Killer Skies

- **Homework 5** due Monday
- Night Observing continuing
- Last time: White Dwarf
- Today: Active Sun

Music: *Invisible Sun*– Police

Night Observing

Night Observing probably last week

- if you do it, need to go one night
- allow about 1 hour

When: Tonight + next week: 8-10pm

3 observing stations:

- Large telescope in observatory dome
- 2 outdoor telescopes
- Night sky constellation tour

Subscribe to Night Observing Status Blog

http://illinois.edu/blog/view/413

Get weather cancellation updates

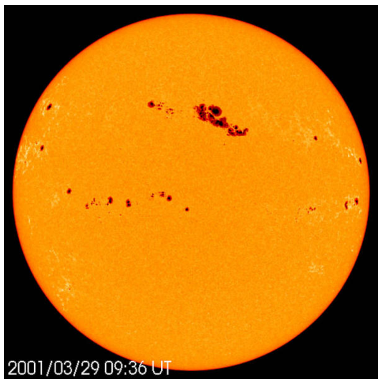
Assignment details on class website

Read rubric before you go!

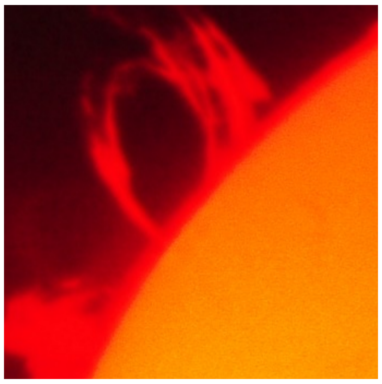
- Complete report due on or before Oct. 25

The Active Sun

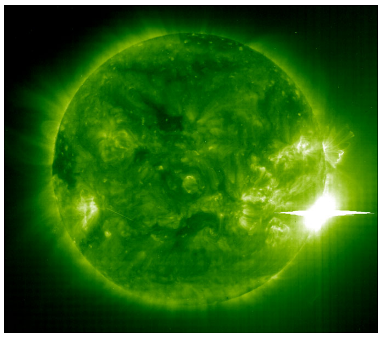
- Periodic disruptions in the Sun's atmosphere
  - **Sunspots**
  - **Prominences**
  - **Solar Flares**
  - **Coronal Mass Ejections**
- Connected to each other and the Sun's magnetic field!



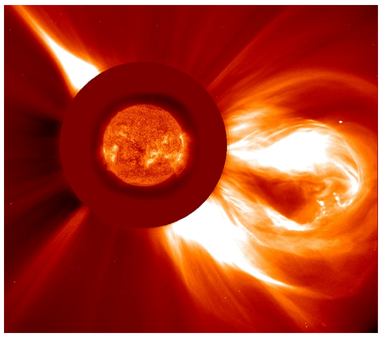
Sunspots



A solar prominence

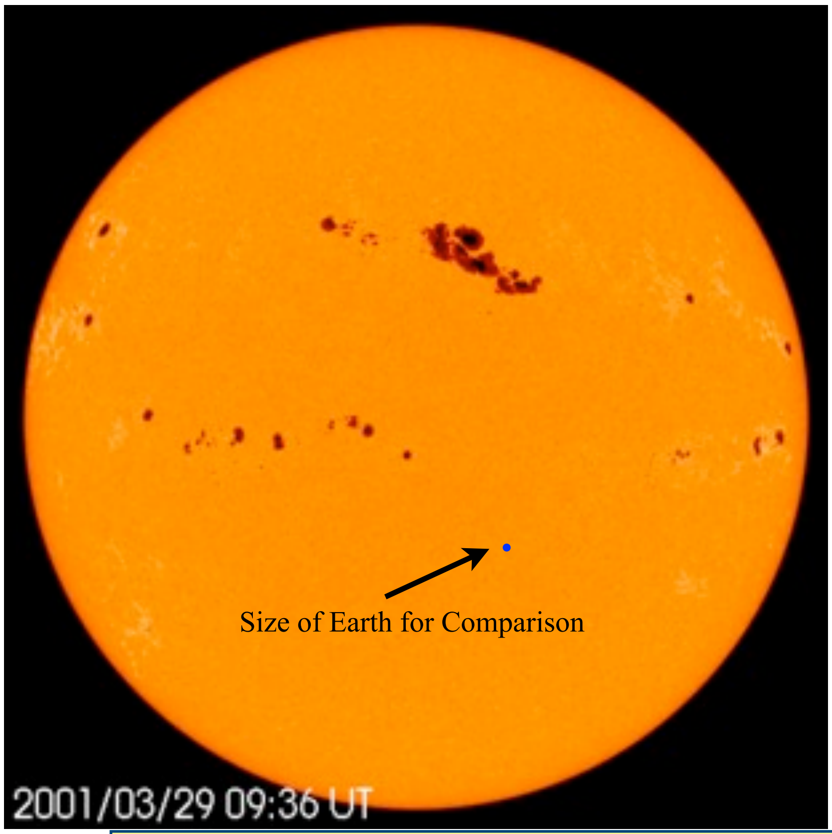


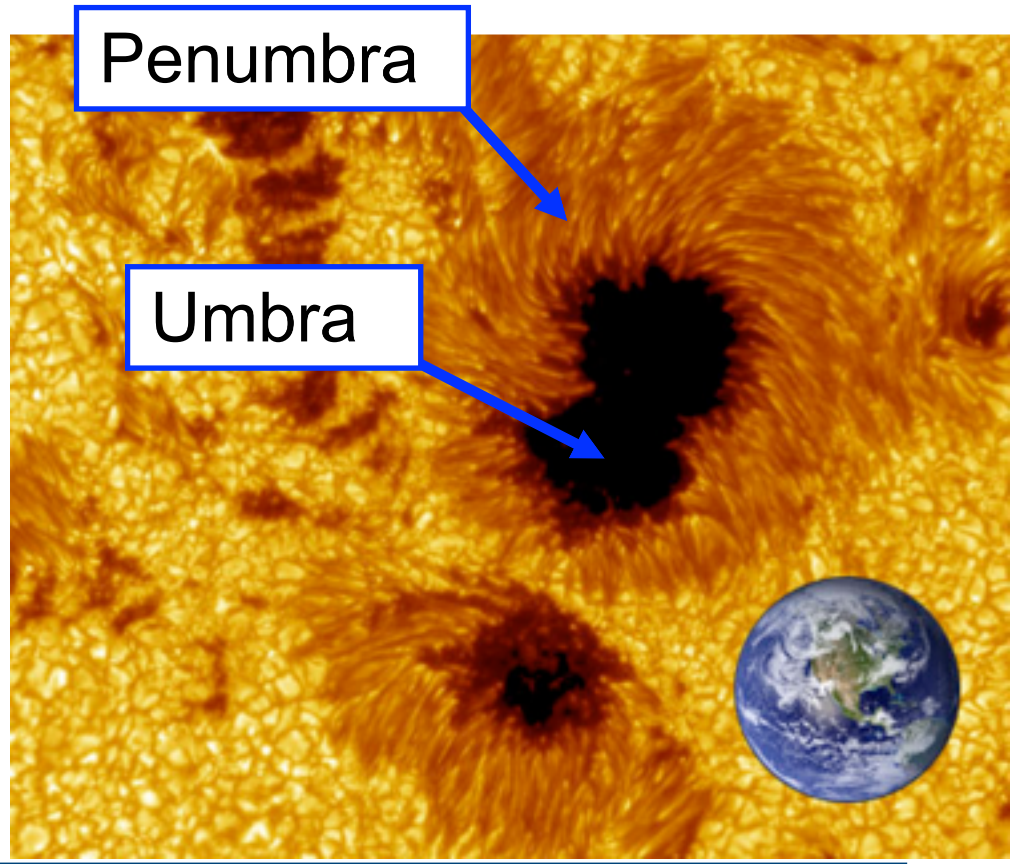
A solar flare



A coronal mass ejection

Sunspots



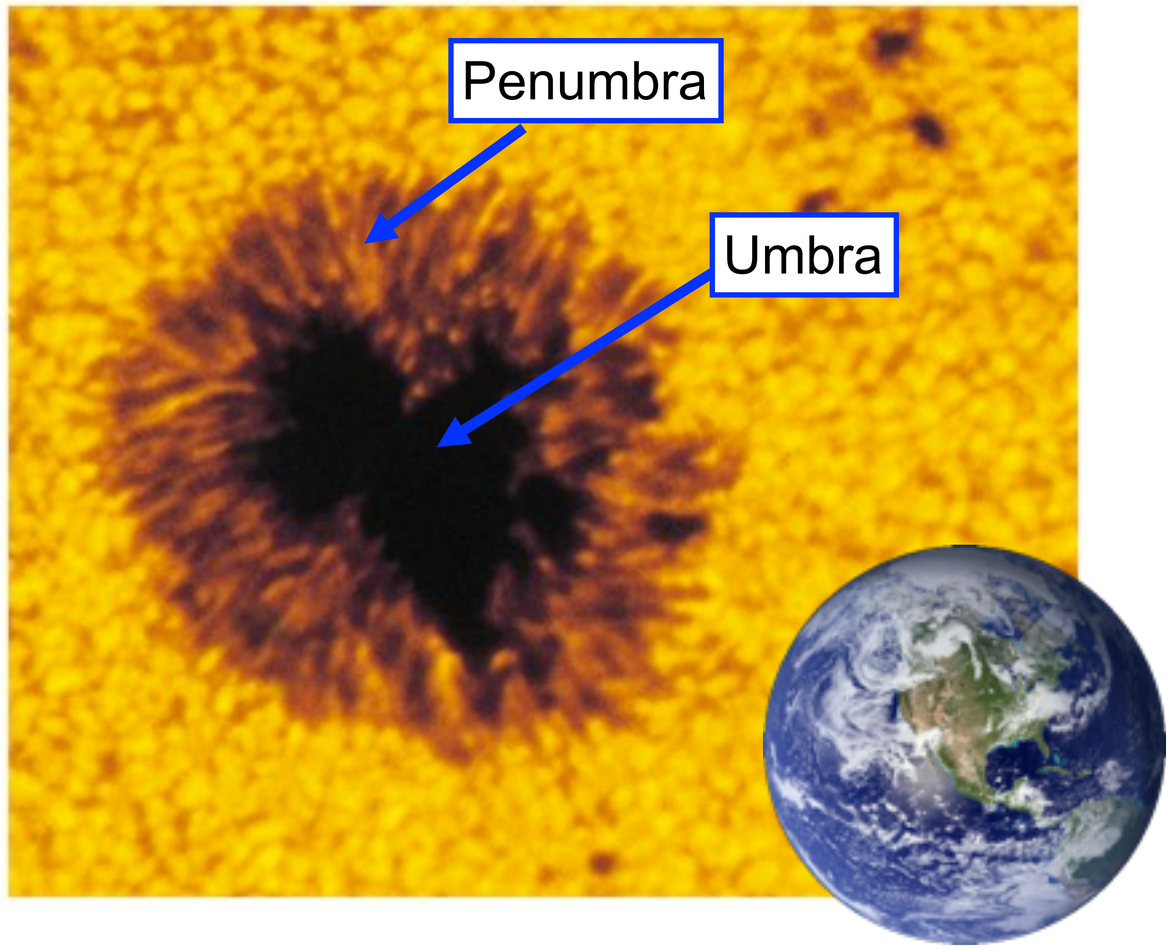


The picture on the left shows the whole Sun with some large sunspot groups on it. The picture on the right is a close-up of some other sunspots. Both images show the Earth for size comparison.

Sunspots are regions of the Sun's photosphere that appear dark because they are cooler than the rest of the surface (4,500 K vs. 5,800 K). Sunspots typically have sizes of 1,500 – 50,000 km (Earth's diameter is 13,000 km, for reference).

Why are Sunspots Dark?

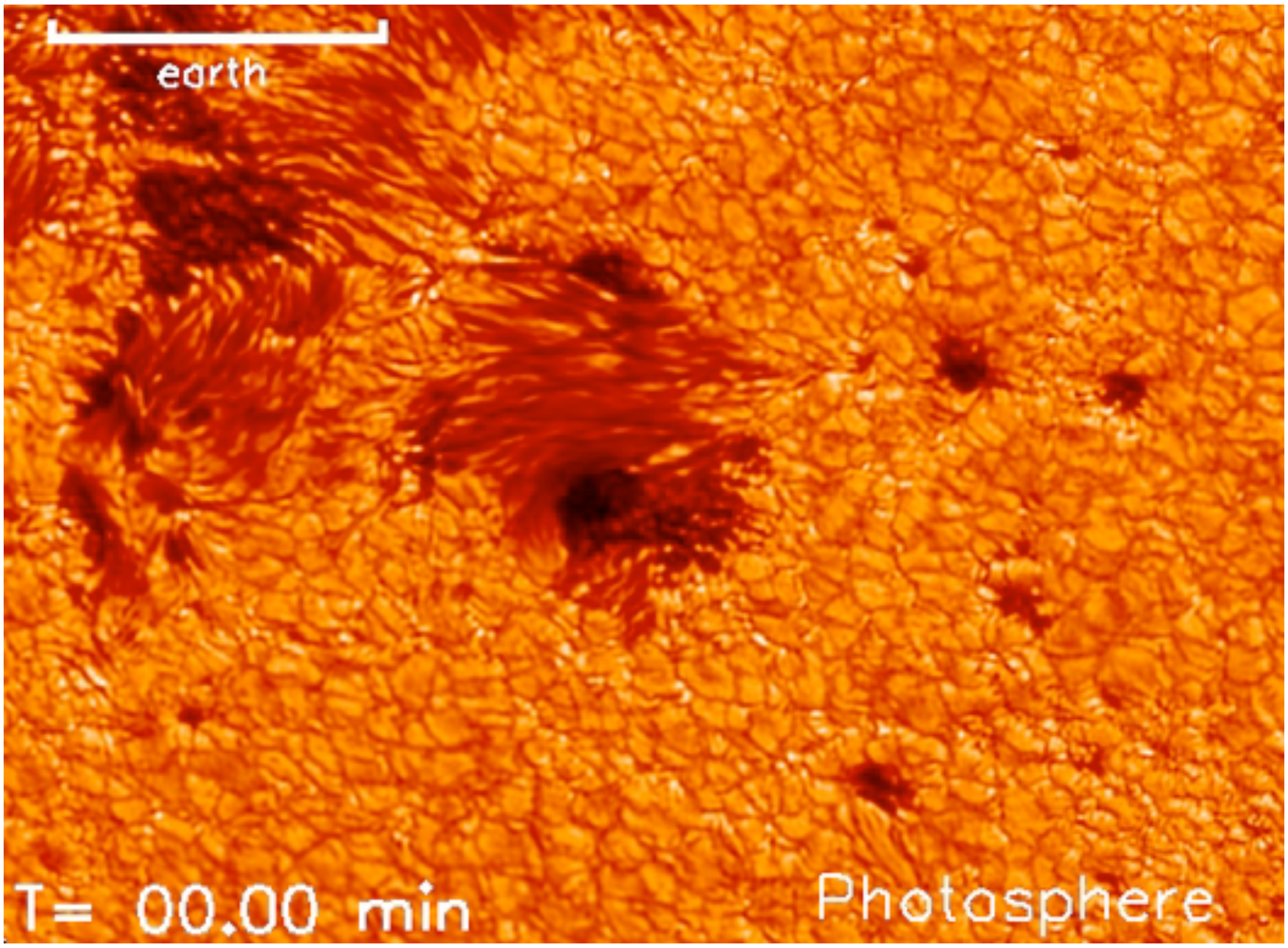
- “Dark” spots on the Sun.
- Slightly cooler than their surroundings: 4000 K vs. 5800 K
- Brightness of thermal glow depends strongly on temperature, so they appear dimmer.
- But still very hot, very bright!



