Killer Skies

- Homework 5 due Monday
- Night Observing continuing
- Solar Computer Lab: decided to not do it
- Last time: Active Sun
- Today: Active Sun 2

Music: *Supernova* – Li Phair

Night Observing

Night Observing probably last week

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

When: M, T so far: 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

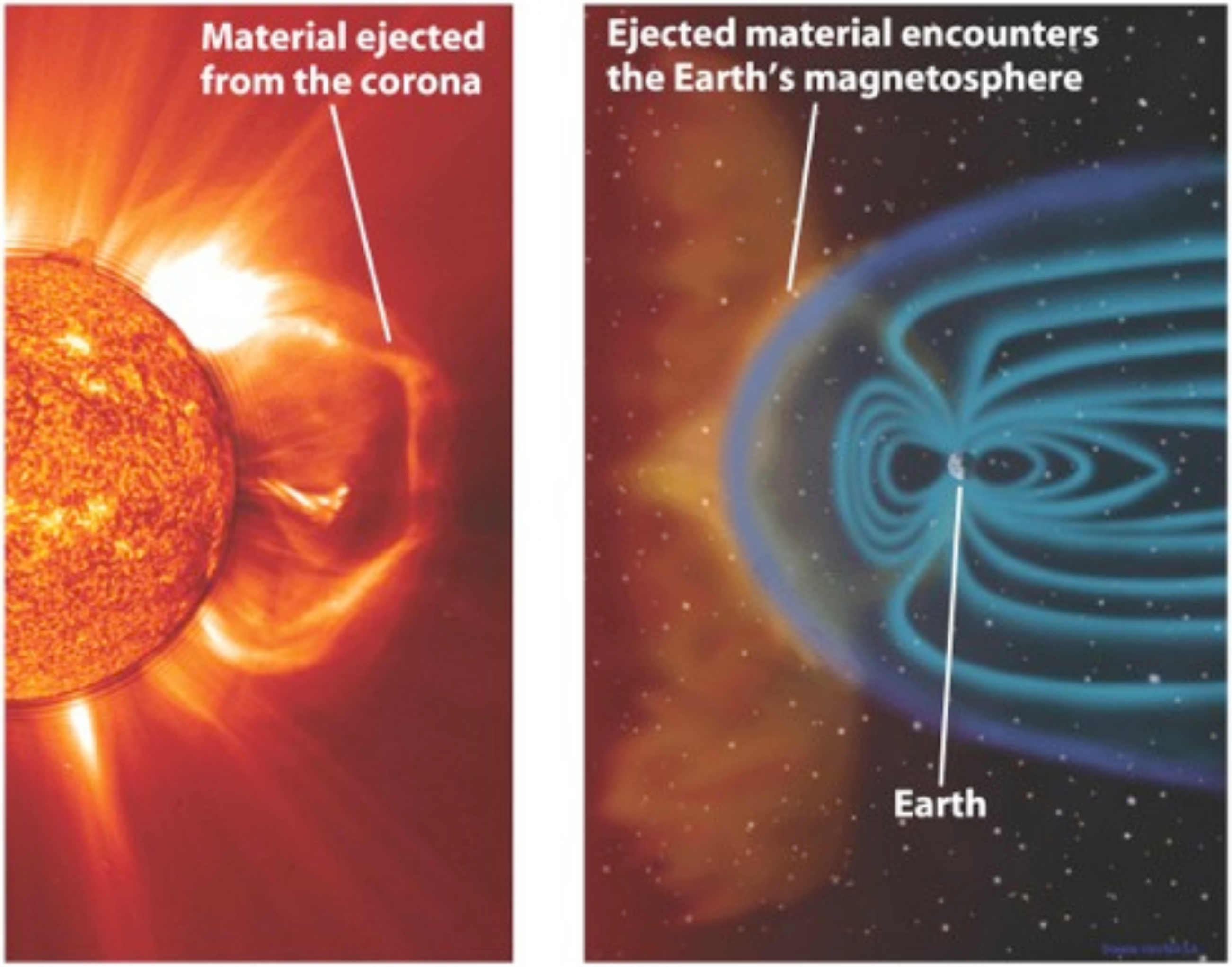
Get weather cancellation updates

Assignment details on class website

Read rubric before you go!

