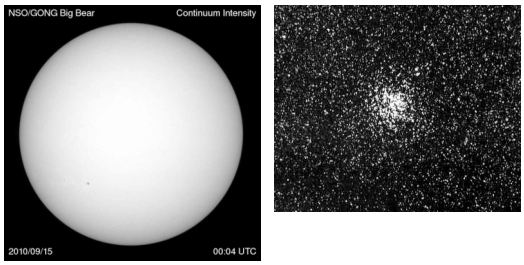
The power plant of the Sun and stars



Nuclear Reactions in Stellar Interiors

$H + H \longrightarrow {}^2H + e^+ + nu$

$H + {}^2H \longrightarrow {}^3He + gamma$

${}^3He + {}^3He \longrightarrow {}^4He + H + H$

Net effect: $4H \longrightarrow {}^4He$

Question: why does this occur exclusively in the core of a star?

Demo

A small mass difference between Hydrogen and Helium

- 4 Hydrogen atoms: 6.693E-27 kg
- 1 Helium atom: 6.645E-27 kg
- Difference = 0.048E-27 kg
- Difference = 0.7 percent

Why is this small difference important?

The Einstein Energy-Mass equivalence relation

$E=mc^2$

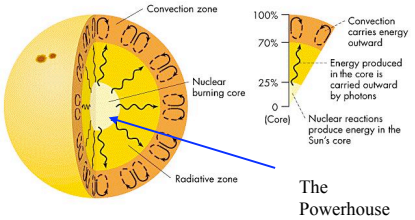
c=speed of light

You get a lot of bang for the buck: 6.3E+14 J/kg. This gives plenty of energy to power the Sun for 4.5 billion years plus

The Power Source of Main Sequence Stars

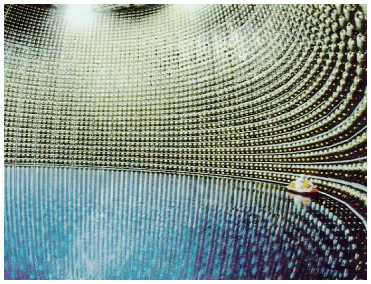
MS stars fuse hydrogen into helium, releasing prodigious amounts of energy in the process. Their fuel source is the matter of which they are made

The Structure of Main Sequence Stars

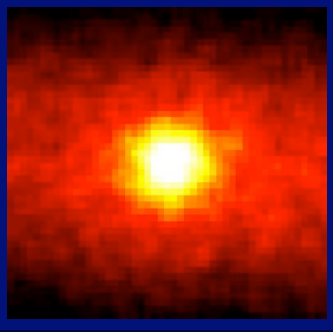


The Powerhouse

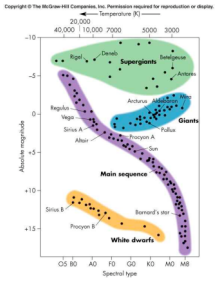
How can we tell if this is right? Detect neutrinos emitted from the center of the Sun.



The Neutrino Sun: A View into the Solar Interior



Nuclear reactions explain a lot about the Sun, but what is going on on the rest of the Main Sequence?



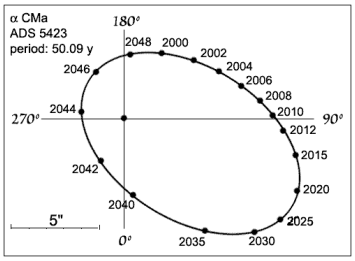
The fuel for a main sequence star is its own mass in the form of hydrogen.
The total amount of fuel is proportional to the total mass of the star.
What are the masses of stars?

