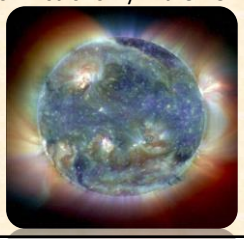
ASTR 1020: Stars & Galaxies

September 18, 2013

- Reading: Chapter 15, section 15.1.
- *MasteringAstronomy* Homework on The Sun is due Sep. 20th.
- Volunteer for "Astronomy in the News".

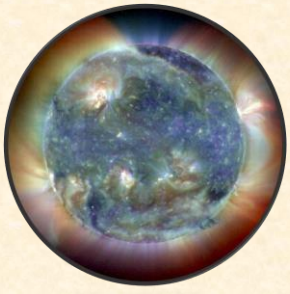


Astronomy Picture of the Day

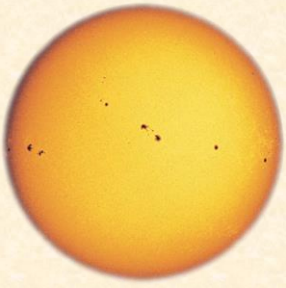
Star Streams and the Sunflower Galaxy: M63, about 25 million light years away (0.8-m telescope at MacDonald Observatory).

Today's Class

- Energy generation in the Sun.
- Proton-proton chain.
- Sun's energy budget.
- Mysterious neutrinos.



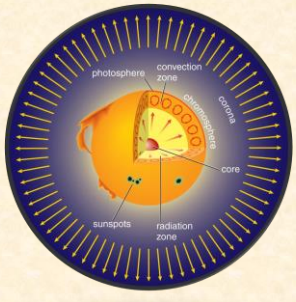
- "Visible surface" of the Sun: photosphere.
- T = only 5800 K.
- Photons free to fly-seen at Earth 8 min later.
- Thermal spectrum, T= 5800 K plus absorption from cooler gasses just on top.



Outer regions are hotter:

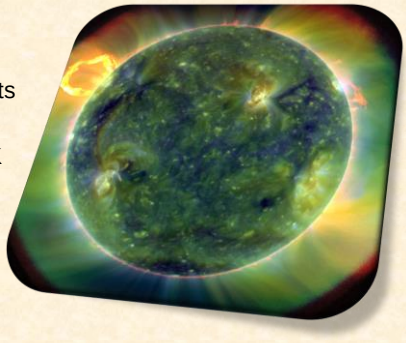
Chromosphere,

- T= 10,000 K, Hydrogen alpha emission from thin gas (pink!)
- Heated by energy twisting and spilling around magnetic field lines?

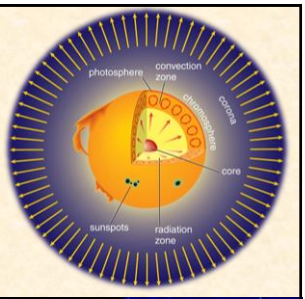


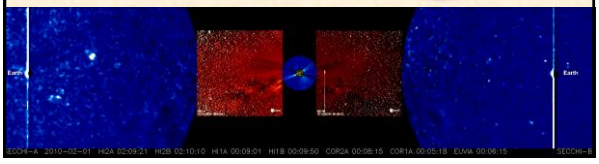
Corona = outermost parts

T = 1 million K
=>X-rays!

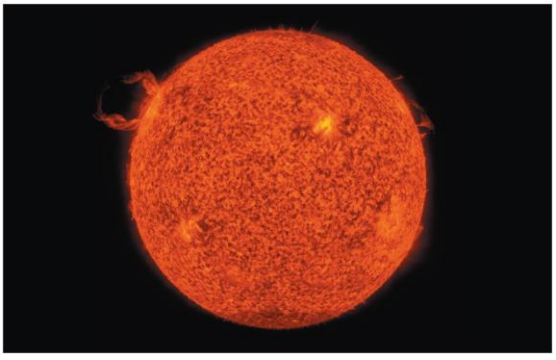


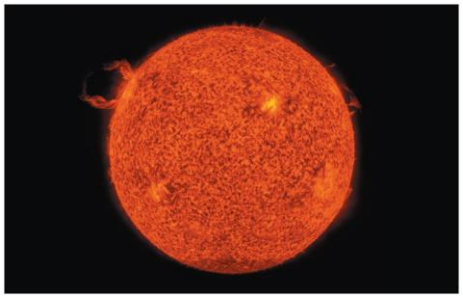
- Solar wind: particles (electrons, protons etc.) streaming into space at 500 km/sec





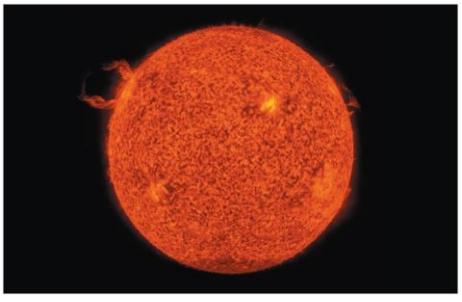
Why does the Sun shine?





