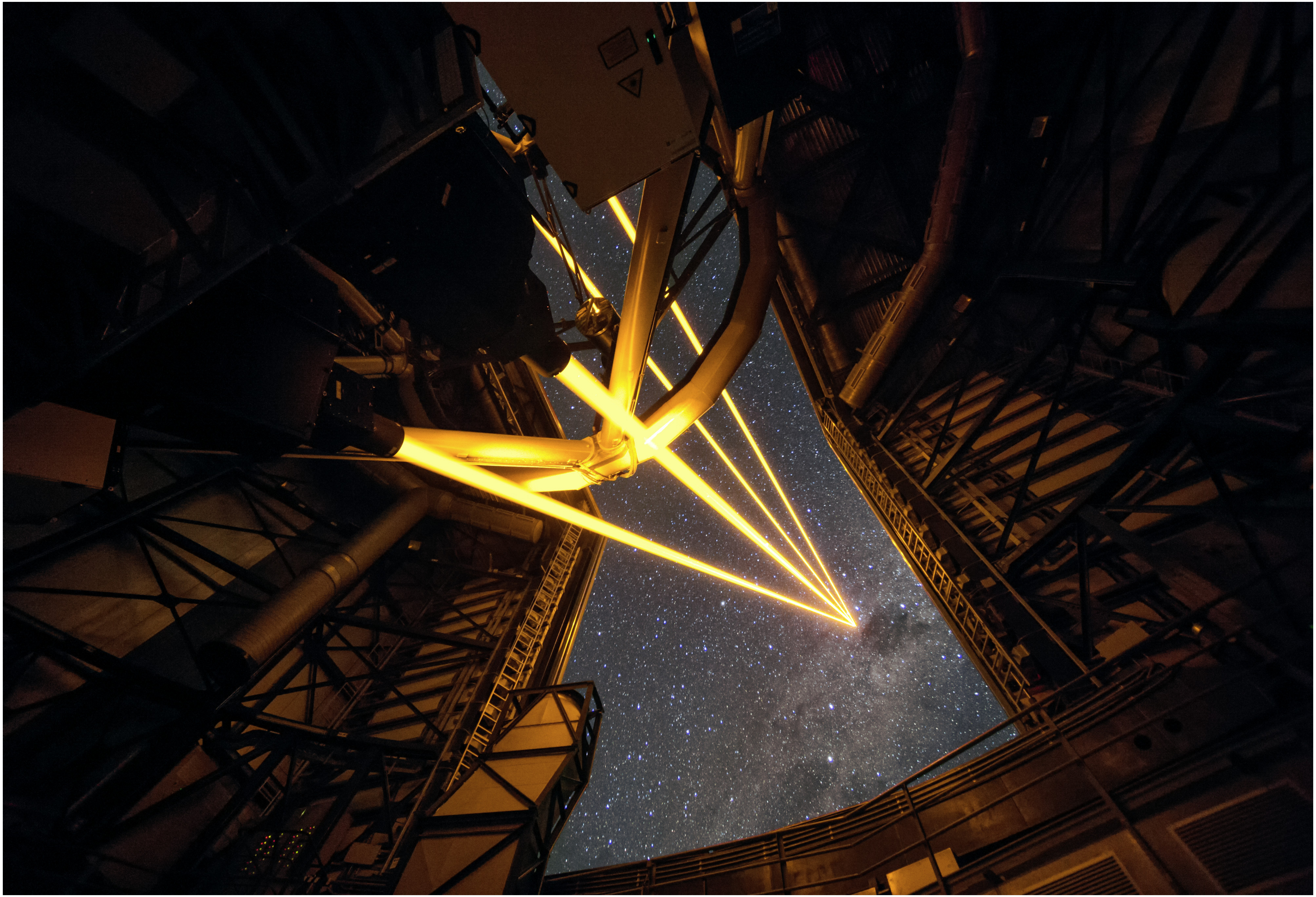
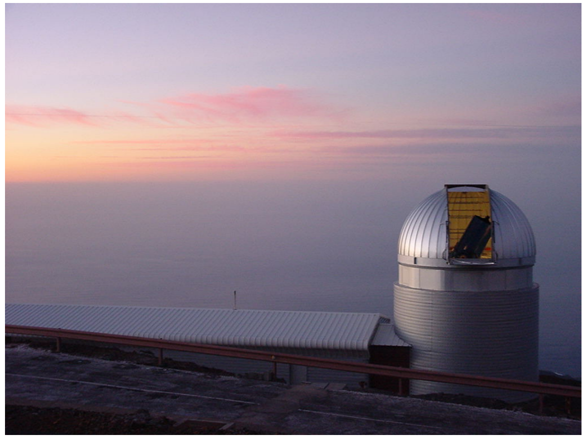
Mercator Telescope

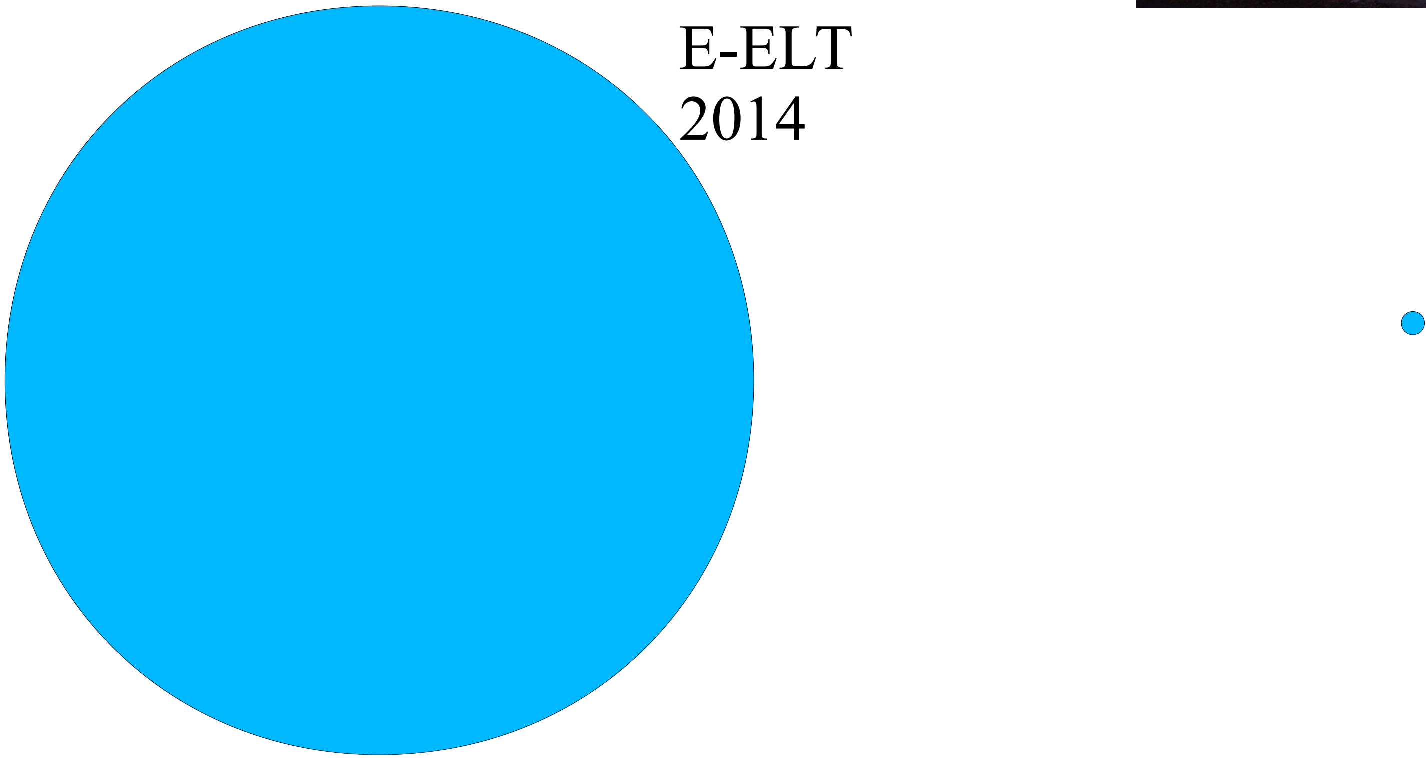
Prof. Hans Van Winckel
Instituut voor Sterrenkunde
KU Leuven

European Southern Observatory La Silla-Paranal observatory



Why Mercator ?





Mercator: Niche in observational astrophysics

Provides complementary unique possibilities to international (& space) facilities: **TIMES-SERIES over a wide range of scales and cadences**

Requirements:

World-class instruments: instrument development programme

Operational model: Pooled observations with priority driven scheduling.

Userfriendly robust operational environment

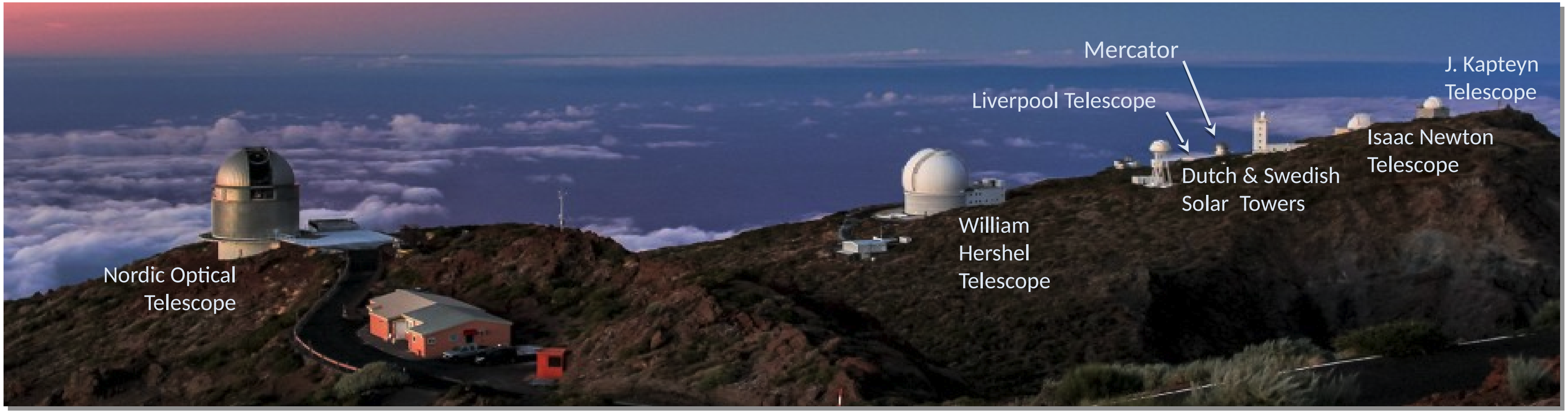
fwo: **Big Science envelope**

Outline

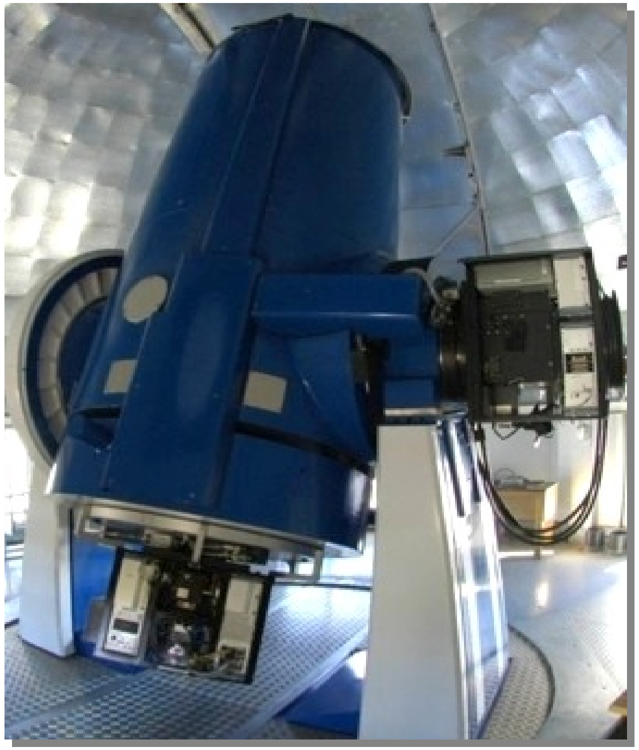
- Mercator for experimental astrophysics
- Instruments: HERMES
- Instruments: Maia
- Mercator Operations
- Science results

