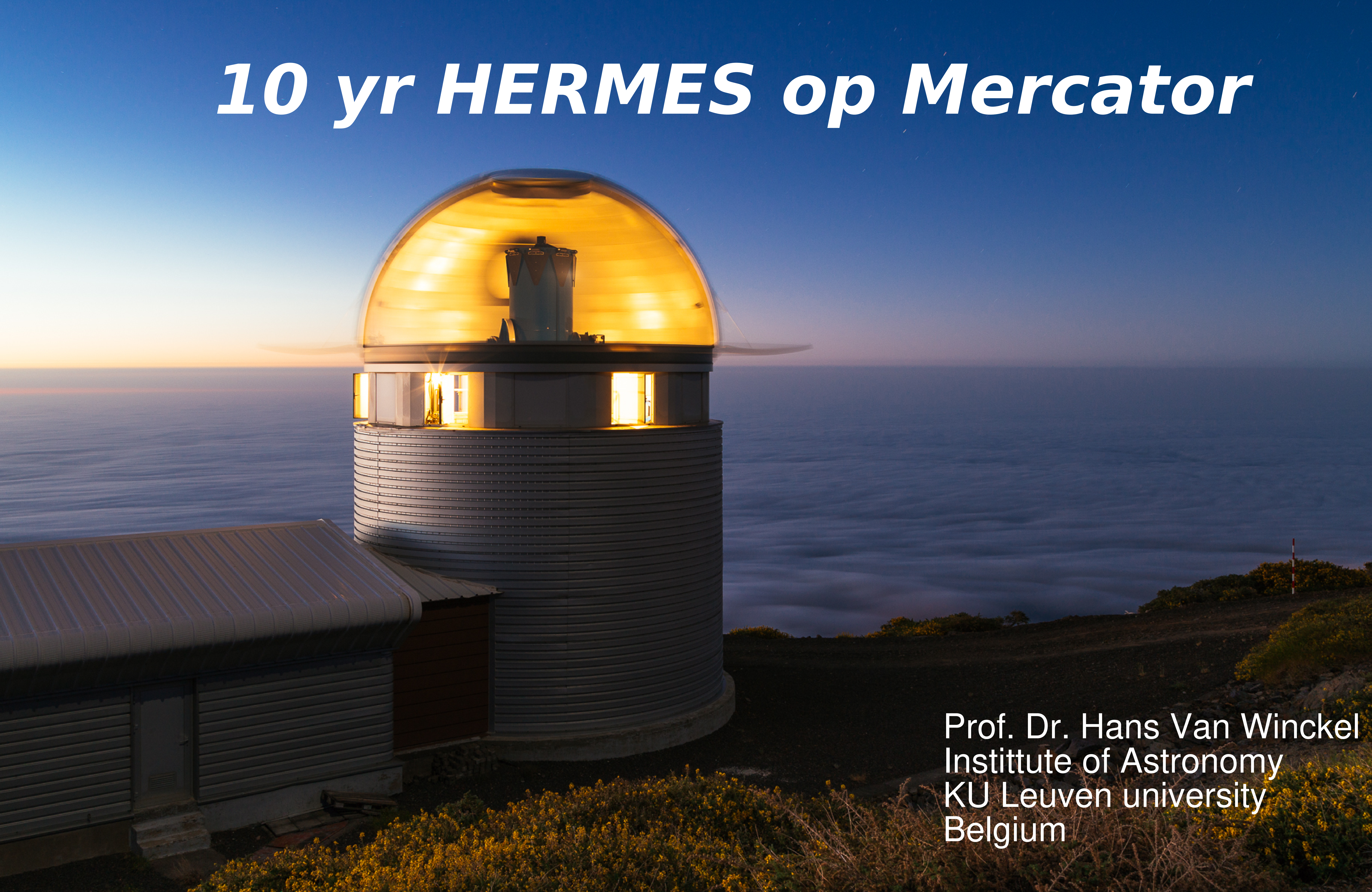


10 yr HERMES op Mercator

Prof. Dr. Hans Van Winckel
Instittute of Astronomy
KU Leuven university
Belgium

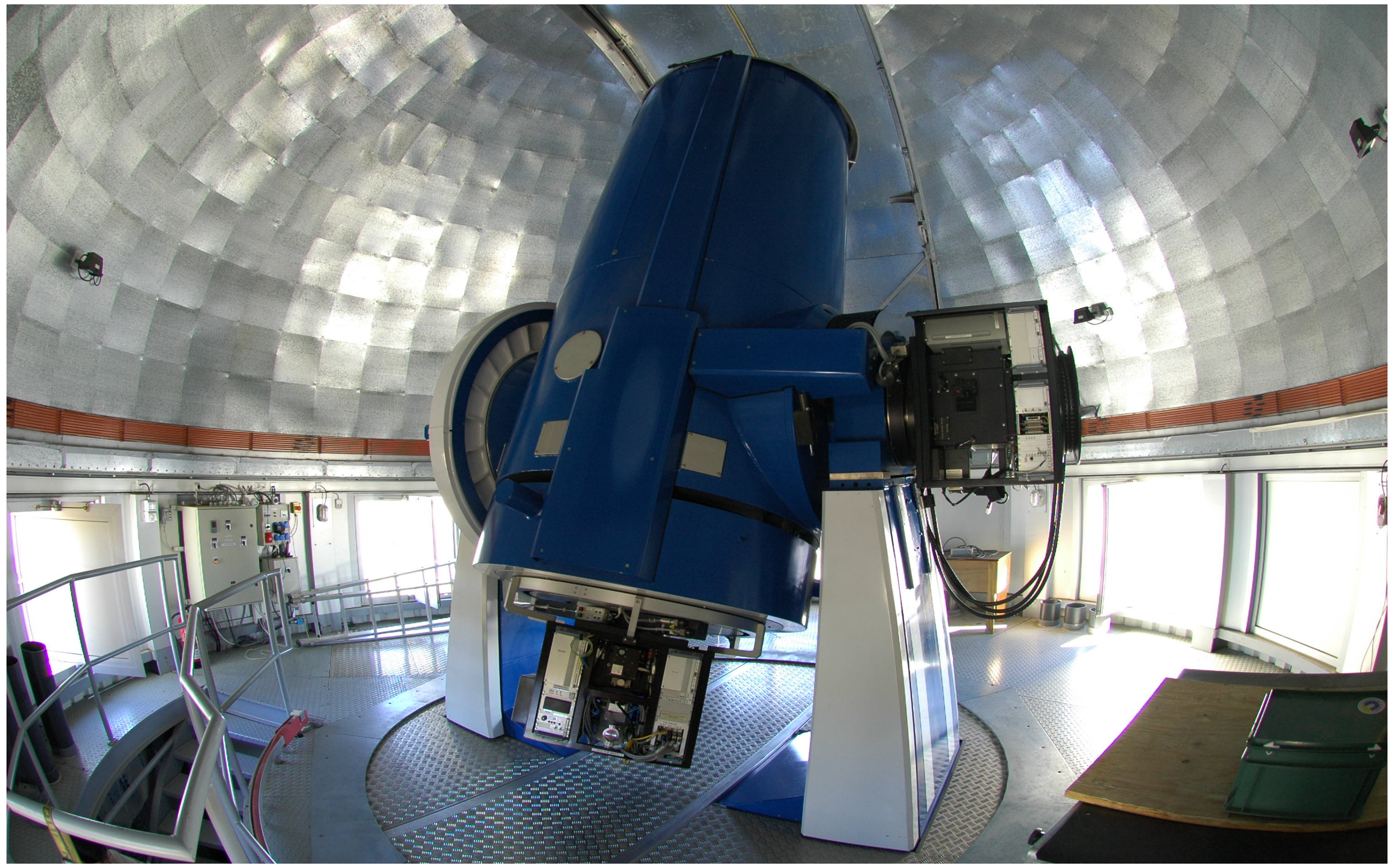
The Mercator Telescope

Roque de los Muchachos observatory
La Palma (Canary Island)

Prime site for astronomical observations
in Europe

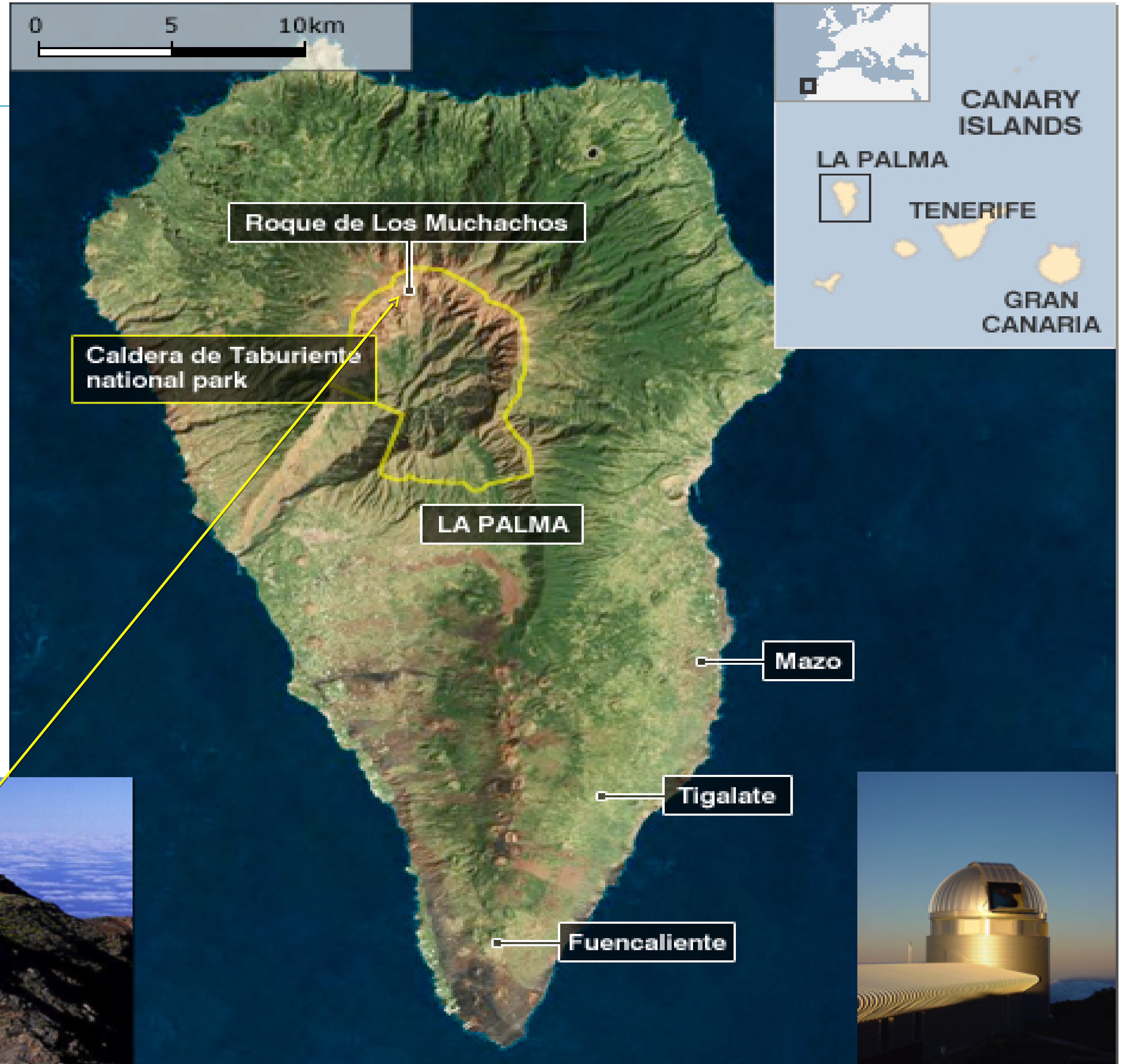
1.2 m telescope

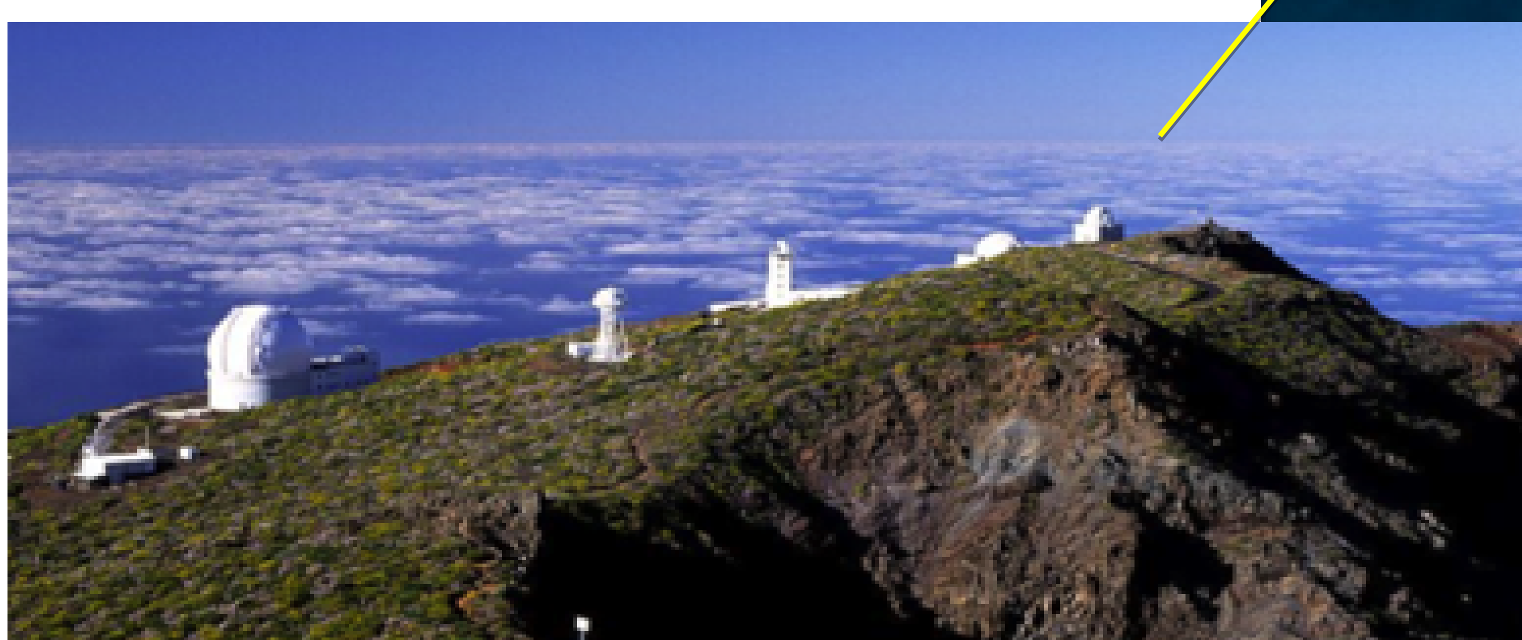
Operated by KU Leuven



Why on La Palma ?

- Remote site: no light pollution
  Ley del Cielo regulates artificial and street lighting
- Clear & transparent sky
- Limited cloud cover (28° latitude)
- Trade winds produce stable, turbulence-free atmosphere
  Very sharp images (0.5 – 1 arcsec)

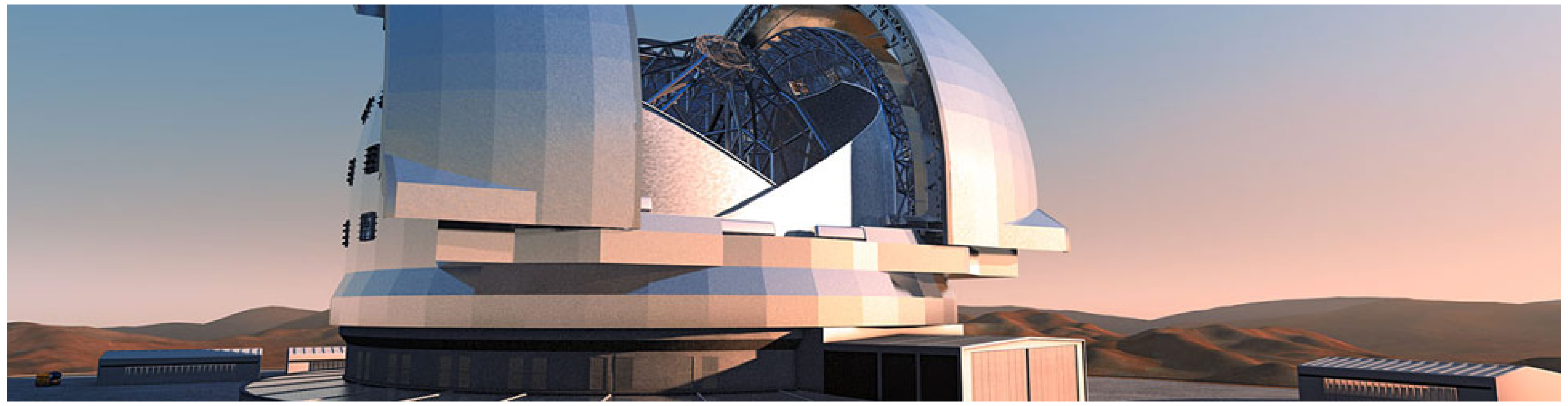


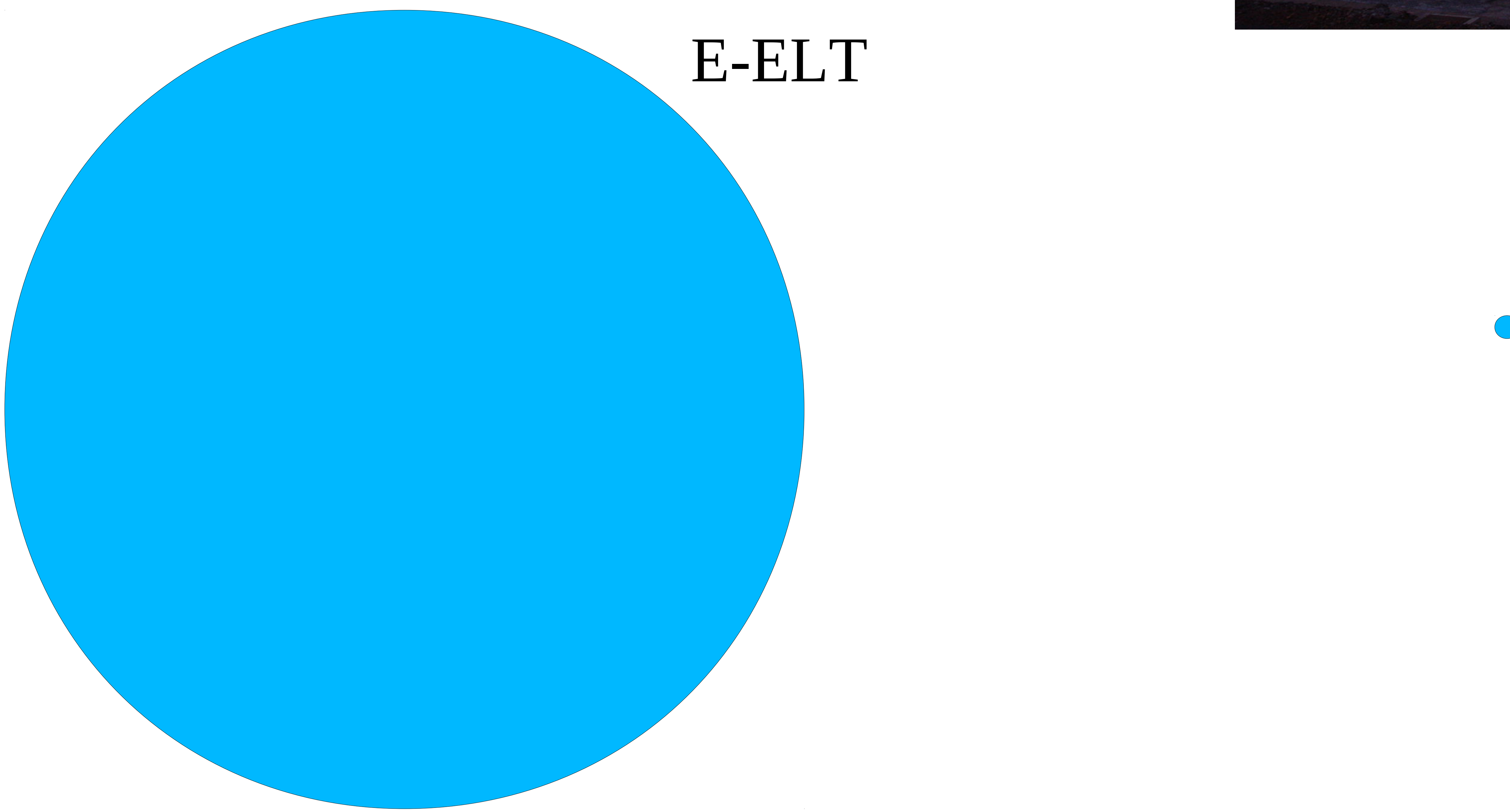


Why Mercator if you have access to the VLT ?

European Southern Observatory La Silla Paranal observatory

Or to the E-ELT (2024) ?





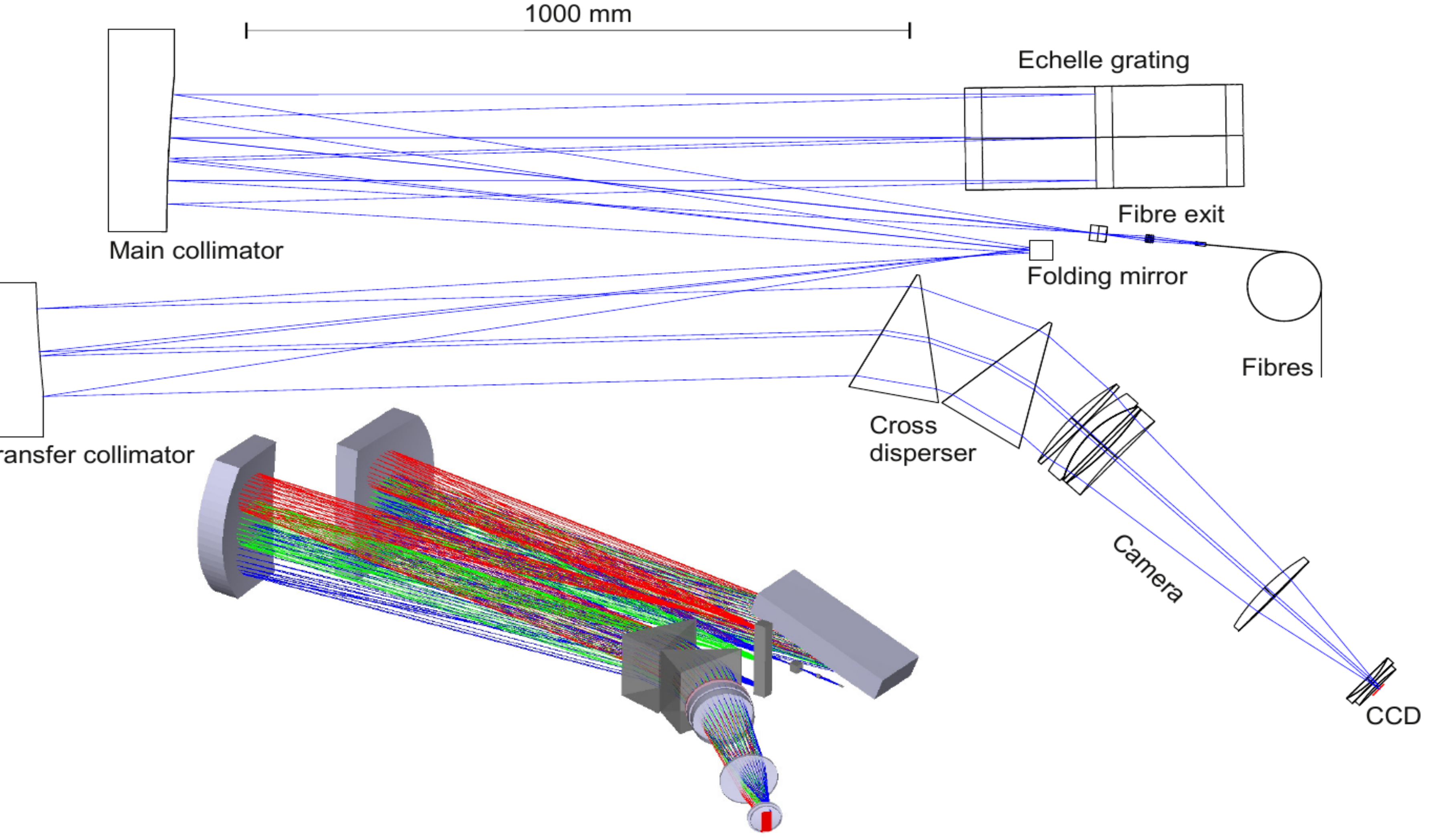
Mercator: Niche in observational astrophysics

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

Requirements:

1) World-class instruments: instrument development programme
2) Operational model: Pooled observations with priority driven scheduling.
3) Userfriendly robust operational environment
4) Continuous improvements/developments

Mercator: Instruments



HERMES

MAIA

HERMES-Consortium: Kick-off 19/01/2005
Science start: 01/06/2009

Project Engineer: Gert Raskin
PI: Hans Van Winckel

fwo
KU LEUVEN

IvS-KUL
co-i: C. Waelkens

ROB
co-i: H. Hensberge, Y Fremat

HERMES

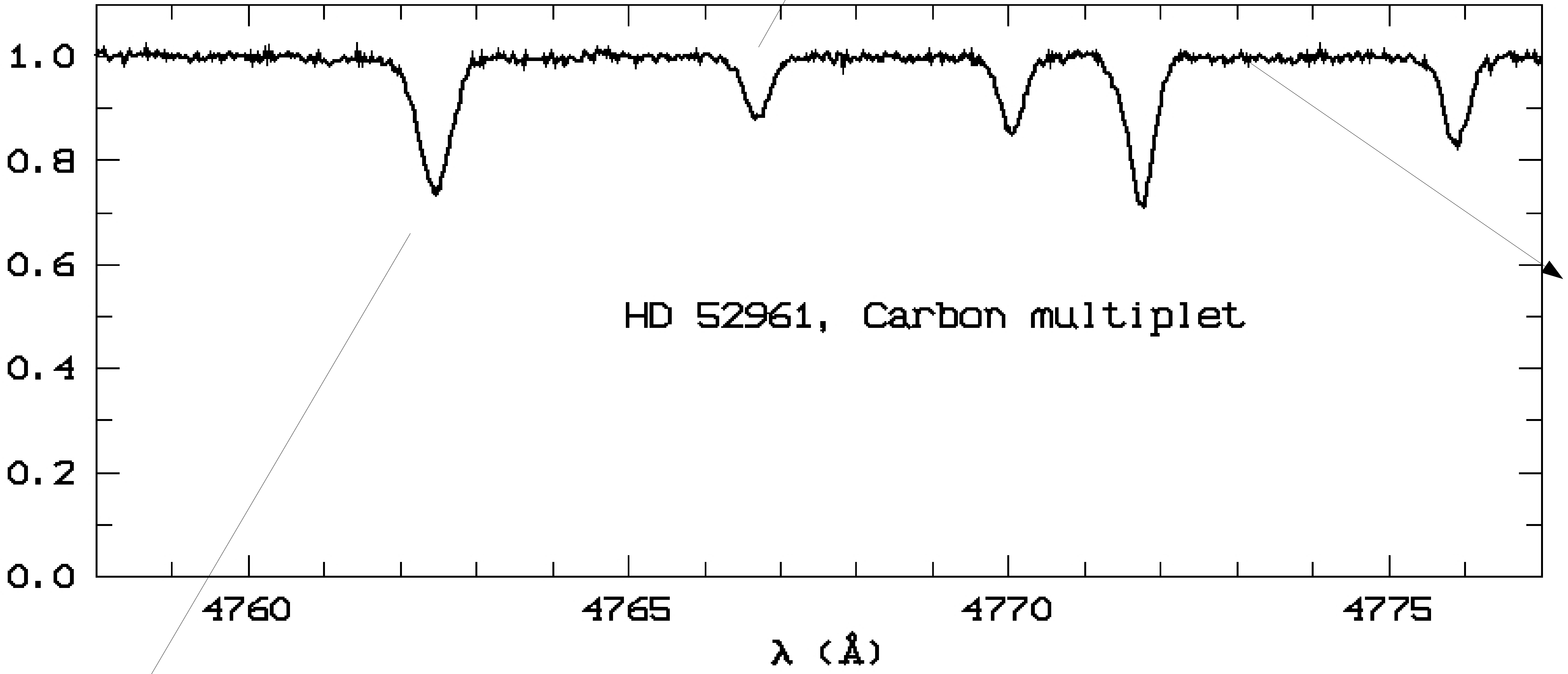
IAA-ULB
co-i: A. Jorissen

Observatoire de Genève

Landessternwarte Tautenburg
co-i: H. Lehman

Why a high-resolution spectrograph ?

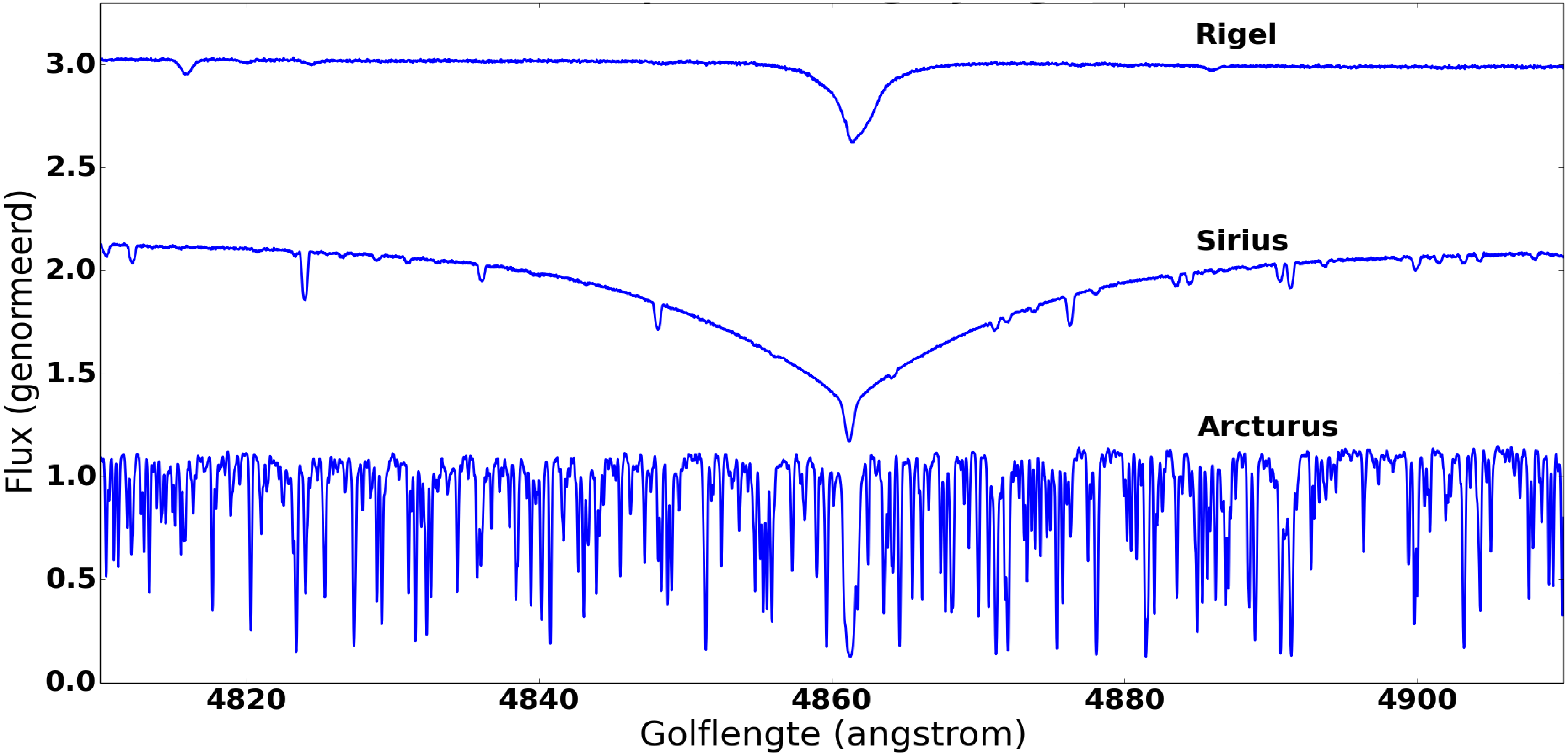
Strength of line = f(Teff, log(g), chemical composition)
Wide spectral coverage !
Good sampling required

