Harnessing the Resolving Power of MATISSE: the origin of mass-loss complexity on the AGB

Claudia Paladini

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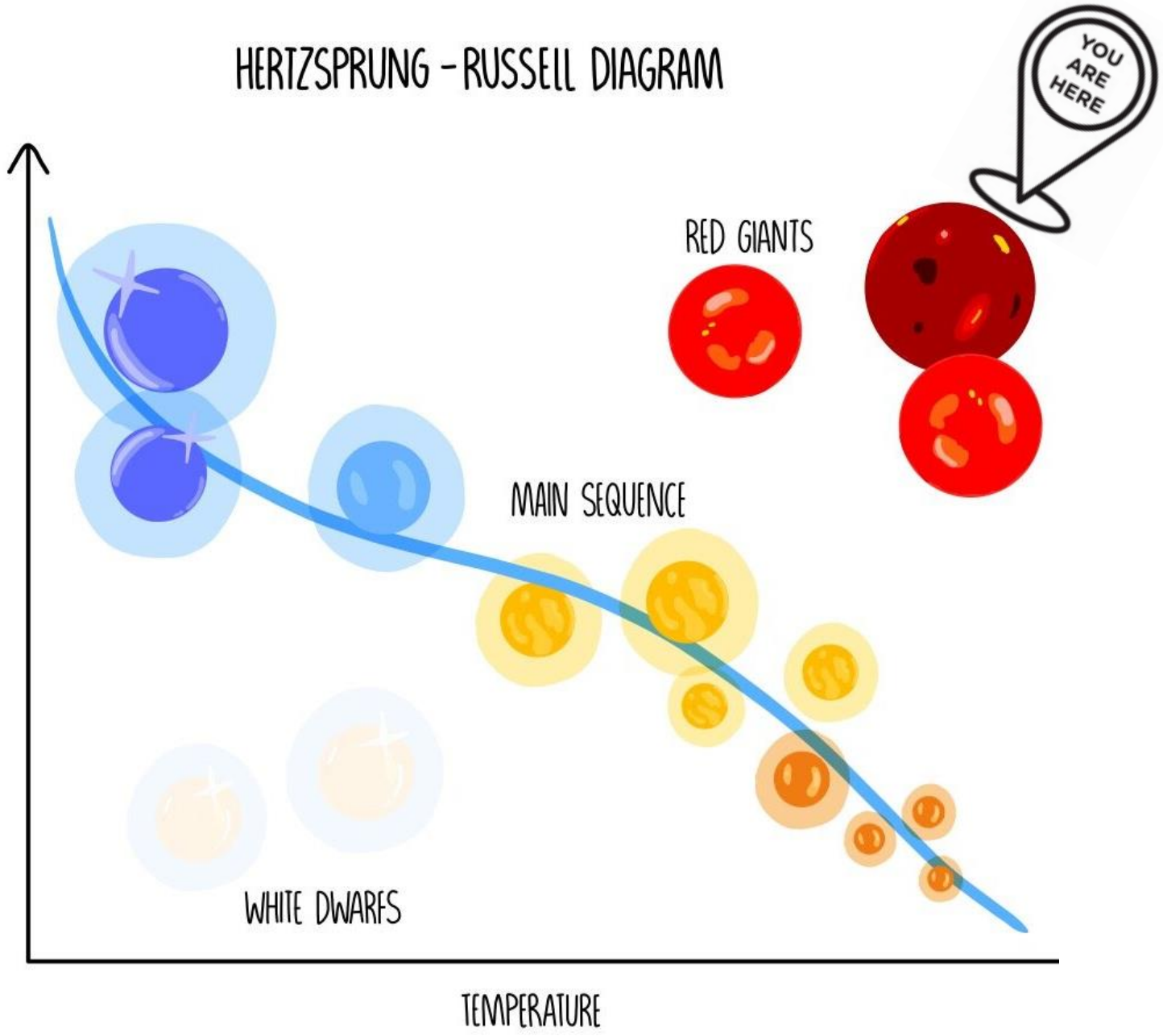
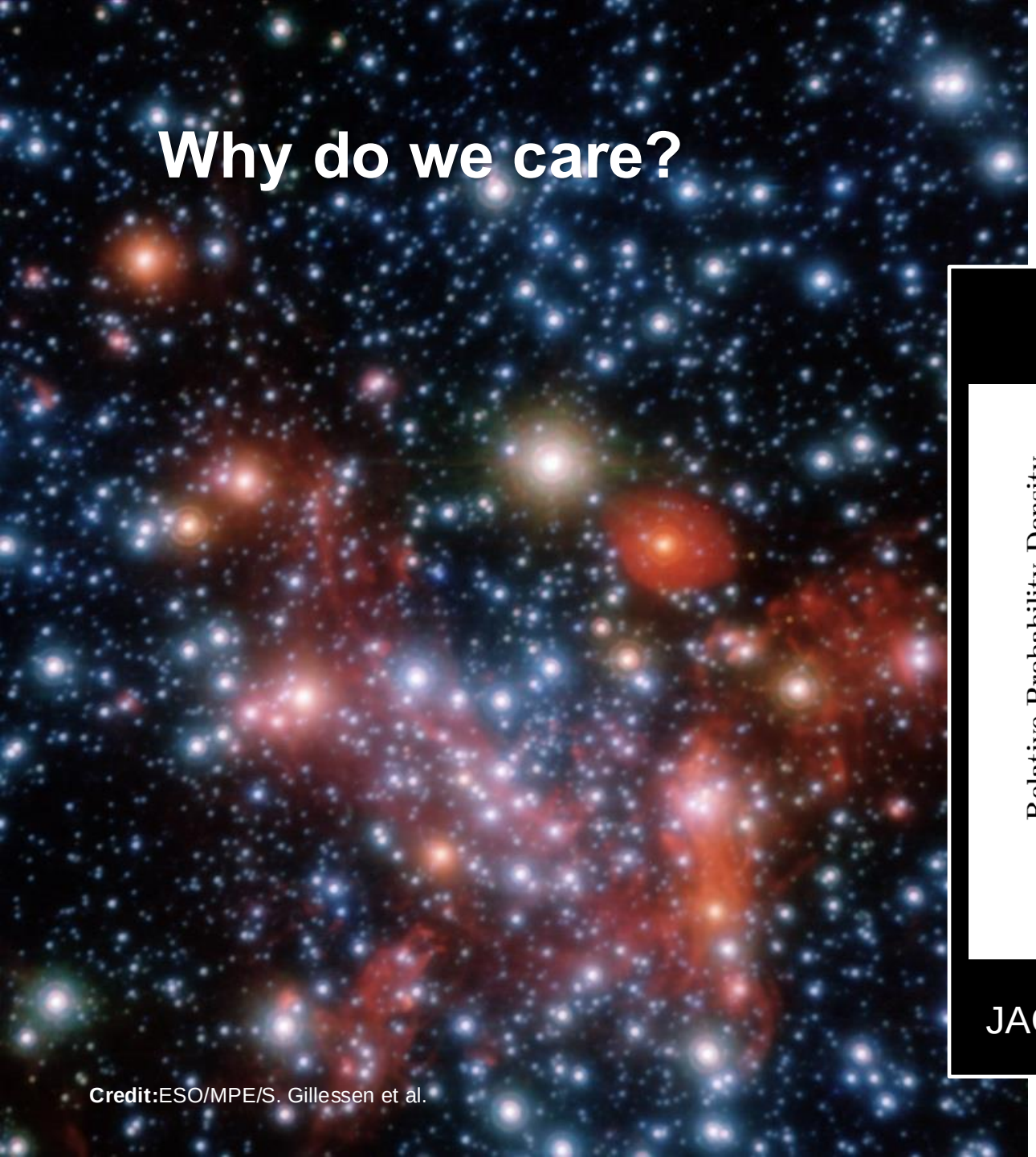
Bruno Lopez, Andrea Chiavassa, Elvire De Beck, Martin Groenewegen, Karl-Heinz Hofmann, Josef Hron, Alain Jorissen, Franz Kerschbaum, Florentin Millour, Eric Lagadec, Miguel Montarges, Pierre Cruzalebes, Hans Olofsson, Peter Scicluna, W.H.T. Vlemmings, Gerd Weigelt, Markus Wittkowski, Keiichi Ohnaka, G. Perrin, Kjell Eriksson, S. Van Eck, Susanne Höfner, Fabien Baron, Frederic Thevenin, Lionel Siess, Theo Khouri, Foteini Lykou, William Danchi, Nicolas Nardetto, Elizabeth Humphreys



