The convective photosphere of the red supergiant CE Tau

M. Montargès, R. Norris, A Chiavassa, B. Tessore, A. Lèbre, and F. Baron

Background

- Many chemical elements in the Universe are forged in evolved stars, but the mechanism that launches the material away from the star is unknown
- Convection in red supergiant (RSG) stars may allow radiation pressure to begin outflow (probably not alone)
- Large RSG convective granules may bias parallax measurements
- Want to understand evolution of bright convective features

Conclusions

- Observed M2Iab-Ib RSG CE Tau with VLTI/PIONIER instrument in NIR H-band in November and December 2016
- Derived angular diameter and basic stellar parameters
- Reconstructed two reliable images of H-band photosphere
- No significant changes in the photosphere between epochs
- Contrast of the convective patterns ($5 \pm 1\%$ and $6 \pm 1\%$) were much lower than simulations, $23 \pm 1\%$ for original and $16 \pm 1\%$ after degradation
- Low contrast possibly due to quiet convective period or warmer T_{eff} compared to simulation

Model

- Used a limb-darkened disk (LDD) model for stellar photosphere with a Gaussian spot
- Normalize $w_{LDD} + w_{spot} = 1$, where w represents the peak flux
- The complex visibility is given by

$$V_{model} = w_{LDD}V_{LDD} + w_{spot}V_{spot},$$

with

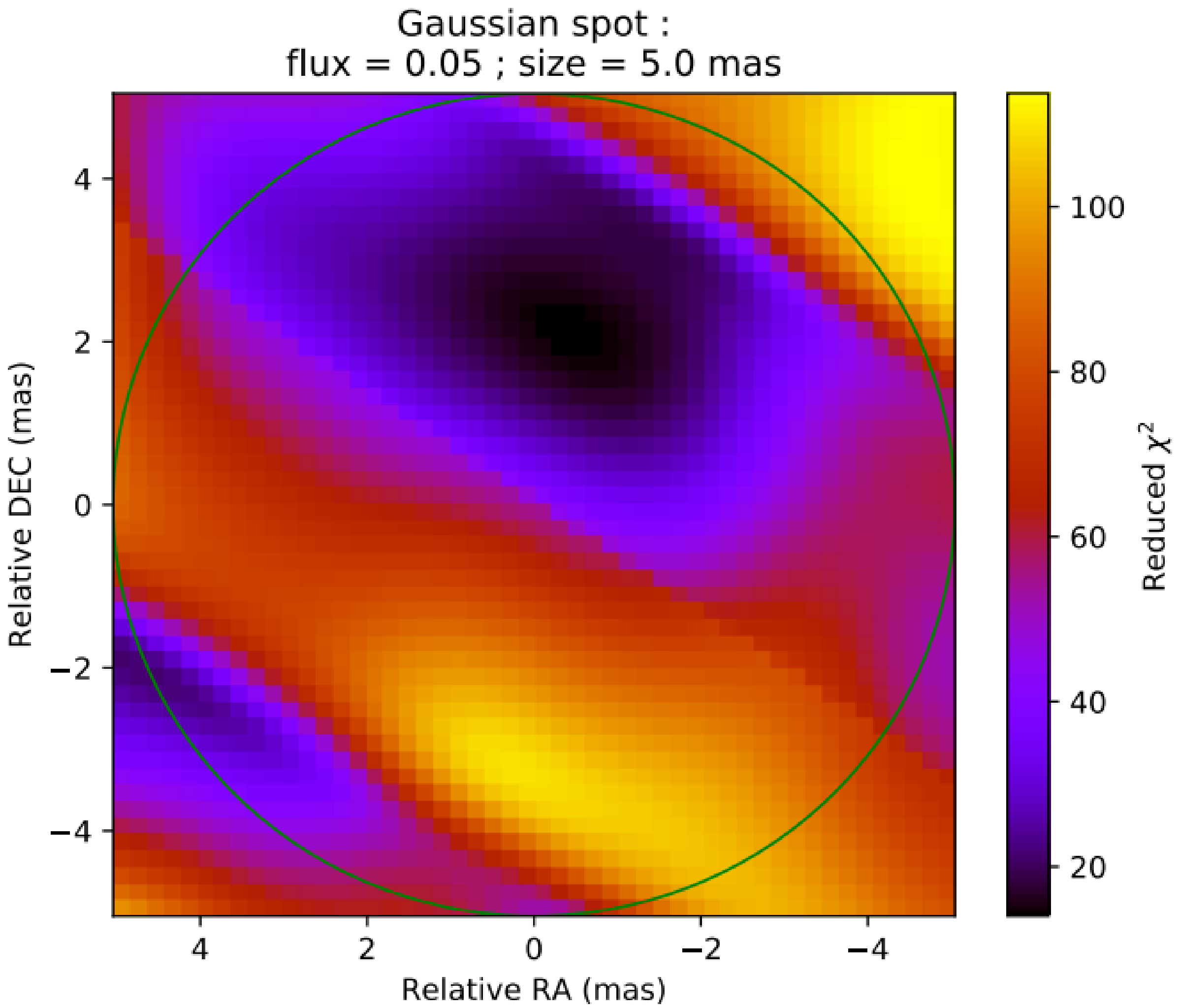
$$V_{spot}(u, v) = e^{-\frac{(2\pi\sigma\sqrt{u^2+v^2})^2}{2}} e^{-2i\pi(ux_{center}+vy_{center})}$$

