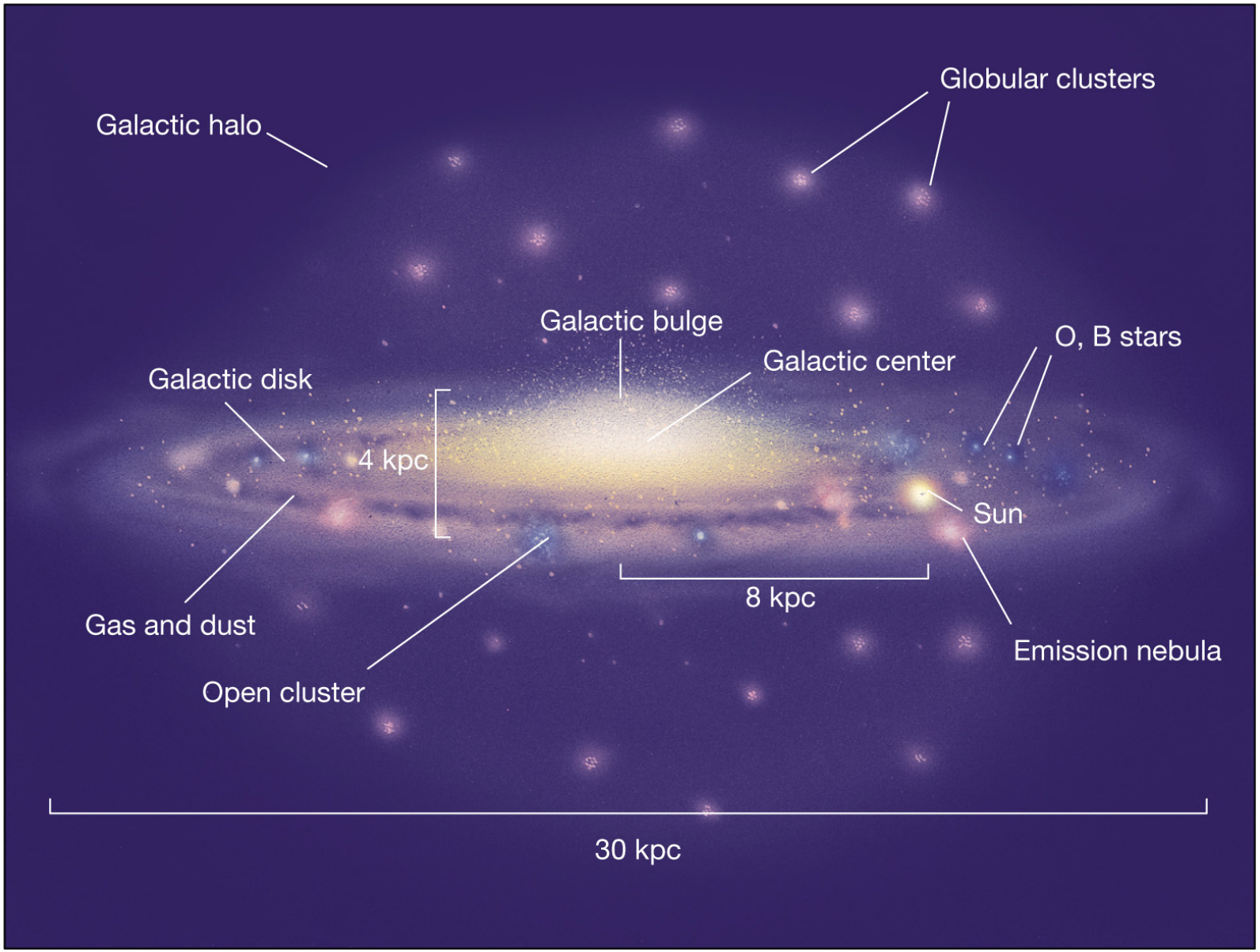
# Supergiants and their shells in young globular clusters

*Dorottya Szécsi*

Group meeting, School of Physics and Astronomy
Birmingham, 25th January 2018

# Globular Clusters



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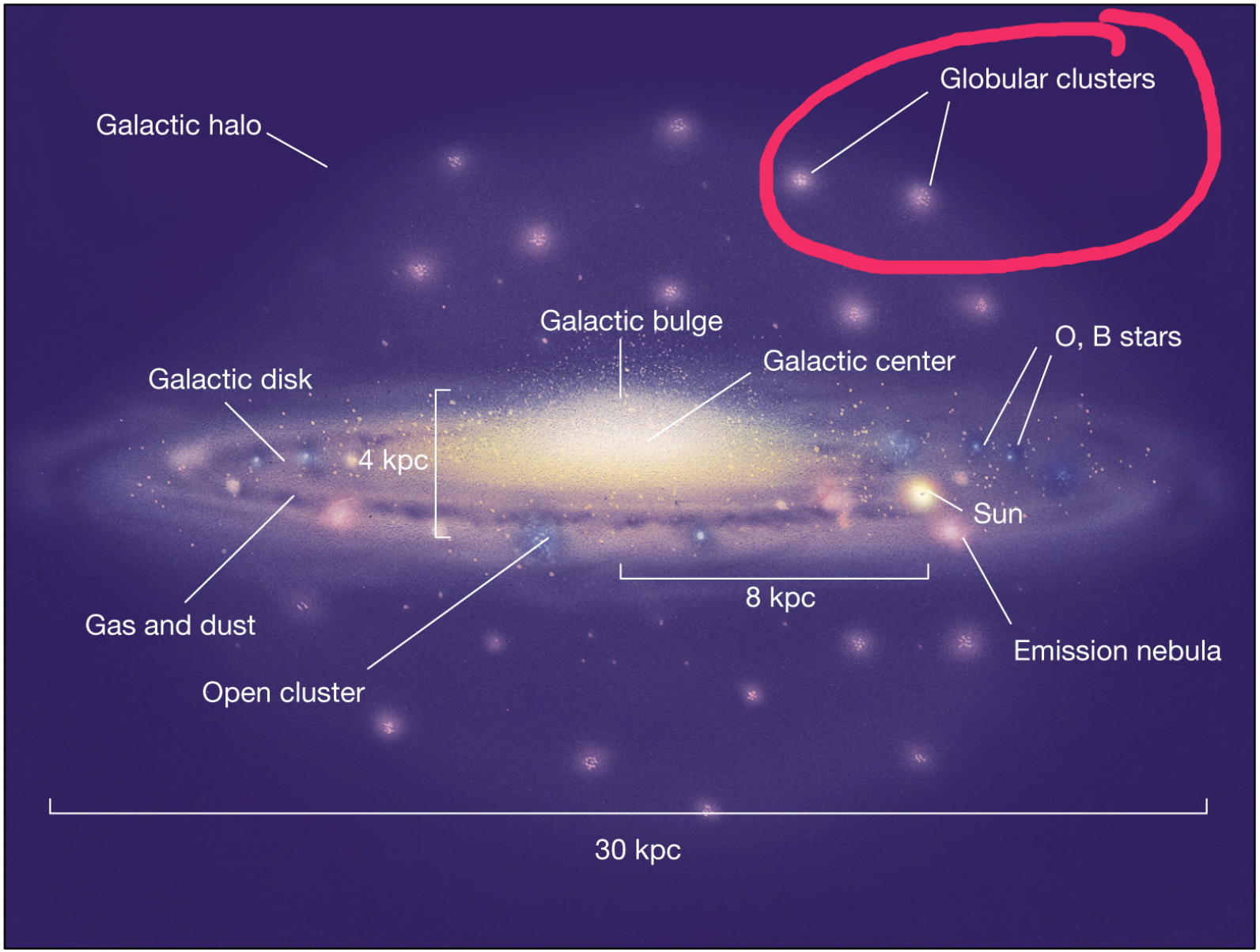

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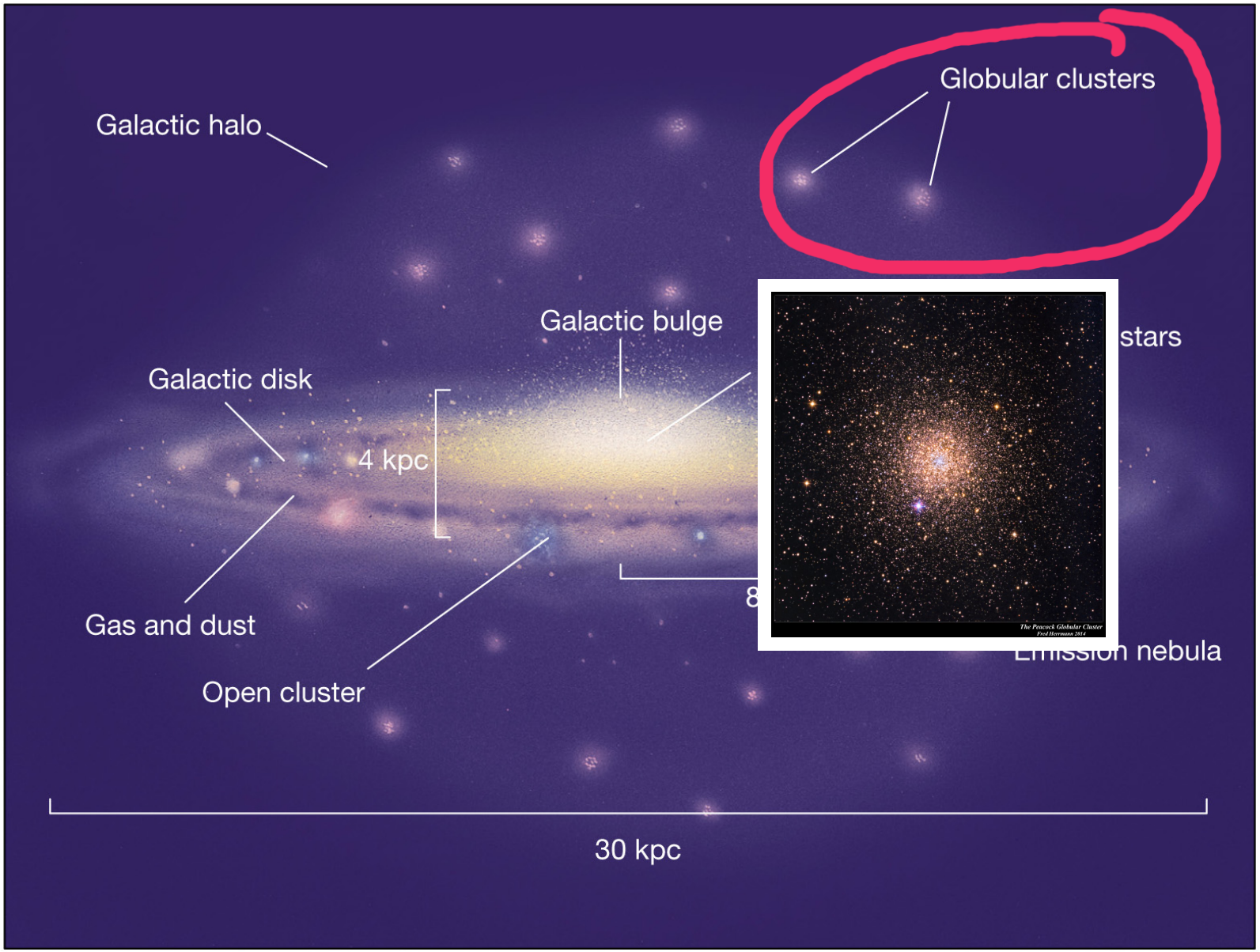

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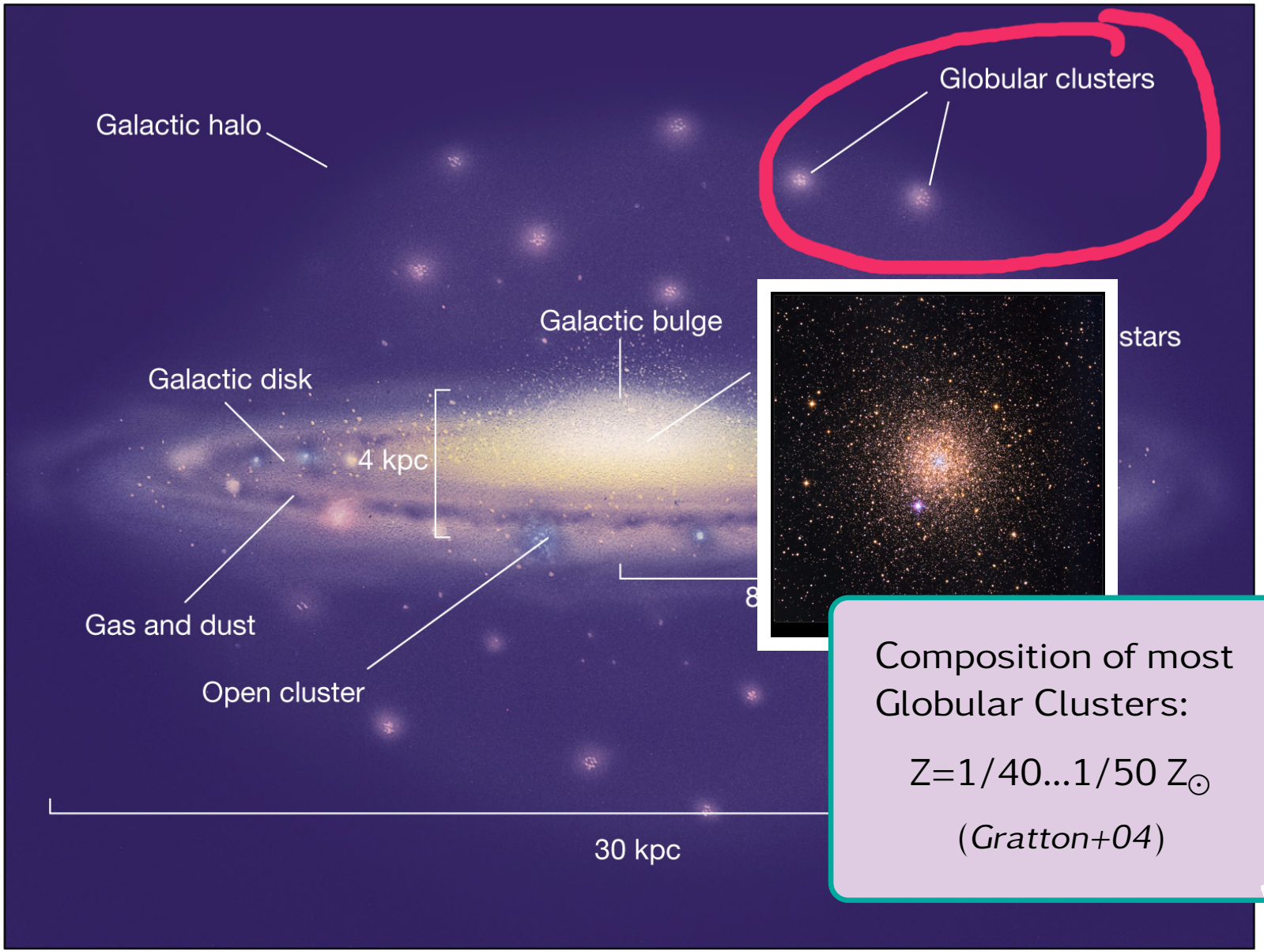


Composition of most Globular Clusters:

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

(*Gratton+04*)

# What is a star?

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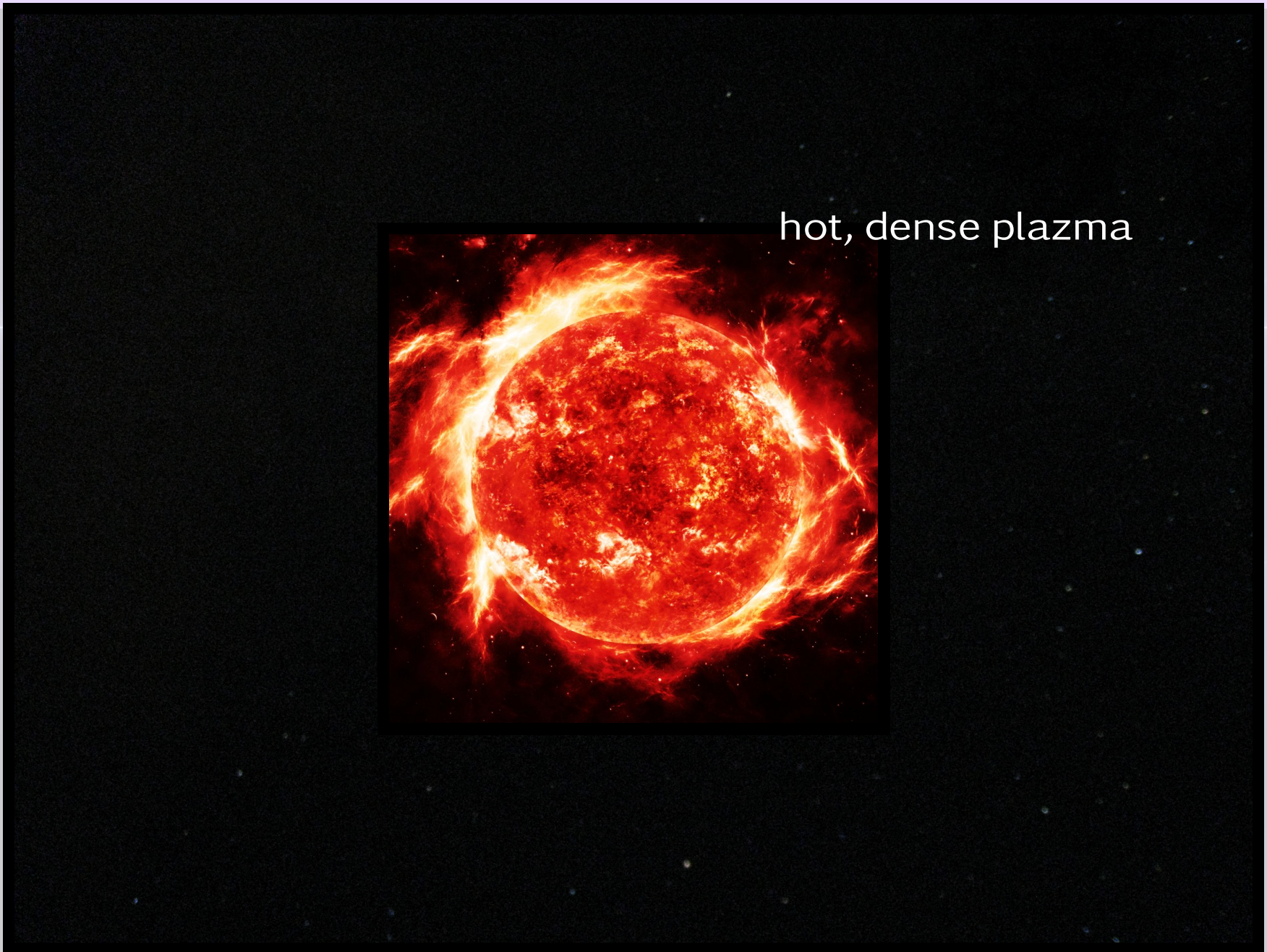
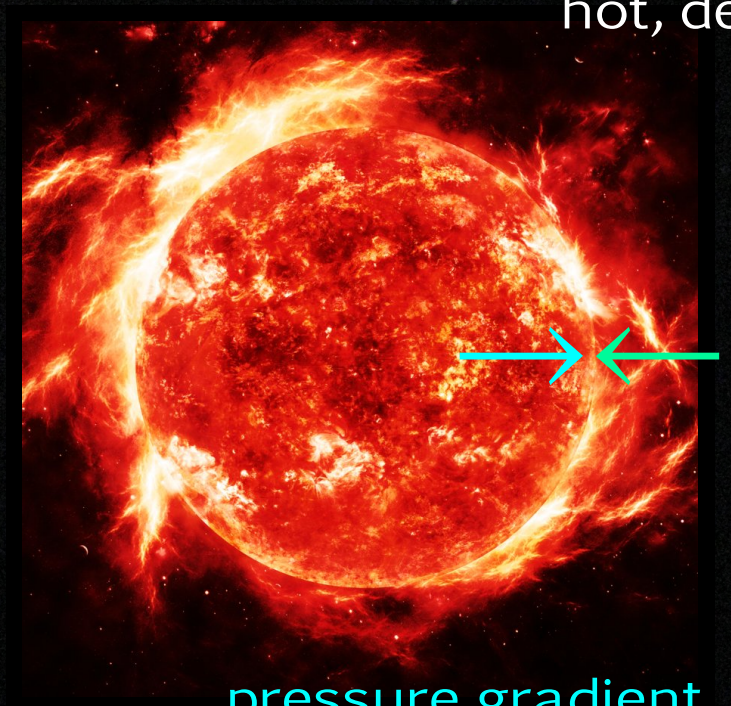