Usually last a few days to few weeks, sometimes months.

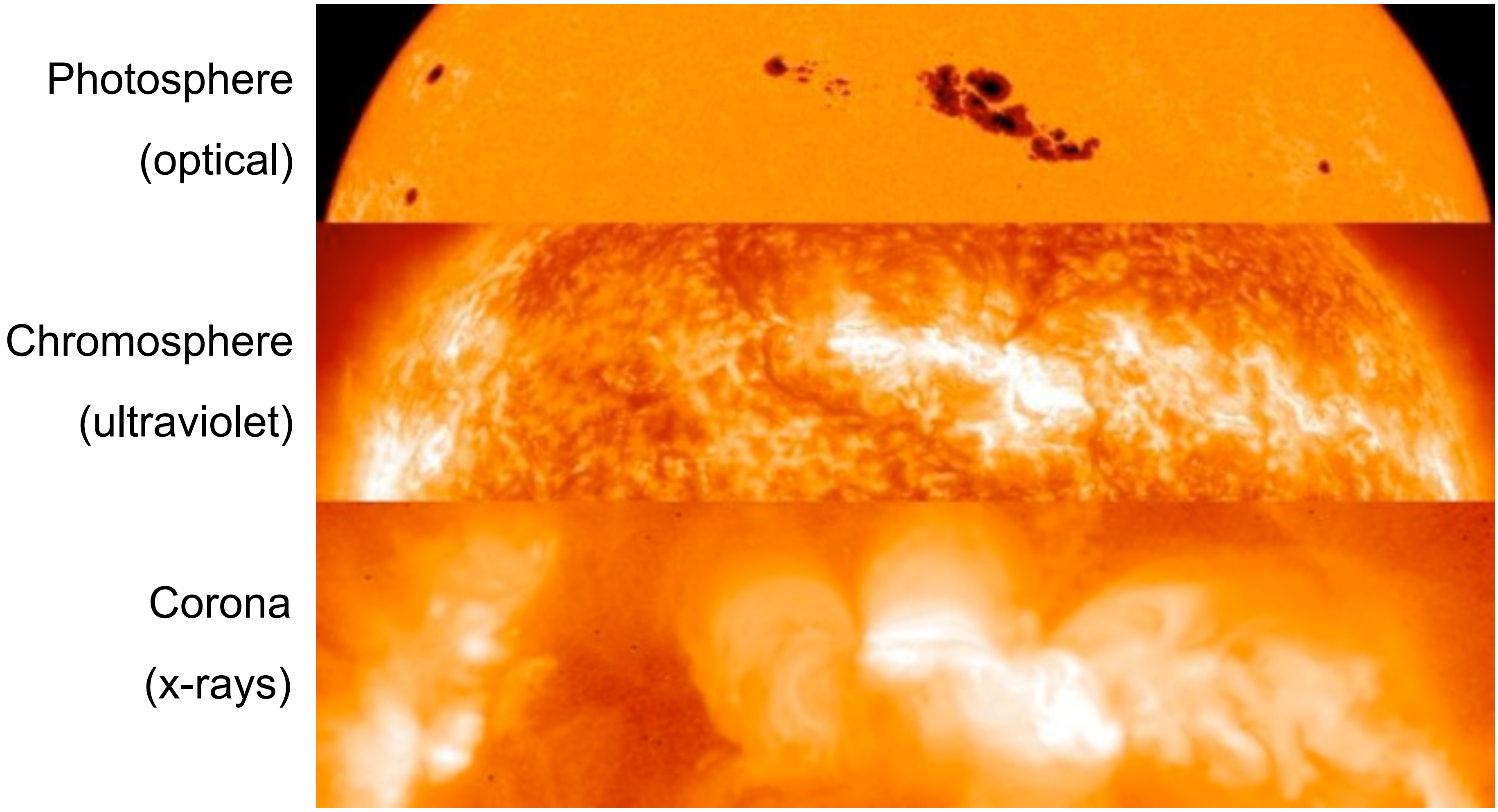
Sunspots change over time. Grow, shrink, merge, rotate.

Sunspots in Motion



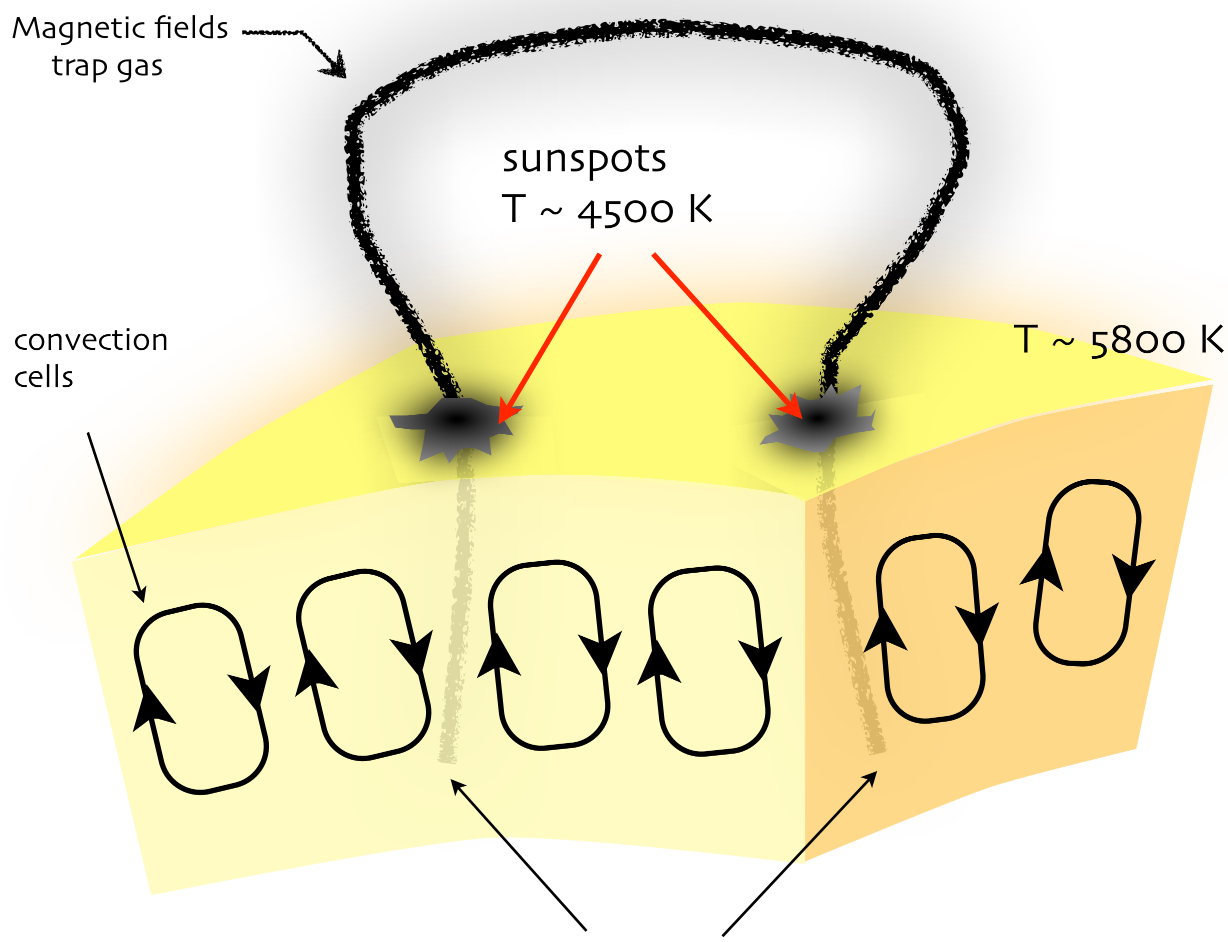
Sunspots are not permanent features. They last a few days to weeks (sometimes months), tend to form in groups. They also change over time: growing, shrinking, merging, and rotating.

Regions above sunspots are alive with activity



Sunspots appear dark in the photosphere, but regions above sunspots appear bright in the Sun’s upper “atmosphere.” This indicates there is tremendous energy associated with the magnetism of sunspots.

Sunspots happen where magnetic fields suppress convection

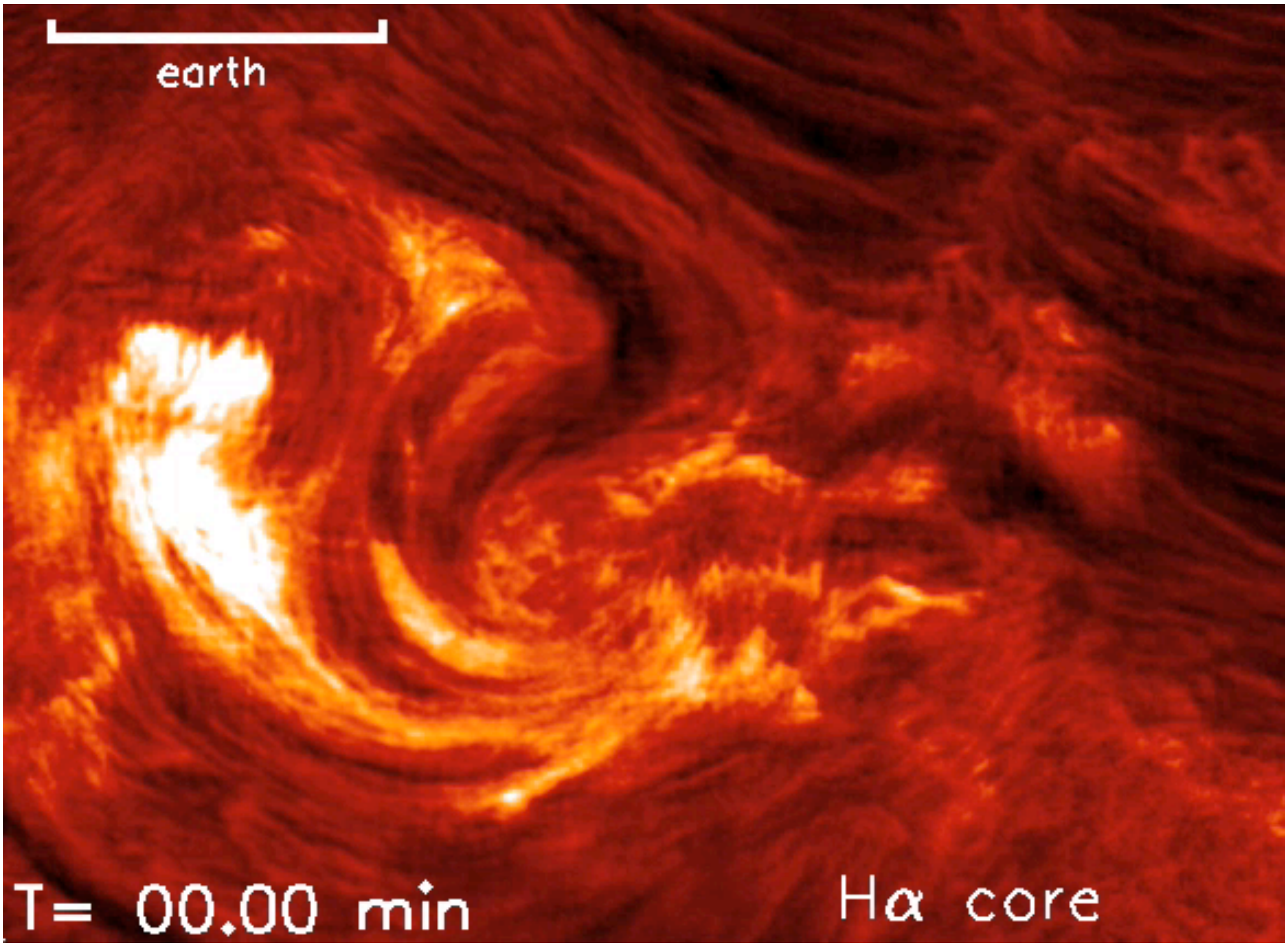


Magnetic fields of sunspots suppress convection and prevent surrounding plasma from sliding sideways into sunspot

Magnetic field strength in a sunspot is ~1,000 times stronger than the magnetic field at Earth's surface.

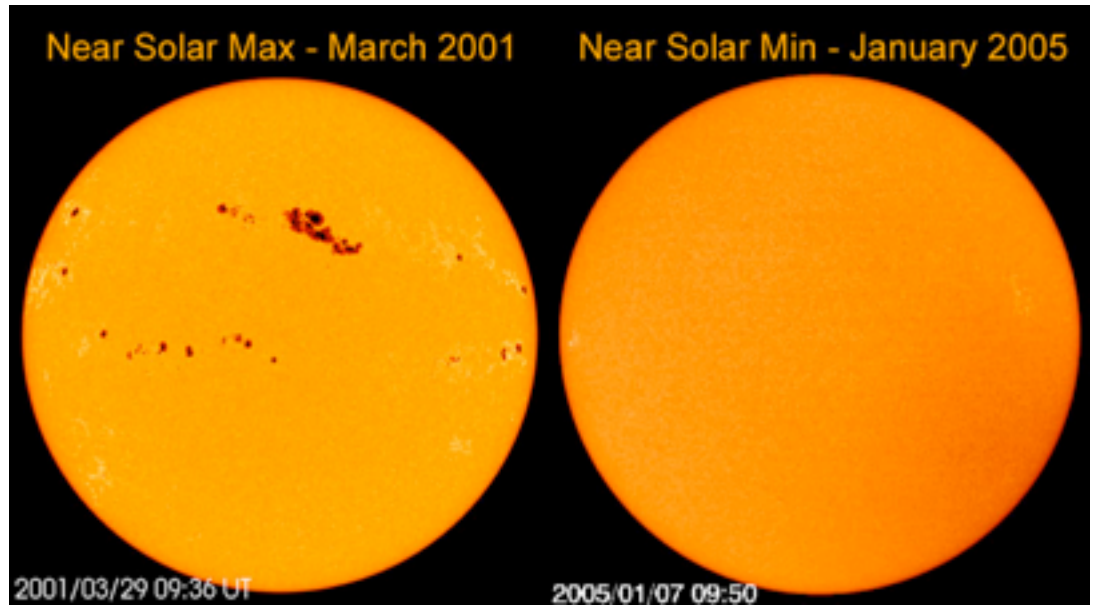
The intense magnetic fields at sunspots inhibit mixture of hot plasma from the surrounding photosphere into the sunspot regions. Sunspots are thus cooler than their surroundings. However, they are still 4500 K, which is very hot; remember hot lava is around 1500 K.

