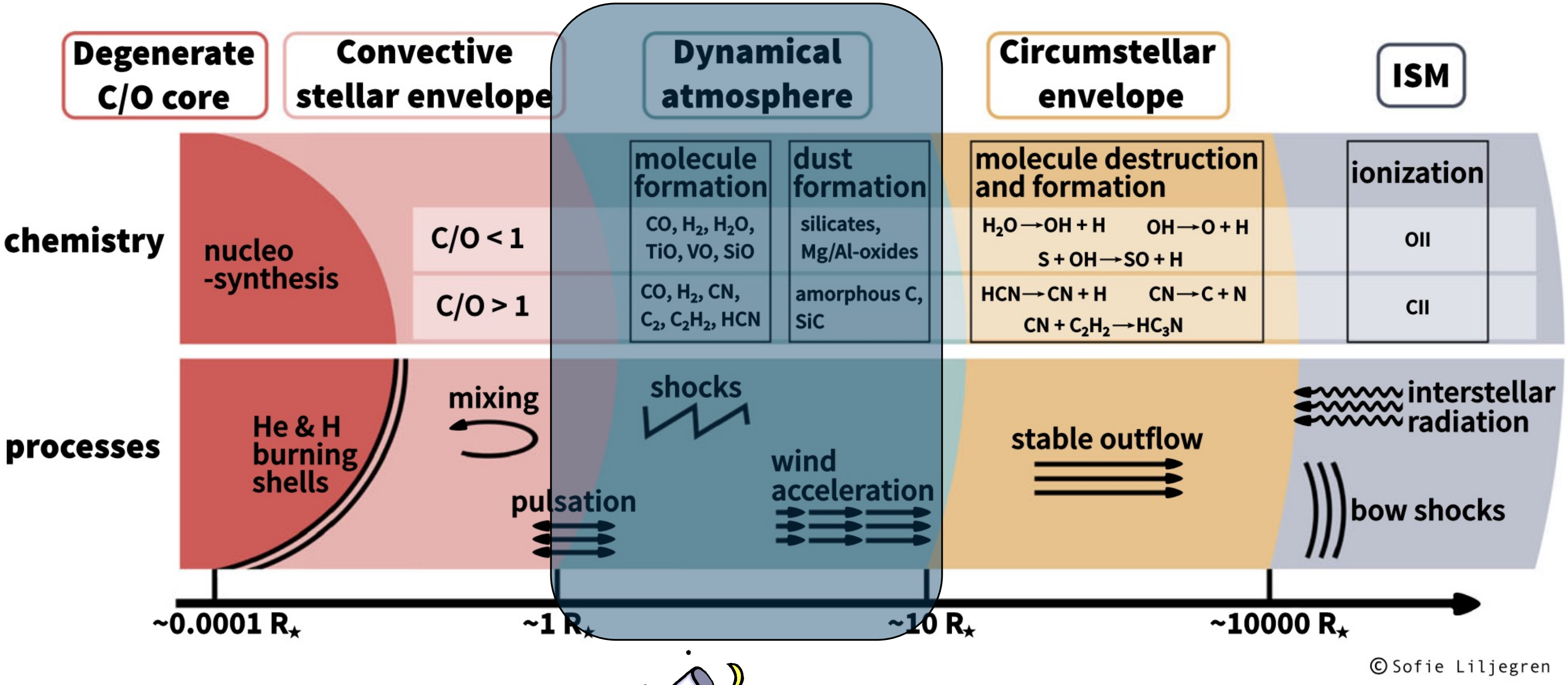
Stellar surfaces through the looking-glass

Claudia Paladini

ESO Staff Astronomer

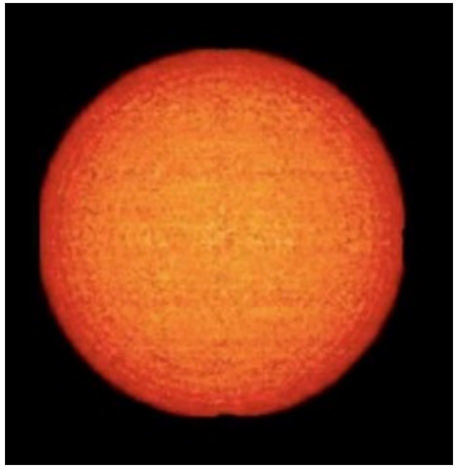
cpaladin@eso.org

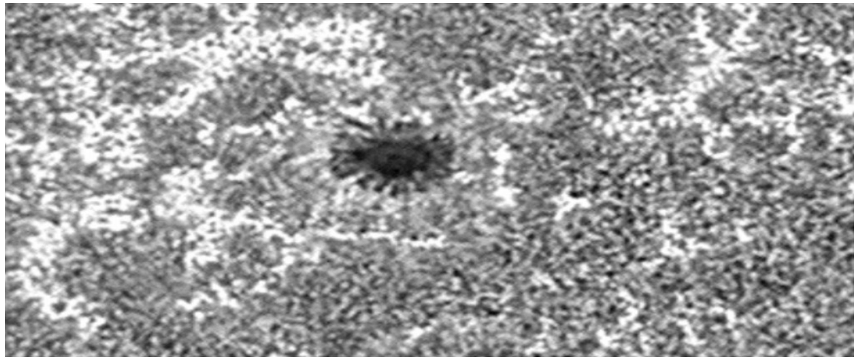
Asymptotic Giant Branch (AGB) Stars in a nutshell



