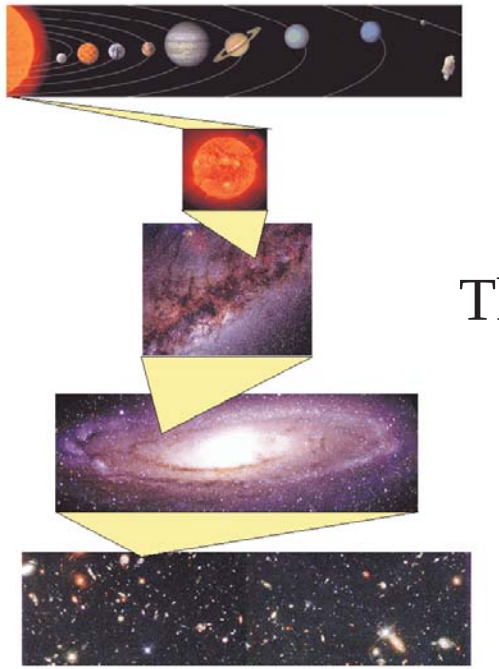
- Nighttime observing is over, but a makeup observing session may be scheduled. Stay tuned.
- Next homework due Oct 24th.
- I will not be here on Wednesday, but Paul Ricker will present the lecture!
- My Tuesday office hour is cancelled.

Outline

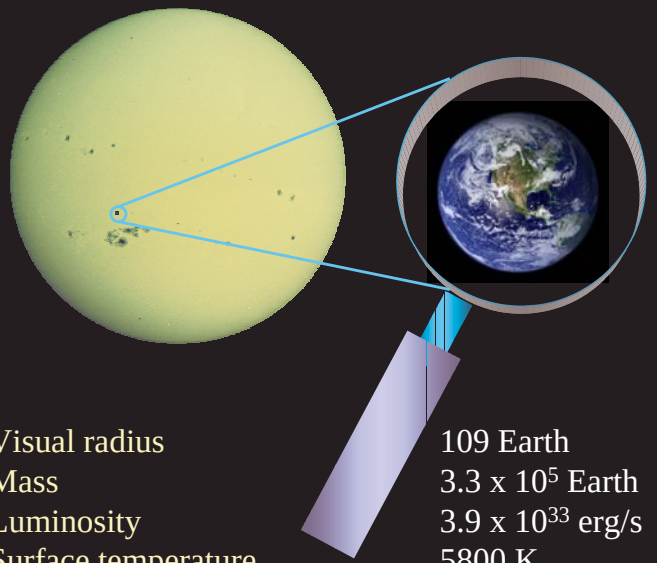
- We turn back to the Sun– our closest star.
- Structure
  - Interior, Photosphere, Chromosphere, Corona
- Limb Darkening
- Sunspots
- The 11 and 22 year Sun cycles
- The Sun's magnetic field



Astronomy: The Big Picture

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!

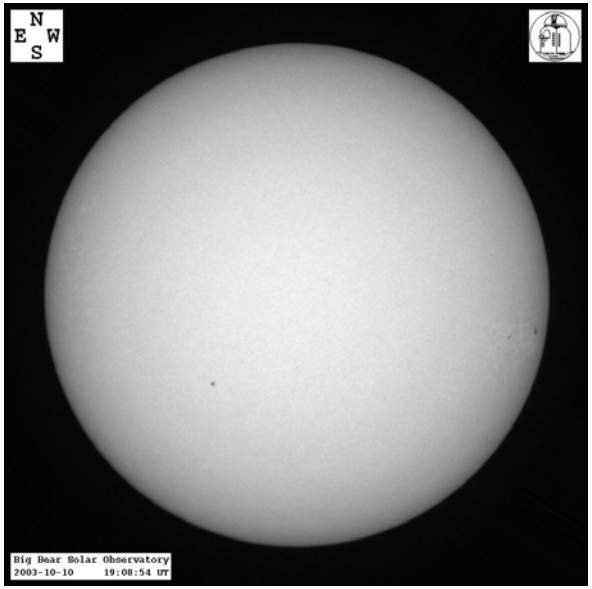
U.S. electricity production in 2000: 3.8 trillion kWh = 1.4×10^{26} erg…

… 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)



