www.solarmovie.com

Educators Guide

Dear Educator,
Welcome to the world of SOLARMAX, and to the mysteries and science of the sun.

This guide has been designed and written as a supplement and accompaniment of the large-format film, SOLARMAX. The activities contained herein can be used before or after viewing the film. If they are to be completed before viewing the film, they will provide learning experiences that will develop understanding of the sun, and that will enhance student viewing of the film. Conversely, if you decide to have students view the film first, the film will present major ideas and "set the stage" for further learning that will follow as students do the activities. In either case, both the film and the activities will help broaden students' understanding of the sun, our solar system and scientific progress that has been made relative to the sun. The activities incorporate many cross-curricular connections, and students will begin to realize that scientific progress has major implications not only in science, but also in social science and mathematics. Activities have also been incorporated that encourage students to utilize their language arts skills, encouraging them to write and put into words what they have learned and to explore their creativity as they expand on what they have learned.

The lessons and activities have been designed primarily for students ages 9 to 11, but many of the activities can be augmented or adapted for younger and older students. The intent has been to provide activities that can be used easily by teachers, will capture and stimulate student interest, and that will be of genuine educational value to your curriculum and overall student learning.

Science has been defined as an interplay of evidence and hypotheses, and we hope as students view the film and do the activities that they will realize the importance of observation, accurate data collection (evidence) and continuing hypotheses.

An Italian proverb states that "All cannot live on the piazza, but everyone may enjoy the sun." We hope that you will both learn from and enjoy SOLARMAX. We also hope you find this guide to be useful as you explore SOLARMAX and many ancillary aspects of the sun and astronomy.

Enjoy!

Donna L. Knoell, Ph.D.
Educational Consultant

Educators Guide - Table of Contents

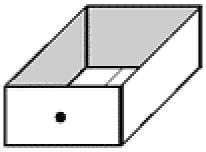
Amazing Facts about the Sun:

Average distance from Earth	93 million miles
Time for light from the sun to reach the Earth	About 8 minutes to reach the Earth
Diameter of the sun	About 865,000 miles. (The diameter of earth at the equator is approximately 8000 miles, so the diameter of the sun is 108 times greater than the diameter of Earth.) If the sun were hollow, it could hold 1,300,000 Earths.
Age of the sun	4.6 billion years
Expected lifetime of the sun	Another 5 billion years
Mass of the sun	About 2 trillion, trillion, trillion tons; if it were possible to clump all the planets together, the sun's mass would be 750 times larger than all the planets together.
Surface temperature of sun	About 11,000 degrees fahrenheit
Core temperature of sun	About 27 million degrees fahrenheit (which is enough to sustain nuclear reactions)
Composition of sun	At least 94% Hydrogen; remainder is mostly helium; with traces of other elements.
Rotation period	At the equator: 25 Earth Days Halfway to the poles: about 28 days Near the poles: about 35 days (The sun does not rotate as a solid body!)
sun's gravity	28 times greater than Earth's
sun's activity	The sun goes through an 11-year cycle of activity, in the form of sunspots, solar flares, solar mass ejections, etc.

WARNING!
NEVER look directly at the sun with the naked eye or with any optical device. The only safe way to observe the sun is with a pinhole camera, or to project its image onto a piece of white paper using binoculars or a small telescope. REMEMBER, the binoculars and telescope are used to project the image onto paper. NEVER use the binoculars or telescope to look directly at the sun.

Observing the Sun with a Pinhole Device

NEVER LOOK DIRECTLY AT THE SUN! IT WILL HARM YOUR EYES!



CONCEPT

Understand how a small hole (pinhole) can form an image of the sun onto a piece of paper. Experiment with the size of the pinhole and the distance of the paper from the pinhole to see the effect on the image observed. Understand the historical perspective of how pinhole observations of the sun were made before telescopes were invented.

VOCABULARY

Pinhole - a small hole, usually 1-2 mm in diameter

Image - the picture of an object that is formed on a white piece of paper on the other side of the pinhole.

Focus - the sharpness of the projected image. The edges of the image are least "fuzzy" when the image is in focus.

Resolution - the amount of detail that is seen in the projected image.

OBJECTIVE

Understand how a pinhole can form an image of the sun. Build a pinhole device and experiment with the size of the pinhole and the distance of the paper from the pinhole on the sharpness of the projected image (focus). Determine if the resolution of the image is good enough to see sunspots.

MATERIALS

- Pinhole optics worksheet
- Cardboard box at least 30 inches wide
- Tinfoil
- Masking tape
- Sharp pointed device, i.e. needle, thumbtack, sharp pencil, etc.
- White paper

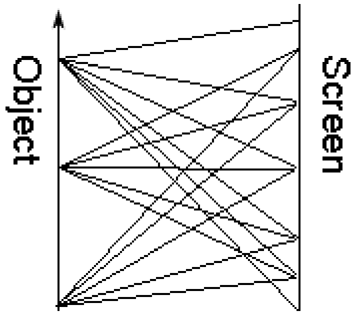
PROCEDURE

1. Study the pinhole optics worksheet and answer questions.
2. Remove one side of the cardboard box.
3. On one end of the box cut a small square hole (approximately one inch square) in the center of the end.
4. Tape a piece of tinfoil over the small hole.
5. Punch a pinhole in the middle of the tinfoil using a needle or other small sharp device.
6. Point the pinhole end of the box towards the sun. NEVER LOOK DIRECTLY AT THE SUN.
7. Place a white piece of paper inside the box and observe the image of the sun.
8. Move the paper closer to the pinhole and describe any change in the image.
9. When the image looks the sharpest (in focus) see if you can see any dark spots (sunspots) in the image.
10. Use a larger needle or sharp device (can be a pencil) to make the pinhole larger.
11. Repeat steps 7 through 9.

