An interferometric study of the post-AGB binary 89 Herculis:

spatially resolving the continuum circumstellar environment at optical and near-IR wavelengths

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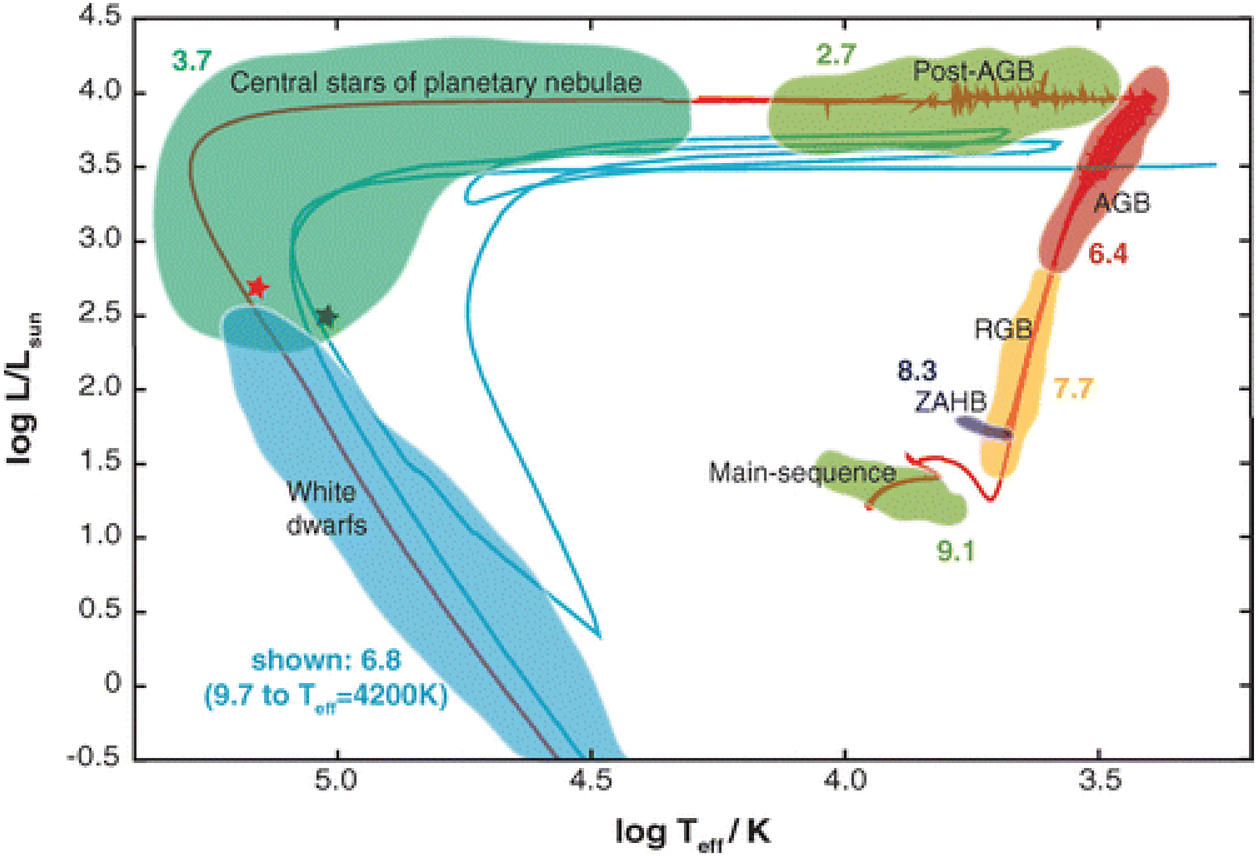
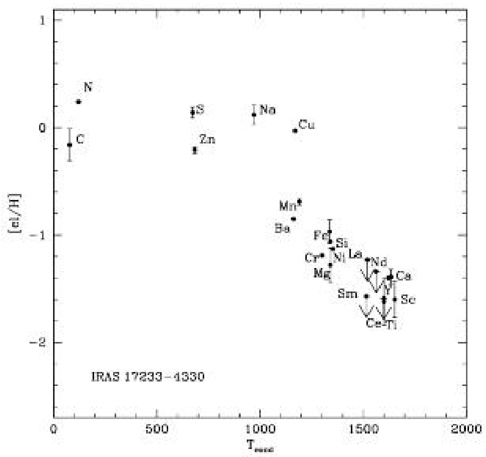
FNRS Contact Group meeting & Astronomy Day of the Royal Observatory, 29-04-2013, Planetarium

Post-AGB stars?

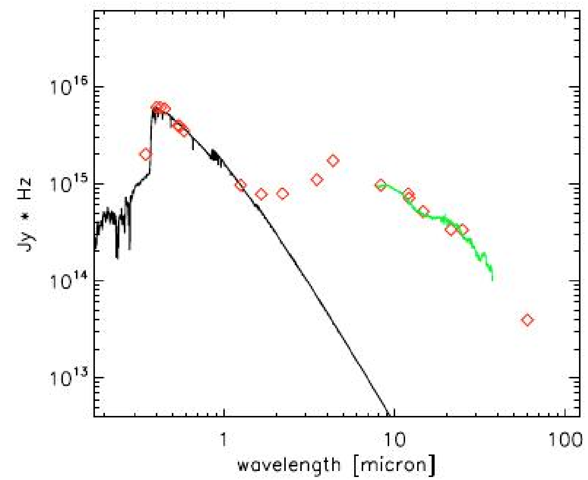


Herwig, F. 2005
Annu. Rev. Astron. Astrophys. 43: 435–79

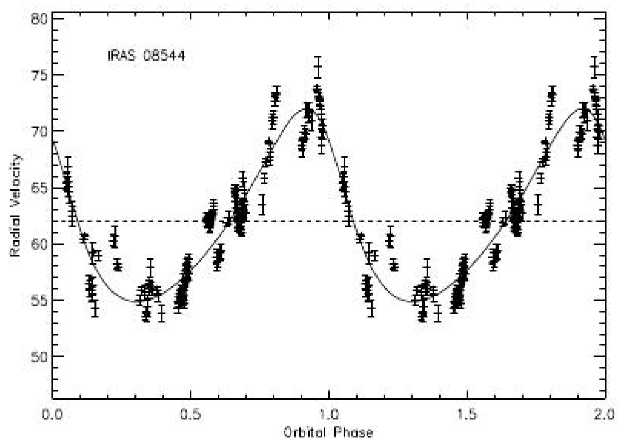
Post-AGB binaries?



Maas et al. (2005)



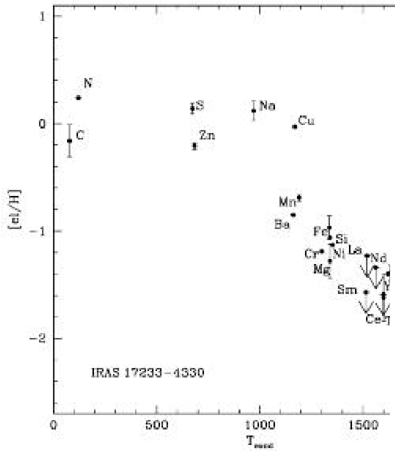
Van Winckel et al. (2009)



Disk formation around post-AGB binaries is a common process!