The surface of our Sun

Credit: Solar simulation @B. Freytag



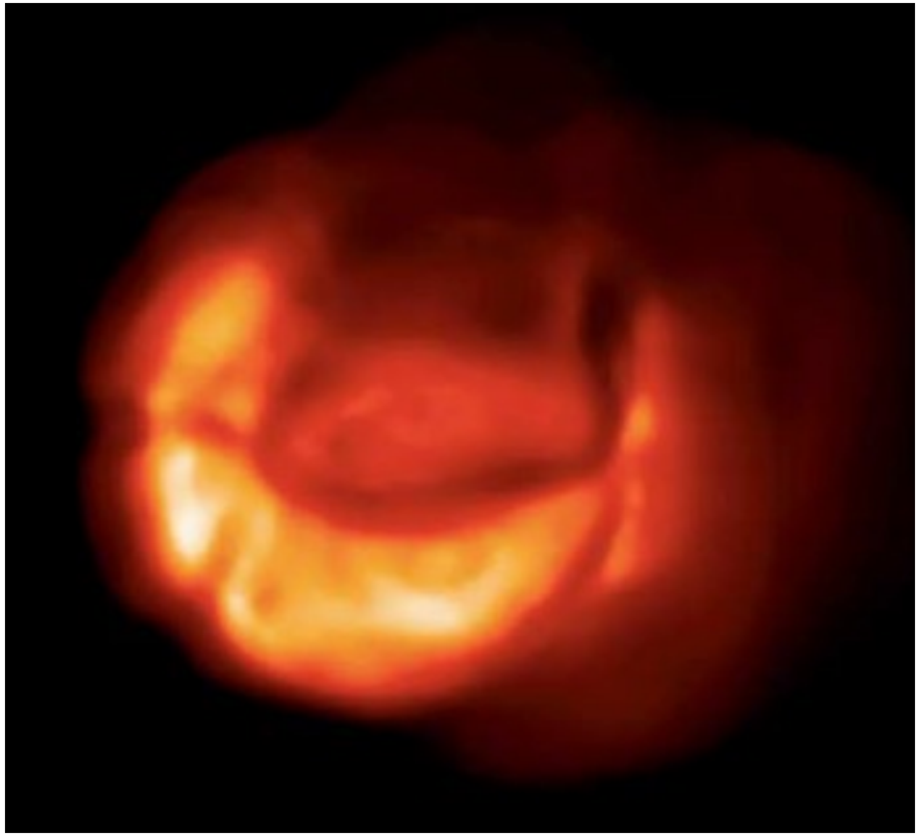


Credit: @SungrazerComets

- R ≈ 700,000 km
- Geometrically thin Photosphere: 300 km
- Convective granules: 2,000 km, few millions
- Sun spots (dark) related to magnetic field
- Corona, flares

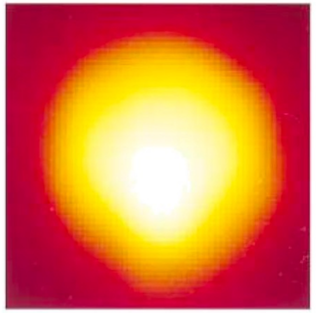
The surface of AGBs

Höfner & Freytag ++2008

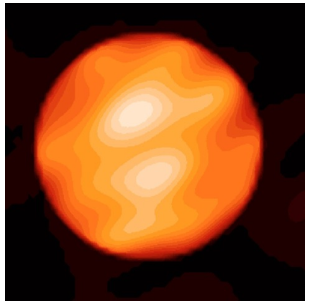


- R ≈ 10^6 km
- Diluted photosphere of the order of the star radius + extended envelope
- Convection
- Magnetic spots, chromosphere…