Pinhole Optics Worksheet

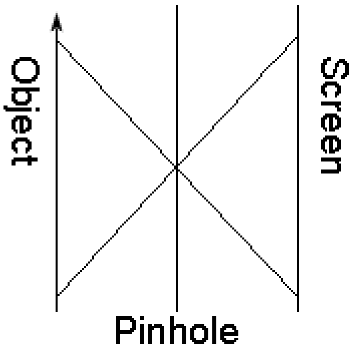
How does a pinhole project an image of an object?

With no pinhole, the object does not form an image onto the screen because any given point on the object projects light to all points on the screen.



When a pinhole is put between the object and the screen, the light rays from each point on the object are projected to only one point on the screen and an image is formed.

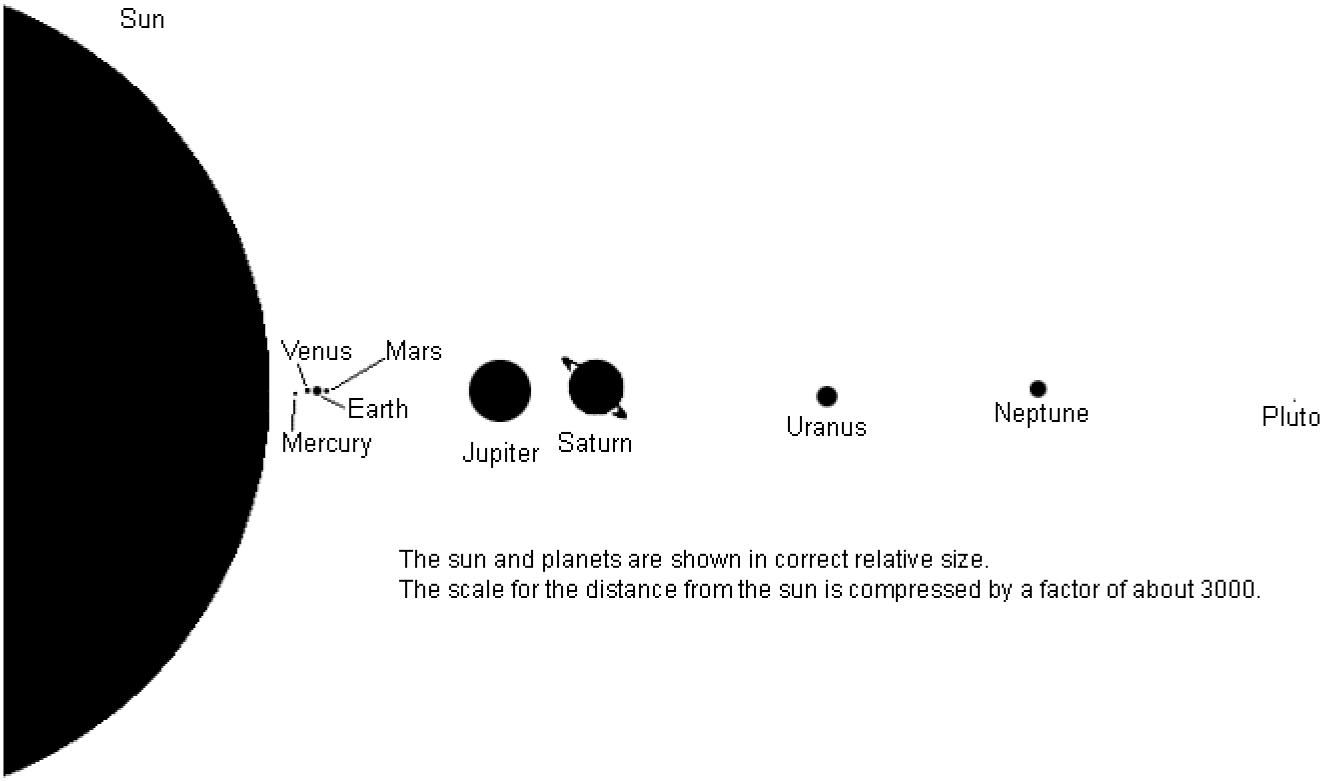
Will the projected image be right side up or upside down when compared to the original object?



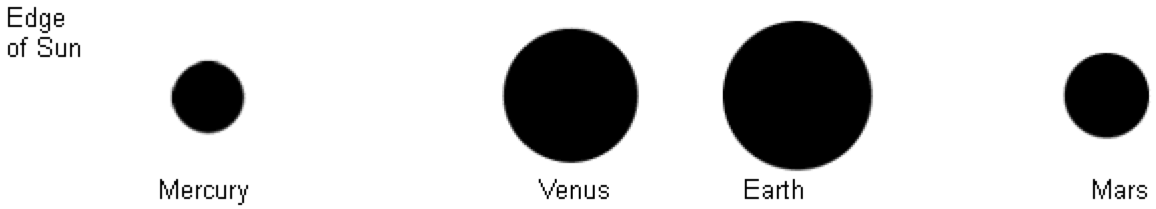
Note for the teacher: The best focus distance will depend on the size of the pinhole. For a pinhole of 1.0 mm diameter, it will be best at about 11"; for a 2mm hole, best at 22".

Labeling Our Solar System

Using the diagram of our solar system, label the planets and the sun.



The sun and planets are shown in correct relative size.
The scale for the distance from the sun is compressed by a factor of about 3000.



The inner planets expanded. The relative size of the sun and planets is correct, but the scale for the distance from the sun is still compressed by about 3000.

Locating Major Observatories Past and Present

1. Using a world map, locate the major observation locations that are listed below.

2. For each location, mark the place with a black dot, and then beside the dot, write the name of the observatory or historical site.

ANCIENT and MODERN OBSERVATORIES:

- Stonehenge, England
- Newgrange, Ireland
- Mount Palomar, California
- Kitt Peak, Arizona (National Solar Observatory)
- Las Palmas Observatory (Canary Islands)
- Mount Stromlo, Canberra, Australia

Additional Activity:

1. Have students locate the places, listed below, that are used in the SOLARMAX film.
2. Have students mark the places on a world map, and mark them with a black dot.

