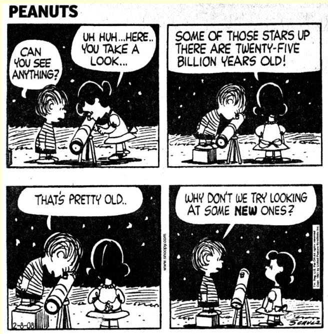
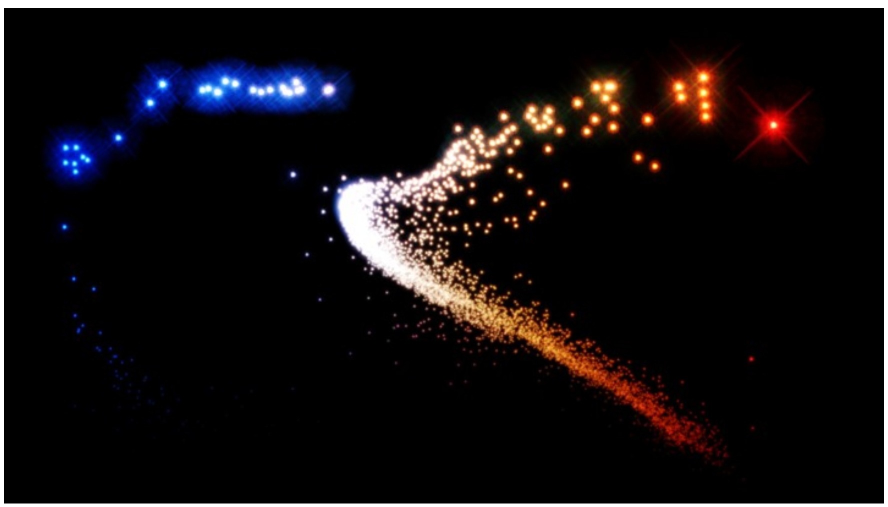
Agenda for Ast 309N, Sep. 27



- Quiz 3
- The role of stellar mass
- Ages of star clusters
- Exam 1, Thurs. Oct. 4
  Study guide out on 9/28
- Next topic: brown dwarfs and extrasolar planets

This image of the central part of the globular cluster Omega Centauri was taken with the Hubble Space Telescope. Let's organize the stars according to their observed properties.



After sorting the stars by color (left to right) and brightness (top to bottom), we have a **Hertzsprung-Russell (HR) Diagram!**

Measuring Masses from Binary Stars

- In Ast 301, you should have learned about Newton's form of Kepler's Third Law:

$$P^2 = \frac{4\pi^2}{G(M_1+M_2)} a^3 \qquad \text{OR} \qquad M_1+M_2 = \left(\frac{4\pi^2}{G}\right)\frac{a^3}{P^2}$$

- A more convenient form, derived by scaling by the Sun-Earth system, we have:

$$\left(\frac{M_1+M_2}{M_{Sun}}\right) = \frac{(a/A.U.)^3}{(P/yr)^2}$$

The Mass-Luminosity Relation

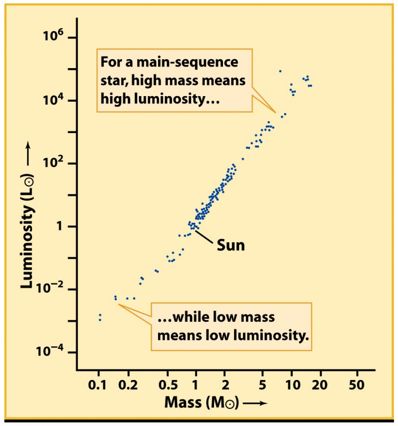


Figure 17-21
Universe, Eighth Edition
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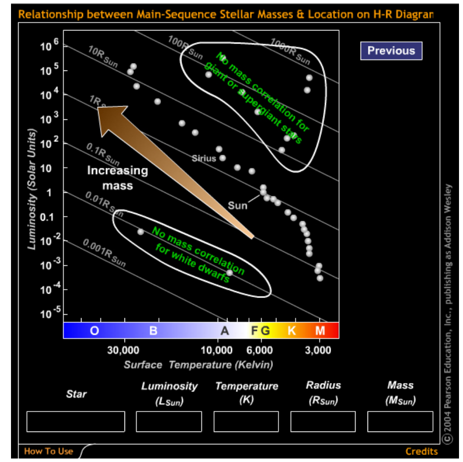
By compiling results from many binary stars, it was discovered that there is a relationship between mass and luminosity.

