Mercator Telescope @ the Roque

P. Papics

HERMES

HERMES: Intro

Consortium

Design Requirements

HERMES: The Project

History of the project

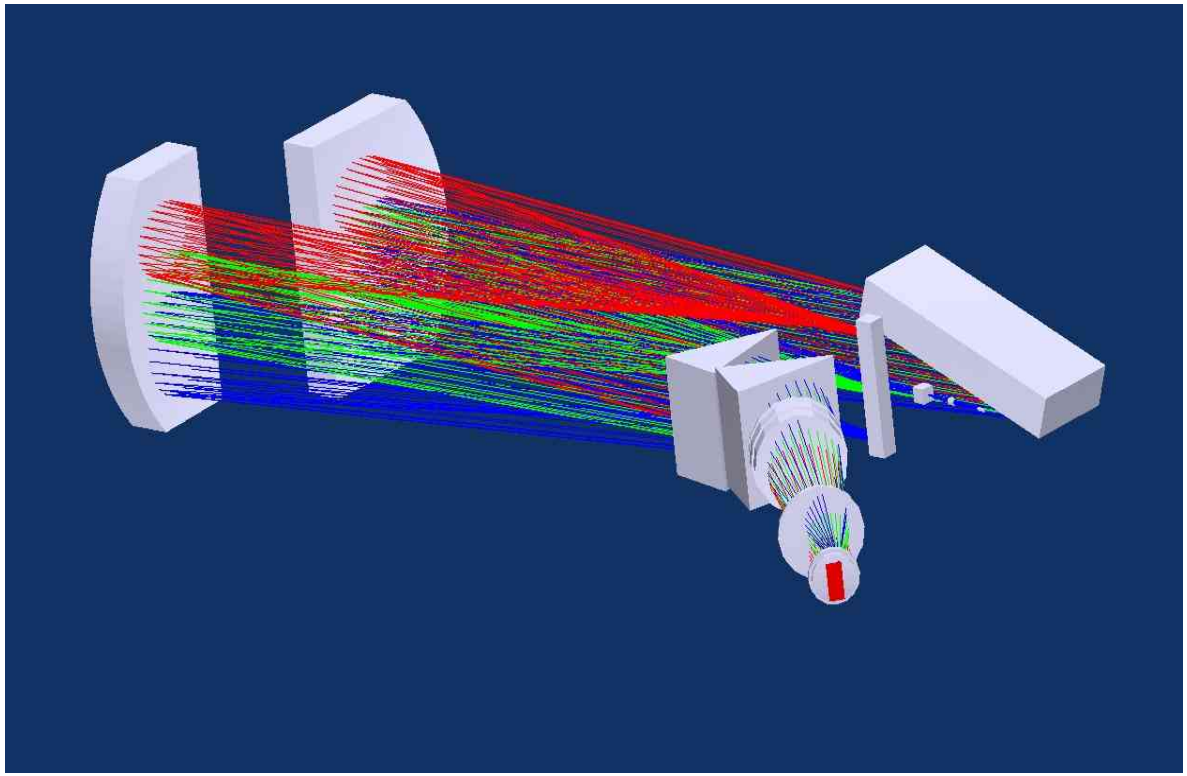
Instrument:

- Design Spectro
- Adaptor, Fibre Link etc.
- Software

Characteristics

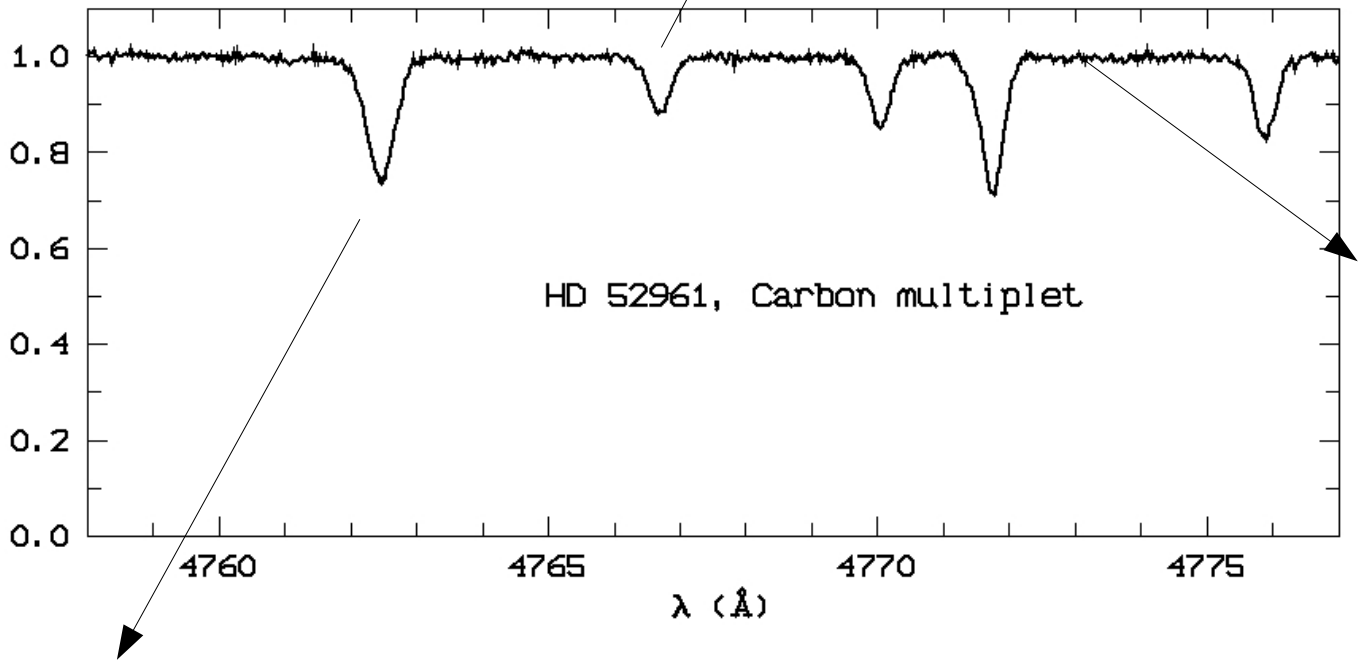
Running Mercator+HERMES

Some illustrative results



Why a high-resolution spectrograph ?

Strength of line = f(Teff, log(g), chemical composition)
Wide spectral coverage !
Good sampling required



S/N: small telescope requires efficient instrument

Radial velocity : $(\lambda - \lambda_0) / \lambda_0$= velocity/c
high resolution: 85 000 corresponds to 3.5 km/s
High stability to allow 10 m/s accuracy. Wide spectral domain helps

HERMES-Consortium: kick-off in Leuven 19/01/2005

Proj. Engeneer: G. Raskin
PI : H. Van Winckel
Co-i: C. Waelkens
W. Pessemier, S. Prins
J. Padilla, F. Merges
J. Morren, P. Degroote
K. Smolders

IvS-KUL

ROB

Co-i: H. Hensberge
Y. Fremat
L. Dumortier
J.P. De Cuyper

Co-i: A. Jorissen
S. Van Eck
C. Siopis

IAA-ULB

HERMES

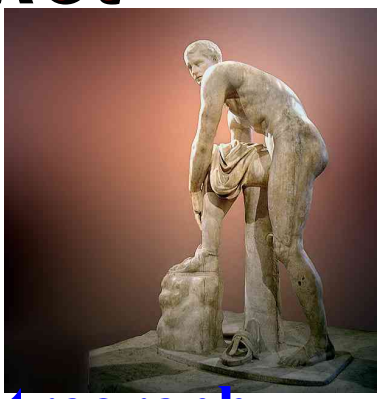
Co-i: H. Lehmann
J. Winkler
U. Laux

Landessternwarte Tautenburg

R. Dubosson
B. Michaud

Observatoire de Genève

HERMES: Niche in the telescope-market



Time series in radial velocity and in individual spectral lines, high S/N spectra of fainter stars: robust, efficient, high-resolution, spectrograph on Mercator

=

HERMES: High-Efficiency and Resolution Mercator Echelle Spectrograph

Pooling of HERMES observations with priority driven scheduling.

Priorities are given by consortium board + external TAC

All HERMES consortium nights are mainly (80%) scheduled from pool.

HERMES consortium time: 50% of remaining telescope time.

HERMES: Science drivers: stellar astrophysics

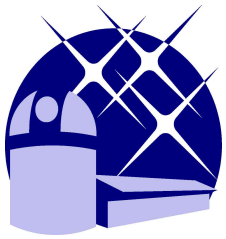
KUL : Asteroseismology (B-stars); late phases of (binary) stellar evolution; AGB Nucleosynthesis (single and binary stars; s-process)

ULB: Late phases of (binary) stellar evolution; Nucleosynthesis (RGB; AGB, s-r-process). Interacting binaries; Doppler tomography

ROB: Asteroseismology; Wind variability in B-stars (single and binaries)

TLS (Tautenburg): Asteroseismology, extra-solar planets

Geneva : Asteroseismology (solar-like oscillations), extra-solar planets



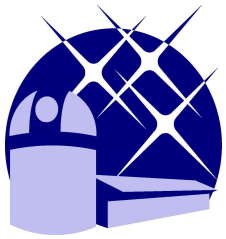
HERMES: User Requirements

HERMES is not a single goal instrument. Some compromise between efficiency and stability is needed. Solution: 2 different Science Fibres

Project requirements include Spectrograph requirements and Operational requirements.

Spectrograph requirements (goals):

- **Range : 380 - 880 in single shot**
- **Fibre Fed**
- **Resolution (500nm): min 40 000 – max 90 000**
- **Efficiency: 25% (maximal efficiency)**
- **Stability: 1 m/s (short term)**
- **Stability: 5 m/s (long term)**
- **Cycling time: 30-60 sec.**
- **DRS**



HERMES: Operational Requirements

Operational requirements:

Automatic: including pointing, centering, guiding

On-line full data reduction pipeline

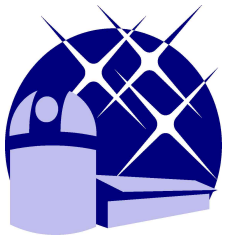
Efficient Semi-automatic Scheduling from pooled programs

Archiving System

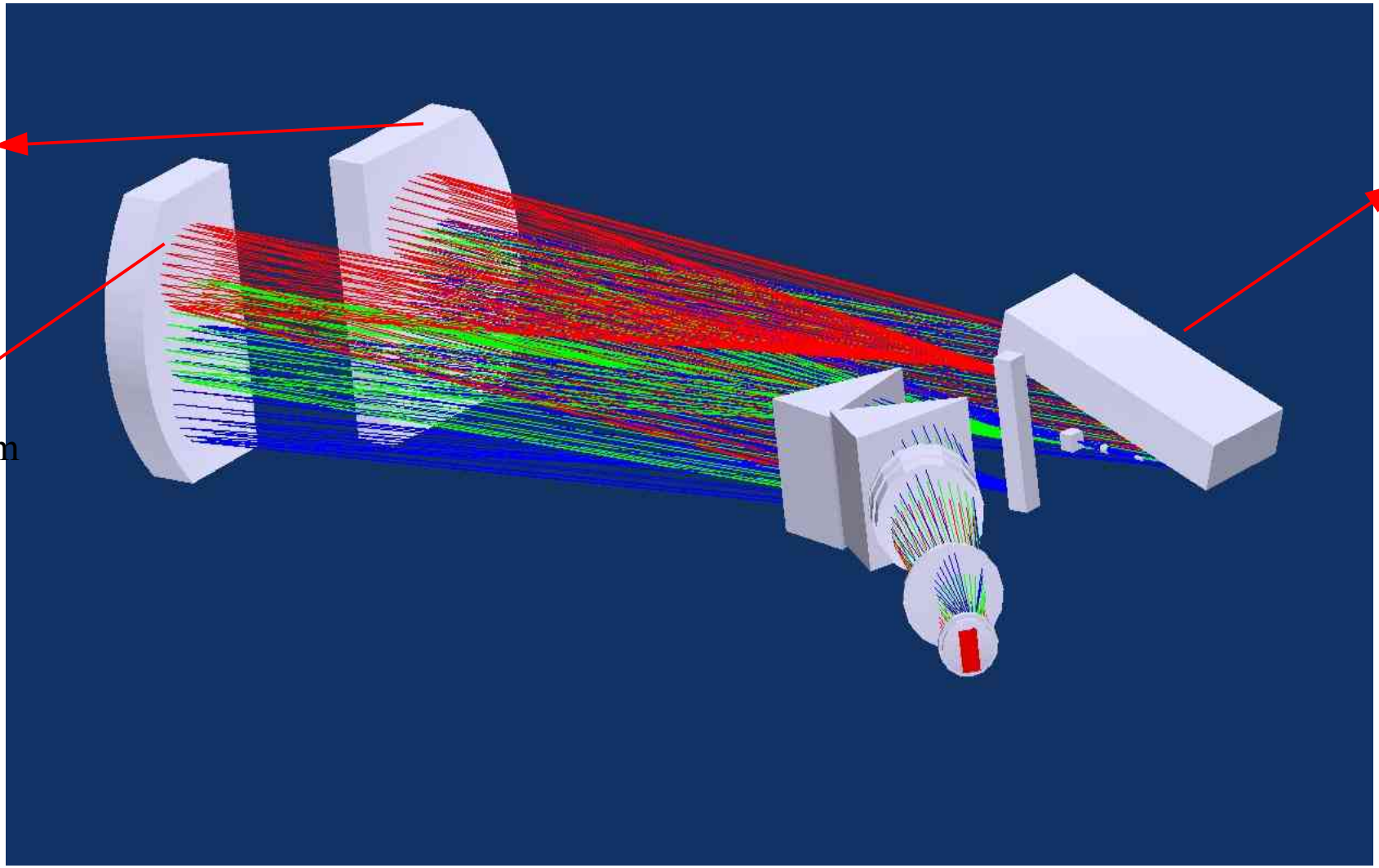
Overall requirements:

