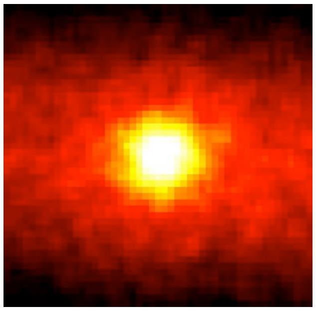
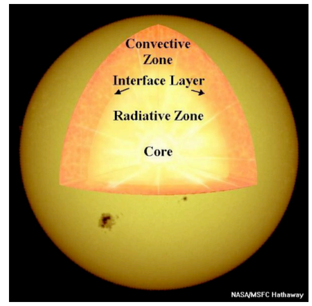
## The Powerhouse at the Center of the Sun

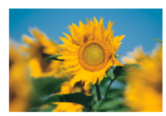


## The interior of the Sun is a region of *extreme* physical conditions




## Next topic: what is the luminosity of the Sun telling us?

- Luminosity = $3.847 \times 10^{26}$ Watts
- What fuel cycle could provide this?
- What fuel cycle could provide this for the lifetime of the Sun?



## Say it with equations! (easy ones)

- Luminosity = power =energy/time
- Energy=powerXtime (Watts X seconds = Joules)
- Time=energy/power

Let's see how long we could keep the Sun shining with a known, powerful energy source

## Coal

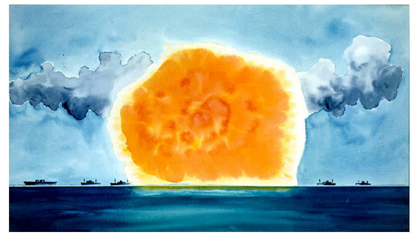
- Coal runs civilization
- Energy content: 24 MegaJoules/kilogram=
- $2.4 \times 10^{7}$ Joules/kg
- If the Sun were made of coal, how long could it "burn", providing its current power or luminosity?

## Power and the Sun

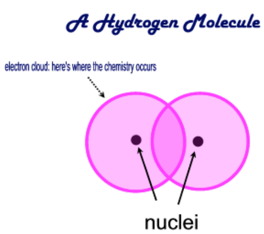
- Mass of Sun = $2 \times 10^{30}$ kilograms
- Total energy content of "coal Sun"=$(2 \times 10^{30}) \times (2.4 \times 10^{7}) = 4.8 \times 10^{37}$ Joules
- Time the Sun could "keep this up" = energy/luminosity $= 4.8 \times 10^{37} / 3.8 \times 10^{26} = 1.3 \times 10^{11}$ seconds
- Is this a lot or a little????

A strong conclusion: energy drawn from coal burning, or any other chemical reaction, is *grossly* inadequate to power the Sun over geological timescales

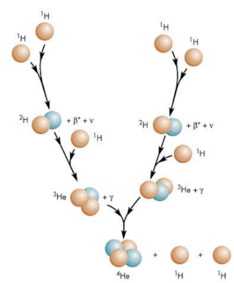
Some vastly more powerful energy source (than chemical reactions) must be occurring in the Sun and stars



A microscopic view of chemical reactions: interactions of the electron cloud




Nuclear reactions: interactions among the nuclei (Figure 17.2)




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?

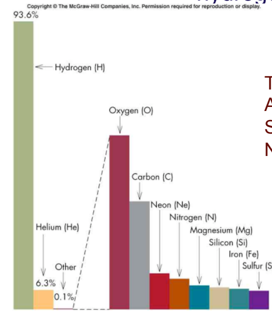
## The Einstein Energy-Mass equivalence relation

$E=mc^2$

c=speed of light

You get a lot of bang for the buck: 6.3E+14 J/kg

## Stars have a lot of fuel in the form of hydrogen

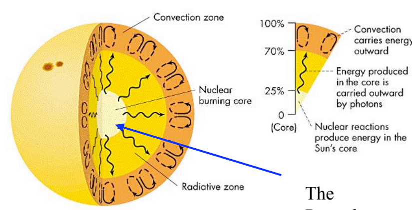



These abundances
Are characteristic of the
Solar photosphere, and
Nearly all other stars

## The Power Source of Main Sequence Stars

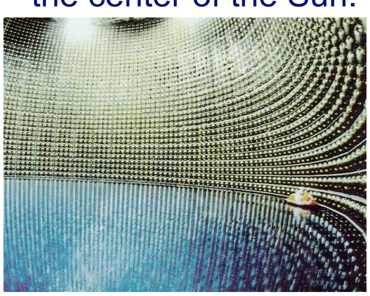
MS stars fuse hydrogen into helium, releasing prodigious amounts of energy in the process. Their fuel source is the matter of which they are made

## The Structure of Main Sequence Stars

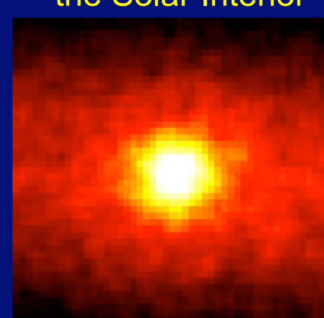



The Powerhouse

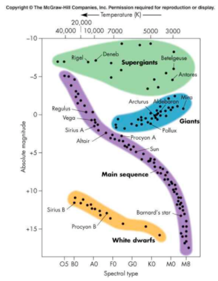
## How can we tell if this is right? Detect neutrinos emitted from the center of the Sun.



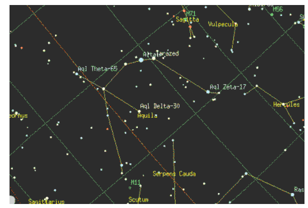
## The Neutrino Sun: A View into the Solar Interior



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



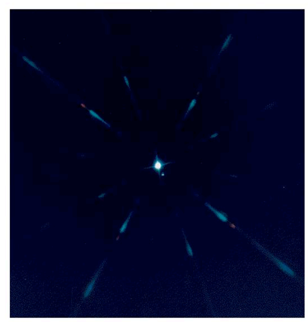

The fuel for a main sequence star is its own mass in the form of hydrogen.
The total amount of fuel is proportional to the total mass of the star.
What are the masses of stars?



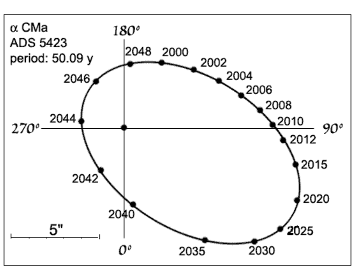
How We Determine Masses of Stars

Method:observation of binary stars (double stars)

Binary stars are numerous (e.g. Sirius)

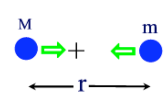


We can see orbital motion of Sirius B around Sirius A




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