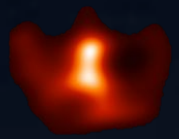


AGB stars as seen by PIONIER and beyond

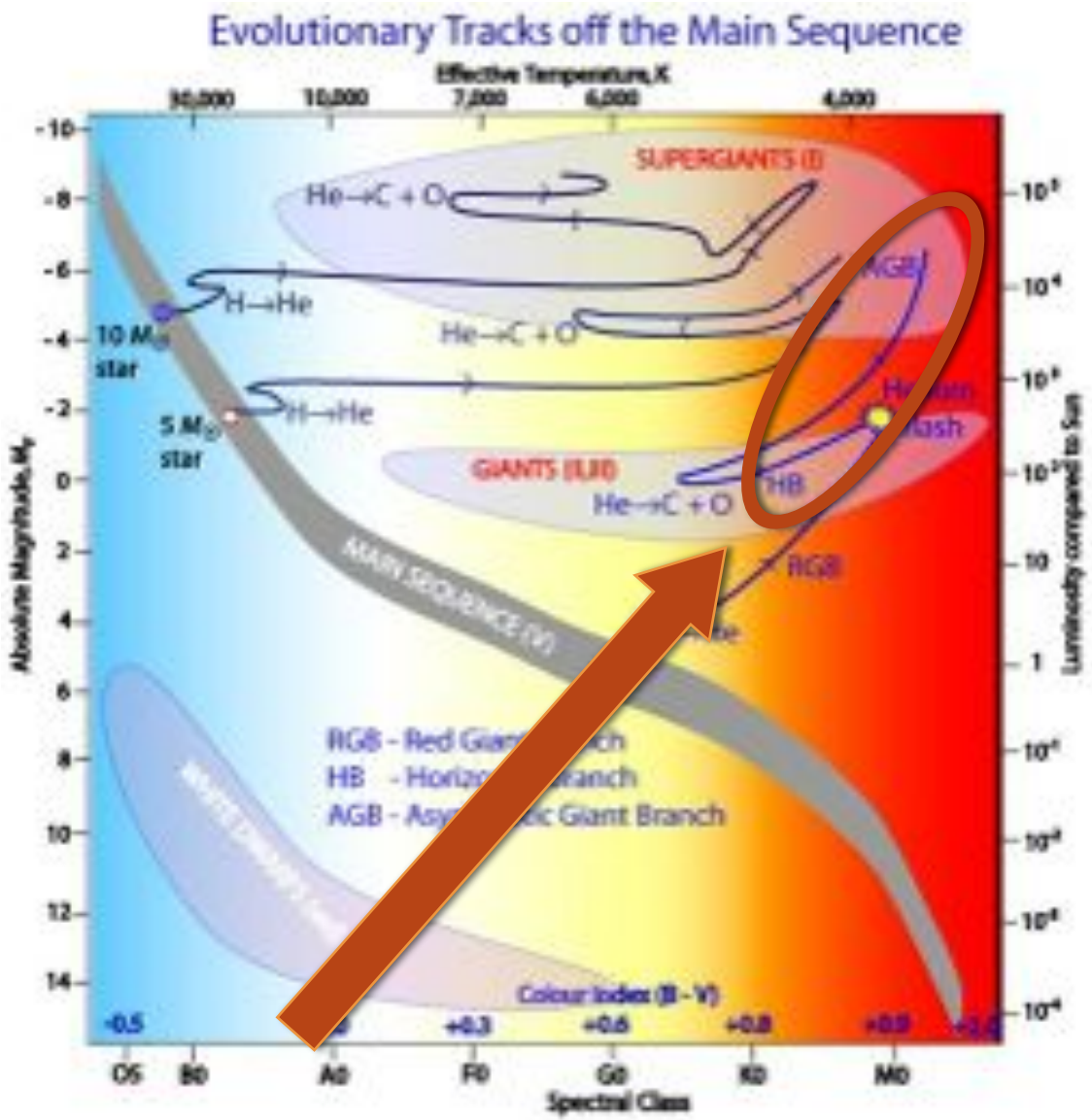
Claudia Paladini

ULB UNIVERSITÉ LIBRE DE BRUXELLES

Belgian Science Policy Office belspo

Outline

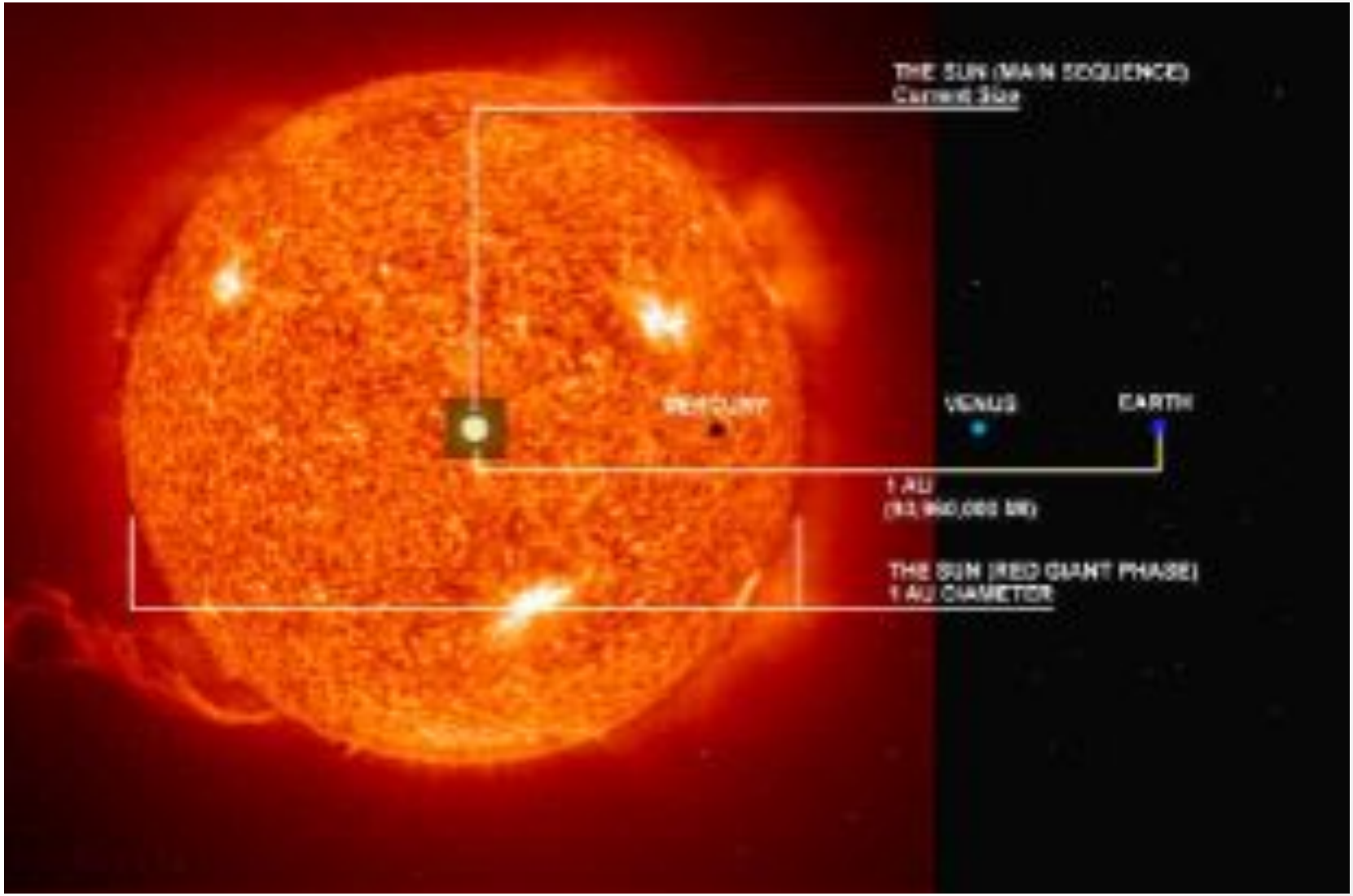
- *Setting the stage:* Asymptotic Giant Branch (AGB) stars
- *Why do we study AGB stars*
- *PIONIER's applications: the present*
  - Diameter measurements
  - Imaging of an AGB star
- PIONIER's applications: the future
  - PIONIER & post-AGB
  - PIONIER, ALMA, Herschel, etc.
- Lessons learned, wish list, discussion



