Optical interferometry to probe the photosphere of red supergiant stars

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&
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and several others.

KU LEUVEN

Bcool meeting
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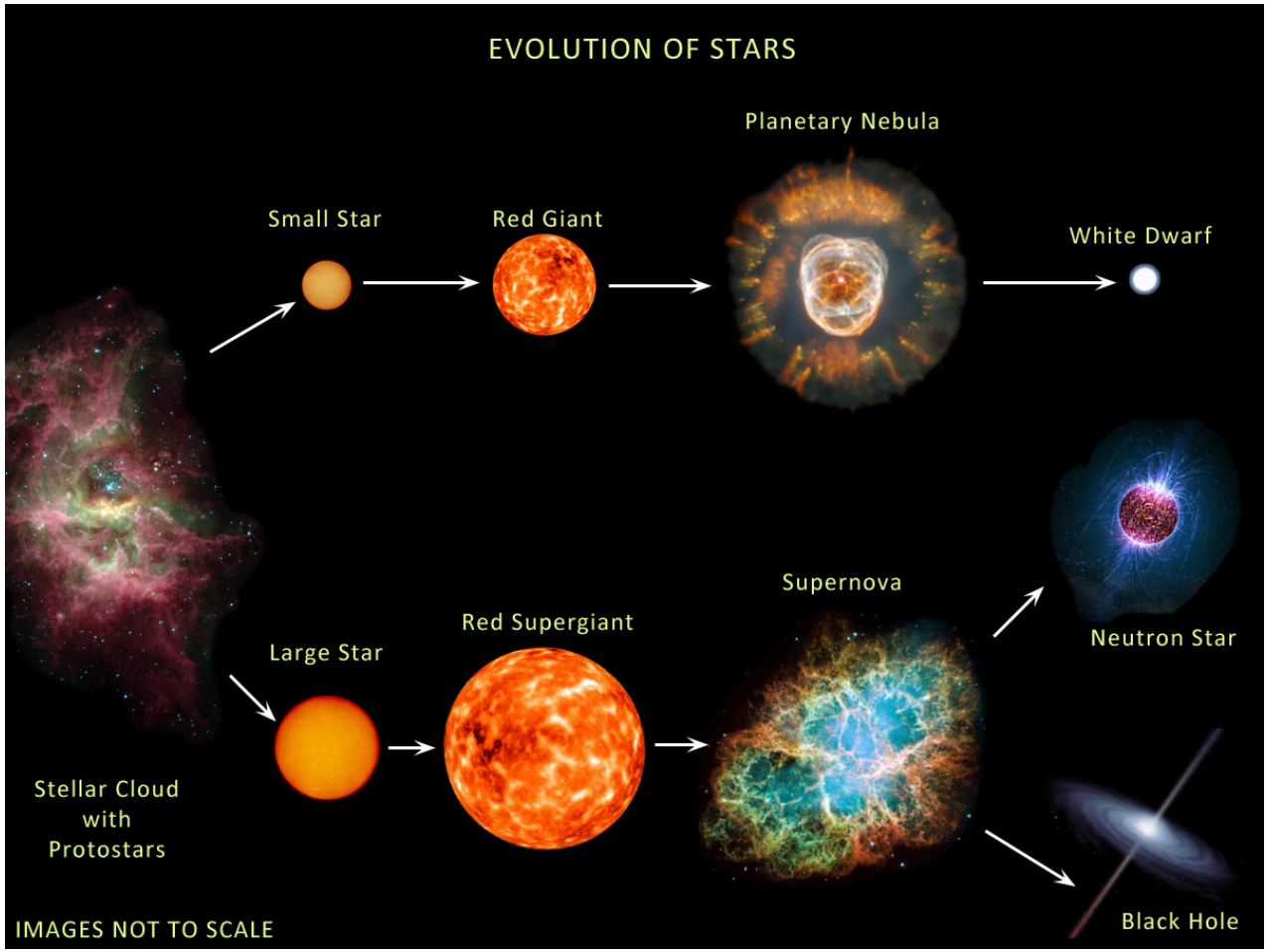
Stellar evolution

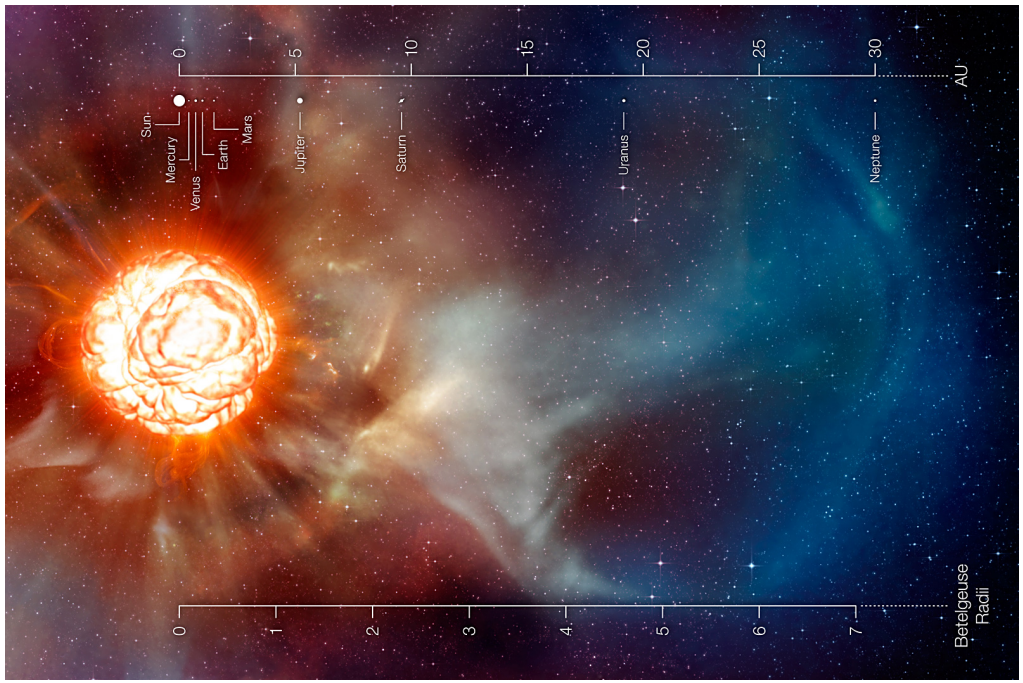


- Asymptotic Giant Branch stars : progenitor $\lesssim 10\ M_\odot$
- Red supergiant stars : progenitor $\gtrsim 10\ M_\odot$

