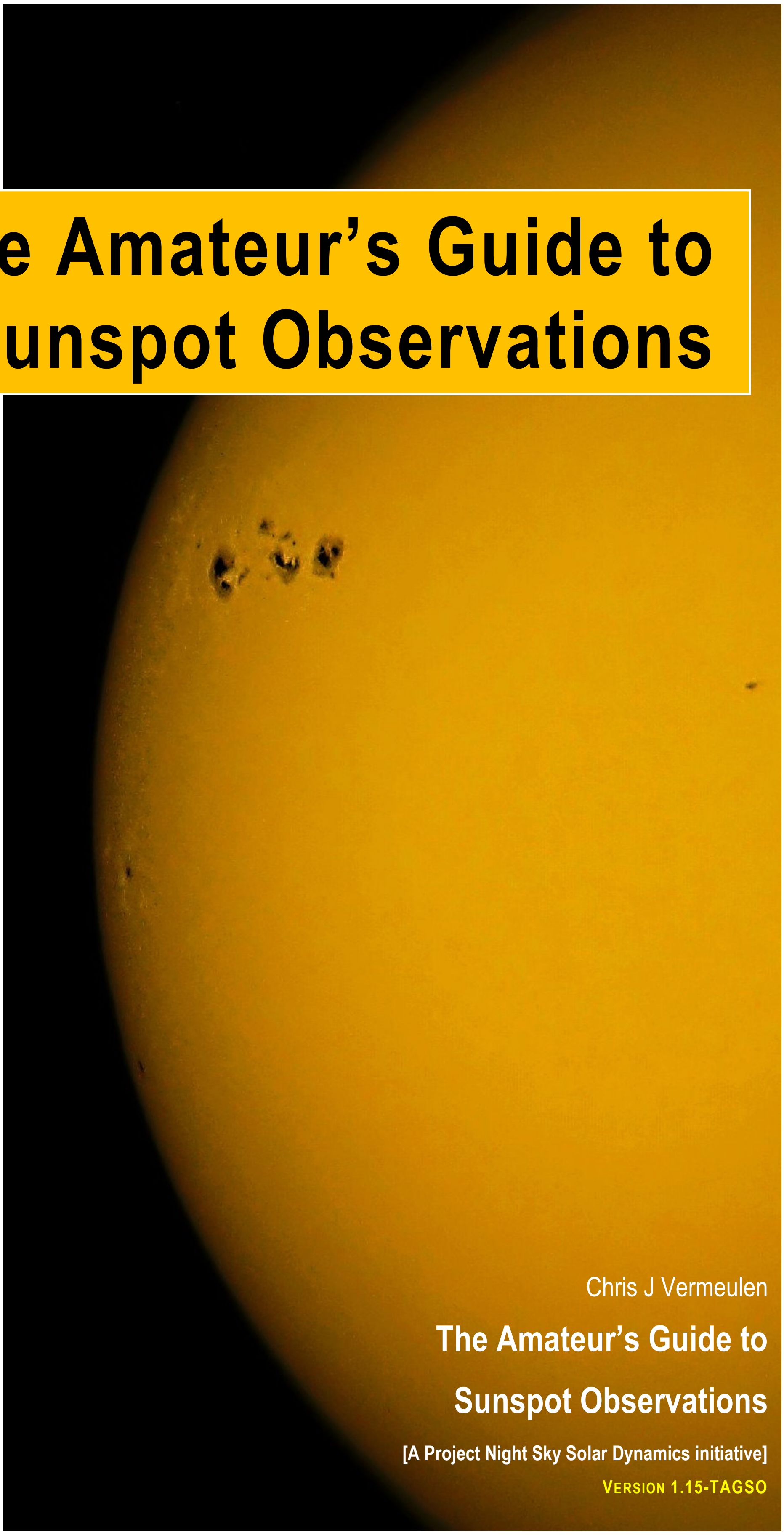
The Amateur's Guide to Sunspot Observations



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[A Project Night Sky Solar Dynamics initiative]

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Introduction

As early as 28 B.C. the Chinese kept records of dark areas observed on the Sun. However, they were attributed to flying birds. In the early 1600's, while surveying the wonders of the heavens revealed by his newly perfected telescope, Galileo observed the same small, dark spots on the surface of the Sun. By watching these spots appear on the western edge of the Sun and then drift across the solar surface to disappear off the eastern edge, Galileo determined that the spots were in fact on the Sun and not shadows cast by some other objects.