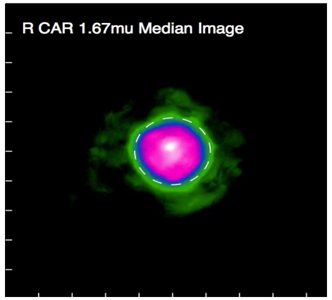
Convection on evolved stars



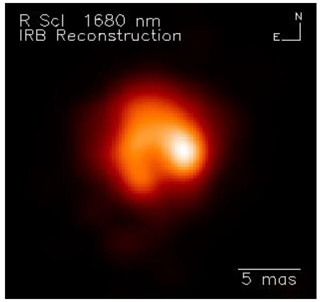
Gilliland++1996



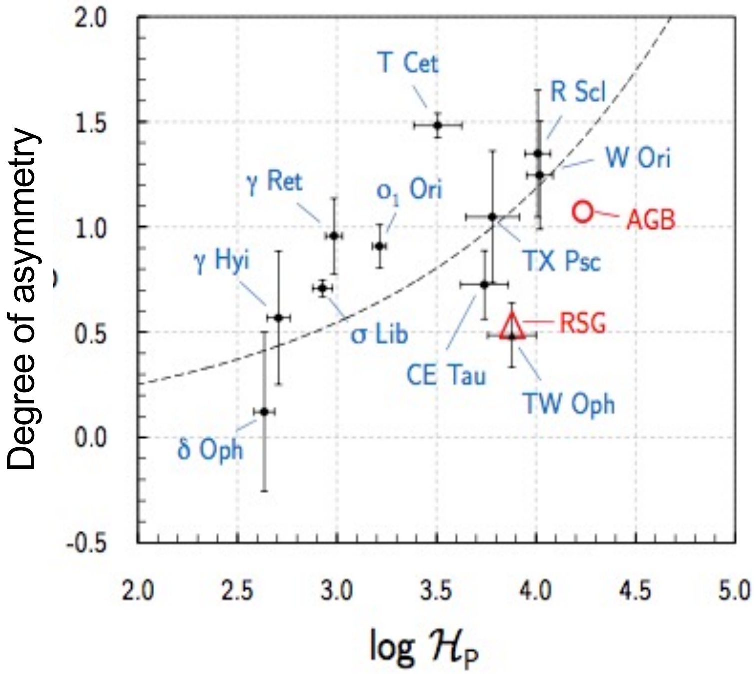
Haubois++2009



Monnier++2014



Wittkowski++2017



Cruzalebes++2015

PIONIER @VLTI

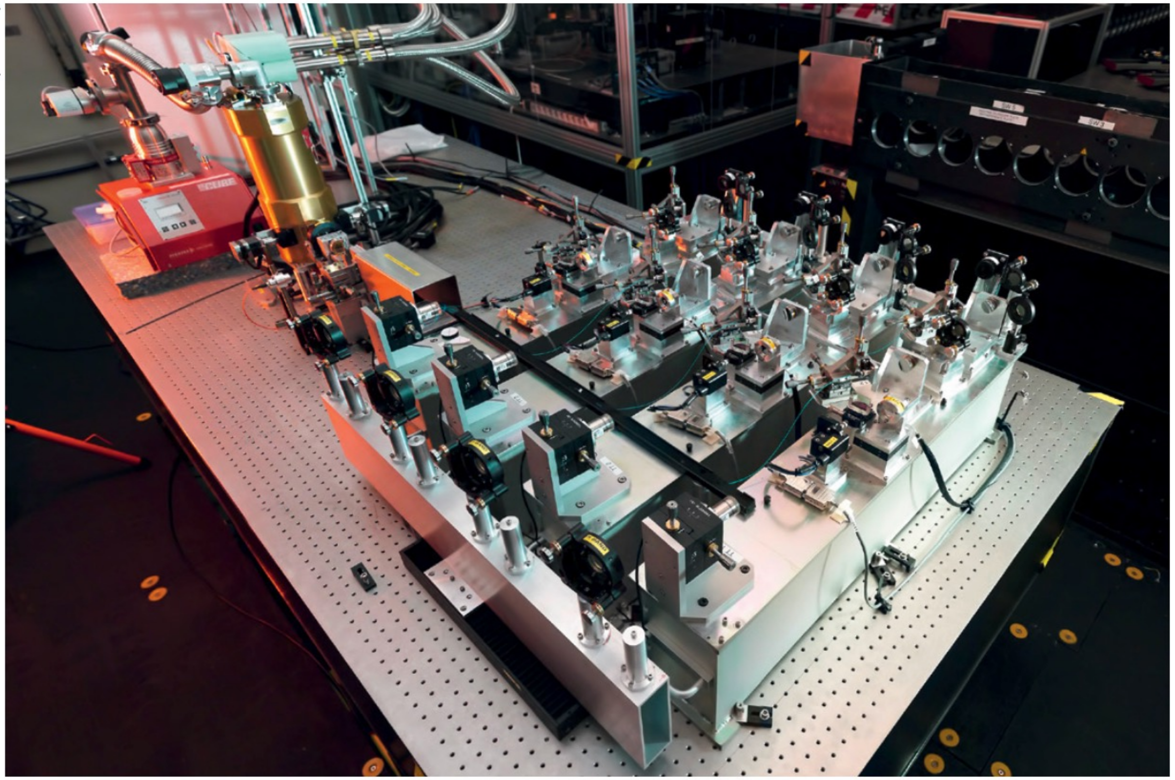
4 telescope beam combiner

H-band (~1.6 μm)

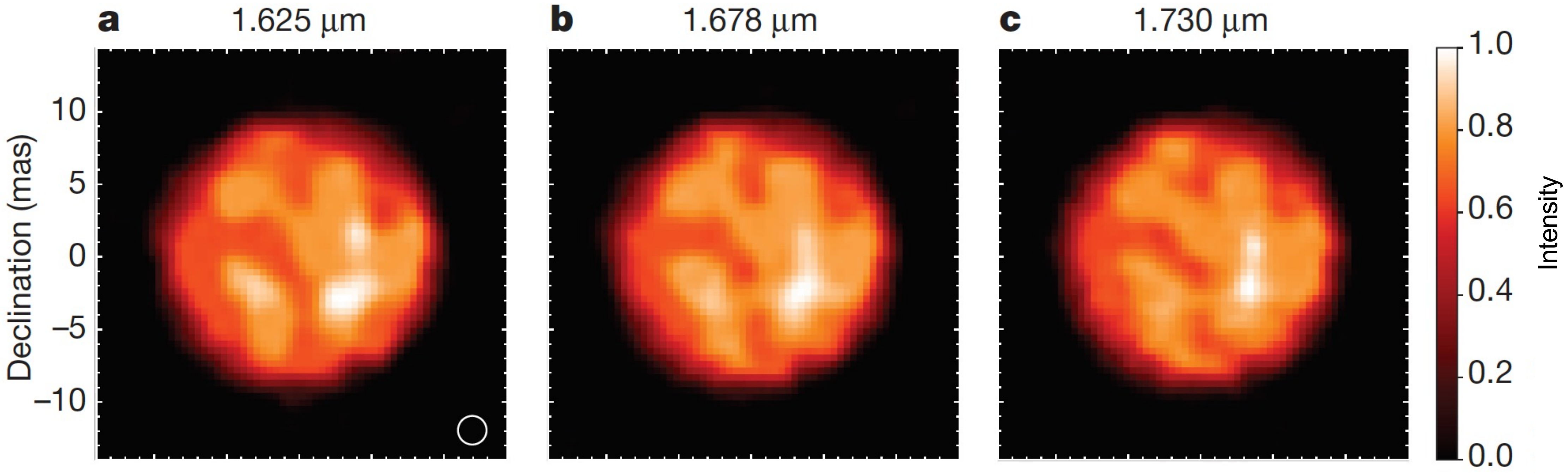
Spectral resolution R~35

1.2 mas angular resolution

ESO & B. Lazareff (LAOG)