Trigerring the RSG mass loss

- Physical process remains unknown (no flares, no large pulsations)
- Josselin & Plez (2007) suggested a convection triggered mass loss
- Auriere et al. (2010) observed magnetic field $\sim$ 1 G

  + Airapetian et al. (2000): model Alfvén-wave triggered outflow



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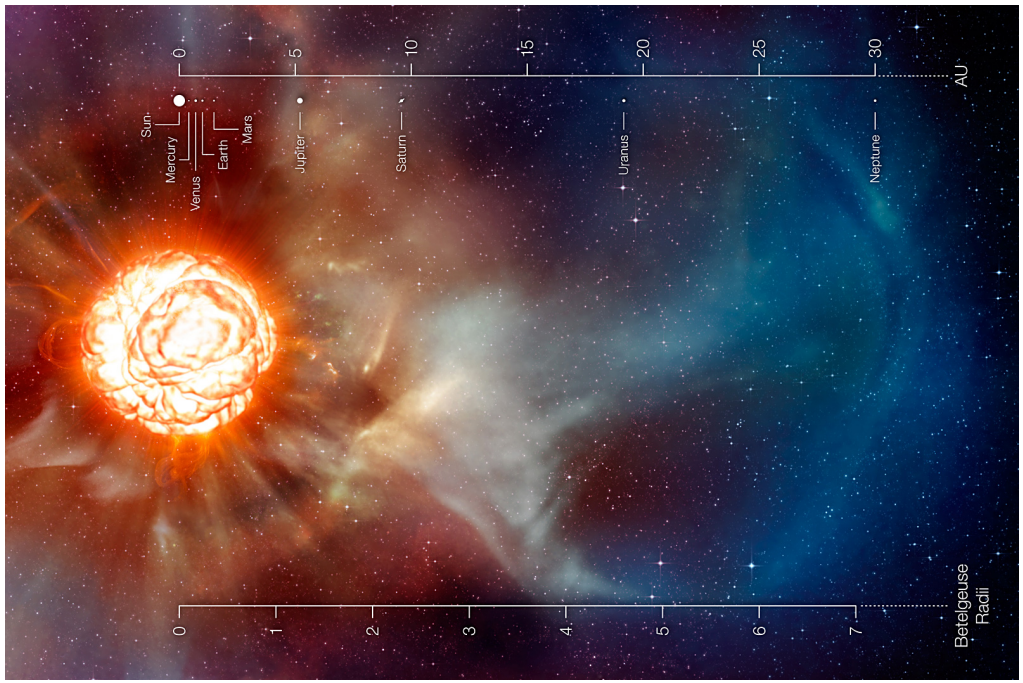
$\rightarrow$ Study of the photosphere $+$ CSE



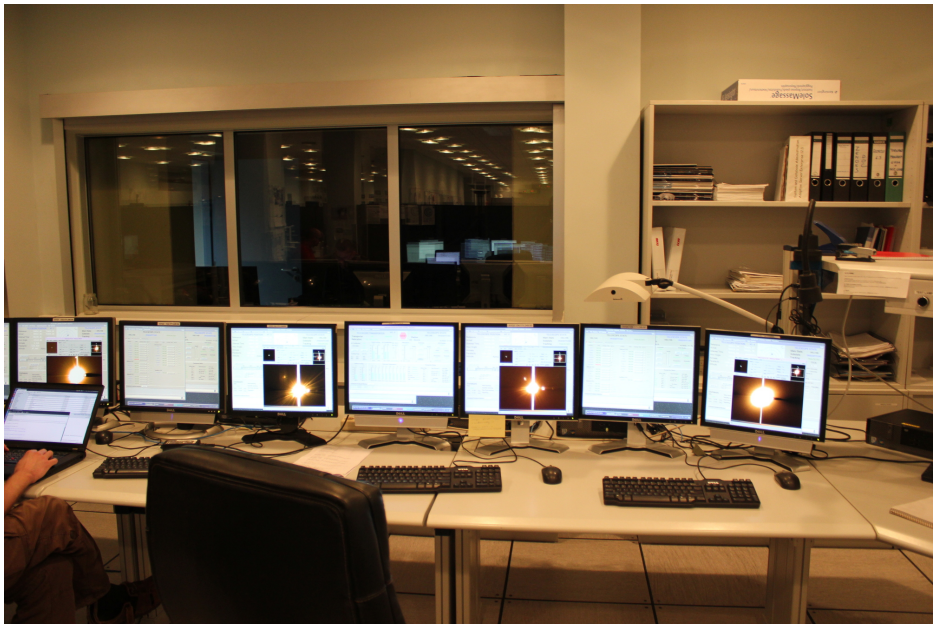
Spatial scales

(P. Kervella)

