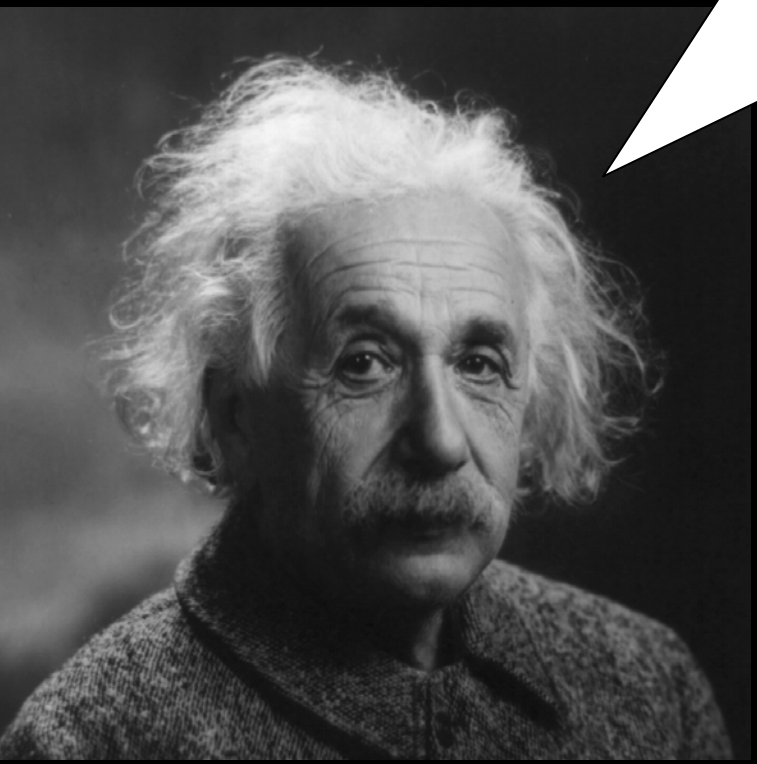


Welcome back to 8.033!

Image courtesy of Wikipedia.

