Announcements

- **The first exam is Wednesday, Sept. 21.**
- **Please e-mail questions for review on Monday**
- After homework is grader, you can see your answers and the correct answers on ICON
- There was a problem with HW#3 and the last two questions were not graded
- Astronomy tutorial: Tuesday 3-5, 7-9 pm in 310 VAN
- Office hours: Tuesday 1–3 pm, Wednesday 10-11 am, or by appointment in 702 VAN
- Remember to set clicker to channel 44

When should homework #4 be due?

A) Monday at midnight
B) Tuesday at 3 pm
C) Tuesday at 6 pm
D) Tuesday at 9 pm
E) Tuesday at midnight

NASA TO ANNOUNCE KEPLER DISCOVERY

Science Journal Has Embargoed Details Until 11 a.m. PDT, Sept. 15

NASA will host a news briefing at 11 a.m. PDT, Thursday, Sept. 15, to announce a new discovery by the Kepler mission. The event will be carried live on http://www.nasa.gov/ntv

Kepler is the first NASA mission capable of finding Earth-size planets in or near the "habitable zone," the region in a planetary system where liquid water can exist on the surface of the orbiting planet. Although additional observations will be needed to achieve that milestone, Kepler is detecting planets and planet candidates with a wide range of sizes and orbital distances to help us better understand our place in the galaxy.

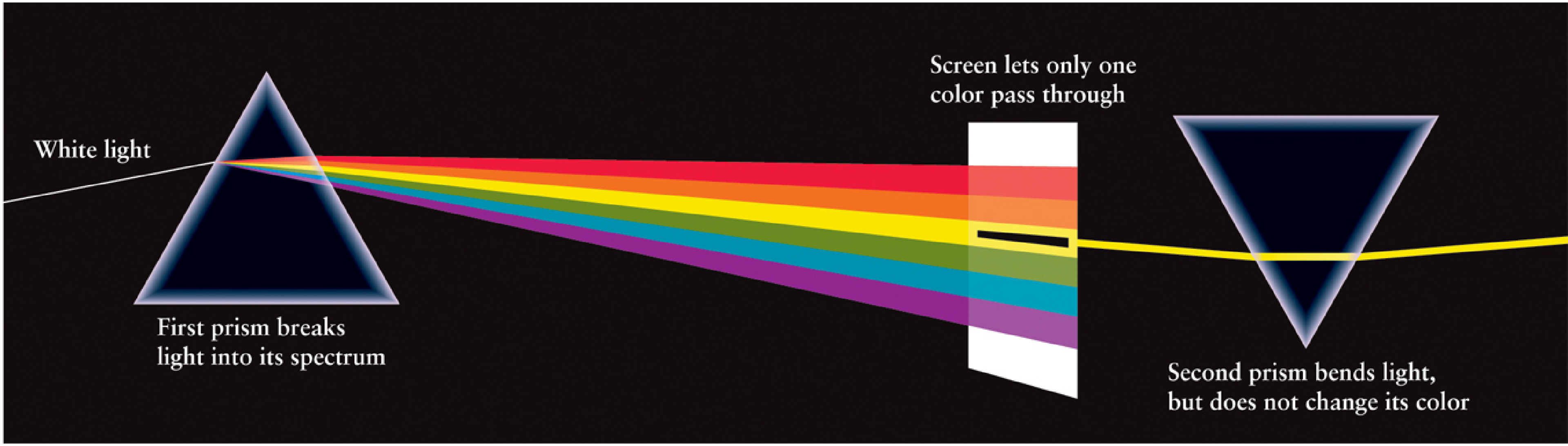
A representative from Industrial Light & Magic (ILM), a division of Lucasfilm Ltd., will join a panel of scientists to discuss the discovery. The briefing participants include Laurance Doyle, lead author, SETI Institute, John Knoll, visual effects supervisor, ILM, and Kepler scientists.

Light

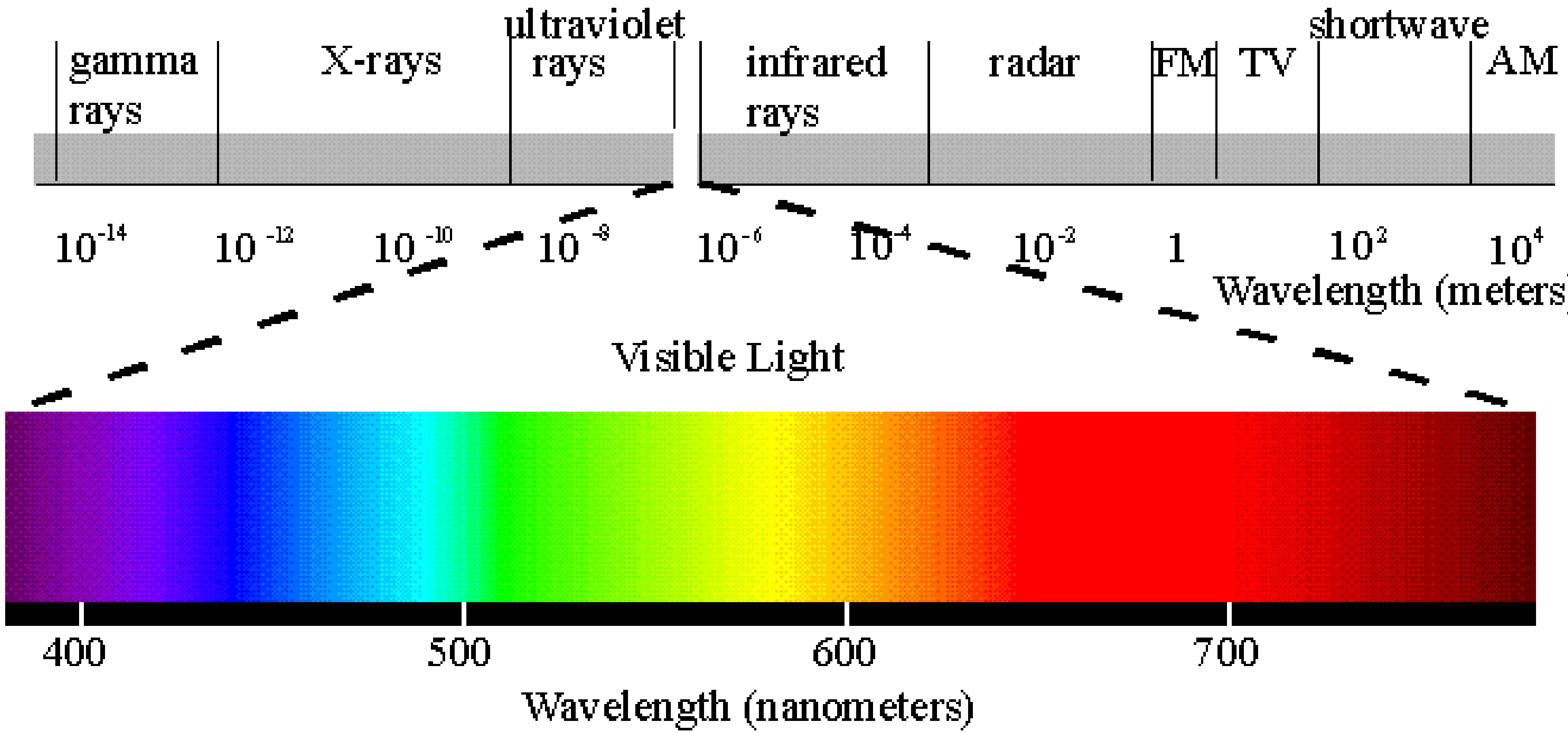
- Spectrum of light
- Photons
- Atomic structure

Sunlight Is a Mixture of All Colors

- White light from the sun contains light with a range of colors
- Prisms, or rainbows, can separate out the different colors