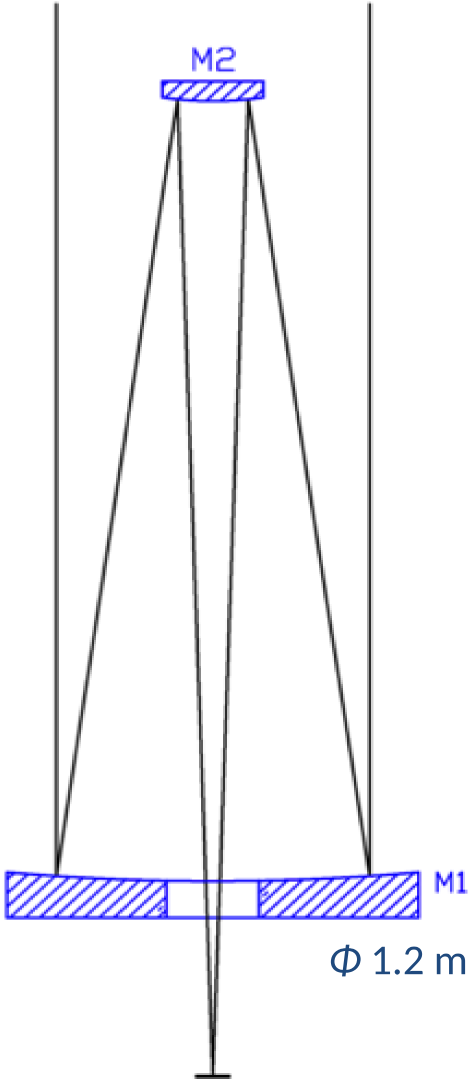
The Mercator telescope

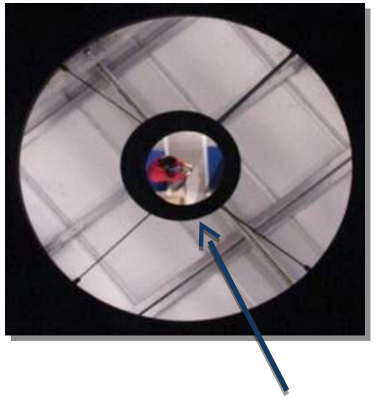
- Owned and operated by the Institute of Astronomy, KU Leuven
- In operation since 2001
- Built in collaboration with the Observatoire de Genève (Euler twin, Chile)
- Roque de los Muchachos Observatory
  - La Palma (Canary Islands, Spain)
  - Altitude: 2400 m
  - Prime site for astronomical observations in Europe
  - Large international collection of telescopes



Mercator telescope optics

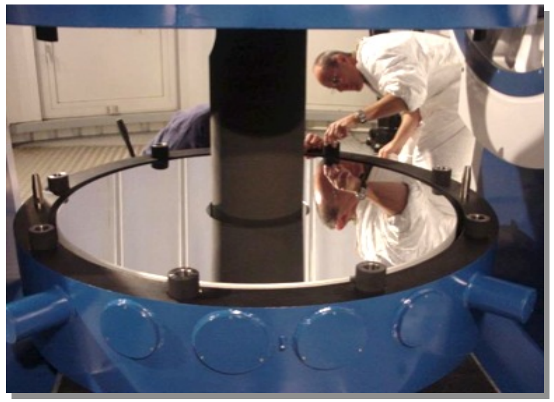






M2

M1



Ritchey-Chrétien optics:

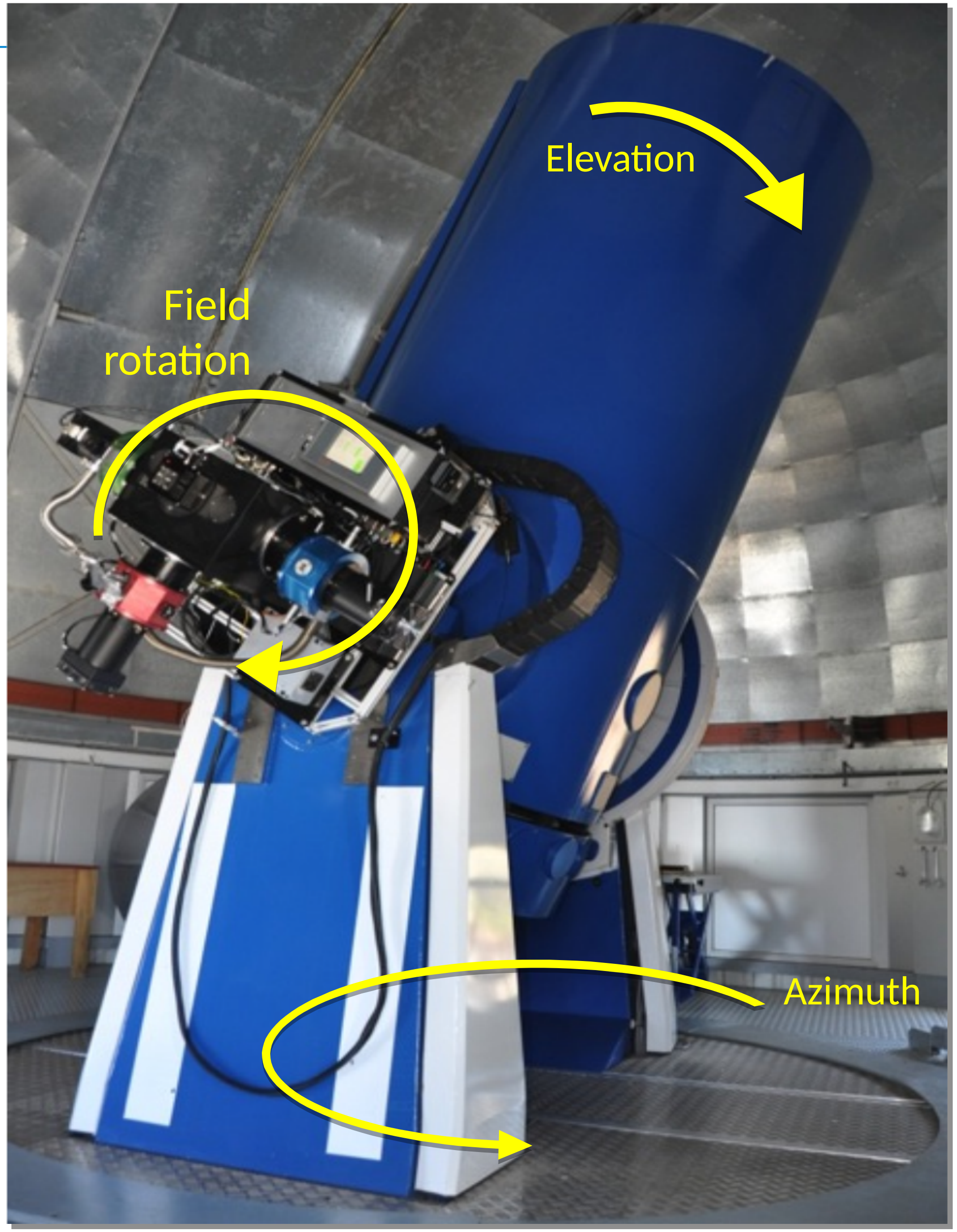
- 2 Hyperbolic mirrors
  flat focal plane free of coma
  and spherical aberration
- Combined focal length:
  $f = 14.4$ m (*f*/12)
- Central obscuration (7.5%)

The Mercator telescope

- Altitude-azimuthal telescope mounting:
  To track targets during observation
  (sync. with daily earth rotation)

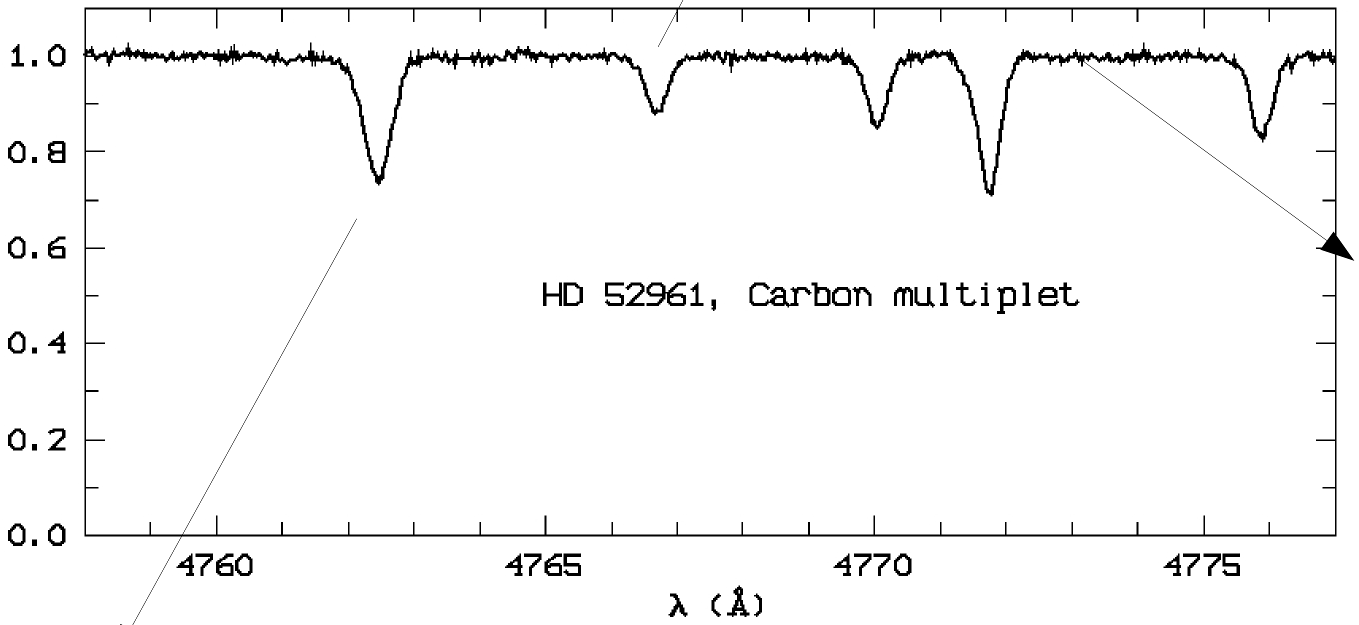
- 3 rotation axes:
  - ✘ Azimuth
  - ✘ Elevation
  - ✘ Instrument rotation
- High-precision mechanisms:
  - 9000 kg moving mass
  - Blind pointing accuracy: 3 – 4 arcsec
  - Closed-loop tracking precision:
    < 0.1 arcsec

0.1 arcsec = **arctan** 0.5 mm / 1 km



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 in V
High stability to allow 10 m/s accuracy. Wide spectral domain helps