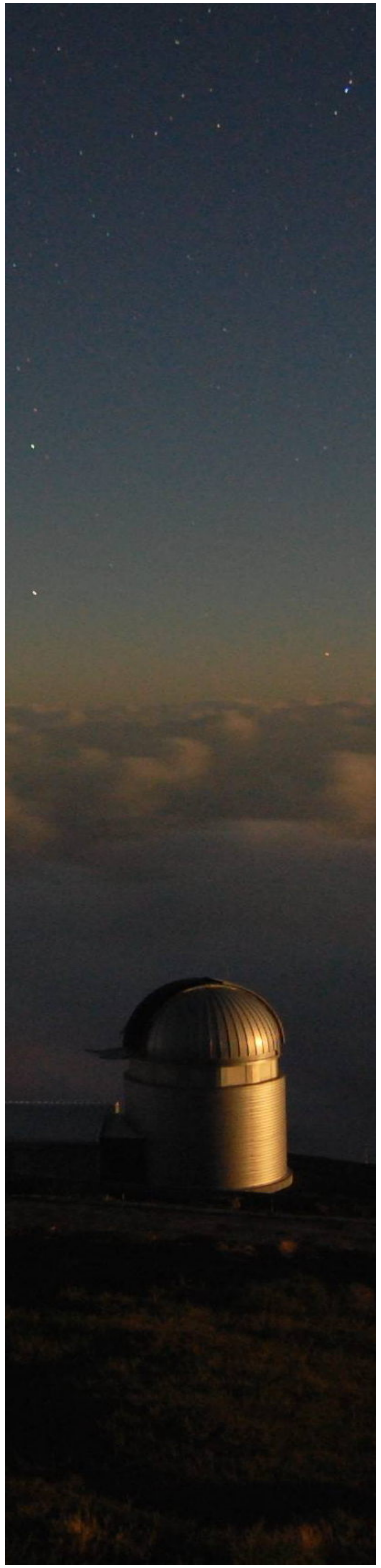


S/N: small telescope requires efficient instrument

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

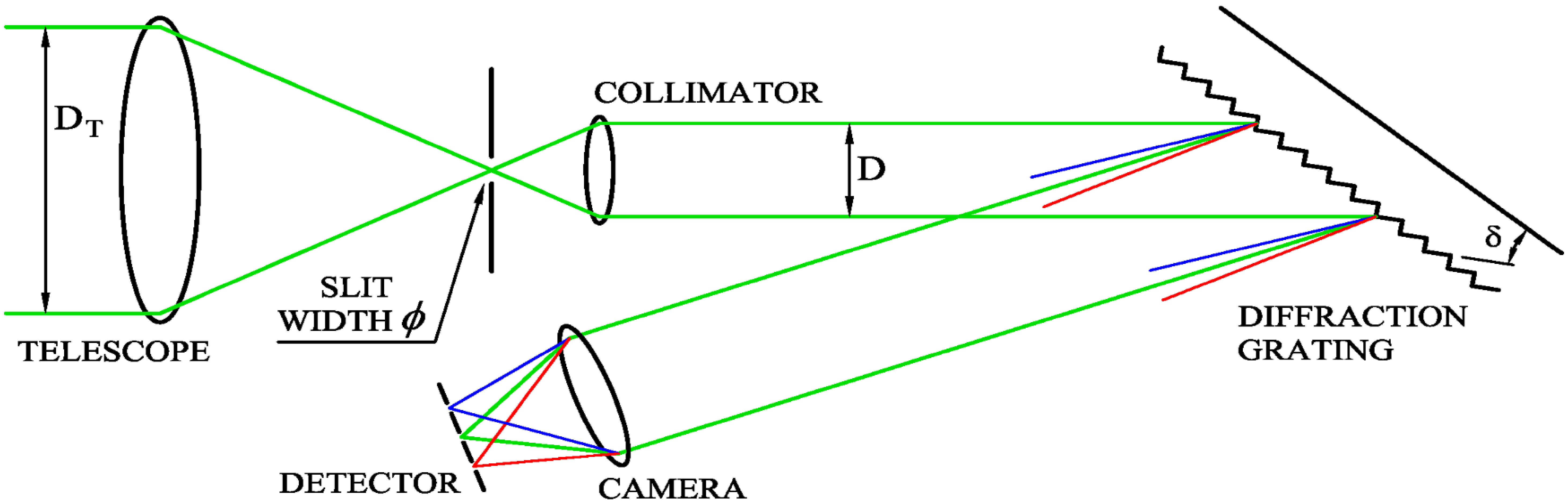
Power of high-resolution spectroscopy





Slit spectrograph resolution

$$R = \lambda / \Delta\lambda = \frac{2\,D \tan\delta}{\Phi\, D_T}$$



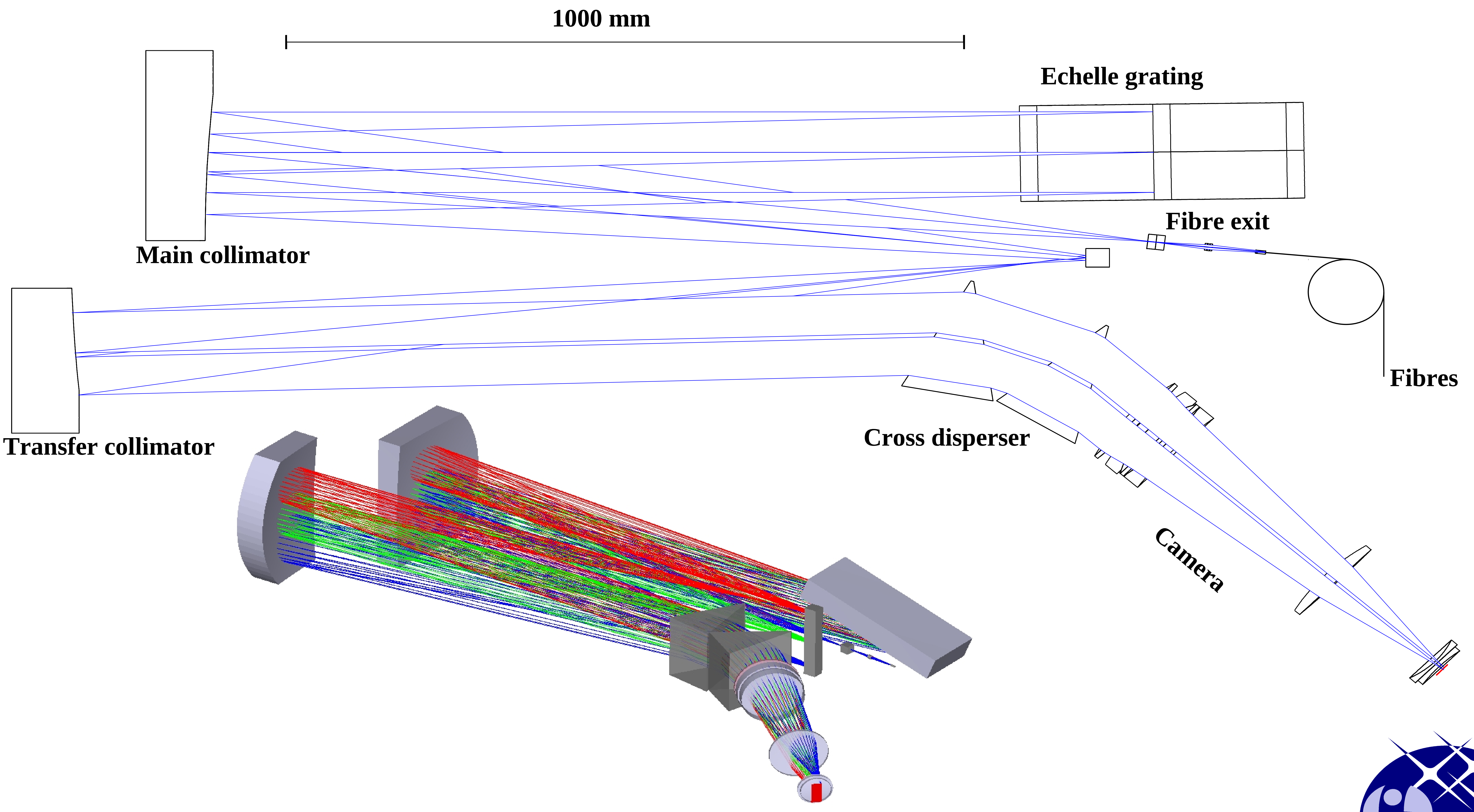
High spectral resolution

- Small telescope diameter D_T
- Small slit Φ
- Large beam diameter D hense Large optical elements

High flux:

- Large D_T
- Wide slit Φ

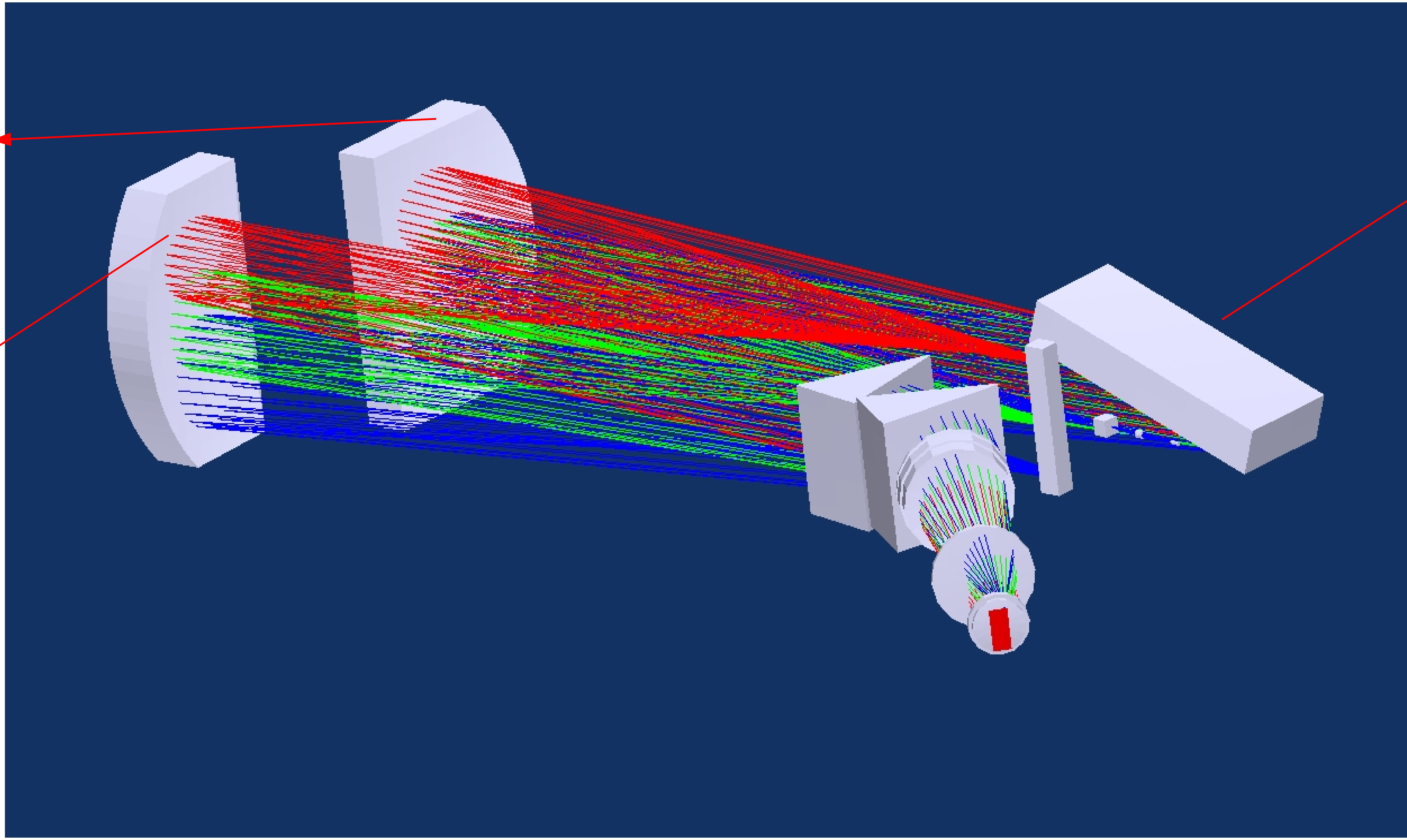
White-pupil layout



Hermes: white pupil Design

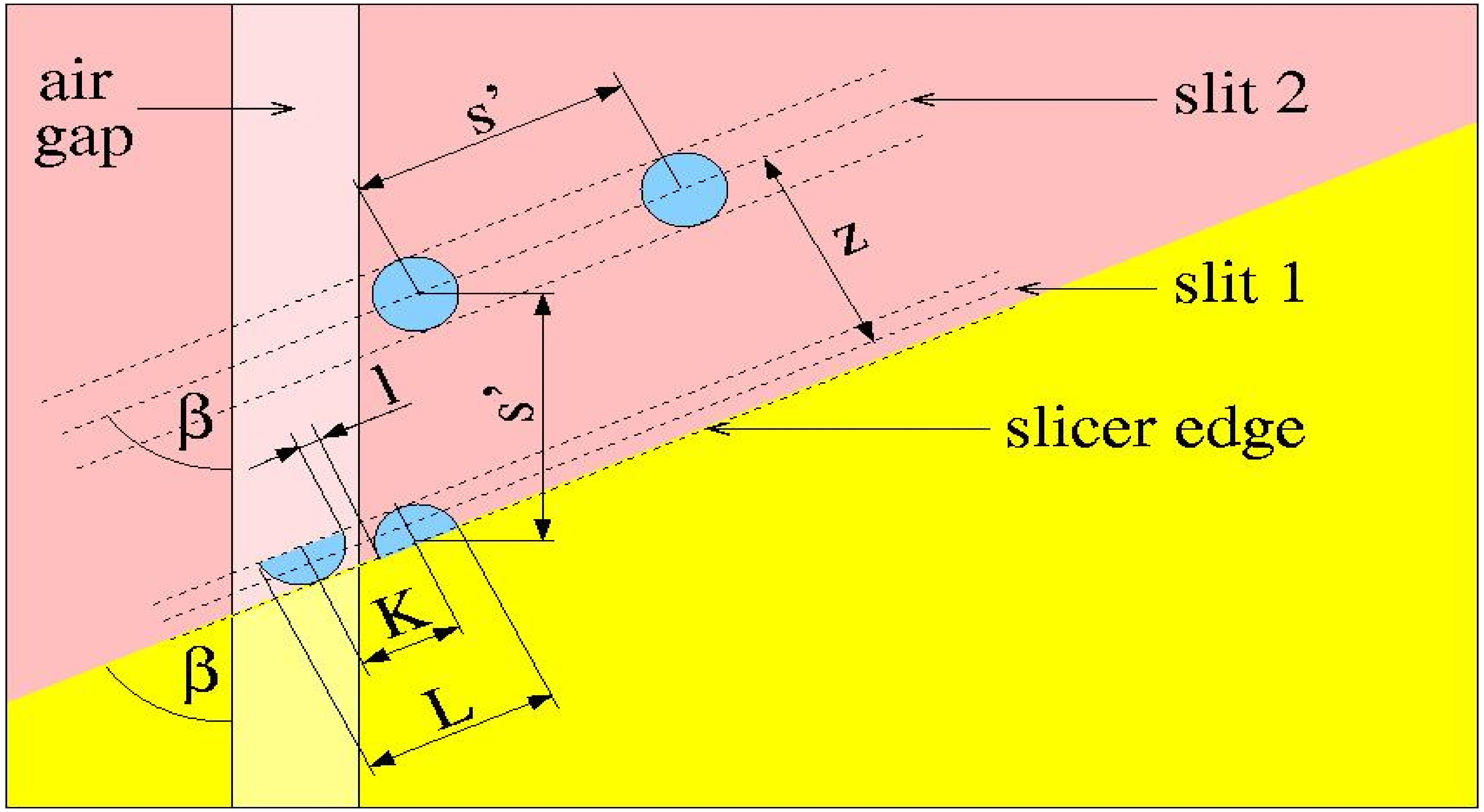
F/10

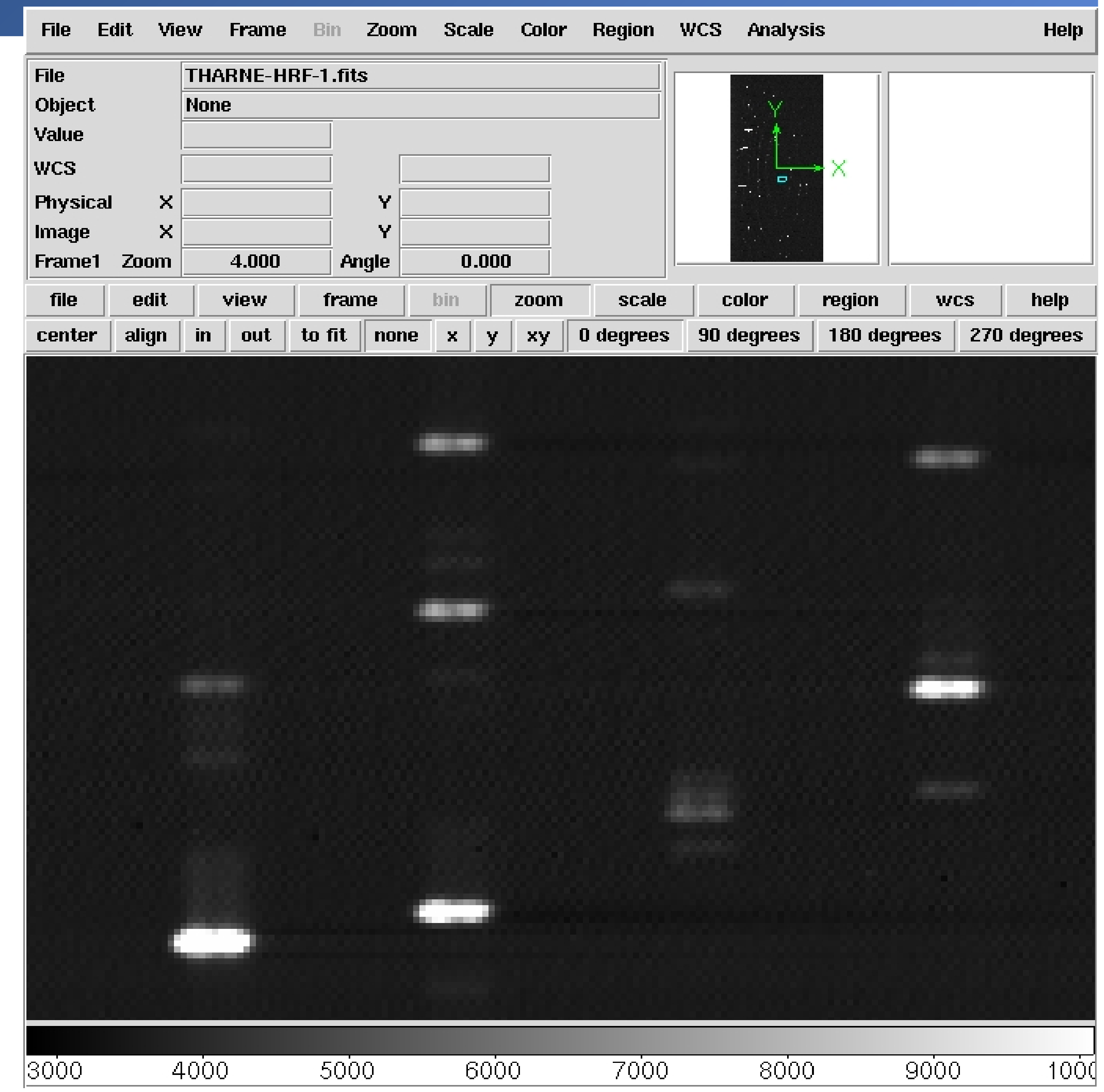
R2.70
blaze:69.7º

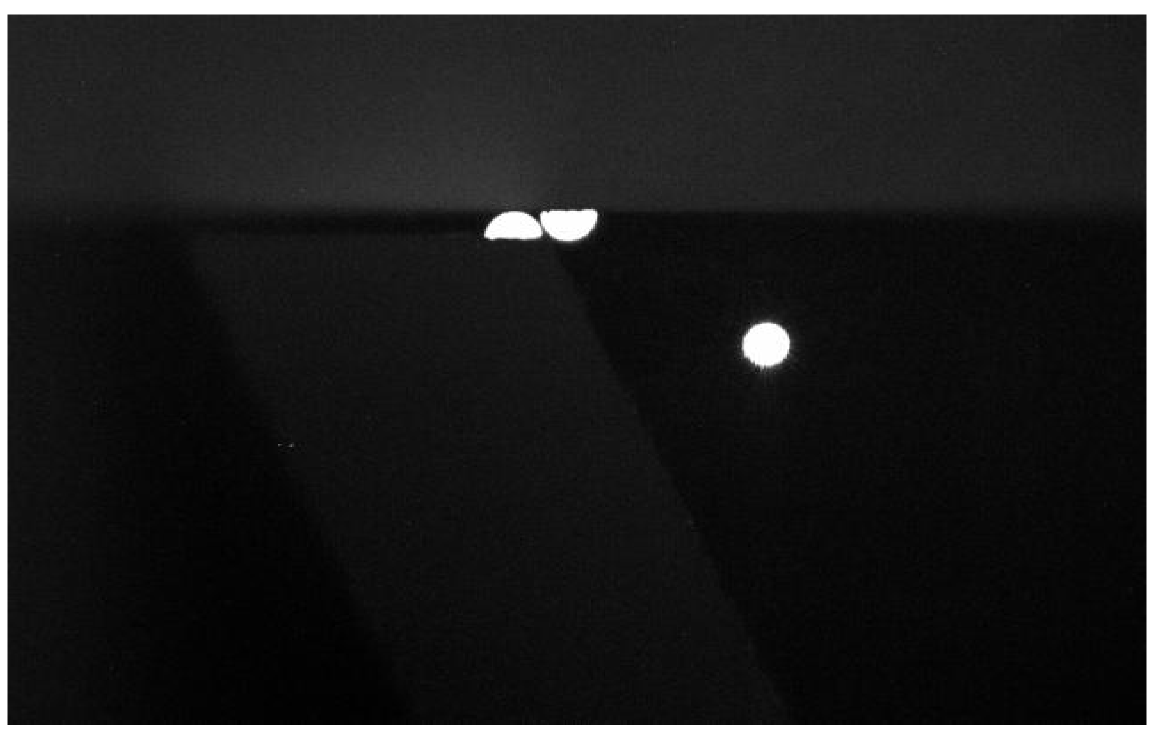


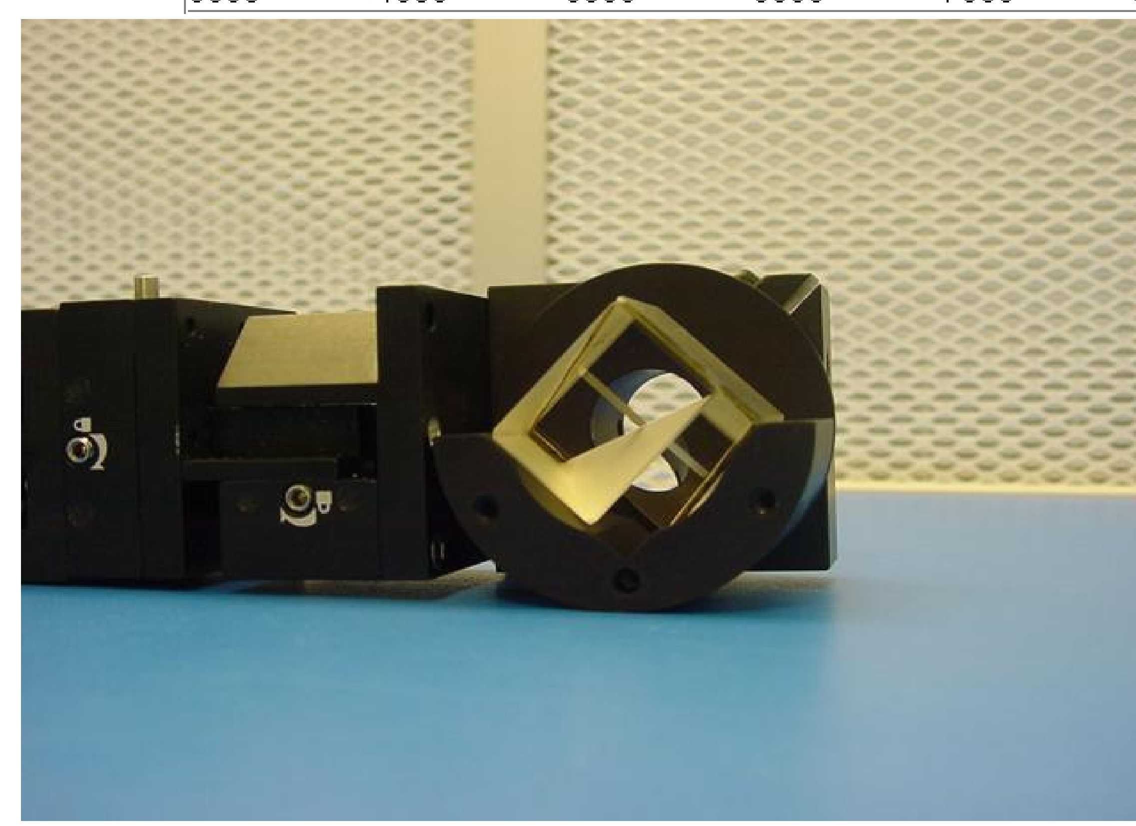
15cm
beam

HRF: slicer


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

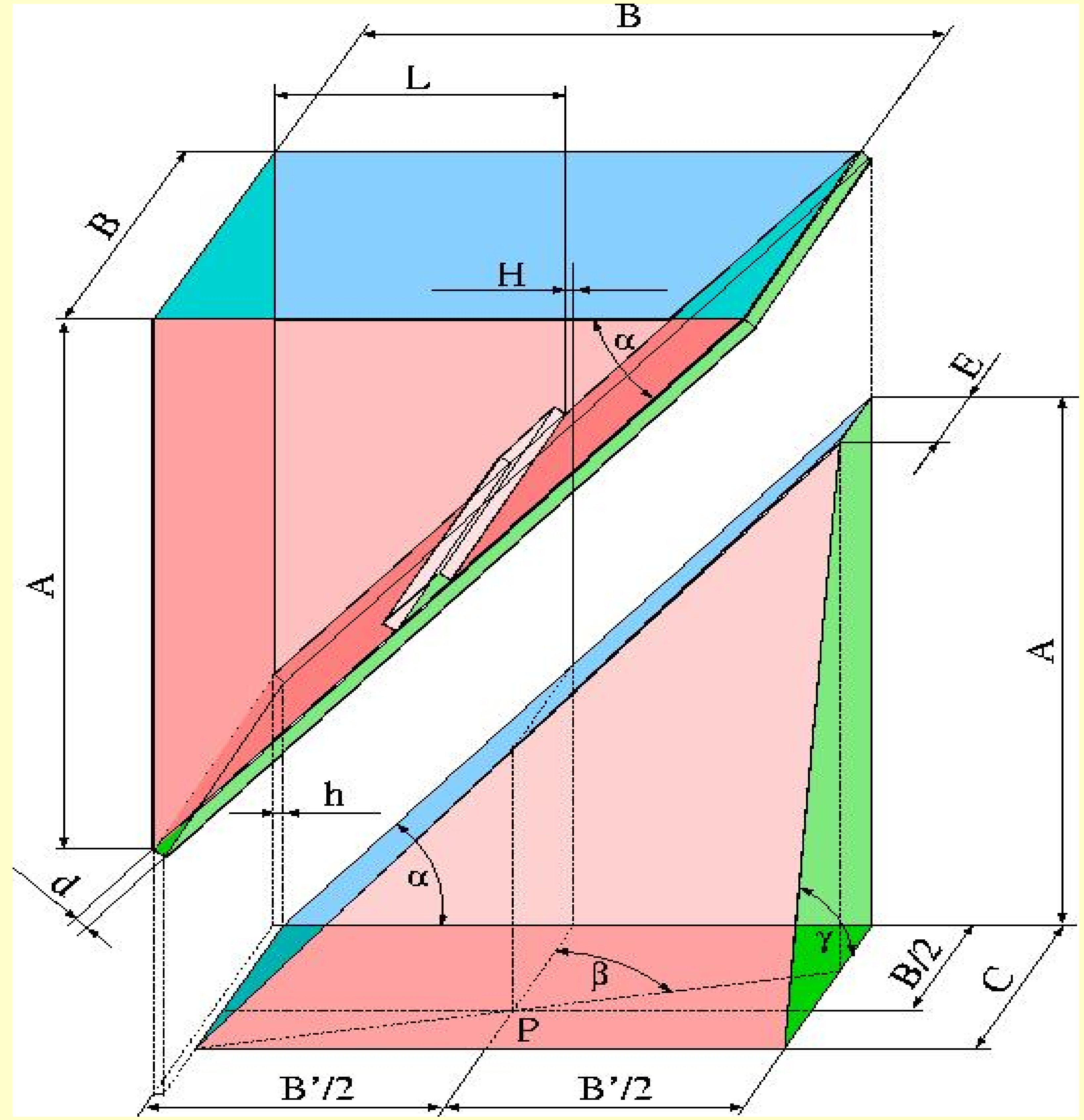

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File THARNE-HRF-1.fits
Object None
Value
WCS
Physical X Y
Image X Y
Frame1 Zoom 4.000 Angle 0.000
file edit view frame bin zoom scale color region wcs help
center align in out to fit none x y xy 0 degrees 90 degrees 180 degrees 270 degrees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



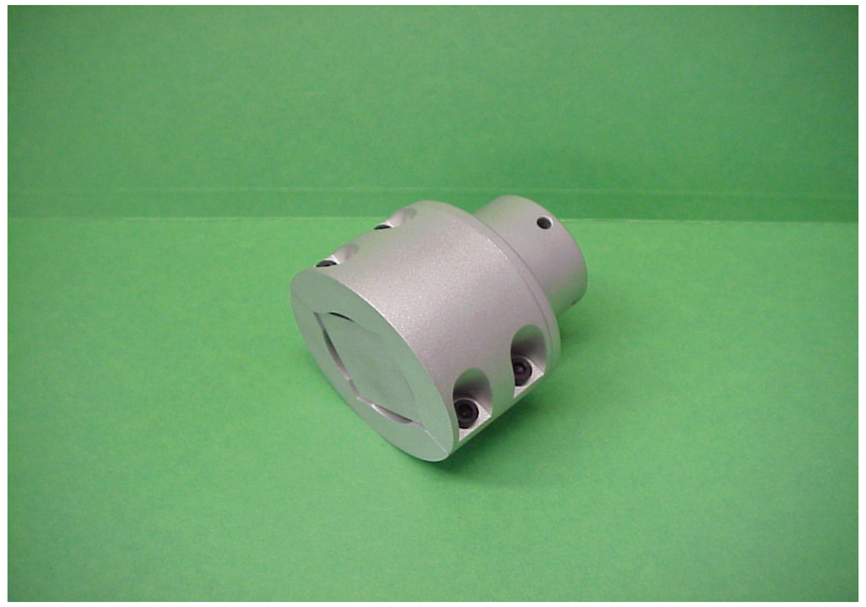


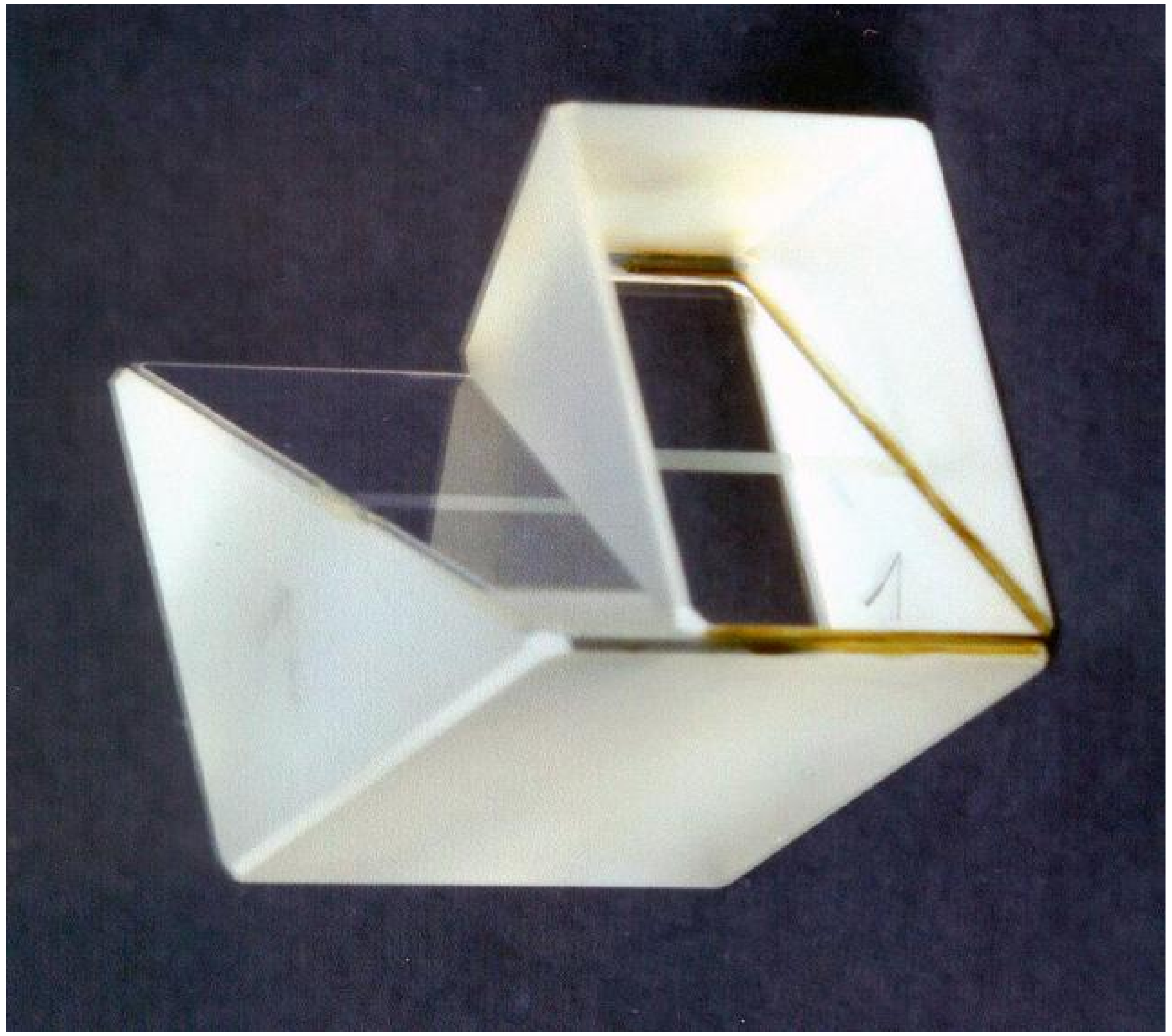
Basic values and dimensions

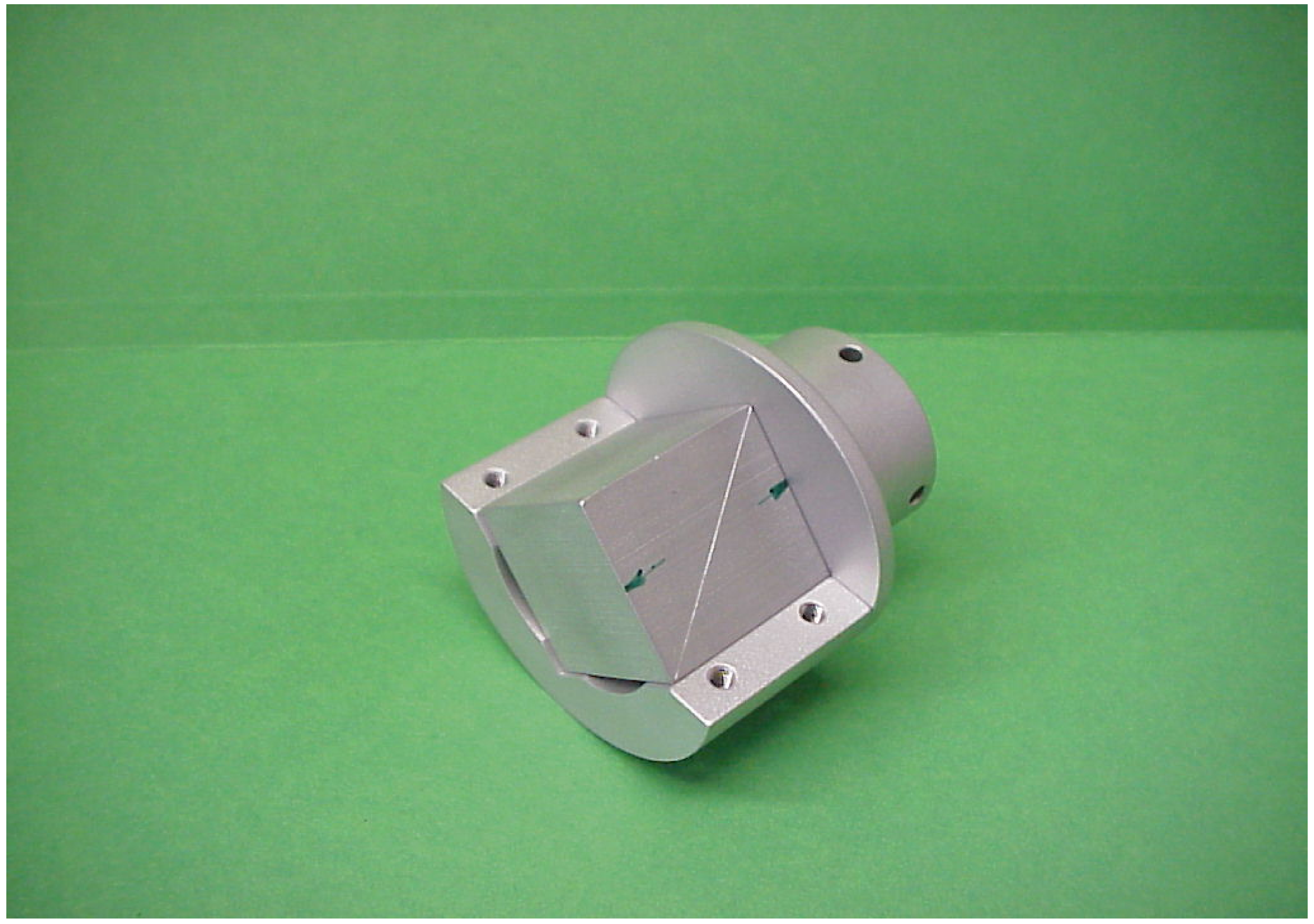
slice angle	65.49°
prism angle	46.50°
prism height	25.00 mm
prism entrance	23.72 mm
slicer plate	0.17 mm
slit width sliced	0.10 mm
distance of slices	0.28 mm
total slit length	0.49 mm
focus difference	0.25 mm