Robust design, sober in maintenance efforts and costs

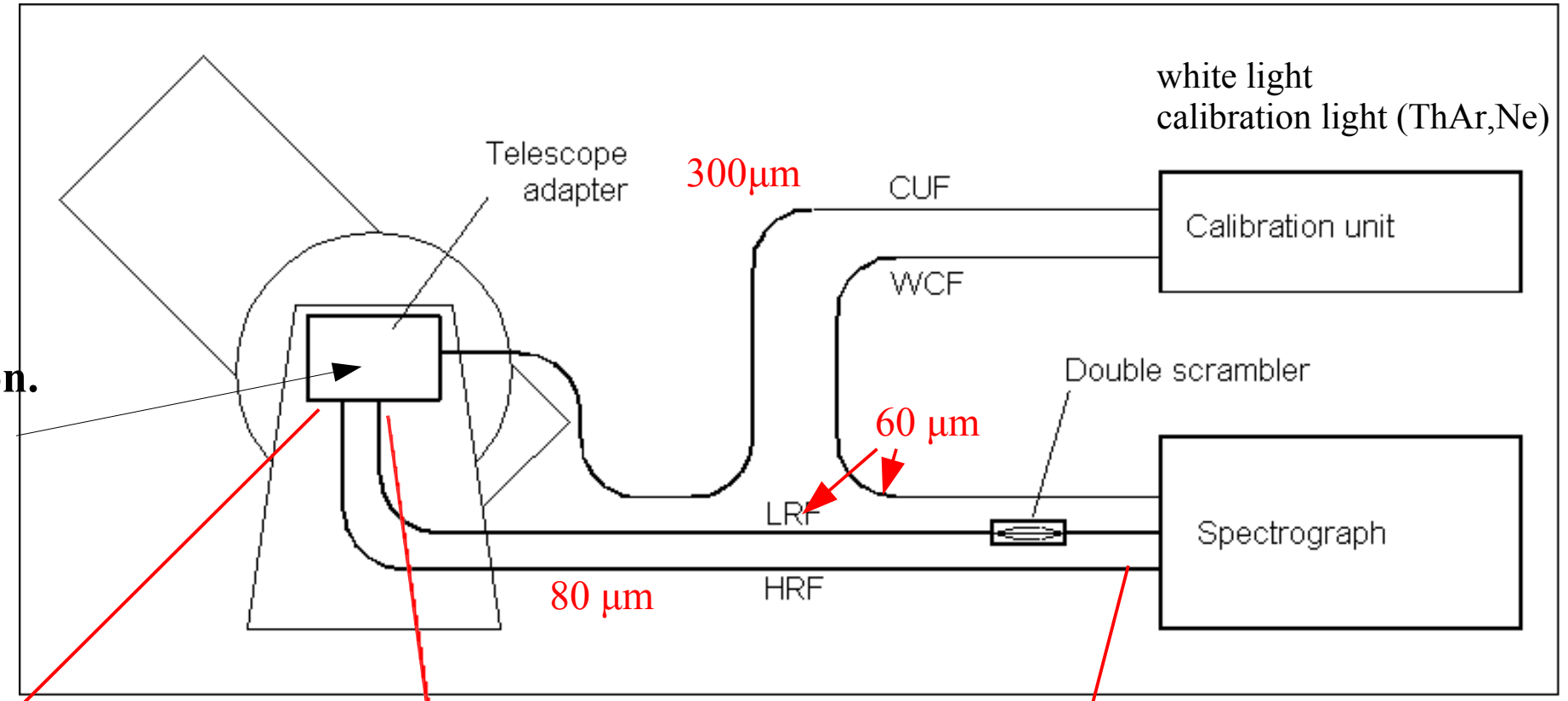
Within Budget (980 kEuro)



Hermes: white pupil Design



Hermes Design



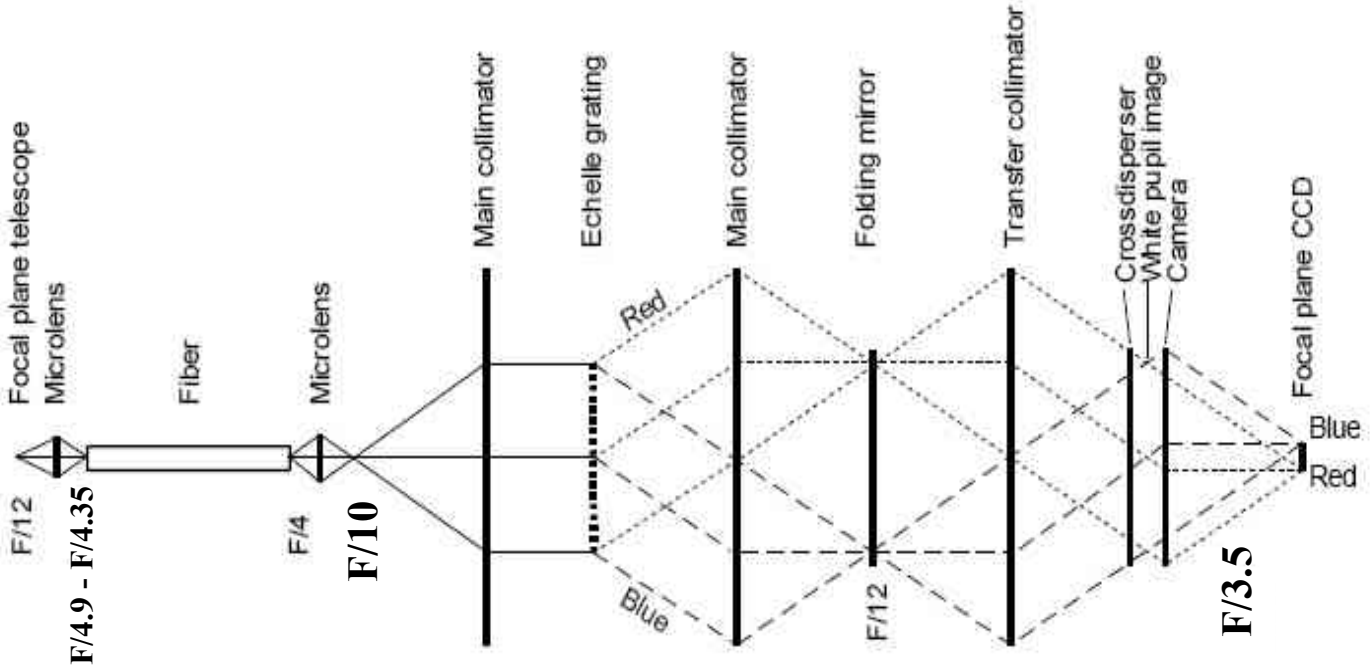
ADC
Aquisition.
Guiding
NDFilter
calib.

2.5 arcsec/fibre

2.15 arcsec/fibre

double slicer

HERMES design



Overview is given following the optical path

FOD

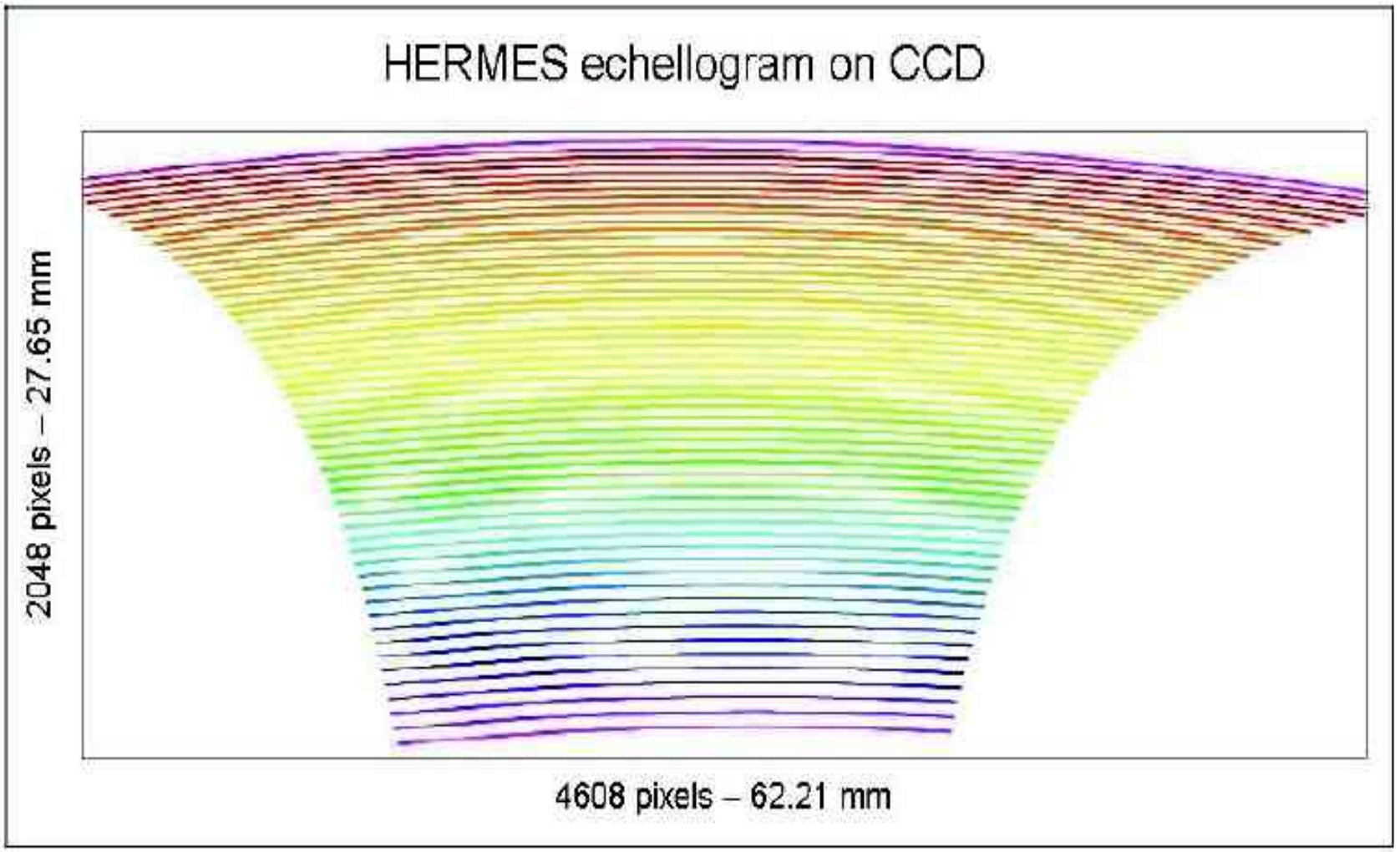


Fig. 17. Layout of the 55 orders on the CCD (color scale is compressed for visibilty).

Project History: milestones

* External Project Reviewers: European Experts in Instrumentation
  Dr. Francesco Pepe (Geneva), Prof. Dr. Otmar Stahl (Heidelberg),
  Dr. Gerardo Avila (ESO), Prof. Dr. Ramon Garcia Lopez (IAC)

  Final Optical Design Review: 12/05/2005, Leuven

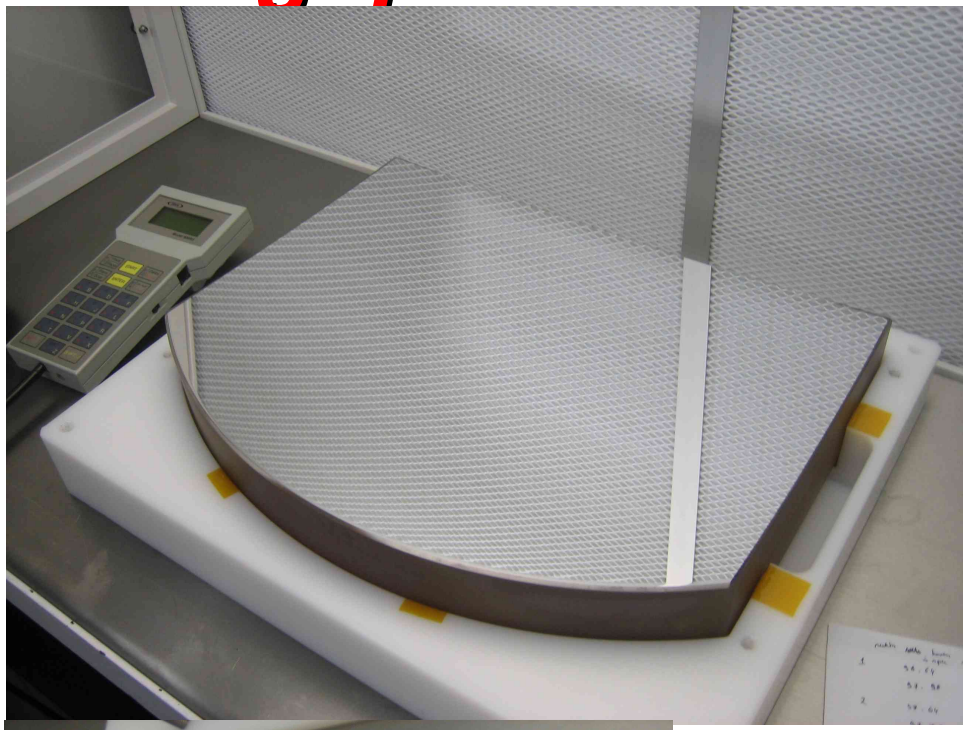
  Preliminary Design Review: 27/01/2006, Leuven

* Web-based document system and version control system for software (adapted from IvS investment in PACS project)

* Feb 2006 – April 2009 optimization design, ordering +quality control optics, final detailed drawings mechanics, procurement (workshops department KUL, Tautenburg and Geneva), integration on site and software, software, software