- Complete report due on or before Oct. 25

CMEs



(a) A coronal mass ejection (b) Two to four days later

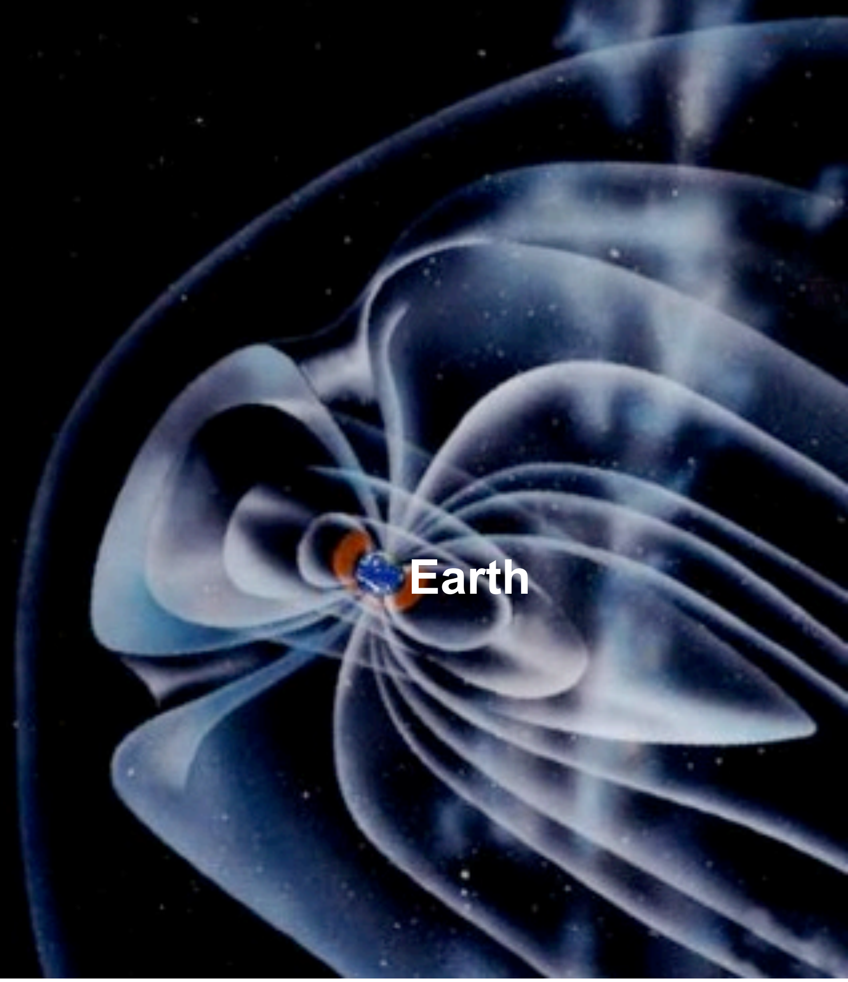
Space Weather:

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.

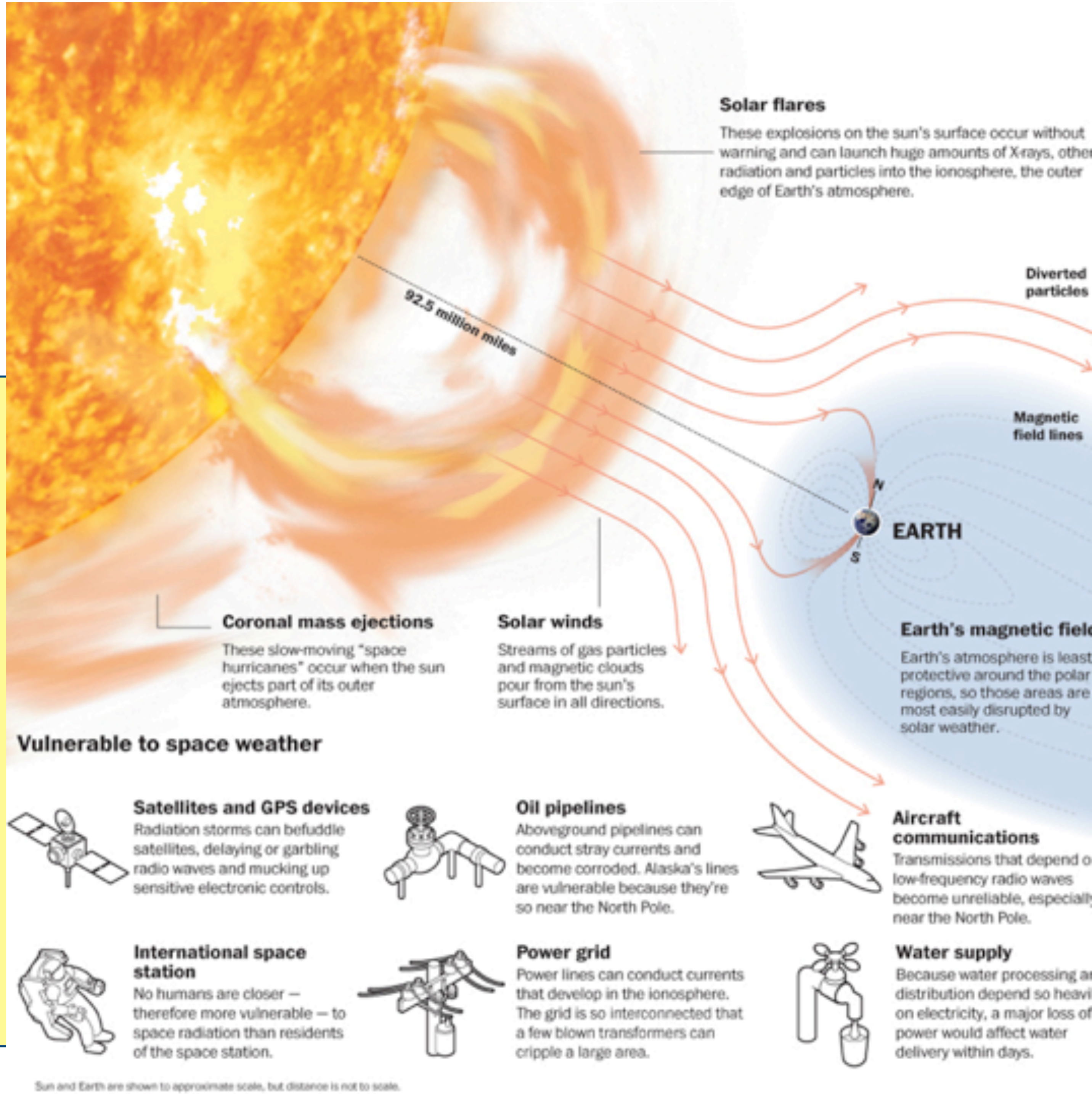
Sun:

- **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**



Effects of Solar Storms

Modern society depends on a variety of technologies susceptible to the extremes of space weather.



Strong electrical currents driven along the Earth's surface during auroral events disrupt electric power grids. Radio communications can be compromised for commercial airliners on transpolar crossing routes. Exposure of spacecraft to energetic particles during solar energetic particle events cause temporary operational anomalies, damage critical electronics, degrade solar arrays, and blind optical systems such as imagers and star trackers. In a worst-case scenario, astronauts exposed to solar particle radiation can reach their permissible exposure limits within hours of the onset of an event.

Thought Question

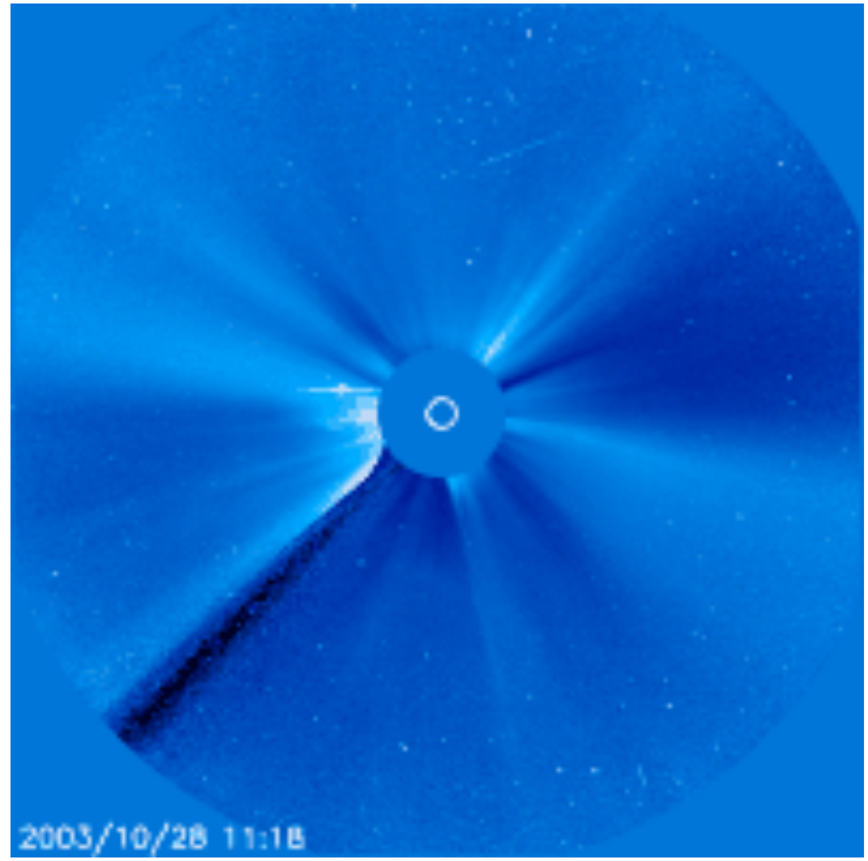
Suppose a large flare is detected optically.
How long until radio interference arrives?

A. about four days
B. simultaneously
C. no relation between the two
D. 8 minutes later
E. 12 hours later

Answer B – they both travel at the speed of light!