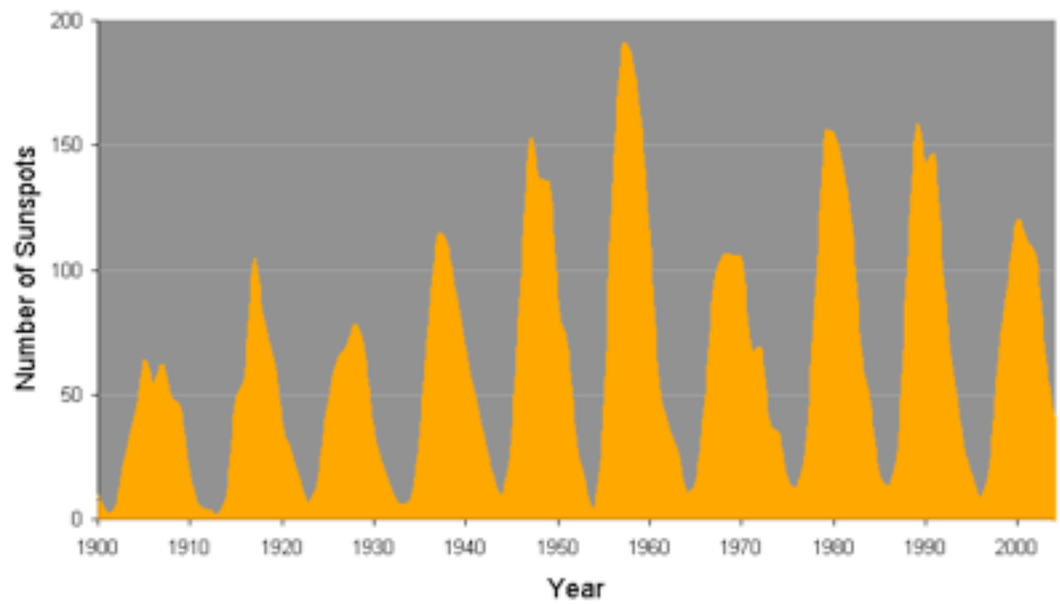
Sunspot and Magnetic Fields



The Sunspot Cycle

Number of sunspots rises and falls in an 11-year cycle



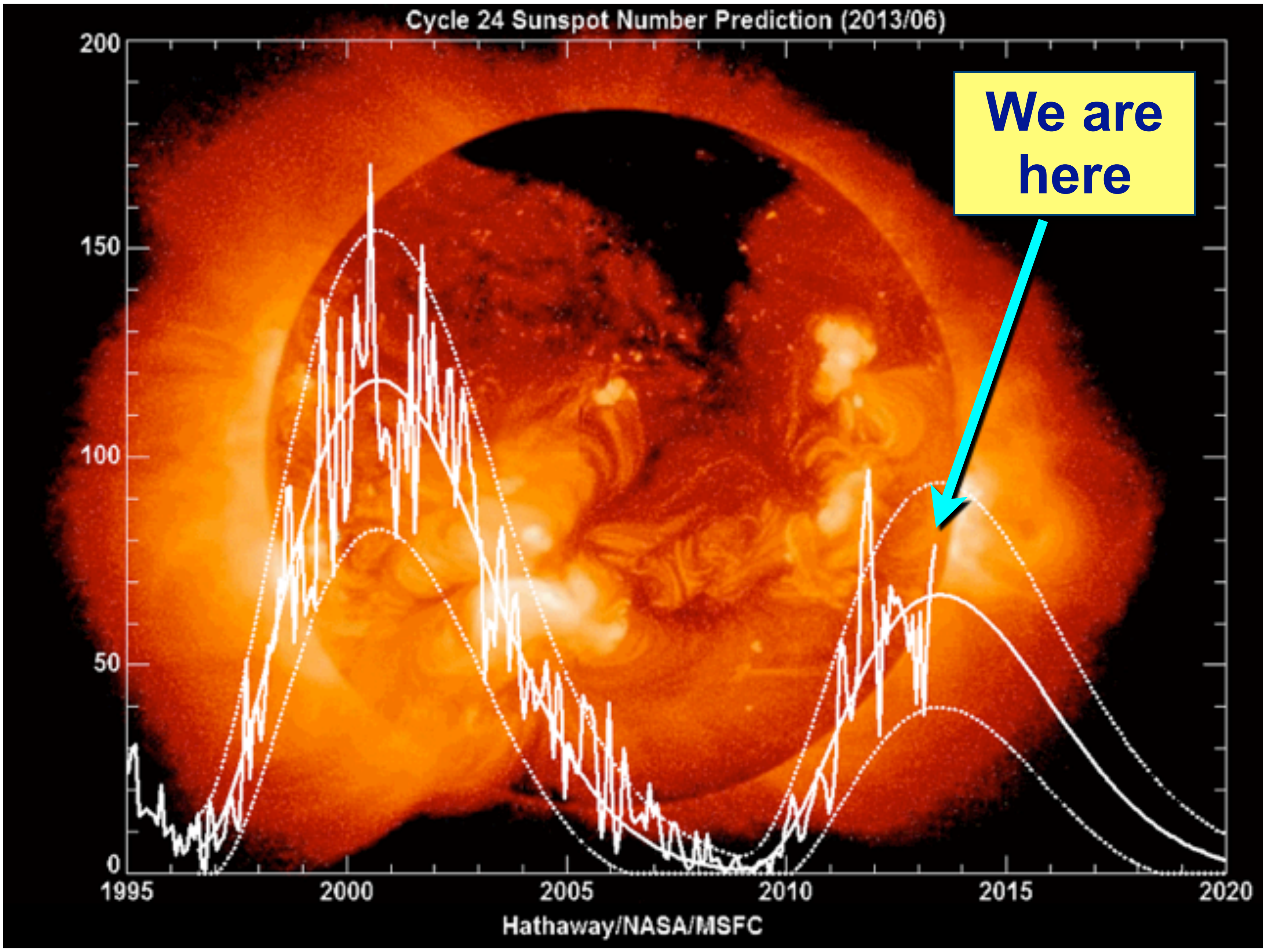


The number of sunspots observed on the "surface" of the Sun varies from year to year. This rise and fall in sunspot counts varies in a cyclical way.

A peak in the sunspot count is referred to as a time of "solar maximum" (or "solar max"), whereas a period when few sunspots appear is called a "solar minimum" (or "solar min").

The duration of the sunspot cycle is, on average, around eleven years. However, the length of the cycle does vary.

Between 1755 and the present, the sunspot cycle (from one solar min to the next solar min) has varied in length from as short as nine years to as long as fourteen years. About 2/3rds are between ten and twelve years.



NASA Solar Cycle 24 Sunspot Number Prediction

Solar Cycle 24 is the 24th solar cycle since 1755, when recording of solar sunspot activity began. It is the current solar cycle, and began on 8 January 2008, but there was minimal activity through early 2009.

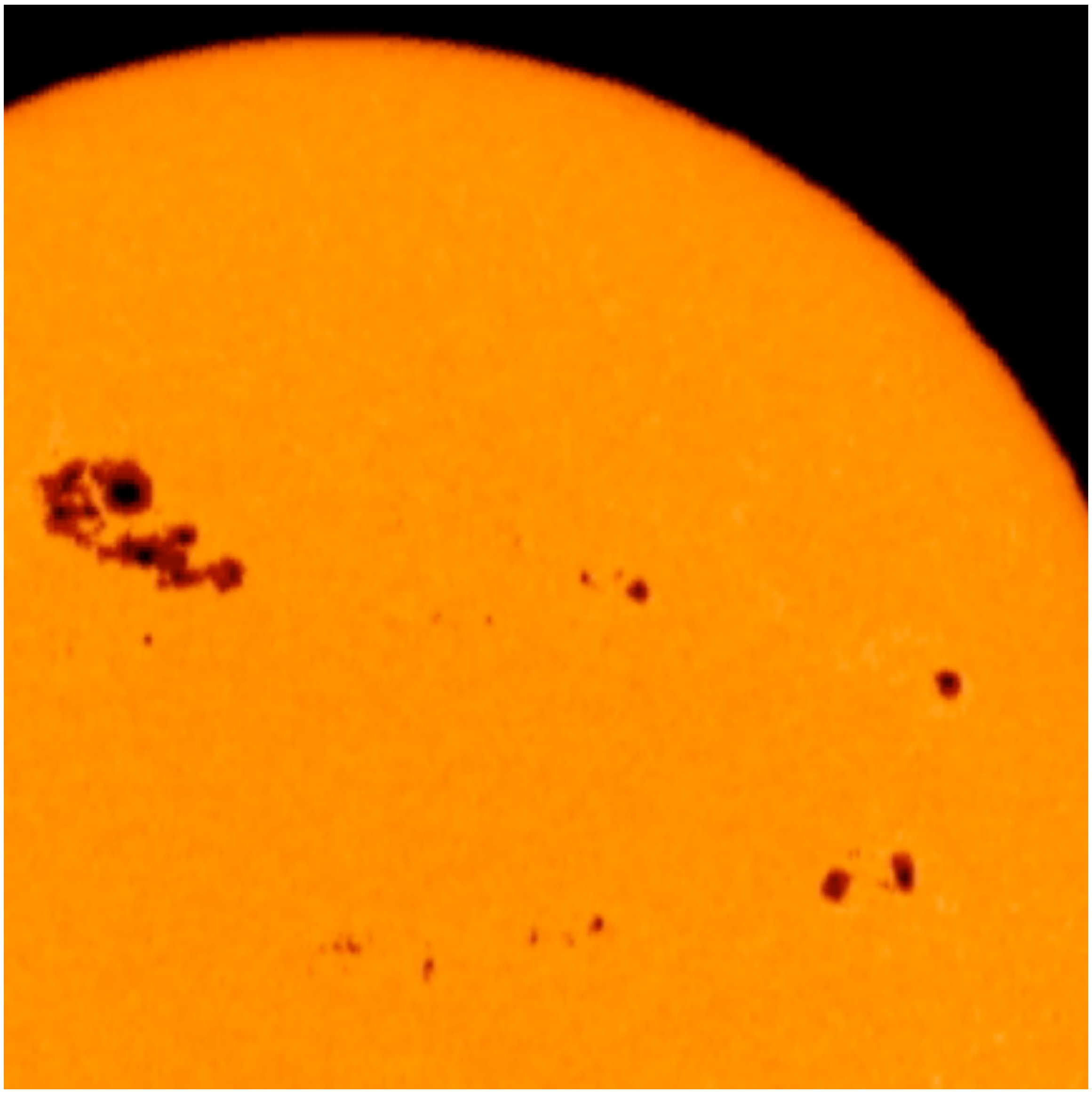
NASA predicts that solar cycle 24 will peak in Fall 2013 with about 70 sunspots.

IClicker Question

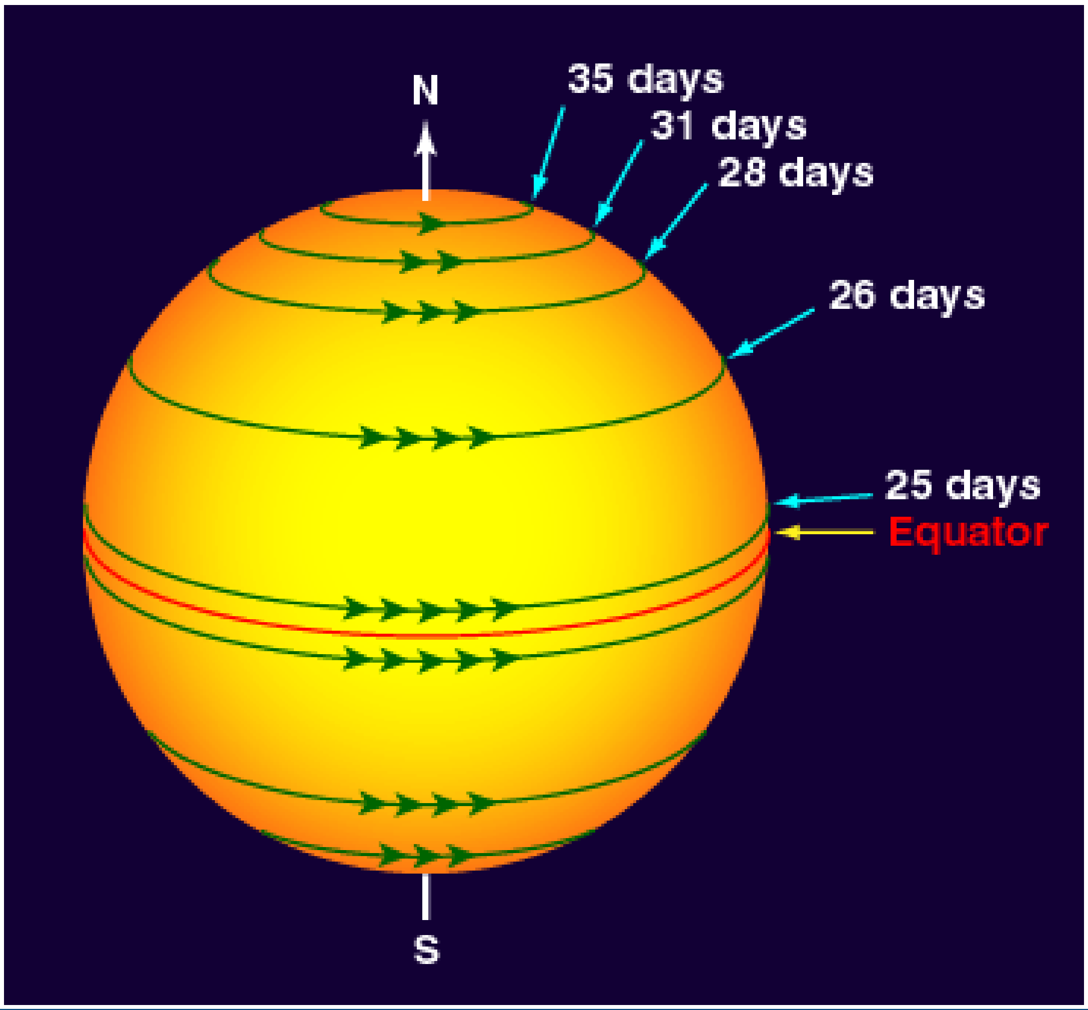
What causes Sunspots?

a) It is a natural feature of a young Sun. It should clean up as it ages.
b) Magnetic fields.
c) Thermonuclear explosions.
d) Granulation
e) Greasy food.

