The dynamic nature of our Sun

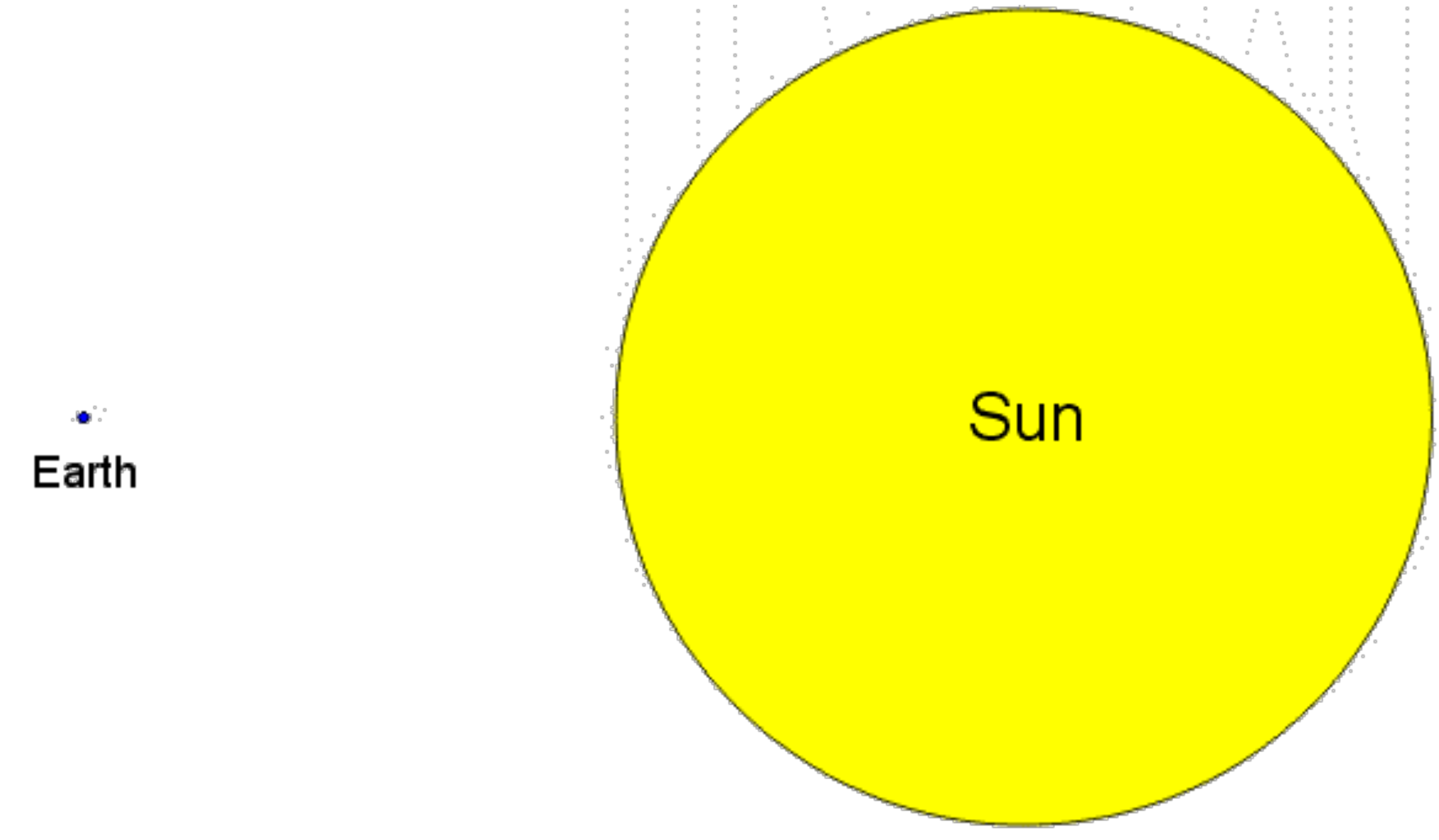
Dr. Laurel Rachmeler, NASA/MSFC
Osher Lifelong Learning Institute
Our Place in the Universe
4 February 2016

Quiz

How many Earths across is the Sun?

✊	✋	👍
10	100	1000

Answer: 100



Quiz

How long does it take the Sun's light to reach the earth?

✊	✋	👍
0.008 sec	8 sec	8 min

Answer: 8 minutes

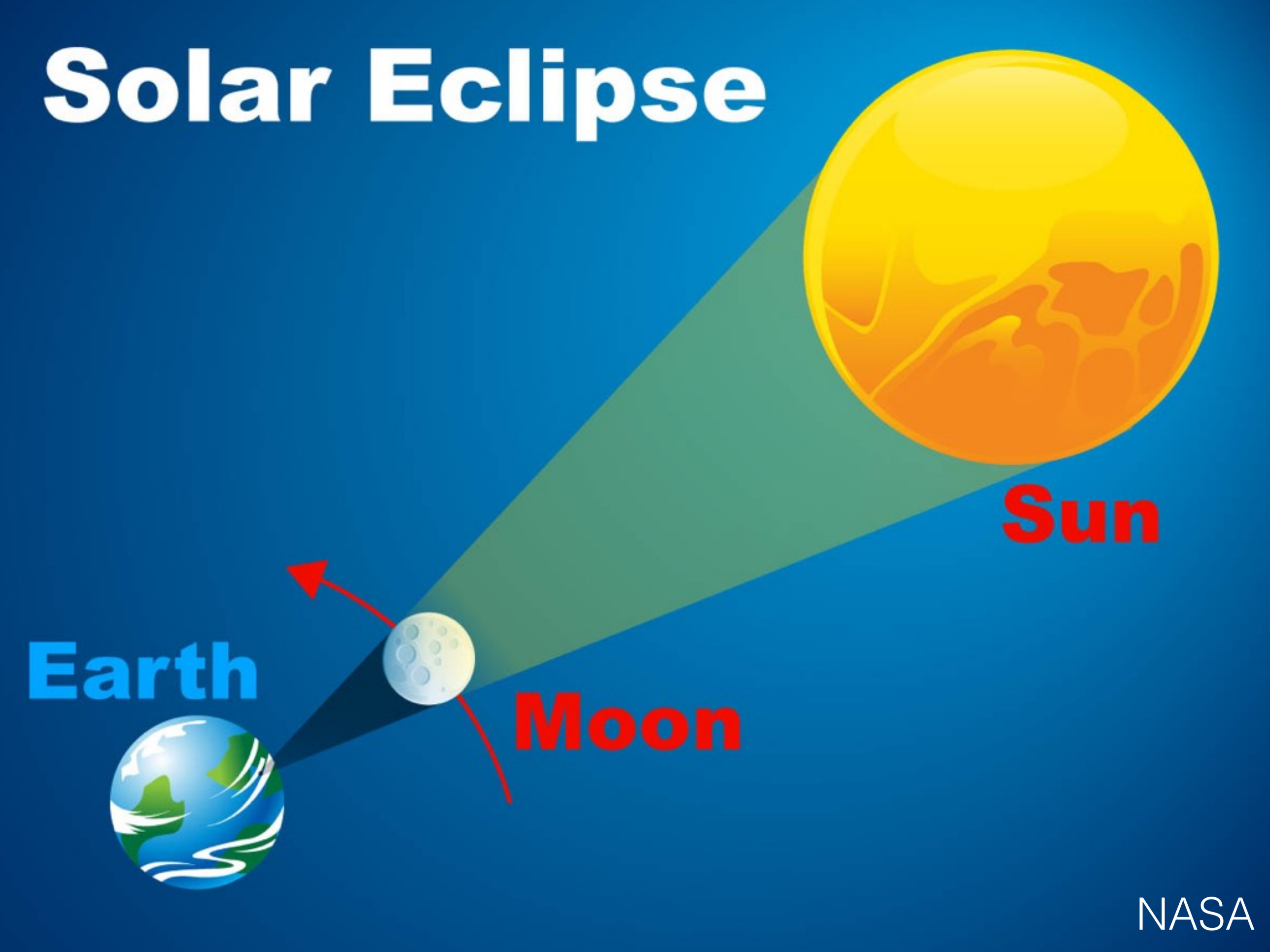
distance to the Sun = 1 astronomical unit
= 93 million miles
= 150 million km

Light travels 300,000 km/s

Our Sun

source: Daisuke Tomiyasu 2014 @ Higashinada-ku, Kobe, Japan

Solar Eclipse



NASA

Petroglyph ~1000 AD (source HAO)

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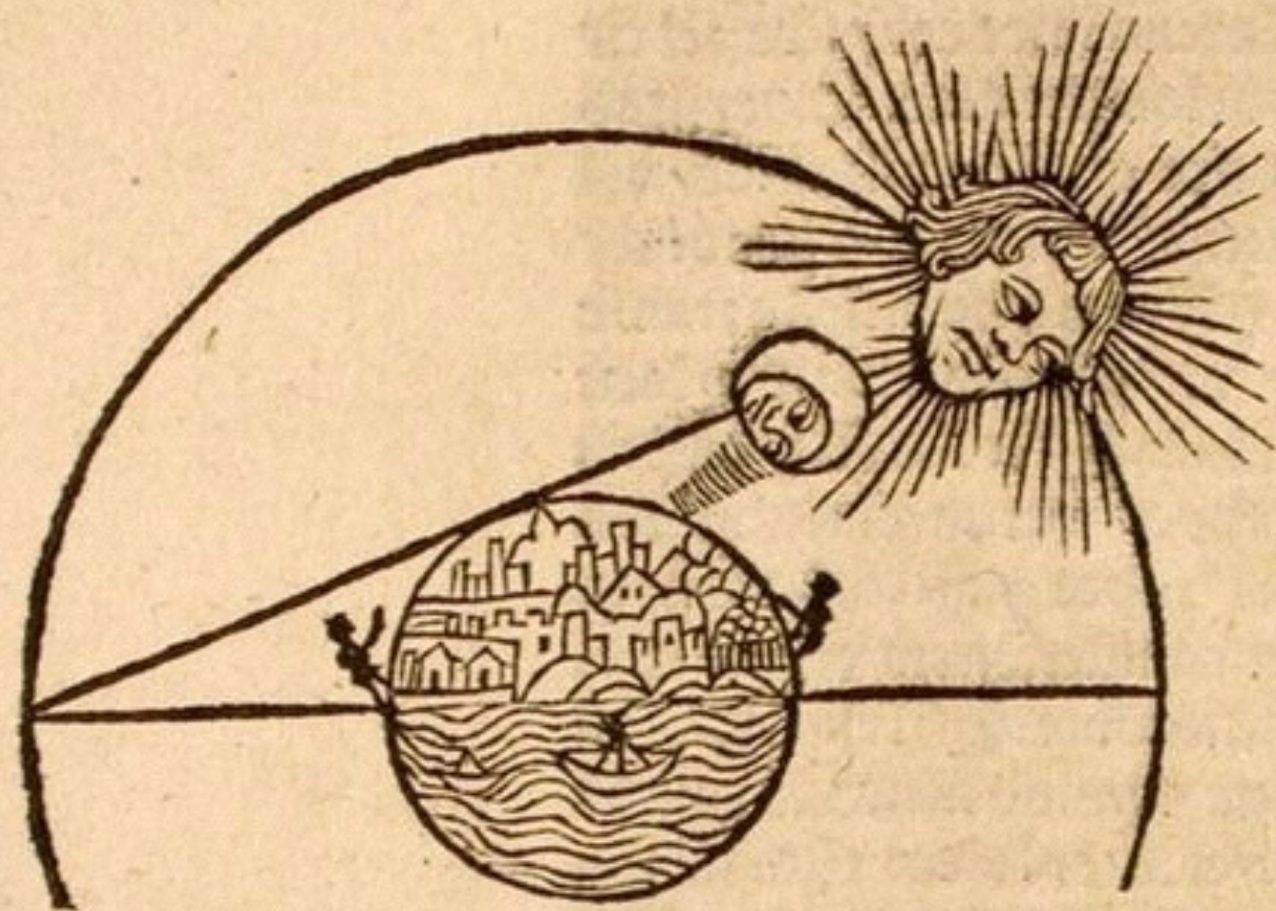

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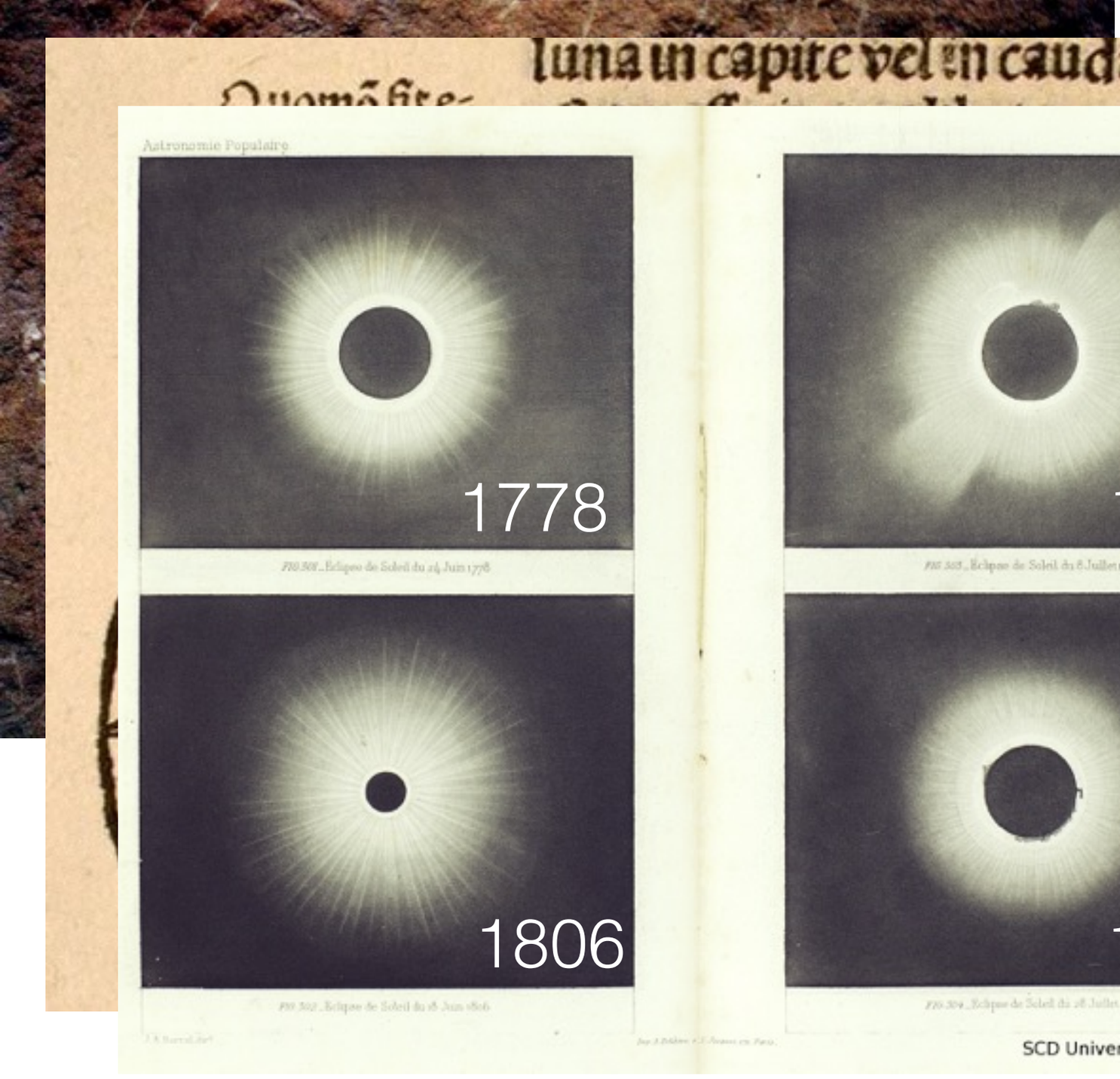
1499, Sacro Busto

