





*Solar Storms and You!* is available in electronic format through NASA Spacelink - one of the Agency's electronic resources specifically developed for use by the educational community.

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*<http://spacelink.nasa.gov>*



# Acknowledgments

**Dr. James Burch,**

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**Dr. William Taylor**

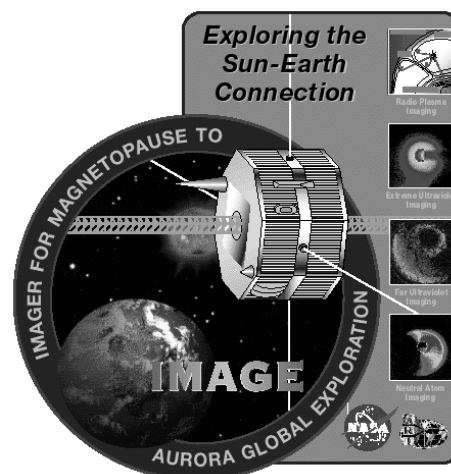
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This resource was developed by  
the NASA Imager for  
Magnetosphere-to-Auroral Global  
Exploration (IMAGE)

Information about the IMAGE  
mission is available at:

<http://image.gsfc.nasa.gov>  
<http://pluto.space.swri.edu/IMAGE>

Resources for teachers and  
students are available at:

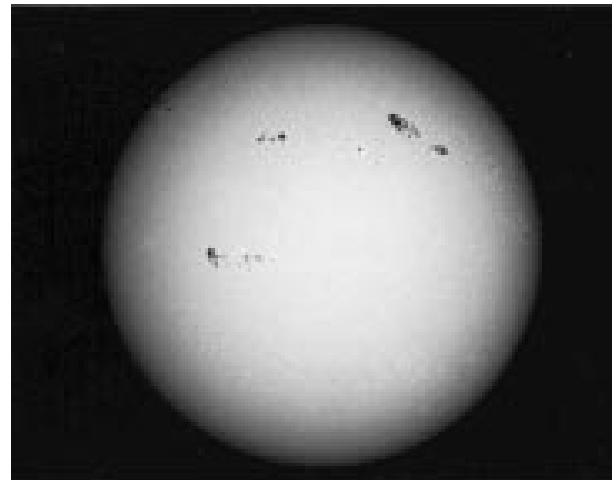
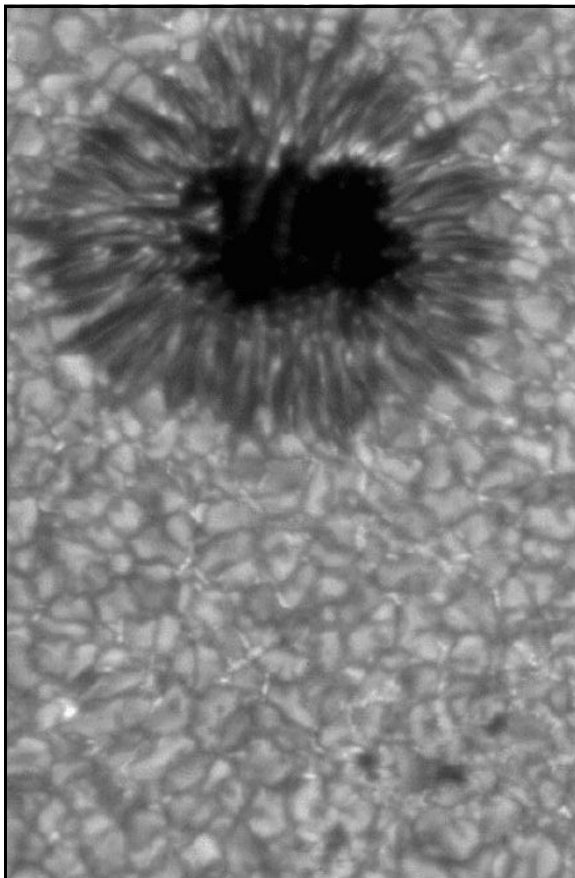
<http://image.gsfc.nasa.gov/poetry>



National Aeronautics and  
Space Administration  
Goddard Space Flight Center

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The Sun, our nearest star, is a powerful, seething furnace that produces light and heat. For thousands of years, naked-eye observers have seen dark spots slowly cross the disk of the Sun. Today, with more powerful instruments, astronomers can zoom-in to see astonishing details in these ‘sunspots’. The image on the left is a closeup view of a sunspot that is about twice the diameter of Planet Earth!

# I N T R O D U C T I O N

## **A gas pipeline in Russia explodes**

**killing hundreds of people.**

## **A satellite mysteriously falls silent**

**interrupting TV and cellular phone traffic.**

## **A power blackout**

**throws millions of people into darkness.**

These are only a few of the many things that solar storms can do when they arrive at the earth unexpected. In an age where we have increasingly come to rely upon the smooth operation of our technology, we have also made ourselves vulnerable to the ebb and flow of the solar storm cycle. Most people are not even aware of these cycles, but long ago we used to be!

Ancient Chinese sun observers knew that, from time to time, dark spots would glide slowly across the face of the setting sun. Once seen only as portends of political upheaval, we now see them as natural phenomena that can forewarn us of impending storms that can have dire consequences for us if we ignore them.

In this activity book, your students will study five key stages in the lifecycle of a solar storm, from its emergence on the solar surface to its impact upon some aspect of our lives. The book may be used in its entirety to study solar activity and how it directly affects us, or you may use individual activities of your choice as stand-alone mini lessons as an enrichment for math and physical science courses.

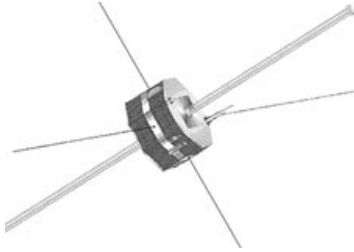
The student activities emphasize basic cognitive skills and higher-order processes such as plotting data, searching for patterns and correlations, and interpreting the results. By the end of the activity series, students will understand why we need to pay more attention to solar storms.