Spectrograph Optics

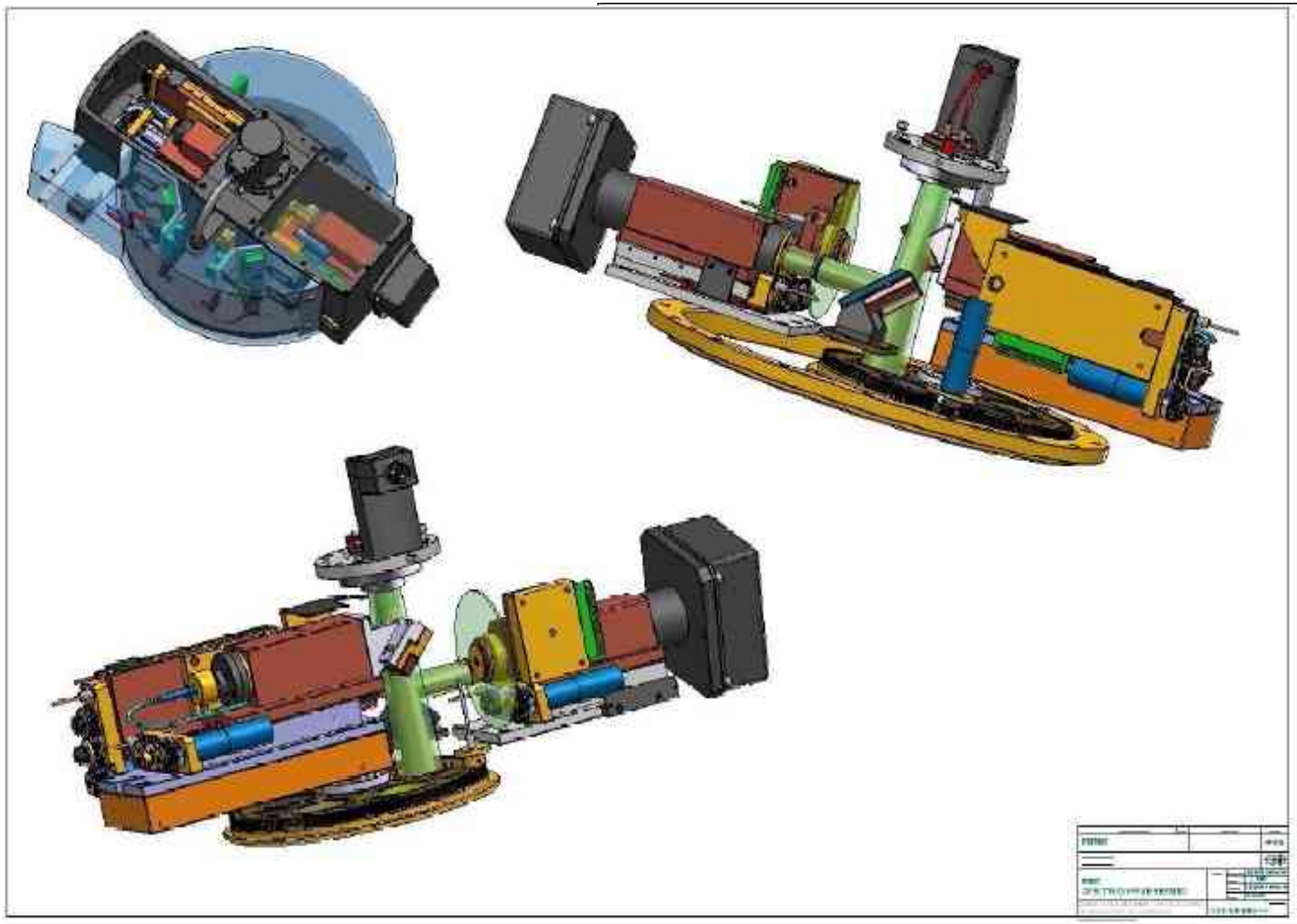
Coating: protected UV-enhanced silver

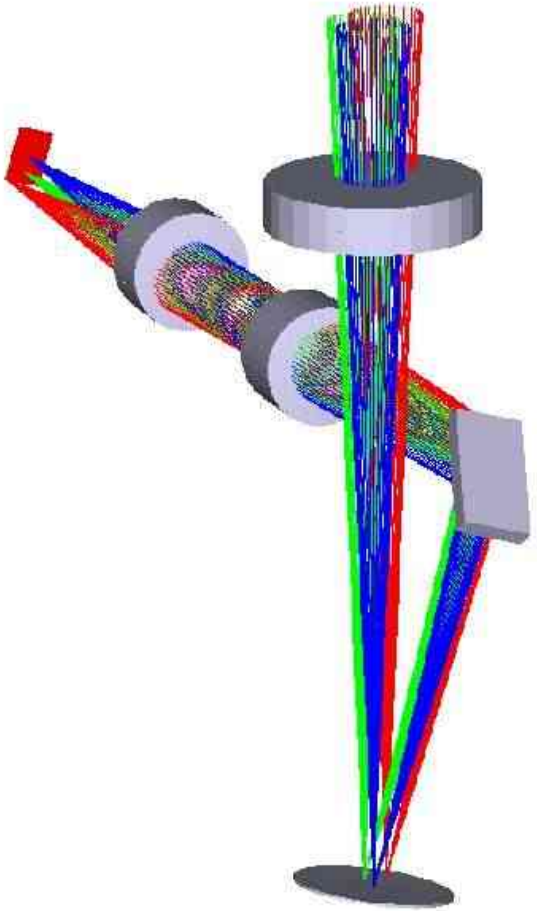


received :
10/9/2008

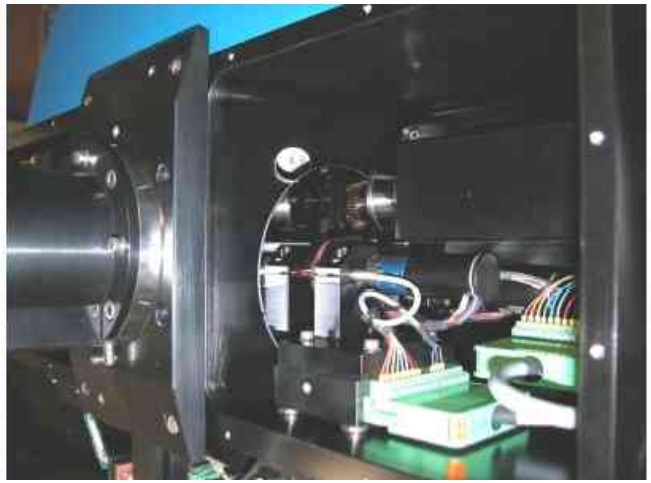
4 discrete ADC positions (380-900nm)

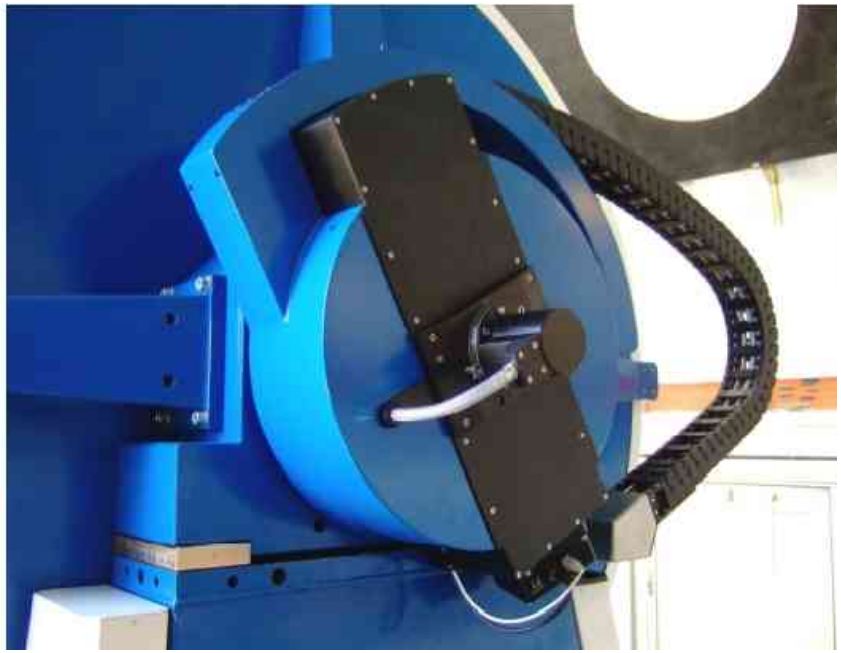
zenith distance	length without ADC	with ADC
31	1.12”	0.61”
60	2.71”	0.33”





