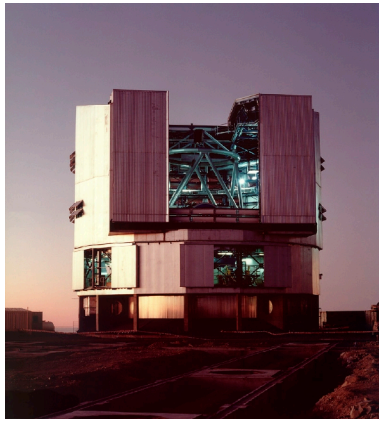
The VLTI/MIDI view on the inner mass loss of evolved stars from the Herschel MESS sample



Claudia Paladini
D. Klotz, S. Sacuto, E. Lagadec, M. Wittkowski, A. Richichi,
J. Hron, A. Jorissen, M. A. T. Groenewegen, F. Kerschbaum,
T. Verhoelst, G. Rau, H. Olofsson, R. Zhao-Geisler, A. Matter

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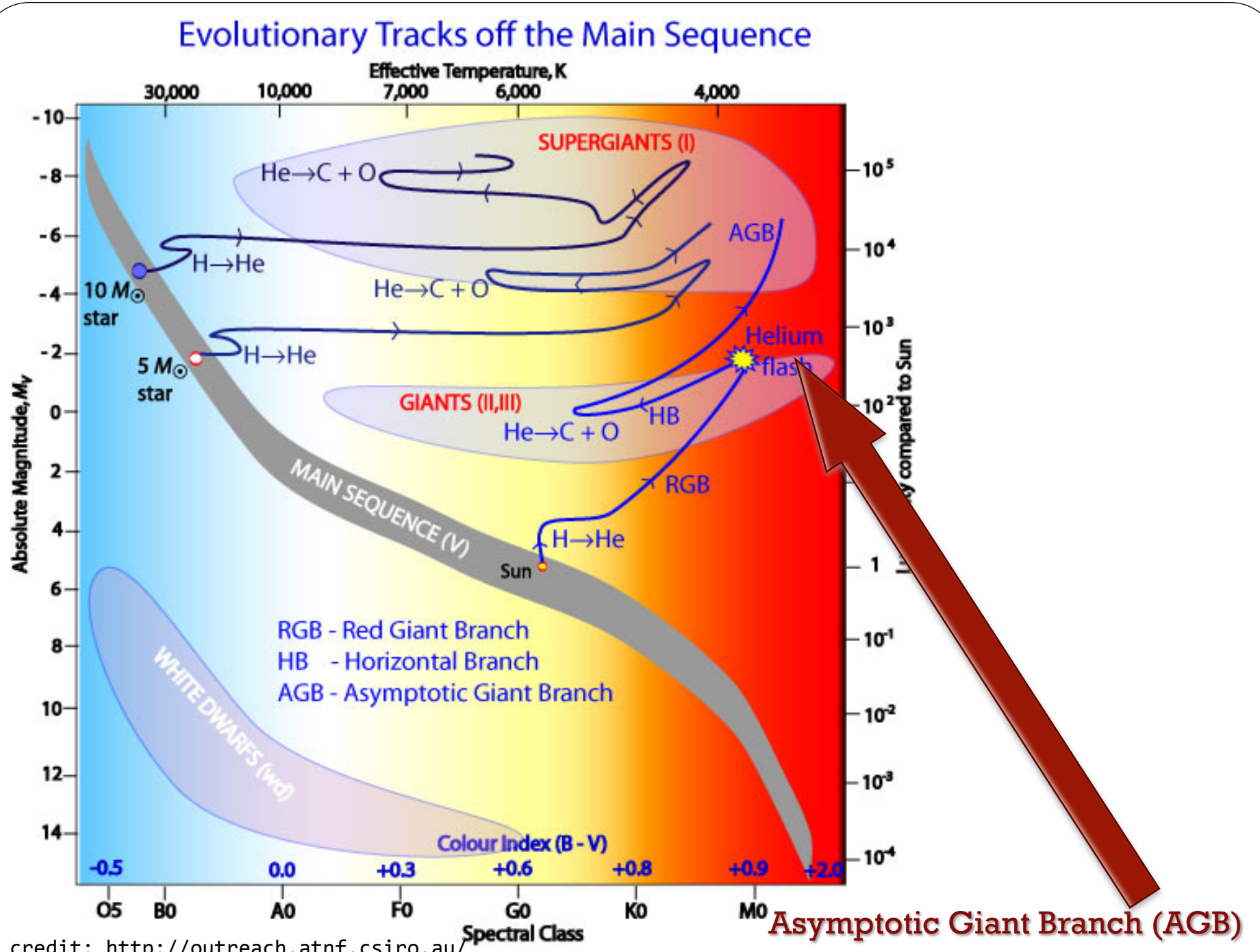
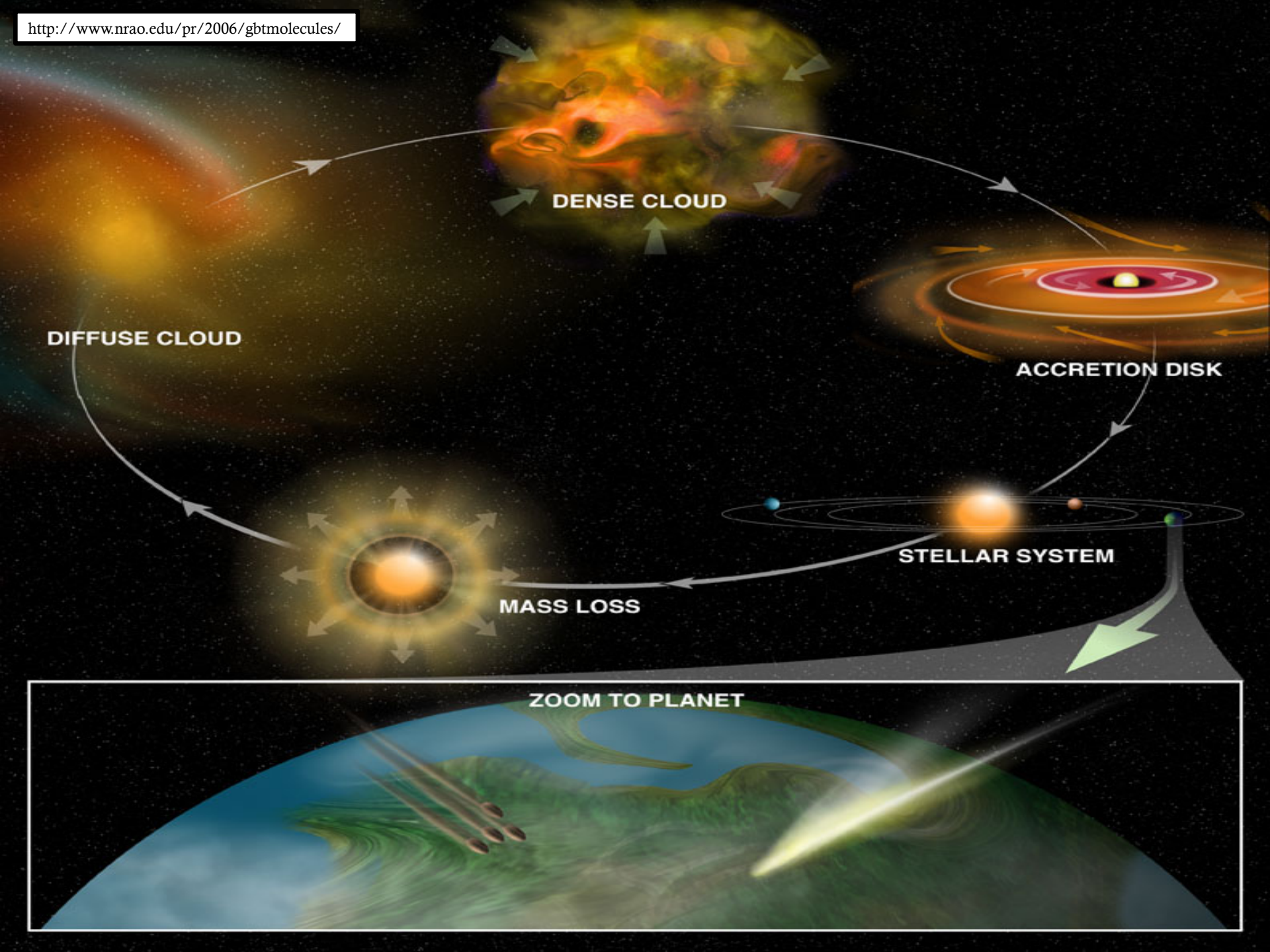
fnrs FREEDOM TO RESEARCH

