Card, 8/30

- (Note: This is an example of the "feedback files" I will be posting for each activity, on the "Cards" page.)
- We watched two clips from a recent PBS video, that discussed solar storms and coronal mass ejections (CMEs), and the dangers that these phenomena pose to modern technological civilization.
- You were asked to restate in your own words two or three major points made in the video, and were invited to ask about confusing or unclear points.
- Just about everyone followed directions and satisfied the assignment! Many students said they found the video interesting, but a bit scary. Programs like this do tend to be sensationalistic, to grab the audience's attention.

Student Responses: Main Points

- "The Sun is not [just] a calm ball of gas."
- "Solar storms … emit large amounts of radiation, which can affect power supplies and cause blackouts."
- "Coronal mass ejections (CMEs) are [made up of] tons of electrically-charged particles."
- "CME's can wipe out entire power grids, as occurred in Canada in 1989… scientists project that it could take more than 10 years to recover from a major CME wave."
- "Since the launching of the Solar Dynamics Observatory (SDO) in Feb. 2010, solar physicists are now able to see clear, constant [no, *continually updated*] images of the Sun, and monitor solar storms."

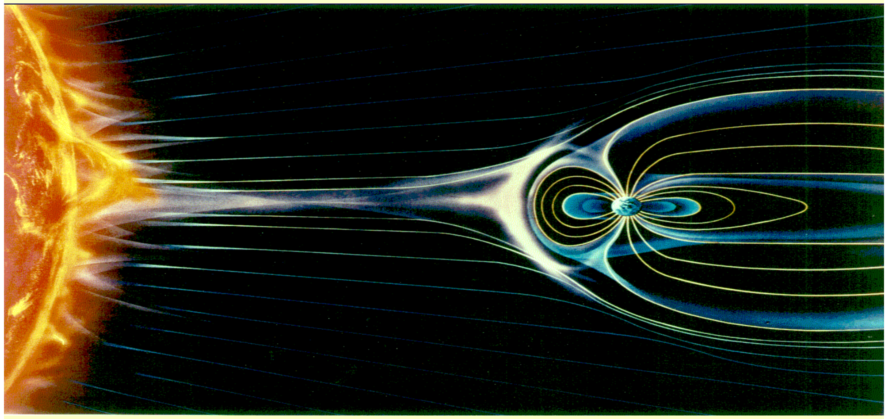
Clarifications & Confusions

- "Solar storms affect the Earth's magnetic field." No, charged particles from the Sun *interact with* the Earth's magnetic field (caused by currents in the liquid iron core).
- There was some confusion over the distinction between *electromagnetic radiation* - electromagnetic waves (pure energy) are actually light of various forms, and *electically charged particles*, which are matter. Notice that the term "Coronal Mass Ejection" refers to ejected *mass* (matter).
- The "one-two punch" of a solar storm consists of:
  - The "flare" = X-rays, traveling at the speed of light, c, which reaches the Earth in just 8.3 minutes
  - The "CME" = sprays of highly energetic, charged particles shot into space; it's a matter of luck whether they hit or miss the Earth

Queries & Concerns

- "There is no protection on Earth from solar radiation."
  - Fortunately, this is not true! The Earth's atmosphere absorbs high-energy electromagnetic radiation (such as X-rays from solar flares). As for the energetic charged particles flowing from the Sun, the Earth's magnetic field provides a shield against them. Instead of traveling straight through and hitting the Earth, they are redirected to travel along the field lines that bend around the Earth.
  - The ongoing, relatively thin flow of particles from the Sun is called the "solar wind." CMEs are rare, occasional events where a lot of mass is expelled in a short period of time.
  - Some particles follow the field lines to the Earth's magnetic poles; when they hit the upper atmosphere in the polar regions, they produce a glow we call the "Northern/Southern Lights" or aurorae.
  - Other particles are trapped in doughnut-shaped regions called the Van Allen belts. These were discovered by the first U.S. satellite.