Sunspots Show Sun's Rotation



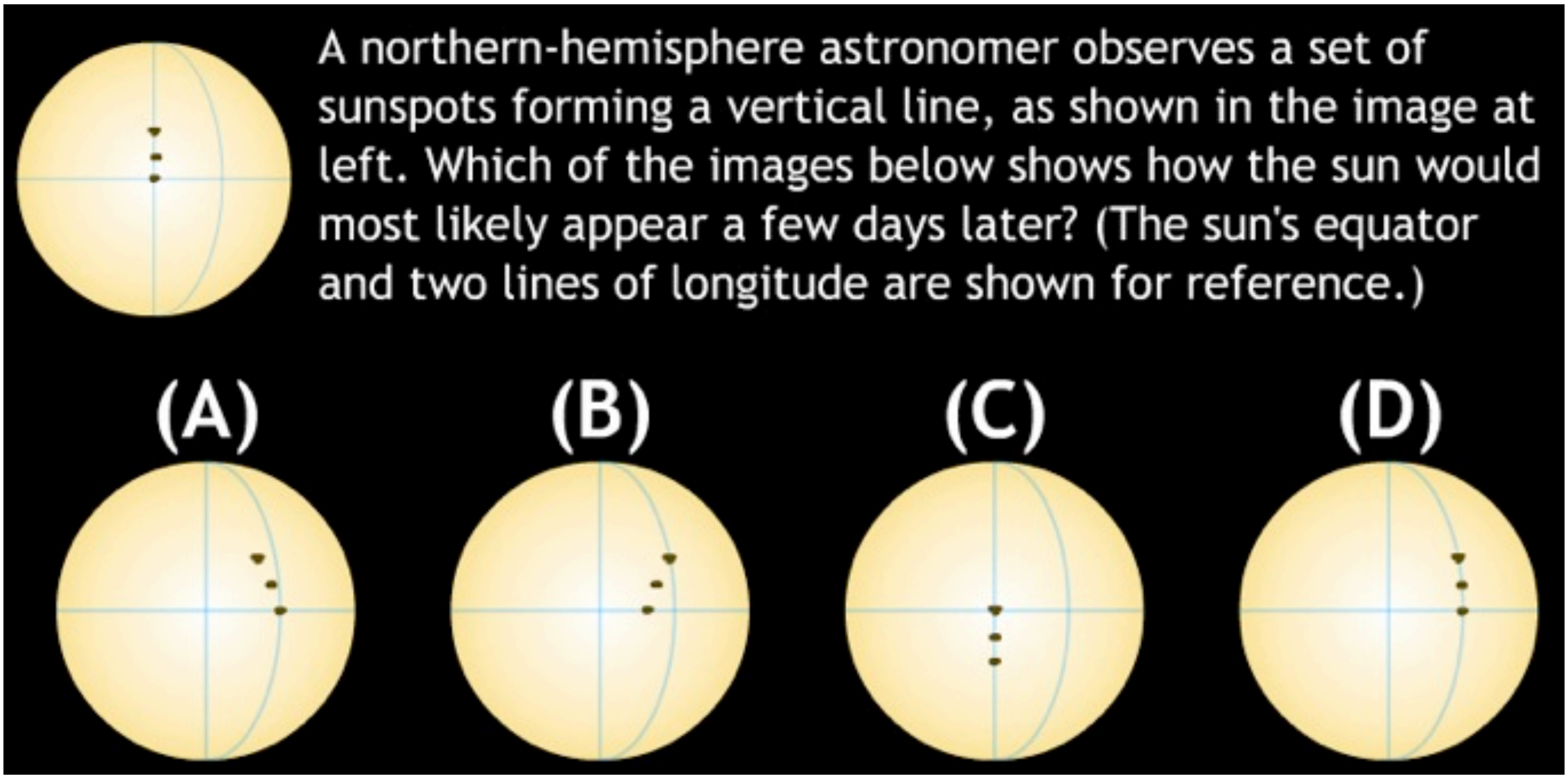
The Sun rotates fastest at the equator, and slowest at the poles



Called *differential rotation*

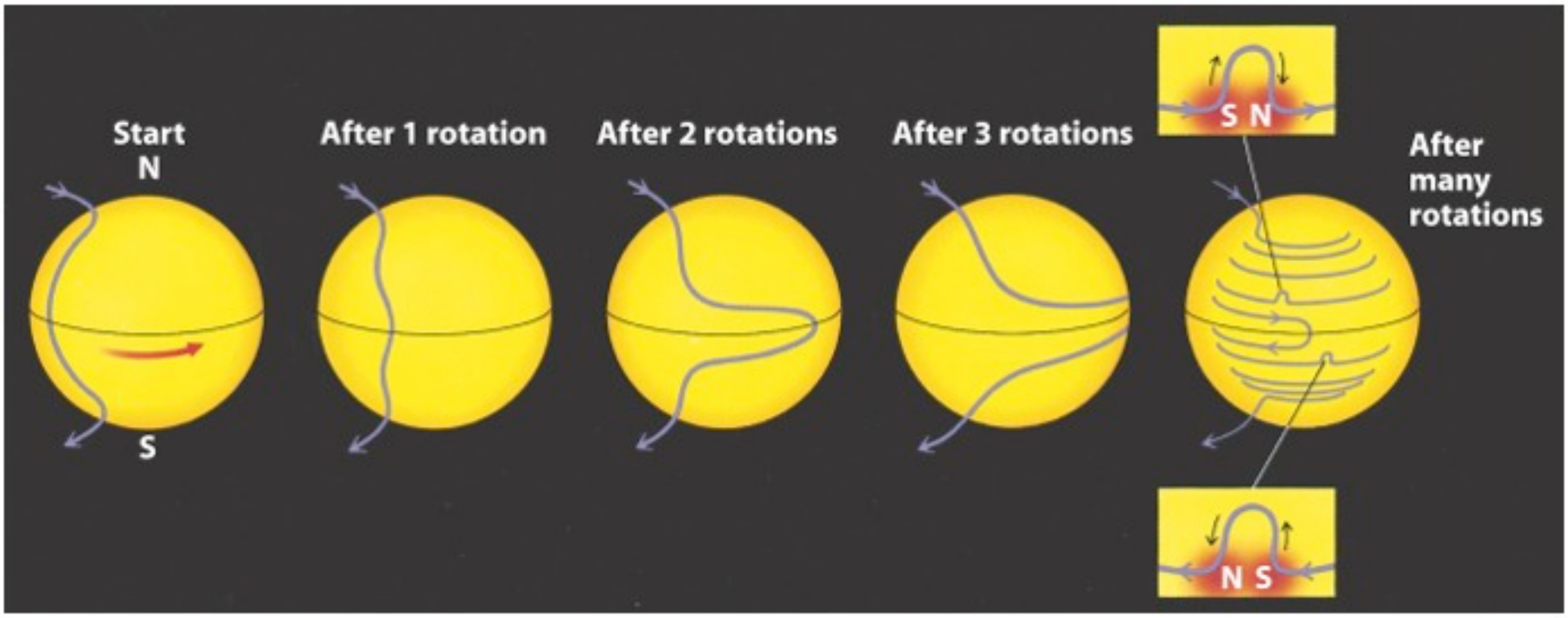
Sun does not rotate as a rigid sphere. Equator of the Sun rotates faster than the poles of the Sun. This is called differential rotation. How is this linked to sunspots?

Thought Question



Answer A
The Sun rotates fastest at the equator, so the sunspot at the equator will be ahead of the other spots.

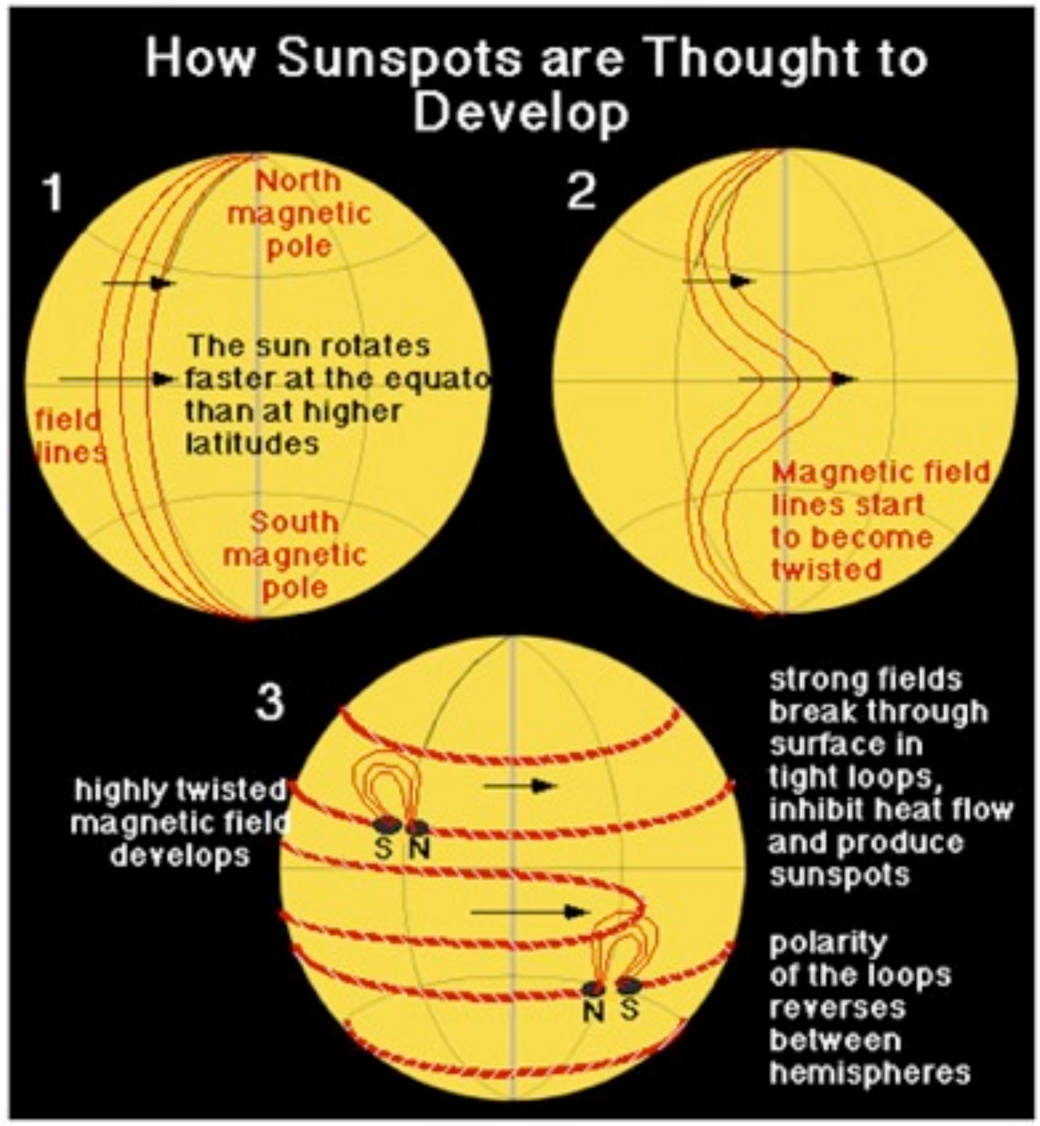
The Magnetic Cycle= Solar Cycle



- Every 11 years, the field breaks apart and reorders itself
  - North and south magnetic poles flip!

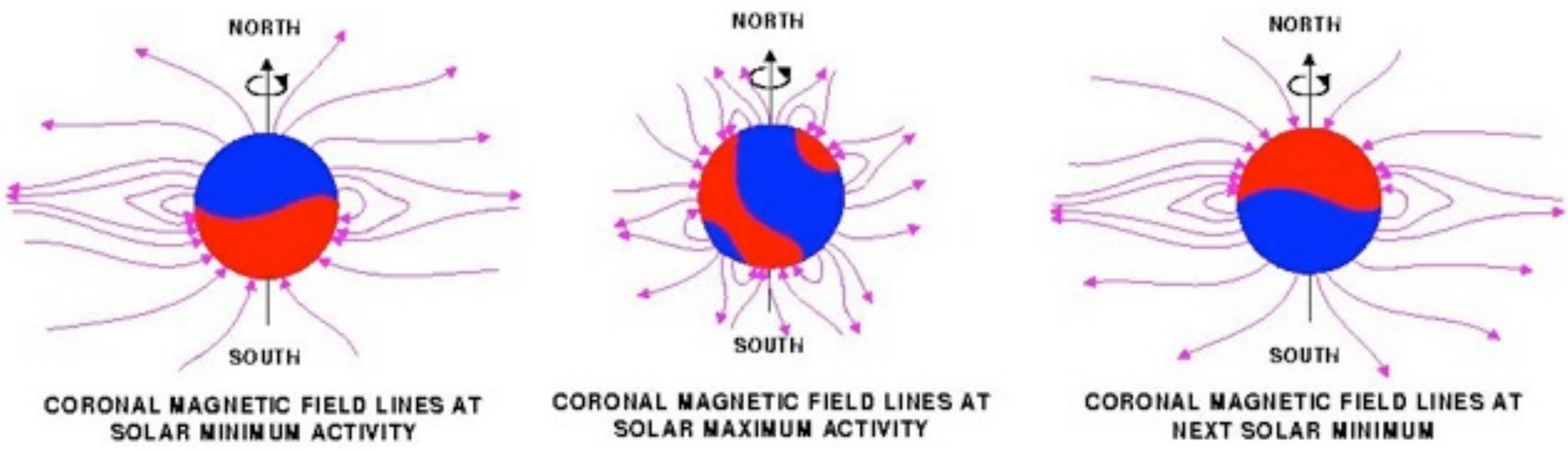
Sun's *differential rotation* twists up the magnetic field

Sunspots form where "kinks" in the magnetic field pop thru the surface



Scientists believe the differential rotation of the Sun is the underlying cause of sunspots. Since the gaseous sphere of the Sun rotates more quickly at its equator than at its poles, the Sun's overall magnetic field becomes distorted and twisted over time. Loops in the tangled magnetic field poke through the Sun's surface sometimes. When they do, they make sunspots.

At the end of the cycle, the field reorders itself



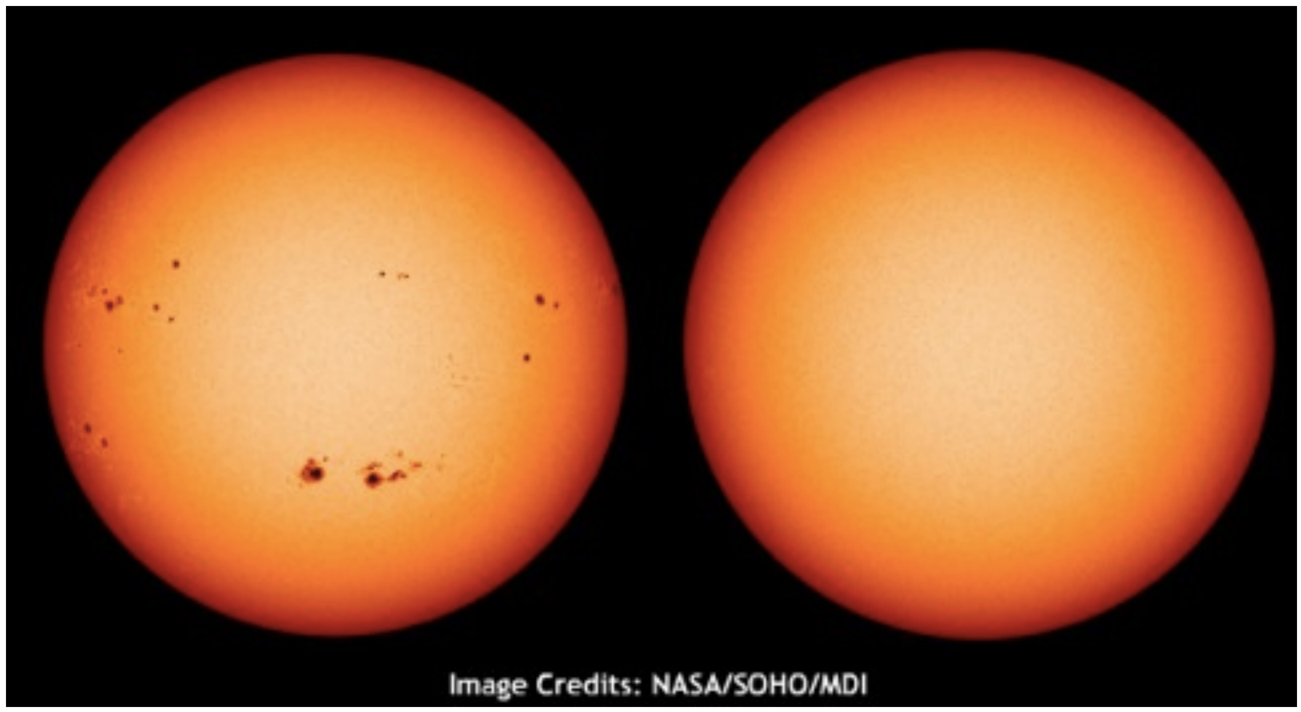
... but magnetic north and south flip!

