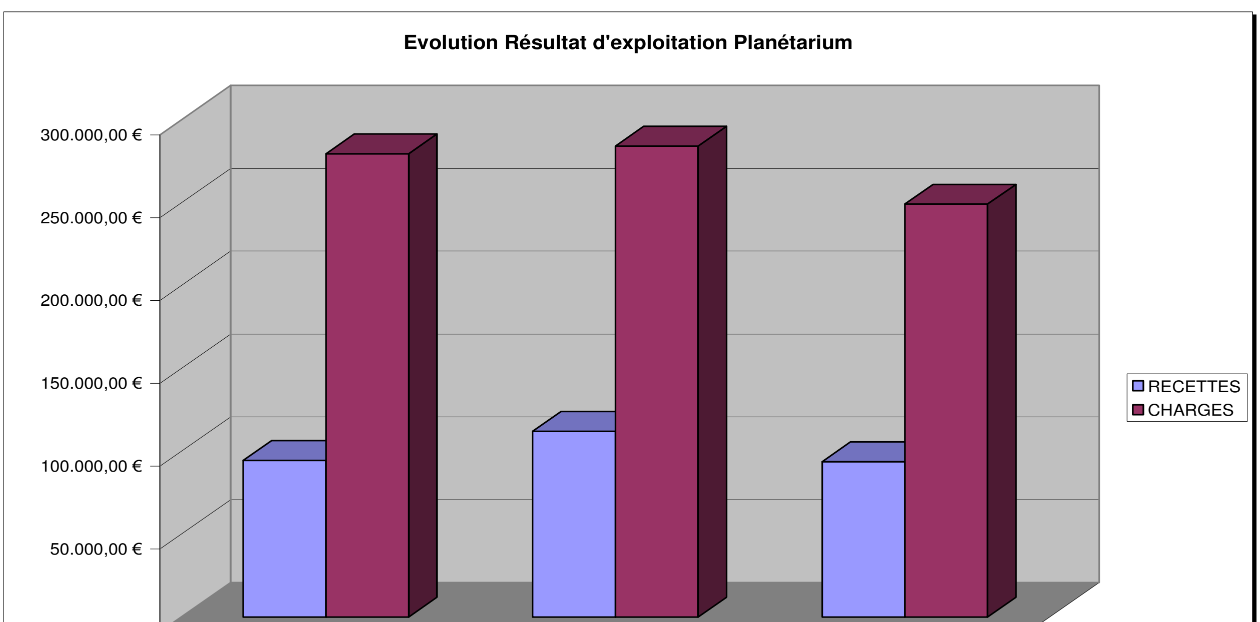
En 2007 les dépenses sur les moyens propres étéaient divisées comme suit :

	ORB Dotation	ORB Services	BELSPO Projet	Projet Externe	Total
Charges 2007					
Personnel	402 074.96€	54 767.20€	705 292.99€	1 613 302.41€	2 775 437.50€
Fonctionnements Subsistances	449 730.20€	102 464.76€	63 235.74€	343 737.41€	959 168.11€
Fonctionnements Spécifiques	20 491.25€	4 085.49€	30 354.46€	37 265.28€	92 646.48€
Equipements Subsistance	58 596.26€	3 617.80€	49 799.94€	56 986.13€	169 000.13€
Equipements Spécifiques	84 401.96€	5 316.64€	324 397.33€	186 015.37€	600 131.30€
Bibliothèque	107 894.39€	100€		3 953.16€	111 947.55€
Total	1 123 639.02€	170 351.89€	1 173 080.46€	2 241 259.70€	4 708 331.07€

Ci-dessous un aperçu des résultats des trois sections de projets de l'observatoire avec un aperçue du résultat de l'année 2007 ainsi que le résultat reporté de l'exercice antérieure.