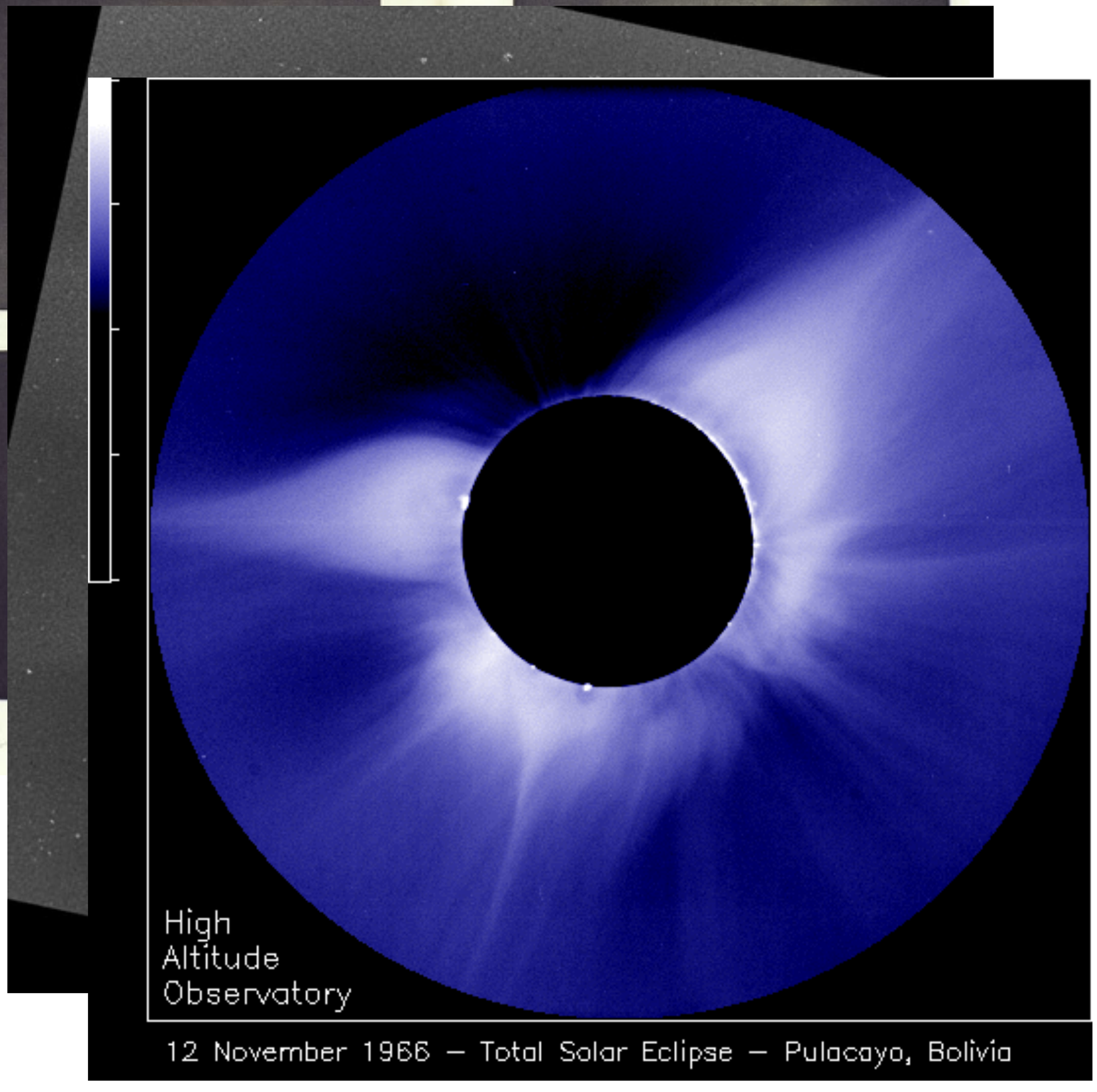


Popular Astronomy

1889 source: HAO eclipse archive

luna in capite vel in cauda

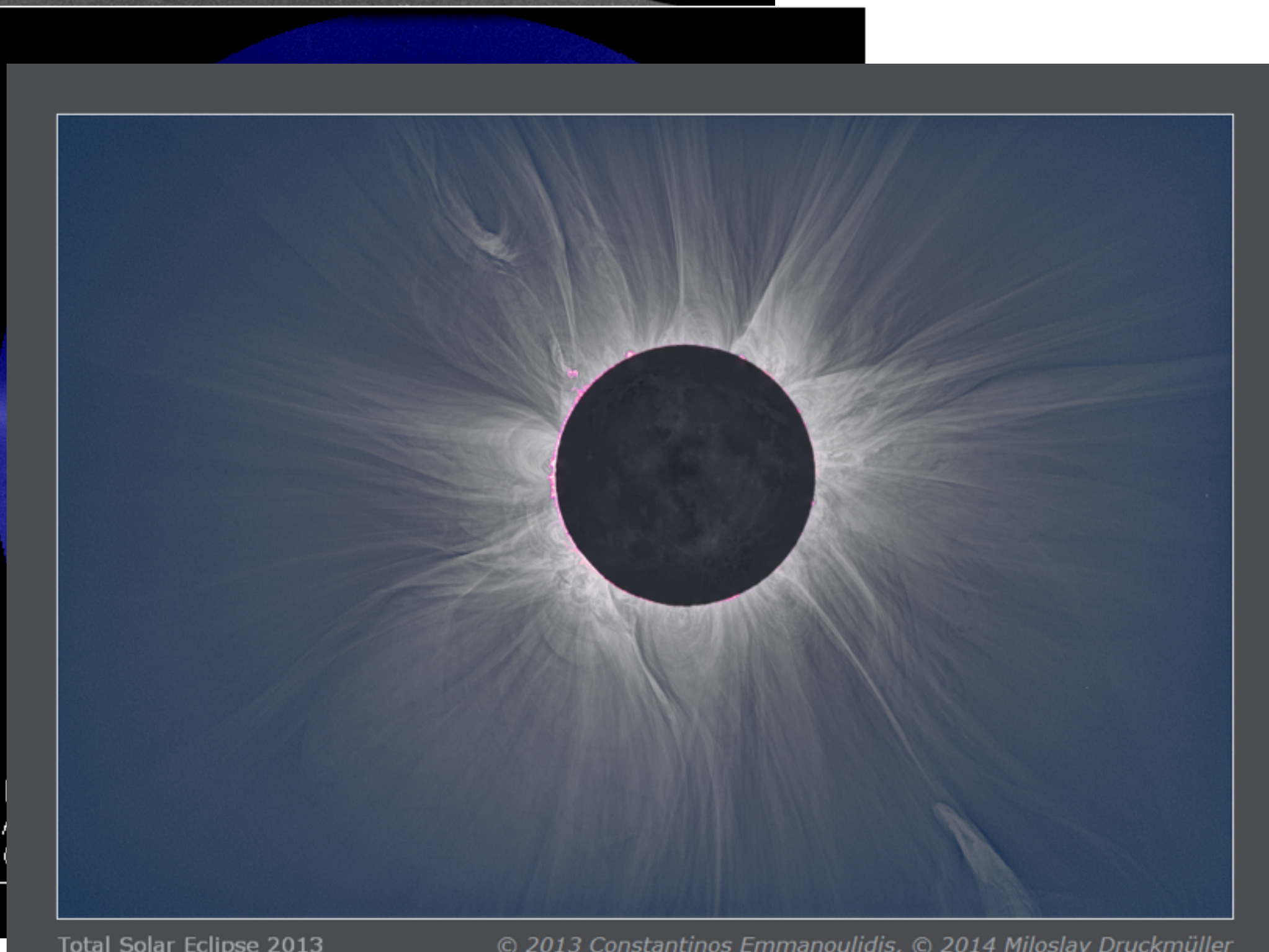
Astronomie Populaire T. II. P. 668



luna in capite vel in cauda

Astronomie Populaire

T. II. P. 668



Total Solar Eclipse 2013

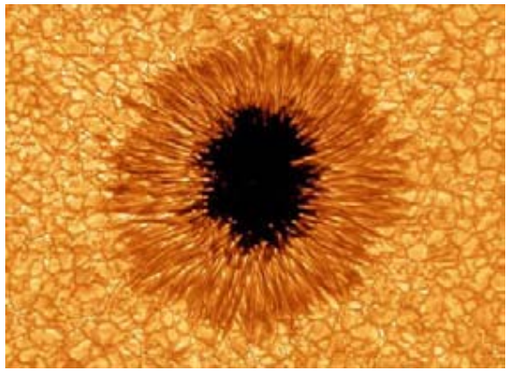
Activity

Get into groups of 4 or 5.

Record your answers.

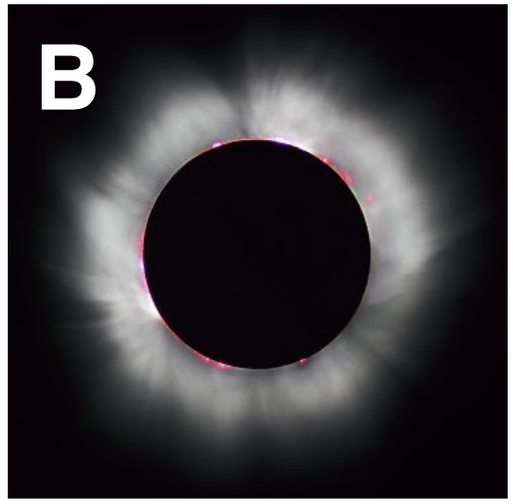
Order from coolest to hottest

A



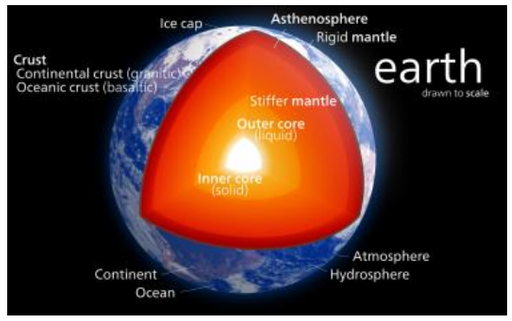
Sunspot

B



The Sun's Corona
("atmosphere")

