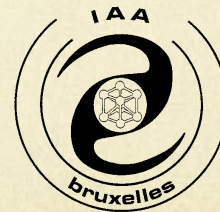


# **3D hydrodynamical simulations of cool stars**

**Andrea Chiavassa**

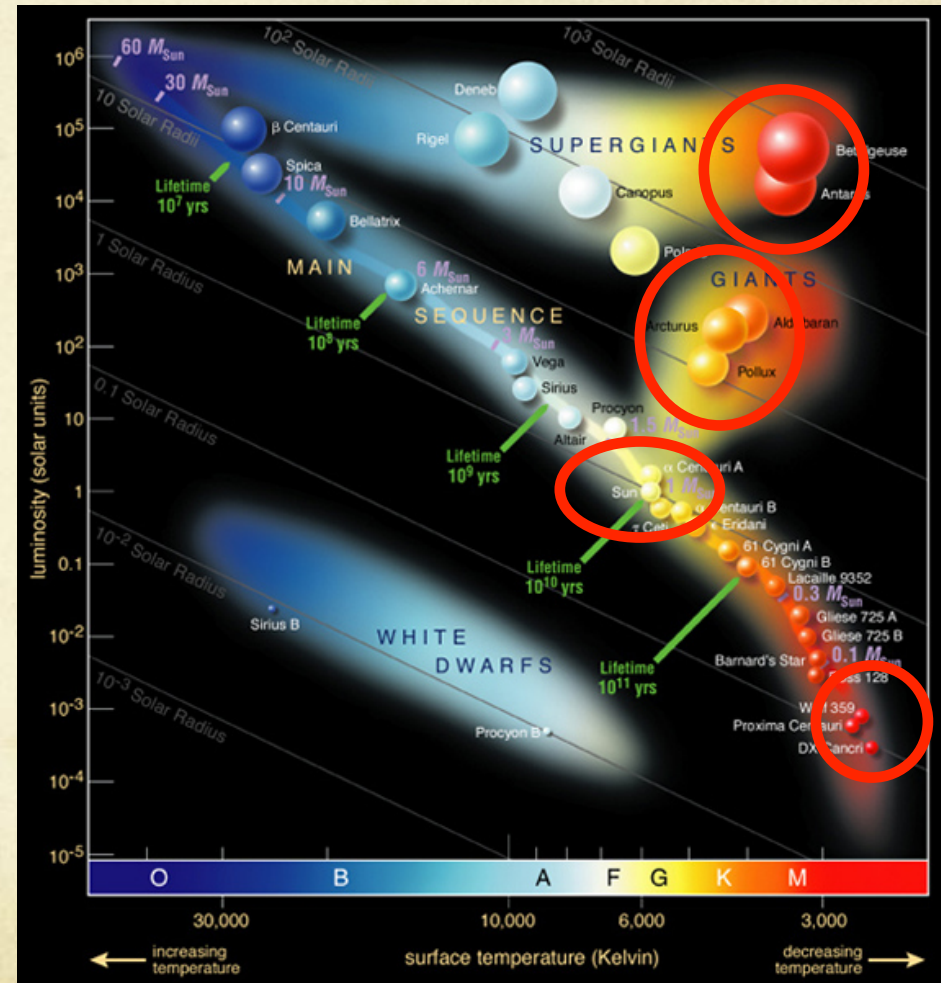
**Institut d'Astronomie et d'Astrophysique  
Université Libre de Bruxelles**