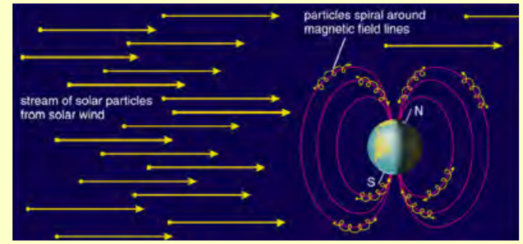
How Solar "Weather" Affects Earth

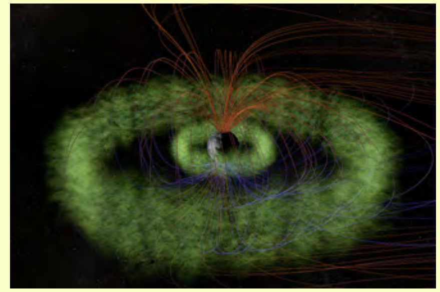


Charged particles from Sun can disrupt electrical power grids, disable communications satellites, and create auroras

Earth's Magnetic Field/Shield

Charged particles can move only *along* field lines; paths of some are "bent" to the poles





Others remain 'caught' in the mixer-like spokes of the rotating field, and fill up regions called the Van Allen belts, which are hazardous to satellites.

Queries & Concerns

- "What is the advantage of seeing a solar storm coming? Can we mitigate its impact?"

  Yes, some steps can be taken. We can put expensive and delicate satellites in "safe" mode. We can keep airplanes (e.g. Air Force One) from flying over the poles and potentially losing radio contact.

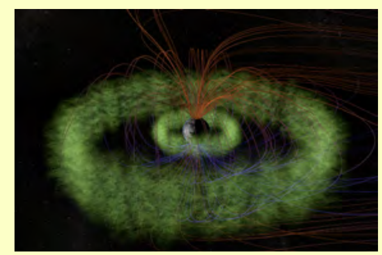
  If we understood more about how the geomagnetic shield works, maybe we could do more. NASA just launched (last Thursday!) the two Radiation Belt Space Probes, which will study the Van Allen belts from the inside, and learn better how to predict their behavior.

- "How do solar storms affect other planets?"

  It depends on whether the planet has a strong global magnetic field. For example, Mars does not, and this might have led to the loss of most of its atmosphere. When considering whether a planet is habitable, the presence or absence of a magnetic field is relevant.

RBSP: Probes to the Van Allen Belts

Launch: Aug. 30, 2012



www.nasa.gov/mission_pages/sunearth/index.html, look for Radiation Belt Space Probes

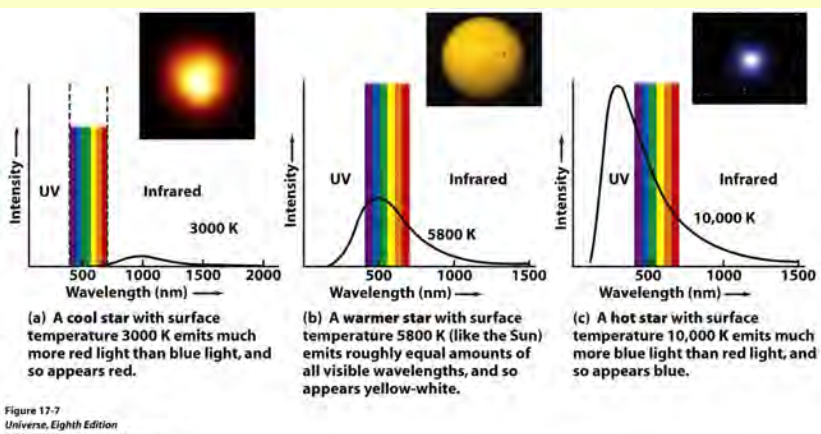
Queries & Concerns

- "How does SDO get such high-quality (detailed) pictures?" By deploying telescopes in space, scientists avoid the blurring effects caused by flows and turbulence in Earth's atmosphere. As a result, even a relatively small telescope can obtain very sharp, high-definition, images.
- "What happened as a result of the solar storm of 1859, when electrical technology was in its infancy?" The storm knocked out long-distance telegraph communications.
- "I need a refresher on the vocabulary." The video mentioned "plasma." This refers to hot, low-density gas in which the atoms are ionized: some electrons have been knocked off, leaving positively charged atoms plus negatively charged free electrons.

