AGB → Post-AGB → Pne

Fast evolution ! ~ 1000- 100000 years

3000K to 100 000K

R_* ~1 AU on the AGB to ~ R_{wd}

Variable (Pop II Ceph. Instability strip) often with large amplitudes

From very obscured to naked

Very diverse and prone to a large variety of observational biases...

Van Winckel et al., 2003, ARAA 41, 391

Toruń catalogue for Galactic post-AGB *

Challenges which I won't cover:

- Shapes and shaping in (proto-)planetary nebulae and role of binary interaction processes are not understood.

- Nucleosynthesis as detected in post-AGB photospheres not too well understood (most s-process rich stars non-enriched stars as well, diverse in ls and hs, but O richer and Pb poorer than expected).

- Very detailed studies of individual objects prevail but they connect not very well by evolutionary channels: AGB, post-AGB and PNe samples.

Outline

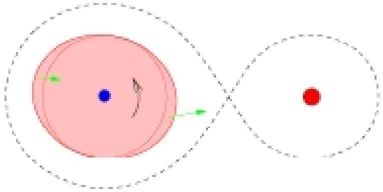
- Intro
- Post-AGB binaries and their circumbinary discs
  - Binary characteristics
  - Jet creation observed: circumcompanion
  - Resolving the second generation of proto-planetary discs
    Multi-wavelength interferometric surveys
  - disc-binary interaction: depletion + lifetime

- Keplerian discs are fundamental to understand properties and evolution of interacting evolved binaries

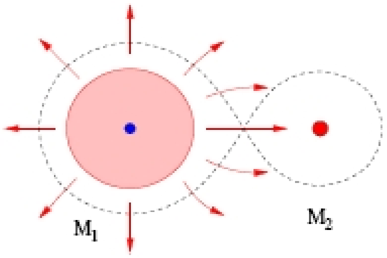
Hans Van Winckel; Michel Hillen; Devika Kamath; Rajeev Manick; Shreeya Shetye; Dylan Bollen; Ana Escorza Santos, Peter Wood; Valentin Bujarrabal; Alain Jorissen; Sophie van Eck; Lionel Siess, Jacques Kluska

Binary Evolution

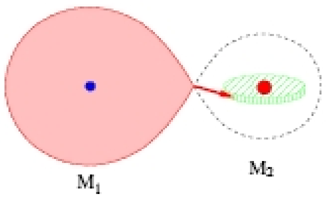
stars in binary systems can interact in various ways:



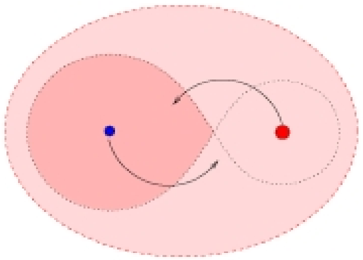
tidal interaction



wind accretion & tidally enhanced winds



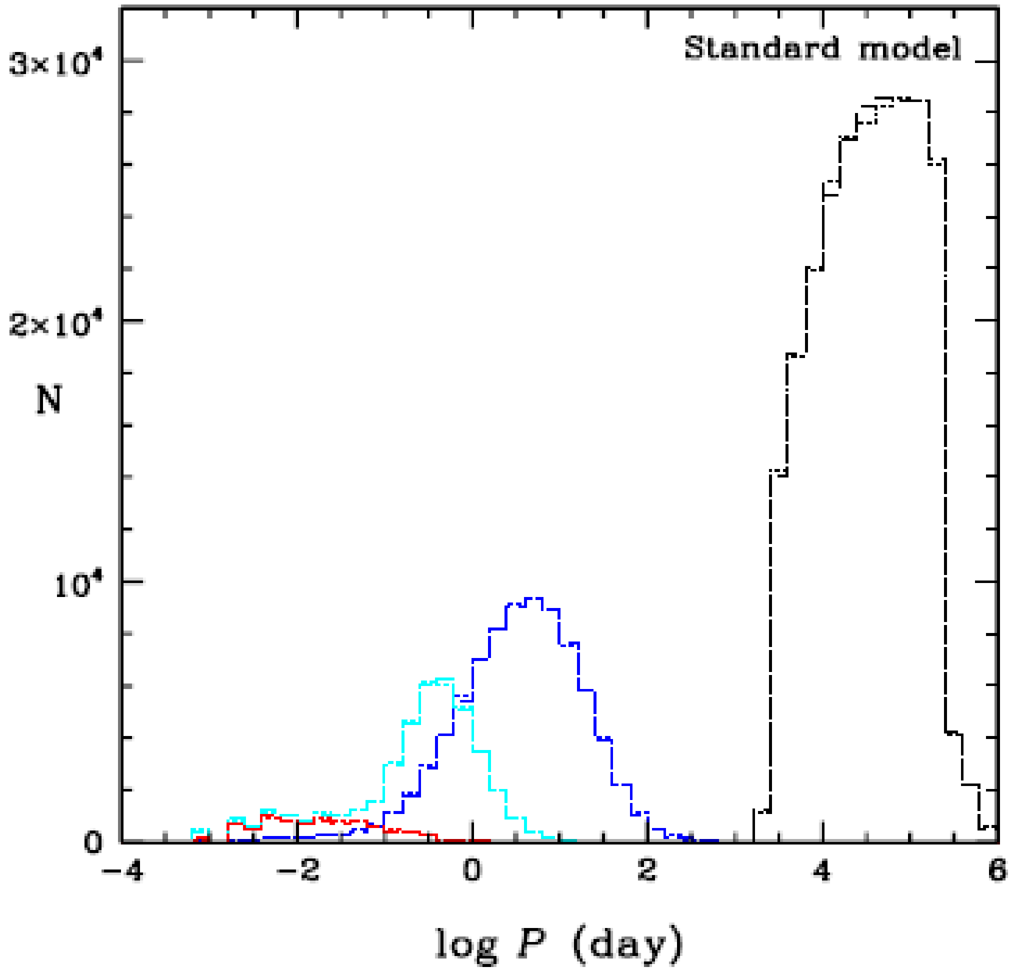
Roche-lobe overflow



common envelope evolution

Fig. from Pols.

What we expect: Orbital evolution low to intermediate mass stars



Population Synthesis:

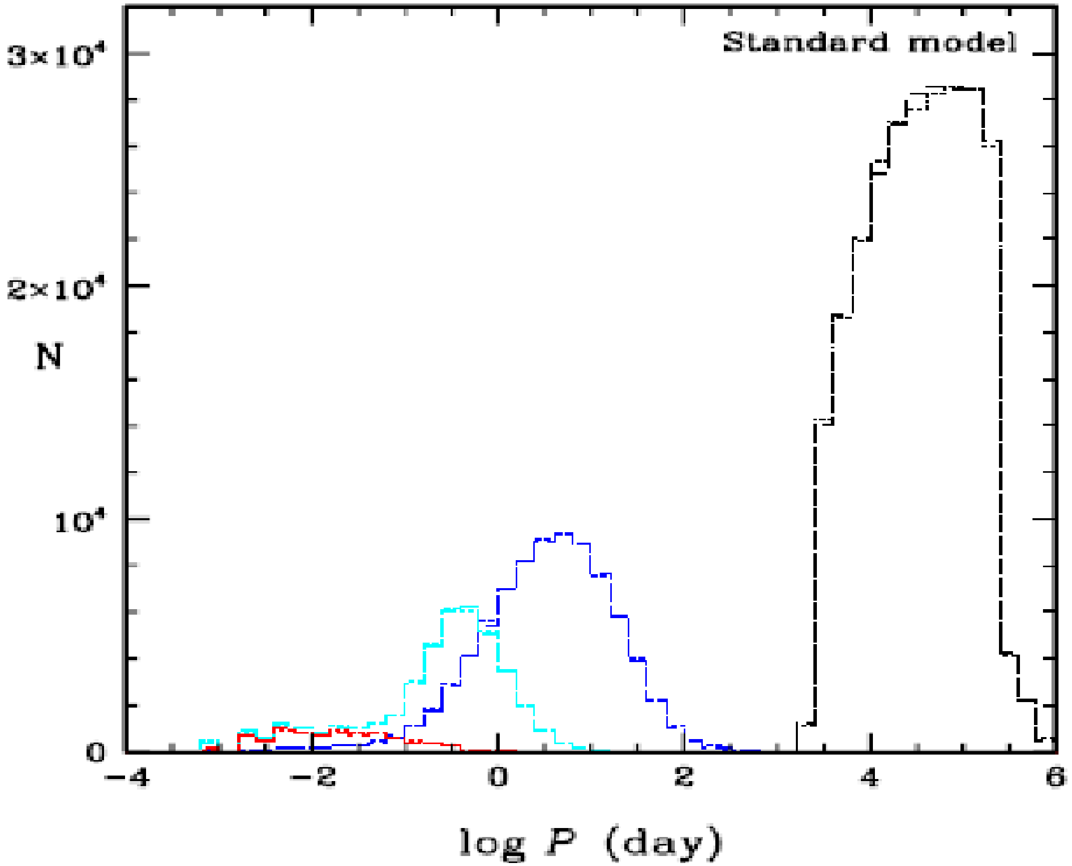
Prediction: bimodal distribution

Common Envelope Results: inspiraling

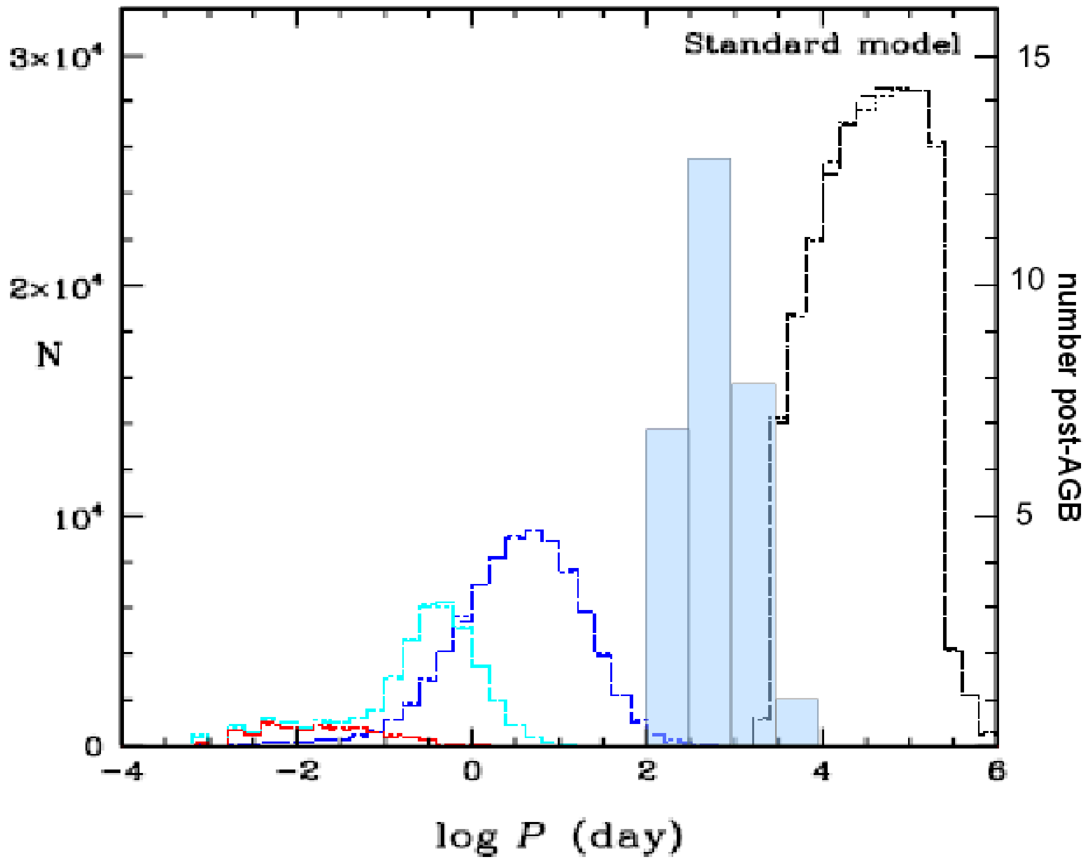
Wind transfer

Nie et al., 2012, talk of Pols yesterday

New interaction physics is needed



Pop. synthesis Nie et al., 2012



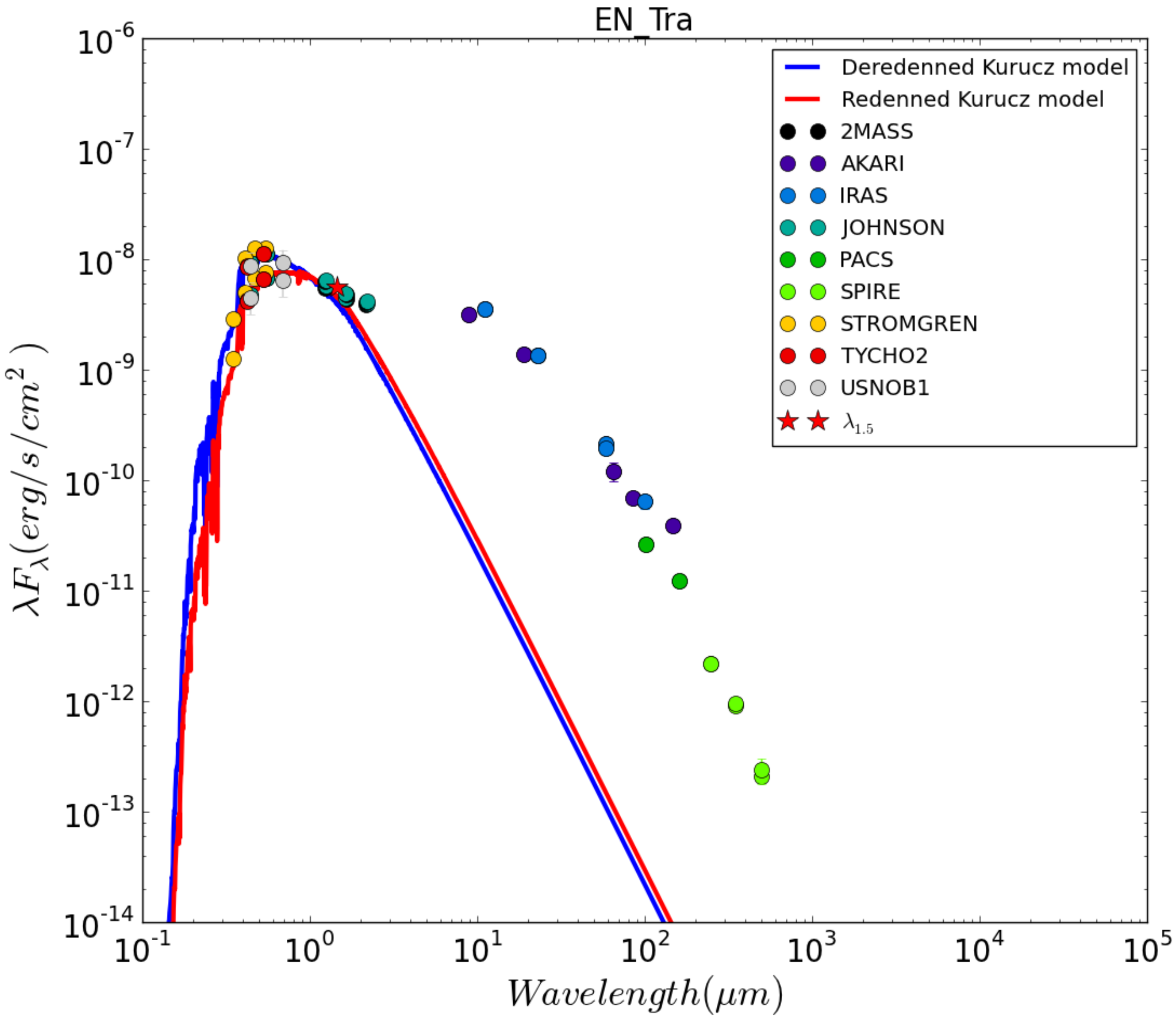
What we observe

SED of a post-AGB binary: disc sources

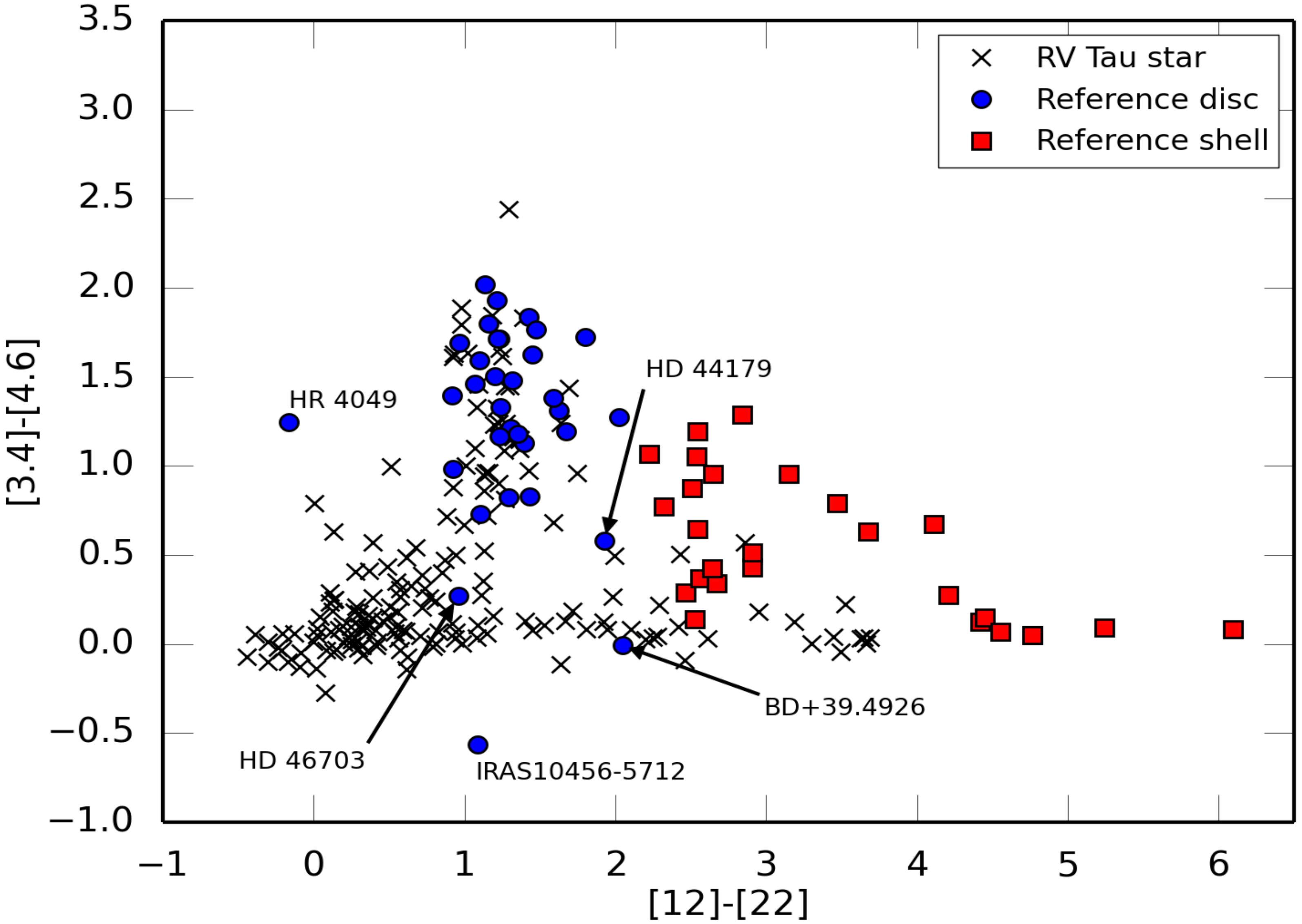
Central star is typically F-K star

No current dust production

Hot dust component is indicative of Keplerian disc



Wise view: selection criteria

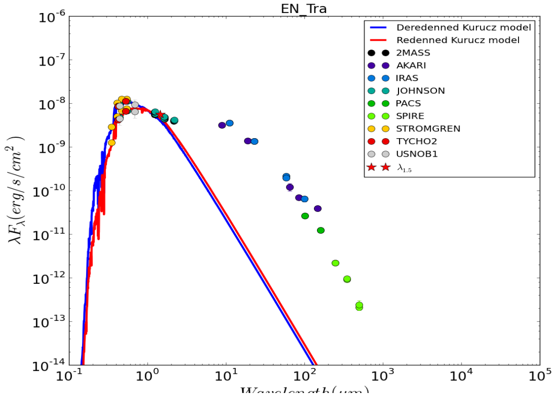


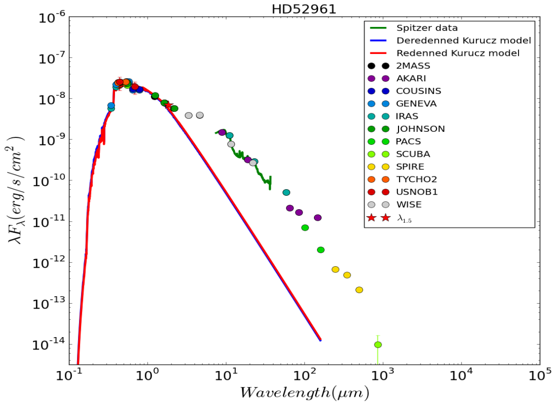
Discs cluster in colour-colour diagram

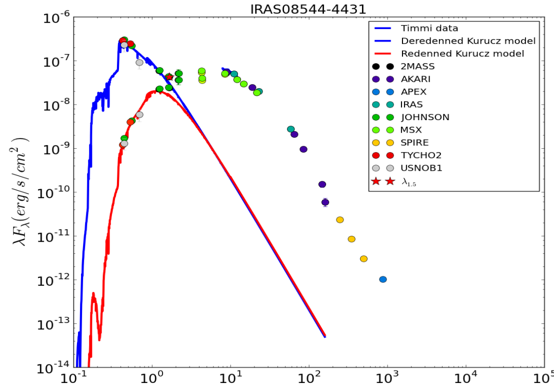
Good selection criterion

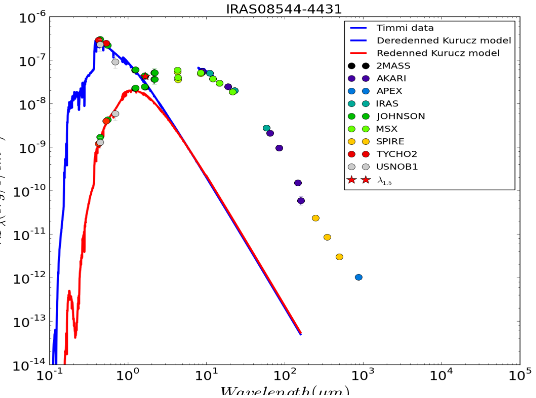
Kamath et al., 2014, 2015; Gezer et al., 2015

SED : commonly observed









SED very similar :

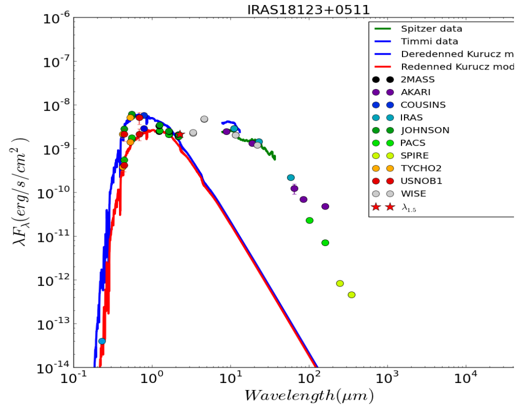
Dust excess stars near sublimation

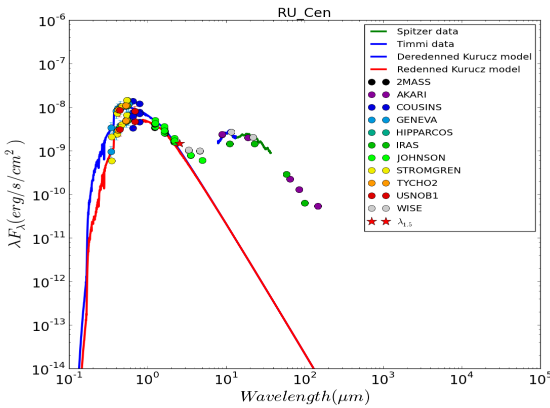
No present dusty mass loss

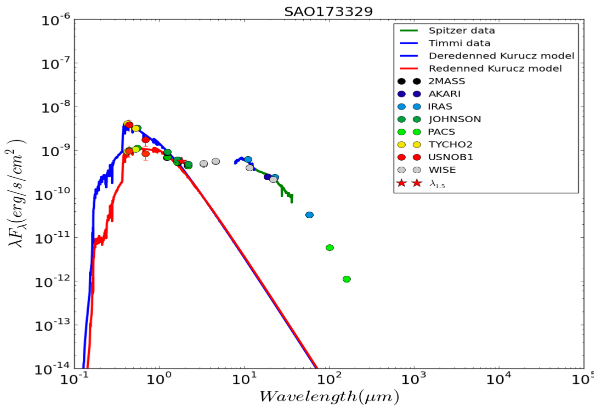
Galactic sample: +/- 80 sources

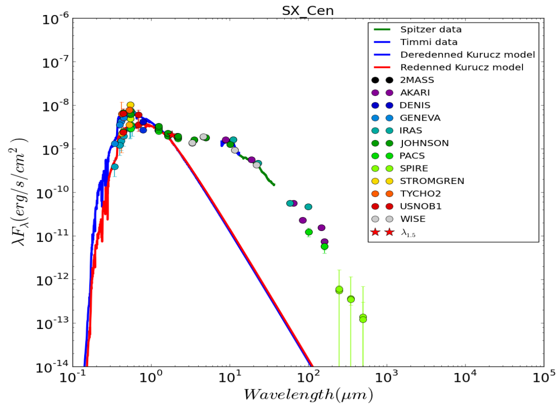
LMC and SMC sample is large

(talk of Devika Kamath)









Mercator: Niche in observational astrophysics

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

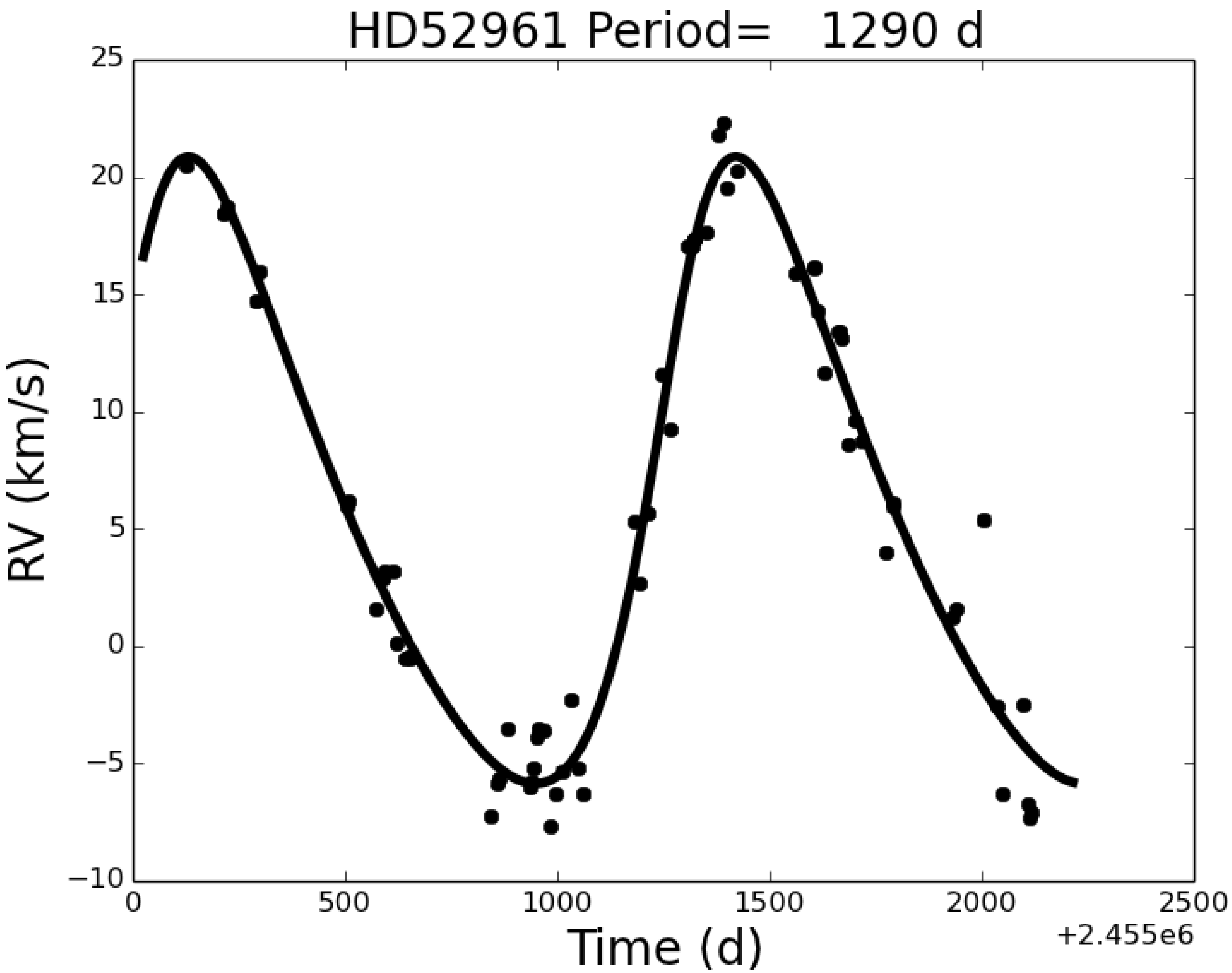
Requirements:
HERMES high-resolution spectrograph (since spring 2009)
Operational model: Pooled observations with priority driven scheduling.

Userfriendly robust operational environment

Large programme (KUL, ULB, ROB)

fwo Science Foundation Flanders

Binary post-AGB stars



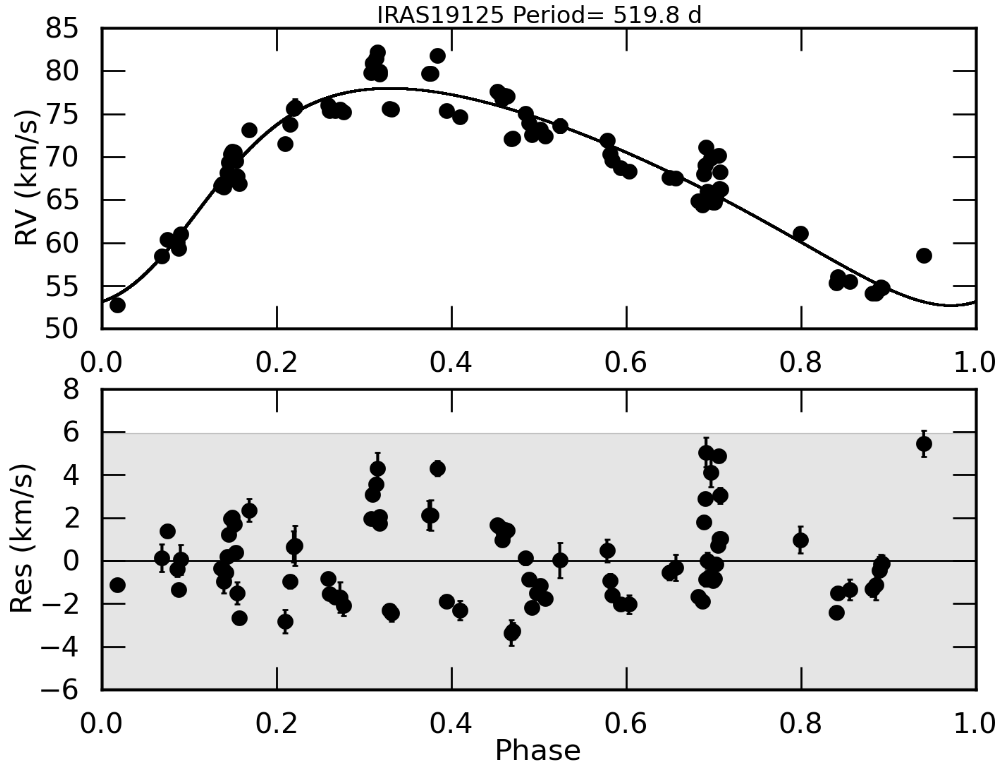
Typical Orbital Periods:
150-2000d
often eccentric

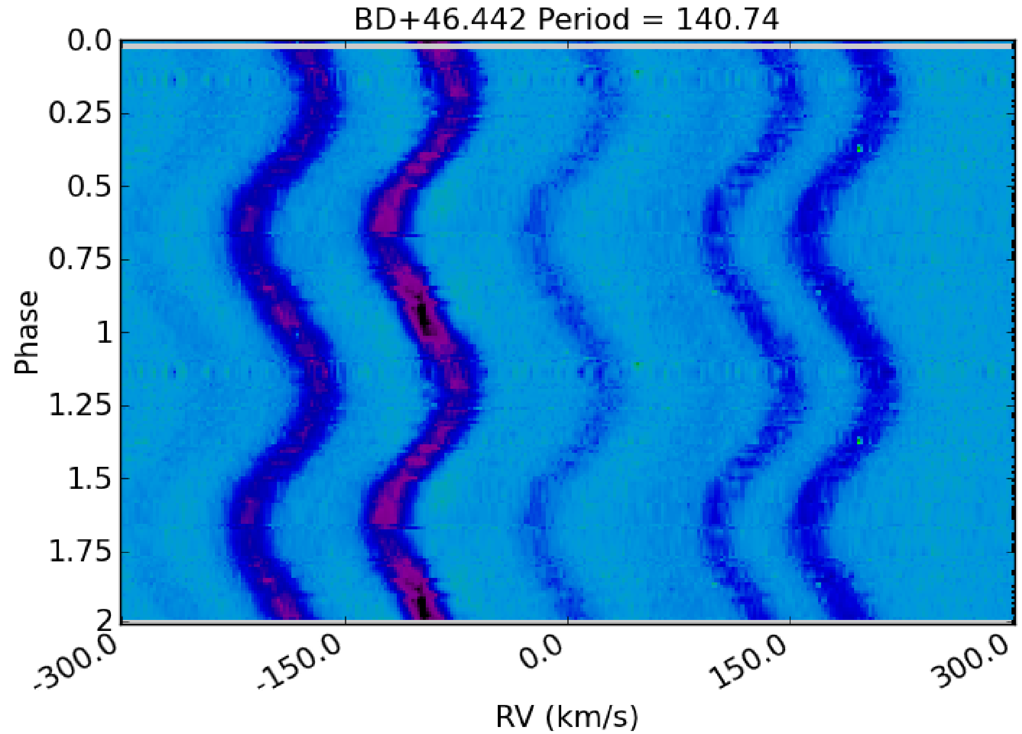
Some 30 orbits known by now...more to come

