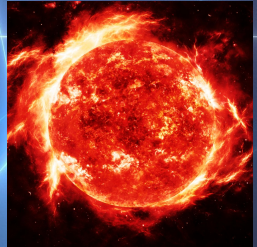


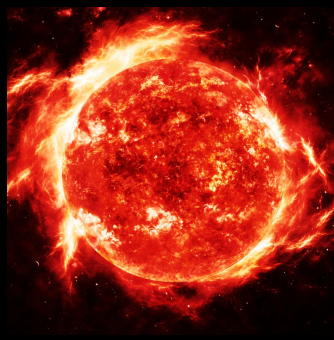
Low-Z Massive Stars  
vs  
High-Z Massive Stars

*Dorottya Szécsi*

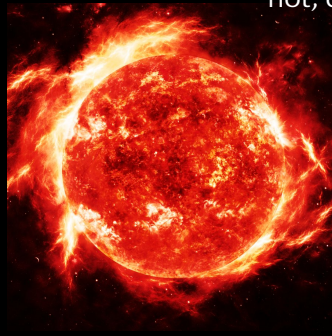


SILCC Workshop  
Bad Neuenahr-Ahrweiler, 15th March 2019

What is a star?

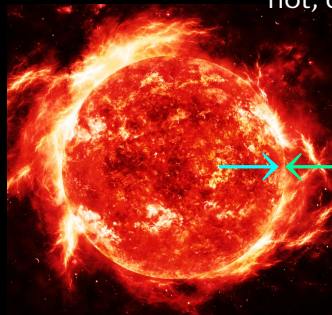


# What is a star?



hot, dense plazma

# What is a star?



hot, dense plazma

equilibrium:

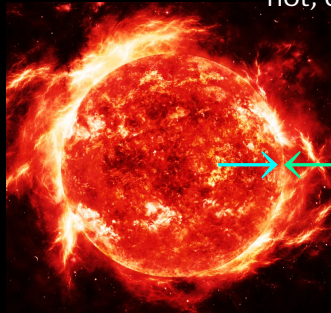
pressure gradient

gravity

# What is a star?

surface?

hot, dense plasma



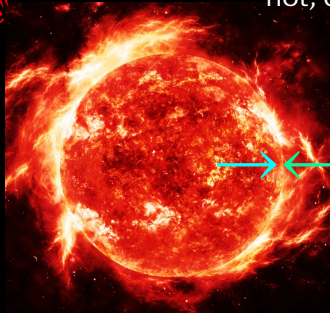
equilibrium:

pressure gradient    gravity

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**surface?**  
→ photons escape  
"photosphere"

hot, dense plazma



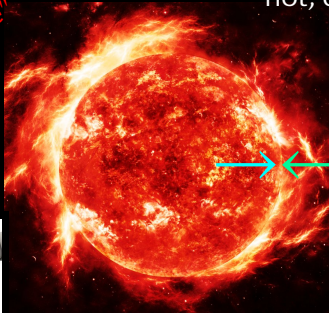
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pressure gradient      gravity



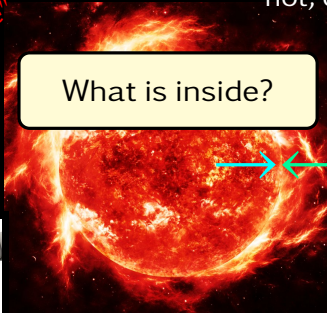
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**surface?**  
→ photons escape  
"photosphere"

hot, dense plazma

What is inside?

pressure gradient      gravity





# What is a star?

**surface?**  
→ photons escape  
"photosphere"

hot, dense plazma

What is inside?

theoretical  
modelling  
of the stellar  
structure

pressure gradient      gravity



# Theoretical modelling of the stellar structure

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

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

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

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

*Guilera et al. 2011*

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*composition change due to nuclear burning ?!*

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Guilera et al. 2011

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



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

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*composition change due to nuclear burning ?!*

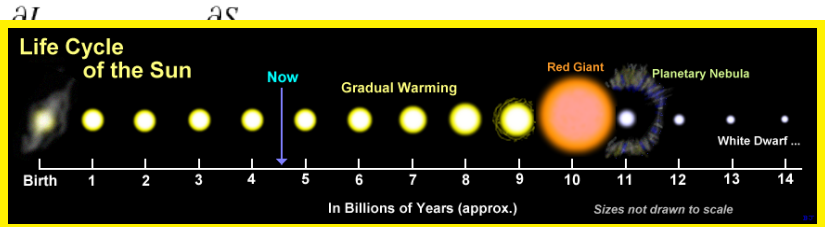
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+ Rotation.

