Low Metallicity Massive Stars

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Argelander-Institut für Astronomie

Gravitation & Relativity Group Seminar

Cologne, 20th October 2015

The night-sky and beyond

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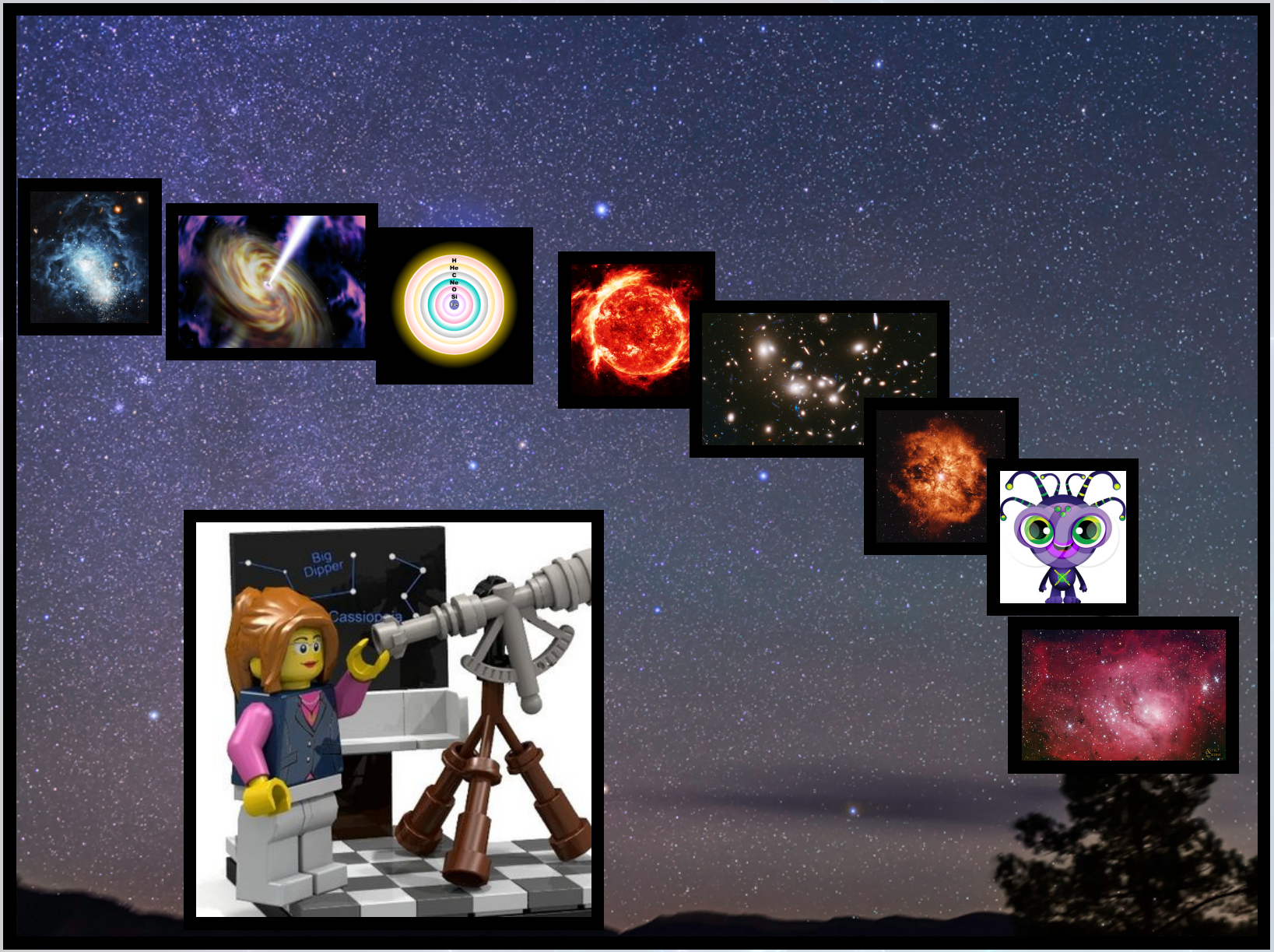
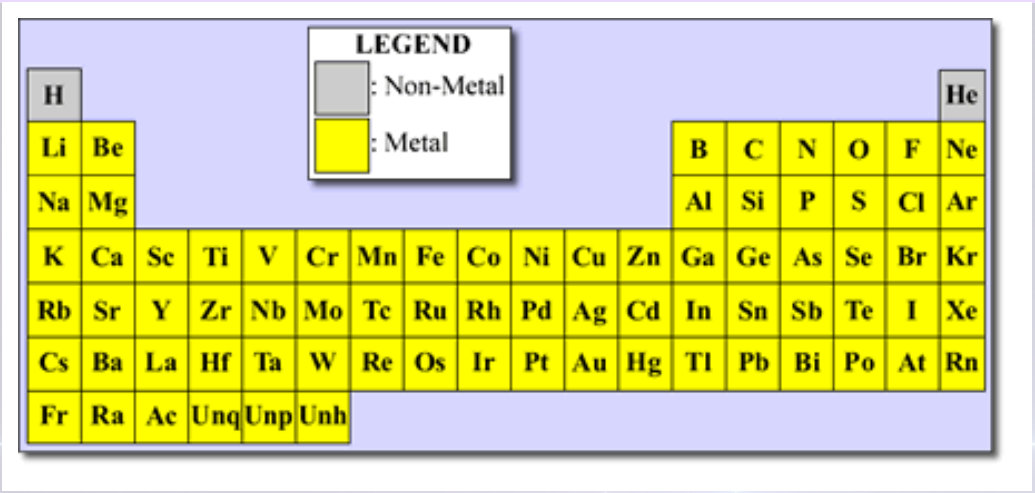


Astronomers and metal



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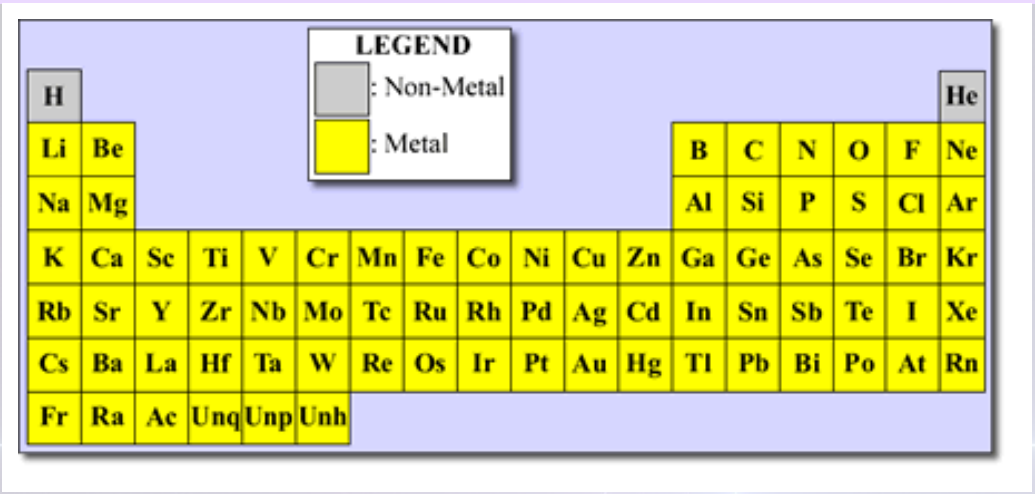

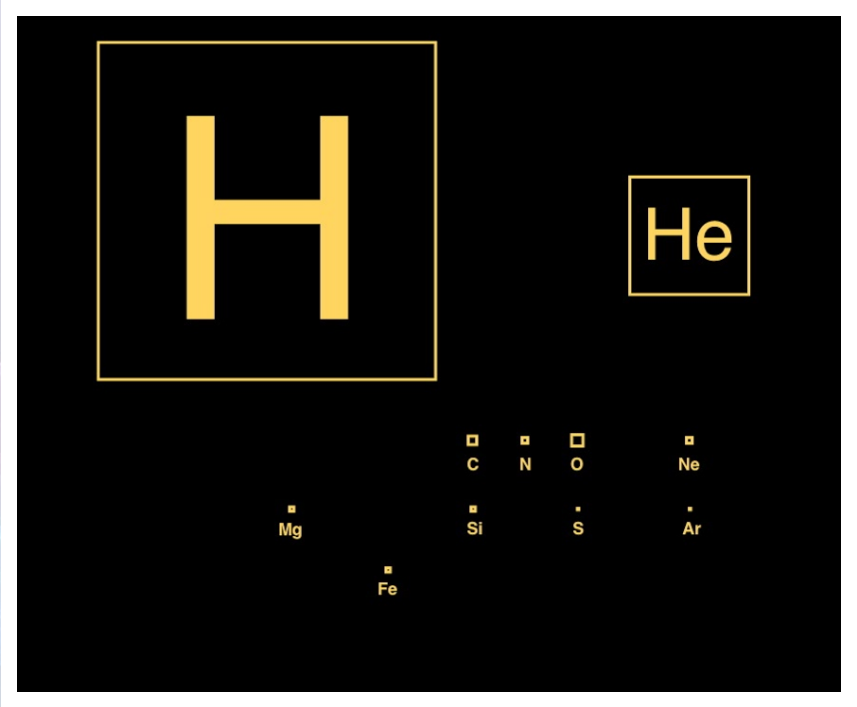

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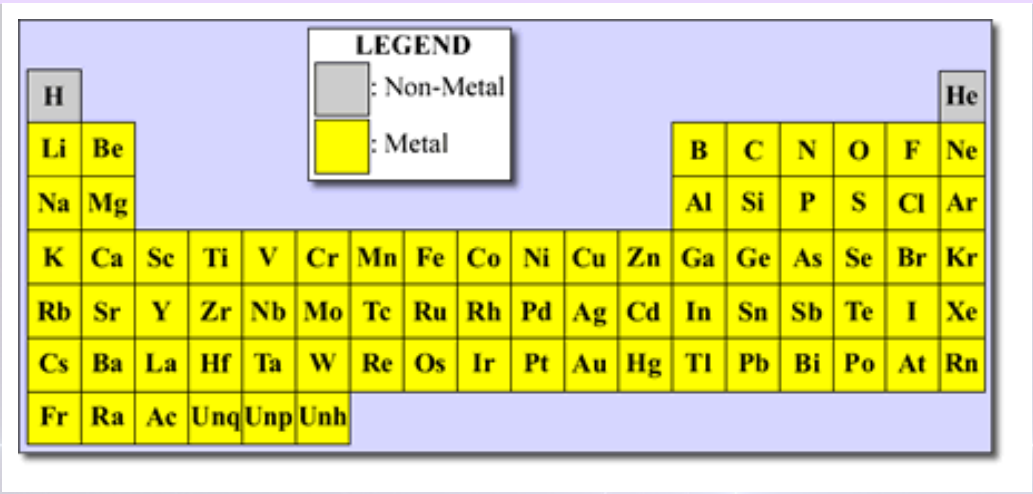

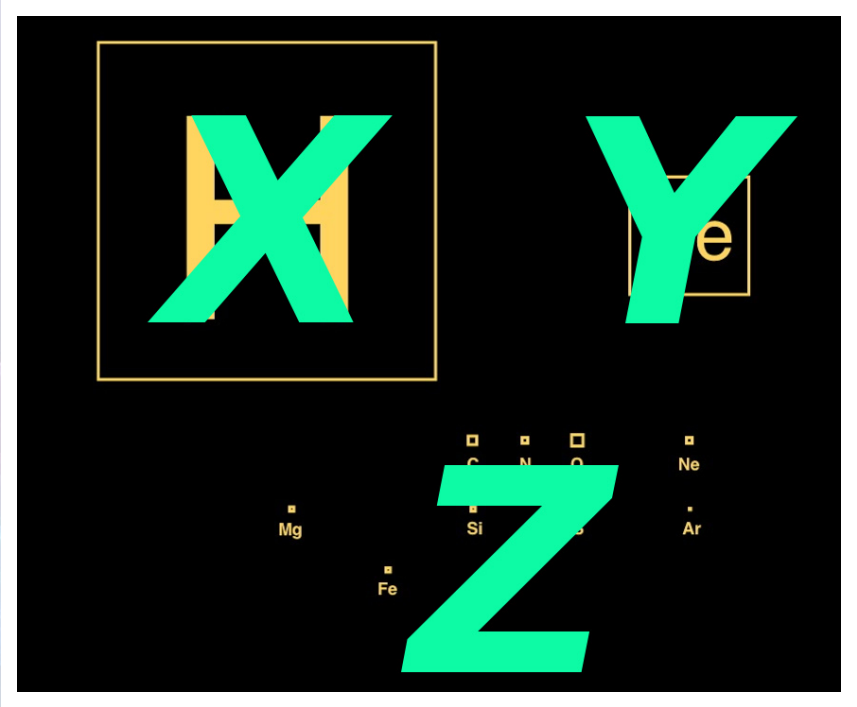

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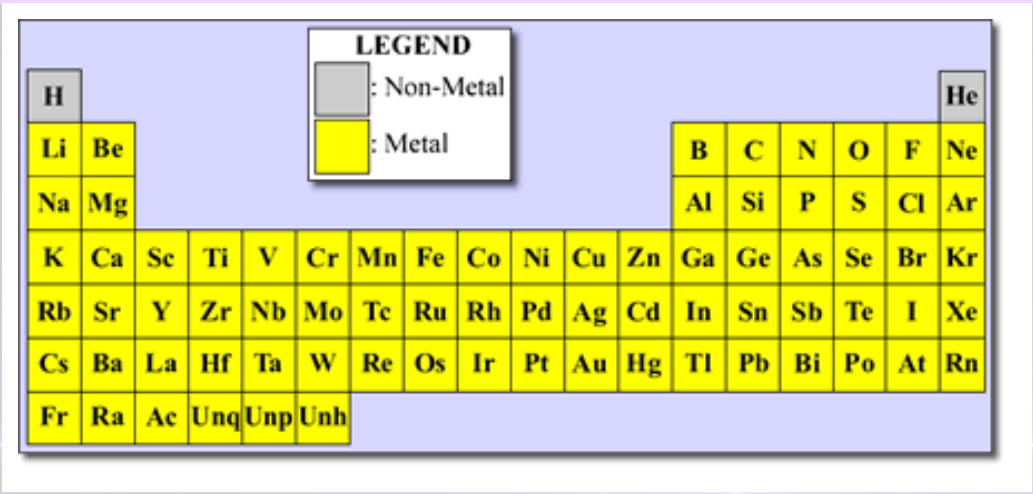

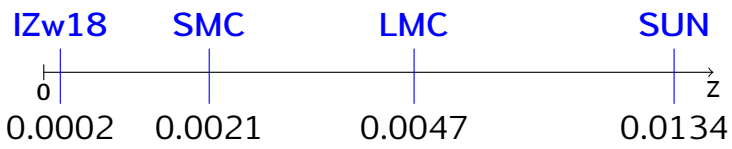

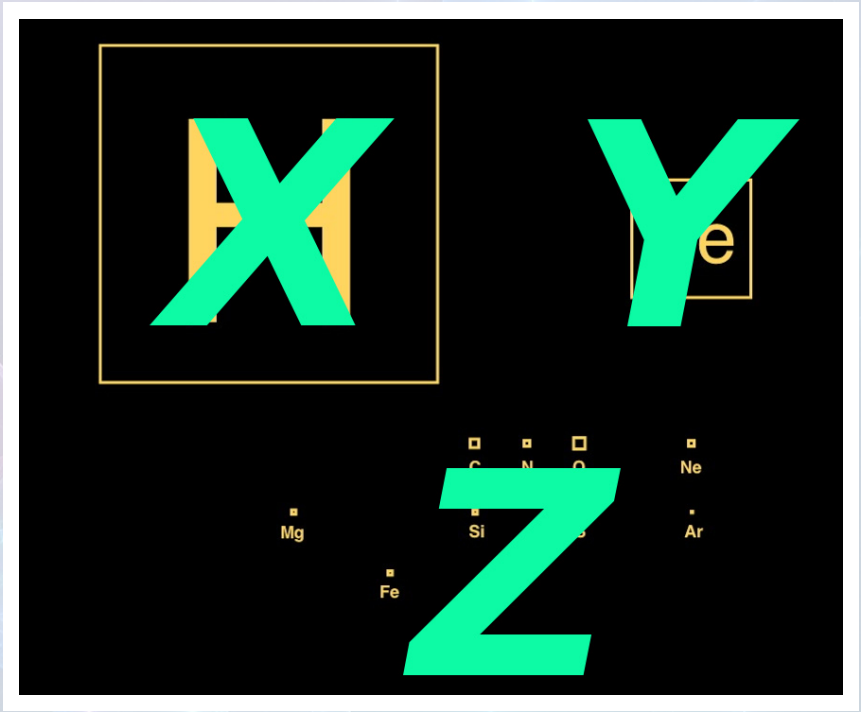

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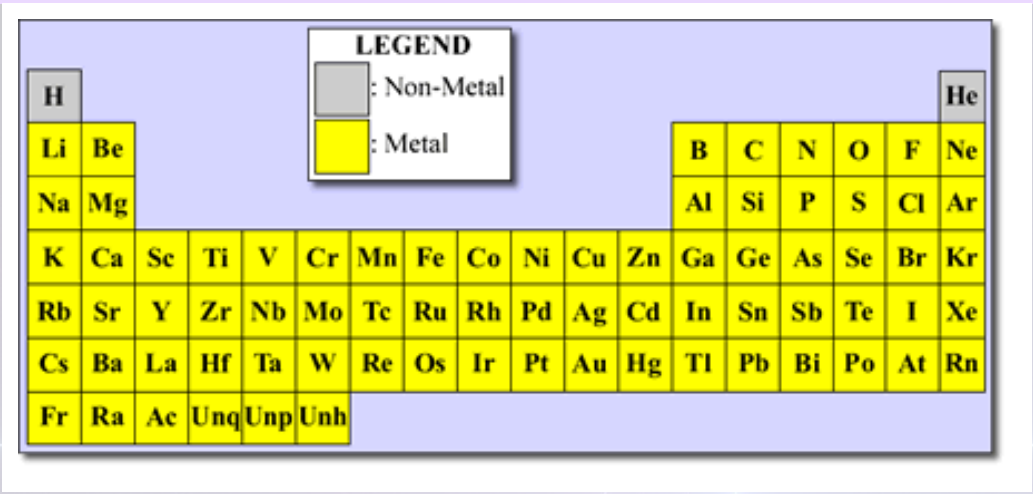
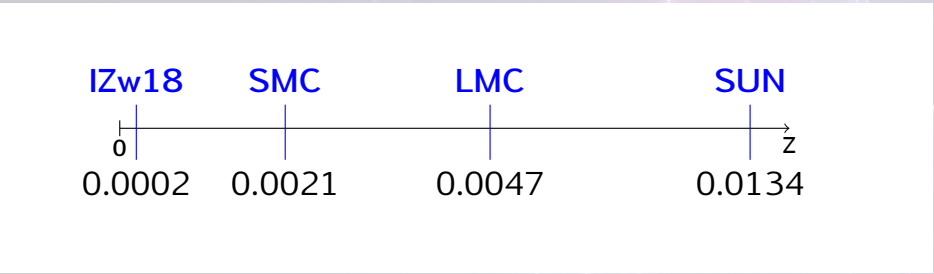
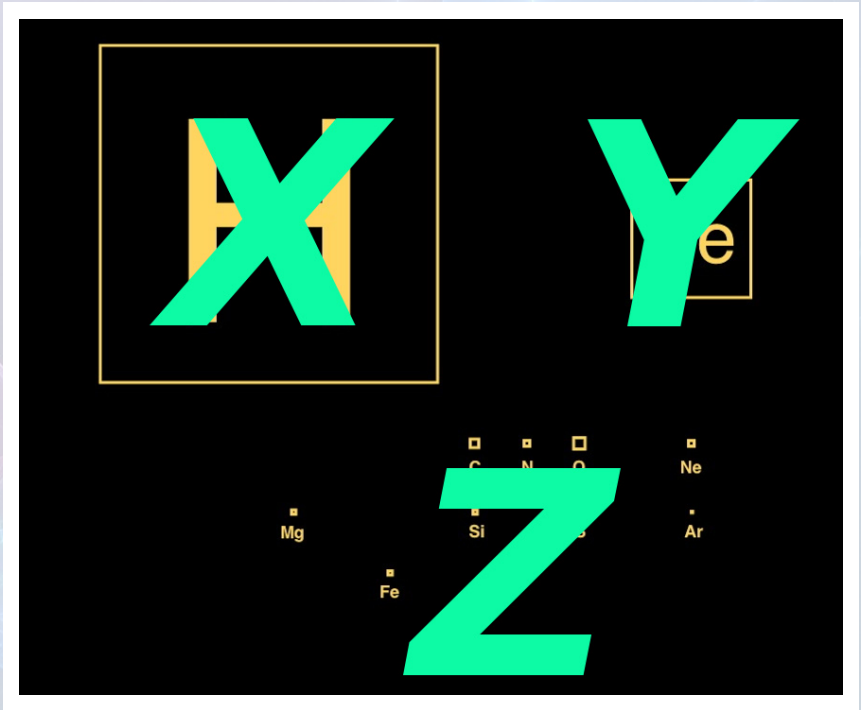
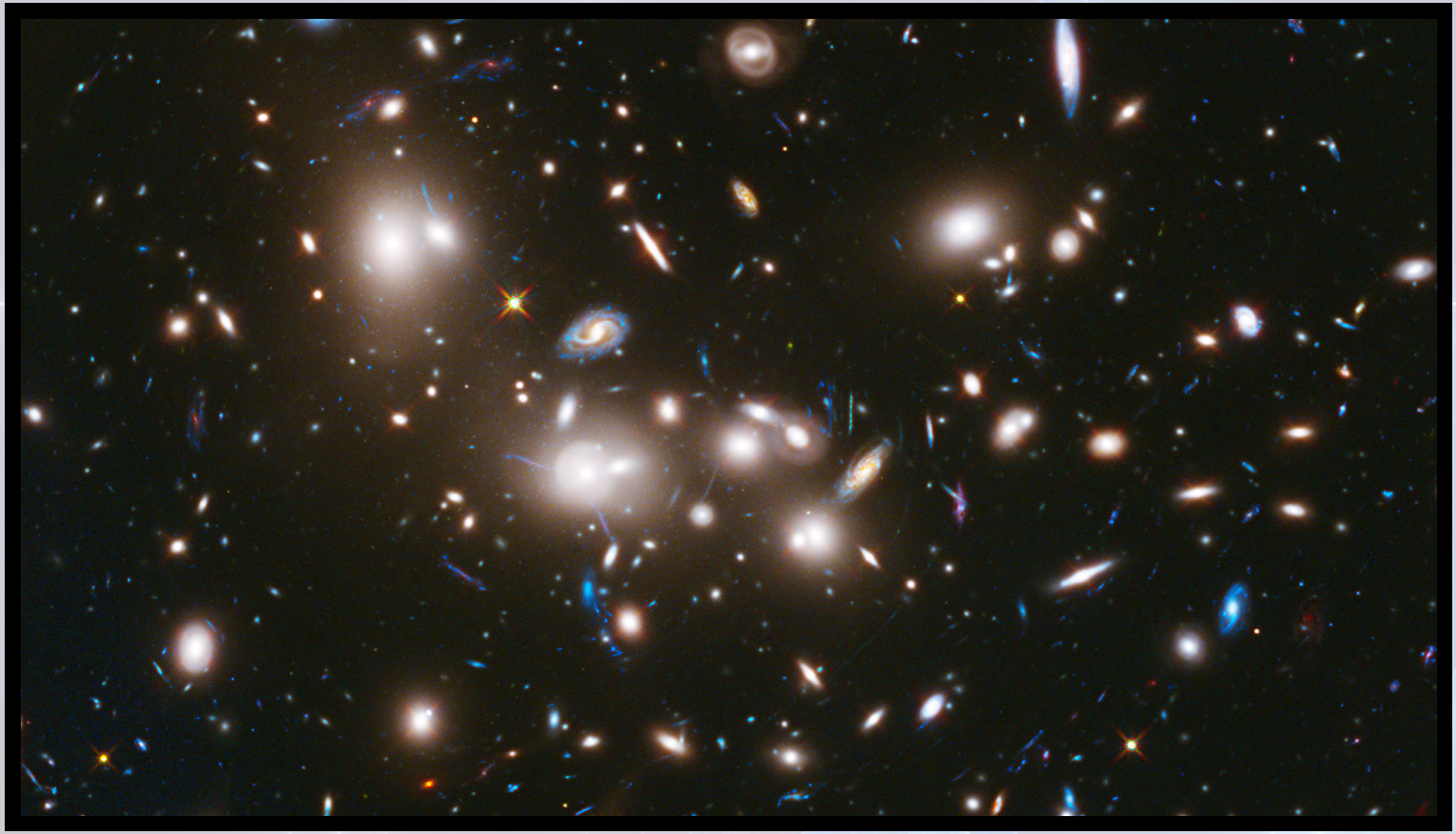


"metallicity"





The early Universe (Z≈0)



Credit: hubblesite.org

Compact Dwarf Galaxies

Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Lebouteiller+13

Compact Dwarf Galaxies

I Zwicky 18

- Blue Compact Dwarf Galaxy
- 18 Mpc → local
- SFR: 1 $M_\odot$/yr
- ionized gas
- low metallicity!

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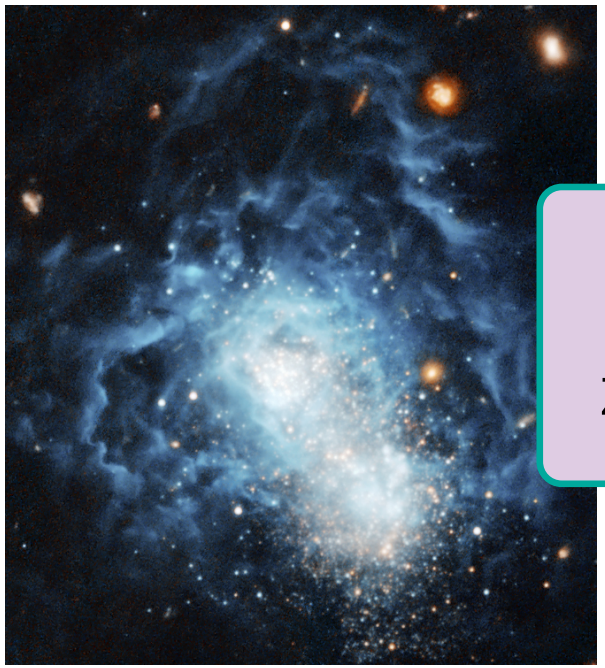

$12+\log(O/H)=7.17$

$\downarrow$

$Z=1/50\ Z_\odot \approx 0.0002$

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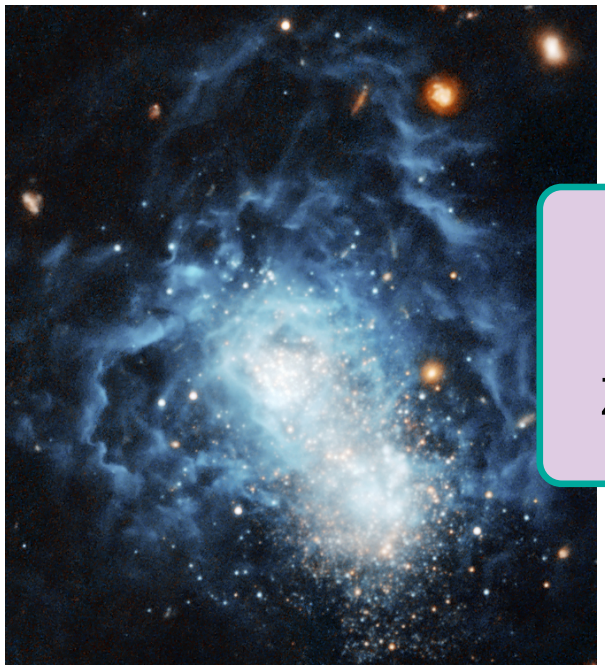

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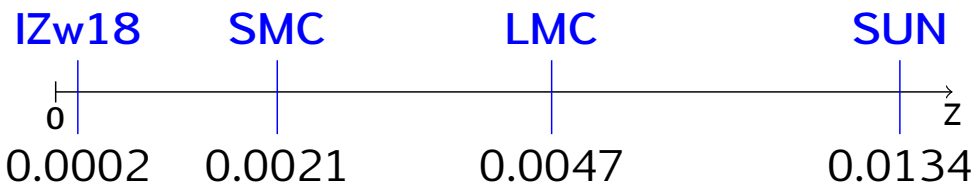

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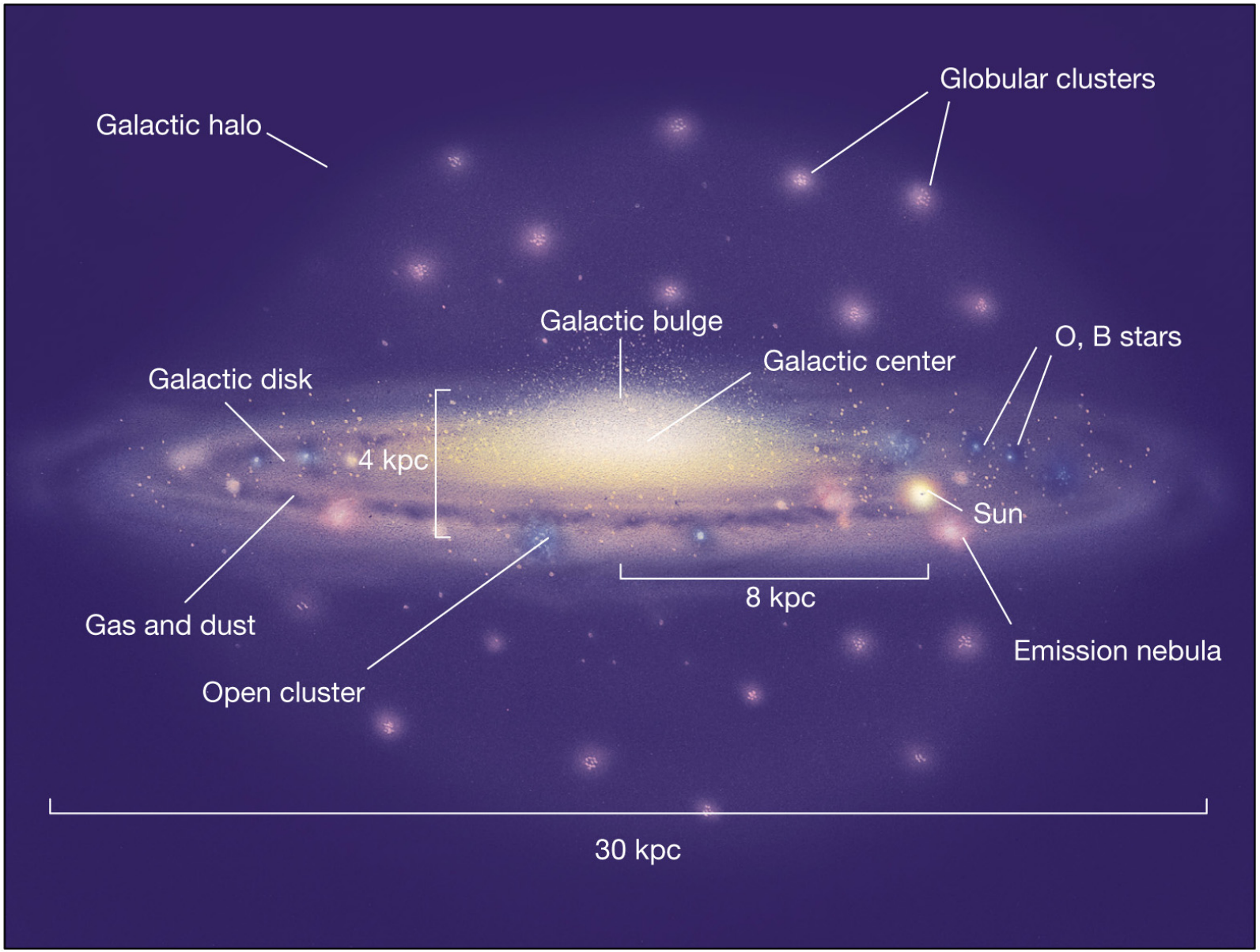
Globular Clusters



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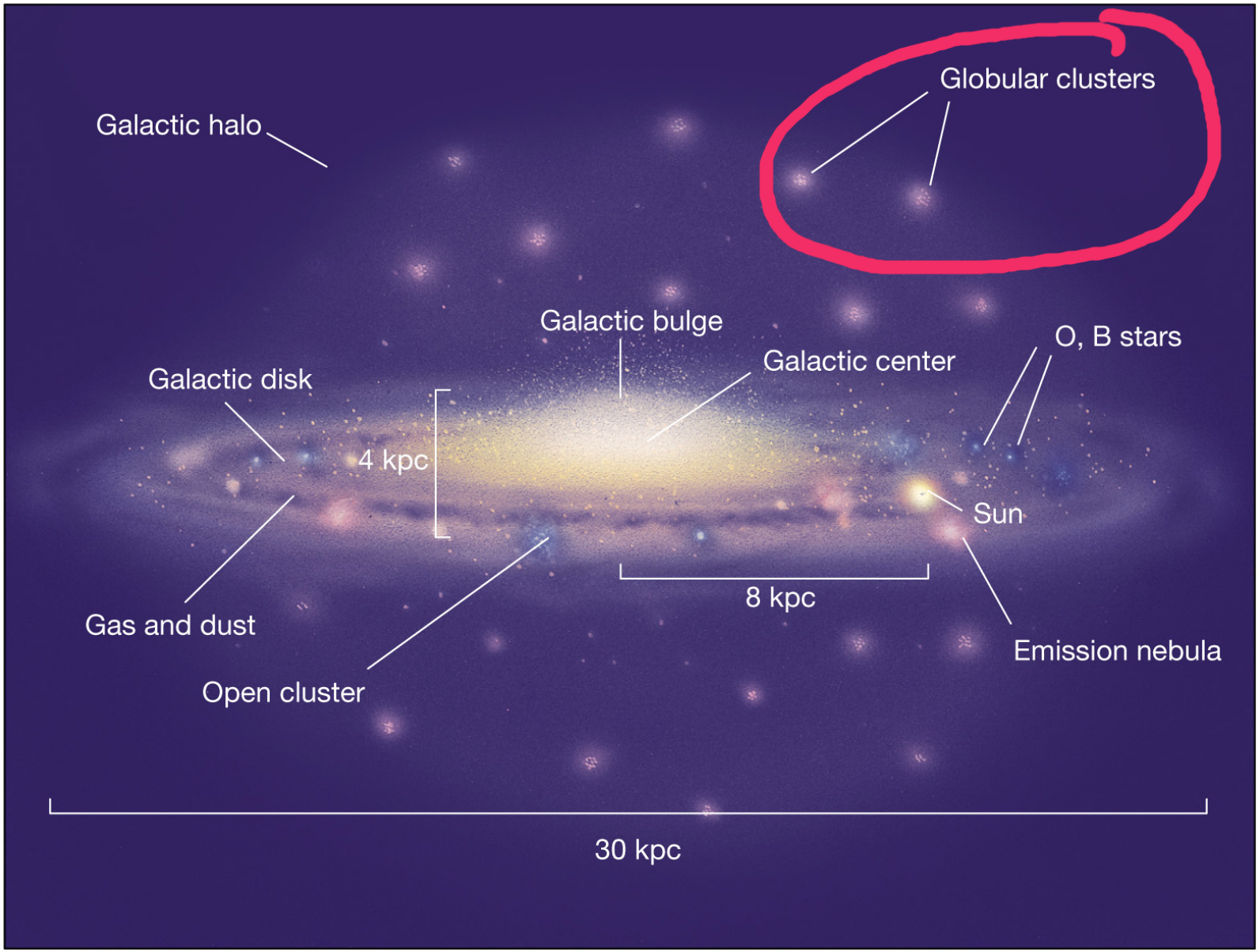