Visit the updated version of this workbook at:

**<http://image.gsfc.nasa.gov/poetry/workbook/workbook.html>**

# Science Process Skills

for *Solar Storms and You!*



*This chart is designed to assist teachers in integrating the activities contained in the guide with existing curricula.*

## Lesson 1

*“The Sunspot Cycle”*

## Lesson 2

*“The Sunspot Activity and Ocean Temperature”*

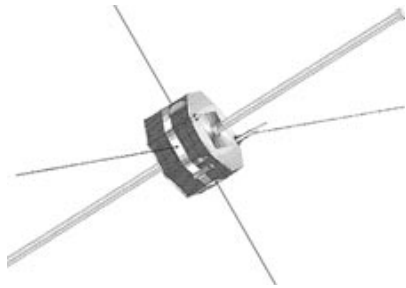
## Lesson 3

*“Sunspot Activity on Other Stars”*

<b>Observing</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Classifying</b>			
<b>Communicating</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Measuring</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Inferring</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Predicting</b>	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Experimental Design</b>			
<b>Gathering Data</b>			
<b>Organizing Data</b>	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Controlling Variables</b>	<input type="checkbox"/>		
<b>Developing a Hypothesis</b>	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Extending Senses</b>			
<b>Researching</b>			
<b>Team Work</b>	<input type="checkbox"/>	<input type="checkbox"/>	
<b>Mathematics</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Interdisciplinary</b>			
<b>Introductory Activity</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Advanced Activity</b>			

# Science and Mathematics Standards

for *Solar Storms and You!*



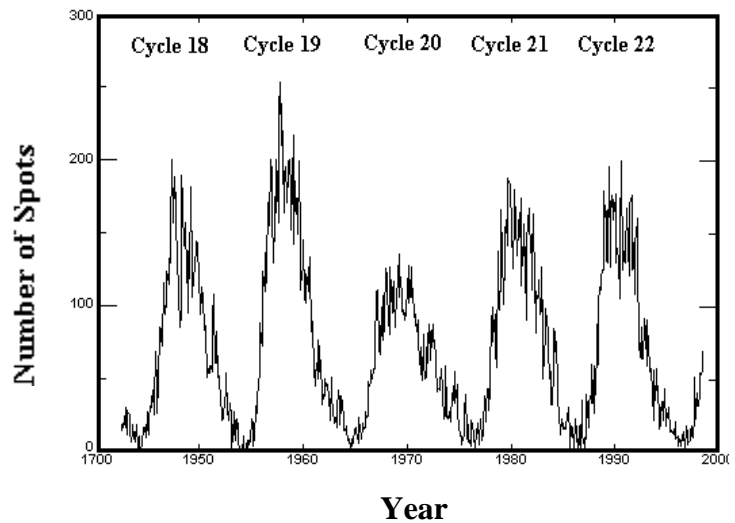
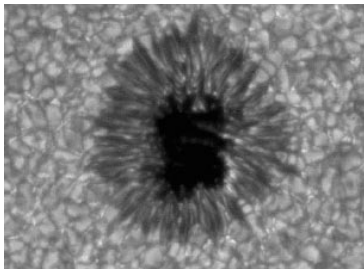
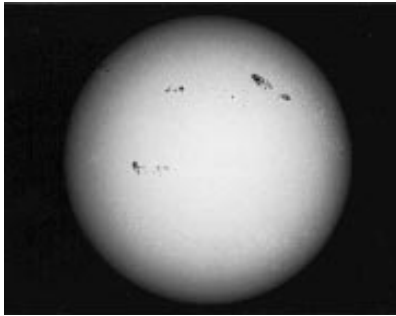
*This chart is designed to assist teachers in integrating the activities contained in the guide with existing curricula.*

<b>Lesson 1</b> <i>"The Sunspot Cycle"</i>	<b>Lesson 2</b> <i>"The Sunspot Activity and Ocean Temperature"</i>	<b>Lesson 3</b> <i>"Sunspot Activity on Other Stars"</i>
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	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Science as Inquiry</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Structure and Energy of the Earth System</b>			
<b>Origin and History of the Earth</b>			
<b>Earth in the Solar System</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Geochemical Cycles</b>			
<b>Physical Science</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Populations and Ecosystems</b>			
<b>Understanding about Science and Technol- ogy</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Science in Personal and Social Perspectives</b>			
<b>History and Nature of Science</b>			
<b>Problem Solving</b>			
<b>Measurement</b>			
<b>Computation and Estimation</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Communication</b>			
<b>Geometry and Advanced Mathematics</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Statistics and Probability</b>			
<b>Number and Number Relationships</b>			
<b>Patterns and Functions</b>			



# Solar Activity Cycles



The Sun, our nearest star, provides us with warmth and light. But as long ago as 2000 BC, Chinese observers noted that black spots occasionally appeared, and that over the course of a week, they drifted across the disk of the setting sun. **Sunspots** are the most well known hints that the Sun's surface is constantly changing. Larger than the Earth, and with 10,000 times more intensity than the Earth's magnetic field, these are the breeding grounds for some of the most violent storms in the solar system!

The number of sunspots comes in cycles lasting from 6 to 17 years; the **Sunspot Cycle**. With modern technology and space satellites, this solar activity cycle can now be detected in the ebb and flow of other phenomena on the Sun and on the Earth. Everything from ocean temperature to coral reef growth has been found to correlate with this cycle. In most cases the exact reason for the correlation is poorly understood by scientists.

Solar activity is a complex process that seems to be driven by the fact that, just below the surface, the sun's gases convect like mush boiling in a pot. The upwelling gases tangle up and amplify the pervasive magnetic field of the sun and force it up through the surface. These concentrated regions of magnetic field cause the gases within them to be thousands of degrees cooler than the rest of the solar surface, which makes them glow with far less light by comparison, so that they only look black by comparison. If you were to put a single sunspot in the night sky, it would glow orange and be brighter than the full moon!

During the last 20 years, astronomers have studied many other stars like our sun, and have discovered that some of these have activity cycles similar to our sun's sunspot cycle. They can vary from cycles as short as 5 years to as long as 30. Many stars also have irregular cycles that seem to come and go. Even the sun went through a phase in the 1600s when there was no sunspot cycle at all for nearly 50 years!

# Teacher's Guide

## The Sunspot Cycle

### Objective

The student will create a list and construct a graph of the number of sunspots using both technology and paper. The student will explore patterns in the data and locate the maximum and minimum.

### Materials

- Graph paper
- Ruler
- Colored pencils
- Sunspot data table

Optional:  
—Teacher notes on the graphing calculator.  
—Graphing calculator.  
TI-83 used in the examples

### Procedure

1) Divide the students into groups and assign a time period from the data table that each group will graph. Some possible lengths are the 1900s, 1800s; every 50 years; a column of the table (be aware that assigning less than 50 data points will prevent pattern recognition).