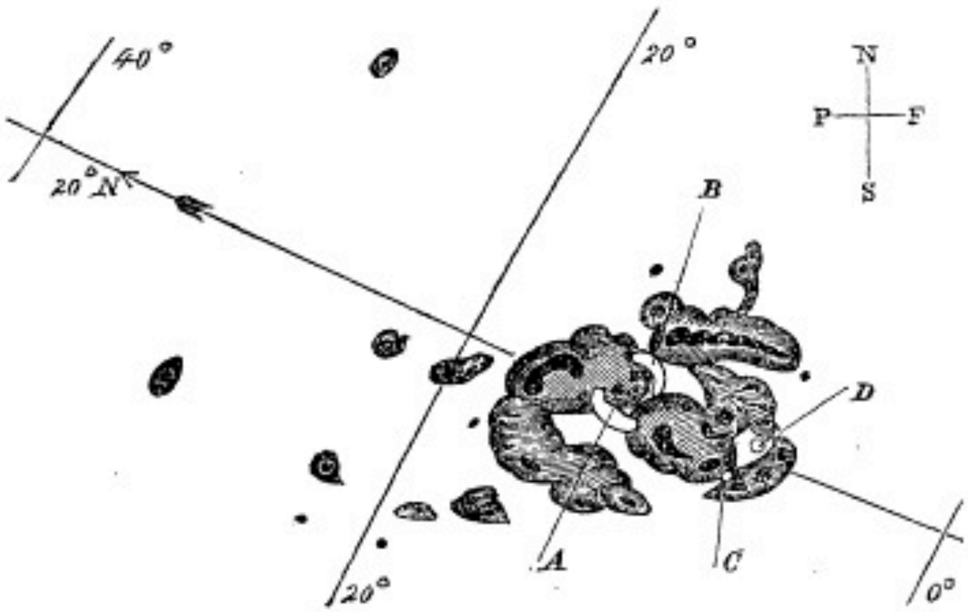
1859: The Perfect Space Storm

- 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.



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

Blackout of 1989

- **March 13, 1989 - a CME knocked out a power transformer in Quebec**
- **Plunged the whole province into darkness!**
- **Affected power grids across North America**

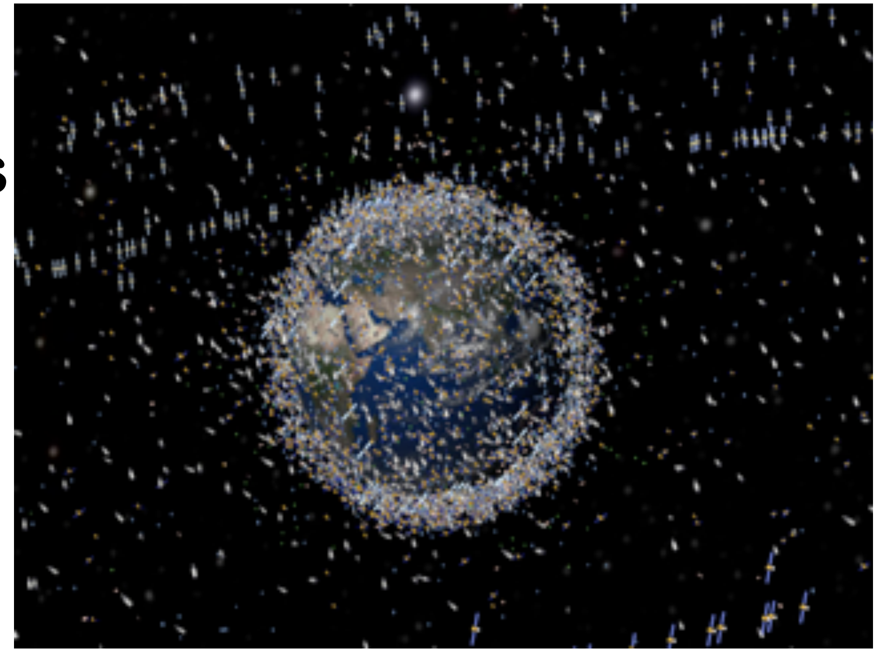
The same storm caused a strange effect in Minnesota: they were unable to pick up their local radio stations but could hear the broadcasts of the California Highway Patrol.

The CMEs are dangerous to modern life, so we have to monitor them carefully, which NASA is currently doing.

