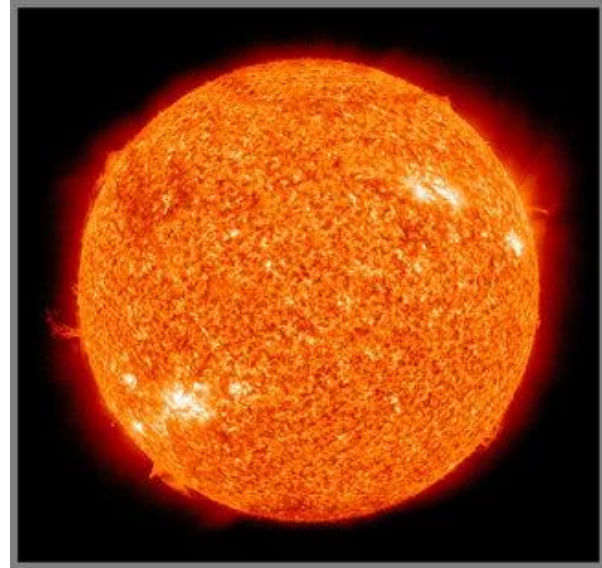


THE SUN

Stars and Light (Part 2)



Astronomy

Why does the Sun shine?

Ancient thinkers... the Sun is a type of _____?

Mid-1800's... _____ showed that burning wood or coal would not account for the Sun's huge output of energy.

Late 1800's... The Sun generates energy by _____ in size (gravitational contraction).

Later calculations showed that this would have kept the Sun shining steadily for 25 million years.

1905... _____ Special Theory of Relativity showed that the energy of the Sun's mass could be converted into thermal energy.

Why does the Sun shine?

By the end of the _____, we learned that the Sun converts mass into energy through the process of **nuclear fusion**.

- For nuclear fusion to occur, high _____ and _____ is required.

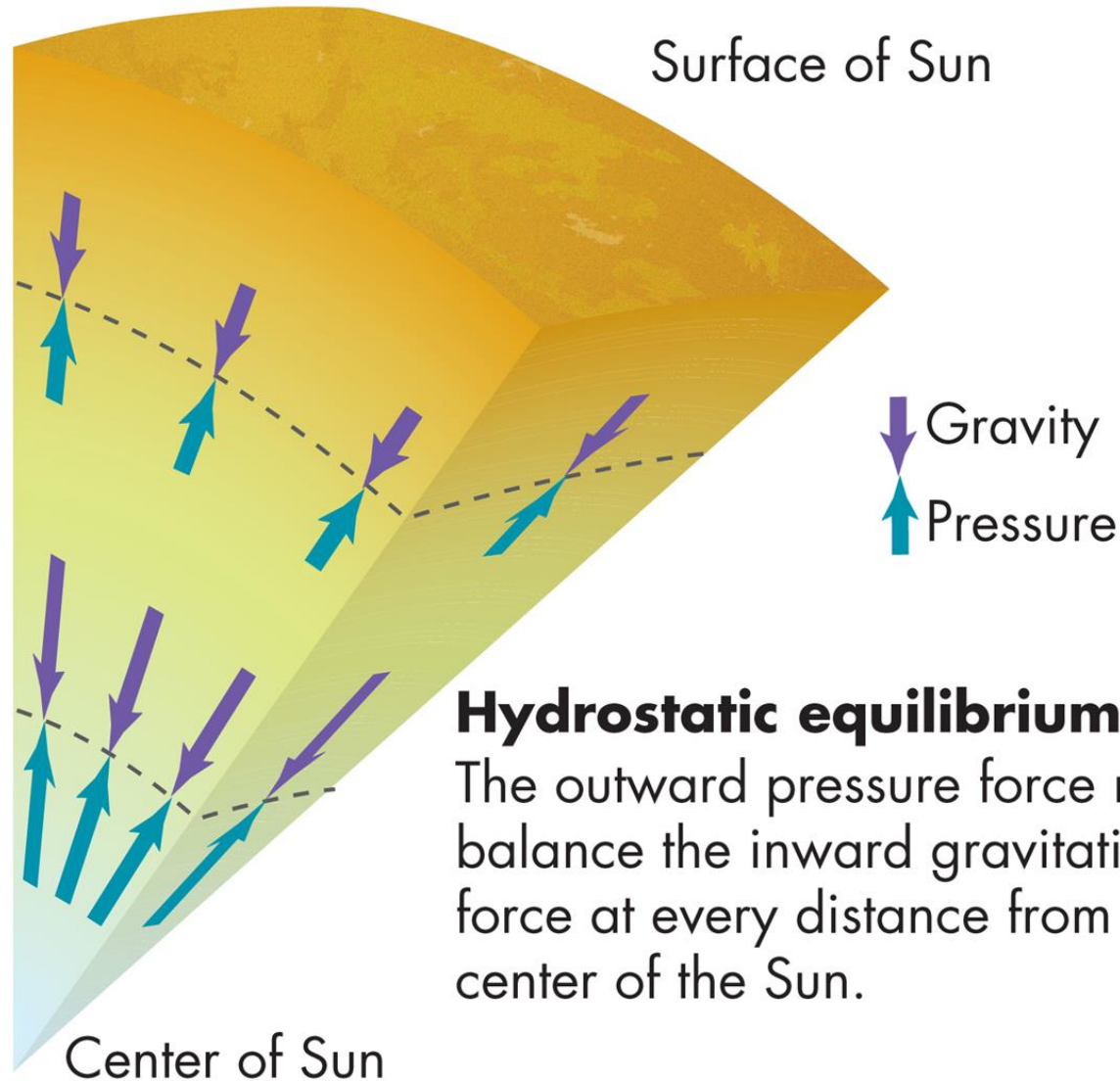
Conditions are present in the core!