# What is a star?

hot, dense plazma



equilibrium: pressure gradient gravity

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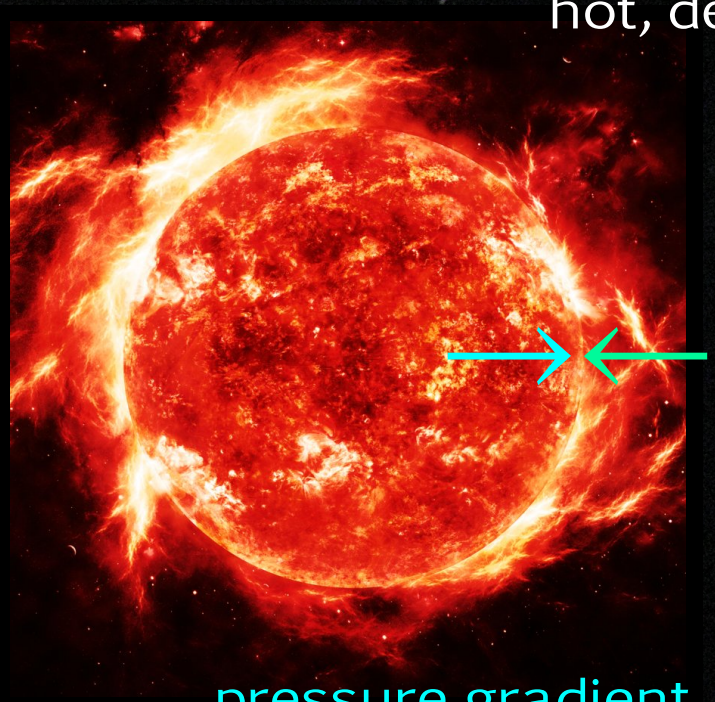

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surface?
→ photons escape
"photosphere"

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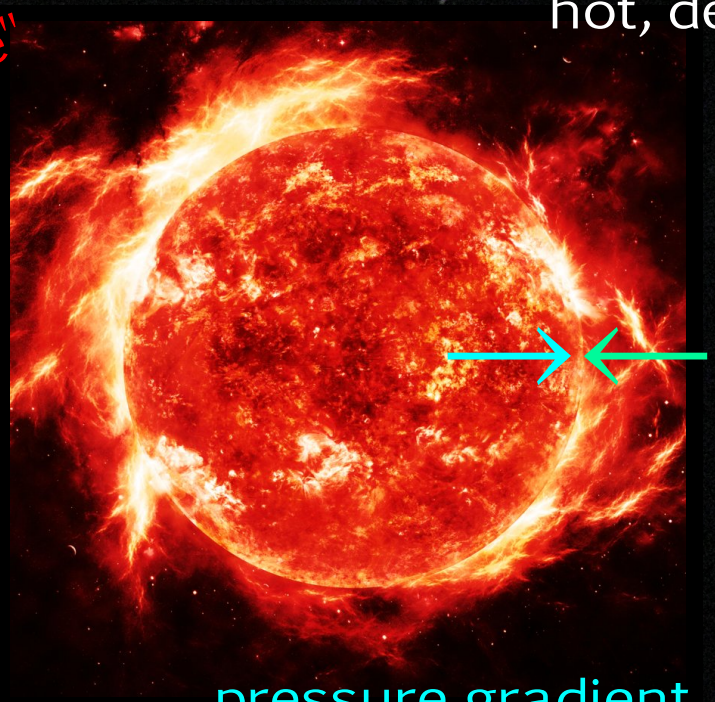

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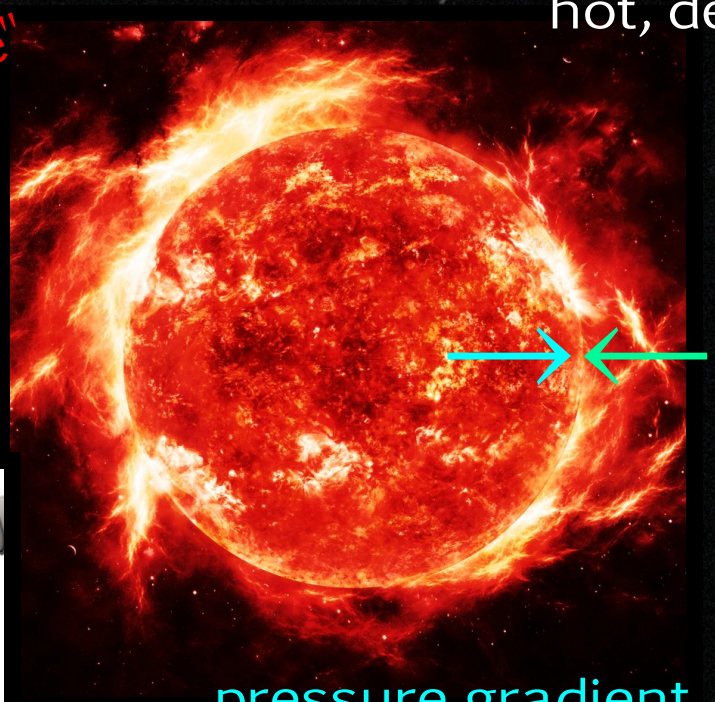

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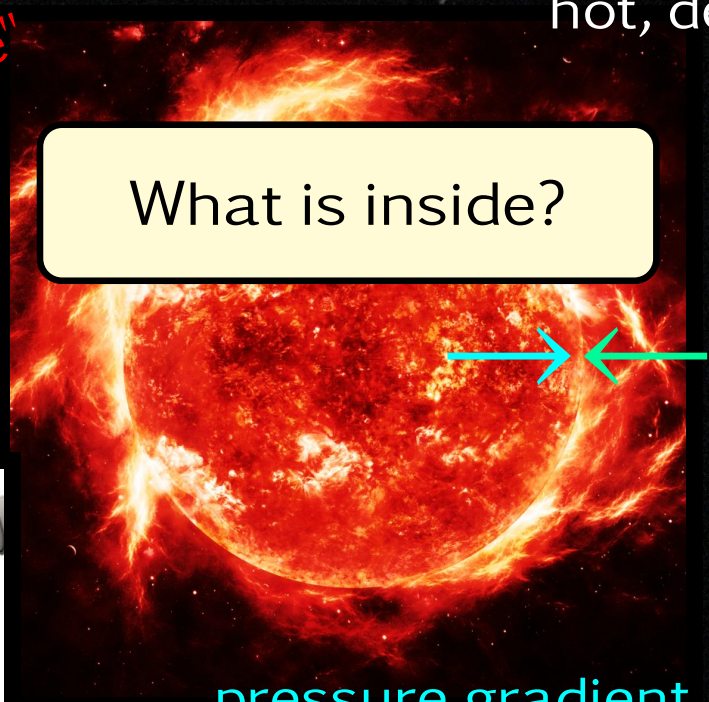

What is inside?

pressure gradient gravity

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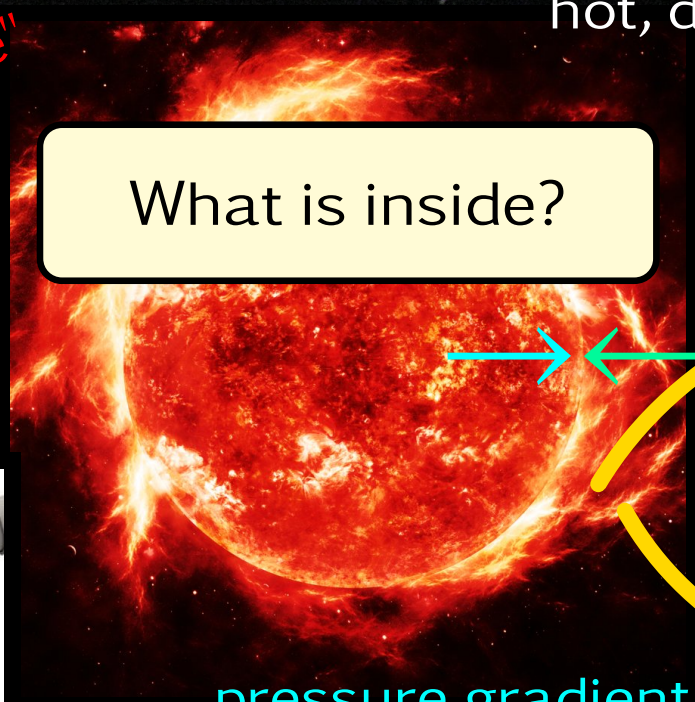

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What is inside?

theoretical modelling of the stellar structure

pressure gradient gravity

# Theoretical modelling of the stellar structure

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

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

$$\frac{\partial L_r}{\partial m_r} = \epsilon_{\mathrm{pl}} - T\frac{\partial S}{\partial t} \qquad \text{equation of energetic balance} \qquad (11)$$

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*Guilera et al. 2011*

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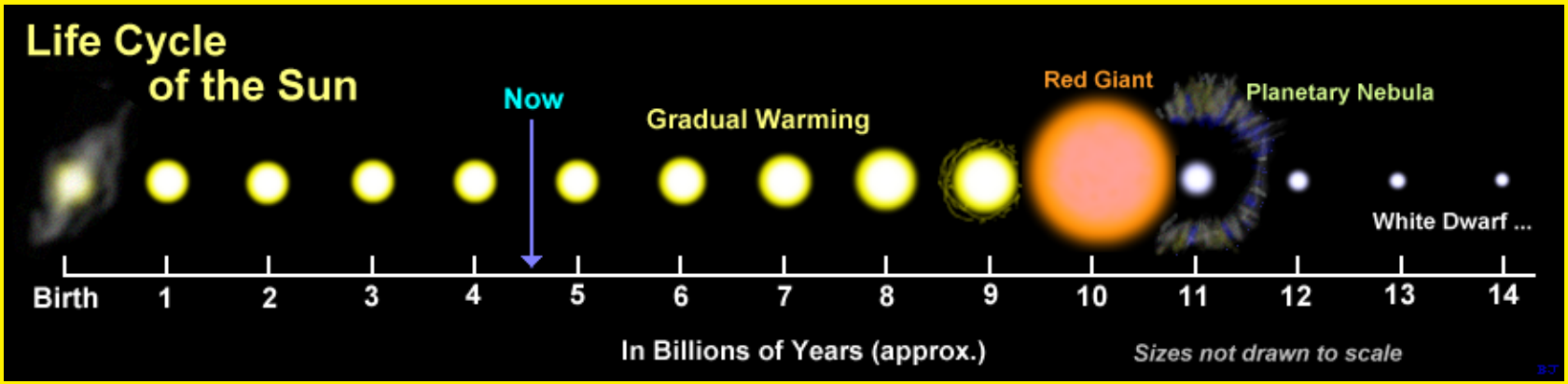


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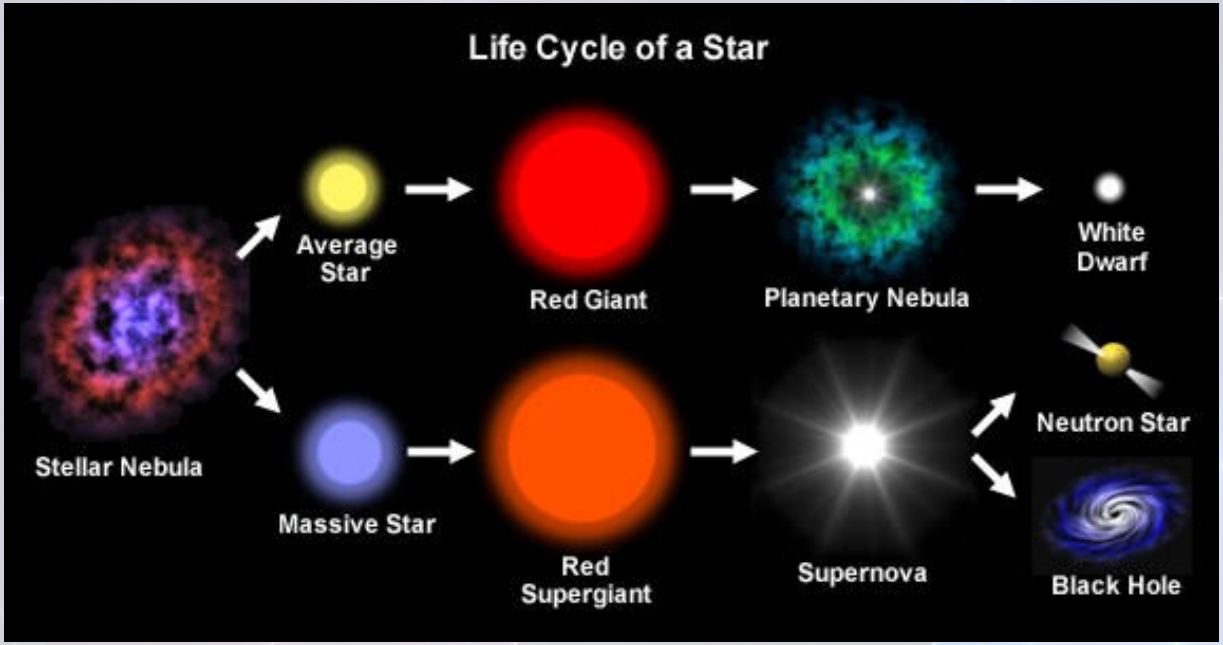
Massive stars: $\gtrsim 9$ times the Sun ($\gtrsim 9\ M_\odot$)



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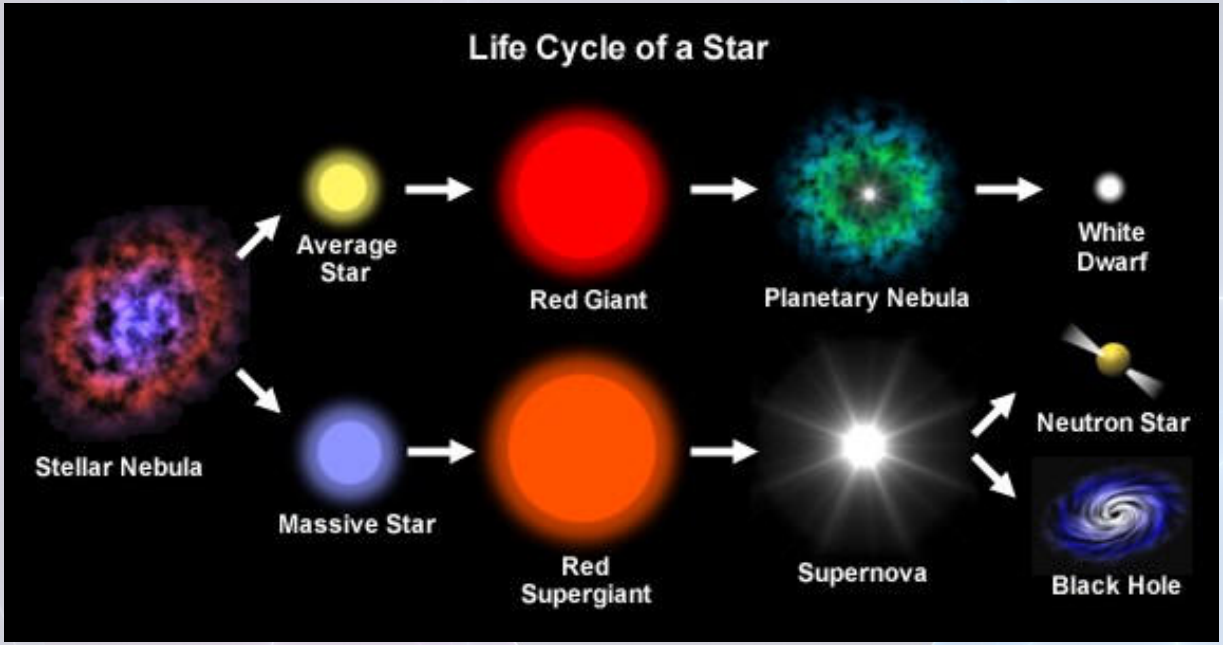


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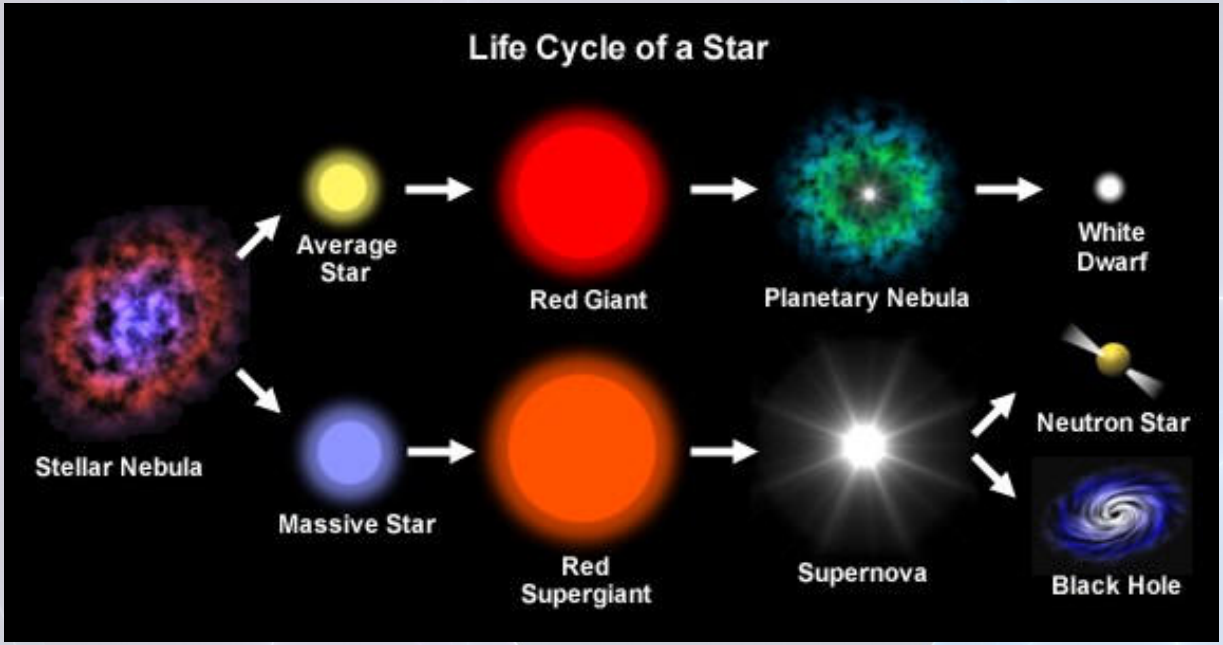


