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Observatoire royal de Belgique

Koninklijke Sterrenwacht van België

Royal Observatory of Belgium

ORB - KSB

Cover illustration: Photo of the solar dome of the Royal Observatory of Belgium in Uccle, with a mosaic image of the Sun taken by the EUI telescope on board Solar Orbiter during the 2022 Space Pole Open Day. Credit: Royal Observatory of Belgium.

Foreword

Dear readers,

I am happy to present you with the annual summary report of the Royal Observatory of Belgium (ORB-KSB). As in the previous years, we have decided to only present the highlights of our scientific activities and public services, rather than providing a full, detailed and lengthy overview of all of our work during the year. We hope to provide you, in doing so, with a report that is more interesting to read and gives a taste of life at the ORB-KSB. If you need more or other information on ORB-KSB and/or its activities, contact rob_info@oma.be or visit our website http://www.observatory.be.

A list of publications and staff statistics are included at the end. To also suit our international readers & collaborators and to give it an as wide visibility as possible, the report is written in English.

Ronald Van der Linden

Director General

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Life at the Royal Observatory of Belgium

End of the COVID-19 Regulation and War in Ukraine

The year 2022 coincided with the relaxation of the COVID-19 restrictions and a massive return to work, with a minimum required presence of two days per week at the office. Since March 2022, the staff of the ORB-KSB at least have to come to the office twice a week. In consequence of the war in Ukraine that started on February 24, 2022, the Belspo Management Committee, comprising the ORB_KSB suspended science collaboration with Russian and Belarussian entities for an indefinite period. That included the second ExoMars mission, in which the ORB-KSB takes part with their LaRa instrument. Hence, the 2022 LaRa and ExoMars outreach campaign, coordinated by the Communication Service and the LaRa Team, was put on hold since the end of February 2022.

Tribute to Eric Elst

Figure 1: Photo of Eric Elst.

In January 2022, the ORB-KSB was informed of the passing away on 2 January 2022 of one of its former collaborators,

Eric Elst was a prolific astronomer and was known for his research on asteroids. With 3760 asteroids discovered by him – a number that will still increase fairly in the future – he holds the worldwide record as the discoverer of the largest number of asteroids by a single individual. He was also the co-discoverer of the comet Elst-Pizarro, which later got the dual status of comet and asteroid.

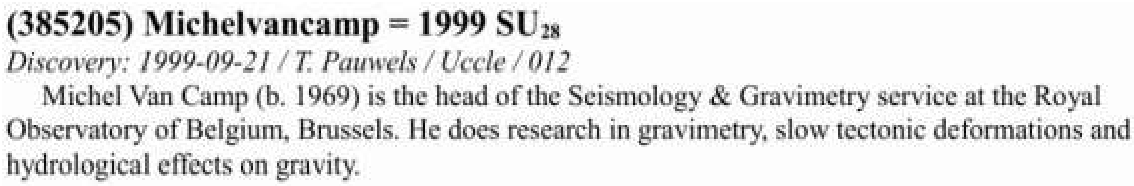
As a tribute to its former colleague, the ORB-KSB gave on its website a full biography of Eric Elst and his achievements.

Two asteroids discovered in Uccle named after two colleagues of the ORB-KSB

On 20 December 2021 and then on 17 January 2022, the International Astronomical Union named two asteroids after two colleagues from the ORB-KSB. They are Michel Van Camp, head of the Seismology and Gravimetry service and researcher in gravimetry, and Anne Vandersyppe, former secretary of the Solar Physics and Space Weather Service, who passed sadly passed away in 2019.

These two asteroids, now named (385205) Michelvancamp and (315579) Vandersyppe, were discovered in Uccle by Thierry Pauwels and Peter De Cat, respectively, both astronomers at the ORB-KSB.

The recent naming of these two asteroids is an opportunity to honour the direct and indirect contribution of our two colleagues to science. It highlights Michel Van Camp's expertise in gravimetry, the science of measuring gravity and its variations. One of his lines of research consists in studying the variations in gravity caused by changes of groundwater masses. For example, he has shown that tree evapotranspiration modifies gravity on hot summer days.

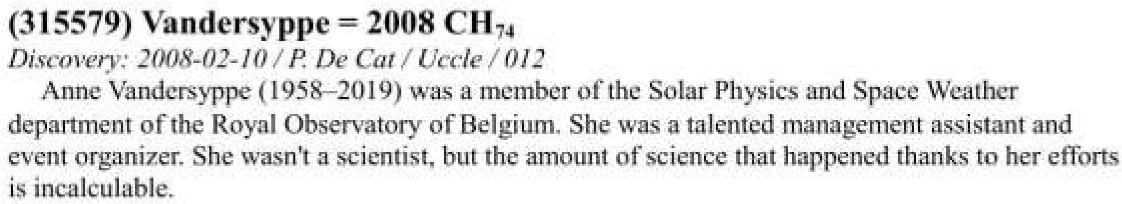


(385205) Michelvancamp = 1999 SU_{28}

Discovery: 1999-09-21 / T. Pauwels / Uccle / 012

Michel Van Camp (b. 1969) is the head of the Seismology & Gravimetry service at the Royal Observatory of Belgium, Brussels. He does research in gravimetry, slow tectonic deformations and hydrological effects on gravity.

Figure 2: Citation for asteroid (385205) Michelvancamp published in the Working Group Small Body Nomenclature (WGSBN) newsletter of 17 January 2022.



(315579) Vandersyppe = 2008 CH_{74}

Discovery: 2008-02-10 / P. De Cat / Uccle / 012

Anne Vandersyppe (1958–2019) was a member of the Solar Physics and Space Weather department of the Royal Observatory of Belgium. She was a talented management assistant and event organizer. She wasn't a scientist, but the amount of science that happened thanks to her efforts is incalculable.

Figure 3: Citation for asteroid (315579) Vandersyppe published in the WSGBN newsletter of 20 December 2021.

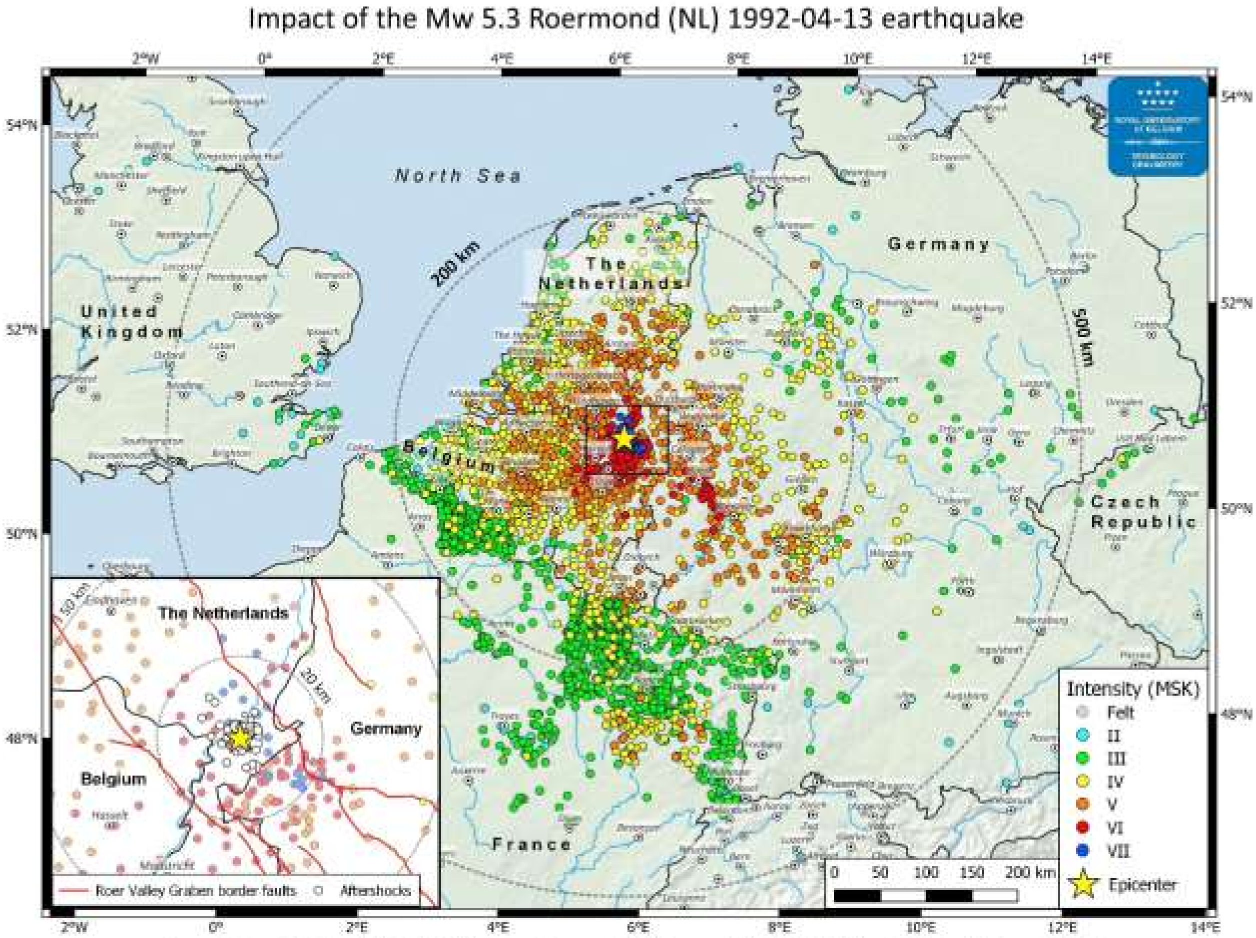
The naming also highlights the substantial, but often poorly acknowledged, contribution of non-scientists to the field of research, such as the one of our late colleague Anne Vandersyppe. The corresponding citation, written by Anne's close collaborators, contains the following mention: 'She was not a scientist, but the amount of science produced through her efforts is incalculable.' Naming an asteroid after her is thus a very nice way to honour her memory and her undeniable contribution to the work of the ORB-KSB's scientists.

The Royal Observatory of Belgium has a rich history and expertise in detecting and measuring the positions and motions of asteroids and comets. Our institute has counted in its ranks prolific discoverers of asteroids and comets, such as Eric Elst, who recently passed away (see Highlight on page 8), for comet Elst-Pizarro, and Sylvain Arend and Georges Roland for comet Arend-Roland.

The asteroids (385205) Michelvancamp and (315579) Vandersyppe were discovered with the ORB-KSB's Schmidt telescope. This large telescope, with a mirror of 1.2 m diameter, was upgraded in the mid-1990s by the installation of a CCD camera. Thanks to this camera, more than two hundred asteroids were discovered. More details on the history of observations with the Schmidt telescope can be found in the issue 66 of Science Connection (in French or Dutch).

Commemoration of the 30th anniversary of the 1992 Roermond (NL) earthquake

On April 13, 2022, at 3:20 a.m., we commemorated the 30th anniversary of the 1992 Roermond (NL) earthquake. This earthquake had a moment magnitude (a measure of energy) of Mw = 5.3 and is to date the strongest instrumentally measured earthquake in NW Europe. The earthquake originated along the NW-SE oriented Peelrand border fault of the Roer Valley Graben. Due to its large hypocentre depth of 17 km, damage was limited to modern buildings but was considerable for older buildings, with damages recorded even as far away as Bonn (DE). Two churches in Roermond were heavily damaged. Locally, there were landslides, river bank collapses and liquefaction (source: KNMI).



Macroseismic intensity data from Haak et al. (1994). The macroseismic map of the 1992 Roermond earthquake, the Netherlands. Geologie en Mijnbouw 73, 265-270.

Many people in Belgium still remember this event as it took place at night and was felt all over Belgium. An international seismological consortium (Haak et al. 1994) studied the impact of this event, leading to the macroseismic map presented below. The event was felt throughout Belgium, the Netherlands, Luxembourg and Germany, and in northern France, northern Switzerland and even as far away as the Czech Republic. In the hours, days and weeks following the main shock, more than 200 aftershocks were recorded.

Publication of the Popular Book 'Le Soleil et nous' by Frédéric Clette

In 2022, a book on the Sun was published in French by Frédéric Clette a researcher at the Royal Observatory of Belgium. Inspired by his career and his experience in popularising science, he presents in this book intended for a wide readership a global panorama of the Sun, its multiple influences on our planet and us, humans, as well as the new dangers it may bring for our present society.

Frédéric Clette's 'Le Soleil et nous' ('The Sun and us' in English) not only presents, in a non-technical language, our latest knowledge about the structure and activity of our star. It also discusses ancient solar myths and deities, the Sun's role in the climate, and the links between the Sun and a wide variety of inexhaustible natural energies: light, heat, wind, biomass, etc.

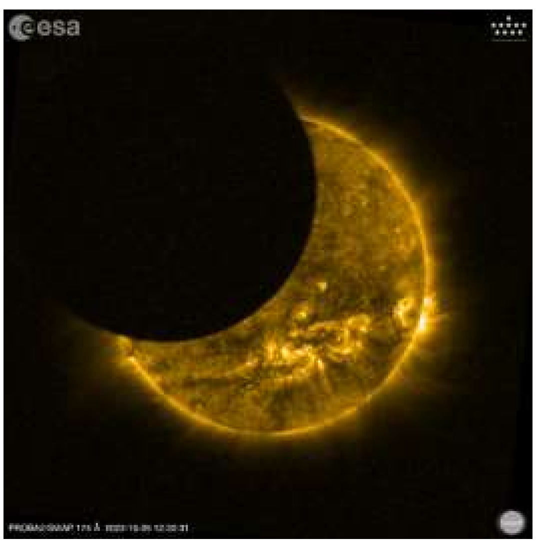
Alongside the vital benefits of our star, it also mentions the new dangers that intense solar flares can pose to our society: the biggest ones can lead to communication blackouts and global power outages in our electrical systems. Frédéric Clette points out: 'Over the past few decades, our society has evolved in a way that makes us much more vulnerable to solar activity. Today, almost everything depends on electricity. We have created a global risk for ourselves that did not exist before.'

More than ever, citizens and political leaders need to know what the Sun is and what it brings to the Earth. We really need to learn to better adapt our activities, so that we can live in harmony with our star.

Reference

Frédéric Clette, '*Le Soleil et nous : Tout comprendre sur notre étoile, de son cœur en fusion jusqu'à la Terre et son climat*', Publisher: Éditions Favre, Lausanne — Paris, 2022, EAN : 9782828918910.

The 25th of October 2022 Solar Eclipse



A partial solar eclipse took place on Tuesday, 25 October 2022 and was partially visible in Belgium. In Uccle, the eclipse was visible between 11:10 (first contact) and 13:00 (last contact), and its maximum took take place at 12:04 in Belgian time (UTC + 2 h). From Belgium, it was a small eclipse, with the Moon covering only about 30% of the Sun's diameter during the maximum. This corresponds to about 19% of the Sun's surface.

Solar instruments operated by the ORB-KSB observed this solar eclipse. This is the case with the SWAP camera and the LYRA radiometer on board of the PROBA2 satellite and the USET solar telescopes at Uccle.

The first astronomical liquid mirror telescope sees first light at the Devasthal observatory

In April 2022, the ILMT (International Liquid Mirror Telescope), located at the Devasthal Observatory in the north of India, has been used for the first time to observe the sky (see Figure 4). This event, called the 'first light', marks the debut of this new telescope.

The Devasthal observatory is a new astronomical site in India, located at an altitude of 2450 metres in the Kumaun region of the Himalayas in the district of Nainital in the state of Uttarakhand. This observatory is operated by ARIES (the Aryabhatta Research Institute of Observational Sciences) in Nainital (India) and currently hosts three telescopes: a 1.3-m optical telescope, the 3.6-m DOT (Devasthal Optical Telescope) and the 4 m ILMT. The latter two are so-called 'Indo-Belgian' telescopes. They are both built by AMOS (Advanced Mechanical and Optical Systems) and CSL (Liège Space Centre; in French: *Centre Spatial de Liège*) in Belgium.

Figure 4: One of the first images from the ILMT, consisting of an overlay of three individual observations in three different colours of a small portion of the sky containing the galaxy NGC 4274 (upper right corner).

After the closure of the observatory for the monsoon (from June to September) and a commissioning phase of a few months, the scientific observations of the ILMT are expected to start at the beginning of

2023. Hence, the ILMT is the second large optical telescope with a diameter of 3 to 4 metres that becomes operational at the Devasthal observatory with access to Belgian astronomers. The ILMT will collect data for (at least) five years, which allows for performing a deep photometric and astrometric variability survey of the objects in the ILMT strip.

The ILMT project is a Belgian initiative led by members of the University of Liège (ULiège) in collaboration with partner institutes in Belgium, Canada, India, Poland, and Uzbekistan. The Royal Observatory of Belgium (ORB-KSB) was involved in the optical design of the corrector and made a financial contribution to the CCD camera. Moreover, Peter De Cat, researcher at the ORB-KSB, is the Belgian driving force behind the Belgo-Indian Network for Astronomy and astrophysics (BINA). The BINA is a network initiated in 2016 to foster collaborations between Belgian and Indian institutes with the aim to make optimal use of the DOT, ILMT, and other telescopes accessible through these collaborations. It is supported by BELSPO in Belgium and DST (International Division, Department of Science and Technology) in India. 'Now that the ILMT is ready, ' says Peter de Cat, 'BINA can finally proceed at full speed.'

Space Missions and scientific services

Unique Images of the Sun by the EUI Telescopes

Since its first light in 2020, the Extreme Ultraviolet Imager (EUI) on board Solar Orbiter reveal details in the Sun that we have never been able to see despite decades of solar observations. In 2022, the EUI got several times the opportunity to make images of the Sun with unprecedented details.

On 15 February 2022, the EUI captured a full image of a solar cloud while it was hurled into space. EUI followed the solar cloud over a distance of 3.5 million km. Never before has a single telescope imaged the journey of a solar cloud from the early start to this far into space.

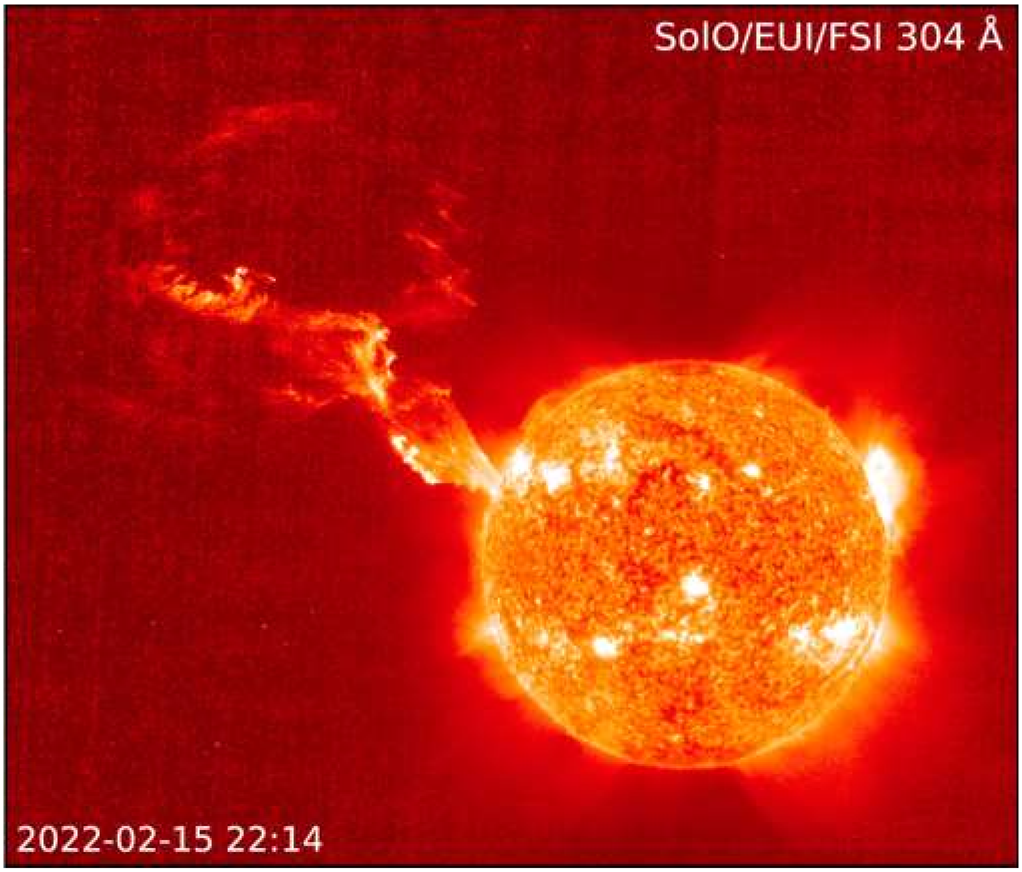


Figure 5: EUI image of the solar cloud of February 15, 2022, escaping the Sun. Credit: Solar Orbiter/EUI Team/ESA & NASA.

Shortly after, on March 7, the high-resolution telescope of the EUI made a mosaic image of the solar disk. Over a period of more than 4 hours, the satellite aimed at different positions each time capturing a small square of the Sun at very high resolution. These images were then stitched together like a patchwork. The result was an extremely detailed image of the entire Sun. The result is the sharpest image of the solar atmosphere ever taken. This patchwork image was printed by the EUI team of Brussels on a support and was exhibited during the Open Doors 2022 next to the USET telescope dome.

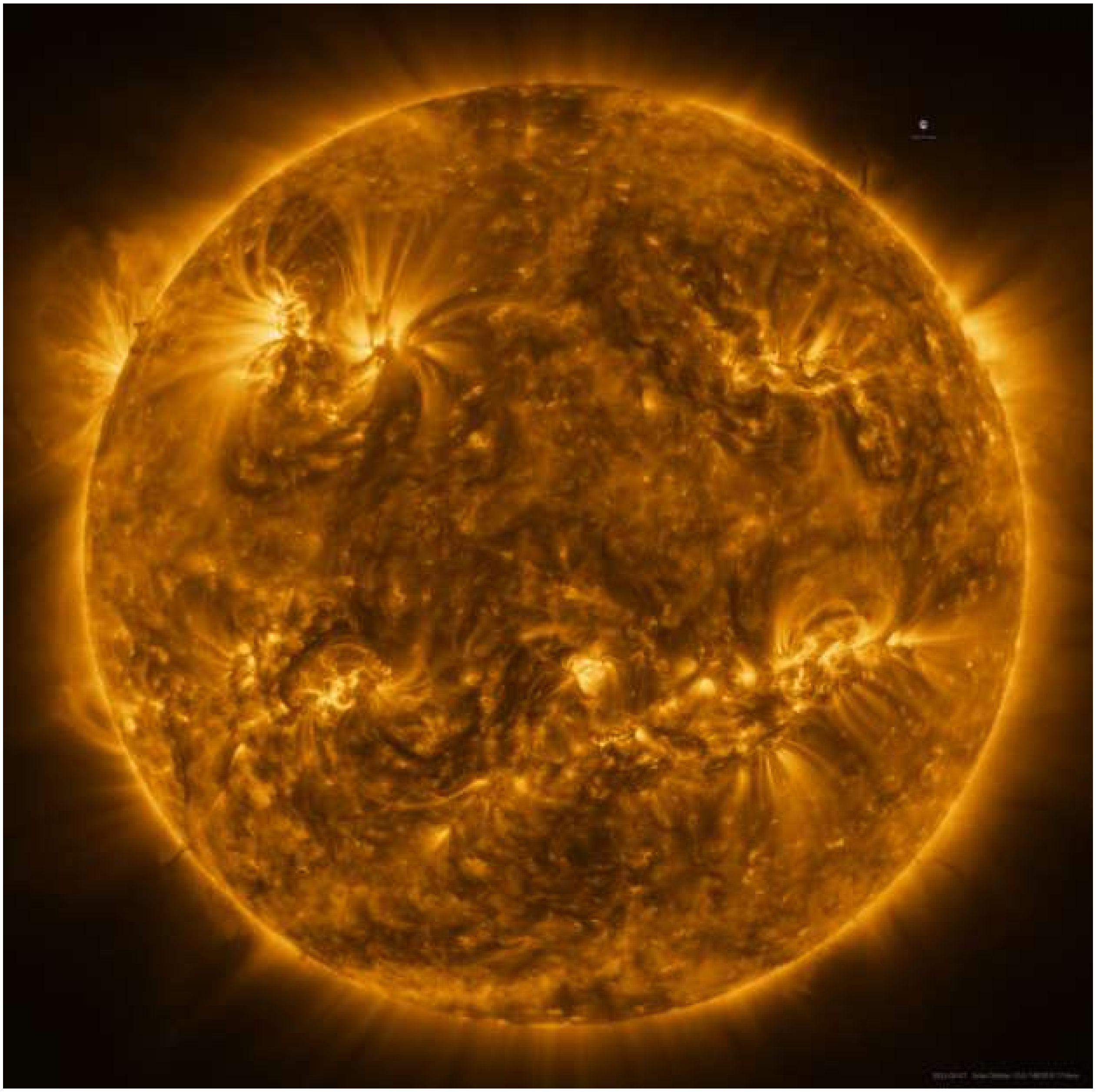


Figure 6: This image is a mosaic of 25 individual images taken on March 7 by the high resolution telescope, part of the Extreme Ultraviolet Imager (EUI) instrument. In total, the final image contains more than 94 million pixels in a 9700 x 9700 pixel grid, making it the highest-resolution image of the solar disk and outer atmosphere ever taken. Zoom to marvel at the details. A full-resolution image can be found [here](). See also the [interactive image]() that allows to zoom in and out. See also [the movie](). Credit: ESA & NASA/ Solar Orbiter/ EUI team; Data processing: E. Kraaikamp (ORB-KSB).

On March 26, 2022, the Solar Orbiter satellite came to the perihelion of the Sun, at the closest point of its orbit. At this distance, EUI could no more image a full Sun. However, its images reveal details never seen before of the solar corona, such as ‘hedgehogs’ (see Figure 7).

Figure 7: This close-up of the solar atmosphere shows a phenomenon that researchers have tentatively nicknamed 'the hedgehog'. What exactly the hedgehog is and how it was formed, further research has yet to reveal. Credit: Solar Orbiter/EUI Team/ESA & NASA.

Many more passages close to the Sun will follow later in the mission. Solar Orbiter's orbit is becoming increasingly tilted, which will allow us to image the solar poles for the first time.

DART impact on an asteroid, a milestone for the Royal Observatory of Belgium

During the night of September 26–27, at approximately 1:15 a.m. (Belgian time), NASA's DART probe crashed into the asteroid Dimorphos (the moon of the binary system Didymos), located more than 10 million kilometres from Earth. The purpose of this impact is to test an asteroid deflection strategy. For the Royal Observatory of Belgium (ORB-KSB), which is involved in planetary defence, this mission represents an important first step.

Figure 8: Artist view of the DART mission

On 24 November 2021, the DART (Double Asteroid Redirection Test) probe took off from the Vandenberg Space Force base in California (USA). Its journey of almost a year will end in a few days. This will allow us to study asteroid deflection by probe impact. The target of the mission is the Dimorphos asteroid. It is the smallest of a binary system of asteroids called Didymos and has a diameter of about 160 m (780 m for the main body, also called Didymos).

It is a full-scale planetary defence experiment with an impact speed of over 22,000 km/h (6.15 km/s). The experiment will also provide a better understanding of the Didymos binary system. By studying the system before and after the impact and comparing observations and numerical simulations, we will learn more about the 'big rocks' that move through space and could pose a threat to the Earth.

Özgür Karatekin and his team of the ORB-KSB are involved in the DART mission as part of the international Asteroid Impact and Deflection Assessment (AIDA) collaboration of which NASA and ESA, with its Hera mission scheduled for launch in 2024, take part. Scientists of the ORB-KSB will participate in the processing of DART data.

Analysing the data from this mission will allow them to better understand the internal structure of asteroids, in the framework of the European projects PIONEERS (Planetary Instruments based on Optical technologies for an iNnovative European Exploration using Rotational Seismology) and NEO-MAPP (Near-Earth Object Modelling and Payloads for Protection) to which the ORB-KSB contributes. The experience with DART will also help to better prepare the next mission, Hera, which will carry the GRASS gravimeter, developed by the Observatory with its Spanish industrial partner EMXYS.

In 2022, scientists of the ORB-KSB involved in DART and Hera participated in various public events to raise public awareness on planetary defence and to let them know of the ORB-KSB's contribution in this field. They held notably an event in June at the Royal Belgian Institute of Natural Sciences on the occasion of the Asteroid Day on June 30 and also another event in September at the Planetarium on the occasion of the DART impact.

The research of the ORB-KSB related to this mission is funded by the Belgian Federal Science Policy (BELSPO) with support from the ESA PRODEX programme. The PIONEERS and NEO-MAPP programmes have received funding from the European Union's Horizon 2020 research and innovation programme.

Seismic Activity in and around Belgium in 2022

In 2022, 99 natural earthquakes occurred in a zone between 1° and 8°E longitude and 49° and 52°N latitude (). During the same period, the Royal Observatory of Belgium (ORB-KSB) also measured 40 induced events, 469 quarry blasts and at least 14 explosions offshore linked to controlled explosions of WW1 and WW2 bombs by the Belgian, Dutch or French Armies. The 2022 ORB-KSB catalogue is complete for natural earthquakes with a magnitude ML larger than 1.0. Events with magnitudes lower than 1.0 were routinely detected where the Belgian seismic network is denser. The 2022 ORB-KSB catalogue also contains a selection of quarry blasts, earthquakes induced by human activities, e.g. linked to (rock) mass removal in quarries or geothermal exploitation, a sonic boom and a public outreach event.

17 natural earthquakes and at least 38 induced earthquakes occurred on the Belgian territory. The largest earthquake was the induced event on 16 November 2022 in Dessel, which local magnitude ML was 2.1. This earthquake was related to geothermal activities and was felt by the population in the neighbouring communes of Dessel, Mol and Retie, who spontaneously answered the online Seismologie.be ‘Did You Feel It?’ questionnaire. Three other events in Ittre, Waimes and Dessel were weakly felt in Belgium in 2022.

In comparison, last year, in 2021, 257 earthquakes occurred in and around Belgium. This larger number of events was related to a seismic swarm that occurred close to the German town of Rott, north-east of Eupen. The largest earthquakes recorded on the Belgian territory in 2021 occurred on 20 June 2021 in Dampremy near Charleroi and 28 August 2021 in Baelen near Eupen. Both events had a local magnitude of 1.7 and were not felt by the local population.

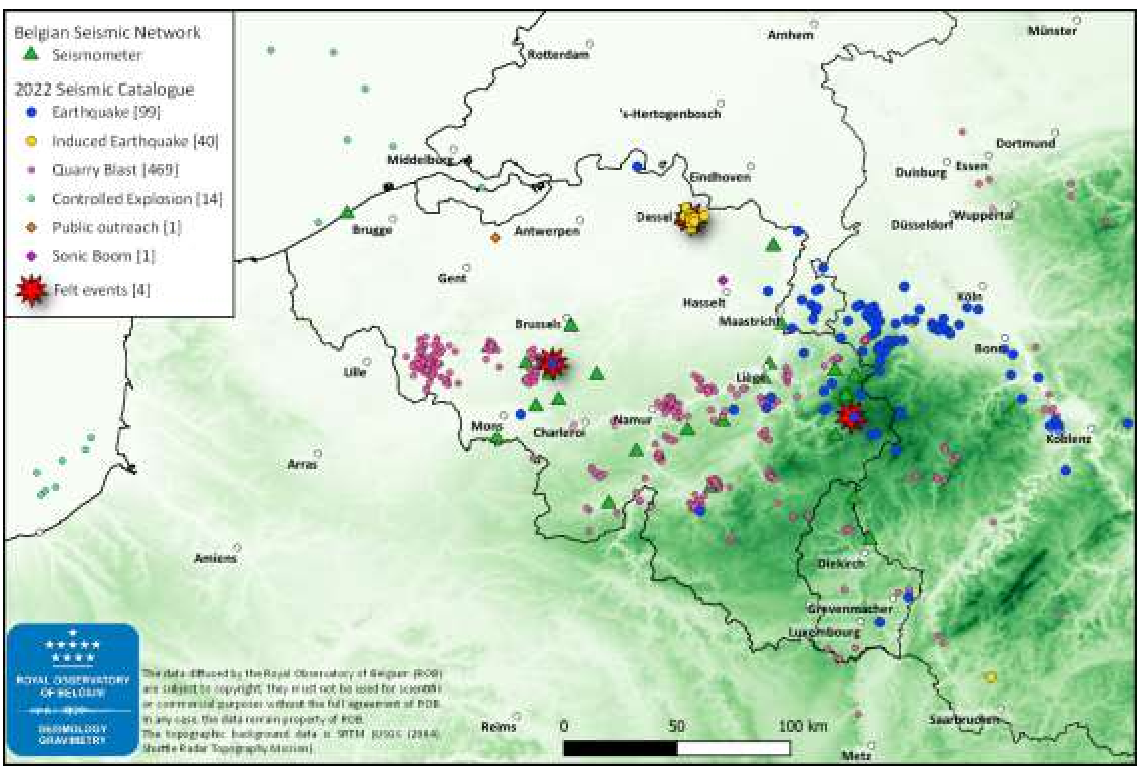


Figure 9: Events recorded in 2022 by the Belgian Seismic Network of the Royal Observatory of Belgium.

Research at the Royal Observatory of Belgium

Seismology and Gravimetry

The largest volcanic explosion after Krakatau in 1883 studied within an international collaboration

On 15 January 2022, the Hunga[1] volcano (Tonga archipelago) produced a major explosion at 4:15 am (Universal Time). This eruption is the culmination of an eruptive sequence that began on 19 December 2021. All eruptions prior to this explosive event were much smaller and impacts were limited to the area around Hunga-Tonga and Hunga Ha'apai. The explosion caused significant atmospheric, acoustic, gravitational, ionospheric and seismic disturbances. It was recorded by a wide range of instrument types, each providing information and constraints on this major event. The frequency content of the event spans a very wide band (from acoustic-gravity to audio: it was heard as far away as Alaska, at a distance of almost 10,000 km) and therefore requires an interdisciplinary collaboration and perspective.