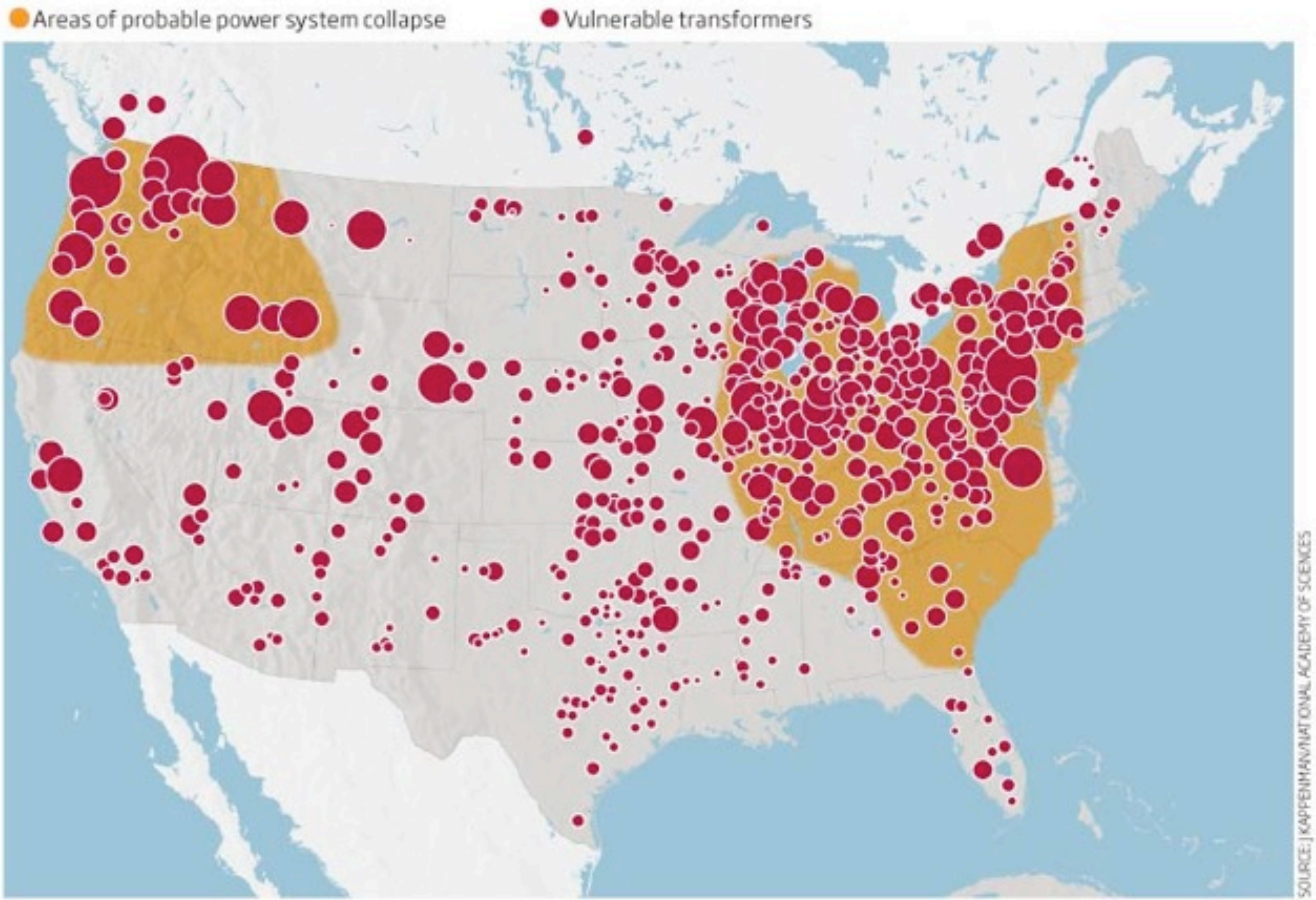
Today: More Vulnerable

- 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

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.

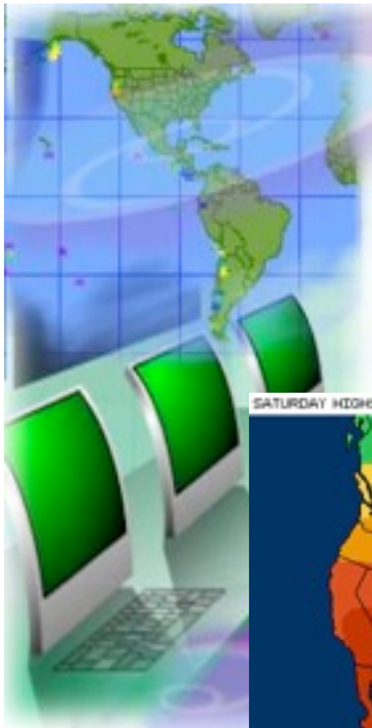


A severe solar storm could lead widespread blackouts!

To estimate the scale of such a failure, scientists looked at the great geomagnetic storm of May 1921, which produced ground currents as much as ten times stronger than the 1989 Quebec storm, and modeled its effect on the modern power grid. They found more than 350 transformers at risk of permanent damage and 130 million people without power. The loss of electricity would ripple across the social infrastructure with "water distribution affected within several hours; perishable foods and medications lost in 12-24 hours; loss of heating/air conditioning, sewage disposal, phone service, fuel re-supply and so on." This map shows the vulnerable transformers and blacked-out regions expected from a severe storm