Places Named in the Film:

- Ancient Babylon
- Ayer's Rock in Australia (near Alice Springs)
- Fairbanks in Alaska
- Lake Titicaca, high in the Andes Mountains between Peru and Bolivia
- Viking Ruins in Greenland (near Narssaq)
- Munich, Germany
- Machu Picchu in Peru
- Tromso in Norway
- Shrine at Ise, Japan (Shrine of the Sun Goddess)

Creating a Timeline of Important Solar and Astronomical Happenings

CONCEPT

In order to give students an overview of major discoveries and activities regarding the sun and man's exploration of space, and to give them a perspective on when they occurred, students will create a timeline.

OBJECTIVE

Students will construct/create a timeline of important solar and astronomical happenings.

MATERIALS

- 25 feet of white or brown butcher paper (or 1/4 inch graph paper)
- ruler
- pens or colored markers

PROCEDURES

1. For class or small group activity, cut a piece of butcher paper 25 feet long. Using a ruler, divide the 25 feet into 25 equal segments (one foot each).

2. Measure one foot in from the left edge and mark that point as 3000 BC.

3. Measure two feet in from the 3000 BC mark, and label that point as zero.

4. Explain to students that the first two feet on the timeline represent 3000 years (BC), and mark an arrow to the left from the zero point, to show that that space represents a much larger time frame than the remaining timeline markings.

5. If the activity is being done individually by each student, use 1/4 inch graph paper to make their timeline, and make the first mark one inch in from the edge of the paper.

6. Students must realize that the beginning (arrowed) segment represents a very large segment of time, but that the remaining segments, to the right of the zero point, represent 100 years (each foot of the big paper or 1/4" of the graph paper).

7. From the selection of dates and major events that follows, have students mark both dates and events on the timeline.

Major Events and Dates:

- **3000 BC:** Known in Gaelic as Uaimh na Greine, "the cave of the sun," Newgrange, Ireland was built. It is the oldest known structure with evidence of scientific thought. On winter solstice, the sunlight perfectly aligns with an opening in the structure to illuminate the inner chamber.
- **2700-1700 BC:** Stonehenge, in England, was built in approximately 3000 BC. It was a giant circle of huge stones that were aligned to the position of the sun.
- **4th Century BC:** Greek philosopher Aristotle invented the camera obscura and became the first known person to use a device to observe the Simi. A camera obscura, a hole punched in a screen, remains a popular way to observe solar eclipses.
- **150 AD:** Ptolemy endorsed the Earth-centered view of the universe.
- **1543:** Nicolaus Copernicus published his theory that Earth travels around the sun. This contradicted the teachings of the Church.
- **1608:** Dutch eyeglass maker Hans Lippershey invented the refracting telescope. Other scientists soon followed suit, making their own instruments.
- **1609:** Johannes Kepler published his work, *New Astronomy*, in which he announced his three laws of planetary motion. His work described the orbits of the planets as elliptical, rather than circular.
- **1610:** Galileo Galilei published his findings of his observations with his telescope. He described spots on the sun, craters on the moon and four satellites of Jupiter. His findings promoted the idea of a sun-centered universe (like Copernicus).
- **1687:** Sir Issac Newton published his findings (*Principia Mathematica*) establishing the theory of gravitation and laws of motion. This allowed astronomers to understand the interacting forces among the sun, the planets and their moons.
- **1814:** Joseph von Fraunhofer built the first accurate spectrometer and used it to study the spectrum of the sun's light.
- **1843:** German amateur astronomer Heinrich Schwabe, who had studied the sun for 17 years, announced his discovery of a regular cycle in sunspot numbers. He discovered that the number and positions of sunspots vary over an 11-year period.
- **1859:** Astronomer Richard Carrington (Britain) discovered solar flares. His discovery helped explain that geomagnetic storms on Earth are related to events on the sun.
- **1868:** During an eclipse, astronomers observed a new, bright emission line in the spectrum of the sun's atmosphere. As a result of observations, British astronomer Norman Lockyer identified and named helium.
- **1908:** American astronomer George Ellery Hale showed that sunspots contain magnetic fields that are thousands of times stronger than Earth's magnetic field.
- **1938:** German physicist Hans A. Bethe and American physicist Charles L. Critchfield demonstrated how a sequence of nuclear reactions, called the proton-proton chain, make the sun shine.
- **1957:** Russian satellite Sputnik 1 was launched into orbit. Four months later, the US launched its first satellite, Explorer.
- **1981:** NASA's first reusable space shuttle, Columbia, made its maiden flight.
- **1983:** Launch of manned SpaceLab gave long term high-resolution photographs of the sun's surface.
- **1990:** Ulysses, an interplanetary spacecraft, was launched with the mission to measure the solar wind and magnetic field over the sun's poles during periods of both high and low solar activity.
- **1991:** Launch of the YOHKOH spacecraft, photographing the sun in x-ray emission over a full solar cycle (11 years).
- **1995:** The Solar and Heliospheric Observatory (SOHO) is a joint project of the United States (NASA) and the European Space Agency (ESA). SOHO is at a point in space where the sun's gravitational pull balances Earth's gravitational pull, so the satellite orbits the sun with Earth. SOHO always faces the sun. SOHO returned some of the amazing images of the sun seen in SOLARMAX.
- **1998:** Launch of the TRACE satellite, giving unprecedented close-up pictures of the sun and its magnetic field lines.
- **1998:** Construction began on a huge new space station, a joint endeavor among many countries.
- **2000:** YOHKOH, SOHO and TRACE images composited to large format film for SOLARMAX.

10 Questions to be Answered about the Sun and Solar System

1. Is the sun a star? If so, explain why it does not look like other stars?

2. Name the seven colors of the sun's spectrum, starting with red.

3. Name the three layers of the sun's atmosphere:

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4. How do we define one year?