Summary of last two lectures: Variational calculus

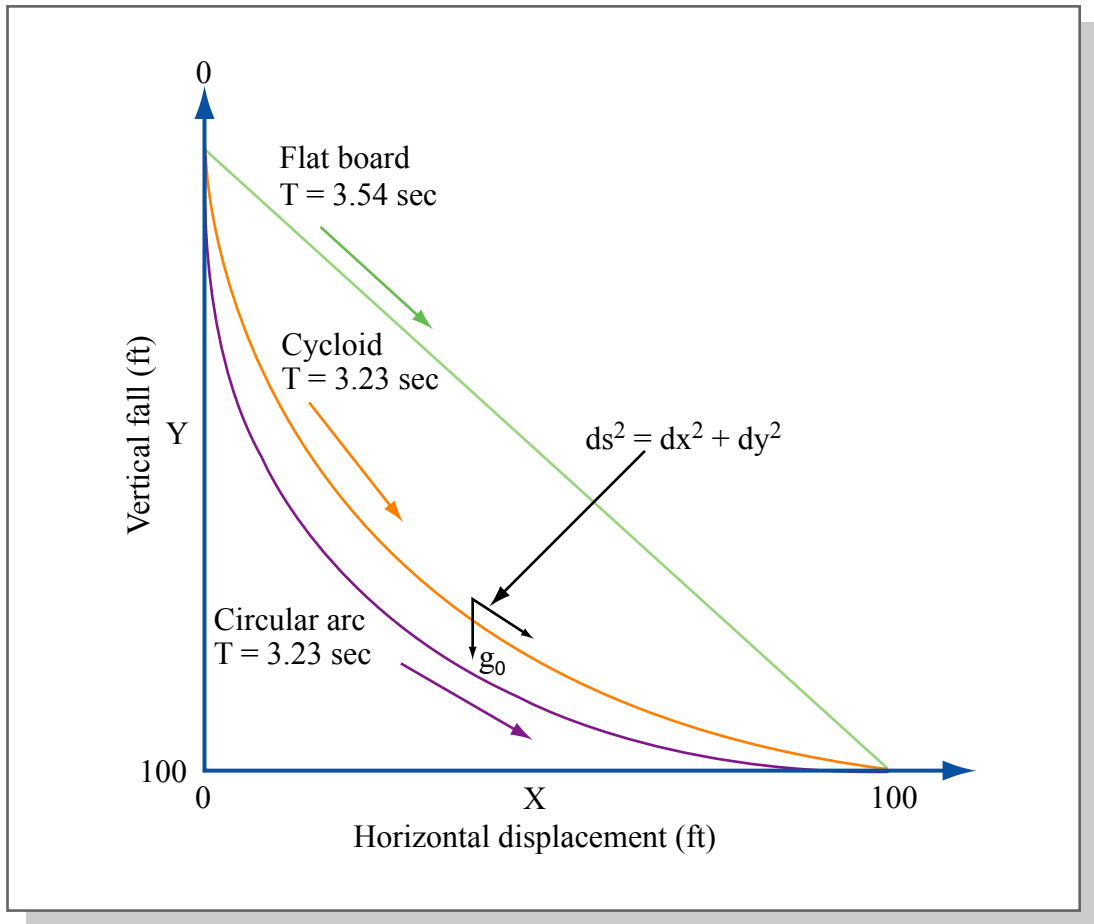


Figure by MIT OCW.

Next lecture:

INSTERSTELLAR SPACE TRAVEL

MIT Course 8.033, Fall 2005, Lecture 10

Max Tegmark

Today's topics:

- Fixing (generalizing) 8.01
- Momentum
- Energy

- Momentum 4-vector
- Kinetic energy, rest energy, mass-energy equivalence
- The three unifications: space & time, E & p, E & m

