Lesson Guide for Sunspot Activity

Background:

While other ancient cultures did not share this conclusion, by the early 1400s Western religious, philosophical, and observational evidence supported a perfect, unchanging, Earth-centered universe. Therefore, the argument by Copernicus for a Sun-centered universe in 1543 and the amazing appearance of a new star (a nova) in 1572 were extremely challenging to the European worldview. However, many more challenges were to come from Galileo Galilei (1564-1642). While Galileo systematically challenged many aspects of contemporary scientific views, his pioneer work in astronomy with a telescope provided evidence to anyone who cared to look with open eyes and open mind that all was not as previously thought in the heavens. Jupiter had moons, Saturn had rings, the Moon had mountains and craters, and the Sun had blemishes – spots that moved across the face of the Sun. Galileo projected the image of the Sun onto parchment and drew the spots on the parchment. He and others recorded sunspots on many consecutive days, revealing a progressive motion across the Sun. Whether sunspots were on the Sun or satellites circling close to the Sun was debated for some time. For more information on Galileo and the other observers of sunspots visit the website *Sunspots* http://es.rice.edu/ES/humsoc/Galileo/Things/sunspots.html .

Many individuals contributed to early research of these strange spots on the Sun in the early 1600's. However, sunspot activity decreased from 1645 until 1715. With so few sunspots, people lost interest. However, in 1843 Heinrich Schwabe discovered the number of sunspots increased and decreased in a cycle. The cycle shows peaks of high sunspot number about 11 years apart. The long period with few sunspots occurred during a period called the "Little Ice Age" in which temperatures decreased globally. This coincidence of the lack of sunspots with a decrease in global temperatures is not sufficient proof of a cause-effect relationship. It does raise interesting questions. More accurate measurements have found the sunspot cycle to be, on average, 11.1 years with ranges between 8 and 16 years.

The causes of solar features such as sunspots have become better understood because of NASA missions such as Ulysses, ACE (Advanced Composition Explorer), Yohkoh, SOHO (Solar and Heliospheric Observatory), and TRACE (Transition Region and Coronal Explorer). However there is much that scientists hope to learn from future missions such as Solar-B, STEREO (Solar Terrestrial Relations Observatory), SDO (Solar Dynamics Observatory), and Sentinels. Sunspots are regions in the Photosphere of the Sun that are relatively cooler than the brighter parts of the Photosphere. Sunspots are only about 3700 K compared to 5700 K for the surrounding Photosphere. About the size of the Earth or larger, sunspots usually last several days, although very large ones may last for weeks. Sunspots occur at regions of intense local magnetism. Possibly the magnetic fields suppress the movement of hot material upward from the underlying convective zone.

Observations of sunspots led to the conclusion that the Sun rotated. The average time of rotation is 27 days. This isn't the whole story, however. Because the Sun's outer zones are not solid, the equator rotates faster than the poles. At the equator the Sun rotates in about 25 days. At about 40º latitude the rotation takes 28 days and at the poles the rotation is in 36 days.

In this lesson students will be able to observe sunspots safely and discover changes in the number and position of sunspots over time. Students will be able to observe the rotation of the Sun, and, in a math extension, will be able to calculate the period of rotation.

National Standards:

National Science Education Standards (NSES)
Content Standards 5-8

- Abilities necessary to do scientific inquiry.
- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
- Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.
- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.
- In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

Benchmarks for Science Literacy

- Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
- Some scientific knowledge is very old and yet is still applicable today.
- Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.
- Telescopes reveal that there are many more stars in the night sky than are evident to the unaided eye, the surface of the moon has many craters and mountains, the sun has dark spots, and Jupiter and some other planets have their own moons.
- Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole.

National Educational Technology Standards (NETS)

- Students use technology to locate, evaluate, and collect information from a variety of sources.

Mathematics Standards (NCTM)

- work flexibly with fractions, decimals, and percents to solve problems
- use two-dimensional representations of three-dimensional objects to visualize and solve problems
- select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision
- solve problems involving scale factors, using ratio and proportion
- apply and adapt a variety of appropriate strategies to solve problems

Instructional Objectives: Students will learn to observe the Sun safely and will discover that the Sun has spots that appear and disappear over time. Students will discover that the Sun rotates. This activity can be extended to determine the average time of rotation of the Sun.