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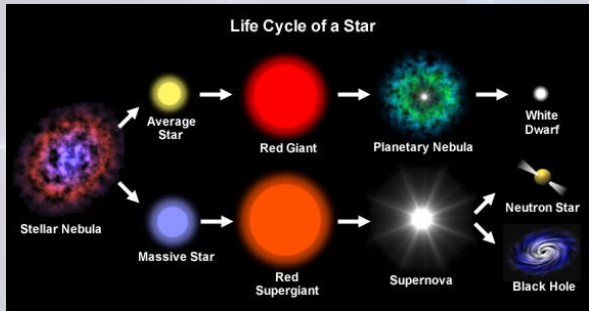
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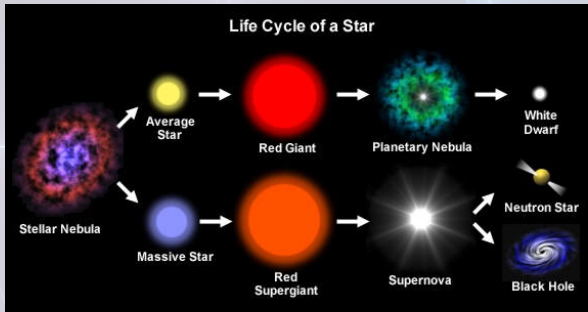
# Massive vs. low-mass stars

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



# Massive vs. low-mass stars

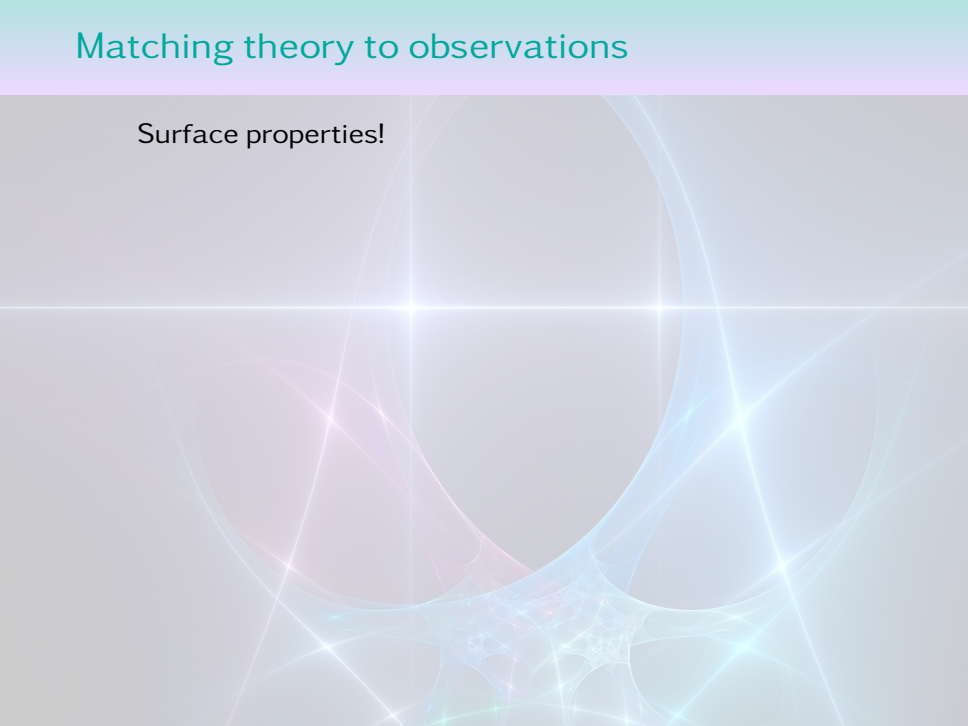
Massive stars:  $\gtrsim 9$  times the Sun ( $\gtrsim 9 M_{\odot}$ )



- nuclear reactions, final composition
- number of stars: massive stars are rare
- lifetime: massive stars have shorter lives
- final fate

