The Sun

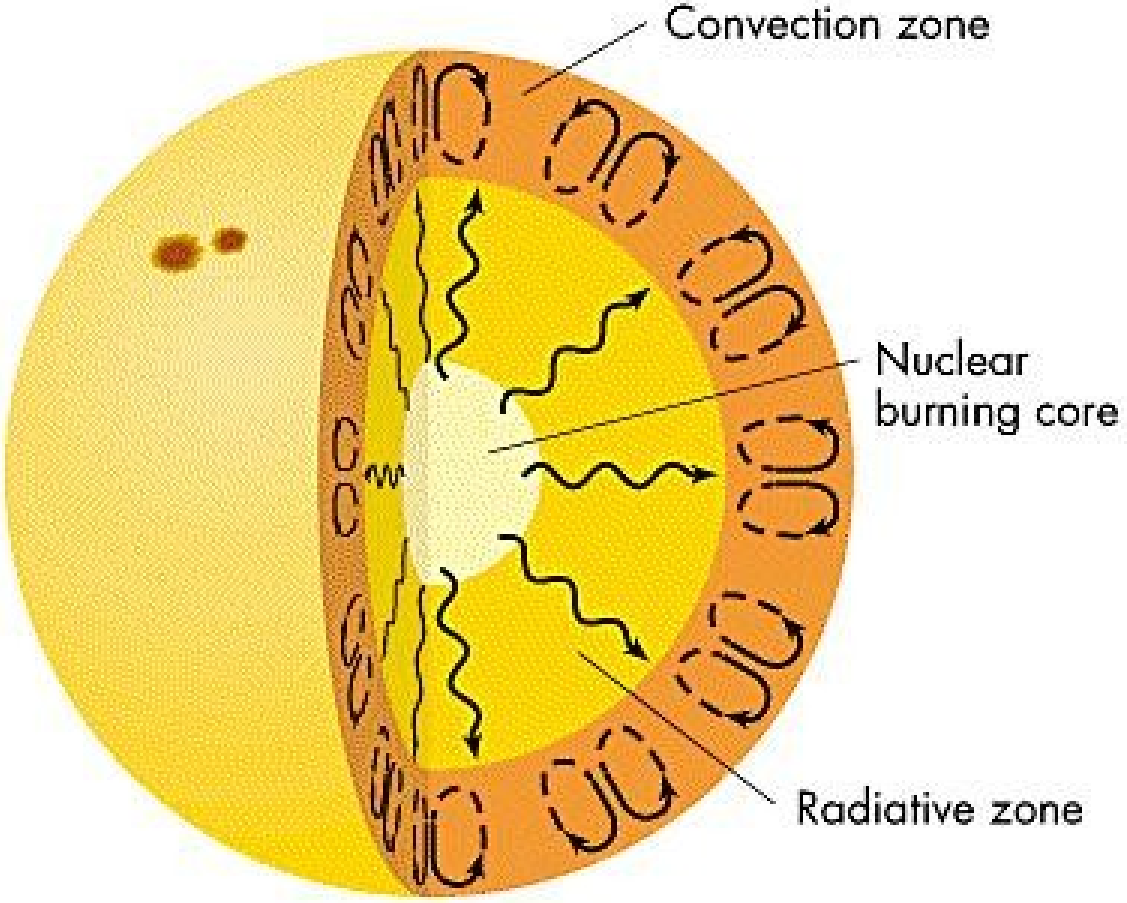
Internal structure of the Sun

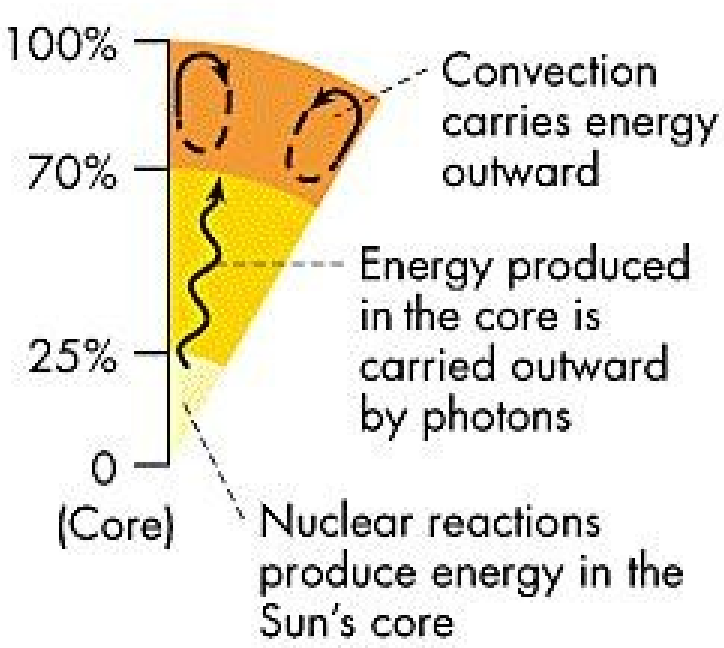
Nuclear fusion

Transport of energy in the sun

Outer layers of the Sun

Internal Structure of the Sun

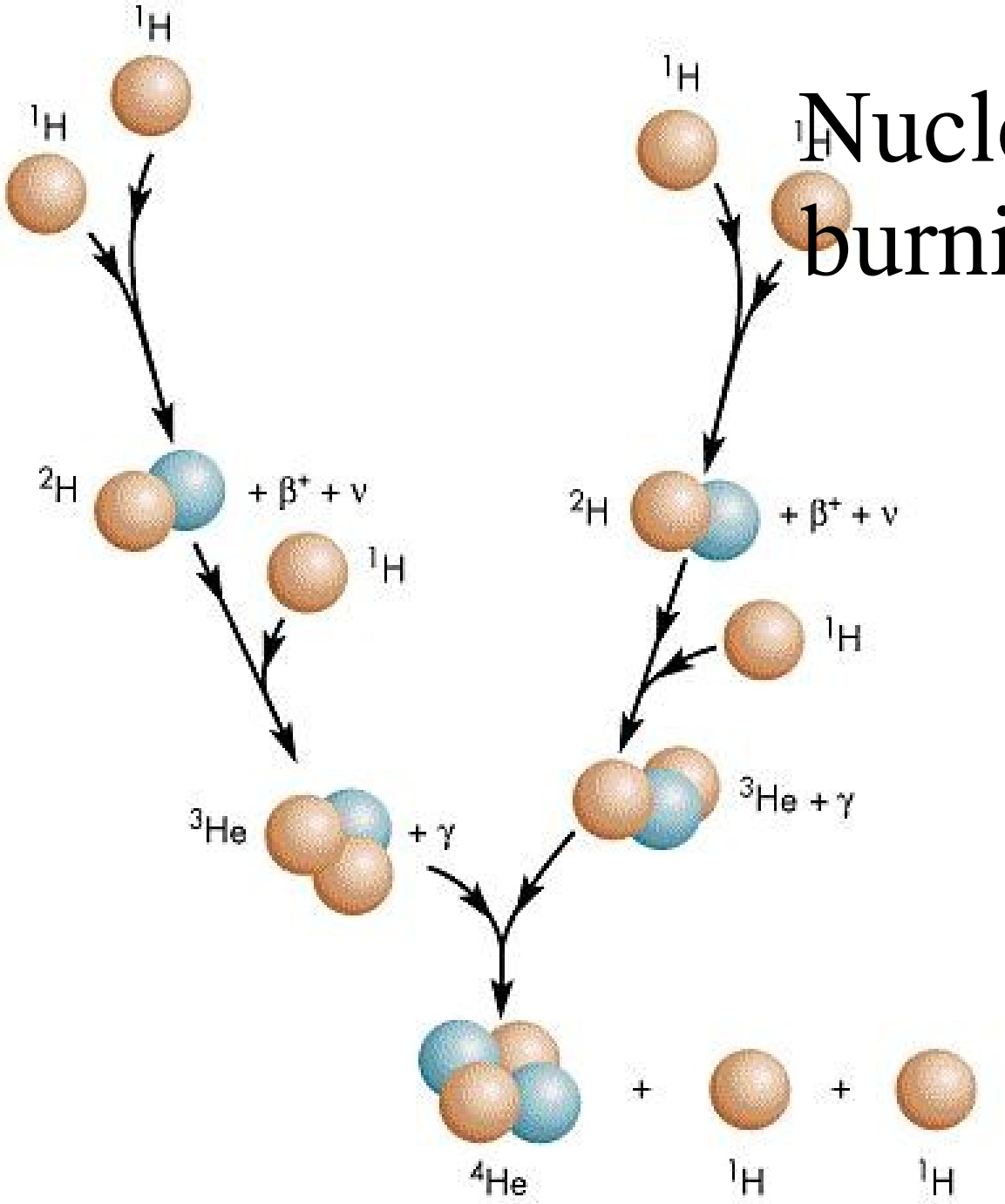




Core temperature 15,600,000 K, density 150× water

Surface temperature 5800 K, average density 1.4× water

Nuclear burning



Nuclear burning

- What do all those funny symbols mean?

Elementary particles

- Protons (orange) – found in nuclei, positive charge
- Neutrons (blue) – found in nuclei, no charge
- Electrons (e^-) – orbit nuclei, negative charge
- Photons (γ) – particles of light (gamma-rays)
- Positrons (β^+) – anti-matter electrons, positive charge (e^+ in book)