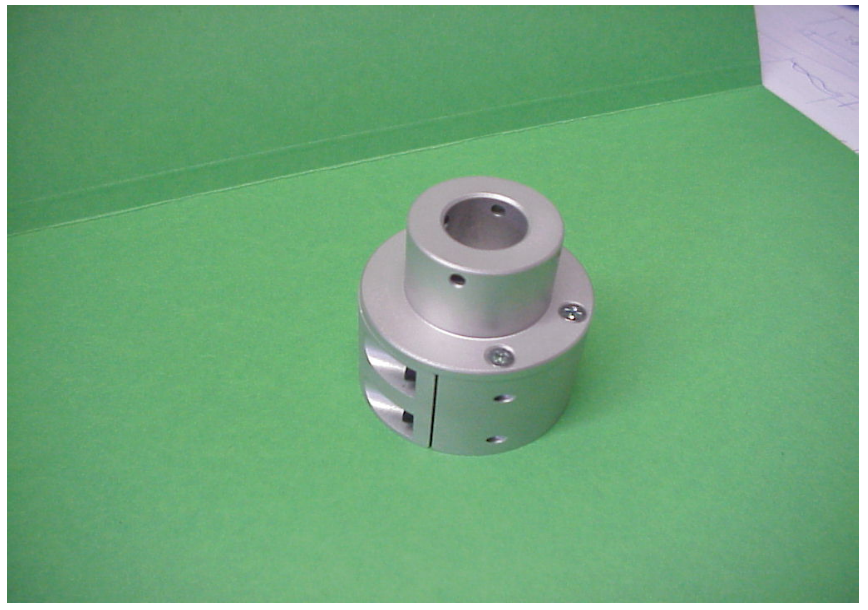


Slicer









FOD

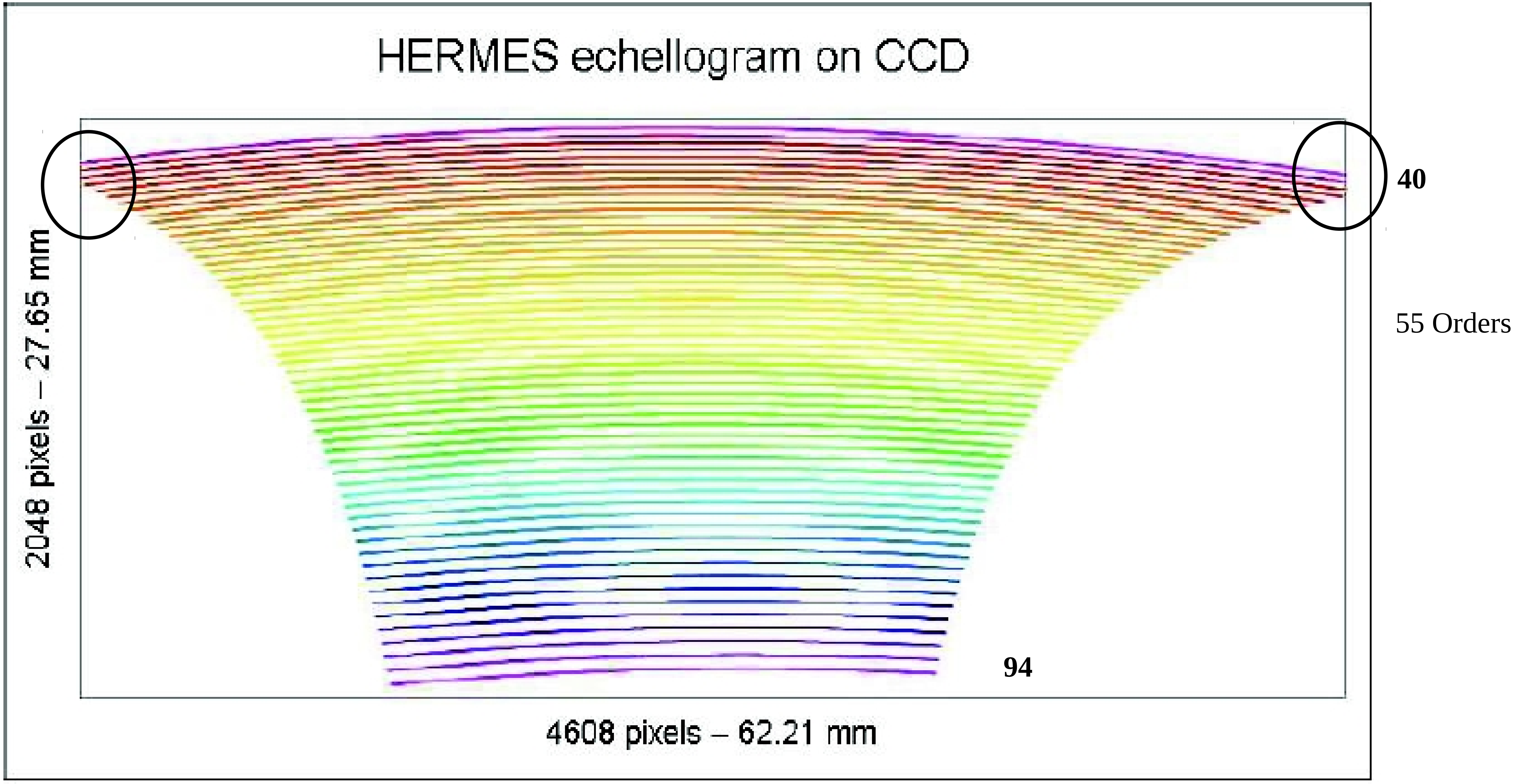
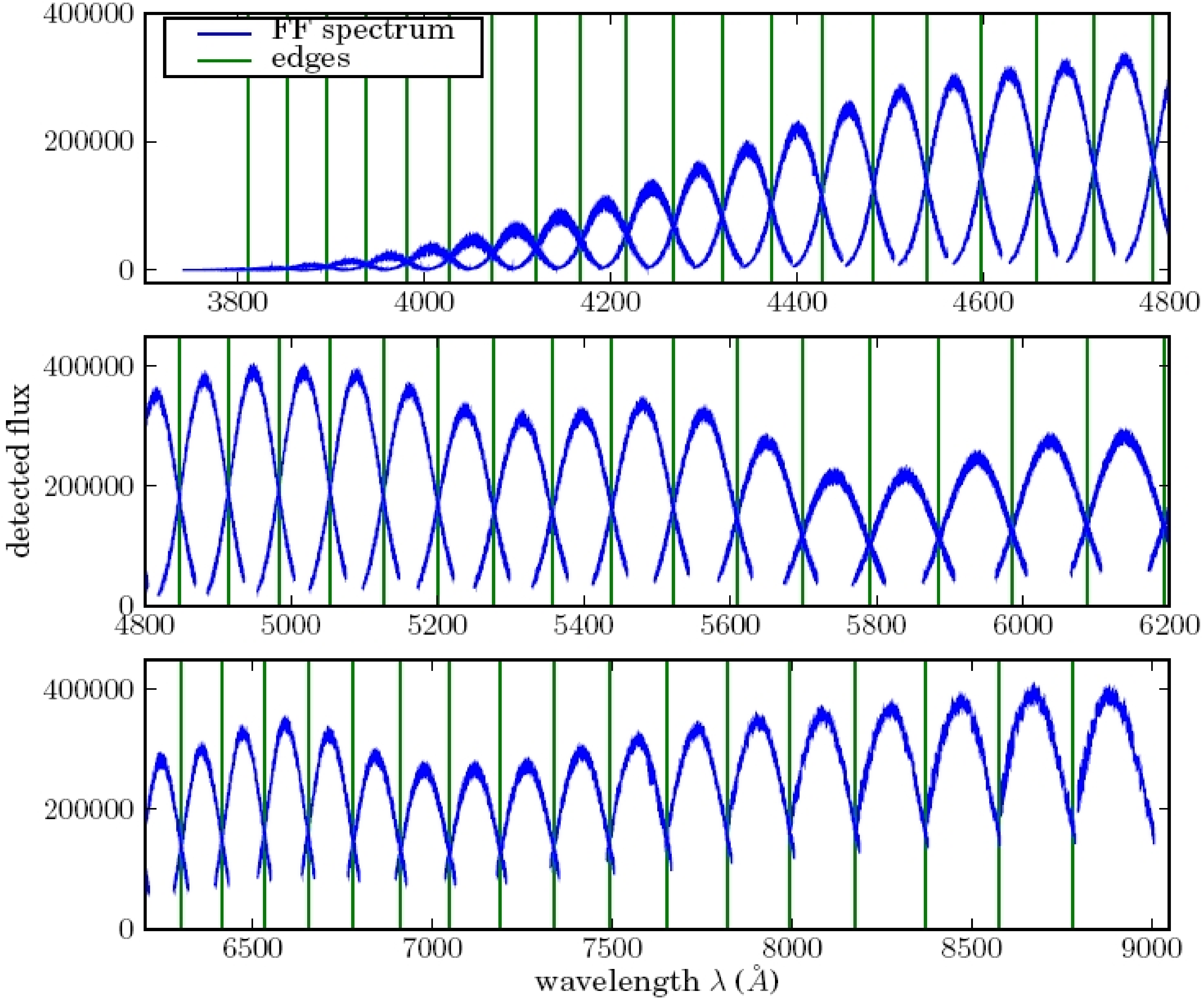


Fig. 17. Layout of the 55 orders on the CCD (color scale is compressed for visibilty).

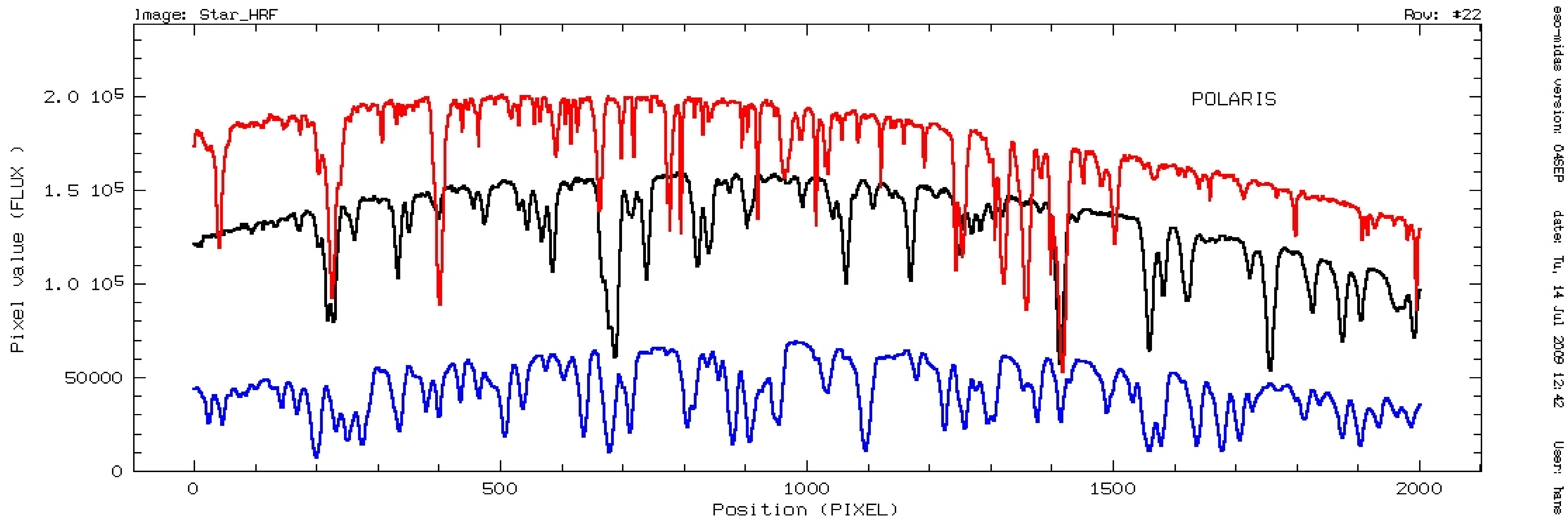


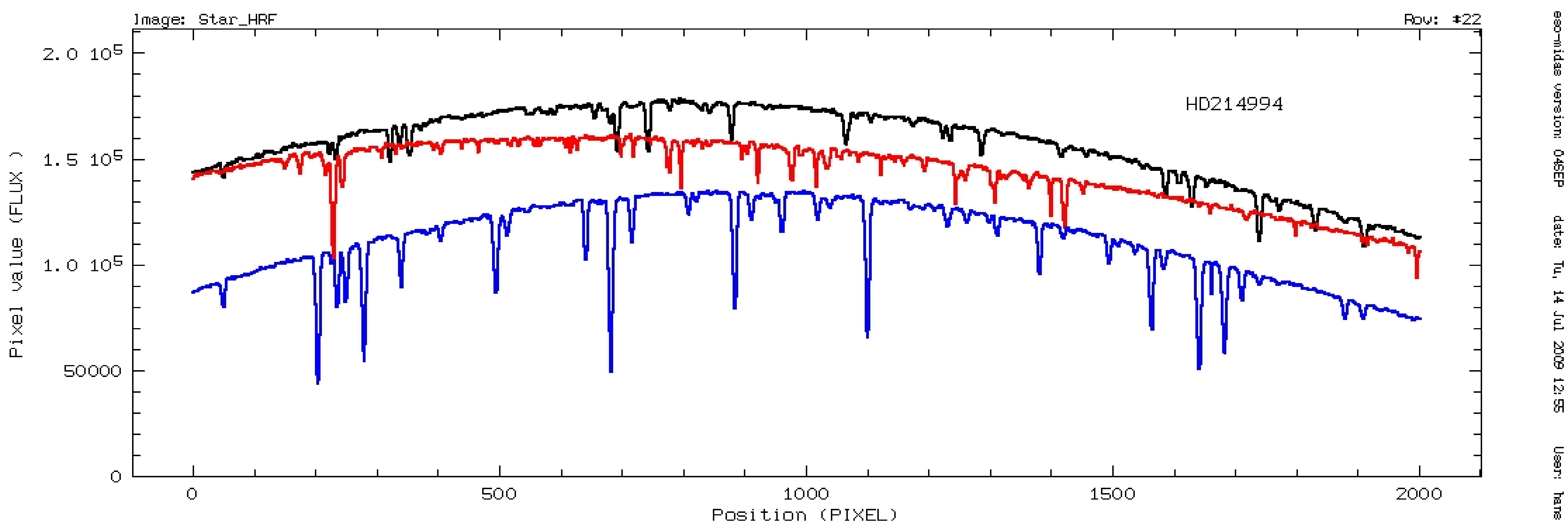
- blaze profiles so S/N is very dependent on the distance from the blazewavelength

- reddest orders do not overlap.

- orders: 40 to 94

Spectrograph Performance



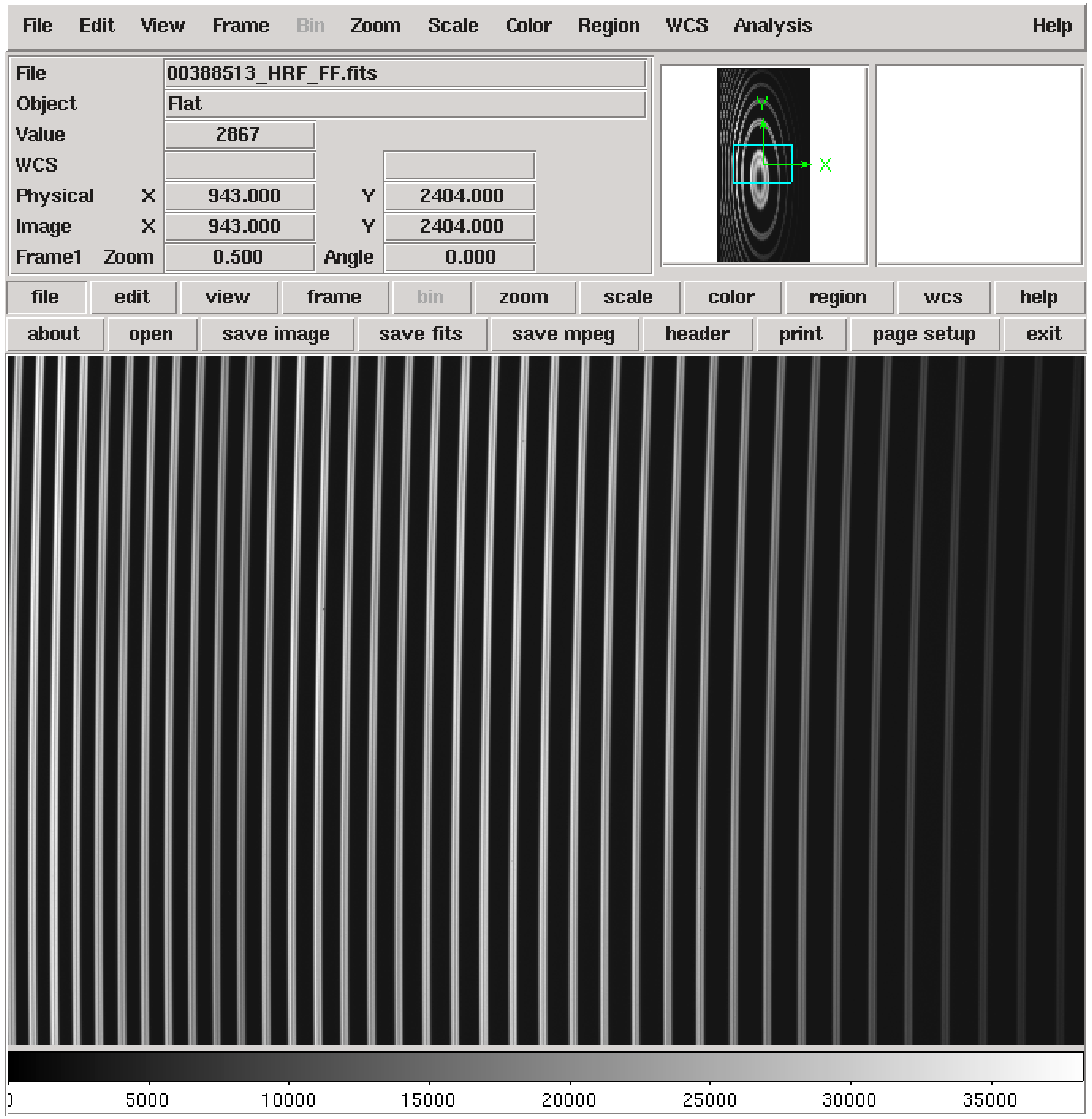


RON ~ 3-4e⁻

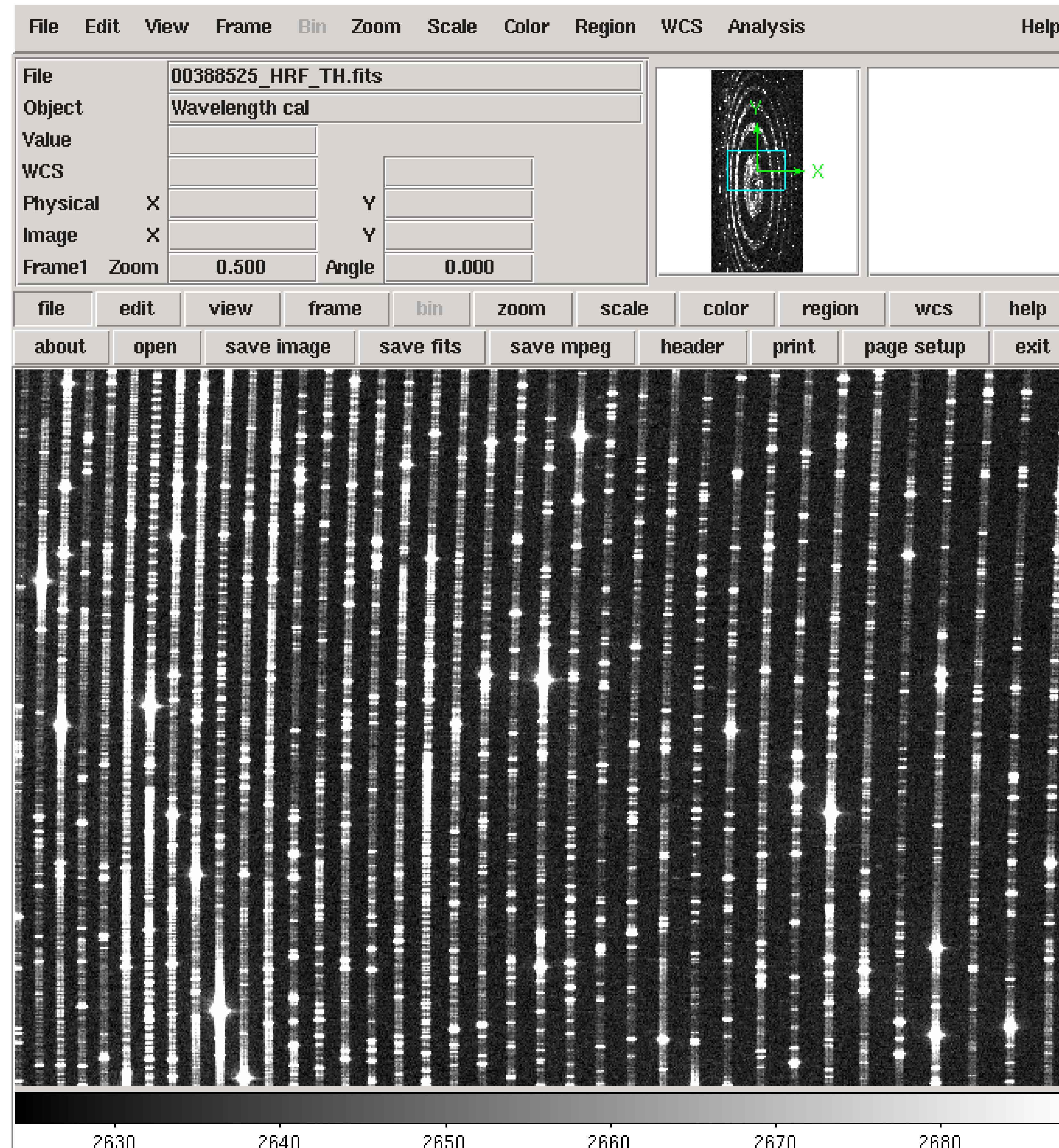
Take multiple exposures

Illustrations: raw frames

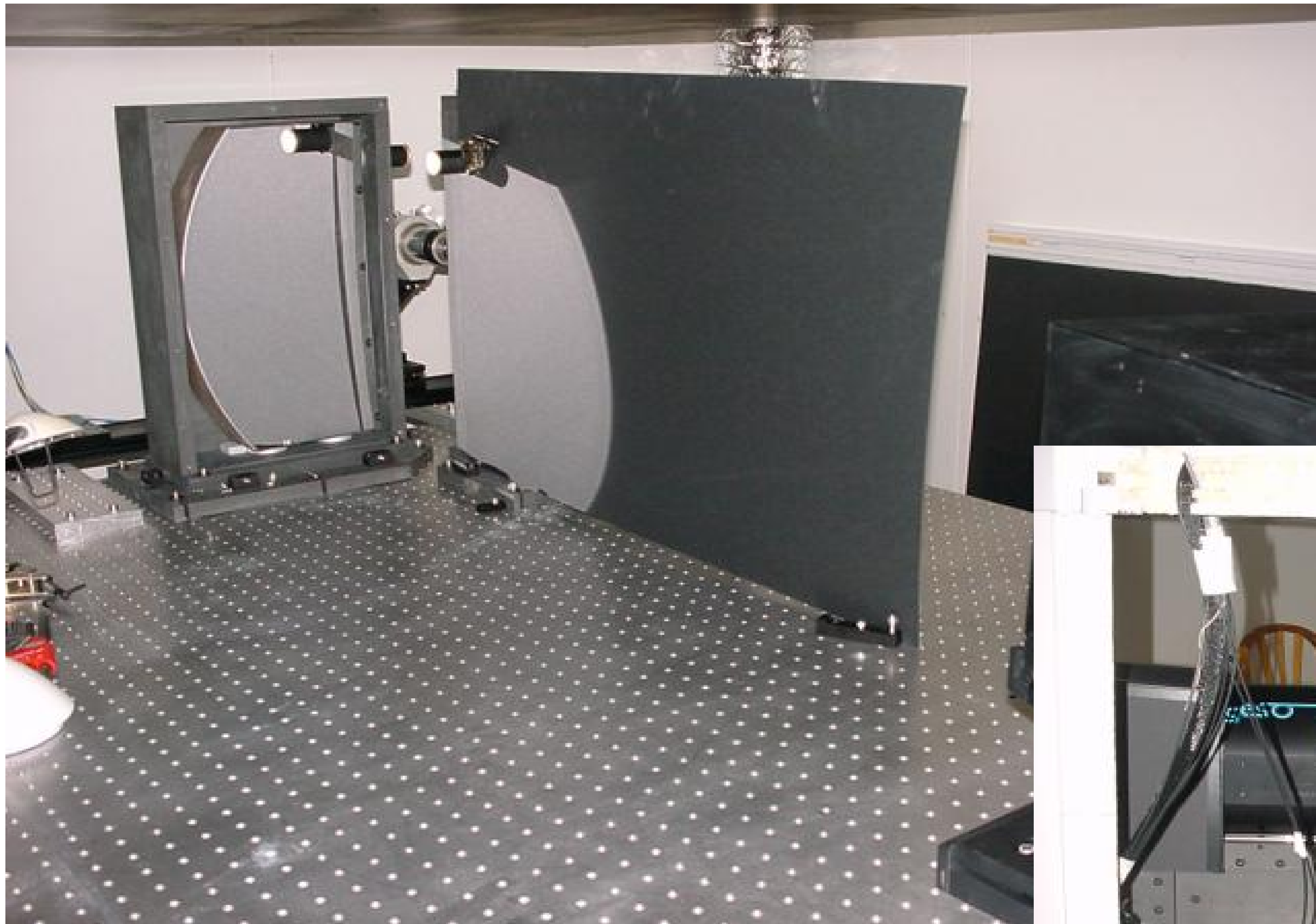
FF HRF fibre

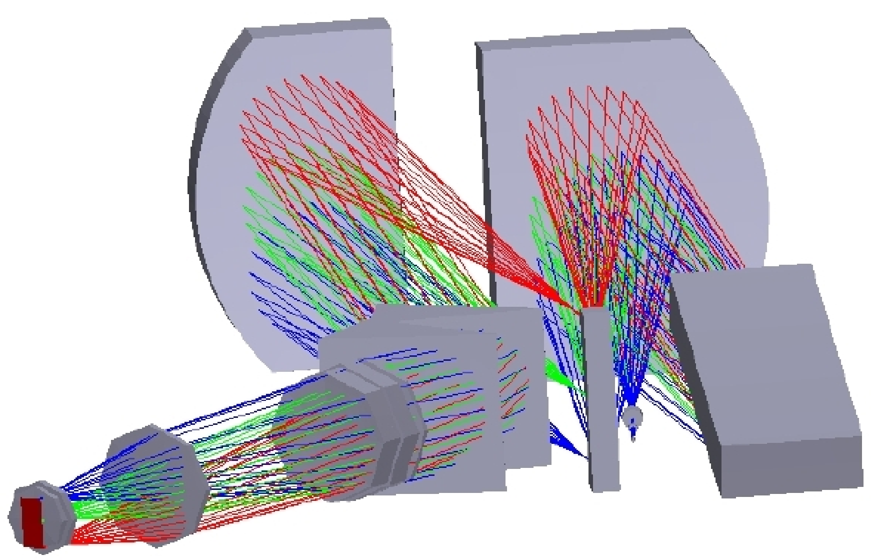


ThArNe HRF fibre

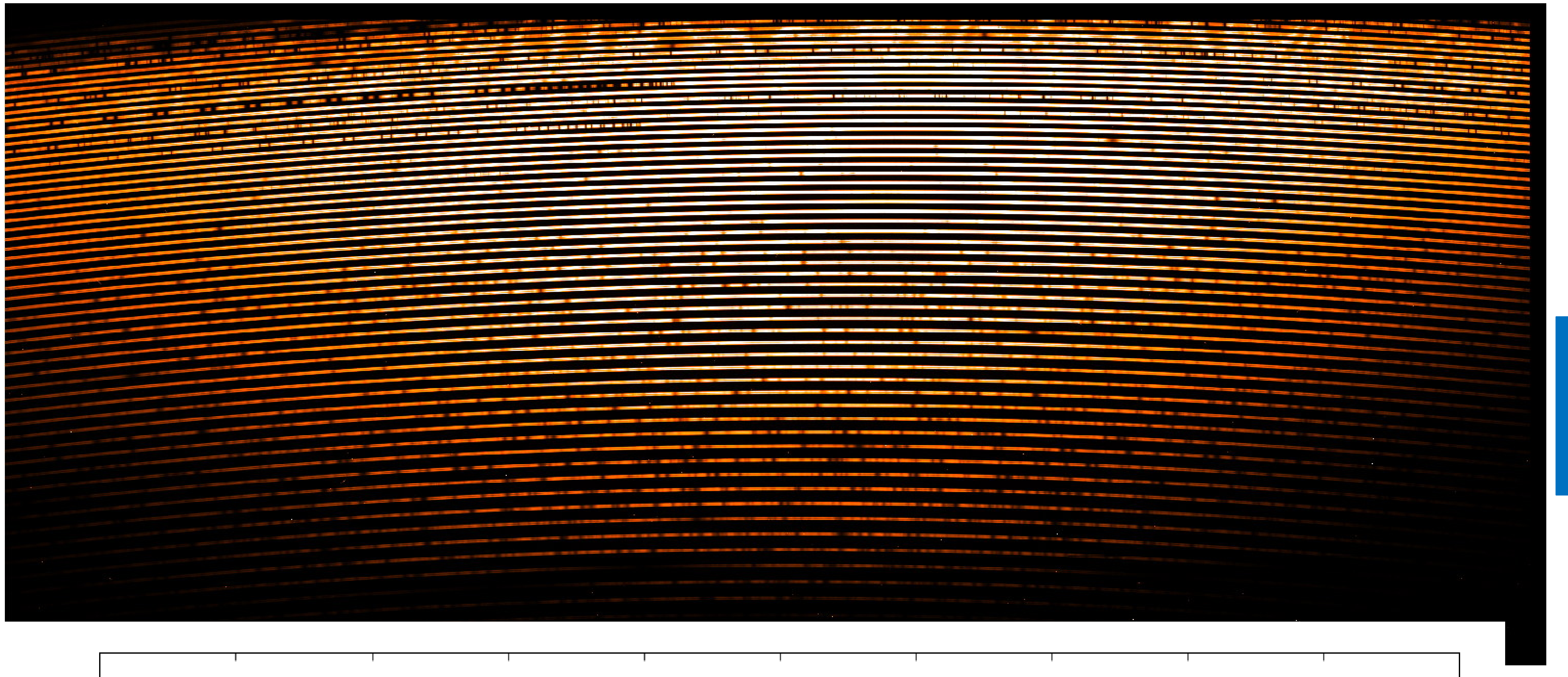


Spectrograph room...