So, the 11-year sunspot cycle is really a 22-year magnetic cycle!

Thought Question

Two pictures of the Sun from the SOHO spacecraft are shown below. How much time likely passed between when they were taken?

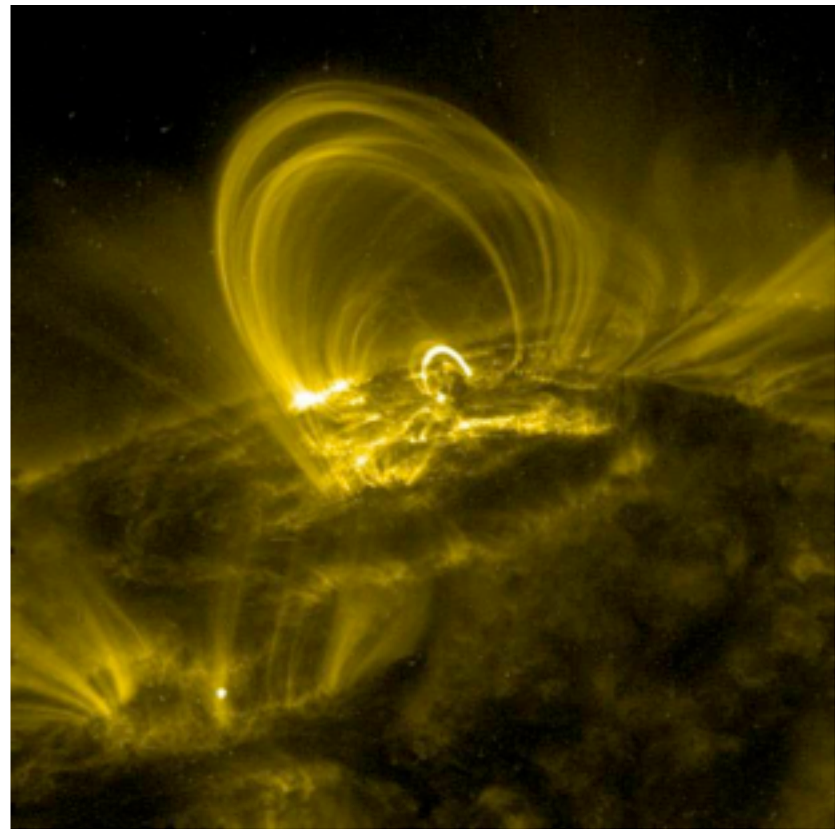
A. 1 day
B. 6 months
C. 1 year
D. 6 years
E. 11 years



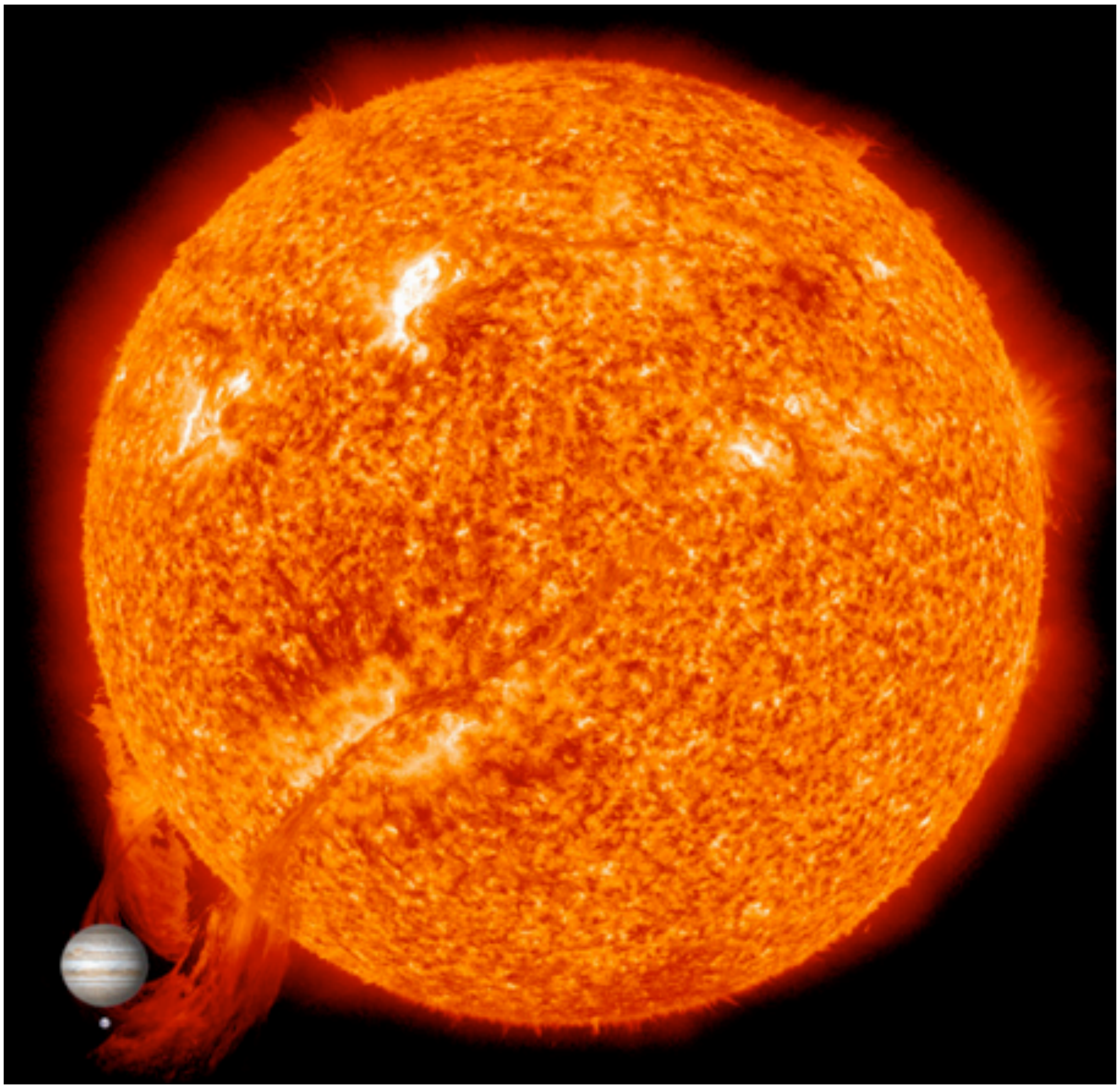
Answer D – 6 years. One is a solar max and one is a solar min It is typically 11 years for the full cycle, and about half that (more or less) for the half cycle.

Prominences

- Magnetic loops can extend up into the Sun's corona
- Gas from the chromosphere can be trapped in the loops
- Cooler and denser than the surrounding corona
- Forms **prominences**



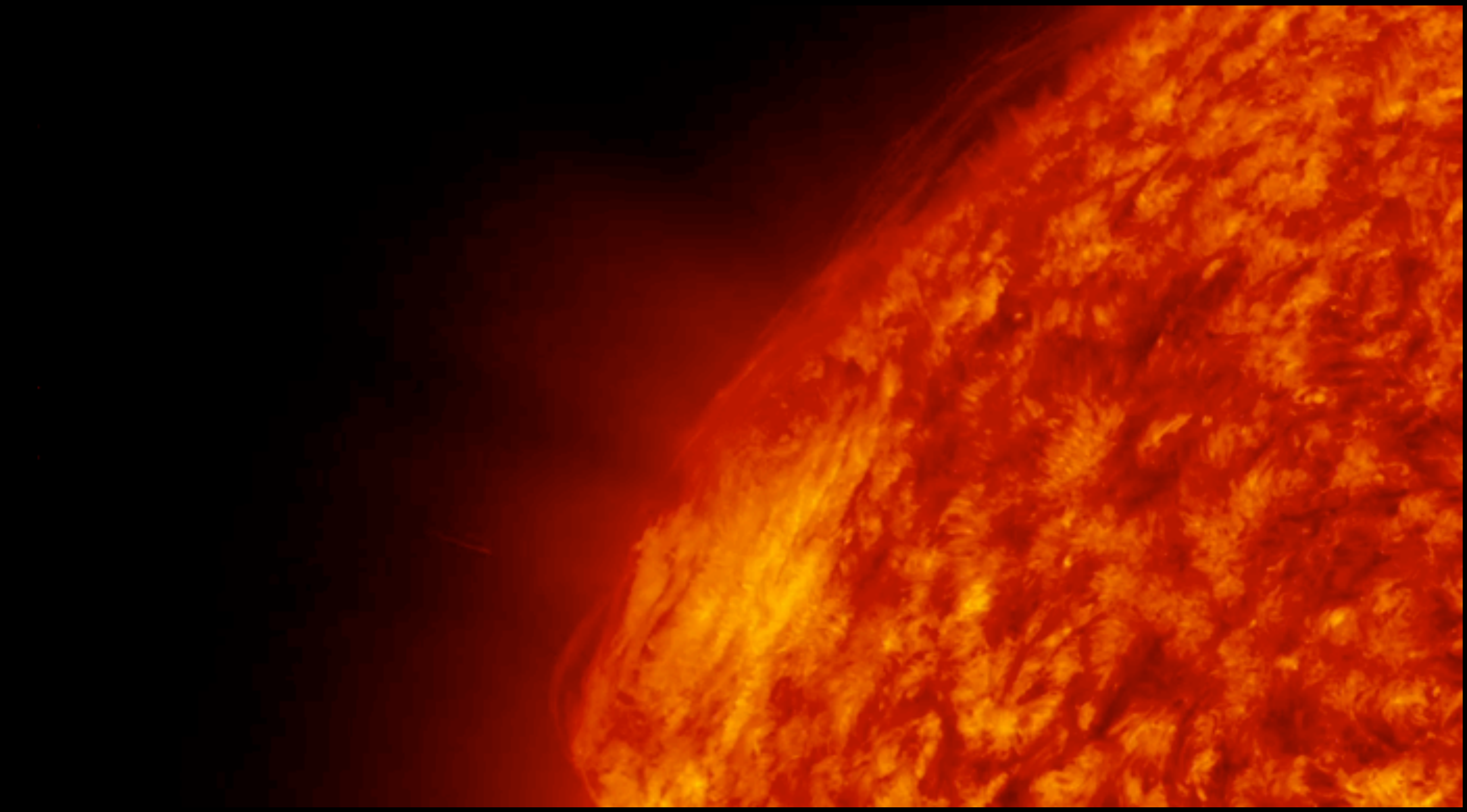
Coronal loops above sunspots



Solar Dynamics Observatory

A solar prominence with images of Jupiter and Earth for size comparison

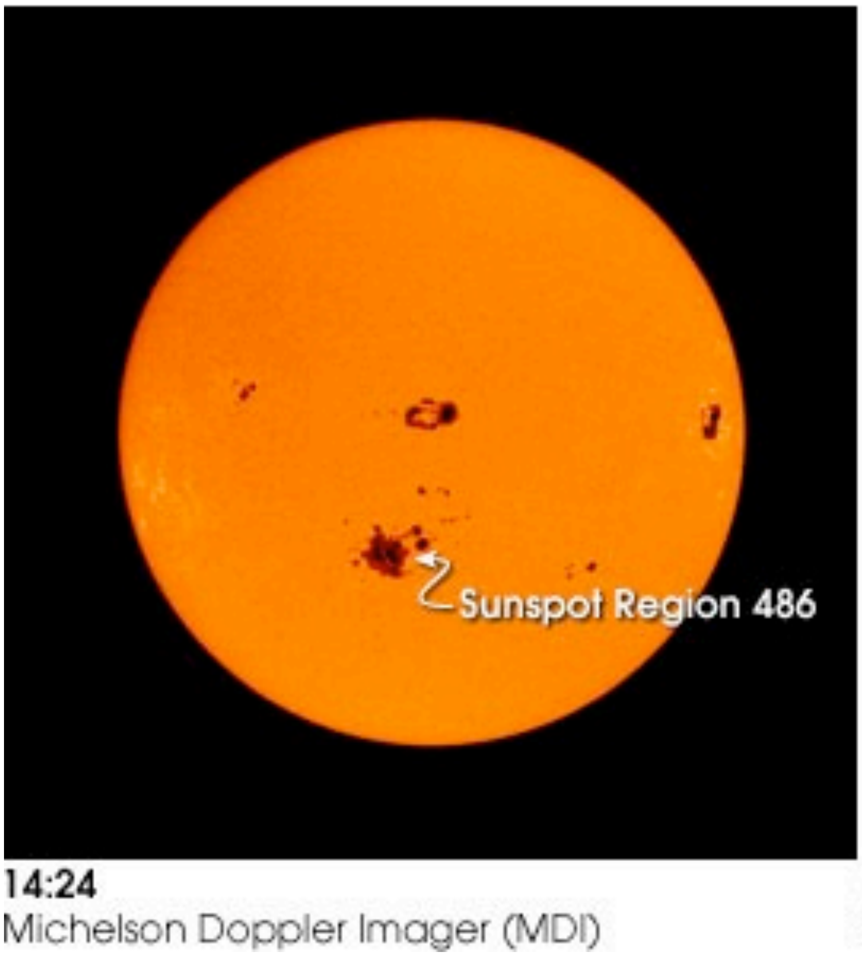
Prominence imaged on Dec 6, 2010 with Jupiter and Earth images superimposed to demonstrate the size. Source Solar Dynamics Observatory

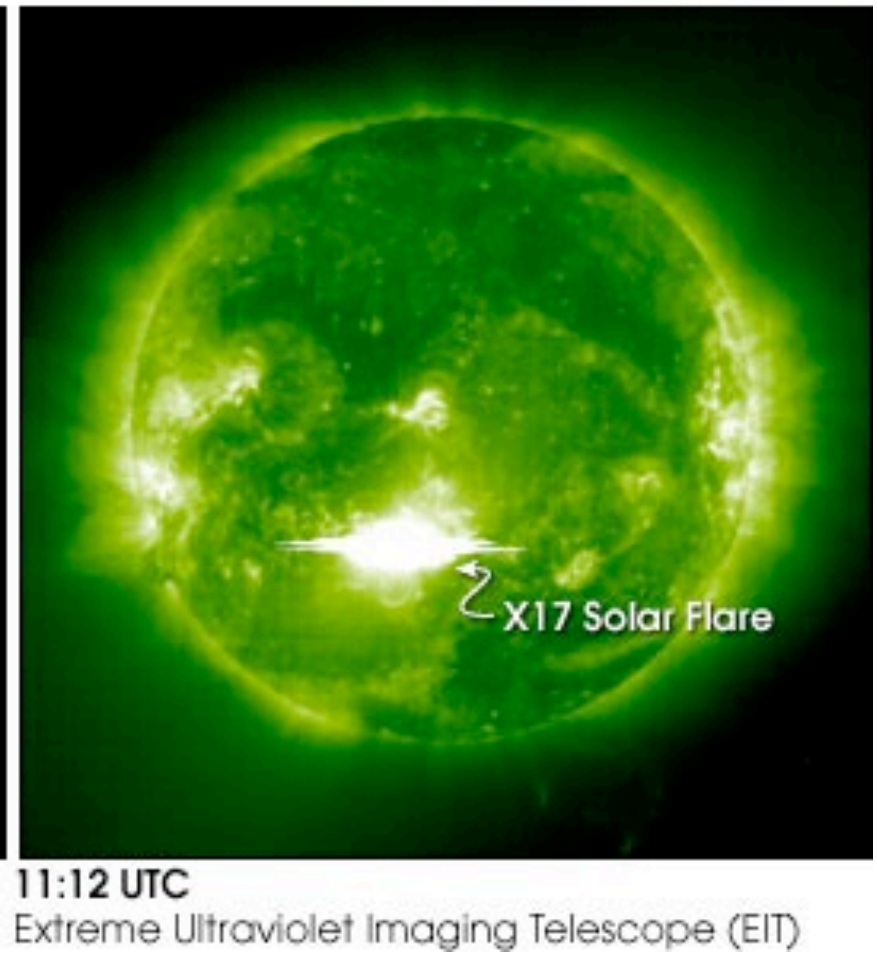


A movie of a March 30, 2010, solar prominence eruption, as seen by the Solar Dynamics Observatory

A movie of the March 30, 2010 prominence eruption, starting with a zoomed in view. The twisting motion of the material is the most noticeable feature. The viewpoint then pulls out to show the entire Sun.