2017 VLTI community days



Asymptotic Giant Branch (AGB)

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


http://www.nrao.edu/pr/2006/gbtmolecules/
DENSE CLOUD
ACCRETION DISK
DIFFUSE CLOUD
STELLAR SYSTEM
MASS LOSS
ZOOM TO PLANET

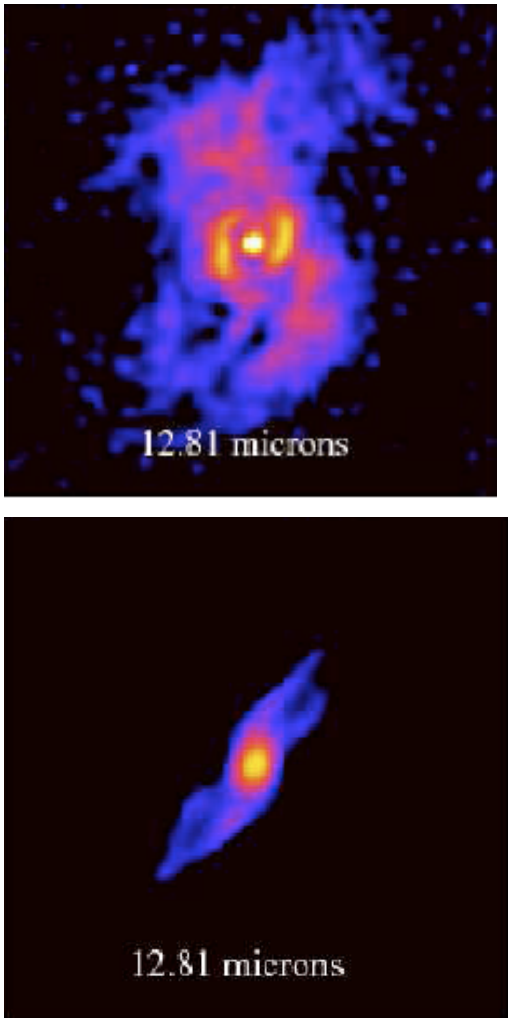
How do we get asymmetric post-AGB?

- 70% post-AGB are asymmetric
- Post-AGB wind considered asymmetric

Probably because of binaries!