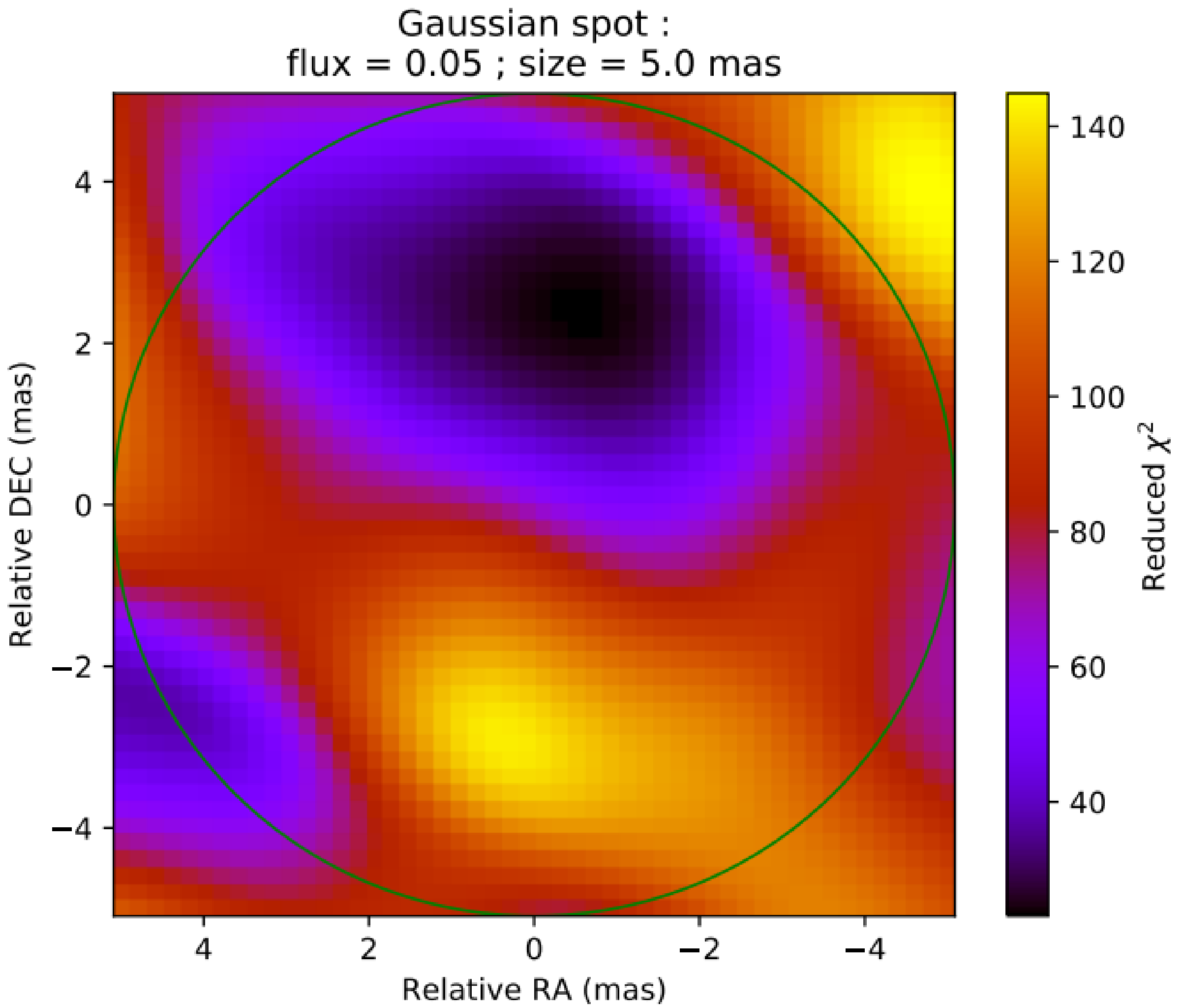
where $\sigma = FWHM/(2\sqrt{2\ln(2)})$

Model

Parameter	Nov. values	Dec. values
θ_{LDD} (mas)	9.94 ± 0.03	10.04 ± 0.03
α_{LDD}	0.34 ± 0.02	0.39 ± 0.02
w_{spot}	0.04 ± 0.01	0.04 ± 0.01
x_{center} (mas)	-0.57 ± 0.14	-0.50 ± 0.16