C

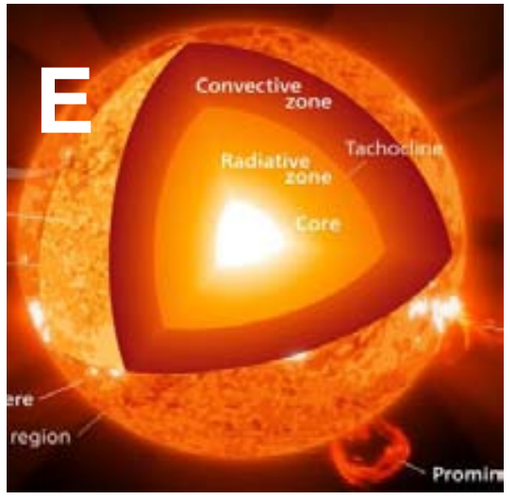


Earth's Core

D

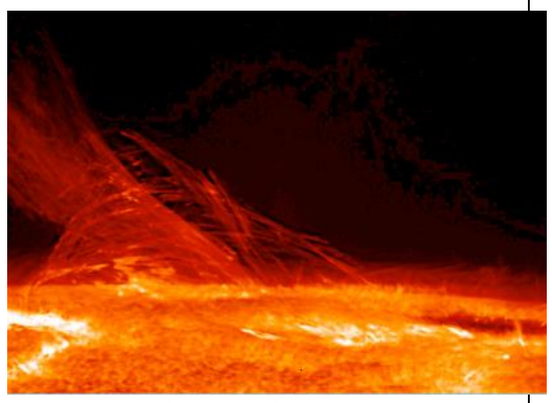
Meteor

E



The Sun's Core

F



Surface of the Sun

G

Volcanic lava

H

Comet

I

Lightning

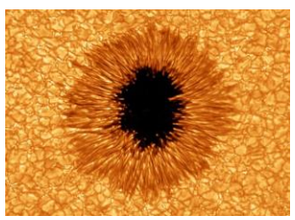
Answer

H 

Comet
-450°F to 200°F

G 

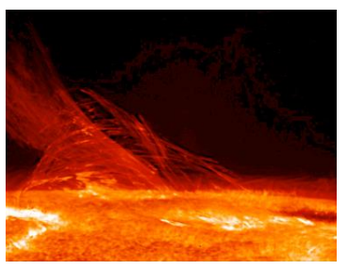
Lava
1450°F to 2000°F

A 

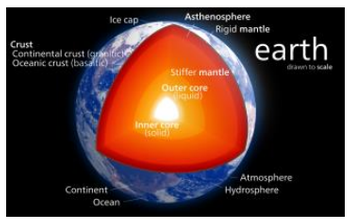
Sunspot
6300°F

D 

Meteor
10,000°F or 5800°K

F 

Sun's surface
6000°K

C 

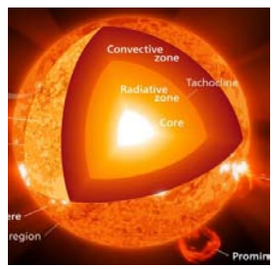
Earth's core
6200°K

I 

Lightning
30,000°K

B 

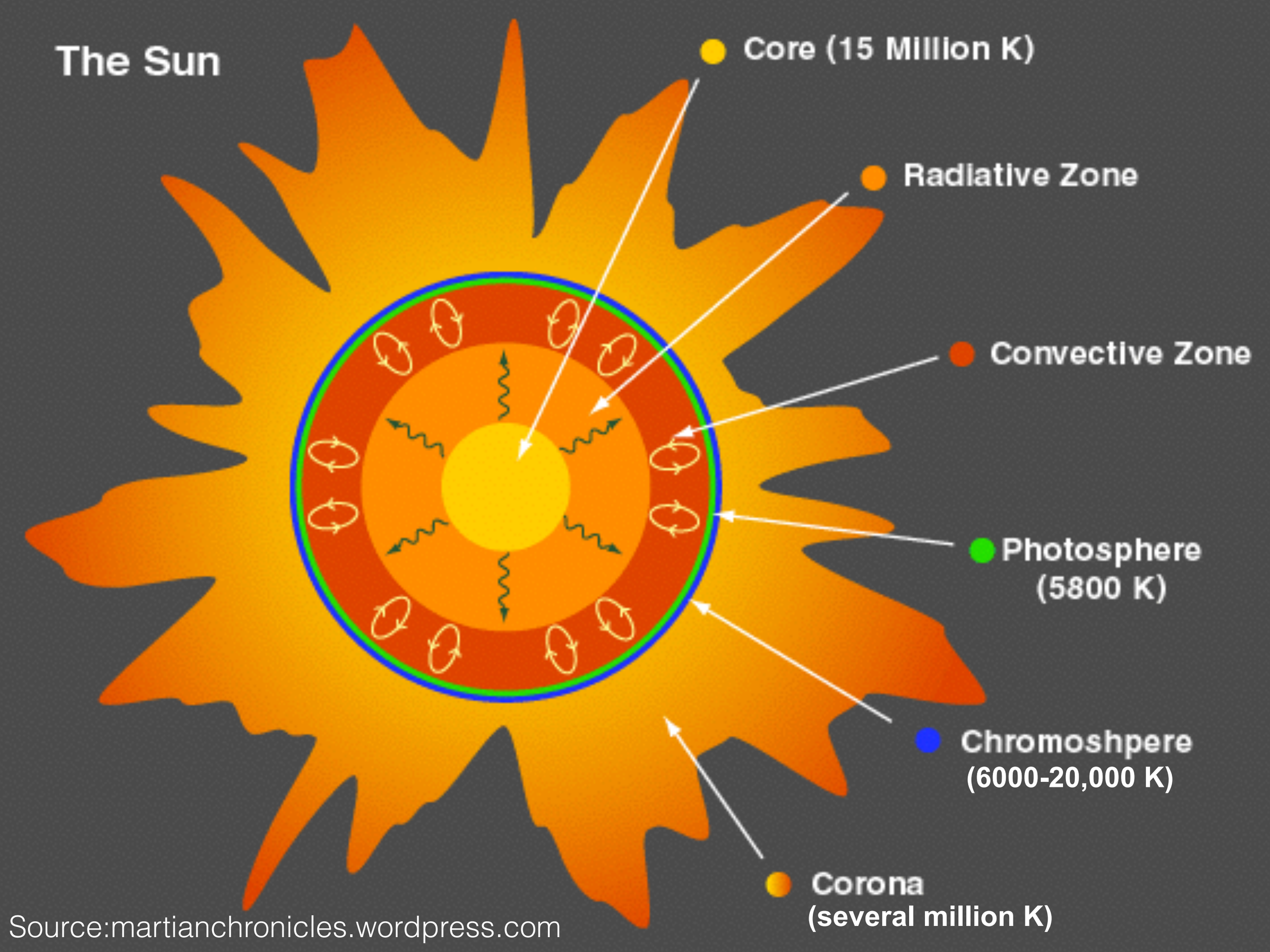
Sun's corona
5 million °K

E 

Sun's core
15 million °K

Source: http://solar-center.stanford.edu/activities/HowBig/How-Big-Far-Hot-Old.pdf

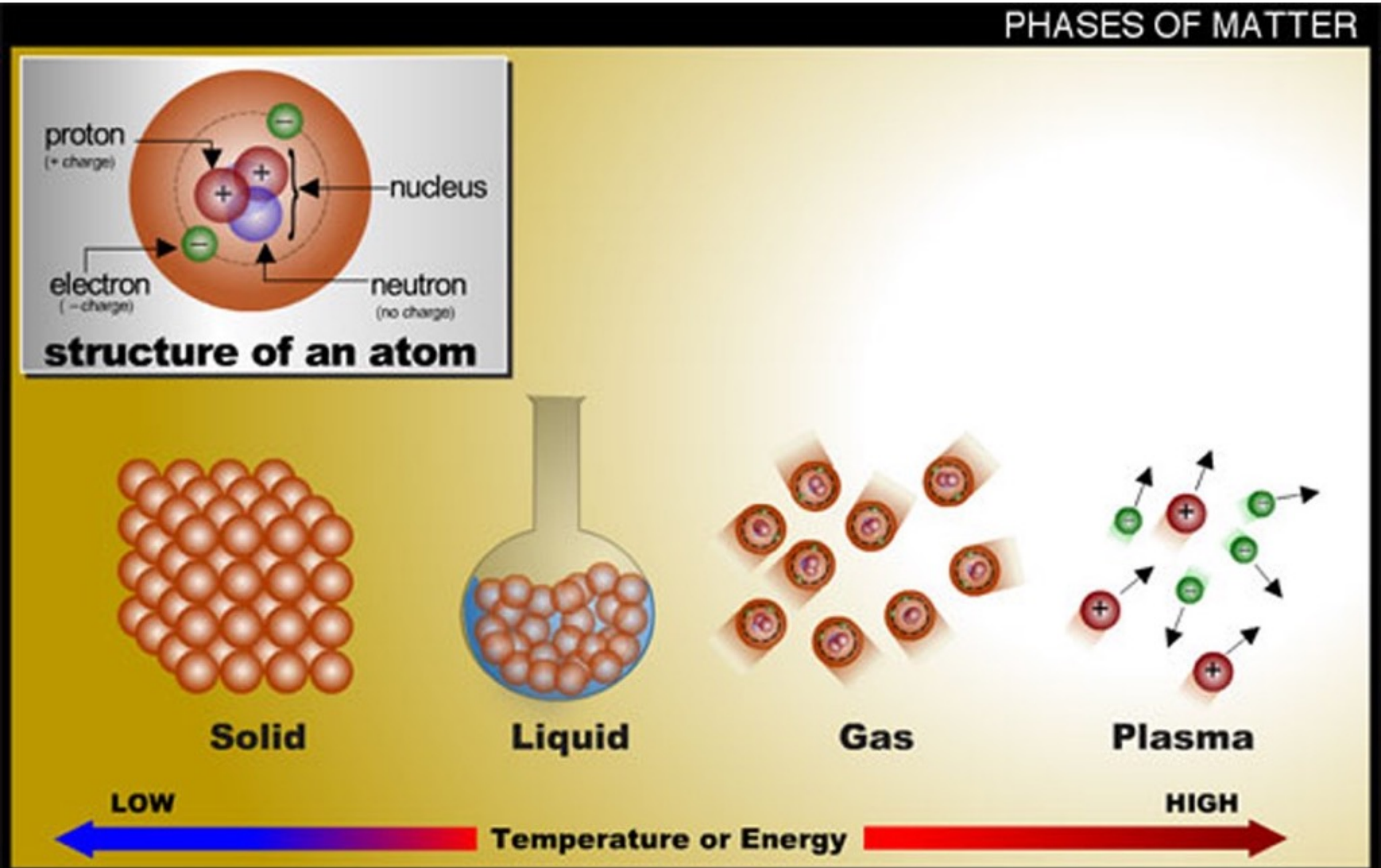
The Sun



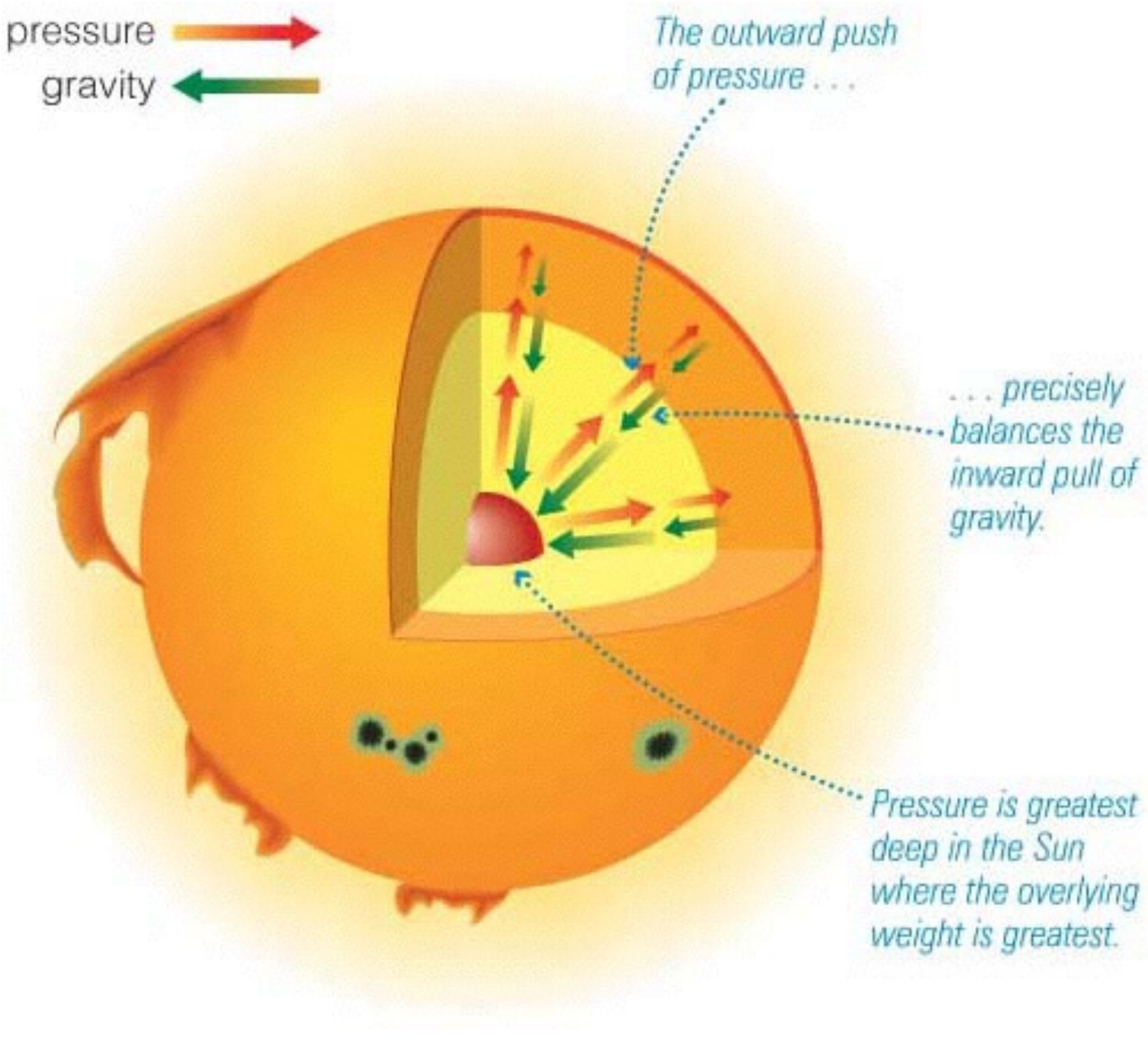
Source:martianchronicles.wordpress.com

Plasma

source: UC Regents



The Core

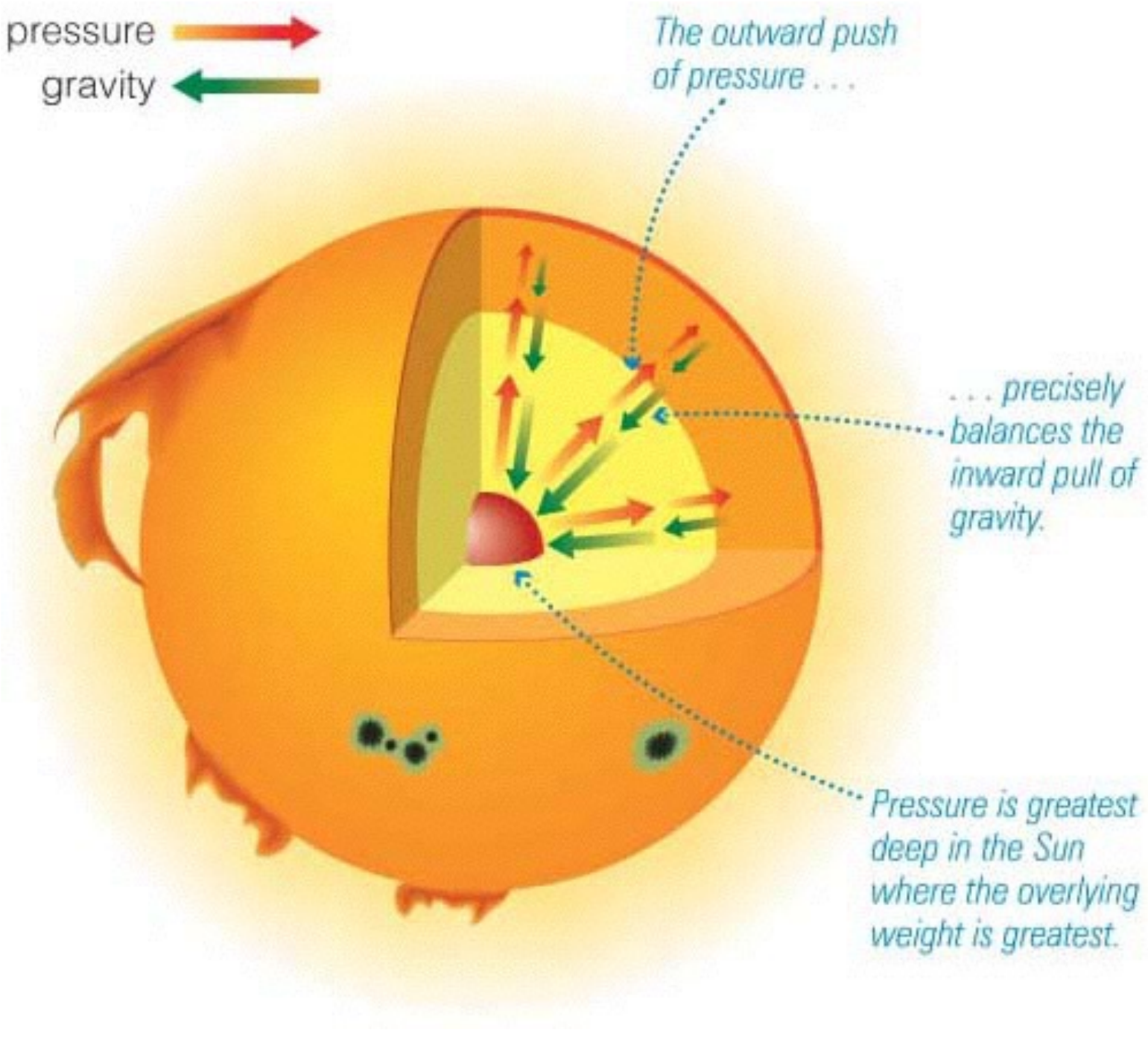


Thermal pressure balances gravity.

