Solar Storms

Objectives

Students use RHESSI X-ray image data of a solar flare to determine how fast a coronal mass ejection (CME) jetisons from the Sun's surface.

This activity supports National Science Education Standard:

- The motion of an object can be described by its position, direction of motion, and speed . . . [NSES 5–8; B: Physical Science: Motions and Forces p. 154.]

Preparation

- Get ready to show the two X-ray images of the 15 April 2002 solar flare. You can make a transparency from the image shown here or use the electronic version to project on a large screen computer display. Alternatively, make paper copies—one for every group of 2 to 6 students.
- Read background material about solar flares in Activity 2 Magnetic Energy and the Cause of Flares as well as activity 3. (http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring%5Fmagnetism/in_Solar_Flares/s4.html#act2)

The basic concepts about energy related to flares include

- Changing electric fields create magnetic fields and that changing magnetic fields create electric fields.
- When energy goes toward heating something up it is transformed into the kinetic energy of individual particles all moving in random directions, called thermal energy.
- Heated objects give off light. Some are hot enough to glow in visible light. Others are hot enough (about 300 K) to glow in infrared light. The cooler an object is, the lower the energy is of light that it gives off.

Activity

1. **What are flares?**

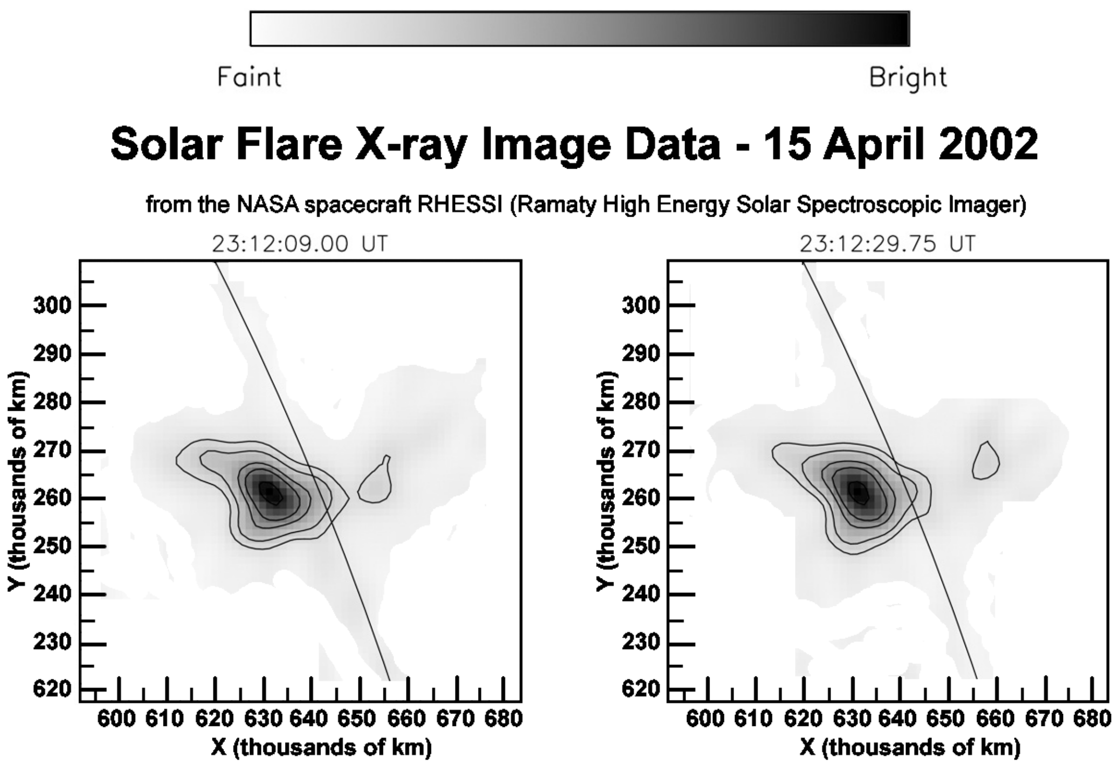
If your class has not studied the Sun much yet, have a discussion leading to what flares are. Solar flares are the most powerful explosions in all the Solar System. They appear as sudden, rapid, and intense increases in brightness in relatively small regions in the Sun's atmosphere. They occur when magnetic fields in the Sun's atmosphere rapidly change shape and generate currents of electrically charged particles called plasmas. Some flares also seem to generate gigantic eruptions of matter that are ejected out into interplanetary space. Such eruptions are called Coronal Mass Ejections (or CME for short). The name is very descriptive as these events are literally ejections of mass from the Sun's corona. These can have impacts on our lives here on Earth and on astronauts living and working in space. The amount of energy released in a single solar flare is ten million times