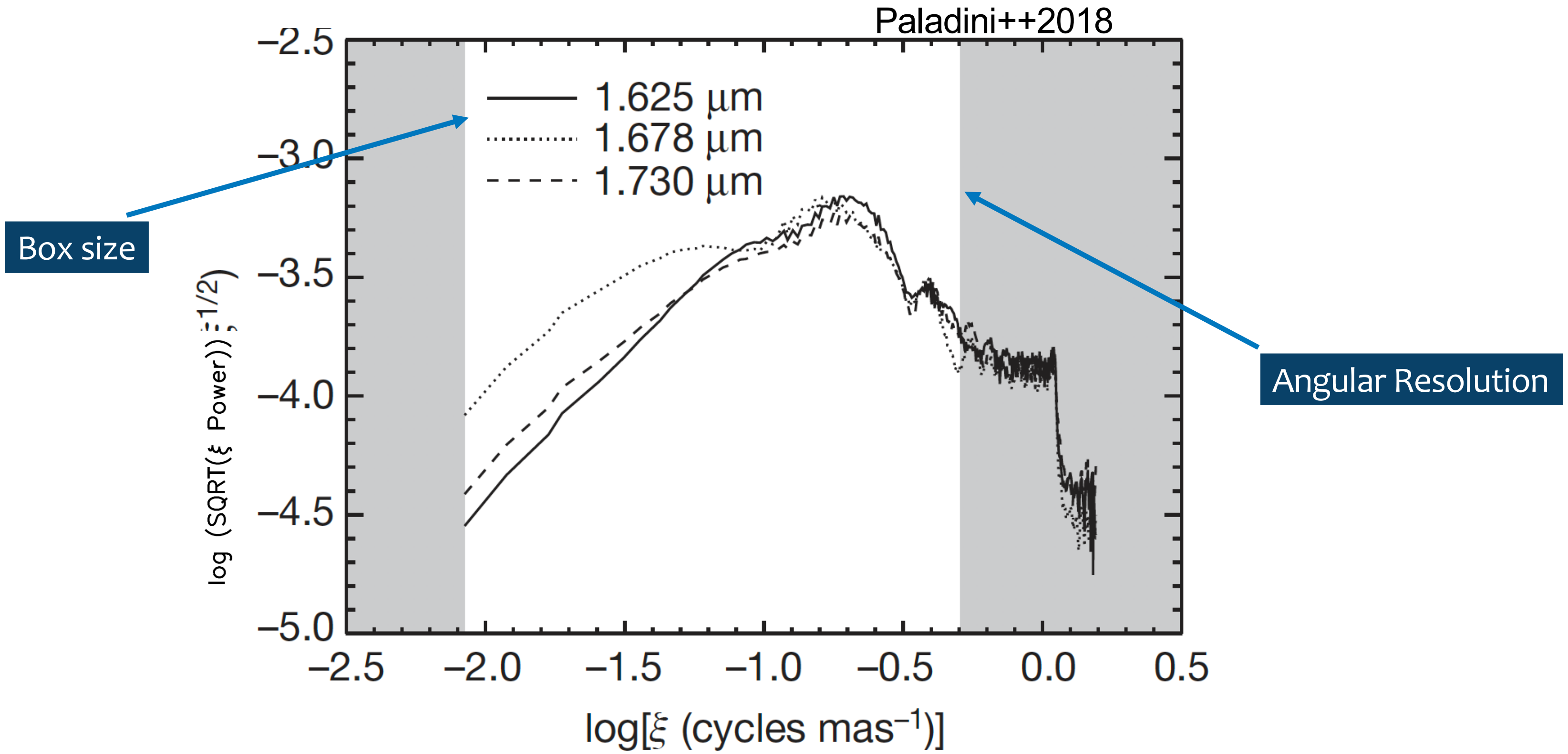


The surface of pi[1] Gru



Paladini++2018

Granulation size from power spectrum density

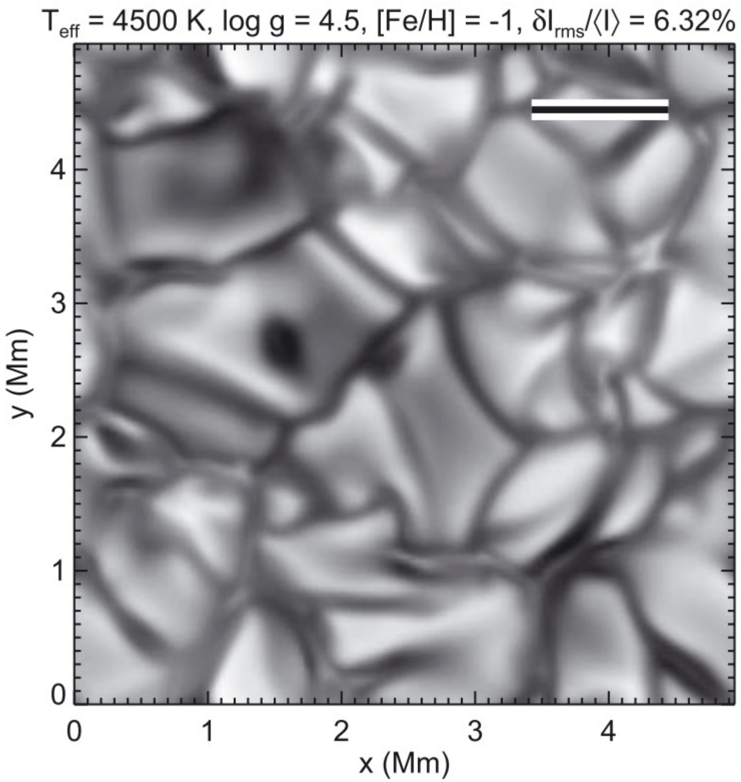


Granulation size = $5.3 \pm 0.5\ mas$ = 1.2 x 10^{11} m

Granulation size across the HR-diagram

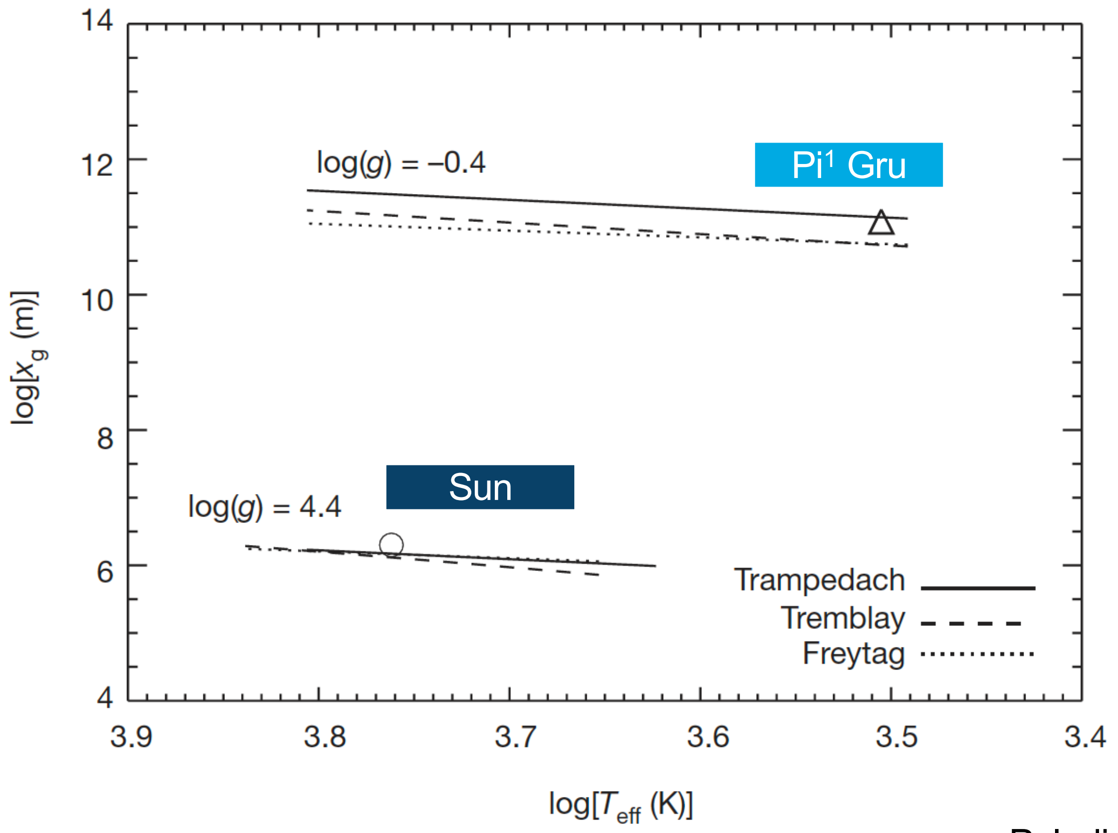
Model grids of convection NOT covering pi[1] Gru parameter space

Freytag++1997, Trampedach++2013, Tremblay++2013 provide parametric formulas relating the granulation size to the stellar parameters