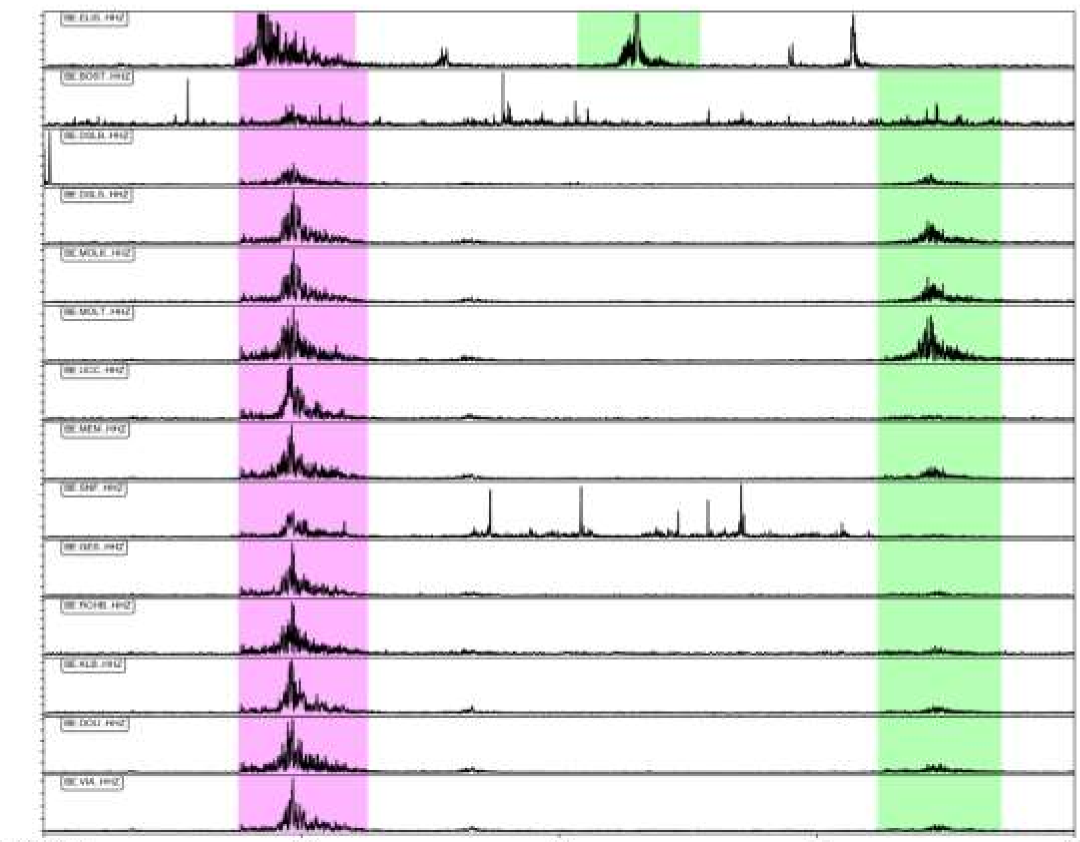


Figure 10: Seismic recordings of 15 January 2022 by the Belgian network of the Royal Observatory of Belgium. The ELIS station is located in Antarctica and therefore shows a different waveform than the stations located in Belgium. Illustration of the arrival of the seismic waves between 4h15 and 7h00 UTC (fuchsia) and of the seismic-acoustic wave (green) from 12h43 at ELIS and 18h50 for the network in Belgium.

1 The name of the volcano is "Hunga", not "Hunga Tonga-Hunga Ha'apai". "Hunga" refers to the whole volcano, rather than the islands of "Hunga Tonga" and "Hunga Ha'apai".

The paper published on Thursday, May 12 in the journal Science is the result of a global scientific effort, with 76 authors from 17 countries, whose expertise includes seismology, acoustics, tsunamis, ionospheric disturbances, volcanology, etc. This is the most comprehensive analysis of a very complex and large-scale eruption. The main eruption was the largest recorded in recent decades and the most exhaustively recorded by global monitoring stations (97 networks, 3189 data sets). It validated theories that had not yet been observed with modern instruments. For example, the acoustic-gravitational waves circled the globe three times over a period of six days, something that had not happened since the eruption of the Krakatau volcano in Indonesia in 1883. Various tsunamis were also triggered at several locations around the world. Unlike the Krakatau eruption, thousands of instruments were used to dissect this major eruption and to analyse its impact on the planet.

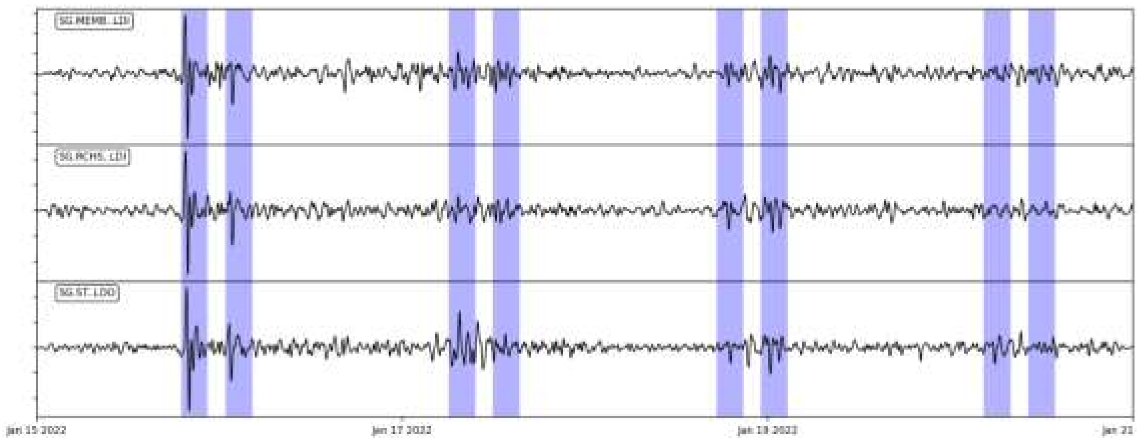


Figure 11: Recording of atmospheric pressure changes by the barometers of the international network of superconducting gravimeters, two of which are located in Belgium: MEMB in Membach (Baelen) and RCHS in Rochefort. The graph shows the different passages of the Lamb wave, which circles the Earth in about 35 hours and 10 minutes. At the 'shortest distance', this wave travels about 6 hours less than at the 'longest distance'.

The Belgian contribution to this international effort was the co-coordination of the seismological analysis (Corentin Caudron, Université libre de Bruxelles) and the global analysis of the data from pressure sensors, barometers and seismometers (Thomas Lecocq, Royal Observatory of Belgium).

Reference:

Robin S. Matoza et al., "Atmospheric waves and global seismoacoustic observations of the January 2022 Hunga eruption, Tonga", Science, Volume 376, Issue 6594, DOI: 10.1126/science.abo7063.

Ten Thousand Days of Continuous Gravity Measurements in Membach

On 20 December 2022, the superconducting gravimeter in Membach (High Fens, Belgium) will have measured variations in gravity for 10 000 consecutive days. Installed on 4 August 1995 by the Royal Observatory of Belgium, this gravimeter has held a double world record since 18 September 2017: that of the instrument that has measured variations in gravity at a single location for the longest period of time in the world, and that of the longest circulation of electric currents in superconducting circuits.

Figure 12: The Membach's superconducting gravimeter and an exploded view of the sensor with the levitating sphere. Left photo: E. Coveliers.

Gravity variations are due to terrestrial tides caused by the relative movements of the Earth, the Moon and the Sun, the movements of atmospheric masses and groundwater, as well as by various geophysical phenomena. In the research of the ORB-KSB, the measurements of the Membach gravimeter, which have the accuracy of one hundredth of a billionth (10^{-11}) of g ($g = 9.81\ m/s^2$), provide a better understanding of long-term variations in gravity, caused by slow tectonic movements or climatic variations. This is also important for the study of the water cycle, which influences gravity.

Among the discoveries made with the Membach gravimeter are the measurement of the effect of tree evapotranspiration on gravity, the possibility of assessing the quality of precipitation observations by weather radars.

To date, this gravimeter participates in many research projects and the ORB-KSB hopes to be able to perform this type of measurement for many years to come.

Global Navigation Satellite Systems and Reference Systems

Towards FAIR GNSS Data

Introduction

The Royal Observatory of Belgium (ORB-KSB) maintains two unique data repositories with more than twenty years of GNSS observation data (RINEX data – Receiver Independent Exchange Format) from Belgian GNSS reference stations as well as stations belonging to the EUREF network (Figure 13). Motivated by user needs and the EU Directive 2019/1024 on open data and the re-use of public sector information (and its implementation in Belgium), the GNSS team tackled the challenge to improve the Findability, Accessibility, Interoperability, and Re-usability of ORB-KSB's GNSS data by applying FAIR data principles. These principles serve as guidelines for making scientific data suitable for re-use, by both people and machines, under clearly defined conditions.

Figure 13: EUREF permanent GNSS network.

However, when moving towards FAIR data, one should consider the complete FAIR ecosystem, which comprises policies, data management plans, identifiers, metadata standards, and data repositories. This requires a substantial change in practices, technologies and implementation procedures that must be supported by the strategic objectives of local and international organisations, and by dedicated funding. To help moving the GNSS community forward, the GNSS team and University of Ghent received funding from BELSPO through the FAIR-GNSS BRAIN 2.0 project (12/2022 – 09/2023).

To reach the project objectives, the FAIR-GNSS team adopted a threefold approach:

1. Reaching community agreement on standardised metadata to be used for GNSS reference station data, requiring ORB-KSB's involvement in several international Working Groups;
2. Completing ORB-KSB's GNSS data with rich metadata, including e.g. data licence of use and Digital Object Identifiers (DOIs), to enable tracing and citing the GNSS data, and therefore requiring a complete restructuring of ORB-KSB's GNSS data repositories;
3. Making the ORB-KSB's GNSS data and metadata accessible to both humans and machines through the development of APIs (Application Programming Interface).

Reaching community agreement on metadata standards

When dealing with GNSS data, one has to distinguish between two types of metadata:

- station-dependent metadata e.g. station owner, equipment, DOI of the station's data set, etc.
- RINEX-dependent metadata i.e. those linked to one specific RINEX observation data file.

As a consequence, the FAIR-GNSS team drafted two proposals for GNSS metadata standardisation, one for GNSS station-dependent metadata and one for RINEX-dependent metadata. During this process, ORB-KSB's GNSS team devoted a great deal of effort in interacting with the scientific GNSS community to take into account: (i) the perspective of the users accessing and using the data; (ii) compliance with FAIR data principles; (iii) European and Belgian initiatives; iv) best practices at other GNSS data repositories worldwide.

For the station-dependent metadata, the FAIR-GNSS team proposed to extend the international GeodesyML[2] schema and make it compliant with FAIR data principles. This proposal was accepted by the International GNSS Service (IGS) and then included in the upcoming version of GeodesyML.

As no metadata standard was available to describe RINEX data, the FAIR-GNSS team proposed to adopt the W3C (World Wide Web Consortium) Data Catalog metadata schema (DCAT) which is used within the European Plate Observing System (EPOS) and to extend the DCAT Application Profile for open datasets and data portals (DCAT-AP)[3] in order to describe GNSS data (GNSS-DCAT-AP). The proposed new GNSS-DCAT-AP profile for GNSS RINEX metadata was documented and made publicly accessible (on GitHub) to enable discussions and collaborations within the community.

To reach out to the scientific community, contribute to disseminating FAIR-GNSS results, get feedback on the FAIR-GNSS proposals, and foster possible future collaborations with experts in the field, the FAIR-GNSS partners organised a webinar 'Putting the FAIR principles into practice: the journey of a GNSS data repository', on October 11, 2022. The webinar attracted great interest: 200 registered participants (from 45 different countries, Fig. 2), including several members of Belgian Federal Scientific Institutes.

Figure 14: Location of the registered participants of the FAIR-GNSS webinar.

Digital Object Identifiers for GNSS Data

The attribution of a Persistent Identifier (PID) to GNSS data is also required by FAIR principles, and DOI is an obvious choice for a PID for GNSS datasets. By actively contributing to the Working Group on 'DOIs for Geodetic Data Sets' of the Global Geodetic Observing System (GGOS), the FAIR-GNSS team raised awareness on the importance of using DOIs for making GNSS data citable and providing stable endpoints to the data. As a result, the community agreed on a proposal, based on the DataCite schema[4], for a minimum set of metadata elements that should accompany the DOI of a GNSS dataset.

Restructuring ORB-KSB's Data Repositories

In order to include the missing information i.e. metadata required by FAIR data principles (such as to identify the origin and all changes occurred to the RINEX files with respect to the original, to include data license, etc.), ORB-KSB completely restructured its repositories containing EUREF and Belgian GNSS data and the corresponding data flows. The revised data repositories now collect information on the provenance of new incoming RINEX files, file changes and corrections, and potential file issues.

2 GeodesyML, an XML implementation of the eGeodesy model, is a schema for transfer of geodetic information. For more information about eGeodesy and GeodesyML, see http://www.geodesyml.org.

3 DCAT-AP is an initiative of the European Commission and the standard for describing Public Sector Information as open government data.

4 The DataCite Metadata Schema is a list of core metadata properties chosen for an accurate and consistent identification of a resource for citation and retrieval purposes, along with recommended use instructions. See https://schema.datacite.org/

Next steps

The last step of the FAIR-GNSS project will consist in implementing the open data portal for ORB-KSB's European and Belgian GNSS data repositories including API to access GNSS data and metadata.

GENESIS mission and associated research

Motivation

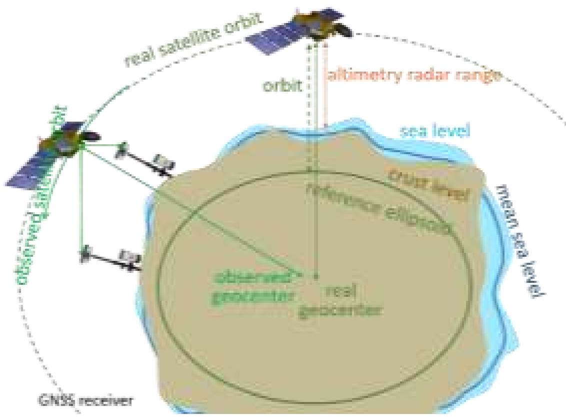


Figure 15: Satellite altimetry for measuring sea level change. Presently based on the observed satellite orbit and geocentre that differ from the real ones.

Improving and homogenising Earth's reference frames with the accuracy of 1 millimetre (mm) and a long-term stability of 0.1 mm/year are relevant for many scientific and societal endeavours (see Delva et al., 2023, in which the ORB-KSB participated). For instance, quantifying sea-level change from satellite altimetry strongly depends on an accurate determination of the geocentric motion and the orbits of satellites (see Figure 15). Sea-level change is also determined from tide gauges that need to be precisely located with respect to continental and island reference stations. Reaching mm-level accuracy in sea-level change needs positioning the satellites and the reference frame with even better accuracy and with a long-term stability of 0.1mm/year. Numerous other applications in geophysics also require such absolute accuracy. This is the case, for instance, when monitoring tectonic motions or crustal deformations. It is thus important to reach high accuracy and precision in such observations in order to advance our understanding of the physical processes involved in the Earth dynamics (see Figure 16), as well as to contribute to a better understanding of natural hazards. Reaching such low errors in the measurements is also essential for positioning and navigation in the civilian applications and for proper georeferencing of geospatial information.

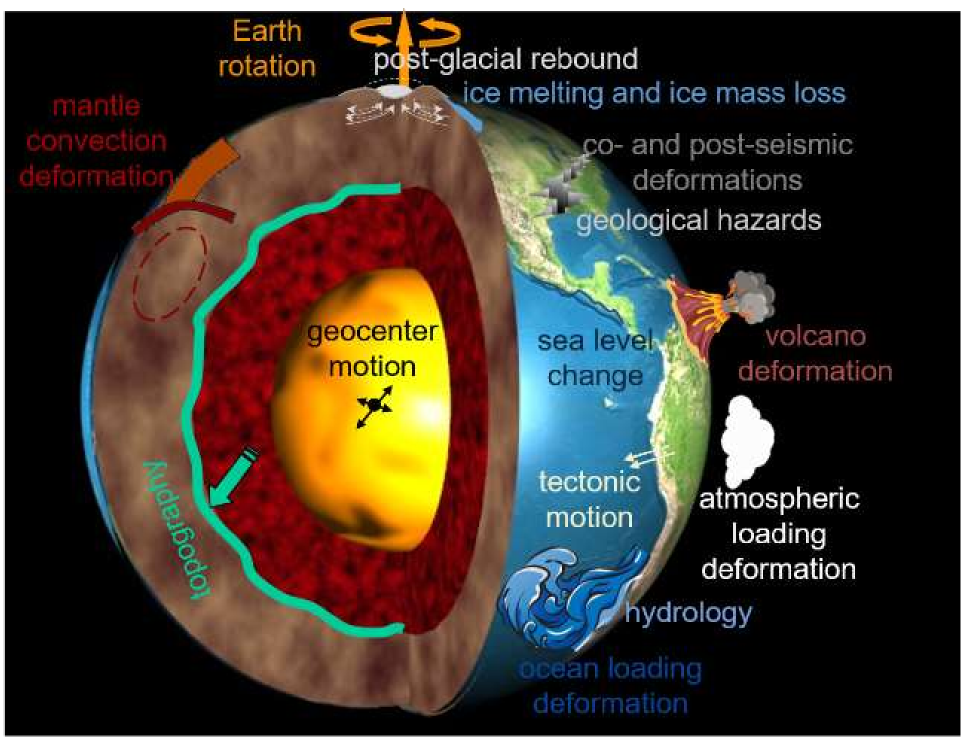


Figure 16: All kinds of deformations requiring at least mm-level precision in their observation.

Needs

The reference frame accuracy to be achieved represents the consensus of various authorities, including the International Association of Geodesy (IAG). Moreover, the United Nations Resolution 69/266[5] states that the full societal benefits in developing satellite missions for positioning, remote sensing and in-situ measurements of the Earth are realised only if they are referenced to a common global accurate reference frame at the national, regional and global levels. Today we are still far from these ambitious accuracy and stability goals (Delva et al., 2023, and the references therein).

(1) The problem related to Earth ground-based observations. The reference frame attached to the Earth is mainly realised and maintained by using GNSS satellites (Global Navigation Satellite System), and also by SLR (Satellite Laser Ranging) and DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) beacons. The positions and velocities are deduced from their orbits that are determined from Earth tracking stations. These orbits have thus important biases, as they are not observed from space. In order to reference them in space, it is necessary to correct for the Earth's rotation and orientation in space.

Very Long Baseline Interferometry (VLBI) is used to determine the Earth rotation parameters. This technique is based on the observation of quasars, which are objects with very stable positions in the sky and emitting in all wavelengths including microwaves. Large antennas on Earth are observing them, and recording the time correlation of the signal arriving at different stations allows us to determine the evolution of the time delays. These observations are used together with models in order to provide the Earth rotation and orientation parameters, which are in turn used for GNSS satellite orbit determination (see Figure 17).

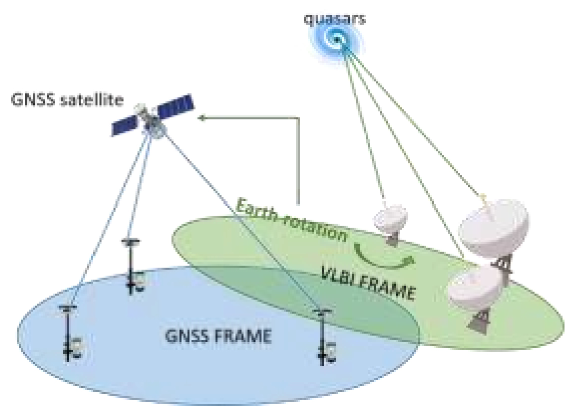


Figure 17. GNSS satellites are tracked from Earth. Their orbits are determined in space from using Earth rotation and orientation parameters determined by VLBI.

(2) The problem related to Earth Rotation and Orientation Parameters. The reference frames attached to the Earth (terrestrial frame) and to the quasars (celestial frame) are linked together by the Earth rotation and orientation parameters. The relationship between these frames is complicated by the fact that the rotation and orientation of the Earth are subject to irregularities induced by time-varying global mass redistribution in the oceans, atmosphere, and liquid core, and also by external forcing such as the gravitational pull of the Sun and the Moon (see Earth rotation highlight of this year).

The Solution

We will, in the future, benefit from the ESA GENESIS mission (to be launched in 2027), a mission that has been accepted at the last ESA Ministerial in November 2022. GENESIS is a spacecraft co-locating four geodesic techniques in order to enable a more precise realisation of the reference frames (see Figure 18), satisfying the UN resolution requirements. The key instrument from this mission is the VLBI transmitter (VT) based on the VLBI (Very Long Baseline Interferometry) technique that currently operates by recording the signals from quasars (see Figure 18).

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5 UN resolution 69/266 https://ggim.un.org/documents/A_RES_69_266_E.pdf

First Steps in Scientific Research

The Earth rotation represented by the difference (UT1–UTC) is one of the Earth orientation parameters (EOP) that can only be determined by VLBI, observing distant celestial sources in order to measure the Earth rotation angle. Earth-orbiting satellites tracked from Earth is not able to determine this angle, and the orbit determination and time synchronisation (ODTS) procedure for GNSS satellites hence requires the UT1–UTC as an input. Today, UT1–UTC is provided by the International Earth Rotation and Reference Systems Service (IERS). As an alternative way, a VT onboard GNSS satellites or any other satellite would allow the direct transfer of this information as an integrated step to the ODTS process thanks to the space tie established between the VLBI and GNSS techniques. Researchers at ORB-KSB have investigated the transfer quality of the UT1–UTC in such a concept by considering different VLBI baselines. Additional quasar observations are acquired with the same VLBI ground stations during the same session, therewith allowing to directly transfer UT1–UTC to the GNSS constellation with the precision of about 30 µs for a long VLBI baseline where the UT1–UTC precision estimated from quasar observations is considered to be fixed. This work has been published (Sert et al., 2022).

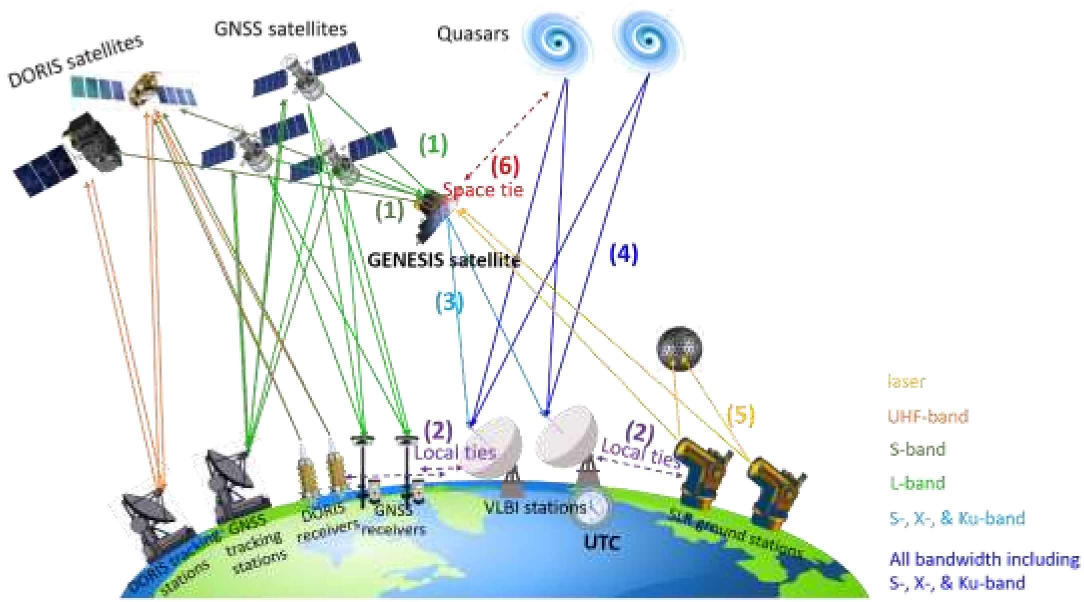


*Figure 18: Principle of the GENESIS mission. GENESIS satellite orbit is determined by **(1)** GNSS Receiver or **(1)** DORIS beacon without absolute position and orientation information. **(2)** The different ground stations have local ties. **(3)** The GENESIS satellite includes a VLBI Transmitter mimicking quasars and observed during **(4)** VLBI intensive sessions. **(5)** There is also satellite laser ranging on GENESIS. **(6)** One performs analysis during intensive sessions observing VT and quasars and determine the absolute position and orientation of GENESIS satellite using all data.*

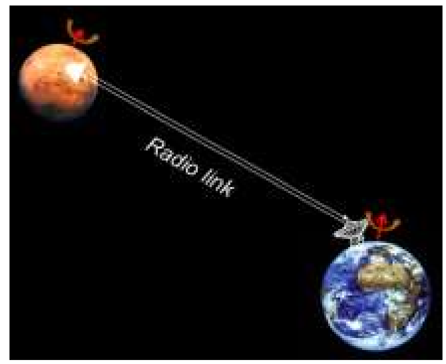
Planetary Science

Discoveries about the Rotation, Interior and Atmosphere of Mars Based on Insight Data

Radioscience Results

The RISE Experiment

Data from the radioscience experiment RISE (Rotation and Interior Structure Experiment) of the NASA InSight mission (Interior exploration using Seismic Investigations, Geodesy, and Heat Transport) have been used to probe both the planet's deep interior and its atmosphere dynamics. The RISE coherent X-band transponder enables to measure the Doppler shift on the two-way radio links between its two medium-gain antennas and the NASA Deep Space Network. These Doppler shifts extremely accurately characterise the relative velocity between the antennas and the Earth and allow identifying tiny variations in the rotation and orientation of Mars that are sensitive to the Martian interior and atmosphere.



The RISE experiment was specifically designed to measure the Martian nutations, periodic motions of the spin axis in space, in order to study the core. For a fluid core, the nutation amplitudes are resonantly amplified by the Free Core Nutation (FCN), a normal mode expressing a slight relative rotation of the core with respect to the mantle. Since the eigenfrequency and the resonance strength of the FCN depend on the mean equatorial moments of inertia of the fluid core and the mantle, on the polar flattenings of the whole planet and of the core, and on deformational properties of the core, measurements of the nutation amplitudes can determine these interior quantities, which are otherwise not directly accessible. Information on the atmosphere can also be obtained because angular momentum exchanges between the atmosphere and the planet modify the planet's rotation.

New Mars Rotation and Orientation Model

In order to correctly interpret the extremely accurate RISE data, we developed a new Mars rotation model. The new model includes hitherto neglected quadratic terms in the three rotation angles, nutation terms at periods related to the orbital motion of Phobos and Deimos, updated relativistic corrections, and an extra set of annual amplitudes in the spin angle to fit a slope observed in the Doppler residuals in the early part of the mission. This slope in the residuals could be due to the decay of the global dust storm that occurred a few months before the InSight landing, which temporarily sped up the planet's spin. Our estimates of those annual amplitudes represent a monotonically decreasing contribution to the spin angle over the first ~150 days of the RISE mission, which might be due to the temporary post-dust-storm deceleration in the rotation of Mars.

Doppler Data

Besides nutation and changes in the spin, the Doppler data also depend on the precession of Mars. To be able to decorrelate the precession rate and the orientation of the spin axis at epoch, we consider Viking data in addition to 30 months of RISE tracking data. The measurement accuracy of RISE (~1.1 mHz noise for data integrated over 60s) is four times better than that of Viking (~4.5 mHz@60s), mainly due to the unknown effects of the interplanetary medium, ionosphere and neutral atmosphere of Mars on the lower frequency S-band Viking data.

Mars Rotation and Orientation Estimates

A long set of data is needed to obtain stable and accurate results. The estimated rotation and orientation parameters converge after 600 days of operations (Figure 19). Our precession rate estimate, $\dot{\psi}$=-7598.1 ± 2.2 mas/year (Figure 19b), converges first, favoured by the combination of Viking and RISE data.

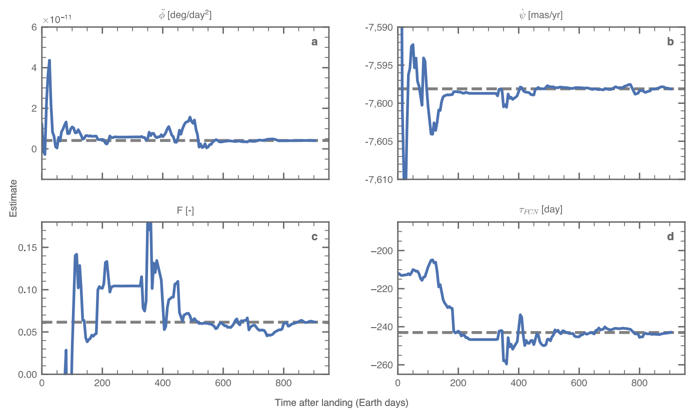


Figure 19: Main rotation parameters estimates. Converging solutions of the quadratic rotation coefficient (a), precession rate (b), core amplification factor (c), and FCN period (d) as a function of time after InSight landing. Horizontal lines are the preferred solutions of this study. Shaded regions are formal uncertainties (1σ).

We detected for the first time the small nutation motions (≤40 cm) of the lander in inertial space due to the effect of the Martian liquid core and estimated the period of the FCN, τ_{FCN}= 2π/ω_{FCN}= -243 ± 3.3 days, and the resonance strength, F=0.0615 ± 0.007 (Figure 19c and d). We also measured a secular trend in the Martian rotation rate ($\ddot{\phi}$=4.11 10^{-12} ±9.1 10^{-13} deg/day^2, see Figure 19a) that has never been observed before. It corresponds to a rotational acceleration of 4.0 ± 0.9 mas/year^2 and could be the expression of a long-term trend in the internal dynamics of Mars or in its atmosphere and ice caps.

Constraints on the Mars interior structure from radioscience

New constraints on the core and mantle of Mars have been derived from the nutation and precession estimates, which required the development of detailed interior structure models that agree with the crustal structure inferred from seismic data.

Since the estimated resonance strength F differs from zero at more than 8σ, the core beneath the solid mantle must be liquid. This independently confirms previous inferences from tidal measurements and seismic observations. From F we determined the equatorial moment of inertia and the radius of the core (Figure 20b). The core radius R_c=1835±55 km agrees well with previous results based on geodesy data and reflected seismic waves from the core-mantle boundary. The FCN period indicates a density jump of 1690-2110 kg/m3 at the core-mantle boundary, and the size of the core radius implies a mean density of 5955-6290 kg/m3, requiring a larger amount of light elements alloyed with iron in the core than in the Earth's core. The FCN period indicates that the core-mantle boundary has a shape close to that expected for a planet in hydrostatic equilibrium. Since the surface and crust of Mars are not in hydrostatic equilibrium, we identified plausible processes that can explain the flattening of the core. The simplest model matching the surface flattening consists in assuming two mass-sheet anomalies, one associated with the surface topography and another emplaced deeper in the lithosphere. We also constructed models with three mass anomalies. All models have one anomaly at the surface and a second at either the bottom of the lithosphere or the Moho. The model with three anomalies has a third load at the bottom of the mantle. The nutation parameters are not compatible with a load at the Moho only.

This research is published in the journal Nature (Le Maistre et al., 2023).

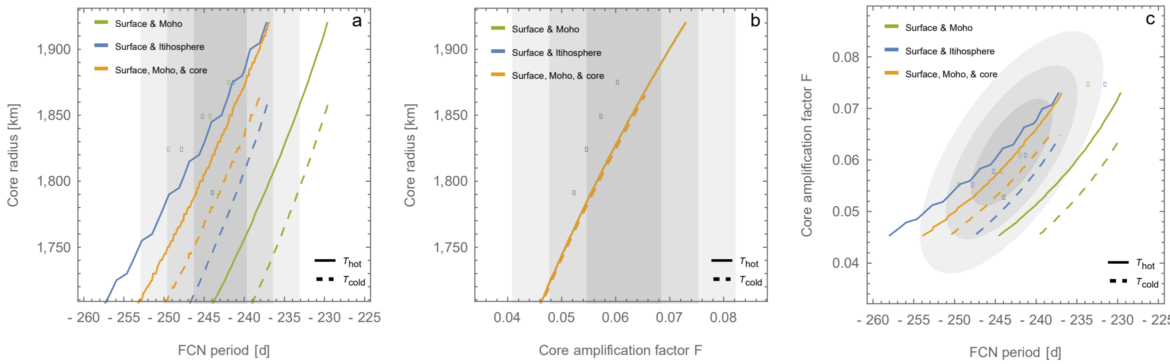


Figure 20: Interpretation of nutation parameters in terms of interior structure. (a) Core radius versus τ_{FCN}, (b) core radius versus F, and (c) correlation between τ_{FCN} and F, for models based on a recent mantle composition (Yoshizaki and McDonough 2020), coloured areas), and models with a stable magma layer at the bottom of the mantle (circles). Colours differentiate models with one internal load at the Moho (green) or at the bottom of the lithosphere (blue), or with two internal loads located at the Moho and at the bottom of the mantle (orange). Blue and green lines are hidden behind orange lines in (b). All models include a surface load associated with the shape of Mars. Solid (dashed) lines represent the hot (cold) end-member mantle temperature model. Grey shaded areas represent 1σ, 2σ, and 3σ.

Seismic results

Seismic detection of a deep mantle discontinuity within Mars

At a depth of about 400 km in the mantle of the Earth, olivine, one of the most abundant minerals in the upper mantle, undergoes a phase transition into its high-pressure polymorphs wadsleyite and ringwoodite. These three minerals have the same chemical composition but a different crystal structure. Since the chemical composition of the Earth's mantle is known, and the elastic properties of upper mantle minerals well studied, knowledge of the transition depth or pressure allows to determine the temperature inside the mantle at that depth. This temperature together with the temperature estimate at the inner-core outer-core boundary is anchor points to determine the current thermal state of the Earth, which provides important information about the Earth's long-term evolution.

Recently, evidence of triplicated arrivals in seismic data collected by the seismometer on the InSight Mission to Mars has enabled to determine the depth of the mantle transition zone in Mars. Triplication off the wave field into a direct, reflected, and transmitted phases, occurs when the wave encounters an abrupt increase in speed, like at the location of a phase transition. The depth of the phase transition is located at a pressure that is comparable to that occurring in the Earth's mantle at a depth of 400 km, but since Mars is smaller and less massive, it is about 600 km deeper. Based on the acquired seismic data, extensive thermodynamic modelling has been done at the Royal Observatory of Belgium to study the effect of the mantle composition and temperature on the depth of the transition zone depth (Figure 21).

Based on these results the temperature at the depth of the transition inside the mantle has been determined. It indicates that Mars is colder relative to the models deduced from geophysical data prior to the InSight mission, but in good agreement with temperature estimates deduced from the chemical analysis of volcanic surface rocks of Amazonian age. Knowledge about the present thermal state of Mars is a fundamental ingredient for our understanding of its thermal evolution. The article relating to this study has been published in PNAS (Huang et al. 2022).

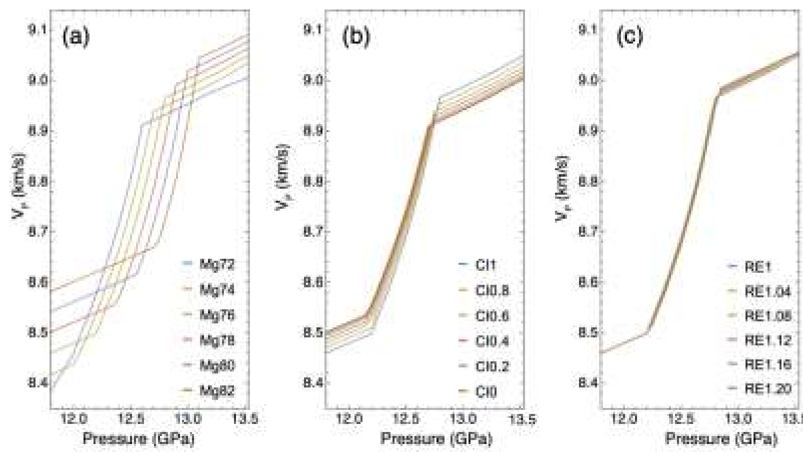


Figure 21: Effects of bulk composition on the transition depth: (a) the Mg# (the atomic ratio Mg/(Mg + Fe) × 100), (b) Mg/Si ratio varied from 1.03 for CI1 to 0.96 for CI0, (c) refractory elements varied between RE=1 and RE=1.20, where RE is the relative enrichment of (Al, Ca) compared to (Si, Mg) and Chondrites. In panel (a) the Mg/Si ratio was kept at CI1 and the refractory elements at RE=1. In panel (b) the Mg# is set to 76 and the refractory elements at RE=1. When varying the refractory elements in panel (c), the Mg# was set to 76 and the Mg/Si ratio was kept at CI1.