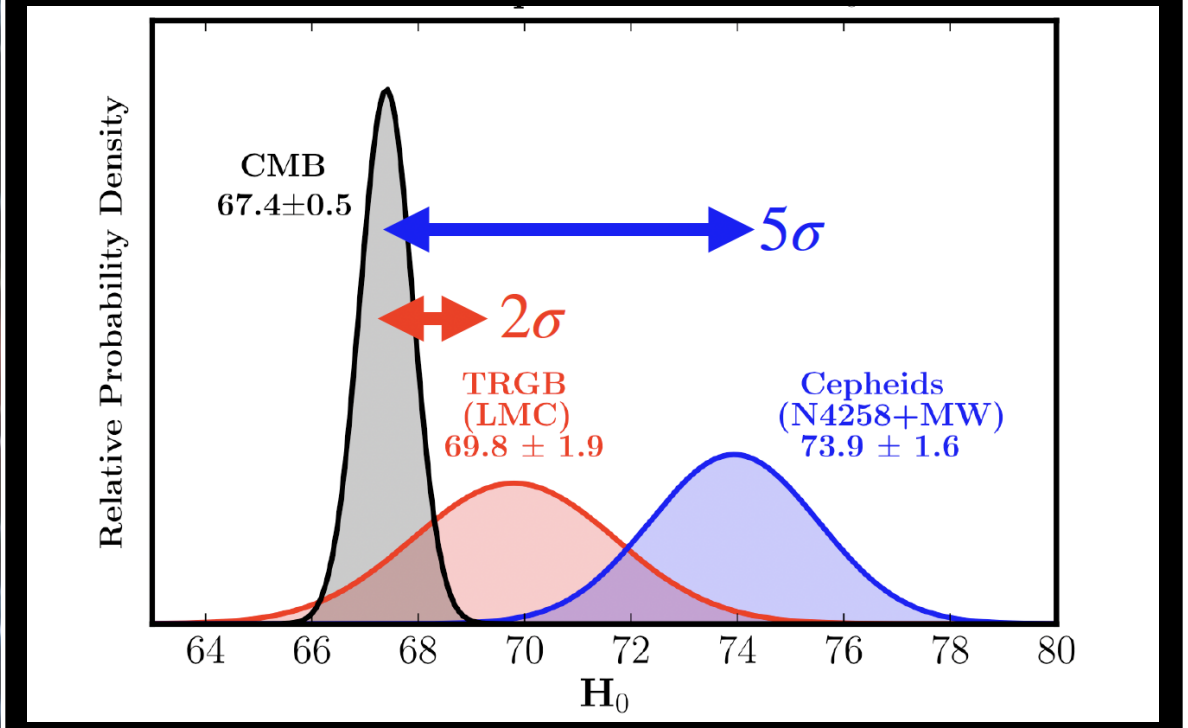
Credit: https://www.thesciencehive.co.uk

Asymptotic giant branch stars are dust factories

Why do we care?



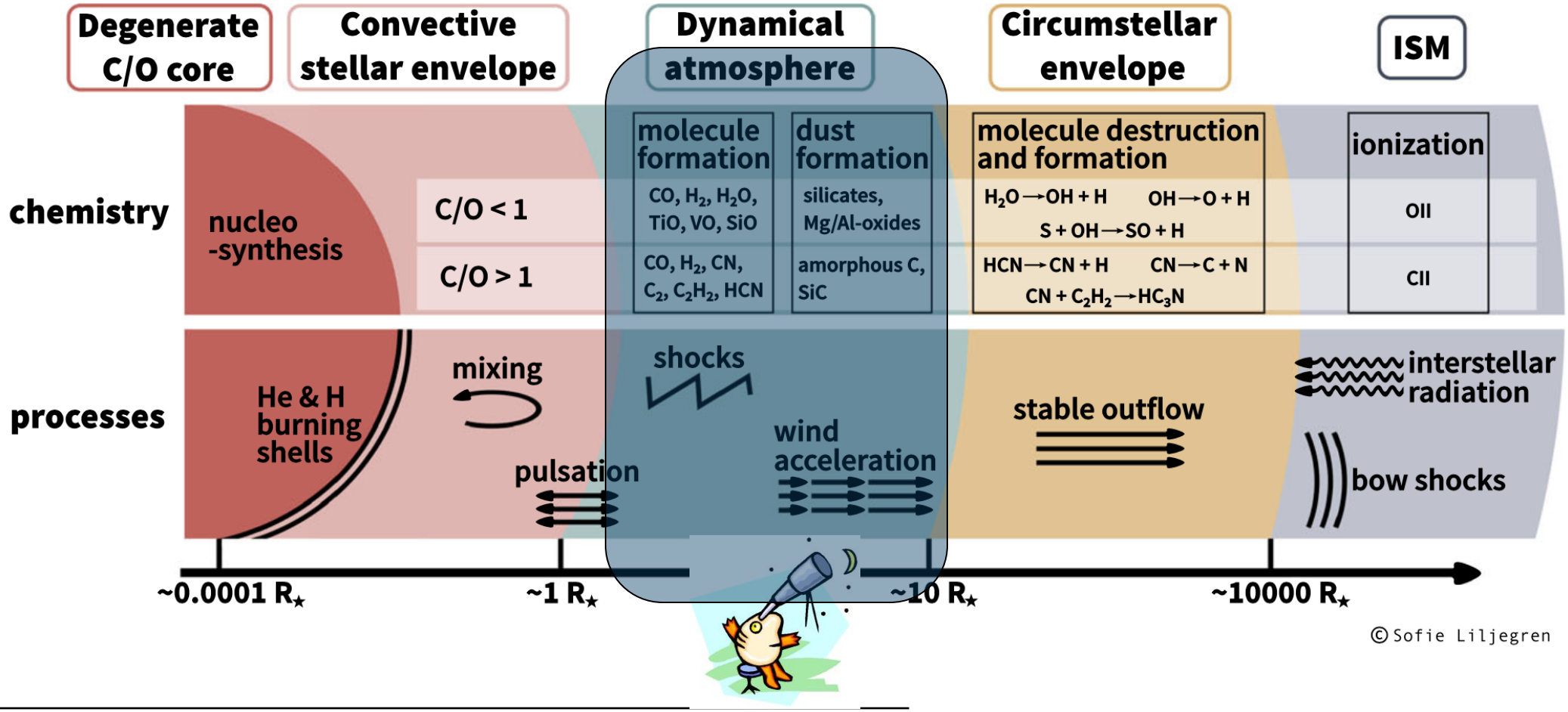
Credit:ESO/MPE/S. Gillessen et al.



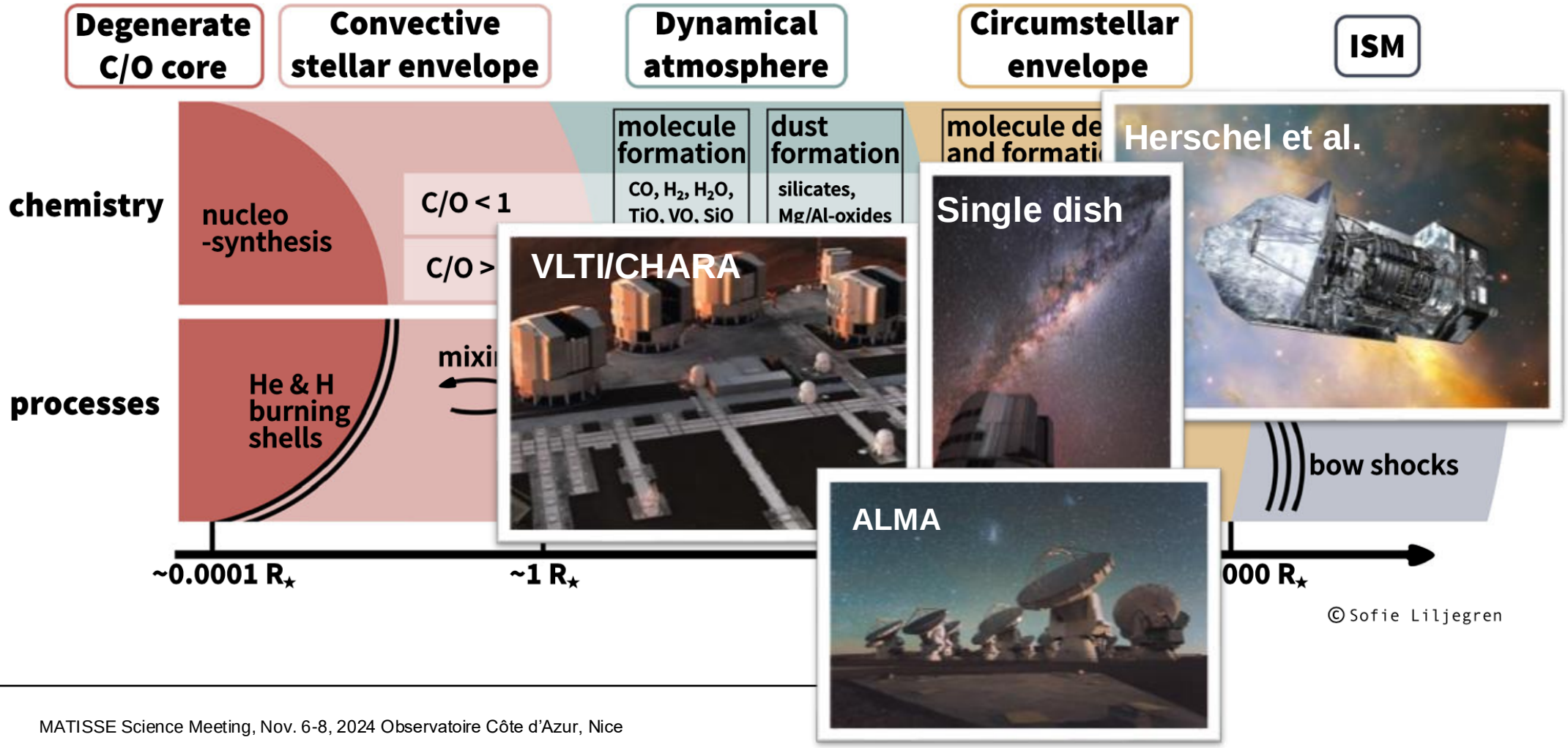
JAGB method: carbon stars as standard candles

