

Astronomy 150: Killer Skies



This Class (Lecture 18):
CMEs

Next Class:
Death of Massive Stars

HW6 due tonight!

Night Obs



Dates:

- Monday, Oct. 4th ✓
- Tuesday, Oct. 5th ✓
- Wednesday, Oct. 6th ✓
- Thursday, Oct. 7th ✓
- Monday, Oct. 11th
- Tuesday, Oct. 12th
- Wednesday, Oct. 13th
- Thursday, Oct. 14th

Starts at 8pm until 10pm
(expect to spend ~40 mins)

Go to assignment page on
class website for more info.

You **MUST** download
worksheet before you go.

Can be cloudy, so check
webpage before you go.

Outline

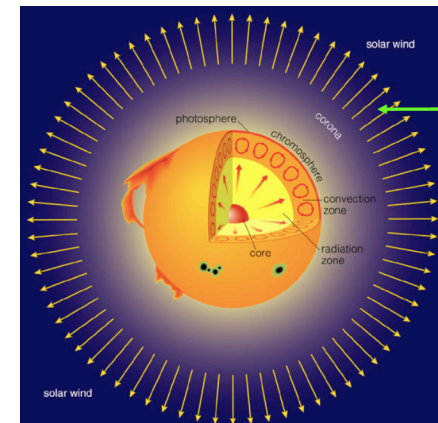


- Sunspots and the magnetic Sun
- The perfect space storm
 - The storm of the century
- The death of a massive star

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

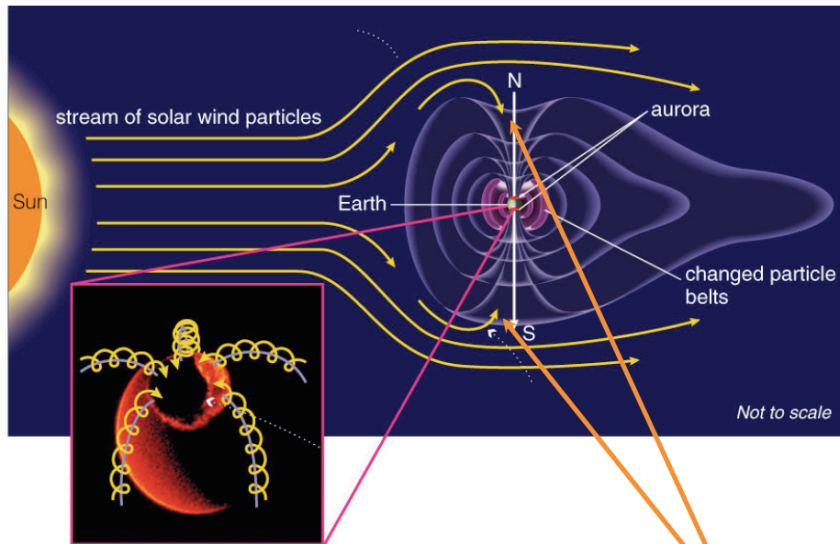


Auroras (Northern/Southern Lights)



<http://www.youtube.com/watch?v=icugqEEOgkg>

Energetic particles from the solar wind cause *auroras*



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

Prominences



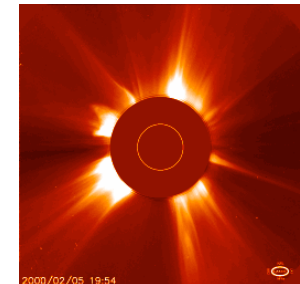
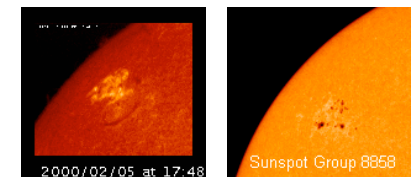
- Ropes of gas trapped in magnetic loops
- Almost always associated with sunspots
- Gas can reach temperatures of 50,000 K!



