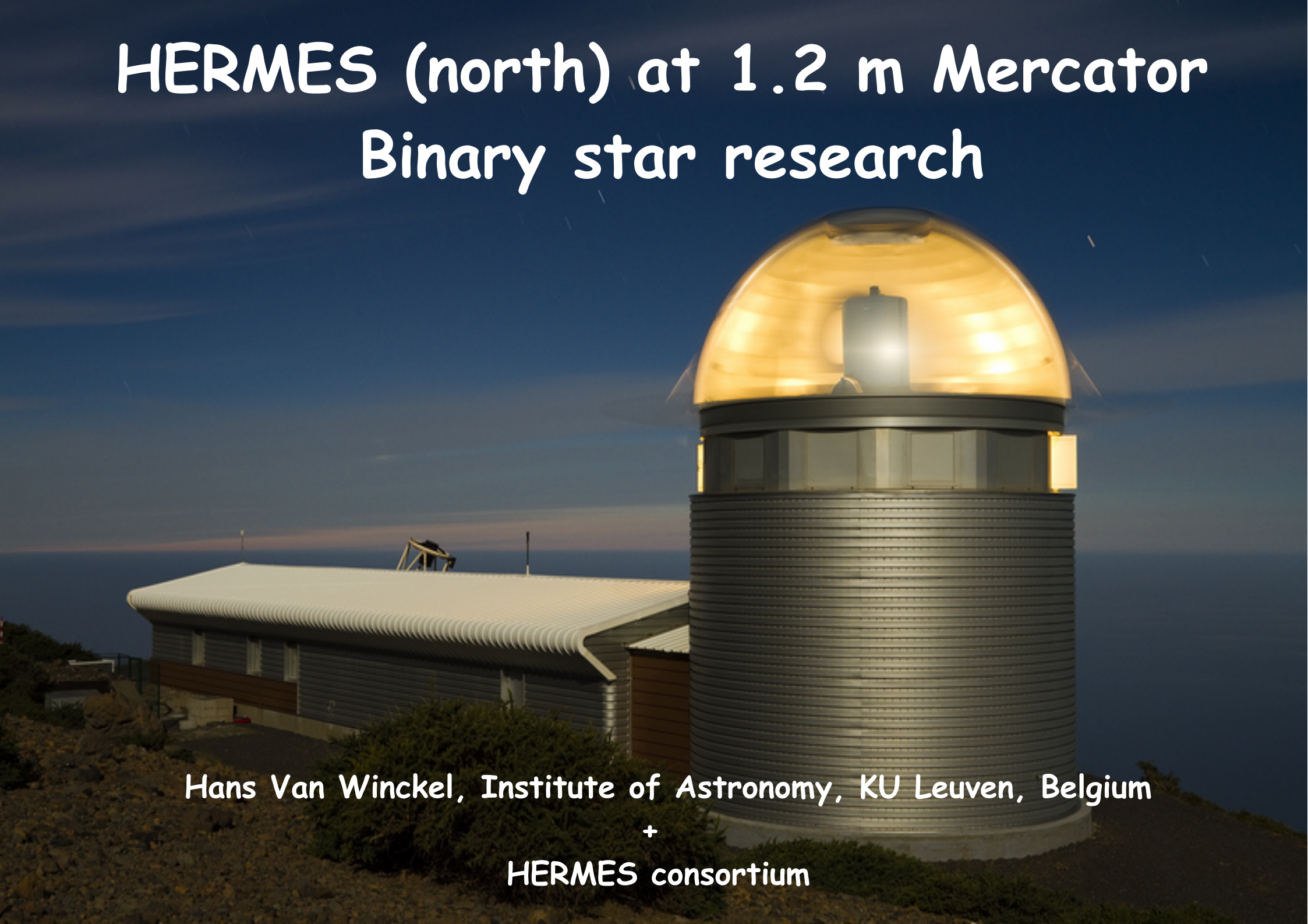
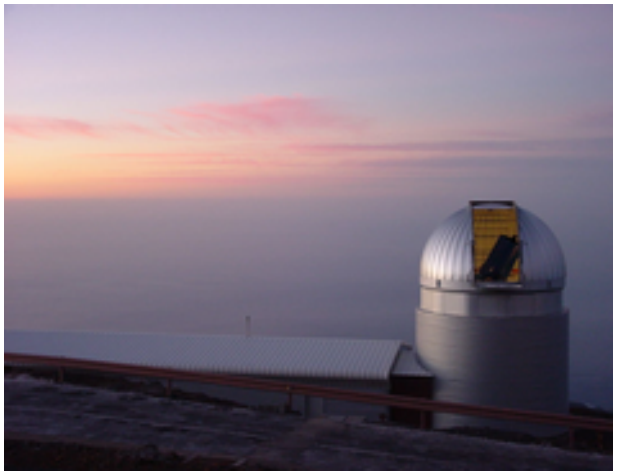
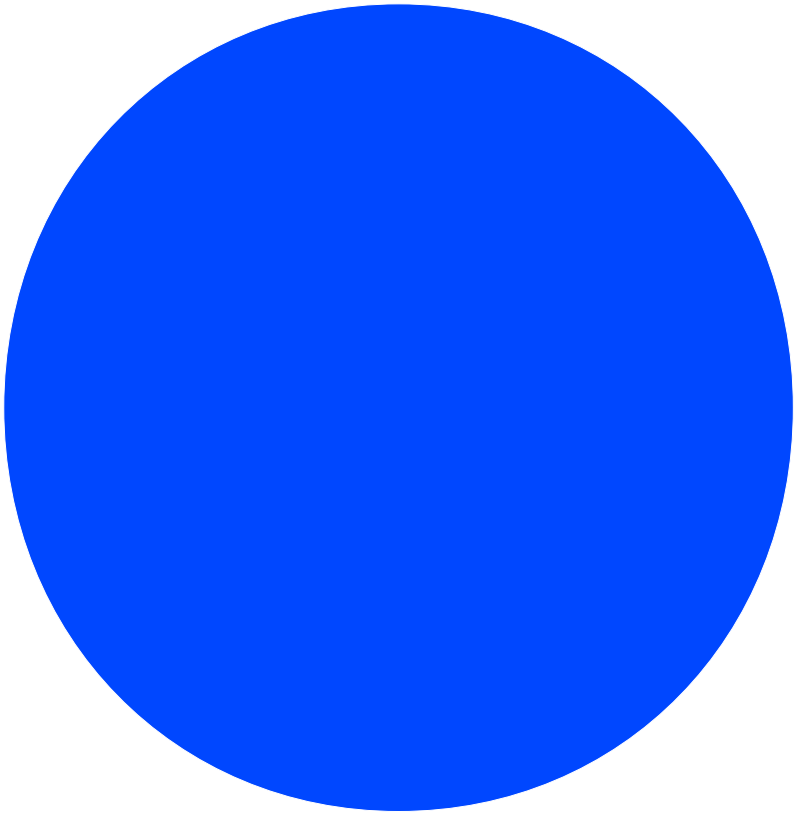
HERMES (north) at 1.2 m Mercator
Binary star research



Hans Van Winckel, Institute of Astronomy, KU Leuven, Belgium
+
HERMES consortium

E-ELT & Mercator





Outline

- Hermes project + exploitation
- Binary programme: Binary Interaction Physics
- Results: Examples
    - Post-AGB binaries: Keplerian discs
    - Pulsating RV Tauri stars in binaries with discs
    - Ongoing binary interaction in post-AGB stars: jets around MS companions
    - PNe in wide orbits
- Conclusions

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

Project Engineer: Gert Raskin
PI: Hans Van Winckel

IvS-KUL
co-i: C. Waelkens

ROB
co-i: H. Hensberge, Y Fremat

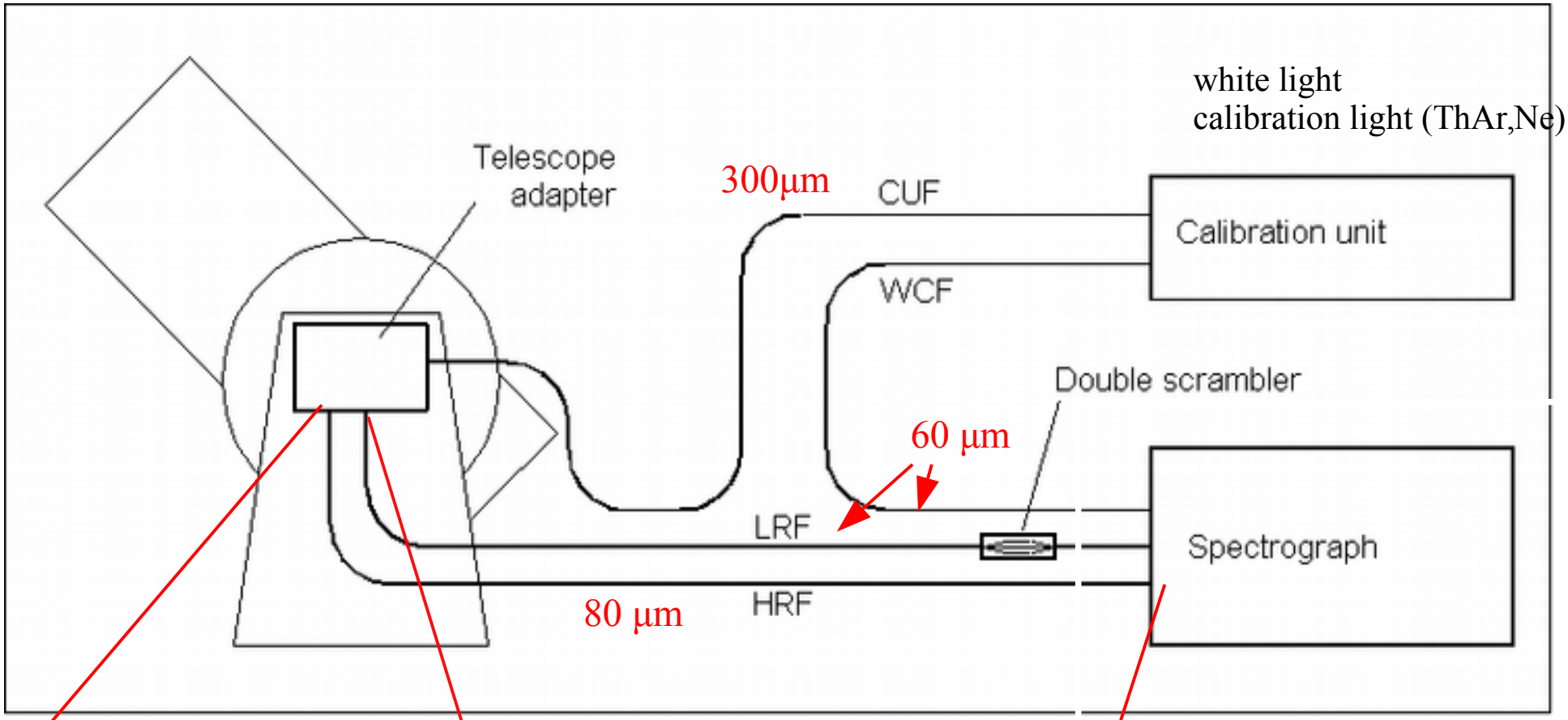
IAA-ULB
co-i: A. Jorissen

HERMES (north)

Landessternwarte Tautenburg
co-i: H. Lehman

Observatoire de Genève

Hermes Design:



2.5 arcsec/fibre

2.15 arcsec/fibre

double slicer

acclimatisation !!
+/- 0.01 K

R ~ 85000
380-900 nm **high throughput: m(v) = 12.0 S/N~40 in 3600s**

Operational Model:

Exploit niche: time IvS + Hermes consortium: 75 % of telescope time

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

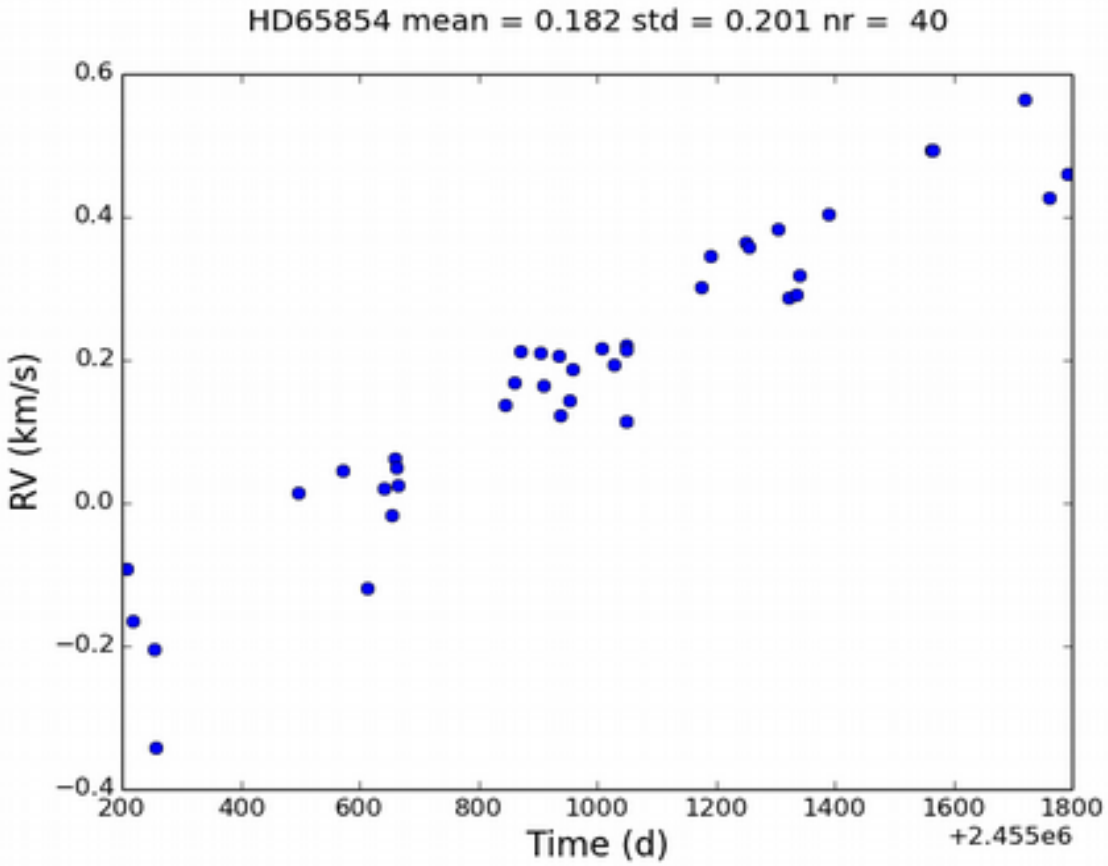
so....: lots of software (MOCS, pooled observations, DRS, quicklook)

