MESA Summer School 2021

White Dwarf Stars

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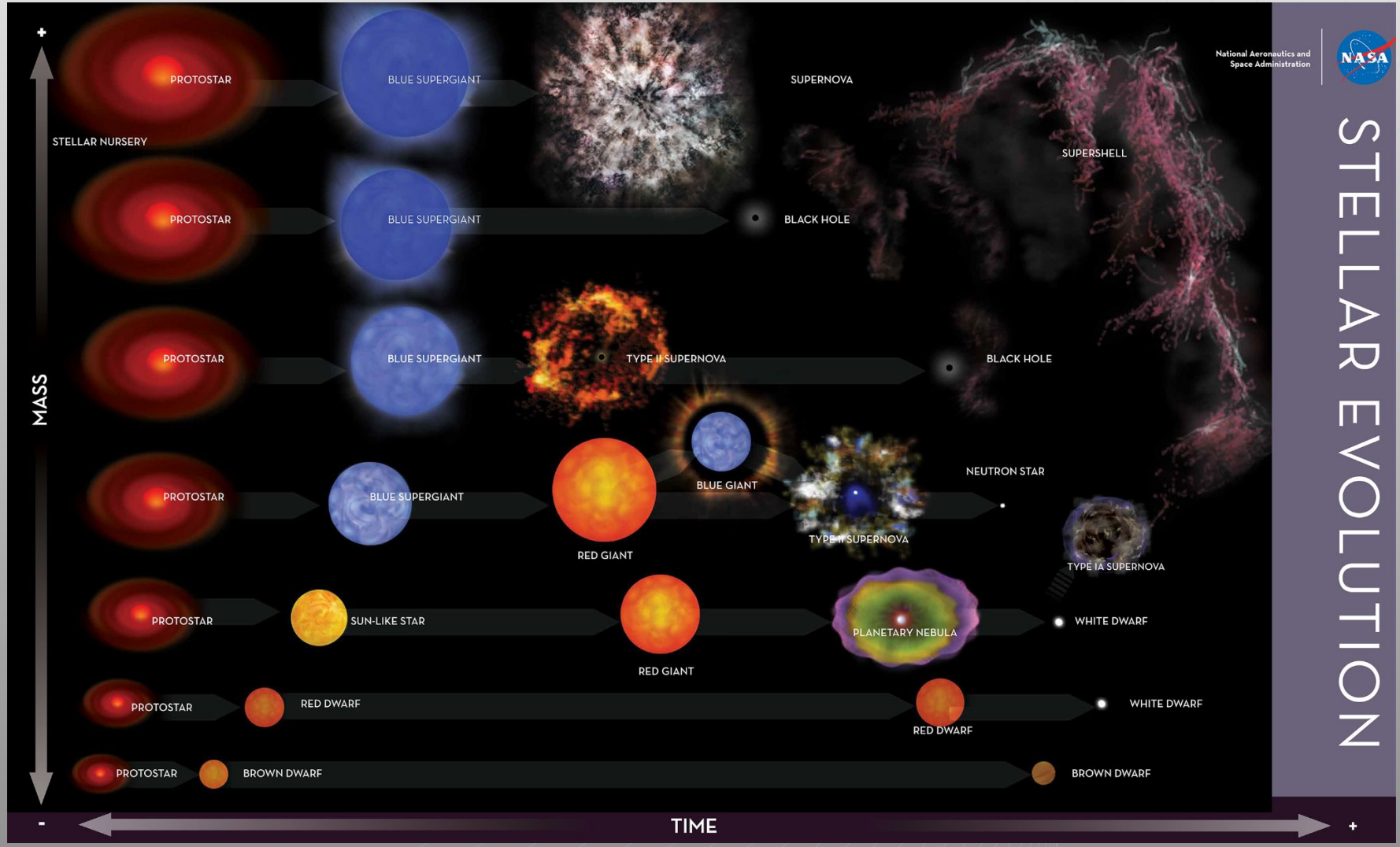
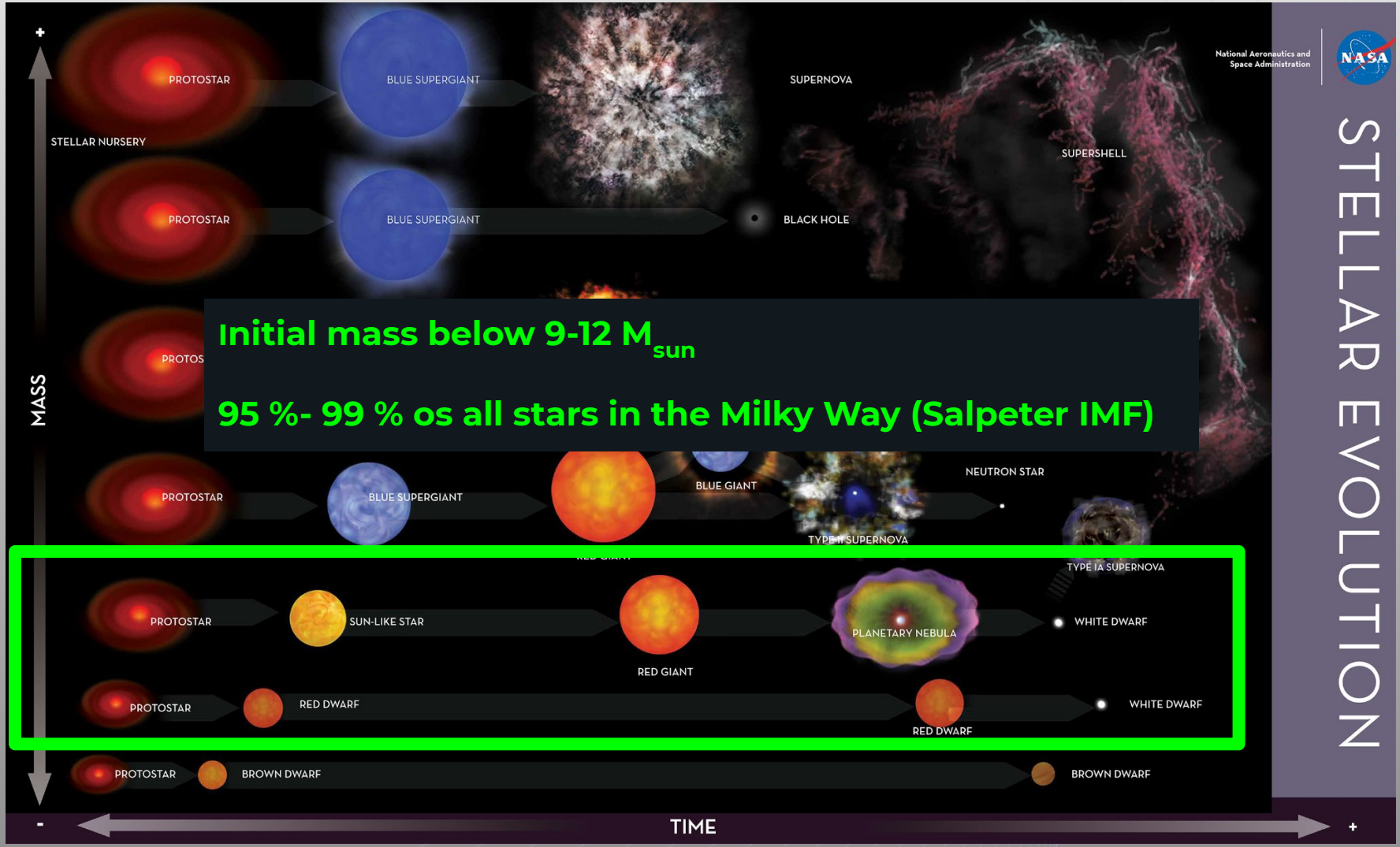
Universidade Federal do Rio Grande do Sul- Brazil