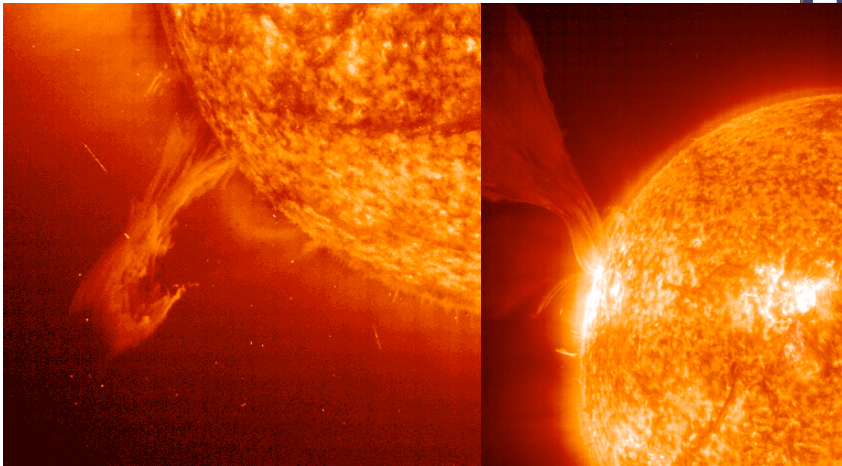
Solar Flares



- Explosive releases of magnetic energy above sunspot groups
- Occur when magnetic loops get tangled
- A “short-circuit” of the magnetic field
- Think of it as cutting a coiled up spring.. It releases energy all at once.



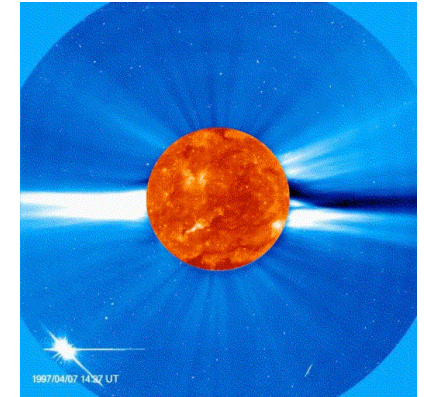
Flares



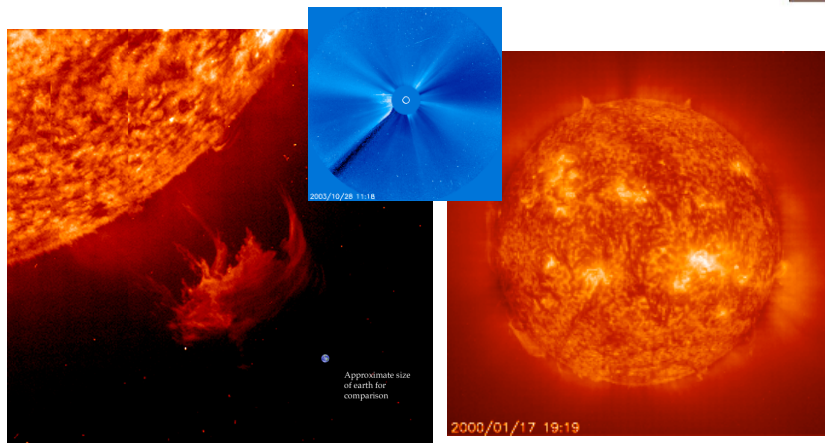
Magnetic activity causes *solar flares* that send bursts of X-rays and charged particles into space from a sunspot group.

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)

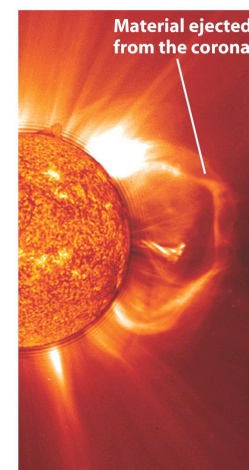


Coronal Mass Ejection: CME

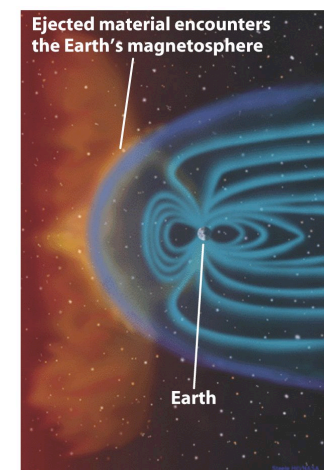


A coronal mass ejection is a much larger eruption (at once) than a solar flare. CMEs eject immense amounts of gas.