2) Use the graphing calculators, the students will input their data. They will use the trace key to explore the graph of their data while they look for a pattern or observation. Allow each group to report on their findings. They may or may not agree on a pattern within the groups as well as within the classroom as a whole.

3) Students will then construct the graph of the table on graph paper. Some possible options here are to have students each construct the graph, have each group use their assigned data and put the results of the class as a whole on the wall, or have the groups do a graph of the entire data. Be sure to agree upon a consistent scale for ease of construction and display.

4) Discuss the results of the entire sunspot table as a whole. Look for patterns such as maximum and minimum.

5) Students then predict when the next maximum will occur. Students will then construct what the graph would look like if this pattern continued on through the year 2099.

### What is a sunspot?

A sunspot is a region on the sun that can be seen as a small dark spot through a telescope. Since their discovery by Galileo in 1609, astronomers have learned that they are regions, about the size of the Earth, where powerful magnetic fields are concentrated. Often the site of solar flares and other storm activity, these spots are dark because the temperature of the solar gases inside them is about 2000 C cooler than the rest of the sun (5500 C). They appear black because they emit less light than the sun. In fact, if they were suspended in the night sky, they would glow a bright red color and be brighter than the full moon. The sunspot cycle has been seen since about 1670 and has a period of about 11 years. Before 1670, no such cycles were seen and this time also corresponded to the 'Little Ice Age' in Europe. Scientists now think that solar activity influences the Earth's weather in some way.

### Conclusion

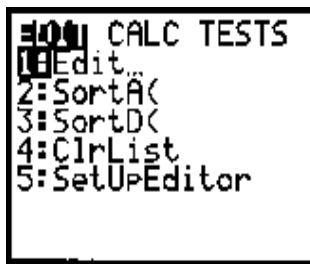
Sunspot activity comes in cycles which come and go with periods of about 11 years. No two cycles, however, are exactly the same shape or size.

# Teacher Notes for the Graphing Calculator

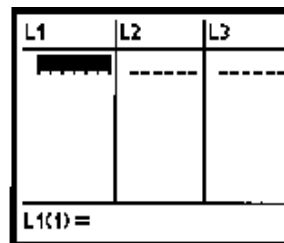
The commands for the calculator are given in bold print below the window you will see in the right-hand screen. Read the setup guide at the end of this section under ‘How to insure success.’

When choosing the group data assignments, the best situation may be to assign the 1700’s, 1800’s and 1900’s, or a minimum of 50 data points to permit pattern recognition.

Entering data into the list will consist of the following key strokes :

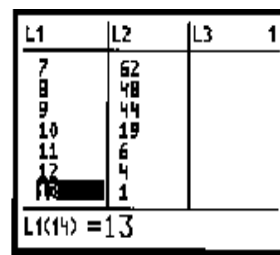
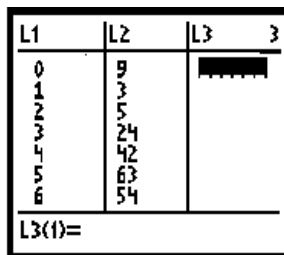


**STAT**

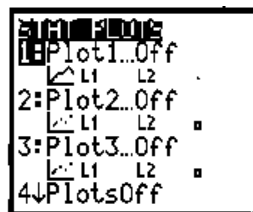


**ENTER**

This will put you at the window to input data for the year in list 1, and the data for the sunspot number in list 2. Screen images for the list beginning in 1900 are shown. The L1 data (year) was entered using only one or two digits for simplicity and to save time. This is acceptable since the scales on the axis are not displayed by the graphing calculator.



After the data has been entered into the lists, the stat plots will need to be turned on. To turn the plots on, use the right-hand key strokes. Note, turn on the second window to the right by using the arrow keys to place the cursor over each of the darkened items shown, and hitting **ENTER**.



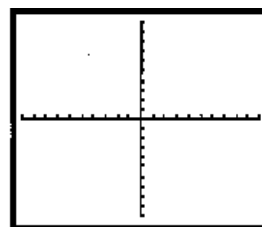
**2ND Y=**



**ENTER**

**Note:** When selecting the type of graph, the student may want to pick the first plot. When they do so, the result is a plot of the individual data points. The second type shows the data as a set of connected points. The second type of graph is best for this example because it shows a continuous cycle. Students need to be aware that the data is continuous.

When the students hit the graph key, they may not see any data. They may see a graph of four quadrants with a small display of data.

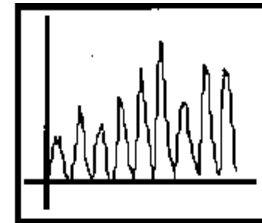


**GRAPH**

In order to get the correct window for the statistics plots, students will need to zoom the window:

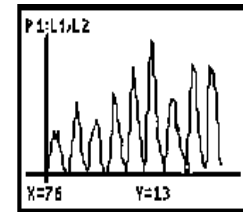
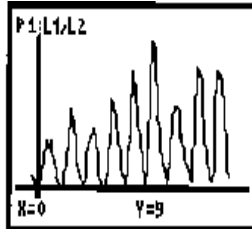


ZOOM



9

In order to check for pattern recognition and to trace the sunspot cycle maxima and minima, the students need to trace the cycle by using the left and right arrow keys to move along the graph. Some examples of the screen when using the TRACE command are shown to the right. When using the TRACE key, the students are able to see the year displayed from L1 and the number of sunspots from L2.

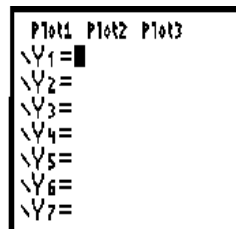


## How to insure success for beginners

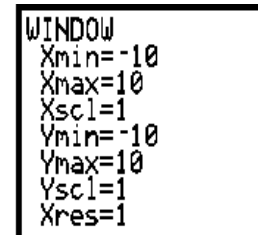
Before starting the activity with the students, have them insure that the following settings are in place on their calculators.