5. Why do we have seasons?

6. What are some of the disadvantages of telling time with a sundial?

7. What is the most basic way to observe scientific phenomena?
Why is this not possible when we study the sun?

8. Why are observatories frequently built on mountaintops?

9. What is solar wind?

10. Where would you travel to see the best auroras?
Can you see auroras in the southern hemisphere? If so, from where?

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Locating NASA's Centers and Affiliate Locations

NASA's missions and research about our solar system are conducted primarily through the following NASA centers and affiliates. The locations listed in bold type provided spacecraft images of the sun for SOLARMAX:

- AMES RESEARCH CENTER, MOUNTAIN VIEW, CALIFORNIA
- **GODDARD SPACE FLIGHT CENTER, GREENBELT, MARYLAND**
- JET PROPULSION LABORATORY, PASADENA, CALIFORNIA
- JOHNS HOPKINS UNIVERSITY, APPLIED PHYSICS LABORATORY, LAUREL, MARYLAND
- JOHNSON SPACE CENTER, HOUSTON, TEXAS
- **LOCKHEED RESEARCH LABORATORIES, PALO ALTO, CALIFORNIA**
- LUNAR AND PLANETARY INSTITUTE, HOUSTON, TEXAS
- **NAVAL RESEARCH LABORATORIES, WASHINGTON, DC**
- SPACE TELESCOPE SCIENCE INSTITUTE, BALTIMORE, MARYLAND

Using the map of the United States of America, locate each of the NASA centers and affiliate research sites, and label each with a black dot on the map. Then, beside each dot, write the name of the center.

Student Reflections on Society's Reluctance to Accept New Ideas

(A Writing Activity)

When Nicolaus Copernicus first put forth his idea that the sun was at the center of our solar system in 1543, it was not readily accepted. Then when Galileo used his telescope to observe the Sun and solar system, he also proclaimed that the sun was at the center of our solar system. He was not only scoffed at, but also persecuted by the Church for his view and forced to withdraw his opinion.

Describe your reaction and feelings to the way people sometimes react to new, "bright" ideas. Give specific examples, if you can.

Solar Max Word Find

C	N	E	W	G	R	A	N	G	E	F	Y	J	M	F	P
R	I	Y	R	F	A	S	Y	P	P	L	K	E	W	D	I
A	A	T	I	A	U	I	G	E	L	A	Q	C	Z	E	O
W	N	E	E	N	E	N	R	R	I	R	B	N	R	S	N
Z	L	O	S	N	R	Y	E	E	G	E	U	E	A	P	O
D	I	P	R	E	G	O	N	H	H	S	H	N	E	E	S
A	O	M	S	O	F	A	E	P	T	P	U	I	L	C	P
T	G	A	H	U	C	Y	M	S	S	W	A	M	C	T	H
R	E	F	R	A	C	T	I	O	N	U	I	O	U	R	E
N	O	I	S	U	F	I	T	M	R	M	G	R	N	U	R
G	A	L	I	L	E	O	N	O	A	T	I	P	O	M	E
P	R	I	S	M	H	Z	R	R	O	X	C	L	F	G	R
D	N	I	W	P	J	A	Z	H	E	L	I	E	K	A	H
E	S	P	I	L	C	E	I	C	E	P	P	M	L	Y	N
E	G	N	E	H	E	N	O	T	S	U	O	O	U	E	U
R	A	D	I	A	T	E	D	D	Z	X	S	C	G	M	S

<u>WORDS FOR THE WORD FIND</u>

AURORA
CHROMOSPHERE
COPERNICUS
CORONA
ECLIPSE
ELECTROMAGNETIC
ENERGY
FIELD
FLARES
FUSION
GALILEO
IONOSPHERE
LIGHT
MAXIMUM
MILKY
NEWGRANGE
NUCLEAR
PHOTOSPHERE
PRISM
PROMINENCE
RADIATE
REFRACTION
SOLAR
SPECTRUM
STONEHENGE
SUN
SUNSPOT
WAY
WIND
YEAR

Observing Sunspots on the Sun's Surface Using Images from the SOHO Spacecraft

CONCEPT

Images from the highly sophisticated spacecraft, SOHO, circling the sun about 1,000,000 miles from Earth towards the sun. We will use SOHO images to observe and record information about the currently visible sunspot groups. These images will be downloaded from the SOHO website located on the Internet.

VOCABULARY

Sunspot - a dark spot on the sun's surface caused by the cooling of the sun's surface by very intense magnetic fields. They occur when a strong magnetic field rises from below the surface of the sun. They are darker than the rest of the solar surface (photosphere) because they are cooler. Most of the visible surface has a temperature of about 9700º Fahrenheit, but big sunspots can drop to about 7000º.

SOHO Space Craft - the Solar and Heliospheric Observatory, a spacecraft that was specially designed to observe and study the sun.

Michelson Doppler Imager (MDI) - images from SOHO that are taken in the in the deep red region of the spectrum. The most prominent solar features are the sunspots on the solar photosphere. This is very much how the sun looks like in the visible range of the spectrum.

Polar Coordinates - a way to describe with numbers every spot on a sphere, like the sun or Earth. The circles that are drawn on the surface of the sphere are called the latitude and longitude. Latitude circles are drawn around the sphere and longitude circles are drawn from the poles at the top to the bottom of the sphere.

Sunspot Data Recording Worksheet - a worksheet to record information about what we see when looking at the sunspots on the images of the sun downloaded from the SOHO spacecraft.

Speed of Revolution - how fast a sphere is rotating about its axis.

Solar Day - the number of Earth days for the sun to revolve once on its axis.

OBJECTIVES

Students will learn how to use the Internet to access and download information about the sun that is current to within 24 hours of when it was observed by the SOHO spacecraft. The systematic observing and recording of data about sunspots will teach the students the value of good experimental processes. The recorded data can be used to estimate the speed of revolution of the sun.

MATERIALS

- A personal computer with access to the Internet and a printer
- Images of sun every day, for about 2 weeks, downloaded from the SOHO website
- Sunspot recording worksheet
- Latitude/longitude grids, copied onto a transparency if possible.

