Learning about Space Weather

Middle School Grades

Lesson Summary

Students will learn about the magnetic fields of the Sun and Earth. This activity is a question-answer activity where the students re using "minds-on" rather than "hands-on" inquiry.

Prior Knowledge & Skills

Understanding of:

- Magnetic field lines
- Magnetic field strength decreases with distance
- Larger magnetic fields dominate smaller ones
- General understanding of the properties and nature of a star

Ability to:

- Pose and respond to questions of a scientific nature

AAAS Science Benchmarks

The Nature of Science
Scientific Inquiry
The Nature of Technology
Technology and Science
The Physical Setting
The Universe
Forces of Nature

NSES Science Standards

Science as Inquiry
Abilities to do Scientific Inquiry
Understandings of Scientific Inquiry
Physical Science
Motions and Forces
Earth and Space Science
Earth in the Solar System
Science and Technology
Understandings about Science and Technology
History and Nature of Science
Science as a Human Endeavor
Nature of Science

Teaching Time: One 45-minute class period

Materials per student

- NASA STERO mission story
- Diagrams of the magnetic field lines around a bar magnet
- Drawing paper and drawing tools (optional)

Advanced Planning

Preparation Time: 10 minutes

1. Read and review the lesson plan
2. Gather required materials
3. Form student teams

Exploring Magnetism, pp. 3-3 to 3-12, UC Berkeley (2004)
http://cse.ssl.berkeley.edu/impact/magnetism/flash/mag_flash.html

LASP
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS

Activity 1: Learning About Space Weather

Now that your students know about electromagnetism, they will learn about the magnetic fields of the Sun and Earth. This activity is a question-answer activity where the students are using “minds-on” rather than “hand-on” inquiry.

Your students should have already learned about atoms, phase transitions, and some basic information about the Sun. In particular, for this activity it is best to ensure that the students know that:

- Atoms are made up of electrons, protons, and neutrons.
- Hydrogen is a common element in the universe and it is made up of one electron and one proton.
- In the right pressure environment, as a solid is heated it turns to liquid. As a liquid is heated it turns to a gas.
- The Sun is made up mostly of hydrogen.
- The Sun is hot because gravity acts to pull the mass together so much that near the core of the Sun atoms are pushed together and join together in fusion reactions. These fusion reactions mostly convert hydrogen into helium plus light energy (in the form of gamma-rays). This light energy interacts with matter and is transformed into heat.
- The Sun is so hot that the electrons cannot stay attached to the nucleus of the atom. This means the Sun is mostly a hot, electrically charged gas, which is known as “plasma.”
- The Sun has different layers and its outer layer is called the corona.

It is possible to include in the activity a lecture about these things but it is more meaningful if they have learned them in another context and you can remind them about those lessons in this activity.

Introducing the Interplanetary Magnetic Field (IMF) and Solar Wind

1. First have the students answer the question: “What objects in space have magnetic fields?” [The Sun, Earth, the Moon, Mars, Jupiter, Saturn, Uranus, and Neptune all have magnetic fields. Other planets and objects, such as Venus, do not have magnetic fields because there is not a fluid or gas dynamo in their core; or because the crust of the planet or object does not contain magnetic material.]

2. Review with your students what they know about the Sun. [The Sun is a star. A Star is a big ball of dense gas made up mostly of hydrogen that generates its own energy through nuclear fusion.]

3. After some discussion, emphasize that Earth and the Sun have largescale magnetic fields near their surfaces that are similar to the magnetic field of a bar magnet. Have the students look at their magnetic field maps from Session 1: Activity 1, and Session 2: Activity 3 of Exploring Magnetism. Then have them draw a circle around the region where the bar magnet was located, making the diameter of the circle the same as the length of the bar magnet.

4. Discuss that this circle and the surrounding magnetic field lines approximately represent the Sun and its large magnetic field lines.

5. Ask your students: “Where does the Sun’s magnetic field come from?” Remind your students about the activities with the electric circuits. [The Sun’s magnetic field comes from currents in and around the Sun that are caused by the moving plasma.]

6. Explain to your students that close to the surface of the Sun, the magnetic fields can be complicated with many north and south poles close to one another. Show the image of such magnetic fields taken by an instrument viewing the Sun in ultraviolet light, located on the NASA TRACE satellite (Figure 3.2).

7. Far from the surface of the Sun, the magnetic fields are also different from the bar magnet. They look more like someone’s very long hair flowing out and away from the Sun with a very flat doughnut of current circling around the Sun. This magnetic field is called the “Interplanetary Magnetic Field.”

