Space Place
At Carter Observatory

A Space Place Project: Solar Cycles Online - Teacher's Notes

Exploring our nearest star

Observing sunspots offer us a great way to learn about the closest star to the Earth, our Sun.

This interactive project will use sunspot data over a period of 25 years along with recent images from a space based telescope. This will allow students to analyse annual sunspot activity and learn about how sunspots form, move, change and disappear.

At the conclusion of the project your students will also be able to estimate how long the Sun takes to rotate at different latitudes and have a better understanding of the effect of solar activity on planet Earth.

Some useful background information….

The Sun, like all stars, produces energy through nuclear fusion at the core. In this process energy is released through heat and light and is eventually lost from the Sun's surface. This energy is what lights our days, drives our weather and allows life on Earth to exist.

Sunspots have been observed for hundreds of years and they have given us interesting insights into the Sun's activity and its long term cycles. Sunspots are cooler regions on the Sun's surface, they appear as dark areas as they are about 2000°C cooler than the normal surface temperature (approximately 5500°C).

Sunspots have strong magnetic fields that can extend above and below the Sun's surface. These can range in size from a few thousand to tens of thousands of kilometres wide.

Early astronomers noticed that sunspots rotated at different speeds at different latitudes. This revealed that the Sun was not solid but behaves as gas or liquid spinning faster at the equator and slower at the poles.

In 1843 astronomer Samuel Schawbe discovered that the number of sunspots visible on the Sun's disk varied over a roughly 11 year cycle. Every cycle starts off with a blank Sun and the sunspots begin to appear near the polar regions. Over the next 5-6 years the number of sunspots and their size increase and they migrate towards the Sun's equator. After reaching a maximum he noticed that the sunspot number then decreases. This cycle repeats itself, on average, every 11 years.

The Sun is moving towards its current peak over the next year after which there will be a gradual decline in the number of sunspots. With the large number of sunspots visible, now is a good time to follow the changing number, position and shape of sunspots on our nearest star.

About this project…

Firstly, students will use data from 1983 – 2008, to plot the annual number of sunspots visible on the Sun's surface. They will then use this data to calculate the period of the sunspot cycle. Astronomers have used data like this over decades to identify an 11 year sunspot cycle.

Secondly, students will map the daily position of sunspots on the surface of the Sun. Today we can safely use the internet to monitor the daily activity of our star, not only in visible light but through many different wavelengths of the spectrum. This project uses images in visible light but you may want to use images of the Sun in different wavelengths for extension work.

Project resources required:

- An Excel or similar computer program to enter, record and understand data. Students will need to know how to enter data and to create graphs. This activity could also be done without a computer.
- The last 25 years of sunspot numbers taken from the annual sunspot data list.
- Full sun daily images from www.spaceweather.com
- A mapping grid to plot their position (best printed on a transparency sheet).
- As an extra resource, you may like your students to use Solar or Eclipse shades to view the Sun. This should never be done with the naked eye or with sunglasses. A class set can be ordered through Space Place.
- A calculator to work out your results.

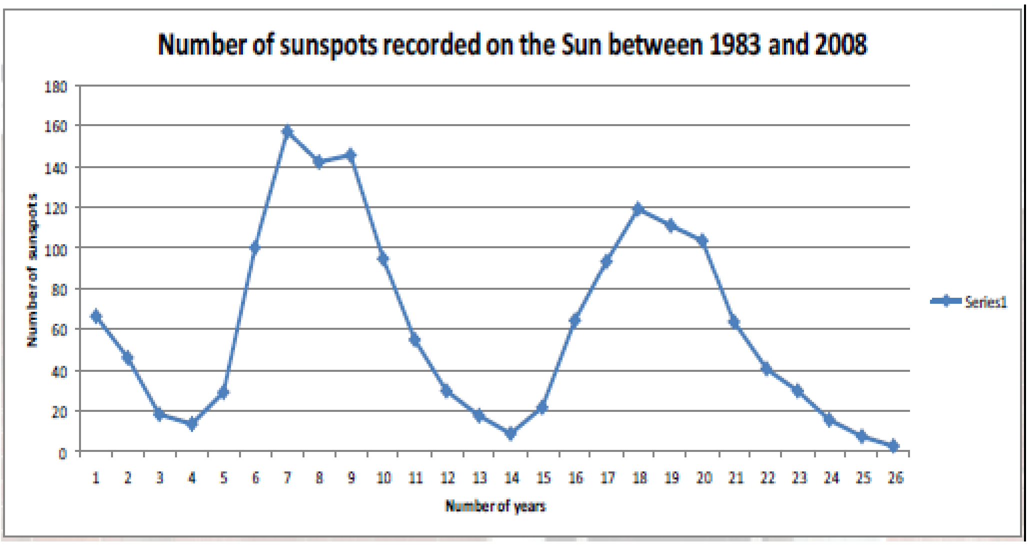
The sunspot data comes from the Zurich Sunspot Number, an organisation in Switzerland which carefully counts and records the number of sunspots seen annually.