Marsquake Locations and 1-D Seismic Models for Mars from InSight Data

The continuous monitoring of the seismic activity of Mars by the InSight seismometer in 2022 has allowed detecting 17 high quality quakes that occurred far enough from the station to sample a sizable section of the mantle of Mars. Although, the number of quakes is far too low to directly determine precisely the velocity and density structure of the deep interior, important and new information about the structure can nevertheless be obtained by supplementing the seismic data with the geodesy data (mass, moment of inertia, tides) and using assumptions about the bulk composition of Mars. This approach requires the usage of parameterised global models that relates internal temperature, bulk composition, and depth of the main reservoirs (crust, mantle, and core) to the seismic and geodesy observations. By using an inverse method the most likely temperature and main reservoir depths, as well as the velocity structure of the crust can be inferred. Since the location of occurrence of the quakes is not known, their location and focal depth are estimated simultaneously with the interior structure parameters.

The study found that the majority of the quakes occurred at depths shallower than 40 km, well within the crust, and mostly located in the Cerberus Fossae region, directly supporting its present-day tectonic active state. We found evidence of a significant velocity jump between the upper and lower crust, which can be attributed to the depth of transition between intrusive and extrusive rocks. Both types of rocks are formed from cooling and solidifying magma, within the crust (intrusive) or on the surface (extrusive). The interior structure models that agree best with the seismic data require that the lithosphere be more than 540 km thick and that the mantle temperature is at the upper end of pre-mission assessments deduced from 3D thermal evolution studies. This temperature is more than 100 K above that inferred from the determination of the mantle transition, hinting at the likely more local character of the latter. Finally, the estimated core radius is in good agreement with previous estimates based on smaller set of seismic events and previous estimates obtained from measuring tides. The study was led by M. Drilleau and has been published in Journal of Geophysical Research in 2022.

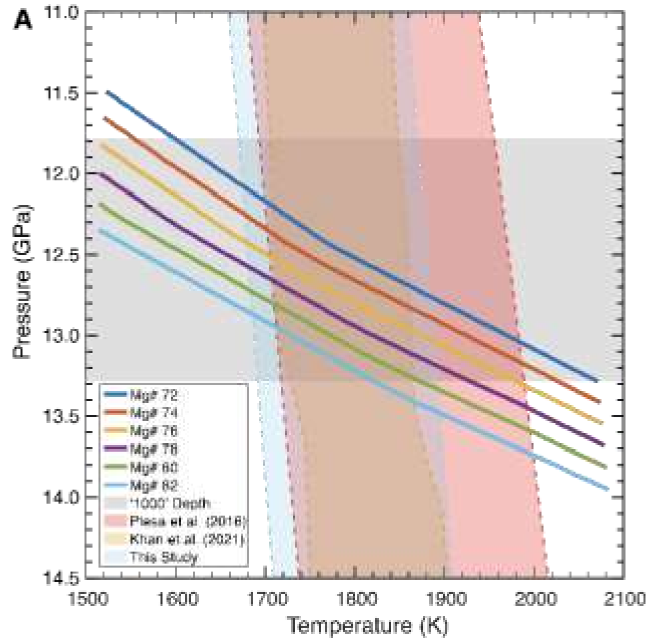


Figure 22: Depth (pressure) of post-olivine transitions as a function of temperature for different assumptions about the mantle composition (coloured lines). The grey shaded area represents the pressure range of the 1000 km deep mantle transition zone. The coloured shaded regions represent pre-InSight mission temperature ranges and the result of this study.

Atmospheric science results

Spectral analysis of the Martian atmospheric turbulence: InSight observations

The dynamics of the lowermost part of the Martian atmosphere, the planetary boundary layer, affects the surface-atmosphere exchange processes on Mars, including the Martian dust cycle, which leads to seasonal and inter-annual variations. Turbulent mixing in the boundary layer drives the transport of momentum, heat, and volatiles between a planet's surface and its atmosphere. To better understand the Martian near-surface meteorology and the atmospheric processes affecting it, boundary-layer turbulence needs to be investigated in depth through observations.

Atmospheric turbulence manifests itself by rapid fluctuations in atmospheric quantities with time scales from seconds to minutes. Several landers and rovers operated on Mars, but only Viking, Pathfinder, Phoenix, Mars Science Laboratory (MSL), and InSight provided in situ meteorological data. Only the InSight lander could detect turbulent fluctuations continuously up to a pressure sampling frequency above 1 Hz and up to 10 Hz. Its long temporal coverage of pressure also allowed us to investigate seasonal variations caused by the Martian dust cycle. We quantified the turbulence energy at different turbulent scales, corresponding to different frequency bands. Large-scale eddies are represented in the lower frequency bands and smaller eddies fall in the high frequency zone.

We investigated the spectral behaviour of turbulence over a wide range of diurnal and seasonal conditions. One of the important findings of our study was related to the effect of gravity waves on the boundary-layer turbulence (see Figure 23). Our data analysis shows that gravity waves can increase the energy contained in large-scale turbulent eddies (with time scales of 500 – 1000 s – approximately 2.5 – 10 km of length scales, corresponding to mesoscale forcing) by up to an order of magnitude. Our results showed that mesoscale forcings can initiate strong turbulence during night time. Our research is published in

Geophysical Research Letters (Temel et al. 2022). Important implications of nighttime turbulence on the dust cycle of Mars are studied in a follow-up work (Temel et al. 2023).

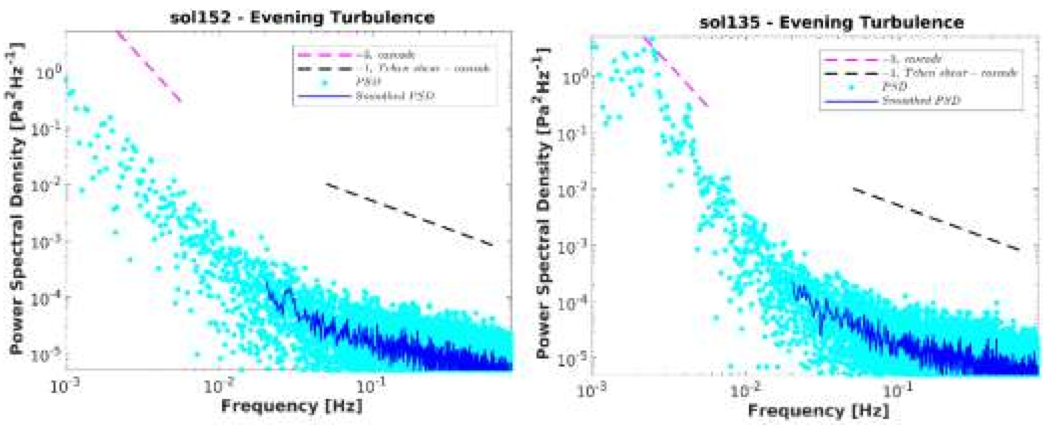


Figure 23: Energy cascade of turbulence obtained by performing spectral analysis to pressure observations for evening conditions without (left panel) and with (right panel) the presence of a gravity wave.

Acknowledgments

The planetary research described above received important support from the PRODEX (Program for the Development of Scientific Experiments) program managed by the European Space Agency in collaboration with the Belgian Federal Science Policy Office, and from FWO.

Solar Physics

FARSUN: Findability and Accessibility of Historical (1610-1980) Raw Sunspot Numbers

The sunspot record is the primary means by which the solar variability over the last 400 years is known and constitutes a benchmark in solar/stellar variability studies and especially the Earth climate. While this record has recently been improved via new or updated observations, data, and methodologies, these improvements need now to be made accessible to the many researchers and users outside of the sunspot community.

At the beginning of 2022, a team from the department of Solar Physics led by L. Lefèvre from the World Data Center SILSO (WDC-SILSO) submitted a project aimed to gather and make FAIR all available raw historical sunspot number data. It was selected in July 2022 and started officially in March 2023.

FARSUN will make the raw historical sunspot data [1610-1980] of national and international origin, on which the World Data Center SILSO deploys its expertise, Findable and Accessible for all users. The project gathers, interprets and valorises the data, where the latter includes data pre-processing, quality assessment and standardisation, as well as to advocate these data to end users. A detailed statistical study will provide quality criteria for these historical data, and the most pertinent criteria will be included in metadata describing the dataset.

This project extends across multiple fields through its network of participants:

1. the WDC SILSO expertise as curator of the International Sunspot Number
2. the statistical expertise from the Université catholique de Louvain, the Université libre de Bruxelles and the Université d'Orléans,
3. the expertise on historical datasets from partners at the University of Extremadura, at the Leibniz-Institut für Astrophysik Potsdam and at the University of Nagoya,
4. Virtual Observatory (VO) expertise from Observatoire de Paris,
5. the time-series expertise from our colleague from the University of Colorado's LASP (US)
6. solar modelling expertise from the Université de Montréal
7. expertise in optical characters recognition from a team of the University of Innsbruck (Transkribus).

The Transkribus tool will help with a novel aspect of the project: exploiting tables of numbers of sunspots and groups observations compiled by the Zurich team from 1945 to 1979. These observations were mentioned in the original Zurich Journals created by Pr. Rudolf Wolf, the Mittheilungen, but not included and remained inaccessible for a long time. Following their recent digitisation at the ETH Zurich, they are now available through e-manuscripts. An example is shown in Figure 24 for observations from 1949 from a station in the Czech Republic.

Over the period 1945 to 1979 there are about 2000 tables to digitise (i.e. transform into machine-readable tables) and the Transkribus tool has developed the capacity to learn from the first character extractions in order to minimise extraction time and maximise efficiency.

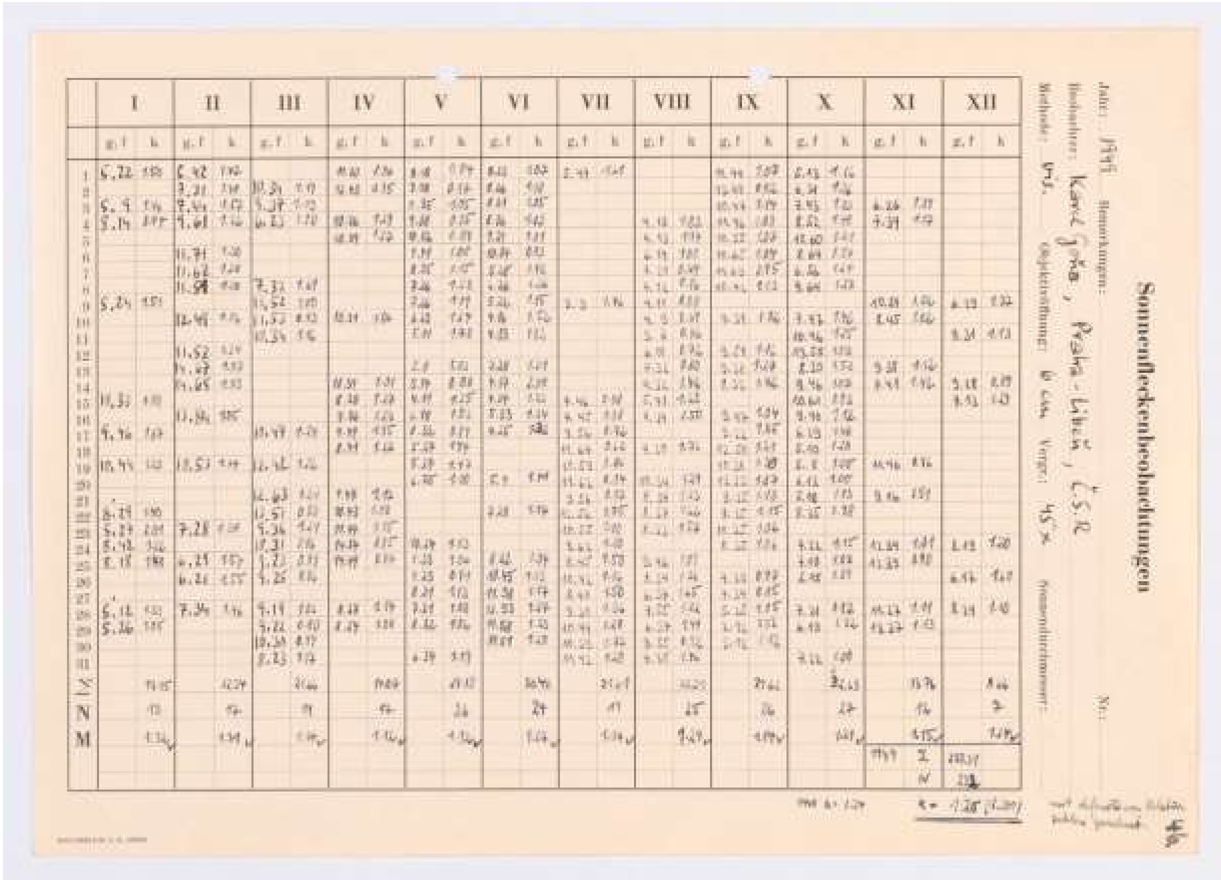


Figure 24: Table of observations from the Czech Republic in 1949.

The output of this project will be a compilation of historical sunspot numbers that will be made available via standard VOtools defined by the International Virtual Observatory Alliance (IVOA), and more specifically via an EPN-TAP (Europlanet-Table Access Protocol) service. This will allow this catalogue to be Findable (via the IVOA Registry) and Accessible by query from a variety of TAP clients. In addition, the standardisation of this VO tool allows other tools (graphical viewers, editors, etc.) to easily access the data, making them Interoperable while the rich catalogue metadata allows the data to be Reusable, i.e. the data will be FAIR-compliant.

Making these validated historical sunspot data collections FAIR will allow solar physicists, Earth-climate modellers, experts in statistics, or anyone with a keen interest in solar variability, to analyse this unique natural record, increase awareness of the public of the effects of solar variability on Earth and thus feed future science in the service of society.

Centennial TSI Variation

A variation of the solar energy received by the earth – quantified by the so-called Total Solar Irradiance (TSI) – is a radiative forcing for climate changes on earth. Since the 1976 Science paper[6] by J. Eddy, solar-climate research has been dominated by the paradigm that solar activity and TSI have been slowly increasing since the Maunder Minimum – extending from about 1645 to 1715 – and the present, which was believed to be a Modern Solar Maximum. If this paradigm were valid, over the last 50 years, when most of the global warming has occurred, this warming would be partly due to anthropogenic greenhouse gas warming, and partly due to natural solar warming.

However, evidence has been accumulating against the 'Modern Solar Maximum paradigm'. Based on this evidence, in 2022 researchers from ORB-KSB, VUB and LATMOS have published a new reconstruction of the centennial TSI variation from 1700 to 2020. This new centennial TSI reconstruction is nothing less than a paradigm shift compared to the 'Modern Solar Maximum paradigm'. Following the TSI reconstruction, the TSI did not gradually increase over the last 320 years, but rather varied with a long-term periodicity of 105 years, and currently we are near the minimum of this 105-year variation. Therefore, over the last 50 years, the sun did not contribute to global warming, but rather tried to cool the earth, partly counteracting greenhouse gas warming. Since we are near the minimum of the 105-year variation, we can expect a trend reversal and for the next 50 years we can expect that the sun will contribute to global warming, making it more difficult for mankind to reach the goals of the Paris Climate Agreement, in order to avoid catastrophic climate change.

Detailed Explanation

In 1612 Galileo Galilei made the first telescope observations of the surface of the Sun, and noticed the existence of small dark spots on the sun, now called sunspots. The observation of sunspots has been continued from the 17th century to the present, and can be considered as the longest running scientific experiment ever. Since 1981, the ORB-KSB hosts the World Data Center for the collection and analysis of sunspot observations. Continuous daily observations are available from 1700 to the present. From these observations, we know that the solar activity – measured by the number of sunspots – varies with an 11-year cycle, and that the amplitude of the cycle is variable. From joint sunspot and solar magnetogram observations, we also know that sunspots correspond to regions of strong magnetic fields on the solar surface.

In 2015, following a series of international workshops under the leadership of ORB-KSB, a revision of the sunspot number time series, was published. The major change of the revised time series (V2), compared to the original time series (V1), is the correction of a discontinuity of the order of 20 % around 1947. In the revised time series, a 'Modern Grand Maximum' no longer appears.

Total Solar Irradiance is continuously monitored with space radiometers since 1978. The occurrence of a dark sunspot causes an instantaneous decrease of the TSI. A sunspot is small and has a relatively short lifetime, of the order of weeks to months. The sunspot decays into large and long-lived regions – with a lifetime of months to years –, which are slightly brighter than the solar background. These regions are called facula, and they cause a long-term increase of the TSI. At the annual mean level, the facular TSI

6 Eddy, J.A., 1976. The Maunder Minimum: The reign of Louis XIV appears to have been a time of real anomaly in the behaviour of the sun. Science, 192(4245), pp.1189-1202.

increase is stronger than the sunspot TSI decrease, and there is a strong positive correlation between TSI, facula and sunspots. Using the space age TSI observations, it is possible to calibrate the relation between annual mean TSI and annual mean sunspot number, and reconstruct the TSI backwards in time before the space age thanks to the long-term sunspot observations. The results are shown in the figure below, where the orange curve is the annual mean TSI observed from space, and the purple curve is the reconstructed TSI based on the long-term sunspot observations.

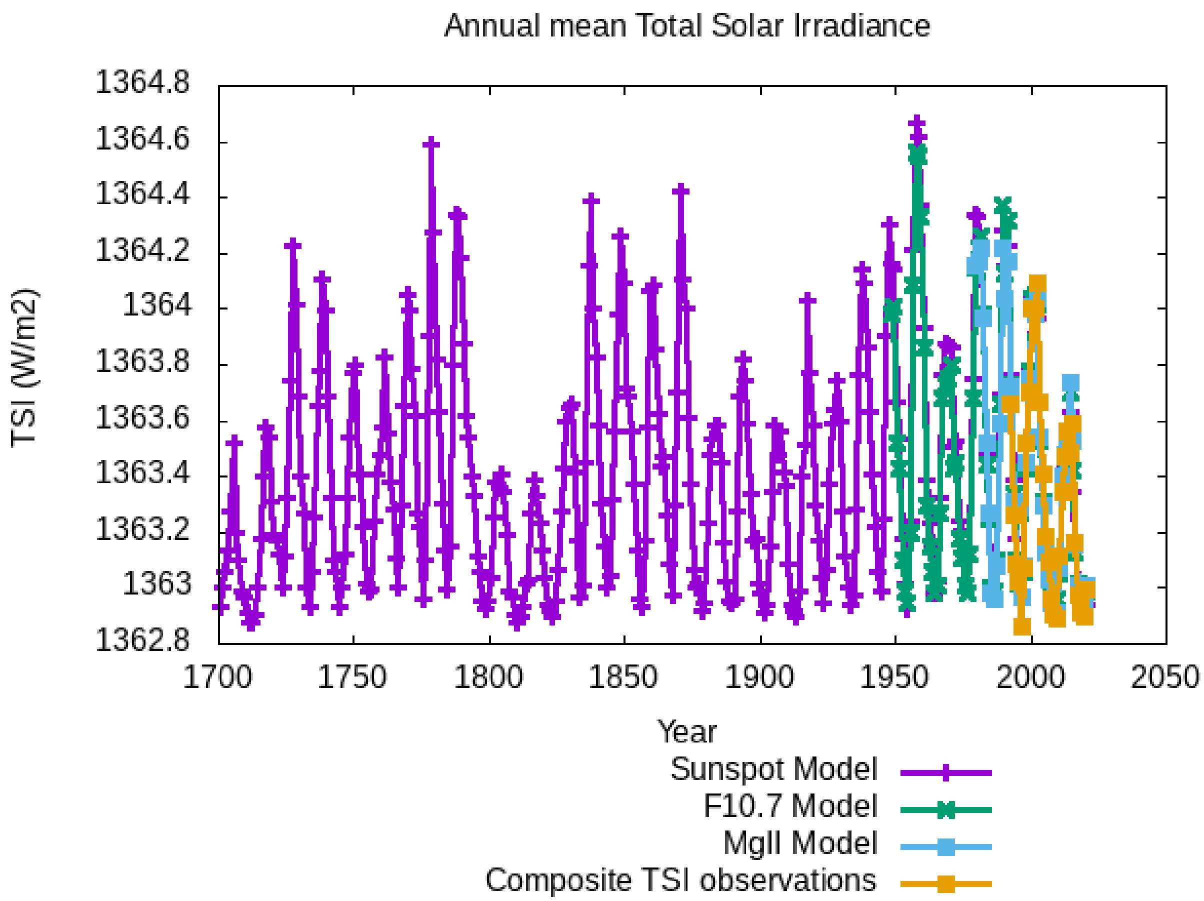


Figure 25: Orange curve: composite TSI space observations. Purple curve: backward TSI reconstruction based on sunspot observations.

More details can be found in the paper: Dewitte, S., Cornelis, J. and Meftah, M., 2022. Centennial total solar irradiance variation. Remote Sensing, 14(5), p.1072.

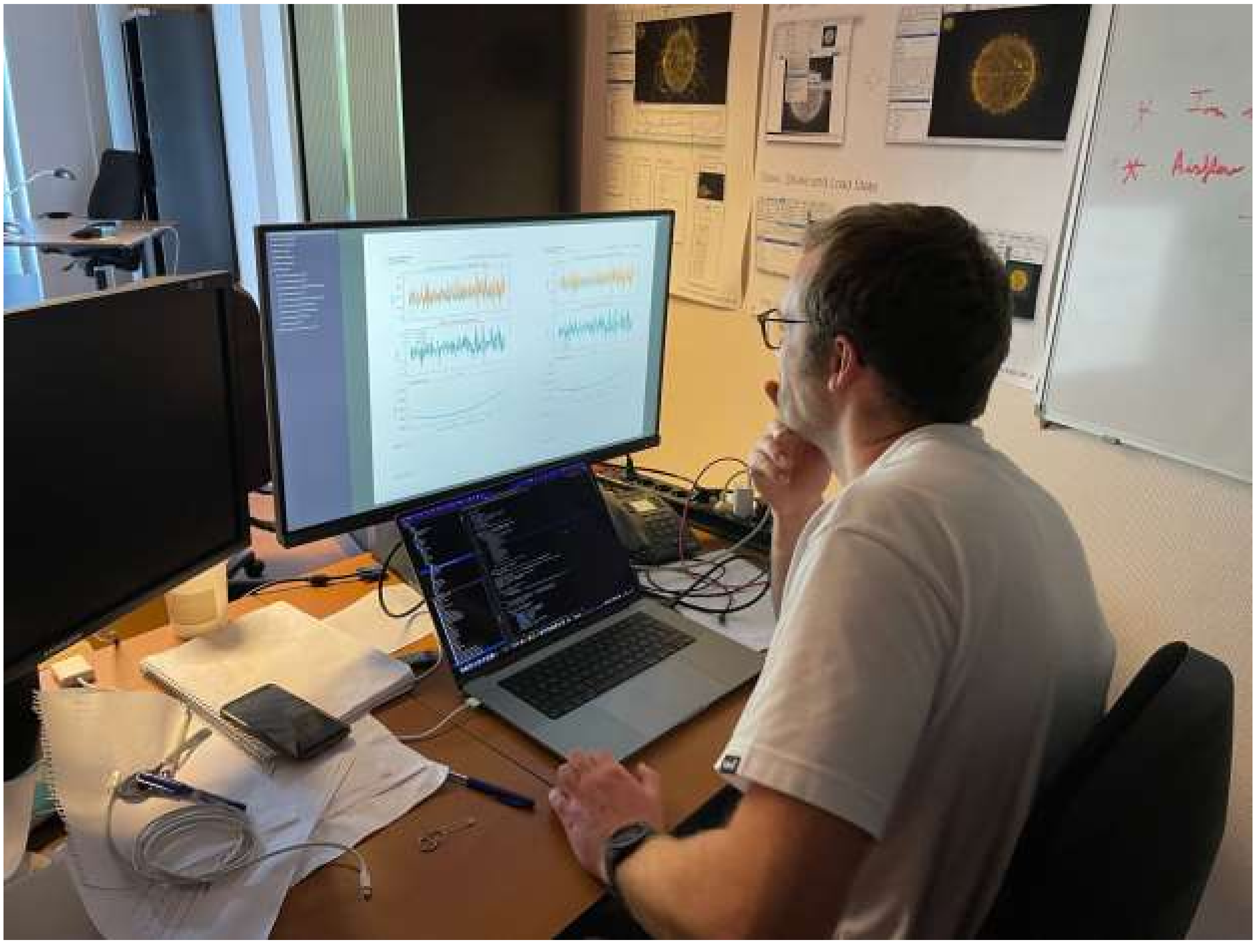
Successful Closure of the Flight Acceptance Review of the Science Operations Centre for PROBA-3/ASPIICS

PROBA-3 is the next mission in the PROBA (PRoject for On-Board Autonomy) line of small satellites developed by the European Space Agency (ESA). It is primarily a mission dedicated to the in-flight demonstration of technologies for precise formation flying. For PROBA-3, this means that its two small spacecraft will be flying together in formation, along a highly elliptical orbit around the Earth. The formation of two spacecrafts will produce a giant solar coronagraph called ASPIICS, which stands for the Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun.

A coronagraph is a telescope that can observe the solar corona, the tenuous outer atmosphere of the Sun that is usually seen only under total solar eclipse conditions. During a total eclipse, the Moon completely covers the bright disc of the Sun, allowing the dim corona to be seen. The ASPIICS coronagraph will consist of two PROBA-3 spacecrafts flying in formation, with one spacecraft carrying the optical telescope, and the second spacecraft carrying the circular occulter that plays the role of the Moon. The inter-spacecraft distance of around 145 metres will allow observing the corona close to the solar limb with unprecedentedly low parasitic light coming from the bright solar disc. Such conditions will be similar to those encountered during a total eclipse. In order to accomplish this task, the two spacecraft have to be aligned with the precision of a few millimetres.

PROBA-3, to be launched in September 2024, will not only demonstrate advanced technologies but is also a mission in the Science Programme of ESA. The scientific objectives of ASPIICS include the investigation of structure and dynamics of the quiescent solar corona and of coronal mass ejections (CMEs), huge eruptions of plasma and magnetic fields that may arrive at the Earth and produce geomagnetic storms.

Since 2017, the Solar Influences Data Analysis Center (SIDC) of the ORB-KSB has been developing the Science Operations Centre (SOC) of ASPIICS. After the mission launch, the SOC will be tasked with creating observation programs for the desired science operations of ASPIICS, sending them to the PROBA-3 Mission Operations Centre in Redu (Belgium), as well as receiving and processing the acquired coronal images. The SOC is developed by a team of software engineers and scientists at SIDC, which has been supported by the SOC international partners from Germany, Italy, Poland, and Romania. An important aspect of the SOC is that it has to take into account the particular nature of this innovative mission, namely the presence of two precisely aligned spacecraft. The SOC will have to calculate the influence of dynamically changing positions and orientations of the two spacecraft on the resulting coronal images.



A committee consisting of experts in software development, space mission operations and science was appointed by ESA to follow the SOC development and to review it at regular intervals. The Flight Acceptance Review was the last in the series of reviews. It had to certify that the SOC is built following the predefined scientific and technical requirements. The committee has thoroughly inspected the SOC software and associated documentation. In April 2022, it concluded that the SOC satisfies all the requirements and the Flight Acceptance Review of the ASPIICS SOC is successfully closed.

Scale Transfer in 1849: Heinrich Schwabe to Rudolf Wolf

The Sun is a fascinating and complex star that scientists have been studying for centuries. One of the ways they measure its activity is by counting sunspots. Scientists have been tracking the number of sunspots over time to understand how the Sun behaves and maintained the records in the form of a series called International Sunspot Number (ISN). ISN is a widely used measure of solar activity that dates back to the 1600s. It is a count of the number of sunspots on the visible disk of the Sun, and it is used to track the 11-year solar cycle and its variability over longer periods. However, the historical record of sunspot observations is far from complete, with gaps and inconsistencies in the data that make it difficult to construct a reliable long-term record of solar activity. To overcome these limitations, scientists have developed methods to reconstruct the ISN using raw data counts, which are being recovered from the archives from observers all over the world.

Overall, reconstructions of the ISN provide a valuable tool for understanding the long-term behaviour of the Sun and its impact on Earth's climate and environment. However, uncertainties and limitations in the data mean that caution must be exercised when interpreting the results, and ongoing efforts are needed to improve the accuracy and consistency of the records.

The historical data on sunspot counts has been a challenge to analyse because there have been inconsistencies in the way observations were made and recorded. To overcome this difficulty, Prof. Rudolf Wolf introduced in 1859, a parameter called k-factors to other sunspot observers to bring them to his scale. In other words, he would adjust their observations to fit his own scale. This was a common practice back in the day, and it was essential to ensure that the data was consistent across all observers. Note that Prof. Wolf started doing his own observations from 1849 and started keeping records of his observations in his logbook called the Mittheilungen. Along with his own data, he started collecting sunspot records from various other observers and included them in the Mittheilungen as well. The Royal Observatory of Belgium conducted a mission between 2017 and 2019 to digitise all the data contained in the published Mittheilungen.

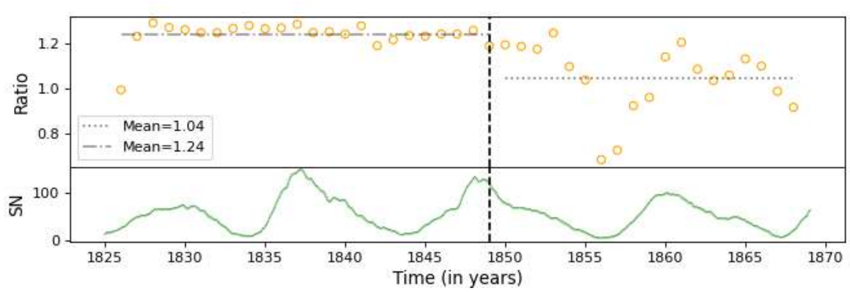


Figure 26: Yearly ratio for ISN versus Schwabe counts with vertical dashed line representing start of Wolf's observation as shown in Leussu et al. (2013).

From 1826 to 1848, Heinrich Schwabe was the primary observer of sunspots, as determined by Rudolf Wolf. In simple words, every observer in that period used to be scaled to Schwabe. However, in 1849, Wolf took over the role of the primary observer, and this shift caused an inconsistency in the Sunspot Number series as can be seen in Figure 26.

In this study, we focused on this specific issue with the International Sunspot Number series. We found that there was a significant jump in the sunspot counts around 1849, which had been a longstanding mystery for researchers. We discovered that this jump was caused by a mistake in the way the data was processed. Specifically, the k-factor, which is a scaling factor used to standardise observations made by different observers, was applied incorrectly to Schwabe's data before 1849.

To address this issue, we carefully examined the available data and conducted statistical analyses to validate the k-factor used by Wolf to scale the observers. We were able to propose a corrected k-factor for Schwabe, which we believe will help to make the sunspot counts more accurate.

Since all other observers were scaled to Schwabe before 1849, we reconstructed the ISN from the period from 1818 to 1848 as seen in Figure 27, using the data from the Mittheilungen but we plan to extend our analysis to other periods in the future. Ultimately, our goal is to reconstruct the sunspot data from raw historical records, which will help scientists to better understand the Sun and its impact on our world.

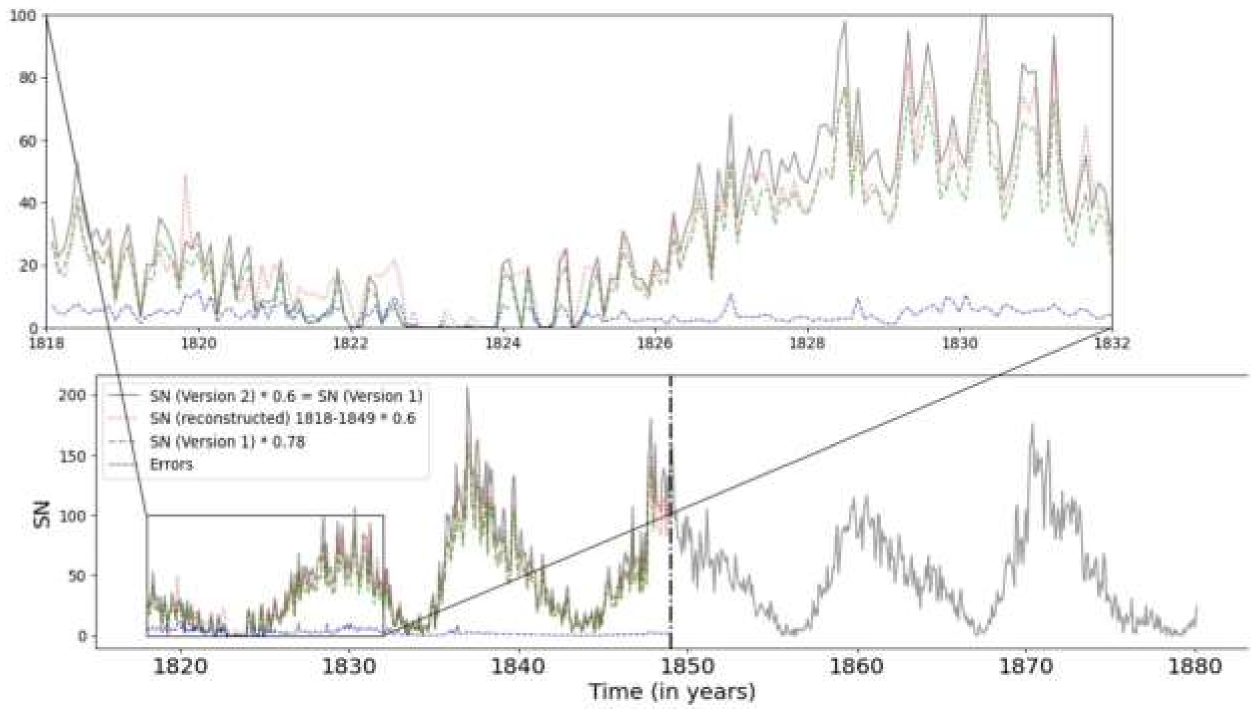


Figure 27: Monthly smoothed SNV1, SNV2, reconstructed SNV1 spanning from 1818 – 1868 and 22% lowered SNV1 from 1818 – 1848. The zoom in the plot is for easy comparisons, with SN in the y-axis and time (in years) in the x-axis.