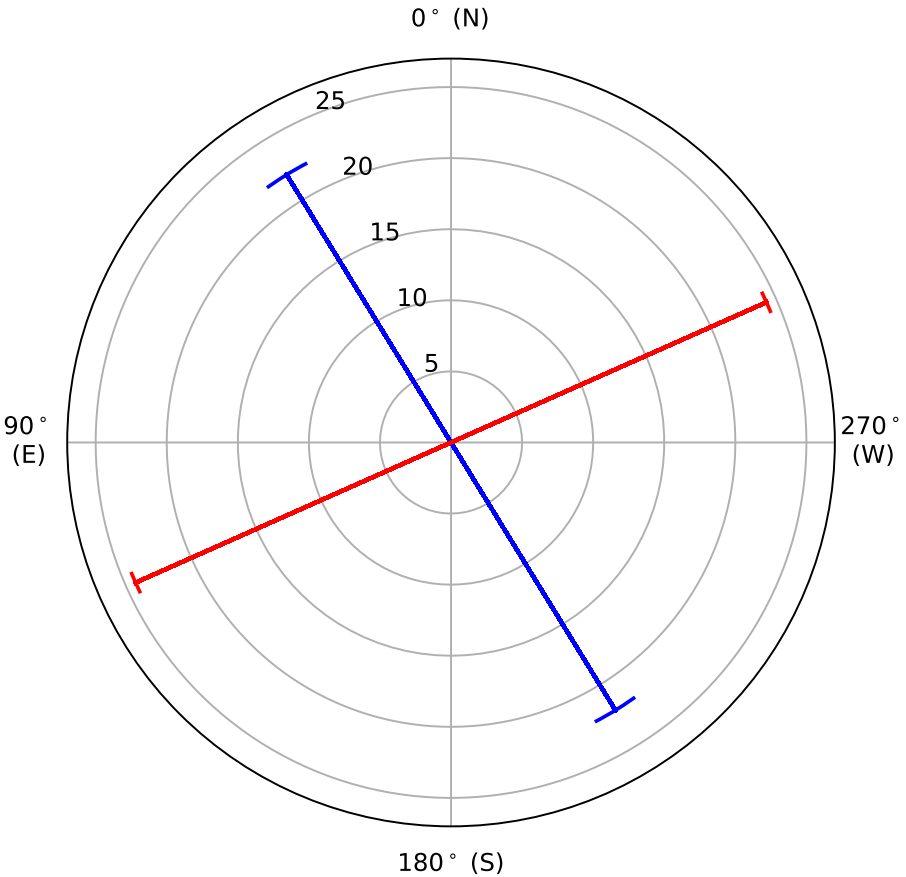
PIONIER monitoring of Betelgeuse (α Ori)

- VLTI/PIONIER observations (4 telescopes, H band, low spectral resolution, R = 40)
- 4 epochs of monitoring: Jan. 2012, Feb. 2013, Jan. 2014 and Nov. 2014
- Only the compact array configuration (baseline length $\in [11; 36\ \mathrm{m}]$)

$\Rightarrow$ Montargès et al. (2016), *A&A*, 588, A130



Betelgeuse@PIONIER: angular diameter (2013)



- Limb-darkened disk fit:

  44.21 vs 48.56 mas

  $\Rightarrow$ 10% difference !

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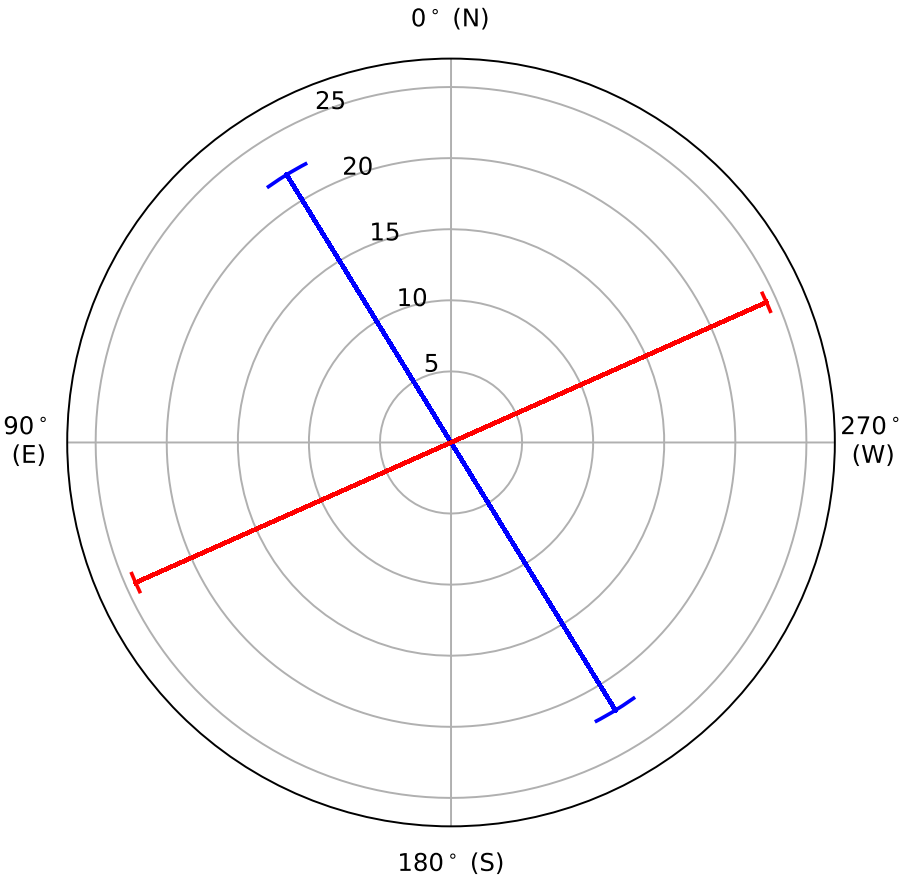