- Fraction of binaries on post-AGB and AGB not in agreement

Picture on the AGB very confusing



Lagadec++2011

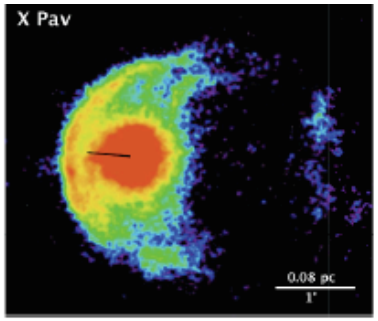
Mass-loss of Evolved StarS (MESS) GTO program

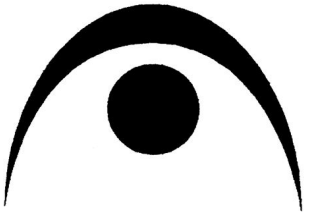
Groenewegen++2011

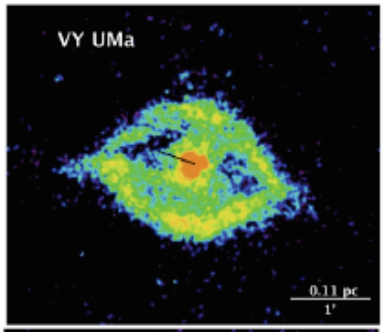
Herschel/PACS mapped the outer envelope of ~80 evolved stars

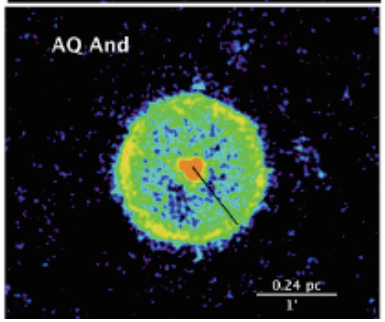
@ 70 and 160 micron

- Fermata wind-ISM interaction
- Eye wind-wind or binary
- Ring wind-wind interaction
- Irregular

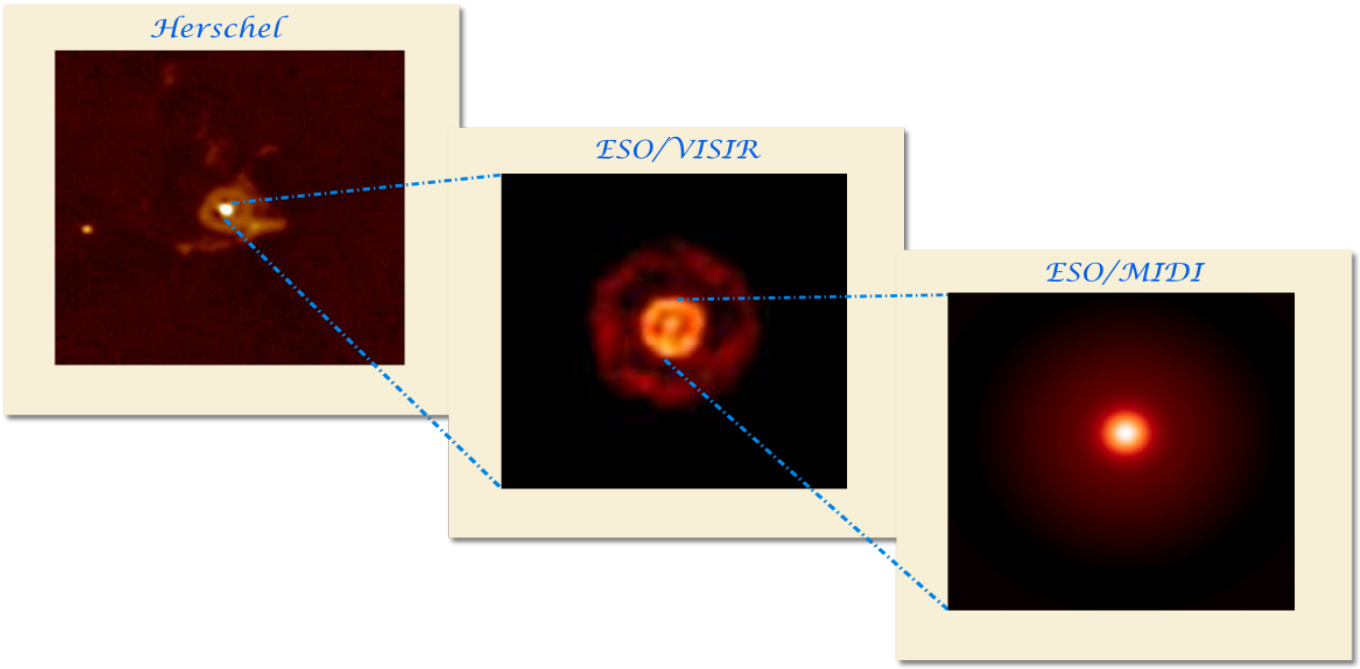








(Cox++2012)



- Is the mass loss an episodic process?
- Where do asymmetries develop?
- How do asymmetries change with evolutionary stage?
- Can we find the asymmetries seen with Herschel also with MIDI?

