Science Lesson

This science lesson is designed to be used with NOVA's two-hour special "Galileo's Battle with the Heavens." The lesson is intended for use in middle and high school classrooms.

Program Contents

NOVA explores the story of Galileo Galilei—his scientific contributions, his clash with the Catholic Church, and his correspondence with his convent daughter.

The program:

- provides an historical backdrop of 17th-century Italy, including the spread of the bubonic plague, the role of the Inquisition, and the influence of powerful court families.
- examines Galileo's astronomical discoveries, including four of Jupiter's moons, sunspots, and the rotation of the Sun.
- highlights Galileo's role as founder of modern physics due to his studies of motion and his experiments with inclined planes.
- shows Galileo's talent as an inventor with his improved telescope design.
- tells of Galileo's correspondence with his illegitimate daughter, Maria Celeste, who embraced the tenets of the Catholic Church and became a nun.
- chronicles Galileo's clash with the Catholic Church following publication of his *Dialogue on the Two Chief World Systems,* a rhetorical masterpiece in support of the Copernican Sun-centered system.

Before Watching

1. Ask students what they know about Galileo Galilei. Where and when did he live? *(In Italy during the 16th and 17th centuries.)* What did he do? *(He was considered the first truly modern scientist because of his systematic observation of the real world; his main contributions were in the fields of physics and astronomy.)* What happened to Galileo? *(He was tried and found guilty in 1633 by the Catholic Church's Inquisition for his scientific beliefs.)*
2. Galileo made a number of scientific observations during his lifetime. As they watch, have students take notes on his contrbutions to science. Have students record what Galileo studied, how he studied it, and any conclusions he drew.

After Watching

1. Lead a discussion about Galileo. What was the most powerful institution in Italy when Galileo lived? How did his discoveries contradict beliefs of his time? What happens when discoveries don't conform to the currently held belief system? How are controversial science research efforts, like fetal tissue research or cloning, handled by today's institutions, such as government or religious organizations?
2. Review students' notes about Galileo's scientific contributions. What areas did he study? Which of his scientific discoveries were the most revolutionary and why?

Standards Connection

The activity found on pages 3 and 4 aligns with the following National Science Education Standards *and* Principles and Standards for School Mathematics.

Grades 5–8

Science Standard D:
Earth and Space Science

Earth in the solar system
- Earth is the third planet from the Sun in a system that includes the Moon,the Sun,eight other planets and their moons, and smaller objects,such as asteroids and comets.The Sun,an average star, is the central and largest part in the solar system.

Mathematics Standard:
Data Analysis and Probability

Grades 9–12

Science Standard D:
Earth and Space Science

Energy in the earth system
- Earth systems have internal and external sources of energy, both of which create heat.The Sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from Earth's original formation.

Mathematics Standard:
Data Analysis and Probability

Activity Setup

Objective
To construct and evaluate graphs of the current sunspot cycle.

Materials for each student
- copy of the *Plotting the Spots* activity sheet on page 3
- 5- or 10-square-per-inch graph paper
- pencil

Procedure

1. Galileo studied sunspots, sketching pictures of the changing pattern of spots on the Sun over time. In this activity, students will study the nature of sunspot cycles.
2. Lead a class discussion about sunspots. (See Activity Answer on page 4 for detailed information on sunspots.)
3. Following the discussion, give each student a copy of the *Plotting the Spots* activity sheet.
4. Review with students the definitions for solar minimum and solar maximum. Have them study the sunspot cycles from 1900 to 1995 on the graph found on the activity sheet. Ask students to look for patterns in the data.
5. Have students label the graph with an *x* for each solar maximum and an *m* for each solar minimum. Have them estimate the year when each cycle started and when it ended, calculate the length of each cycle, and calculate the average length for the nine cycles shown on the graph. Discuss their results. Be flexible with the accuracy of reading the years of solar maximum and minimum.The average should be approximately 11 years.
6. Provide students with graph paper. Have them graph the data for Solar Cycle 23. If using 5-quadrille paper, students will each require three sheets; if using 10-quadrille, students will require two sheets.
7. When students' graphs are complete, discuss their results using the questions on the activity sheet. You might want to make an overhead copy of the graphs to facilitate the discussion.
8. As an extension, have students research whether the year 2000 solar sunspot maximum caused any significant disruptions in communications on Earth. Were any abnormal auroras reported? Were any satellites, Earth-bound communications, or power systems influenced by the solar maximum? For more information, see: www.exploratorium.edu/solarmax/news.html