Orbits too short to accomodate AGB star

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

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

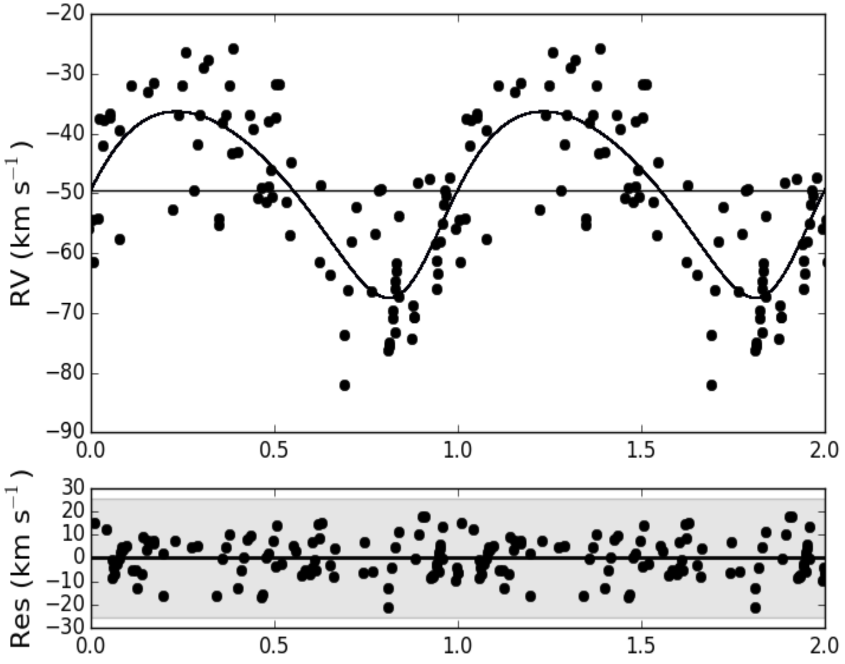




6/6 binaries, P between 120-1800 days

Van Winckel et al., 2009

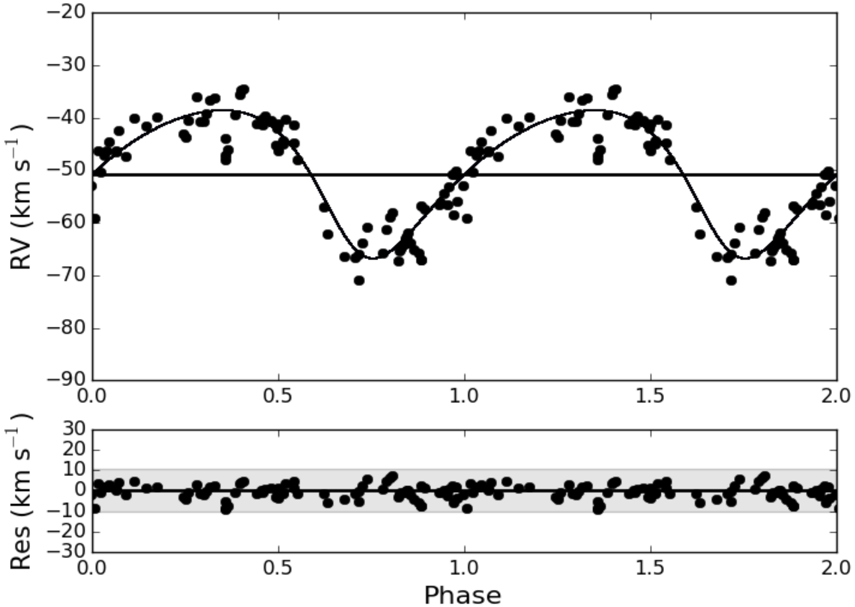
Pulsations versus Orbital Motion



Example: TW Cam (RV Tauri pulsator)
Pulsation period: 43d
Orbital Period: 654d

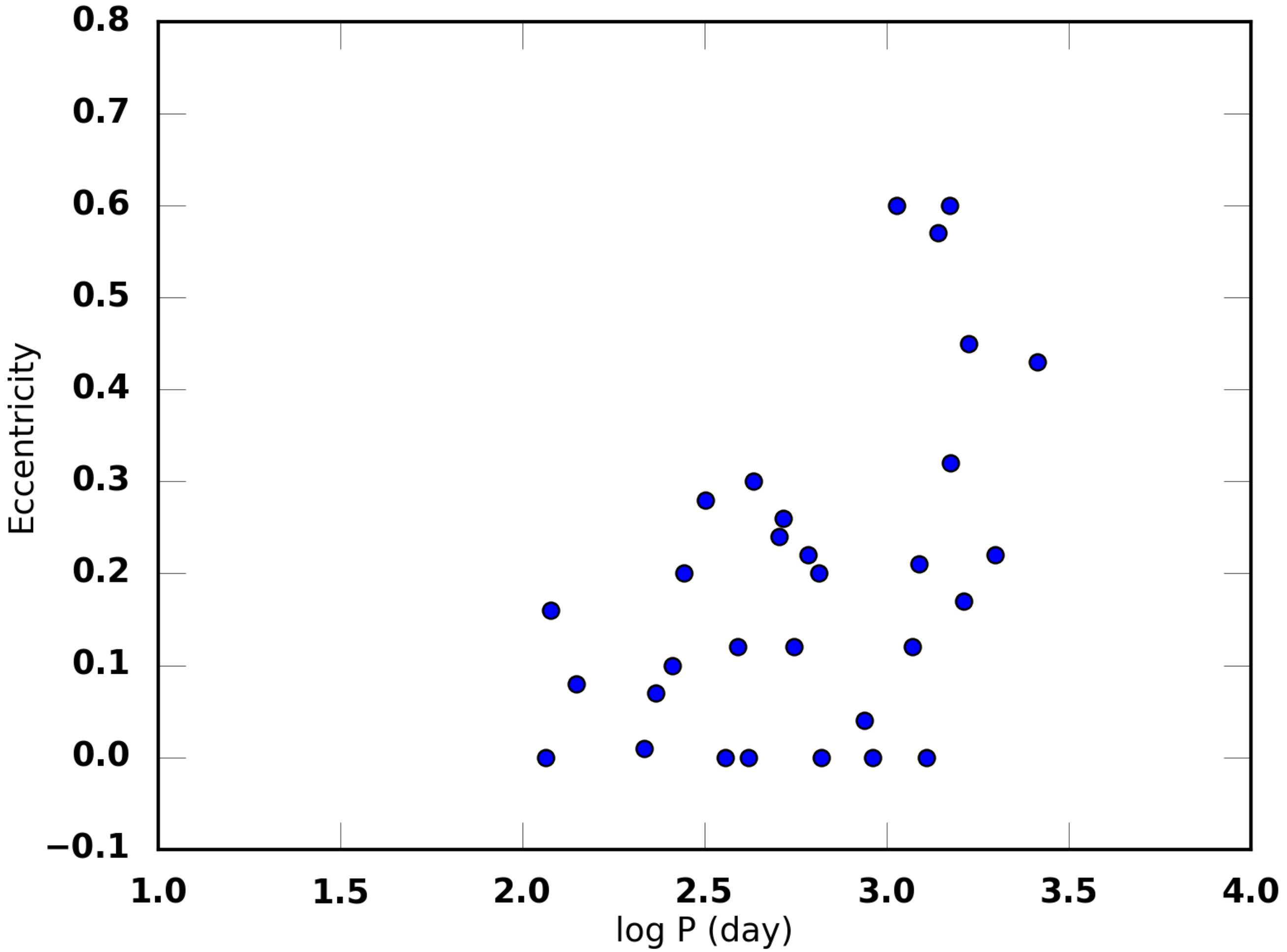
Good sampling is needed !!

Photospheric shocks induce line-deformation.



Manick et al., 2017

Disc sources are all binaries



Typical Orbital Periods: 150-2500d

None is spiralled in !!

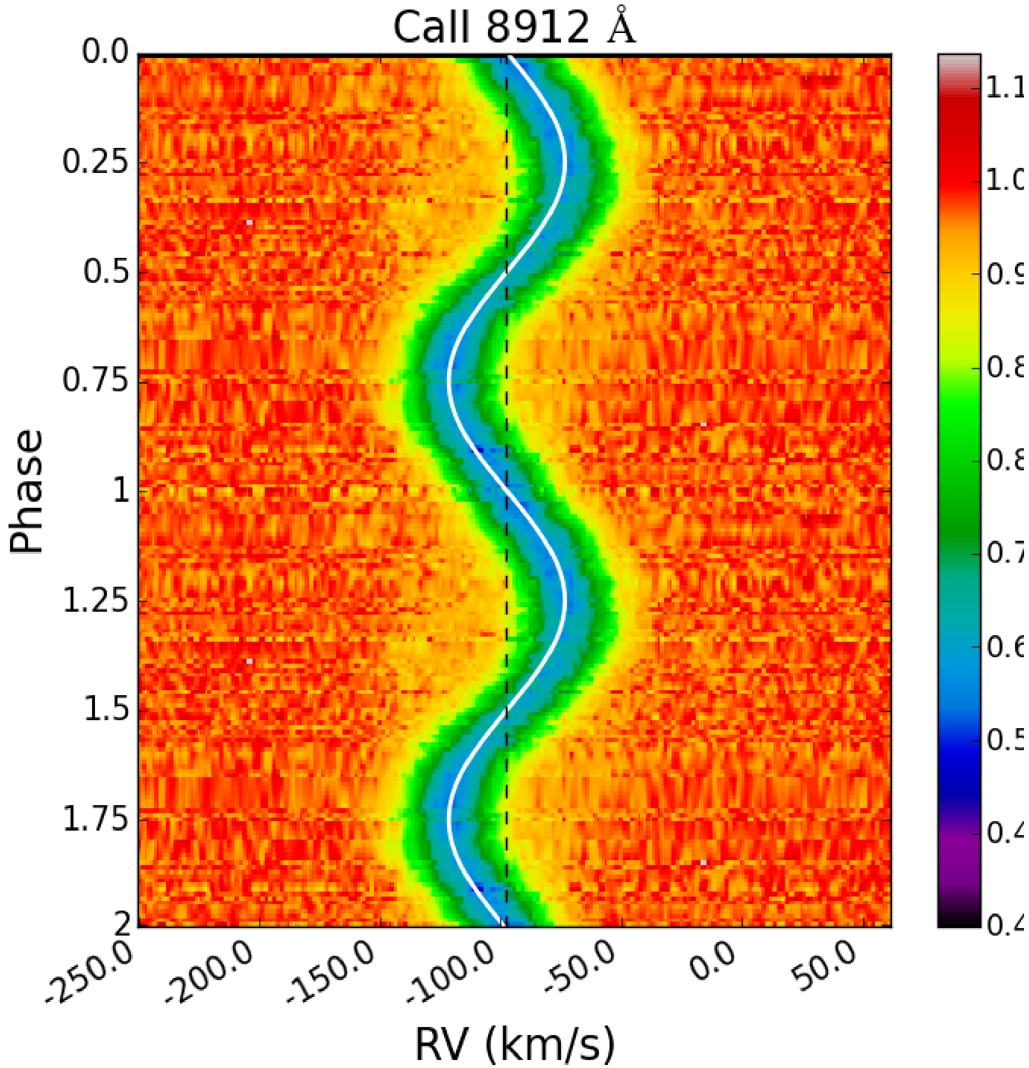
Often eccentric !!!

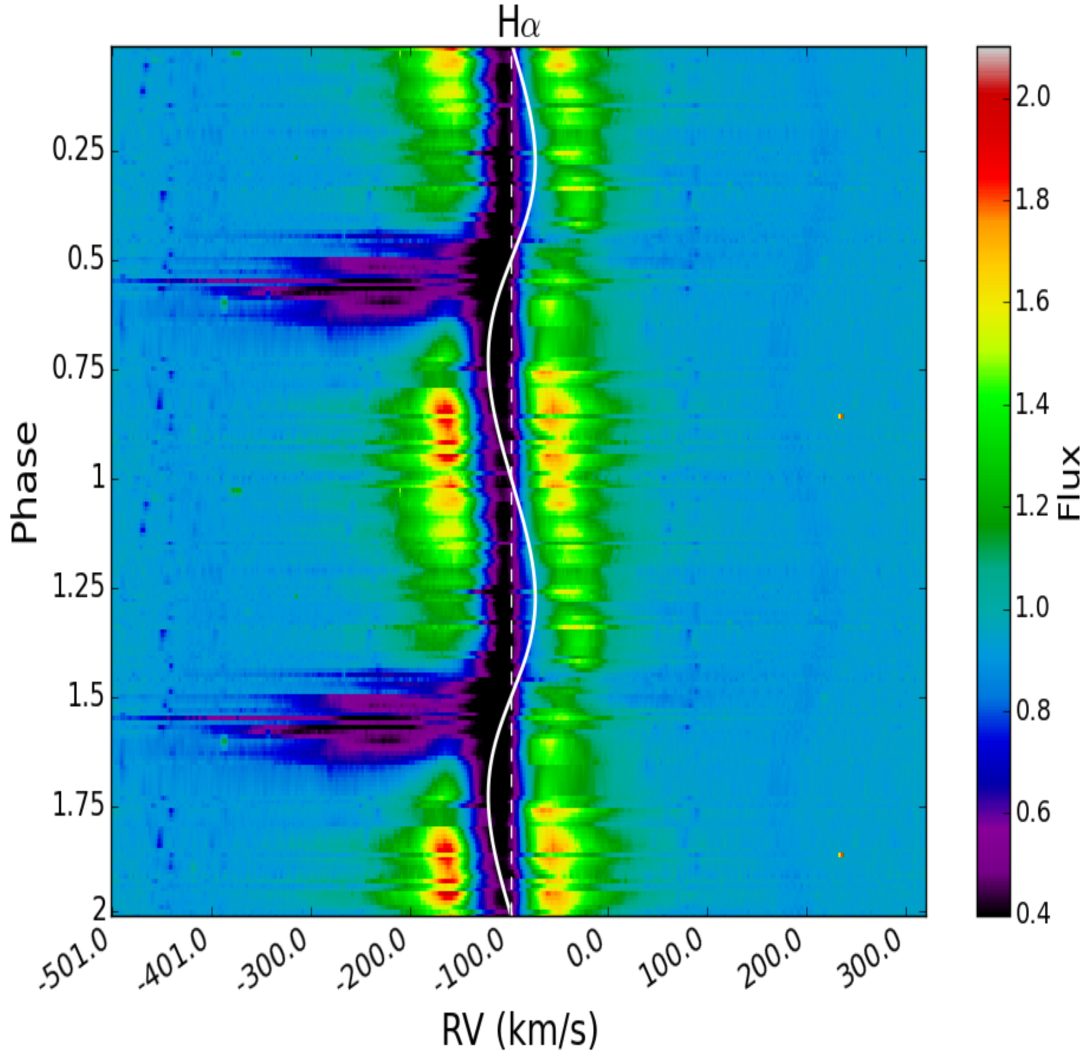
Some 30 orbits known by now...more to come

Orbits too short to accomodate AGB star (or RGB star)

Evolution is determined by binary interaction processes !!

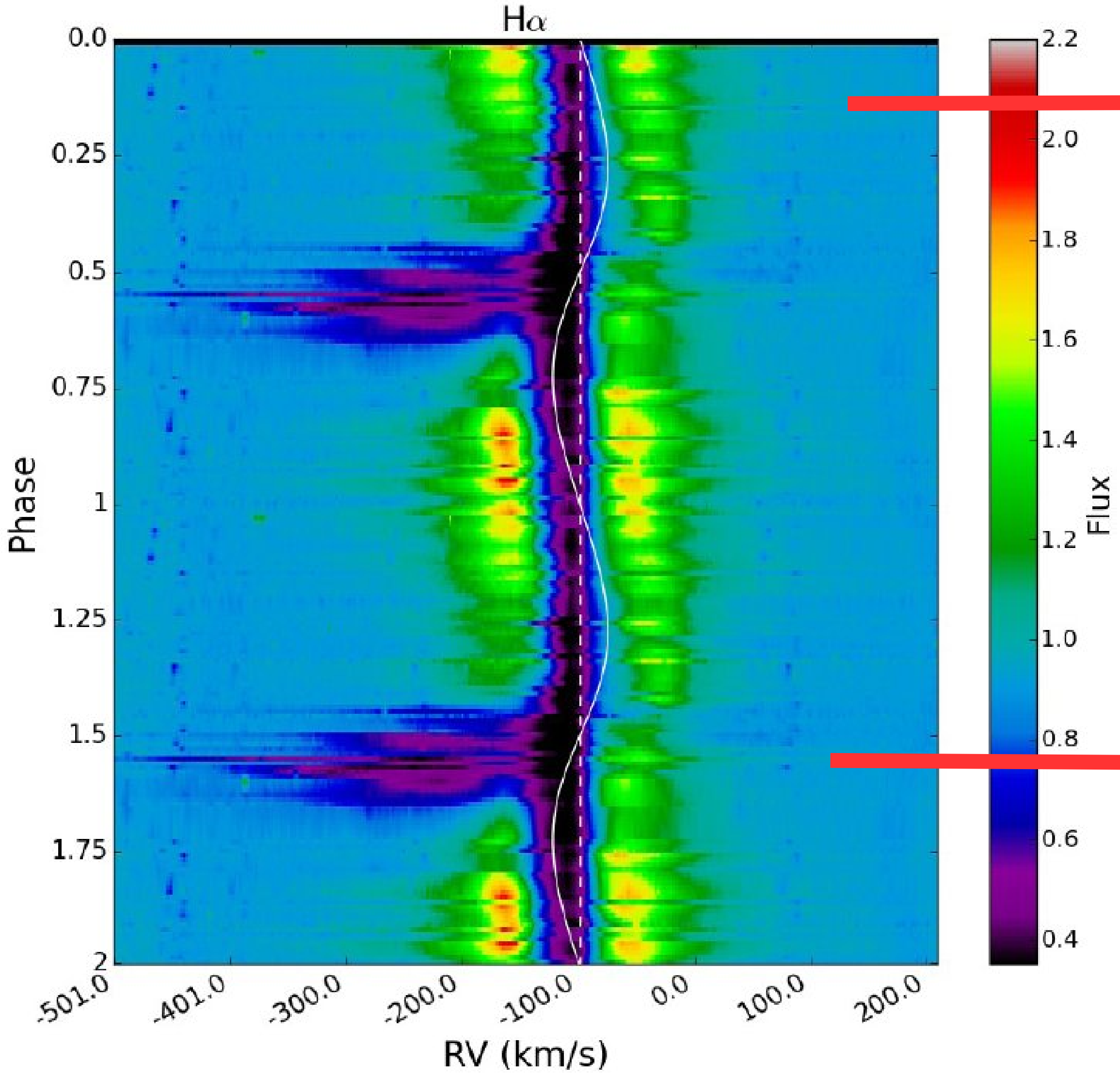
Binary processes: BD+46.422. Period=140.7 d