Adaptor

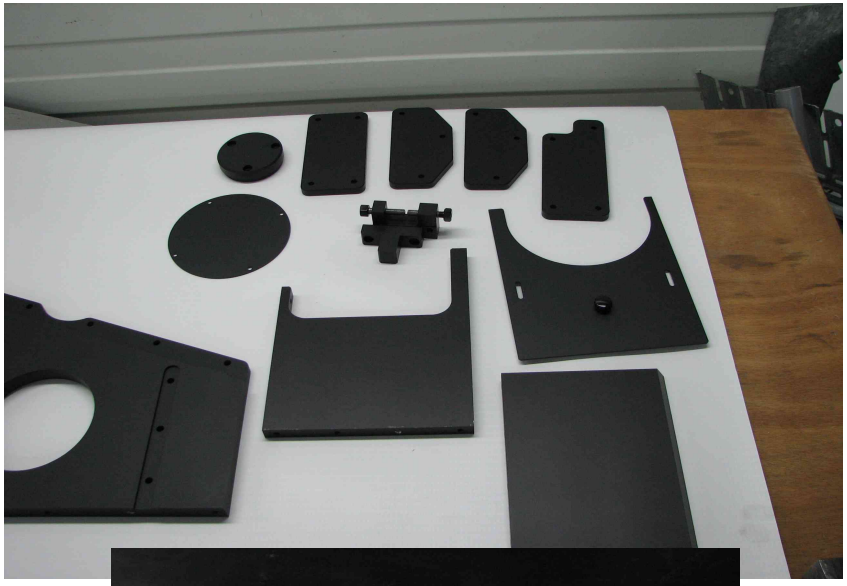


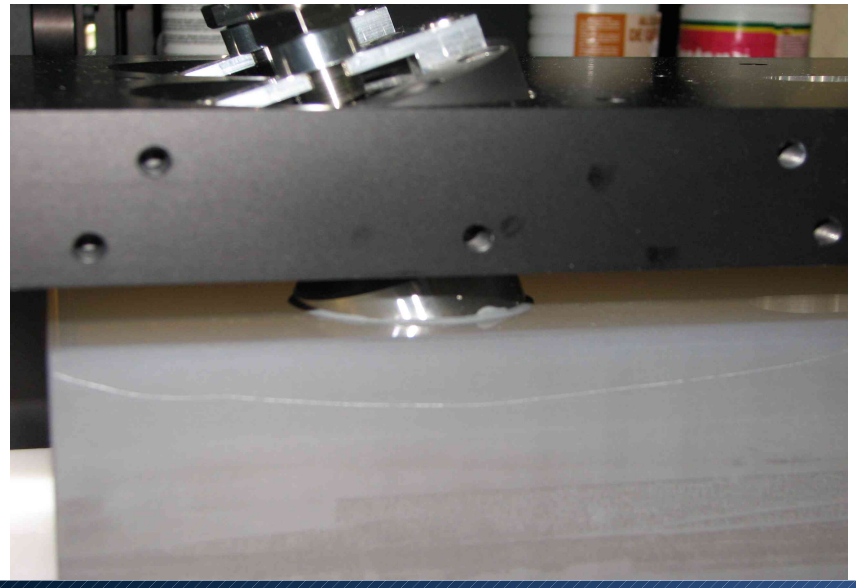


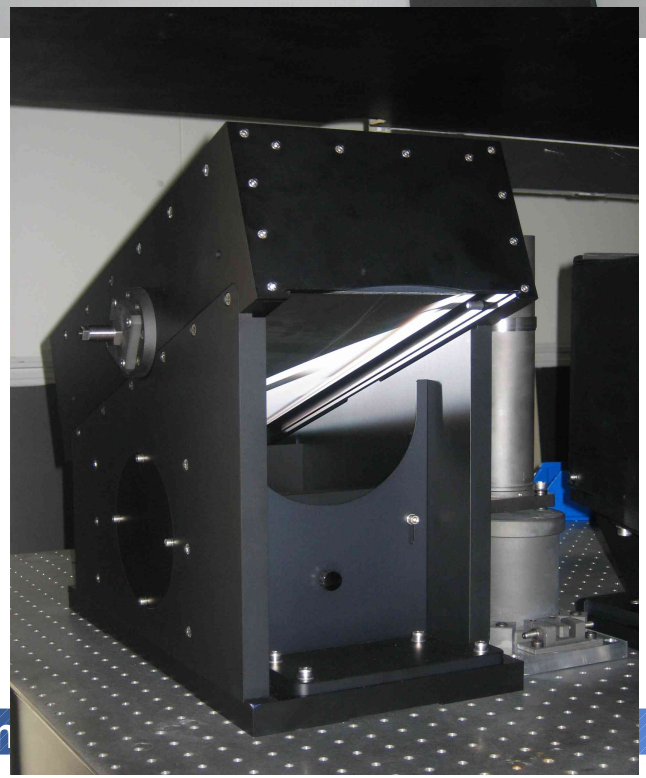
8 July 2008

Mounts: 320 kg of mechanics were shipped in August 2008

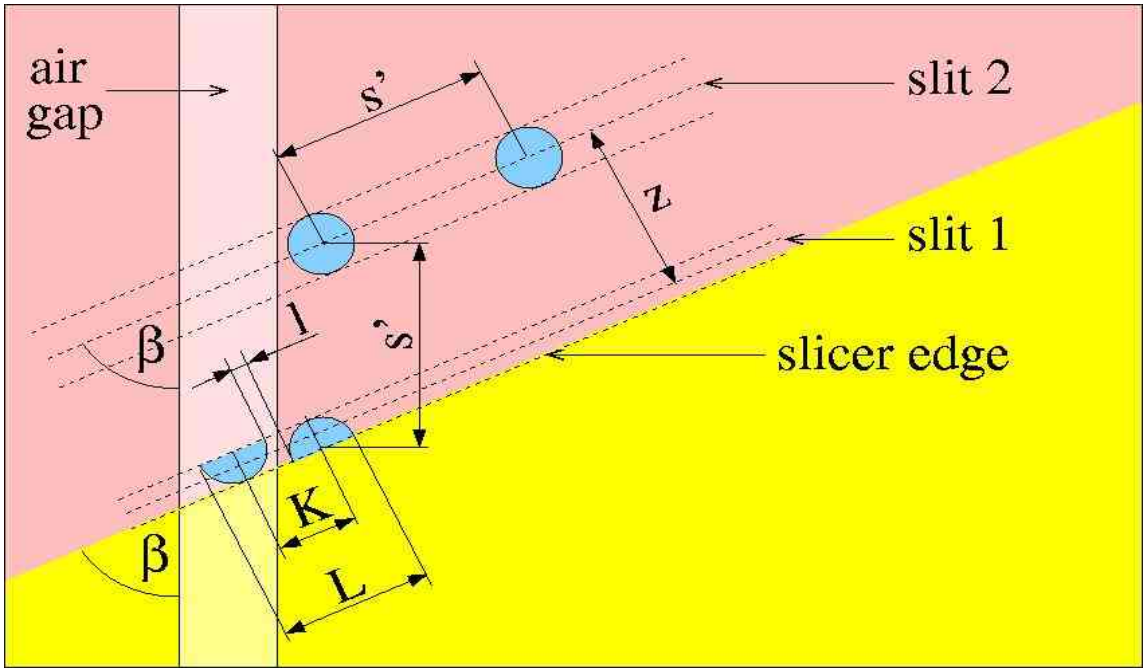
Grating

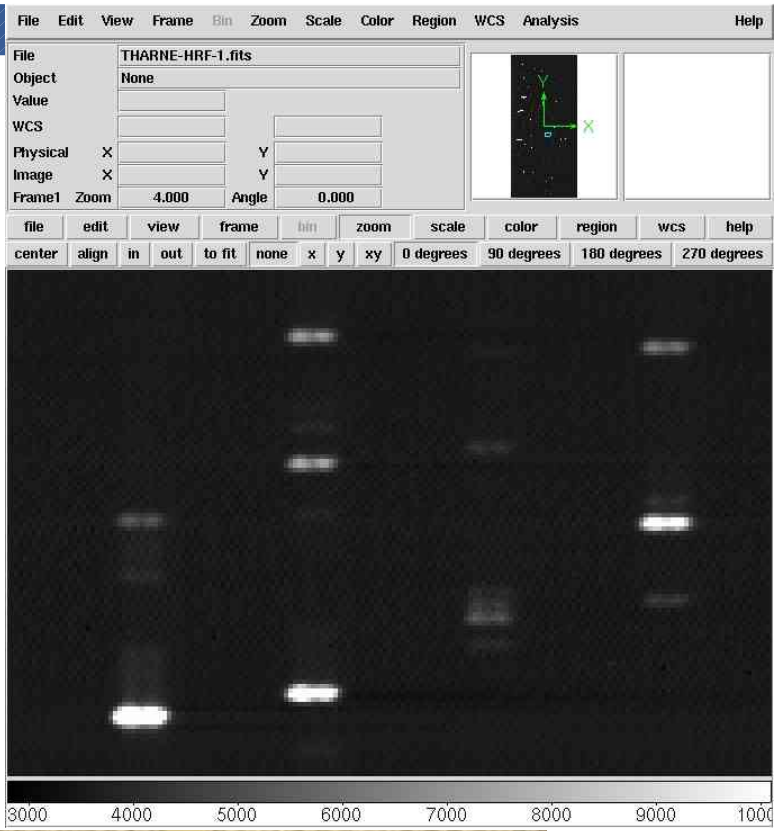


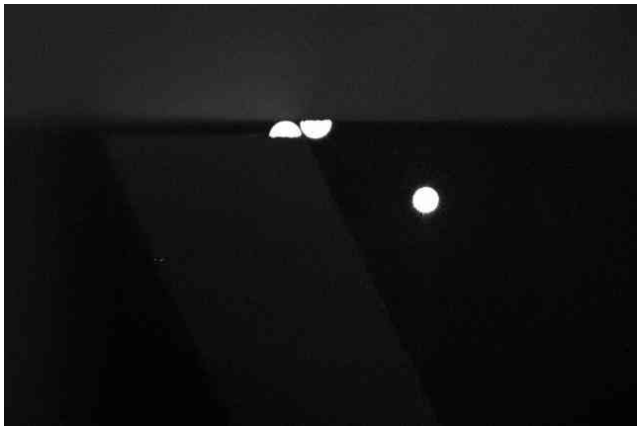




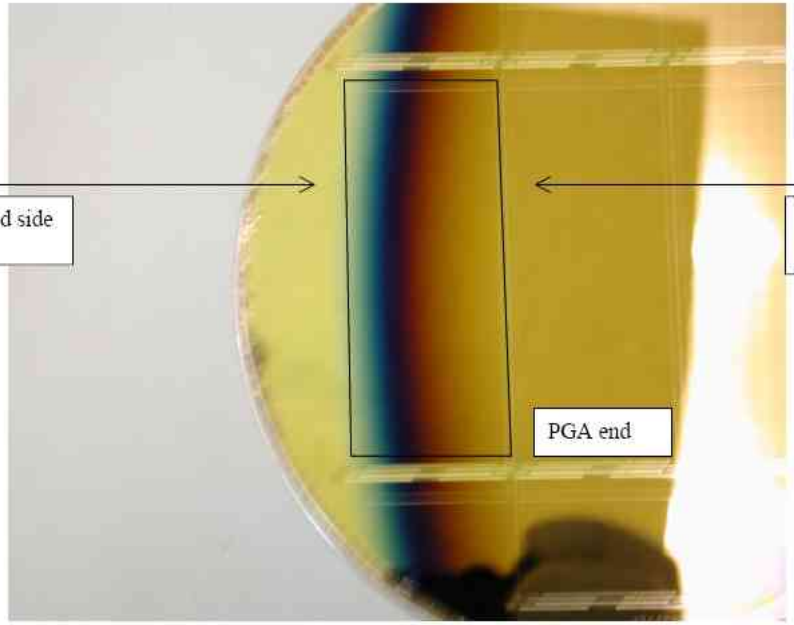
HRF: slicer

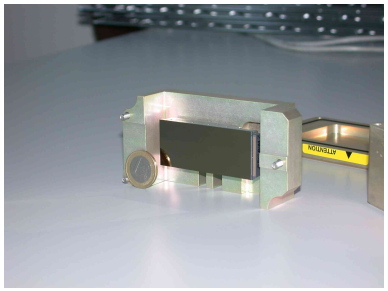

air
gap
s'
slit 2
z
slit 1
β
l
's
slicer edge
K
β
L

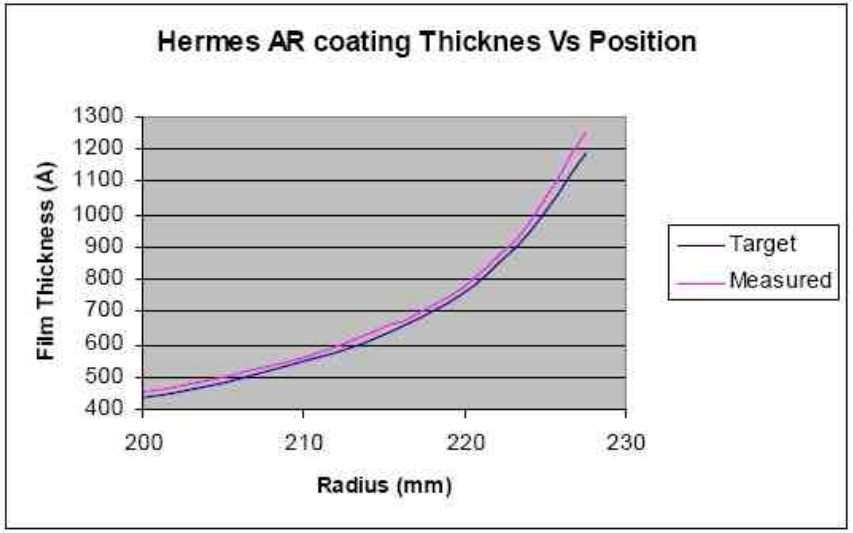

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File THARNE-HRF-1.fits
Object None
Value
WCS
Physical X Y
Image X Y
Frame1 Zoom 4.000 Angle 0.000
file edit view frame bin zoom scale color region wcs help
center align in out to fit none x y xy 0 degrees 90 degrees 180 degrees 270 degrees
3000 4000 5000 6000 7000 8000 9000 1000

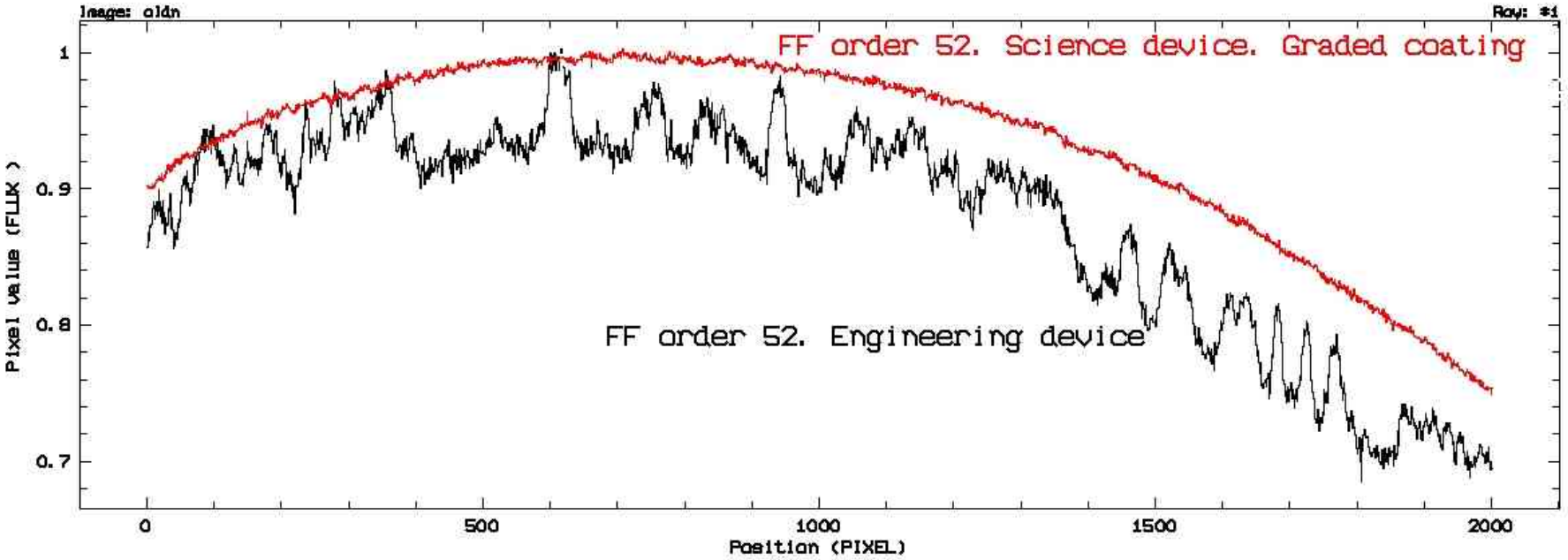


Graded AR coating: Anti-fringing



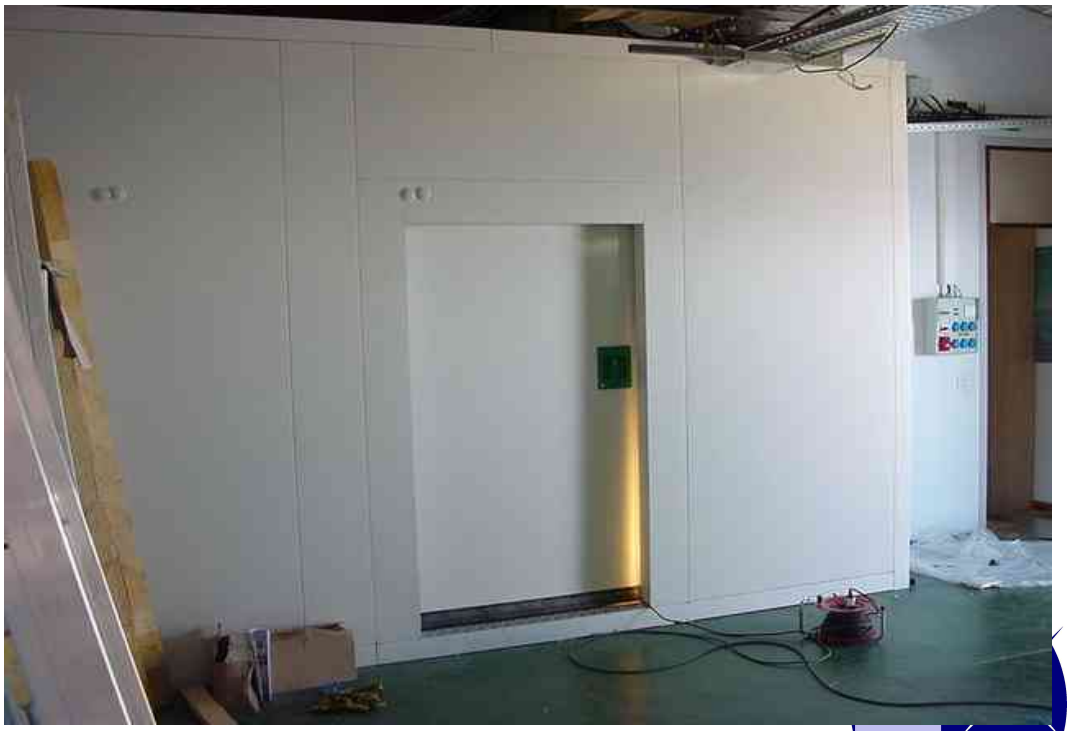




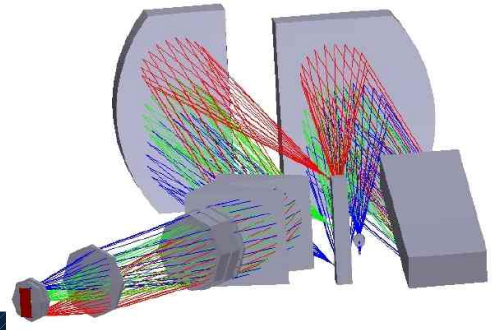


Hermes spectrograph room: tripple isolation

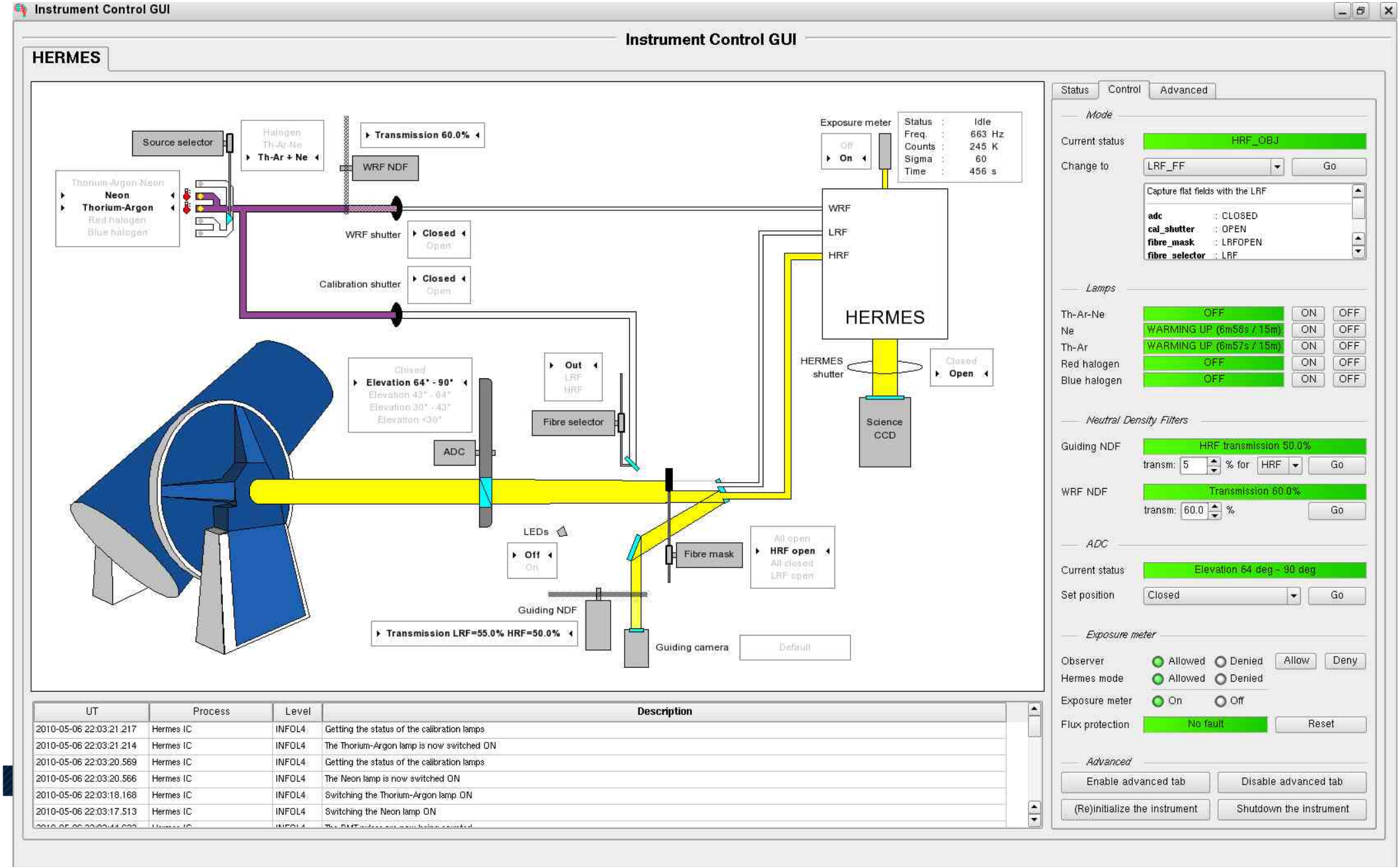
1) Room 1: ΔT +/- 0.1 degree (working)
2) Room 2: ΔT +/- 0.01 degree
3) Room 3: passive (installed around table)
4) Absolute pressure controle