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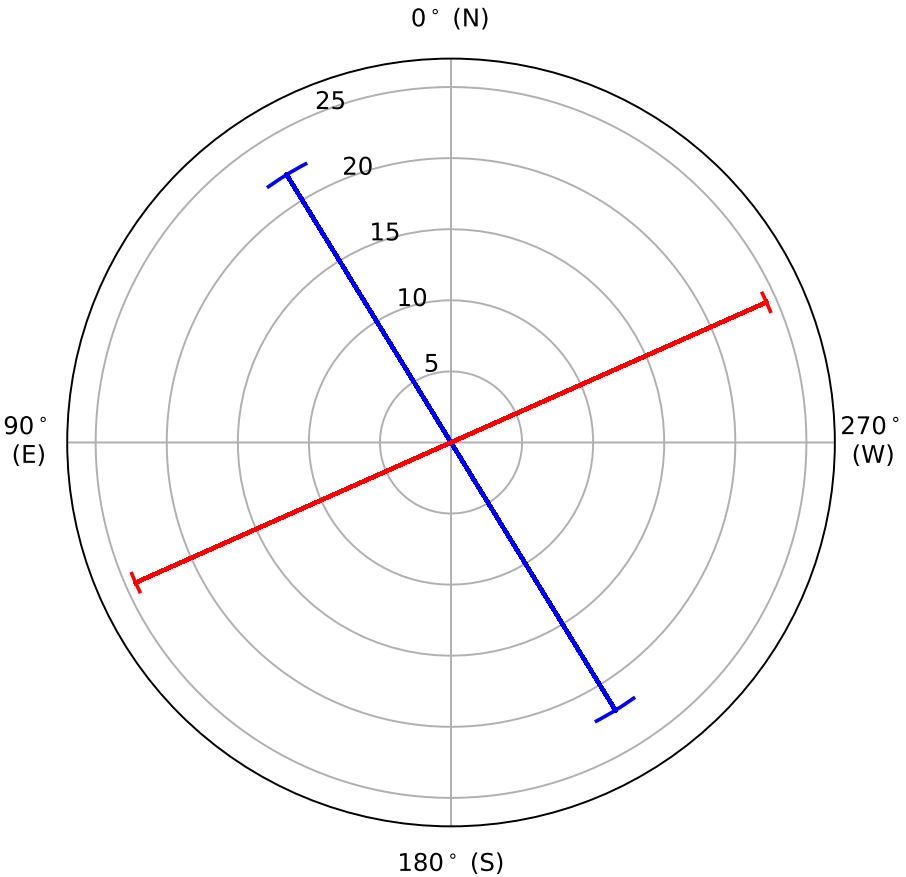

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- Consistent between the 4 epochs (3 different features to avoid detector saturation)

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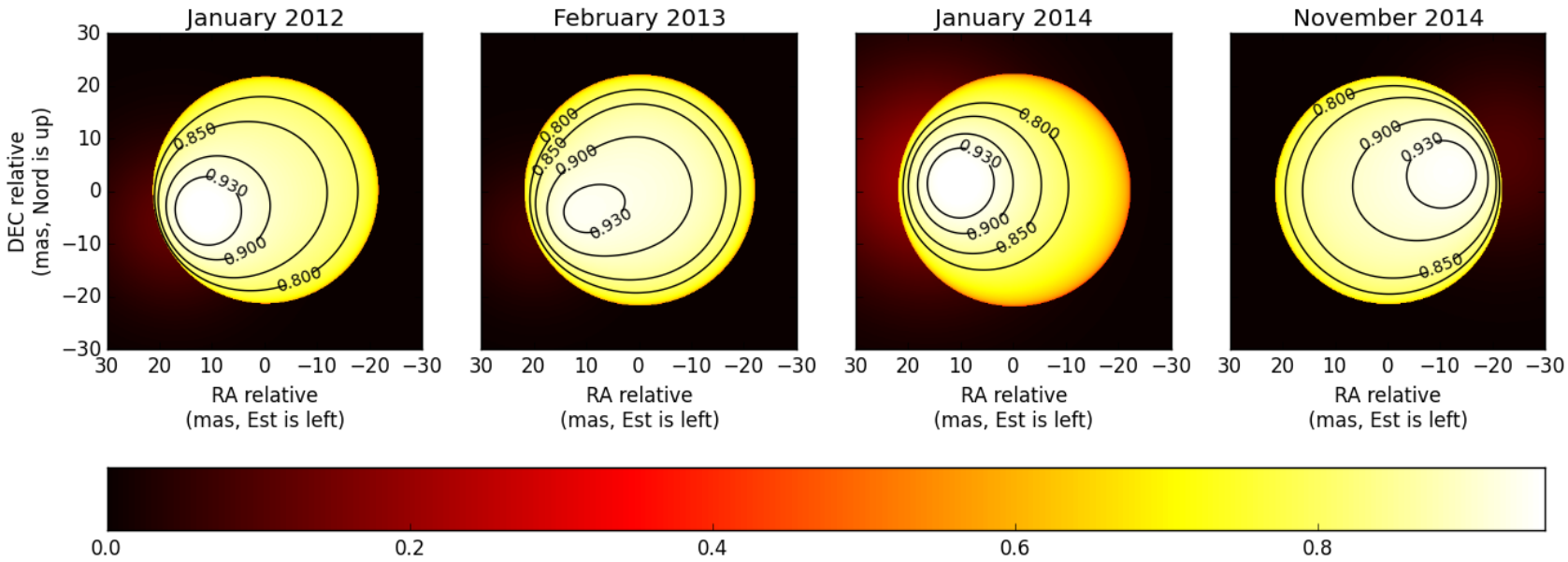
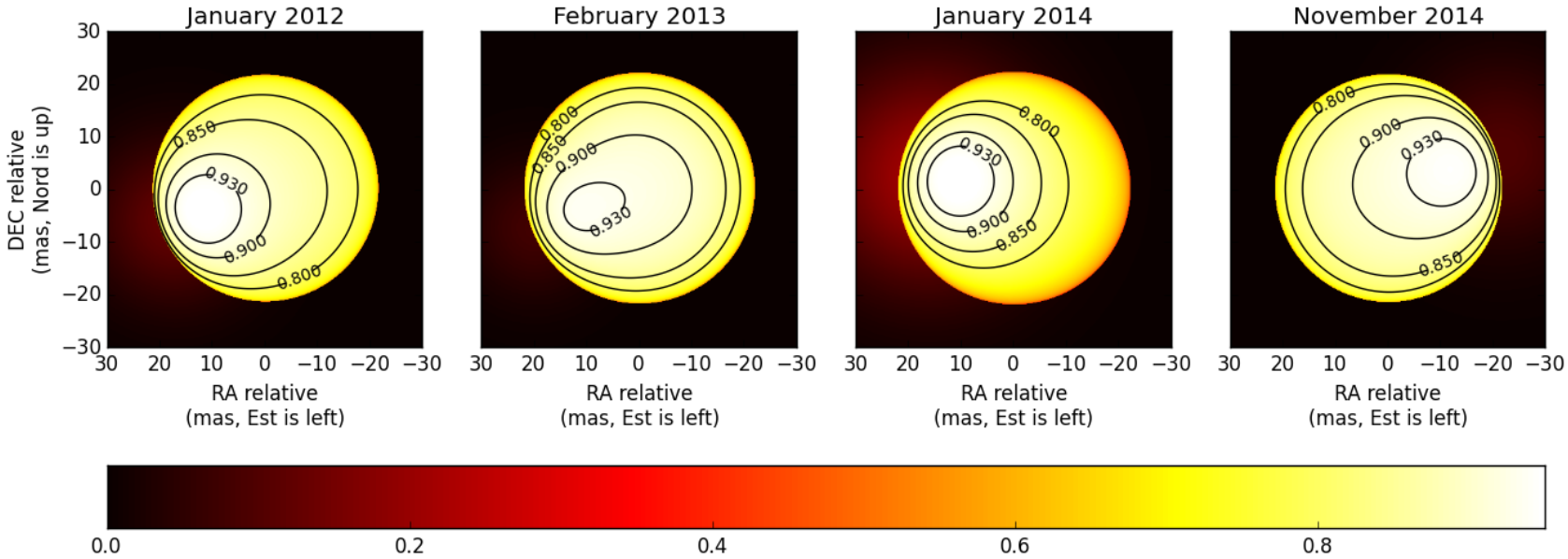
- Chiavassa et al. (2009, 2010) showed that convection can bias angular diameter measurements
- LDD disk + bright spot : good agreement + angular diameter consistent with literature ($\sim$ 43 mas)