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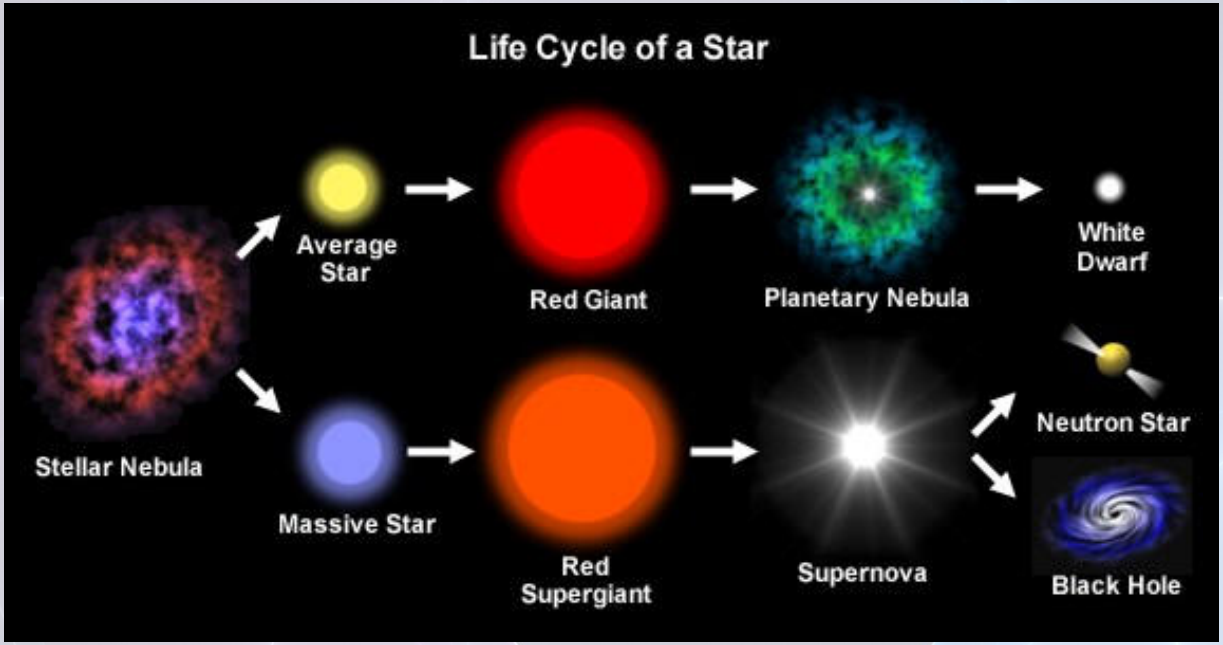


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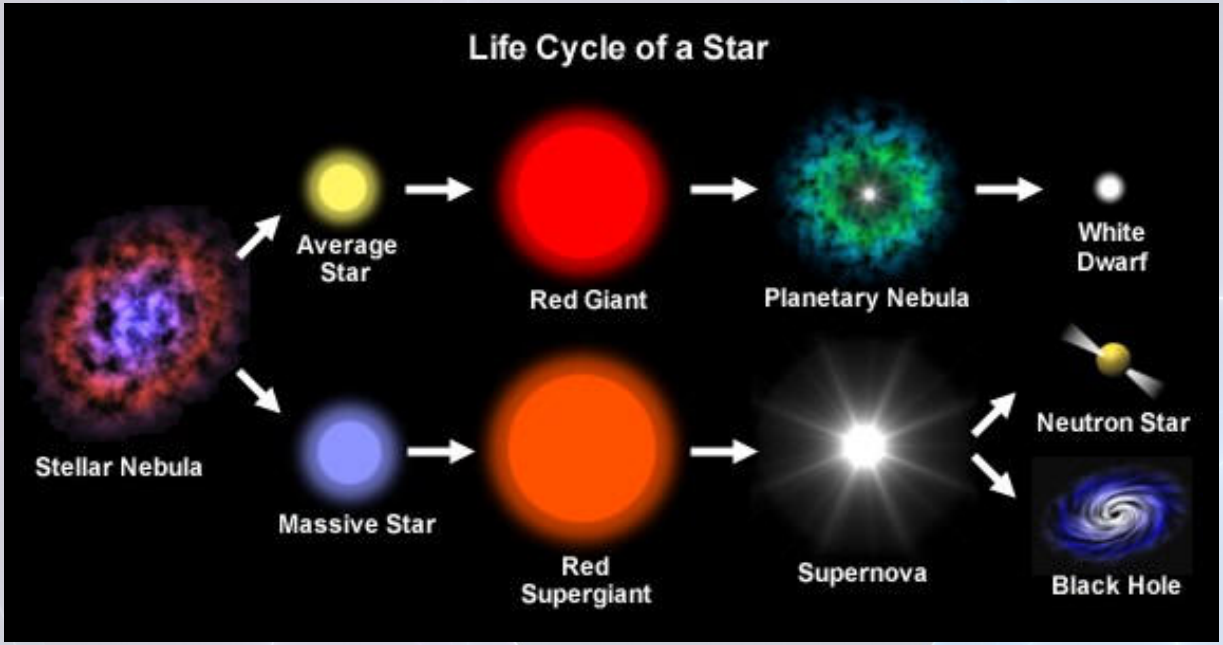


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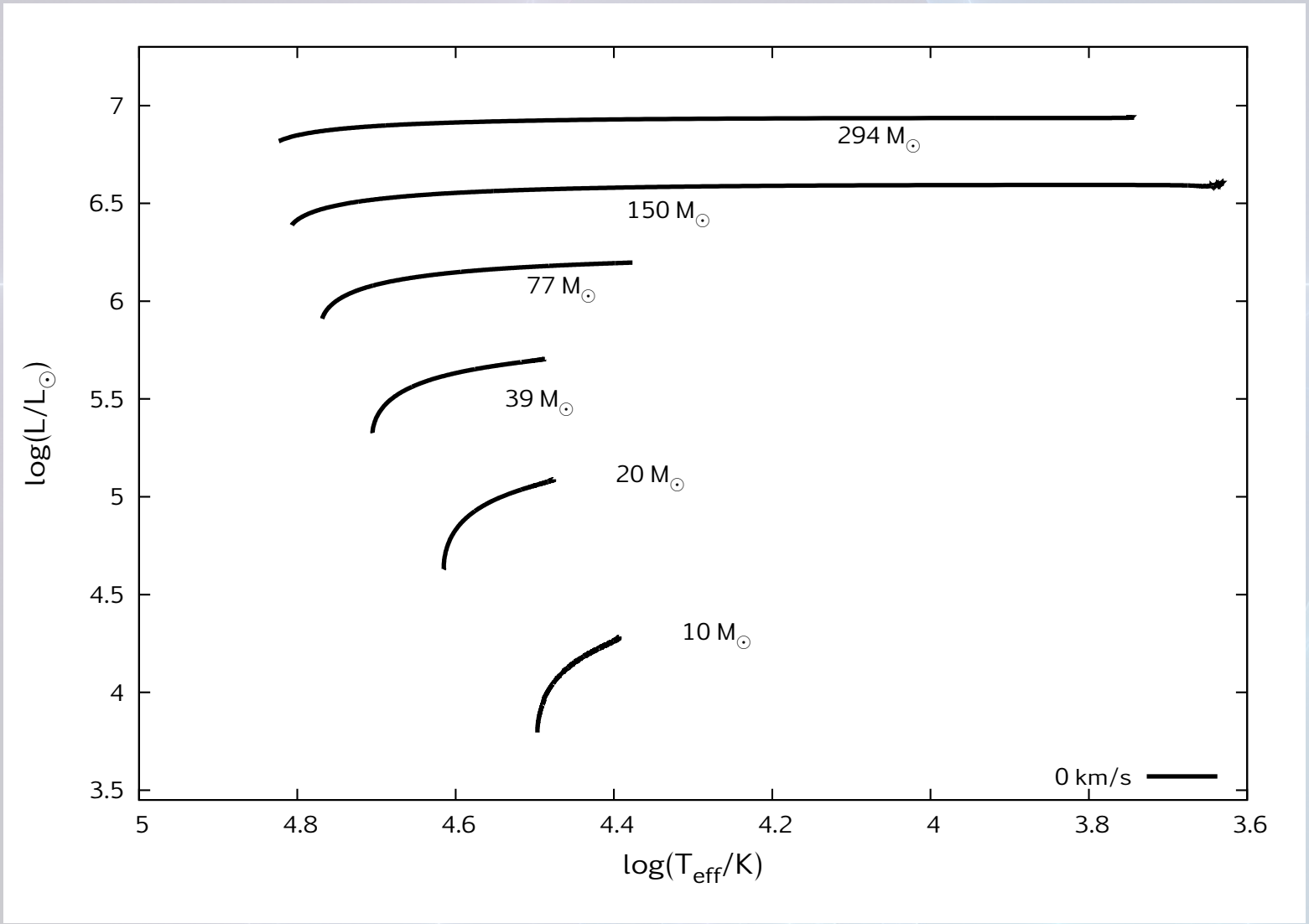

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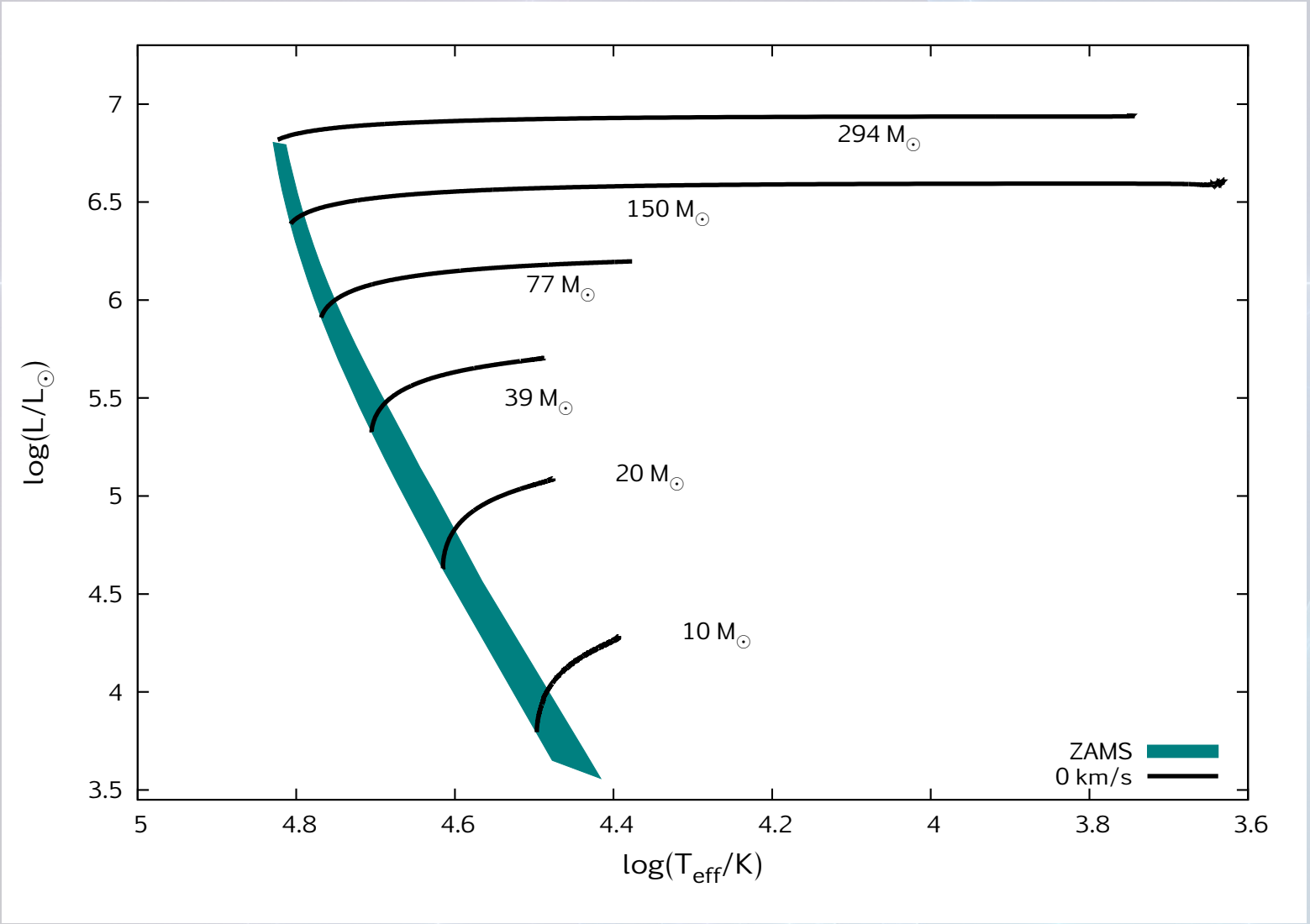

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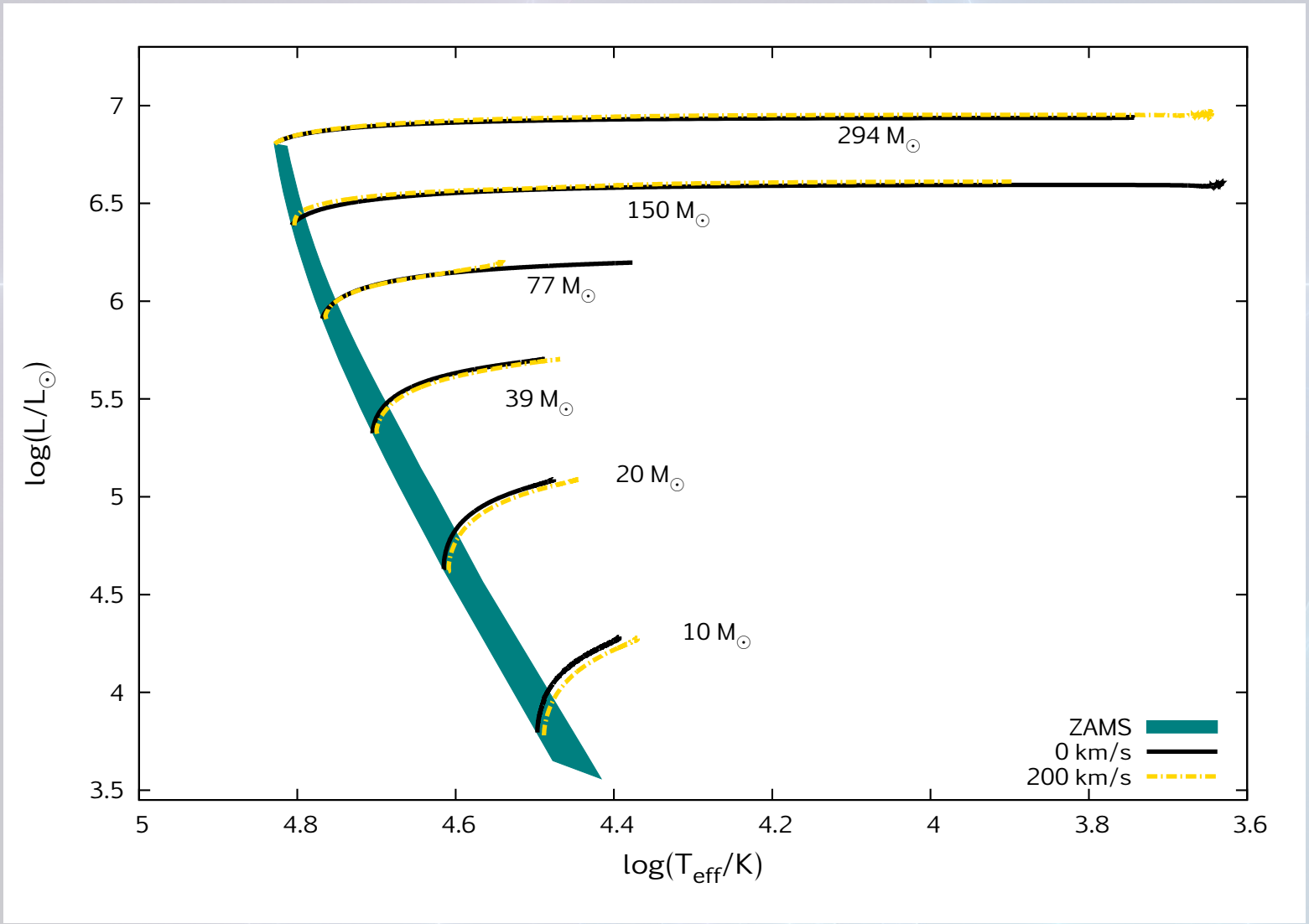

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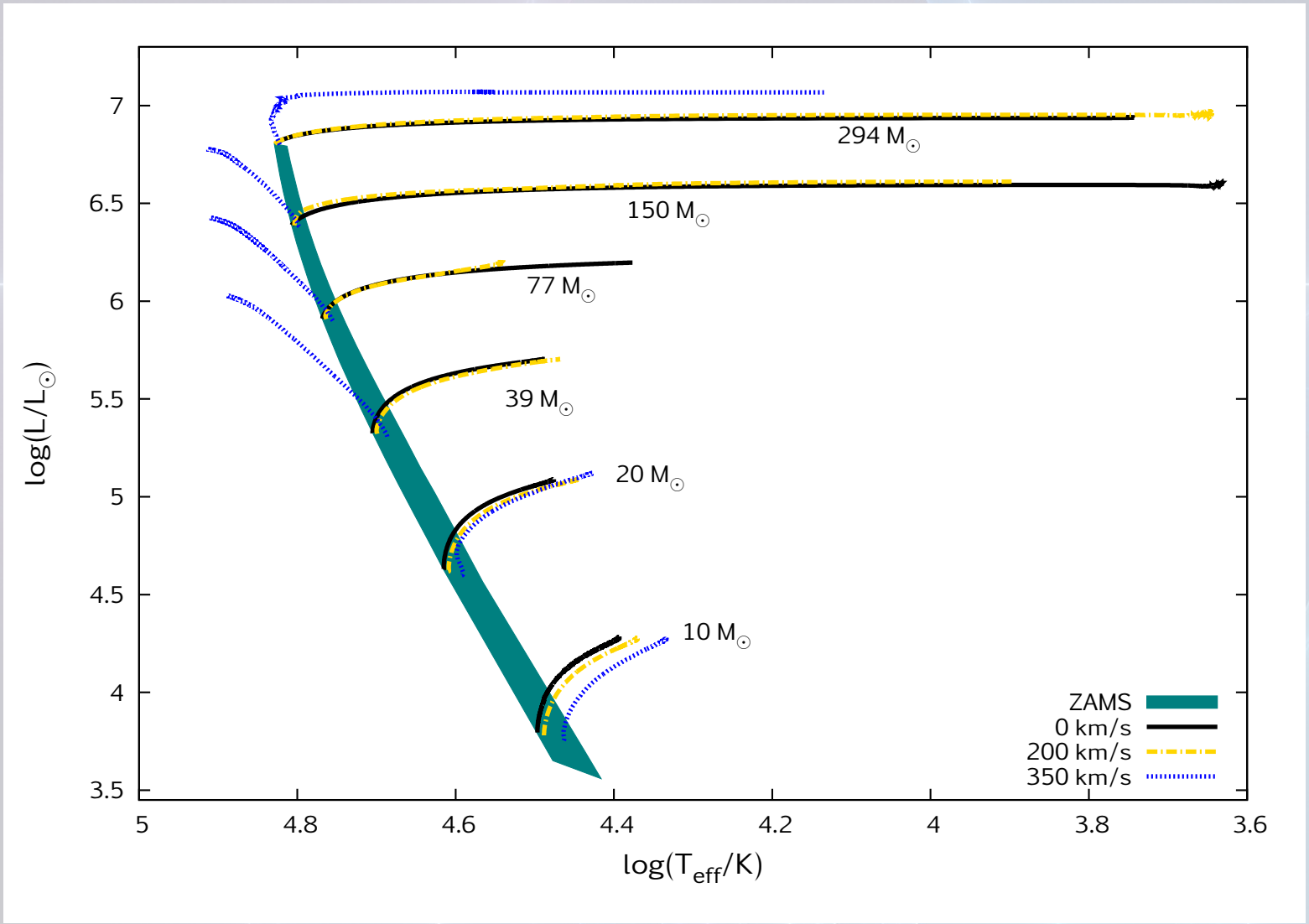

