Quiz 1 Feedback

1. What usually happens to energetic charged particles from the Sun when they approach the Earth?

   There is a continual flow of particles from the outer layers of the Sun, sometimes called the "solar wind." We are protected from them by the **Earth's magnetic field**, which **deflects them away** (changes their direction) so that they don't hit the Earth head-on. Some of the particles travel along the field lines to the Earth's magnetic poles, where they collide with molecules in the atmosphere, causing the Northern and Southern lights, the **aurorae**. (Aside: The light is produced when electrons within the molecules are "knocked" up to higher energy states, and then fall back down, emitting photons of light.)

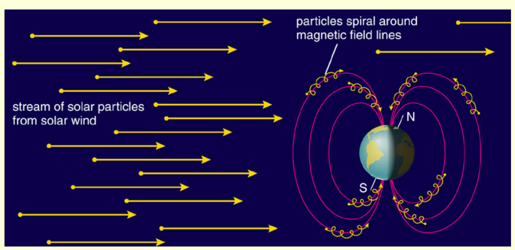
Queries & Concerns

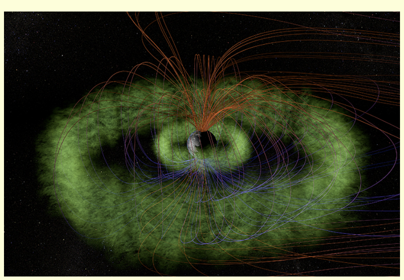
- "There is no protection on Earth from solar radiation."
  - Fortunately, this is not true! The Earth's atmosphere absorbs high-energy electromagnetic radiation (such as X-rays from solar flares). As for the energetic charged particles flowing from the Sun, the Earth's magnetic field provides a shield 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.

From Card File for Aug. 30

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.

From Card File for Aug. 30

Quiz 1 Feedback

1., continued: Why is it hazardous for society when a large burst of such particles heads towards the Earth?

A large burst of energetic particles thrown off by the Sun is known as a **Coronal Mass Ejection**, or **CME**. This was featured prominently in the video we watched clips from, during the first 3 class meetings. (You didn't have to give the specific name to get full credit.)

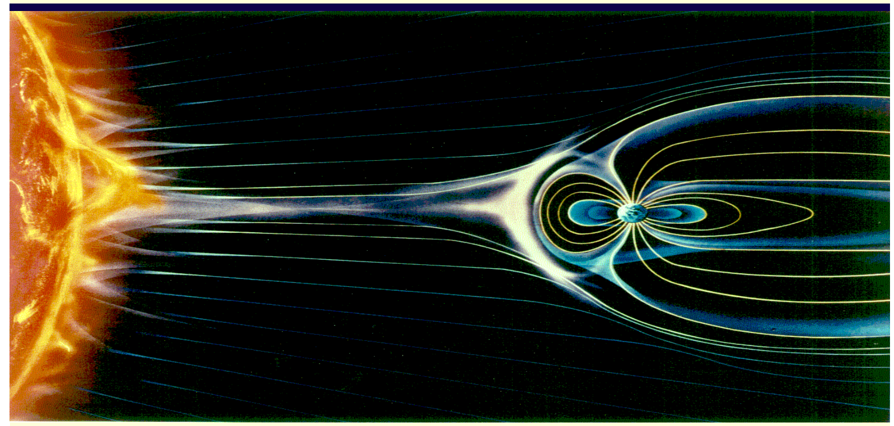
With so many particles coming in, they overwhelm the Earth's magnetic shield and "zap" humanity's electrical systems, **knocking out power grids, causing power outages,** and/or **disrupting communications**. They can also push the aurorae down towards the Equator, producing so-called "low-latitude aurorae."

Student Responses: Main Points

- "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."

From Card File for Aug. 30

How Solar "Weather" Affects Earth



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

From Card File for Aug. 30

Quiz I Feedback

2. What was the original purpose for looking for solar neutrinos?

The motivation for seeking to detect solar neutrinos was **to prove that the Sun is powered by nuclear fusion.**

> Only neutrinos, with their extremely small interaction cross sections, can enable us to see into the interior of a star and thus verify directly the hypothesis of nuclear energy generation in stars. ---John Bahcall, PR, (1964)

Incorrect Answers:

To prove that neutrinos existed. No, we knew they exist.

To find out how old the Sun was. Nope. Wrong answer.

To learn more about neutrinos. That's the way it ended up, but the original purpose was to study *the Sun*, not the neutrinos.

Quiz I Feedback

2. continued. Did the early results find what was expected?

Although the early experiments **did** detect neutrinos from the Sun (that's the good news), **they saw fewer than they had predicted** they would see (that was the bad news). This discrepancy came to be called the Solar Neutrino Problem. It later turned out that the predictions of the number of neutrinos produced by the Sun were correct, but the (originally electron-type) neutrinos were changing into different types of neutrinos along the way, and early detectors were not able to "see" the other types. The experiment that solved the solar neutrino problem was SNO, which was able to detect all three types of neutrinos.

A Problematical Answer

- "The original purpose was to find out information about the Sun and predict any changes or things occurring there." Too vague, and "changes" were not predicted.
- "They predicted to have up-to-date information, but .. they found out [that] neutrinos made in the core take many years to arrive to us." This student is vaguely recalling the index card question on 9/6, but has things *backwards*: neutrinos arrive quickly, it is **photons** which take a long time to travel from the Sun's core to surface.
- "The situation has changed, they started to find another way to detect things coming from the Sun not just in neutrinos." The new experiments are still measuring neutrinos, but can now detect all neutrino types.

Sample Correct Responses

- "Photons travel through the Sun's radiative zone in a 'random walk,' being absorbed and re-emitted by atoms ~~constantly~~ [better: repeatedly] until they escape the Sun's surface. Neutrinos travel though the Sun and reach the Earth in a little over 8 minutes."
- "A photon does not '~~travel to~~' [travel ***directly*** to] the surface; it ends up there after taking many side trips, ≈ 100,000 years' worth of side trips."

From Card File for Sep. 6

Quiz 1 Score Distribution

Score	# Papers	% Class
0	2	1%
½	1	<1%
1	3	2%
1 ½	9	6%
2	11	7%
2 ½	16	10%
3	28	18%
3 ½	26	17%
4	61	39%