Electromagnetic spectrum

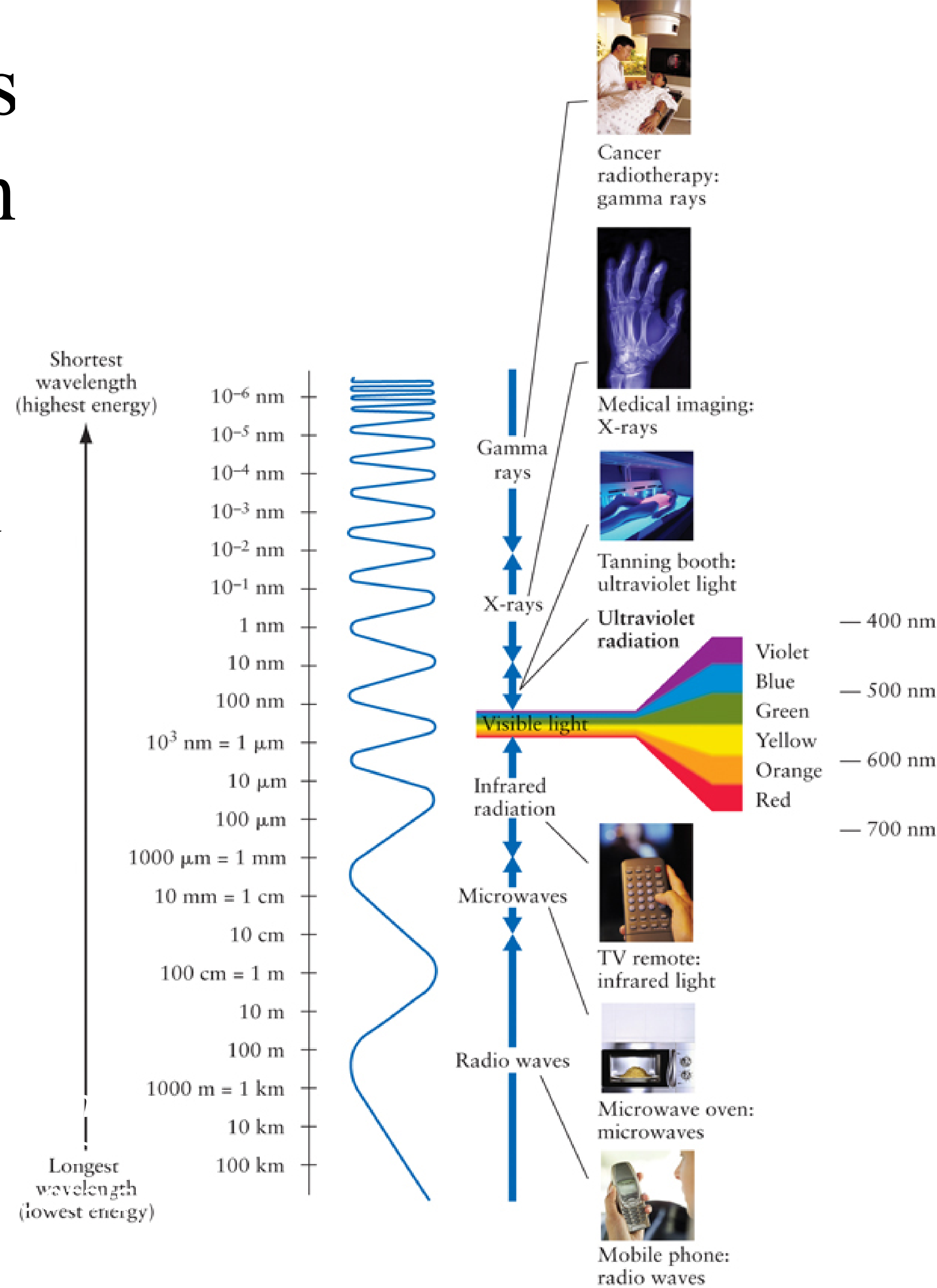


The color of light corresponds to its wavelength:

Red = long wavelength, Blue = short wavelength

The spectrum extends past what our eyes can see

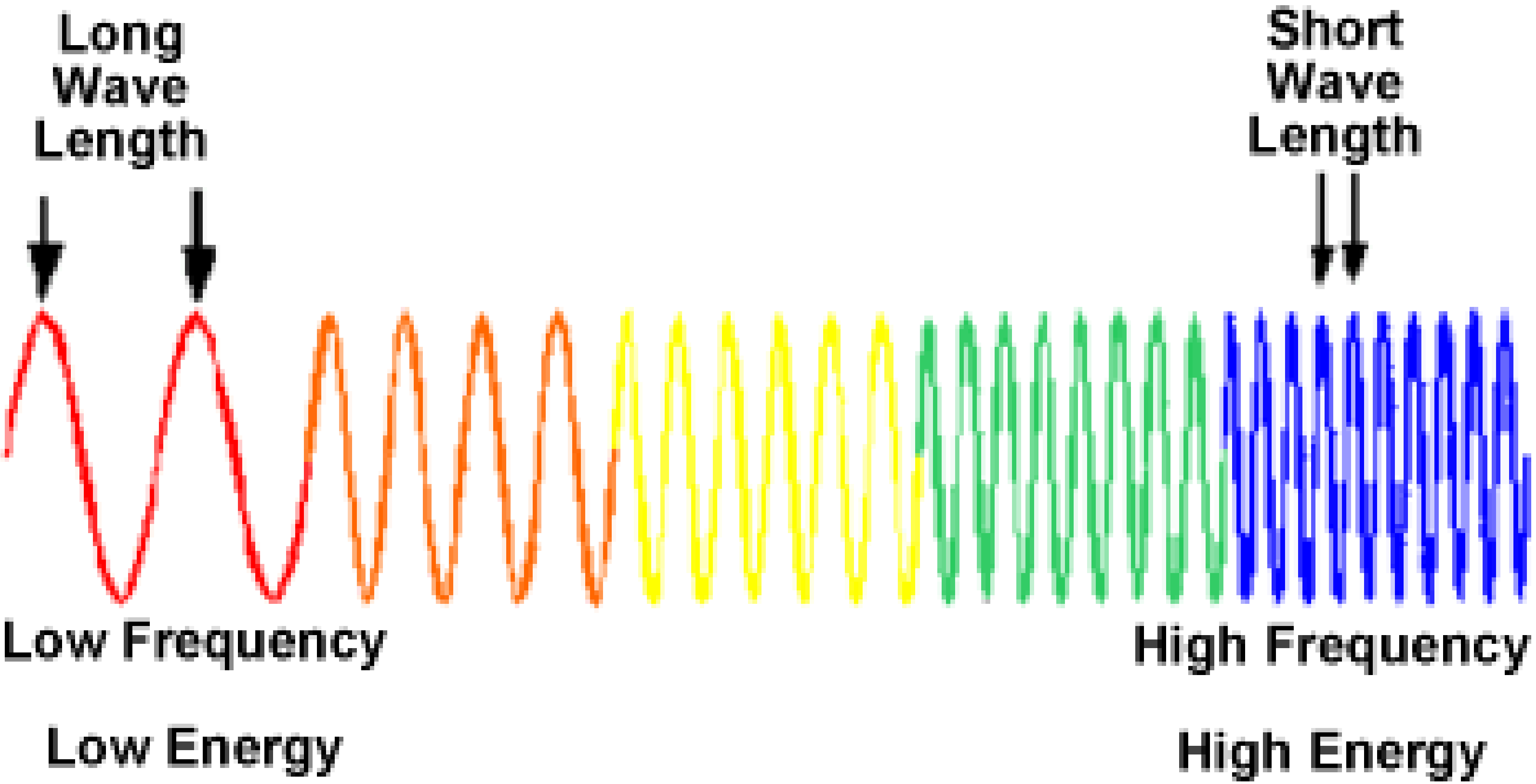
Half of this image was taken with a visible light camera, half with a UV camera.



