Stellar Evolution

90% of its lifetime: star converts Hydrogen to Helium

- p-p cycle Main Sequence

Helium builds up in the core, but not yet burning

- gravity compresses which increases temperature
- helium starts burning, more energy produced

Different equilibrium, less stable

- NOT on main sequence
- where on HR diagram is complicated
- simplistically Red Giants=He burning

Stellar Evolution

- test out model of stellar evolution using Star Clusters
- HR diagram of a cluster gives "snapshot" of stars with the same age but different masses
- Birth → Main Sequence ➔ Red Giant → "live+die" faster if higher mass
- tell age of cluster by most massive star still on Main Sequence. Young clusters still have massive bright stars on main sequence

Star Clusters

stars are usually near other stars - CLUSTER

- formed at the same time from same “gas cloud”
- similar chemical composition
- about the same distance from us

Can classify by appearance and use to:

- study stellar lifetimes
- measure distances (earlier: spectroscopic parallax)

Open Star Clusters

can see individual stars by eye or with modest telescope

- usually some bright, hot stars
- 100-1000 stars in region of about 50 LY with few LY separating stars
- have significant amount of heavy elements like Carbon and Oxygen

Understood as group of recently formed stars

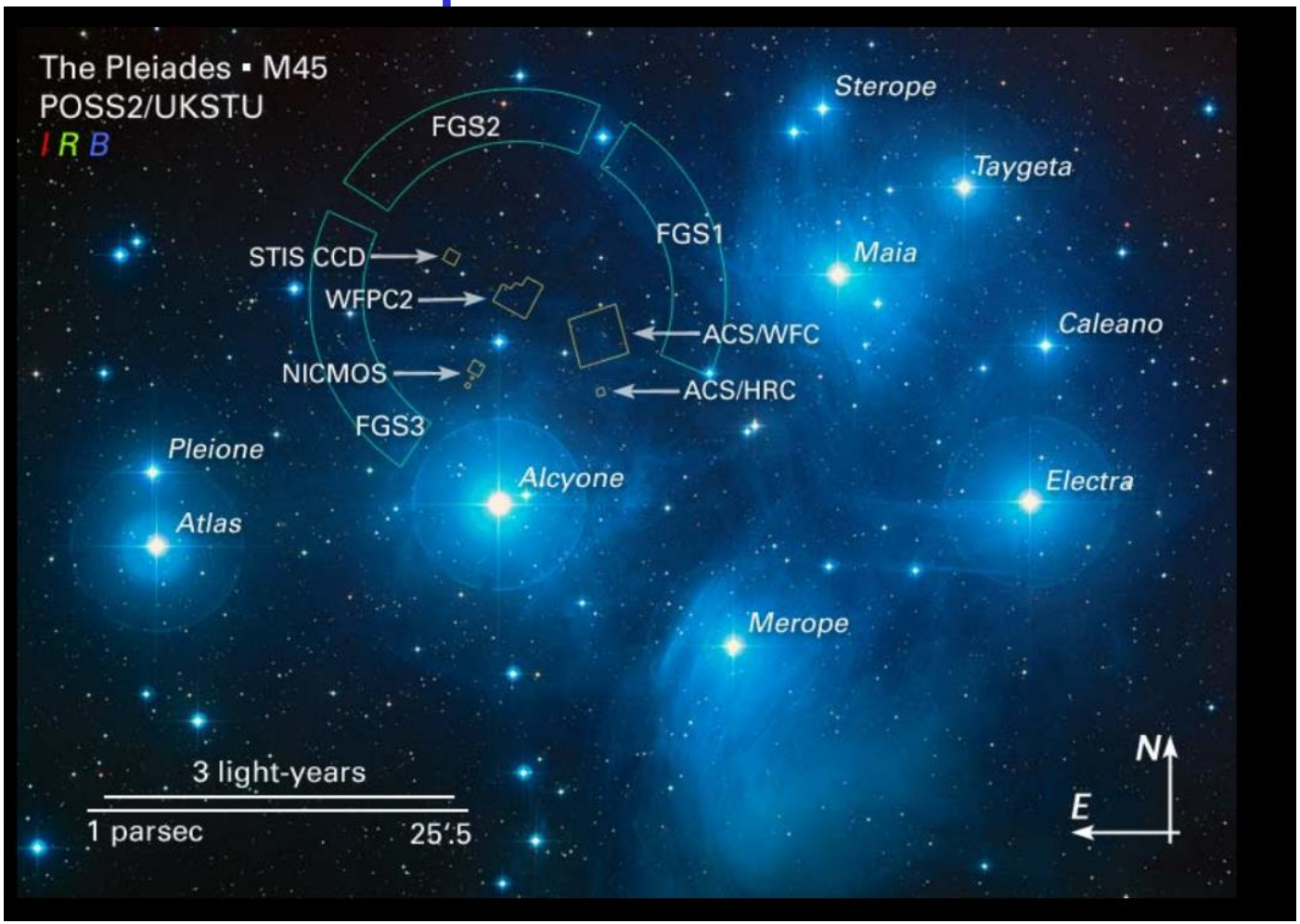
Open Star Clusters - Pleiades

"Seven Sisters" being chased by Orion the hunter (Greek), Orion also chasing Taurus the bull. Called Subaru star cluster in Japan

Subaru Car insignia

Subaru Telescope Hawaii

Open Star Clusters - Pleiades



Also have emission nebula around some stars.
6 brightest stars can be seen by unaided eye if in dark locale and you have good eyesight

7 daughters of Atlas and Pleinoe: Alcyone, Merope, Electra, Caleano, Taygeta, Maia (mother of Hermes), Sterope