Pressure, and density, are greatest at the core.

source: http://lasp.colorado.edu

The Core

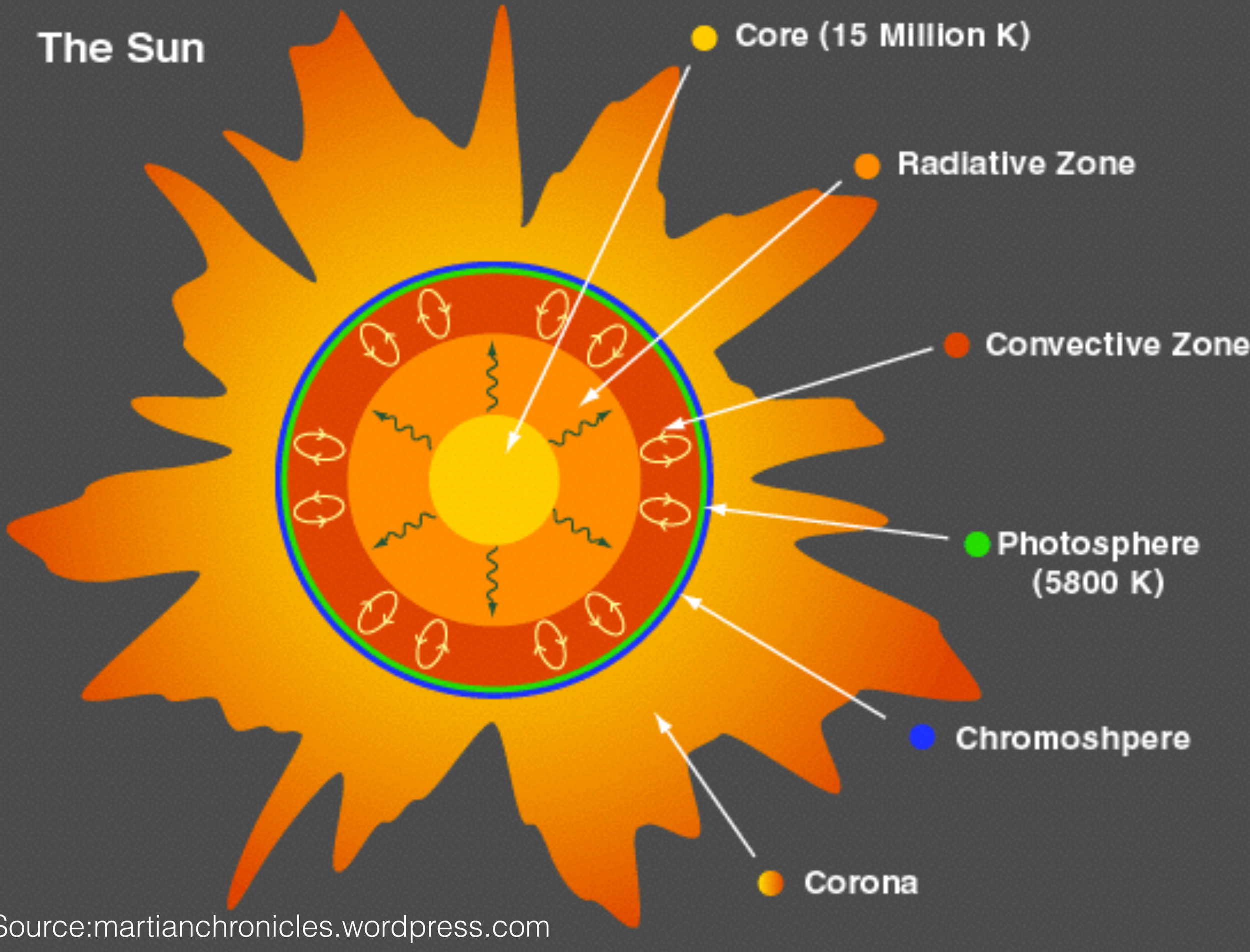


High densities at the core enable nuclear ***fusion***.

Hydrogen is combined into Helium, releasing energy ($E=mc^2$) as light and heat.

source: http://lasp.colorado.edu

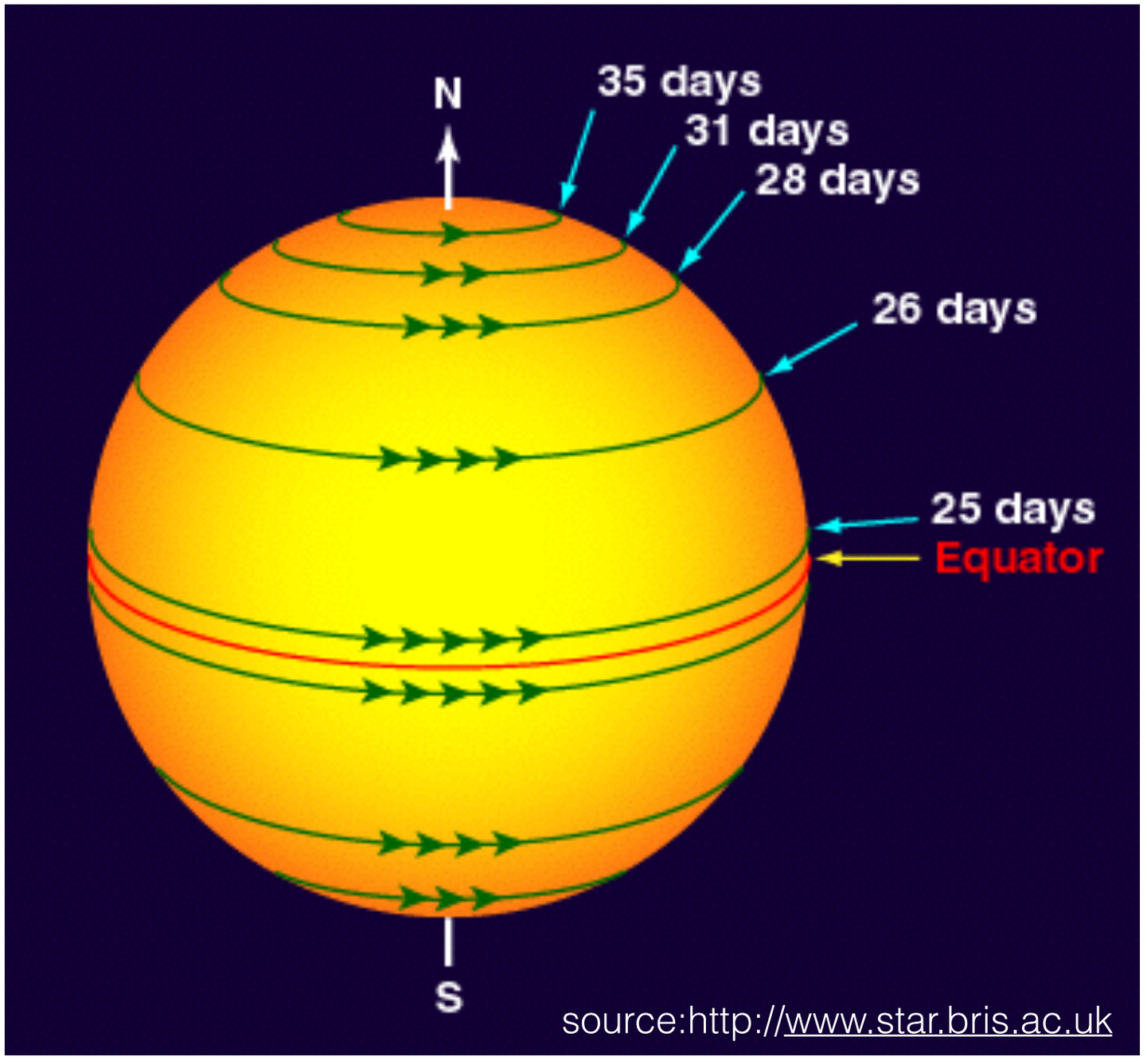
The Sun



Source:martianchronicles.wordpress.com

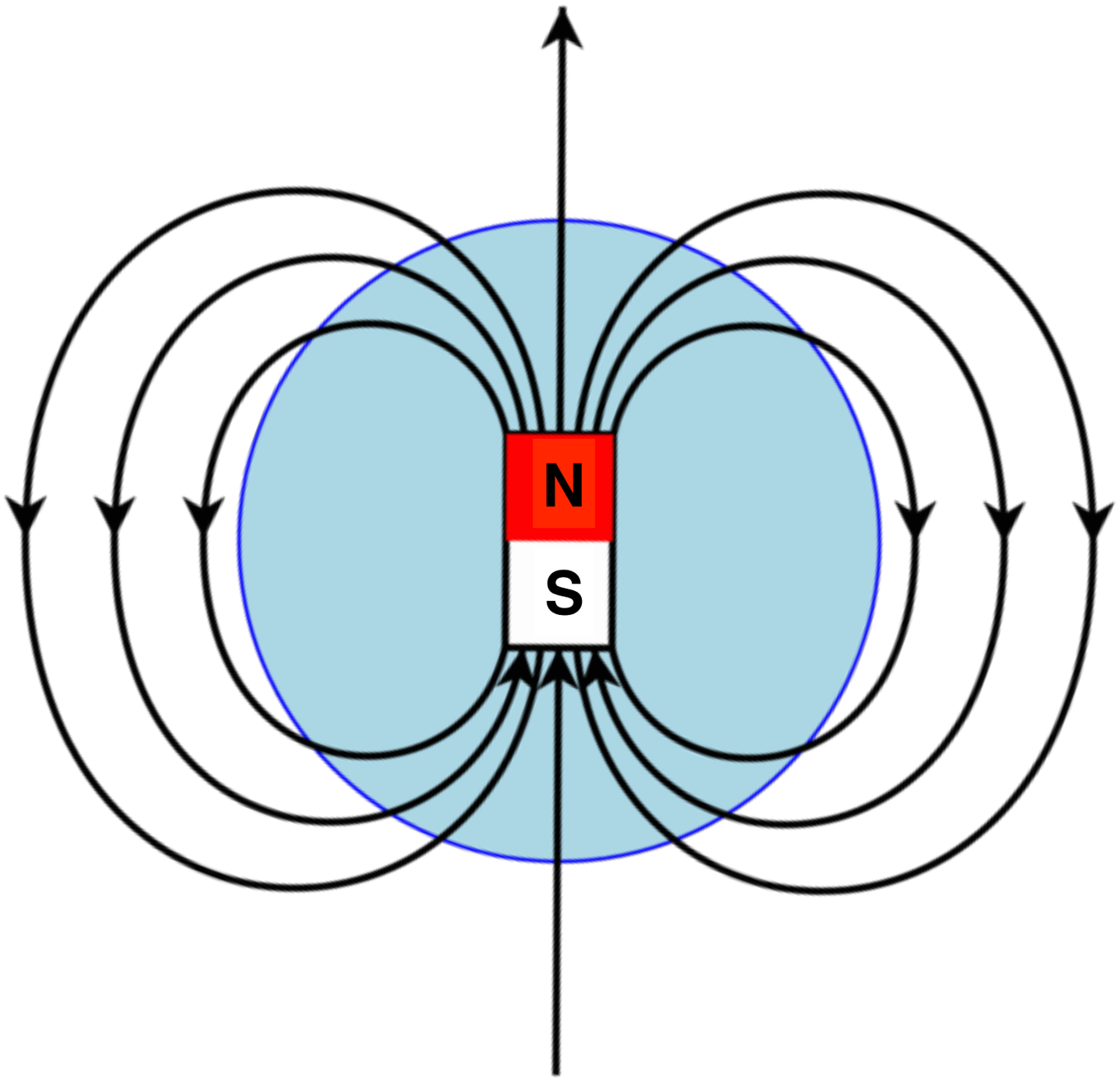
Solar Rotation

The equator spins faster than the poles: ***differential rotation***.



Magnetic field

The Sun, like the Earth, has a global magnetic field.



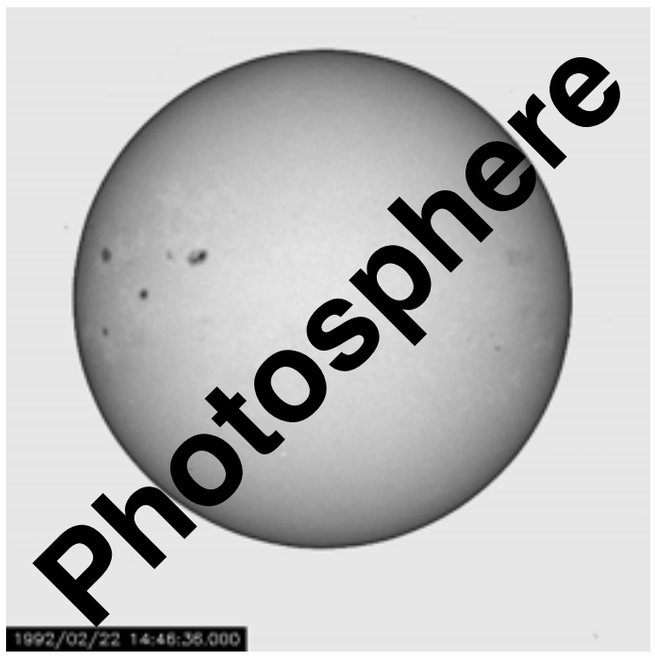
Solar Dynamo

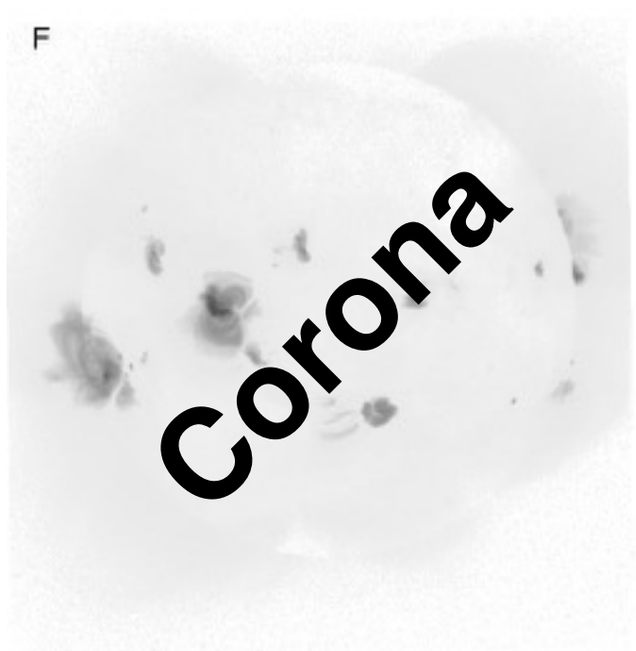
Spinning plasma drags the magnetic field.

Activity

Get into groups of 4 or 5.

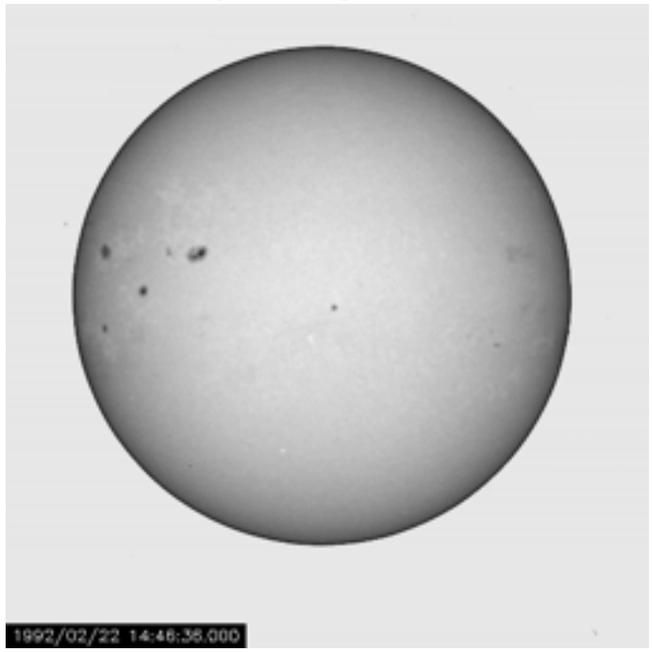
Match each photosphere picture to the corresponding corona picture.