"Scientists love mysteries. When you solve something, then it becomes a lot less interesting, and you go find another question to ask."

- David Dearborn

When we say "surface", there is no hard surface such as we have on Earth, because the Sun is entirely made of hot plasma gas. What we see as a surface is called the "Photosphere", meaning 'sphere of light'. Its temperature is around 5700° C and it is the region of the Sun where visible light can at last escape the Sun and flow out into space.

The photosphere has a matted appearance often referred to as "granulation". These are the tops of vast convection cells and are called "Granules". They have a lifetime of no more than 20 minutes before they disappear and are replaced by new ones.

It has since been learned that the average lifetime for a given sunspot is about one week. However, some spots live for only a few hours, while others may live a few months. The sunspots range in size from the smallest observable objects, about 800 km in diameter, to huge areas that are over 80,000 km in diameter. Sunspots are cooler regions of the solar surface caused by intense localized magnetic fields that bring the upward convection of internal material to a virtual standstill. Although they appear almost black, this is merely a contrast effect. If it were possible to place a modest-size sunspot into the night sky, it would shine 10 times brighter than the full Moon!

Sunspots may occur single or in groups of two to more than 100. Records of sunspots show that there is no strict periodicity either in the time when maximum or minimum numbers occur, or in the total number of spots. The average period between sunspot minimum is about 11 years, but individual sunspot cycles have varied in length from 8 to 13 years. The number of sunspots at maximum has varied from 46 to 154.

Tracking the visibility of large spots provides an interesting project for observers. In addition to sunspots, look for decreasing brightness toward the edge of the Sun's disk. The Sun is not bright all over. Through a telescope it appears as a brighter centre and a slightly darker edge (or "limb" as solar observers call it). This gentle fading of light is called "limb darkening", and is the result of looking through a progressively thicker cross section of the darker, cooler upper photosphere near the Sun's limb.

Sunspots come in a wide variety of shapes and sizes. While the simplest sunspots are isolated dark areas, larger spots are quite dramatic. Complex spots feature a dark central region called the umbra surrounded by a gray penumbra. The penumbra normally appears as a smooth fringe, but under steady seeing conditions it may exhibit radial patterns or knots of light and dark. During those fleeting moments of good seeing you may also see tiny circular sunspots. These are called pores. Sometimes they erupt into full-fledged spots but usually they simply disappear — sometimes after a lifetime of only a few minutes.

Most sunspots are associated with groups that can change dramatically in a matter of hours. These groups usually consist of a large "flagship" spot, surrounded by several smaller ones. Others can have a pair of large spots accompanied by a retinue of smaller spots and pores. Normally the large pair will have opposite magnetic polarity — one positive and the other negative.

The solar viewing I've described above is known as white-light observing. If you find this to your liking, you may choose to investigate more advanced forms of observation that use special filters to isolate portions of the spectrum for spectacular views of a wide range of phenomena. Coronagraphs, hydrogen-alpha filters, and other observing gear are available — but at a significantly greater cost than the simple filters needed for white-light observing.

History of Sunspot Observations

The ancient Greeks believed that the sun was the chariot of the god Helios, driven across the heavens by four horses. For the ancient peoples of Peru, the Inca and the Maya, the sun was a god, and they carefully observed and recorded the changing arc that the sun inscribed in the sky throughout the year, forming detailed calendars.

The earliest surviving record of sunspot observation dates from 364 BC, based on comments by Chinese astronomer Gan De in a star catalogue.[1] By 28 BC, Chinese astronomers were regularly recording sunspot observations in official imperial records,[2] as they believed sunspots foretold important events, kept records off and on of sunspots for hundreds of years.