HERMES-Consortium: Kick-off 19/01/2005

Science start: 01/06/2009

Project Engineer: Gert Raskin

PI: Hans Van Winckel

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KU LEUVEN

IvS-KUL
co-i: C. Waelkens

Lotto

ROB
co-i: H. Hensberge, Y Fremat

FNRS

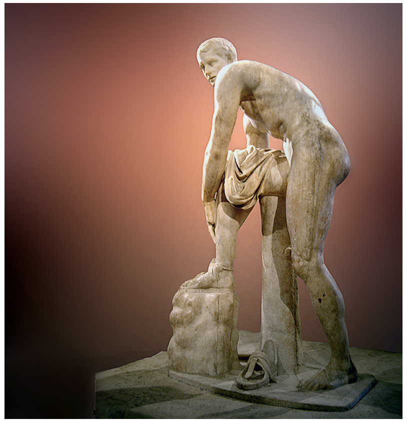
HERMES

IAA-ULB
co-i: A. Jorissen

Landessternwarte Tautenburg
co-i: H. Lehman

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

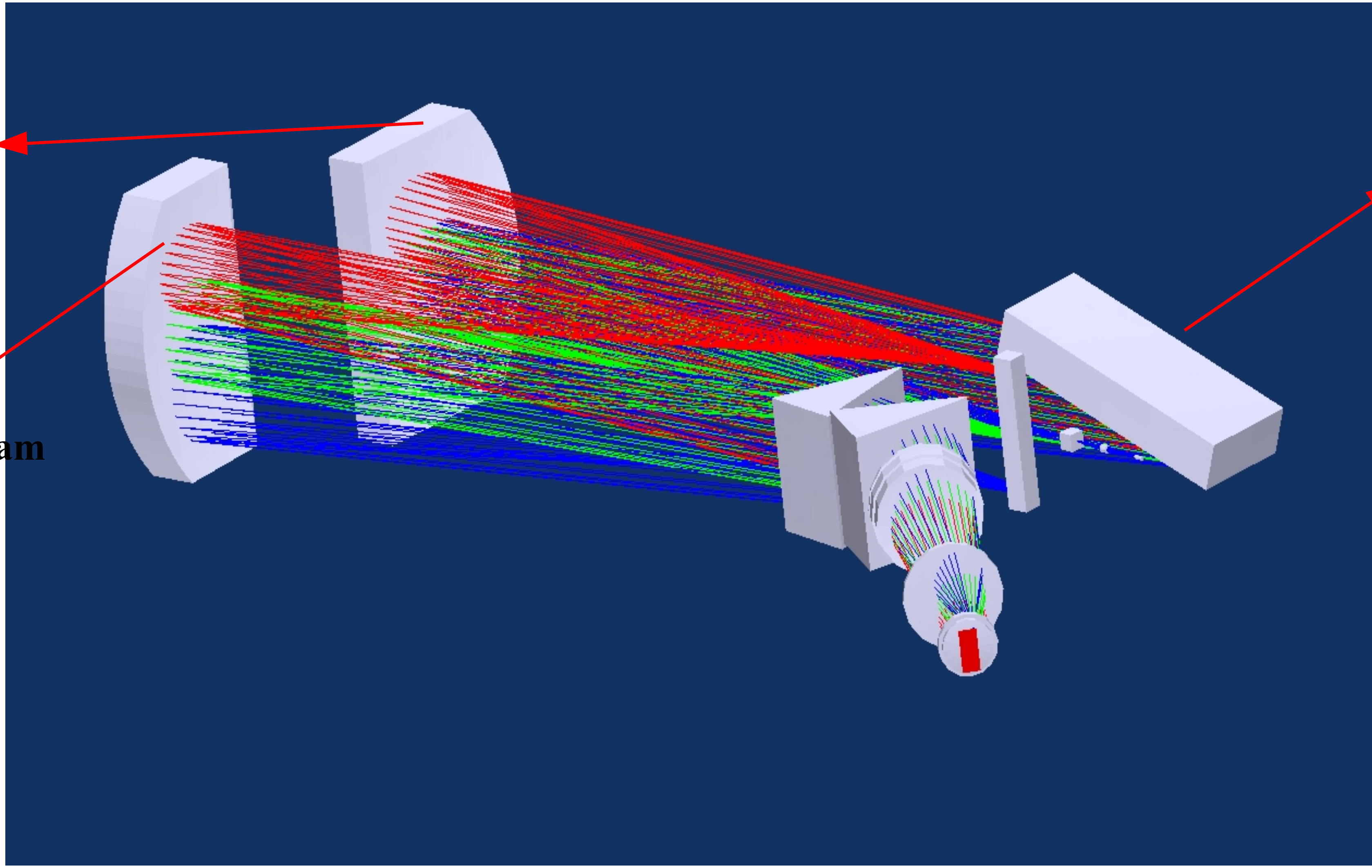
=

HERMES: High-Efficiency and Resolution Mercator Echelle Spectrograph

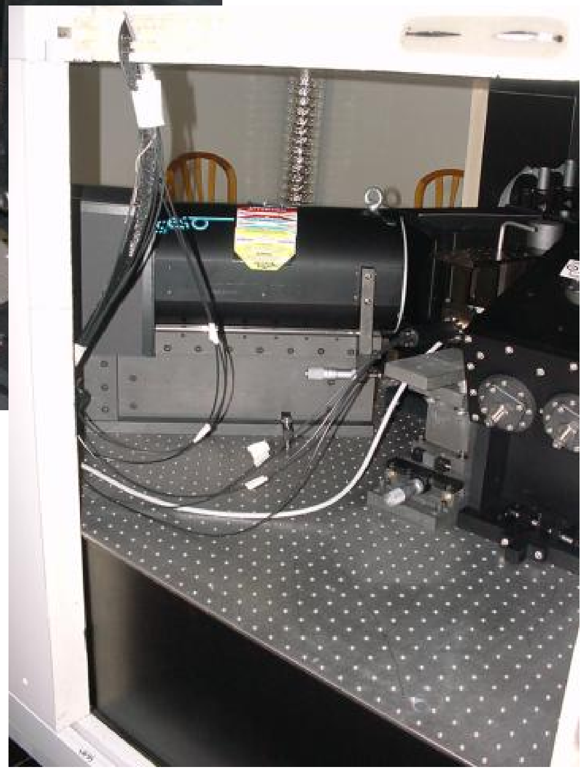
Pooling of HERMES observations with priority driven scheduling.

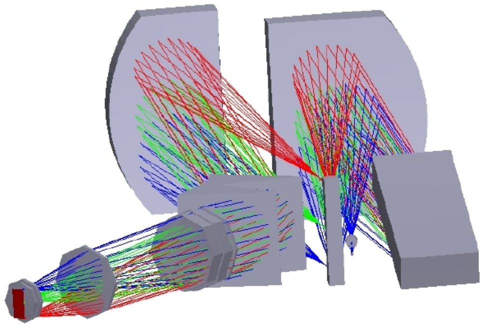
All HERMES consortium nights are mainly (80%) scheduled from pool.

Hermes: white pupil Design

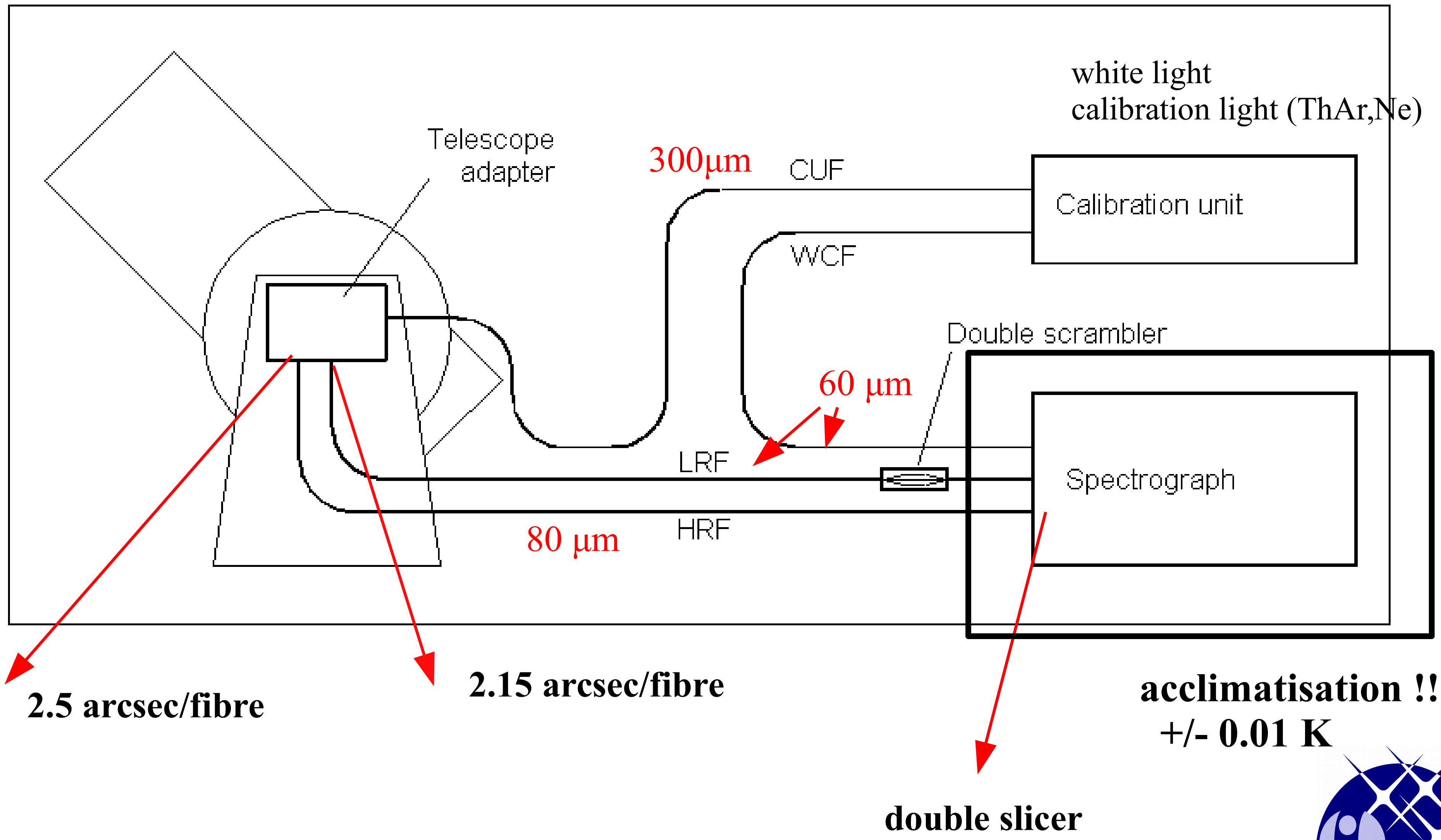


Spectrograph room...

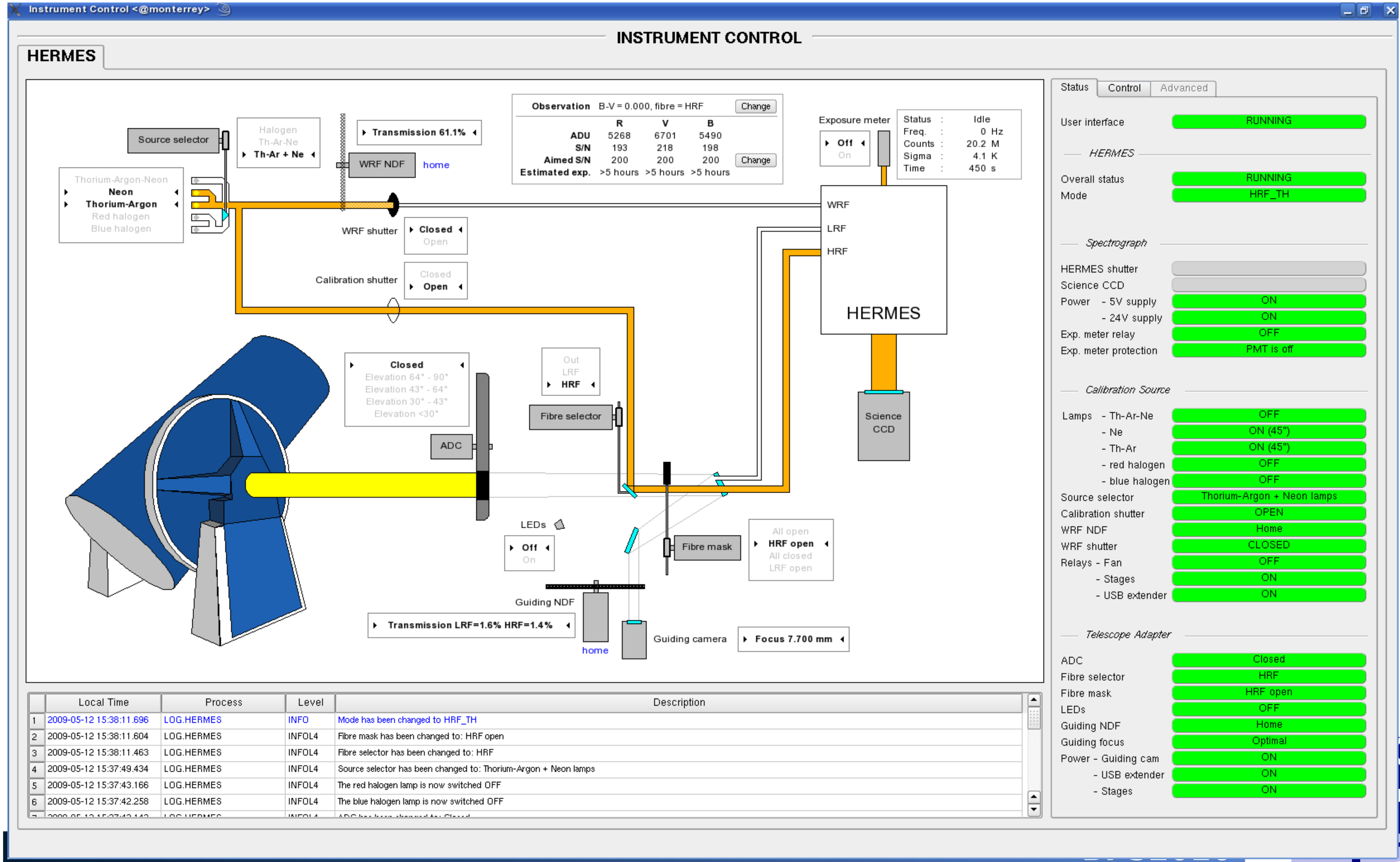




Hermes Design



Software



Instrument Control <@monterrey>
INSTRUMENT CONTROL
HERMES
Source selector
Halogen
Th-Ar-Ne
Th-Ar + Ne
Transmission 61.1%
WRF NDF
home
Thorium-Argon-Neon
Neon
Thorium-Argon
Red halogen
Blue halogen
Observation B-V = 0.000, fibre = HRF
Change
R V B
ADU 5268 6701 5490
S/N 193 218 198
Aimed S/N 200 200 200
Estimated exp. >5 hours >5 hours >5 hours
Exposure meter
Off
On
Status : Idle
Freq. : 0 Hz
Counts : 20.2 M
Sigma : 4.1 K
Time : 450 s
WRF
LRF
HRF
HERMES
WRF shutter
Closed
Open
Calibration shutter
Closed
Elevation 64° - 90°
Elevation 43° - 64°
Elevation 30° - 43°
Elevation <30°
ADC
Out
LRF
HRF
Fibre selector
Science CCD
LEDs
Fibre mask
All open
HRF open
All closed
LRF open
Guiding NDF
Transmission LRF=1.6% HRF=1.4%
Guiding camera
Focus 7.700 mm
Status
Control
Advanced
User interface RUNNING
HERMES
Overall status RUNNING
Mode HRF_TH
Spectrograph
HERMES shutter
Science CCD
Power - 5V supply ON
- 24V supply ON
Exp. meter relay OFF
Exp. meter protection PMT is off
Calibration Source
Lamps - Th-Ar-Ne OFF
- Ne ON (45")
- Th-Ar ON (45")
- red halogen OFF
- blue halogen OFF
Source selector Thorium-Argon + Neon lamps
Calibration shutter OPEN
WRF NDF Home
WRF shutter CLOSED
Relays - Fan OFF
- Stages ON
- USB extender ON
Telescope Adapter
ADC Closed
Fibre selector HRF
Fibre mask HRF open
LEDs OFF
Guiding NDF Home
Guiding focus Optimal
Power - Guiding cam ON
- USB extender ON
- Stages ON
Local Time | Process | Level | Description
1 2009-05-12 15:38:11.696 LOG.HERMES INFO Mode has been changed to HRF_TH
2 2009-05-12 15:38:11.604 LOG.HERMES INFOL4 Fibre mask has been changed to: HRF open
3 2009-05-12 15:38:11.463 LOG.HERMES INFOL4 Fibre selector has been changed to: HRF
4 2009-05-12 15:37:49.434 LOG.HERMES INFOL4 Source selector has been changed to: Thorium-Argon + Neon lamps
5 2009-05-12 15:37:43.166 LOG.HERMES INFOL4 The red halogen lamp is now switched OFF
6 2009-05-12 15:37:42.258 LOG.HERMES INFOL4 The blue halogen lamp is now switched OFF