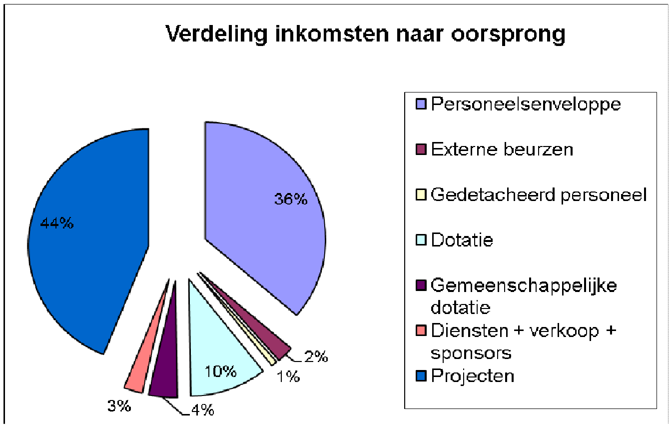


Les entrées du Planétarium pour 2007 ont atteint 66 522.50 €, une diminution par rapport à 2006 qui était de 78 279.29 €. Par rapport à 2005 les recettes des visites ont diminué de 18.58%. Ci-dessous l'évolution des résultats depuis 2005.

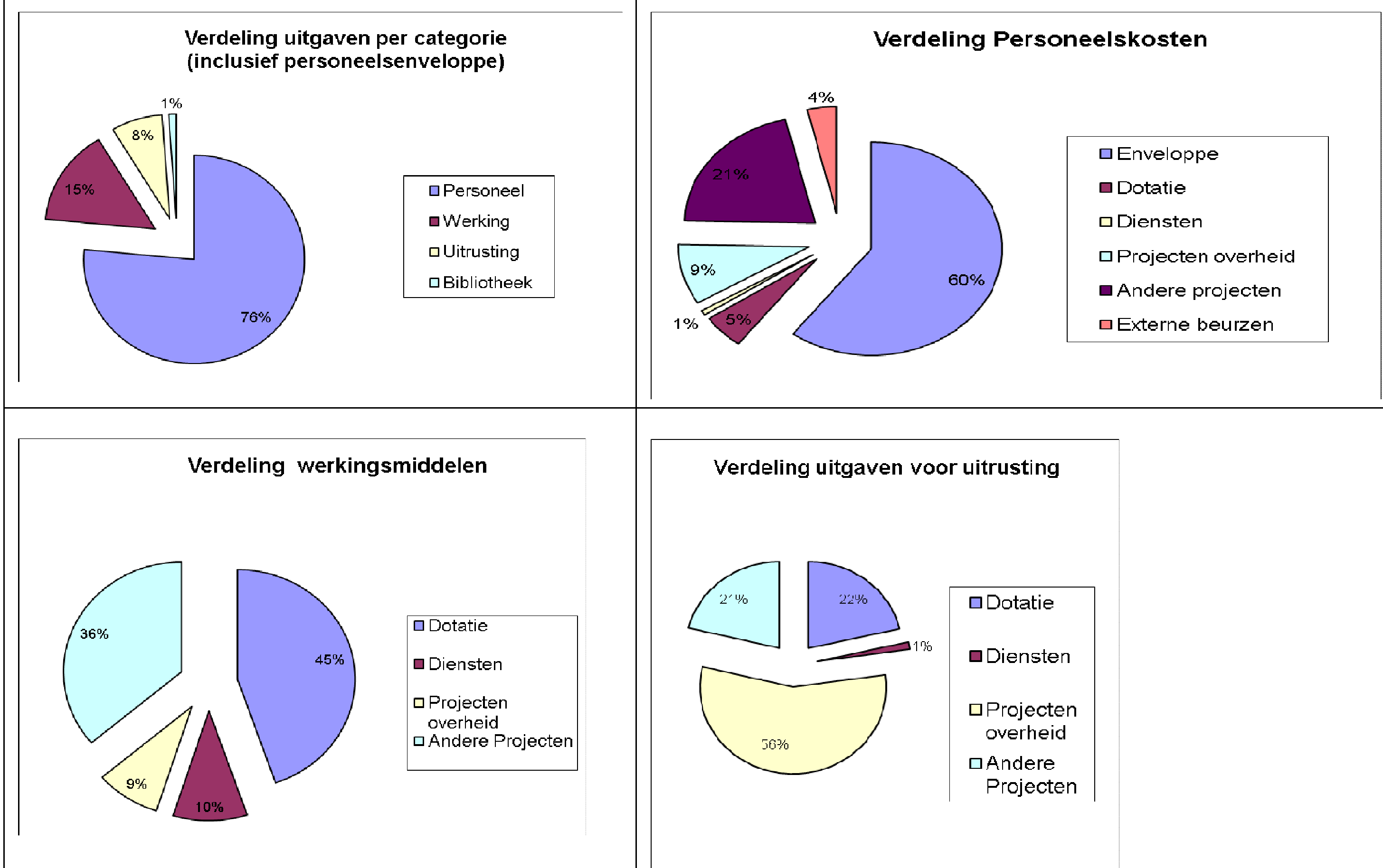


	2005	2006	2007
RECETTES	94.637,76 €	112.116,71 €	93.773,00 €
CHARGES	279.689,12 €	284.251,36 €	249.290,48 €

A.2.2. Statistieken / Statistiques



Figuur/Figure 5. Verdeling inkomsten 2007 naar oorsprong / Distribution revenues selon origine.



Figuur/Figure 6. Verdeling uitgaven over posten en oorsprong / Distribution dépenses selon origine et types

A.2.3. Betrokken personeel / Personnel concerné

Asselberghs Somnina	Boekhouder
Barthélémy Julie	Collaborateur service comptabilité
Mouling Ilse	Medewerker dienst boekhouding
Vanden Elshout Ronny	Collaborateur service comptabilité

B. ALGEMEEN BEHEER / GESTION GENERALE

B.1.1. Betrokken personeel / Personnel concerné

Asselberghs Somnina	Algemeen Beheerder
Christian Brebant	Téléfoniste
Béatrice Depasse	Téléfoniste
Martine Bruyninx	Onthaal
De Wachter Rudi	Tuinman
Van Den Brande Theophilis	Tuinman
Wijns Erik	Tuinman
El Amrani Malika	Nettoyage
Gonzales Sanchez Bénédicte	Nettoyage
Herman Viviane	Nettoyage (Humain)
Ipuz Mendez Adriana	Nettoyage (Planetarium)
Sayer Amina	Nettoyage (Planetarium)
Vermeylen Jacqueline	Nettoyage

C. TECHNISCHE DIENST / SERVICE TECHNIQUE

C.1.1. Betrokken personeel / Personnel concerné

Vander Putten Eric	Diensthoofd
De Knijf Marc	Ing electromechanica
Rogge Vincent	Preventieadviseur
Peeters Roger	Mechanica
Renders Francis	Mechanica
Strubbe Marc	Verwarming
Van Damme Daniel	Electronica
Van Der Gucht Ignace	Informatica
Mues Christian	Electricité
Bizerimana Philippe	Ouvrier
Philippe Motte	Chauffeur

D. IT SERVICES

D.1. Description and Objectives

The computing facilities and the network of the Observatory as well as of the Planetarium are managed by the IT department.

For researchers at the Observatory, the IT staff provides a logistic support for the installation and maintenance of intensive compute machines such as clusters, number crunchers, compute servers, etc ... as well as users PCs.