The first clear mention of a sunspot in Western literature, around 300 BC, was by the ancient Greek scholar Theophrastus, student of Plato and Aristotle and successor to the latter.[3] A more recent sunspot observation was made on 17 March 807 AD by the Benedictine monk Adelmus, who observed a large sunspot that was visible for eight days; however, Adelmus incorrectly concluded he was observing a transit of Mercury.[4]

A large sunspot was also seen at the time of Charlemagne's death in 813 AD.[5] Sunspot activity in 1129 was described by John of Worcester, and Averroes provided a description of sunspots later in the 12th century;[6] however, these observations were also misinterpreted as planetary transits, until Galileo gave the correct explanation in 1612.[7]

Sunspots were first observed telescopically in late 1610 by the English astronomer Thomas Harriot and Frisian astronomers Johannes and David Fabricius, who published a description in June 1611.

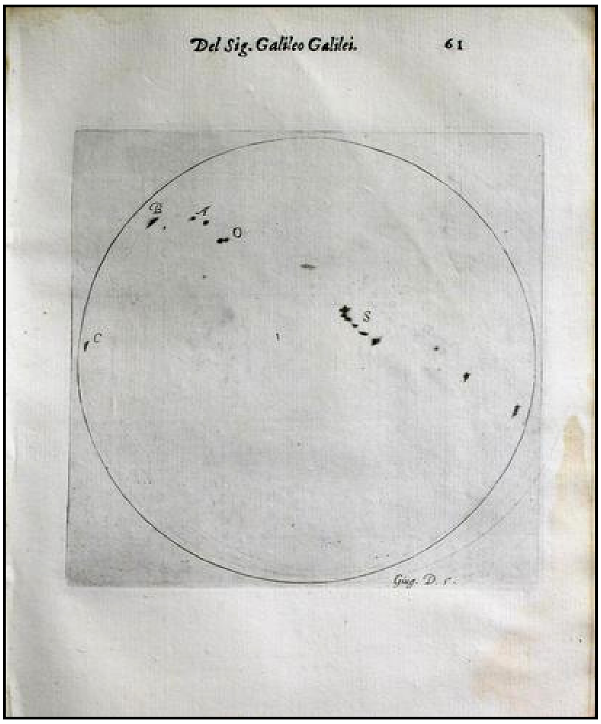

Figure 1: Recorded Sunspot Observations by Galileo

At the latter time, Galileo had been showing sunspots to astronomers in Rome, and Christoph Scheiner had probably been observing the spots for two or three months using an improved helioscope of his own design.

Sunspots had some importance in the debate over the nature of the Solar System. They showed that the Sun rotated, and their comings and goings showed that the Sun changed, contrary to Aristotle (who taught that all celestial bodies were perfect, unchanging spheres).

Sunspots were rarely recorded during the second part of 17th century. Later analysis revealed the problem not to be a lack of observational data but included references to negative observations.

Building upon Spörer's earlier work, Edward Maunder suggested that the Sun had changed from a period in which sunspots all but disappeared from the solar surface to a renewal of sunspot cycles starting in about 1700. Adding to this understanding of the absence of solar cycles were observations of aurorae, which were absent at the same time. Even the lack of a solar corona during solar eclipses was noted prior to 1715. The period of low sunspot activity from 1645 to 1717 is known as the "Maunder Minimum".

