# A "medical" scan of the velocities in the atmosphere of evolved stars.

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#### Context

- Velocity fields in evolved stars
- Tomographic method
- Observing the Red Supergiant µ Cep
- Conclusions







The surface structures and dynamics of cool stars are characterised by the presence of convective motions and turbulent flows which shape the emergent spectrum.

The size of granules depends on the stellar parameters of the star and, as a consequence, on the extension of their atmosphere.

Courtesy of M. Carlsson





#### • Velocity fields in evolved stars

#### Velocity fields in evolved stars



#### Velocity fields in evolved stars



Wavelength [Å]

#### Velocity fields in evolved stars



• Tomographic method

#### Tomographic method



# Tomography in Red Supergiant stars



Temperature (and density) structure permeated by random shocks

# Tomography in Red Supergiant stars



# Tomography in Red Supergiant stars

Retrieve the vertical component of the velocity field as a function of depth in the stellar atmosphere, sorting spectral lines according to their formation depth.

Mask are produced.





Kravchenko et al. (2018, A&A, 610, A29)

#### Tomography in Red Supergiant stars: Cross Correlation Function



#### Tomography in Red Supergiant stars: Cross Correlation Function



• Observing the Red Supergiant µ Cep

HERMES spectrograph (MERCATOR telescope, La Palma, Spain)
Spectral resolution: 85000
95 high-resolution spectra with S/N ~ 100

► Time span of 2500 days (~ 7 years)



Kravchenko et al. 2019, submitted to A&A



 $\mu$  Cep displays several photometric period. Among with the one at 840 days (similar to the 860 days of Betelgeuse, Kiss et al. 2006)

Kravchenko et al. 2019, submitted to A&A



Mu Cep - prototypical RSG. Convection turn-over of the material in stellar atmosphere.

Velocity maps reveal upward and downward motions of matter extending over large portions of the stellar surface.

Extraction of the convective timescales (from 300 to 850 days).



6.15 years

# Conclusions

- The tomographic method allows to recover the distribution of the component of the velocity field projected on the line of sight at different optical depths in the stellar atmosphere.
- Convective motions develop all the way from the center of the star to the surface, separated by the downdrafts appearing as fingers



Radial Velocity in simulations