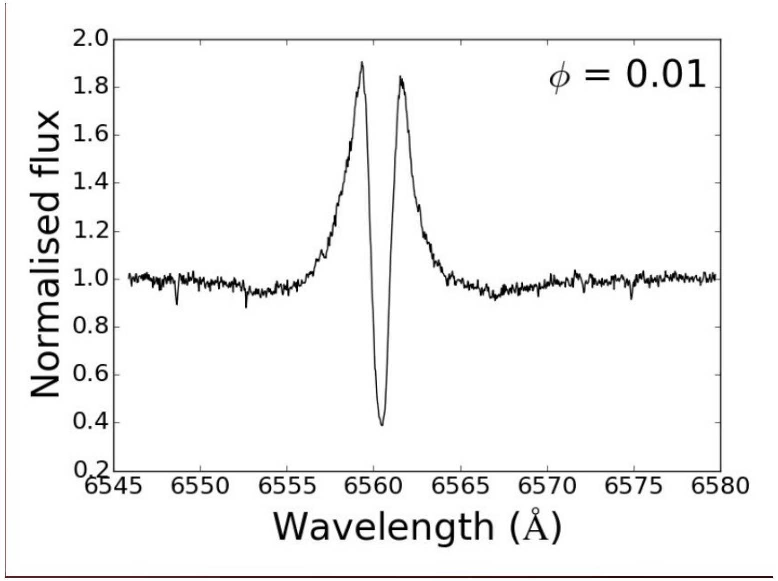


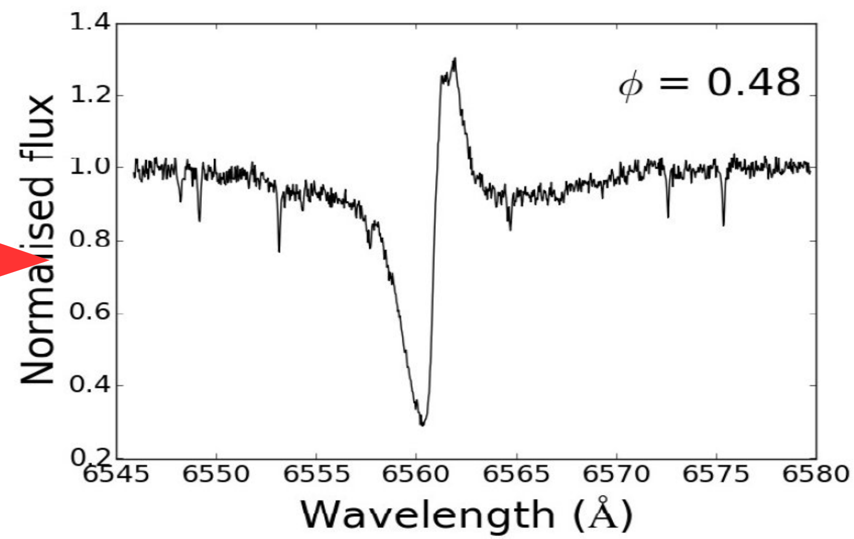


Gorlova et al., 2012; Bollen et al. 2017

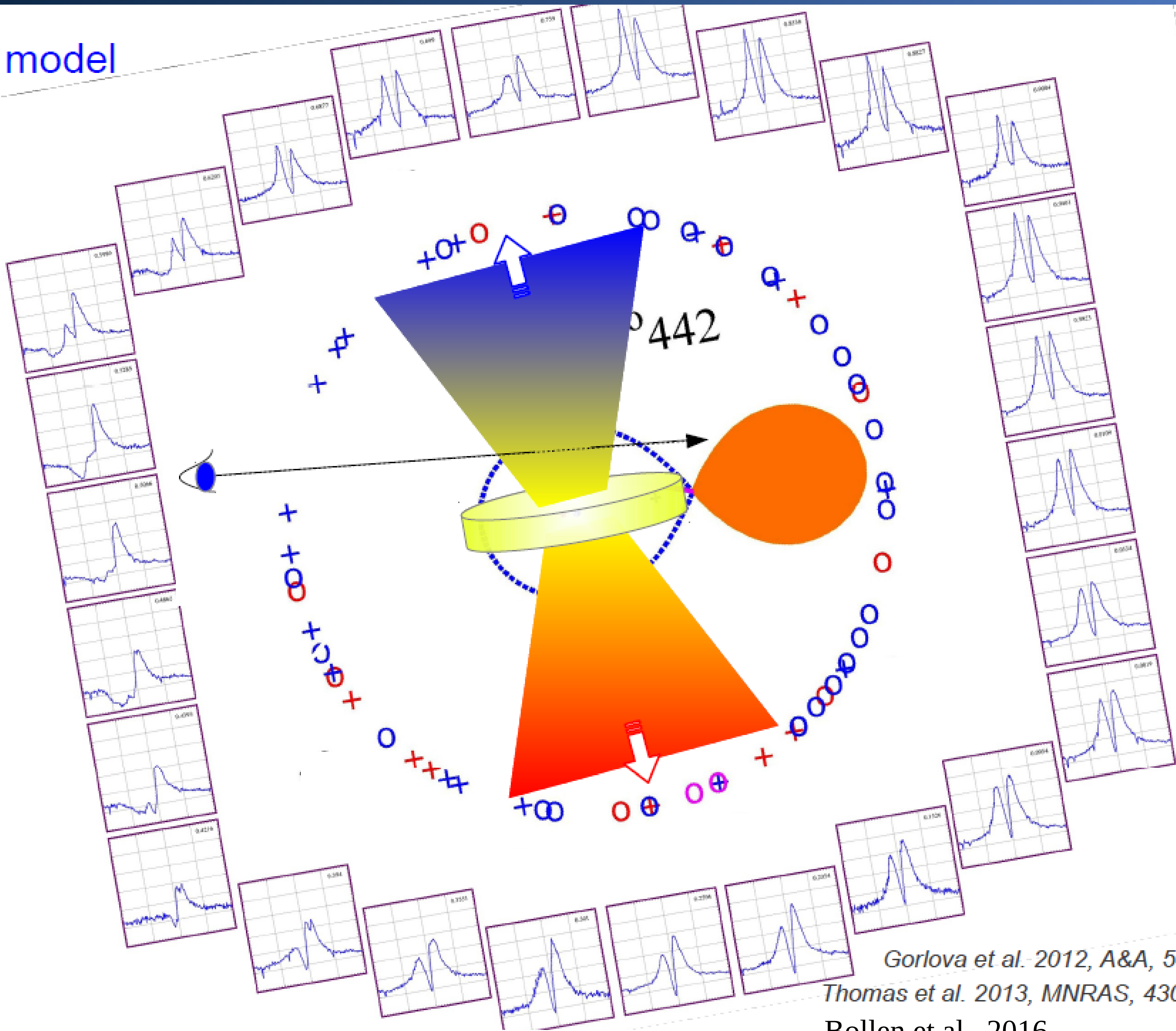
Dynamic Spectra







Jet model

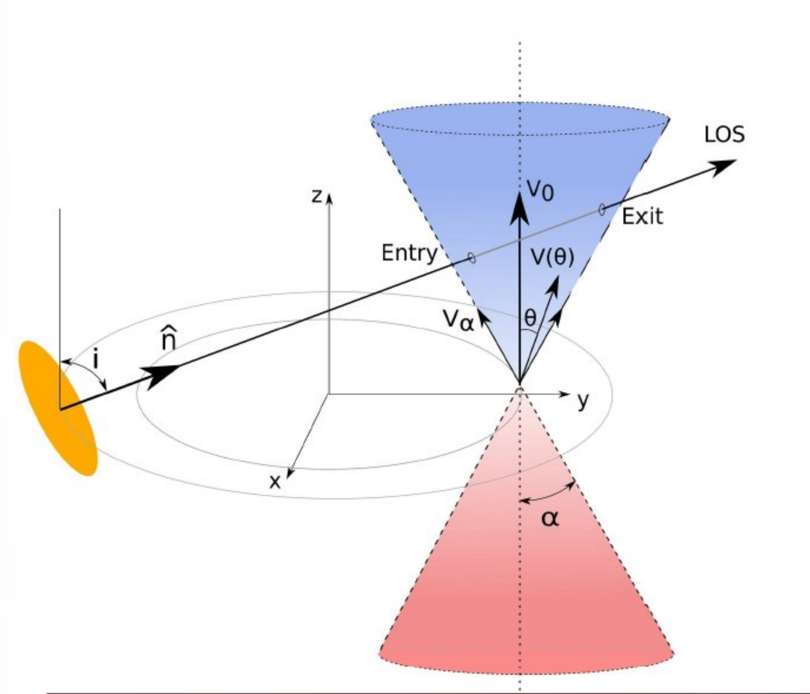


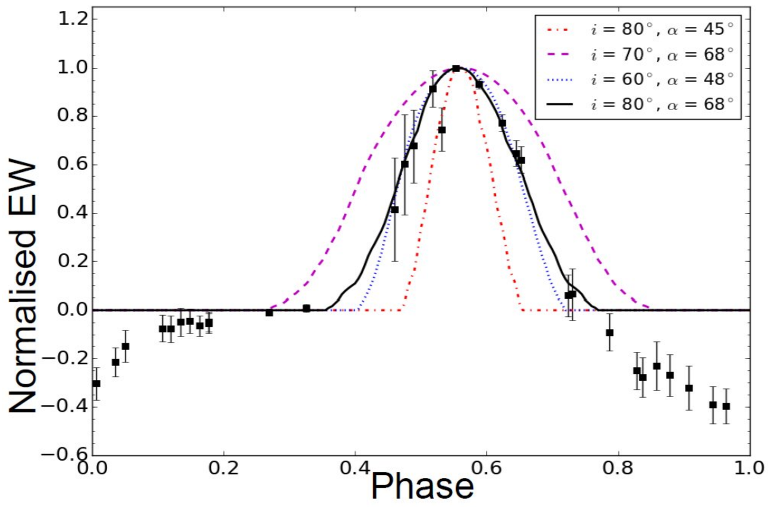
Gorlova et al. 2012, A&A, 542, 27

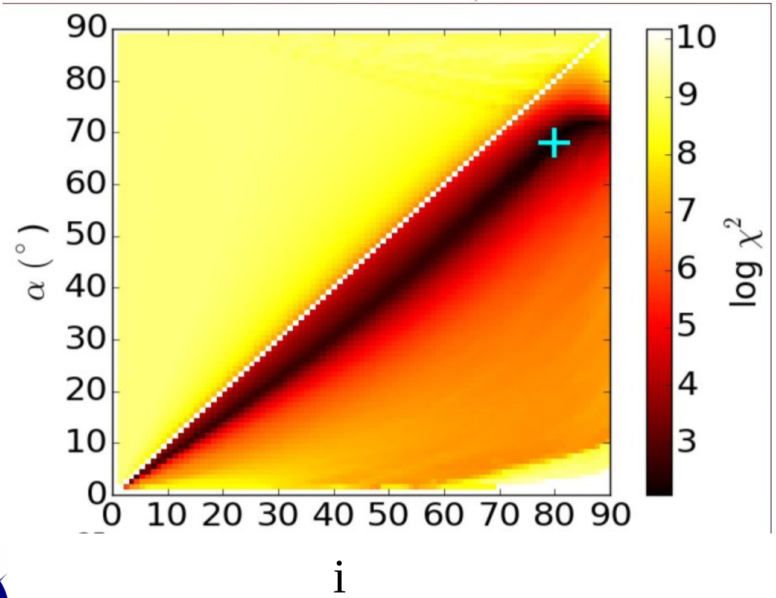
Thomas et al. 2013, MNRAS, 430, 1230

Bollen et al., 2016

High velocity ouflow: wide cone



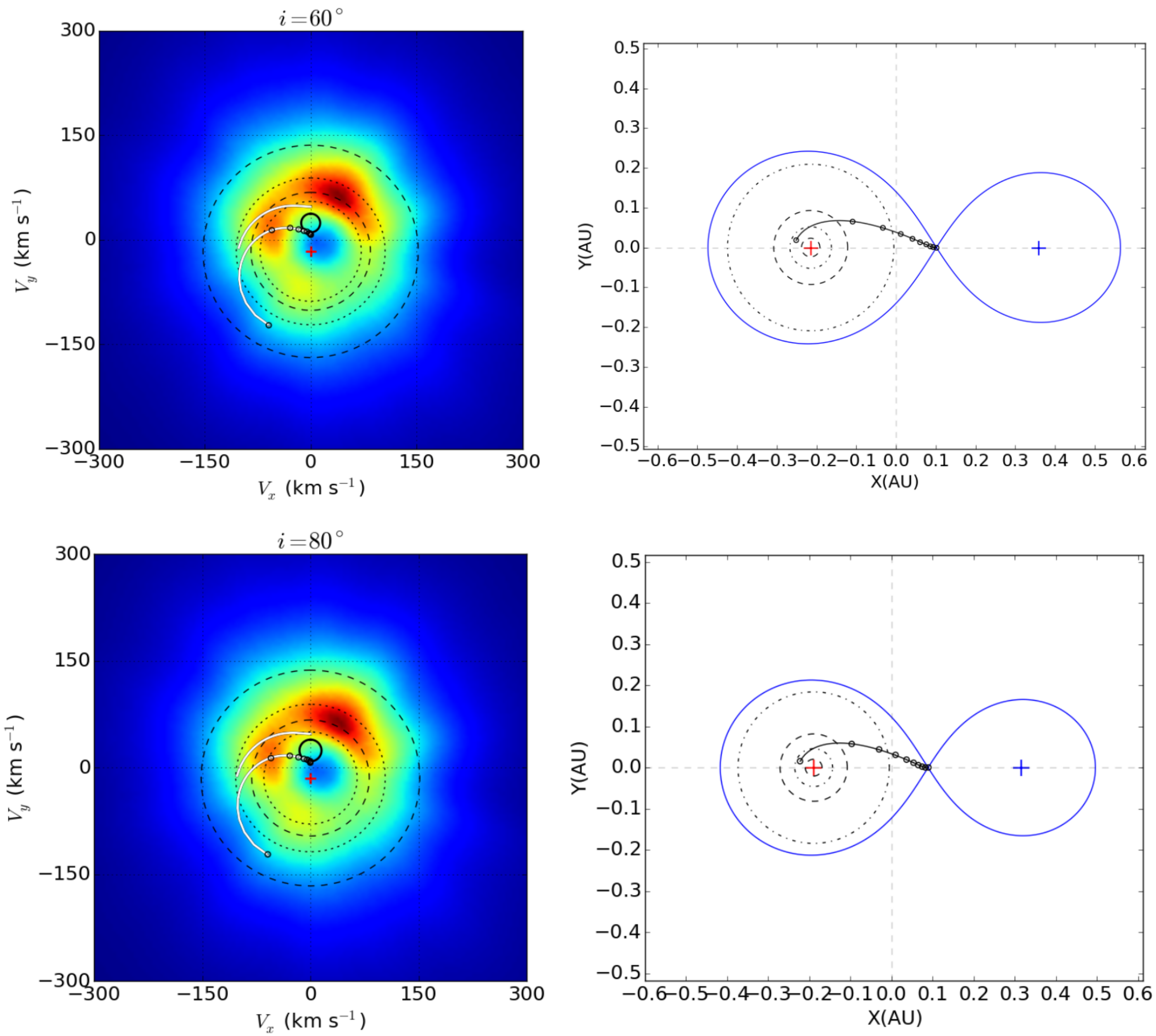




Wide opening angle
Inclination dependent
Angle dependent velocity law in cone
Deprojected outflow velocity escape velocity of MS not WD

Bollen et al., 2017, submitted

Doppler Tomography



Circum-Companion accretion disc

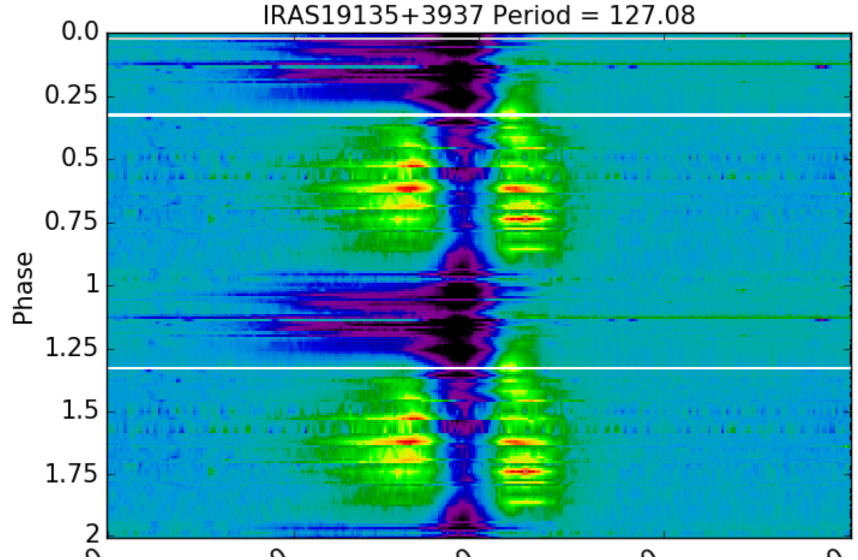
Sampling is inhomogeneous so structure may be artificial.

