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Our Solar Connection: A Themed Set of Activities for Grades 5-12

By Dr. Wil van der Veen

Introduction

The Sun is our nearest star and for that reason the best studied one. Even in the largest telescopes stars are only pinpoints of light. With the naked eye we see the Sun as a disk about the size of the full Moon. With telescopes we can see lots of details on the solar surface. Over the last decades Earth orbiting satellites have greatly increased our understanding of the Sun. In *Our Solar Connection* students explore various solar phenomena and how they affect us on Earth.

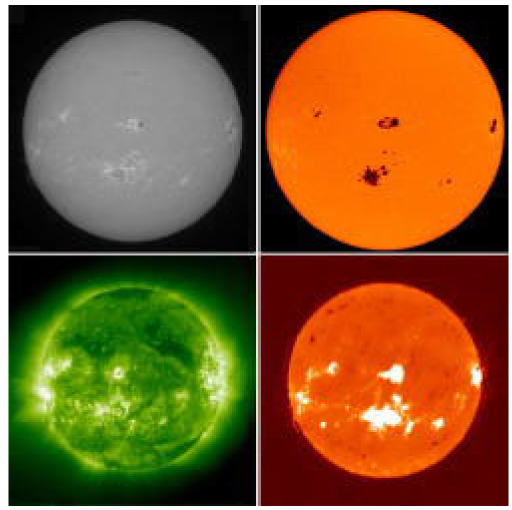
The National Education Standards as published by the National Research Council in 1995, includes the teaching of astronomy as part of the Earth and Space Science Standard. One of the challenges in teaching astronomy, especially the observational aspects, is that only a few astronomical objects can be seen during the day when classes are in session. Besides the Moon, our Sun is a wonderful object to observe during the day, provided appropriate safety measures are taken.

We have put together a set of seven activities for grades 5-12 with a theme centered on the Sun. Some of the activities were adapted from existing activities, others were created by us. This issue includes a brief summary of the seven activities, followed by a more detailed description of one of the most popular activities: "What Causes Sunspots?" The activities meet the National Science Process Standards and Content Standards in Earth and Space Science and Physics (http://www.nsta.org/standards).

A Brief Summary of the Activities

Activity 1—How Big, How Far?
Students use a Sunspotter (http://astrosociety.org/astroshop/index.php?p=product&id=32&parent=4) to measure the Sun's angular diameter. They center the image of the Sun within a drawn circle and observe that the image is moving. They time how

long it takes for the Sun to move completely out of the circle. Given that it takes 24 hours for the Sun to move 360°, they calculate the angular diameter of the Sun. Given the distance to the Sun, they then use the angular diameter to calculate the Sun's actual diameter. A scale model of the Sun and Earth is constructed in the classroom to illustrate the size and relative distances of the two.



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 then use spectrographs (http://www.starlab.com/psprod.html#Anchor-Plastic-23240) to look at the spectrum of a lamp, fluorescent light, and the Sun. In each case, they determine the shortest and longest wavelengths visible to their eye, and note whether there are spectral lines. This experience is used to introduce the electromagnetic spectrum. The students are then given images of the Sun at 4 different wavelengths (radio, white light, UV, and H-alpha) taken on 4 different dates, and they try to arrange the images according to date by matching features.

Activity 3—Observing the Sun
Students observe the Sun using the Sunspotters and the Coronado SolarMax 40 H-alpha telescope (http://www.coronadofilters.com/cgi/display_catalog.cgi?w=1920), 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. Finally, students receive magnetograms for each of the dates from Activity 2 and match the magnetograms with the other images.

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. Afterwards, students are given several time-sequenced images of a region with a growing sunspot group in white light and H-alpha, and are

challenged to put them in time order. Finally, students look back at the images from activities 2 and 4 and rank each of the dates in order of probability that a flare would occur that day.