y_{center} (mas)	2.84 ± 0.15	2.81 ± 0.24
$FWHM$ (mas)	4.41 ± 0.29	3.87 ± 0.33
$\tilde{\chi}^2_{\mathrm{LDD}}$	9.1	13.6
F	4860	4851

Model

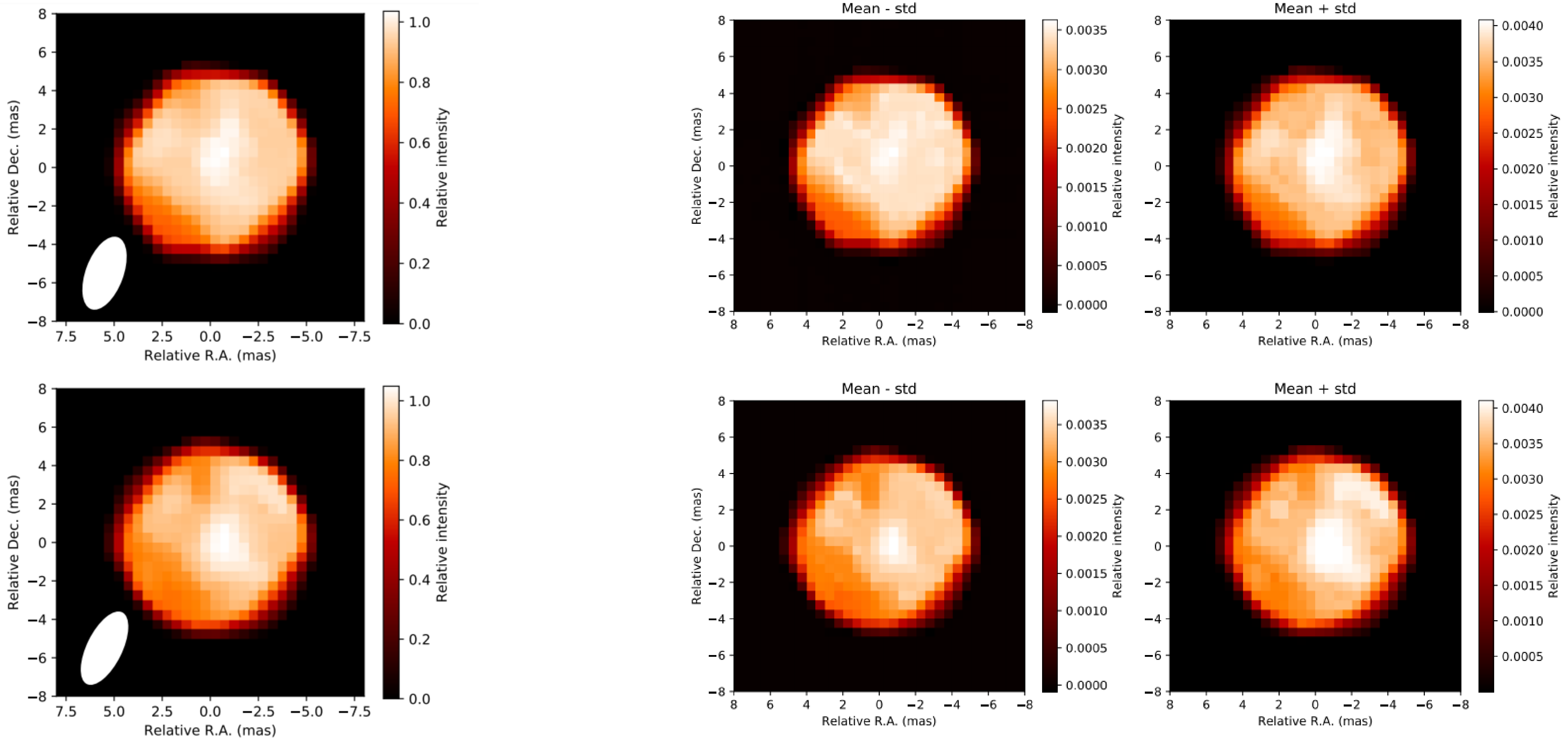

Gaussian spot :
flux = 0.05 ; size = 5.0 mas
Relative DEC (mas)
Relative RA (mas)
Reduced χ^2
4
2
0
−2
−4
100
80
60
40
20


