Max Planck Institute
for Astrophysics

MAX-PLANCK-GESELLSCHAFT

INTERPRETATION OF INTERFEROMETRIC OBSERVATIONS WITH 3D RADIATIVE HYDRODYNAMICS SIMULATIONS OF COOL STARS

Andrea Chiavassa

MPA

ESO workshop – 3 March 2010

OUT LINE

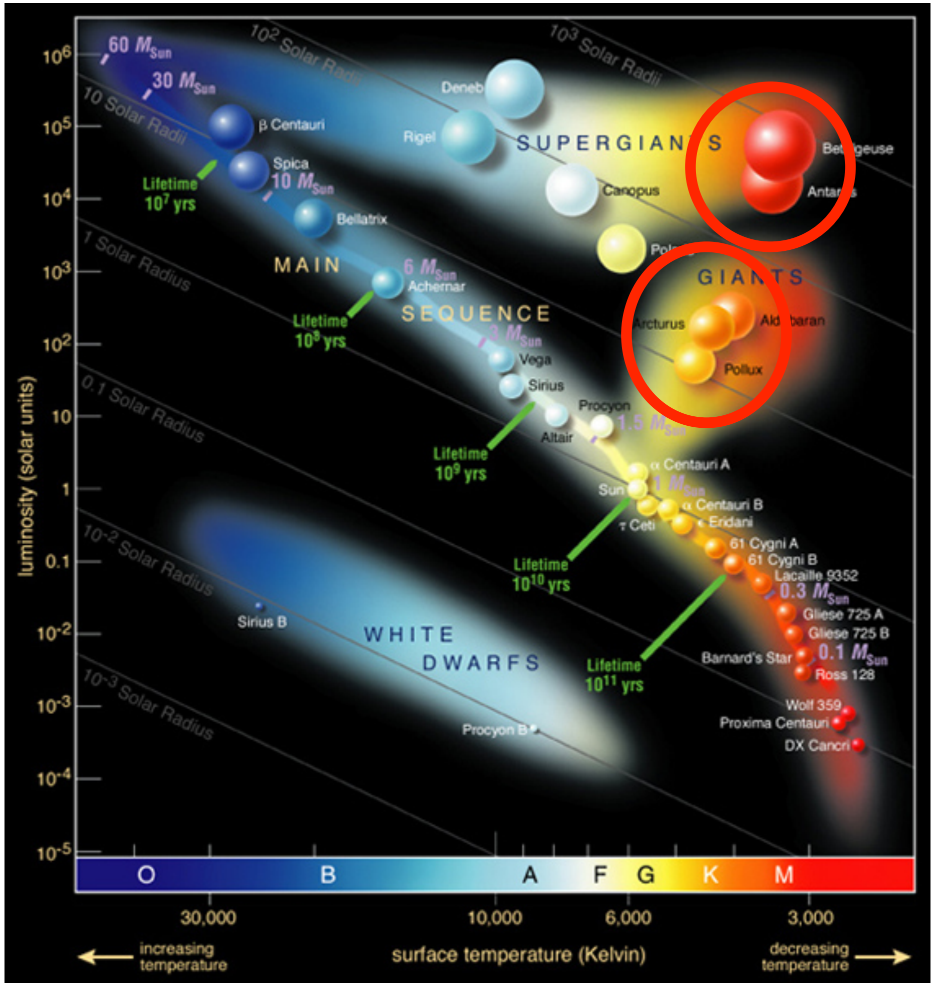
- Modelling
- Red supergiant stars
- Giant stars
- Conclusions

OUT LINE

- Modelling
-
-
-

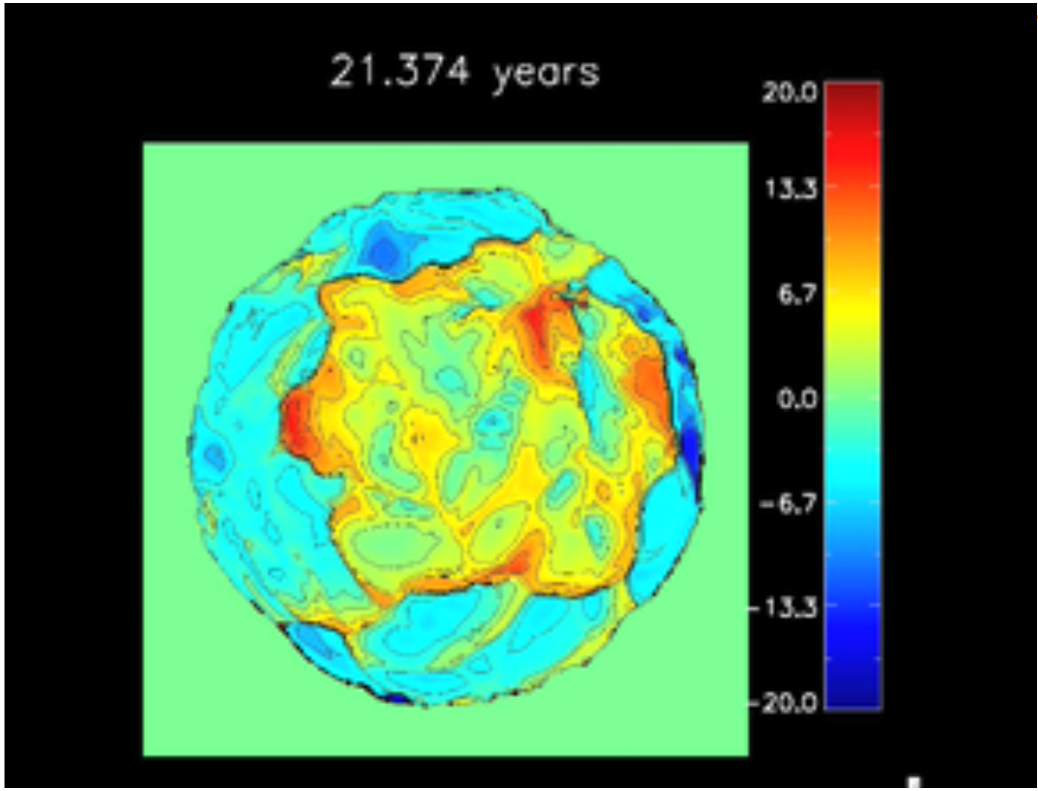
WHY STUDY THE ATMOSPHERE OF COOL STARS?

- The atmosphere is the boundary to the invisible stellar interior: link between models of stars and stellar evolution and observations. Study of chemical composition due to dredge-up process and fundamental stellar parameters.
- The atmosphere is the inner boundary to the outer atmospheric region: effects on the interstellar medium, throughout radiation or mass loss. Contribution to the chemical evolution of the Galaxy.



The modeller's point of view

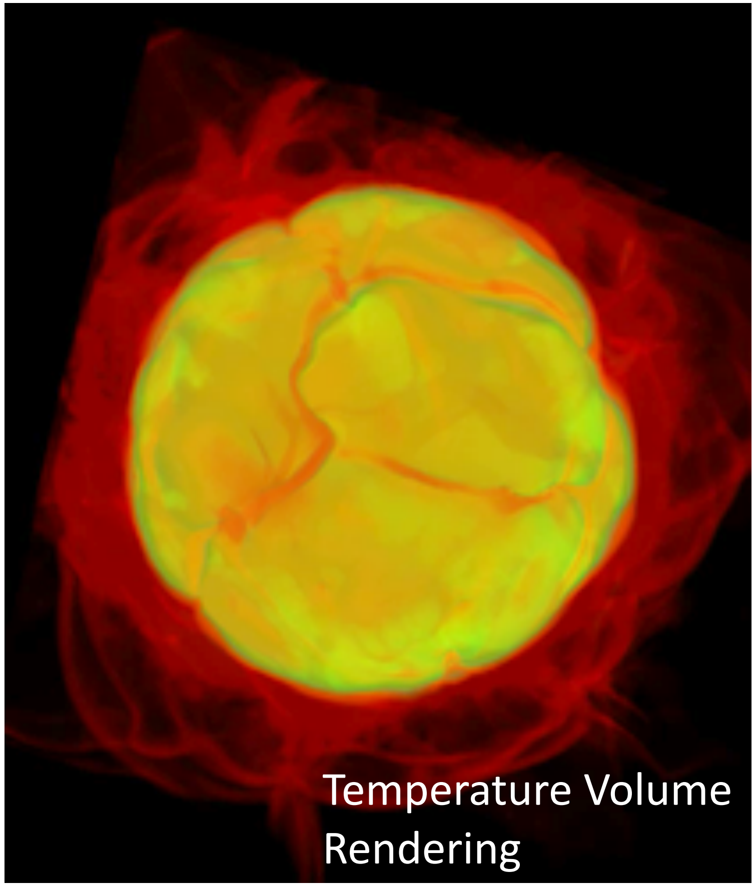
CO5BOLD (Freytag et al. 2002)



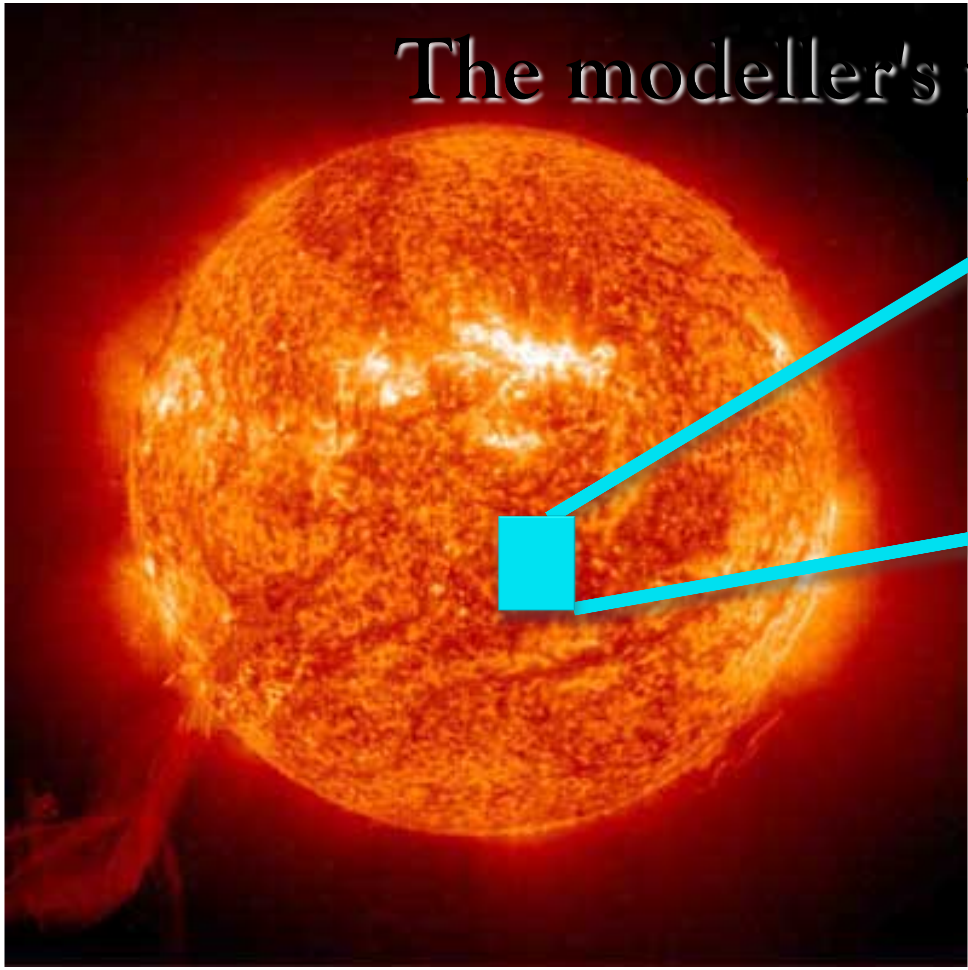
Velocity at 1.6 micron computed with OPTIM3D

STAR-IN-A-BOX setup:

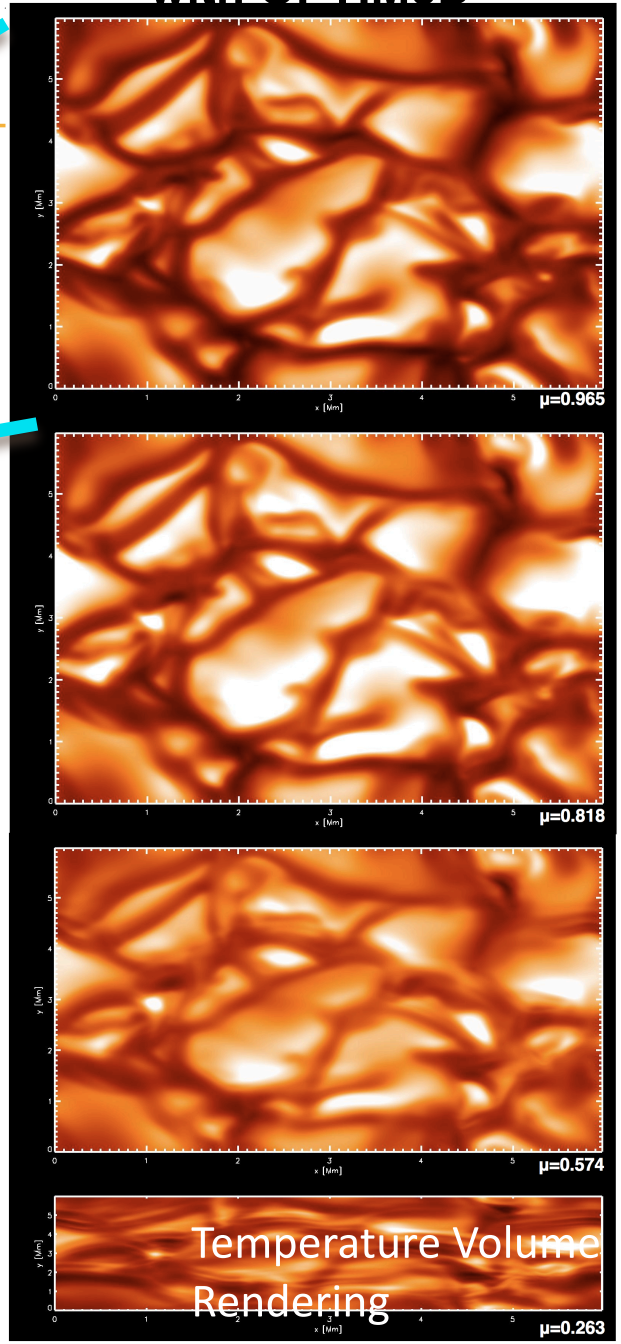
- Used to model RSG stars



The modeller's point of



Sun at 6700Å computed
- with OPTIM3D



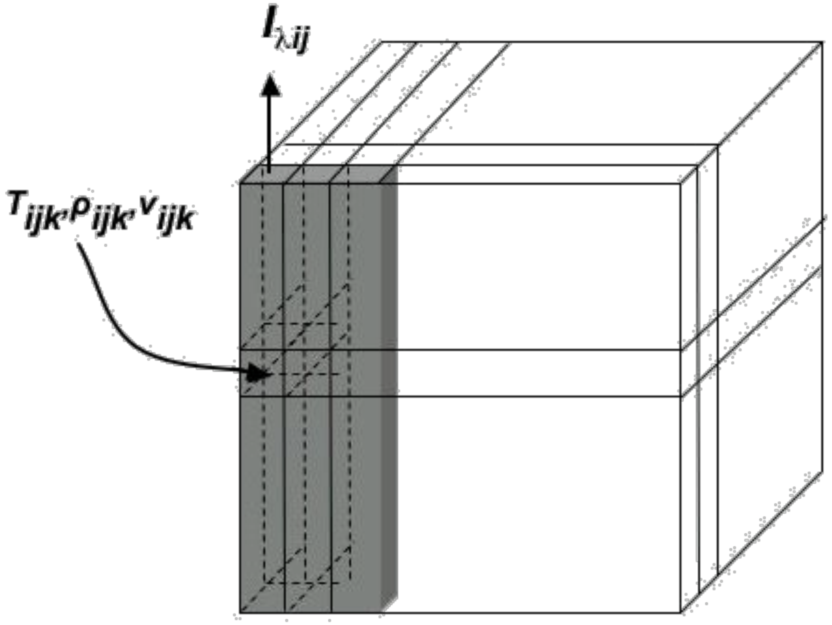
STAGGER CODE (Nordlund et al. 2009)

BOX-IN-A-STAR setup:

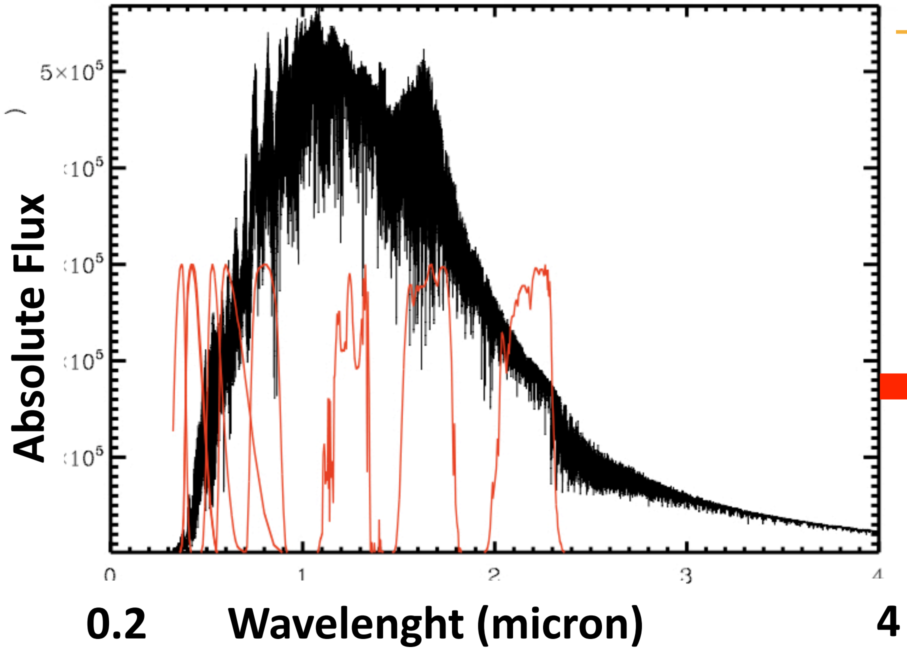
- Used to model Giant, Dwarf stars and the Sun

3D RADIATIVE TRANSFER CODE OPTIM3D

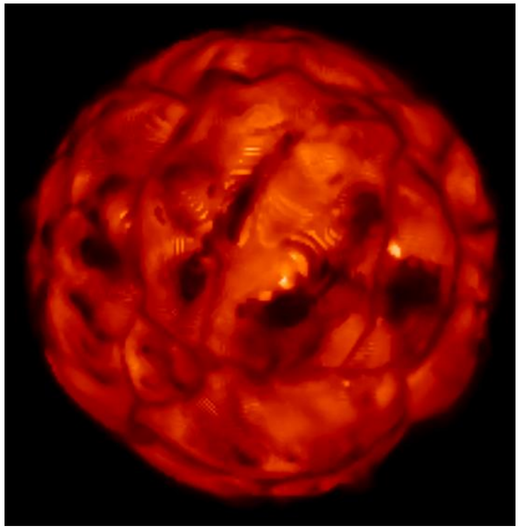
- Opacity tables generated with MARCS with billion of molecular (see Gustafsson et al., 2008) and atomic (VALD) lines



OPTIM3D PRODUCES:



Atmospheric dynamics and stellar parameters



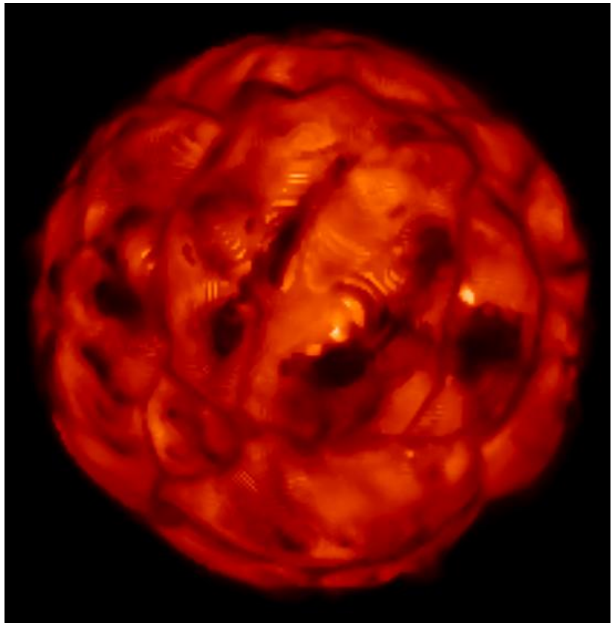
To constrain the structure size

OUT LINE

- Red supergiant stars

INTENSITY PROFILES – EASY AND COMPLEX MODELS

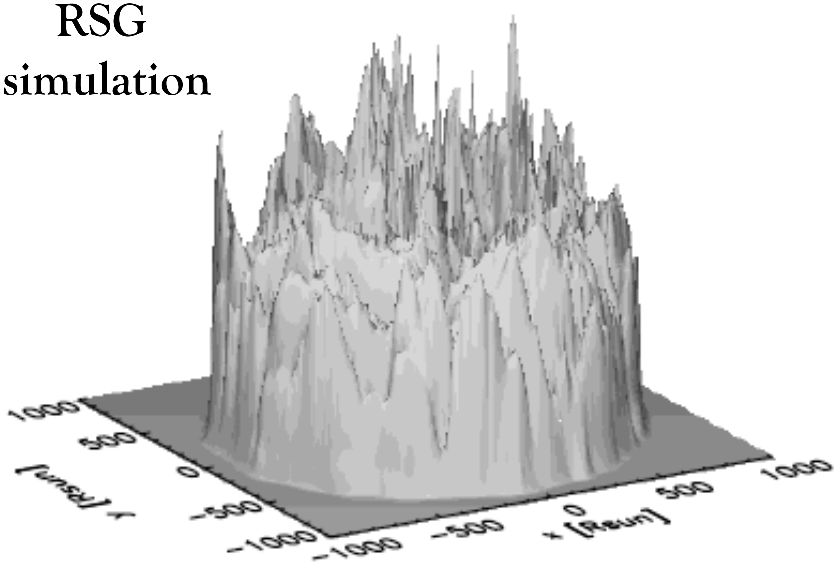
RSG
simulation

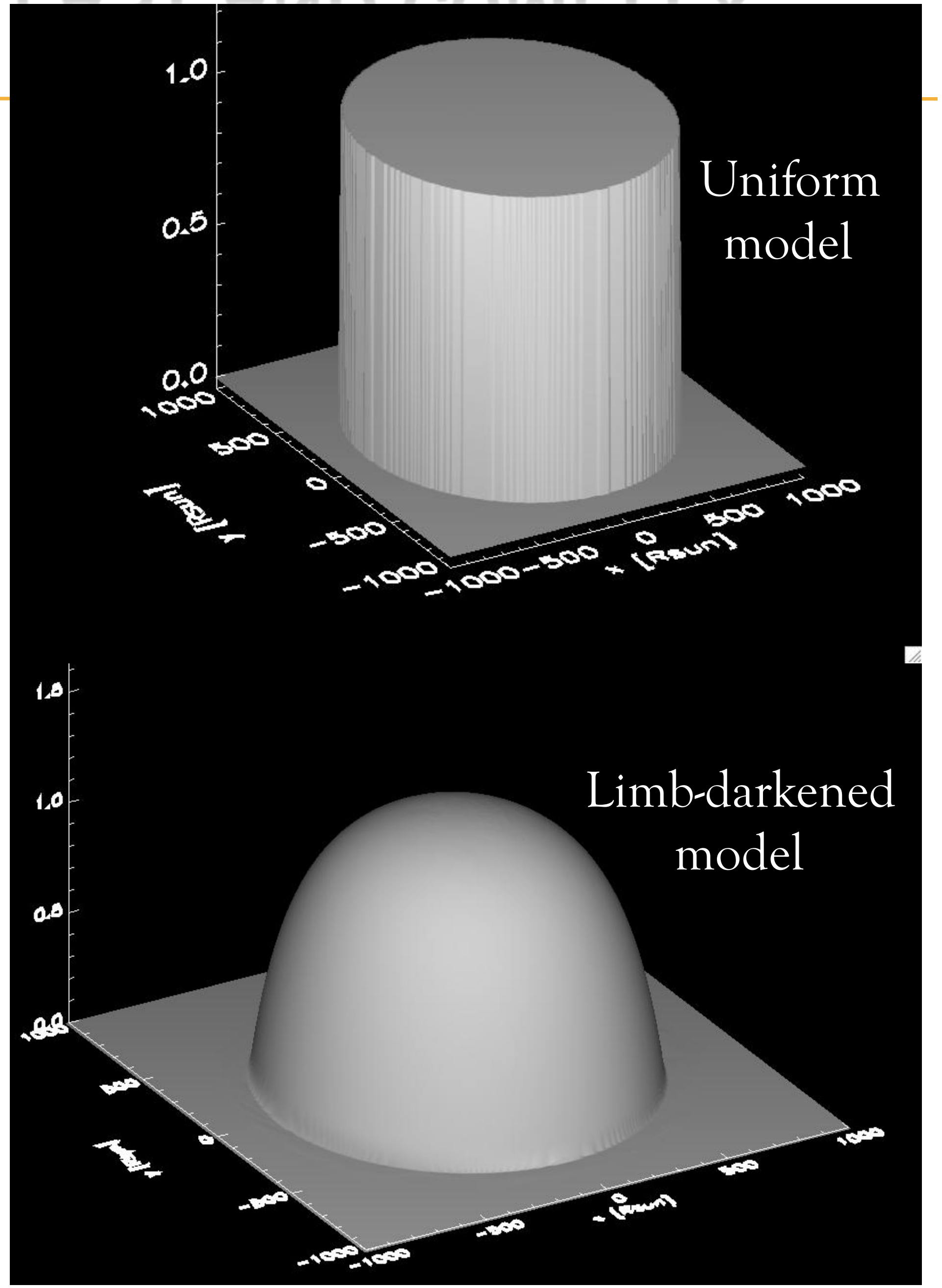


r

INTENSITY PROFILES – EASY AND COMPLEX MODELS

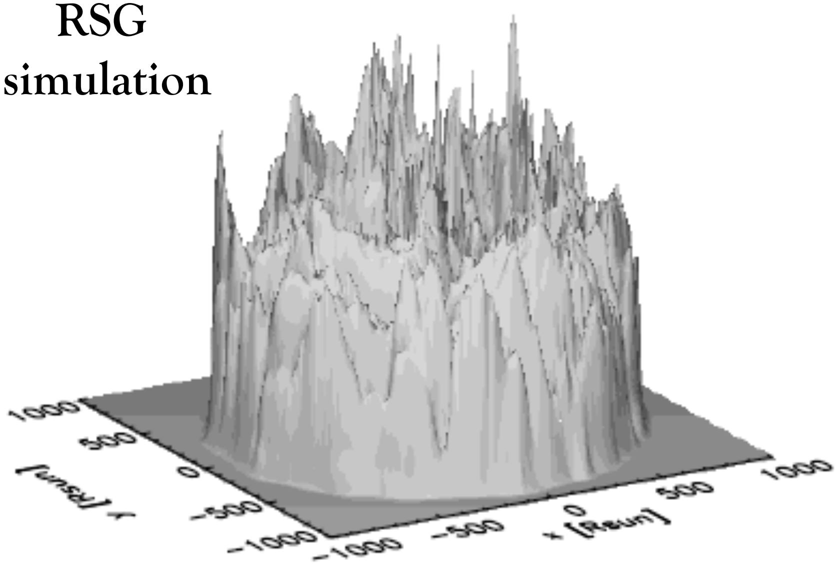
RSG simulation

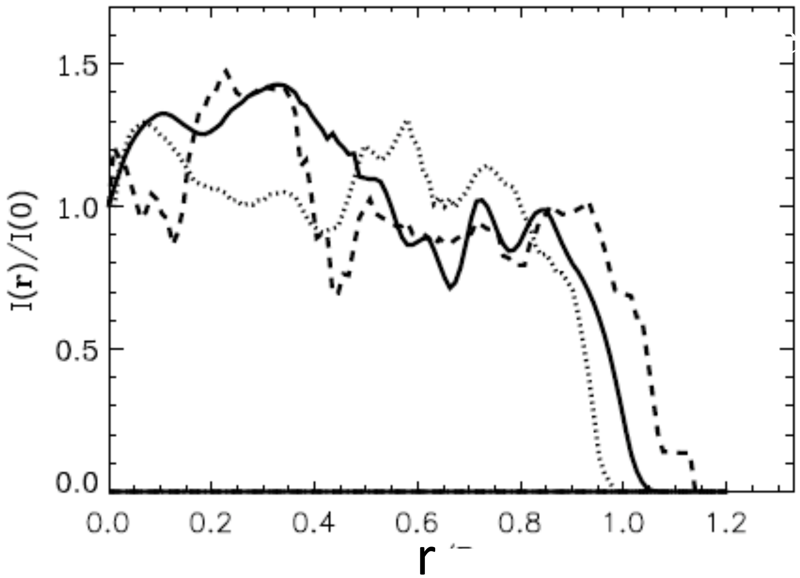




INTENSITY PROFILES – EASY AND COMPLEX MODELS

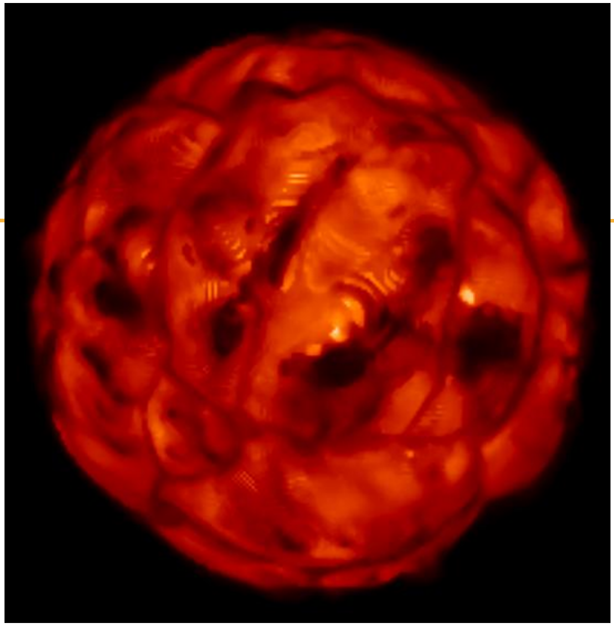
RSG simulation



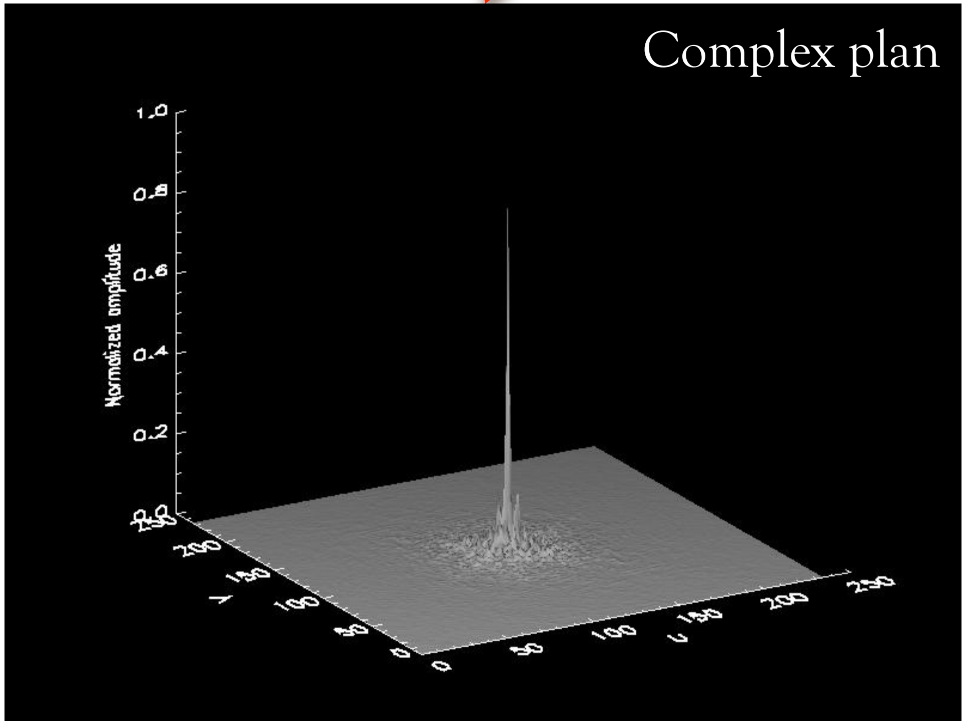


Clear deviations from spherical symmetry. Maximum deviations up to 10% with respect to average value

INPUT:
2D simulation images



Fourier Transformer



VISIBILITY – FIRST LOBE

- Incertitude on the radius determination

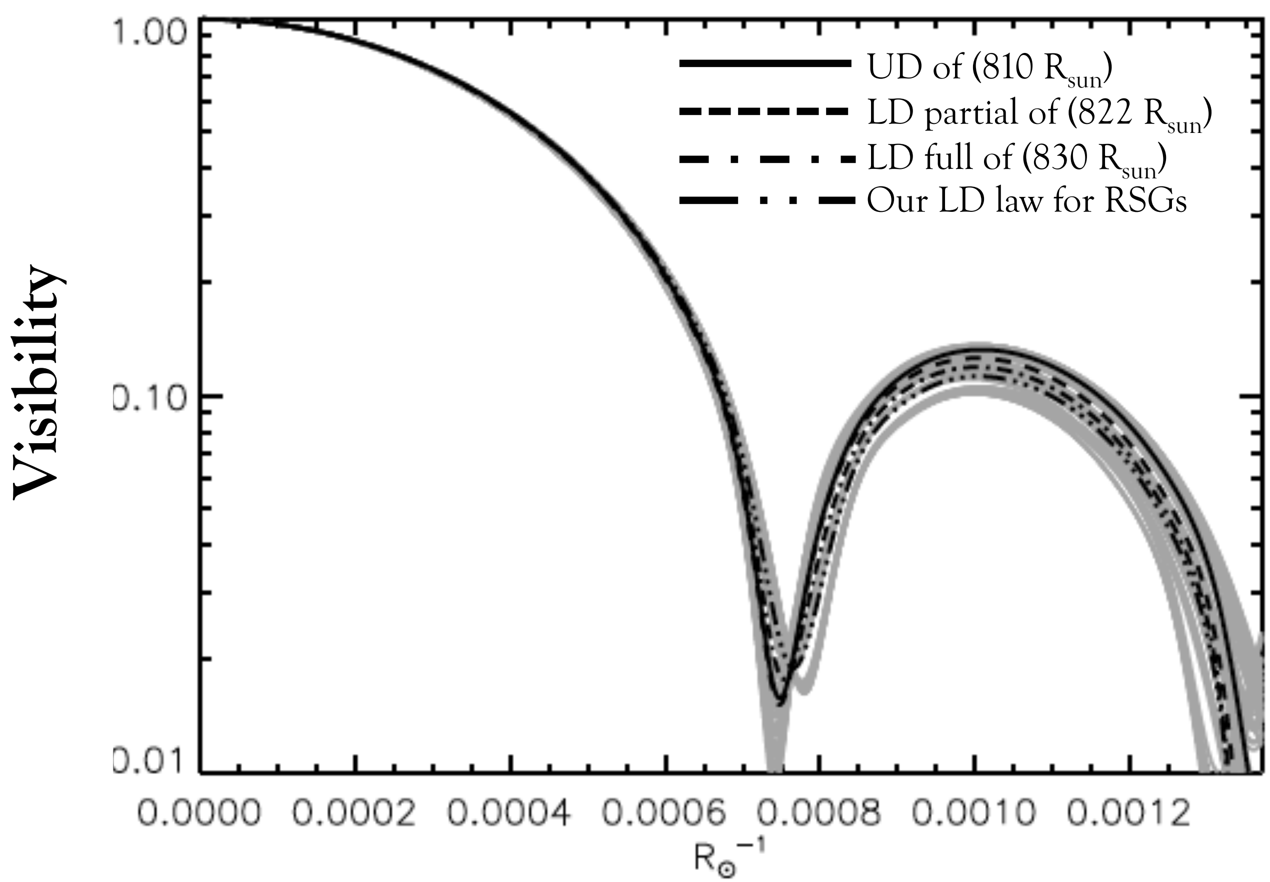
L=93000±1300 $L_\odot$

Teff=3490±13 K

R=832±0.7 $R_\odot$

log(g)=-0.337±0.001

M=12 $M_\odot$

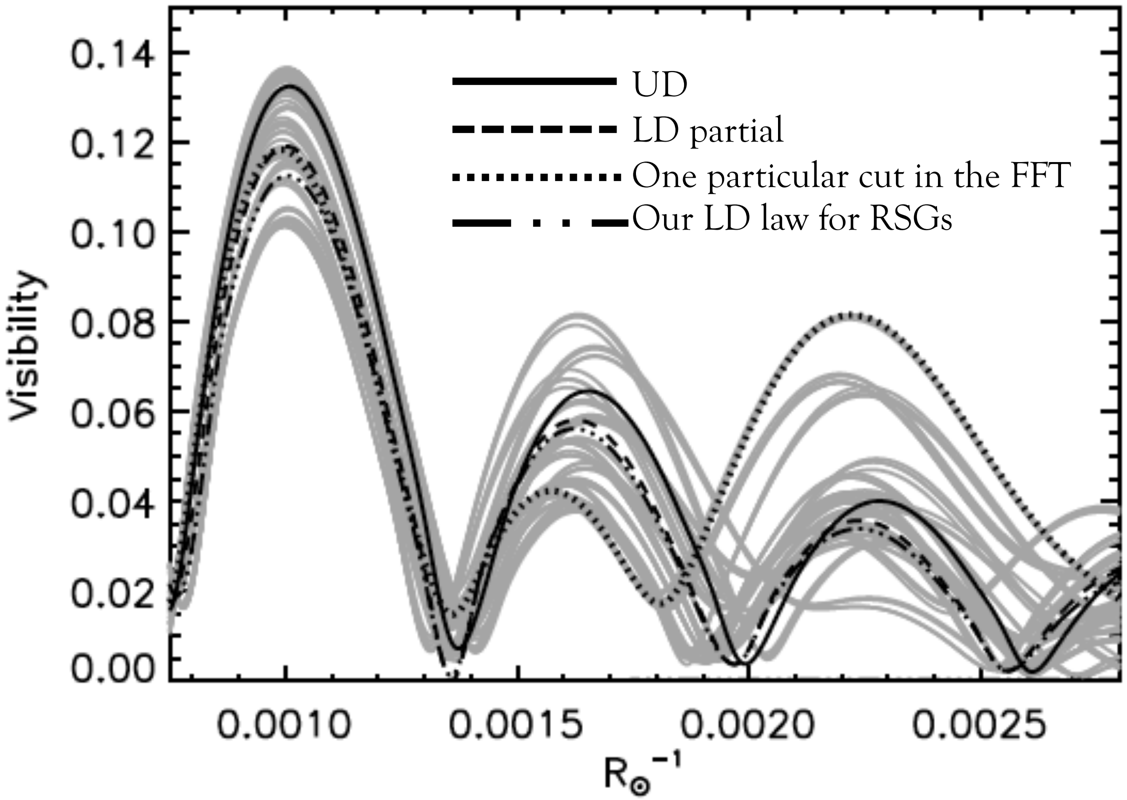


$v\,[\mathrm{arcsec}^{-1}] = v\,[R_\odot^{-1}] \times d\,[\mathrm{pc}] \times 214.9$