The team also maintains the global computing infrastructure consisting of amongst others the email services, application servers, printing facilities, database servers, network infrastructure, etc…

As a public service, the IT team provides access to the web site www.astro.oma.be. They also supply access to the services provided by the different scientific work groups (NTP time server from the Atomic clocks, Seismic charts, GPS data, Space weather, ..)
The IT Department also takes part in developments related to scientific projects with international partners.

More precisely, the IT department sections could be detailed as follow:

[1] **Network and Security**: the objective is to maintain the network infrastructure operational, safe and at top performance, 24 hours a day.
[2] **Servers and user PCs**: The objective is to install and maintain powerful compute servers, servers providing global computing infrastructure (i.e. email services, application servers, printing facilities, database servers, login server, ...) and desktop user PCs
[3] **Helpdesk**: The objective is to provide help and support to the users of the Observatory.
[4] **AMABEL Project**: AMABEL is a join project between three institutes: ROB, RMI and BIRA. The AMABEL project finances common resources such as file servers and compute servers.
[5] **Purchases**: All the IT purchases are done by the IT department. This includes all the procedure, from defining the need of the user or group to the installation of the chosen material. This include also the purchase of IT consumables (printer cartridges, printer toners, data storage media, etc …).

D.2. Progress and results

NETWORK BACKBONE:

- We have updated our network infrastructure. We have now 3 server rooms which are connected by 10 Gbit optical fibers. Both the passive part (the cables) and the active part (the switches) have been upgraded in 2007.
- A new UPS has been installed in order to meet the new requirements of our new server rooms.