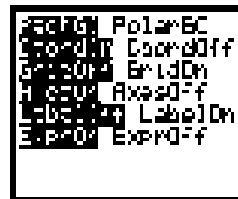
MODE



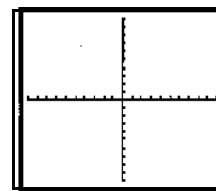
Y=



WINDOW



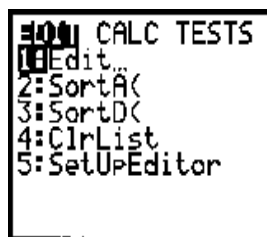
2ND ZOOM



GRAPH

To insure that the lists are cleared beforehand:

Then select 'ClrList' and use the keystrokes: 2ND 1, 2ND 2, ENTER, CLEAR. You can now begin the activity.



STAT

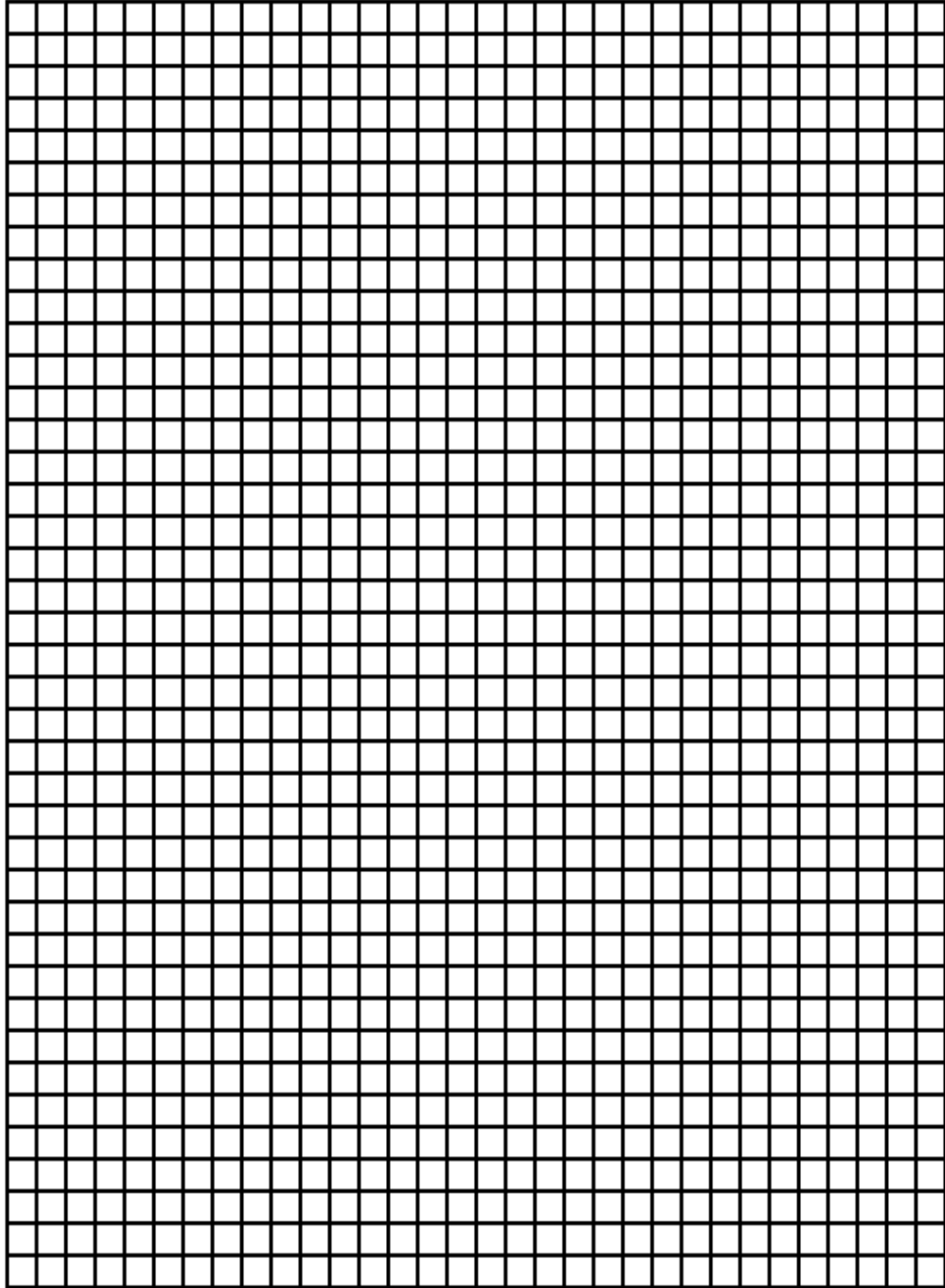
## The Sunspot Cycle Data Table

The following numbers give the maximum sunspots counted during each year from telescopic observations on the ground. They are listed by year, and by the corresponding number seen 'N'. Example, for 1880 there were N = 32 sunspots counted.

Year....N	Year....N	Year...N	Year...N	Year.....N
1700... 5	1760...63	1820...16	1880...32	1940...68
1702...16	1762...61	1822...4	1882...60	1942...31
1704...36	1764...36	1824...9	1884...64	1944...10
1706...29	1766...11	1826...36	1886...25	1946...93
1708...10	1768...70	1828...64	1888...7	1948...136
1710... 3	1770...101	1830...71	1890...7	1950...84
1712... 0	1772...67	1832...28	1892...73	1952...31
1714...11	1774... 31	1834...13	1894...78	1954...4
1716...47	1776...20	1836...121	1896...42	1956...142
1718...60	1778...154	1838...103	1898...27	1958...185
1720...28	1780...85	1840...65	1900...9	1960...112
1722...22	1782...38	1842...24	1902...5	1962...38
1724...21	1784...10	1844...15	1904...42	1964...10
1726...78	1786...83	1846...61	1906...54	1966...47
1728...103	1788...131	1848...125	1908...48	1968...106
1730...47	1790...90	1850...67	1910...19	1970...104
1732...11	1792...60	1852...54	1912...4	1972...69
1734...16	1794...41	1854...20	1914...10	1974...34
1736...70	1796...16	1856...4	1916...57	1976...13
1738...111	1798...4	1858...59	1918...81	1978...92
1740...73	1800...14	1860...96	1920...38	1980...154
1742...20	1802...45	1862...59	1922...14	1982...116
1744... 5	1804...48	1864...47	1924...17	1984...46
1746...22	1806...28	1866...16	1926...64	1986...14
1748...60	1808...8	1868...38	1928...78	1988...98
1750...83	1810...0	1870...139	1930...36	1990...146
1752...48	1812...5	1872...102	1932...11	1992...94
1754...12	1814...14	1874...45	1934...9	1994...30
1756...10	1816...46	1876...11	1936...80	
1758...48	1818...30	1878... 3	1938...110	

Name \_\_\_\_\_

Date \_\_\_\_\_



# Teacher's Guide

# Sunspot Activity and Ocean Temperature

## Introduction

Scientists have found there is a possible correlation between the average ocean temperature and solar sunspot activity. By comparing the results from data that has been collected since the 1800's to the present, scientists have found a possible pattern. For example, there are many instances when the average ocean surface temperature and the sunspot activity were at a high or low at about the same time. The source of the controversy is that there are also times in which a correlation is not seen in the data.