The cyclic variation of the number of sunspots was first observed by Heinrich Schwabe between 1826 and 1843 and led Wolf to make systematic observations starting in 1848. The Wolf number is a measure of individual spots and spot groupings, which correlates to a number of solar observables. Also in 1848, Joseph Henry projected an image of the Sun onto a screen and determined that sunspots were cooler than the surrounding surface.[8]

The American solar astronomer George Ellery Hale, as an undergraduate at MIT, invented the spectroheliograph, with which he made the discovery of solar vortices. In 1908, Hale used a modified spectroheliograph to show that the spectra of hydrogen exhibited the Zeeman-effect whenever the area of view passed over a sunspot on the solar disc. This was the first indication that sunspots were basically magnetic phenomena, which appeared in pairs that corresponded with two magnetic poles of opposite polarity.[9]

Subsequent work by Hale demonstrated a strong tendency for east-west alignment of magnetic polarities in sunspots, with mirror symmetry across the solar equator; and that the magnetic polarity for sunspots in each hemisphere switched orientation, from one sunspot cycle to the next.[10] This systematic property of sunspot magnetic fields is now commonly referred to as the "Hale–Nicholson law",[11] or in many cases simply "Hale's law".

Basic Heliophysics

The Sun has an atmosphere, which is in two parts: the corona (outer atmosphere) and the chromosphere (inner atmosphere). The corona is not visible from Earth except during a total eclipse or with a special telescope called a coronagraph. The chromosphere can be observed with special (and expensive) filters known as H-alpha filters. In the chromosphere we can see some of the activity surrounding sunspots.

The Sun is nearly all hydrogen, with a small amount of helium and a tiny amount of other trace elements that have come from other stars.

Despite the consumption of a fantastic amount of hydrogen every second (about 6,000,000 tonnes) it is estimated that there is enough hydrogen left for a further 5 billion years. The Sun, although very slightly variable in nature, is highly stable allowing life as we know it here on the Earth.

The Sun is large, with a diameter of just over 1,425,000 km at the equator, and it would take about 1,300,000 Earths to equal its volume. It travels around the Milky Way Galaxy taking about 225,000,000 years to make one complete orbit. It would take 109 Earths to fit across the face of the Sun from one edge to the other.

At the centre there would be the solar "Core". It is unimaginably hot, and dense, at around 15 million° C. It is here, that the simplest most abundant element in the Universe, hydrogen, is fused into helium under immense gravitational pressure. The core is the powerhouse of the Sun; the outward pressure of energy neatly counterbalanced by the inward gravitational pressure of gas.

The region above the core is called the "Radiative Zone" because energy is transported through it by radiation alone. While the radiative zone is less dense than the core, it is dense enough that energy (such as high energy photon of light) can take a very long time to make its way through. Such a photon is continually absorbed and re-emitted in a "Random Walk" and it can take thousands of years for the photon to make its way through and escape to the next layer, called the "Convective Zone".

The "Convective Zone" is so called because energy (such as light and heat) is carried to the surface by large convection cells. As the top of the convection cells cools, the now slightly cooler gas sinks back down to be re-heated from below and the process starts again in a continuous cycle of heating and cooling making it a highly turbulent layer.

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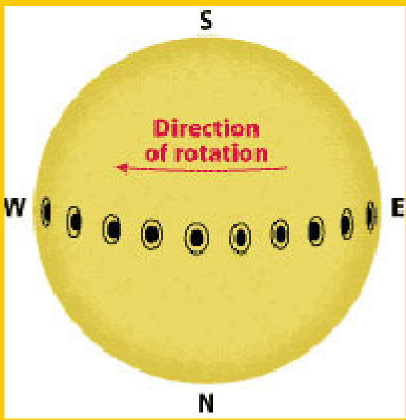
Although the details of sunspot generation are still a matter of research, it appears that sunspots are the visible counterparts of magnetic flux tubes in the Sun's convective zone that get "wound up" by differential rotation. If the stress on the tubes reaches a certain limit, they curl up like a rubber band and puncture the Sun's surface. Convection is inhibited at the puncture points; the energy flux from the Sun's interior decreases; and with it surface temperature.

The Wilson-effect implies that sunspots are actually depressions on the Sun's surface. Observations using the Zeeman-effect show that prototypical sunspots come in pairs with opposite magnetic polarity.

From cycle to cycle, the polarities of leading and trailing (with respect to the solar rotation) sunspots change from north/south to south/north and back.