Chiavassa, Plez, Josselin & Freytag 2009, A&A, 506, 1351-1365

VISIBILITY - THE SECOND, THIRD AND FOURTH LOBES

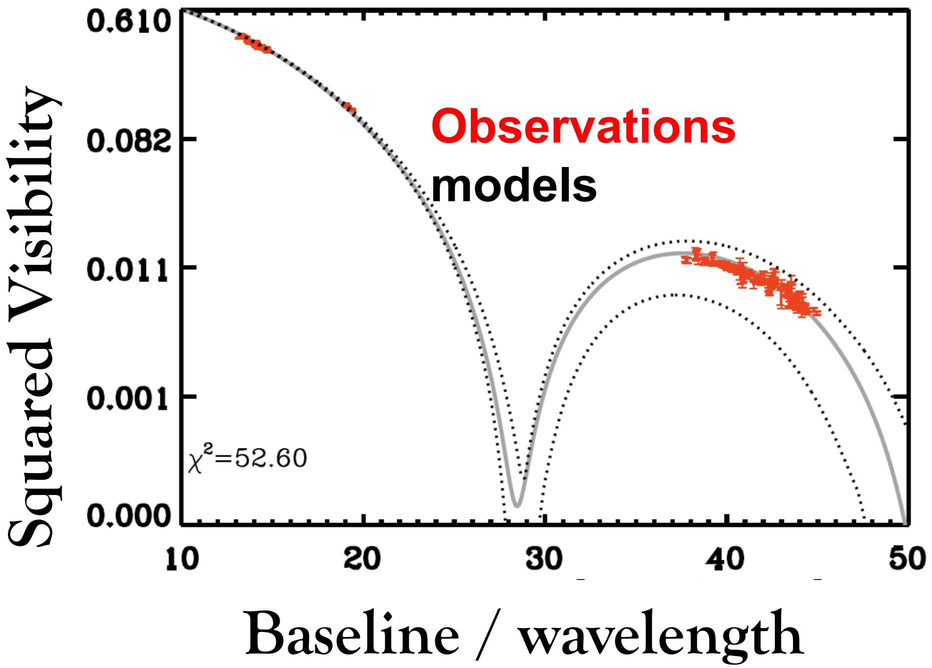
- Clear deviation from circular symmetry. Signal higher than UD or LD predictions!!!
- Scatter becomes larger with spatial frequencies
- Signature of the convective cells

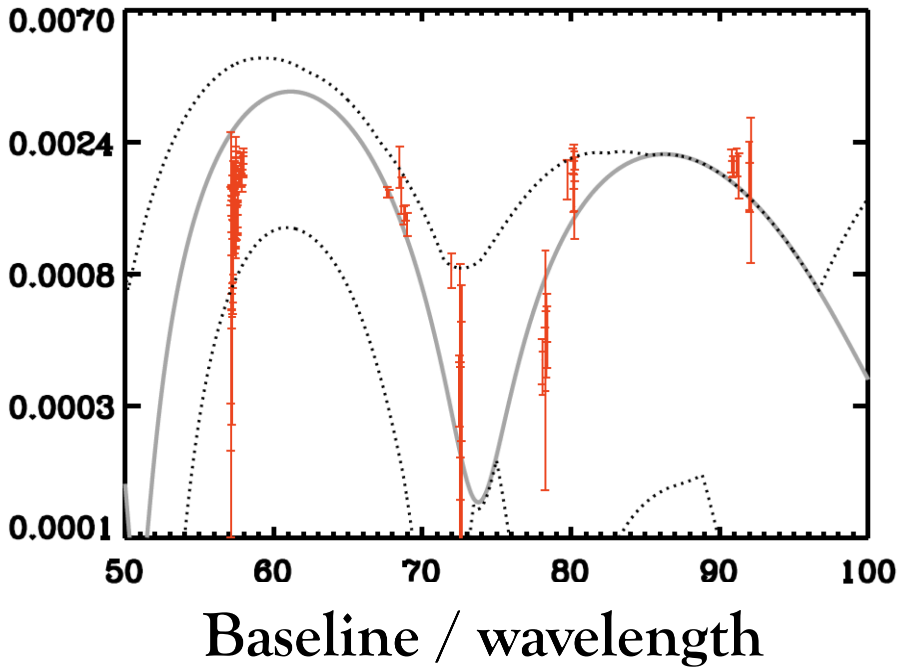


IONIC filer H band

AND A LOOK IN THE H BAND...

Very good fits from the optical to the H-K band!! Convection cells on Betelgeuse



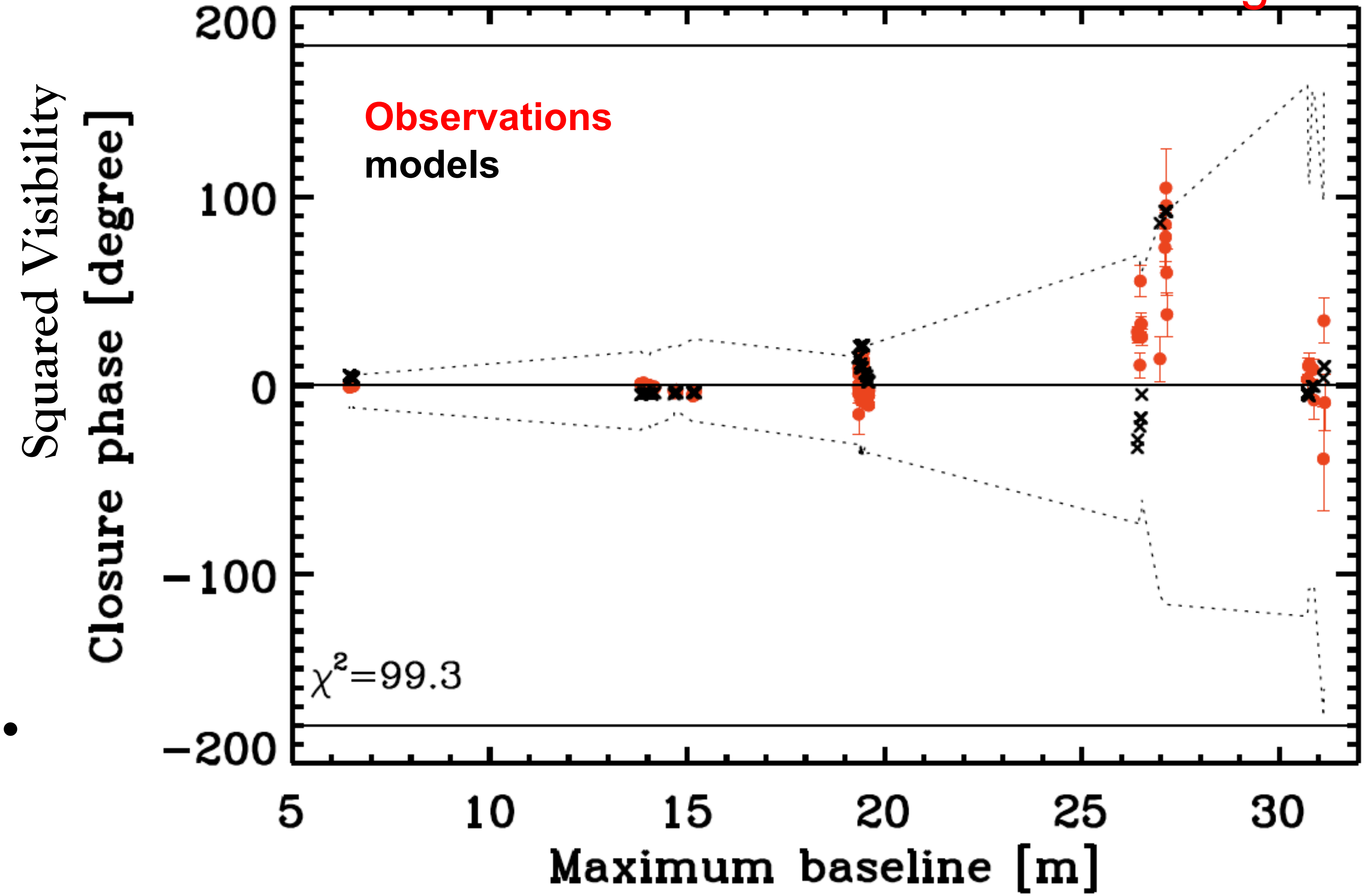


Grey – bestfitting visibility
Dots – max/min fluctuations

- IONIC H band (Haubois et al. 2009, red)

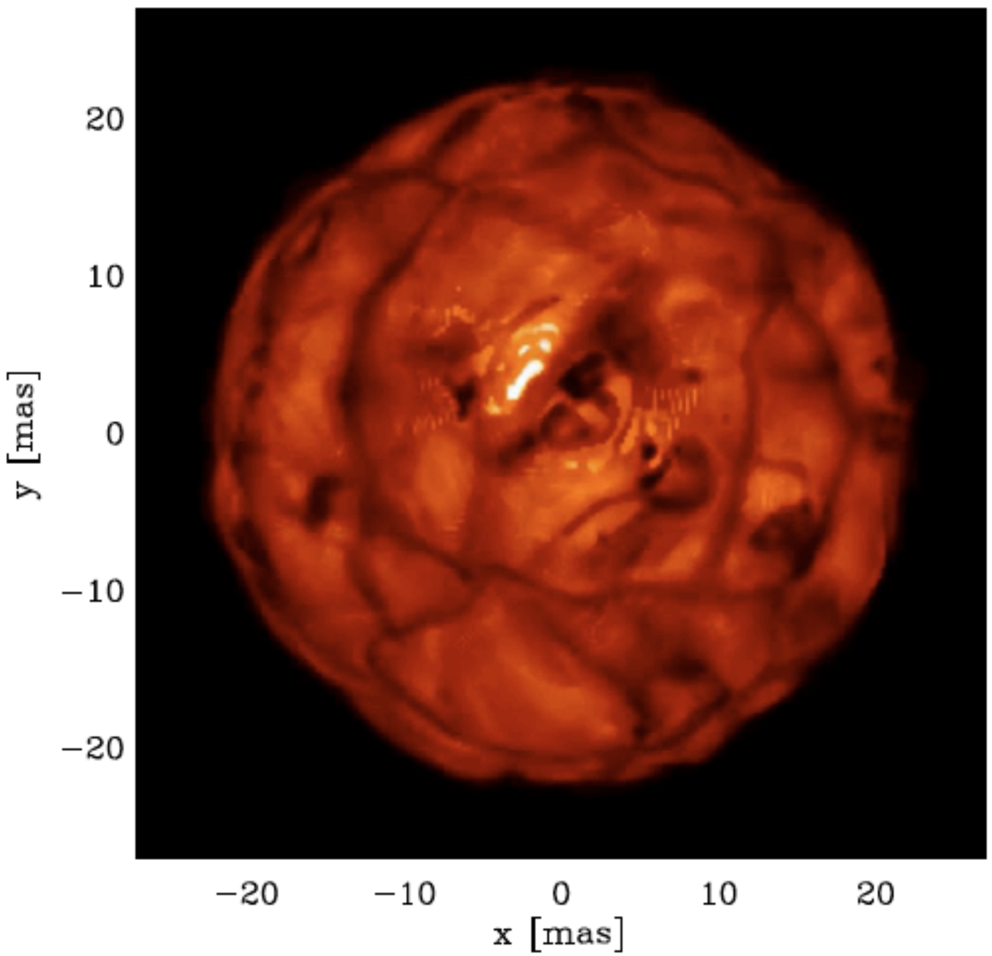
AND A LOOK IN THE H BAND…

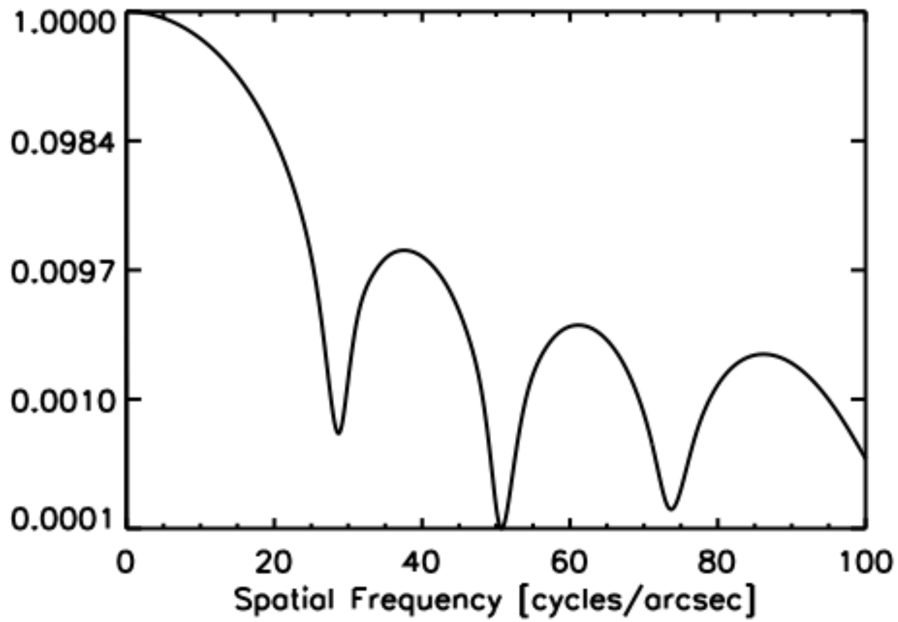
Very good fits from the optical to the H-K band!! Convection cells on Betelgeuse



