

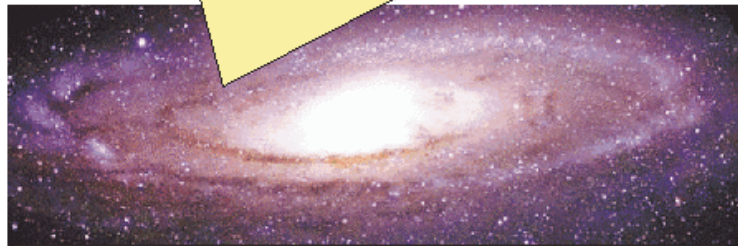
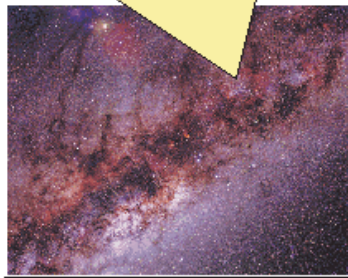
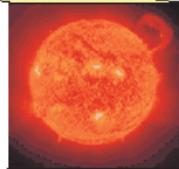
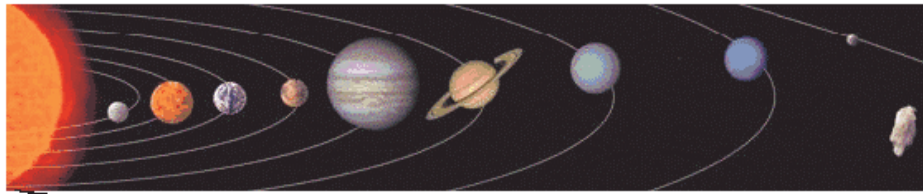


- Nighttime observing is over, but a makeup observing session may be scheduled. Stay tuned.
- Next homework due Oct 24th.
- I will not be here on Wednesday, but Paul Ricker will present the lecture!
- My Tuesday office hour is cancelled.

Outline



- We turn back to the Sun— our closest star.
- Structure
 - Interior, Photosphere, Chromosphere, Corona
- Limb Darkening
- Sunspots
- The 11 and 22 year Sun cycles
- The Sun's magnetic field



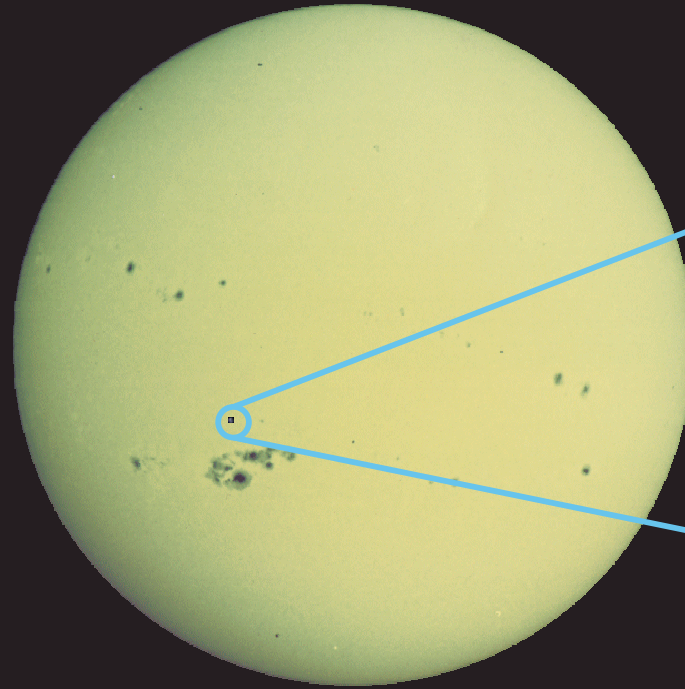
Astronomy: The Big Picture

Oct 13, 2003

Astronomy 100 Fall 2003

Earth – Sun comparison

In general, a very typical star. Emits most of its visible light from a thin region called the photosphere.



Visual radius

109 Earth

Mass

3.3×10^5 Earth

Luminosity

3.9×10^{33} erg/s

Surface temperature

5800 K

Central temperature

1.6×10^7 K

Equatorial rotation period

25 days

Comparing the Sun's energy output to everyday things



1 erg = a fly landing on your nose...



... Sun = 4×10^{33} flies on your nose *every second*

A 100W light bulb uses 1 billion ergs per second...



...the Sun could supply 4×10^{24} light bulbs!

U.S. electricity production in 2000: 3.8 trillion kWh = 1.4×10^{26} erg...



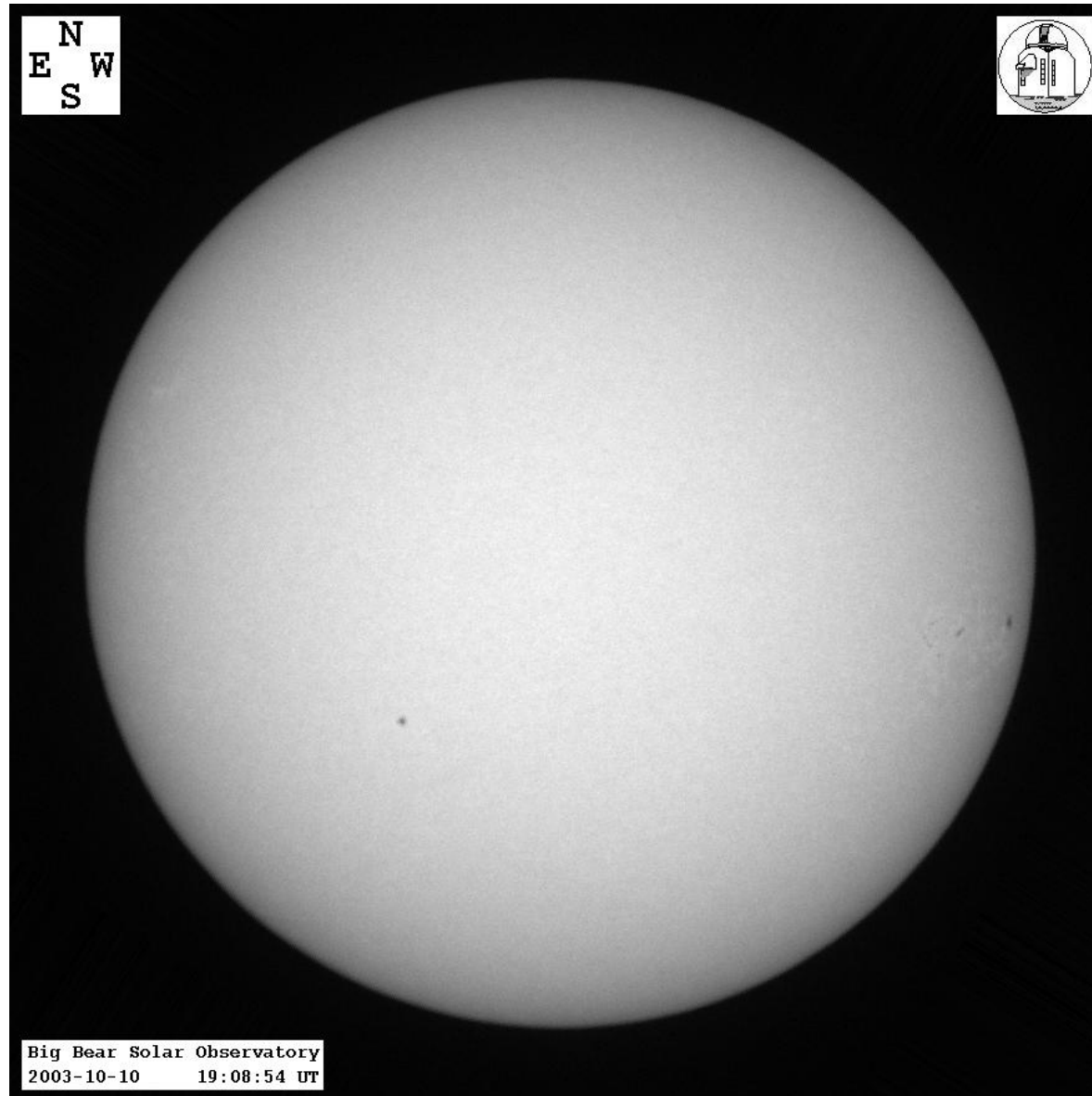
... Sun = 3×10^7 times this *every second*

World nuclear weapon stockpile: 3×10^4 megatons...

... Sun = 4 million times this *every second*



Today's Sun (Actually Friday's)



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<http://www.bbso.njit.edu/cgi-bin/LatestImages>

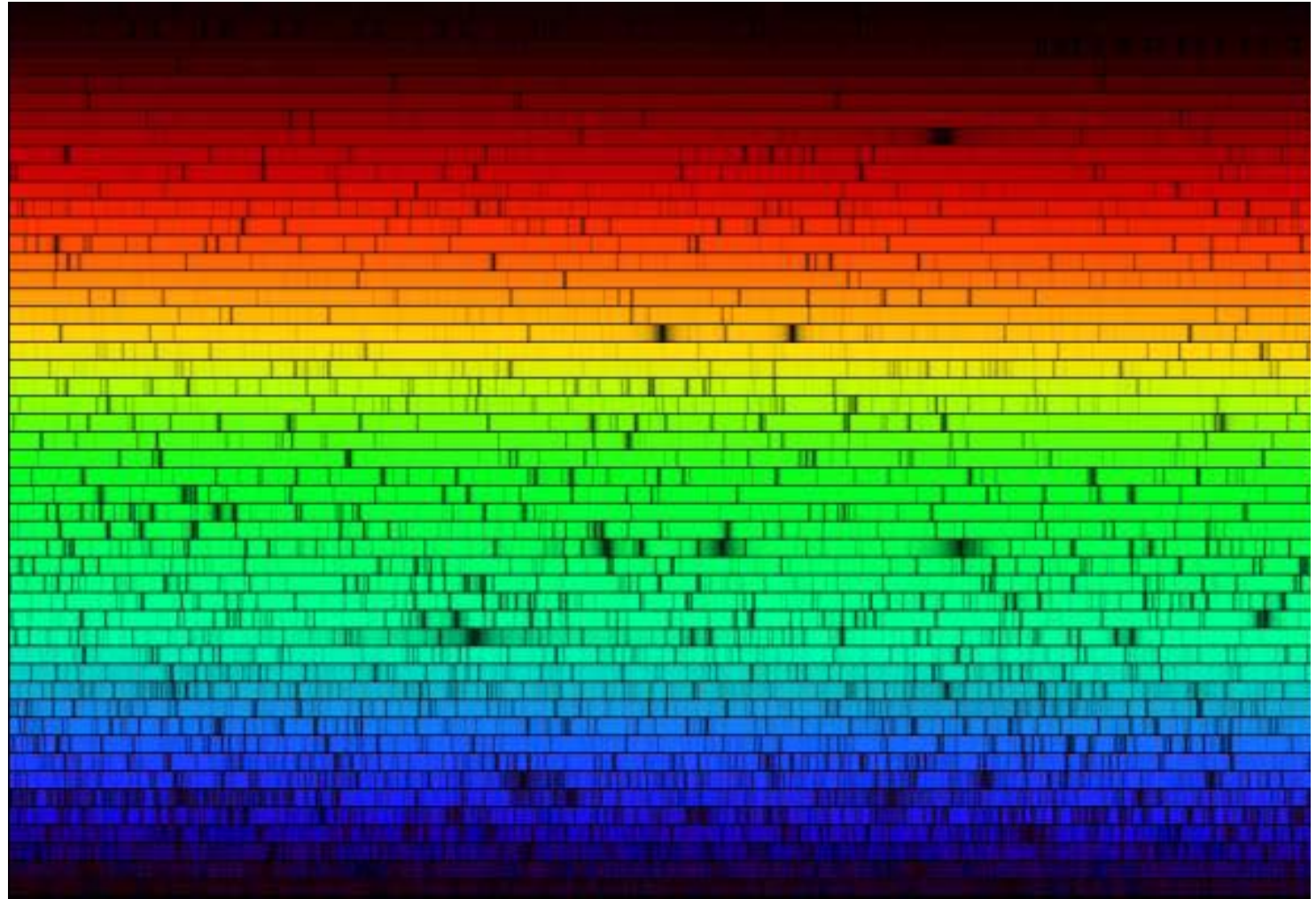
What Color is Sunlight?