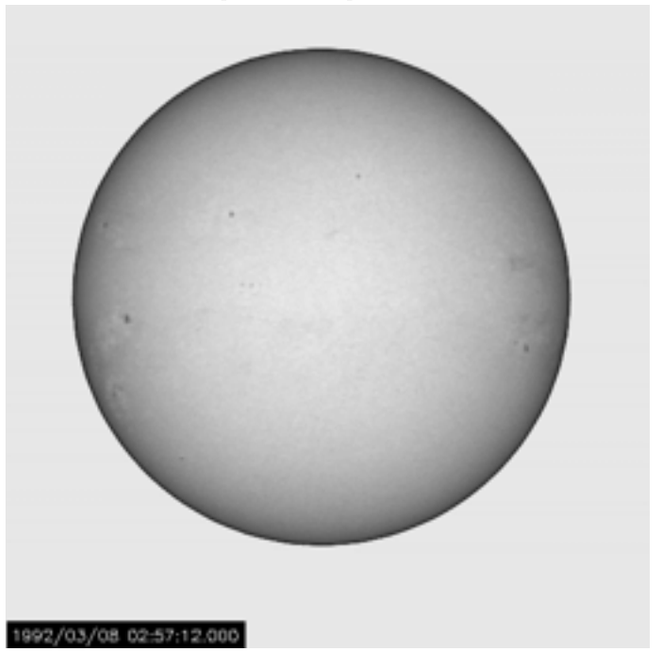


Answer

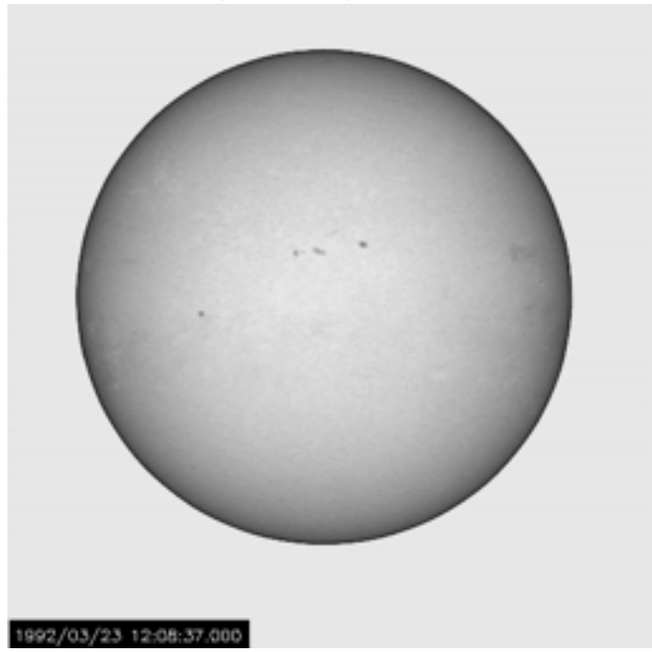
1992/02/22



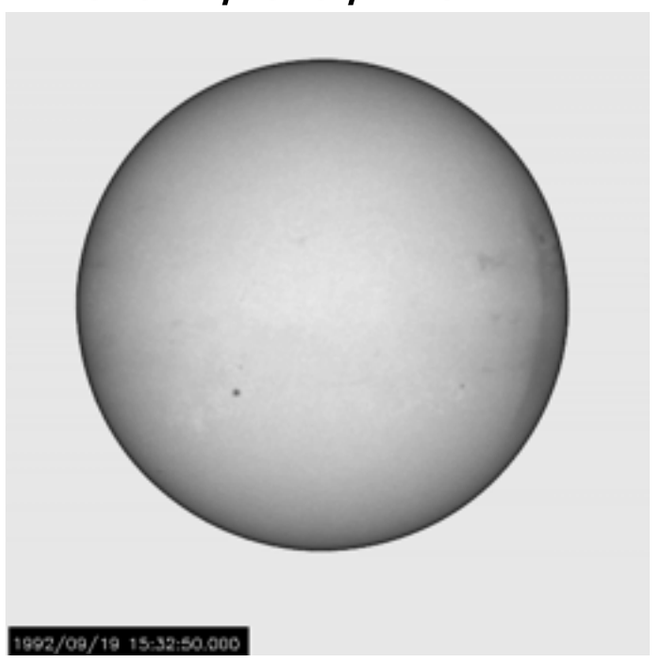
1992/03/08



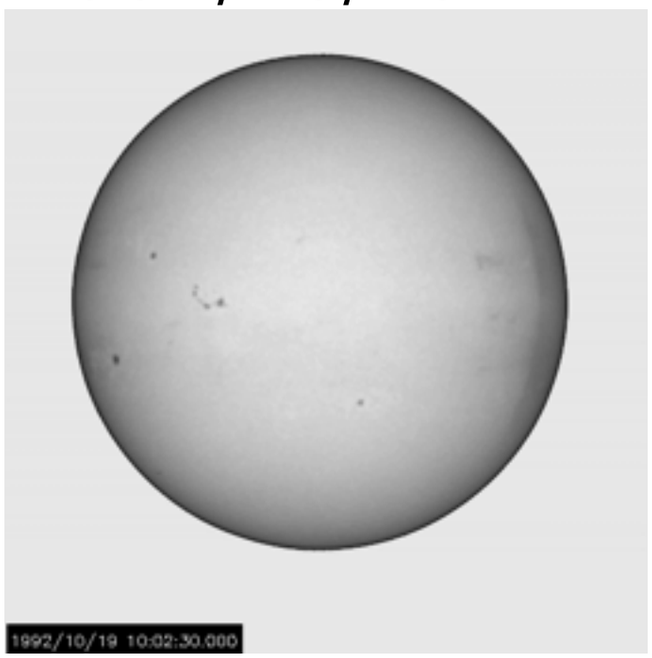
1992/03/23



1992/09/19

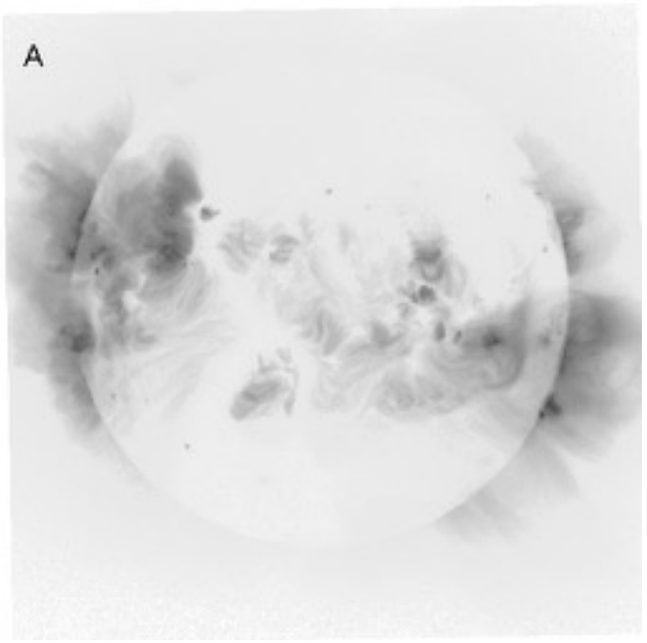


1992/10/19

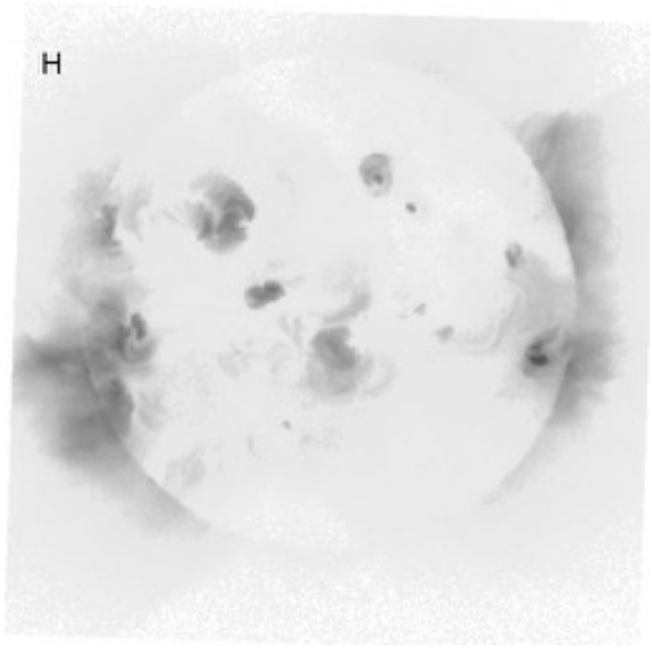


Answer

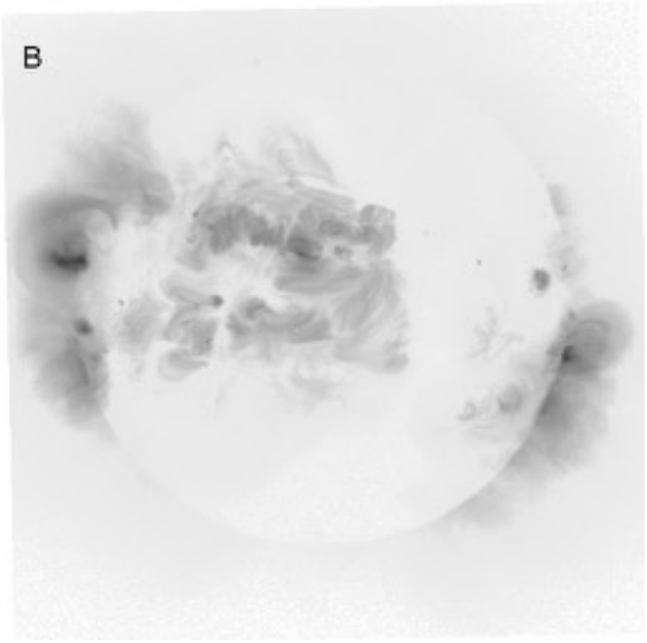
1992/02/22 **A**



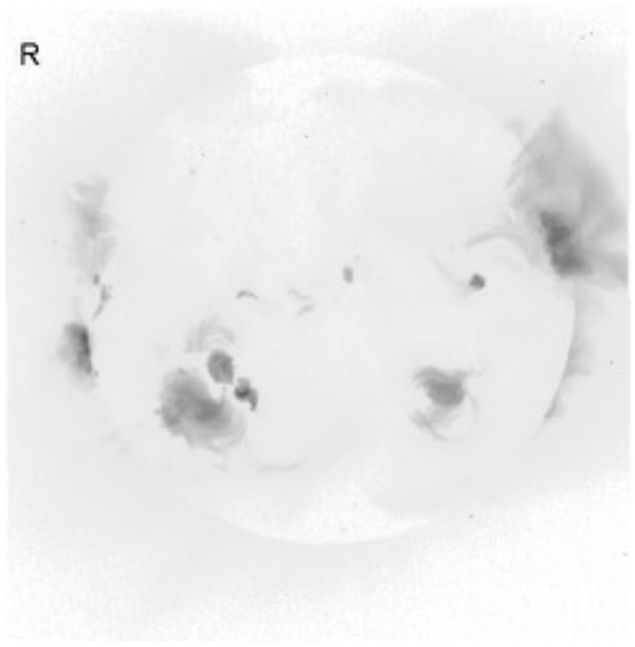
1992/03/08 **H**



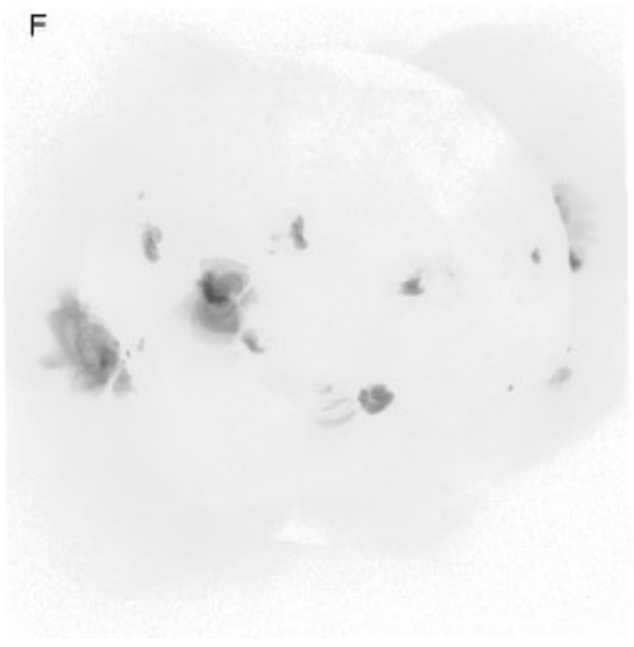
1992/03/23 **B**