Relation of wavelength to temperature?

- The video spoke rather imprecisely about SDO observing light of "different temperatures," for example mentioning "hotter wavelengths." Some of you took this literally, although it is really kind of a "short-cut" expression.
- What they are really talking about is a property of thermal emitters (sometimes called "blackbodies"). In your intro astronomy class, you should have learned that warm or hot bodies emit light over a range of wavelengths, but that the light is most intense – brightest – at a specific wavelength that is related to the surface temperature of the object. The formula that relates the wavelength of peak brightness to the temperature is called "Wien's law."

Temperature and Color



(a) A cool star with surface temperature 3000 K emits much more red light than blue light, and so appears red.

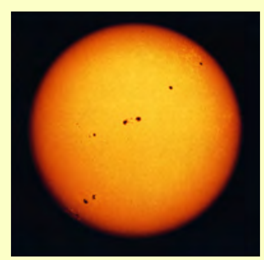
(b) A warmer star with surface temperature 5800 K (like the Sun) emits roughly equal amounts of all visible wavelengths, and so appears yellow-white.

(c) A hot star with surface temperature 10,000 K emits much more blue light than red light, and so appears blue.

Figure 17-7
Universe, Eighth Edition

Relation of wavelength to temperature

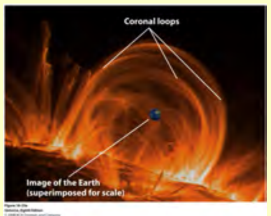
- Cooler objects emit most strongly at longer wavelengths, in the red or infrared part of the spectrum. Objects at the temperature as most of the Sun's surface, about 6000 K (close to 10,000 °F) peak in "visible" light. At shorter wavelengths, we see hotter regions and layers. (This is also an oversimplification, to be clarified later.)

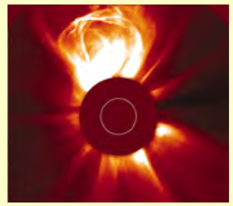


The Corona and the Solar Wind

The highest layer above the Sun's surface is the "corona." While seen as a glow in visible light during eclipses, it emits mostly X-rays, due to its high temperatures.

The corona is not a "flat" layer, but shows many loops and "prominences" that project from the surface. In a coronal mass ejection (CME), energetic particles are shot off into space, sometimes reaching the Earth.





Solar Eclipses: A Cosmic Coincidence

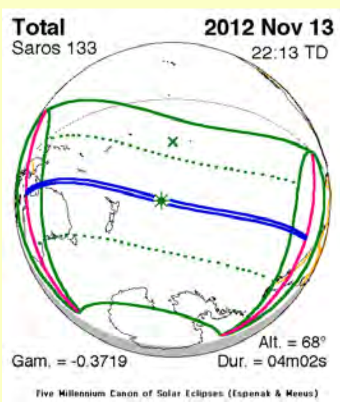
If the Moon did not just happen to have about the same angular diameter as the Sun's, we would not have the present rare, striking phenomenon of total solar eclipses.

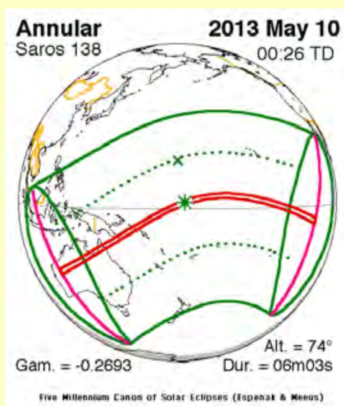
What if the Moon's angular size were larger?

Why don't we have a total eclipse every month?

The Next Two Solar Eclipses

Source: eclipse.gsfc.nasa.gov





Why are there "annular" solar eclipses?

In an "annular" solar eclipse, the Moon is in front of the Sun, but doesn't cover it completely; instead, an annulus (ring) of sunlight is seen around the edge of the Moon. This happens when the angular size of the Moon is slightly smaller than that of the Sun.