

The Betelgeuse/Leona occultation 12th December 2023

Miguel Montargès

LESIA l'Observatoire de Paris | PSL 

Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

 Région
Île de France



 GEMINI
COOPÉRATION
ASTRONOMES PRO-AM

 S A F

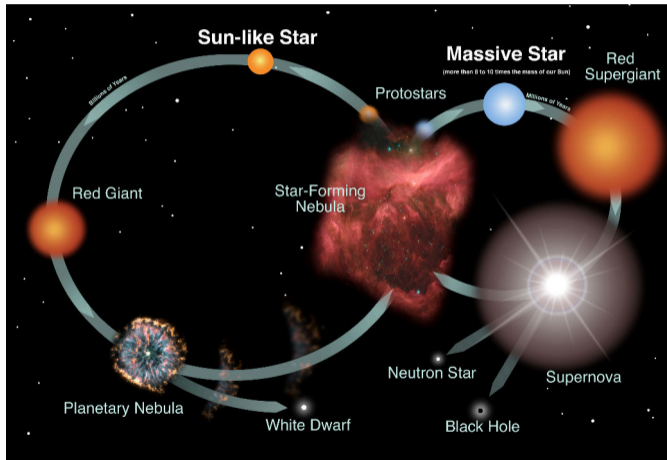
SOCIÉTÉ
ASTRONOMIQUE
DE FRANCE

SAF international briefing
11th November 2023

Derrick Lim
APOD 21 Mar, 2018

This project received funding under the Framework Program for Research and Innovation "Horizon 2020" under the Marie Skłodowska-Curie Grant Agreement No. 945298.

Stellar evolution cycle

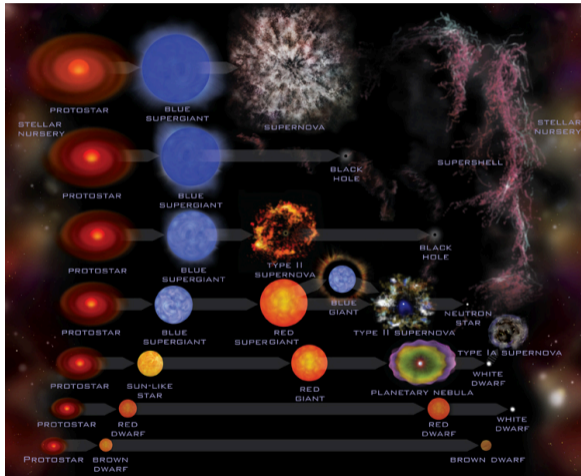


Asymptotic
Giant Branch
(AGB,
 $M_{\text{init}} \lesssim 8 M_{\odot}$)

Red
supergiant
(RSG,
 $M_{\text{init}} \gtrsim 8 M_{\odot}$)

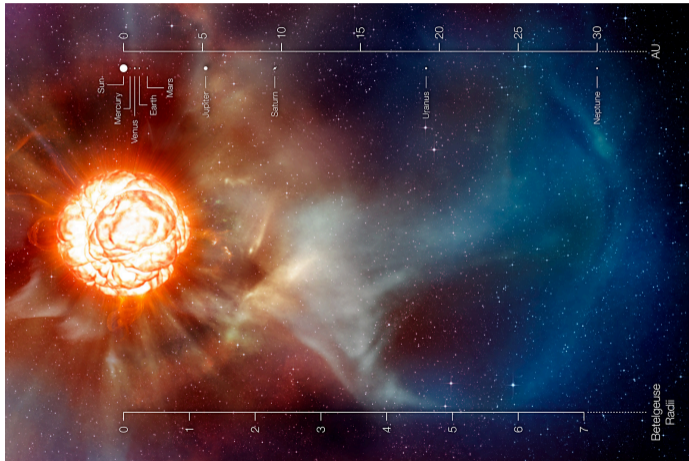
Credits: NASA and the Night Sky Network

Stellar evolution cycle



Credits: NASA/Chandra

Mass loss of red supergiant stars



1 M_{\odot} / 500 000 years

Credits: ESO/L. Calçada / Video st35gm04b0n002_I3brm_1

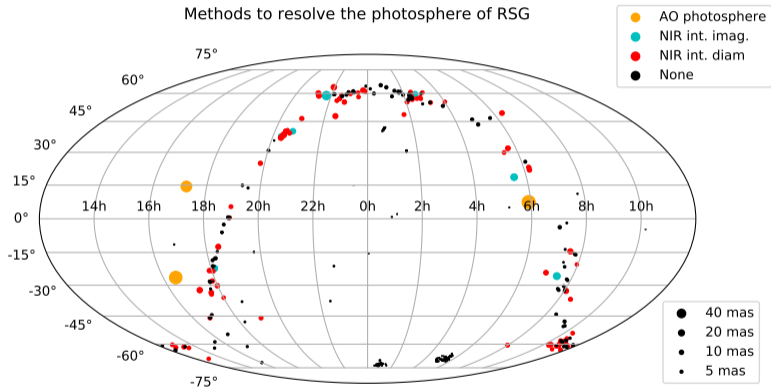
The unknown

- How to start dust condensation (location, ambient conditions, first dust species, dust precursors) ?
- How to launch material from the photosphere ?