Post-AGB binaries: the transient torus scenario

Frankowski & Jorissen (2007)



Maas et al. (200

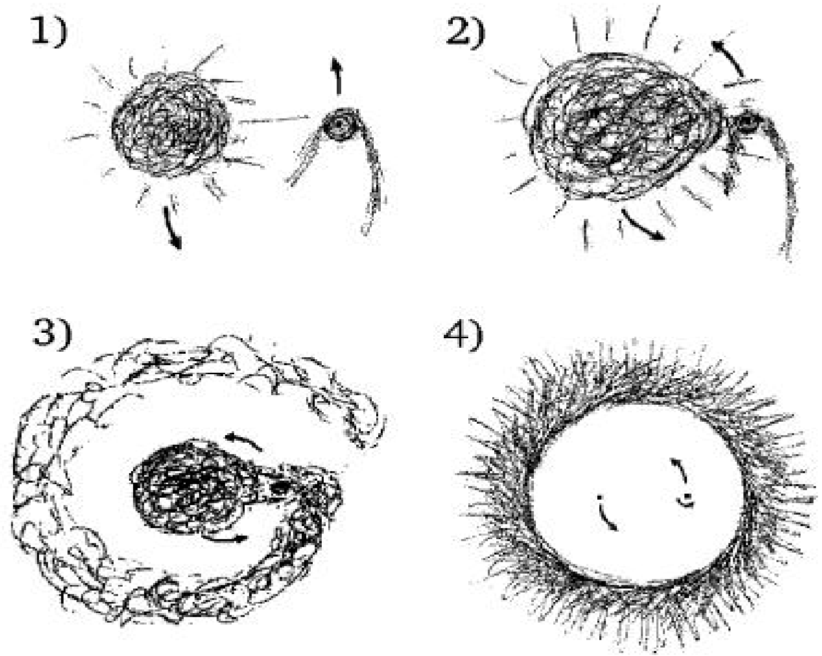
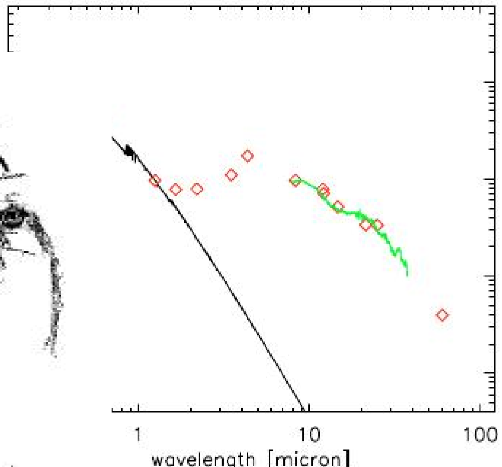
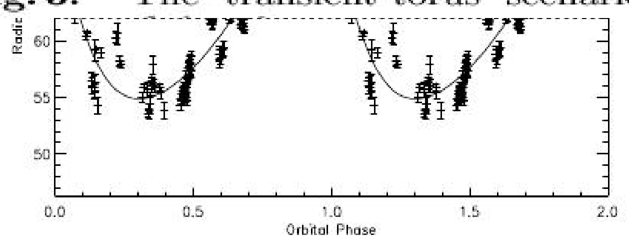


Fig. 3. The 'transient torus' scenario. For



Winckel et al. (2009)

Mastrodemos & Morris (1998)



Disk formation around post-AGB binaries is a common process!

Why study post-AGB binaries?

- Binary evolution
  - ➡ connect with other objects and evolutionary channels in the "binary zoo"
- Disk evolution
  - ➡ study processes that lead to planet formation etc.

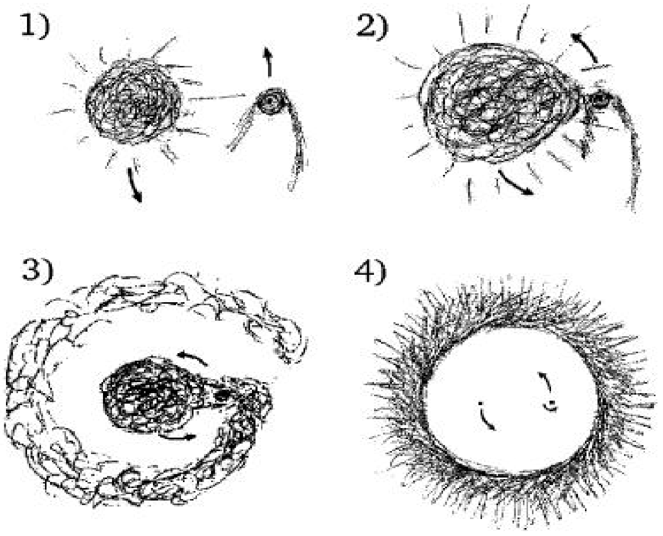
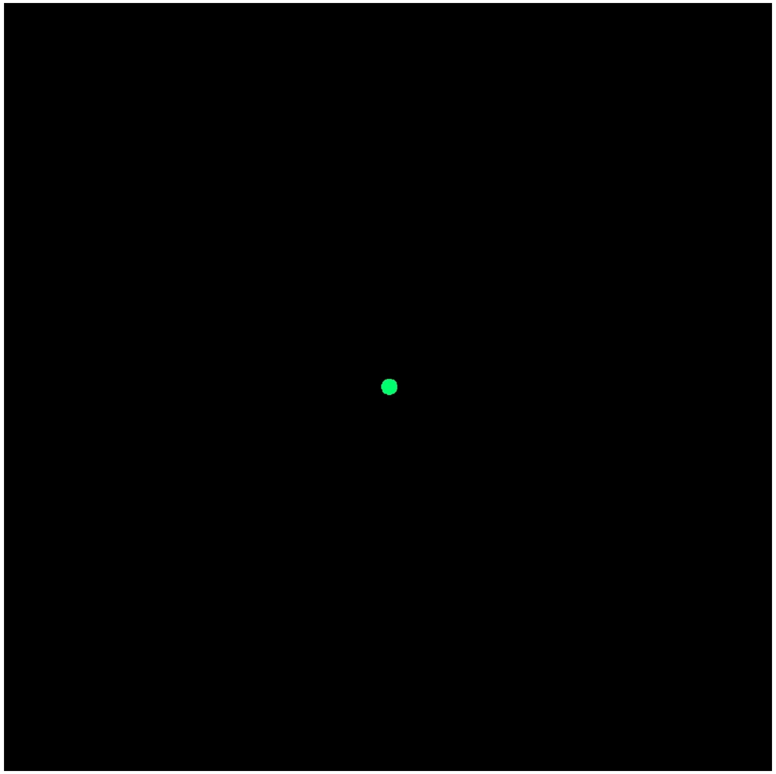
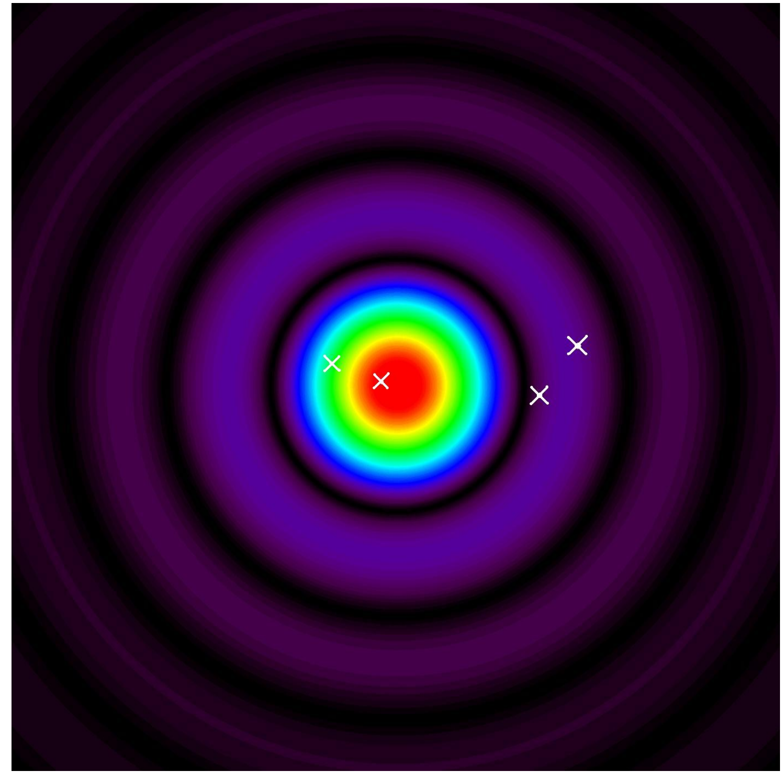


Fig. 3. The 'transient torus' scenario. For

“Optical” interferometry?