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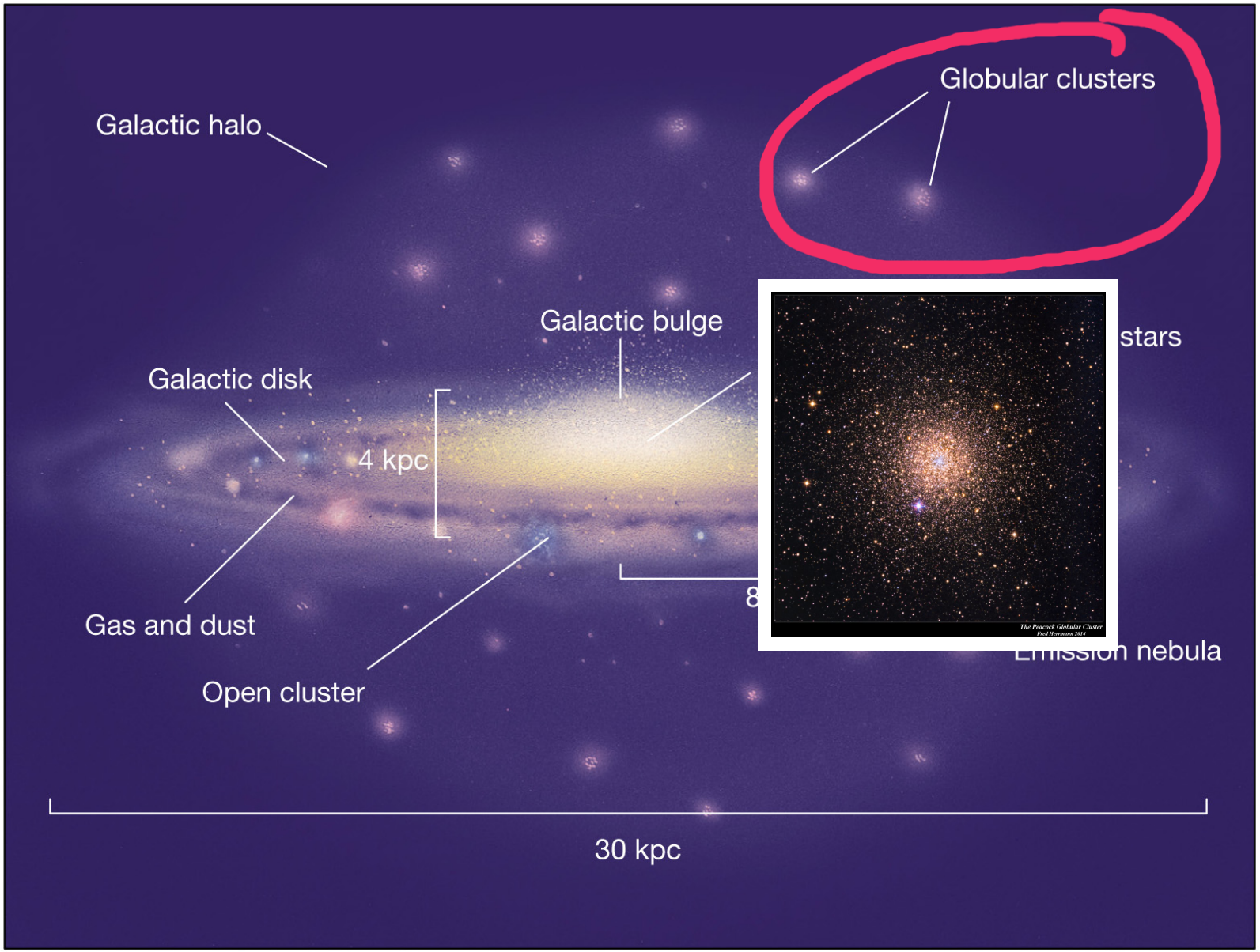

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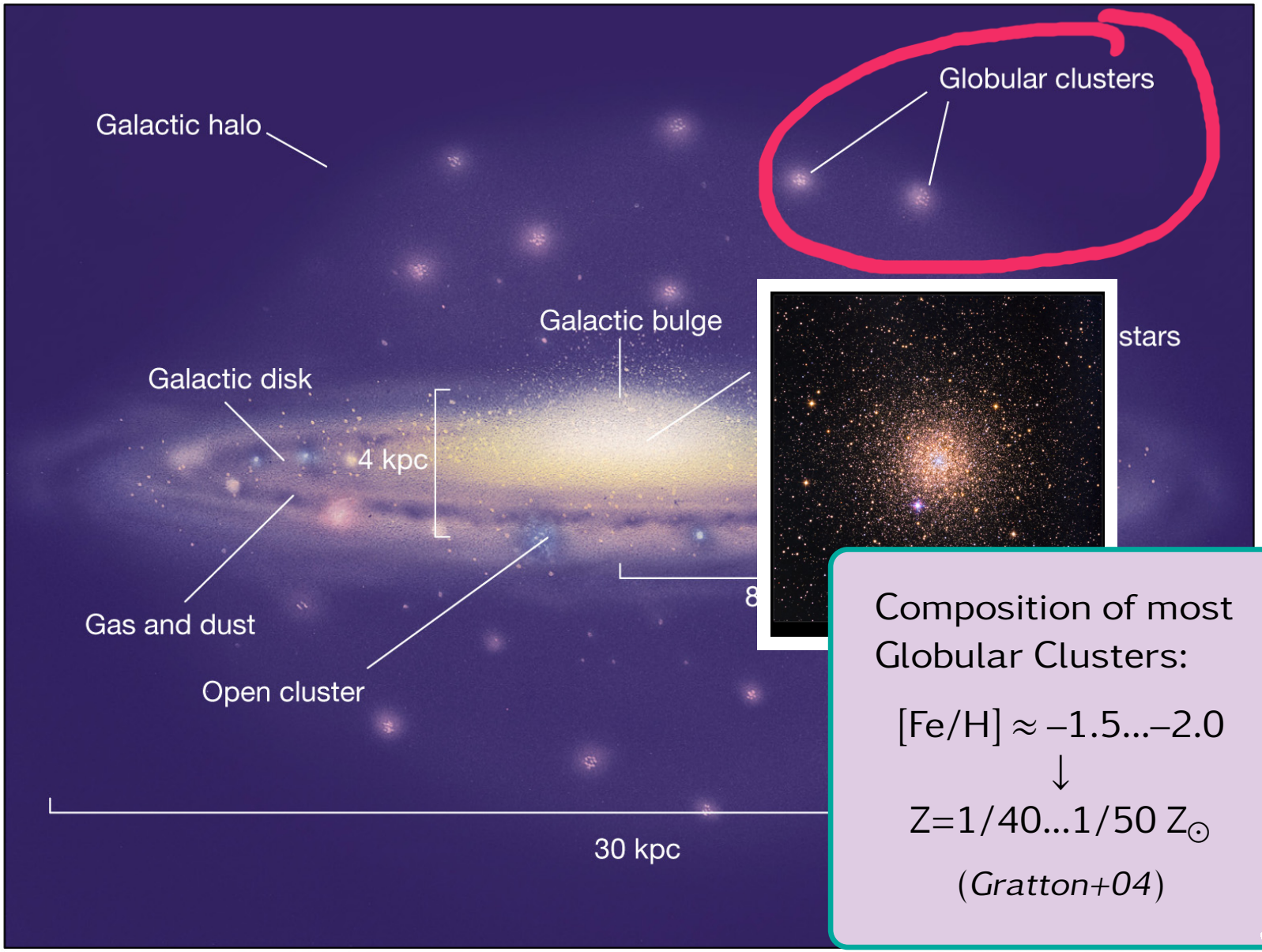

Composition of most Globular Clusters:

$[Fe/H] \approx -1.5 \ldots -2.0$

$\downarrow$

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

(*Gratton+04*)

What is a star?

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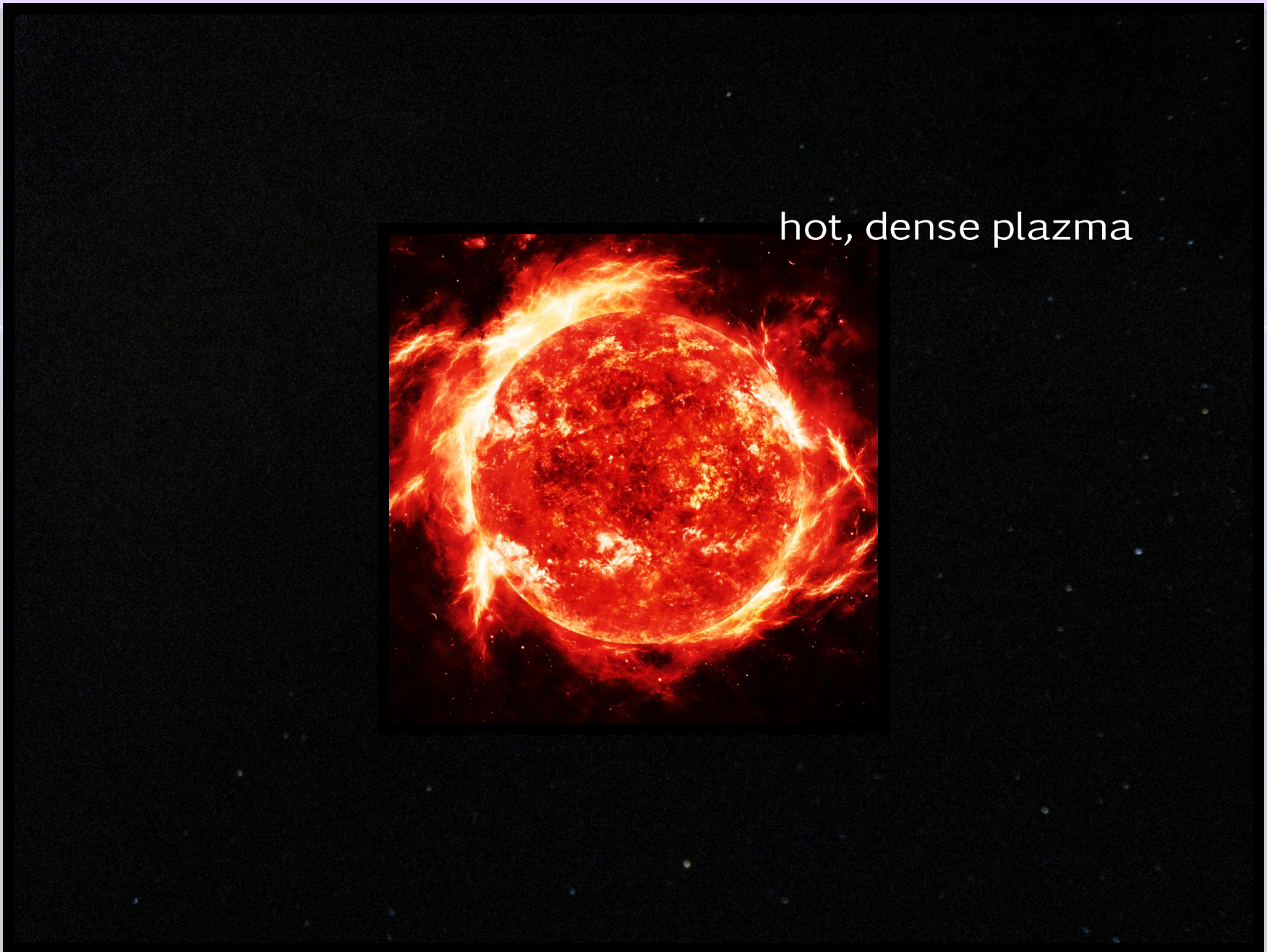
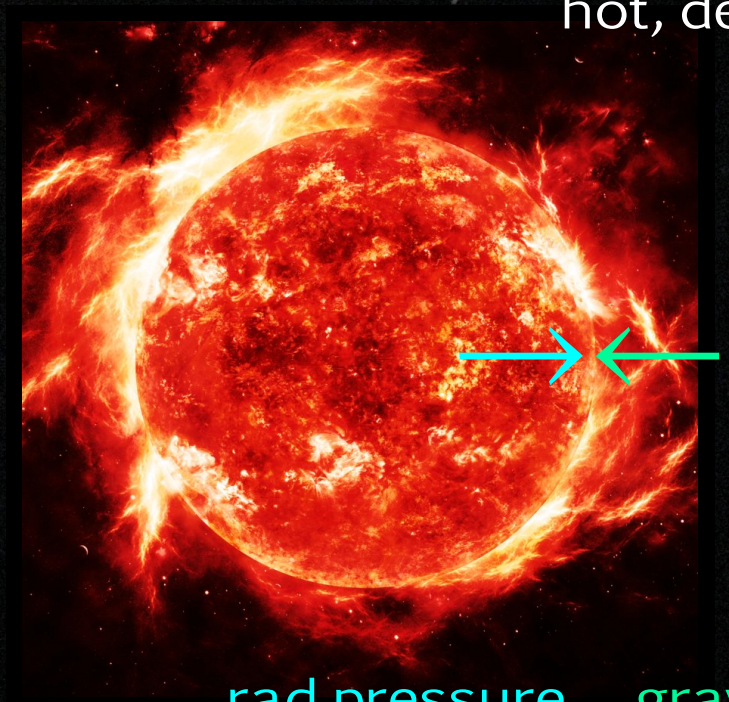


What is a star?

hot, dense plazma



equilibrium: rad.pressure gravity

What is a star?

surface?

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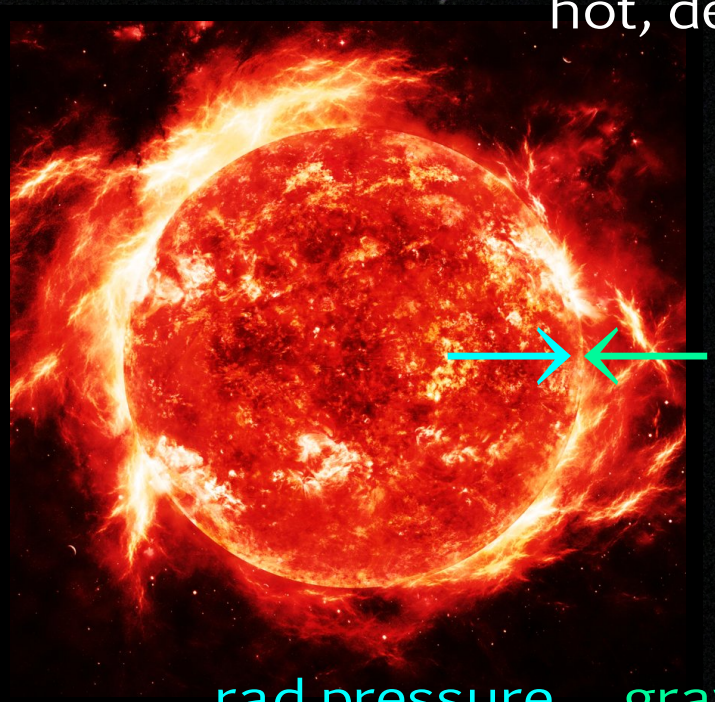

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surface?
→ photons escape
"photosphere"

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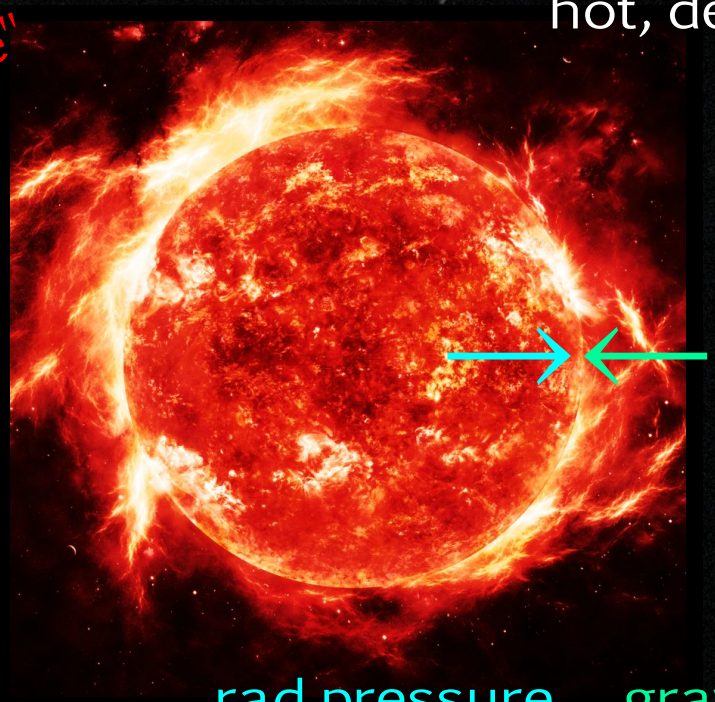

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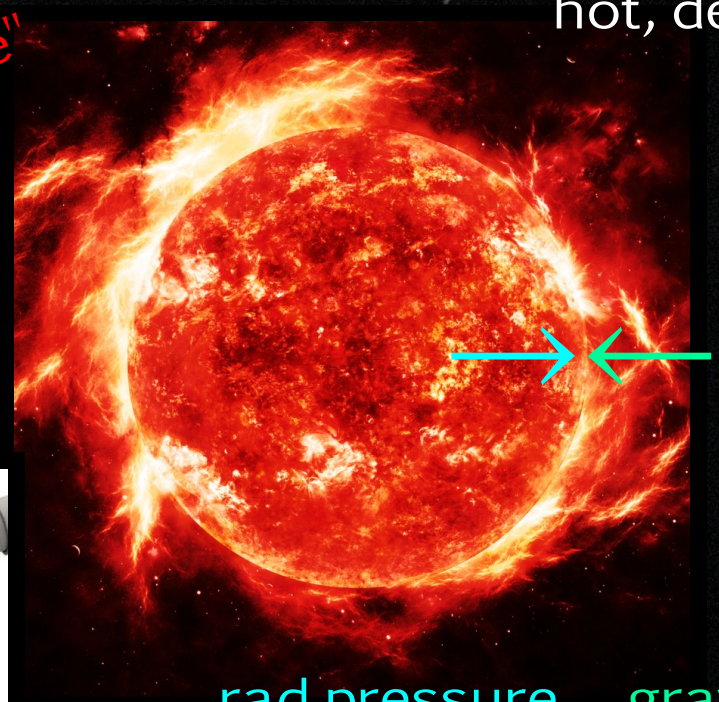

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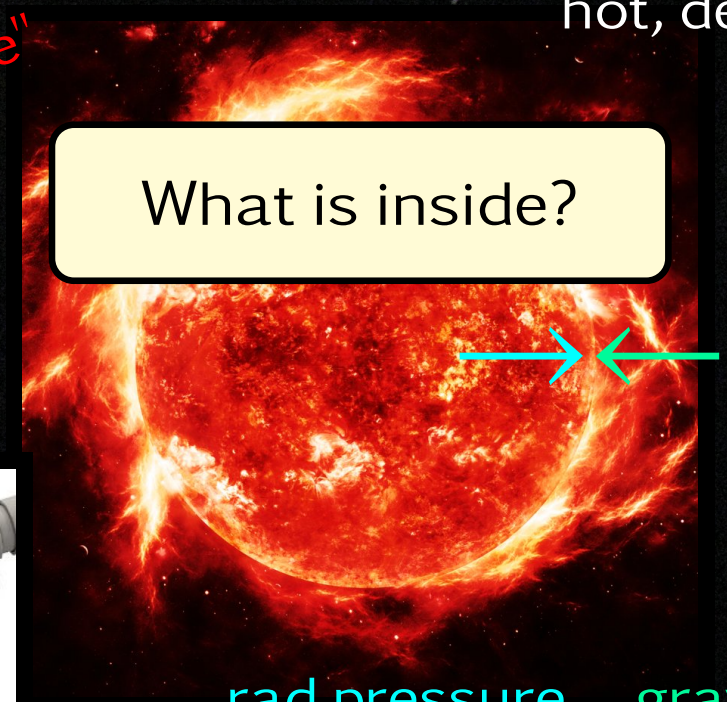


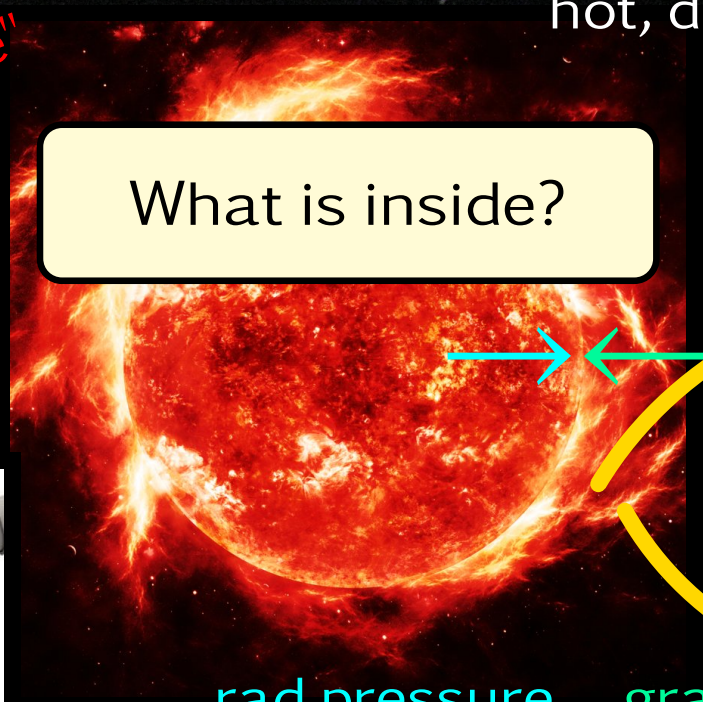
What is inside?

rad.pressure gravity

What is a star?

surface?
→ photons escape
"photosphere"

hot, dense plazma



What is inside?

theoretical modelling of the stellar structure

rad.pressure gravity

Theoretical modelling of the stellar structure

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

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

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

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

Guilera et al. 2011

Theoretical modelling of the stellar structure

$$\frac{\partial r}{\partial m_r} = \frac{1}{4\pi r^2 \rho}$$ eq — mass conservation (9)

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composition change due to nuclear burning ?!

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Guilera et al. 2011

composition change due to nuclear burning ?!

$$\frac{\partial X_i}{\partial t} = \frac{A_i m_u}{\rho}\left(-\Sigma_{j,k} r_{i,j,k} + \Sigma_{k,l} r_{k,l,i}\right) \qquad (13)$$

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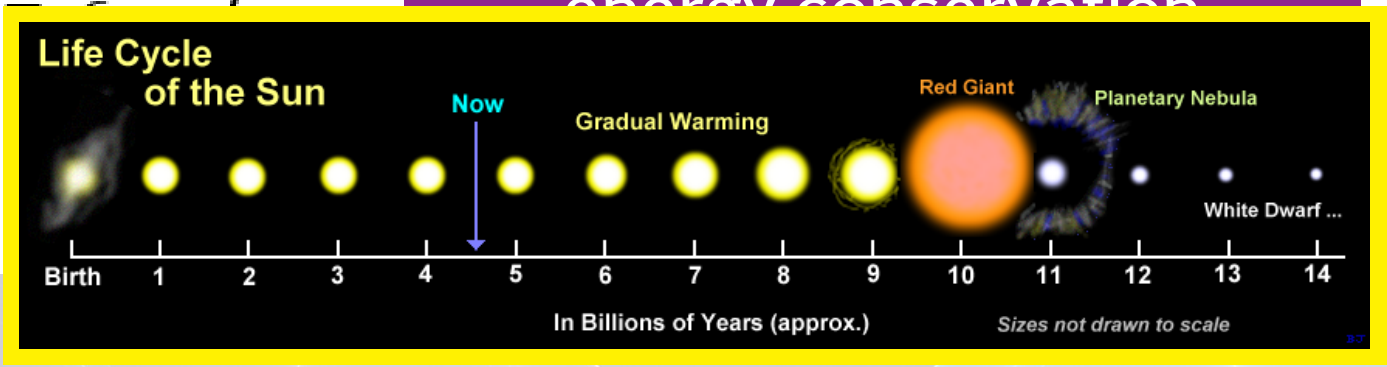

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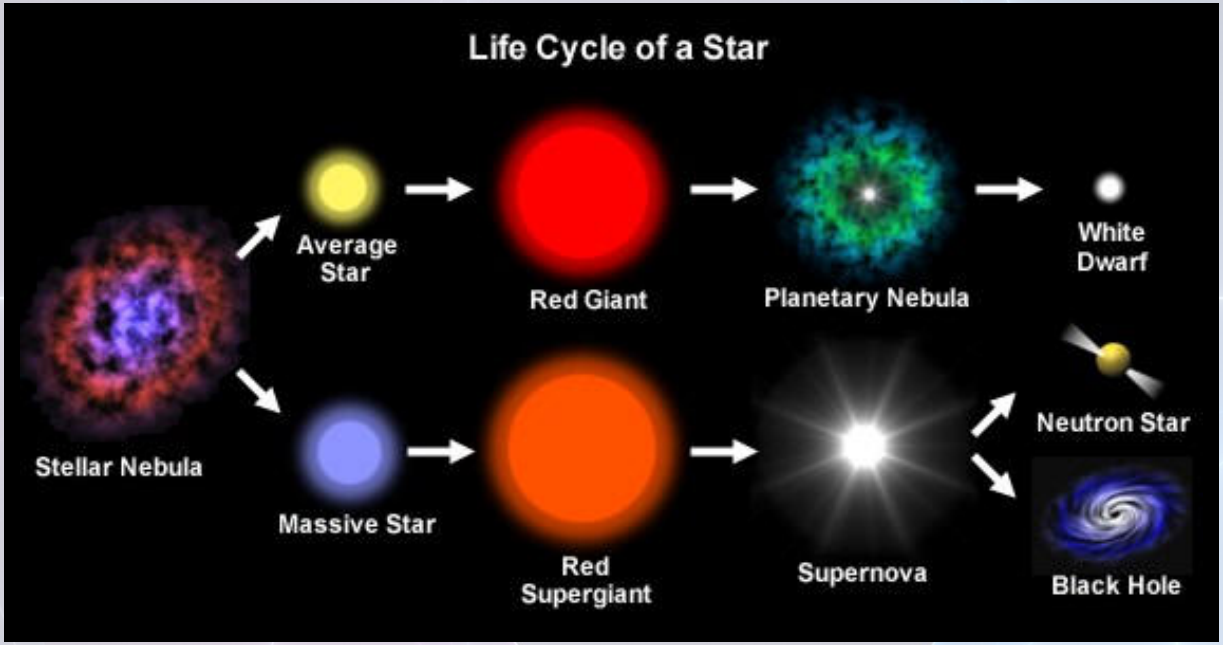
Massive vs. low-mass stars

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



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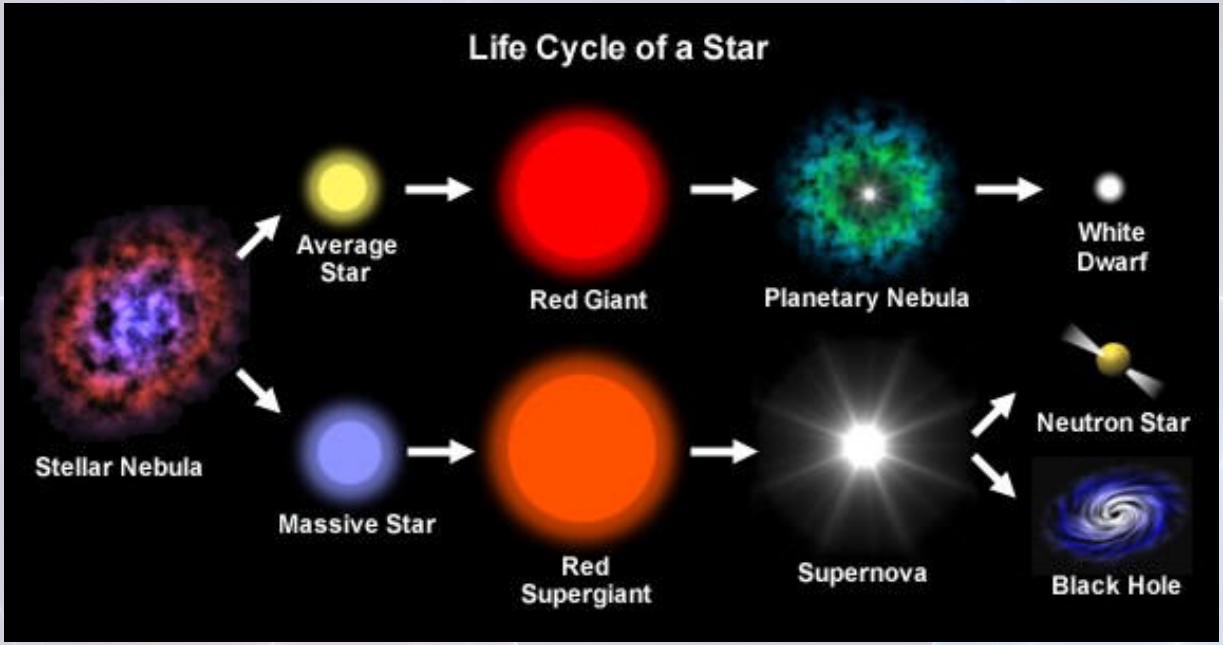

- nuclear reactions, final composition

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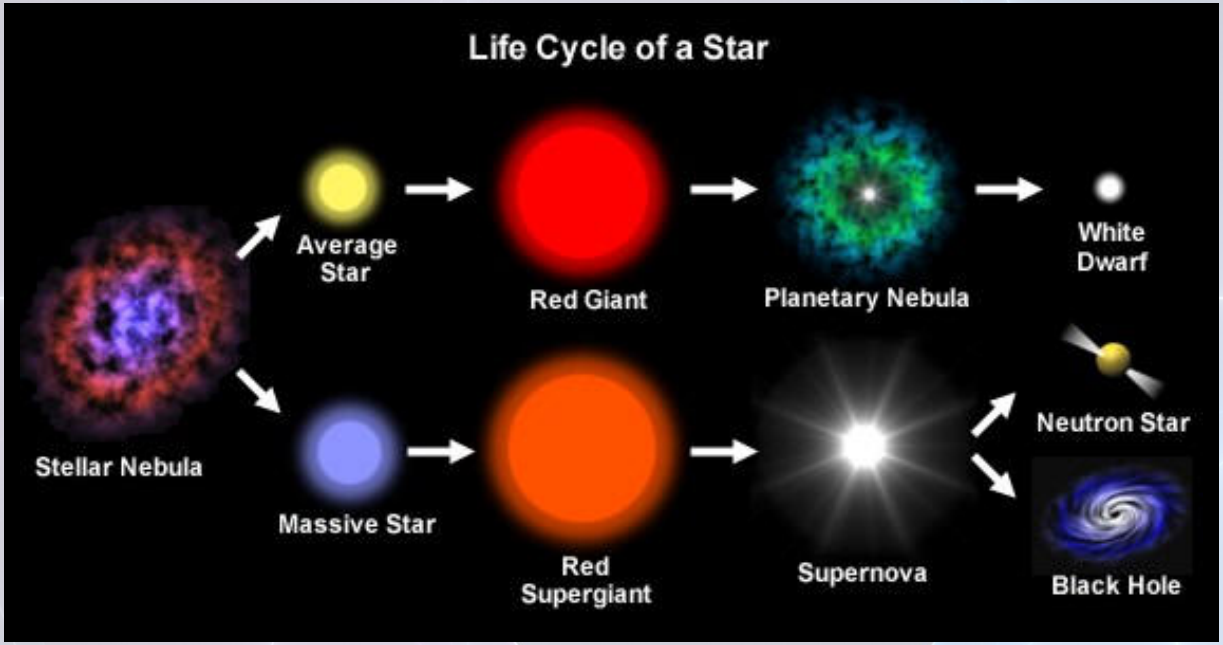

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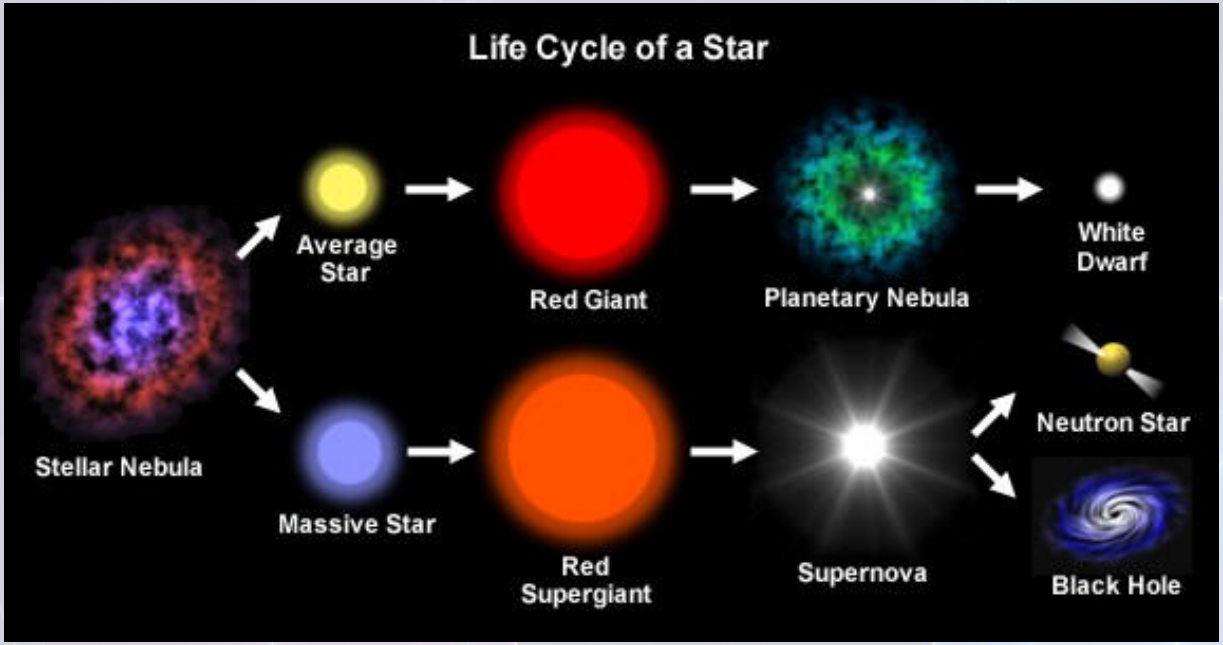

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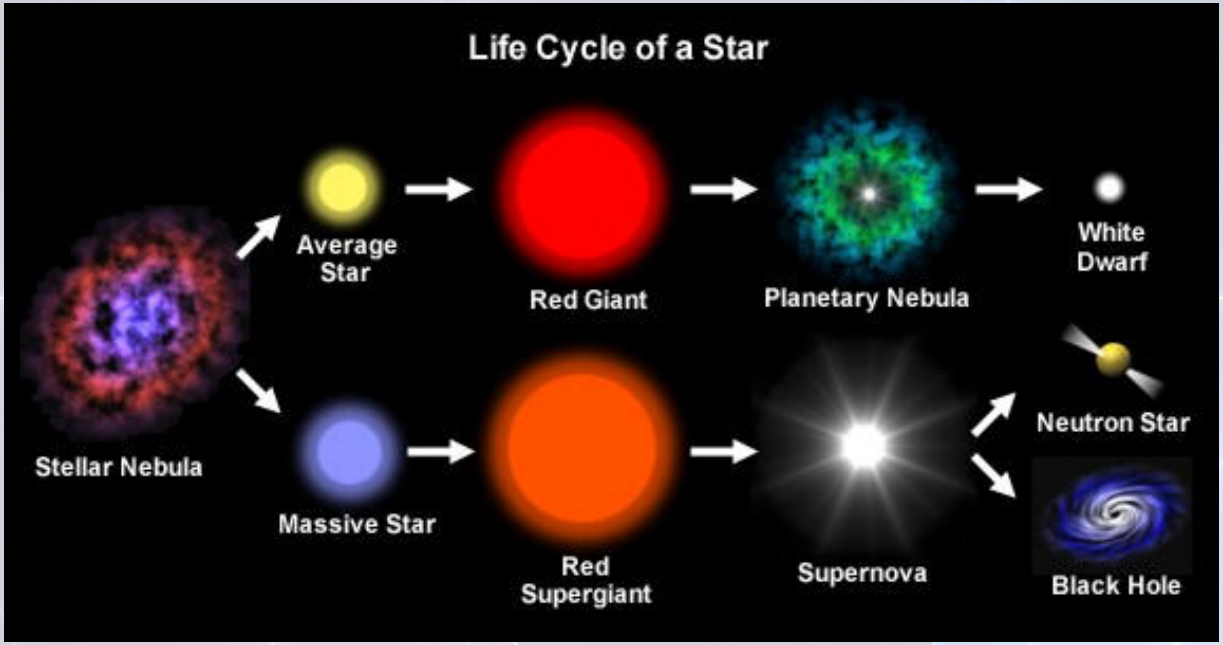

- nuclear reactions, final composition
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- final fate

Matching theory to observations

Surface properties!