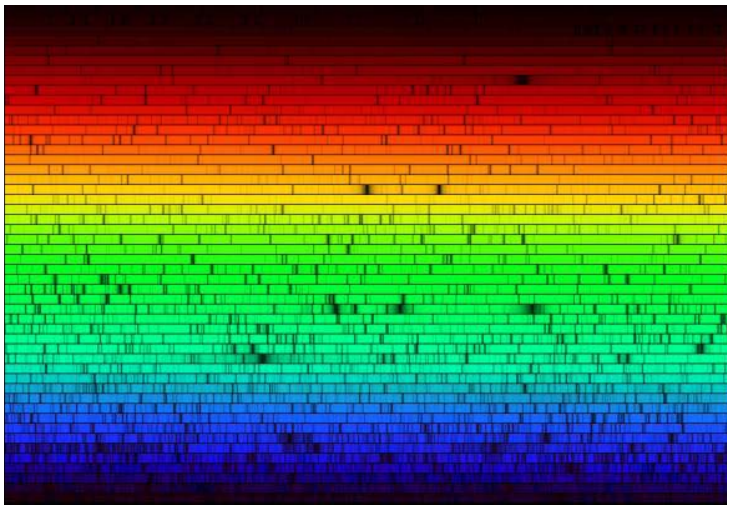
http://www.bbso.njit.edu/cgi-bin/LatestImages

What Color is Sunlight?

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

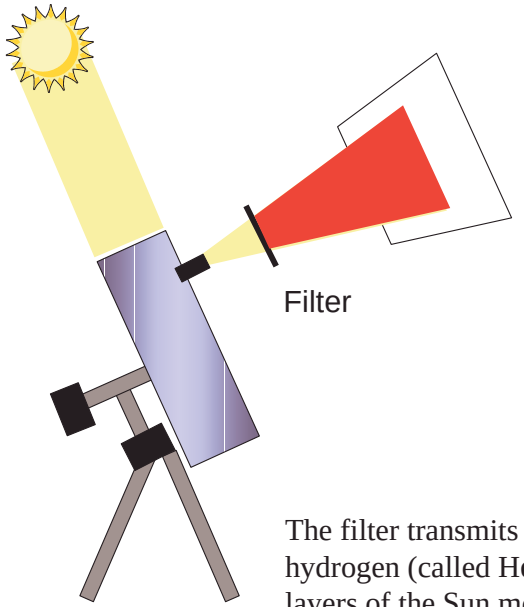
Dark spots are absorption from the surface.

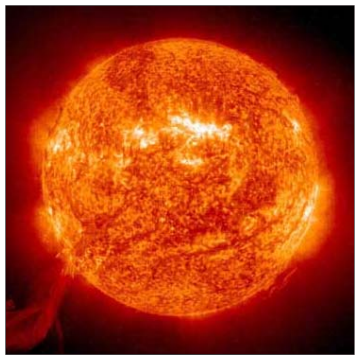
Helium was first detected in the Sun.