VLT(I) Large Program

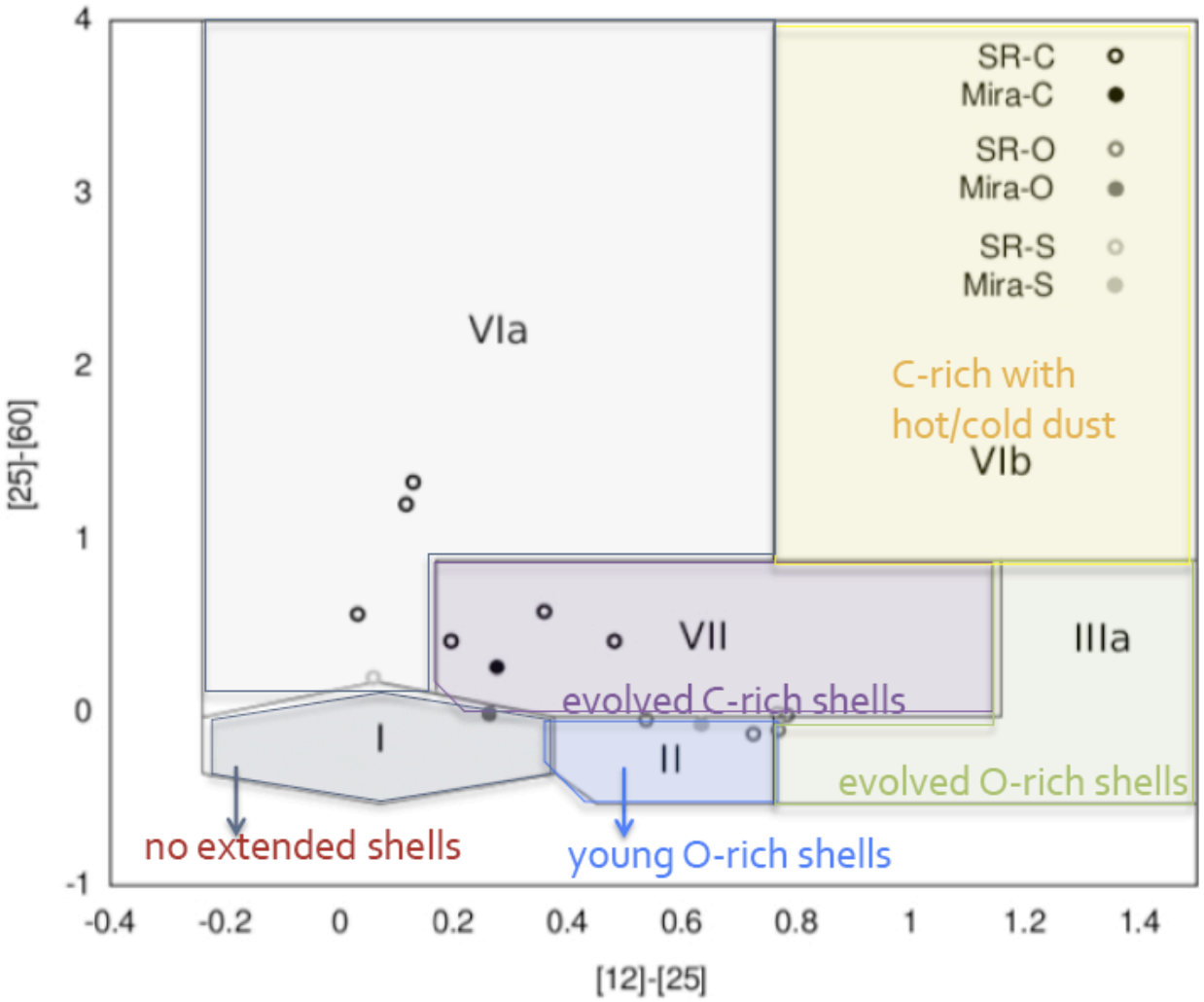
15 targets (M-, S-, C-type AGB stars; different variability classes)

- ~ 140 hours of MIDI + VISIR time over 2 periods
- 2 observations x 3 triangular configurations with VLTI/ MIDI (N-band interferometry)
- *N*+*Q* band observations (imaging) with VISIR