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Surface properties! → temperature (i.e. colour) X axis
→ luminosity (i.e. brightness) Y axis

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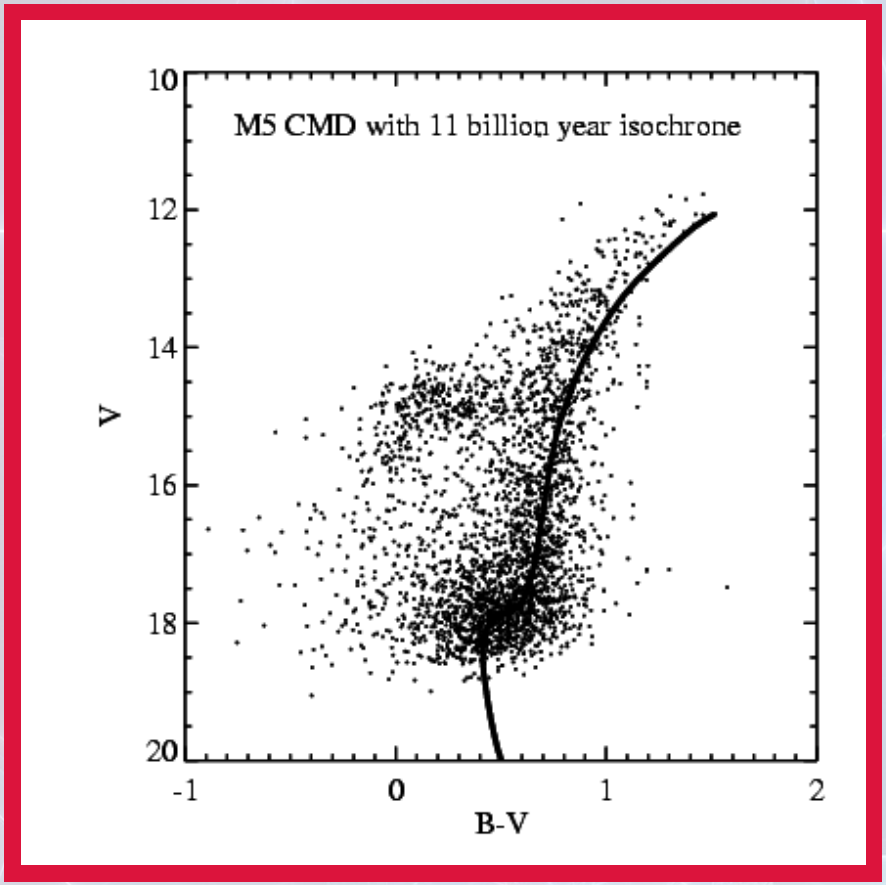
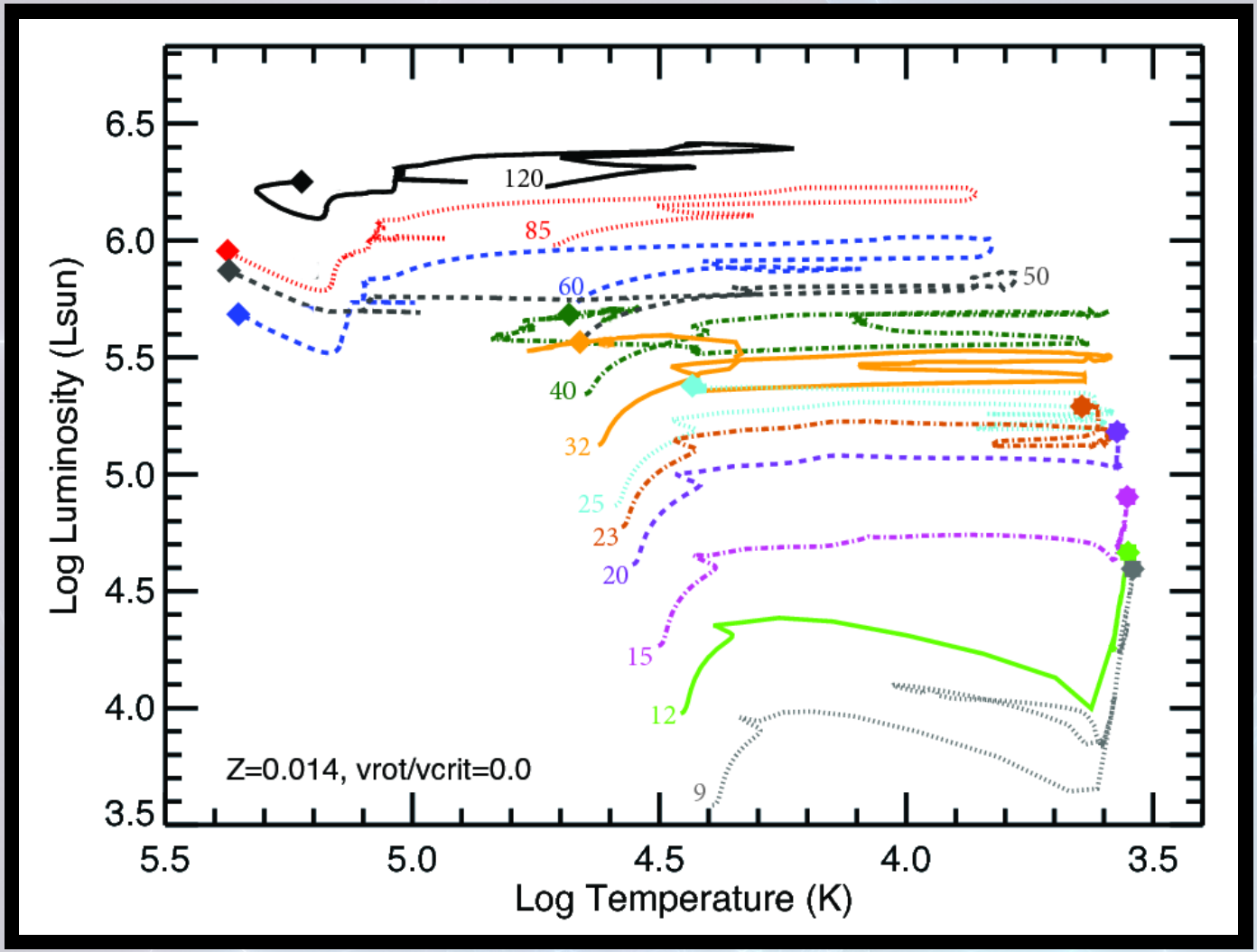


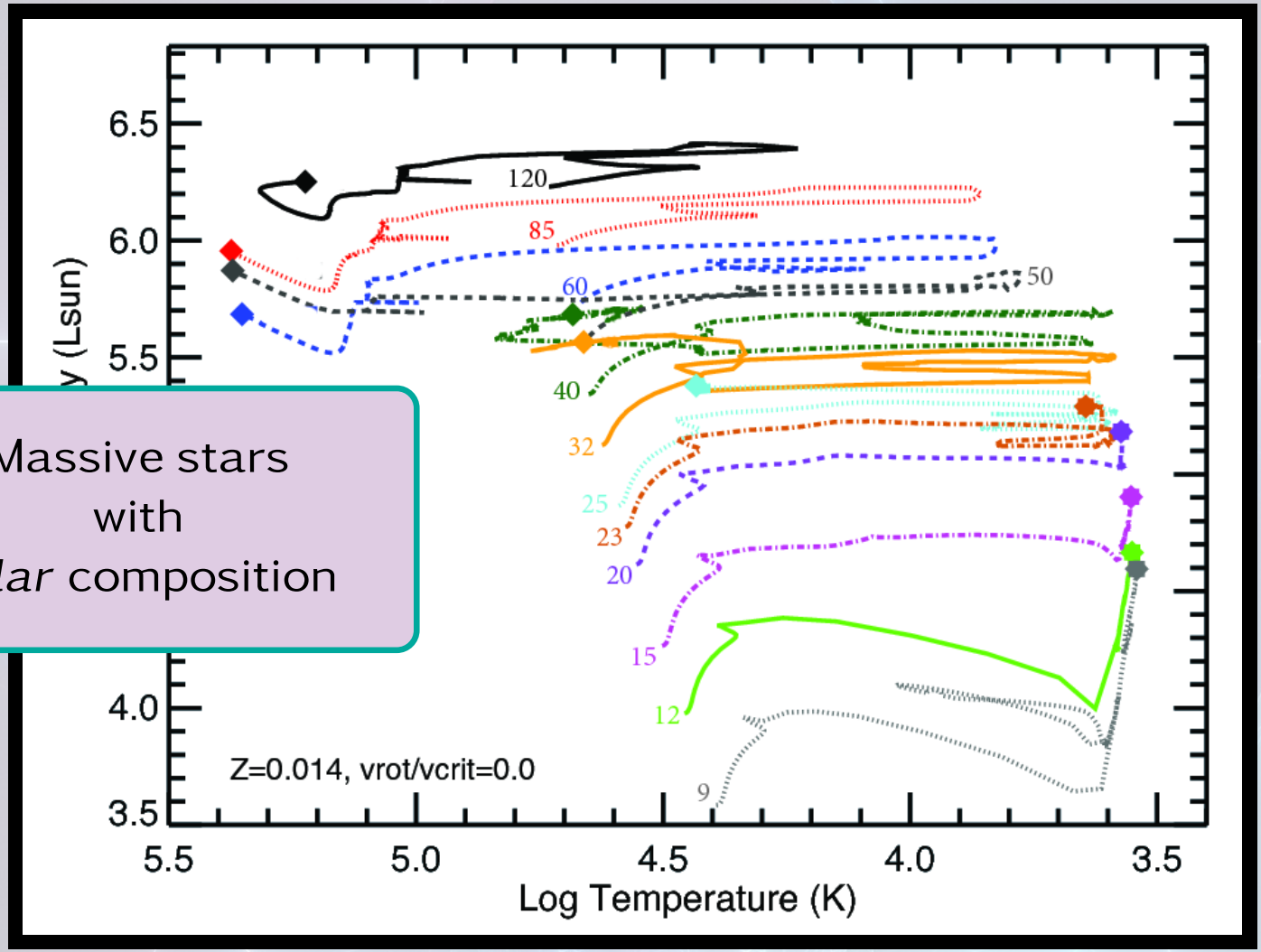
Hertzsprung–Russell diagram (HR diagram)

Hertzsprung–Russell diagram



Groh et al. 2013

Hertzsprung–Russell diagram



Massive stars
with
solar composition

Groh et al. 2013

Low Metallicity Massive Stars

Low Metallicity Massive Stars

– my thesis ☺

Low Metallicity Massive Stars

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

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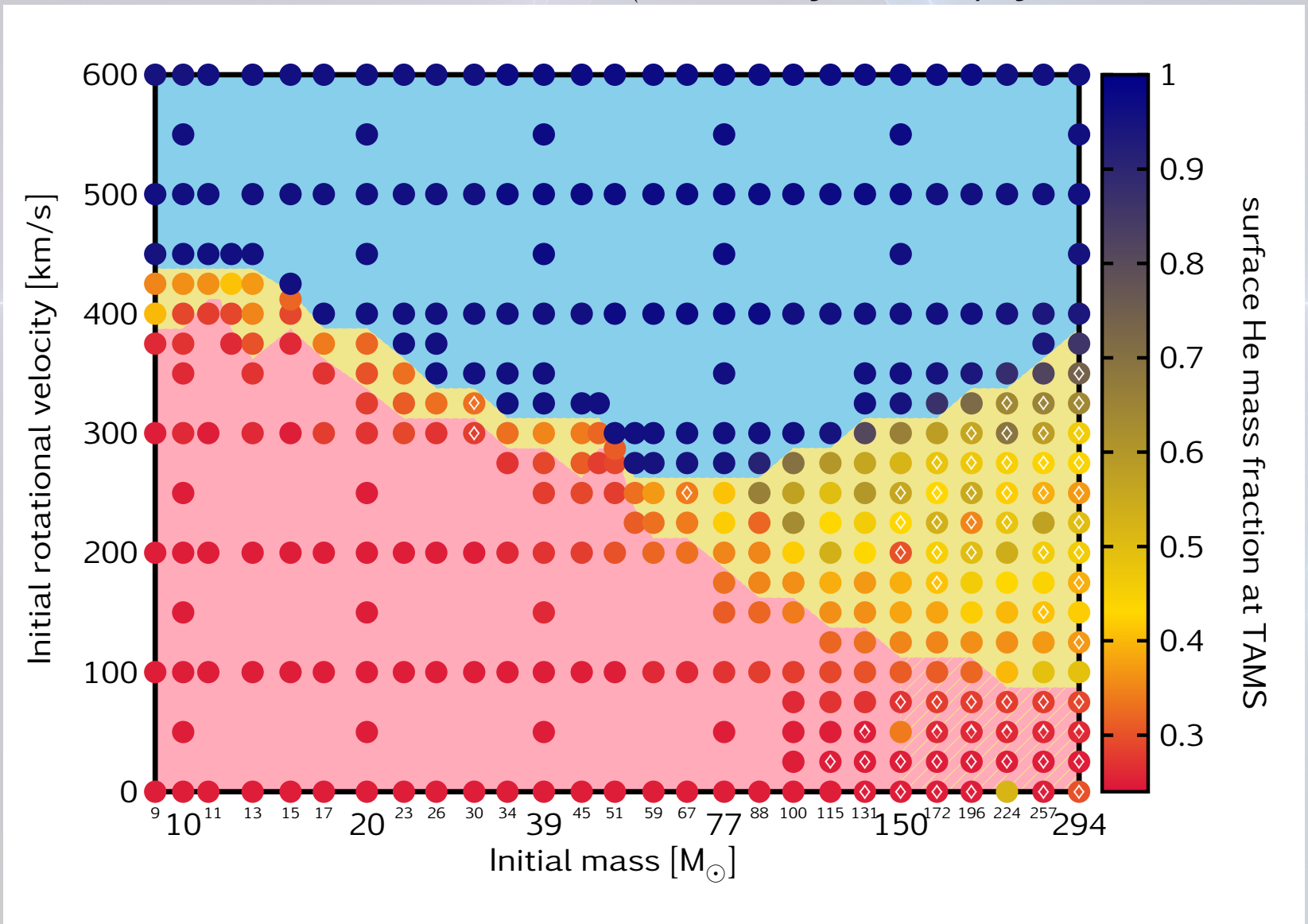

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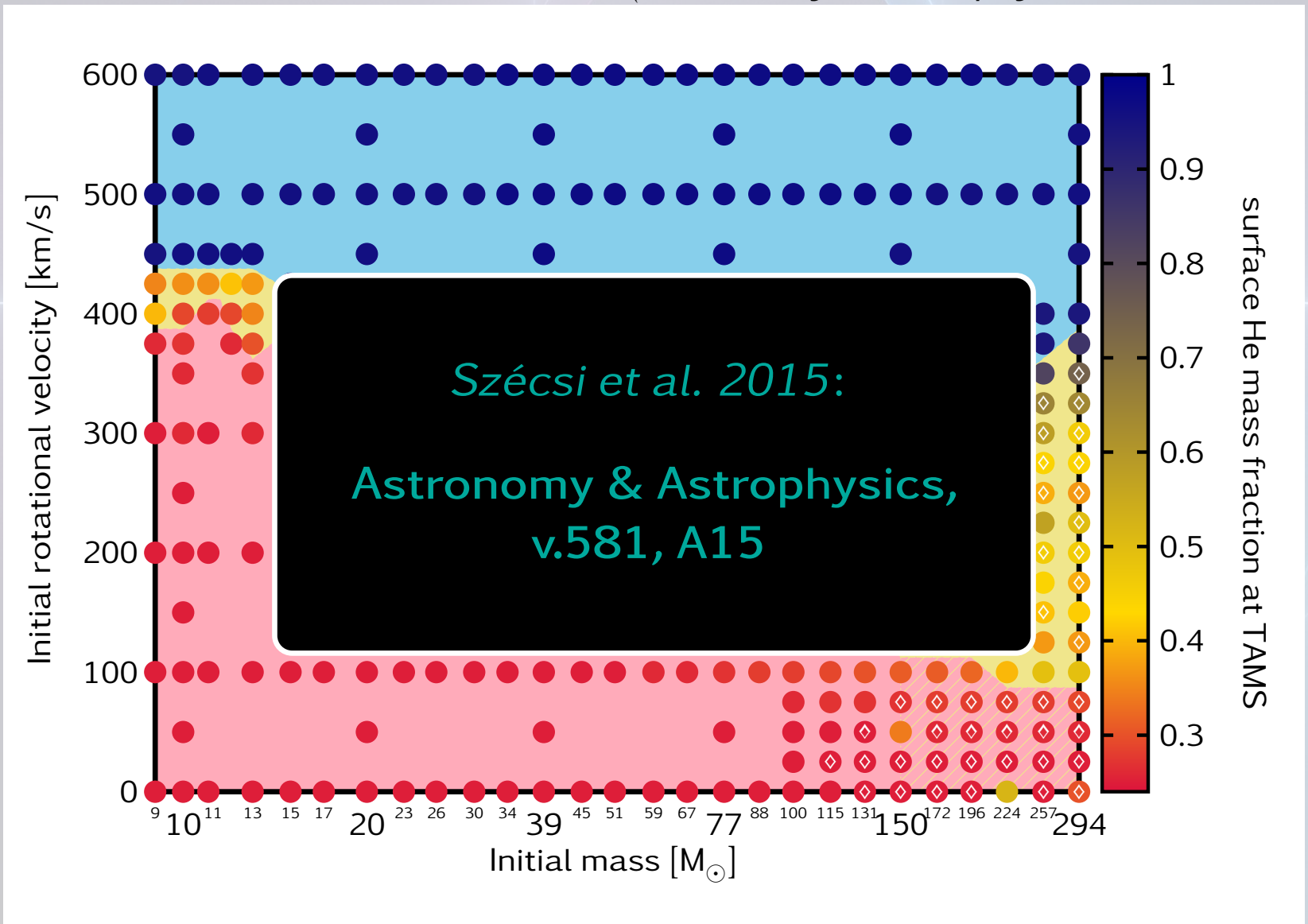

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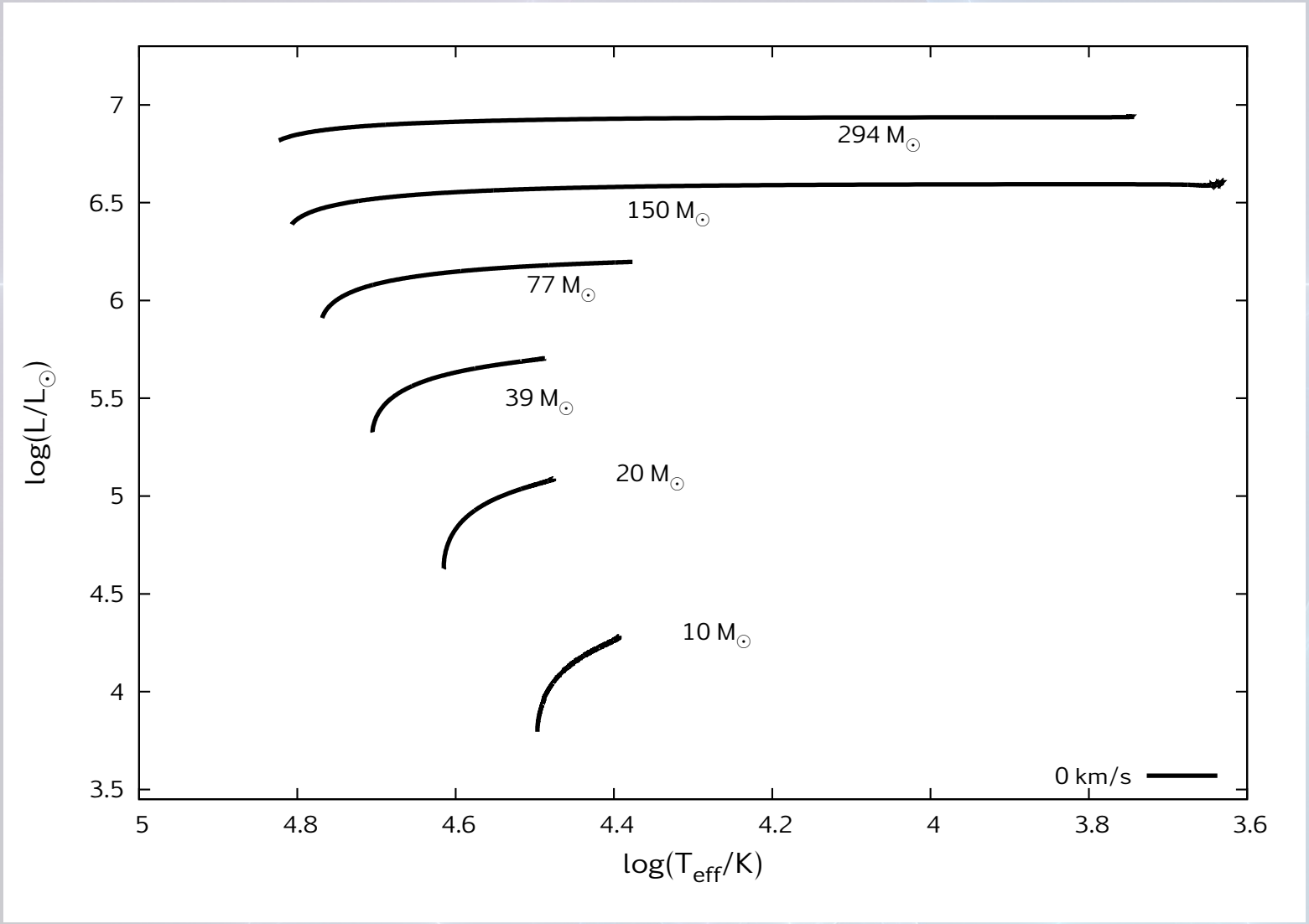

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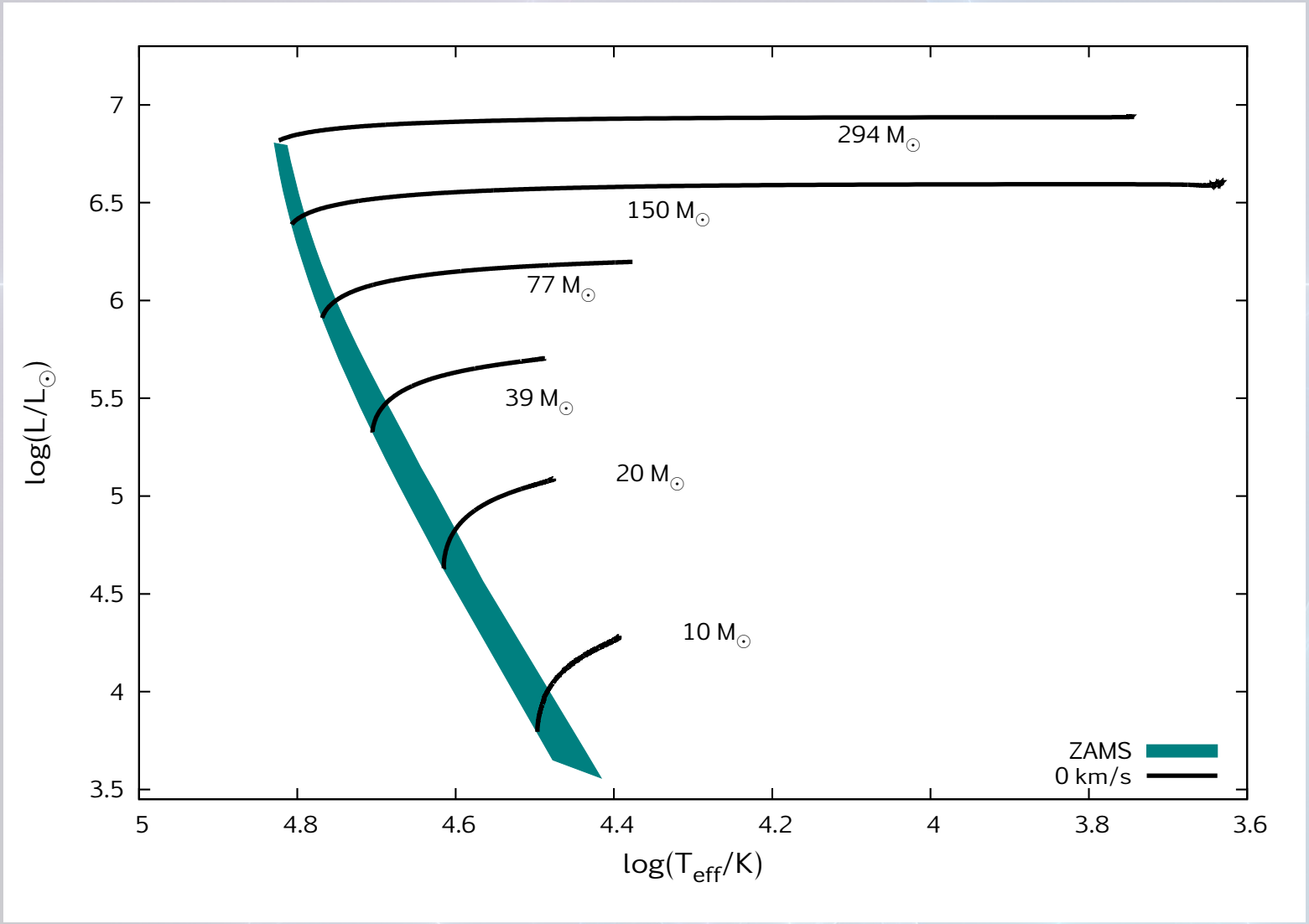

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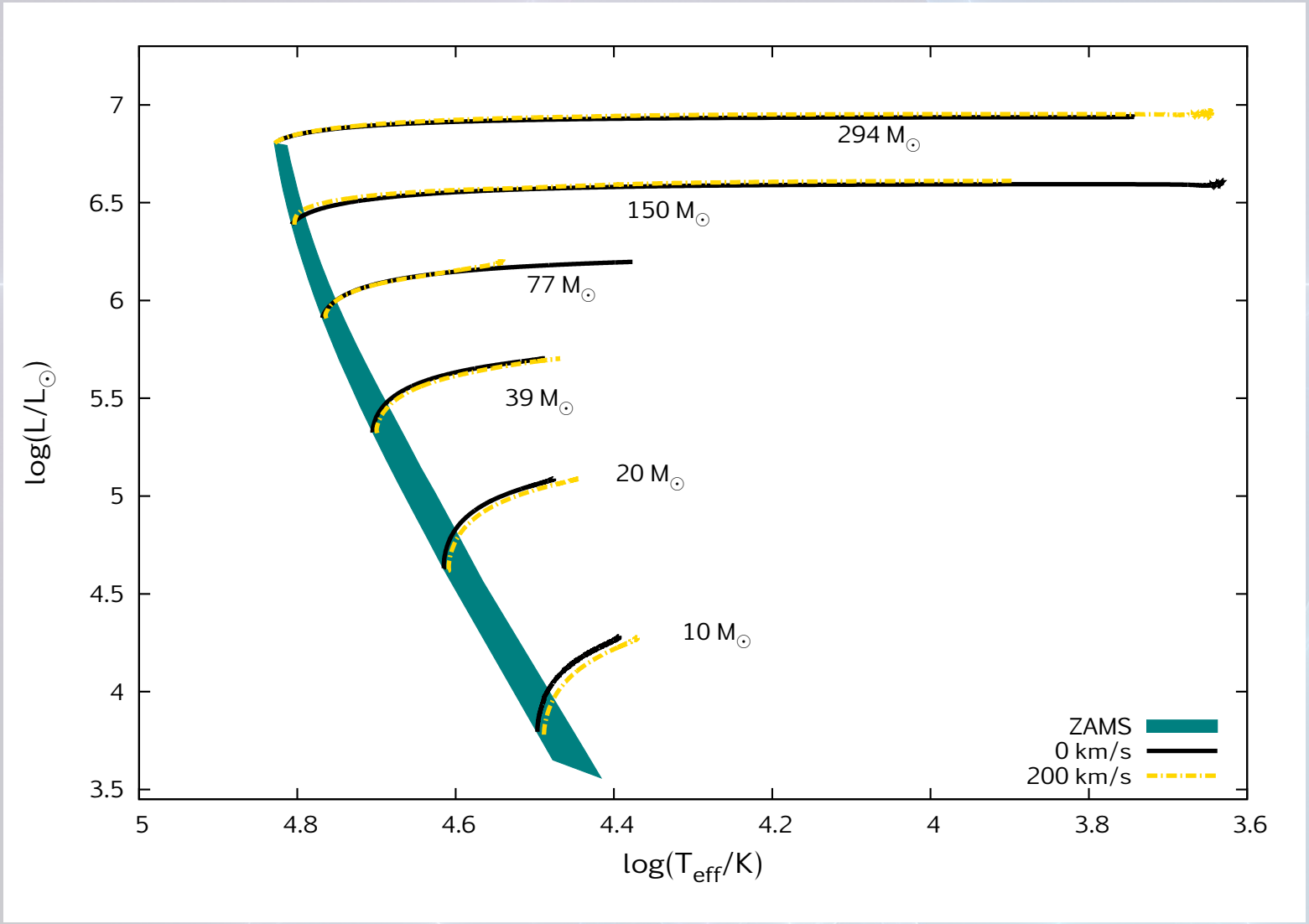

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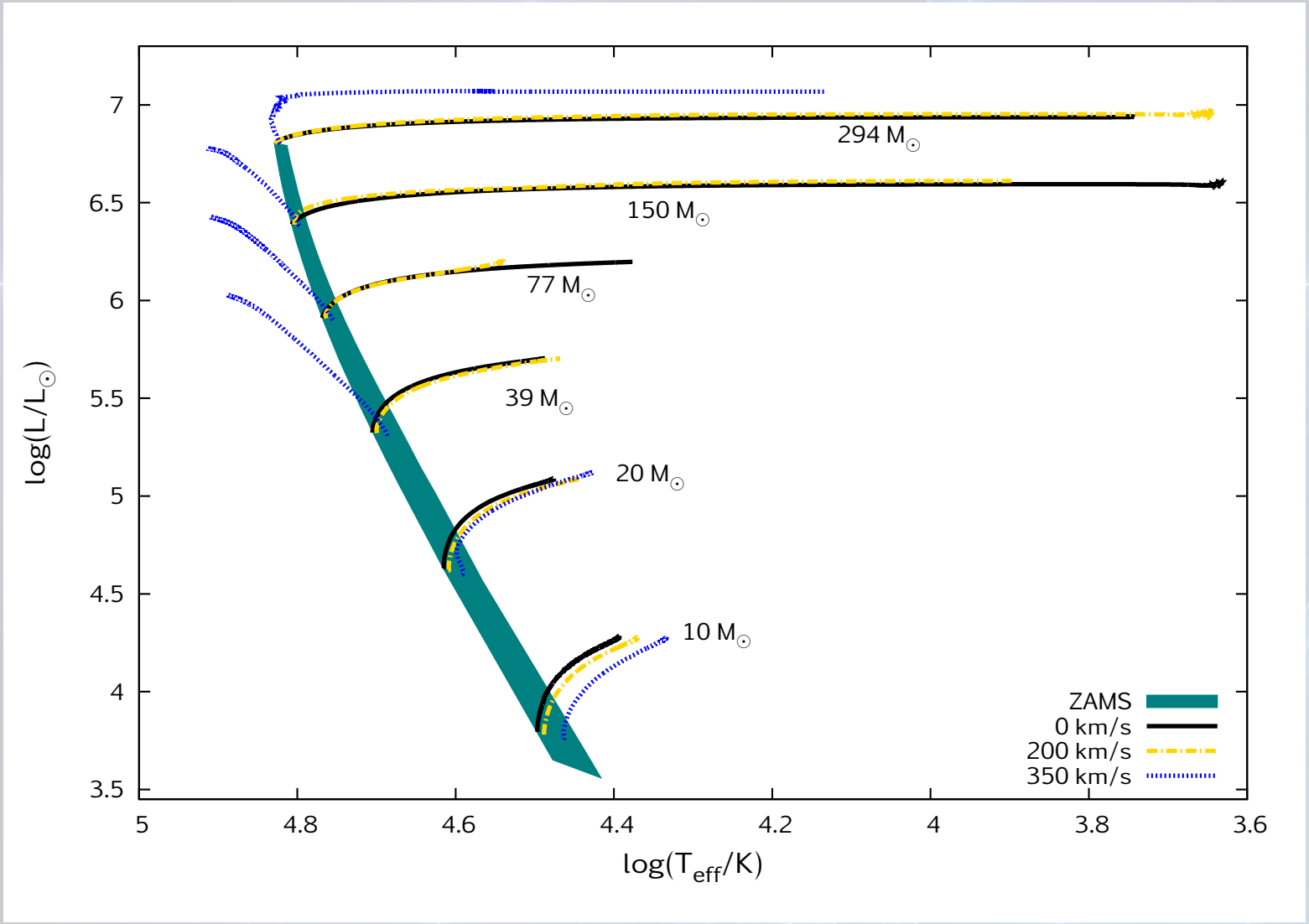