**Brussels 17 May 2011**

# 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**.





# 3D hydrodynamical simulation of stellar atmosphere

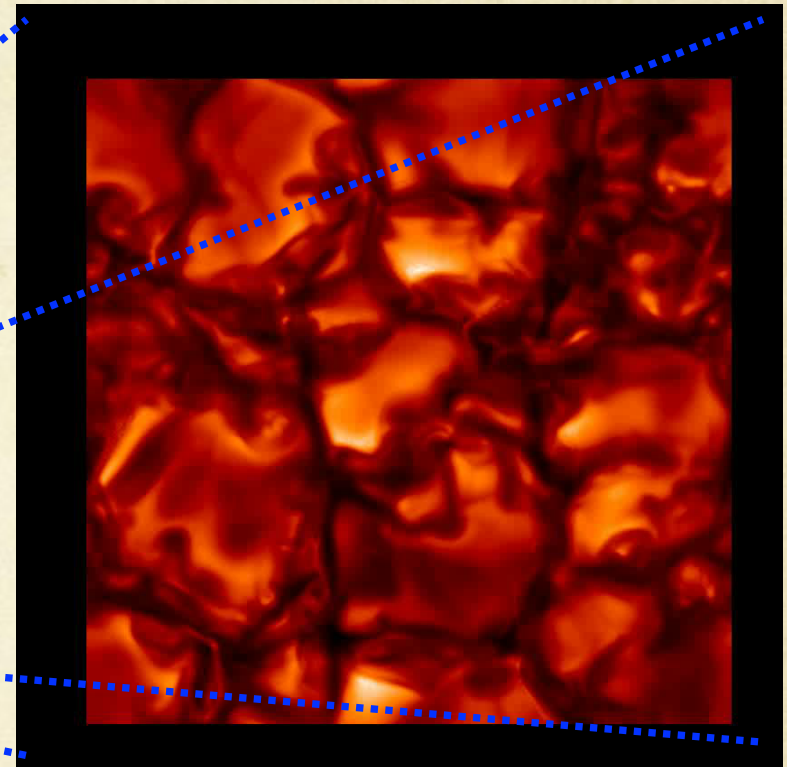
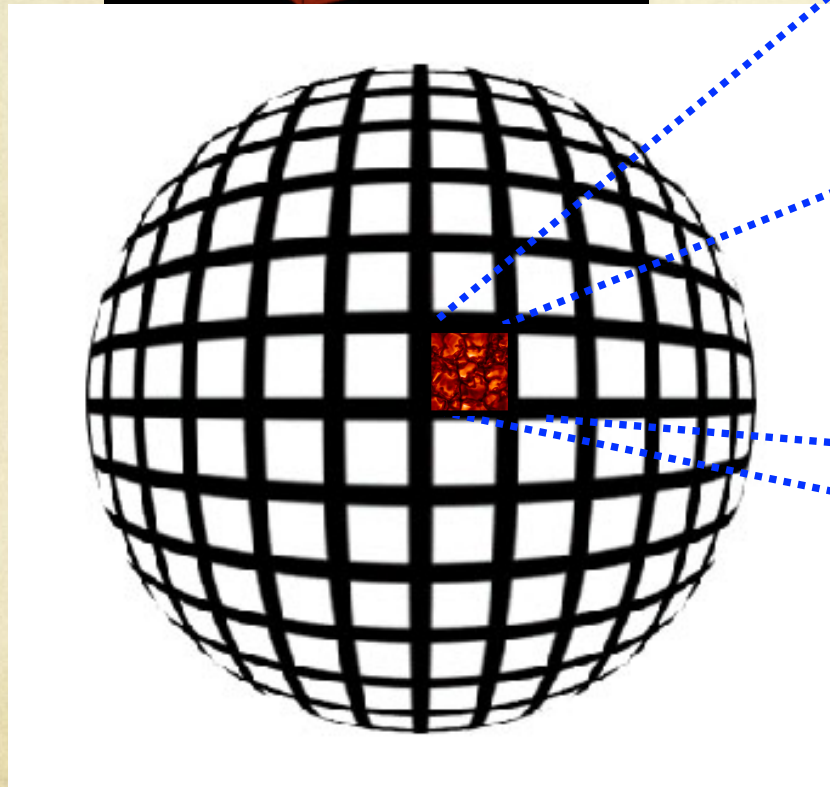
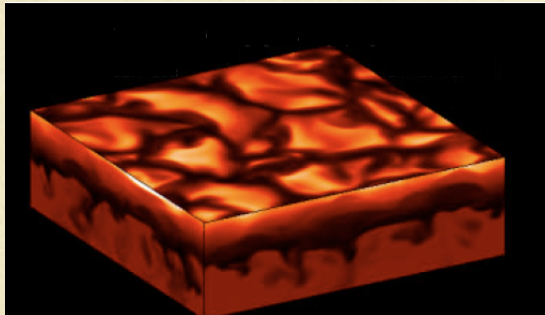
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## New generation of atmospheric models

- 3D Hydrodynamics (Grid:  $200^3$  -  $300^3$  -  $500^3$ )
- Radiative transfer, EOS & detailed opacities

# 3D hydrodynamical simulation of stellar atmosphere

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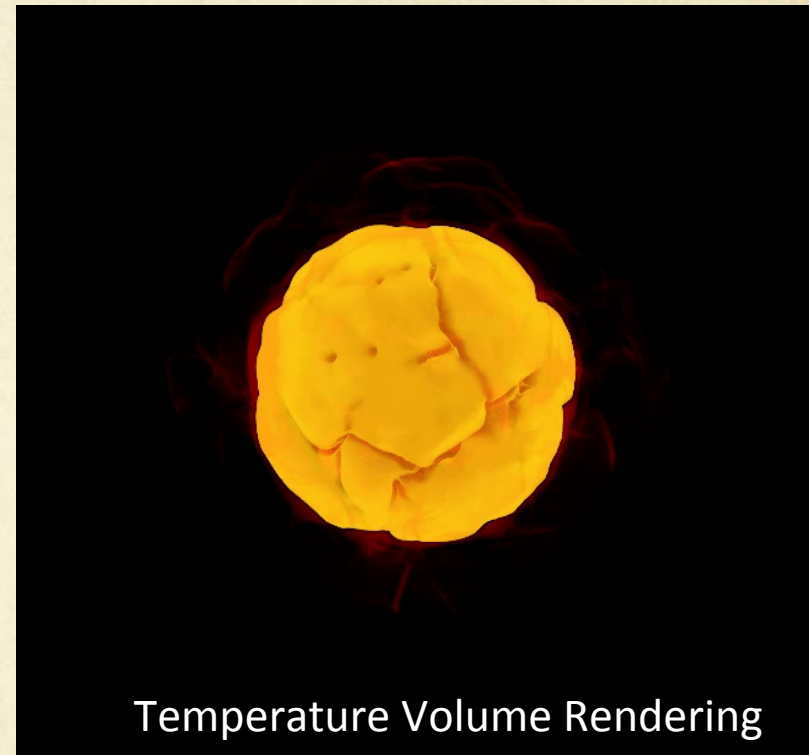
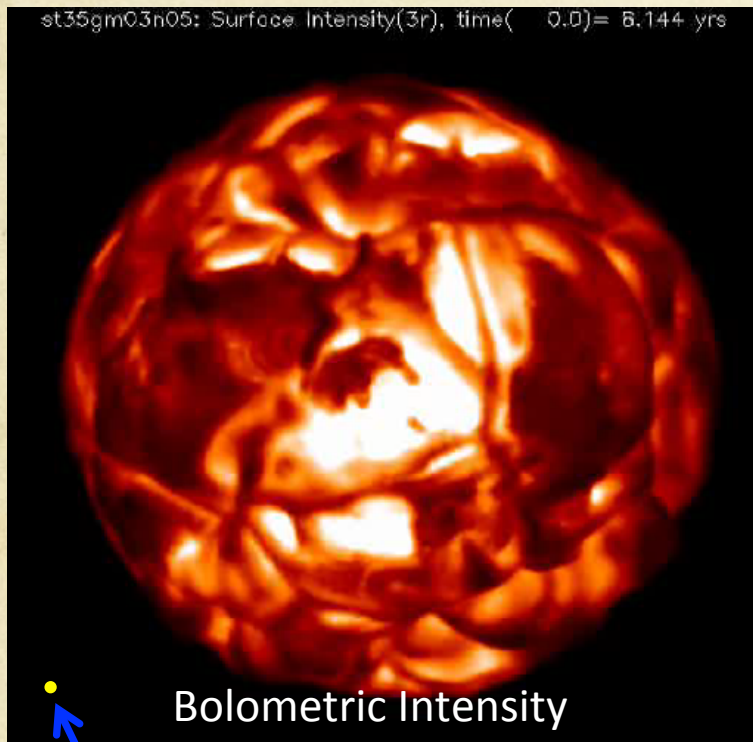
## LOCAL SIMULATIONS