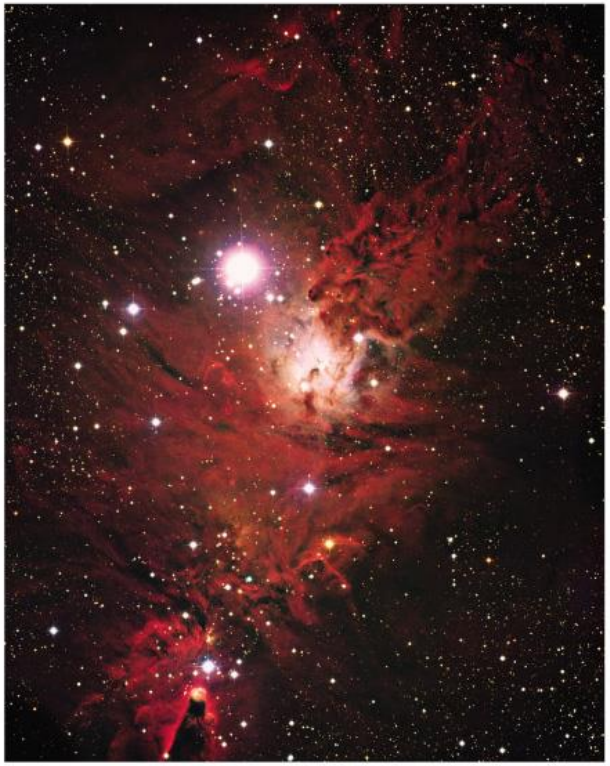
Globular Star Clusters

"fuzzy cotton ball" by eye or with modest telescope

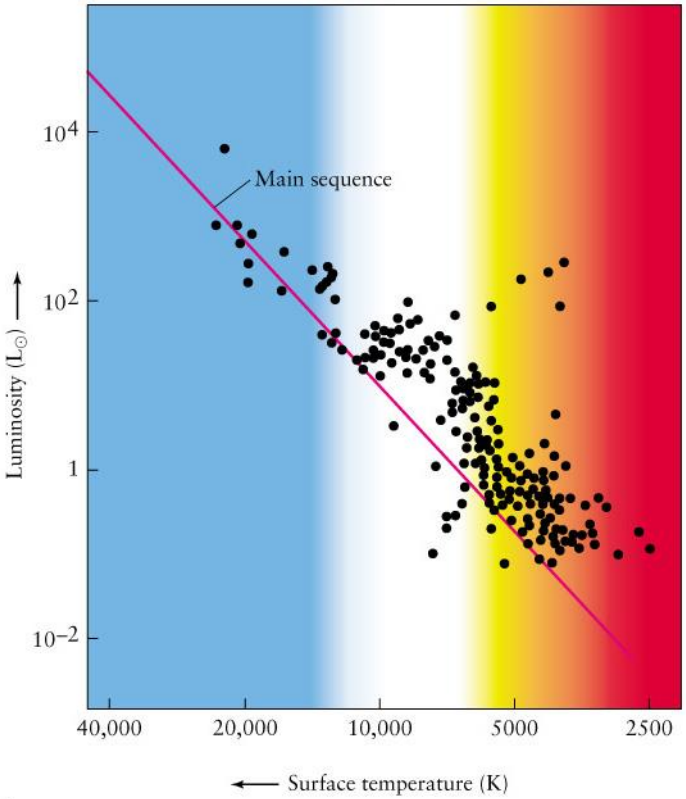
- usually dim red stars
- dense with 100,000 stars in 50-300 LY region with less than one light year separating stars
- no heavy elements. Just Hydrogen and Helium
- often outside plane of galaxy

Understood as group of old stars formed in early history of the galaxy 3-12 billion years old

Very Young (few million years) Star Cluster



NGC 2264



"moving" to main sequence

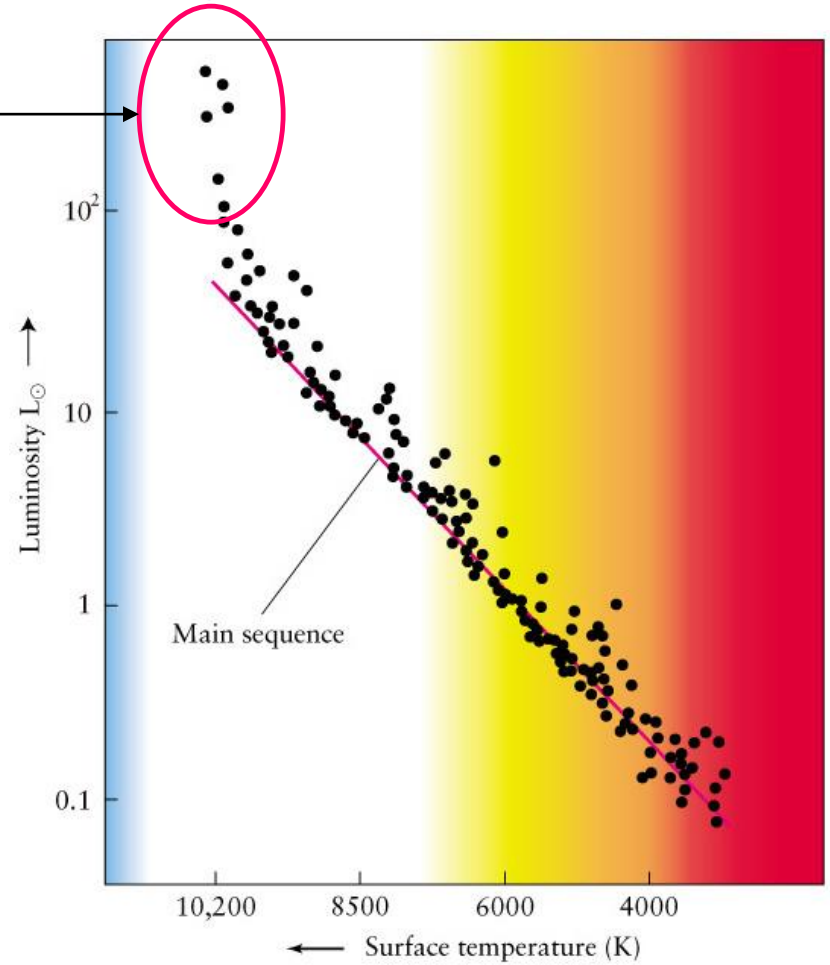
Note many more low mass stars

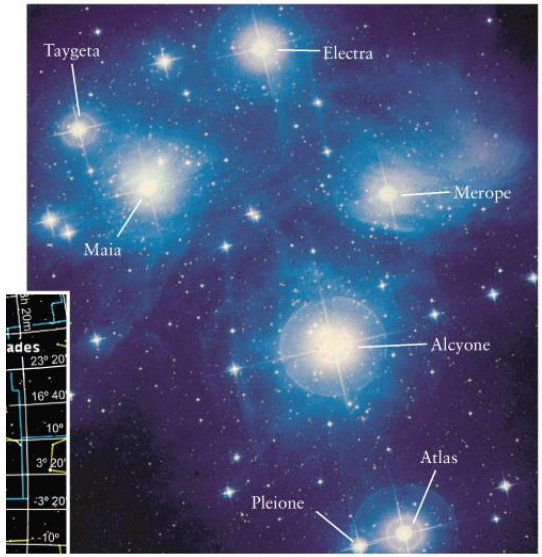
Some with high surface temp (25,000) have made it to the main sequence

Stars in nebula region, typical of young stars

100 million year old Star Cluster

Six brightest stars can be seen by unaided eye.