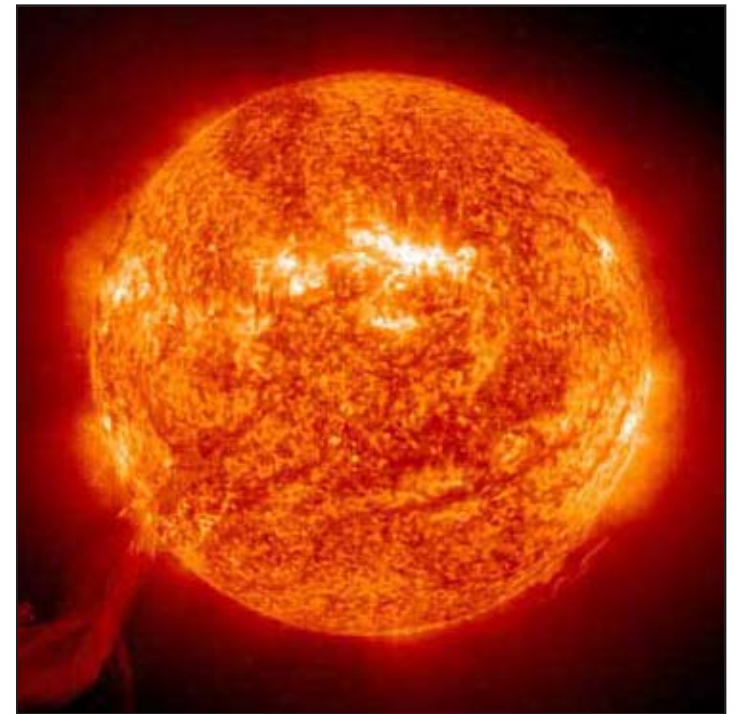
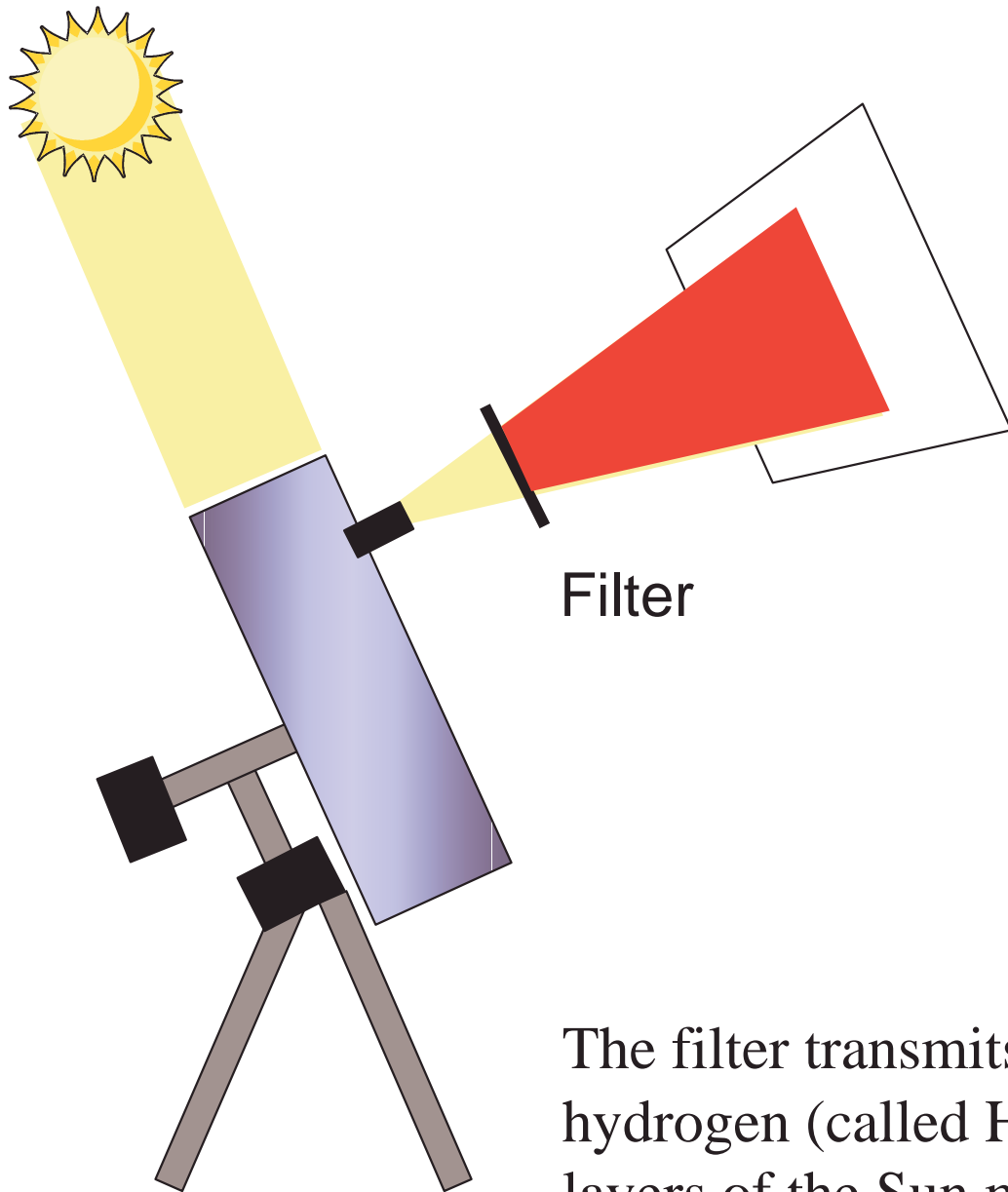
Spectrum of Sun
(prism-like). Is
indeed brighter
in the
yellow/green.

Dark spots are
absorption from
the surface.

Helium was first
detected in the
Sun.



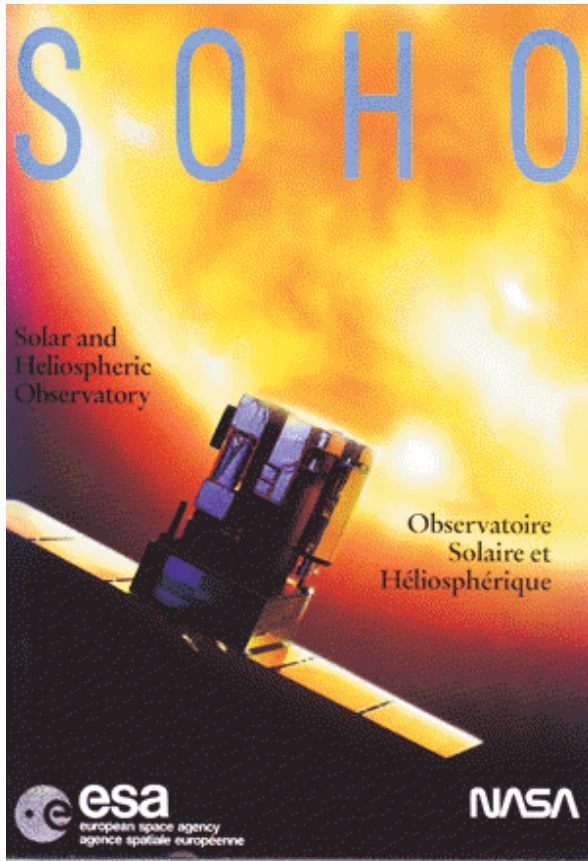
Safely Observing the Sun



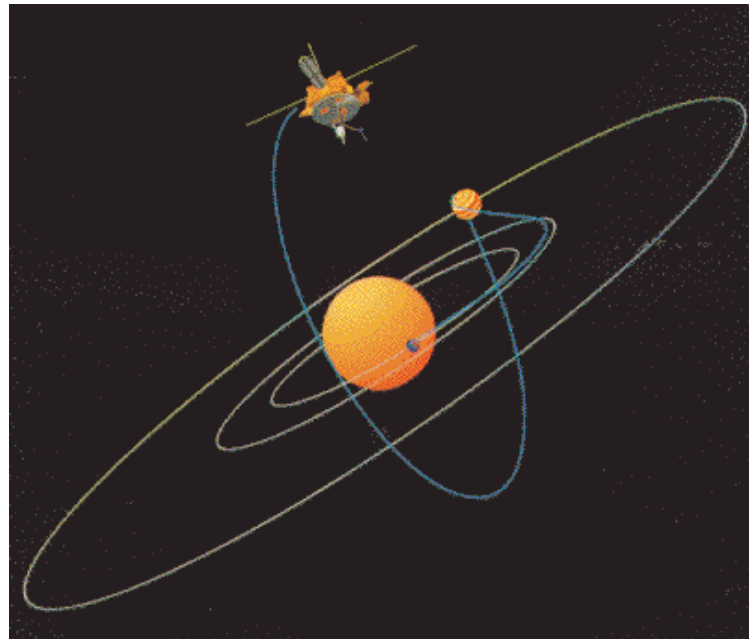
With H α filter

The filter transmits only the red light from hydrogen (called H α). This allows us to see other layers of the Sun more easily.