Database of pooled observations: 80% pooled, 20% own experiments

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

HERMES observing

HERMES: Constant developments to maximally exploit biggest scientific asset



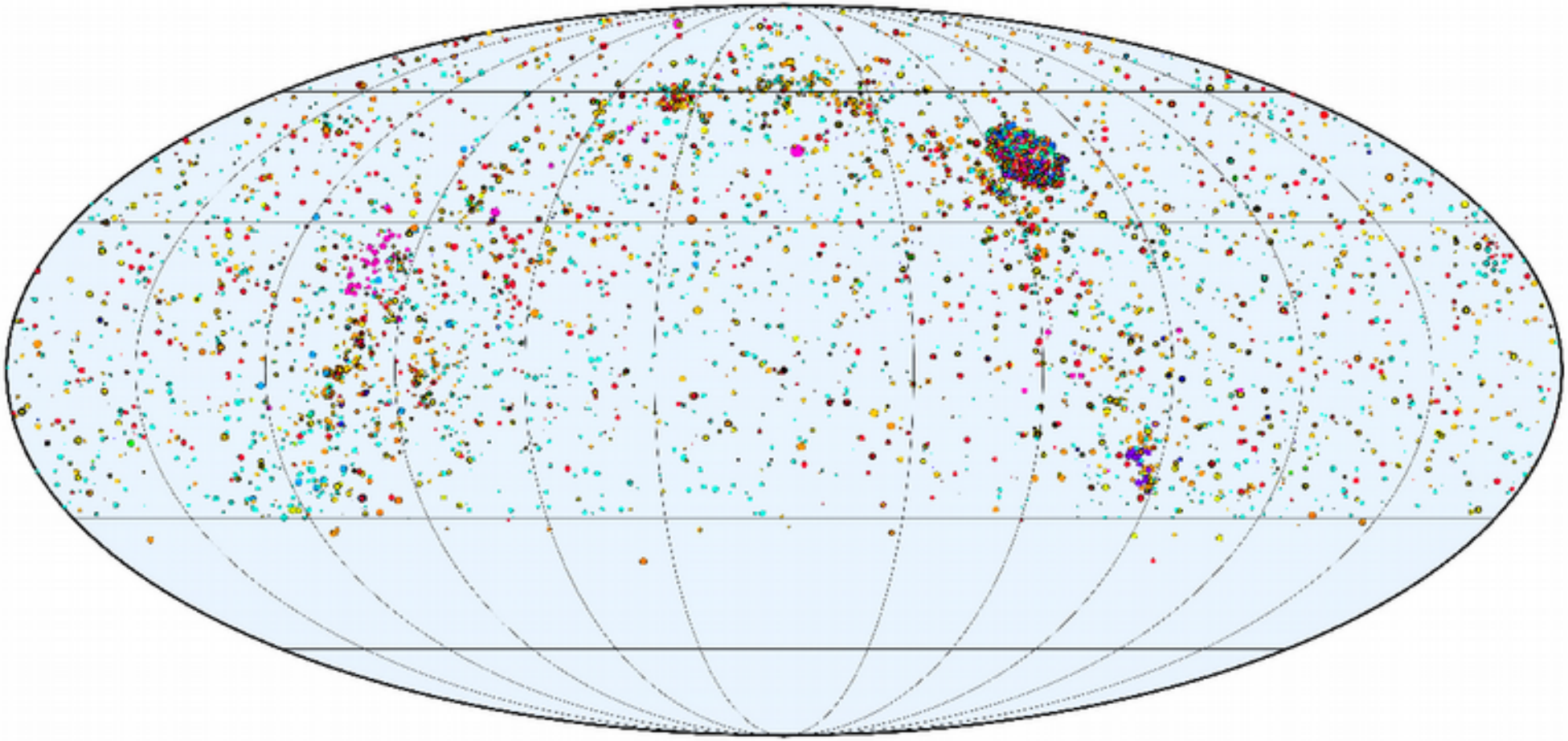
Long timeseries
Intense timeseries

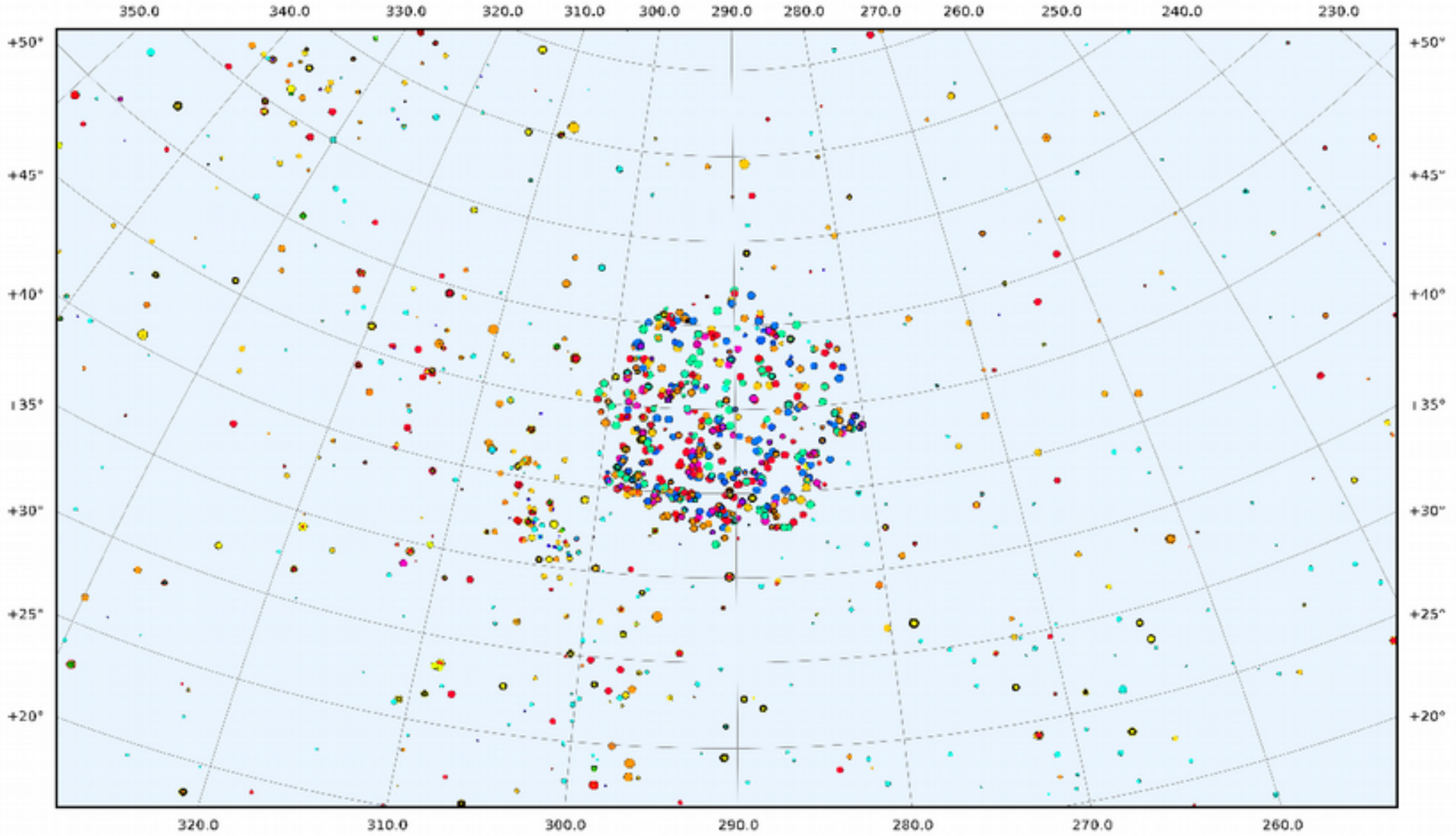
Not vacuum: 6yr stability
is ~ 80 meter/second

Ideal complement to
(space) projects and
larger infrastructure

Unique science is possible

References to Raskin et al., 2011, A&A 526, 69: 123 citations




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

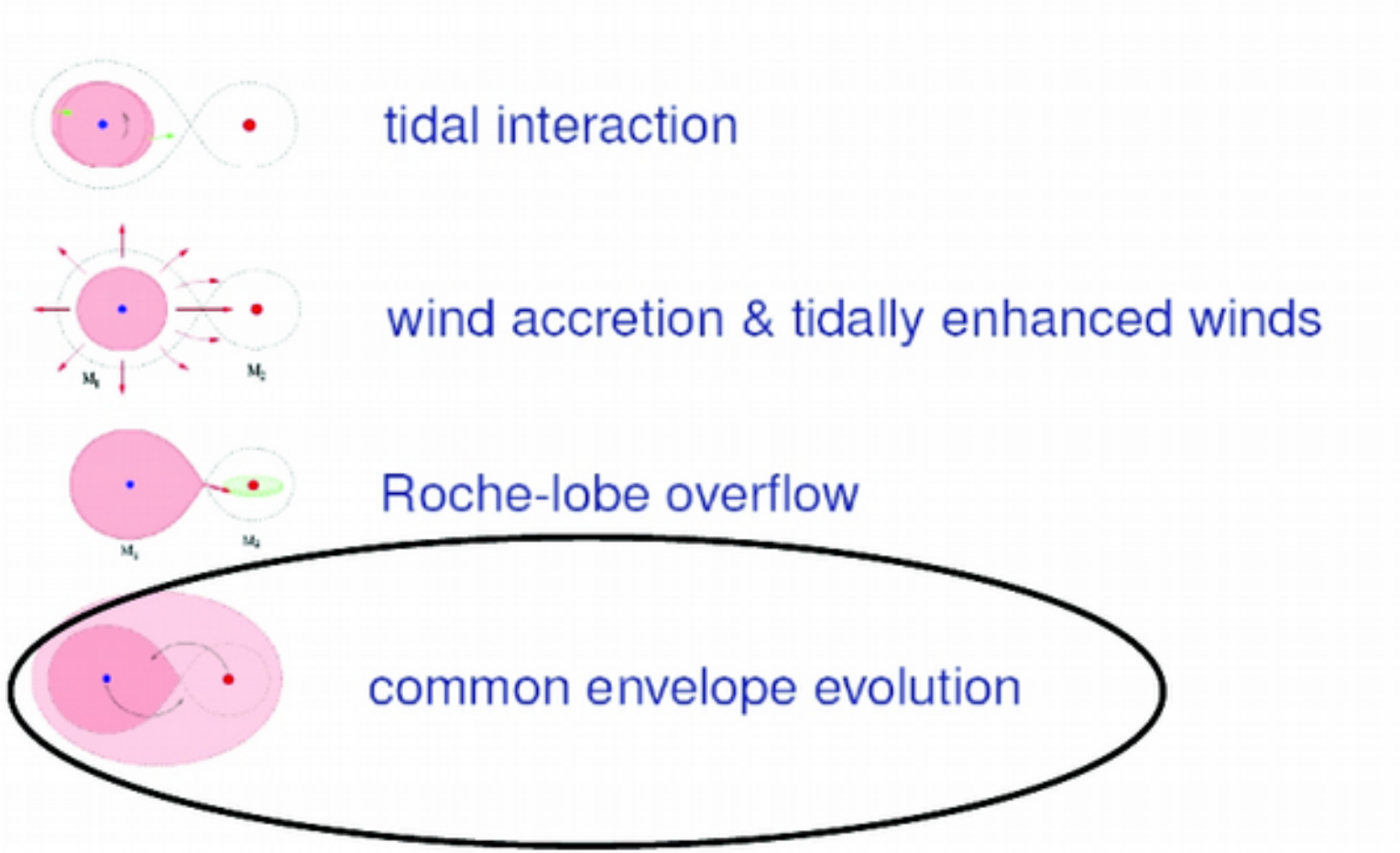
Binaries in evolution: AGB to Post-AGB to PNe to WD ?

Samples: we do not talk about the same ....

* Galactic AGB stars: very few orbits are known Herschel/ALMA:
  very wide systems
* Post-AGB stars: Keplerian discs are common and occur in binaries
* Similar discs are found in FS CMa stars (B[e])
* Nebulae around some post-AGB stars (Proto-PNe):
  Momentum excess is widespread (due to binaries) ?
  Asymmetries in nebular shapes are very common
* PNe: binarity is thought to be very widespread, known orbits are
  spiralled-in systems except 2
  some PNe have off-centred central stars.
* Wide WD binaries like extrinsically enriched Ba stars, CH stars, symbiotic
  CEMP-s do not connect well with post-AGB binaries
* Some do not make it to the AGB (sdBs, He-WD)

Binary interaction physics

Binary channels plagued with uncertainties



Evolved objects in binaries: the evolutionary connection

(PI: H. Van Winckel (KUL) + ULB + ROB)

A. Jorissen, N. Gorlova, R. Manick, S. Van Eck, G. vdSteene, M. Hillen, T. Merle R. Oestensen, K. Exter, D. Kamath, K. De Smedt, J. Vos