- How does the core stay hot and dense?

_____ **Equilibrium**- A natural balance between the inward force of gravity and the outward pressure of hot gases.

Hydrostatic Equilibrium

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Solar Basics

- The Sun is a ball of **plasma**– a _____ in which many of the atoms are ionized because of high temperature.
- _____ is created in the core



Basic Properties of the Sun

- **Composition** is almost entirely _____ and _____.
 - Revealed using spectroscopy
- **Radius** is about 700,000 km (100 X _____ radius)
 - Determined from angular distance measurements
- **Mass** is 2×10^{30} kg (300,000 x _____ mass)
 - Using Newton's and Kepler's Laws
- It has **Sunspots**, or dark spots that are regions of intense magnetic fields.

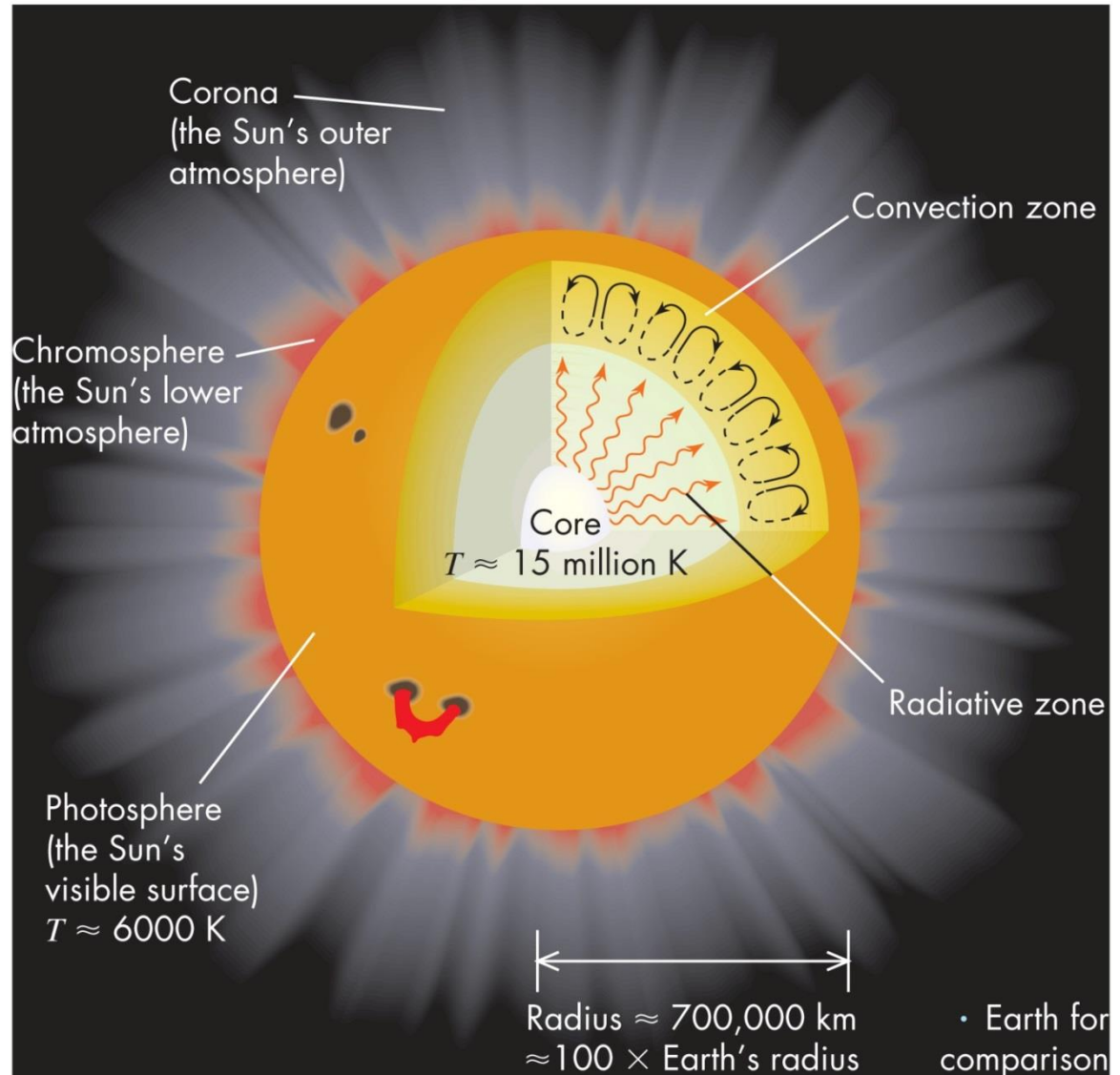
