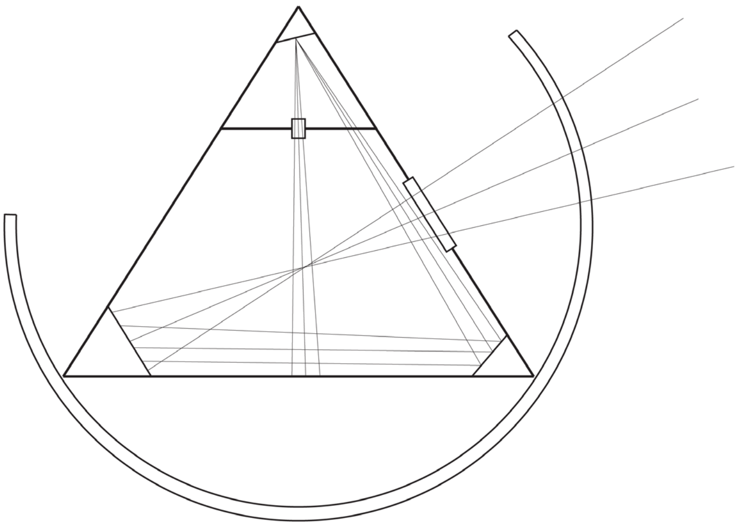
SUN-100 Sunspotter®

What it is, How to Use it, and What to Look For

What is the Sunspotter®?

The Sunspotter® is a refracting telescope. Like all telescopes of this design, it has a large objective lens and a smaller eyepiece lens. The objective lens magnifies an image, and the eyepiece lens focuses it. All refracting telescopes have worked this way for centuries. The Sunspotter® is an ordinary refracting telescope that has been modified. Instead of a tubular body, it is folded into a triangle. Three mirrors bounce the light from the objective lens to the eyepiece to the viewing area. In this way, we can get all the benefit of a refracting telescope while projecting the image of the sun onto a card for easy viewing. Please see below for a diagram of the light path of the Sunspotter®:



Why would we build a telescope this way? We consider the target we are viewing. The sun is quadrillions upon quadrillions of tons of fusing hydrogen and helium, operating at 20 million degrees in the core. It produces power measurable in yottawatts. While clouds can sometimes make this mighty furnace look cold and damp, that is an illusion. The sun is far too bright and hot to look at, even with the naked eye. To look at it through magnifying lenses will quickly destroy your retinas.

There are two possible solutions. This first is to make the sun less bright. You do this by looking at the sun through a filter, usually a piece of welding glass or mylar. This dims the image of the sun enough that you can look at it without burning your eyes. However, this method has certain disadvantages. For one, you need to be able to trust the filter. Even a tiny crack could let enough light in to hurt your eyes. Second, reliable filters tend to be rather expensive. If you are buying a solar filter for an ordinary telescope, expect to spend lots of money on it. Risking the integrity of your eyes is not worth saving money for.

The other way to view the sun safely is to view a projected image of it. We consider this to be a better solution, because of a simple fact: at no point do the sun, lenses, and eyes form a straight line with each other. This means that the sunlight is not magnified directly into a student's eyes, which eliminates the possibility of injury. With the Sunspotter®, students will only look at an image of the sun, not the sun itself.

Sunspotter® Quick Start Guide:

To use your Sunspotter® effectively, please refer to the directions below:

- Begin by unpacking the unit and removing all of the protective covers. There is a plastic cover on each of the three mirrors, as well as one on each lens. These covers must be removed before the Sunspotter® can be used.
- Place a card or piece of paper under the four clips on the base of the triangle. This will give you a white screen to view the sun on.
- On a bright, sunny day, place the Sunspotter® outside. It is best to place it on a level, stable surface where it won't wobble. You can try to use the Sunspotter® through a window, but the glass may interfere with the image. For best results, the it is best to use it outside.
- Adjust the Sunspotter® until the shadow od the gnomon disappears. The gnomon is a small brass rod sticking out of the triangle above the objective lens. You can get the shadow to disappear by adjusting the angle and position of the unit. The Sunspotter® will rotate freely in its cradle. Angle it towards the sun. You may also need to adjust the unit laterally. Rotate the cradle until the Sunspotter® is aimed at the sun and the gnomon's shadow is completely gone. The goal here is to point the objective lens directly at the sun. If you cannot make the gnomon disappear, the sun may be too low in the sky. Trying flipping the cradle around to angle the triangle lower.
- To fine tune the alignment, observe that there are two small holes on either side of the objective lens. When the Sunspotter® is properly aligned, light will pass through these two holes and fall inside the small white circles on either side of the large mirror.
- When the Sunspotter® is properly aligned, you will see a bright image of the sun appear on the viewing card. Since the Earth rotates, the Sunspotter® will need to be realigned slightly every minute or so to keep the image of the sun centered.

