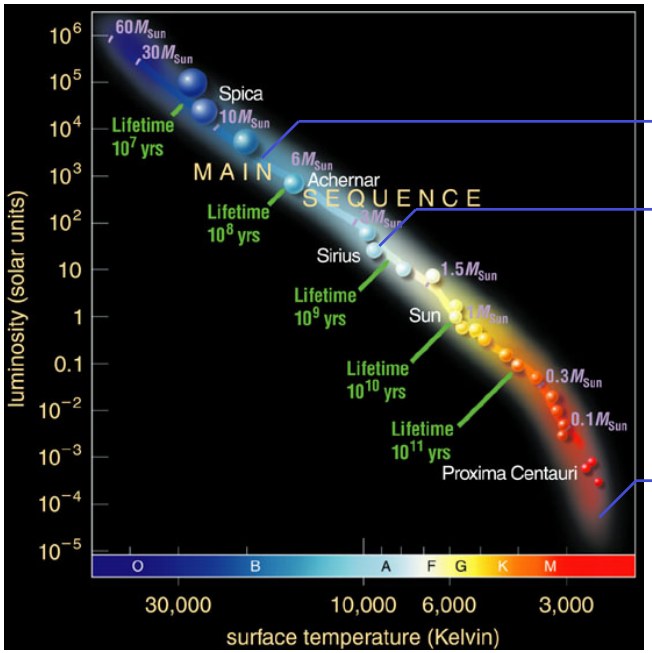
Agenda for Ast 309N, Oct. 18

- Quiz 5
- Evolution of low-mass stars: protostar to red giant
- A few animations and videos
- Participation card
- Reading for this week:
  - Kaler, ch. 3; Wheeler, pp. 27 – 37

Stellar Life Stories

- Stars are born, mature, and die.
- A star's mass determines what life path it will take.
- We divide all stars into two broad groups:
  - Low and Intermediate Mass (up to 8 $M_\odot$)
  - High Mass (greater than 8 $M_\odot$)
- The first group ends their lives as *white dwarfs*; the high-mass stars end up as *neutron stars* or *black holes*.
- We "track" the life story of a star through its changing position in the H-R Diagram (changes in L, R, and T). This trace is called an "evolutionary track."



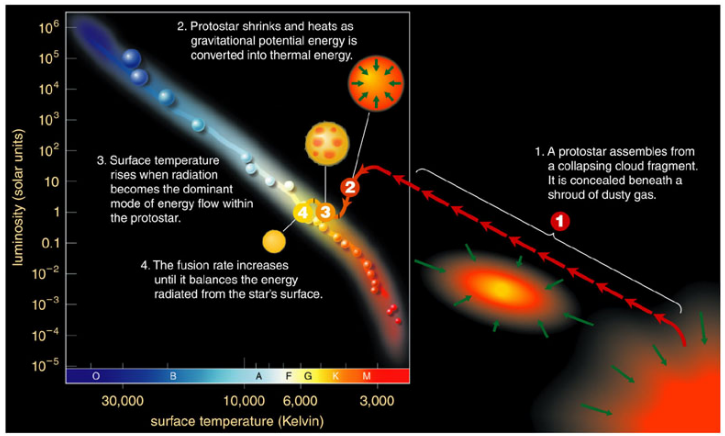
High-Mass Stars
> 8 $M_\odot$

Intermediate-Mass Stars

Low-Mass Stars
< 2 $M_\odot$

Brown Dwarfs

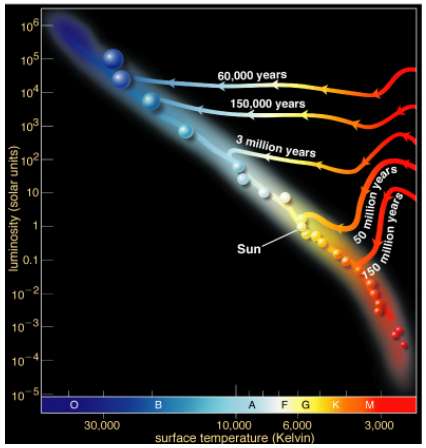
Pre-Main Sequence Evolutionary Track



The Pre-Main Sequence (Protostar) Phase

- As a contracting protostar heats up, thermal energy is radiated away from the surface, enabling it to continue collapsing.
  - at first, energy is transported to surface via **convection**
  - as core gets hotter, transport via **radiation** takes over
- Due to conservation of angular momentum, the protostar spins faster; it must get rid of some of this angular momentum, or it will tear itself apart
  - Most of the angular momentum goes into the spinning disk
  - Outflows may develop, in the form of "jets" (these are seen)
  - The protostar may break up into two stars (a binary system)
- **Fusion reactions begin when core reaches 10^7 K.**

Arrival on the Main Sequence

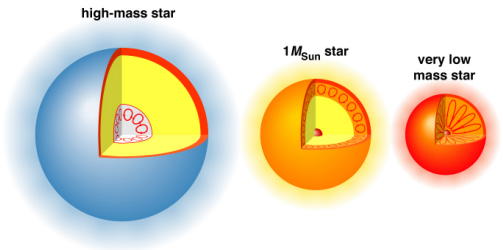


- The mass of the protostar determines:
  - how long the protostar phase will last (higher-mass stars do everything faster)
  - where the newborn star lands on the Main Sequence
  - what spectral type the star will have on the main sequence

The Internal Structure of Stars

- The life of any star can be described as a battle between gravity (inwards) vs. pressure (outwards)
- Gravity wants everything to collapse to the center.
- Pressure resists gravity and holds up the star.
  - in most stars it is *thermal pressure* that does this
  - in special cases, it is *degeneracy (quantum) pressure*
- Remember Newton's Law of Gravity
  - the amount of gravitational force depends on the mass
  - gravitational potential energy is turned into heat as a star collapses, enabling fusion reactions to begin