http://antwrp.gsfc.nasa.gov/apod/ap000815.html

Safely Observing the Sun

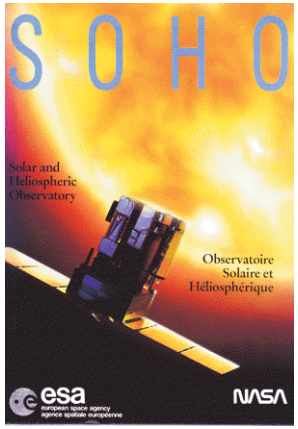




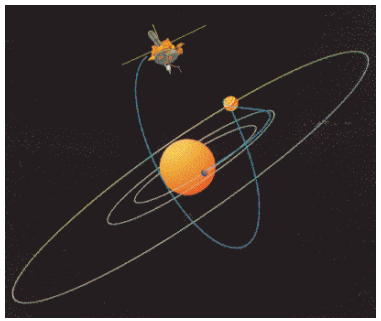
With Hα filter

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

Some Spacecraft Now Observing the Sun

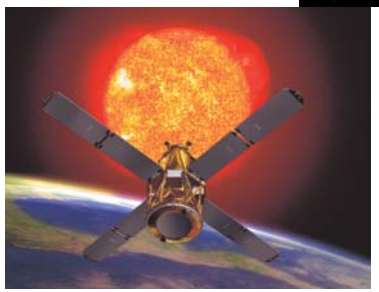


SOHO



Ulysses

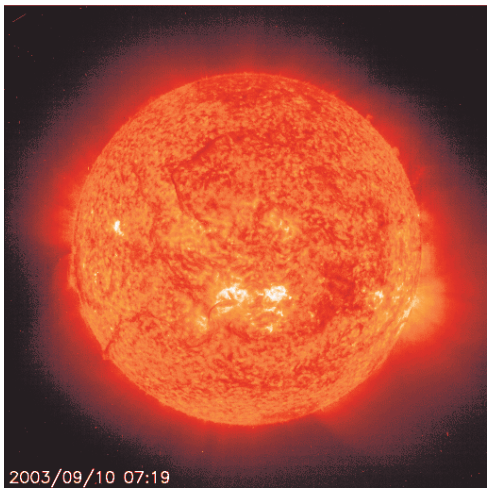
TRACE



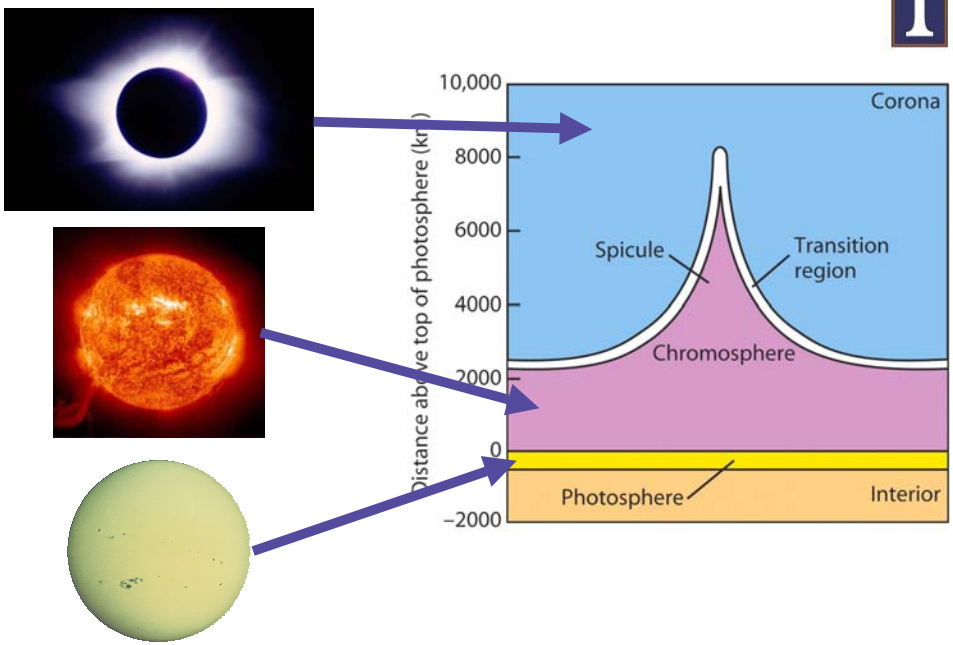
RHESSI

LIVE from the Sun

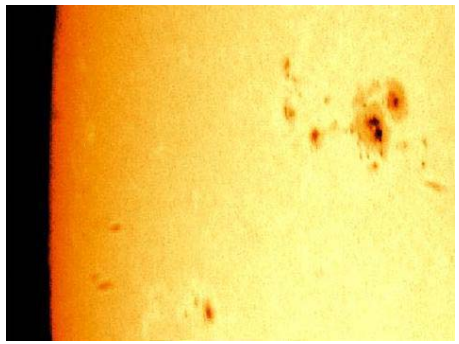
http://sohowww.nascom.nasa.gov/data/realtime/mpeg/