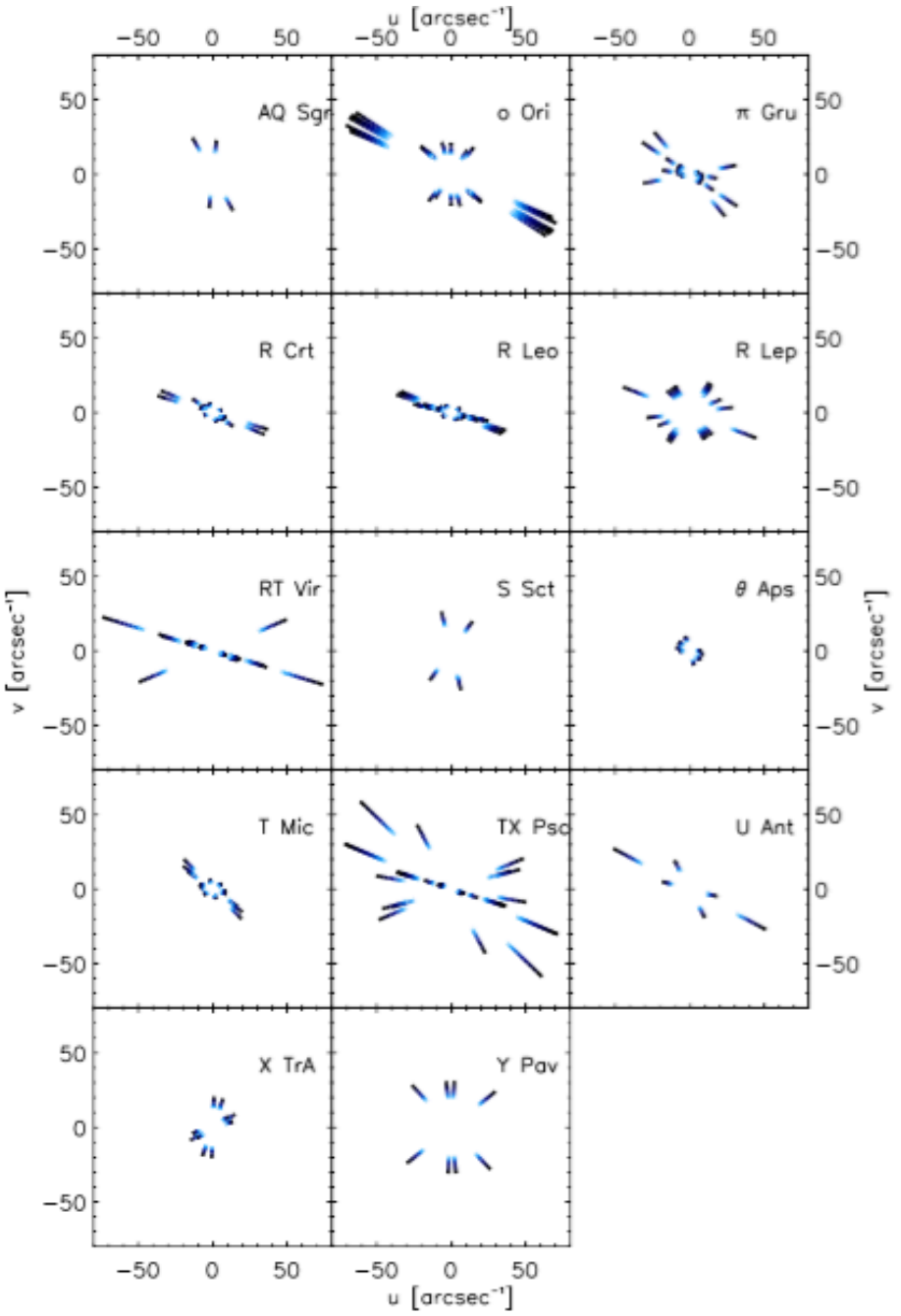
IRAS color-color diagram

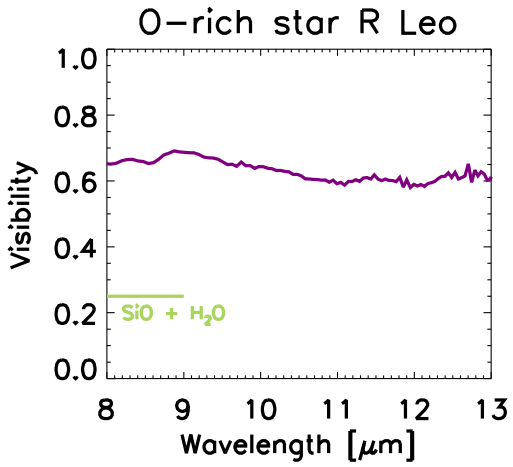
Mass-Loss rate
10^{-9} - 10^{-6} $M_{\odot}yr^{-1}$

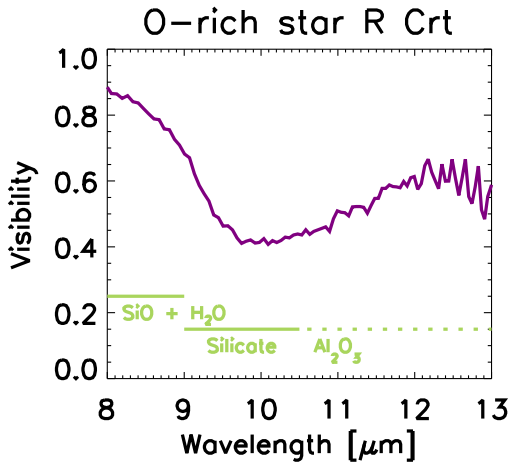
No extreme or infrared objects!

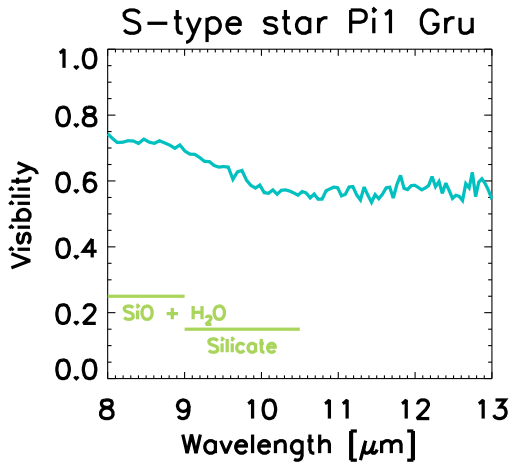


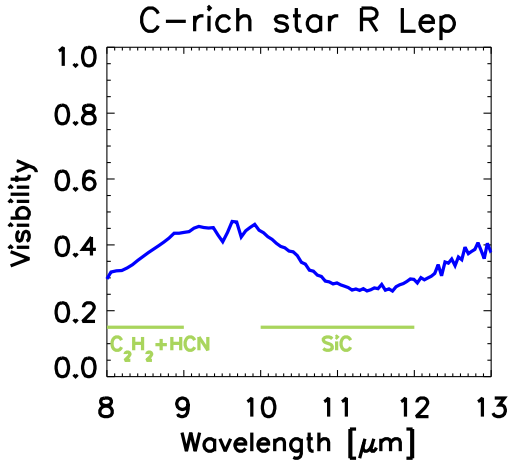
- Archive data analysed
- Data spanning period 2004 - 2012
- ~ 200 (science) visibilities and differential phases
- A bunch of spectra
- 60% data good quality