This study also highlights the importance of meticulous record-keeping, consistency in data collection, and the need for correcting historical data to maintain the accuracy of scientific datasets. It is fascinating to think that a small adjustment made over 170 years ago could affect our understanding of solar activity today. This study, Battacharya et al. 2023 is published in the journal Solar Physics.

Astronomy and Astrophysics

First results from the James Webb Space Telescope

In 2022, infrared images of the Southern Ring Nebula NGC 3132 taken by James Webb Space Telescope (JWST) were released as part of its Early Release Program. The sensitivity and precision of 10 JWST near- and mid-infrared images, taken with the NIRCAM and MIRI instruments respectively, show this planetary nebula in unprecedented detail. It revealed multiple stars at the heart of the Southern Ring and helped to shed light into the underlying history of NGC 3132.

An international team of almost 70 astronomers, led by Orsola De Marco of Macquarie University in Sydney, Australia, and including astronomers of the ORB-KSB, analysed and modelled these most detailed observations of the planetary nebula NGC 3132 to find out how these intricate shapes could have been produced.

The Southern Ring Nebula is a 'planetary nebula' about 2000 light years from earth. It formed when a red giant dying star, similar or somewhat heavier than the Sun, sheds its outer layers into space, exposing its hot and compact nucleus, a white dwarf, which then illuminates the gas and dust expelled before.

Figure 28: NASA's James Webb Space Telescope offers dramatically different views of the Southern Ring Nebula. Each image combines NIRSPEC and MIRI data from three filters. At left, Webb's image of the Southern Ring Nebula highlights the very hot gas that surrounds the two central stars. At right, Webb's image traces the star's scattered molecular outflows that have reached farther into the cosmos. In the image at left, blue and green were assigned to Webb's near-infrared data taken in 1.87 and 4.05 microns (F187N and F405N), and red was assigned to Webb's mid-infrared data taken in 18 microns (F1800W). In the image at right, blue and green were assigned to Webb's near-infrared data taken in 2.12 and 4.7 microns (F212N and F470N), and red was assigned to Webb's mid-infrared data taken in 7.7 microns (F770W). Credits: NASA, ESA, CSA, and O. De Marco (Macquarie University). Image processing: J. DePasquale (STScI).

In the MIRI JWST images two stars are visible. However, the hot white dwarf appears reddish, which indicates the presence of a dust disk around it. The bright blue-white star that can be seen in JWST's images is a main-sequence star orbiting the white dwarf at a radius of over 1200 AU, making this pair a wide binary. This bright blue-white star did not interact with the central system to produce the nebular features, however, its steady, slow orbit around the central white dwarf helped to measure the initial mass of the central star. It was the first time ever that the initial mass of a star of a planetary nebula could be measured with great precision. The team calculated that the central star in NGC 3132 was nearly three times the mass of the Sun before it ejected its layers of gas and dust to form the nebula. Now it is only about 60% the mass of the Sun. Knowing the initial mass is a critical piece of evidence that helped the team reconstruct the scene and model how the shapes in this nebula may have been produced. When the nebula originates from a lone star, these ejecta are generally spherical. However, if the former red giant star interacted gravitationally with a stellar companion during envelope ejection, then one would expect the planetary nebula to contain evidence of these interactions. These signs are seen in departures from spherical symmetry in the shape of the nebula, as well as structures such as rings, arcs, spirals, and jets in the gas. The average size and separation of the arcs seen in the JWST images indicate the presence of a second companion which has orbited the central white dwarf at a radius of about 50 AU. Hence the bright A-star is too far away to be responsible for these features, which implies that there must be a third unseen star in the system and that NGC 3132 contains at least a triple star system. Given the fact that the hypothetical new star is not directly visible in the glare of the dwarf, the authors place an upper limit of 0.2 solar masses on the unseen companion. The disk of hot dust around the central white dwarf also favours the existence of a close binary companion, which would have donated a significant amount of material and angular momentum to form the disk. Sahai et al. 2023 showed that the dust disk is composed of a mixture of carbon and silicate grains which may also have originated from a planetary system around the companion star.

Combining the JWST images with spectroscopic observations from ground-based telescopes of NGC 3132, the authors were able to reconstruct a 3D visualisation of this component of the nebula, as can be seen in Figure 29. In the 3D reconstruction, the shape of this cavity is very clearly not smooth – it is covered in numerous protuberances, which could be due to intermittent jets. If this is the case, these jets are being generated over a huge range of axes – too many for a close binary to cause. This leads the authors to conjecture that the central dwarf is not a member of a close binary, but at least a close triple, which either also escapes detection or perished in an interaction with the giant. While speculation about the nature of the origin of these features still remains, the authors are confident in claiming that the original star system that became NGC 3132 was probably a quartet (or even a quintuple system).

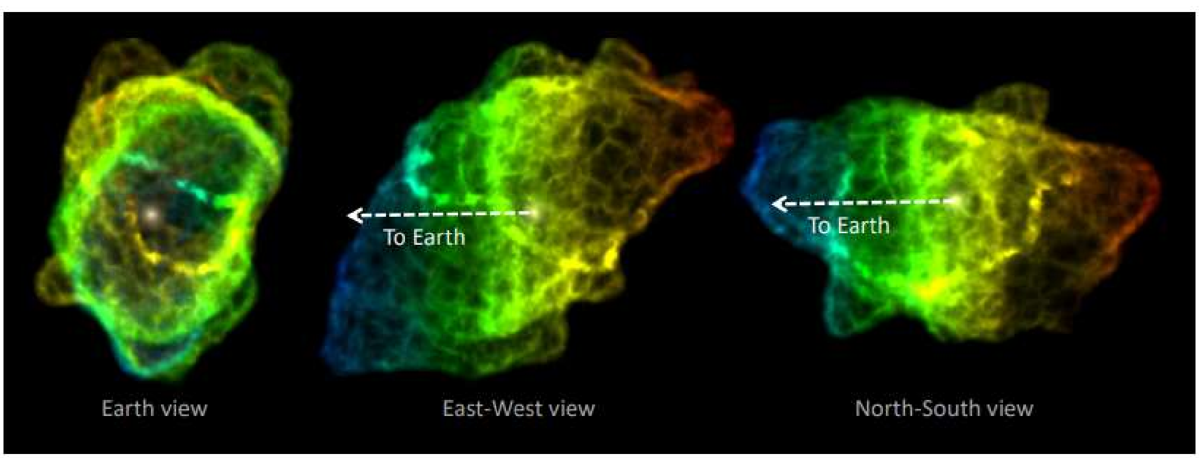


Figure 29: Reconstruction of the ionised cavity of NGC 3132. Colour coding indicates Doppler shift as seen from Earth, with bluer regions approaching the observers and redder regions moving away.

The observed detailed structure in the nebula has been important in constructing the evolution of this multiple-star system. Discoveries like these are only the start in the era of JWST. Understanding which molecules are present, and where they lie throughout the shells of gas and dust will help researchers refine their knowledge of these objects. Just like Hubble Space Telescope in the past, JWST has the potential to revolutionise what we know about the formation and evolution of planetary nebulae and the role of stellar companions in shaping these impressive clouds of gas and dust expelled by dying stars. Astronomers at the ORB-KSB are involved in other studies using JWST instruments and expect more impressive images and results in the coming years.

References

De Marco, O., Akashi, M., Akras, S., Van de Steene, G.C., et al. ,2022, Nature Astronomy, 6, 1421. doi:10.1038/s41550-022-01845-2

Sahai, R., Bujarrabal, V., Quintana-Lacaci, G., Van de Steene, G.C., et al., 2023, Apj, 943, 110. doi:10.3847/1538-4357/aca7ba

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Gaia Data Release 3: Building the Largest and Most Precise 3D Map of the Galaxy

Gaia is a European space mission aimed to create a 3D map of our Galaxy. It measures with an unprecedented precision the sky positions of about 2 billion stars, as well as quasars, galaxies and asteroids several times (8 times a year on average). In order to achieve its goals, the satellite has three instruments on board (Figure 30): an astrometric instrument, a set of complementary low-dispersion spectrophotometers (BP and RP), and a high-dispersion spectrograph (RVS). It was launched in December 2013 to the second Lagrange point (L2), and is mapping since 2014 the Milky Way. By the end of the mission in 2025, it is expected to have acquired about one petabyte of information. To extract, calibrate, and analyse these data, a large (mainly) European team made of scientists and engineers was brought together to form the Data Processing and Analysis Consortium (DPAC). The processing and analysis of the measurements do not only derive the 3D positions of stars in the Milky Way. It also deduces their nature and main characteristics, as well as their proper motions in the sky and their speed relative to the Earth (what we name radial velocity or RV), which combined informs us of how they move through space while orbiting the Milky Way centre. Because of the high precision of its measurements obtained for an unprecedentedly high number of stars, Gaia revolutionises our knowledge of the structure and dynamics of our Galaxy. It is in recognition of all these efforts and major contributions to astronomy, that Gaia and its DPAC have been honoured in November 2022 by the 2023 Berkeley prize awarded by the American Astronomical Society.

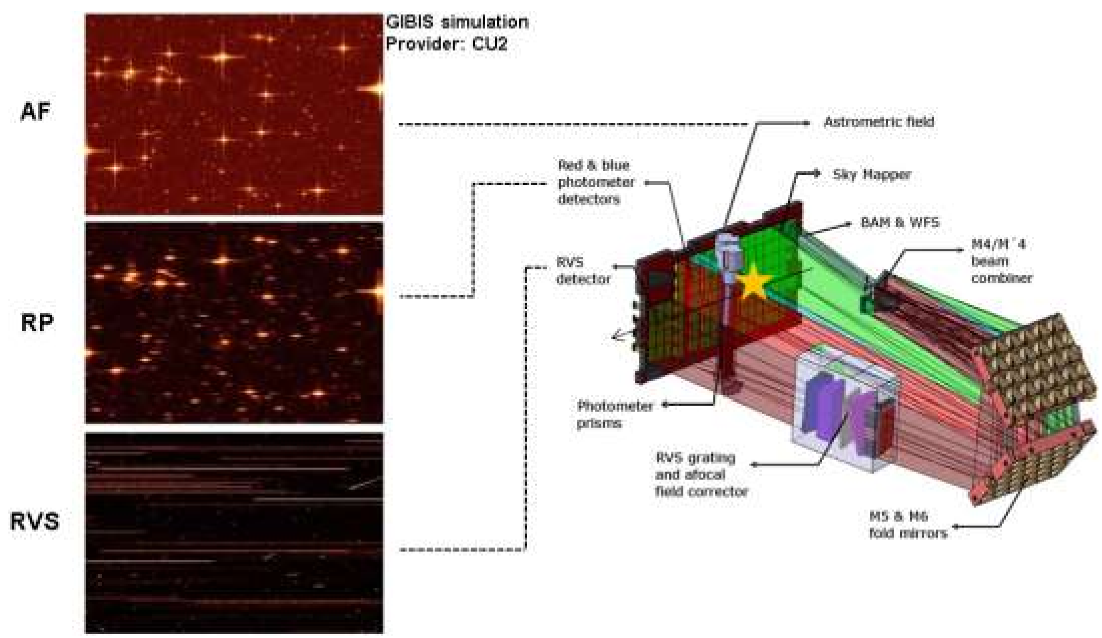


Figure 30: Optical bench of Gaia's payload module (right). Simulations of the images obtained by the three instruments on board are shown on the left. The astrometric field (AF) is used to measure the target position, the Red (RP)/Blue (BP) photometer provides low-resolution spectra used to characterise the object, while the RVS grating produces the high-resolution spectrum analysed to estimate its radial velocity and line-broadening velocity.

Since 2006, and thanks to funding provided by the Belgian Federal Science Policy Office (BELSPO) via the PRODEX Programme of ESA, astrophysicists of the ORB-KSB are actively involved in the DPAC. They directly contribute to the measurement and scientific validation of the radial velocity of stars, the estimation of their astrophysical parameters and characteristics, and to the accurate measurement of the position of asteroids. While the final catalogue of the Gaia mission (Gaia DR5) is expected to be published in 2030, four intermediate Gaia data releases have been planned. The third one (Gaia DR3) took place on 13 June 2022. It includes the results of the ORB-KSB commitment to the project from the beginning of the DPAC. To celebrate it, as well as the contribution from other Belgian institutes, the ORB-KSB organised at its Planetarium a public session, to which the national press was invited. In what follows, we summarise some of the results.

The Radial Velocity of Stars and the Galactic Rotation

The motion of stars through space depends on the rotation of the Galaxy, on its interaction with other galaxies, and on the stars' birth environment. Therefore, its knowledge tells us a lot about the history and evolution of the Milky Way. The component of this motion in the direction of Earth is the radial velocity (RV). To measure its value for a fraction of stars observed by Gaia, the satellite has a high-resolution spectrometer on board: the Radial Velocity Spectrometer (RVS, Figure 30). The RVS covers a wavelength domain that ranges from 845 to 872 nm with a medium resolving power of 11 500. The physical phenomenon allowing the RV measurement is the Doppler effect, as the motion of a star relative to Gaia induces in its RVS spectrum a wavelength shift which is proportional to its speed along the line-of-sight. By measuring the wavelength displacement of each spectral line relative to their laboratory position at rest, the DPAC determines the RV of each star. The combination of this information with its proper motion on the sky and distance provides not only a 3D view of where the star is, but also gives a hint of its future and past locations giving means to study the dynamics of a significant portion of the Milky Way.

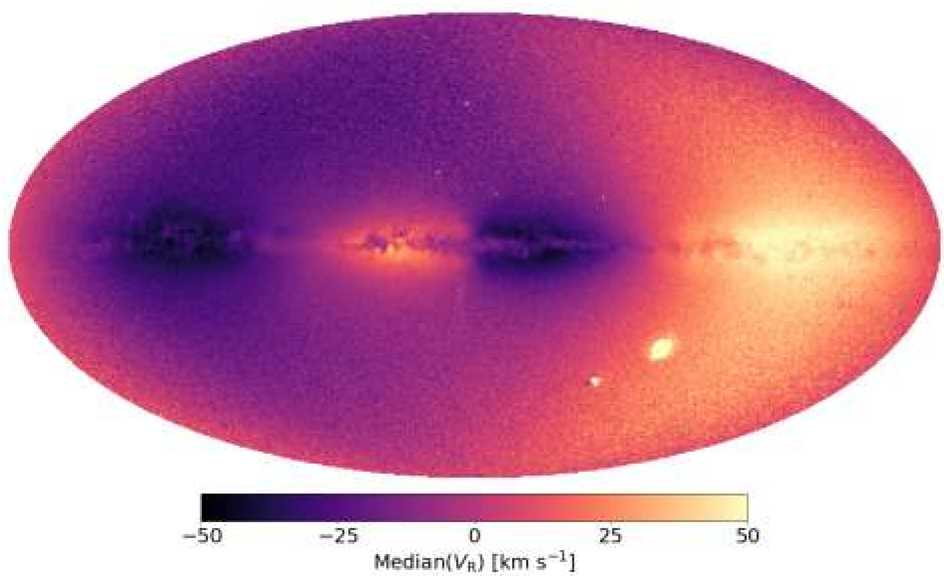


Figure 31: Sky distribution of median radial velocities sampled in ~0.2 square degree bins. The map is a Mollweide projection of the sky in galactic coordinates (l,b). The centre of the image is the Galactic centre, while the galactic longitudes increase to the left (see Katz et al. 2023). The component on the line-of-sight of the Galactic disk rotation is visible through the variation of the median RV alternating from positive (bright areas) to negative (dark areas) values.

In Gaia DR3 the radial velocities of about 33 million stars have been published in the catalogue (Figure 31 shows how they distribute over the sky). In practice, the published RV represents the median of 22 measurements done at different epochs, which allows the detection of variations due, for example, to the presence of stellar companions. It is indeed expected that more than one third of the stars observed by Gaia are members of a multiple system made of two or more stellar components orbiting its centre of mass. In Gaia DR3, about 185 000 such systems have been identified thanks to the RV variations, which represents 45 times more than what could be achieved in the recent days with ground-based spectroscopic surveys.

The Characterisation of Young Stars and the Galactic Spiral Arms

From the advent of spectroscopy 200 years ago, astrophysicists have made great efforts to make a catalogue of stars in ever-greater detail. Since then, stars' colours and spectroscopic line features are used to estimate their astrophysical parameters (effective temperature, surface gravity and chemical composition). These parameters usually suffice to describe the physical conditions in the stellar photospheres, which can be linked to their fundamental parameters (intrinsic luminosity, mass, radius) if combined with their distance from Earth. Therefore, in order to also identify and characterise the stars (as well as any other object that Gaia observes), the satellite has a second spectrograph on board made of two prisms: one observing the blue (BP: Blue Photometer) and red (RP: Red Photometer) part of the visible spectrum of light, from 330 to 1100 nm. The resolving power of this spectrophotometer is much lower than the RVS, but it has the advantage to cover a much larger fraction of their spectral energy distribution (Figure 32), where most stars seen by Gaia radiate most of their light and present many representative spectroscopic features. However, a smaller part of the stars, with effective temperatures larger than 8000 K and spectral types A, B and O, emit most of their radiation at wavelengths shorter than 330 nm. Their Gaia BP/RP and RVS spectra also exhibit much fewer and often broader features, which make them more difficult to analyse, to derive their RVs, and to characterise. Despite the challenge to measure RVs in these younger stars (see Blomme et al. 2023), about half a million have radial velocities published in Gaia DR3 (Figure 33).

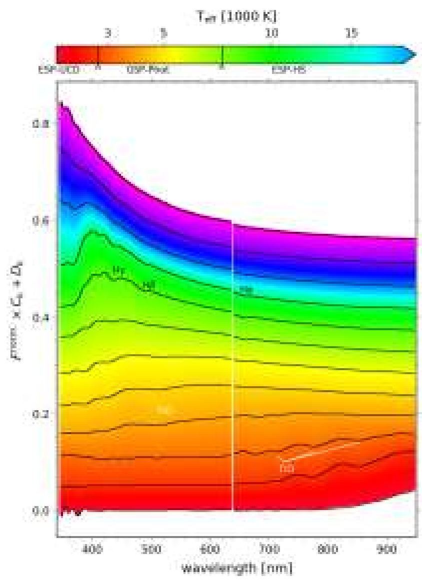


Figure 32: Variation with stellar effective temperature (Teff) of the mean BP and RP spectrum (black) of cooler (low red areas) to hotter (upper purple areas) stars. Source: Fouesneau et al.2023.

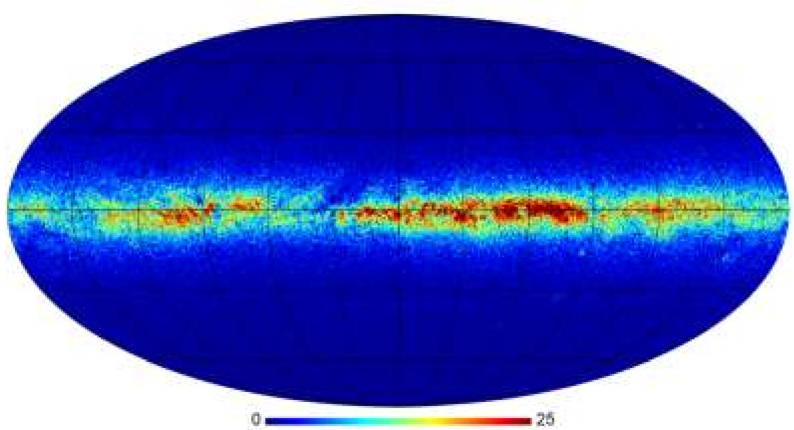


Figure 33: Sky distribution (in galactic coordinates, same projection as in Figure 2) of the approximately half a million hot stars with Gaia DR3 radial velocities. The colour scale gives the number of stars per ~0.2 square degree.

In addition, a specific DPAC software, developed by the ROB Gaia team, is dedicated to the study of 'hot' stars. It aims to identify these among the huge amount of data collected by the satellite and to derive their astrophysical parameters. This led to the publication in the Gaia DR3 of astrophysical parameters for 2 million A-, B- and O-type stars (Figure 34).

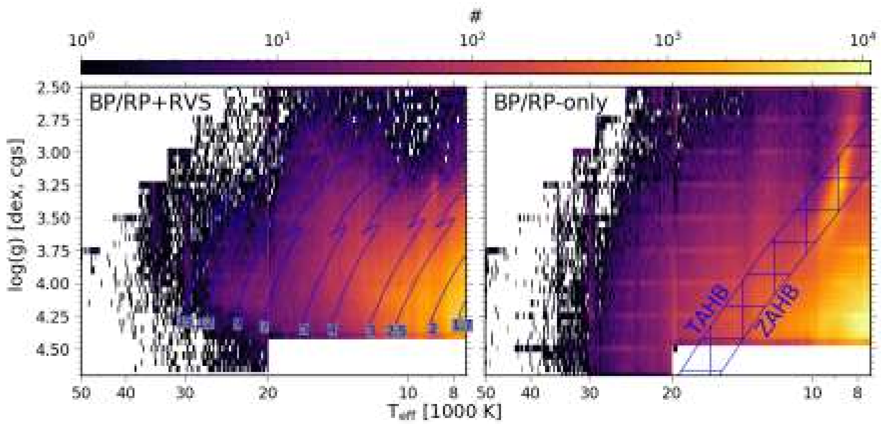


Figure 34: Gaia DR3 surface gravity versus effective temperature of O-, B-and A type stars. The 'hot stars' part of the DPAC pipeline processes the data in two modes: BP/RP + RVS spectra for the brighter targets (left panel) and BP/RP spectra only (right panel) for the fainter ones. Left panel: the blue lines represent the expected evolution in time across the diagram of stars of a given mass from the beginning of the main sequence (lower point in each curve). Right panel: the hatched area identifies the region partly occupied by older lower mass stars burning helium in their cores. Source: Creevey et al. 2023 and Fouesneau et al. 2023.

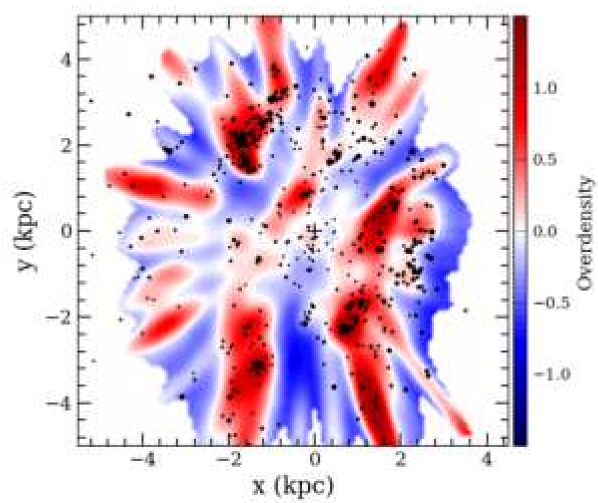


Figure 35: Overdensity map of the Gaia DR3 O- and B-type stars sample over plotted with the positions of the open clusters younger than 63 Myr. The cross indicates the position of the Sun. Source: Drimmel & Gaia Collaboration 2023.

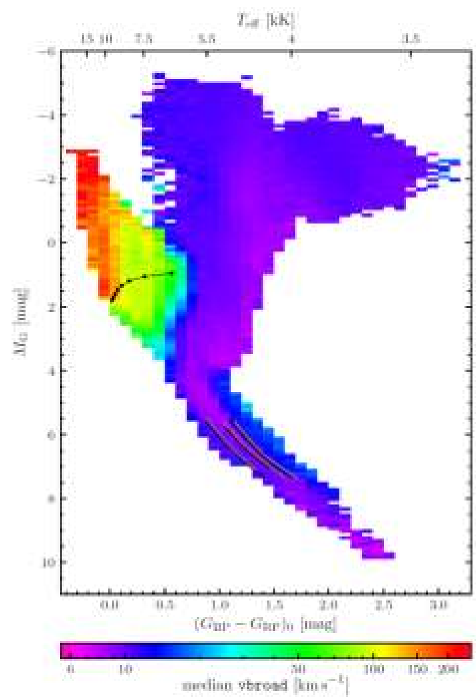


Figure 36: Hertzsprung-Russell diagrams for a subsample of the Gaia DR3 vbroad catalogue. The binning size is 0.1 by 0.1 mag. The colour code follows the median vbroad value (in logarithmic colour scale) per bin. Source: Frémat et al. 2023.

Because their radiation is more intense, hot stars consume more rapidly their energy and evolve faster than cooler objects. They have less time to migrate from their birthplace located in the galactic spiral arms. Therefore, their identification is a key element in the framework of the study of the Milky Way, as the precise knowledge of their distance, position, proper motion and RV allows astronomers to study its outer disk structure and dynamics (see Drimmel & Gaia Collaboration 2023).

Finally, as hot stars are younger than the Sun and have weaker magnetic fields, they usually undergo less or no magnetic braking and are known to be rotating faster. This rapid rotation, which originates during the collapse of the protostellar interstellar cloud and the star's birth, induces, through the differential Doppler effect (one end of the star approaching the observer and the other moving away), a broadening of the spectral lines observed in the RVS. This broadening is proportional to the projected rotation speed of the star (named vbroad) and has been measured for more than 3 million targets, including cool stars. In Figure 36, we show how a subsample distributes across the Hertzprung-Russell (HR) diagram (see Frémat et al. 2023).

Asteroids

Closer to the Sun than the objects we have discussed so far are the asteroids. Accurate astrometry for these small body objects was already present in the Gaia's second data release on April 25, 2018. This was for a small sample of about 15 000 asteroids as a feasibility demonstration. In Gaia DR3, we now have a much larger sample of some 150 000 asteroids with very accurate astrometry. In addition, the observations in the third release span a longer time interval, such that each asteroid has on average more positions. This leads to an impressive 23 million individual astrometric positions of asteroids in the Gaia DR3 catalogue. Since Gaia has a predefined scanning law, one cannot choose when to observe which asteroid. Therefore, the selection of asteroids to include in the third release was mainly driven by the number of observations of each object.

The SSO (Solar System objects) Gaia DPAC group is divided in development units (DUs). Each DU has the task of developing the software for a specific part of the data reduction. The upstream DUs are responsible for the basic treatment leading to accurate astrometry, while downstream DUs deliver derived products, such as orbits, photometry, rotational properties and masses. The ORB-KSB has been highly involved in DU454, the DU responsible for the software to convert coordinates in the focal plane to coordinates in the sky, and this ever since the creation of DPAC in 2006. Apart from doing the conversion of coordinates, an important task of DU454 is the efficient filtering of the bad detections: removing detections that are clearly not asteroids, or detections of poor quality.

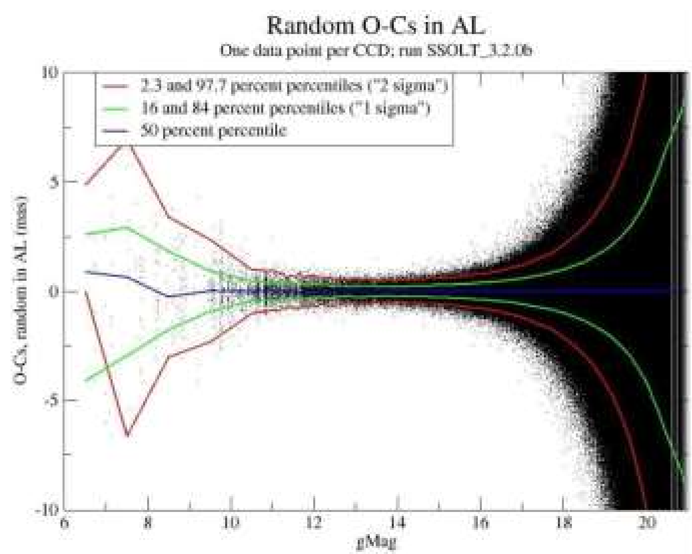


Figure 37: Quality check of the astrometry of asteroids is done by computing for each asteroid an orbit from all the gathered data. The deviations between the positions derived from the orbit and the observed positions will tell us something about the accuracy of the astrometric positions. On the figure, we see that positions are most accurate in the magnitude range 12-16. Fainter asteroids have larger errors in their positions, but also brighter asteroids show larger errors.

The best astrometry is found for objects of intermediate brightness. Bright objects are larger in apparent size, and are no longer point sources, while they suffer from saturation in the image. Therefore fitting a standard point-spread function (PSF) to bright objects is less successful. On the other hand, faint objects have a lower signal-to-noise ratio and therefore the fitting of PSF will be less accurate. However, in the magnitude range of 12-16, individual Gaia positions of asteroids reach an unprecedented accuracy of better than one milliarcsecond.

This very high positional accuracy has already had some spin-offs. Using the Gaia data one was able to find the signature of the motion of the photocentre of an asteroid due to its satellite. Moreover, observers of stellar occultations by asteroids greatly benefit from the Gaia data. Not only are the ephemerides of the asteroids so much more accurate, also the positions of the target stars are so much better known, so that the uncertainty of the shadow paths on Earth is reduced to a few kilometres, whereas a few tens of years ago this was still hundreds of kilometres, sometimes thousands of kilometres. This led in the past years to an exponential increase in the number of positive observations of stellar occultations by asteroids, with observers who were at the right place to observe the predicted event.

The third data release is not yet the end. In the next data releases, we expect even more asteroids with more observations for each asteroid. With the use of PSFs especially adapted to the motion and the shape of the asteroids, we expect even better orbits and better ephemerides.

Outreach and Communication

The year 2022 is also full of outreach activities, notably because of the 2022 Open Days, a big event requiring a full year of preparation, but also for other outreach events (co-)organized by the Observatory or by colleagues from the Observatory. The high activity of the ORB-KSB in 2022 is also reflected in the published news on the ORB-KSB's website (25 topics in 2022 compared to a mean of 14.6 publications per year between 2017 and 2021).

Open Days 2022

The Royal Observatory of Belgium (ORB-KSB), the Royal Meteorological Institute (IRM-KMI) and the Royal Belgian Institute for Space Aeronomy (IASB-BIRA), in collaboration with the Royal Academia of Overseas Sciences, opened their doors on 24–25 September 2022.

Almost ten thousand visitors came to the Space Pole site and interacted with scientists, visit the telescopes and learn more about the stars, the Sun, the asteroids, the planets and the Earth (earthquakes, interior of the Earth, weather, climate…). The theme of this year was 'Space for Climate', on the occasion of the future opening of the Climate Centre and of the engagement of the IRM-KMI and IASB-BIRA relating to climate. A social media campaign was also organised for this event.

On this occasion, balloons representing the Earth and the Moon are exhibited for one week at the front of the main building. A VIP event was held on Tuesday, September 20, 2022, in the evening, with guests from the Observatory and the representatives of the South Moravian region in the UE. It was also an occasion for the solar physics department to exhibit a high-resolution image made by the camera EUI on board the ESA Solar Orbiter spacecraft. There was no school event organised this time.




A Calendar of the Space Pole (ORB-KSB, IRM-KMI and IASB-BIRA) was also made on this occasion, and was sold during the Open Days, in the Planetarium, by order and internally to colleagues of the Space Pole, who got the advantage to get their first copy for 1 € instead of 5 € (1 € being the cost of printing per copy). About 300 calendars were sold.

SUN Exhibition at the AfricaMuseum

SUN is an installation by British artist Alex Rinsler and solar expert Prof. Robert Walsh (University of Central Lancashire). It is a lifelike representation of the SUN, as a 6-meter diameter balloon on which is broadcast a 3D projection with state-of-the-art telescope images on a gigantic hanging shows 10 weeks of the life of our Sun. Smoke and sound effects complement the unique experience.

With this installation in the AfricaMuseum, in cooperation with the Solar-Terrestrial Centre of Excellence (STCE) in Uccle, the spectacular artwork was shown outside the United Kingdom for the very first time at the AfricaMuseum.

Figure 38: Illustration of the SUN installation.

The SUN exhibition took place from April 5 to April 24, 2022. In addition to the spectacle of SUN, the AfricaMuseum and the STCE also took this opportunity to show to the visitors their research projects linked to the SUN and Climate. There were also special events such as the VIP opening in which directors of the Federal Scientific Institutes are invited and the Family Sunday in which families can listen to traditional tales.

Opening of the Climate Centre

On 29 November 2022 at 10:00, Secretary of State Thomas Dermine, Scientific Director Valérie Trouet and Operational Director Ella Jamsin officially opened the Climate Centre at the Space Pole in Uccle. Belgian and international scientific, industrial, academic, federal and political representatives attended this event. Bertrand Piccard, who flew around the world with the solar plane Solar Impulse, was the special guest.

The official opening of the Climate Centre offered guests and the press the opportunity to meet the directors of the Climate Centre and to discover the climate research carried out within the Federal Scientific Institutes. To mark the opening of the Climate Centre, a work of art, exhibited on the Avenue

Circulaire, was unveiled to the public. Created by the Wall Street Colours collective, the work depicts human silhouettes covered in patterns ranging from microscopic views of bacteria to heat waves seen from the sky, evoking the link between all scales of our ecosystem and the central role played by Humankind and Nature.

The Climate Centre was created at the instigation of the State Secretary for Federal Science Policy, Thomas Dermine. This centre brings together and coordinates the climate research of the Federal Scientific Institutes: the Royal Meteorological Institute (IRM-KMI), the Royal Belgian Institute for Space Aeronomy (IASB-BIRA), the Royal Observatory of Belgium (ORB-KSB), the Royal Belgian Institute of Natural Sciences (RBINS), Royal Museum for Central Africa (AfricaMuseum) and Sciensano. It aims to strengthen their collaboration with other research centres and universities and to focus more on the needs of economic and political actors (adaptation measures, mitigation strategies, etc.).

A significant part of the research of the ORB-KSB is related to climate: measurements of the effects of water masses on gravity and ground deformations, observation of atmospheric water vapour with GNSS satellites, study of seismic noise related to storms, seismic studies for geothermal energy and the study of the influence of the Sun on climate.

ASGARD balloon launch

The ASGARD 11th balloon launch took place on April 28, 2022. This event is organised by the Planetarium and the institutes of the Space Pole, the ORB-KSB, the IRM-KMI and the IASB-BIRA, participated in it.

The ASGARD Contest is geared to primary and high school classes who proposed an original experiment that will be loaded on a stratospheric balloon. Like every year, the finalists of the contest spent a day at the Space Pole site, during which the balloon launch of their experiments is the climax. In addition to the balloon launch, the participants also attended sessions in which scientists explain science topics in their fields and 'Meet and Greet' sessions in the afternoon in which scientists from different fields present themselves and their research.

Exhibition at the Royal Palace

After an absence of three years due to COVID-19, the annual exhibition at the Royal Palace took place from July 23 to August 28, 2022. This exhibition is a 'light' version, only open to visitors who booked their visit in advance via the Palace website.

This 15th edition, presented by BELSPO is entitled 'Belgian Science Policy: Ensuring the Future', a theme that will valorise the way in which the department and the 10 Federal Scientific Institutes (FSIs) are preparing themselves for the future, by reaffirming themselves as essential players in research and the related applications. For this edition, the ORB-KSB provide a maquette of the GRASS instrument, which will be part of the future ESA Hera mission (launch schedule in 2024). GRASS will analyse the gravity field of Dimorphos, allowing us to better understand its internal structure and to find a strategy to deflect asteroids.