National Aeronautics and Space Administration
NASA
STELLAR EVOLUTION
+
MASS
-
STELLAR NURSERY
PROTOSTAR
BLUE SUPERGIANT
SUPERNOVA
SUPERSHELL
PROTOSTAR
BLUE SUPERGIANT
BLACK HOLE
PROTOSTAR
BLUE SUPERGIANT
TYPE II SUPERNOVA
BLACK HOLE
PROTOSTAR
BLUE SUPERGIANT
BLUE GIANT
NEUTRON STAR
RED GIANT
TYPE II SUPERNOVA
TYPE IA SUPERNOVA
PROTOSTAR
SUN-LIKE STAR
RED GIANT
PLANETARY NEBULA
WHITE DWARF
PROTOSTAR
RED DWARF
RED DWARF
WHITE DWARF
PROTOSTAR
BROWN DWARF
BROWN DWARF
TIME
-
+


+
MASS
-
TIME
+
STELLAR NURSERY
PROTOSTAR
BLUE SUPERGIANT
SUPERNOVA
SUPERSHELL
PROTOSTAR
BLUE SUPERGIANT
BLACK HOLE
PROTOS
Initial mass below 9-12 M sun
95 %- 99 % os all stars in the Milky Way (Salpeter IMF)
PROTOSTAR
BLUE SUPERGIANT
BLUE GIANT
NEUTRON STAR
TYPE II SUPERNOVA
TYPE IA SUPERNOVA
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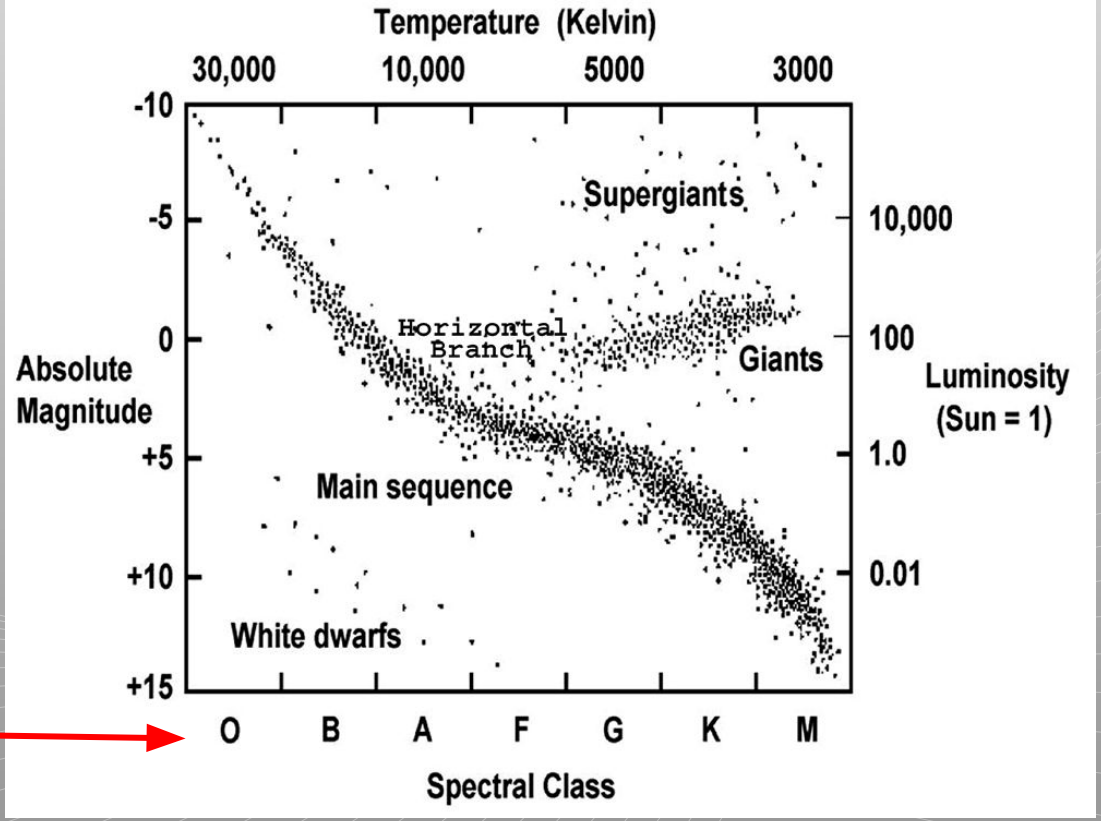
National Aeronautics and Space Administration
NASA
STELLAR EVOLUTION

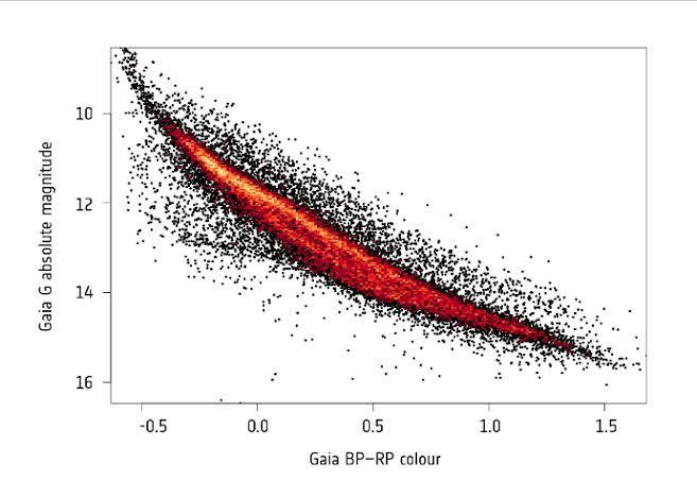
Where are the WD in the HR diagram?

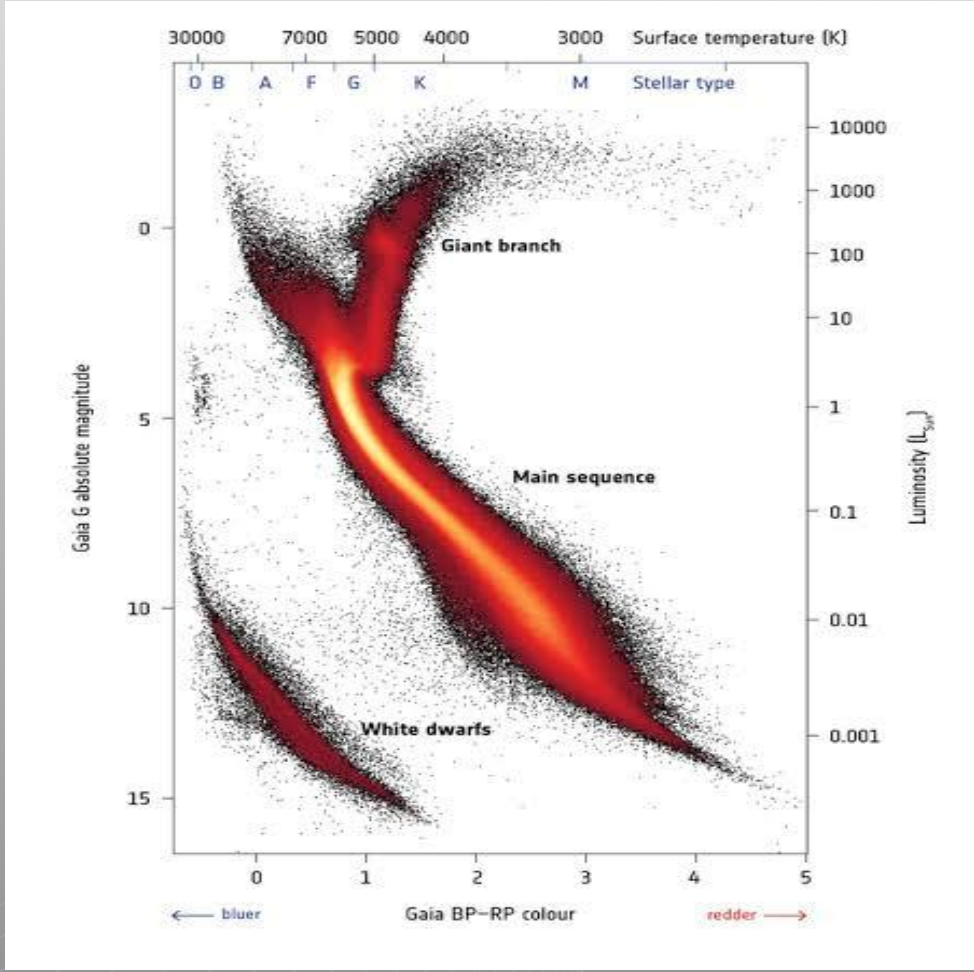


Spectral type
O-B-A-(F)