Basic Properties of the Sun

- **Rotation rate** = 25 days (_____); 30 days (_____)
 - Observed by looking at the sunspots or by measuring Doppler Shifts on opposite sides of the Sun.
- The Sun radiates energy!
 - **Luminosity** = 3.8×10^{26} Watts
- **Surface Temperature** is 5,800 K (_____)
 - Determined through intensity analysis of solar spectra

Solar Structure

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1. Corona
2. Chromosphere
3. _____
4. Convection Zone
5. _____ Zone
6. Core



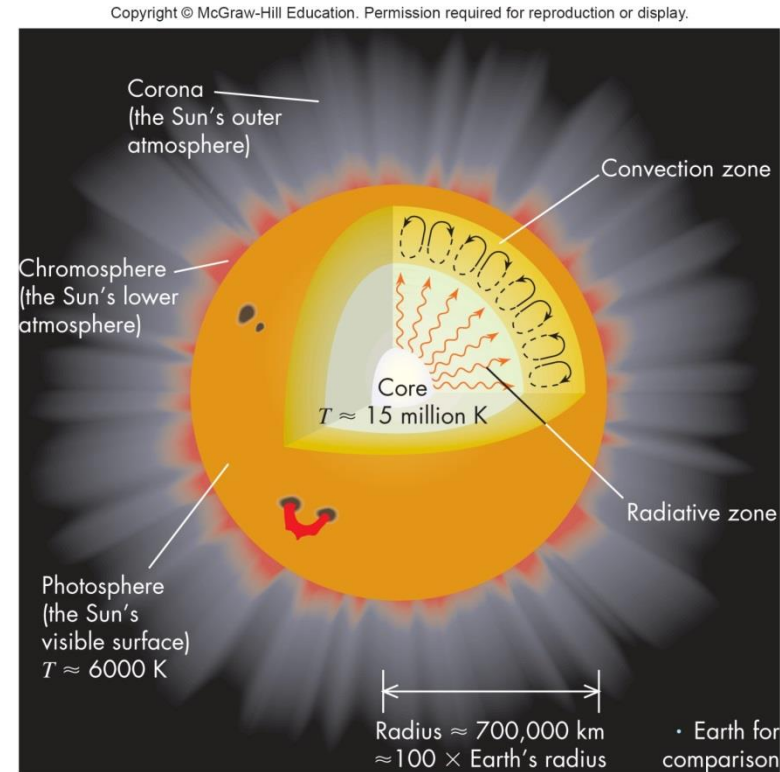
Solar Structure

ATMOSPHERE

Corona- the _____ layer of the atmosphere, extends several million km above visible surface. (_____)

Chromosphere- middle layer of solar atmosphere. (UV _____)

Photosphere- The visible surface of the Sun; where _____ can be seen.