Freedman+ 2019
Lee, A. et al 2024

Asymptotic Giant Branch (AGB) Stars in a nutshell

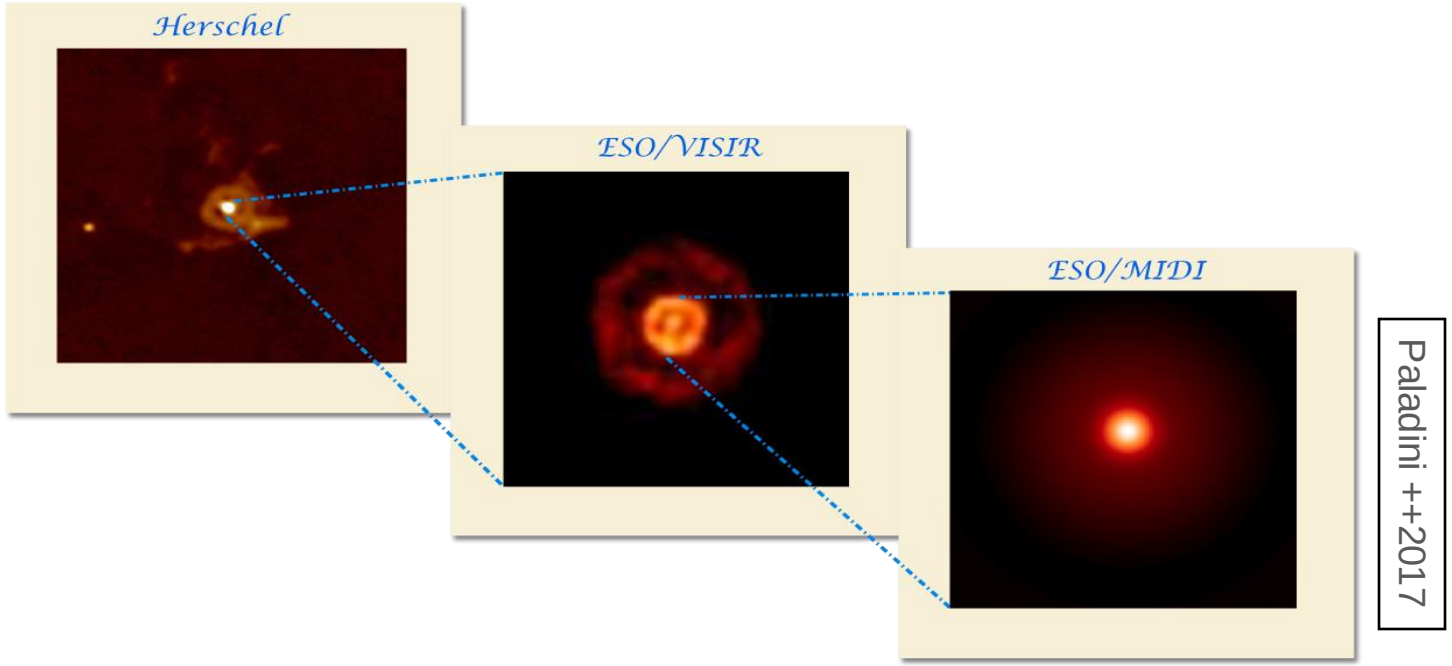


Asymptotic Giant Branch (AGB) Stars in a nutshell



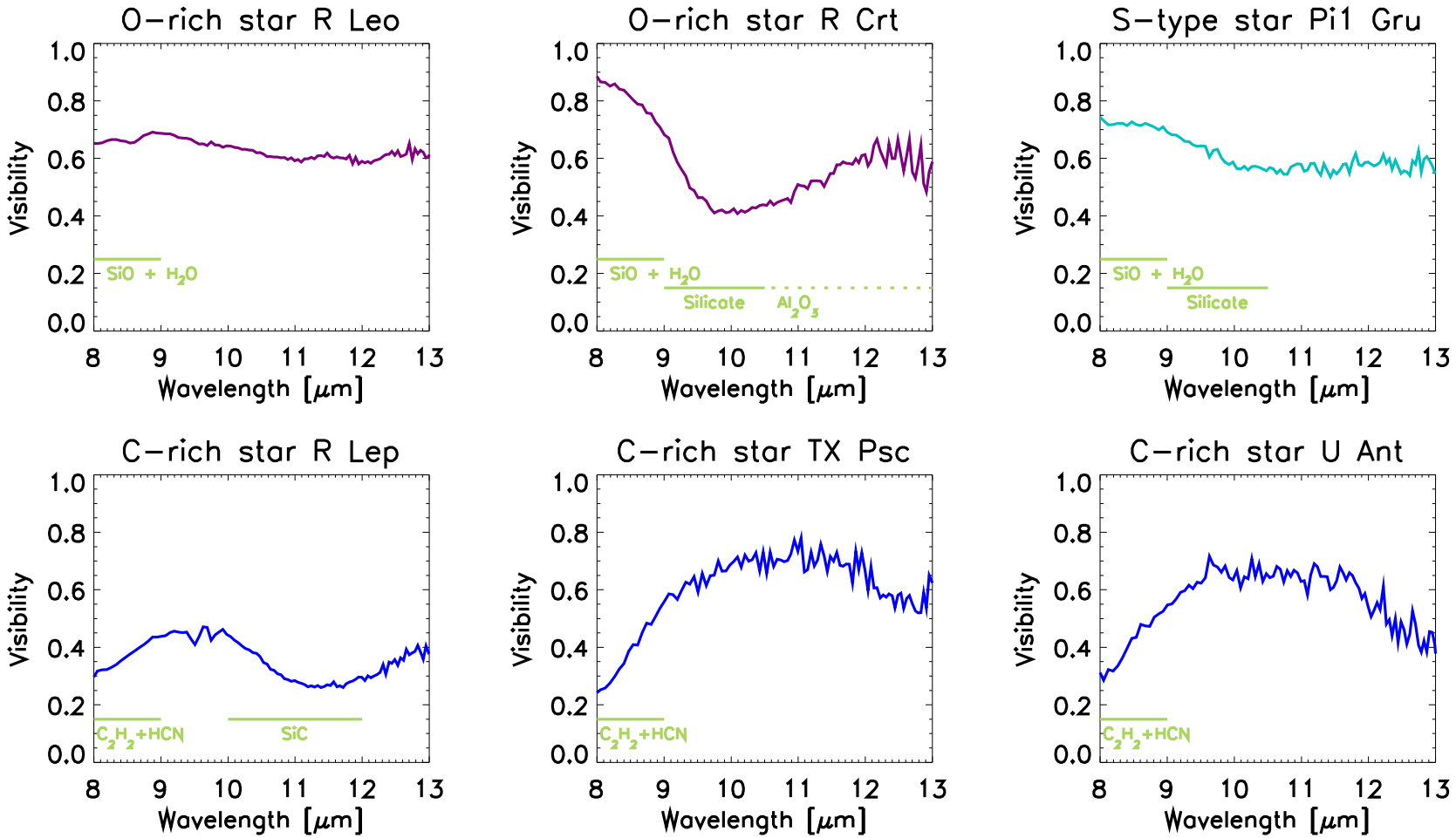

How does nature create such shapes?

MIDI AGB Large Program



- 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?

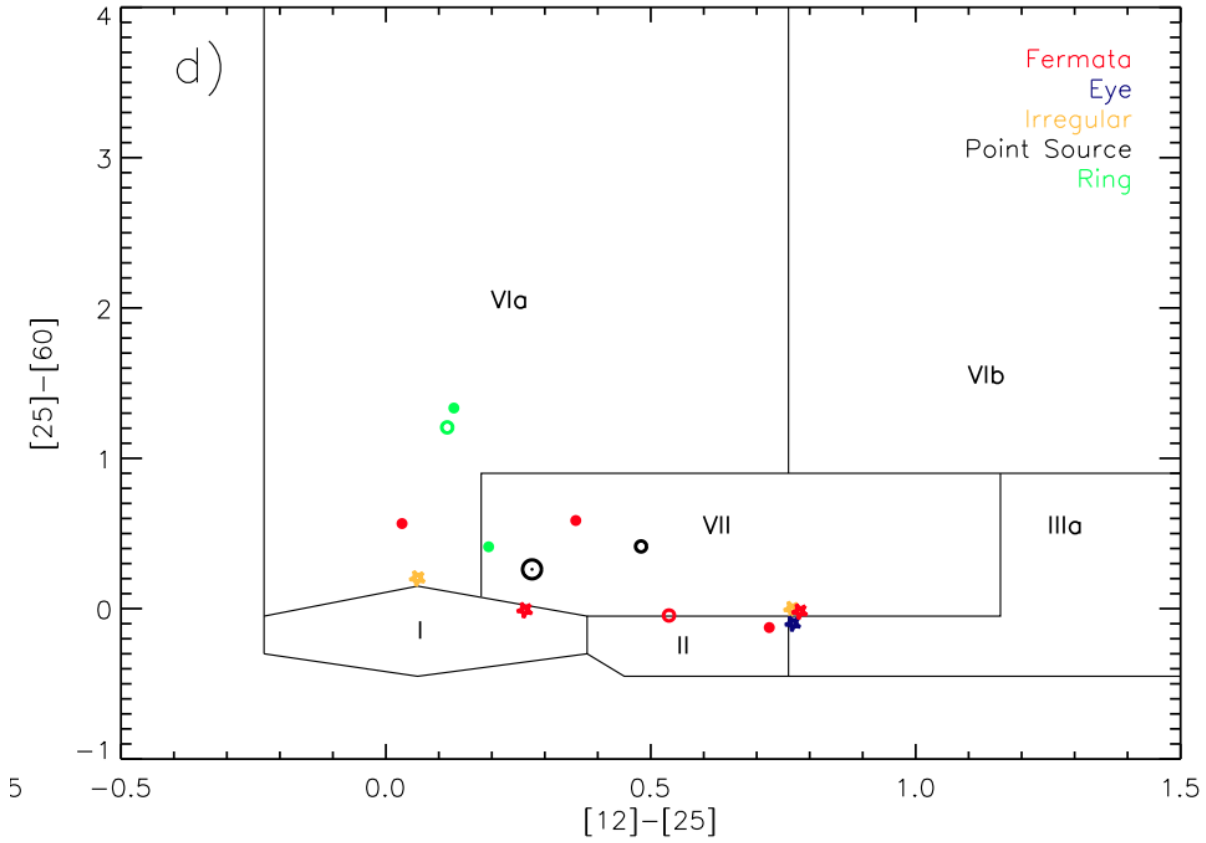
MIDI Visibility spectra



Paladini ++2017

MIDI Large Program inheritance

- MIDI observed spectroscopic variability
- Asymmetries develop already at few stellar radii, nature unclear need MATISSE images
- More evolved stars are dustier and show more ``asymmetric'' (clumpy?) environment
- Asymmetries are observed, more often among the Herschel "Fermata" targets
- Intermediate spatial scales needed