- Neutrinos (ν) – `ghost particles', no charge, can easily pass through normal matter

Convert proton to neutron

- To convert a proton to a neutron
- A positron (β^+) and a neutrino (ν) must be produced and released

Make nuclei out of protons and neutrons

^{1}H = normal hydrogen nucleus = proton

^{2}H = deuterium hydrogen nucleus (unstable)

= proton plus neutron (in heavy water)

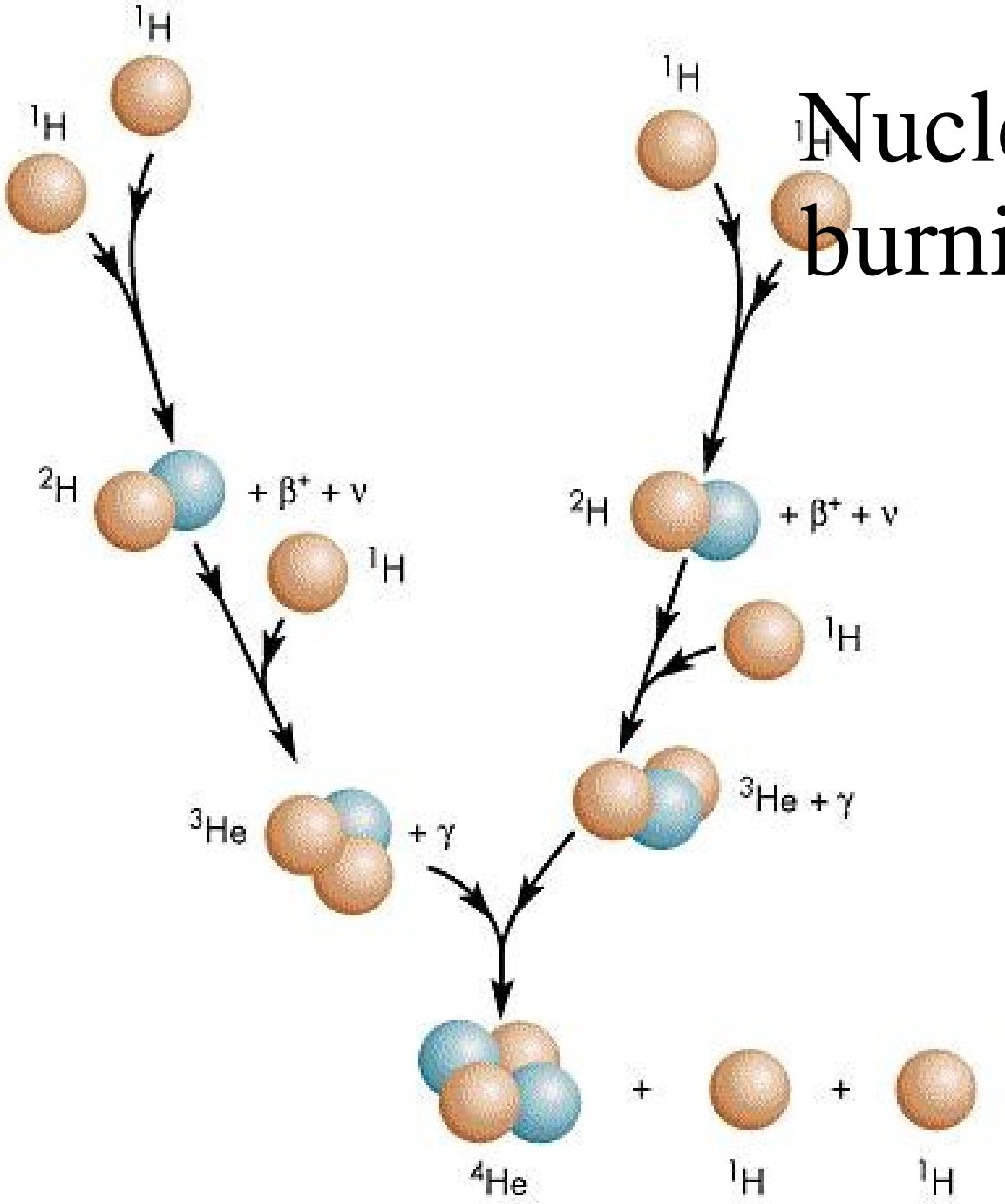
^{3}He = light helium nucleus (unstable(

= two protons plus one neutron

^{4}He = normal helium nucleus

= two protons plus two neutrons

Nuclear burning



Nuclear burning

- OK, so you turn 4 hydrogen nuclei into on helium nucleus, but why do you get energy out?