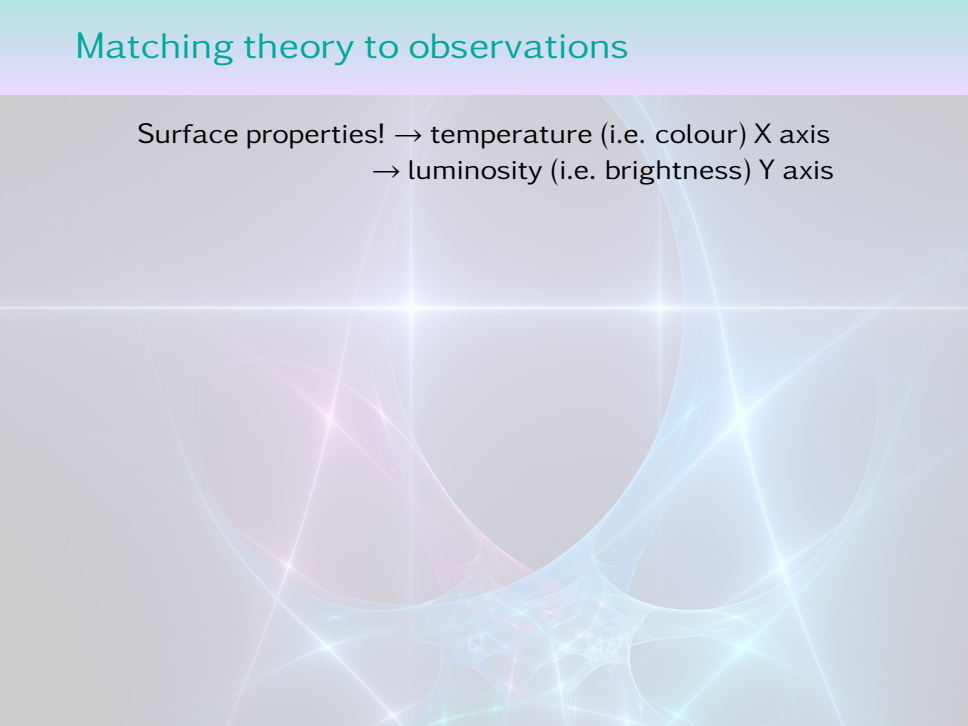
# Matching theory to observations

Surface properties!

The background features a large, semi-transparent sphere in the center. Overlaid on this are several glowing, ethereal lines in shades of blue, cyan, and magenta. These lines form a complex, web-like structure that appears to be a mathematical or physical model, possibly representing a surface or a network. The lines intersect and curve around the sphere, creating a sense of depth and complexity. The overall aesthetic is futuristic and scientific.

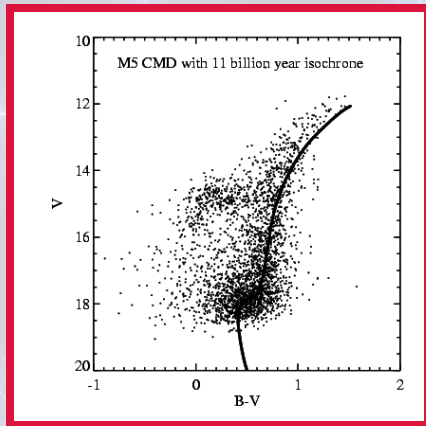
# Matching theory to observations

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



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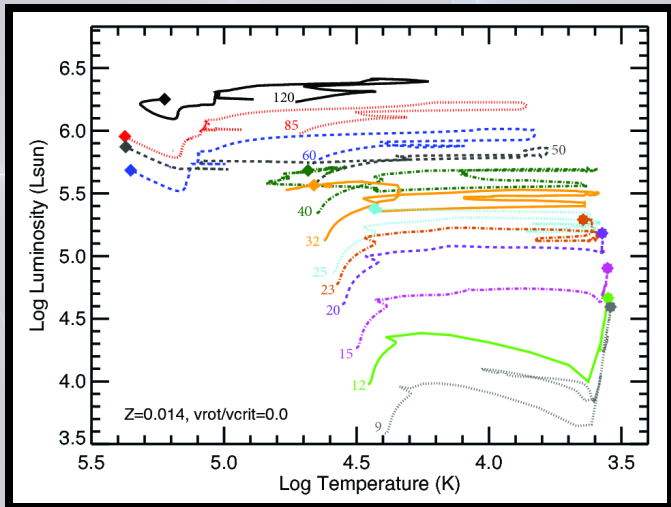
Hertzsprung–Russell diagram (HR diagram)