Paladini ++2017

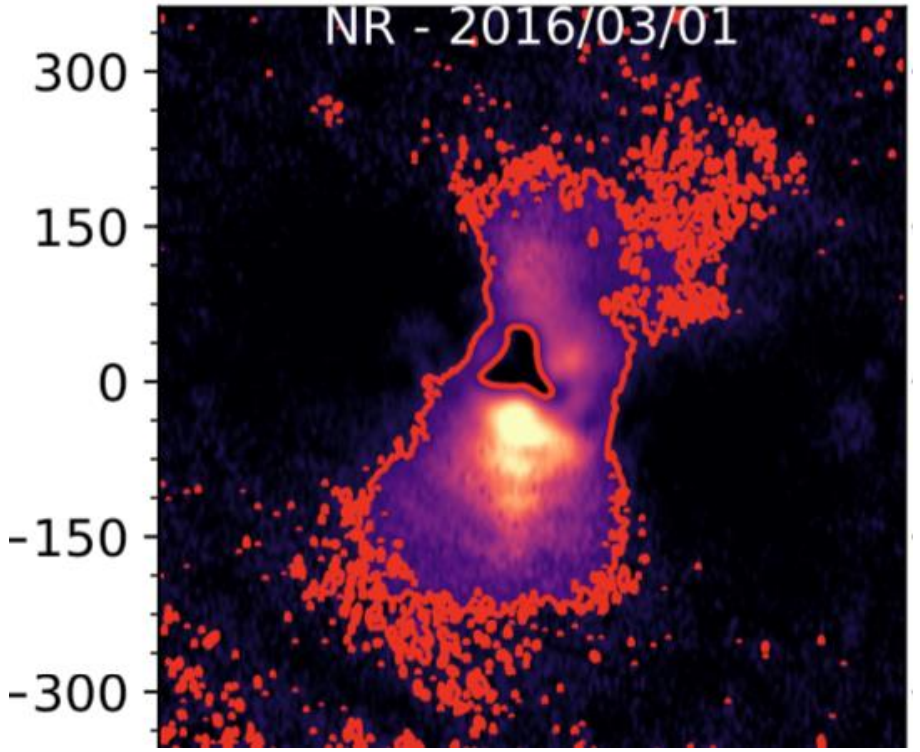
Hunting elusive binaries

Detection

- Symbiotic activities
- Radial velocities
- Photometric campaign
- Astrometry
- Submm-radio interferometry

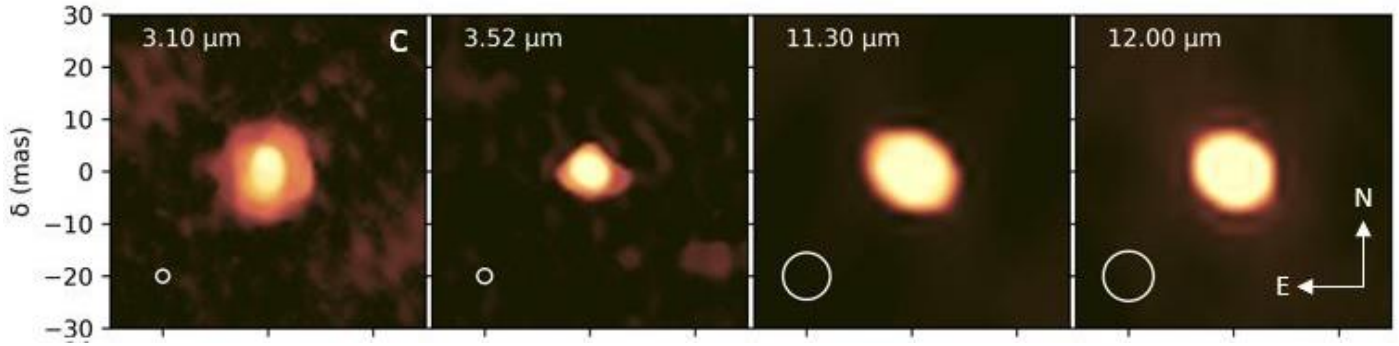
Missing population of close binaries

- Need for very high spatial resolution!



Khouri++2020

MATISSE BIN-AGB Large Program



Drevon++2022

180h MATISSE time to image 10 AGBs with known asymmetric environment

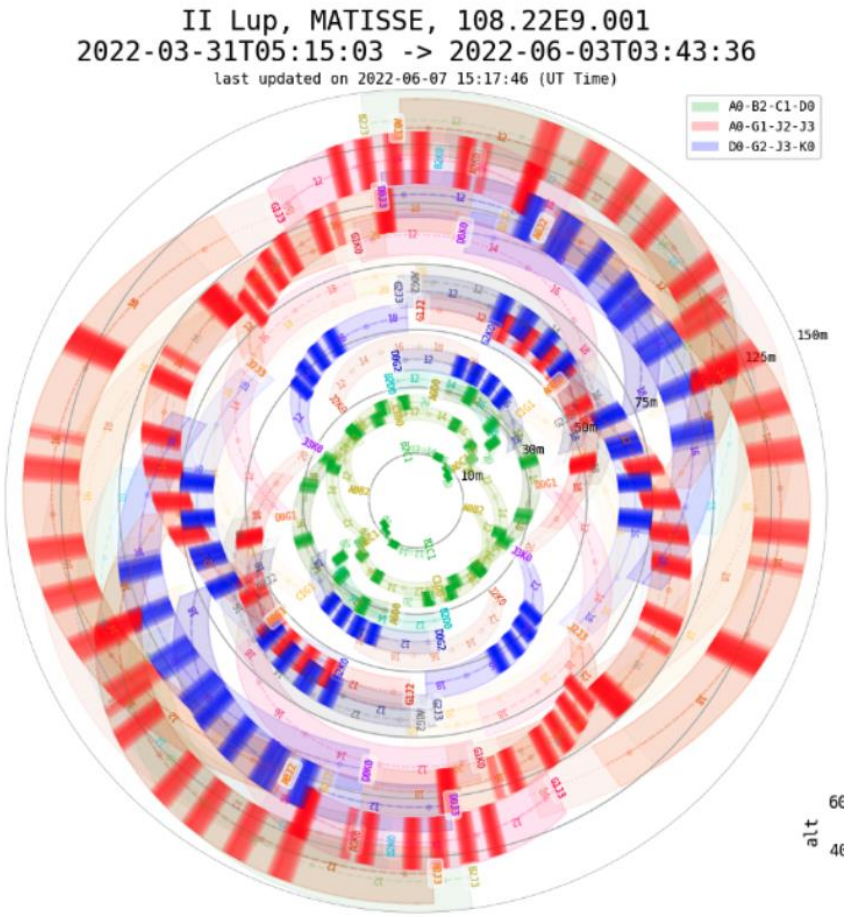
What is causing the asymmetric outflow?

What is the dust-mineralogy?

disk/binary signature?

Status

- Program declared completed, last data taken end of 2023
- First star obtained with LOW-HIGH setup repeated one year later because HIGH-N did not deliver good data for imaging
- Because of VLTI imaging limits we had to compromise between uv-coverage feasibility and astrophysical variability (referees asking for justification)
- Some data quality issues… N-band most interesting but also hardest to deal with; compact array (see next slide)



Data quality analysis

Main coding contributor J. Drevon

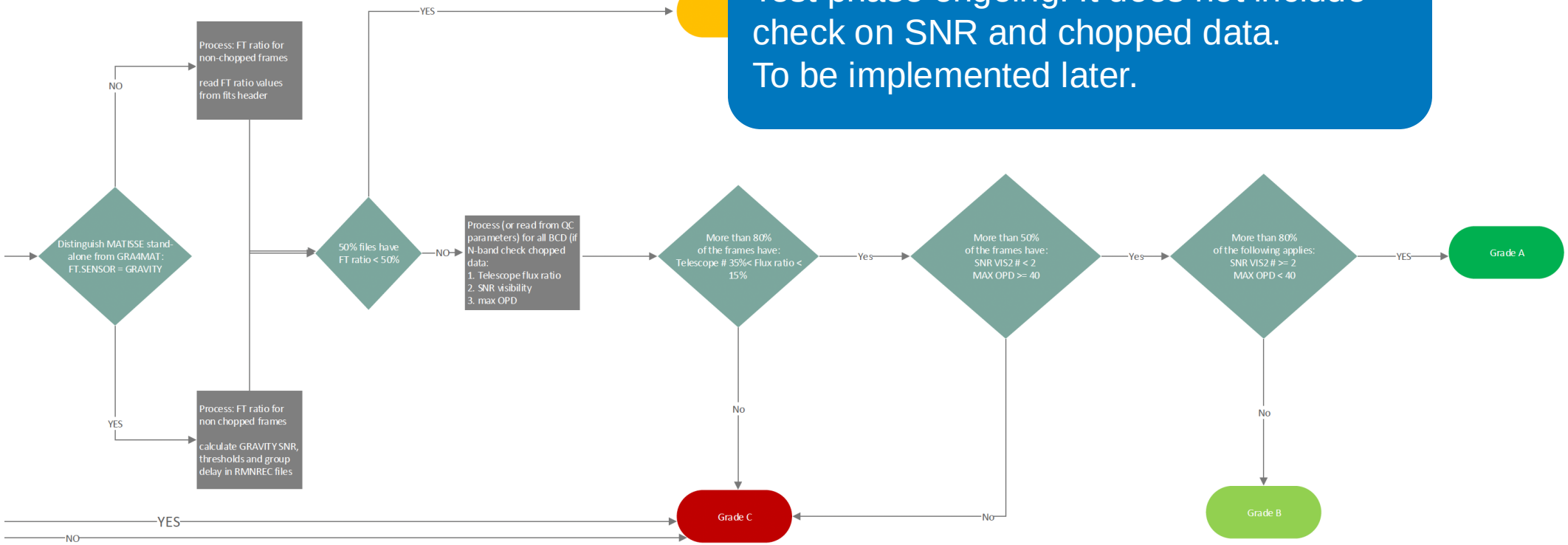
- Before calibration
  - Check SNR of the visibility
  - Check FT ratio
  - Check telescope flux ratio
  - Check max OPD
- After calibration
  - Check relative difference between BCD (for visibility and CP)