Solar Flares

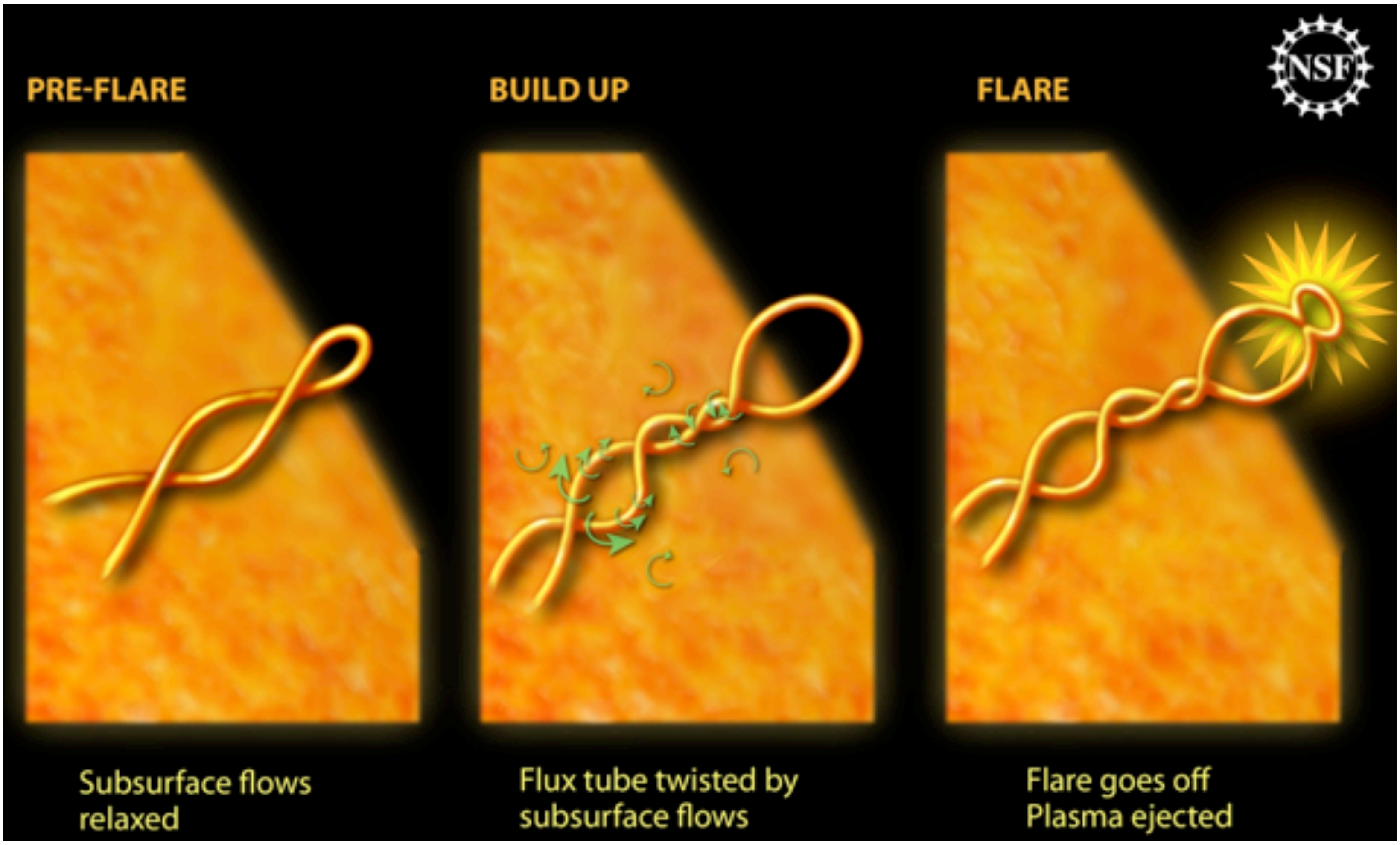




Flares occur when intense magnetic fields in sunspot regions release their energy explosively

A solar flare is a violent explosion in the Sun's atmosphere with an energy equivalent to tens of millions of hydrogen bombs. Solar flares emit huge bursts of electromagnetic radiation, including X-rays, ultraviolet radiation, visible light, and radio waves. They are capable of disrupting long-distance radio communications.

Why Solar Flares Occur



Twisting magnetic fields beneath the surface of the Sun erupt into a large solar flare

Solar flares probably form when the magnetic loops above sunspots get so twisted, that they snap violently, releasing tremendous amounts of energy. The magnetic loops get twisted by gas motions beneath the Sun’s surface.

Large amounts of ionized gas can be ejected in a flare. Unlike the material in prominences, the solar flare material moves with enough energy to escape the Sun's gravity.

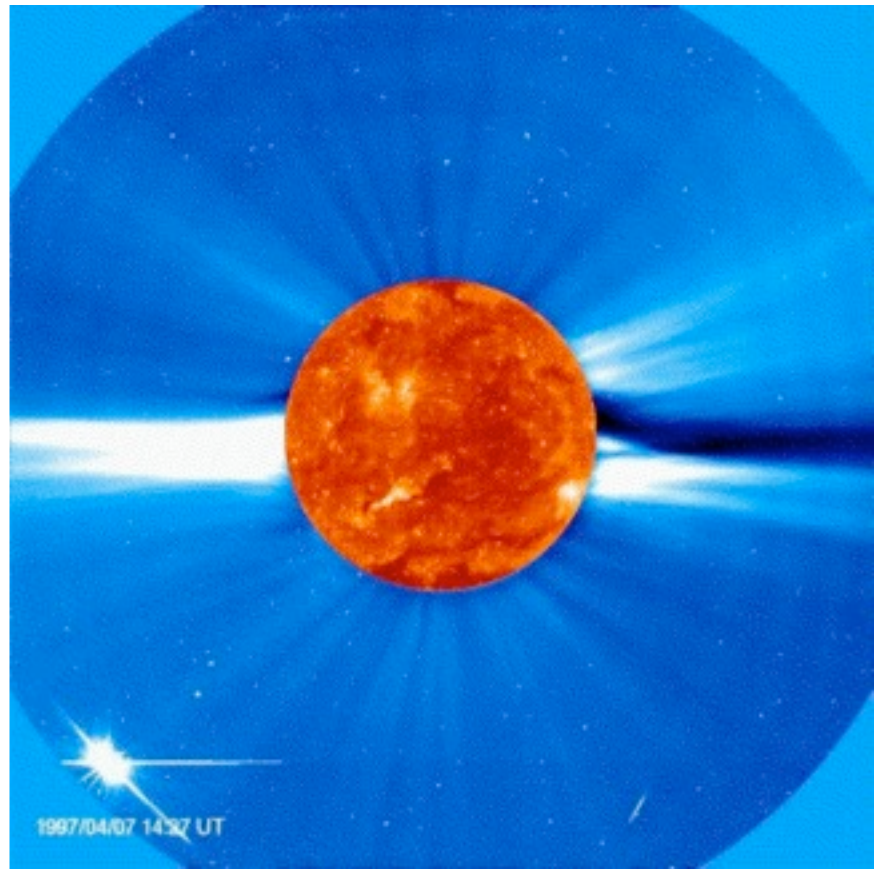
Coronal Mass Ejections

Huge bubbles of gas ejected from the Sun

Often associated with flares and/or prominences

2 trillion tons of ionized gas hurled into the solar system

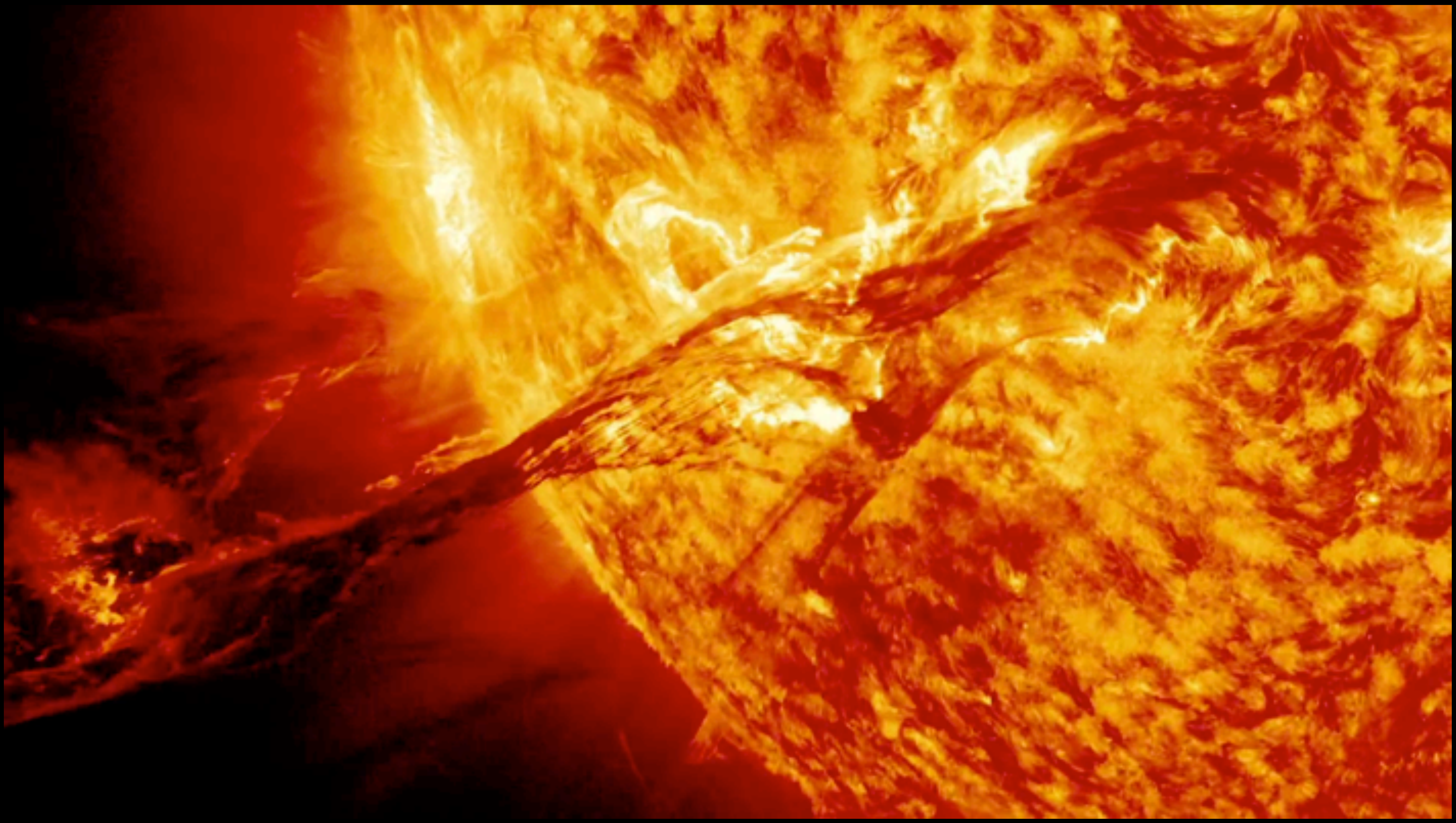
2-3 day at solar maximum
(1 per week normally)



Huge bubbles of gas ejected from the Sun, often associated with flares.

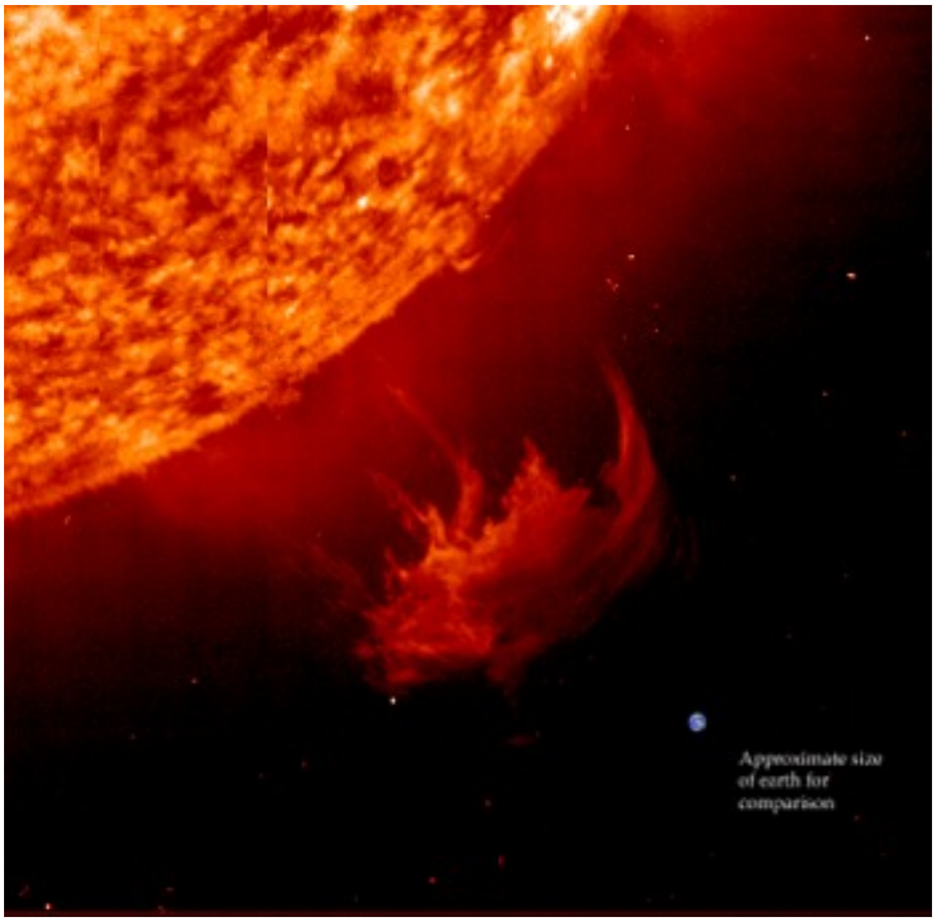
Coronal Mass Ejections (CMEs) are huge bubbles of gas ejected from the Sun, often associated with flares. These can eject up to 10 billion tons of charged particles into the solar system at millions of kilometers per hour. About 2-3 per day at solar maximum (1 per week normally). CMEs are believed to be driven by energy release from the solar magnetic field. How this energy release occurs, and the relationship between different types of solar activity, is one of the many puzzles facing solar physicists today.