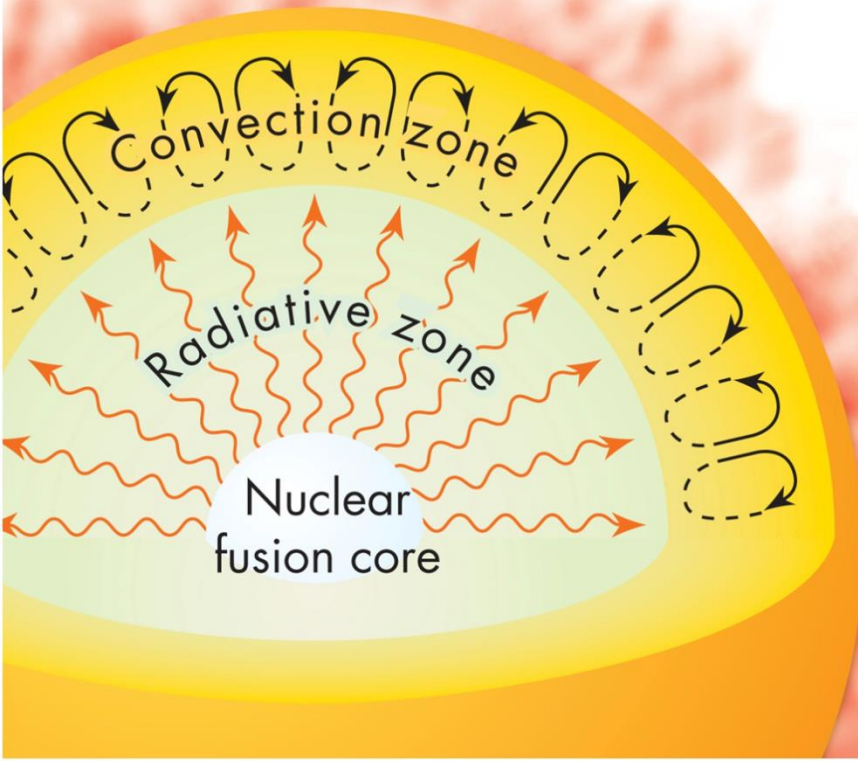
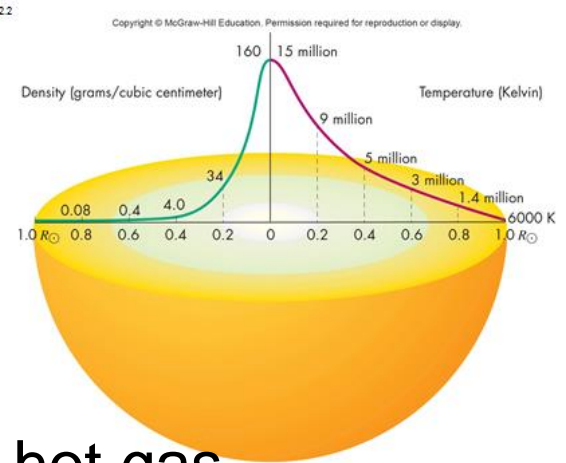
Solar Structure

INTERIOR

Convection Zone- _____ and falling of hot gas

Radiation Zone- where energy moves _____ in the form of photons.

Core- The Sun's center; source of energy- transforming _____ to helium in the process of nuclear fusion. (T = 15 million K)



Nuclear Fusion

15 million K plasma in the solar core is like a “soup” of hot gas with atomic nuclei and electrons whizzing around.

- Nuclei _____ and sometimes they “_____” together to form a heavier nucleus (and heavier element).
 - **Fusion-** the process by which two atomic nuclei fuse together to make a single more massive nucleus.
- Energy is released in the process

Fusion converts about 600 million tons of hydrogen into 596 millions tons of helium every second