Let’s get started!

You may want students to do all these activities in pairs or individually.

- **Issue each pair or individual with a list of annual sunspot numbers.**
- **Students will need to enter annual sunspot numbers into a spread sheet.**
- **Using the ‘line chart’ function create a line graph showing the changing number of sunspot over this period.**
- **You may want to talk about a suitable scale to the graph and which type of graph would be best to use.**
- **Ensure students label the axis correctly. This will help in understanding and analysing the graph later on.**

Your students should end up with a graph like this:



Students will have two solar cycles plotted (from trough to trough).

Mapping sunspots…

Issue each pair or individual with a mapping grid. Students will need to download and print the daily Sun image from the www.spaceweather.com website.
On the first day, choose 2 or 3 sunspots that are initially towards the left hand side. Ask them to draw on their printed grid exactly where the sunspots are, and note the date, sunspot shape and size. It may be useful to number each sunspot.

Write down its position in terms of latitude and longitude (for example, spot 1 appears at 15 latitude and -60 longitude, Spot 2 appears at 30 latitude and -15 longitude). Latitude runs North to South, longitude runs East to West.

The next day follow the same process on the same grid but mark the new position of the same sunspots.

Over the next 10 – 20 days continue to record the position of the original sunspots. Date each sunspot. You may want to create a table to show the movements of the sunspots.

Students should review their data to make sure that the numbers match the drawings.

Students should be able to work out how many degrees of longitude their sunspot moved each day.

To get the average daily movement, determine the total degrees of change noted from one day to the next then add these up and divide by the number of days these represent. (This should be around 12 degrees per day.)

Just to make life difficult you now need to add an extra degree to your result. This is to take into account the Earth's annual motion around the Sun (your amount should now be around 13 degrees per day).

<u>Example of a data table</u>

Date	Spot One Long	Spot One Lat	Spot Two Long	Spot Two Lat	Spot Three Long	Spot Three Lat
August 22			-60	31		
August 23	-45	31	-58	-16	-45	-55
August 24	-30	32	-30	-16	-33	-54
August 25	-18	33	-23	-15	-20	-53
August 26	-12	32	-12	-16	-13	-53
August 27	8	33	-7	-15	4	-53
August 28	23	34	5	-15	17	-54
August 29	33	34	17	-15	30	-54
August 30	43	34	23	-16	38	-55
Sept. 1	55	33	42	-16	53	-55

Analysing your results…

You may want to ask students to analyse the results individually or as a discussion group.

First, look at the sunspot graph.

- **What is the maximum number of sunspots recorded over this time? What is the minimum?**
- **What is the period between the two peaks (maxima) and two troughs (minima)? They should be about 11 years apart.**
- **Explain the patterns. Are the cycles the same or different?**

The first cycle has a double peak; these double peaks are fairly common. The decrease in sunspots was fast, from over 140 to just under 100 in one year. The second cycle has a lower sunspot maximum and tappers off without a second peak. The minimum number of sunspots in this second cycle is also much lower than the first cycle. The decrease in sunspots following the second cycle was much slower and its minima was the start of a long period (18 months) with very few sunspots.

Now look at your sunspot table.

- **Did all of the sunspots move the same average amount?**
- **How long would it take each sunspot to do one rotation?**
- **Do sunspots always move in the same direction? Explain your idea.**
- **Why do you think that the sunspots move at different speeds?**
- **Did the sunspots change shape or size and if so how?**
- **How long would it take for each sunspot to rotate 360 degrees?**

Because the Sun is NOT solid, it spins faster at the equator and slower at the poles (differential rotation). The Sun, along with gas giants Jupiter and Saturn, has an equatorial bulge so these objects are called oblate spheres. Generally any celestial body that is rotating (and that is sufficiently massive to draw itself into spherical or near spherical shape) will have an equatorial bulge linked to its rotation rate. Saturn is the planet with the largest equatorial bulge in the Solar System (11808 km), Earths is 42km.