CMEs

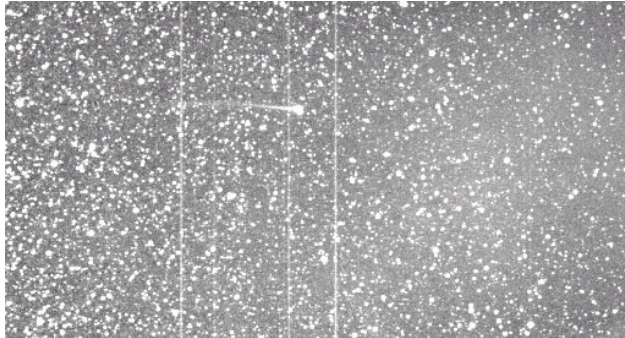



(a) A coronal mass ejection



(b) Two to four days later

A CME Ripping Off Comet Encke's Tail



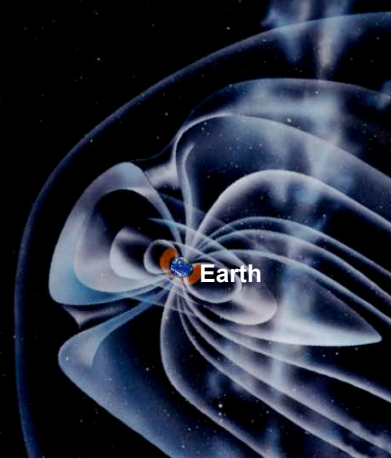


Sun:

- Energy released in the form of photons, particles, and magnetic fields
- Sources of major disturbances:
 - Coronal Holes
 - Solar Flares
 - Coronal Mass Ejections
 - Solar Particle Events

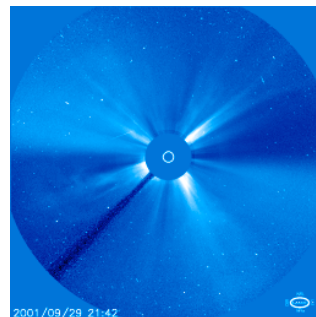
Space Weather:
What is it?

Space Weather refers to conditions in space that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health.



1859: The Perfect Space Storm

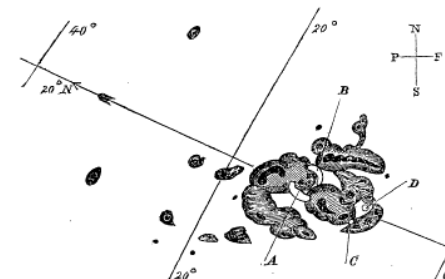
- Most CMEs don't hit the Earth.
- To hit, CME must be from the Sun's equator and in proper orbital phase.
- The bigger the more of an effect
- And, the magnetic field of the event can make a larger impact on the Earth.



Pulkova, October, 1859.

Description of a Singular Appearance seen in the Sun on September 1, 1859. By R. C. Carrington, Esq.

While engaged in the forenoon of Thursday, Sept. 1, in taking my customary observation of the forms and positions of the solar spots, an appearance was witnessed which I believe to be exceedingly rare. The image of the sun's disk was, as usual with me, projected on to a plate of glass coated with distemper of a pale straw colour, and at a distance and under a power which presented a picture of about 11 inches diameter. I had secured diagrams of all the groups and detached spots, and was engaged at the time in counting from a chronometer and recording the contacts of the spots with the cross-wires used in the observation, when within the area of the great north group (the size of which had previously excited general remark), two patches of intensely bright and white light broke out, in the positions indicated in the appended diagram by the letters A and B, and of the forms of the spaces left white. My



first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass, by

Monthly Notices of
the Royal
Astronomical Society,
Volume 20,
November 11, 1859

The great magnetic
storm hit 18 hours
later, traveling at 2300
km/s!



1859: The Perfect Space Storm

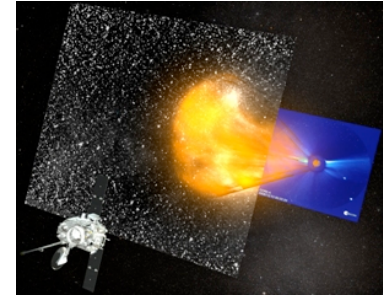


- Plasma blob ejected from the Sun right at the Earth.
- The blob had extremely high speeds
- The plasma blob's magnetic field were opposite from the Earth's field
- High technology at the time was telegraphs.
 - The charged particles overloaded the system
 - Melted wires, starting wildfires
 - Aurora were seen as far South as Rome and Hawaii

