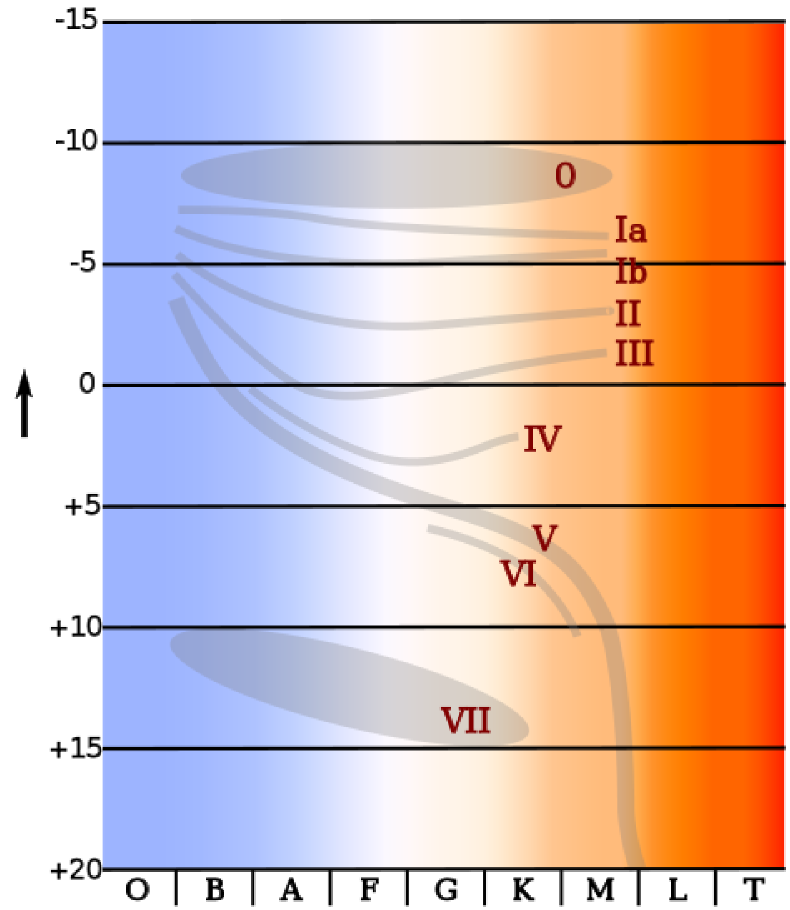
Stellar Evolution

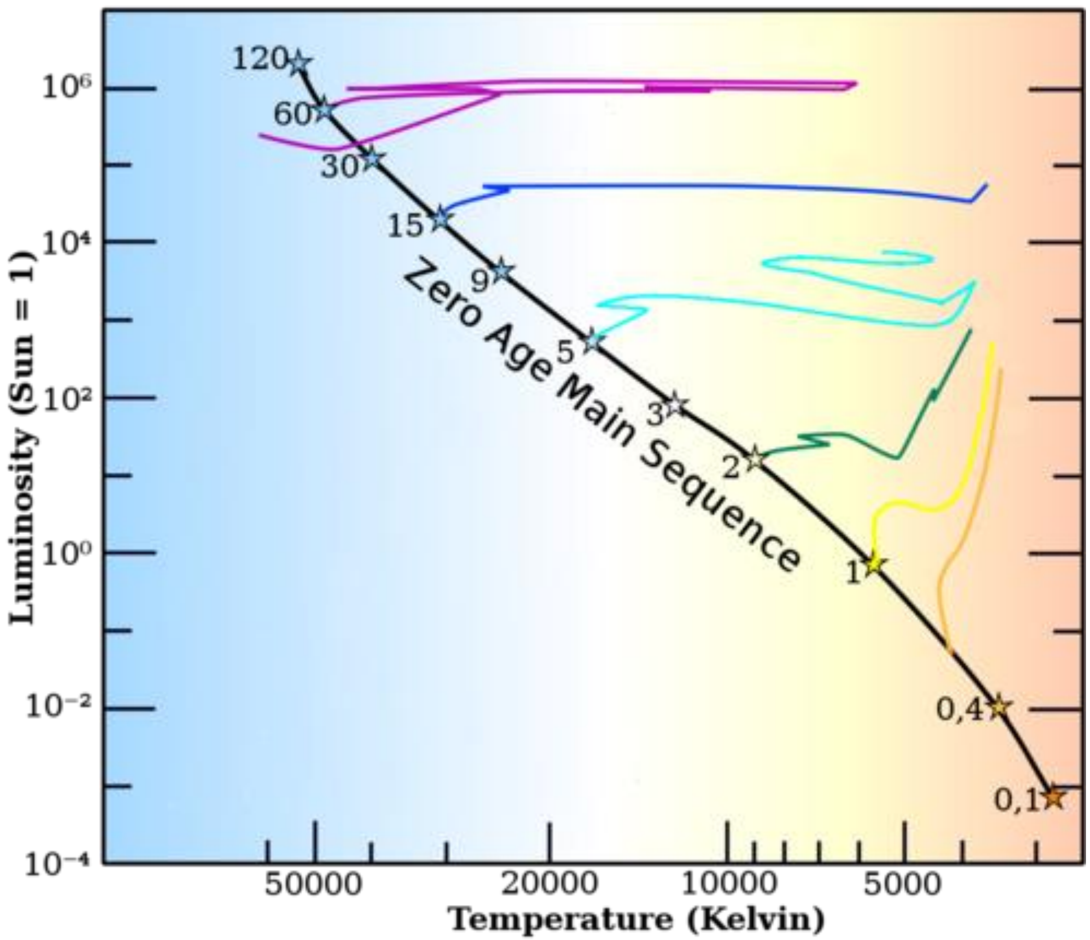
From Protostars to Black Holes

Absolute magnitude/Spectral type

0 – Hypergiants
Ia, Ib – Super-giants
II – Bright Giants
III – Giants
IV – Sub-giants
V – Main Sequence
VI – Sub-dwarfs
VII – White dwarfs



Hertzsprung-Russel diagram



Young Stars

- Protostars – Condensed, super-hot gas clouds
- Hydrogen fusion
  - More massive stars reach about 10 million Kelvin thus allowing the fusion of Hydrogen
  - Star enters the Main Sequence
- Brown dwarfs
  - Less massive stars never hot enough for nuclear fusion of Hydrogen to occur
  - Around 0.0125 solar masses
  - Stars below this mass are sub-brown dwarfs (classified as planets if orbiting a stellar object)

Mature Stars

- Once a star runs out of Hydrogen, it leaves the main sequence
- Either
  - core becomes hot enough to fuse Helium
  - Electron degeneracy pressure balances gravitational forces causing stability

Which process occurs depends upon the mass of the star.

Low-mass stars

- Red dwarfs – low temperature, low intensity
- Post-fusion behaviour has not been observed due to the age of the universe
- Models suggest
  - Red dwarfs of 0.1 solar mass could stay on main sequence for 6-12 trillion years
  - Could take hundreds of billions of years to collapse into White dwarfs

