

# What is Matter made from?

Protons,  $p^+$



Neutrons,  $n$



Electrons,  $e^-$



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Neutrons,  $n$



Electrons,  $e^-$



Neutrinos,  $\nu$



# What is Matter made from?

Protons,  $p^+$



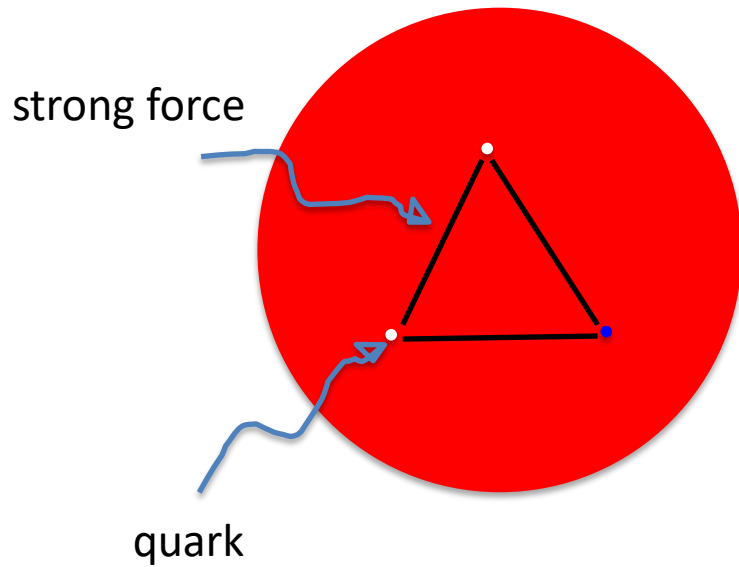
Neutrons,  $n$



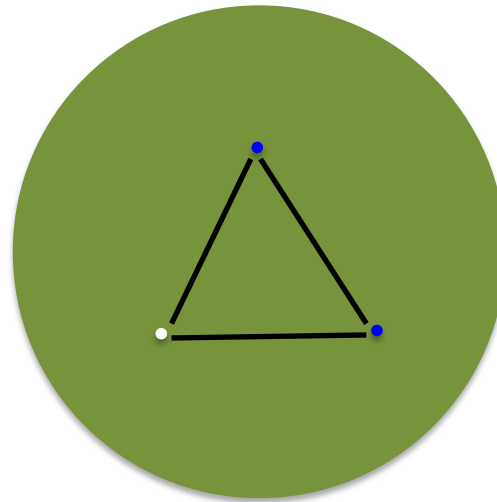
Are Constructed from smaller Particles:

Quarks

# What is Matter made from?



Protons,  $p^+$

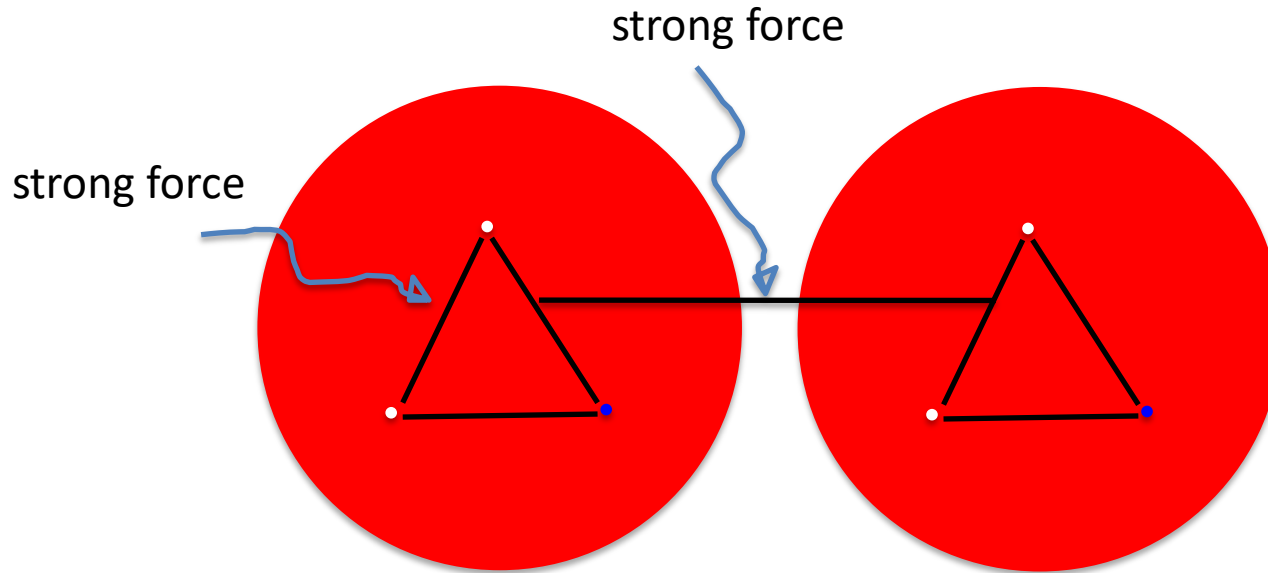


Neutrons,  $n$

up    ◯    •    down

quarks

# What is Matter made from?




In an atom, the strong force keeps protons (and neutrons) inside the atomic nucleus

Electrons,  $e^-$       ●

Neutrinos,  $\nu$       •

Are Fundamental Particles

# Normal Matter

Protons,  $p^+$  


Neutrons,  $n$  

Electrons,  $e^-$  

Neutrinos,  $\nu$  

# Normal Matter

# Anti-Matter

Protons,  $p^+$  

anti-Protons,  $p^-$  

Neutrons,  $n$  

anti-Neutrons,  $\bar{n}$  

Electrons,  $e^-$  

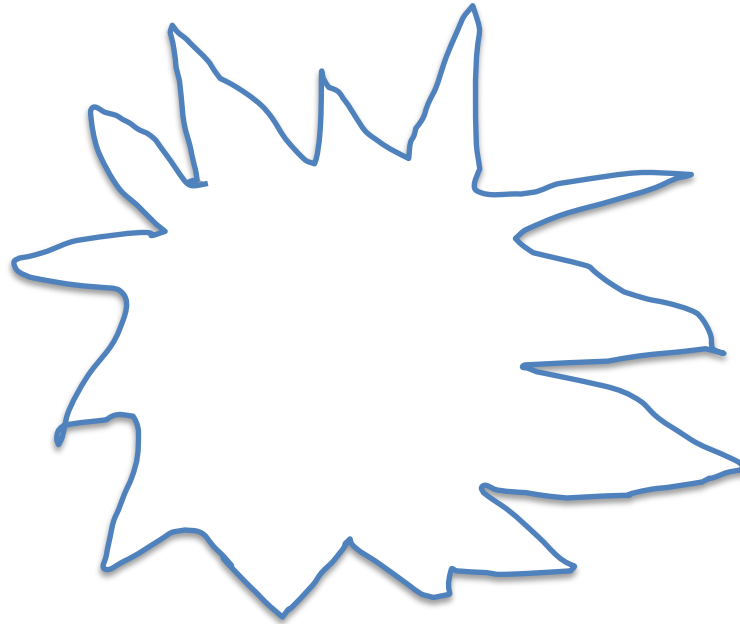
anti-Electrons,  $e^+$  

Neutrinos,  $\nu$  

anti-Neutrinos,  $\bar{\nu}$  



When an anti-proton meets a proton....



They annihilate each other and turn into  
pure light

IF an anti-nickel and a nickel met up



They would put out  $9 \times 10^{16}$  J — at 10 cents a J, those two nickels would be worth \$ 90 trillion

# Elements are DEFINED by their number of PROTONS

Protons,  $p^+$



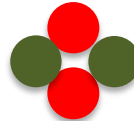
Neutrons,  $n$



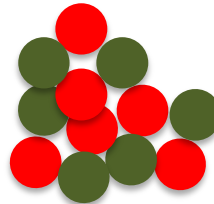
Hydrogen:



Helium:

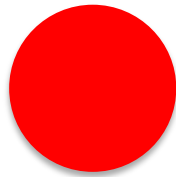


Carbon:



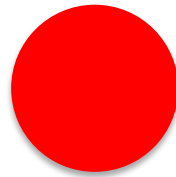
smallest piece  
of an element is  
an ATOM

# Model of the Atom

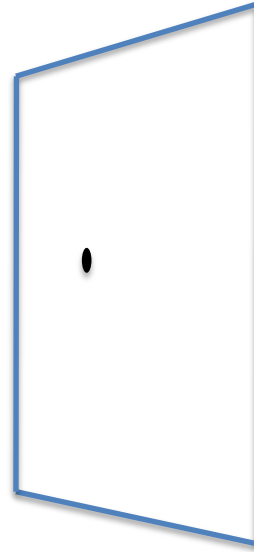
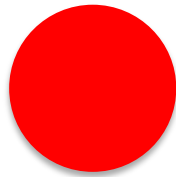


Hydrogen Atom: 1 P<sup>+</sup> and 1 e<sup>-</sup>

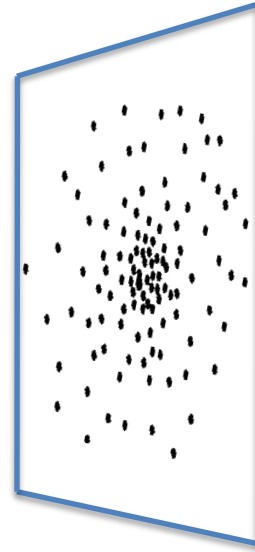
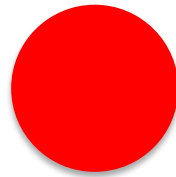
# Model of the Atom



# Model of the Atom

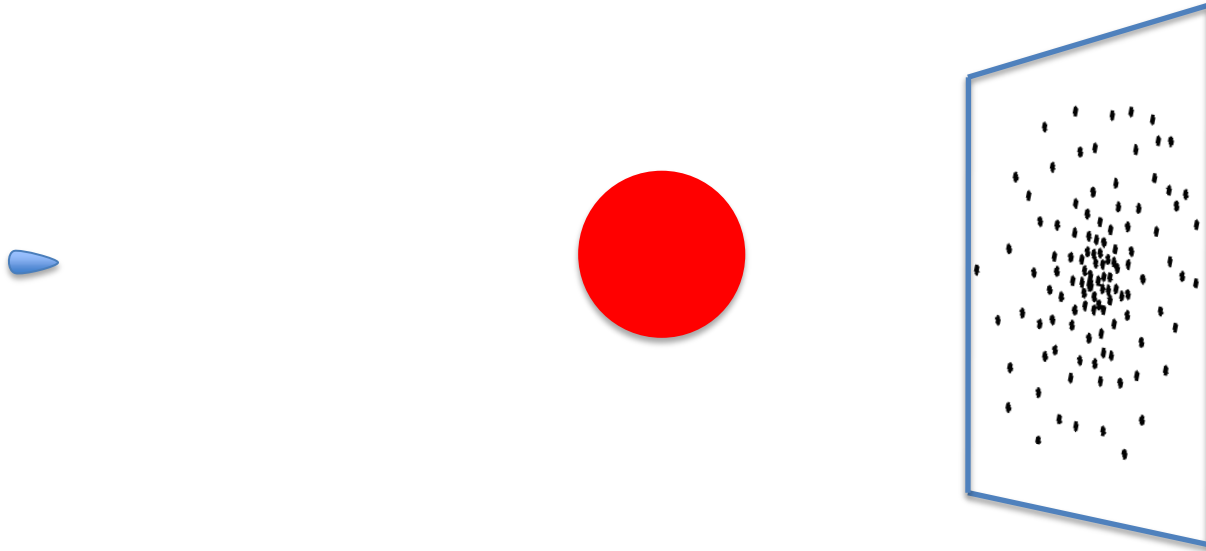


Very few hit solid material!



# Model of the Atom

## Mostly empty space!

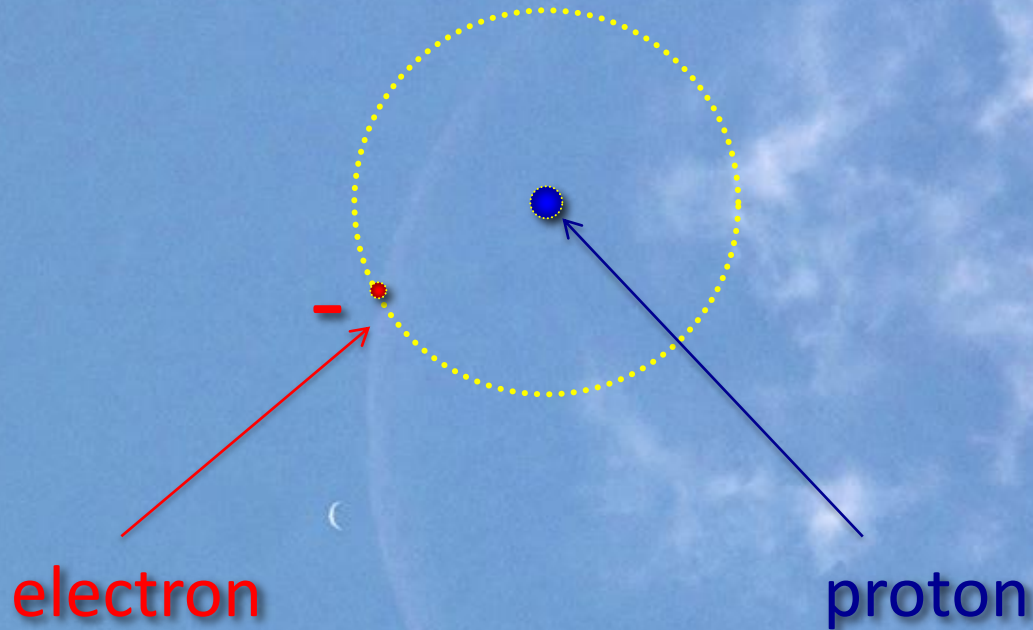


empty space to solid mass =  
a hundred trillion to 1!  
or, 99.9999999999999999% empty space!



# Bohr Model of the Atom

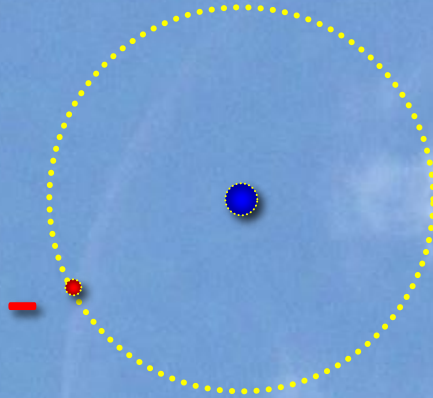
*electrons exist as  
solid particles*



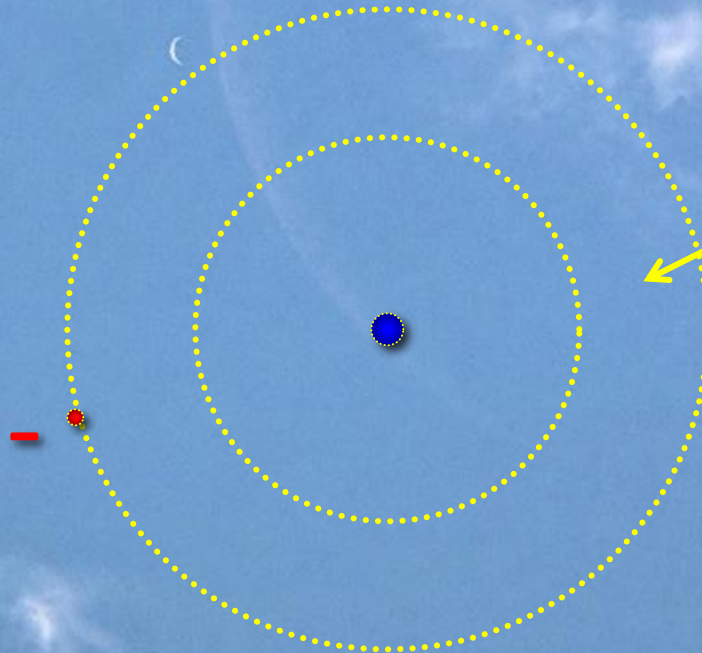
# Bohr Model of the Atom

*electrons exist as  
solid particles*

*$e$  in low energy  
state*



*$e$  in high energy  
state*

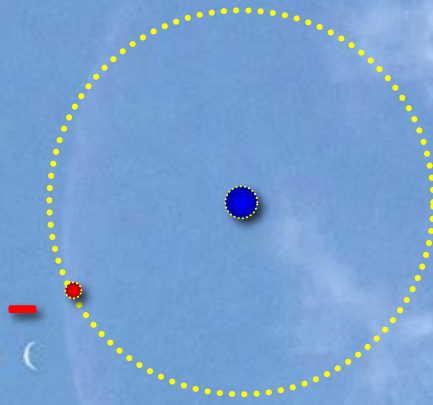


*$e$  cannot exist  
in between these  
energy levels*



# Bohr Model of the Atom

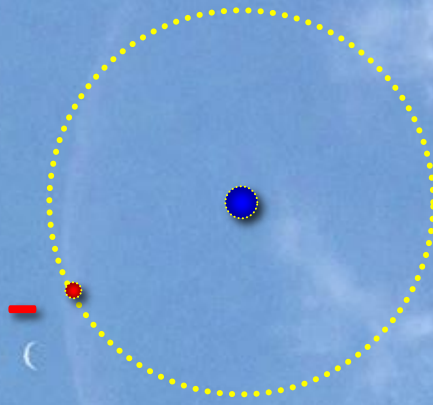
*electrons exist as  
solid particles*



If this model were correct, the **e** would lose energy and an atom would last only a billionth of a second!!

# Bohr Model of the Atom

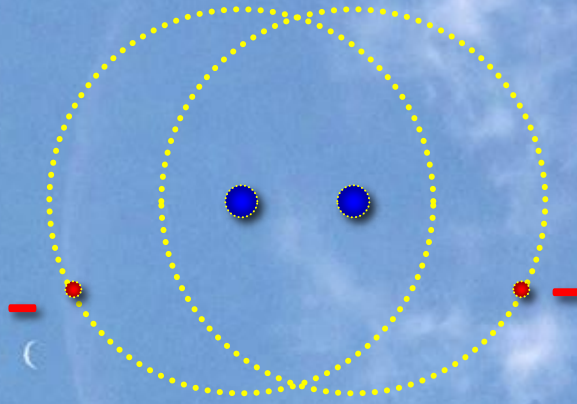
*electrons exist as  
solid particles*



if the atom is mostly empty space, why can't we walk through walls?

# Bohr Model of the Atom

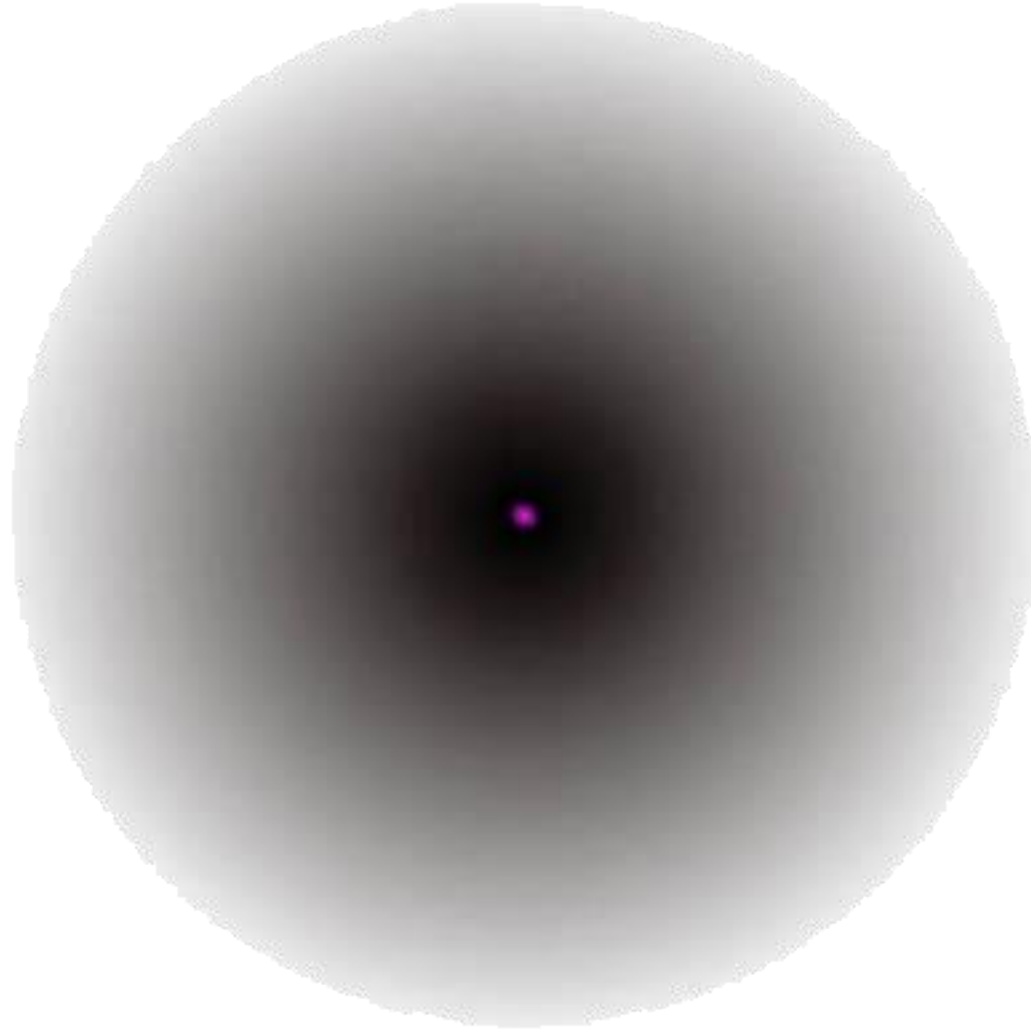
*electrons exist as  
solid particles*



– The atom is mostly space.... So we should be able to push one atom through another.

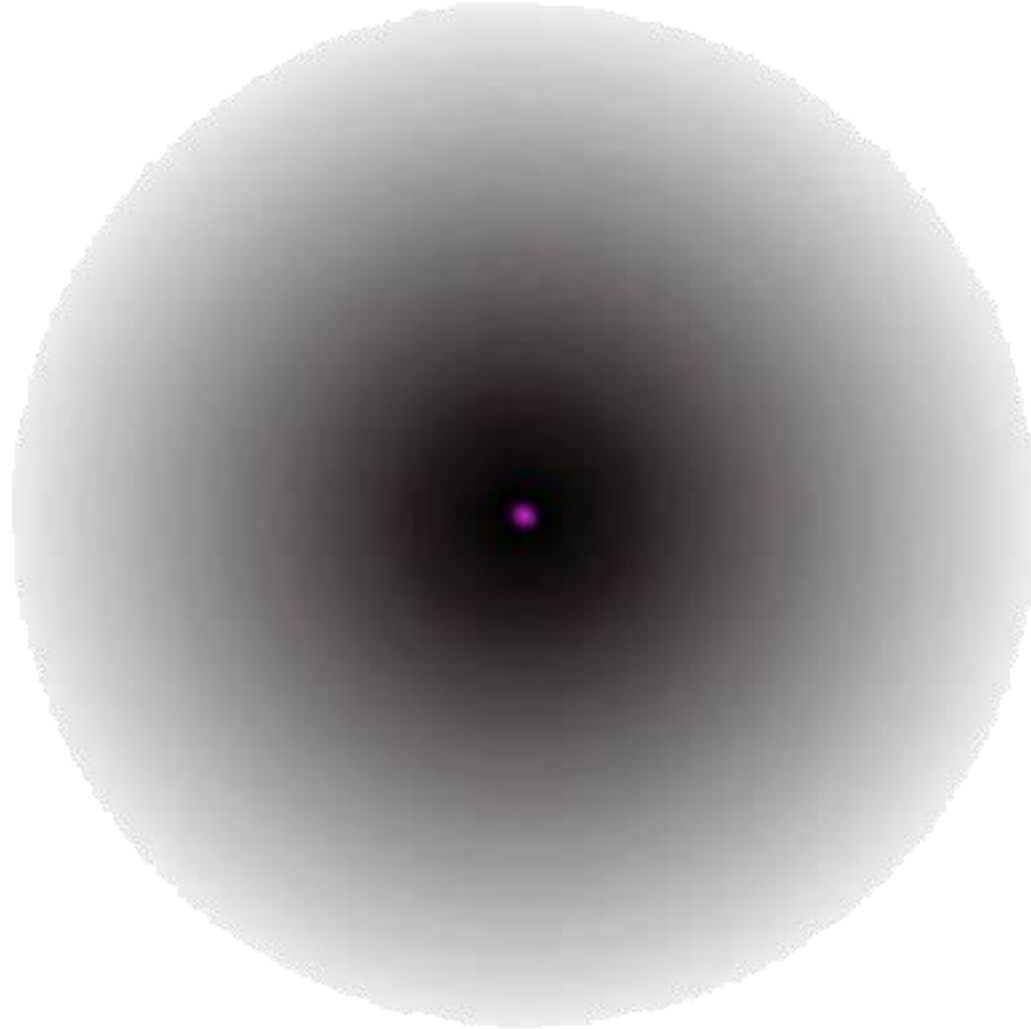
– the Bohr model is **WRONG!**

# Electron Cloud Model of the Atom



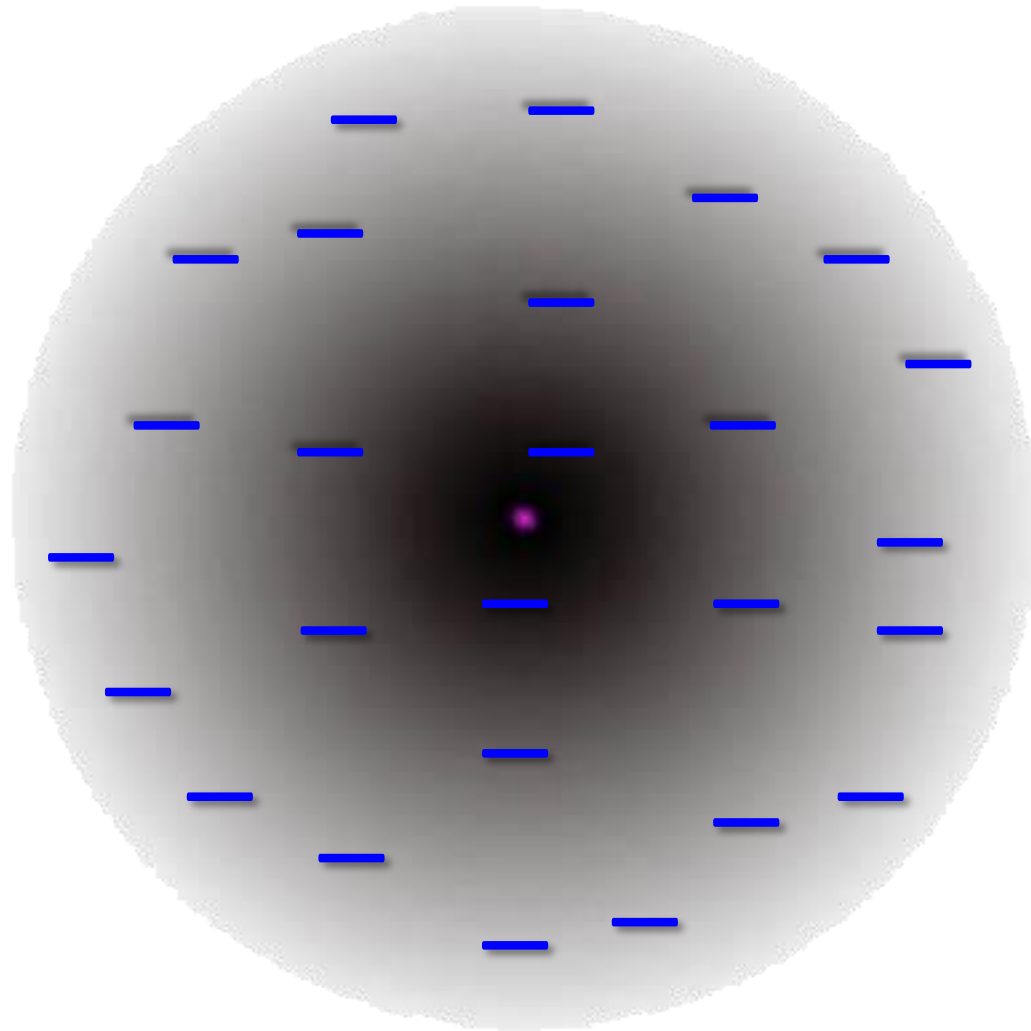
e exists as a probability distribution around the atom

# Electron Cloud Model of the Atom



So why can't we walk through walls?