https://www.rpubs.com/Papercut/HRdiagram

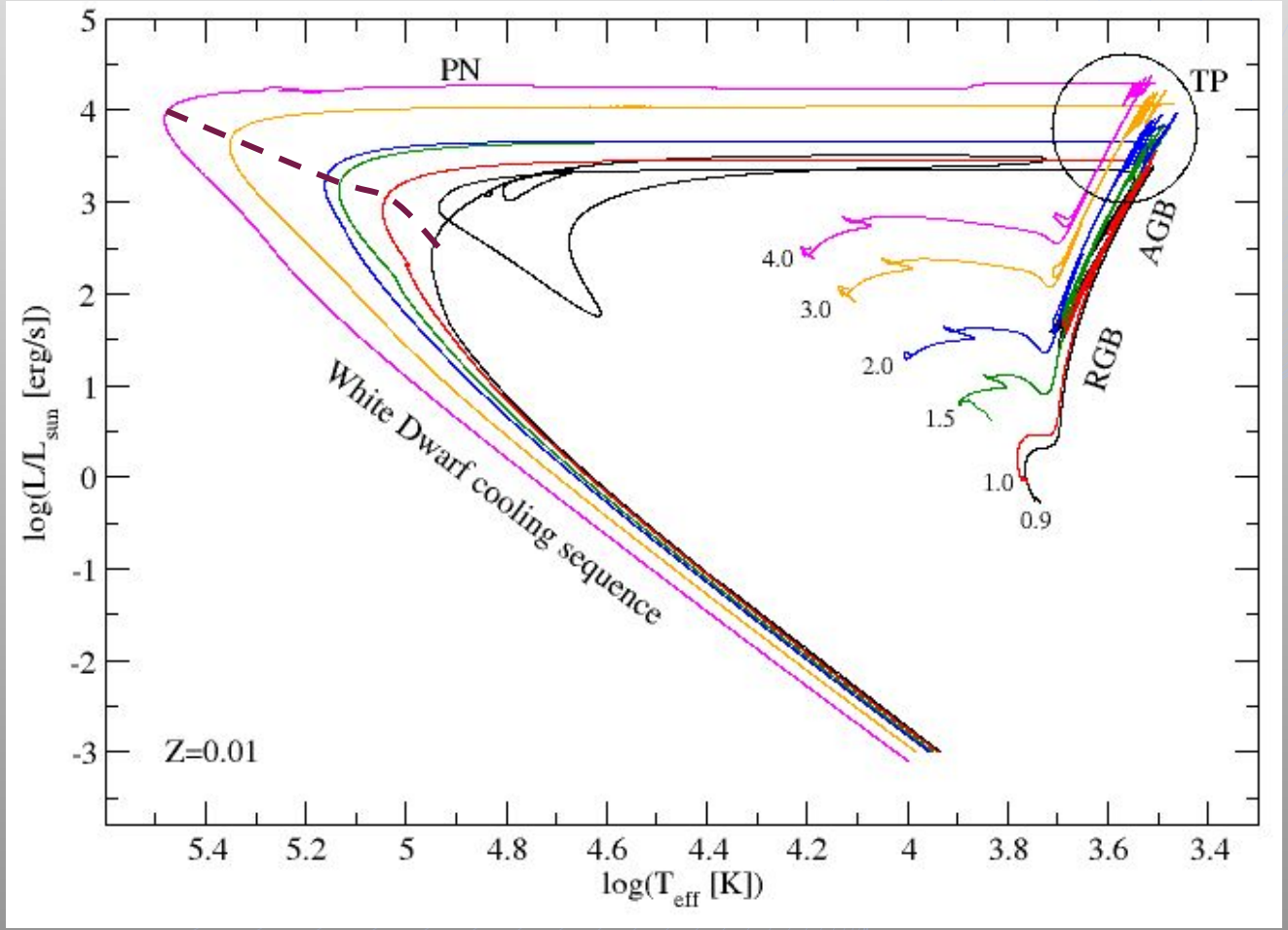
Where are the WD ?



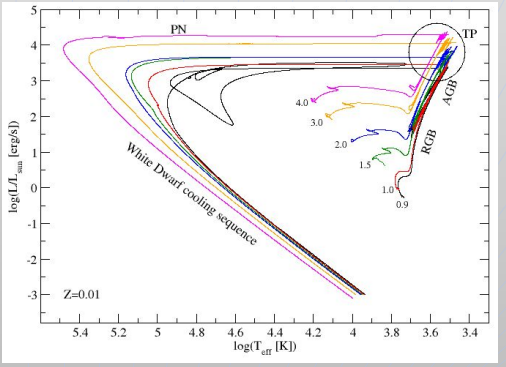


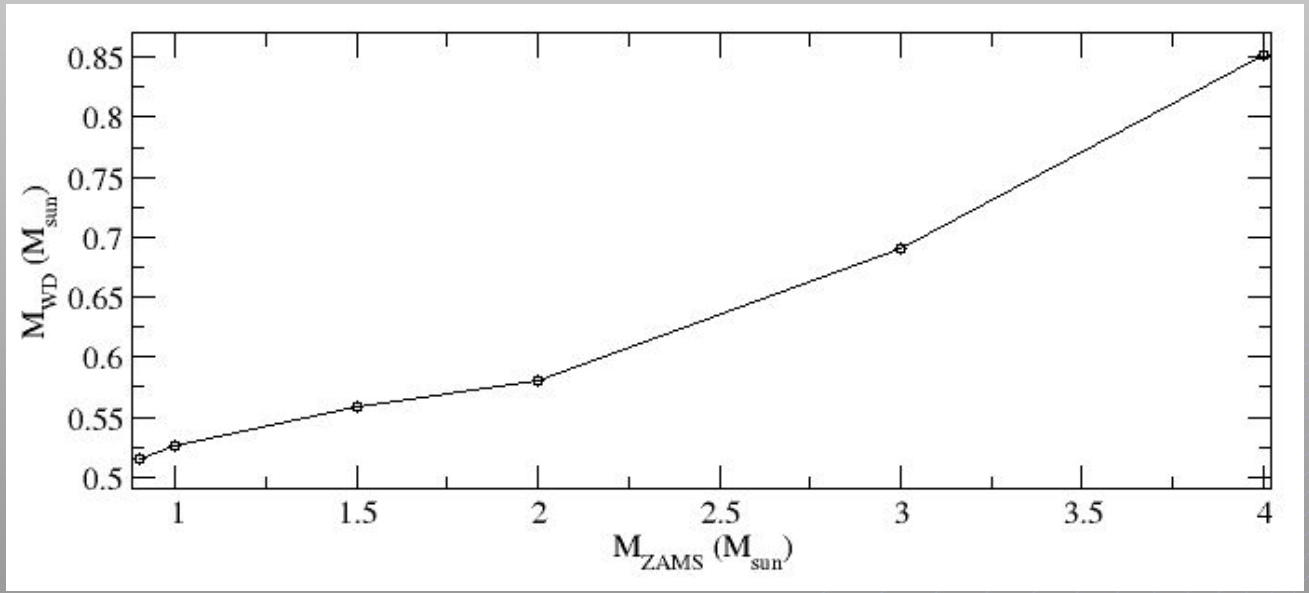
Gaia (ESA)