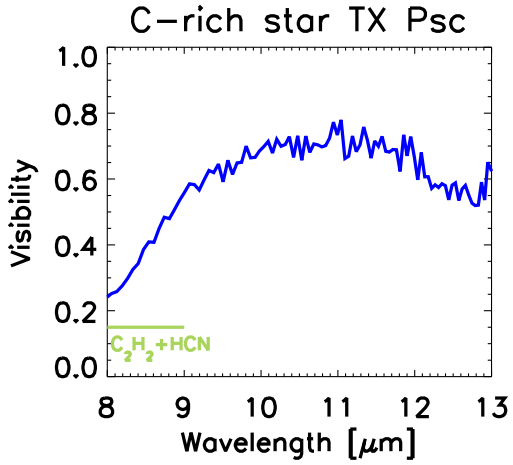


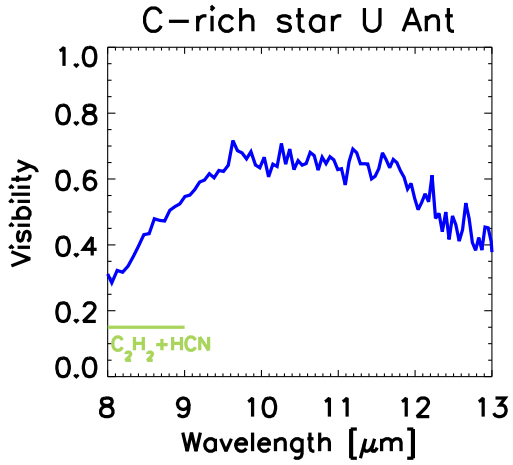

O−rich star R Leo
Visibility
Wavelength [μm]
SiO + H2O


O−rich star R Crt
Visibility
Wavelength [μm]
SiO + H2O
Silicate
Al2O3


S−type star Pi1 Gru
Visibility
Wavelength [μm]
SiO + H2O
Silicate


C−rich star R Lep
Visibility
Wavelength [μm]
C2H2+HCN
SiC


C−rich star TX Psc
Visibility
Wavelength [μm]
C2H2+HCN

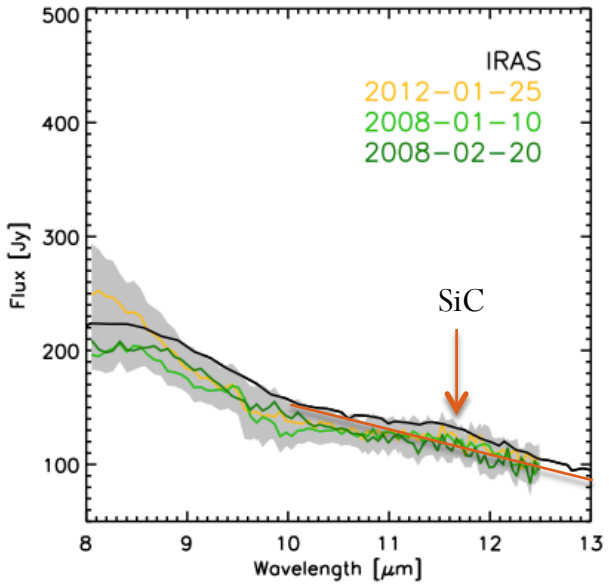

C−rich star U Ant
Visibility
Wavelength [μm]
C2H2+HCN

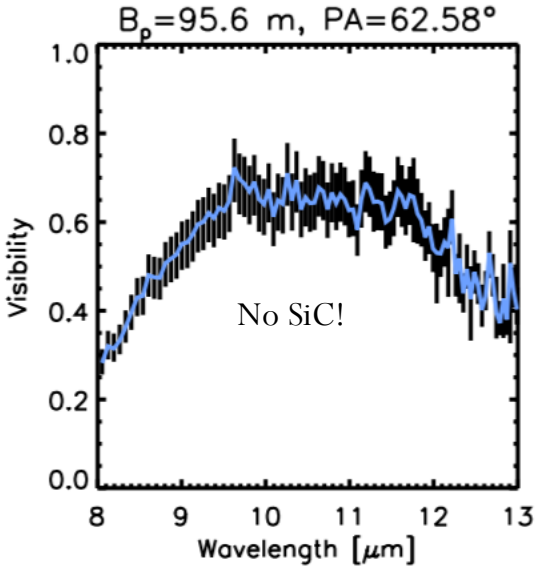
Constraining dust formation

- SiC dust observed in the spectrum but not in the visibility
- Like in the protoplanetary disc case (van Boekel ++ 2004)