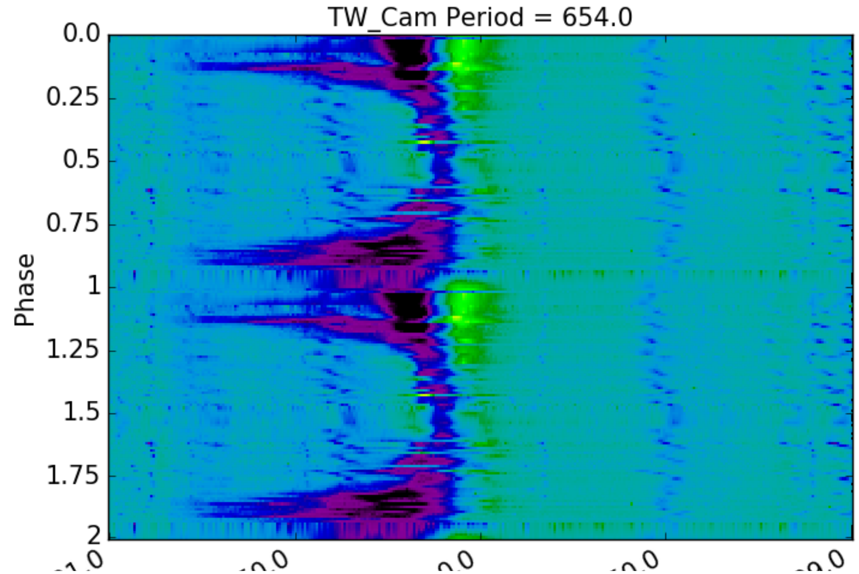
Jet launching happens around the companion

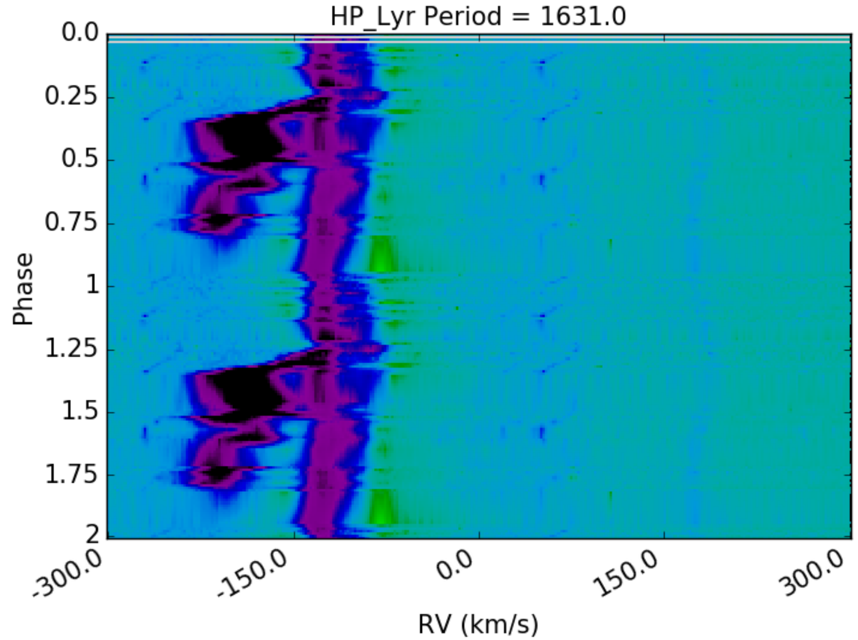
Velocity: MS and not WD

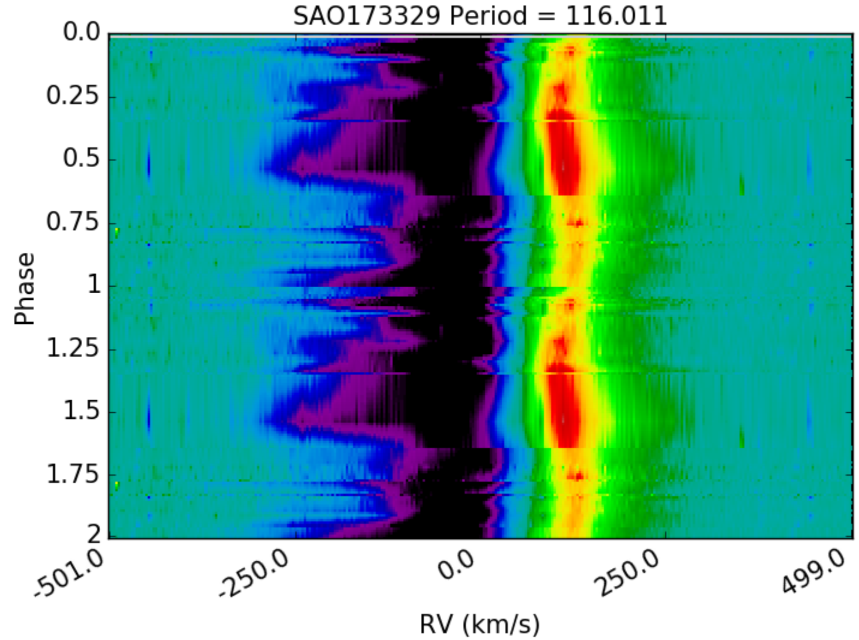
Bollen et al., 2017, submitted

Often detected: jets created by circumcompanion accretion disc

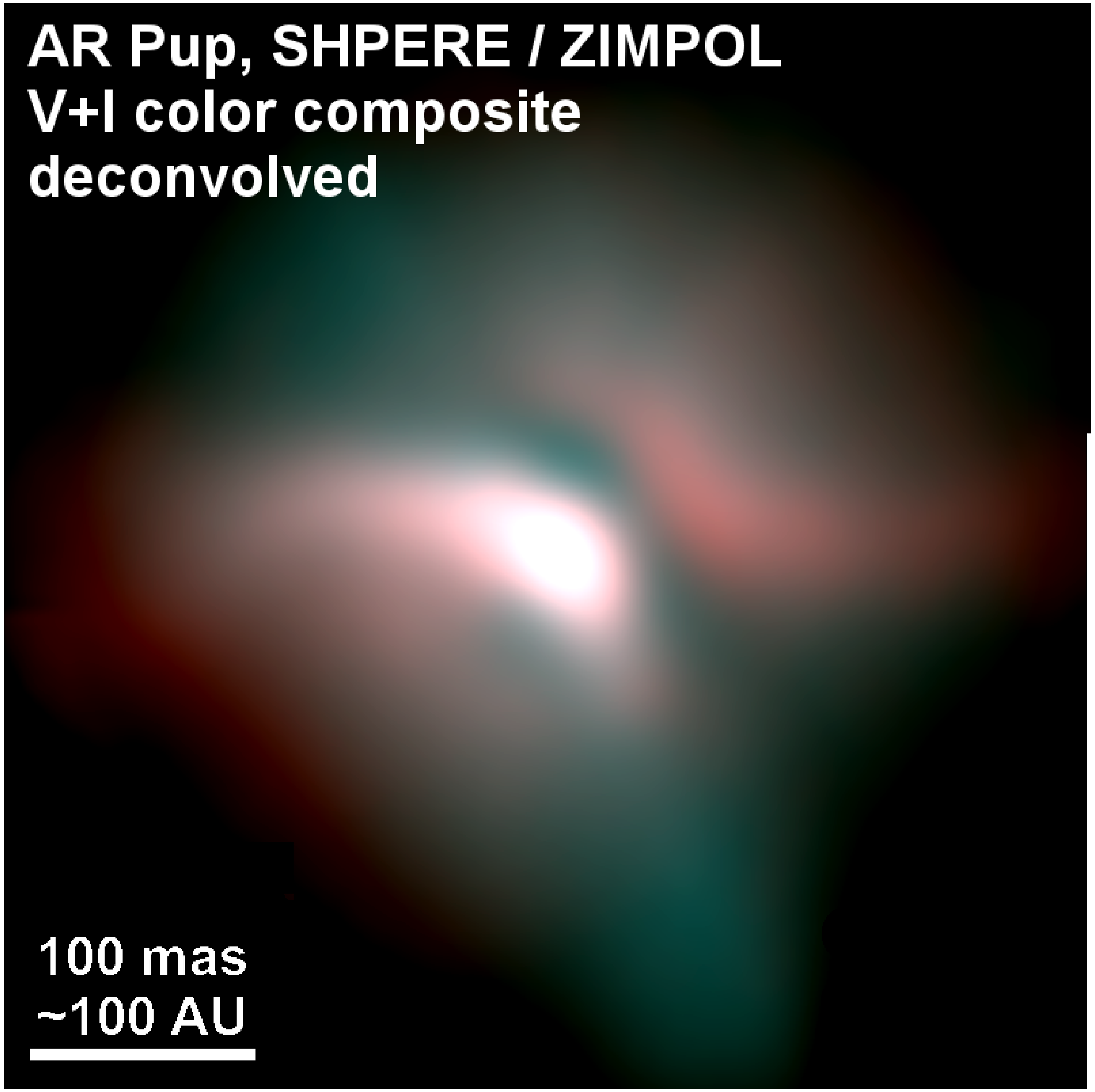








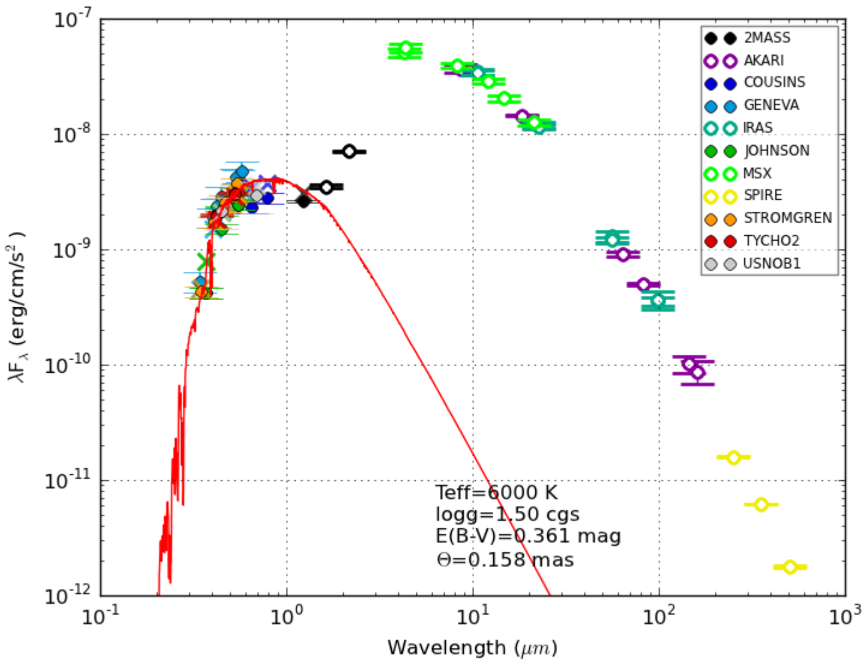
Resolving the circumbinary disc



Extreme AO

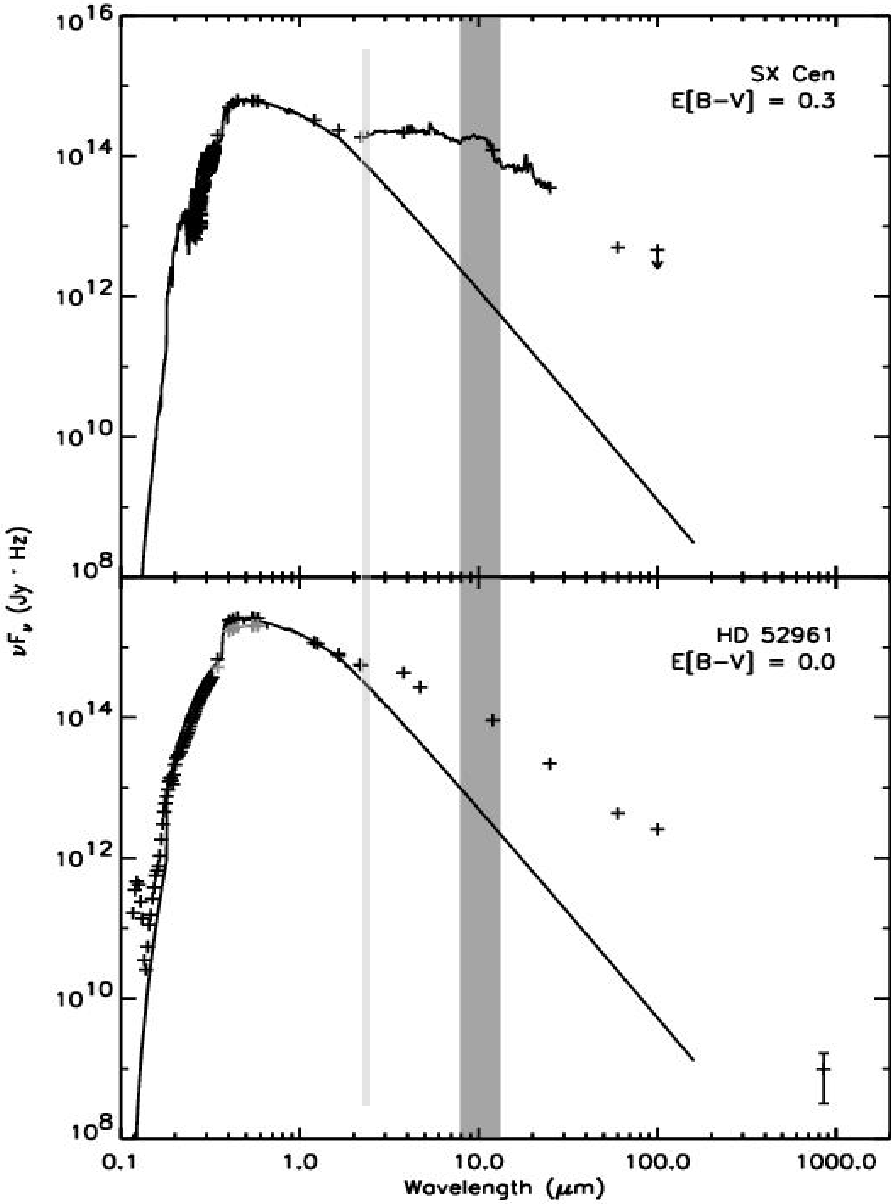
Sphere imaging

Edge-on disc: only scattered light in optical.



Ertel et al., 2017, in prep, see poster

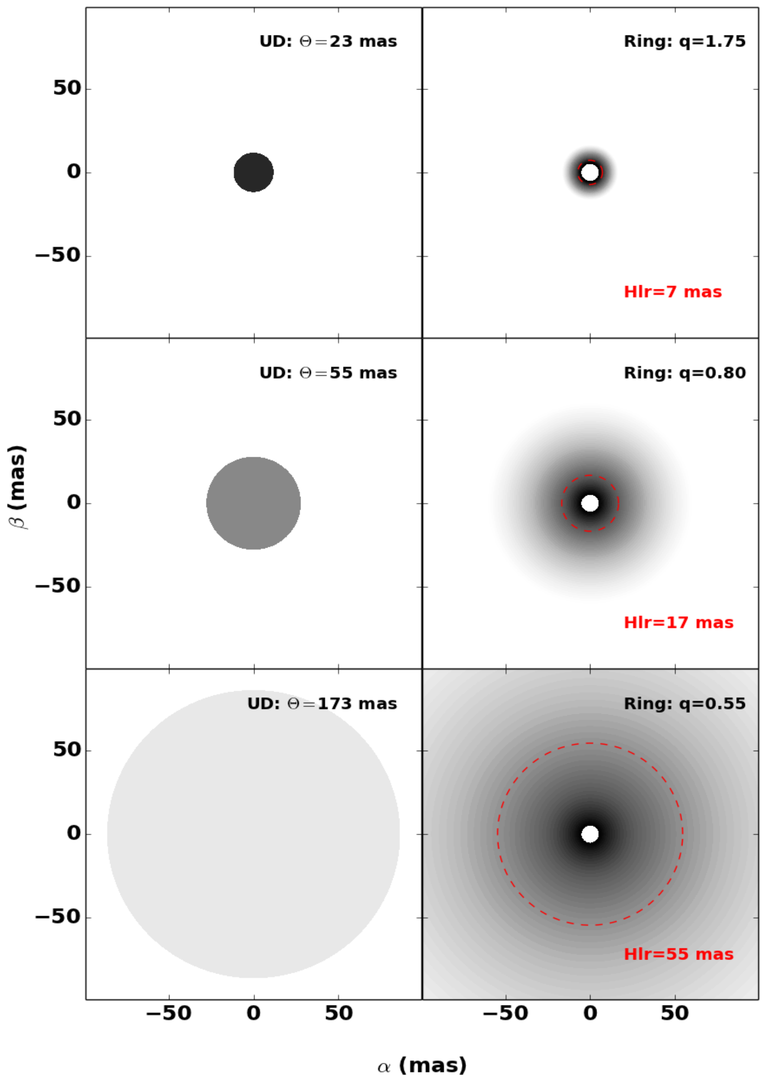
Resolving the circumbinary discs: Multi-wavelength interferometry