Trampedach++2013

Granule scale vs. stellar parameters

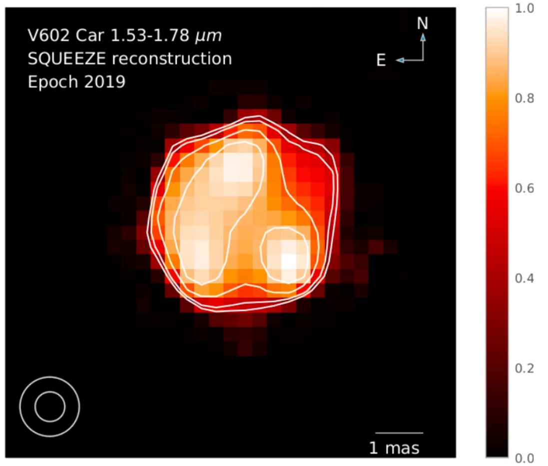


Paladini++2018

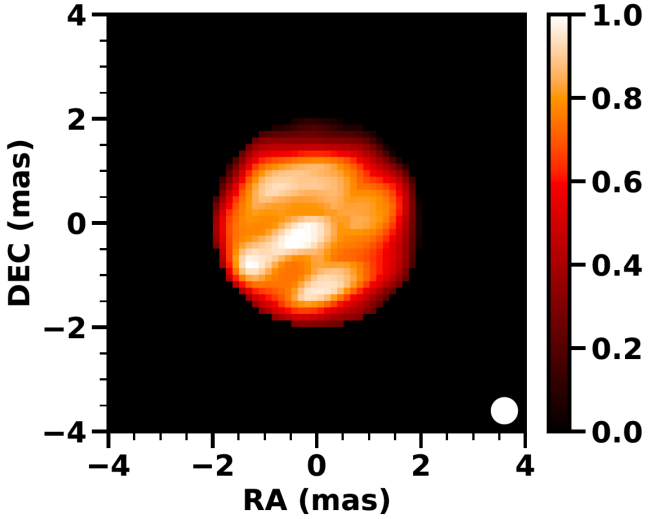
The case of Red Supergiants

- Red Supergiants do not fit the model predictions
  - Size measured are larger than predictions by factor of 5

- Climent+2020:
  - *What we observe are merge of convective granules or "pressure fluctuation due to instationary convection"…*