$I(\alpha,\beta)$



$V(u,v) = FT(I(\alpha,\beta))$

“Optical” interferometry and disks?

Aim: “directly probe the innermost regions where the interaction between star and circumstellar environment occurs”

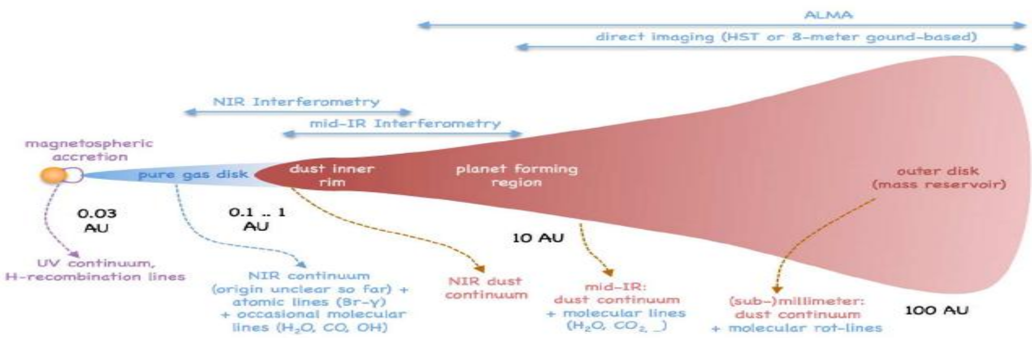
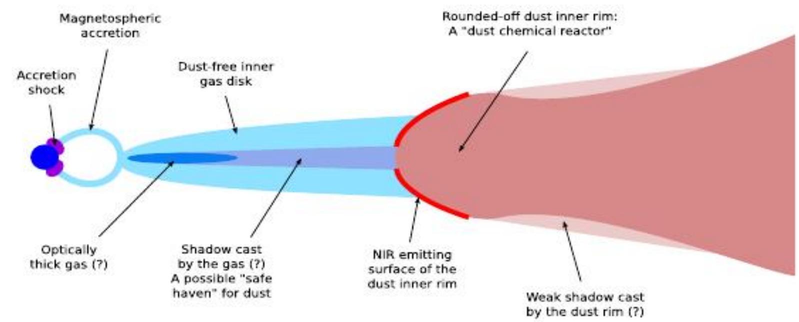


Figure 1: Pictogram of the structure and spatial scales of a protoplanetary disk. Note that the radial scale on the x-axis in not linear. Above the pictogram it is shown which techniques can spatially resolve which scales. Below it is shown which kind of emission arises from which parts of the disk.

Dullemond & Monnier (2010)



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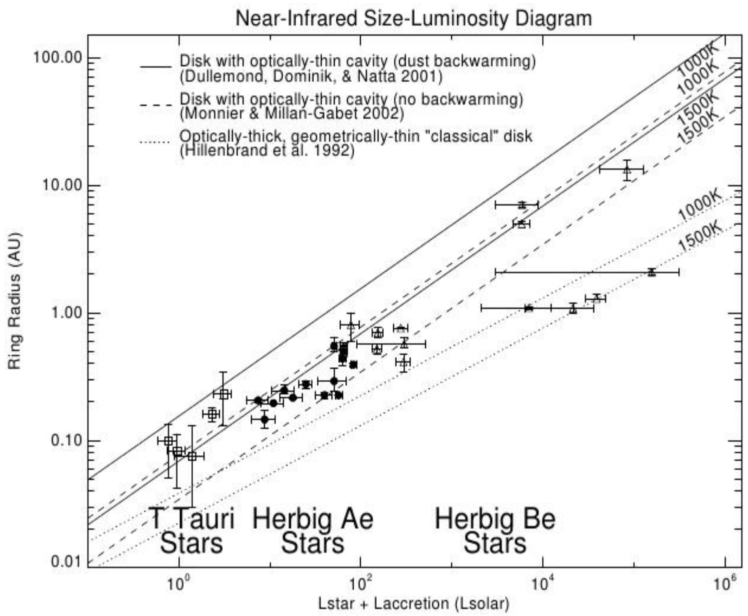
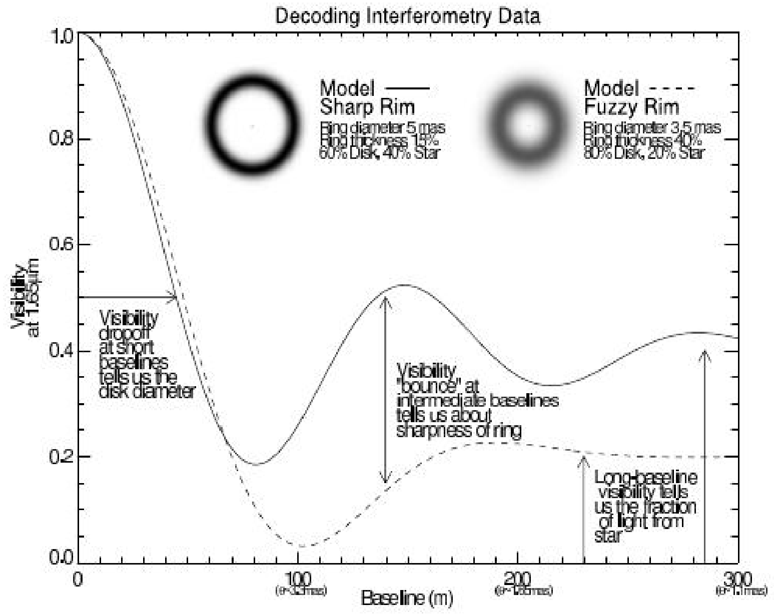
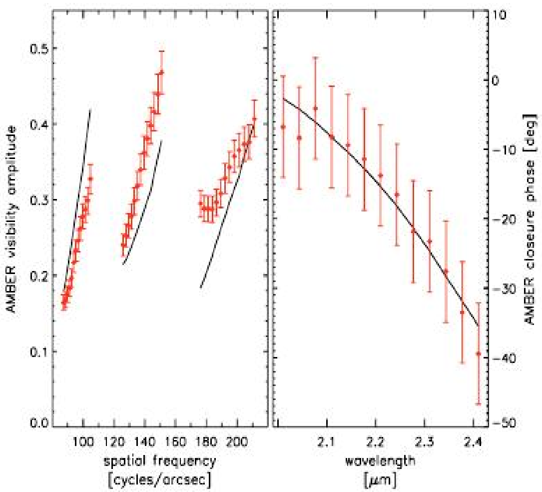


