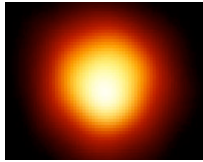
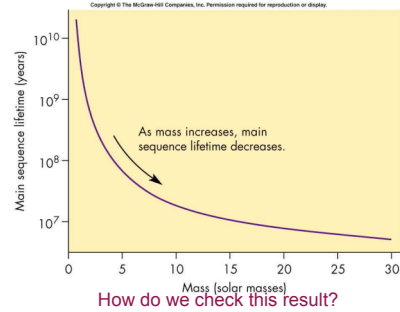


Stars after the Main Sequence. Example: Betelgeuse (Alpha Orionis)

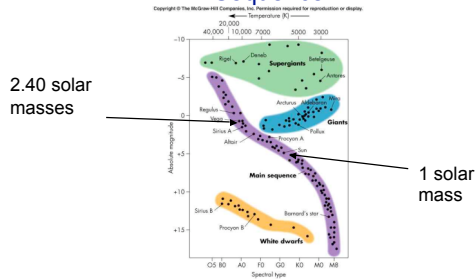


A Hubble telescope Picture of Betelgeuse

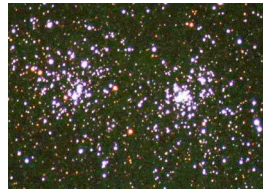
Last time, concluded that the Main Sequence lifetime of a star is strongly dependent on its mass



The masses of Main Sequence stars increase as one goes "up" the Main Sequence



A young star cluster and a "more mature" one



H & Chi Perseid.... Contain O stars



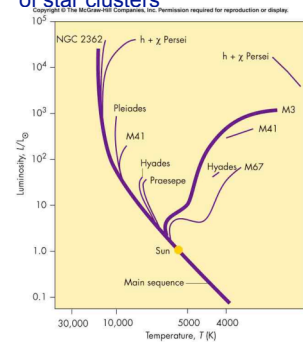
The Pleiades...no Main Sequence stars more massive than class B

M67-the most massive Main Sequence stars not much more massive than the Sun



Let's look at the Hertzsprung-Russell diagrams of star clusters

These data make sense as a sequence in age, beginning with the youngest (NGC2362) and going to the oldest (M67)



Betelgeuse is a red supergiant

Deep in its interior is a Massive, incredibly compact Stellar remnant

Size of Star

Size of Earth's Orbit

Size of Jupiter's Orbit

When you look at a Main Sequence star, the appearance of it exterior tells you what it is like inside

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Convection zone

Convection carries energy outward.

Energy produced in the core is carried outward by photons.

Nuclear burning core

Radiative zone

100%

70%

25%

0 (Core)

Nuclear reactions produce energy in the Sun's core.

In an evolved star, the appearance of the surface is not a good indicator of its deep interior

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Hydrogen-rich outer layer

Core

Hydrogen-burning shell

Helium-rich shell

Helium-burning shell

Carbon- and oxygen-rich core

As cores contract, the density goes to “astronomical” levels, matter acts in funny ways

- Gas in this room, the “perfect gas law” $PV=nRT$. Pressure depends on both density and temperature
- Extremely dense, “degenerate” gas $PV=Kn$. Pressure depends only on density
- Demo →

The structure of a star: a balance between gravity and gas pressure

Self gravity

Gas pressure

Technical term: hydrostatic equilibrium

Major result of stellar evolution: post-main sequence stars move around on the Hertzsprung-Russell diagram

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Luminosity, L/L_{\odot}

Temperature [K]

Planetary nebula

Asymptotic giant branch

Red giant

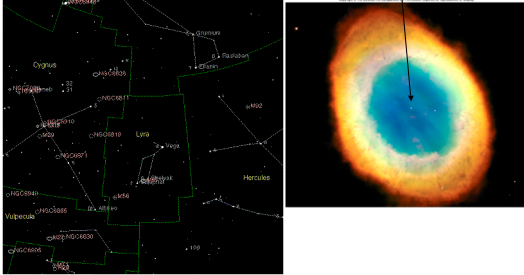
Horizontal branch

Main sequence

Pre-main sequence

White dwarf

Old evolved stars throw off their outer layers, producing objects called planetary nebulas, revealing the weird cores



Another planetary nebula: M27 (we saw it during the field trip)



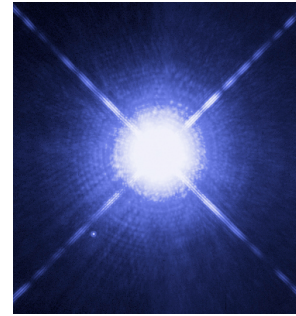
These compact cores exist...the white dwarf stars



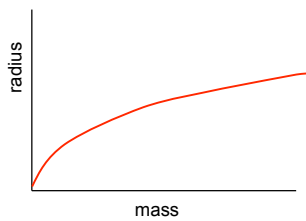
Nearby examples: Sirius B and Procyon B

The physics of white dwarf stars

- What holds them up?
- What determines their properties?

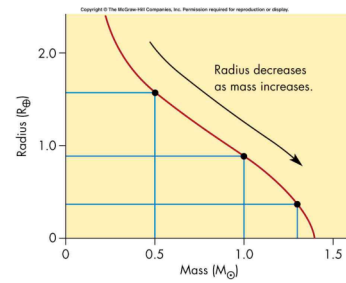


Equations give radius of white dwarf as a function of its mass



What one might expect for how R depends on M

What the solution really is for a white dwarf star



Main features to note about white dwarf solution

- Note the size: objects with masses like the sun, but radii like the Earth
- The size becomes *smaller* with increasing mass
- There is an upper limit (the Chandrasekhar mass) to the mass of a white dwarf