Betelgeuse@PIONIER: LDD model + gaussian bright spot

- Consistent on the 4 epochs
- ⚠ Photocenter displacement up to 2 mas ($\pi \sim 6$ mas)
- Spots already observed on Betelgeuse (see Haubois et al. 2009, Ravi et al. 2011, Ohnaka et al. 2011)



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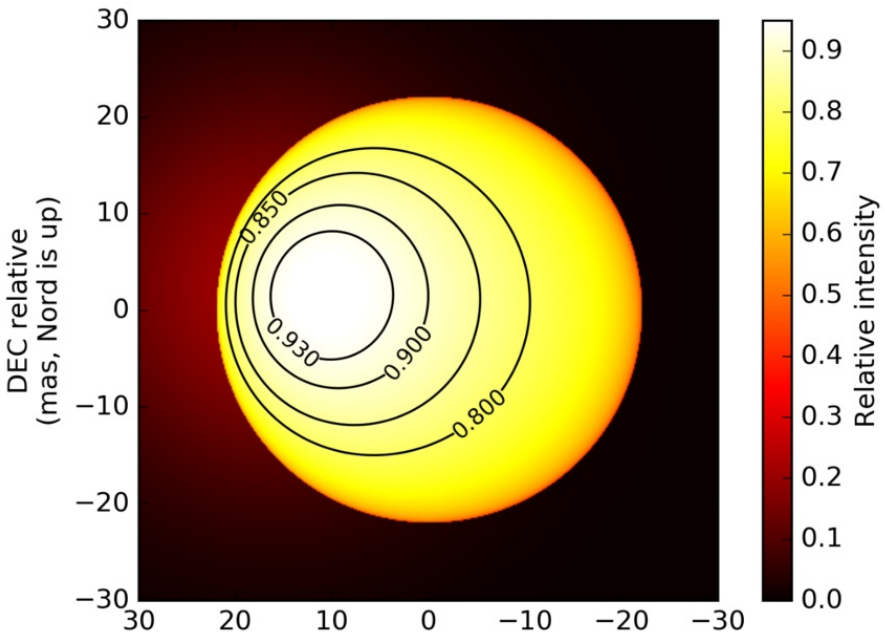
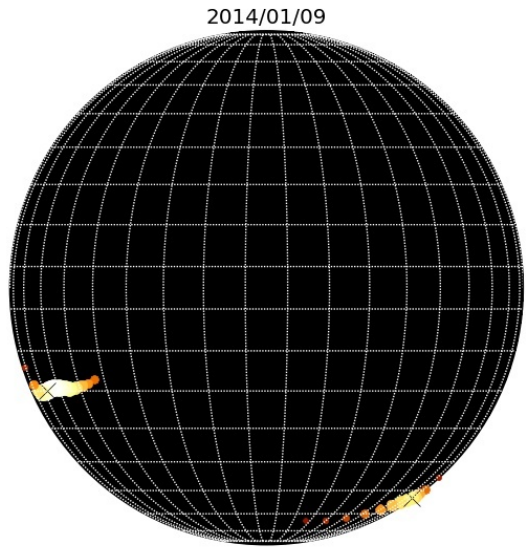
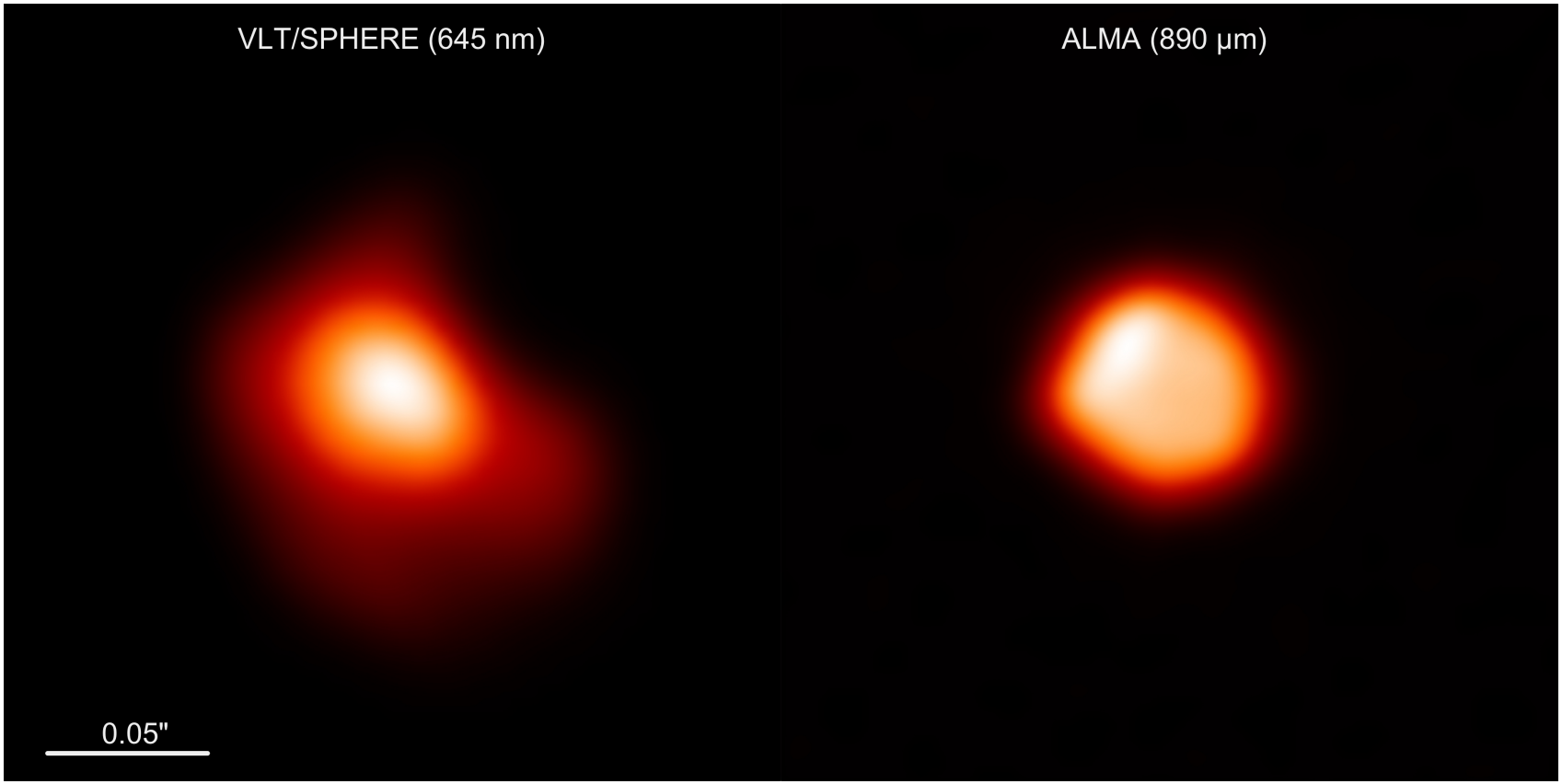
- Consistent with spectro-polarimetric observations at TBL/NARVAL (Aurière et al. 2016)