Troubleshooting:

It is recommended that if you are having problems with your Sunspotter® you contact Science First® for assistance. However, if you wish to adjust it yourself, please follow the directions below:

- Hazy, cloudy, or exceptionally humid days can interfere with the image. If your Sunspotter® appears to be out of focus, please consider the weather before adjusting it.
- Make sure that all the lenses and mirrors are clean. You can use a lens cleaning cloth to wipe dirt or dust away. Do not use water, as this can leave a residue on the surfaces and possibly damage the mirrors. Pure alcohol can also be used, but do not use any type of solvent.
- The focus can be adjusted using the eyepiece. If you examine the tray that holds the eyepiece in place, you will notice that the eyepiece is threaded into it. You can screw the eyepiece up or down to adjust the focus.
- You can also adjust the objective lens. It is threaded into the body of the triangle, meaning you can adjust the length between it and the main mirror, which also changes the focus. You will notice that you received a black, circular key with your unit. Place this over the objective, inside the body of the triangle. The tabs will lock into slots along the perimeter of the objective. By turning the key, you can now thread the objective in and out.
- If you are still having problems, please contact us for assistance.

History: what are sun spots?

Many years ago, it was believed that the surface of the sun was perfect. It was uniformly bright and luminous, with no imperfections or darkness at all. The surface was considered to be pure light. This view was held for millennia, and perhaps not unreasonably. After all, if you look at the sun with the naked eye it certainly seems to be perfect, and this view dovetailed nicely with most religious beliefs. Of course, the narrative is never as clean as the reality. Chinese astronomers knew of sunspots by the third century B.C. Greek astronomers discovered them around the same time. There is also evidence the Maya knew of their existence. We don't know about the Maya or Chinese, but the Greeks thought the sunspots were planetary transits. This was not true, but was a reasonable conclusion for the time.

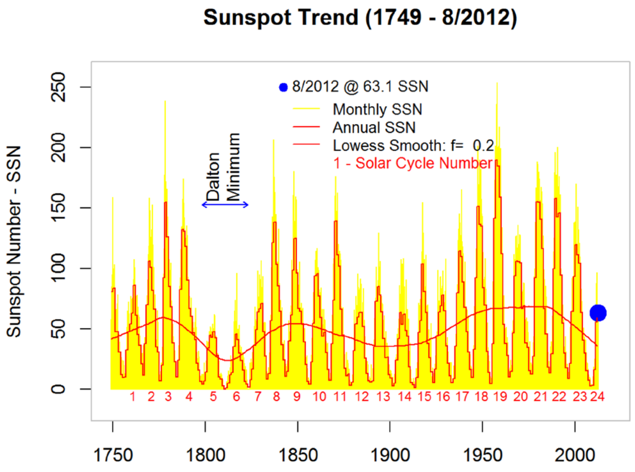
Most people think that Galileo discovered sunspots. While he did show them off and make a fuss about them (which got him into some hot water), he was not the first European astronomer to see them. They were viewed a few years before, notably by Thomas Harriot in 1610. However, in 1612 Galileo gave the first known accurate description of them: that they were an imperfection on the surface of the sun. This, along with his other astronomical antics, got him into trouble with the Catholic Church, and the rest is history.

Today we know that sunspots are a product of the sun's magnetic field. Now, solar magnetics are hideously complicated. The sun is made of plasma, which is ionized gas, or gas that has electrons liberated from the nucleus. Plasma is a highly conductive material, and when it swirls around it creates a magnetic field. On Earth, our magnetic field is made by our spinning iron/nickel core. This is a relatively simple mechanism, and even it has variations over time. With the sun, all of the material is conductive, and it is all swirling and moving due to convection. Plasma is a fluid, and the massive heat in the sun's core and the coldness of space conspire to create massive convection currents. These currents flow throughout the sun, in effect forming massive rivers of fire, each with its own magnetic field. These fields twist and writhe around each other, canceling or bolstering one another as the case may be. The sun has uncountable numbers of magnetic fields, all of them interfering with and feeding off of other ones. It's simply a mess.