The background features a large, semi-transparent white circle centered in the upper half. Overlaid on this are several glowing, ethereal lines in shades of light blue and pink. These lines form a complex, web-like pattern that resembles a fractal or a network of energy paths. The lines are semi-transparent and have a soft, glowing aura around them. The overall color palette is light and airy, with a mix of cool blues and warm pinks against a pale, off-white background.

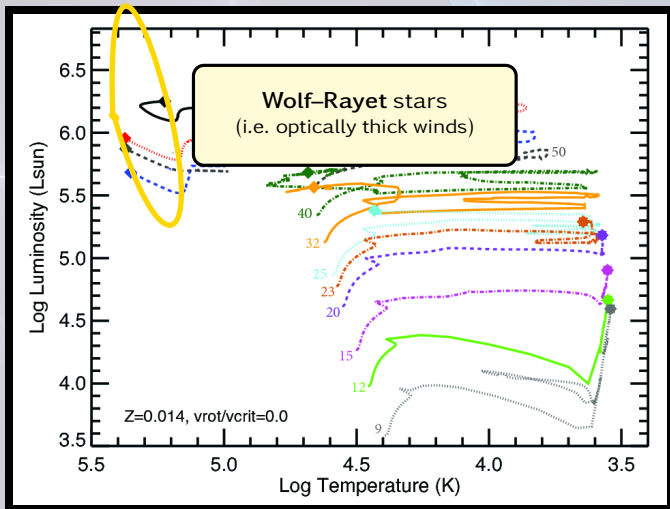
# High Metallicity Massive Stars



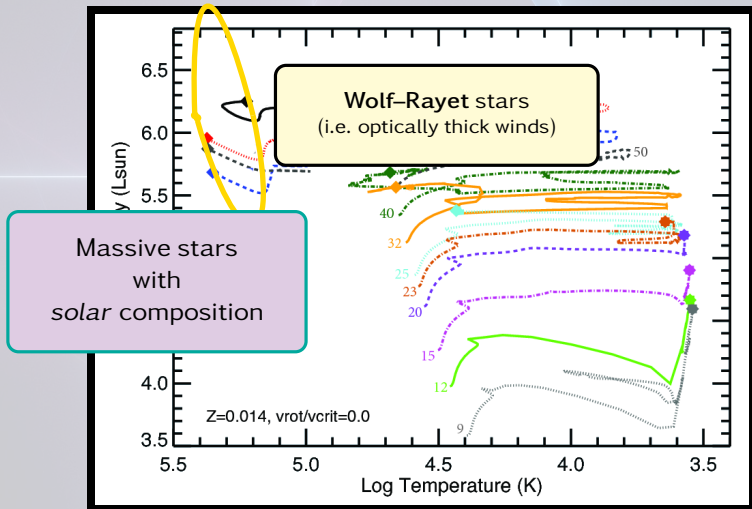
# Hertzprung–Russell diagram



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# Hertzprung–Russell diagram

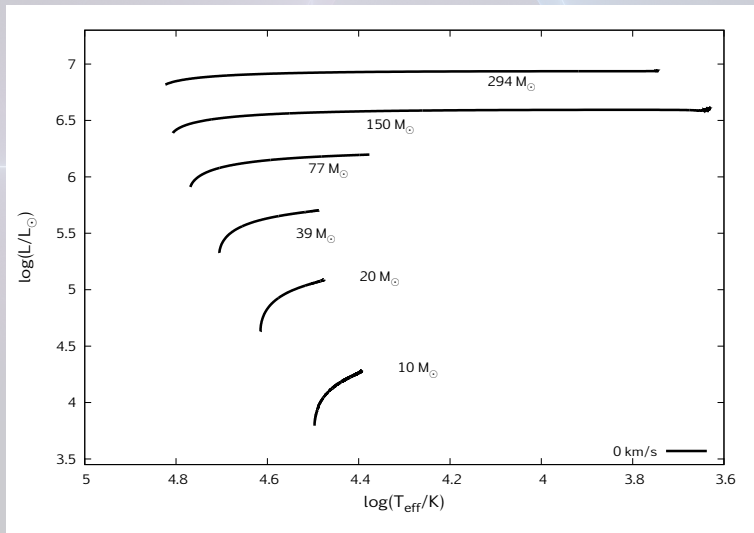


The background features a large, semi-transparent circle in the center. Overlaid on this are several thin, glowing lines in shades of blue, cyan, and magenta that curve and intersect, creating a sense of motion and depth. The overall color palette is soft and ethereal, with a light grey background.