Some Spacecraft Now Observing the Sun



SOHO



Ulysses



TRACE

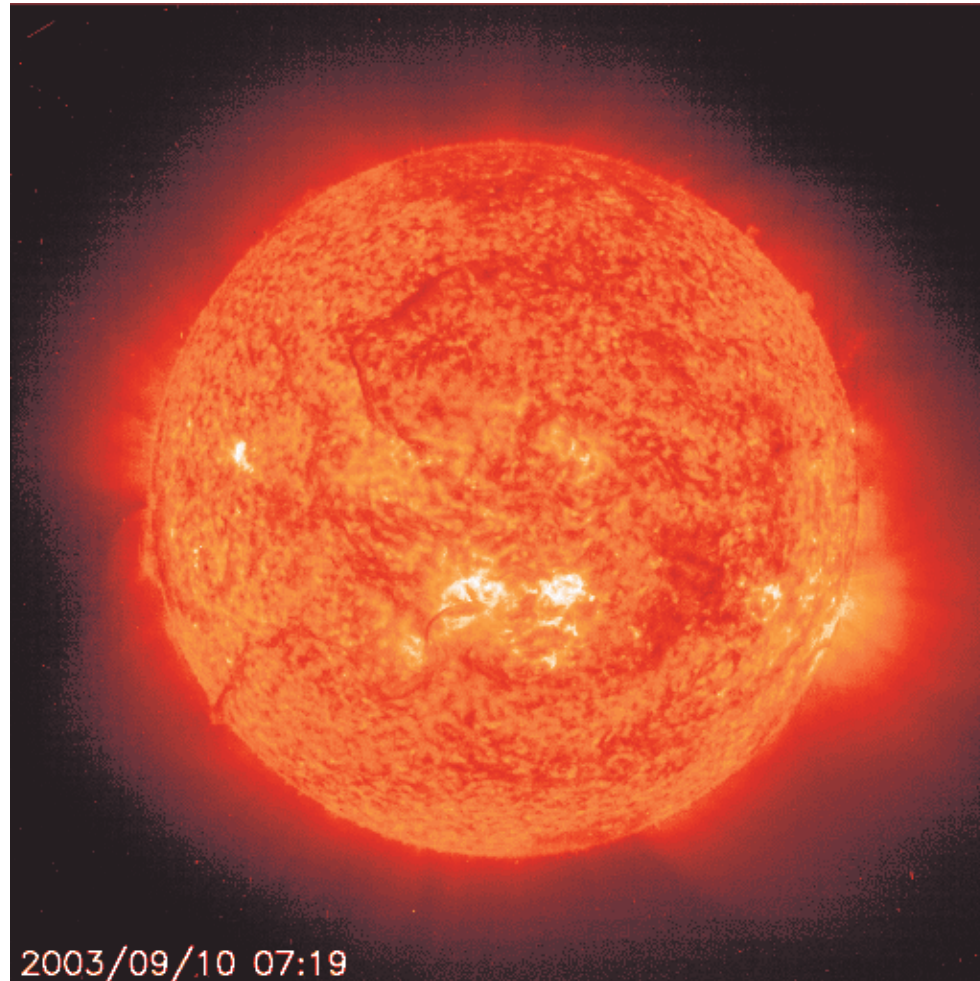
RHESSI



LIVE from the Sun



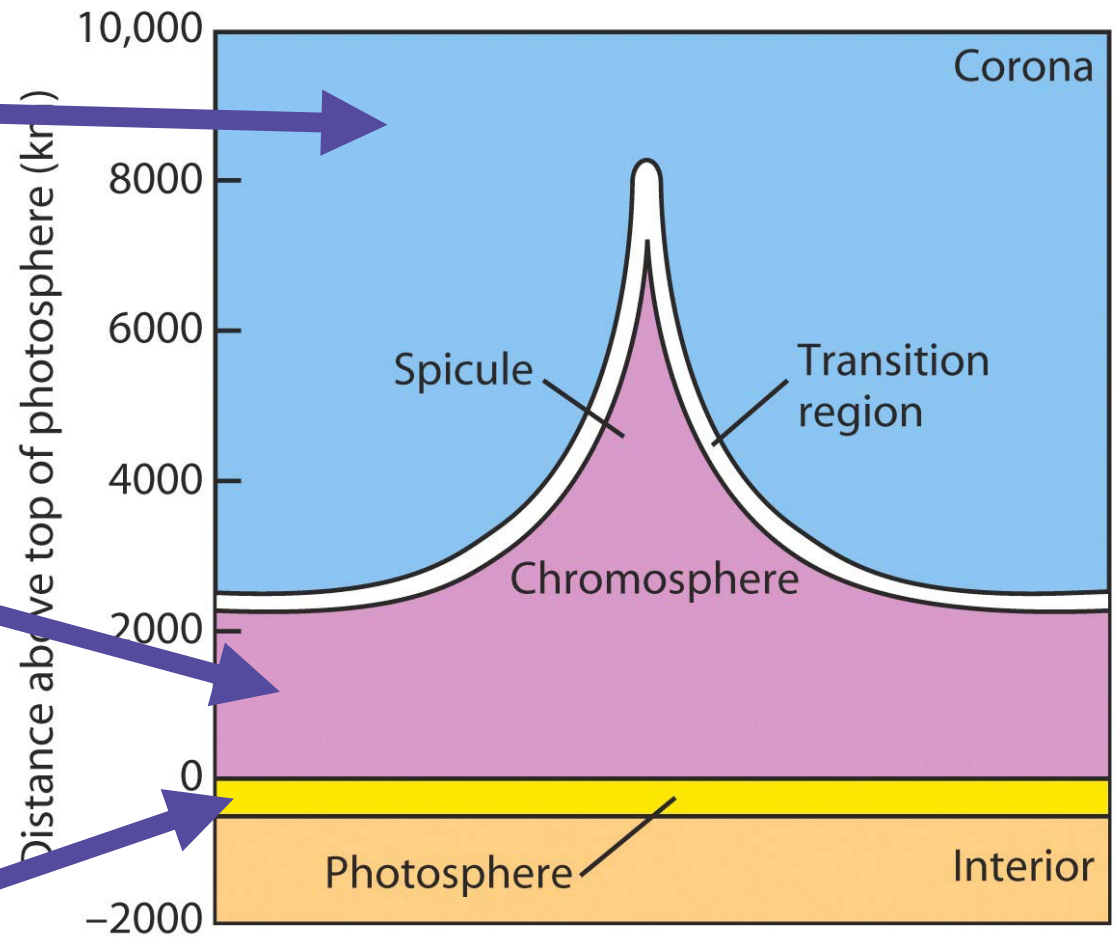
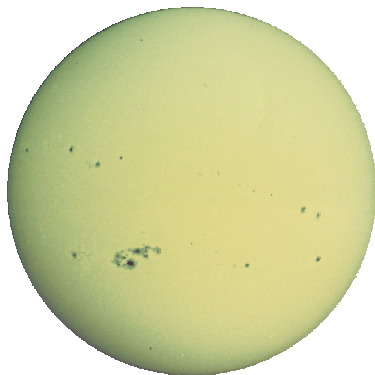
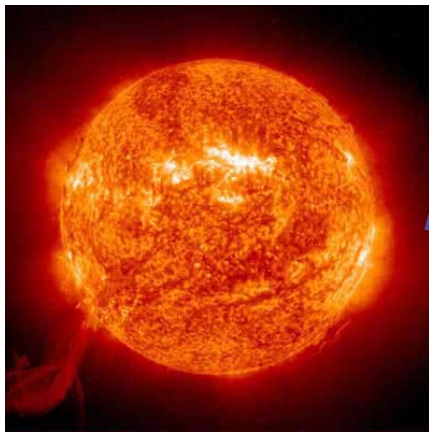
<http://sohowww.nascom.nasa.gov/data/realtime/mpeg/>



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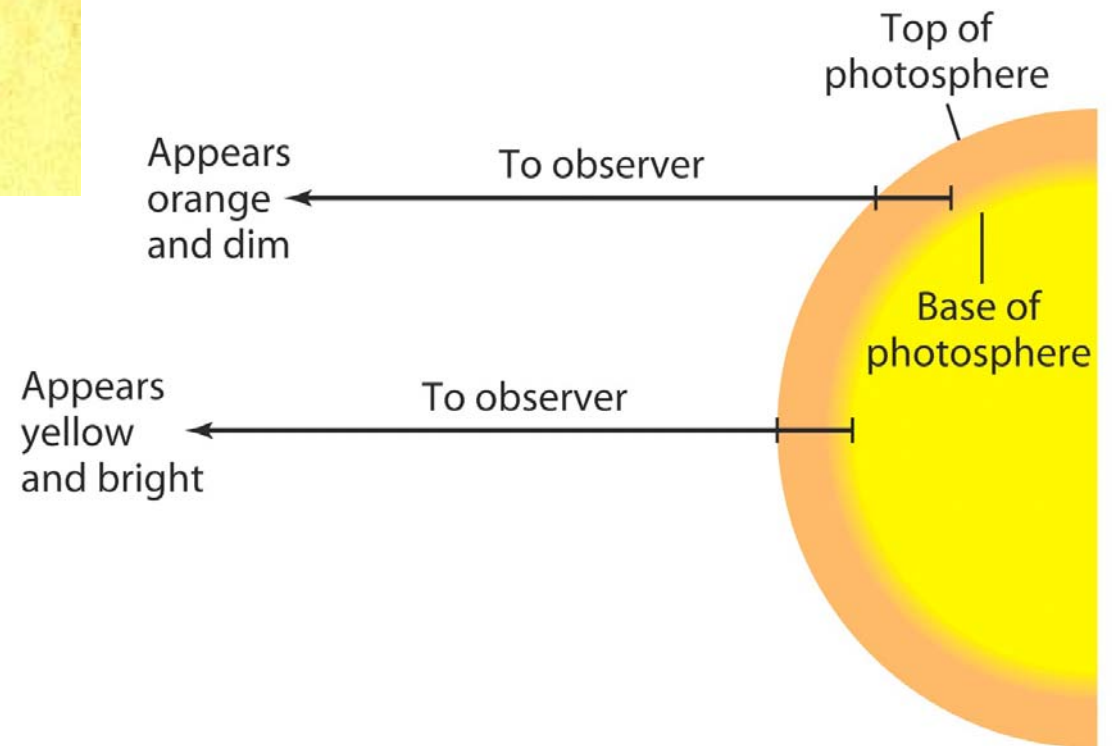
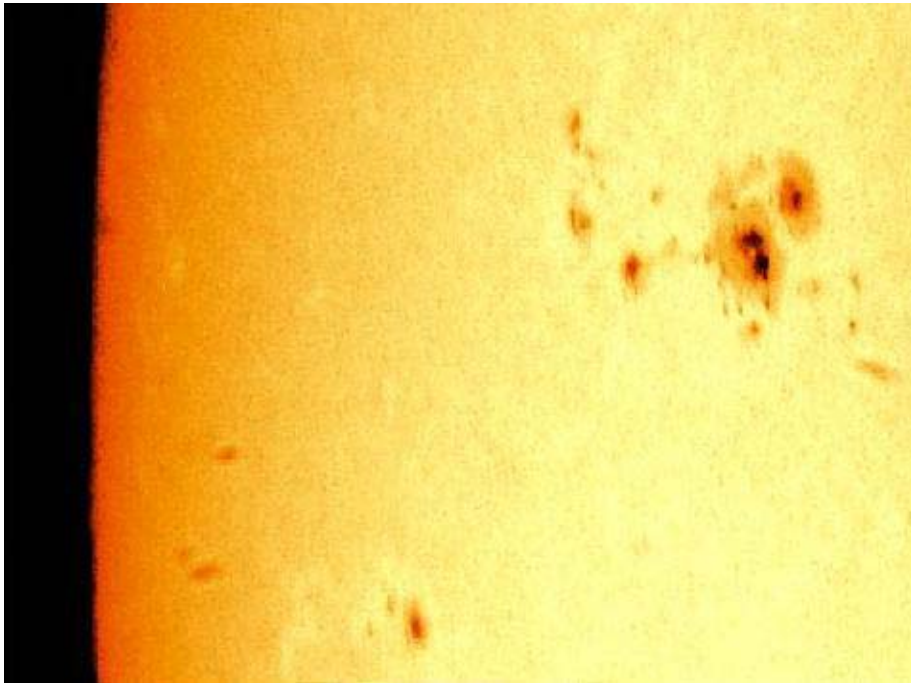
Structure of the Sun's outer layers



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Photosphere – Limb Darkening

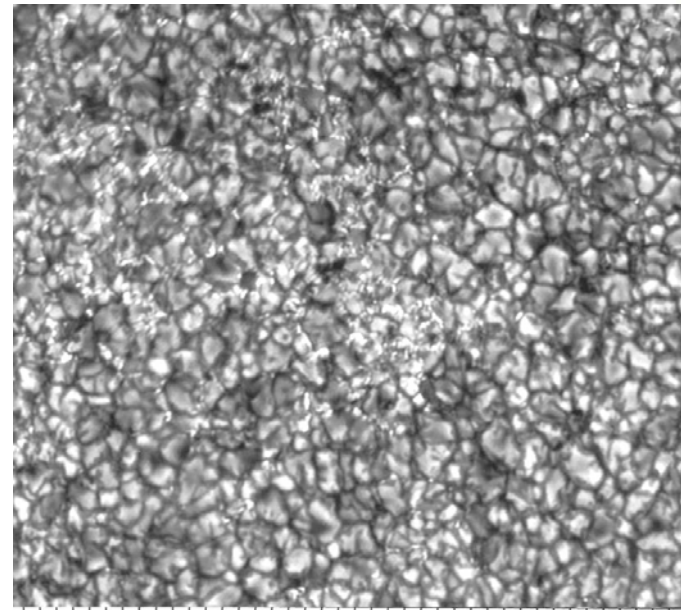


The Photosphere



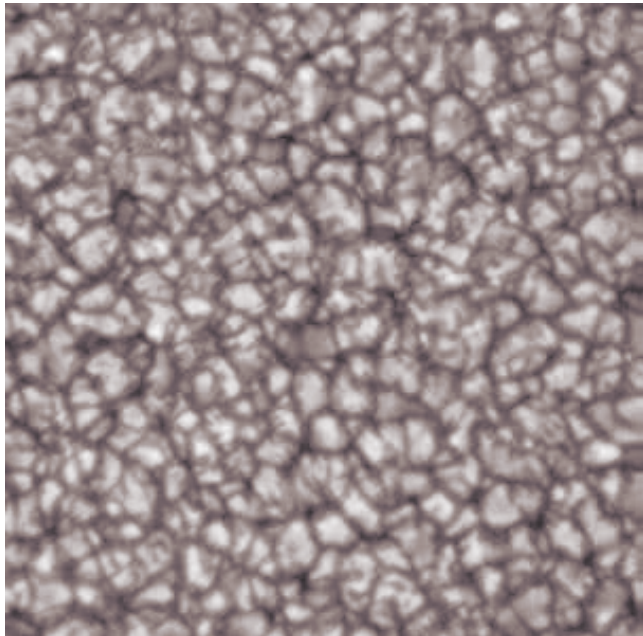
- **Photosphere**

- Where light starts to escape
- Features
 - Granules
 - Sunspots
- Temperature ~ 5800 K



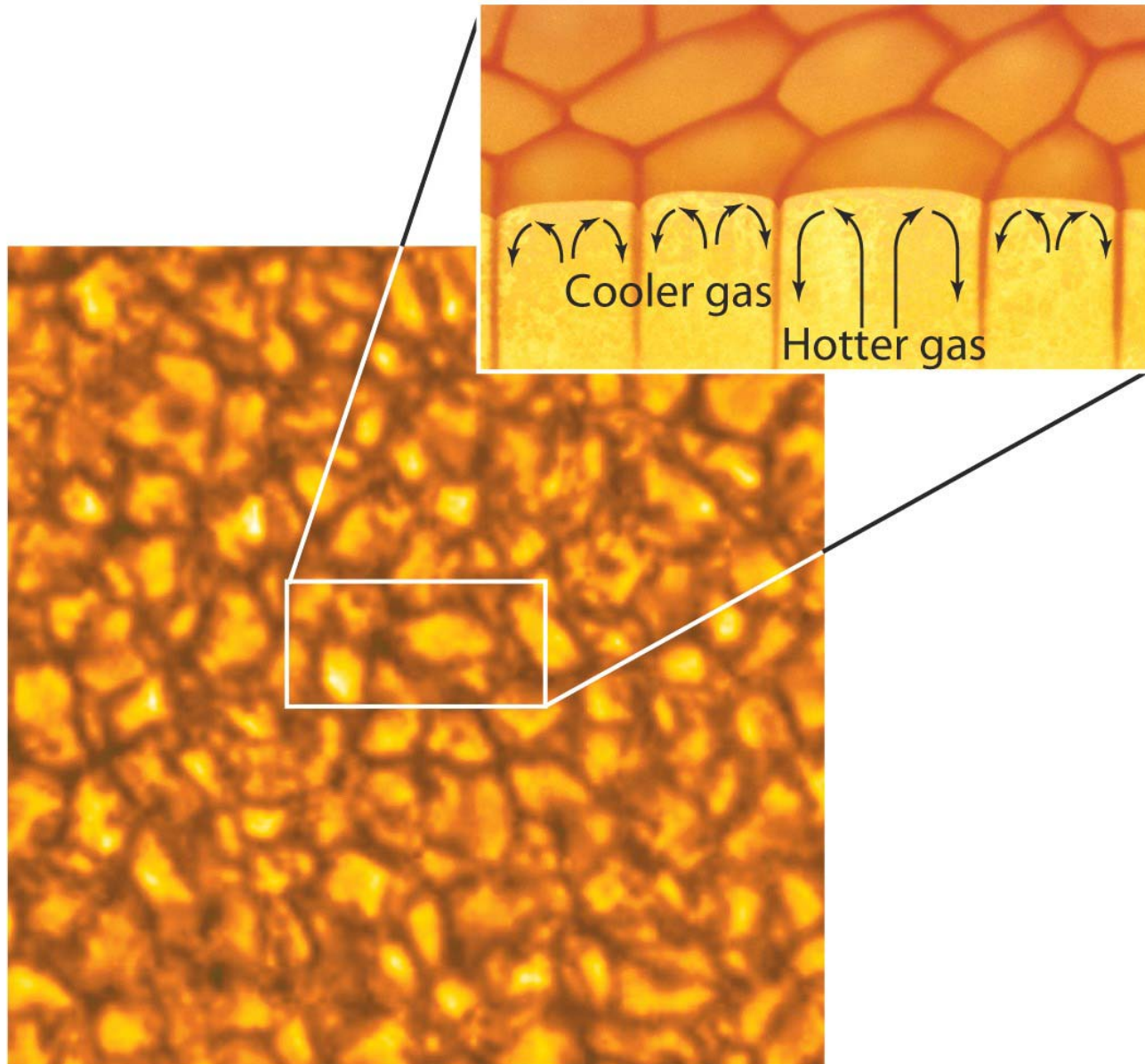
Photospheric granulation, G. Scharmer
Swedish Vacuum Solar Telescope
10 July 1997