The Sun

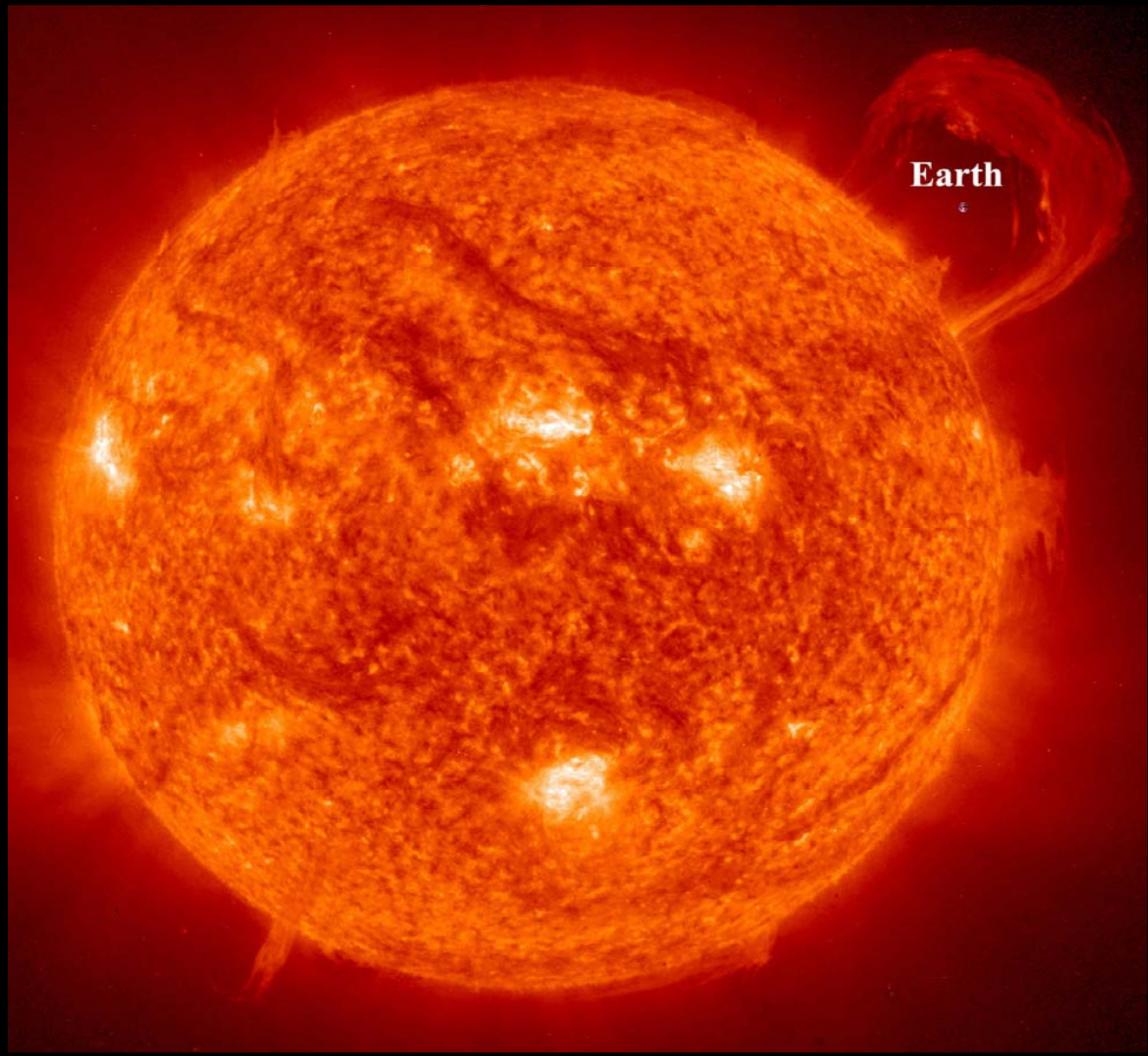


Image courtesy of NASA.

Basic Properties of the Sun

Distance: = 1 A.U.

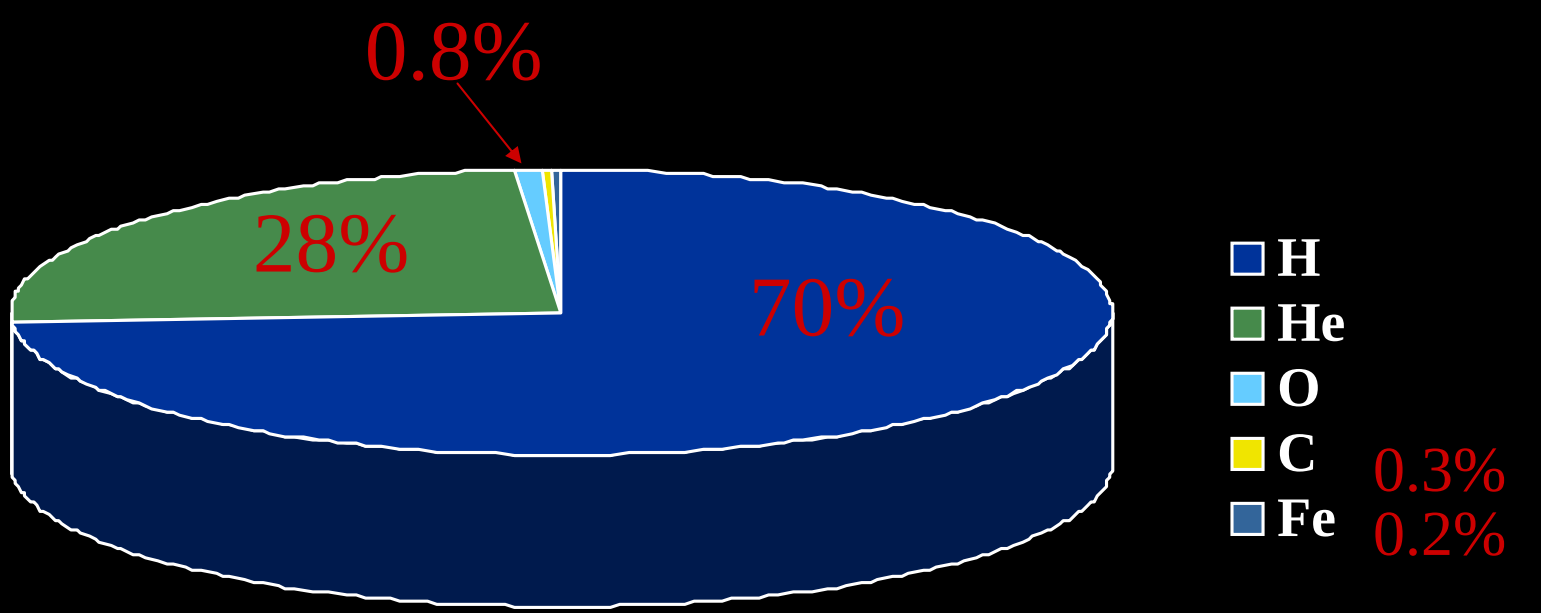
Mass: 2×10^{30} kg

Radius: 100 times Earth

Density: Similar to water

Luminosity: 4×10^{26} watts

Composition of the Sun



How do we know this?

Composition of the Sun

We know this by identifying the **absorption lines** in the Sun's spectrum.