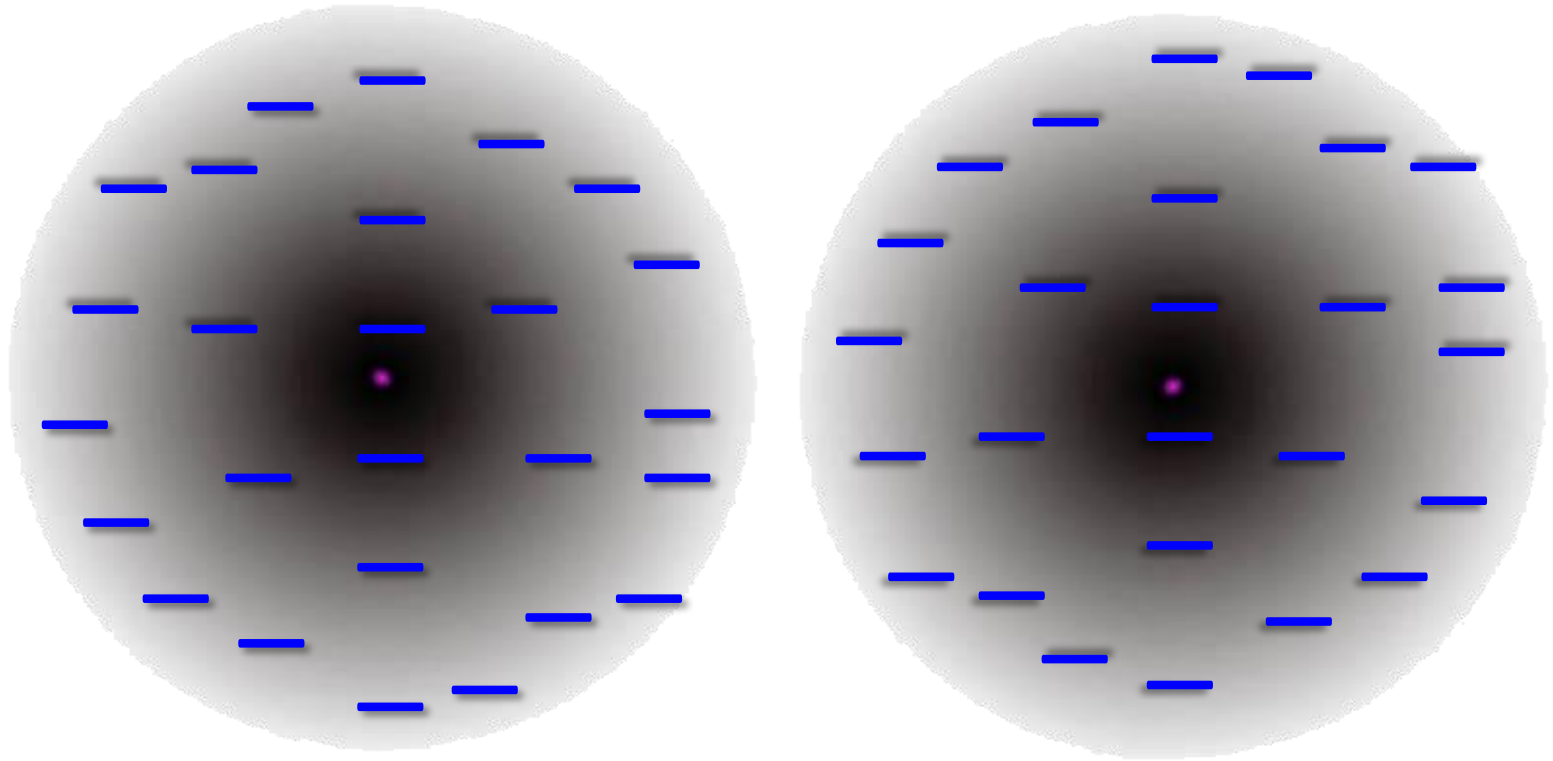
# Electron Cloud Model of the Atom



Because the  $e$  charge (and mass) is spread out all over the atom

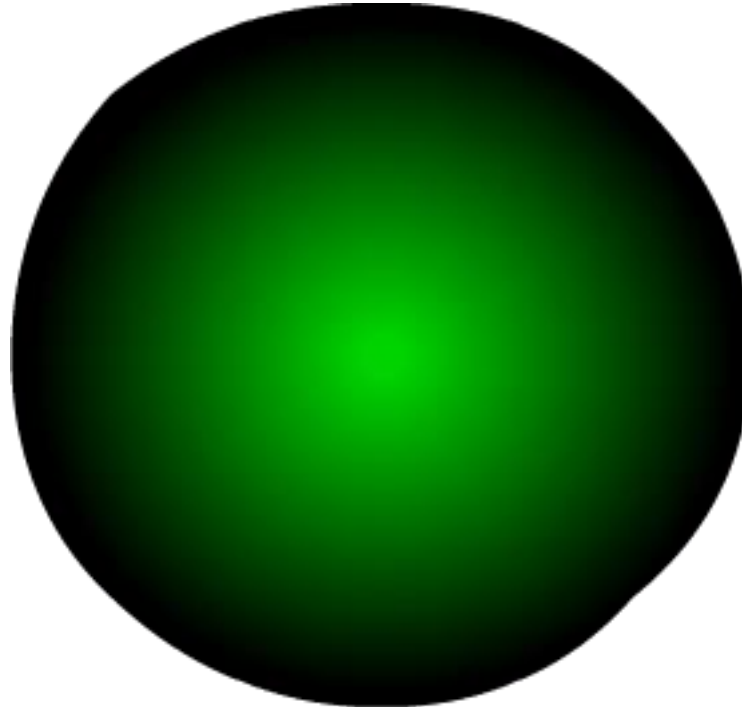


# Electron Cloud Model of the Atom



So the **Electromagnetic Force** prevents one atom moving through another.

e Cloud with e in the lowest Energy level



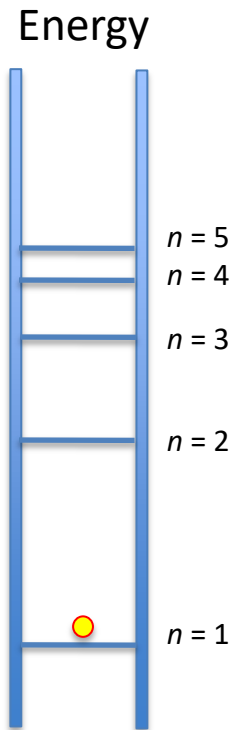
$n = 1$

e Cloud with e in the next higher Energy level



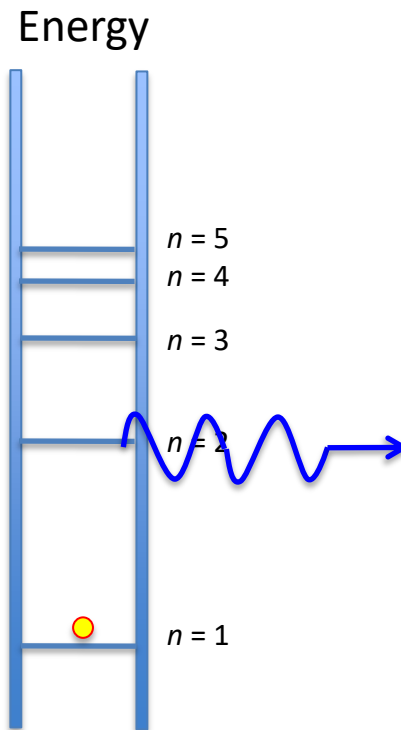
$n = 2$

It is easier to imagine an Energy Ladder:



with an electron on one of the "rungs"

# Energy Ladder



electrons can jump to different energy levels IF they can find exactly the right energy

VIDEO: Energy Ladder of Hydrogen

<https://youtu.be/QI50GBUJ48s>

# Elements are DEFINED by their number of PROTONS

Protons,  $p^+$



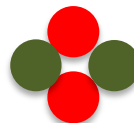
Neutrons,  $n$



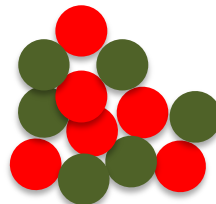
Hydrogen:



Helium

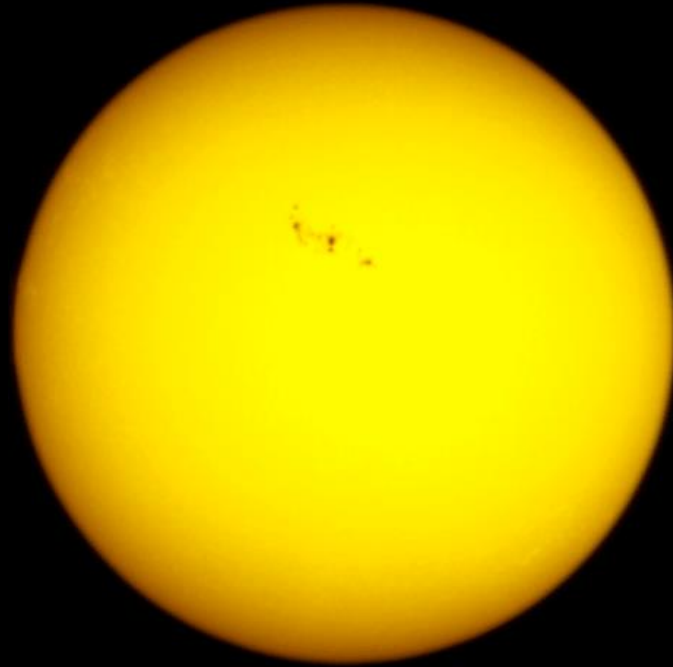


Carbon

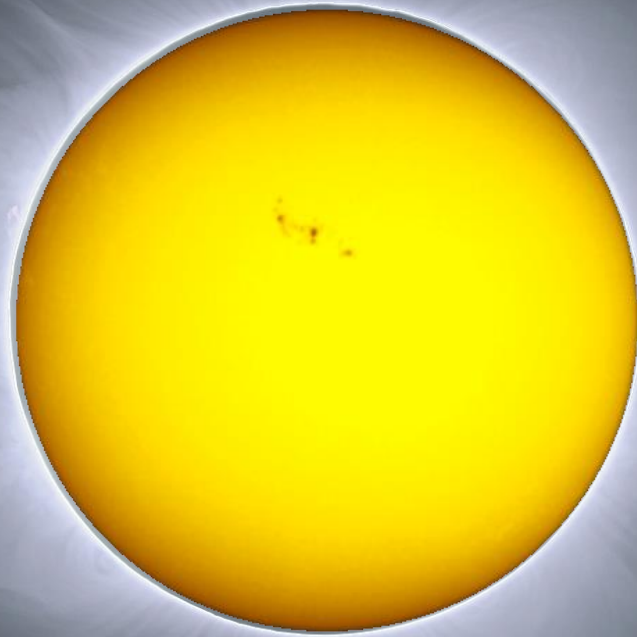








Sun as you see it in visible light with a filter —  
the "photosphere"

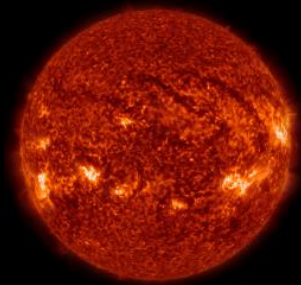


Sun as you see don't see it —  
the photosphere and corona

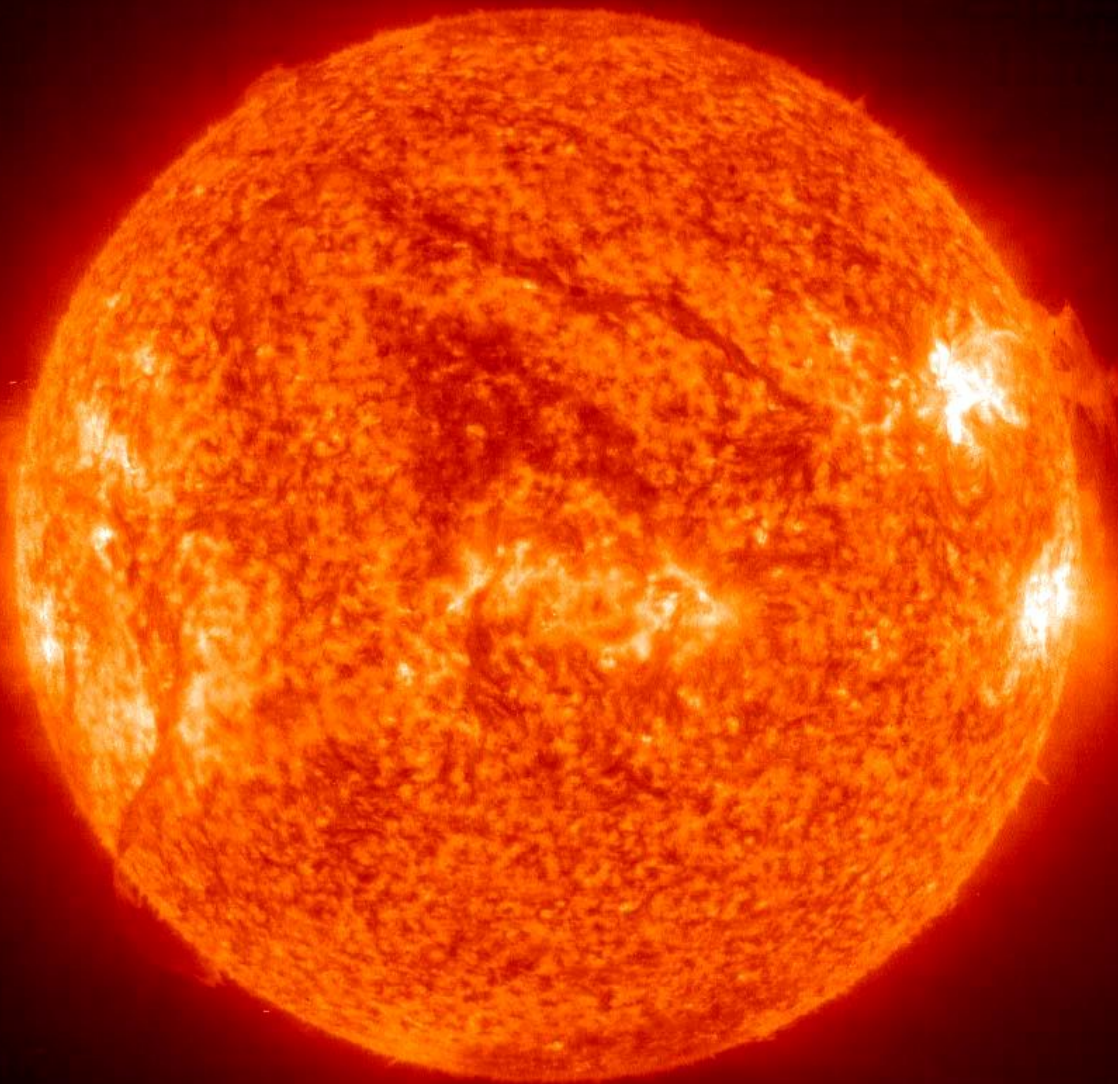


Corona seen during total solar eclipse





Sun filtered to see somewhat cooler H gas



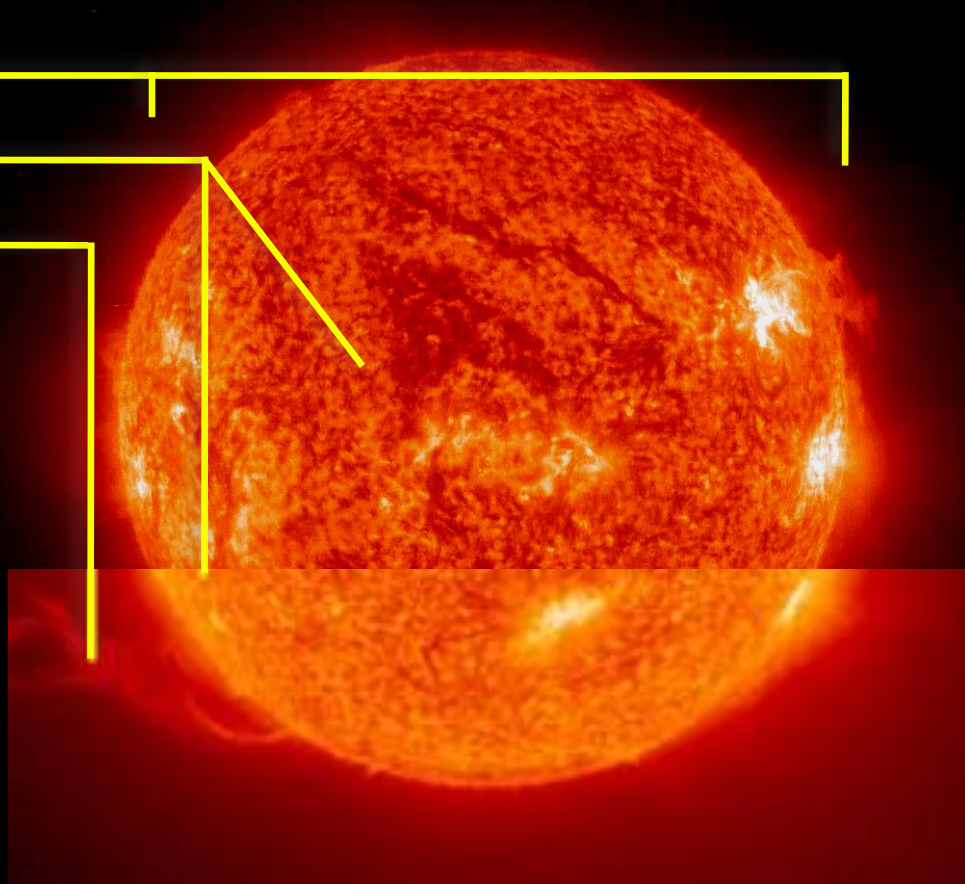
Sun with very narrow  
Hydrogen filter



**2004/04/17 20:48**

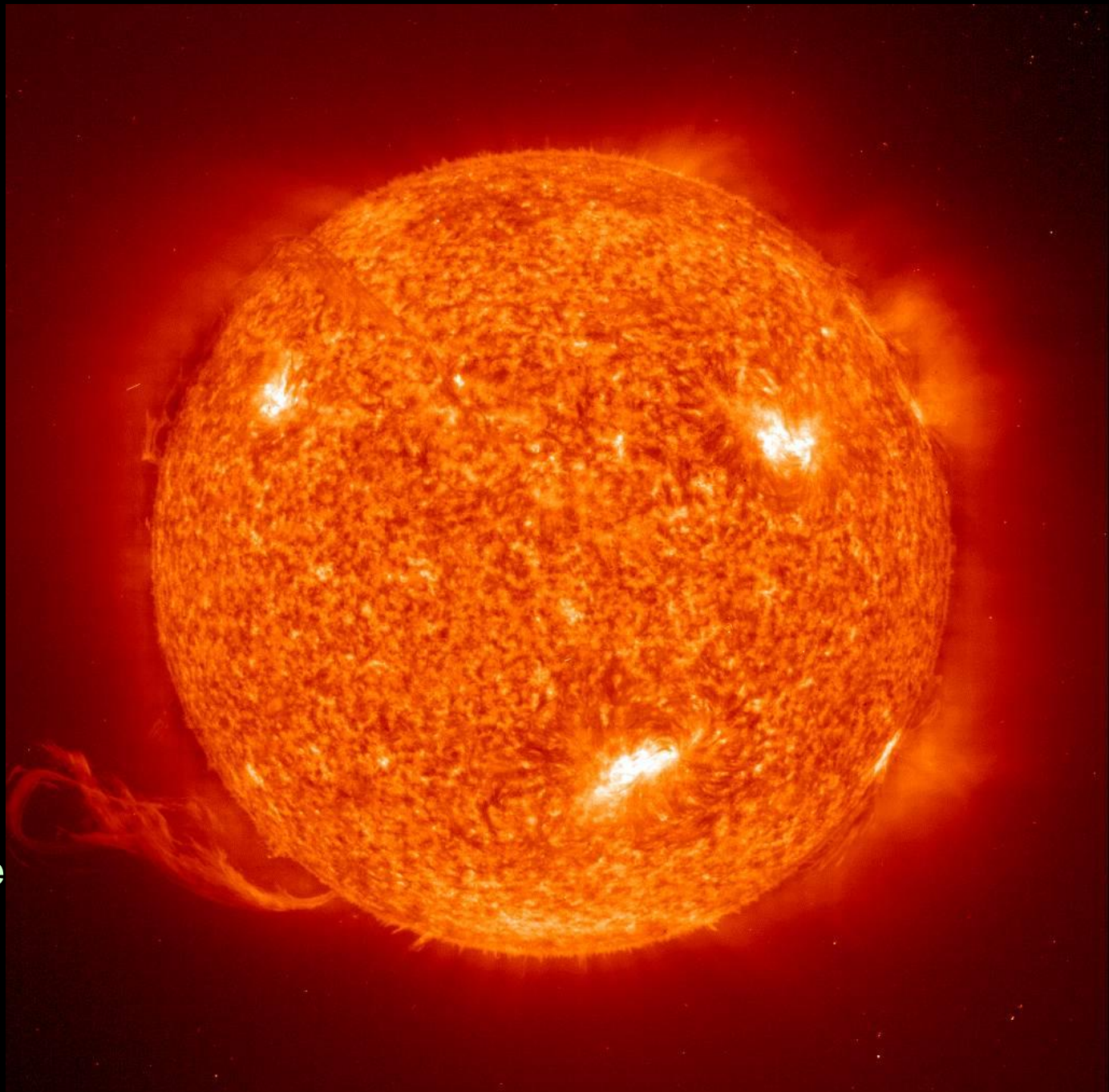
Sun with red light filter  
— rotates about once a month  
month

