Recent VLTI results on stellar winds and perspectives with second generation instruments

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Outline

- The VLTI and its instruments
- Massive stars
- HMXBs
- AGBs
- Planetary Nebulae
- Perspectives with MATISSE and GRAVITY

Presentation of the VLTI

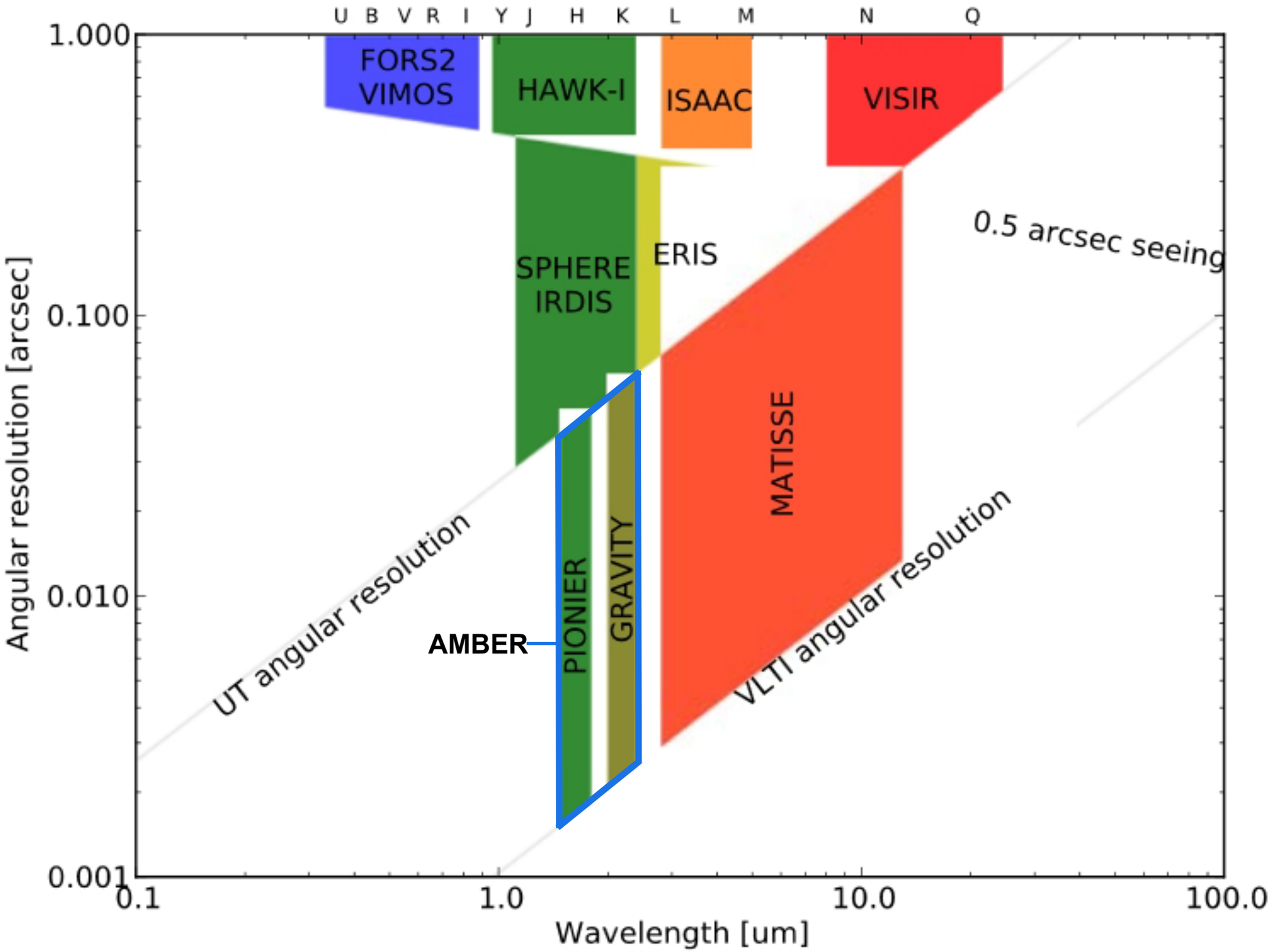
Blowing in the wind - X Haubois - Quy Nhơn - 12/08/2016

Current instruments

	AMBER	PIONIER	GRAVITY	MATISSE
Telescopes	3	4	4	4
Spectral range and res	H-K (35,1500,12000)	H (none,30)	K (22,500,4000)	L, M and N simultaneously (30 - 5000)
Fringe tracker	FINITO		Dedicated internal FT	GRAV4MAT

\+ astrometry in the near-future

Presentation of the VLTI



Massive binaries

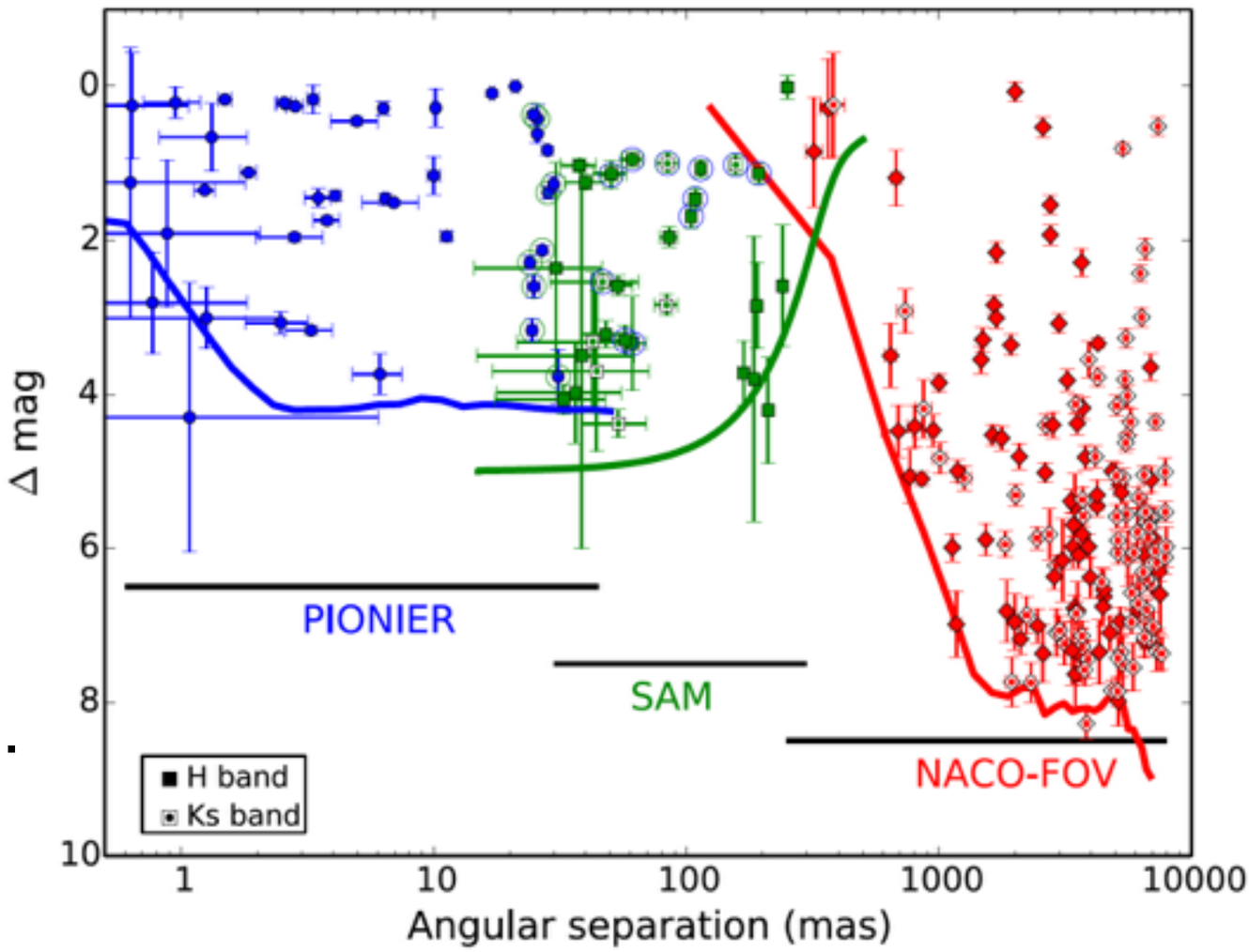
- **Sana+14**: Test the formation of massive stars via multiplicity study (SMaSH+ survey)

- <u>174 O stars</u>

1) 200 new companions

2) Fraction of object with at least 1 companion within 200 mas is 53% .