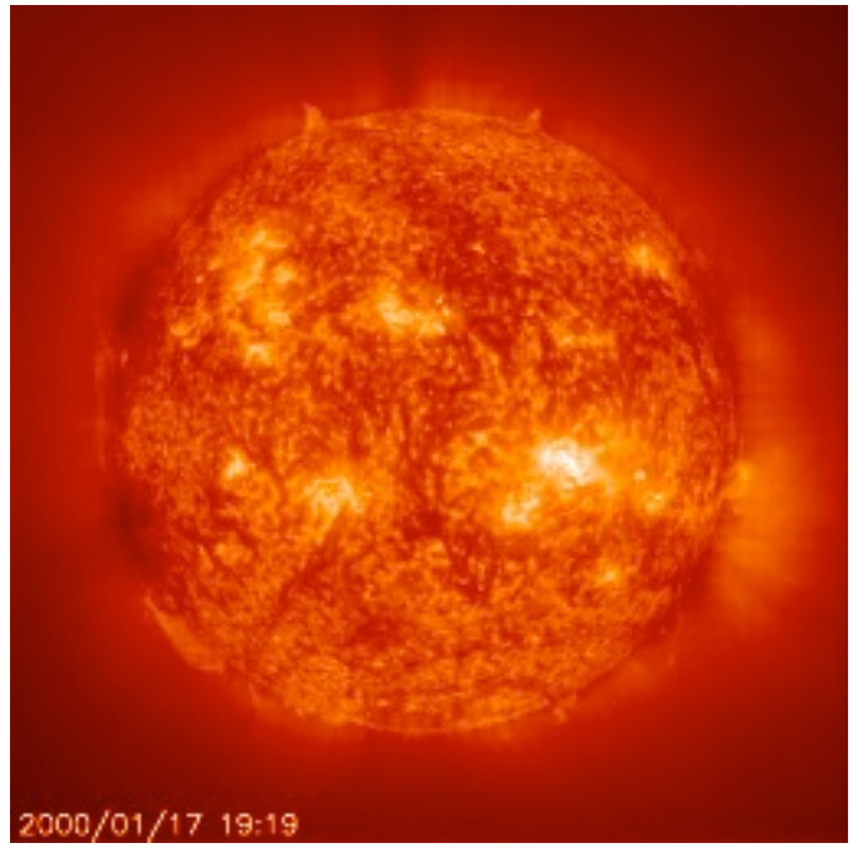
Coronal Mass Ejections



http://www.youtube.com/watch?v=GrnGi-q6iWc

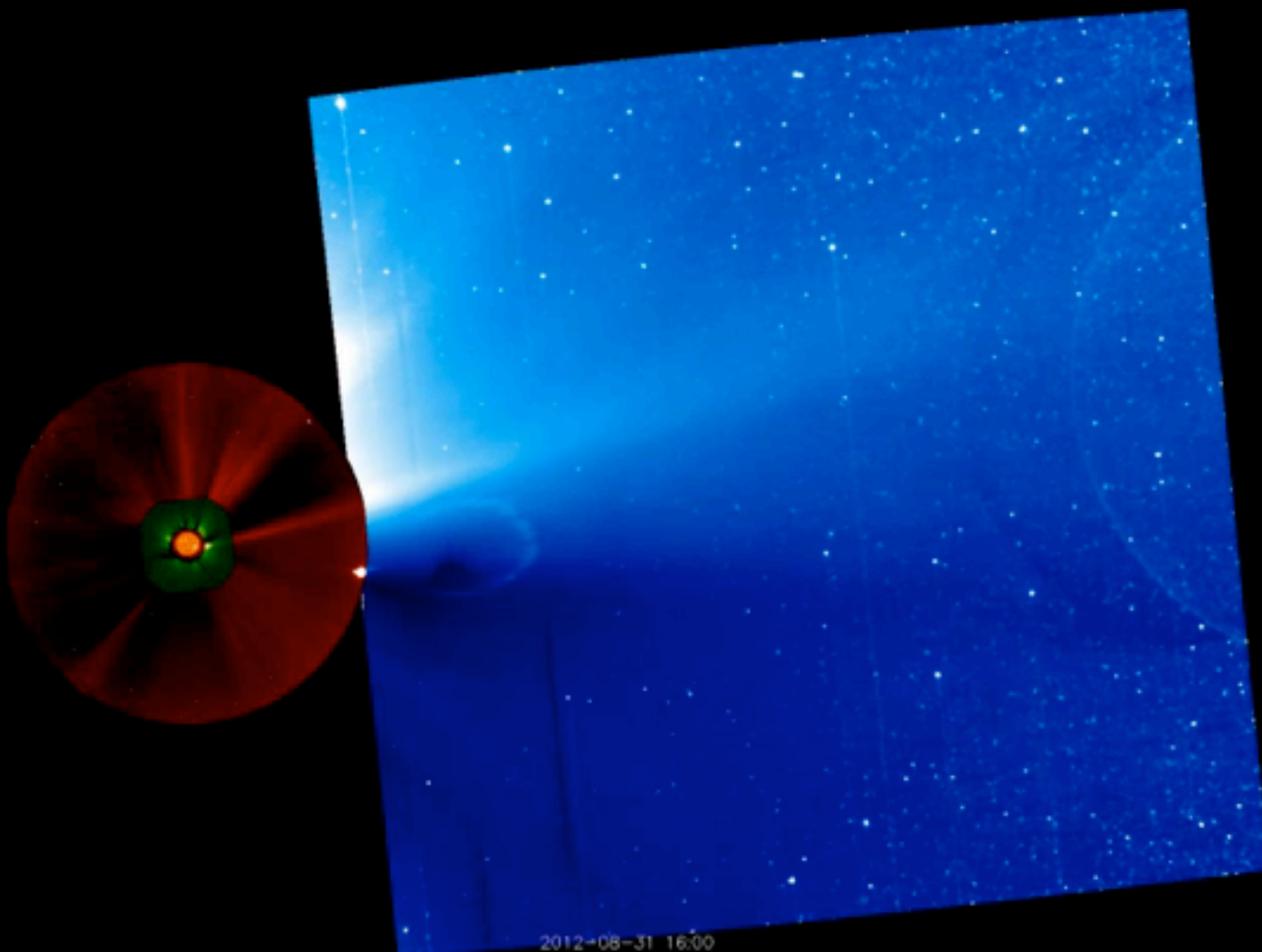
Coronal Mass Ejection: CME





A coronal mass ejection is a much larger eruption (at once) than a solar flare. CMEs eject immense amounts of gas.