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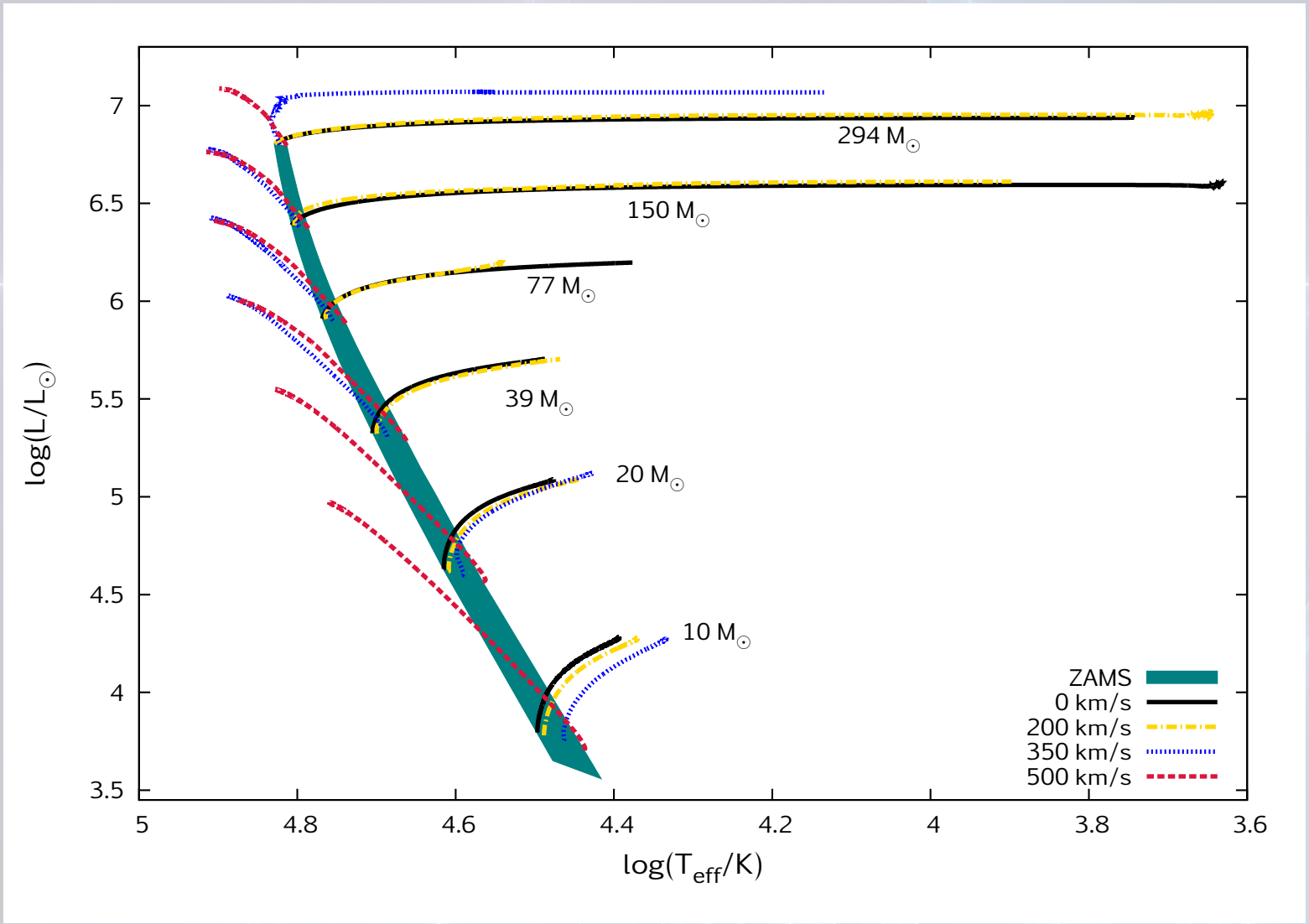

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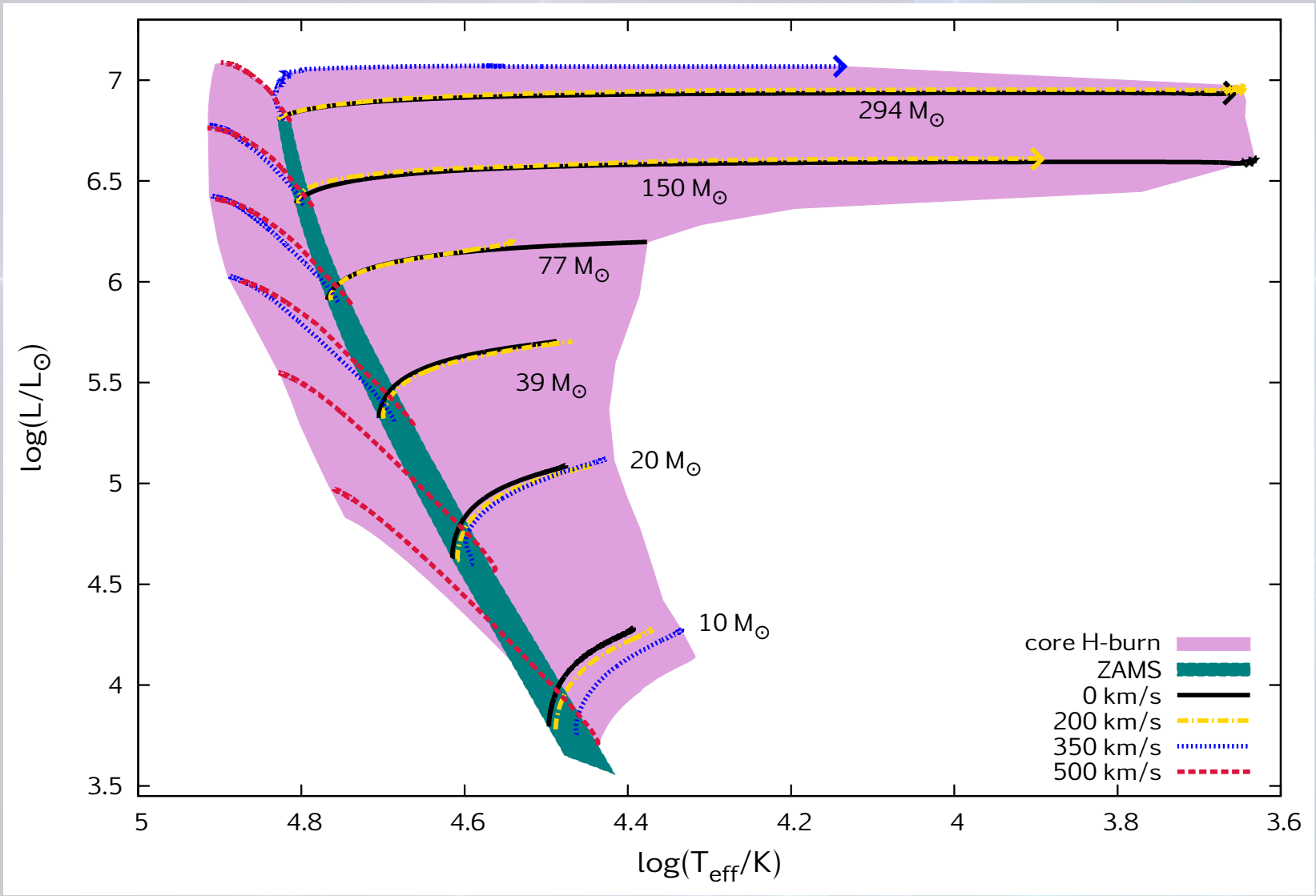

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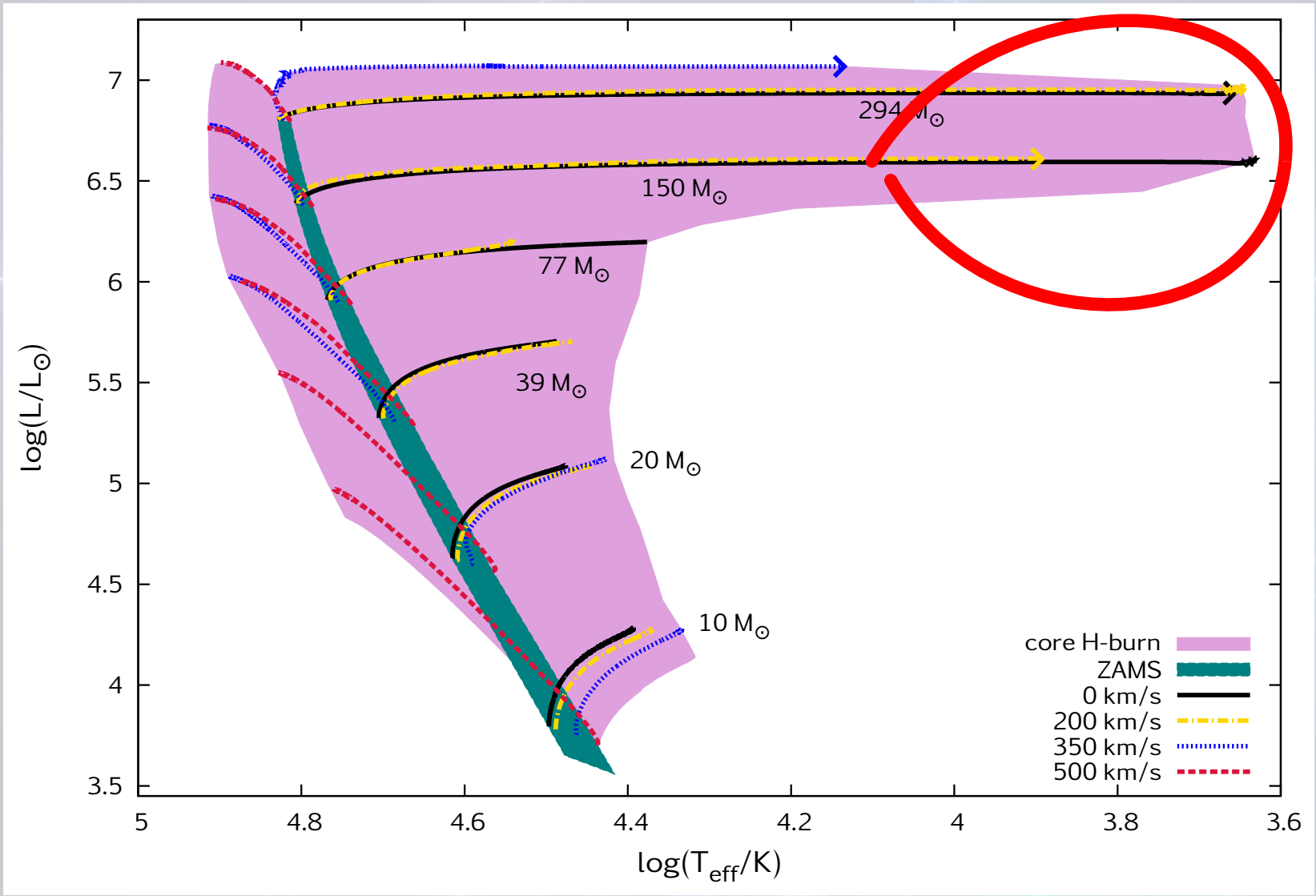

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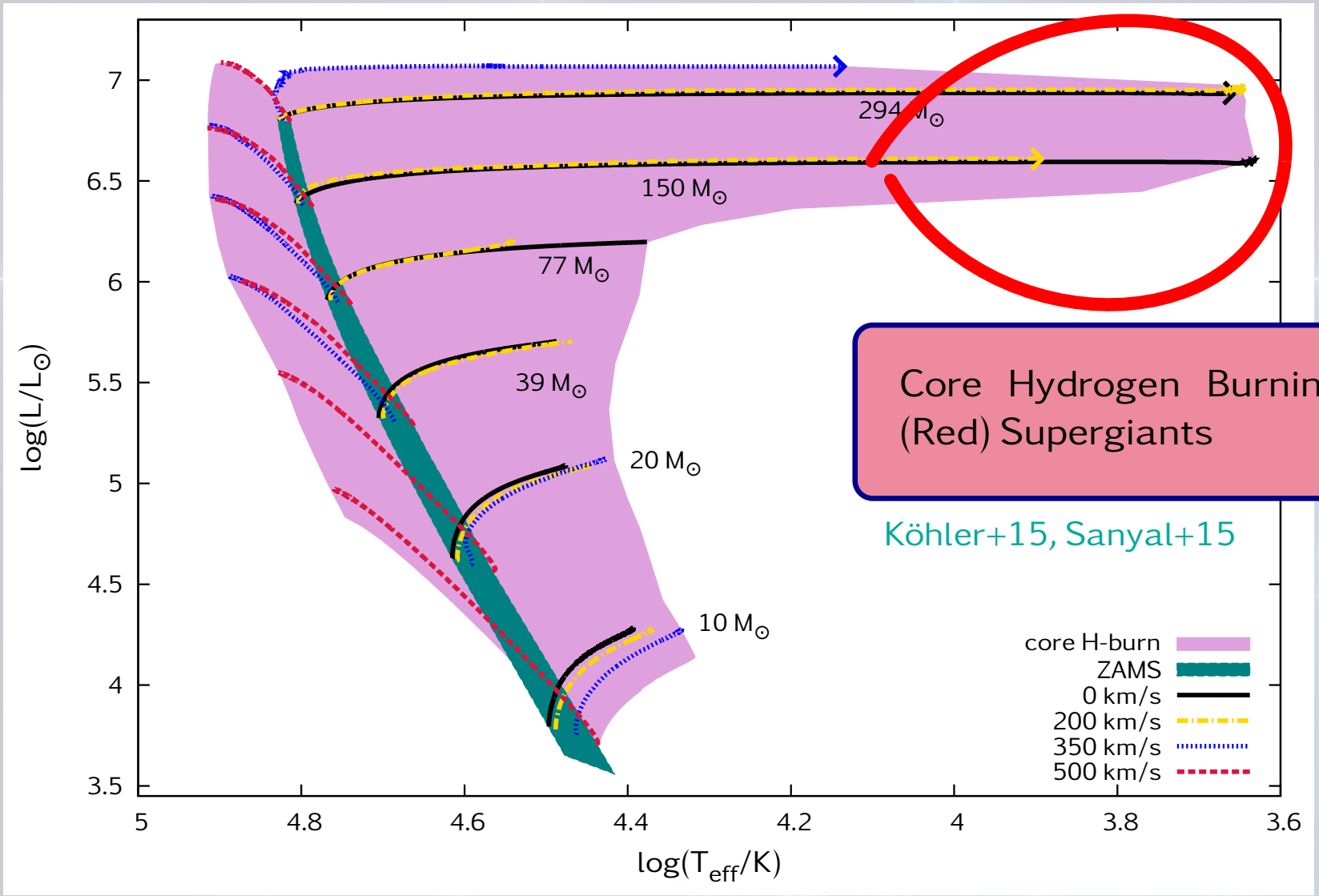

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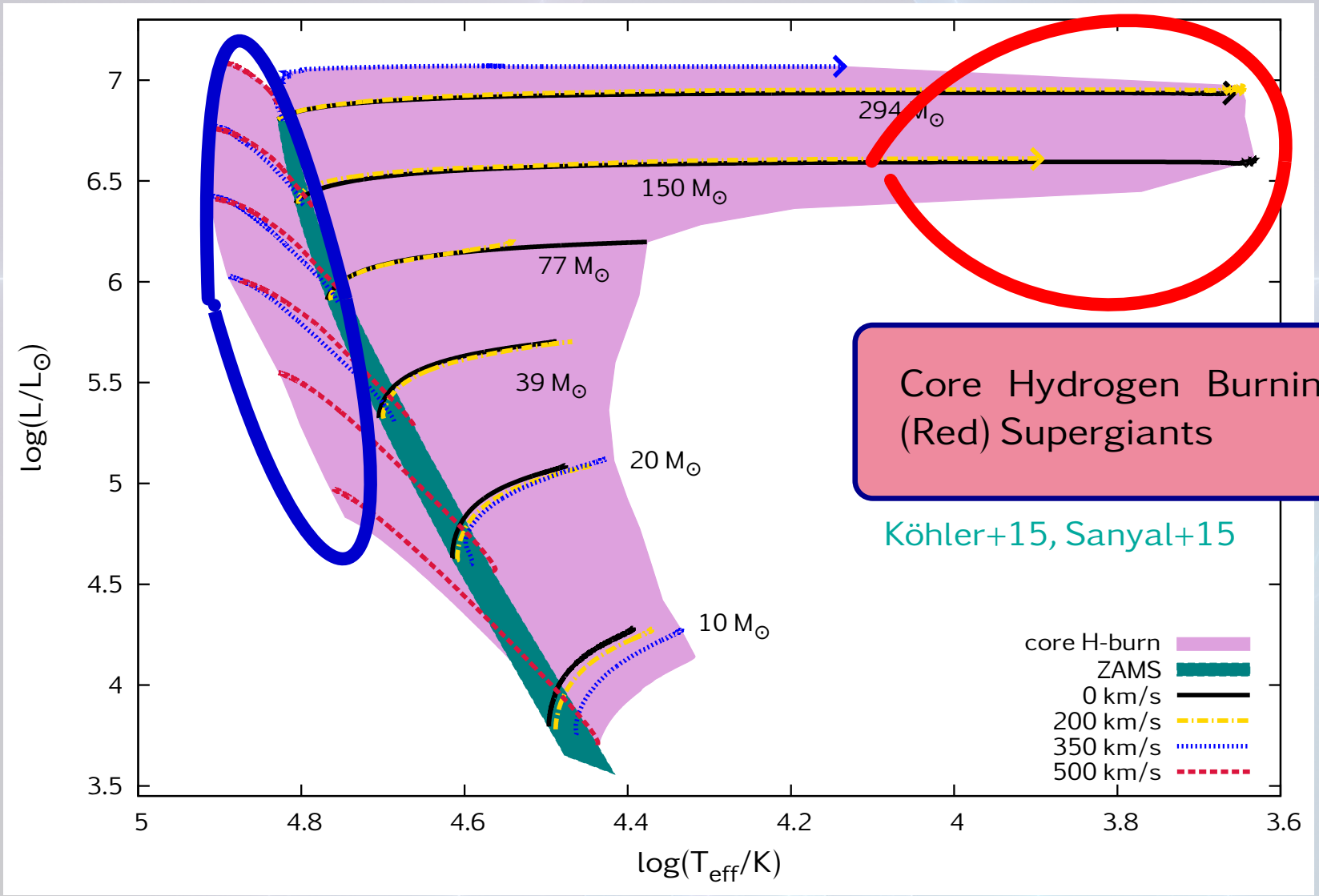