- N-band data overall worst quality, interactions with A. Matter and J. Leftley to explore additional checks as well as the use of V instead of V2 (QC parameters are based on V2!)
- Compact array data overall worst quality

Data quality analysis

Quality issues of few graded A data brought to new grading system in Paranal

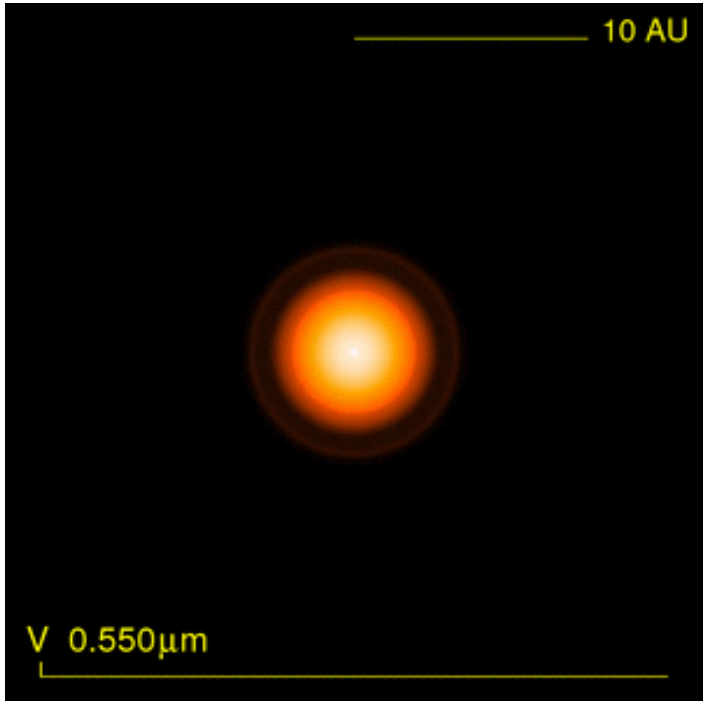
Test phase ongoing. It does not include check on SNR and chopped data.
To be implemented later.



2/6/20

Modelling & Imaging

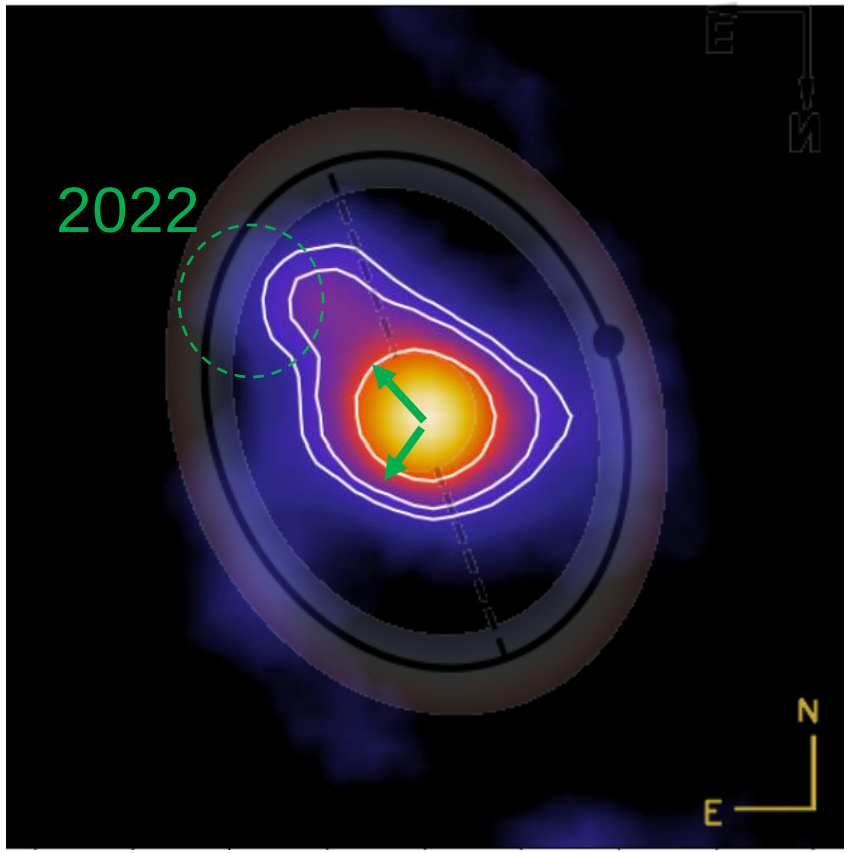
- Geometric modelling
- Imaging with MiRa and SQUEEZE
  - Tools for automatic scan parameter space
  - Tools for best image selection
  - Tools for comparison in Fourier Space (using also AHMRA)
- Future: model atmosphere comparison (see talk @Hron and @Hoefner)



An impressionist & dynamic view of V Hya

Comparison of the orbit prediction with the reconstructed images

Planquart et al. 2024



- Dusty clump position (distance and orientation) is compatible with the orbital prediction, assuming the clockwise rotation.
- Dichotomy between orbit orientation resolved using MIDI observations from 2009.

➢ The northeast clump appears as related to the presence of enhanced (dust) particles surrounding the companion

➢ Mostly SiC dust

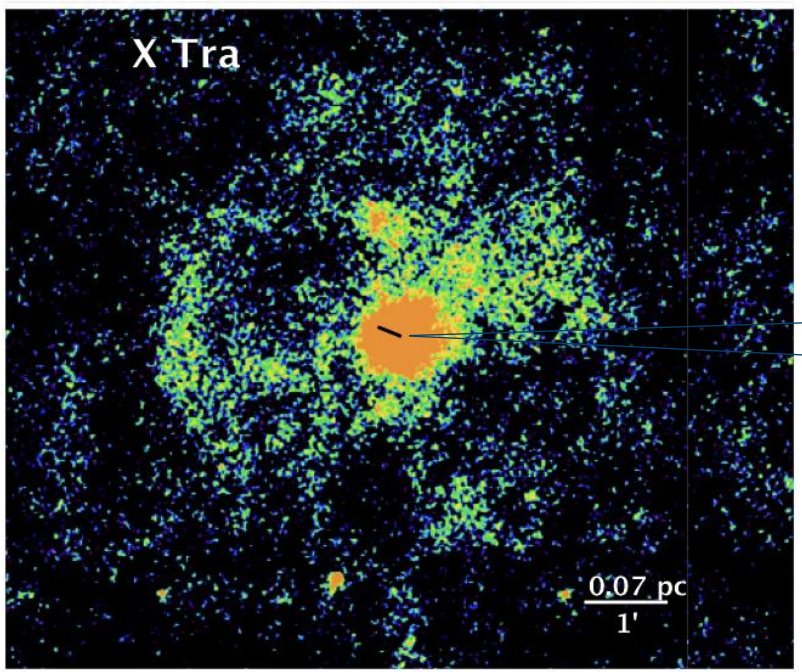
See Planquart talk!

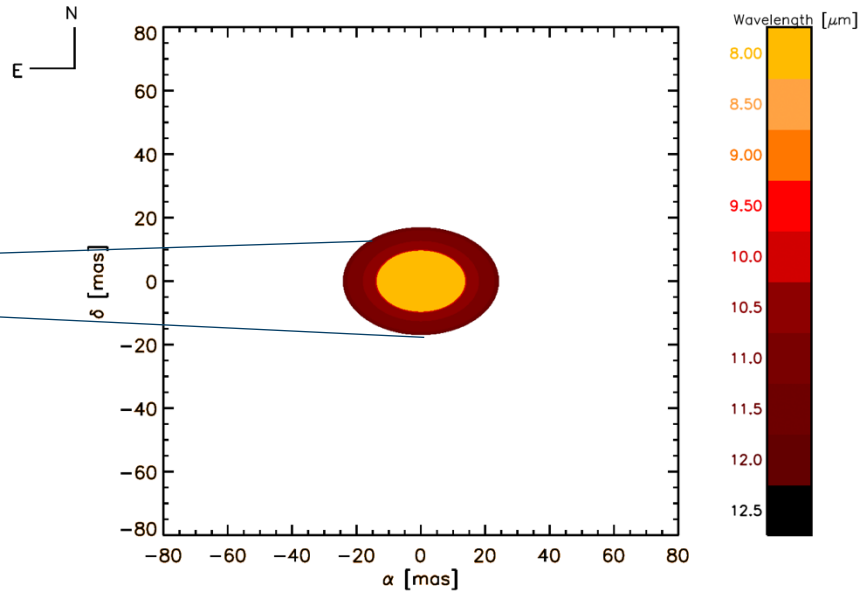
Field of view of 80x80 mas; spectral bandwidth: 10.5->11.5 µm

MATISSE Science Meeting, Nov. 6-8, 2024 Observatoire Côte d'Azur, Nice

The case of X Tra

Rastau et al. prep.