(done with Stagger Code, Nordlund, Stein, Asplund 2009)

Main sequence and red giant stars



# 3D hydrodynamical simulation of stellar atmosphere



Sun

## GLOBAL SIMULATIONS

(CO5BOLD – Freytag et al. 2002; Chiavassa, Freytag, Masseron, Plez 2011, to be submitted)

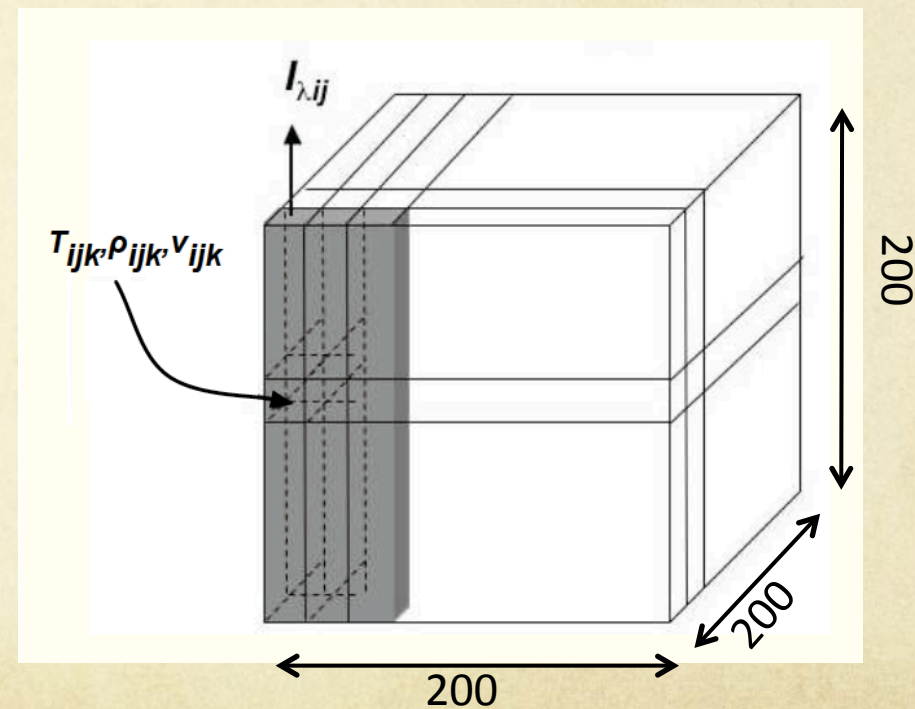
Red supergiant and AGB stars

# Detailed 3D radiative transfert code

## OPTIM3D : 3D radiative transfert code

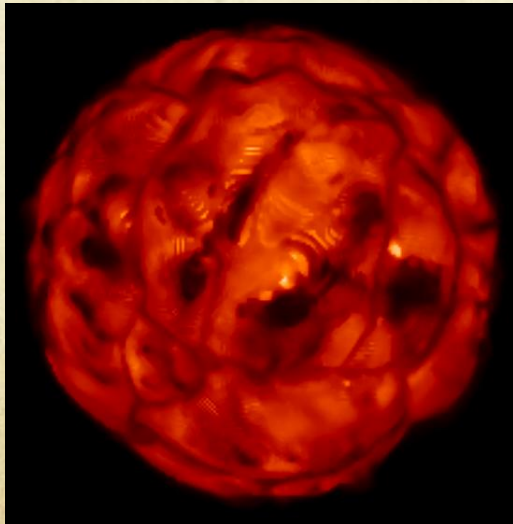
**Detailed** (billions of atomic and spectral lines) and **fast** (computational time slightly larger than 1D computation) post processing of 3D simulations.

