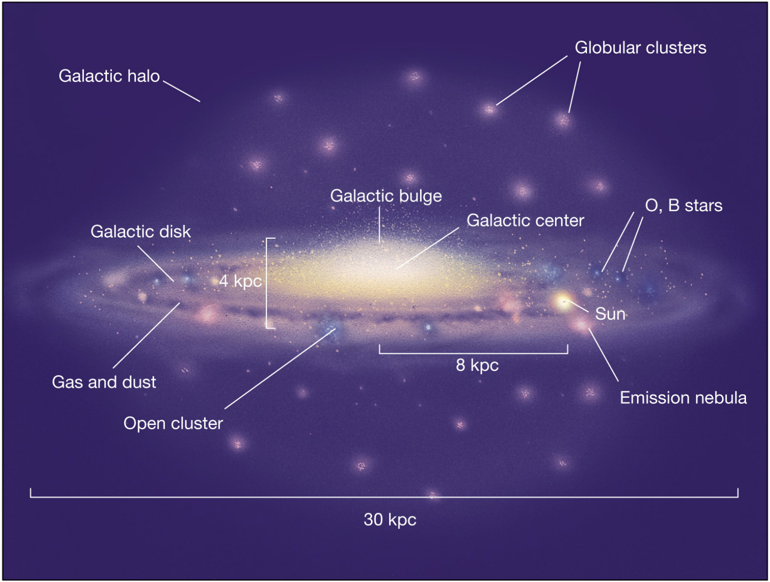
Supergiants and their shells in young globular clusters

Dorottya Szécsi

Seminar of the Konkoly Observatory
Budapest, 1st February 2018

Globular Clusters



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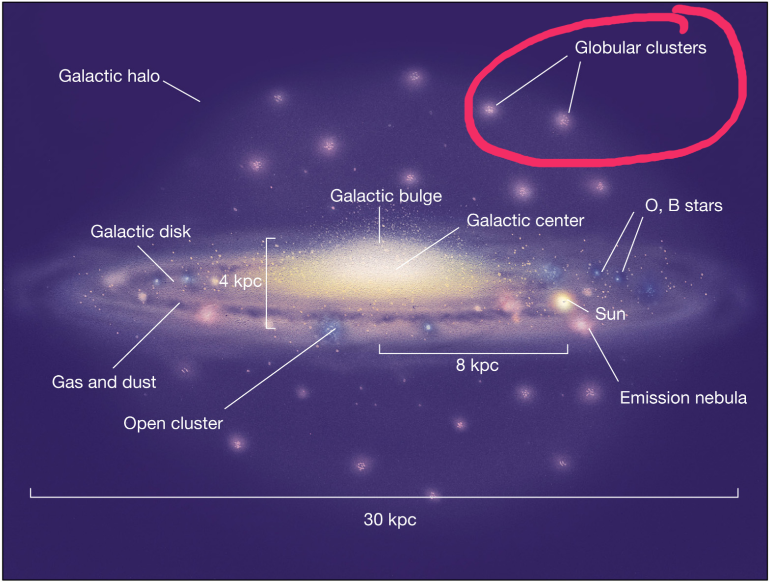

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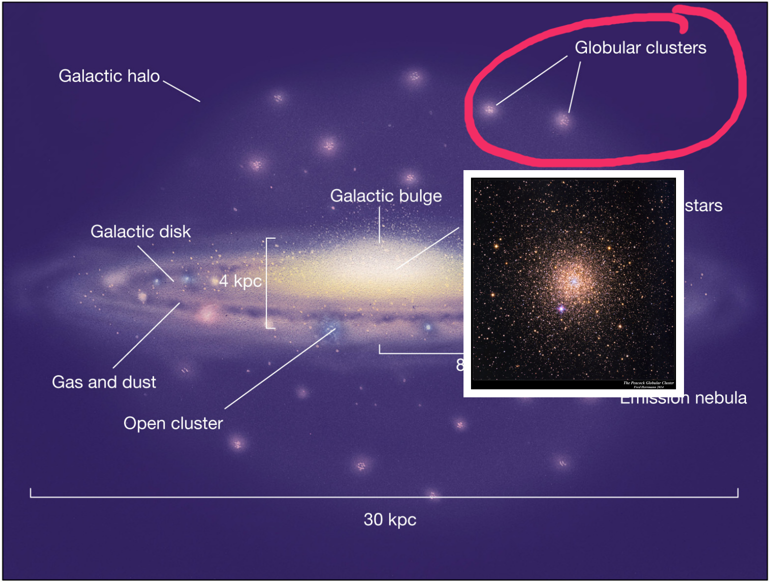

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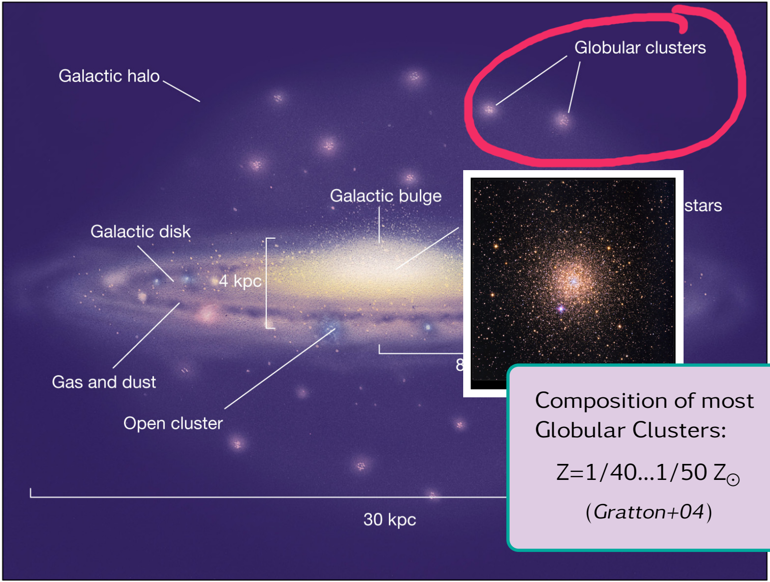

Composition of most Globular Clusters:

$Z = 1/40 \ldots 1/50\, Z_{\odot}$

(*Gratton+04*)

What is a star?

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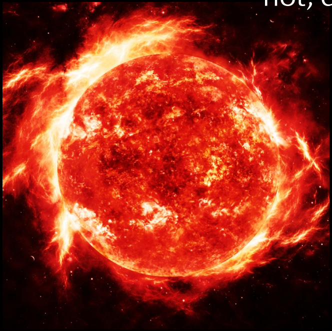

hot, dense plazma

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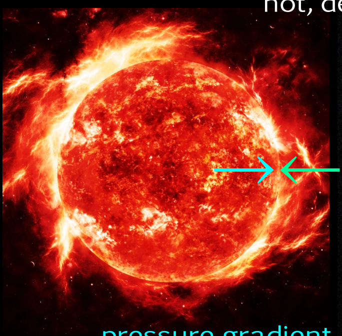

equilibrium: pressure gradient gravity

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surface?