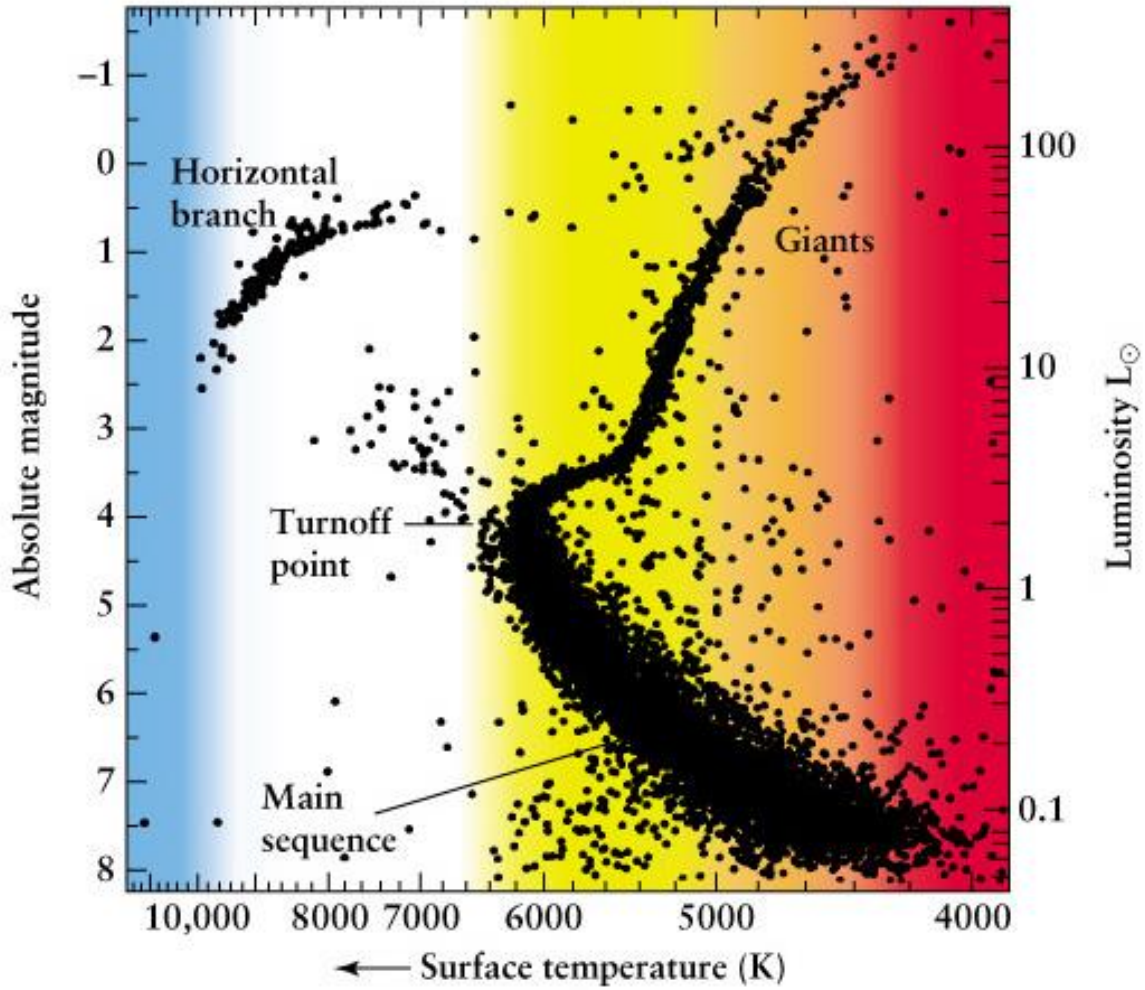
PLEIADES

largest stars

"moving" off main sequence to become giants

Modest highest temp (10,000). Larger and hotter stars have "disappeared" mostly as supernovas