Corona  
Photosphere  
Prominence



**Outside  
the Sun**



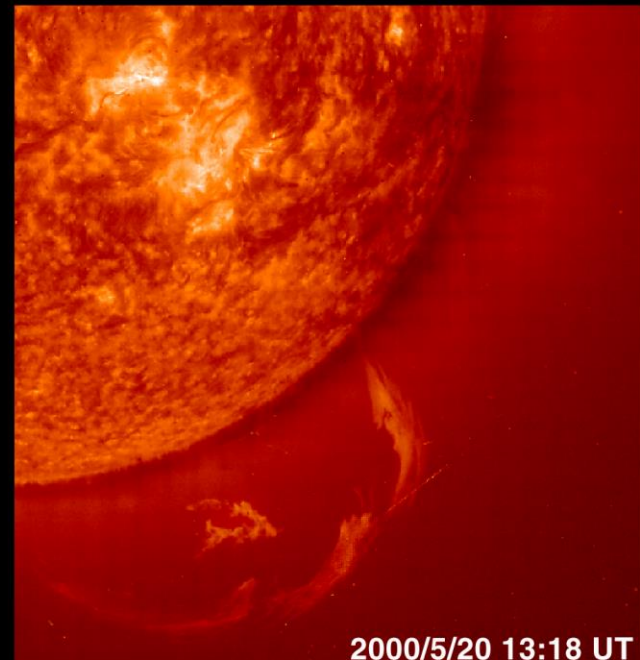
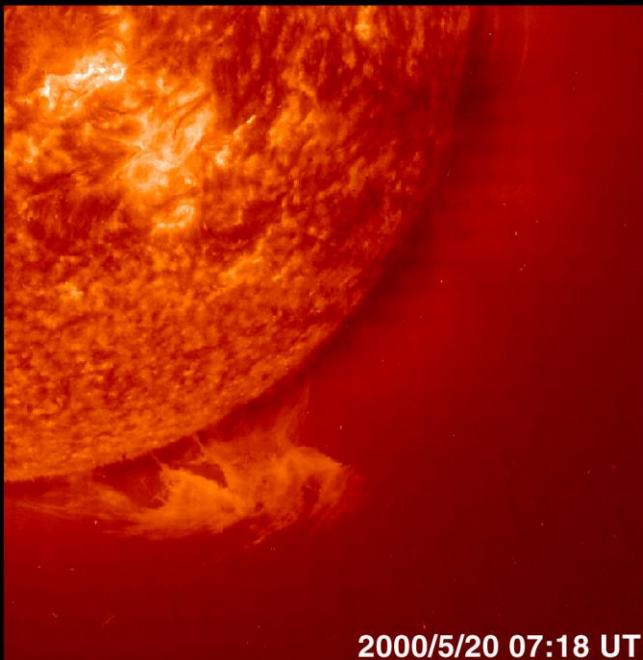
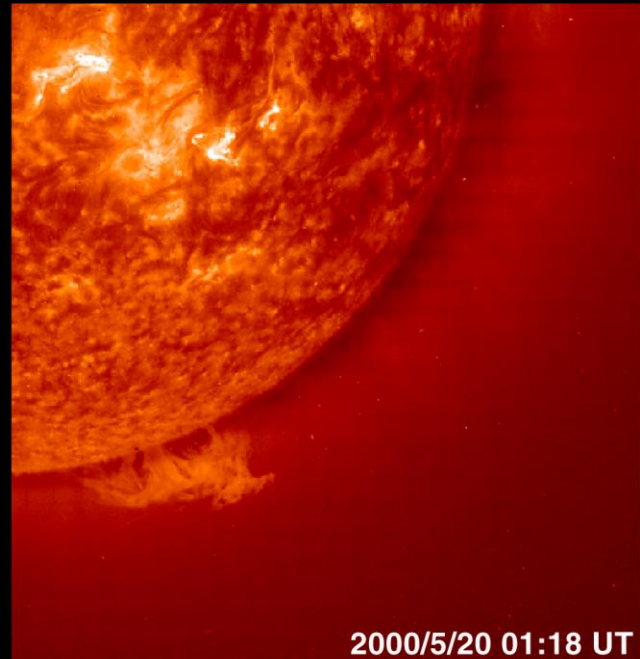
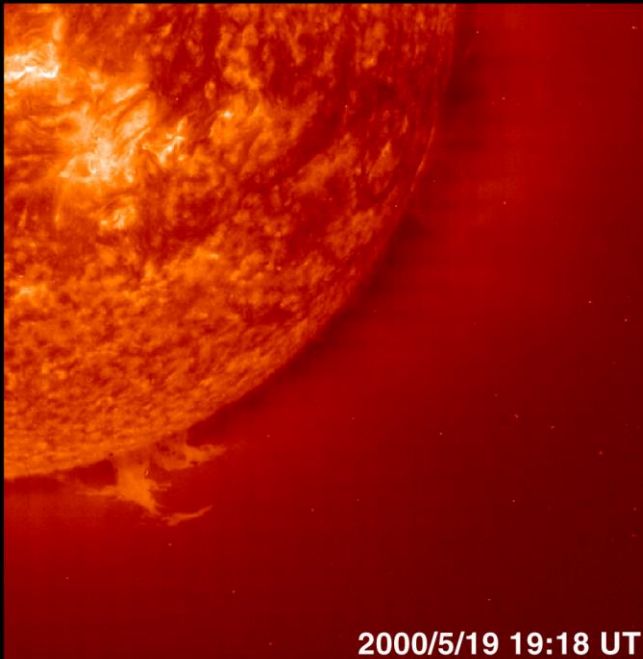


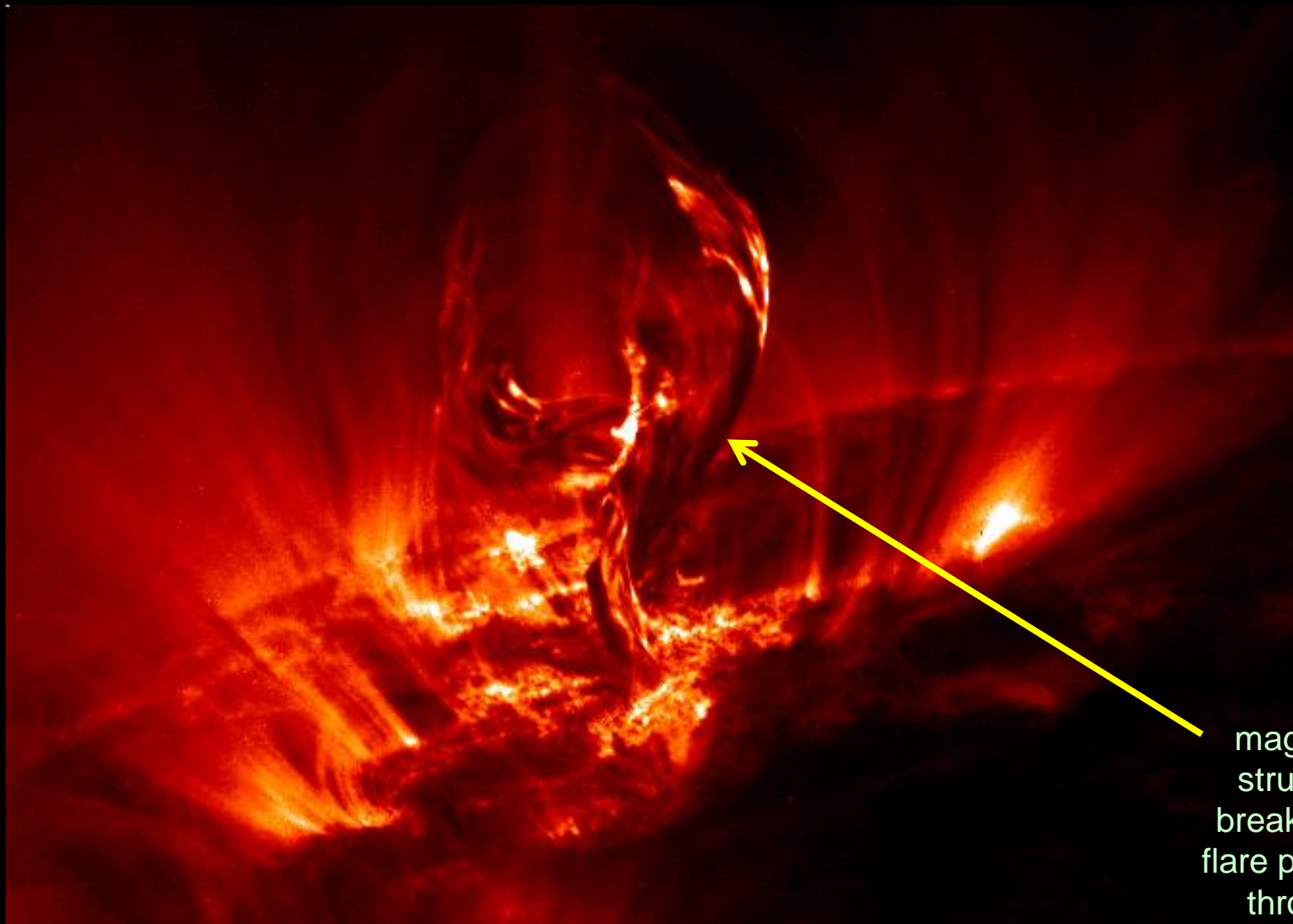
Prominence





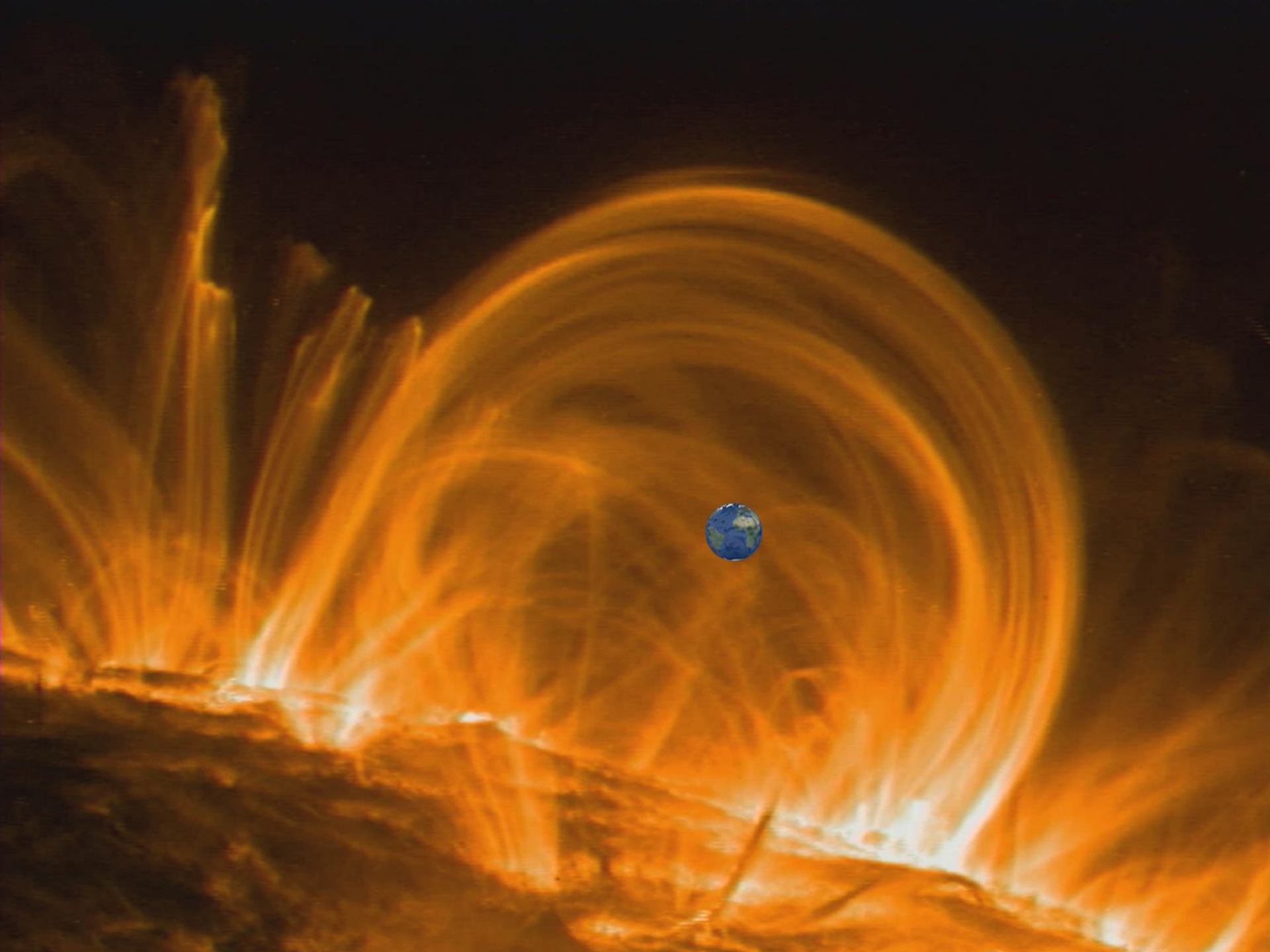
solar prominence

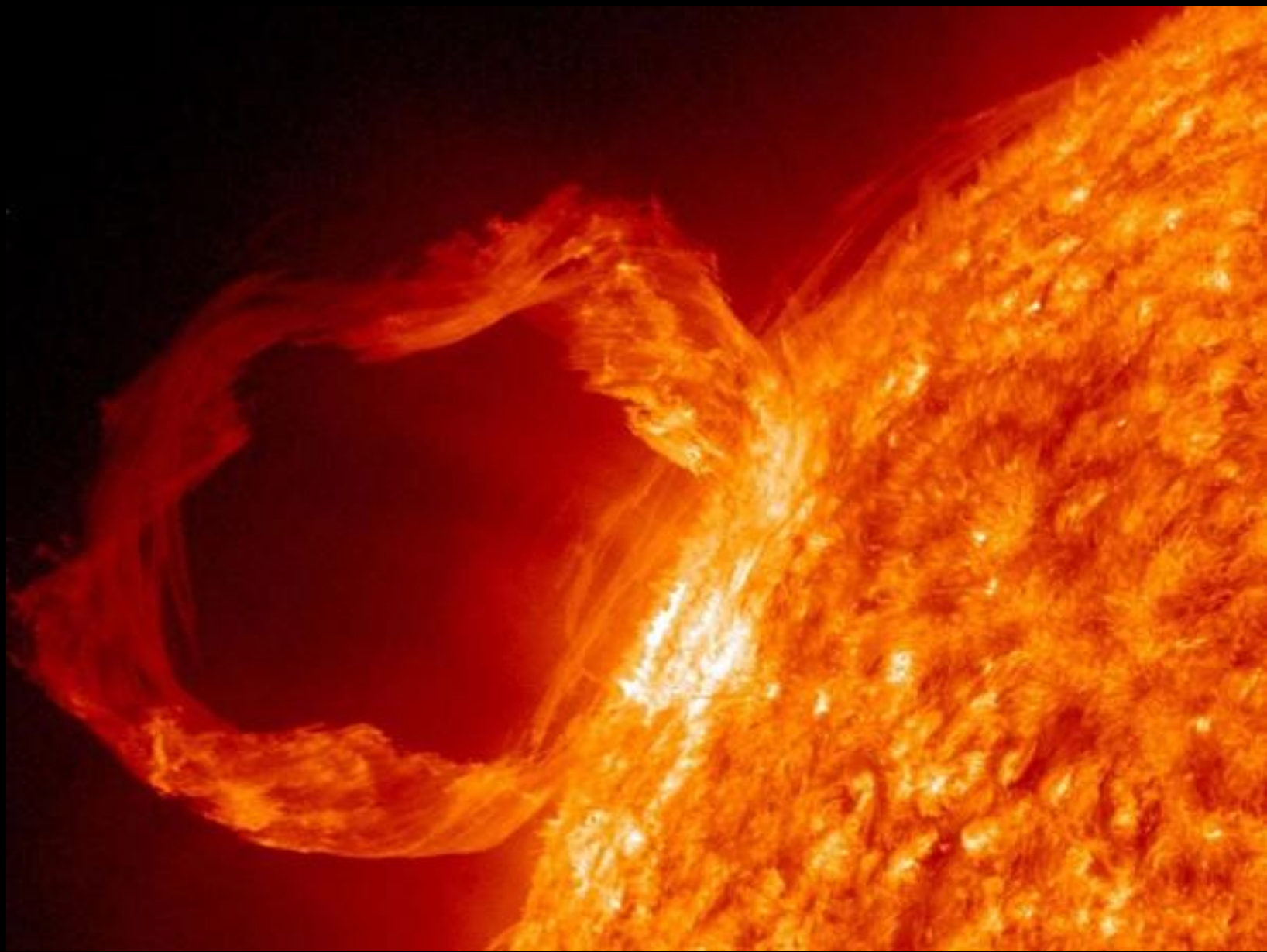


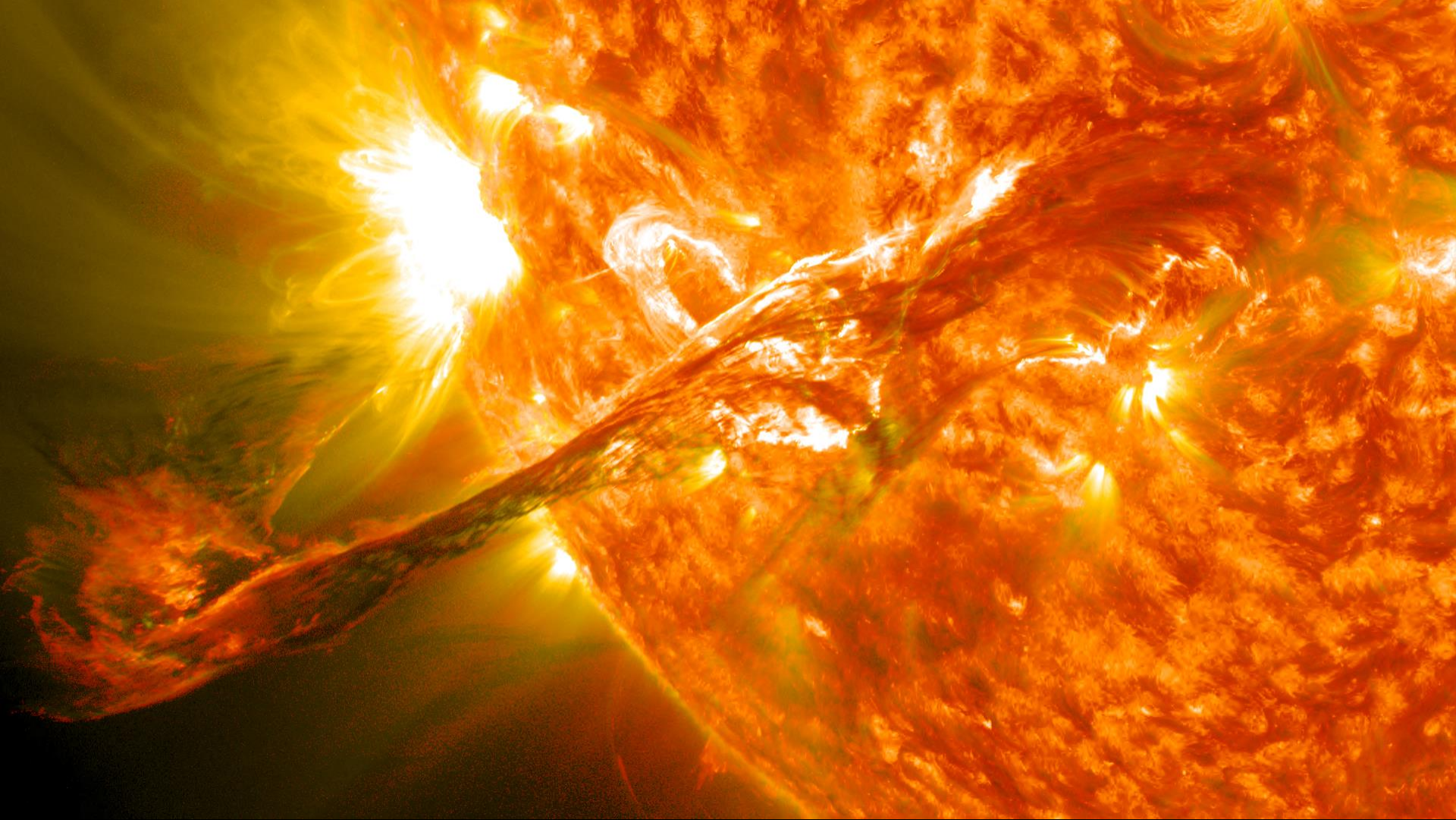


magnetic structure breaking as flare punches through

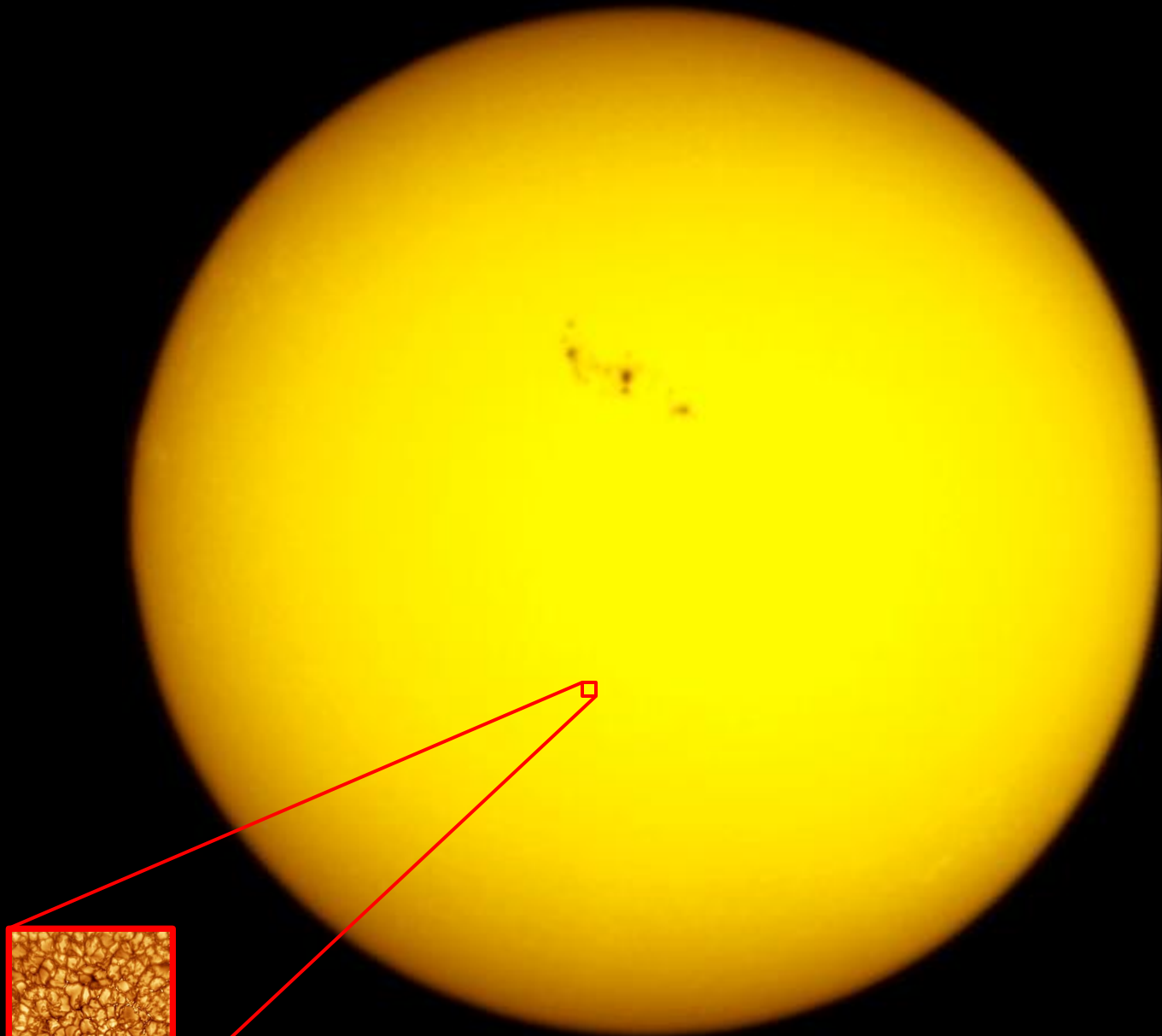
(x-ray light)