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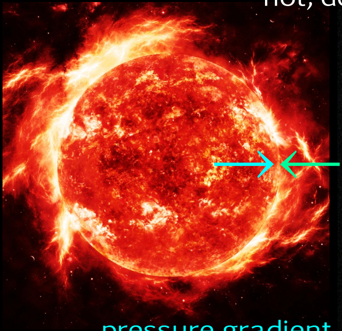

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→ photons escape
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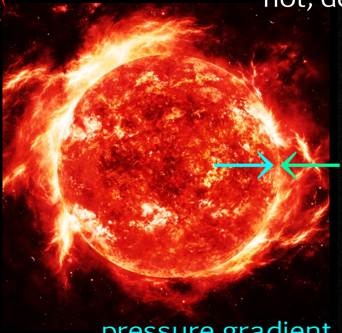

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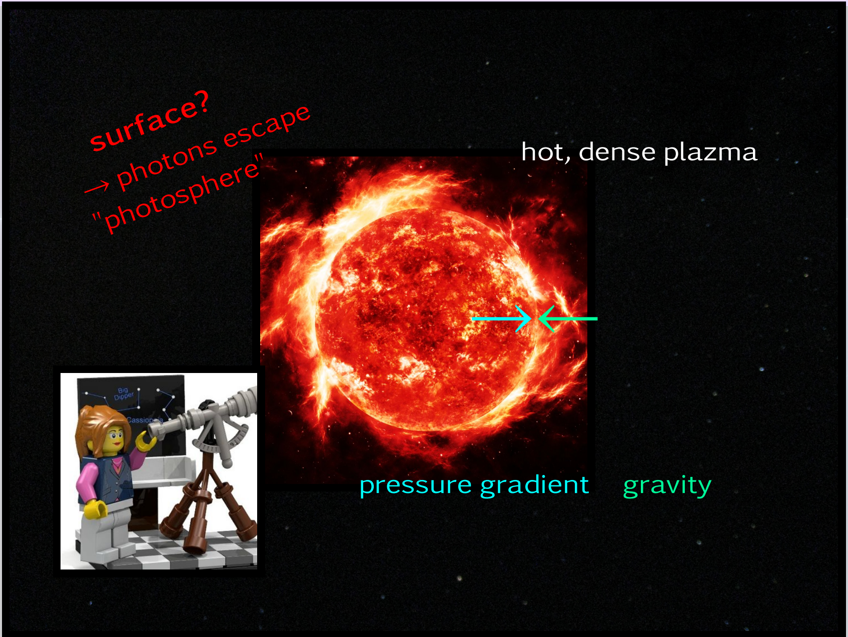

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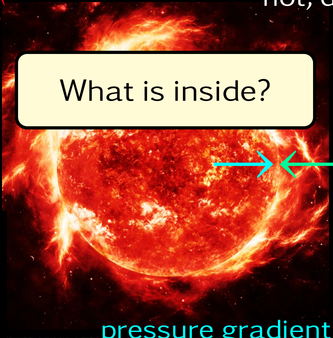
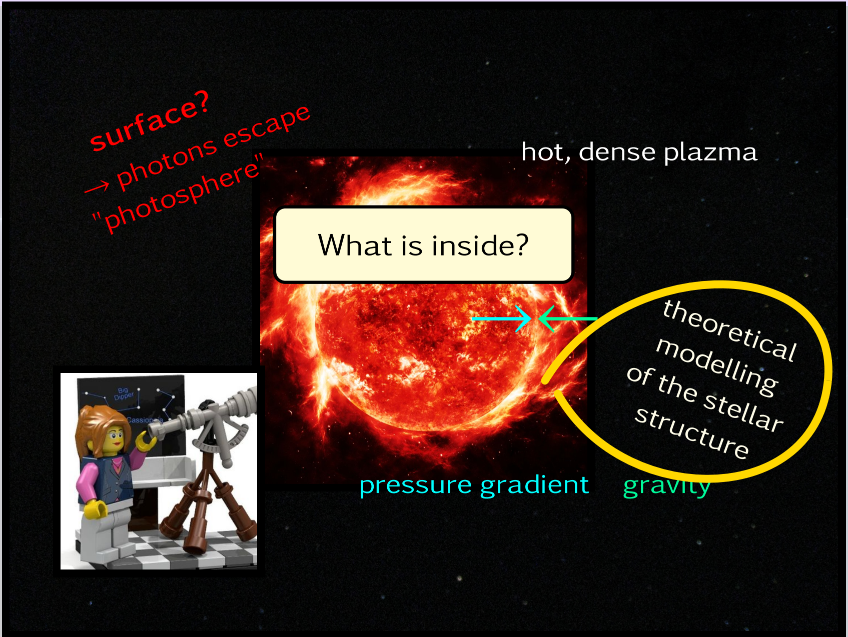


What is inside?

pressure gradient gravity

What is a star?



Theoretical modelling of the stellar structure

$$\frac{\partial r}{\partial m_r} = \frac{1}{4\pi r^2 \rho} \quad \text{equation of definition of mass} \tag{9}$$

$$\frac{\partial P}{\partial m_r} = -\frac{G m_r}{4\pi r^4} \quad \text{equation of hydrostatic equilibrium} \tag{10}$$

$$\frac{\partial L_r}{\partial m_r} = \epsilon_{\rm pl} - T\frac{\partial S}{\partial t} \quad \text{equation of energetic balance} \tag{11}$$

$$\frac{\partial T}{\partial m_r} = -\frac{G m_r T}{4\pi r^4 P}\nabla \quad \text{equation of energy transport,} \tag{12}$$

Guilera et al. 2011

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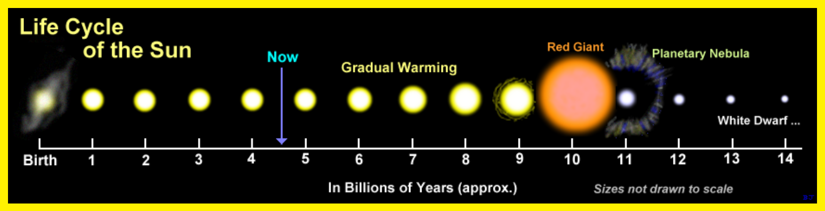

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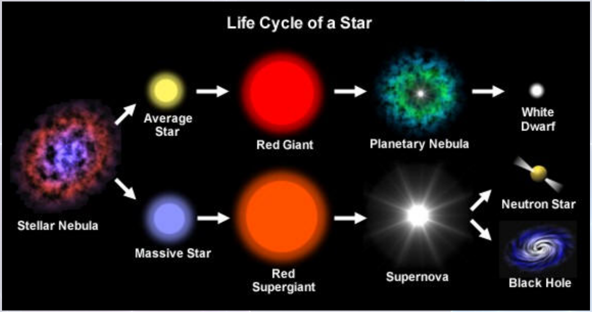
Massive stars: $\gtrsim 9$ times the Sun ($\gtrsim 9\,M_\odot$)



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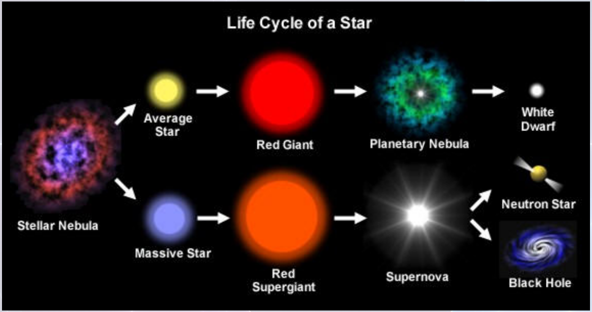