5 billion year old Star Cluster



largest stars are gone

stars little more massive the Sun have become giants

Highest temp on main sequence now 6200

Many small stars with low surface temperature remain on main sequence

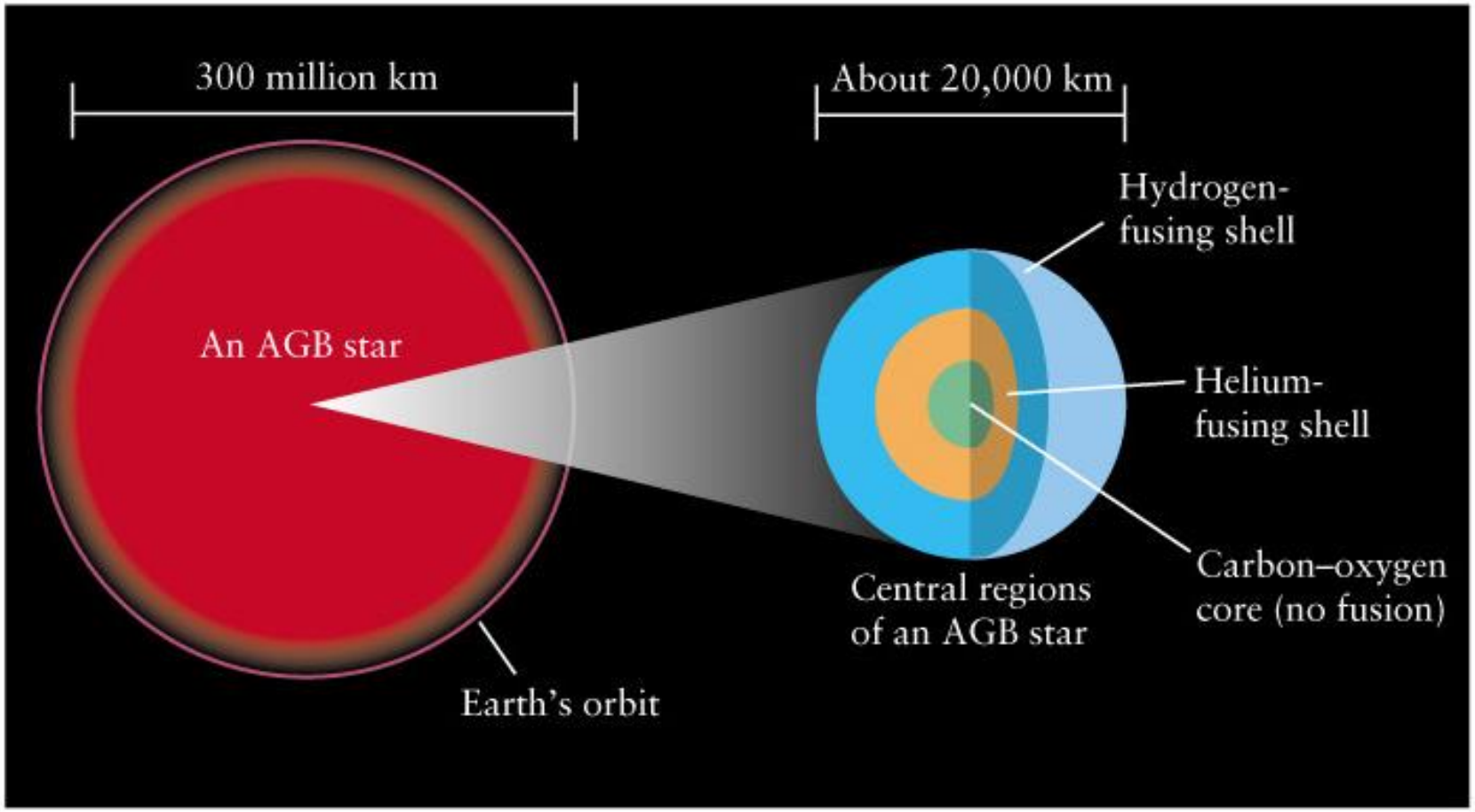
Fate of Stars

INITIAL MASS	Final State
relative to Sun's mass	
M < 0.01	Planet Never a star
.01 < M < .08	Brown dwarf (not true star)
0.08 < M < 0.25	not Red Giant→ White Dwarf
0.25 < M < 12	Red Giant→White Dwarf
12 < M < 40	Supernova: neutron star
M > 40	Supernova: black hole

2017: Some very massive stars go directly to a Black Hole without a supernova. Postulated for a while as the number of massive stars seems greater that the number of SN remnants. A BH has been detected without a SN remnant, which seems to confirm this. Some WD can become SN by acquiring mass from companion star

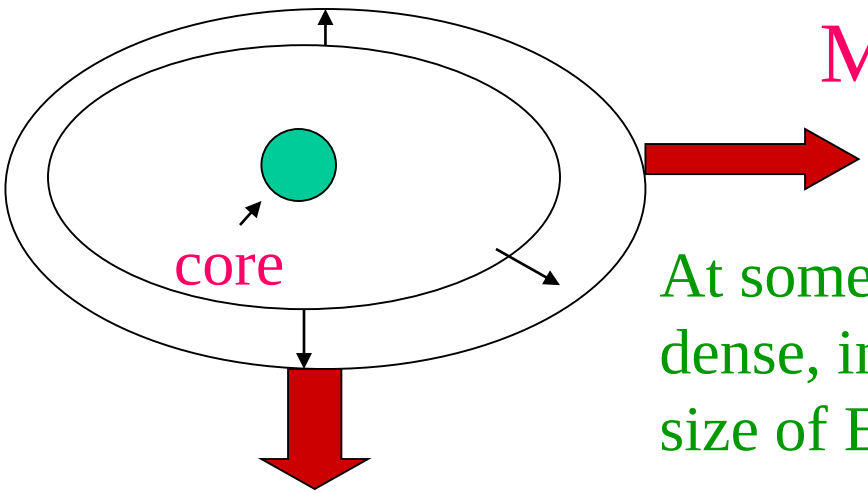
Red Giants → White Dwarves

- for "light" stars (less than 10 times the mass of the Sun) burning of He to Carbon creates Oxygen (whose mass is slightly less than He+C mass) which is final fusion stage and an inert C-O core (no fusion) is built up inside the Red Giant



Red Giants → White Dwarves II

- Stars "oscillate" (change radius growing bigger and then smaller) and lose over 1/2 of their mass during Red Giant phase



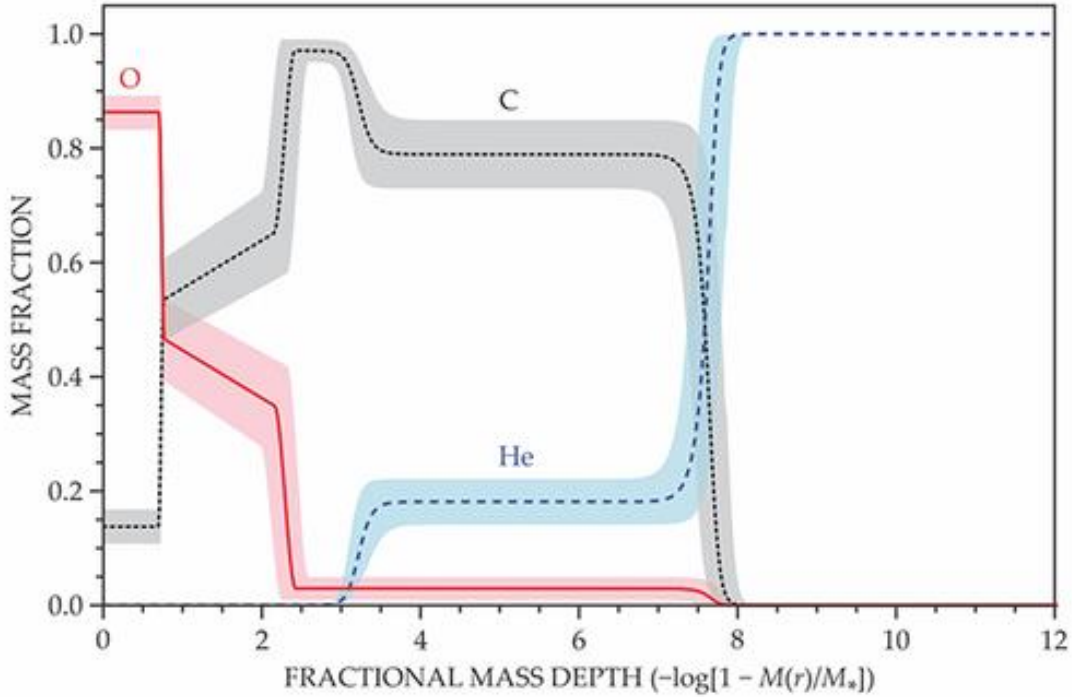
Mass being lost

At some point all that is left is the hot, dense, inert (no fusion) C/O core about size of Earth: WHITE DWARF