Mitigation:Monitoring

Weather

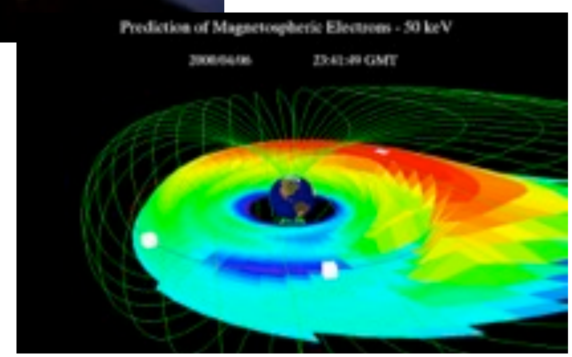


NOAA National Weather Service

Accuweather

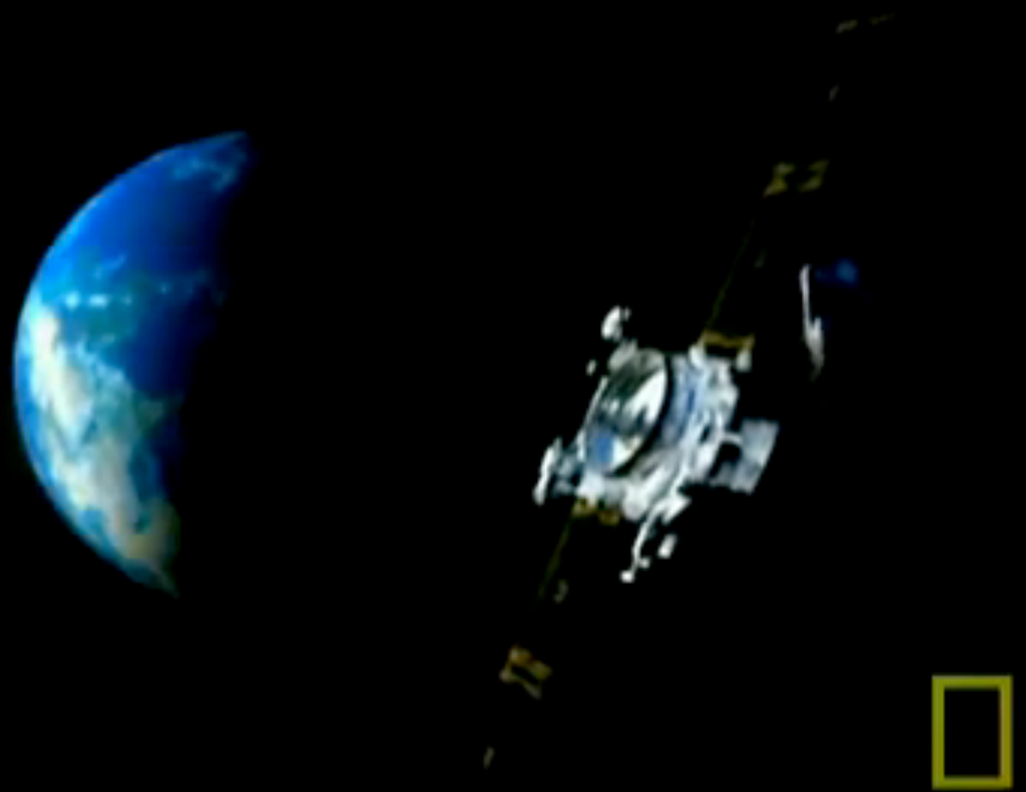
Space Weather

NOAA Space Environment Center



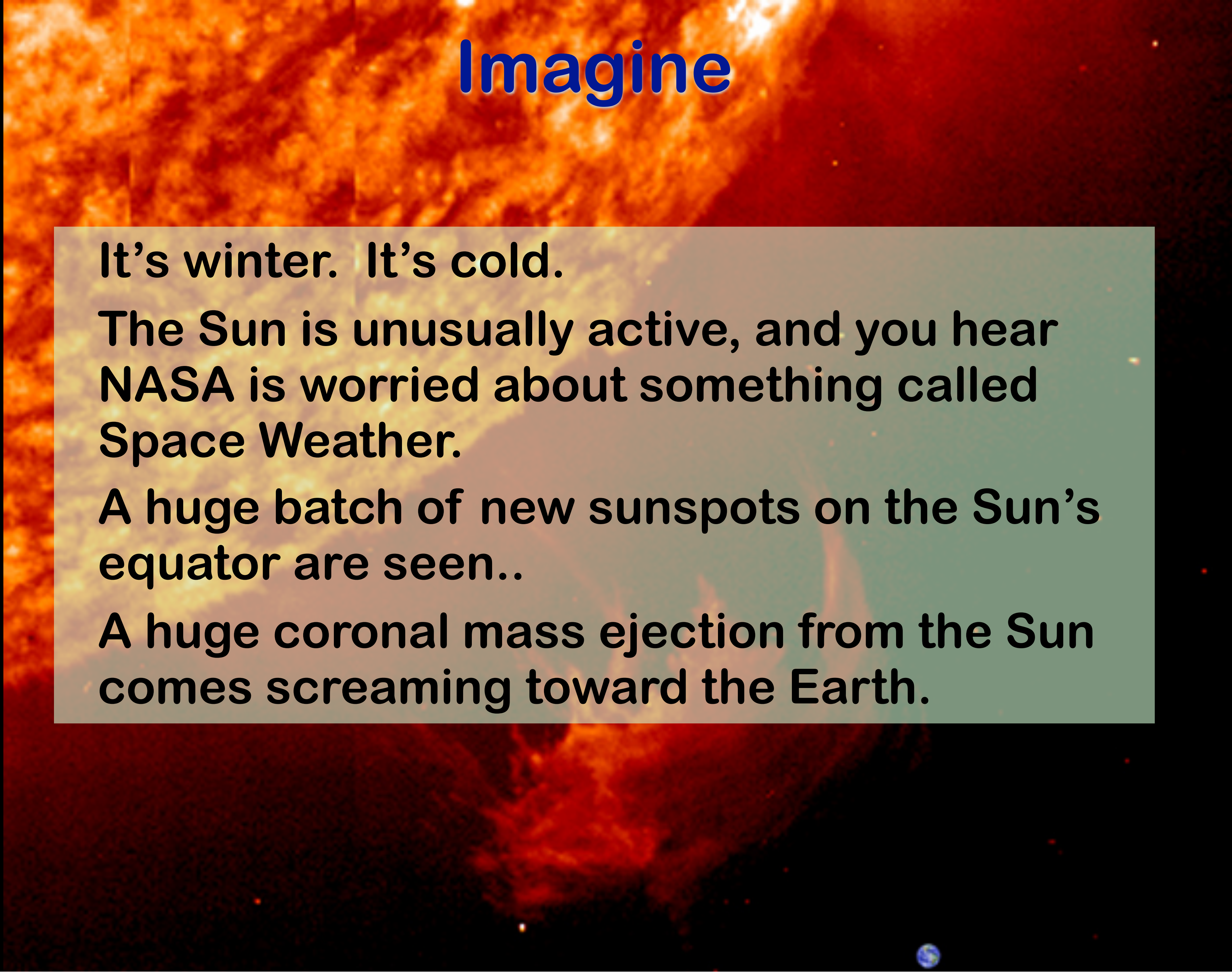
Just like weather on Earth, the first step to mitigation is monitoring.