This activity is Exploring Magnetism, Session 4 Solar Flares, Activity 3 Measuring the Speed of an Ejected Blob of Plasma, developed by staff from Center for Science Education at Space Science Laboratory, University of California, Berkeley:

(http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring%5Fmagnetism/in_Solar_Flares/s4.html#act3)

Materials

- **Solar Flare X-ray Image Data - 15 April 2002 (two images).**
- **Ruler(s)**



greater than the energy released from a volcanic explosion here on Earth. The energy is released in several different forms:

- kinetic energy of tons upon tons of moving plasma in a CME—several billion tons of matter that are spewed out into interplanetary space..
- kinetic energy in the chaotic and random motions of particles in matter: thermal energy.
- Electromagnetic radiation from plasma moving through a magnetic field with accelerations that cause charged particles to radiate light.
- Electromagnetic radiation from heated matter. One way that heated matter cools is by releasing energy in the form of light.

Deeper inside the Sun there is convection of gas as well as nuclear fusion (a reaction where nuclei of hydrogen fuse together to create helium.

2. Measure displacement of the plasma blob in the time interval shown on the images

Have students either work in groups, or have a volunteer com up and measure with a ruler. [displacement is about 5,000–6,000 km in 20.75 sec]

3. Determine the speed of the plasma blob

Ask the students how they could determine how fast the CME/blob is moving. [speed = displacement/time.] Have them determine the speed. [250 to 290 km/sec]

4. How fast is that in mph?

[250 km/sec x .6 mi/km x 3600 sec/hr ≈ 500,000 mph]

5. At that speed, how long would it take the plasma material to reach Earth?

[150 million km ÷ 250 km/sec = 0.6 million sec ÷ 86,400 sec/day ≈ 7 days. More violent eruptions would travel faster and take less time. Also, the Sun's gravity would slow the speed down over time.]

Here are a variety of resources for teaching about solar storms as well as a variety of other topics about the Sun.

I. From the NASA Living With a Star project (http://lws.gsfc.nasa.gov), find resources and activities at http://stargazers.gsfc.nasa.gov/educators/activities.htm

- The Dynamic Sun: A student activity sheet to accompany The Dynamic Sun version 4.0 CD (developed by the Solar and Heliospheric Observatory (SOHO) . . . a mission of international cooperation between NASA and the European Space Agency.)_ A student activity sheet to accompany The Dynamic Sun version 4.0 (CD developed by the Solar and Heliospheric Observatory, SOHO). a multimedia educational presentation on the Sun and its effects on the Earth.
- Sunspot Classification
- In a Different Light—six lessons for grades 6-12 that develops the understanding that visible light is composed of a full range (spectrum) of colors of light from red to violet, that extends the concept of a spectrum to include non-visible light (infrared and ultraviolet) through discovery, and that develops tools and strategies for student inquiry.

II. From the Center for Science Education at Space Science Laboratory, University of California, Berkeley, at http://cse.ssl.berkeley.edu/ you will find the following titles pertaining to solar storms:

- Coronal Weather Report
- Exploring Magnetism
- Solarmax
- Space Weather
- SunEarth Media Viewer
- Sunspots

III. From Astronomical Society of the Pacific, Universe in the Classroom has a good collection of solar activities focusing on magnetism and the Sun at:

http://www.astrosociety.org/education/publications/tnl/68/solar.html

- Activity 1—How Big, How Far?—Students use a Sunspotter to measure the Sun's angular diameter.
- Activity 2—The Sun Has Many Faces—Students create a rainbow using

a light source and common items like a glass of water or reflections from a CD. They use spectrographs to look at the spectrum of a lamp, fluorescent light, and the Sun.

- Activity 3—Observing the Sun—Students observe the Sun using the Sunspotters and the Coronado SolarMax 40 H-alpha telescope making sketches of their observations. Students learn to recognize sunspots, filaments, and other features on the Sun. Students then compare their observations to those of ground-based and satellite observatories via the internet.