PROCEDURE

1. Use the personal computer to connect to the Internet and access the website, http://sohowww.nascom.nasa.gov/data/realtime-images.html
2. Select from the list of images one that is labeled an "MDI Continuum." Print the image. If a printer is not available, try to sketch the image from the screen using the latitude/longitude grid that has been copied onto a transparency.
3. For each of the major sunspot groups, record on your sunspot recording worksheet:

   a. The name of each spot group. Make up any name you want, but make sure to keep track of which group has which name so the data you record is consistent. Note where the spot groups lay, i.e. latitude and longitude.

   b. Note whether there were any observable changes in your sunspot groups, i.e. size, shape, appearance and disappearance.

4. Collect images and record data for 10 consecutive days. Weekend data can be collected on the following Monday by going back in the image file using the previous day button.

   a. Try to get images from roughly the same time each day.

   b. Work with only the large dark areas; do not use smaller black dots.

   c. When measuring the latitude and longitude, use the center of the sunspot group, the larger dark areas.

5. Using the data you have collected, go to the activity; calculate the sun's speed of rotation.

Sunspot Data Recording Worksheet

Name: ____ Date: __________________________

Sunspot Group Name	Latitude	Longitude	Observations

Some More Information on Sunspots:

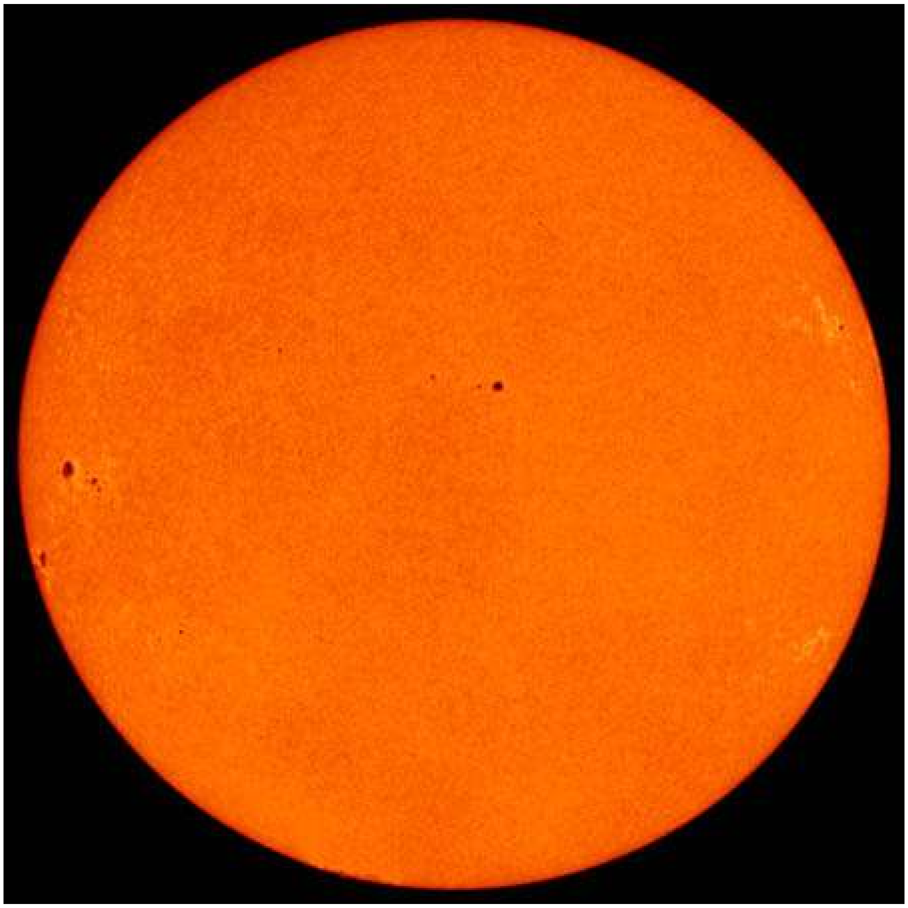
When were sunspots first discovered?
Usually stated as 1610, coincident with the discovery of the telescope. An official world-wide network of observatories started continuous observation in 1849.

How big are they?
Small ones are of the order of 1,000 miles across; large ones can be as big as 30,000 miles across. For comparison, the diameter of the Earth is 8,000 miles across.

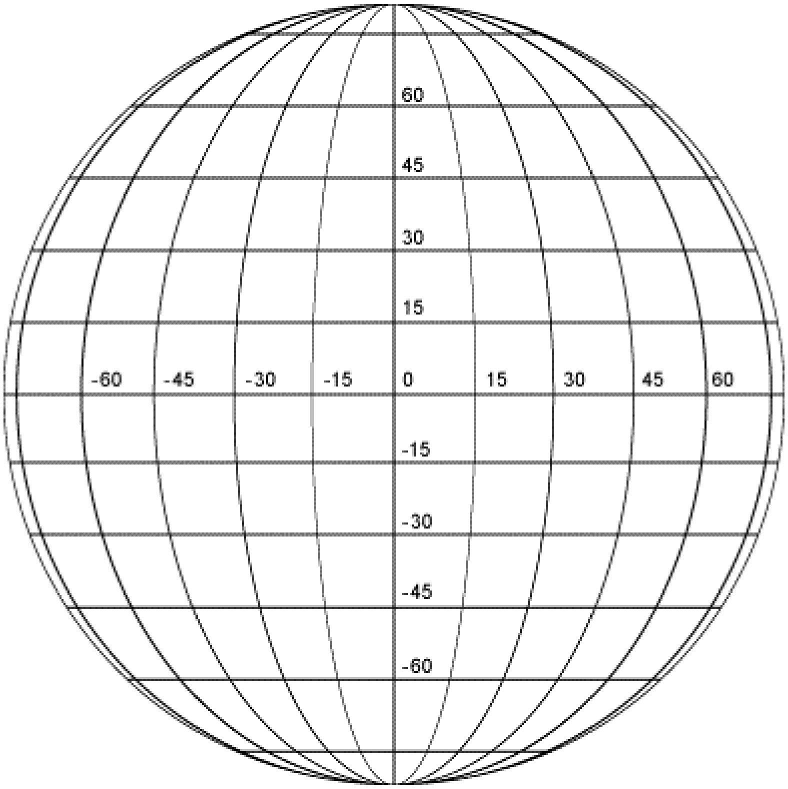
How many are there usually on the sun?
On some days, none are seen; on other days you can see as many as 100 to 200. There is an 11-year cycle where at the minimum, few sunspots are seen but at the maximum, the typical number of sunspots is 100.