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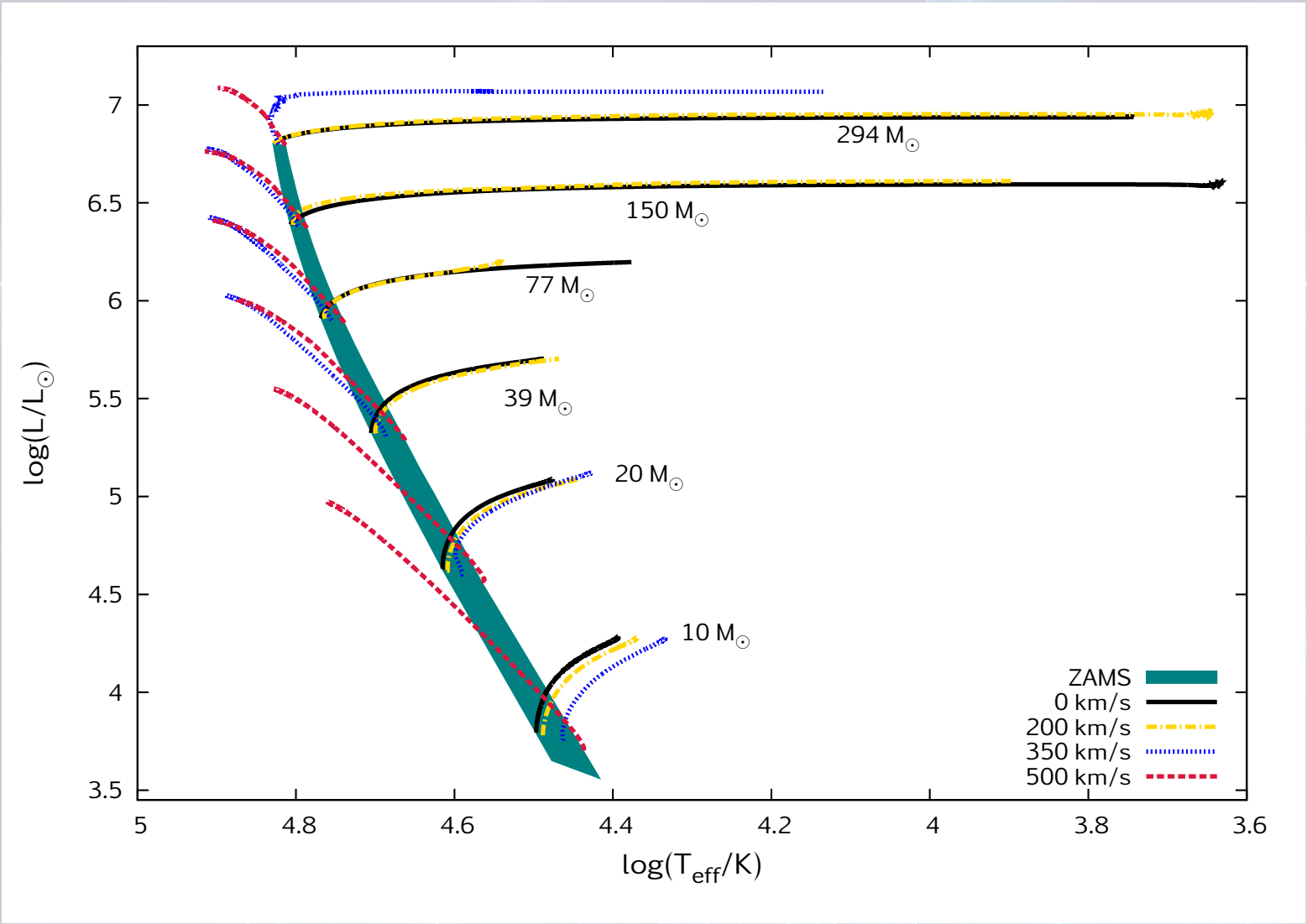

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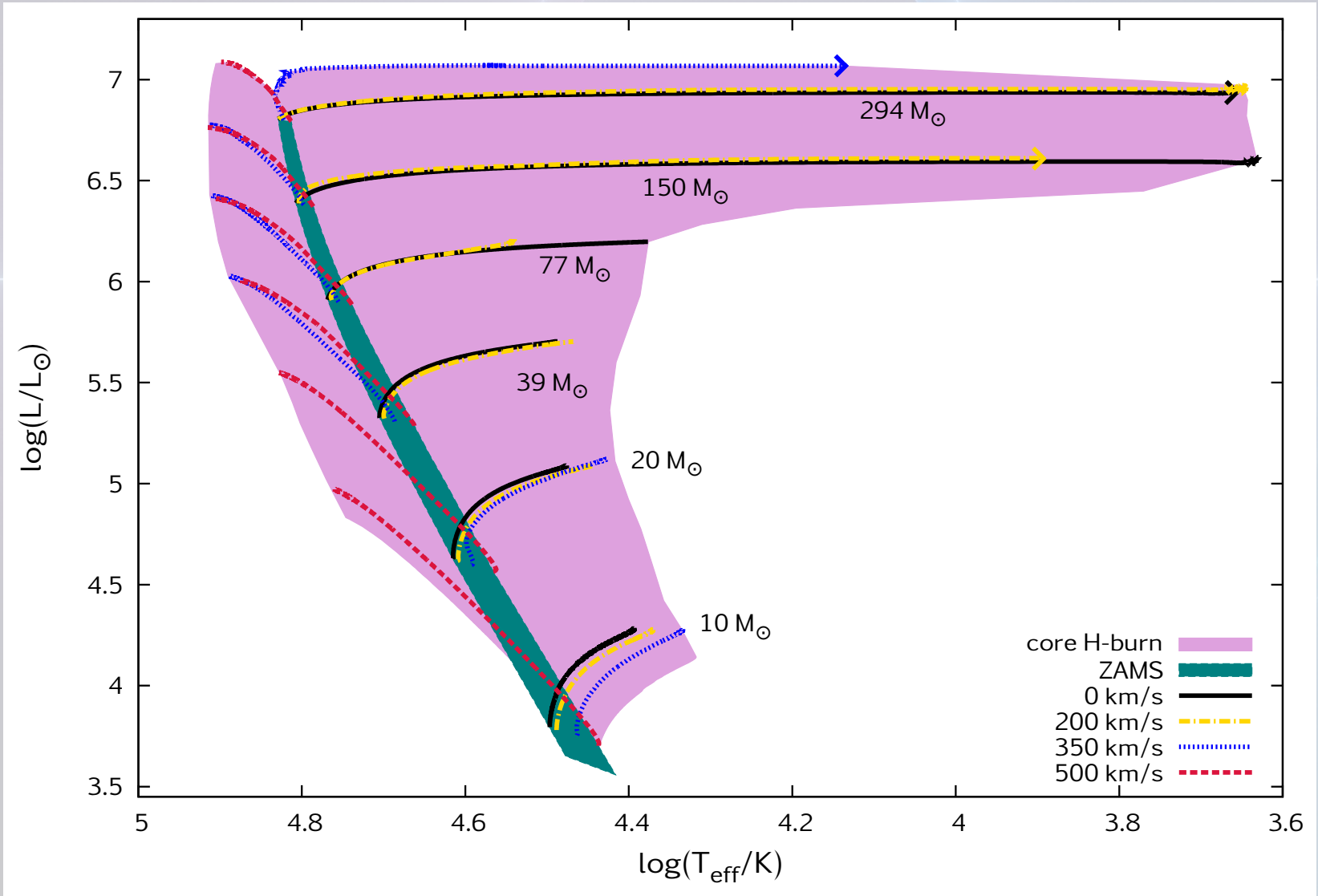

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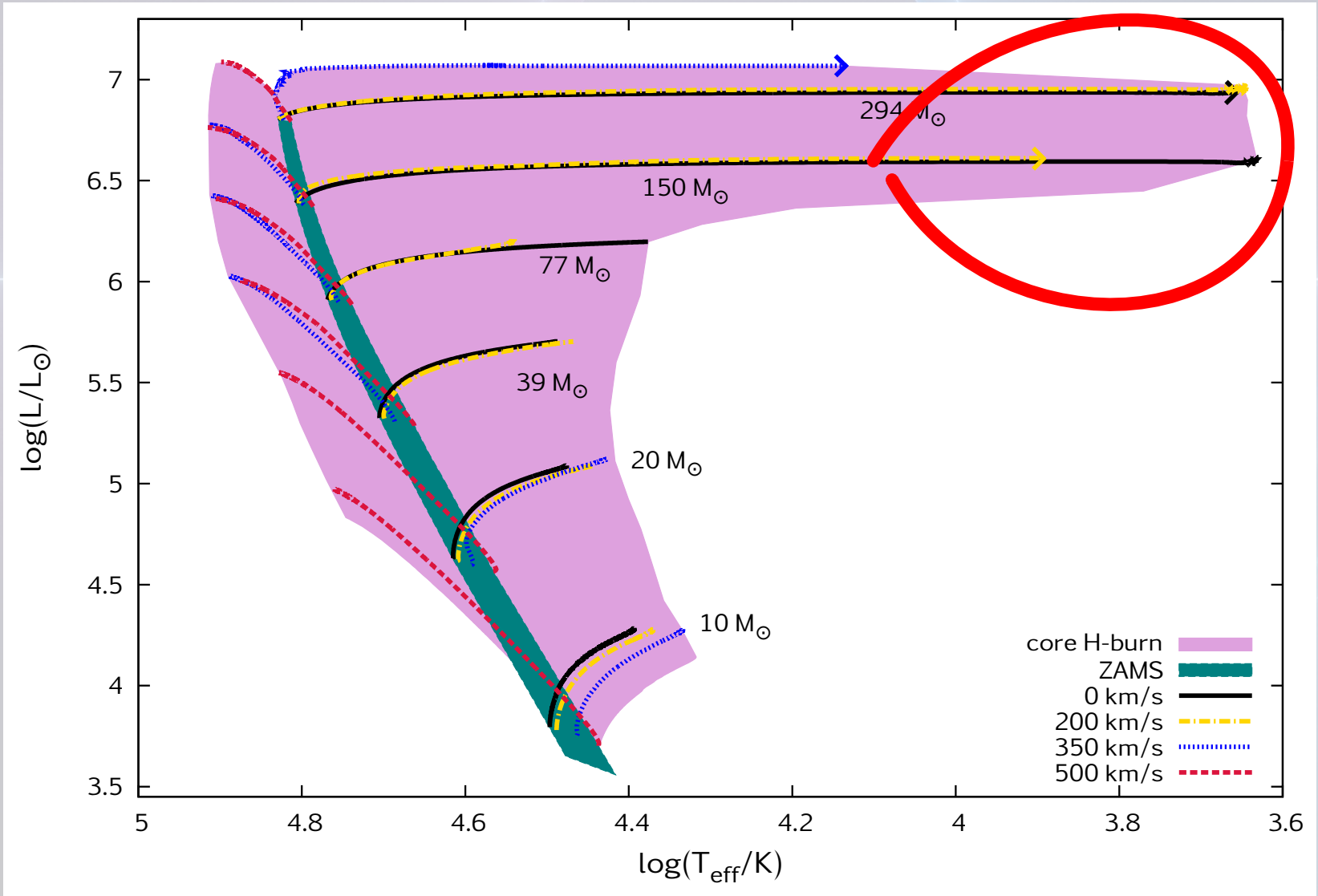

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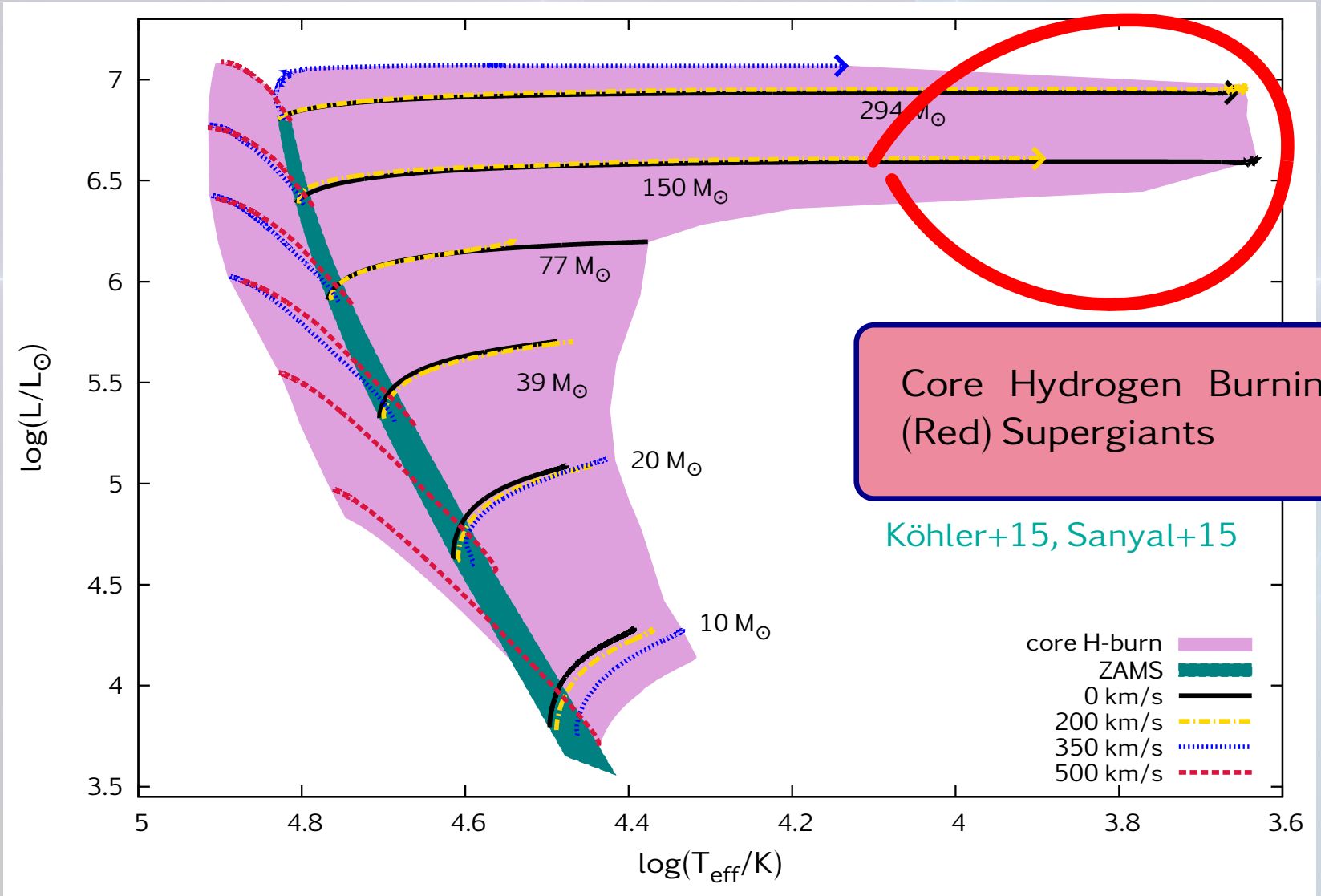

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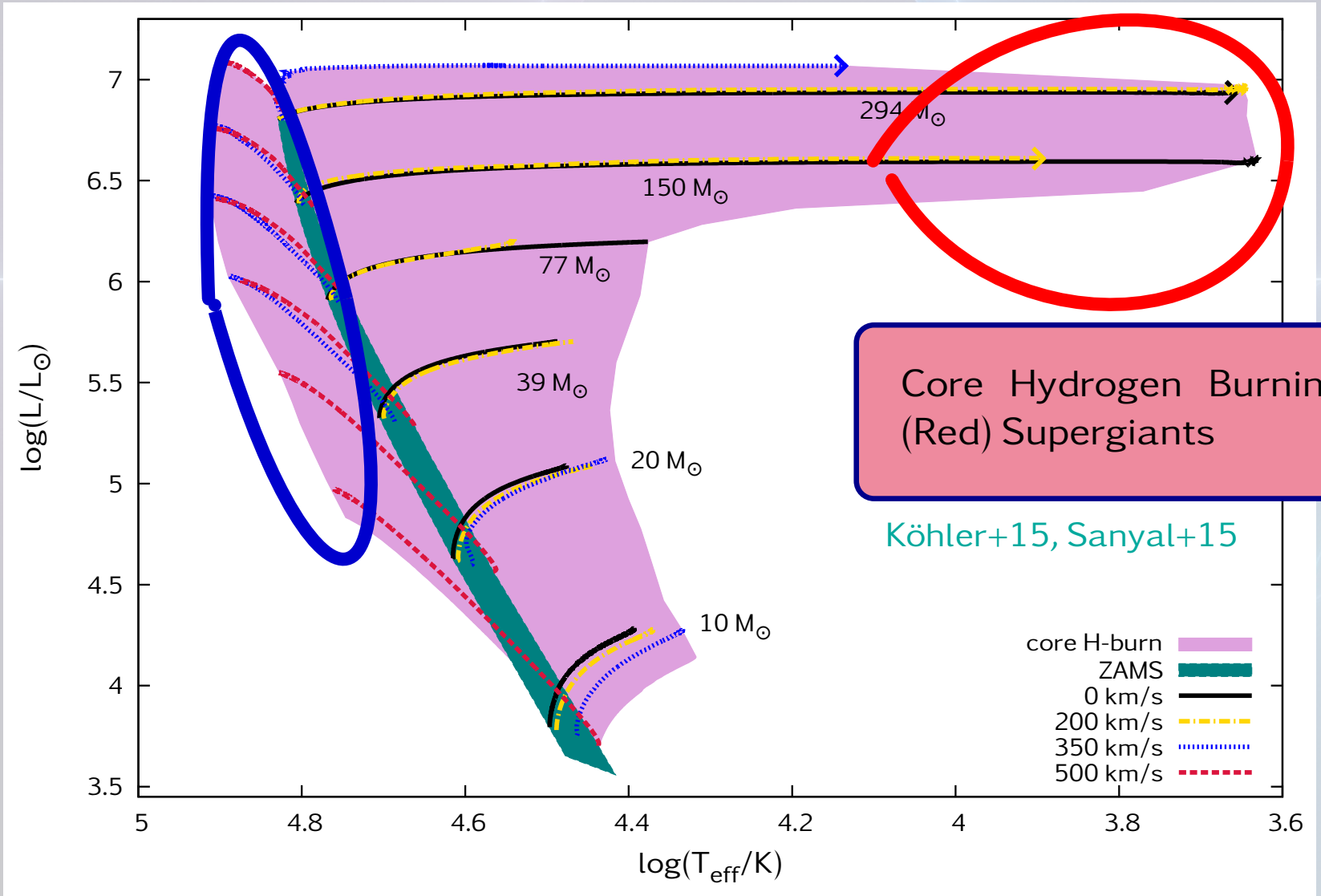

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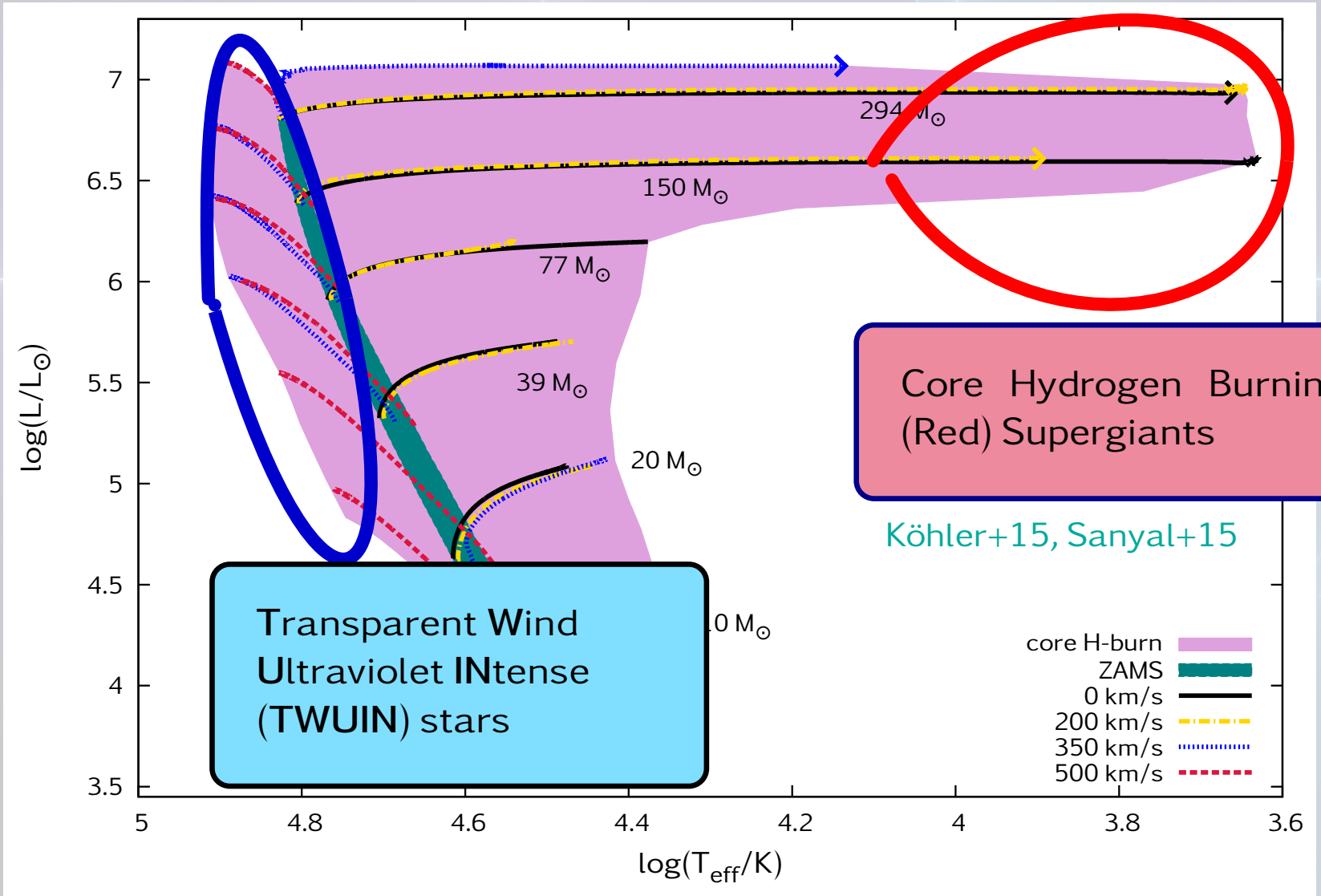

Transparent Wind
Ultraviolet INtense stars
(TWUIN stars)

– in the

starburst galaxy I Zwicky 18

TWUIN stars and their stellar winds

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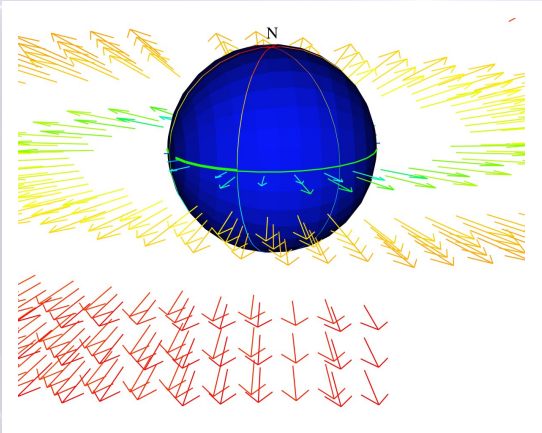

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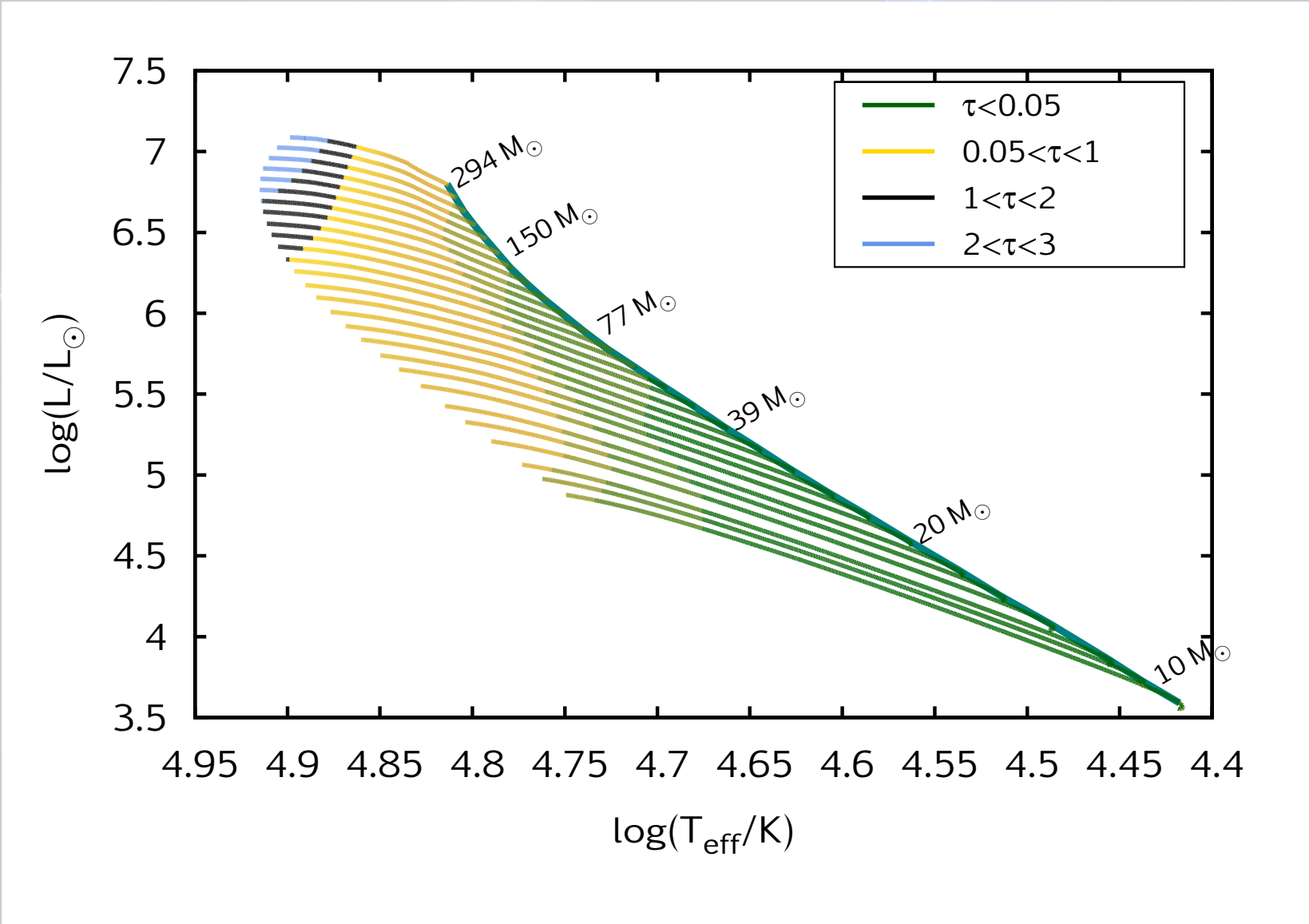

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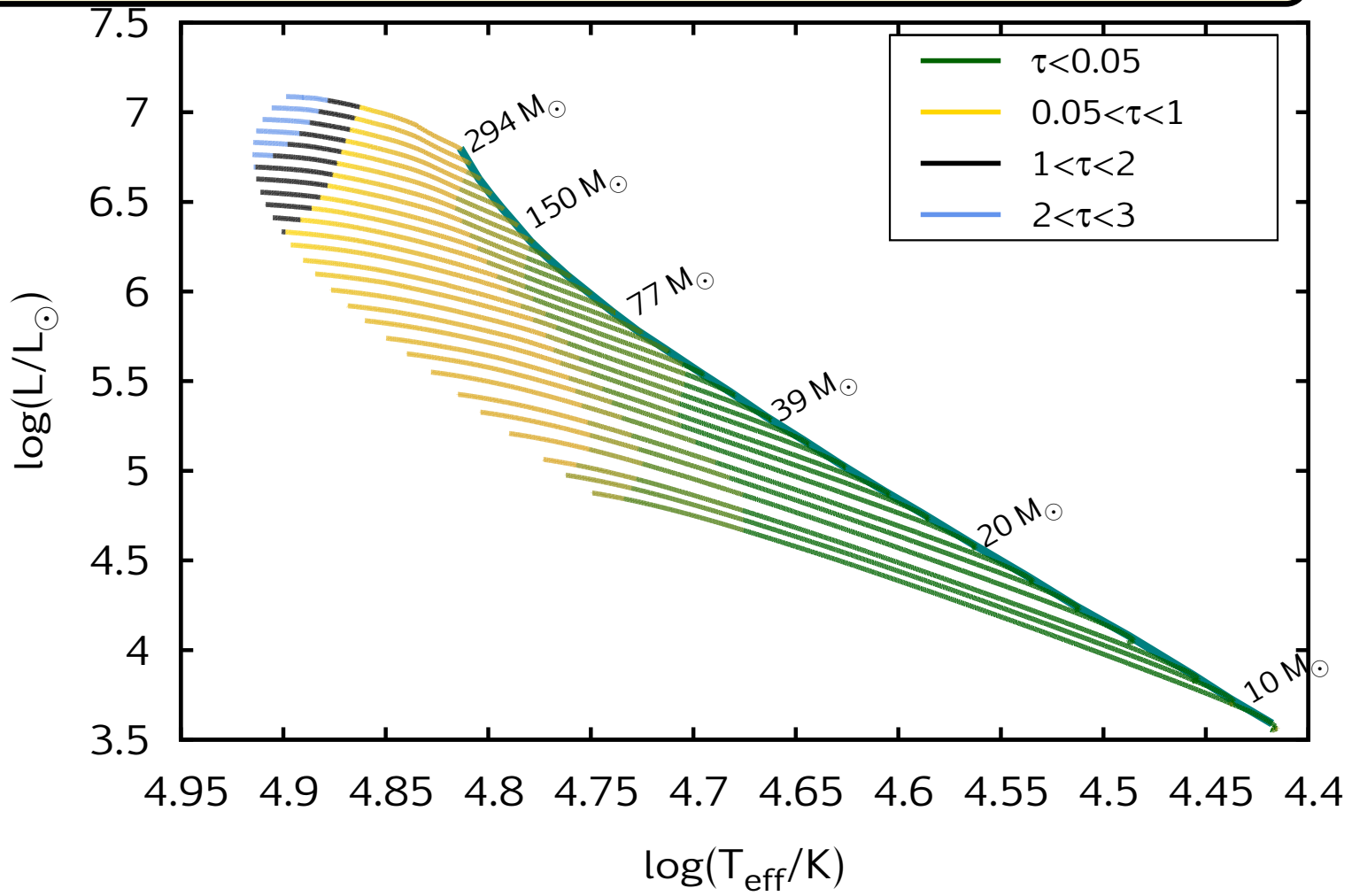

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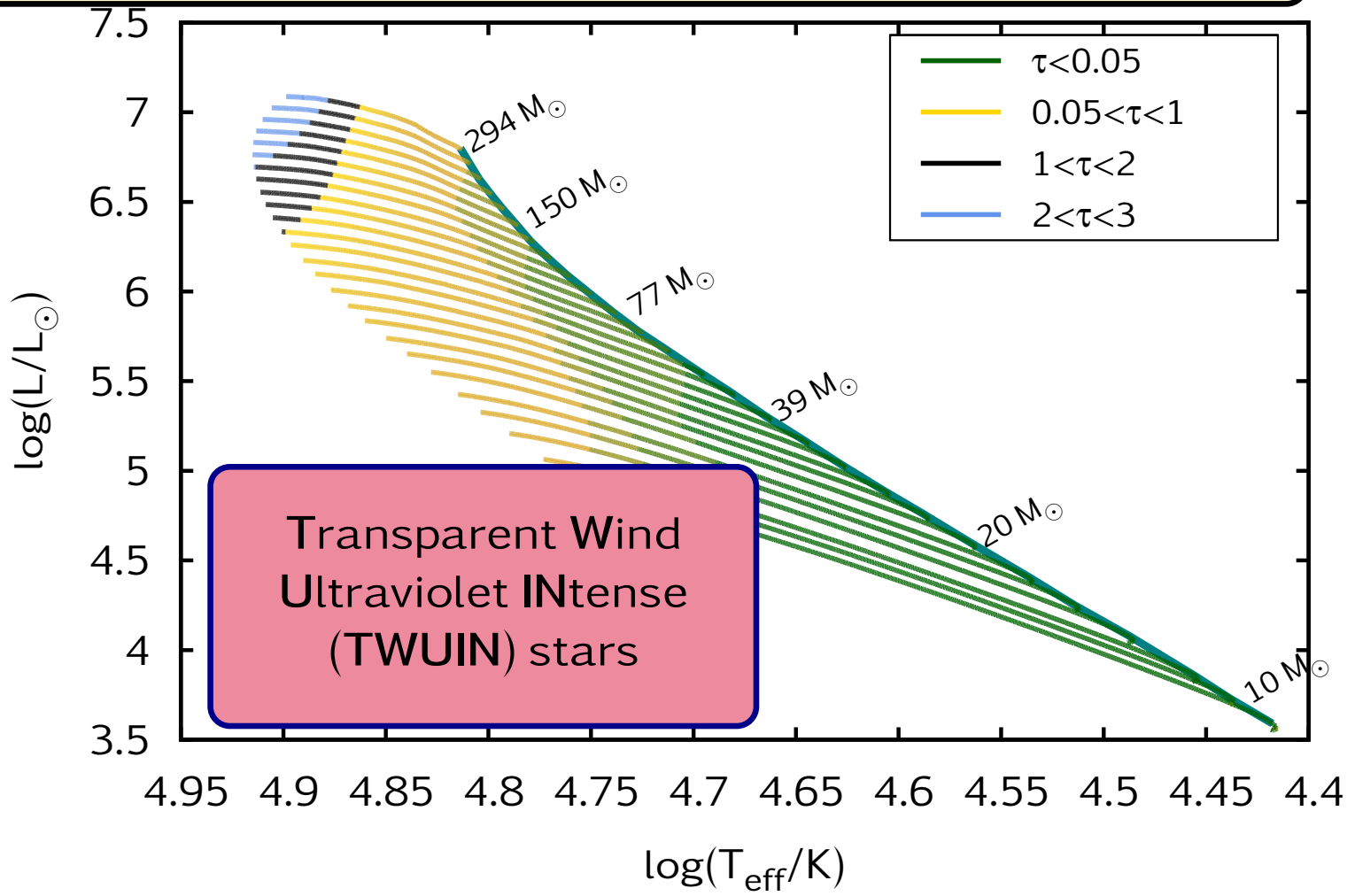

Back to I Zw 18

I Zwicky 18

- Blue Compact Dwarf Galaxy
- 18 Mpc → local
- SFR: 0.1-1 $M_\odot$/yr
- ionized gas
- low metallicity:
  12+log(O/H)=7.17
  ↓
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Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Lebouteiller+13