Will slowly cool down over time

White Dwarves

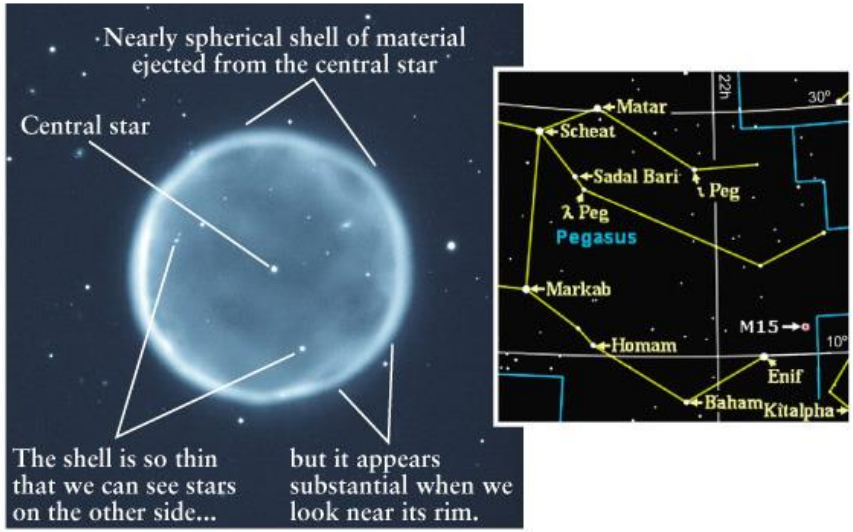
- About 0.4 – 1.4 times the mass of the Sun and about the size of the earth. Composed of oxygen, carbon, and some helium
- By looking at the variation in the light from a white dwarf, the Kepler telescope (described in the exoplanet section) can use "seismology" to determine the interior composition. From Physics Today March 2018



The He is at the surface while most of the O is at the core.
WD KIC08626021
1000 LY away

Planetary Nebula

- NOT planets (historic term) the material ejected by “pulsating” Red Giant can emit light as heated up by star at center
- Can lose over half the star’s mass. Red Giant moving towards WD



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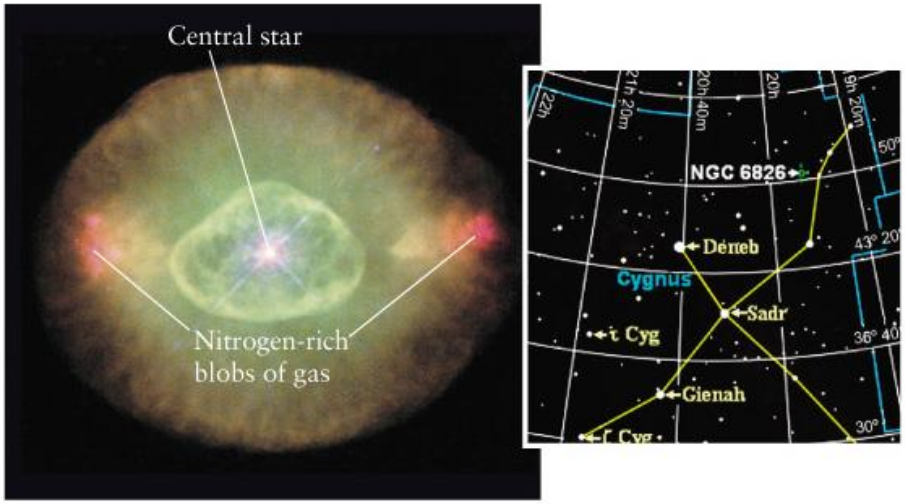
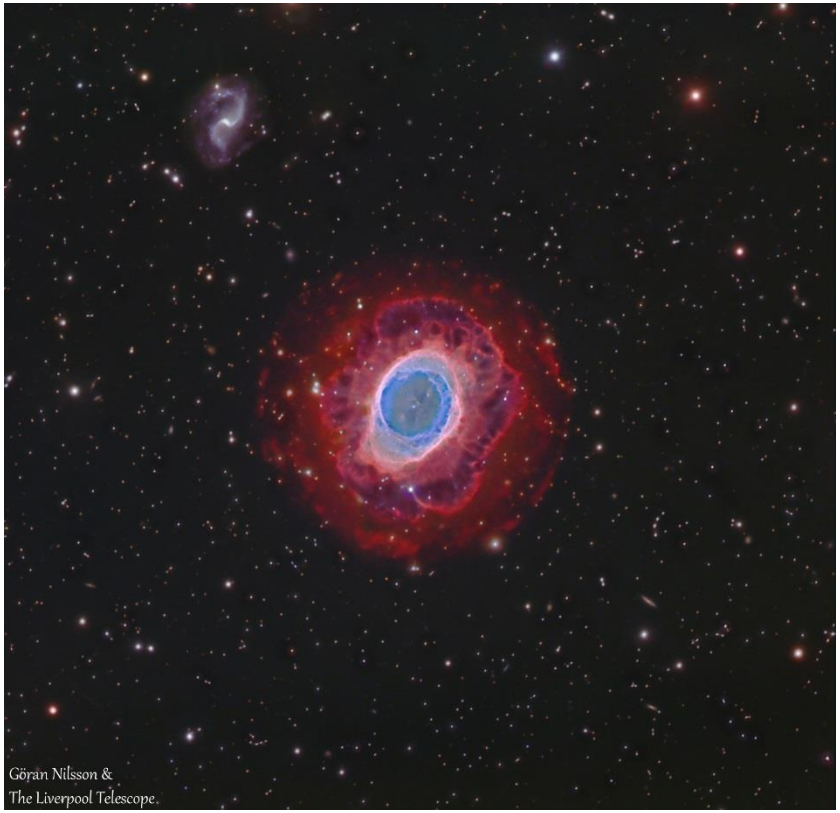
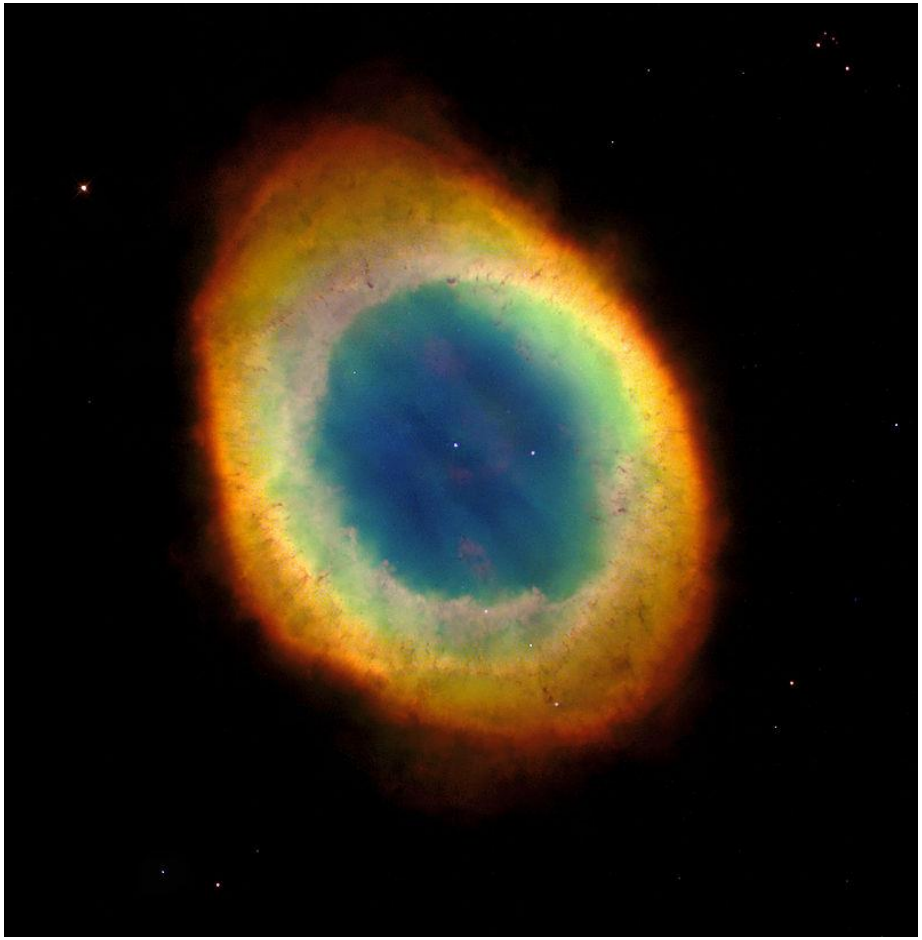