Distance in units of
1000 kilometers



http://science.msfc.nasa.gov/ssl/pad/solar/images/SVST_granulation.mpg

Convection in the Sun's outer layers



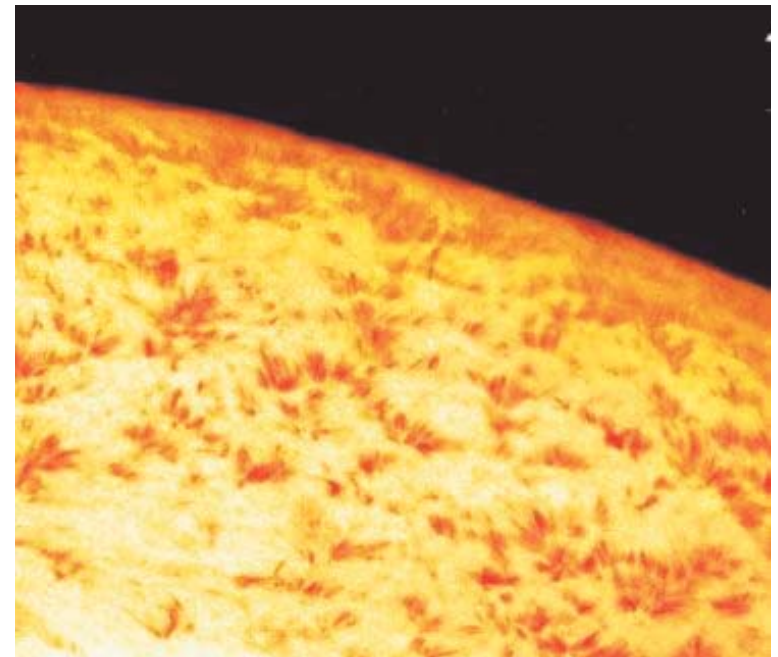
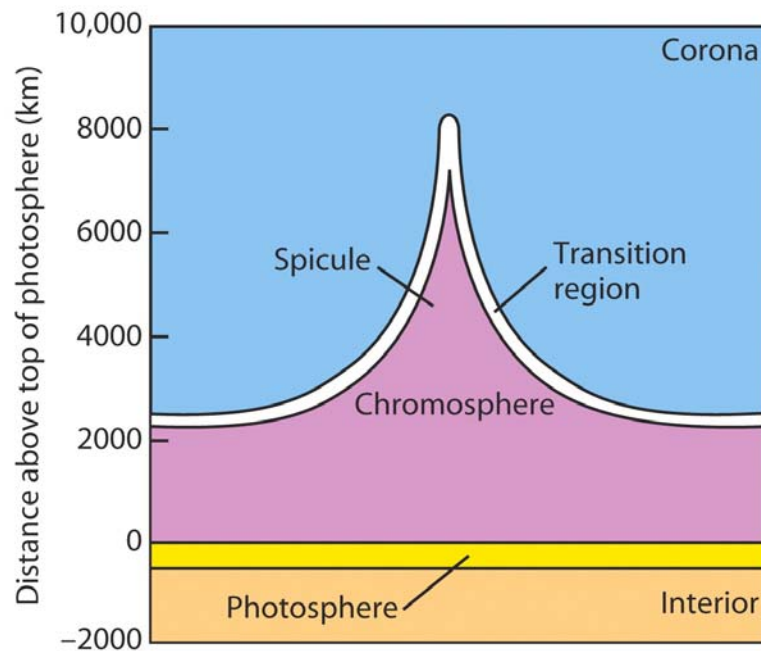
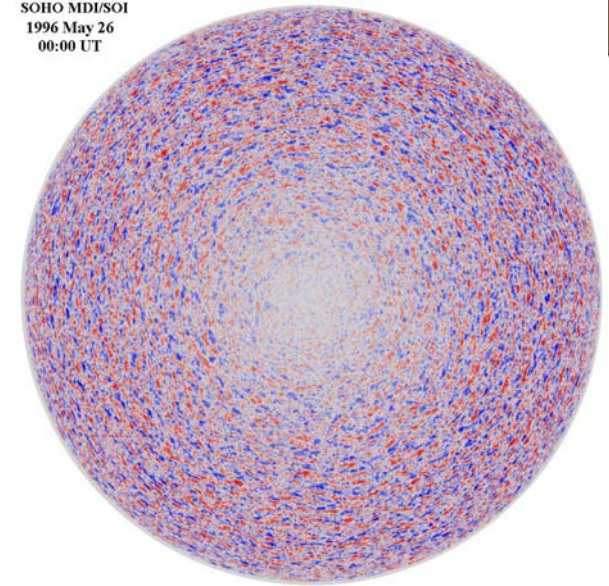
The Chromosphere



- **Chromosphere**

- Partly transparent gas above photosphere
- Features
 - Supergranules
 - Spicules
- Temperature $\sim 50,000$ K

SOHO MDI/SOI
1996 May 26
00:00 UT



Oct 13, 2003

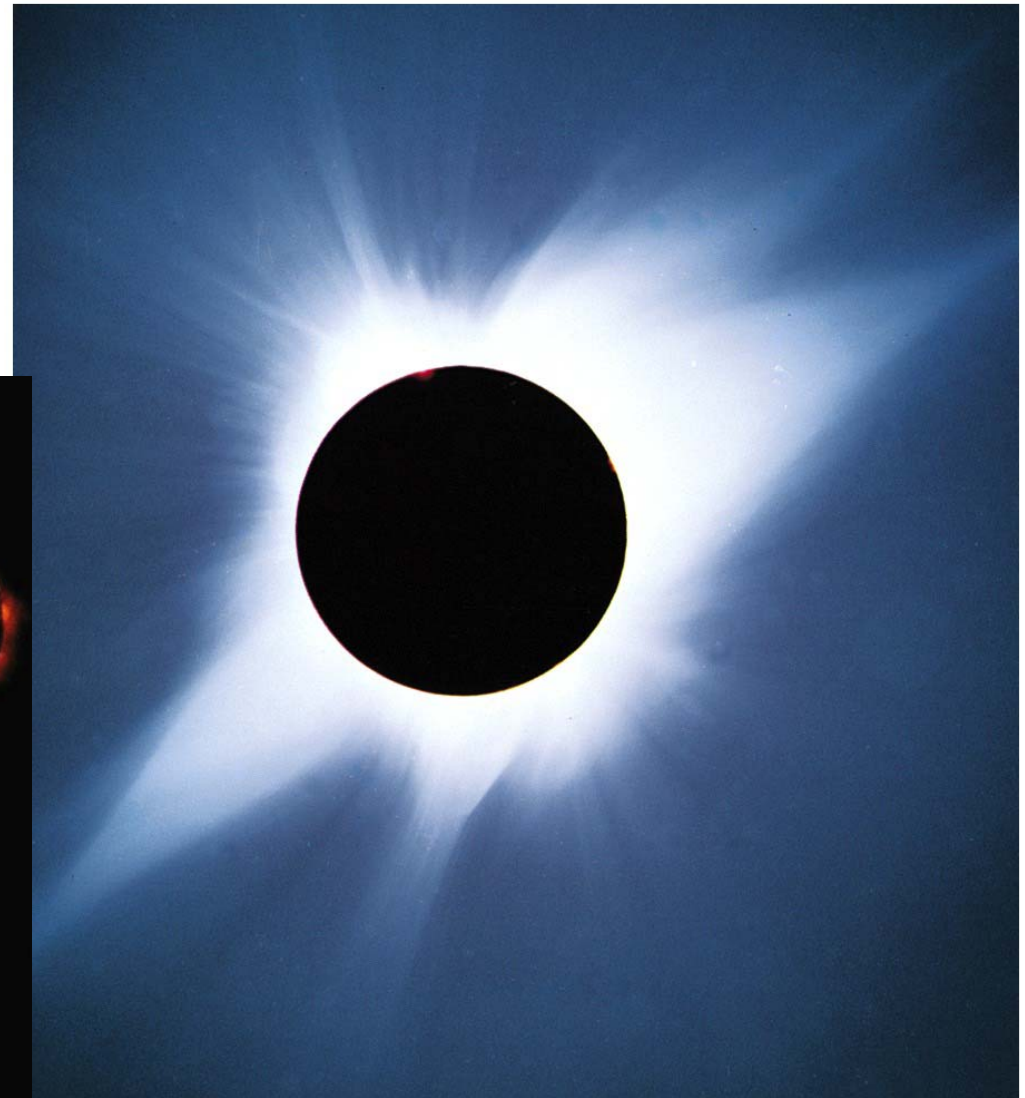
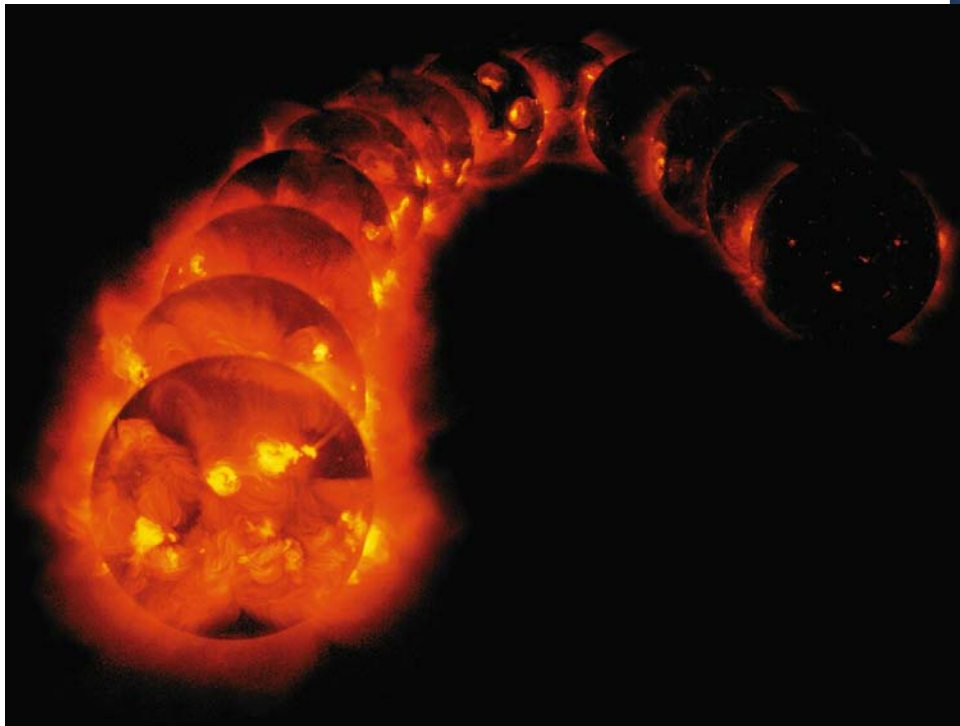
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<http://www.urania.be/sterrenkunde/zonnestelsel/zon.php>

The Corona



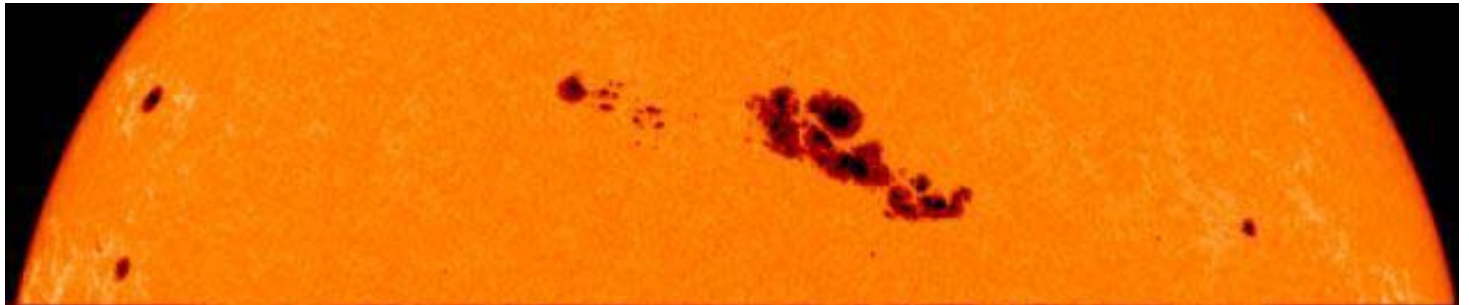
- Sun's outer atmosphere
- Visible only by blocking light from photosphere
- Mystery:
temperature $> 10^6$ K!