Out of this chaos unusual things occur. The constant twisting and rotating magnetic fields sometimes double back on themselves, much like a rubber band. They can then actually puncture the surface of the sun, causing a depression. This depression inhibits convection, so heat that would reach the depressed region is instead shunted somewhere else. Ultimately, this makes the depression colder than the surrounding areas, which makes it appear black on a telescope. This is what causes a sunspot. Sunspots can last anywhere from days to months. In some cases, it appears that the sunspots form powerful magnetic vortices around themselves, in effect becoming stellar hurricanes. Some of the longer lived ones are probably a result of this, in effect becoming giant magnetic storms. This explanation is simplistic, but it fits both the current understanding of sunspots and the scope of this guide.

Sunspots also appear in cycles, for reasons we do not understand. The cycle in 22 years long, with 11 years of increasing sunspot activity, followed by 11 years of decreasing activity. More curiously, this is not the only cycle. On longer time scales, there appear to be other cycles as well. In some cases, the sun will go ‘quiet’, showing many years of extremely low activity. It is postulated that this might reduce solar irradiance on earth, contributing to ice ages. In other cases, the sun is much more active, showing many years of great sunspot activity.

The sunspot cycle was first noticed by Heinrich Schwab in the 1850’s. It was not until 1908 that George Ellery Hale proposed that they might be caused by variations in magnetic fields, and also codified the 22 year cycle. Please see the next page for a graph indicating sunspot activity over the years:


Sunspot Trend (1749 - 8/2012)

As you can see, sunspot activity clearly is not constant. There are noticeable dips beyond the normal cycle around 1820 and the early 21st century. There is a peak around 1775, 1850, and a long plateau from 1950 to 2000. It is known that total radiation by the sun is affected by sunspot activity; what is not know is the impact this has on Earth.

Students might expect that increased sunspot activity would lead to lower surface temperatures on the sun. After all, sunspots are colder, and more of them would suggest a colder surface overall. However, sunspots simply shunt heat around, but do not affect the total. The sun’s heat is generated by nuclear fusion in the core, and no surface process can change that. Instead, the only thing that can be changed is the rate of heat transfer from the core into space. As it happens, while sunspots are colder, they make the surrounding areas brighter and hotter. The overall effect is that more heat is radiated when there are more sunspots. Thus, high sunspot activity causes the heat radiated by the sun as a whole to increase. On the flip side, low activity leads to less heat escaping.

It seems likely that sunspot activity has an effect on Earth’s climate. After all, the heat from the sun is what makes Earth have weather at all, so logically a change in the sun would cause a change on Earth. In addition, the Little Ice Age and the Dalton Minimum occurred at the same time, which may or may not be a coincidence. However, at the time this guide was written there is no strong evidence for or against sunspots influencing Earth’s climate. Greater study of the phenomenon will be needed. When we can understand sunspots in greater detail, then we will be able to understand their effects.

Activities:

Activity 1: predictions and observations

Prediction is an important part of science, arguably the most important part. After all, if your pet theory has no ability to predict future events, then it probably isn’t science at all. In any case, the reason we do science in the first place is to understand the present with the aim of predicting the future.

Before using the Sunspotter®, it’s best to go over the basics of what the sun is and what sunspots are, and then let students make predictions about what they will see. You can give them blank circles and ask them to draw what they expect to see through the Sunspotter®. Later, these predictions can be compared against the reality to see how accurate they are.

The best use of a Sunspotter® for the first time is to set it up and simply let the students observe. Don’t make drawings or take data. Don’t explain what is going on. Simply let them observe for themselves. The root of all scientific discovery is curiosity, because it alone can make someone reach for things they do not understand. Feeding students information kills the curious part of them. Let the image of the sun waltz across the viewing car and disappear before talking about it. Some great questions to ask your students are these:

- What did you see? What do you think it meant?
- Do you think those little black spots come from the Sunspotter® or the sun itself? How can you tell?
- How many spots did you see? Did they group together, or were they single?
- Which direction did the image move? Why do you think it is moving?
- What color would you say the sun is?
- How would you describe the edge of the sun? Is it fuzzy or sharp?
- Can you see anything else besides just spots? Other dark or bright areas?
- If you looked at the sun later, do you think you would see the same things? Why or why not?