## Objective

Students will analyze and compare two graphs to determine if there is a correlation between solar activity and ocean temperature.

## Procedure

- 1) Group students into either pairs or teams of four. Read the introduction to the students concerning the controversy.
- 2) Review with the students an example of how the graphs may be similar and different. Be sure to mention shape, distribution, highs, lows, scale, axis and time frame.
- 3) Provide students with sufficient time to compare the two graphs. A transparency used as an overlay may be useful for some students.
- 4) Have the groups present their findings to the class. Some of the groups will argue that the highs and lows of the ocean temperature correlate to the sunspot cycle. Other groups may not see a relationship, and still others may say that there is a relationship in

some areas but not in others which leads to incomplete conclusions. This is precisely why the controversy exists.

**Note:** The start date for each graph is not the same year. Students will need to locate the appropriate year to begin the comparison. The temperature plots show the deviations in the number of degrees from an average global ocean temperature, so that -0.5 degrees means '0.5 C below the average' ocean temperature. You should also mention other factors that could alter the correlation such as El Nino events. **Be sure to mention this to the students.**

## Materials

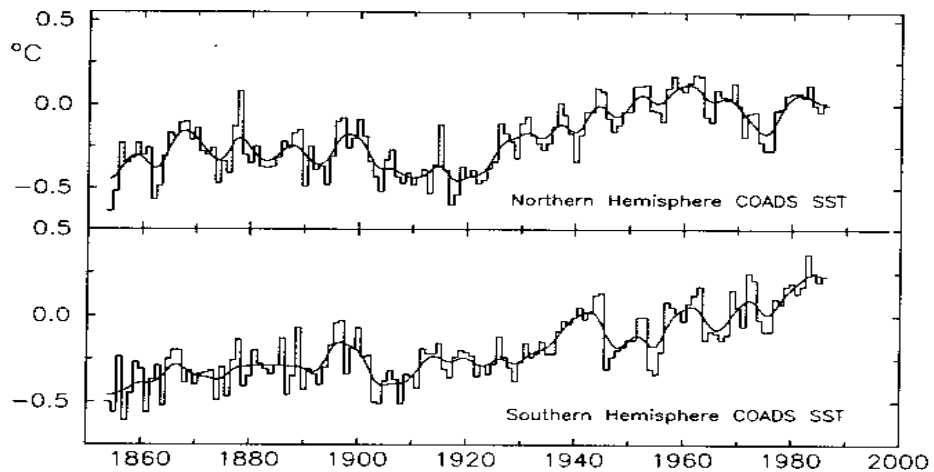
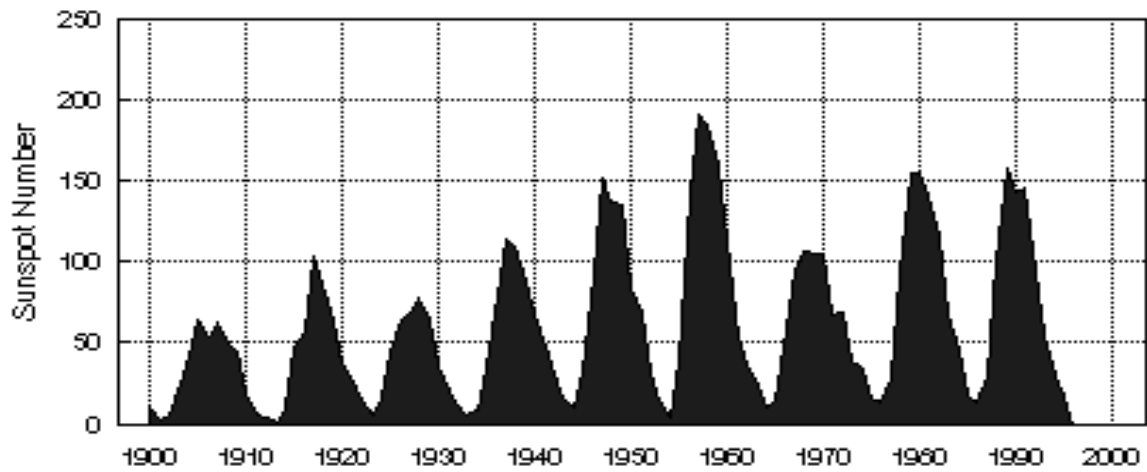
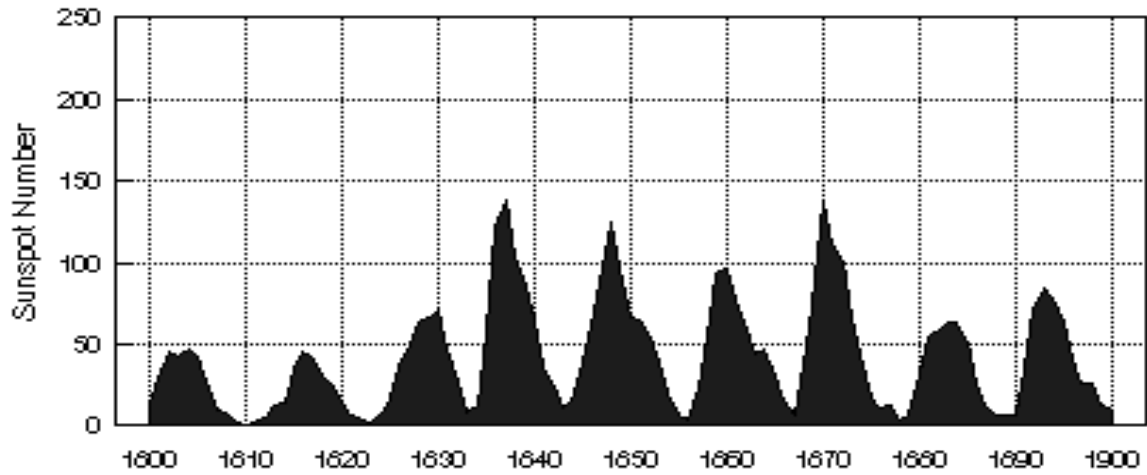
—Student Worksheet

Note: The ocean temperature data are based on over 80 million measurements made by hundreds of ships that, every hour, dumped a bucket overboard to collect sea water.