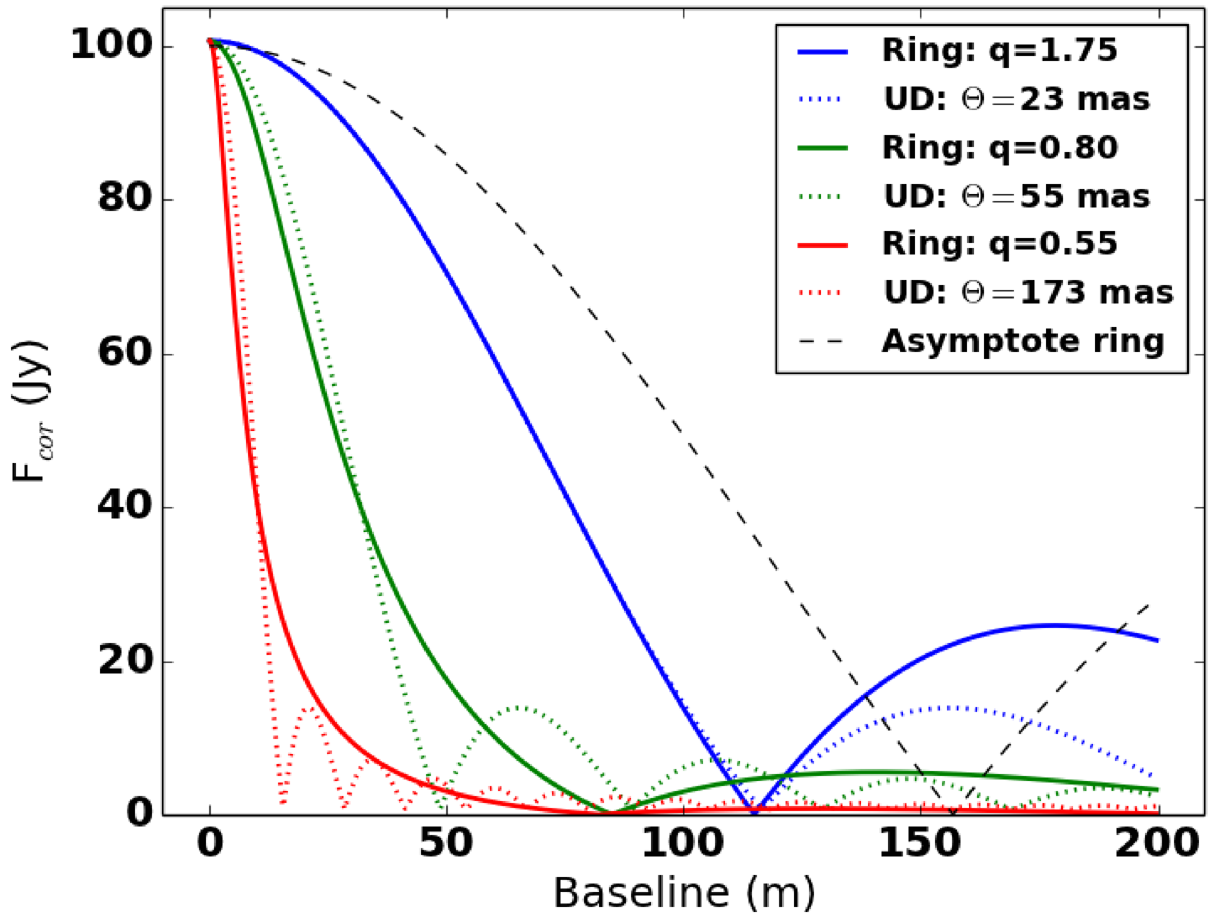


MIDI : N-band: near peak SED
MATISSE (soon)

AMBER &: photosphere-hot dust region
PIONIER

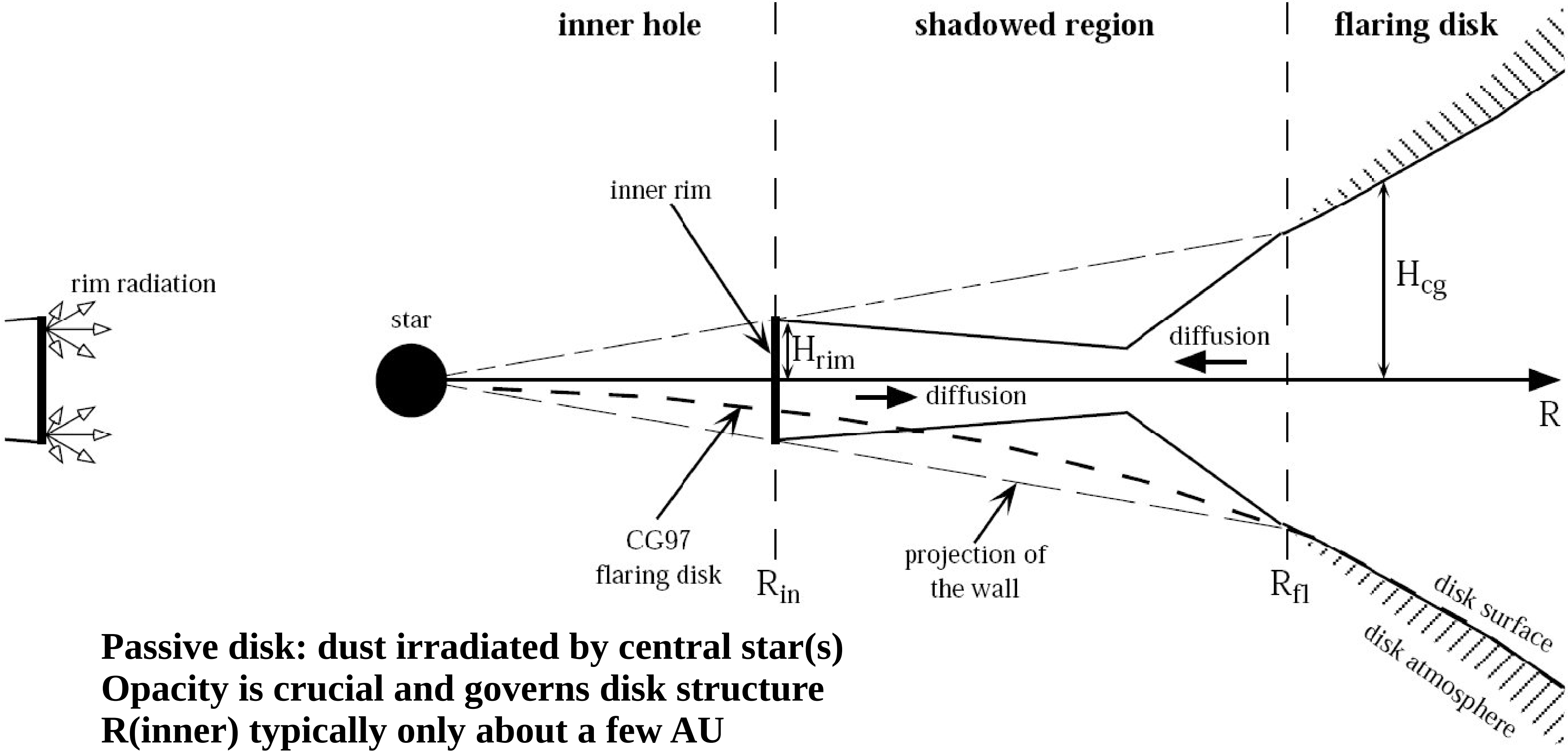
Multiwavelength interferometric surveys





Different wavengths: very sensitive to inner rim.
(opacities, dustcomposition, radiative transfer:
N-band (done Hillen et al., 2016)
H-band (data is partly obtained)
MATISSE, new instrument at ESO

Basic Disk structure: Radiative Transfer modelling

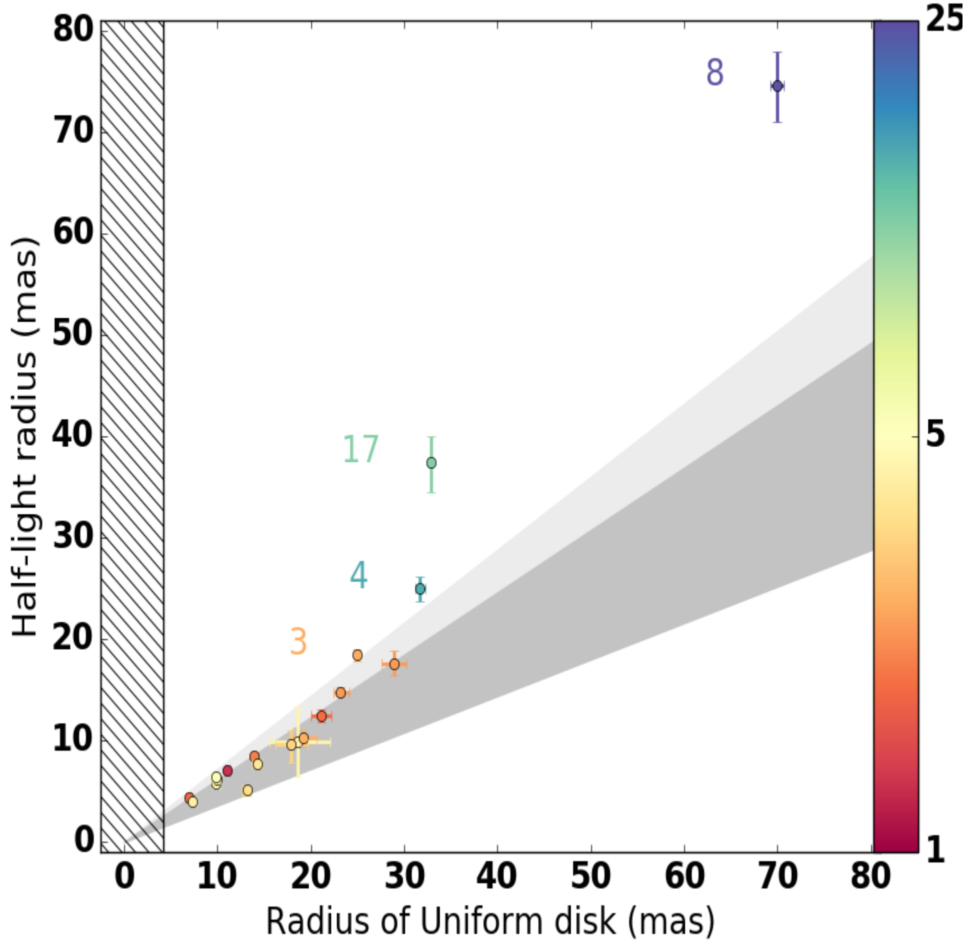


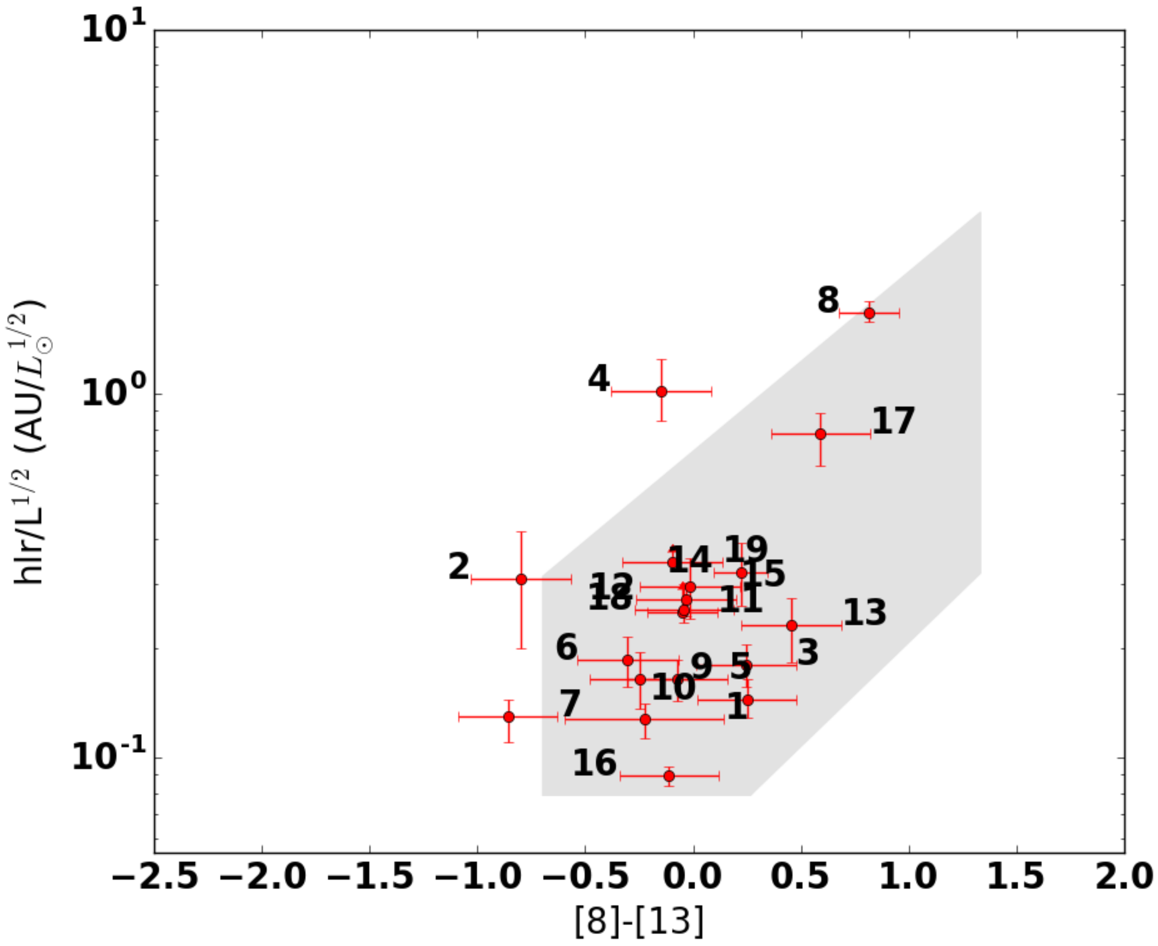
Passive disk: dust irradiated by central star(s)
Opacity is crucial and governs disk structure
R(inner) typically only about a few AU

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, 2015, 2016

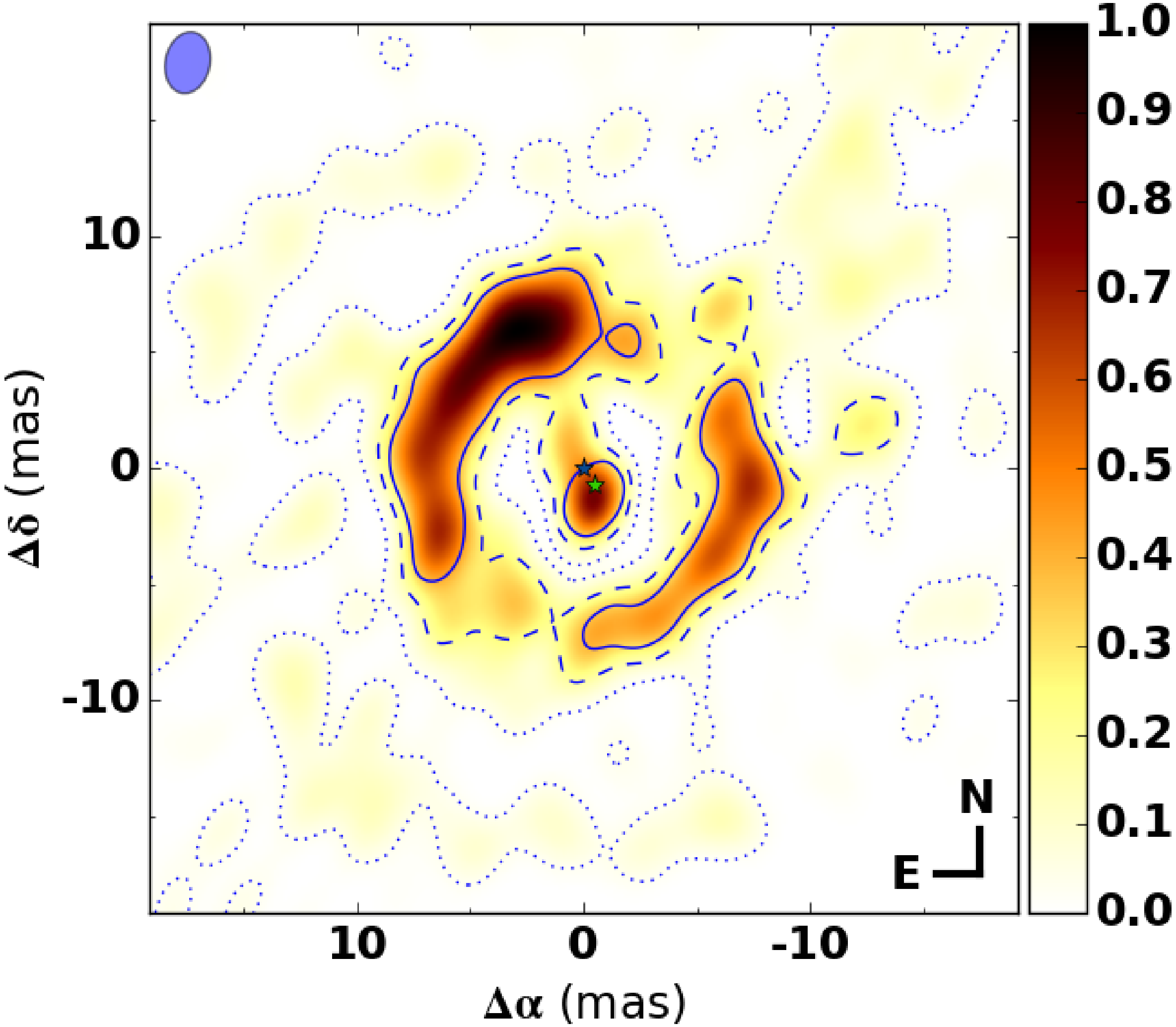
MIDI survey (N-band): limited uv coverage