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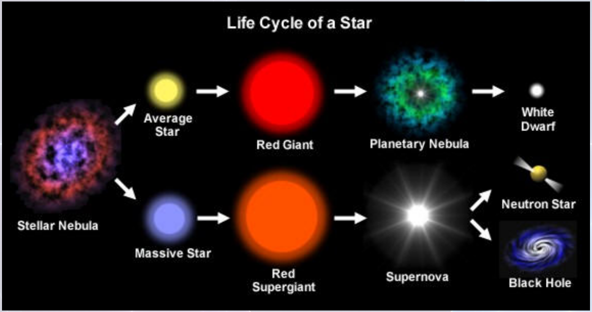

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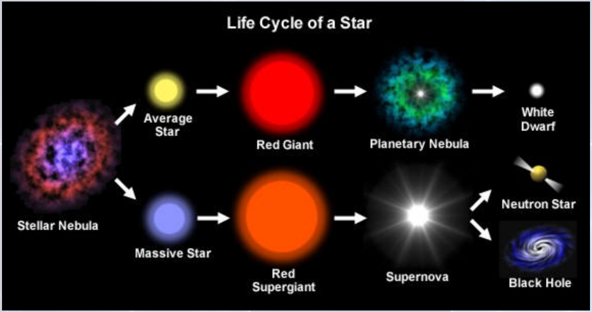

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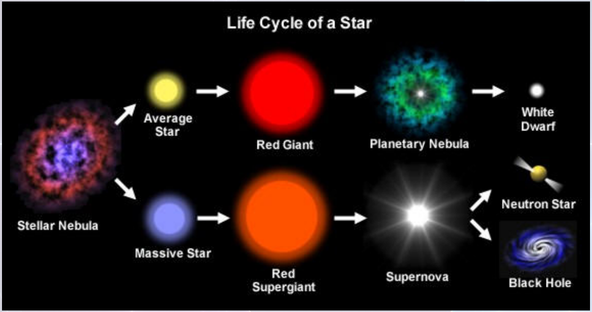

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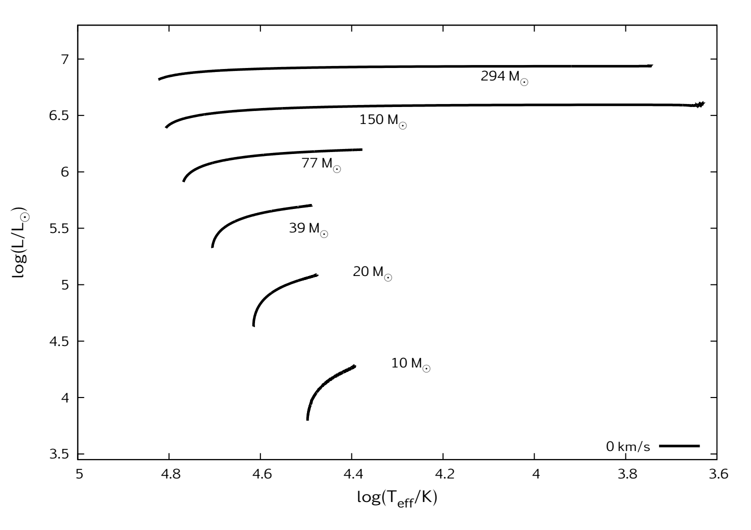
Szécsi et al. 2015 (Astronomy & Astrophysics, v.581, A15)



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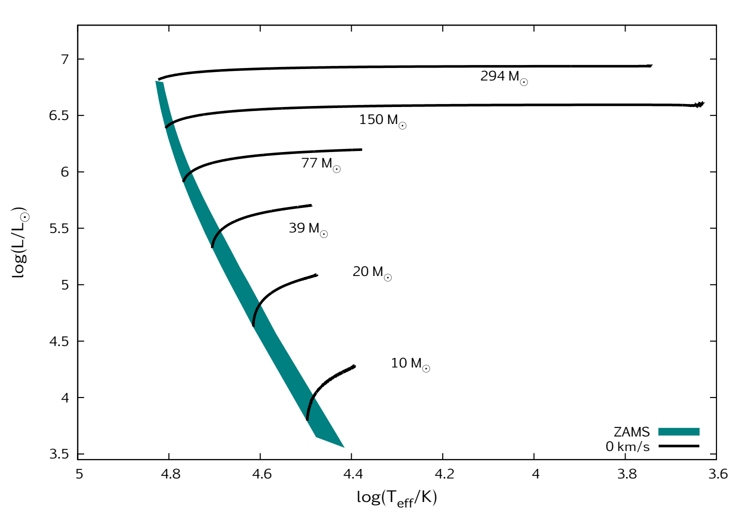

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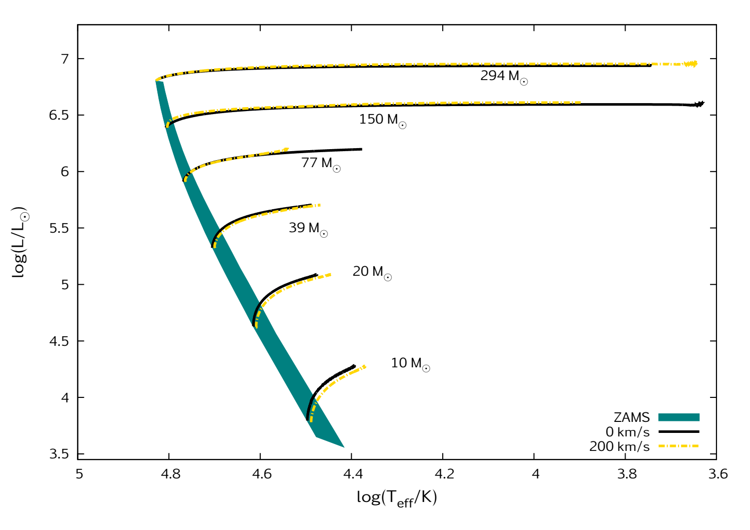

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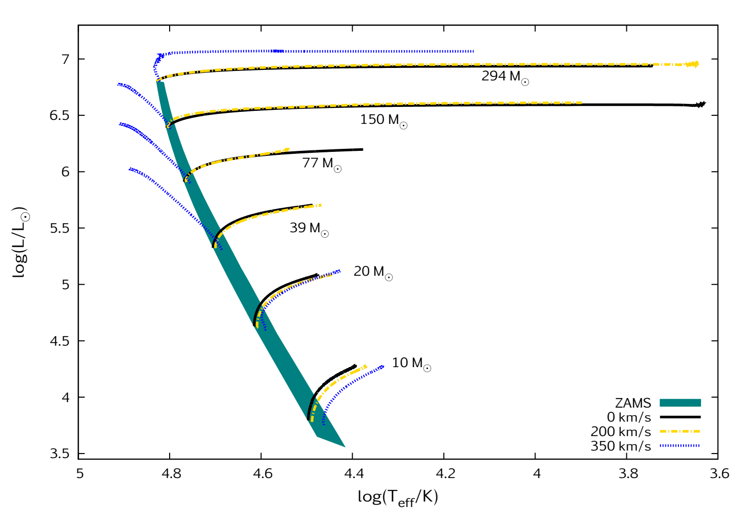