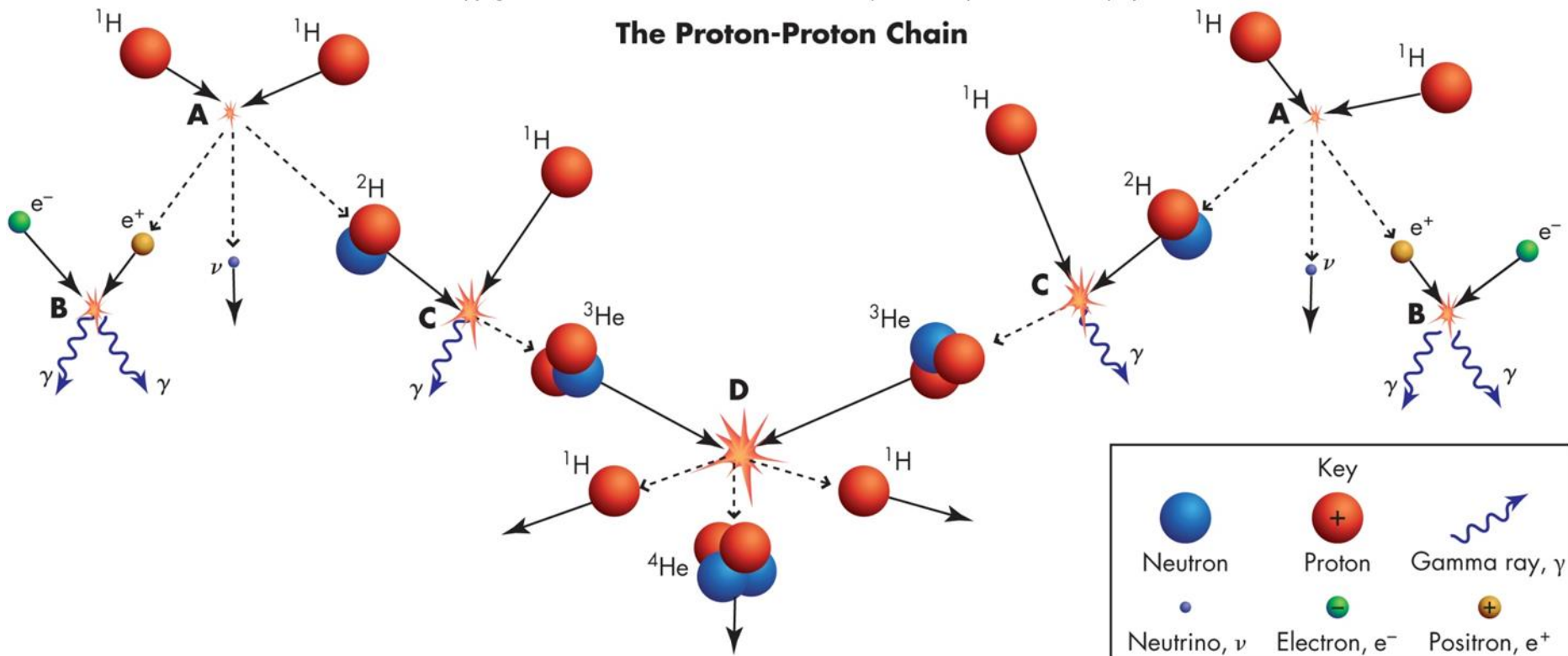
Nuclear Fusion in the Sun

4 Steps (Proton-Proton Chain)

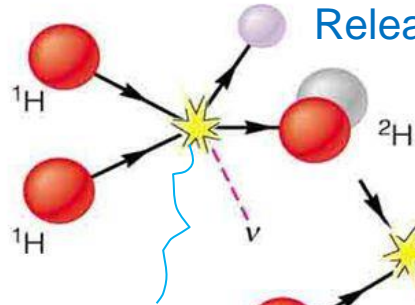
- **RESULT: 4 _____ Atoms fuse to create 1 _____ Atom during the process of fusion.**

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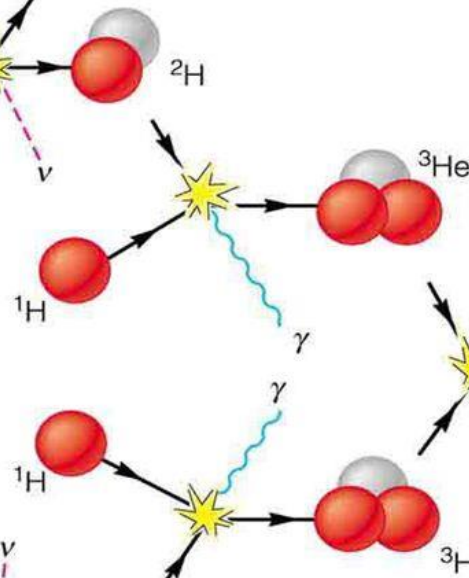
The Proton-Proton Chain



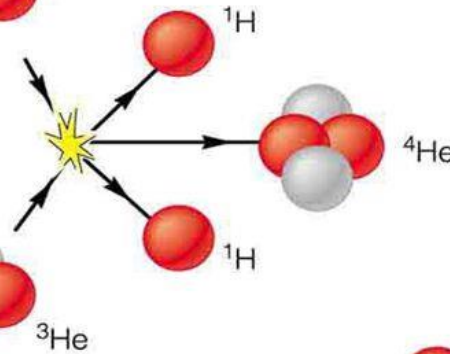
1. Two protons fuse to make a deuterium nucleus