Medium-size stars

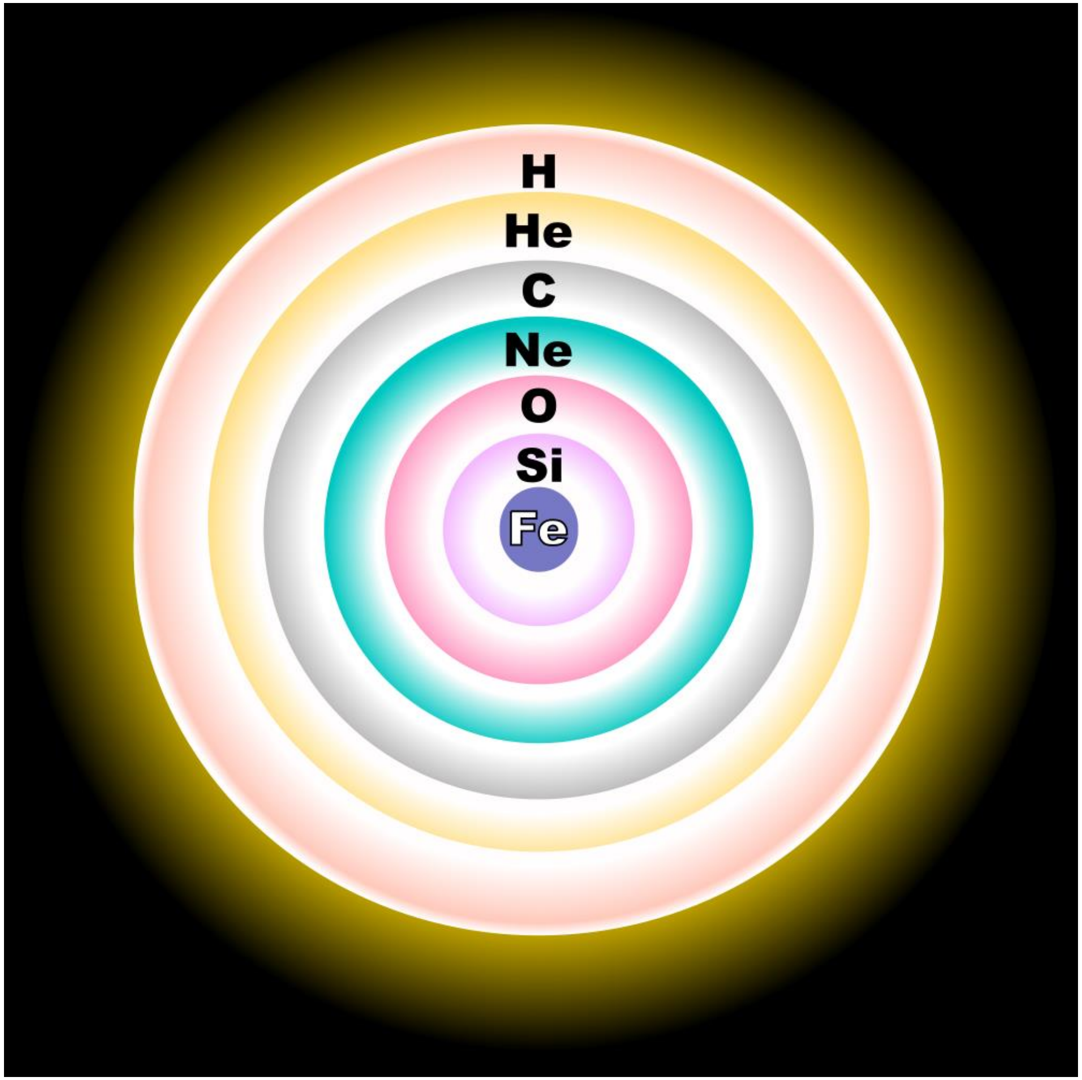
- 0.5-10 solar masses -> Red Giants
- Accelerated fusion in outer layers causes expansion
- Furthest out layers begin to cool so star becomes more red
- Red-giant-branch phase – inert Helium core
- Asymptotic-giant-branch phase – inert Carbon core

Massive stars

- Red Supergiants – brighter than red giants, hotter
- Unlikely to survive -> Supernova
- Extremely massive stars lose envelope gasses due to rapid stellar winds
  - Do not expand into super giants
  - Maintain very high surface temperatures (blue/white colour)

Star Collapse

- Temperatures are high enough that the star can fuse elements up to Iron
- Once the process reaches Iron-56, it begins to consume energy
- If the core mass exceeds the Chandrasekhar limit (2.765×10^{30} kg), the star will collapse to form a Neutron star
- Exceeding the Tolman–Oppenheimer–Volkoff limit, (1.5-3.0 solar masses) leads to the formation of a Black Hole



Supernova

- A star collapse is accompanied by a supernova
- Explosion brighter than a galaxy
- Lasts for a few weeks
- Radiation burst expels star’s material at about 30,000 km/s
- Leaves behind a gas and dust cloud – Supernova Remnant

Stellar Remnants

- White and Black dwarfs
  - 0.6 solar mass compressed to the size of the Earth
  - Extremely hot (100,000 K at surface)
  - Once all material is burned, a cold, dark star is formed – Black dwarf (yet to be observed)
- Neutron Stars
  - core collapse -> electron capture, protons -> neutrons
  - Radius ~10km, incredibly dense
  - Rotational period of less than a few seconds
  - Radiation pulses can be detected from each revolution, range from radio to gamma rays (pulsars)
- Black Holes