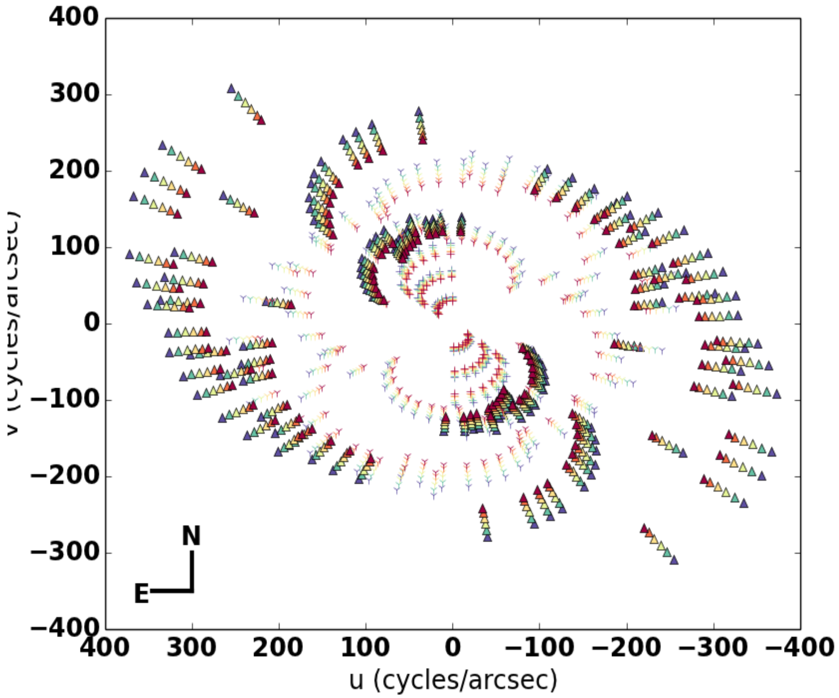




Very compact N-band emission. Very similar as YSO passive discs: The second-generation of protoplanetary discs resolved

IRAS08544-4431: interferometric imaging





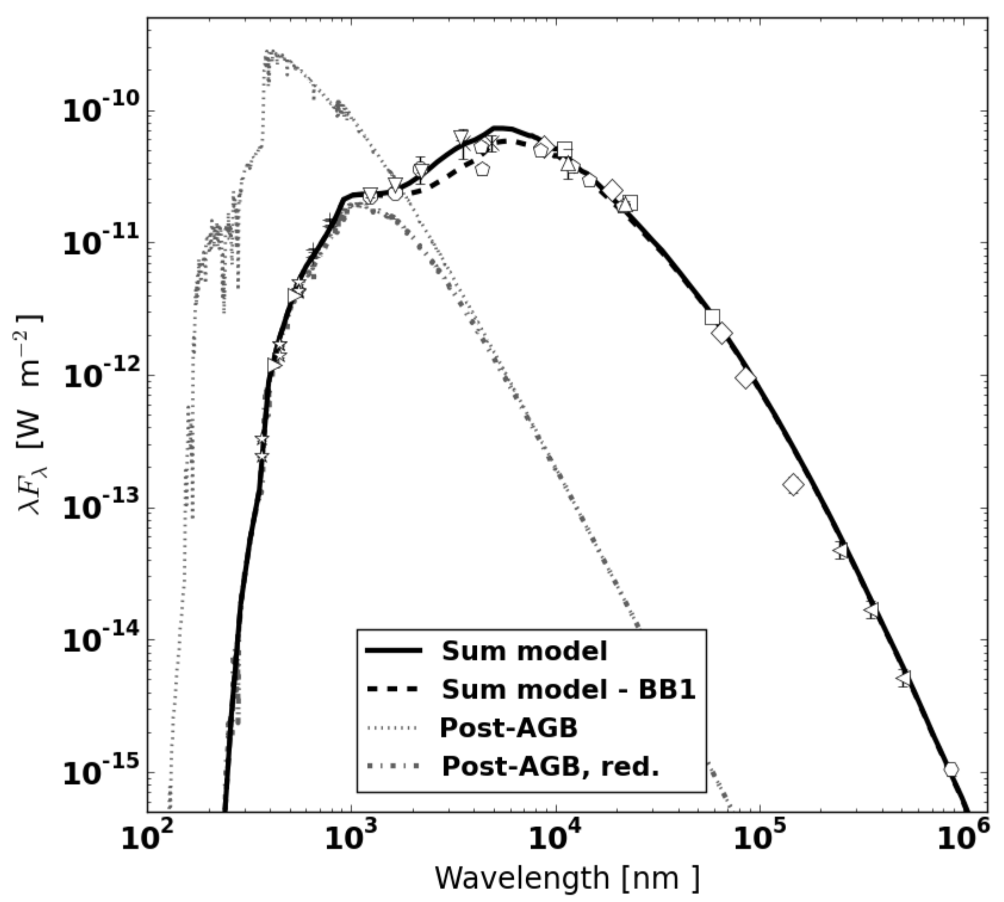
H-band reconstruction PIONIER
Inner rim at sublimation radius

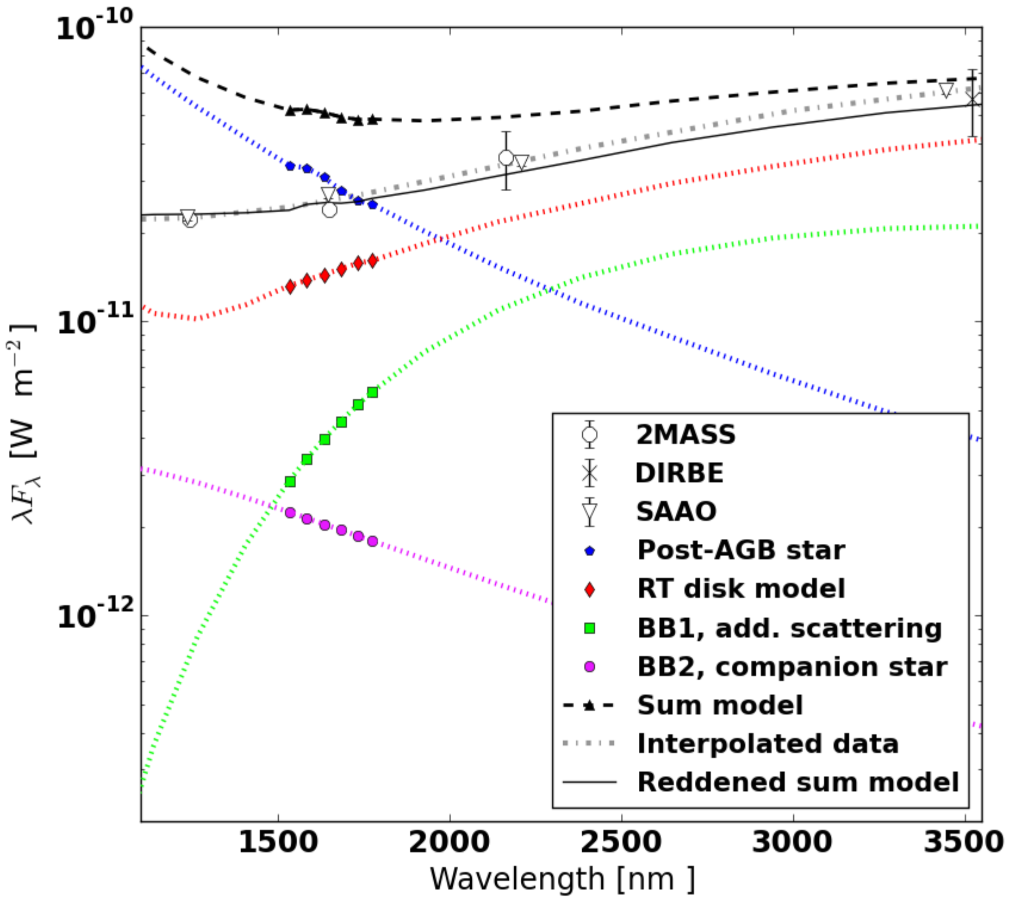
Contribution from circumcompanion accretion disc

Hillen et al., 2016

ESO press release: eso1608a

IRAS08544: interferometric dissection

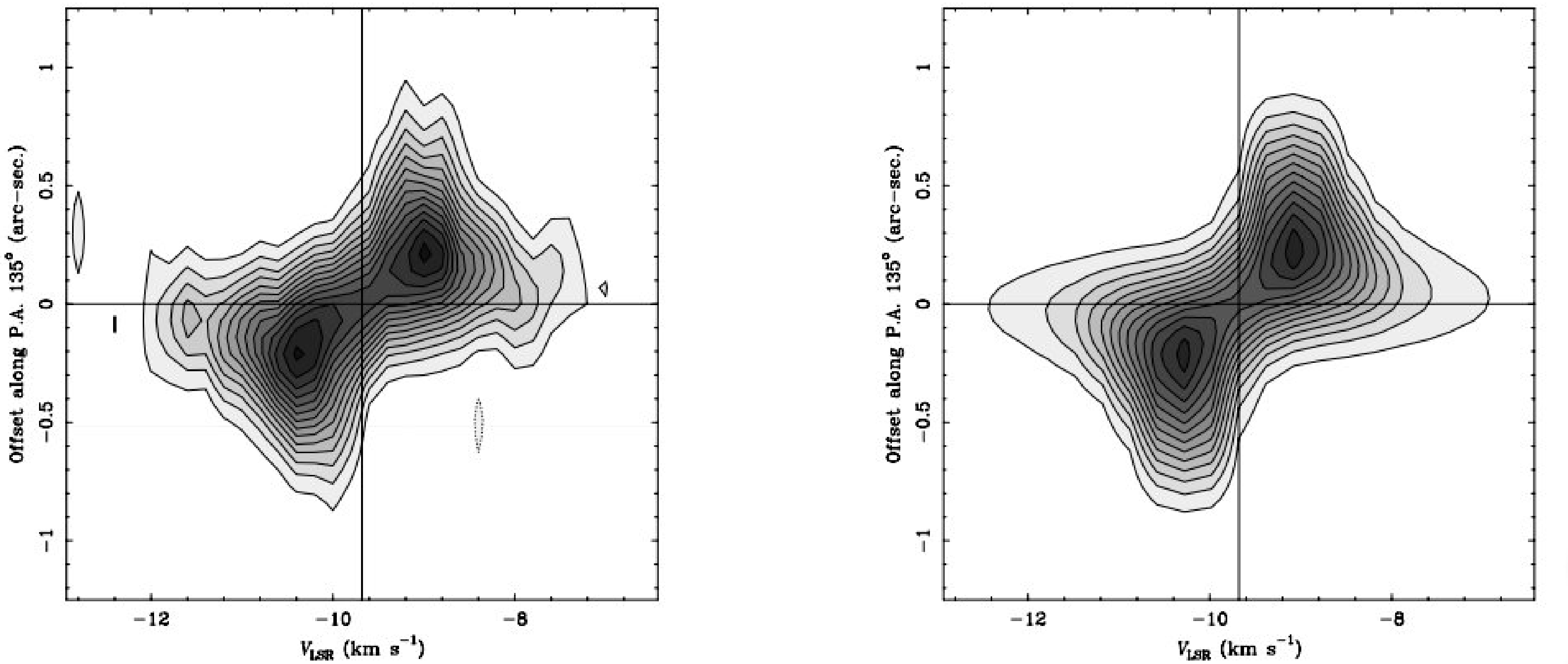




Dissection of all components: Post-AGB star, companion with accretion disc, circumbinary disc, scattering component.

Hillen et al., 2016

ALMA-PdB: rotation resolved



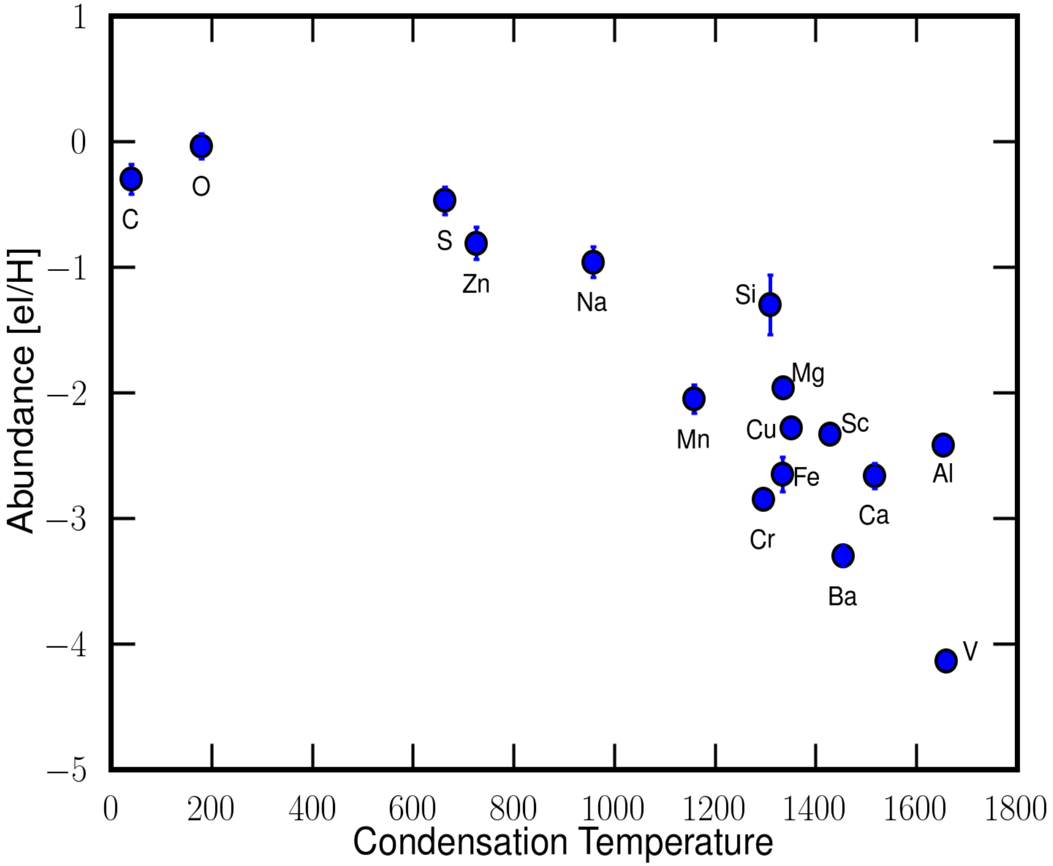
Keplerian kinematics resolved in Red Rectangle, AC Her and IW Car, too compact for 89 Her

Keplerian Rotation + outflow in combination

Single dish: narrow CO profiles omnipresent

Bujarrabal et al., 2013, 2015, 2016, 2017

Photospheric Depletion: Feedback from disc



Abundance patterns ~ gas phase abundance of ISM

You lose the nucleosynthetic history

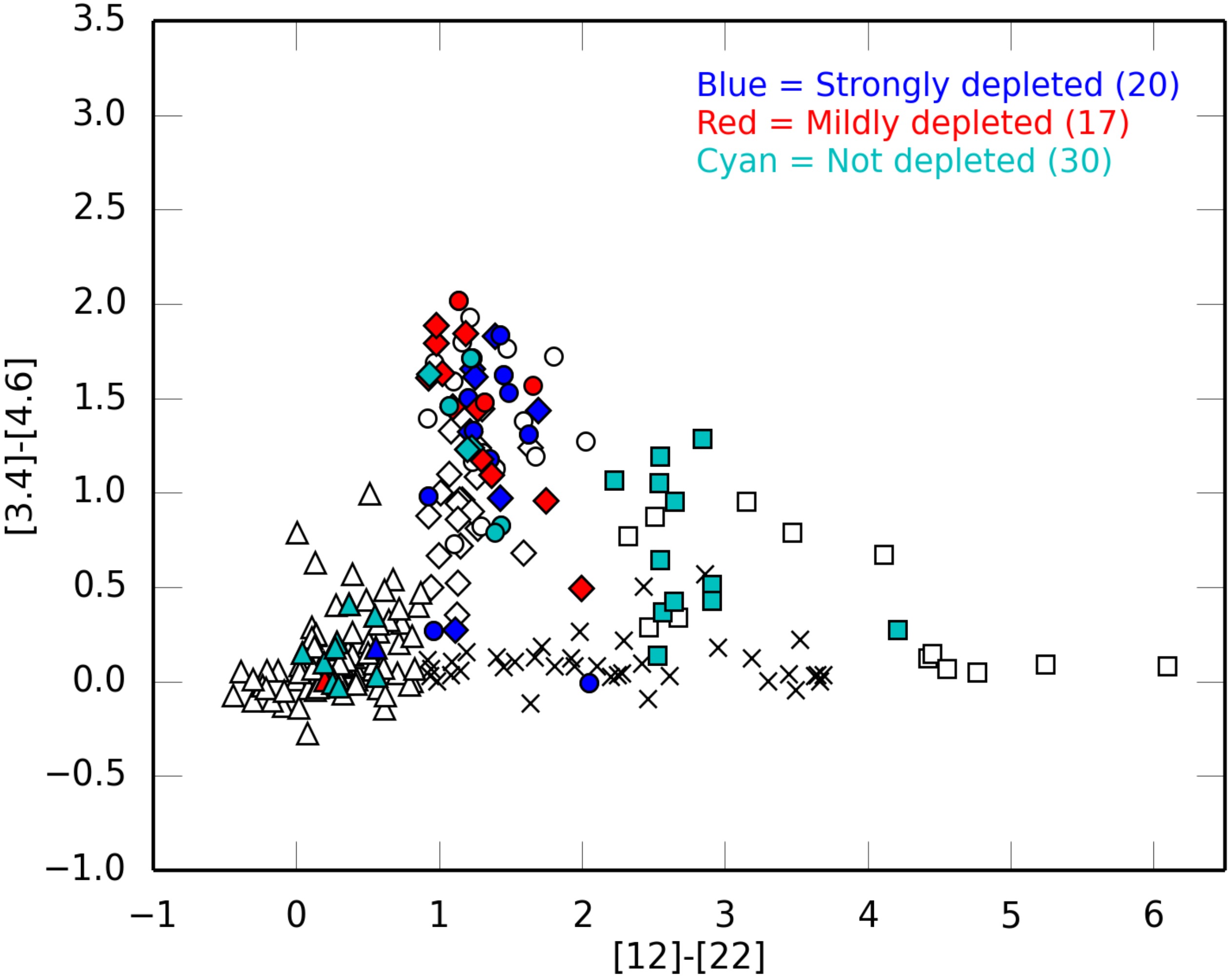
Can be very efficient (down to [Fe/H]=-4.8)