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. The Earth's magnetic field is briefly reviewed and the influence of a coronal mass ejection on the Earth's magnetic field is explained using video simulations of the interaction. The observable effects on Earth such as aurora sightings and changes in magnetic field strength and direction are discussed. Students then build a simple magnetometer to monitor changes in the direction of the Earth's magnetic field in their classroom.

An Activity for the Classroom: What Causes Sunspots?

What You Need

- Overhead projector
- A light fixture with a 100-200 watt frosted light bulb
- Sheets of blank paper
- Wooden blocks
- Iron filings *(Educational Innovations (http://teachersource.com, 1-888-912-7474)*
  Edmund Scientific (http://scientificsonline.com,1-800-728-6999).
- Bar magnets and / or ring magnets for each group of students *(Educational Innovations (http://teachersource.com, 1-888-912-7474) or Edmund Scientific (http://scientificsonline.com,1-800-728-6999).*

Preparing for the Activity

1. Have an overhead projector and light bulb ready to demonstrate why sunspots appear dark compared to their surroundings.

2. For students to make a sunspot, have ready for each group of 2 students a container with iron filings, a bar magnet, three or more blocks to make a workbench, and a blank piece of paper. Each group will also need 2 ring magnets midway through the activity.

Introduction to Sunspots

The surface temperature of the Sun is about 5,800 kelvin (10,000° F). This is so hot that the gas that makes up the Sun becomes a plasma. A plasma is a gas in which the electrons are stripped of their atoms and are free to move. This is similar to the gas in fluorescent light tubes. The bright light we see from the Sun is not due to a fire, but is a result of the hot glowing plasma. Sunspots are areas on the surface of the Sun that are slightly cooler than the surrounding areas. Sunspots are cooler by about 1,500 kelvin, which makes them appear dark compared to their hotter surroundings. If you could pull a sunspot off the Sun and hang it in space, it would shine brightly. Scientists have found that it is the strong magnetic fields in the sunspots that make them cooler. The Sun's surface is like a pot of boiling water. Convection normally moves material and heat from hotter regions to cooler regions, keeping the surface temperature constant. The strong magnetic field of a sunspot blocks this convection flow. The flow of heat into the sunspot is smaller and so the sunspot is cooler than its surrounding and appears dark.

1. Ask students what a sunspot is, and what may cause it. List responses.

2. Explain that sunspots are areas on the surface of the Sun that are slightly cooler than the surrounding areas, give off less light and therefore appear dark.

3. To demonstrate this, use a regular overhead projector and a 100-200 watt light bulb.

   a. Turn the light bulb on, and keep the overhead off. Place the light bulb on top of the overhead and show how some light projects through the lenses of the overhead projector.

   b. Keeping the light bulb in place, turn the overhead projector on. Observe how the light bulb now appears dark compared to the surrounding light.

4. Tell the students that scientists have found that it is the strong magnetic fields in the sunspots that make them cooler. The Sun's surface is like a pot of boiling water. Convection moves material and heat from hotter regions to cooler regions. The strong magnetic field of a sunspot blocks this convection flow. The flow of heat into the sunspot is smaller and so the sunspot is cooler than its surrounding and appears dark.

Making Sunspots

1. Tell students they will recreate the magnetic structures of sunspots using magnets and iron filings. They will visualize a simple, bipolar magnetic field.

2. Divide the class into groups of two to four students each. Distribute a set of materials to each group.

- Iron filings
- A bar magnet
- Two ring magnets
- Three blocks
- One piece of paper

3. Show the students how to make a work bench for the experiment by laying several blocks on the table in a U-shape slightly smaller than letter size paper (See Figure 1)

Figure 1. Example of work bench

4. Place the bar magnet in the work bench (near the center). Place a piece of paper on top of the work bench. Sprinkle the iron filings on top of the piece of paper. A thin layer works best. The iron filings will align themselves with the magnetic field and will make a pattern similar to Figure 2.