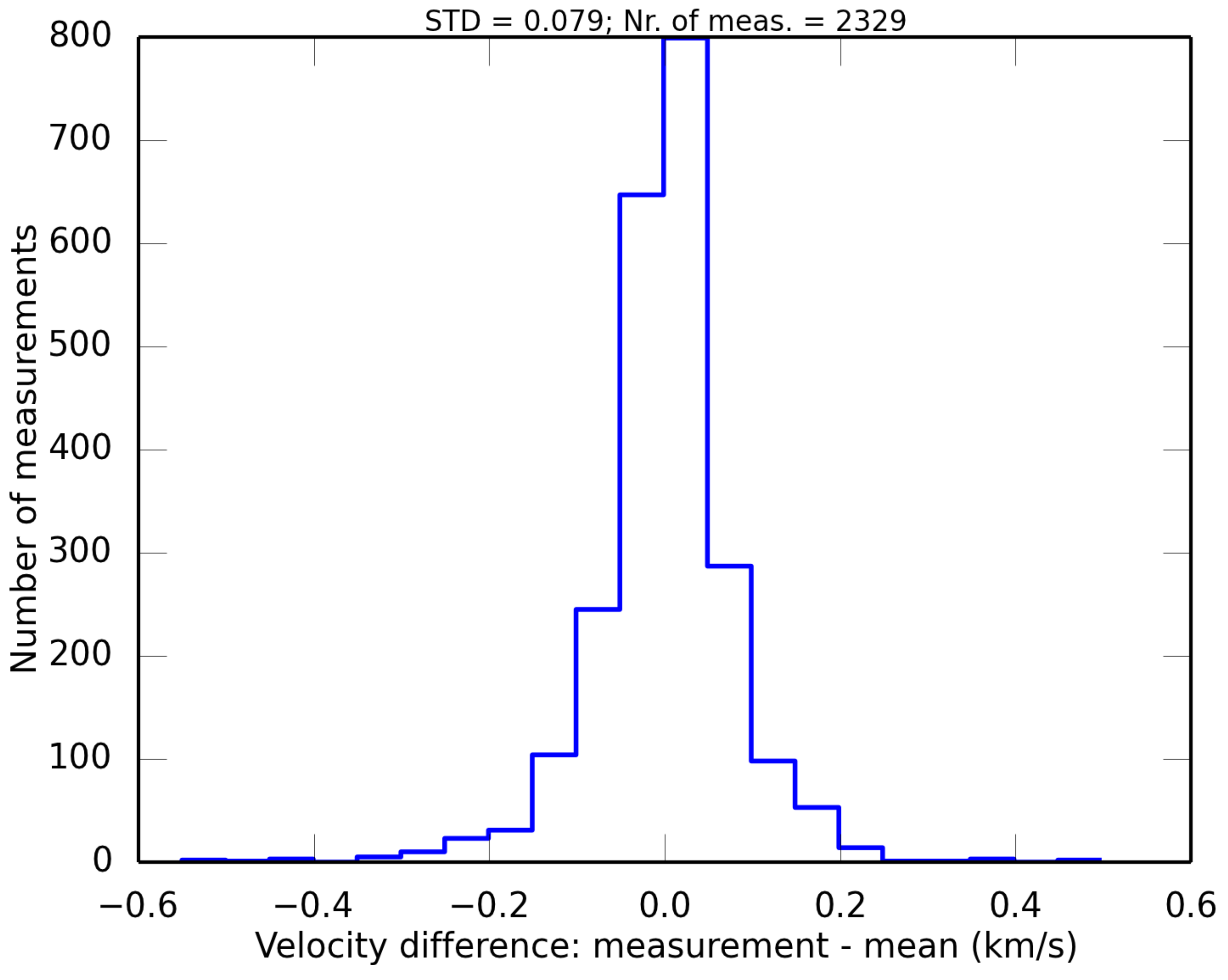
MOCS GUI - Mercator Observatory Control System GUI
Services
Telescope
Merope
Hermes
LAST 13:38:16
UT 21:38:11
HERMES
Mercator Telescope
Instituut voor Sterrenkunde
K. U. Leuven
Dewar temperatures
Hermes
159.8 K
114.2 K
CCD
Cryo
Merope
160.0 K
91.3 K
Telescope GUI
Dome

PR slide...

	D_T [m]	R [$\lambda/\Delta\lambda$]	Coverage [nm]	Flux [e^-/nm]	Flux/m^2 [e^-/(nm m^2)]	M [R x Flux]	M/m^2 [R x Flux/m^2]
HARPS	3.6[a]	115 000	378–691	31 070	3050	3570 k	351 k
Espadons	3.6[b]	80 000	369–1048	44 250	4350	3540 k	348 k
SARG	3.5[c]	86 000	370–1000**	18 680	1940	1610 k	167 k
FIES	2.5[d]	67 000	364–736	8620	1760	580 k	118 k
FEROS	2.2[e]	48 000	360–920	31 400	8260	1510 k	397 k
Sophie	1.93[f]	75 000	387–694	7200	2460	540 k	185 k
Coralie	1.2[g]	60 000	390–681	3550	3140	213 k	188 k
HERMES	1.2[h]	85 000	377–900	9360	**8270**	795 k	**703 k**

more details: PhD Gert Raskin

Radial Velocity Stability



First 7 years of science data: some numbers

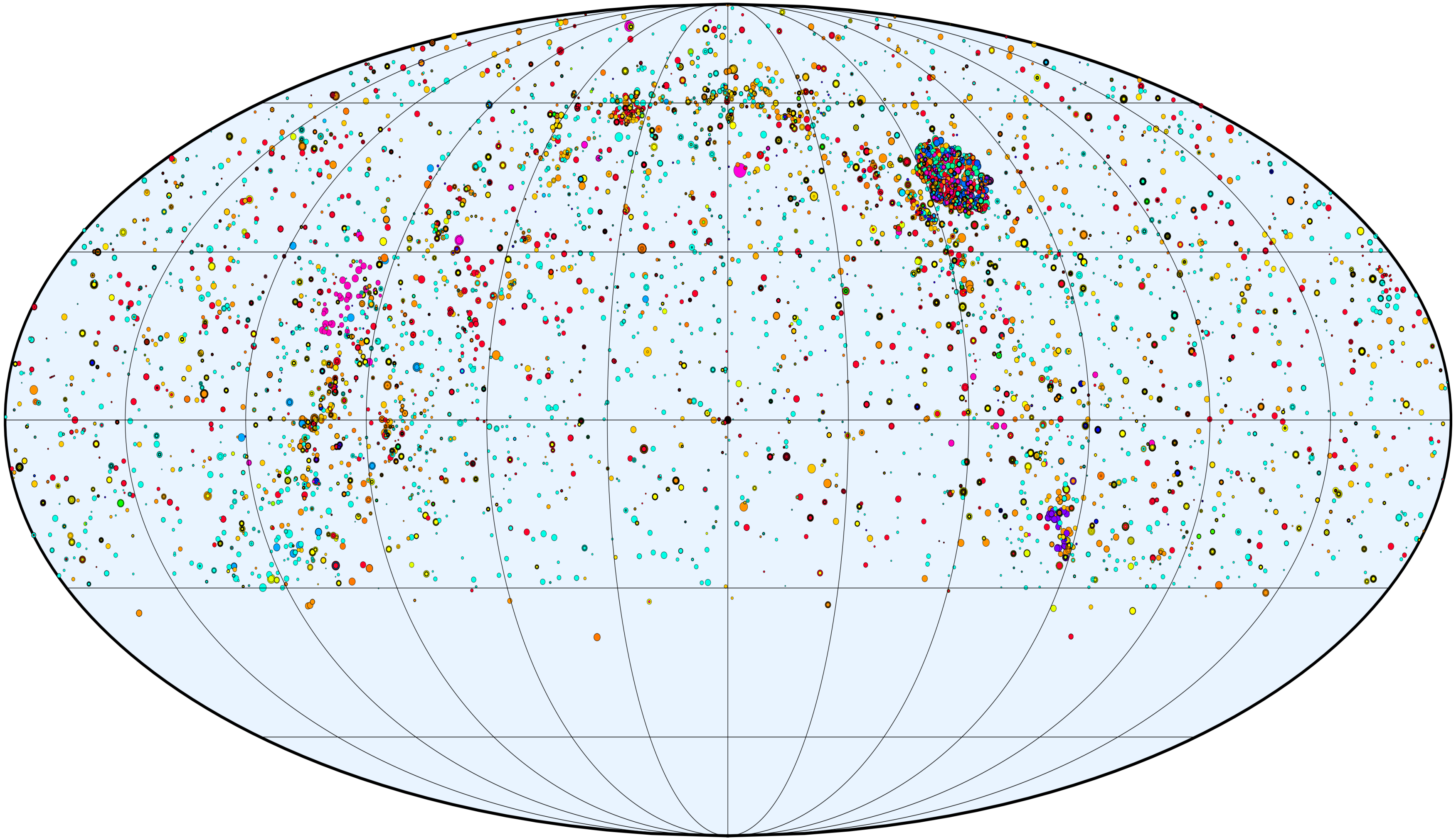
On **15/5/2016** there were:

225904 fits files of which
67409 science exposures
5.7 Tb data (raw+reduced)

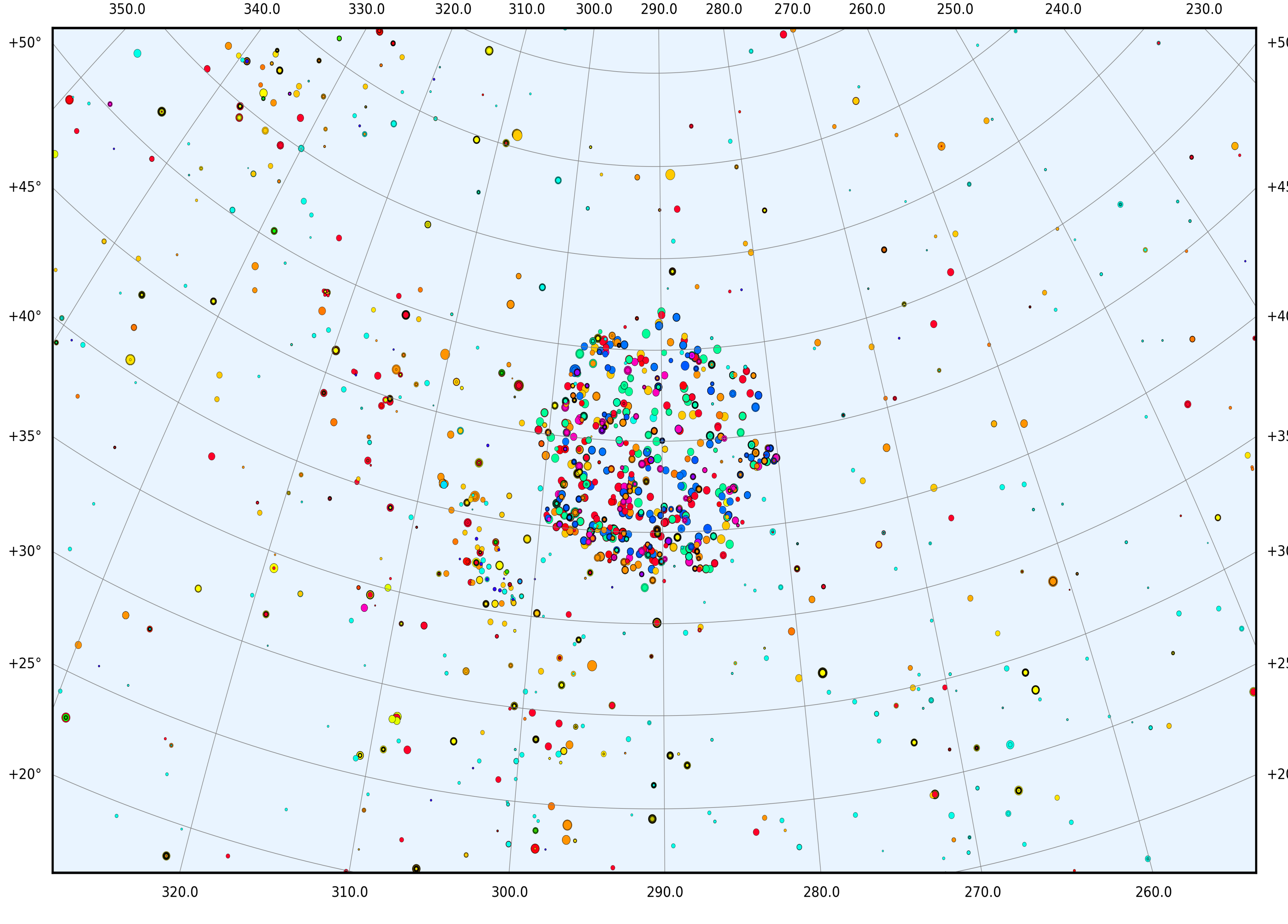
All data quicklook (on site) + fully reduced in Leuven + distributed rsync