Magnetic pressure should tend to remove field concentrations, causing the sunspots to disperse, but sunspot lifetimes are measured in days or even weeks. In 2001, observations from the Solar and Heliospheric Observatory (SOHO) using sound waves traveling below the Sun's photosphere (local helioseismology) were used to develop a three-dimensional image of the internal structure below sunspots; these observations show that there is a powerful downdraft underneath each sunspot, forming a rotating vortex that concentrates the magnetic field.[12] Sunspots can thus be thought of as self-perpetuating storms, analogous in some ways to terrestrial hurricanes.



The Wilson-effect, which is greatly exaggerated in this diagram, shows how the umbra and penumbra of a typical sunspot become more and more symmetric as they near the center of the Sun's disk.

The modern understanding of sunspots starts with George Ellery Hale, who first linked magnetic fields and sunspots in 1908.[9] Hale suggested that the sunspot cycle period is 22 years, covering two polar reversals of the solar magnetic dipole field. Horace W. Babcock later proposed a qualitative model for the dynamics of the solar outer layers. The Babcock Model explains that magnetic fields cause the behavior described by Spörer's law, as well as other effects, which are twisted by the Sun's rotation.

The Solar Cycle

One solar cycle is never the same as the next and an important task for the amateur solar astronomer is to monitor the Sun for changes. As the Sun rotates on its axis, the equatorial regions rotate quicker than the higher latitudes.

For example, the solar equator takes nearly 25 days to rotate once but the Polar Regions take around 35 days to make one revolution. This "Differential Rotation", as it is called, tangles up the magnetic lines bound-up in the plasma. Where the magnetic lines twist and break through the photosphere, sunspots appear. Where the magnetic lines disappear, sunspots decay and fade from view.

Sunspot activity cycles about every eleven years. The point of highest sunspot activity during this cycle is known as Solar Maximum, and the point of lowest activity is Solar Minimum. Early in the cycle, sunspots appear in the higher latitudes and then move towards the equator as the cycle approaches maximum: this is called Spörer's law.

Wolf number sunspot index displays various periods, the most prominent of which is at about 11 years in the mean. This period is also observed in most other expressions of solar activity and is deeply linked to a variation in the solar magnetic field that changes polarity with this period, too.

Sunspot populations quickly rise and more slowly fall on an irregular cycle of 11 years, although significant variations in the number of sunspots attending the 11-year period are known over longer spans of time. For example, from 1900 to the 1960s, the solar maxima trend of sunspot count has been upward; from the 1960s to the present, it has diminished somewhat.[13]

Over the last decades the Sun has had a markedly high average level of sunspot activity; it was last similarly active over 8,000 years ago.[14]

The 11-year solar cycles are numbered sequentially, starting with the observations made in the 1750s.[15]

Solar Phenomenon

Prominences and Filaments

Prominences that are associated with active regions are characteristically short-lived. They often appear as closed loops or as violent ejections of matter in sprays and surges.

A prominence is a dense cloud of material that can be seen just outside the bright photosphere of the Sun. The gas is created and held there by the Sun's vast, arching magnetic fields.

The Baader coronagraph can be used to show prominences. It uses an occulting disc to 'eclipse' the Sun. A coronagraph is ideal for photographing prominences, although other Hydrogen-alpha filters can be used as well. A coronagraph gives a bright image and so allows short exposures with small telescopes.

A filament is the same as a prominence, except that whereas prominences are seen outside the Sun's disc, filaments are seen against the disc, which makes them a little harder to pick out.

Flares

Solar flares are a sudden release of the Sun's energy. They can have an effect on Earth in that it can break up radio communications and cell-phone calls. They can cause electrical power to go out. And they can cause beautiful colored lights to appear in the Arctic skies of our planet, known as auroras.

Solar flares are observed in the chromosphere and are short-lived. Large bright flares usually last an hour or more. Smaller ones may disappear in a few minutes.

They begin with a sudden brightening, usually near sunspots, and increase to maximum brightness in 5 to 10 minutes. During this time the solar flare spreads to surrounding areas. The most favorable times for flares to occur are when sunspot groups are decaying or growing.