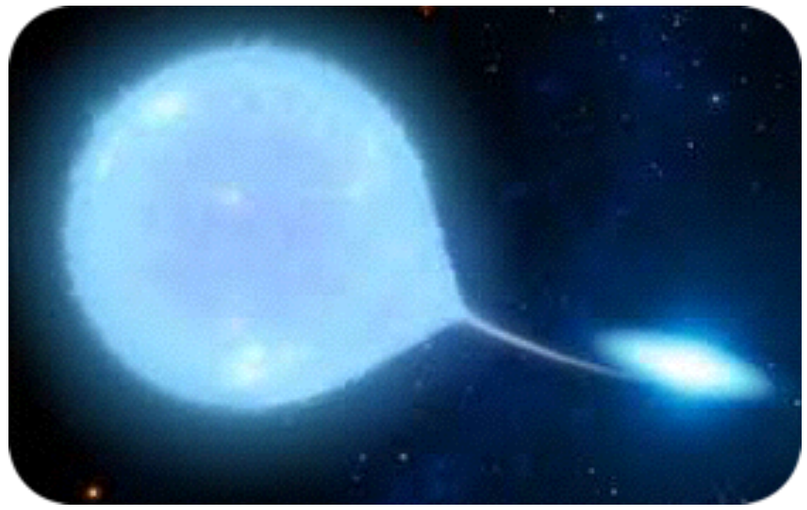
3) Adding everything for sep < 8”, **multiplicity fraction is 91 ± 3 %**



4) 9 Non-thermal emitters are resolved into pairs of similar masses
—> wind-wind collision to explain non-thermal emission
(see also De Becker+12)

HMXBs

Choquet+14:



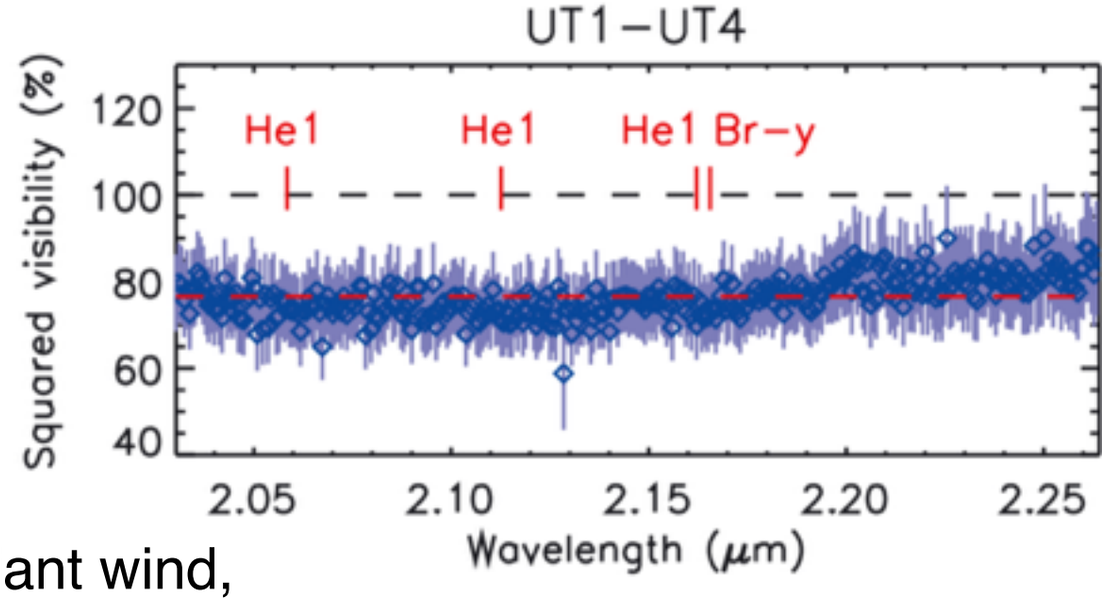
- Vela X1 = Pulsar + B0.5I supergiant
  How is the SG wind shaped and accreted?

- AMBER, PIONIER + UTs:

—> structure size = 8 ± 3 R★ in K (2010) and 2 ± 1 R★ in H (2012)

—> similar size in lines

—> no closure phase —> symmetric shape



Scenarios:

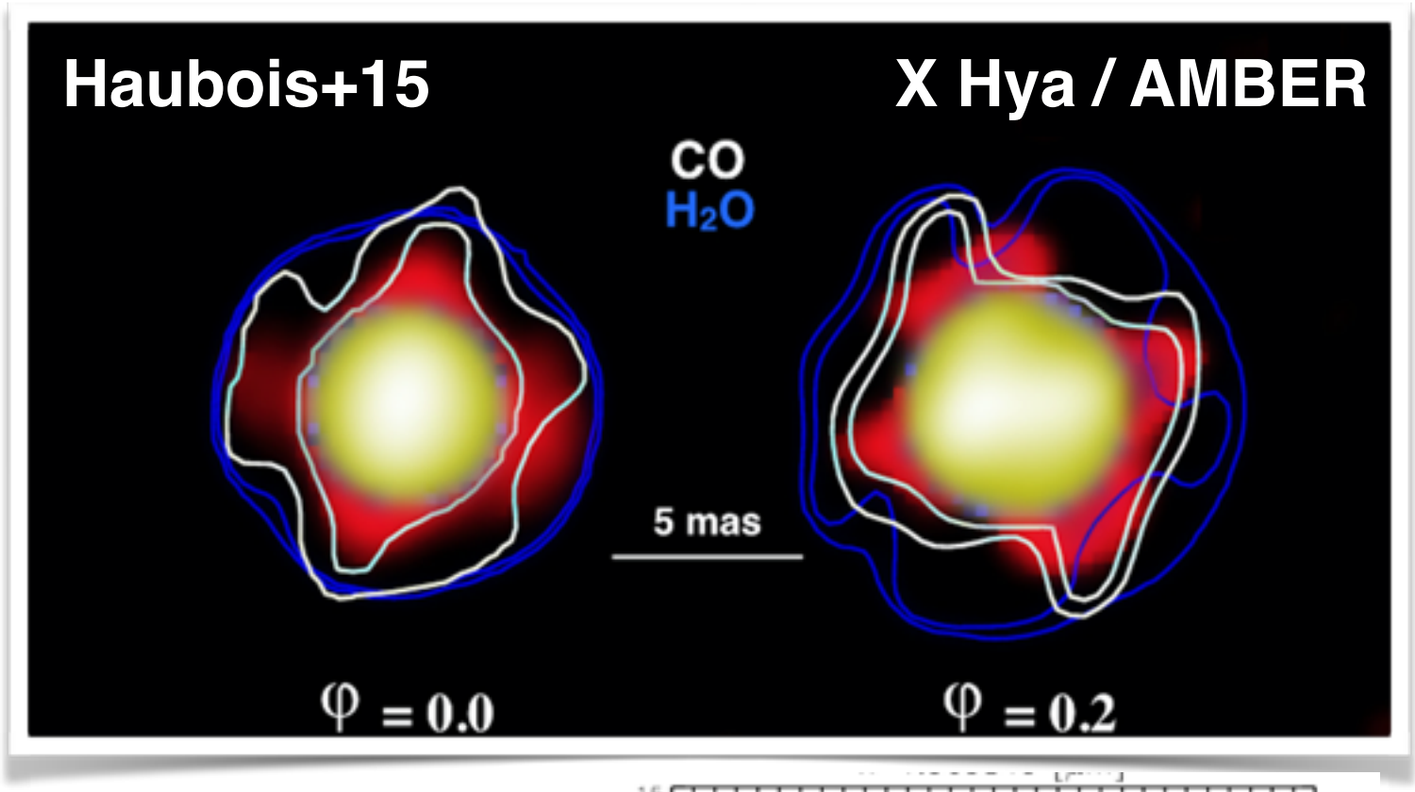
1) Strong temperature gradient in the supergiant wind,
hot component more compact than the cool part in K.