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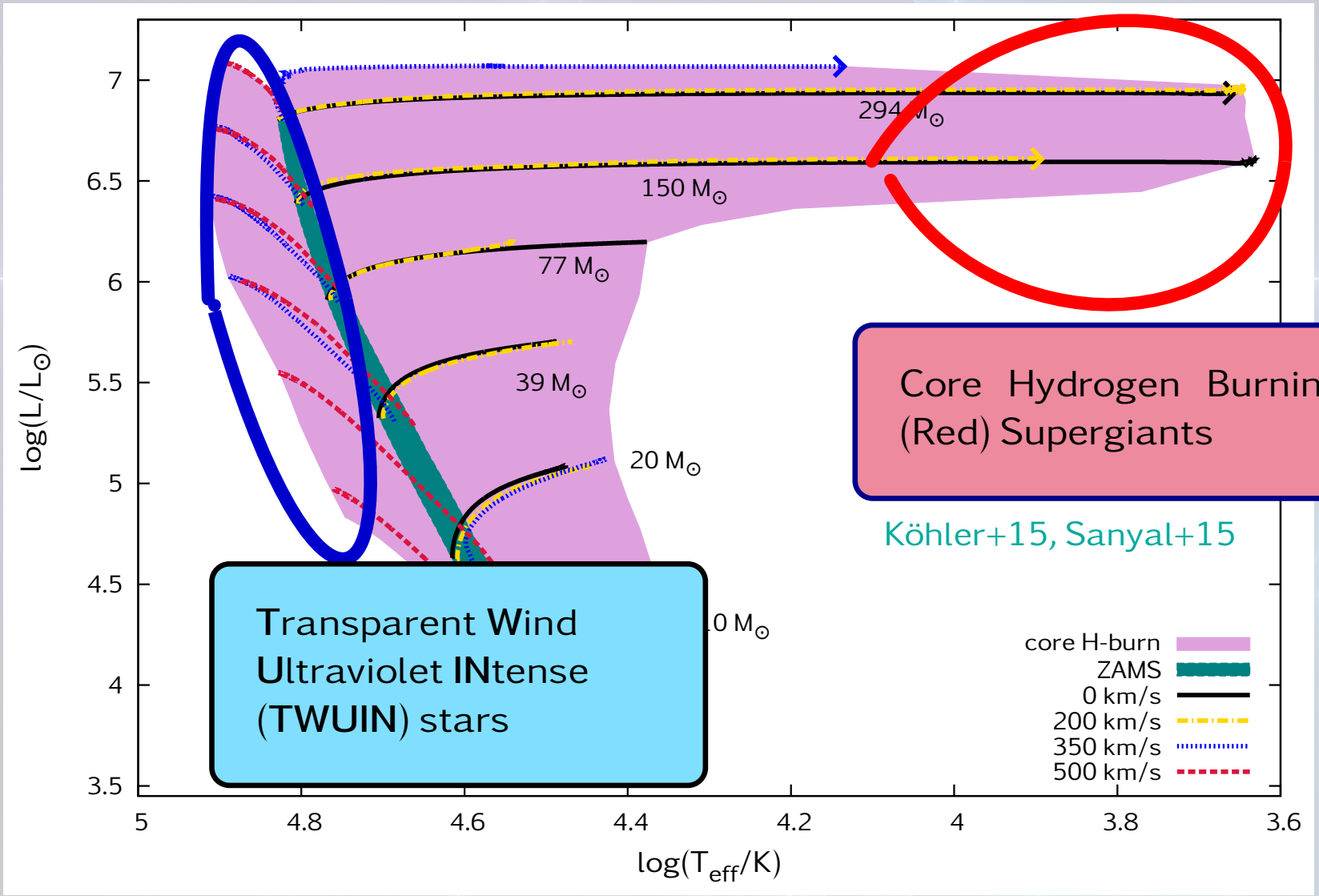
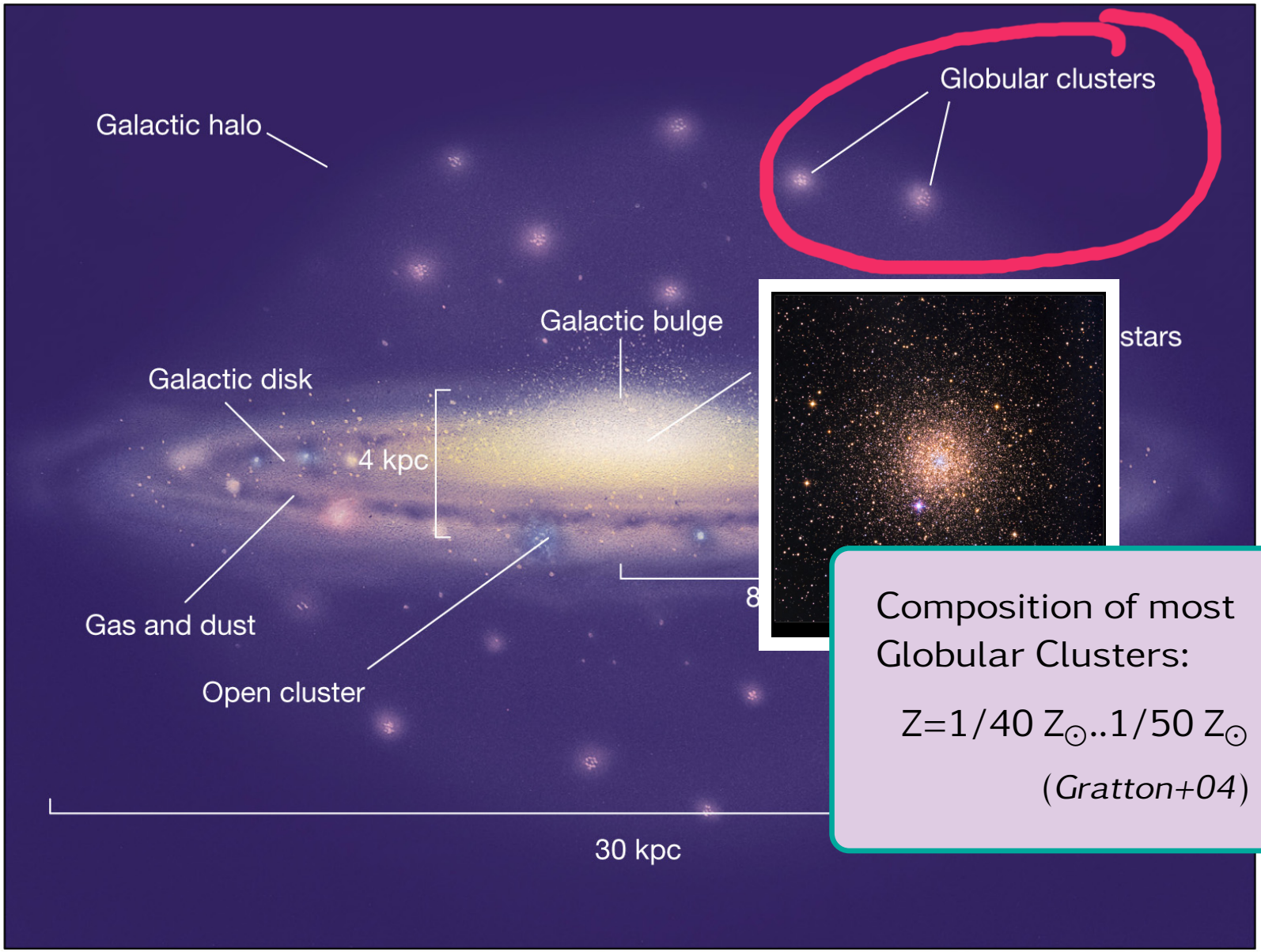


# Globular Clusters & Abundance Anomalies

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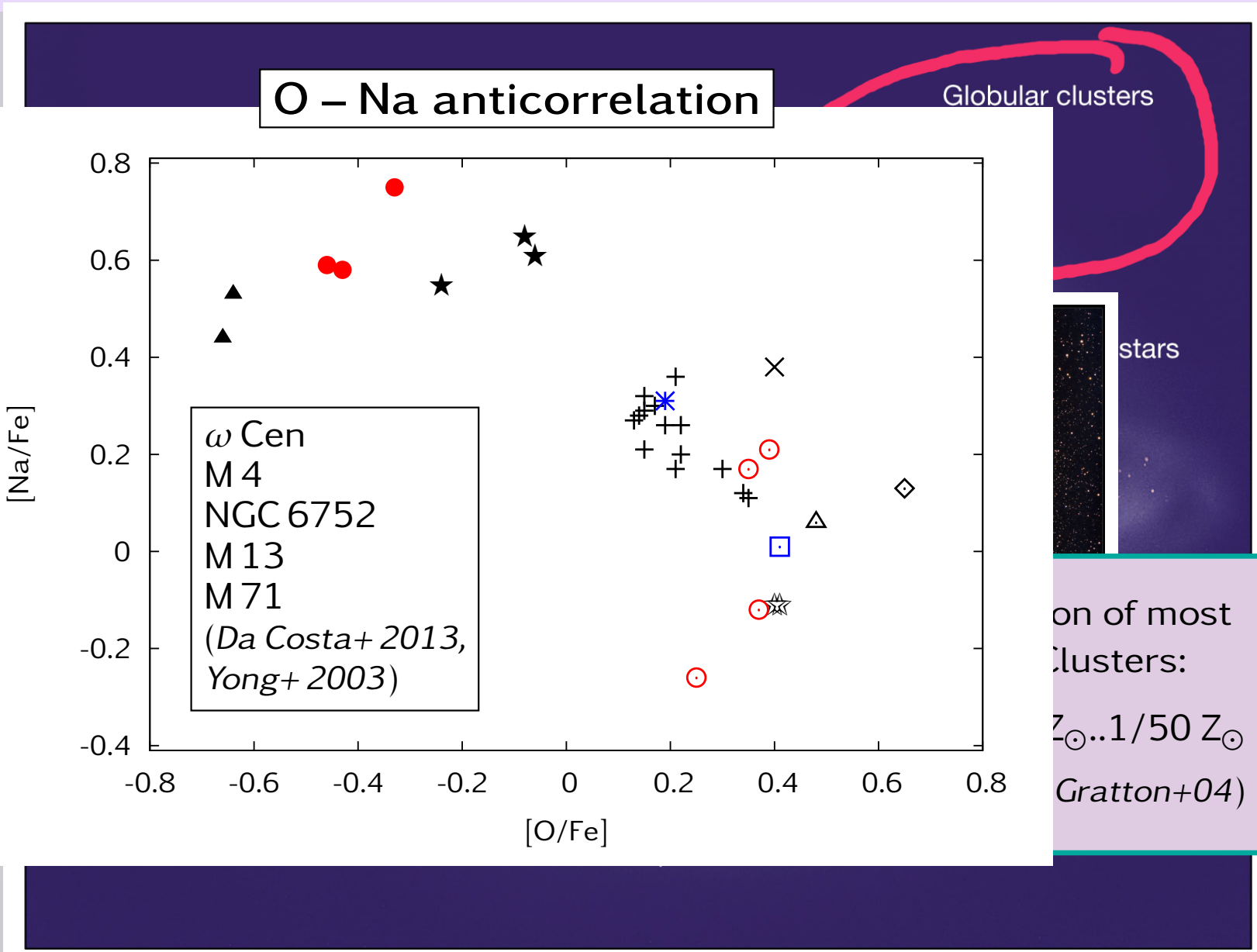

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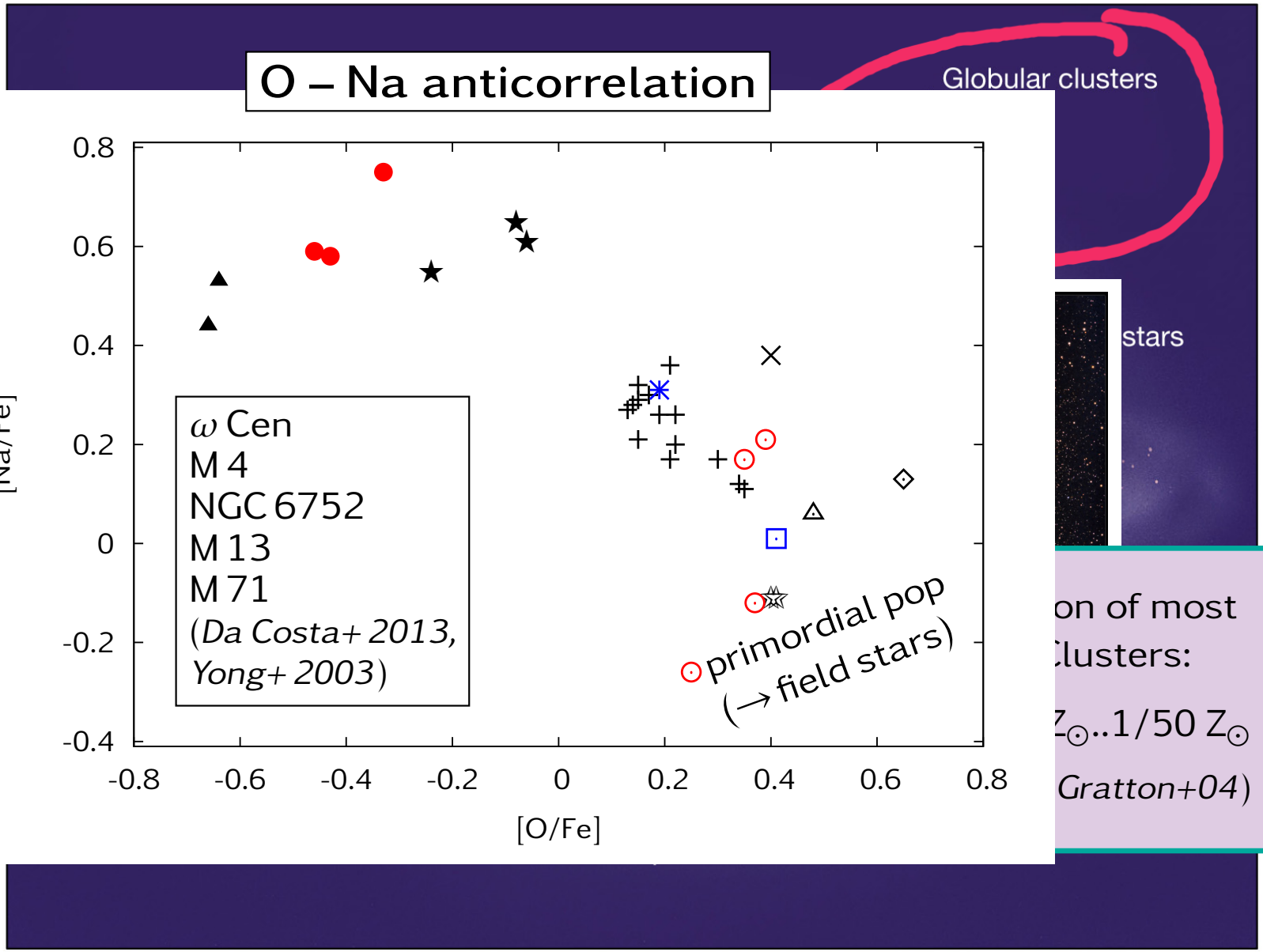

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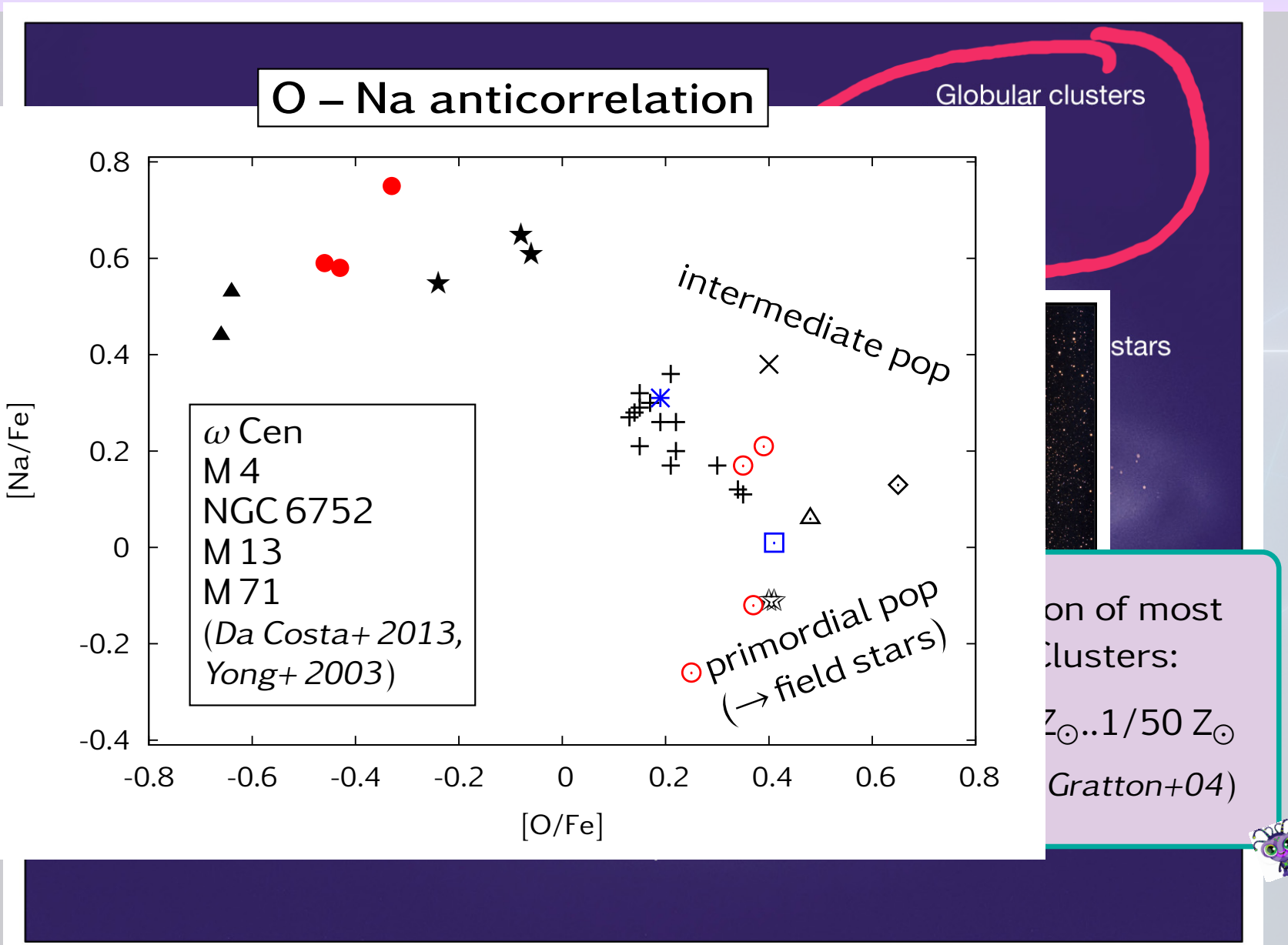

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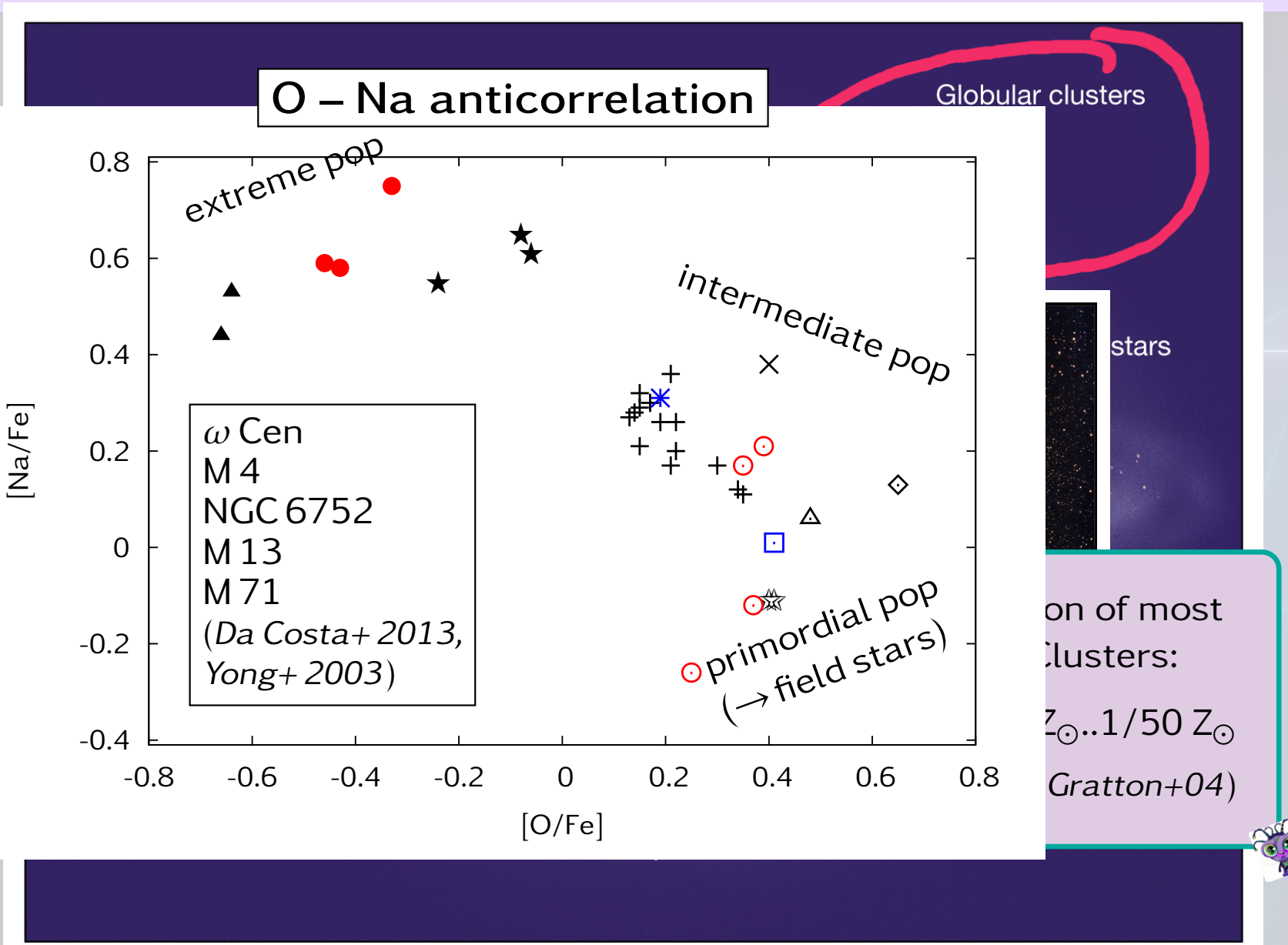