Sunspot usually change shape over a period of days. They may grow, shrink, split in two or a group of spots may grow around the original spot.

It would take 27 days for an equatorial sunspot to rotate 360 degrees; although this number will increase for a sunspot that is further from the equator (at a higher latitude).

Research questions….

You may want to extend the students' knowledge of sunspots and solar cycles by posing these questions for them to research.

<u>What causes sunspots</u>?

This is very complicated and still poorly understood process. Sunspots appear to be associated with the Sun's magnetic field being twisted by the differential motion of the Sun's interior. The Sun's magnetic field also flips with every cycle (North magnetic field flips to the South and then flips back again at the end of one cycle)

<u>Do other stars have sunspots and sunspot cycles</u>?

A number of stars (Betelgeuse in Orion is one) have been seen to have sunspots and sunspot cycles. Due the difficulty in imaging these sunspots it is not known if they follow similar patterns.

<u>What effect could the solar cycle have on Earth</u>?

The increased solar activity around the time of solar maximum sees solar radiation increased by about 0.1% (1.3 watts per square meter). This is a time when aurora and solar storms are particularly prevalent .

Extended solar minima may lead to cold periods and 'mini-ice ages'. The 'Maunder Minimum' (1645 to 1715) was a period associated with very cold winters. Period of extended sunspot activity may be linked to increase temperatures and plant growth.

Your students could investigate why this is different to the effect of 'global warming' or 'climate change'.

<u>Was there any connection with sunspot activity and aurora geomagnetic storms during your observation period</u>?

During periods of solar activity the number of solar flares and aurora tend to increase. www.spaceweather.com will give notification of solar activity and students may have the opportunity to observe an aurora.
Students could discuss the effects of these events on radio communication, satellites and power grids.

<u>Are there any longer term trends in sunspot cycles</u>?

You could use the historical sunspot charts to help this discussion.

<u>Why are sunspots important</u>?

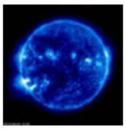
Extension activity…

The human eye can only see in a small part of the electro-magnetic spectrum called visible light. The Sun, and many other objects may give off light that our eyes cannot detect. Infra-red is an example of this. Your students can use images of the Sun taken at the same time but at different wavelengths using the Extreme Ultraviolet Imaging Telescope (EIT).

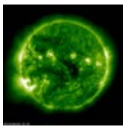
This telescope is attached to a space craft called SOHO (Solar and Heliospheric Observatory) that orbits between us and the Sun. This spacecraft is used to observe the Sun and gives warnings of solar storms. In these images we see different temperatures in the Sun’s atmosphere. The colours are not natural, the original black and white photos have had colour added to them to help us analyse them.

- Look at the images of the Sun at different wavelengths. What patterns do you observe?
- What are the similarities or differences between these pictures?
- Why do you think it is important to observe the Sun in different wavelengths?

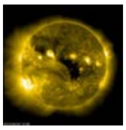
This red image was taken at 30.4 nm, the longest wavelength and it shows material at 60,000 to 80,000 Kelvin. This image reveals flares around the solar limb and bright gas above sunspots. It is also showing the hot gasses that sit above the surface of the Sun that we can see with our eyes.



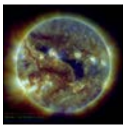
This blue image was taken at 17.1 nm showing gas at 1 million Kelvin. This is the shortest wavelength.



This green image is taken at 19.5 nm and corresponds to about 1.5 million Kelvin.



This yellow image is taken at 28.4 nm and shows gas up to 2 million Kelvin in temperature. The hotter the temperature, the higher you look above the Solar surface and higher into the Sun’s atmosphere. This shows very hot gases in flares and magnetic fields.



A combination of three blue, green and yellow wavelengths, this image makes a stunning view of the "hidden" Sun. The dark inactive region is a coronal hole allowing the Sun's atmosphere to escape outwards and through the Solar System.

<u>Useful information</u>:

Wavelengths: Ultra-violet light 10—400 nm, visible light 400—750 nm, infra-red light 750 nm—1 mm.
1 nm is 1 billionth (10^{-9}) of a metre.

The Kelvin is a unit of measurement for temperature with the unit symbol K. The Kelvin scale is a scale of temperature with a zero point at absolute zero, the temperature at which all motion is said to stop. This is equal to −273 °C .