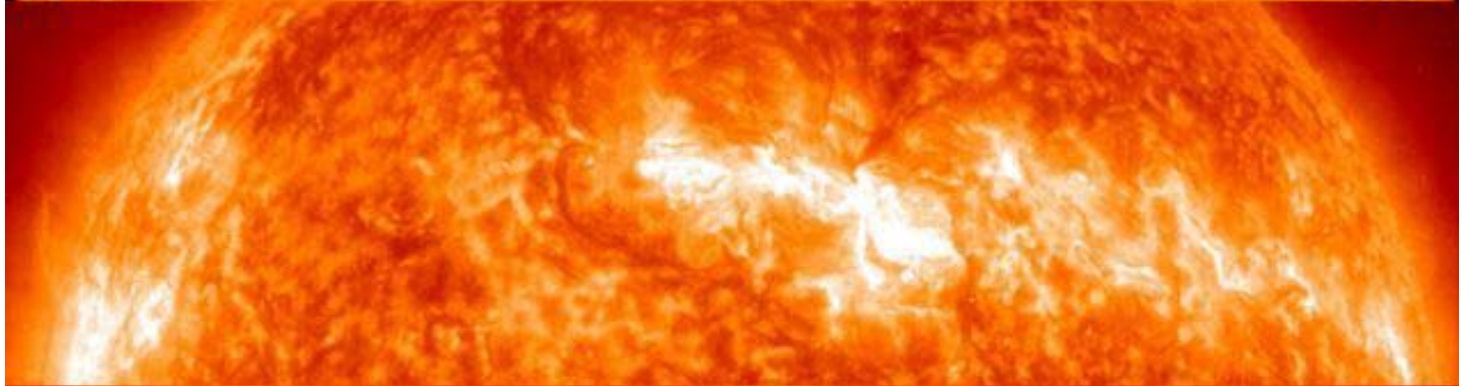
The Various Layers



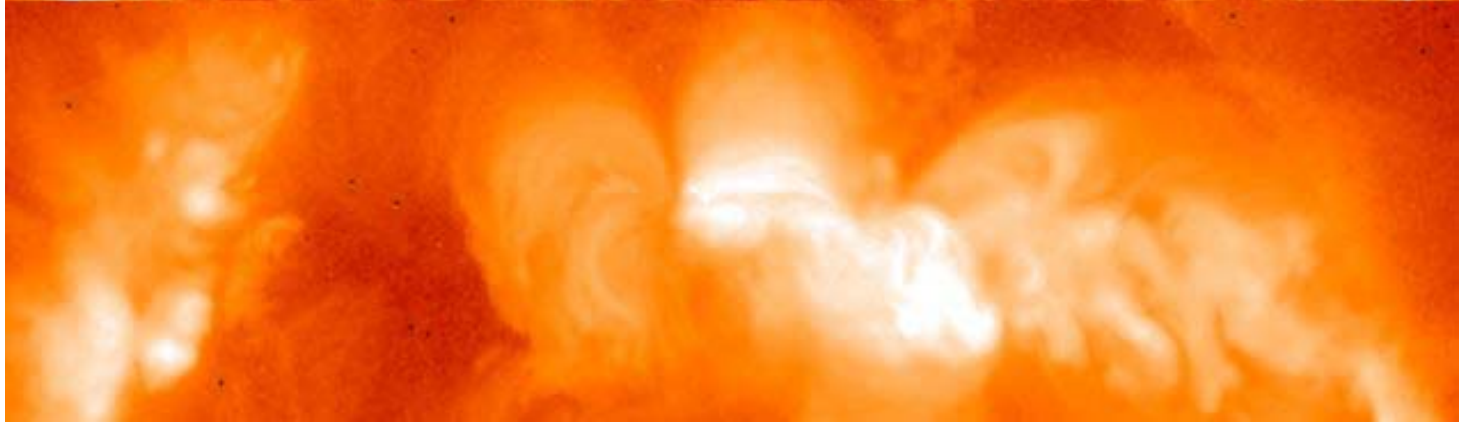
Photosphere
(optical)



Chromosphere
(ultraviolet)



Corona
(x-rays)



<http://antwrp.gsfc.nasa.gov/apod/ap010419.html>

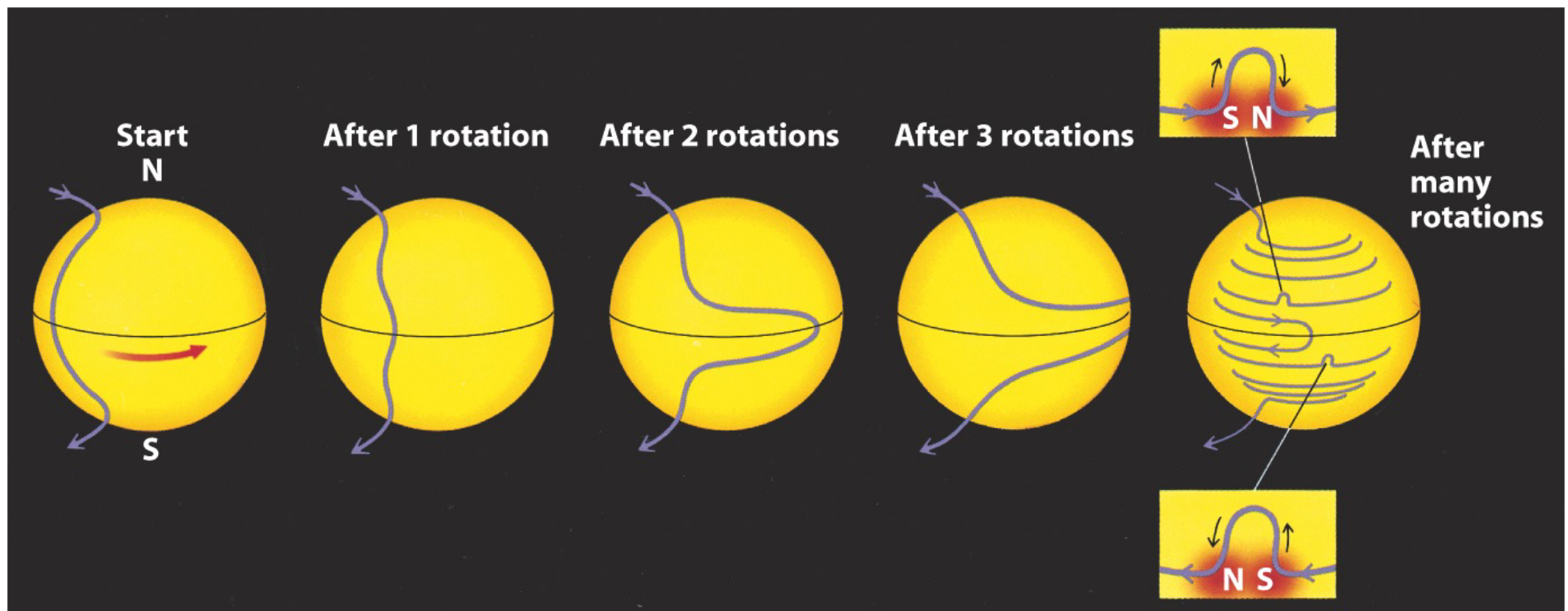
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The Sun's Magnetic Field



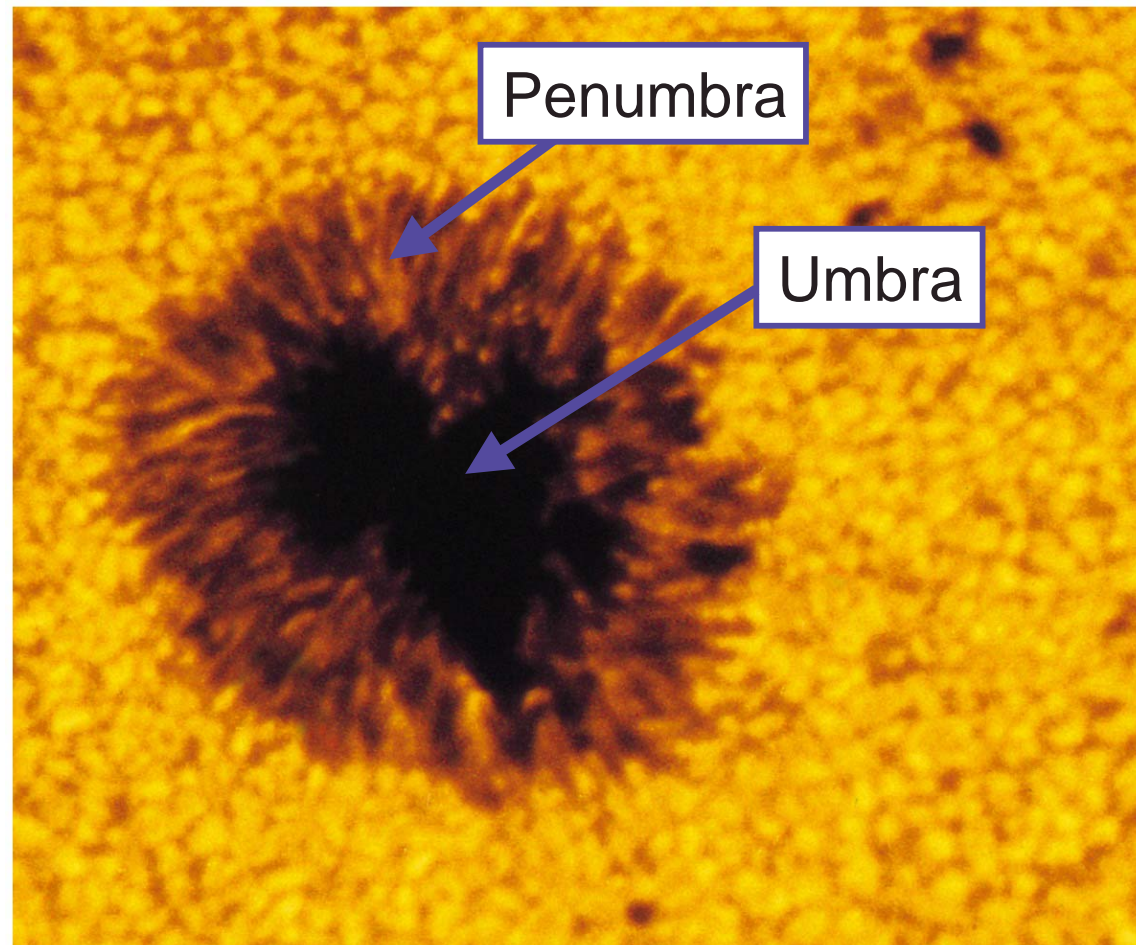
- Not a bar magnet!
- Convection and differential rotation twist and wrap field lines
- Unlike the Earth or even Jupiter, the magnetic field is from the surface of the Sun, not the interior (from the plasma— ionized gas at surface)