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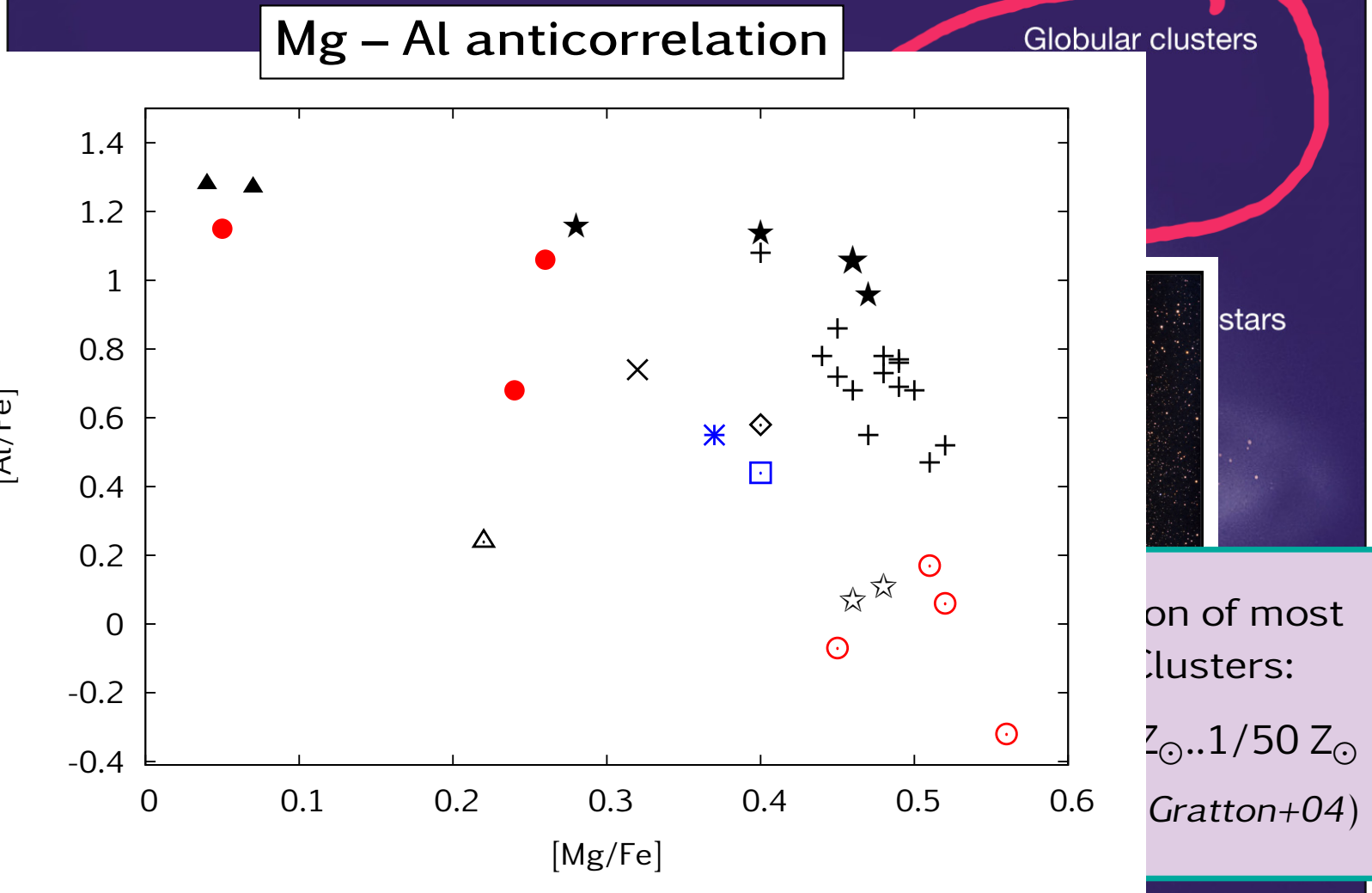

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## Mg – Al anticorrelation

- extreme & intermediate pop: **polluted** by hot hydrogen burning
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  - AGB stars: hot bottom burning (*Ventura+ 2001*)
  - fast rotating massive stars: close to break-up (*Decressin+ 2007*)
  - supermassive stars ($10^4$ $M_\odot$): continuum-driven wind (*Denissenkov+ 2014*)
  - massive binaries: non-conservative mass transfer (*de Mink+ 2009*)

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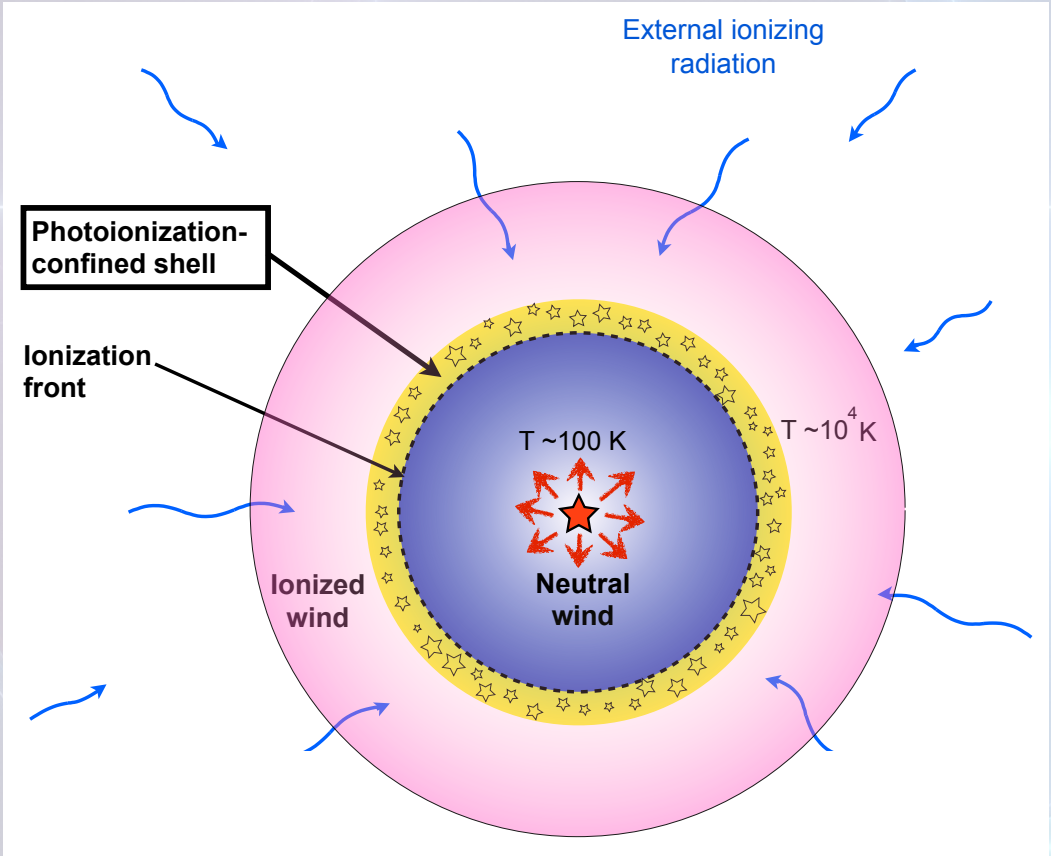
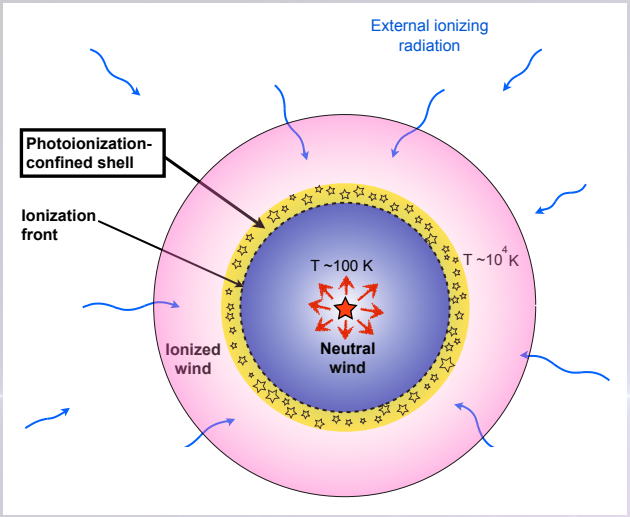



PICO shell: *Mackey+ 2014 (Nature)*

# Simulating the PICO shell



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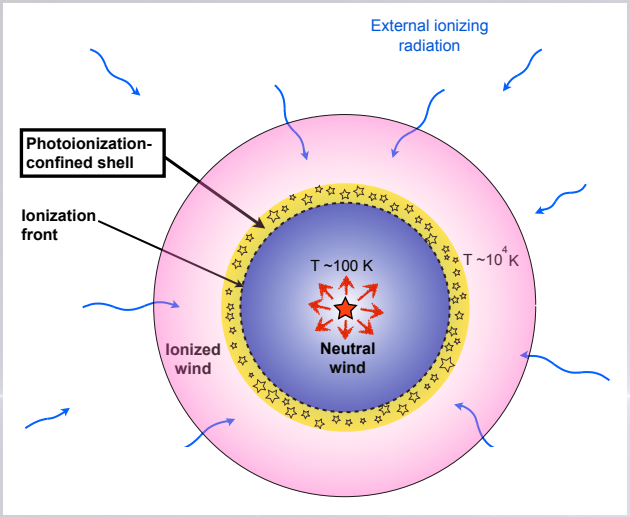


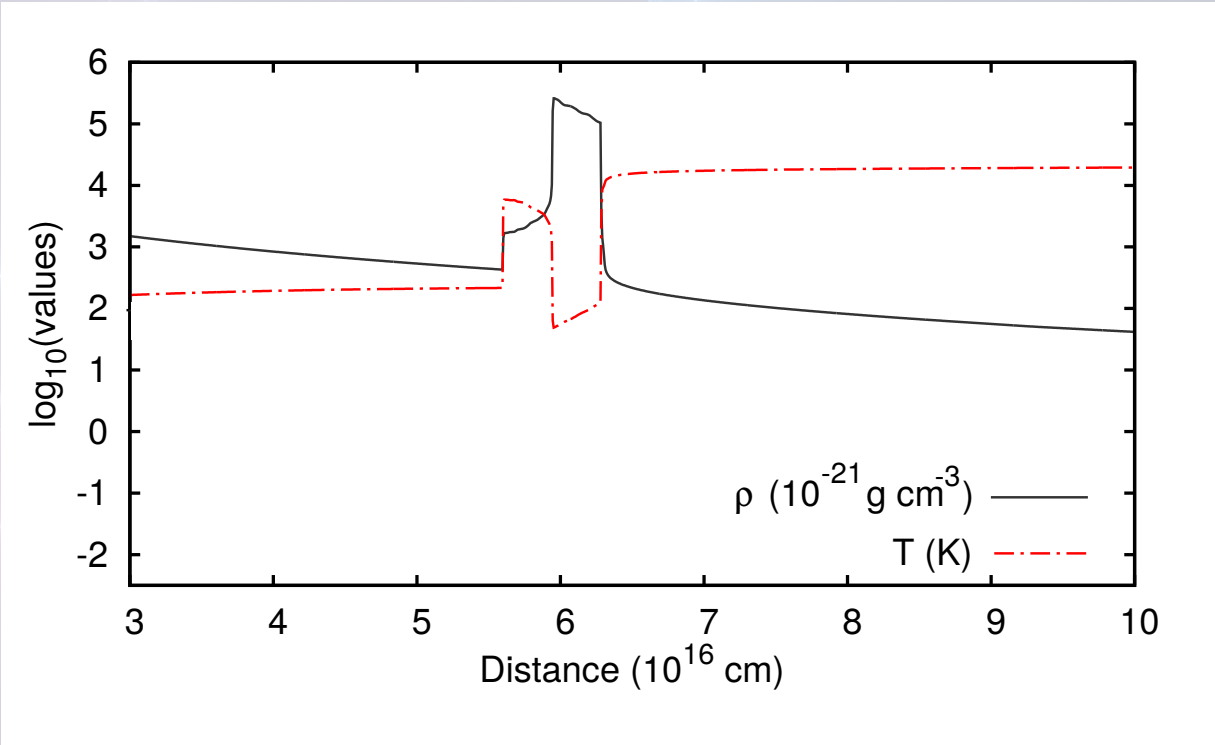

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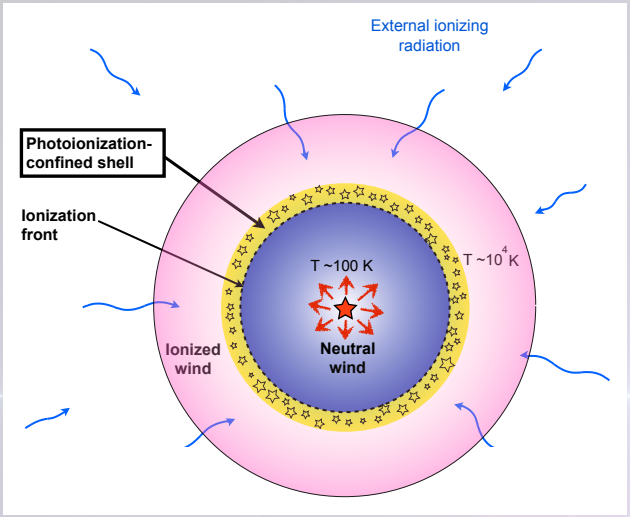


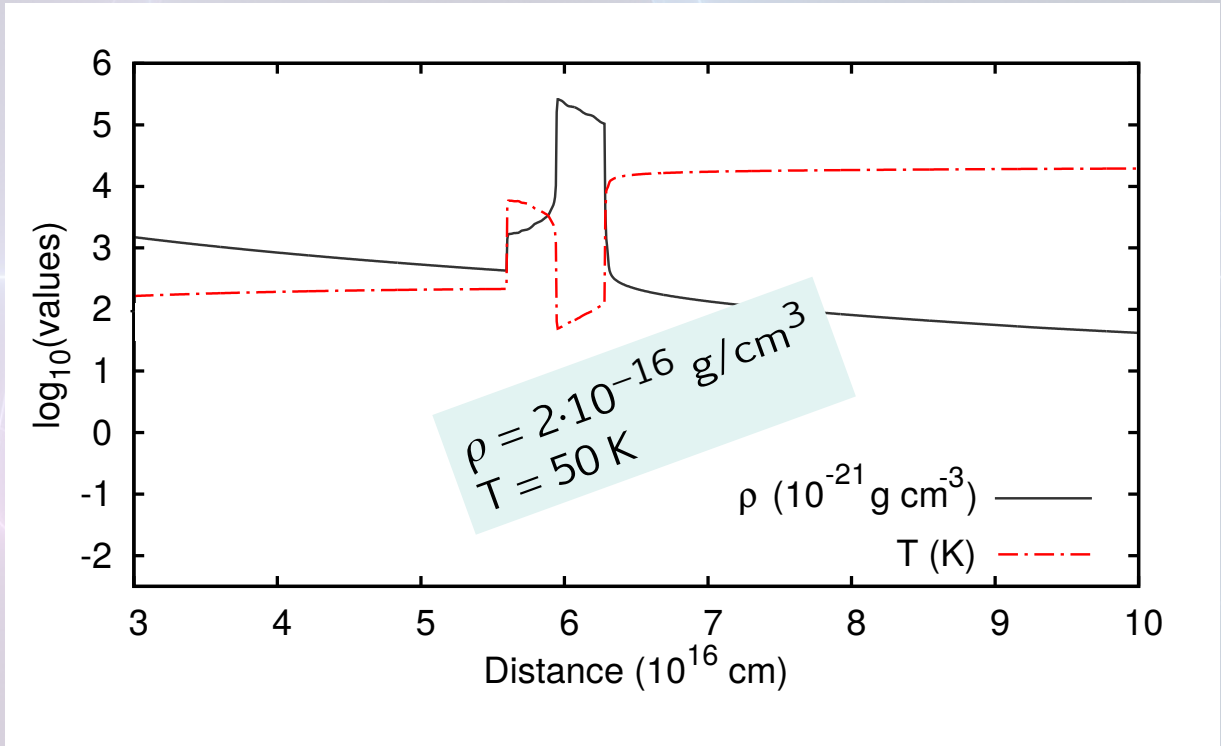

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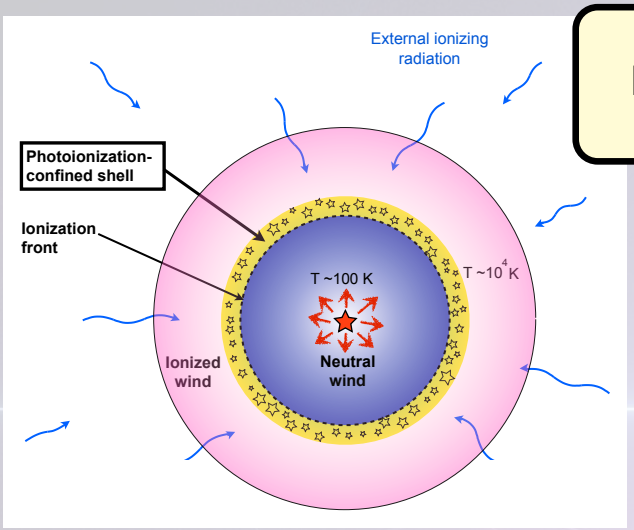
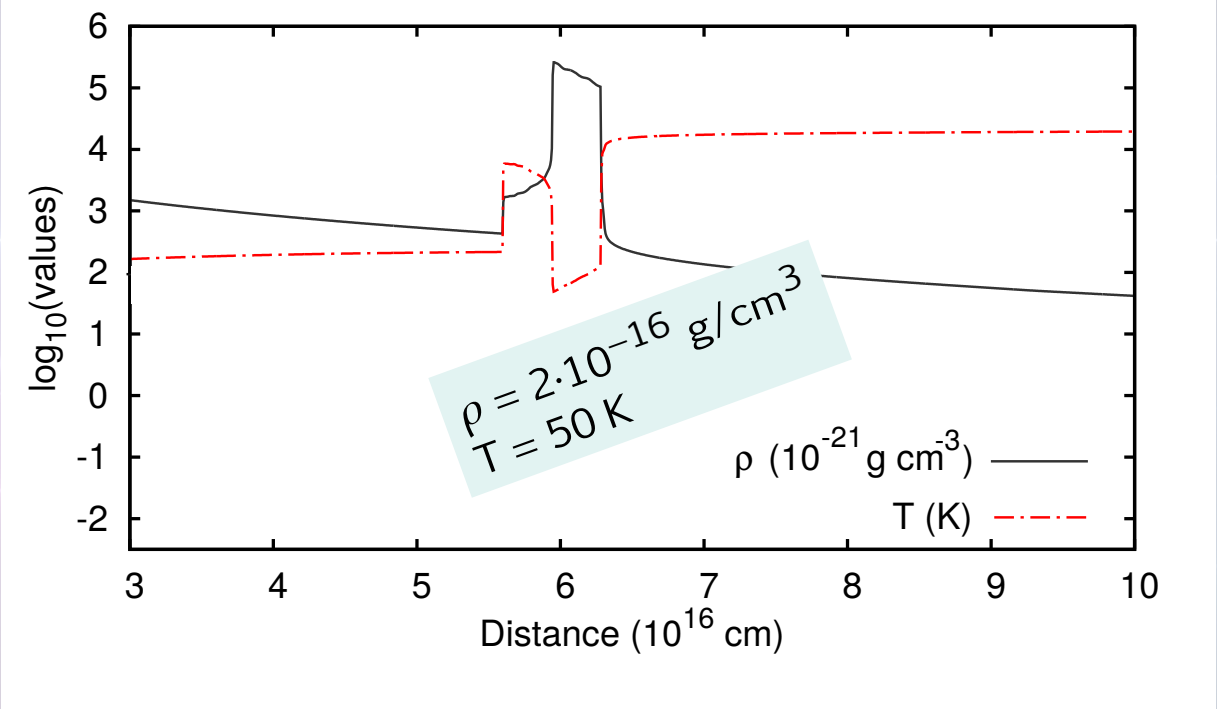