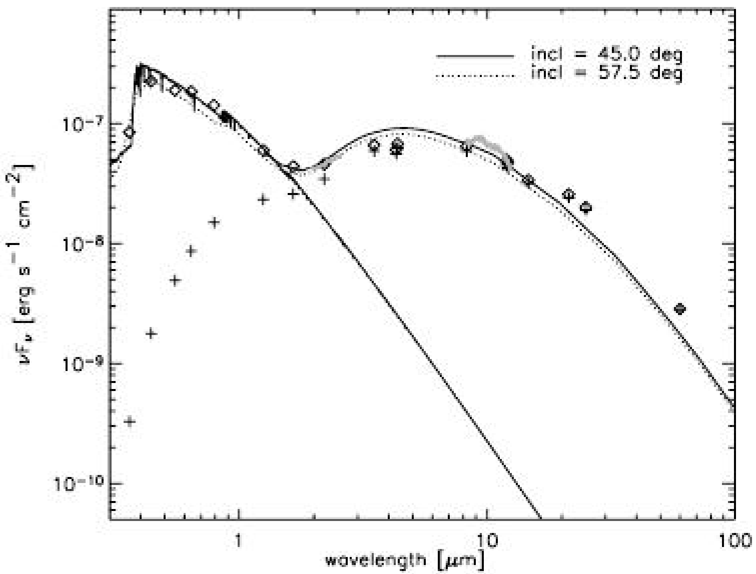
Dullemond & Monnier (2010)

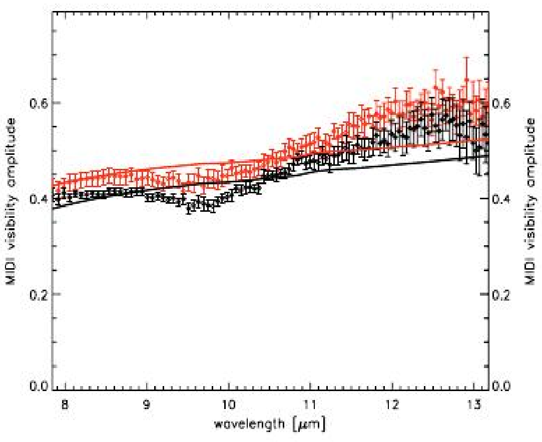


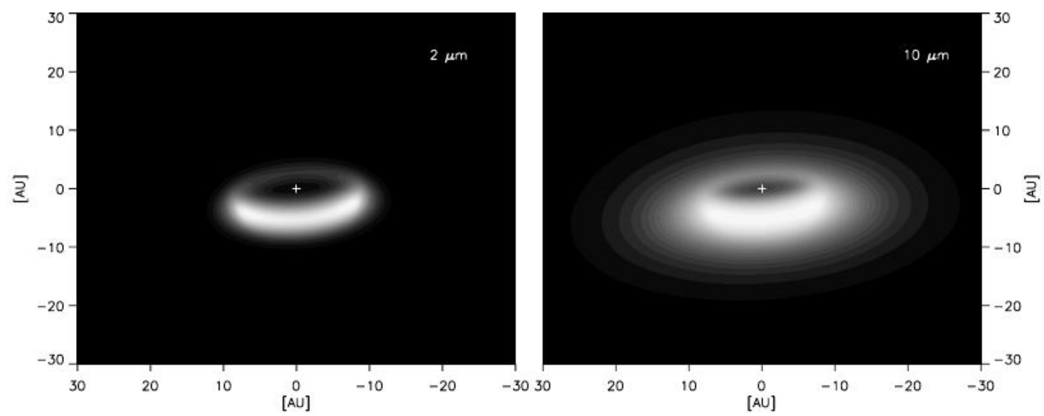
Interferometry of post-AGB binaries?

IRAS08544-4431 (Deroo et al. 2007)









Some background on 89 Herculis

- Waters et al. (1993)

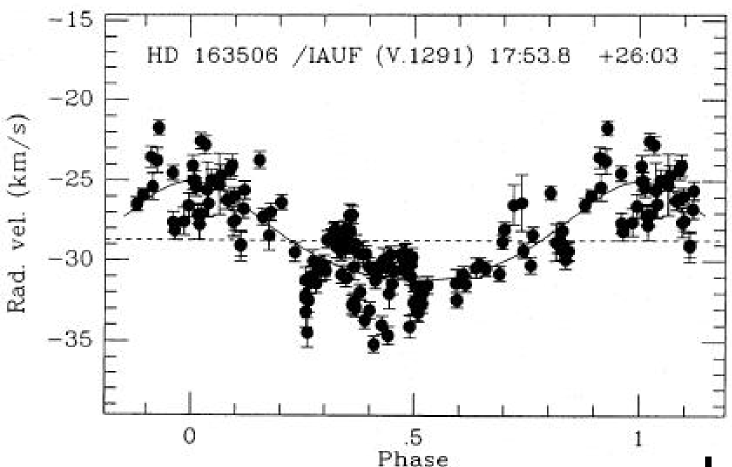
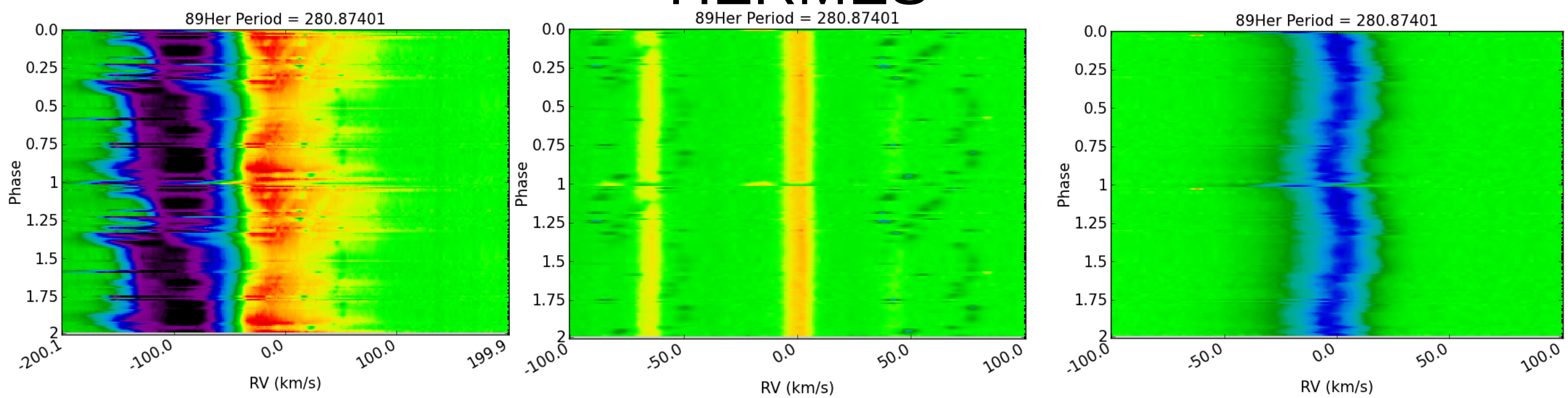


Table 1: The stellar and binary parameters of 89 Herculis.