# Low Metallicity Massive Stars

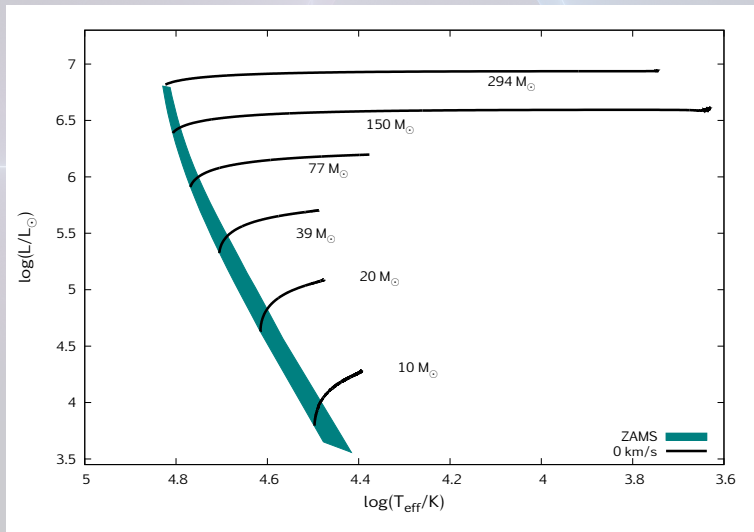
# Low Metallicity Massive Stars

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



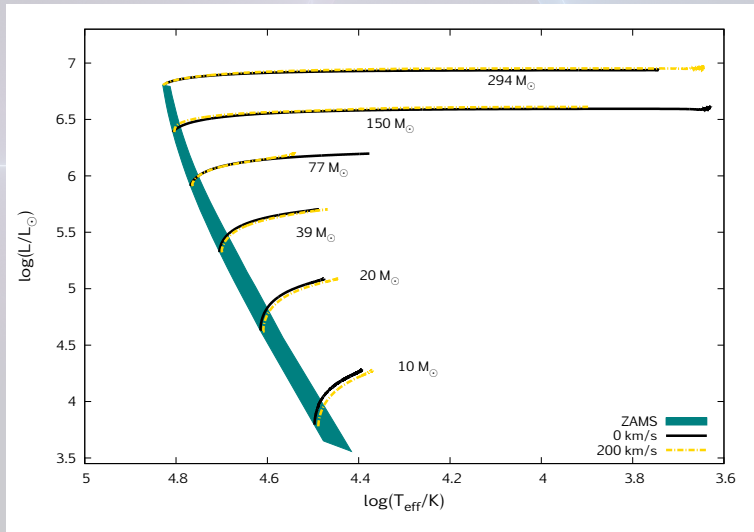
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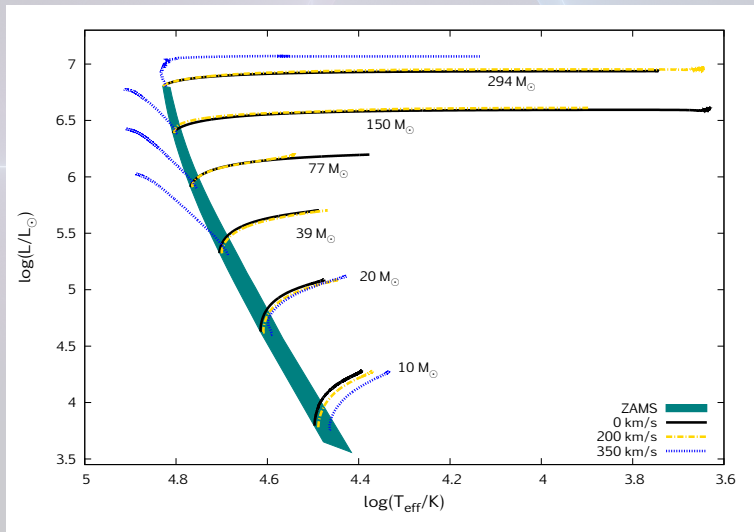
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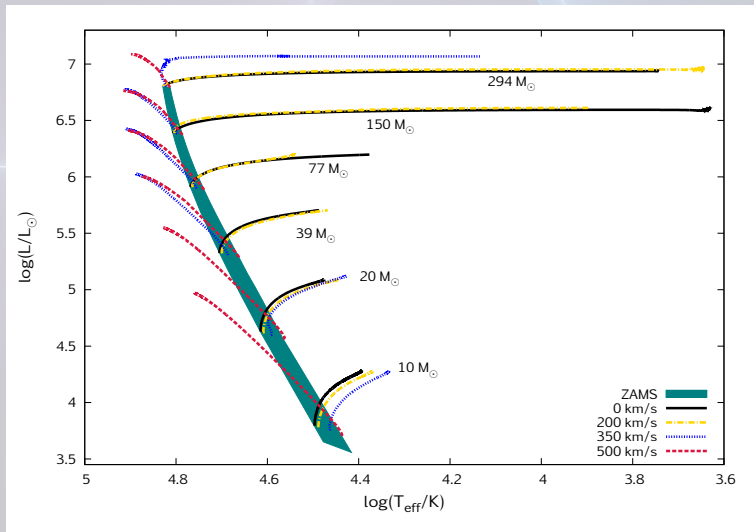
Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)