How do they affect the Earth?
There is no direct connection with day-to-day weather. But there appears to be a connection with long-term climate changes. For example, in the late 1600s there were very few sunspots, and there was a mini-Ice Age in the northern hemisphere. There is, however, a direct connection with magnetic activity measured on the Earth, and the appearance of the aurora borealis (northern hemisphere) and aurora australis (southern hemisphere).

Sunspot Data Recording



Sunspot Data Recording



SOLAR COORDINATES B=+0

The horizontal lines are Parallels of Latitude [0 to $^{\pm}$90º]

The curved vertical lines and Meridians of Longitude [0 to $^{\pm}$180º]

Earth-Sun Geometry

SEASONS TEMPERATURE AND TIME

CONCEPT

Since the time of Copernicus, we have known that the Earth orbits about the sun. But how does the angle of the Earth's rotation axis, relative to the sun, affect the seasons we experience and the temperature of the hot summers and cold winters? How did man decide to measure the passing of time using the Earth's relationship to the sun? All these things can be explained by understanding the GEOMETRY of the Earth as it relates to the sun.

VOCABULARY

Earth's Rotation Axis - the imaginary line that goes through the north and south geographic poles and that the Earth rotates around. Earth's rotation causes day and night to occur. The rotation axis is slanted by 23.5 degrees relative to the plane of the Earth's orbit around the sun.

Earth's Orbit - the path that the Earth follows as it moves around the sun.

Summer Solstice (Northern Hemisphere)- Occurs when the northern end of Earth's rotation axis is leaning as close to the Sun as possible. The solstice takes place around June 21. The sun will be at its highest point in the sky, and this is the longest day of the year.

Winter Solstice (Northern Hemisphere) - Occurs when the northern end of Earth's rotation axis is leaning as far away from the sun as possible. The solstice takes place around December 21. The sun will be at its lowest point in the sky, and this is the shortest day of the year.

Vernal Equinox (Northern Hemisphere) - Day and night will be of equal (equinox) length. It is usually referred at the first day of spring and occurs around March 21.

Autumnal Equinox (Northern Hemisphere) - Day and night will be of equal (equinox) length. It is usually referred to as the first day of autumn and occurs around September 21.

Seasons of the Year - Summer, fall, winter and spring. The seasons are opposite in the southern hemisphere, so when it is summer in the northern hemisphere, it is winter in the southern hemisphere.

Seasonal Temperatures - a result of how much energy from the Sun is absorbed by the Earth's atmosphere and surface. Because of the tilt of the Earth's rotation axis, the angle of the Earth's surface relative to the sun changes as the Earth orbits the sun. The greater the angle of the Earth's surface to the sun's light, the less energy per square foot is received from the sun; also the greater the angle, the shorted the days, so there is less time to absorb energy from the sun. And the greater the angle, the lower the sun is in the sky, so the sun's light has to pass through more of the Earth's atmosphere, which absorbs some of the energy. It is a combination of these three reasons that results in winter having much colder temperatures than summer. And the difference in summer and winter temperatures is greatest at higher latitudes (the nearer you are to the poles).

Time Measurement - One Earth year is the time taken for the Earth to complete one orbit around the sun. One Earth day is the time it takes the Earth to rotate once about its rotation axis. The Earth rotates approximately 365 1/4 times for each complete orbit around the sun.

Leap Year - Normally there are 365 days in one year, but every fourth year we add an extra day to our calendar, to adjust for this extra 1/4 of a rotation each year. This correction was introduced at the time of Julius Caesar (46 B.C.) and allows our calendar to always measure the location of the Earth in its orbit about the sun accurately. The Spring equinox should always occur around March 21st, so farmers know when to plant their crops just by looking at the calendar. If we did not have a leap year, the spring equinox would be later on the calendar by 1/4 of day each year. This would mean that, in 100 years, the spring equinox would occur around April 15 (25 days later than it should be).

Leap Century - Normally at the end of the century, we do not have a leap year. This means that there are eight years between leap years instead of just four years. However every four centuries we do have a leap year at the end of the century as we did in the year 2000. Pope Gregory developed this correction to our calendars in the 1500s because religious holidays (such as Easter) were not consistent with the position of the sun, and had in fact changed by 11 days since the time of Caesar! This is because the Earth orbits the sun in 365 days, 5 hours and 48 minutes, a little less than 365 1/4 days. This refinement by Pope Gregory makes the current calendar a very accurate measure of where the Earth is in its orbit about the sun.

MATERIALS

a globe

one flashlight or slide projector

observation sheets

PROCEDURE

1. Position the globe and light source so that they are at the same level and far enough apart so that the light beam shines evenly on the globe. Use two desks/tables or one long table.

2. Dim the room lights so it is easy to see the shadow line separating the illuminated ("day side") on the globe from the dark ("night side").