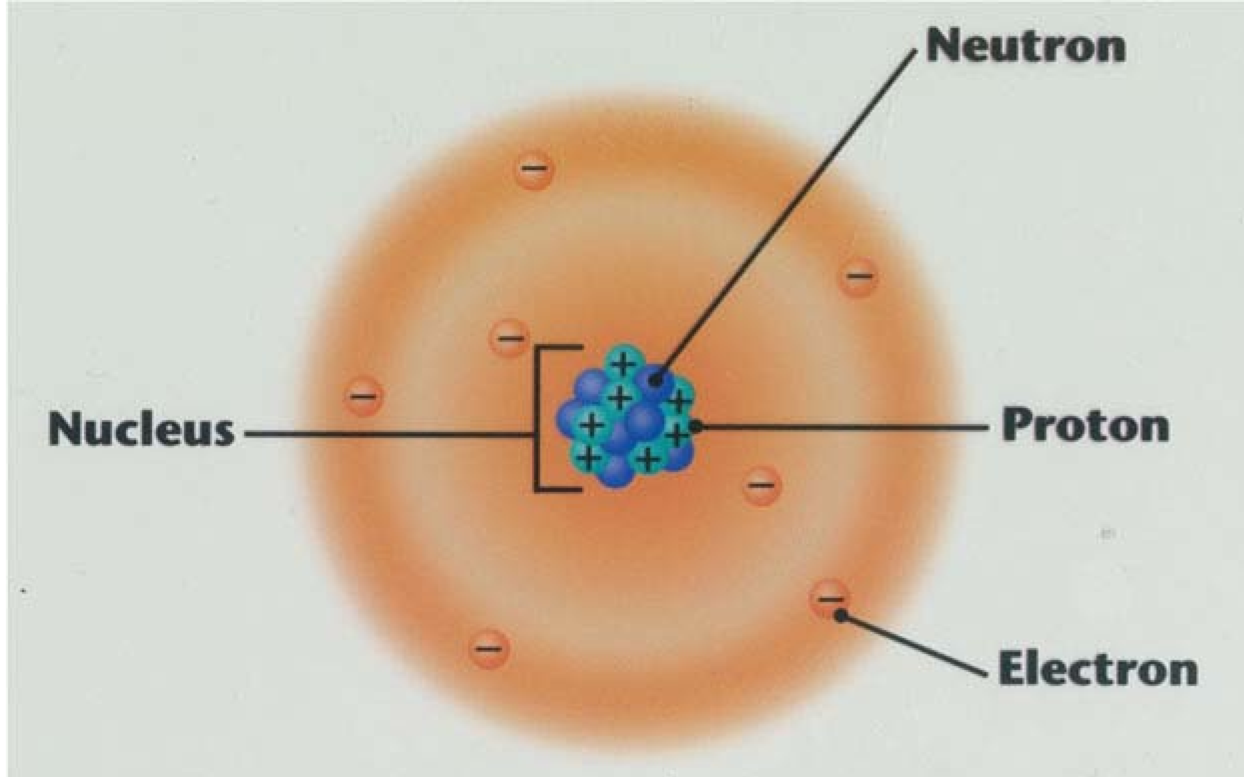
Photons

- Up to now, we have been discussing the wavelength of light as determining it color
- However, light comes in discrete packets called photons and the energy of each photon is set by its color or wavelength
- From Einstein, we known that the photon energy is inversely proportional to wavelength

Photon energy



Atomic structure



- Nucleus at center contains protons and neutrons
- Electrons orbit around nucleus
- Atom held together by electric force between positive charge on protons and negative charge on electrons
- Nucleus held together by nuclear (or “strong) force between protons and neutrons

Compared to optical light, X-rays have

A) Shorter wavelength, lower energy
B) Shorter wavelength, higher energy
C) Longer wavelength, lower energy
D) Longer wavelength, higher energy
E) Amazing superpowers

When Mars is full it must rise

A) At dawn
B) At sunset
C) At either dawn or sunset
D) None of the above

The Sun

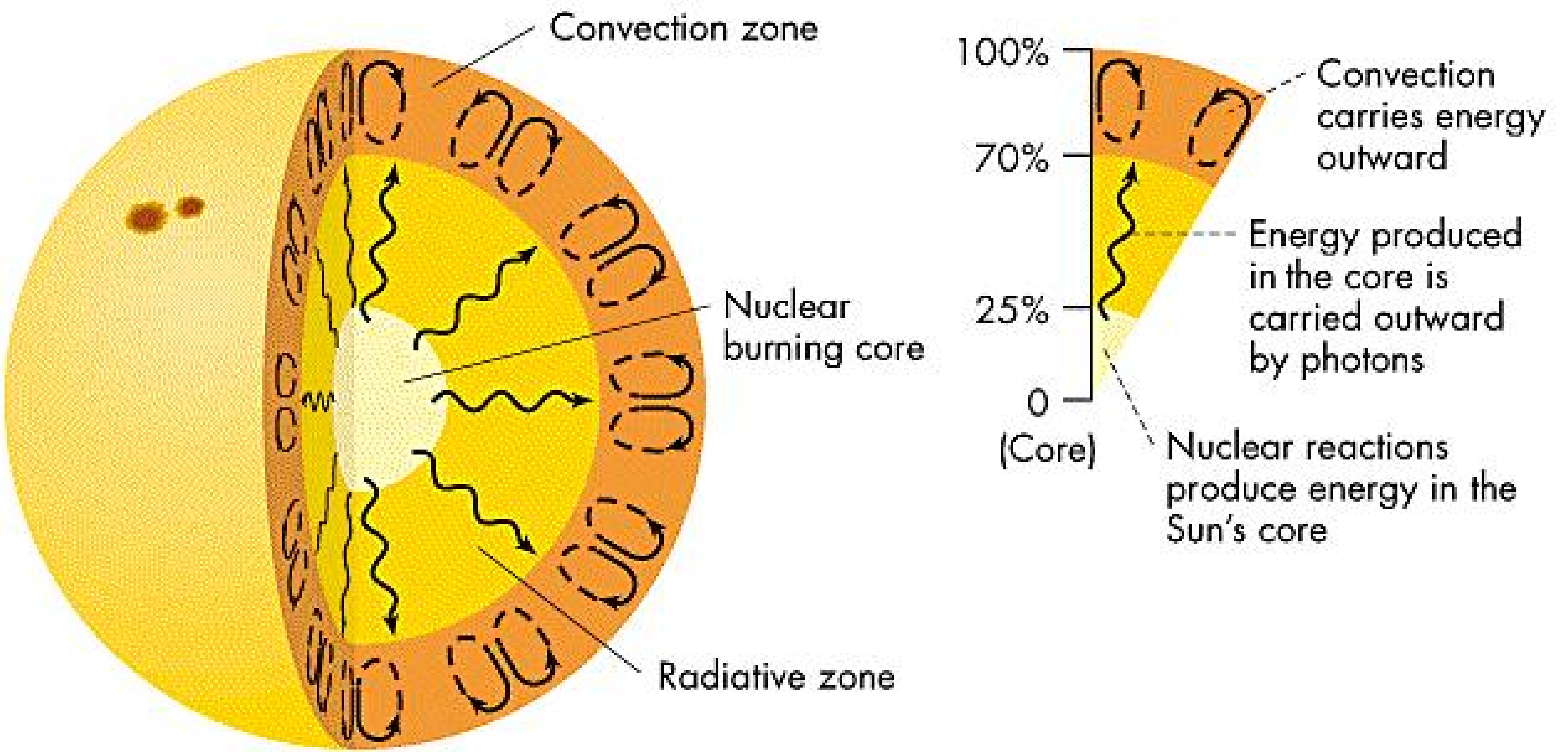
Internal structure of the Sun

Nuclear fusion

Transport of energy in the sun

Outer layers of the Sun

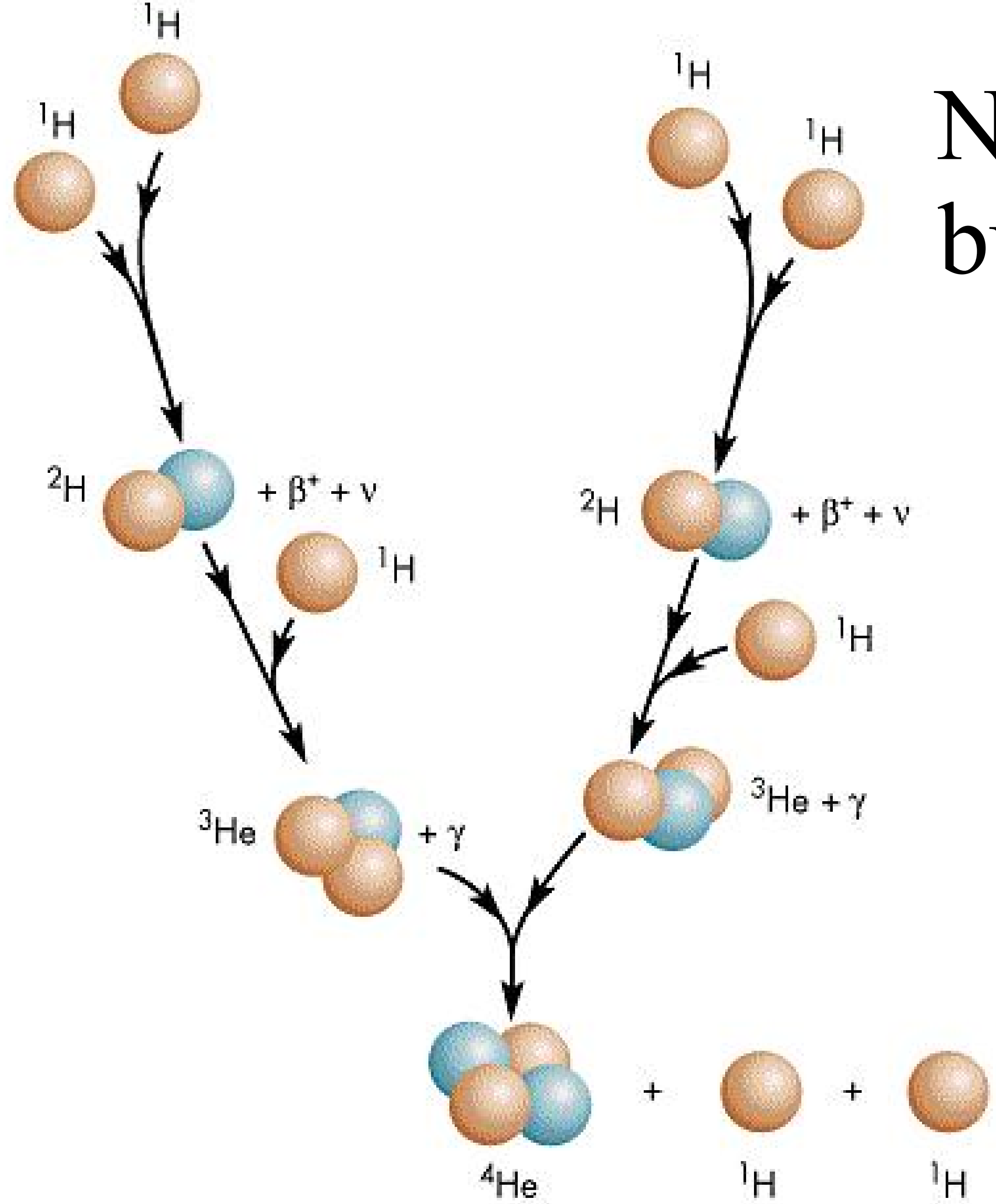
Internal Structure of the Sun



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

Average density 1.4× water, surface temperature 5800 K

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)