Extraction of  
interferometric,  
spectroscopic,  
photometric observables



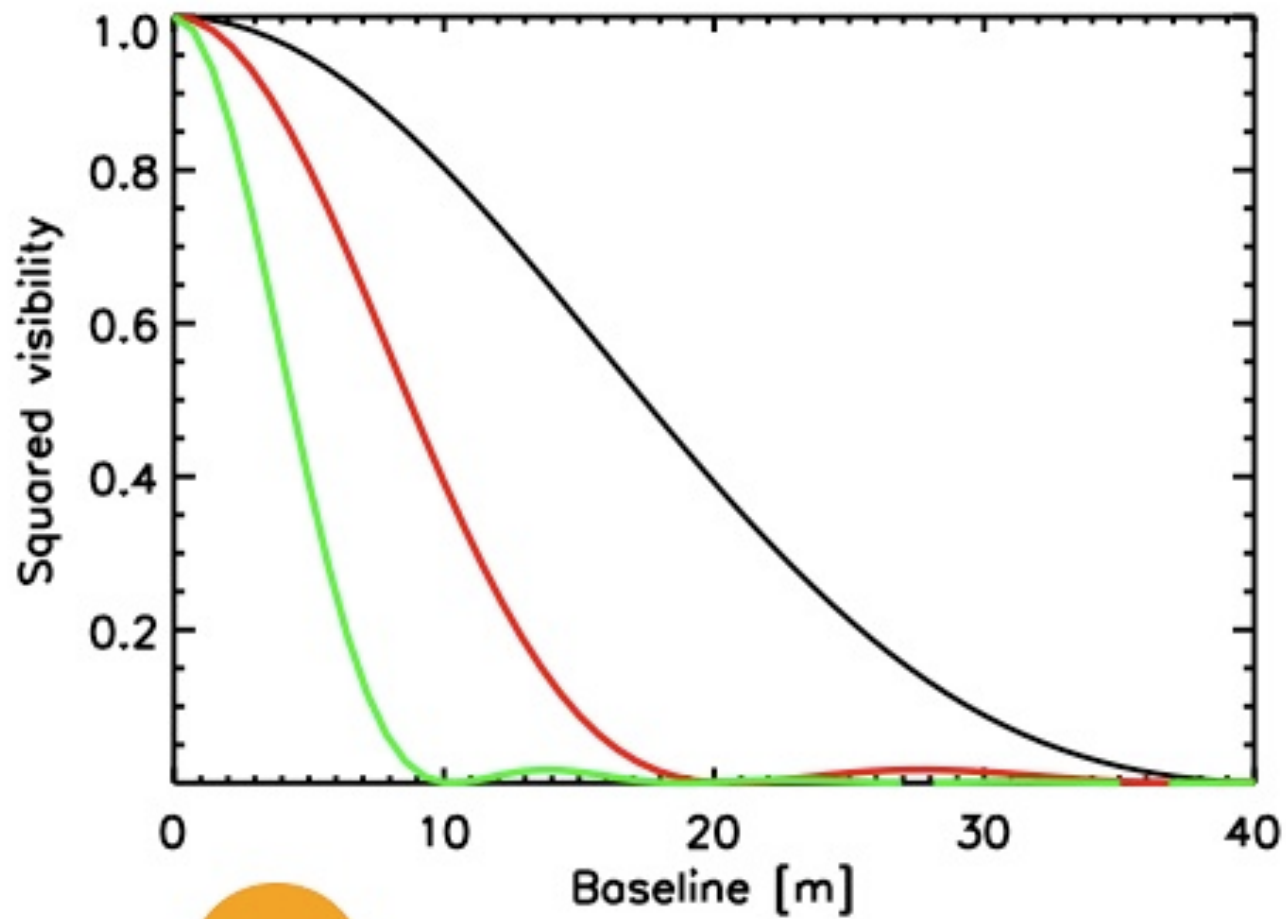
**3D**  $\rightarrow$  200 x 200 x 100 x 100  
 $10^8$  times **1D computations**