2) The wind structure partially dissolved between 2010 and 2012

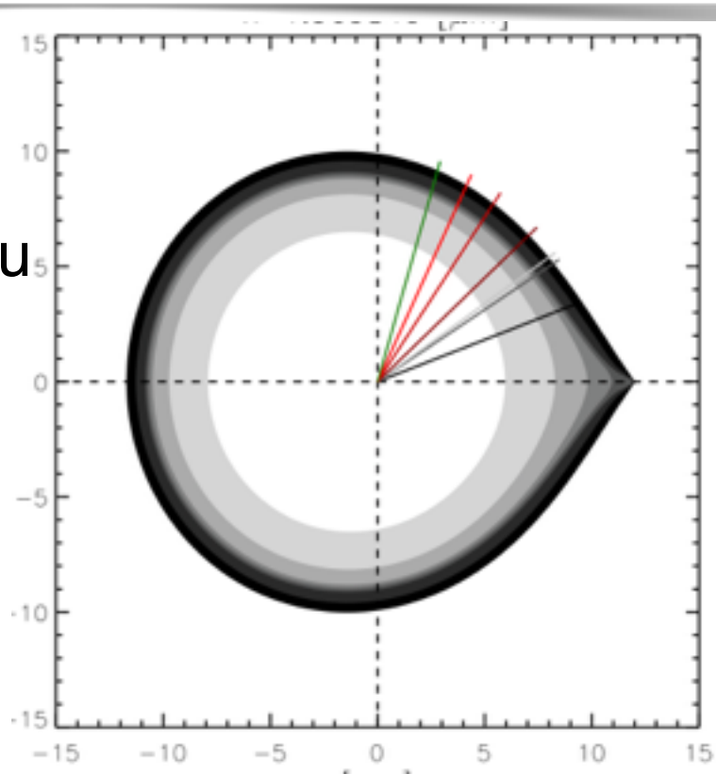
3) Size in H band was the stellar photosphere, wind not detected

Onset of AGB winds: morphologies

- Dust-driven winds initiated above convective/pulsative atmosphere

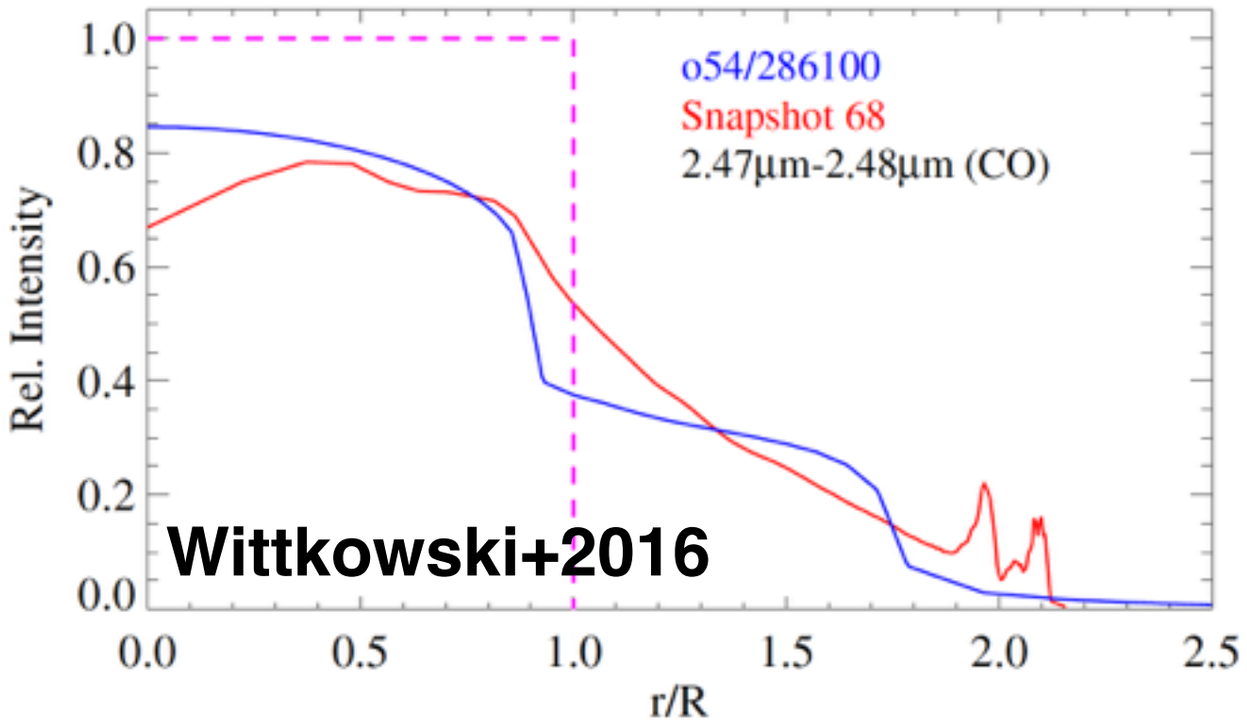


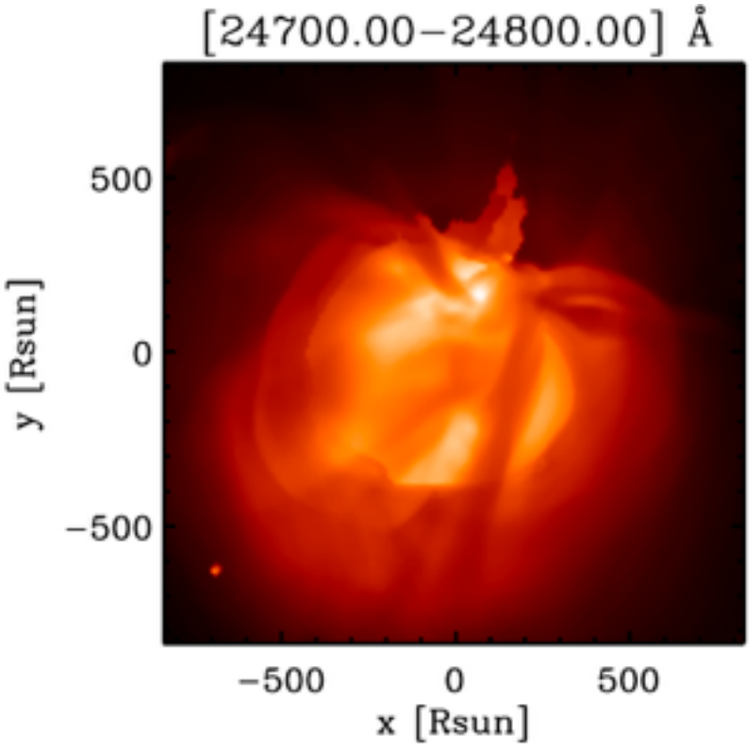
- **Mayer+14**: MIDI and AMBER (archived) data on Pi Gru
  Roche-Lobe modeling for V^2 and CP
  -> a second, closer, companion?