1-8 solar mass stars

credit: http://outreach.atnf.csiro.au/

AGB stars:
the future of our Sun



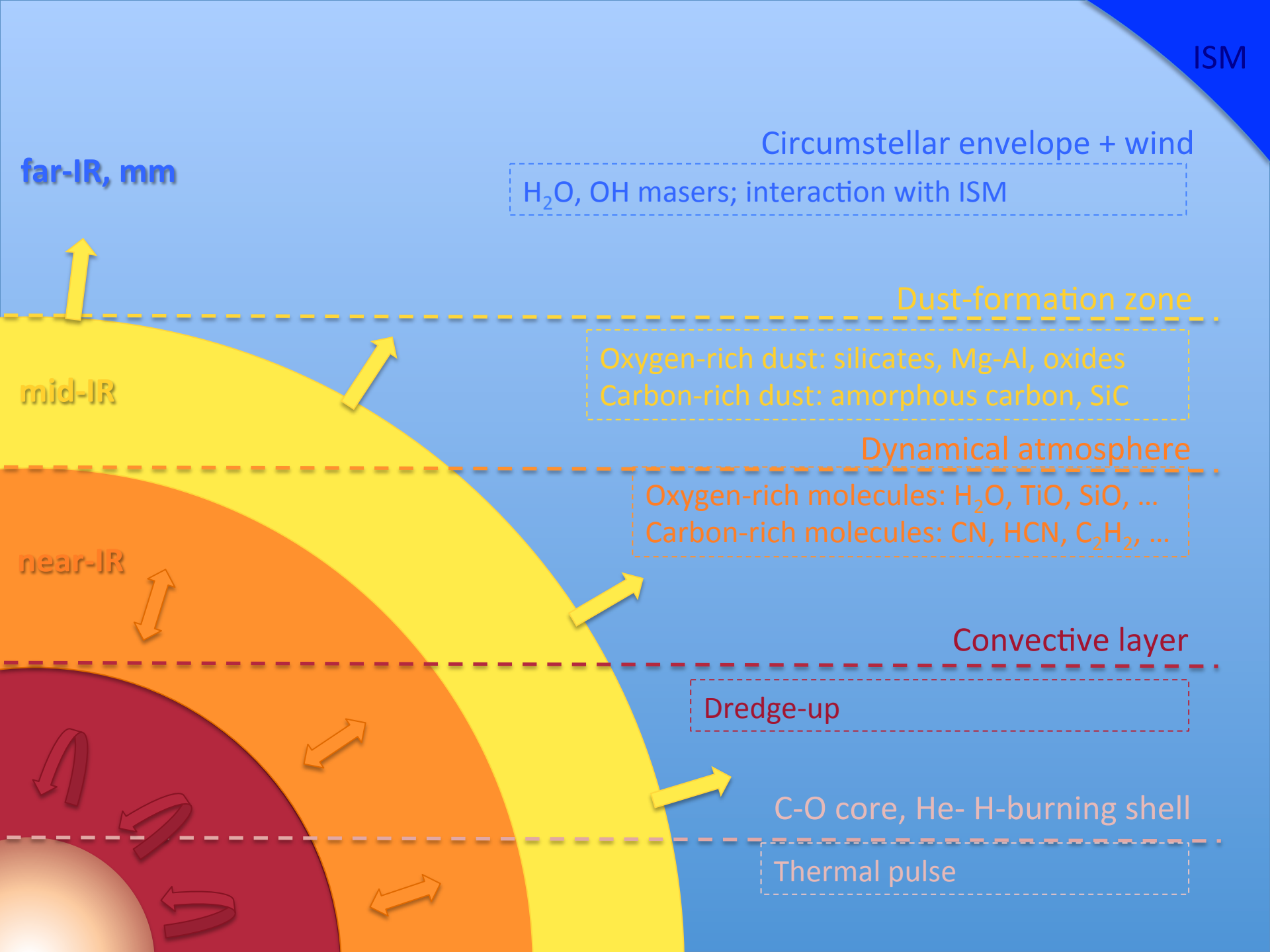
Why AGB stars?

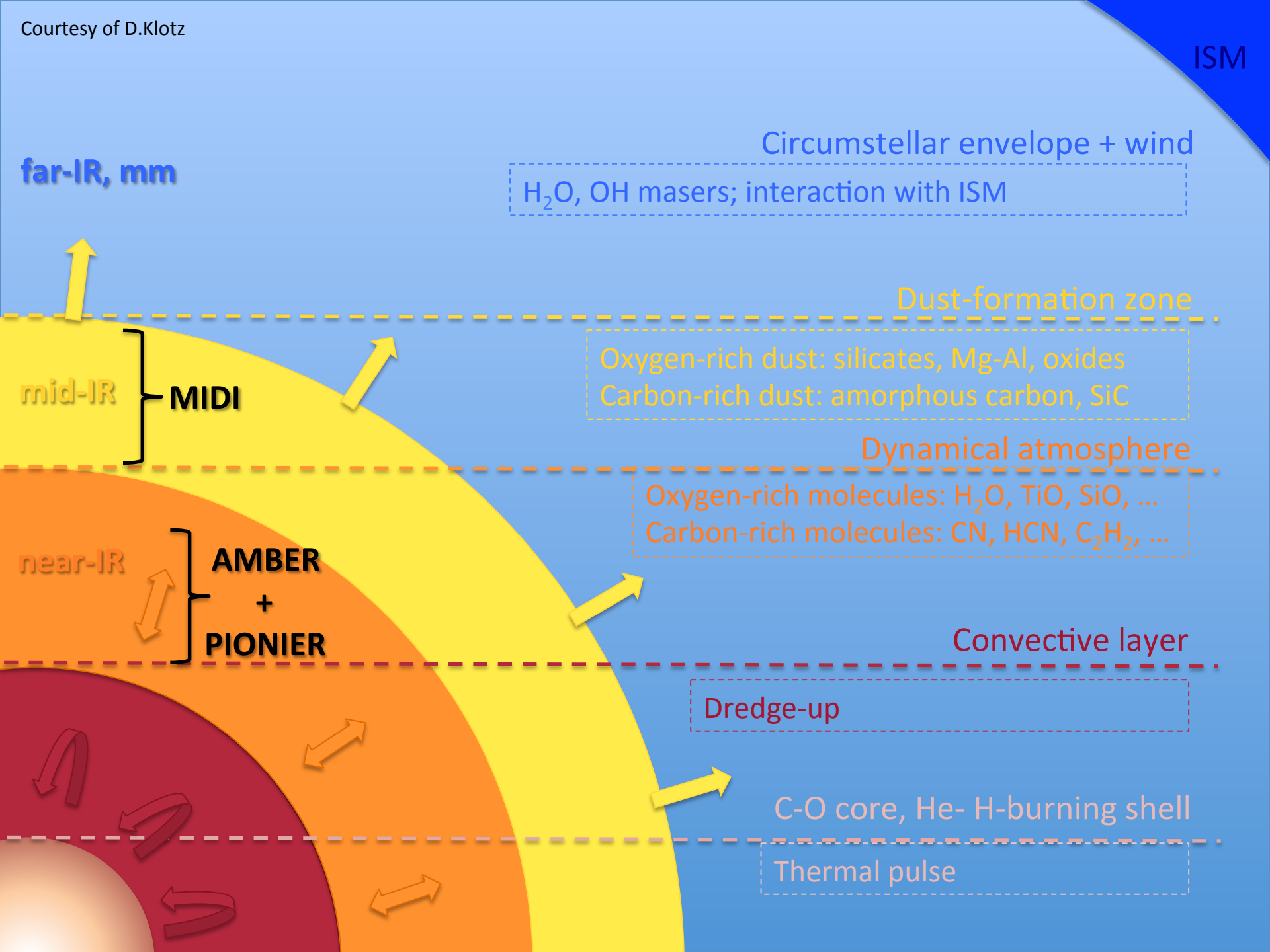
- Nucleosynthesis
- Mass-loss through stellar wind

Chemical enrichment of galaxies

Building blocks of the next generation of stars, planets… life.

Artistic impression of a Red Giant


ISM
Circumstellar envelope + wind
far-IR, mm
H_2O, OH masers; interaction with ISM
Dust-formation zone
mid-IR
Oxygen-rich dust: silicates, Mg-Al, oxides
Carbon-rich dust: amorphous carbon, SiC
Dynamical atmosphere
Oxygen-rich molecules: H_2O, TiO, SiO, …
Carbon-rich molecules: CN, HCN, C_2H_2, …
near-IR
Convective layer
Dredge-up
C-O core, He- H-burning shell
Thermal pulse


Courtesy of D.Klotz
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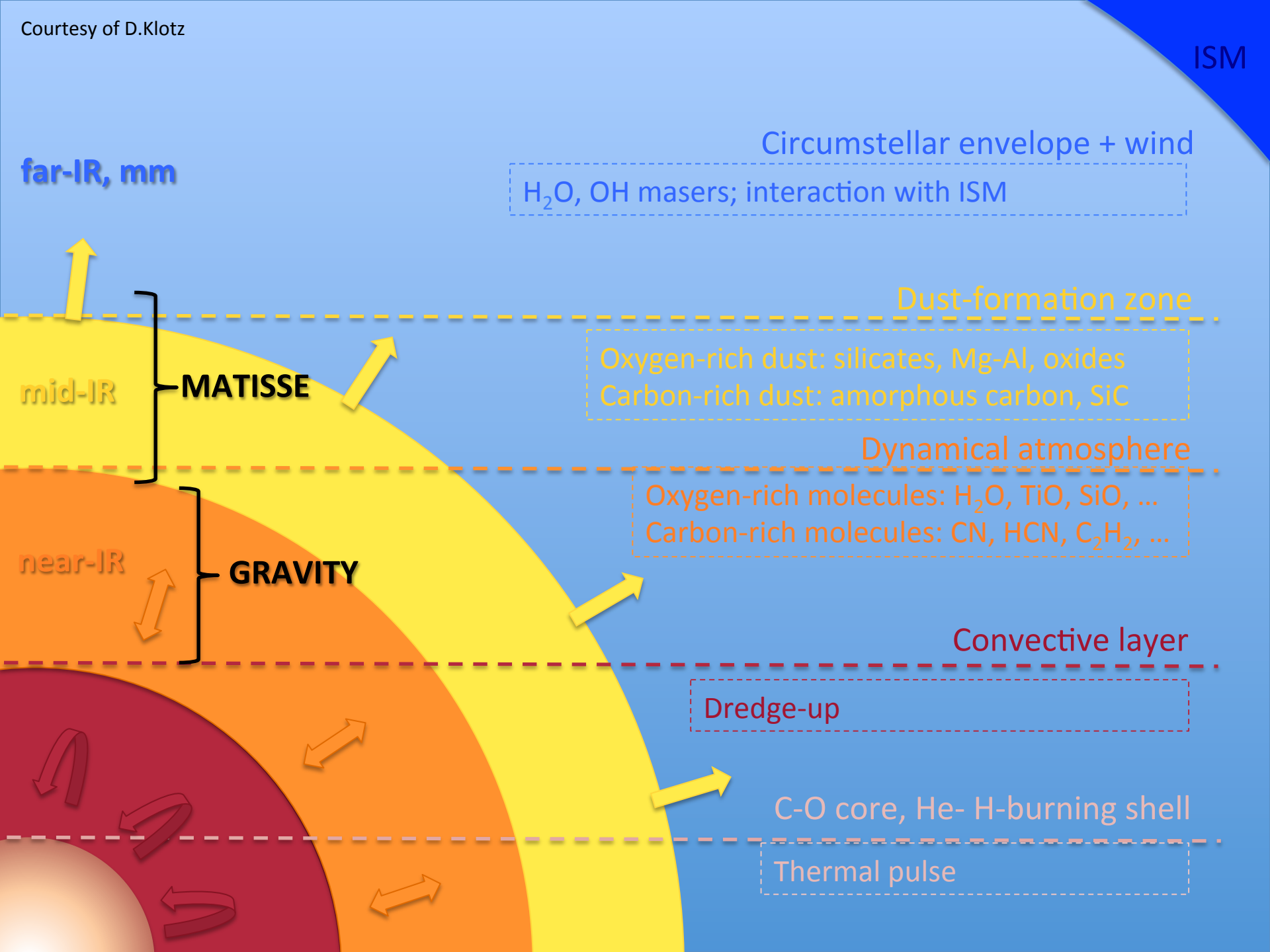
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Thermal pulse