Blinking eye nebula. In Cygnus. 2000 LY away

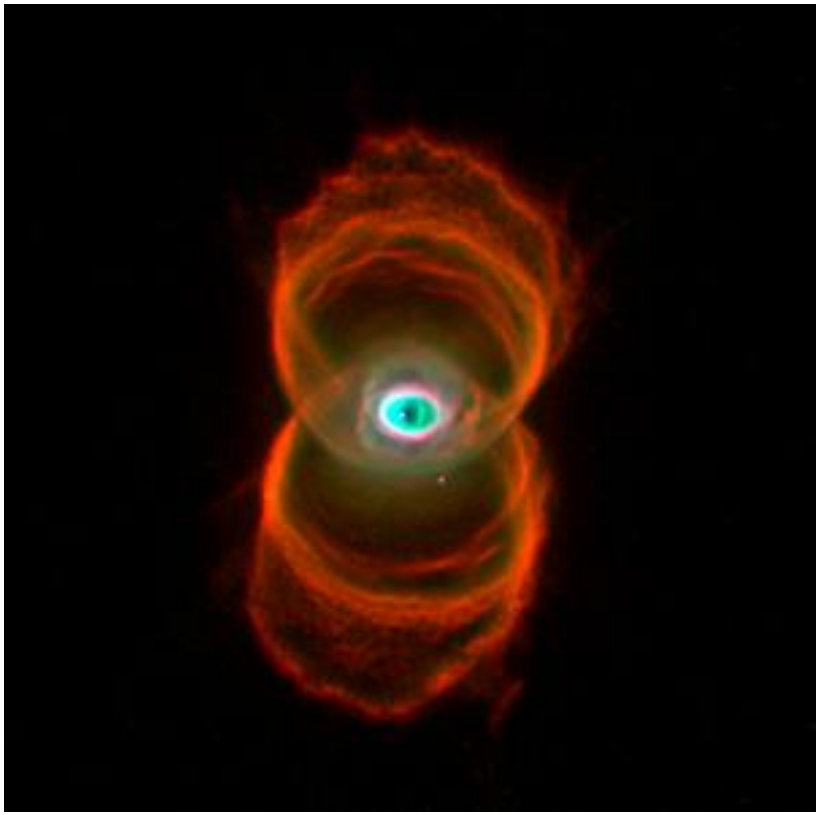
Planetary Nebula – Ring Nebula

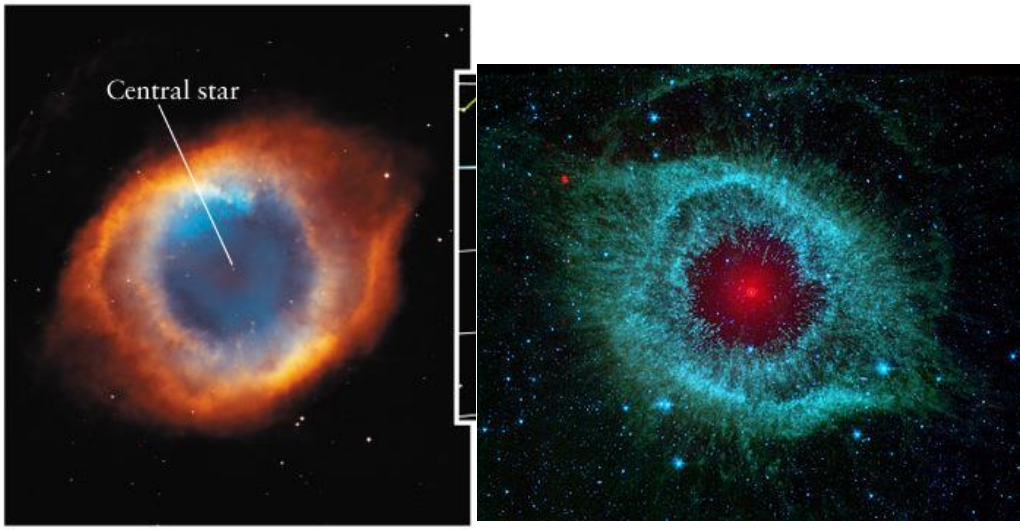




Ring nebula in Lyra M57. 2,300 LY away. Can only see with a telescope. Emission lines of Hydrogen and Oxygen are prominent