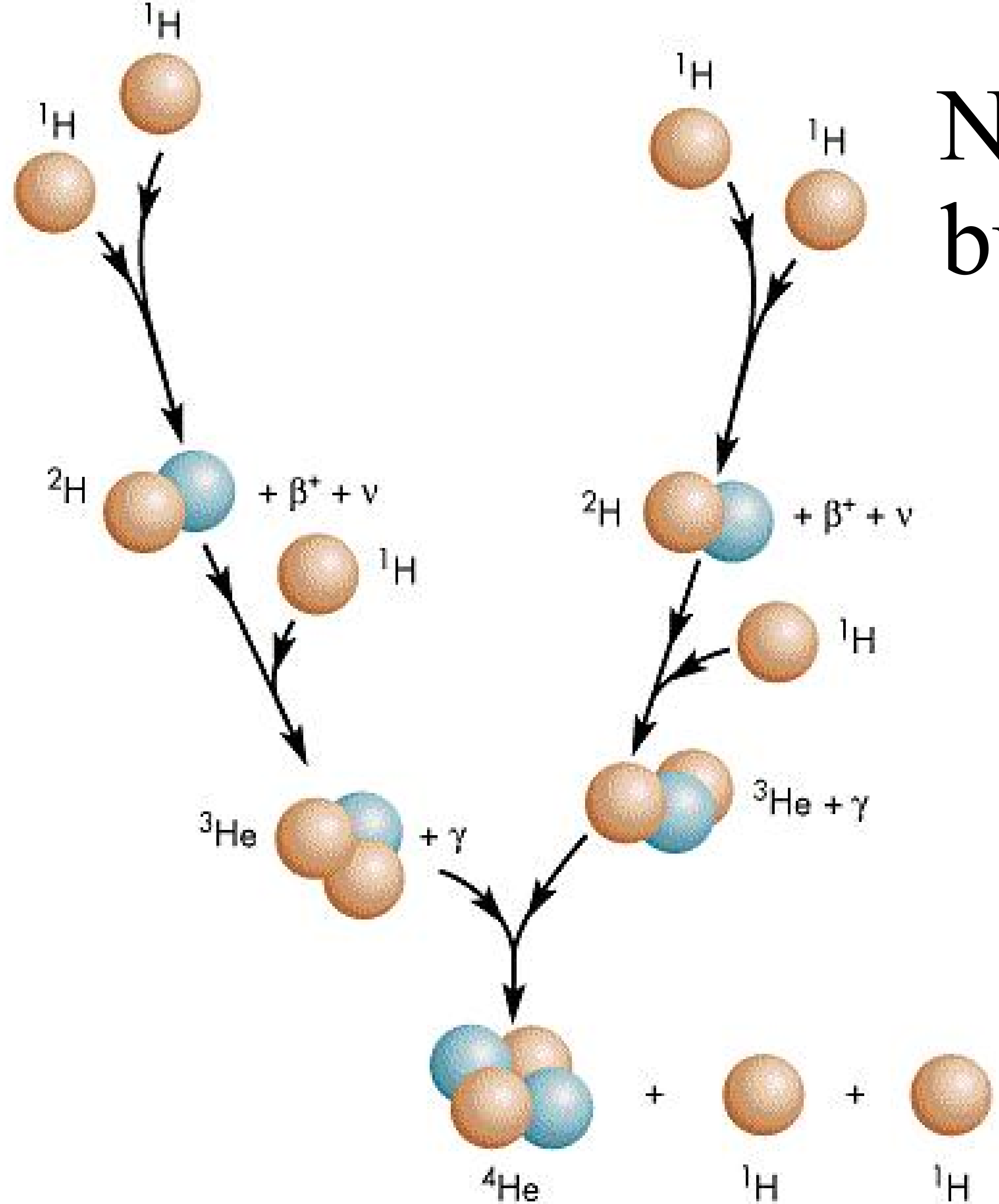
^{3}He = light helium nucleus (unstable(