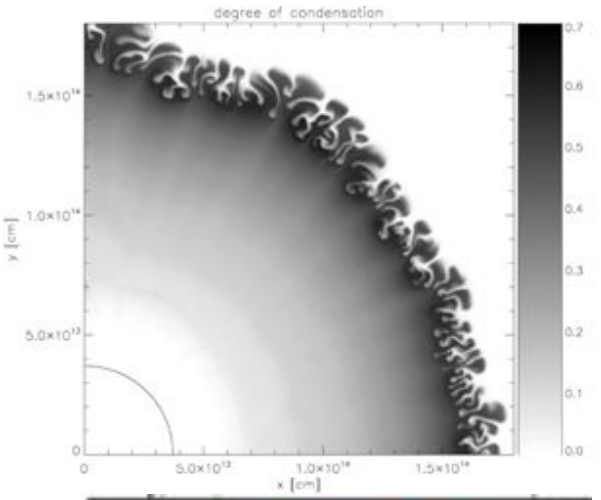
Mass-Loss mechanism

- Carbon-rich AGB stars
  - Radiative pressure on dust grains
  - Gas & dust accelerated away from the star
  - Models can reproduce observations

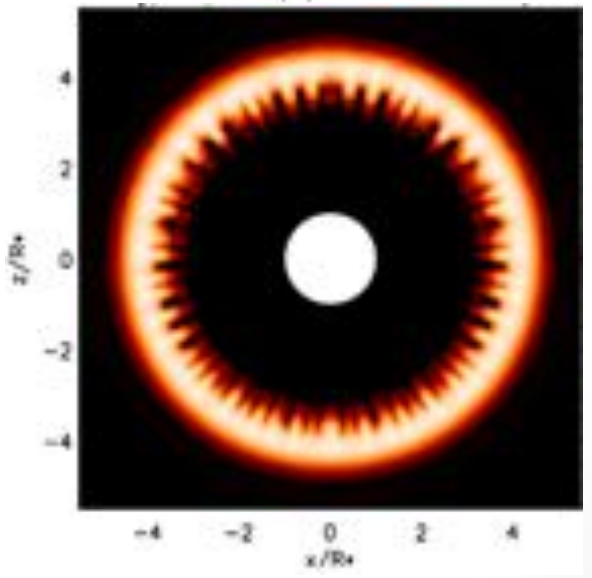
- Oxygen-rich AGB stars
  - Dust grains have to be close (iron-free) and have enough absorption cross-section in near-IR (iron-rich) (Woitke 2006)
  - Scattering cross-section of forsterite particles high enough to drive the wind for micron-sized particles (Hoefner 2008, Bladh 2013)

Physical mechanisms (I)

- Pulsation induce shock-waves
  - Dust shells formation
  - Length scale ~ few stellar radii
- Drift instabilities
  - System switches between high/low mass-loss state
  - Shell structures
  - Length scale ~ few 100 stellar radii
- Radiative instabilities
  - Dust clouds
  - Cool dust structures are surrounded by warmer gases



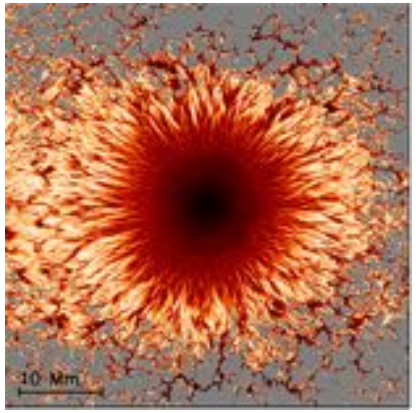
Woitke 2006



Woitke & Niccollini 2004

Physical mechanism (II)

- Magnetic activity = formation of magnetic spots
  - Locally facilitates dust formation
  - Possible cause for deviation from spherical outflows
- Rotation = more dust on equatorial plane
  - Increase density scale height in the equatorial plane
  - Dust formation more efficient
- Binarity = companion transfers angular momentum
  - Influence of rotation on dust distribution
  - System may capture lost mass in circum-binary disc



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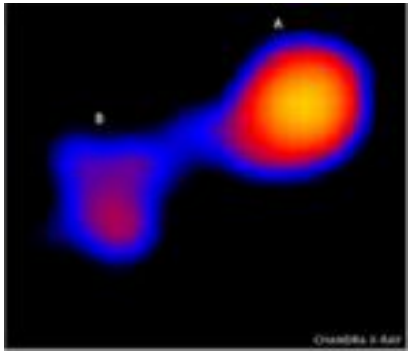


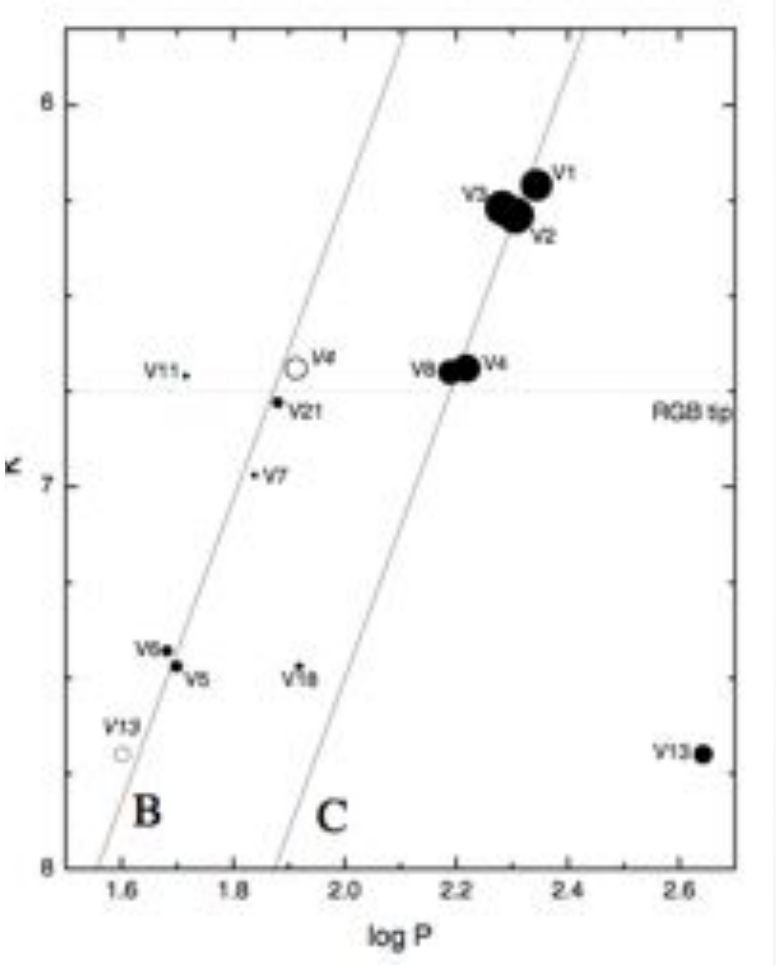
chandra.harvard.edu

PIONIERing diameter measurements of globular cluster giants

J. Hron, J.-B. Le Bouquin, T. Lebzelter, C. Paladini, H. Boffin, I. Soszynski, J.-P. Berger, M. Wittkowski

The science case

- First attempt to resolve a Mira star in a globular cluster
- 47 Tuc distance ~4 Kpc
- Expected visibility ~0.9