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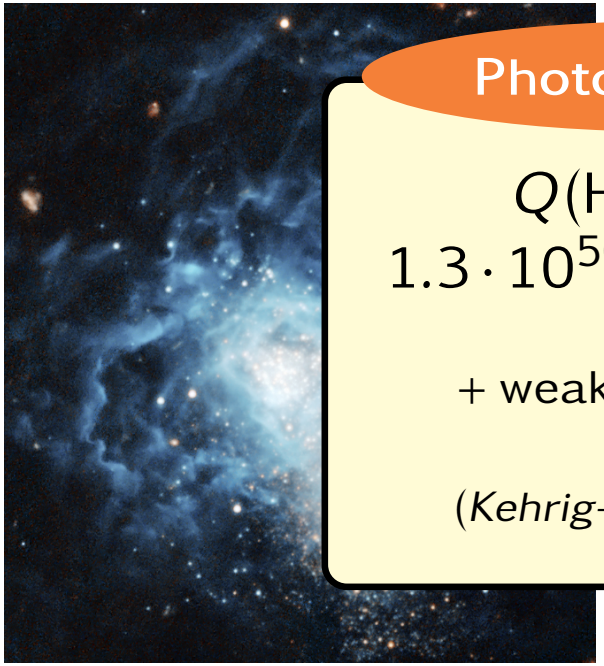

Photoionization

$Q(\mathrm{HeII})^{obs} = 1.3 \cdot 10^{50}$ photons s^{-1}

+ weak WR features

(*Kehrig+15, Crowther+06*)

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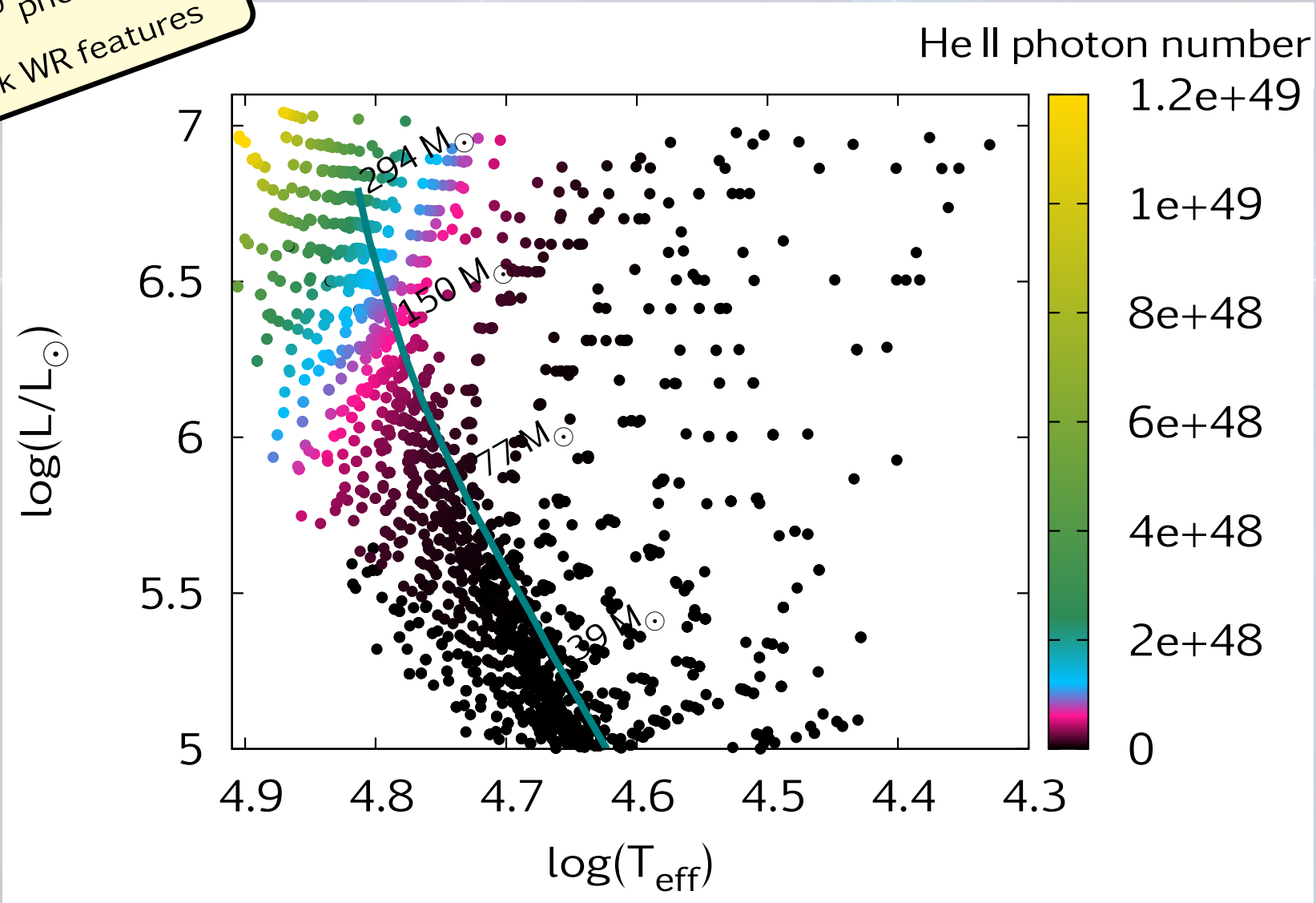

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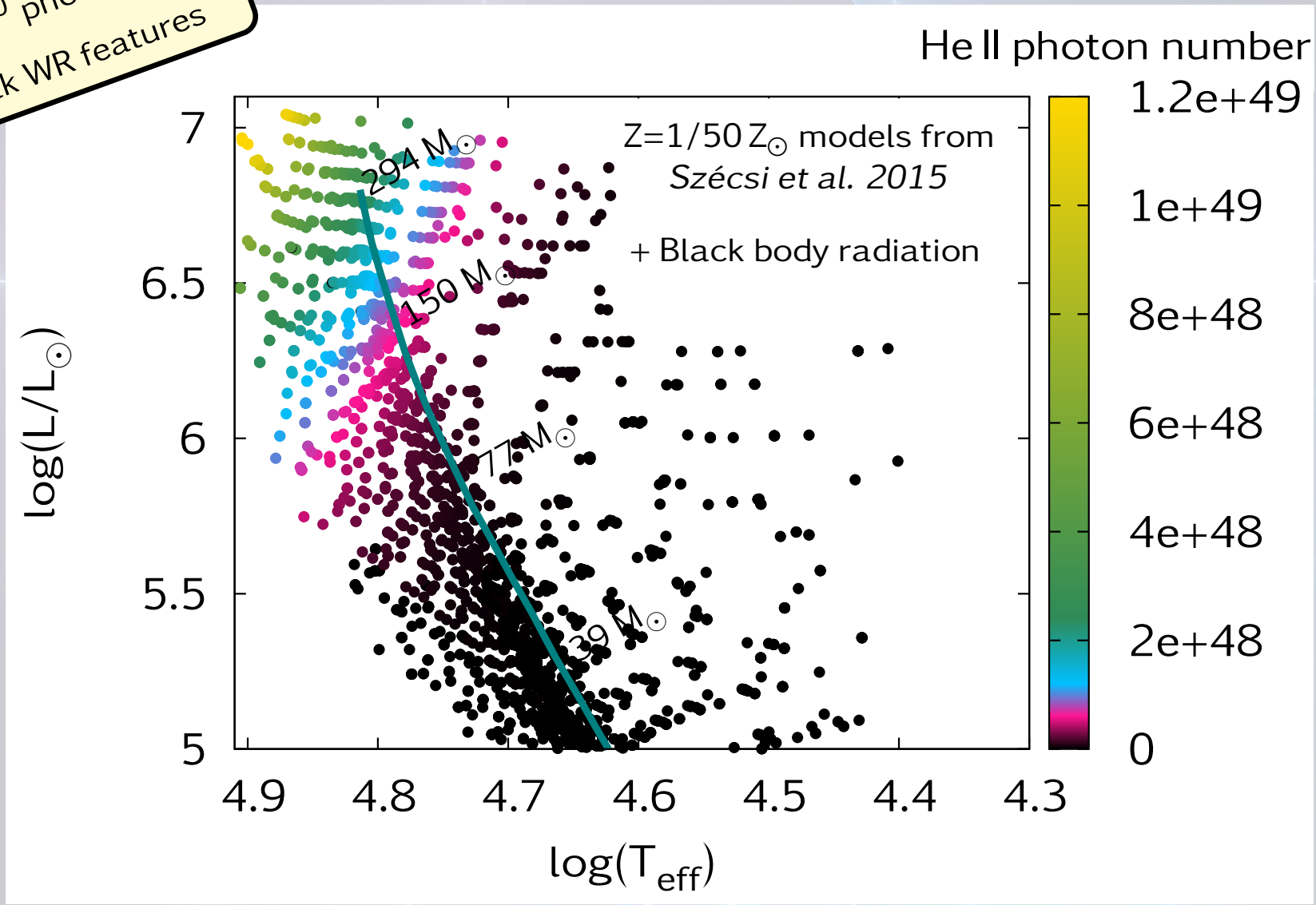

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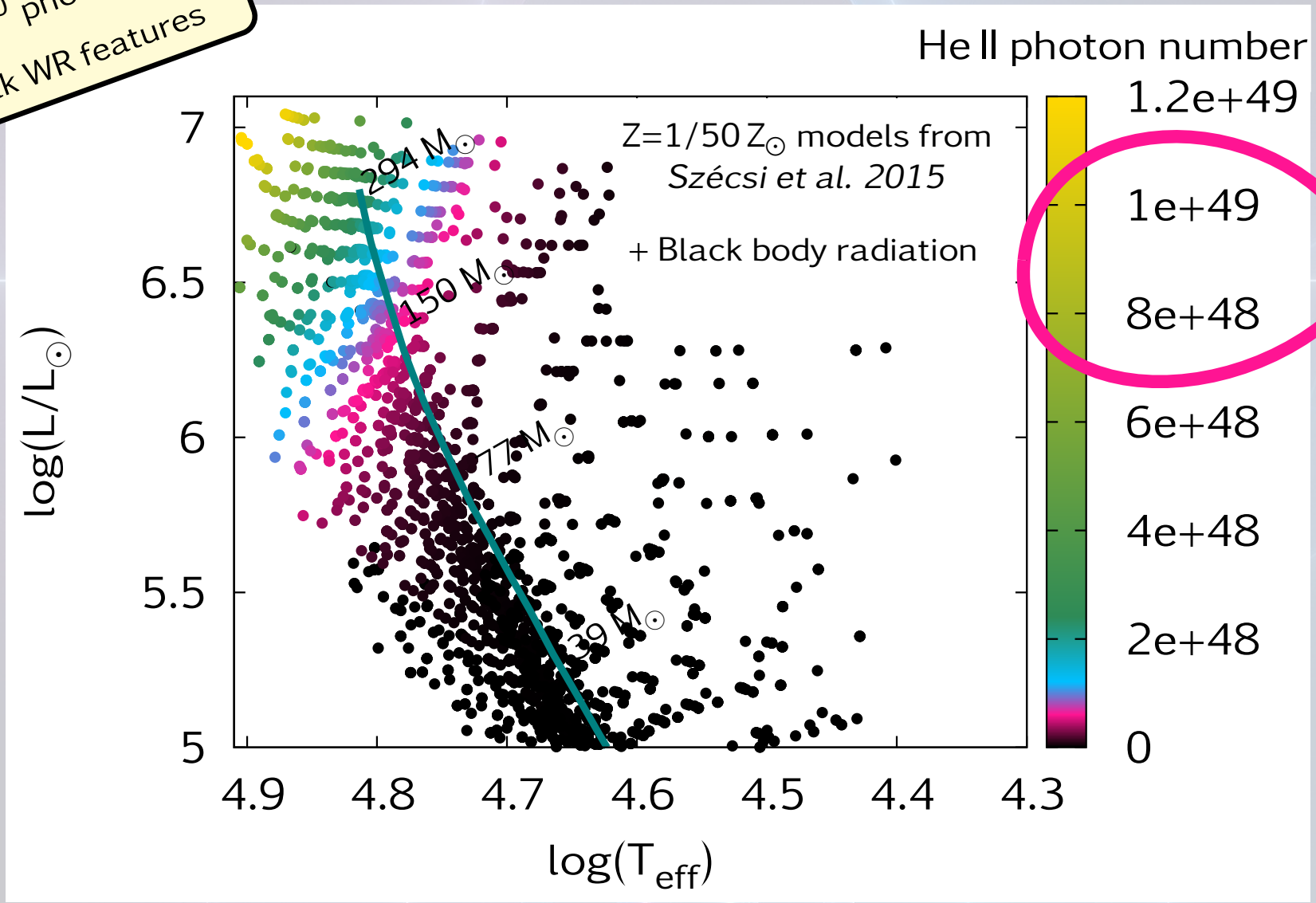

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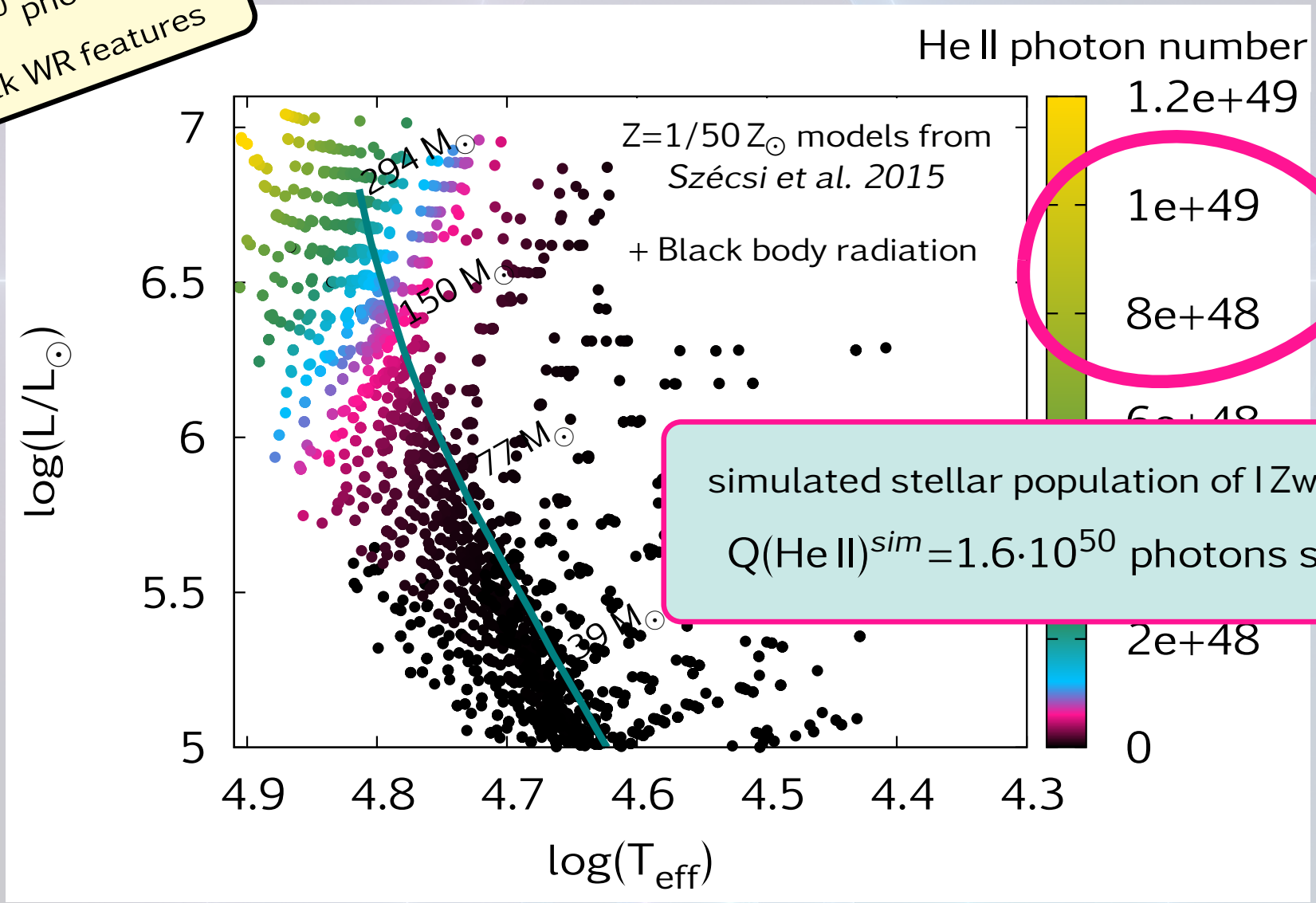

simulated stellar population of I Zw 18:

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Cowther+06, Shirazi+12, Kehrig+15, Heap+15

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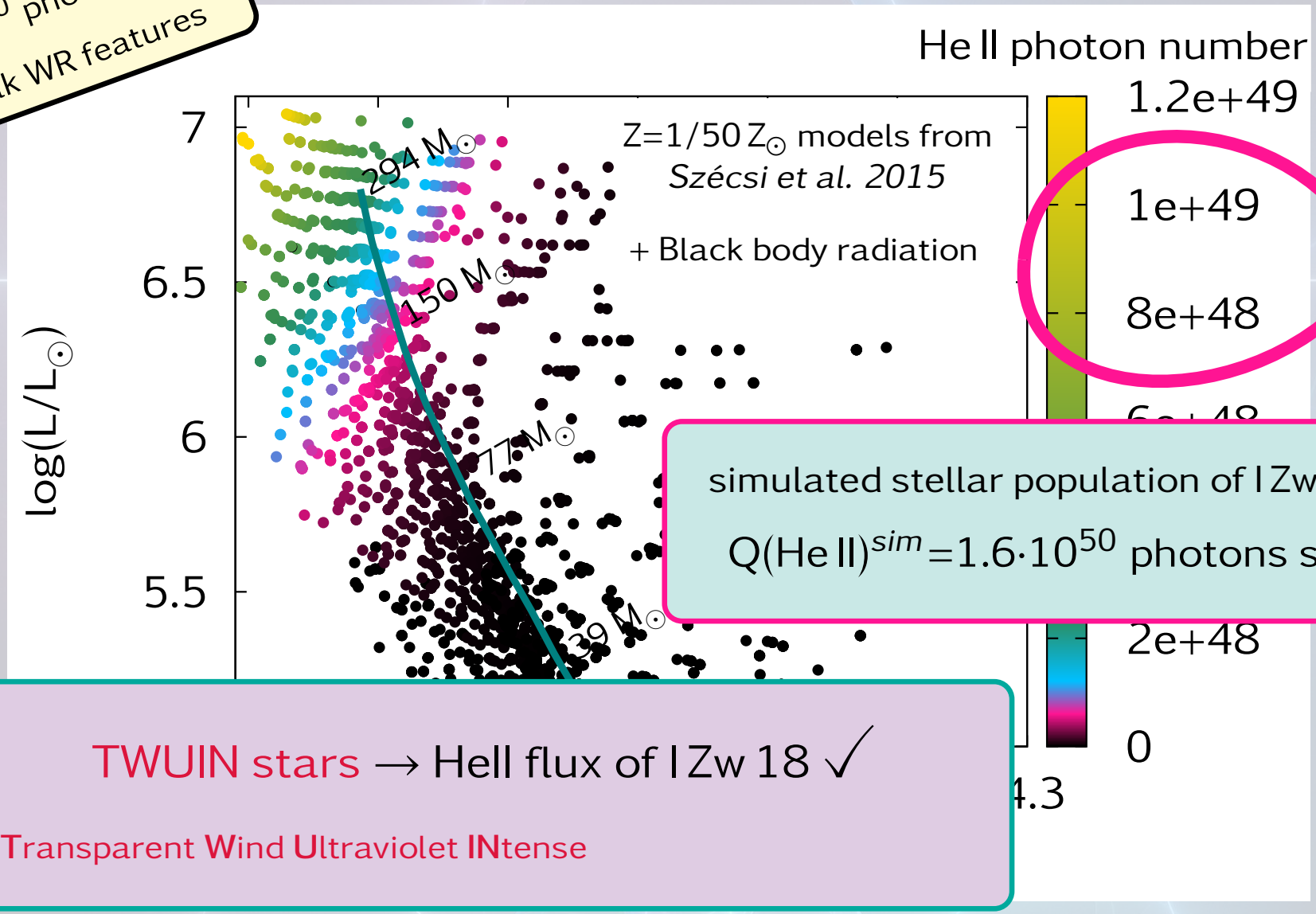

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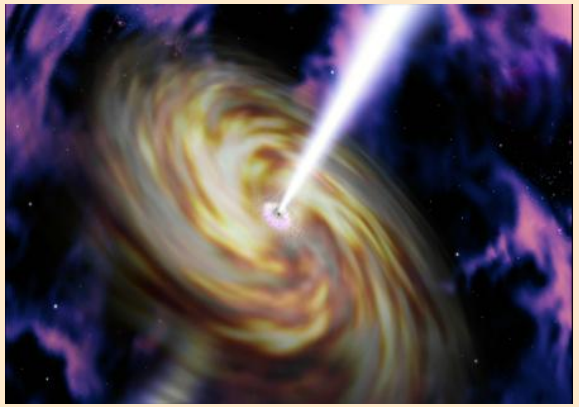
TWUIN stars → HeII flux of I Zw 18 ✓

Transparent **W**ind **U**ltraviolet **IN**tense

Cowther+06, Shirazi+12, Kehrig+15, Heap+15

Life and Death of Massive Stars

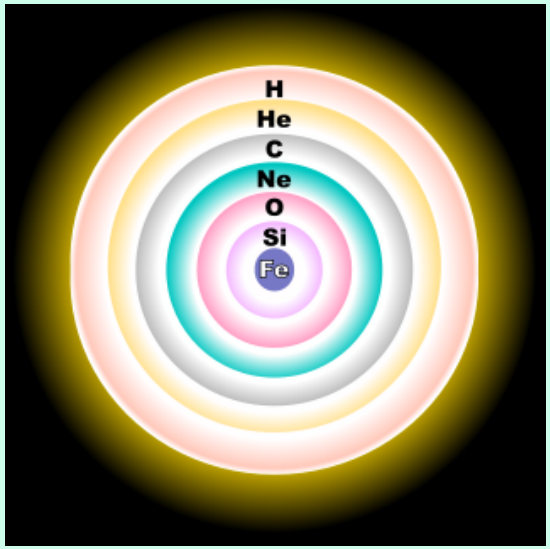
Collapsar → lGRB



Yoon&Langer'05; Woosley&Heger'06; Yoon+06; Yoon+12

Life and Death of Massive Stars

Massive stars



?

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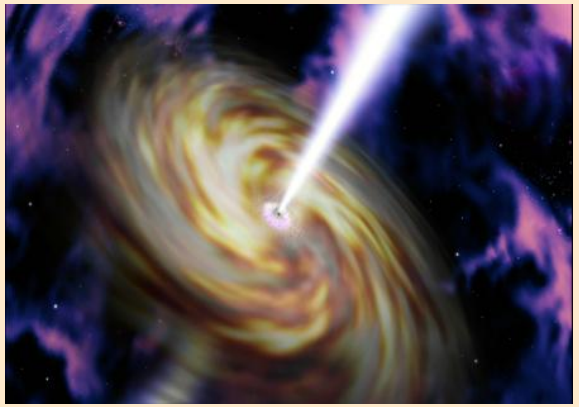

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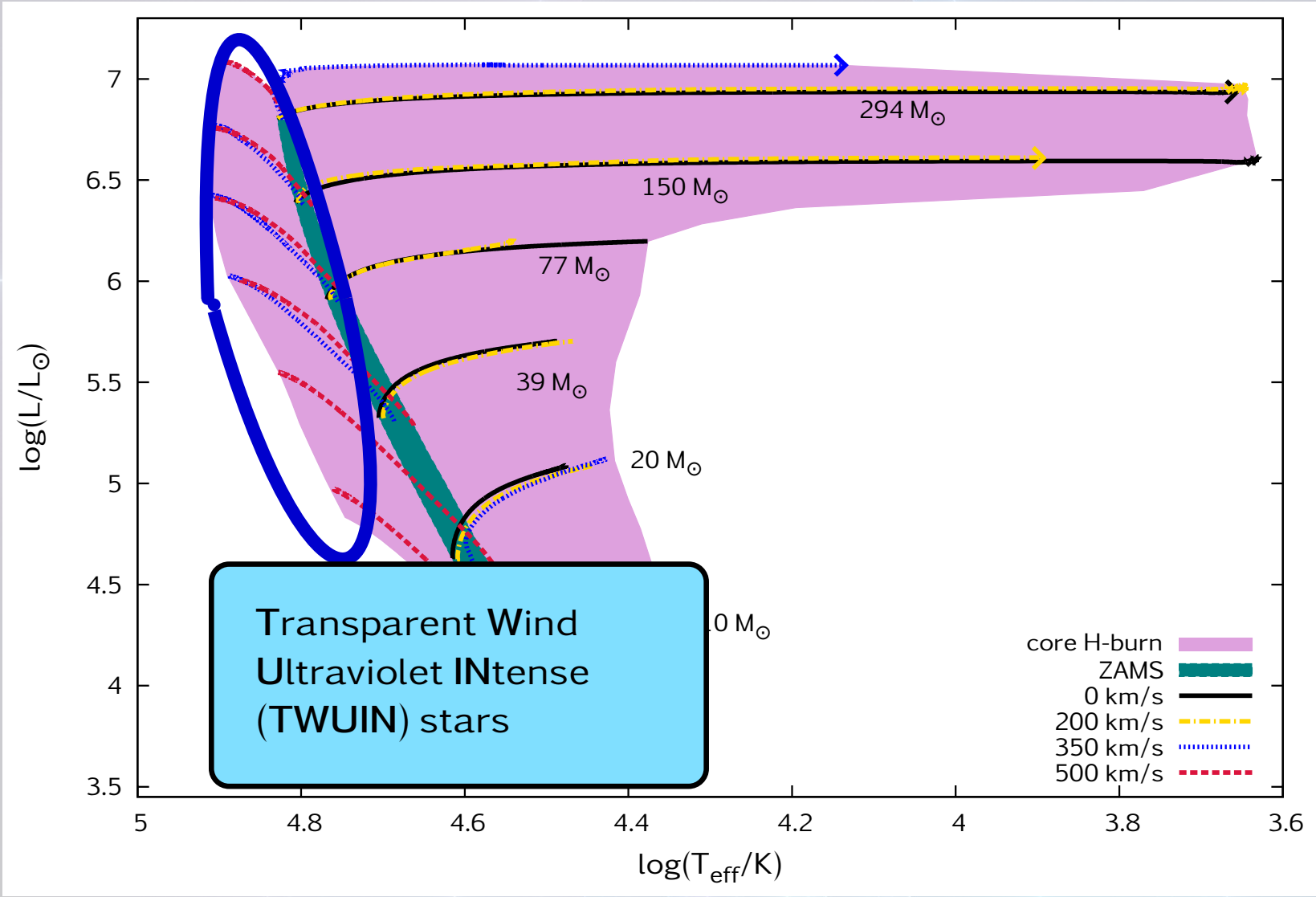

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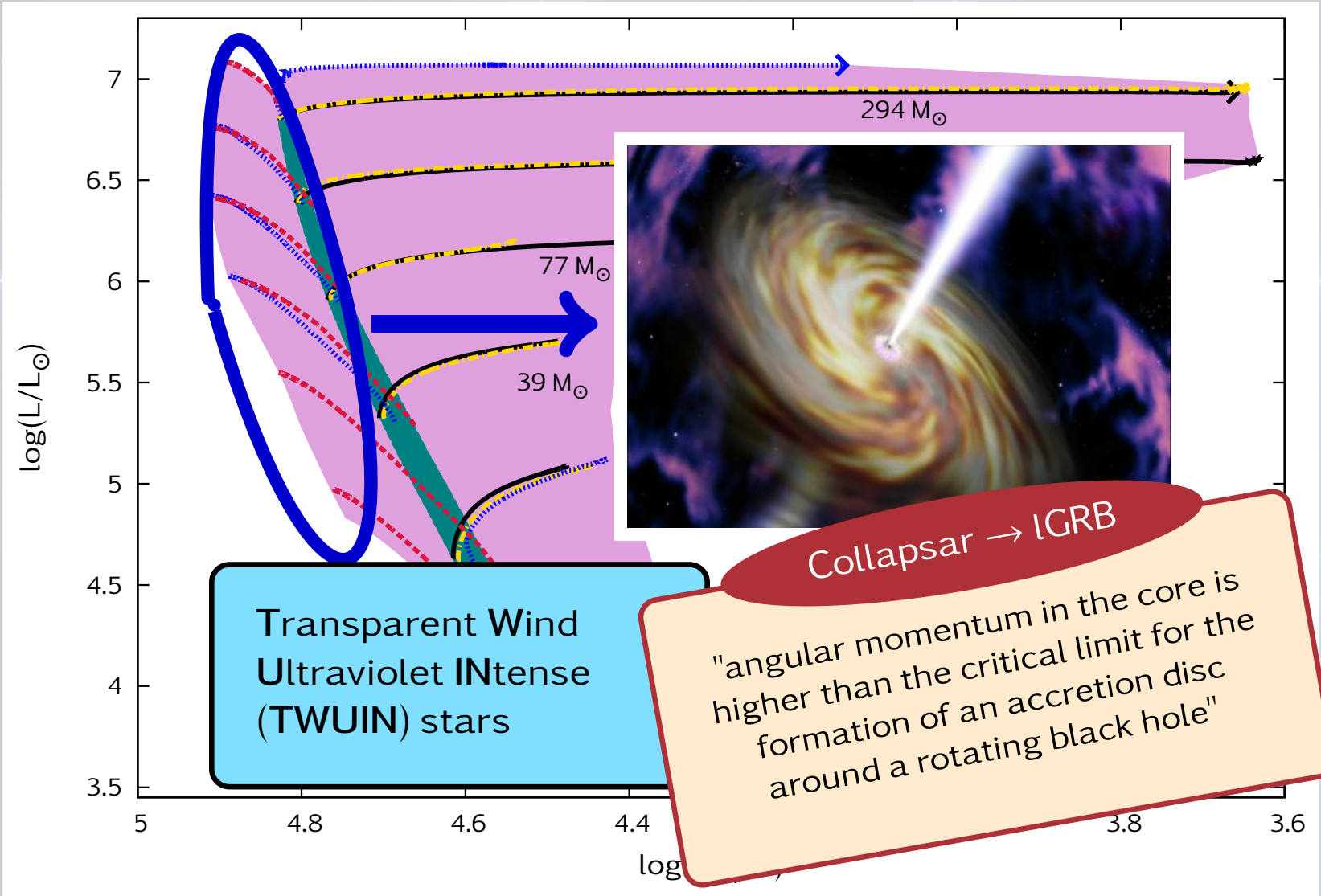

Life and Death of Massive Stars

Life of Massive Stars

He II photons

(*Shirazi+12, Kehrig+15*)

Death of Massive Stars

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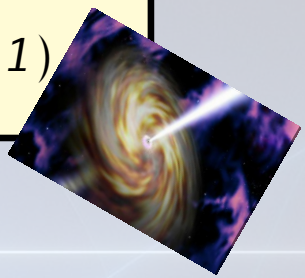
(*Levesque'10, Niino'11*)



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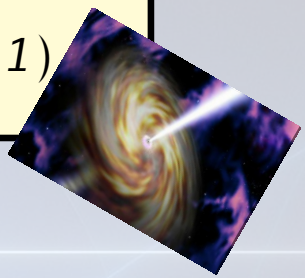

Explanation

Hot stars with weak winds

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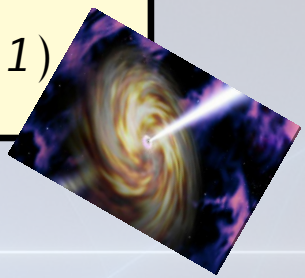

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Chemically Homogeneous Evolution

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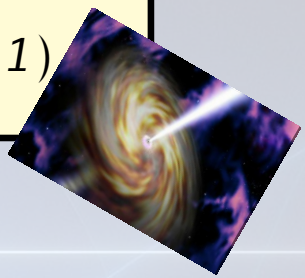

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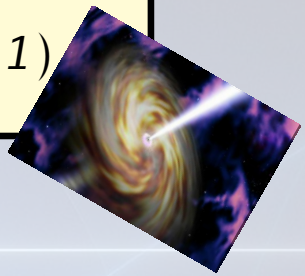

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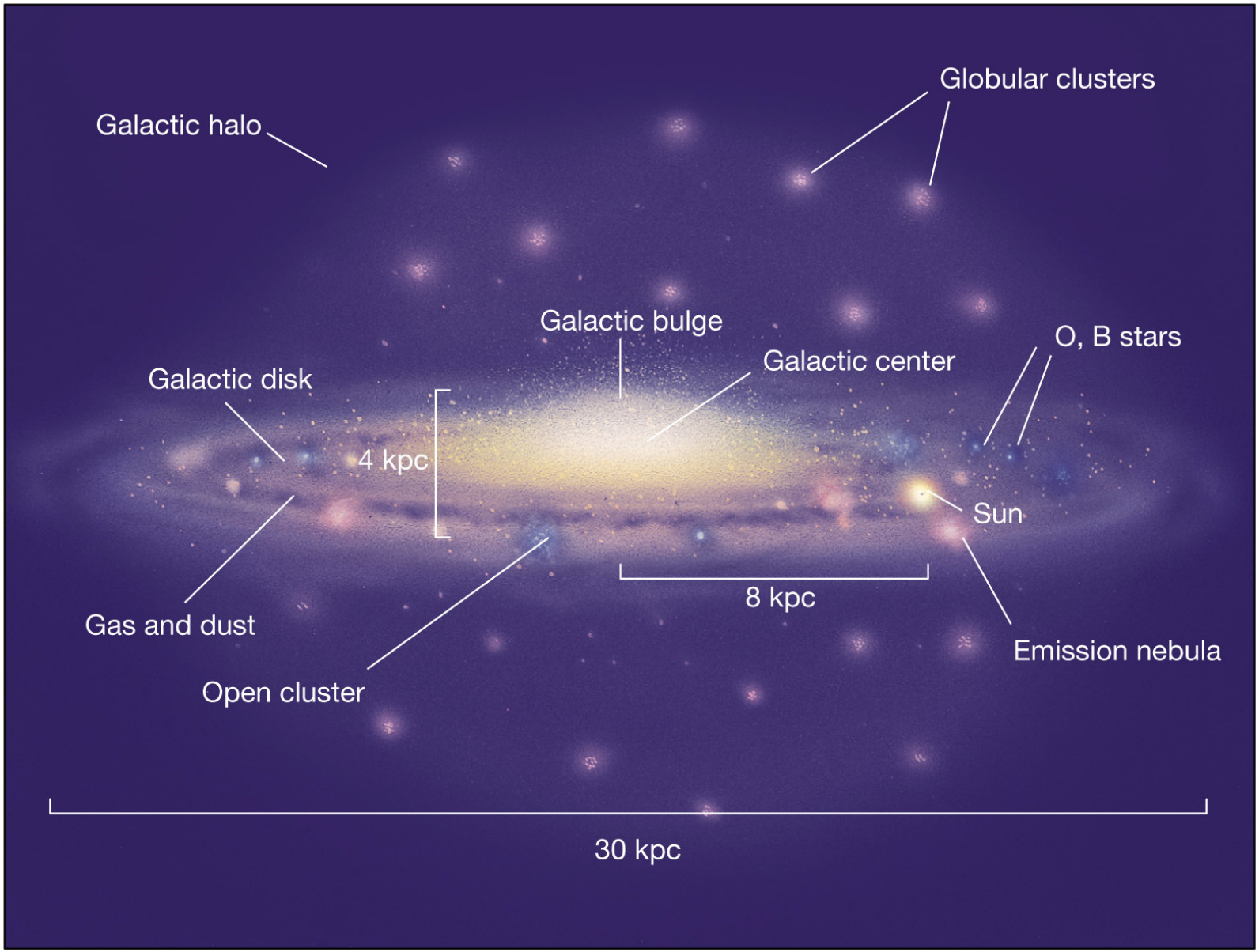
Core Hydrogen Burning Supergiants