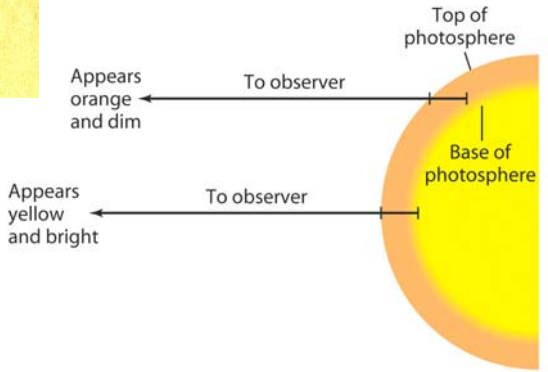


Structure of the Sun's outer layers



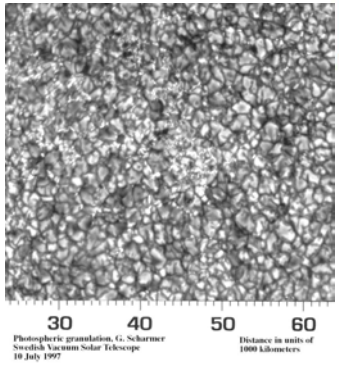
Photosphere – Limb Darkening

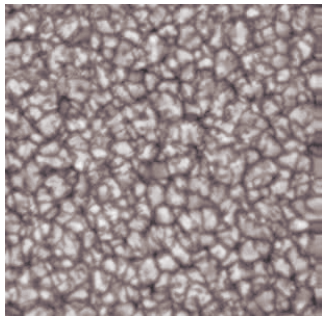




The Photosphere

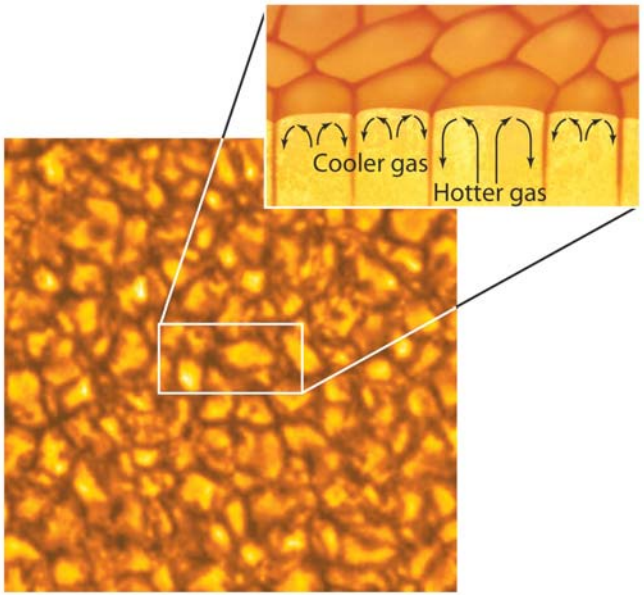
- **Photosphere**
  - Where light starts to escape
  - Features
    - Granules
    - Sunspots
  - Temperature ~ 5800 K





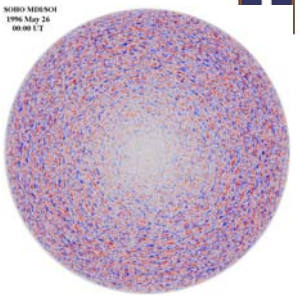
http://science.msfc.nasa.gov/ssl/pad/solar/images/SVST_granulation.mpg

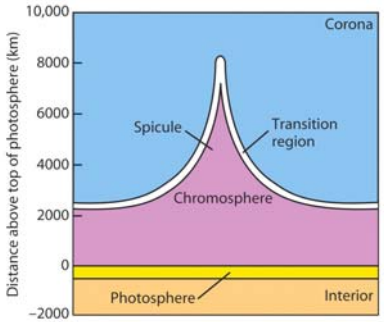
Convection in the Sun's outer layers

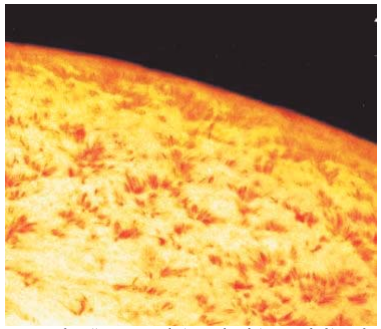


The Chromosphere

- **Chromosphere**
  - Partly transparent gas above photosphere
  - Features
    - Supergranules
    - Spicules
  - Temperature ~ 50,000 K