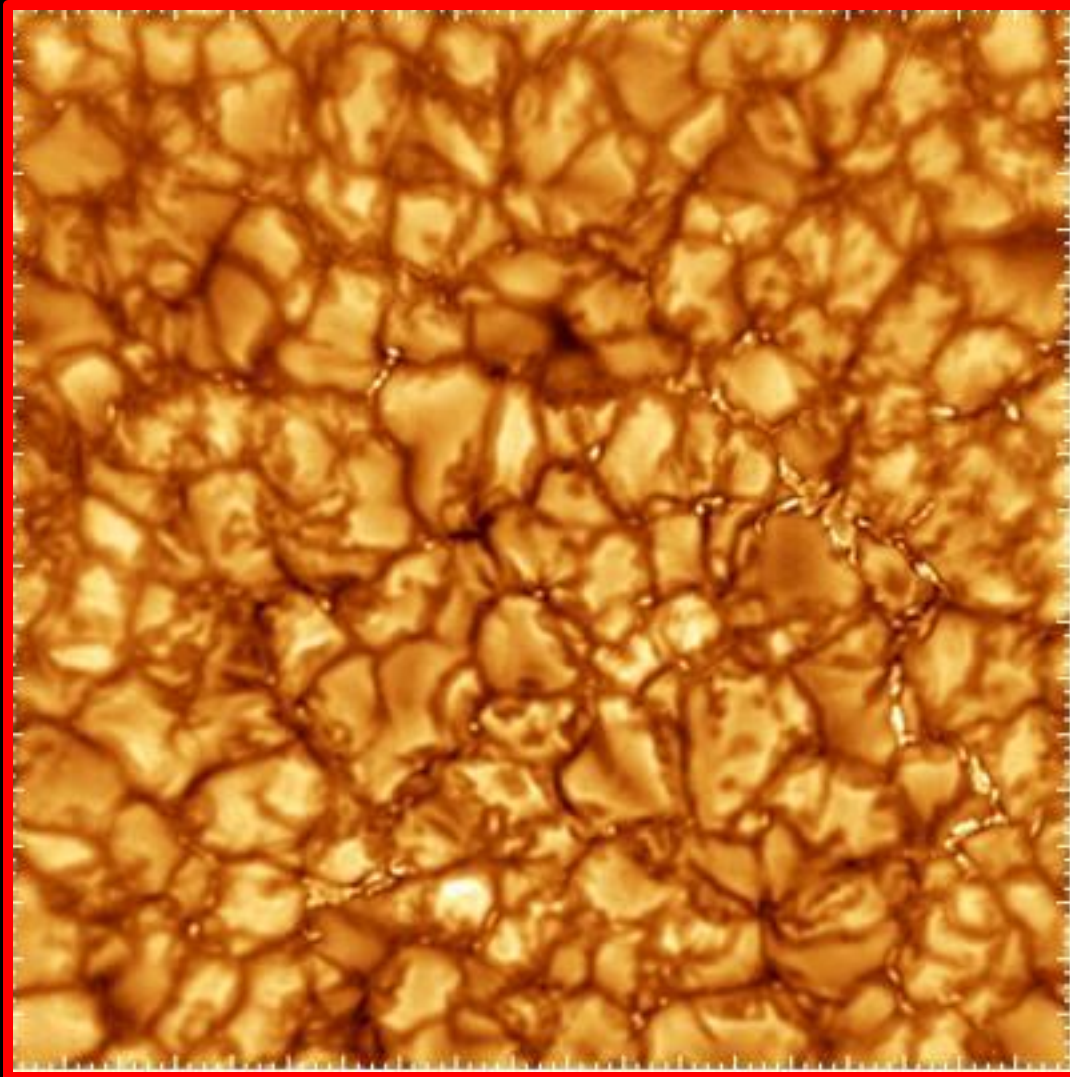






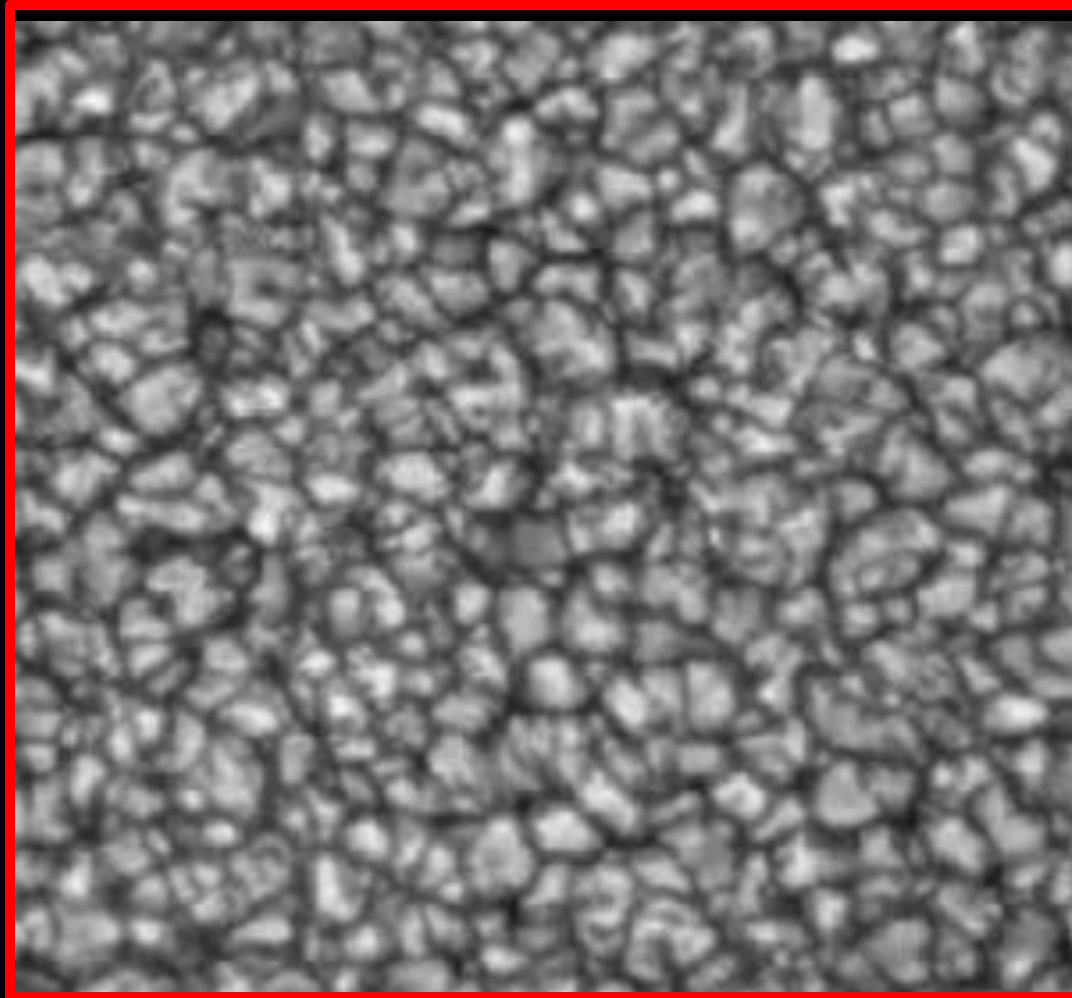


The photosphere is caldron of convective cells



**Size of the  
United States**

Convective cells break at the photosphere. Hot H gas rises to the photosphere in cells, cools and then gas descends.



**Size of the  
United States**

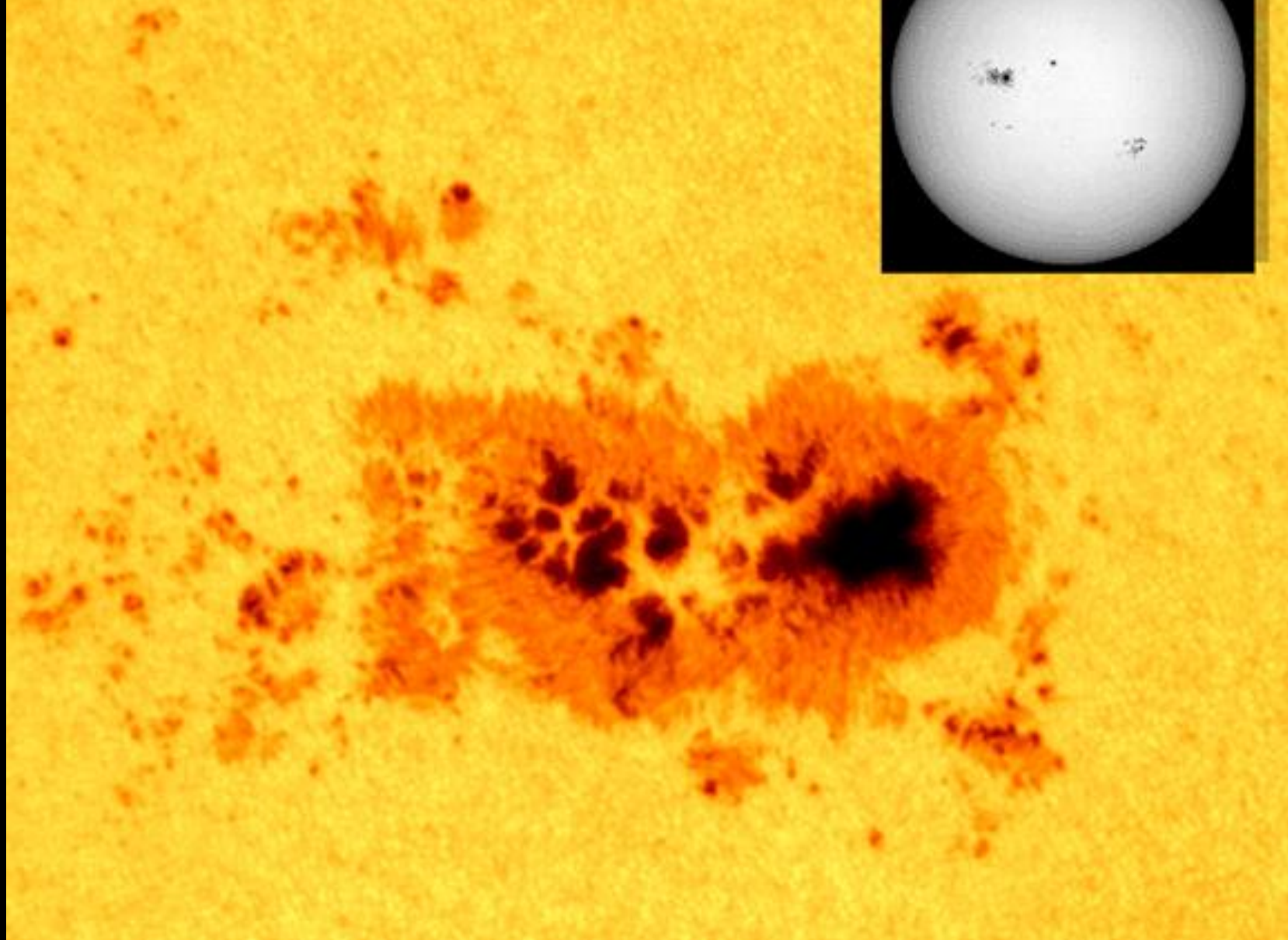
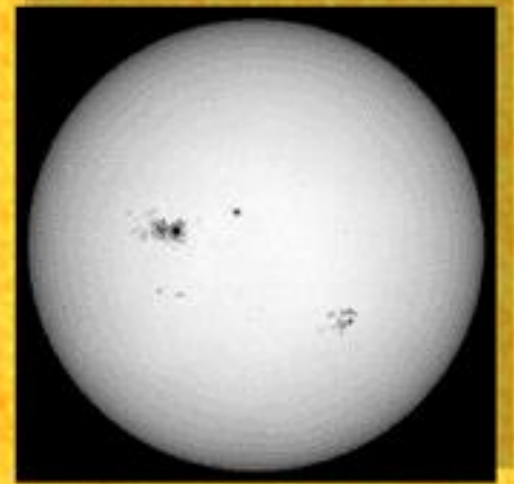
Convective cells in motion (time lapse)

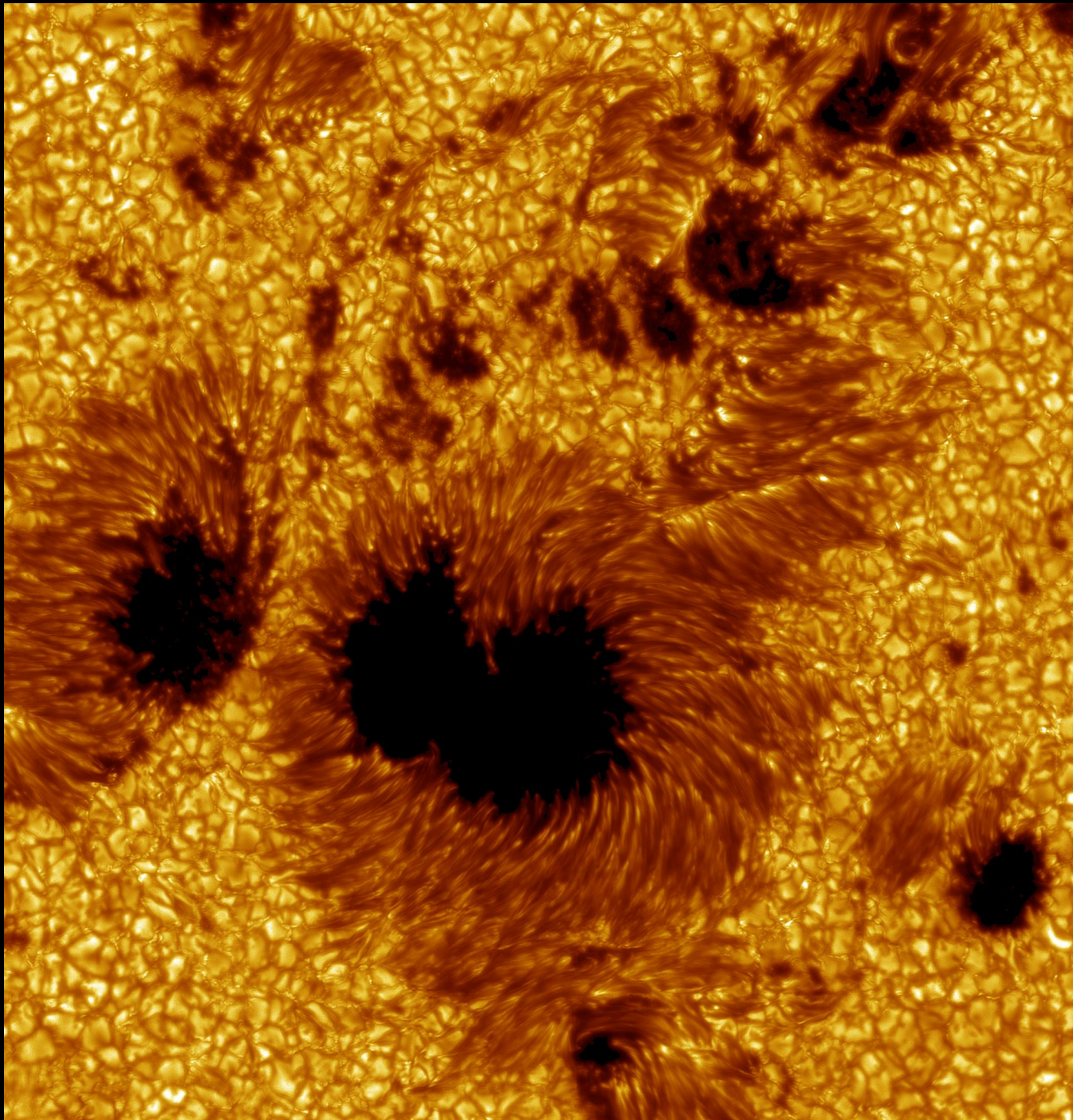
A large, bright yellow sun is shown against a black background. A red arrow points from a yellow-bordered box on the left towards a small, dark sunspot on the sun's surface. The box contains the text "Size of Earth".

**Size of Earth**

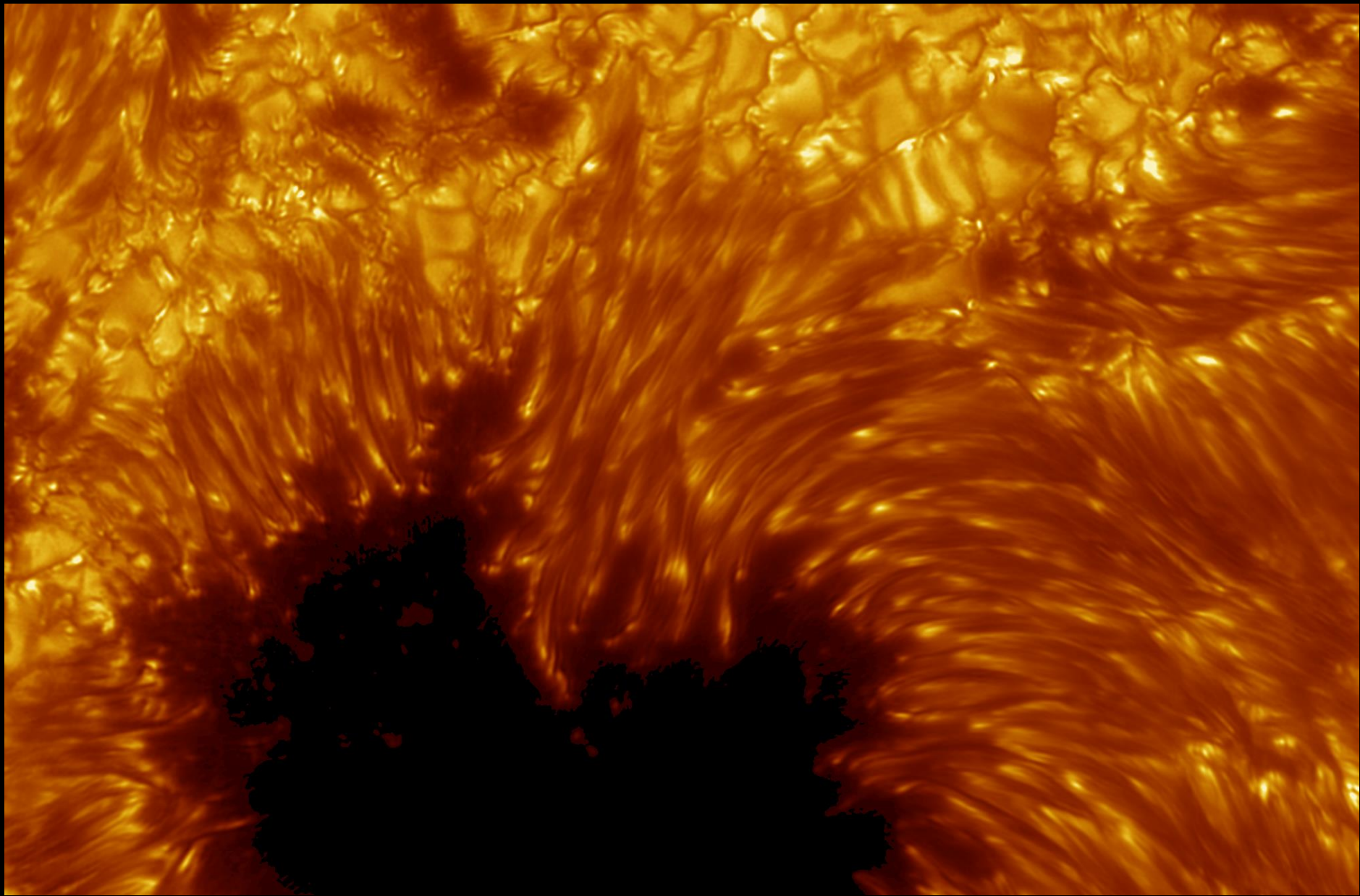
Sunspots are cooler than the surrounding  
photosphere