2. Gamma Ray Photon & Neutrino Released

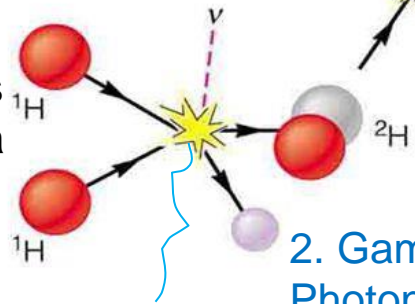


3. Helium-3 is created from the deuterium nucleus and a proton fusion



4. Two He-3 nuclei fuse to form Helium-4, releasing two excess protons in the process

1. Two protons fuse to make a deuterium nucleus



2. Gamma Ray Photon & Neutrino Released



Proton-Proton Chain (4 steps)

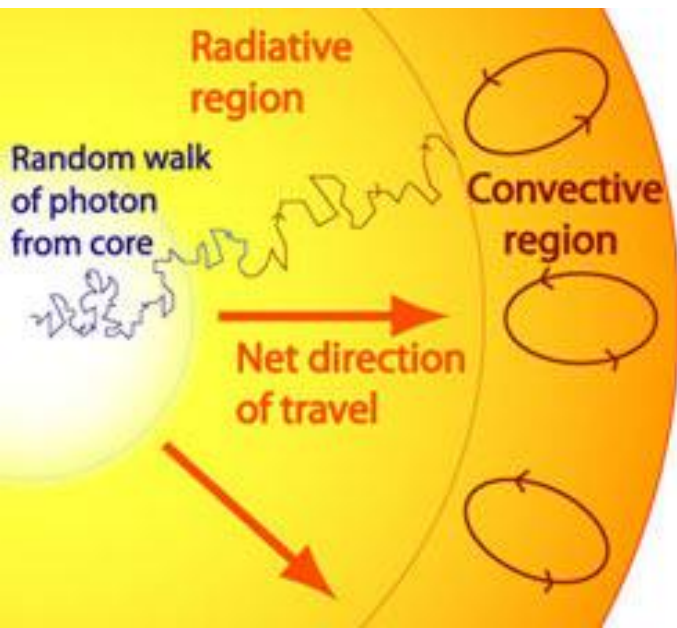
- A. Two protons fuse to make a _____ nucleus** (1 proton and 1 neutron). This occurs twice.
- B. 2 Gamma-Ray photons** are released + 1 _____ (tiny subatomic particle)
- C. Helium-3 is created** from the deuterium nucleus and a _____ fusion (occurs twice). Also releases **two gamma ray photons.**
- D. Two He-3 nuclei** fuse to form _____ (2 protons, 2 neutrons), releasing two excess protons in the process.

The Solar Energy Journey

It takes _____ of thousands of years for solar energy from the core to get to the photosphere.

Radiative Diffusion- the slow, outward _____ of photons.

- Photons bounce around haphazardly, called a “*random walk*”, and gradually work outward from the core.

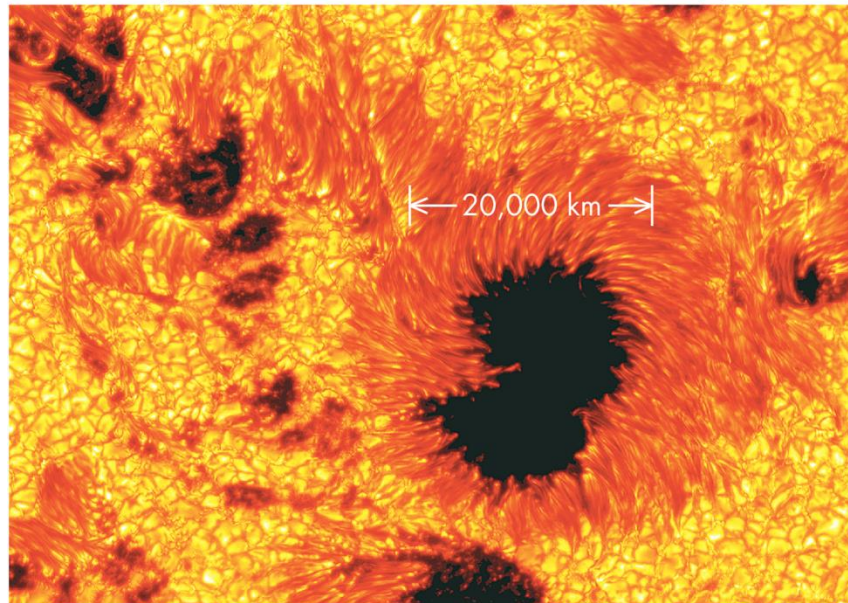


_____ can finally escape when they reach the photosphere, where they travel in a straight path at the speed of light.

Solar Activity

- **Sunspots-** most _____ feature on surface.
 - _____ spots with strong magnetic fields
 - Less bright because those places are cooler (about 1200 K less than surrounding plasma)