= two protons plus one neutron

^{4}He = normal helium nucleus

= two protons plus two neutrons

Nuclear burning



Nuclear burning

- 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

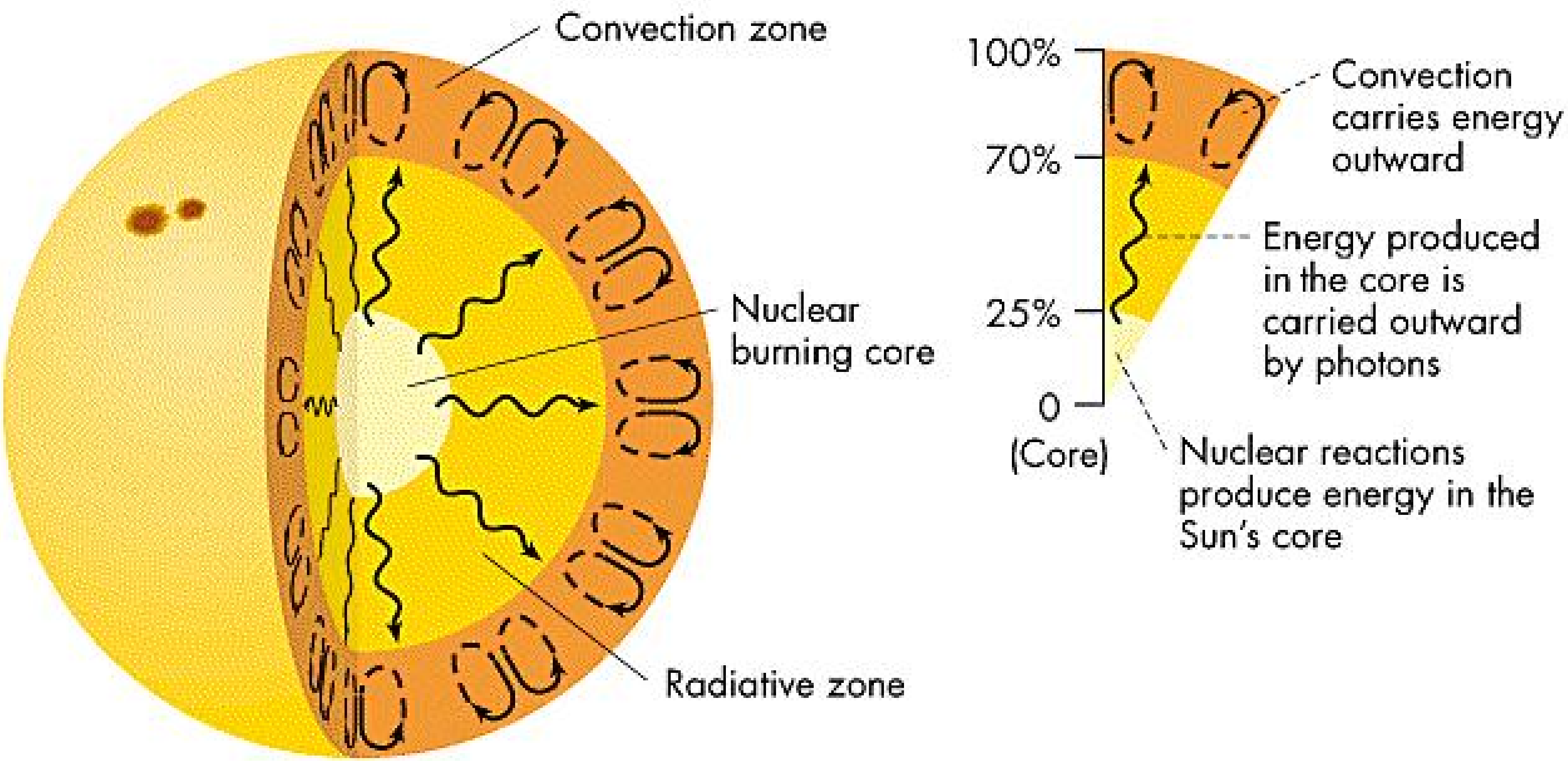
$$E = mc^2$$

$E = mc^2$

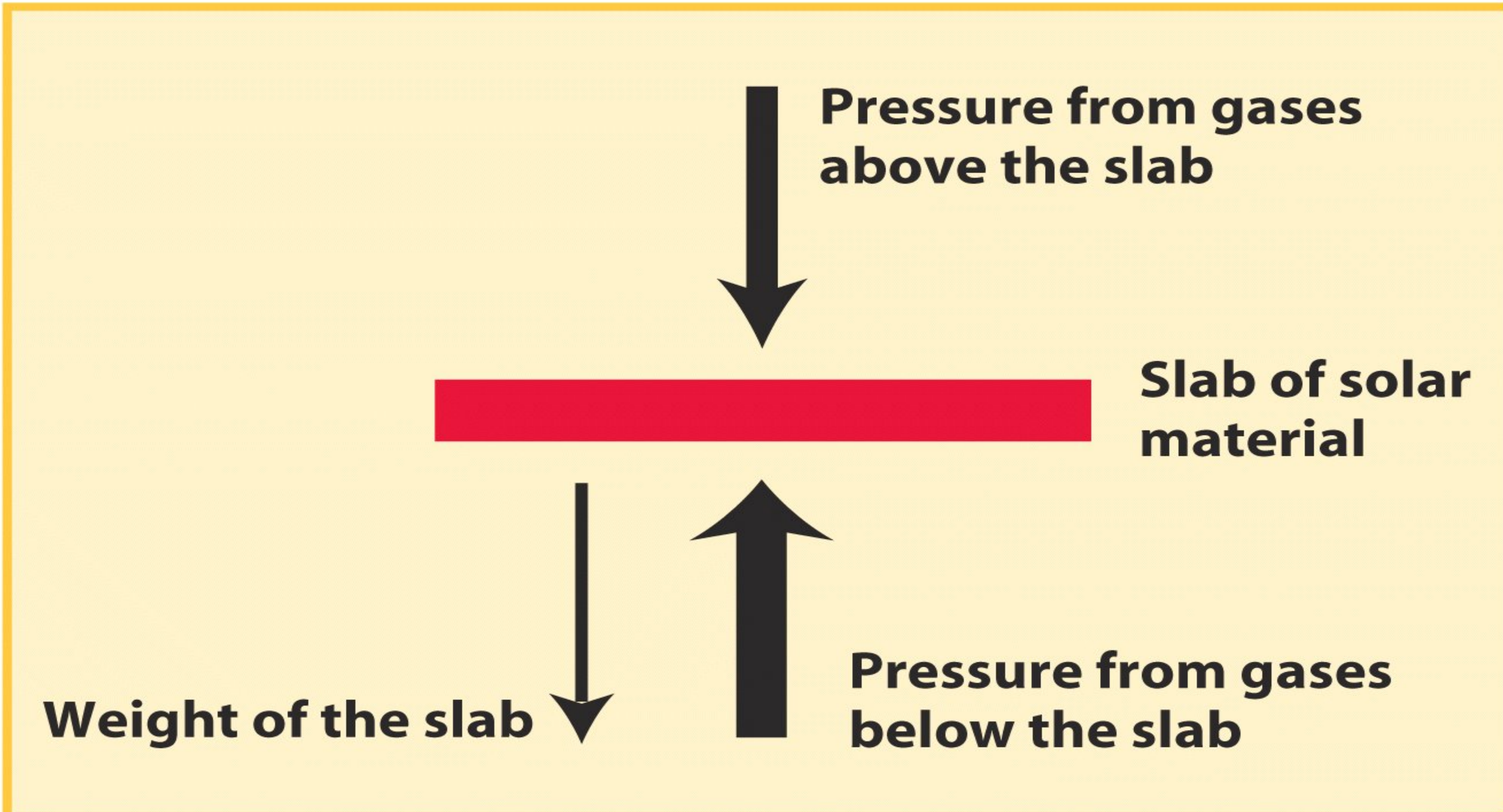
- Einstein showed that mass and energy are equivalent (c = speed of light)
- Mass can be converted to energy, and
- Energy can be converted to mass