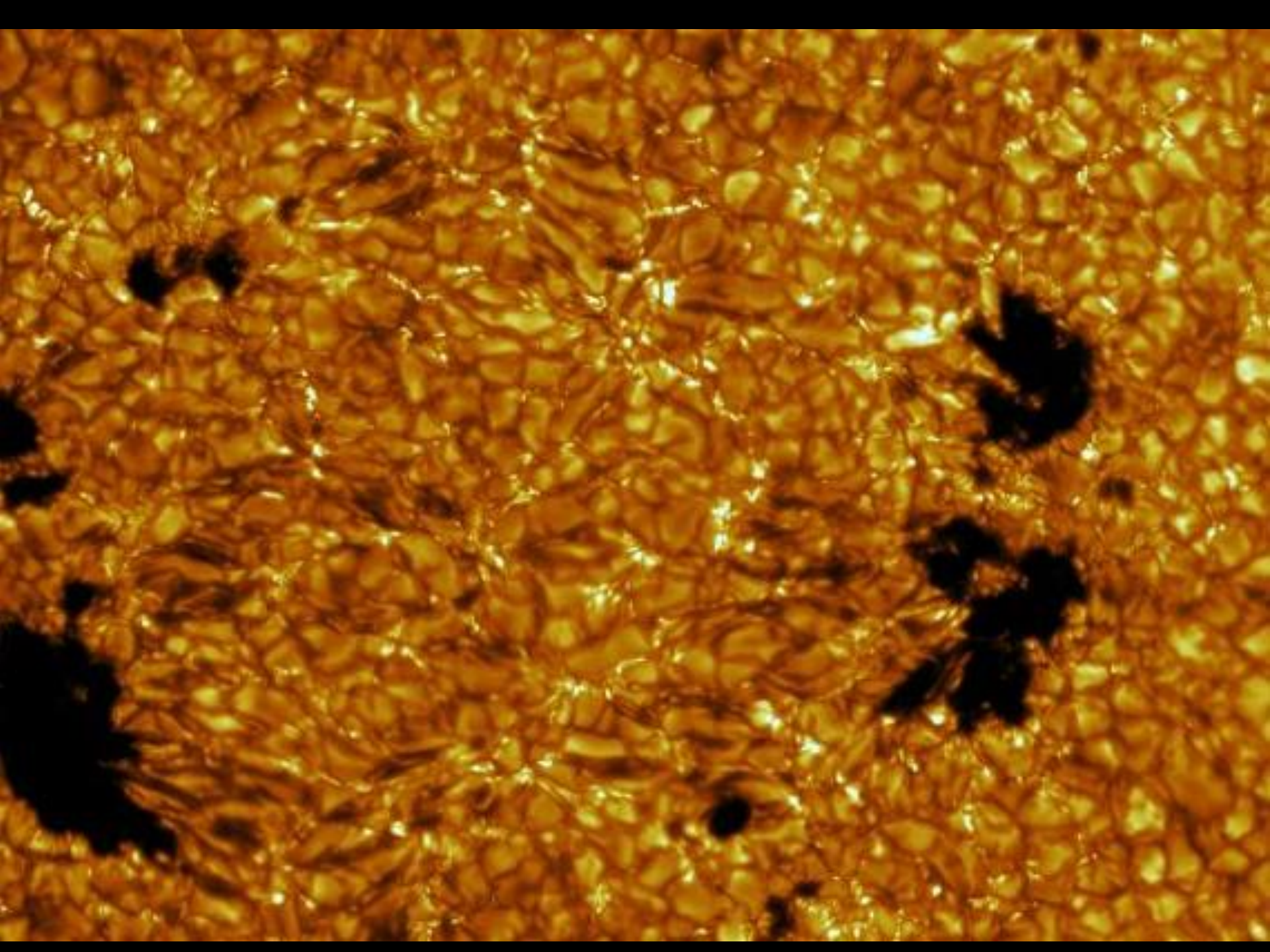
September 23, 2000





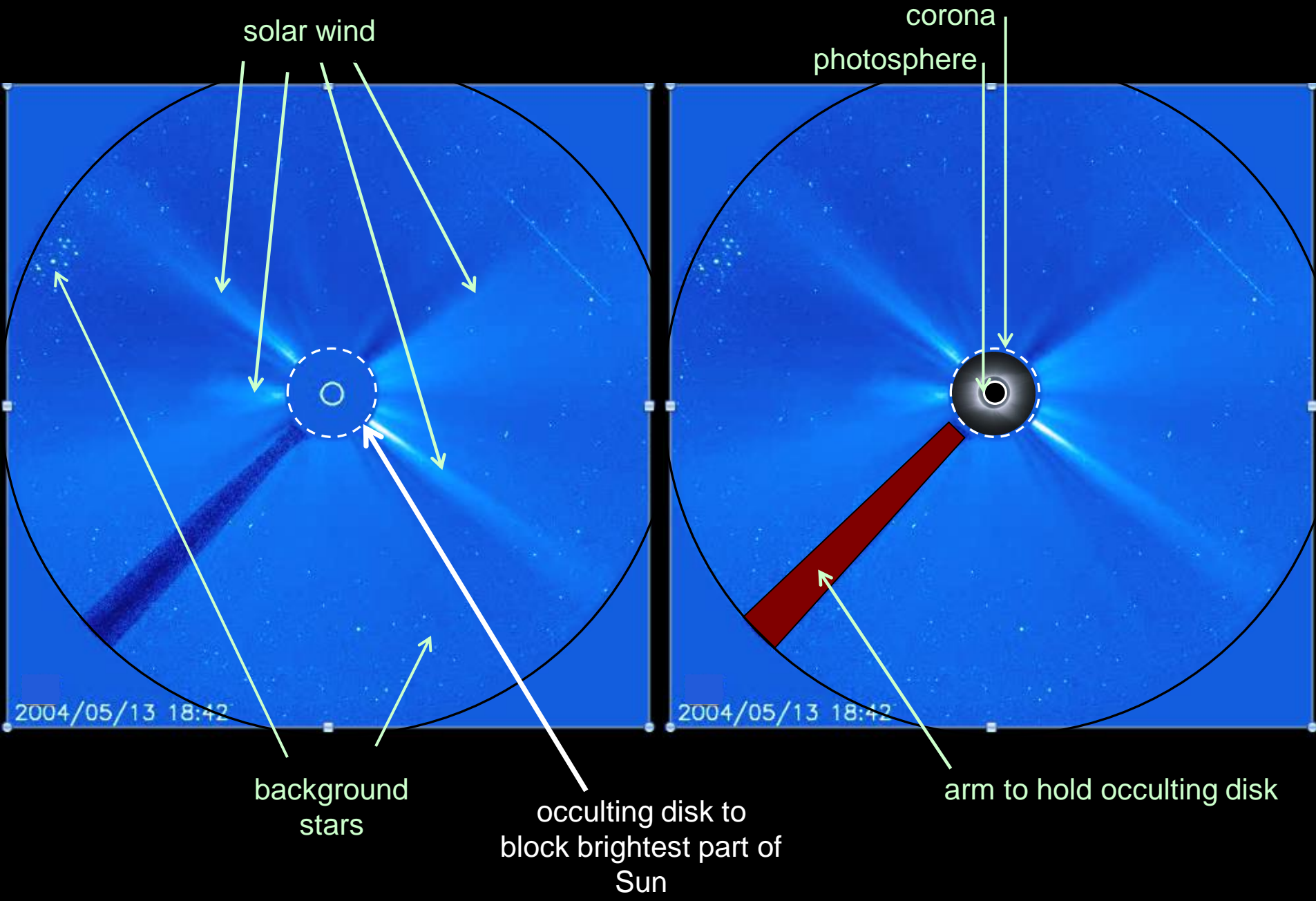
Sunspots



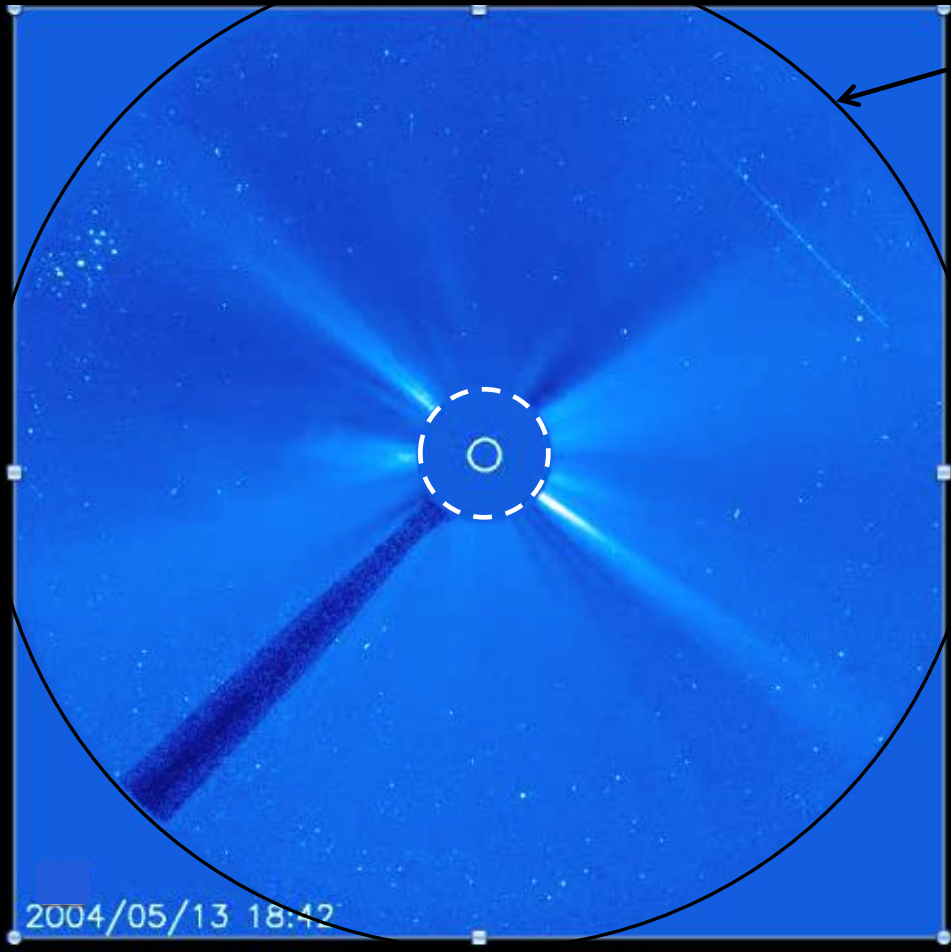




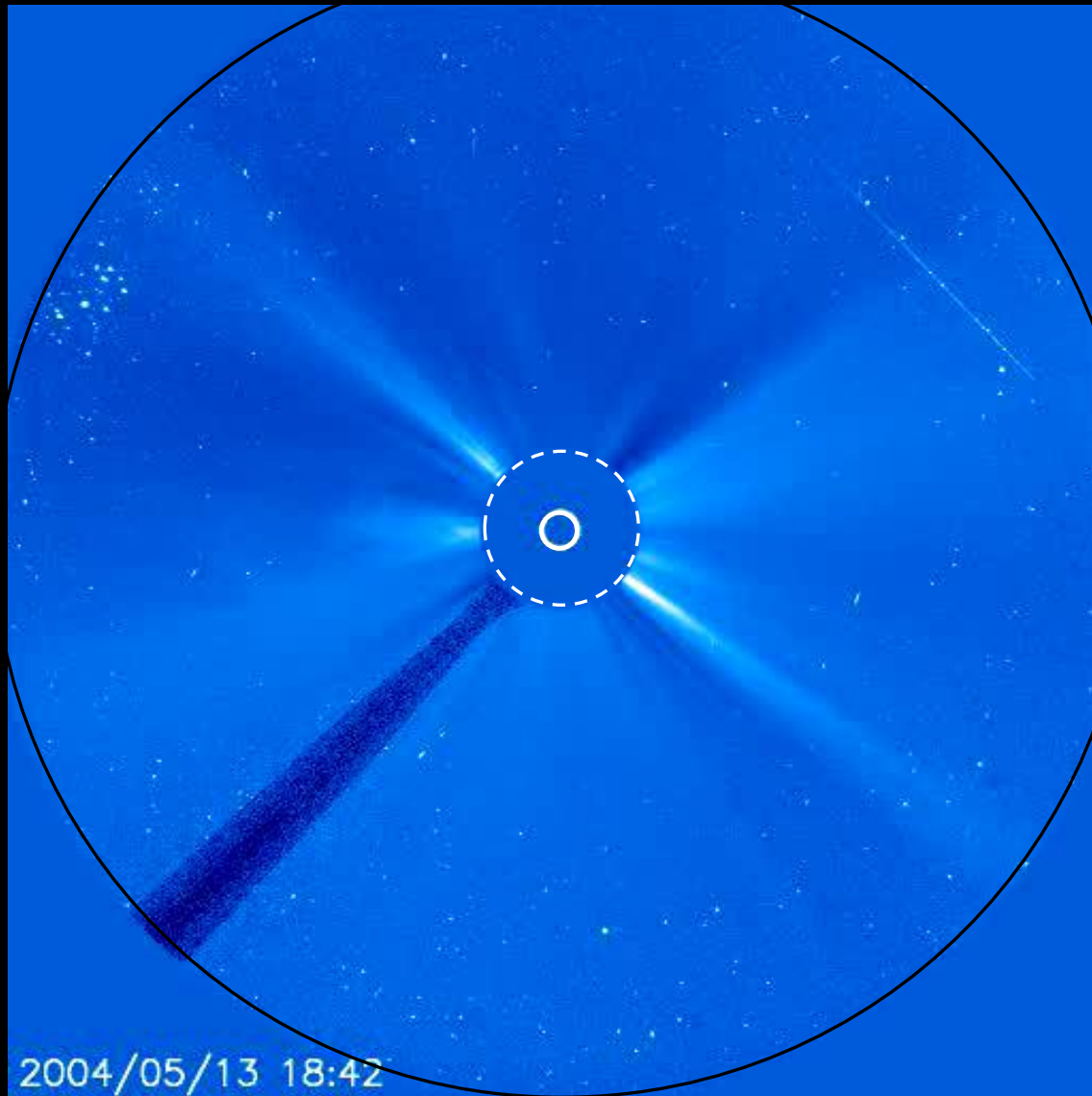
SDO/HMI lc:20121115\_044755



view of Sun and sky through SOHO  
space telescope with **occulting disk**



view of telescope

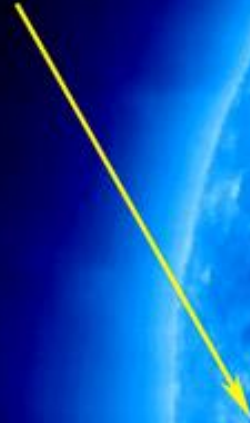


solar wind particles have speeds about 400 km/s

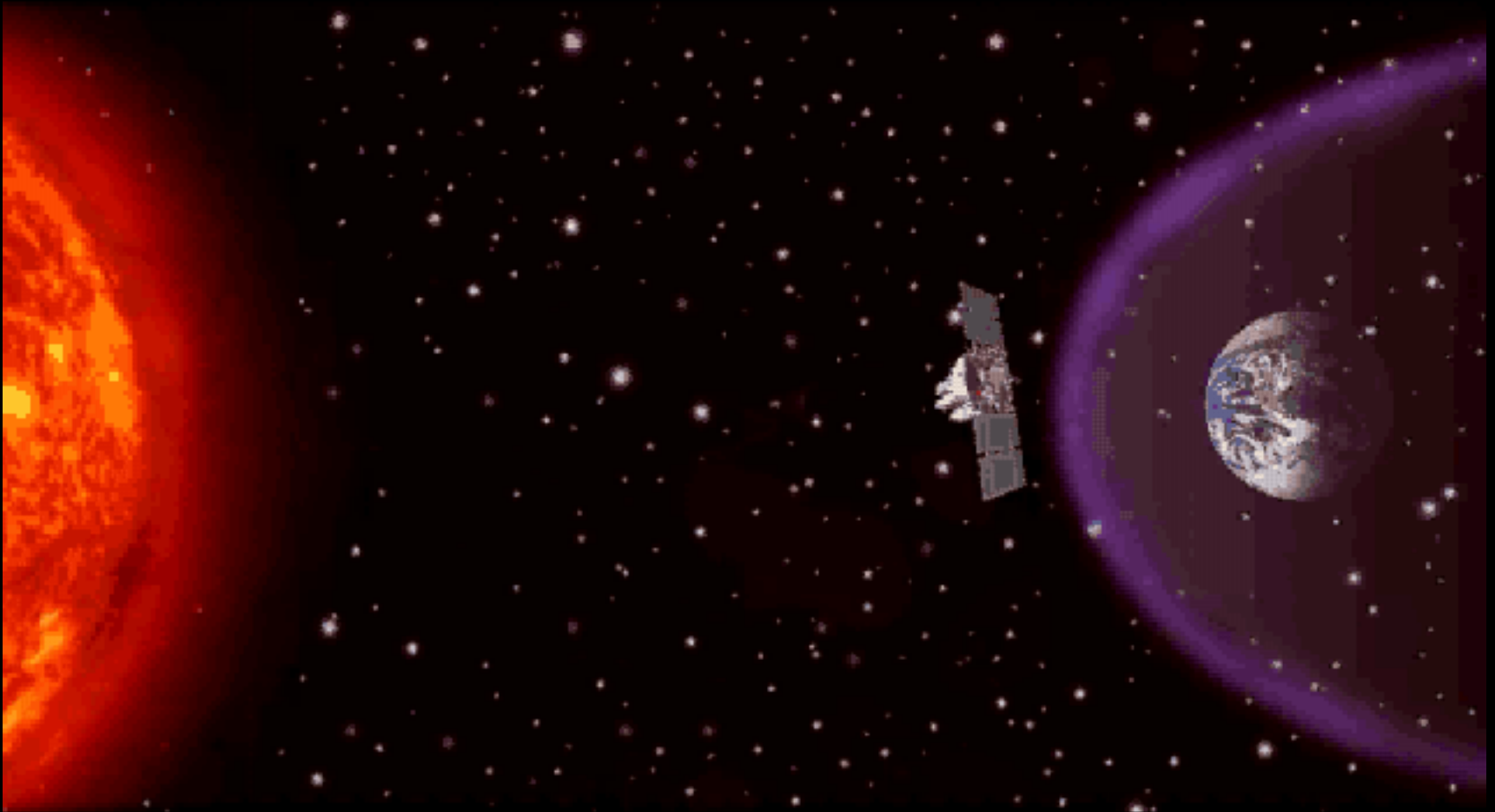
(75 million mph)

Flares  
and  
Coronal Mass Ejections  
(CME)

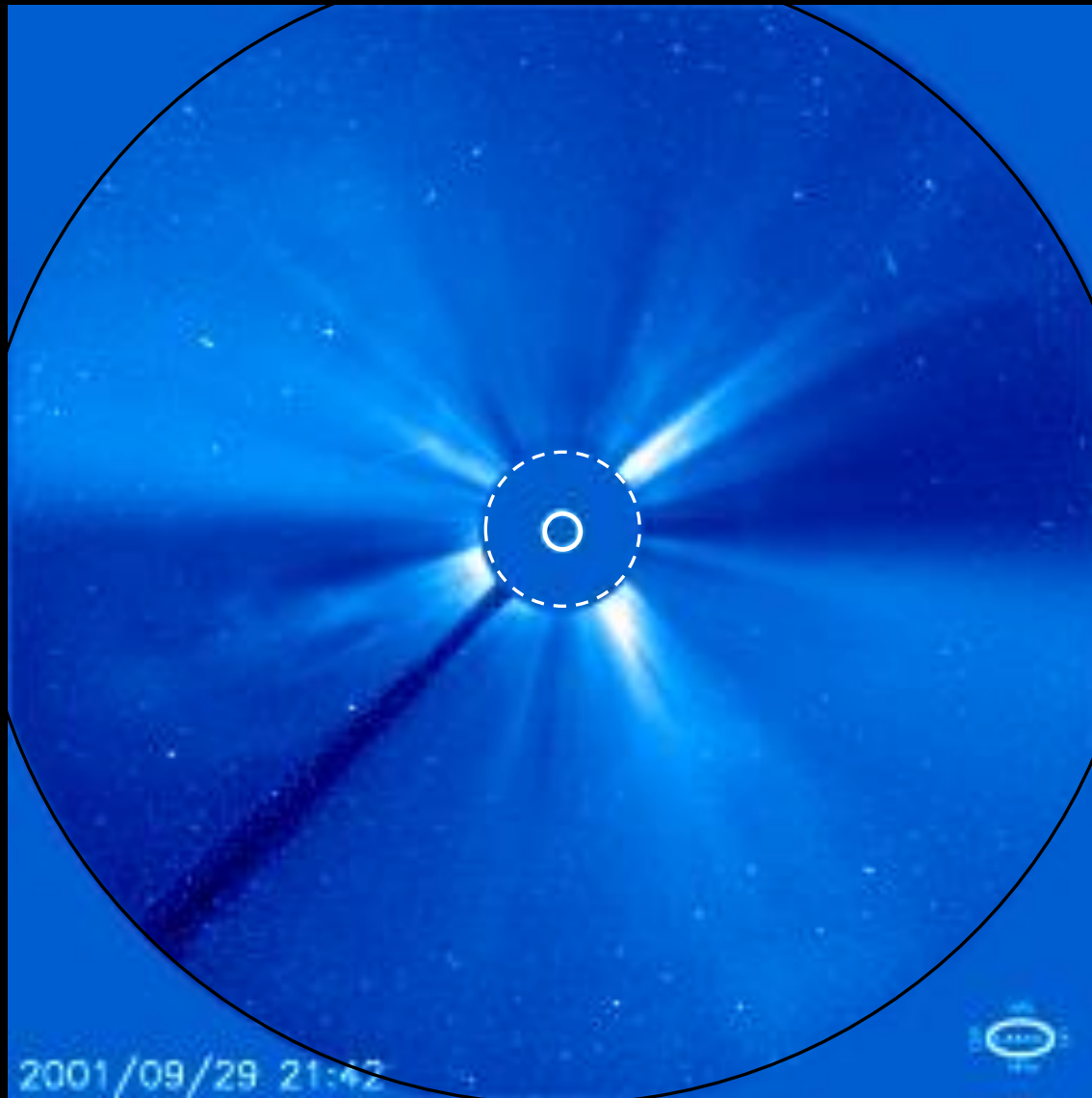
**Flare**



**Flares** punch through the photosphere, corona, and particles can reach up to 20% of the speed of light

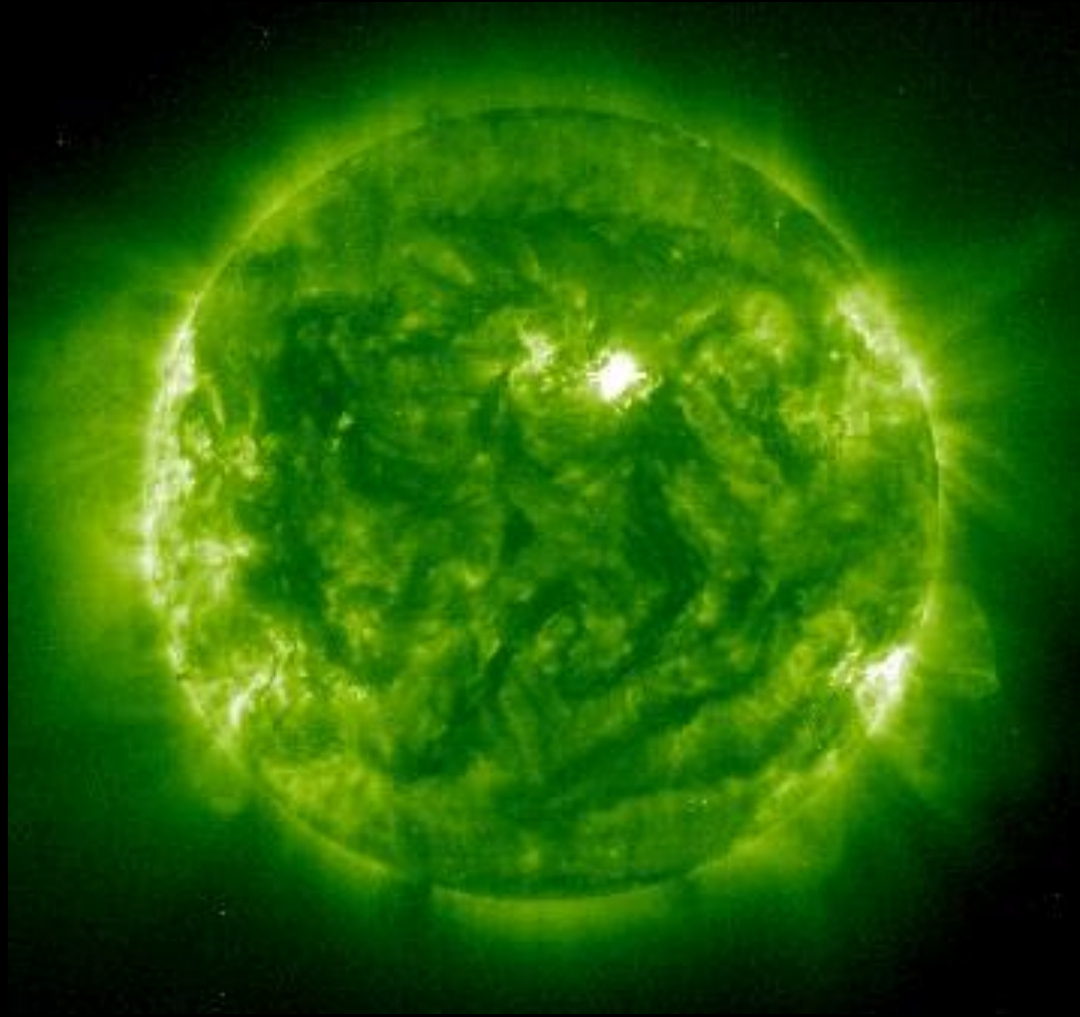


Coronal Mass Ejections (CME)  
160 x 10<sup>9</sup> MTons TNT  
atomic bomb: 0.015 MTon TNT

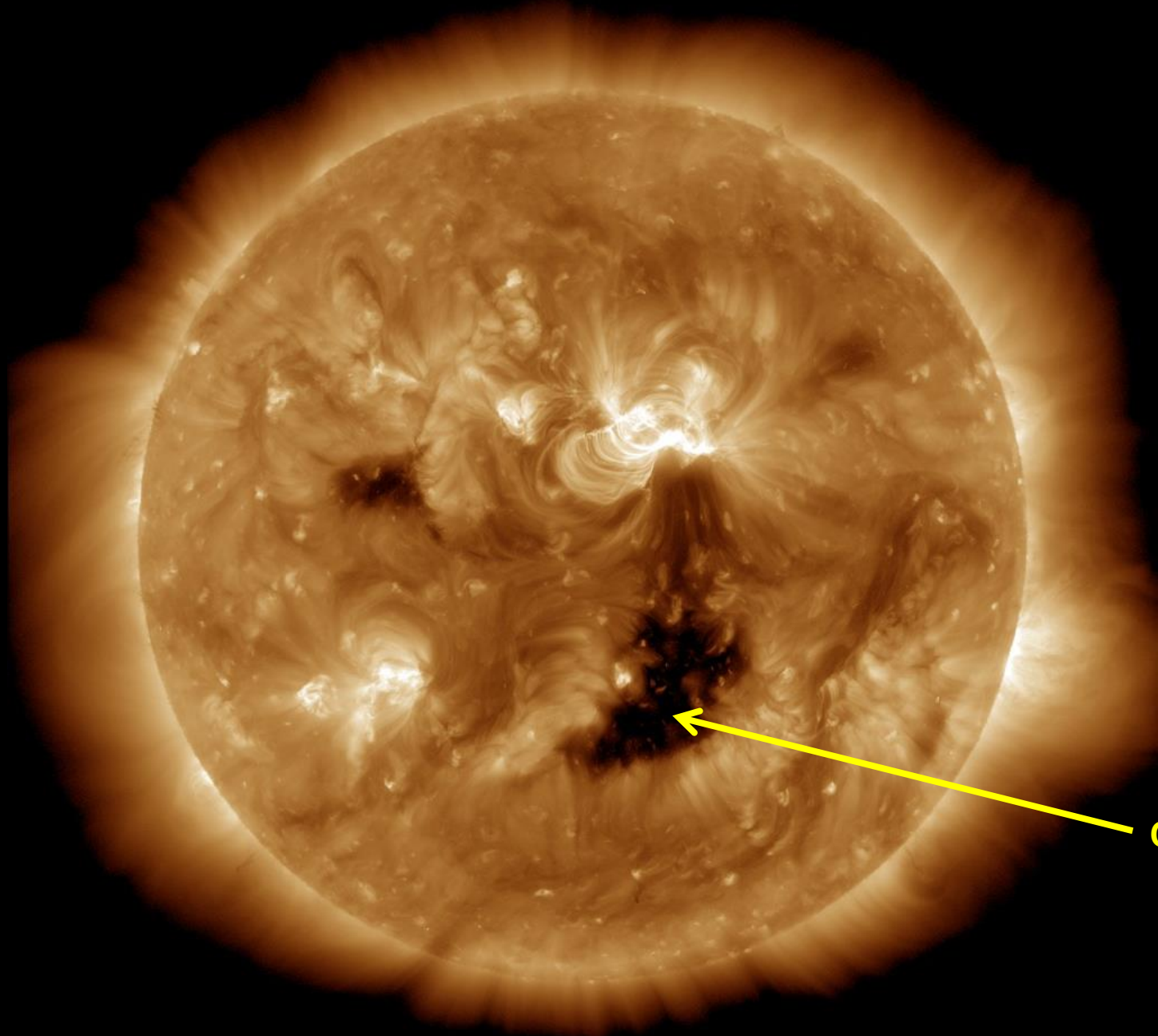


particles have speeds to 3200 km/s for **Flare** for  
**Coronal Mass Ejection (CME)** (7 million mph)



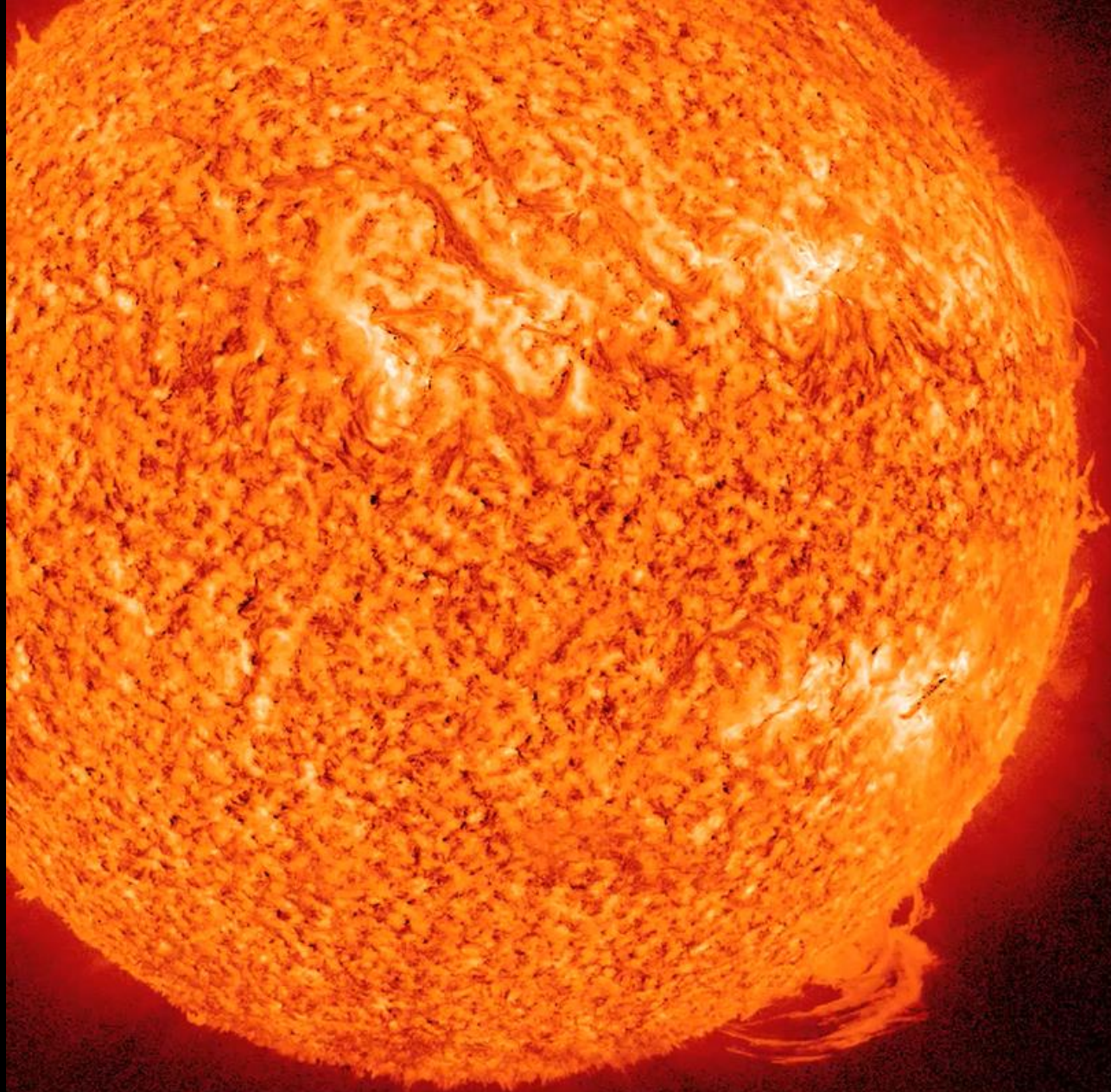


Sun in x-ray light — light emitted by the hottest material hovering above the Sun in the CORONA