Final stages



Initial-final Mass Function

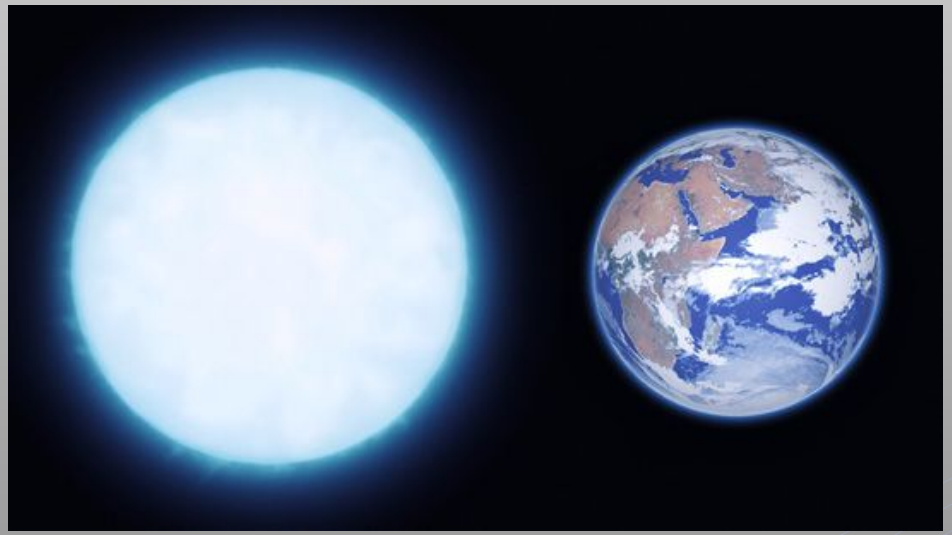




What are WDs?

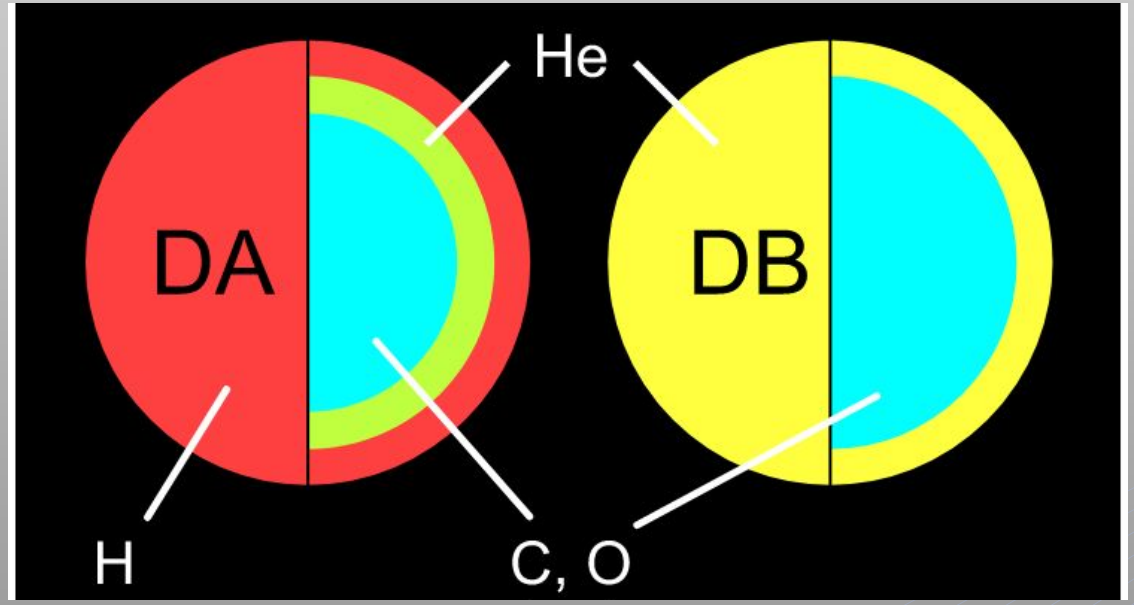
Compact object: $M < 1.4\ M_{sun}$ Chandrasekhar limit

$R \sim 0.01\text{-}0.001\ R_{sun}$



- ★ Pressure is dominated by a degenerate electron gás (does not depend on temperature);
- ★ Thermal structure dominated by the non-degenerate ions;
- ★ “Simple” cooling process.

Spectral classification



“Dominant element in the outer layers”

DA: Hydrogen (84 %)

non-DA: other (mainly He)

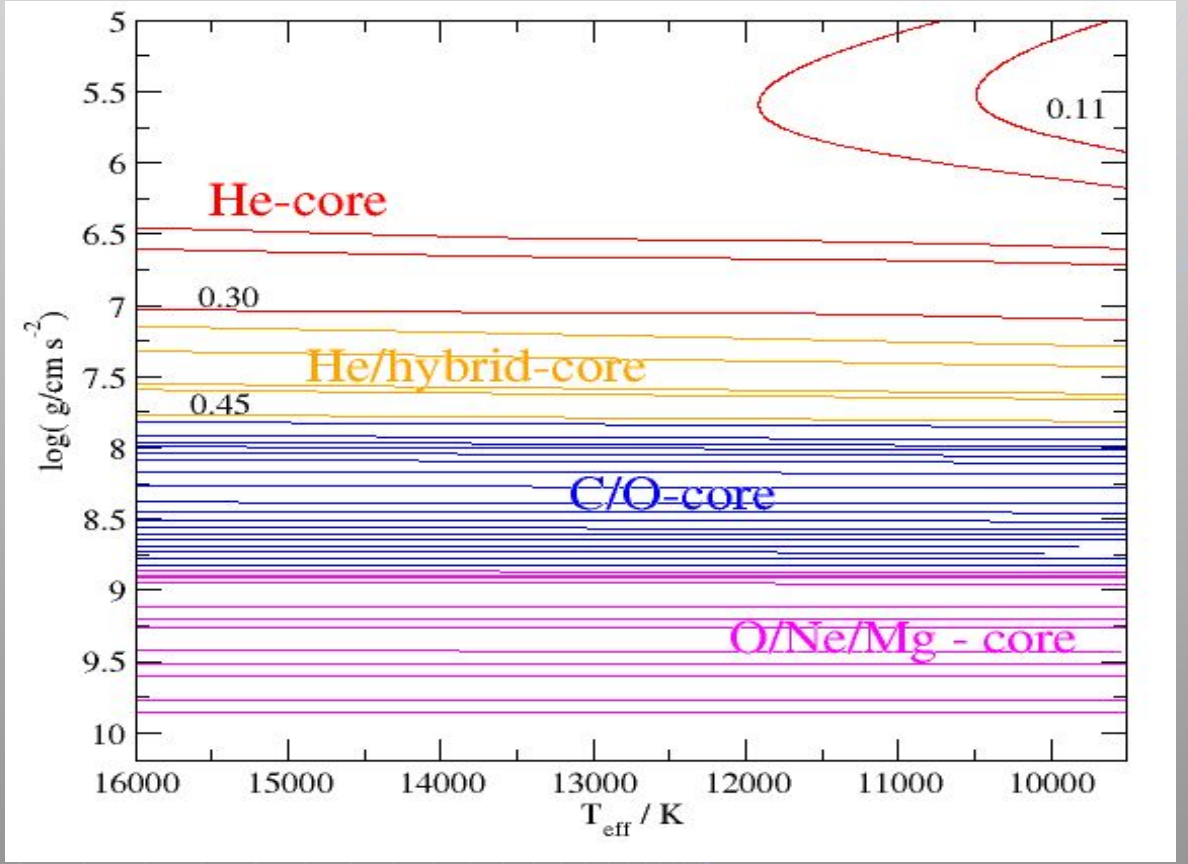
Core composition

He-core: < 0.3 M_{sun}

He- or Hybrid-core 0.30 to 0.45 M_{sun}

C/O -core: ~0.45 to ~1.05 M_{sun}

O/Ne/Mg > 1.05-1.10 M_{sun}



Althaus et al. (2013), Althaus et al. (2009), Romero et al. (2015), Lauffer et al. (2008)