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

Internal Structure of the Sun

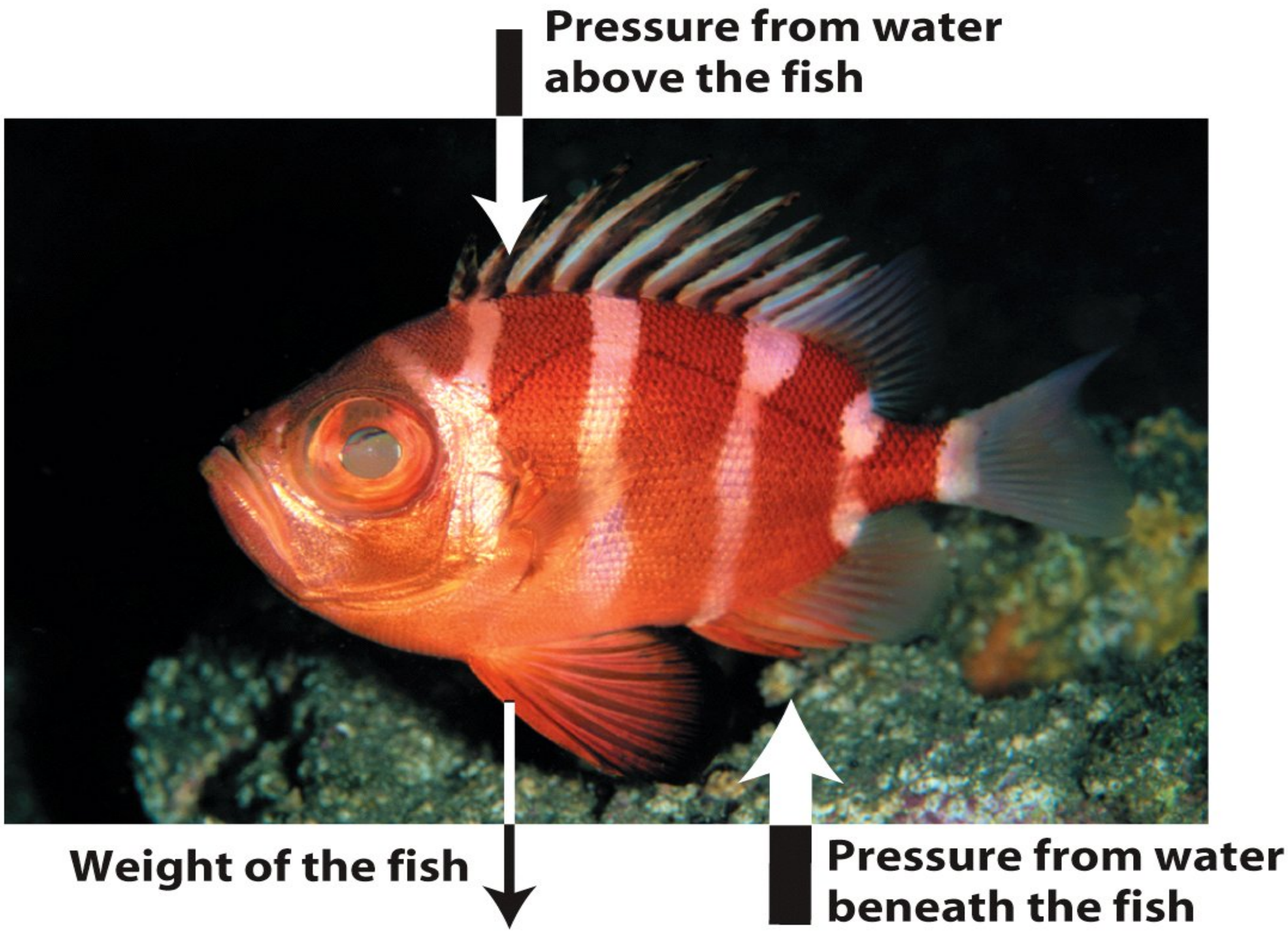


Gas in the Sun is in hydrostatic equilibrium



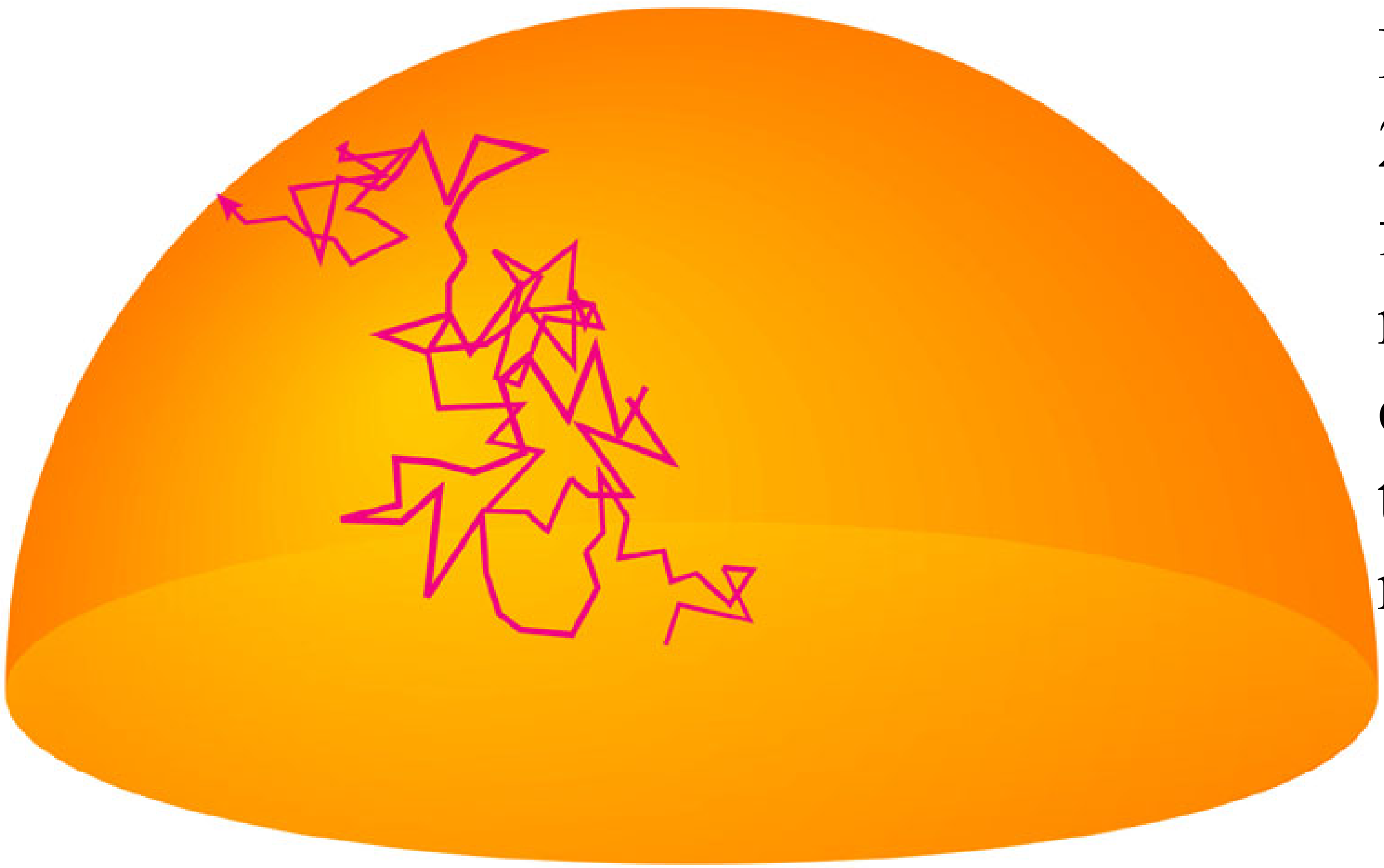
Material inside the sun is in hydrostatic equilibrium, so forces balance

Fish in water are in hydrostatic equilibrium



A fish floating in water is in hydrostatic equilibrium, so forces balance

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

Which of following transport energy by convection?

A) A gas oven
B) A microwave
C) A heat lamp
D) An electric radiator

Which of the following transport energy by radiation?

A) A gas oven
B) A microwave
C) A heat lamp
D) An electric radiator

Is there direct evidence for fusion in the Sun?

Neutrinos don't bounce around like photons, they 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.

Where in the Sun is energy created?

A) Throughout the whole interior
B) In the central 25 percent of the Sun
C) In the radiative zone
D) In the convective zone

Why don’t photons flow freely through the convective zone?

A) The density of the convective zone is too high.

B) Temperatures are low enough that atoms form and absorb the photons.

C) Free electrons scatter the photons in different directions.

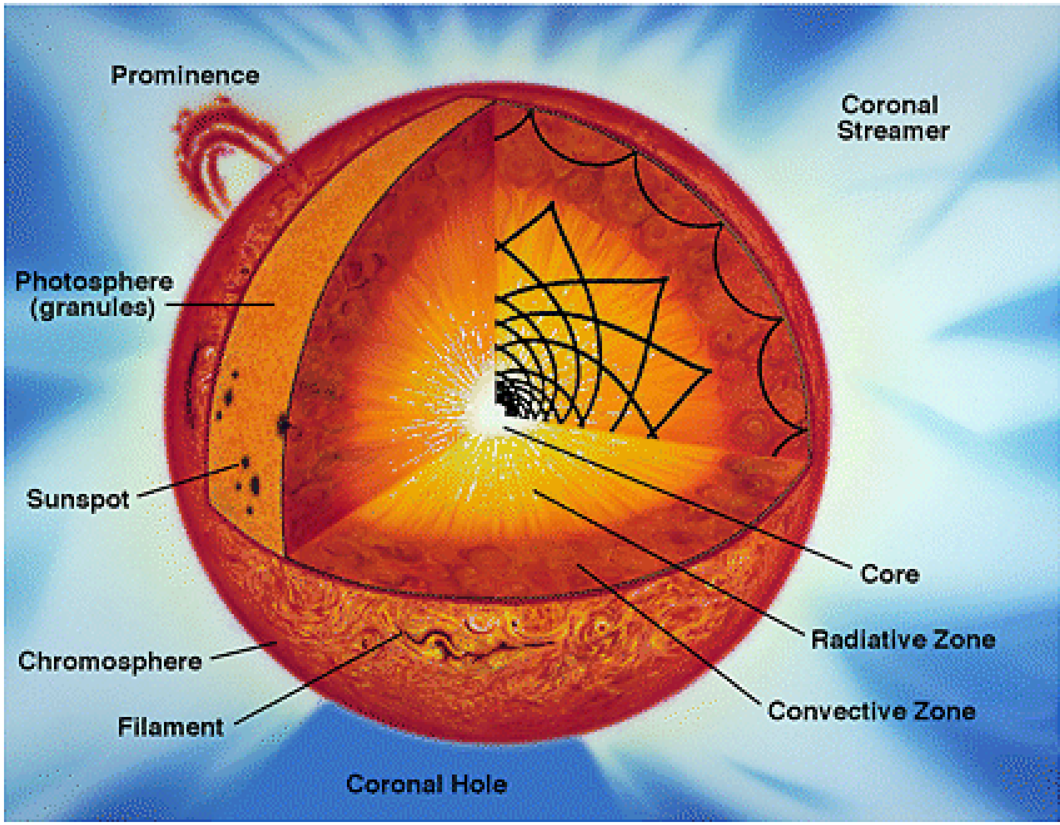
D) The photons have lost too much energy by this point to travel freely.

I check Facebook

A) Several times during every class
B) A couple of times a day
C) Maybe once a day
D) Once a week
E) Why facebook when you can twitter?
F) Long live myspace