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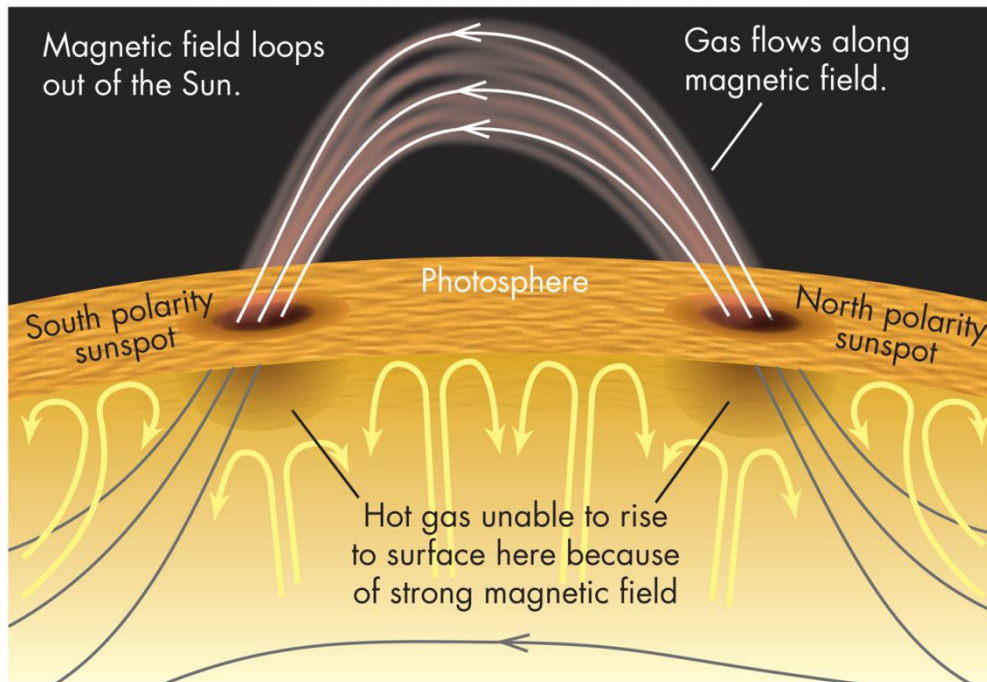
Courtesy of Royal Swedish Academy of Sciences

Solar Activity, cont'd.

SUNSPOTS

- Occur in pairs, connected by a loop of _____ field lines that arc above the Sun's surface.

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_____ in the Sun's chromosphere and corona becomes trapped in the loops, making giant **solar prominences**.

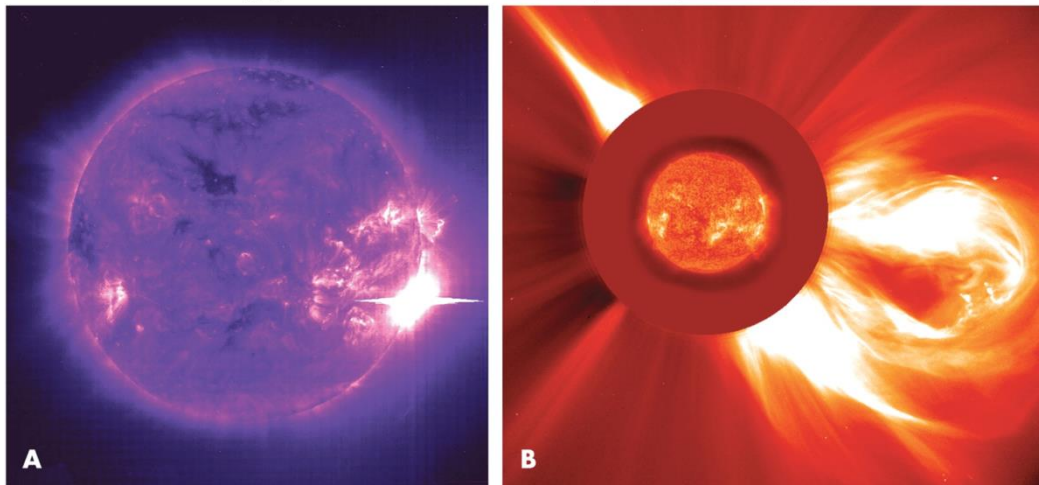


Solar Activity, cont'd.