Sunspots



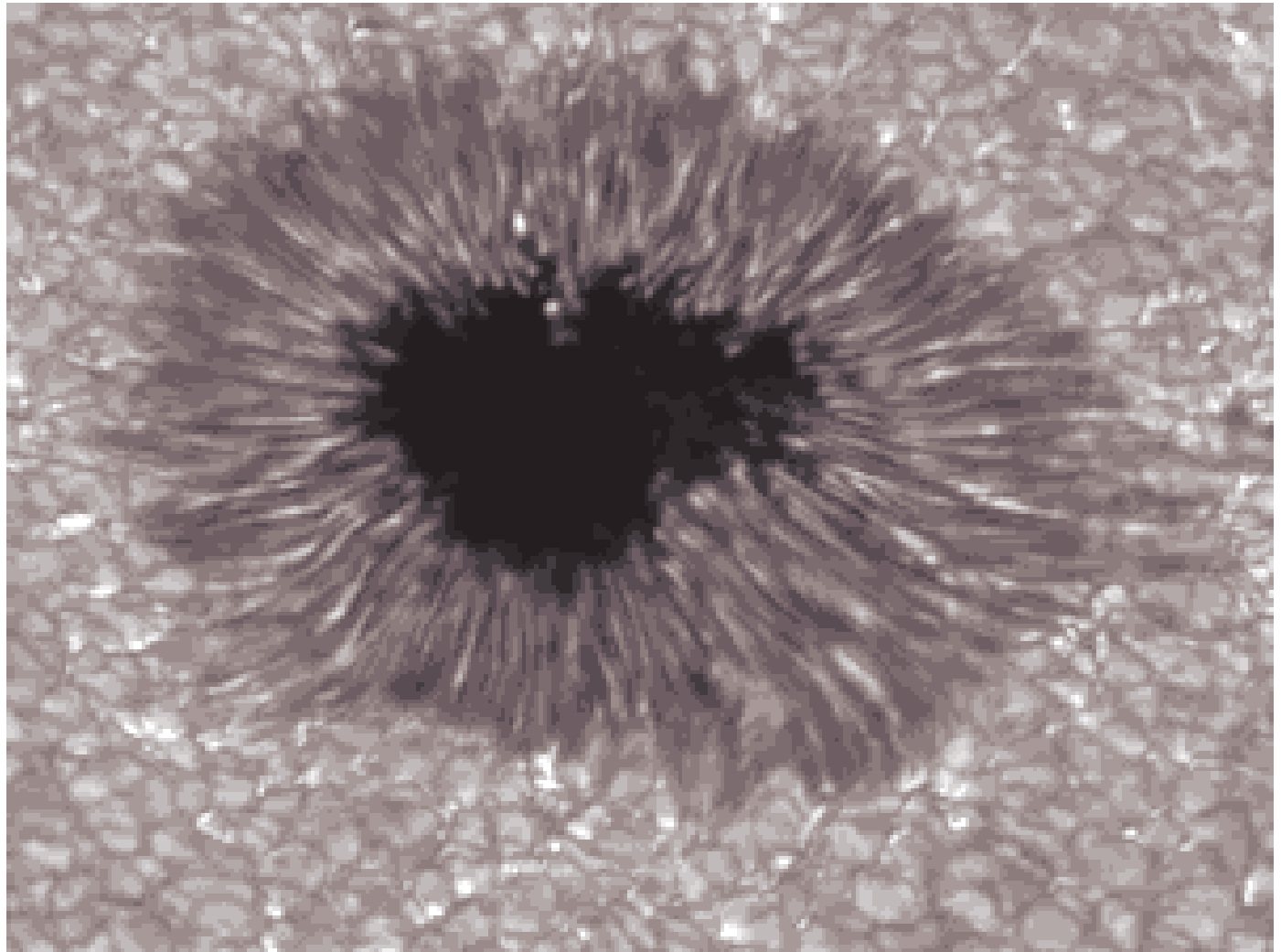
- Magnetic field “loops” popping through photosphere
- Cooler than surroundings (4000 K) – but still hot!
- Sizes ~ 1,500 – 50,000 km



Sunspots



- Can be used to find the rotation rate of Sun.
- Usually last for around 2 months.

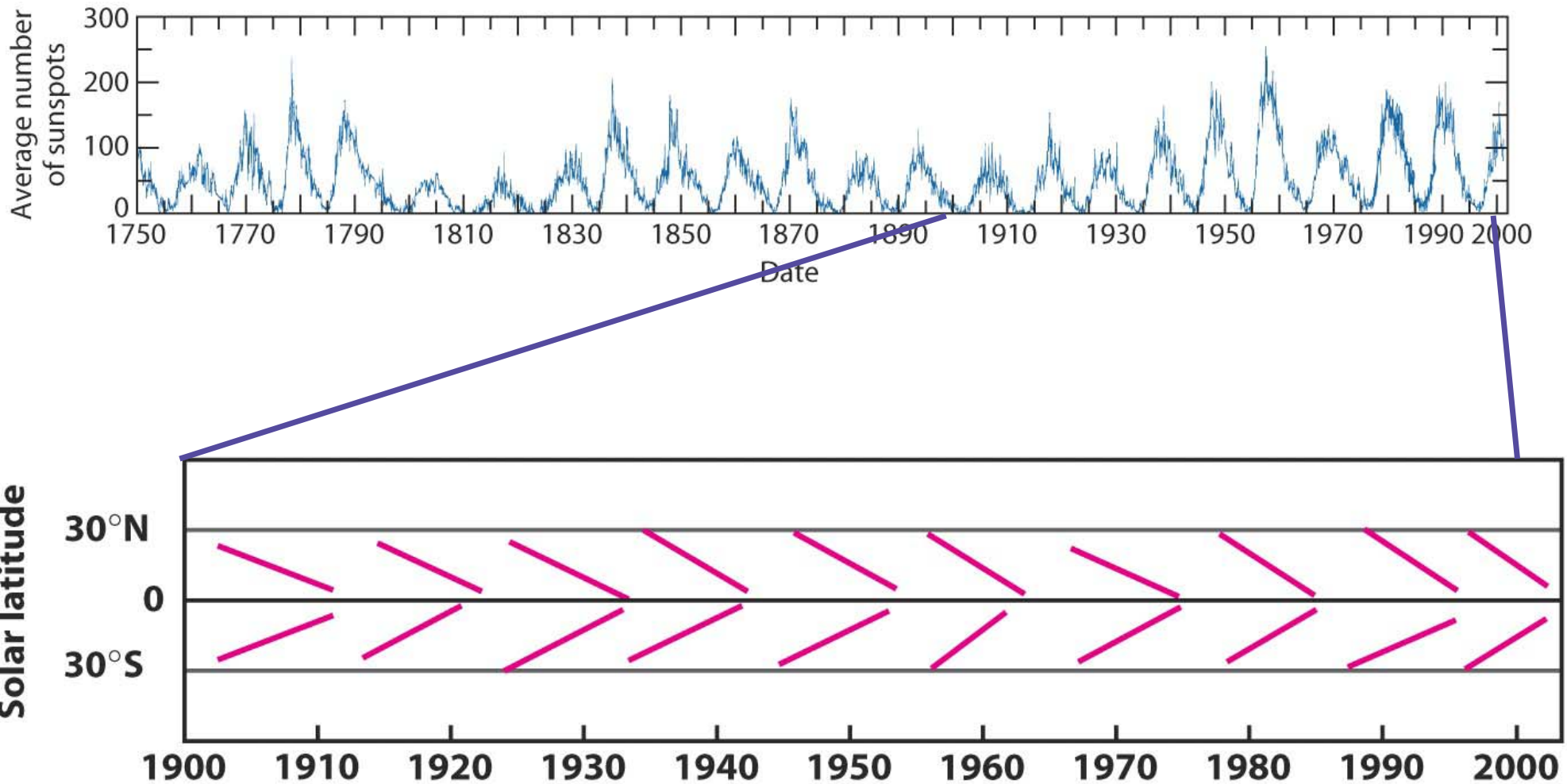


<http://antwrp.gsfc.nasa.gov/apod/ap000223.html>

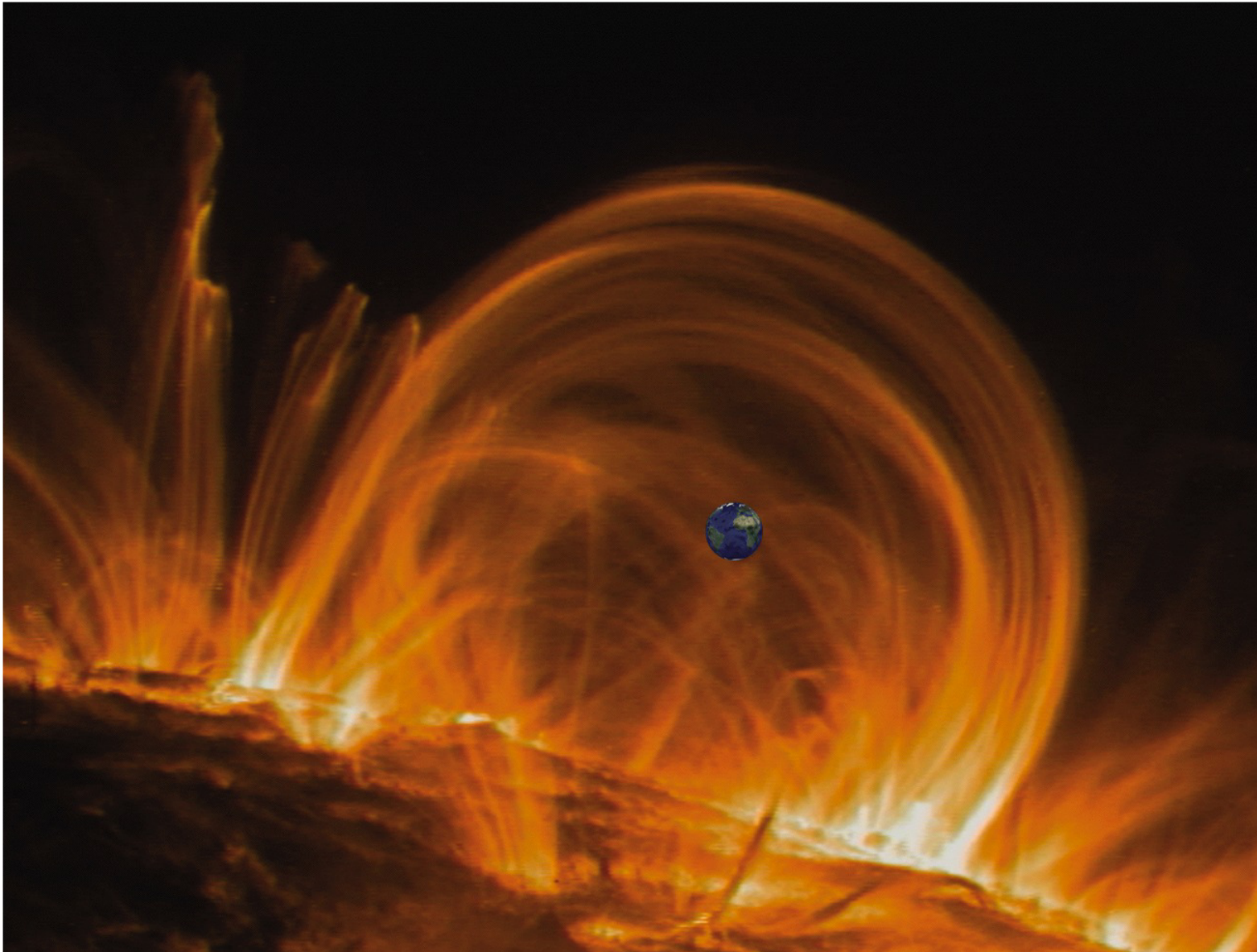
Sunspot Cycles



- Start near 30°N/S , migrate toward equator
- More numerous every 11 years (**solar maximum**)
- Magnetic field reversal every 22 years

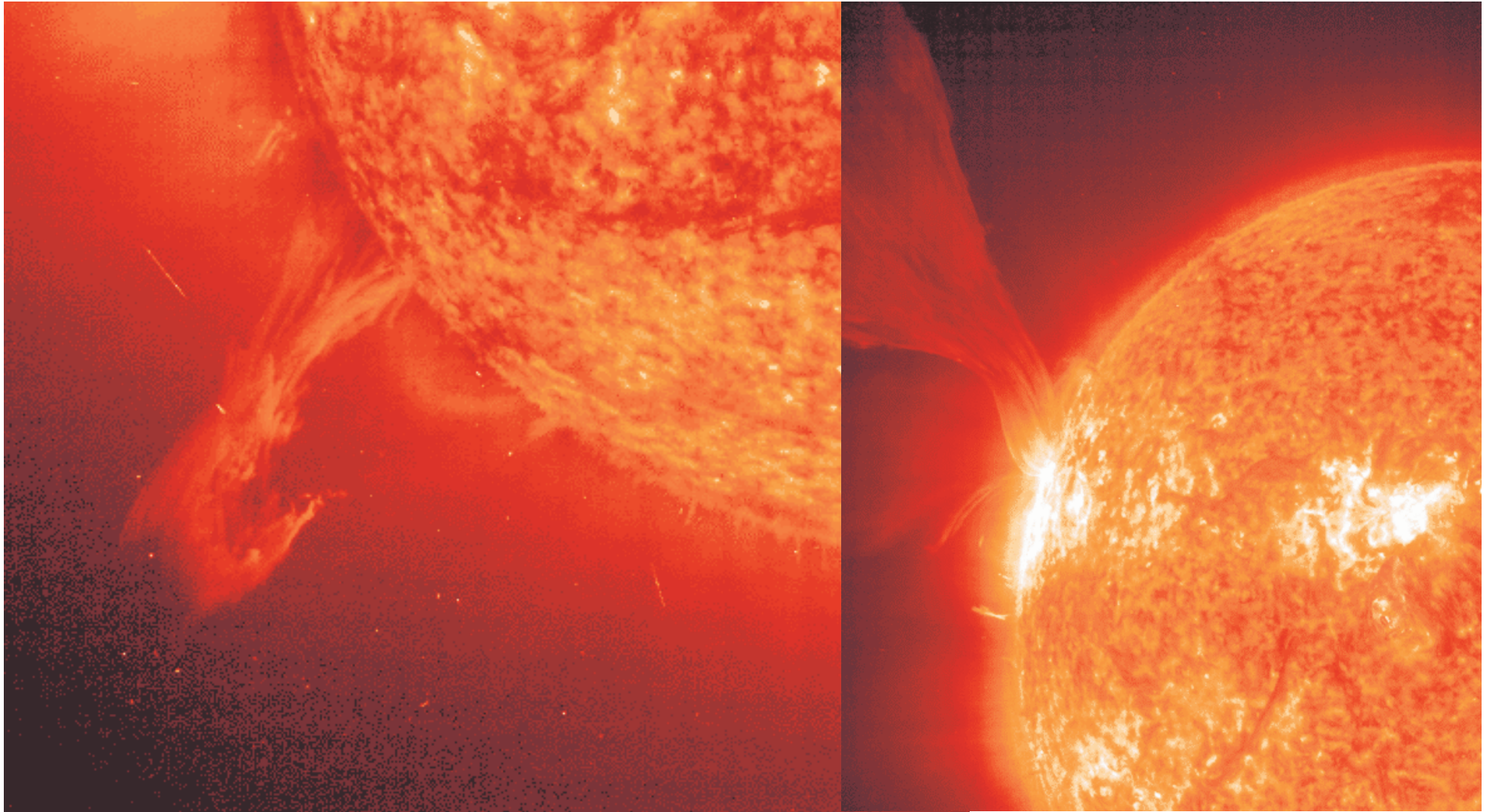


Prominences



- Temps of up to 50,000 K
- Almost always associated with sunspots.
- Can last for hours or months.