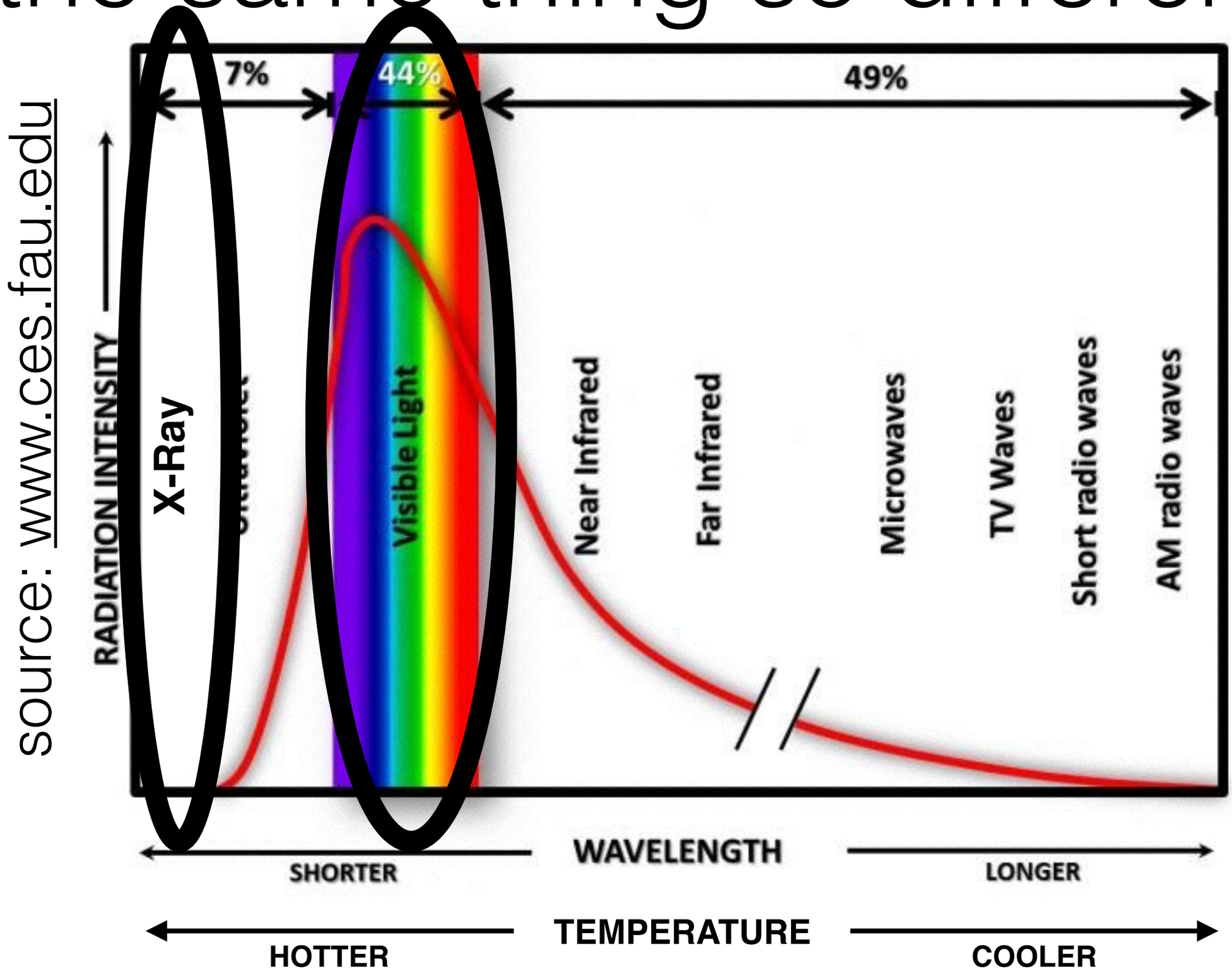
1992/09/19 **R**



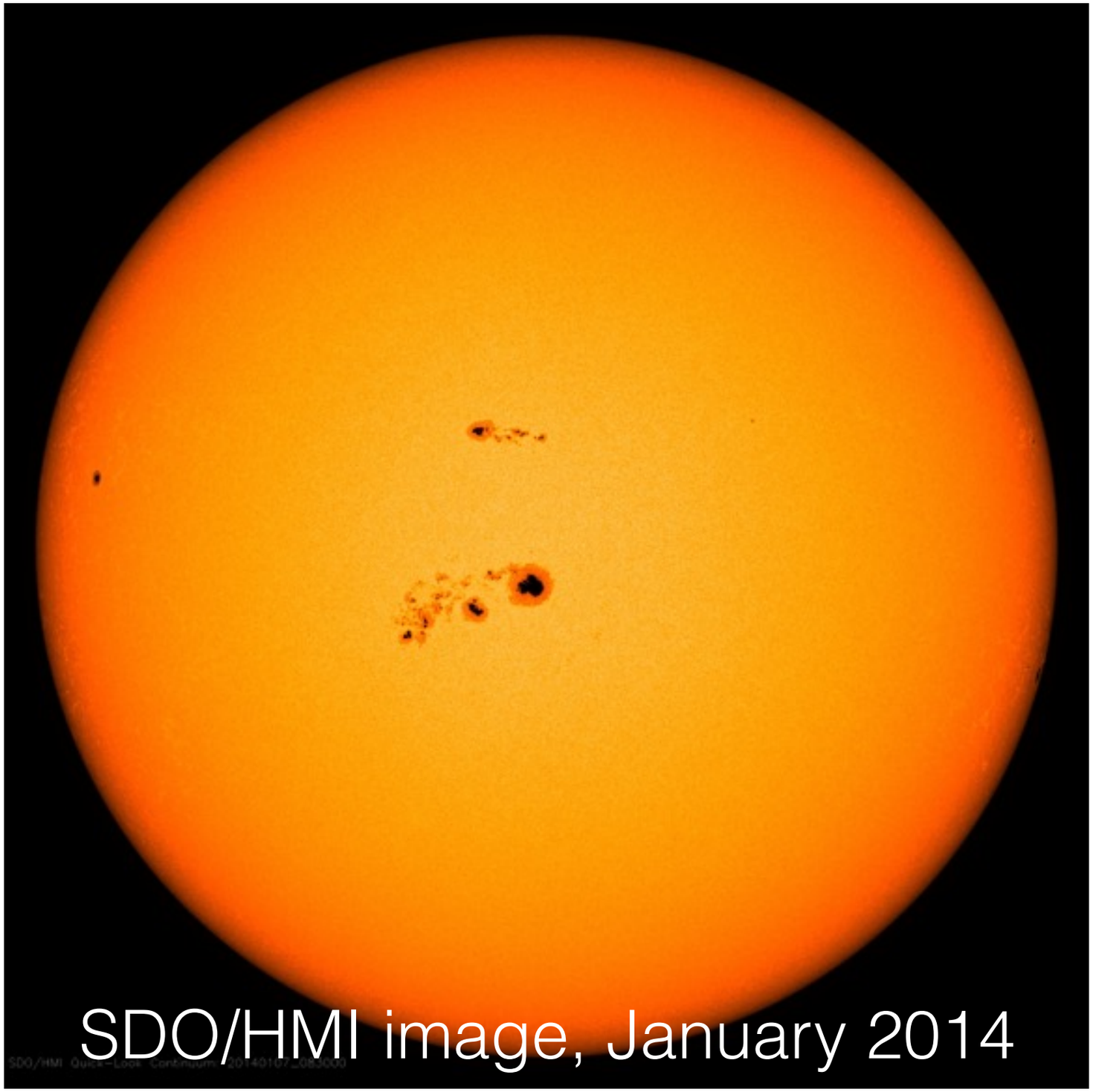
1992/10/19 **F**



Why are those pictures of the same thing so different?



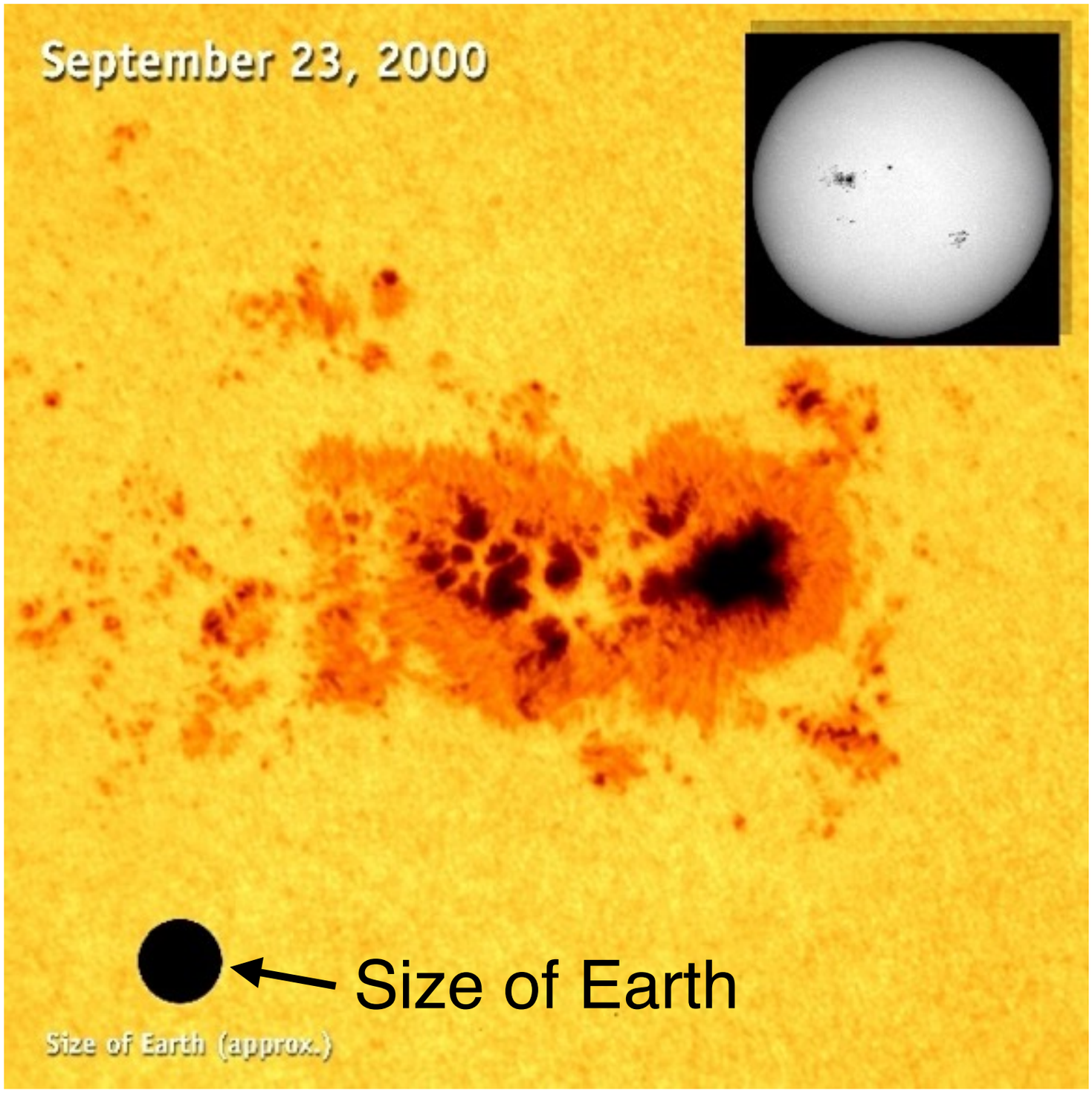
source: www.ces.fau.edu



Sunspots

Sunspots form where concentrated magnetic field emerges through the photosphere.

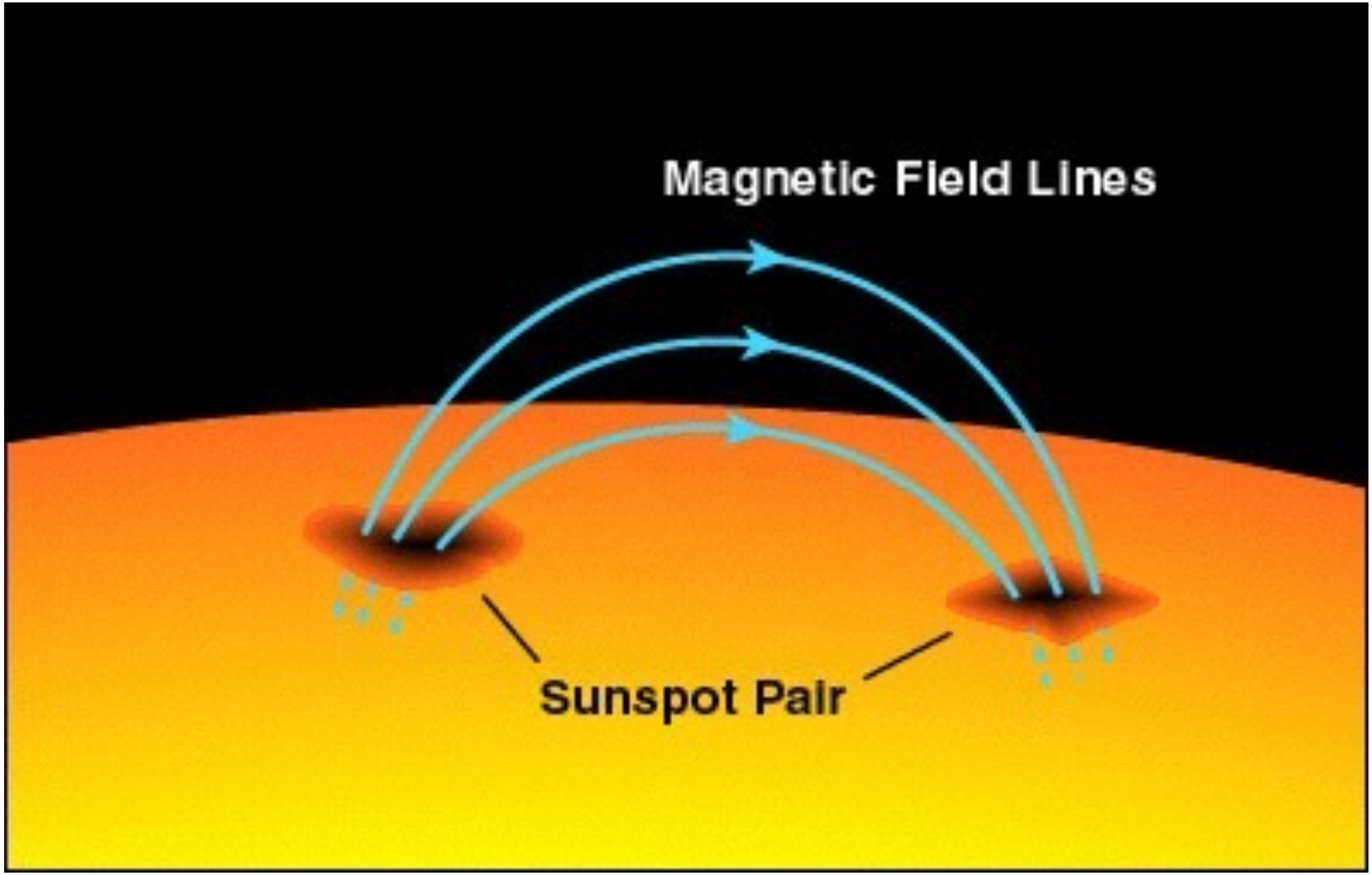
source: http://www.thesuntoday.org



Sunspots

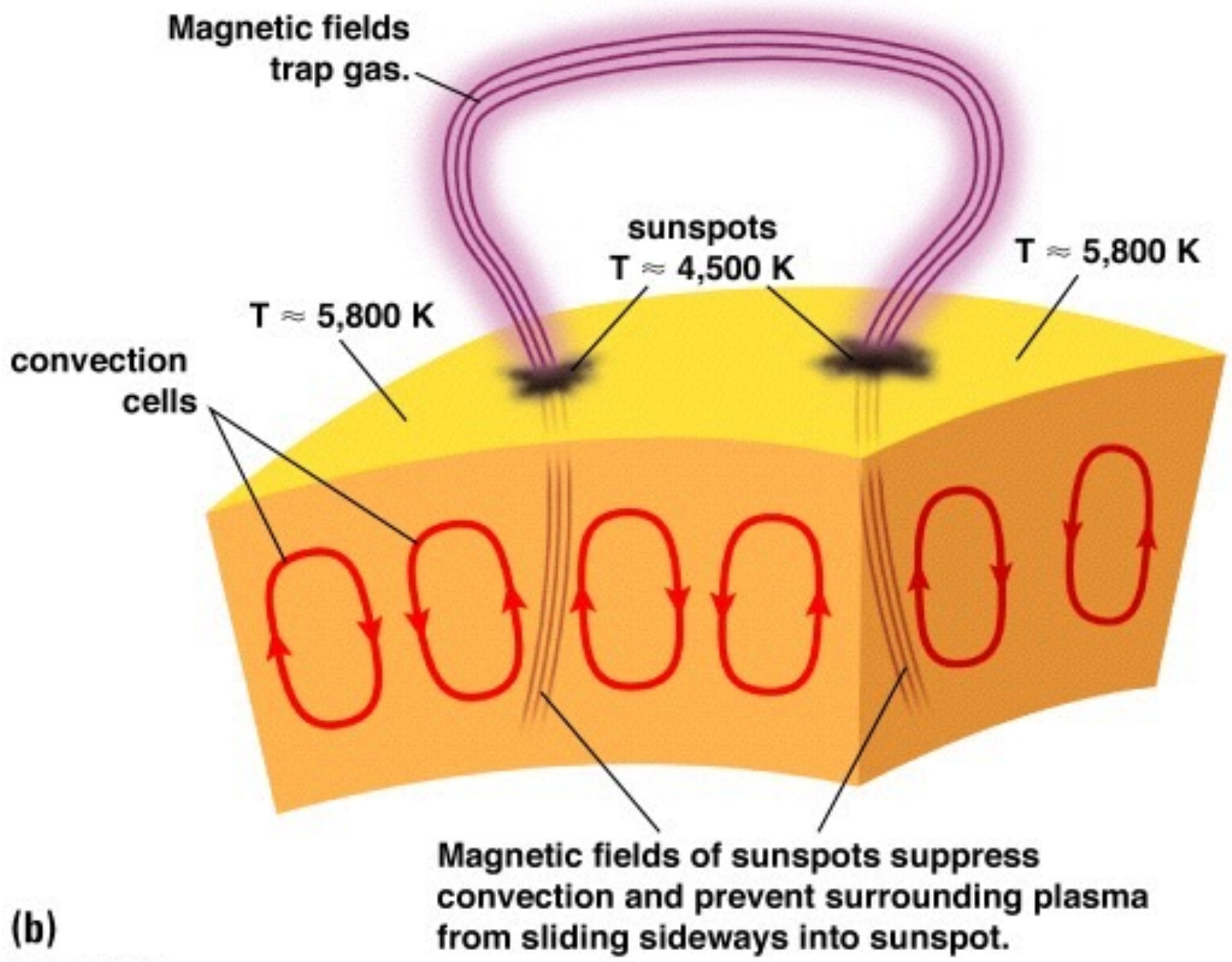
Smaller sunspots are about the size of the Earth.