Mitigation:Monitoring



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

If we know what’s coming we can mitigate the effects.
Monitoring


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.

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 and water.

Thousands die the first night…

Then, more sunspots…

And you can’t remember what Leslie mentioned about CMEs….

Bigger is Better?

We have learned that stars can be mean.

But, remember that our star is a low-mass star.

Can other stars hurt us?

Yes!

So we better learn more about them!

Imagine

- Astronomers are the first to know.
- Neutrino detectors around the world are overwhelmed by the blizzard of signals
- 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.
- Can easily be seen during the daytime!
- 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

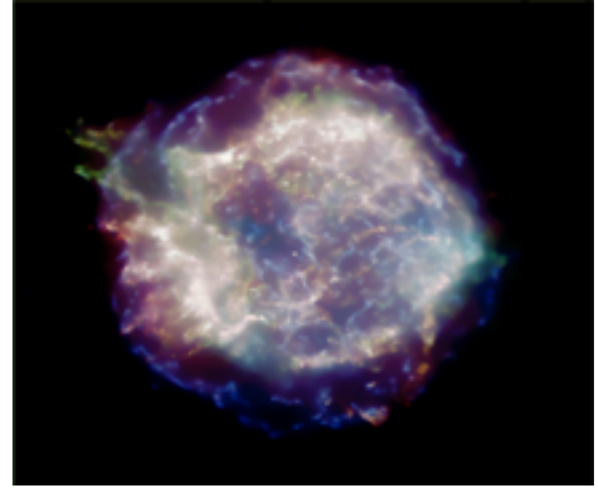
4. **Supernova in the face!**

Extreme energy! Can destroy the ozone layer!

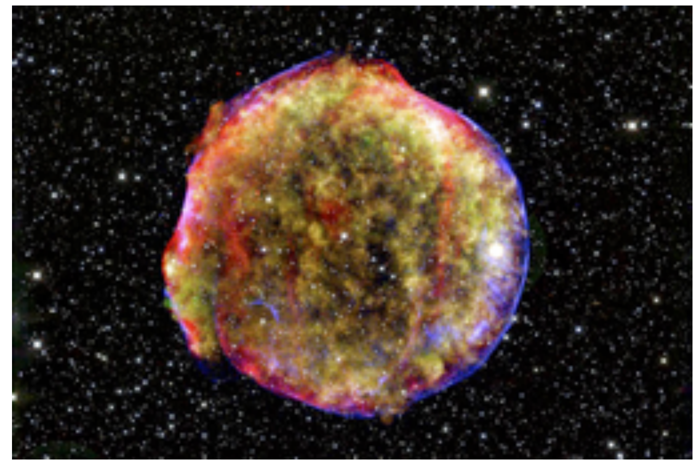
Supernova

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

Killer Stars: Threat Assessment

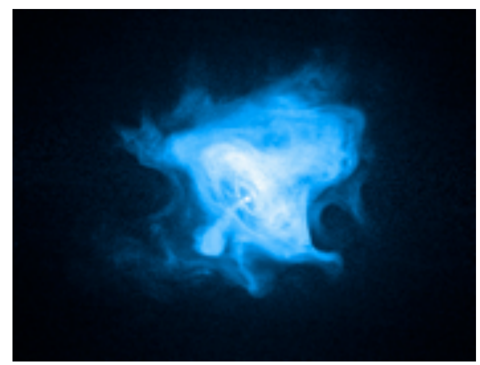


Space beyond the solar system is filled with stellar weapons of mass destruction!



- exploding stars: supernovae
- death rays: gamma-ray bursts
- black holes

these all come from the lives and deaths of stars



so to understand the threat, we need to understand stars

The Astronomer's Toolbox

From here on out, we will be interested in (and worried about!) objects beyond the solar system

- These are too far to visit!
- at least with current technology

But don't give up hope: we can still learn a lot even when stuck on Earth (or in orbit around it)

The Astronomer's Toolbox

Talk to you neighbor, and come up with a list:

From Earth, what are things we can directly measure about stars?