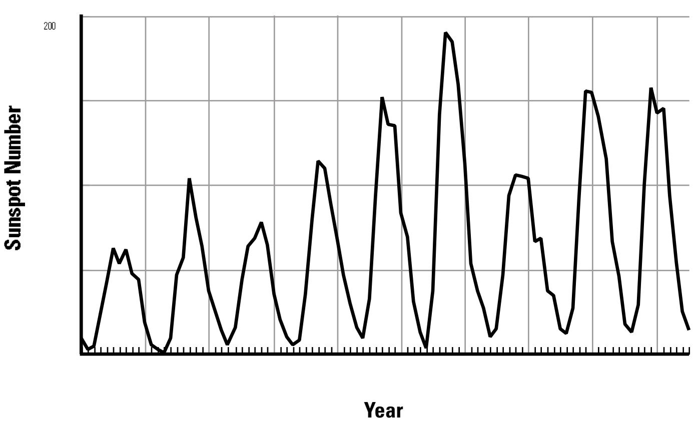
Plotting the Spots

Sunspots are cooler areas on the Sun that appear as dark spots.These spots tend to occur in cycles that start at the solar minimum (when the fewest spots occur), reach their solar maximum (when the most spots occur), and reduce again in number until the cycle begins again. Can these spots and their cycles tell us anything? Do this activity to find out.

Procedure

1. Observe the following graph of the sunspot cycles from 1900 to 1995. List any patterns that you notice. How is each cycle similar? How is each cycle different?
2. Label the graph with an *x* for each solar maximum and an *m* for each solar minimum.
3. From the graph, estimate the year when each cycle started and when it ended. Calculate the length of each cycle and the average length for the nine cycles shown.
4. Graph the data from Solar Cycle 23 below on your sheets of graph paper.

Sunspot Cycles 1900–1995



Source: National Geophysical Data Center Sunspot Numbers Web site at: **www.ngdc.noaa.gov/stp/SOLAR/SSN/ssn.html**

Questions

Write your answers on a separate sheet of paper.

1. When did Solar Cycle 23 begin?
2. Did Solar Cycle 23 reach its solar maximum? If so, when did this occur?
3. Based on the average you calculated for the other solar cycles, when do you predict this cycle will end?
4. Can you predict when the next solar maximum might occur? Explain your prediction.

Solar Cycle 23

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	24.2	29.9	31.1	14.0	14.5	15.6	14.5	14.3	11.8	21.1	9.0	10.0
1996	11.5	4.4	9.2	4.8	5.5	11.8	8.8	14.4	1.6	0.9	17.9	13.3
1997	5.7	7.6	8.7	15.5	18.5	12.7	10.4	24.4	51.3	22.8	39.0	41.2
1998	31.9	40.3	54.8	53.4	56.3	70.7	66.6	92.2	92.9	55.5	74.0	81.9
1999	62.0	66.3	68.8	63.7	106.4	137.7	113.5	93.7	71.5	116.7	133.2	84.6
2000	90.1	112.9	138.5	125.5	121.6	124.9	170.1	130.5	109.7	99.4	106.8	104.4
2001	95.6	80.6	113.5	107.7	96.6	134.0	81.8	106.4	150.7	125.5	106.5	132.2
2002*	114.1	107.4	98.4	120.4	120.8	88.5	88.2	85.7	83.2	80.7	78.1	75.6
2003*	73.0	70.5	67.9	65.4	62.9	60.4	58.0	55.6	53.2	50.9	48.6	46.4

*Years 2002–2003 contain estimated and predicted values.