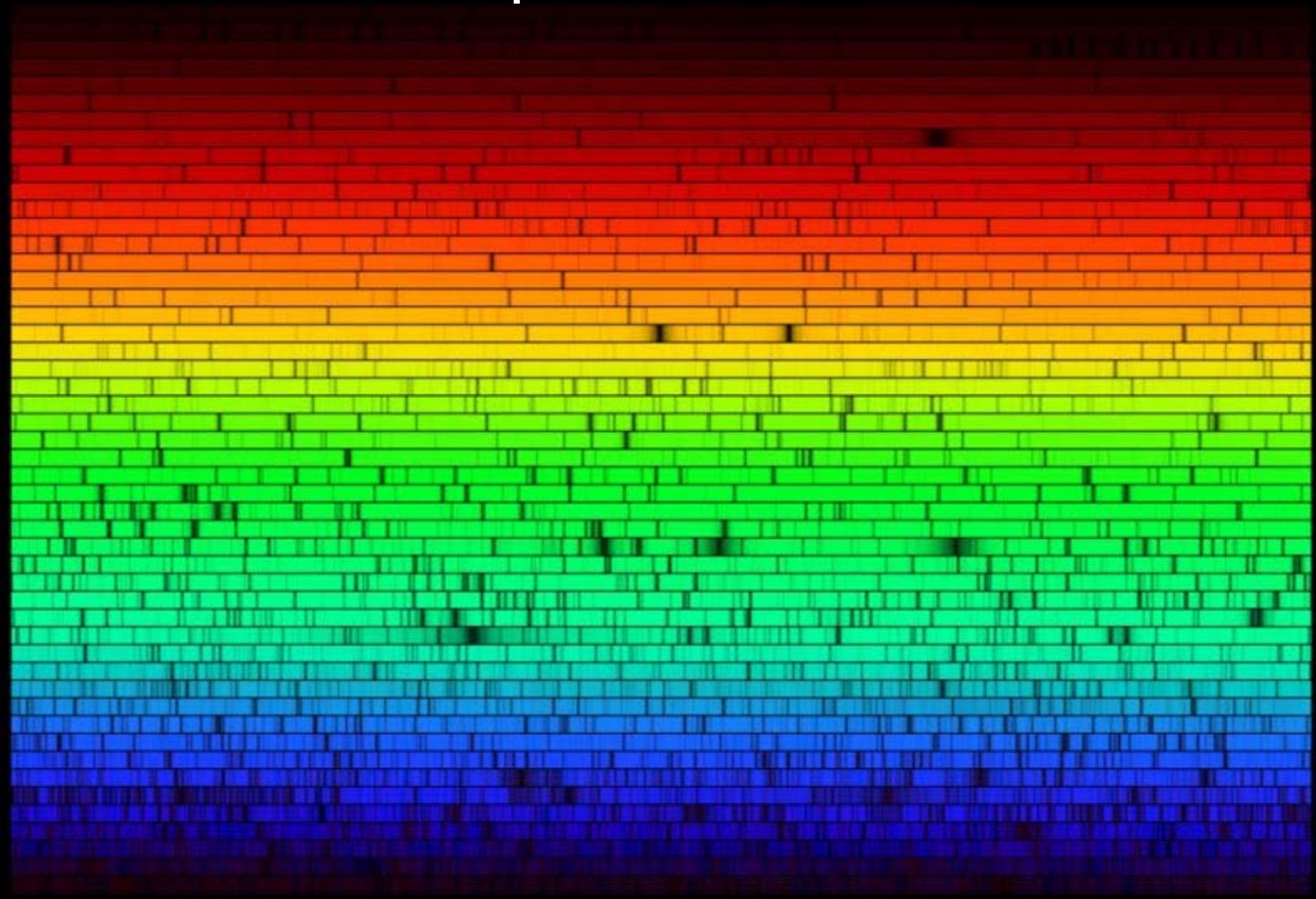


Image courtesy of Wikipedia.

These lines are formed in the photosphere.

What did they know when my Dad was born?

WHAT IS THE SUN?

WHY DOES IT SHINE?

WHY FOR SO LONG?