Hopefully, your students will be confused about what they are seeing. This is a good thing, as it will drive them to find out more about it.

Activity 2: Tracing the Sun

Tracing the image of the sun is a great way to record sunspot activity. It is best to do it in teams. To speed the data collection process, you can prepare blanks. These will have a circle of the appropriate size and lines for the date and names of the students doing the tracing. They can then place these blanks on the viewing area for rapid data gathering.

When you have the blank in place, align the sunspotter for a good image. Begin tracing the sunspots, starting with the largest one. After a spot is traced, the Sunspotter® will have to be realigned. This is because the Earth rotates and the sun image will drift out of center. This is why teams are nice: one student can trace and the other can realign the unit. When the tracings are complete, you can compare the sunspot activity to other days. You can also determine the motion of the sunspot. Find a sunspot that is near the edge of the sun and watch it intently. It will move. Put faint marks on it every minute or so to track it as it moves. Later, you will draw an arrow through these marks in order to show which way the sunspot is moving. This arrow will point to the west of the image, as that is the direction the Earth rotates. You can compare this motion to other days and see if they correlate.

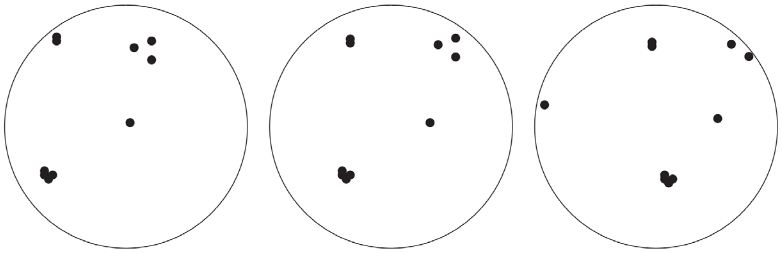
Activity 3: Changes over time

Sunspots are not constant things. They come and go according to their own schedule. In addition, not only does the sun's image move across the card during viewing, but it also rotates during the day.

The Sunspotter® is an altitude-azimuth telescope design, which results in image rotation. This is true for all telescopes of this type. They are popular for viewing as they do not require a wedge and tedious polar alignment, but they do have a disadvantage: the image will turn slowly, making photography with long exposure times impossible. As the Earth rotates, so will the image. This is why we tracked the motion and drew an arrow in the previous activity. This lets us note the direction of the Earth's rotation, which allows us to predict where the spots will be.

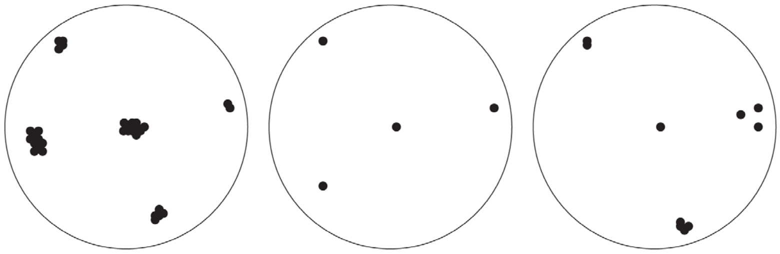
If you view the sunspots for a matter of hours, they will rotate out of sight, but not change their position relative to each other. This is because the Earth has moved relative to the sun, changing your frame of reference.

The next activity requires you to view the sunspots at the same time of day for a few days. You will notice something interesting happening. Take the Sunspotter out each day and note the position of the spots. You may see something similar to the diagrams below:



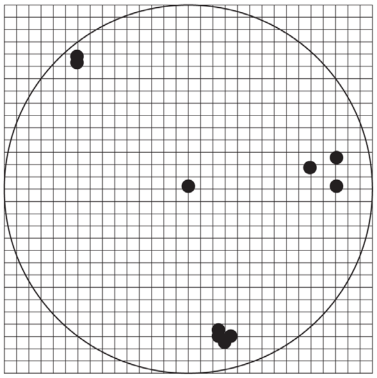
You will notice that the sunspots march across the face of the sun from day to day. Eventually, they will disappear over the edge, and new ones may appear. Why would this be? The sun is rotating on its axis, and the surface, sunspots and all, must rotate with it. This means that the sunspots will appear to move across the face of the sun. We see nothing special about the sun rotating, but back in the 1600's it caused quite a stir. After all, the celestial bodies were supposed to behave themselves and move around the Earth, not go off and do their own thing.