- One helium nucleus has less mass than 4 hydrogen nuclei by about 0.1%, and

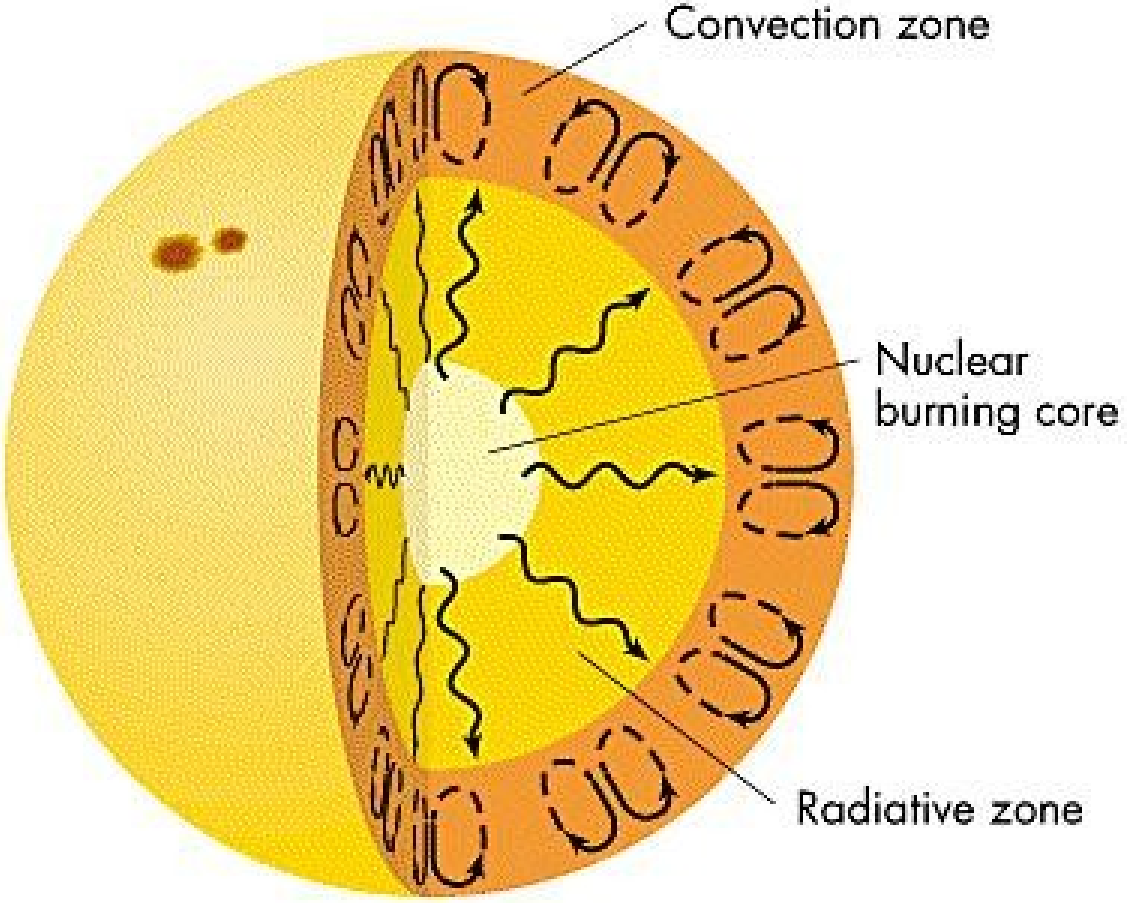
$$E = mc^2$$

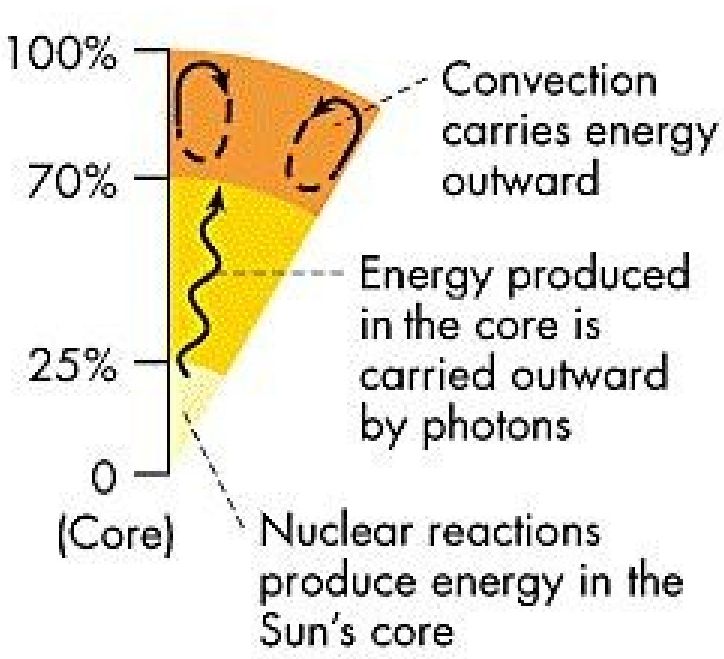
$E = mc^2$

- Einstein showed that mass and energy are equivalent (c = speed of light)
- Mass can be converted to energy, and
- Energy can be converted to mass