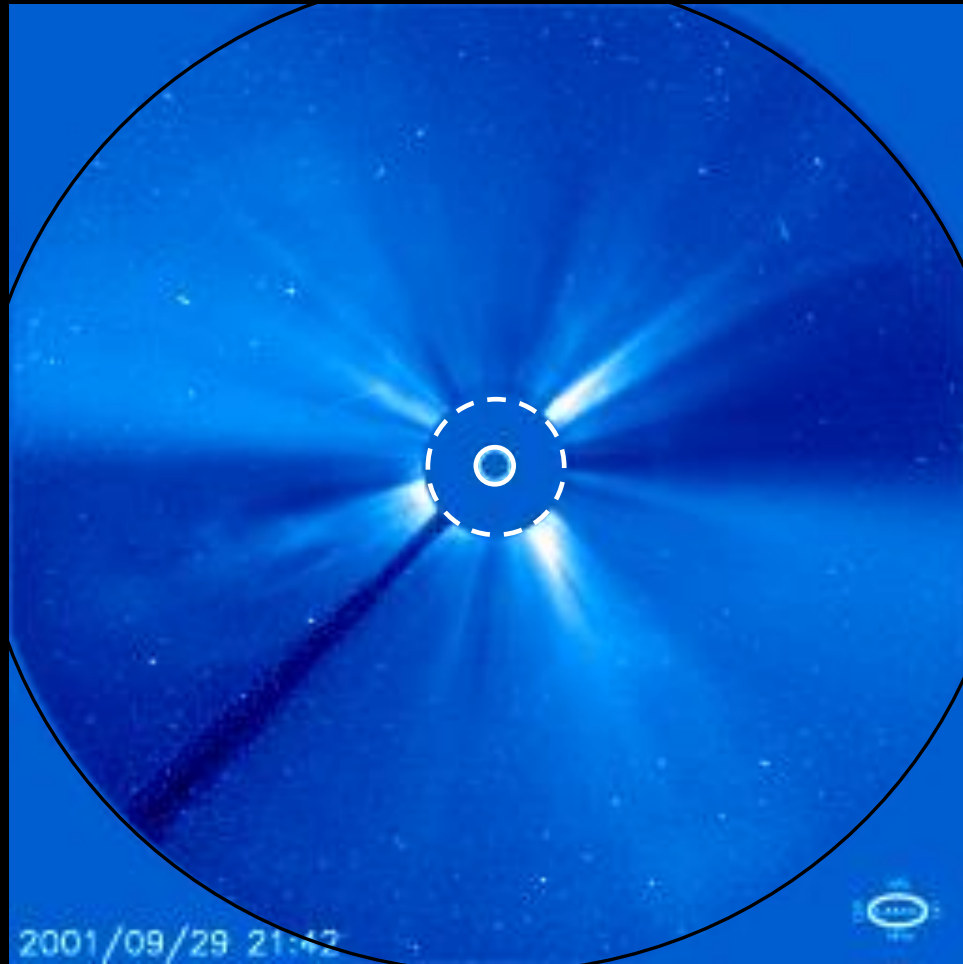


**CORONAL  
HOLE**

Sun in x-ray light — CORONA

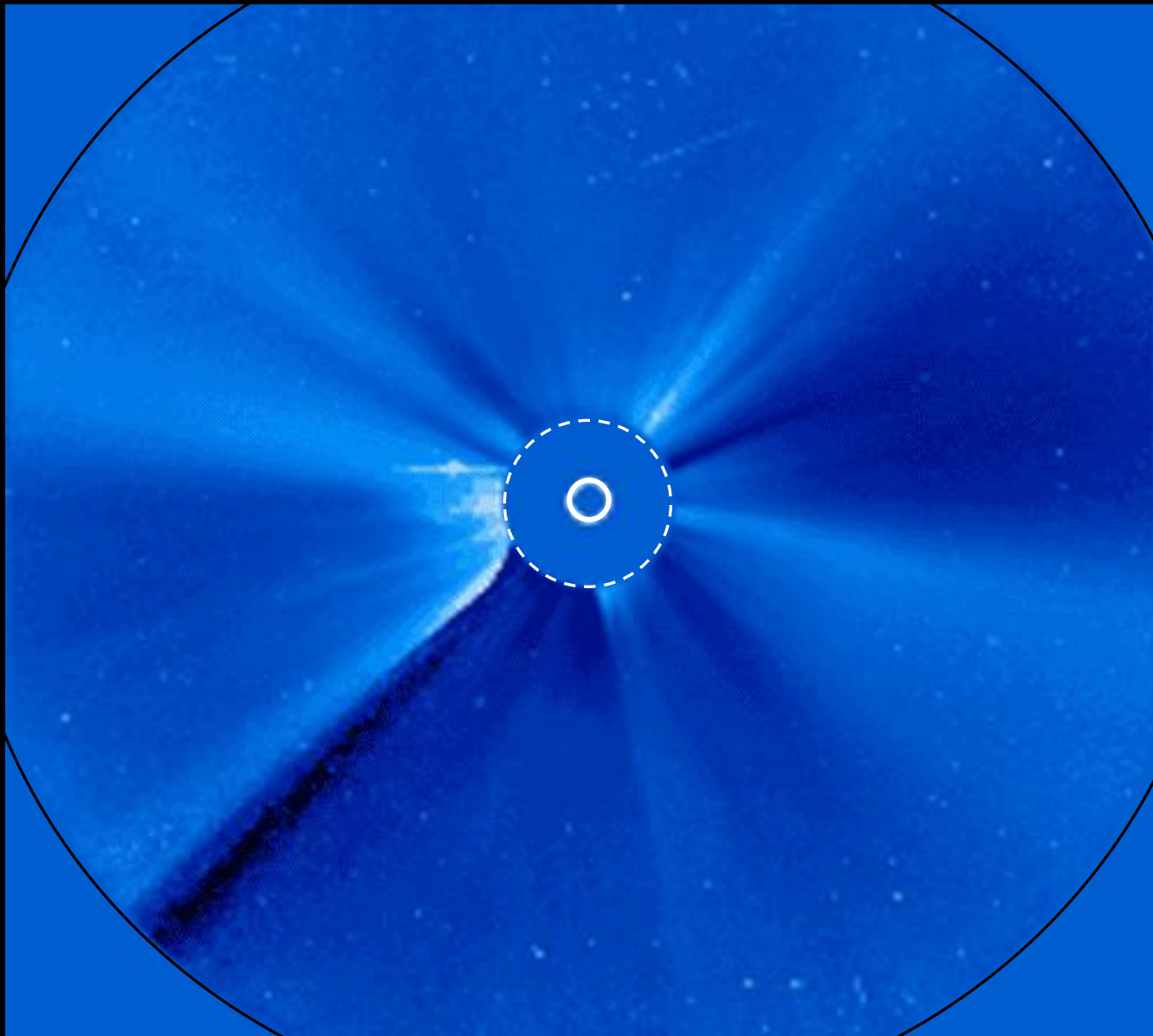




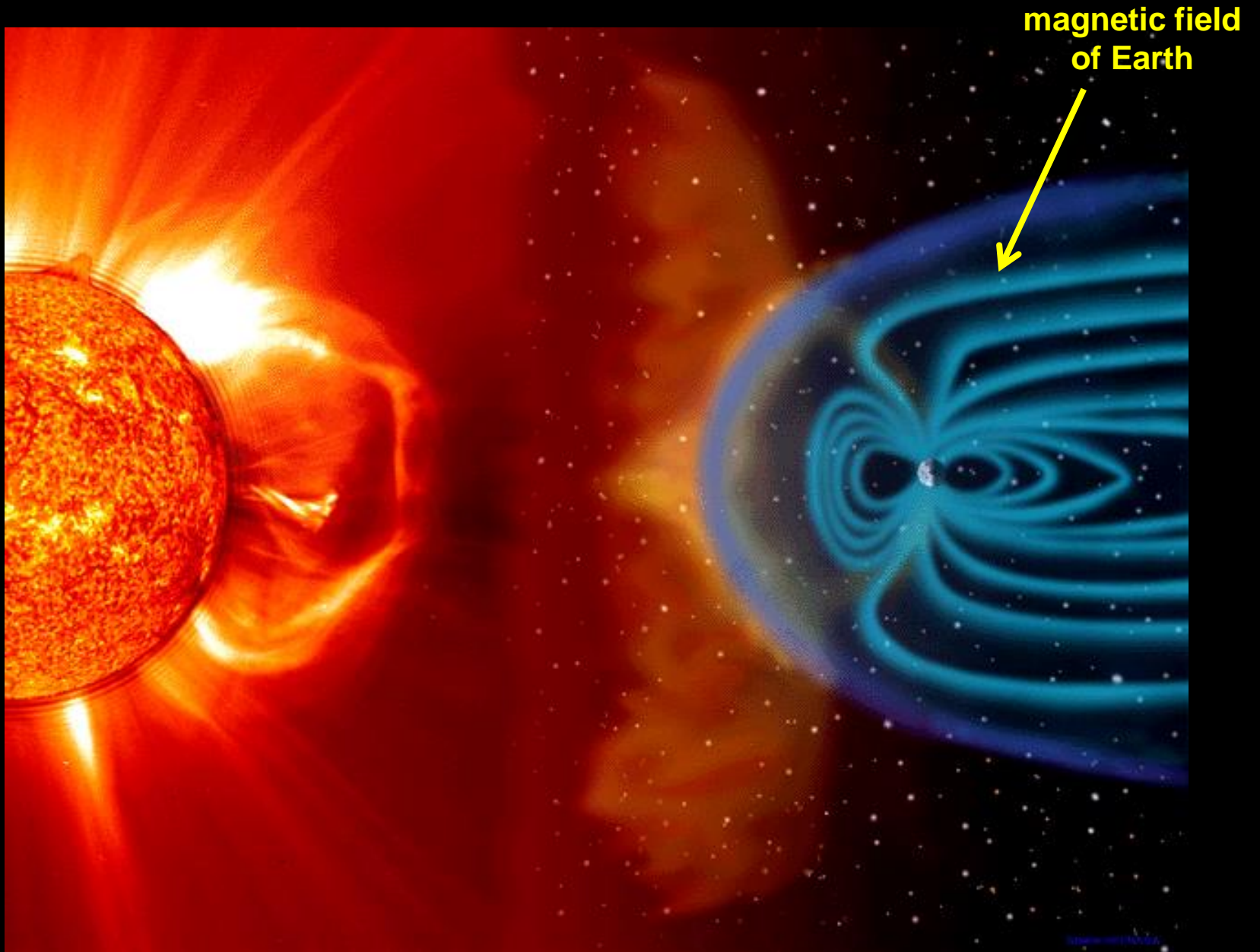


2001/09/29 21:47



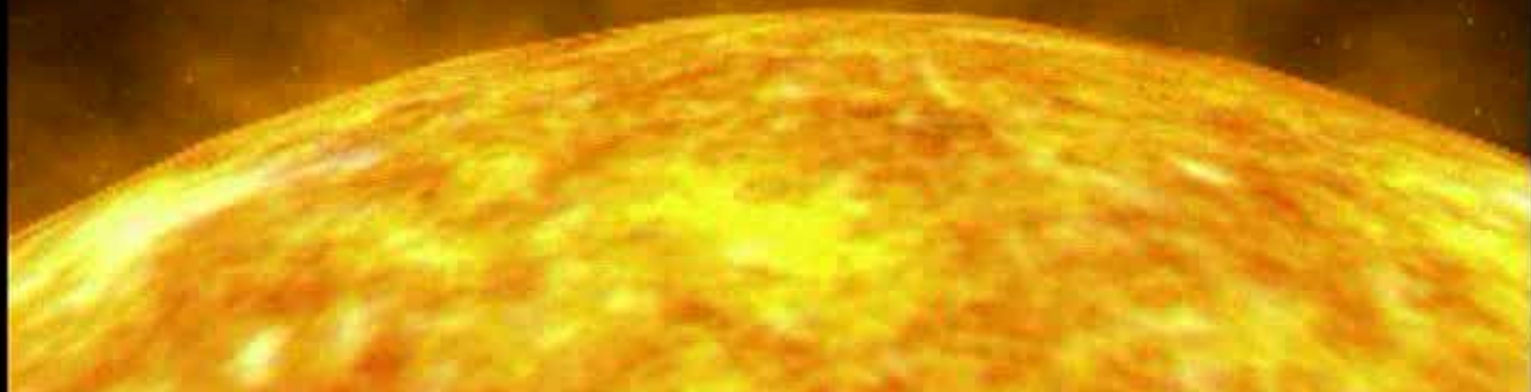


This Flare was aimed directly at Earth. The spots are hits from protons and electrons on the telescope's detector.

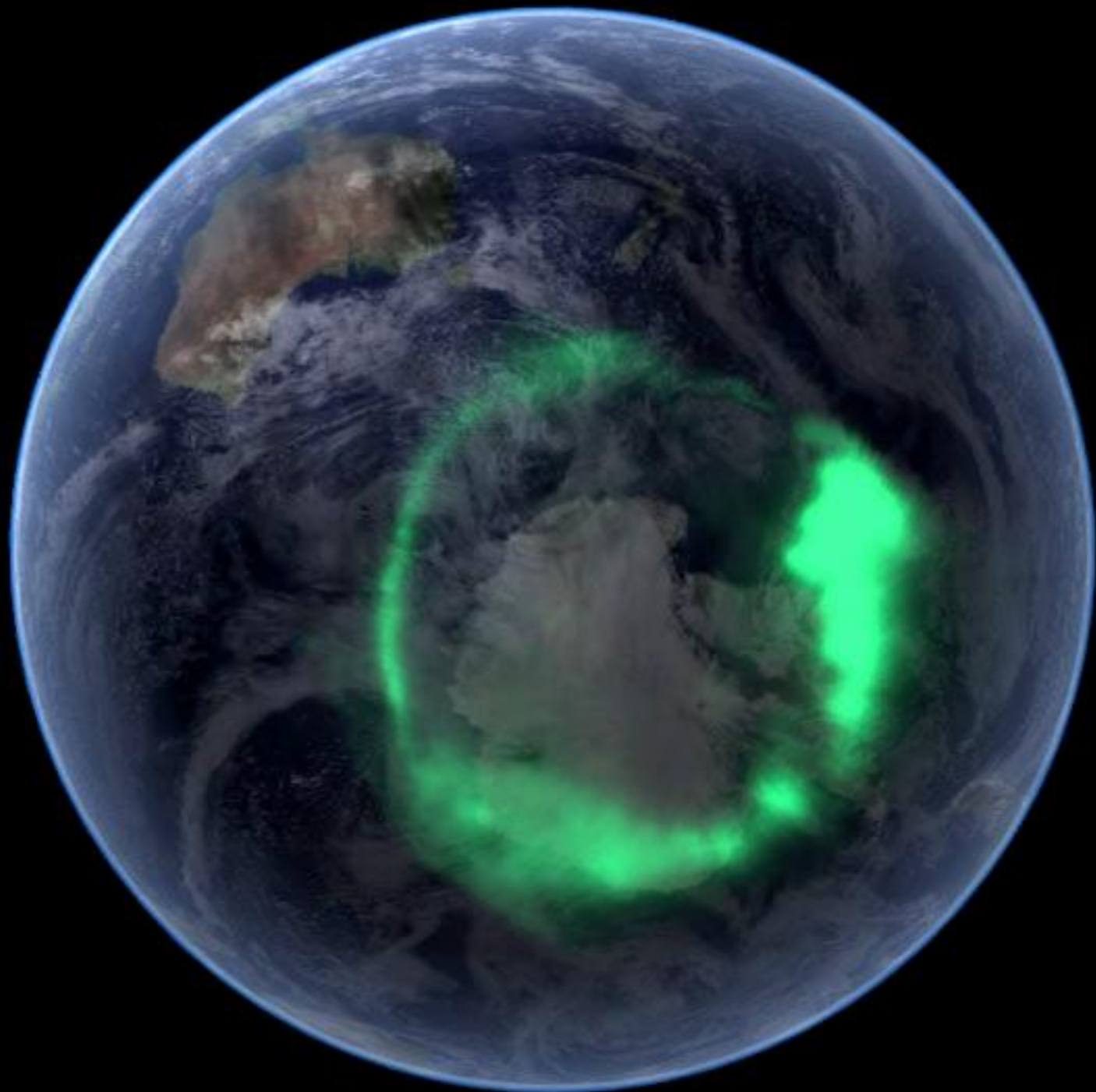


magnetic field  
of Earth

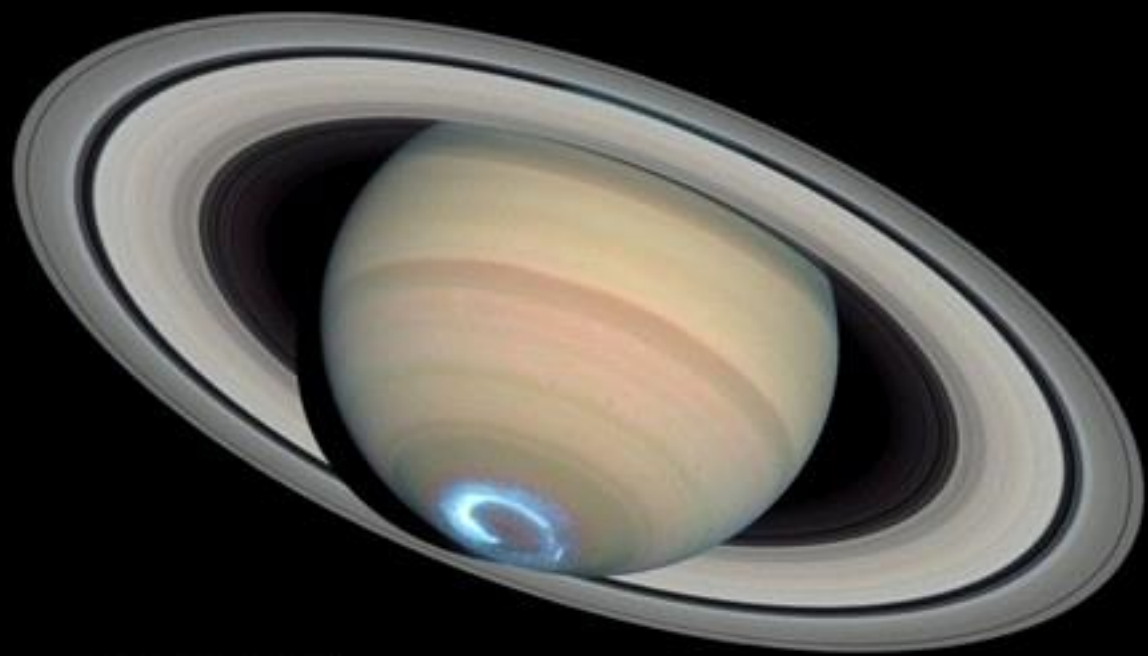
How does this affect us on Earth?









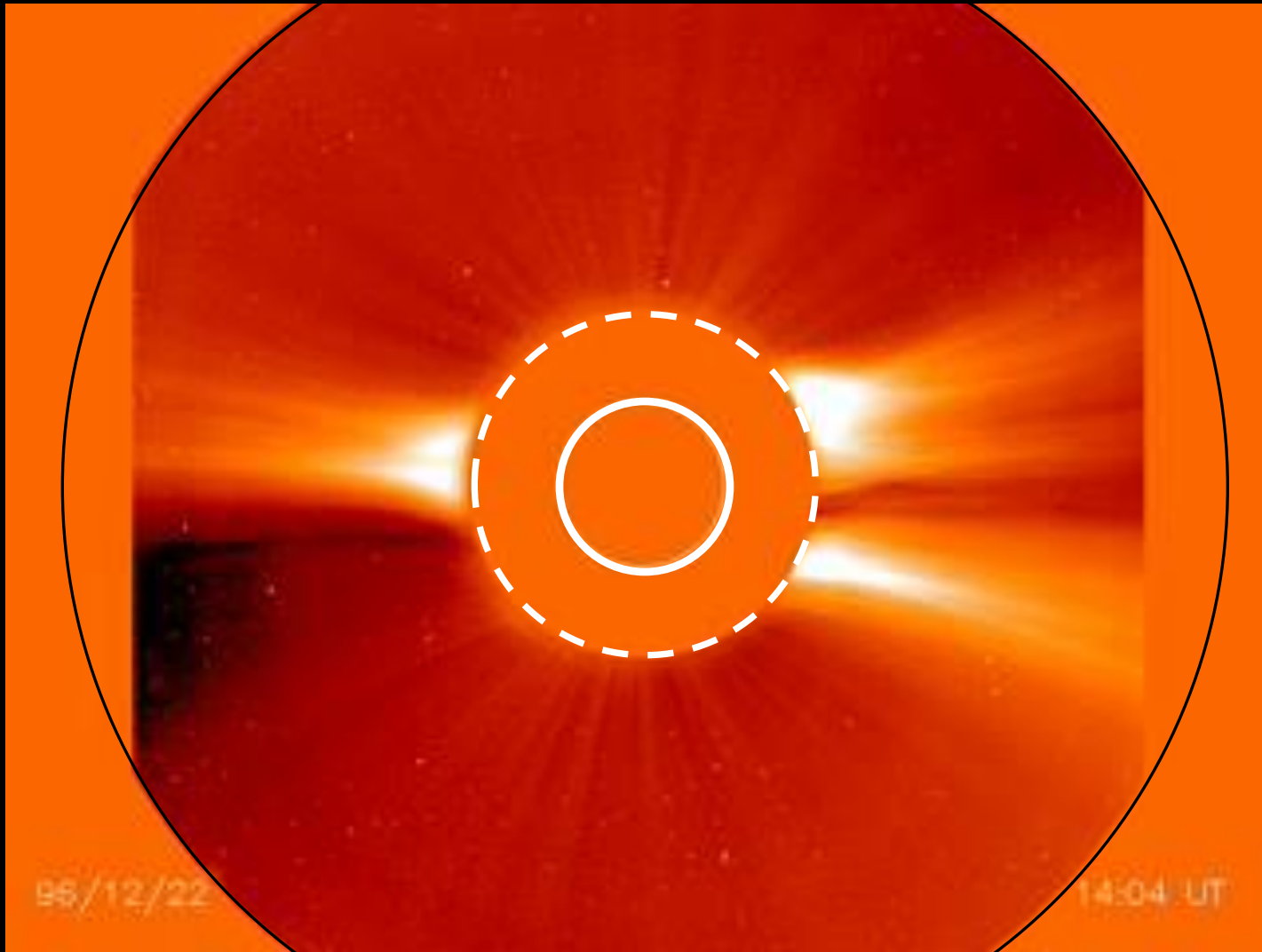






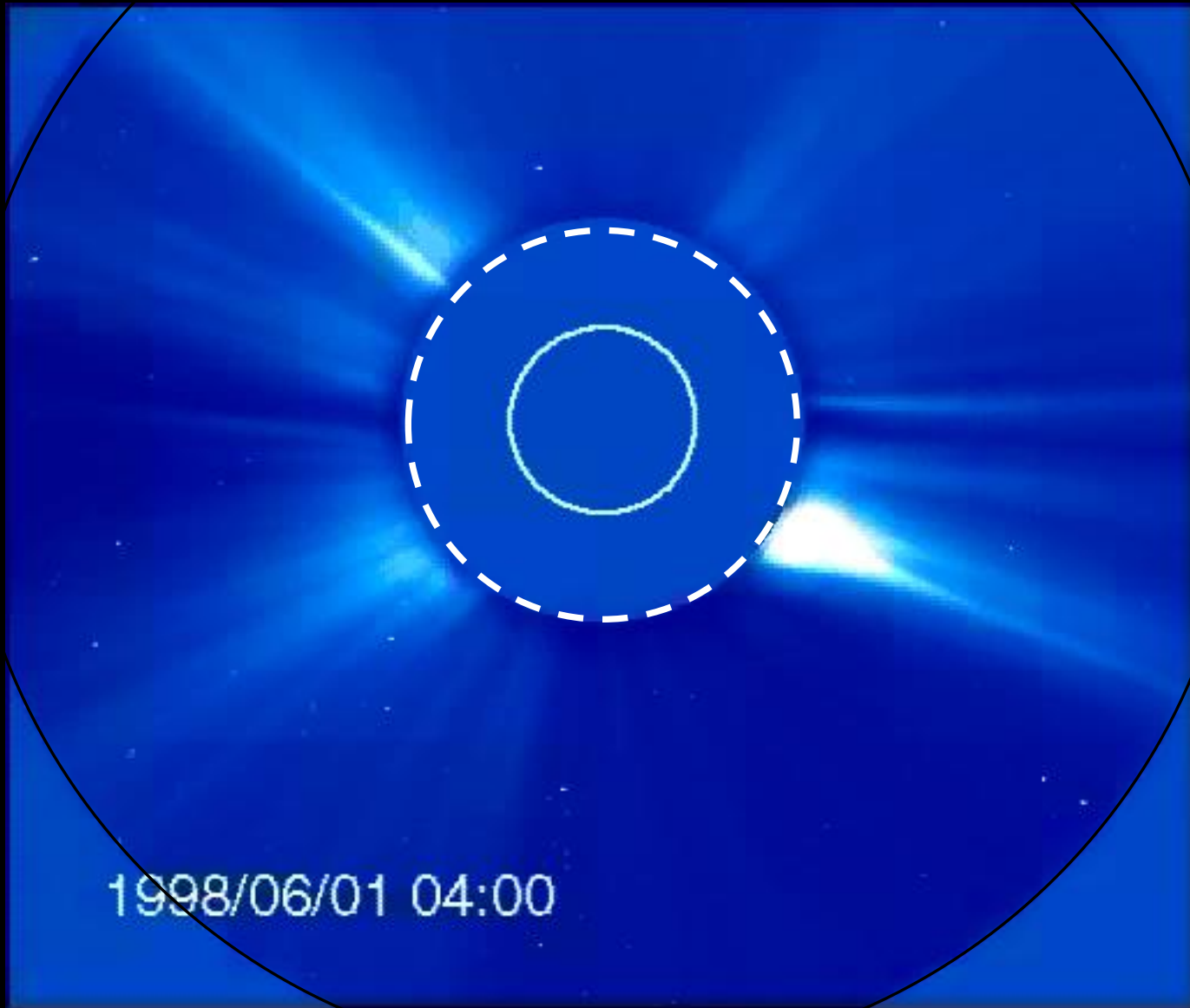






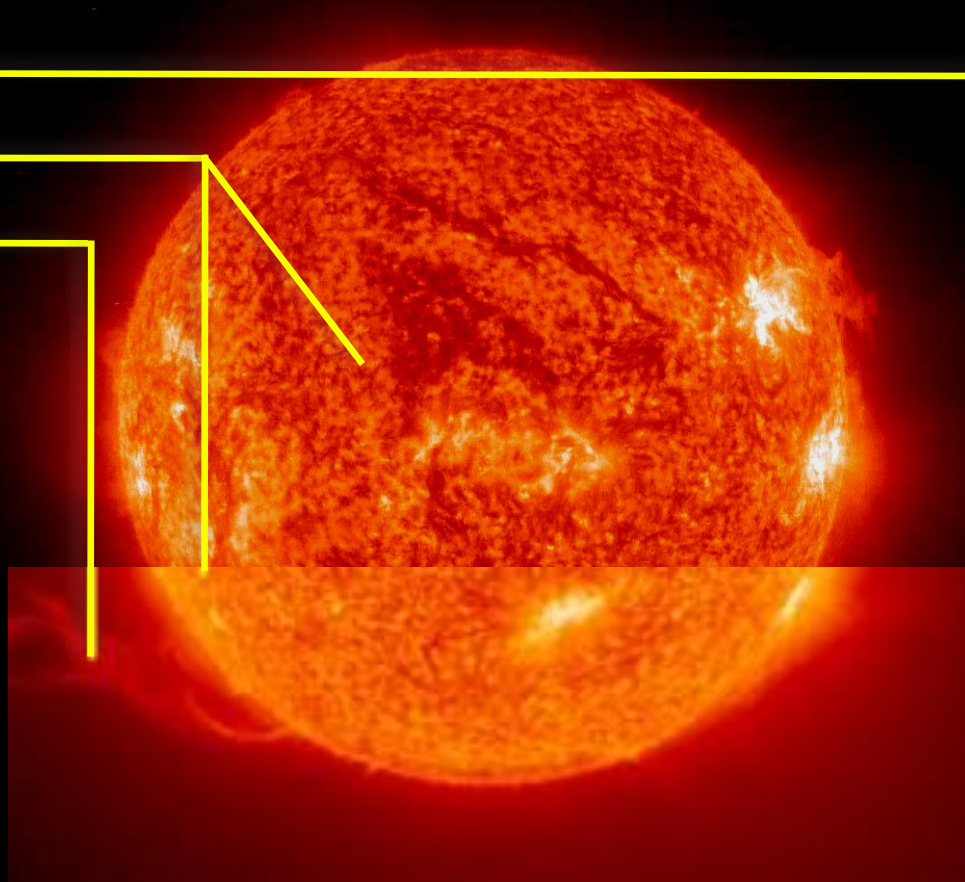
A comet crashes into the  
Sun on 22 Dec 2006