Gaussian spot :
flux = 0.05 ; size = 5.0 mas
Relative DEC (mas)
Relative RA (mas)
Reduced χ^2
4
2
0
−2
−4
140
120
100
80
60
40

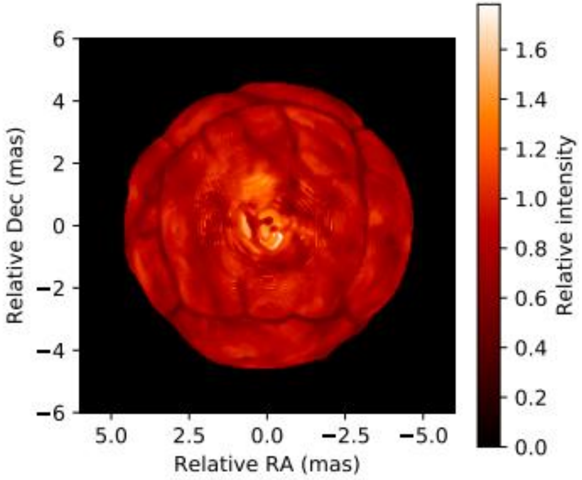
Stellar Parameters

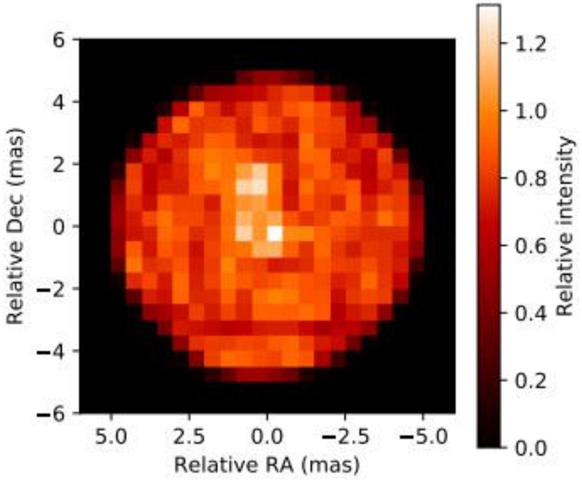
This Paper	Literature
$R = 587 \pm 85\ R_{\odot}\ /\ 593 \pm 86\ R_{\odot}$	$601 \pm 83\ R_{\odot}$, Cruzalèbes et al. (2013)
$F_{UBVRIJHKLN} = 7.01 * 10^{-9} \pm 8.98 * 10^{-10}\ Wm^{-2}$	
$T_{eff} = 3820 \pm 135\ K\ /\ 3801 \pm 134\ K$	$3660\ K$, Levesque et al. (2005), $3700\ K$, Luck & Bond (1980)
$\log L/\ L_{\odot} = 4.82^{+0.12}_{-0.16}$	$4.63 \pm 13\%$, Cruzalèbes et al. (2013)
$M = 14.37^{+2.00}_{-2.77}\ M_{\odot}$	
$\log g = 0.05^{+0.11}_{-0.17}$	0.07, Luck & Bond (1980)
$13.9^{+1.0}_{-2.5}\ Myr$	

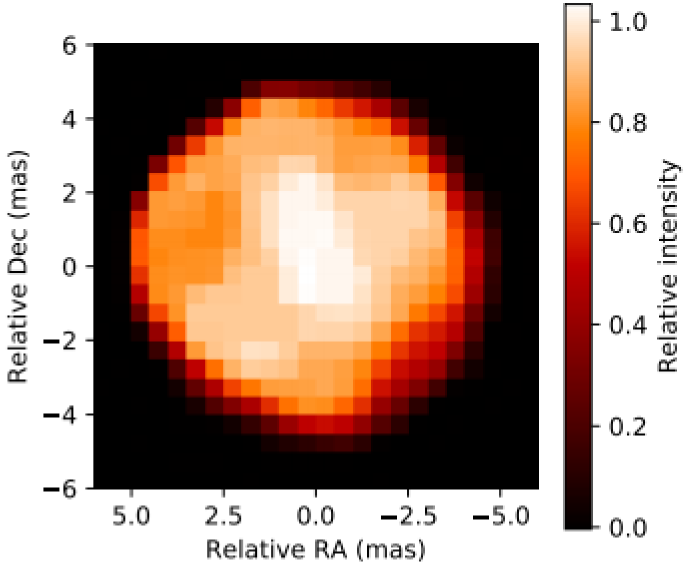
Image Reconstruction



3D Radiative Hydrodynamics Simulation







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