## Conclusion

Explain that the relationship between the sunspot cycle and the ocean temperature has not been proven or disproven. However, there seems to be a grudging consensus that there is something going on between the two.

# Student Worksheet





# Teacher's Guide

# Sunspot Activity on Other Stars

## Introduction

Since the 1970's, astronomers have been studying dozens of other stars that resemble the Sun in size and temperature. By monitoring the month to month changes in the brightness of these stars using the light they emit at specific wavelengths, they can investigate how storms on these stars ebb and flow over time. These 'stellar activity cycles' may be caused by the same processes as our own Sun's sunspot cycle, but may have properties that make them unique.

## Objective

Students will analyze and compare stellar activity graphs to determine how similar or different they are to the solar sunspot cycle.

## Procedure

1) Group students into either pairs or teams of four. Read the introduction to the students concerning the current issues in astronomy having to do with solar activity.

2) Review with the students an example of how graphs may be similar and different. Be sure to mention shape, distribution, highs, lows, scale, axis and time frame.

3) Provide students with sufficient time to compare the stellar activity cycle graphs with the solar sunspot graphs.

4) Have the groups present their findings to the class.

## Materials

—Student Worksheet

### Answers:

The Sun.....11 years  
HD136202.....28 years  
HD81809.....8 years  
HD16160.....12 years

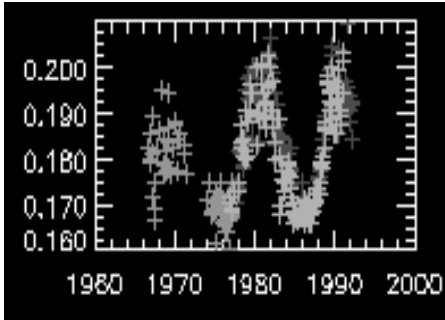
Student answers may vary from these by a few years.

## Conclusion

Explain that astronomers do not yet know why the sun has a sunspot cycle, or whether these cycles are permanent in the history of the sun, or come and go with time. By studying other stars we can learn just how typical our sun is, and study the possible factors that influence these cycles, such as the star's mass, temperature and age.

Name \_\_\_\_\_

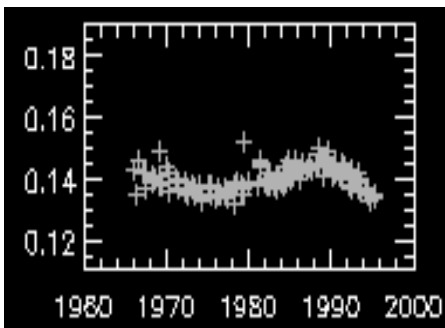
Date \_\_\_\_\_



## The Sun

Average length of cycle:

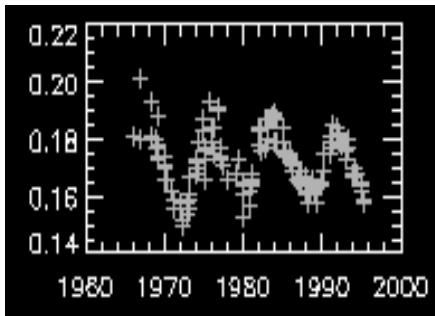
Temperature: **5770 K**



## HD 136202

Average length of cycle:

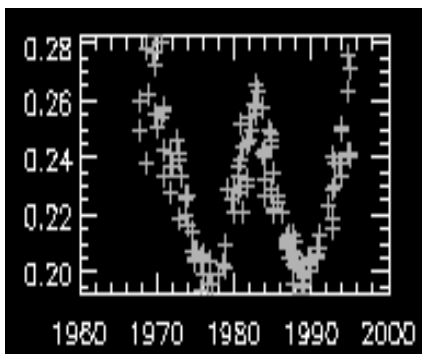
Temperature: **8400 K**



## HD 81809

Average length of cycle:

Temperature: **4100 K**



## HD 16160

Average length of cycle:

Temperature: **4800 K**

# What is Solar Activity?

The Sun, our nearest star, provides us with warmth and light. For many civilizations, it was once thought to be a perfect orb, free of blemishes, eternal and changeless. **Sunspots** are the most well known hints that the Sun's surface is constantly changing. Larger than the Earth, and with magnetic fields that are 10,000 times stronger than the Earth's, sunspots are the breeding grounds for some of the most violent storms in the solar system!

The number of sunspots increases and decreases in cycles that last from 6 to 17 years; the **Sunspot Cycle**. With modern technology and space satellites, this solar activity cycle can now be detected in the ebb and flow of other phenomena on the Sun and on the Earth. Among the most enigmatic storms are the **solar flares** that erupt near sunspots. In a matter of 20 minutes, magnetic fields can heat gases to tens of thousands of degrees and release more energy than a thousand atomic bombs. Some of this gas can be hurled out from the Sun at millions of kilometers per hour in what are called **coronal mass ejections**. Both solar flares and coronal mass ejections can be very disruptive to human activity on earth and in space.

The outer atmosphere of the Sun, the **corona**, is familiar to many people who have watched total eclipses of the sun. The solar wind extends billions of kilometers further out into space than the corona. Like invisible roadways spanning the solar system, the magnetic field from the Sun flows out from the solar surface. Matter ejected from the Sun flows radially outwards from the solar surface. From the time a solar storm is seen on the Sun, it can take 2-3 days for the gas to travel to the orbit of the Earth, and if the Earth happens to be in the wrong place at the wrong time, it will be hit by a million-kilometer wide wall of high temperature gases and magnetic fields.