Vocabulary:

- **convective zone –** the outer most region of the interior of the Sun. The convective zone lies just below the visible surface of the Sun (the photosphere) and is about 200,000km thick. Within this region energy is transferred through the mass motion of plasma. Hotter plasma moves upward and cooler plasma sinks.
- **magnetic field** – the region of magnetic influence around a magnetic object such as a bar magnet, a current carrying wire, the Sun, Earth and an of the magnetic planets.
- **photosphere** – the lowest layer of the solar atmosphere where the Sun's visible spectrum of light is released. It is the visible "surface" we see in white-light images of the Sun.
- **plasma** - One of the four states of matter. (The other three are solid, liquid and gas.) Consists of a gas of positively charged and negatively charged particles with approximately equal concentrations of both so that the total gas is approximately charge neutral. A plasma can be produced from a gas if enough energy is added to cause the electrically neutral atoms of the gas to split into positively and negatively charged atoms and electrons.
- **sunspots** - An area seen as a dark spot on the photosphere of the Sun. They appear dark because they are cooler than the surrounding photosphere.

Preparing For The Activity:

Student materials

- Galileo's sunspot drawings
- 4x6 index cards with reference circle (use Circle Template provided p. 7)
- Pencils
- Sunspotter for each group
- Sunspot Observation Graphs (p. 8)

Teacher Materials

- Sun
- Copies of Sunspot drawings from Galileo web site
- Daily images of sunspots taken by SOHO ((Solar and Heliospheric Observatory) spacecraft from the past 5 days

Time

- 2 full periods (40 – 50minutes), one at the beginning and one at the end
- 3 sunspot-viewing sessions (at least) of 15-20 minutes each on consecutive days (or as nearly as possible) and the same time of day, if possible.

Advance Preparation

- A critical component of this activity is a device to project an image of the Sun on a piece of paper. **Remember: never look directly at the Sun, especially through a telescope or binoculars unless you have specially prepared solar filters.** One of the best devices is a commercial product, the Sunspotter, available directly from Learning Technologies, Inc (800-537-8703). This lesson is designed for use with the Sunspotter,however, you can use a small telescope or binoculars to project the image of the Sun. Instructions are available on the Solar Terrestrial Probes Education website (http://stp.gsfc.nasa.gov/educ_out/summer01_pr/activities/Sunspot_Viewer.pdf).
- Practice with the Sunspotter before class! The Sunspotter must be pointed correctly at the Sun. The image of the Sun will move due to the Earth's rotation, so the Sunspotter must be constantly adjusted.
- Read **Background** with this lesson. (If you do not know very much about Galileo, the Galileo web site referenced in the Background is highly recommended.)
- Prepare 4x6 index cards with reference circle (use Circle Template provided p. 7)
- Prepare Sunspot drawings from Galileo web site. (http://es.rice.edu/ES/humsoc/Galileo/Things/g_sunspots.html) Print two sets of at least four drawings from consecutive days. Keep a master with the dates for yourself. Then randomly rearrange the pictures of the second set, white out the dates and label them A, B, C, D, etc. and make copies for each group of students.
- Print the daily images of the Sun taken by SOHO showing sunspots from the last 5 days (http://sohowww.nascom.nasa.gov). At the SOHO site click on *The Sun Now* in the upper left hand corner. You want images of the MDI Continuum, so click on *More MDI Continuum* (second row, left side). Try to get images that were taken at the same time of day. The date and time is provided for each image. Click on the image you want, and then print the enlarged image.
- Prepare Student Observation Graphs for each student.

The Activity:

1. Assign groups according to the number of sunspotters available to enable participation for all students. Provide each student with a 4x6 card, a pencil, and a Sunspot Observation Graph.
2. Tell students about Galileo and his observations of the Sun. However, do not tell the students that Galileo discovered that the Sun rotated. Pass out the Galileo drawings of sunspots with the dates erased and randomly arranged (see Advanced Preparation). Tell the students the pictures were drawn on consecutive days, but you accidentally dropped the drawings and the pictures are out of order. Within their assigned groups, have them make a prediction about the correct order of Galileo's original drawings. Tell them this is only a prediction. Have each group record its prediction of the order of drawings on the board. After every group has recorded predictions, have each group explain their rationale for its prediction. This will tell you what they know about the topic. (Collect Galileo drawings at the end of the discussion for use later.)

3. Use the images taken by the SOHO spacecraft. Identify the sunspots charted for the previous few days. Discuss the differences you see and make predictions for observations you will take during the next few days. Don't forget to relate these observations to the Solar Cycle and predict where you think we are in the cycle now, and what you think the solar activity will be for the next year. Will it increase or decrease? Why do they think so?

4. Configure the Sunspotter□ in an area of direct sunlight. Assign each of the student groups to one Sunspotter□. Have each student place their 4x6 card in the Sunspotter□ and draw the sunspots they see. Encourage discussion of other physical characteristics if any. **Always remind the student to never look directly at the sun.** Have students record the number of sunspots on the Sunspot Observation Graph. Remind students that the Day axis refers to the number of days since the beginning of observations. If a day is skipped because of a weekend or cloudy weather, that day must be skipped on the graph.

5. Encourage small group discussions, especially if one drawing varies from the others.

6. Have one student go to the SOHO website address listed above and check the image for that day. If a printer is available, print a copy and post it in the classroom for comparison and discussion.