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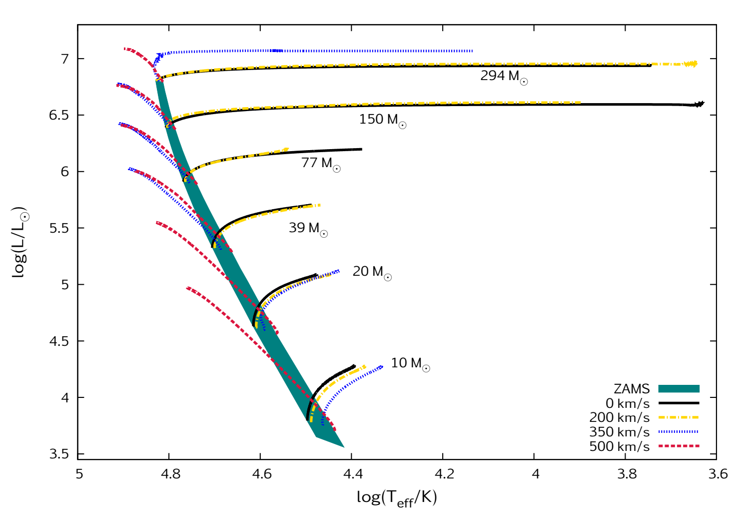

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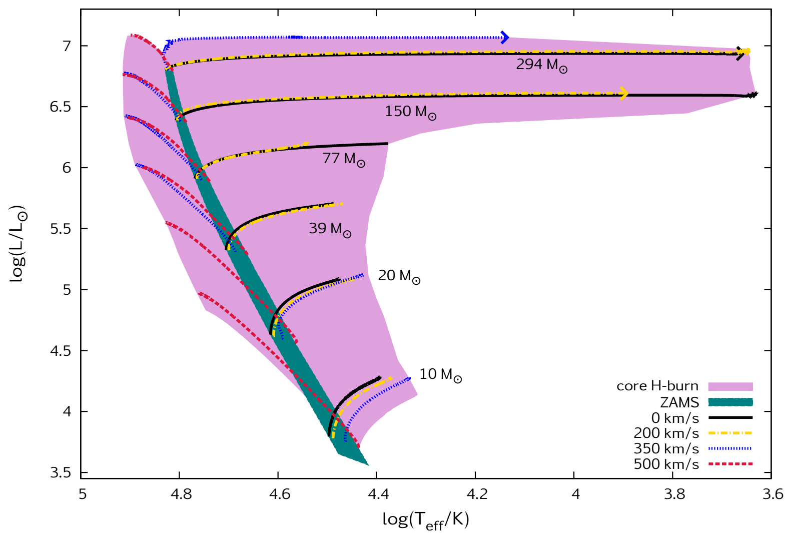

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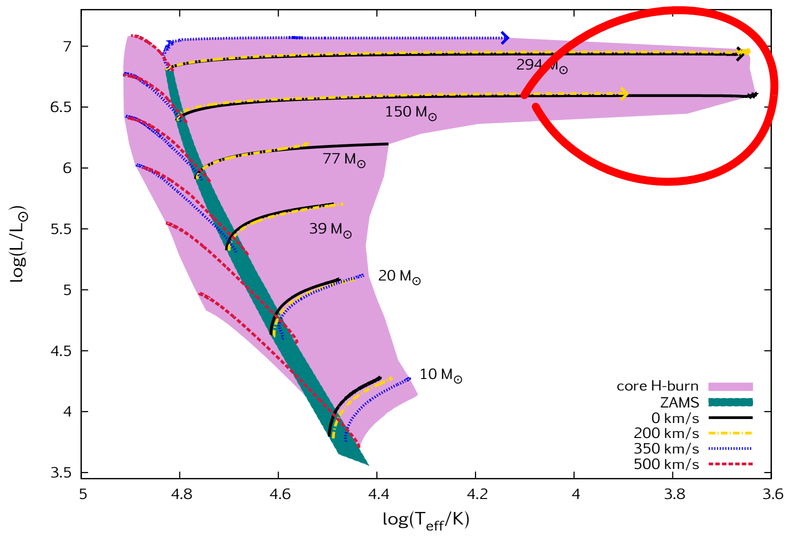

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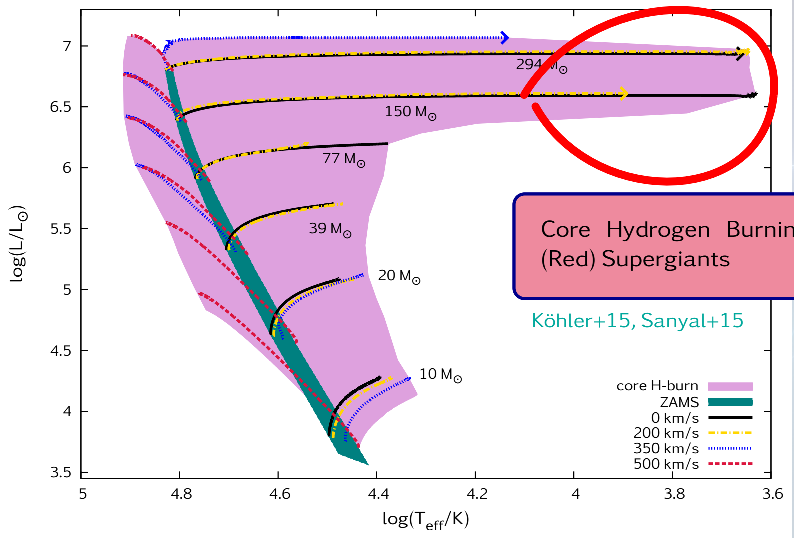

Core Hydrogen Burning (Red) Supergiants

Köhler+15, Sanyal+15

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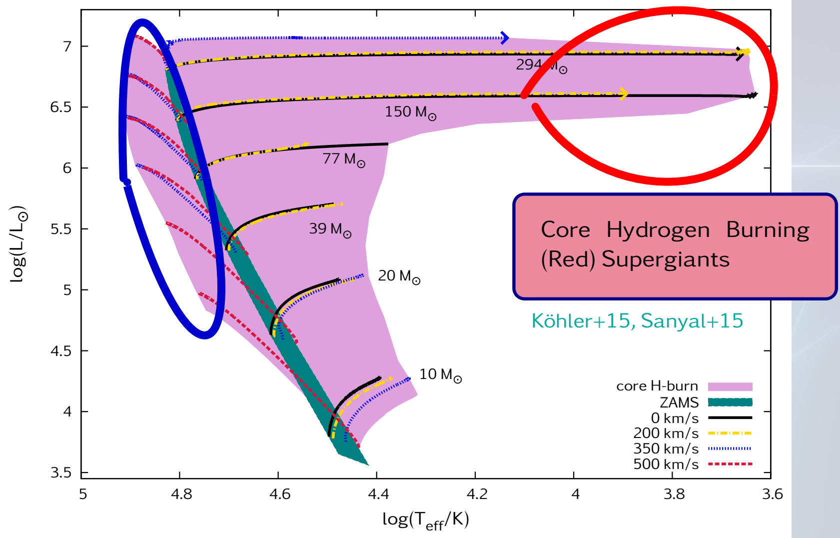