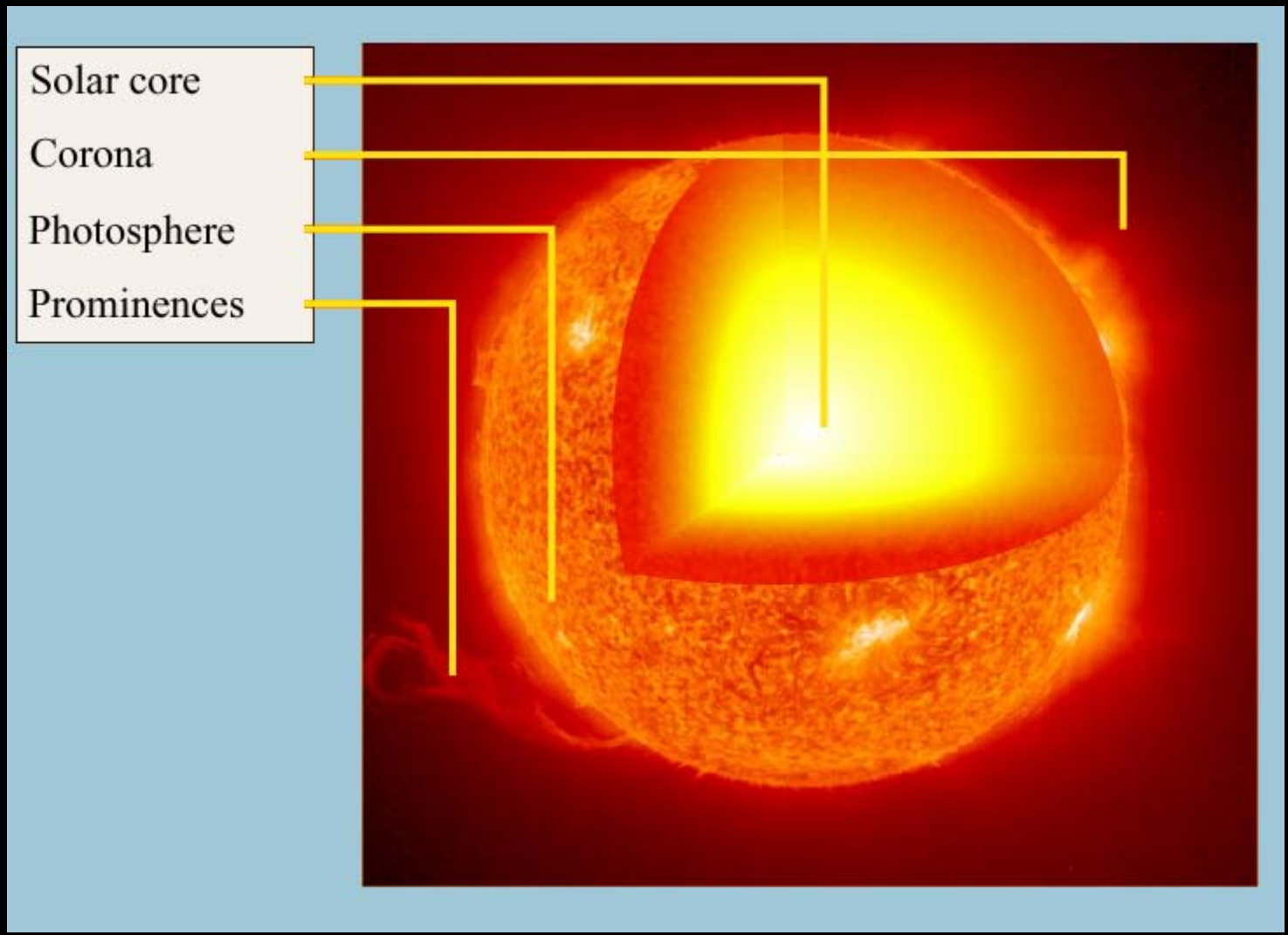


Image courtesy of Wikipedia.

Why does fusion occur in the Sun’s core ?

At low speeds, electromagnetic repulsion prevents the collision of nuclei.

At high speeds, nuclei come close enough for the strong nuclear force to bind them together.

What is nuclear fission ?

- a reaction where lighter nuclei are created by splitting heavier nuclei.

Humans have only achieved controlled fission, not controlled fusion.

It is easier to destroy than to create.

Neutrons

Neutrons are not stable! They do not exist alone for long!

$n \longrightarrow p^+ + e^- + \bar{\nu}_e$ (β-decay)

$p^+ \longrightarrow n + e^+ + \nu_e$ (inverse β-decay)

ν_e is a **neutrino** **----** a weakly interacting particle which has almost no mass and travels at nearly the speed of light.

Proton-Proton Chain

IN: 6 H, (2 e^-)
OUT: He, 2 H, 2 ν_e, 4 γ

Effectively 4 H nuclei are converted into 1 He nucleus and energy is released.