VMWARE:

- This year considerable effort was placed in the virtualization of our server infrastructure. Each individual physical server has been replaced by a virtual machine. This has allowed us to provide better performance & reliability and a lot of cost reductions. At the present time, all the IT infrastructure is hosted on 5 physical servers located in the 3 server rooms. All of our servers are now virtual (helios, winsrv, ...) and can be launched indifferently on any physical server.

SECURITY & MONITORING

- Different kind of security tests are regularly made at different network levels. Modifications are made keeping the objectives in mind.

BACKUP SYSTEM:

- A backup system for the desktop PC has been setup. Each desktop PC is now backuped based on the following schedule: 7 daily snapshots + 12 weekly snapshots at the ROB and 1 year of weekly snapshots off-site at the planetarium

WINDOWS SERVER:

- We provide a centralized Windows server for all of our Linux users. This allows them to run MS software from time to time (mainly for Powerpoint presentations and Word articles).

LINUX SERVER:

- In the same way as for the Windows server, we provide a centralized Linux server for all of our Windows users. This allows them to run Linux software from time to time (mainly Latex, bash scripting, programming languages).

HELDESK:

- We provide to the users a direct support in the form of a helpdesk. In practice, anybody can send an email to helpdesk@oma.be and a sysadmin will help the user.
- In 2007, continuous support for users has been provided, including installation of machines and configuration.

AMABEL:

- The three institutes of the Space Pole share a common part of the IT infrastructure. Certain services are centralized such as the mail facilities, the large file servers, the central compute server and several other secondary servers. We participate in the maintenance of the central machines (file server, mail server, and compute server). In 2007, we have participated to the tests and installation of the new compute server.

KAOS:

- KAOS was a set of 4 high performance compute servers for heavy scientific tasks, shared by the 3 institutes (RMI, BISA and ROB). The repartition of the Kaos machines (interactive high performance servers) has been changed in 2007, Kaos 1 through 3 have been decommissioned, Kaos4 is now fully dedicated to applications from the Observatory, and finally, Kaos5 has been moved to the Meteorological Institute.

TECHNET:

- Technet is the equivalent of intranet but for IT specific topics. One could find news about major changes to our computer infrastructure, FAQs, extensive information about our hardware infrastructure including statistic graphs about our server resources and status of the different services.

- We have setup a new template with professional and clean look with the possibility to select two modes: Standard / Advanced by using cookies.
- The sysadmins have now the possibility to publish news on technet via a new cms using ajax. A RSS feed is also available for these news, so the users can read the news with their mail client, desktop applet or from any rss reader applications.
- A new tool has been created: an advanced search engine for the DNS for all classes in oma.
- Another tool has been created in order to manage all cartridges/printers (stock).
- A new version of the application for managing purchases has been created and installed.

DEPARTMENTAL SERVERS:

- Continuous maintenance of departmental servers.

USER PC & SOFTWARE:

- We install & configure either Ubuntu (Linux) or Windows XP/Vista on the user desktop PC. We also install & maintain many kind of software on these PC.

SMS SERVER:

- This system is used, for example, in the time lab of the observatory: if the temperature (which must be as stable as possible for the sanity of the atomic clocks) reaches a certain level, a SMS is send to the GSM of the scientific in charge as well as to the electronic lab.

LOGIN & SERVICES SERVER (HELIOS):

- Continuous maintenance of Helios, the login server of the Observatory (the only server available from outside) as well as the server which run some central services: DNS, NIS, DHCP, WINS,
- We are still using the NIS for user authentication. In agreement with the 3 other institutes an active directory will be installed in the near future. Servers for this purpose have already been bought.

FILE SERVER:

- The file server is shared between the 3 institutes. It is used for common disk space like the incoming mails and for offering easy sharable disk space for the users of the 3 institutes.
- In 2007, the new NetApp file servers have been delivered and installed. The transition to these new file servers has been almost transparent for the users.
- As we use the snapshot technology, users now have the possibility to restore their proper files, if not older than 3 months.

COMPUTE SERVER (ZENO/PLATO):

- Two common non-interactive compute servers are available for the 3 institutes. They allow users to submit heavy computation with a queuing system. They are intended to be used mainly for batch processes. In that context several different queues are defined with different specifications. The queuing system being used is PBS Pro
- In 2007, as agreed in the contract a new SGI server (PLATO) has been installed. The new server runs SLES10, service Pack1. Zeno will be upgraded later, to give the users the

possibility to recompile their programs. The queuing system will in the beginning be local on both servers, but the goal is to configure queuing over both servers, so that users will not have to choose between the servers.