– in the

Early Globular Clusters

Globular Clusters & Abundance Anomalies



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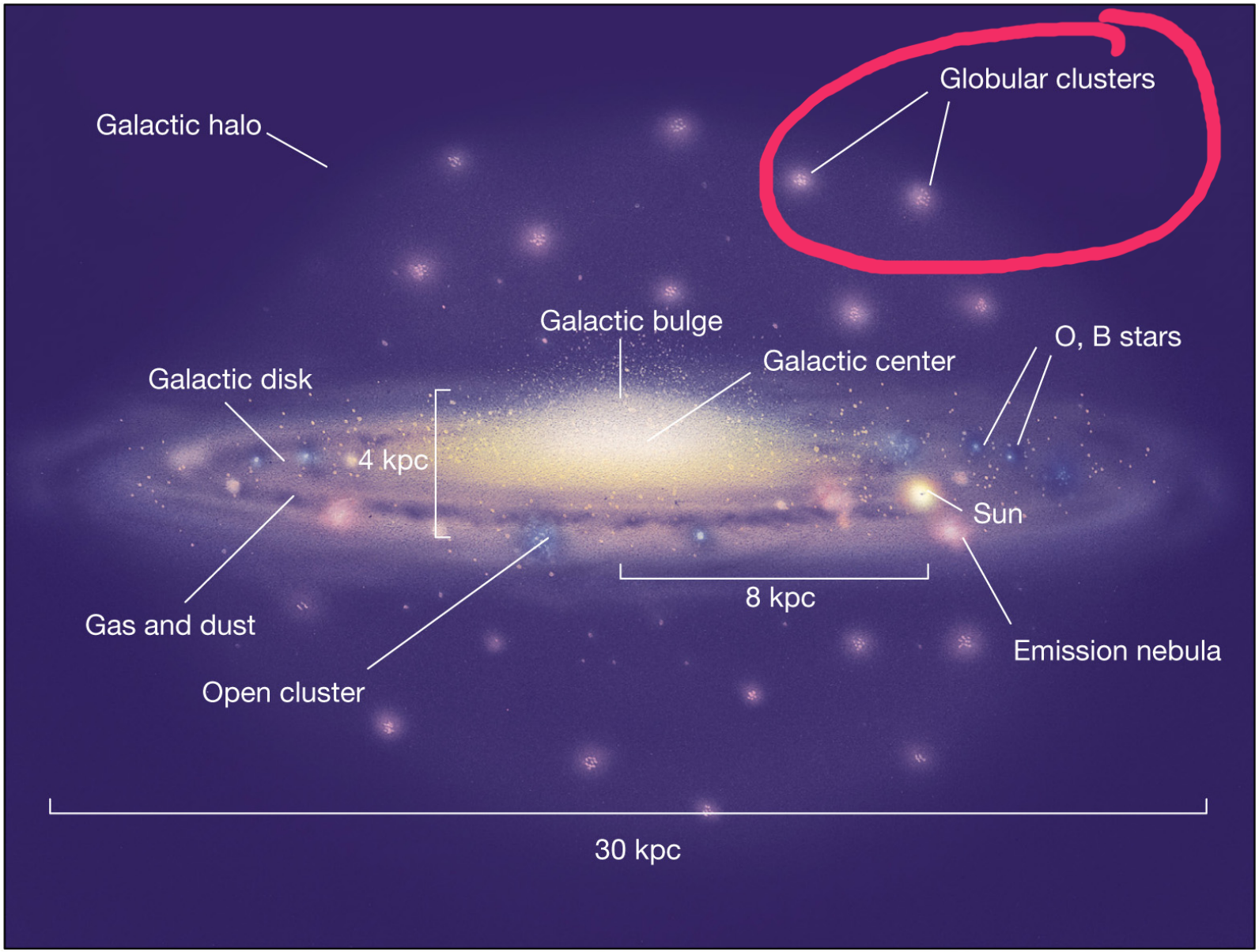

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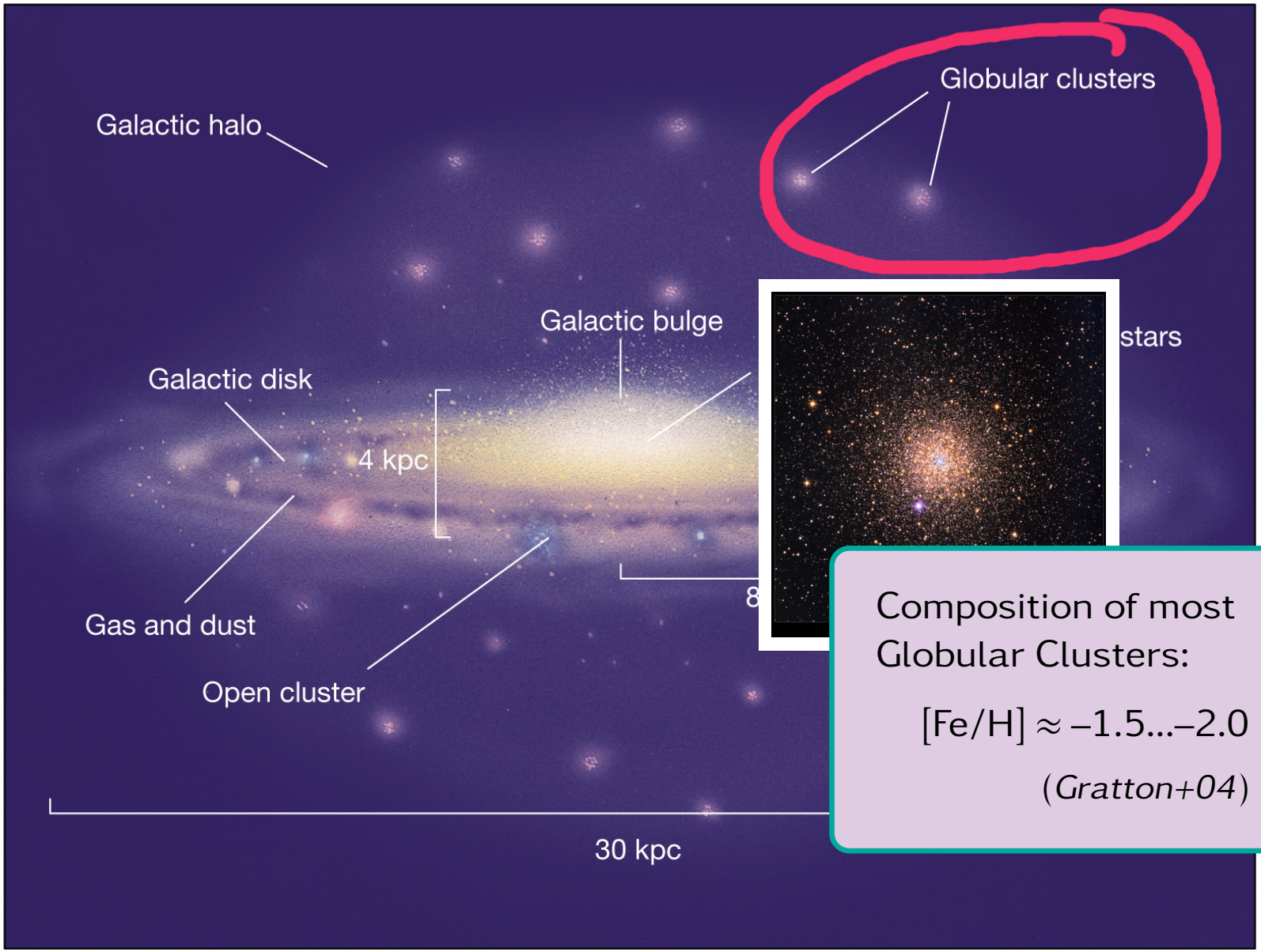
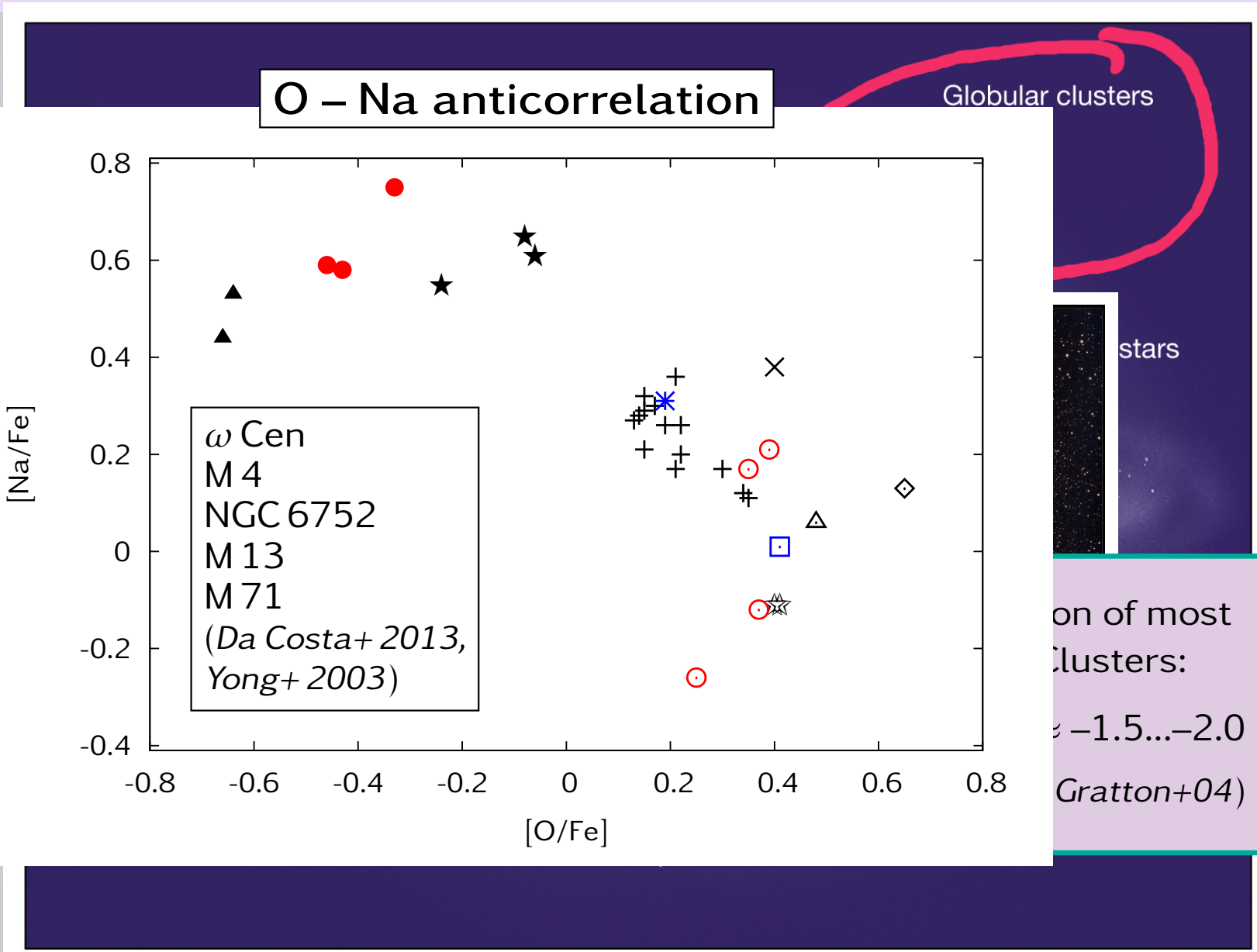


Composition of most Globular Clusters:

$[Fe/H] \approx -1.5 \ldots -2.0$

(*Gratton+04*)

Globular Clusters & Abundance Anomalies



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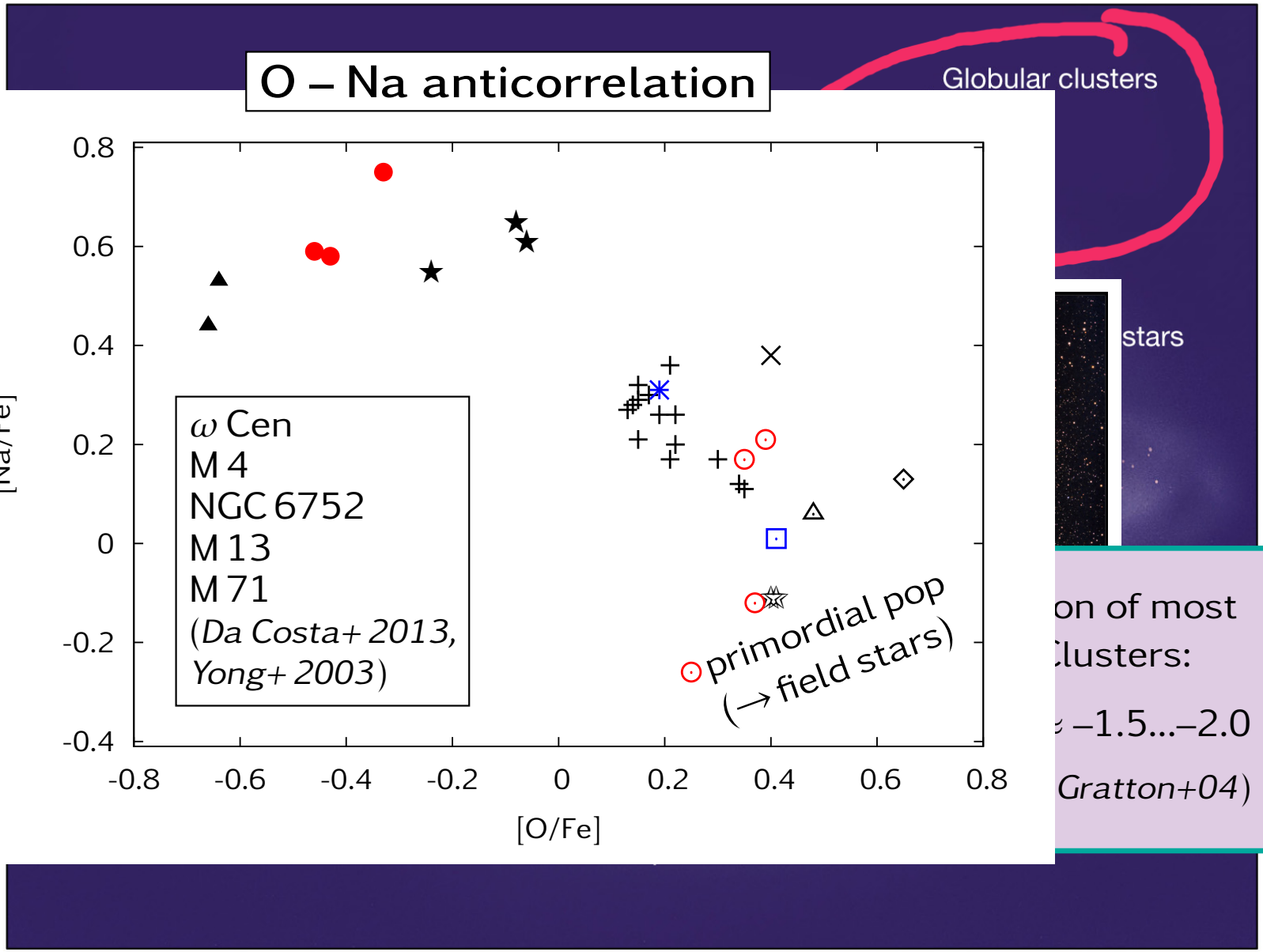

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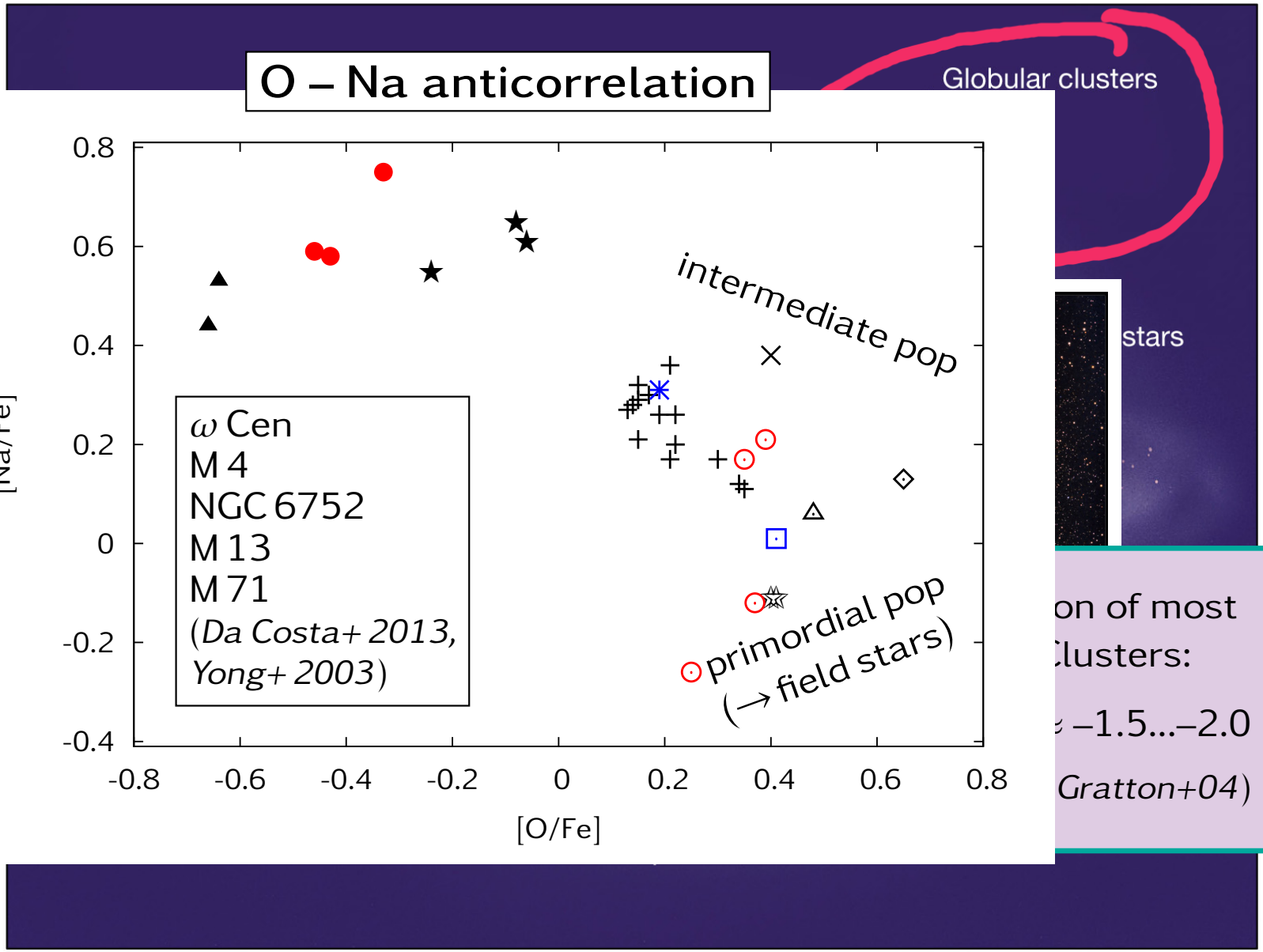

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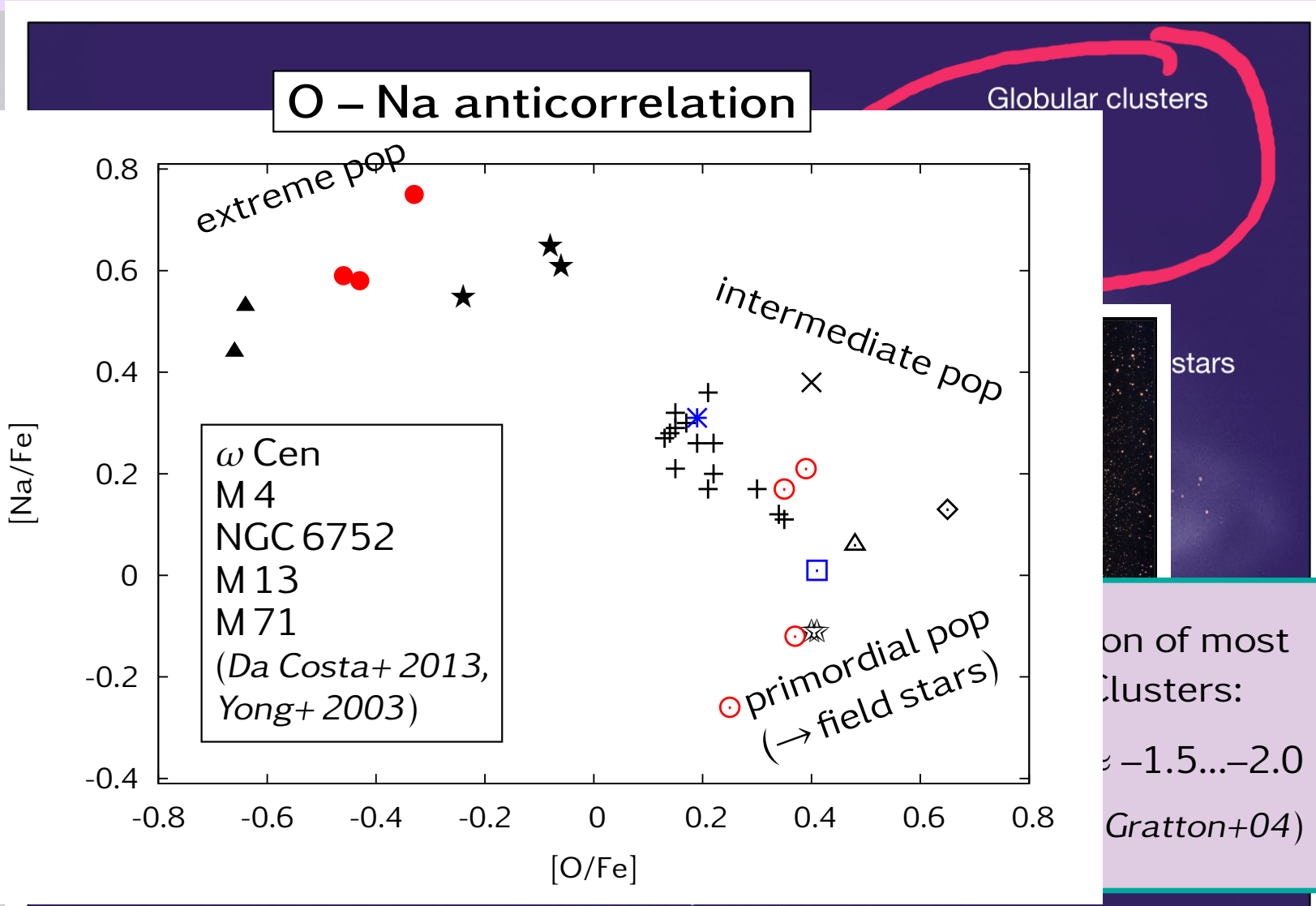

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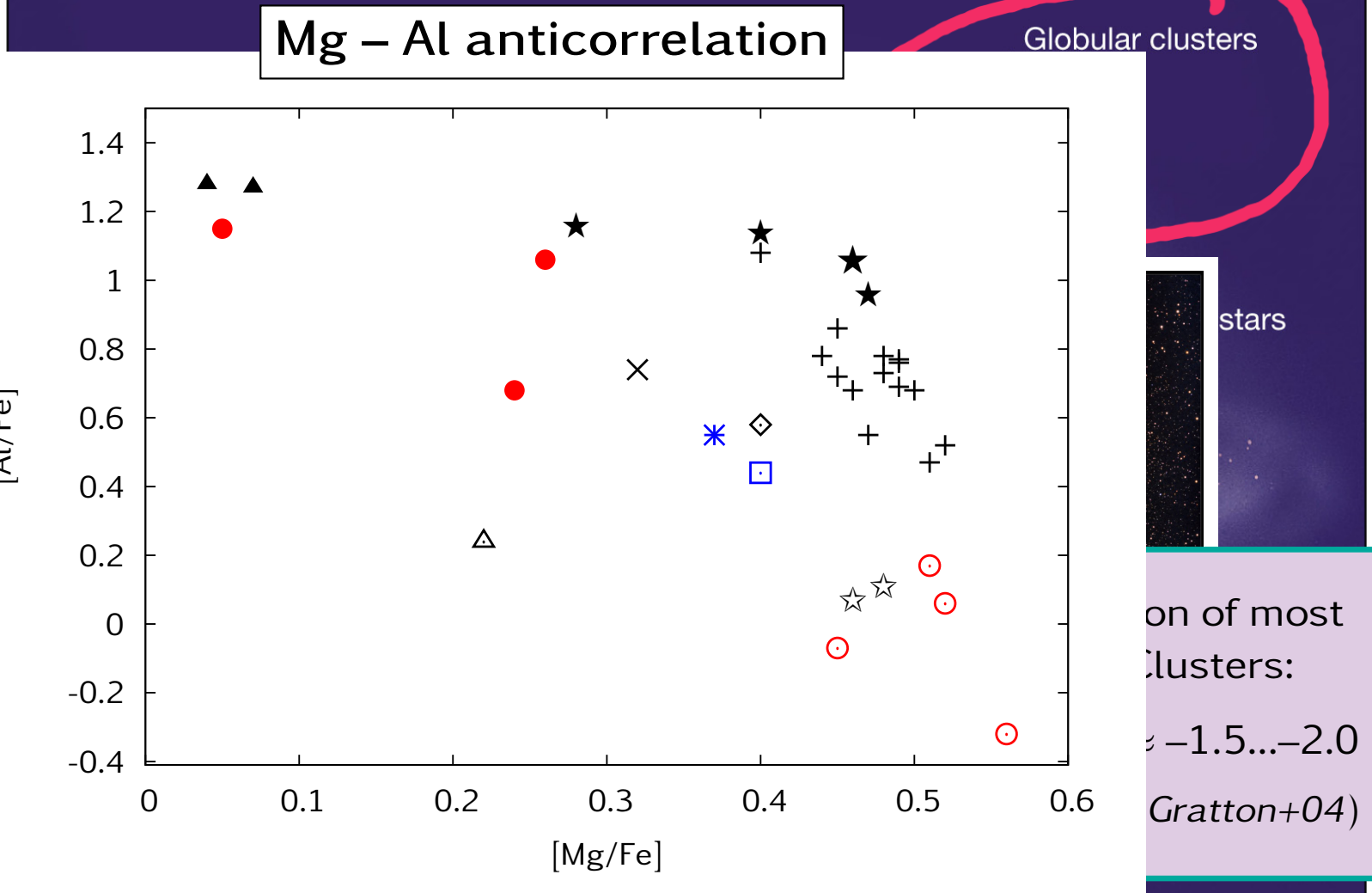

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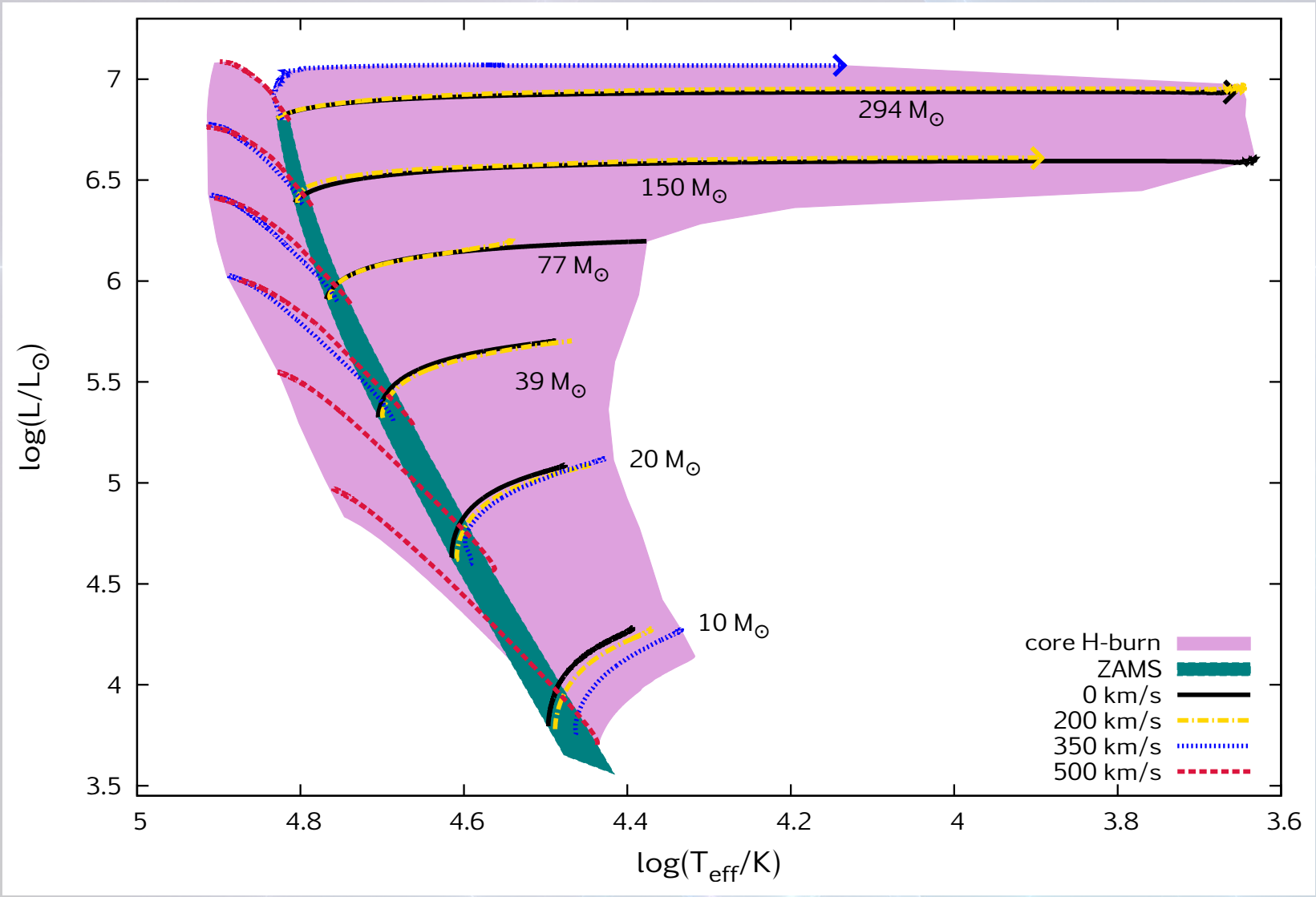
→ New scenario...