Intense bursts of X-rays and radio signals emitted from the corona are associated with many solar flares. These radiations are observed simultaneously with the solar flare, but following intense solar flares there are often greatly enhanced fluxes of energetic protons and alpha particles in a half hour to a few days, as recorded by particle detectors near the earth.

Such an event was recorded in December 2006, when a shockwave spread across the surface of the Sun about 20 minutes after a planet-sized sunspot erupted into a colossal solar flare.

The protons and alpha particles from solar flares are accelerated from the corona above chromospheric flare regions at the time of the visual burst. Their arrival at the Earth is delayed because their velocity is lower than the velocity of electromagnetic radiations, and sometimes by their complicated trajectories in the solar magnetic fields.

Sunspots

Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly as dark spots compared to surrounding regions. They correspond to concentrations of magnetic field that inhibit convection and result in reduced surface temperature compared to the surrounding photosphere. Sunspots usually appear as pairs, with each spot having the opposite magnetic polarity of the other.[16]

Manifesting intense magnetic activity, sunspots host secondary phenomena such as coronal loops (prominences) and reconnection events. Most solar flares and coronal mass ejections originate in magnetically active regions around visible sunspot groupings. Similar phenomena indirectly observed on stars other than the sun are commonly called starspots and both light and dark spots have been measured.[17]

Sunspots are carried by the Sun's rotation from east to west, taking nearly 14 days to cross the face of the Sun. From the Earth the Sun appears to make a complete rotation in about 27 days. A complete solar rotation (of around 27 days) is often called a "Carrington Rotation". This numbering system was started by the English solar amateur astronomer, Richard Carrington, in 1853 starting at "1". This system has survived to this day and it is still widely used particularly by amateurs. We are now at Carrington Rotation Number 2155 and this number will go on increasing by one every 27.2753 days into the future.

If a sunspot group contains one or more spots it is designated an "Active Region" (or "AR") number by NOAA (the National Oceanic and Atmospheric Administration). The current numbering system was restarted at zero again by NOAA in 1972 (there was a similar previous numbering system in place before that) and they are widely used. We also use these numbers to identify the sunspot groups as they cross the face of the Sun. If a group disappears over the western limb and then re-appears 14 days later on the eastern limb, it is designated a new AR number. These AR numbers continue to increase with time.

The first mention of possible periodic behaviour in sunspots came from Christian Horrebow who wrote in his 1776 diary:

"Even though our observations conclude that changes of sunspots must be periodic, a precise order of regulation and appearance cannot be found in the years in which it was observed. That is because astronomers have not been making the effort to make observations of the subject of sunspots on a regular basis. Without a doubt, they believed that these observations were not of interest for either astronomy or physics. One can only hope that, with frequent observations of periodic motion of space objects, that time will show how to examine in which way astronomical bodies that are driven and lit up by the Sun are influenced by sunspots."

(Wolf, 1877, translation by Elke Willenberg)

Observing Sunspots

There are several ways you can observe Sunspots. The easiest and safest is to project the Sun by building your own pinhole camera. Or, if you have your own telescope, you will need to obtain a solar filter. There are even solar telescopes online, which you can access via the web to observe the Sun – e.g SOHO (Solar and Heliospheric Observatory http://sohowww.nascom.nasa.gov).

For most visual astronomy, bigger is better and the larger the scope, the more light collected and the greater the theoretical resolution. However, when it comes to solar observing, the playing field is tipped in favor of smaller scopes. Light-gathering is not an issue since we are trying to dim the Sun's intense glare.