Planetary Nebula – Hourglass and Helix Nebula



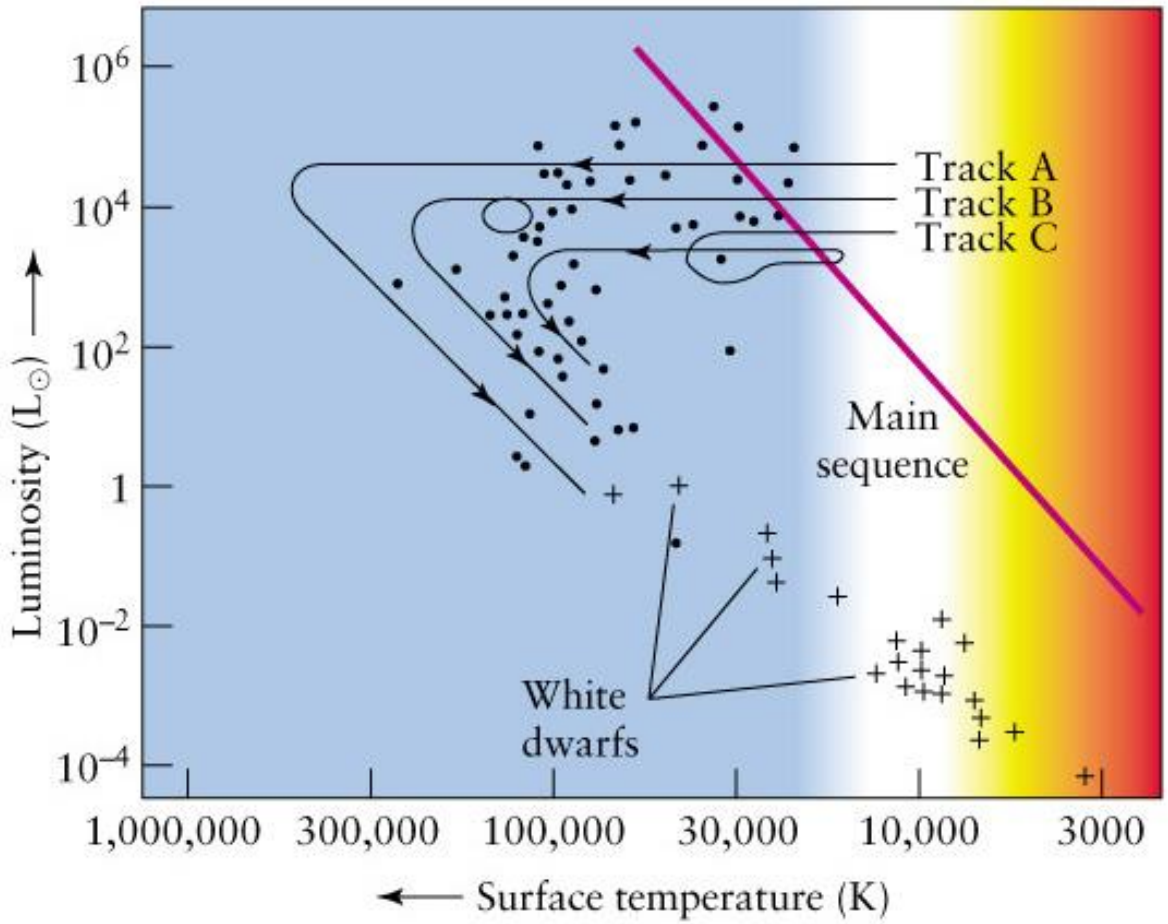


Helix nebula. In Aquarius, 700 LY away

Sometimes called “Eye of God” or “Eye of Sauron”

Hourglass nebula in constellation Musca. 8,000 LY away. Helium, oxygen, nitrogen, carbon shells give different colors