8. Give a short lecture (5-10 minutes) about the solar wind and explain that it is connected to the Sun’s magnetic field. [The corona is the outer-most layer of the Sun that is so hot that it streams out and away from the Sun’s gravitational pull, producing the solar wind. This wind is not a neutral wind and nothing like wind on Earth. It is an electric wind with a very low density. The solar wind is attached to the Sun’s magnetic fields and together they stream out into space, past all the planets.] See the background resources to learn more about the solar wind and to obtain movies of the corona and features flowing out into the solar wind.

Introducing the Magnetosphere

9. Now have the students look again at their drawings of the bar magnetic field with the circle. Tell them that this circle and the field lines could also approximate Earth and Earth's large magnetic field lines.

10. Ask "where does Earth's magnetic field come from?" [Earth's magnetic field comes from the currents in the molten Iron core inside Earth's crust. These currents create a complex magnetic field that is approximated by a dipole magnetic field, like that of a bar magnet].

11. Explain that far from Earth, the magnetic field lines are modified by something blowing through space. Show a transparency of Figure 3.3 on an overhead projector. Explain that this is a cartoon of Earth's magnetosphere if we could look at it with "compass eyes."

12. Ask "what in space is making the magnetosphere look different from the bar magnet dipole field?" [The solar wind! It blows past Earth's magnetic field from the left on this image and pushes the magnetic field lines on the side facing the Sun and lengthens the field-lines on the side opposite from the Sun.]
13. Show a transparency of Figure 3.4 on an overhead projector and explain that if we did not rotate with the Sun and we looked down on the "top" of the Sun, the solar wind and the interplanetary magnetic field would look like a giant spiral coming off of the Sun, like the water coming off of a sprinkler.

14. Hand out to students "A NASA story of STEREO/IMPACT: Introductory Material," found in the Background Material section. Have the students read these pages at home and write a paragraph explaining in their own words one concept that they learned from the handout.

15. Collect the students' paragraphs the following day and read them to assess their understanding of the lecture and the reading.

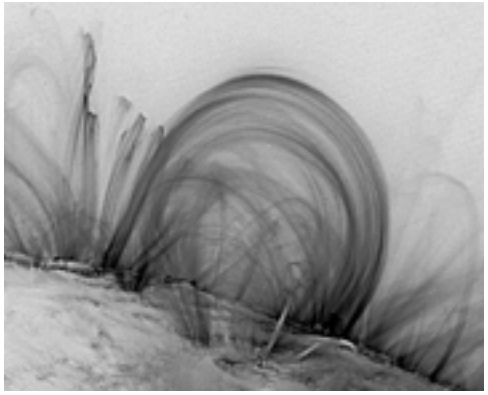

Figure 3.2
An image of magnetic field lines near the surface of the Sun (the photosphere) is shown. This image was taken by collecting ultraviolet light in an imager on the NASA TRACE satellite.

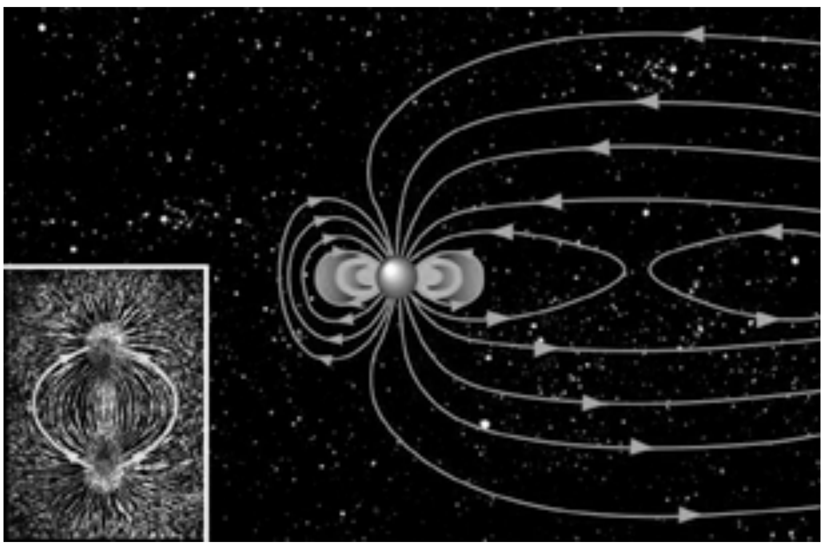

Figure 3.3
A depiction of the magnetic fields around Earth, known as the Magnetosphere, is shown as viewed from the ecliptic plane. The “North” pole is really a magnetic south pole which attracts the north poles of compasses. The solar wind modifies the dipole field lines far from Earth. Image courtesy of NASA.