Post-AGB 92
phot. binaries
disks and outflows
depleted

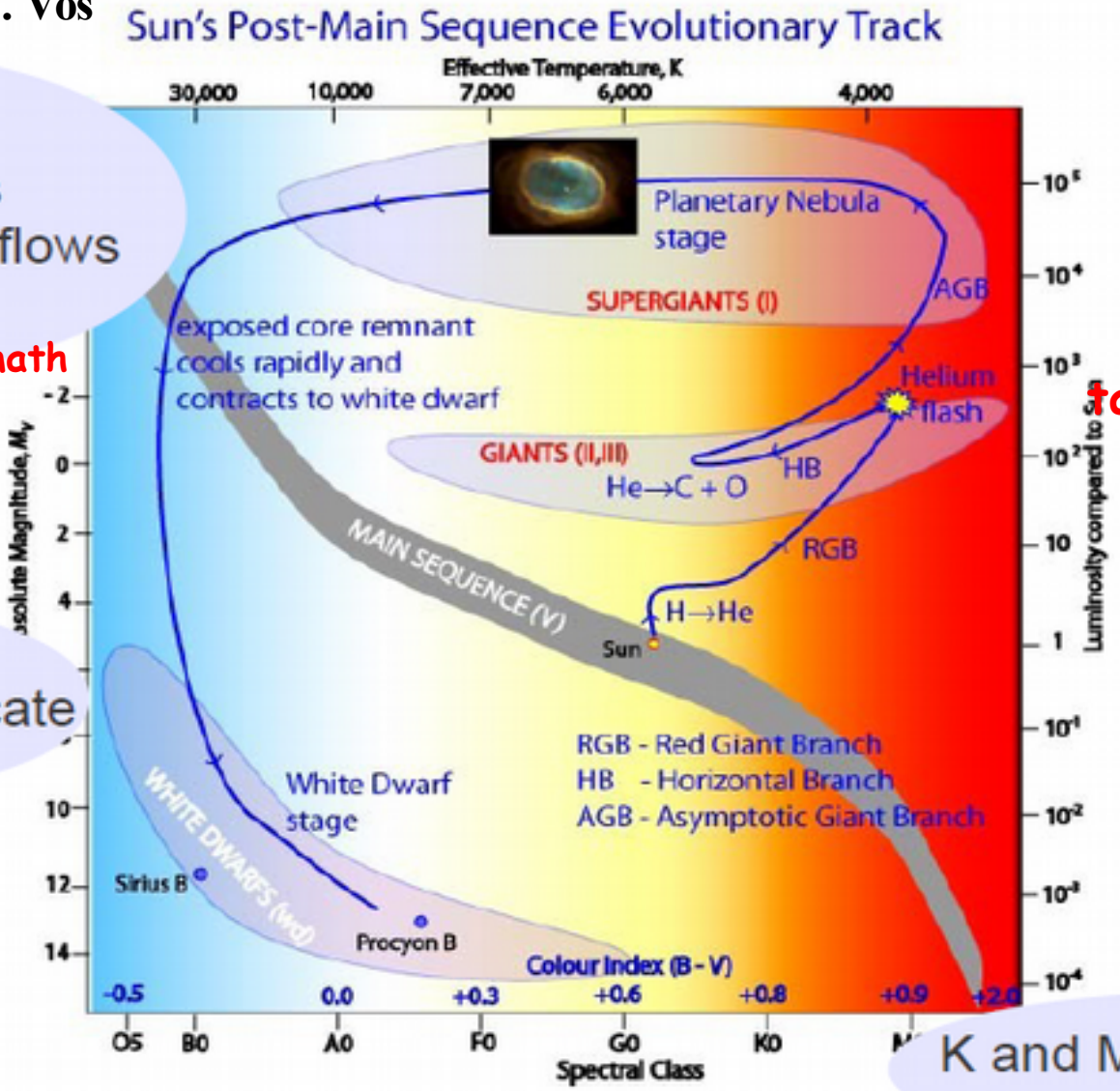
talk Michel Hillen; Devika Kamath

PNe 24

J-type 21
carbon and silicate

SdB 27

talk Joris Vos



Barium 60

CEMP 19

talk Sophie Van Eck

S 38
R 30
N10

WSer 8

dusty RGB 13

Symbiotic 15

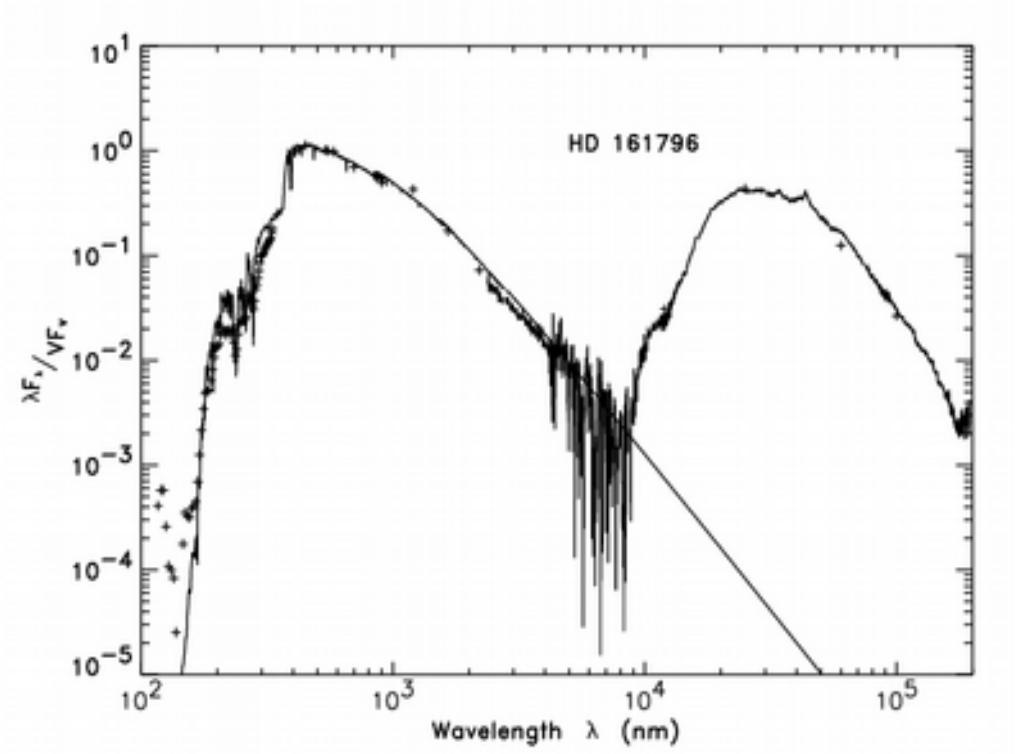
K and M giants in bin. 60

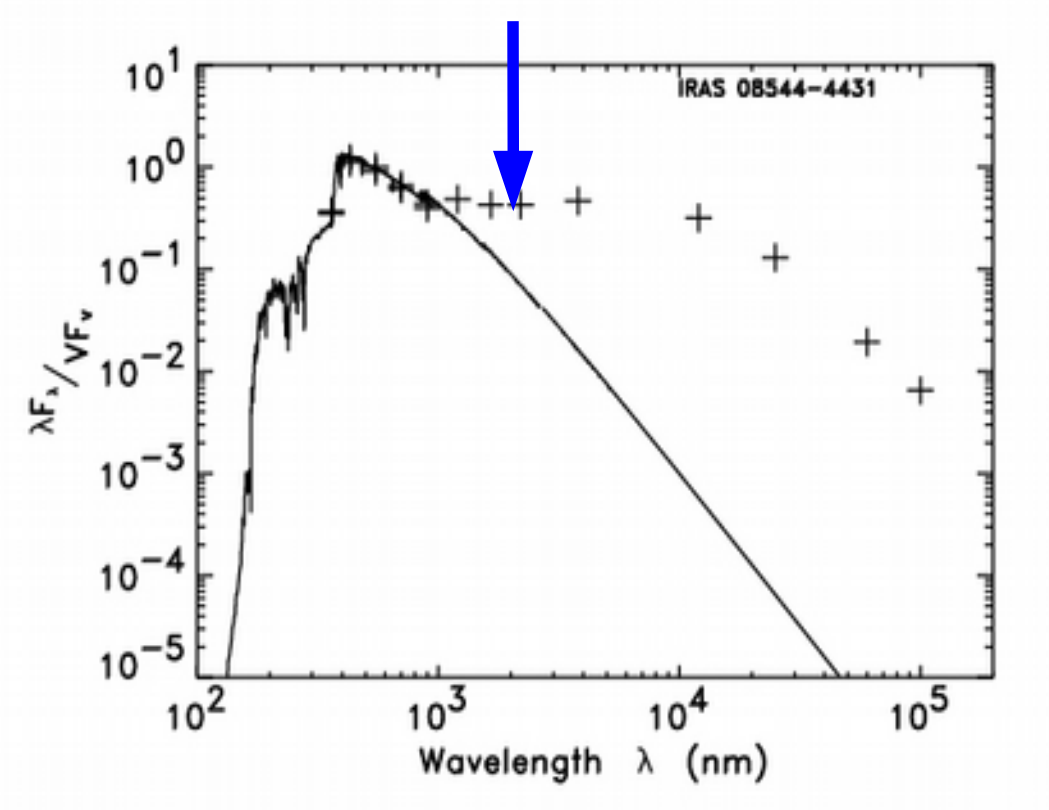
see also posters: T. Merle et al.; A. Jorissen et al.; B. Hrivnak et al.,

(see also our websides: PhD positions + 1 post-Doc)

Example: optically bright post-AGB stars

Dust at sublimation temperature
= stable circumbinary disc

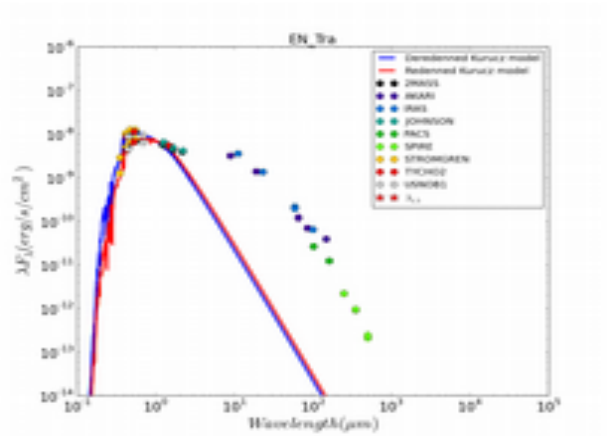


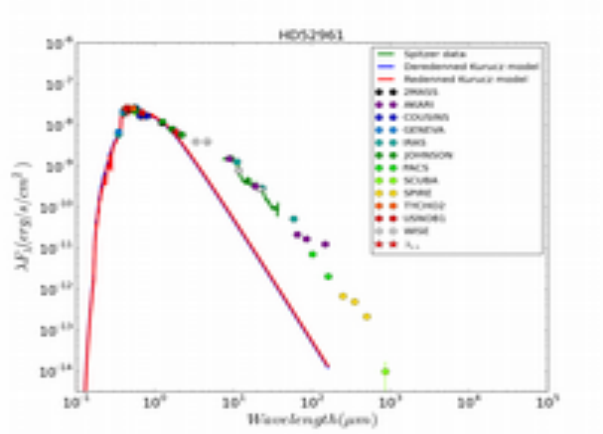


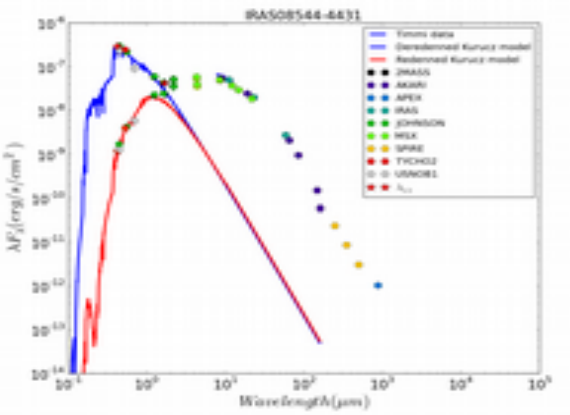
Shell sources
either very wide > 25yr or
single (poster Hrivnak et al.)

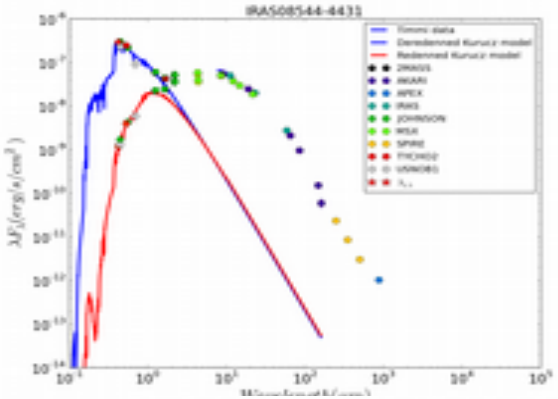
these are the binaries !
companion not seen: MS

SED : commonly observed







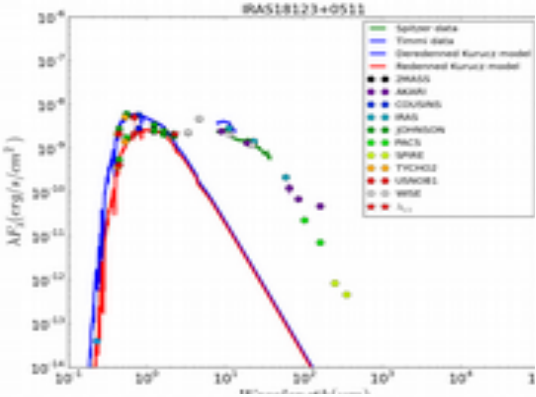


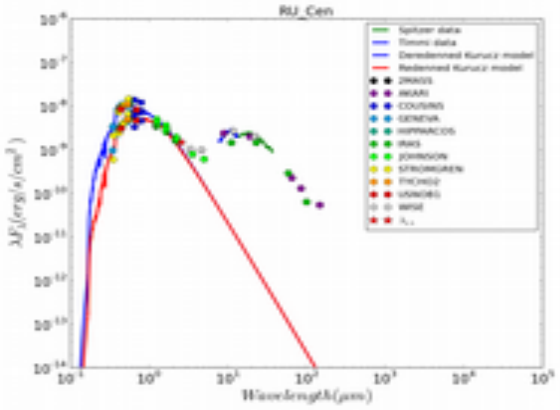
SED very similar :