source: http://lifeng.lamost.org



Sunspots

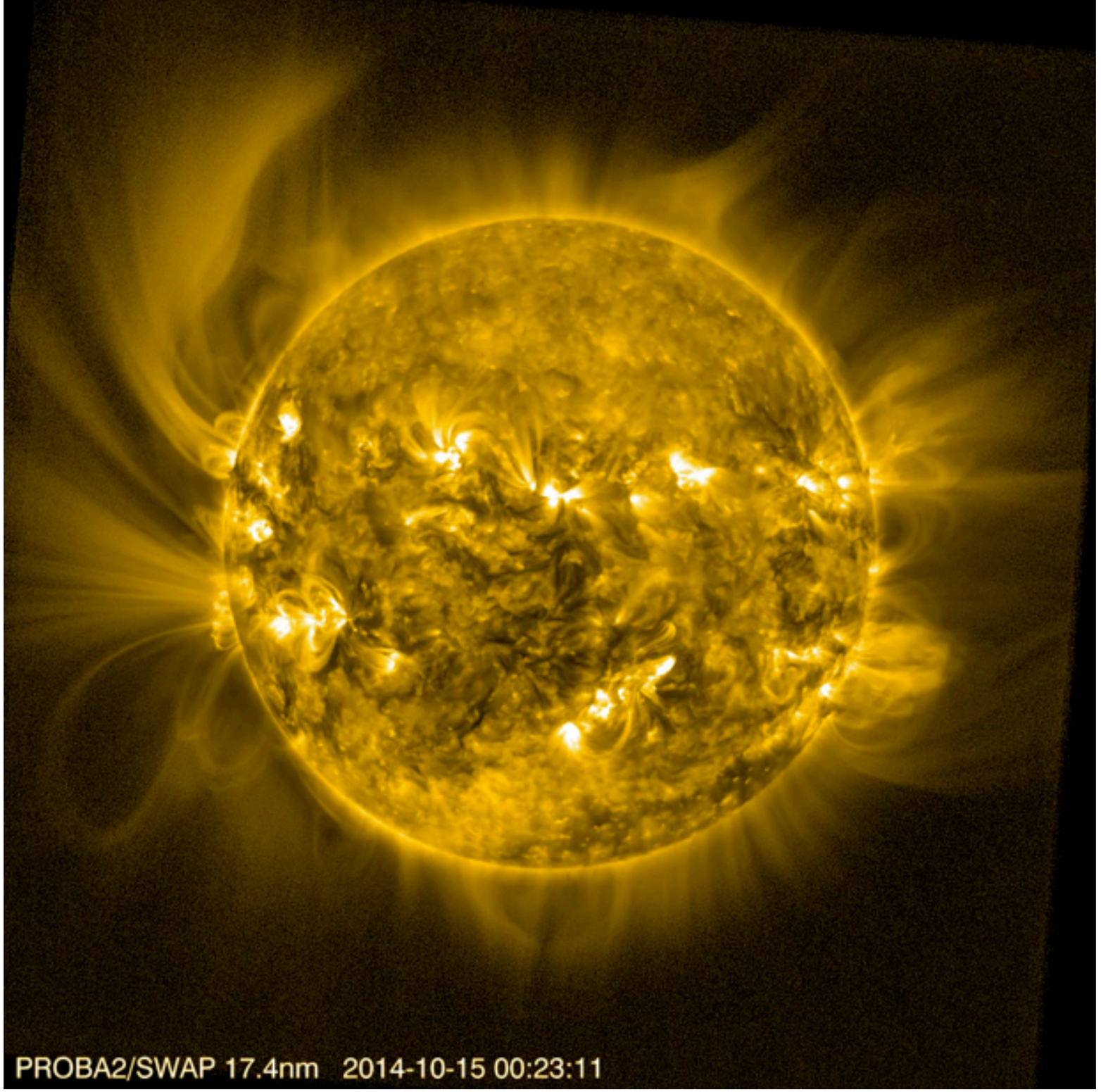
Strong magnetic field threads through sunspots.



Sunspots

Strong vertical field inhibits convection, making sunspots cooler than the surrounding photosphere.

Above Sunspots: Active Regions

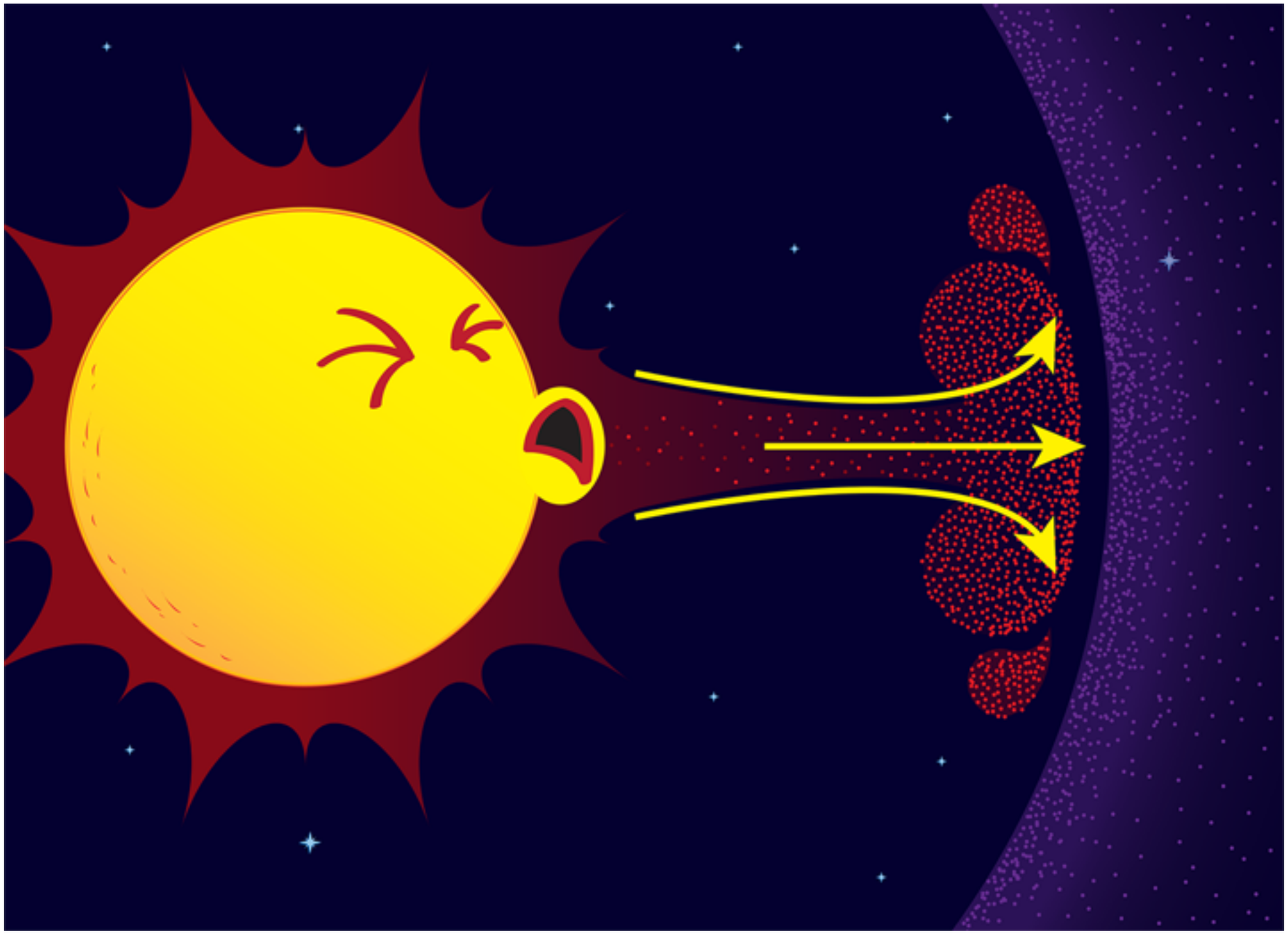


The dynamic corona

PROBA2/SWAP movie of 3 solar rotations

Heliosphere

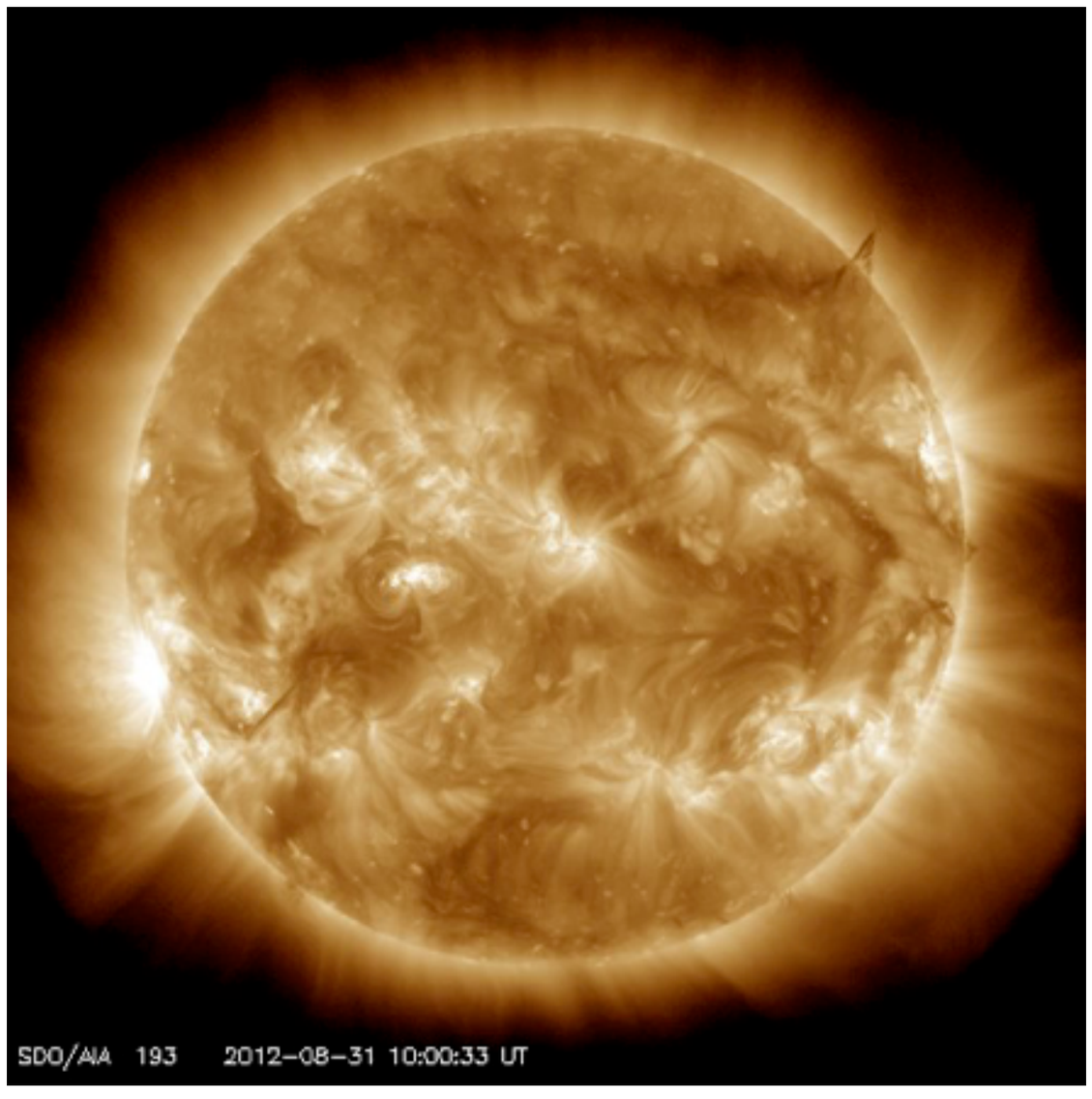
The bubble-like volume surrounding solar system caused by the *solar wind*. Outside the heliosphere is *interstellar space*.



source: http://spaceplace.nasa.gov

Eruptions

Major disturbances in the heliosphere are caused by massive explosions in the Sun's atmosphere: ***coronal mass ejections***.



NASA SDO/AIA movie

Eruptions

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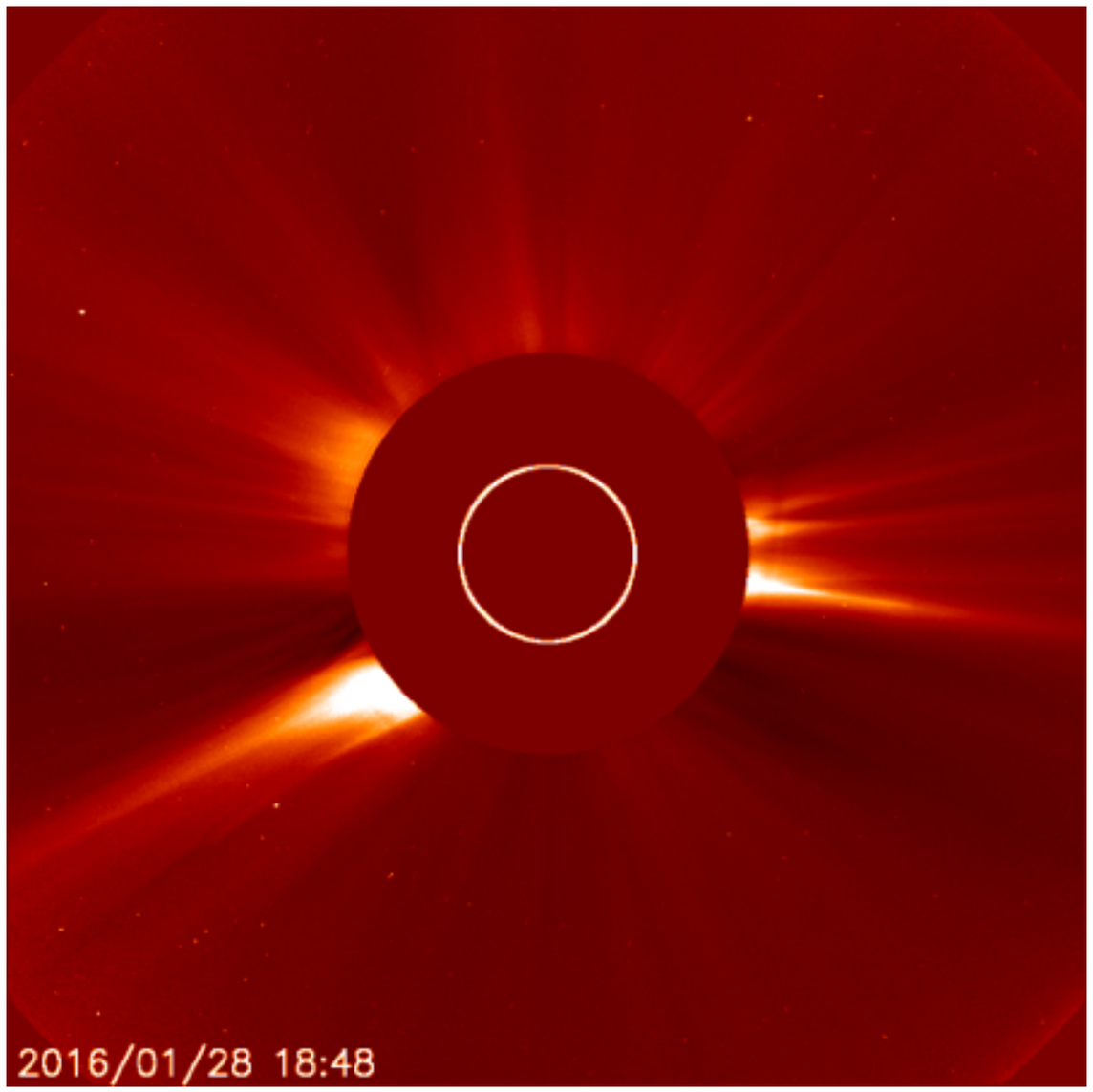