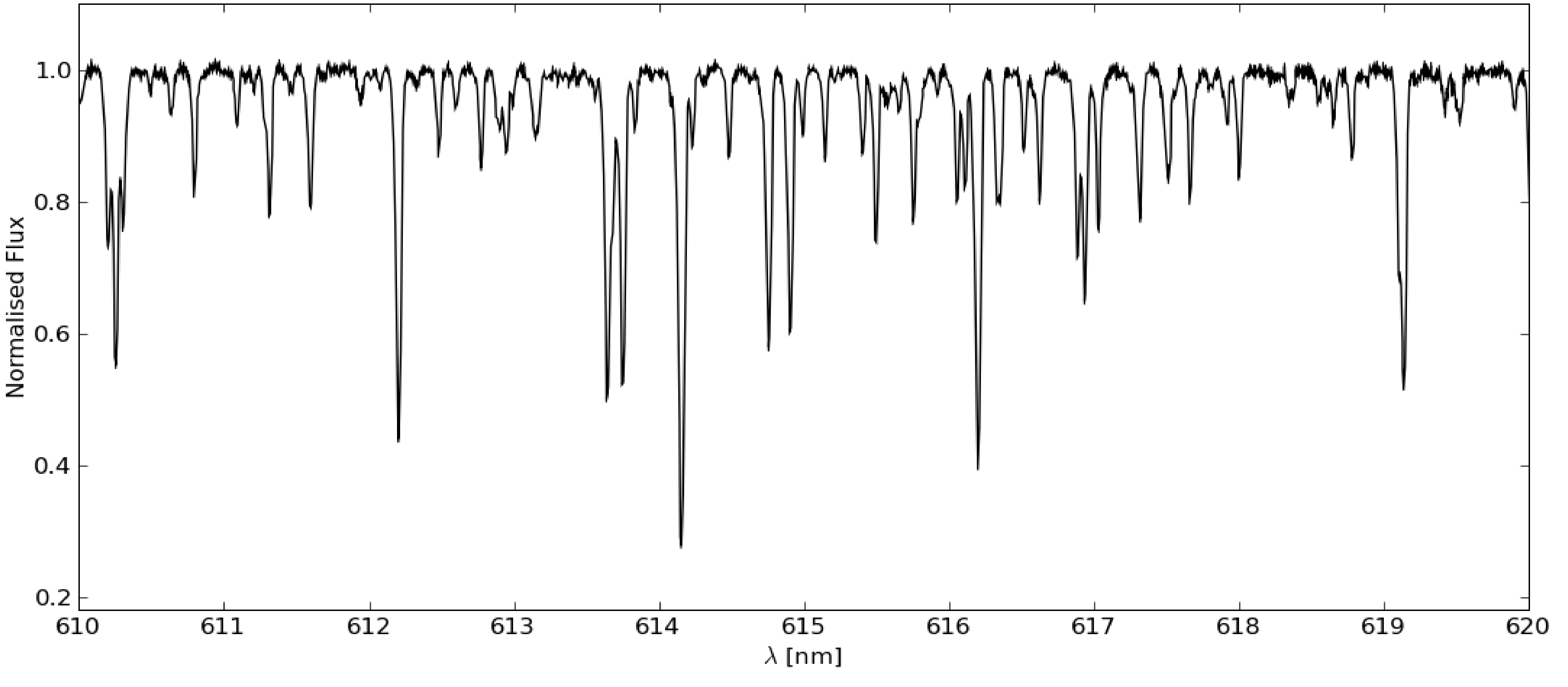


Final result: example spectrum of Polaris



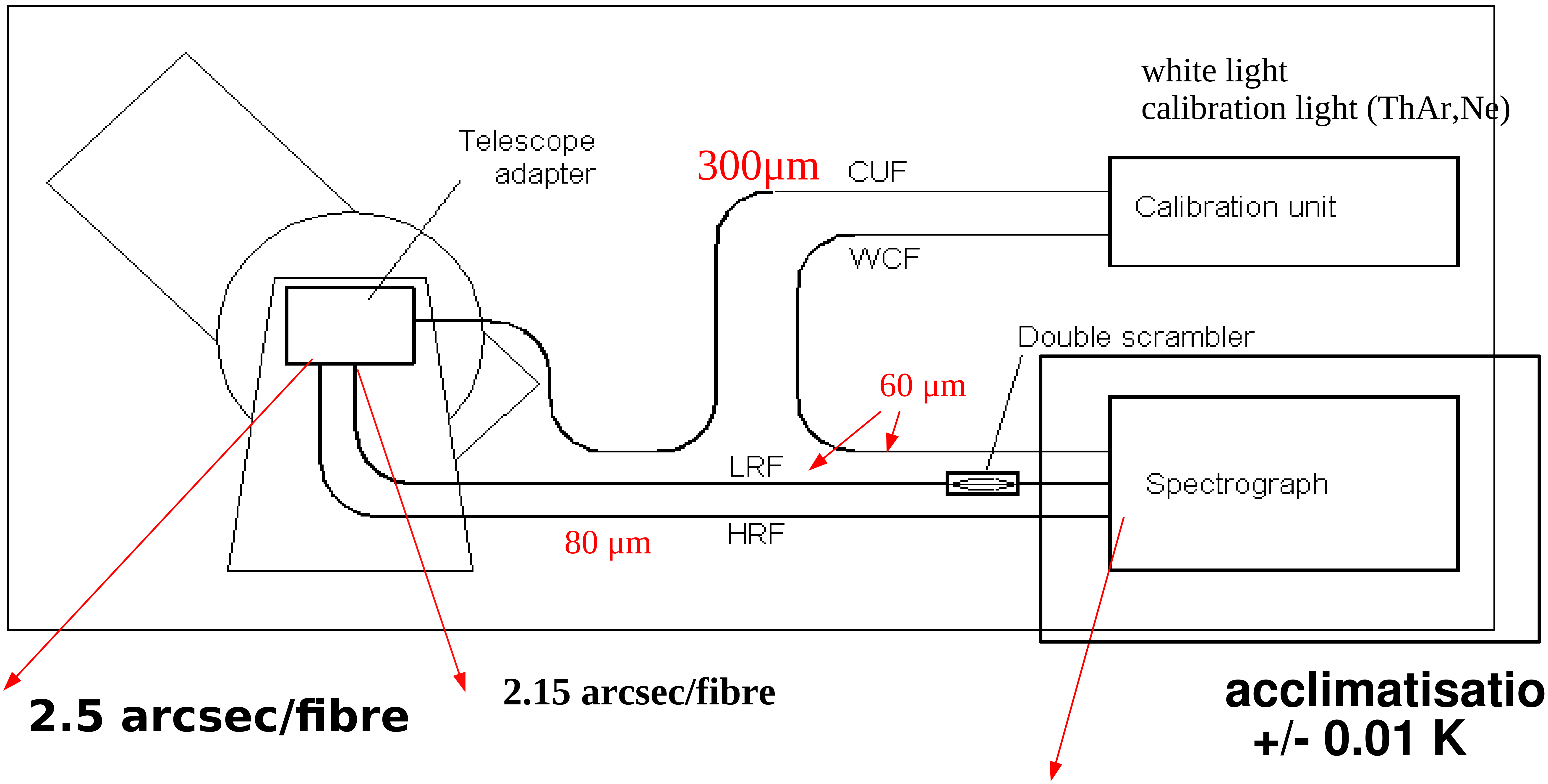
Raw frame
All spectral orders (40-94)

Data reduction



Small spectral part
610-620 nm

Hermes Design



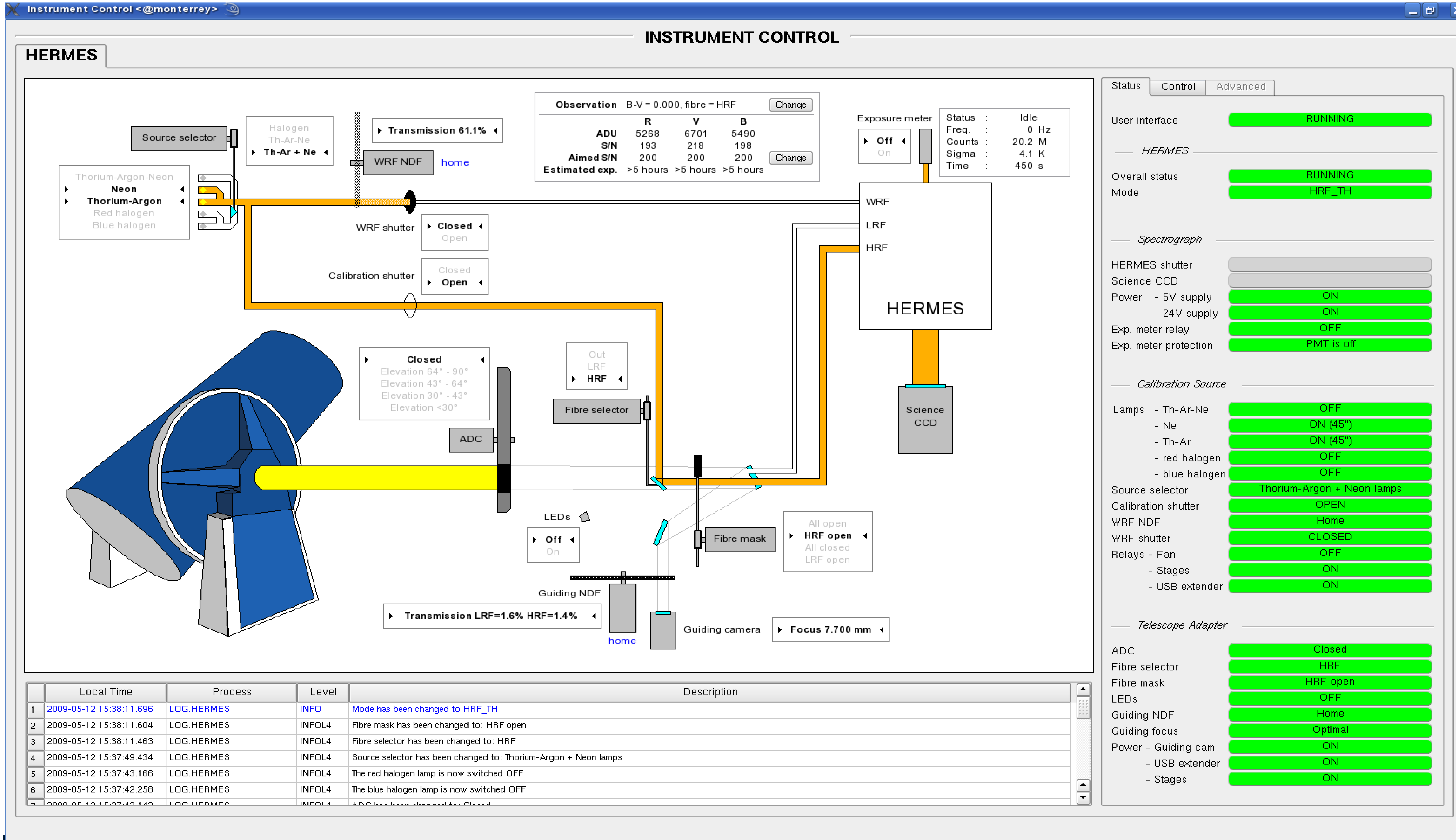
2.5 arcsec/fibre

2.15 arcsec/fibre

acclimatisation !!
+/- 0.01 K

double slicer

Software



Instrument Control <@monterrey>
INSTRUMENT CONTROL
HERMES
Source selector
Halogen
Th-Ar-Ne
Th-Ar + Ne
Thorium-Argon-Neon
Neon
Thorium-Argon
Red halogen
Blue halogen
Transmission 61.1%
WRF NDF
home
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
Open
Science CCD
Closed
Elevation 64° - 90°
Elevation 43° - 64°
Elevation 30° - 43°
Elevation <30°
ADC
Out
LRF
HRF
Fibre selector
LEDs
Off
On
Fibre mask
All open
HRF open
All closed
LRF open
Guiding NDF
Transmission LRF=1.6% HRF=1.4%
home
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

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**

Raskin, et al., 2011, A&A 526, 69

https://fys.kuleuven.be/ster/pub/pub#PhD

more details: PhD Gert Raskin

Mercator: Operational Model

Priority driven pooled observations after peer review process

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))

Science Programmes: Phase I, Phase II converted into DB

Trouble shooting: night report + fast feedback (7/7)

Weekly skype conferences with whole team

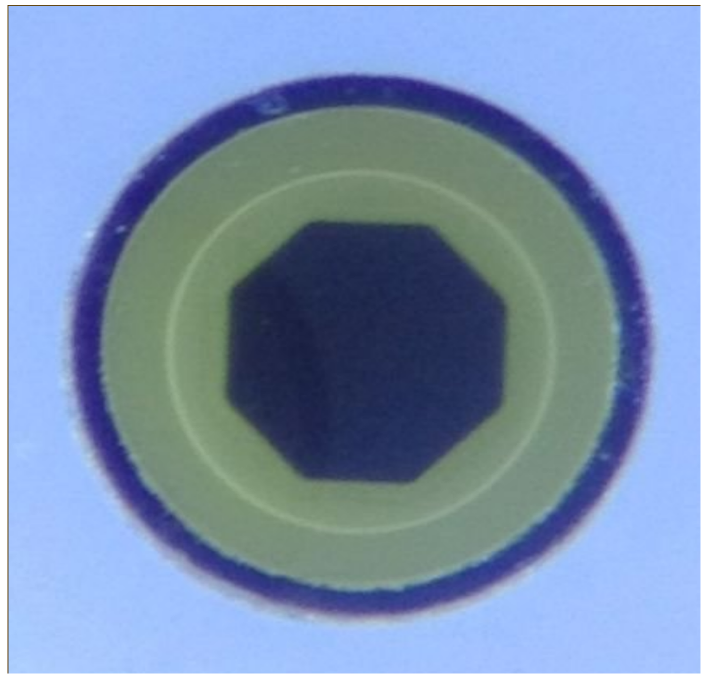
All nights are service nights: 80% from the pool, 20% for own experiments

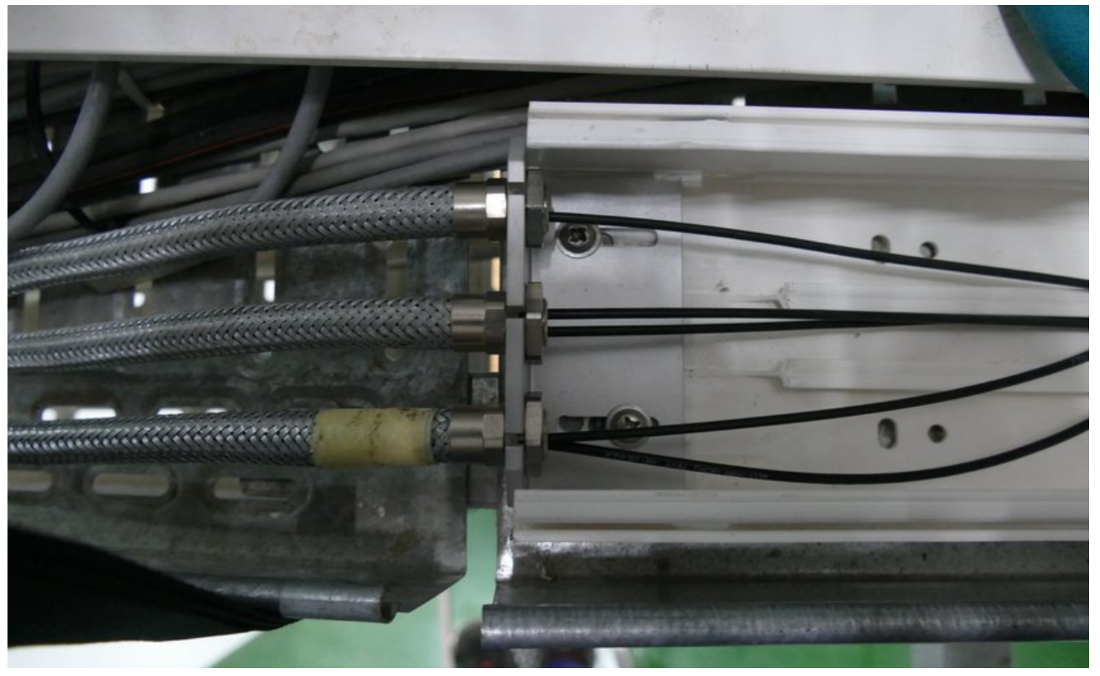
Continuous Technical Developments

- 2018: new fibre link (octogonal fibres)
- 2018-2019: upgrade network and all computers
- 2020: New Wavelength Calibration Unit

  (cotutelle Macquarie: PhD project)

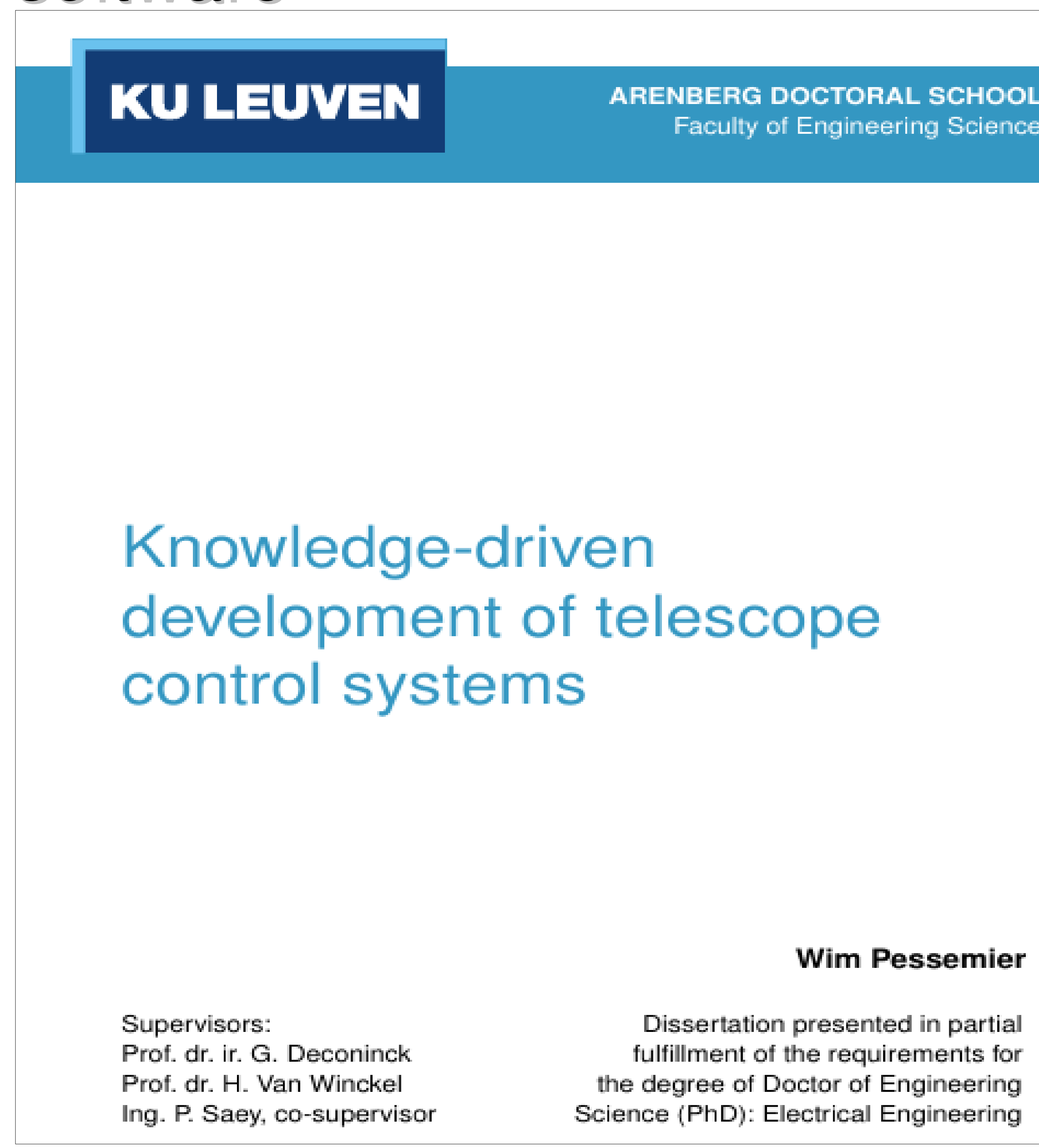
Next talk by Gert Raskin





The new TCS

- The development methodology: *knowledge-driven development*
  - based on multi-disciplinary modeling of the system requirements, mechanics, electronics and software
  - not only the system itself is modeled using a vocabulary, but also the meaning (semantics) of this vocabulary is formally described
    => increased reusability of the models
    => a consistent, verifiable, and evolvable new TCS for Mercator


KU LEUVEN

ARENBERG DOCTORAL SCHOOL
Faculty of Engineering Science

Knowledge-driven development of telescope control systems

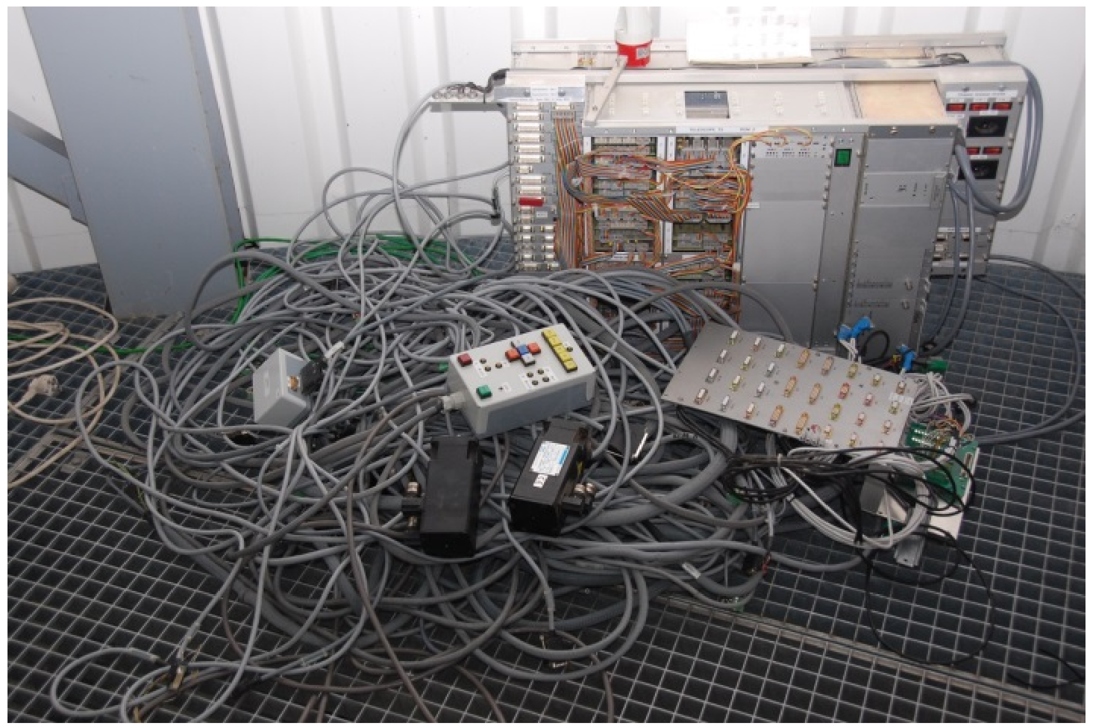
Wim Pessemier

Supervisors:
Prof. dr. ir. G. Deconinck
Prof. dr. H. Van Winckel
Ing. P. Saey, co-supervisor

Dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Engineering Science (PhD): Electrical Engineering

The new TCS

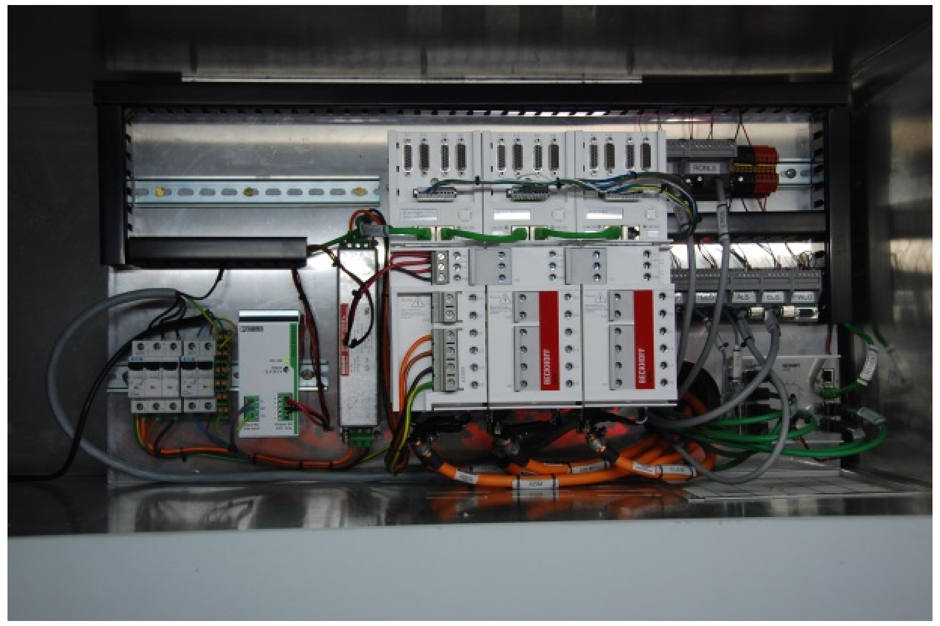
- **...** a big change for the telescope!



The new TCS

- New electronics for the telescope's:
  - cover
  - M1
  - M2
  - M3
  - hydrostatic bearing
  - safety system
  - time reference system
  - axes motion control system
  - telemetry


new telescope motors


new motor drive electronics


new sensor and actuator interface electronics

Mercator: Science and Leverage

Science Results:

~ 90 000 science spectra over ~ 80 science programmes
~ 388 publications among which ~ 244 in peer reviewed journals
(Nature, Astronomy and Astrophysics, Astrophysical Journal, MNRAS etc.)

Leverage for science exploitation funding:

- HERMES spectrograph (KU Leuven, ULB, ROB, Tautenburg, Geneva)
- BRAIN projects (KUL, ULB, ROB)
- Baekeland (technology development with idustry partner)
- WPs 3 ERC Advanced/Consolidator grants (Prof. Aerts; Prof. Sana)
- several FWO grants; KU Leuven grants

Leverage for Education and outreach:

- Master course
- STEM module (full trimester) for highschool (astronomy as gateway to STEM)
- Teachers@Mercator
- Local outreach

Science return... biased and non-complete

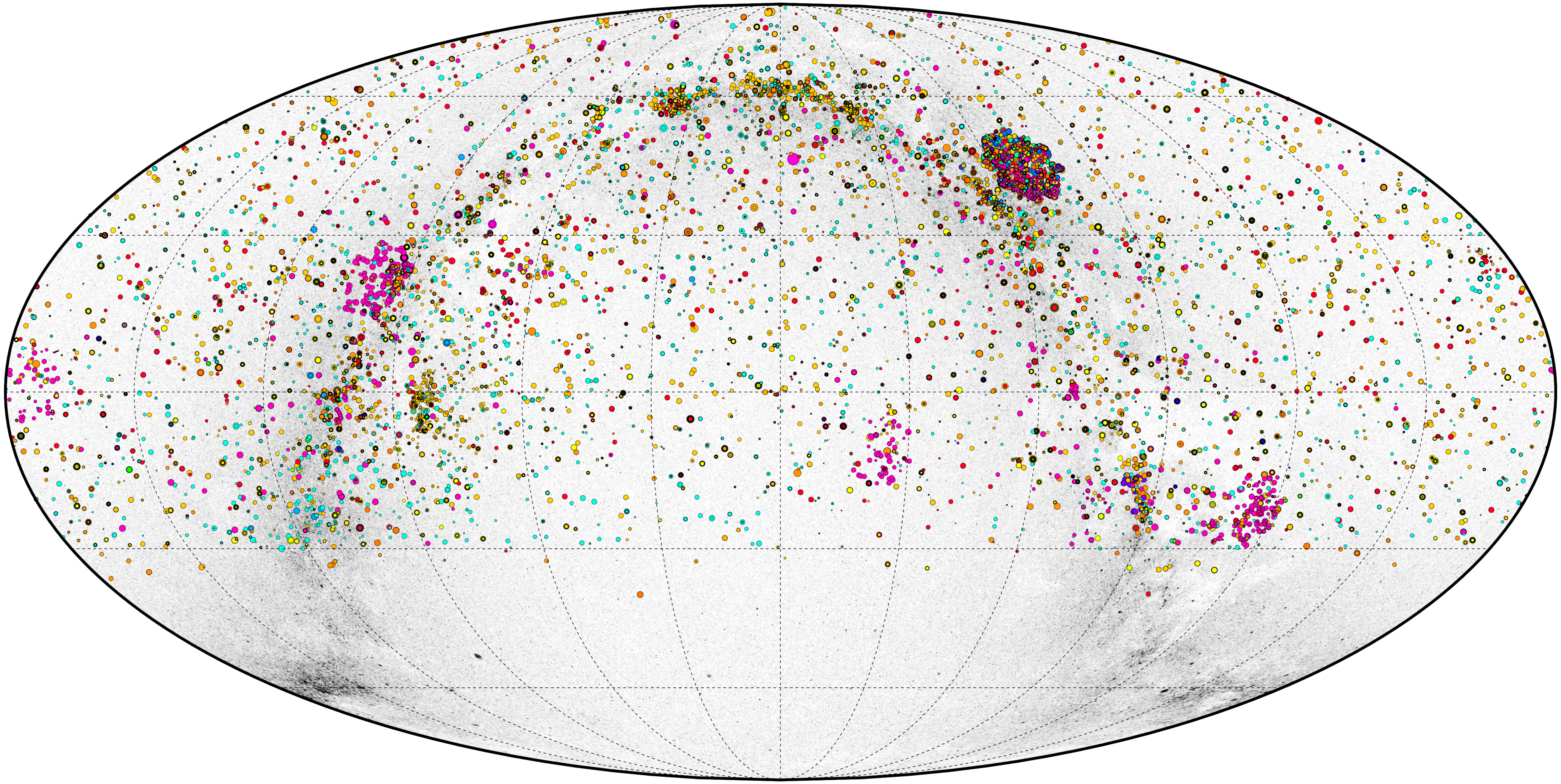
Raskin, et al., 2011, A&A 526, 69:

Common themes (among others) :

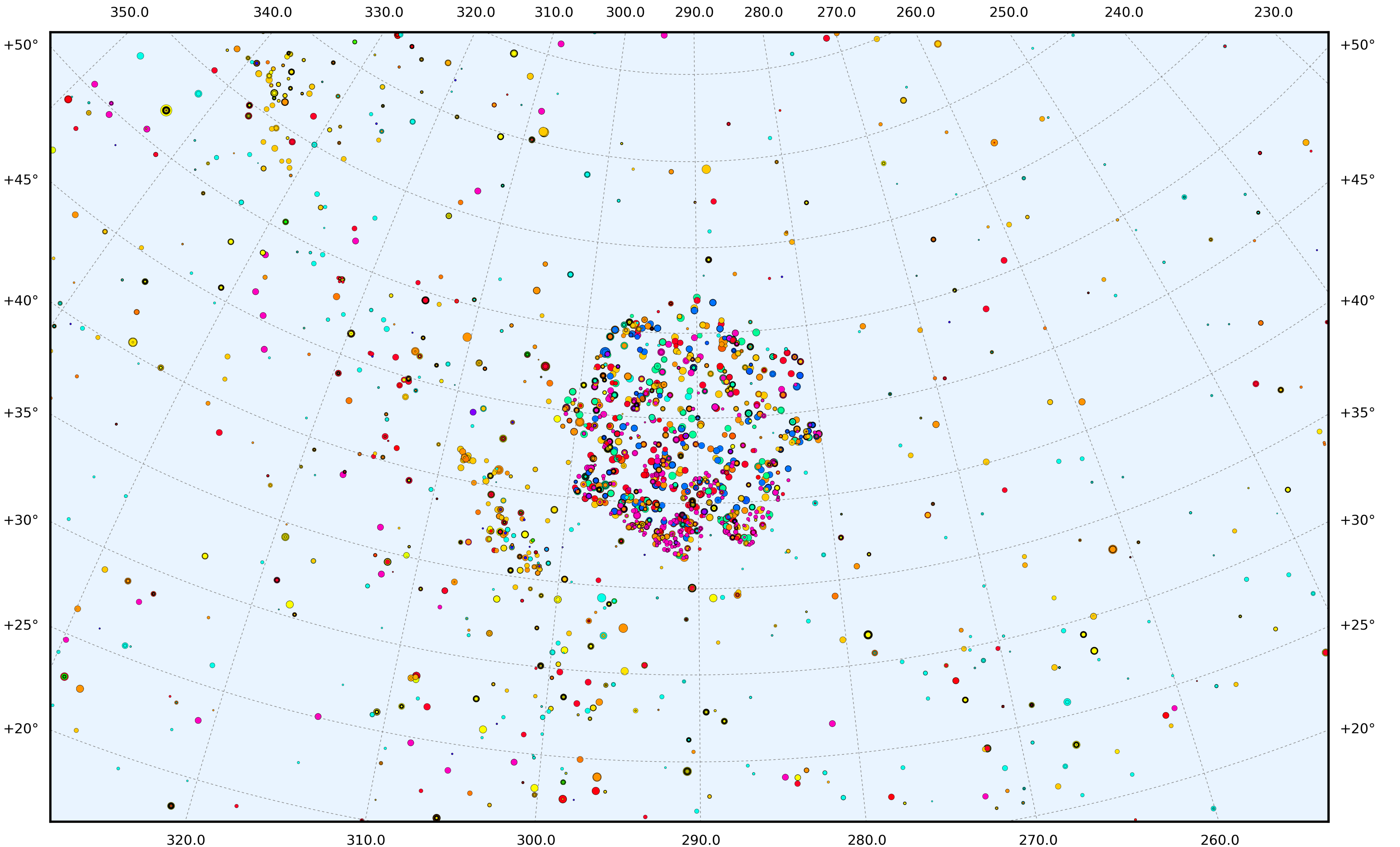
Follow-up Space (Kepler, CoRot)