Soapbox Science Brussels 2022

Soapbox Science is an international science outreach initiative that aims to promote the visibility of women and non-binary scientists and their research by bringing them on the streets to reach the public. Soapbox Science events transform public areas in discussion forums based on Hyde Park's Speaker's Corner where women and non-binary scientists, on their soapboxes, talk about their research to the people passing by.

Soapbox Science was founded in 2011 in London, by Dr Seirian Sumner, from the University of Bristol, and Dr Nathalie Pettorelli, from the Zoological Society of London. The concept went on with great international success, with, during some years, more than 40 events in at least 13 countries, including Belgium. The Soapbox Science Brussels local organisation what founded in 2019 by researchers and science communication officers of Royal Observatory of Belgium (ORB-KSB) and the Royal Belgian Institute of Space Aeronomy (IASB-BIRA). The ORB-KSB became the host institute of Soapbox Science Brussels and the administrative cost are managed by the ORB-KSB and the IASB-BIRA. Funding of Soapbox Science Brussels goes through sponsoring from different entities.



The 2022 event was the third one organised by Soapbox Science Brussels, after a first online event in 2020 that was broadcast live on social media, and one real-life event in 2021. It took place on June 25, 2022, at the Place de la Bourse. Talks were in French, Dutch and English, three languages widely used in Brussels.

In 2022, Soapbox Science Brussels Sponsors are the VIB, SCK-CEN, Marc Vandenbrande and Europlanet Benelux. The ORB-KSB and the IASB-BIRA also contributed to this event for the logistics (transportation, catering…). Thanks for investments from UHasselt, ULiege (which pays back the lab coat costs paid by the ORB-KSB) and Belspo last year (for the lab coats, the soapboxes…), the need for funds is reduced in 2022 (no need to buy soapboxes, lab coats or flags). Soapbox Science Brussels still needed some funds for filming a promotional video, but, thanks to the partial compensation from Marc Vandenbrande, they could afford it. Looking for new sponsors in 2023 will be a main task of the Soapbox Science Organisation Team.

There was a good reception from the visitors, from the communication from the institutes of the speakers, and from the press, with which some interview where done. On this occasion, videos of the event were made by Marc Vandenbrande. Those video can be watched in the Soapbox Science Brussels YouTube channel. The organising team intends to renew the initiative and to organise a new event on June 24, 2023.

Information to the Public, Website, News and Press Releases

In 2022, the Communication and Information service replied to questions from authorities, public and the media send by email (449, with 221 in French, 175 in Dutch and 55 in English), by telephone (88), by social media of the Observatory (Facebook: 7 and Twitter: 3) and by paper letters or fax (6), hence 433 replies in total. 32 questions came from authorities (courts, police…) or particulars such as lawyers, with 22 in Dutch and 10 in French. In order to reply to some of the questions, more specific research are performed.

As usual, most questions were about sunset and sunrise, astronomical phenomena, calendars and time, satellite and space station flybys, night observations, and the history of ORB-KSB. Questions related to other fields of expertise such as seismology or space weather are forwarded to the respective services. Due to lockdown and COVID-19 safety measurements (put in place since March 12, 2020), visits are restricted and strongly discouraged.

In 2022, 25 topics were published in the 'News' section of the ORB-KSB's website (always in three languages: NL/FR/EN), including 8 press releases. This is big increase compared to 2021 (17 topics, including 2 press releases).

Social Media

On 31 December 2022, the ORB-KSB Facebook webpage has 1431 likes (with 232 new likes since end 2021), and the ORB-KSB Twitter account got 1195 followers (173 new followers since end 2021). The themes of the published posts and videos are related to all services of the institutes, comprising shared posts from the Planetarium Facebook page, from the Seismologie.be Facebook page and Twitter account, from the EUI Twitter account and also from the Royal Belgian Institute of Spatial Aeronomy and the Royal Meteorological Institute.

The most successful Facebook post of the year is a post announcing the October 25, 2022, solar eclipse, which is partially visible in Belgium. The most successful tweet is on Twitter is related to the Perseid meteor shower, which got an exceptional number of 56,457 impressions and 877 engagements while the other tweets of the top 12 tweets only got an impression below about 9000.

In 2022, the Information and Communication service got the admin permission to manage the LinkedIn page of the Royal Observatory of Belgium, which was automatically created since several (ex-)colleagues have LinkedIn profiles. At the beginning of 2023, there are 693 followers in the ORB-KSB LinkedIn account.

The Planetarium

Daily Activities

Frequentation, Social Media and Website

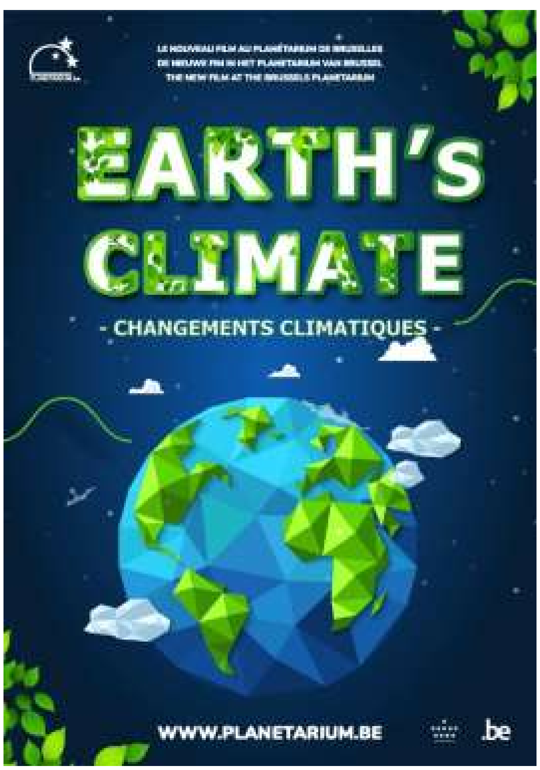
Although 2022 saw a gradual return to normal after the previous two years, which were marked by the COVID-19 pandemic, the start of the year was nevertheless well below normal levels due to the fact that many schools were unable to take school trips until spring. However, strong momentum in the last three quarters enabled us to reach a total of 44,121 paying visitors, thanks to figures from April to December that were very close to those for 2019 (the pre-COVID year).

A total of 828 sessions were given, divided between 83 lessons for school groups, 6 workshops and 739 film screenings (for individuals, families and tourists). Compared with a normal year such as 2019 (1,657 sessions, including 222 courses for school groups, 40 workshops and 1,395 film screenings), these figures give a clear idea of the impact of school closures and lockdowns on the Planetarium's day-to-day activities.

The Planetarium's Facebook page continued to grow, closing the year 2022 with 3,581 likes (up 735 on the previous year). An Instagram account was also created in March 2022 to reach a younger audience. By the end of the year, it had 482 followers.

The year 2022 also saw the launch of the Planetarium's new website, as the previous one no longer met current standards. The new website is intended to be more attractive and clearer for visitors, and easier to maintain internally. Its positive impact was quickly felt, with the number of requests for practical information by telephone or email falling after the site was launched in the spring.

A New Planetarium Film on Climate Change



In collaboration with the IRM-KMI and the BIRA-IASB, and as part of the launch of the Climate Centre, a new Planetarium film on the Earth's climate has been added to the portfolio. The preview of *Earth's Climate* took place on June 20 in the presence of a large audience. As well as climate and meteorology, of course, this film covers a number of research themes being carried out at the Space Pole. Although the film stands out from the other offerings, which tend to focus on astronomy, it was well received by the audience.

Special Activities

As usual, a number of events promoting science and educational and cultural activities have been organised in 2022.

Thomas Pesquet at the Planetarium

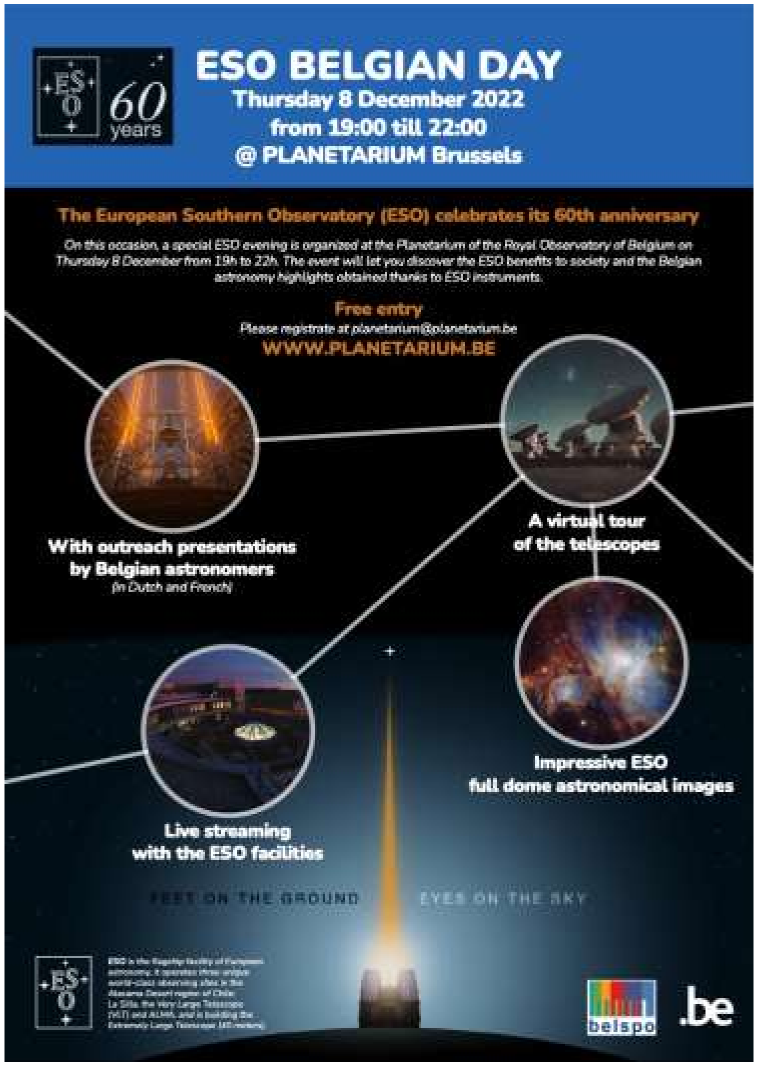
On June 27, 350 primary school pupils had the chance to put their questions to astronaut Thomas Pesquet, who came to present life on board the ISS during a day organised by Science Policy and the ESA. Media coverage was extremely extensive, with the day ending with a press conference led by Thomas Pesquet and Secretary of State Thomas Dermine.

Space Week

Nearly 200 people were able to listen to and interact with Dirk Frimout, Frank De Winne and four North American astronauts as part of Space Week on October 20. The question-and-answer session was preceded by presentations by four scientists from the Space Pole on their space-related research themes (solar physics, the Galileo system, volcanism and the earth’s climate).

ESO Day

To mark ESO's 60th anniversary, the Planetarium, Belspo, BNEC and ESO organised a day and evening on December 8 celebrating ESO through its astronomical discoveries and technological achievements. The Astronomy and Astrophysics Contact Group held a special day dedicated to ESO results, alongside a session presenting ESO professions to engineering students from several faculties and a meeting between Belgian technology players and ESO representatives. The evening was devoted to an event for the public, with live streaming of ESO astronomers from the VLT site in Chile and talks by Belgian astrophysicists who have used ESO telescopes.



Also in 2022

- The mobile planetarium and VR system were made available to the public at the KNAL Festival on March 13;
- Special sessions were offered as part of the Printemps des sciences event on March 27;
- The Planetarium took part in the VeLeWe grant (science teachers) held at UGent on April 23;
- The dome, auditorium and exhibition hall were the setting for the recording of an episode of the Val so Classic You Tube channel on April 26 (image: extract);
- The ASGARD project was co-organised from April 27 to 29 by the Planetarium, the Observatory and several partners (see highlight on page);
- The 2022 edition of the Nocturnes des Musées at the Planetarium on May 19 saw the participation of dancer xxxx (with dancer);
- A conference on the latest Data Release from the Gaia mission was held on June 13 (see highlight on page);
- Colleagues from the solar physics and space weather department came to give their input at the Zonnekijkedag on July 3;
- A new edition of the Planetarium Brussels Poetry Festival took place on September 9 and 10;

- A temporary exhibition on the Czech humanist Arnost Lustig was open to visitors throughout the autumn (with an opening at the Observatory on September 22);
- An event presenting the DART mission was held on September 27;
- The Planetarium took part in the Night of Darkness at the Rouge-Cloître on October 8;
- Telescopes fitted with solar filters and solarscopes were made available to the public during the solar eclipse on October 25;
- Several colleagues from the Space Unit came to run workshops during the Dag van Wetenschap on November 27.

Room rental (projection room or auditorium): as with the number of visitors, there was a marked increase in the frequency of room rental compared with previous years, with a gradual return to normal. The Planetarium hosted the Ketchum company on February 4, the PIEN-Dag on March 16, the Listen!2020 festival on March 31, the Geography Olympics on April 20, a society of dermatologists on April 28, the VVS on May 7, a programme for RTL-TVI on May 31 and a BIFFF festival client evening on September 2.

The internationally renowned **Ars Musica festival** chose the Planetarium to host one of the concerts in its 2022 programme, which was themed around ‘Big Science’. On November 19, the dome welcomed 350 people to hear works by Brian Eno and Denis Bosse (original creation) performed by the musical group Sturm und Klang, set to images by François Schuiten from the book ‘On Mars’.

Media interviews: the National Lottery came to film two subjects on the Planetarium and the new digital projection system on February 14 and 16. The Planetarium also responded to requests from various media: RTL-TVI on May 25, LN24 on May 16, Radio Alma on 1 June, Télépro on July 8, RTBF on July 13 and September 21, Radio Vivacité on November 6.

Annexe 1: Publications

Publications With Peer Review

[1] Abdul-Masih, Michael ; Escorza, Ana ; Menon, Athira ; Mahy, Laurent ; Marchant, Pablo
Constraining the overcontact phase in massive binary evolution. II. Period stability of known O+O overcontact systems
Astronomy & Astrophysics, 666 issue A18, pp. 11 (2022). http://dx.doi.org/%2010.1051/0004-6361/202244148

[2] Agrusa, H.F., Ballouz R., Meyer A.J., Tasev E., Noiset G., Karatekin Ö., Michel P., Richardson D.C., Hirabayashi M.
Rotation-induced granular motion on the secondary component of binary asteroids: Application to the DART impact on Dimorphos
Astronomy & Astrophysics, 664, id. L3, 1-13, (2022). http://dx.doi.org/10.1051/0004-6361/202244388

[3] Alfonsi, Lucilla ; Bergeot, Nicolas ; Cilliers, Pierre J. ; Pottiaux, Eric ; et, al.
Review of Environmental Monitoring by Means of Radio Waves in the Polar Regions: From Atmosphere to Geospace
Surveys in Geophysics, 43 issue 6, pp. 1609-1698 (2022). http://dx.doi.org/10.1007/s10712-022-09734-z

[4] Alipour, N. ; Safari, H. ; Verbeeck, C. ; Berghmans, D. ; ManyOtherAuthors, X. ; Dolla, L. ; Gissot, S. ; Zhukov, A. N.
Automatic detection of small-scale EUV brightenings observed by the Solar Orbiter/EUI
Astronomy & Astrophysics, 663, pp. A128 (2022). http://dx.doi.org/https://doi.org/10.1051/0004-6361/202243257

[5] Ammirati, Jean Baptiste ; Mackaman-Lofland, Chelsea ; Zeckra, Martin ; Gobron, Kevin
Stress transmission along mid-crustal faults highlighted by the 2021 Mw 6.5 San Juan (Argentina) earthquake
Scientific Reports, 12 issue 1, pp. Article number: 17939 (2022). http://dx.doi.org/10.1038/s41598-022-22752-6

[6] Banyard, G. ; Sana, H. ; Mahy, L. ; Bodensteiner, J. ; Villaseñor, J. I. ; Evans, C. J.
The observed multiplicity properties of B-type stars in the Galactic young open cluster NGC 6231
Astronomy & Astrophysics, 658 issue A69, pp. 28 (2022). http://dx.doi.org/10.1051/0004-6361/202141037

[7] Barczynski, K. ; Meyer, K. A. ; Harra, L. K. ; Mackay, D. H. ; Auchère, F. ; Berghmans, D.
A Statistical Comparison of EUV Brightenings Observed by SO/EUI with Simulated Brightenings in Nonpotential Simulations
Astronomy & Astrophysics, Solar Physics issue 297:141 (2022). http://dx.doi.org/https://doi.org/10.1007/s11207-022-02074-6

[8] Bell, C.P.M. ; Cioni, M.-R.L. ; Wright, A.H. ; Nidever, D.L. ; Chiang, I-Da ; Choudhury, S. ; Groenewegen, M.A.T. ; Pennock, C.M. ; Choi, Y ; de Grijs, R. ; Ivanov, V.D. ; Massana, P. ; Nanni, A ; Noel, N.E.D. ; Olsen, K. ; van Loon, J.Th. ; Vivas, A.K. ; Zaritsky, D.
The intrinsic reddening of the Magellanic Clouds as traced by background galaxies – III. The Large Magellanic Cloud
MNRAS, 516, pp. 824-840 (2022). https://doi.org/10.1093/mnras/stac1545

[9] Bemporad, A. ; Andretta, V. ; Susino, R. ; Mancuso, S. ; Spadaro, D. ; Mierla, M. ; Berghmans, D. ; D'Huys, E. ; Zhukov, A. N. ; Talpeanu, D.-C. ; Colaninno, R. ; Hess, P. ; Koza, J. ; Jejčič, S. ; Heinzel, P. ;

Antonucci, E. ; Da Deppo, V. ; Fineschi, S. ; Frassati, F. ; Jerse, G. ; Landini, F. ; Naletto, G. ; Nicolini, G. ; Pancrazzi, M. ; Romoli, M. ; Sasso, C. ; Slemer, A. ; Stangalini, M. ; Teriaca, L.
Coronal mass ejection followed by a prominence eruption and a plasma blob as observed by Solar Orbiter
Astronomy & Astrophysics, 665 issue A7 (2022). http://dx.doi.org/10.1051/0004-6361/202243162

[10] Blomme, R ; Daflon, S ; Gebran, M ; Herrero, A ; Lobel, A ; Mahy, L ; Martins, F ; Morel, T ; R Berlanas, S ; Blazère, A ; Frémat, Y ; Gosset, E ; Maiz Apellaniz, J ; Santos, W ; Semaan, T ; Simon-Diaz, S ; Volpi, D ; Holgado, G ; Jiménez-Esteban, F ; F Nieva, M ; Przybilla, N ; Gilmore, G ; Randich, S ; Negueruela, I ; Prusti, T ; Vallenari, A ; J Alfaro, E ; Bensby, T ; Bragaglia, A ; Flaccomio, E ; Francois, P ; J Korn, A ; Lanzafame, A ; Pancino, E ; Smiljanic, R ; Bergemann, M ; Carraro, G ; Franciosini, E ; Gonneau, A ; Heiter, U ; Hourihane, A ; Jofré, P ; Magrini, L ; Morbidelli, L ; G Sacco, G ; C Worley, C ; Zaggia, S
The Gaia-ESO Survey: The analysis of the hot-star spectra
Astronomy & Astrophysics, 661 issue A120 (2022). http://dx.doi.org/10.1051/0004-6361/202142349

[11] Borzì, A.M. ; Minio, V. ; Cannavò, F. ; Cavallaro, A. ; D'Amico, S. ; Gauci, A. ; De Plaen, R. ; Lecocq, T. ; Nardone, G. ; Orasi, A. ; Picone, M. ; Cannata, A.
Monitoring extreme meteo-marine events in the Mediterranean area using the microseism (Medicane Apollo case study)
Scientific Reports, 12 issue 21363 (2022). http://dx.doi.org/10.1038/s41598-022-25395-9

[12] Boulkaboul, A. ; Damerdji, Y. ; Morel, T. ; Frémat, Y. ; Soubiran, C. ; Gosset, E. ; Abdelatif, T. E.
Analysis of Gaia radial-velocity standards: stability and new substellar companion candidates
Monthly Notices of the Royal Astronomical Society, 517 issue 2, pp. 1849–1866 (2022). http://dx.doi.org/10.1093/mnras/stac2674

[13] Bragaglia, A. ; Alfaro, E. J. ; Flaccomio, E. ; Blomme, R. ; Donati, P. ; Costado, M. ; Damiani, F. ; Franciosini, E. ; Prisinzano, L. ; Randich, S. ; Friel, E. D. ; Hatztidimitriou, D. ; Vallenari, A. ; Spagna, A. ; Balaguer-Nunez, L. ; Bonito, R. ; Cantat Gaudin, T. ; Casamiquela, L. ; Jeffries, R. D. ; Jordi, C. ; Magrini, L. ; Drew, J. E. ; Jackson, R. J. ; Abbas, U. ; Caramazza, M. ; Hayes, C. ; Jiménez-Esteban, F. M. ; Re Fiorentin, P. ; Wright, N. ; Bayo, A. ; Bensby, T. ; Bergemann, M. ; Gilmore, G. ; Gonneau, A. ; Heiter, U. ; Hourihane, A. ; Pancino, E. ; Sacco, G. ; Smiljanic, R. ; Zaggia, S. ; Vink, J. S.
The Gaia-ESO Survey: Target selection of open cluster stars
Astronomy & Astrophysics, 659, pp. A200 (16pp) (2022). http://dx.doi.org/10.1051/0004-6361/202142674

[14] Breuer, Doris ; Spohn, Tilman ; Van Hoolst, Tim ; van Westrenen, Wim ; Stanley, Sabine ; Rambaux, Nicolas
Interiors of Earth-Like Planets and Satellites of the Solar System
Surveys in Geophysics, 43 issue 1, pp. 177-226 (2022). http://dx.doi.org/10.1007/s10712-021-09677-x

[15] Breuer, Doris ; Spohn, Tilman ; Van Hoolst, Tim ; van Westrenen, Wim ; Stanley, Sabine ; Rambaux, Nicolas
Correction to: Interiors of Earth-like planets and satellites of the Solar System
Surveys in Geophysics, 43 issue 1, pp. 227-228 (2022). http://dx.doi.org/10.1007/s10712-021-09687-9

[16] Buccino, Dustin ; Border, James S. ; Folkner, William M. ; Kahan, Daniel ; Le Maistre, Sebastien
Low-SNR Doppler Data Processing for the InSight Radio Science Experiment
Remote Sensing, 14 issue 8, pp. 1924 (2022). http://dx.doi.org/10.3390/rs14081924

[17] Büyükakpınar, P. ; Cannata, A. ; Cannavò, F. ; Carbone, D. ; De Plaen, R.S.M. ; Di Grazia, G. ; King, T. ; Lecocq, T. ; Liuzzo, M. ; Salerno, G.
Chronicle of processes leading to the 2018 eruption at Mt. Etna as inferred by seismic ambient noise along with geophysical and geochemical observables
Journal of Geophysical research, Volume127, Issue10 (2022).
https://doi.org/10.1029/2022JB025024

[18] Camelbeeck, Thierry ; Van Noten, Koen ; Lecocq, Thomas ; Hendrickx, Marc
The damaging character of shallow 20th century earthquakes in the Hainaut coal area (Belgium)
Solid Earth, 13 issue 3, pp. 469-495 (2022). http://dx.doi.org/10.5194/se-13-469-2022

[19] Caudron, C. ; Soubestre, J. ; Lecocq, T. ; White, R.S. ; Brandsdóttir, B. ; Krischer, L.
Insights into the dynamics of the 2010 Eyjafjallajökull eruption using seismic interferometry and network covariance matrix analyses
Earth and Planetary Science Letters, 585, pp. 117502 (2022).
http://dx.doi.org/10.1016/j.epsl.2022.117502

[20] Caudron, C. ; Aoki, Y. ; Lecocq, T. ; De Plaen, R. ; Soubestre, J. ; Mordret, A. ; Seydoux, L. ; Terakawa, T.
Hidden pressurized fluids prior to the 2014 phreatic eruption at Mt Ontake
Nature Communications, 13 issue 6145 (2022). http://dx.doi.org/10.1038/s41467-022-32252-w

[21] Chené, André-Nicolas ; Mahy, Laurent ; Gosset, Eric ; St-Louis, Nicole ; Dsilva, Karan ; Manick, Rajeev
WR 63: a multiple system (O+O) + WR?
Monthly Notices of the Royal Astronomical Society, 516 issue 1, pp. 1022-1031 (2022).
http://dx.doi.org/10.1093/mnras/stac1762

[22] Chitta, L. P. ; Peter, H. ; Parenti, S. ; Berghmans, D. ; Auchère, F. ; Solanki, S. K. ; Aznar Cuadrado, R. ; Schühle, U. ; Teriaca, L. ; Mandal, S. ; Barczynski, K. ; Buchlin, E. ; Harra, L. ; Kraaikamp, E. ; Long, D. ; Rodriguez, L. ; Schwanitz, C. ; Smith, P. ; Verbeeck, C. ; Zhukov, A. N. ; Liu, W. ; Cheung, M.
Solar coronal heating from small-scale magnetic braids
A&A 667, A166 (2022). https://doi.org/10.1051/0004-6361/202244170

[23] Cotton, D.V. ; Buzasi, D.L. ; Aerts, C. ; Bailey, J. ; Burssens, S. ; Pedersen, M.G. ; Stello, D. ; Kedziora-Chudczer, L. ; De Horta, A. ; De Cat, P. ; Lewis, F. ; Malla, S.P. ; Wright, D.J. ; Bott, K.
Polarimetric detection of nonradial oscillation modes in β Crucis
Nature Astronomy, 6, pp. 154—164 (2022). http://dx.doi.org/10.1038/s41550-021-01531-9

[24] da Silva, R. ; Crestani, J. ; Bono, G. ; Braga, V.F. ; D'Orazi, V. ; Lemasle, B. ; Bergemann, M. ; Dall'Ora, M. ; Fiorentino, G. ; Francois, P. ; Groenewegen, M.A.T. ; Inno, L. ; Kovtyukh, V. ; Kudritzki, R.-P. ; Matsunaga, N. ; Monelli, M. ; Pietrinferni, A. ; Porcelli, L. ; Storm, J. ; Tantalo, M. ; Thevenin, F.
A new and homogeneous metallicity scale for Galactic classical Cepheids II. The abundance of iron and alpha elements
A&A, 661 issue A104 (2022). https://doi.org/10.1051/0004-6361/202142957

[25] De Marco, Orsola; ; Akashi, Muhammad; ; Akras, Stavros; ; Alcolea, Javier; ; Aleman, Isabel; ; Amram, Philippe; ; Balick, Bruce; ; De Beck, Elvire; ; Blackman, Eric G.; ; Boffin, Henri M. J.; ; Boumis, Panos; ; Bublitz, Jesse; ; Bucciarelli, Beatrice; ; Bujarrabal, Valentin; ; Cami, Jan; ; Chornay, Nicholas; ; Chu, You-Hua; ; Corradi, Romano L. M.; ; Frank, Adam; ; García-Hernández, D. A.; ; García-Rojas, Jorge; ; García-Segura, Guillermo; ; Gómez-Llanos, Veronica; ; Gonçalves, Denise R.; ; Guerrero, Martín A.; ; Jones, David; ; Karakas, Amanda I.; ; Kastner, Joel H.; ; Kwok, Sun; ; Lykou, Foteini; ; Manchado, Arturo; ; Matsuura, Mikako; ; McDonald, Iain; ; Miszalski, Brent; ; Mohamed, Shazrene S.; ; Monreal-Ibero, Ana; ; Monteiro, Hektor; ; Montez, Rodolfo; ; Baez, Paula Moraga; ; Morisset, Christophe; ; Nordhaus, Jason; ; Mendes de Oliveira, Claudia; ; Osborn, Zara; ; Otsuka,

Masaaki; ; Parker, Quentin; ; Peeters, Els; ; Quint, Bruno C.; ; Quintana-Lacaci, Guillermo; ; Redman, Matt; ; Ruiter, Ashley J.; ; Sabin, Laurence; ; Sahai, Raghvendra; ; Contreras, Carmen Sánchez; ; Santander-García, Miguel; ; Seitenzahl, Ivo; ; Soker, Noam; ; Speck, Angela K.; ; Stanghellini, Letizia; ; Steffen, Wolfgang; ; Toalá, Jesús A.; ; Ueta, Toshiya; ; Van de Steene, Griet; ; Van Winckel, Hans; ; Ventura, Paolo; ; Villaver, Eva; ; Vlemmings, Wouter; ; Walsh, Jeremy R.; ; Wesson, Roger; ; Zijlstra, Albert A.
The messy death of a multiple star system and the resulting planetary nebula as observed by JWST
Nature Astronomy, 6 issue dec, pp. 1423-1432 (2022). http://dx.doi.org/10.1038/s41550-022-01845-2

[26] De Plaen, R.S.M. ; Mordret, A. ; Arámbula-Mendoza, R. ; Vargas-Bracamontes, D. ; Márquez-Ramírez, V.H. ; Lecocq, T. ; Vázquez, C.A.R. ; Amezcua, M.G.
The shallow three-dimensional structure of Volcán de Colima revealed by ambient seismic noise tomography
Journal of Volcanology and Geothermal Research, 428, pp. 107578 (2022). http://dx.doi.org/10.1016/j.jvolgeores.2022.107578

[27] Defraigne, Pascale ; Achkar, Joseph ; Coleman, Mikael ; Gertsvolf, Marina ; Ichikawa, Ruichy ; Levine, Judah ; Uhrich, Pierre ; Whibberley, Peter ; Wouters, Michael ; Bauch, Andeas
Achieving traceability to UTC through GNSS measurements
Metrologia, 59 issue 6 (2022). https://doi.org/10.1088/1681-7575/ac98cb

[28] Dehant, V. ; Campuzano, S.A. ; De Santis, A. ; van Westrenen, W.
Structure, materials and processes in the Earth's core and mantle
Space Science Reviews, S.I.: 'Probing Earth's Deep Interior using Space Observations Synergistically' (2022). http://dx.doi.org/10.1007/s10712-021-09684-y

[29] Dehant, V. ; Campuzano, S.A. ; De Santis, A. ; van Westrenen, W.
Correction to: Structure, materials and processes in the Earth's core and mantle
Survey Geophysics, 43 issue 1, pp. 303-304 (2022). http://dx.doi.org/10.1007/s10712-022-09706-3

[30] Delforge, D. ; de Viron, O. ; Durand, F. ; Dehant, V.
The Global Patterns of Interannual and Intraseasonal Mass Variations in the Oceans from GRACE and GRACE Follow-on records
Remote Sensing, 14 issue 1861, pp. 1-12 (2022). http://dx.doi.org/10.3390/rs14081861

[31] Dewitte, Steven ; Cornelis, Jan ; Meftah, Mustapha
Centennial Total Solar Irradiance Variation
Remote Sensing, 14 issue 5 (2022). http://dx.doi.org/10.3390/rs14051072

[32] Drilleau, Mélanie ; Samuel, Henri ; Garcia, Raphaël F. ; Rivoldini, Attilio ; Perrin, Clément ; Michaut, Chloé ; Wieczorek, Mark ; Tauzin, Benoît ; Connolly, James A. D. ; Meyer, Pauline ; Lognonné, Philippe ; Banerdt, William B.
Marsquake Locations and 1-D Seismic Models for Mars From InSight Data
Journal of Geophysical Research: Planets, 127 issue 9 (2022). http://dx.doi.org/10.1029/2021JE007067

[33] Edmund, E. ; Morard, G. ; Baron, M. A. ; Rivoldini, A. ; Yokoo, S. ; Boccato, S. ; Hirose, K. ; Pakhomova, A. ; Antonangeli, D.
The Fe-FeSi phase diagram at Mercury's core conditions
Nature Communications, 13 issue 1 (2022). http://dx.doi.org/10.1038/s41467-022-27991-9

[34] Erdélyi, R. ; Damé, L. ; Fludra, A. ; Mathioudakis, M. ; Amari, T. ; Belucz, B. ; Berrilli, F. ; Bogachev, S. ; Bolsée, D. ; Bothmer, V. ; Brun, S. ; Dewitte, S.
HiRISE – High-Resolution Imaging and Spectroscopy Explorer – Ultrahigh resolution, interferometric and external occulting coronagraphic science

Experimental Astronomy (2022). http://dx.doi.org/10.1007/s10686-022-09831-2

[35] Fernandes, Rui; Bruyninx, Carine; Crocker, Paul; Menut, Jean-Luc; Socquet, Anne; Vergnolle, Mathilde; Avallone, Antonio; Bos, Machiel; Bruni, Sergio; Cardoso, Rui; Carvalho, Luis; Cotte Nathalie; D'Agostino, Nicola; Deprez Aline; Fabian, Andras; Steffen, Holger; Janex, Gael; Kenyeres, Ambrus; Legrand, Juliette; Ngo, Khai-Minh, Lidberg, Martin; Liwosz, Tomasz; Manteigueiro, José; Miglio, Anna; Soehne, Wolfgang; Toth, Sandor; Dousa, Jan; Ganas, Athanassios, Kapetanidis, Vassilis; Batti, Gabriela
A new European Service to share GNSS Data and Products
Annals of Geophysics, Vol. 65 No. 3, DM317 (2022). https://doi.org/10.4401/ag-8776

[36] Fernando, Benjamin ; Wójcicka, Natalia ; Maguire, Ross ; Stähler, Simon C. ; Stott, Alexander E. ; Ceylan, Savas ; Charalambous, Constantinos ; Clinton, John ; Collins, Gareth S. ; Dahmen, Nikolaj ; Froment, Marouchka ; Golombek, Matthew ; Horleston, Anna ; Karatekin, Ozgur ; et, al.
Seismic constraints from a Mars impact experiment using InSight and Perseverance
Nature Astronomy, 6, pp. 59-64 (2022). http://dx.doi.org/10.1038/s41550-021-01502-0

[37] Franci, Luca ; Papini, Emanuele ; Micera, Alfredo ; Lapenta, Giovanni ; Hellinger, Petr ; Del Sarto, Daniele ; Burgess, David ; Landi, Simone
Anisotropic electron heating in turbulence-driven magnetic reconnection in the near-Sun solar wind
Astronomy and space sciences, Volume 9, 3 August 2022 (2022).
https://doi.org/10.3389/fspas.2022.951628

[38] Frasca, A. ; Molenda-Żakowicz, J. ; Alonso-Santiago, J. ; Catanzaro, G. ; De Cat, P. ; Fu, J. N. ; Zong, W. ; Wang, J.X. ; Cang, T. ; Wang, J.T.
Characterization of Kepler targets based on medium-resolution LAMOST spectra analyzed with ROTFIT
Astronomy & Astrophysics, 664, pp. 1--30 (id. A78) (2022). http://dx.doi.org/%2010.1051/0004-6361/202243268

[39] Frost, A. J. ; Bodensteiner, J. ; Rivinius, Th. ; Baade, D. ; Merand, A. ; Selman, F. ; Abdul-Masih, M. ; Banyard, G. ; Bordier, E. ; Dsilva, K. ; Hawcroft, C. ; Mahy, L. ; Reggiani, M. ; Shenar, T. ; Cabezas, M. ; Hadrava, P. ; Heida, M. ; Klement, R. ; Sana, H.
HR 6819 is a binary system with no black hole. Revisiting the source with infrared interferometry and optical integral field spectroscopy
Astronomy & Astrophysics, 659 issue L3, pp. 12 (2022). http://dx.doi.org/10.1051/0004-6361/202143004