7. Repeat steps 4-6 for the next 3-5 consecutive days or longer, depending on the weather. After the first day the observations will take only 15-20 minutes, so you should plan other activities about the Sun.

8. On one of the observing days have the each student choose a favorite sunspot and estimate its size. They could use their own drawings, or, for greater accuracy, use the SOHO images. It is often useful to compare the size of a sunspot to the size of Earth. They will need to do some research on the size of the Sun and the size of the Earth. The "Sun and Earth Size Comparison" as part of the Athena Curriculum (http://inspire.ospi.wednet.edu:8001/curric/space/sun/sunearth.html) could be a good place to start this exploration.

9. Students can create their own "flip" book of index cards to see how the sunspots have changed position.

10. Have each student complete the Sunspot Observation Graph. Then have students access the International Sunspot Number compiled by the Sunspot Index Data Center in Belgium at http://science.nasa.gov/ssl/pad/solar/greenwch/spot_num.txt. (The numbers tabulated in are the monthly averages of SunSpotNumber (SSN) and standard deviation (DEV) derived from the International Sunspot Numbers. The students only need the SSN.) Have students graph the last 3 to 5 years of data. You may wish to have students graph different years and then put all graphs together to observe long-term trends. Students should be aware that official sunspot numbers will probably be higher than their count. Researchers use a different system for determining sunspot numbers (see http://www.sunspot.noao.edu/IMAGES/sunspot_numbers.html) and their equipment is

better. Ask students to compare the pattern they observed for numbers of sunspots on the Sunspot Observation graph with the trend they can see on the graph of data from the International Sunspot Number data.

11. Facilitate a large group discussion on the last day to analyze final observations and compare charts. Students may observe that the size or number of sunspots may change. Students should observe that the sunspots change position in a regular way. This observation is the most important for this investigation. Ask the students to provide an explanation for the change in position of the spots. Several explanations are common; that the Sun rotates (correct), that the Earth's daily rotation is responsible, or that the Earth's orbit around the Sun is responsible. (Hopefully, no one will suggest that the spots are alien craft motoring in the plasma sea of the photosphere.)

    If they believe that the Earth's rotation is responsible, draw a circle with a dot in it on the board to represent the Sun and a sunspot or use a ball with a dot on it. Ask a student to stand at the back of the room and face the board. Then ask the student to turn around until he/she is facing the board again. Ask the student if the sunspot changed position. It hasn't!

    It is more difficult to show that the Earth's orbit isn't responsible for the observed motion. Scale is important to this argument. You would need to have a ball of about 21.2cm (or draw a circle on the board). The Earth would be the size of a peppercorn (a little less than 2mm) about 23m away. The peppercorn Earth would then move about 40cm a day in a circle centered on the ball Sun. (You can divide all dimensions by one half or one third to fit the demonstration into the classroom.) Students can see that the small amount the Earth moves each day cannot explain the motion of the spots.

    If any student proposes that each spot is self-powered, see if anyone can realize this is unlikely because the spots all move together.

12. Hand out Galileo drawings from first day and again ask each group to determine the correct order for the drawings and reflect upon their original predictions. Have each group record its solution of the order of drawings on the board. After every group has recorded results, have each group explain their rationale for its solution.

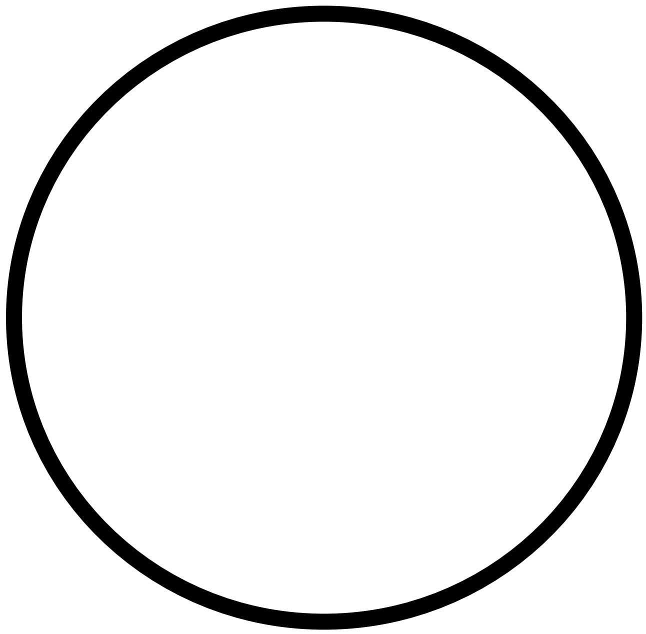
13. Assign readings about Galileo. Visit http://es.rice.edu/ES/humsoc/Galileo for more information