# Detailed 3D radiative transfert code



To constrain the  
structure size





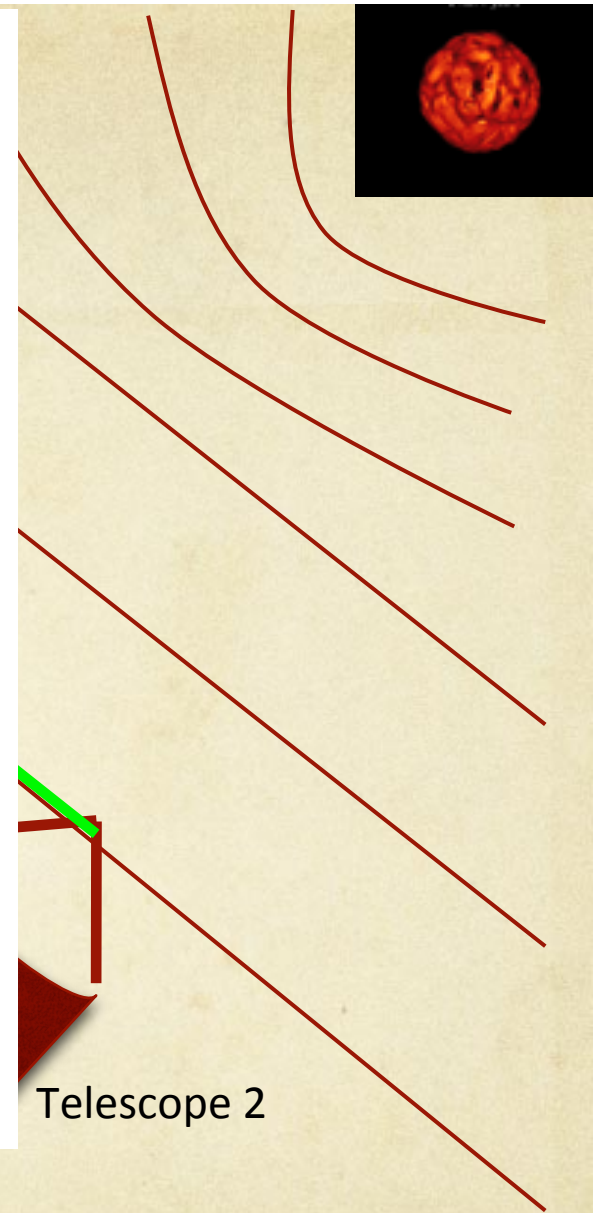
40 mas



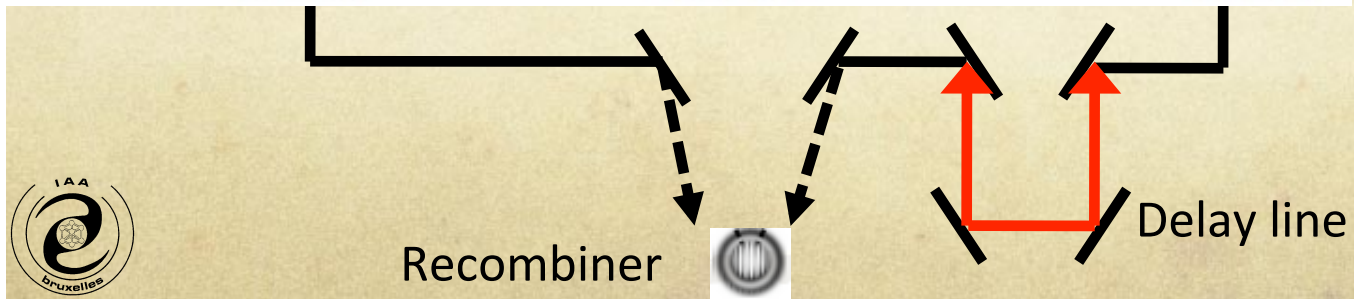
20 mas