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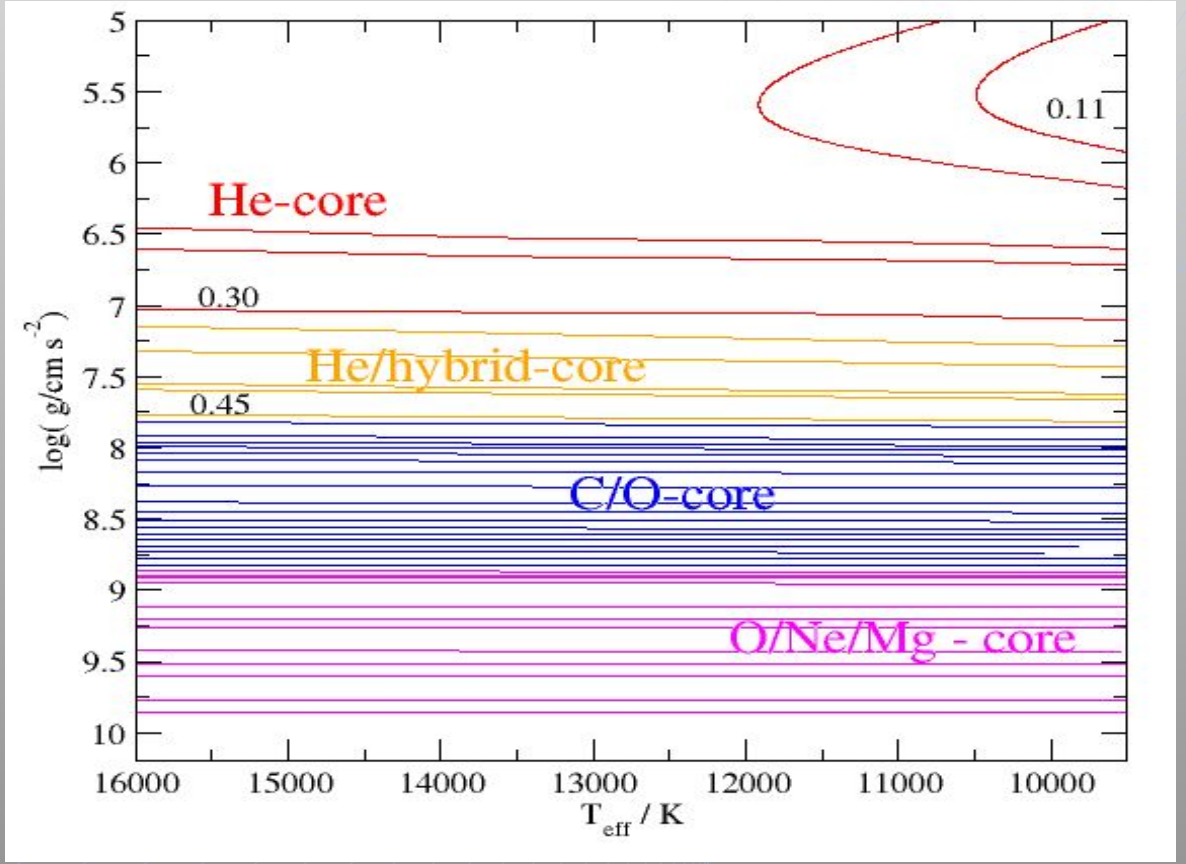
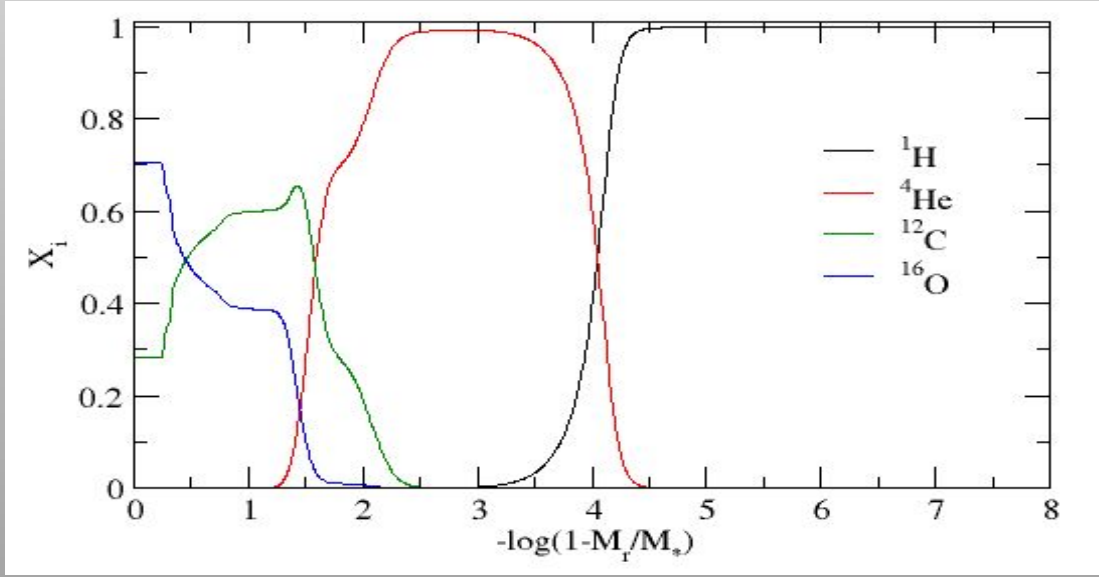
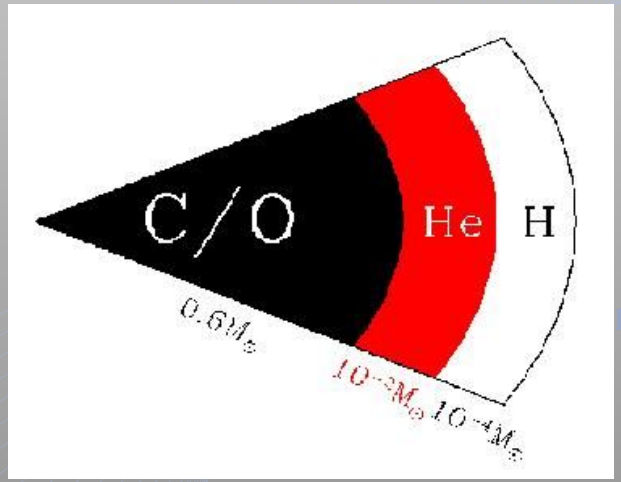


Althaus et al. (2013), Althaus et al. (2009), Romero et al. (2015), Lauffer et al. (2008)