The unknown

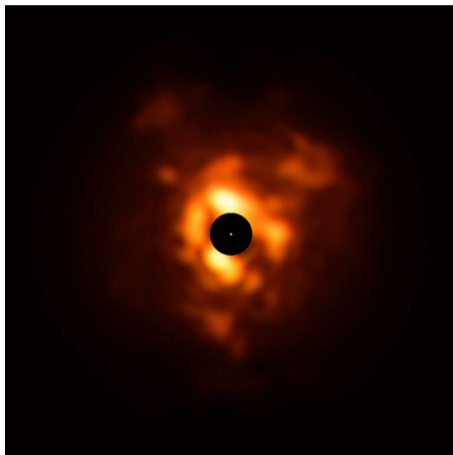
- How to start dust condensation (location, ambient conditions, first dust species, dust precursors) ?
- How to launch material from the photosphere ?
 - Convection timescale ?
 - Convective cell sizes ?
 - Turbulent velocity in the convective cells ?
 - Convection at the origin of the magnetic field ?

RSGs as seen from Earth



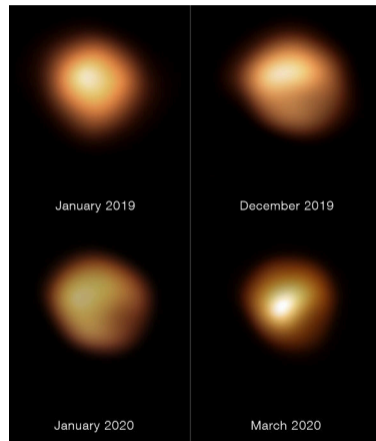
Credits: M. Montargès

Betelgeuse with high angular resolution



VLT/VISIR at $10\mu\text{m}$ - FoV : 5.63"

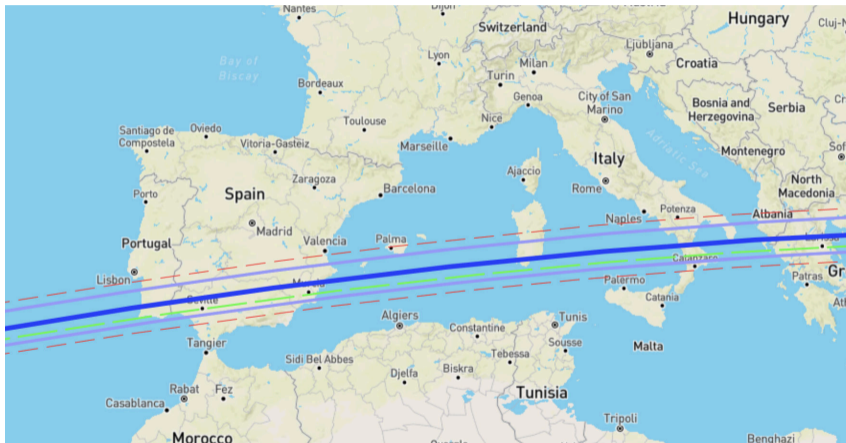
Credits: ESO/P. Kervella/M. Montargès et al., Ackn.: E. Pantin



VLT/SPHERE at 645nm - FoV : 0.100"

(Montargès et al. 2021, *Nature*)