10 mas



Telescope 2



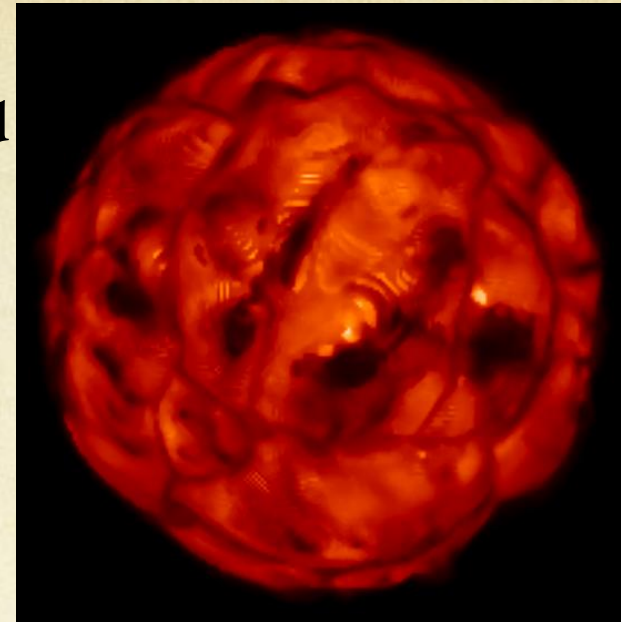
Recombiner



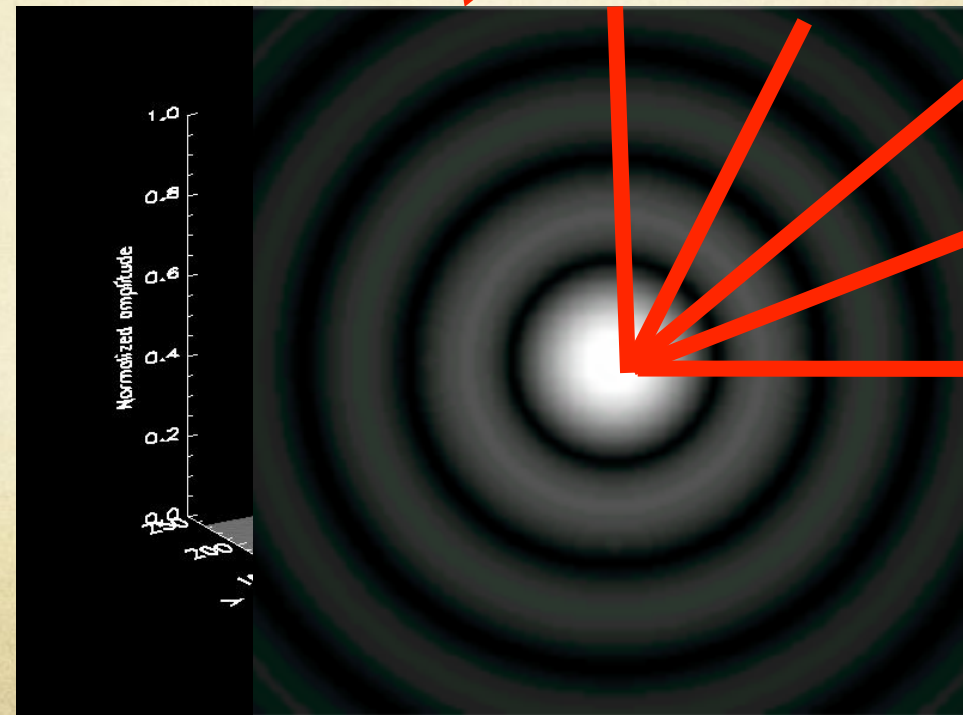
Delay line



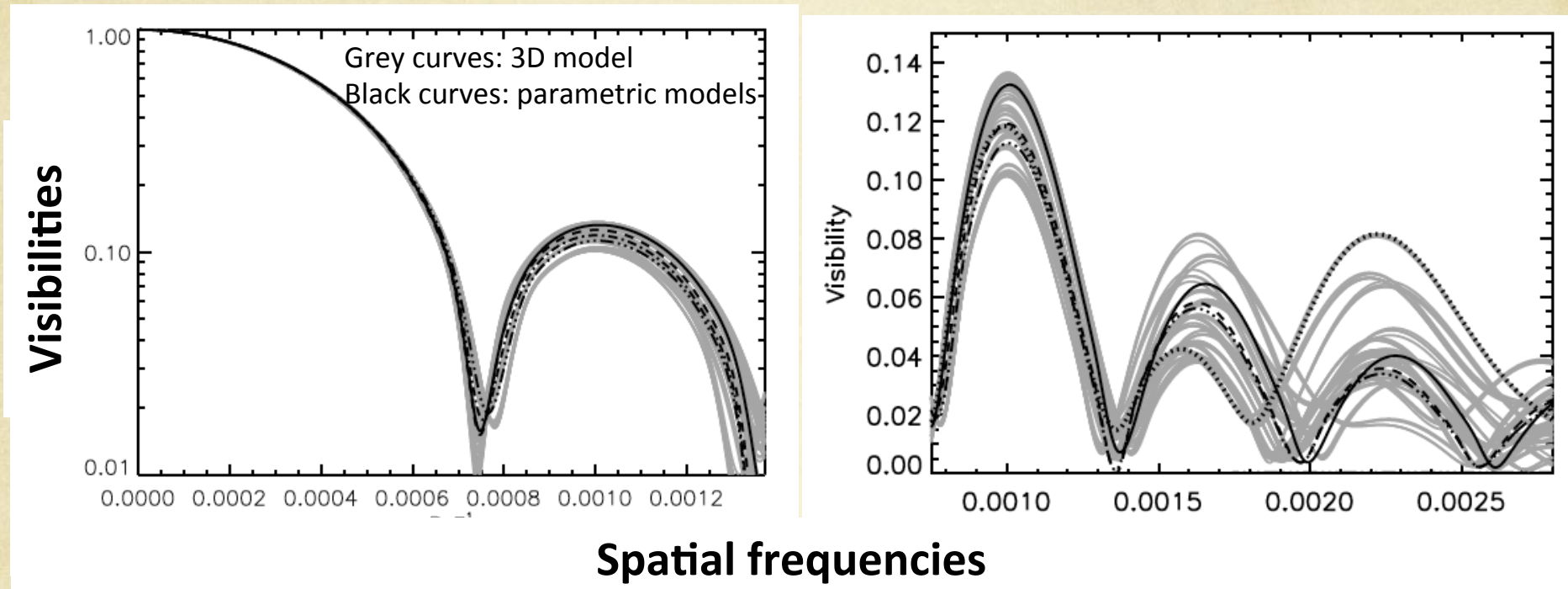
INPUT:  