- Activity 4—What Causes Sunspots?—Students investigate the idea that sunspots are caused by magnetic fields rising from under the surface of the Sun. They use iron filings on a piece of paper lying above a bar magnet to simulate the shape of a classical bipolar sunspot. Students are introduced to magnetograms of the Sun and how they are made.

- Activity 5—Flares on the Sun—When magnetic fields on the Sun intertwine, the resulting sunspots look very different from a classical bipolar sunspot. The ensuing magnetic energy can generate a sudden, violent release of energy called a solar flare. Students use a variety of magnets (bar, ring, spherical) in a variety of orientations under iron filings to simulate complex sunspot regions that would be flare-productive.

- Activity 6—Coronal Mass Ejections—Students are introduced to coronal mass ejections, often associated with solar flares, as material coming from the Sun and are shown several video sequences of such coronal mass ejections. Given 4 time-sequenced images of classical coronal mass ejections, students measure height above the solar surface versus time and calculate the speed and possible acceleration of the ejected material. Given the distance to Earth, students calculate how long it would take before this material reaches Earth.

- Activity 7—Earth-Sun Connection—In this final activity, students learn how solar activity such as flares and coronal mass ejections affect us on Earth.

IV. From the Stanford Solar Center (http://solar-center.stanford.edu/) there are these 20 activities:

1. Build Your Own Spectroscope—Students build a working spectroscope to study the nature of light.

2. Effects of the Sun on our Planet—Students experiment with plants, light, heat, and water evaporation. They experiment with solar cells to design a simple solar cooker, create a "solar-powered" method to perform a routine task, or build a parabolic solar collector.

3. What is Ultraviolet Light?—Explores ultraviolet light—what it is, where it comes from, how we can detect it, and what effects it has upon us and our Earth. Using (inexpensive to order) UV sensitive beads, the students test the beads with various levels of sunscreen protection, as well as the quality of UV protecting sunglasses.

4. Retrieving Solar Images—daily . . .

5. The Spinning Sun—Students use their solar data to (estimate or) compute, using angular velocity, the Sun's rotation period.

6. Sunspot Races—Using daily solar images, students predict when spots will disappear or reappear from view on the solar disk.

7. Observing the Sun—Information on building pinhole cameras, using telescopes, accessing an online solar telescope, observing eclipses, and sketching sunspots. Includes pointers to related activities.

8. An Interview with Mr. Sol—Students do some research on the Sun then, generate an "interview" with The Star.

9. Sun-Centered Physics—Sun-related physics-based lessons on energy, motion, electromagnetic radiation, fission and fusion.

10. Are Sunspots Really on the Sun?—Students measure sunspot speeds and shapes across the solar disk to determine whether the spots are on the Sun or are planets revolving around it (Galileo's dilemma).

11. Solar Music—Introduction to helioseismology—Solar music.

12. Hearing the Sun—Students listen to sound waves generated from acoustical waves on the Sun.

13. Quick Quizzes

14. Earth-based Solar Phenomena—Suggested questions and topics for research on ways the Sun affects our Earth. Touches on auroras, rainbows, sun pillars, the green flash, sun pillars, etc.

15. Make Your Own Sundial—Exploratorium activity where students determine their latitute and construct a sundial.

16. Art Based on Science—Selection of images used to visualize or process scientific data. Images were chosen because of their visual appeal.

17. Solar Art, Literature, Poetry—Students are invited to generate and submit images, poetry, or literature inspired by the Sun or solar science.

18. Multicultural Solar Interpretations—A selection of information about folklore, ancient astronomy, rock art, and other interpretations of the Sun's connection with Earth.

19. Global Warming—To what extent does the Sun's variability contribute to global warming? Students are given guidelines and places to start for independent research projects on the causes and effects of global warming.

20. Magnetism—Students will learn the basic principles of magnetism and how they apply to the Sun.

V. From the NASA IMAGE Education and Public Outreach (http://image.gsfc.nasa.gov/index.php?education), there is:

- An archive of weekly math problems pertaining to space weather found at http://image.gsfc.nasa.gov/poetry/weekly/weekly.html
- Activities on magnetism, the sun, and solar activity can be found at http://image.gsfc.nasa.gov/poetry/activities.html
- Space weather website — http://www.solarstorms.org/

Check the Planetarium Activities for Student Success (PASS) website for links to more recent news, articles and resources.

http://www.lhs.berkeley.edu/pass