1958: Storm Hard



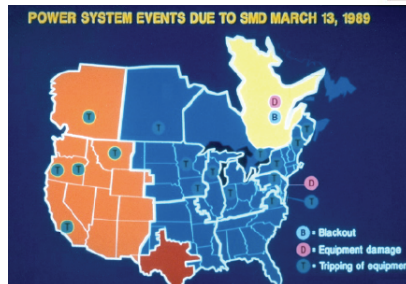
- Feb 1958 CME observed
- 28 hours later, one of the greatest magnetic storms
- Effects:
 - Toronto area plunged into temporary darkness
 - Western Union experienced serious interruptions on its nine North Atlantic telegraph cables
 - Overseas airlines communications problems



1989: Storm Hard



- March 13, 1989 – a CME knocked out a power transformer in Quebec
- Plunged 6 million customers into darkness!
- Affected power grids across North America



High Latitude HF (High-Freq) Communications

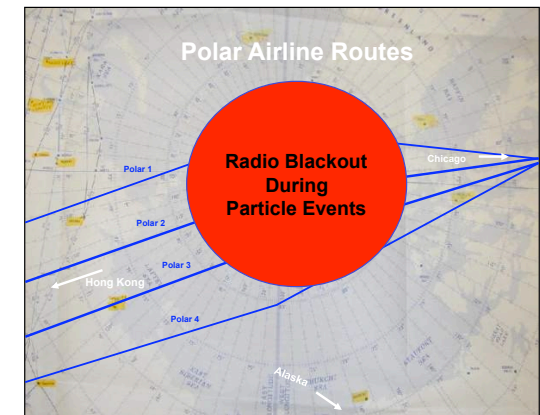


- Polar airline routes lose ground communications
- Alternate routes required

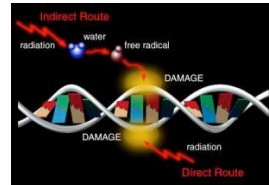
Uses more fuel
Flight delays

Sample of Flights Affected:

- 10/26/00: Lost of HF prior to 75N, re-route off Polar route with Tokyo fuel stop. 15:00 flight now 20:30
- 11/10/00: Due to poor HF, ORD to HKG flown non-polar at 47 minute penalty
- 3/30/01-4/21/01: 25 flights operated on less than optimum polar routes due to HF disturbances resulting in time penalties ranging from 6 to 48 minutes
- 11/25/00: Polar flight re-route at 75N due to Solar Radiation, needed Tokyo fuel stop
- 11/26/00: Operated non-polar at 37 minute penalty due to solar radiation
- 11/27/00: Operated non polar at 32 minute penalty due to solar radiation.
- 11/28/00: Operated non-polar at 35 minute penalty due to solar radiation



Radiation Hazard



Health Hazards from Energetic Particles

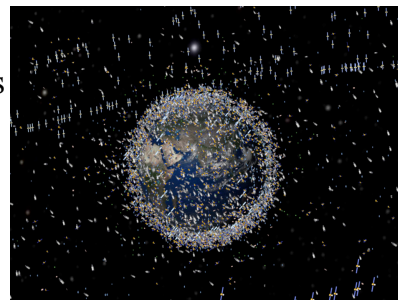
- Humans in space
- Space Shuttle, International Space Station, missions to Mars
- Crew/Passengers in high-flying jets



Today: Reliance on Satellites



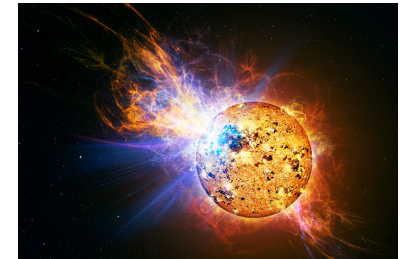
- Besides being fried by energetic particles, satellites can be dragged down when the atmosphere puffs up after CME event.
 - We lose satellites every year
- Why are the power transmission lines so vulnerable?
 - We are near the operational limit, when extra charge is added from fluctuation mag field, they overload, which can melt the transmission lines.
 - Knock out expensive and hard to replace transformers.