Evolution of low metallicity massive stars

Szécsi et al. 2015 (A&A)



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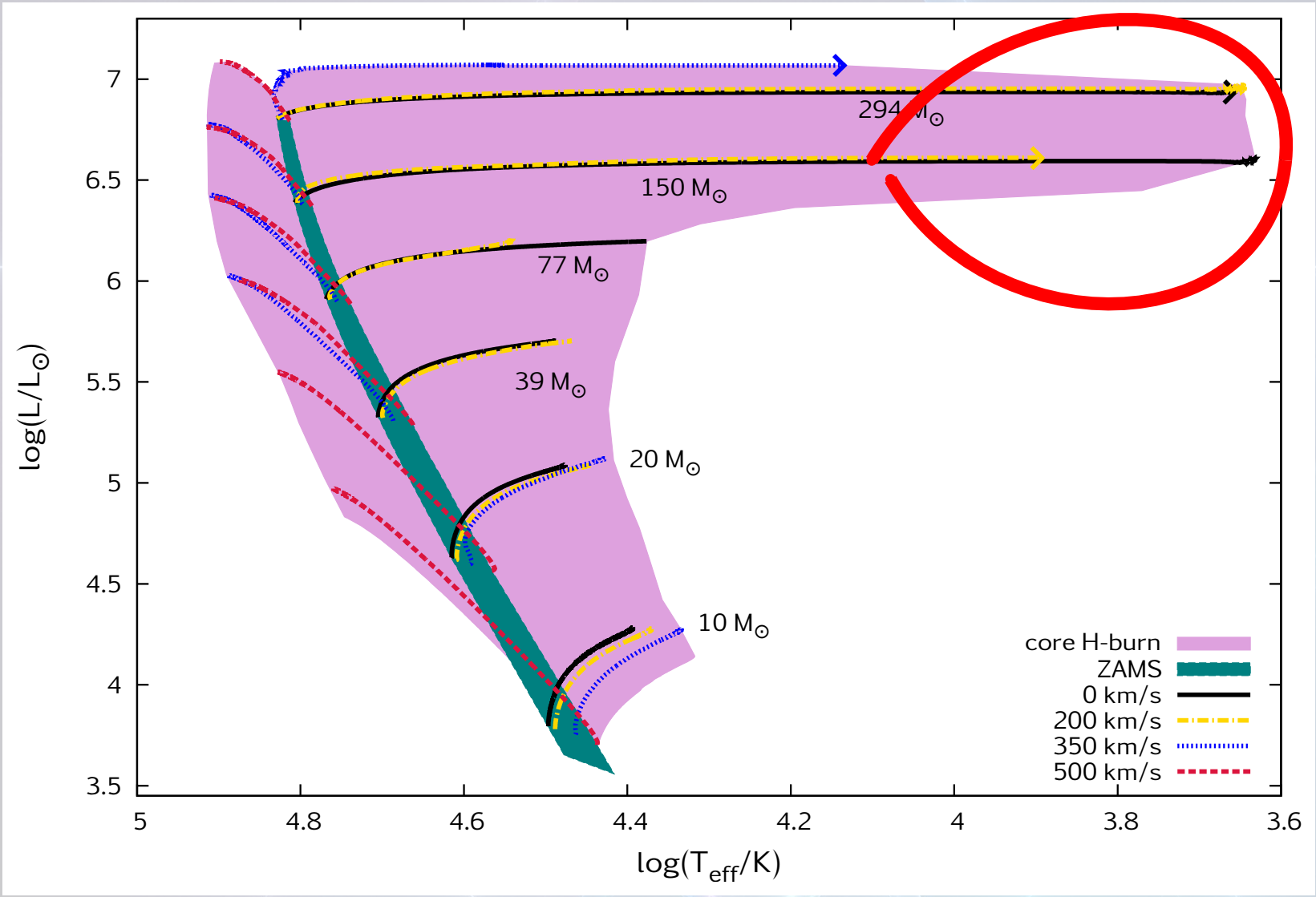

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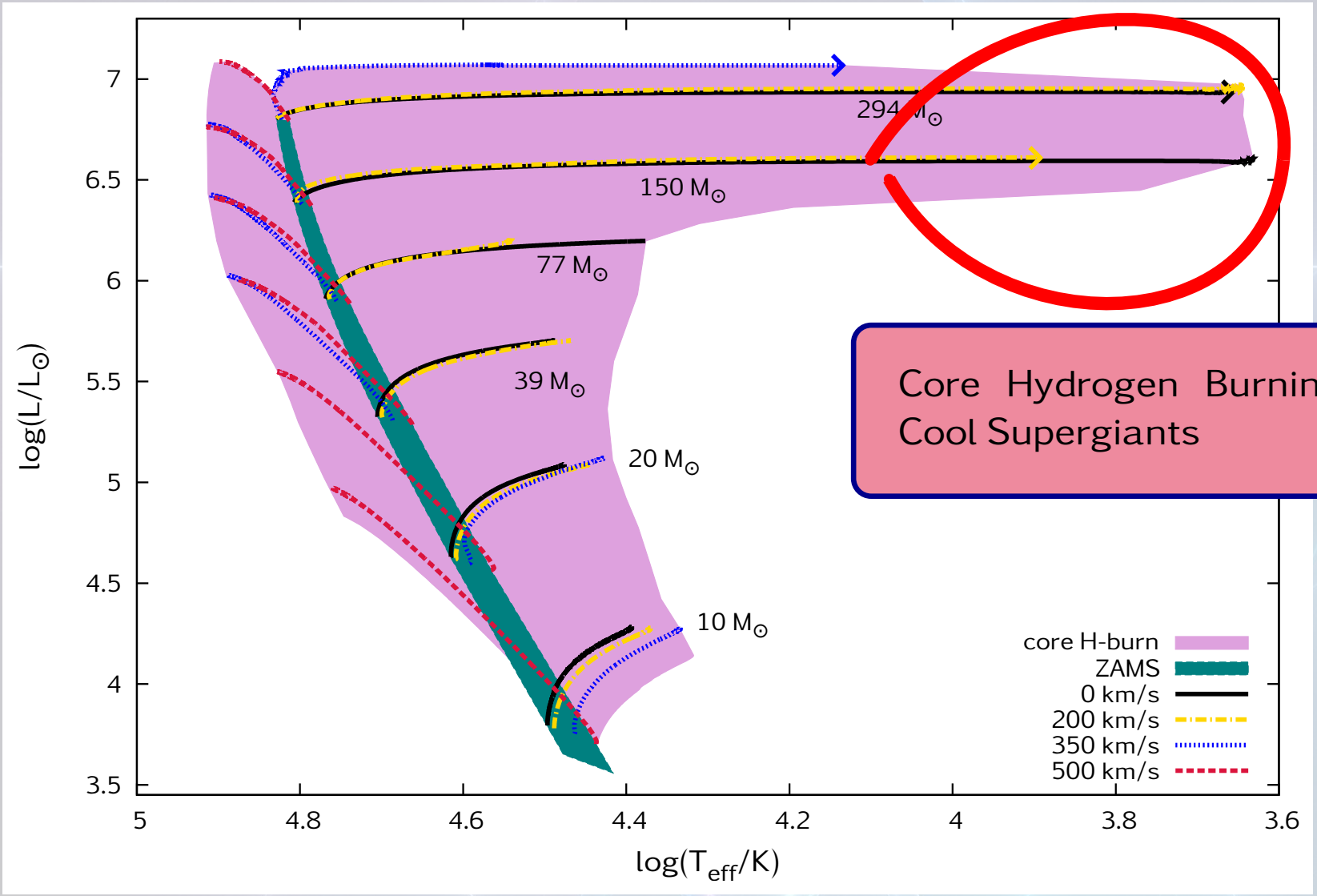

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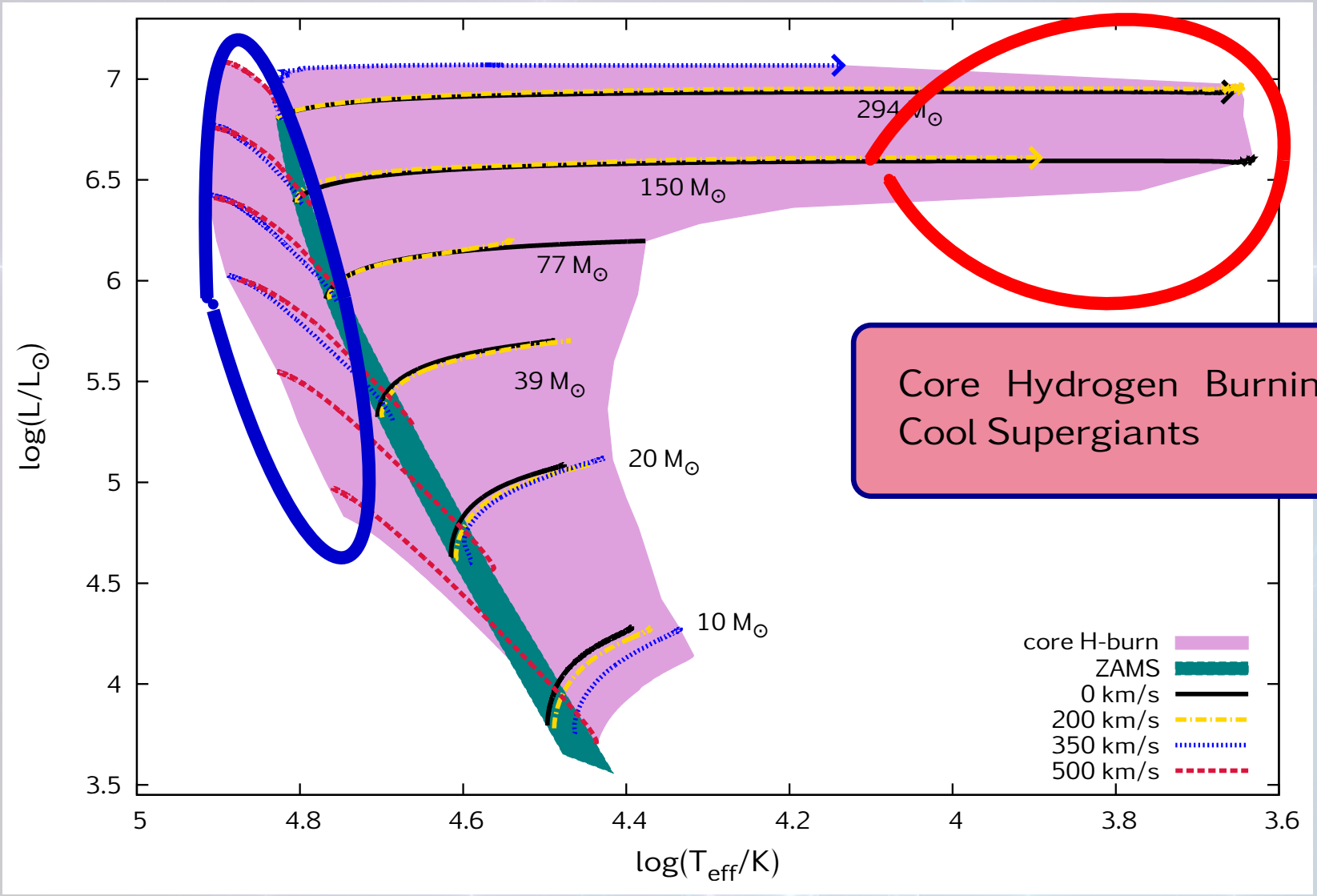

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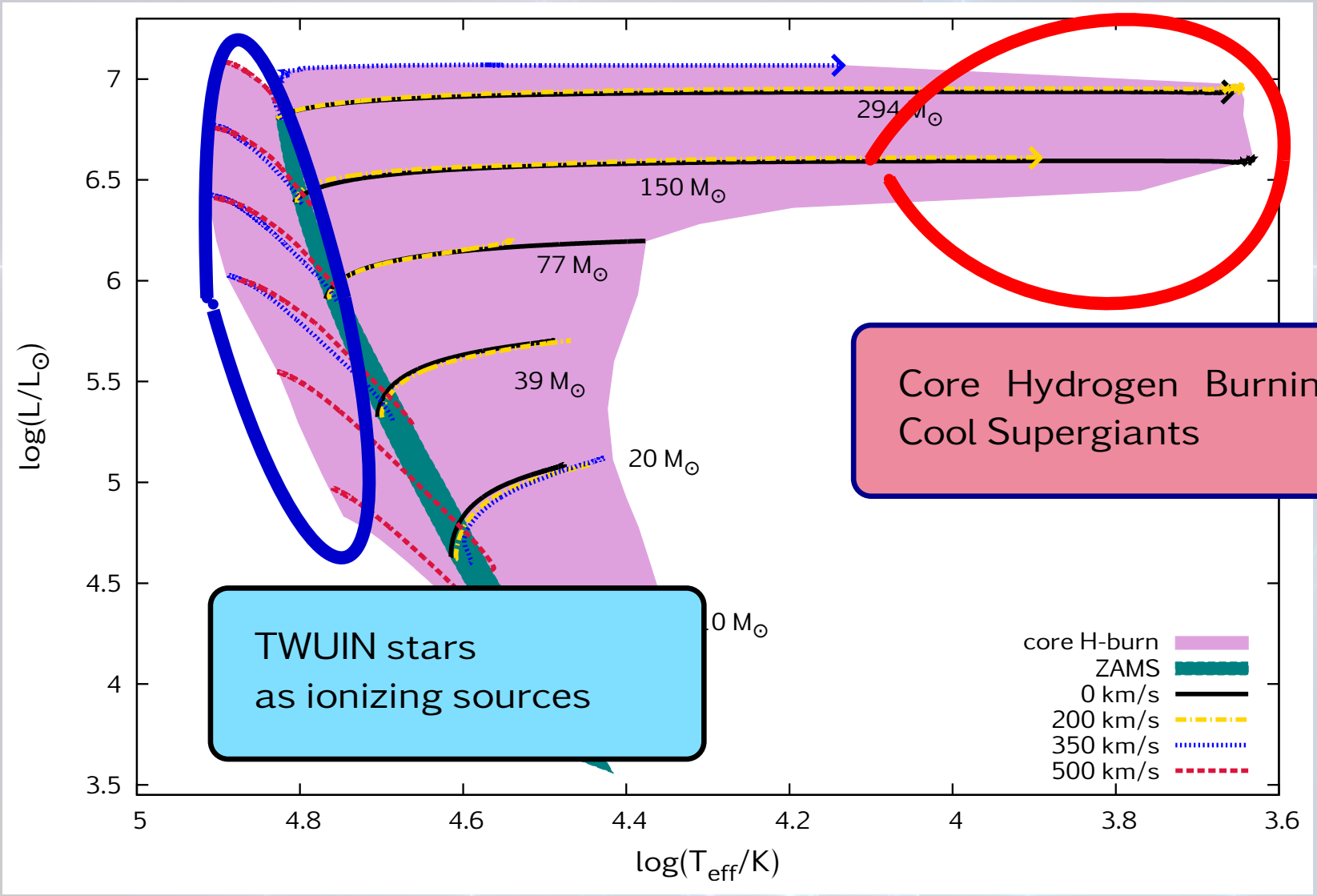

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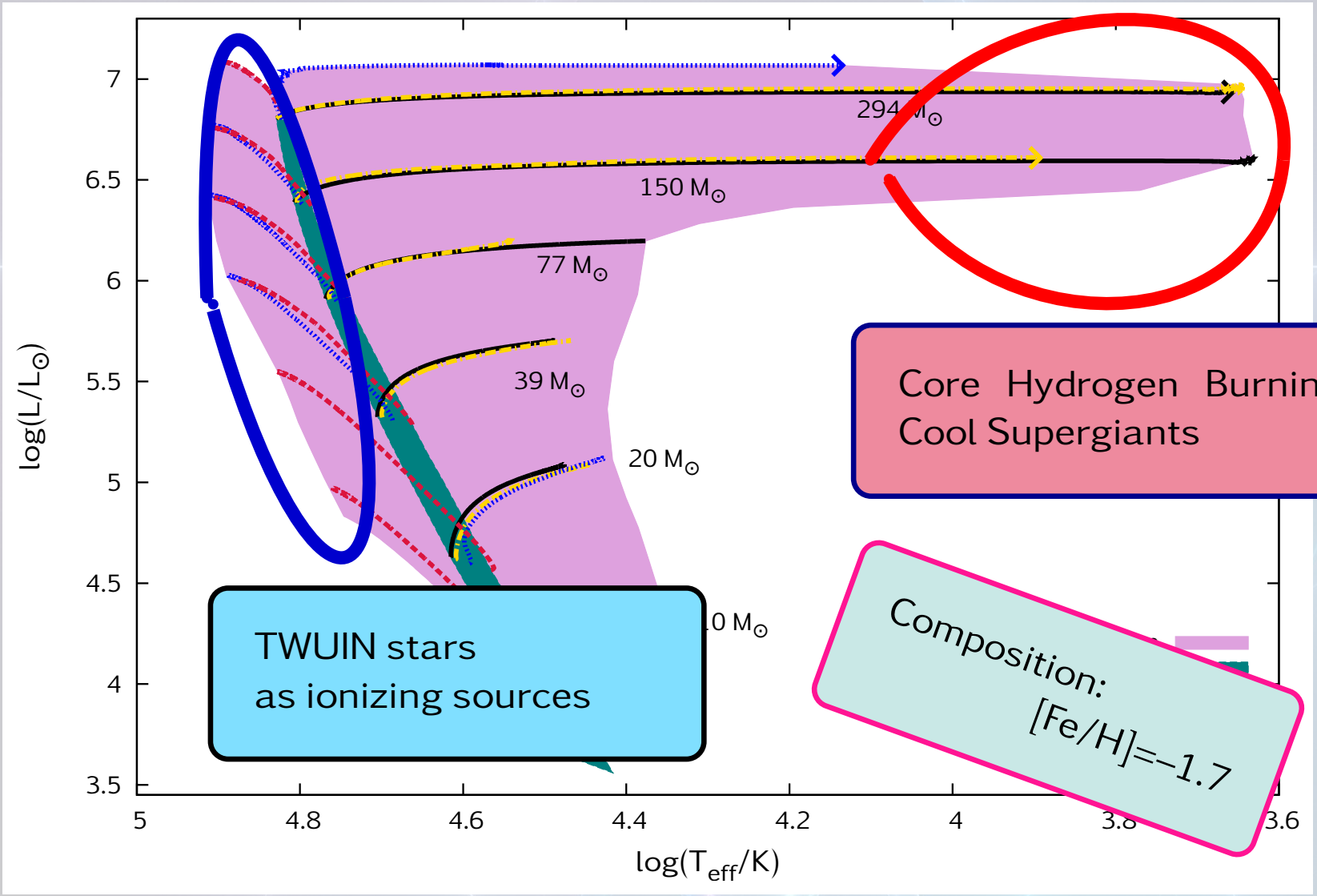

New scenario:

Starforming Supergiant Shells

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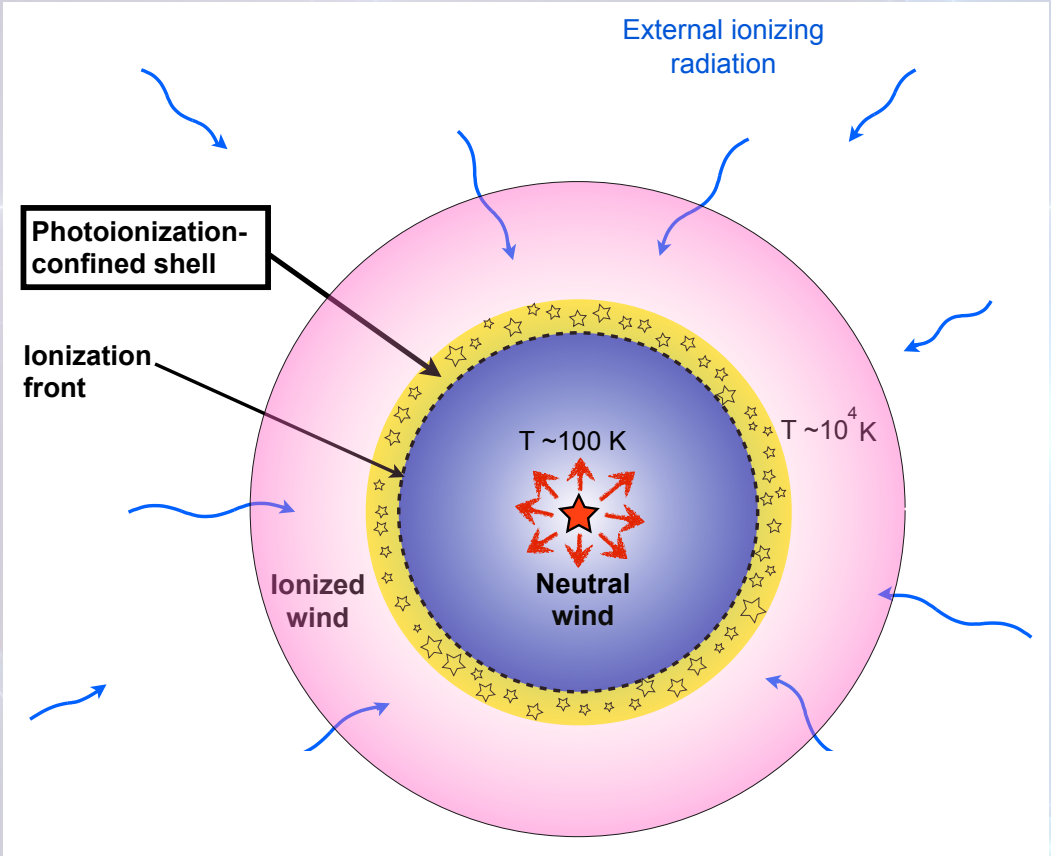
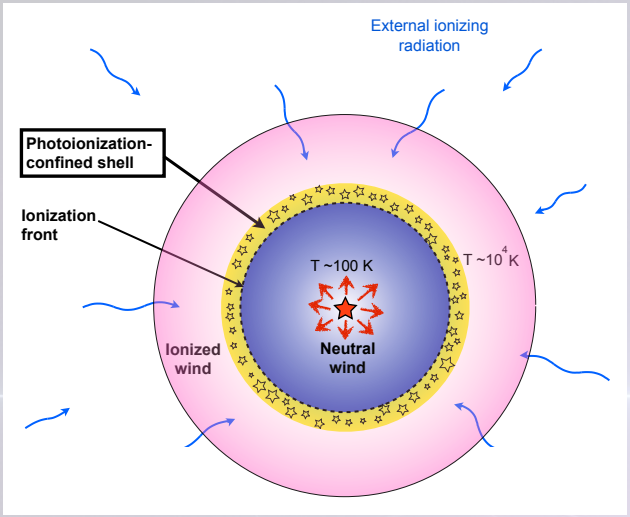


PICO shell: *Mackey+ 2014 (Nature)*

Simulating the PICO shell



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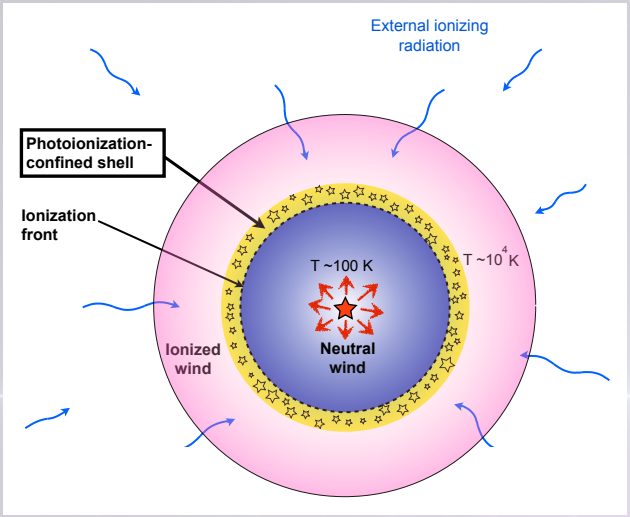

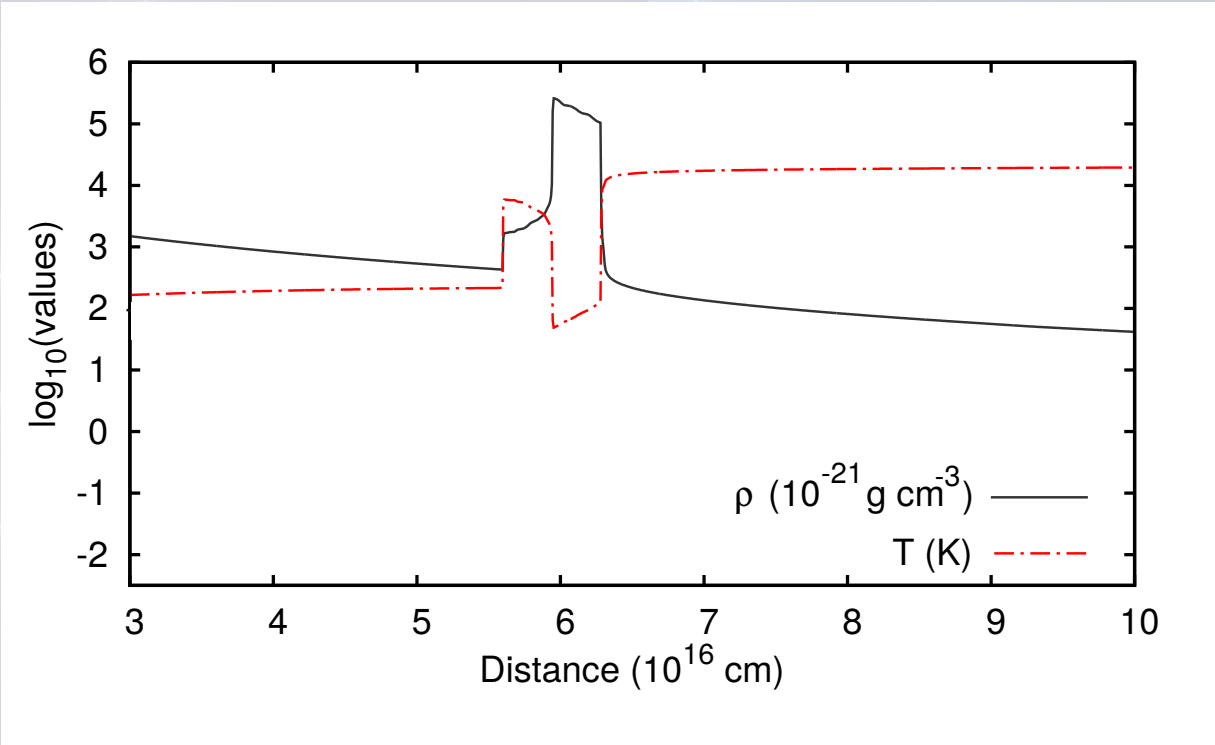

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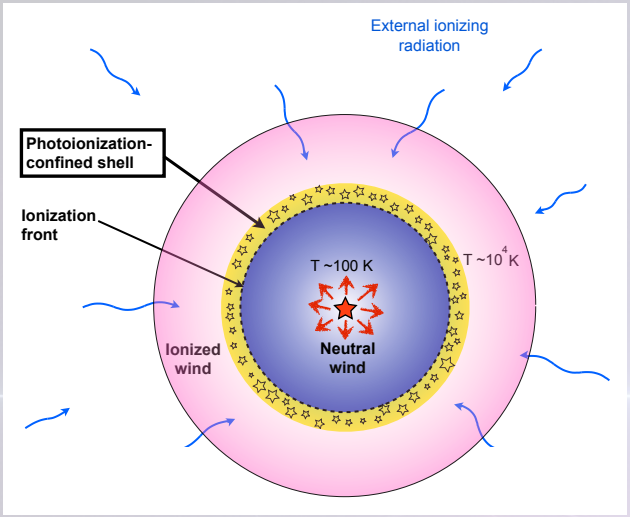

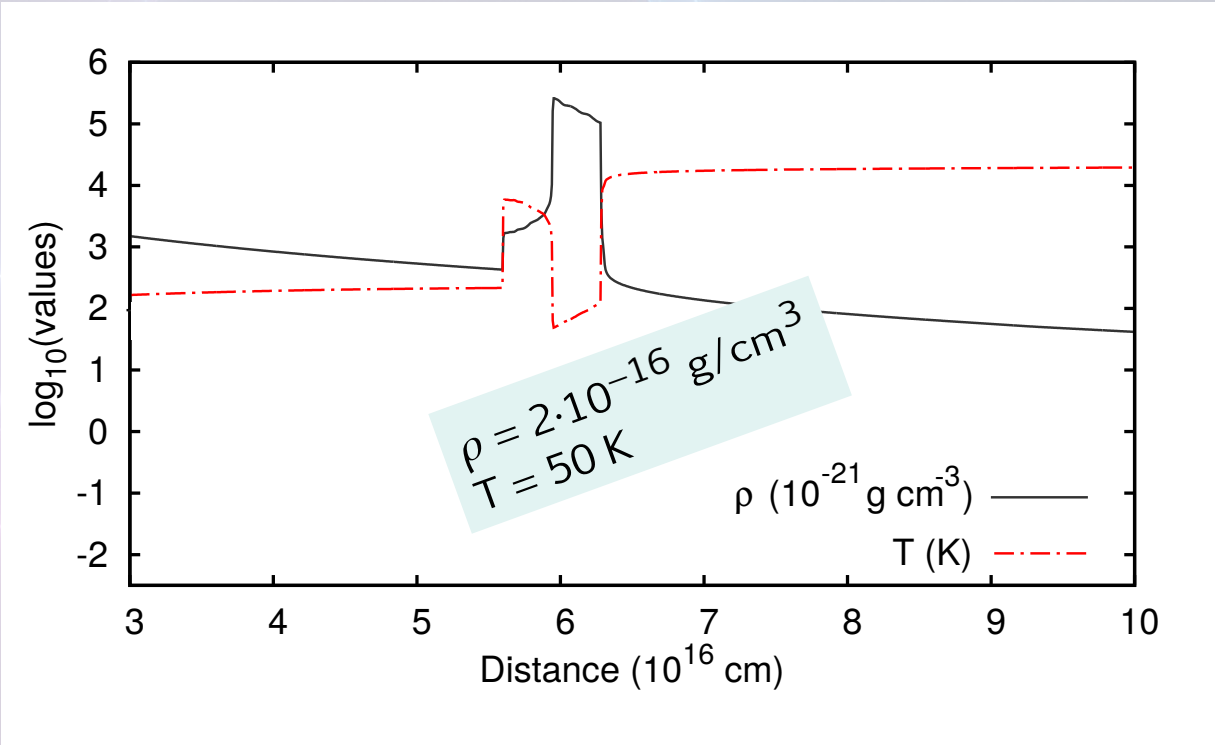

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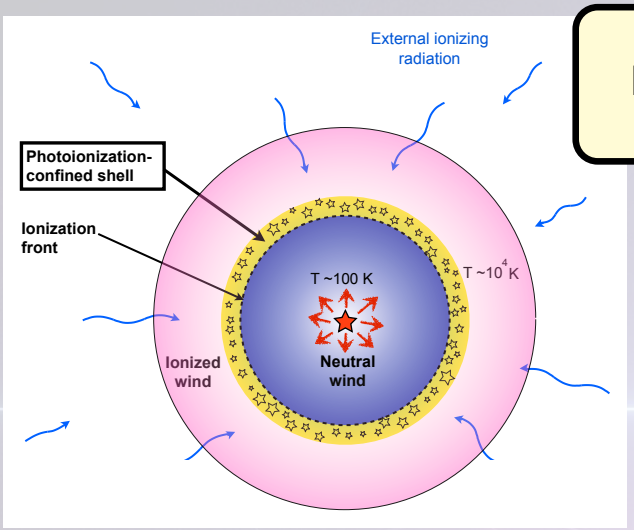
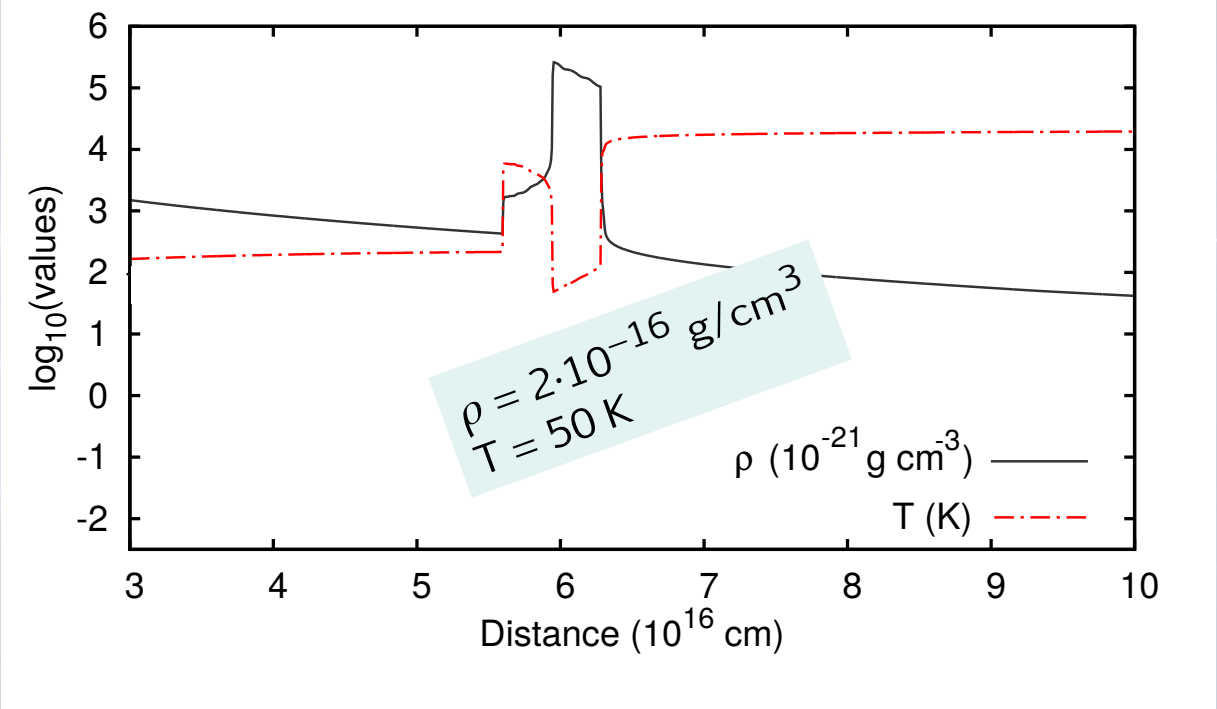


Mass of the photoionization-confined (PICO) shell: ~14 $M_\odot$



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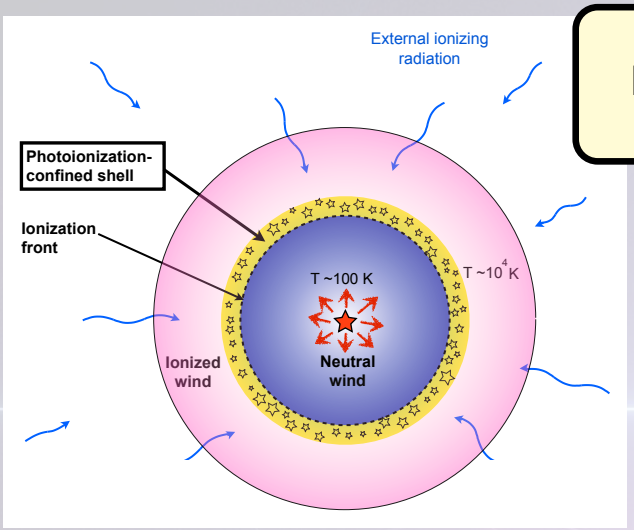

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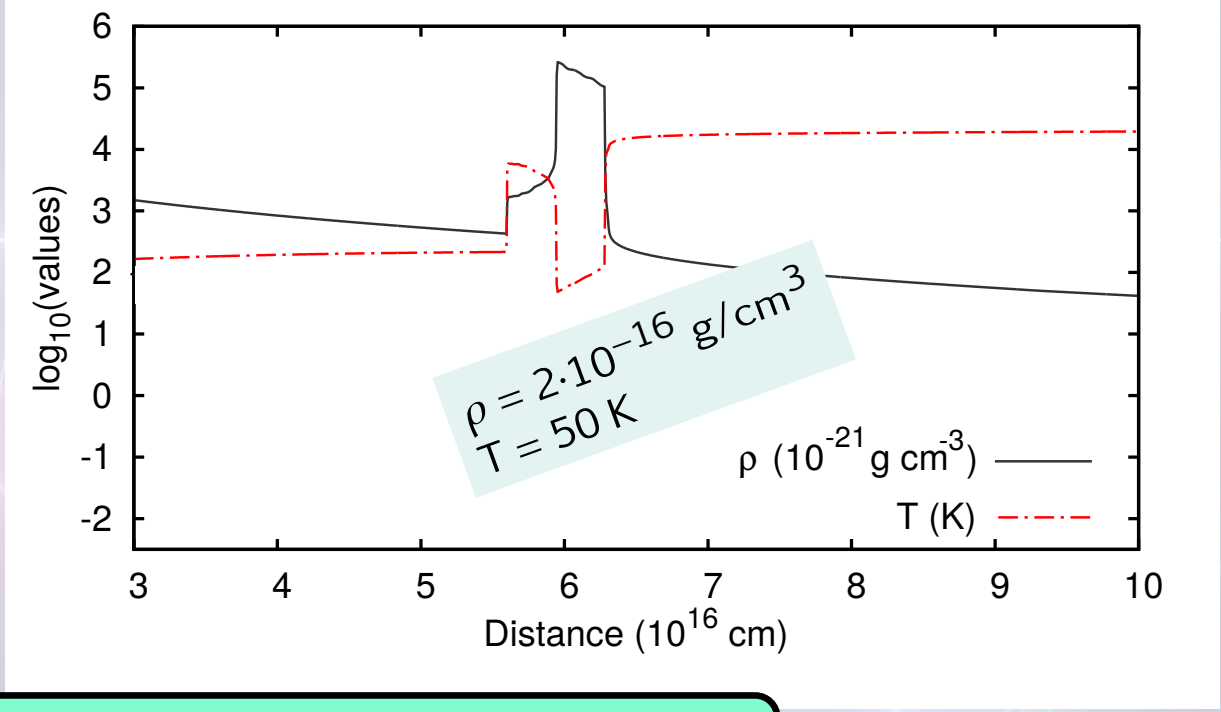

Lifetime of the shell: ~10^5 yr
>>
Growth timescale of grav. unstable perturbations: ~10^4 yr

Compared to observations:

O – Na anticorrelation

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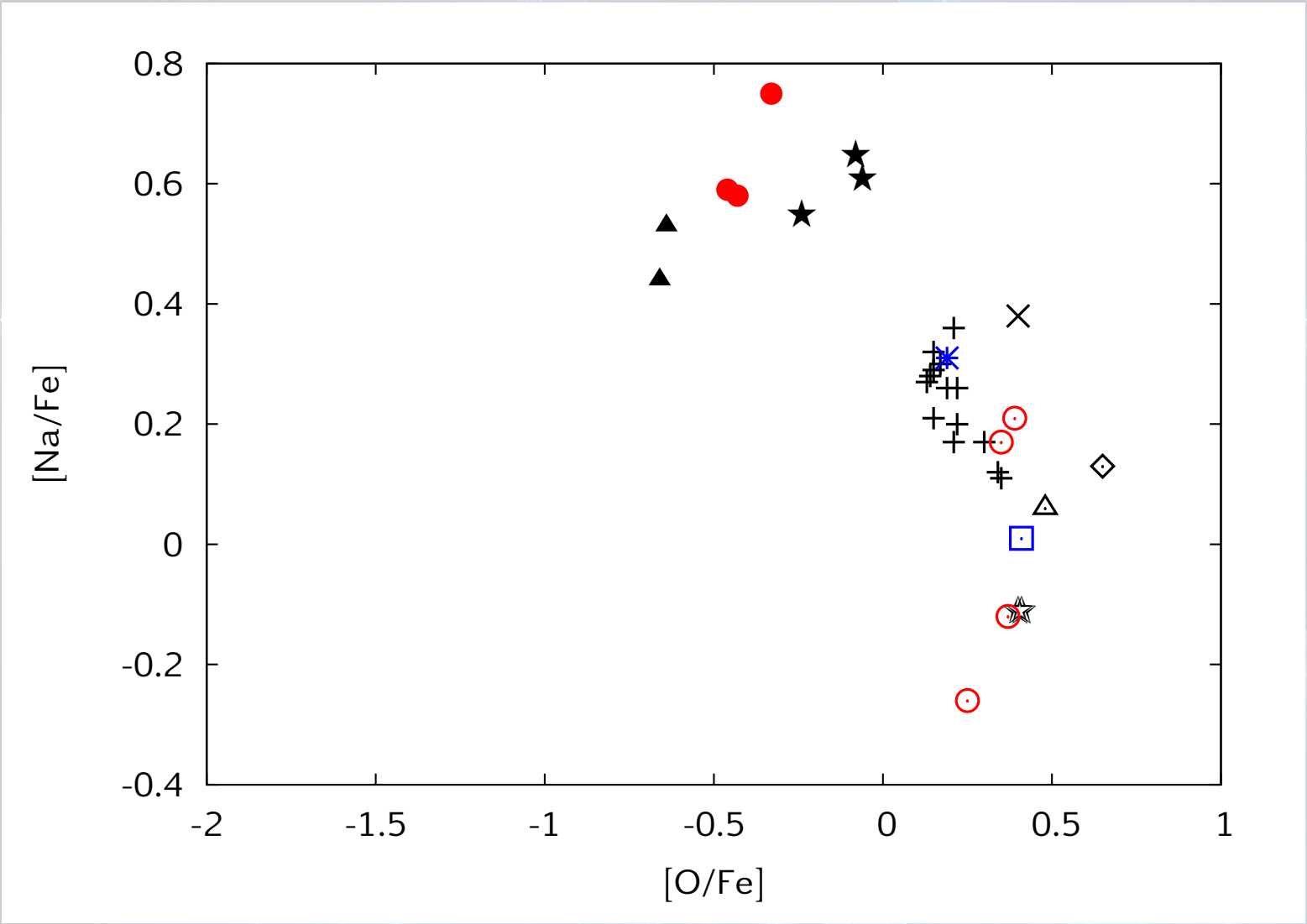

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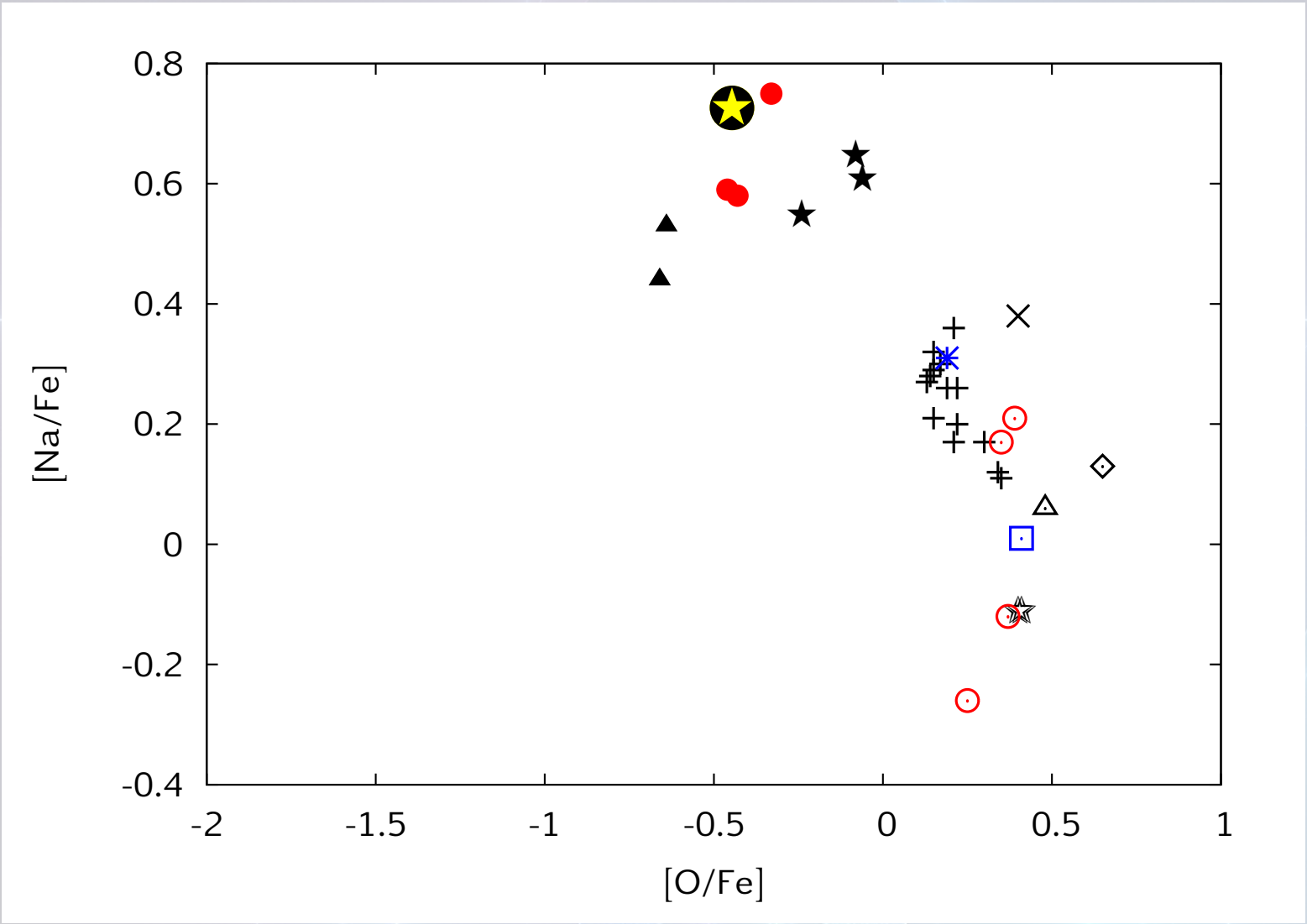

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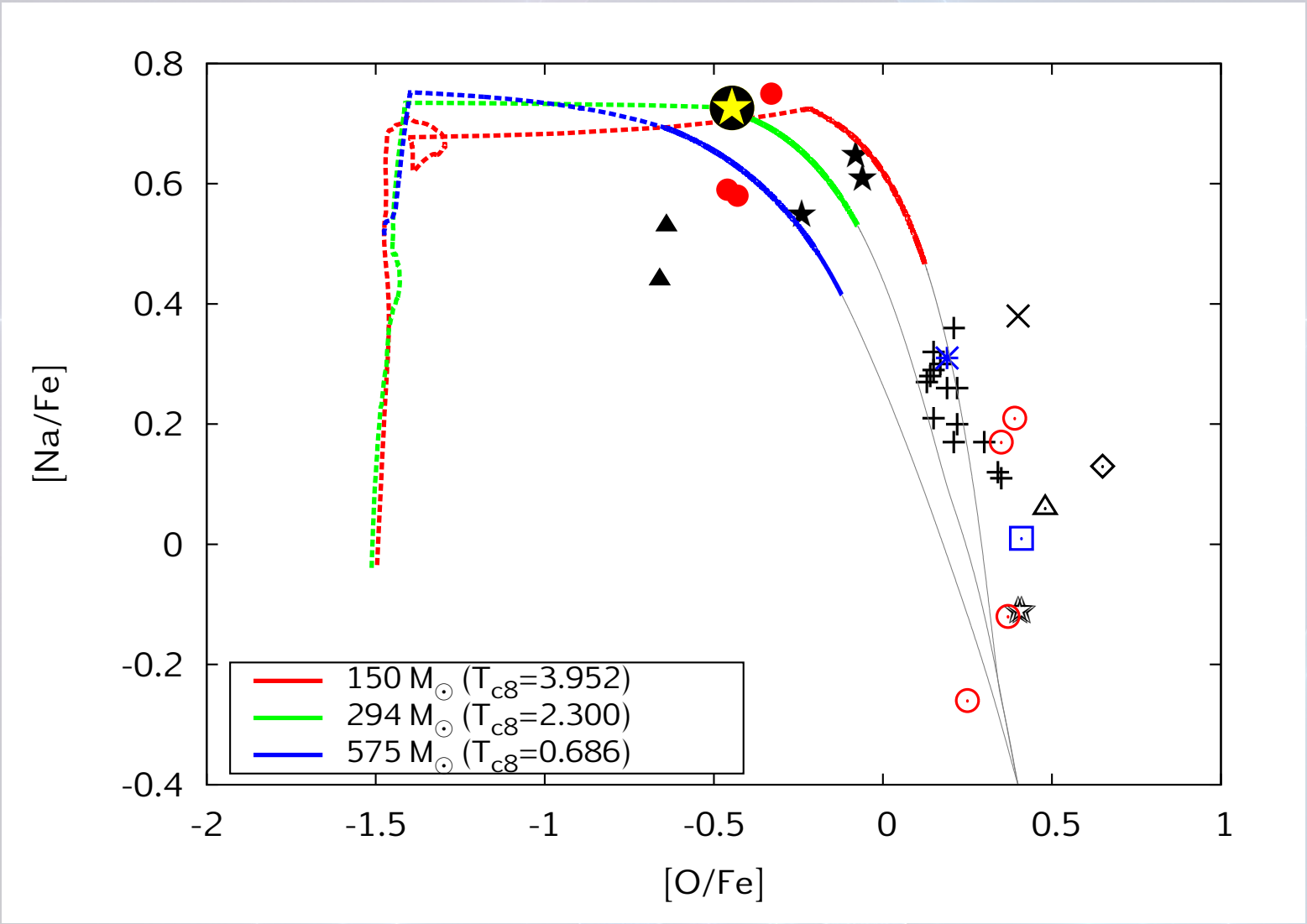

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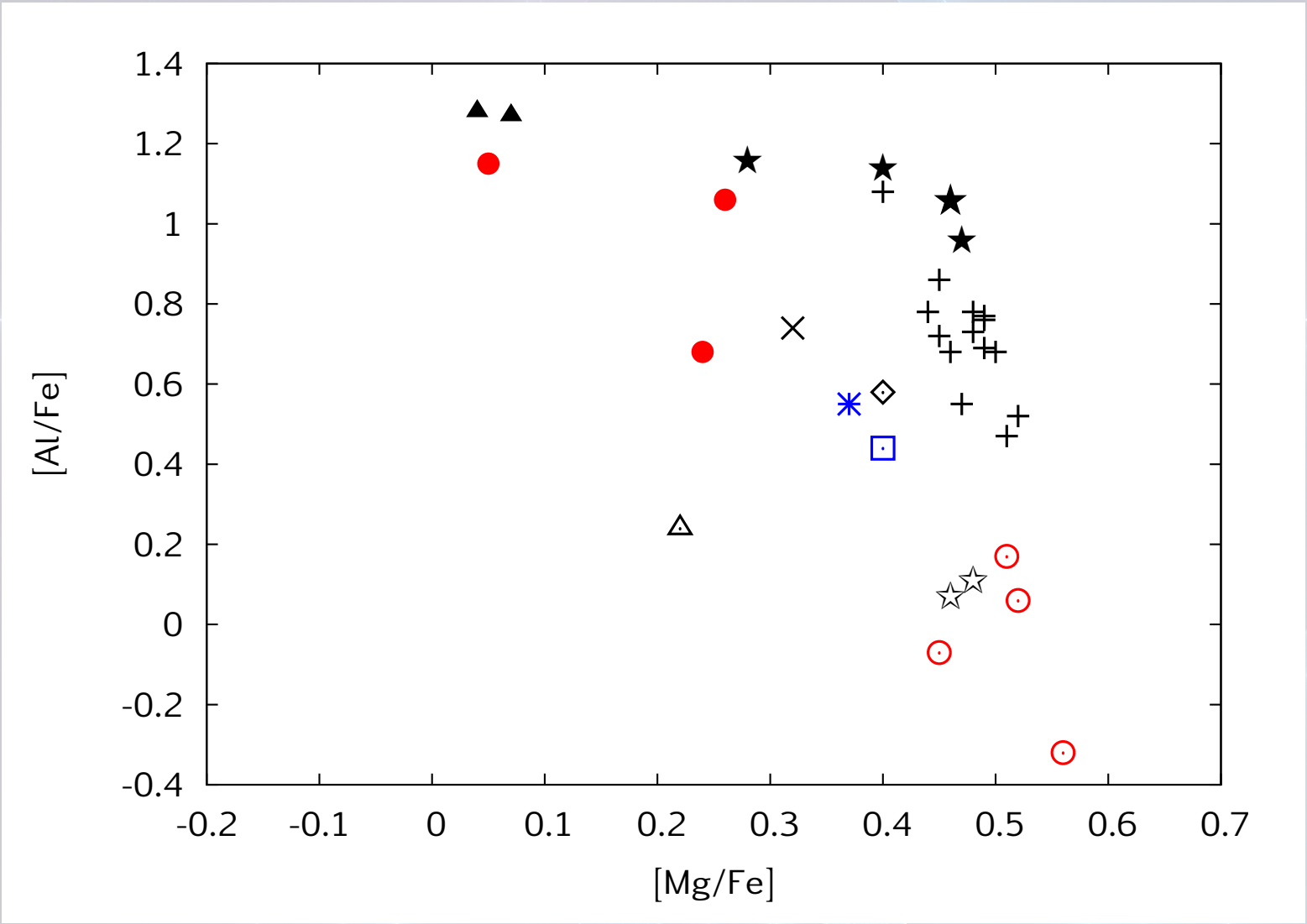

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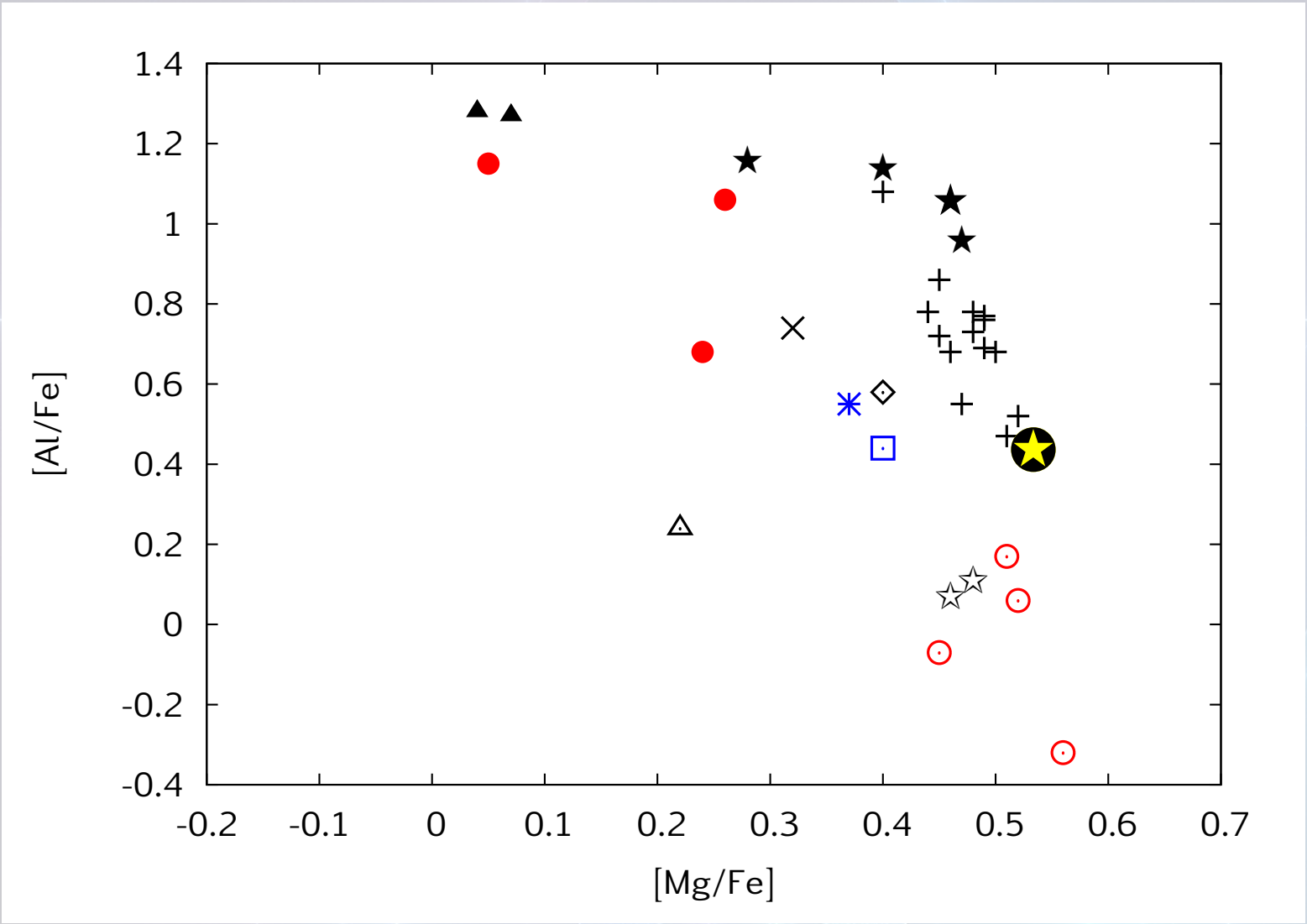

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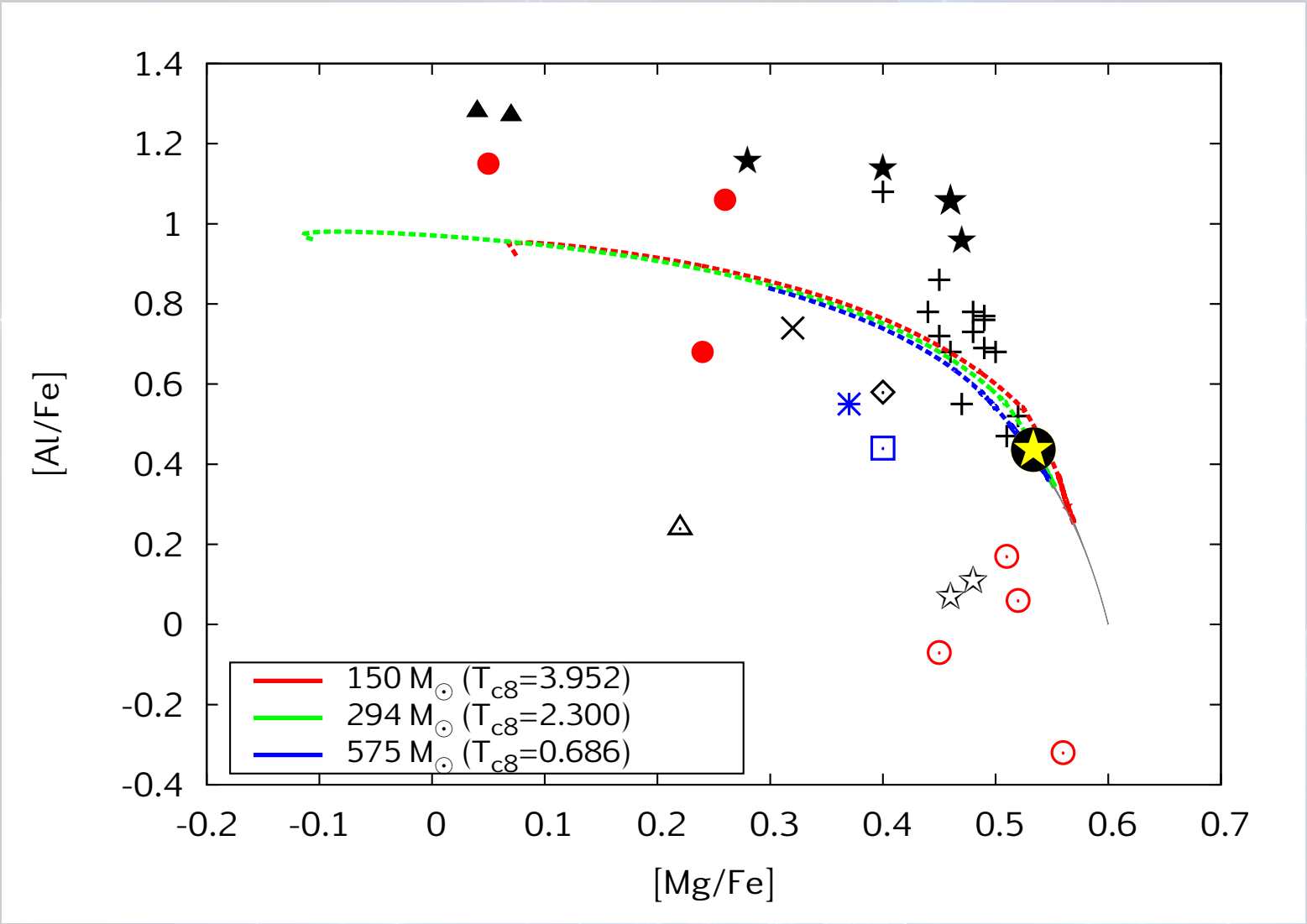

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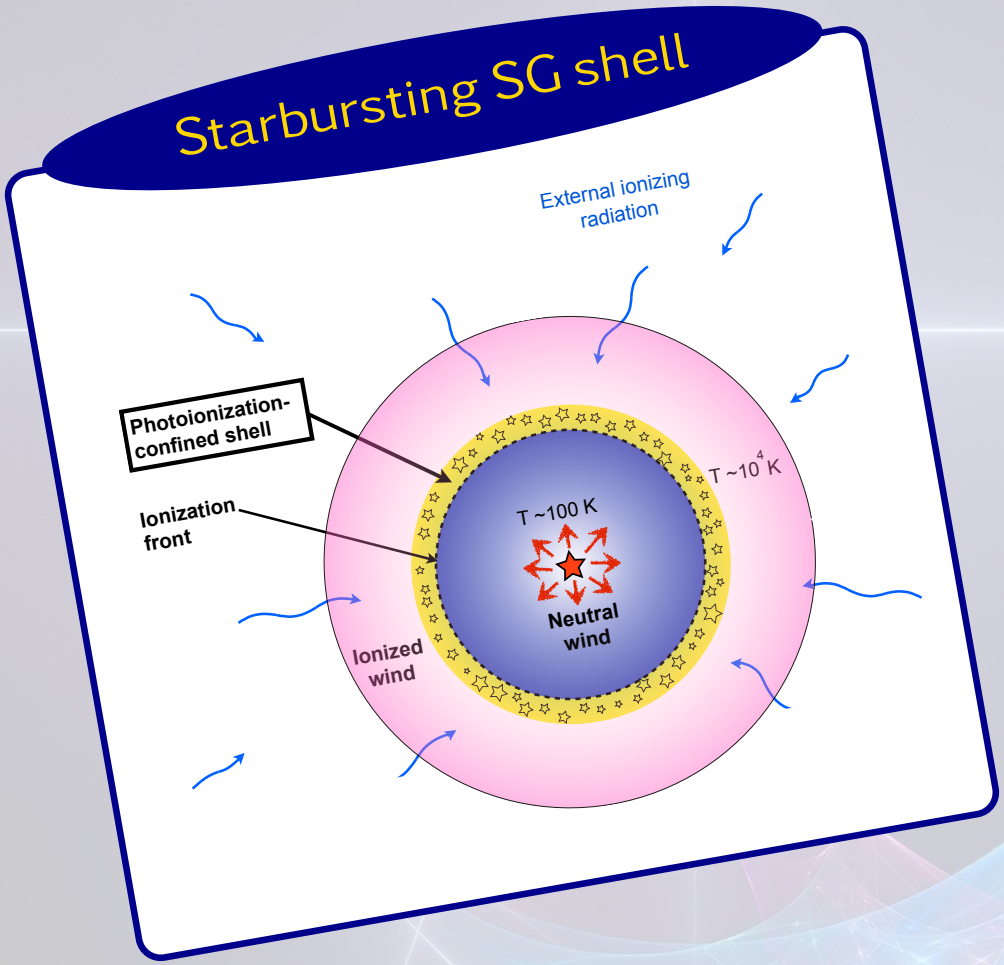
RSGs as polluters

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

Core-H-burning Supergiants in the Early GCs



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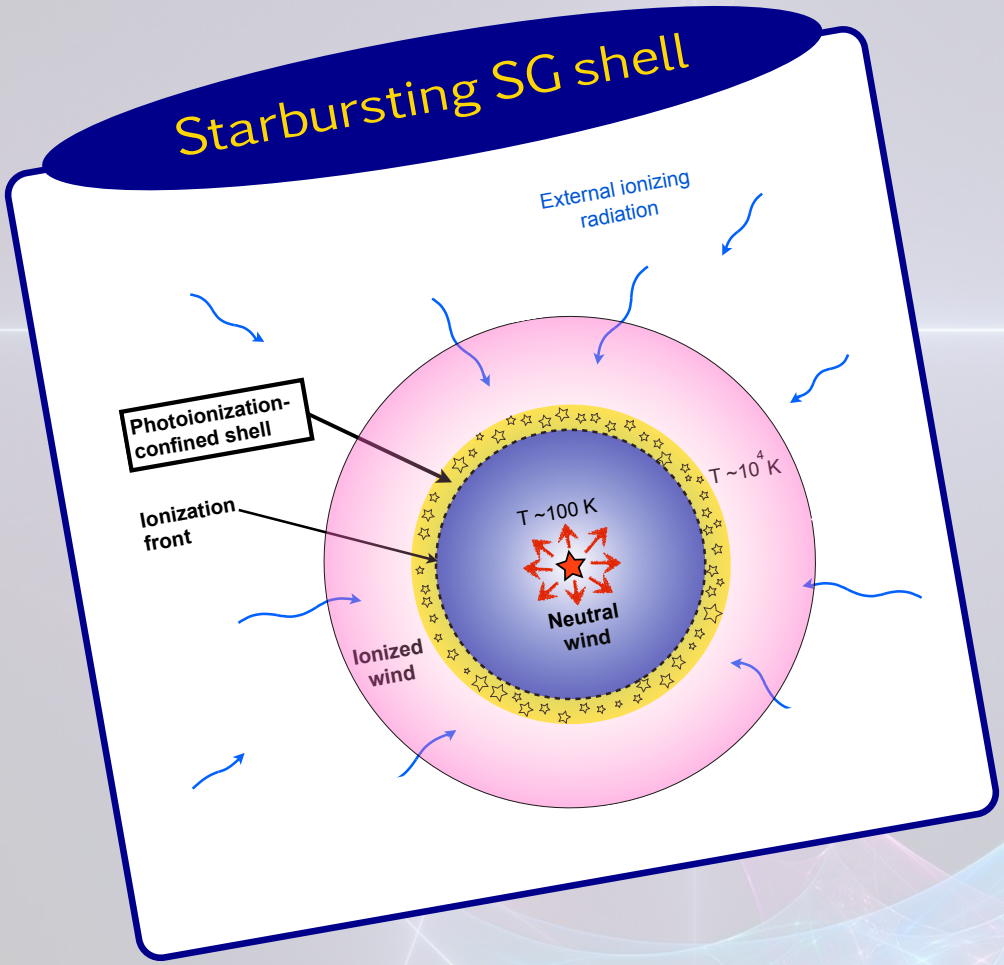

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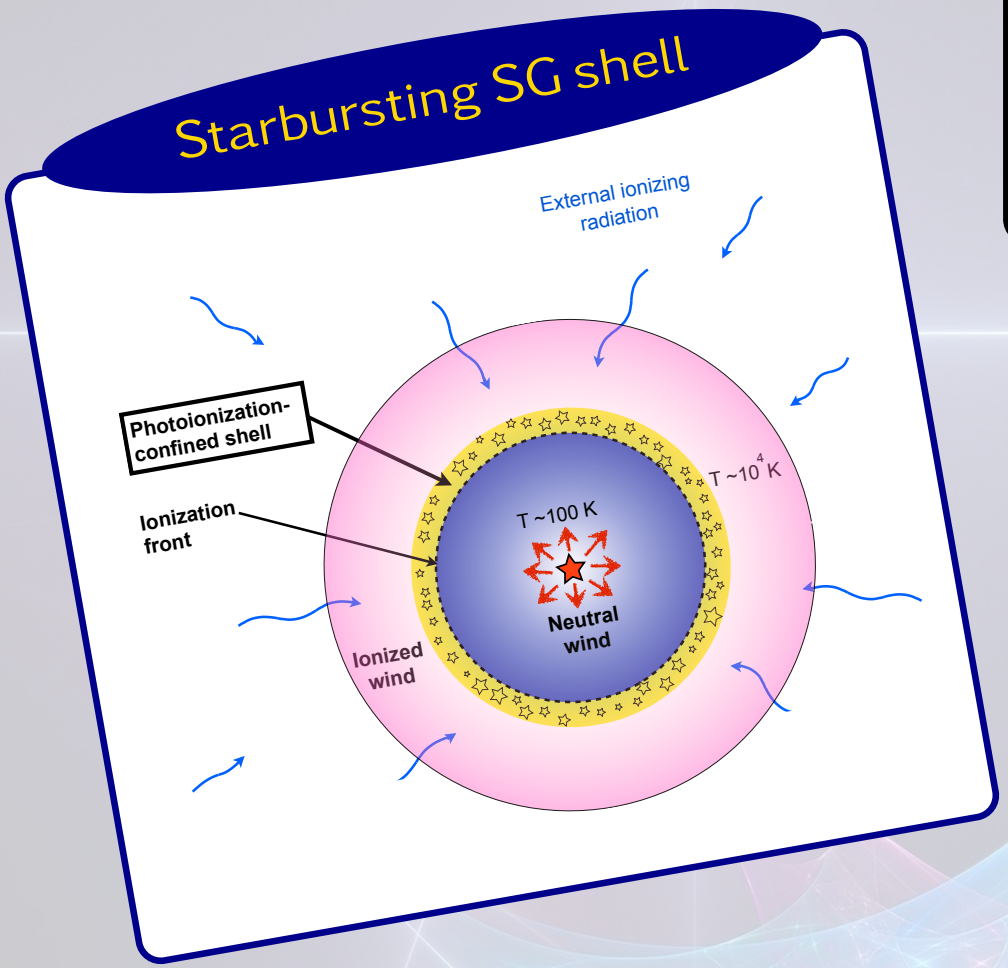

Szécsi et al. 2015
(A&A, vol. 581, A15)

Szécsi & Mackey & Langer 2016
(in preparation)

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Beyond the night-sky: Low-Z Massive Stars

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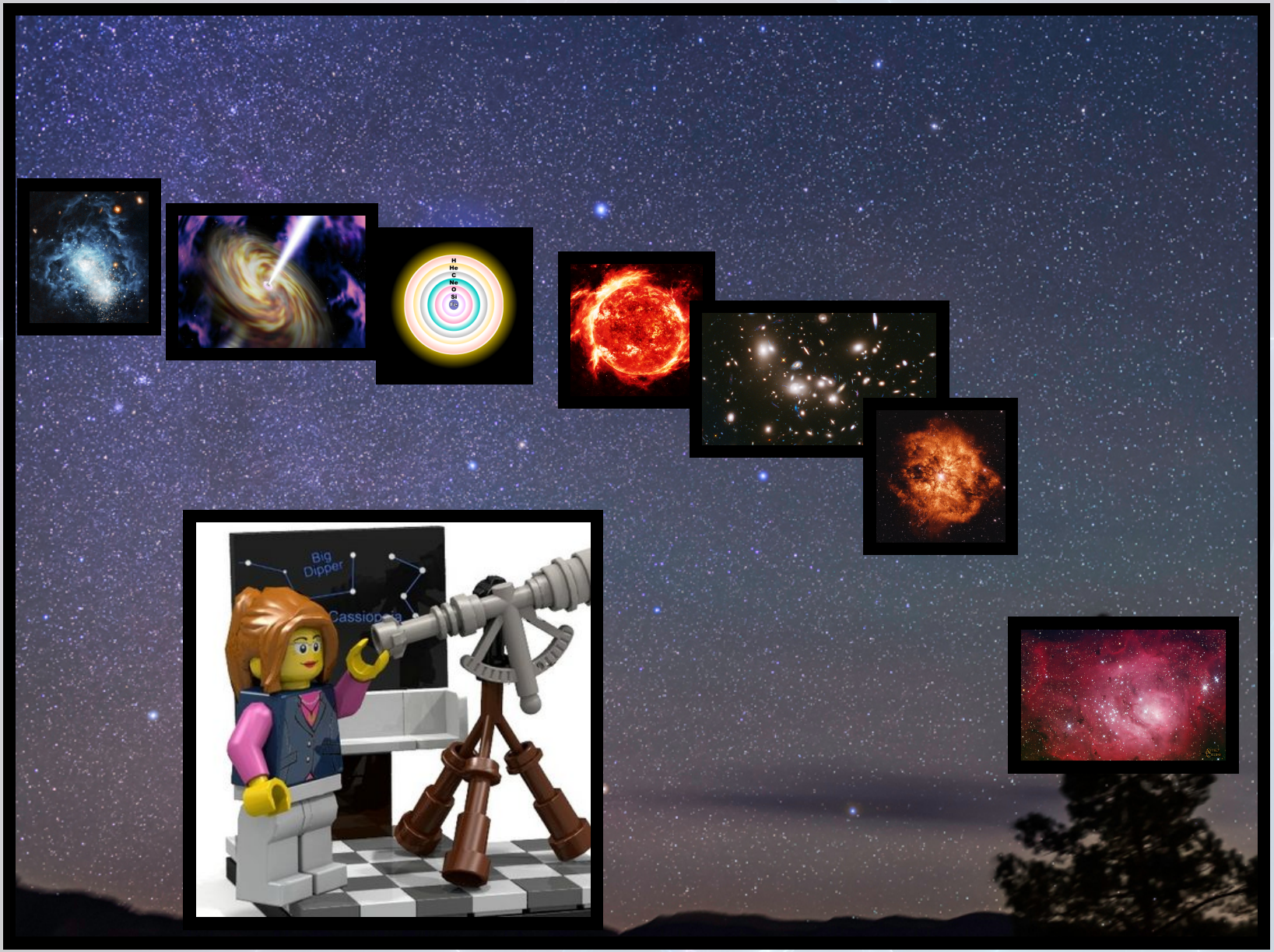

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