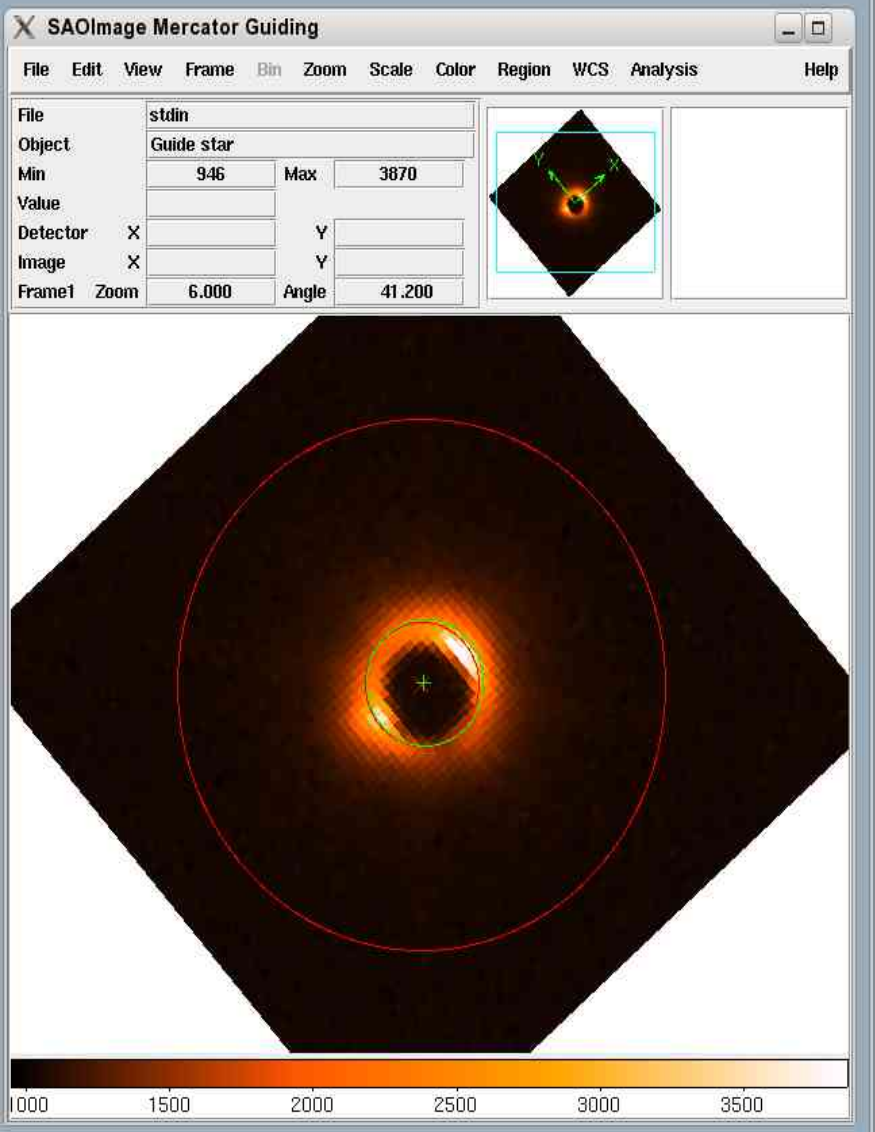


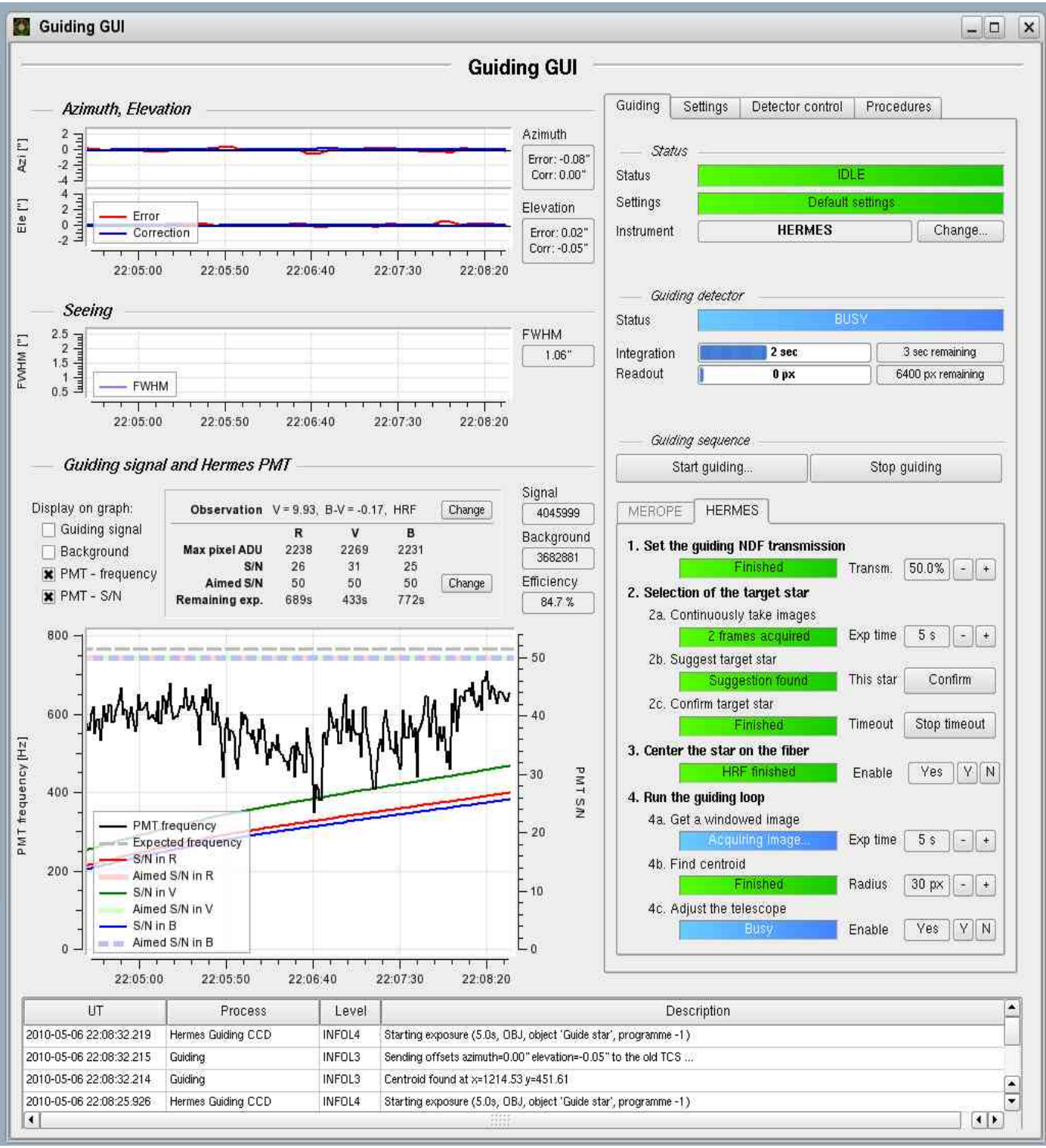
Spectrograph room now



Software: control + user gui




SAOImage Mercator Guiding
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File stdin
Object Guide star
Min 946 Max 3870
Value
Detector X Y
Image X Y
Frame1 Zoom 6.000 Angle 41.200
1000 1500 2000 2500 3000 3500


Guiding GUI
Guiding GUI
Azimuth, Elevation
Azi ["]
Ele ["]
Error
Correction
22:05:00 22:05:50 22:06:40 22:07:30 22:08:20
Azimuth
Error: -0.08"
Corr: 0.00"
Elevation
Error: 0.02"
Corr: -0.05"
Seeing
FWHM ["]
FWHM
FWHM
1.06"
Guiding signal and Hermes PMT
Display on graph:
Guiding signal
Background
PMT - frequency
PMT - S/N
Observation V = 9.93, B-V = -0.17, HRF
Change
R V B
Max pixel ADU 2238 2269 2231
S/N 26 31 25
Aimed S/N 50 50 50
Remaining exp. 689s 433s 772s
Change
Signal
4045999
Background
3682881
Efficiency
84.7 %
PMT frequency [Hz]
PMT S/N
PMT frequency
Expected frequency
S/N in R
Aimed S/N in R
S/N in V
Aimed S/N in V
S/N in B
Aimed S/N in B
Guiding
Settings
Detector control
Procedures
Status
Status IDLE
Settings Default settings
Instrument HERMES
Change...
Guiding detector
Status BUSY
Integration 2 sec
3 sec remaining
Readout 0 px
6400 px remaining
Guiding sequence
Start guiding...
Stop guiding
MEROPE
HERMES
1. Set the guiding NDF transmission
Finished
Transm. 50.0%
2. Selection of the target star
2a. Continuously take images
2 frames acquired
Exp time 5 s
2b. Suggest target star
Suggestion found
This star
Confirm
2c. Confirm target star
Finished
Timeout
Stop timeout
3. Center the star on the fiber
HRF finished
Enable
Yes
4. Run the guiding loop
4a. Get a windowed image
Acquiring image...
Exp time 5 s
4b. Find centroid
Finished
Radius 30 px
4c. Adjust the telescope
Busy
Enable
Yes
UT
Process
Level
Description
2010-05-06 22:08:32.219 Hermes Guiding CCD INFOL4 Starting exposure (5.0s, OBJ, object 'Guide star', programme -1)
2010-05-06 22:08:32.215 Guiding INFOL3 Sending offsets azimuth=0.00" elevation=-0.05" to the old TCS ...
2010-05-06 22:08:32.214 Guiding INFOL3 Centroid found at x=1214.53 y=451.61
2010-05-06 22:08:25.926 Hermes Guiding CCD INFOL4 Starting exposure (5.0s, OBJ, object 'Guide star', programme -1)

Scheduler GUI

Scheduler GUI

STATUS	T	I	G	E	Instrument	Obs-mode	R.A.	Dec.	Object	Progr.	Misc.	mV	B-V	S/N (V)	Exp Time	#	C
FINISHED	X	X	X	X	HERMES	HRF_OBJ	10h 37m 33.5"	-13° 23' 4.3"	HD92055	10	every 20 days	4.93	2.740	200	60.0	1	blueN last obs: 2455322
FINISHED	X	X	X	X	HERMES	HRF_OBJ	9h 13m 50.1"	+14° 12' 39.1"	HD79319	10	every 20 days	8.57	1.670	40	200.0	1	blueJ-R last obs: 2455322
FINISHED	X	X	X	X	HERMES	HRF_OBJ	11h 38m 44.9"	+45° 6' 30.2"	HD101177	1		6.45	0.570	10	40.0	1	RV stand
BUSY	X	X	X	X	HERMES	HRF_OBJ	10h 38m 55.4"	+10° 3' 48"	V*DNLeo	10	every 20 days	9.93	-0.170	50	800.0	1	pagb last obs: 2455295
	X	X	X	X	HERMES	HRF_OBJ	15h 35m 28"	+43° 28' 49.1"	YY Boo	26	every night 2 exposures well ...	11.9	0.000	20	600.0	2	!!!!!! observed at
	X	X	X	X	HERMES	HRF_OBJ	10h 56m 57.7"	+15° 16' 46.3"	HIP53522	10	every 20 days	10.11	1.290	50	900.0	1	R:ORB last obs: 2455296
	X	X	X	X	HERMES	LRF_WRF_OBJ_TH	15h 8m 51.5"	+2° 20' 35.9"	WASP-24	6		11.3	0.800	50	2000.0	1	!!!!! Every night two times LRF+WRF!
	X	X	X	X	HERMES	HRF_OBJ	11h 7m 26.3"	+24° 3' 12.6"	PG1104+243	10	every 10 days	11.29	0.000	30	1200.0	1	sdOB+G last obs:
									STOP								Stop the observations
	X	X	X	X	HERMES	HRF_OBJ	11h 0m 48.5"	+40° 42' 10.5"	HIP53832	10	every 20 days	10.0	1.170	50	820.0	1	R:ORB last obs: 2455297
	X	X	X	X	HERMES	HRF_OBJ	11h 14m 36.6"	+33° 40' 26.8"	PG1111+339	10	every 30 days	12.52	0.000	99	2700.0	1	sdB+G last obs:
	X	X	X	X	HERMES	HRF_OBJ	11h 15m 23"	-11° 35' 17.5"	V*UUCrt	10	every 20 days	7.3	1.500	50	120.0	1	M:ORB last obs: 2455287
	X	X	X	X	HERMES	HRF_OBJ	11h 18m 30.2"	+52° 41' 41.9"	DZUMa	10	every 10 days	12.0	0.000	20	2700.0	1	disk last obs:
	X	X	X	X	HERMES	HRF_OBJ	11h 22m 49"	+43° 28' 57.1"	HD98839	10	every 50 days	4.99	0.980	200	60.0	1	Ba:ORB last obs: 2455294
	X	X	X	X	HERMES	HRF_OBJ	11h 23m 18.5"	-21° 38' 33"	HE1120-2122	10	every 20 days	11.93	1.510	30	1800.0	1	CEMP:SB? last obs:
	X	X	X	X	HERMES	HRF_OBJ	11h 35m 42.4"	-14° 35' 36.6"	CGCS3066	10	every 20 days	8.73	1.080	50	300.0	1	J-RDisk last obs: 2455292
	X	X	X	X	HERMES	HRF_OBJ	11h 35m 42.8"	-14° 35' 36.4"	HD 100764	10	every 30 days	8.73	1.080	30	600.0	1	R - IR excess last obs:
	X	X	X	X	HERMES	HRF_OBJ	11h 37m 54.4"	-1° 9' 3.1"	HD101079	10	every 30 days	8.2	1.020	50	200.0	1	Ba:ORB last obs: 2455292
	X	X	X	X	HERMES	HRF_OBJ	11h 49m 48.3"	-8° 17' 20.3"	IRAS11472-0800	10	every 20 days	11.7	0.500	20	2700.0	1	disk last obs: 2455298
	X	X	X	X	HERMES	HRF_OBJ	11h 55m 56.4"	+9° 50' 49.9"	BD+10.2357	10	every 10 days	8.87	0.000	50	800.0	1	sdO+A last obs: 2455291
	X	X	X	X	HERMES	HRF_OBJ	12h 7m 10.7"	+12° 59' 7.8"	HD105262	10	every 20 days	7.09	0.010	80	200.0	1	pagb last obs: 2455287
	X	X	X	X	HERMES	HRF_OBJ	12h 12m 52.1"	+33° 54' 2.5"	HZ19	10	every 30 days	12.72	0.000	20	2700.0	2	sdOB+F last obs: 2455308
	X	X	X	X	HERMES	HRF_OBJ	12h 24m 32"	-28° 18' 55.4"	V420Hya	10	every 20 days	10.1	0.900	50	900.0	1	S:symbio last obs: 2455293
	X	X	X	X	HERMES	HRF_OBJ	12h 24m 49"	+31° 2' 1.8"	HD108078	10	every 20 days	7.55	1.140	70	200.0	1	K:SB+abun last obs: 2455287
	X	X	X	X	HERMES	HRF_OBJ	12h 37m 23.1"	+25° 3' 59"	Feige66	10	every 30 days	10.51	0.000	40	2700.0	1	sdOB last obs: 2455297
	X	X	X	X	HERMES	HRF_OBJ	12h 43m 56.7"	+61° 5' 35.9"	V*SUMa	10	every 20 days	8.87	2.430	50	600.0	1	M:ORB last obs: 2455320
	X	X	X	X	HERMES	HRF_OBJ	12h 44m 7"	+2° 44' 38"	BD+03.2688	10	every 20 days	10.5	1.000	50	1200.0	1	mdBa last obs: 2455292
	X	X	X	X	HERMES	HRF_OBJ	12h 46m 37.1"	+47° 22' 20.8"	V*BYCVn	10	every 20 days	7.94	1.400	50	300.0	1	M:ORB last obs: 2455308
	X	X	X	X	HERMES	HRF_OBJ	12h 52m 58.4"	-14° 37' 14.7"	V*VWCrv	10	every 50 days	7.59	1.600	50	250.0	1	M:ORB last obs: 2455308
	X	X	X	X	HERMES	HRF_OBJ	12h 53m 32.4"	-22° 52' 22.8"	V*LWHya	10	every 30 days	9.69	0.830	50	800.0	1	Abell-35 last obs:
	X	X	X	X	HERMES	HRF_OBJ	12h 54m 21.2"	-9° 32' 20"	V*psiVir	10	every 50 days	4.81	1.580	50	30.0	1	M:ORB last obs: 2455284

Insert row(s) after the selection

Empty row(s) | Duplicate

Insert calibrations

Multiple... | Single ...