Betelgeuse with VLT/SPHERE and ALMA

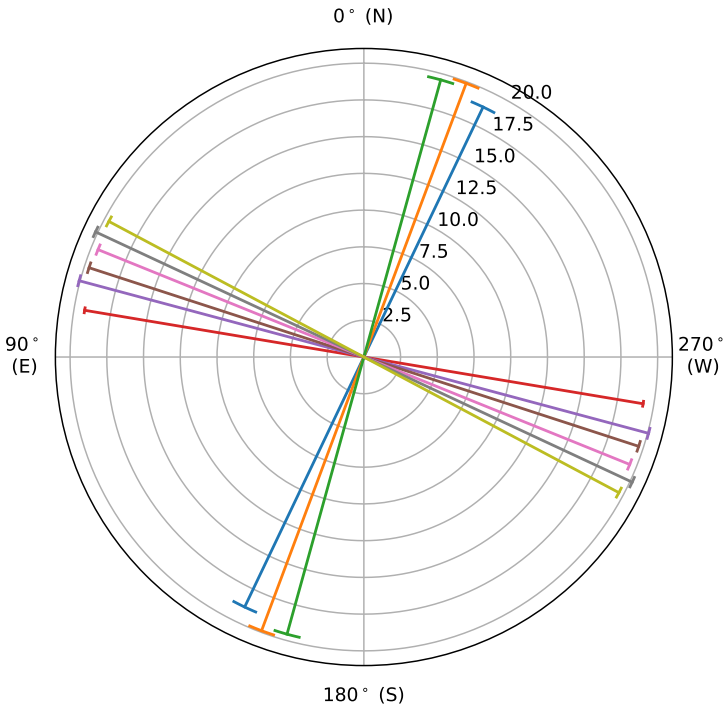


Kervella et al. 2016 & O'Gorman et al. 2017

Antares@PIONIER

- VLTI/PIONIER observations (4 telescopes, H band, low spectral resolution, R = 40)
- 3 different configurations (baseline lengths : 11-150 m)

$\Rightarrow$ Montargès et al. 2017, *A&A*, in press.



LDD diameters (at 1.61 μm):
37.70-39.03 mas
$\Rightarrow$ 4% difference

AND does not fit the closure phases !

Antares@PIONIER: modeling

⚠ Weak signal compared to Betelgeuse → small spots ?

⚠ Angular resolution ∼ 1/16th of the stellar diameter !

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⇒ Modeling using random distribution of spots with a fixed size !

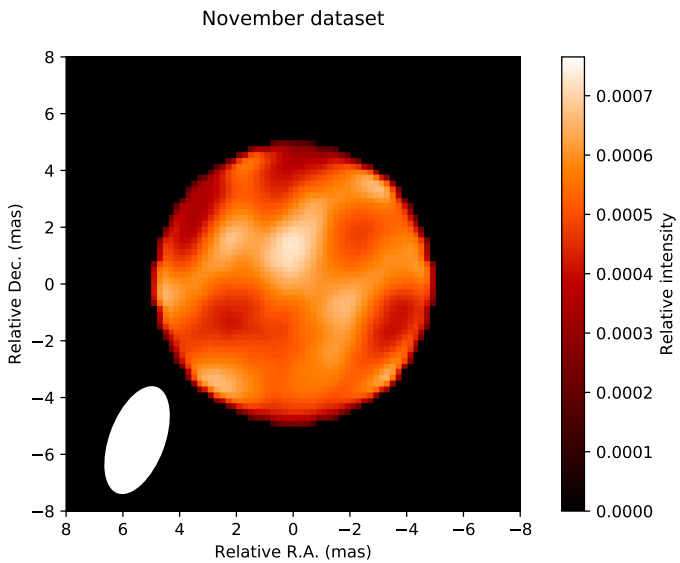
Best match:

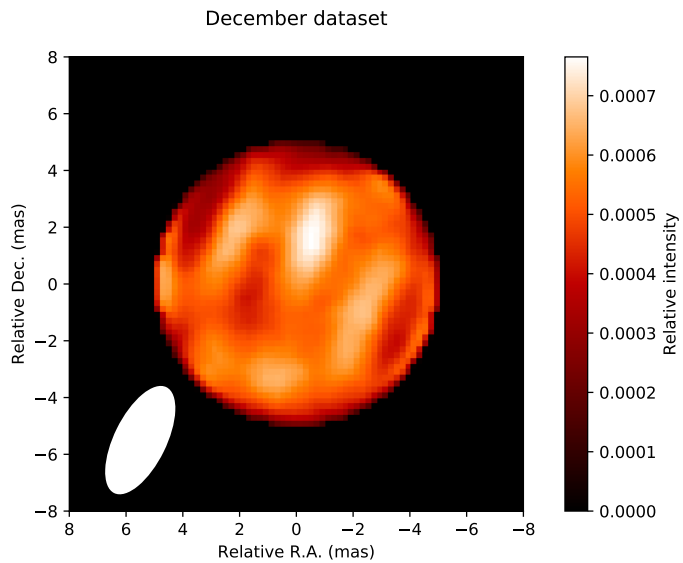
- Gaussian spot distributions with a FWHM of 17 and 2 mas (not resolved !)
- LDD diameter: 37.89 ± 0.10 mas at 1.61 μm
- $\chi^2(V^2 + CP)$ as low as 28 (627 for best LDD alone)

CE Tau@PIONIER : images

- VLTI/PIONIER DDT program (4 telescopes, H band, low spectral resolution, R = 40)
- 2 configurations (baseline lengths : 7-97 m)

⇒ Montargès et al., *A&A*, subm.





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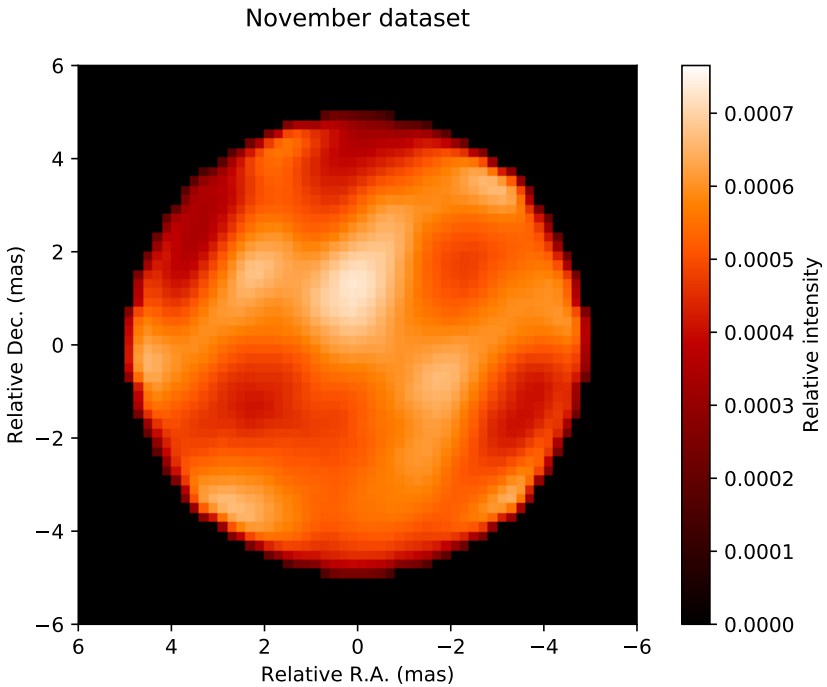
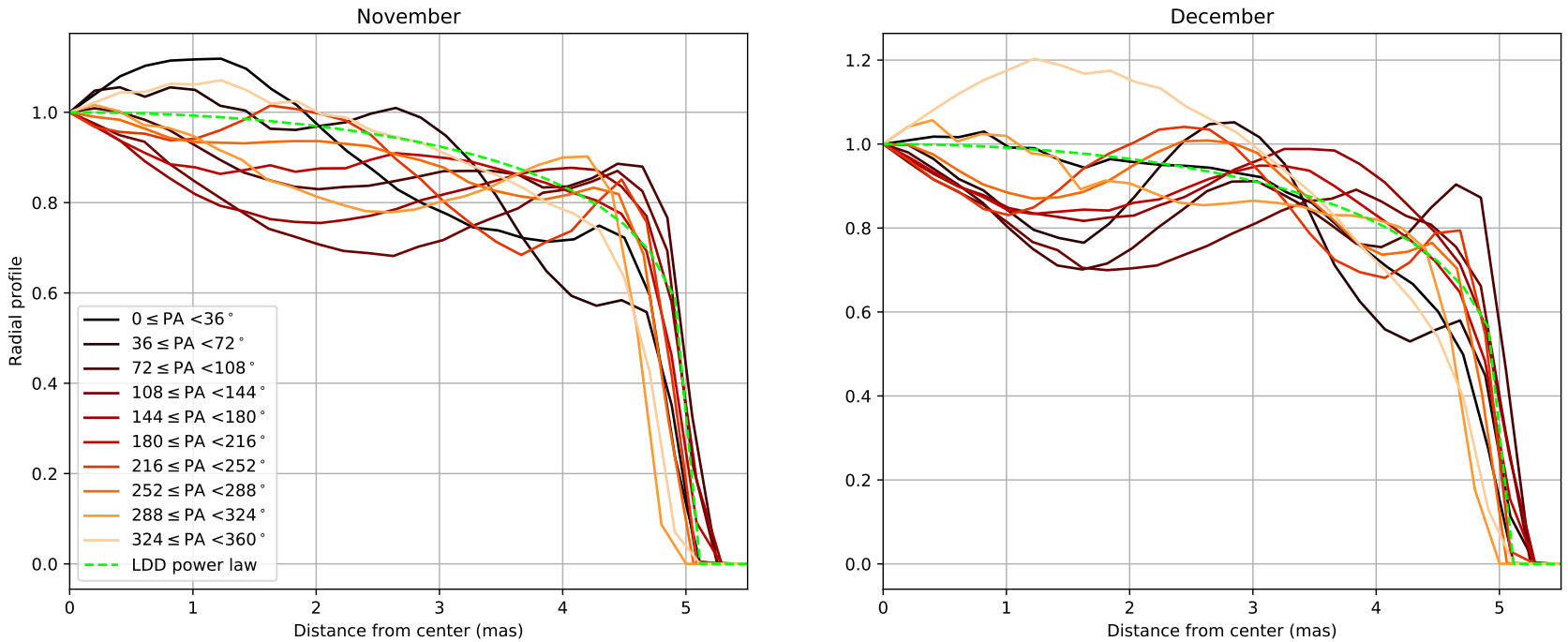
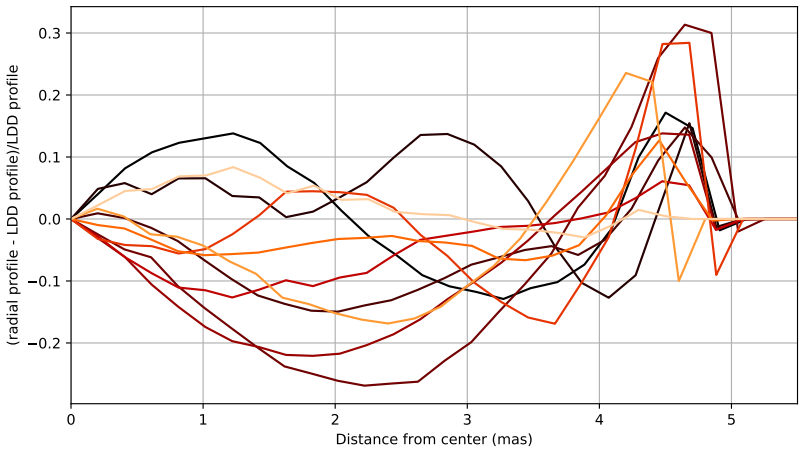