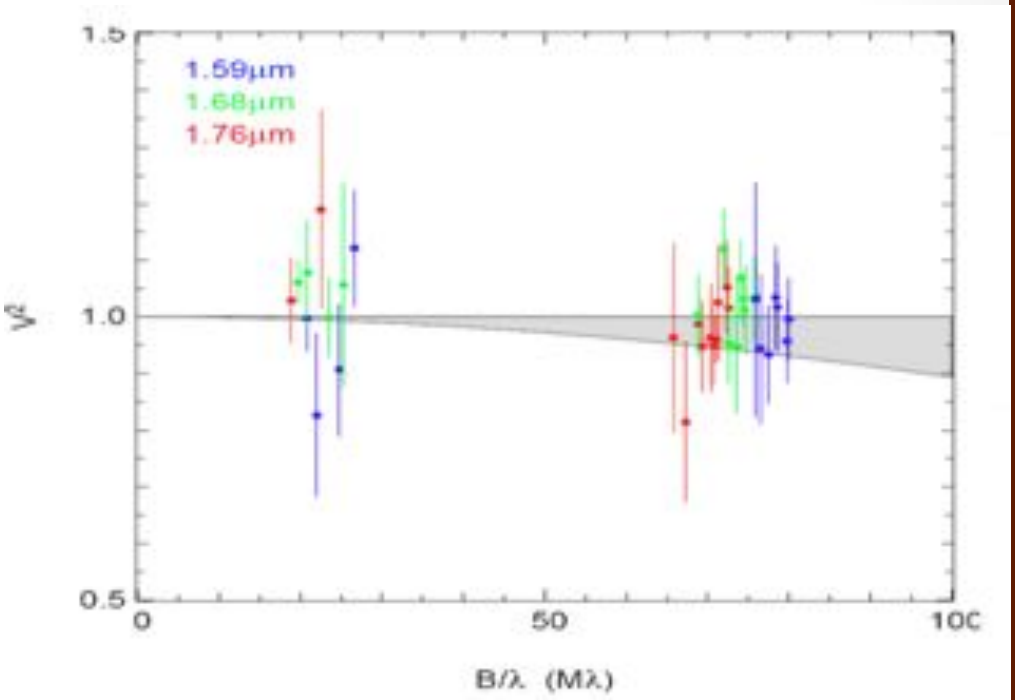
Lebzelter et al. 2005

Results

- Unfortunately unresolved ☹
- Size estimated ~0.4 mas

Wish list

- Shorter wavelengths (but the object gets fainter J~7, V~11)
- Longer baselines (>300 m)



A postcard from the dust forming region of a carbon-rich Mira with PIONIER

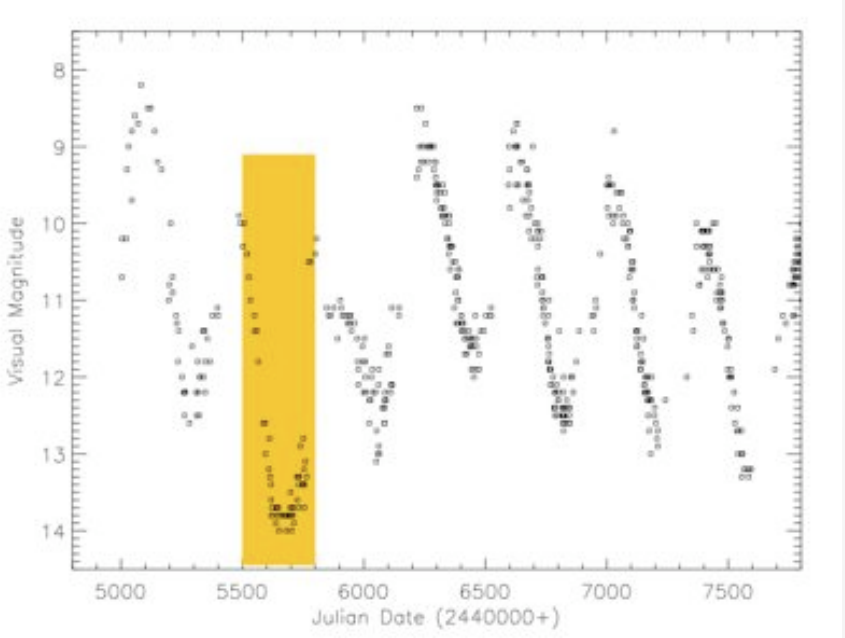
C. Paladini, J.-B. Le Bouquin, W. Nowotny, J. Kluska, K. Eriksson, F. Baron, J. Monnier, C. Lykou, J. Hron, M. Wittkowski, K.Ohnaka, J.-P. Berger, E. Thiebaut, D. Klotz, A. Luntzer & PIONIER team

Dust obscuration events

Deep minima in the light curves of AGB stars because of increased dust obscuration.

Different scenario:

- Symmetric mass loss
- Discs or dust clumps



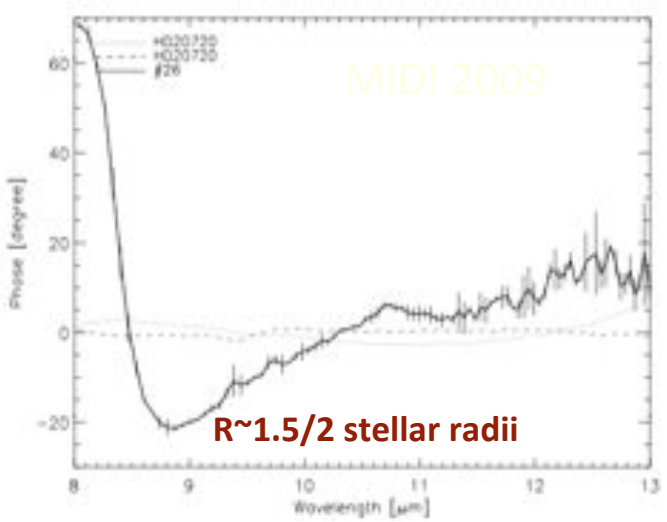
Visual light curve of RFor from AAVSO

To be or not to be asymmetric?

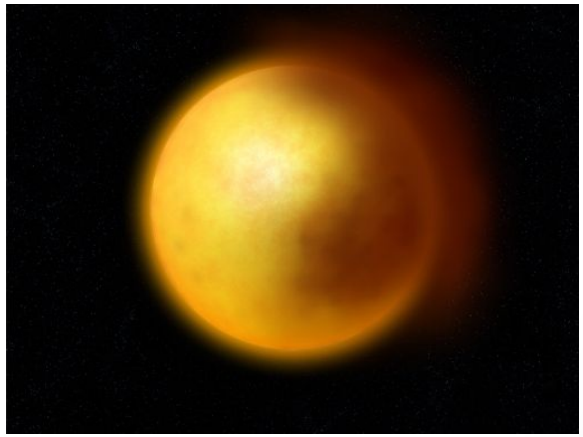
Detection of signature of **deviation from central-symmetric structure with MIDI ~1.5-2 stellar radii** (Paladini et al., 2012)

Signature in the SiC dust and C2H2 molecular layer
⇒ C_2H_2 is dust building block

Asymmetric dust emission like in RCoronae Borealis stars?



Paladini et al., 2012



Leao et al. (2007); Jeffers et al. (2012)

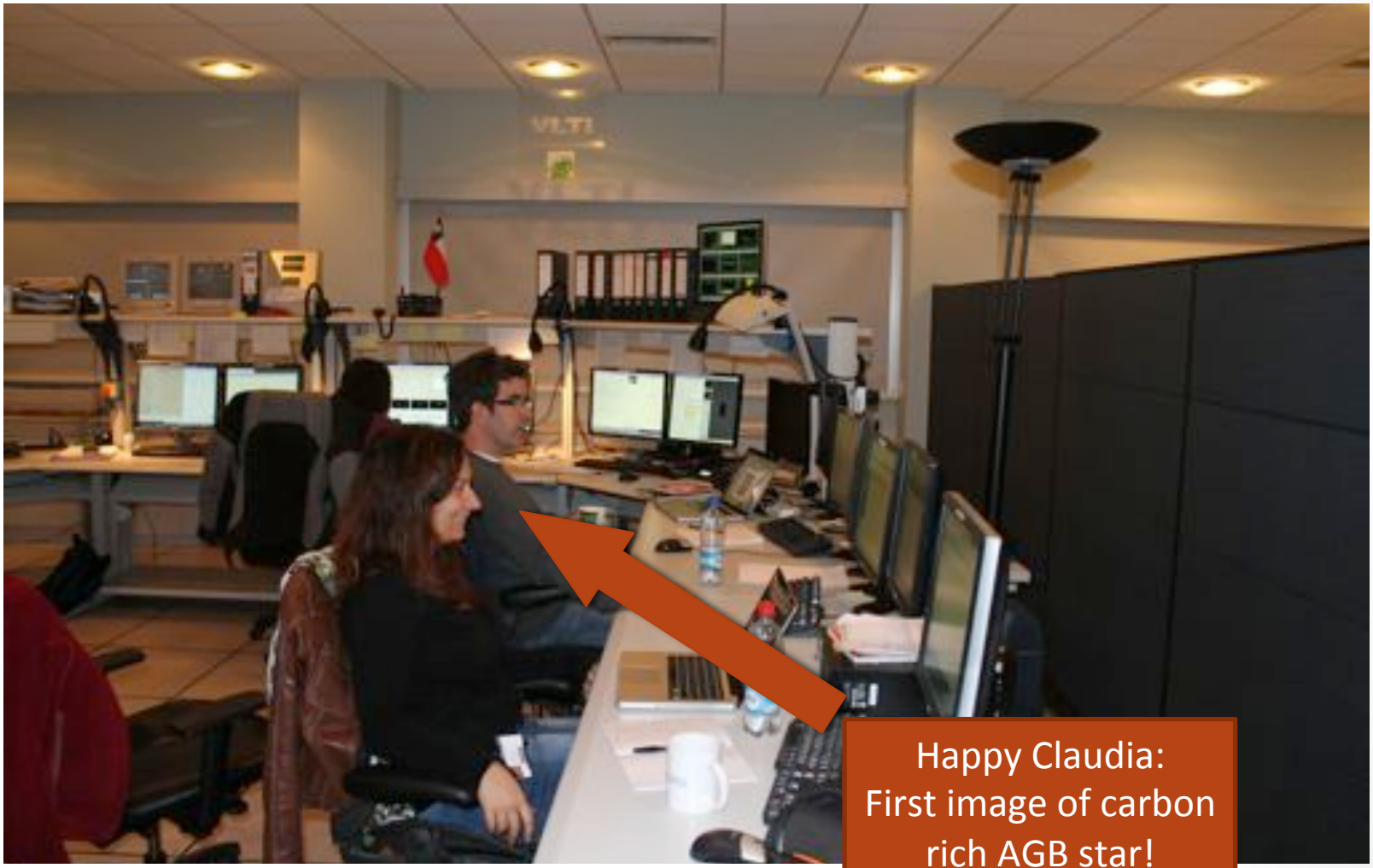
Let's make an image…

Imaging AGB stars: things to be aware of

Not an easy task. Why?