Chemical Composition

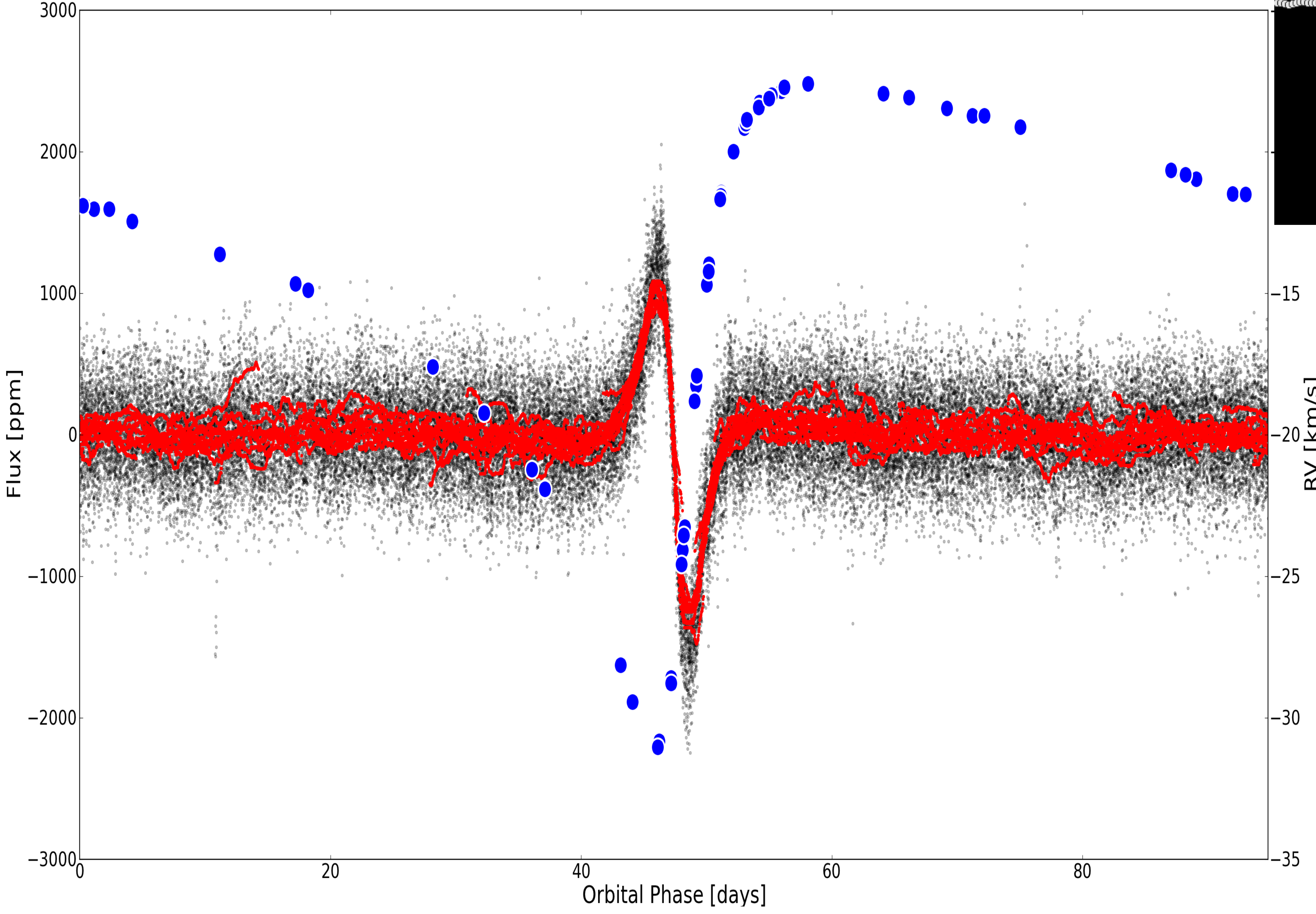
Binaries

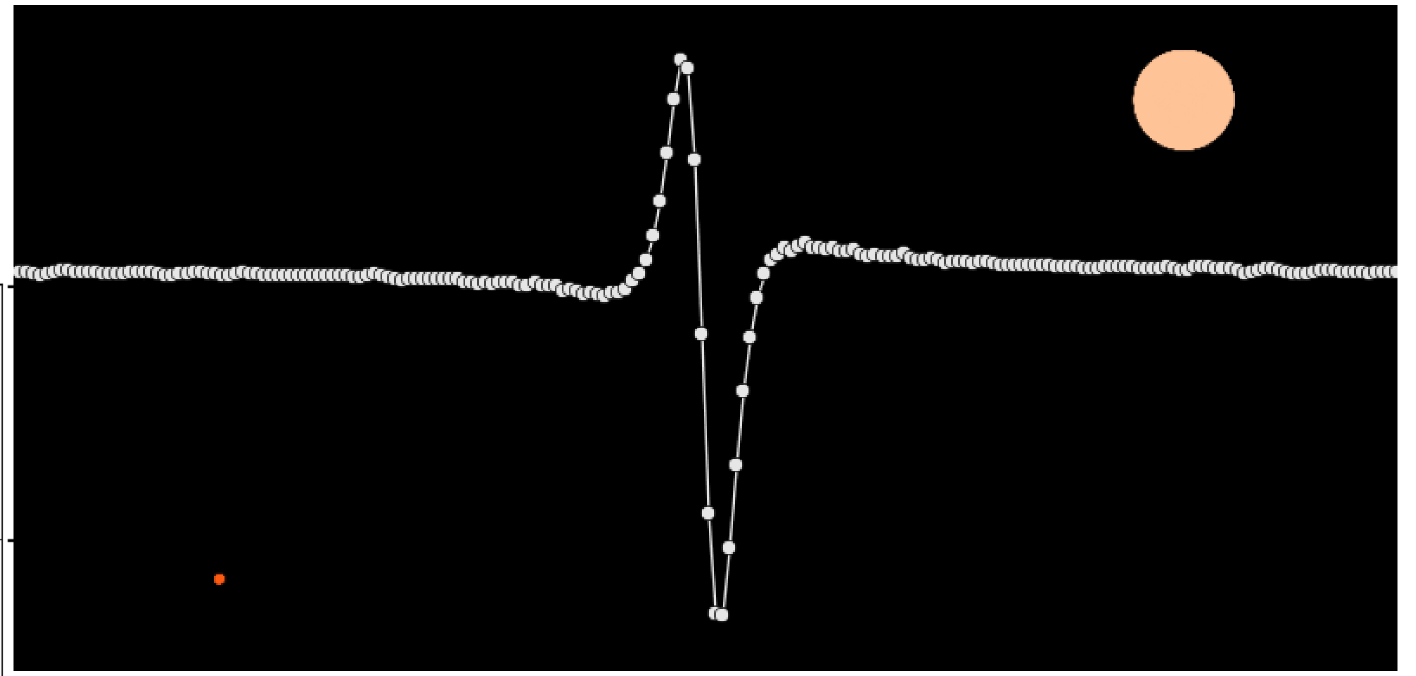


We ran/are running in total ~80 science programmes


350.0
340.0
330.0
320.0
310.0
300.0
290.0
280.0
270.0
260.0
250.0
240.0
230.0
+50°
+45°
+40°
+35°
+30°
+25°
+20°
320.0
310.0
300.0
290.0
280.0
270.0
260.0

RGB in wide binaries



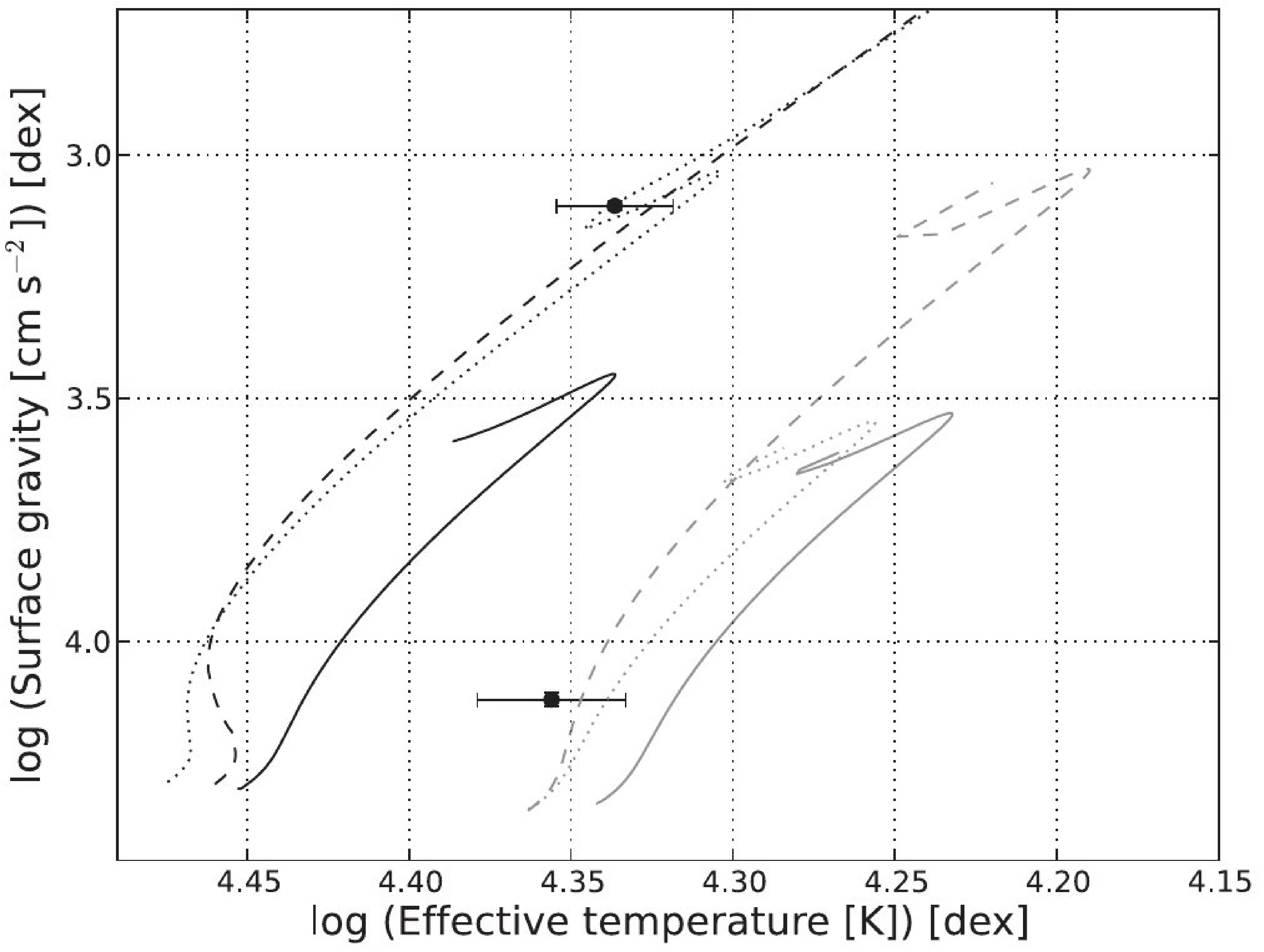


- RGB in eccentric orbits
- seismology + binarity
- working of tides

Kepler field

Beck et al., 2012; 2014; 2018

Kepler follow-up: mass discrepancy problem in massive binaries



452 HERMES spectra + Kepler: V380 Cyg

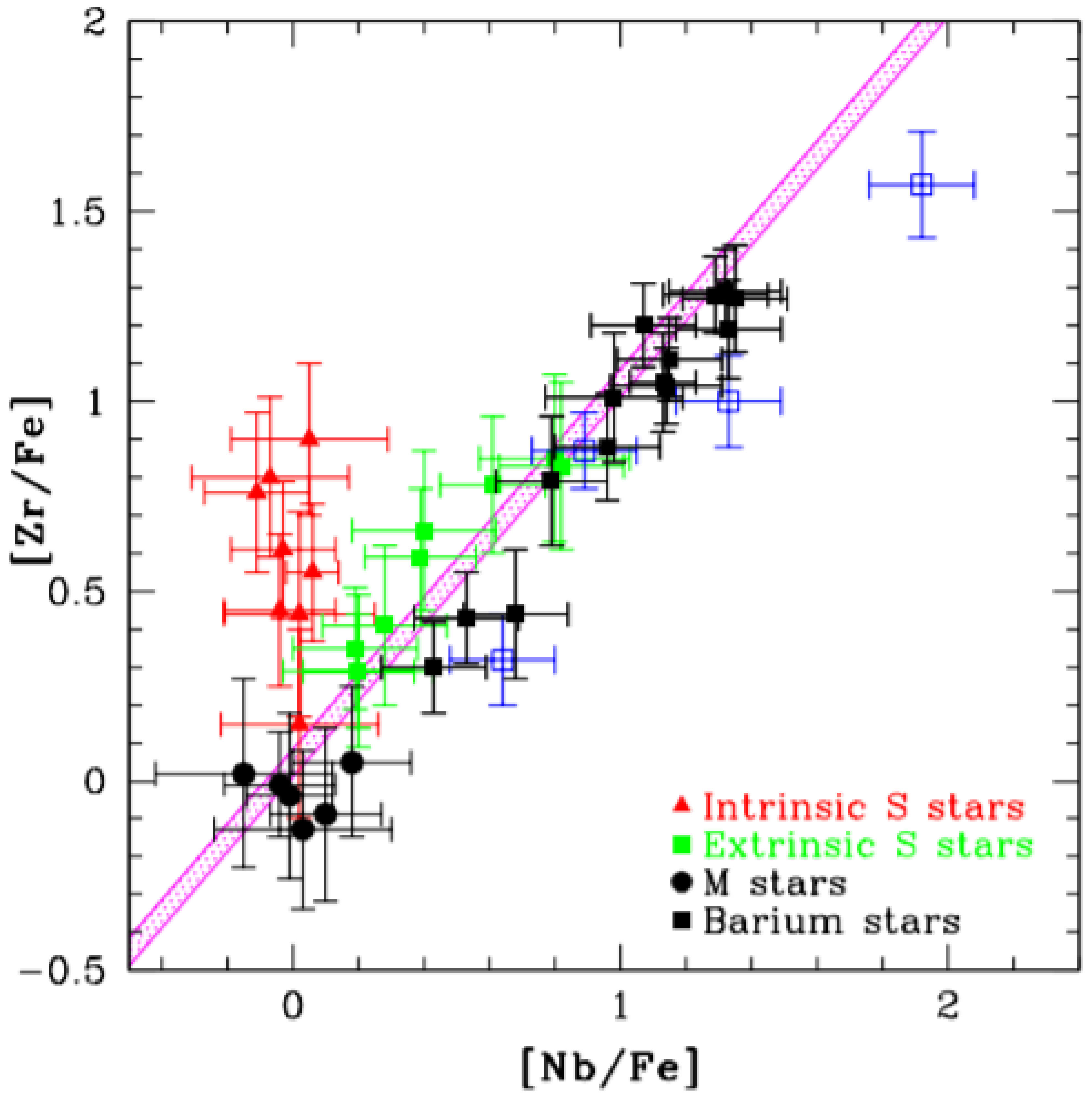
masses: 11.43 and 7.00 Solar masses

evolutionary tracks versus observed HR location:

large overshoot or extreme rotation are needed

Tkachenko et al., 2014; similar tests Garcia et al., 2014

Chemical Composition



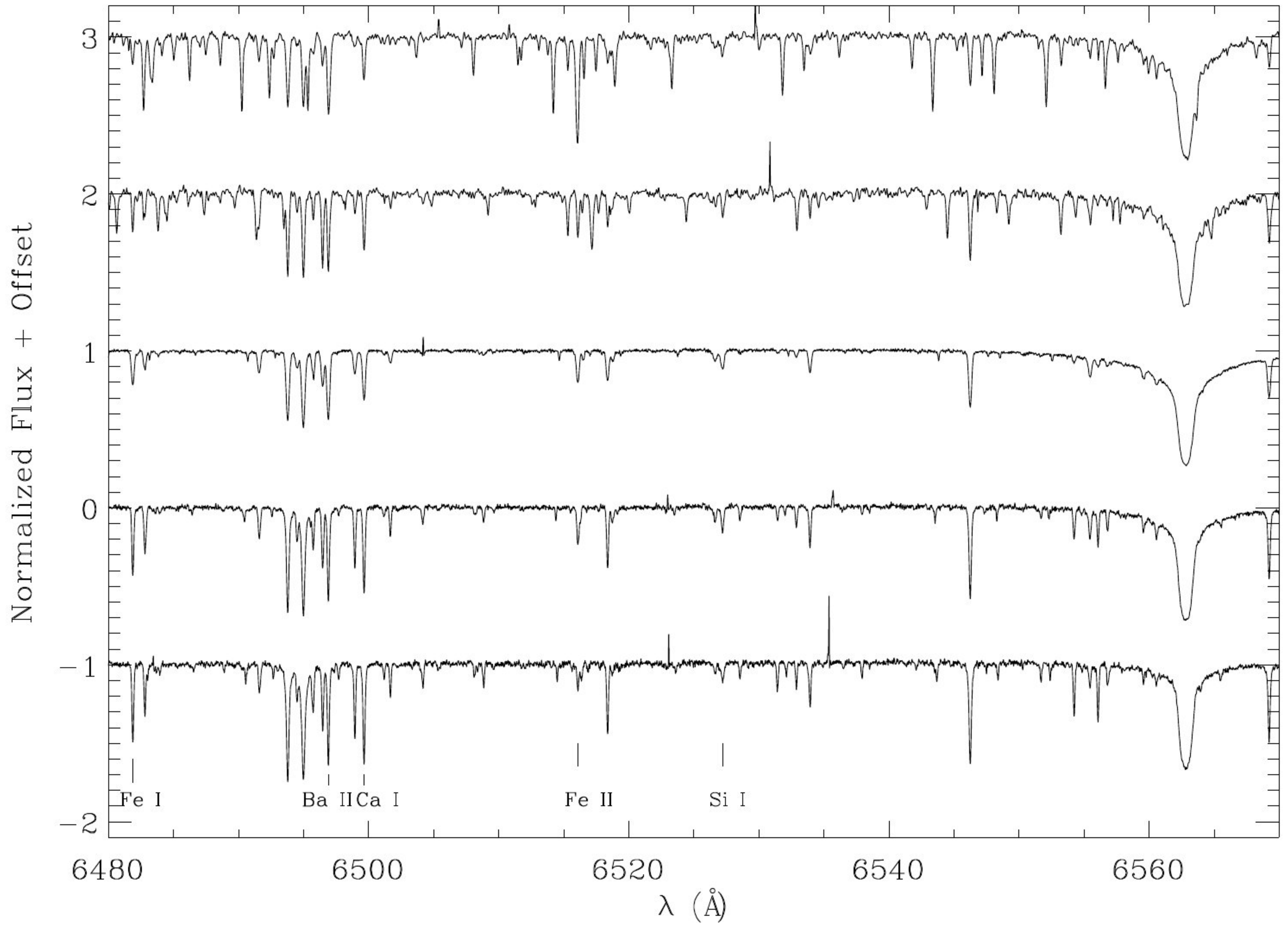
Nb is mono-isotopic as Beta-decay product of ^{93}Zr

So in extrinsic S stars: ^{93}Nb is equal to ^{93}Zr and hence A(Zr)/A(Nb) equals to A(Zr)/A(^{93}Zr) on the AGB.

T-indicator: ^{13}C(α,n)^{16}O is neutron source

Neyskens et al., 2015, Nature; Karinkuzhi et al., 2018, A&A

Chemical tagging of Moving groups and Streams



Stellar kinematic groups are kinematically coherent groups of stars that might have a common origin.

Galactic kinematics

Analyses of differential abundances to trace orgin

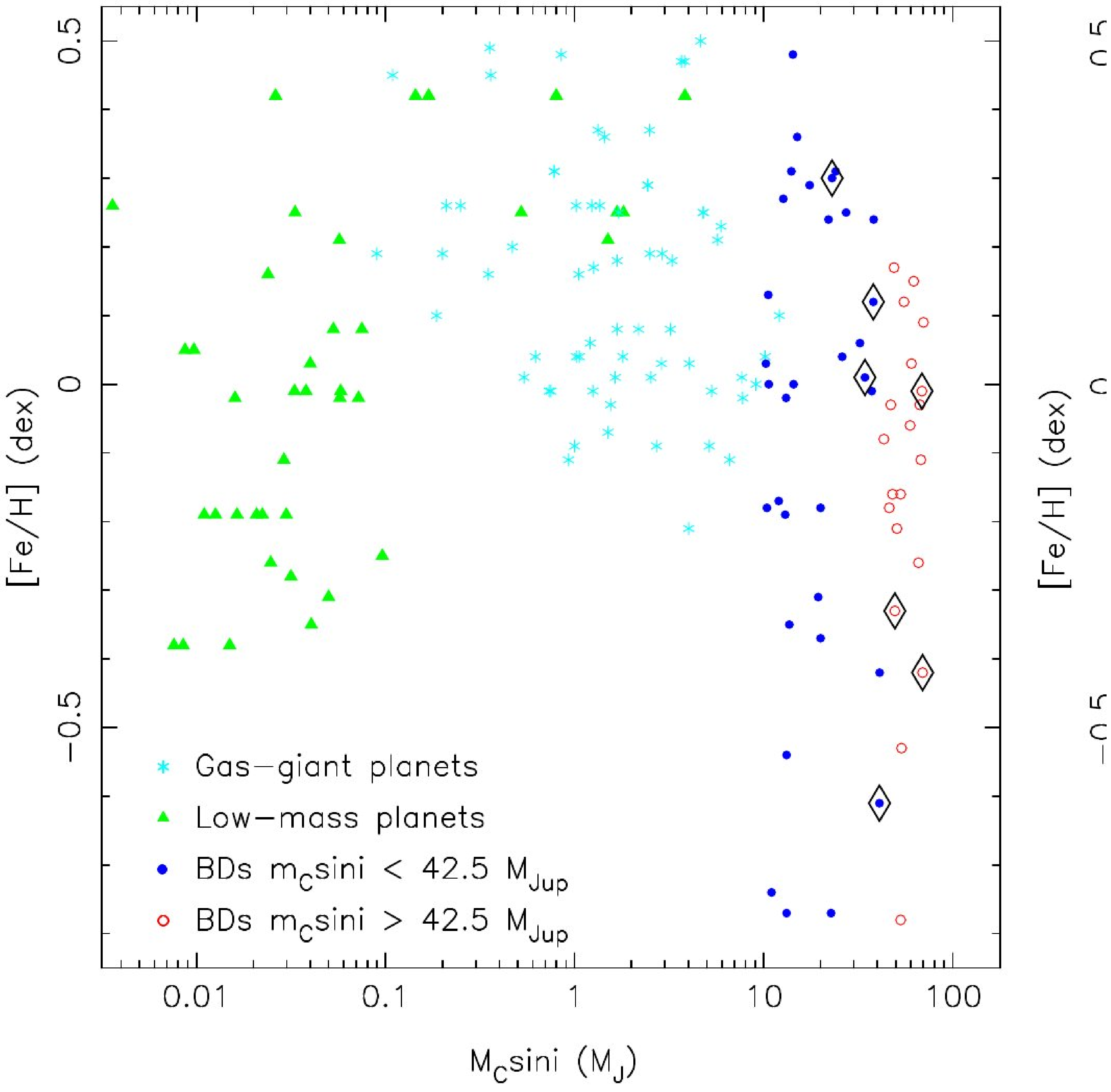
Many objects wide apart: HERMES

Hyades supercluster stream can only partly come from Hyades cluster

Ursa Major Moving group is less affected by field star contamination

Pompeia et al., 2011; Tabernero et al. 2012, 2017

Chemical composition of stars with Brown Dwarfs



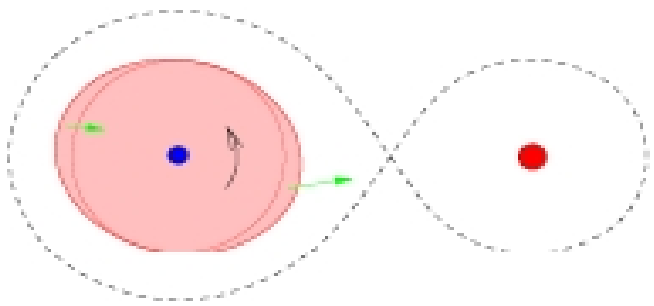
Stars with Brown Dwarf companions or not metal rich

BD are failed stars, not failed planets

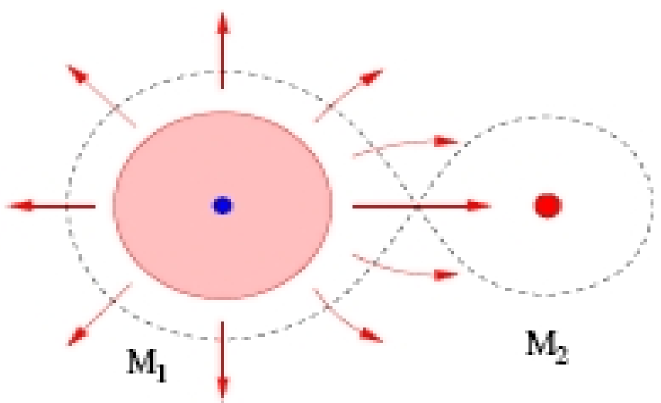
Maldonado et al., 2017; 2015

Binary Evolution

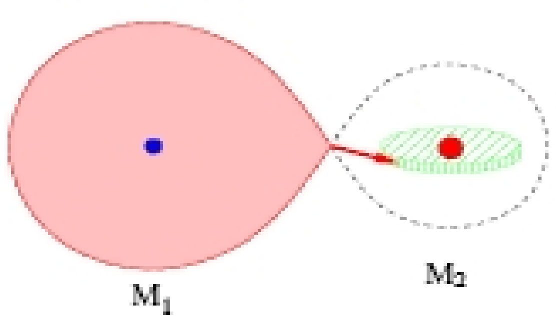
stars in binary systems can interact in various ways:



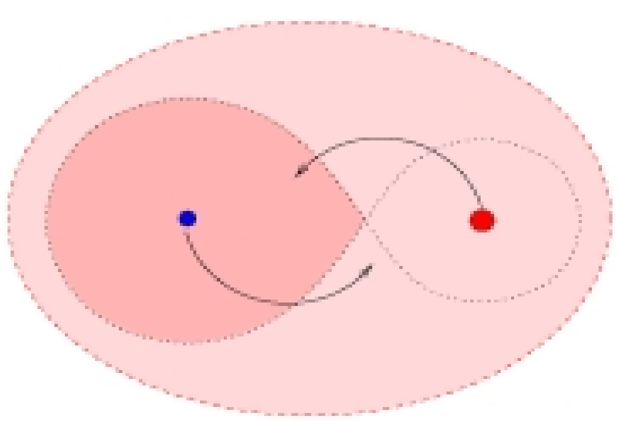
tidal interaction



wind accretion & tidally enhanced winds



Roche-lobe overflow



common envelope evolution

Common theme : Binary Evolution

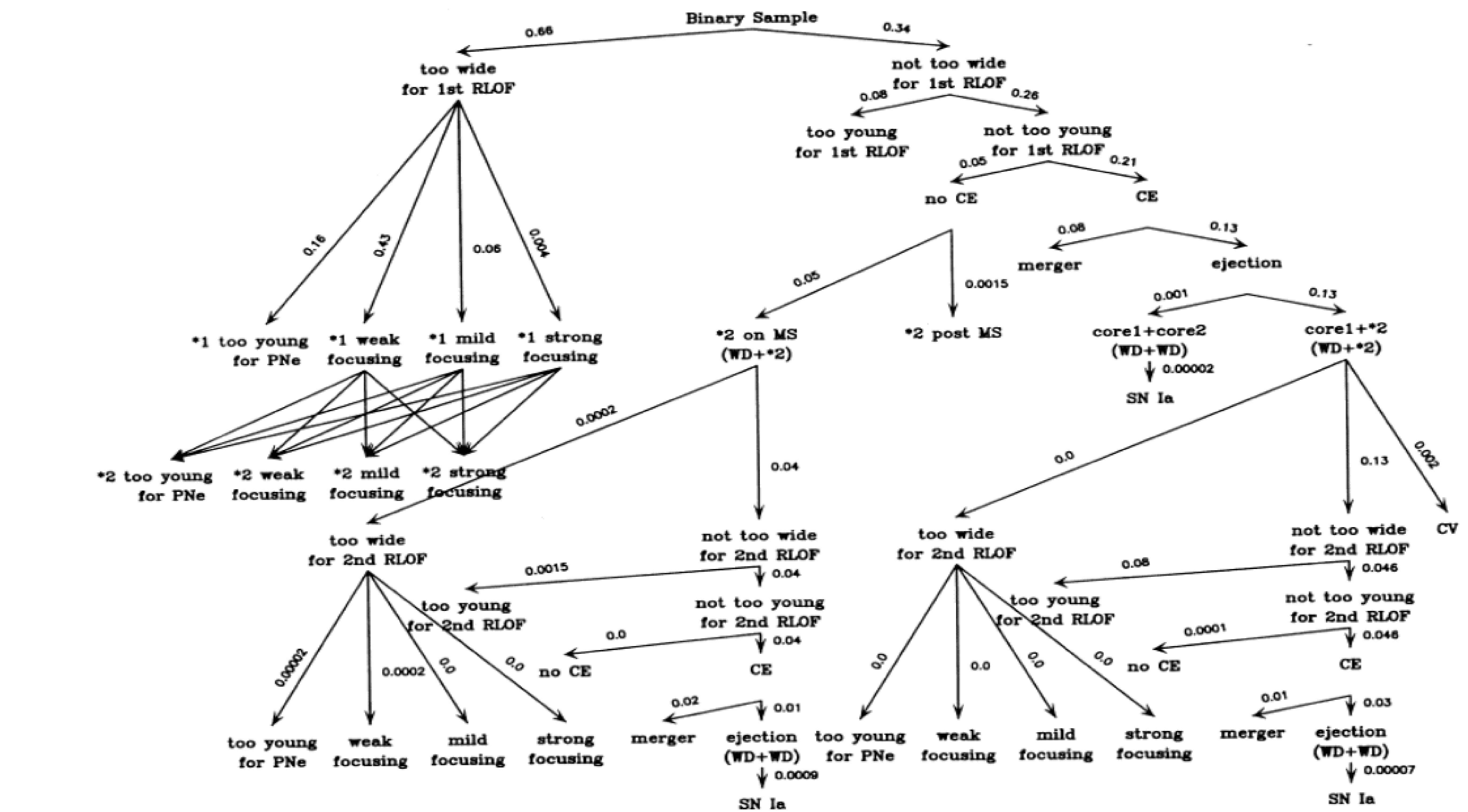
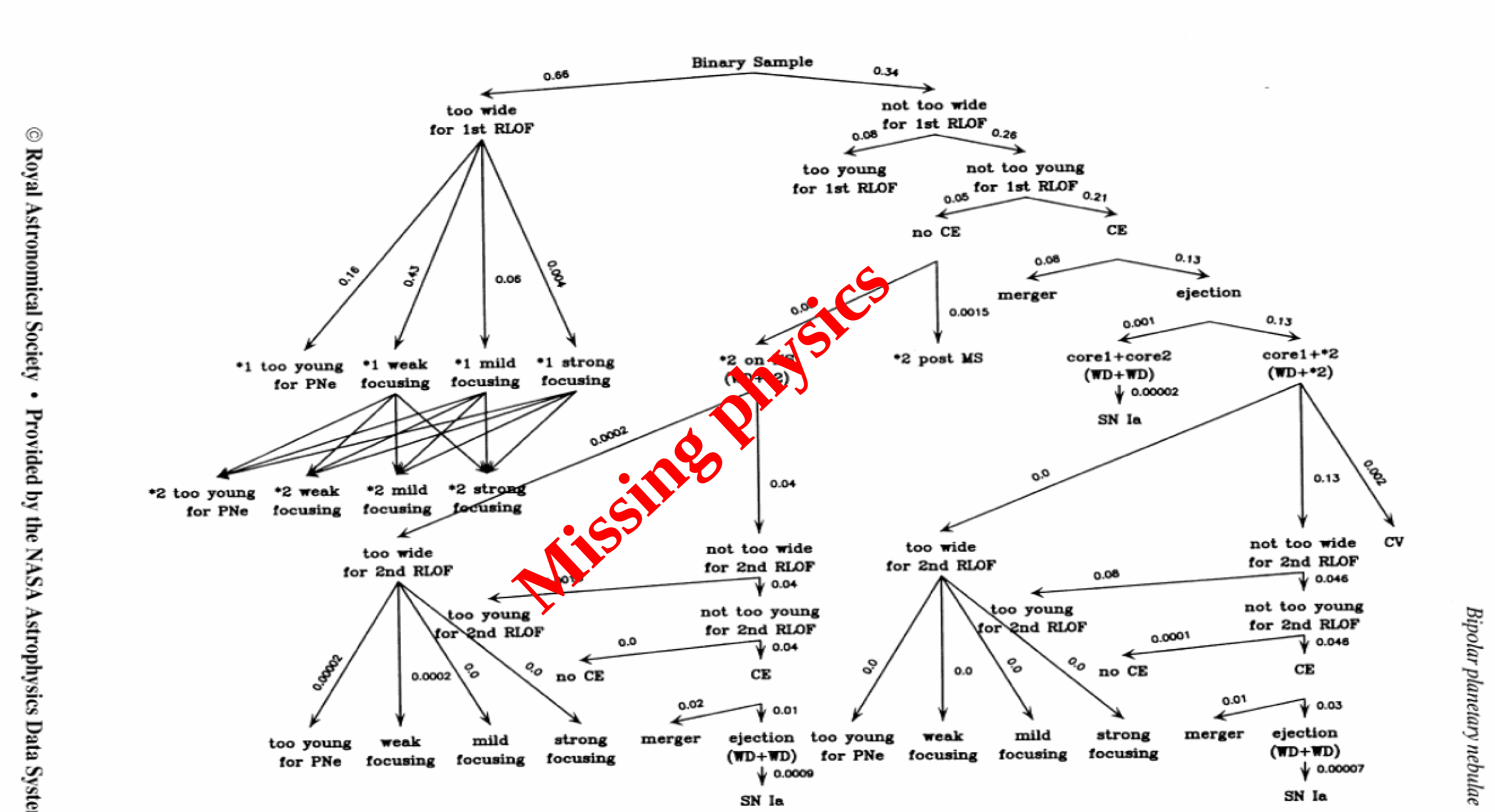


Figure 2. Flow chart for the Monte Carlo simulations. RLOF stands for Roche lobe overflow, CE for common envelope, MS for main sequence, WD for white dwarf, *1 for star 1 (primary), and *2 for star 2 (secondary). The figures give the percentages for each evolutionary channel in simulation 6. See text for further explanations.