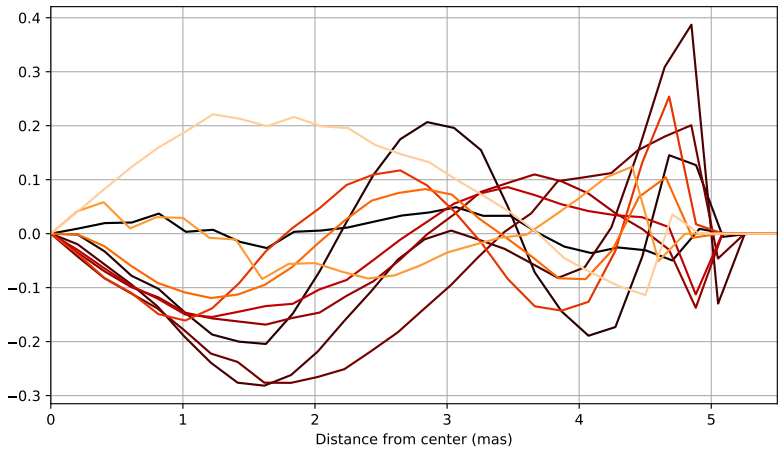
CE Tau@PIONIER : intensity profiles



→ Fit of best LDD profile for each PA range

CE Tau@PIONIER : contrast profiles

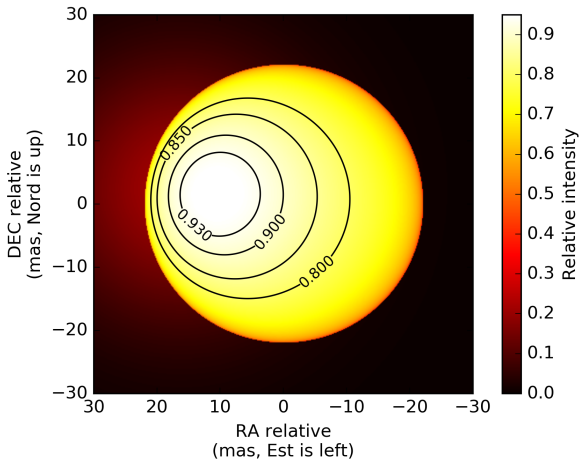




- Dark spots : as low as 30%
- Bright spots : as high as 20%

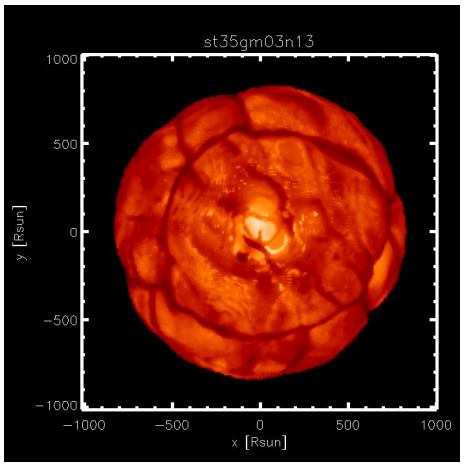
Conclusions

- Better characterization of convection: constraints on processes trigerring the mass loss
- Convection → biases on :
  - Angular diameter
  - Photometry
  - Parallax



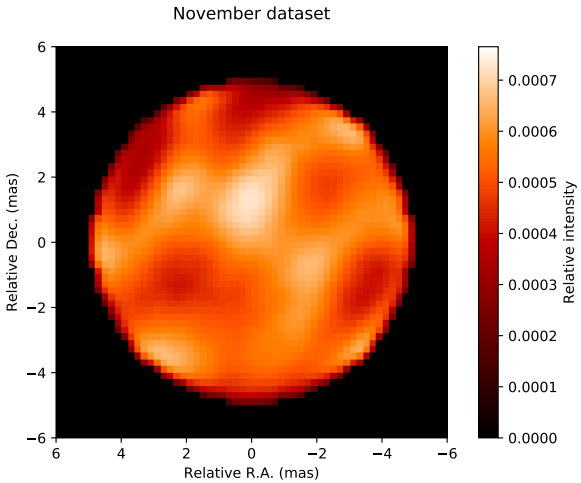
Model

Montargès et al. 2016



Simulation

Chiavassa et al. 2011



Image

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