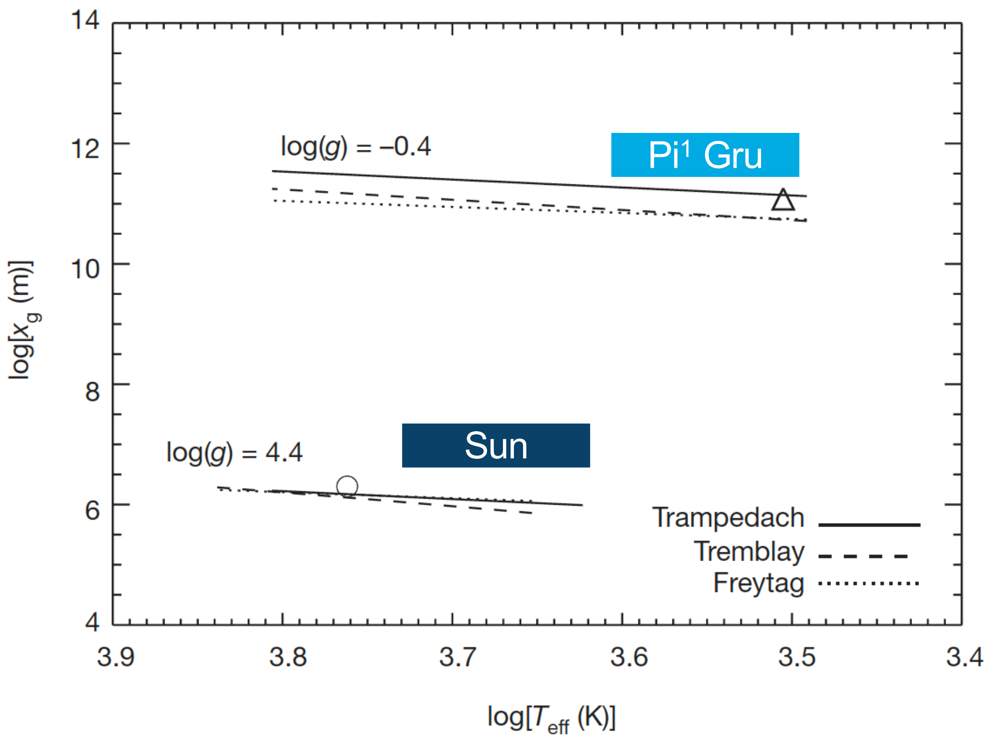


Climent++2020



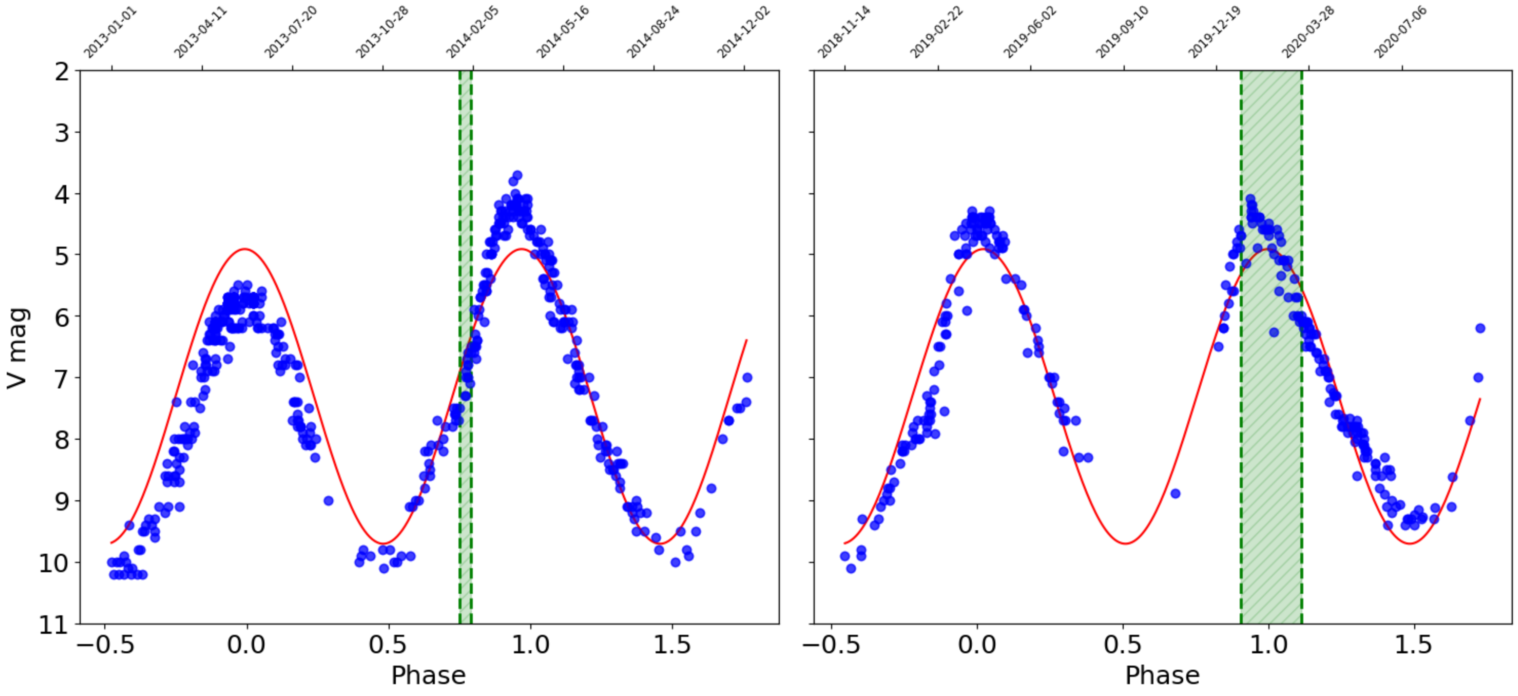
Norris++2021

AGB nice fit



RSG bad fit

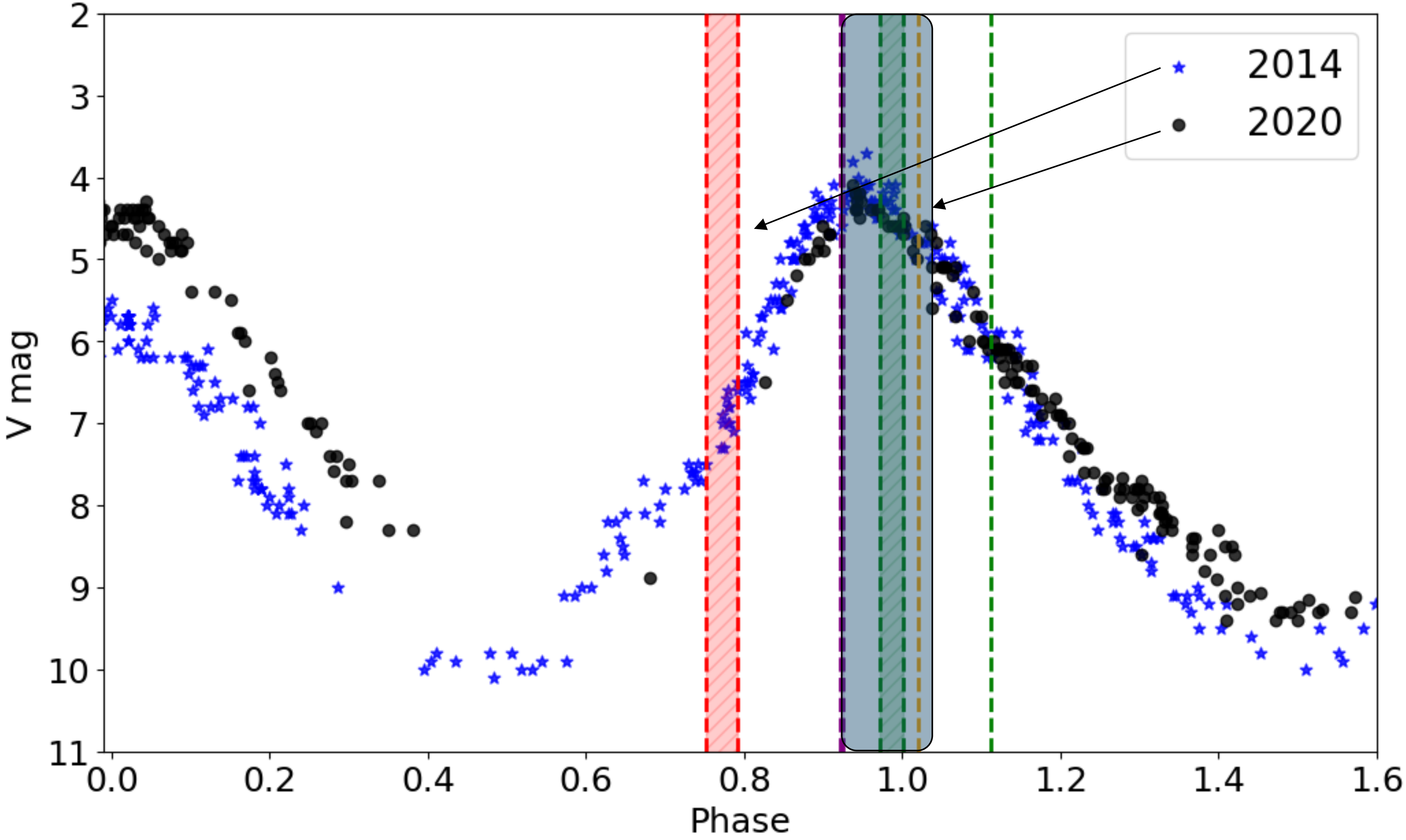
The case of R Car
(Rosales-Guzman et al. 2024)



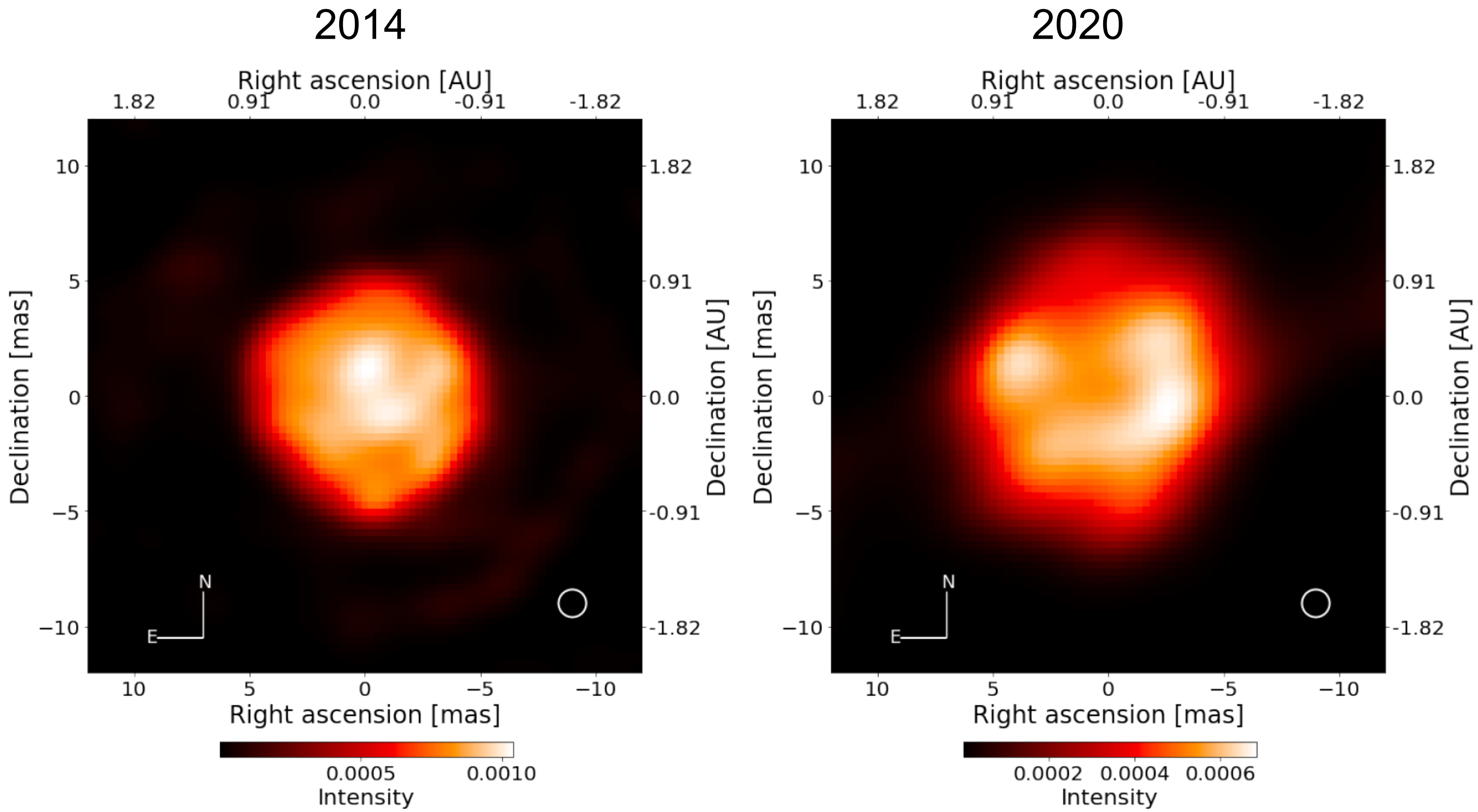
- AGB Mira variable
- Period 314 days
- Temperature 2800 K
- ~1 Solar mass