Extensions:

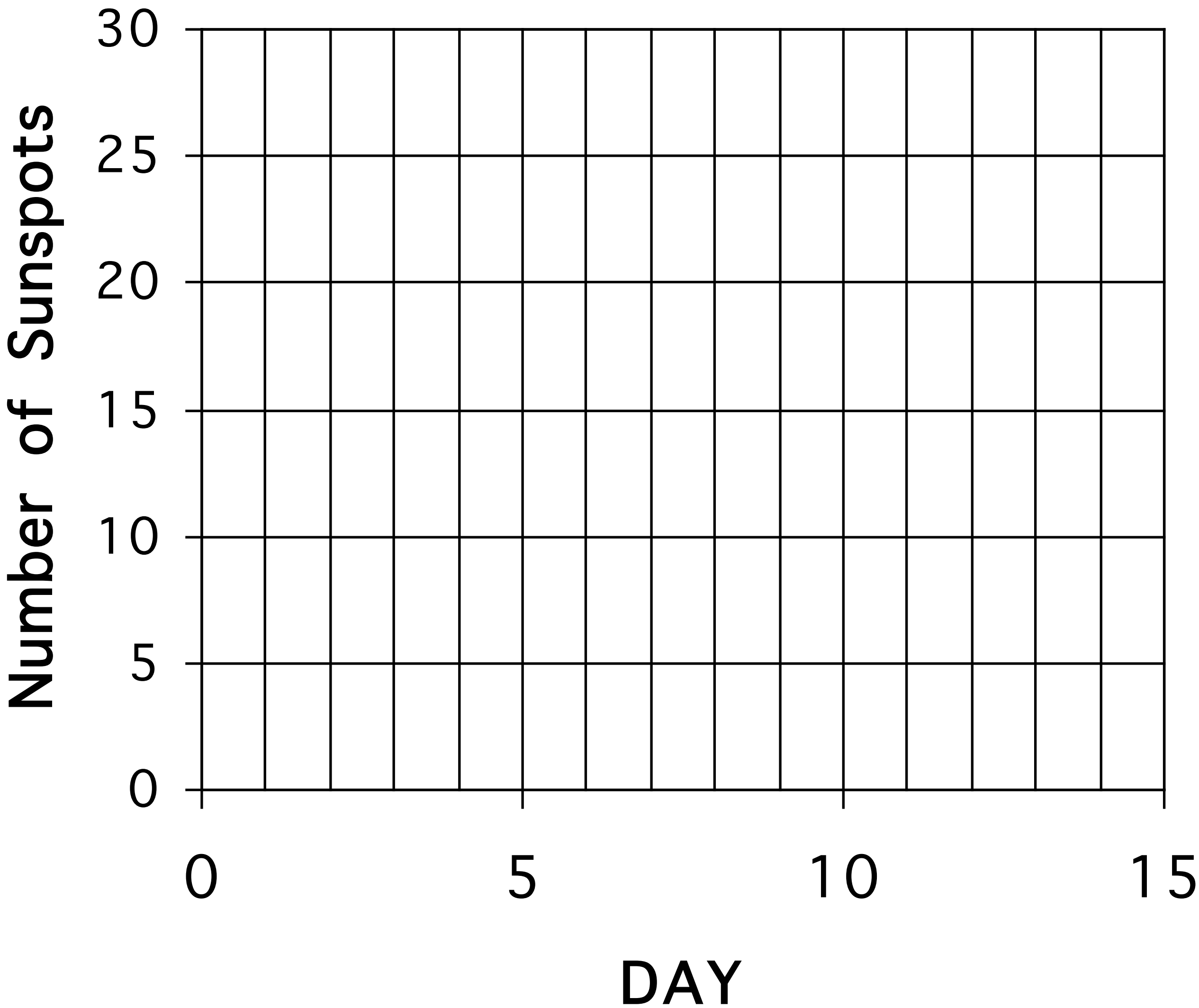
1. The data obtained from the student investigations or from the SOHO images can be used to calculate the period of rotation in an excellent math lesson. The Stanford Solar Center offers *The Spinning Sun*. (http://solar-center.stanford.edu/spin-sun/spin-sun.html)
2. The Science Education Gateway (SEGWAY) web site offers excellent activities to extend the students understanding of sunspots and their dynamics in a lesson called "Sunspots". This lesson covers solar science, ancient and modern, features an interactive research exercise in which students attempt to correlate the areas of sunspots with those of x-ray active regions. Self-guided sections on history and modern study include researcher interviews. (http://cse.ssl.berkeley.edu/segwayed/abtsunspots.html).

Circle Template:

Below is a circle the size of the Sun's image on the Sunspotter™. Copy this image onto the 4x6 index cards before the observations.



Sunspot Observation Graph



What can you conclude from this graph?