How We Determine Masses of Stars

Method:observation of binary stars (double stars)

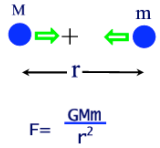
Binary stars are numerous (e.g. Sirius)

We can see orbital motion of Sirius B around Sirius A



Masses of stars determine the gravitational force, and thus the acceleration of the stars

Gravitational Force between Two Masses



$$F = \frac{GMm}{r^2}$$

The greater the masses, greater the acceleration

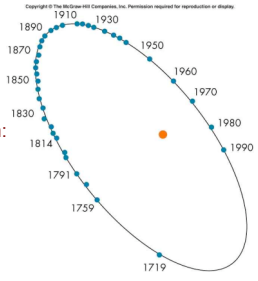
Binary Stars (Chapter 21 of book)

Astronomers can learn a lot about how stars are created by studying binary stars, like the binary duet in this artist's rendering.

The Types of Binary Stars

- Visual Binaries
- Eclipsing Binaries
- Spectroscopic Binaries

Visual binaries…you can see them as two stars in a telescope



Alpha Geminorum: Castor

Like Albireo, Sirius, Nu Draconis

With visual binaries, if you know the distance, you know the orbital speed and orbital radius (actually the semi-major axis)

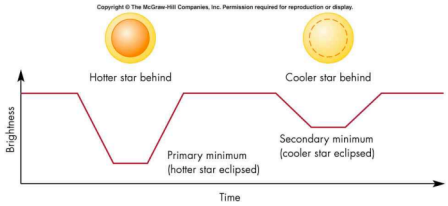
Bright double stars…find them on your SC1 Chart and look at them in a telescope

Star	Separation (arcseconds)	Period (years)
Alpha Herculis	4.7	3600
Epsilon Lyrae	2.6	1200
Beta Cygni	34.5	?
Gamma Andromedae	9.6	?

Visual binaries have wide separations and very long periods

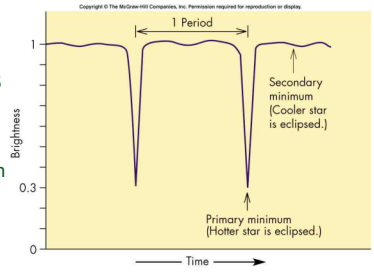
Second class of binary…eclipsing binaries

One star in a binary comes in front of
The other and blocks its light



The classic example of an eclipsing binary…Algol, Beta Persei

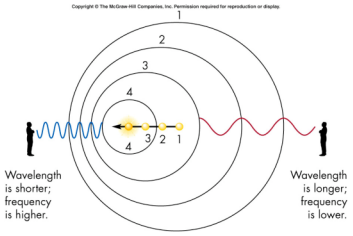
Period of Algol=2.867315 Days; orbital Period much Shorter and Precisely known



Upcoming minima of Algol (Beta Persei)

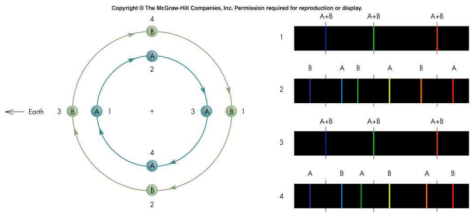
- October 1, 0:39 AM
- October 3, 9:28 PM
- October 6, 6:17 PM
- Also check eclipsing binary Beta Lyrae,
- P=12.939412 days

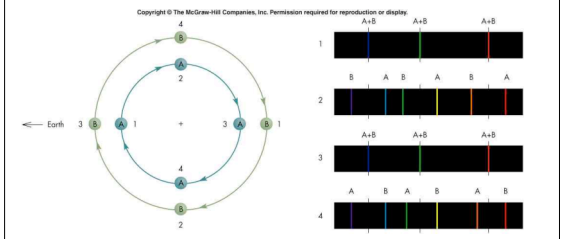
The final class of binary stars: spectroscopic binaries



demo

Spectroscopic binaries (3rd class of binaries); known to be binaries only because of periodic variations in the spectrum





From periodic wobbling back and forth of the spectral lines of a (blended) binary, we can often determine the radius of the orbit, and orbital speeds, and thus the masses of the stars

From observations of binaries, we have the masses Of a sample of stars, and can study how stellar Properties depend on mass.

The masses of stars (and their luminosities)