Source: National Geophysical Data Center/Solar Terrestrial Physics at: **ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/**

Learning More

Drake, Stillman.
Galileo: A Very Short Introduction.
New York: Oxford Univ. Press, 2001.

Presents a short introduction to Galileo's life and achievements focusing on his conflicts with theologians but supporting the hypothesis that he was a zealot for, rather than against, the Catholic Church.

MacLachlan, James.
Galileo Galilei: First Physicist.
New York: Oxford Univ. Press, 1997.

Contains a detailed chronology of Galileo's life and sidebars explaining his scientific contributions.

Sobel, Dava.
Galileo's Daughter: A Historical Memoir of Science, Faith, and Love.
New York: Walker and Co., 1999.

Presents a human picture of Galileo the scientist and Galileo the father.

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The Galileo Project of Rice University
es.rice.edu/ES/humsoc/Galileo/
Contains an illustrated biography of Galileo, translations of letters from his daughter, information about other scientists of his time, a portrait gallery, and links to other resources.

NOVA Online—Galileo's Battle for the Heavens
www.pbs.org/nova/galileo/
Learn all about Galileo, from his place in science to his mistaken belief that Earth's daily rotation and its annual orbit around the Sun triggered ocean tides. Includes online activities.

Activity Answer

Historical records show that sunspots may have been observed as dark spots on the Sun at least 2,000 years ago. Ancient people might have seen these dark spots when the Sun was low on the horizon and partially obscured by clouds or mist, since it would have been impossible to look directly at the bright Sun without damaging the eyes. It was not until about 1610, following the invention of the telescope, that Galileo and others began observing and writing about the dark spots they observed.

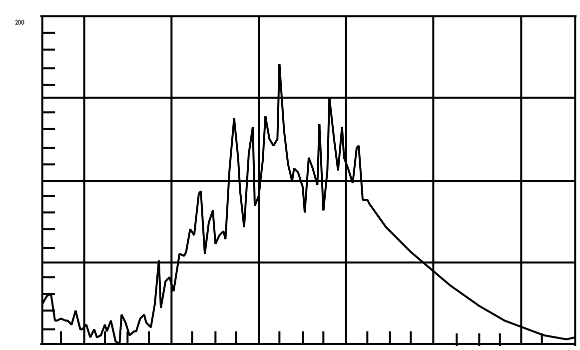
Sunspots are cooler areas on the Sun that appear as dark spots. While most of the visible surface of the Sun has a temperature of about 5700°K, sunspots are only about 4,000°K. Though they vary in size, most are larger in size than the diameter of Earth. Scientists say sunspots would be expected to glow orange in the sky, many times brighter than the full Moon, if pulled away from the Sun. They theorize that the spots are the result of magnetic fields. The number of sunspots is cyclical, with periods of many sunspots (solar maximum) and periods of fewer sunspots (solar minimum). Solar flares, or explosions on the Sun, often occur near sunspots.

Students will notice the cyclical nature of the sunspot cycle. Each cycle is similar in shape and lasts about the same amount of time. The number of sunspots observed at solar maximum varies, however, from a maximum of nearly 200 sunspots to a low of about 60 (sunspot numbers are averaged monthly).

Students will have to estimate from the graph exactly the year and month. The average will be approximately 11 years.

Solar Cycle 23 began about mid-1996, and reached solar minimum about October 1996. Solar maximum occurred about mid-2000. The next solar minimum is predicted to occur sometime about 2006 and peak sometime about 2010. Predictions are based on approximate 11-year cycles with solar maximum occurring on average a bit less than halfway through each cycle.

Solar Cycle 23



Source: NASA Solar Physics Web site at: **science.msfc.nasa.gov/ssl/pad/solar/predict.htm**
Data for part of 2002 and all of 2003–2006 represent estimated predictions.

NOVA®

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