Onset of AGB winds: morphologies

- Dust-driven winds initiated above convective/pulsative atmospheres
- Gioia Rau's talk on C-rich AGBs with MIDI
- O-rich:
  —> AMBER observations of 6 M-type stars in K band
  —> Comparison of CODEX (1D) and CO5BOLD 3D-simulations



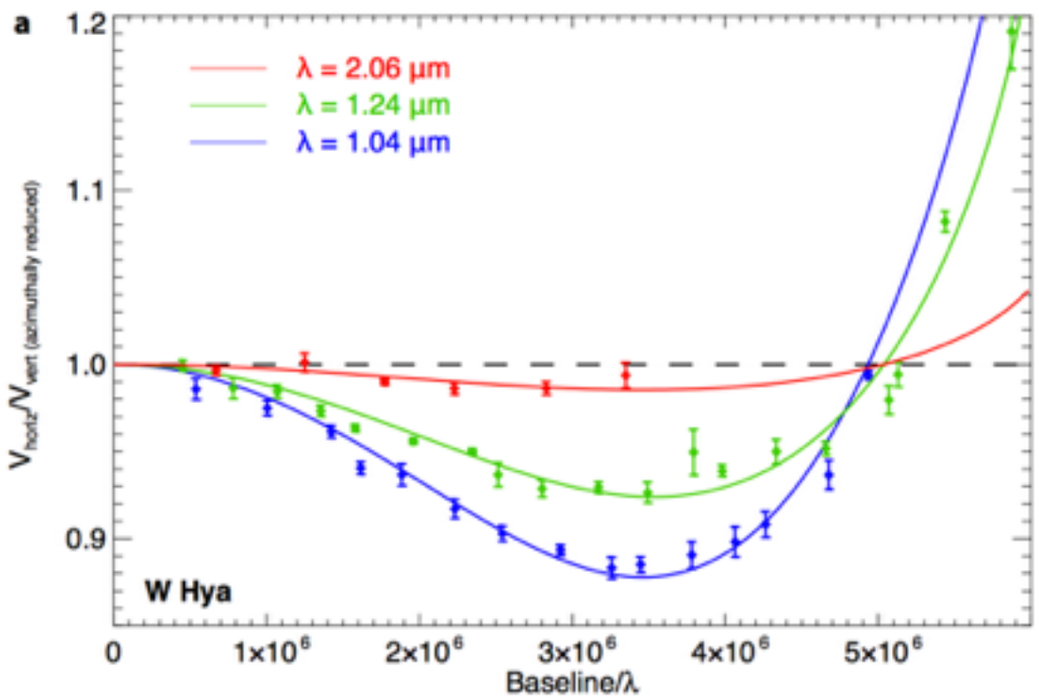


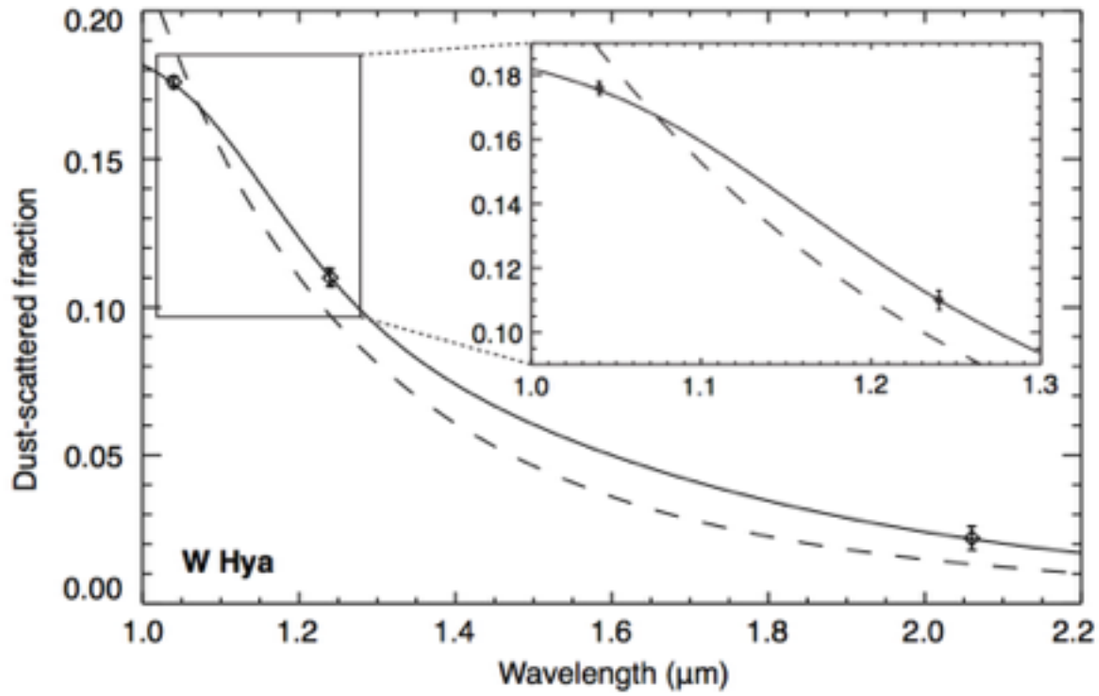
- Globally: spherical symmetry above 10% of flux (Freytag & Höfner 2008)
- But inhomogeneities of a few mas and few % of flux -> Convective nature ?
- Cruzalèbes+15, ~15 AGBs with AMBER: asymmetry increases with the atmospheric-pressure scaleheight

Onset of AGB winds: dust composition

- Sacuto+13, MIDI + Dust winds of RT Vir
-> silicate dust present in shells within 2-3 R★ (9.8 micron)

- Norris et al. 2012 —> Dust Fe-free Silicates/Al_2O_3 present at ~2 R★ in 3 M-type grain size about ~0.3 micron (Höfner 2008)