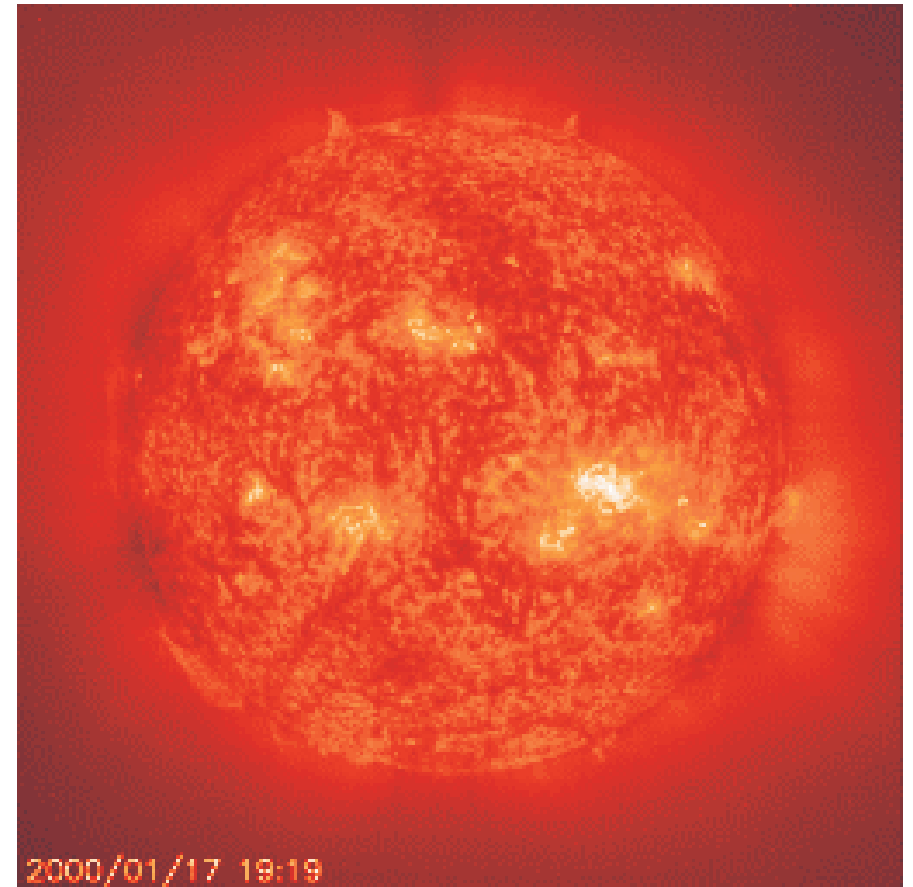
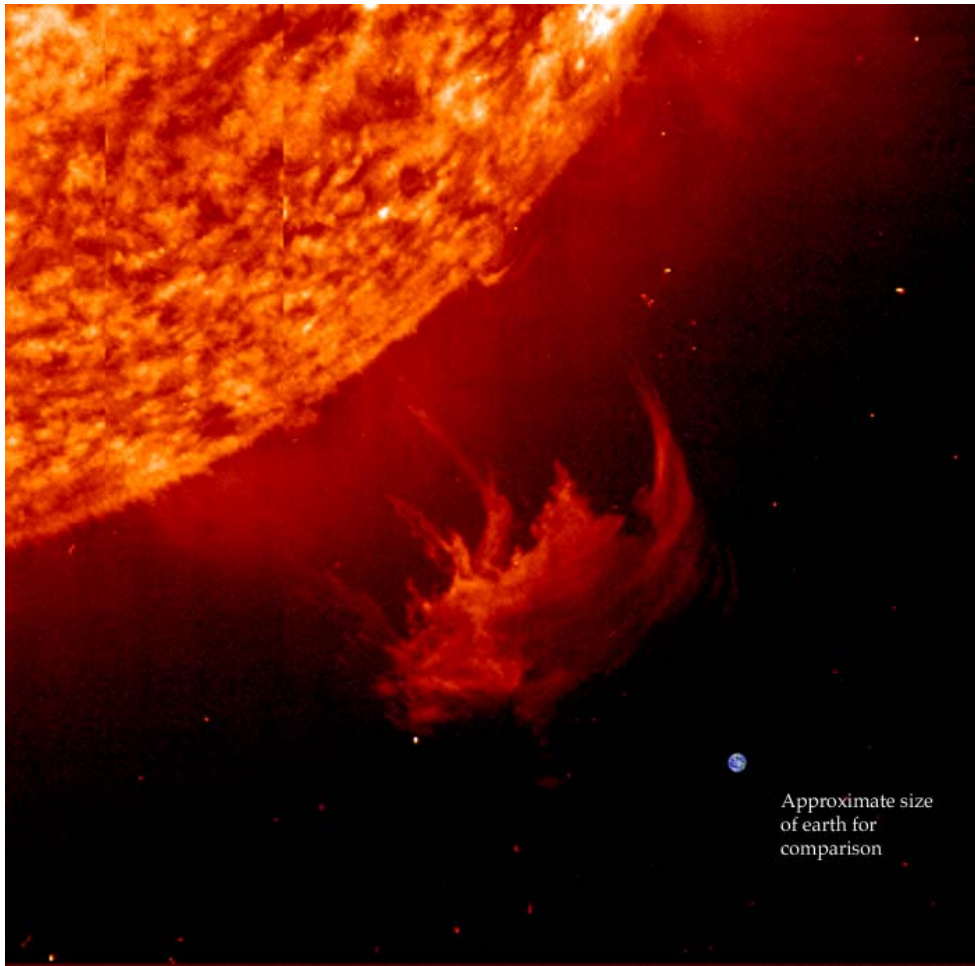
And more



Oct 13, 2003

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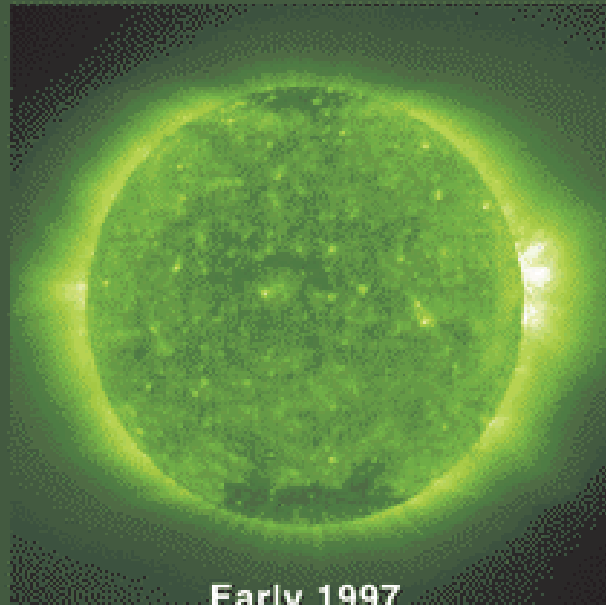
And more



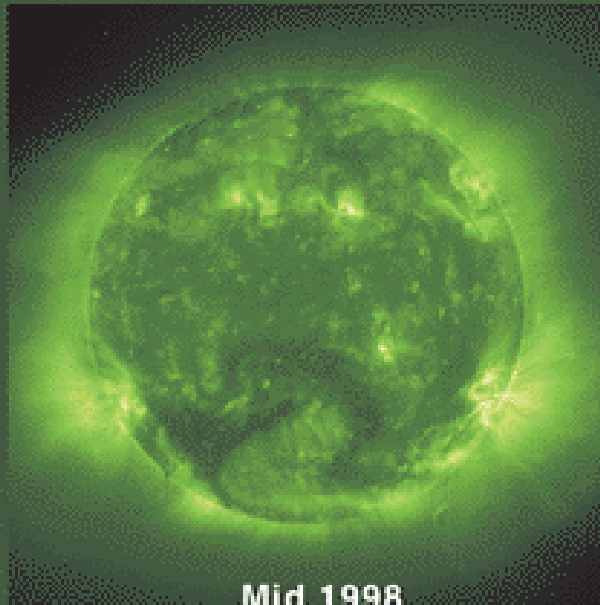


The Sun Approaching Solar Maximum

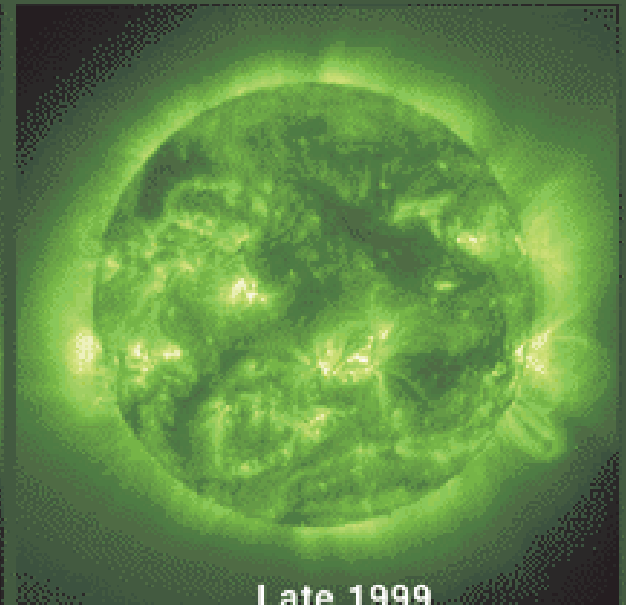
Solar and Heliospheric Observatory, Extreme ultraviolet Imaging Telescope