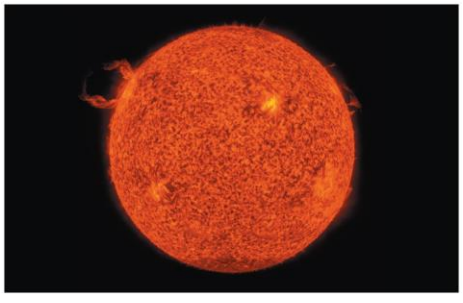
Is it on FIRE? … NO!

$$\frac{\text{Chemical energy content}}{\text{Luminosity}} \sim 10{,}000 \text{ years}$$



Is it CONTRACTING? … NO!

$$\frac{\text{Gravitational potential energy}}{\text{Luminosity}} \sim 25 \text{ million years}$$



It can be powered by NUCLEAR ENERGY! ($E = mc^2$)

$$\frac{\text{Nuclear potential energy (core)}}{\text{Luminosity}} \sim 10 \text{ billion years}$$

Reading Clicker Question

Fusion in the Sun occurs between...

A) protons
B) electrons and protons
C) electrons and neutrons
D) neutrons and protons
E) electrons

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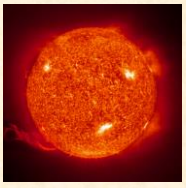


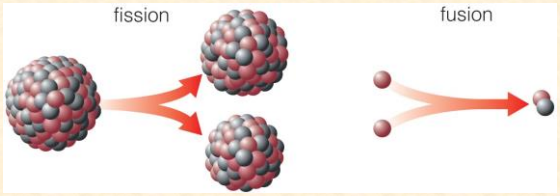
The Sun

Where does all that energy come from?

Nuclear FUSION

(not FISSION)

Hydrogen → Helium



Fission

Big nucleus splits into smaller pieces.

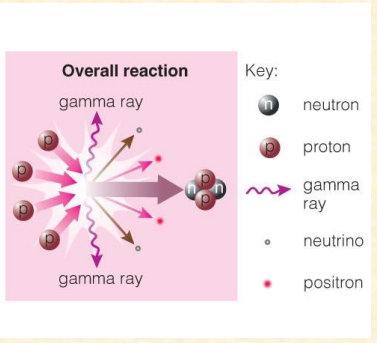
(Example: nuclear power plants)

Fusion

Small nuclei stick together to make a bigger one.

(Example: the Sun, stars)

"Where hydrogen is built into helium…"



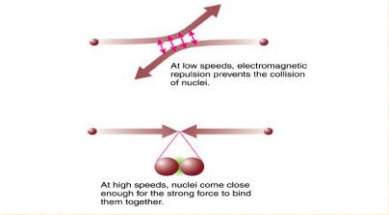
IN
4 protons

OUT
^{4}He nucleus
2 gamma rays
2 positrons
2 neutrinos

Total mass is 0.7% lower.

Proton-Proton Chain

- Two protons collide at high speeds.
- Normally electric force would keep them apart (two positive charges repel).
- Extreme temperatures mean they have enough energy to overcome this.
- Once very close, the nuclear STRONG FORCE binds the particles together.



Energy budget

- Helium has atomic mass 3.97 times that of hydrogen, NOT exactly 4 times
- Tiny amount of the protons' mass is lost to energy via $E = mc^2$
- Rates are fast enough that 4 tons of mass are converted each second!

Clicker Question

Imagine that the Sun's energy generation rate (fusion rate) suddenly increases by a factor of 10. What will happen?

A) The Sun will increase in brightness by a factor of 10; after 1 million years the Earth's climate will start to heat, and after another 2000 years, all life will cease.

B) The core of the Sun will quickly expand and cool, slowing the fusion rate to its previous level.

C) The core of the Sun will heat up, causing a runaway reaction and catastrophic explosion.

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Those Mysterious Neutrinos

- With very small masses, travel close to speed of light.
- Don't interact with other matter: requires a lead wall 1 lightyear thick to stop a neutrino! (Fewer at night...?)
- Lots of them: 10^{38} neutrinos/sec from the Sun, 10^{15} coming through YOU each second!

Clicker Question: Do you think neutrinos flowing through our bodies are a cause of cancer or other damage?

A) Yes

B) No

- (B) Neutrinos don't deposit any energy in our bodies- they simply don't do anything to us!