3. Answer questions on observation sheet.

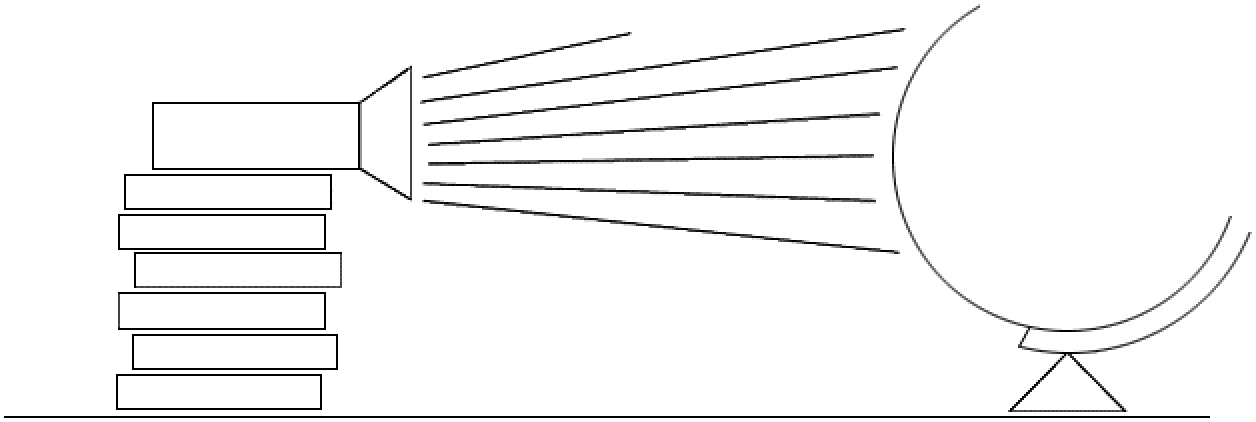
4. Move the Earth 90 degrees around the sun to Position 2. Keep the Earth's rotation axis constant. It is easier to visualize the movement of the earth around the sun if you can physically move the globe in a circle around the light source, turning the light source to follow. Thus it is best to use a small globe so that the demonstration can be carried out on a table (or two tables pushed together). If there is not enough room to do this, you can show the Earth's relationship to the sun as it moves around the sun by rotating the base of the globe 90 degrees.

Note to Teacher:

You should be careful with the demonstration in this exercise, or it will end up confusing rather than explaining. The important thing to emphasize is that the Earth's rotational axis always keeps the same direction in space.

5. Answer questions on observation sheet.

6. Repeat steps 4 and 5 for Positions 3 and 4.



Earth-Sun Geometry

SEASONS, TEMPERATURE AND TIME OBSERVATION SHEET

For each position (1,2,3 and 4) of the Earth in its orbit, ask the following questions:

QUESTION	ANSWER
Which hemisphere will have the longest days?	
Which hemisphere will have the shortest days?	
Which pole will experience the "Midnight Sun?"	
Which pole will experience a full day with no sunlight?	
Which hemisphere will have the most direct sunlight (where the sun's light is closest to being perpendicular to the Earth's surface)?	
What season is occurring in the Northern Hemisphere?	
What season is occurring in the Southern Hemisphere?	

Are You Ready for Solar Max?

GRAPHING SUNSPOT ACTIVITY

CONCEPT

Sunspot activity is directly related to the frequency of major solar storms. It is important that we know when these major solar storms are likely to occur because they can cause electrical blackouts, communication outages and satellite problems here on Earth. This is referred to as "Space Weather" forecasting. Using historical sunspot activity data, you will try to find a pattern of activity in the number of sunspots that have been observed since 1900 and then predict when the next maximum sunspot activity will occur (solar max).

VOCABULARY

Sunspot - a dark spot on the sun's surface caused by the cooling of the sun's surface by very intense magnetic fields.

Sunspot Number - the number of sunspots that can be seen on a given day varies greatly throughout the year. Usually the daily numbers are averaged over a period of one month, and this monthly average is referred to as the sunspot number. These monthly averages can then be averaged for a whole year to give the yearly sunspot number. (In practice, it is a little more complicated that this, as individual sunspots, and sunspot groups, are counted differently.)

Sunspot Cycle - the average length of time between maximum sunspot activity.

Maximum and Minimum - when a graph shows the highest and lowest values for a variable that is measured over a period of time.

OBJECTIVE

Students will use graphing techniques to analyze historical sunspot activity and try to identify patterns in the data that will identify the maxima and minima of the sunspot cycle. They will then use this data to predict when the next maximum will occur and what the average number of years between maximums is for sunspot activity.

MATERIALS

- graph paper
- pencils
- sunspot activity data

PROCEDURE

1. Tape two or three pieces of graph paper together so that there will be at least 105 data points on the x-axis. Label the x-axis from zero to 110, representing the year 1900 to 2010.
2. Label the Y-axis from zero to 200. (Increments of 5 for each line on the Y-axis.)
3. Have the students plot the sunspot activity from 1900 to 1999.
4. Connect all the data points on the graph and observe the resulting pattern.
5. Measure the number of years between each peak value.
6. Find the average number of years between the peaks by adding up all the numbers in step 5 and dividing by the number of values you used.
7. Forecast the year that the next maximum sunspot activity will occur by adding, the average number of years between peaks calculated in step 6 to the last known peak on the graph.

Sunspot Activity Data

Year	Sunspot Number	Year	Sunspot Number	Year	Sunspot Number
1900	9.50	1936	79.70	1972	68.90
1901	2.70	1937	114.40	1973	38.00
1902	5.00	1938	109.60	1974	34.50
1903	24.40	1939	88.80	1975	15.50
1904	42.00	1940	67.80	1976	12.60
1905	63.50	1941	47.50	1977	27.50
1906	53.80	1942	30.60	1978	92.50
1907	62.00	1943	16.30	1979	155.40
1908	48.50	1944	9.60	1980	154.60
1909	43.90	1945	33.20	1981	140.40
1910	18.60	1946	92.60	1982	115.90
1911	5.70	1947	151.60	1983	66.60
1912	3.60	1948	136.30	1984	45.90
1913	1.40	1949	134.70	1985	17.90
1914	9.60	1950	83.90	1986	3.40
1915	47.40	1951	69.40	1987	29.40
1916	57.10	1952	31.50	1988	100.20
1917	103.90	1953	13.90	1989	157.60
1918	80.60	1954	4.40	1990	142.60
1919	63.60	1955	38.00	1991	145.70
1920	37.60	1956	141.70	1992	94.30
1921	26.10	1957	190.20	1993	54.60
1922	14.20	1958	184.80	1994	29.90
1923	5.80	1959	159.00	1995	17.50
1924	16.70	1960	112.30	1996	8.60
1925	44.30	1961	53.90	1997	21.50
1926	63.90	1962	37.60	1998	64.30
1927	69.00	1963	27.90	1999	93.30
1928	77.80	1964	10.20		
1929	64.90	1965	15.10		
1930	35.70	1966	47.00		
1931	21.20	1967	93.80		
1932	11.10	1968	105.90		
1933	5.70	1969	105.50		
1934	8.70	1970	104.50		
1935	36.10	1971	66.60		