Parameter	Value	Error	References
Sp.T.	F2Ibe	-	-
Teff (K)	6550	100	1,2
log g	0.55	0.25	1,2
[Fe/H]	-0.5	0.2	1,2
P_{orb} (d)	288.36	0.71	3
e	0.189	0.074	3
$a_1 \sin i$ (AU)	0.080	0.007	3
f(m) ($M_\odot$)	0.00084	0.00022	3
i(°)	12	3	4
π (mas)	0.76	0.23	5
d (kpc)	1.5	0.5	5

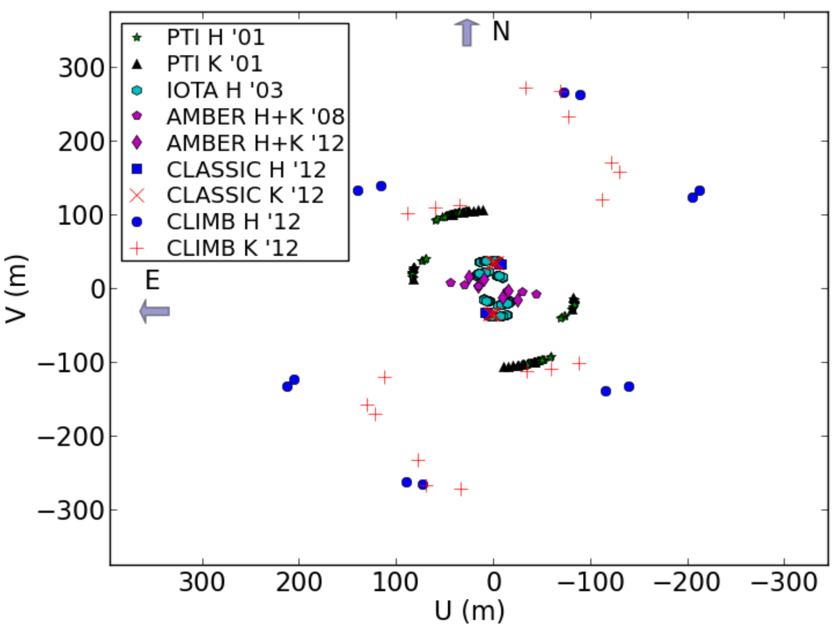
References. (1) Luck et al. (1990), (2) Kipper (2011); (3) Waters et al. (1993); (4) Bujarrabal et al. (2007); (5) van Leeuwen (2007)

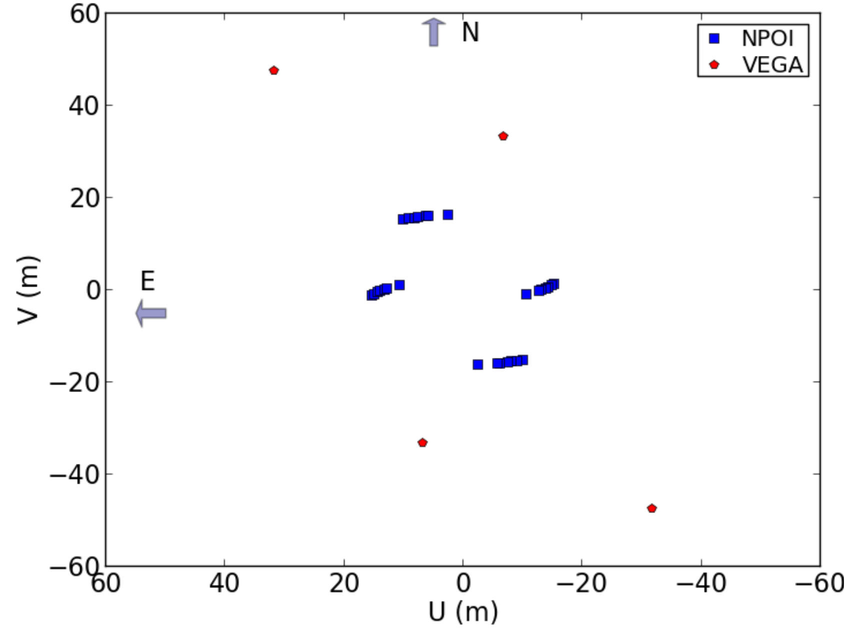
HERMES



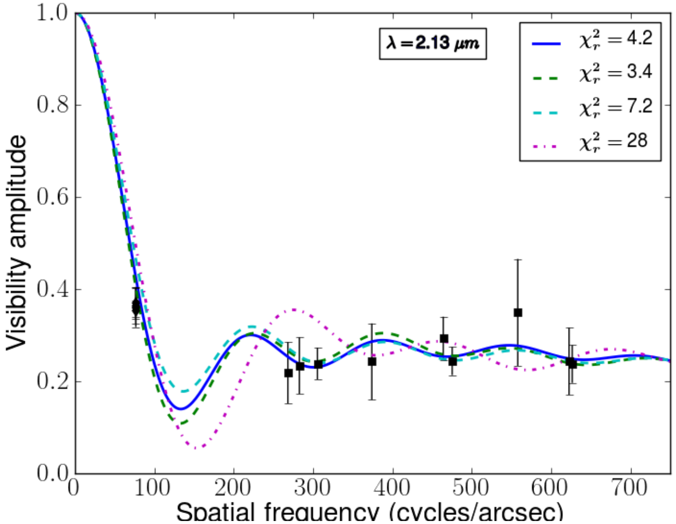
The data

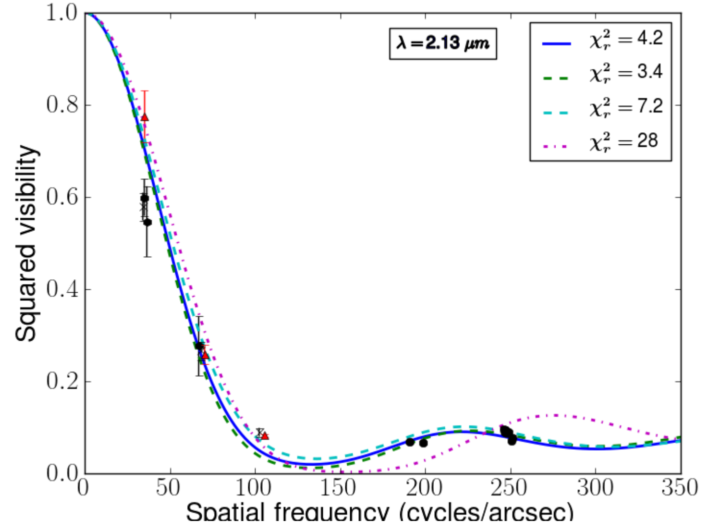
- Optical data: NPOI + VEGA/CHARA
- Near-IR data: AMBER/VLTI + CLASSIC/CHARA + CLIMB/CHARA + PTI + IONIC3/IOTA (H)
- Mid-IR data: MIDI/VLTI