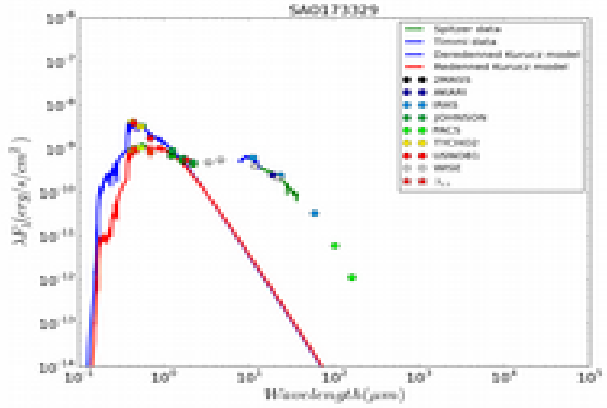
Dust excess stars near sublimation T

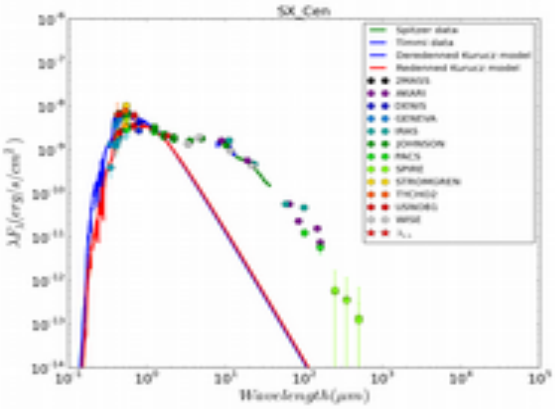
No present dusty mass loss

Galactic sample: +/- 100 sources

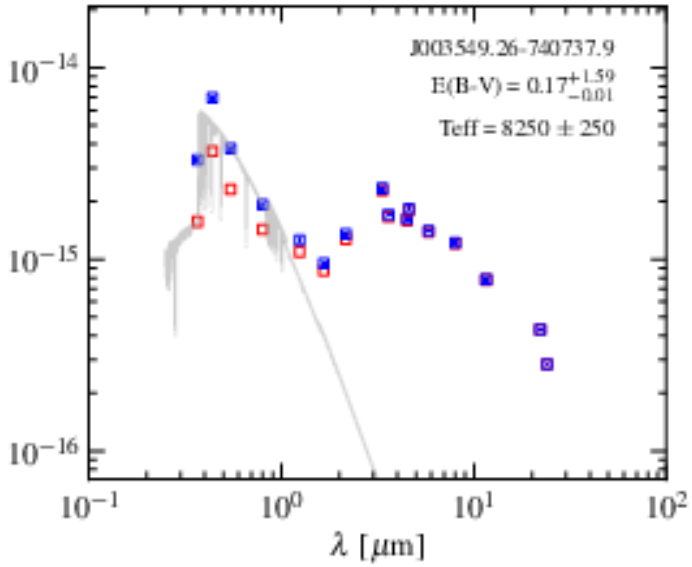


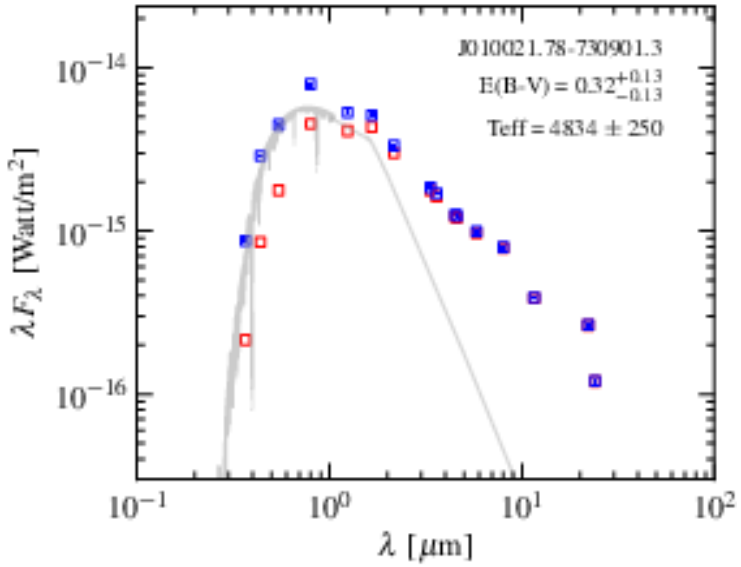


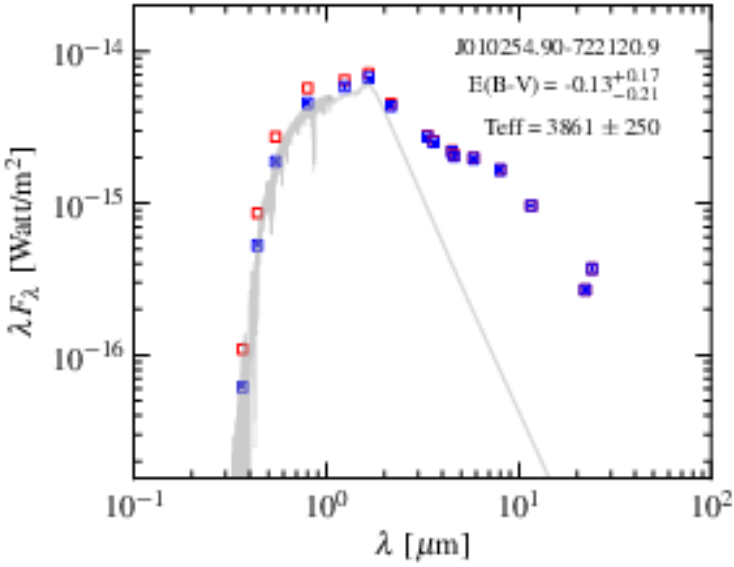


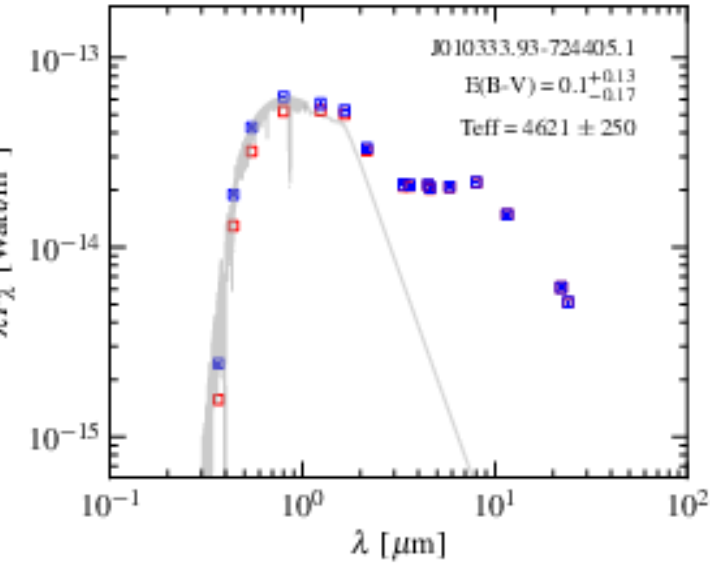


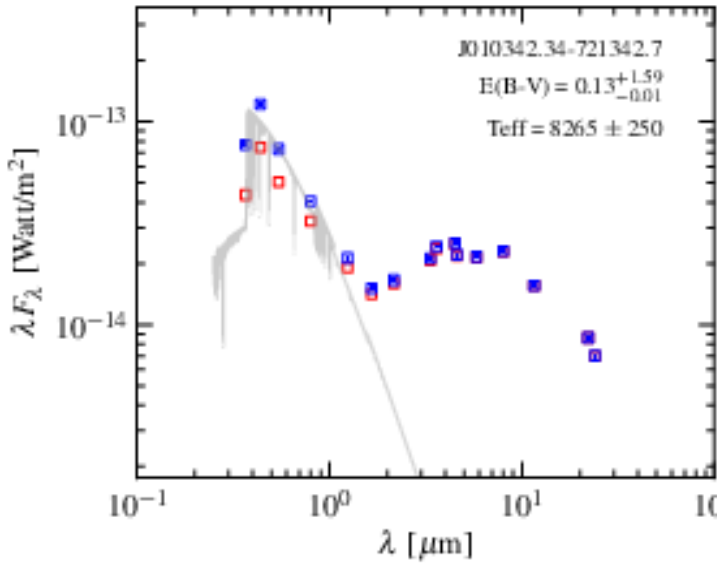
LMC-SMC: disc sources likely binaries

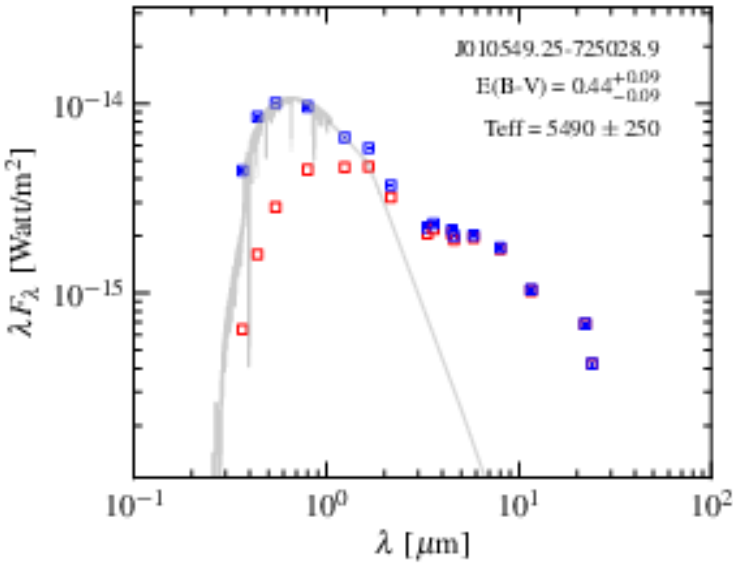






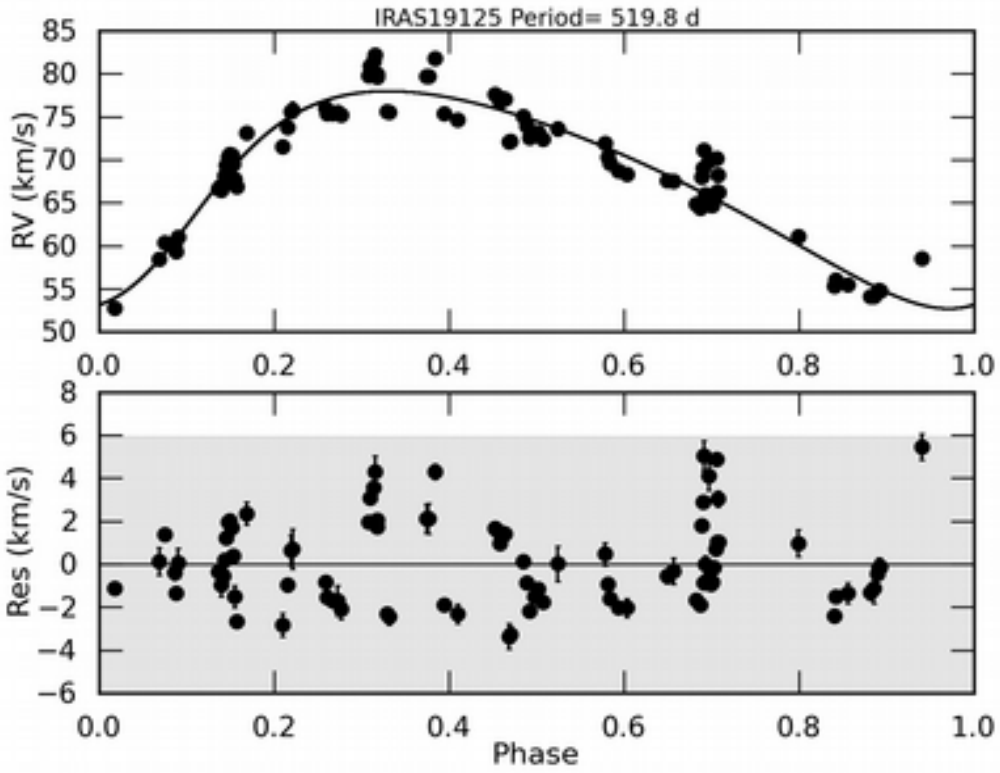




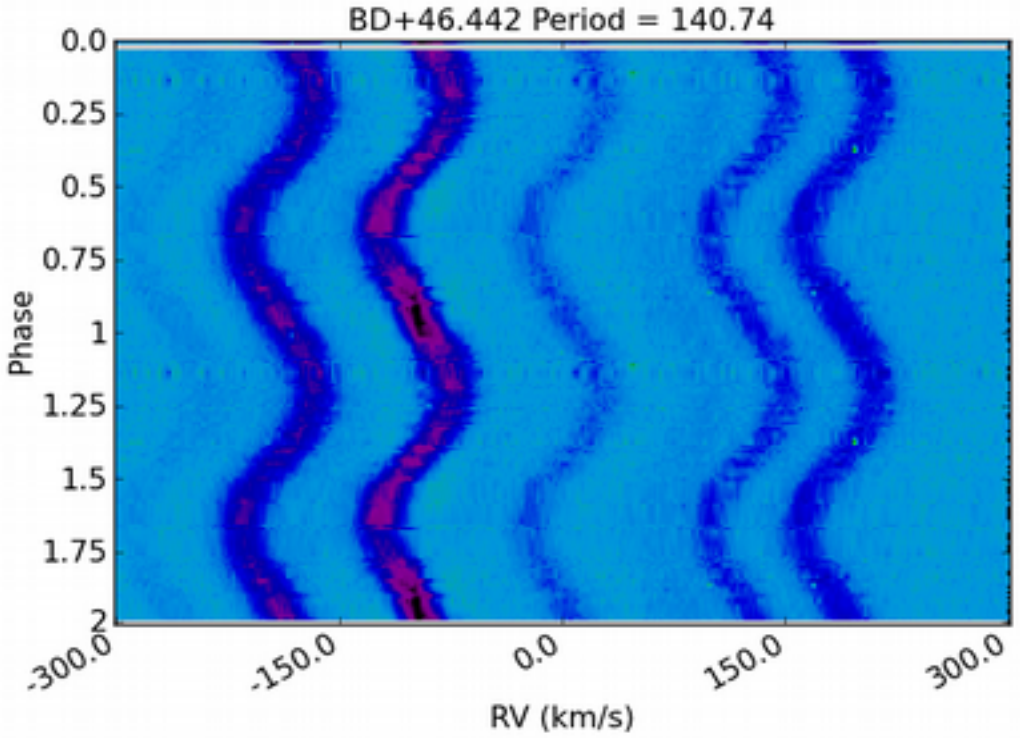


Kamath et al., 2014, 2015 + Next talk

Binarity rate disc sources: 100% (non pulsating ones)