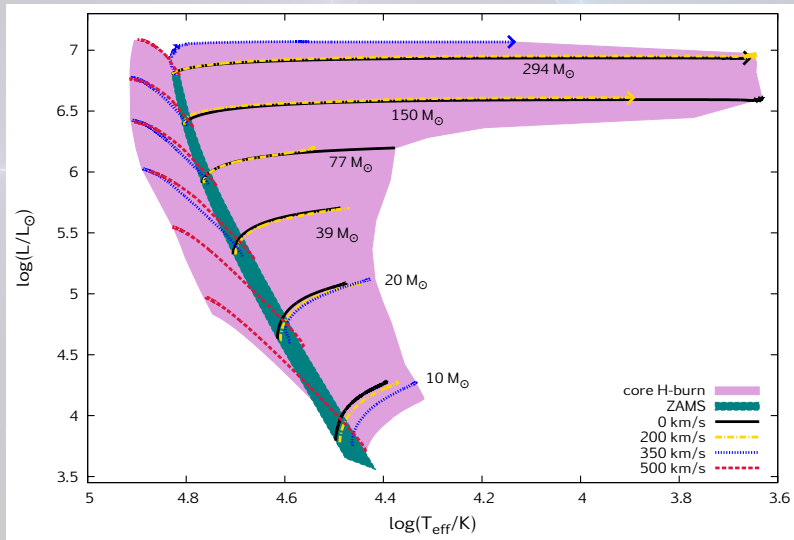
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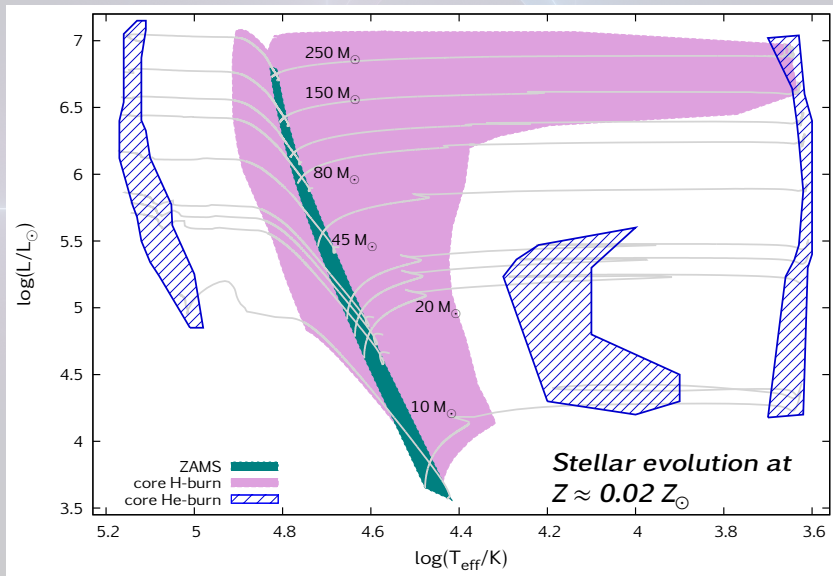