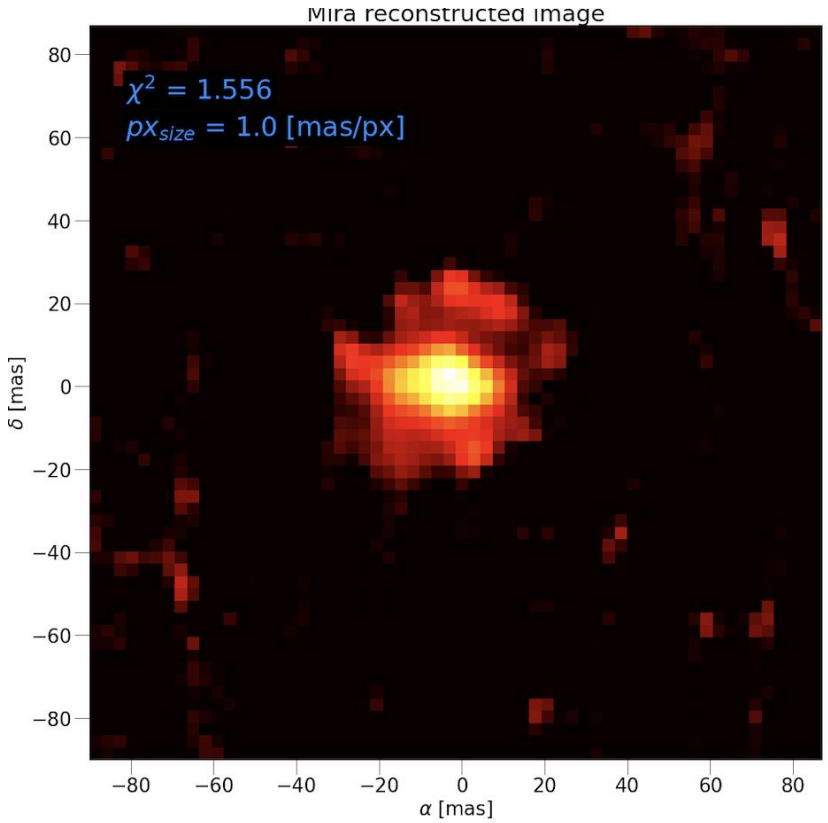
Cox++2012

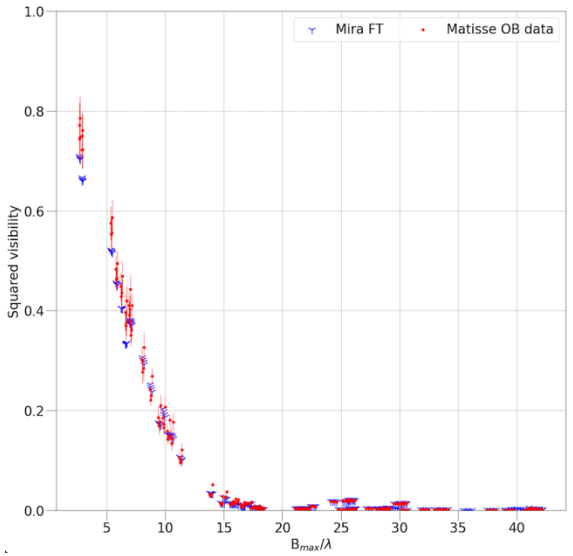
Paladini++2017

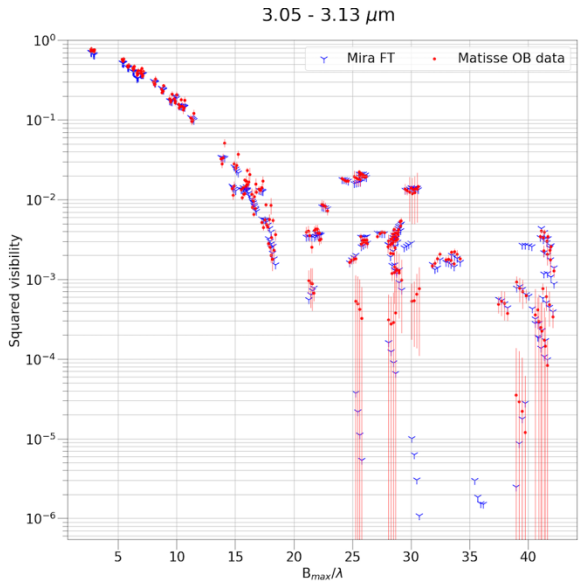
C-rich star, irregular variable, no sign of binarity, detached shell object (Izumiura++1995). For MIDI it could be a UD as well as an ellipse. Flux change between MIDI and IRAS

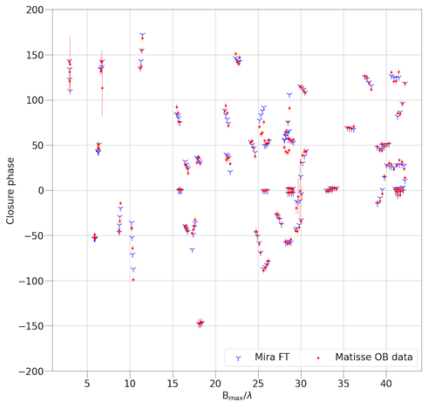
The case of X Tra: L-band C2H2+HCN feature

Rastau et al. prep.



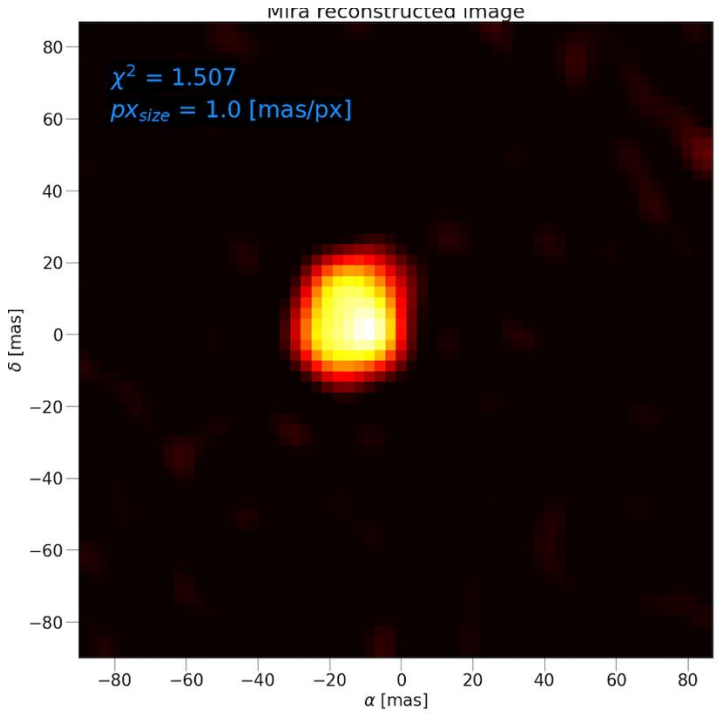


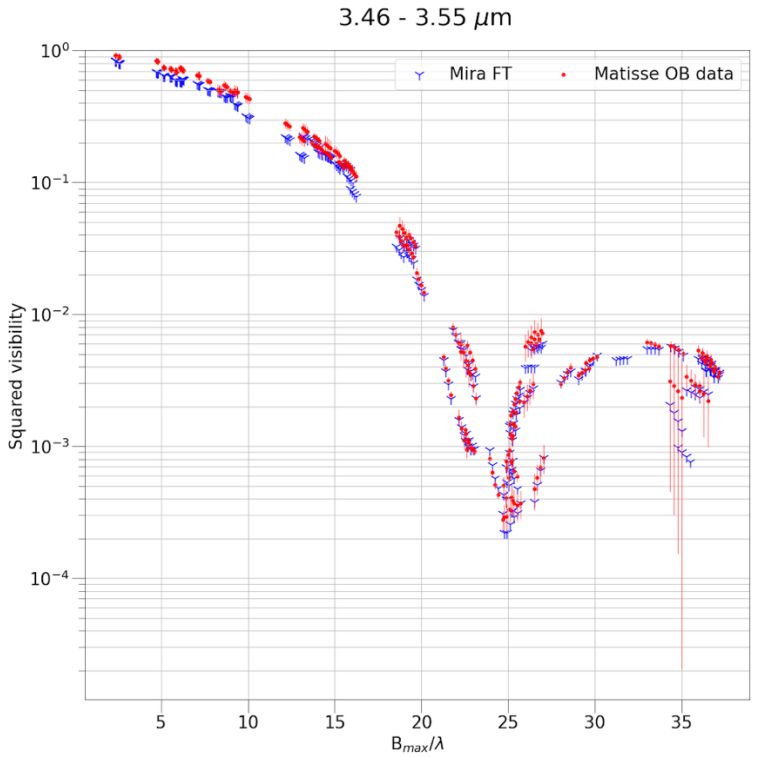


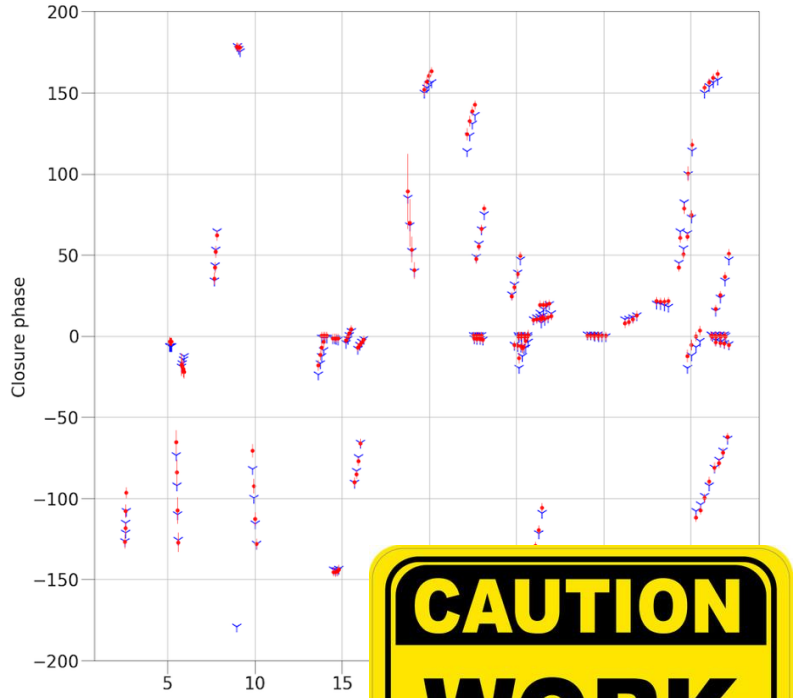


The case of X Tra: L-band continuum

Rastau et al. prep.