But note: this holds <u>only</u> for stars on the Main Sequence.

The Main Sequence is a sequence in ***mass***



It's a fairly common misconception that stars evolve by moving along (e.g. down) the Main Sequence; this is **not** the case.

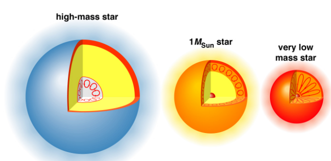
In fact, each point on the Main Sequence is occupied by stars of a specific initial mass.

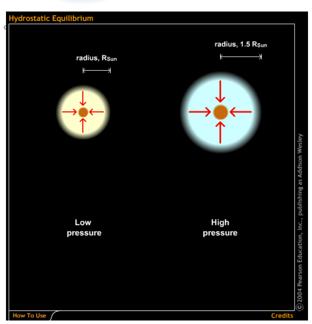
Why is there a Mass-Luminosity Relation?

- All Main sequence stars fuse H → He in their cores.
- Larger masses exert greater weight (force) at center
- Requires higher central pressure to balance this
- Result: faster rate of nuclear fusion reactions

⇒ Luminosity increases strongly with mass.

L varies as mass cubed, or $L \propto M^3$





Corollary: The Mass-Lifetime Relation

The "lifetime" is the total length of a time (e.g. years) a star can stay on the Main Sequence, fusing *Hydrogen.*

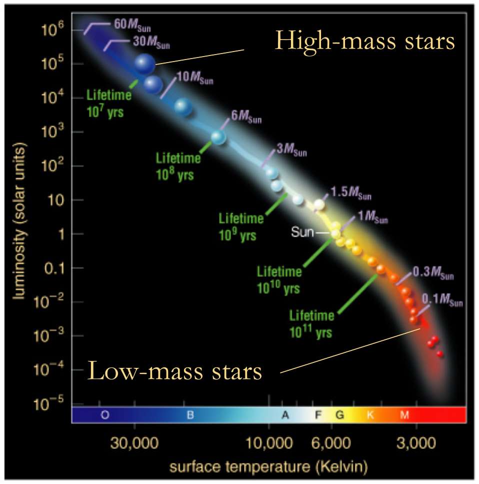
The amount of fuel is proportional to M

It is used up at a rate proportional to $L \propto M^3$

How long does it last? $M/L = M/M^3 = 1/M^2$

- High-mass stars burn fuel like a bus!
- Low-mass stars burn fuel like a compact car!
- The Sun will last 10^{10} years = 10 billion yrs.

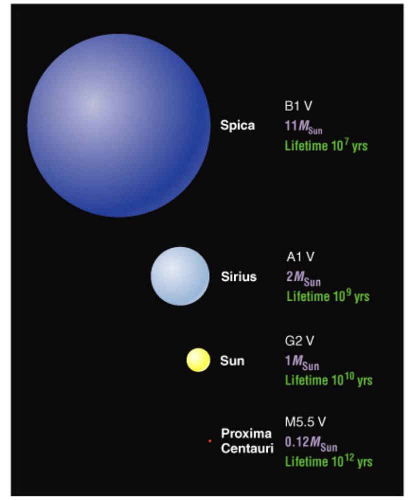
The Mass-Lifetime Relation



The mass of a star determines its spectral type, luminosity, and lifetime while on the Main Sequence.

The lowest-mass stars, 0.8 $M_{\odot}$ or below, have lifetimes greater than 13.7 billion years, the age of the Universe. So such stars formed long ago are *still on* the Main Sequence.

Summary: Main-Sequence Stars



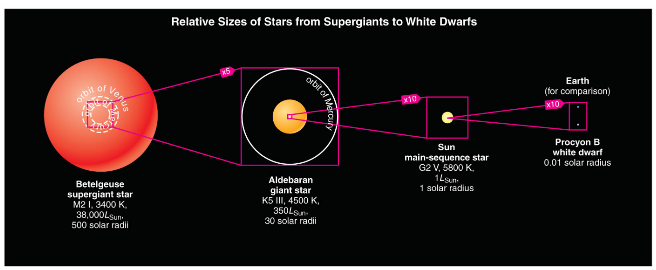
High Mass:

- High Luminosity
- Short-Lived
- Large Radius
- Hot surface (blue)

Low Mass:

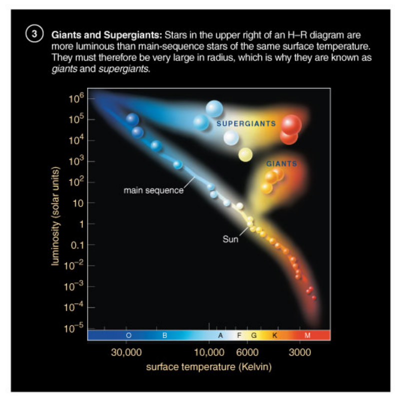
- Low Luminosity
- Long-Lived
- Small Radius
- Cool Surface (red)

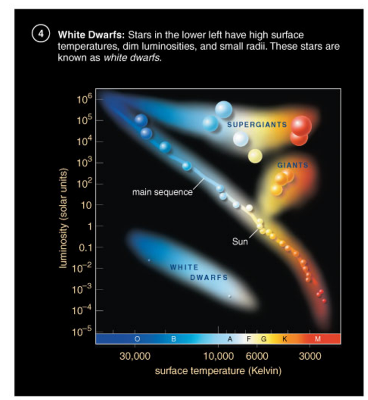
What are the non-Main Sequence stars?



- Stars that have finished fusing Hydrogen to Helium in their cores are no longer on the Main Sequence.
- Stars tend to become larger and cooler (**giants** and **supergiants**) after exhausting their core hydrogen.
- Later on, most stars end up as small, hot **white dwarfs** after fusion has ceased and the outer layers are expelled.

Non-Main Sequence stars: Giants & Dwarfs





Star Clusters: stars of all possible masses, all formed at the same place and time