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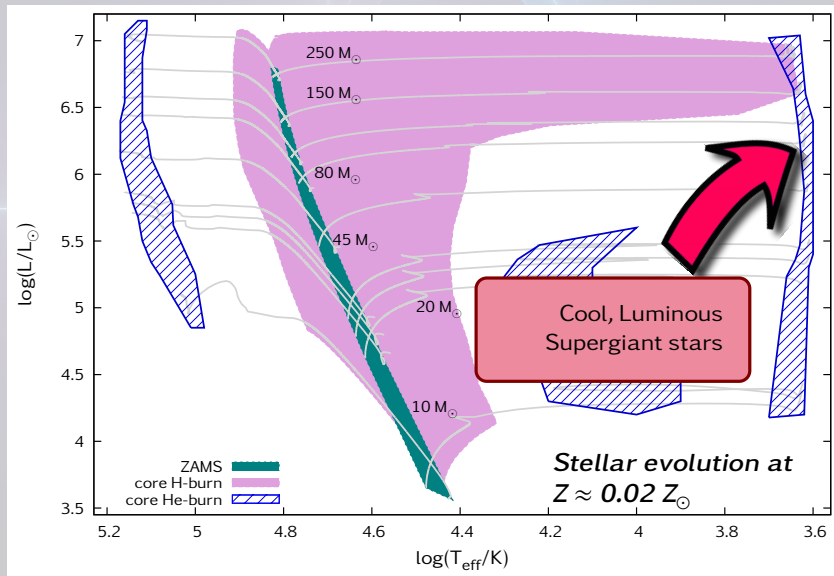
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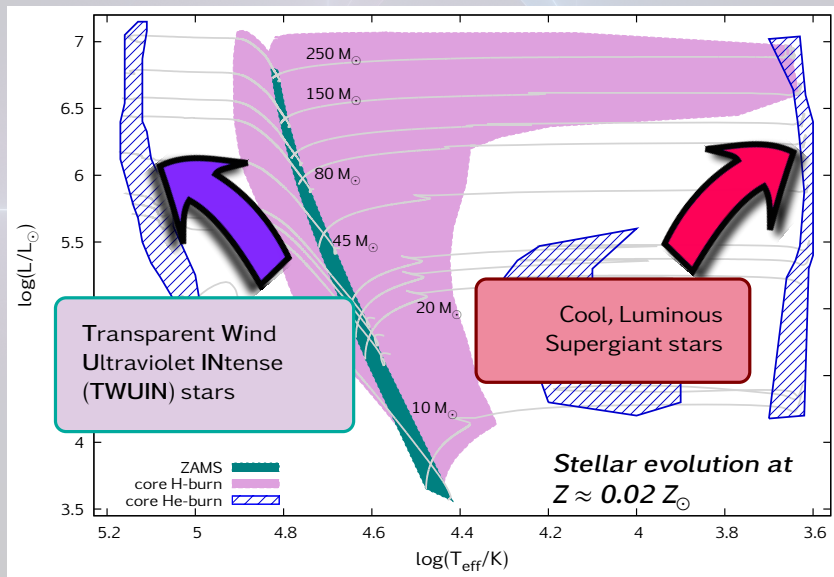
# Low Z Massive Stars – the whole picture



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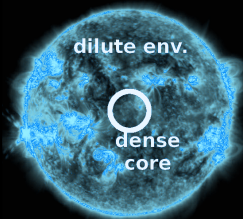
*Red supergiant:*

*Normal OB-star:*

*TWUIN star:*

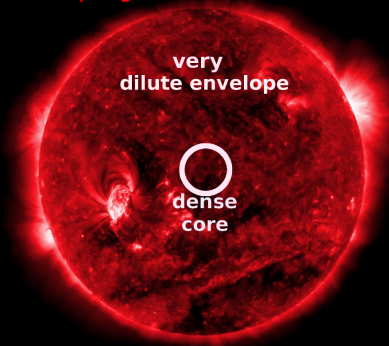


no  
core-  
env.  
structure



dilute env.