Special actions

Insert stop | Insert wait...

Move/Cut/copy/paste/delete

Append/save/save as file

Scheduler settings

- [ ] Stop after each line
- [x] Beep after each line
- [x] Autofocus at each pointing

Actions during AUTO sequence

- [x] T: Telescope pointing
- [x] I: Instrument / filter wheel
- [x] G: Guiding (+acquisition)
- [x] E: Exposure

Object

RA: 11 38 44.9 | Dec: +45 6 30.2 | V mag: 6.45 | B-V: 0.570

Object: HD101177 | Programme ID: 1 | S/N in V: 10

Comments: RV stand

Observation

- ( ) Merope
- (•) Hermes

Obs mode: HRF_OBJ | Exp time: 40.000 s | #: 1

Sequence

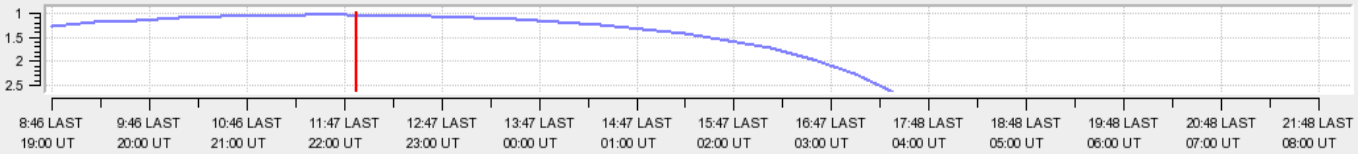
Telescope	Thermal focus finished
Instrument	ADC has been set
Guiding	OK
Exposing	Exposure(s) busy

AUTO sequence

START | STOP

MANUAL sequence

Point telescope | Set instrument | Start guiding | Start exposure(s)



WP900: Data Reduction System

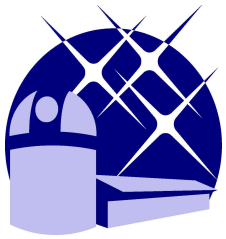
Herman Hensberge, Yves Fremat, Louis Dumortier, Alain Jorissen, Sophie Van Eck, Christos Siopis, Hans Van Winckel

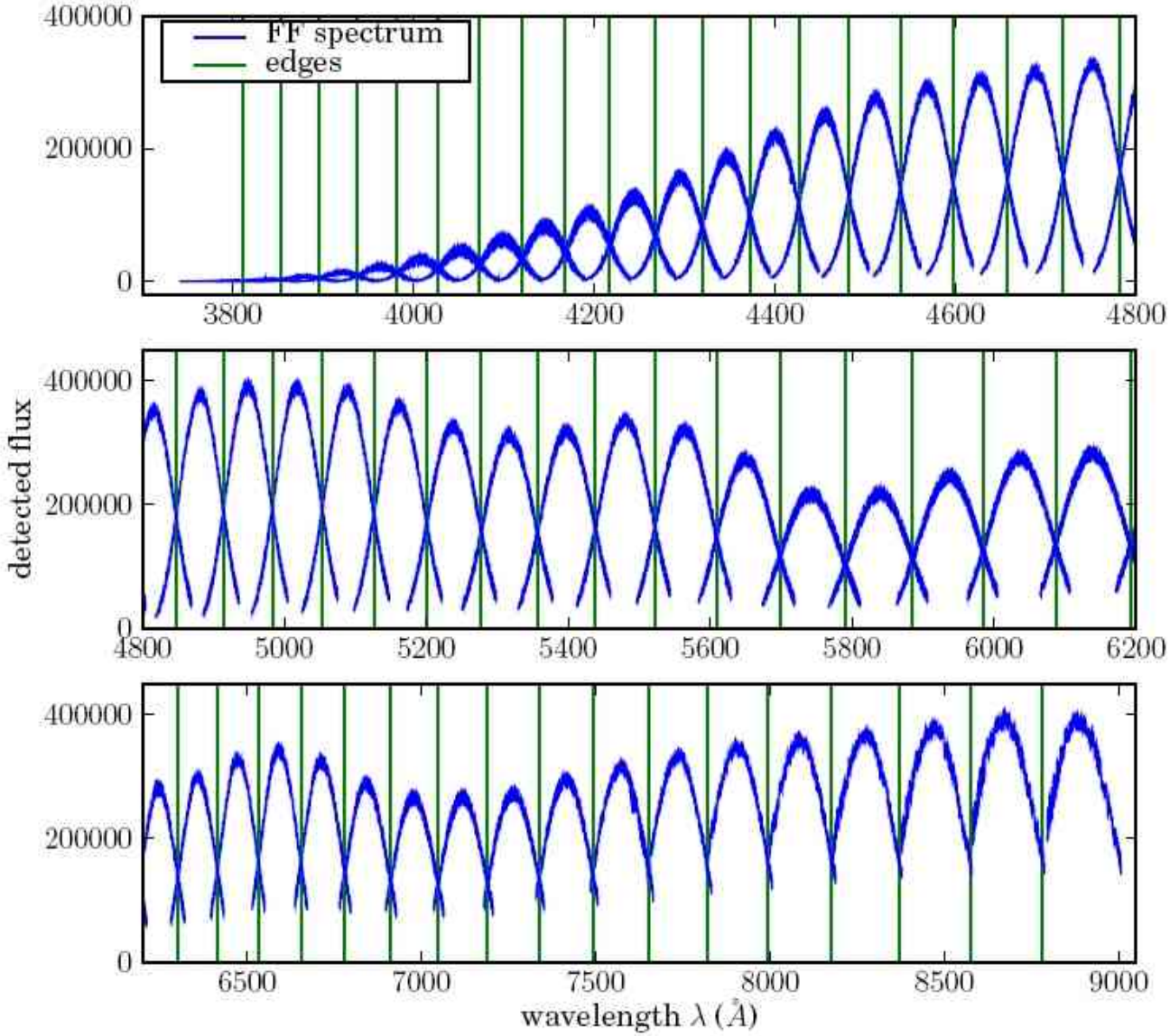
WP that ran during whole project (and is still running)

Take maximal advantage of stability of spectrograph

- good instrumentmodel !
- detailed algorithms
- coded in python
- quality control during observations, fine detailed reduction/night

- order tracing, bias correction, background mapping/correction, extraction with/w.o. clipping, wavelengthcalibration, merging, CCF routines



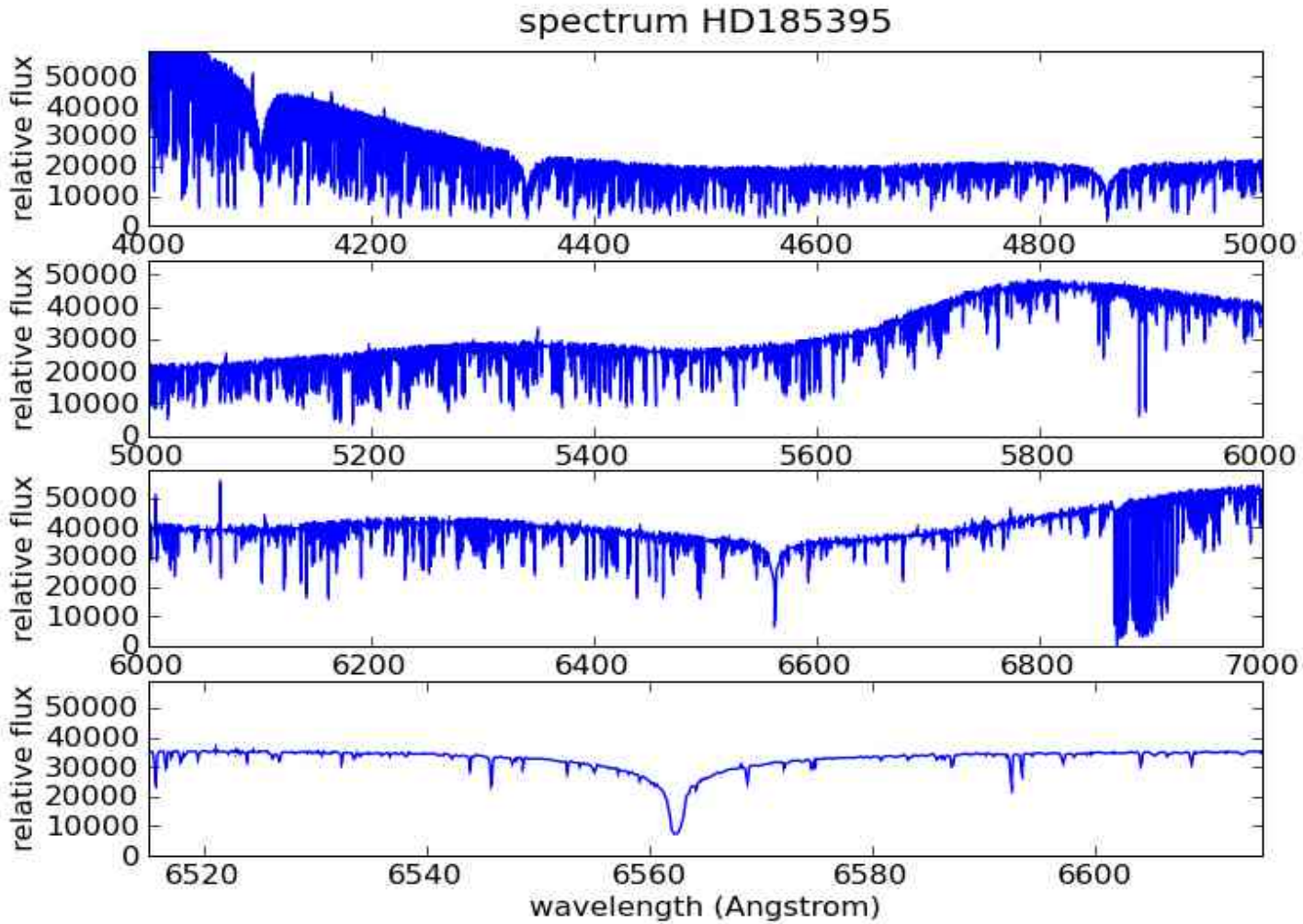


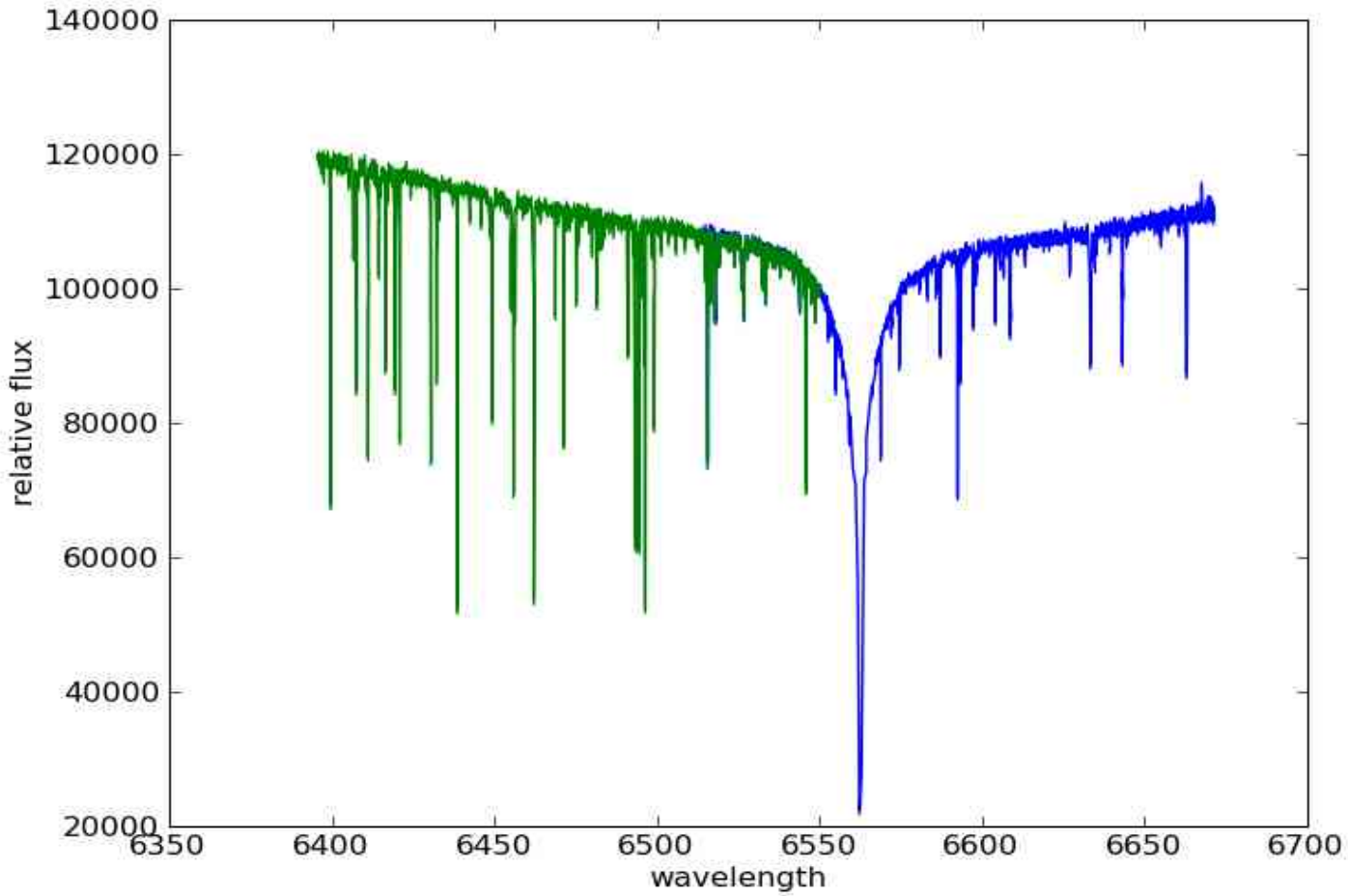
- blaze profiles so S/N is very dependent on the distance from the blazewavelength

- reddest orders not overlap.