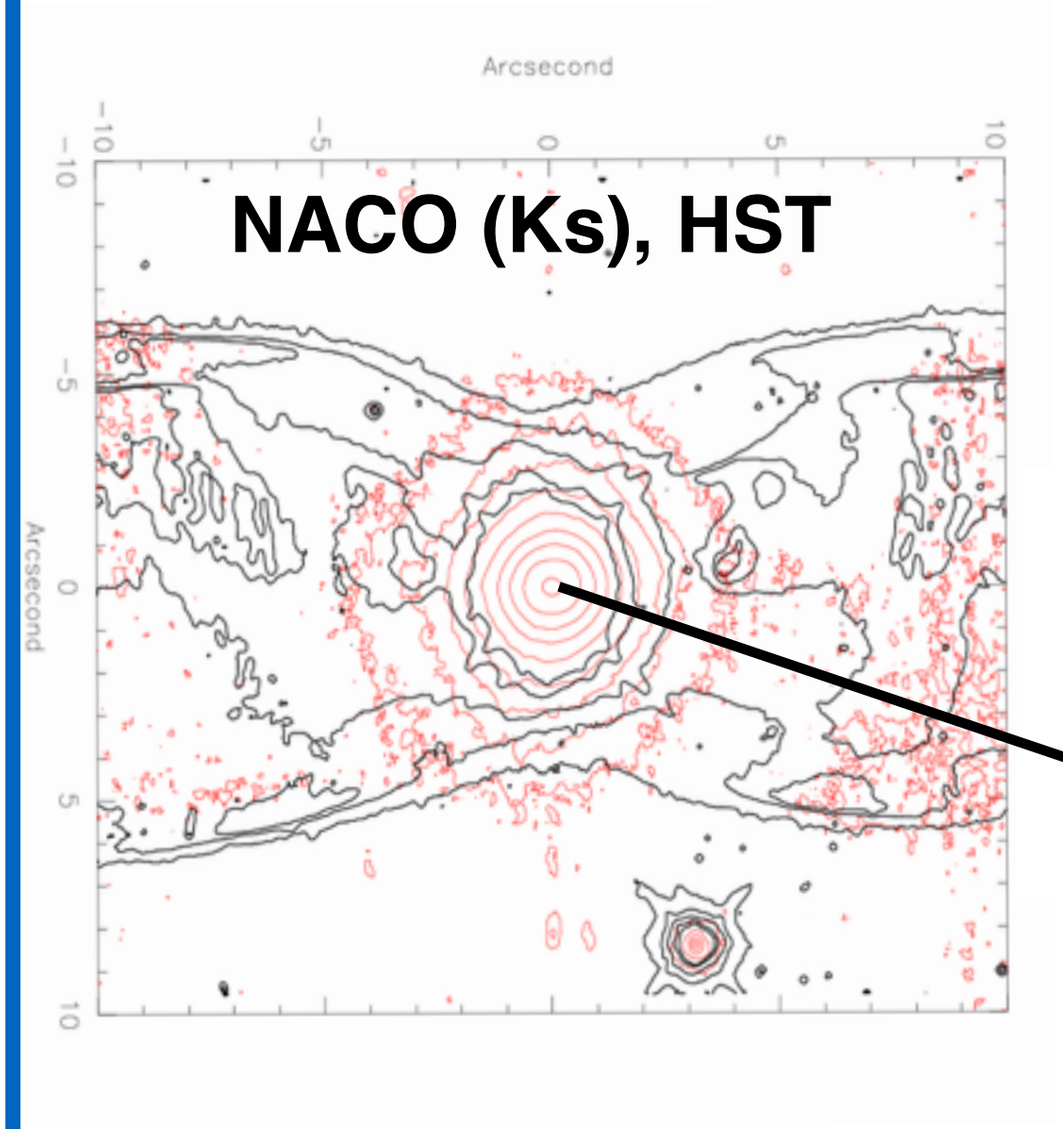


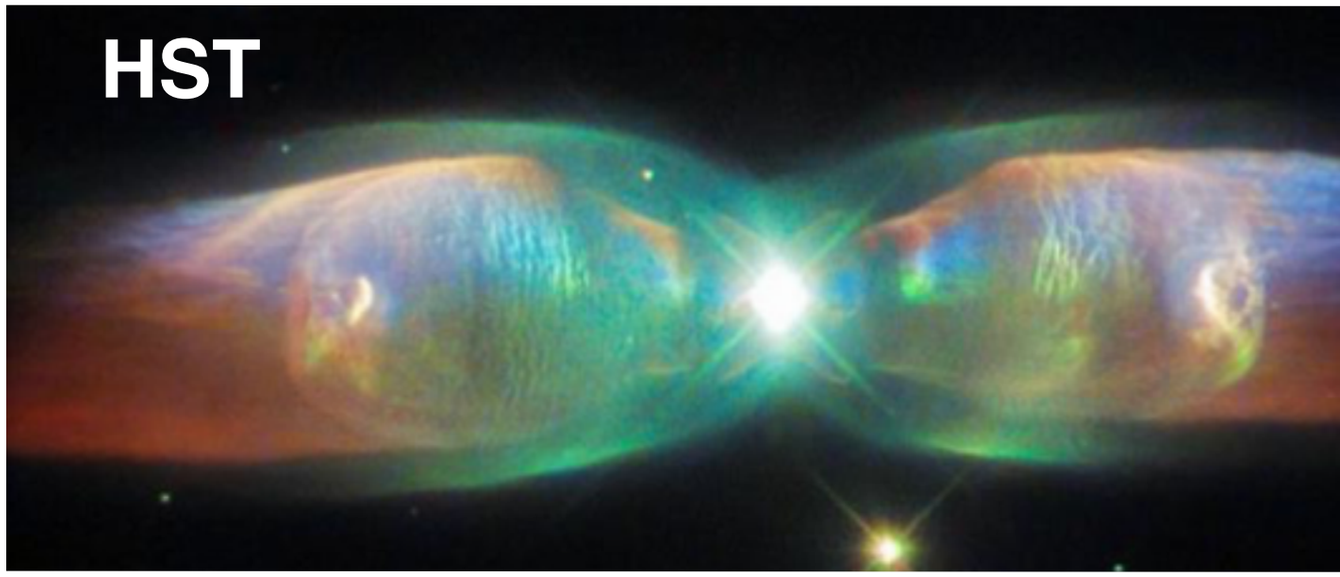


- Zhao-Geisler, R. 15: dust shell of W Hya, imaging attempt, MIDI, Al_2O_3 reproduces spectral diameter variation.
- Ohnaka+16 with AMBER+SPHERE on W Hya: coexistence of Al2O3 + silicate dust and molecular gas within 2-3 R★