The sunspots come, go, and change. If you view them for a period of months, you may see something like the diagrams below:



Activity 4: Sunspot area

Some days we only see tiny spots on the sun, and on other days there are huge ones. A transparent overlay of fine grid paper allows us to estimate the area of the largest sunspot on each day, and also to estimate the total area covered by all the spots put together. Keep records for a few weeks and then use your data to answer this question: is the total area covered by sunspots constant? In other words, does the sun have a constant area covered by sunspots, regardless of the number of size? Refer to the diagram below to see how the grid overlay works.



You can estimate the size of a sunspot by drawing a square around it. Sunspots are not perfect circles, so measuring one without using specialized equipment is difficult. However, a circle is three quarters of the area of a square that touches all its edges, so if you draw a square around a sunspot, you can assume that the area of the sunspot is roughly equivalent to three quarters of the area of the square. The true value is pi/4; however, given the already inexact nature of this method, 3/4 will work.

As with most things, the sunspot starts small, then grows, shrinks, and finally disappears. You can investigate this process by overlaying some 1mm grid graph paper on the image and calculating the area of the sunspots. Once you have measured the area of the sunspot at regular intervals for several weeks, plot a graph of this data with area on one axis and time on the other. Is the growth or death of the sunspot quicker? Is the process symmetrical?

Measure many different spots over several weeks and plot the data for each. Then, try to answer the following questions:

- Is the curve for sunspots in the northern hemisphere different from the curve in the southern hemisphere?
- Does the lifetime of a spot depend at all on its area?
- Does the lifetime depend on the number of spots in the same group or other groups?
- Does the lifetime depend on the sunspot's latitude?
- Is the total area of sunspots constant over time?

Solar Vocabulary:

Below are a list of useful terms that students should know when talking about the sun:

Aurora: faint, ethereal lights in the sky caused by the sun's emissions. As charged particles get expelled from the sun, they get caught in Earth's magnetic field. They interact with particles in the upper atmosphere to produce light. They most often occur near the poles where the magnetic fields are strongest, but during periods of extreme solar activity have been seen as close to the equator as Honolulu.

Corona: the solar atmosphere, visible to the naked eye only during a solar eclipse. It can be 40 times as hot as the surface, for reasons we do not understand.

Differential Rotation: the different speeds of rotation on the sun's surface.

Disk: the round appearance of the surface of the sun against the sky.

Penumbra: the outside area of a sunspot made up of bright and dark features.

Photosphere: the surface of the sun, where sunspots lurk.

Plage: a faint, bright, large area around sunspots.

Prominence: dark filaments seen on the sun's surface which stand off from the limb when viewed edgewise.

Solar cycle: the 11 year cycle in the number of sunspots and other solar activities.

Solar flare: a massive release of energy and mass from the surface of the sun.

Solar limb: the edge of the sun's disc as seen in the sky. It appears slightly darker than the rest of the sun.

Solar eclipse: when the moon is between the Earth and the sun, blocking the solar disc and revealing the corona.

Sunspot: Areas on the sun which appear darker because they are cooler than the surrounding areas.

Umbra: The dark inner region of a sunspot, with an average temperature of 4,200K.

Important notes:

- Always remove the plastic covers from the mirrors and lenses when in use, and replace them when not in use. Place the blue cover over the unit when not in use.
- Avoid touching any of the optics as you will leave oil from your skin behind.
- Clean the optics with a soft lens cloth, and pure alcohol if necessary.
- Be careful when touching the eyepiece lens, as the focused light from the sun can burn you if you get too close.
- If your unit requires refocusing, first check the atmospheric conditions, and only then attempt to refocus it.
- Do not hesitate to contact us if you have any questions. It is much better to spend a few minutes with us on the phone than an hour or more getting frustrated.