The occultation path

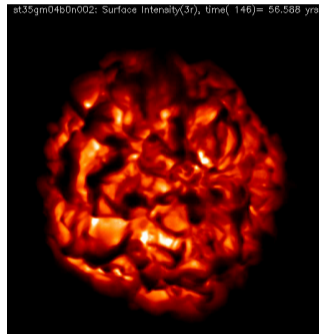


Last news on: <https://lesia.obspm.fr/lucky-star/occ.php?p=124370>

Not an occultation, but an annular eclipse

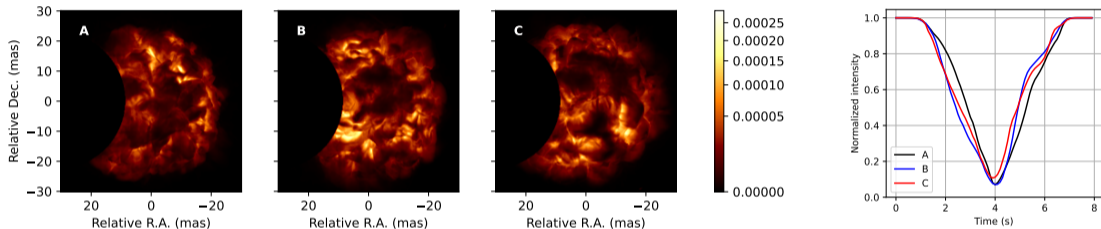


Artist impression of the asteroid Steins
Estimated angular diameter of Leona ~ 45-50 mas



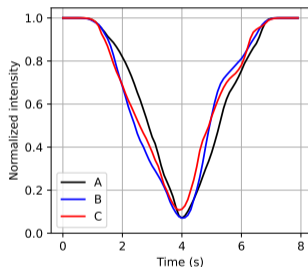
3D RHD simulation of the photosphere of Betelgeuse
(Freytag/Chiavassa)
Angular diameter of Betelgeuse ~ 50-55 mas (visible)

The light curve



Credits: M. Montargès

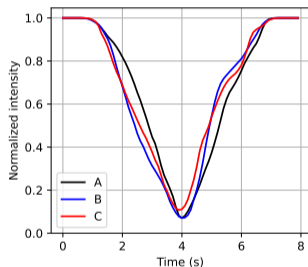
Photometry



- Short integration time ($\sim 10\text{-}50$ ms) to get the ingress and the egress
- Time-box (accurate time) !
- Several cords to probe several regions of the star

- Priority 0: filters R and V (TiO bands)
- Priority 1: R and B (chromosphere)
- Priority 2: R and $H\alpha$ (extended atmosphere)

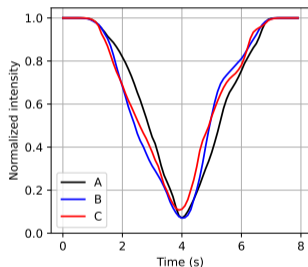
Photometry



- Short integration time ($\sim 10\text{-}50$ ms) to get the ingress and the egress
- Time-box (accurate time) !
- Several cords to probe several regions of the star

- Priority 0: filters R and V (TiO bands)
- Priority 1: R and B (chromosphere)
- Priority 2: R and $H\alpha$ (extended atmosphere)

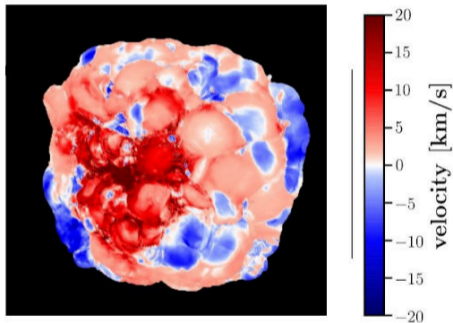
Photometry



- Short integration time ($\sim 10\text{-}50$ ms) to get the ingress and the egress
- Time-box (accurate time) !
- Several cords to probe several regions of the star
- Priority 0: filters R and V (TiO bands)
- Priority 1: R and B (chromosphere)
- Priority 2: R and $H\alpha$ (extended atmosphere)

Probing convection at wavelengths not accessible to interferometers

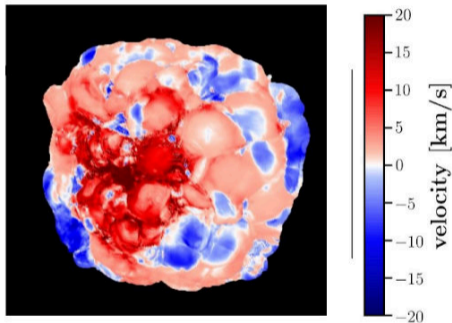
Spectroscopy



Kravchenko et al. 2019

- Getting the evolution of the width and position of metallic lines during the event:
 - Priority 0 : 635 ± 25 nm \rightarrow V, Cr, Ti et $H\alpha$
 - Priority 1 : 860 ± 25 nm \rightarrow Ca
- $R \sim 40\,000 \rightarrow$ Star'Ex HR (see with Christian Buil for details)