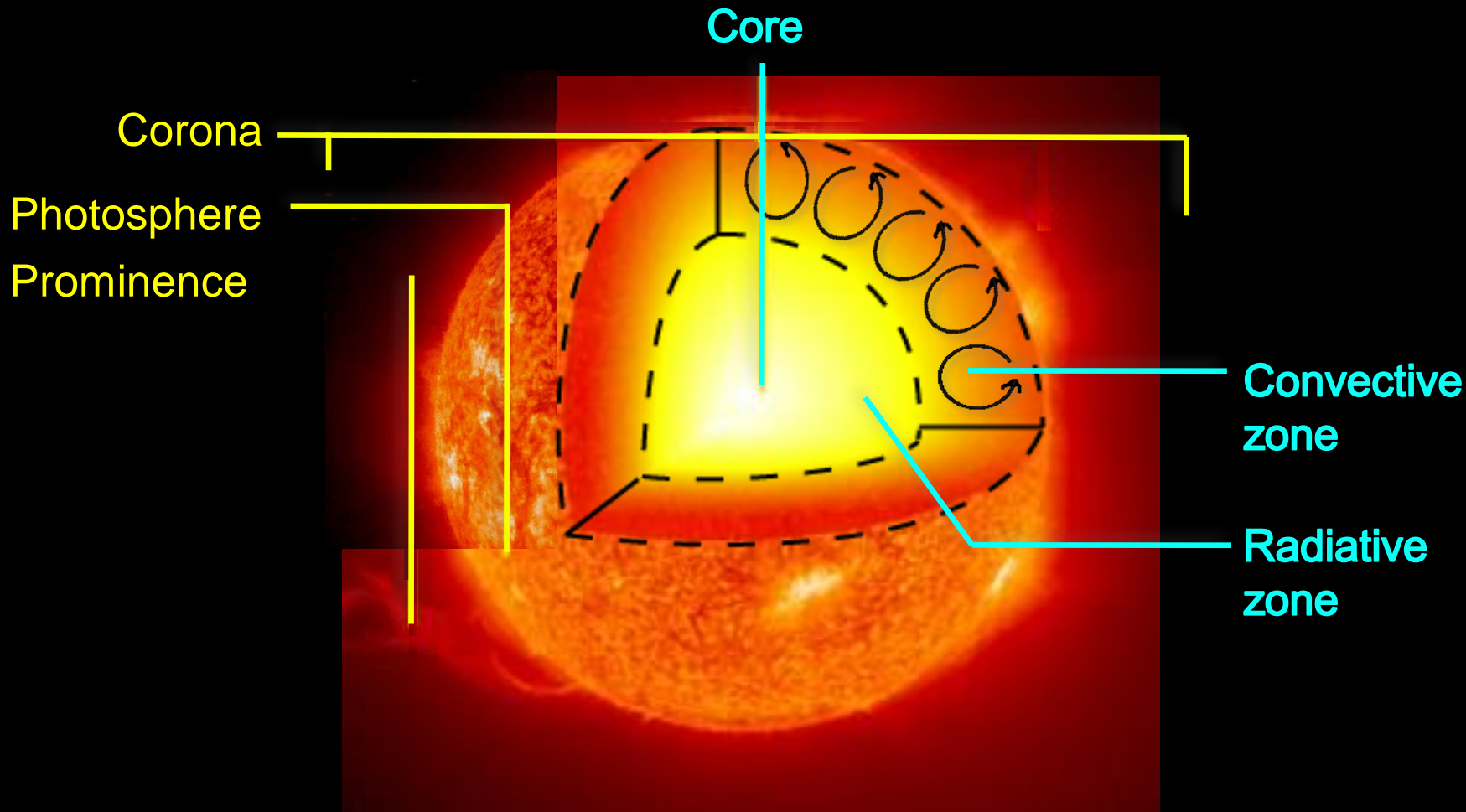


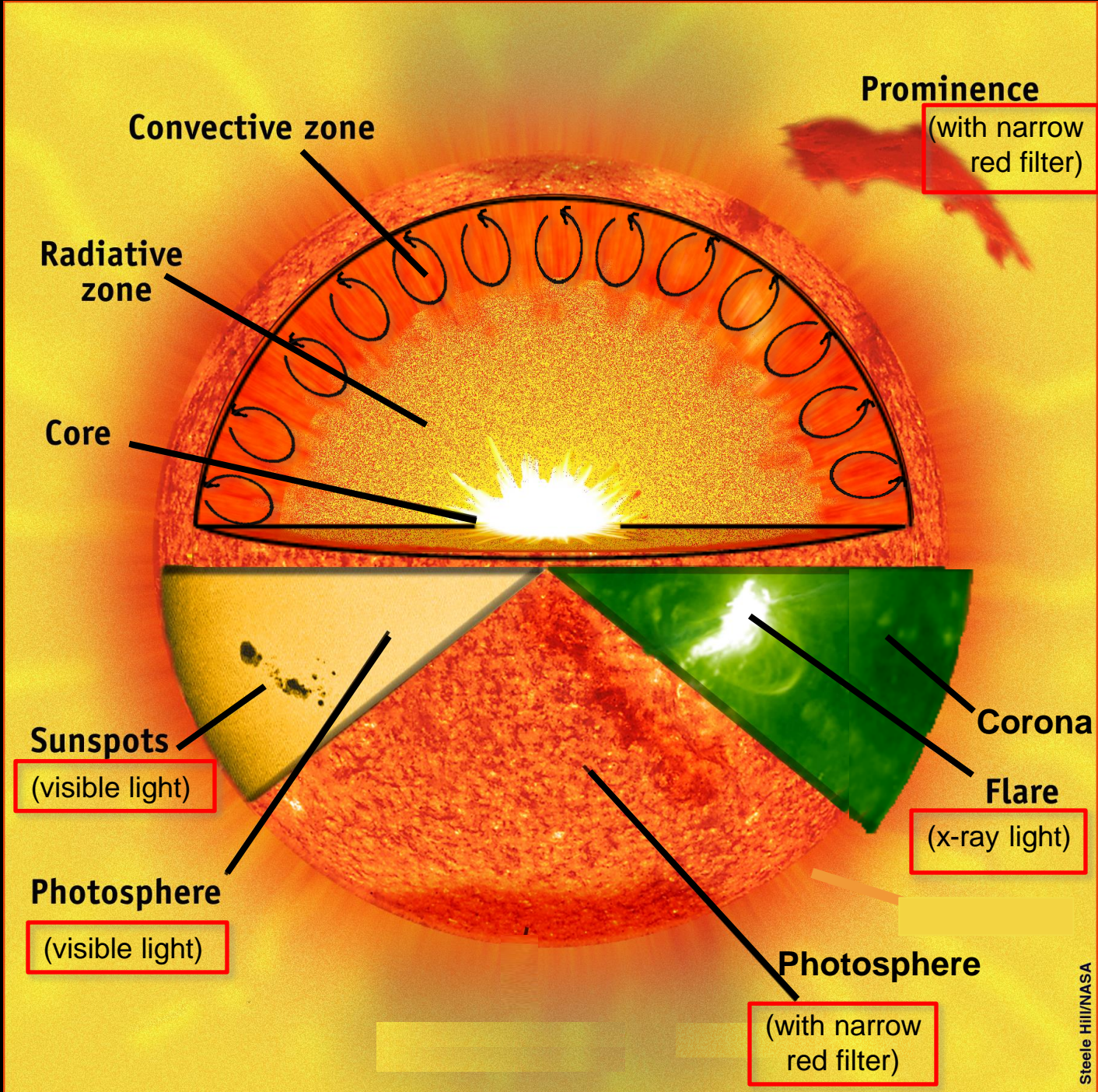
Two comets crash into  
the Sun on 6 Jan 1998!!

Corona  
Photosphere  
Prominence



**Outside  
the Sun**





**Convective zone**

**Radiative zone**

**Core**

**Prominence**

(with narrow red filter)

**Sunspots**

(visible light)

**Photosphere**

(visible light)

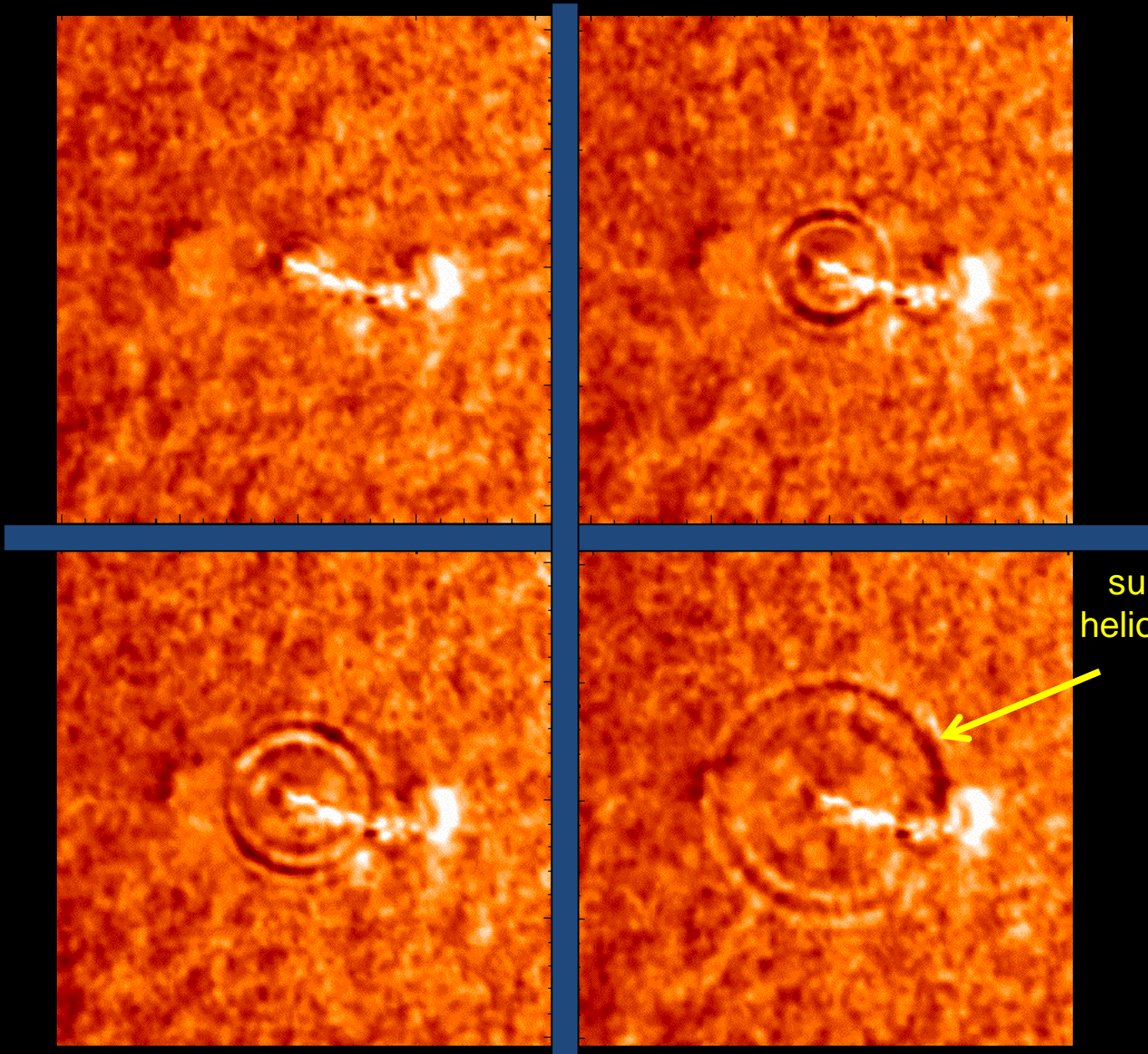
**Corona**

**Flare**

(x-ray light)

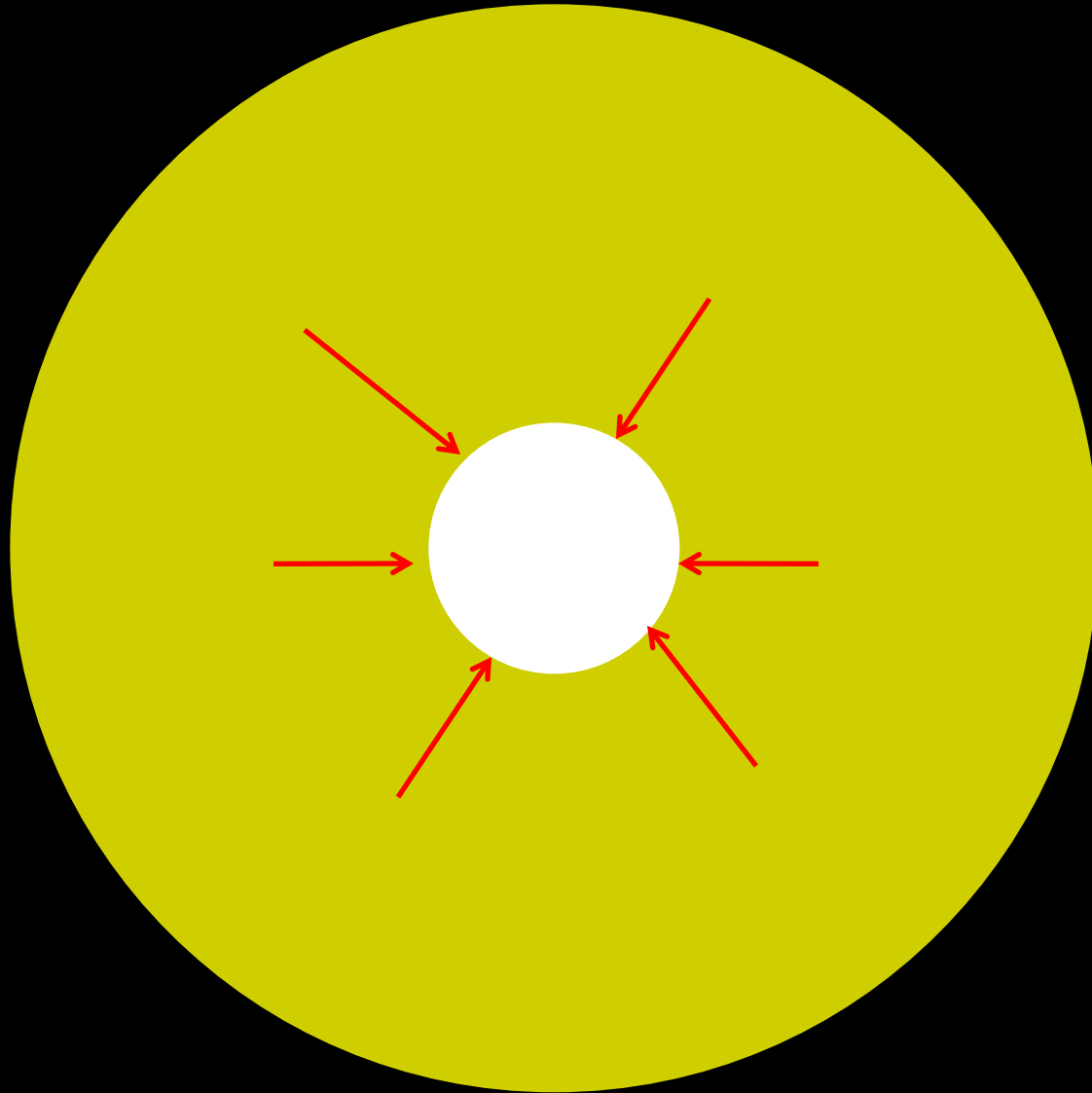
**Photosphere**

(with narrow red filter)

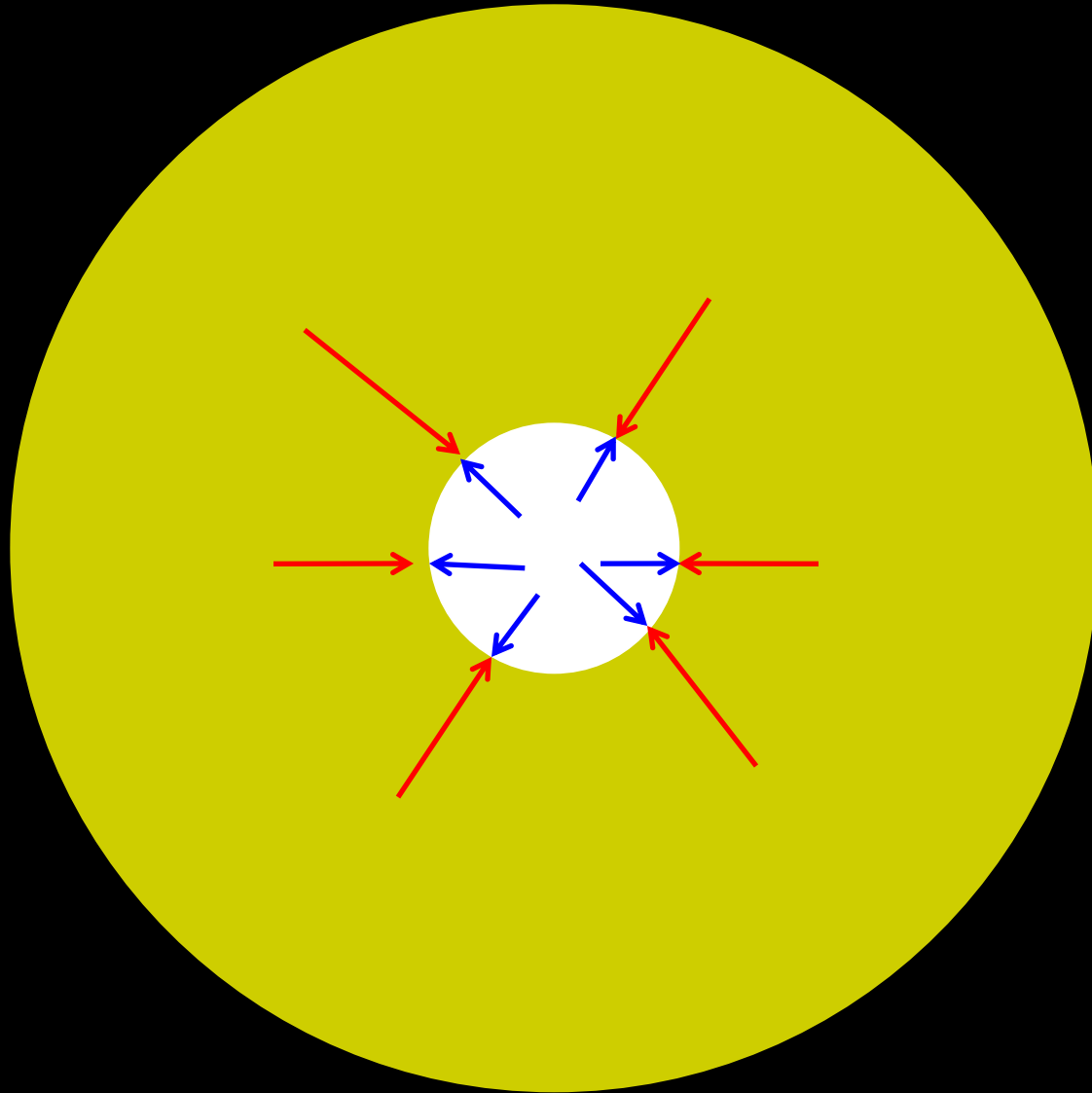


sun-quake =  
helioseismology

Flares originate just under the photosphere



The outer layers squeeze the core due to Gravity



Light due to Fusion pushes back

There are two kinds of **nuclear** reactions

**Fission** tears large atoms apart

**Fusion** brings light atoms together

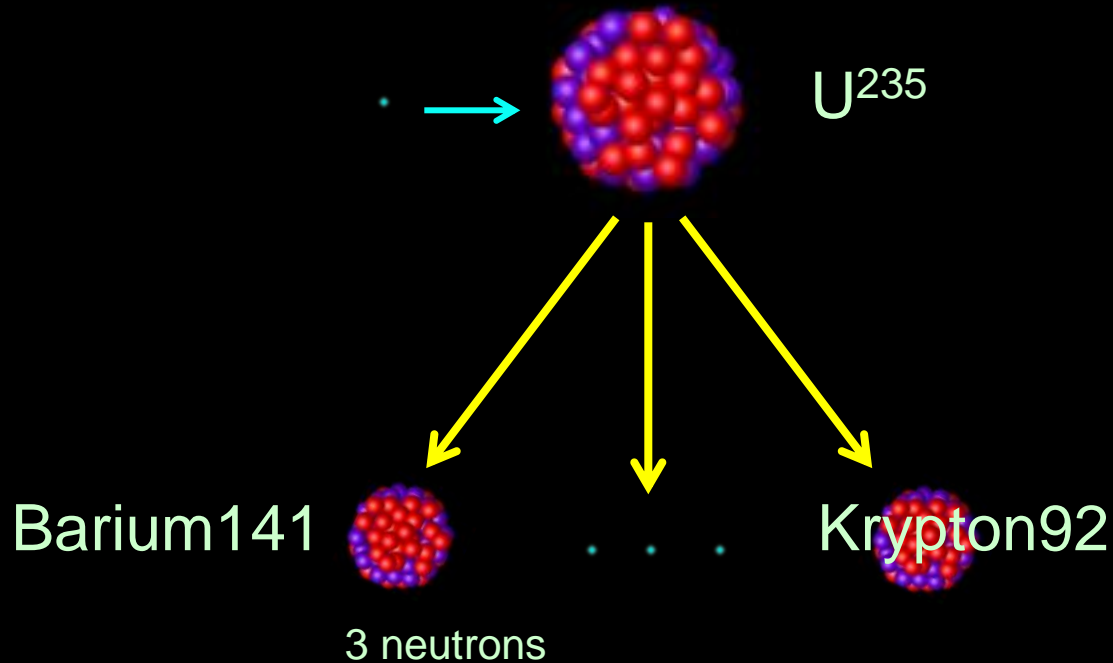
is what happens in the Sun's core





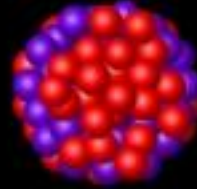
# Fission

Massive nuclei (like U with 235 protons and neutrons in its nucleus) spit out a fast moving neutron and splits the nucleus into "daughter" nuclei which are, in turn, radioactive (Weak force)