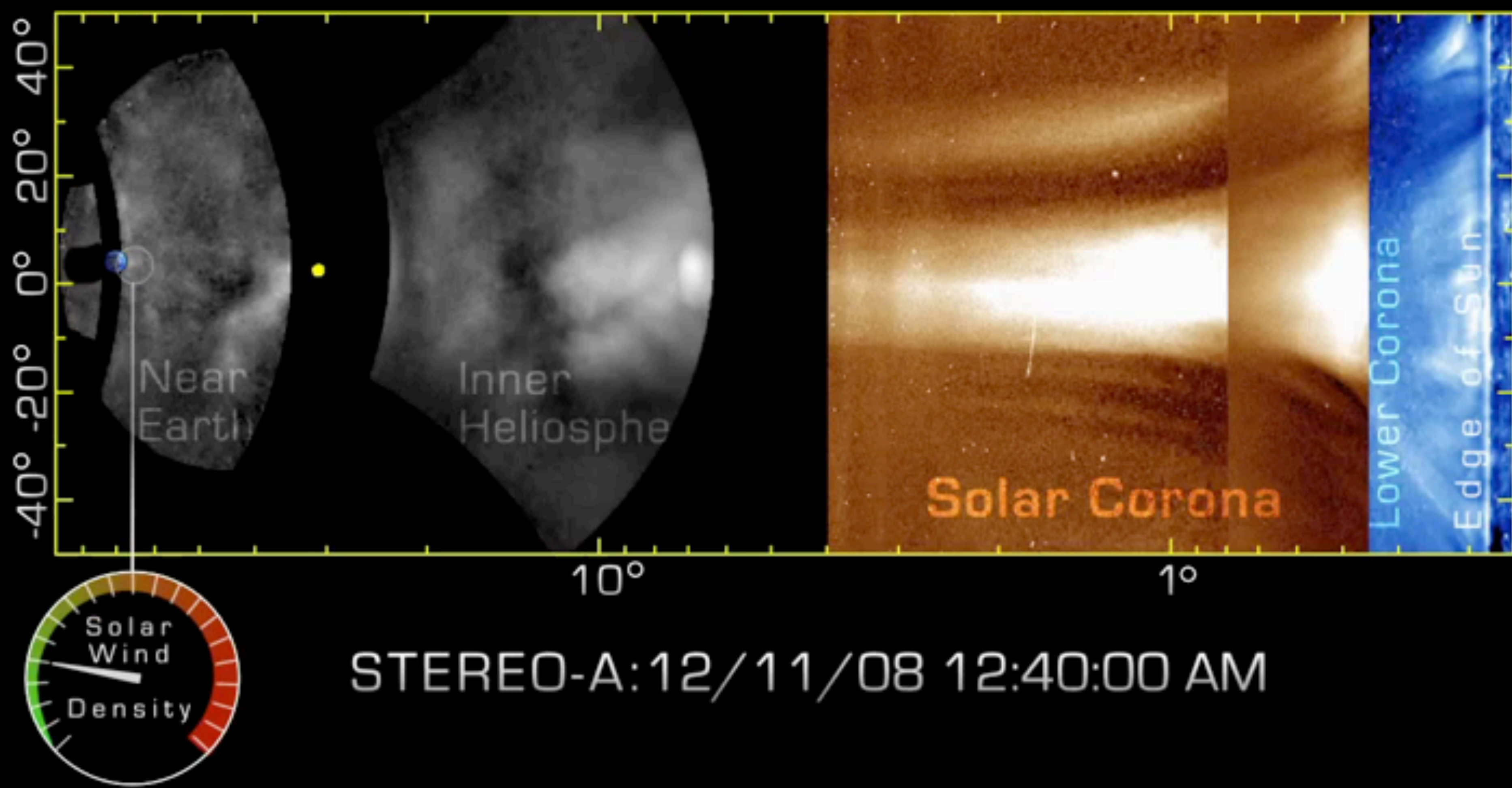
Coronal Mass Ejections



http://www.universetoday.com/97286/stereo-spots-a-cme-soaring-into-space/

Same CME with different view

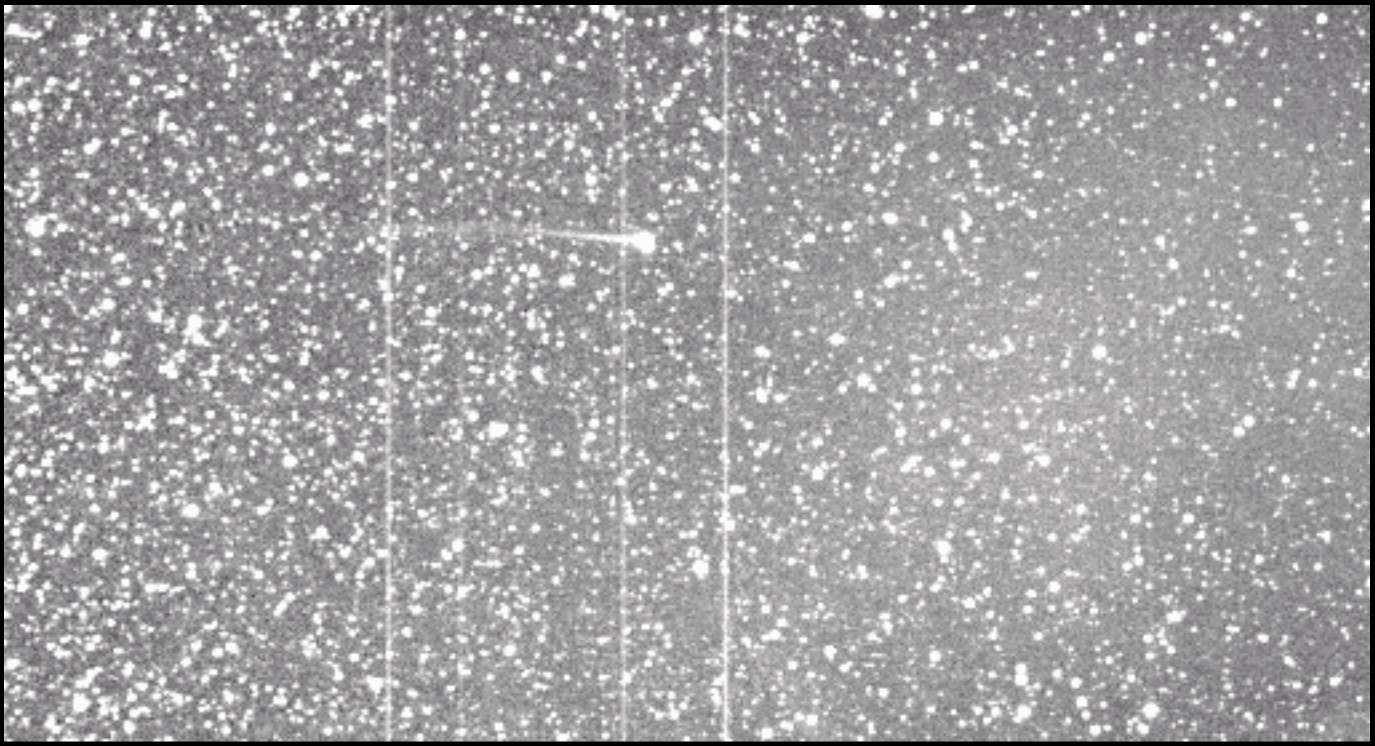
Coronal Mass Ejections



http://www.youtube.com/watch?v=B_xroLaoZYk

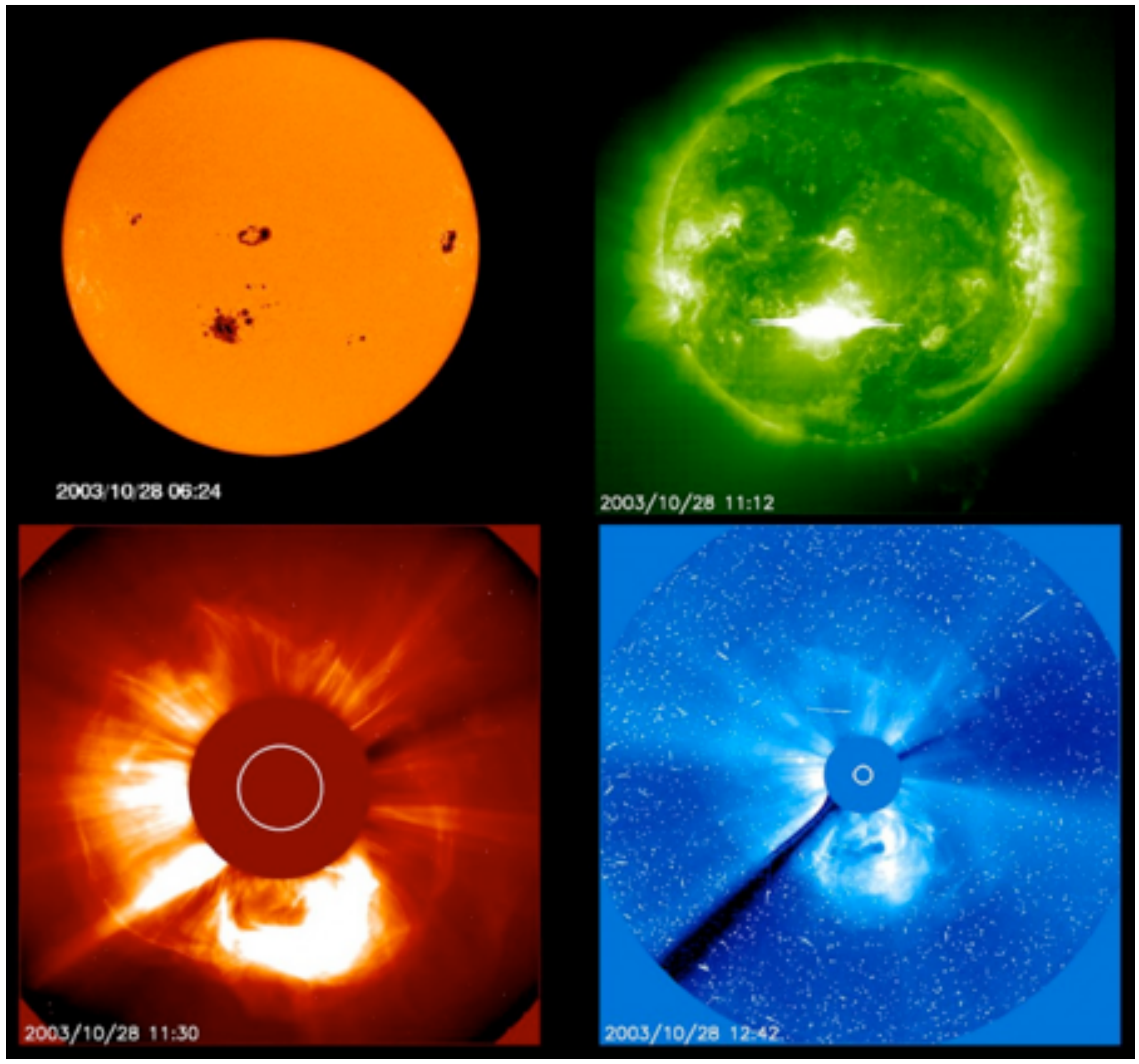
And impact with Earth

A CME Ripping Off Comet Encke's Tail



X17 Solar Flare and Solar Storm of October 28, 2003

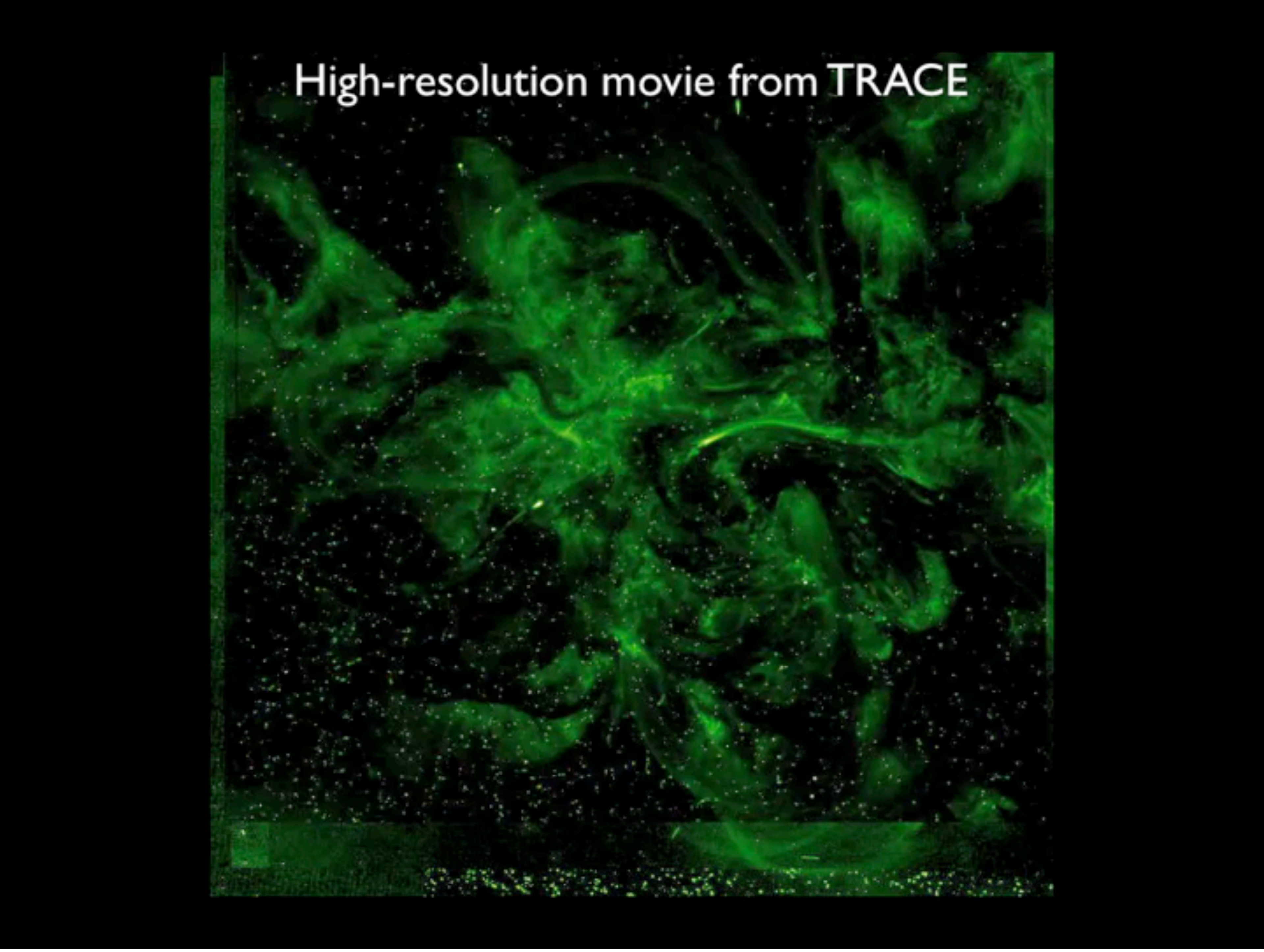
Images of the sunspot group, flare, and CME taken by the SOHO spacecraft



From the top left the orange image is a visible light image of the solar disk showing the sunspot group that produced the solar eruption. The green image is an extreme ultraviolet view of the sun including a bright flash from the X17 solar flare. The red image shows a view of the coronal mass ejection (CME) and the blue image shows a farther out view of the CME

On October 26th, Active Region 10486 had grown to over 10 times the diameter of the Earth and could be seen with the naked eye from Earth. Two days later the region was directly inline with our planet when it released a flare with the energy of fifty billion atomic bombs. The accompanying coronal mass ejection (CME) raced past SOHO at a phenomenal 2300 kilometers per second! Most CMEs take 2 to 3 days to cross the 150 million kilometers between the Sun and the Earth. This one made it in less than 18 hours!

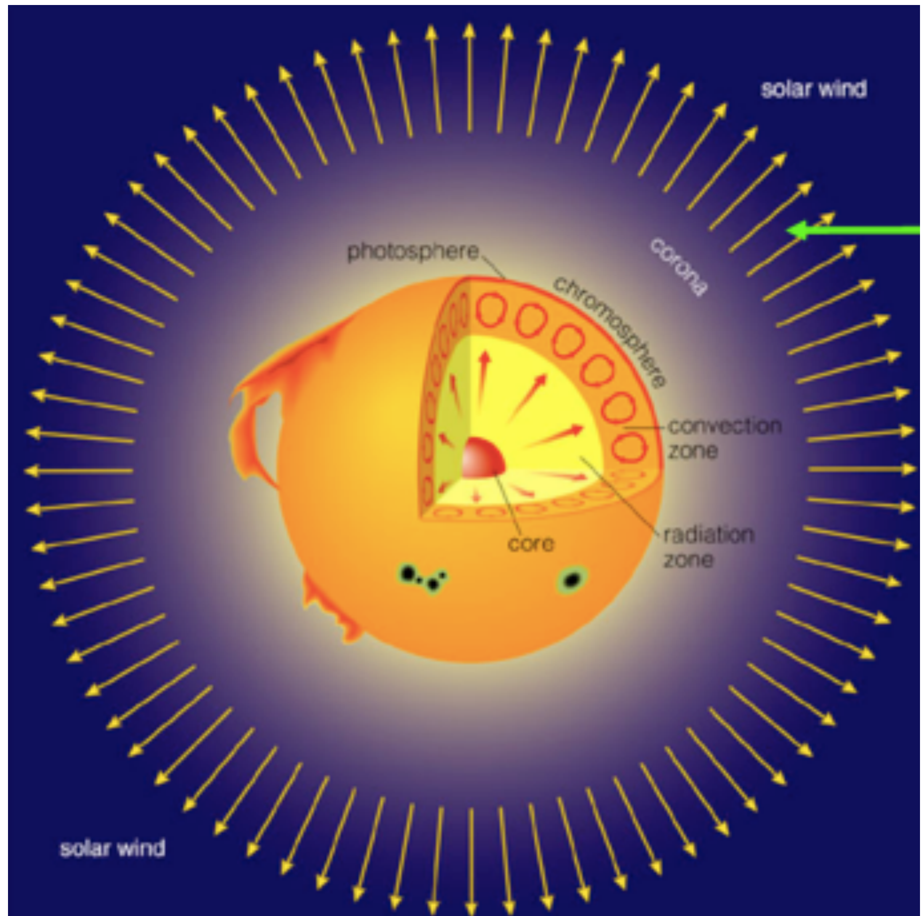
Many satellites in earth orbit began behaving erratically. Airlines redirected polar flights to below the Arctic circle, resulting in major delays across the US. Additionally, planes were instructed to fly at much lower altitudes (25,000 ft instead of 35,000 ft) where the thicker atmosphere protected the passengers and crew from harmful radiation. Power grids in Sweden were overloaded resulting in prolonged blackouts. Power consumption at two nuclear stations in New Jersey had to be reduced to prevent similar disruption. On the International Space Station astronauts had to take shelter in shielded parts of the station.



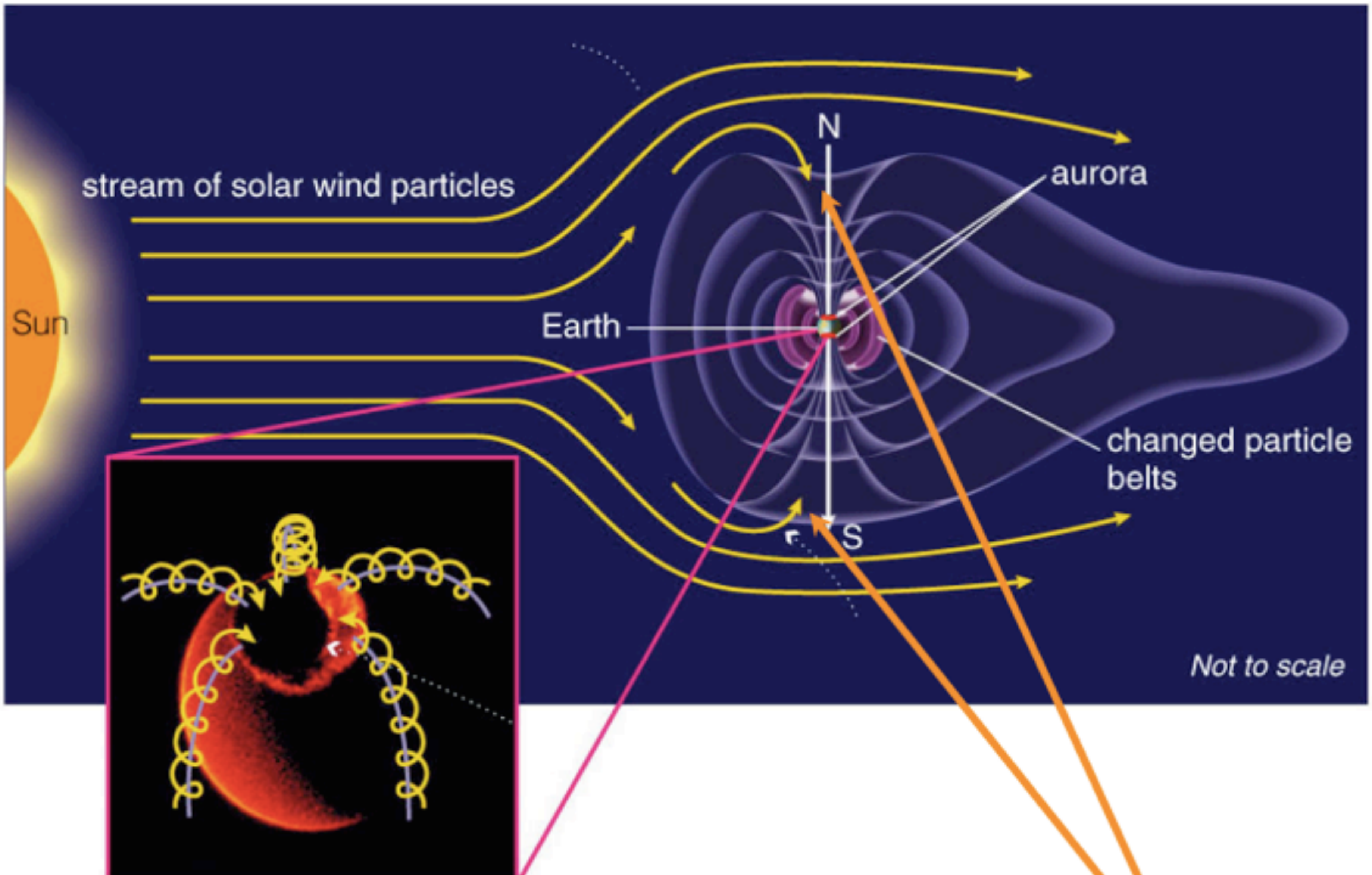
A high-resolution video of the October 2003 flare taken by NASA's TRACE (Transition Region and Coronal Explorer) satellite. TRACE gives scientists a close-up view of solar flares and sunspot groups thanks to higher spatial and temporal resolution.

Solar Wind

- Some of the gas in the Sun's corona is moving fast enough to escape the Sun's gravity
- Accelerated by the Sun's magnetic field
- Flows out into the solar system
- Made of charged particles



http://sohowww.nascom.nasa.gov/data/LATEST/current_c2.gif



Most solar wind particles are deflected by Earth's magnetic field, but some enter at the poles

Aurora Borealis (Northern Lights)

Joshua Strang, USAF, Wikipedia

Energetic solar wind particles that enter Earth's atmosphere can create *auroras*

Auroras are the interaction between the charged particles from the Sun and atoms in the Earth's atmosphere. Oxygen emission is green or brownish-red, and nitrogen is blue or red

The auroras happen closer to the poles because the Earth's magnetic field funnels the charged particles to the poles. The more solar activity, the more beautiful the auroras will be.

Southern Lights