The Sun’s Atmosphere

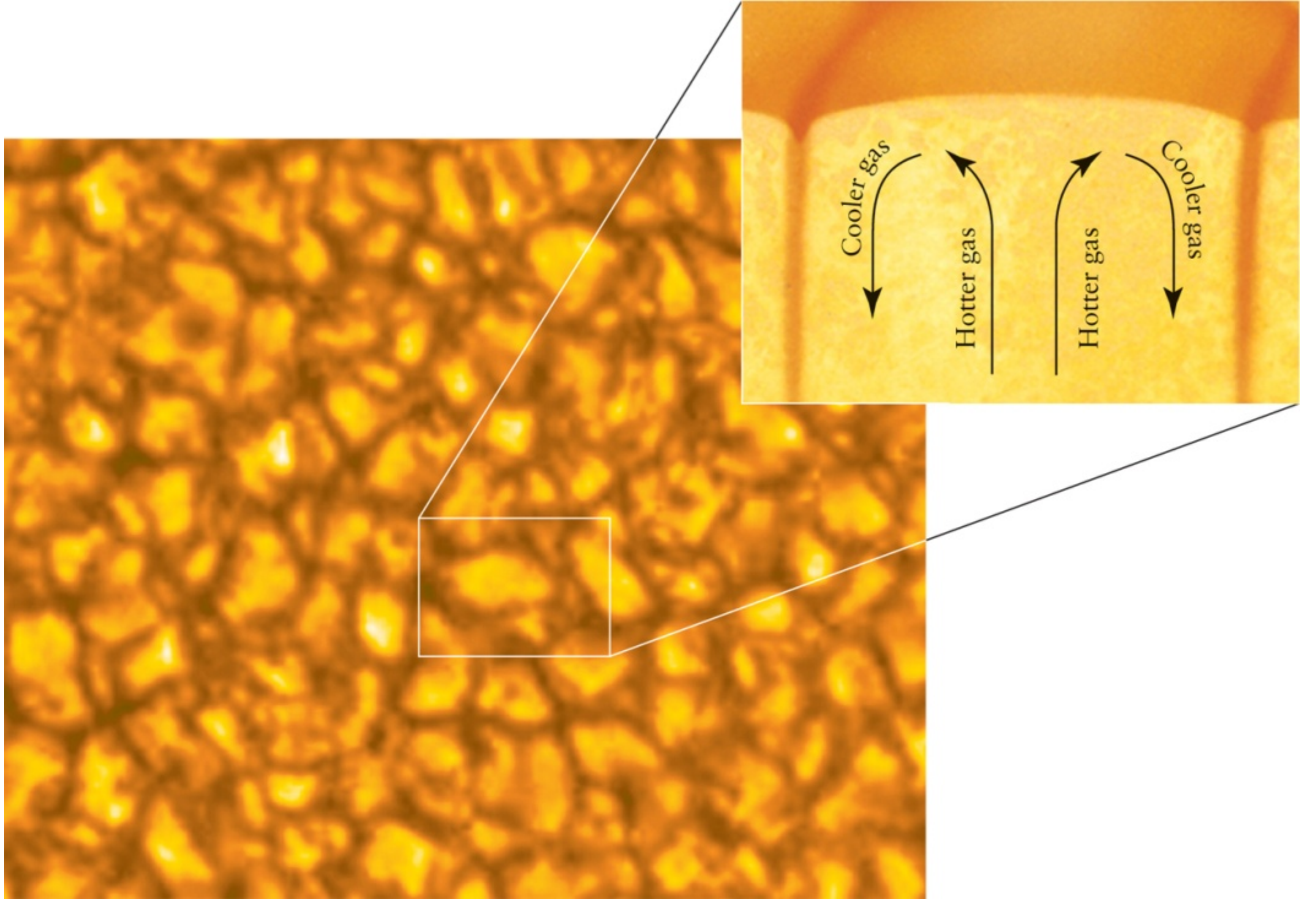
- ***Photosphere*** - the 5800 K layer we see.
- ***Chromosphere*** – a thin layer, a few 1000 km thick, at a temperature of about 10,000 K.
- ***Corona*** – Outermost layer, 1,000,000 km thick, at a temperature of about 1,000,000 K.



Photosphere

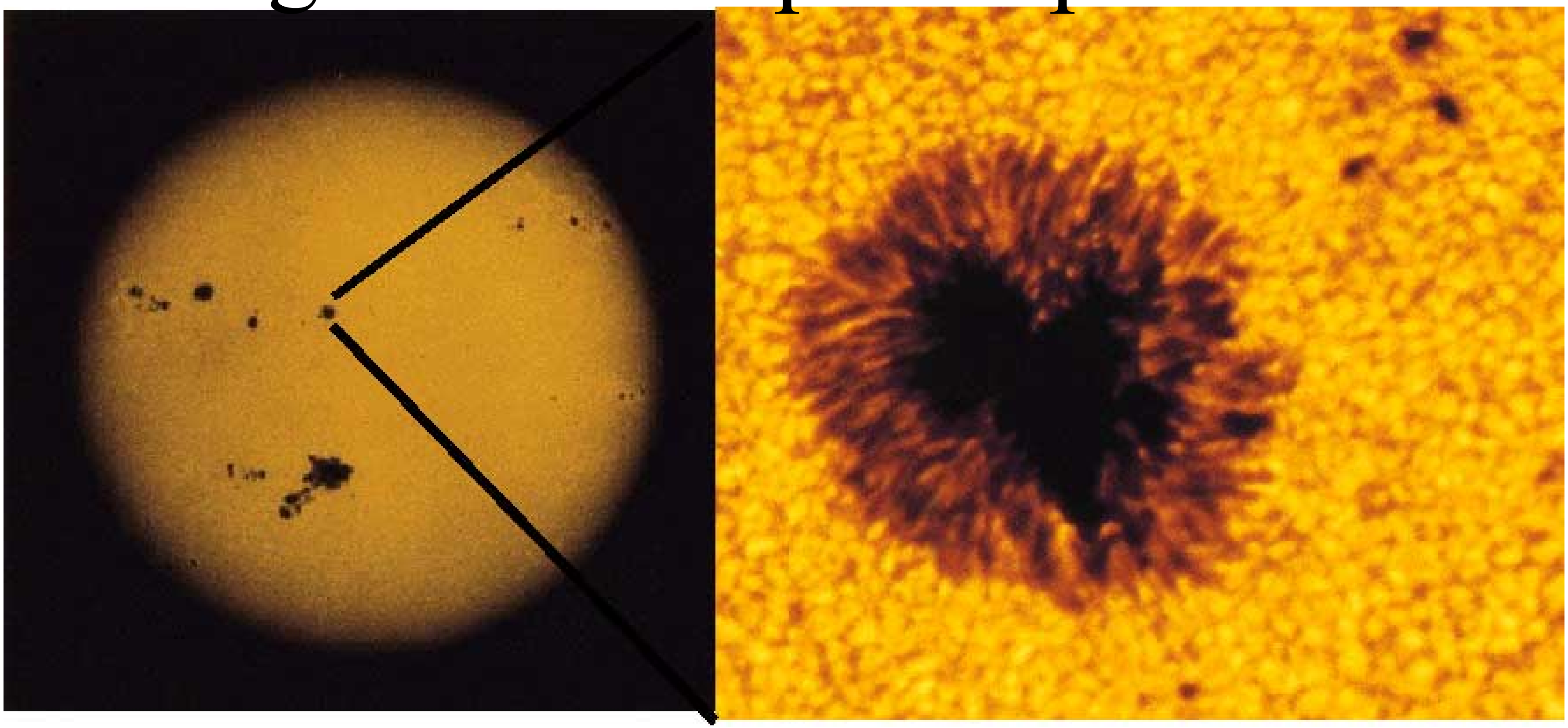
The part of the Sun that we see.
Temperature at surface ~ 5800 K
Density at surface ~ 0.01% of Earth's atmosphere at sea level

Granulation



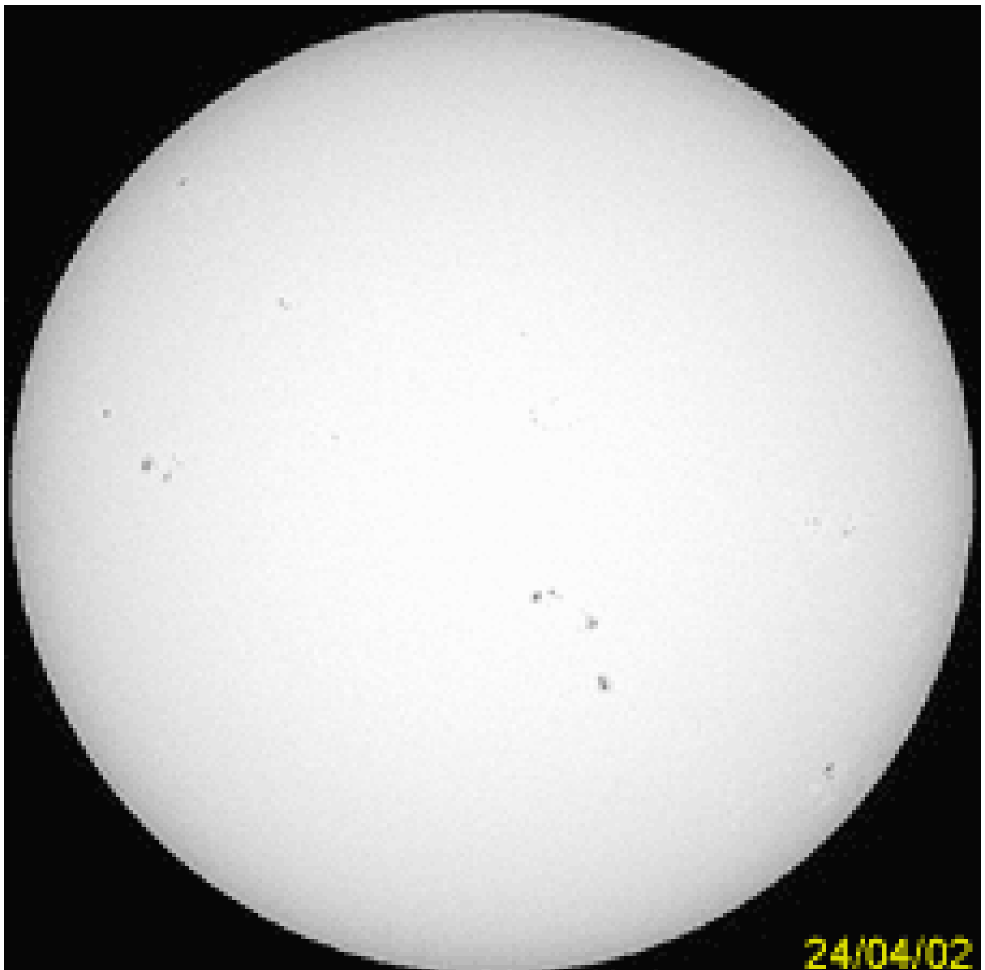
- High-resolution images of the Sun's surface reveal a blotchy pattern called ***granulation.***
- Granules are convection cells about 1000 km (600 mi) wide in the Sun's photosphere produced by rising hot gas.
- Cooler gas sinks downward along the boundaries between granules; this gas glows less brightly, giving the boundaries their dark appearance.
- This convective motion transports heat from the Sun's interior outward to the solar atmosphere.