Mass of the photoionization-confined (PICO) shell: ~14 $M_\odot$



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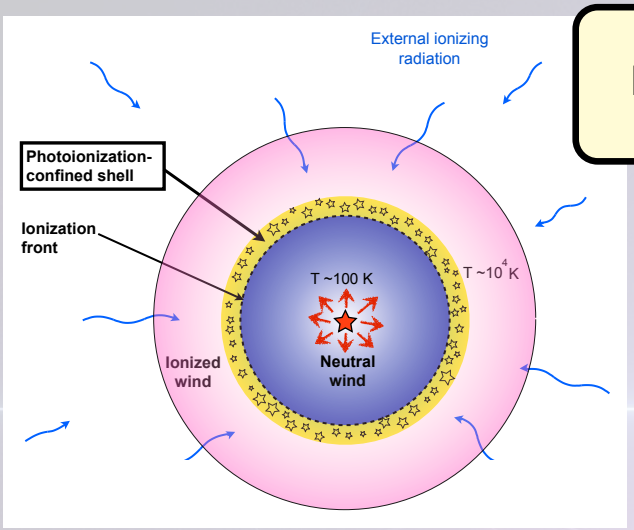


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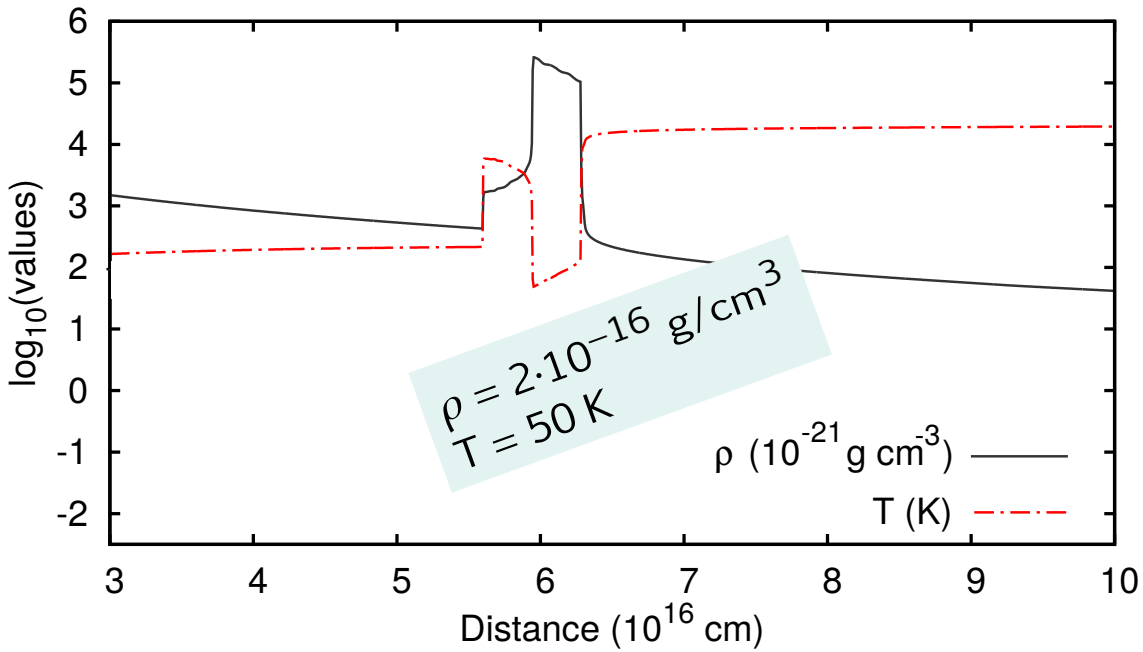


Lifetime of the shell: ~$10^5$ yr
>>
Growth timescale of grav. unstable perturbations: ~$10^4$ yr

Compared to observations:

O – Na anticorrelation

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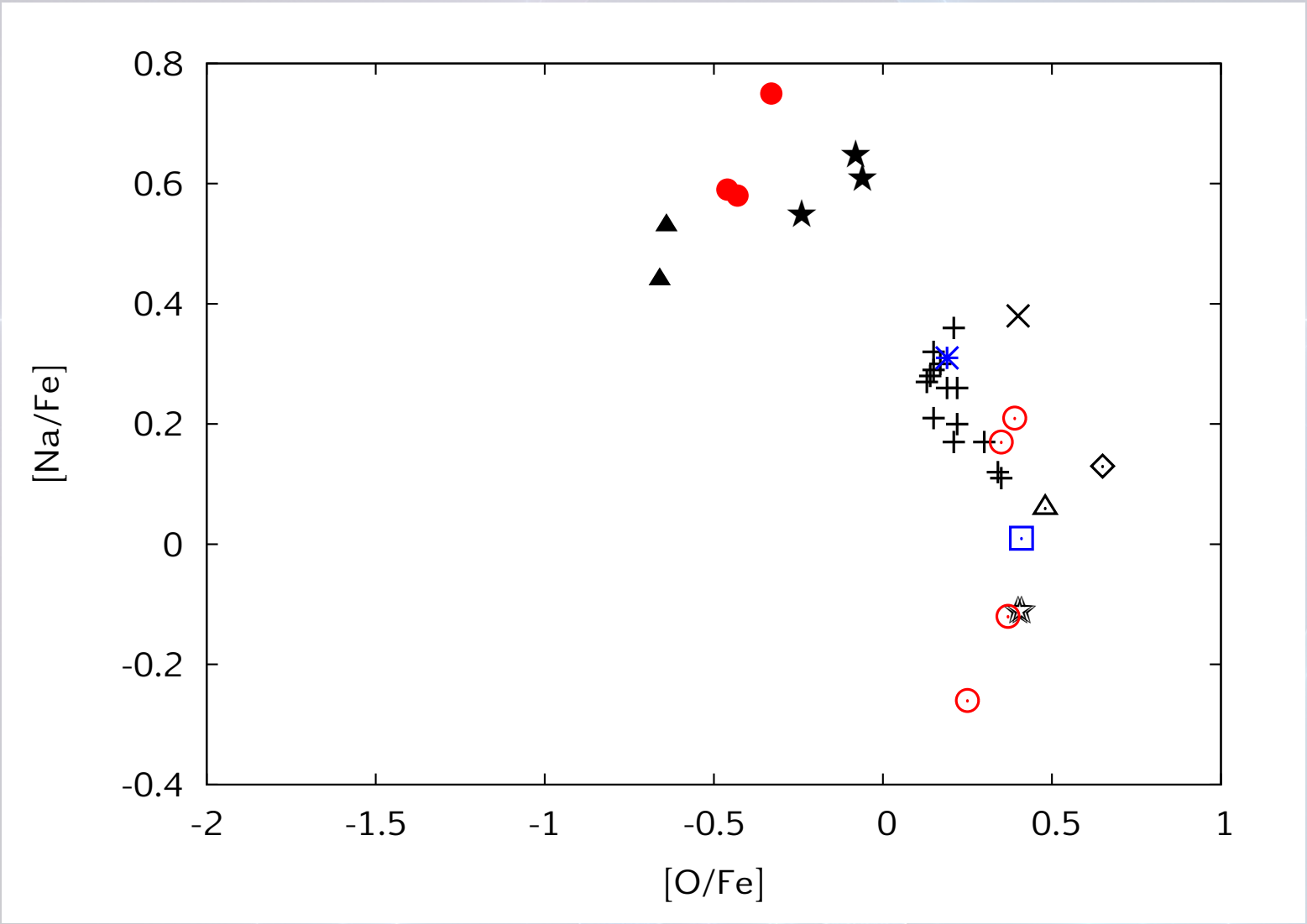

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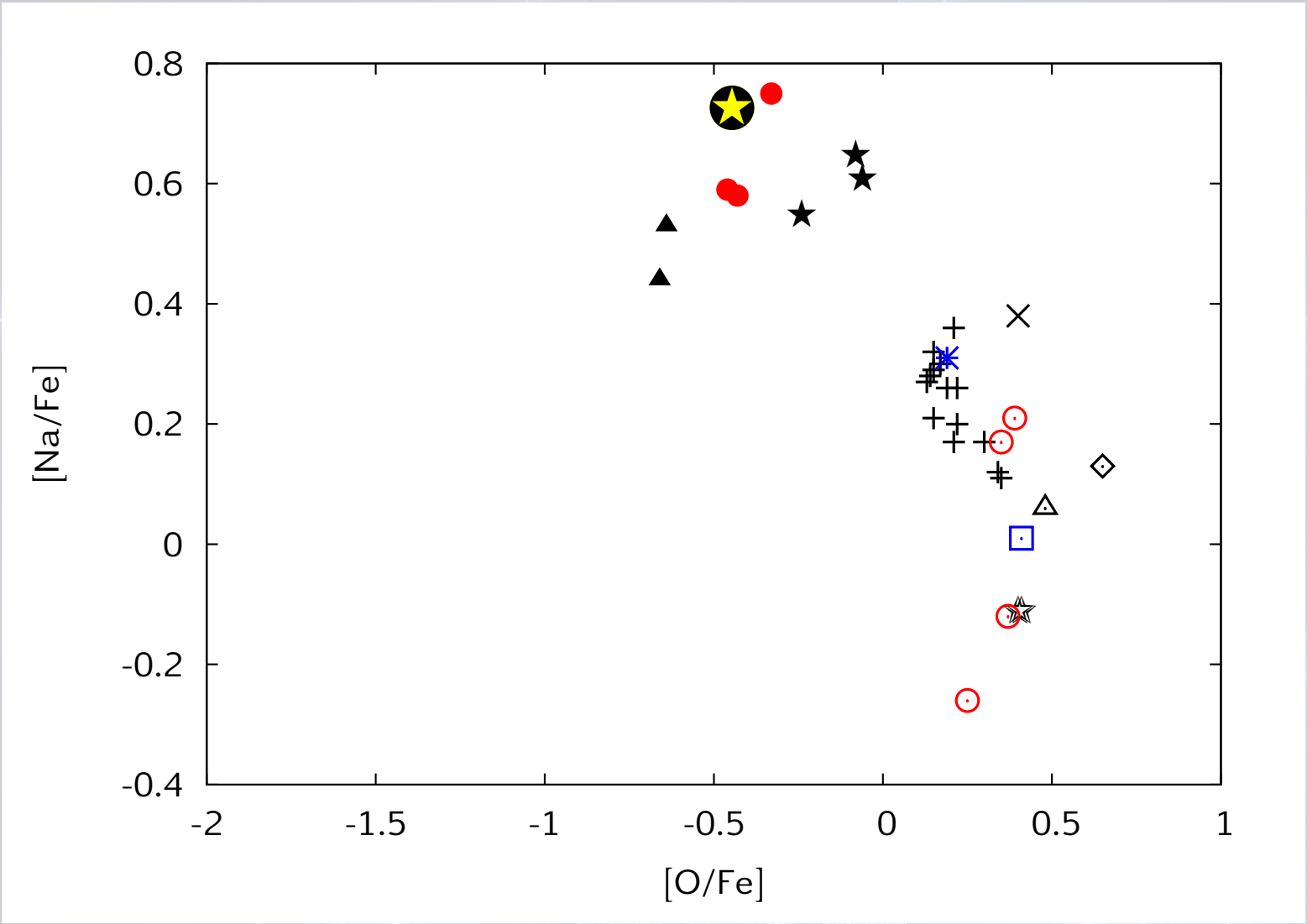

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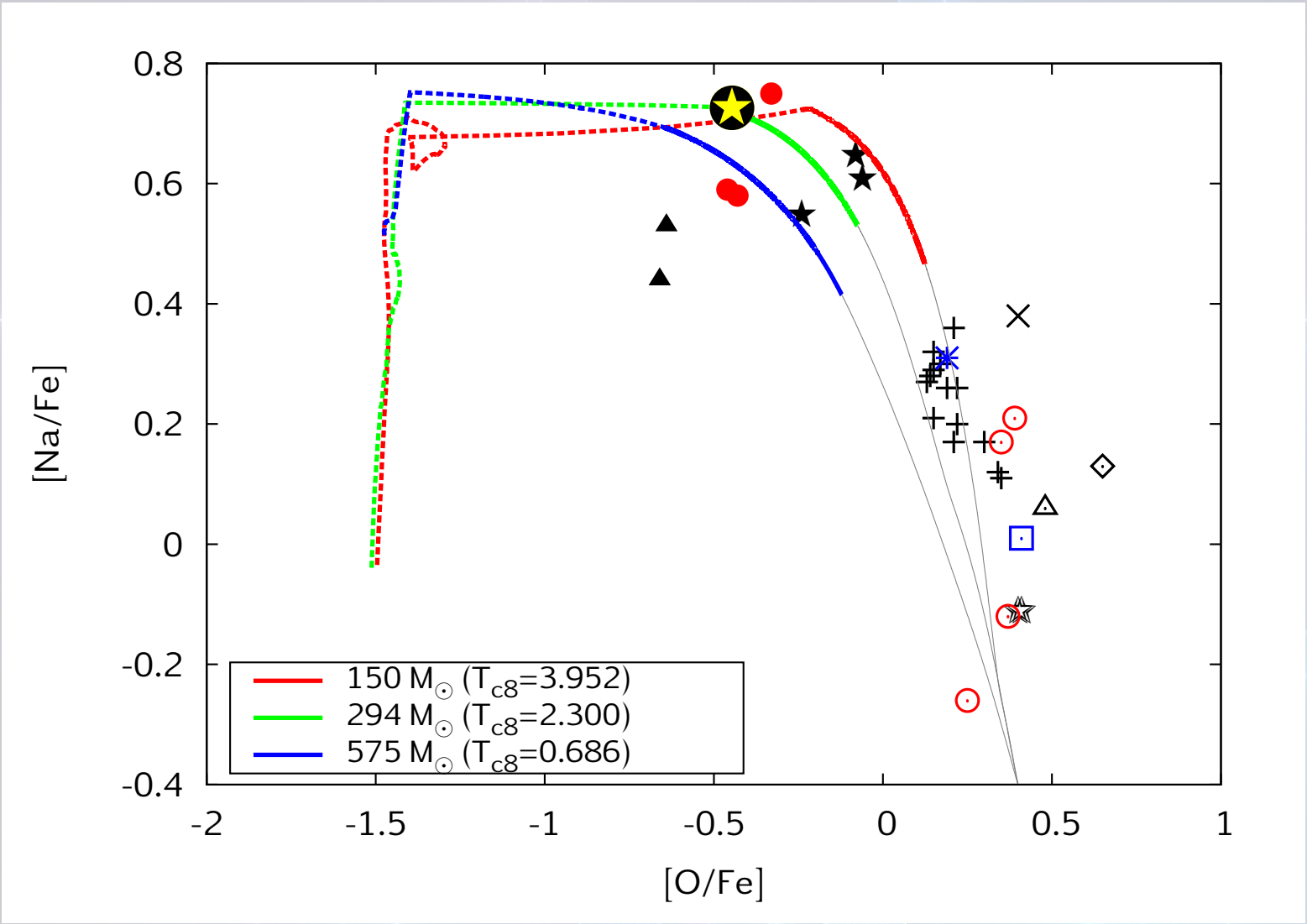

Compared to observations:

Mg – Al anticorrelation

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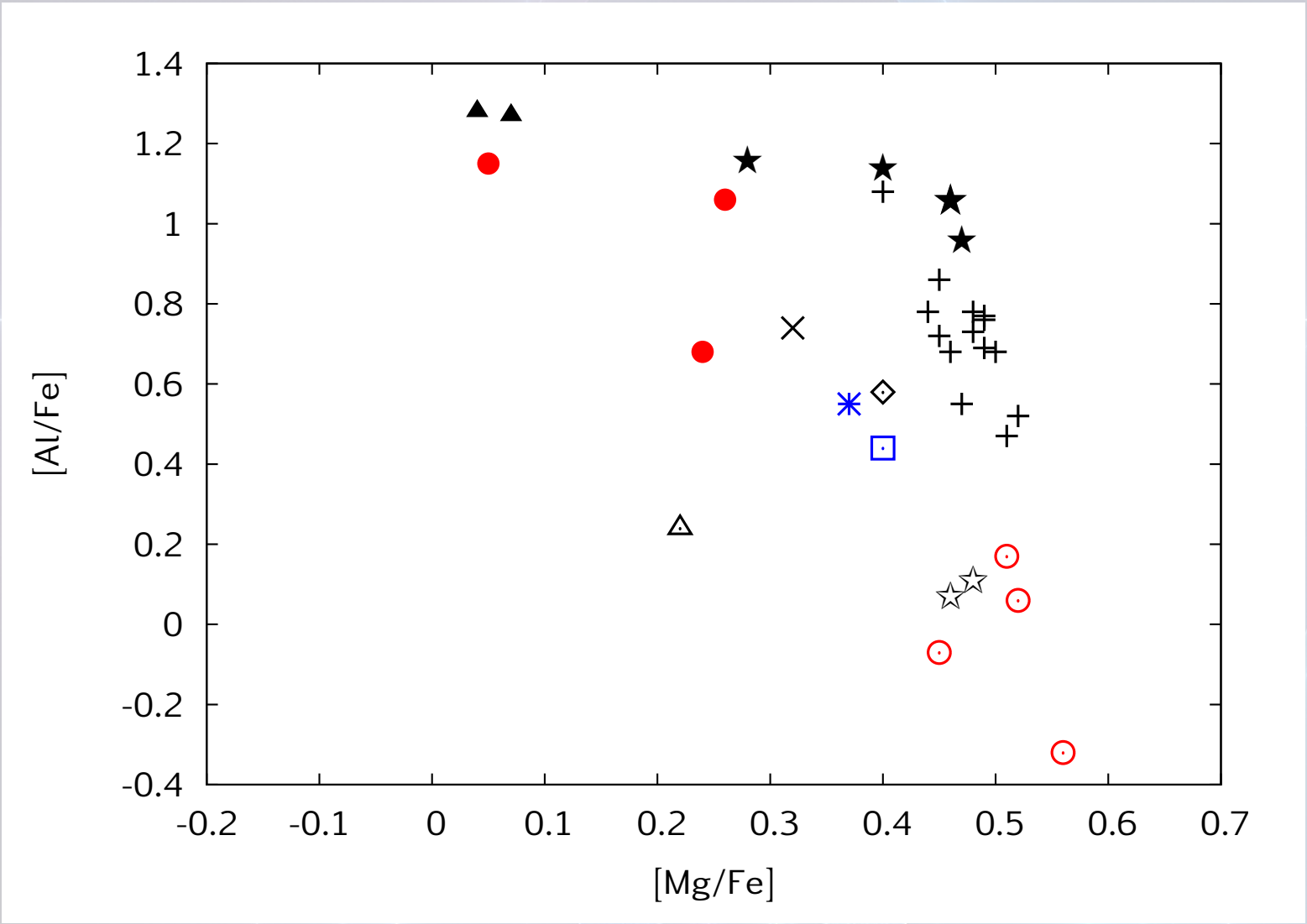