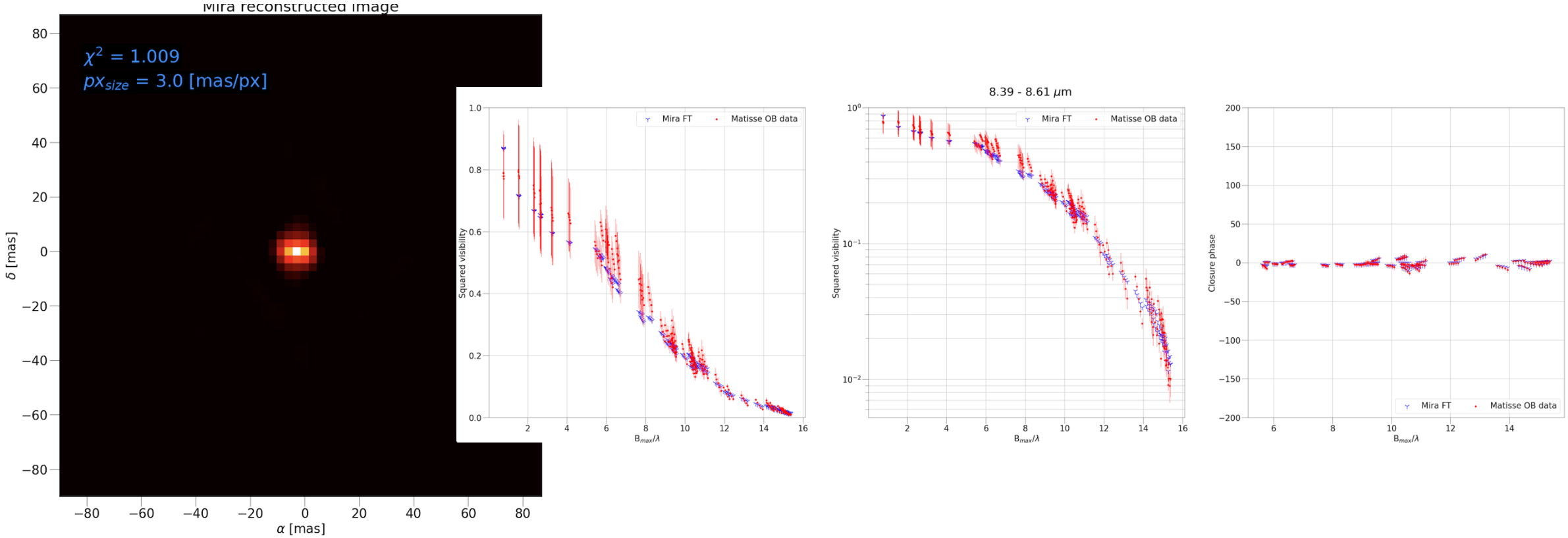




2/6/2025

The case of X Tra: N1- MATISSE band

Rastau et al. prep.

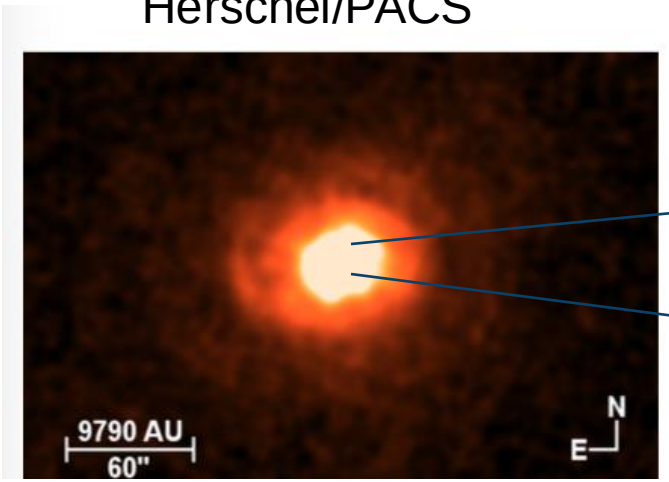


Consistent with L-band C2H2 image, as well as with old MIDI models

The case of pi1 Gru

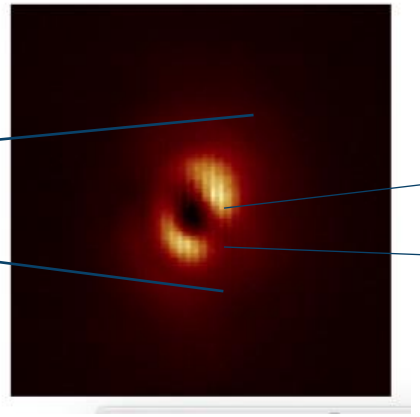
Drevon et al. prep.

Herschel/PACS



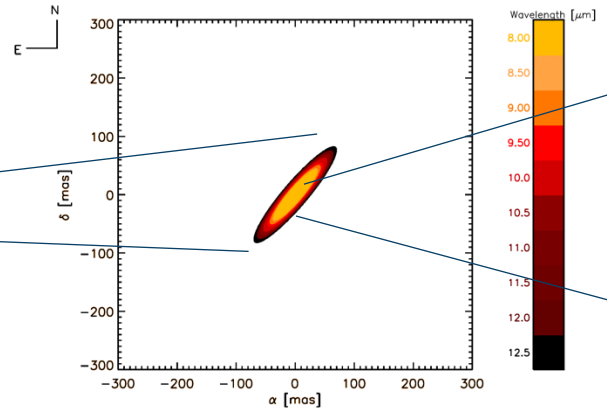
Cox et 2012

VLT/VISIR



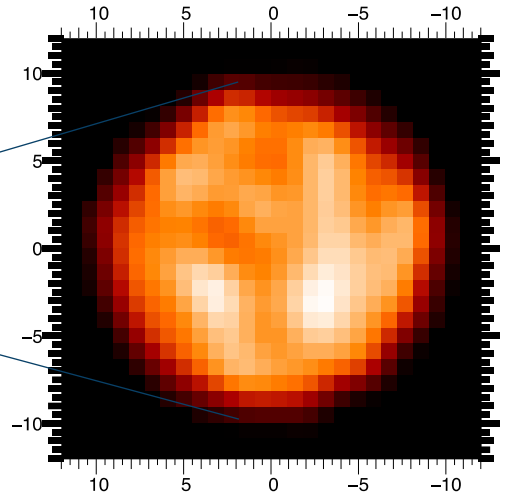
Drevon et al. prep.

VLTI/MIDI (model)



Paladini++2017

VLTI/PIONIER

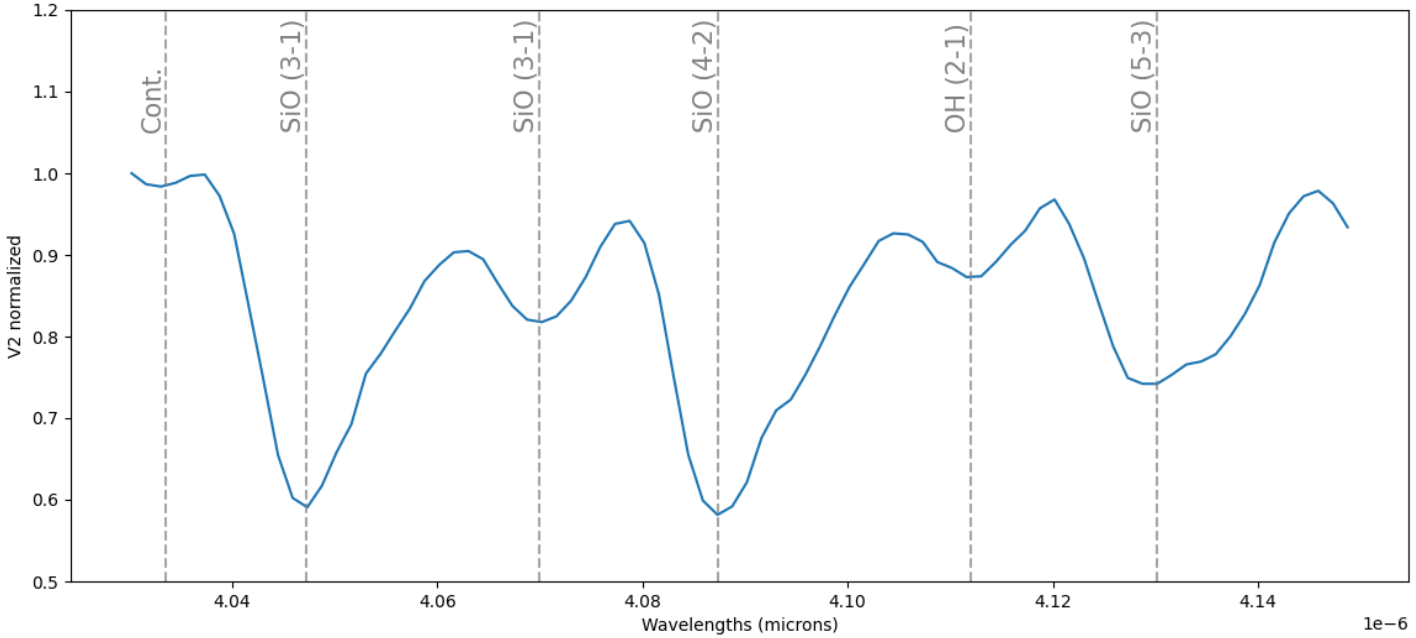


Paladini++2018

S-type star; known binary, possible triple (Mayer++2014; Homan++2020).
Pi1 Gru c expected in the FOV of MATISSE