Hydrogen envelope - % core

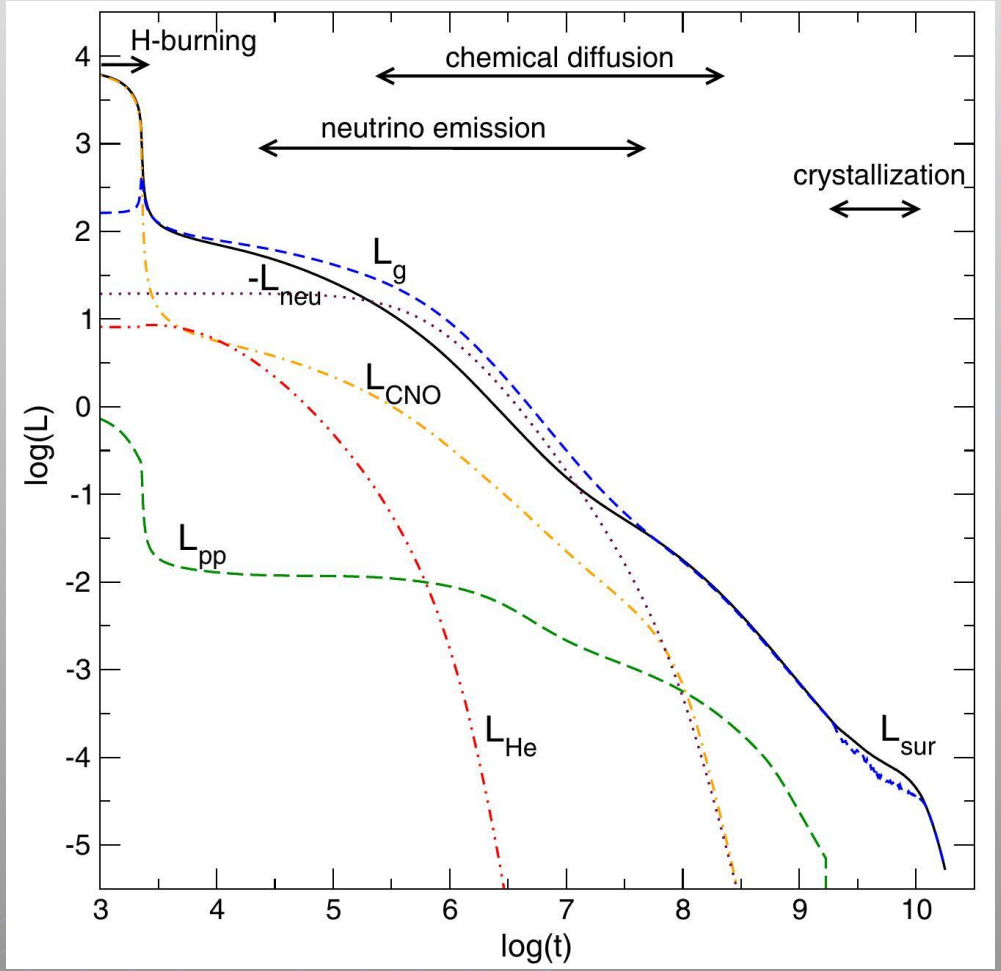




White Dwarf Cooling

Simple vision: WD start as very hot object and it cools down by releasing the thermal energy stored in the ions of the core.

"True" version: Thermal cooling, residual nuclear sources, particle emission, gravitational contraction, cristalization...



Renedo et al. (2010)

MINILAB 1

Compute the evolution of a white dwarf on the cooling sequence

The cooling rate

Cooling evolution on the WD sequence

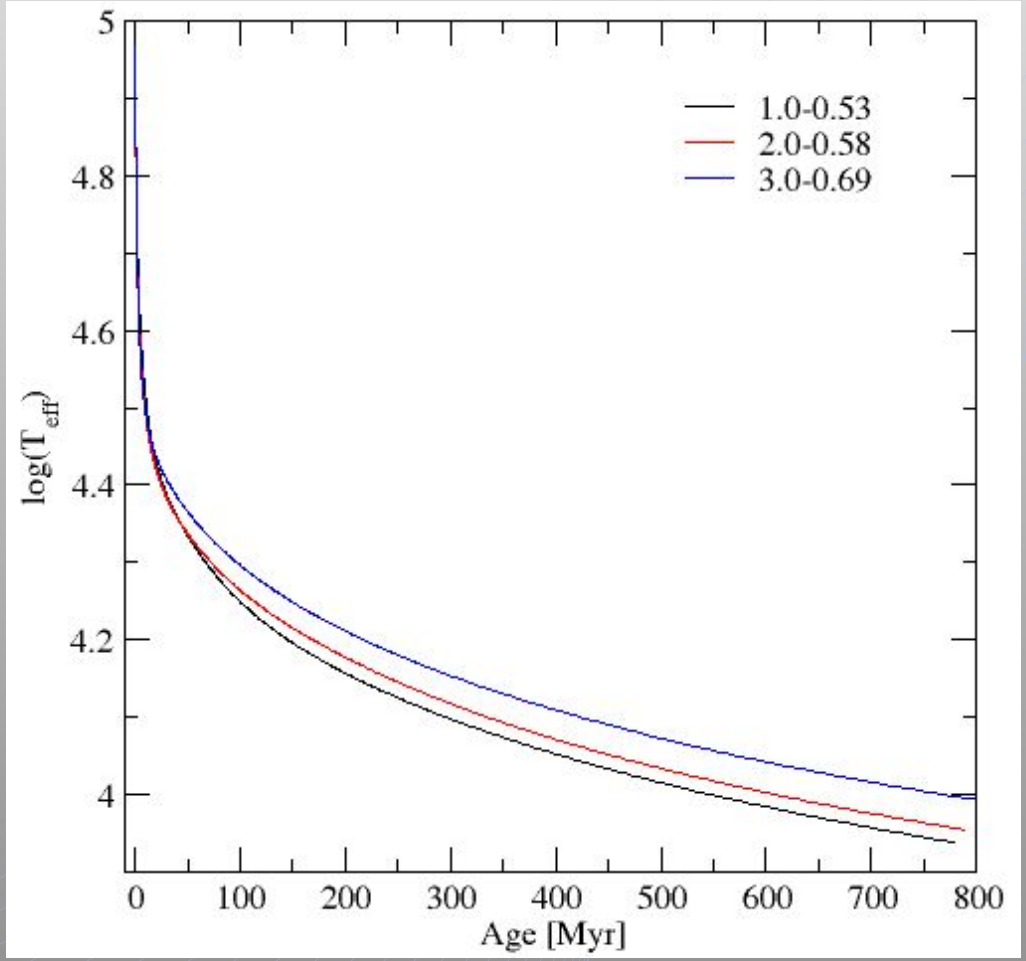
WARNING!