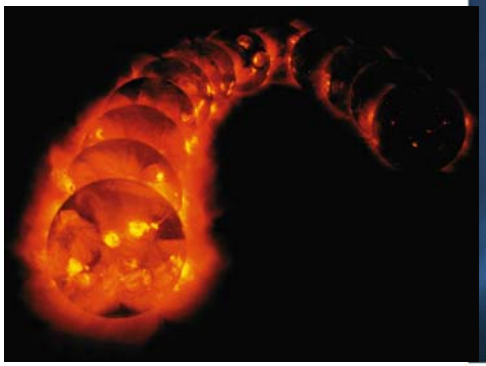


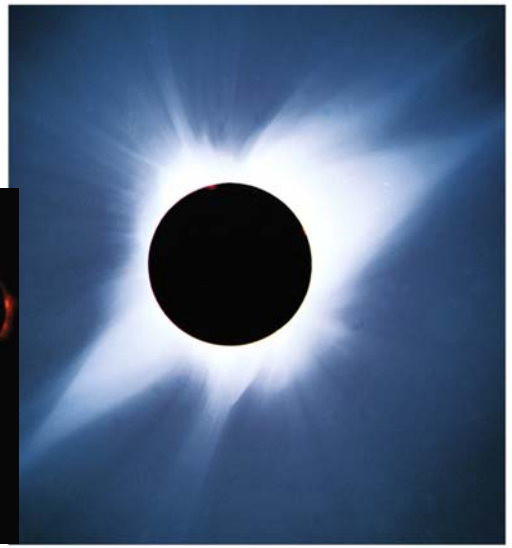


http://www.urania.be/sterrenkunde/zonnestelsel/zon.php

The Corona

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



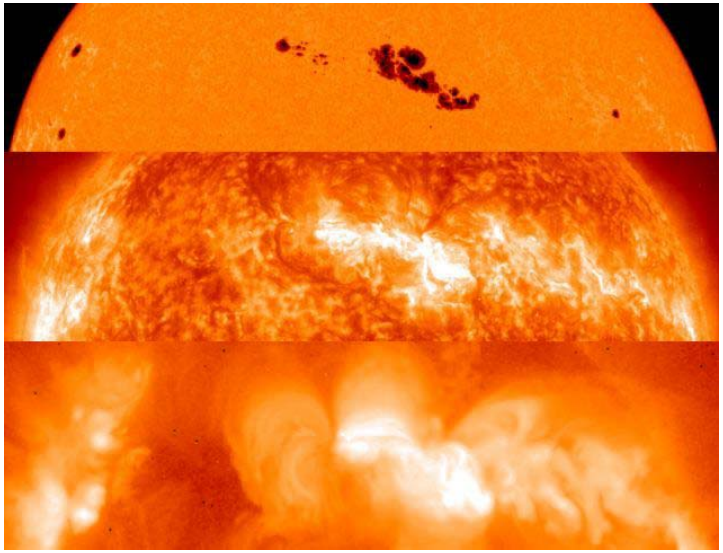


The Various Layers

Photosphere (optical)

Chromosphere (ultraviolet)

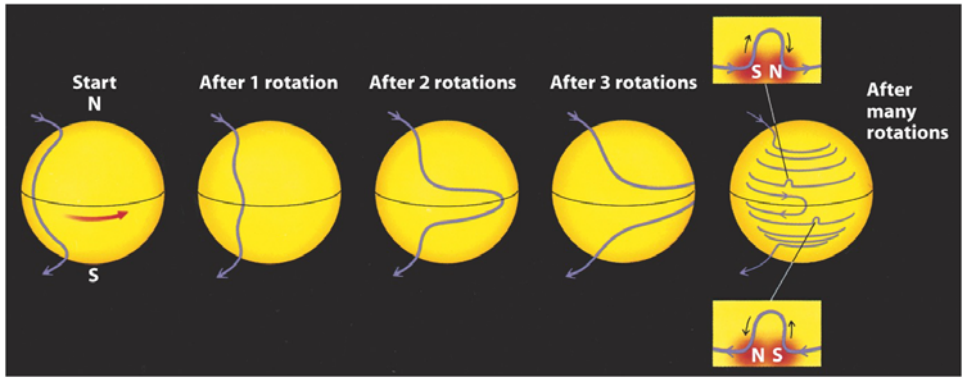
Corona (x-rays)