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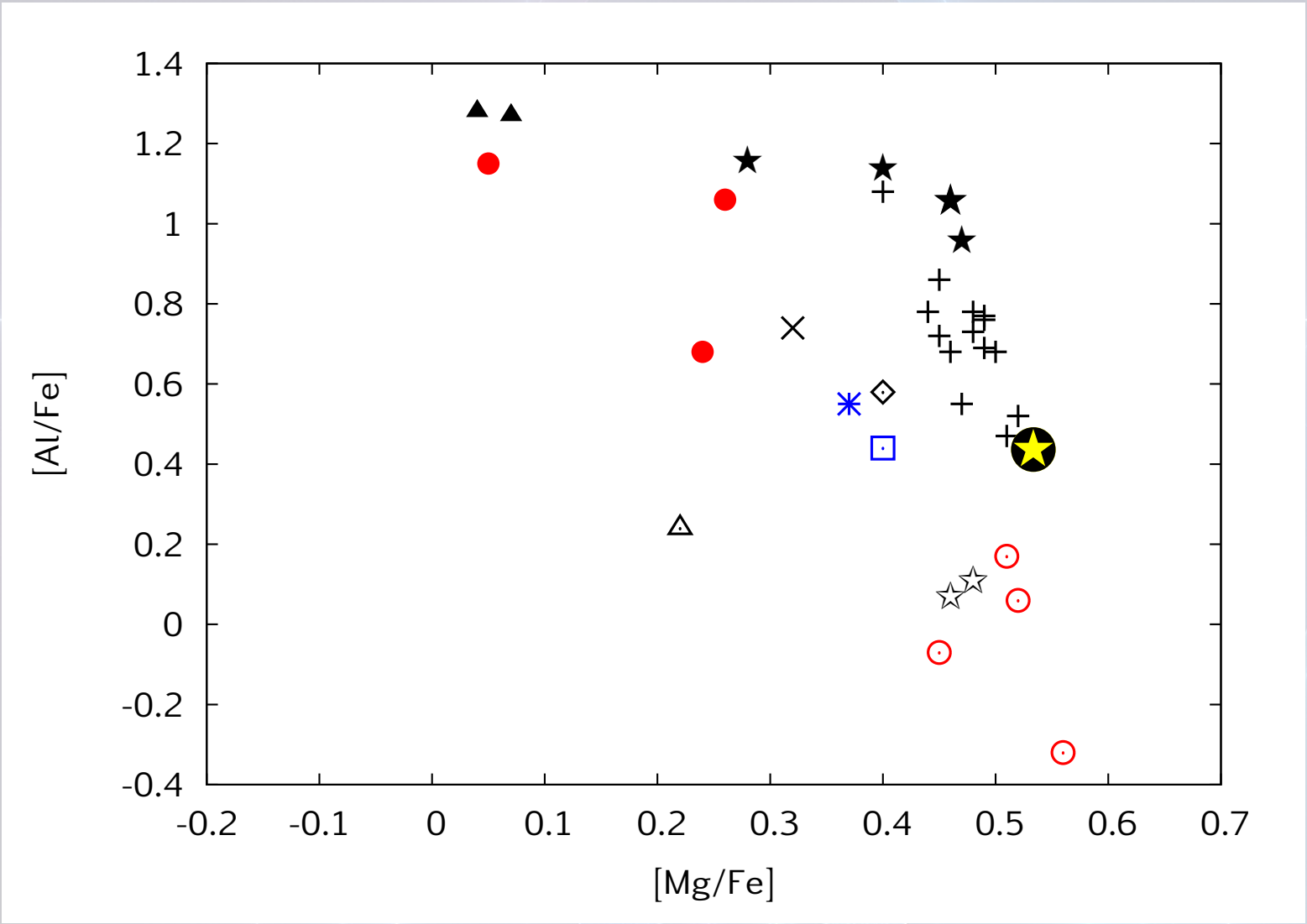

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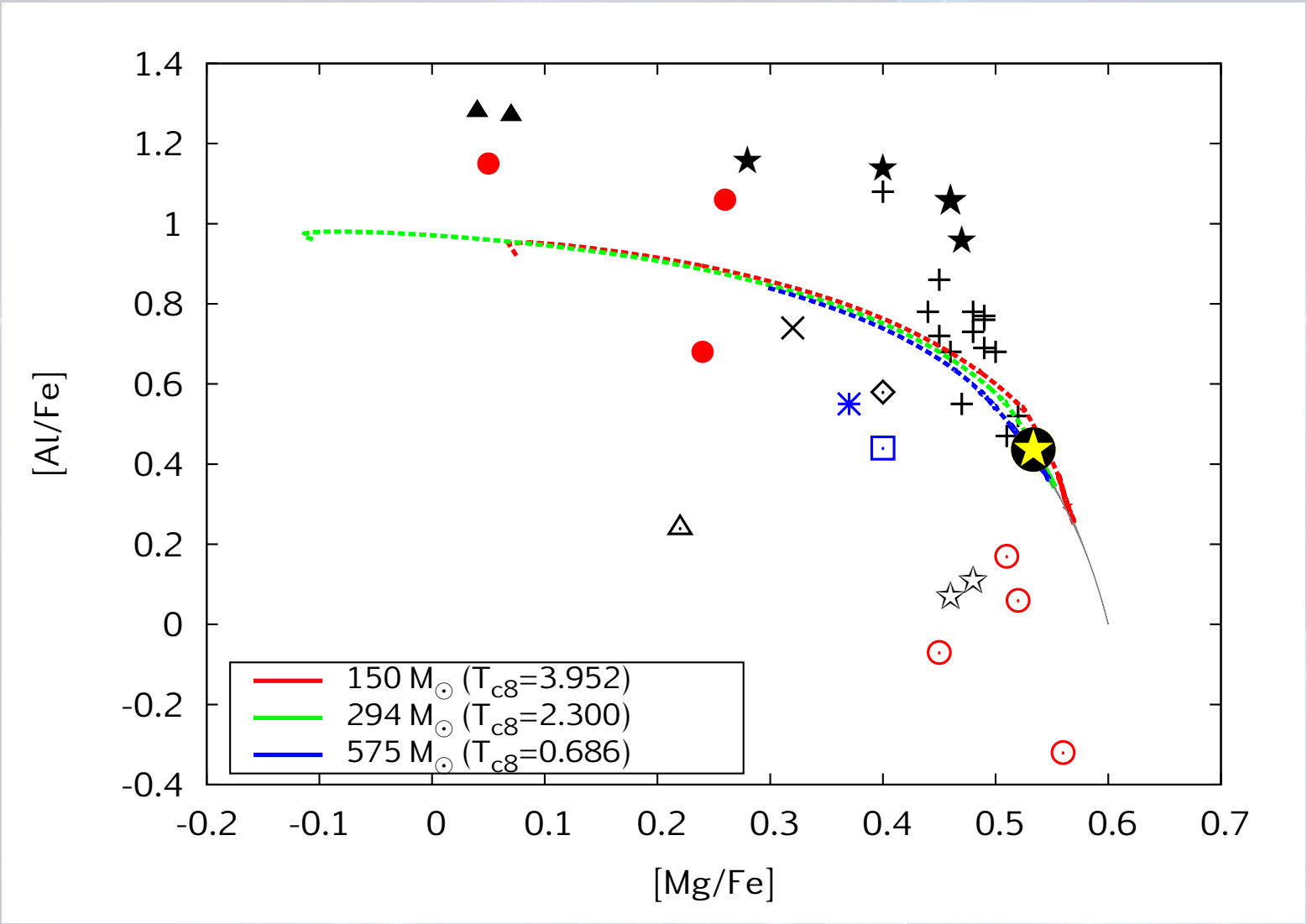

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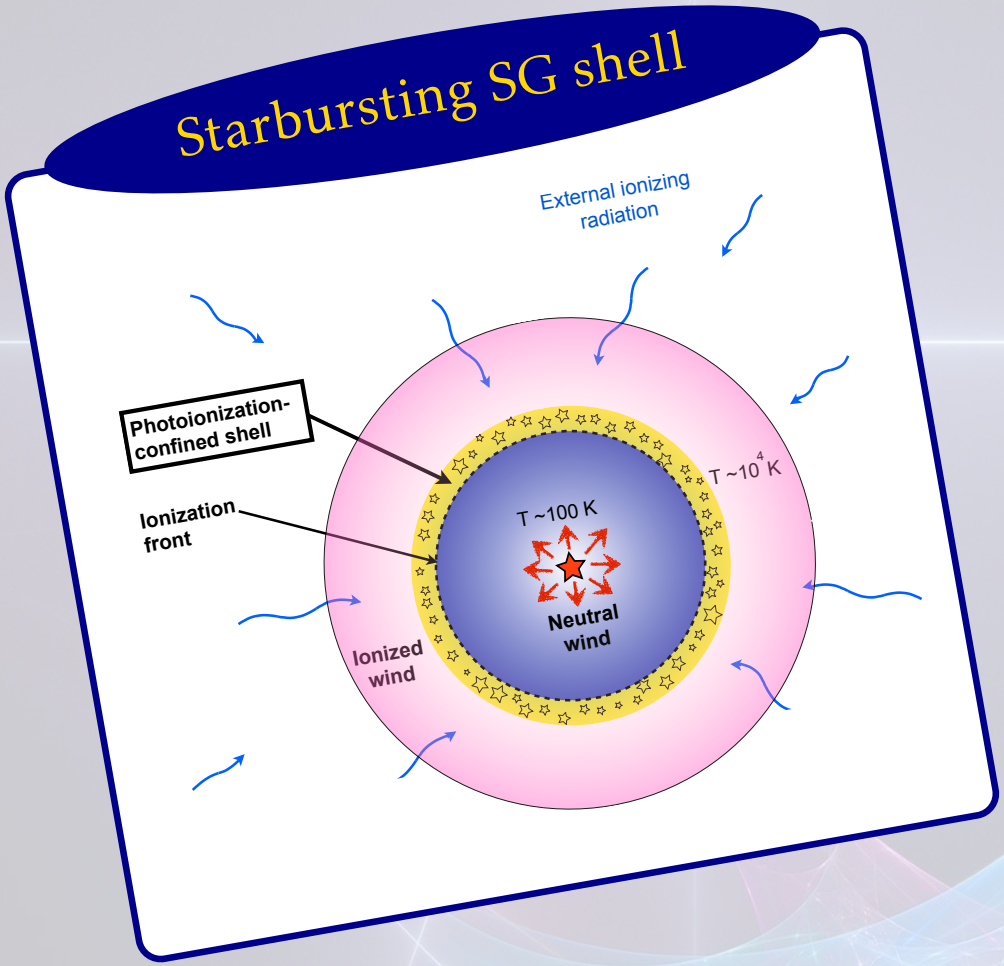
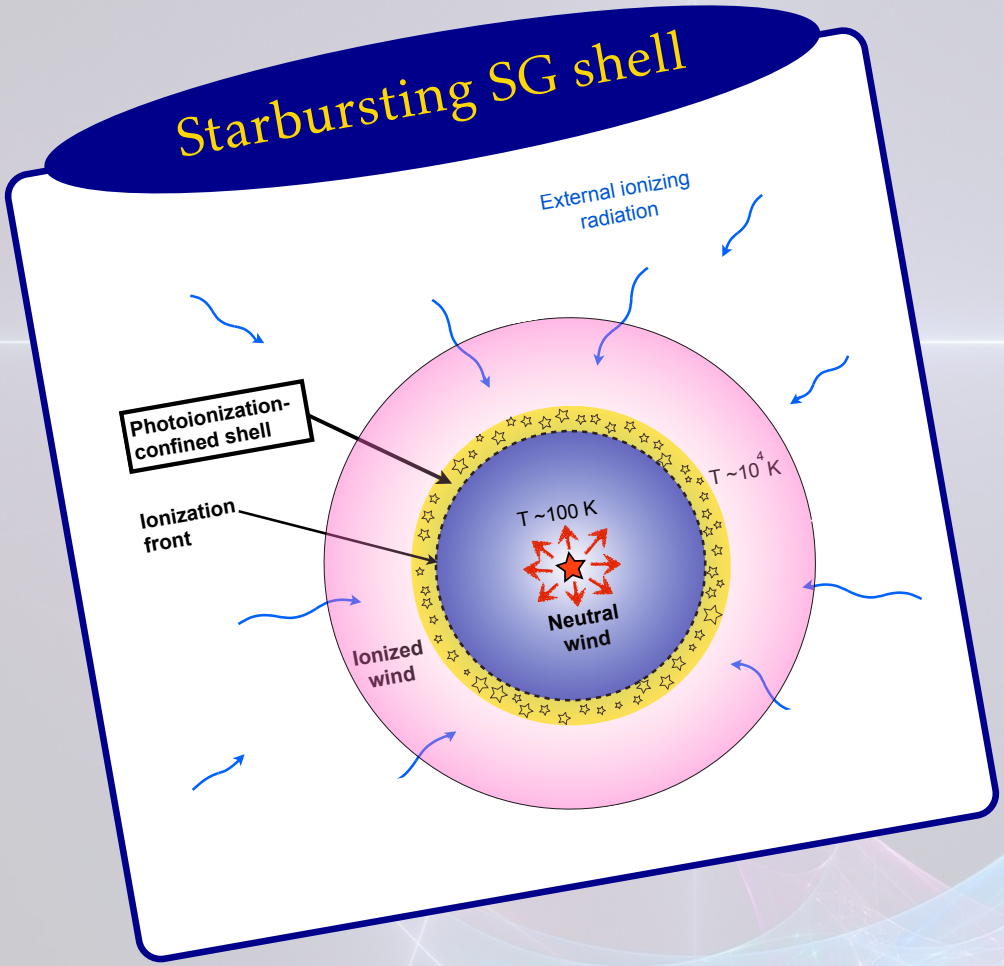
## RSGs as polluters

- 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

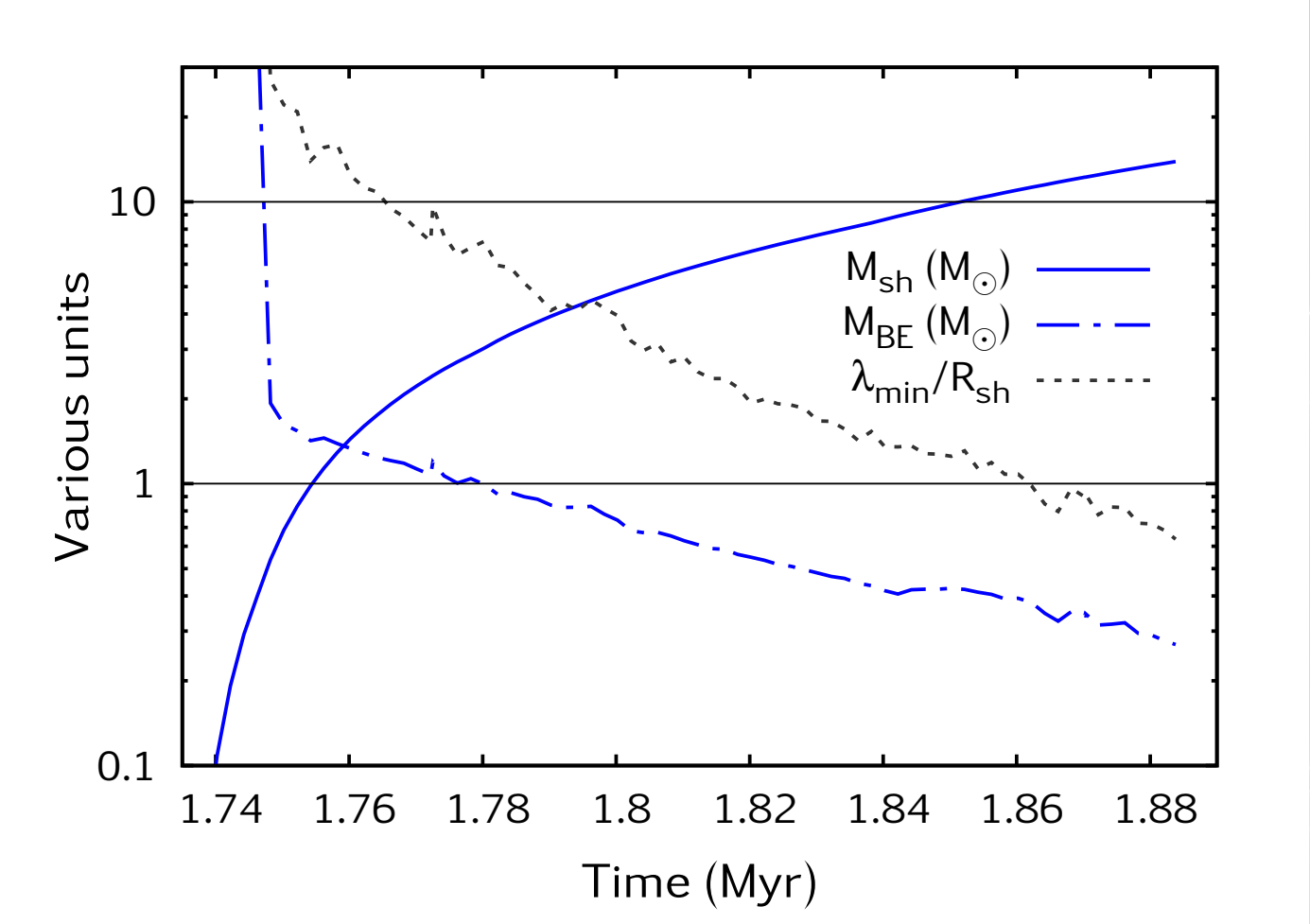
# Summary



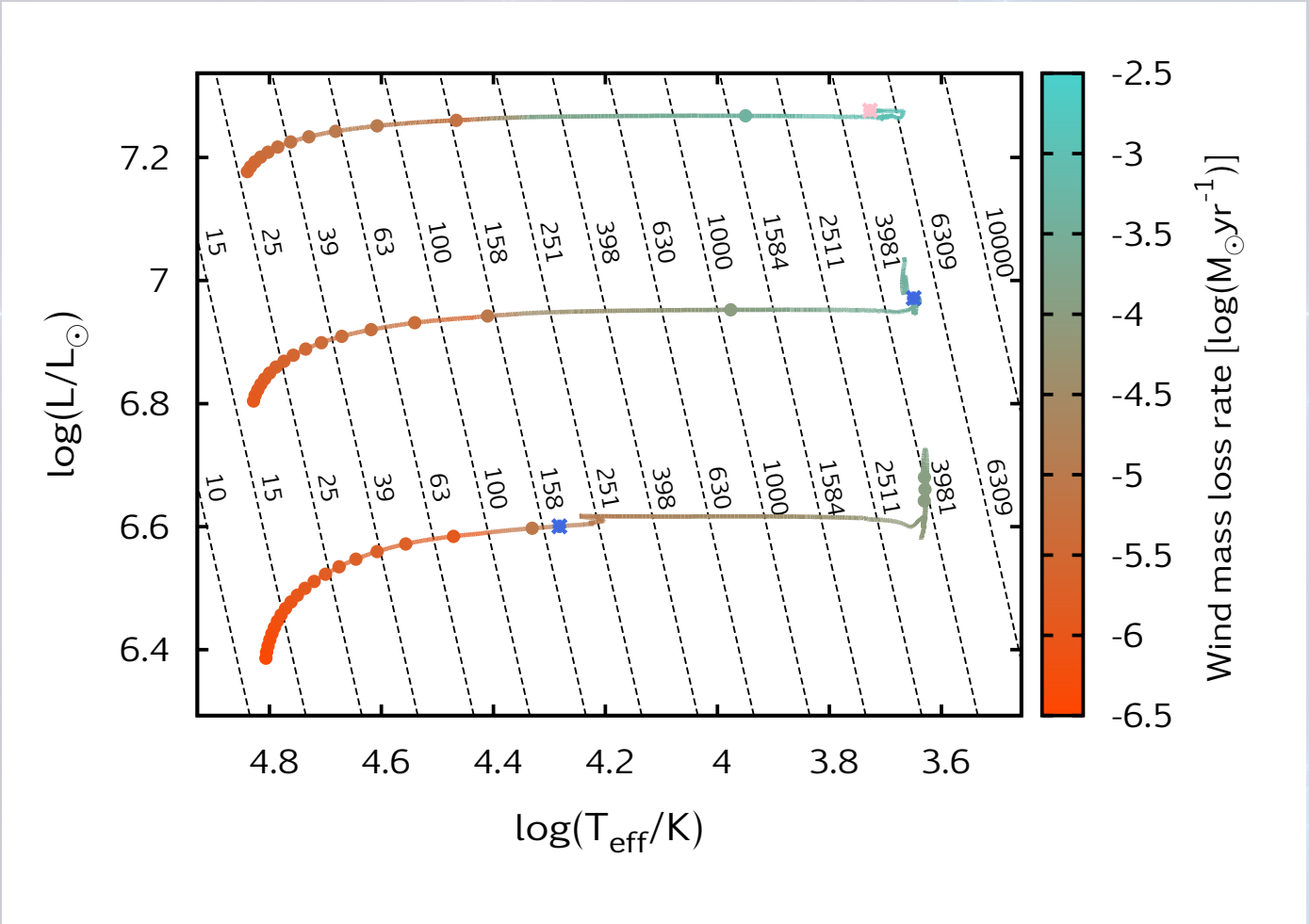

- early GCs
- PICO shell around core-H burning cool/red SGs
- grav. unstable → low-mass starformation
- simulated composition fits the 2nd generation stars
- explains abundance anomalies in GCs

Thank you for your attention!

# Appendix: Time evolution of the shell



# Appendix: HR diagram of core-H burning RSGs



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