•

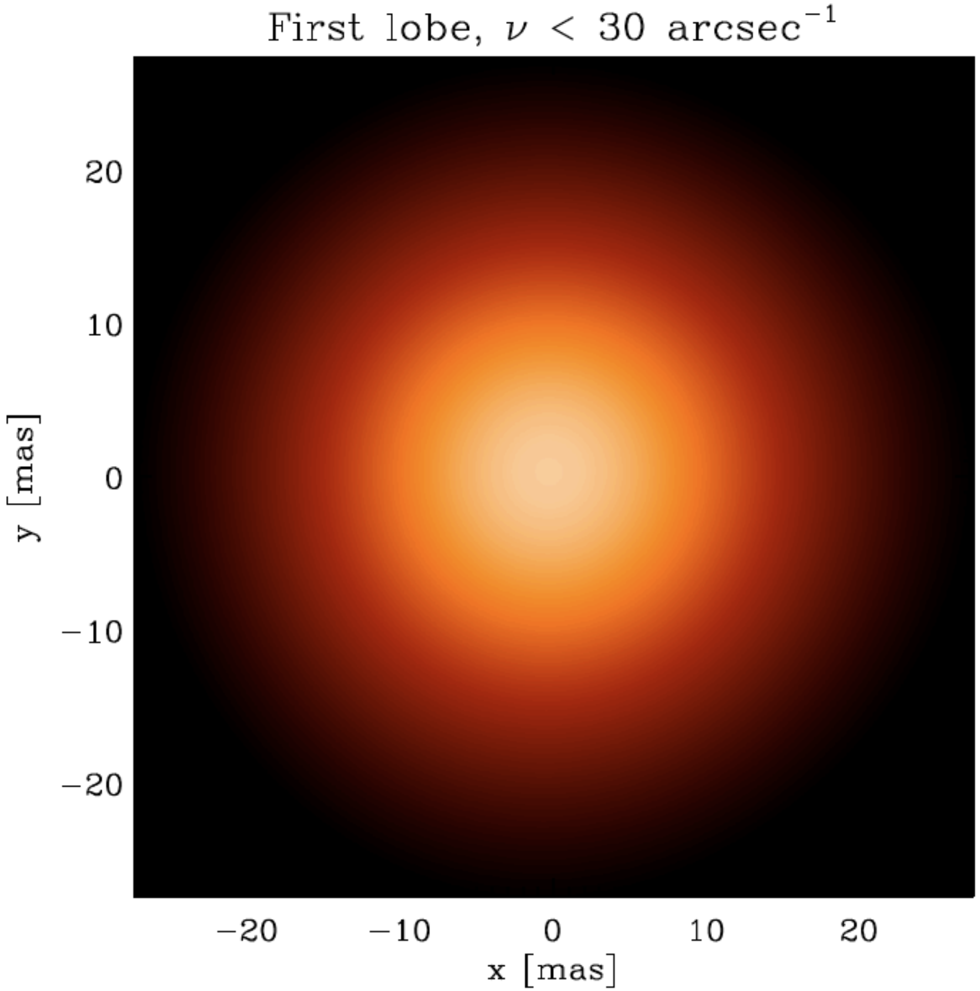
SIZE DISTRIBUTION ON STELLAR SURFACE

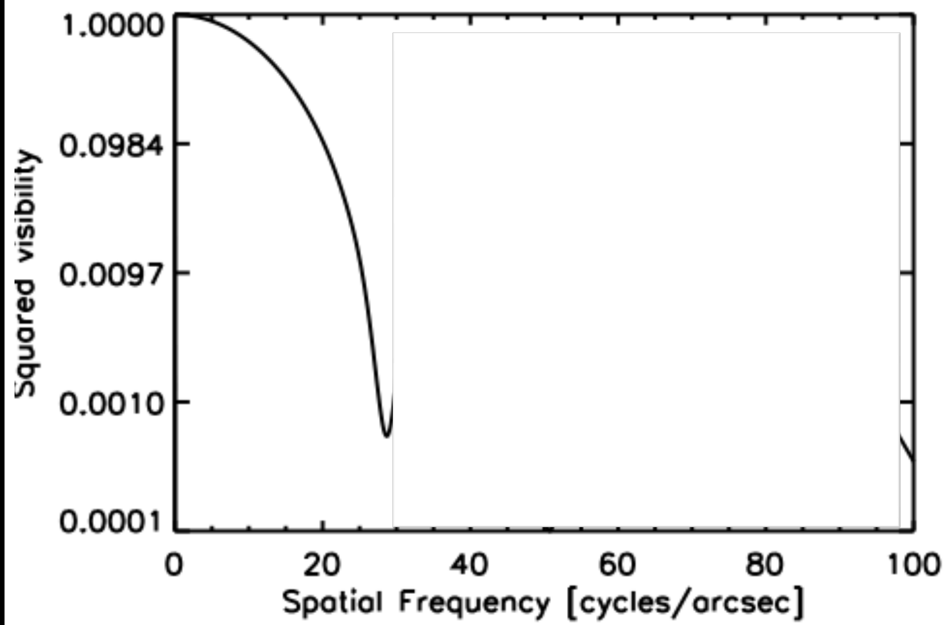




Chiavassa, Haubois, Young. et al., http://arxiv.org/abs/1003.1407

SIZE DISTRIBUTION ON STELLAR SURFACE

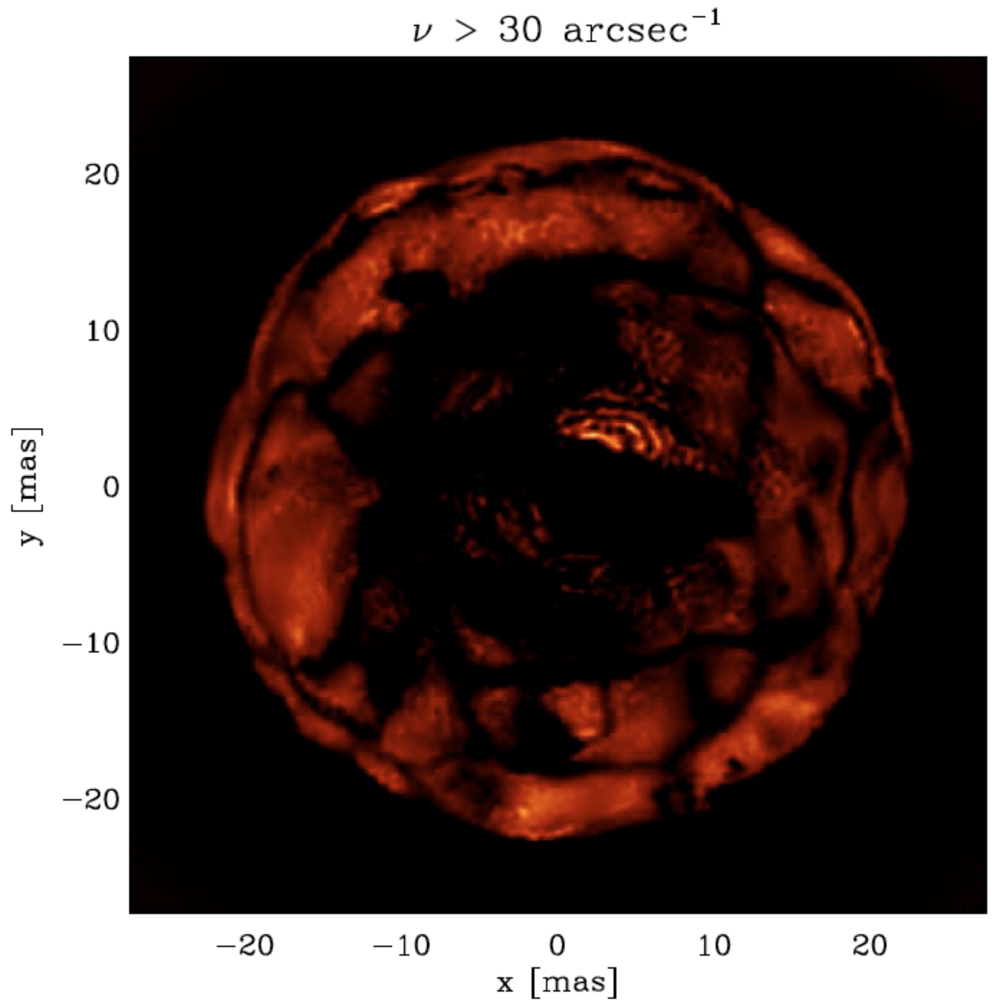


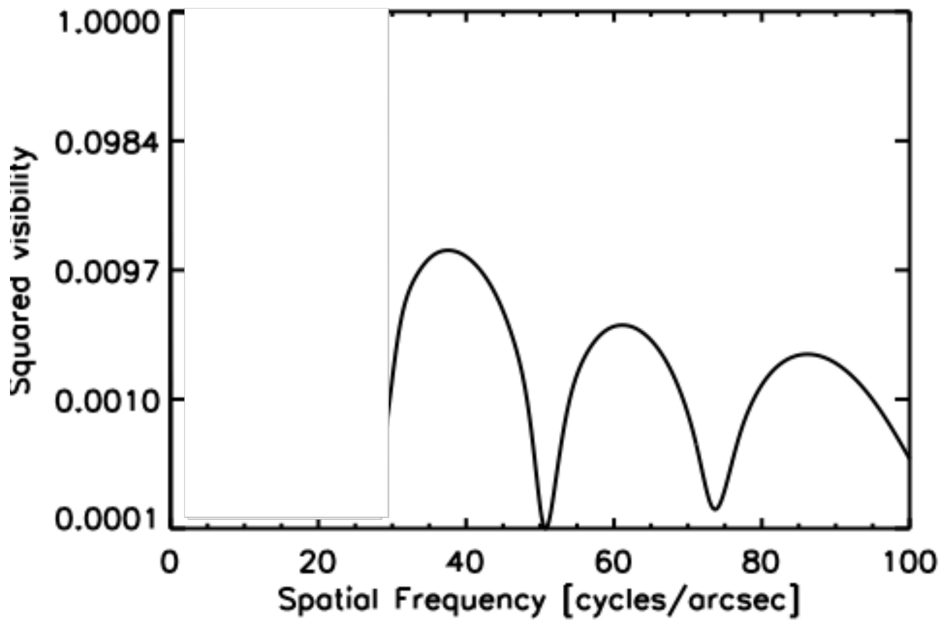


Need: real images!!!

Chiavassa, Haubois, Young. et al., http://arxiv.org/abs/1003.1407

SIZE DISTRIBUTION ON STELLAR SURFACE

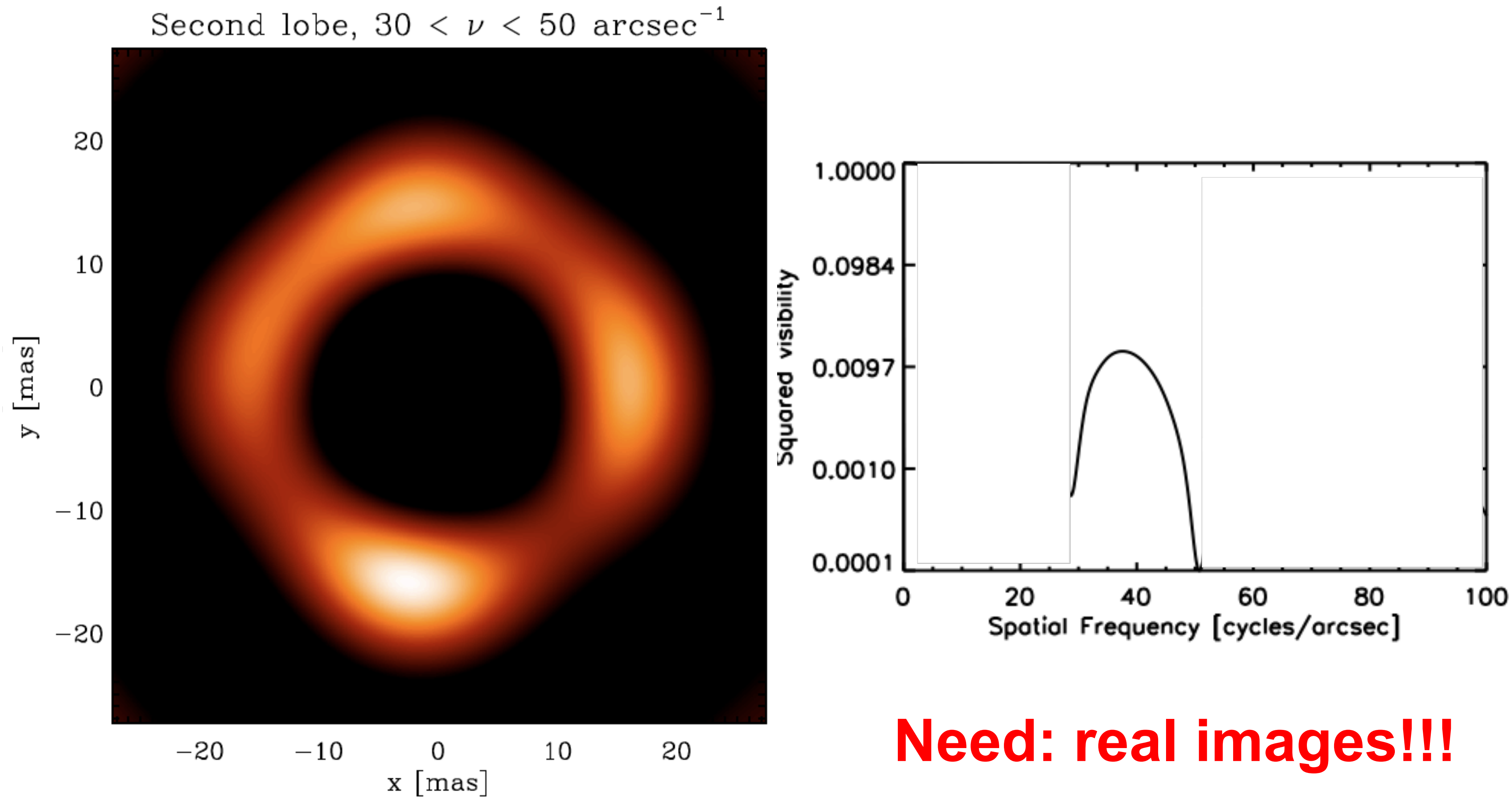




Need: real images!!!