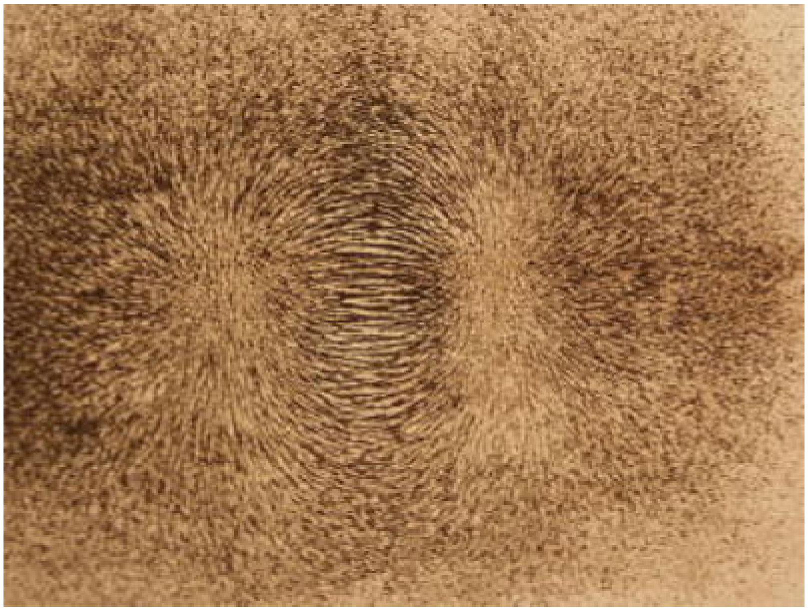


Figure 2. Simulation of a classical bipolar sunspot using a bar magnet and iron filings

5. Students should draw and describe what they observe. Encourage students to view the iron filings from the side by placing their eye at the level of the paper to see if any of the iron filings are standing up. (Option: take a digital picture of the filings.)

6. Explain to students that these are the *lines of force* of a classic bipolar magnetic field. Sunspots almost always appear in pairs, with a north and a south magnetic pole. Point out that the magnetic field lines extend above (and below) the paper and the iron filings that are standing up illustrate this.

7. Have students pour the iron filings back into container so they can be reused in step 8.

8. Remove the piece of paper from the work bench and the bar magnet. Get the two ring magnets and find their opposite poles. To find opposite poles, place ring magnets on top of each other so they attract. Lay them on the table. Take the top one off and flip it over, like opening a book. Put the two ring magnets in the work bench (near the center) with opposite poles up, leaving a small gap between them. Put the piece of paper on top of the work bench.

9. Sprinkle a thin layer of iron filings on the paper. Observe from above and the side, draw, and describe how the iron filings line up.

10. Ask students to describe the similarities and differences of the two experiments. List responses.

Reflections

Each sunspot is like one pole of a magnet. Sunspots usually appear in pairs with opposite magnetic poles. The iron filings trace the lines of force which extend from the sunspot with the north polarity to the sunspot with the south polarity. The regions on the paper where the filings are standing up are the regions where the sunspots appear darkest. This region is called the umbra, as shown in figure 3. The iron filings that lay flat on the paper trace horizontal fields. These correspond to the less dark area around the umbra called the penumbra, also shown in Figure 3.