62 science programmes (excluding the Spanish allocation, calibration institutes numbers)

References to Raskin et al., 2011, A&A 526, 69: 154 citations

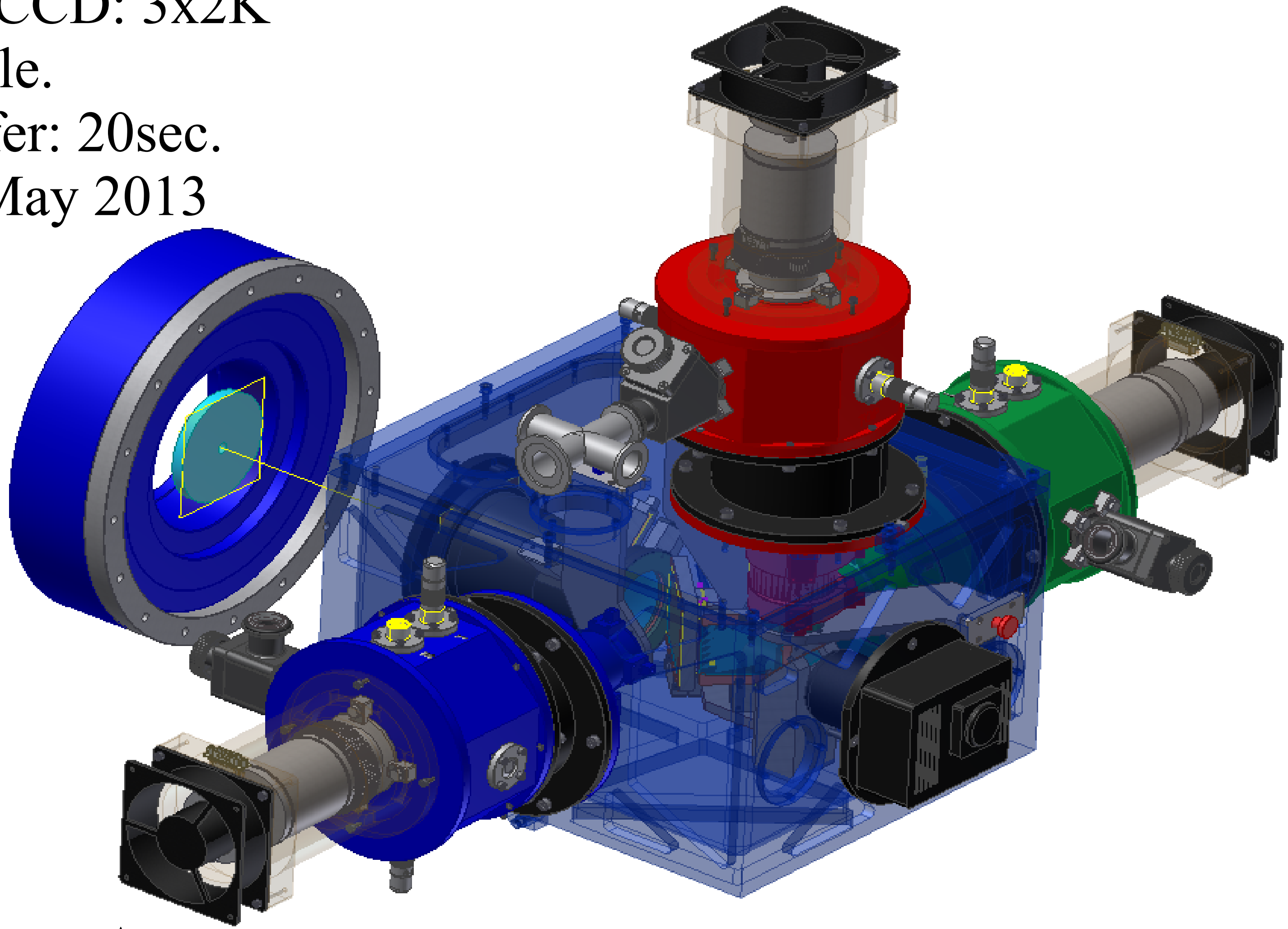


Complementary with space: the Kepler field in HERMES pointings



MAIA 3-arm camera

3 arms: U, V+G and R filters
Unique Frame Transfer CCD: 3x2K
 Fast-photometry possible.
Full Frame Frame transfer: 20sec.
Commissioning: April-May 2013



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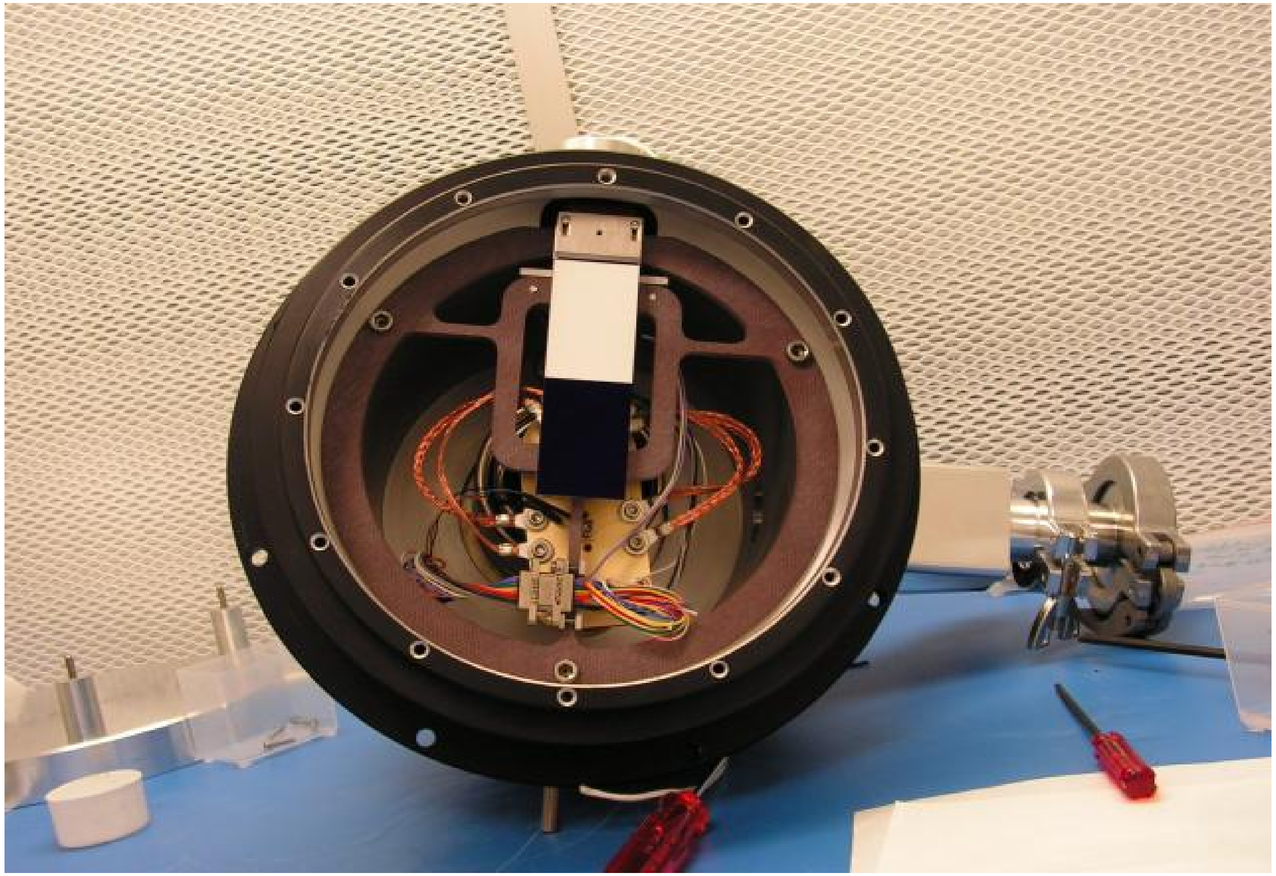
erc
European Research Council
Established by the European Commission

Prosperity: Conny Aerts

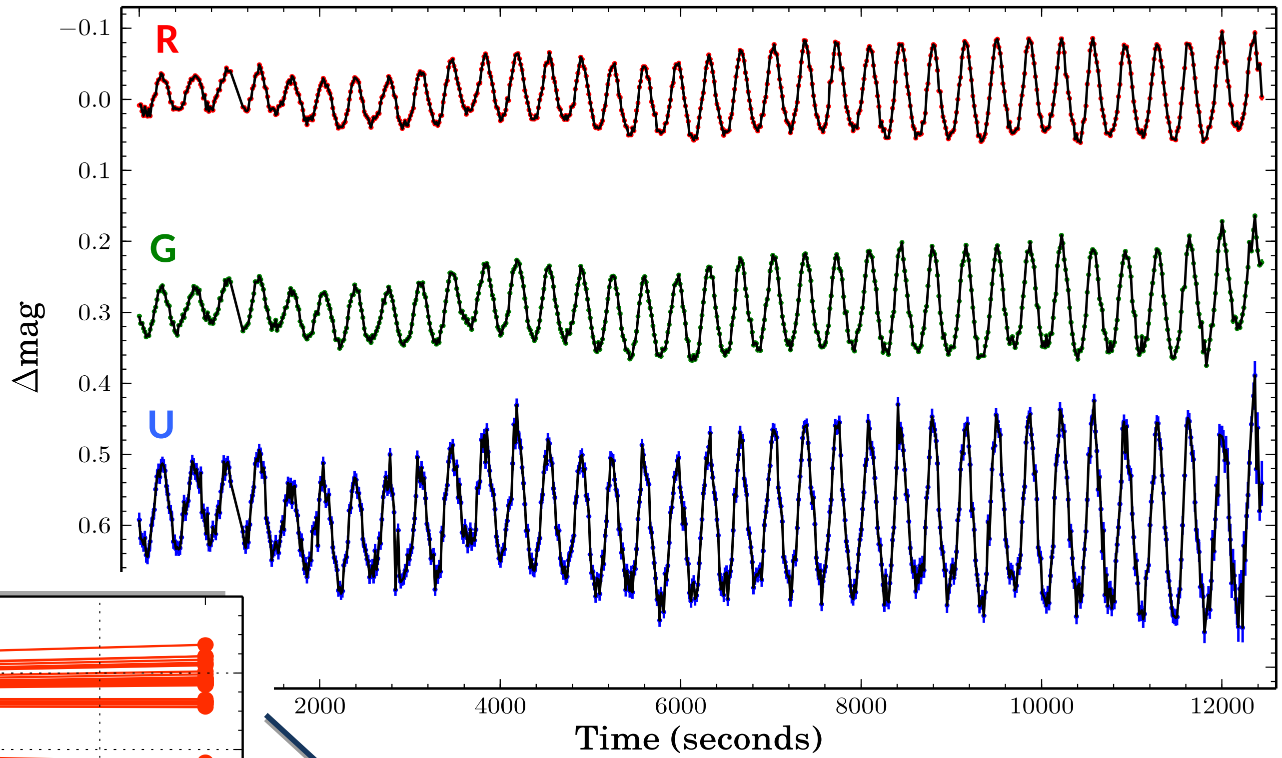
MAIA 3-arm camera: Frame Transfer

3x2K frame transfer CCDs of the late Eddington mission
0.28" per pixel
1 controller so windowing is equal in all channels, exposure times are multiplications of a given time

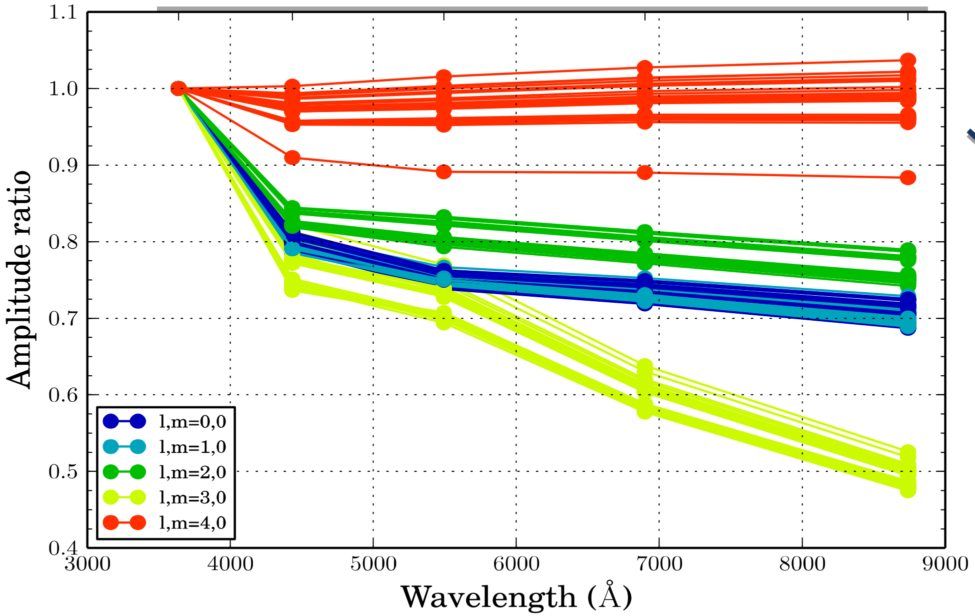


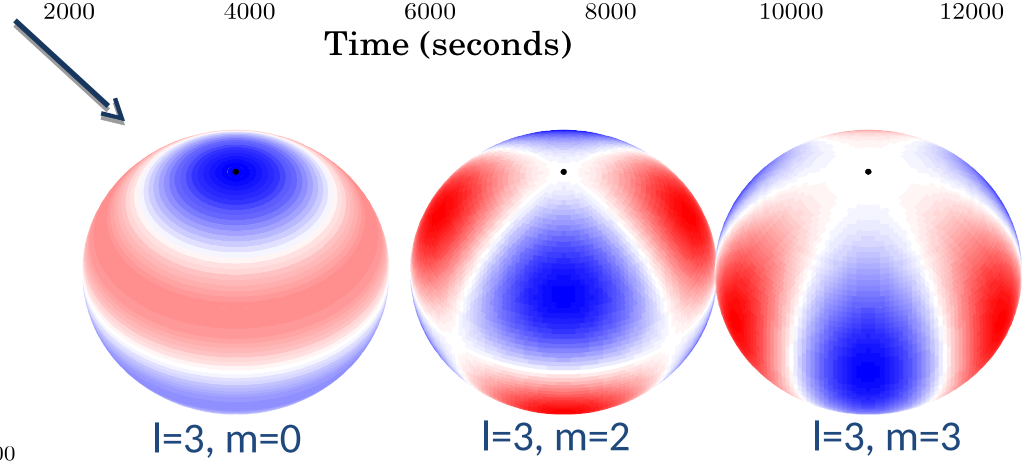
Studying and exploiting stellar variability with MAIA