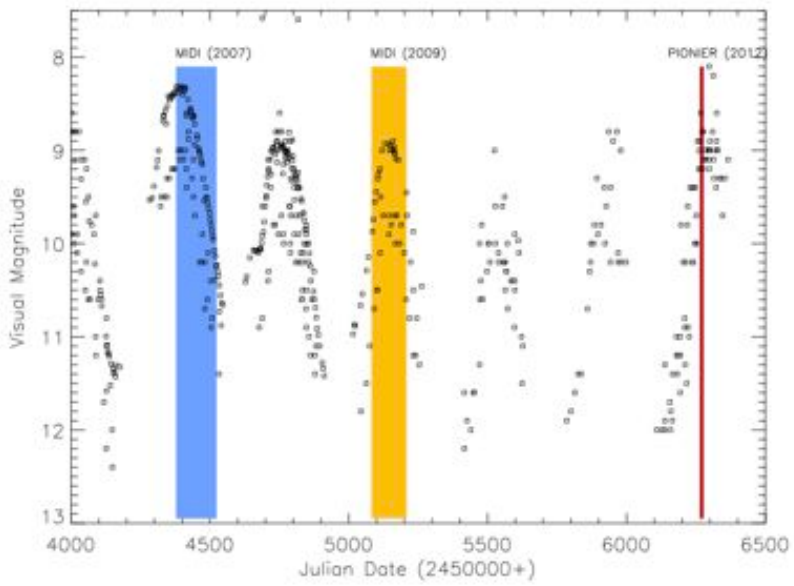
- Very extended objects bright sources means very low visibilities
- Good uv-coverage needed
- Different wavelength cannot be combined
- Stars are variable: need to have all configurations in a short time
- Image reconstruction algorithms & multi-wavelength

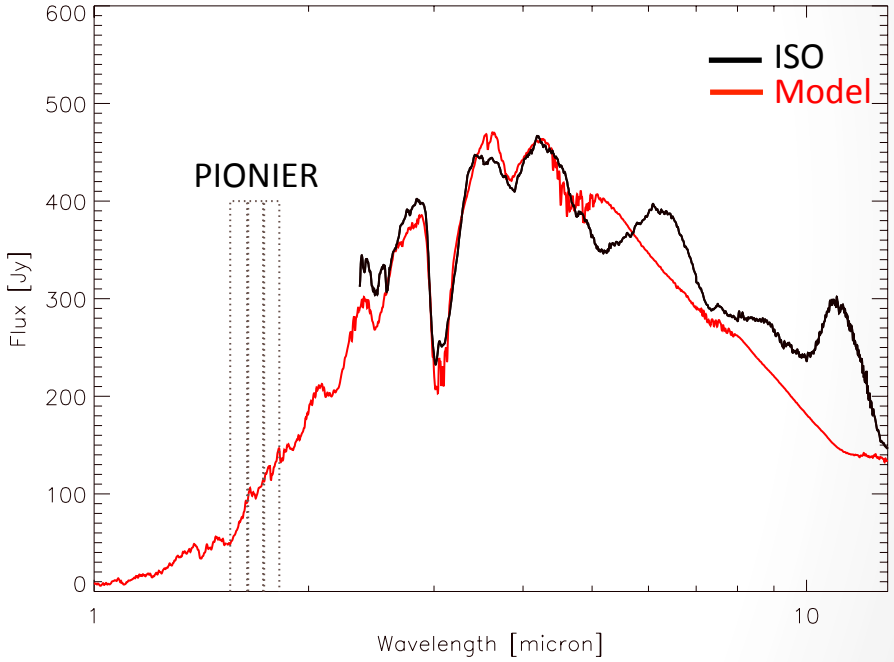
December 2012 in Paranal…



RFor as seen by PIONIER

(Paladini et al. prep.)



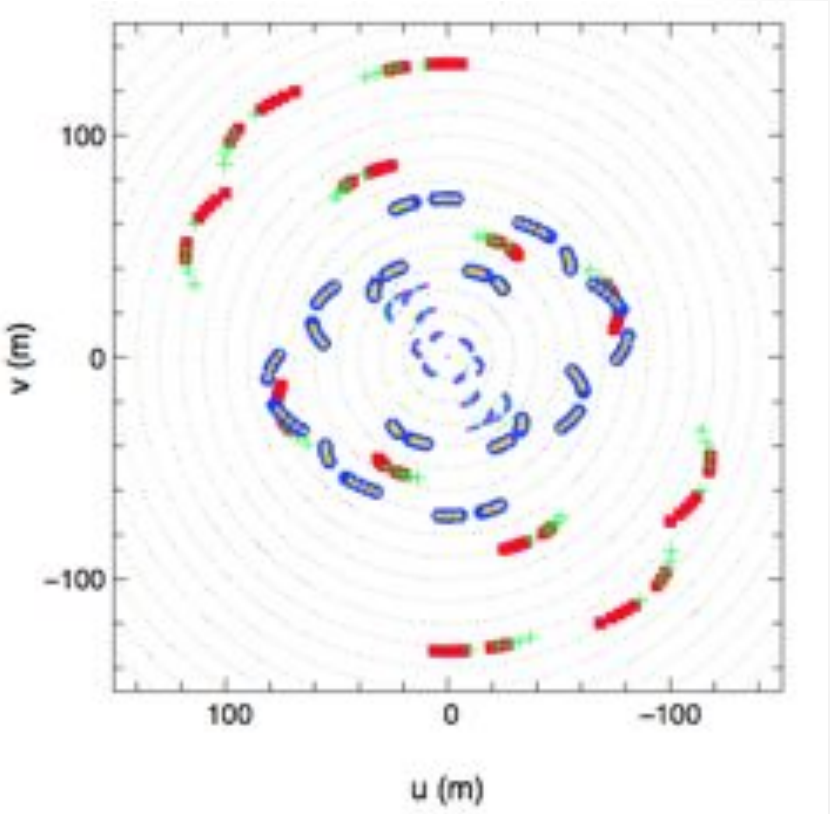


Molecular opacity in PIONIER range:
C_2, C_2H_2, CO, CN

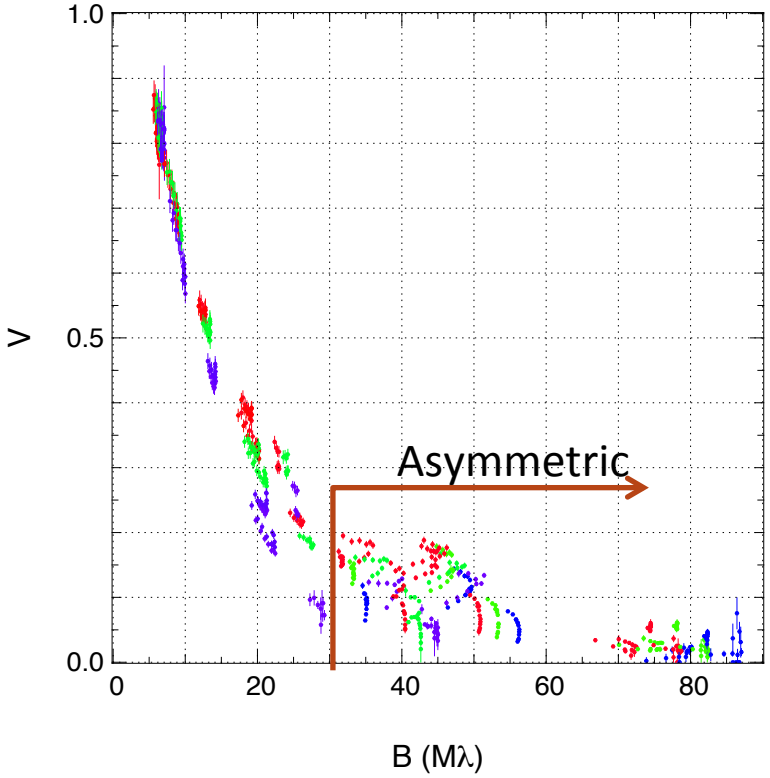
The observations

3 quadruplets, 6 half nights Within 3 weeks!