=> Connection to mass-loss history

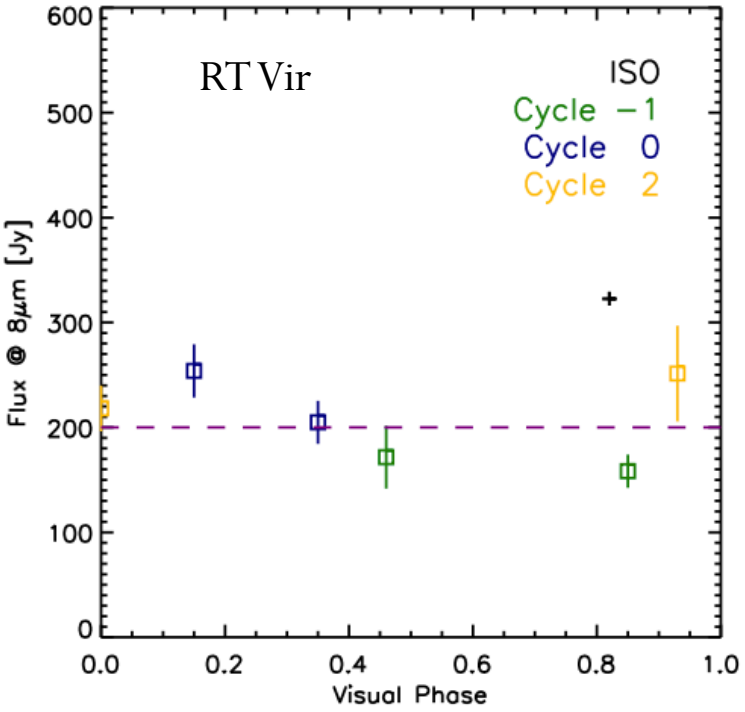
=> Where does SiC form





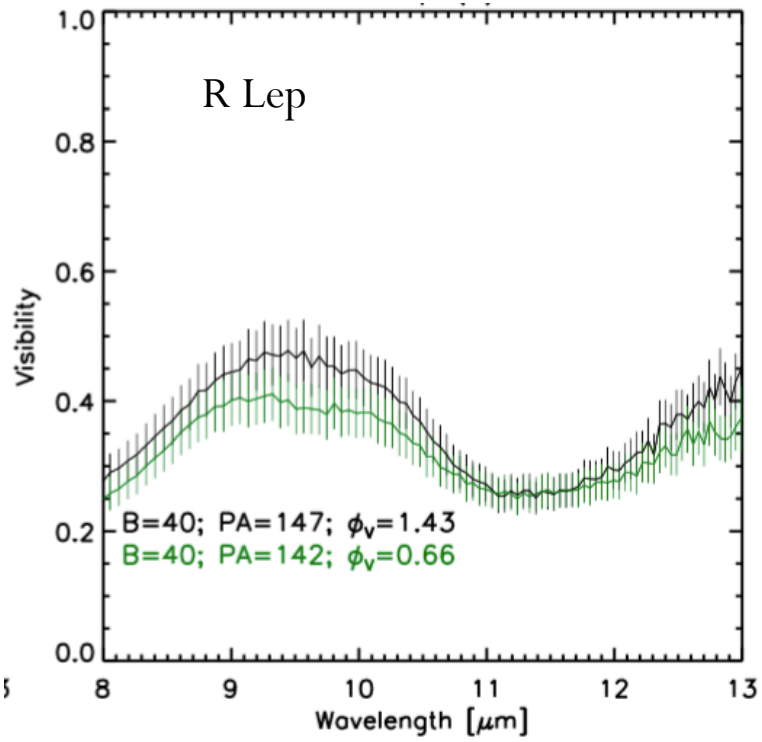
Mid-infrared Variability

Spectroscopic



Agreement with literature finding
~ 0.4@8 and 0.7@10 micron

Interferometric

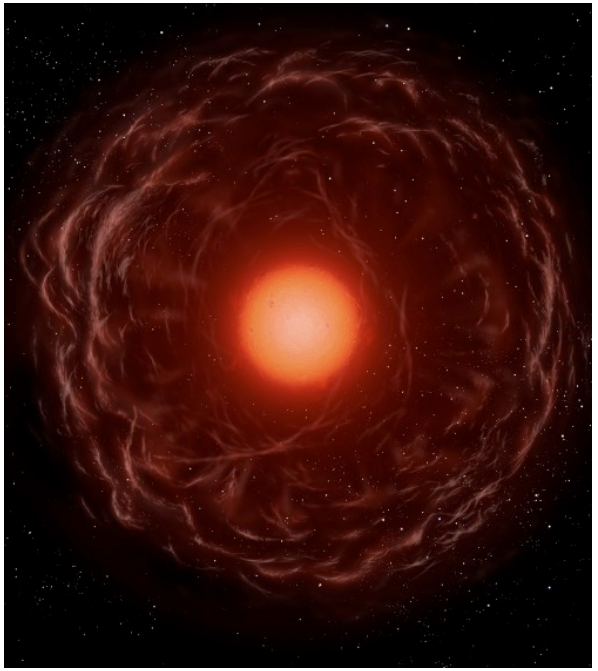


<10%, *detected* only for C-rich stars
Agreement with Ohnaka++2007

Mid-infrared diameters

- Dust signatures observed already ~1.5 stellar radii
- Some exceptions (SiC quest)
- Mira stars much more extended

Diameters to be used as reference for MATISSE observations



Artistic impression of a Red Giant

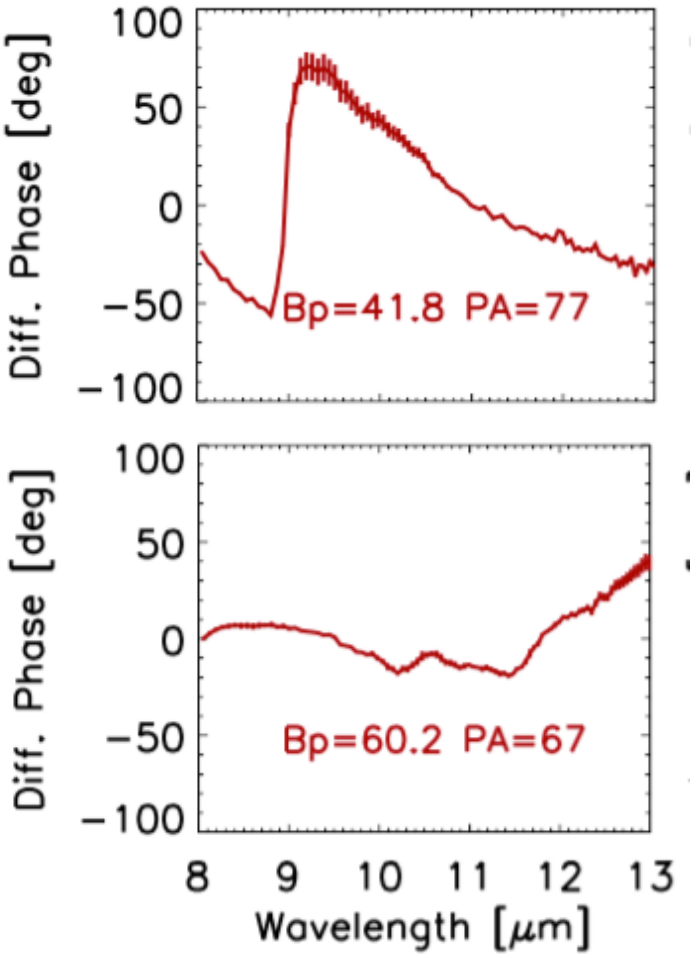
Morphology

- 5 (of 7) O-rich stars are asymmetric
  - ➢ non-zero differential phase
  - ➢ Geometric modelling
- All C-stars appear symmetric