Planetary Nebulae

- Stacey Bright's talk last Monday
- Lykou et al. 2010, MIDI + UTs, M2-9





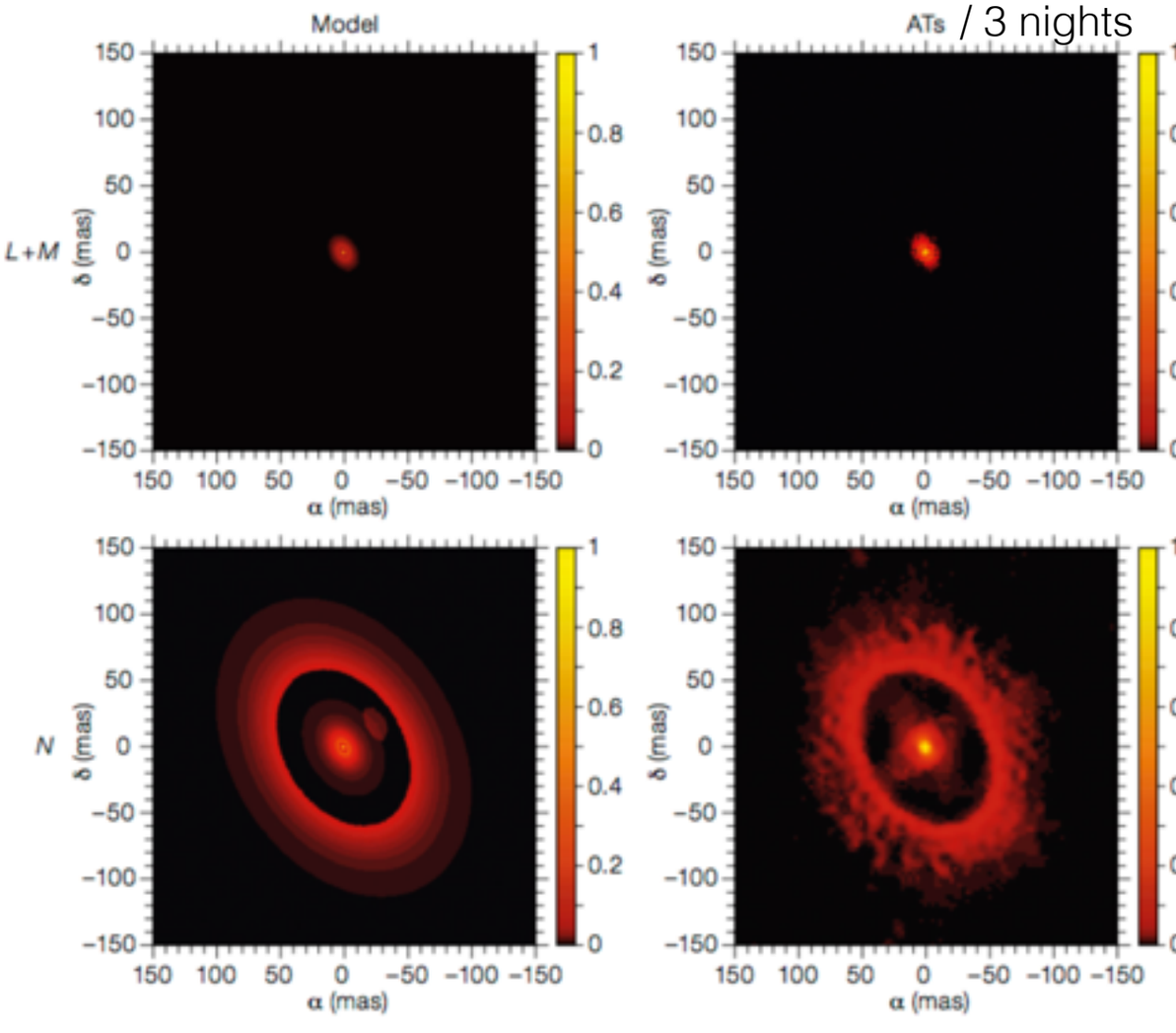
MIDI

- Disk perpendicular to the lobes
- Size: ~35x50 AU, inner rim ~15 AU
- Composed of amorphous silicates
- Constraints on the companion orbit, mass and nature

MATISSE

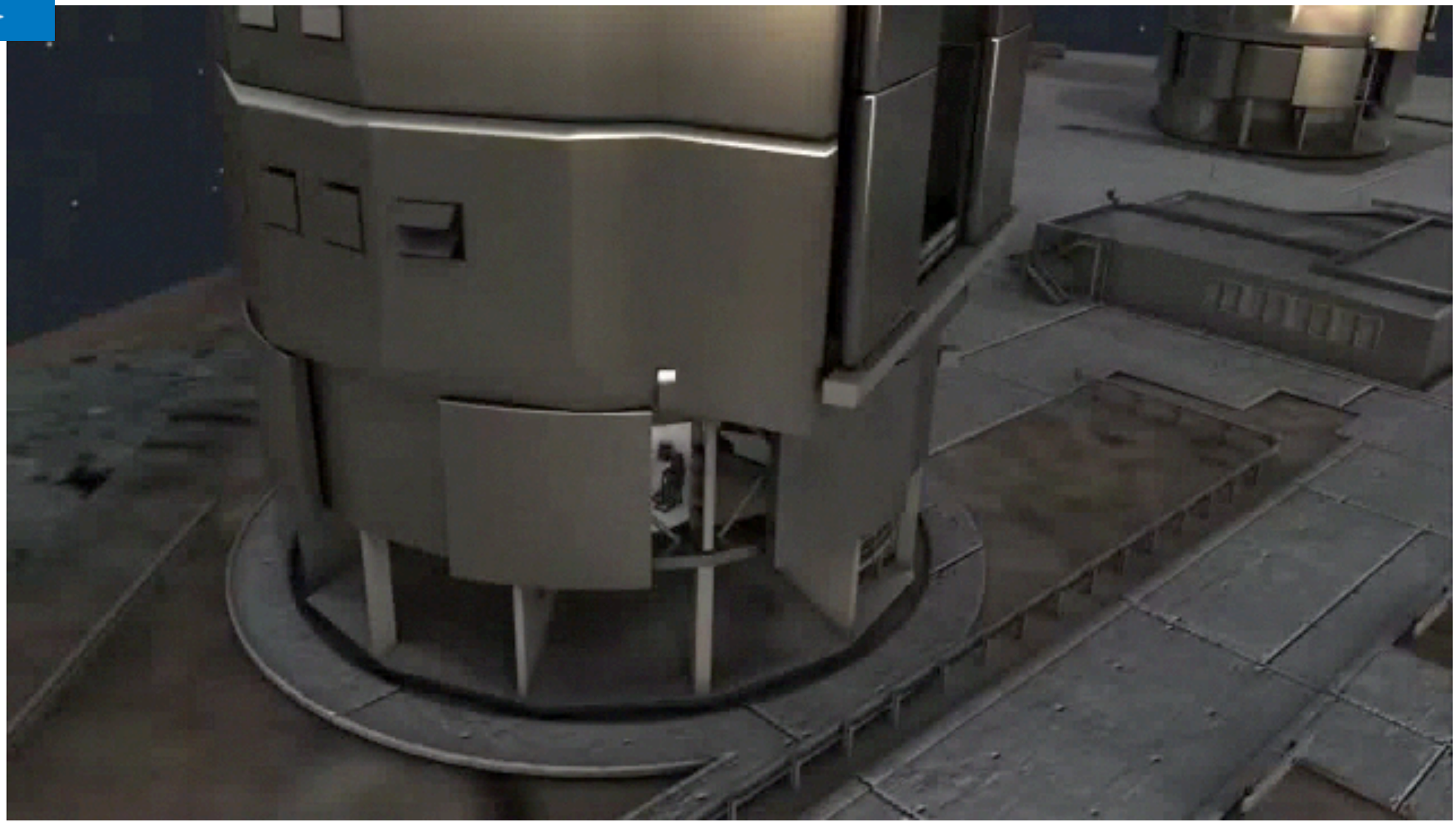
- Combines 4 telescopes in L, M and N bands
- Main objectives: AGNs, Protoplanetary disk but also… spectro-imaging—> dynamics and chemistry of winds/discs
- First light foreseen late 2017

Feature	Wavelength (μm)
L- and *M*-bands (~ 2.8–5.0 μm)	
H_2O (ice)	3.14
H_2O (gas)	2.8–4.0
H lines (Br-α, Pf-β)	4.05, 4.65
PAHs	3.3, 3.4
Nano-diamonds	3.52
CO fundamental transitions	4.6–4.78
CO (ice)	4.6–4.7
N-band (~ 8.0–13.0 μm)	
Amorphous silicates	9.8
Crystalline silicates (olivines and pyroxenes)	9.7, 10.6, 11.3, 11.6
PAHs	8.6, 11.4, 12.2, 12.8
Fine structure lines (e.g., [S IV], [Ne III], [Ne II])	10.5, 10.9, 12.8



Lopez et al., The ESO Messenger, 157, 2014
Matter et al., 2016, arXiv:1608.02351

GRAVITY: presentation



Credit: MPE, link to the full video here

Eisenhauer et al., 2011

GRAVITY: presentation

- 4 telescope beam-combiner
- Internal fringe tracker:
  ~ few 100s « phased » integration
- High angular resolution down to ~3 mas
- Two modes: single or dual field
- Three spectral settings in K-band:
  R~20, R~500 and R~4000

- Offered for the first time starting October 1st in « imaging » mode
- Near future, astrometry mode with ~ 50 micro-arcsecond accuracy