The Structure of Main Sequence Stars

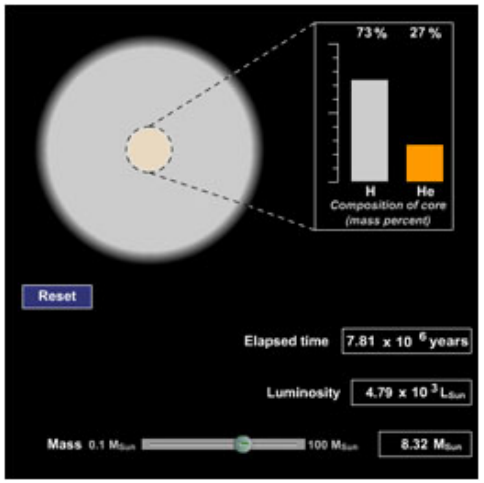


Main Sequence stars of different masses have different arrangements of radiation and convection zones in their interiors.

These stars stay on the Main Sequence until they use up their fuel

More massive stars *start out* with more fuel, but because they are more luminous, they use up their fuel faster.

Stellar Aging ("Evolution")

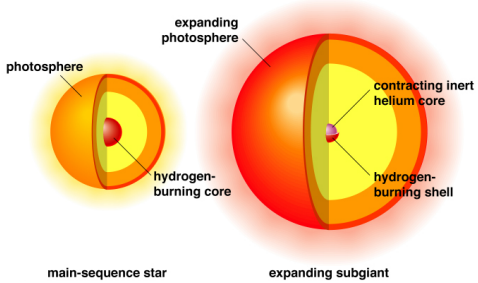


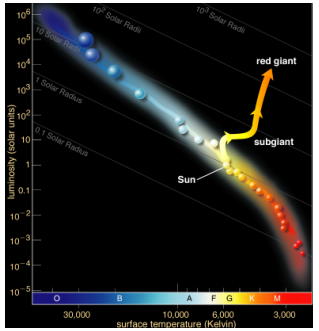
A star remains on the Main Sequence as long as it can fuse hydrogen into helium in its core

Things change only when it has used up ("exhausted") all the H in its core, & the star leaves the Main Sequence.

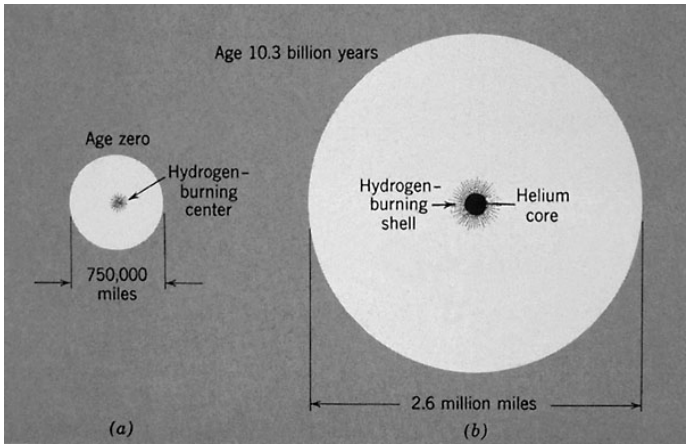
Leaving the Main Sequence

- The core begins to contract
  - the region just above the core heats up & H fusion begins there; this is called a "**hydrogen-burning shell**"
  - the higher pressure in this hot region pushes outward, so the outer layers of the star expand. It becomes a red giant.

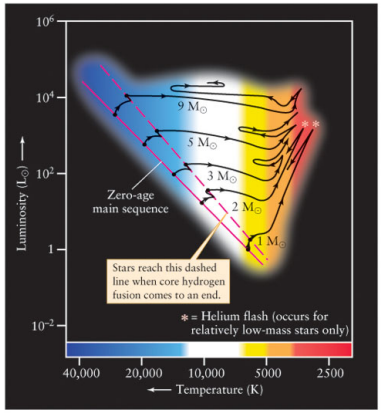




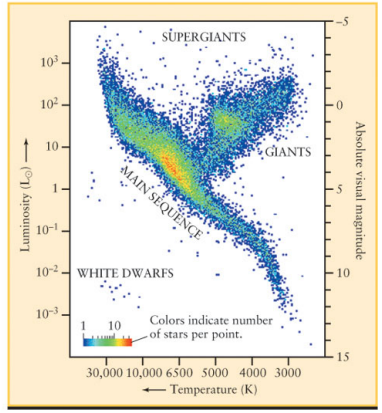
The Main Sequence vs. Red Giant Sun



Evolution off the Main Sequence



(a) Post-main-sequence evolutionary tracks of five stars with different mass

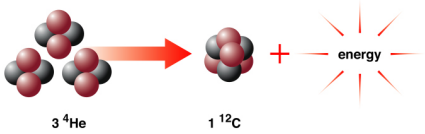


(b) H-R diagram of 20,853 stars—note the width of the main sequence

Helium "Burning" (Fusion)

The He core contracts until it heats up to 10^8 K

- **He fusion begins** (3 He ⇒ 1 C, + He ⇒ O)
- sometimes called the **"triple-α process"**



The star, now fusing He in its core, is again stable.

- gravity vs. pressure from He fusion reactions
- red giants create and release most of the Carbon from which organic molecules (and life) are made

Core Helium-Burning Stage

When He fusion begins in the core, the star becomes smaller and hotter - moves onto what we call the 'horizontal branch.'