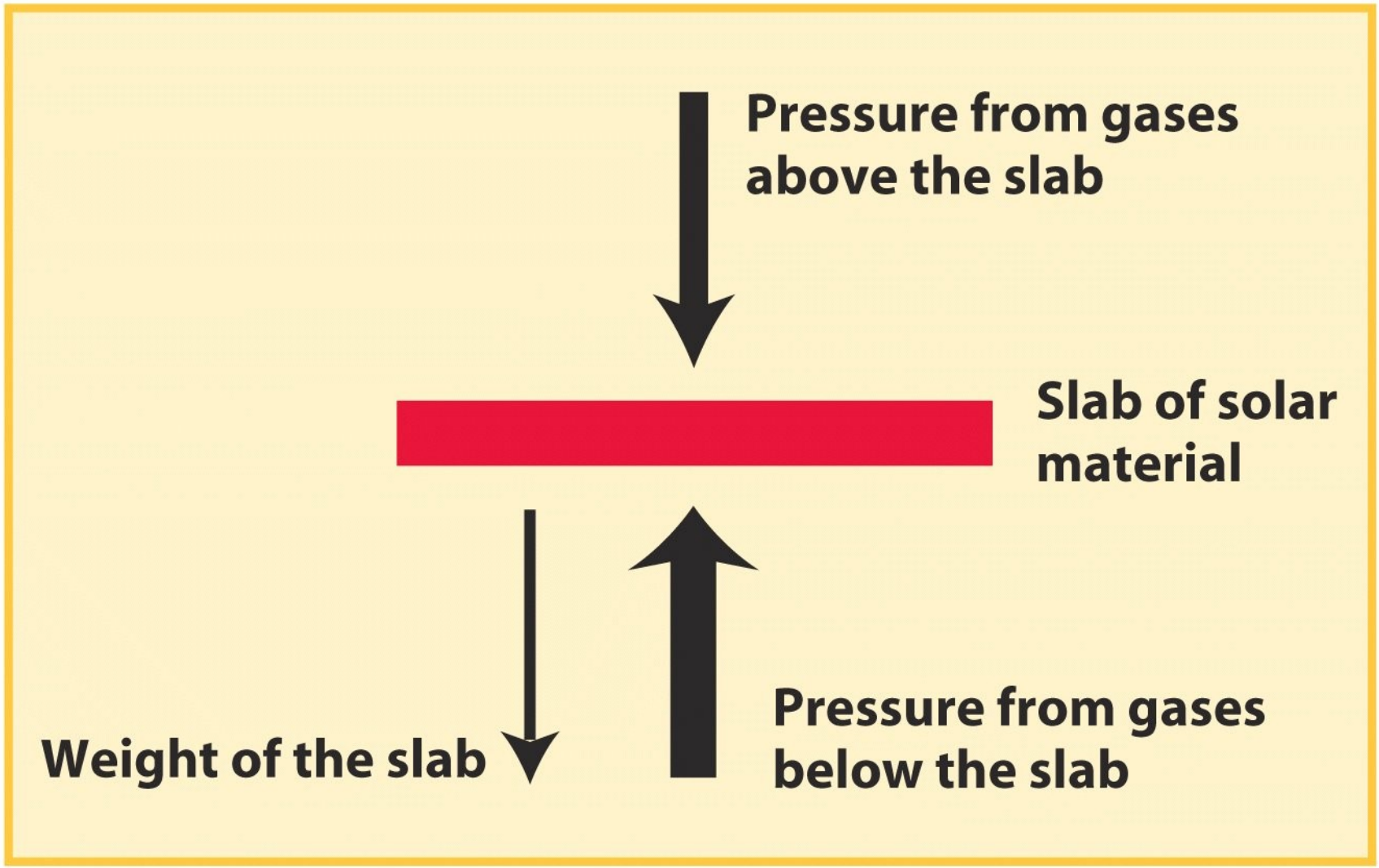
- The Sun is powered by the conversion of mass into energy
- So are nuclear reactors and nuclear bombs