Orders: 40 to 94

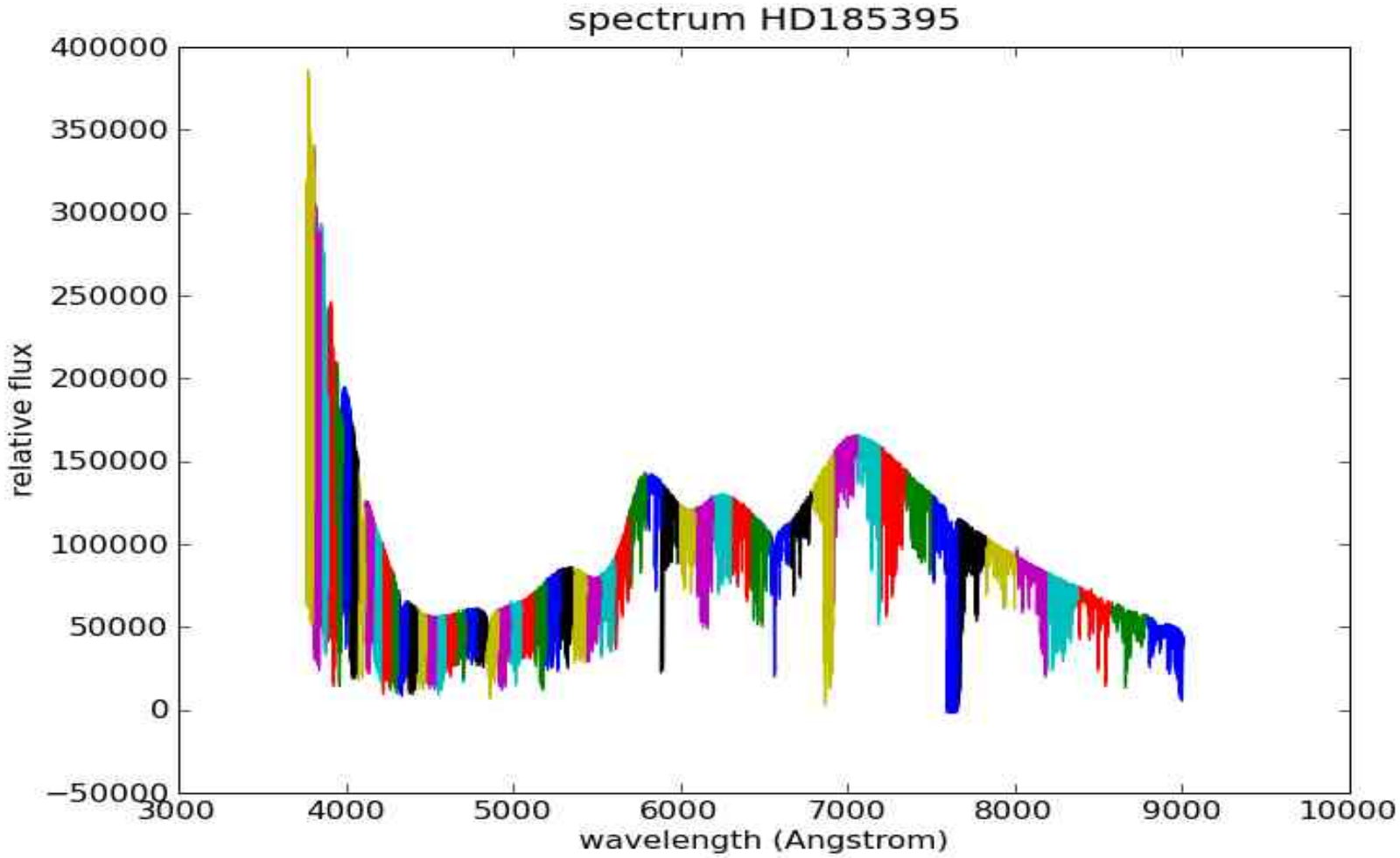
DRS: Merged Spectrum 1D




140000
120000
100000
80000
60000
40000
20000
relative flux
6350
6400
6450
6500
6550
6600
6650
6700
wavelength

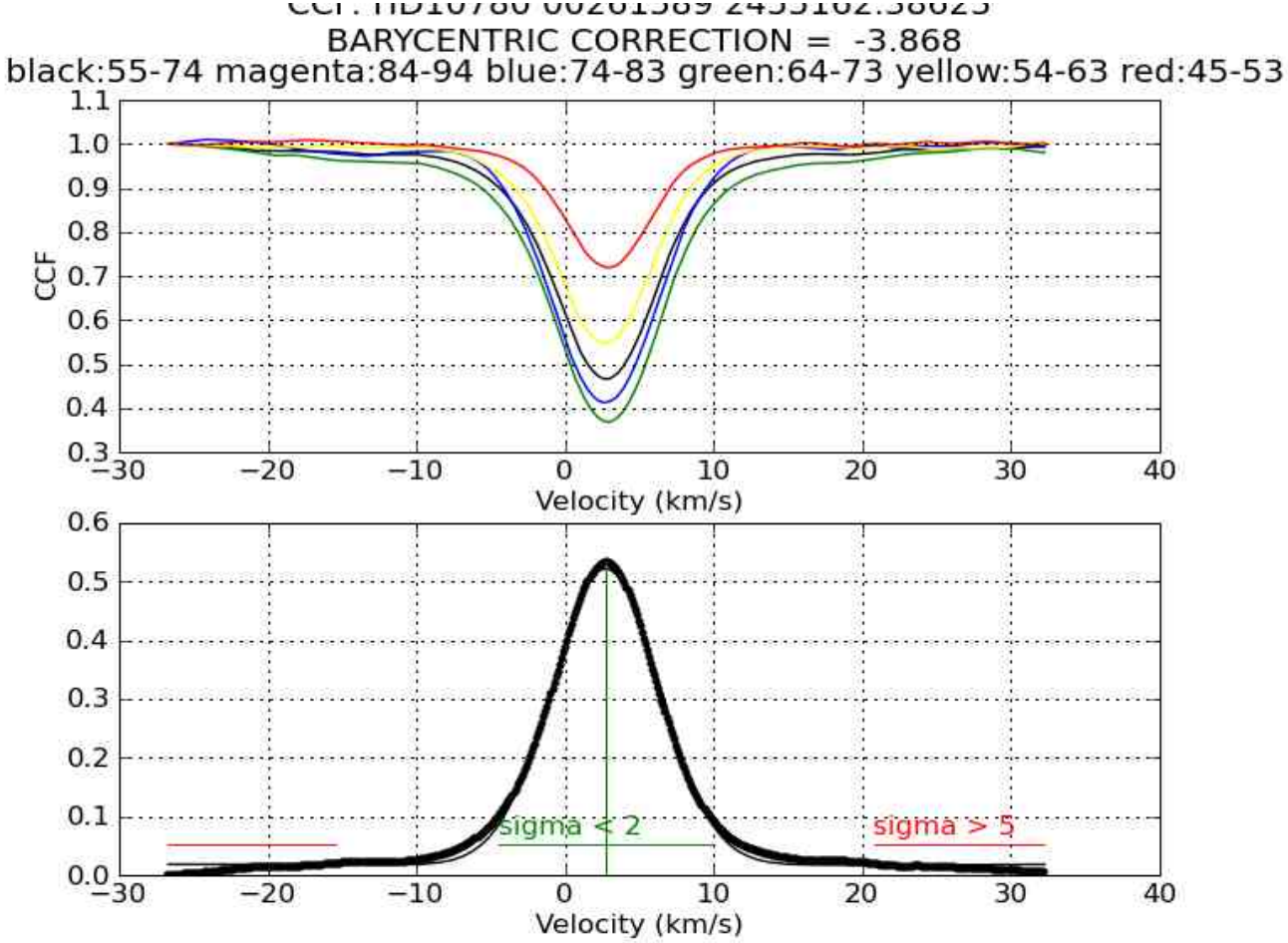
Slope = star + filtered FF lamp combination

FF normalisation is by devision of median of whole extracted FF



Spectral Masks: HD 10780 (K0V) v_helio: 2.7 km/s

file 00261589 of 20091126



Efficiency of Mercator-HERMES

λ nm	LRF	HRF	F/N+Slic.	4 mirrors	Echelle	CrossD.	Camera	Spectro.	CCD	Total LR	Total HR
380	0.49	0.70	0.90	0.60	0.60	0.85	0.75	0.21	0.75	0.08	0.11
400	0.51	0.71	0.90	0.83	0.60	0.86	0.80	0.31	0.80	0.13	0.18
450	0.51	0.73	0.90	0.91	0.61	0.86	0.85	0.37	0.85	0.16	0.23
500	0.52	0.74	0.90	0.95	0.62	0.88	0.85	0.40	0.90	0.19	0.26
600	0.52	0.75	0.90	0.93	0.63	0.88	0.85	0.39	0.85	0.17	0.25
700	0.52	0.75	0.90	0.92	0.64	0.89	0.85	0.40	0.80	0.17	0.24
800	0.52	0.75	0.90	0.90	0.65	0.89	0.85	0.40	0.60	0.12	0.18
900	0.52	0.75	0.90	0.89	0.65	0.89	0.85	0.39	0.30	0.06	0.09

Table 9. Estimated efficiency in low-and high-resolution mode.

Example:
Good seeing 1.2 arcsec
10 min exposure , 9th magn star: S/N 110 per resolution element for the HRF
S/N 74 per pixel for the HRF
60 min exposure, 14th magn star: S/N 40 per resolution element for the HRF
S/N 29 per pixel for the HRF

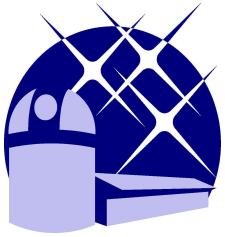
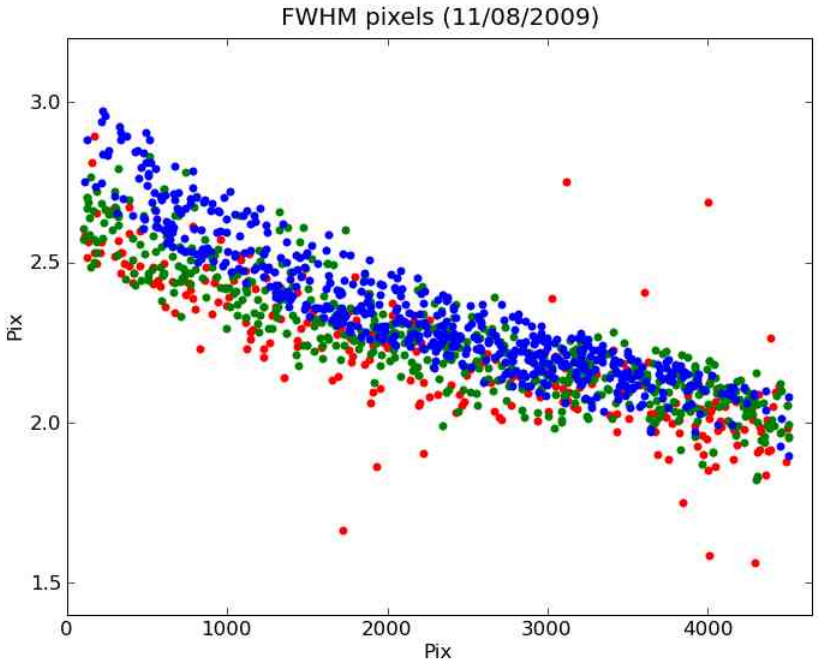
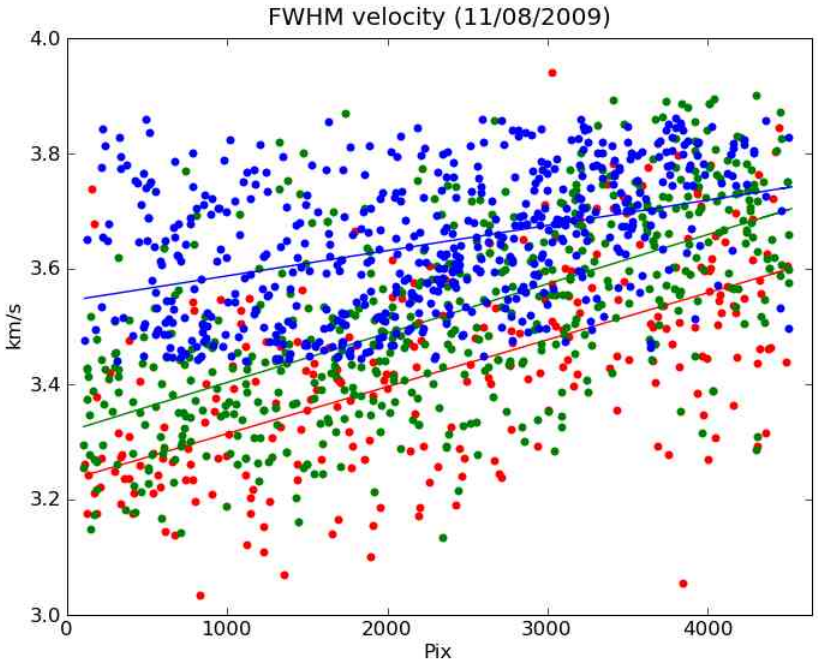