e.g. Han et al., 2005, MNRAS 272, 800

Common theme : Binary Evolution



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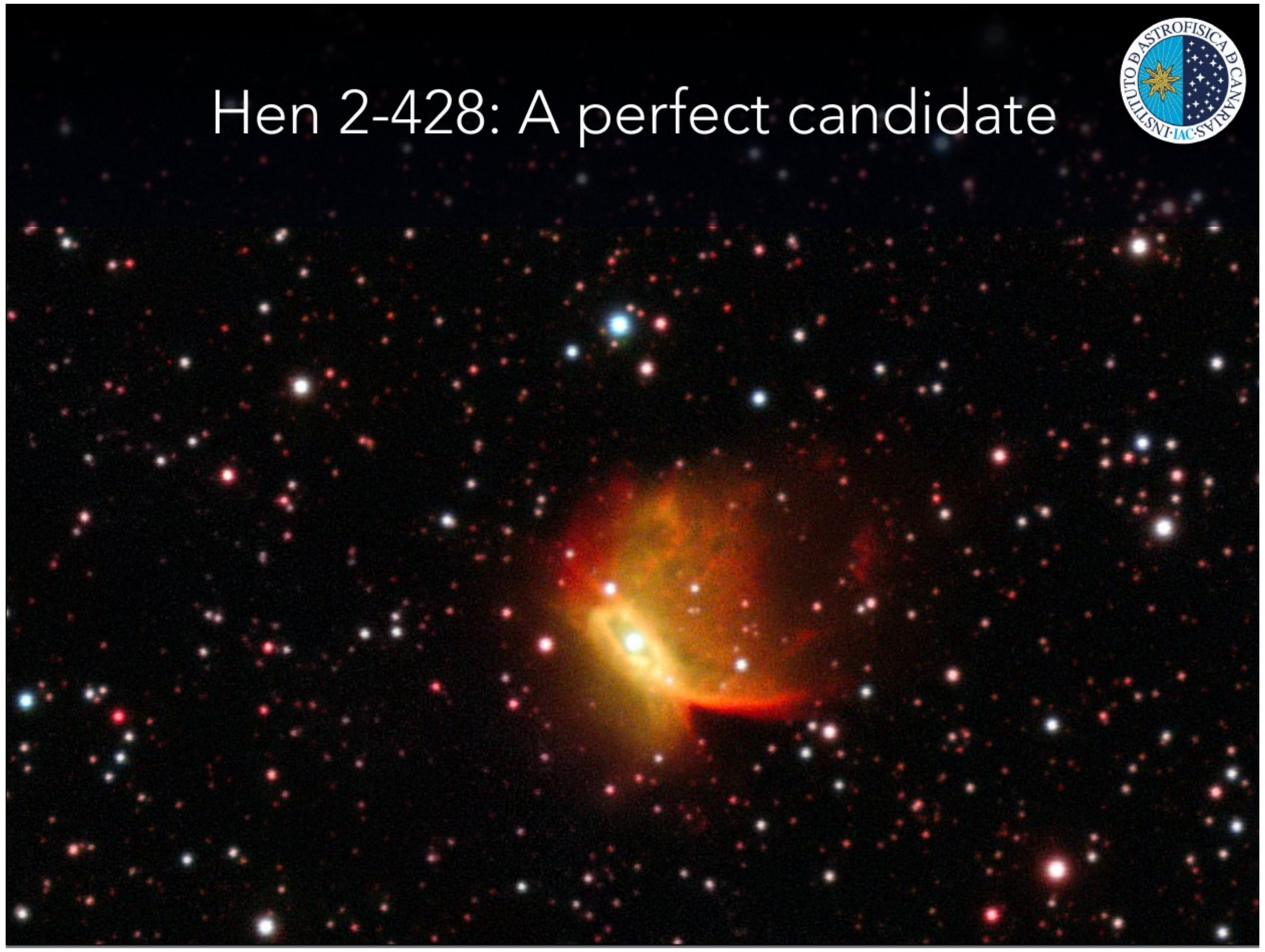
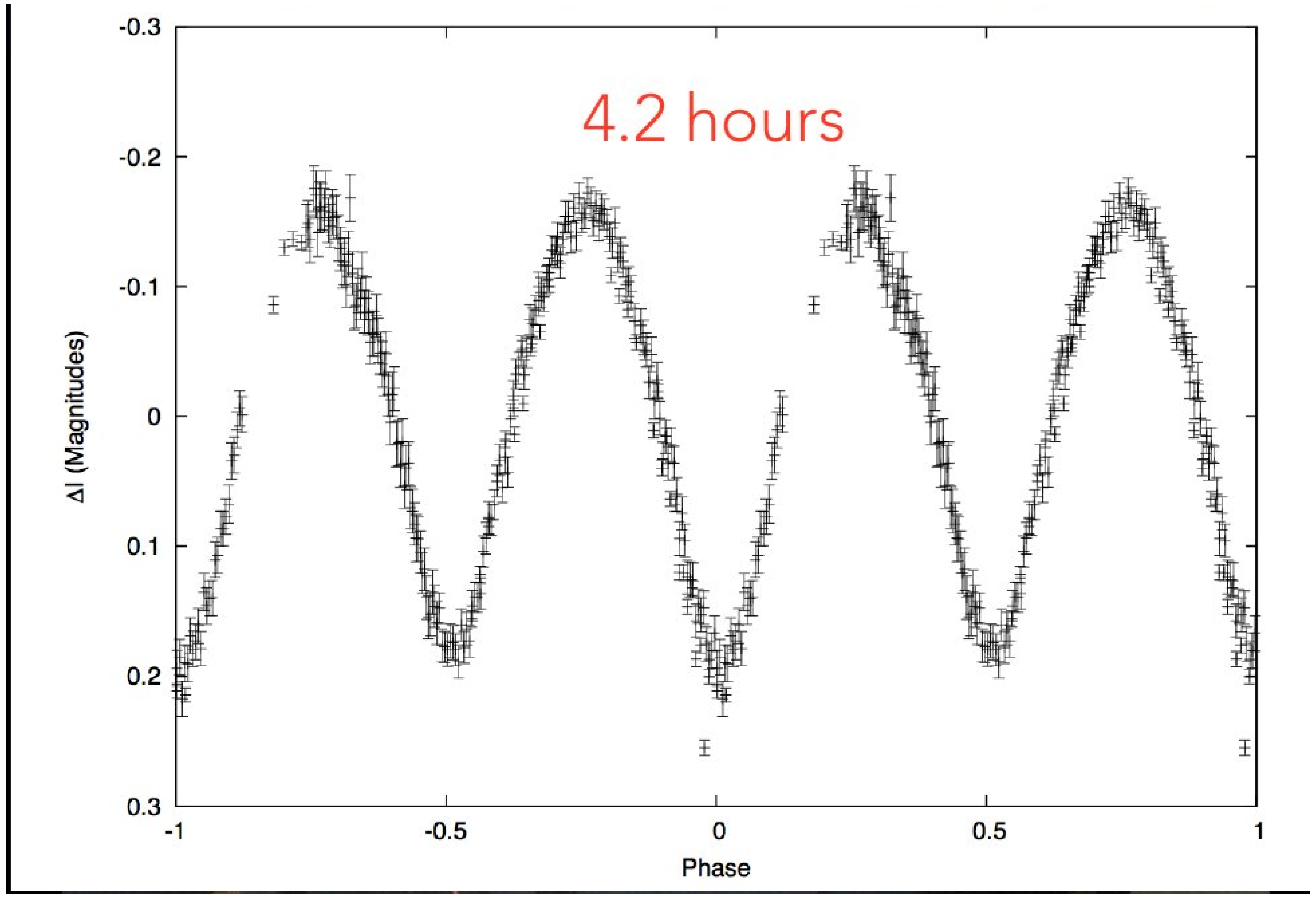
e.g. Han et al., 2005, MNRAS 272, 800

PNe binaries are spiralled-in systems

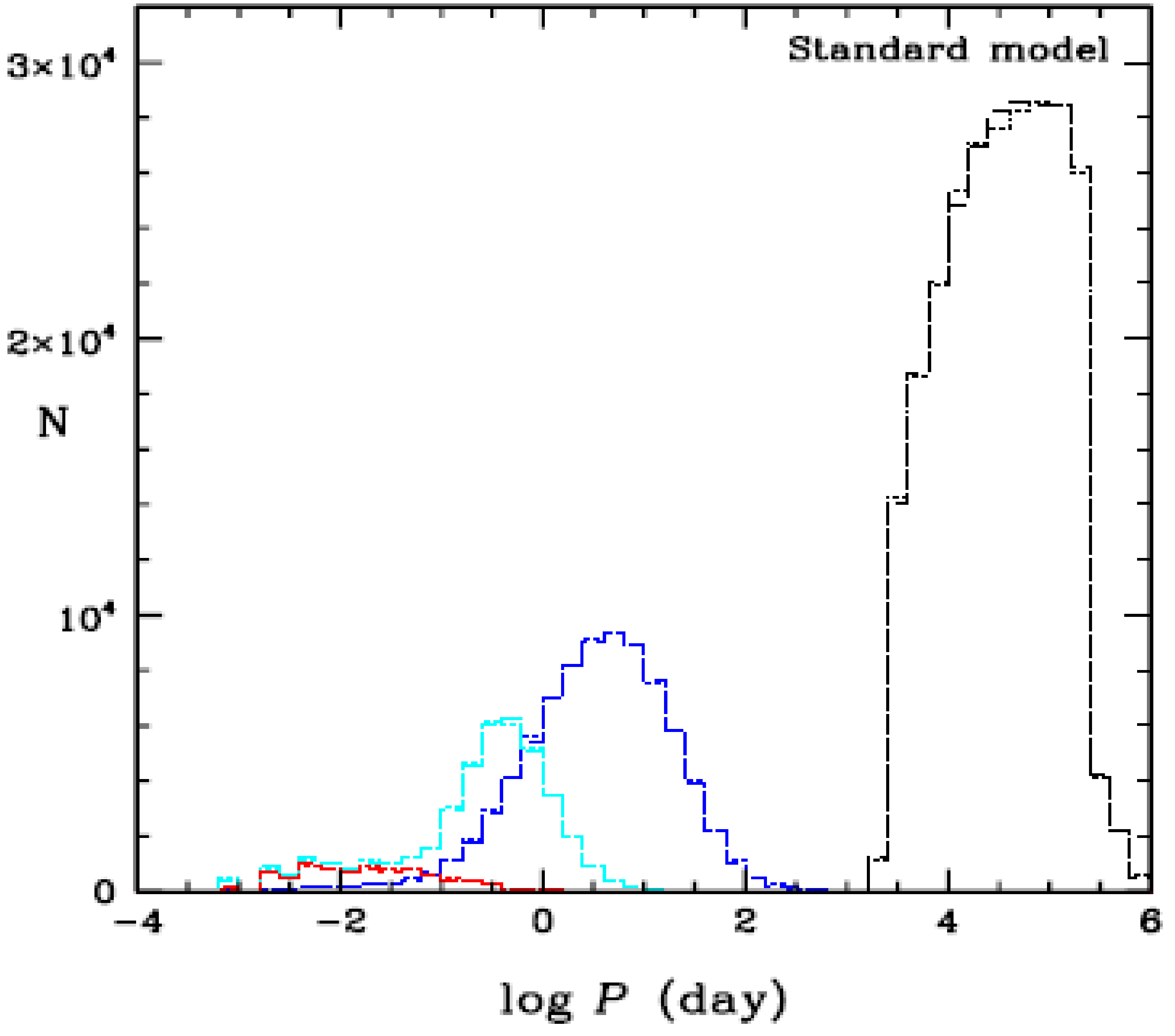




Hen 2-428
Overcontact, double degenerate
2 x 0.88 Msun
SN type 1a progenitor !!

Santander-Garcia et al, 2015, Nature

What we expect: Orbital evolution low- to intermediate-mass stars



Nie et al., 2012

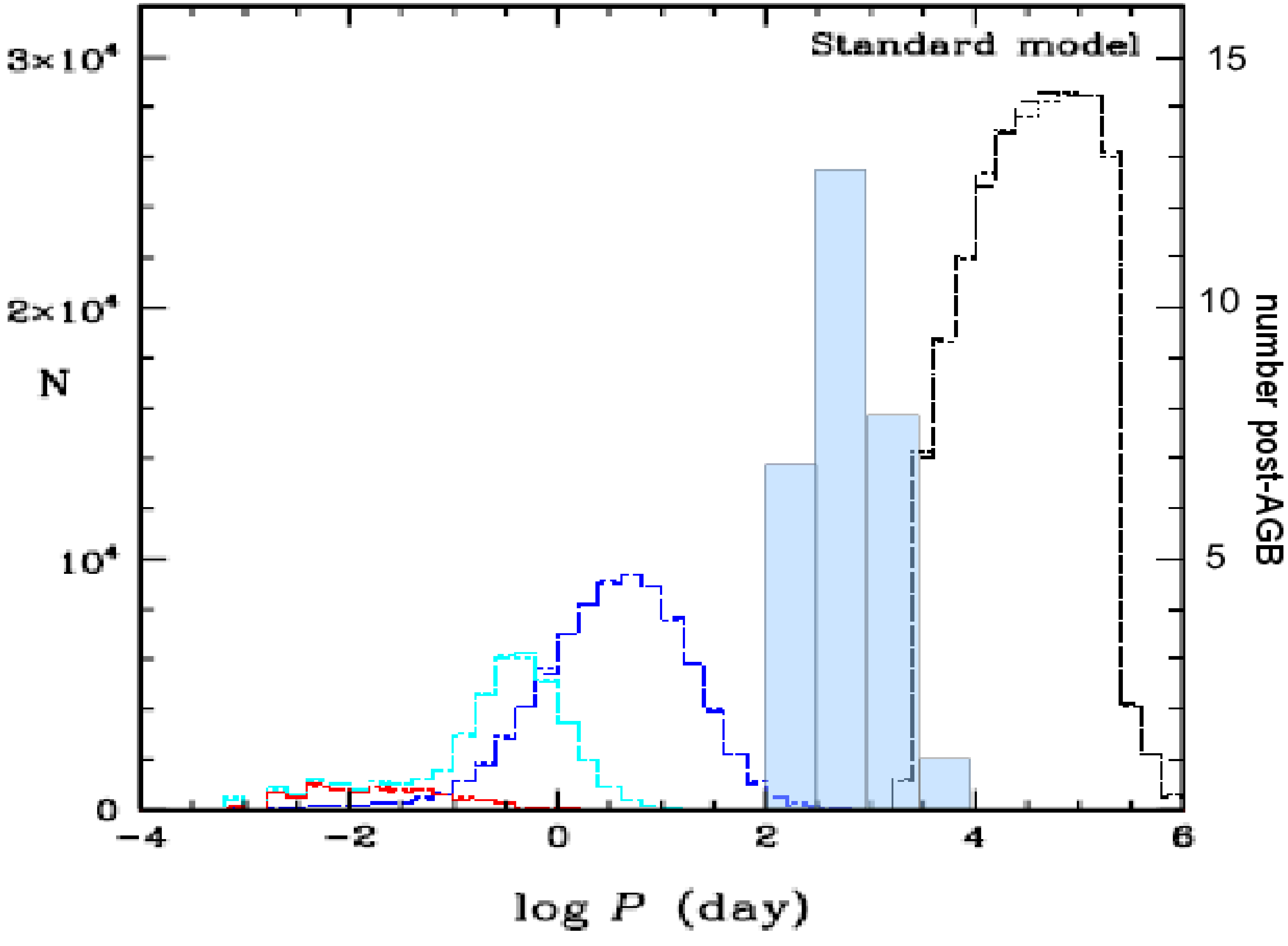
Population Synthesis:

Prediction: bimodal distribution

Common Envelope Results: inspiraling

Wind transfer

Orbital evolution post-AGB binaries: many unknowns remain

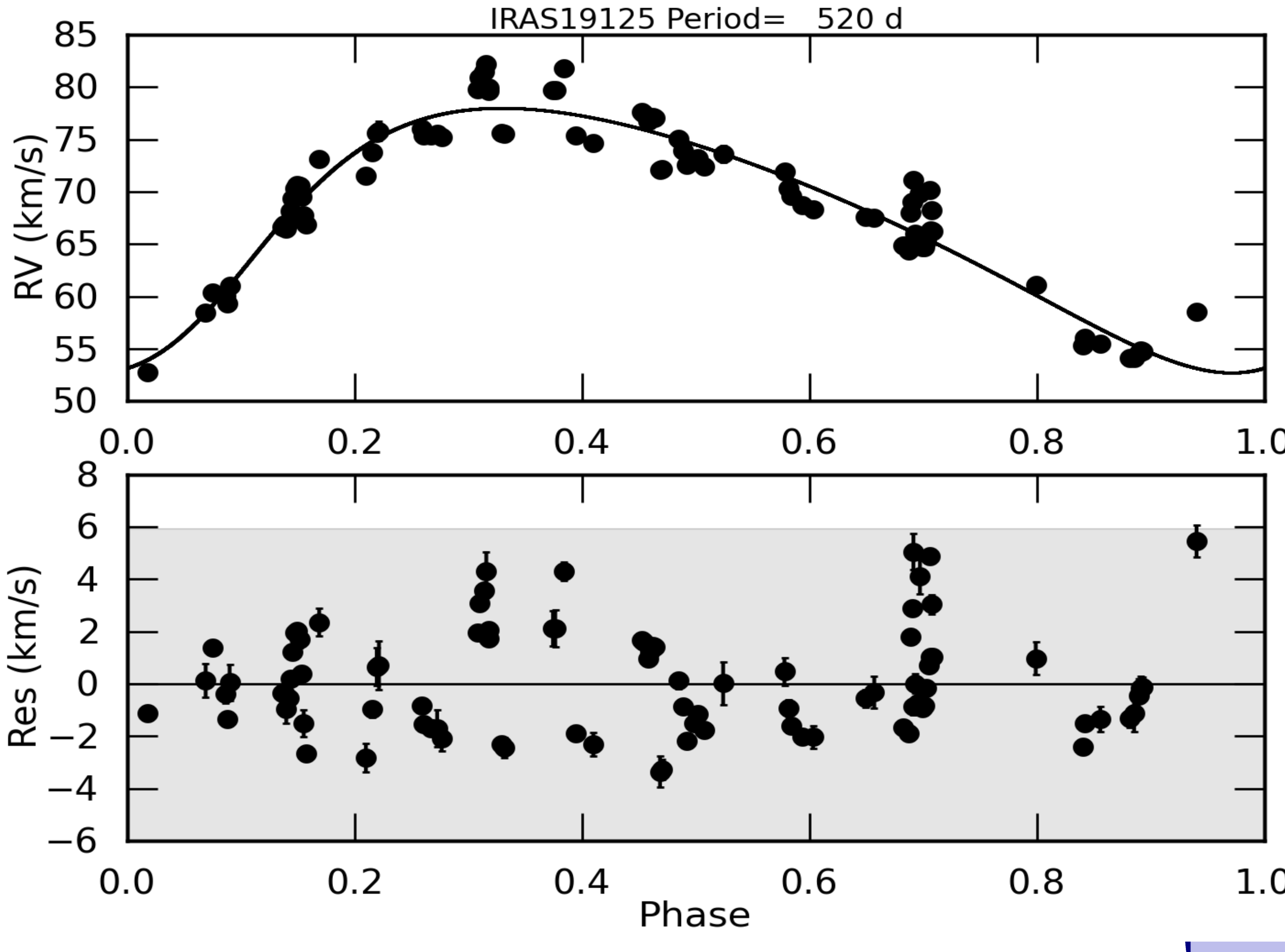


Van Winckel, 2018

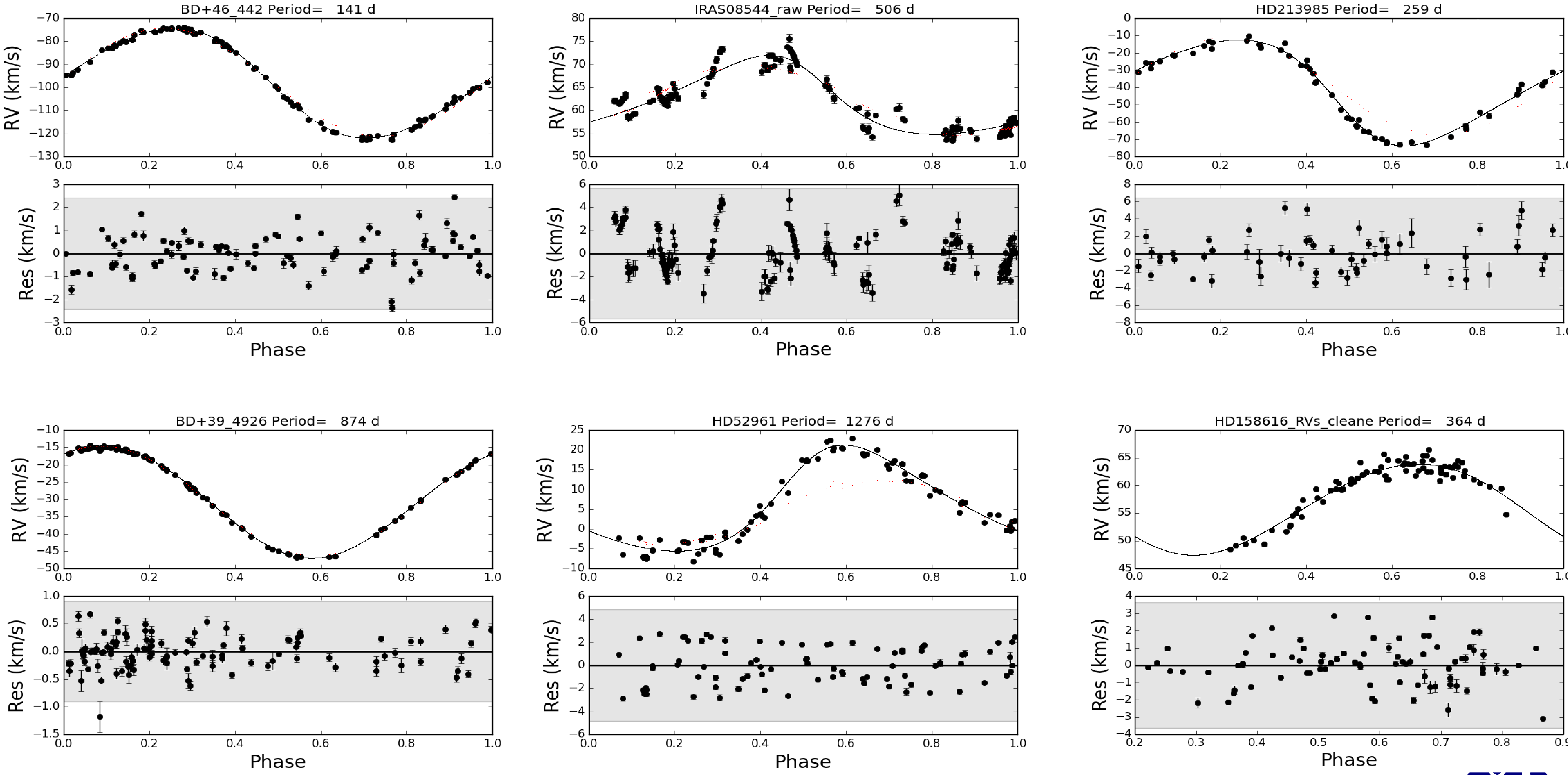
We detect many stars with orbits NOT expected....

Observational driven research:

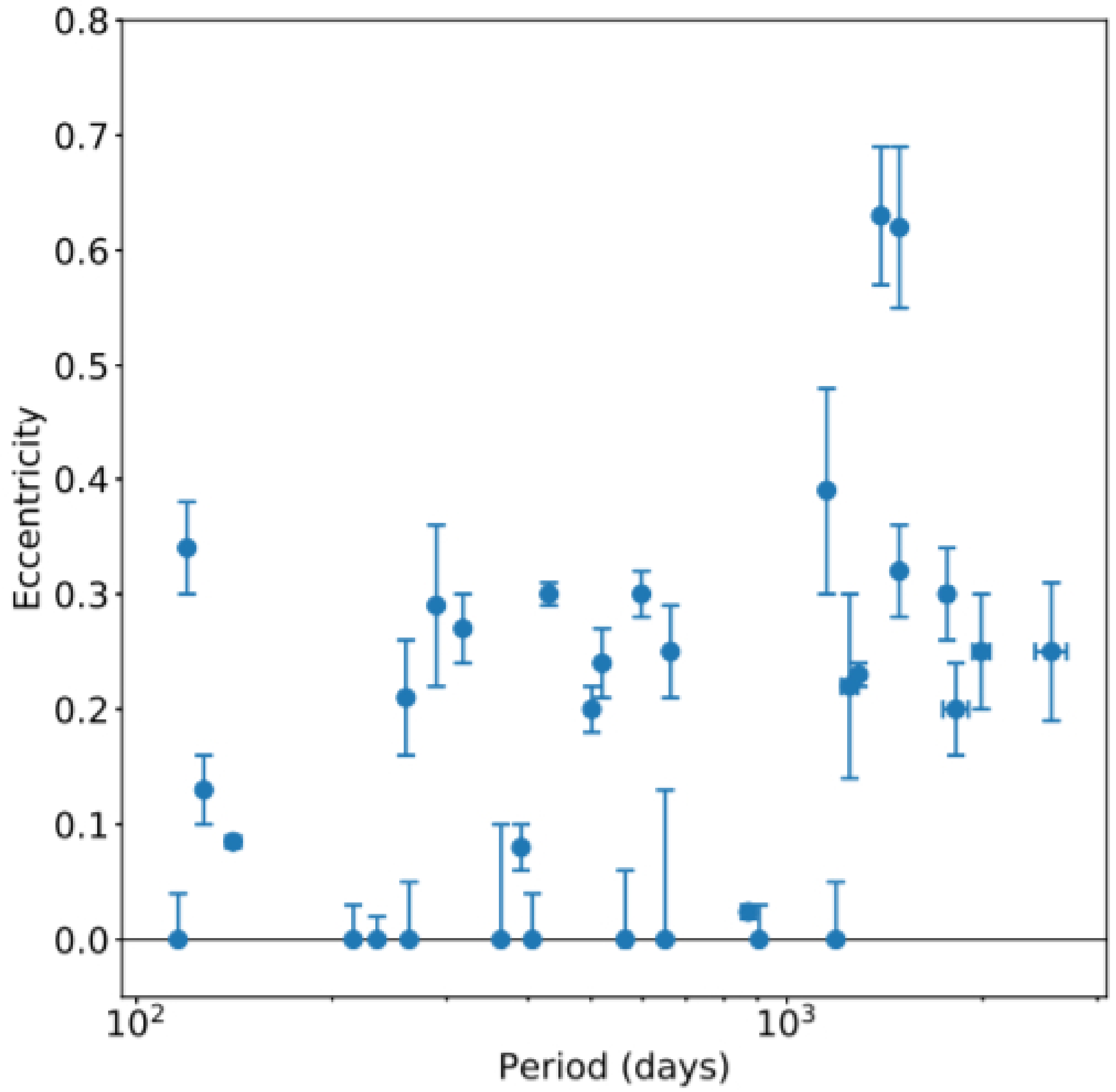
New Binary Interaction Mechanisms

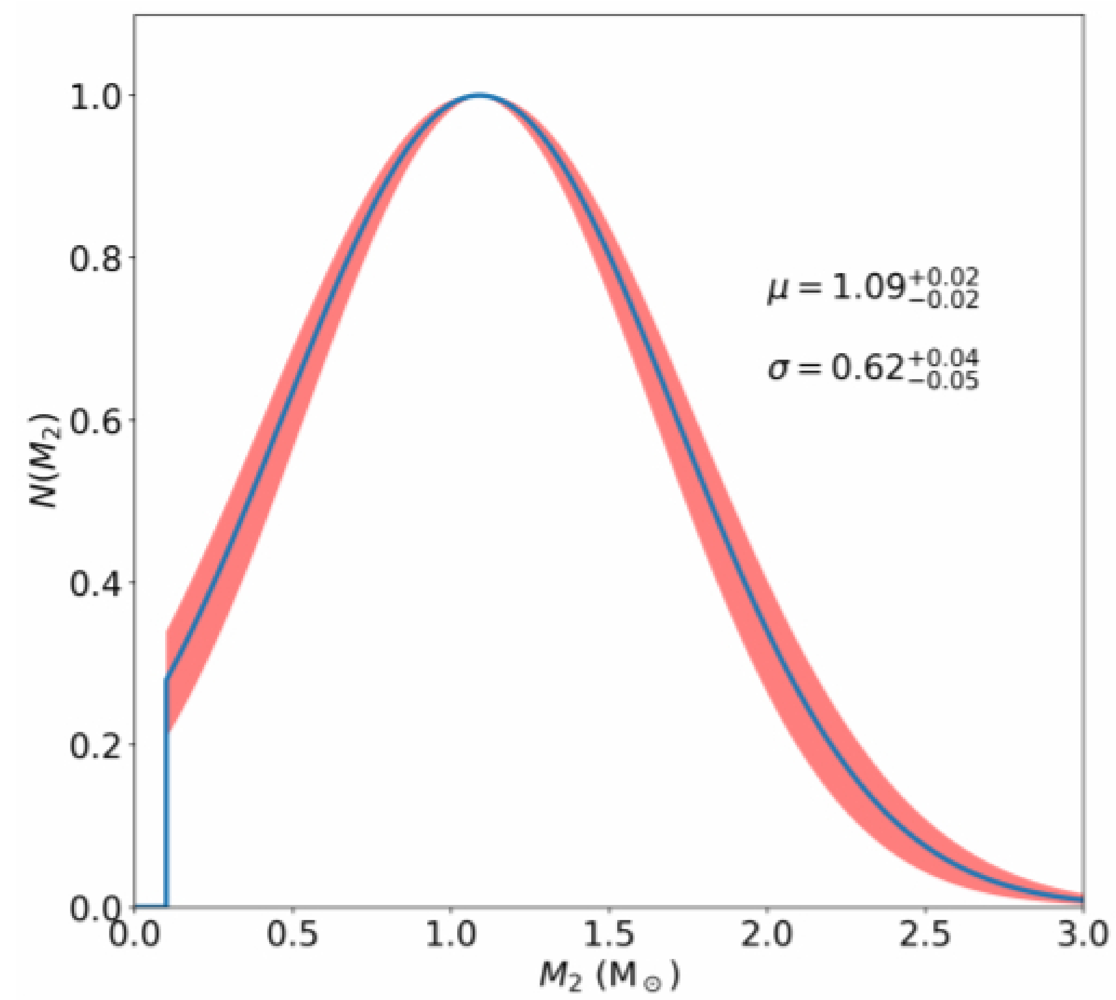


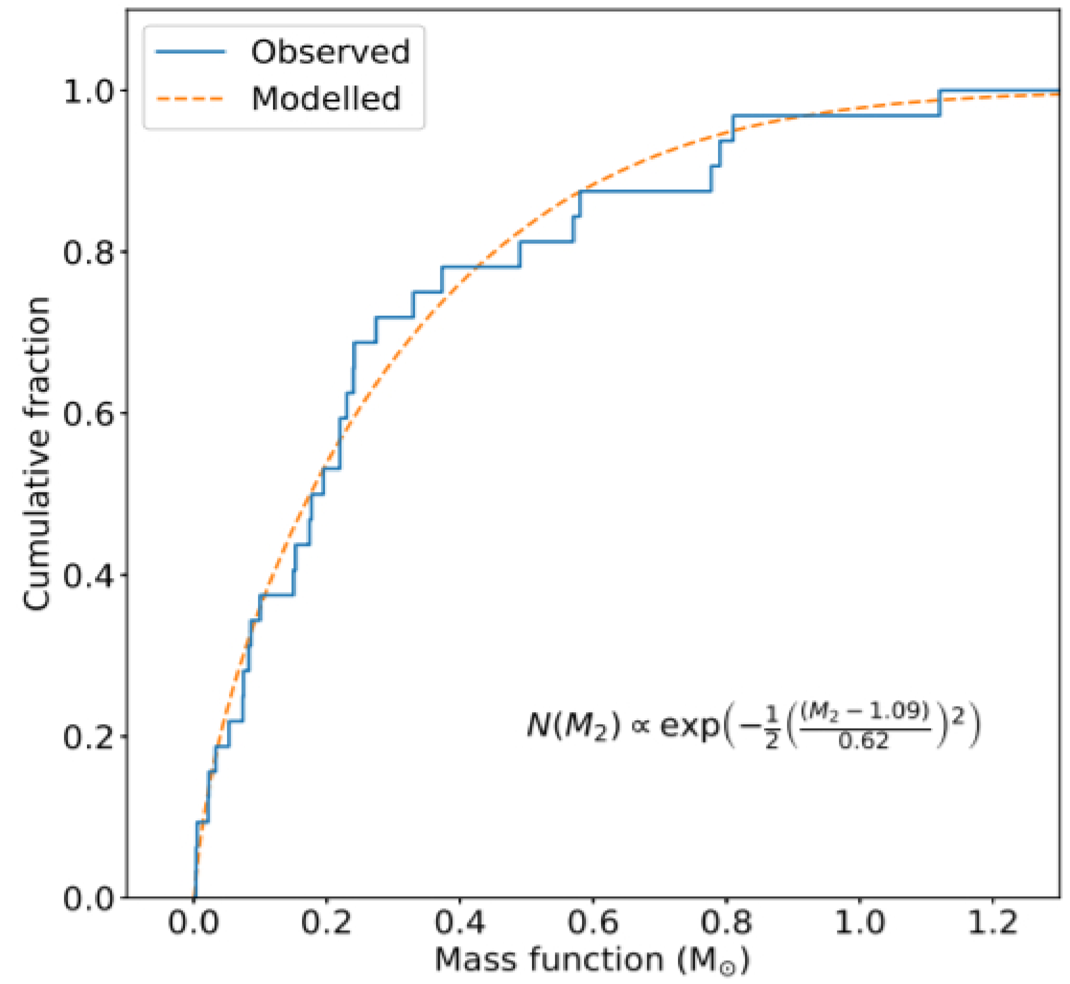
Binaries: ranges in P and e



Post-AGB binaries

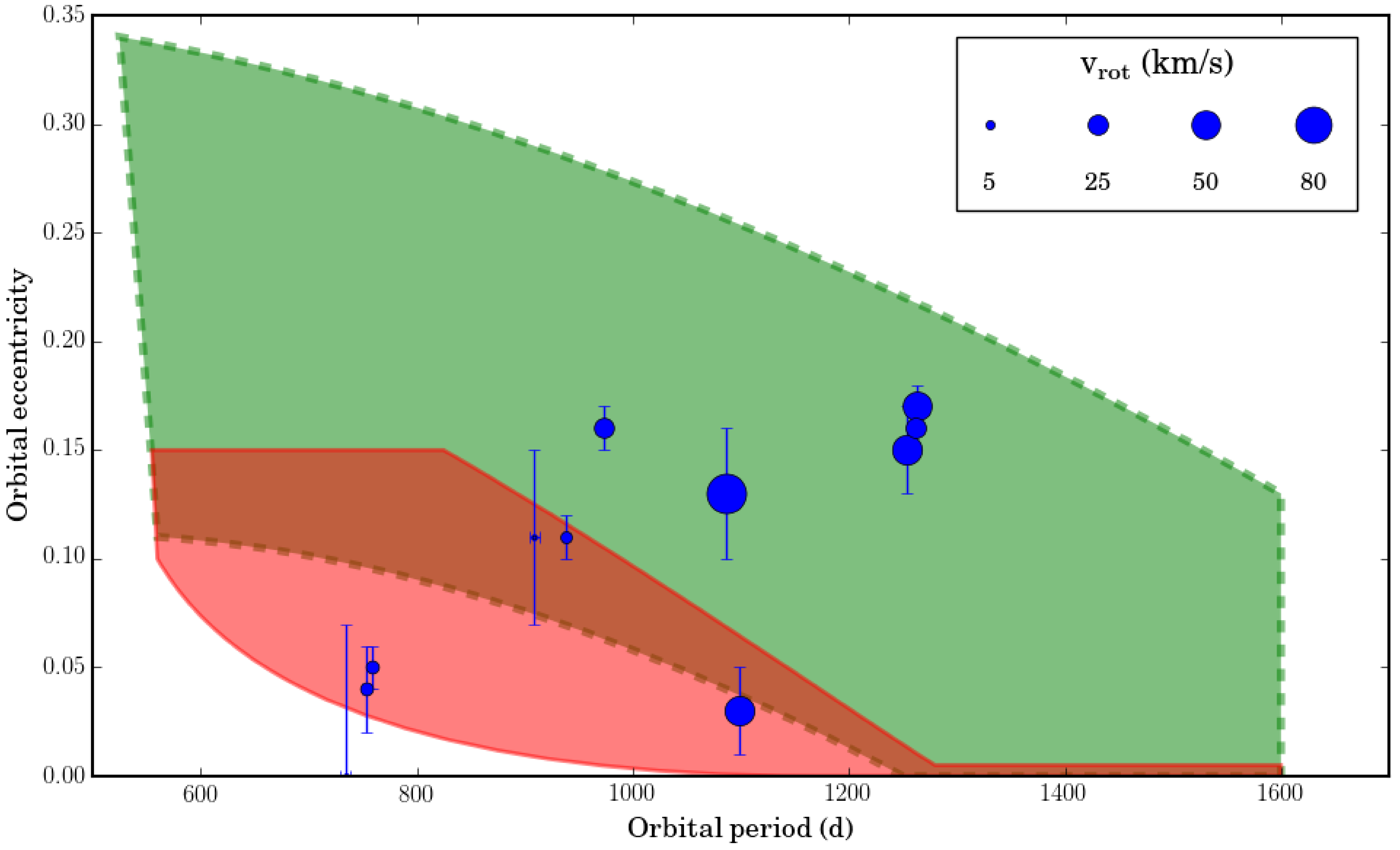






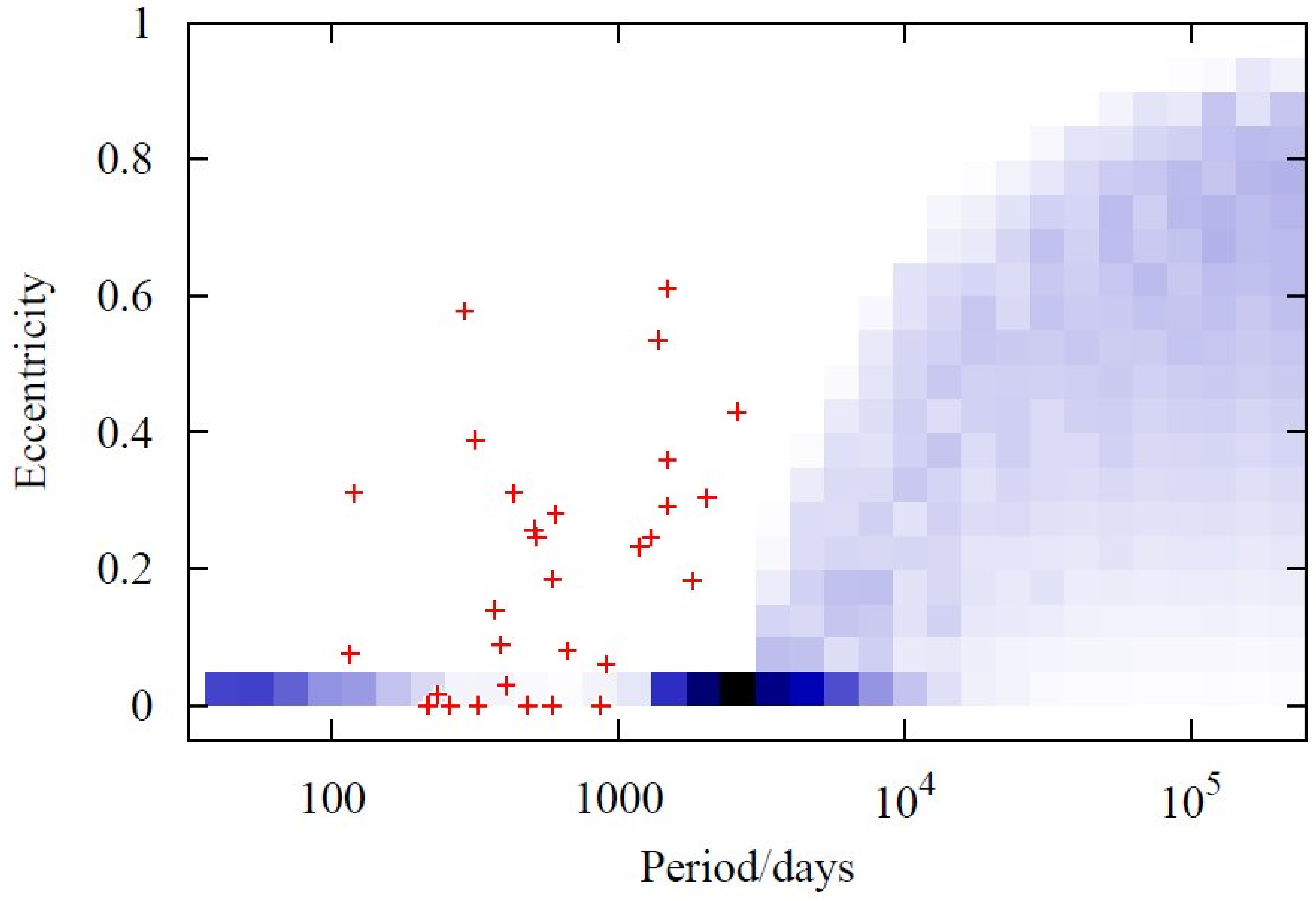
Oomen et al., 2018, A&A; Van Winckel, 2018

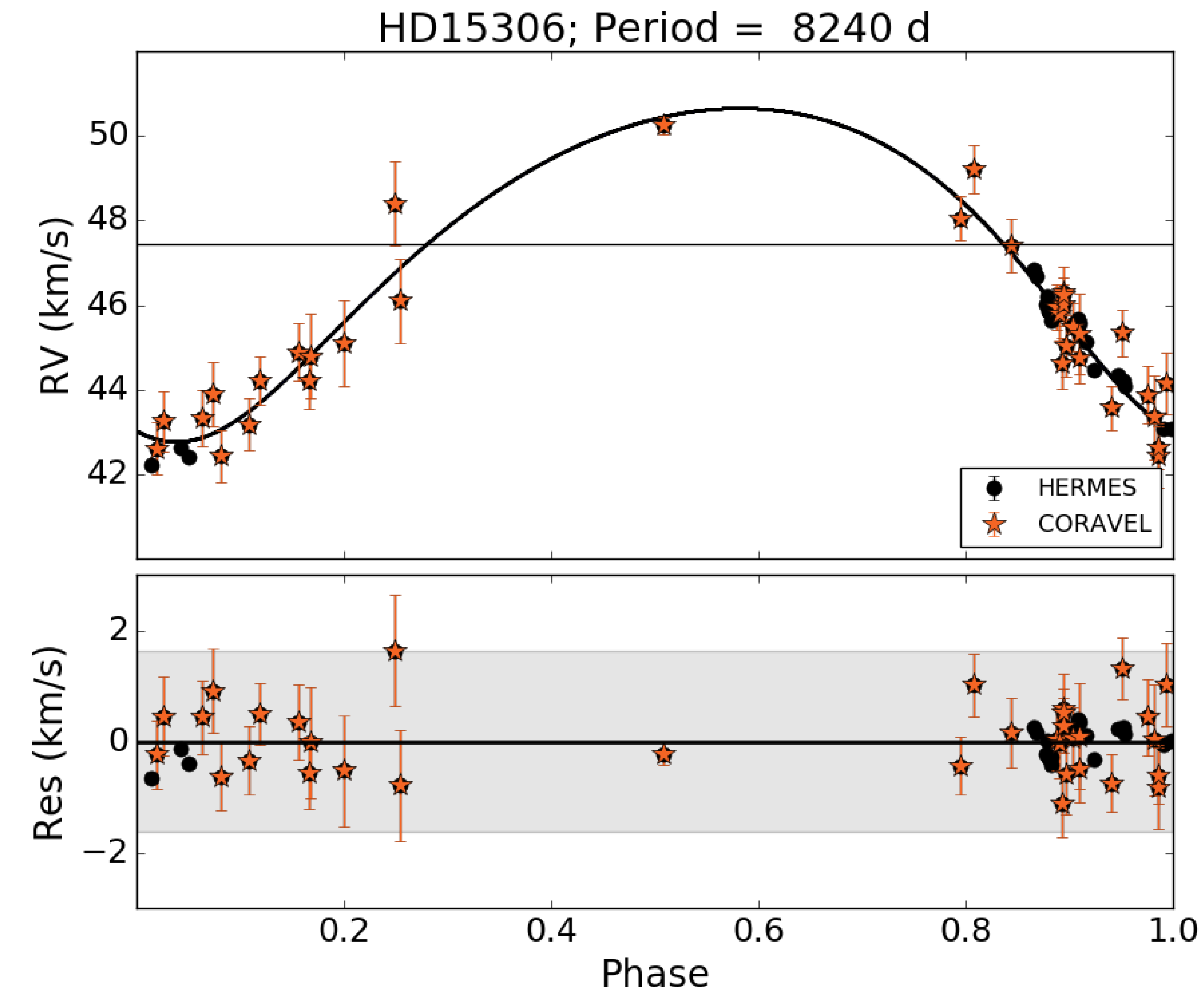
sdB wide binaries

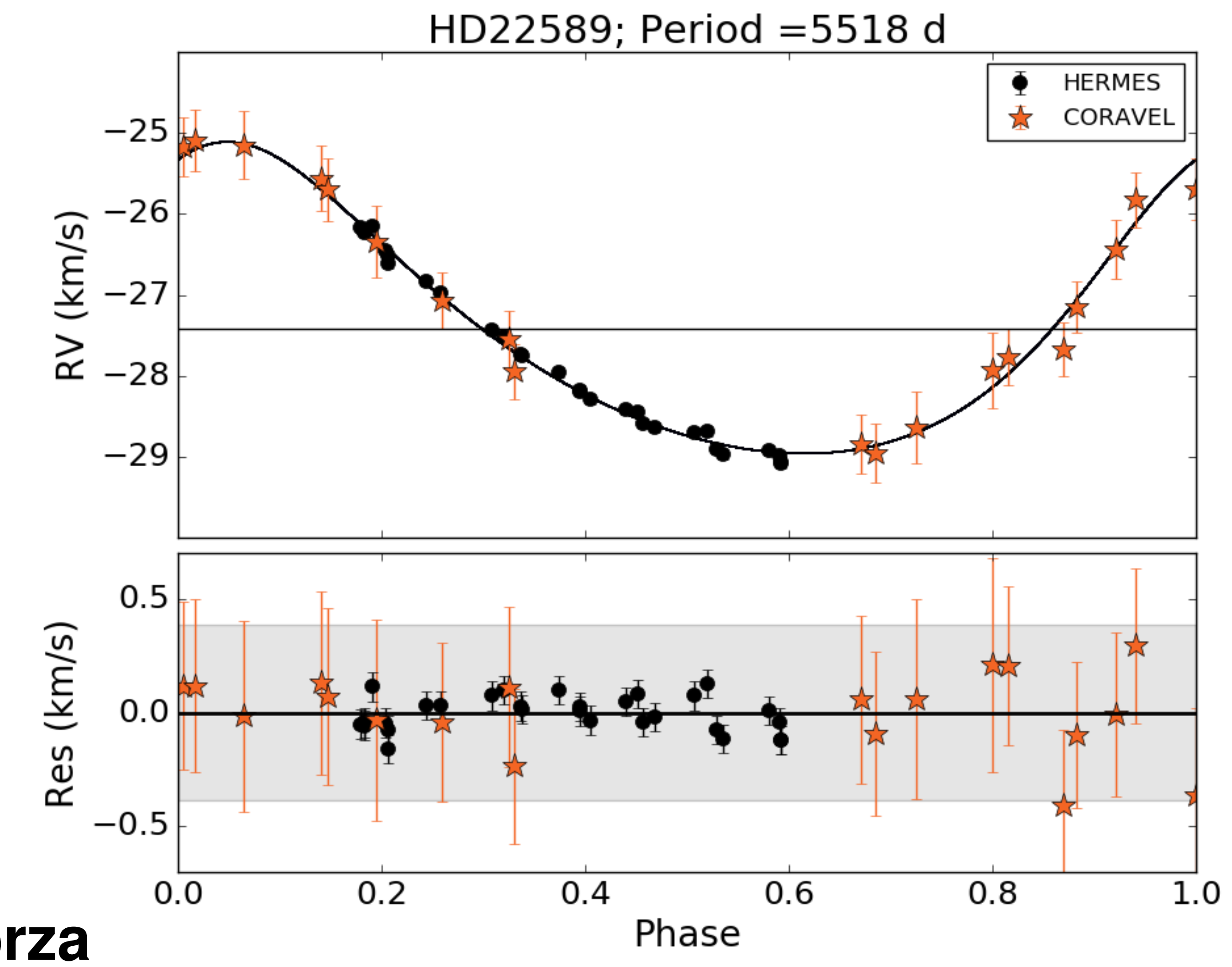


Vos et al., 2018; 2017; 2015; 2013 ; 2011

Ba stars

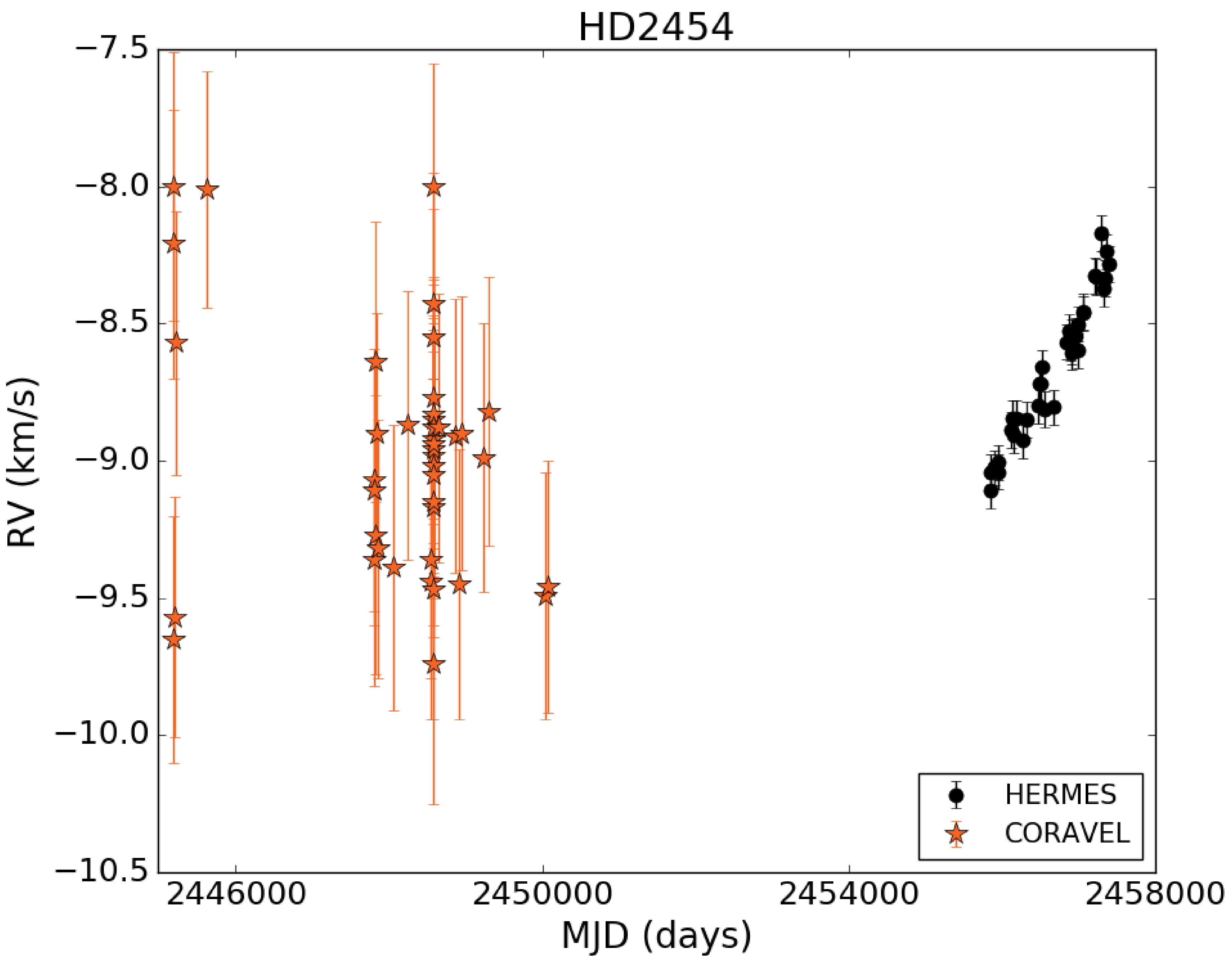


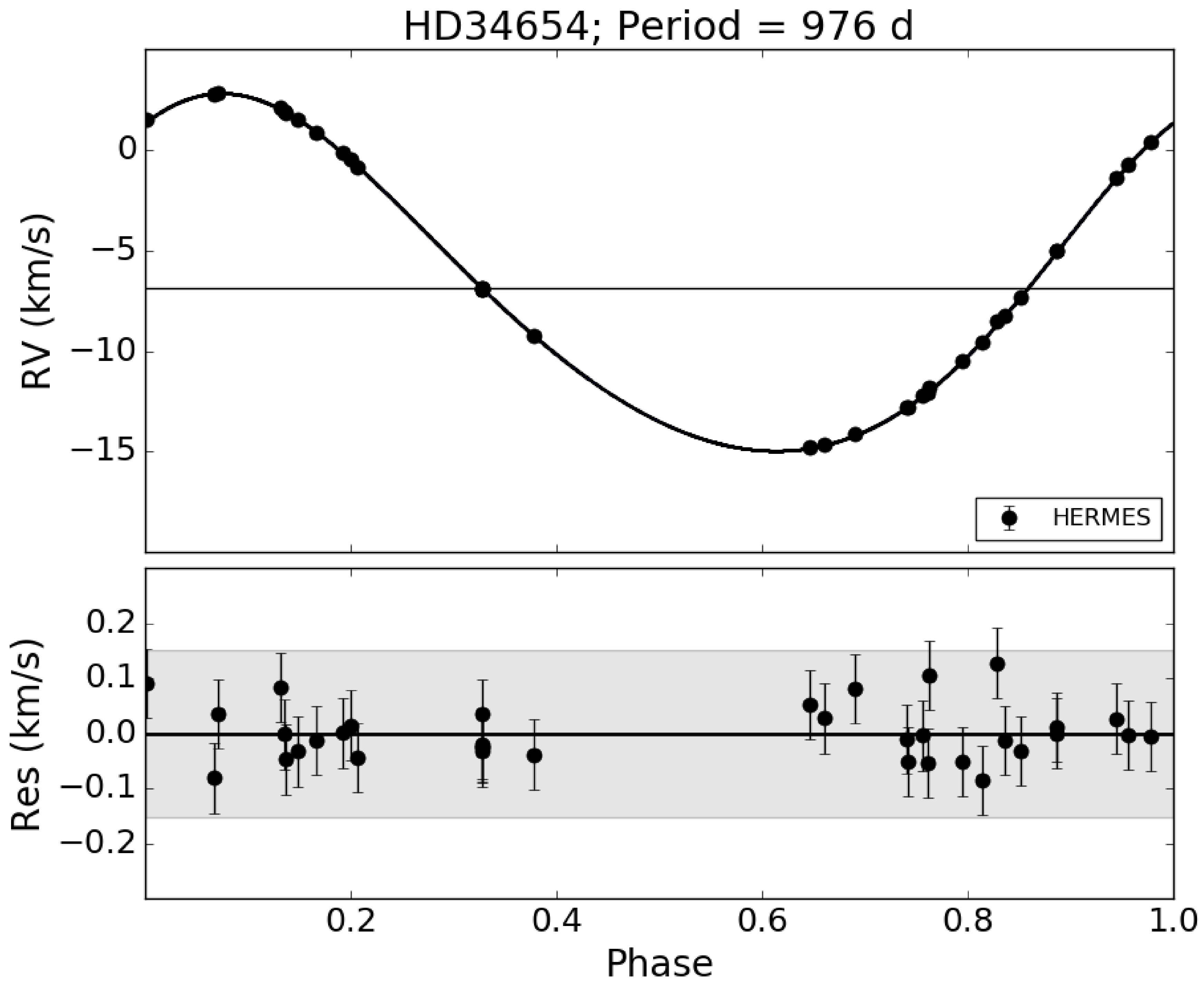




Van der Swaelmen et al., 2017; Jorissen et al. 2016; PhD Ana Escorza

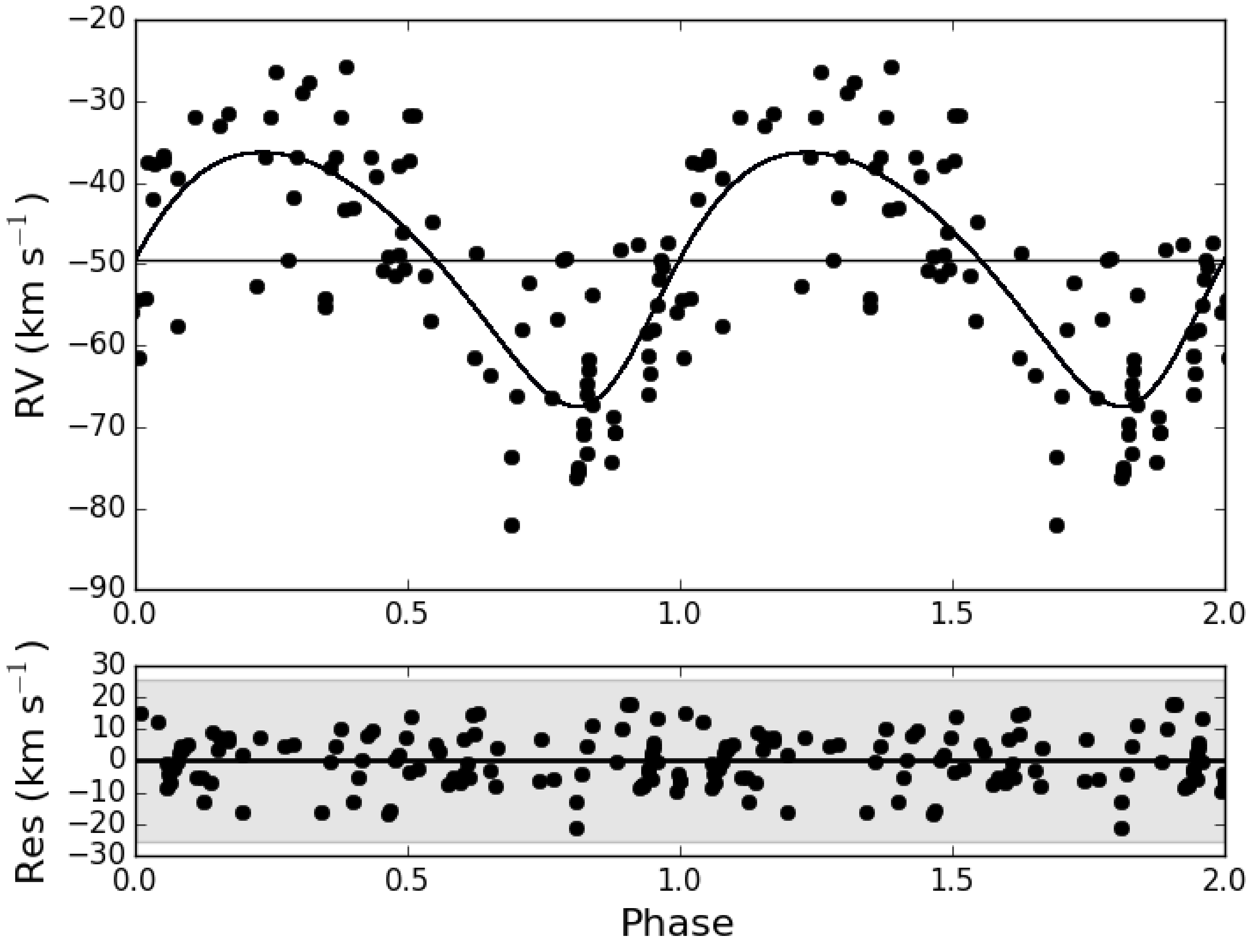
Ba stars

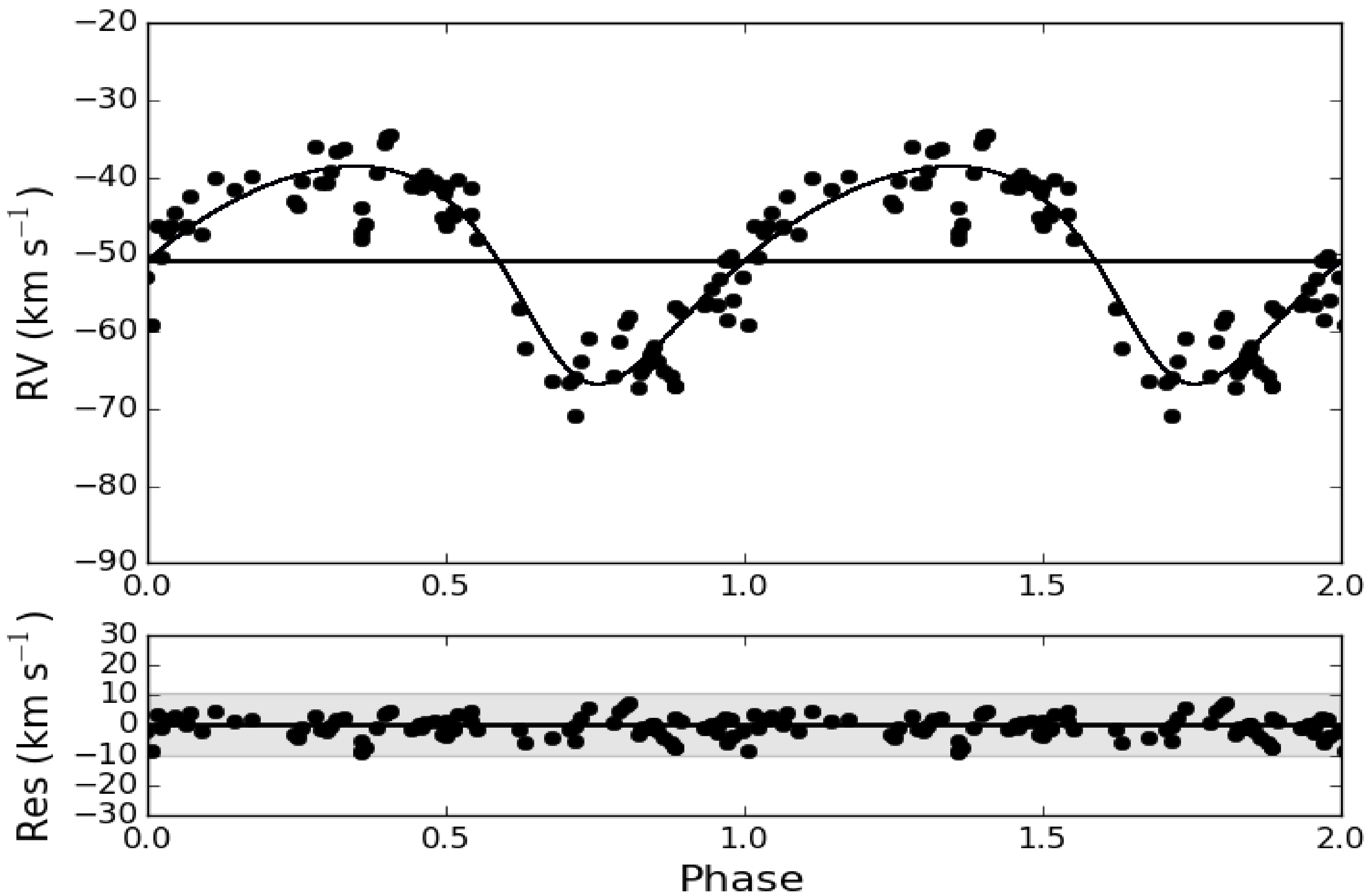




Phd Ana Escorza

Pulsations versus Orbital Motion





Example: TW Cam (RV Tauri pulsator)

Pulsation period: 43d

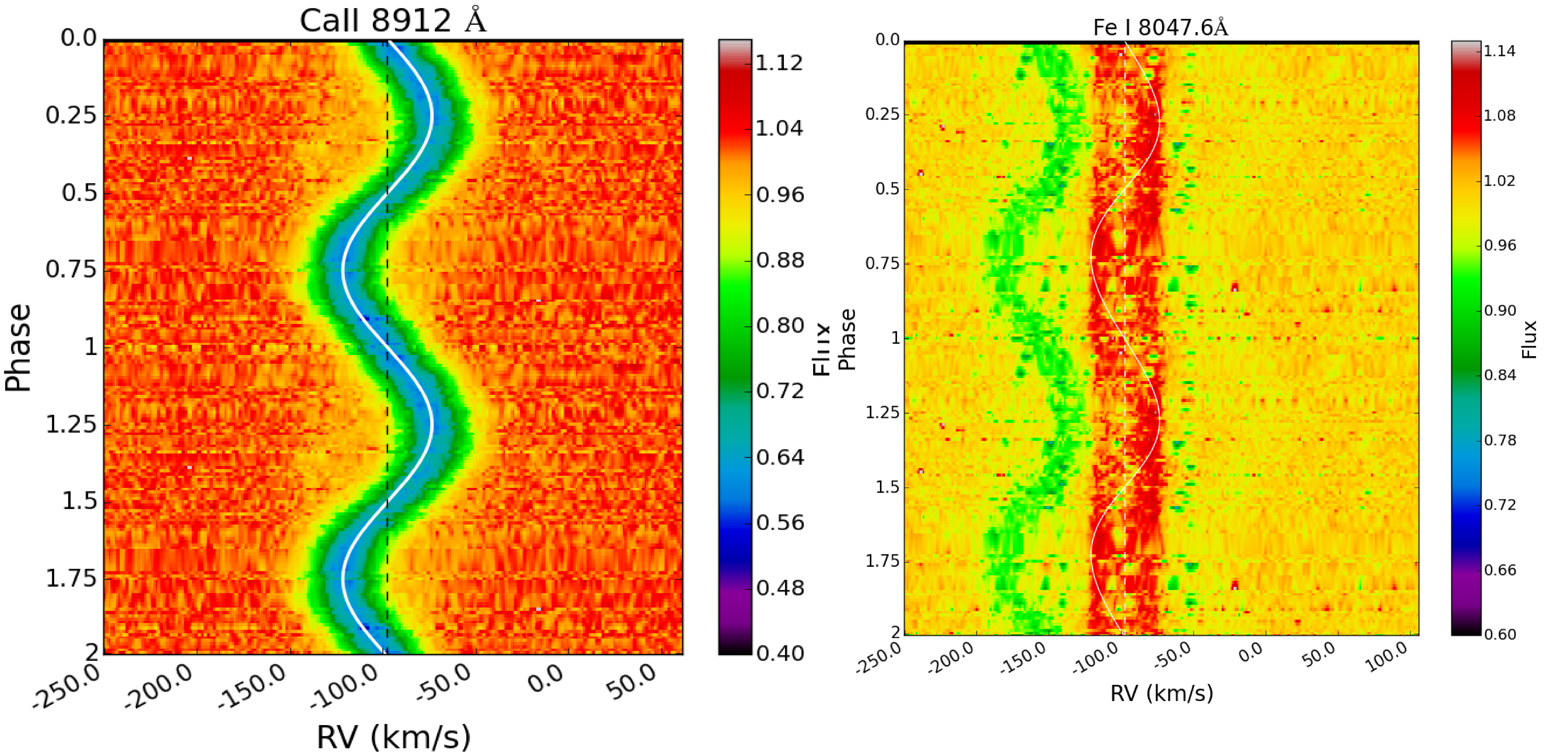
Orbital Period: 654d

Good sampling is needed !!

Photospheric shocks induce line-deformation.