Internal Structure of the Sun

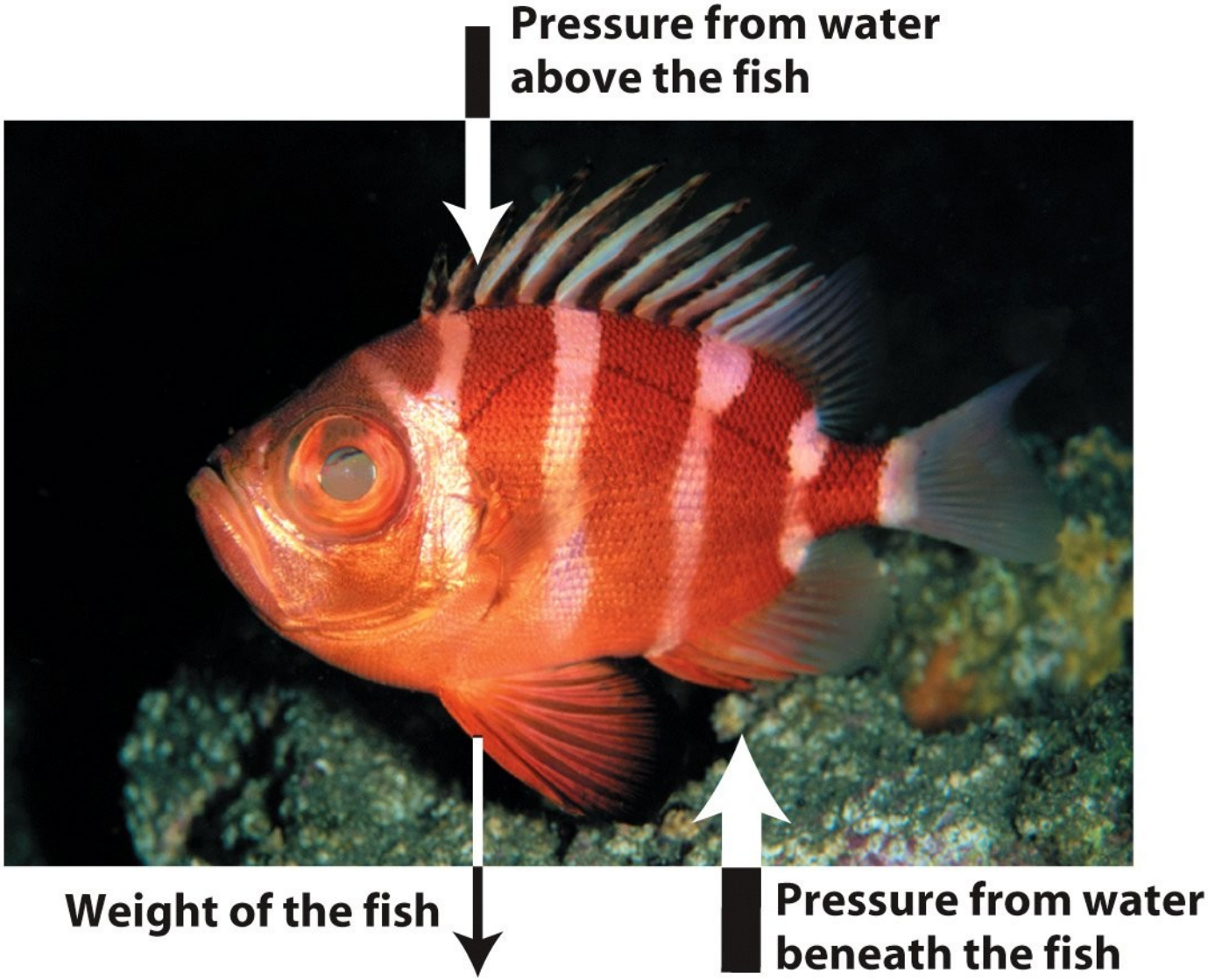




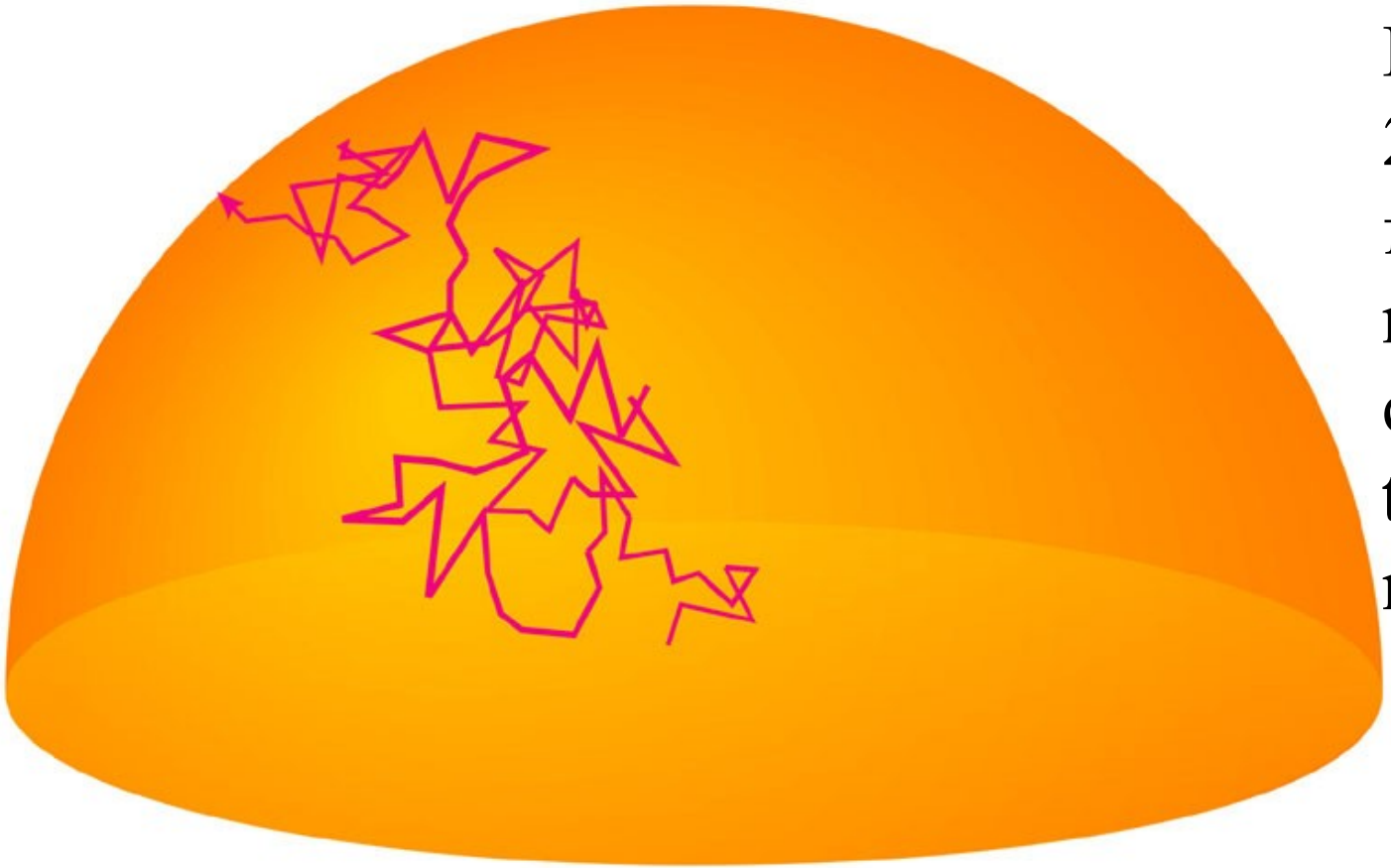
Gas in the Sun is in hydrostatic equilibrium



Fish in water are in hydrostatic equilibrium