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

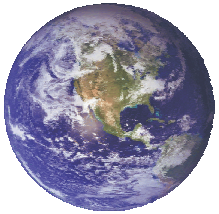
The Sun's Magnetic Field

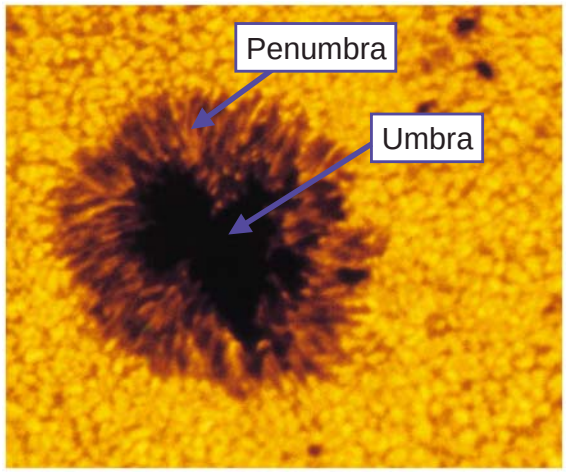
- Not a bar magnet!
- Convection and differential rotation twist and wrap field lines
- Unlike the Earth or even Jupiter, the magnetic field is from the surface of the Sun, not the interior (from the plasma– ionized gas at surface)



Sunspots

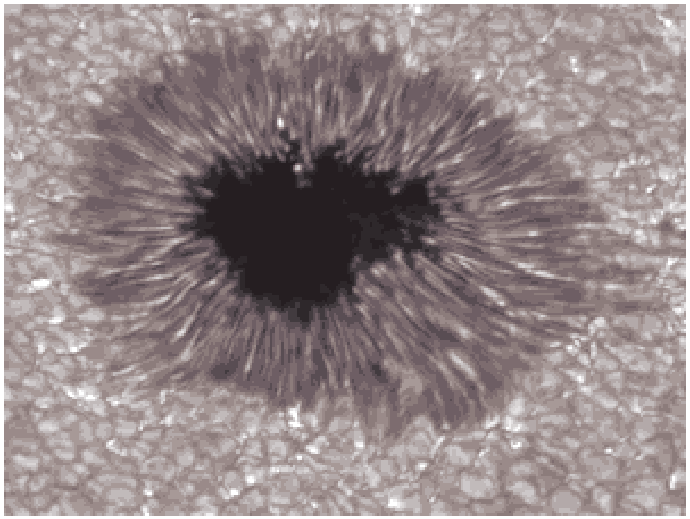
- Magnetic field "loops" popping through photosphere
- Cooler than surroundings (4000 K) – but still hot!
- Sizes ~ 1,500 – 50,000 km





Sunspots

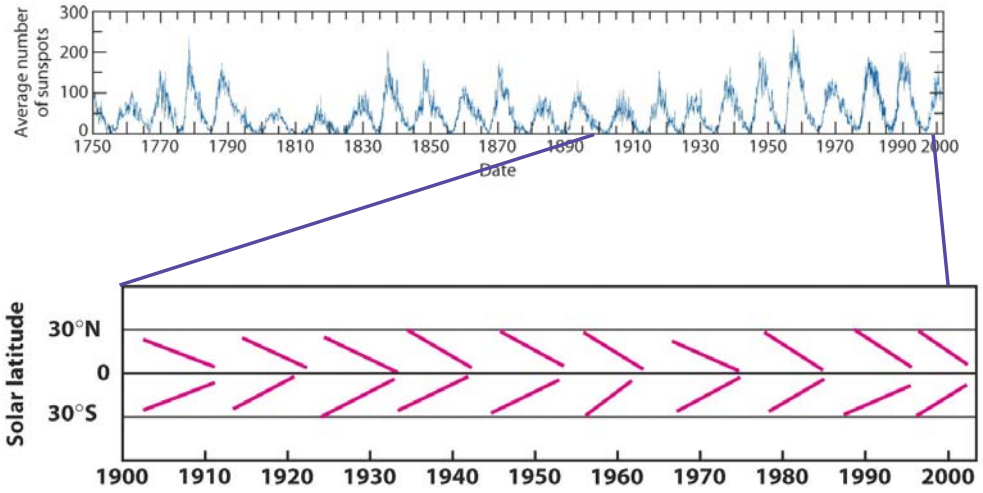
- Can be used to find the rotation rate of Sun.
- Usually last for around 2 months.