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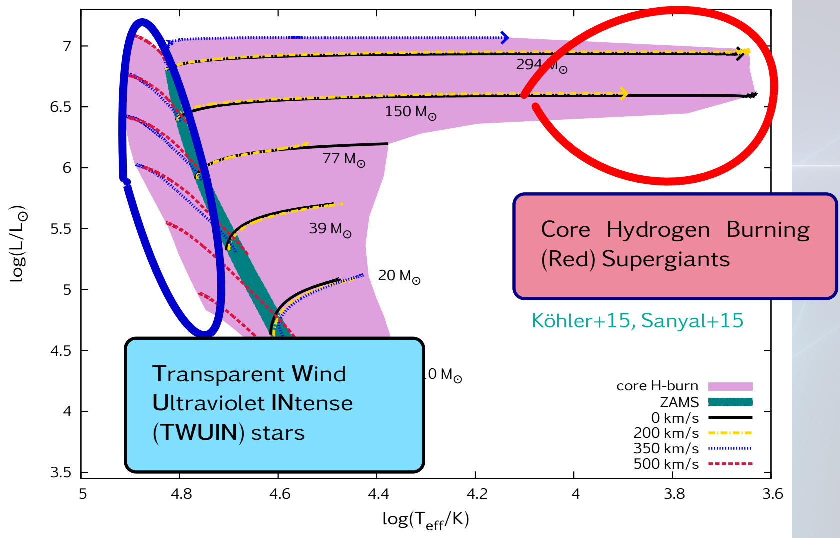
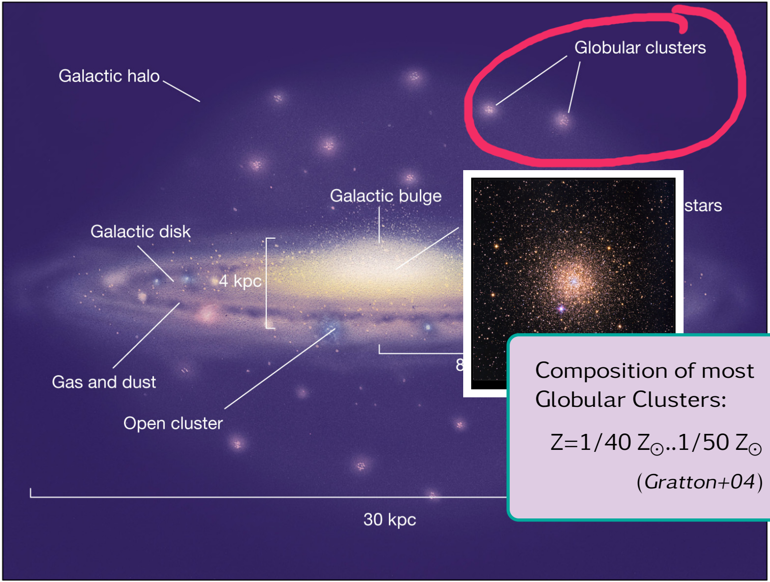


Globular Clusters & Abundance Anomalies



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(*Gratton+04*)

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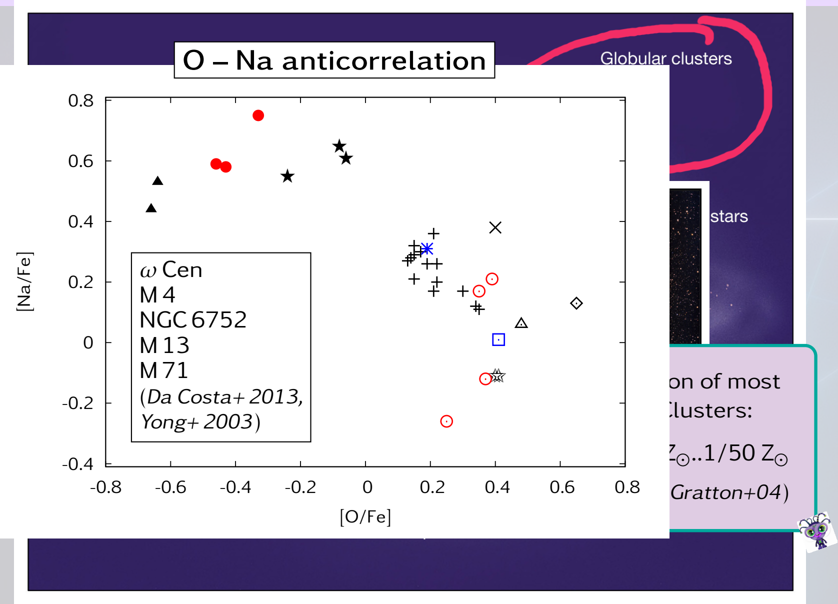

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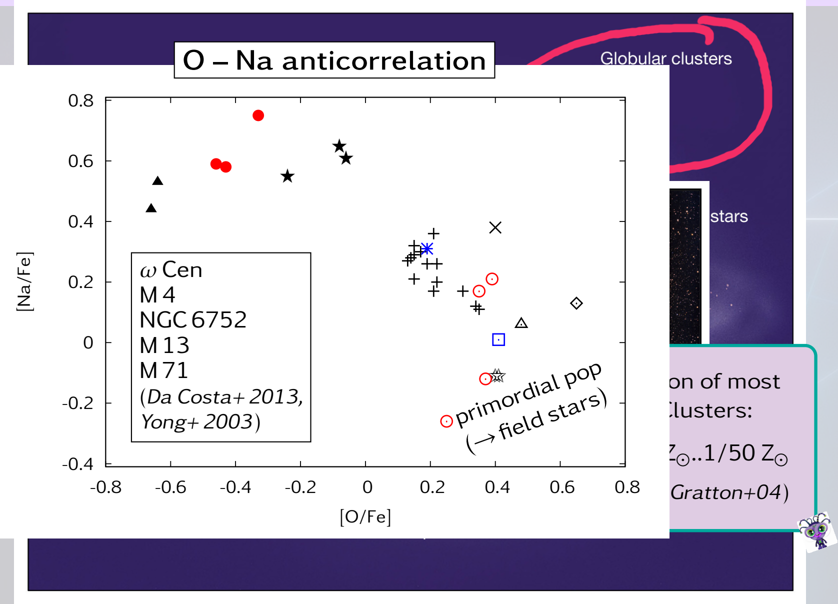

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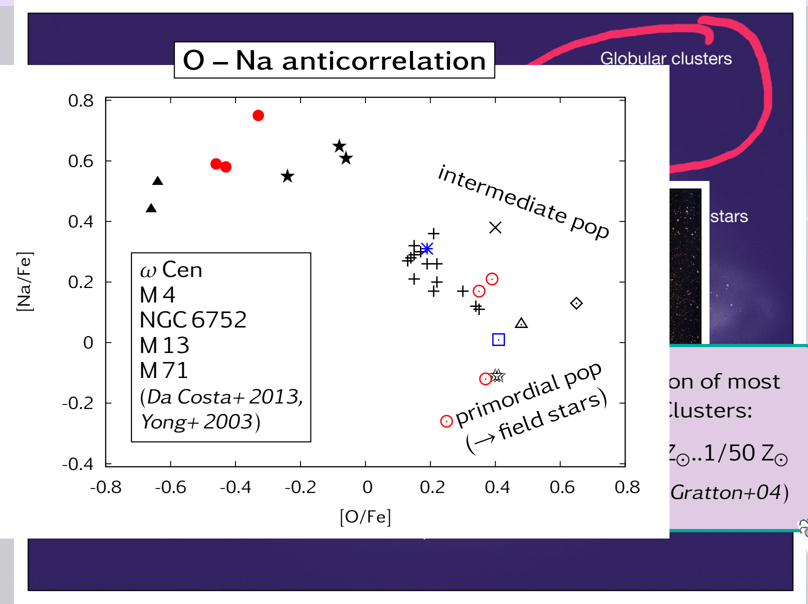