MAIA: identify pulsation modes from pulsation amplitude ratios



Pulsation amplitudes depend on wavelength and pulsation mode





Operational Model :

Requirements: Robust (Telescope, Instruments)
Easy to use
Direct evaluation of quality
Optimal monitoring schemes
Science graded pipeline

so....: lots of software (MOCS, MESA, DRS (release 6))

Programmes: Phase I, Phase II converted into DB

Trouble Shooting: Night Report + fast feedback (7/7)
Weekly skype conferences with whole team

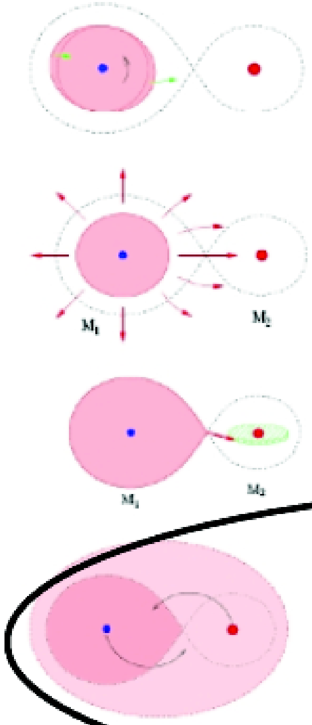
Current-Future Developments

Towards a new Telescope Control System based on soft-PLC, industrial standardisation, integrated approach.
Proof of concept for control international instrument programmes (ESO E-ELT-METIS)

New fiber link for HERMES

Important Science themes: Binary interaction physics

Binary channels plagued with uncertainties



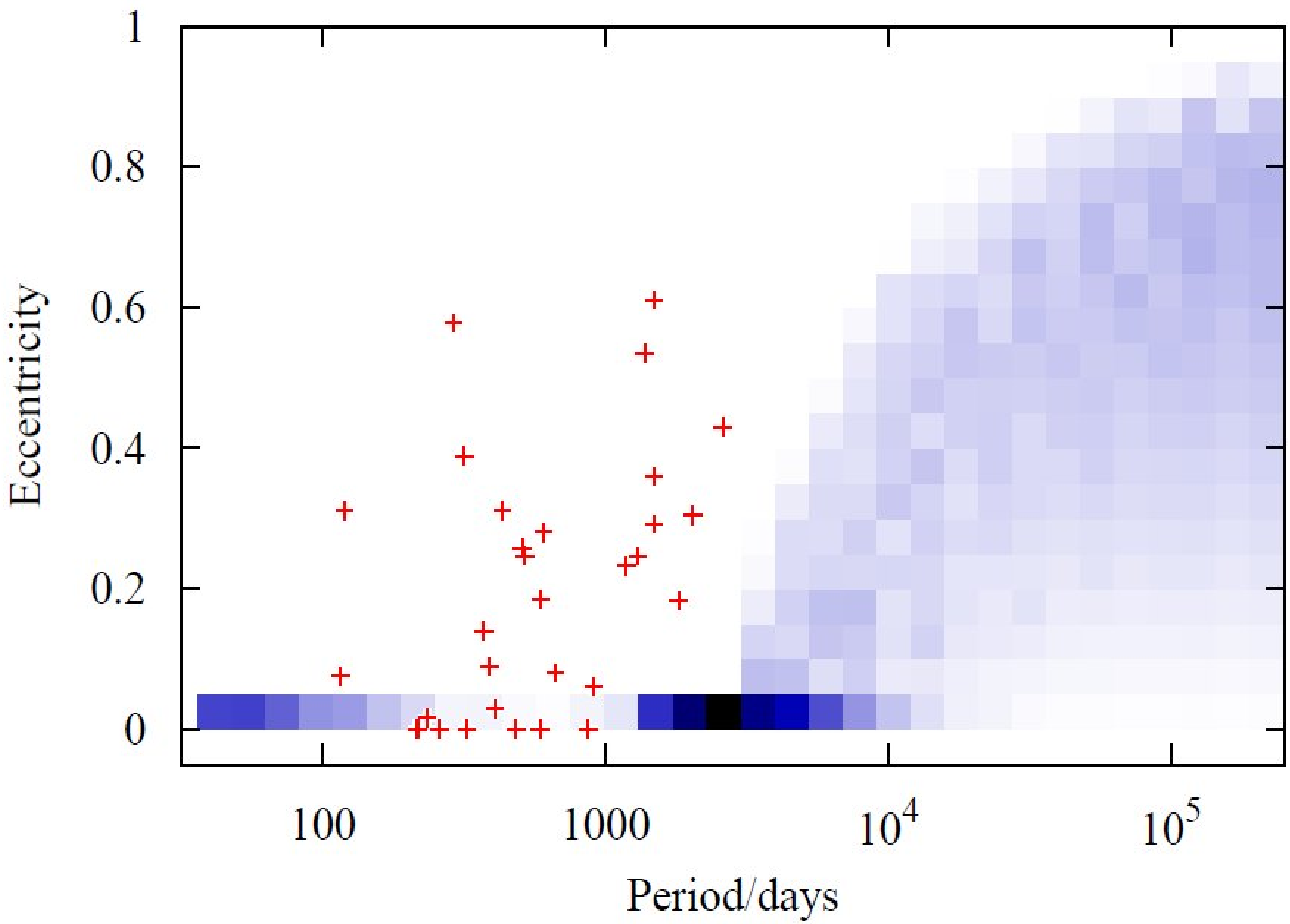
- tidal interaction
- wind accretion & tidally enhanced winds
- Roche-lobe overflow
- common envelope evolution

Binary evolution

$\neq$

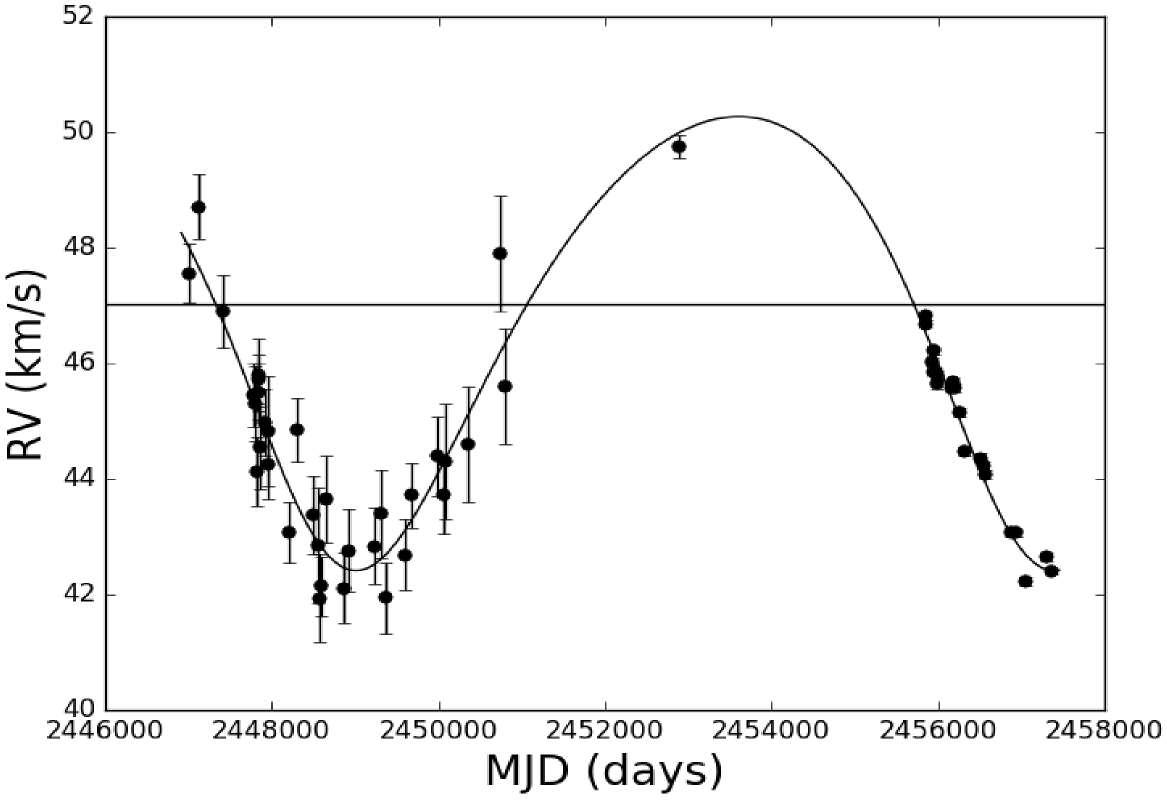
Singe star evolution

Theory versus Observations



Izzard, 2010; Jorissen, 2015,Escorza 2016

HERMES: binary star programme



HD5306. P=8380 days

Long timeseries

Intense timeseries

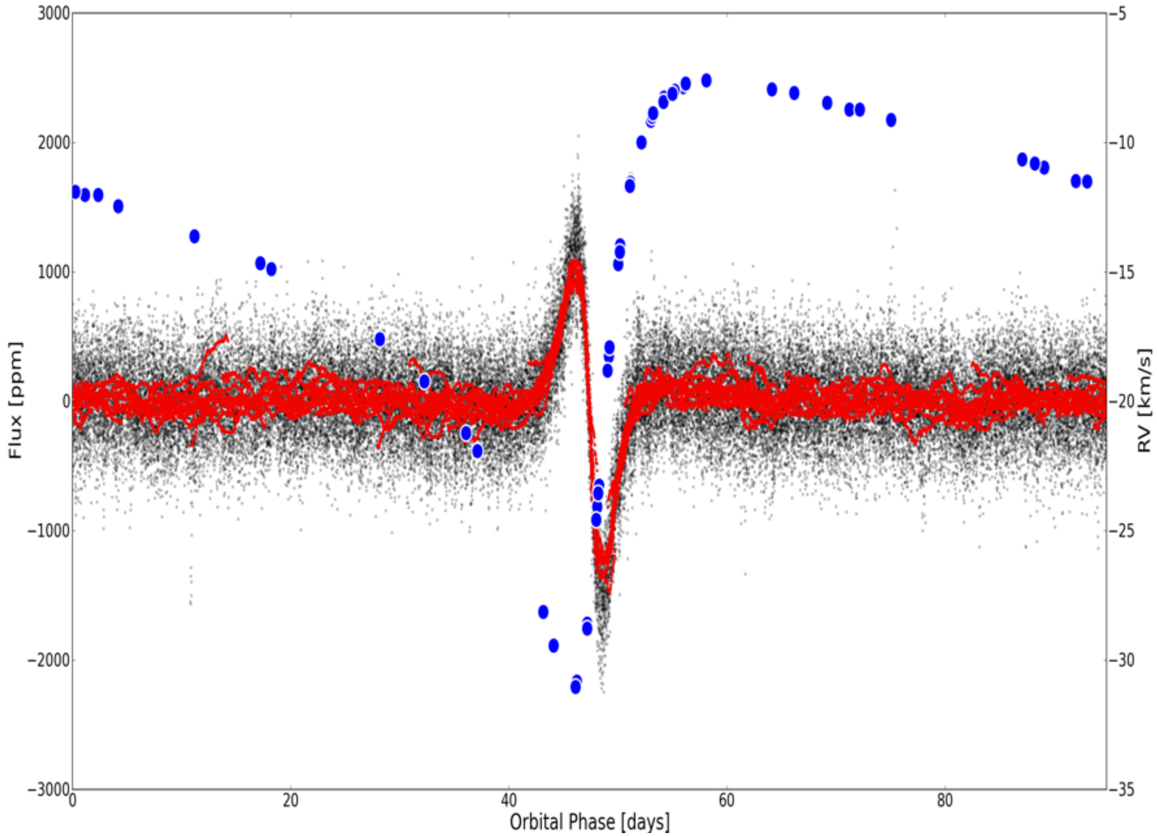
Not vacuum: 7yr stability
is ~ 80 meter/second