The Sun's Fuel

The sun's energy is the source for all life on Earth. Its heat allows water to remain a liquid on our planet and sustains life as we know it. For thousands of years, scientists and philosophers have tried to understand just what process could produce this enormous energy over so many years. It is interesting to look at some early scientific ideas:

1. In the late 1700s, the philosopher Immanuel Kant calculated that if the sun generated energy chemically (such as by burning coal), it could only last for a few thousand years.

2. In the late 1800s, the German physicist Hermann von Helmholtz calculated the energy that might be generated if the sun was still contracting under gravity, and came up with an answer that the sun would only last about 20 million years.

These mechanisms then could never hope to explain the sun's energy, as we now know the sun is about four billion years old!

Early in the 20th century, the famous scientist Albert Einstein showed that if you can somehow combine two particles (such as atoms or molecules) to form a new and heavier particle, it is possible that the total mass of the new particle may be slightly less that the particles forming it, and that "leftover" mass can be converted to energy. He showed that just a little mass (m) can result in an enormous amount of energy (E), according to his famous equation:

$E = m \text{ x } c^2$

where c is the speed of light, a very large number: 186,000 miles/sec.

The process of forcing two particles together to form a new heavier particle is called nuclear fusion, and requires very high pressures and temperatures (approx. 15,000,000 degrees) for it to work. These pressures and temperatures are found in the core of the sun, where a continuous nuclear reaction is taking place. The process converts 600 million tons of hydrogen to 596 million tons of helium every second. (This is about half the weight of Mt. Everest!) The difference of four million tons is converted to energy as shown in Einstein's equation. This is sufficient to explain the energy of the sun. There is enough hydrogen on the sun for this process to continue for another five billion years.

1. Can you describe two ways that nuclear reactions take place on the Earth? (e.g. nuclear reactors, nuclear bombs)

2. Why is it very dangerous when something goes wrong at a nuclear power plant?

3. How can you make two particles fuse together to form a new heavier particle?

Glossary

- **Atmosphere** - a layer of gas held around a planet by gravity.
- **Aurora** - electrical particles (mainly electrons and protons) flow from the sun to the Earth (the solar wind). They are guided by the Earth's magnetic field to two oval-shaped regions around the north and south poles (actually the magnetic poles, which are a little different from the geographic poles). There they bombard the upper layers of the Earth's atmosphere and cause the oxygen and nitrogen atoms and molecules to emit light, which is the light of the aurora.
- **Chromosphere** - from the Greek chromos, color. The layer just above the photosphere (see below); it is seen during a solar eclipse, and appears as spikes of light that are a pinkish color.
- **Corona** - from the Latin for crown. The sun's very hot, upper atmosphere; it appears as a ghostly white halo during a solar eclipse.
- **Electromagnetic spectrum** - the complete range of radiation given off by the sun, and includes heat, light, x-rays, radio waves and other kinds of energy.
- **Ionosphere** - the region of the Earth's atmosphere which is electrically charged; between 50 km and 600 km above the surface of the Earth.
- **Light Year** - a scientific way of measuring huge distances, it is the distance that light travels in one year; light travels at 186,300 miles per second, or 6 trillion miles per year. Our nearest star (other than the sun) is Alpha Centuri, which is 4.2 light years away.
- **Milky Way** - our galaxy; contains over 200 billion stars.
- **Nuclear Fusion** - the process in which hydrogen atoms are combined or fused into helium atoms. The sun changes 600 million tons of hydrogen into 596 tons of helium every second, and loses 4 million tons of mass that has been converted into light and heat energy.
- **Photosphere** - from the Greek photos, light. The lowest layer of the sun's atmosphere, it is the layer we see in visible light.
- **Prominences** - huge eruptions of glowing gas from the sun, they can extend from 20,000 miles above the surface to over 300,000 miles; a huge arch of gas in the sun's lower corona.
- **Solar flares** - spectacular, forceful eruptions that burst forth from sunspots; waves of intense heat, light and radiation. It takes about two days for solar wind particles associated with solar flares to reach Earth's atmosphere.
- **Solar Maximum** - the peak of the 11-year solar activity cycle. The last one occurred in 1989-90, and the next one is expected in 2000-01. It is a time in which we are more vulnerable to "space weather."
- **Solar system** - the sun and everything that moves around it, including the planets, comets and asteroids.
- **Solar wind** - a high-speed flow of low-density electrical particles, mainly electrons and protons, emitted by the sun in all directions into space. The speed of the solar wind varies from about 200 to 1000 miles per second, so takes between one and five days to reach the Earth.
- **Spectroscope** - an optical instrument used by scientists to analyze what elements are present on the sun; it can also be used to detect motion and the speed of motion of gaseous objects.
- **Spectrum** - the rainbow of colors of light that make up the white light of the sun. The spectrum may be seen by passing the sun's light through a prism.
- **Sun** - our star; the central and largest body in our solar system; the essential energy source for life on Earth.
- **Sunspots** - a cool, dark spot on the sun's surface, that is created by regions of very strong magnetic field near the sun's surface. The magnetic field restrains circulation of hot gases from lower, hotter levels in the sun to the surface.

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