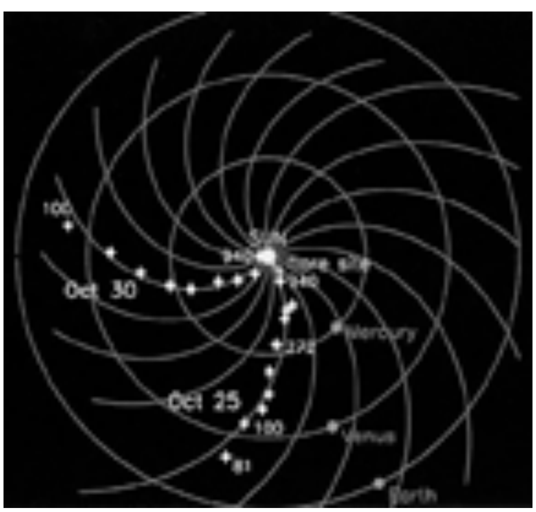

Figure 3.4
A model of the magnetic field (spiral lines) of the Sun (in the middle) is shown as one looks down on the Sun’s axis of rotation. This magnetic field is known as the Interplanetary Magnetic Field (IMF). The orbits of Mercury, Venus, and Earth are shown as circles. The spiral of the IMF shown here is due to the fact that the IMF is attached to the rotating Sun, but we draw it from a non-rotating perspective from above. Image courtesy of NASA.

A NASA "Story" of STEREO/IMPACT: Introductory Material

There are many scientists who want to understand more about the Sun. They know that the Sun is a fiery ball of gas that gets so hot that gas flies out from the Sun at very high speeds. Many of the electrons in the Sun's atoms have enough energy to leave the atoms. These new particles are called ions. These ions and electrons are flowing from the Sun and together they are known as the solar wind. The ions and electrons dance in the Sun's magnetic field.

Scientists discovered that the solar wind and its magnetic field flow together out past Mercury, past Earth, and continue out past Pluto. Because the magnetic field is threaded throughout the solar system, we call it the interplanetary magnetic field, that is the magnetic field found between (inter) the planets (planetary).

Scientists have also noticed that the Sun goes through different cycles, just like moody people who are calm and quiet some days but other days, they explode with anger. But of course the Sun doesn't have emotions to drive its cycles! Physical principles, such as magnetic and electric forces, drive its cycles. During the Sun's active cycle, parts of the Sun will explode, sending out even more solar wind and magnetic fields than it typically sends out.

What happens to the solar wind and magnetic fields that the explosions send flying out into space? Well, sometimes the explosive solar wind will flow by Earth, where we all live. Luckily Earth has a magnetic field and a thick layer of atmosphere, which protect all living creatures on Earth from the particles and radiation that can come from such solar explosions. But when astronauts are up in space, sometimes the magnetic field isn't strong enough to protect them and they have to run, or rather float, back into their space vehicles, such as the space station. Scientists asked themselves: "What triggers these explosions?" How do these explosions flow out and away from the Sun? How do these explosions make ions and electrons go so fast?"

How are the scientists going to answer these questions? Well, they have studied the solar explosions while sitting (or standing) on Earth using telescopes. They named these explosions coronal mass ejections. Scientists like to give names to specific types of events so that everyone knows what they are talking about using only a couple of words. That is efficient. NASA scientists like to make it even easier by making an acronym out of the name. An acronym is made with the first letter of each word in the name. What acronym would you use for the term: interplanetary magnetic field? What does the acronym NASA stand for? NASA scientists make a Coronal Mass Ejection into an acronym too: a CME.

With just one satellite, scientists can only measure magnetic fields at one point in space, and that's just what they have done. And with one satellite at a time, they have discovered many things about the Sun. But really, scientists need to measure the interplanetary magnetic field and the solar wind at more than just one point. Two instruments studying the Sun from two different places will help them understand better how the explosions move outward.

So, several scientists proposed to put up two satellites at the same time. These two satellites would be able to take photographs of the Sun from two perspectives, and instruments on the satellites would measure the Interplanetary Magnetic Field in two locations. If we converted the data into sound and listened through headphones, the data could come out in stereo! And so, this mission was named STEREO, which is short for Solar Terrestrial Realations Observatory. As they say, "Two ears are better than one!" The reviewers at NASA, who are other space scientists, said: "Yes! These are good science questions and a feasible mission. Let's do it!" And the U.S. Congress agreed to pay for it. And so instruments and a satellite are being built for the NASA STEREO mission in order to study the Sun's explosions. And now you too can be a part of this mission.

We never really answered the question: "How are the scientists going to measure the interplanetary magnetic field?" This is what you are going to answer in the next activities centered on electromagnetism. First, you have to remember what you know about magnetic fields and how to measure them. Then you have to design a model experiment that could work on a spacecraft to measure the interplanetary magnetic field. And then you have to create your design, test it, and share your design and model with your fellow scientists and engineers, that is — your fellow students. This is exactly what scientists and engineers working on the STEREO/IMPACT NASA mission have had to do.