Transport of energy through the radiative zone



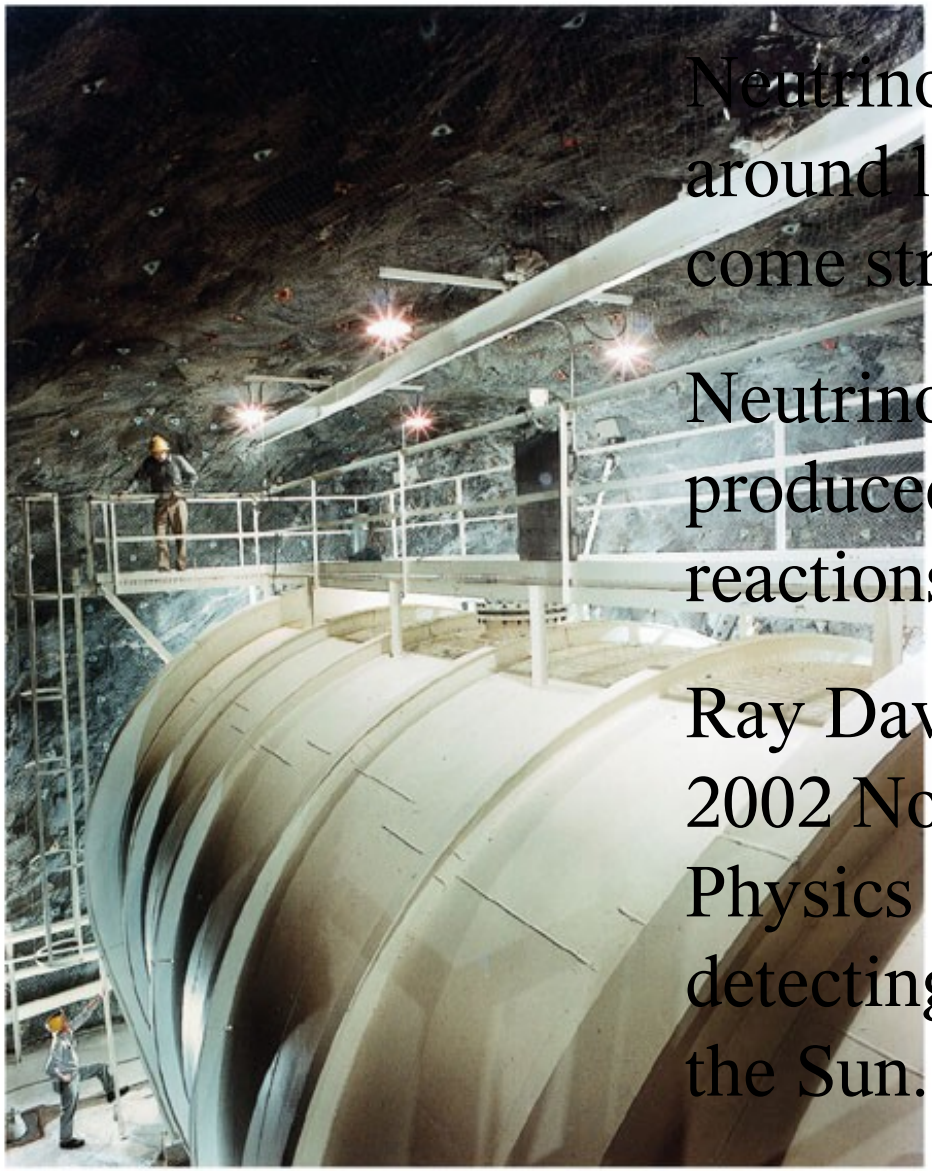
It takes about 200,000 years for photons made in the core to make it through the radiative zone