Image Quality

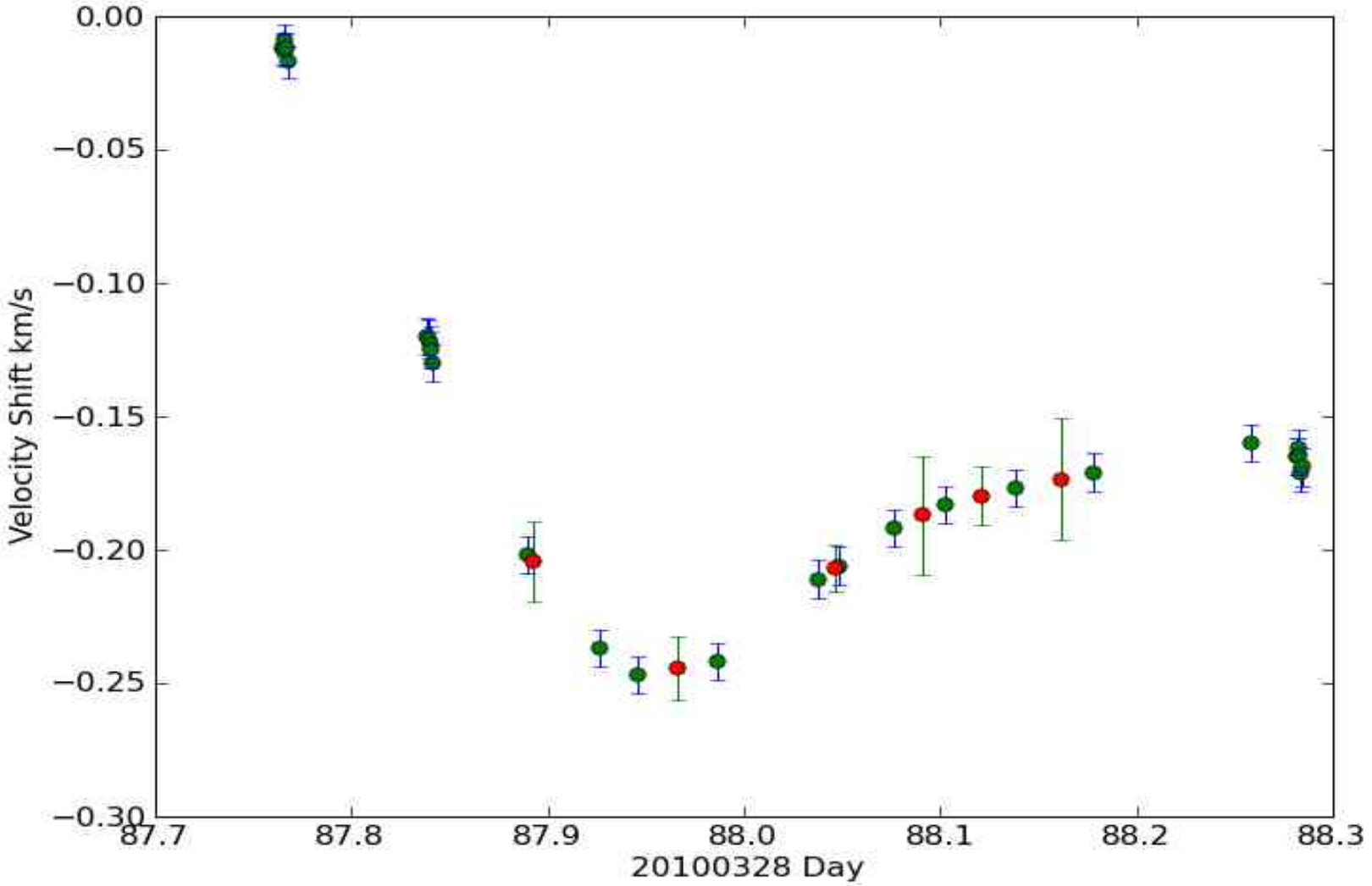


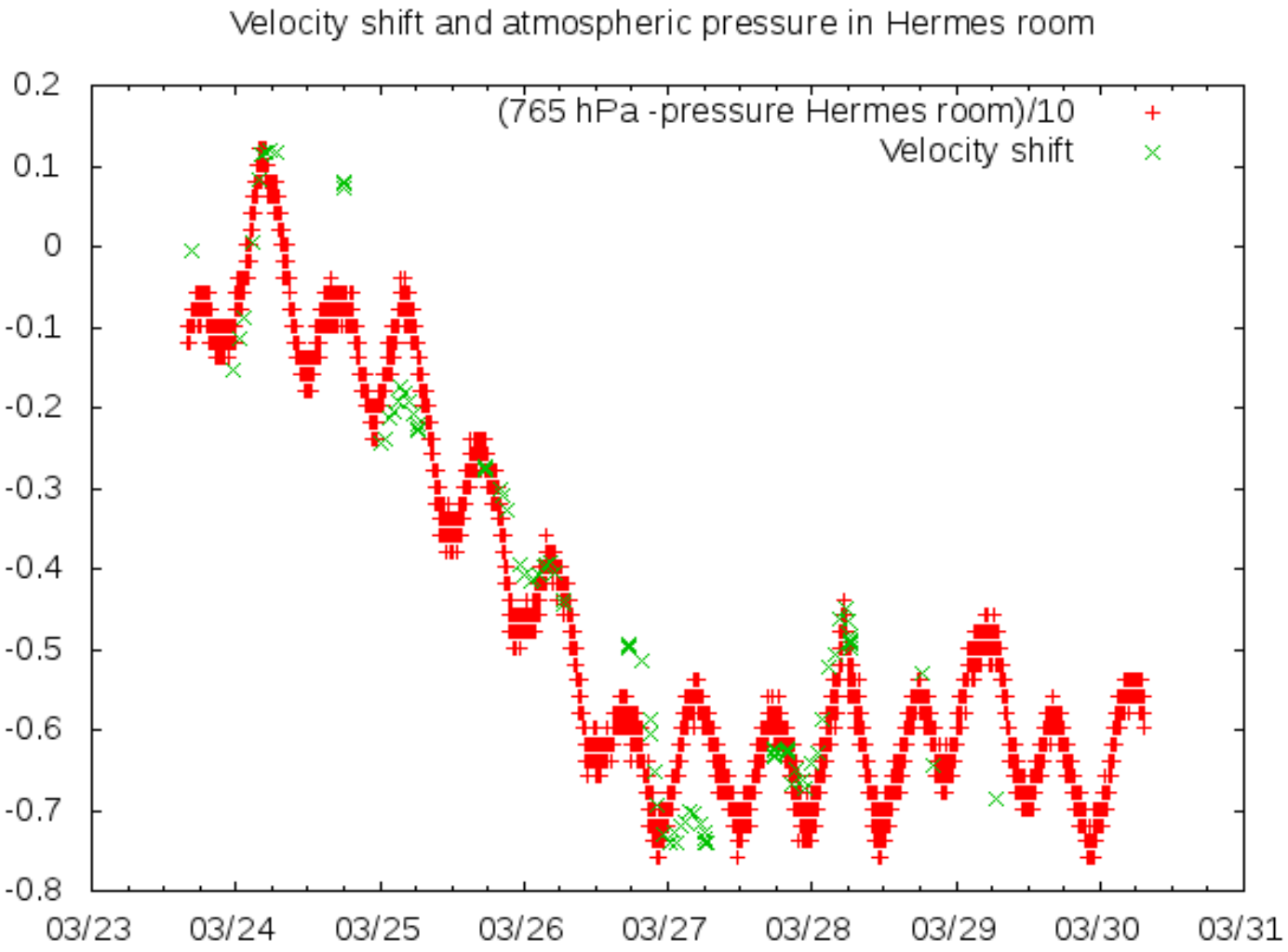


HRF pixel space.
FWHM of a resolution element

Velocity space

Stability of Hermes



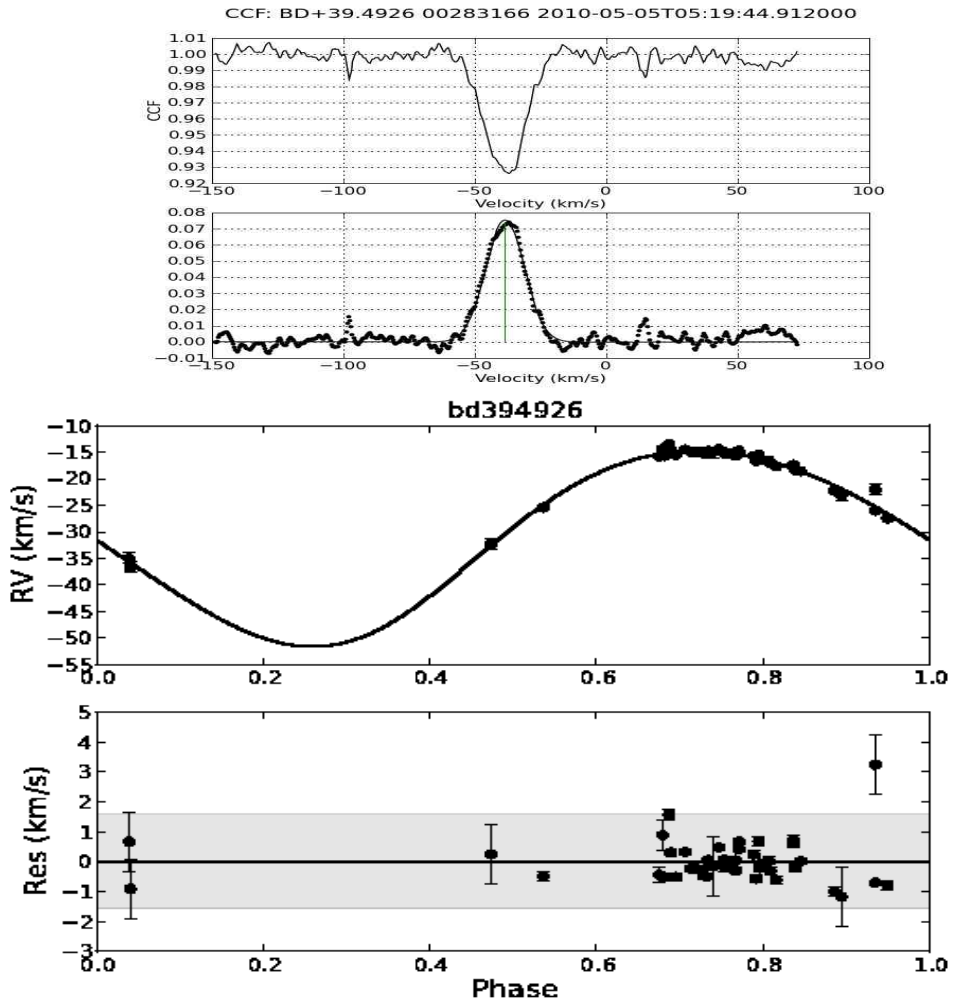


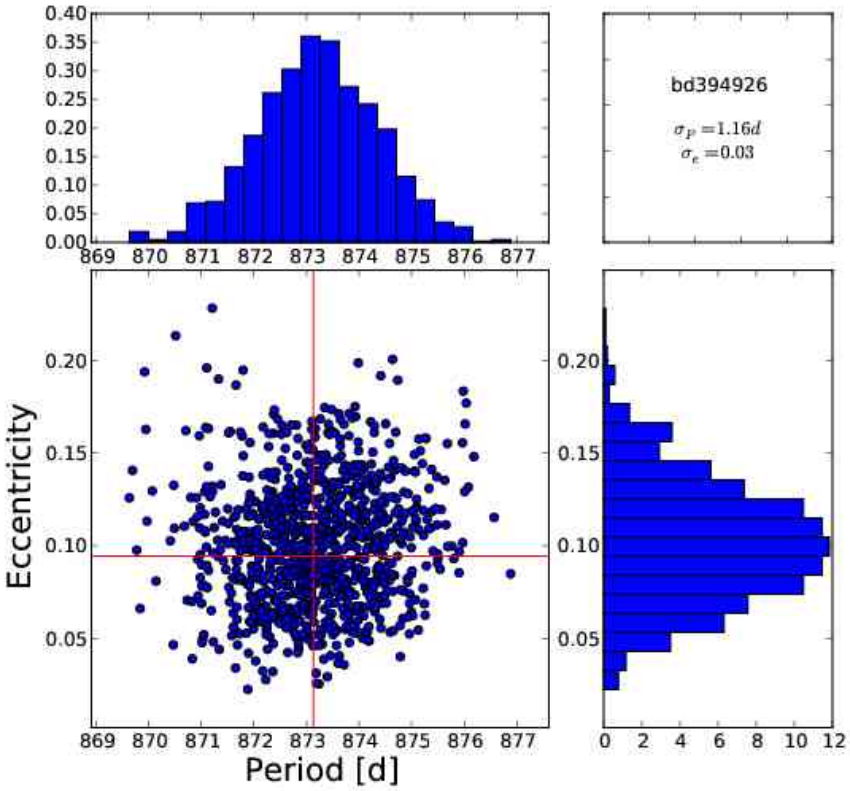
For high-accurate vr Work use the LRF

Noise in limited LRF Experiments till now 2 m/s

Some illustrative results: BD+39.4926

Very depleted post-AGB binary [Fe/H]= -3.2. Binary Orbit 873 days





Hyades stream: evaporated population / thin disc resonance effect ?

Pompeia et al.

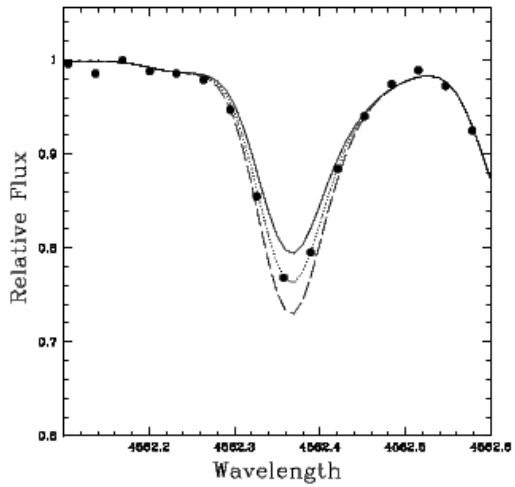
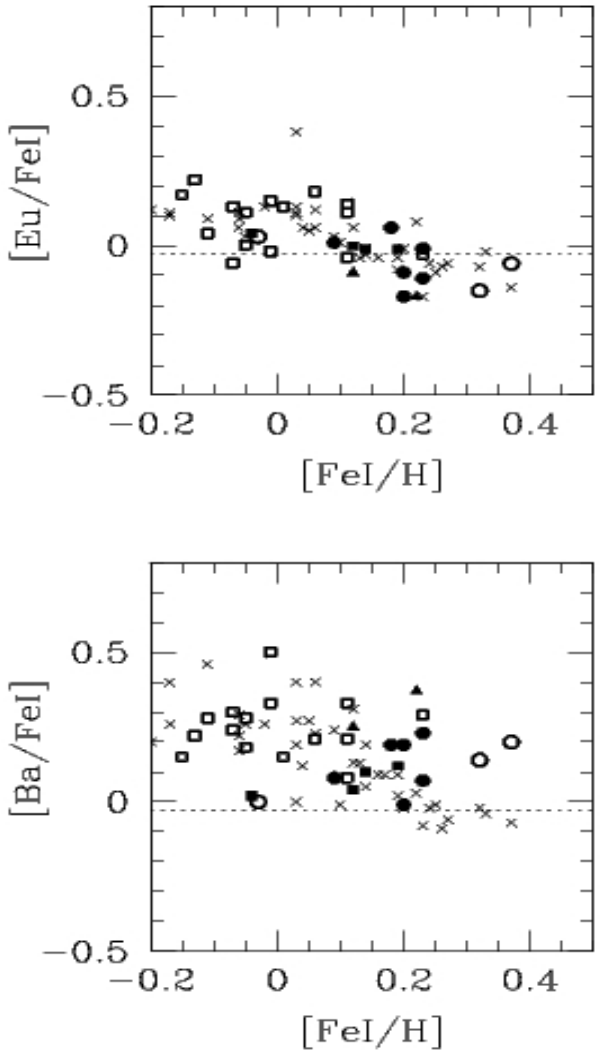


Fig. 7. Example of line synthesis for the Ce II line at 456.2 nm in HD 171067. The dots depict the observed spectrum, the dashed line shows the synthetic spectrum for [Ce/Fe] = 0.35 dex, the dotted line for [Ce/Fe] = 0.25 dex and the solid line for [Ce/Fe] = 0.15 dex.



Resolution + spectral coverage ideal
For abundance studies of bright stars.

Hermes project

After:

- many hundreds of mails, skype sessions, discussions
- detailed optical, mechanical design figs.+ (electronic) control
(very much instrument of Gert Raskin)
- hundreds of ATBs and puchased items (administration...)
- thousands of lines of codes,

Science exploitation at full swing !

- *semester allocation*
- *pooled observation*
- *DB+ more automatic Scheduling*
- *DRS fully relative*