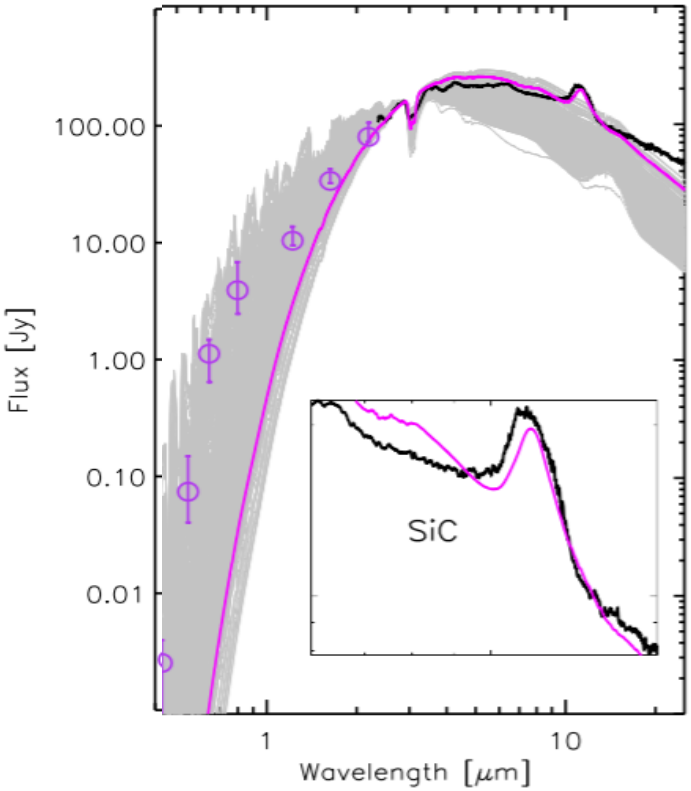
In the near-infrared the situation is the opposite! (Ragland++2006; van Belle++2013 Cruzalebes++2014…)

In the thermal infrared it's ~50%-50% (Blasius++2012)

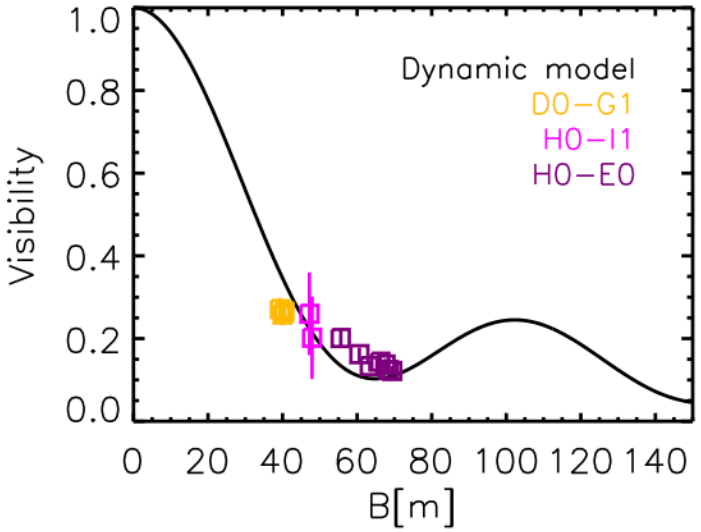
➔ **Dust properties!**



Ongoing comparison with model atmosphere



- Constraining mass-loss process, dust formation
- Stellar parameters

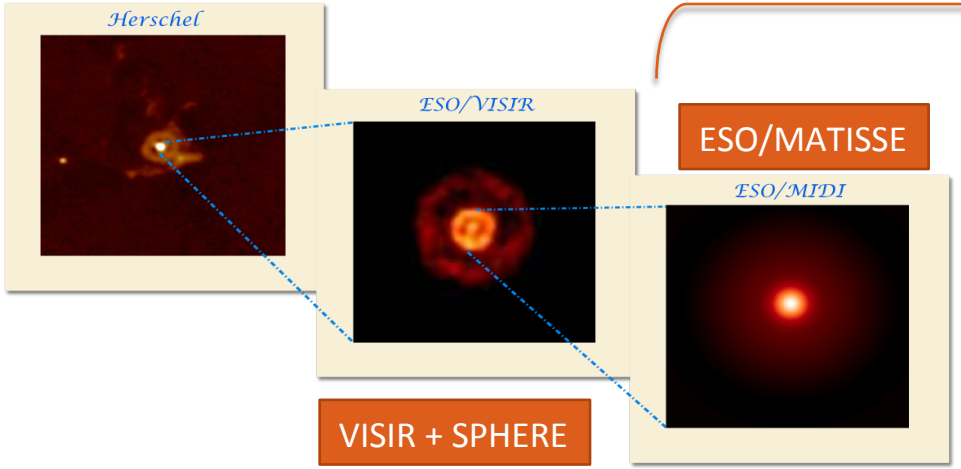


C-rich cases: Rau et al. 2015; 2016
O-rich cases to come

What we need...

Stars are variable, how about
☺ i-Shooter interferometer? ☺

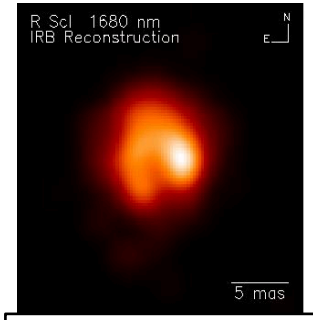
Herschel + ALMA



VISIR + SPHERE

ESO/MATISSE

GRAVITY+
PIONIER



Wittkowski++2017

Conclusions

- Is the mass loss an episodic process?
  - Yes it is, and MIDI can observe this: see detached shells, and spectroscopic variability
- Where do asymmetries develop?
  - Asymmetries do develop in the inner parts but beside exceptional cases we expect/observe only small asymmetric structures (=>MATISSE)
- How do asymmetries change with evolutionary stage?
  - More evolved stars are more dusty and show more ``asymmetric" (clumpy) environment
- Can we find the asymmetries seen with Herschel also with MIDI?
  - Asymmetries are observed, more often among the Fermata targets
  - Intermediate spatial scales needed