Red Giant→White Dwarves

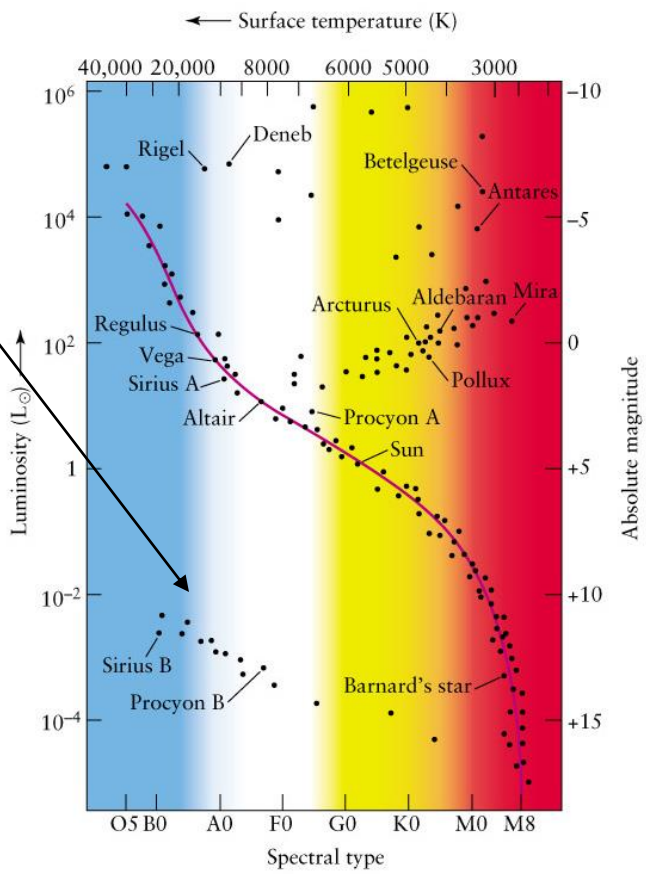


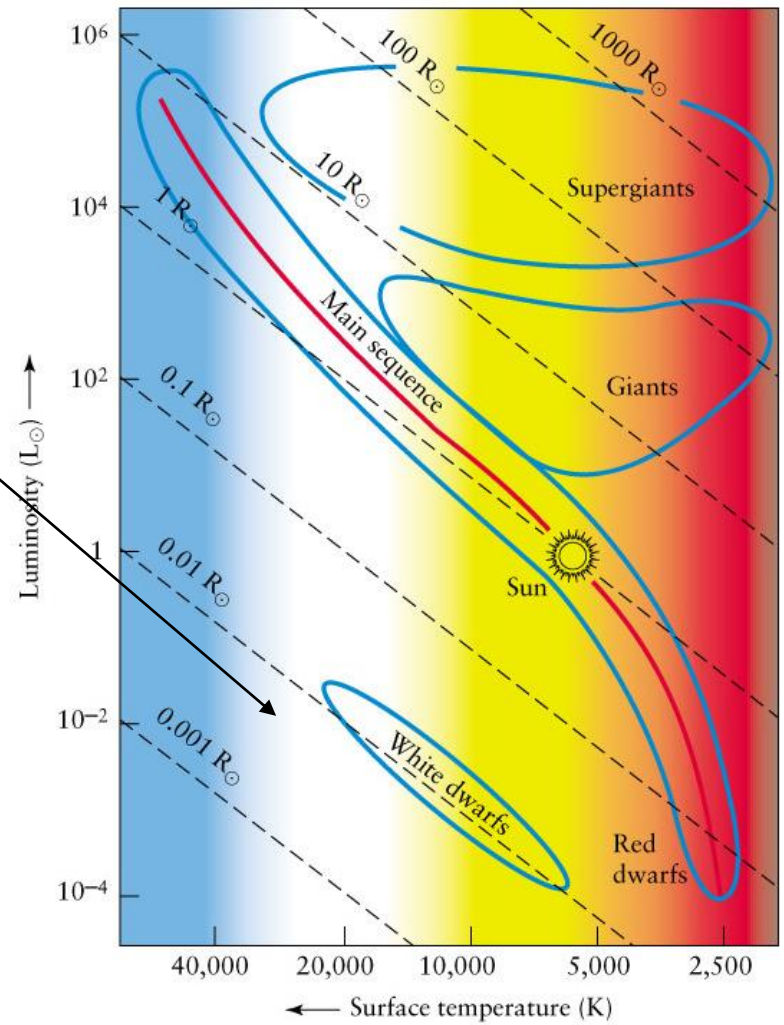
Evolution of star changes its position on HR diagram over time

Star becomes smaller but hotter as inner layers being exposed. Note very high surface temperatures which cool down very rapidly from about 200,000 degrees to 40,000 degrees.

Hertzprung-Russell Diagram Reminder

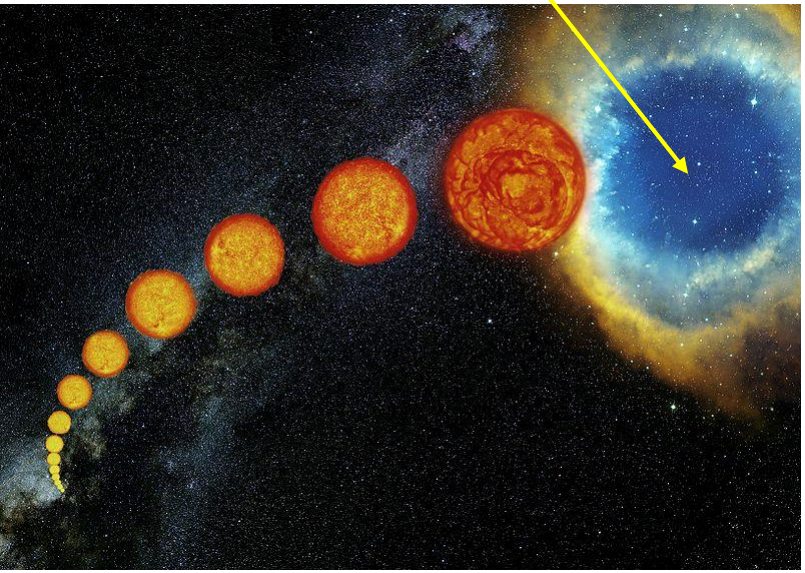
Plot Luminosity versus surface temperature. Star size is diagonal line large stars in upper right hand corner. White Dwarf radius 0.01 Sun = size of Earth

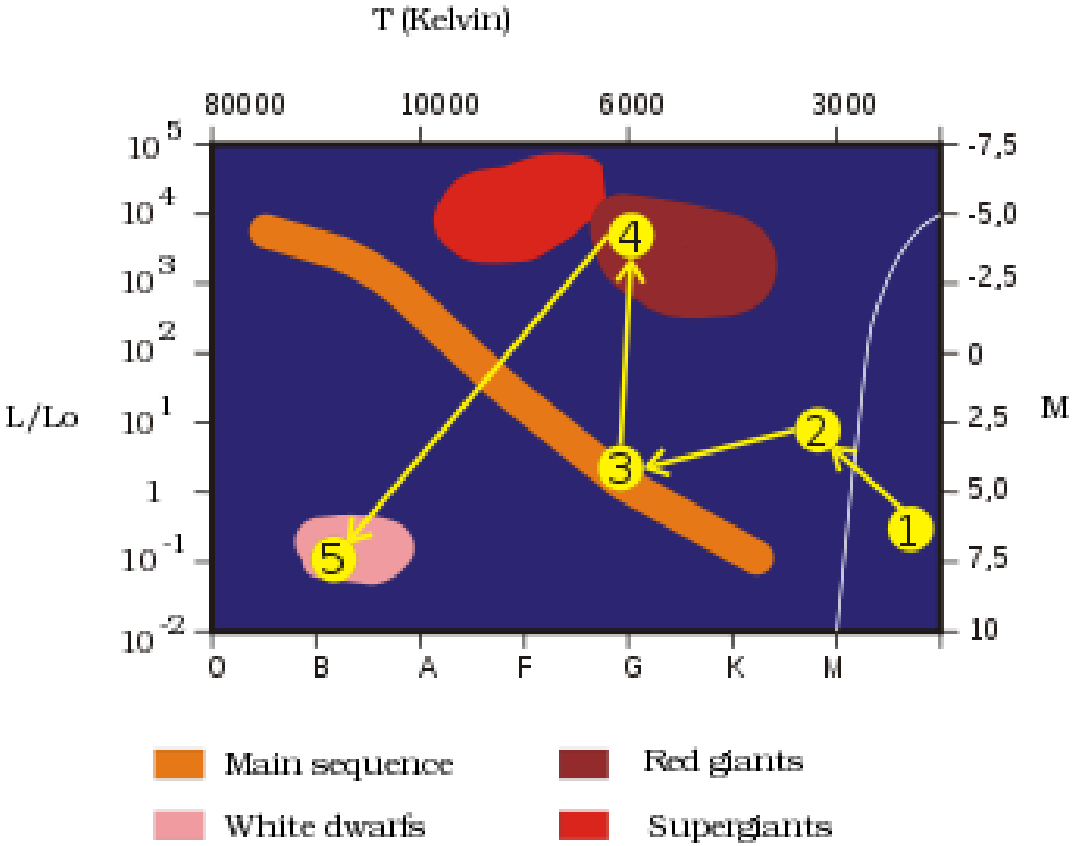




Sun: Main Sequence→Red Giant→White Dwarves

white dwarf





Lecture Feedback

E-mail me a few sentences describing one topic you learned from this set of presentations. Please include the phrase “White dwarves are about the size of the Earth but have about the mass of the Sun” in your mini-report but do not use that as your “one topic”.