[40] Garcia, Raphael F. ; Daubar, Ingrid J. ; Beucler, Éric ; Karatekin, Ozgur ; Et, al.
Newly formed craters on Mars located using seismic and acoustic wave data from InSight
Nature Geoscience, 15, pp. 774-780 (2022). http://dx.doi.org/10.1038/s41561-022-01014-0

[41] Gebruers, Sarah ; Tkachenko, Andrew ; Bowman, Dominic M. ; Van Reeth, Timothy ; Burssens, Siemen ; IJspeert, Luc ; Mahy, Laurent ; Straumit, Ilya ; Xiang, Maosheng ; Rix, Hans-Walter ; Aerts, Conny
Analysis of high-resolution FEROS spectroscopy for a sample of variable B-type stars assembled from TESS photometry
Astronomy & Astrophysics, 665 issue A36, pp. 17 (2022). http://dx.doi.org/10.1051/0004-6361/202243839

[42] Gillet, N. ; Gerick, F. ; Angappan, R. ; Jault, D.
Correction to: A Dynamical Prospective on Interannual Geomagnetic Field Changes
Surveys in Geophysics, 43 issue 1, pp. 1263-1264 (2022). http://dx.doi.org/10.1007/s10712-022-09714-3

[43] Gillet, Nicolas ; Gerick, Felix ; Jault, Dominique ; Schwaiger, Tobias ; Aubert, Julien ; Istas, Mathieu

Satellite magnetic Data reveal interannual waves in Earth's core
Proceedings of the National Academy of Sciences, 119 issue 13, pp. e2115258119 (2022). http://dx.doi.org/10.1073/pnas.2115258119

[44] Gilmore, G. ; Randich, S. ; Worley, C. C. ; Hourihane, A. ; Gonneau, A. ; Sacco, G. G. ; Lewis, J. R. ; Magrini, L. ; François, P. ; Jeffries, R. D. ; Koposov, S. E. ; Bragaglia, A. ; Alfaro, E. J. ; Allende Prieto, C. ; Blomme, R. ; Korn, A. J. ; Lanzafame, A. C. ; Pancino, E. ; Recio-Blanco, A. ; Smiljanic, R. ; Van Eck, S. ; Zwitter, T. ; Bensby, T. ; Flaccomio, E. ; Irwin, M. J. ; Franciosini, E. ; Morbidelli, L. ; Damiani, F. ; Bonito, R. ; Friel, E. D. ; Vink, J. S. ; Prisinzano, L. ; Abbas, U. ; Hatzidimitriou, D. ; Held, E. V. ; Jordi, C. ; Paunzen, E. ; Spagna, A. ; Jackson, R. J. ; Maíz Apellániz, J. ; Asplund, M. ; Bonifacio, P. ; Feltzing, S. ; Binney, J. ; Drew, J. ; Ferguson, A. M. N. ; Micela, G. ; Negueruela, I. ; Prusti, T. ; Rix, H. -W. ; Vallenari, A. ; Bergemann, M. ; Casey, A. R. ; de Laverny, P. ; Frasca, A. ; Hill, V. ; Lind, K. ; Sbordone, L. ; Sousa, S. G. ; Adibekyan, V. ; Caffau, E. ; Daflon, S. ; Feuillet, D. K. ; Gebran, M. ; Gonzalez Hernandez, J. I. ; Guiglion, G. ; Herrero, A. ; Lobel, A. ; Merle, T. ; Mikolaitis, Š. ; Montes, D. ; Morel, T. ; Ruchti, G. ; Soubiran, C. ; Tabernero, H. M. ; Tautvaišienė, G. ; Traven, G. ; Valentini, M. ; Van der Swaelmen, M. ; Villanova, S. ; Viscasillas Vázquez, C. ; Bayo, A. ; Biazzo, K. ; Carraro, G. ; Edvardsson, B. ; Heiter, U. ; Jofré, P. ; Marconi, G. ; Martayan, C. ; Masseron, T. ; Monaco, L. ; Walton, N. A. ; Zaggia, S. ; Aguirre Børsen-Koch, V. ; Alves, J. ; Balaguer-Nunez, L. ; Barklem, P. S. ; Barrado, D. ; Bellazzini, M. ; Berlanas, S. R. ; Binks, A. S. ; Bressan, A. ; Capuzzo-Dolcetta, R. ; Casagrande, L. ; Casamiquela, L. ; Collins, R. S. ; D'Orazi, V. ; Dantas, M. L. L. ; Debattista, V. P. ; Delgado-Mena, E. ; Di Marcantonio, P. ; Drazdauskas, A. ; Evans, N. W. ; Famaey, B. ; Franchini, M. ; Frémat, Y. ; Fu, X. ; Geisler, D. ; Gerhard, O. ; González Solares, E. A. ; Grebel, E. K. ; Gutiérrez Albarrán, M. L. ; Jiménez-Esteban, F. ; Jönsson, H. ; Khachaturyants, T. ; Kordopatis, G. ; Kos, J. ; Lagarde, N. ; Ludwig, H. -G. ; Mahy, L. ; Mapelli, M. ; Marfil, E. ; Martell, S. L. ; Messina, S. ; Miglio, A. ; Minchev, I. ; Moitinho, A. ; Montalban, J. ; Monteiro, M. J. P. F. G. ; Morossi, C. ; Mowlavi, N. ; Mucciarelli, A. ; Murphy, D. N. A. ; Nardetto, N. ; Ortolani, S. ; Paletou, F. ; Palouš, J. ; Pickering, J. C. ; Quirrenbach, A. ; Re Fiorentin, P. ; Read, J. I. ; Romano, D. ; Ryde, N. ; Sanna, N. ; Santos, W. ; Seabroke, G. M. ; Spina, L. ; Steinmetz, M. ; Stonkuté, E. ; Sutorius, E. ; Thévenin, F. ; Tosi, M. ; Tsantaki, M. ; Wright, N. ; Wyse, R. F. G. ; Zoccali, M. ; Zorec, J. ; Zucker, D. B.
The Gaia-ESO Public Spectroscopic Survey: Motivation, implementation, GIRAFFE data processing, analysis, and final data products
Astronomy & Astrophysics, 666, pp. A120 (36pp) (2022). http://dx.doi.org/10.1051/0004-6361/202243134

[45] Gobron, K. ; Rebischung, P. ; de Viron, O. ; Demoulin, A. ; Van Camp, M.
Impact of offsets on assessing the low-frequency stochastic properties of geodetic time series
Journal of Geodesy, 96 issue 46 (2022). http://dx.doi.org/10.1007/s00190-022-01634-9

[46] Gormaz-Matamala, A C ; Curé, M ; Lobel, A ; A Panei, J ; Cuadra, J ; Araya, I ; Arcos, C ; Figueroa-Tapia, F
New self-consistent wind parameters to fit optical spectra of O-type stars observed with the HERMES spectrograph
Astronomy & Astrophysics, 661 issue A51 (2022). http://dx.doi.org/10.1051/0004-6361/202142383

[47] Groenewegen, M.A.T.
A WISE view on extreme AGB stars
Astronomy & Astrophysics, 659, pp. A145 (2022). https://doi.org/10.1051/0004-6361/202142648

[48] Huang, Quancheng ; Schmerr, Nicholas C. ; King, Scott D. ; Kim, Doyeon ; Rivoldini, Attilio ; Plesa, Ana-Catalina ; Samuel, Henri ; Maguire, Ross R. ; Karakostas, Foivos ; Lekić, Vedran ; Charalambous, Constantinos ; Collinet, Max ; Myhill, Robert ; Antonangeli, Daniele ; Drilleau, Mélanie ; Bystricky, Misha ; Bollinger, Caroline ; Michaut, Chloé ; Gudkova, Tamara ; Irving, Jessica C. E. ; Horleston, Anna ; Fernando, Benjamin ; Leng, Kuangdai ; Nissen-Meyer, Tarje ; Bejina, Frederic ; Bozdağ, Ebru

; Beghein, Caroline ; Waszek, Lauren ; Siersch, Nicki C. ; Scholz, John-Robert ; Davis, Paul M. ; Lognonné, Philippe ; Pinot, Baptiste ; Widmer-Schnidrig, Rudolf ; Panning, Mark P. ; Smrekar, Suzanne E. ; Spohn, Tilman ; Pike, William T. ; Giardini, Domenico ; Banerdt, W. Bruce
Seismic detection of a deep mantle discontinuity within Mars by InSight
Proceedings of the National Academy of Sciences, 119 issue 42 (2022).
http://dx.doi.org/10.1073/pnas.2204474119

[49] Jing, Jie-Jun ; Lin, Yanhao ; Knibbe, Jurrien S. ; van Westrenen, Wim
Garnet stability in the deep lunar mantle: Constraints on the physics and chemistry of the interior of the Moon
Earth and Planetary Science Letters, 584, pp. 117491 (2022).
http://dx.doi.org/10.1016/j.epsl.2022.117491

[50] Joshi, S. ; Trust, O. ; Semenko, E. ; Williams, P.E. ; Lampens, P. ; De Cat, P. ; Vermeylen, L. ; Holdsworth, D.L. ; García, R.A. ; Mathur, S. ; Santos, A.R.G. ; Mkrtichian, D. ; Goswami, A. ; Cuntz, M. ; Yadav, A.P. ; Sarkar, M. ; Bhatt, B.C. ; Kahraman Aliçavuş, F. ; Nhlapo, M.D. ; Lund, M.N. ; Goswami, P.P. ; Savanov, I. ; Jorissen, A. ; Jurua, E. ; Avvakumova, E. ; Dmitrienko, E.S. ; Chakradhari, N.K. ; Das, M.K. ; Chowdhury, S. ; Abedigamba, O.P. ; Yakunin, I. ; Letarte, B. ; Karinkuzhi, D.
Study of Chemically Peculiar Stars-I : High-resolution Spectroscopy and K2 Photometry of Am Stars in the Region of M44
Monthy Notices of the Royal Astronomical Society, 510, pp. 5854--5871 (2022).
http://dx.doi.org/10.1093/mnras/stab3158

[51] Kahil, F. ; Hirzberger, J. ; Solanki, S. ; ManyAuthors, X. ; Berghmans, D. ; Verbeeck, C. ; Kraaikmap, E. ; Gissot, S.
The Magnetic drivers of campfires seen by the Polarimetric and Helioseismic Imager (PHI) on Solar Orbiter
A&A 660, A143 (2022). https://doi.org/10.1051/0004-6361/202142873

[52] Kahraman Aliçavuş, F. ; Handler, G. ; Aliçavuş, F. ; De Cat, P. ; Bedding, T. R. ; Lampens, P. ; Ekinci, Ö. ; Gümüs, D. ; Leone, F.
Mass transfer and tidally tilted pulsation in the Algol-type system TZ Dra
Monthly Notices of the Royal Astronomical Society, 510, pp. 1413—1424 (2022).
https://doi.org/10.1093/mnras/stab3515

[53] Kawamura, Taichi ; Grott, Matthias ; Garcia, Raphael ; Wieczorek, Mark ; de Raucourt, Sébastien ; Lognonné, Philippe ; Bernauer, Felix ; Breuer, Doris ; Clinton, John ; Delage, Pierre ; Drilleau, Mélanie ; Ferraioli, Luigi ; Fuji, Nobuaki ; Horleston, Anna ; Kletetschka, Günther ; Knapmeyer, Martin ; Knapmeyer-Endrun, Brigitte ; Padovan, Sebastiano ; Plesa, Ana-Catalina ; Rivoldini, Attilio ; Robertsson, Johan ; Rodriguez, Sebastien ; Stähler, Simon C. ; Stutzmann, Eleonore ; Teanby, Nicholas A. ; Tosi, Nicola ; Vrettos, Christos ; Banerdt, Bruce ; Fa, Wenzhe ; Huang, Qian ; Irving, Jessica ; Ishihara, Yoshiaki ; Miljković, Katarina ; Mittelholz, Anna ; Nagihara, Seiichi ; Neal, Clive ; Qu, Shaobo ; Schmerr, Nicholas ; Tsuji, Takeshi
An autonomous lunar geophysical experiment package (ALGEP) for future space missions
Experimental Astronomy (2022). http://dx.doi.org/10.1007/s10686-022-09857-6

[54] Kawo, Abdisa ; Van Malderen, Roeland ; Pottiaux, Eric ; Van Schaeybroeck, Bert
Understanding the Present-Day Spatiotemporal Variability of Precipitable Water Vapor over Ethiopia: A Comparative Study between ERA5 and GPS
Remote Sensing, 14 issue 3 (2022). http://dx.doi.org/10.3390/rs14030686

[55] Khan, A. ; Sossi, P. A. ; Liebske, C. ; Rivoldini, A. ; Giardini, D.
Geophysical and cosmochemical evidence for a volatile-rich Mars

Earth and Planetary Science Letters, 578 (2022). http://dx.doi.org/10.1016/j.epsl.2021.117330

[56] Kobzar, O. ; Khalack, V. ; Bohlender, D. ; Mathys, G. ; Shultz, M. E. ; Bowman, D. M. ; Paunzen, E. ; Lovekin, C. ; David-Uraz, A. ; Sikora, J. ; Lampens, P. ; Richard, O.
Analysis of eight magnetic chemically peculiar stars with rotational modulation
Monthly Notices of the Royal Astronomical Society, 517, pp. 5340 - 5357 (2022).
http://dx.doi.org/10.1093/mnras/stac279

[57] Lampens, P. ; Mkrtichian, D. ; Lehmann, H. ; Gunsriwiwat, K. ; Vermeylen, L. ; Matthews, J. ; Kuschnig, R.
Updated modelling and refined absolute parameters of the oscillating eclipsing binary AS Eri
Monthly Notices of the Royal Astronomical Society, 512, pp. 917 - 925 (2022).
http://dx.doi.org/10.1093/mnras/stac289

[58] Le Bars, Michael ; Barik, Ankit ; Burmann, Fabian ; Lathrop, Daniel P. ; Noir, Jerome ; Schaeffer, Nathanael ; Triana, Santiago A.
Fluid Dynamics Experiments for Planetary Interiors
Surveys in Geophysics, 43 issue 1, pp. 229-261 (2022). http://dx.doi.org/10.1007/s10712-021-09681-1

[59] Lòpez, R.~A. ; Micera, A. ; Lazar, M. ; Poedts, S. ; Lapenta, G. ; Zhukov, A.~N. ; Boella, E. ; Shaaban, S.~M.
Mixing the Solar Wind Proton and Electron Scales. Theory and 2D-PIC Simulations of Firehose Instability
The Astrophysical Journal (2022). http://dx.doi.org/10.3847/1538-4357/ac66e4

[60] Maharana, A. ; Isavnin, A. ; Scolini, C. ; Wijsen, N. ; Rodriguez, L. ; Mierla, M. ; Magdalenic, J. ; Poedts, S.
Implementation and validation of the FRi3D flux rope Model in EUHFORIA
Advances in Space Research (2022). http://dx.doi.org/10.1016/j.asr.2022.05.056

[61] Mahy, L. ; Sana, H. ; Shenar, T. ; Sen, K. ; Langer, N. ; Marchant, P. ; Abdul-Masih, M. ; Banyard, G. ; Bodensteiner, J. ; Bowman, D. M. ; Dsilva, K. ; Fabry, M. ; Hawcroft, C. ; Janssens, S. ; Van Reeth, T. ; Eldridge, C.
Identifying quiescent compact objects in massive Galactic single-lined spectroscopic binaries
Astronomy & Astrophysics, 664 issue A159, pp. 38 (2022). http://dx.doi.org/10.1051/0004-6361/202243147

[62] Mandal, S. ; Chitta, L. P. ; Peter, H. ; Solanki, S. K. ; Aznar Cuadrado, R. ; Teriaca, L. ; Schühle, U. ; Berghmans, D. ; Auchère, F.
A highly dynamic small-scale jet in a polar coronal hole
Astronomy & Astrophysics, 664 issue A28 (2022). http://dx.doi.org/https://doi.org/10.1051/0004-6361/202243765

[63] Mandal, S. ; Chitta, L. P. ; Antolin, P. ; Peter, H. ; Solanki, S. K. ; Auchère, F. ; Berghmans, D. ; Zhukov, A. N. ; Teriaca, L. ; Cuadrado, R.A. ; Schühle, U. ; Parenti, S. ; Buchlin, E. ; Harra, L. ; Verbeeck, C. ; Kraaikamp, E. ; Long, D. M. ; Rodriguez, L. ; Pelouze, G. ; Schwanitz, C. ; Barczynski, K. ; Smith, P. j.
What drives decayless kink oscillations in active region coronal loops on the Sun?
Astronomy & Astrophysics, 666 issue L2, 16 pp. (2022). https://doi.org/10.1051/0004-6361/202244403

[64] Mathieu, Sophie ; Lefèvre, Laure ; von Sachs, Rainer ; Delouille, Veronique ; Ritter, Christian ; Clette, Frédéric
Nonparametric monitoring of sunspot number observations
Journal of Quality Technology, (2022). http://dx.doi.org/10.1080/00224065.2022.2041376

[65] Matoza, R.S. ; Fee, D. ; Assink, J.D. ; Iezzi, A.M. ; Green, D.N. ; Kim, K. ; Toney, L. ; Lecocq, T. ; Krishnamoorthy, S. ; Lalande, J.-M. ; Nishida, K. ; Gee, K.L. ; Haney, M.M. ; Ortiz, H.D. ; Brissaud, Q. ; Martire, L. ; Rolland, L. ; Vergados, P. ; Nippress, A. ; Park, J. ; Shani-Kadmiel, S. ; Witsil, A. ; Arrowsmith, S. ; Caudron, C. ; Watada, S. ; Perttu, A.B. ; Taisne, B. ; Mialle, P. ; Le Pichon, A. ; Vergoz, J. ; Hupe, P. ; Blom, P.S. ; Waxler, R. ; De Angelis, S. ; Snively, J.B. ; Ringler, A.T. ; Anthony, R.E. ; Jolly, A.D. ; Kilgour, G. ; Averbuch, G. ; Ripepe, M. ; Ichihara, M. ; Arciniega-Ceballos, A. ; Astafyeva, E. ; Ceranna, L. ; Cevuard, S. ; Che, I.-Y. ; De Negri, R. ; Ebeling, C.W. ; Evers, L.G. ; Franco-Marin, L.E. ; Gabrielson, T.B. ; Hafner, K. ; Harrison, R.G. ; Komjathy, A. ; Lacanna, G. ; Lyons, J. ; Macpherson, K.A. ; Marchetti, E. ; McKee, K.F. ; Mellors, R.J. ; Mendo-Pérez, G. ; Mikesell, T.D. ; Munaibari, E. ; Oyola-Merced, M. ; Park, I. ; Pilger, C. ; Ramos, C. ; Ruiz, M.C. ; Sabatini, R. ; Schwaiger, H.F. ; Tailpied, D. ; Talmadge, C. ; Vidot, J. ; Webster, J. ; Wilson, D.C.
Atmospheric waves and global seismoacoustic observations of the January 2022 Hunga eruption, Tonga
Science, First Release (2022). http://dx.doi.org/10.1126/science.abo7063

[66] Meißenhelter, Hermann ; Noeker, Matthias ; Andert, Tom ; Weller, René ; Haser, Benjamin ; Karatekin, Özgür ; Ritter, Birgit ; Hofacker, Max ; Balestrero Machado, Larissa ; Zachmann, Gabriel
Efficient and Accurate Methods for Computing the Gravitational Field of Irregular-Shaped Bodies
IEEE Aerospace Conference (AERO), pp. 1-17 (2022).
http://dx.doi.org/10.1109/AERO53065.2022.9843753

[67] Michel, Patrick ; Küppers, Michael ; Bagatin, Adriano Campo ; Carry, Benoit ; Charnoz, Sébastien ; de Leon, Julia ; Fitzsimmons, Alan ; Gordo, Paulo ; Green, Simon F. ; Hérique, Alain ; Juzi, Martin ; Karatekin, Özgür ; et, al.
The ESA Hera Mission: Detailed Characterization of the DART Impact Outcome and of the Binary Asteroid (65803) Didymos
The Planetary Science Journal, 3 issue 7, pp. 160 (2022). http://dx.doi.org/10.3847/PSJ/ac6f52

[68] Mierla, M. ; Zhukov, A. N. ; Berghmans, D. ; Parenti, S. ; Auchère, F. ; Heinzel, P. ; Seaton, D. B. ; Palmerio, E. ; Jejcic, S. ; Janssens, J. ; Kraaikamp, E. ; Nicula, B. ; Long, D. M. ; Hayes, L. A. ; Jebaraj, I. C. ; Talpeanu, D.-C. ; D'Huys, E. ; Dolla, L. ; Gissot, S. ; Magdalenic, J. ; Rodriguez, L. ; Shestov, S. ; Stegen, K. ; Verbeeck, C. ; Sasso, S. ; Romoli1, M. ; Andretta, V.
Prominence Eruption Observed in He II 304 Å up to >6 R by EUI/FSI aboard Solar Orbiter
Astronomy & Astrophysics (2022). http://dx.doi.org/10.1051/0004-6361/202244020

[69] Mierla, Marilena ; Inhester, Bernd ; Zhukov, Andrei ; Shestov, Sergei ; Bemporad, Alessandro ; Lamy, Philippe ; Koutcmy, Serge
Polarimetric Studies of a Fast Coronal Mass Ejection
Solar Physics, 297 issue 7 (2022). http://dx.doi.org/10.1007/s11207-022-02018-0

[70] Morard, Guillaume ; Antonangeli, Daniele ; Bouchet, Johann ; Rivoldini, Attilio ; Boccato, Silvia ; Miozzi, Francesca ; Boulard, Eglantine ; Bureau, Hélène ; Mezouar, Mohamed ; Prescher, Clemens ; Chariton, Stella ; Greenberg, Eran
Structural and Electronic Transitions in Liquid FeO Under High Pressure
Journal of Geophysical Research: Solid Earth, 127 issue 11 (2022).
http://dx.doi.org/10.1029/2022JB025117

[71] Morel, T ; Blazère, A ; Semaan, T ; Gosset, E ; Zorec, J ; Frémat, Y ; Blomme, R ; Daflon, S ; Lobel, A ; F Nieva, M ; Przybilla, N ; Gebran, M ; Herrero, A ; Mahy, L ; Santos, W ; Tautvaisiene, G ; Gilmore, G ; Randich, S ; J Alfaro, E ; Bergemann, M ; Carraro, G ; Damiani, F ; Franciosini, E ; Morbidelli, L ; Pancino, E ; C Worley, C ; Zaggia, S
The Gaia-ESO survey: A spectroscopic study of the young open cluster NGC 3293
Astronomy & Astrophysics, 665 issue A108 (2022). http://dx.doi.org/10.1051/0004-6361/202244112

[72] Mousis, O. ; Bouquet, A. ; Langevin, Y. ; Dehant, V. ; Le Maistre, S. ; Van Hoolst, T. ; and, et al.
Moonraker – Enceladus Multiple Flyby Mission
Planetary Science Journal, 3 issue 268, pp. 1-12 (2022). http://dx.doi.org/10.3847/PSJ/ac9c03

[73] Mrak, Sebastijan ; Zhu, Qingyu ; Deng, Yue ; Dammasch, Ingolf E. ; Dominique, Marie ; Drob, Douglas ; Hairston, Marc R. ; Nishimura, Yukitoshi ; Semeter, Joshua
Modeling Solar Eclipses at Extreme Ultra Violet Wavelengths and the Effects of Nonuniform Eclipse Shadow on the Ionosphere-Thermosphere system
JGR: Space Physics, 127 issue 12 (2022). https://doi.org/10.1029/2022JA031058

[74] Noeker, Matthias ; Karatekin, Özgür
The wedge-pentahedra method (WPM): Topographic reduction of local terrain in the context of solar system surface gravimetry and robotic exploration
Frontiers in Space Technologies, pp. 1-17 (2022). http://dx.doi.org/10.3389/frspt.2022.982873

[75] Oliva, F. ; D'Aversa, E. ; Bellucci, G. ; Carrozzo, F. G. ; Ruiz Lozano, L. ; Altieri, F. ; Thomas, I. R. ; Karatekin, O. ; Cruz Mermy, G. ; Schmidt, F. ; Robert, S. ; Vandaele, A. C. ; Daerden, F. ; Ristic, B. ; Patel, M. R. ; López-Moreno, J. -J. ; Sindoni, G.
Martian CO2 Ice Observation at High Spectral Resolution With ExoMars/TGO NOMAD
Journal of Geophysical Research: Planets, 127 issue 5, pp. e07083 (2022).
http://dx.doi.org/10.1029/2021JE007083

[76] Olofsson, H. ; Khouri, T. ; Sargent, B.A. ; Winnberg, A. ; Blommaert, J.A.D.L. ; Groenewegen, M.A.T. ; Muller, S. ; Kastner, J.H. ; Meixner, M. ; Otsuka, M. ; Patel, N. ; Ryde, N. ; Srinivasan, S.
CO line observations of OH/IR stars in the inner Galactic Bulge: Characteristics of stars at the tip of the AGB
Astronomy &Astrophysics, 665, pp. A82 (2022). https://doi.org/10.1051/0004-6361/202244053

[77] Panchal, A. ; Joshi, Y. ; De Cat, P. ; Tiwari, S.
Long-term photometric and low-resolution spectroscopic analysis of five contact binaries
The Astrophysical Journal, 927, pp. 1--18 (id. 12) (2022). http://dx.doi.org/10.3847/1538-4357/ac45fb

[78] Pinat, Elisa ; Defraigne, Pascale
In-depth analysis of UTC information broadcast in GNSS navigation messages
GPS Solutions (2022). http://dx.doi.org/10.1007/s10291-022-01276-6

[79] Plesa, Ana-Catalina ; Wieczorek, Mark ; Knapmeyer, Martin ; Rivoldini, Attilio ; Walterová, Michaela ; Breuer, Doris
Geophysical Exploration of the Solar System: Interior dynamics and thermal evolution of Mars – a geodynamic perspective
Advances in Geophysics, 63 (2022). http://dx.doi.org/10.1016/bs.agph.2022.07.005

[80] Podladchikova, Tatiana ; Jain, Shantanu ; Veronig, Astrid M. ; Sutyrina, Olga ; Dumbović, Mateja ; Clette, Frédéric ; Pötzi, Werner
Maximal growth rate of the ascending phase of a sunspot cycle for predicting its amplitude
Astronomy & Astrophysics, 663, pp. id. A88, 11 pp. (2022). http://dx.doi.org/%2010.1051/0004-6361/202243509

[81] Pou, L. ; Nimmo, F. ; Rivoldini, A. ; Khan, A. ; Bagheri, A. ; Gray, T. ; Samuel, H. ; Lognonné, P. ; Plesa, A.-C. ; Gudkova, T. ; Giardini, D.
Tidal Constraints on the Martian Interior
Journal of Geophysical Research: Planets, 127 issue 11 (2022).
http://dx.doi.org/10.1029/2022JE007291

[82] Quintero Noda, Q. ; Schlichenmaier, R. ; Bellot Rubio, L R. ; ManyOtherAuthors, X. ; Berghmans, D. ; Vansintjan, R.
The European Solar Telescope
Astronomy & Astrophysics, 666, pp. A21 (2022). http://dx.doi.org/10.1051/0004-6361/202243867

[83] Randich, S. ; Gilmore, G. ; Magrini, L. ; Sacco, G. G. ; Jackson, R. J. ; Jeffries, R. D. ; Worley, C. C. ; Hourihane, A. ; Gonneau, A. ; Viscasillas Vazquez, C. ; Franciosini, E. ; Lewis, J. R. ; Alfaro, E. J. ; Allende Prieto, C. ; Bensby, T. ; Blomme, R. ; Bragaglia, A. ; Flaccomio, E. ; François, P. ; Irwin, M. J. ; Koposov, S. E. ; Korn, A. J. ; Lanzafame, A. C. ; Pancino, E. ; Recio-Blanco, A. ; Smiljanic, R. ; Van Eck, S. ; Zwitter, T. ; Asplund, M. ; Bonifacio, P. ; Feltzing, S. ; Binney, J. ; Drew, J. ; Ferguson, A. M. N. ; Micela, G. ; Negueruela, I. ; Prusti, T. ; Rix, H. -W. ; Vallenari, A. ; Bayo, A. ; Bergemann, M. ; Biazzo, K. ; Carraro, G. ; Casey, A. R. ; Damiani, F. ; Frasca, A. ; Heiter, U. ; Hill, V. ; Jofré, P. ; de Laverny, P. ; Lind, K. ; Marconi, G. ; Martayan, C. ; Masseron, T. ; Monaco, L. ; Morbidelli, L. ; Prisinzano, L. ; Sbordone, L. ; Sousa, S. G. ; Zaggia, S. ; Adibekyan, V. ; Bonito, R. ; Caffau, E. ; Daflon, S. ; Feuillet, D. K. ; Gebran, M. ; Gonzalez Hernandez, J. I. ; Guiglion, G. ; Herrero, A. ; Lobel, A. ; Maiz Apellaniz, J. ; Merle, T. ; Mikolaitis, Š. ; Montes, D. ; Morel, T. ; Soubiran, C. ; Spina, L. ; Tabernero, H. M. ; Tautvaišiene, G. ; Traven, G. ; Valentini, M. ; Van der Swaelmen, M. ; Villanova, S. ; Wright, N. J. ; Abbas, U. ; Aguirre Børsen-Koch, V. ; Alves, J. ; Balaguer-Nunez, L. ; Barklem, P. S. ; Barrado, D. ; Berlanas, S. R. ; Binks, A. S. ; Bressan, A. ; Capuzzo-Dolcetta, R. ; Casagrande, L. ; Casamiquela, L. ; Collins, R. S. ; D'Orazi, V. ; Dantas, M. L. L. ; Debattista, V. P. ; Delgado-Mena, E. ; Di Marcantonio, P. ; Drazdauskas, A. ; Evans, N. W. ; Famaey, B. ; Franchini, M. ; Frémat, Y. ; Friel, E. D. ; Fu, X. ; Geisler, D. ; Gerhard, O. ; Gonzalez Solares, E. A. ; Grebel, E. K. ; Gutierrez Albarran, M. L. ; Hatzidimitriou, D. ; Held, E. V. ; Jiménez-Esteban, F. ; Jönsson, H. ; Jordi, C. ; Khachaturyants, T. ; Kordopatis, G. ; Kos, J. ; Lagarde, N. ; Mahy, L. ; Mapelli, M. ; Marfil, E. ; Martell, S. L. ; Messina, S. ; Miglio, A. ; Minchev, I. ; Moitinho, A. ; Montalban, J. ; Monteiro, M. J. P. F. G. ; Morossi, C. ; Mowlavi, N. ; Mucciarelli, A. ; Murphy, D. N. A. ; Nardetto, N. ; Ortolani, S. ; Paletou, F. ; Palouš, J. ; Paunzen, E. ; Pickering, J. C. ; Quirrenbach, A. ; Re Fiorentin, P. ; Read, J. I. ; Romano, D. ; Ryde, N. ; Sanna, N. ; Santos, W. ; Seabroke, G. M. ; Spagna, A. ; Steinmetz, M. ; Stonkuté, E. ; Sutorius, E. ; Thévenin, F. ; Tosi, M. ; Tsantaki, M. ; Vink, J. S. ; Wright, N. ; Wyse, R. F. G. ; Zoccali, M. ; Zorec, J. ; Zucker, D. B. ; Walton, N. A.
The Gaia-ESO Public Spectroscopic Survey: Implementation, data products, open cluster survey, science, and legacy
Astronomy & Astrophysics, 666, pp. A121 (29pp) (2022). http://dx.doi.org/10.1051/0004-6361/202243141

[84] Rebekka S. R., Legrand J., Agren J., Steffen H., Lidberg M.
HV-LSC-ex2: Velocity field interpolation using extended least-squares collocation
Journal of Geodesy 96, 15, (2022). http://dx.doi.org/10.1007/s00190-022-01601-4

[85] Reichel, Martin A. ; Kimeswenger, Stefan ; van Hoof, Peter A. M. ; Zijlstra, Albert A. ; Barría, Daniela; ; Hajduk, Marcin ; Van de Steene, Griet C. ; Tafoya, Daniel
Recombination of Hot Ionized Nebulae: The Old Planetary Nebula around V4334 Sgr (Sakurai's Star)
The Astrophysical Journal, 939 issue 2, pp. 103-114 (2022). http://dx.doi.org/10.3847/1538-4357/ac90c4

[86] Rekier, Jérémy
Free Core Nutation and Its Relation to the Spin-over Mode
The Planetary Science Journal, 3 issue 6, pp. 133 (2022). http://dx.doi.org/10.3847/PSJ/ac6ce2

[87] Rekier, J. ; Chao, B.F. ; Chen, J. ; Dehant, V. ; Rosat, S. ; Zhu, P.
Earth's Rotation: Observations and Relation to Deep Interior
Interior. Surv Geophys 43, 149–175 (2022). https://doi.org/10.1007/s10712-021-09669-x

[88] Richardson, Derek C. ; Agrusa, Harrison F. ; Barbee, Brent ; Bottke, William F. ; Cheng, Andrew F. ; Eggl, Siegfried ; Ferrari, Fabio ; Hirabayashi, Masatoshi ; Karatekin, Özgür ; et, al.
Predictions for the Dynamical States of the Didymos System before and after the Planned DART Impact
The Planetary Science Journal, 3 issue 7, pp. 157 (2022). http://dx.doi.org/10.3847/PSJ/ac76c9

[89] Ripepi, V. ; Chemin, L. ; Molinaro, R. ; Cioni, M.R.L. ; Bekki, K. ; Clementini, G. ; de Grijs, R. ; De Somma, G. ; El Youssoufi, D. ; Girardi, L. ; Groenewegen, M.A.T. ; Ivanov, V. ; Marconi, M. ; McMillan, P.J. ; van Loon, J.Th.
The VMC Survey – XLVIII. Classical cepheids unveil the 3D geometry of the LMC
Monthly Notices of the Royal Astronomical Society, 512, pp. 563-582 (2022).
https://doi.org/10.1093/mnras/stac595

[90] Rochus, P. ; Auchere, F. ; Berghmans, D. ; Harra, L. ; Schmutz, W. ; Schühle, U. ; Addison, P. ; Appourchaux, T. ; Aznar Cuadrado, R. ; Baker, D. ; Barbay, J. ; Bates, D. ; BenMoussa, A. ; Bergmann, M. ; Beurthe, C. ; Borgo, B. ; Bonte, K. ; Bouzit, M. ; Bradley, L. ; Büchel, V. ; Buchlin, E. ; Büchner, J. ; Cabé, F. ; Cadiergues, L. ; Chaigneau, M. ; Chares, B. ; Choque Cortez, C. ; Coker, P. ; Condamin, M. ; Coumar, S. ; Curdt, W. ; Cutler, J. ; Davies, D. ; Davison, G. ; Defise, J.-M. ; Del Zanna, G. ; Delmotte, F. ; Delouille, V. ; Dolla, L. ; Dumesnil, C. ; Dürig, F. ; Enge, R. ; François, S. ; Fourmond, J.-J. ; Gillis, J.-M. ; Giordanengo, B. ; Gissot, S. ; Green, L. ; Guerreiro, N. ; Guilbaud, A. ; Gyo, M. ; Haberreiter, M. ; Hafiz, A. ; Hailey, M. ; Halain, J.-P. ; Hansotte, J. ; Hecquet, C. ; Heerlein, K. ; Hellin, M.-L. ; Hemsley, S. ; Hermans, A. ; Hervier, V. ; Hochedez, J.-F. ; Houbrechts, Y. ; Ihsan, K. ; Jacques, L. ; Jérôme, A. ; Jones, J. ; Kahle, M. ; Kennedy, T. ; Klaproth, M. ; Kolleck, M. ; Koller, S. ; Kotsialos, E. ; Kraaikamp, E. ; Langer, P. ; Lawrenson, A. ; Le Clech', J.-C. ; Lenaerts, C. ; Liebecq, S. ; Linder, D. ; Long, D. M. ; Mampaey, B. ; Markiewicz-Innes, D. ; Marquet, B. ; Marsch, E. ; Matthews, S. ; Mazy, E. ; Mazzoli, A. ; Meining, S. ; Meltchakov, E. ; Mercier, R. ; Meyer, S. ; Monecke, M. ; Monfort, F. ; Morinaud, G. ; Moron, F. ; Mountney, L. ; Müller, R. ; Nicula, B. ; Parenti, S. ; Peter, H. ; Pfiffner, D. ; Philippon, A. ; Phillips, I. ; Plesseria, J.-Y. ; Pylyser, E. ; Rabecki, F. ; Ravet-Krill, M.-F. ; Rebellato, J. ; Renotte, E. ; Rodriguez, L. ; Roose, S. ; Rosin, J. ; Rossi, L. ; Roth, P. ; Rouesnel, F. ; Roulliay, M. ; Rousseau, A. ; Ruane, K. ; Scanlan, J. ; Schlatter , P. ; Seaton, D. B. ; Silliman, K. ; Smit, S. ; Smith, P.J. ; Solanki, S.K. ; Spescha, M. ; Spencer, A. ; Stegen, K. ; Stockman, Y. ; Szwec, N. ; Tamiatto, C. ; Tandy, J. ; Teriaca, L. ; Theobald, C. ; Tychon, I. ; van Driel-Gesztelyi, L. ; Verbeeck, C. ; Vial, J.-C. ; Werner, S. ; West, M. J. ; Westwood, D. ; Wiegelmann, T. ; Willis, G. ; Winter, B. ; Zerr, A. ; Zhang, X. ; Zhukov, A. N.
The Solar Orbiter EUI instrument: The Extreme Ultraviolet Imager (Corrigendum)
Astronomy & Astrophysics, 665, C1 (2022). http://dx.doi.org/https://doi.org/10.1051/0004-6361/201936663e

[91] Rodriguez, L. ; Hosteaux, S. ; Davies, J. A. ; Willems, S. ; Pant, V. ; Harrison, R.A. ; Berghmans, D. ; Bothmer, V. ; Eastwood, J.P. ; Gallagher, P.T. ; Kilpua, E.K.J. ; Magdalenic, J. ; Mierla, M. ; Moestl, C. ; Rouillard, A.P. ; Odstrcil, D. ; Poedts, S.
Comparing the HELCATS manual and automatic catalogues of CMEs using STEREO-HI data
Solar Physics volume 297, Article number: 23 (2022). http://dx.doi.org/10.1007/s11207-022-01959-w

[92] Ruiz Lozano, L. ; Karatekin, Ö. ; Dehant, V. ; Bellucci, G. ; Oliva, F. ; Aversa, E.D. ; Carrozzo, F.G. ; Altieri, F. ; Thomas, I. ; Willame, Y. ; Robert, S. ; Vandaele, A.C. ; Daerden, F. ; Ristic, B. ; Patel, M.R. ; Lopez Moreno, J.J.
Evaluation of the capability of ExoMars-TGO NOMAD infrared nadir channel for water ice clouds detection on Mars
Remote Sensing, 14 issue 4143, pp. 1-22 (2022). http://dx.doi.org/10.3390/rs14174143

[93] Samadi-Ghadim, A. ; Lampens, P. ; Gizon, L.