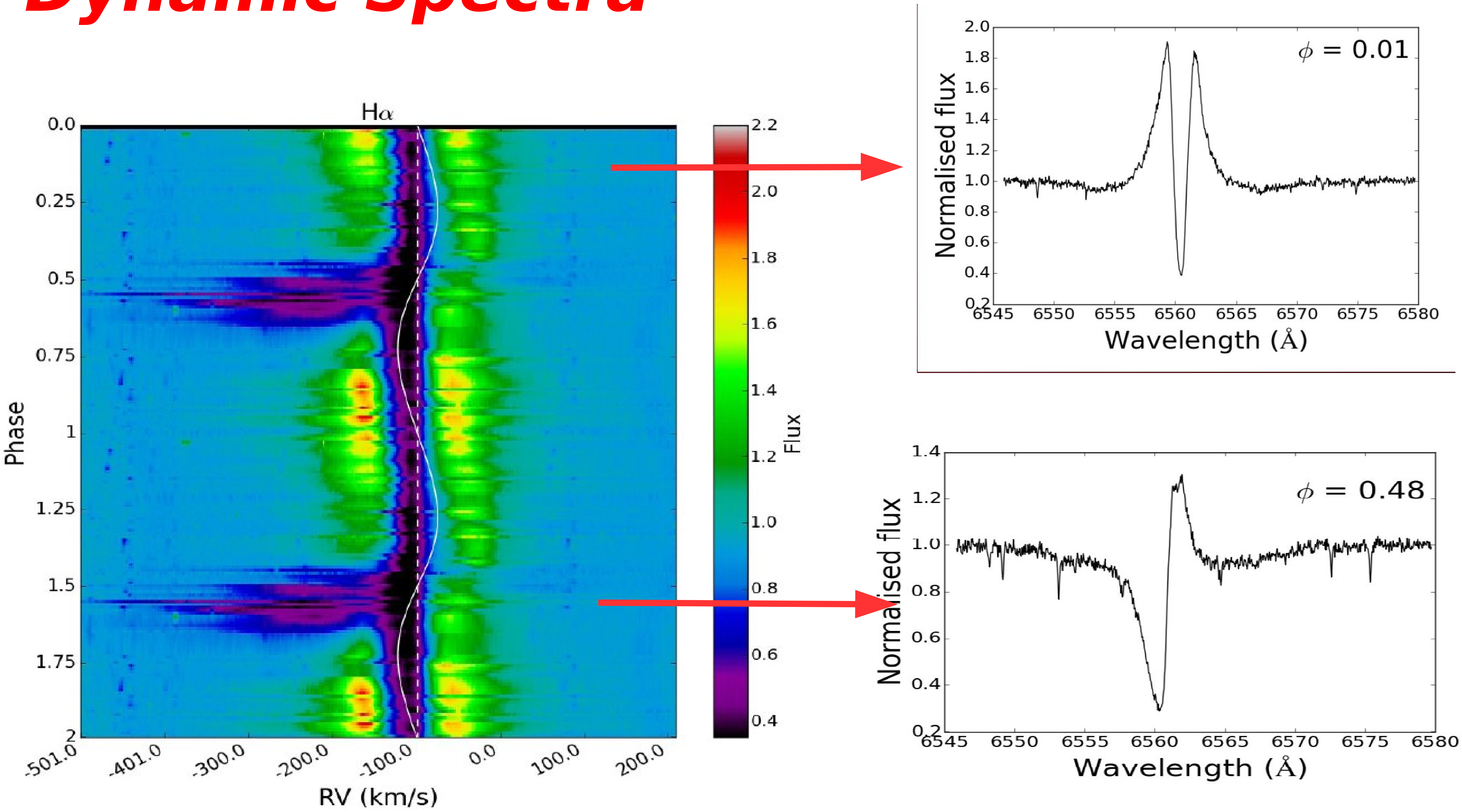
Manick et al., 2017; PhD Manick

Orbits, circumstellar gas and jets

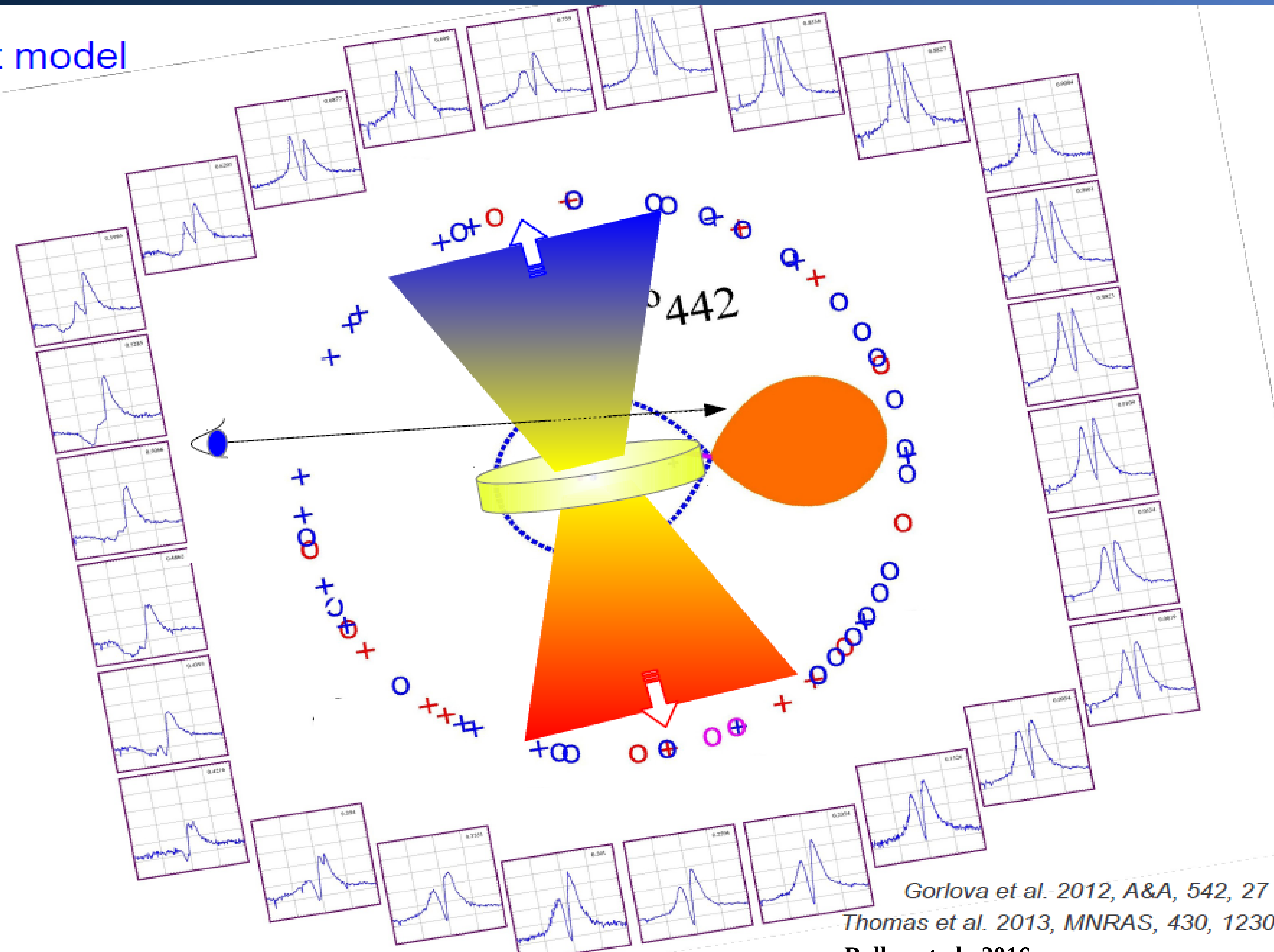


Gorlova et al., 2012; Bollen et al. 2016, 2017, PhD Bollen

Dynamic Spectra

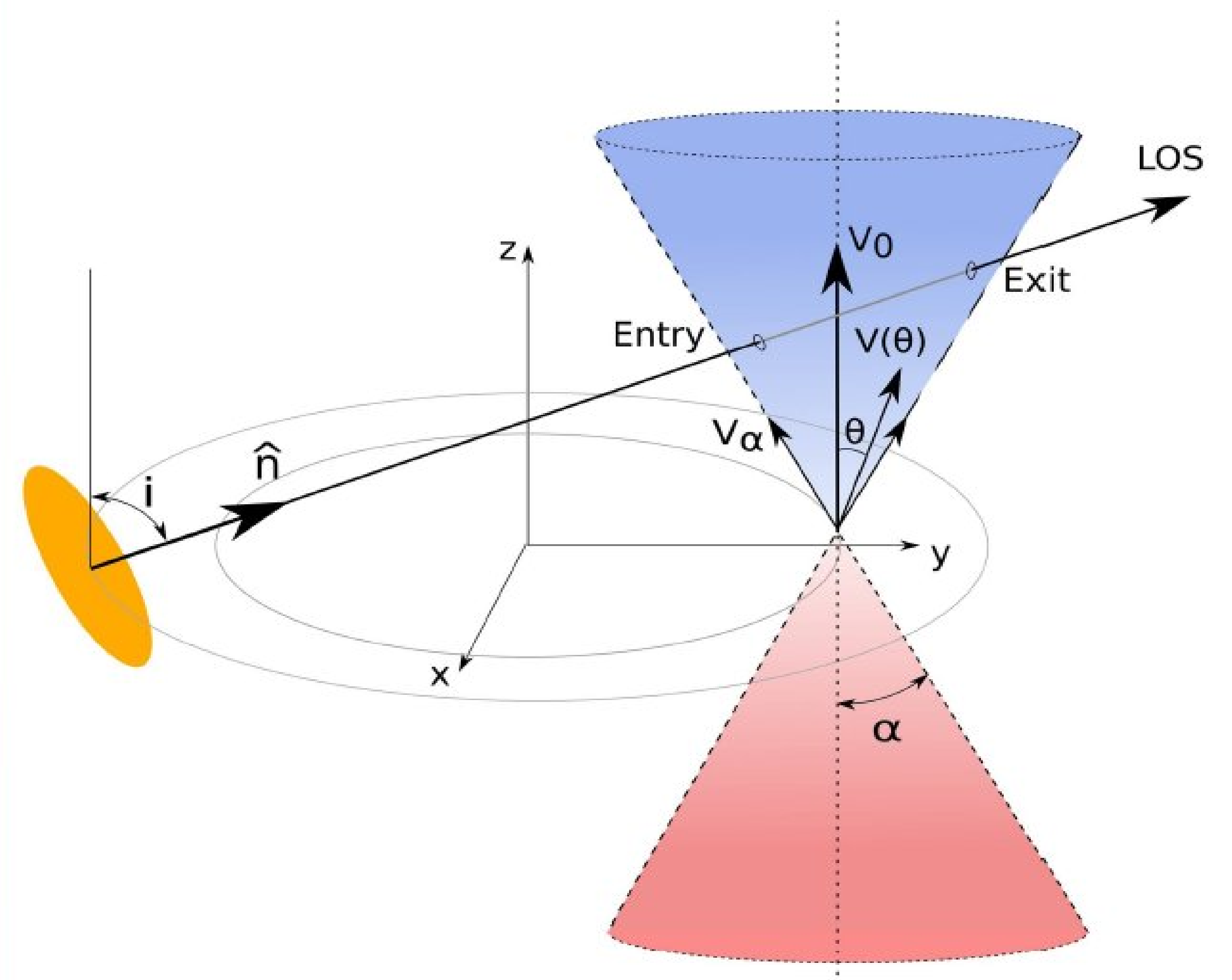


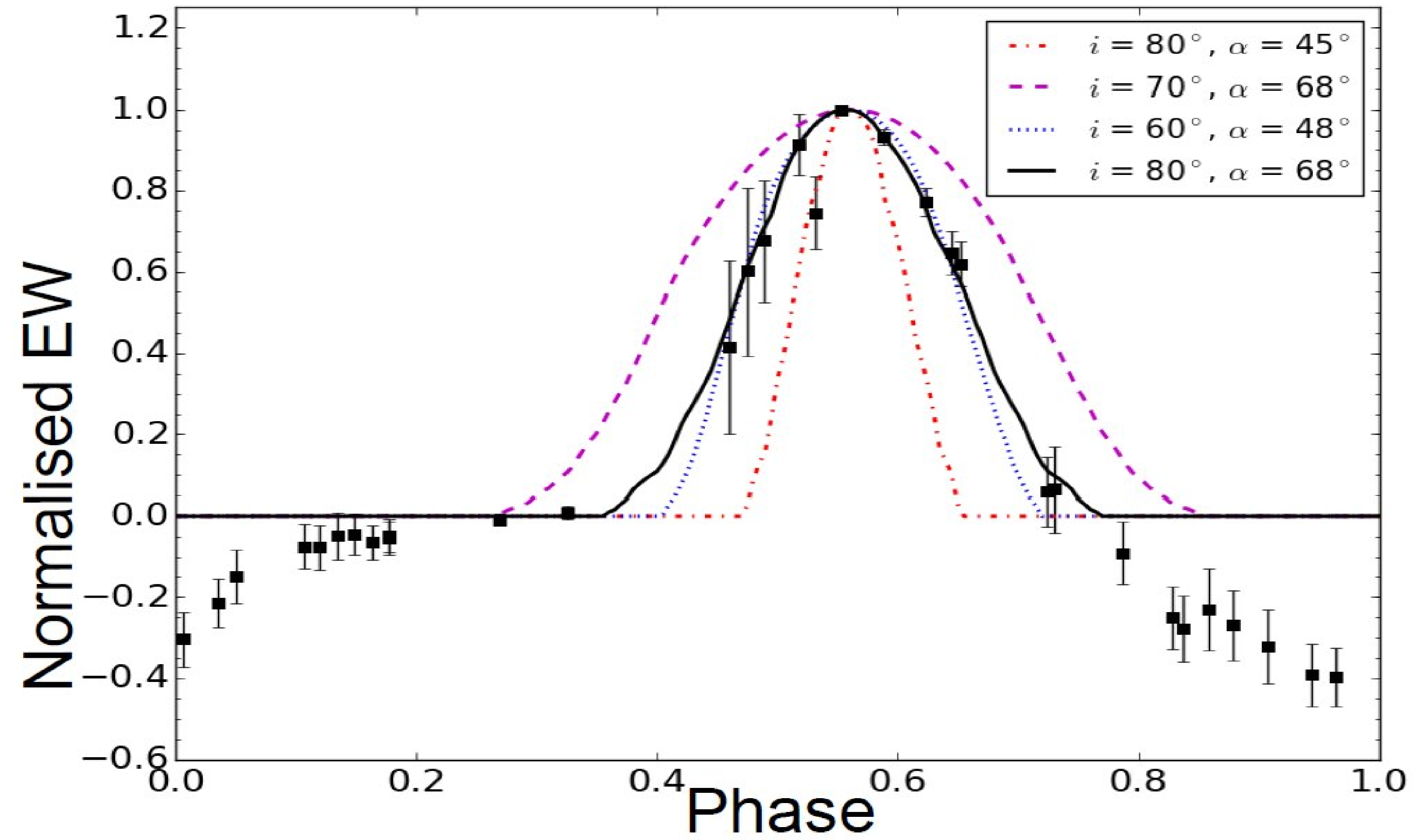
Jet model

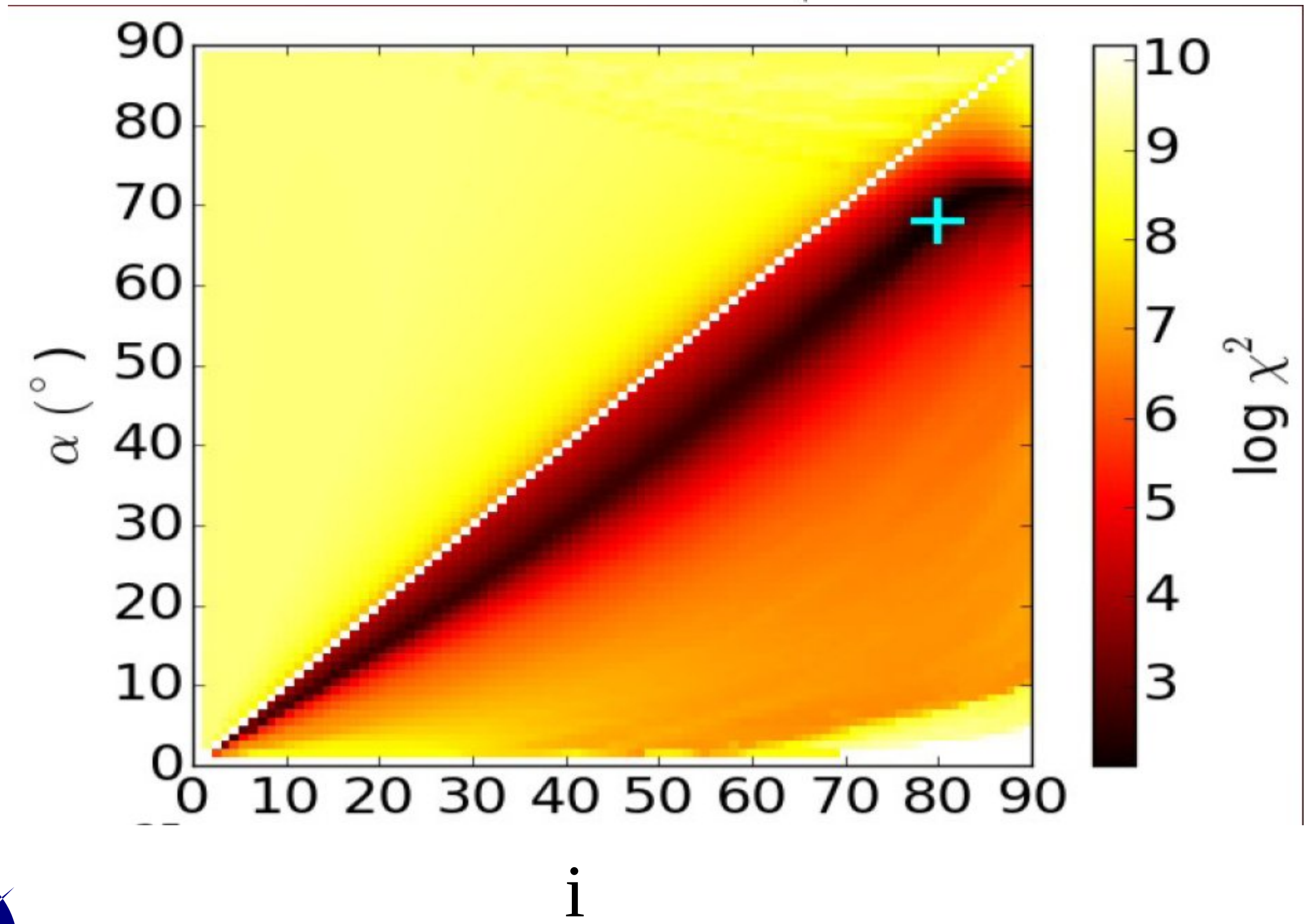


Gorlova et al. 2012, A&A, 542, 27
Thomas et al. 2013, MNRAS, 430, 1230
Bollen et al., 2016

High velocity ouflow: wide cone



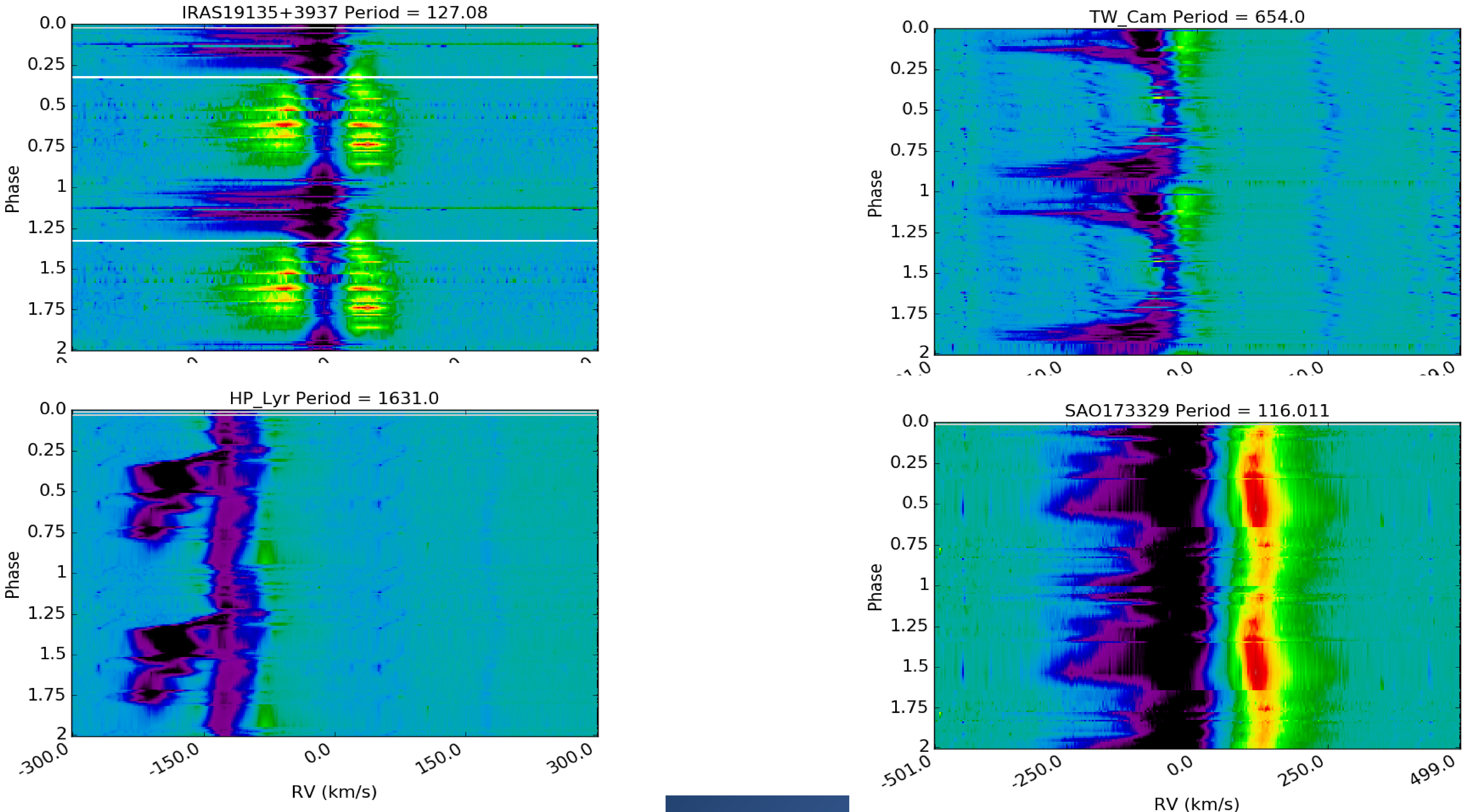




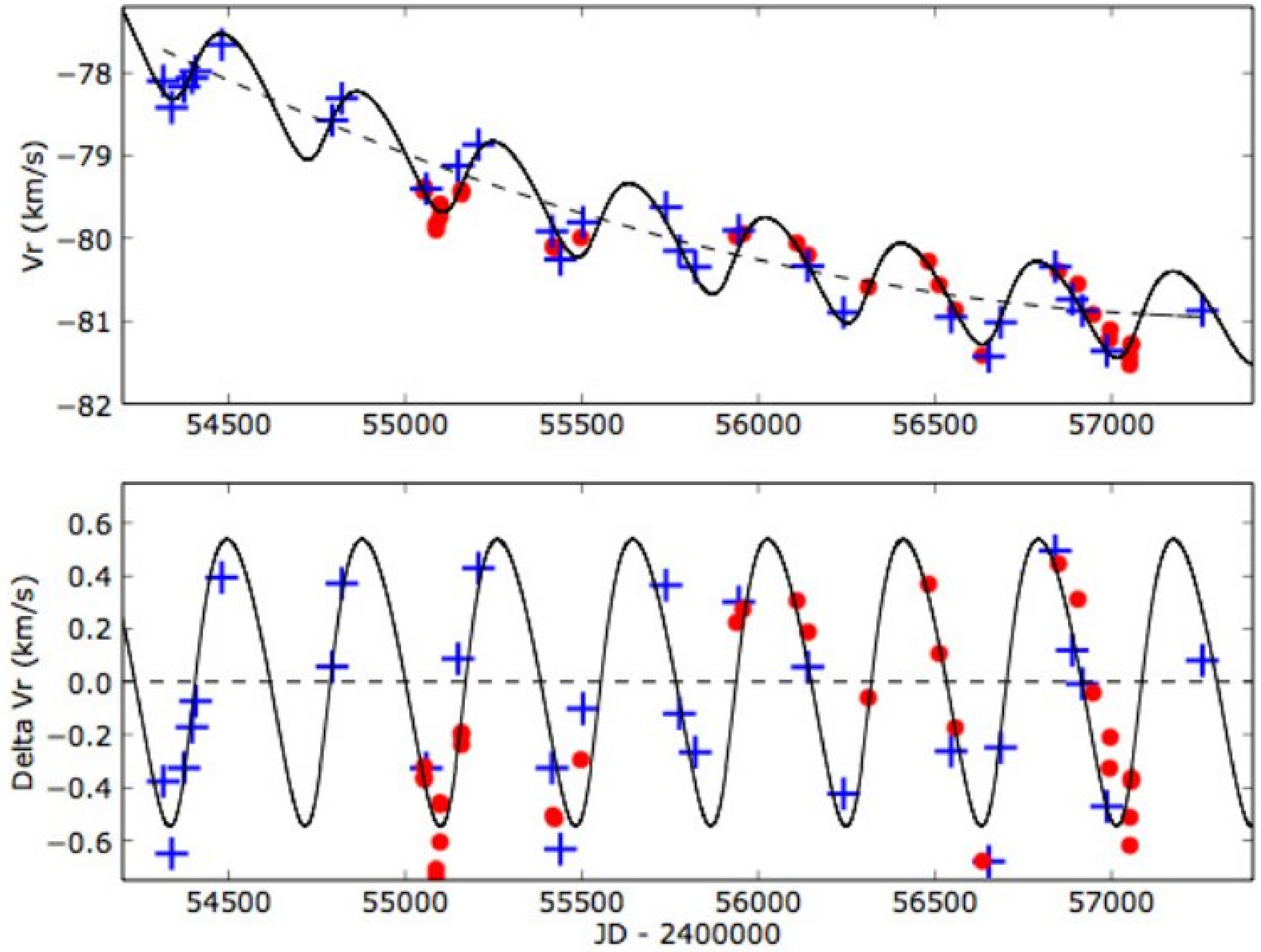
- Wide opening angle
- Inclination dependent
- Angle dependent velocity law in cone

Bollen et al., 2017, A&A; 2018, in prep

Often detected: jets created by circumcompanion accretion disc



Giants with planets (or Brown Dwarfs)



HE0017+0055 (CEMP rs star)
Long Period: 2940 days
Short Period: 384 days

very low mass function

Planet candidate system:
HD175370 (88 years (!) 350 days)

Problem:
Other systems reveal similar properties

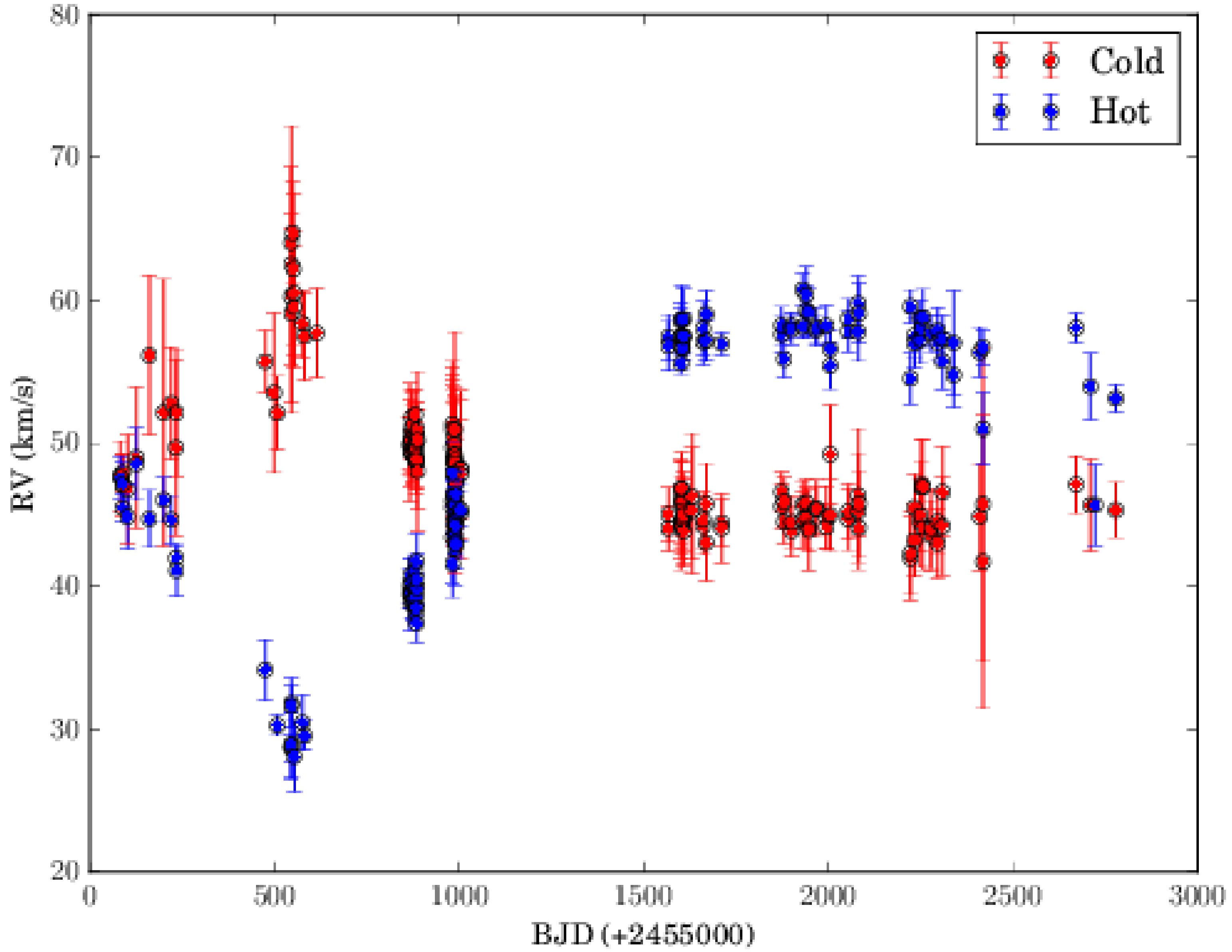
HE 1120-2122 (~1 year short period on long period)
HD76396 (~1 year short period on long period)

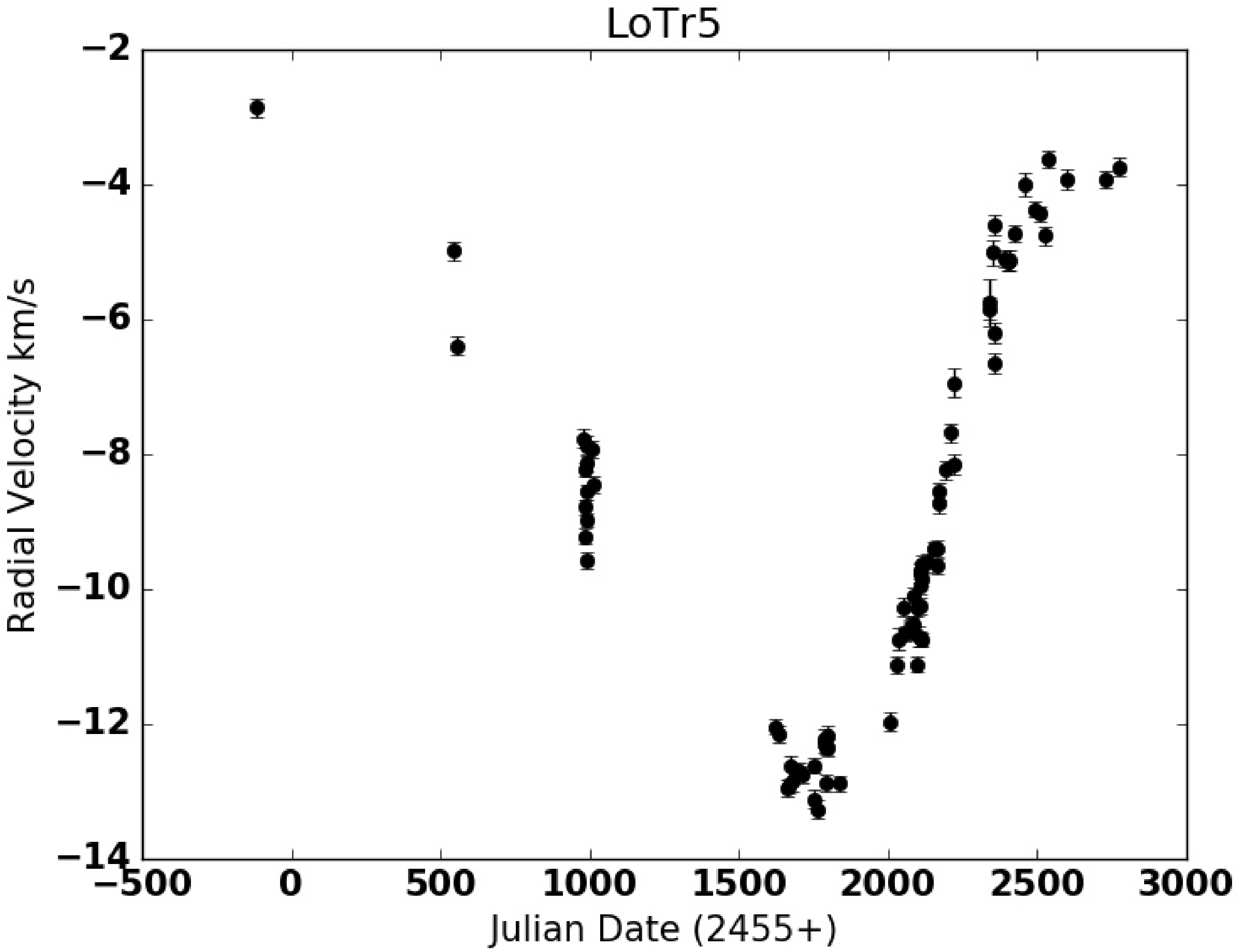
Pulsational Modulation ?

Jorissen et al., 2016; Hrudkova et al., 2017

First PNe central stars on wide spectroscopic orbits

NGC1514





Van Winckel et al., 2014; Jones et al., 2017; Aller et al. 2018

Why 1.2m Mercator ?

Niche in experimental astrophysics
Thanks to:
- Instrument development programme
  (HERMES,Maia and....pipeline reduction)
- Technology development programme
  (TCS, fibre link, Fabry Perot)
- Adequate operational model

Ideal complement to space photometry as well as large international infrastructure !