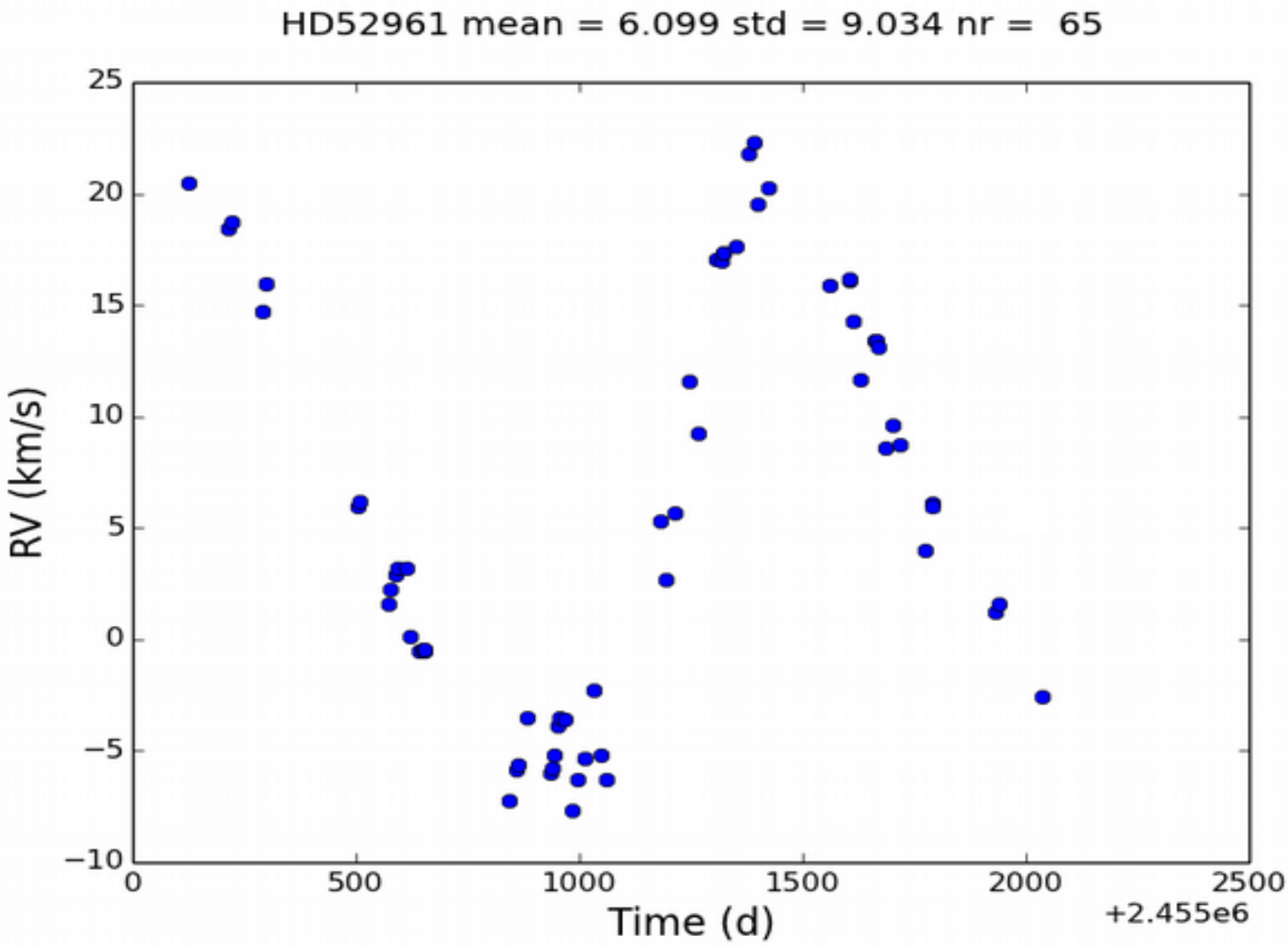


P = 520 +/- 2 d: Remain WIDE
e = 0.25 +/- 0.03
f(M) = 0.097 solar mass

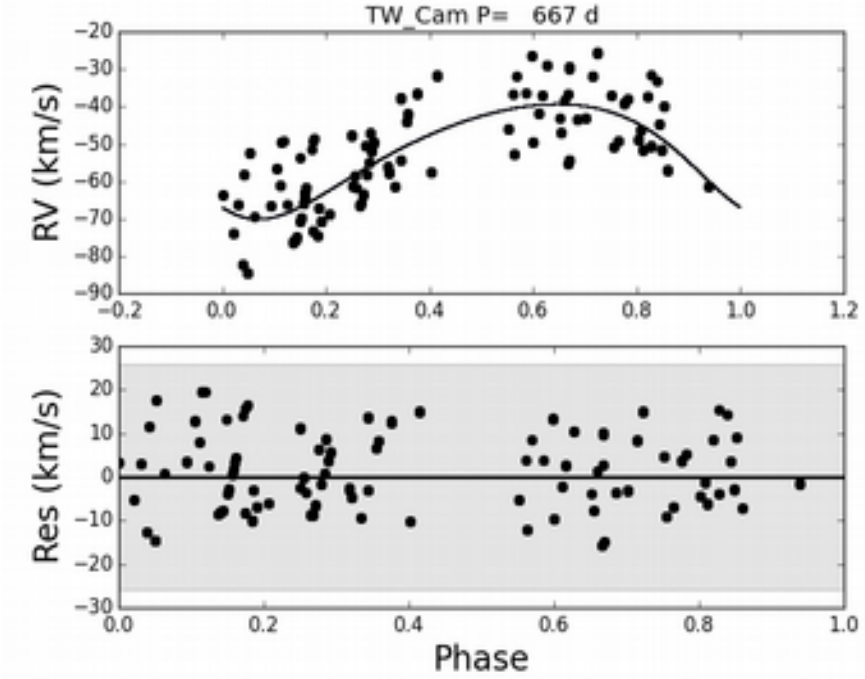


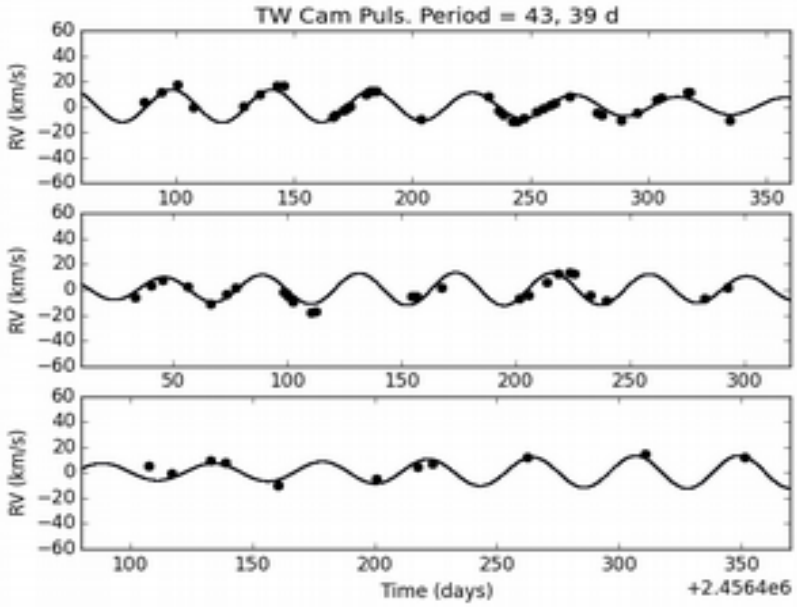
6/6 binaries, P between 120-1800 days

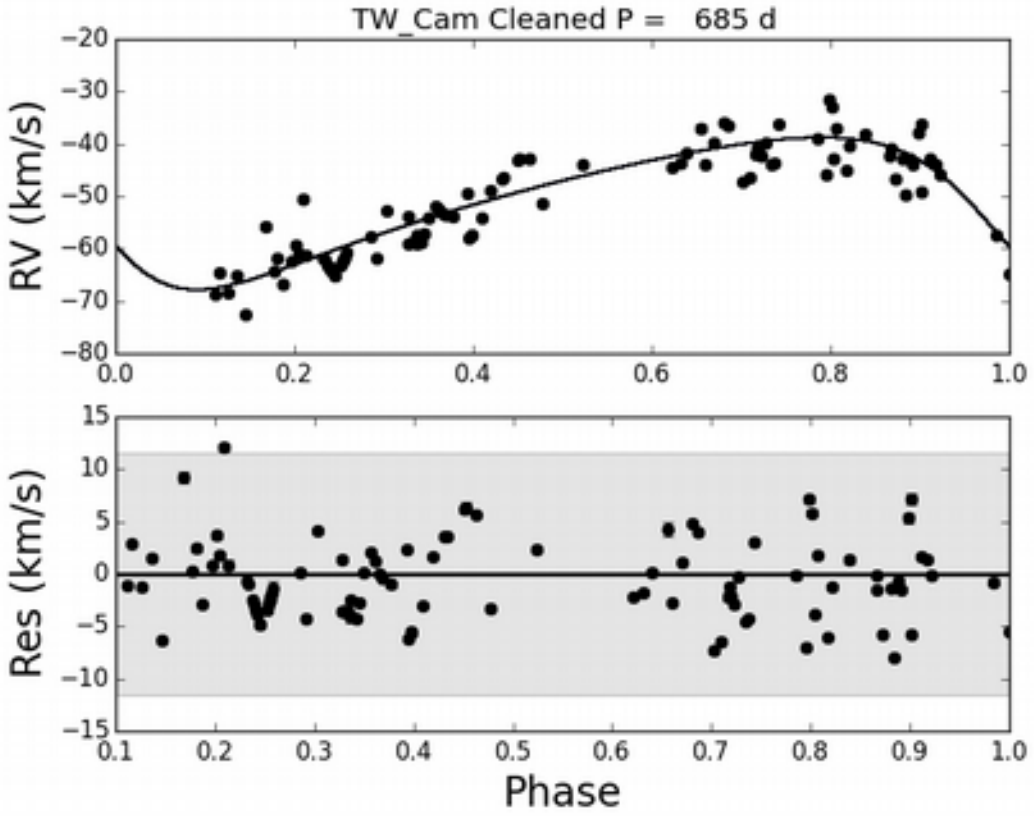
Van Winckel et al., 2009, 2012 ; Hrivnak et al., 2008,Gorlova et al., 2012, 2015


HD52961 mean = 6.099 std = 9.034 nr = 65
RV (km/s)
Time (d)
+2.455e6
25
20
15
10
5
0
−5
−10
0
500
1000
1500
2000
2500

Pulsators (RV Tau stars) and binarity





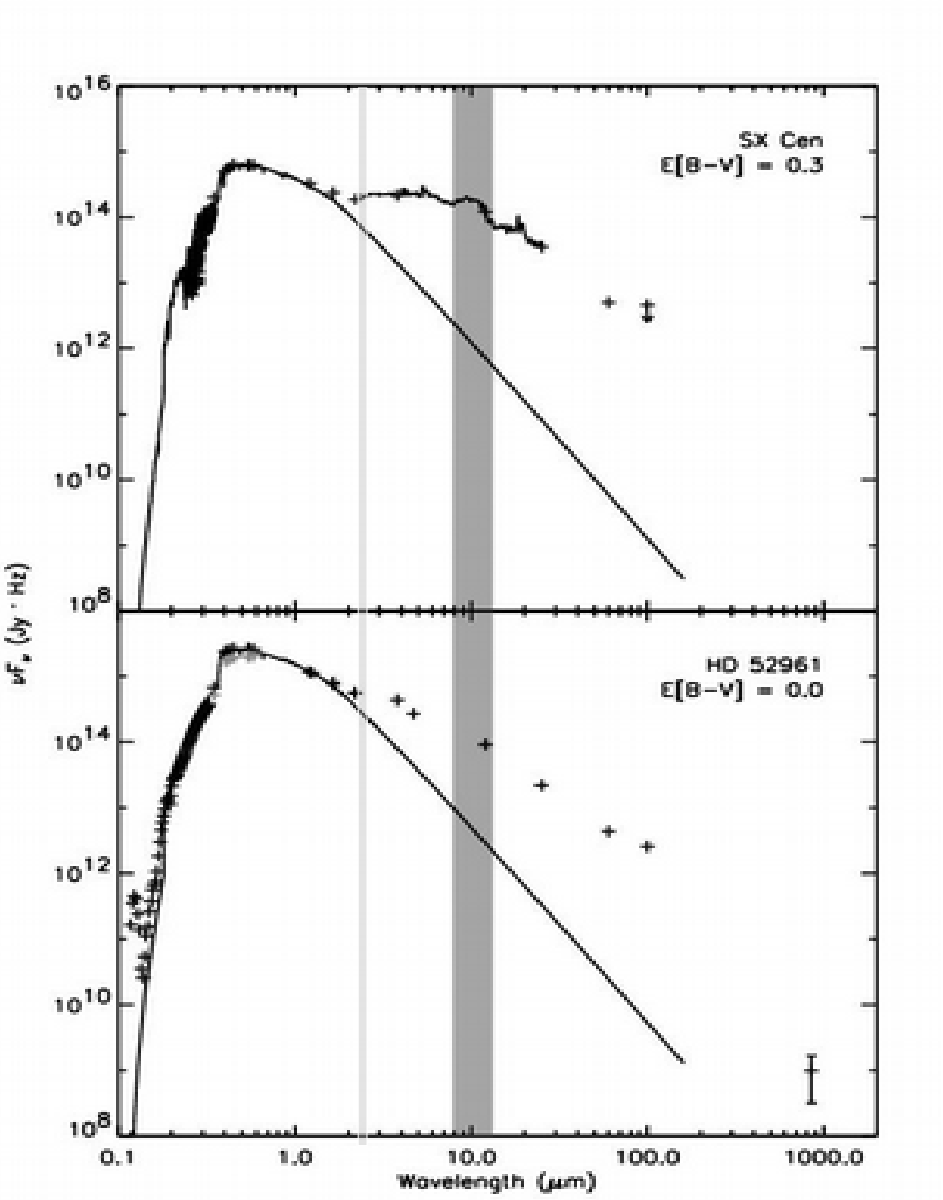


Large Amplitude Pulsations

Binary Motion

Manick R. et al., in prep

Interferometry: resolving the processed CS environment



The VLT Array on the Paranal Mountain

ESO PR Photo 16a/00 (24 May 2000) ©European Southern Observatory

MIDI : N-band: near peak SED

AMBER: photosphere-hot dust region

PIONIER: photosphere-hot dust region

scattering component

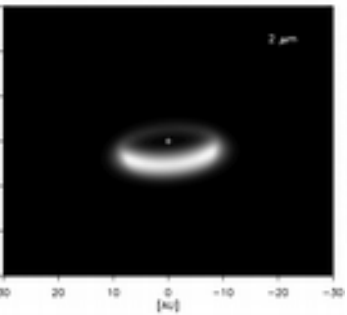
Olivier Chesneau connection

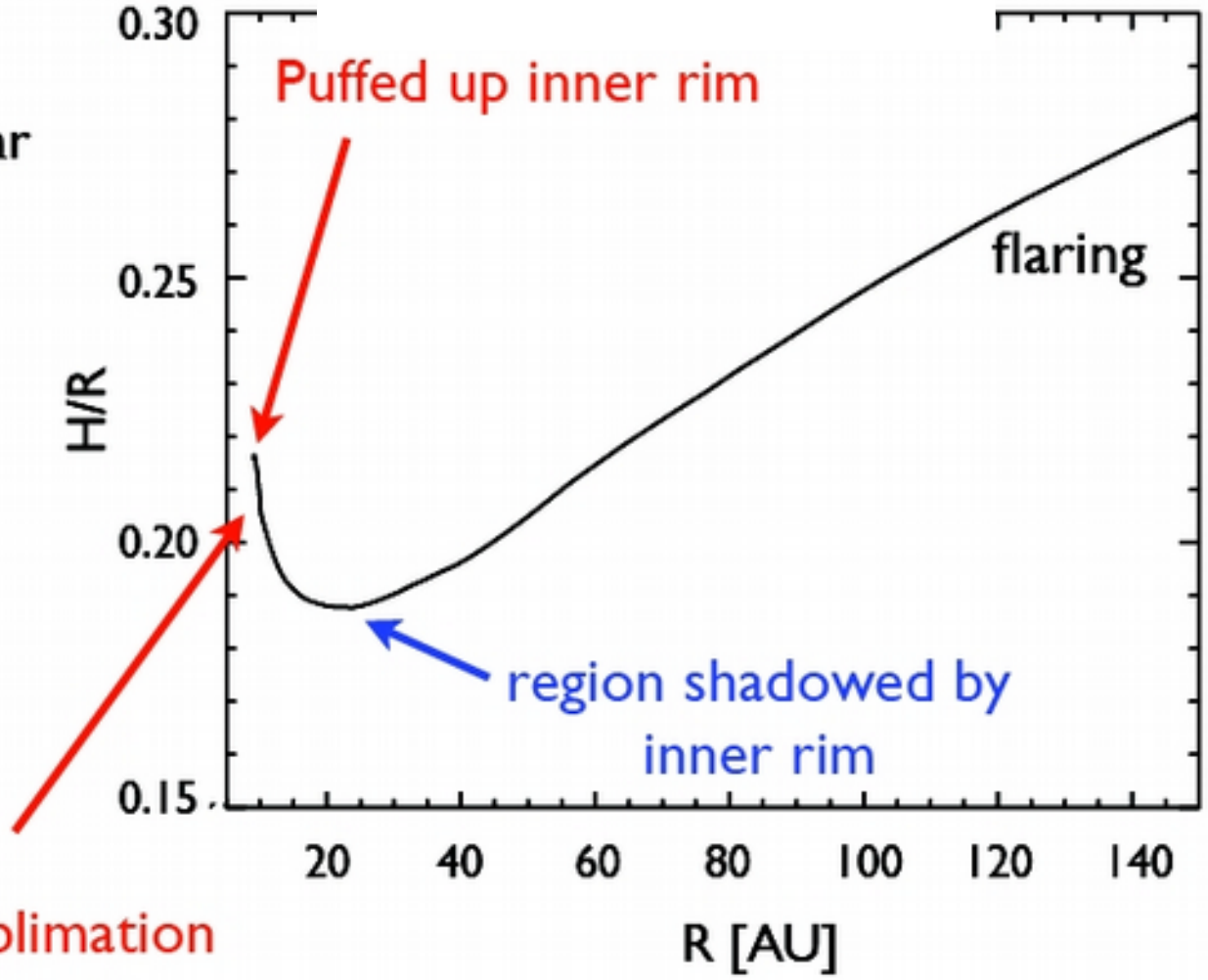
(hear talk Michel Hillen)