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 Gezer et al. 2015

Depletion is commonly observed

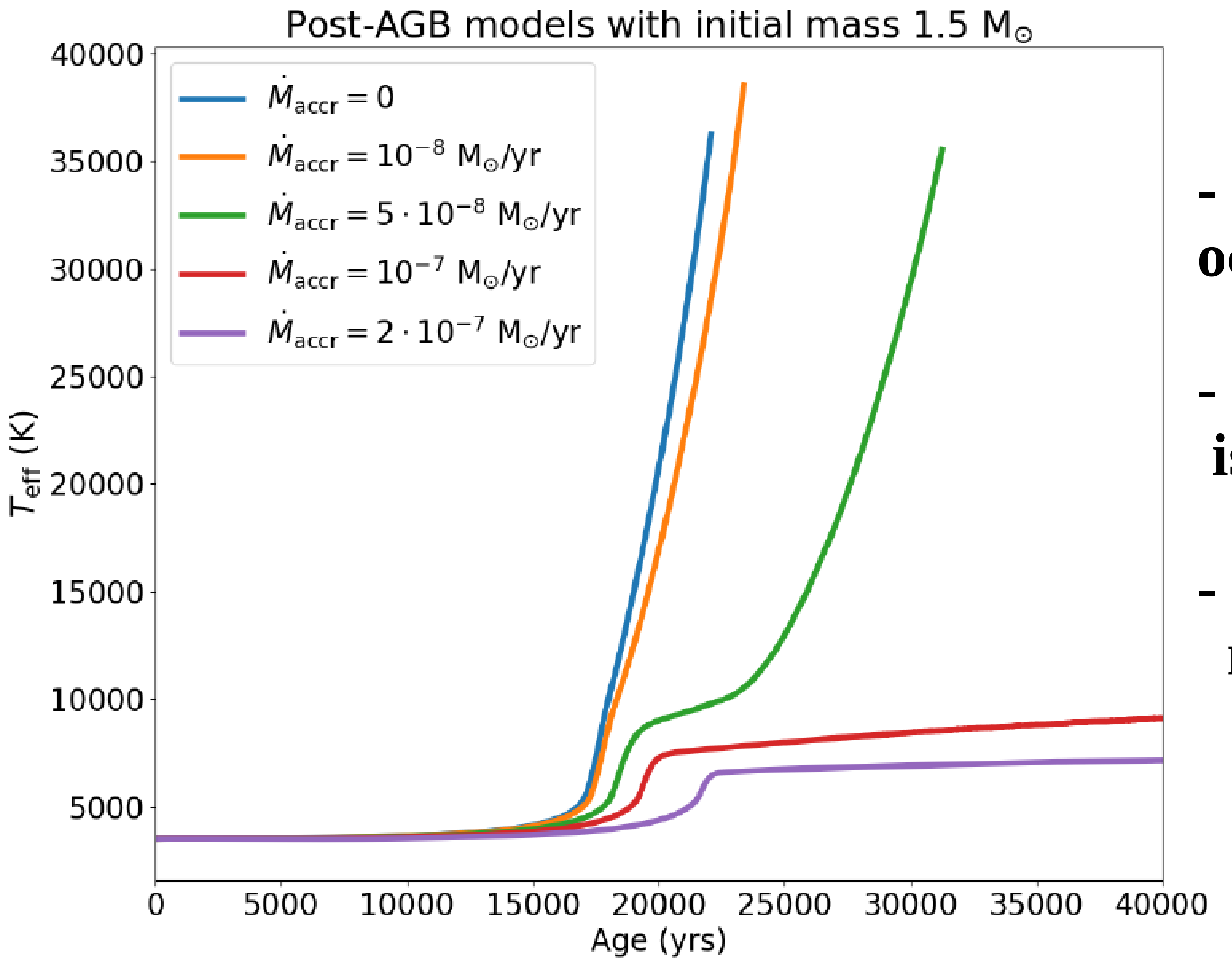


- Depletion only observed in disc sources !

- Galactic post-AGB disc sources
- Galactic post-AGB stars with expanding shells measured with CO do not show depletion

Gezer et al., 2015

Accretion can slow-down the evolution



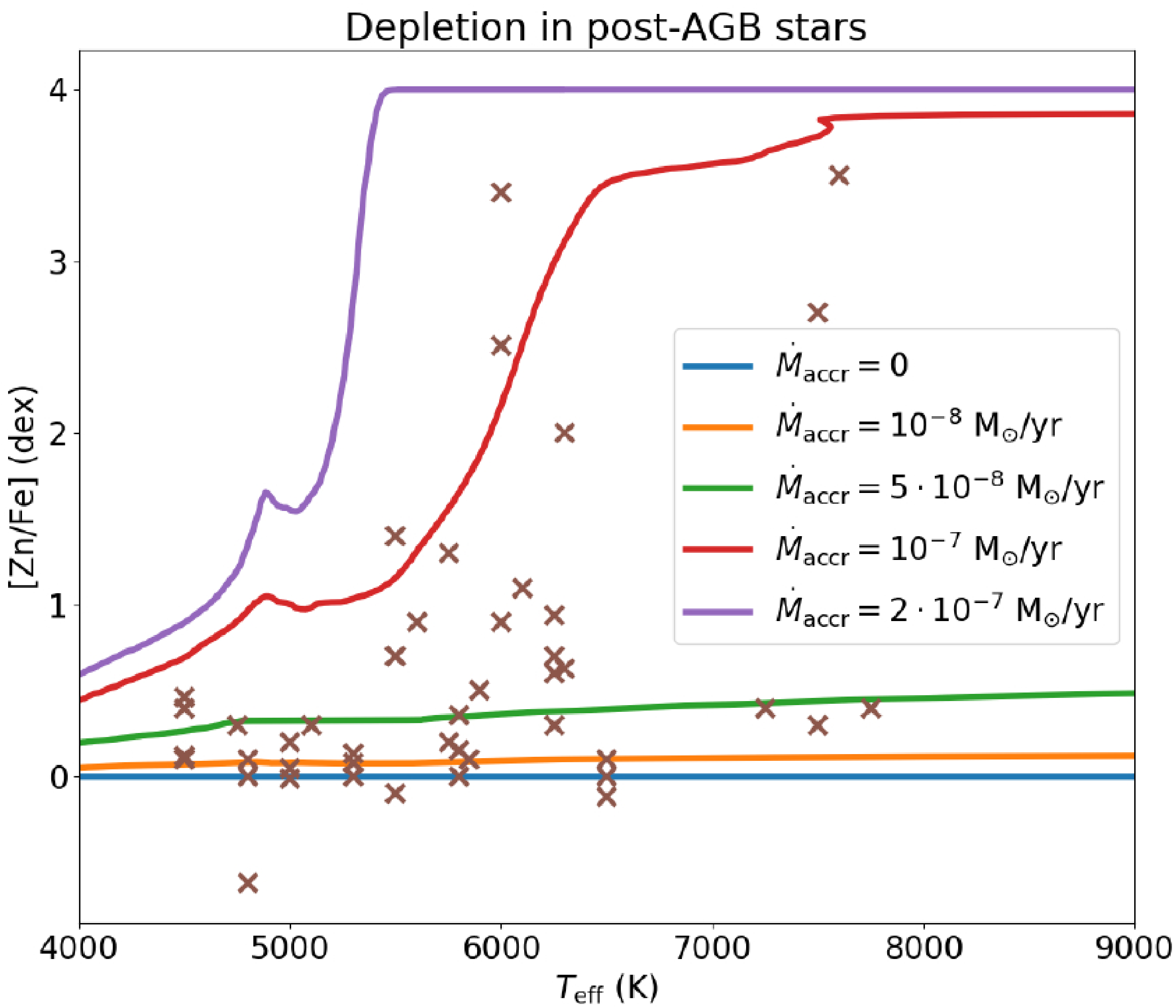
- mass accretion has to occur given the abundances

- if large enough, the lifetime is prologued

- balance between mass-loss, nucleosynthesis and accretion

Oomen et al., in prep.

Accretion can slow-down the evolution



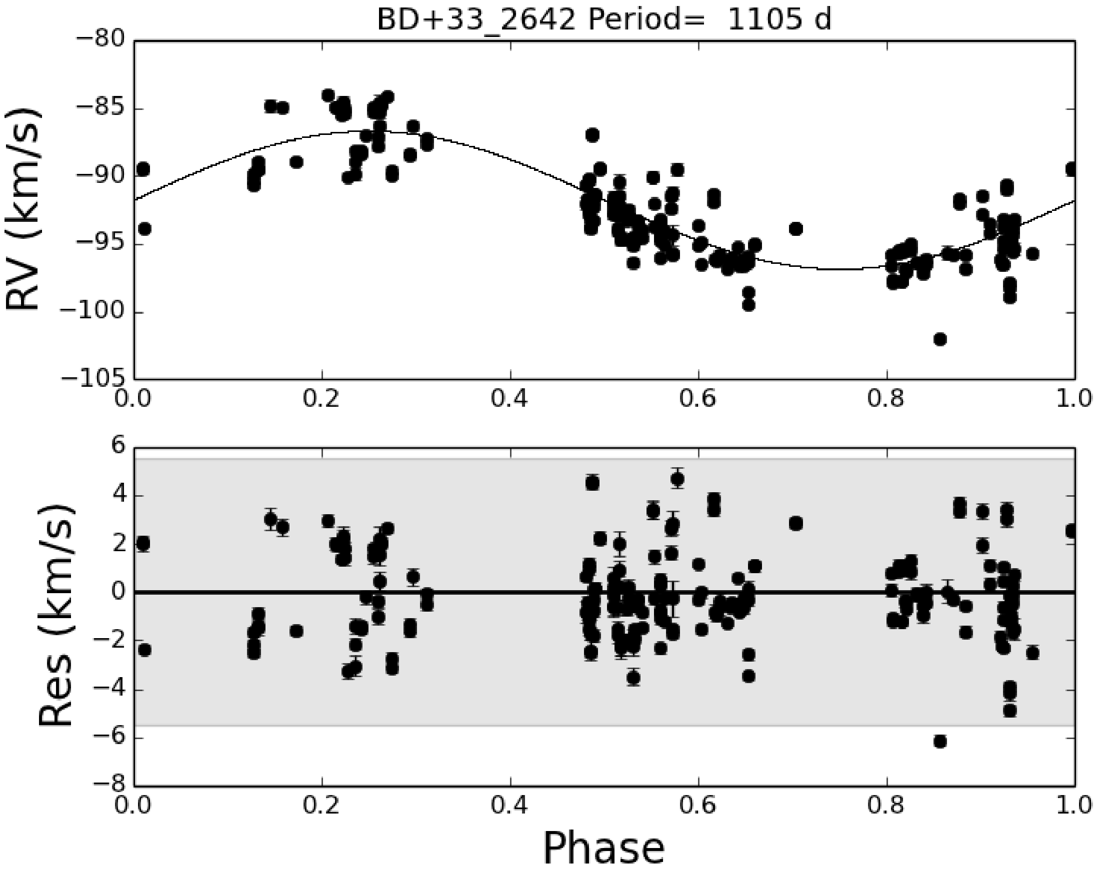
- **depletion can be very extreme with [Fe/H] < -4.8**

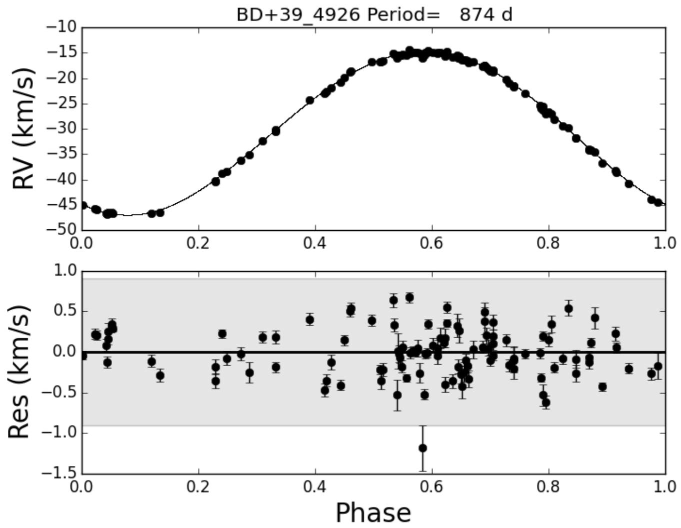
- **depletion tracer is e.g. [Zn/Fe] [S/Ti] etc.**

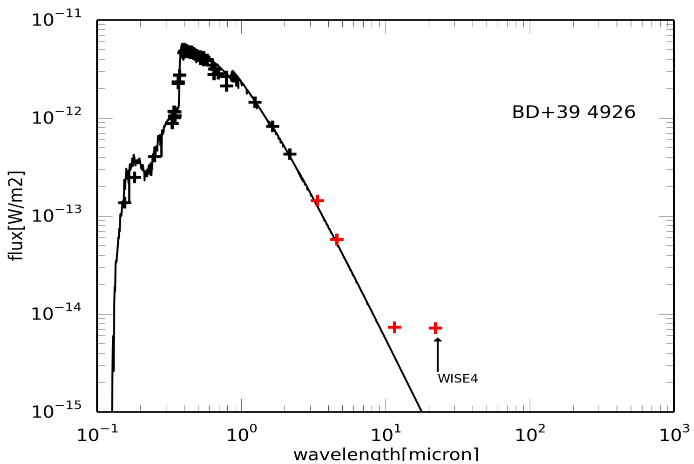
- **surface abundances trace accretion onto the primary**

Oomen et al., in prep., see poster

PNe connection:
Photospheric Depletion: last long, longer then lifetime disc







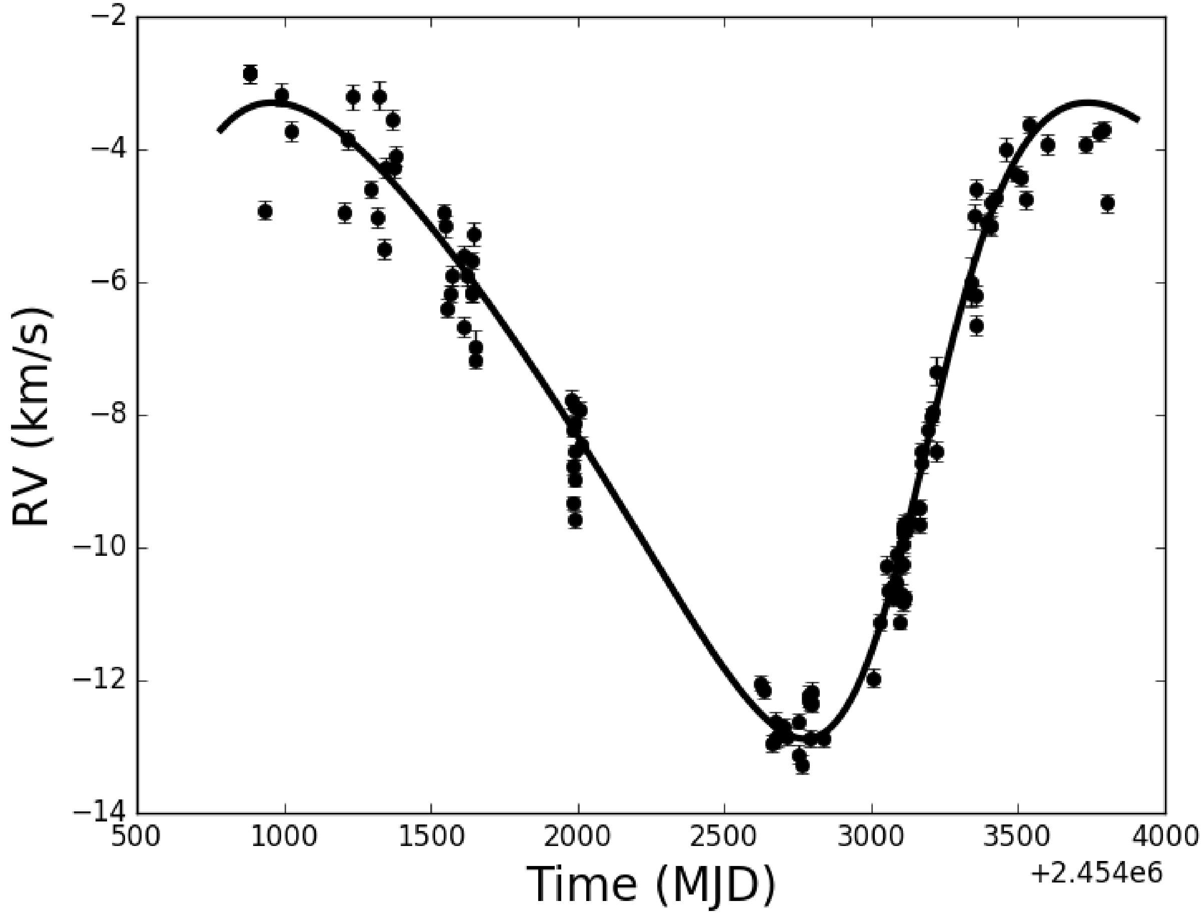
PN BD+33 2642 is depleted

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

Wide binaries in PNe

LoTr5 : 2700 days



Spectroscopic wide binaries in PNe

Velocity comes from companion

Van Winckel et al., 2014; Jones et al., 2017; Miszalski et al., 2017

Keplerian Discs in Post-AGB binaries

- Associated with binary evolution and circumbinary !

- Oribits are not explained (orbits, high eccentricities)
  (also poster by Vos, Oomen; talk by Pols, Escorza Santos, Kamath).

- Commonly observed: disc evolution determines IR lifetime

- Ongoing strong interaction. Accretion discs around companions induce jets (not strongly collimated); gasaccretion induce depletion; (angular momentum, e-pumping); grazing jets ? (N. Soker)

- Resolvable from inner rim (optical interferometry) to outside
  (ALMA, PdB) despite their distances

- The circumbinary discs are secondary protoplanetary discs (similar structure of passive discs) and impact strongly on the evolution !!!!