- 3 spectral channels
- 294 visibility points
- 201 closure phases
- 40% data redundant



PIONIER data



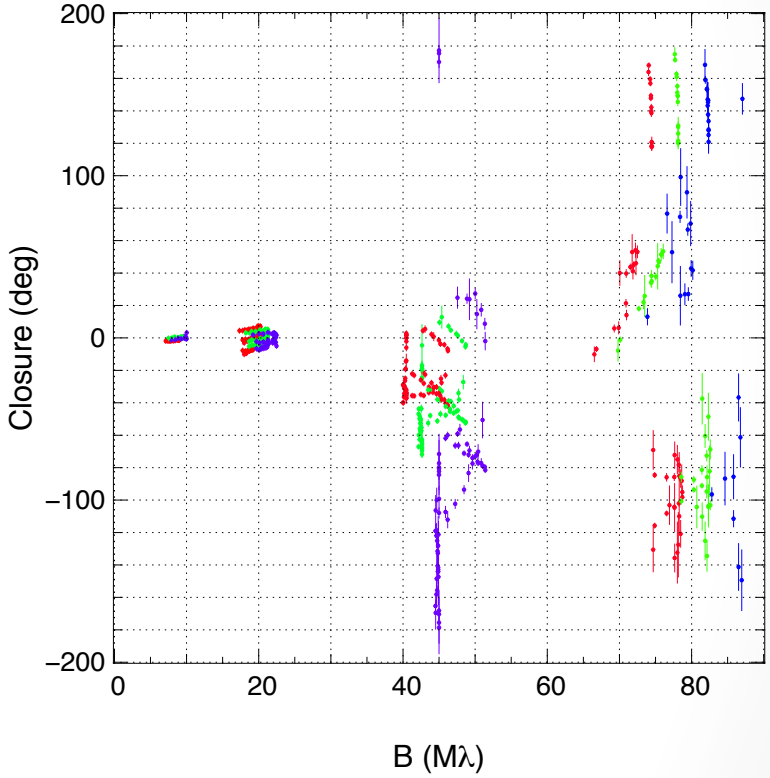


Image reconstruction

Blind reconstruction with different tools.

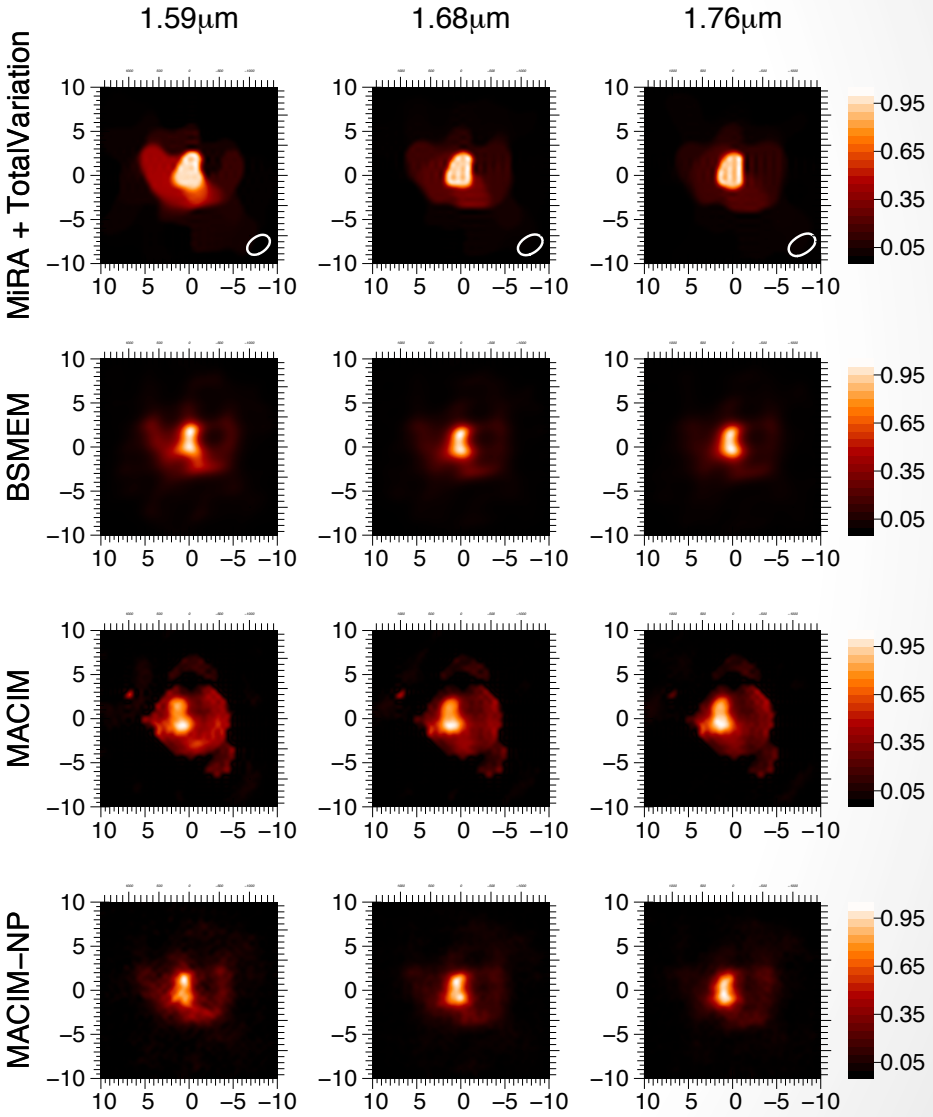
What we trust:

- Elongated structure + diffuse environment
- FWHM of the elongated structure ~2-4 mas
- Extended bright arc in the first channel

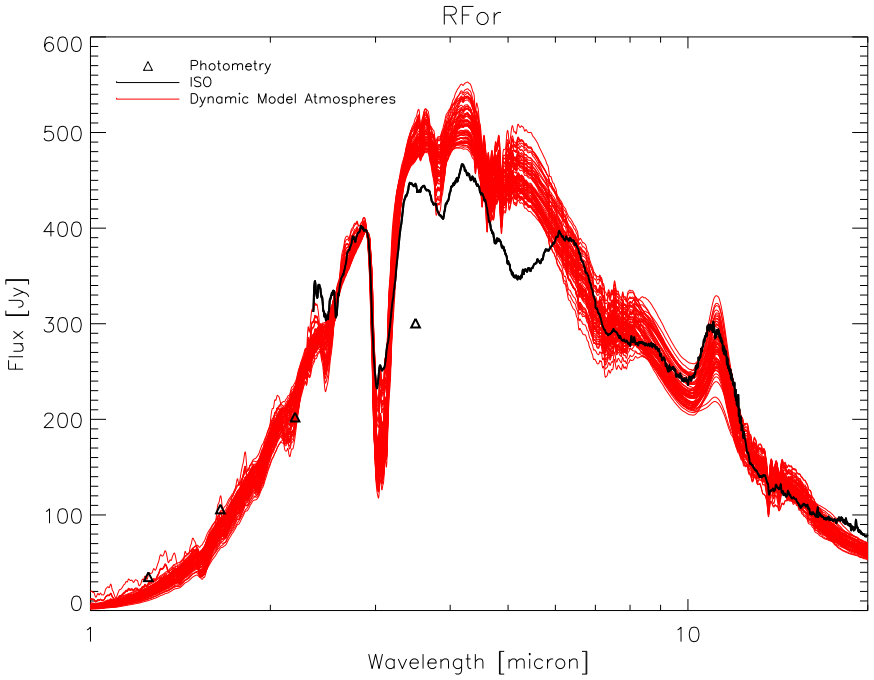
Previous images (Le Bouquin et al., 2009; Chiavassa et al. 2010) are mostly roundish…

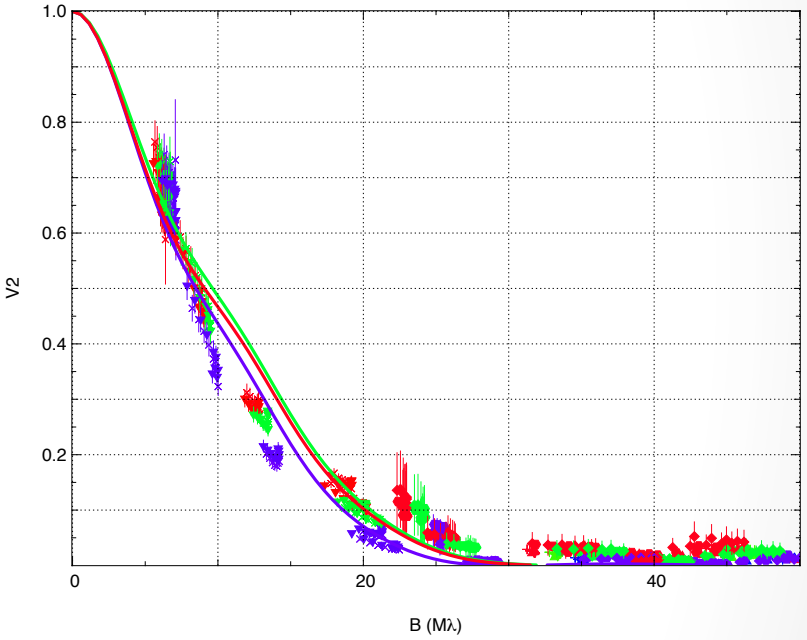
Why?