Basic Disc structure is like a protoplanetary discs

passive **disc** radiative transfer model: Dullemond et al., 2002; 2004

- mixture of gas and dust
- dust irradiated by central star
- structure:
  hydrostatic equilibrium
- dimensions:
  SED constrained
  - ➡ large and processed grains
  - ➡ R_{in} = 9 AU
  - ➡ H/R_{in} = 0.22
    (total height = 4.0 AU)

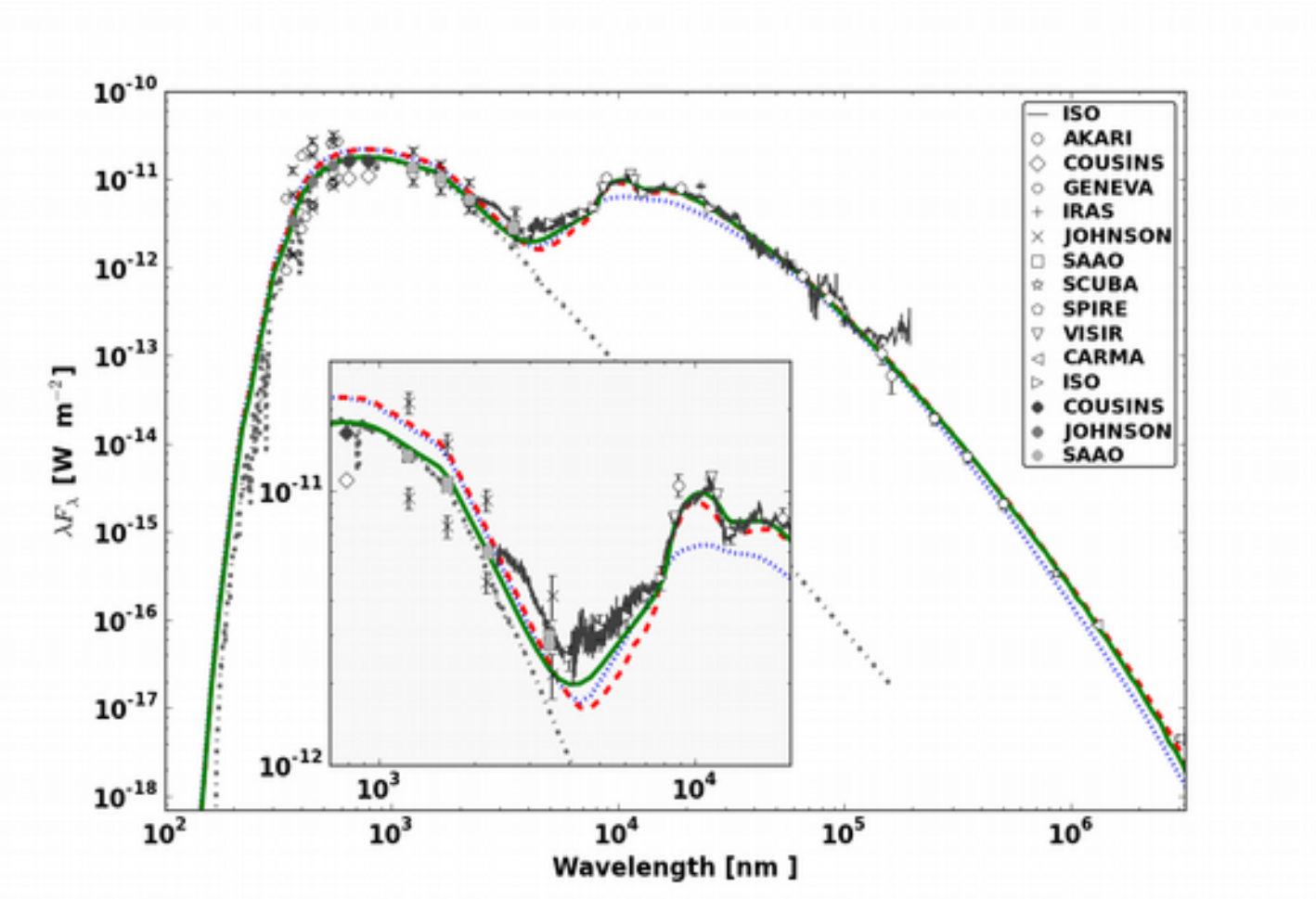




main difference with YSO: effective gravity is lower

Dominik et al., 2003, Deroo et al. 2006, 2007, Gielen 2008, 2009, 2011, Hillen et al., 2013, 2014

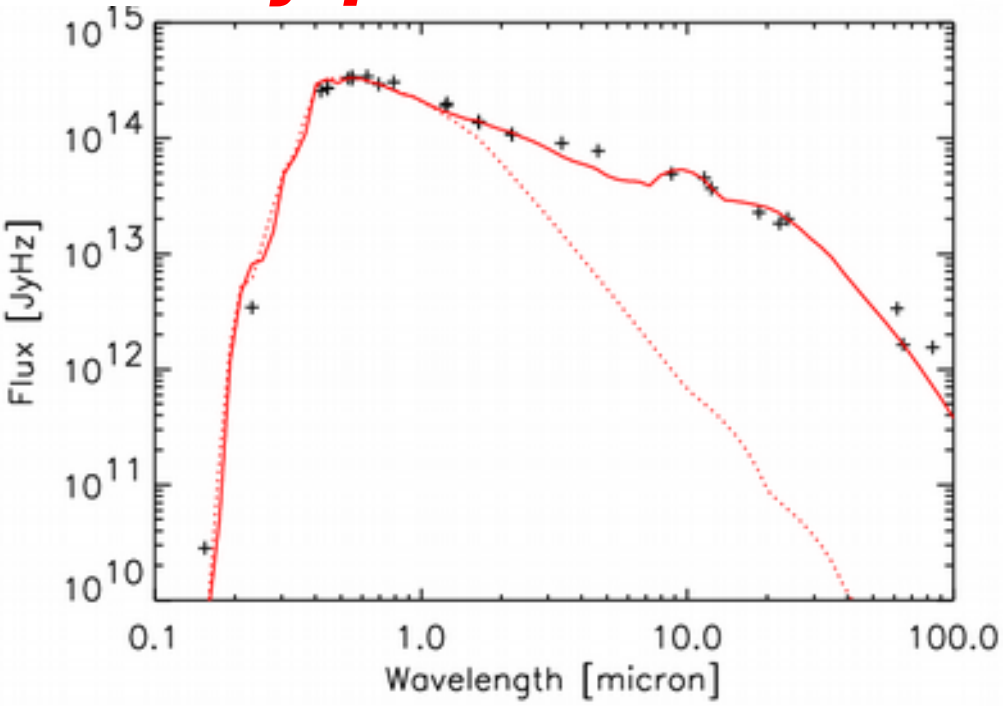
SED : RT models of stable passive discs work

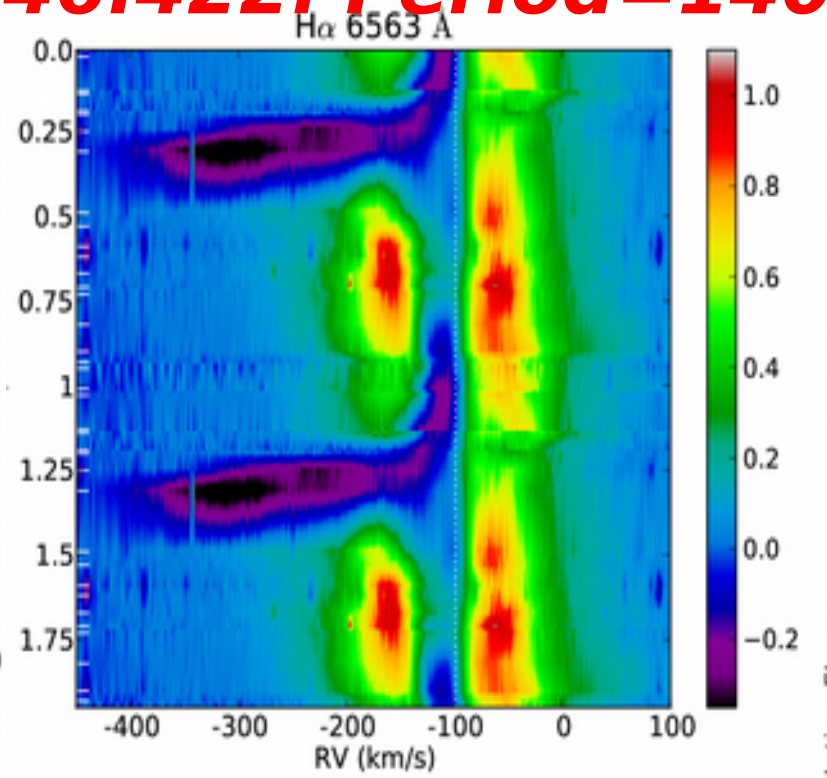


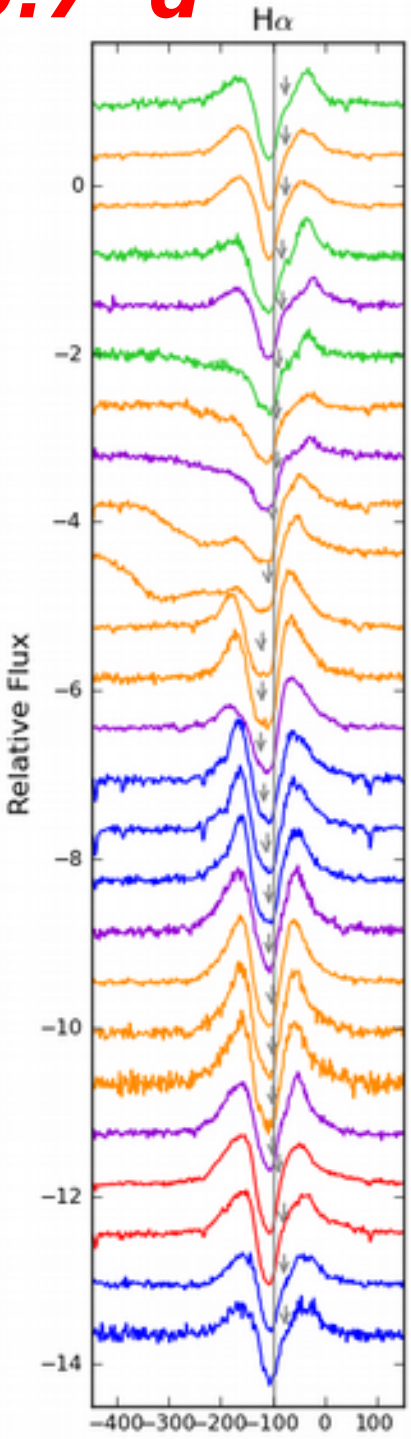
- large grains settle in midplane: you do need to take this into account
- large contribution of OPTICAL scattering ! (need for blue interferometry)
- MIDI survey: basic model works
  Talk Michel Hillen
- discs are rotating (PtB, ALMA)

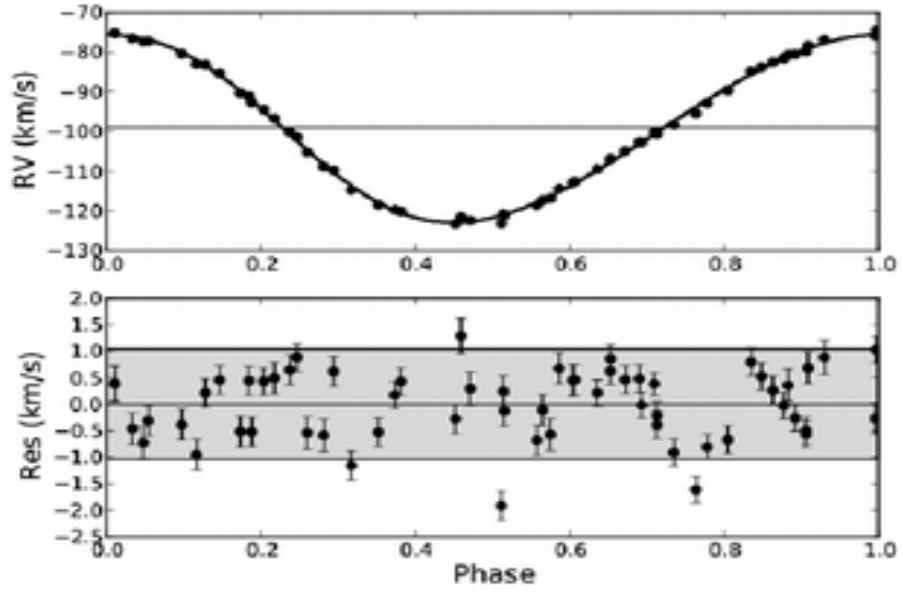
Hillen et al., 2013a,b, 2015; Hillen et al., in prep; Bujarrabal et al., 2013; 2015;