Today: More Vulnerable



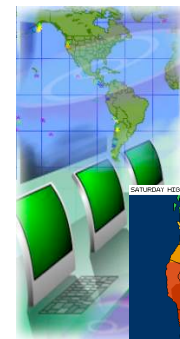
- With technology today a big solar storm would have more significant impact
- 1989 solar storm took out the Hydro-Quebec power grid causing hundreds of millions of dollars in damages
- 1994 solar storm caused several satellites to malfunction and newspaper, radio, and television services to experience problems
- None of these were as powerful as the perfect solar storm of 1859



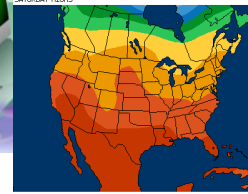
Mitigation: Monitoring



Weather



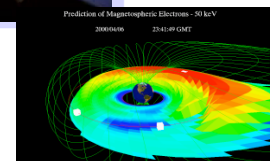
NOAA
National
Weather
Service



Accuweather

Space Weather

NOAA Space
Environment Center



<http://www.youtube.com/watch?v=DU4hpsistDk>

2012: End of Mayan Calendar?



- I'm not going to say too much about this, but the concept is bogus, all pseudoscience.
- Except maybe kinda Solar weather, which is sometimes mentioned.
 - Although 2012 is 1 year before solar maximum, the 1859 CME was 1 year before maximum.
 - Still it doesn't mean anything.
 - We have been hit by bad space weather many times in the past and will again in the future.
 - Not the end of the world.
- Science aside though, it was kinda a fun movie:

<http://www.youtube.com/watch?v=ce0N3TEcFw0>

Space Weather on Weather?



- There is some correlation between the Solar Cycle and weather on Earth.
- Sunspots reduce brightness of Sun, but surrounded by brighter region, so we have a net gain.
- Sun is actually brighter when covered in spots.
- The Maunder minimum: 1645-1715 (hardly any spots)
 - Lower than average temperatures
 - Little Ice Age: river Thames froze over
 - Sun brightness only one factor though, also more than usual volcanism

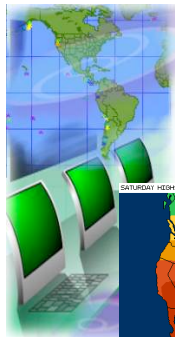


<http://www.youtube.com/watch?v=T1p4GR90IZQ>

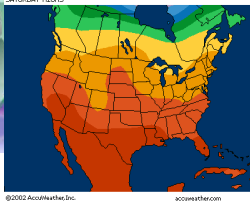
Mitigation: Monitoring



Weather



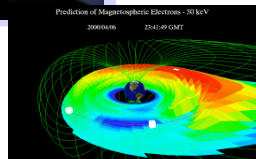
NOAA
National
Weather
Service



Accuweather

Space Weather

NOAA Space
Environment Center



Imagine

- It's winter. It's cold.
- The Sun is unusually active, and you hear NASA is worried about something called Space Weather.
- A huge batch of new sunspots on the Sun's equator are seen..
- A huge coronal mass ejection from the Sun comes screaming toward the Earth.

Approximate size
of earth for

Imagine

- All of our satellites are knocked out.
- Airplanes are left without communication
- Electrical transmission lines overload and melt, causing wildfires.
- Half the planet is without power.
- Thousands die the first night...
- Then, more sunspots...
- And you can't remember what Leslie mentioned about CMEs....

Approximate size
of earth for

Top 10 Ways Astronomy Can Kill you or your Descendents



1. Impacts!
Splat.. Boom... Watch out for space rocks!
2. Solar Evolution.
MS to Red Giant to White Dwarf.
3. Coronal Mass Ejections
Cold winter days..
4. Supernova in your face!
Super sunburn.

Imagine

- Astronomers are the first to know.
- A clear detection of neutrinos surprised everyone
- Gamma and x-ray telescopes are quickly blinded by the bright light from the object
- Then in the night sky a star gets brighter and brighter, easily seen with the naked eye and still getting brighter.
- The first supernova in 400 years!

Imagine

- The power grid collapses
- The sky around the star is blue!
- Gamma Rays have already destroyed the ozone layer, we just don't know it yet.
- Severe sunburn, but UV radiation will kill off phytoplankton, the base of the food chain
- A new mass extinction is happening!
- As you die blissfully, you wonder what Leslie was going to talk about this week.

Top 10 Ways Astronomy Can Kill you or your Descendents



4. Supernova in the face!

Extreme energy! Can destroy the ozone layer!

<http://www.youtube.com/watch?v=0J8srN24pSQ>

Hertzsprung-Russell Diagram