PIONIER data in 2014 & 2020

Variability



PIONIER images
(Rosales-Guzman et al. 2024)



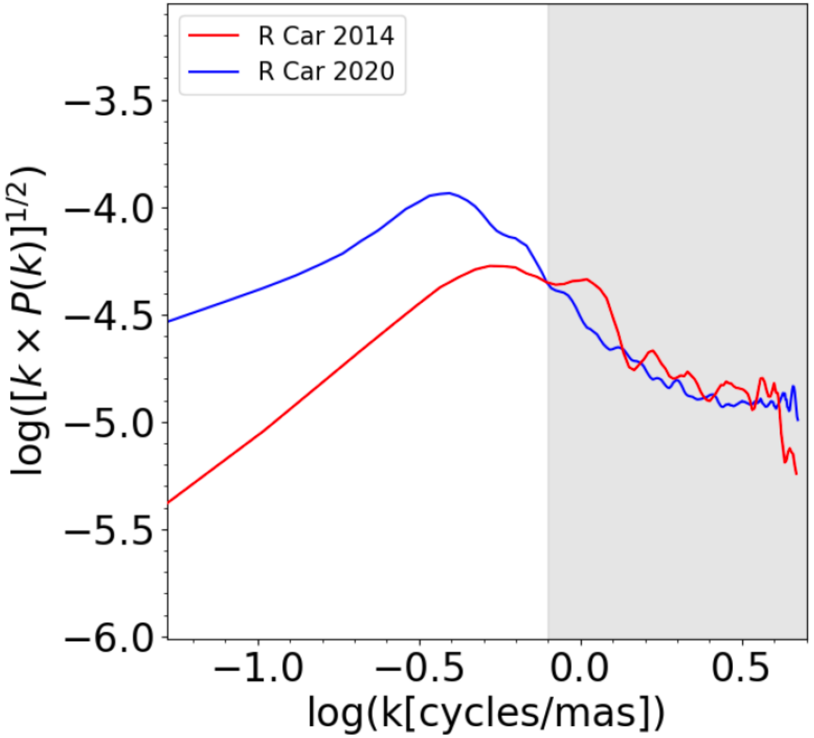
Star is smaller pre-maximum phase (2014)
and larger after the maximum (2020) confirming models

Power spectrum analysis
(Rosales-Guzman et al. 2024)

The size of the structures on the surface follow the diameter change:

- Patches are larger when the star is larger

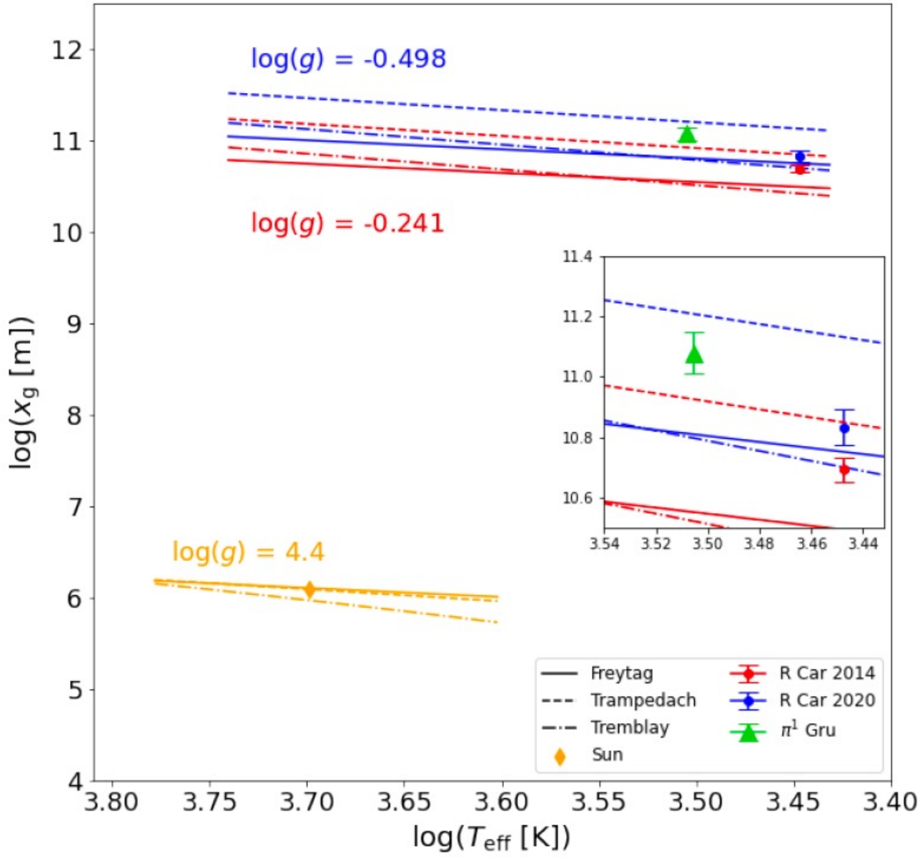
We are entering a new dimension in the studies of stellar variability



Comparison with literature
(Rosales-Guzman et al. 2024)