Chiavassa, Haubois, Young. et al., http://arxiv.org/abs/1003.1407

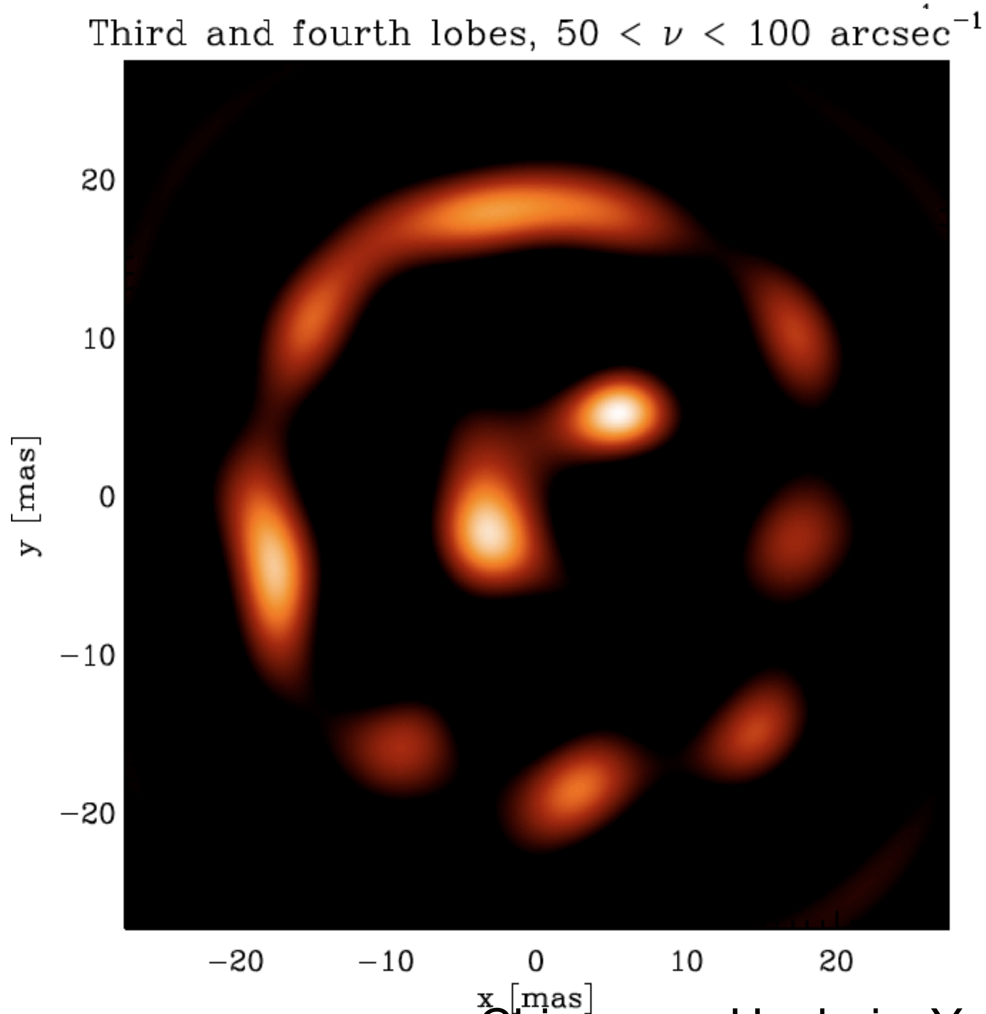
SIZE DISTRIBUTION ON STELLAR SURFACE

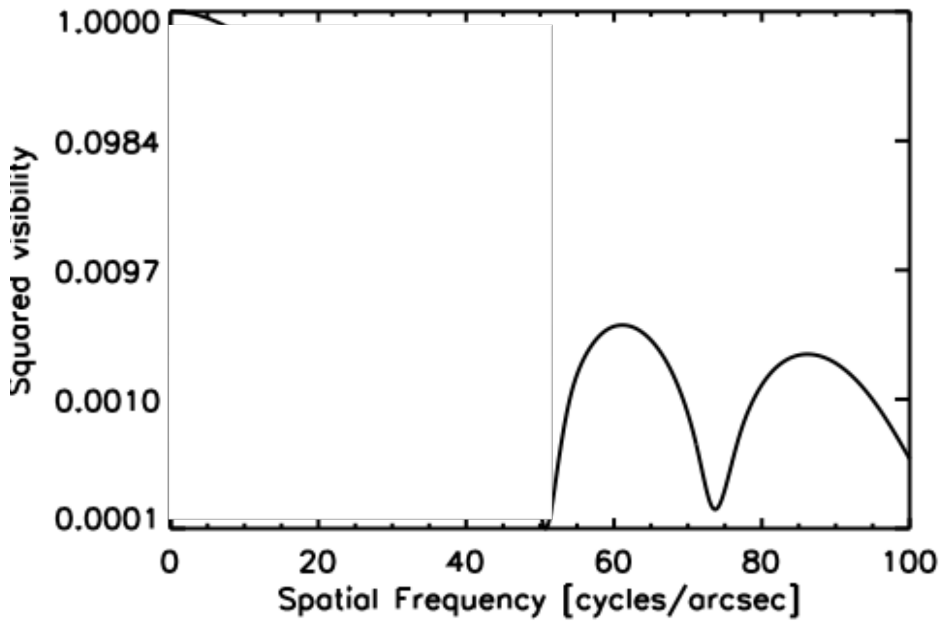


Need: real images!!!

Chiavassa, Haubois, Young. et al., http://arxiv.org/abs/1003.1407

SIZE DISTRIBUTION ON STELLAR SURFACE

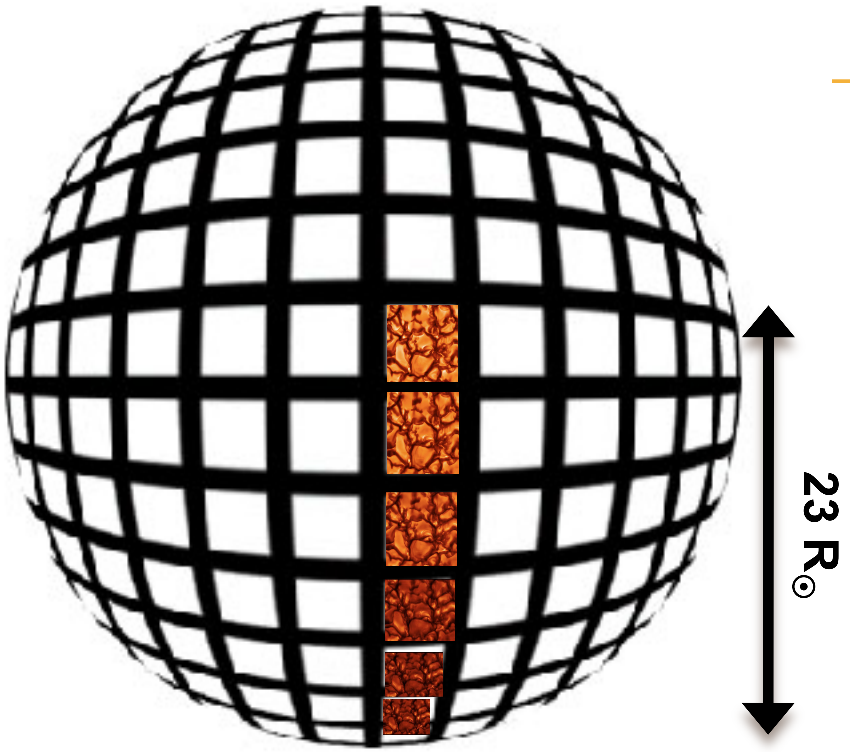


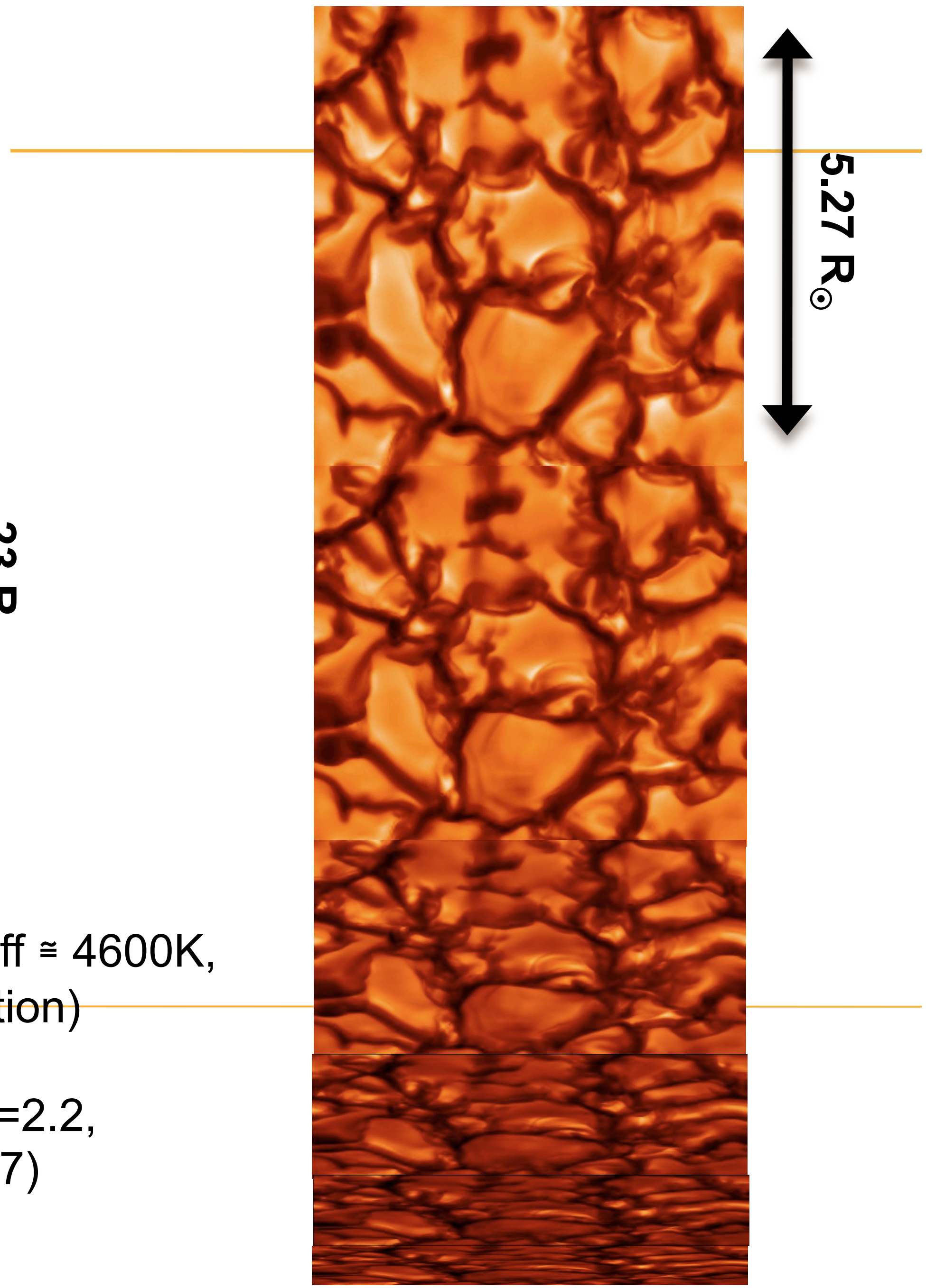


Chiavassa, Haubois, Young. et al., http://arxiv.org/abs/1003.1407

OUT LINE

-
-
- Giant stars
-

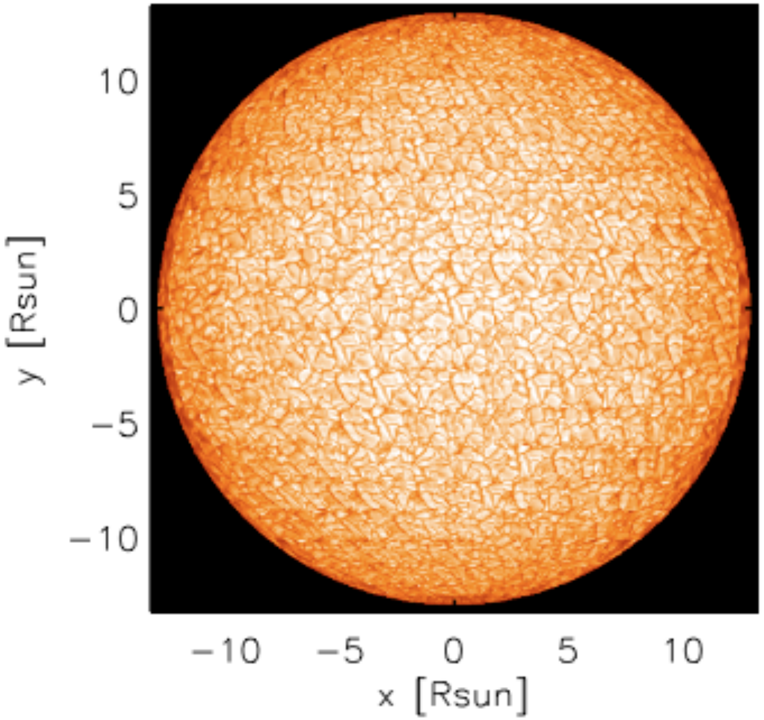




Metal poor 0.8 M$_\odot$, 23 R$_\odot$, log(g)=1.6, Teff ≅ 4600K, [Fe/H]=-3.0 (Collet et al. 2010, in preparation)