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.

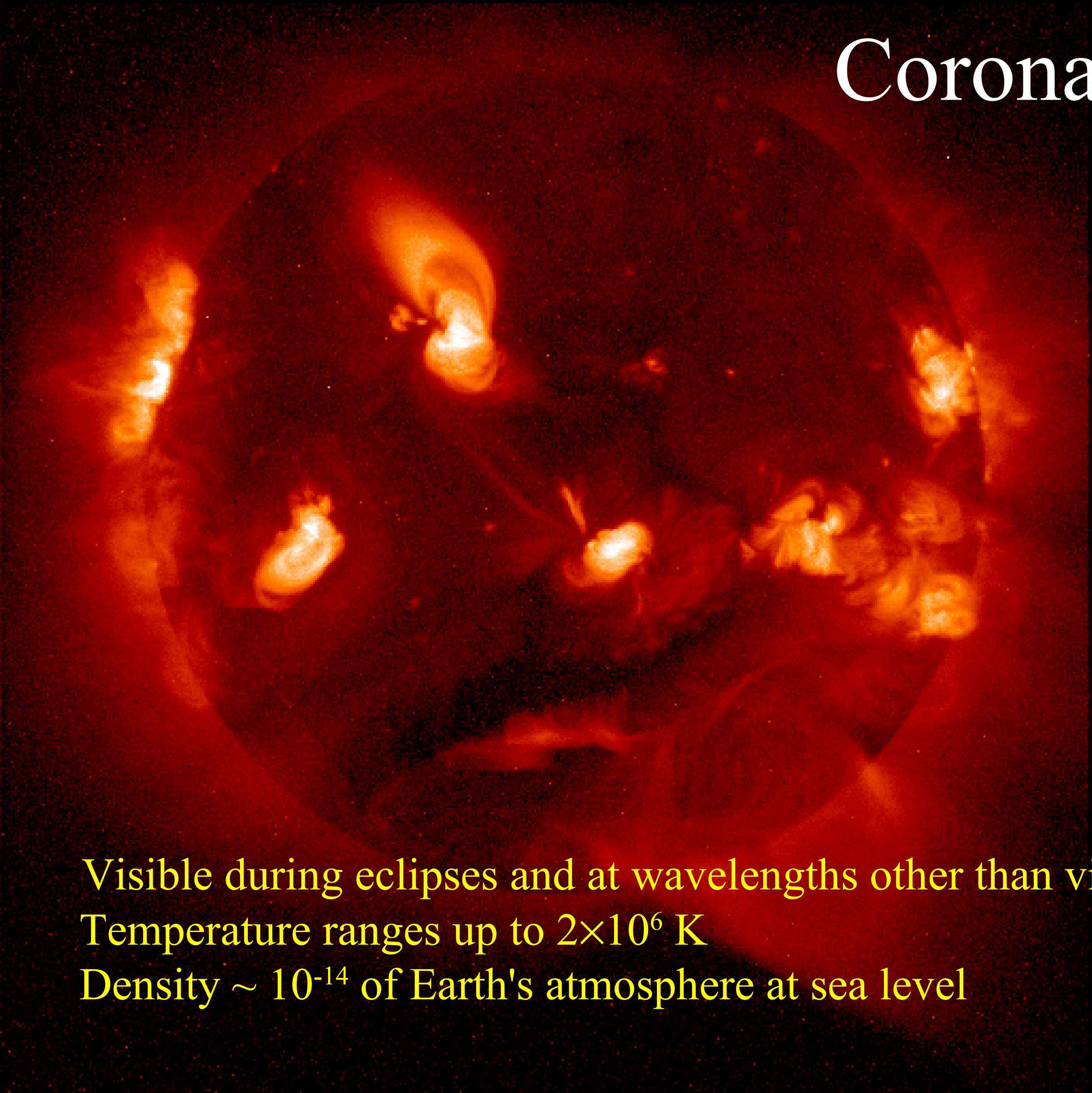
The poles rotate more slowly, about once every 36 days.

Chromosphere

Only visible during eclipses (or with special telescopes).
Temperature ranges from 4400 K to 25,000 K
Density ~ 10^{-8} of Earth's atmosphere at sea level

Corona

Corona



Visible during eclipses and at wavelengths other than visible

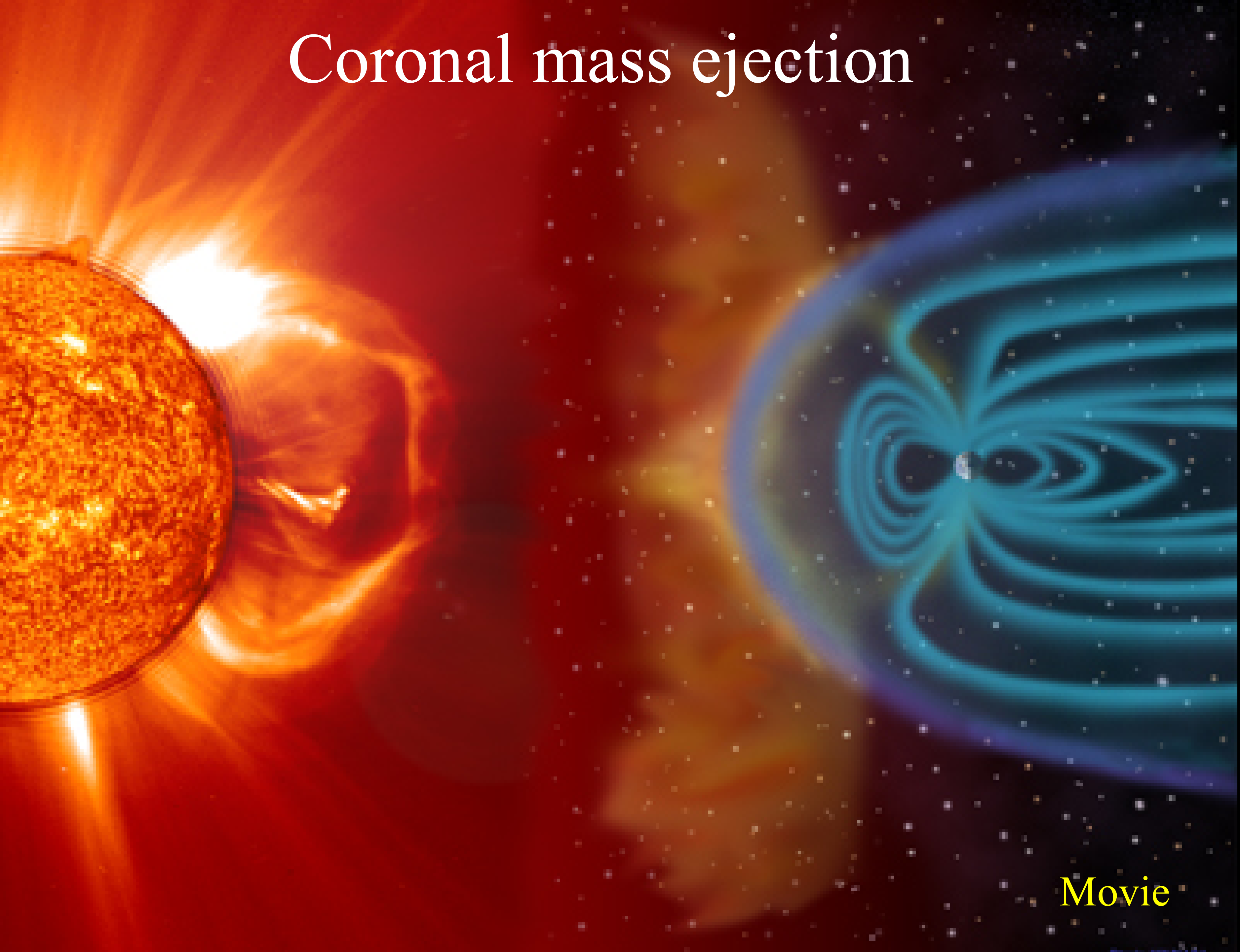
Temperature ranges up to 2×10^6 K

Density ~ 10^{-14} of Earth's atmosphere at sea level

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

Movie

Coronal mass ejection



Movie