SOLAR STORMS

- **Solar Flares-** _____ storm event
 - Brief, bright eruptions of hot gas in the chromosphere.
- Sometimes followed by _____ **mass ejections** (enormous bubbles of hot gas trapped in magnetic fields that burst from the corona into space.

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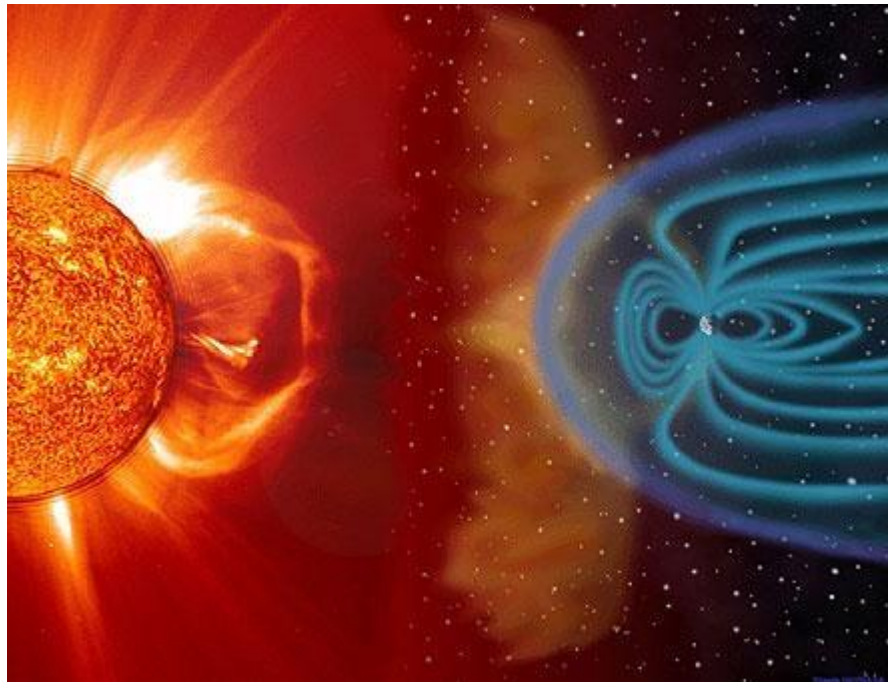


a: Courtesy of SOHO-EIT Consortium, ESA, NASA; b: Courtesy NOAA/AURA/NSF

Solar Activity, cont'd.

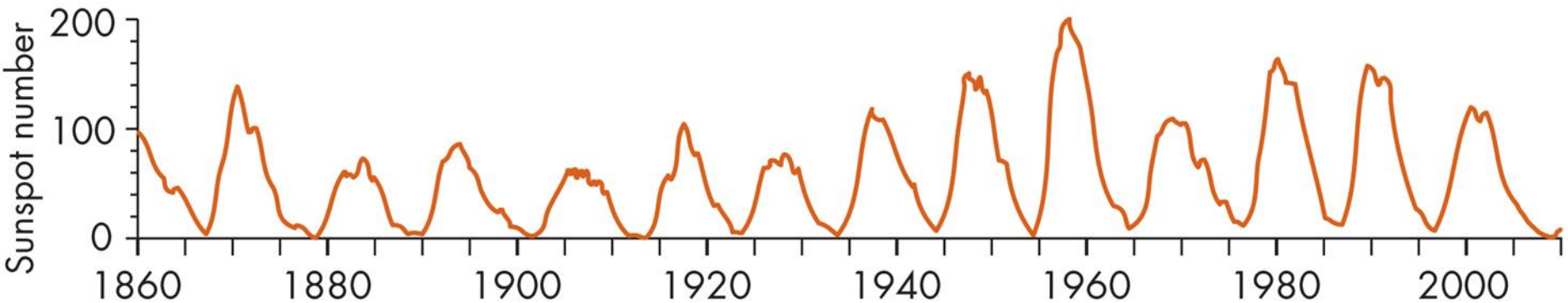
THE SOLAR WIND

- **Solar Wind**- a constant flow of _____ and helium that sweeps across the Solar System.
- *Wind Speed is about 500 km/s, but speeds up and slows down in response to magnetic fields*



The Solar Cycle

- The number of _____ changes from year to year is called the **solar cycle**.
- # of sunspots rise and fall every 11 _____ (avg)
- *The Sun's magnetic field flip-flops every 11 years, resulting in a 22 year magnetic cycle*



Peaks in 1958, 1969, 1980, etc