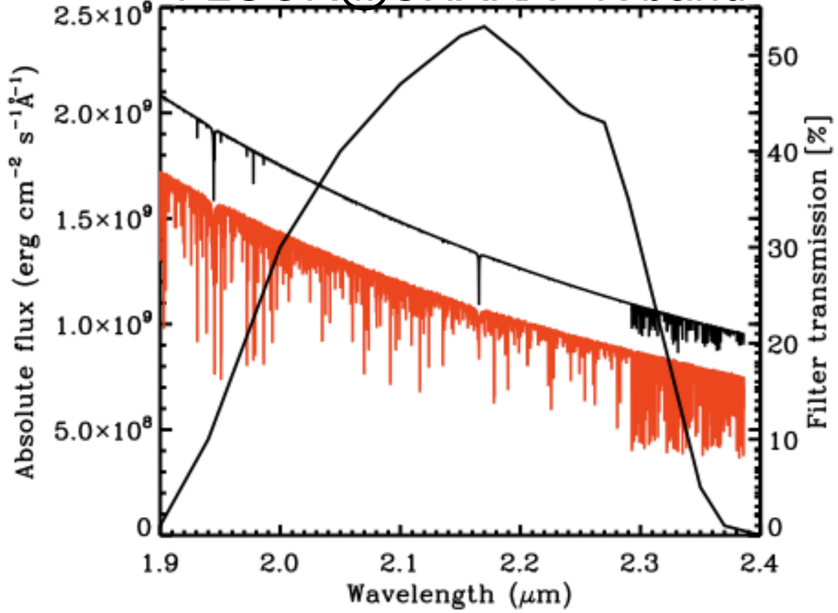
Solar metallicity 0.8 M$_\odot$, 12.9 R$_\odot$, log(g)=2.2, Teff ≅ 4700K, [Fe/H]=0.0 (Collet et al. 2007)

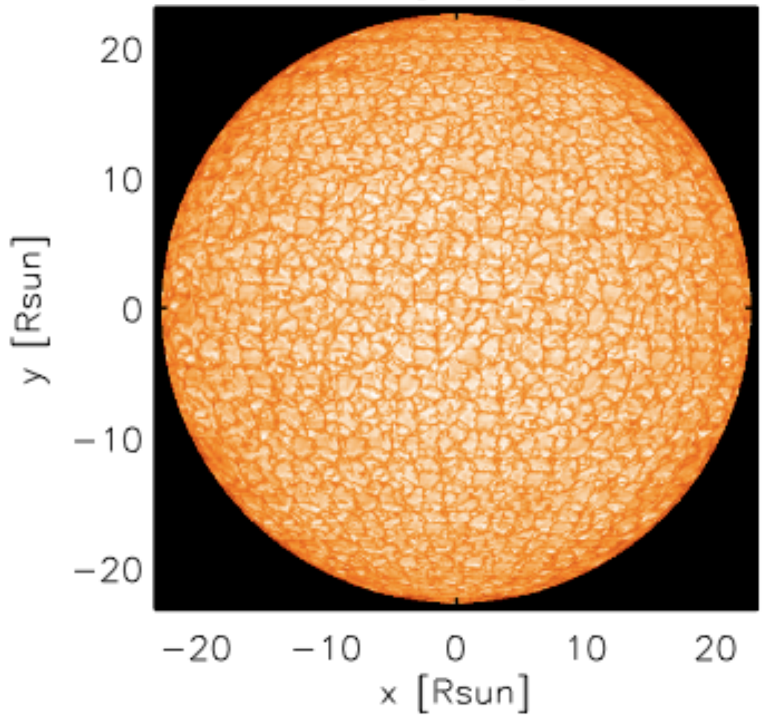
(Chiavassa, Collet et al. 2010, in preparation)



Solar metallicity giant

FLUOR@CHARA– K band

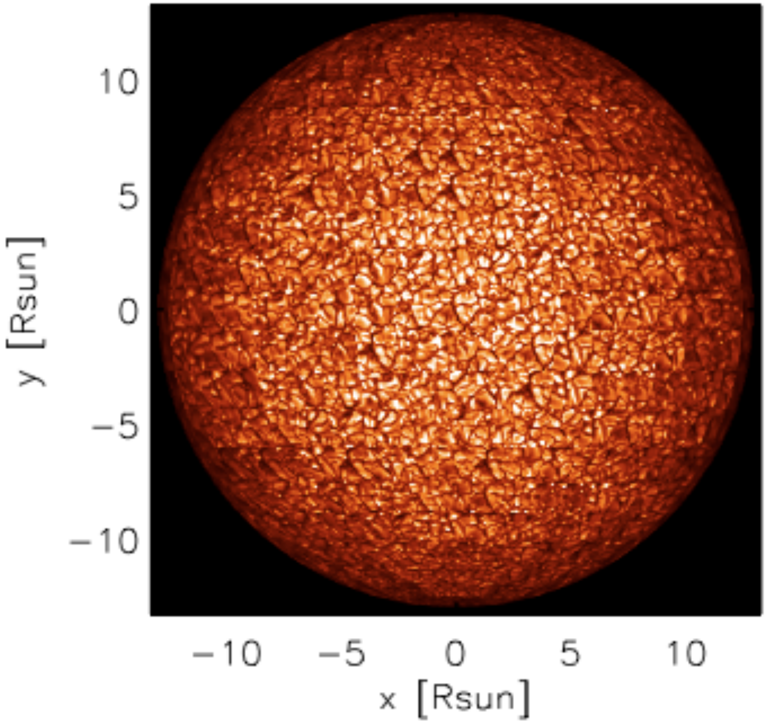




Metal poor giant

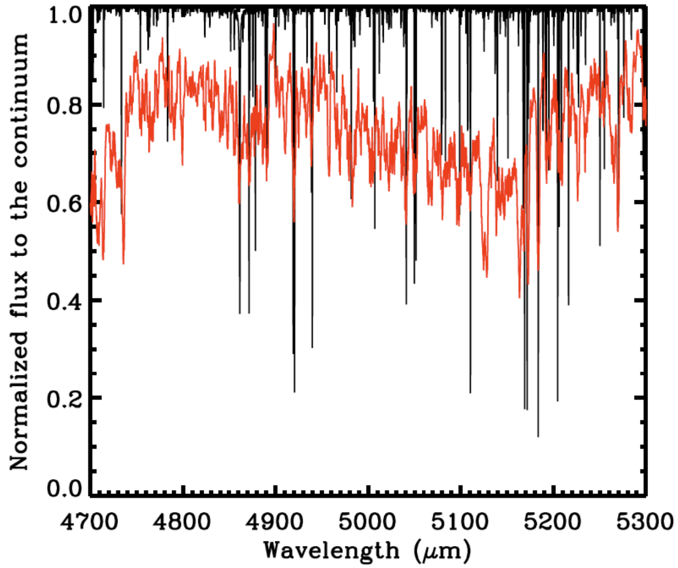
Intensity maps range: [4000,120000] erg/s/cm^2/Å

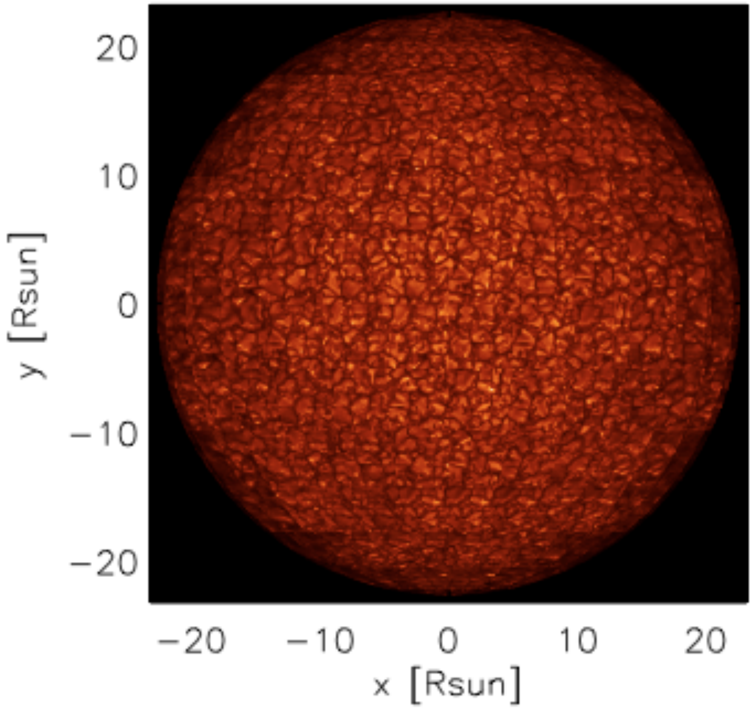
(Chiavassa, Collet et al. 2010, in preparation)



Solar metallicity giant

Optical: 4700-5300 Å

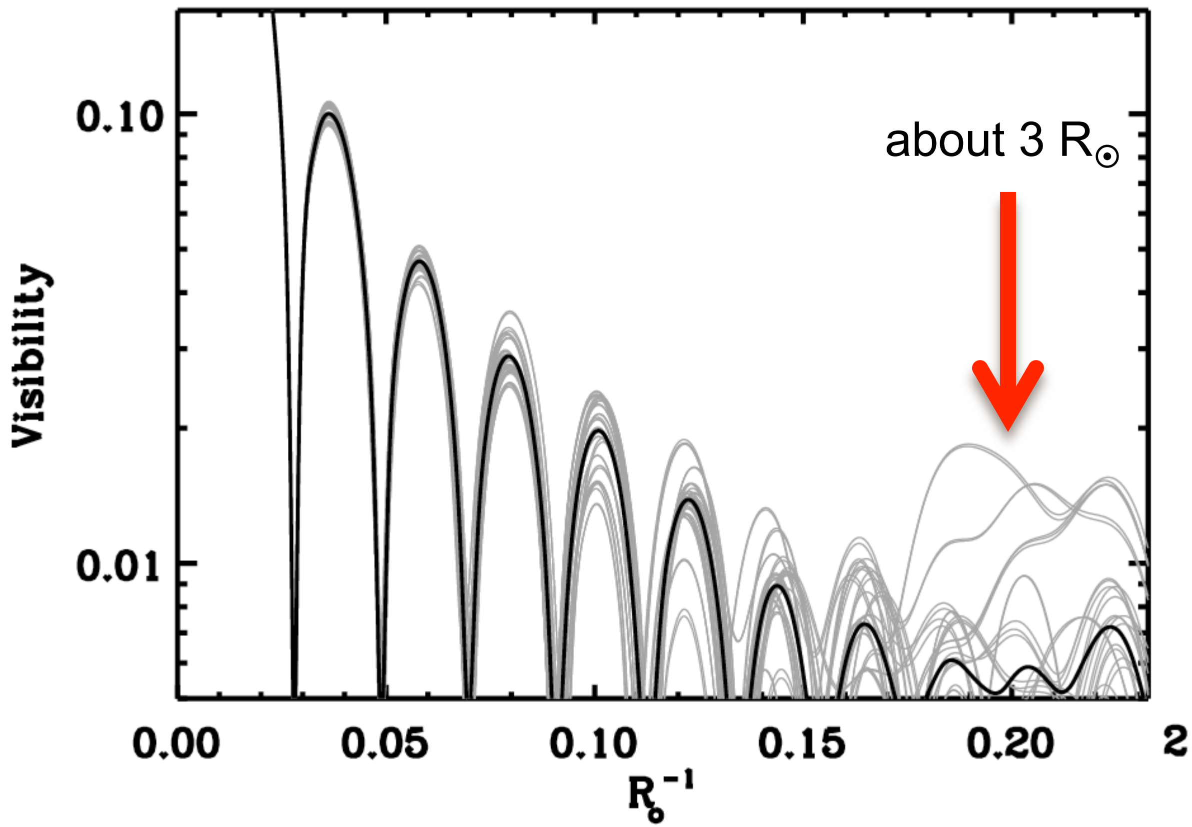




Metal poor giant

Intensity maps range: [4000,1.5×10^6]erg/s/cm^2/Å

VISIBILITIES FOR METAL POOR GIANT



Optical: 4700-5300 Å

Synthetic visibilities (grey)
Average visibility(black)

FLUOR K band

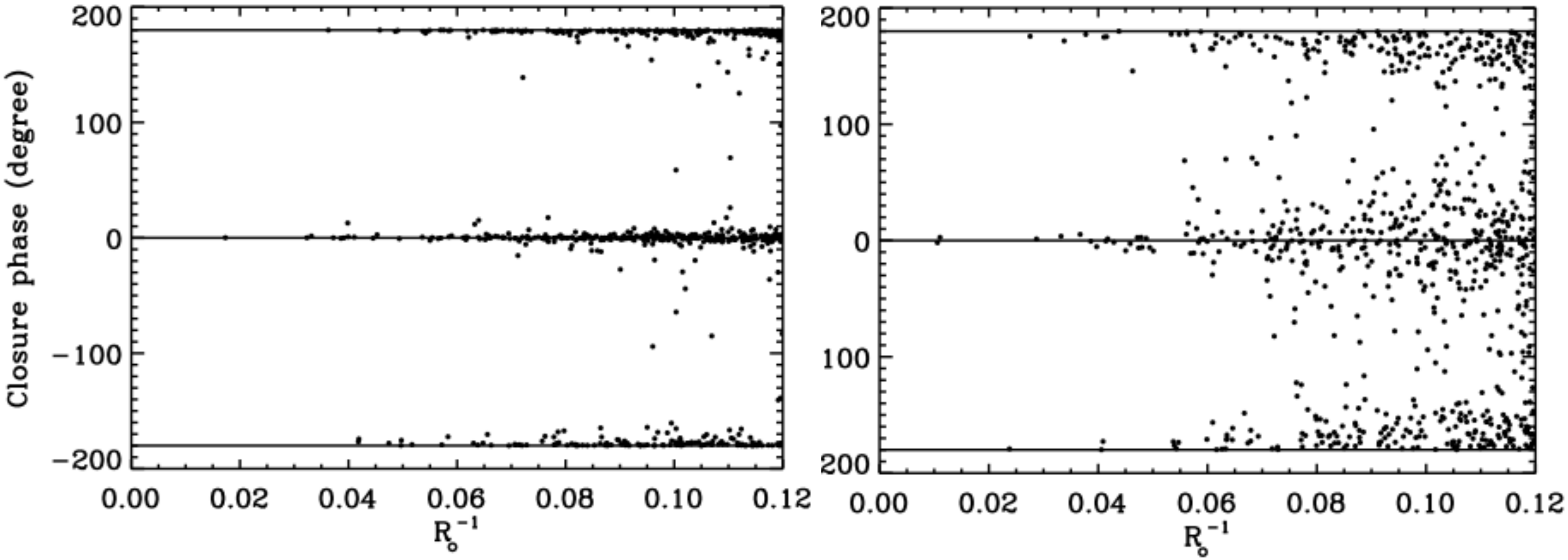
Synthetic visibilities (grey)
Average visibility(black)