KIC 6951642: A confirmed Kepler gamma Doradus – delta Scuti star with intermediate to fast rotation in a possible single-lined binary system
Astronomy & Astrophysics, 667, pp. A60 (2022). http://dx.doi.org/10.1051/0004-6361/202243507

[94] Samara, Evangelia ; Laperre, Brecht ; Kieokaew, Rungployphan ; Temmer, Manuela ; Verbeke, Christine ; Rodriguez, Luciano ; Magdalenic, Jasmina ; Poedts, Stefaan
Dynamic Time Warping as a means to assess solar wind time series
The Astrophysical Journal, Volume 927, Number 2, p187 (2022). http://dx.doi.org/10.3847/1538-4357/ac4af6

[95] Samara, E. ; Magdalenic, J. ; Rodriguez, L. ; Heinemann, S. G. ; Georgoulis, M. K. ; Hofmeister, S. J. ; Poedts, S.
Influence of mid-latitude coronal hole morphology on the solar wind speed at Earth
Astronomy & Astrophysics, 662, A68, 19 pp. (2022). https://doi.org/10.1051/0004-6361/202142793

[96] Sana, H. ; Ramírez-Agudelo, O. H. ; Hénault-Brunet, V. ; Mahy, L. ; Almeida, L. A. ; de Koter, A. ; Bestenlehner, J. M. ; Evans, C. J. ; Langer, N. ; Schneider, F. R. N. ; Crowther, P. A. ; de Mink, S. E. ; Herrero, A. ; Lennon, D. J. ; Gieles, M. ; Maíz Apellániz, J. ; Renzo, M. ; Sabbi, E. ; van Loon, J. Th. ; Vink, J. S.
The VLT-FLAMES Tarantula Survey. Observational evidence for two distinct populations of massive runaway stars in 30 Doradus
Astronomy & Astrophysics, 668 issue L5, pp. 7 (2022). http://dx.doi.org/10.1051/0004-6361/202244677

[97] Schifano, L. ; Vervaeke, M. ; Rosseel, D. ; Verbaenen, J. ; Thienpont, H. ; Dewitte, S. ; Berghmans, F. ; Smeesters, L
Freeform Wide Field-of-View Spaceborne Imaging Telescope: From Design to Demonstrator
Sensors, 22(21), pp. 8233 (2022). http://dx.doi.org/10.3390/s22218233

[98] Schifano, Luca ; Berghmans, Francis ; Dewitte, Steven ; Smeesters, Lien
Optical Design of a Novel Wide-Field-of-View Space-Based Spectrometer for Climate Monitoring
Sensors, 22 issue 15 (2022). http://dx.doi.org/10.3390/s22155841

[99] Sen, K. ; Langer, N. ; Marchant, P. ; Menon, A. ; de Mink, S. E. ; Schootemeijer, A. ; Schürmann, C. ; Mahy, L. ; Hastings, B. ; Nathaniel, K. ; Sana, H. ; Wang, C. ; Xu, X. T.
Detailed models of interacting short-period massive binary stars
Astronomy & Astrophysics, 659 issue A98, pp. 33 (2022). http://dx.doi.org/10.1051/0004-6361/202142574

[100] Sermeus, Jan ; Elen, Jan
Twee dimensies van kritisch denken
Dimensies: Tijdschrift voor didactiek van de Mens- en Maatschappijvakken, 4, pp. 11-26 (2022). https://dimensies.nu/twee-dimensies-van-kritisch-denken-nr-4-feb-2022/

[101] Sert, H. ; Hugentobler, U. ; Karatekin, O. ; Dehant, V.
Potential of UT1–UTC transfer to the Galileo constellation using onboard VLBI transmitters
Journal of Geodesy, 96 issue 83 (2022). http://dx.doi.org/10.1007/s00190-022-01675-0

[102] Shenar, T. ; Sana, H. ; Mahy, L. ; Maíz Apellániz, J. ; Crowther, Paul A. ; Gromadzki, M. ; Herrero, A. ; Langer, N. ; Marchant, P. ; Schneider, F. R. N. ; Sen, K. ; Soszyński, I. ; Toonen, S.
The Tarantula Massive Binary Monitoring. VI. Characterisation of hidden companions in 51 single-lined O-type binaries: A flat mass-ratio distribution and black-hole binary candidates
Astronomy & Astrophysics, 665 issue A148, pp. 42 (2022). http://dx.doi.org/10.1051/0004-6361/202244245

[103] Shenar, Tomer ; Sana, Hugues ; Mahy, Laurent ; El-Badry, Kareem ; Marchant, Pablo ; Langer, Norbert ; Hawcroft, Calum ; Fabry, Matthias ; Sen, Koushik ; Almeida, Leonardo A. ; Abdul-Masih, Michael ; Bodensteiner, Julia ; Crowther, Paul A. ; Gieles, Mark ; Gromadzki, Mariusz ; Hénault-Brunet, Vincent ; Herrero, Artemio ; de Koter, Alex ; Iwanek, Patryk ; Kozłowski, Szymon ; Lennon, Daniel J. ; Maíz Apellániz, Jesús ; Mróz, Przemysław ; Moffat, Anthony F. J. ; Picco, Annachiara ; Pietrukowicz, Paweł ; Poleski, Radosław ; Rybicki, Krzysztof ; Schneider, Fabian R. N. ; Skowron, Dorota M. ; Skowron, Jan ; Soszyński, Igor ; Szymański, Michał K. ; Toonen, Silvia ; Udalski, Andrzej ; Ulaczyk, Krzysztof ; Vink, Jorick S. ; Wrona, Marcin
An X-ray-quiet black hole born With a negligible kick in a massive binary within the Large Magellanic Cloud
Nature Astronomy, 6, pp. 1085-1092 (2022). http://dx.doi.org/%2010.1038/s41550-022-01730-y

[104] Shestov, Sergei ; Voitenko, Yuri ; Zhukov, Andrei
Initiation of Alfvénic turbulence by Alfvén wave collisions: A numerical study
Astronomy & Astrophysics, 661, pp. A93 (2022). http://dx.doi.org/10.1051/0004-6361/202142362

[105] Statler, Thomas S. ; Raducan, Sabina D. ; Barnouin, Olivier S. ; DeCoster, Mallory E. ; Chesley, Steven R. ; Barbee, Brent ; Agrusa, Harrison F. ; Cambioni, Saverio ; Cheng, Andrew F. ; Dotto, Elisabetta ; Eggl, Siegfried ; Fahnestock, Eugene G. ; Ferrari, Fabio ; Graninger, Dawn ; Herique, Alain ; Herreros, Isabel ; Hirabayashi, Masatoshi ; Ivanovski, Stavro ; Jutzi, Martin ; Karatekin, Özgür ; et, al.
After DART: Using the First Full-scale Test of a Kinetic Impactor to Inform a Future Planetary Defense Mission
The Planetary Science Journal, 3 issue 10, pp. 244 (2022). http://dx.doi.org/10.3847/PSJ/ac94c1

[106] Steffen, Rebekka ; Legrand, Juliette ; Agren, Jonas ; Steffen, Holger ; Lidberg, Martin
HV-LSC-ex2: velocity field interpolation using extended least-squares collocation
Journal of geodesy, 96 issue 15 (2022). http://dx.doi.org/10.1007/s00190-022-01601-4

[107] Sulzbach, R. ; Wziontek, H. ; Hart-Davis, M. ; Dobslaw, H. ; Scherneck, H.-G. ; Van Camp, M. ; Omang, O.C.D. ; Antokoletz, E.D. ; Voigt, C. ; Dettmering, D. ; Thomas, M.
Modeling Gravimetric Signatures of Third-Degree Ocean Tides and their Detection in Superconducting Gravimeter Records
Journal of Geodesy, 96 issue 35 (2022). http://dx.doi.org/10.1007/s00190-022-01609-w

[108] Talpeanu, Dana-Camelia ; Poedts, Stefaan ; D'Huys, Elke ; Mierla, Marilena
Study of the propagation, in situ signatures, and geoeffectiveness of shear-induced coronal mass ejections in different solar winds
Astronomy & Astrophysics, 658 issue A56 (2022). http://dx.doi.org/10.1051/0004-6361/202141977

[109] Talpeanu, Dana-Camelia ; Poedts, Stefaan ; D'Huys, Elke ; Mierla, Marilena ; Richardson, Ian G.
Interaction of coronal mass ejections and the solar wind – A force analysis
Astronomy & Astrophysics, 663 issue A32 (2022). http://dx.doi.org/10.1051/0004-6361/202243150

[110] Telloni, D. ; Many, coauthors ; ROB, only ; Berghmans, D. ; Kraaikamp, E. ; Rodriguez, L. ; Verbeeck, C. ; Zhukov, A. N.
Observation of Magnetic Switchback in the Solar Corona
The Astrophysical Journal Letters (2022). http://dx.doi.org/10.3847/2041-8213/ac8104

[111] Temel, Orkun ; Senel, Cem Berk ; Spiga, Aymeric ; Murdoch, Naomi ; Banfield, Don ; Karatekin, Ozgur
Spectral Analysis of the Martian Atmospheric Turbulence: InSight Observations
Geophysical Research Letters, 49 issue 15, pp. L3 (2022). http://dx.doi.org/10.1051/0004-6361/202244388

[112] Thuillier, Gerard ; Zhu, Ping ; Snow, Martin ; Zhang, Peng ; Ye, Xin

Characteristics of solar-irradiance spectra from measurements, modeling, and theoretical approach
Light Science and Applications (2022). http://dx.doi.org/10.1038/s41377-022-00750-7

[113] Tiwari, S. K. ; Hansteen, V. H. ; De Pontieu, B. ; Berghmans, D.
SolO/EUI Observations of Ubiquitous Fine-scale Bright Dots in an Emerging Flux Region: Comparison with a Bifrost MHD Simulation
The Astrophysical Journal, Volume 929, Number 1 (2022). https://doi.org/10.3847/1538-4357/ac5d46

[114] Triana, Santiago A. ; Guerrero, Gustavo ; Barik, Ankit ; Rekier, Jérémy
Identification of Inertial Modes in the Solar Convection Zone
The Astrophysical Journal Letters, 934 issue 1, pp. L4 (2022). http://dx.doi.org/10.3847/2041-8213/ac7dac

[115] Triana, Santiago A. ; Dumberry, Mathieu ; Cébron, David ; Vidal, Jérémie ; Trinh, Antony ; Gerick, Felix ; Rekier, Jérémy
Core Eigenmodes and their Impact on the Earth's Rotation
Surveys in Geophysics, 43 issue 1, pp. 107-148 (2022). http://dx.doi.org/10.1007/s10712-021-09668-y

[116] Triantafyllou, Ioanna ; Katsiyannis, Athanassios C. ; Papadopoulos, Gerassimos A.
Historical earthquakes, tsunamis, volcanic eruptions and comets in the eastern Mediterranean and the Sina sub-plate: evidence from two little-known Greek documents
Natural Hazards (2022). http://dx.doi.org/10.1007/s11069-022-05736-7

[117] Valenzuela-Malebrán, Carla ; Cesca, Simone ; López-Comino, José Ángel ; Zeckra, Martin ; Krüger, Frank ; Dahm, Torsten
Source mechanisms and rupture processes of the Jujuy seismic nest, Chile-Argentina border
Journal of South American Earth Sciences (2022).
http://dx.doi.org/https://doi.org/10.1016/j.jsames.2022.103887

[118] Van Camp, M. ; Pereira dos Santos, F. ; Murbröck, M. ; Petit, G. ; Müller, J.
Lasers and Ultracold Atoms for a Changing Earth
EOS, 103 issue 1, pp. 32-37 (2022). http://dx.doi.org/10.1029/2021EO210673

[119] Van Camp, M. ; de Viron, O. ; Dassargues, A. ; Delobbe, L. ; Chanard, K. ; Gobron, K.
Extreme hydrometeorological events, a challenge for gravimetric and seismology networks
Earth's Future (2022). http://dx.doi.org/10.1029/2022EF002737

[120] Van Camp, M. ; de Viron, O. ; Ferreira, A.M.G. ; Verhoeven, O.
A naive Bayesian method to chase mantle plumes in global tomography models
Geophysical Journal International (2022). http://dx.doi.org/10.1093/gji/ggac415

[121] Van Malderen, Roeland ; Pottiaux, Eric ; Stankunavicius, Gintautas ; Beirle, Steffen ; Wagner, Thomas ; Brenot, Hugues ; Bruyninx, Carine ; Jones, Jonathan
Global Spatiotemporal Variability of Integrated Water Vapor Derived from GPS, GOME/SCIAMACHY and ERA-Interim: Annual Cycle, Frequency Distribution and Linear Trends
Remote Sensing, 14 issue 4 (2022). https://doi.org/10.3390/rs14041050

[122] Van Noten, Koen ; Lecocq, Thomas ; Goffin, Céline ; Meyvis, Bruno ; Molron, Justine ; Debacker, Timothy N. ; Devleeschouwer, Xavier
Brussels' bedrock paleorelief from borehole-controlled power laws linking polarised H/V resonance frequencies and sediment thickness
Journal of Seismology, 26, pp. 35-55 (2022). http://dx.doi.org/10.1007/s10950-021-10039-8

[123] Van Reeth, T. ; De Cat, P. ; Van Beeck, J. ; Prat, V. ; Wright, D.J. ; Lehmann, H. ; Chené, A.-N. ; Kambe, E. ; Yang, S.L.S. ; Gentile, G. ; Joos, M.

The near-core rotation of HD112429: a γ Doradus star with TESS photometry and legacy spectroscopy
Astronomy & Astrophysics, 662, pp. 1--15 (id. A58) (2022). http://dx.doi.org/10.1051/0004-6361/202142921

[124] Verbeke, Christine ; Baratashvili, Tinatin ; Poedts, Stefaan
ICARUS, a New inner heliospheric Model With a flexible grid
Astronomy & Astrophysics, 662 (2022). http://dx.doi.org/10.1051/0004-6361/202141981

[125] Verscharen, Daniel ; Chandran, Benjamin D.~G. ; Boella, Elisabetta ; Halekas, Jasper ; Innocenti, Maria Elena ; Jagarlamudi, Vamsee K. ; Micera, Alfredo ; Pierrard, Viviane ; Stverak, Stepan ; Vasko, Ivan Y. ; Velli, Marco ; Whittlesey, Phyllis L.
Electron-driven instabilities in the solar wind
Frontiers in Astronomy and Space Sciences (2022). http://dx.doi.org/10.3847/1538-4357/ac7da6

[126] Vincent, D. ; Lambrechts, J. ; Karatekin, Ö. ; Dehant, V. ; Deleersnijder, E.
A numerical study of the liquid motion in Titan's subsurface ocean
Icarus, 388 issue 115219 (2022). http://dx.doi.org/10.1016/j.icarus.2022.115219

[127] Wauters, Laurence ; Dominique, Marie ; Milligan, Ryan ; Dammasch, I.E Ingolf ; Kretzschmar, Matthieu ; Machol, Janet
Observation of a Flare and Filament Eruption in Lyman-α on 8 September 2011 by the PRoject for OnBoard Autonomy/Large Yield Radiometer (PROBA2/LYRA)
Solar Physics, 297 issue 36 (2022). http://dx.doi.org/10.1007/s11207-022-01963-0

[128] West, M. J. ; Seaton, D. B. ; D'Huys, E. ; Mierla, M. ; Laurenza, M. ; Meyer, K. A. ; Berghmans, D. ; Rachmeler, L. ; Rodriguez, L. ; Stegen, K.
A Review of the Extended EUV Corona Observed by the Sun Watcher with Active Pixels and Image Processing (SWAP) Instrument
Solar Physics, 297 issue 136 (2022). http://dx.doi.org/https://doi.org/10.1007/s11207-022-02063-9

[129] Wieczorek, Mark A. ; Broquet, Adrien ; McLennan, Scott M. ; Rivoldini, Attilio ; Golombek, Matthew ; Antonangeli, Daniele ; Beghein, Caroline ; Giardini, Domenico ; Gudkova, Tamara ; Gyalay, Szilárd ; Johnson, Catherine L. ; Joshi, Rakshit ; Kim, Doyeon ; King, Scott D. ; Knapmeyer-Endrun, Brigitte ; Lognonné, Philippe ; Michaut, Chloé ; Mittelholz, Anna ; Nimmo, Francis ; Ojha, Lujendra ; Panning, Mark P. ; Plesa, Ana-Catalina ; Siegler, Matthew A. ; Smrekar, Suzanne E. ; Spohn, Tilman ; Banerdt, W. Bruce
InSight Constraints on the Global Character of the Martian Crust
Journal of Geophysical Research: Planets, 127 issue 5 (2022). http://dx.doi.org/10.1029/2022JE007298

[130] Yates, Alexander ; Caudron, Corentin ; Lesage, Philippe ; Mordret, Aurélien ; Lecocq, Thomas ; Soubestre, Jean
Assessing Similarity in Continuous Seismic Cross-Correlation Functions Using Hierarchical Clustering: Application to Ruapehu and Piton de La Fournaise Volcanoes
Geophysical Journal International (2022). http://dx.doi.org/10.1093/gji/ggac469

[131] Ying, Beili ; Feng, Li ; Inhester, Bernd ; Mierla, Marilena ; Gan, Weiqun ; Lu, Lei ; Li, Shuting
Three-dimensional analyses of an aspherical coronal mass ejection and its driven shock
Astronomy and Astrophysics (2022). http://dx.doi.org/10.1051/0004-6361/202142797

[132] Zhao, H. ; Schultheis, M. ; Zwitter, T. ; Bailer-Jones, C. A. L. ; Panuzzo, P. ; Sartoretti, P. ; Seabroke, G. M. ; Recio-Blanco, A. ; de Laverny, P. ; Kordopatis, G. ; Creevey, O. L. ; Dharmawardena, T. E. ; Frémat, Y. ; Sordo, R. ; Drimmel, R. ; Marshall, D. J. ; Palicio, P. A. ; Contursi, G. ; Álvarez, M. A. ; Baker, S. ; Benson, K. ; Cropper, M. ; Dolding, C. ; Huckle, H. E. ; Smith, M. ; Marchal, O. ; Ordenovic, C. ; Pailler, F. ; Slezak, I.

Solid confirmation of the broad DIB around 864.8 nm using stacked Gaia-RVS spectra
Astronomy & Astrophysics, 666, pp. L12 (7pp) (2022). http://dx.doi.org/10.1051/0004-6361/202244343

[133] Zhong, S. ; Nakariakov, V. M. ; Kolotkov, D. Y. ; Verbeeck, C. ; Berghmans, D.
Two-spacecraft detection of short-period decayless kink oscillations of solar coronal loops
MNRAS, 516, pp. 5989-5996 (2022). http://dx.doi.org/https://doi.org/10.1093/mnras/stac2545

Non-Refereed Publications

[134] Agrusa H., Richardson D., Meyer A., Barbee B., Bottke W., Cheng A., Eggl S., Ferrari F., Hirabayashi M., Karatekin O., McMahon J., Schwartz S., and DART Dynamics Working Group
Predictions for the Dynamical State of the Didymos Binary System Before and After the DART Impact
AAS Division on Dynamical Astronomy meeting #53, 53rd Lunar and Planetary Science Conference, held 7-11 March, 2022 at The Woodlands, Texas. LPI Contribution No. 2678, 2022, id.2447, Bulletin of the American Astronomical Society, Vol. 54, No. 4 e-id 2022n4i200p05, extended abstract (2022).

[135] Caldiero, A. ; Le Maistre, S. ; Dehant, V.
A parametric level-set approach to the global gravity inversion of small bodies
Proc. European Planetary Science Congress 2022, 2022 issue 16, pp. 1118 (2022).
http://dx.doi.org/10.5194/epsc2022-1118

[136] D'Huys, Elke ; Vanlommel, Petra ; Janssens, Jan ; Van der Linden, Ronald
Come fly with us: services provided by the Space Weather Education Centre
4th Symposium on Space Educational Activities Proceedings (2022).
https://sseasymposium.org/ssea-proceedings/

[137] Dehant, V.
Habitabilité
Dictionnaire juridique du changement climatique, sous la direction de Marta Torre-Schaub, Aglaé Jézéquel, Blanche Lormeteau, Agnès Michelot, 2022 issue ISBN13 978-2-84934-624-2, pp. EAN 9782849346242 (2022).

[138] Dehant, V. ; Mandea, M. ; Cazenave, A.
Guest Editorial: International Space Science Institute (ISSI) Workshop on Probing Earth's Deep Interior Using Space Observations Synergistically
Survey Geophysics, 43 issue 1, pp. 1-3 (2022). http://dx.doi.org/10.1007/s10712-022-09696-2

[139] Delbo, Marco ; Galluccio, Laurent ; De Angeli, Francesca ; Pauwels, Thierry ; Tanga, Paolo ; Miagnard, Francois ; Cellino, Alberto ; Brown, Anthony ; Muinonen, Karri ; Penttila, Antti
Gaia spectroscopic view of asteroid collisional families: preliminary results
16th Europlanet Science Congress 2022, held 18-23 September 2022 at Palacio de Congresos de Granada, Spain (2022). http://dx.doi.org/10.5194/epsc2022-237

[140] De Meyer, Cédric ; Sintubin, Manuel ; Van Noten, Koen
Focal mechanism determination for earthquakes in and around Belgium based on P-wave first motions
Geologica Belgica, 25 issue 3-4, pp. 186-187 (2022). https://popups.uliege.be/1374-8505/index.php?id=7030

[141] Ge, J. ; Zhang, H. ; Zang, W.C. ; Deng, H.P. ; Mao, S. ; Xie, J.-W. ; Liu, H.-G. ; Zhou, J.-L. ; Willis, K. ; Huang, Ch. ; Howell, S.B. ; Feng, F. ; Zhu, J.P. ; Yao, X.Y. ; Liu, B.B. ; Aizawa, M.T. ; Zhu, W. ; Li, Y.-P. ; Ma, B. ; Ye, Q.Z. ; Yu, J. ; Xiang, M.S. ; Yu, C. ; Liu, S.F. ; Yang, M. ; Wang, M.-T. ; Shi, X. ; Fang, T. ; Zong, W.K. ; Liu, J.Z. ; Zhang, Y. ; Zhang, L.Y. ; El-Badry, K. ; Shen, R.F. ; Tam, P.-H. T. ; Hu, Z.C. ; Yang, Y. ; Zou, Y.-C. ; Wu, J.-L. ; Lei, W.-H. ; Wei, J.-J. ; Wu, X.-F. ; Sun, T.-R. ; Wang, F.-Y. ; Zhang, B.-B. ; Xu, D. ; Yang, Y.-P. ; Li, W.-X. ; Xiang, D.-F. ; Wang, X.F. ; Wang, T.G. ; Zhang, B. ; Jia, P. ; Yuan, H.B. ; Zhang, J.H. ; Xuesong, Wang S. ; Gan, T.J. ; Wang, W. ; Zhao, Y.N. ; Liu, Y.J. ; Wei, Ch.X. ; Kang, Y.W. ; Yang, B.Y. ; Qi, C. ; Liu, X.H. ; Zhang, Q. ; Zhu, Y. ; Zhou, D. ; Zhang, C.C. ; Yu, Y. ; Zhang, Y.S. ; Li, Y. ; Tang, Z.H. ; Wang, C.Y. ; Wang, F.T. ; Li, W. ; Cheng, P.F. ; Shen, C. ; Li, B.P. ; Pan, Y. ; Yang, S. ; Gao, W. ; Song, Z.X. ; Wang, J. ; Zhang, H.F. ; Chen, C. ; Wang, H. ; Zhang, J. ; Wang, Z.Y. ; Zeng, F. ; Zheng,

Z.H. ; Zhu, J. ; Guo, Y.F. ; Zhang, Y.H. ; Li, Y.D. ; Wen, L. ; Feng, J. ; Chen, W. ; Chen, K. ; Han, X.B. ; Yang, Y.Q. ; Wang, H.Y. ; Duan, X.L. ; Huang, J.J. ; Liang, H. ; Bi, S.L. ; Gai, N. ; Ge, Z.H. ; Guo, Z. ; Huang, Y. ; Li, G. ; Li, H.N. ; Li, T. ; Yuxi, . ; Lu, . ; Rix, H.-W. ; Shi, J.R. ; Song, F. ; Tang, Y.K. ; Ting, Y.-S. ; Wu, T. ; Wu, Y.Q. ; Yang, T.Z. ; Yin, Q.-Z. ; Gould, A. ; Lee, C.-U. ; Dong, S. ; Yee, J.C. ; Shvartzvald, Y. ; Yang, H.J. ; Kuang, R.K. ; Zhang, J.Y. ; Liao, S.L. ; Qi, Z.X. ; Yang, J. ; Zhang, R.H. ; Jiang, C. ; Ou, J.-W. ; Li, Y.G. ; Beck, P. ; Bedding, T.R. ; Campante, T.L. ; Chaplin, W.J. ; Christensen-Dalsgaard, J. ; García, R.A. ; Gaulme, P. ; Gizon, L. ; Hekker, S. ; Huber, D. ; Khanna, S. ; Li, Y. ; Mathur, S. ; Miglio, A. ; Mosser, B. ; Ong, J.M.J. ; Santos, Â.R.G. ; Stello, D. ; Bowman, D.M. ; Lares-Martiz, M. ; Murphy, S. ; Niu, J.-S. ; Ma, X.-Y. ; Molnár, L. ; Fu, J.-N. ; De Cat, P. ; Su, J. ; the, ET consortium
ET White Paper: To Find the First Earth 2.0
arXiv, 2206.06693, pp. 1--116 (2022). https://doi.org/10.48550/arXiv.2206.06693v

[142] Gelenbe, E. ; Brasseur, G. ; Chefneux, L. ; Dehant, V. ; Fabjańska, A. ; Halloin, V. ; Judkiewicz, M. ; Mrša, V. ; Perez-Ariaga, I.J.
Challenges for European Science and Technology Driven Innovation in Europe
Report to Euro-CASE, 2022 (2022). https://www.euro-case.org//wp-content/uploads/Eurocase/Publications/PDF/ReportEuro-CASE2_220722.pdf

[143] Gillmann, C. ; Golabek, G. ; Raymond, S.N. ; Schonbachler, M. ; Tackley, P.J. ; Dehant, V. ; Debaille, V.
The Consequences of Late Accretion Volatile Delivery and Loss Mechanisms on Venus' Evolution
Proc. European Planetary Science Congress 2022, 2022, pp. 62 (2022). http://dx.doi.org/10.5194/epsc2022-62

[144] Hambly, N. ; Andrae, R. ; De Angeli, F. ; Antonio, M. ; Arenou, F. ; Audard, M. ; Babusiaux, C. ; Bailer-Jones, C. ; Bakker, J. ; Bastian, U. ; Bauchet, N. ; Bellas-Velidis, I. ; Blomme, R. ; Bombrun, A. ; Brouillet, N. ; Brugaletta, E. ; de Bruijne, J. ; Busonero, D. ; Busso, G. ; Carballo, R. ; Carnerero, M. I. ; Clementini, G. ; Creevey, O. L. ; Damerdji, Y. ; Delchambre, L. ; Distefano, E. ; Drimmel, R. ; Ducourant, C. ; Duran, J. ; Fabricius, C. ; Eyer, L. ; Faigler, S. ; Findeisen, K. ; Jevardat de Fombelle, G. ; Fouesneau, M. ; Frémat, Y. ; Galluccio, L. ; Garabato, D. ; Gavras, P. ; Giuffrida, G. ; Gomel, R. ; González, Á. ; González-Núñez, J. ; Gosset, É. ; Gracia-Abril, G. ; Halbwachs, J. -L. ; Harrison, D. L. ; Heiter, U. ; Hernandez, J. ; Hestroffer, D. ; Hobbs, D. ; Hodgkin, S. ; Holl, B. ; Hutton, A. ; Katz, D. ; Klioner, S. ; Leccia, S. ; Lebreton, Y. ; Lecoeur-Taïbi, I. ; van Leeuwen, M. ; Lindegren, L. ; Lobel, A. ; Luri, X. ; Mantelet, G. ; Marrese, P. M. ; Marinoni, S. ; Marshall, D. J. ; Masana, E. ; Mazeh, T. ; Michalik, D. ; Molinaro, R. ; Mora, A. ; Mowlavi, N. ; Nienartowicz, K. ; Ordenovic, C. ; Panahi, A. ; Pancino, E. ; Pauwels, T. ; Pichon, B. ; Portell, J. ; Pourbaix, D. ; Raiteri, C. M. ; Recio-Blanco, A. ; De Ridder, J. ; Riello, M. ; Rimoldini, L. ; Ripepi, V. ; Rixon, G. ; Robin, A. C. ; Rybizki, J. ; Sartoretti, P. ; Sarro Baro, L. M. ; Seabroke, G. ; Segovia Serrato, J. C. ; Siopis, C. ; Smart, R. ; Soubiran, C. ; Sozzetti, A. ; Spoto, F. ; Tanga, P. ; Teyssier, D. ; Utrilla, E. ; Masip Vela, A. ; Wyrzykowski, Ł. ; Zucker, S.
Gaia DR3 documentation Chapter 20: Datamodel description
Gaia DR3 documentation, European Space Agency; Gaia Data Processing and Analysis Consortium. (2022). https://gea.esac.esa.int/archive/documentation/GDR3/index.html

[145] Huang Q., Schmerr N.C., King S.D., Rivoldini A., Plesa A.-C., et al.
Constraints on the Depth of Martian Mantle Transition Zone from Triplicated Waveforms
53rd Lunar and Planetary Science Conference, held 7-11 March, 2022 at The Woodlands, Texas. LPI Contribution No. 2678, 2022, id. 1673, extended abstract (2022).

[146] Khan A., Sossi P., Liebske C., Rivoldini A., Giardini D.
Geophysical and Cosmochemical Evidence for a Volatile-Rich Mars
53rd Lunar and Planetary Science Conference, held 7-11 March, 2022 at The Woodlands, Texas. LPI Contribution No. 2678, 2022, id. 1121, extended abstract (2022).