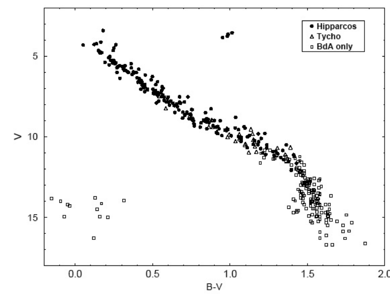
Open Clusters

A few thousand loosely packed stars, usually relatively **young**

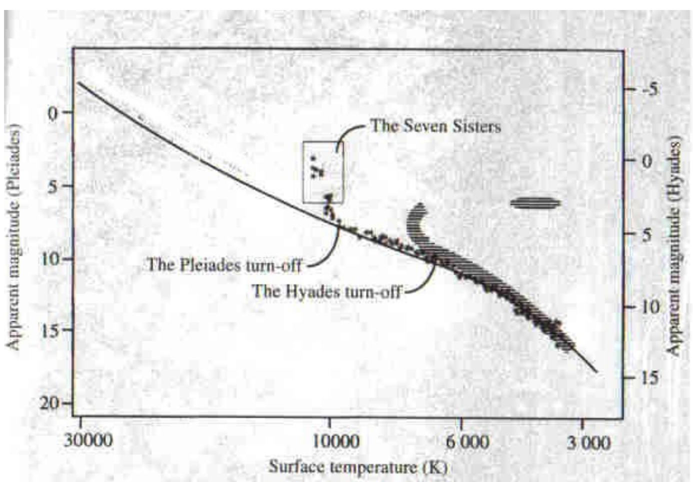
Globular Clusters

Up to a million or so stars tightly bound by gravity, usually very **old**

The Hyades: A Young Star Cluster

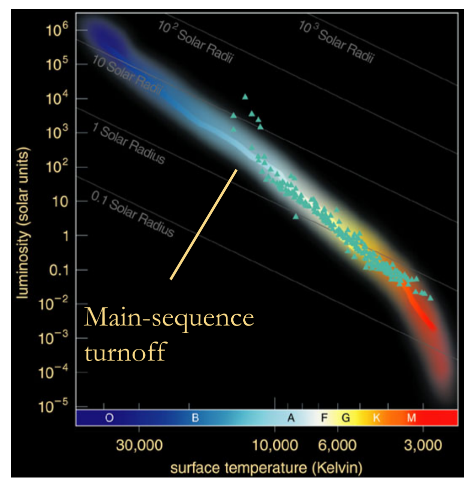


Using HR Diagrams to Find Cluster Ages

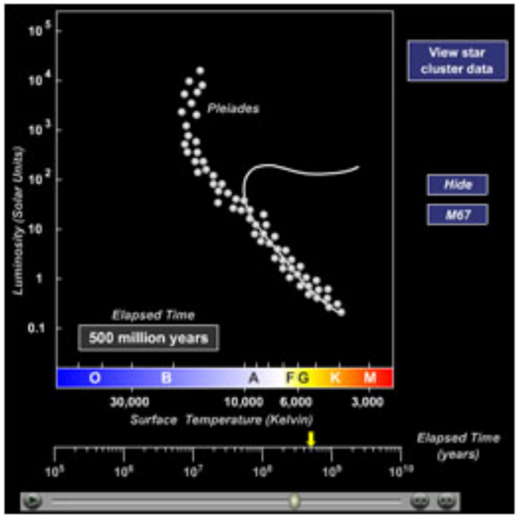


 http://bdaugherty.tripod.com/gcseAstronomy/images/HRcluster.jpg

The Main Sequence "Turn-off" Point

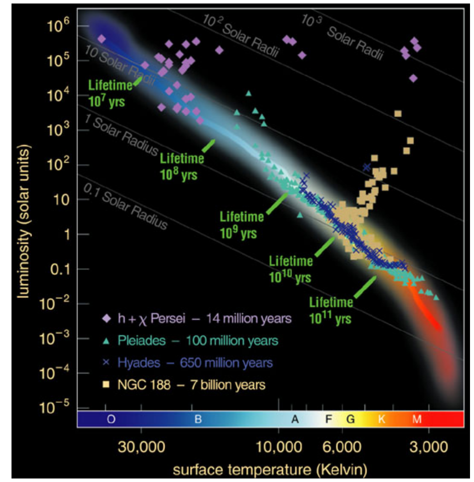


- At first, there are stars of all masses on the cluster's Main Sequence
- The most massive stars "die off" first
- As time passes, lower-mass stars begin to move off the Main Sequence
- Find this "turn-off" point: the cluster's age is equal to the Main Sequence lifetime of stars at the turn-off.



Animation of stars "peeling off" the Main Sequence, as times passes

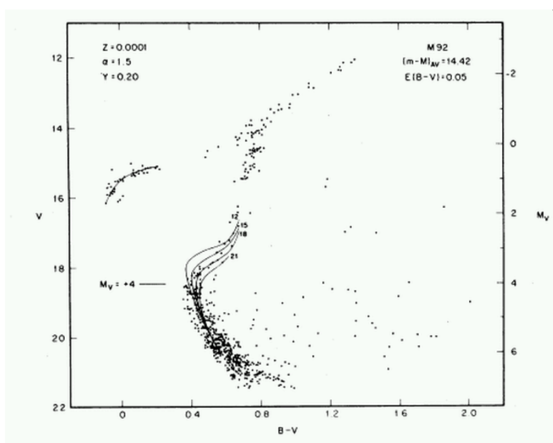
Determining the Ages of Star Clusters



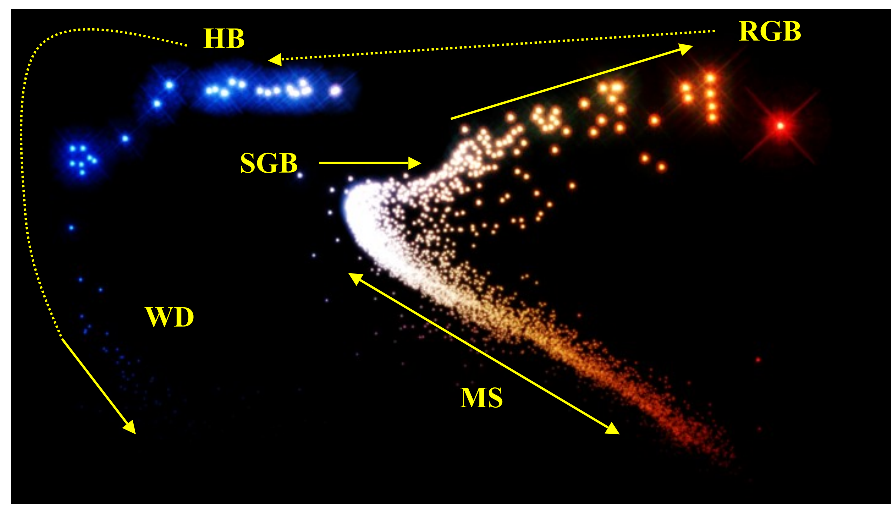
Star clusters of different ages have different turn-off points; younger ones still have high-mass Main Sequence stars, for older clusters, more of the M.S. has "peeled off."

HR Diagrams of Old Star Clusters

http://www.dur.ac.uk/ian.smail/gcCm/gcCm_intro.html



http://s94958815.onlinehome.us/angryastronomer/m92isochrones.gif



Indicated regions: Main Sequence (MS), subgiant branch (SGB), red giant branch (RGB), horizontal branch (HB), white dwarfs (WD)