# Fission

Fission takes heavy elements and makes lighter ones



Power plants



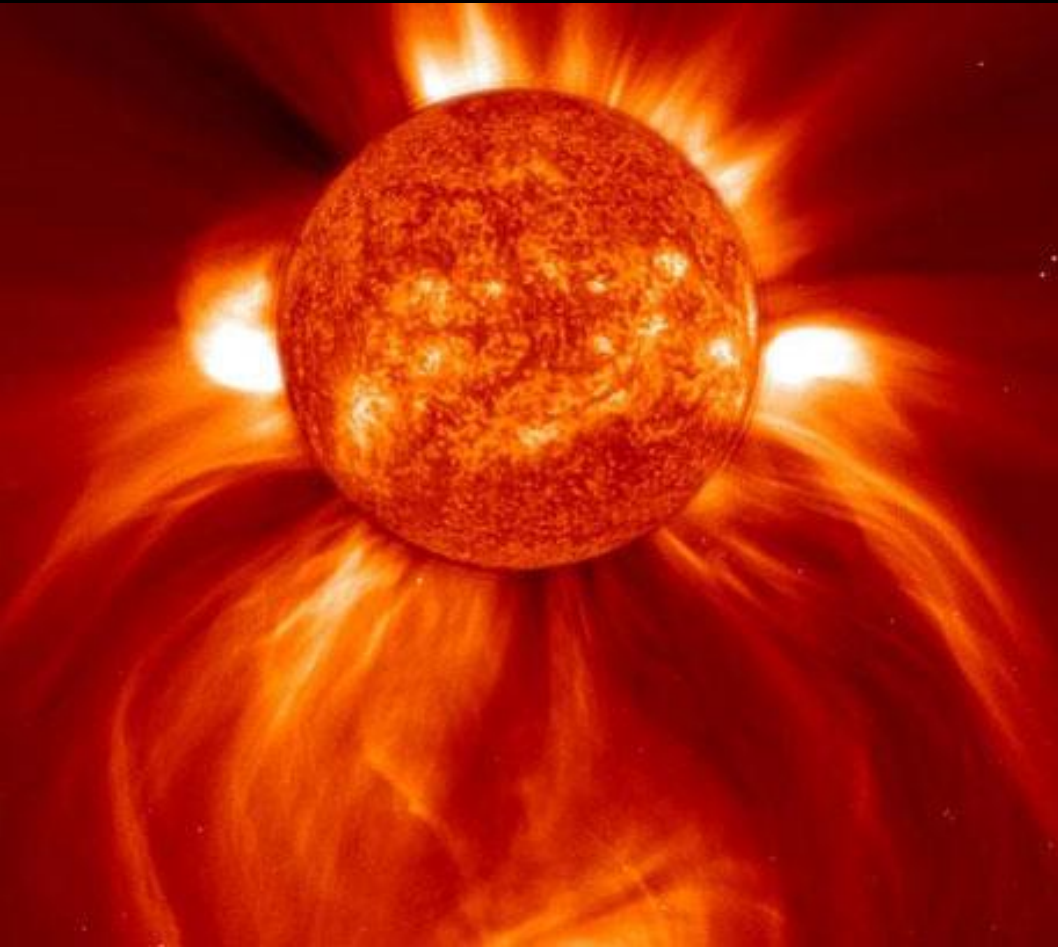
atomic (uranium) bomb



# Fusion

Fusion takes light elements and makes heavier ones

In one second our Sun processes 600 MTons H and puts out  $10^6$  more energy than the sum of all earth's nuclear bombs



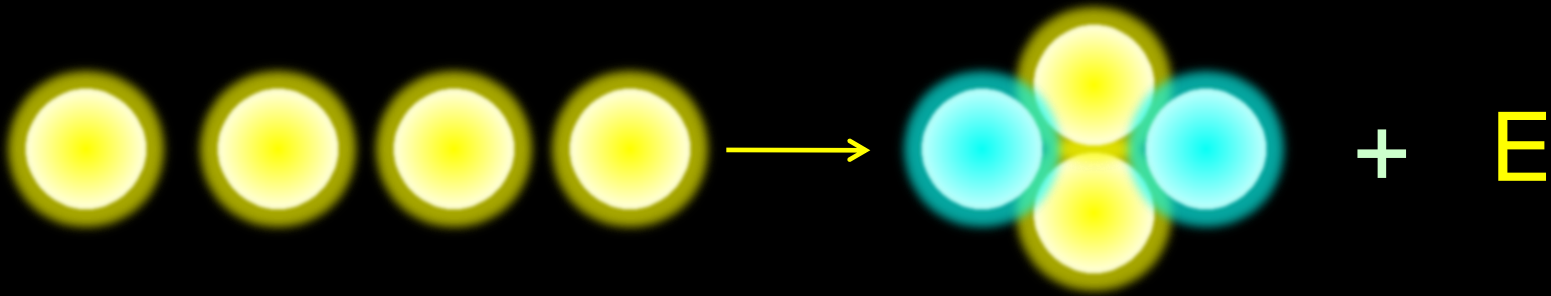
hydrogen bomb—100,000 times more powerful than an atomic bomb



# Fusion

The basic fusion reaction:

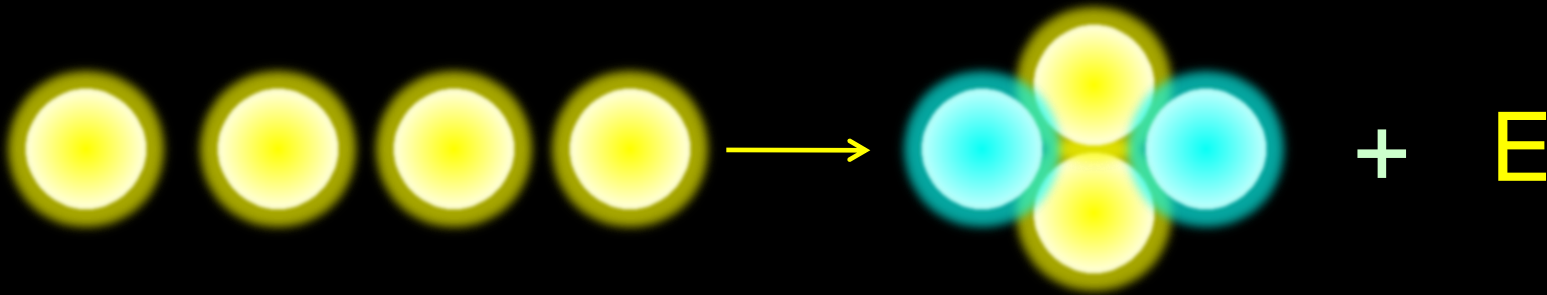
4 Protons  $\longrightarrow$  1 Helium atom + Energy ( $\gamma$ -ray)



# Fusion

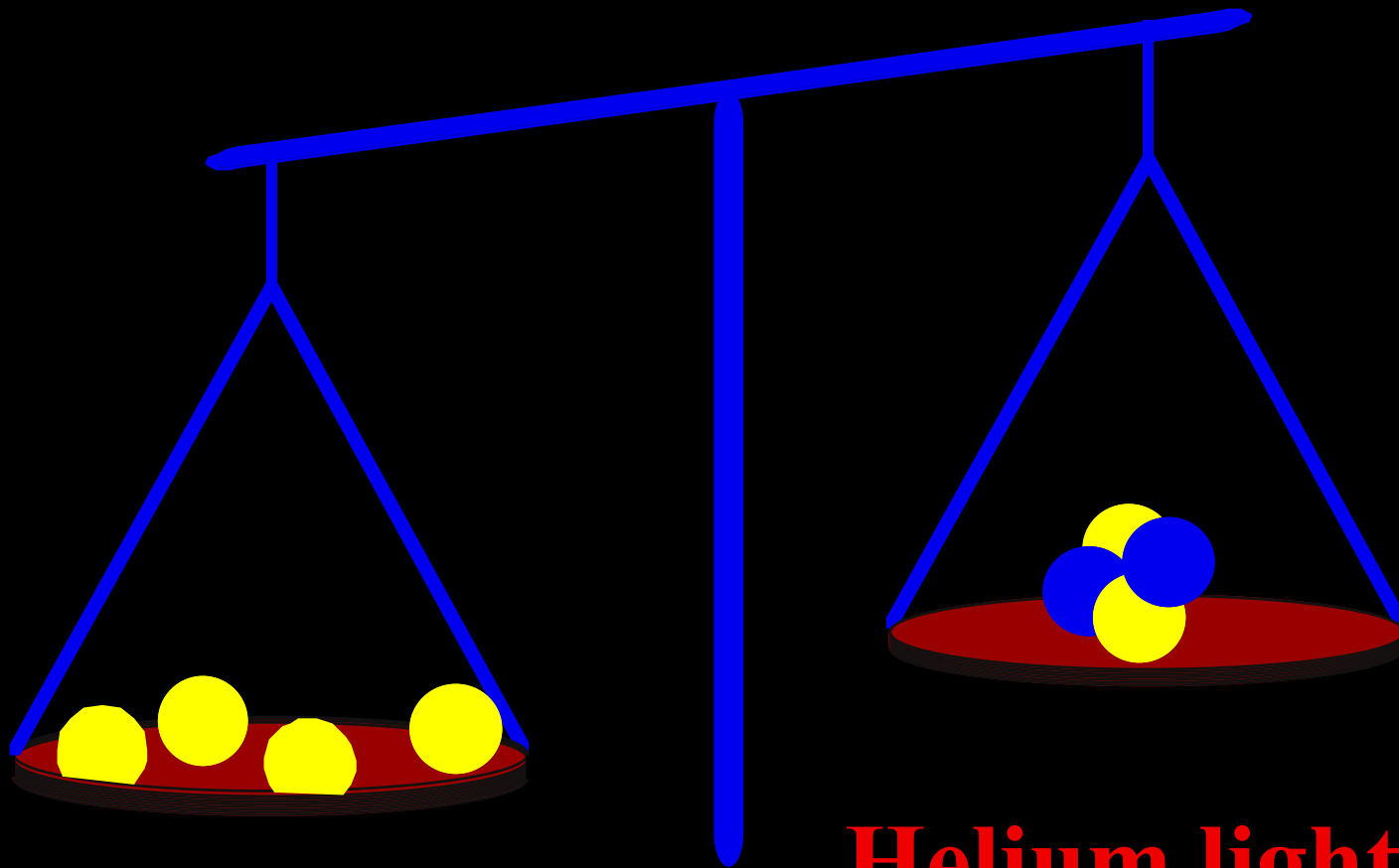
The basic reaction:

4 Protons  $\longrightarrow$  1 Helium atom + Energy ( $\gamma$ -ray)



Mass of 4 P's  $>$  Mass of He !!!

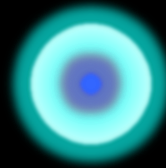
meaning: 0.7% of the mass of 4 p's is turned into energy via  $E = mc^2$







**Helium lighter  
by 0.7 % !!**

$$\mathbf{E = mc^2}$$

# Hydrogen Fusion Reaction



heavy hydrogen

Step 1: two protons  collide (Strong force), one turns into a neutron  (Weak force),  and an anti-electron,  and a neutrino

# Hydrogen Fusion Reaction



Light Helium

Step 2: one proton  collides with heavy hydrogen to make light He



# Hydrogen Fusion Reaction



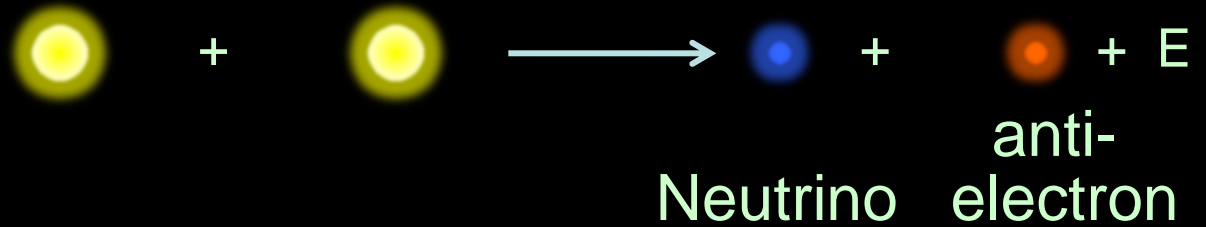
Helium

Step 3: two light He nuclei collide to make stable He and two protons are ejected.

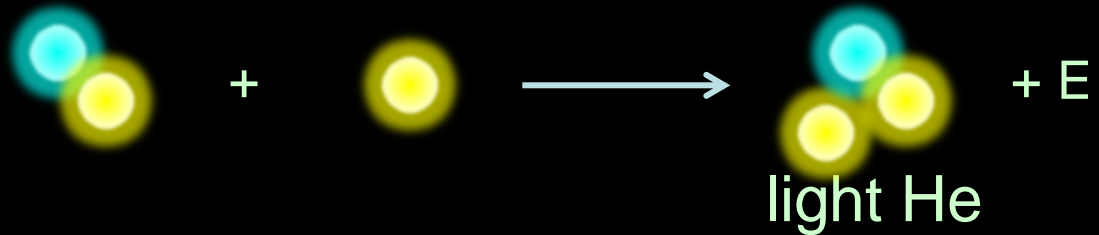


# Hydrogen Fusion Reaction

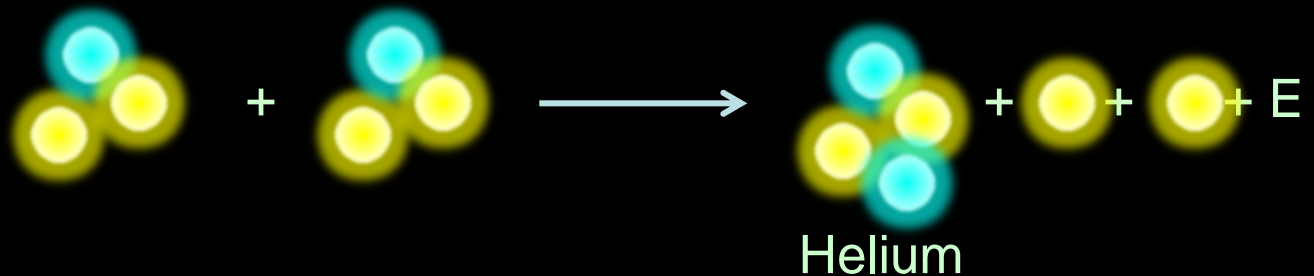
Step 1:



Step 2:

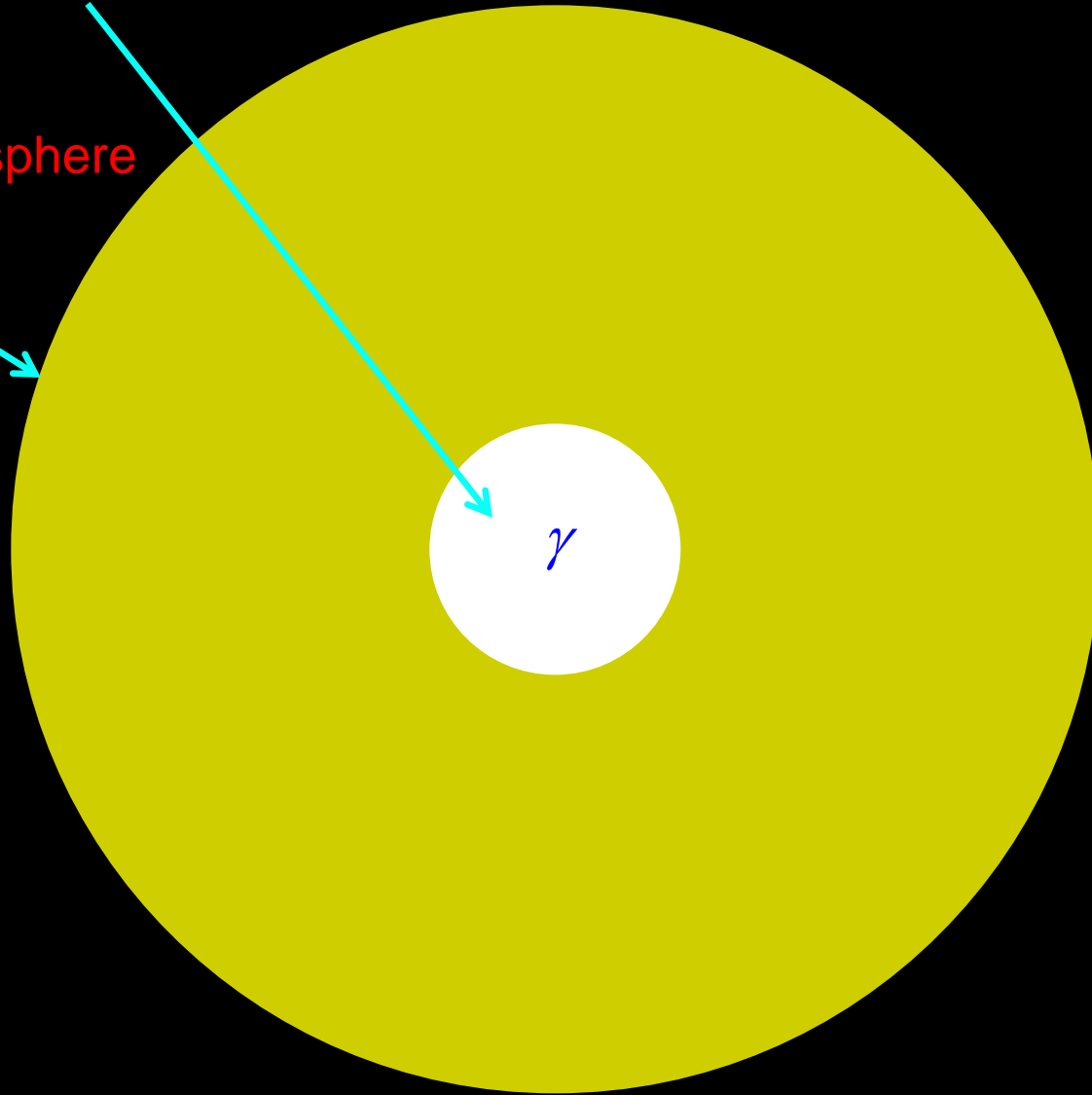


Step 3:



20 x 10<sup>6</sup> K in core

5800 K photosphere



Why the great difference in Temperature?

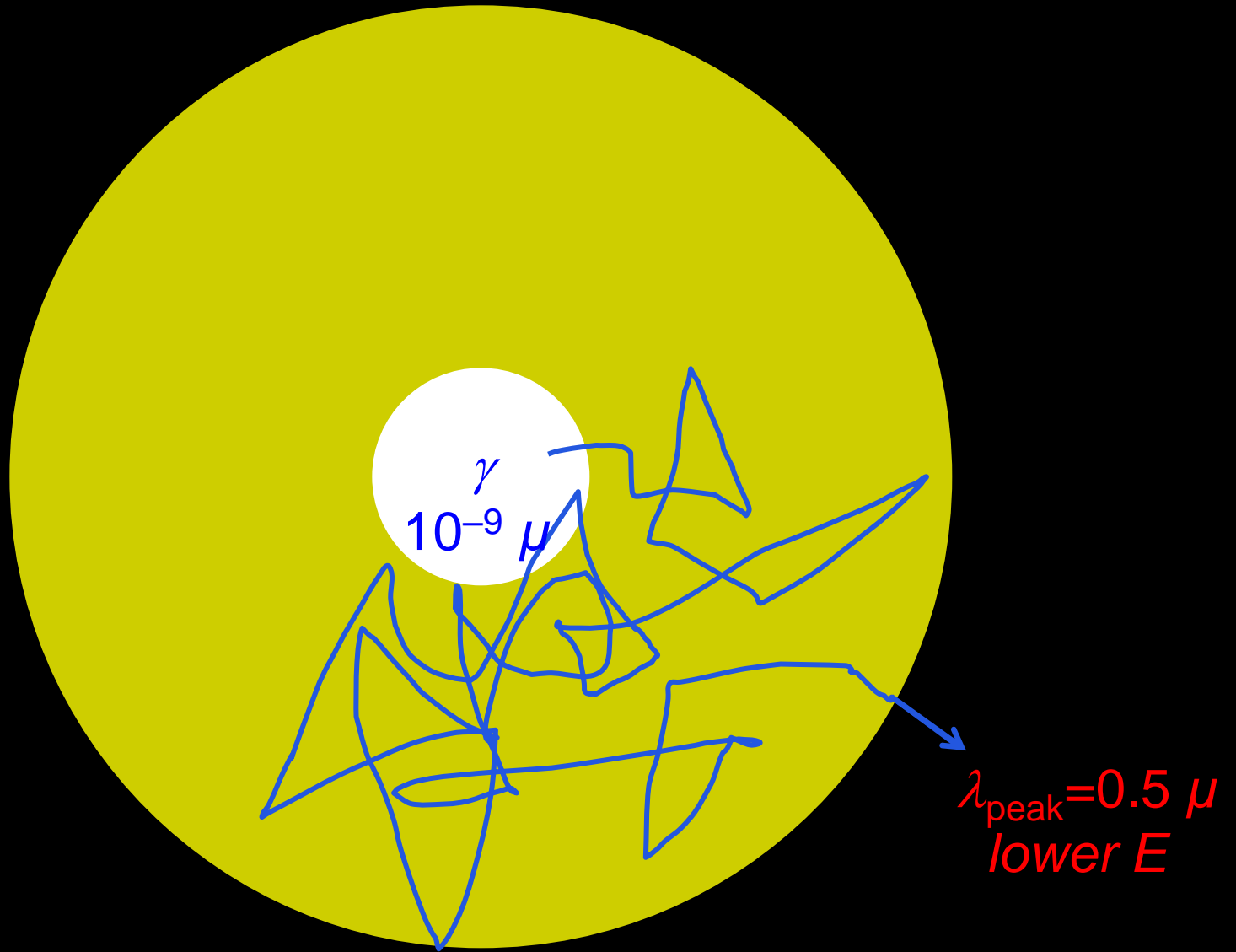
20 x 10<sup>6</sup> K in core

5800 K photosphere

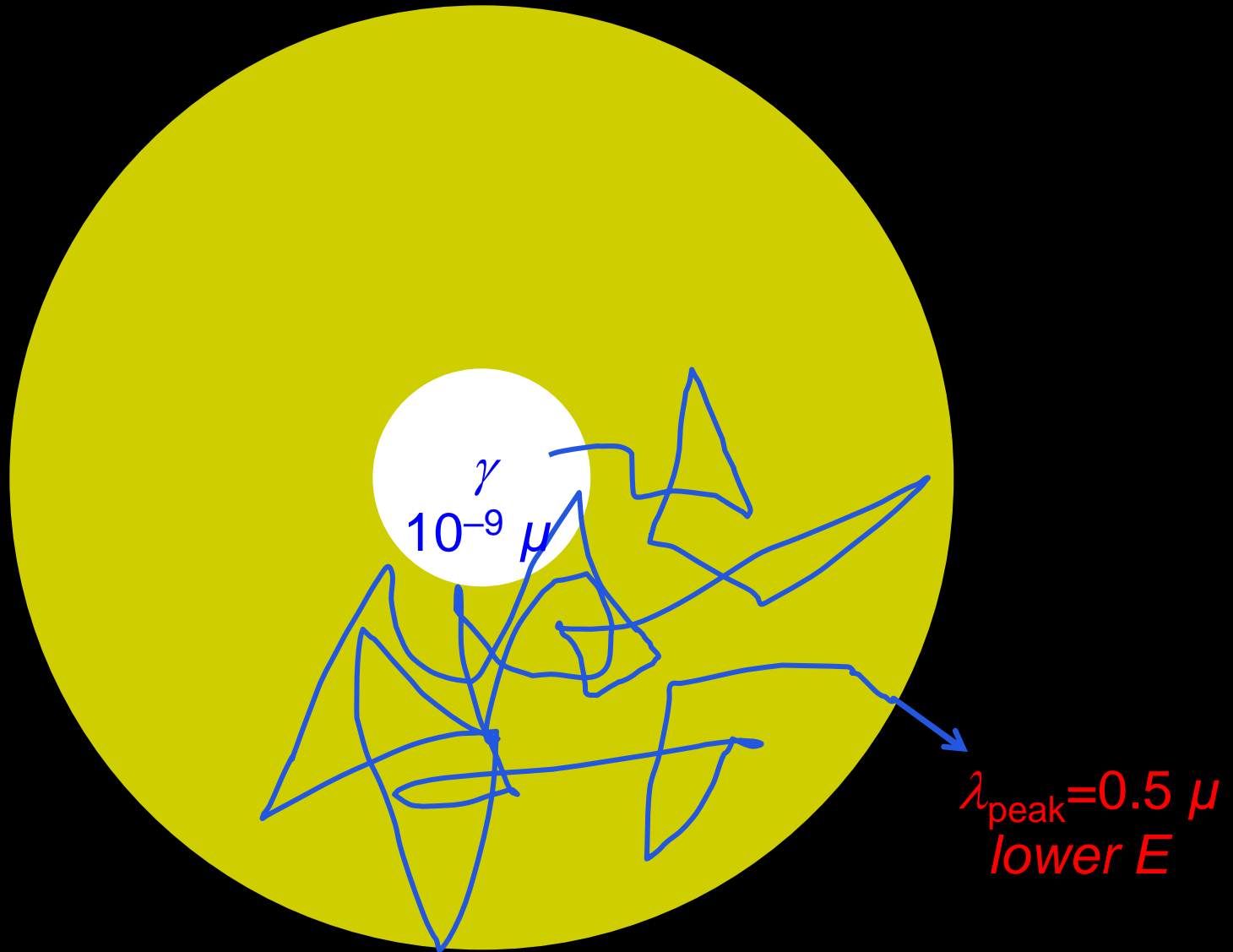
$\lambda_{\text{peak}} = 0.5 \mu$

$\gamma$   
10<sup>-9</sup>  $\mu$

The photons ( $\gamma$ -ray-energy) lose energy pushing back on matter on their journey to the surface.



Energy lost went into pushing back on GRAVITY



The photons ricochet around the interior of the sun and take at least 150,000 yrs to get out.