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

Sunspot Cycles

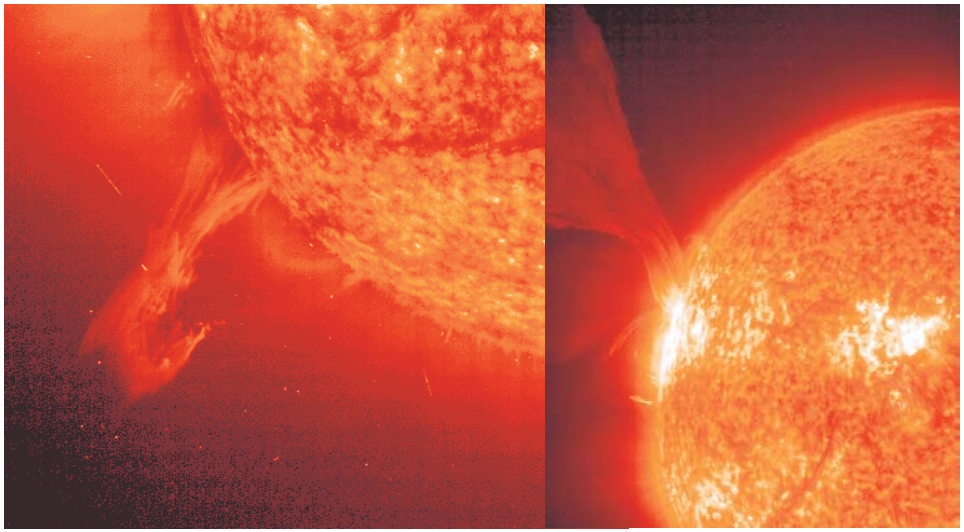
- Start near 30°N/S, migrate toward equator
- More numerous every 11 years (**solar maximum**)
- Magnetic field reversal every 22 years