FTP SERVER:

- A common FTP server is available for the 3 institutes. This allows anybody to share files with the outside world. This system is administrated by the ROB system administrators. This server resides in the DMZ (De-militarized Zone) and has Gentoo linux as OS. The available user disk space has been divided in 4 main parts:
  - /dist in which user files for distribution are put. These directories are not cleaned up automatically
  - /pub in which temporary files are put. These directories are cleaned up once a month
  - /incoming in which anonymous ftpusers can put files for the user. These directories are cleaned up regularly as well.
  - /private, which is only used for certain users and is password protected.

ROB INTERNET & INTRANET WEB SITES:

- The new layout of astro.oma.be is online. Updates are regularly done.
- Intranet is regularly updated too.
- A new interface for the publications has been installed on the web server and will be available for all in 2008.

PUBLIC PC:

- Two public PCs are available. The first one is Linux based, the second one is Windows based. They are located in the printer room. This allows visitors (or users without personal PC) to have access to internet, to scan and print documents or to read/write DVD or tapes.

ADMINISTRATION:

- A new version of PIA has been installed on admsrv.oma.be

NTP SERVER (JOIN PROJECT WITH THE TIME LAB OF THE ROB):

- Two NTP servers (ntp1.oma.be & ntp2.oma.be) are reliable time synchronization sources to allow anybody to synchronize on UTC(ORB) and by extend to UTC. All the servers and PCs of the 3 institutes (ROB, RMI, BISA), as well as a huge number of external anonymous clients use these time sources.

SUPPLIES:

- The IT department is responsible of the IT consumables (printer cartridges, printer toners, data storage media, etc …). We are in charge of the purchase of these consumables.

PURCHASES & RMA:

- The IT staff is in charge of the IT purchases & RMA. This includes the definition of the user needs, contacting different resellers, making the buying proposal and checking the received material.

USERCOM:

The USERCOM is a working group of user's representatives and system administrators. The aim is, on the one hand, to learn about the user's wishes, and the other hand, to share IT knowledge. We have participated to 4 USERCOM meetings in 2007.

D.3. Perspective for next years

- NETWORK BACKBONE:
  1. The network infrastructure and our internet connection will be upgraded following the new SCIENCEMAN network.
  2. The distribution switches will be upgraded and the connection from the desktop PC to the network will be improved.
  3. Checking, inventorying and monitoring the network.
- TECHNET:
  1. The new interface for the publications on the web server will be available
  2. Some forms will be created on Technet for IP requests, backup requests, access to the wireless network...
  3. A new application will be created and installed on Technet in order to manage all pcs of the Observatory in interaction with a new form for the helpdesk. (Gestion d'un parc informatique)
- LOGIN & SERVICES SERVER (HELIOS): We want to separate the login facility from the other services.
- INTRANET: New Intranet using SPIP cms.
- VOIP will be investigated
- VMWARE: The setup of an ESX VMWare infrastructure. At the present time, we are working with the free version of VMWare. This was a necessary step to be sure that virtualization was interesting for the ROB. But we miss a lot of tools of the non-free version like for example "vmotion" for moving virtual servers from one physical server to another one without interruption. This non-free version is only supported on "certified" hardware. So, the next step in virtualization for the ROB consists in installing 3 new ESX servers with the necessary tools.
- BACKUP: The off-site backup procedure to the planetarium will be improved with the dedicated 100 Mbits network connection between the ROB and the planetarium
- PUBLIC INFORMATION: A new server will be installed for the Information department.
- ROB INTERNET WEB SITE: Improvement of the website of the Observatory (www.astro.oma.be). The changes will be done on the layout but also in the code (xhtml/css) in order to have a clean and valid code.
- FILE SERVER: Installation of the new fileservers of the FS_SPACE project
- POSTMASTER: Do tasks related to postmaster "for the ROB institute".

D.4. Personnel involved

- David Herreman (System Administrator)
- Oleg Rezabek (System Administrator)
- Fabian Roosbeek (IT Coordinator)
- André Somerhausen (System Administrator)
- Katinka Vermeiren (System Administrator)

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