A simple model: the best uniform rings





K-band

- Blue

  Inner = 3.0

  Width = 4.6
- Green

  Inner = 4.1

  Width = 4.0
- Cyan

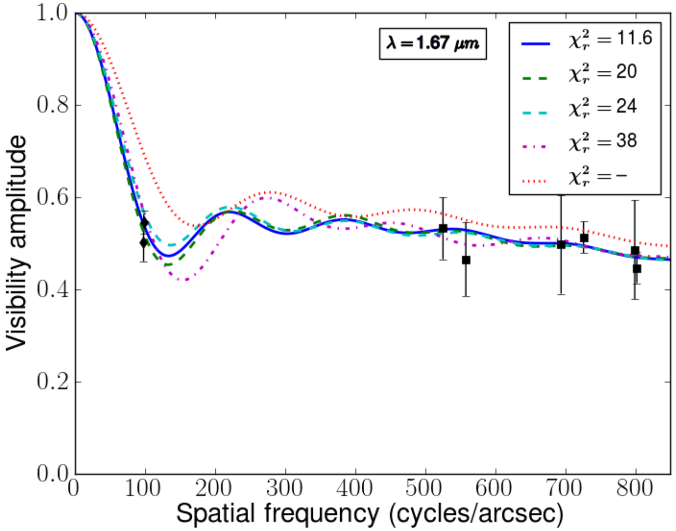
  Inner = 1.0

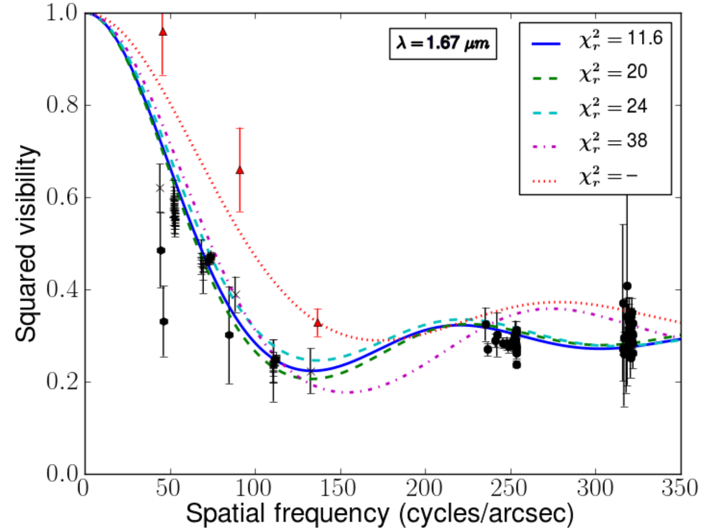
  Width = 5.5
- Magenta

  Inner = 5.0

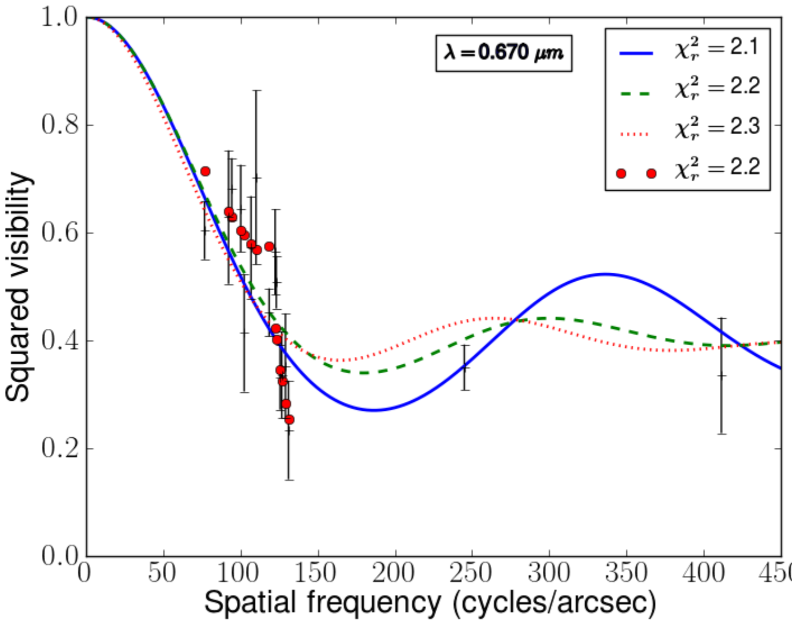
  Width = 2.5

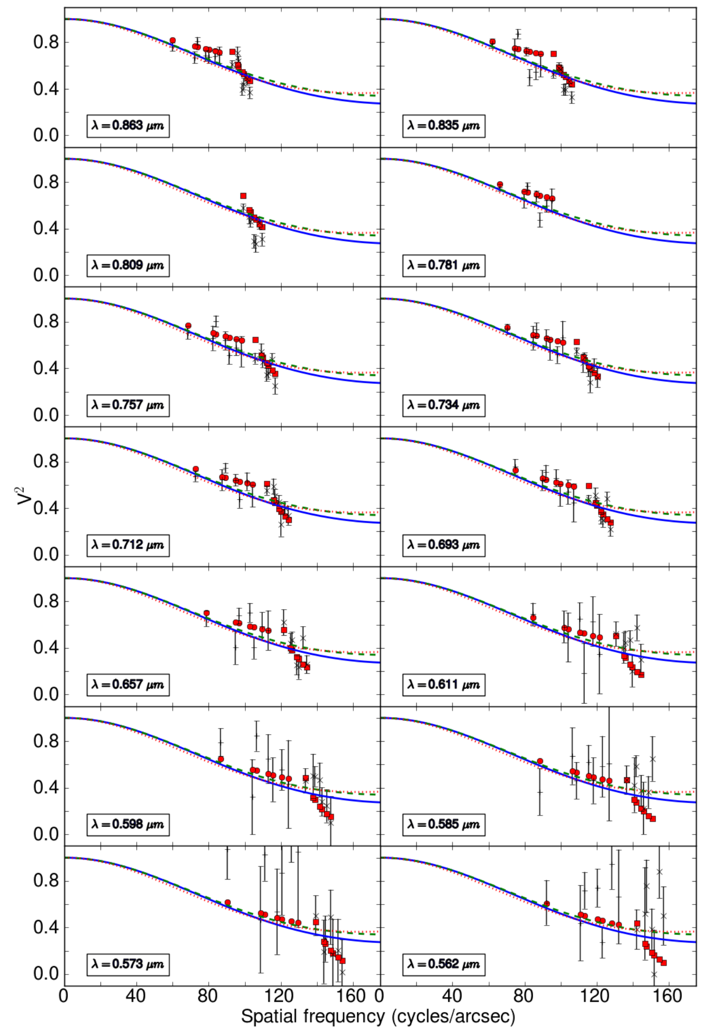
H-band





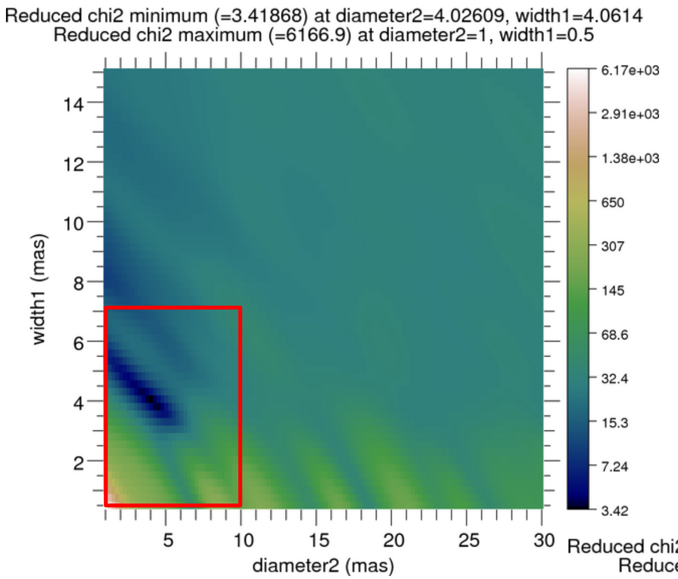
A simple model: the best uniform optical ring





35-40% of the total optical flux @ 673 nm is resolved, but from (within) the inner rim!