dense  
core



very  
dilute  
envelope

dense  
core

T ~ 80 000 K

T ~ 15 000 K

T ~ 4000 K

5.2

5

4.8

4.6

4.4

4.2

4

3.8

3.6

log(T<sub>eff</sub>/K)

# Low Z Massive Stars – the whole picture



~20%

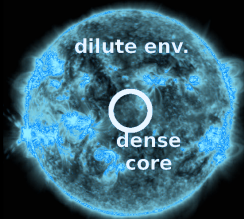
*TWUIN star:*



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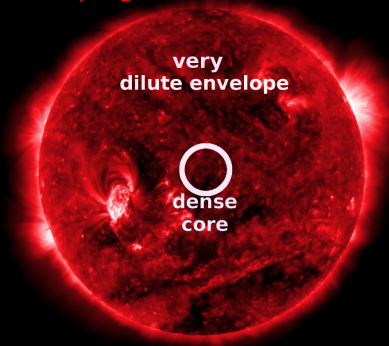
$T \sim 80\,000\text{ K}$

*Normal OB-star:*



$T \sim 15\,000\text{ K}$

*Red supergiant:*



$T \sim 4000\text{ K}$

5.2

5

4.8

4.6

4.4


4.2

4

3.8

3.6

$\log(T_{\text{eff}}/\text{K})$

The background features a large, semi-transparent circle in the center. Overlaid on this are several glowing, multi-colored lines (pink, blue, green) that form a complex, web-like pattern. The lines intersect and curve, creating a sense of depth and movement. The overall color palette is soft and ethereal, with a light gray background.

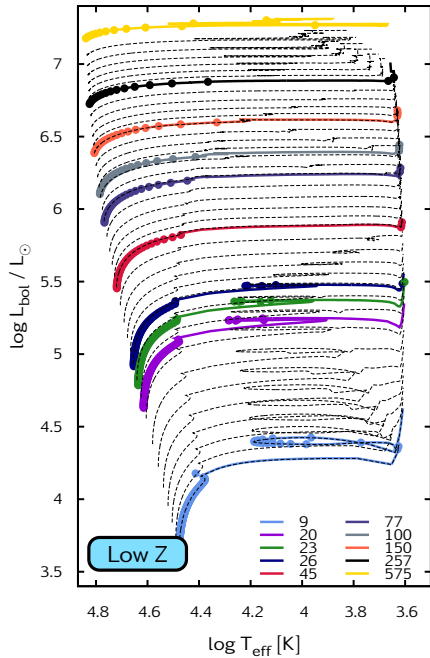
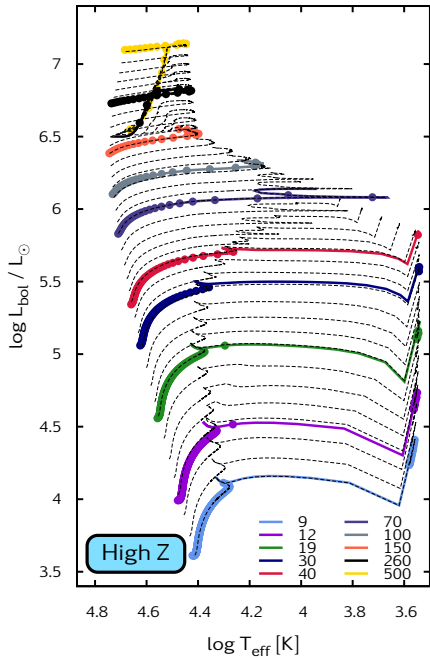
*IMF matters...*



The background features a large, semi-transparent white circle centered on the page. Overlaid on this are several glowing, ethereal lines in shades of light blue and pink. These lines form a complex, web-like pattern that resembles a fractal or a network of connections. The lines are semi-transparent and have a soft, glowing aura around them, creating a sense of depth and movement. The overall aesthetic is clean, modern, and scientific.

*IMF matters...*

"population synthesis"



# Low-Z starforming regions today

## Compact Dwarf Galaxies

- local universe
- clues for strong ionizing sources
- TWUIN stars may play a role! :)
- 20% is enough apparently...

Szécsi+15,+15b,'17,  
Kubátová&Szécsi+19



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Thank you  
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attention!

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