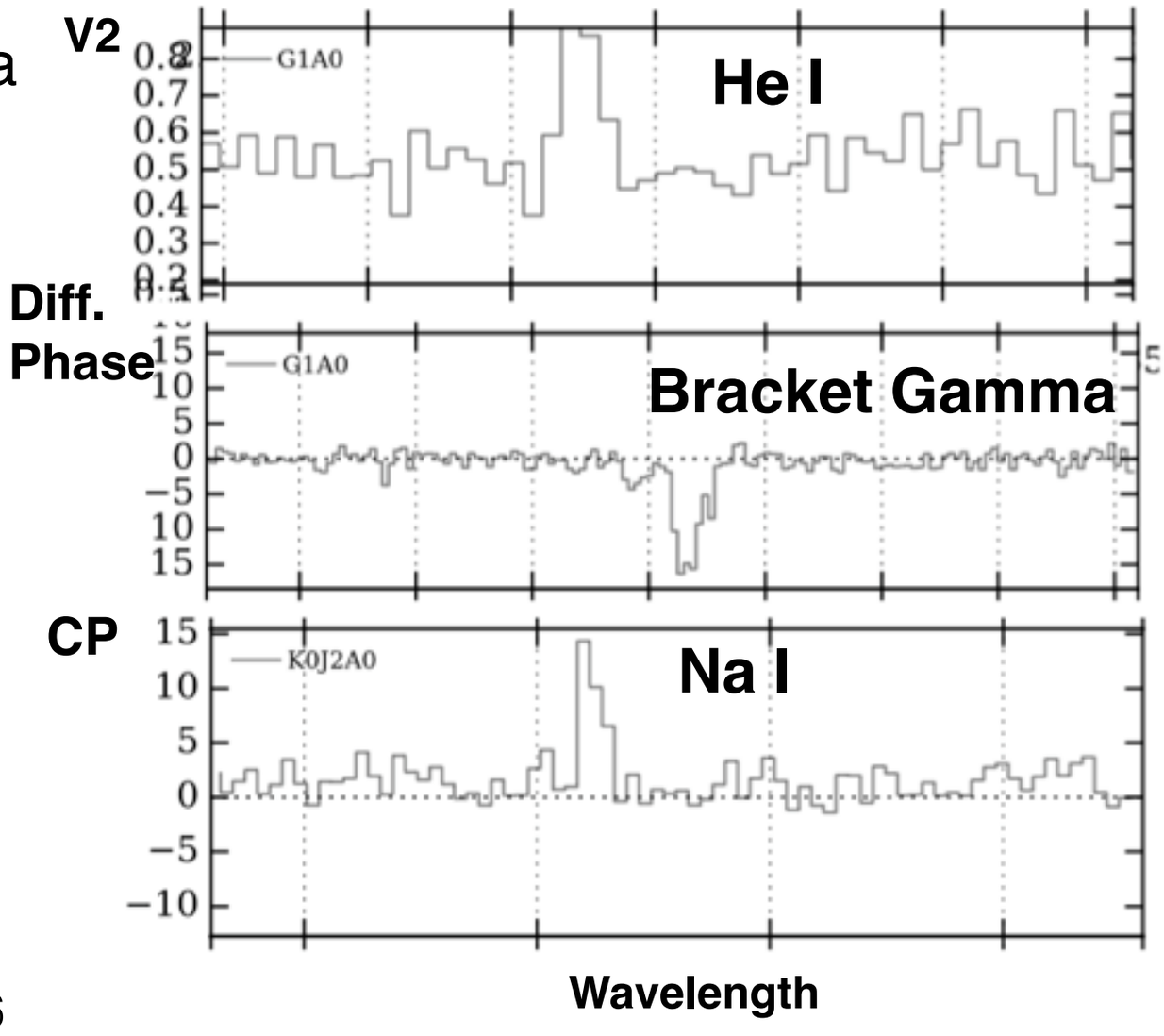
First GRAVITY results on stellar winds (1)

Science verification, raw data are public!
—> Look at the GRAVITY SV page!

1) Wind-wind interaction in an Eta-Car-like system,
what is the spatial structure of the Br gamma emission? Link to binarity?

- Asymmetric morphology in Br gamma

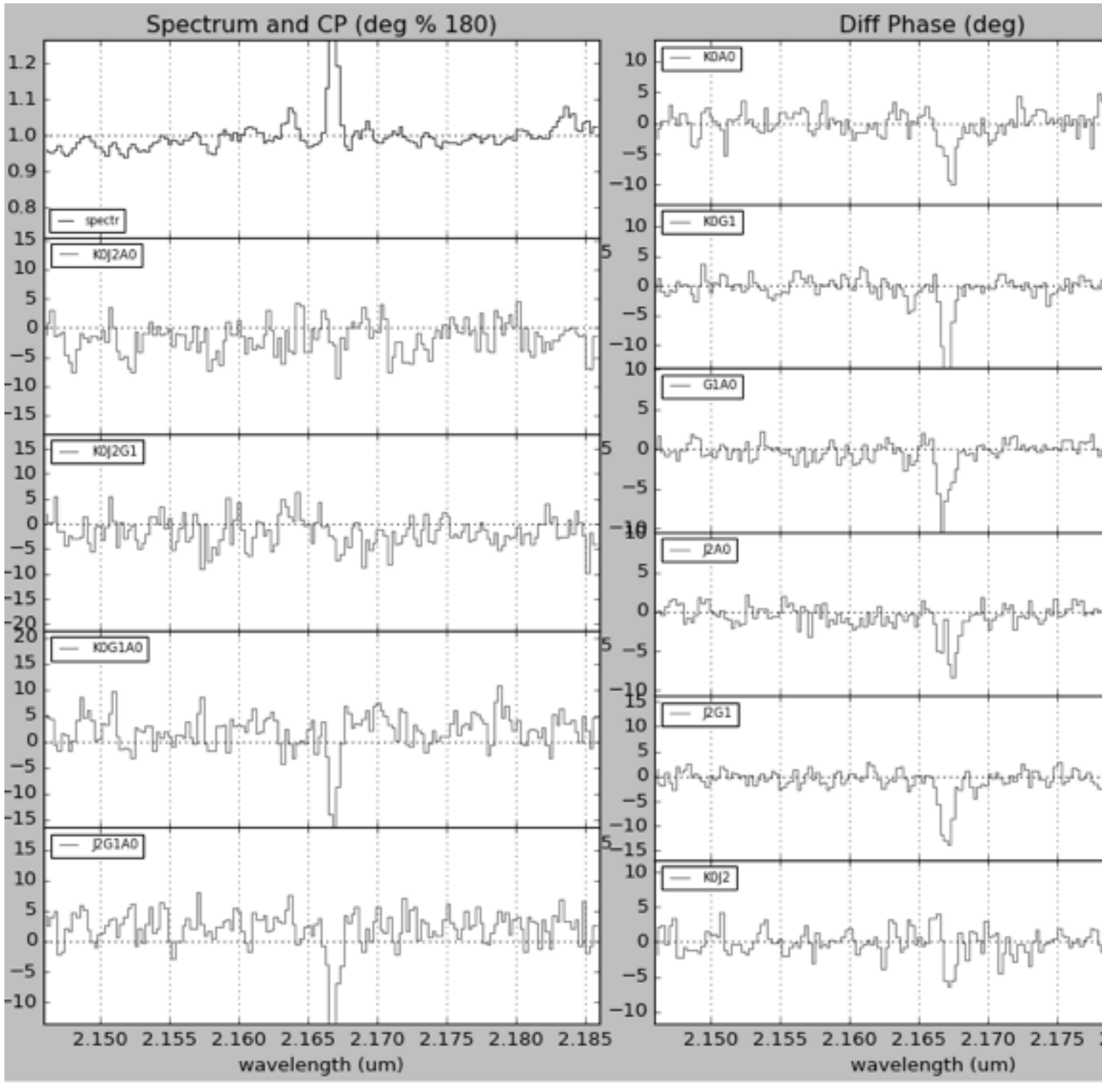
- Many more signatures in other lines



First GRAVITY results on stellar winds (2)

2) Yellow hyper giant: transition from RSG to WR, what's the wind structure like?