- More than one right answer!

Click A when you are finished

Star Properties?

What can we directly measure?

Hard-nosed list:

- position on sky
- color/spectrum
- intensity/brightness
- time changes (if any) in the position, color, brightness

All other information (all the really interesting stuff!) is indirect!

Lesson:

⇒ can only measure light!

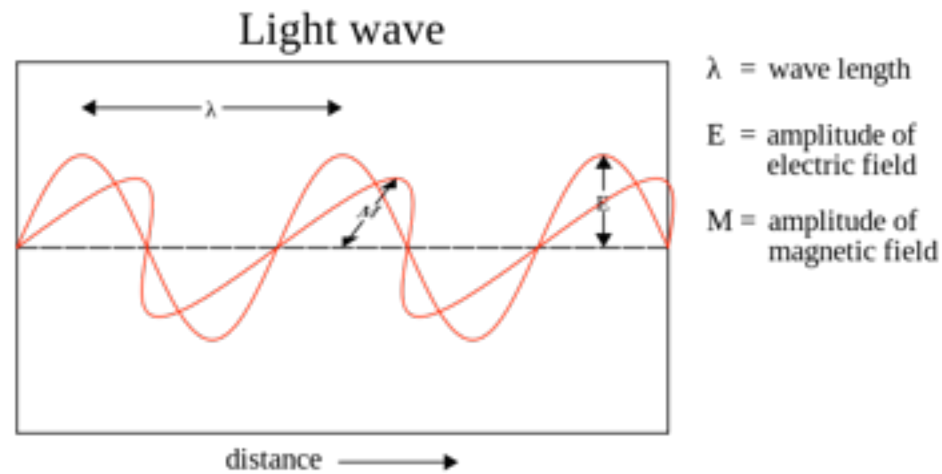
can look but can't touch!

⇒ need to understand light to understand stars

Light

Light deeply connected to

- electric charge,
- electric and magnetic forces



Experiments show:

- changing E force generates M force
- changing M force generates E force

And so:

1. E&M linked: “electromagnetic force”
2. EM disturbances can travel through space: each regenerates the other:

   E→M→E→M→...

electromagnetic waves = “EM radiation”

Technology Tim's Terminology Tip: "Radiation"

Warning!

meaning of "radiation" in Physics, Astronomy, Cosmology is different from "radiation" in everyday talk!

In Physics, Astronomy, Cosmology...and more importantly... In this course and on the exams:

- radiation = movement of energy through space
- carried by particles or waves

Technology Tim's Terminology Tip: "Radiation"

Examples: ordinary visible light! e.g., flashlight, sunlight, starlight, ...

completely benign and indeed necessary for life!

- but also invisible EM waves: radio, UV, X-ray...
- and even non-EM particles: neutrinos...

Beware Confusion: "radiation" so defined is not radioactivity!

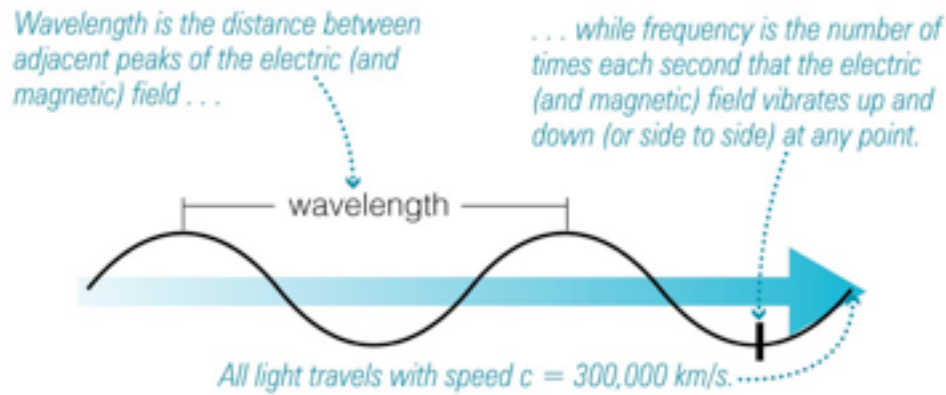
Light Waves

light is a type of wave:
a wave is oscillating disturbance in a medium
wave can travel, medium does not

Demo: Illini waves!

Wave snapshot:

- wavelength λ (greek: lambda)
  size of one cycle → wave "ID number"
- intensity I
  "strength" of wave = "height of peaks"



Wave snapshot at one instant of time

Demo: slinky:

- pulse
- same wavelength, diff't intensities

Q: Sound waves: how do we experience λ? I?

Q: Light waves: how do we experience λ? I?

Waves: Sound vs Light

Sound:

sound wavelength λ ↔ pitch

- high pitch (treble): small λ
- low pitch (bass): large λ

sound intensity = loudness

Light:

light λ ↔ color

- visible light: larger λ: more red
- smaller λ: more blue

intensity = brightness