The case of pi1 Gru: L-band data

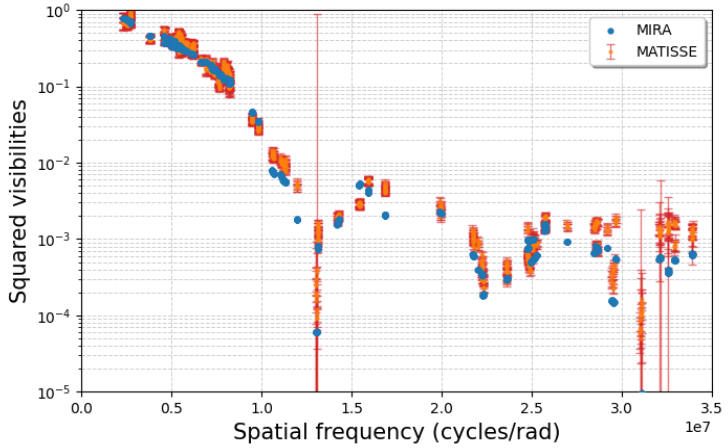
Drevon et al. prep.

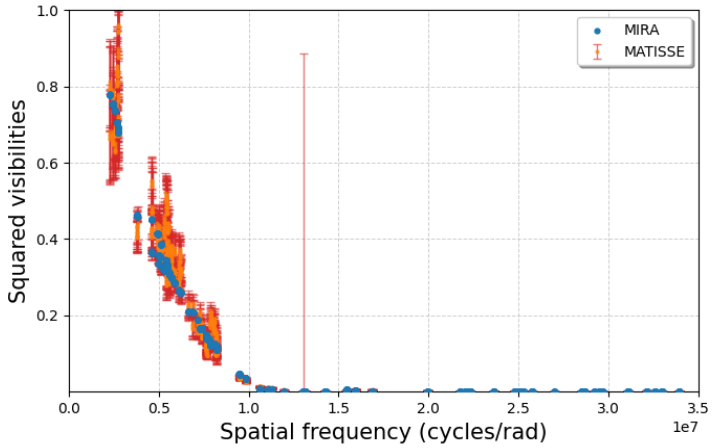


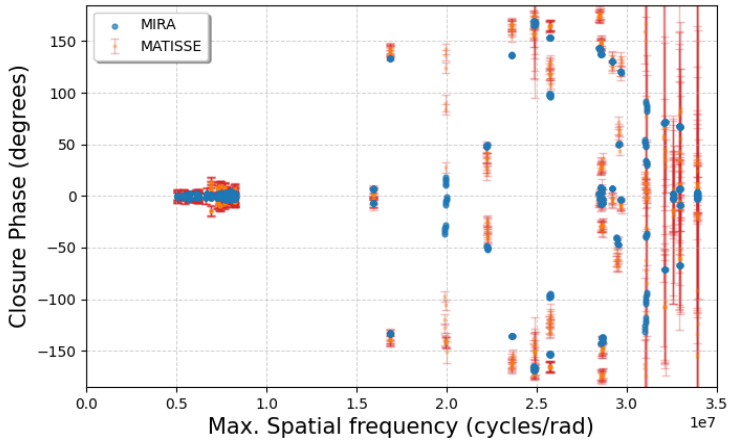
Dealing with medium resolution data, trying to reconstruct SiO bands, see also Drevon++2023 Betelgeuse paper

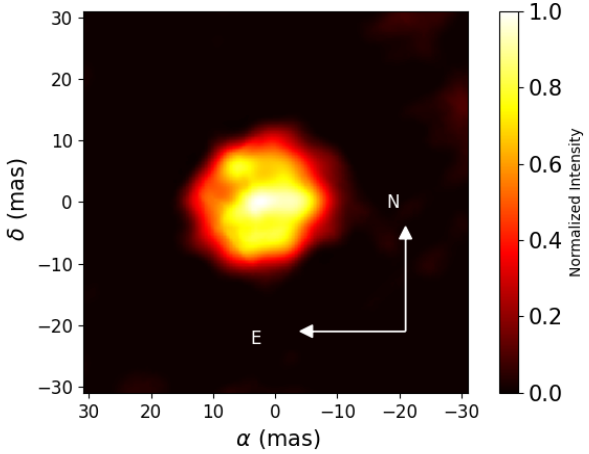
The case of pi1 Gru: L-band SiO (3-1)

Drevon et al. prep.



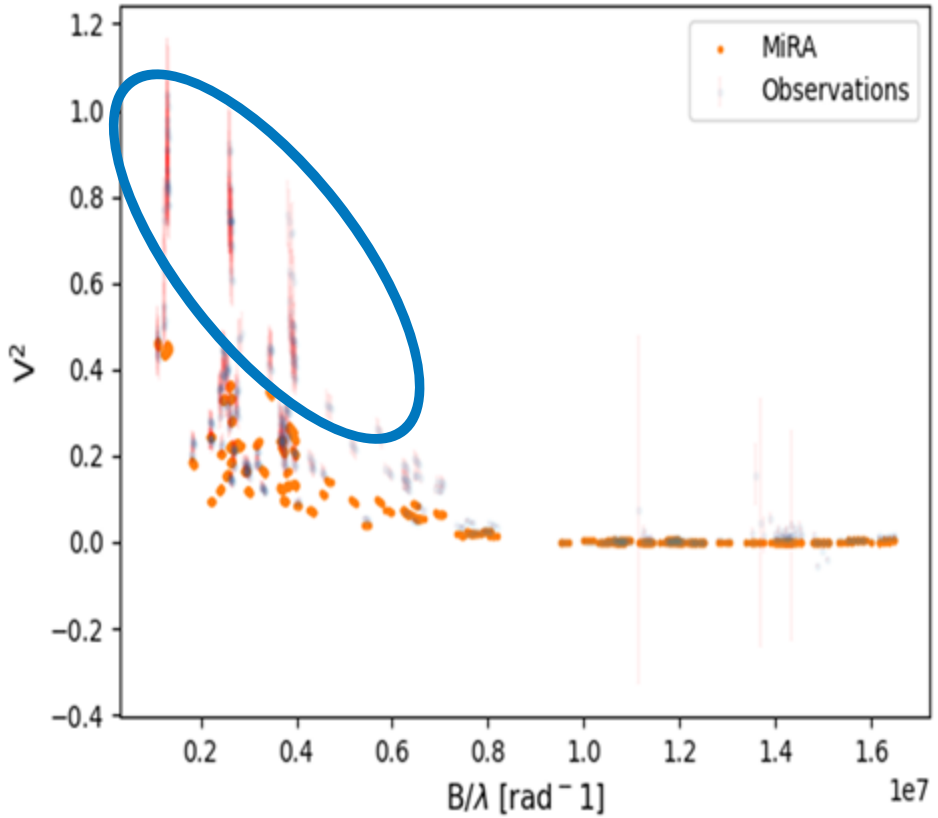


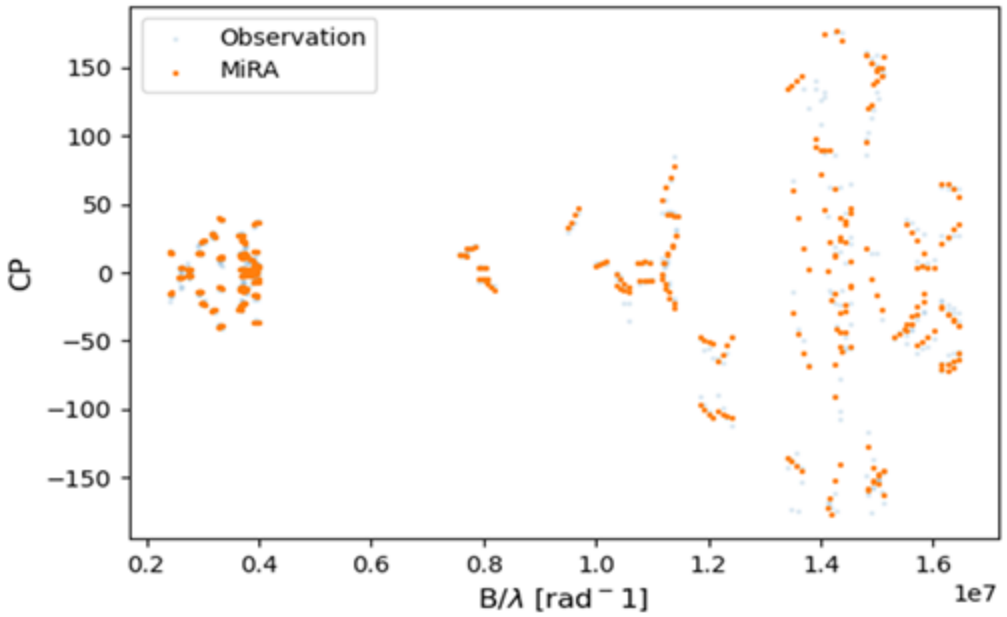




The case of pi1 Gru: N-band

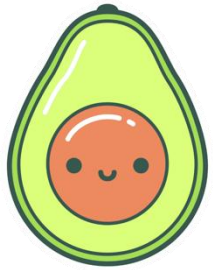
Drevon et al. prep.





Struggling to reconstruct the images, evaluating again data quality. Very complex environment expected

Thank you!



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