Ideal complement to
(space) projects and
larger infrastructure

Unique science is possible

Science Exploitation Examples

Kepler Space Photometry + HERMES spectroscopy: Giant Binary stars in action



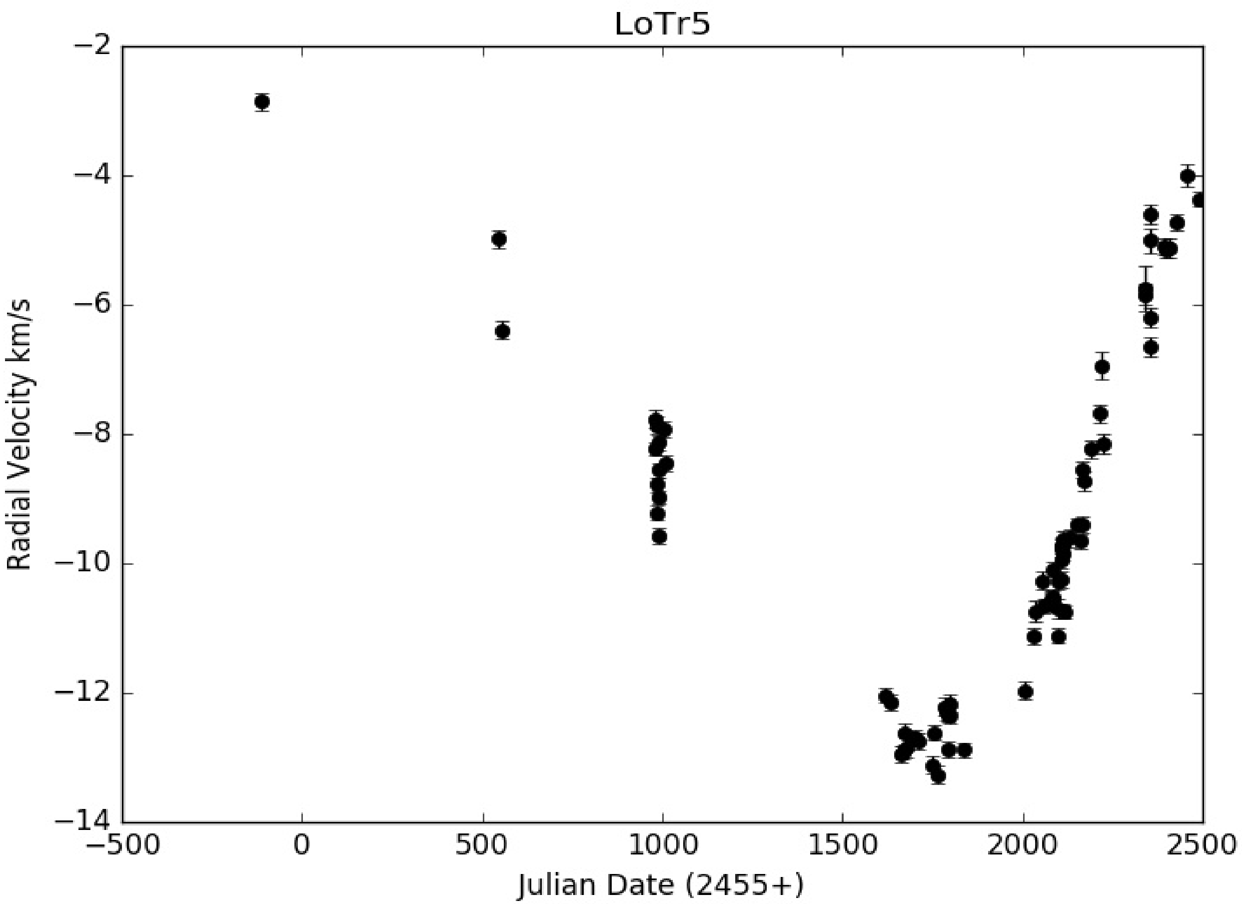
Heart-beat stars

At periastron

Orbits are strongly elliptical

e.g.Beck et al., 2014, A&A564, 36; 2012, Nature 481, 55

PNe: first wide binaries detected: LoTr5

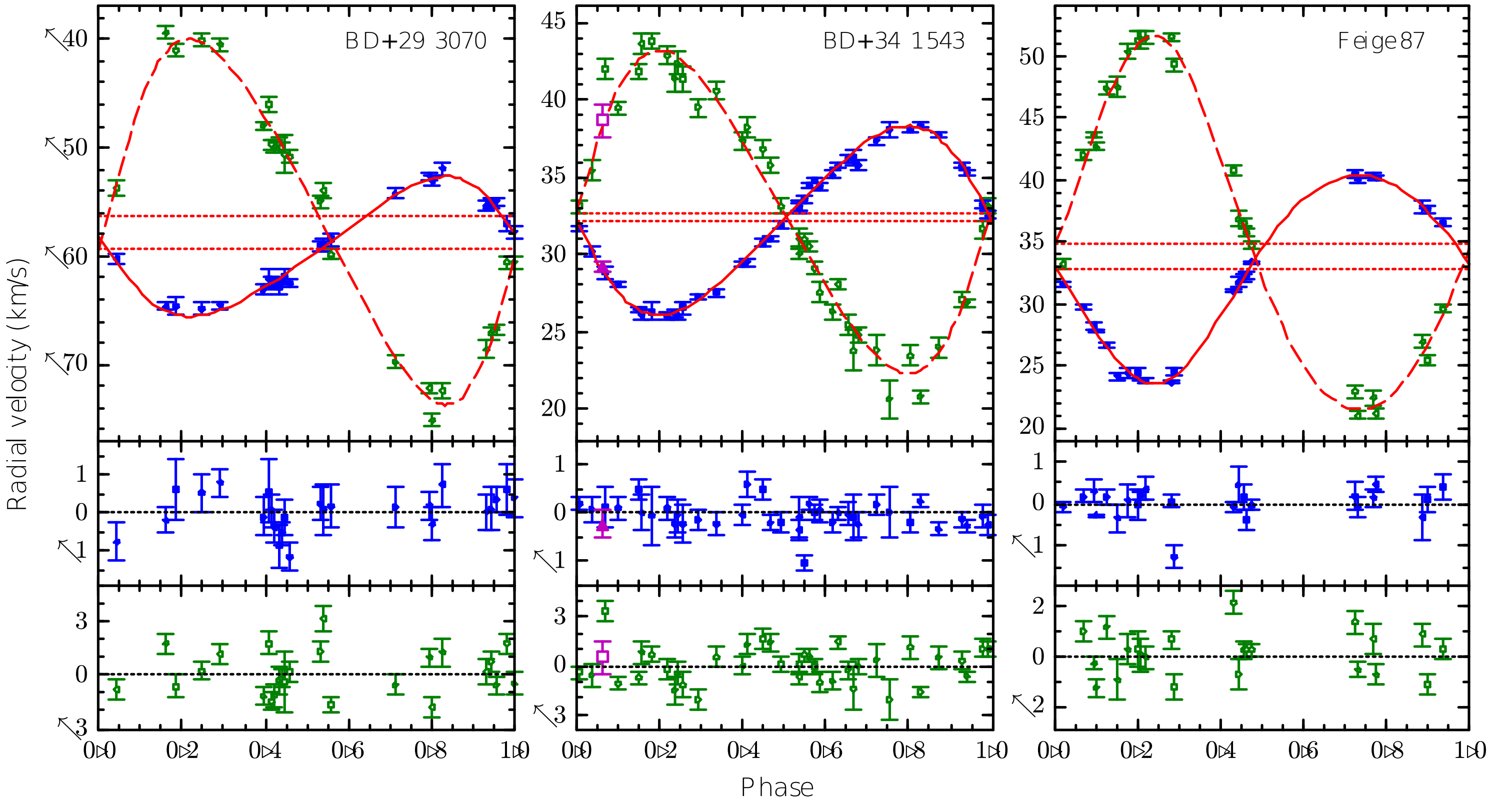


Companion:

- rapidly rotating s-process enhanced companion
- very hot WD
- Halo PNe

Van Winckel et al., 2014, A&A 563, L10

Long-Period sdB

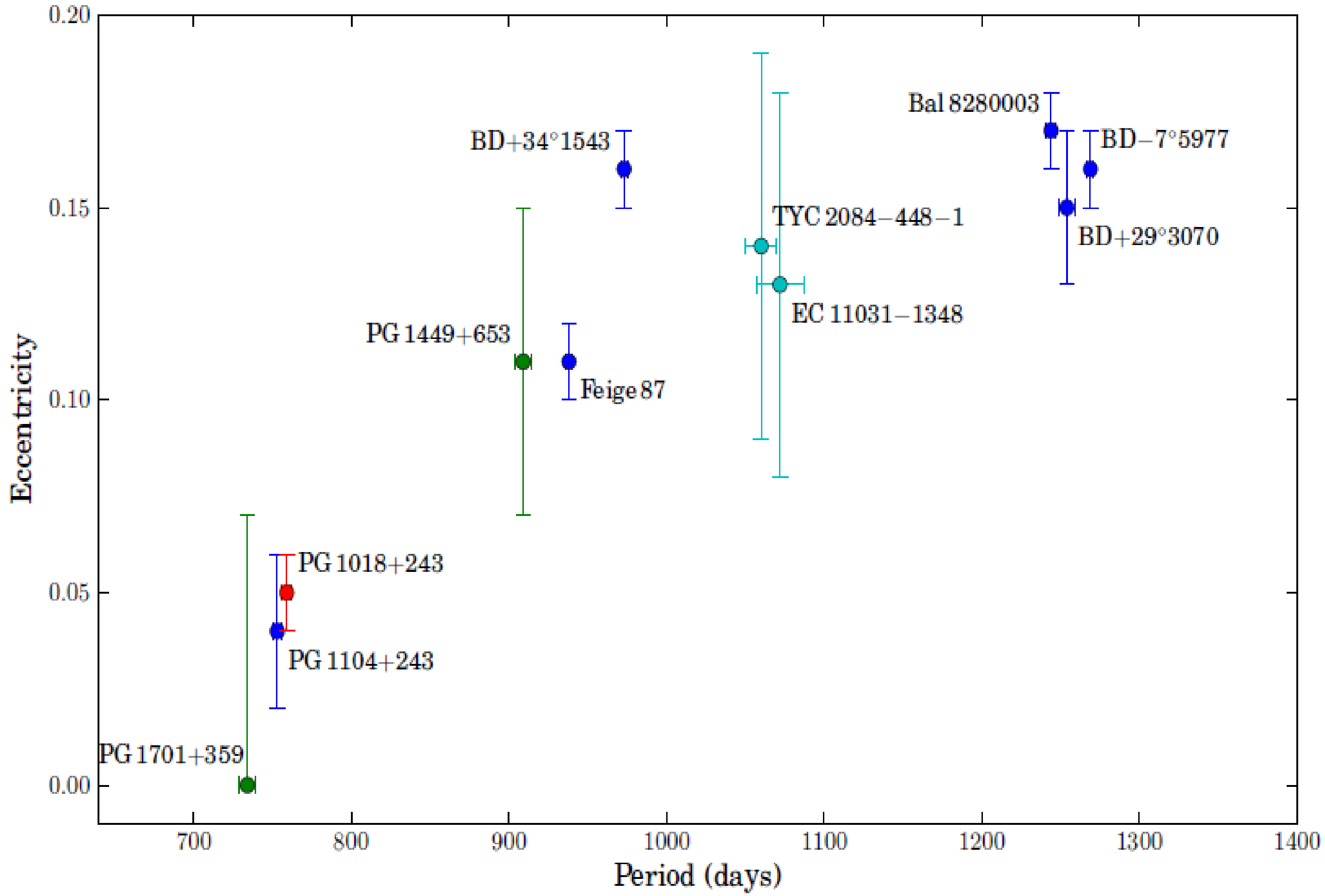


P=1254 d 972 d 938 d

- core He post-RGB stars with tiny envelope
- wide binaries are now being detected
- gravitational redshift