- Asymmetric structure of the ionized wind in Br gamma



First GRAVITY results on stellar winds (2)

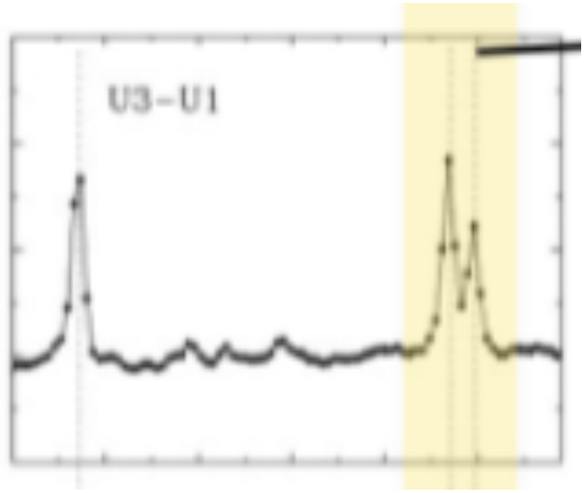
2) Yellow hyper giant: transition from RSG to WR,
what's the wind structure like?

- Asymmetric structure
of the ionized wind
in Br gamma

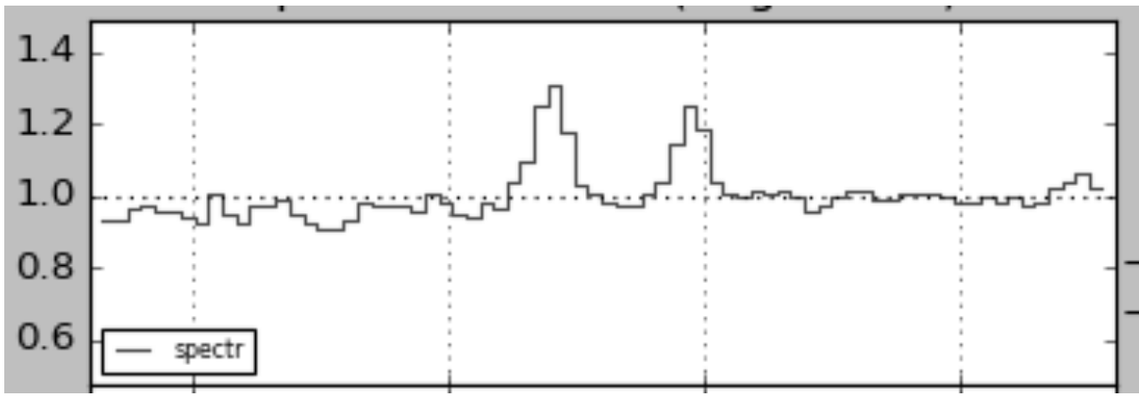
- Na I doublet: strong mass loss event

- Previously detected with UTs,
—> better observed with GRAVITY+ATs!

UTs



GRAVITY+ATs



Conclusion

- VLTI powerful diagnosis tool to study stellar winds at the mas scale and related phenomena (e.g., multiplicity survey with PIONIER)

- 2nd generation instruments:
  —> GRAVITY and MATISSE spectro-imaging
  —> Powerful combination with other instr.: SPHERE or ALMA (CO lines)
  —> GRAVITY astrometry (~50 μas accuracy) coming soon

- Interested? —> next proposal deadline late September/early October

The Optical Interferometry Database

oidb.jmmc.fr

- Science-ready (published) data and observation logs, downloadable in one click

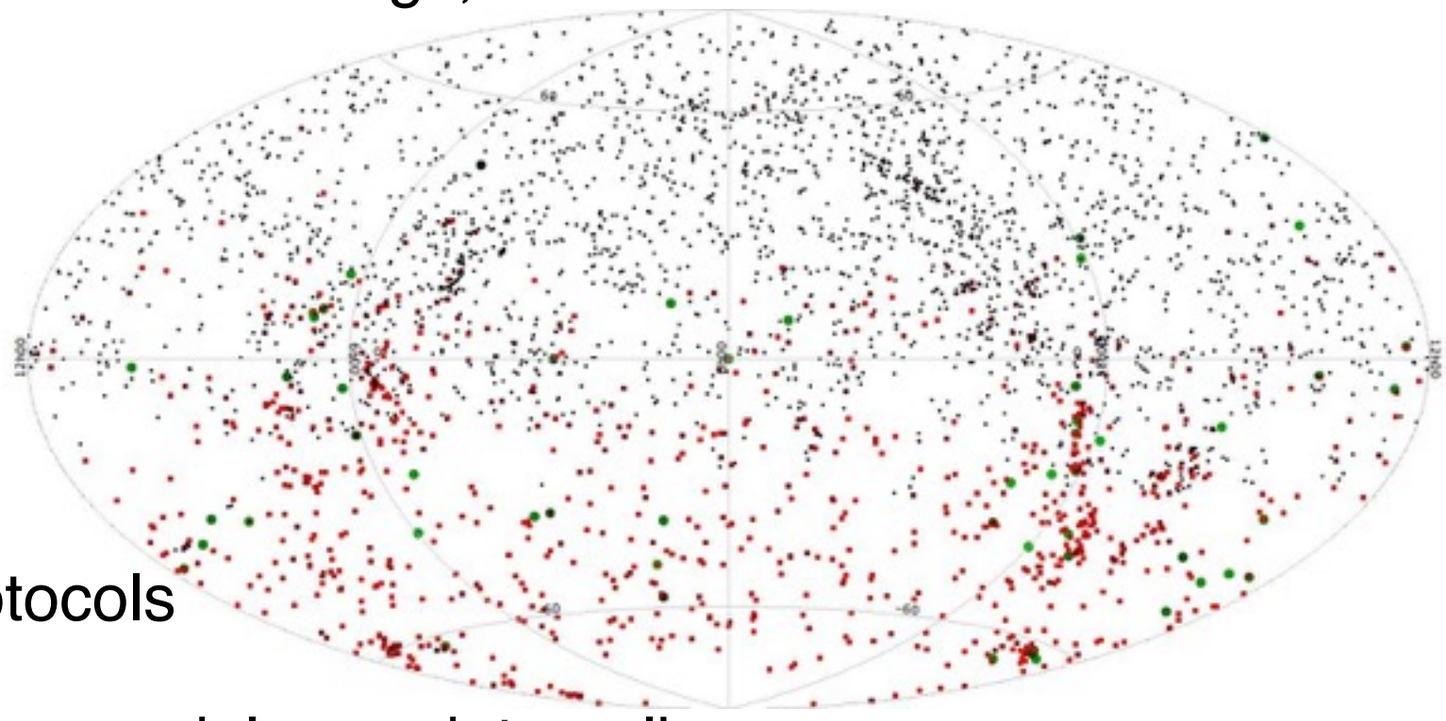
- Data from more than 10 instruments

- Sky coverage: ~ 3600 stars

- Interoperability with VO tools and protocols

- Very easy to have a first look and even model your data online

- Terms of use



Observation logs
Science ready OIFITS
Published OIFITS L3

Thank you for your attention!