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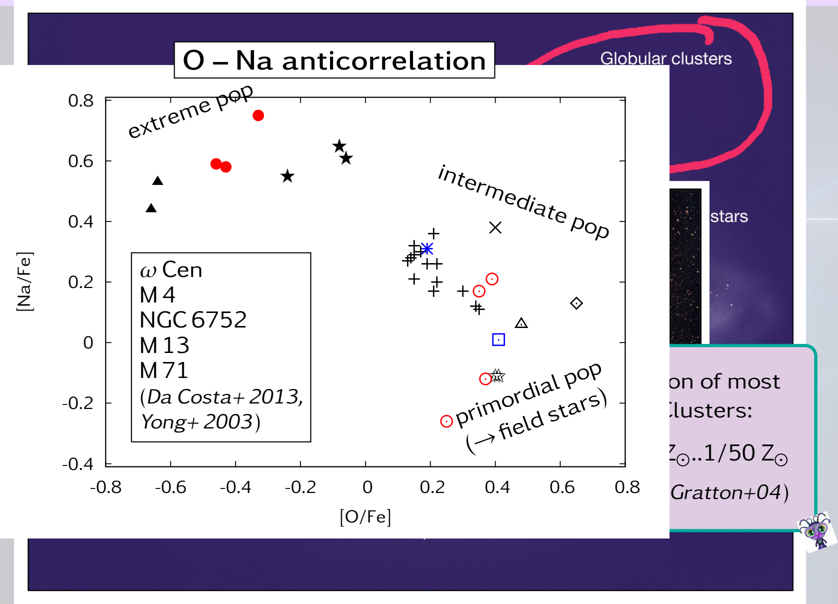

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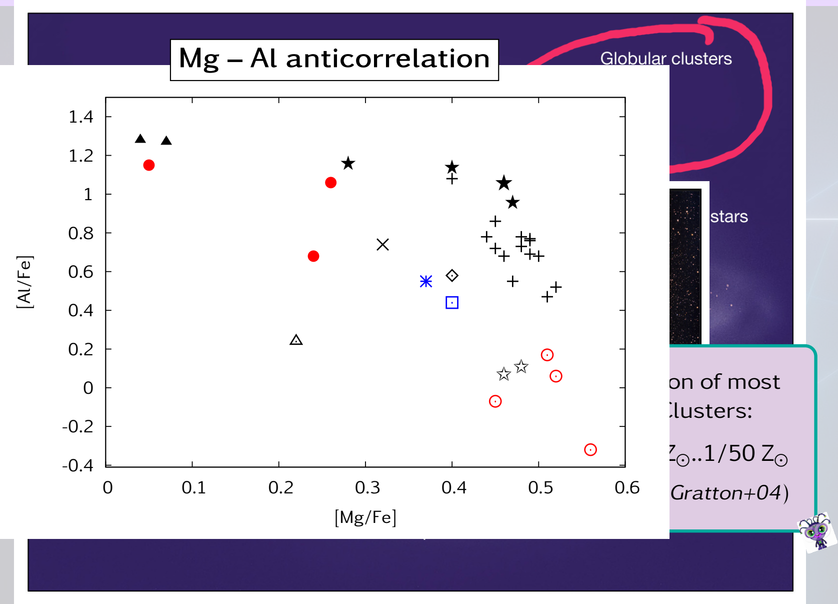

Globular Clusters & Abundance Anomalies

Mg – Al anticorrelation

Globular clusters

- extreme & intermediate pop: **polluted** by hot hydrogen burning
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  - fast rotating massive stars: close to break-up (*Decressin+ 2007*)
  - supermassive stars (10^4 $M_\odot$): continuum-driven wind (*Denissenkov+ 2014*)
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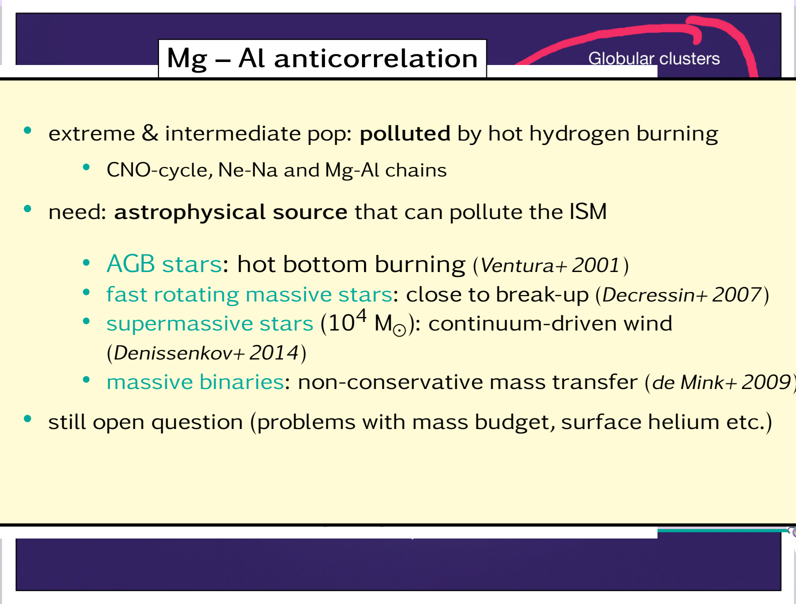

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→ New scenario...

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Starforming Supergiant Shells

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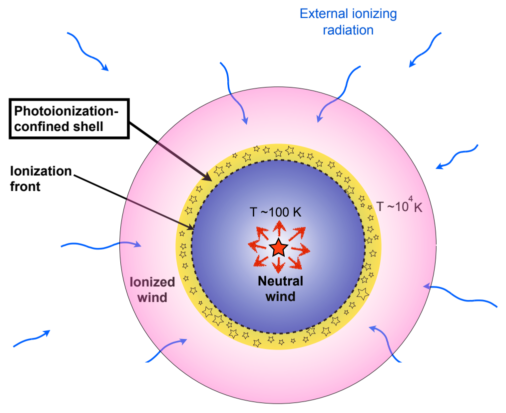
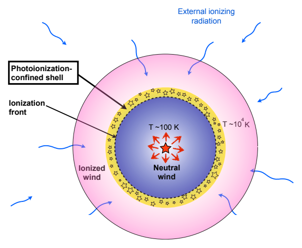


PICO shell: *Mackey+ 2014 (Nature)*

Simulating the PICO shell



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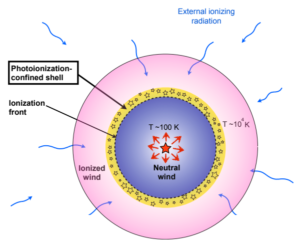

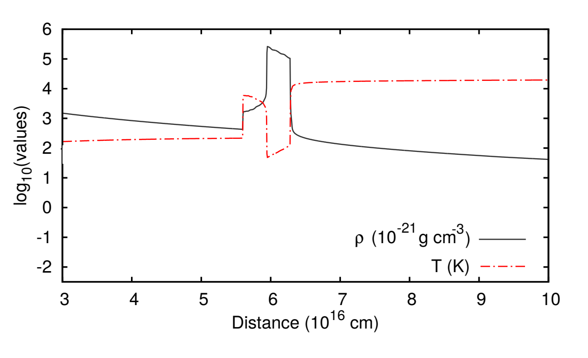

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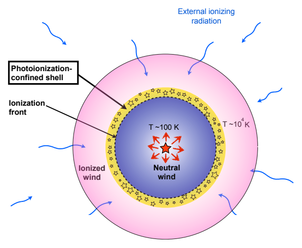