Anyone can tell you that a compass points 'north' because the Earth has a magnetic field, but until the advent of the Space Age, no one understood what this field really looked like or was capable of doing. Since Gilbert proposed in the 17th century that the Earth was a giant magnet, scientists have wondered just how this field is shaped, and how it has changed with time. The geomagnetic field which gives us our familiar compass bearings, also extends thousands of kilometers out into space in a region called the **magnetosphere**. On the Sun-side, it forms a protective boundary called the **bow shock**. Stretching millions of kilometers in the opposite direction behind the Earth is the **magnetotail**.

The solar wind blows upon the magnetosphere and gives it a wind-swept shape, but when solar storms and solar wind streams reach the Earth, the magnetosphere reacts violently. On the side nearest the impact, the magnetosphere compresses like squeezing a balloon, leaving communications satellites exposed. On the opposite side, it is stretched out, past the orbit of the Moon, or Mars and even Jupiter! The geomagnetic field is remarkably stiff, and so most of the solar wind is deflected or just slips by without notice. But some of the matter leaks in and takes up residence in donut-shaped clouds of trapped particles, or can penetrate to the atmosphere to produce the Aurora Borealis.

For thousands of years, humans have been treated to spectacles of glowing clouds above the northern horizon at night. Reports of these mysterious Northern Lights abound in the oral histories of the northern natives. On rare occasions, even ancient Greek and Chinese texts have mentioned them. It wasn't until 1896 that the Norwegian physicist Kristian Birkeland deduced that flows of electrons from the Sun were channeled into the polar regions by the geomagnetic field, and upon colliding with the outer atmosphere, would stimulate oxygen and nitrogen atoms to cast their ghostly and inspiring curtains of light.

The **Aurora Borealis** (near the north pole) and the **Aurora Australis** (near the south pole), as the 'Northern Lights' are more formally called, are seen most often in a band located at a latitude of 70 degrees, and about 10 degrees wide in latitude. From space, the auroral zone looks like a ghostly, glowing donut of light hovering over the north and south poles. This **auroral oval** can easily be seen in images from satellites designed to detect it. Its brightness and size change with the level of solar activity. Auroras come in many shapes and colors depending on what is happening to the geomagnetic field and the flows of charged particles and plasmas trapped in this field.

**Magnetic sub-storms** happen when the geomagnetic field is suddenly changed because of small changes in the magnetic polarity of the solar wind as it passes the Earth. Typically, magnetic storm auroras, also called **auroral storms**, last only a few hours. They begin in the evening as arcs of colored light which slowly change into rayed-arcs and the familiar folded ribbons or bands. Expanding over the whole sky, the folded bands are colorful, with green rays and red lower borders which change from minute to minute and move rapidly across the sky like some phantasmagoric serpent. After an hour, the auroral shapes become more diffuse and less distinct.

**Geomagnetic storms** are more severe than magnetic sub-storms and are caused by major changes in the direction and density of the solar wind as it reaches the Earth. These events are the most remembered historically as 'Great Auroras' or as the most disruptive to radio communications. The entire geomagnetic storm can last for several days as the particles and fields around the Earth continue to readjust themselves to the passing and ebbing solar wind. They begin with an ejection of mass by the Sun, and the impact of this plasma on the magnetosphere. Fast-moving coronal mass ejections produce shock waves in the solar wind, and this compression intensifies the density of particles impacting the magnetosphere. As the solar wind shock passes across the magnetosphere and magnetotail, magnetic fields re-orient and reconnect, releasing enormous amounts of energy and accelerating trapped particles to high speeds. These charged particles then travel down the geomagnetic field in huge currents, which cause bright and long lasting auroral displays.

Solar storms and the effects they produce in the Earth's environment, have been known for decades to be responsible for many harmful effects upon human technology on the ground and in space. Solar storms are known to do far more than just paint the sky with pretty colors! The multi-billion dollar 'Global Positioning System' consists of a constellation of two dozen navigation satellites orbiting within the Van Allen radiation belts. These satellites let humans find their position anywhere on Earth using a receiver no bigger than a watch.

During solar storms, these positions are quite a bit less accurate than under calm conditions, which in turn impacts the navigation of ships at sea and jets in the air. Solar storms have disabled multi-million dollar communication and navigation satellites such as Anik-A, Molynia, Marecs-A, and they have been implicated in many electrical problems that were experienced by other satellites.

Solar storms were responsible for causing the Skylab to burn up in the atmosphere sooner than expected, and for altering the orbits of hundreds of other satellites and even the Space Shuttle itself. A storm on March 13, 1989 knocked out the Quebec-Hydro power system, plunging 6 million people into darkness for 9 hours. Geomagnetic storms cause the magnetic field near the Earth's surface to change rapidly in just a matter of minutes or hours. These changes cause electrical currents to flow within long power transmission lines, telephone wires, and even in pipelines which makes the pipes corrode, sometimes with tragic consequences. On June 5, 1991 a natural gas pipeline in Russia was weakened by corrosion and began to leak its deadly, flammable cargo. A passenger train, loaded with 1,200 people, ignited the liquefied gas and caused an explosion equal to 10,000 tons of TNT. Over 500 people were killed, and 700 more were badly injured.

## Would you believe...

**Aurora can never get closer to the ground than about 60 kilometers.**

**A sunspot has a temperature of nearly 4000 C, and would be brighter than the full moon if placed in the night sky.**

**Sunspots are often several times larger than the entire earth.**

**The Sun rotates once every 25 days at the equator, but takes up to 36 days to rotate once around at the poles.**

**The corona of the Sun is over 5 million degrees hotter than the surface of the Sun.**

**The Earth's magnetic north pole is actually a magnetic south pole because the north end of a bar magnet is attracted to it.**

**The total power produced by an auroral event can exceed 1 million megawatts and produce voltages over 100,000 volts in the upper atmosphere.**

**Aurora are produced where the atmosphere has the same density as the vacuum inside a light bulb.**

**Some aurora occur at altitudes of over 1000 kilometers above the Earth's surface.**

**Lightning storms can eject particles into space at nearly the speed of light, and they are seen as 'sprites' on the top side of a thundercloud.**

**A single lightning storm can be detected on the other side of the earth because some of its radio energy travels along the local magnetic field lines that connect the pairs of points on the surface of the Earth that can be thousands of kilometers apart.**

### Glossary

**Aurora** : Also called the ‘Northern Lights’ in the Northern hemisphere, or the ‘Southern Lights’ in the Southern hemisphere. These wispy curtains of light in the sky are caused by energetic electrons which collide with atoms of oxygen and nitrogen in the air to cause these atoms to emit shades of green, red and blue light. They never descend nearer than 60 kilometers from the Earth’s surface.