Convective zone

Do the following transport energy by convection or radiation?

1. A gas oven (A = convection, B= radiation)
2. A microwave
3. A heat lamp
4. An electric radiator

Is there direct evidence for fusion in the Sun?



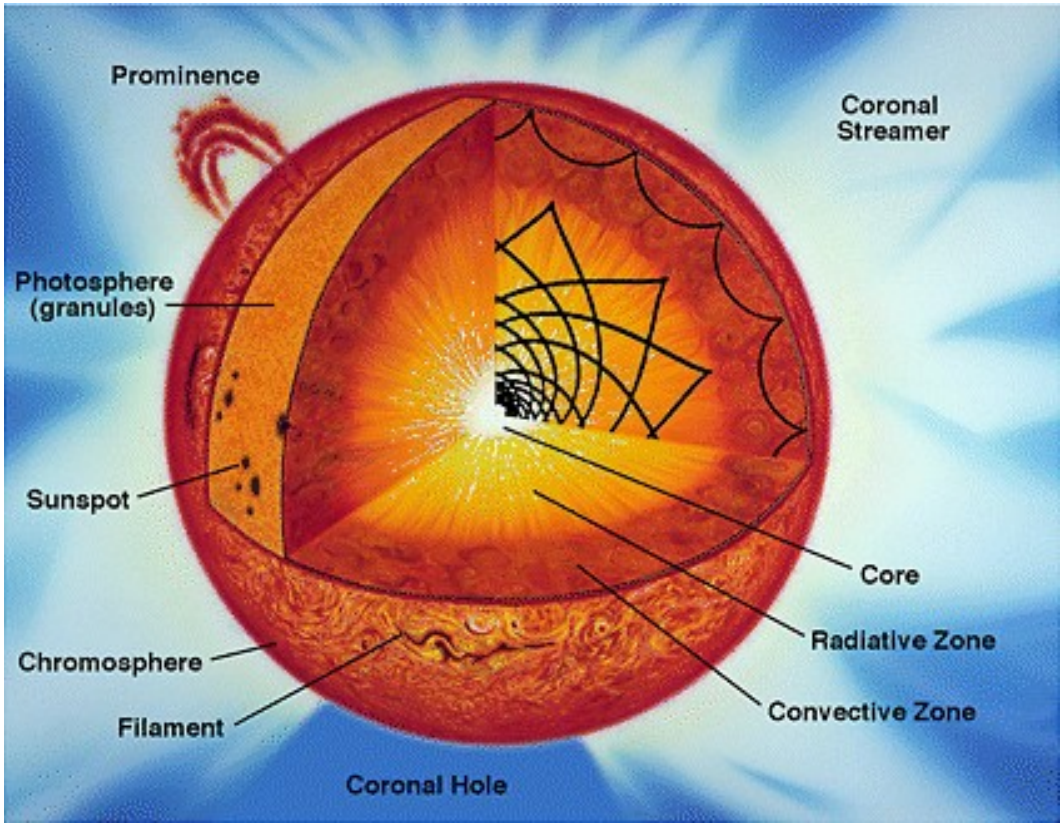
Neutrinos don't bounce around like photons, come straight out.

Neutrinos are only produced in nuclear reactions.

Ray Davis shared the 2002 Nobel prize in Physics for originally detecting neutrinos from the Sun.

The Sun's Atmosphere

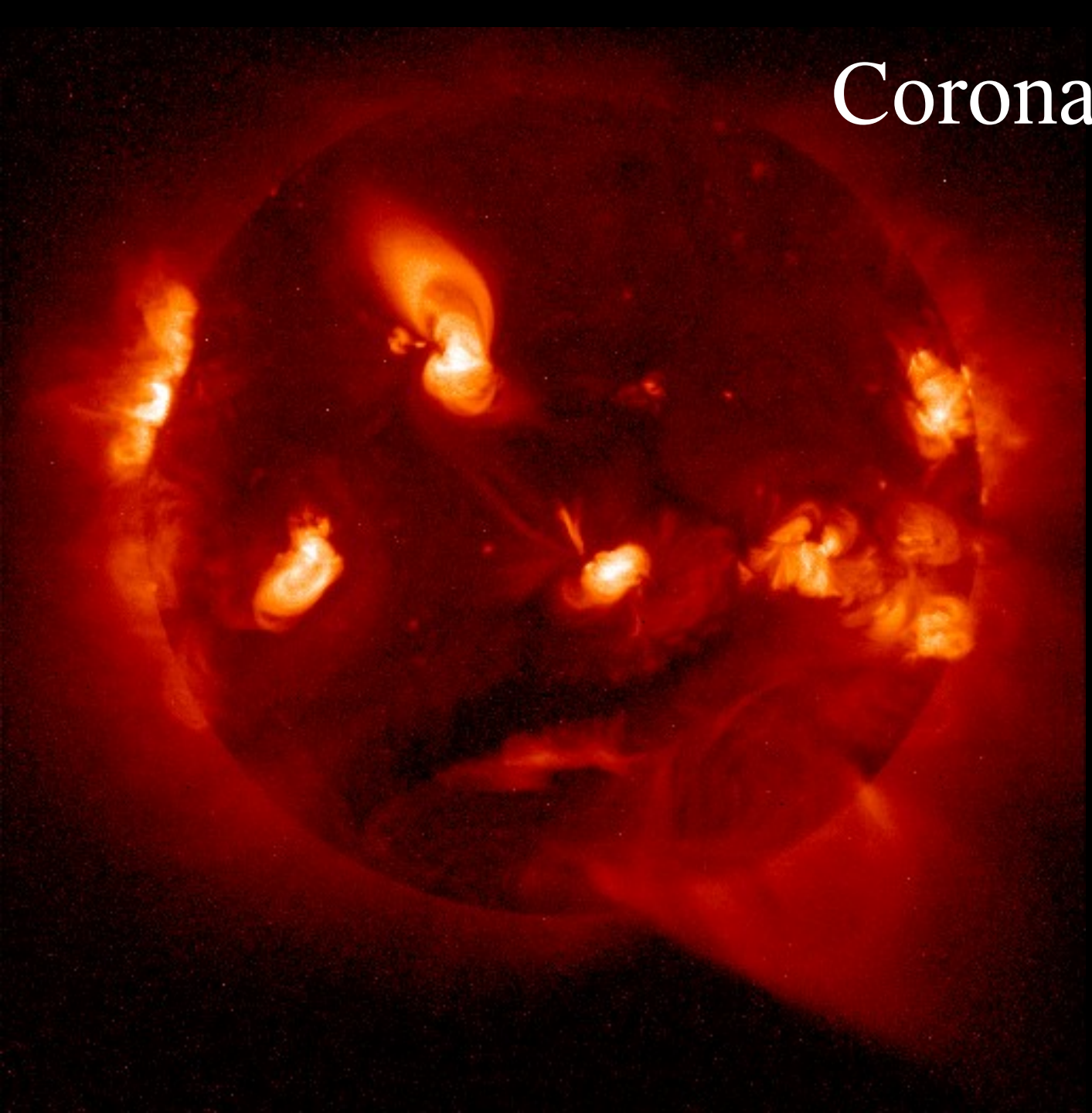
- ***Photosphere*** **-** the 5800 K layer we see.
- ***Chromosphere*** – a thin layer, a few 1000 km thick, at a temperature of about 10,000 K.
- ***Corona*** – Outermost layer, 1,000,000 km thick, at a temperature of about 1,000,000 K.