pre-WD age

1 M_{sun} ~10 Gyr

2M_{sun} ~ 1 Gyr

3M_{sun} ~0.4 Gyr



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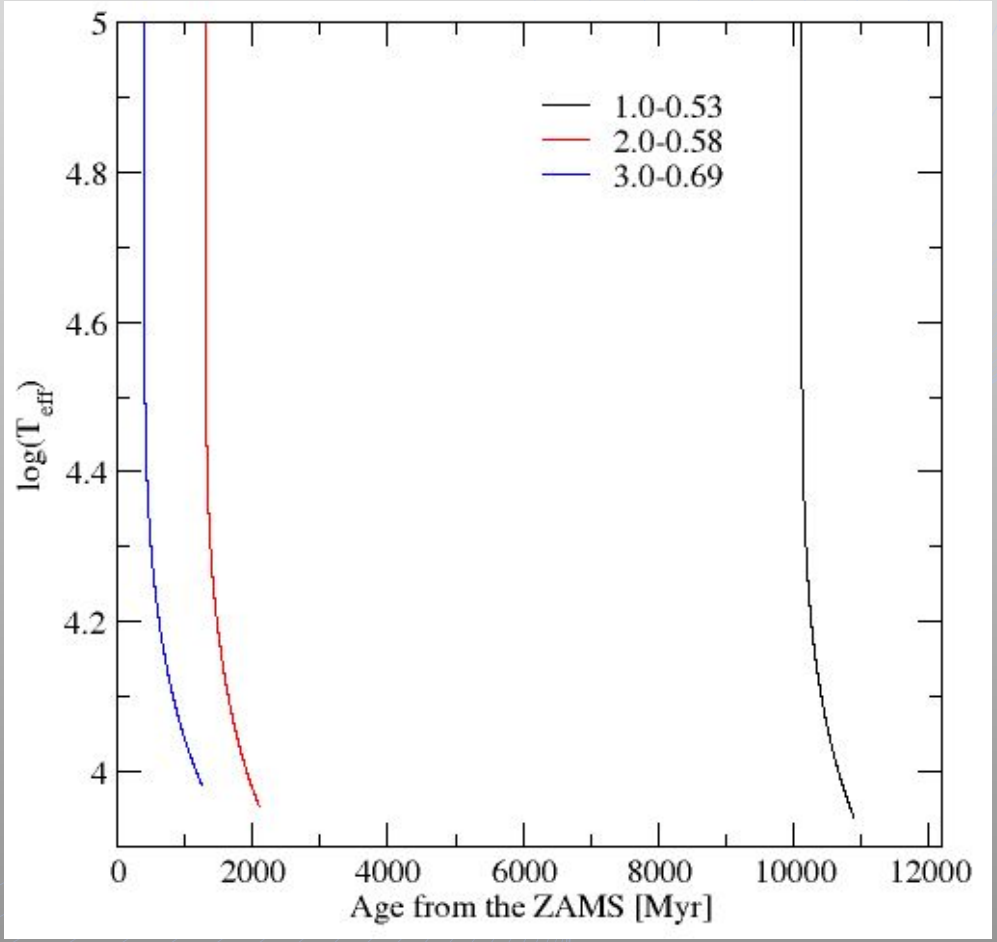


Cooling evolution on the WD sequence

WARNING!