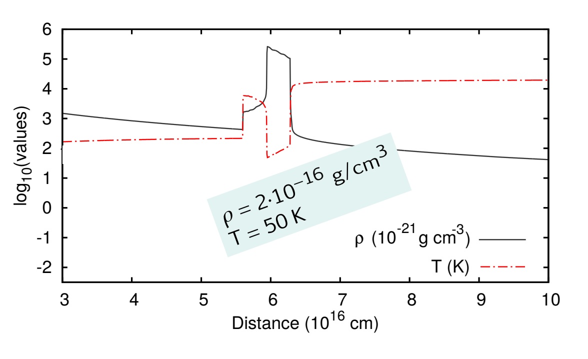

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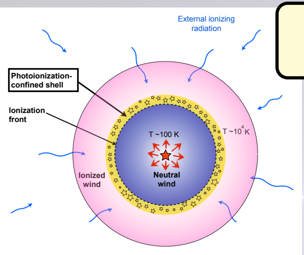
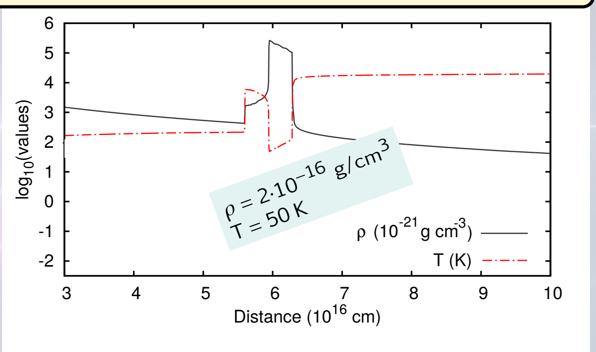


Mass of the photoionization-confined (PICO) shell: ~14 $M_\odot$



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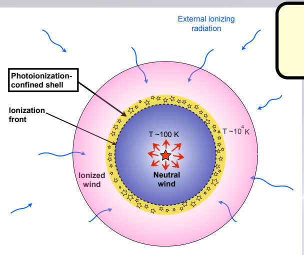
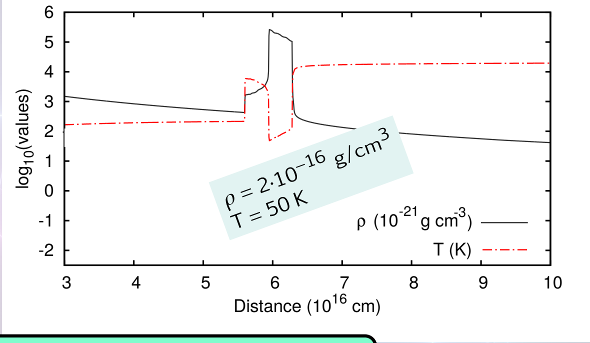


Mass of the photoionization-confined (PICO) shell: $\sim 14\ M_\odot$



Lifetime of the shell: $\sim 10^5$ yr

>>

Growth timescale of grav. unstable perturbations: $\sim 10^4$ yr

Compared to observations:

O – Na anticorrelation

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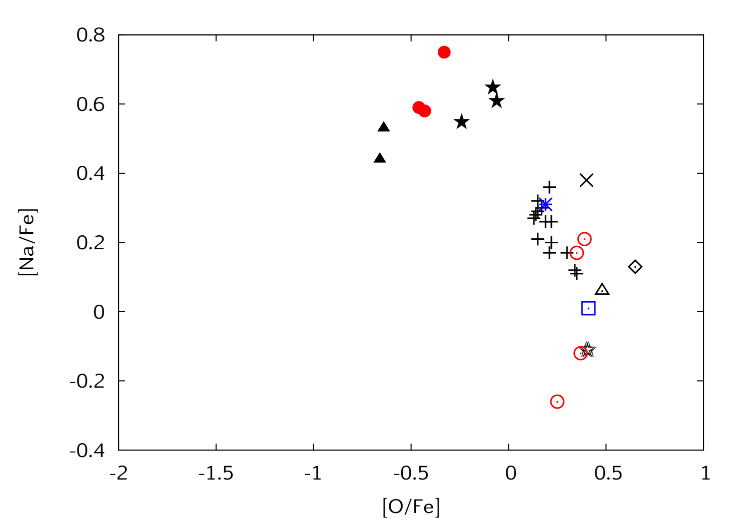
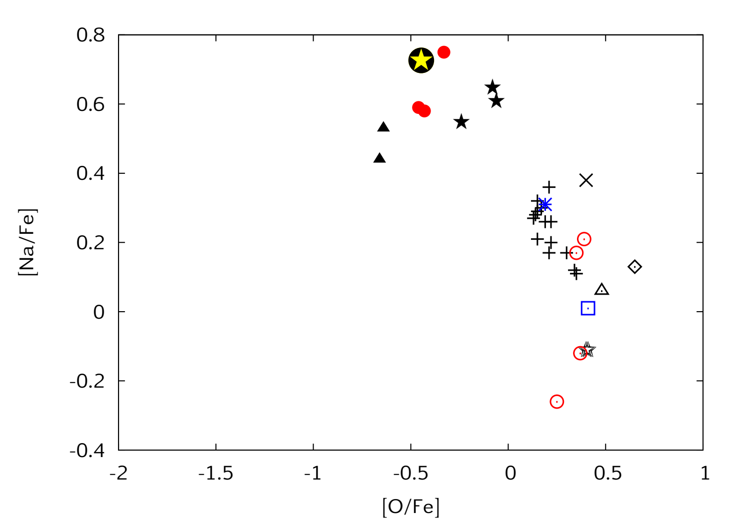
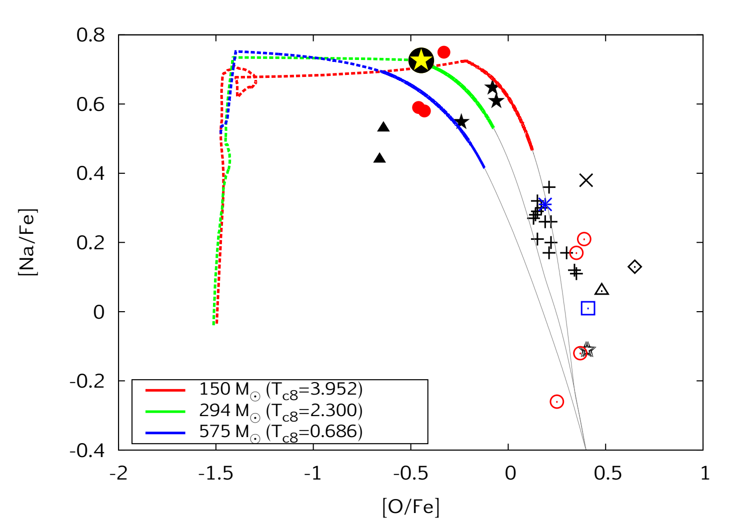


Compared to observations: O – Na anticorr.



Compared to observations: O – Na anticorr.