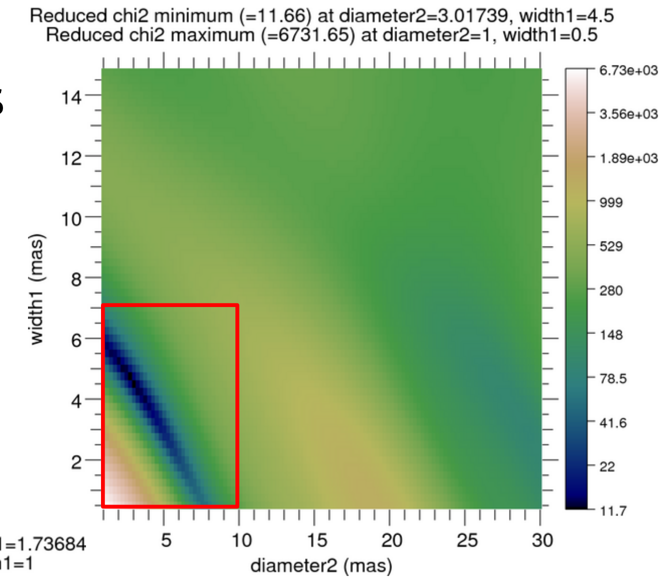
A simple model: χ^2–maps for a uniform ring



$\Theta_* = 0.45 \pm 0.15$ mas

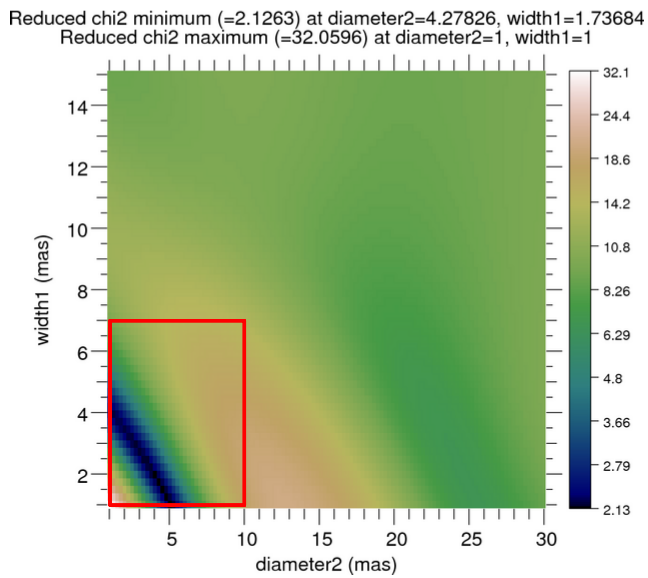
R-band ~ 0.70µm

$F_* = 65 \pm 7\%$



$F_* = 28 \pm 5\%$

K-band ~ 2.2µm



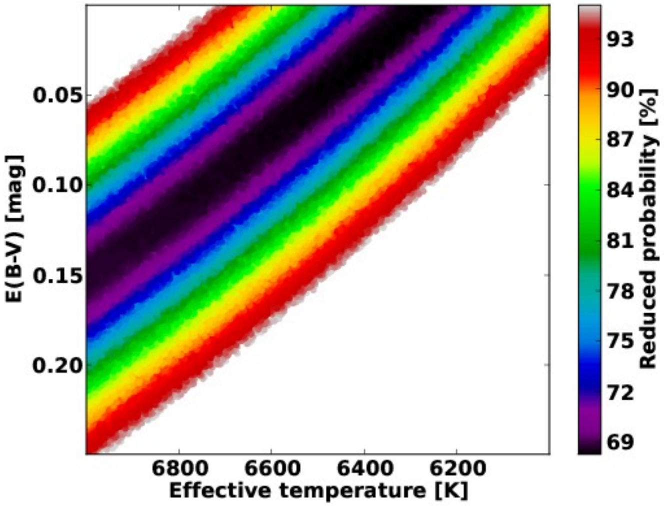
$F_* = 56 \pm 5\%$

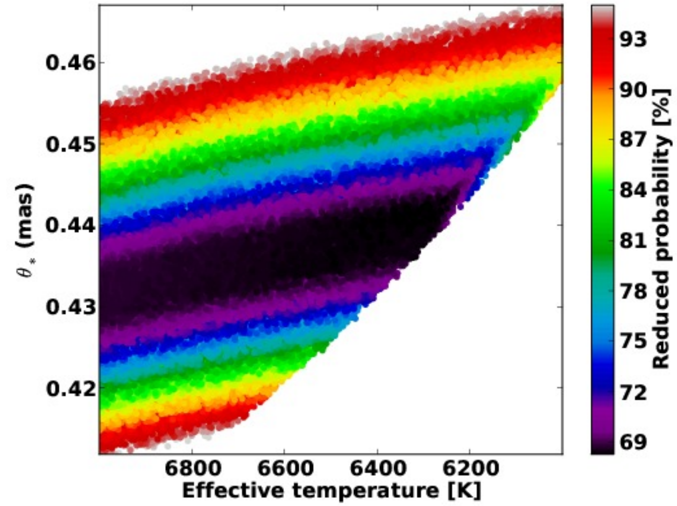
H-band ~ 1.65µm

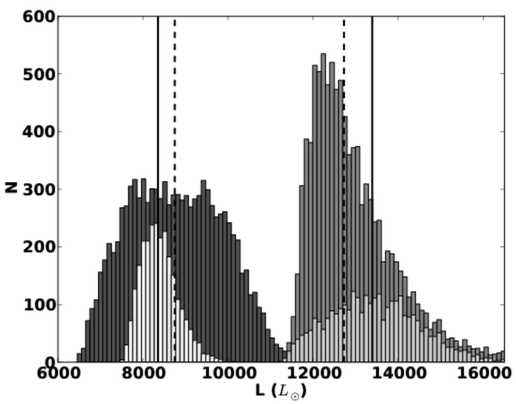
Size ↘ if λ ↘ !

Not a thin ring!

A redefined “Stellar and circumstellar SED”