NASA LASCO C2 movie

Eruption statistics

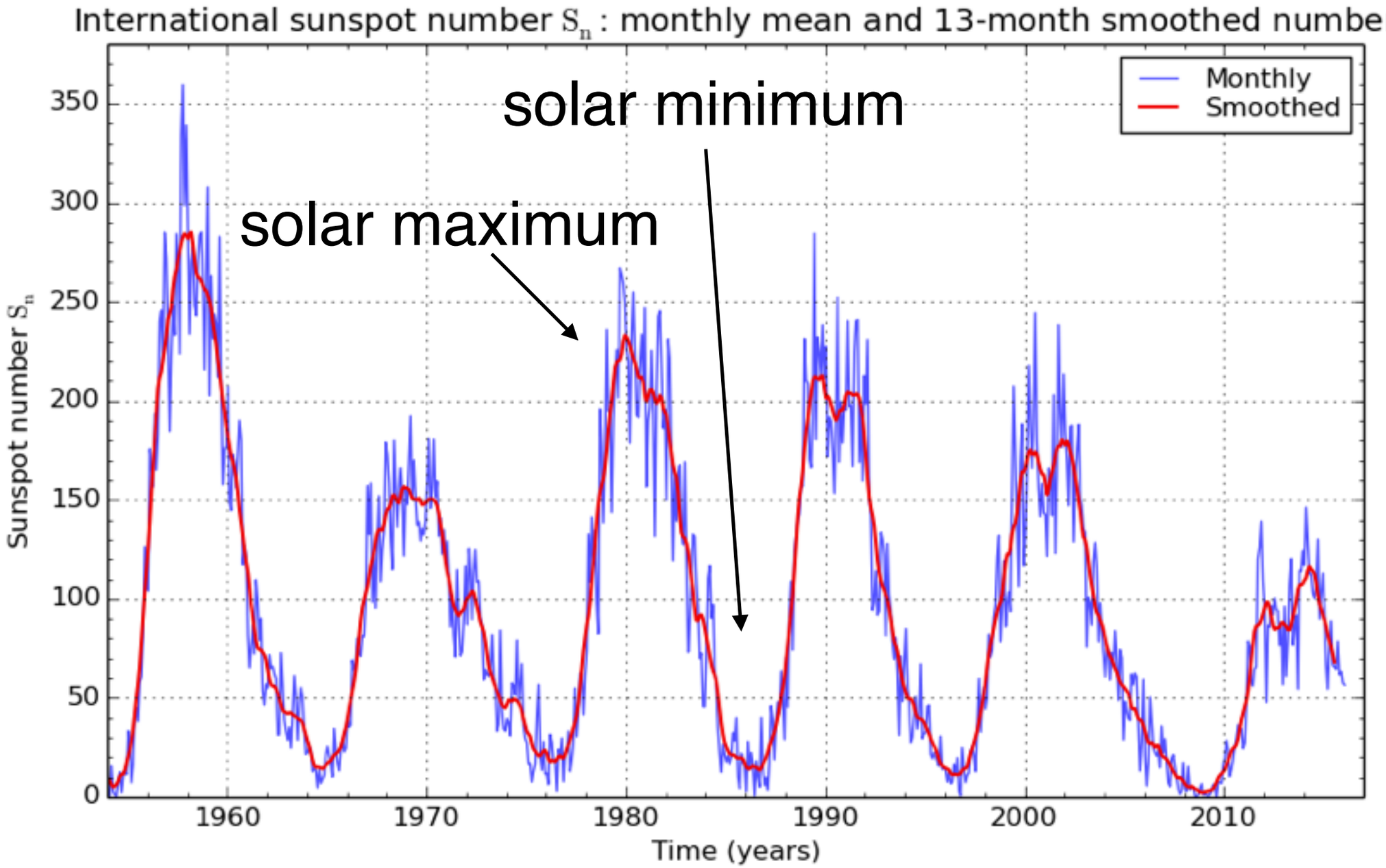
- How big? About as 1 cubic km^3 of water
- How fast? About 500 km/s (1100 mph)
- How much energy? About 20x the last year's global energy consumption

Eruptions in the heliosphere

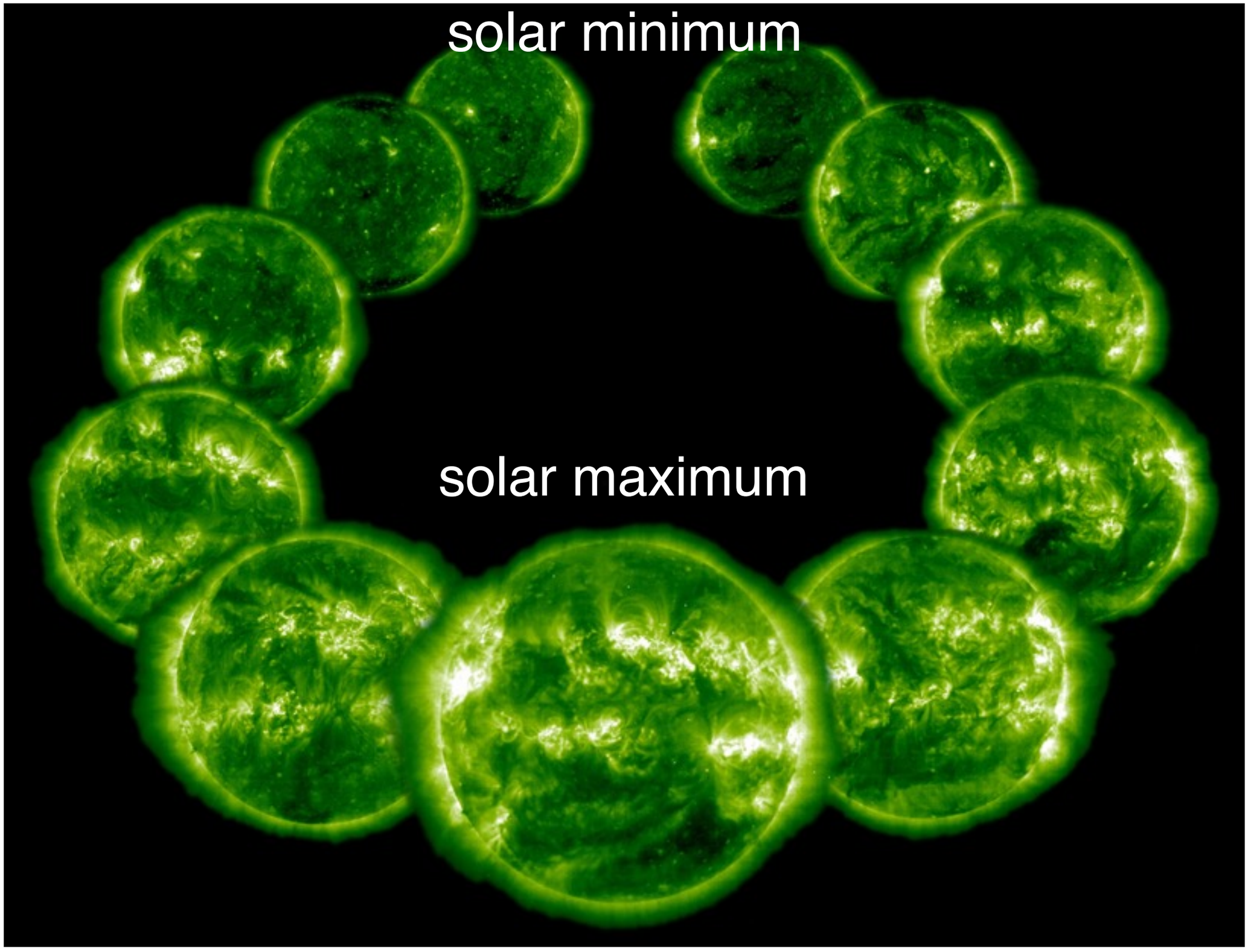
NASA Scientific Visualization Studio

Activity cycle

There are times when the Sun is more active than others. It is linked to the solar dynamo. The activity cycle period is roughly 11 years.



Activity cycle



Source: ESA & NASA/SOHO

How do we know all of this?

- Solar data:
  - remote sensing: images, total brightness, spectra, polarimetry, helioseismology
  - in-situ plasma density, velocity, magnetic field information
- Computer modeling of the sun at all scales.

NASA Heliophysics Satellites

Formulation
Implementation
Primary Ops
Extended Ops

STEREO (2)
SOHO–ESA
RHESSI
Cluster–ESA (4)
ACE
SDO
GOLD
ICON
AIM
IBEX
Solar Probe
Voyager (2)
Solar Orbiter–ESA
CINDI
Van Allen Probes (2)
TIMED
TWINS (2)
Hinode–JAXA
THEMIS (3)
WIND
Geotail–JAXA
SET-1
IRIS
ARTEMIS (2)
MMS (4)

soho
Facing the Sun

venus express
Studying Venus' atmosphere

proba-2
Observing solar events

bepicolombo
Exploring Mercury

Proba3
artificial
eclipse

juice
Studying Jupiter's icy moons

esa

cassini-huygens
Studying the Saturnian system
and landing on Titan

mars express
Investigating the Red Planet

rosetta
Chasing and landing on a comet

solar orbiter
The Sun up close

cluster
Measuring Earth's magnetic shield

→ ESA'S FLEET IN THE SOLAR SYSTEM

The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.

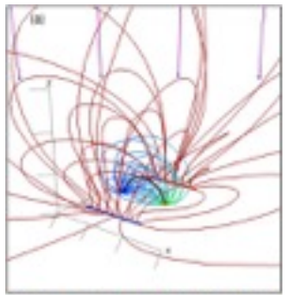
CLASP launch 3 September 2015, White Sands Missile Range

MSFC Sounding Rocket

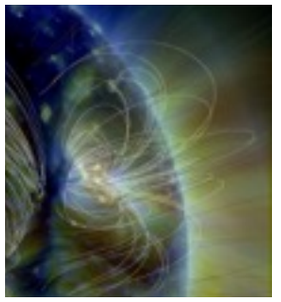
LASP Sounding Rocket

My research: magnetic fields in the corona

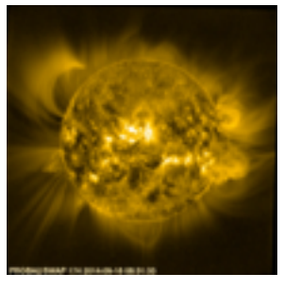
- Computer models of eruptions.



- Measurements of the coronal magnetic field.

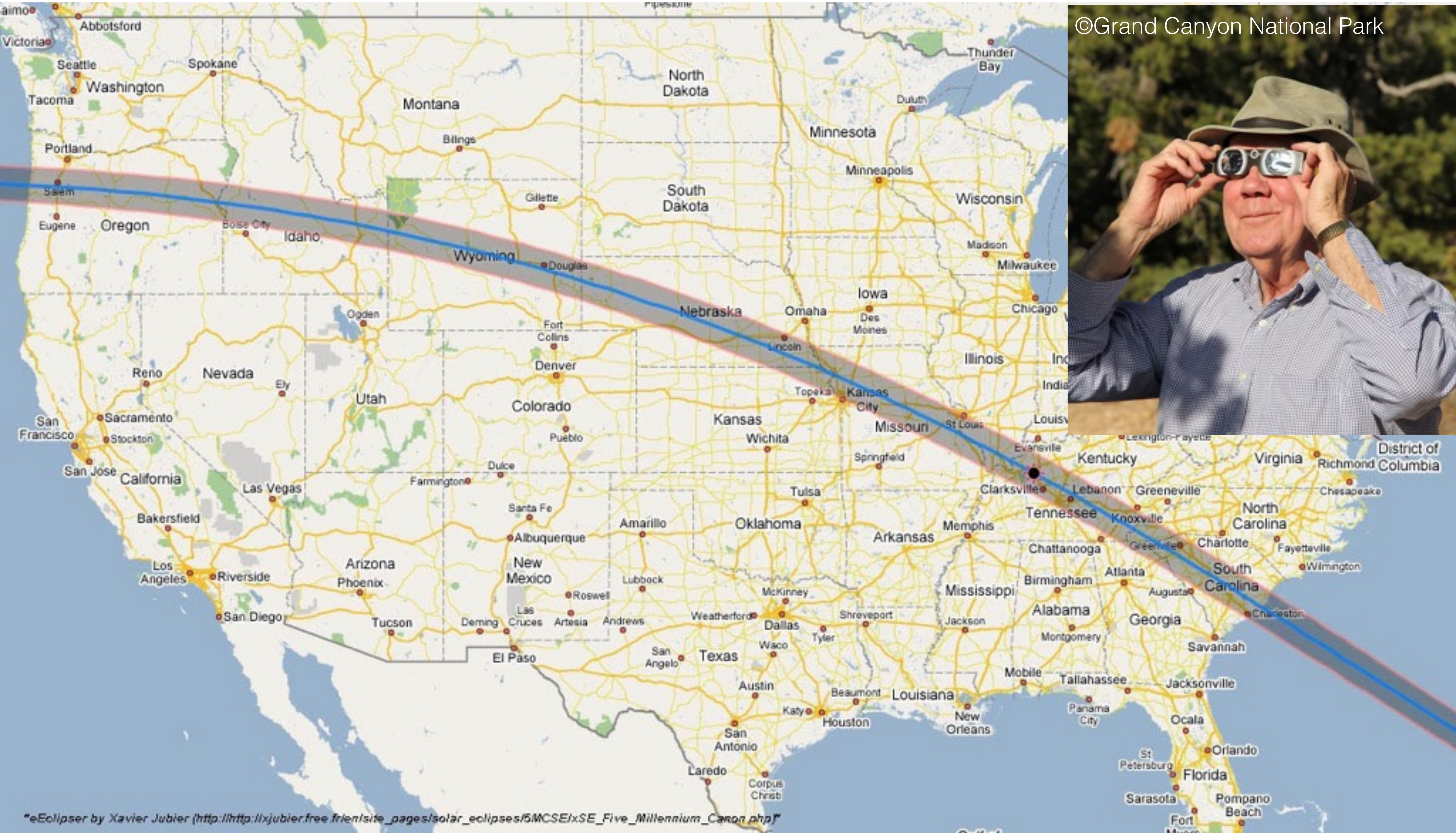


- Large-scale structure of the corona.



- Sounding rockets, measurements of the magnetic field in the chromosphere.

Eclipse Aug 21, 2017!



Thank you!

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