Early 1997

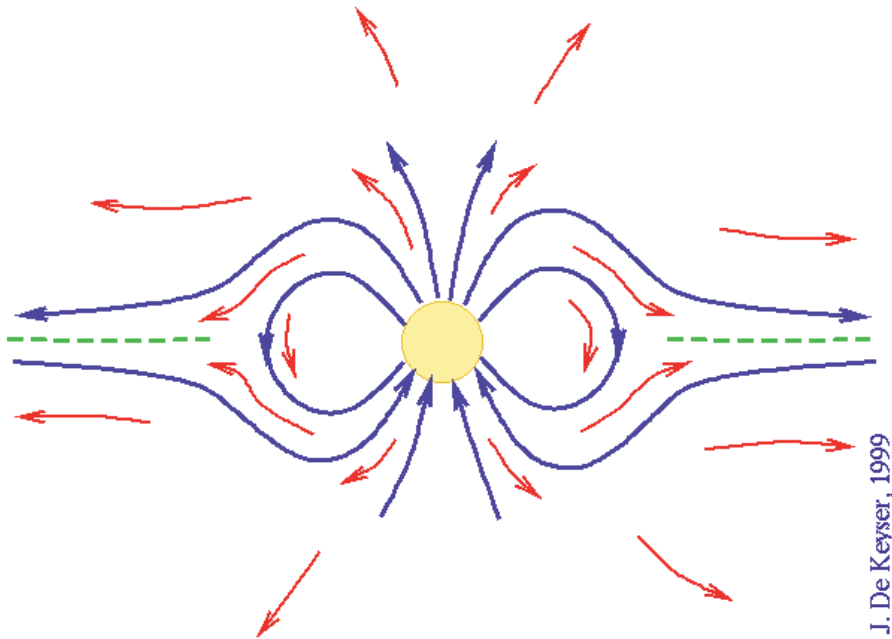


Mid 1998

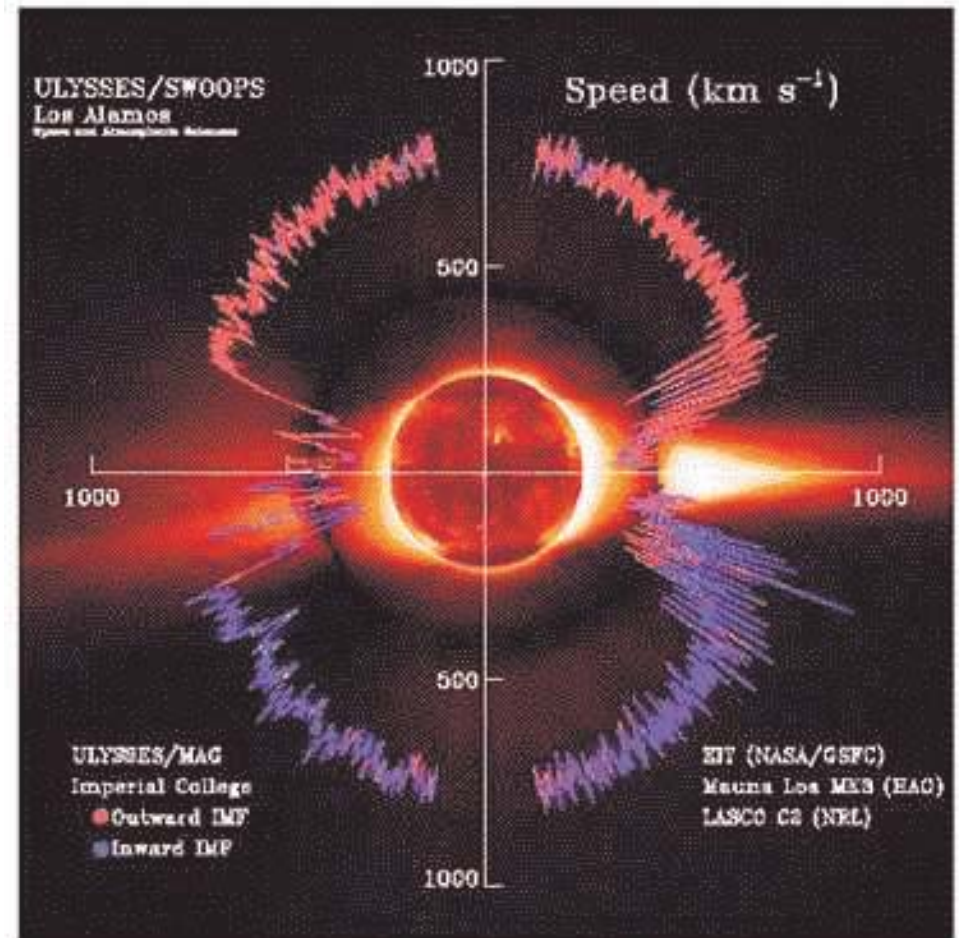
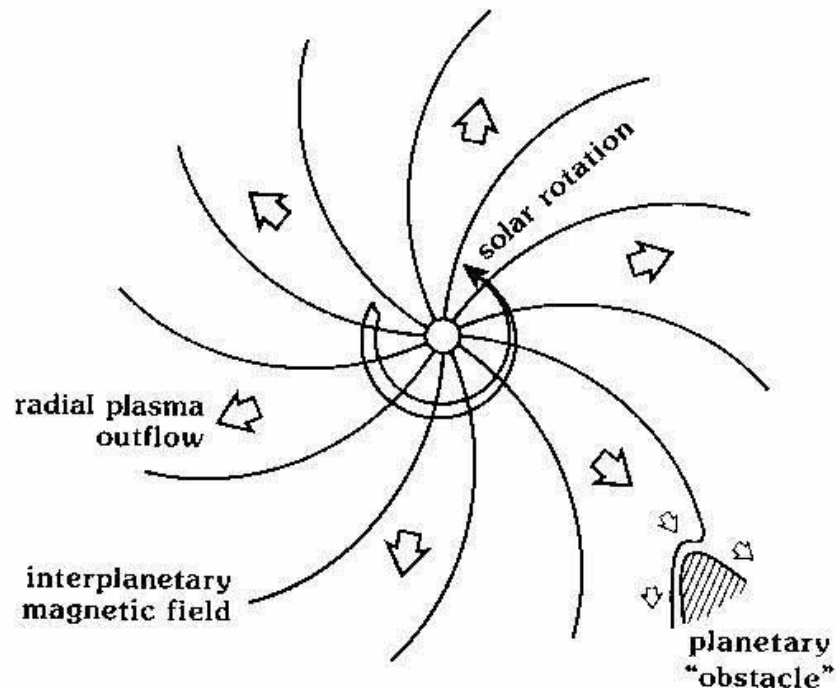


Late 1999

The Solar Wind and the Interplanetary Magnetic Field



J. De Keyser, 1999



McComas, D.J., et al., Geophys. Res. Lett., 25, 1-4, 1998

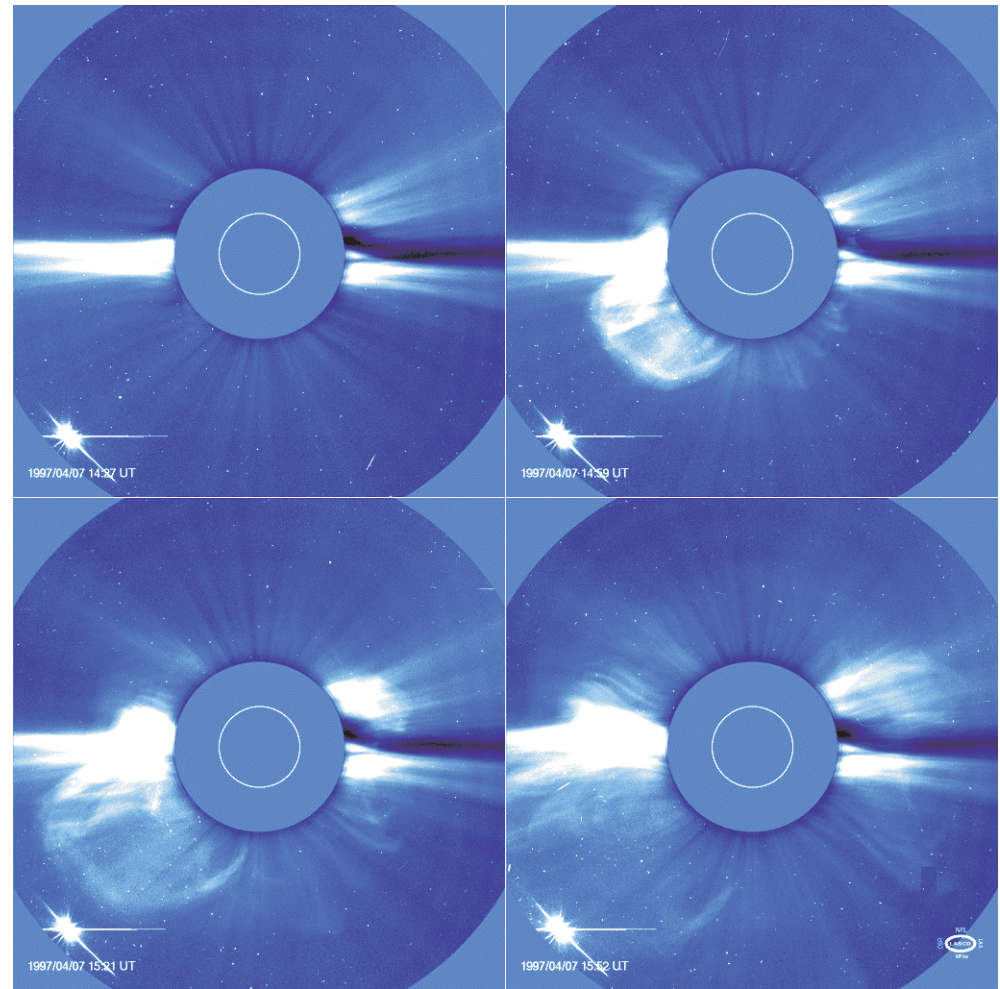
Solar Flares and Coronal Mass Ejections



- **Solar flare** – “storm” on Sun from sudden magnetic field change
- **Coronal mass ejection** – eruption of material from the Sun

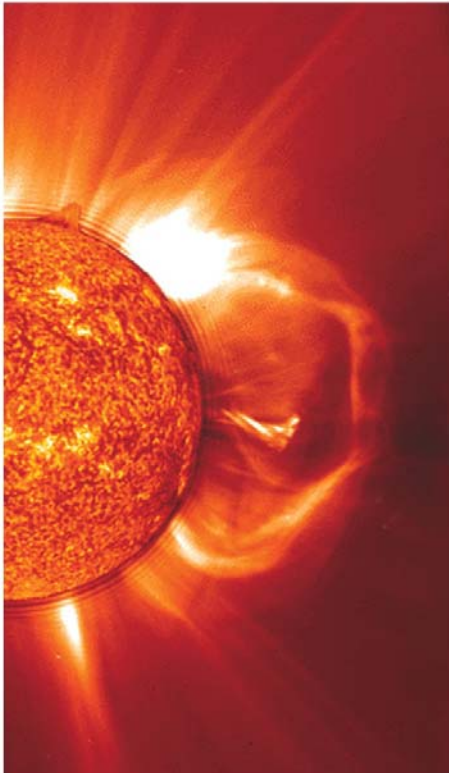


Solar Flare of July 14, 1996 – Big Bear Observatory
Oct 13, 2003

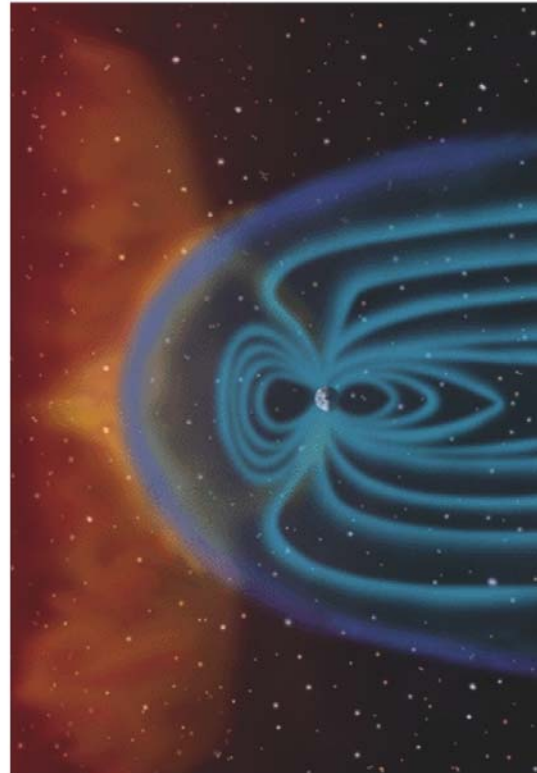


CME of April 7, 1997 – SOHO (UV coronagraph)
Astronomy 100 Fall 2003

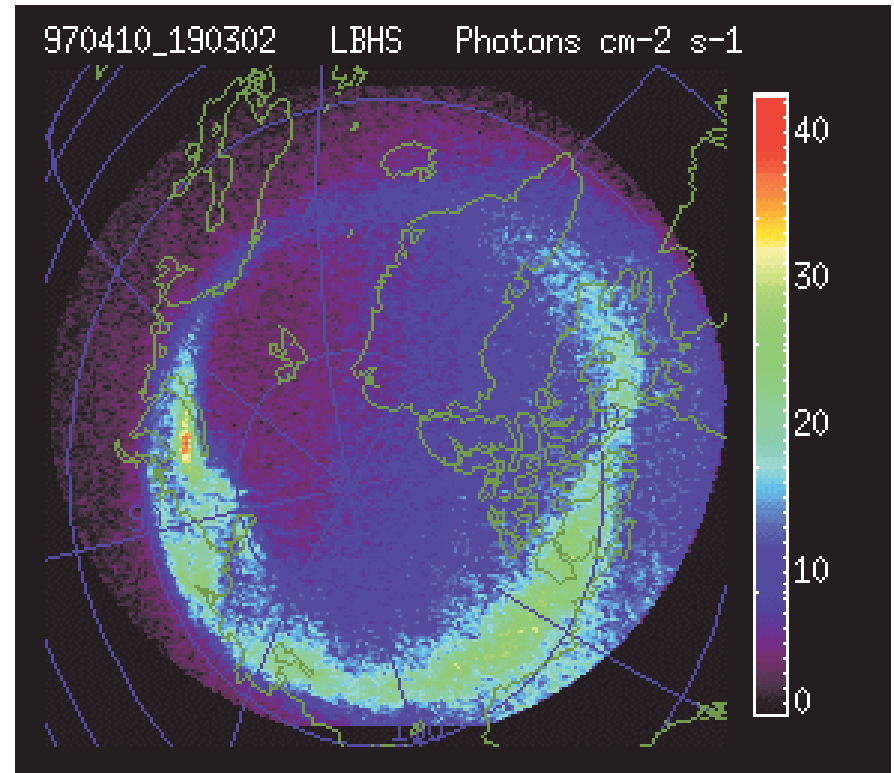
Space Weather



Coronal mass ejection



Two to four days later



Aurora produced by the
April 7, 1997 CME