Binary processes: BD+46.422, Period=140.7 d







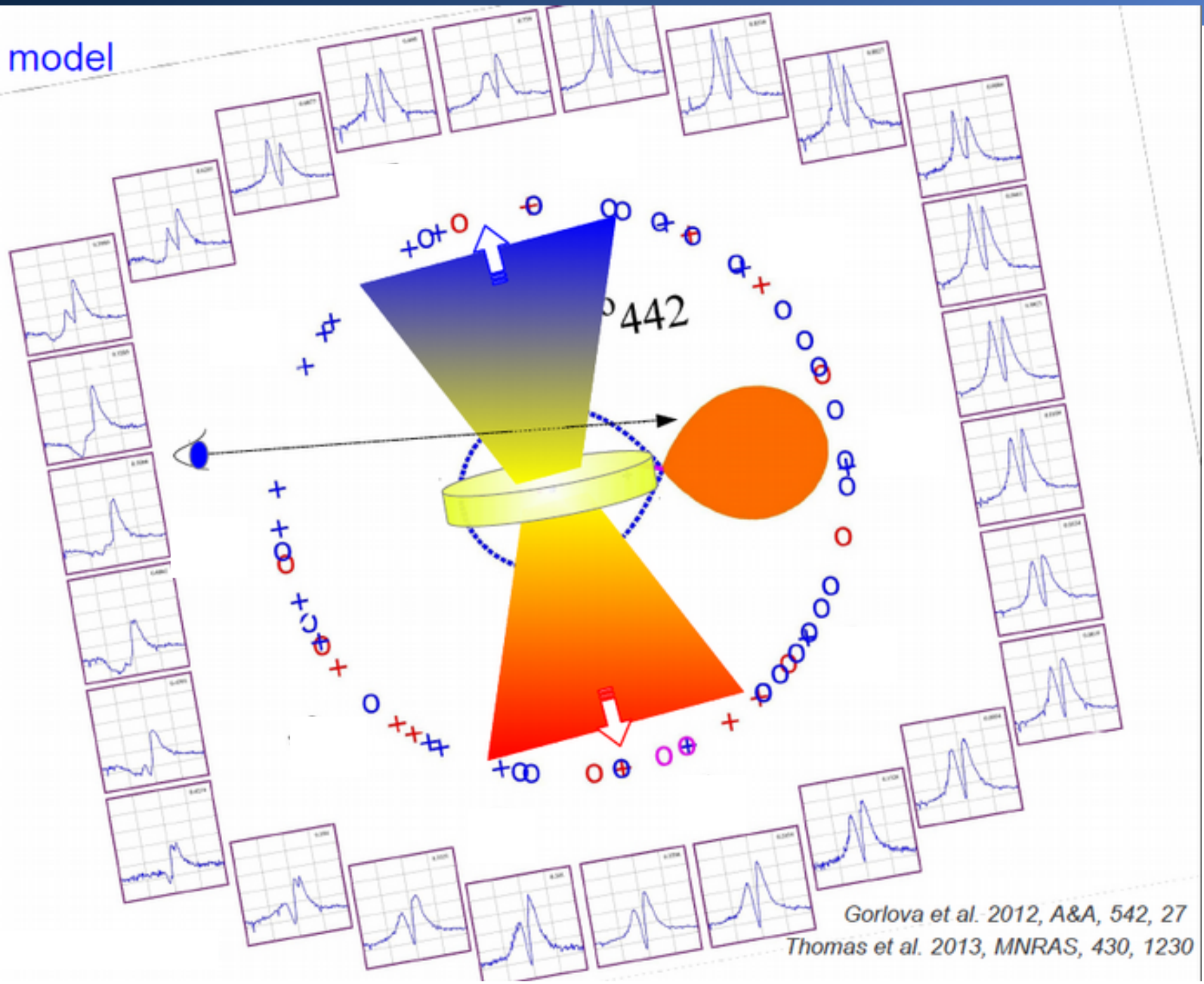


Binary + circumbinary disc

H-alpha: conjunction
Circum-companion disc +
jet seen in projection
onto the evolved primary

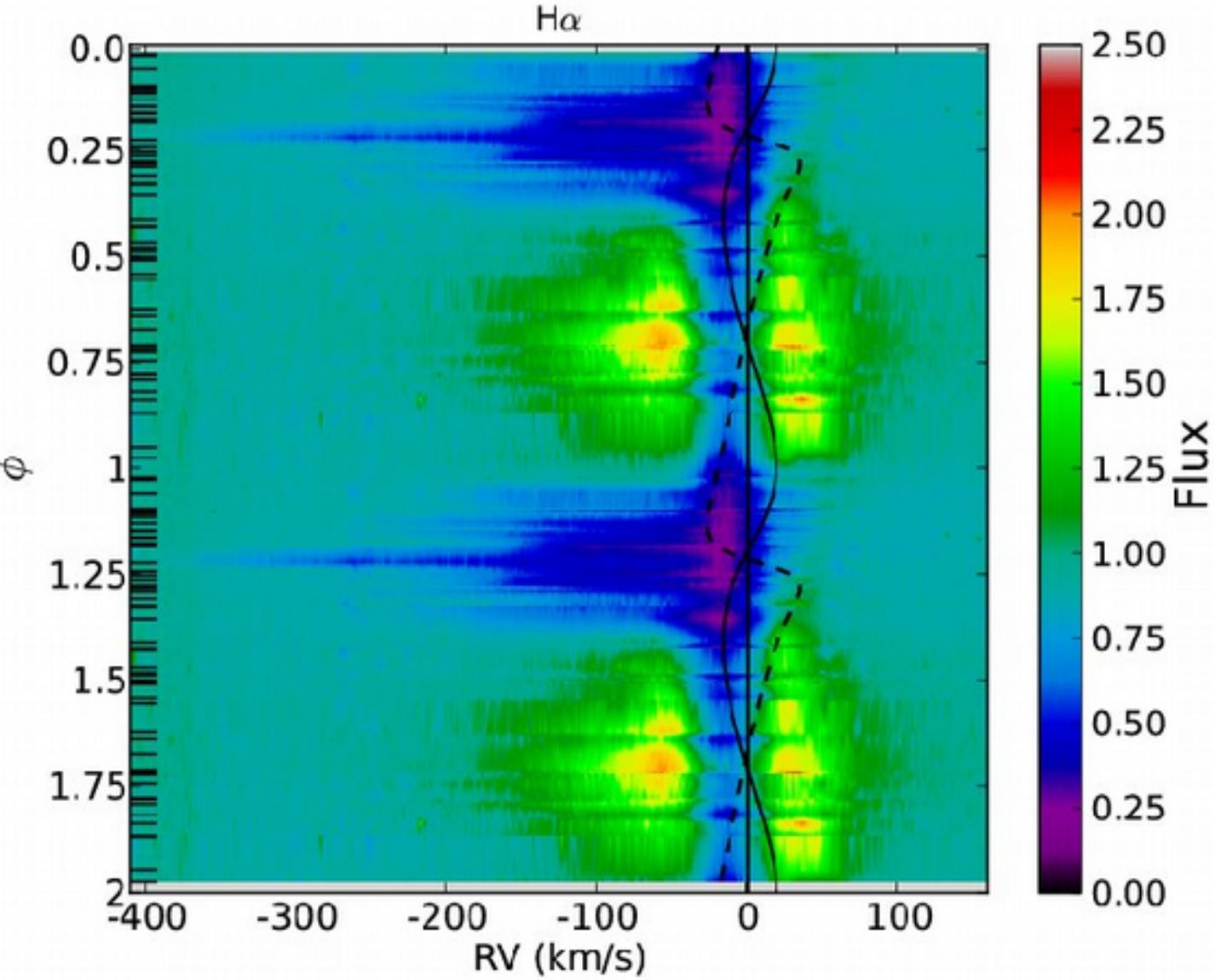
Gorlova et al., 2012

Jet model



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

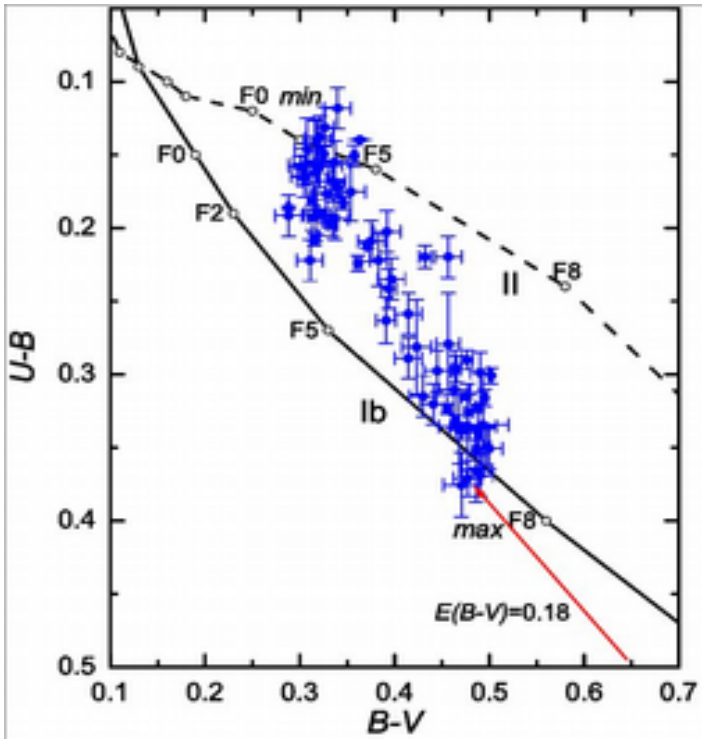
Jets are common: 2nd example



IRAS19135+3937

period: 127 d.