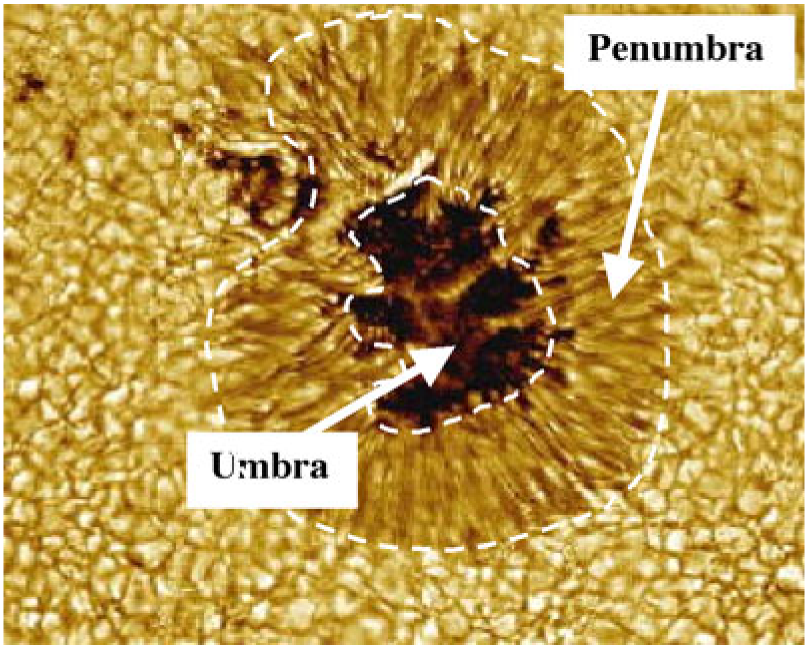


Figure 3. A close-up of a sunspot. The darkest part of the sunspot is called the umbra, and is where the magnetic fields tends to be standing vertically out of the surface. The region surrounding the umbra is called the penumbra, and is a place where the magnetic fields are lying flat in the surface.

Teachers Guide & CD ROM

The Teachers Guide includes a Time Frame to give teachers guidance how long each activity may take. Each activity section starts with a list of materials and preparations needed before each lesson. The guide comes with a CD-ROM which contains all Image Sets and worksheets in addition to pictures, video clips, and links for further exploration. The CD-ROM also contains a printable version of the Teacher Guide, descriptions and printable materials for the activities, as well as videos, images, and background info. The CD-ROM is available from the New Jersey Astronomy Center for Education; contact Dr. Wil van der Veen at 908-526-1200 x 8566 or email wvanderv@raritanval.edu.

Training & Solar Resource Center

The New Jersey Astronomy Center for Education (NJACE) at Raritan Valley Community College (North Branch, New Jersey) in collaboration with the New Jersey Institute of Technology (NJIT) provide training for the activities and in the use of the solar observing equipment. The training is in the form of a one-day 6-hour workshop; for more information see http://www.raritanval.edu/planetarium/ or contact Dr. Wil van der Veen at 908-526-1200 x 8566 or email wvanderv@raritanval.edu.

The solar Observing Equipment, which consists of a set of 3 Sunspotters, one Coronado SolarMax 40 H-alpha telescope with equatorial telescope mount, and a set of 15 spectrometers, is available for trained teachers for our Solar Resource Centers at NJACE and NJIT.

The set of seven activities was presented on three different occasions to a total of 58 teachers in grades 5-12. At the workshop the teachers were led through all 7 activities, and were given training in the use of the solar equipment. Individual activities were presented additional 23 teachers at a Project ASTRO training and at an Astronomy Summer Institute. In all, 81 teachers from around New Jersey have been exposed to the some or all of the activities.

The assessment of the workshops and resource center was carried out by Lisa Rothenburger, Rutgers Cooperative Research and Extension and Somerset County 4-H Program. According to forms filled out at the workshops, the training and individual activities were highly rated (better than 4 out of 5). The feature of the workshops that they liked best was the hands-on activities, followed by the availability of the equipment. The activity presented in this issue "What Causes Sunspots" was ranked highest. About 1/3 of teachers returned the follow-up questionnaires show very high satisfaction levels with the activities and solar observing equipment when used in the classroom.

Resources

For a good introduction on the history of Solar Physics see the following three websites:

- http://www.hao.ucar.edu/Public/education/spTimeline.html

For a good introduction to Sunspots see:

- http://www.exploratorium.edu/sunspots/

Acknowledgements

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