[147] Le Maistre, S. ; Dehant, V. ; Baland, R.-M. ; Beuthe, M. ; Caldiero, A. ; Filice, V. ; Goli, M. ; Péters, M.-J. ; Steenput, B. ; Rivoldini, A. ; Umit, E. ; Van Hoolst, T. ; Yseboodt, M. ; and, the LaRa team
LaRa, an X-band coherent transponder ready to fly
Proc. European Planetary Science Congress 2022, 2022 issue 16, pp. 1169 (2022).
http://dx.doi.org/10.5194/epsc2022-1169

[148] Montabone L., Heavens N. G., Pankine A., Wolff M., Cardesin-Moinelo A., Geiger B., Forget F., Guerlet S., Millour E., Spiga A., Guzewich S. D., Smith M. D., Karatekin O., Ritter B., Ruiz Lozano L., Senel C. B., Temel O., Lillis R. J., Olsen K. S., Read P. L., et al.
The Case and Approach for Continuous, Simultaneous, Global Mars Weather Monitoring from Orbit
Seventh International Workshop on the Mars Atmosphere: Modelling and Observations, held 14-17 June, 2022 in Paris, France. Edited by F. Forget and M. Millour, id. 4406, extended abstract (2022).
http://dx.doi.org/10.5194/epsc2022-4406

[149] Mousis, O. ; Bouquet, A. ; Langevin, Y. ; the Moonraker, team ; Dehant, V. ; Le Maistre, S. ; Van Hoolst, T.
Moonraker – an Enceladus Multiple Flyby Mission Submitted to the ESA 2021 M-class Call
Proc. European Planetary Science Congress 2022, 2022 issue 16, pp. 329 (2022).
http://dx.doi.org/10.5194/epsc2022-329

[150] Muinonen, K. ; Berthier, J. ; Cellino, A. ; David, P. ; De Angeli, F. ; Delbó, M. ; Dell-Oro, A. ; Galluccio, L. ; Hestroffer, D. ; Mignard, F. ; Pauwels, T. ; Spoto, F. ; Tanga, P.
Gaia DR3 documentation Chapter 8: Solar System Objects
Gaia DR3 documentation, European Space Agency; Gaia Data Processing and Analysis Consortium (2022). https://gea.esac.esa.int/archive/documentation/GDR3/index.html

[151] Murdoch, N. ; Garcia, R. ; Cadu, A. ; Wilhelm, A. ; Drilleau, M. ; Stott, A. ; Dehant, V. ; Bernauer, F. ; Schmelzbach, C. ; Stähler, S. ; Igel, H. ; Lecamp, G. ; Ferraoili, L. ; Karatekin, Ö. ; Lognonné, P. ; Giardini, D. ; Mimoun, D.
Compact In-Situ Instruments for the Geophysical Exploration of Small Bodies
Lunar and Planetary Institute Contribution Series, Apophis T-7 Years: Knowledge Opportunities for the Science of Planetary Defense issue 2681, pp. 2022 (2022).
https://www.hou.usra.edu/meetings/apophis2022/pdf/2022.pdf

[152] Noeker, Matthias ; Van Ransbeeck, Emiel ; Ritter, Birgit ; Karatekin, Özgür
The GRASS Gravimeter Rotation Mechanism for ESA Hera Mission On-Board Juventas Deep Space CubeSat
Aerospace Mechanisms Symposium, 46th, pp. 159-172 (2022).
https://ntrs.nasa.gov/api/citations/20220006415/downloads/46th_AMS_Proceedings_Final.pdf#page=173

[153] Noeker, Matthias ; Karatekin, Özgür
Gravity Traverse Simulations for Small Bodies and Moons of the Solar System using the Wedge-Pentahedra Method
Europlanet Science Congress 2022, 16, pp. 1-4 (2022). http://dx.doi.org/%2010.5194/epsc2022-361

[154] Noeker, Matthias ; Meißenhelter, Hermann ; Andert, Tom ; Weller, René ; Karatekin, Özgür ; Haser, Benjamin
Comparing Methods for Gravitational Computation: Studying the Effect of Inhomogeneities
Europlanet Science Congress 2022, 16, pp. 1-6 (2022). http://dx.doi.org/10.5194/epsc2022-562

[155] Noeker, Matthias ; Tasev, Elisa ; Ritter, Birgit ; Karatekin, Özgür
Application of the Wedge-Pentahedra Method (WPM) to the Apollo 17 Landing Site and Comparison to the Traverse Gravimeter Experiment Measurements

Lunar and Planetary Science Conference (2022), 53rd, pp. 1-2 (2022).
https://www.hou.usra.edu/meetings/lpsc2022/pdf/1442.pdf

[156] Okada T., Tanaka S., Sakatani N., Shimaki Y., Arai T., Senshu H., Demura H., Sekiguchi T., Ishizaki T., Kouyama T., Blommaert J., Karatekin O.
Development of Thermal Infrared Multiband Imager TIRI for Hera Mission
53rd Lunar and Planetary Science Conference, held 7-11 March, 2022 at The Woodlands, Texas. LPI Contribution No. 2678, 2022, id.1319, extended abstract (2022).

[157] Pauwels, Thierry
Minor Planet Observations [012 Uccle]
Minor Planet Circulars (2022).

[158] Pou L., Nimmo F., Rivoldini A., Khan A., Bagheri A., Gray T., Samuel H., Lognonné P., Plesa A. -C., Gudkova T., Giardini D.
Development of Thermal Infrared Multiband Imager TIRI for Hera Mission
53rd Lunar and Planetary Science Conference, held 7-11 March, 2022 at The Woodlands, Texas. LPI Contribution No. 2678, 2022, id. 1776, extended abstract (2022).

[159] Rivoldini, A. ; Le Maistre, S. ; Caldiero, A. ; Yseboodt, M., ; Baland, R.M. ; Beuthe, M. ; Van Hoolst, T. ; Dehant, V. ; and, the RISE team
A view into the deep interior of Mars from nutation measured by InSight RISE
Proc. European Planetary Science Congress 2022, 2022 issue 16, pp. 1101 (2022).
http://dx.doi.org/10.5194/epsc2022-1101

[160] Rowe, Christie ; Agius, Matthew ; Convers, Jaime ; Funning, Gareth ; Galasso, Carmine ; Hicks, Stephen ; Huynh, Tran ; Lange, Jessica ; Lecocq, Thomas ; Mark, Hannah ; Okuwaki, Ryo ; Ragon, Théa ; Rychert, Catherine ; Teplitzky, Samantha ; van den Ende, Martijn
The launch of Seismica: A seismic shift in publishing
Seismica, 1 issue 1 (2022). http://dx.doi.org/10.26443/seismica.v1i1.255

[161] Ruiz Lozano, L. ; Karatekin, Ö. ; Dehant, V. ; Bellucci, G. ; Oliva, F. ; Altieri, F. ; Carrozzo, F.G. ; D'Aversa, E. ; Daerden, F. ; Thomas, I.R. ; Ristic, B. ; Willame, Y. ; Depiesse, C. ; Mason, J. ; Patel, M.R. ; Lopez-Moreno, J.-J. ; Vandaele, A.C.
Evaluation of the capability of ExoMars-TGO NOMAD infrared nadir channel for water ice clouds detection on Mars
Proc. European Planetary Science Congress 2022, 2022 issue 16, pp. 946 (2022).
http://dx.doi.org/10.5194/epsc2022-946

[162] Sartoretti, P. ; Blomme, R. ; David, M. ; Seabroke, G.
Gaia DR3 documentation Chapter 6: Spectroscopy
Gaia DR3 documentation, European Space Agency; Gaia Data Processing and Analysis Consortium. (2022). https://gea.esac.esa.int/archive/documentation/GDR3/index.html

[163] Schifano, L. ; Duerr, F. ; Berghmans, F. ; Dewitte, S. ; Smeesters, L.
Towards a demonstrator setup for a wide-field-of-view visible to near-infrared camera aiming to characterise the solar radiation reflected by the Earth
SPIE Optics, Photonics and Digital Technologies for Imaging Applications VII, 12138, pp. 111-120 (2022). http://dx.doi.org/10.1117/12.2622144

[164] Trust, O. ; Jurua, E. ; De Cat, P. ; Joshi, S.
High-resolution spectroscopy of 'hump and spike' stars
Proceedings of the 6th East African Astronomical Society Workshop (2022).

[165] Ulla, A. ; Creevey, O. L. ; Álvarez, M. A. ; Andrae, R. ; Bailer-Jones, C. A. L. ; Bellas-Velidis, I. ; Brugaletta, E. ; Carballo, R. ; Dafonte, C. ; Delchambre, L. ; Dharmawardena, T. ; Drimmel, R. ;

Fouesneau, M. ; Frémat, Y. ; Garabato, D. ; Hatzidimitriou, D. ; Heiter, U. ; Kordopatis, G. ; Korn, A. J. ; Lanzafame, A. ; Lobel, A. ; Manteiga, M. ; Marshall, D. J. ; Pailler, F. ; Pallas-Quintela, L. ; Recio-Blanco, A. ; Rybizki, J. ; Sarro Baro, L. M. ; Schultheis, M. ; Sordo, R. ; Soubiran, C. ; Thévenin, F. ; Vallenari, A.
Gaia DR3 documentation Chapter 11: Astrophysical parameters
Gaia DR3 documentation, European Space Agency; Gaia Data Processing and Analysis Consortium (2022). https://gea.esac.esa.int/archive/documentation/GDR3/index.html

[166] Van Camp, Michel ; Gobron, Kevin ; Pattyn, Frank ; Huybrechts, Philippe
Zeespiegelstijging voor Vlaanderen: Vraag 2: Vertical land motions
Expertise report, pp. 13 pp (2022).

[167] Van den Broeck, laura ; De Wachter, Sara ; Sermeus, Jan ; De Schrijver, jelle
Learn to think: developing a cross- curricular teaching method to enhance critical thinking in the first stage of secundary education
EAPRIL 2021 Conference Proceedings, pp. 206-215 (2022).

[168] van Leeuwen, F. ; de Bruijne, J. ; Babusiaux, C. ; Busso, G. ; Castañeda, J. ; Ducourant, C. ; Fabricius, C. ; Hambly, N. ; Hobbs, D. ; Luri, X. ; Marrese, P. M. ; Mora, A. ; Muinonen, K. ; Pourbaix, D. ; Rimoldini, L. ; Roegiers, T. ; Sartoretti, P. ; Teyssier, D. ; Ulla, A. ; Utrilla, E. ; Vallenari, A. ; van Leeuwen, M. ; Altavilla, G. ; Altmann, M. ; Álvarez, M. A. ; Andrae, R. ; Antoja, T. ; Antonio, M. ; Arenou, F. ; Audard, M. ; Bailer-Jones, C. A. L. ; Bakker, J. ; Balbinot, E. ; Barache, C. ; Barblan, F. ; Bastian, U. ; Bauchet, N. ; Bellas-Velidis, I. ; Bellazzini, M. ; Berthier, J. ; Biermann, M. ; Blomme, R. ; Bombrun, A. ; Bossini, D. ; Brouillet, N. ; Brown, A. ; Brugaletta, E. ; Busonero, D. ; Butkevich, A. ; Cacciari, C. ; Cánovas, H. ; Cantat-Gaudin, T. ; Carballo, R. ; Carnerero, M. I. ; Carrasco, J. M. ; Cellino, A. ; Cheek, N. ; Clementini, G. ; Clotet, M. ; Creevey, O. L. ; Crowley, C. ; Dafonte, C. ; Damerdji, Y. ; David, M. ; David, P. ; Davidson, M. ; De Angeli, F. ; De Ridder, J. ; De Teodoro, P. ; Delbó, M. ; Delchambre, L. ; Delisle, J. -B. ; Dell-Oro, A. ; Dharmawardena, T. ; Diakité, S. ; Distefano, E. ; Drimmel, R. ; Duran, J. ; Evans, D. W. ; Eyer, L. ; Fabrizio, M. ; Faigler, S. ; Fernández-Hernández, J. ; Figueras, F. ; Findeisen, K. ; Fouesneau, M. ; Frémat, Y. ; Galluccio, L. ; Garabato, D. ; Garcia-Gutierrez, A. ; Garofalo, A. ; Gavras, P. ; Giacobbe, P. ; Giuffrida, G. ; Gomel, R. ; González, Á. ; González-Núñez, J. ; Gosset, É. ; Gracia-Abril, G. ; Guerra, R. ; Halbwachs, J. -L. ; Harrison, D. L. ; Hatzidimitriou, D. ; Heiter, U. ; Helmi, A. ; Henar Sarmiento, M. ; Hernandez, J. ; Hestroffer, D. ; Hodgkin, S. ; Holl, B. ; Hutton, A. ; Jevardat de Fombelle, G. ; Jordi, C. ; Jorissen, A. ; Katz, D. ; Khanna, S. ; Klioner, S. ; Kordopatis, G. ; Korn, A. J. ; Krone-Martins, A. ; Kruszyńska, K. ; Lammers, U. ; Lanzafame, A. ; Lattanzi, M. G. ; Le Campion, J. -F. ; Lebreton, Y. ; Lebzelter, T. ; Leccia, S. ; Leclerc, N. ; Lecoeur-Taïbi, I. ; Licata, E. ; Lindegren, L. ; Lobel, A. ; Löffler, W. ; Manteiga, M. ; Mantelet, G. ; Marinoni, S. ; Marshall, D. J. ; Martín-Fleitas, J. ; Masana, E. ; Masip Vela, A. ; Mazeh, T. ; Messineo, R. ; Michalik, D. ; Mignard, F. ; Molinaro, R. ; Monguió, M. ; Montegriffo, P. ; Morel, T. ; Mowlavi, N. ; Muraveva, T. ; Nicolas, C. ; Nienartowicz, K. ; Ordenovic, C. ; Osinde, J. ; Pailler, F. ; Pallas-Quintela, L. ; Panahi, A. ; Pancino, E. ; Panem, C. ; Pauwels, T. ; Pichon, B. ; Portell, J. ; Rainer, M. ; Raiteri, C. M. ; Ramos, P. ; Recio-Blanco, A. ; Reylé, C. ; Riello, M. ; Ríos Diaz, C. ; Ripepi, V. ; Riva, A. ; Rixon, G. ; Robin, A. C. ; Romero-Gómez, M. ; Rowell, N. ; Rybicki, K. A. ; Rybizki, J. ; Sadowski, G. ; Sáez-Núñez, A. ; Sahlmann, J. ; Sanna, N. ; Sarro Baro, L. M. ; Schultheis, M. ; Seabroke, G. ; Segovia Serrato, J. C. ; Segransan, D. ; Siddiqui, H. ; Siopis, C. ; Smart, R. ; Sordo, R. ; Soubiran, C. ; Sozzetti, A. ; Spina, L. ; Spoto, F. ; Stephenson, C. ; Tanga, P. ; Teixeira, R. ; Thévenin, F. ; Torra, F. ; Trabucchi, M. ; Turon, C. ; Weiler, M. ; Wyrzykowski, Ł. ; Zucker, S.
Gaia DR3 documentation
Gaia DR3 documentation, European Space Agency; Gaia Data Processing and Analysis Consortium. (2022). https://gea.esac.esa.int/archive/documentation/GDR3/index.html

Other Publications

[169] Blanc, M. ; Lewis, J. ; Bousquet, P. ; Dehant, V. ; Foing, B. ; Grande, M. ; Guo, L.L. ; Hutzler, A. ; Lasue, J. ; Perino, M.A. ; Rauer, H. ; Ammannito, E. ; Capria, M.T.
Introduction to the Planetary Exploration, Horizon 2061 foresight exercise
Planetary Exploration Horizon 2061 – A Long-Term Perspective for Planetary Exploration, Chapter 1 issue ISBN 9780323902267, pp. 1-16 (2022). http://dx.doi.org/10.1016/%20B978-0-323-90226-7.00004-0

[170] Boulard, Coline
H/V spectral ratio analysis in urban areas interested in shallow geothermal wells
Master thesis supervised by Van Noten, Koen; Zeckra, Martin (Université libre de Bruxelles) (2022).

[171] Bruyninx C., E. Brockmann, A. Kenyeres, J. Legrand, T. Liwosz, R. Pacione, W. Söhne, C. Völksen
EUREF permanent network Technical Report 2021
IGS technical report 2021, pp. 119-128 (2022). https://doi.org/10.48350/169536

[172] Bruyninx C. for the EPN Central Bureau
Procedure for Becoming an EPN station
https://epncb.oma.be/_documentation/guidelines/procedure_becoming_station.pdf updated on August 30, 2022.

[173] Bruyninx C.
Guidelines for EPN Stations and Operational Centres
https://epncb.oma.be/_documentation/guidelines/guidelines_station_operationalcentre.pdf updated on March 22, 2022.

[174] Clette, F.
Le Soleil et nous
Lausanne, Switzerland, Favre (494 pages). ISBN: 978-2-8289-1891-0 (2022).

[175] Defraigne, P.
Precise Time and Frequency in Geodesy
in Encyclopedia of Geodesy (part of the Encyclopedia of Earth Sciences Series) (6 pages – Sc. Ed. Springer Nature Switzerland AG 2022, M. G. Sideris) (2022). https://doi.org/10.1007/978-3-319-02370-0_14-1

[176] Dehant, V. ; Blanc, M. ; Mackwell, S. ; Soderlund, K.M. ; Beck, P. ; Bunce, E. ; Charnoz, S. ; Foing, B. ; Filice, V. ; Fletcher, L.N. ; Forget, F. ; Griton, L. ; Hammel, H. ; Höning, D. ; Imamura, T. ; Jackman, C. ; Kaspi, Y. ; Korablev, O. ; Leconte, J. ; Lellouch, E. ; Marty, B. ; Mangold, N. ; Michel, P. ; Morbidelli, A. ; Mousis, O. ; Prieto-Ballesteros, O. ; Spohn, T. ; Schmidt, J. ; Sterken, V.J. ; Tosi, N. ; Vandaele, A.C. ; Vernazza, P. ; Vazan, A. ; Westall, F.
From science questions to Solar System exploration
Planetary Exploration Horizon 2061 – A Long-Term Perspective for Planetary Exploration, Chapter 3 issue ISBN 9780323902267, pp. 65-175 (2022). http://dx.doi.org/10.1016/B978-0-323-90226-7.00006-4

[177] De Meyer, Cédric
Focal mechanism determination for earthquakes in and around Belgium based on P-wave first motions
Master thesis supervised by Sintubin, Manuel; Van Noten, Koen (KULeuven) (2022).

[178] Koukras, Alexandros

Understanding the acceleration of the fast solar wind by linking remote sensing and in situ observations
PhD thesis supervised by Keppens, Rony; Dolla, Laurent (KULeuven) (2022).

[179] Pauwels, T., Bruyninx, C. and Roosbeek, F.
Annuaire de l'Observatoire royal de Belgique – Jaarboek van de Koninklijke Sterrenwacht van België 2023
EPO, ISBN: ISSN-0373-4900 (2022).
https://www.astro.oma.be/common/pdf/ybook/yearbook_2023.pdf

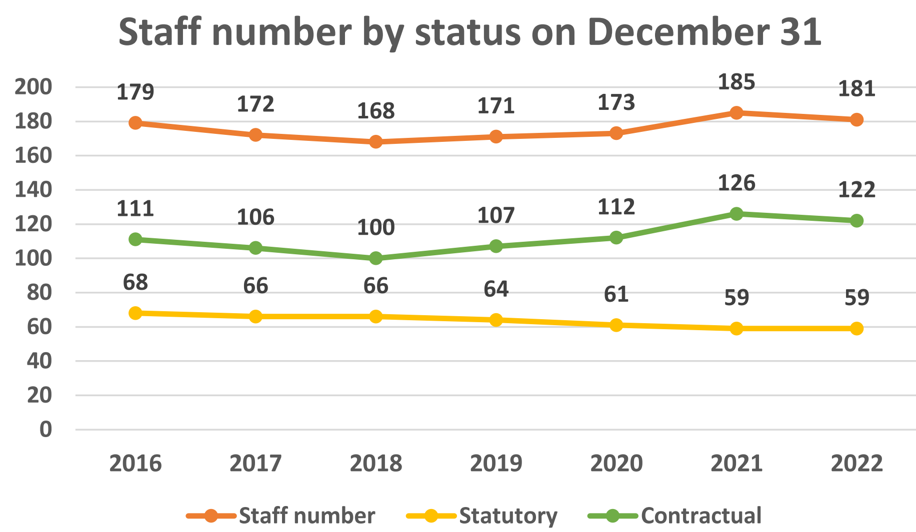
[180] Rauer, H. ; Blanc, M. ; Venturini, J. ; Dehant, V. ; Demory, B. ; Dorn, C. ; Domagal-Goldman, S. ; Gaudi, S. ; Helled, R. ; Heng, K. ; Kitzman, D. ; Kokubo, E. ; Le Sergeant d'Hendecourt, L. ; Mordasini, C. ; Nesvorny, D. ; Noack, L. ; Owen, J. ; Paranicas, C. ; Qin, L. ; Snellen, I. ; Testi, L. ; Udry, S. ; Wambganss, J. ; Westall, F. ; Zarka, P. ; Zong, Q.
Solar System/Exoplanet Science Synergies in a multi-decadal Perspective
Planetary Exploration Horizon 2061 – A Long-Term Perspective for Planetary Exploration, Chapter 2 issue ISBN 9780323902267, pp. 17-64 (2022). http://dx.doi.org/10.1016/B978-0-323-90226-7.00001-5

[181] Talpeanu, Dana-Camelia
Numerical and Observational Study of Stealth and Consecutive Coronal Mass Ejections
PhD thesis supervised by Poedts, Stefaan; D'Huys, Elke (KU Leuven) (2022).

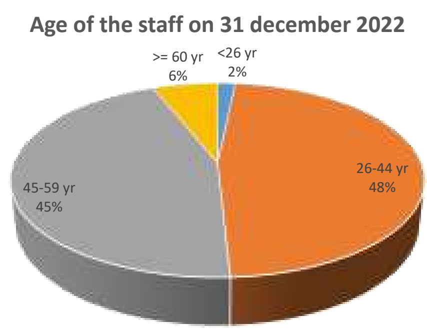
Annexe 2: Workforce

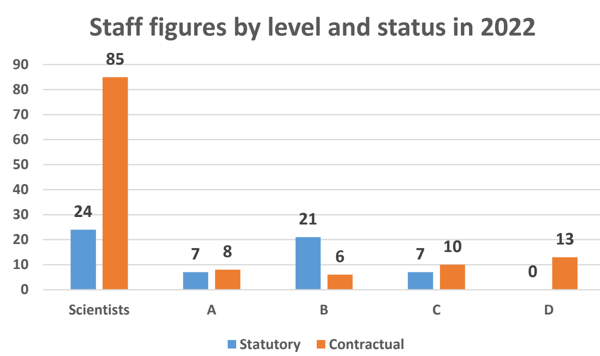
Staff Statistics

On 31 December 2022, 181 employees are working at the ORB-KSB, including people working at the Planetarium. Compared to last year, there was a net decrease of four contractual employees, corresponding to 10% of the contractual staff. The mean age of the staff is 43.5 years, with 93% of the workers between 26 and 59 years.

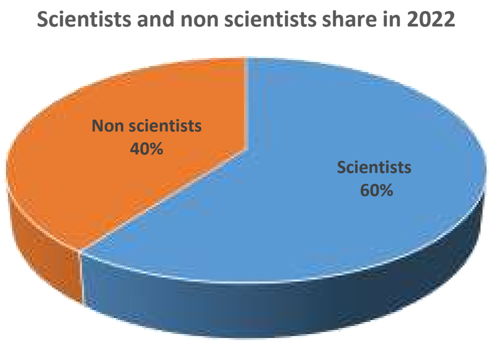


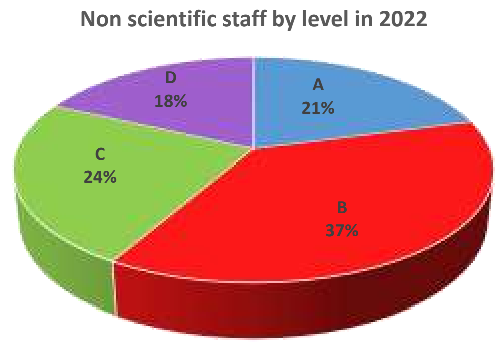
The majority of the staff (67%) are contractual agents. This is particularly true for scientists, in whom 78% are contractual, and particularly for employees of level D, for whom all of the staff is contractual.



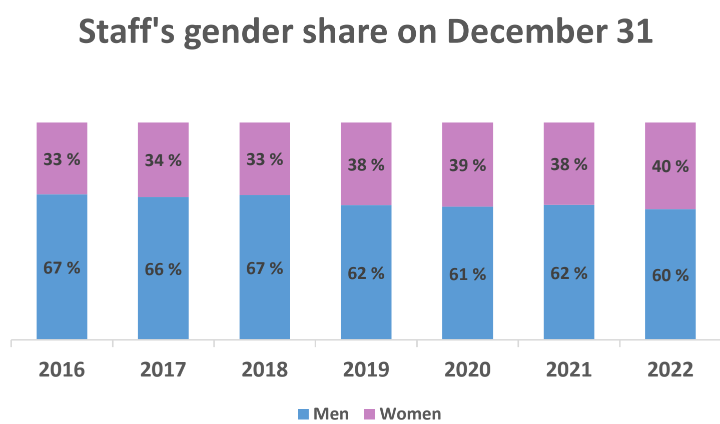


The fact that more and more scientists are contractual is because scientific research is more and more funded by external projects. Moreover, scientists constitute the majority of the staff (60% in 2022), highlighting the fact that the ORB-KSB is a research institute.



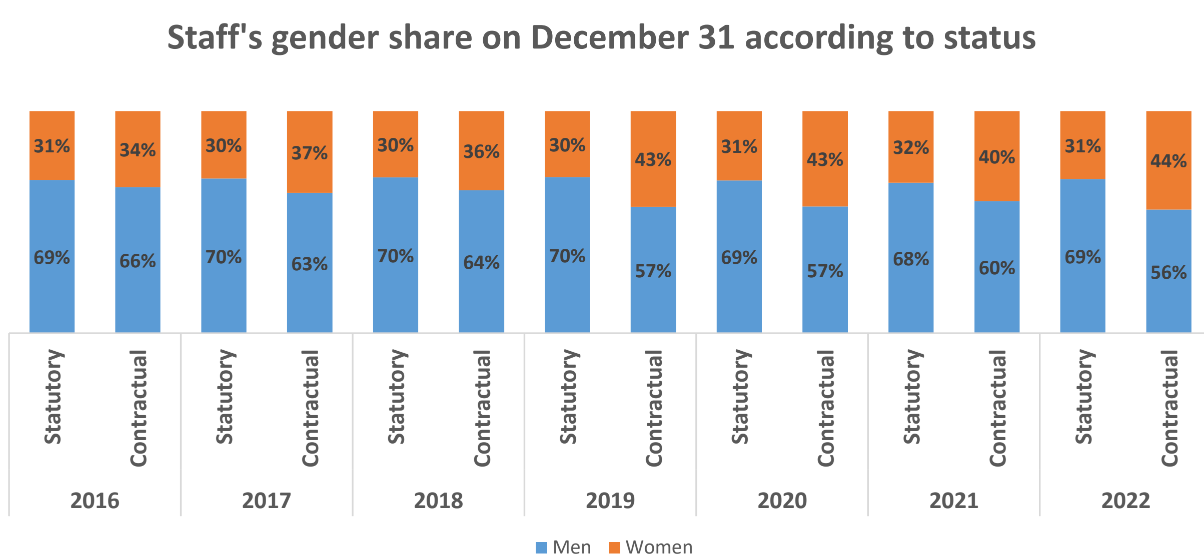


Analysis by Gender



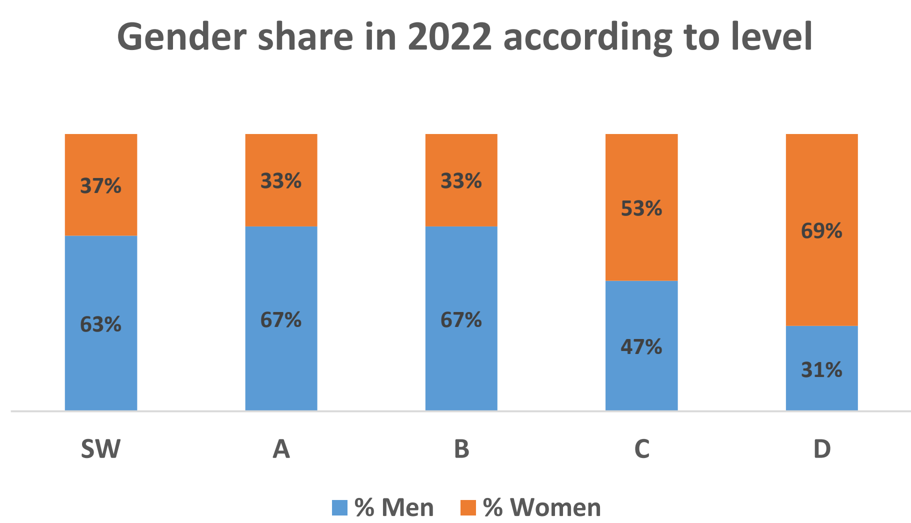
On 31 December 2022, female staff constituted 40% of the employees at the ORB-KSB. This is a slight increase in the share of female employees compared to 2021 (38% of women), and particularly compared to 2016, where only 33% of the staff is female.

This increase of females in the workforce concerns mainly contractual where, between 2016 and 2022, female contractual staff increases by 42% (from 38 on 31 December 2016 to 54 on 31 December 2022) while male contractual staff remain stable (from 71 on 31 December 2016 to 68 on 31 December 2022). Meanwhile, the gender balance of the statutory staff does not change.

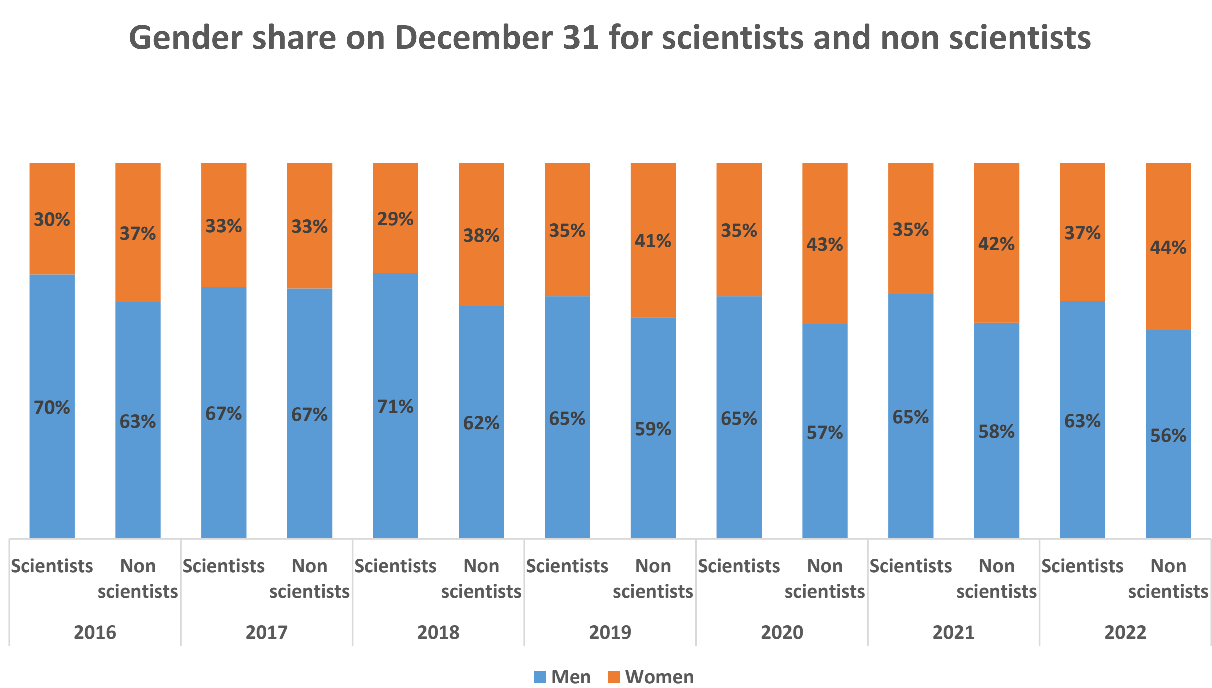


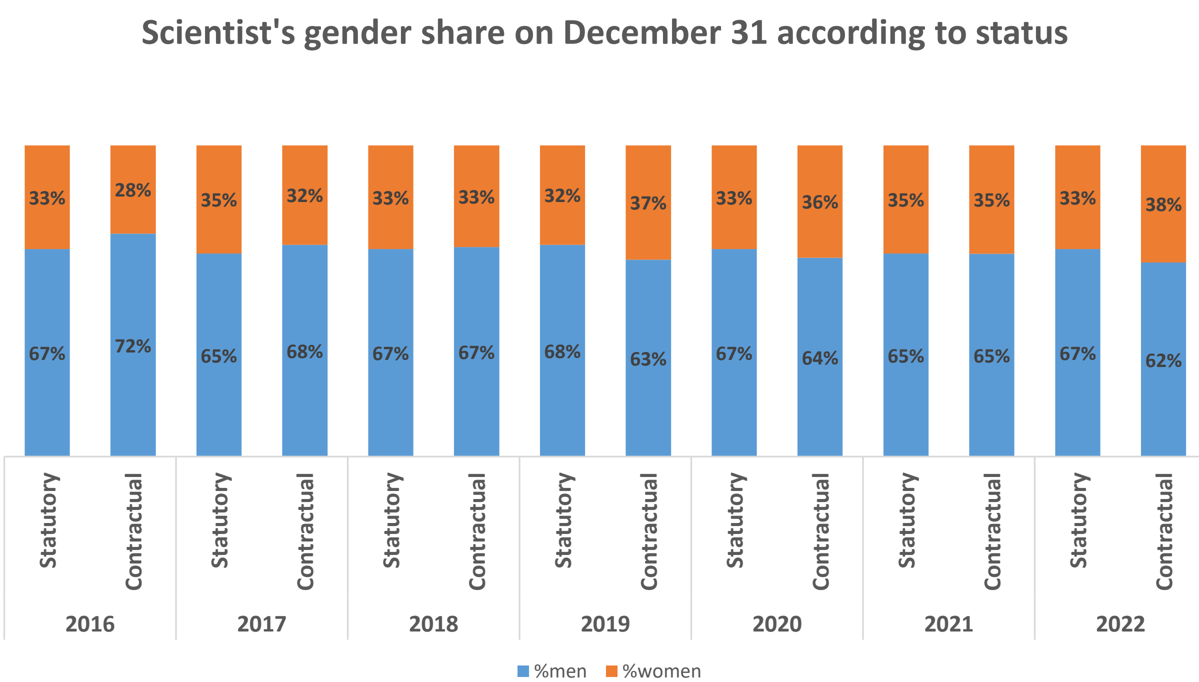
When looking through the staff hierarchy, we can see an inversion of women to men proportion between:

- C- and D-level workers, where women are the majority (53% for C-level workers and 69% for D-level workers), and scientists and
- A- and B-level workers, where women only make about one third of their corresponding level (33% for A- and B-level workers), with a slightly higher proportion for scientists (37% of scientists being women).



Compared to the administrative staff, women to men proportion is slightly lower among scientists, with only 37% of scientists being women on 31 December 2022, while this proportion amounts to 44% for the administrative staff. The gender share of contractual and statutory scientists remains, however, relatively constant between 2016 and 2022, with slight increases for contractual scientists in 2019 and 2022.




Scientist's gender share on December 31 according to status
33%
28%
35%
32%
33%
33%
32%
37%
33%
36%
35%
35%
33%
38%
67%
72%
65%
68%
67%
67%
68%
63%
67%
64%
65%
65%
67%
62%
Statutory
Contractual
2016
2017
2018
2019
2020
2021
2022
%men
%women

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