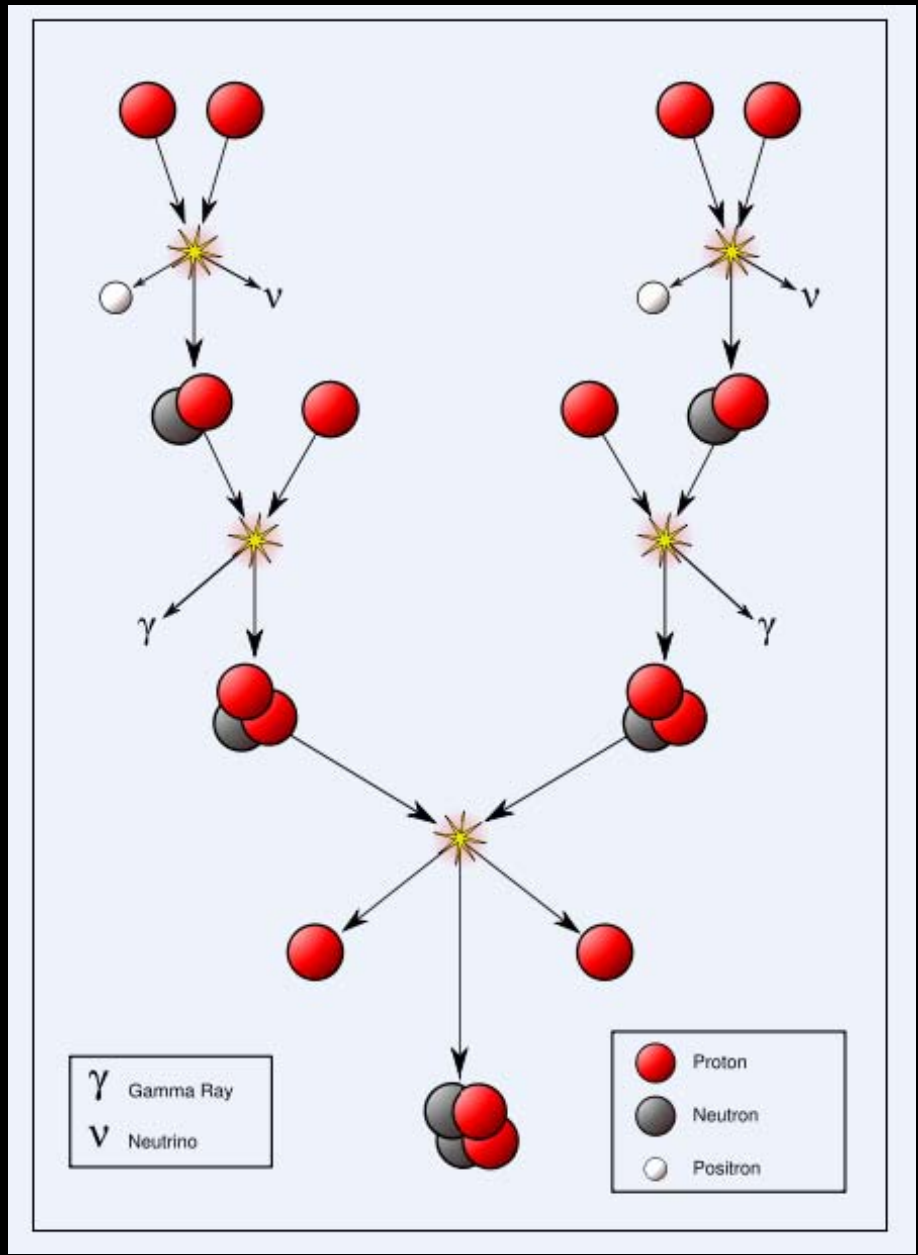


Image courtesy of Wikipedia.

Why does the Sun shine ?

But….

Rest mass of He = 99.3% of 4 x rest mass of H.

where did the .007 x 4 m_H go?

Into other forms of energy!!!

$$E = mc^2$$

How do we know what is happening inside the Sun?

“Observing” the Solar Interior

- The Sun’s interior is opaque…
  - we can not see directly into it with light
- We can construct mathematical computer models of it.
  - the models are a grid of temperature, pressure, & density vs. depth
  - these values are calculated using known laws of physics
  - they are tested against the Sun’s observable quantities

- We can directly measure sound waves moving through the interior
  - we observe “sunquakes” in the photosphere by using Doppler shifts
  - motion of sound waves can be checked against interior conditions predicted by models
- There is another way to see directly into the core…**neutrinos**!