**Corona** : The very tenuous outer layers of the Sun which are seen during a total eclipse of the sun, but extending millions of miles into interplanetary space. It is heated to temperatures of over one million degrees by magnetic activity at the surface of the Sun. For decades, scientists puzzled over why the Corona could be so much hotter than the balmy 5770 degree Kelvin surface of the Sun.

**Coronal Mass Ejection** : The sudden expulsion of matter from the coronal regions of the sun, often involving billions of tons of plasma ejected at over one million miles per hour. During sunspot minimum conditions, about one ‘CME’ can be expelled every few days. During sunspot maximum conditions, as many as 3-5 can occur each day.

**Magnetopause** : A region that defines the outer edge of the magnetosphere where the pressure of the solar wind is balanced by the pressure of the earth’s own magnetic field.

**Magnetosphere** : The region surrounding the Earth in space where its magnetic field is important in controlling the movements of charged particles. Also sometimes referred to as ‘Geospace’.

**Magnetotail** : The solar wind pulls the magnetosphere into a comet-like shape. The long tail of this field, called the magnetotail’ or also the ‘geotail’, extends millions of miles into space in a direction opposite to the Sun from the Earth.

**Solar flare** : A powerful release of energy on the surface of the sun usually lasting less than a few hours, but releasing as much energy as 1000 hydrogen bombs. These are often associated with active regions of the solar surface where magnetic fields have become badly tangled, and then snap, releasing energy and heating local gases to over 1 million degrees.

**Solar storm** : Although scientists prefer not to use this term because it is technically rather vague, it has come to mean any of a number of active conditions on the Sun’s surface including flare activity or coronal mass ejections.

**Sunspot** : A dark spot on the Sun’s surface that indicates a concentration of magnetic forces. They are actually about 2000 degrees cooler than the solar surface, and only look dark because they emit light faintly.

**Sunspot Cycle** : The change in the number of sunspots from one period of its maximum to the next, over the course of about 11 years.

**Sunspot Maximum** : The period during the sunspot cycle when you will see the largest number of sunspots. Also called the ‘Solar Maximum’.

**Sunspot Minimum**: The period during the sunspot cycle when you will see the fewest number of sunspots. Also called the ‘Solar Minimum’

# Solar Storms and You!

# Exploring Sunspots and Solar Activity Cycles

## Resources

IMAGE	<a href="http://image.gsfc.nasa.gov">http://image.gsfc.nasa.gov</a>
POETRY	<a href="http://image.gsfc.nasa.gov/poetry">http://image.gsfc.nasa.gov/poetry</a>
SOHO	<a href="http://sohowww.nascom.nasa.gov">http://sohowww.nascom.nasa.gov</a>
NASA Sun-Earth Connection Resources	<a href="http://sunearth.gsfc.nasa.gov">http://sunearth.gsfc.nasa.gov</a>
The Earth's Magnetic Field	<a href="http://image.gsfc.nasa.gov/poetry/magneto.html">http://image.gsfc.nasa.gov/poetry/magneto.html</a>
Satellite Glitches -Space Environment Info	<a href="http://envnet.gsfc.nasa.gov">http://envnet.gsfc.nasa.gov</a>
Magnetic North Pole	<a href="http://www.nrcan.gc.ca/gsc/cpdnew/magnet.html">http://www.nrcan.gc.ca/gsc/cpdnew/magnet.html</a>
Solar Sounds	<a href="http://soi.stanford.edu/results/sounds.html">http://soi.stanford.edu/results/sounds.html</a>
Sunspot Number Archives / Resources	<a href="http://image.gsfc.nasa.gov/poetry/sunspots.html">http://image.gsfc.nasa.gov/poetry/sunspots.html</a>
CME Archives at MLSO	<a href="http://www.hao.ucar.edu/public/research/mlso/movies.html">http://www.hao.ucar.edu/public/research/mlso/movies.html</a>
Stellar Activity Cycles at Mt. Wilson	<a href="http://www.mtwilson.edu/Science/HK_Project/">http://www.mtwilson.edu/Science/HK_Project/</a>
Satellite Data	<a href="http://cdaweb.gsfc.nasa.gov">http://cdaweb.gsfc.nasa.gov</a>
Space Weather Resources	<a href="http://image.gsfc.nasa.gov/poetry/weather.html">http://image.gsfc.nasa.gov/poetry/weather.html</a>
Magnetic Observatories and Data	<a href="http://image.gsfc.nasa.gov/poetry/maglab/magobs.html">http://image.gsfc.nasa.gov/poetry/maglab/magobs.html</a>
Space Environments and Effects	<a href="http://see.msfc.nasa.gov/sparkman/Section_Docs/sparkman.html">http://see.msfc.nasa.gov/sparkman/Section_Docs/sparkman.html</a>
Sun-Earth Classroom Activities Archive	<a href="http://sunearth.gsfc.nasa.gov/educators/class.html">http://sunearth.gsfc.nasa.gov/educators/class.html</a>
Storms from the Sun	<a href="http://www.istp.gsfc.nasa.gov/istp/outreach/learn.html">http://www.istp.gsfc.nasa.gov/istp/outreach/learn.html</a>
The Aurora Page	<a href="http://www.geo.mtu.edu/weather/aurora/">http://www.geo.mtu.edu/weather/aurora/</a>
Space Weather Human Impacts	<a href="http://image.gsfc.nasa.gov/poetry/storm/storms.html">http://image.gsfc.nasa.gov/poetry/storm/storms.html</a>
Ionosphere density and sunspot numbers	<a href="http://julius.ngdc.noaa.gov:8080/production/html/IONO/ionocontour_90.html">http://julius.ngdc.noaa.gov:8080/production/html/IONO/ionocontour_90.html</a>
Space Weather Daily Reports	<a href="http://windows.engin.umich.edu/spaceweather/index.html">http://windows.engin.umich.edu/spaceweather/index.html</a>
Solar wind density and speed	<a href="http://www.sel.noaa.gov/wind/rtwind.html">http://www.sel.noaa.gov/wind/rtwind.html</a>
Mees Solar Observatory Archives	<a href="http://www.solar.ifa.hawaii.edu/MWLT/mwlt.html">http://www.solar.ifa.hawaii.edu/MWLT/mwlt.html</a>

# *Teacher Reply Card*