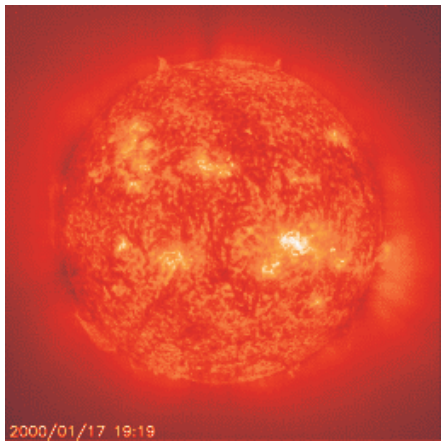
Prominences

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

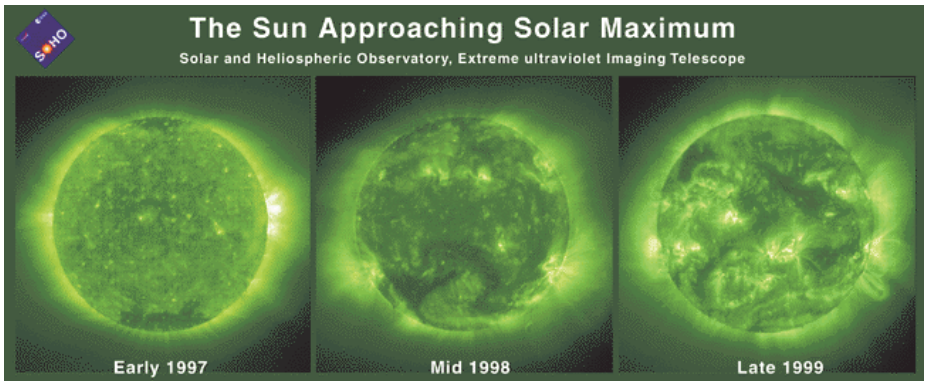
And more



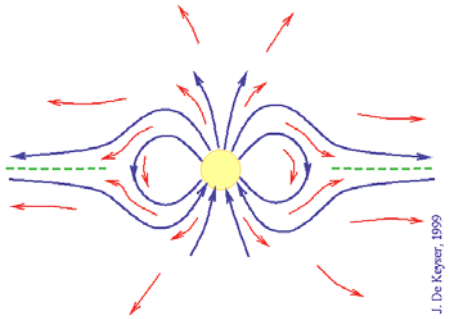
And more

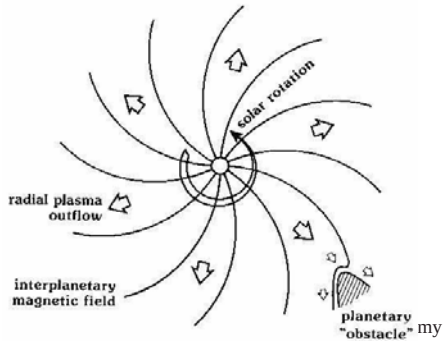


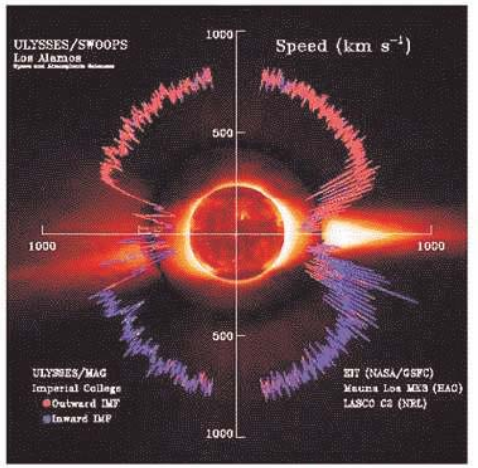
http://science.nasa.gov/headlines/y2000/ast20jan_1.htm



The Solar Wind and the Interplanetary Magnetic Field



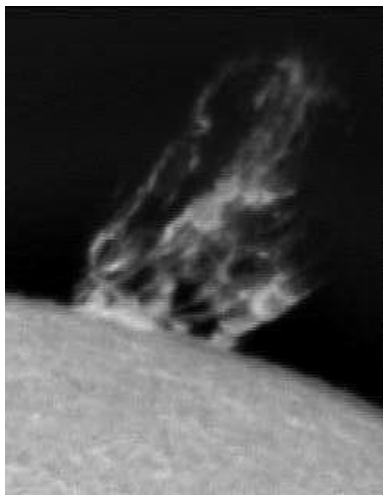




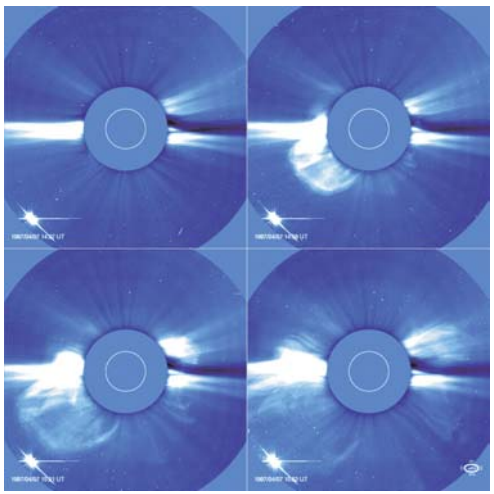
McComas, D.J., et al., Geophys. Res. Lett., 25, 1-4, 1998

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

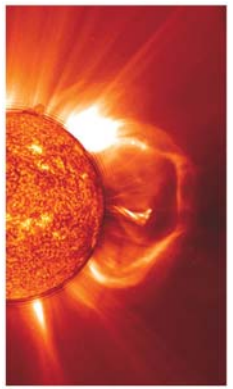


Solar Flare of July 14, 1996 – Big Bear Observatory

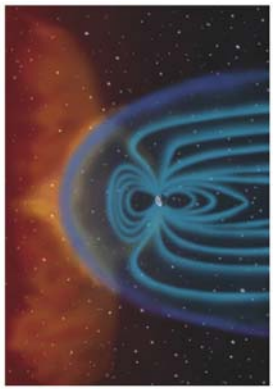


CME of April 7, 1997 – SOHO (UV coronagraph)

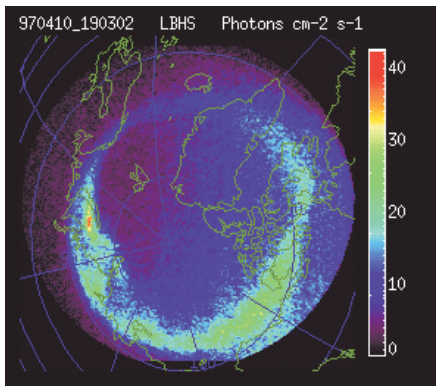
Space Weather



Coronal mass ejection



Two to four days later



Aurora produced by the April 7, 1997 CME