More images needed…



Modelling the data (ongoing)



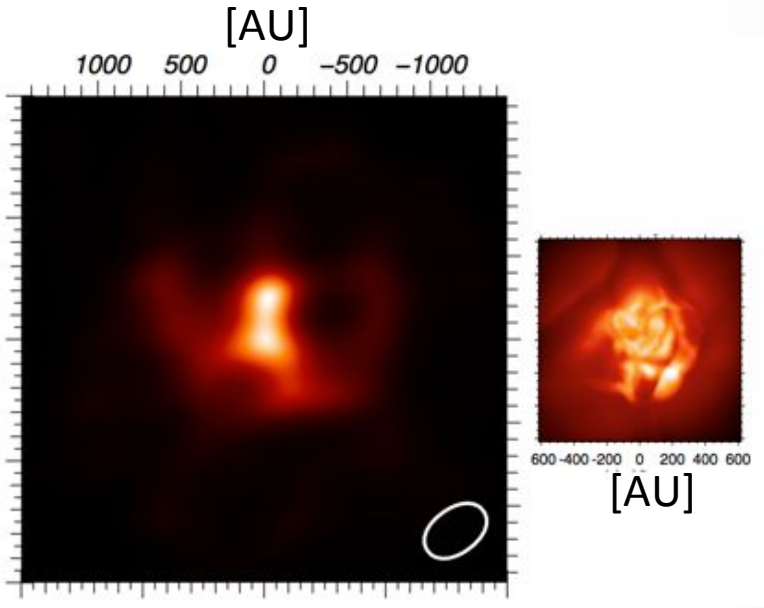


Dynamic model atmospheres (Hoefner et al. 2003, Mattsson et al. 2010)

What about using the model atmosphere as prior for imaging?

Preliminary interpretation

- Image compatible with models from Freytag & Hoefner 2008
- Exotic explanation:
  - Binary merger
  - Magnetic field disc accretion to a rotating star with an inclined dipole magnetic field (similar to YSO)

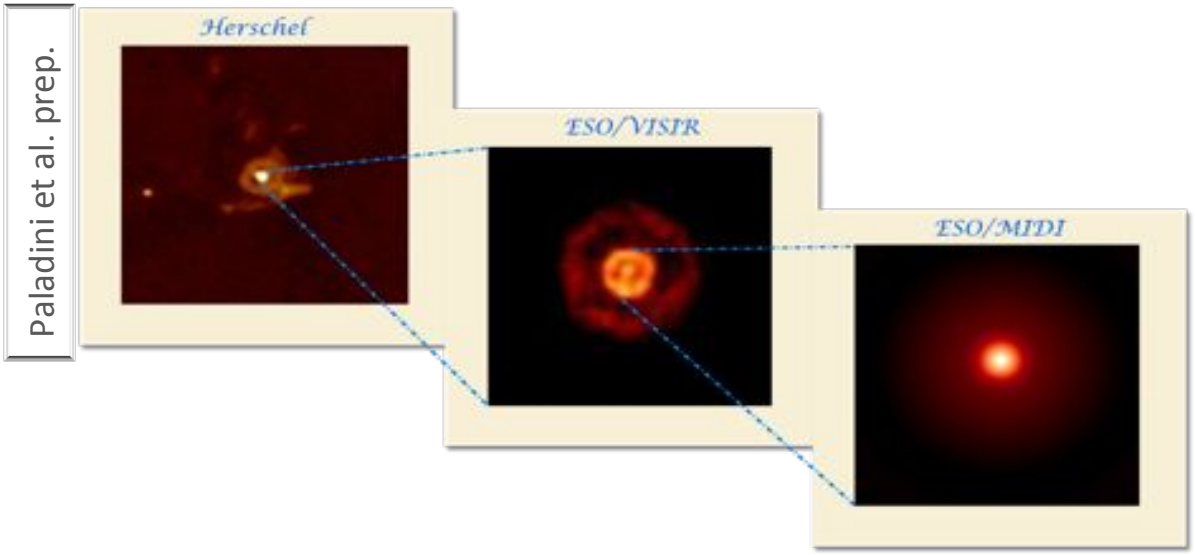


Time series (monitoring program) needed!

Future: a statistical sample

To understand properly the physics of the environment of AGB stars, coordinated works on large samples of stars are needed.

Multi-wavelength + multi-techniques



Paladini et al. prep.

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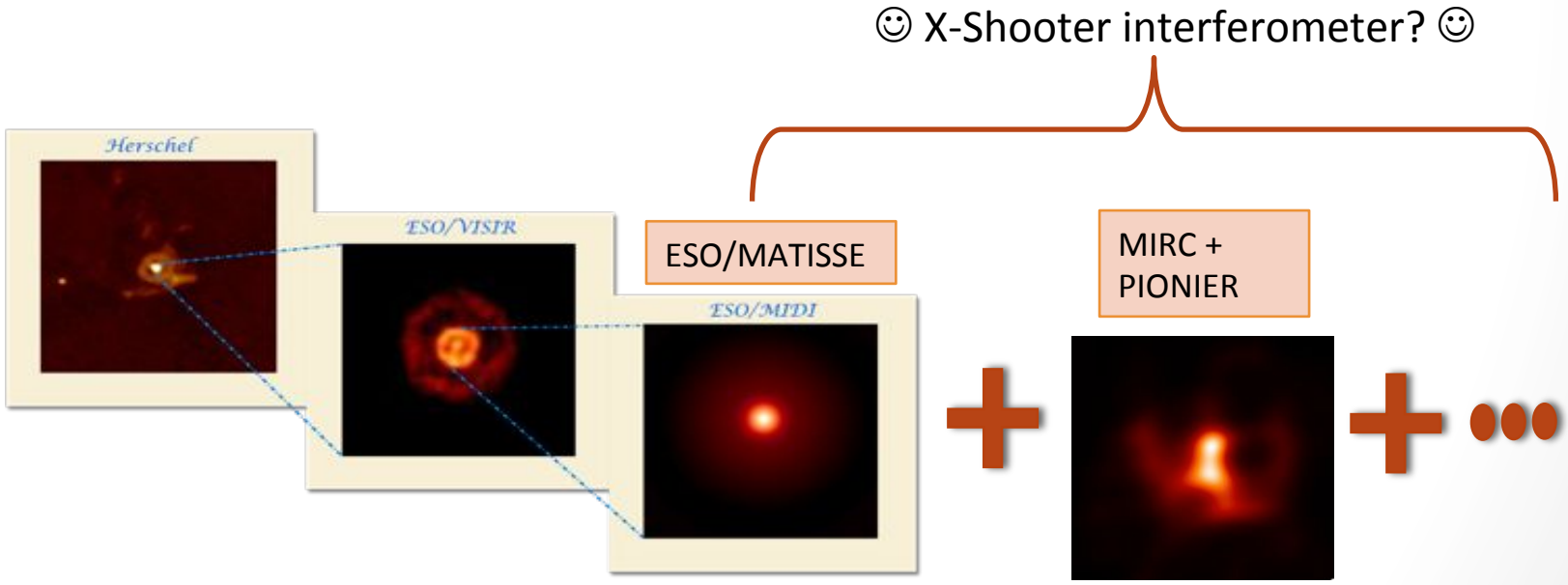


Period 93: Spirals? Discs?

Synergy between PIONIER and ALMA:

- Locate the onset of the spiral (PI M.Wittkowski)
- Spot the binary companion (PI A.Mayer)

Wish list

- Better uv coverage
- Better image reconstruction tools

Maercker et al., 2012

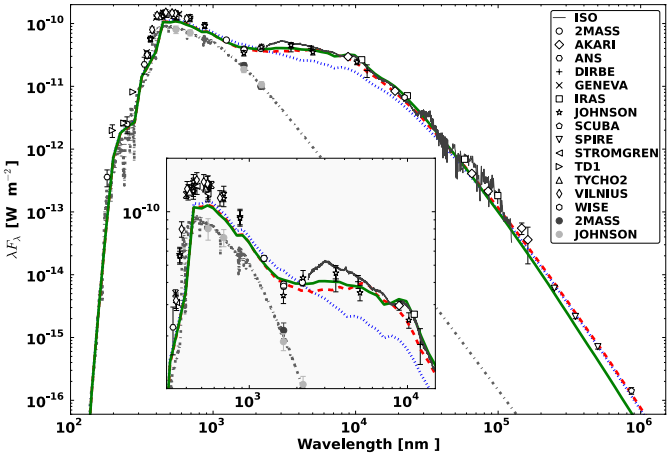
Period 93: post-AGB

H-band survey of post-AGB binaries with discs

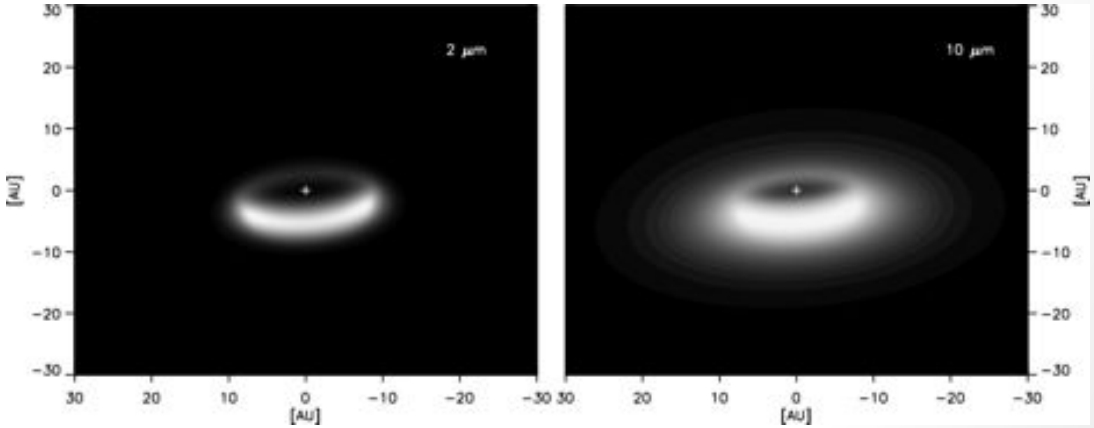
(PI M. Hillen 2.5 nights ~13 objects)