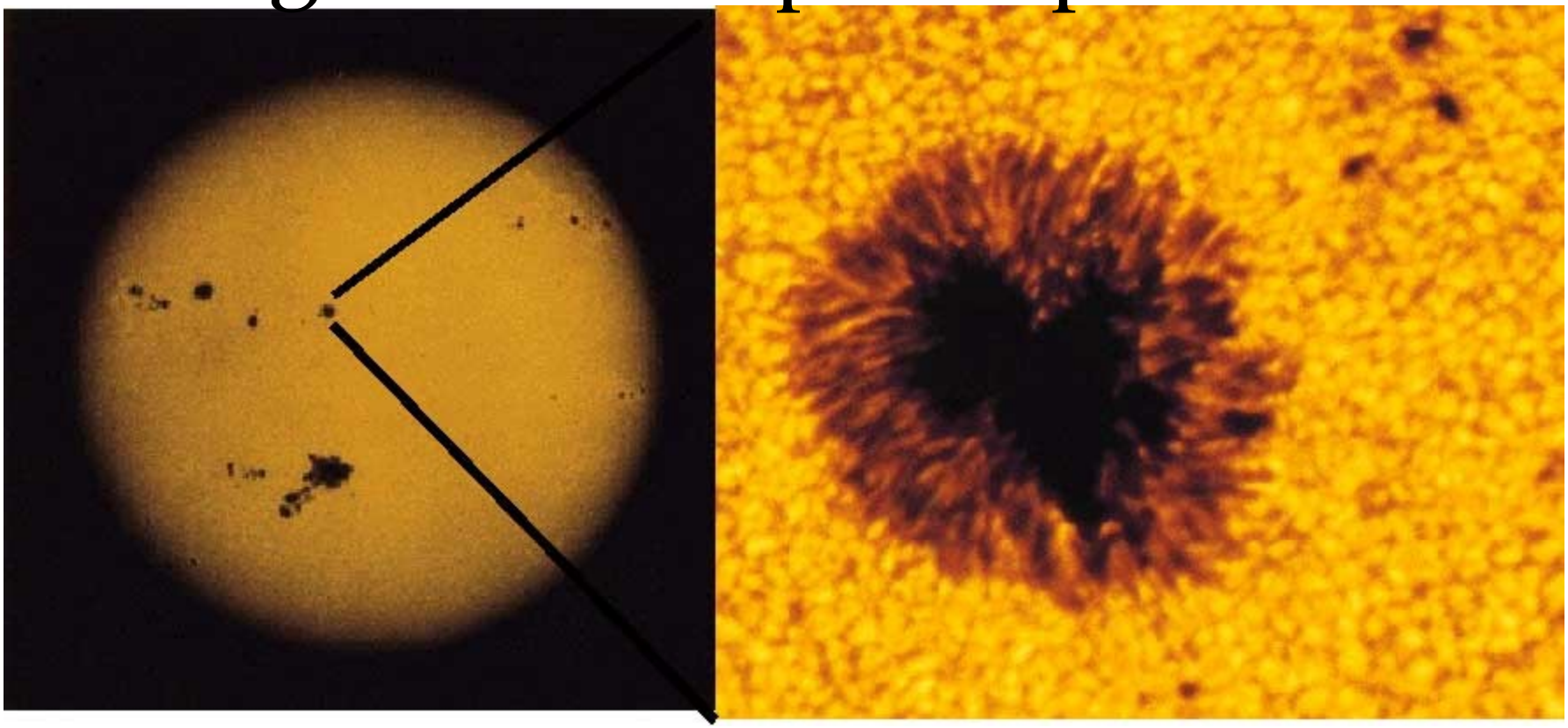
Photosphere

Chromosphere

Corona

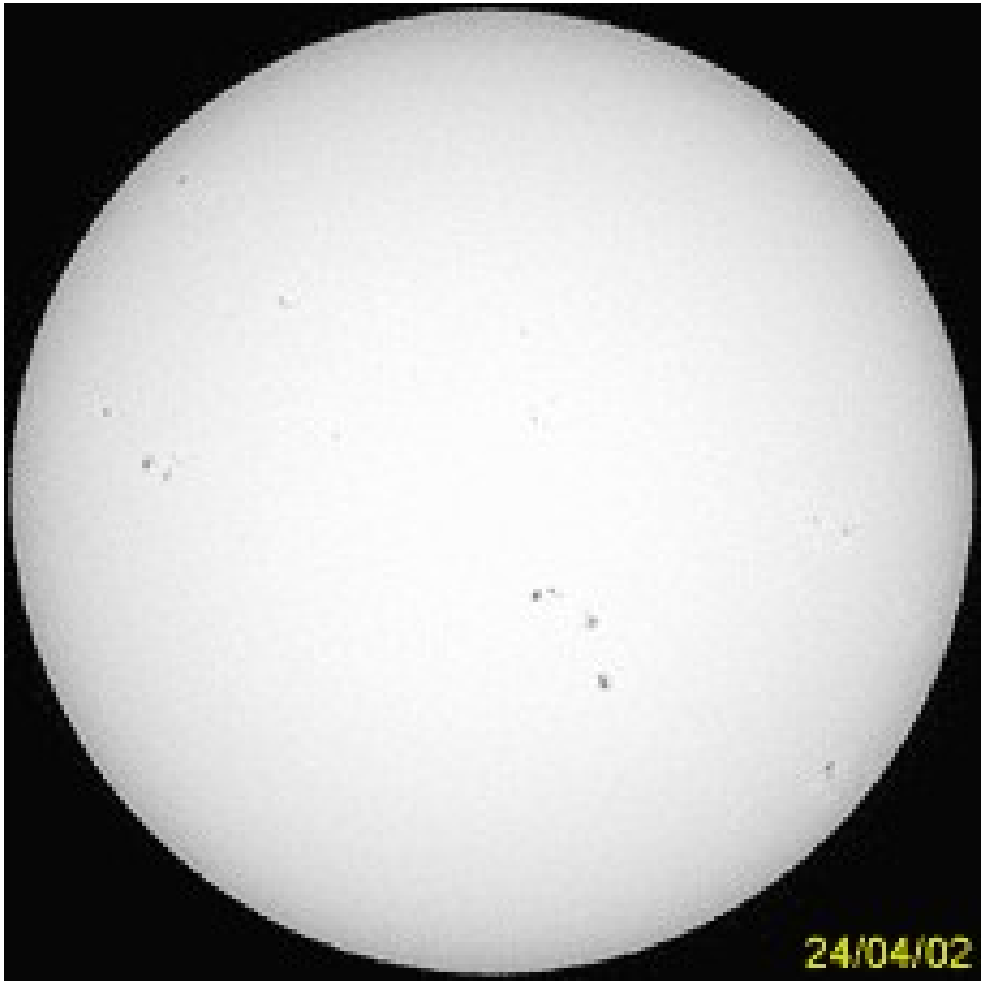


Sunspots are low temperature regions in the photosphere



Sun spots are about 4000 K (2000 K cooler than solar surface) and have magnetic fields up 1000× the normal solar magnetic field. They can be as large as 50,000 km and last for many months.

Sunspots can be used to measure the rotation of the Sun



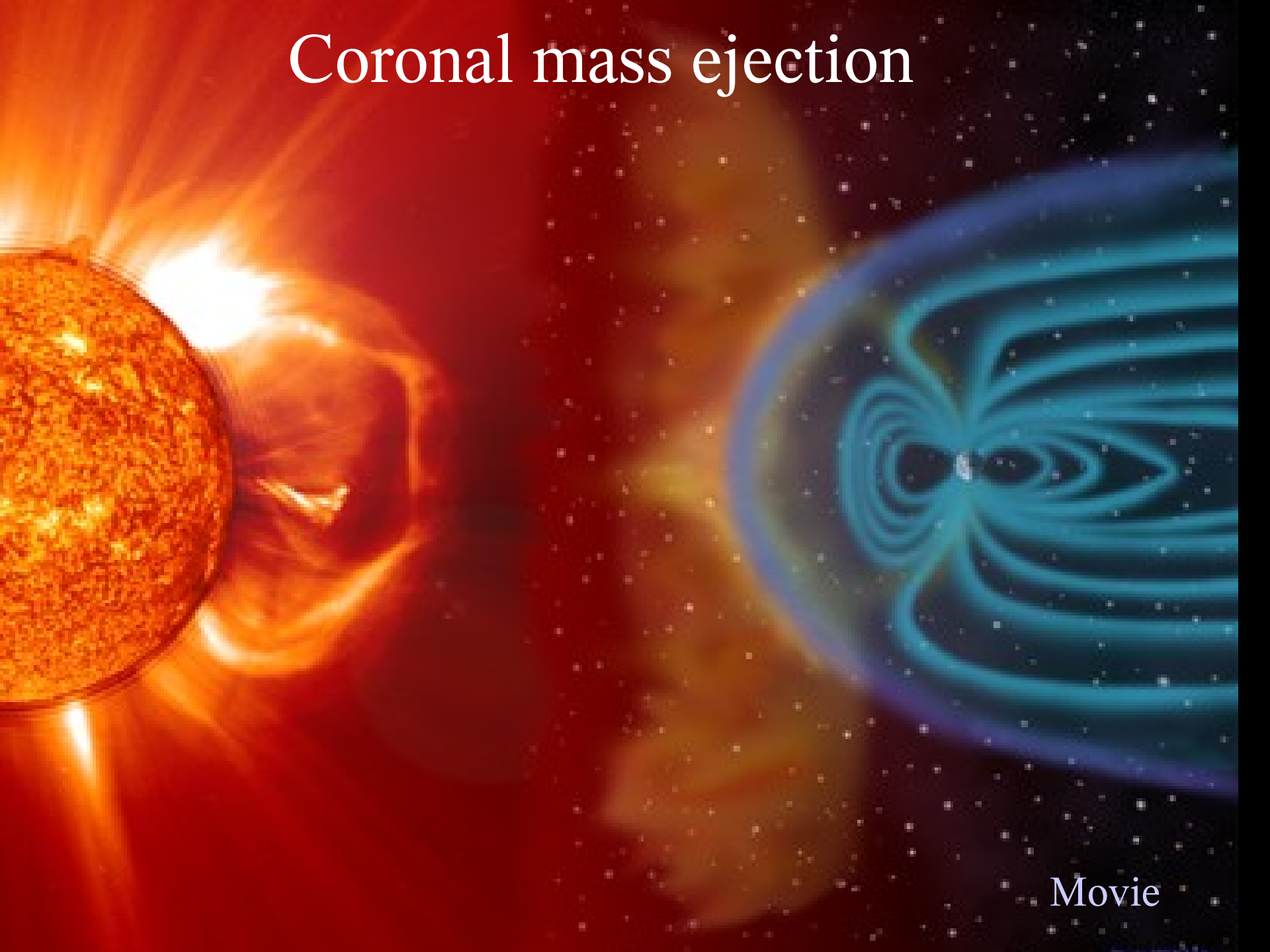
Near the equator the Sun rotates once in 25 days.

The poles rotate more slowly, about once every 36 days.

Coronal mass ejections - eruption of gas, can reach Earth and affect aurora, satellites

Movie

Coronal mass ejection



Movie