3D computed image at the desired  
wavelength filter



Fourier Transform



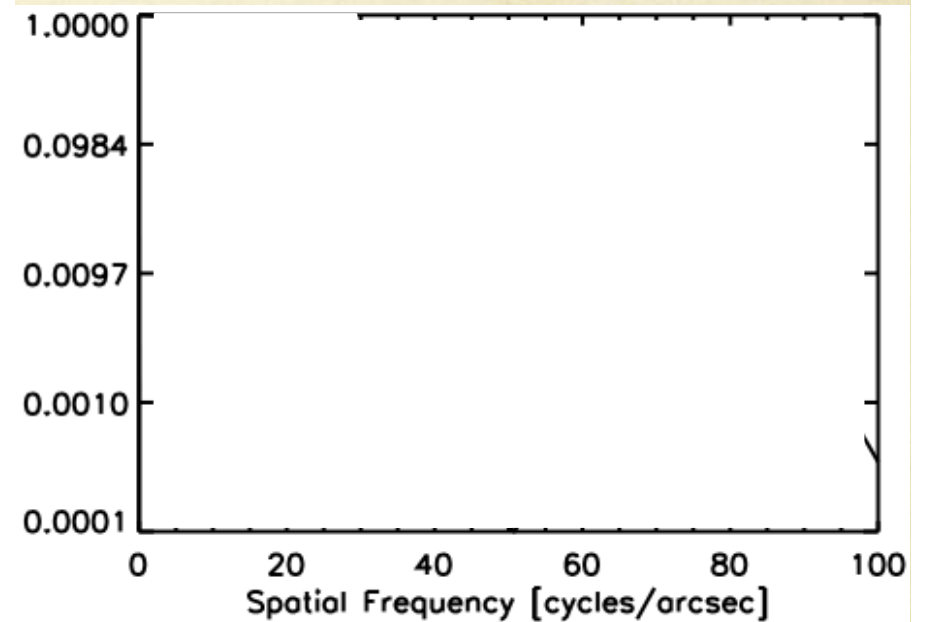
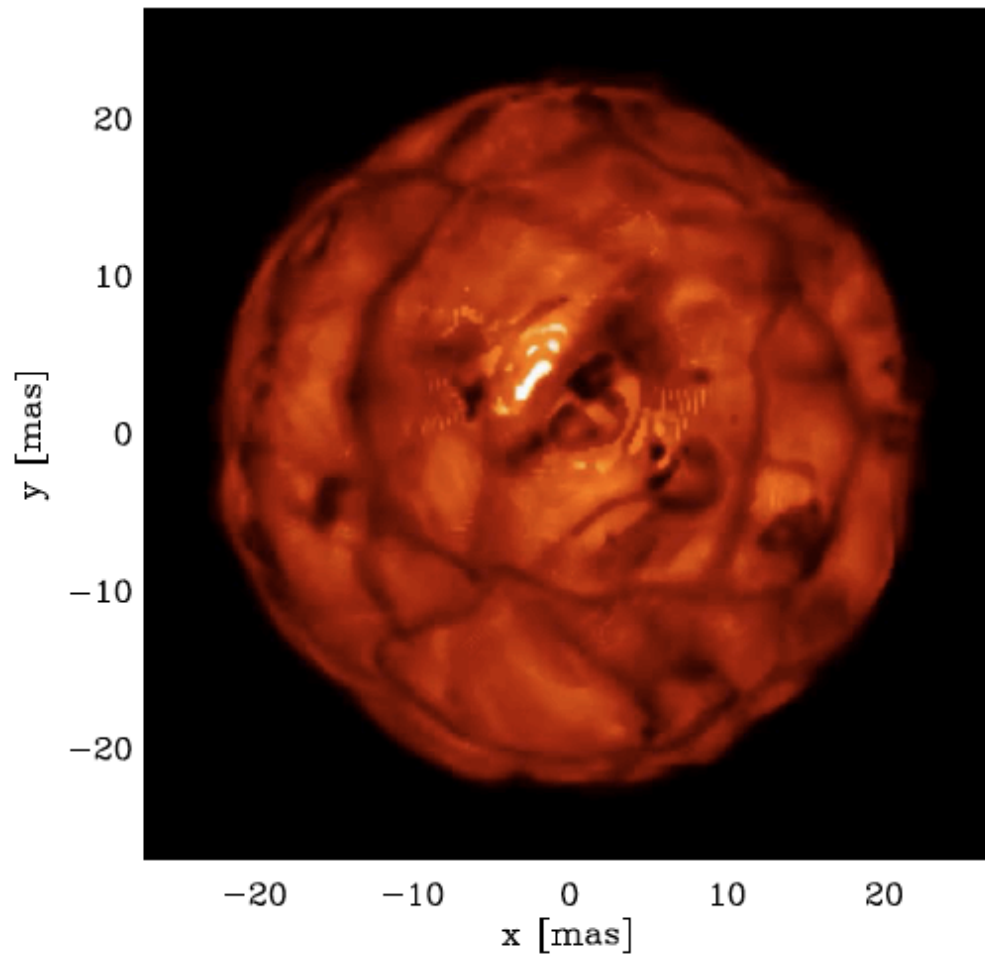
# Visibility curves