Wish list

- J-band
- Survey 30 targets



Deroo et al. 2007



Lessons learned

- Plenty of physics to investigate!
  - mass-loss; variability; dust formation
  - geometry of the environment at different spatial scales

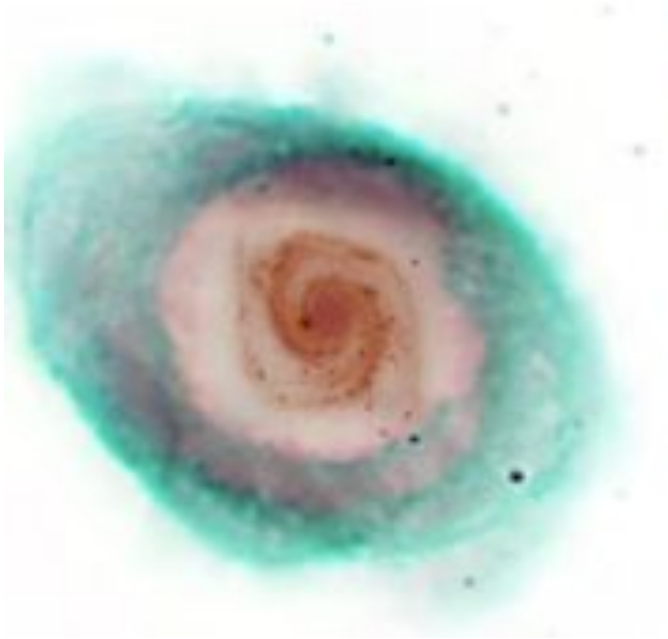
- Very challenging for imaging programs
  - uv-coverage (minimum 3 half night!)
  - multi-wavelength image reconstruction
  - observations to be taken in a short time (variability!)
  - Simultaneous spectroscopy

Discussion

- Wish-list:
  1. Careful scheduling or more telescopes (brightness with UTs?)
  2. H (and J?) band
  3. Spectral resolution

- Is using model atmospheres as prior the future of interferometric imaging? What does it mean imaging?

- If PIONIER will stay in PARANAL:
  - Monitoring program => real breakthrough in the field!
  - Large sample (30+) of objects (PIONIER+ MIRC)



Why Galaxies Care About AGB Stars III

July 28 - August 1, 2014
Vienna, University Campus

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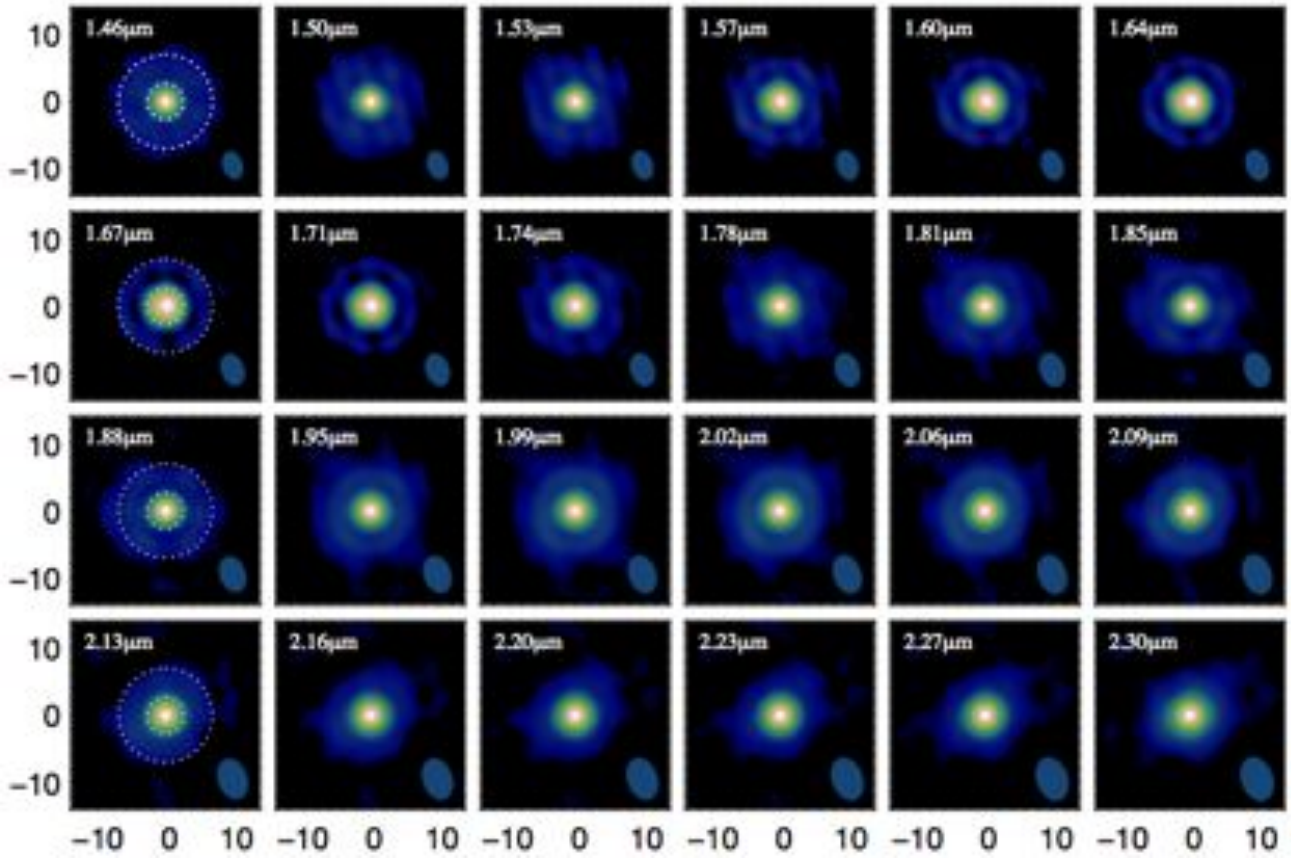
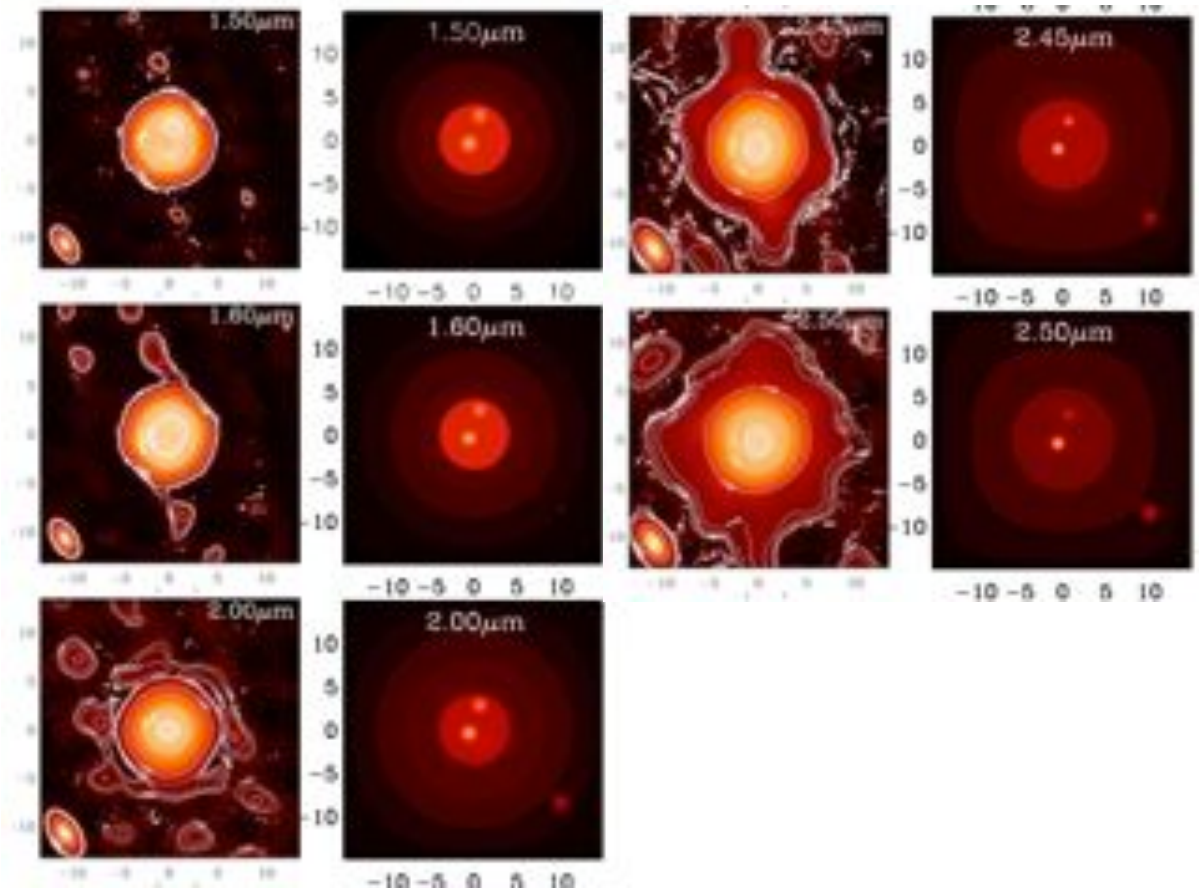
T Lep (Le Bouquin et al. 2009)



VX Sgr (Chiavassa et al. 2010)



R Aqr (Ragland 2008)