Vos et al., 2012; 2013, 2015

Long-period sdB



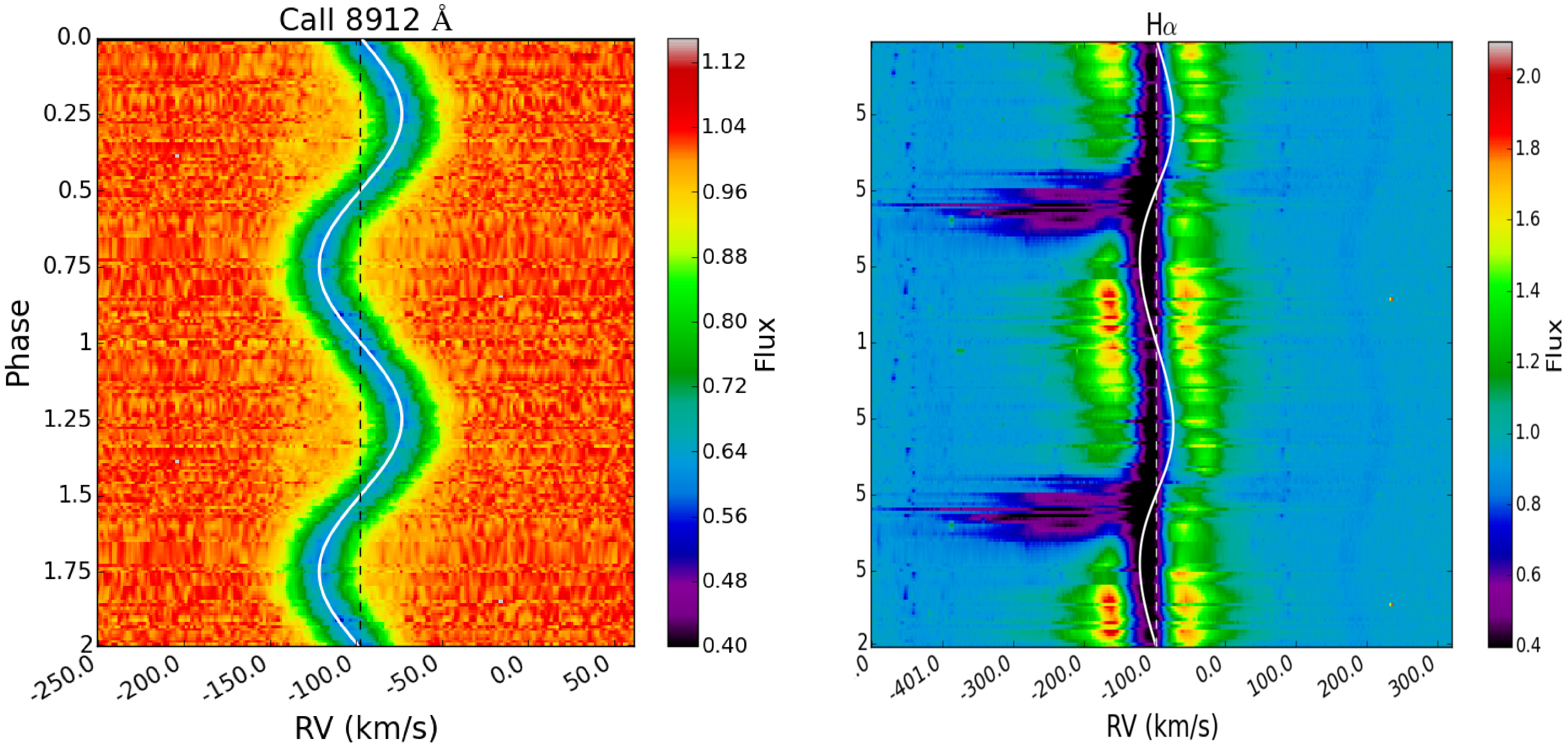
- e - problem similar than post-AGB

- e-pumping mechanisms are needed

*asymmetric RLOF
* disc pumping by discs
* included in MESA binary module

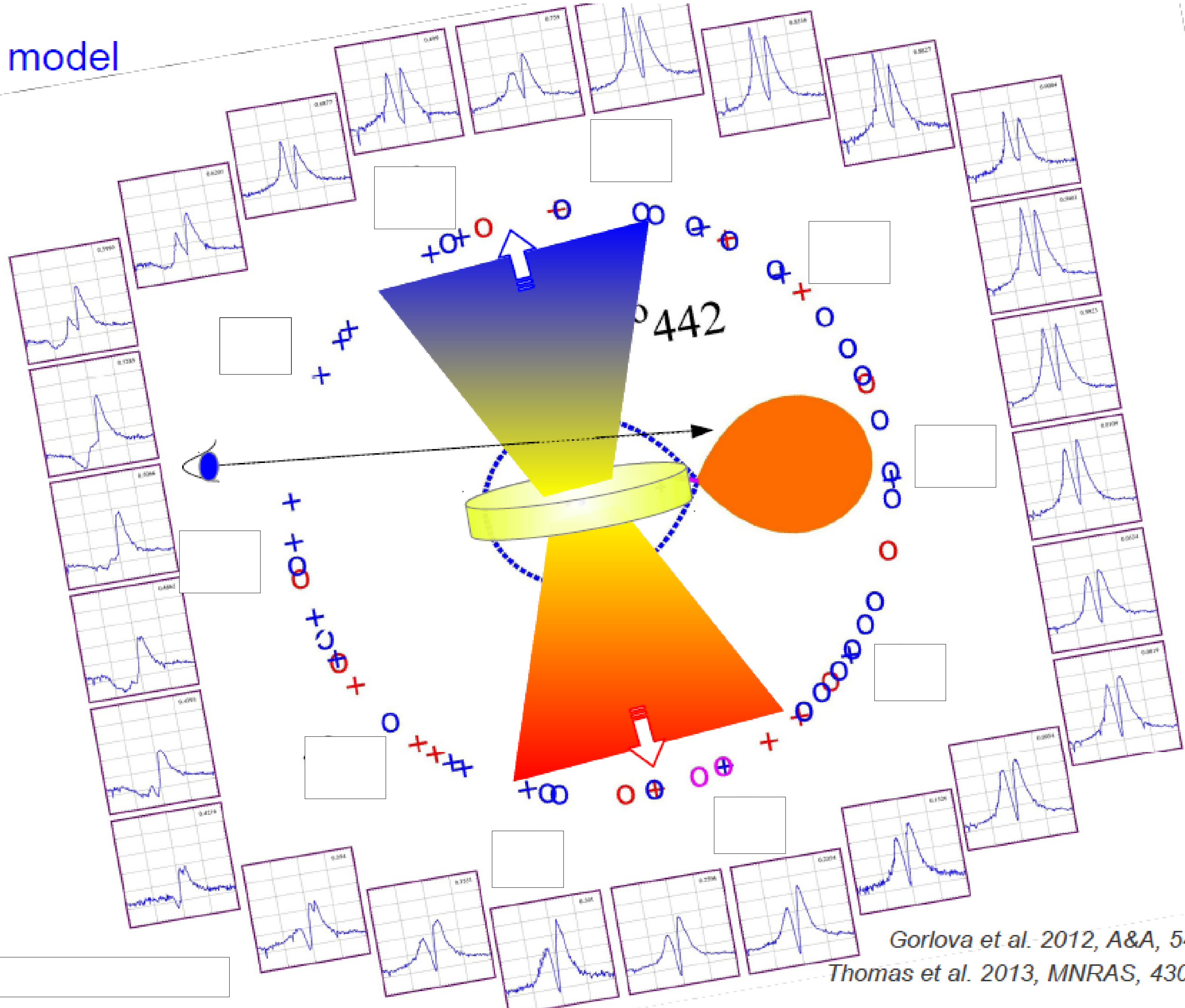
Vos et al, 2015

Binary processes: BD+46.422. Period=140.7 d



Gorlova et al., 2012; Bollen et al. 2016

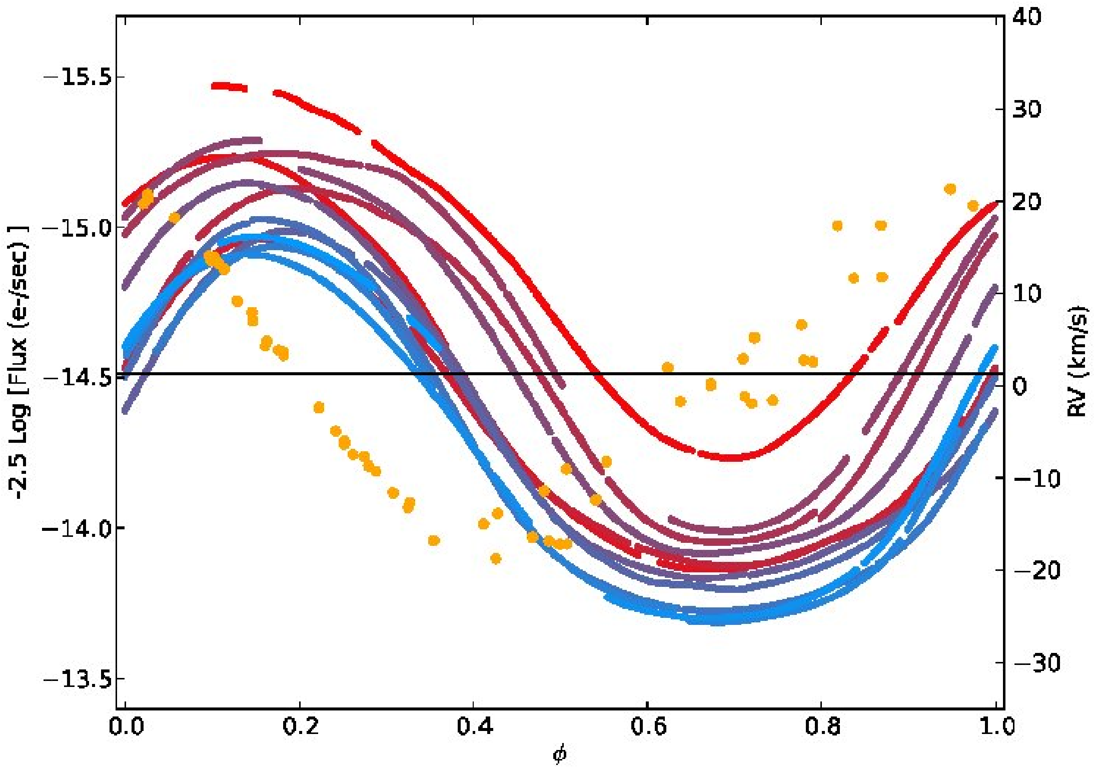
Jet model

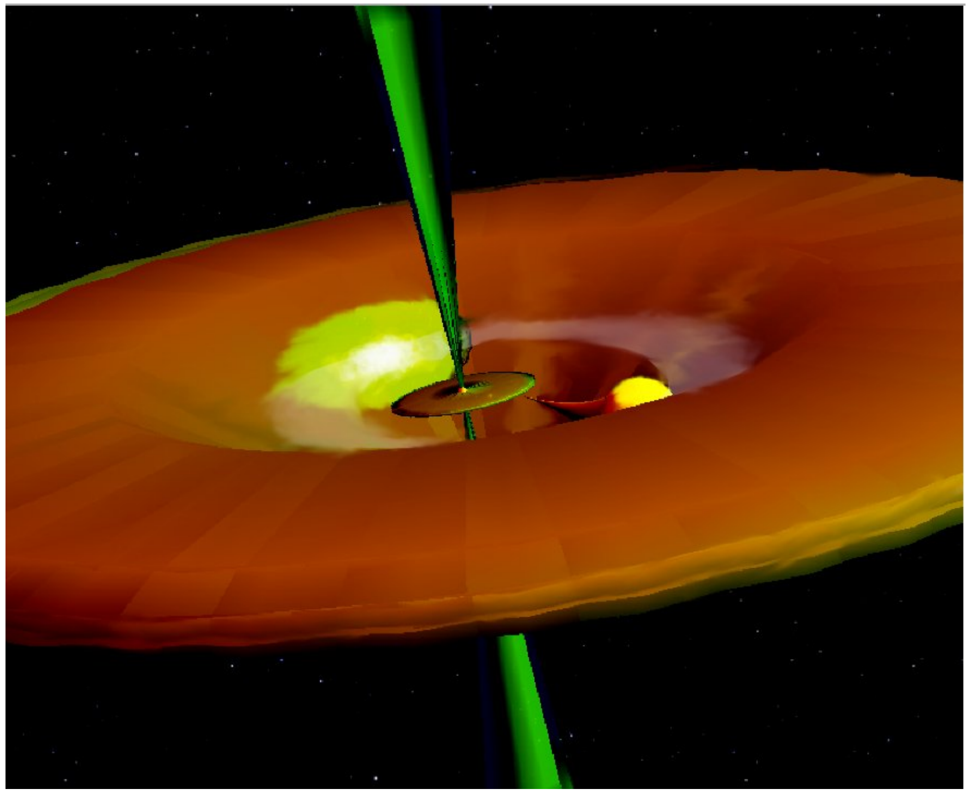


Gorlova et al. 2012, A&A, 542, 27
Thomas et al. 2013, MNRAS, 430, 1230

Detailed studies of Interaction processes

IRAS19135+3937





Kepler lightcurve: very smooth
P is orbital period

Gorlova et al., 2015; Bollen et al. 2016

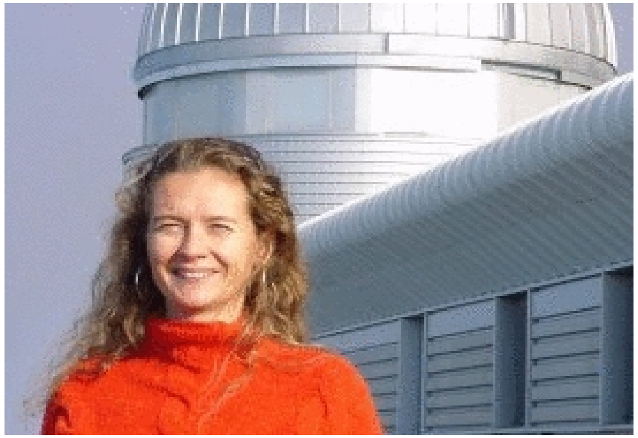
Why Mercator ?

Niche in experimental astrophysics

Thanks to:

- instrument development programme (HERMES,Maia)
- technology development programme (TCS, fibre link)
- adequate operational model

Only possible thanks to (Local) Team



Saskia Prins

IvS Mercator Team:
CCI: Christoffel Waelkens
Proj Scientist: Hans Van Winckel
Proj. Engineer: Gert Raskin
PhD student Wim Pessemier
Mech. Johan Morren

Jesus Perez Padilla

Florian Merges

Thank you.

HERMES observing