**Incertitude** on radius determination.  
Clear deviations from spherical symmetry! **Signature of convection**

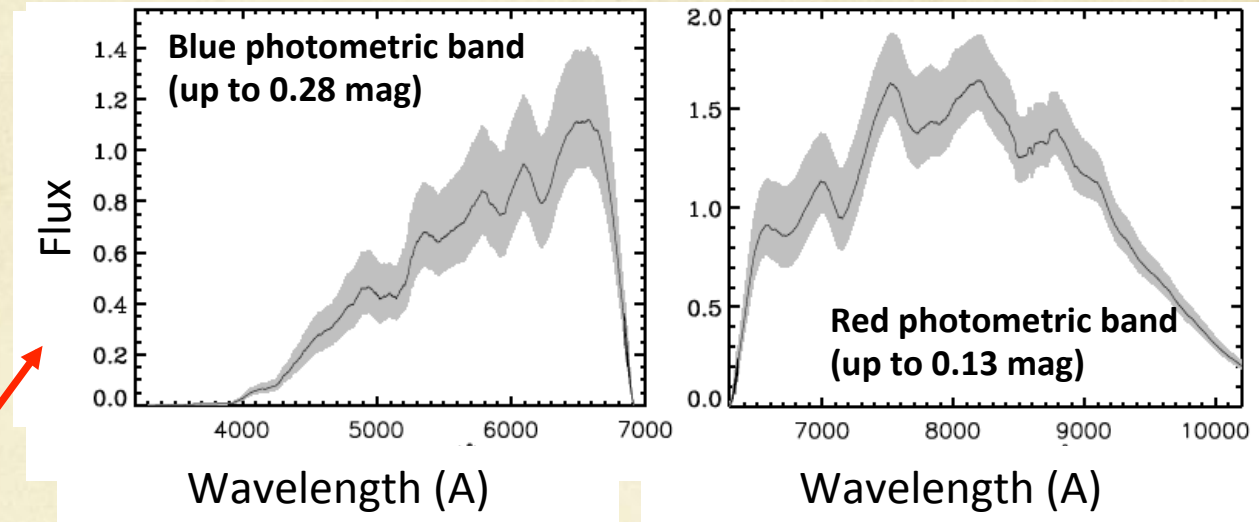


# Convective cells distribution on red supergiants

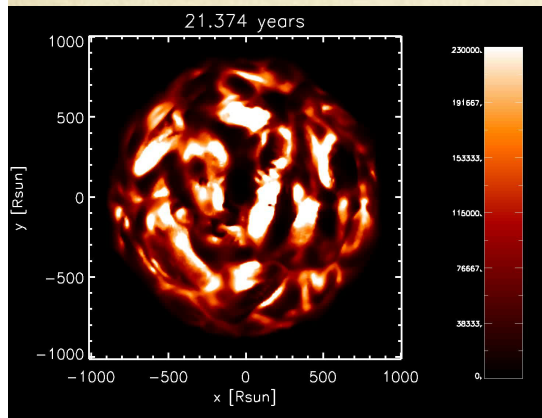


# and applications to Gaia

## Predicted photometric variability over 5 years



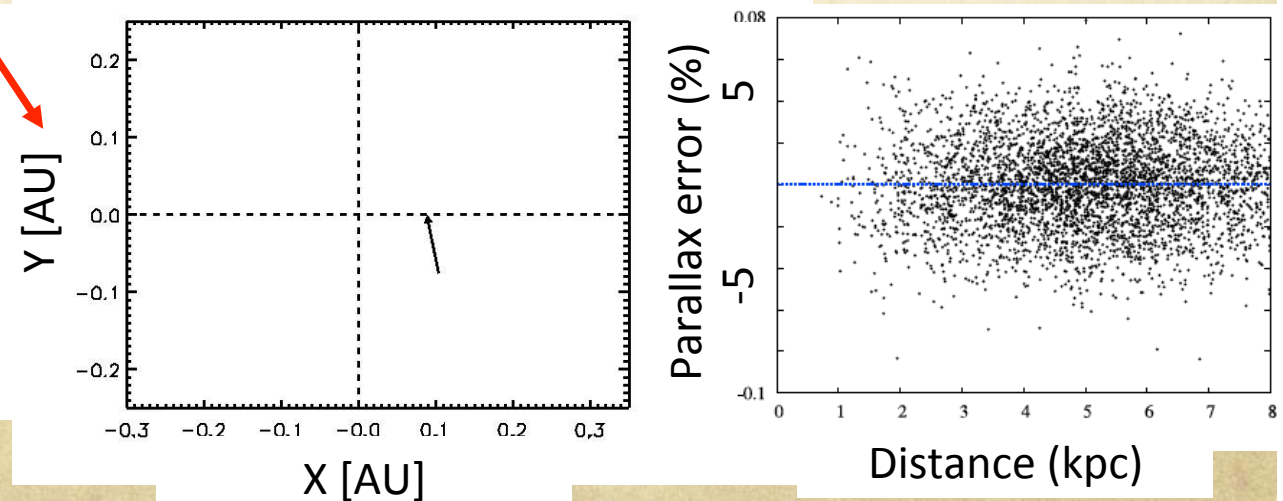
Images computed in Gaia – G band



Consequences of Gaia measurements

Chiavassa, Pasquato, Jorissen, et al. 2011 A&A, 528, id.A120

## Predicted photocenter variability over 5 years





# TODO list: photocenter correction for late type stars

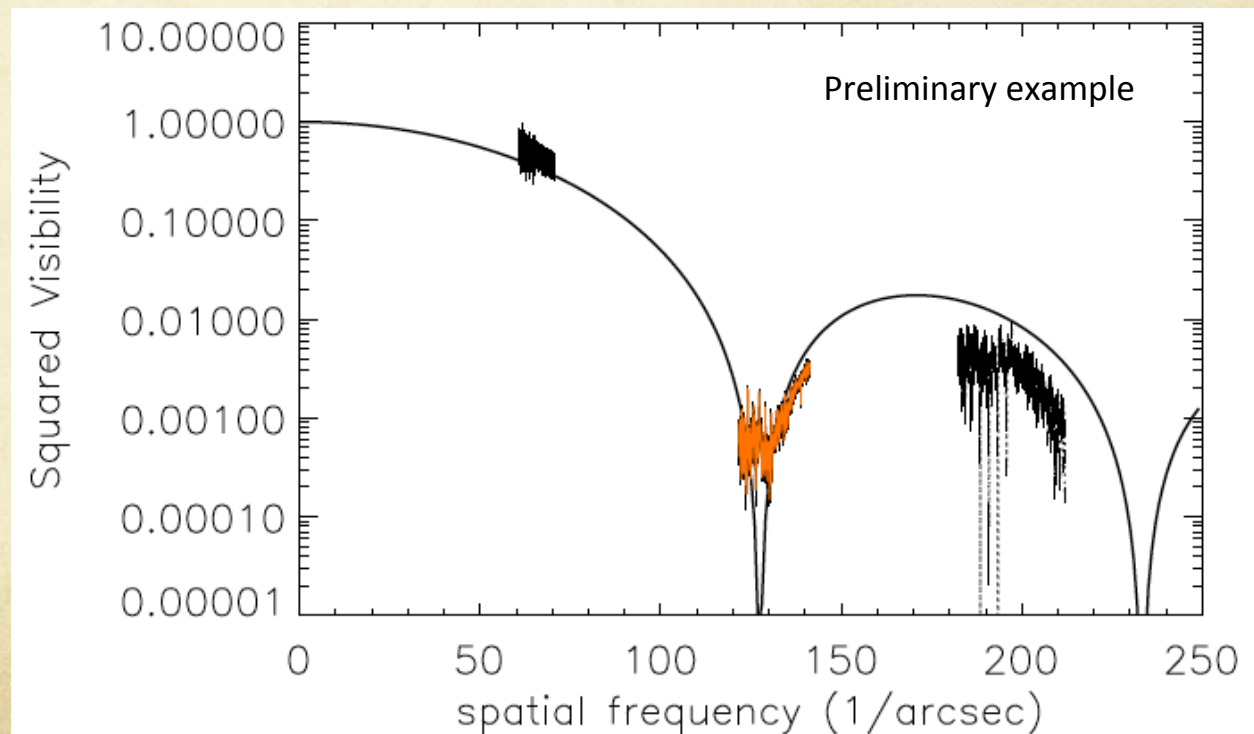
- Large set of observed evolved stars: 18 stars (red giants, carbon stars, red supergiants)
- Long temporal sample of AMBER/VLTI observations (Belgian guaranteed time: 03/ 05/ 08/2009, 03/ 10/ 12/2010)



Aim: **Investigation of the impact of surface brightness asymmetries**

1 paper published,  
1 paper to be submitted,  
1 paper in preparation +

...



# Conclusions

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- Today parallel computers are performing enough to compute large simulations
- 3D hydrodynamical simulations are needed for a quantitative analysis of large set of observations
- Stellar grids of local and global models are under development



Thank you