Model	2014 $\psi \sim 0.78$	2020 $\psi \sim 1.01$
$\log(x_{g,\mathrm{Freytag}})$	10.49	10.75
$\log(x_{g,\mathrm{Trampedach}})$	10.85	11.15
$\log(x_{g,\mathrm{Tremblay}})$	10.42	10.70
$\log(x_{g,\mathrm{PSD}})$	10.69 ± 0.04	10.83 ± 0.06

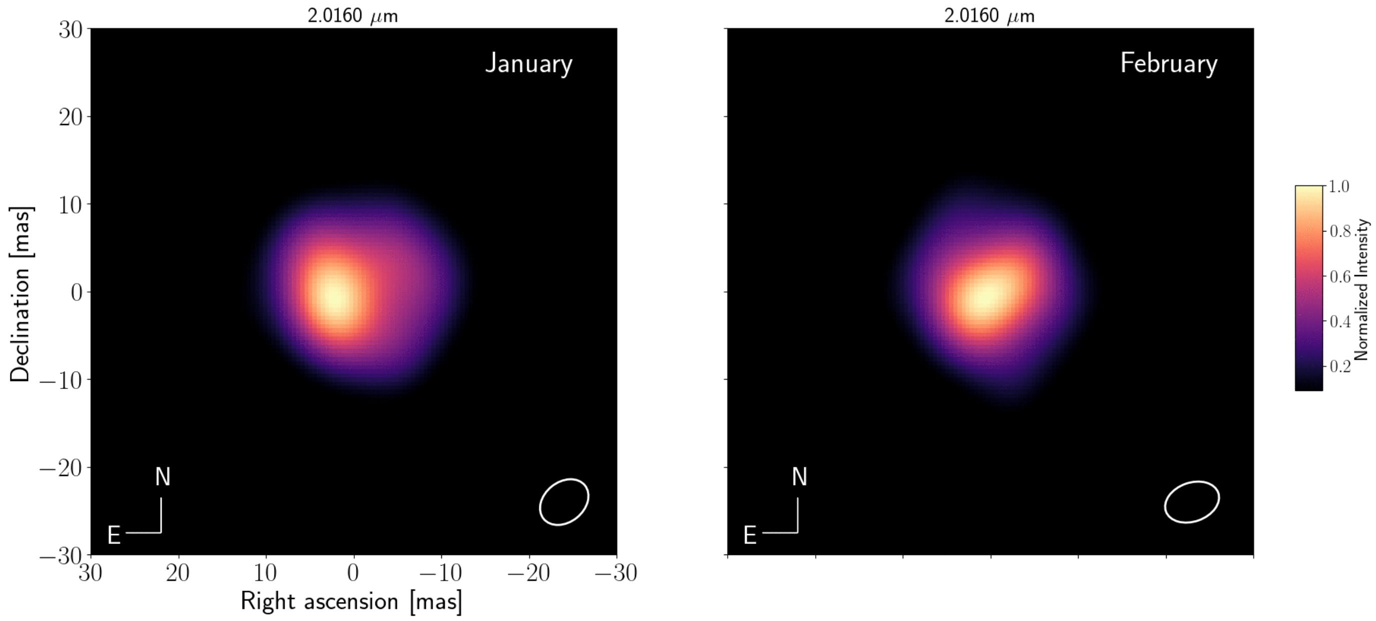
R Car results are along the same line of pi1 Gru



Take home messages & food for thought

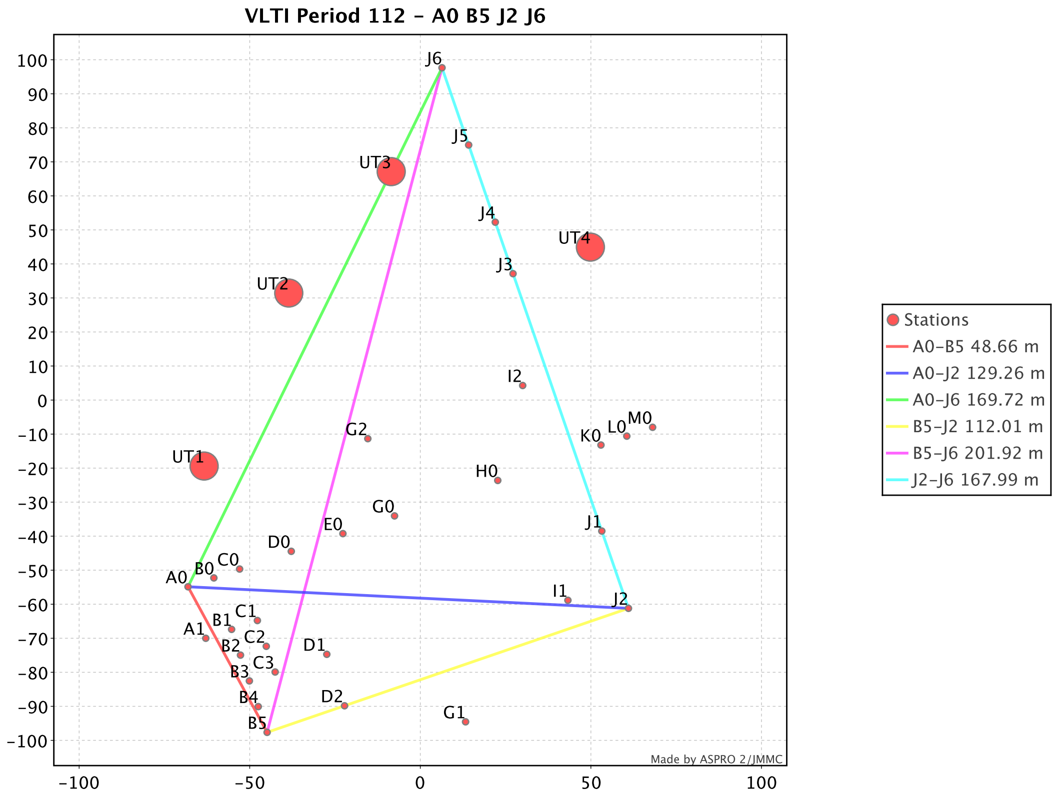
- Current interferometric facilities allow resolving stellar surfaces and structures on it
- Size, contrast, time-scale of the structures are derived
- In AGB stars size of surface structures follow increase of size of diameter within the pulsation phase
- What are exactly those structures? Convective granules or not?
- Why AGBs fit the models while RSG don't?
  - Spectral resolution?
  - By chance?
  - Physics?

Need for higher spectral resolution



RCar @GRAVITY Rosales-Guzman, A. et al. 2023 A&A
High spectral resolution will allow providing velocity maps

Higher angular resolution



VLTI opened 200 meters baseline in October 2023

~ 0.8 mas @ 1.6 micron; ~ 1 mas @2 micron

Community speaking about km baseline in the next decade

2 more AGBs being currently analysed by a master student L. Hamel

To be continued…

Thank you!

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