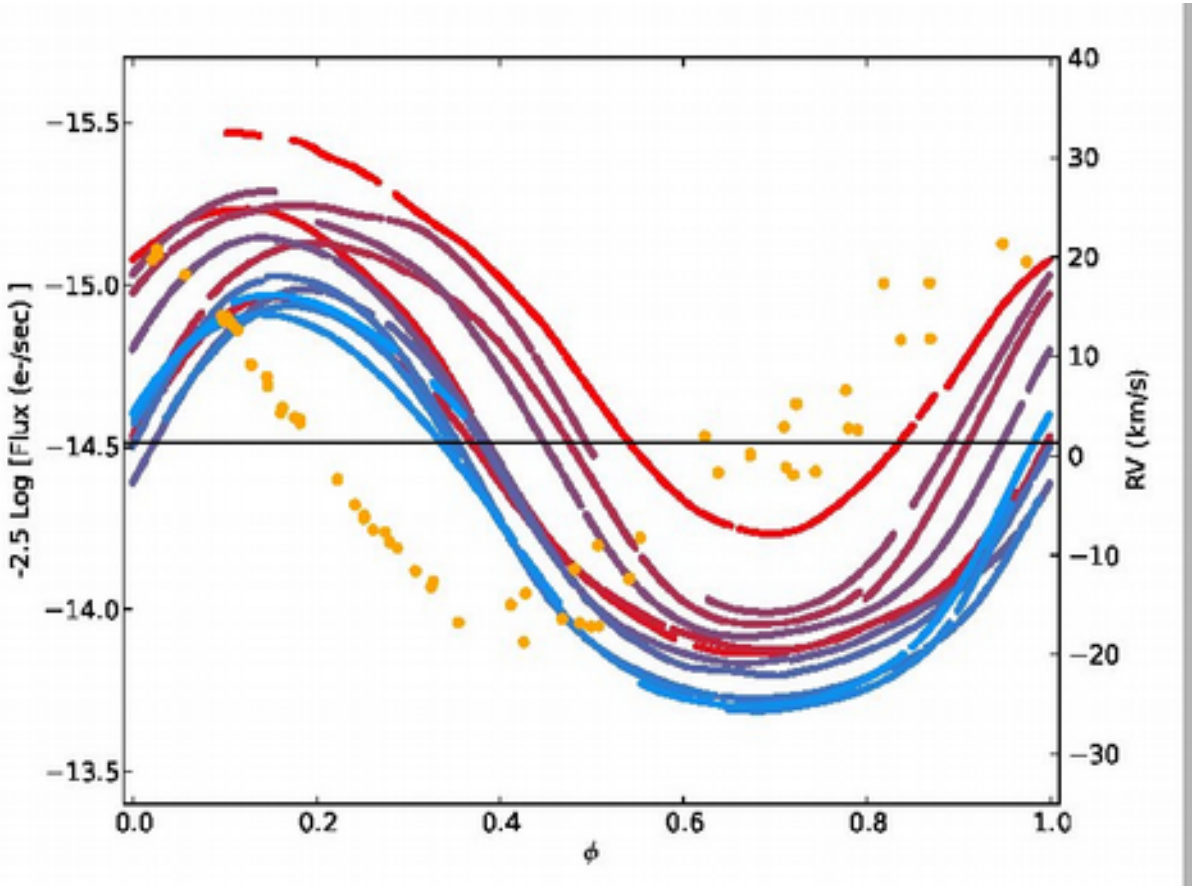
bluer when fainter

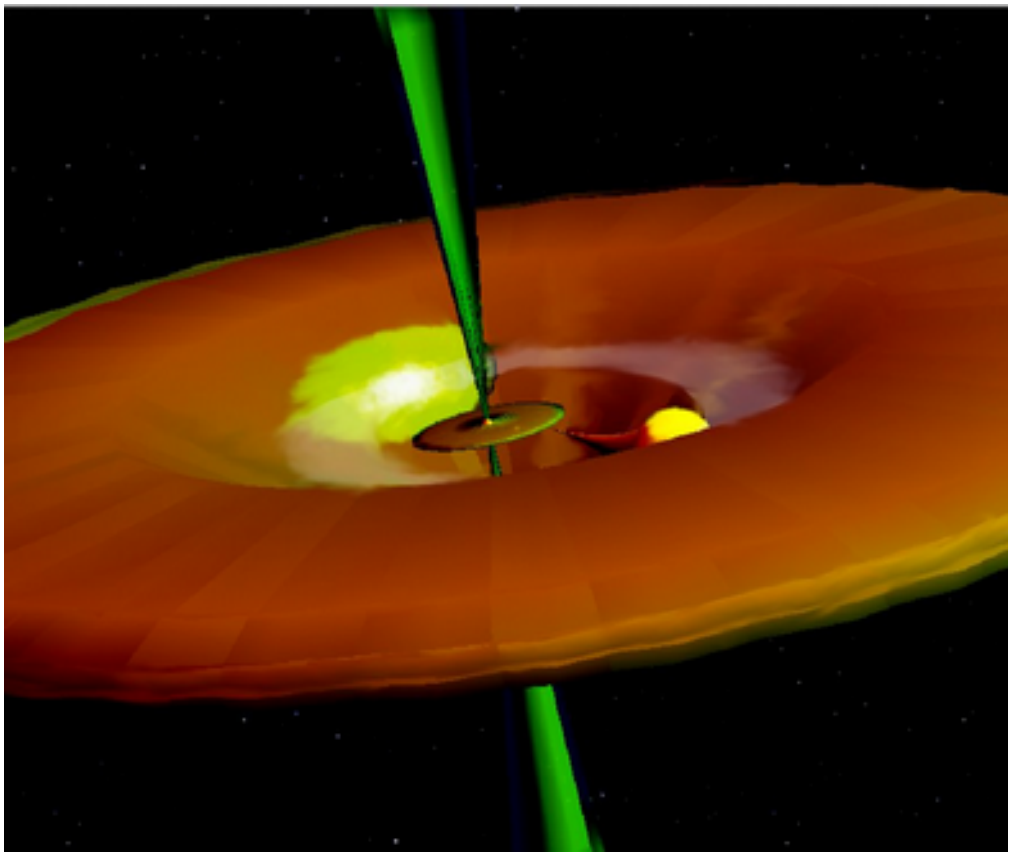


Gorlova et al 2015, in press

Detailed studies of Interaction processes

IRAS19135+3937

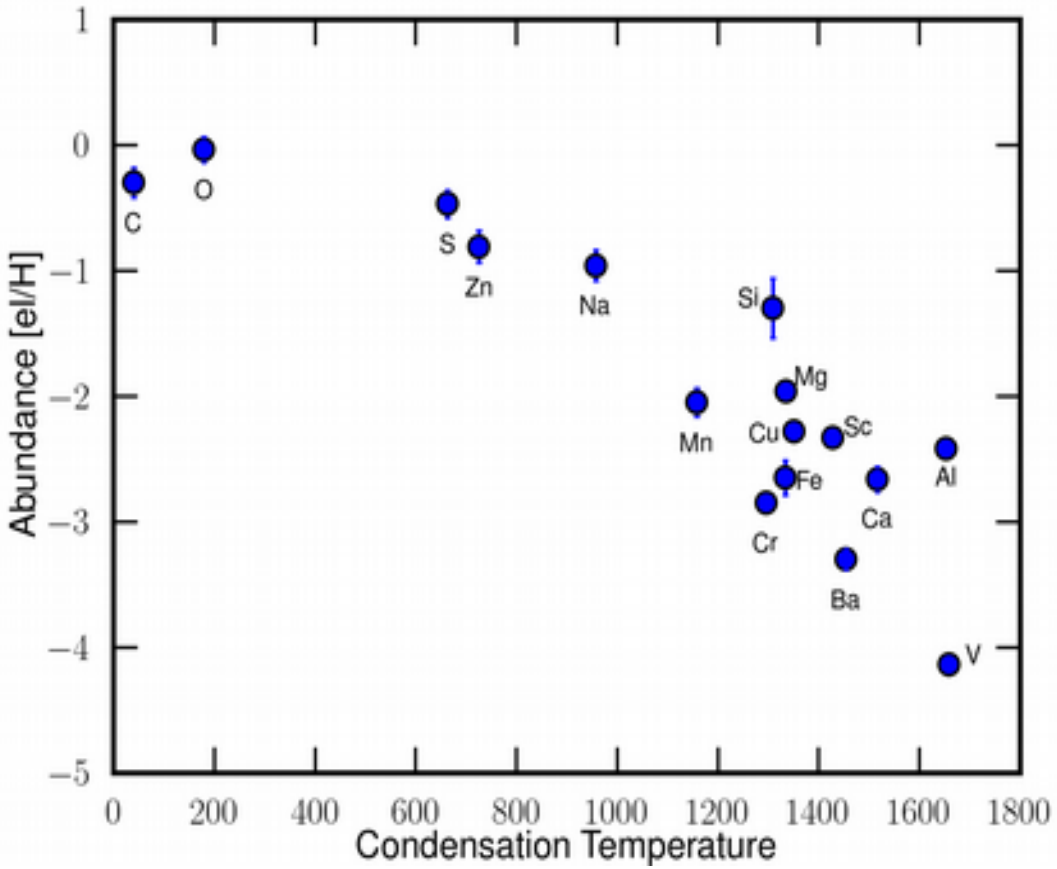




Kepler lightcurve: very smooth
P is orbital period

Gorlova et al. 2015, in press

Photospheric Depletion: Feedback from disc



Abundance patterns ~ gas phase abundance of ISM

You lose the nucleosynthetic history

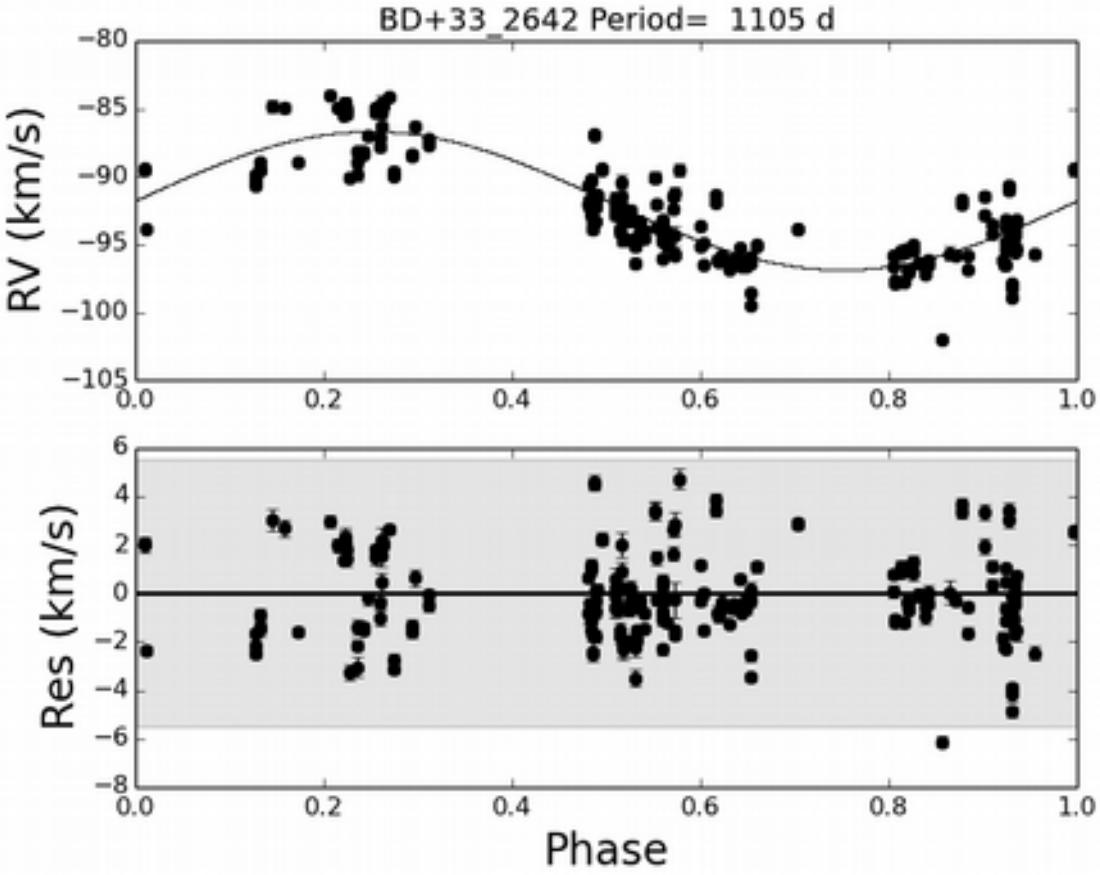
Can be very efficient (down to [Fe/H]=-4.8)

Accretion of circumstellar gas hence you slow down the evolution

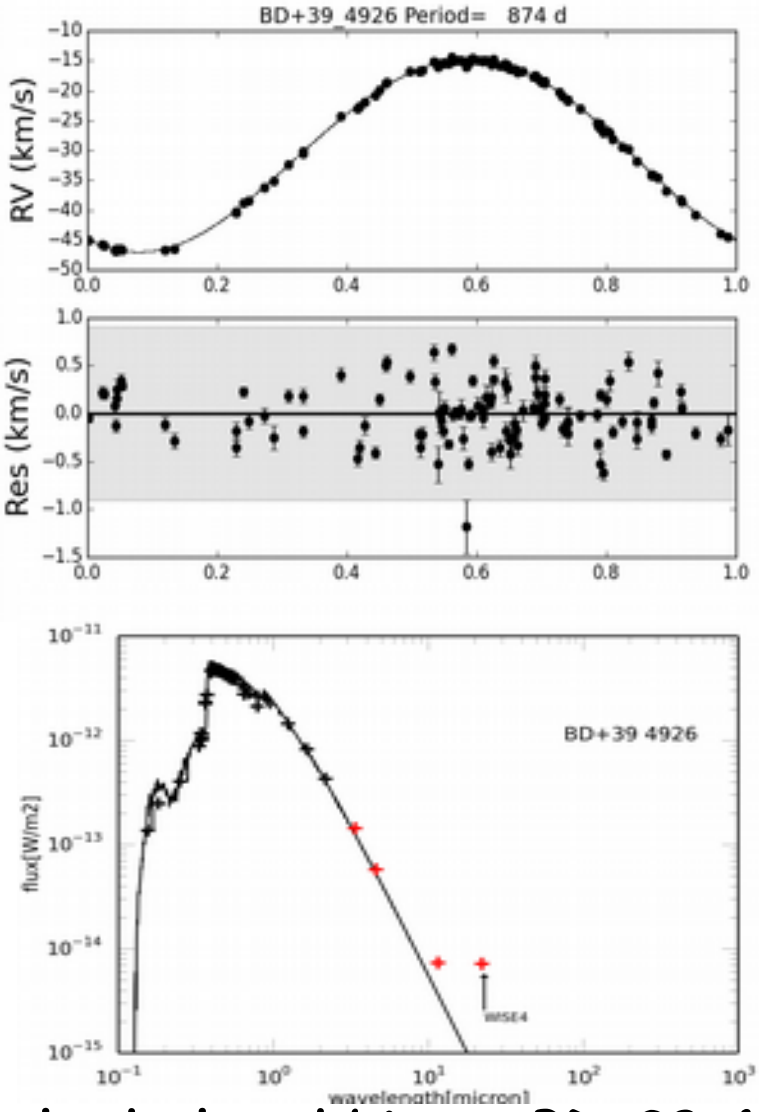
Disc is needed to guarantee low density and long timescale.

Waters et al., 1992; Van Winckel et al., 1992, 2003 ; Giridhar et al., 2005; Gielen et al., 2009, Rao 2013 etc

Photospheric Depletion: last long, longer then lifetime disc



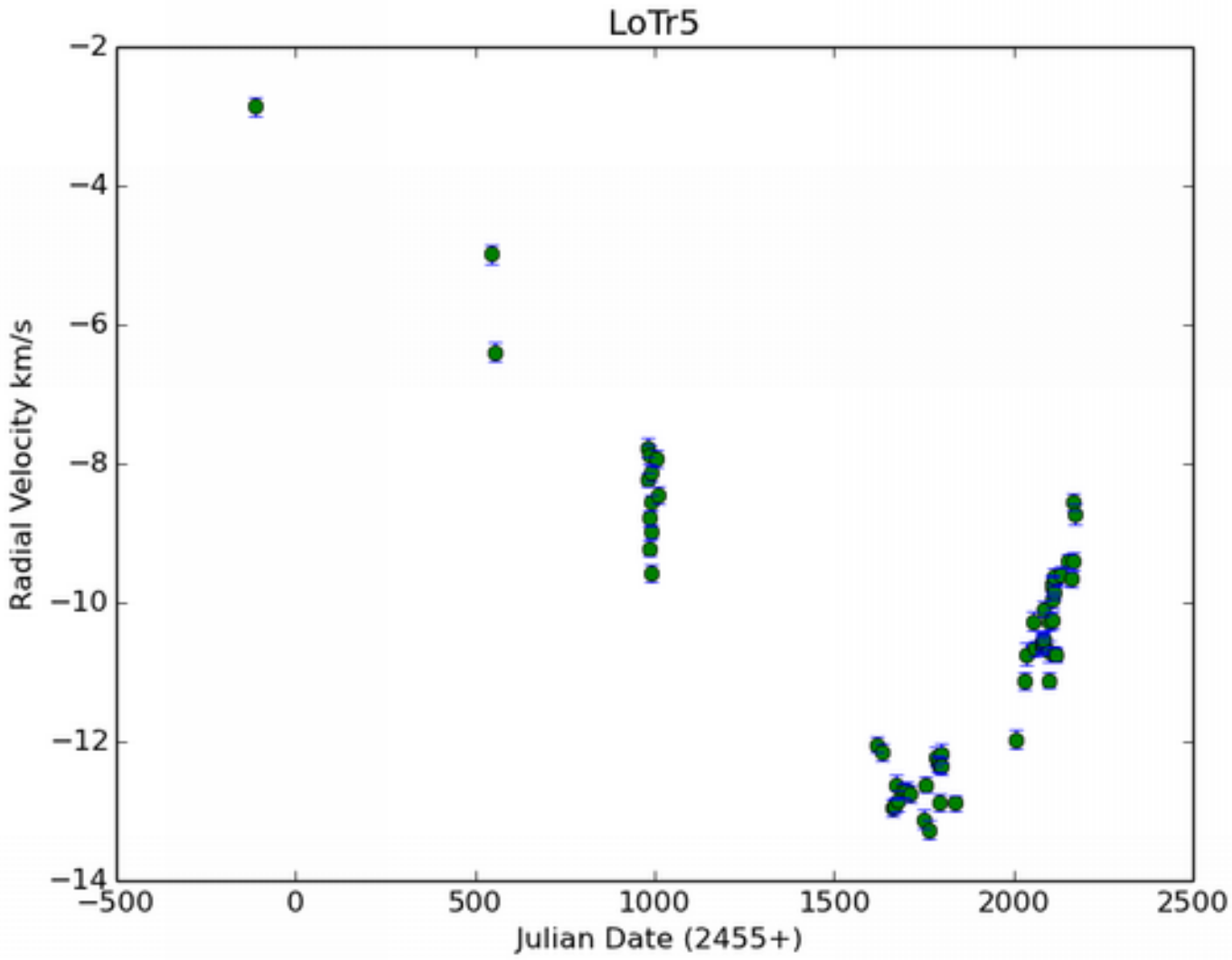
PN BD+33 2642 is depleted



Strongly depleted binary BD+39 4926 has a small IR excess

Venn et al., 2014; Napiwotski et al., 1994, Van Winckel et al., 2014; Gezer et al 2015 subm.

PNe: wide binaries: LoTr5



Companion:

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

Van Winckel et al., 2014

Compact Keplerian Discs in Post-AGB stars

- Circumbinary
- Associated with binary evolution : avoid spiral-in !!
- Commonly observed (also in LMC and SMC) (talk Devika Kamath)
- Ongoing strong interaction (accretion discs around companions; jets are common and originate at the companion)
- Scattering in visible can be very large. Energetics !
- Impact strongly on the evolution
- Resolvable from inner rim (optical interferometry) to outside (ALMA,PdB) despite their distance (talk Michel Hillen)
- Longevity impacts on orbital parameters (talk Joris Vos)

How do they form and how do they evolve ?

Directions for (future) research

- Formation, Structure and Evolution of the Keplerian discs
  (PIONIER (J-band PIONIER?), ALMA, MATISSE, Sphere)
- Binary orbits and eccentricity
  (e-pumping mechanisms, pop synth.studies)
- Sample studies: exploit distribution (f(M), e-log(P))
- LMC+SMC exploitation
  (radvel monitoring (!) with big telescopes, ALMA,
  VISIR, theory tests are best there !, statistics)
- Connection with (P)PNe (jet formation is seen + resolved)
- Connection with other systems (Ba family, CEMP-s, CH,
  symbiotics, sdBs): exploit the samples !
- Hermes+Mercator good compliment to study binary physics