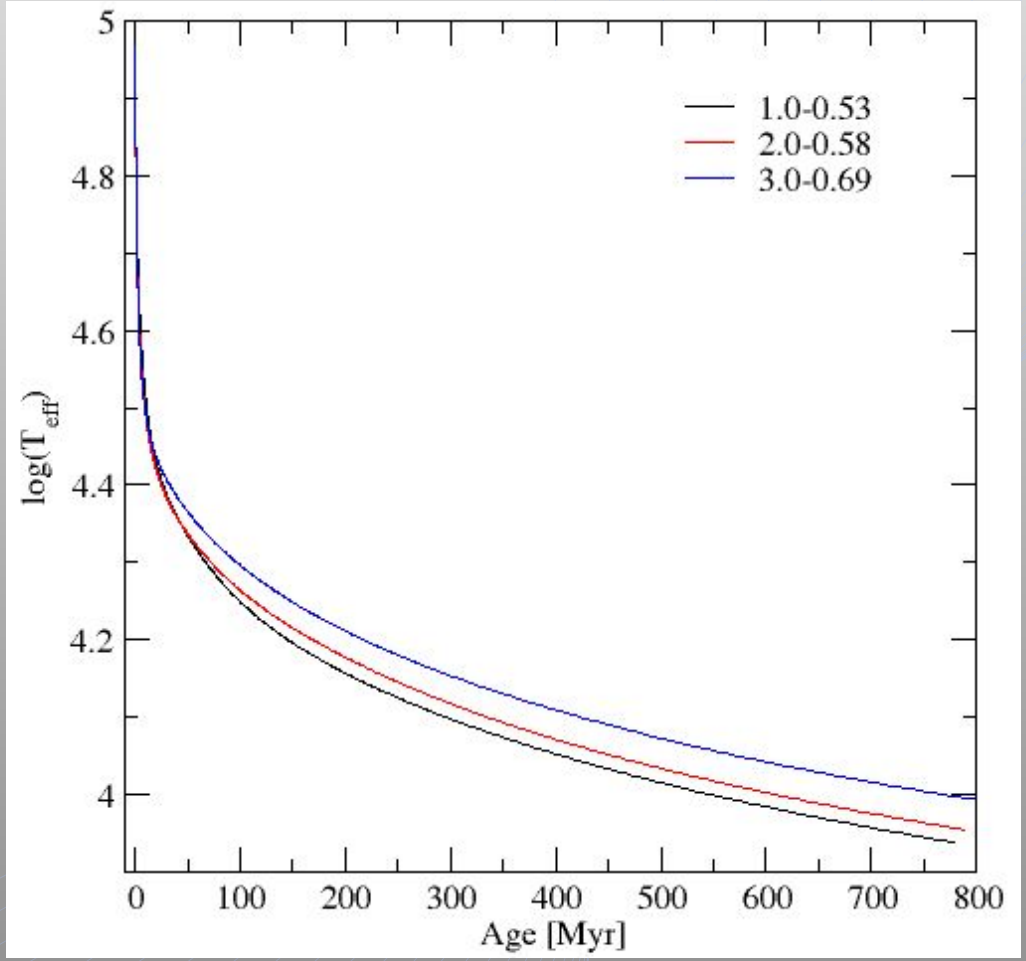
<u>pre-WD age</u>

1 M_{sun} ~10 Gyr

2M_{sun} ~ 1 Gyr

3M_{sun} ~0.4 Gyr

$t_{cooling} = t_{total} - t_{pre\text{-}WD}$



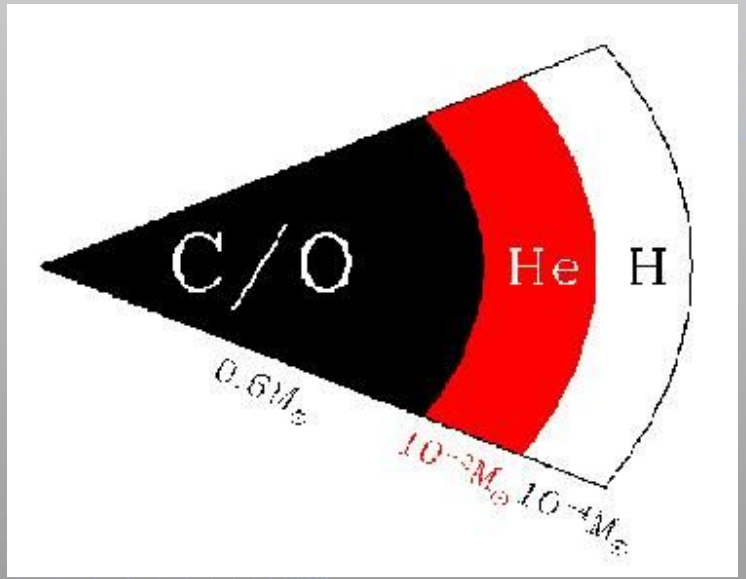
Minilab 2

Compute the cooling rate

Cooling rate

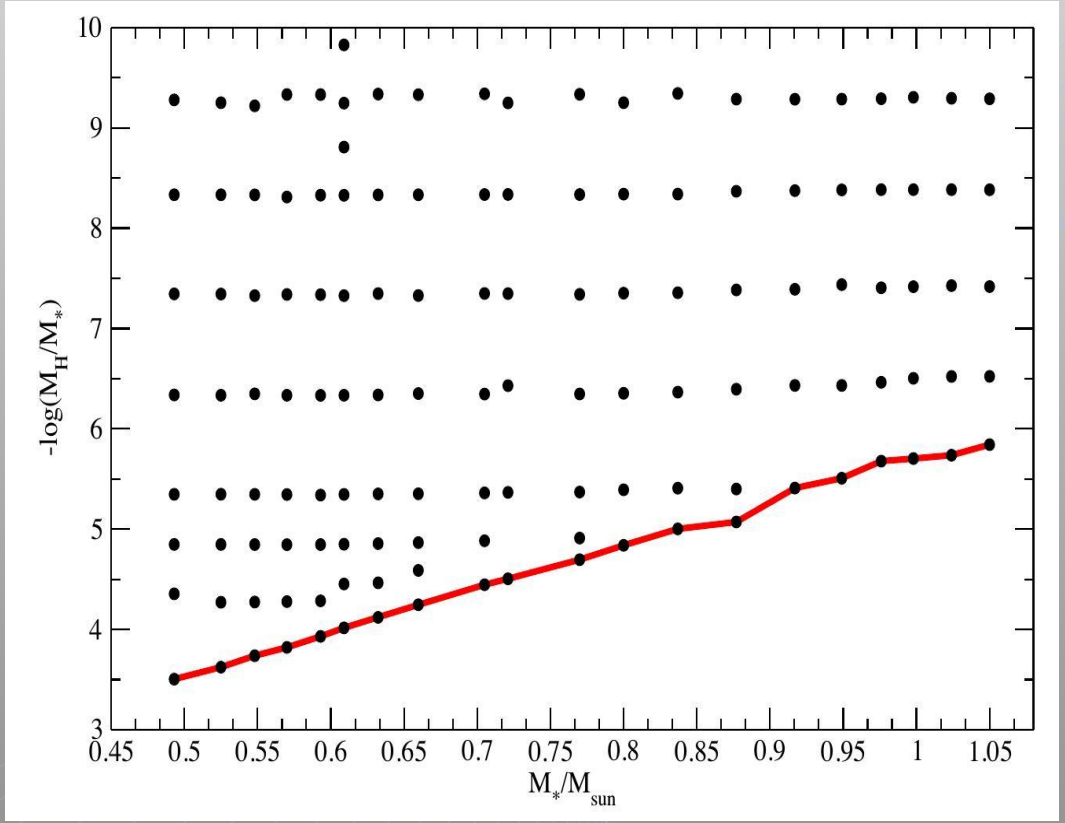
$$\text{cooling\_rate} = \frac{T_{\text{eff},i} - T_{\text{eff},(i-1)}}{dt}$$

The hydrogen envelope



The hydrogen envelope

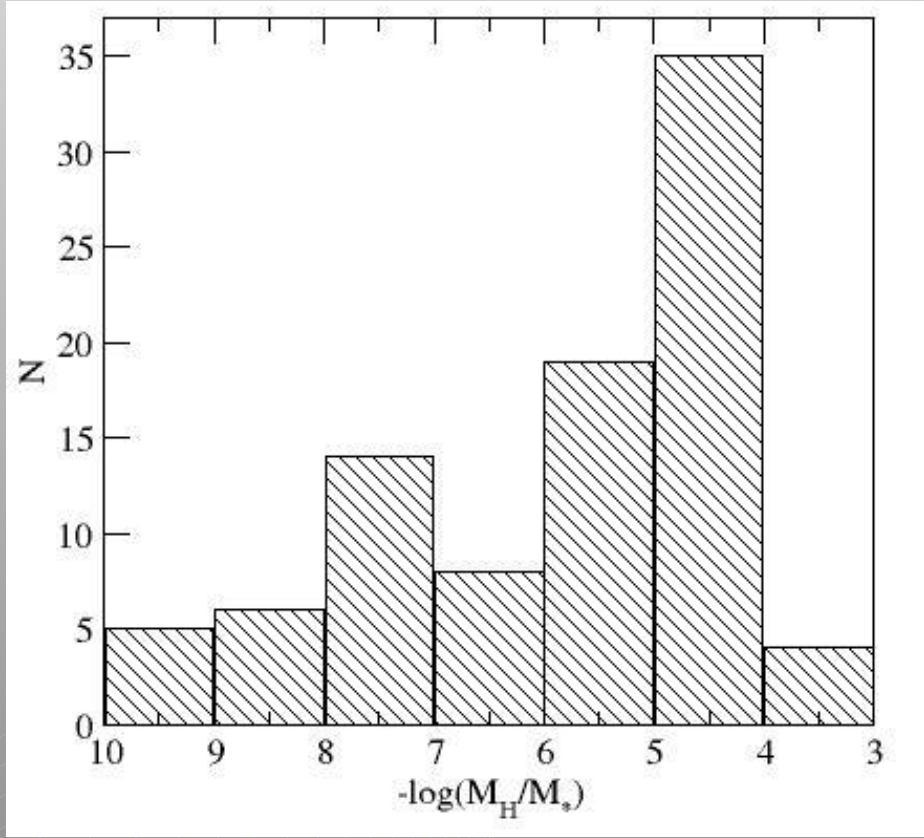
Hydrogen envelope mass decreases with increasing stellar mass



The hydrogen envelope

From Asteroseismology:

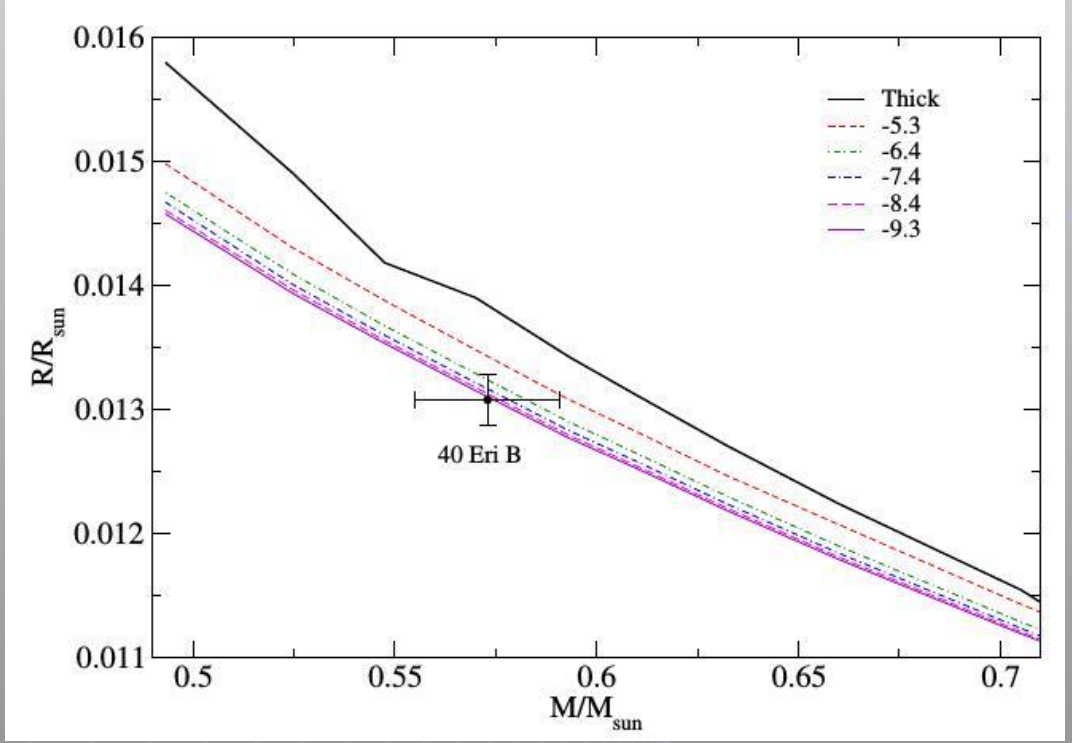
Distribution of the hydrogen envelope



The hydrogen envelope

Mass-Radius from binary systems:

The radius decrease for thinner hydrogen envelopes (up to ~30%)



Maxilab

Change the hydrogen envelope mass