$v[\text{arcsec}^{-1}]=v[R_\odot^{-1}] \times d\ [\text{pc}] \times 214.9$

… AND CLOSURE PHASES FOR METAL POOR GIANT

FLUOR – K band

Optical, 4700 – 5300 Å



500 random baseline triangles

- Clear deviation from circular symmetry

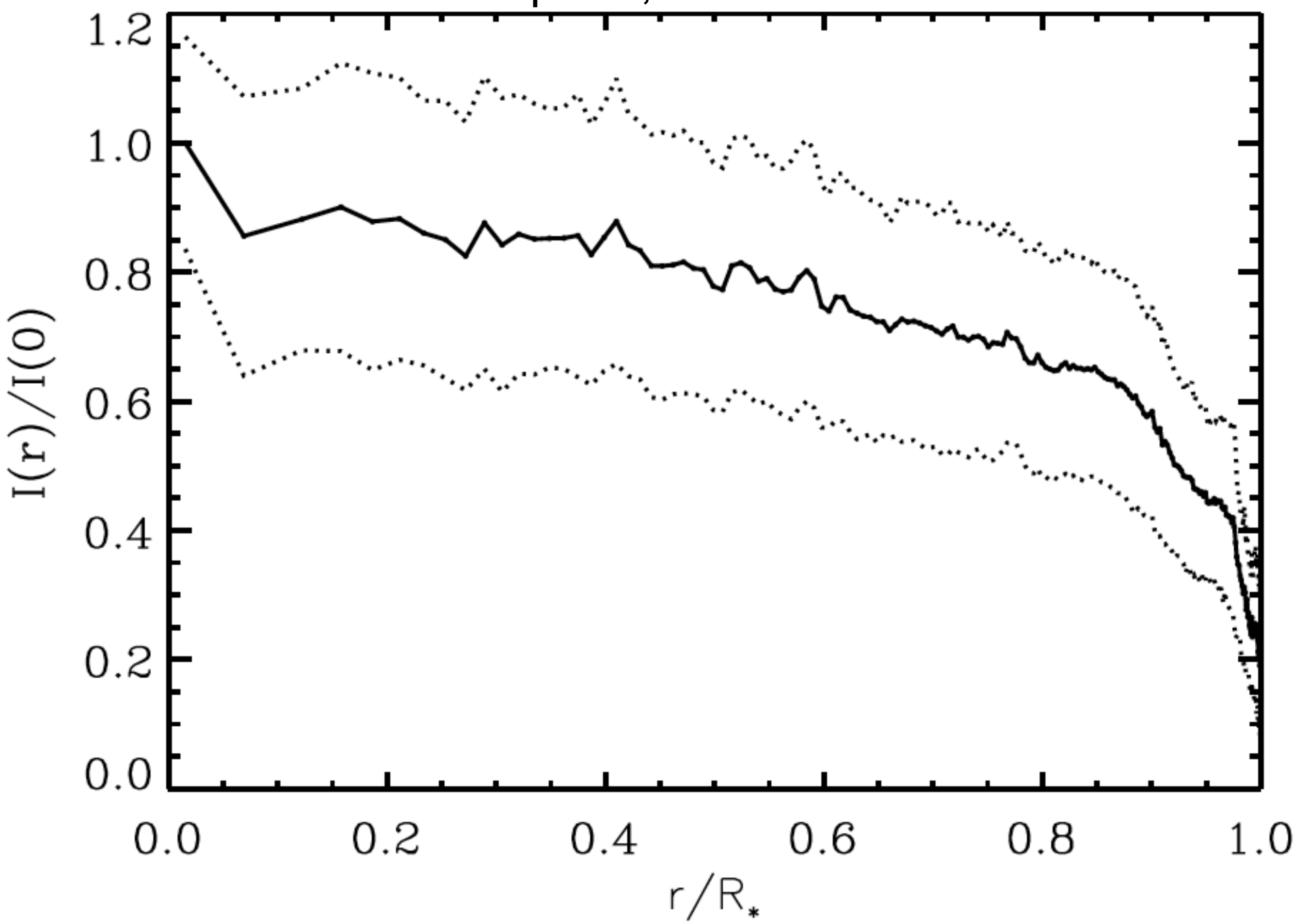
(Chiavassa, Collet et al. 2010, in preparation)

LIMB DARKENING FIT

(Chiavassa, Collet et al. 2010, in preparation)

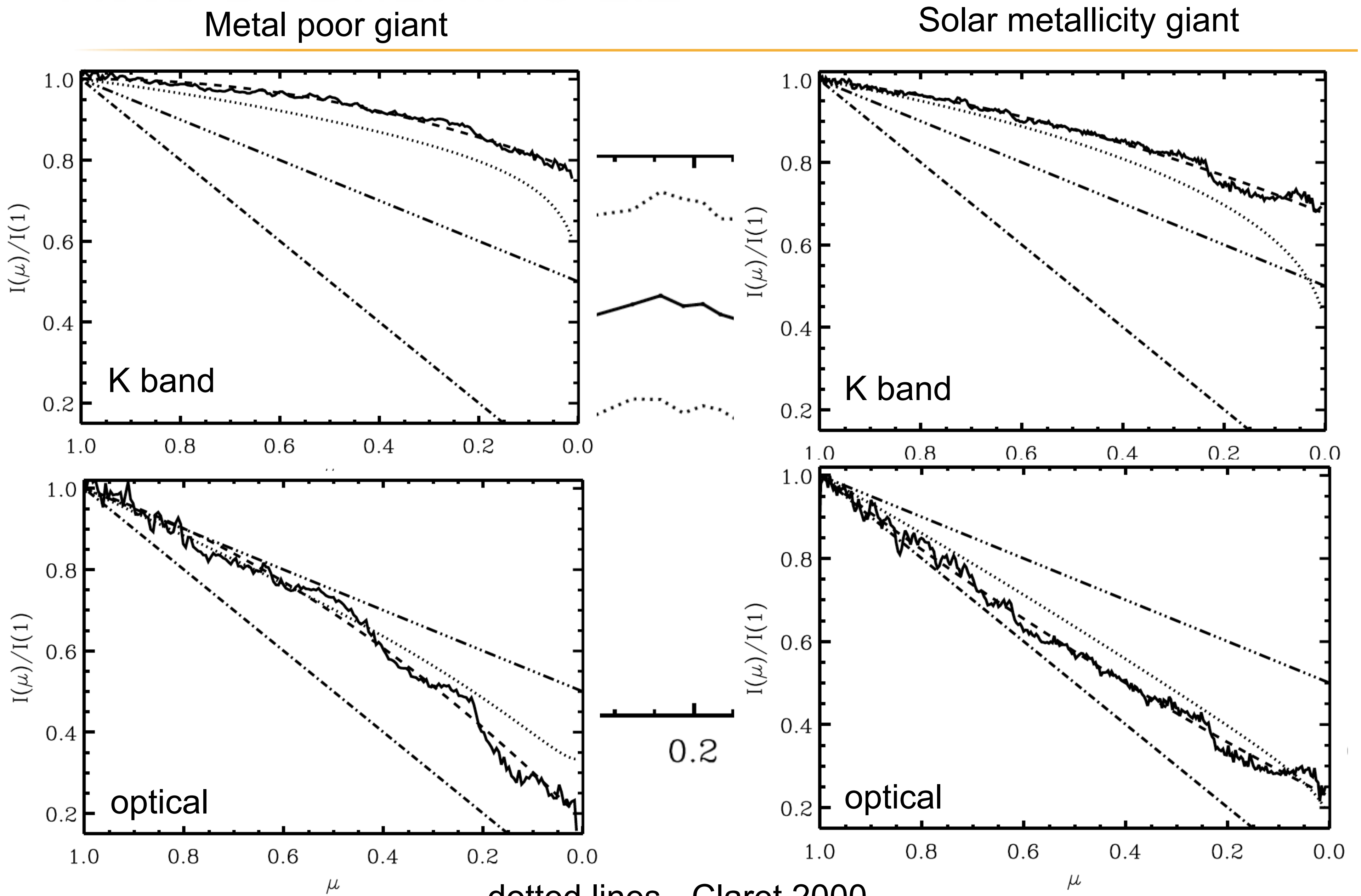
Average profile (solid black line)
1 sigma fluctuations (dotted line)

Optical, 4700 – 5300 Å



LIMB DARKENING FIT

(Chiavassa, Collet et al. 2010, in preparation)



dotted lines - Claret 2000

OUT LINE

-
-
-
- Conclusions

CONCLUSIONS

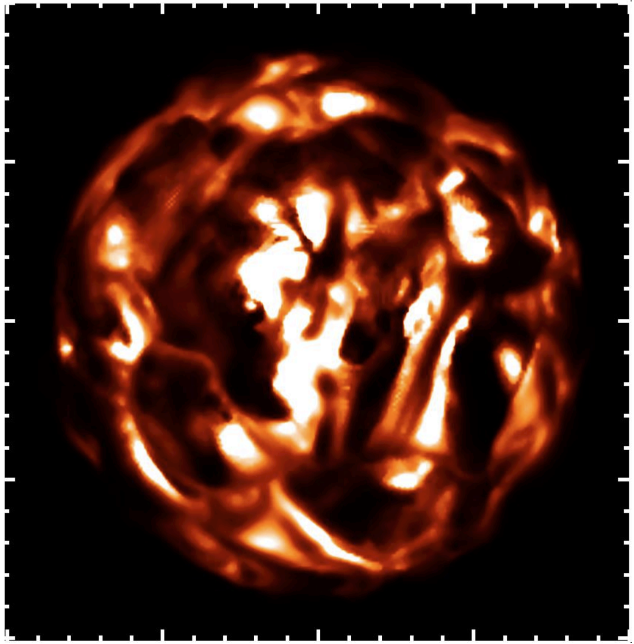
- Convection-related surface structures cause visibility/ phase fluctuations that:

1. Add uncertainty on radius measurement (RSG)
2. Clearly deviate from circular symmetry at high frequency: size distribution

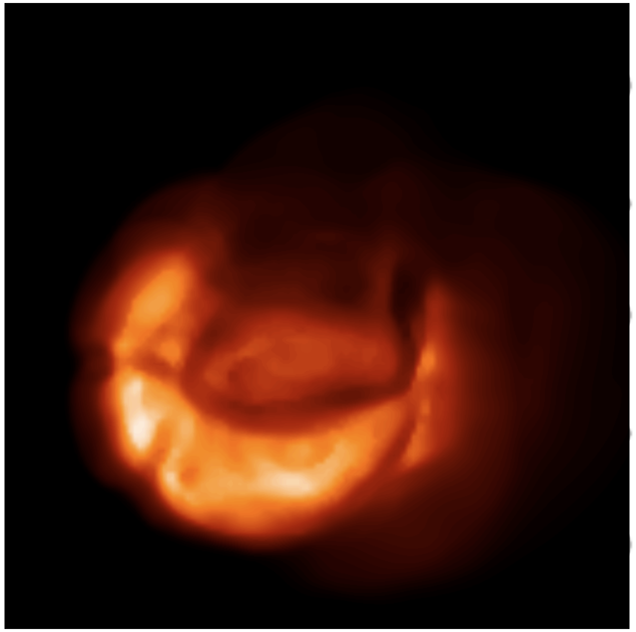
- Predicitons for giant stars at different metallicity

- Synergy between observation and modelisation: both in terms of verifying the simulations, and understanding the observations.

3D MODELS TO BE USED

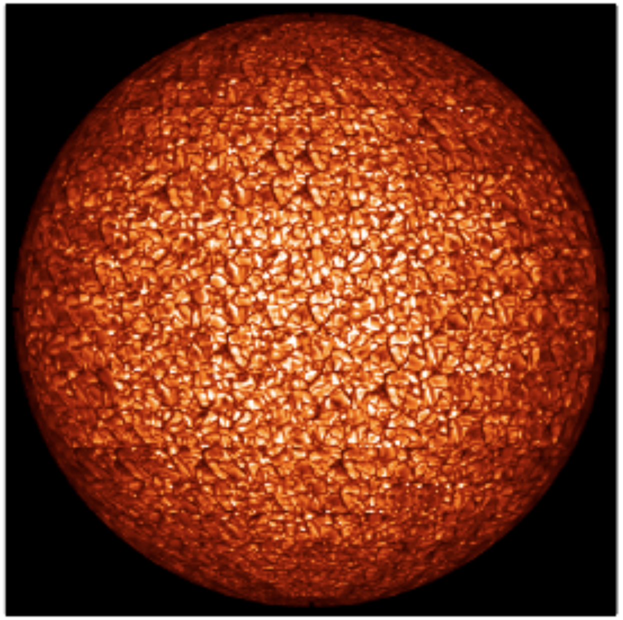


Red Supergiants (Freytag et al. 2002; Chiavassa & Freytag 2010, in prep.)



AGB (Freytag & Hoefner 2008)

See applications in Chiavassa, Lacour, Millour et al. 2010, A&A in press



Red Giant Branch

THANK YOU