Compared to observations:

Mg – Al anticorrelation

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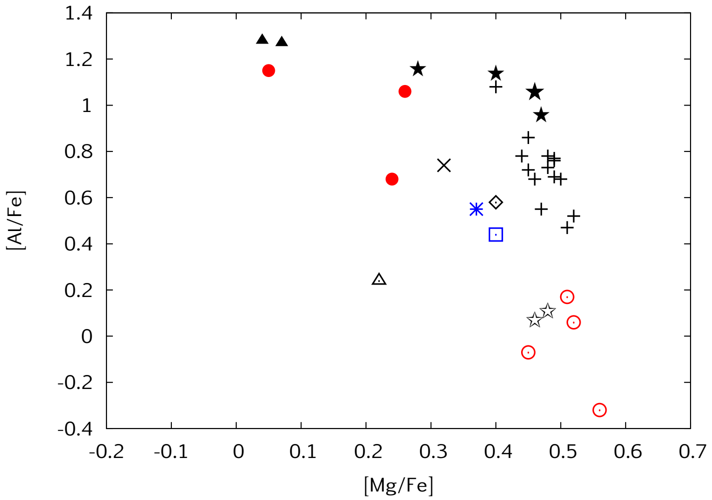
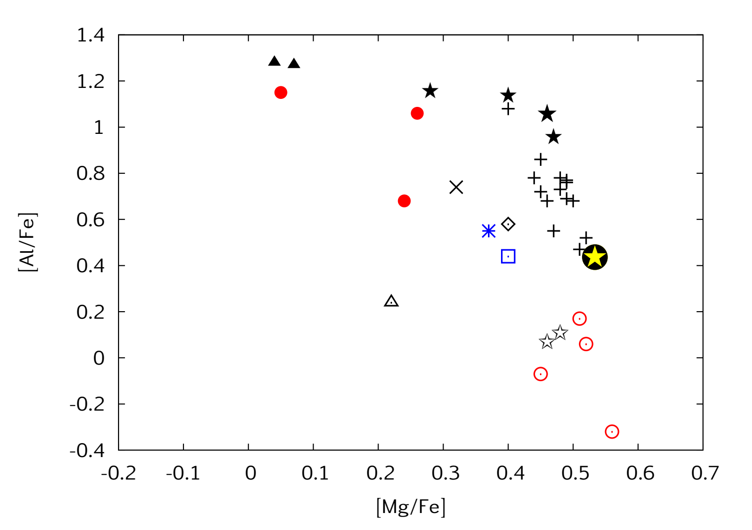
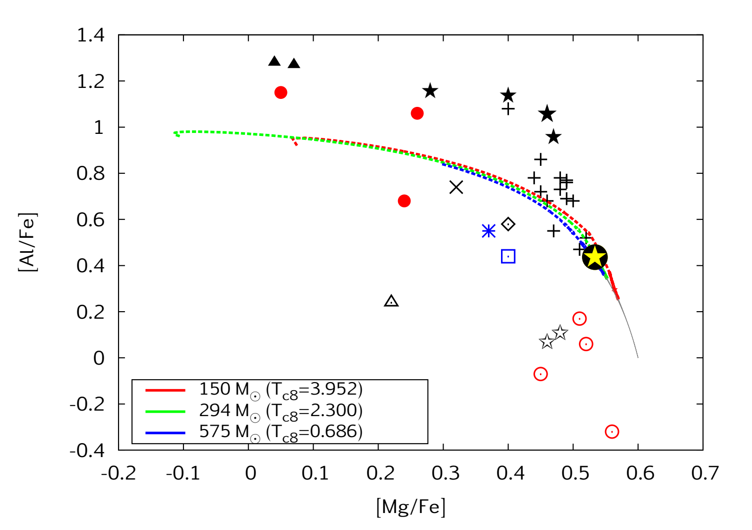


Compared to observations: Mg – Al anticorr.



Compared to observations: Mg – Al anticorr.



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Mass budget

- second generation IMF only contains low-mass stars!

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He-spread

- some GCs (but not all): $Y \sim 0.4$ observed
- shell-stars are predicted to have $Y_{sh}=0.48$
- $\longrightarrow$ undilluted material explains most extreme Y values!
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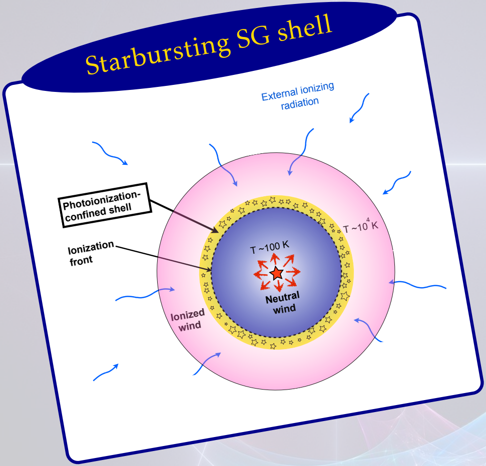
RSGs as polluters

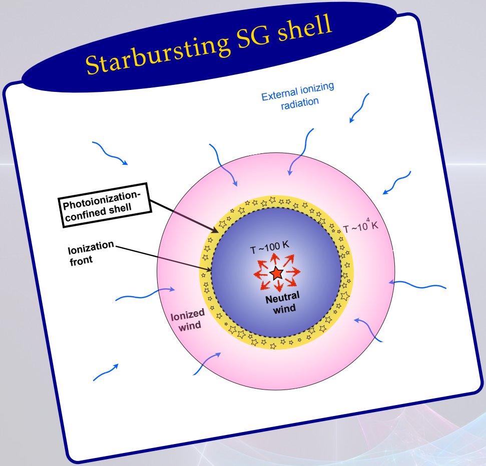
- at low-Z, core-H burning RSGs
- even without PICO shell: contributing to the general pollution of the GC!

Summary



Starbursting SG shell
External ionizing radiation
Photoionization-confined shell
Ionization front
T ~100 K
T ~10^4 K
Neutral wind
Ionized wind

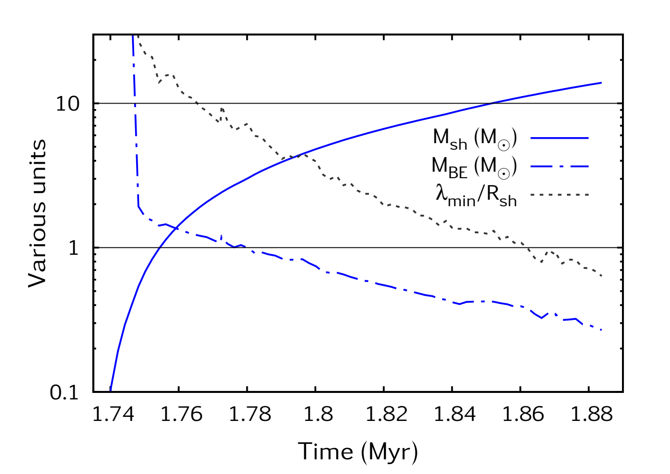
Summary



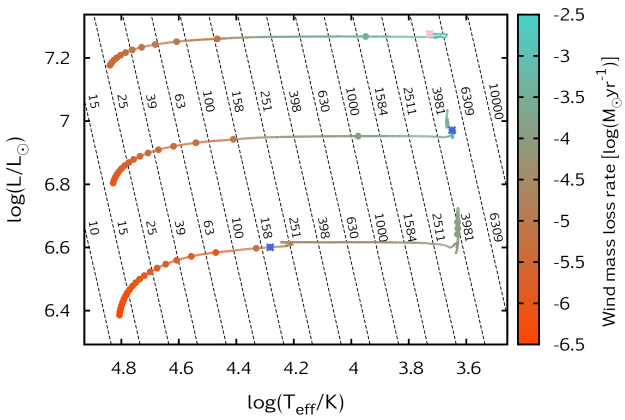
- early GCs
- PICO shell around core-H burning cool/red SGs
- grav. unstable → low-mass starformation
- simulated composition fits the 2nd generation stars
- explains abundance anomalies in GCs

Thank you for your attention!

Appendix: Time evolution of the shell



Appendix: HR diagram of core-H burning RSGs



Appendix: HR diagram of core-H burning RSGs