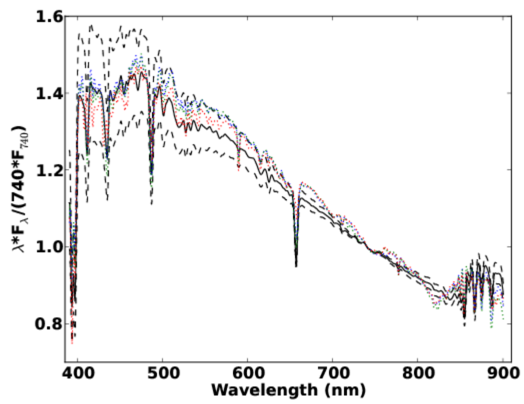




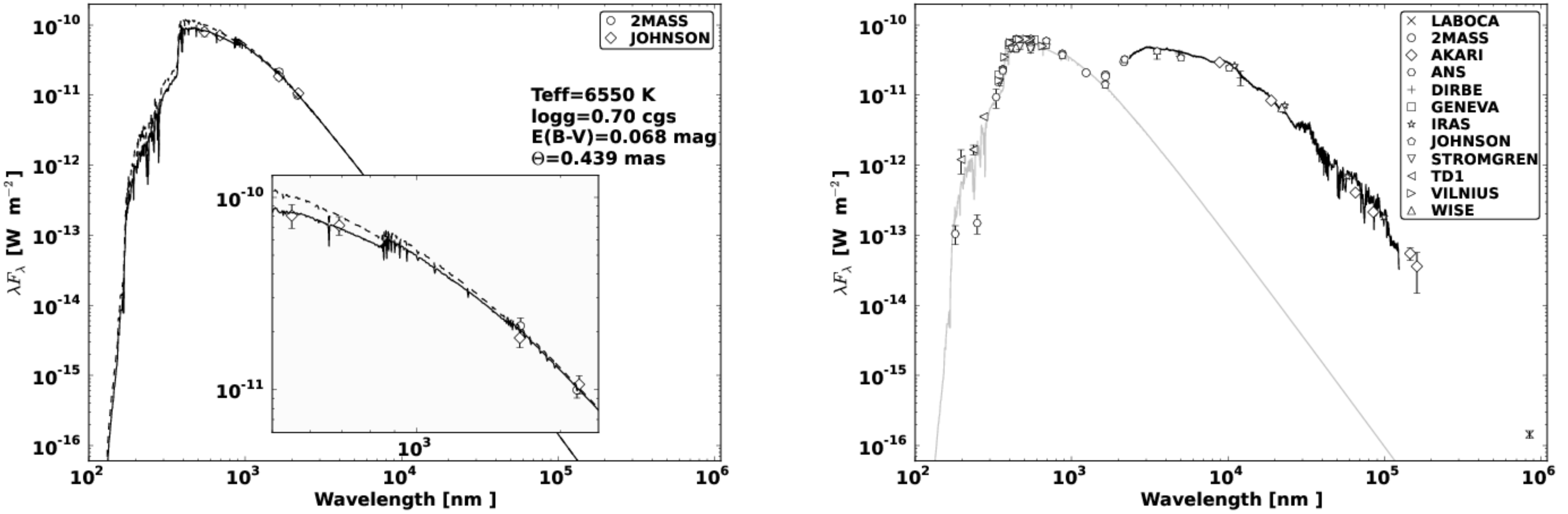
Based on H, K, R, V “corrected” photometry

@ 1.5 kpc → 8350 L_{sol}

+ Hermes



A redefined "Stellar and circumstellar SED"



Circumstellar flux: scattering!

Discussion: three possible models

- The circumbinary disk → half-opening angle 52 degrees? !
- The circumbinary disk + an inner gas disk → H^- b-f + f-f ?

  + can be close

  + CO emission

  - high T

  - high density

  - flat intensity gradient

  - flux drops off for $\lambda < 600$ nm → not seen in SED and HERMES spectra
- The circumbinary disk + a bipolar outflow

  + flat intensity gradient

  + K → H → V

  + spectrum~stellar

  + material at high altitude → scattering efficiency, not at angle of 80-100°

  - confinement?

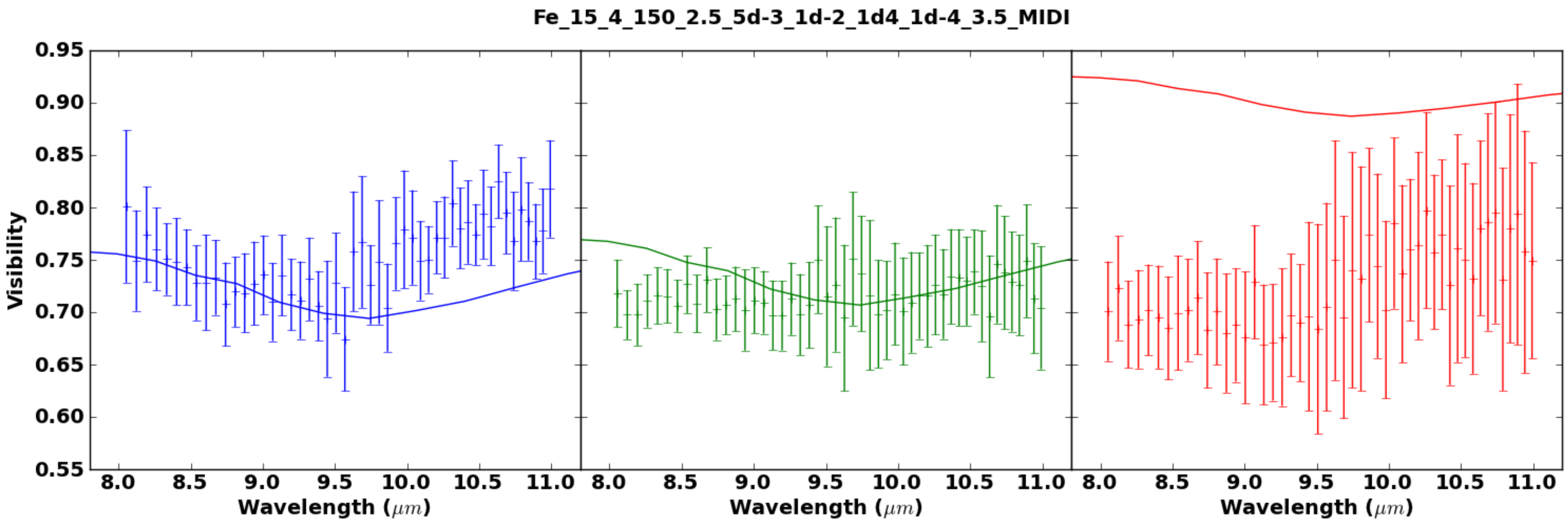
  - reddening?

Conclusion/outlook

- Complex close circumstellar environment reveiled with multi-wavelength interferometry
- “Projected inner rim” of dust disk resolved → smooth emission profile with inner radius (~2 mas) close to binary in near-IR
- First detection of “extended emission” at 550-850 nm at i~10

  → 40% of total flux from a ring with outer radius 2.5-5 mas
- SED redefined
- Three solutions proposed
- MCMax modelling of case 1 ongoing → difficult, case 2 very unlikely, so a bipolar outflow?

Future observational work

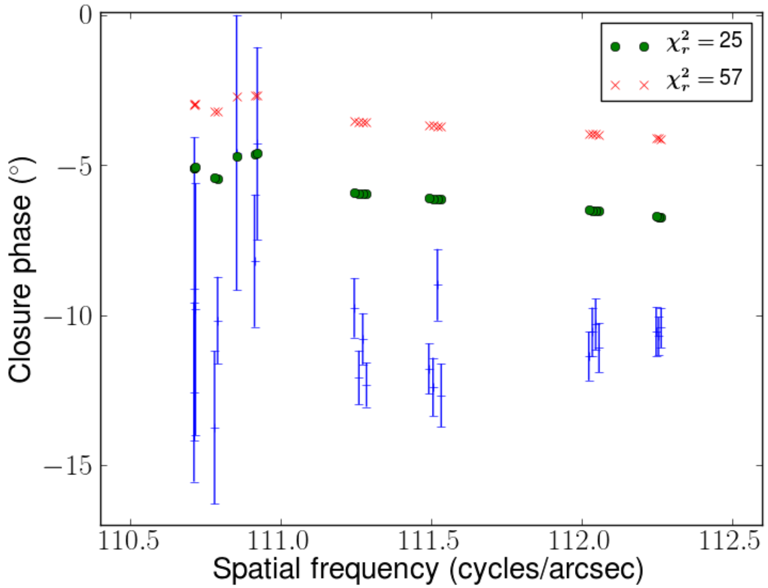


B~30m B~31m B~15m

Thank you for your attention!
Questions?

If you liked this work and are planning to open up a post-doc position, please let me know:

michelh@ster.kuleuven.be or michel.hillen2@gmail.com



Closure phase (°)
Spatial frequency (cycles/arcsec)
$\chi_r^2 = 25$
$\chi_r^2 = 57$
0
−5
−10
−15
110.5
111.0
111.5
112.0
112.5