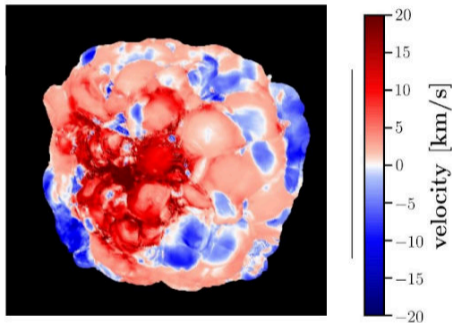
Spectroscopy



Kravchenko et al. 2019

- Getting the evolution of the width and position of metallic lines during the event:
 - Priority 0 : 635 ± 25 nm \rightarrow V, Cr, Ti et $H\alpha$
 - Priority 1 : 860 ± 25 nm \rightarrow Ca
 - $R \sim 40\,000 \rightarrow$ Star'Ex HR (see with Christian Buil for details)
- \rightarrow Best solution : having the slit parallel to the tracking direction, without tracking.

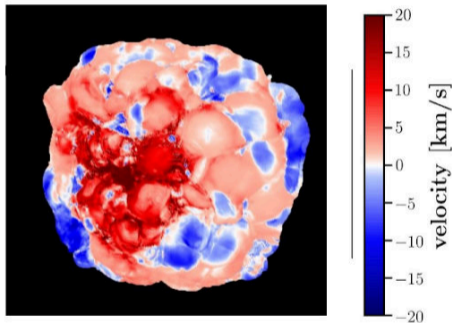
Spectroscopy



Kravchenko et al. 2019

- Getting the evolution of the width and position of metallic lines during the event:
 - Priority 0 : 635 ± 25 nm \rightarrow V, Cr, Ti et $H\alpha$
 - Priority 1 : 860 ± 25 nm \rightarrow Ca
 - $R \sim 40\,000 \rightarrow$ Star'Ex HR (see with Christian Buil for details)
- \rightarrow Best solution : having the slit parallel to the tracking direction, without tracking.
- \Rightarrow Will probe the photospheric convection velocity field

Spectroscopy



Kravchenko et al. 2019

- Getting the evolution of the width and position of metallic lines during the event:
 - Priority 0 : 635 ± 25 nm \rightarrow V, Cr, Ti et H α
 - Priority 1 : 860 ± 25 nm \rightarrow Ca
 - $R \sim 40\,000 \rightarrow$ Star'Ex HR (see with Christian Buil for details)
- \rightarrow Best solution : having the slit parallel to the tracking direction, without tracking.
- \Rightarrow Will probe the photospheric convection velocity field

Unprecedented measurement

We need the shape of Leona to analyze the data!

Other regular occultations predicted:

- 30th et 31th December 2023 (sorry)

Precise times and location to be checked.

No need for filters or spectroscopy here, just regular occultation observations.

The occultation of September 13th

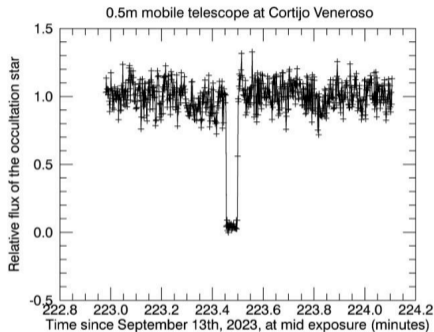


Fig. 3: Light curve derived from the observations carried out at Cortijo Veneroso.

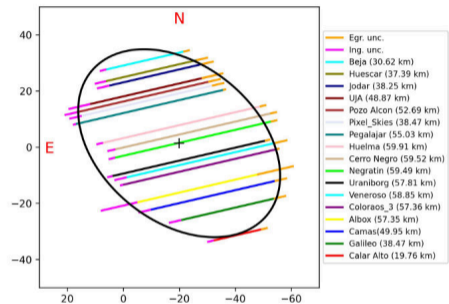


Fig. 4: Chords of the stellar occultation and an elliptical fit to the extremities. The ingress uncertainties are shown with pink color and the egress uncertainties in clear brown. The values in parenthesis are the chords lengths. The scale is in km. The chords were built using the JPL#69 ephemeris.

Ortiz et al. 2023, arXiv 2309.12272

17 positive observations, send to arXiv on September 21st!

Conclusion

- On December 12th : an annular eclipse, not an occultation
- Ingress and egress most interesting: **unique opportunity to study convection of RSGs**
- Shape of Leona needed from other regular events
- Photometry:
 - Short integration time (→ earlier training on other stars between magnitude 0 and 10)
- Spectroscopy:
 - R ~ 40 000
 - Single shot with no tracking (R.A. || slit)
 - Practicing mandatory

Registration/Coordination

<http://betelgeuse.proam-gemini.fr/#EN>