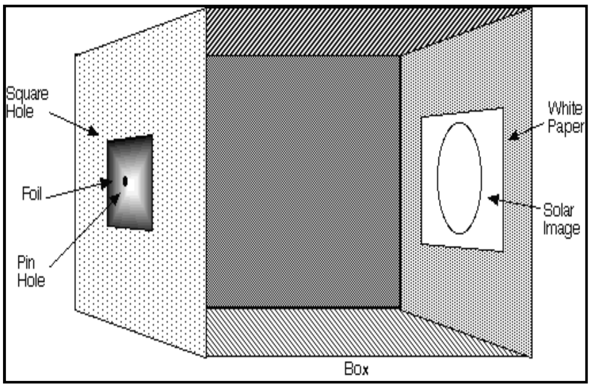


Figure 2: Pinhole Camera

A refractor is the best all-round telescope and can be used to project an image. A small telescope is best, since it is portable and can be used on short notice. An equatorial, driven mount is desirable but not essential.

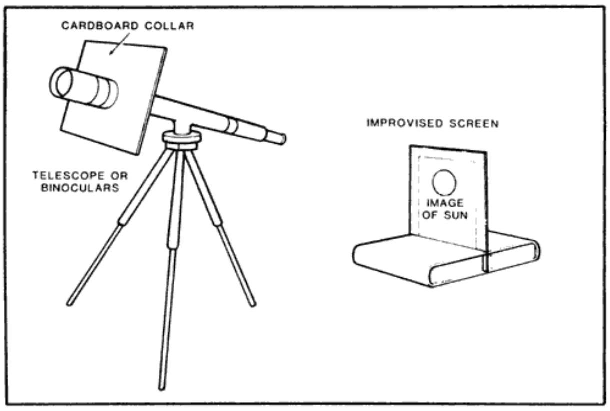


Figure 3: Projection of the Sun

What to look for:

Look carefully at the Sun's disk (either the projected solar image, or by using a full aperture solar filter over the front of your telescope). It will take a while for you to notice all of the sunspots that are visible so be patient.

Try to observe at the same time each day in order to maintain familiarity with the locations of groups. Scan both limbs carefully. Often they contain spots that are hard to detect in cursory scans. Be certain to count all of the groups and spots that you see. Make several passes at counting groups and spots in order to take advantage of sudden improvements in seeing conditions. Observe as frequently as you can in order to keep track of group evolutions and, thereby, improve the accuracy of your counts. When you cannot observe for several days, use online resources to help keep track of evolutions.

- Are there any groups (clusters) of sunspots?
- Are there any single large sunspots?
- Are there any single small spots?
- Where are they? Are they near the centre (the Central Meridian) of the solar disk?
- Are they near the edge (called the "limb") of the solar disk?
- If any large sunspots are near the limb, do any of them look oval?

- If there are sunspot umbrae, are there any bright lanes of light through them? (These are called "light bridges")
- Are there any bright patches (faculae) near the limb? Are they on their own or (more likely) are they near sunspots?

If there are none, then we record this as a blank solar disk. If there are sunspots, count how many groups there are, then carefully count how many individual sunspots there are too.

Recording Observations:

Use this to record all your astronomical observations. Don't record your observations on pieces of paper as these will become lost unless you put them in a ring binder or something similar. Over time your book will fill up and you can look back at them later. It also helps you develop as an observer if you make the right start.

Write the date – i.e. **2015-02-21**, then the time using the 24-hour format in UT (Universal Time). For South Africa it is -2 hours of the current time – **13h30 (11h30 UT)**. Next write the aperture of your telescope and the type, such as: **6" Donsonian; or 60mm Refractor**. If you know the magnification of the eyepiece used write it down too, i.e. **x40**

Add the seeing conditions (how steady is the solar image?) and then the transparency of the sky (how clear is it? Is it hazy?) '**Excellent seeing**' means the image hardly moves, '**Poor seeing**' means the image is moving so much the limb appears to "boil" and the sunspots go in and out of focus. '**Excellent**' or '**Good**' transparency means the sky is clear and blue while '**Poor**' transparency means you can hardly make out any sunspots on the Sun's disk.

Next write down the number of sunspot groups you saw. Then write down the number of individual sunspots you saw. Also write down anything unusual or interesting. The more you observe the Sun the more you will notice each time you do it. This will help you develop your skills as an observer.

Drawing images:

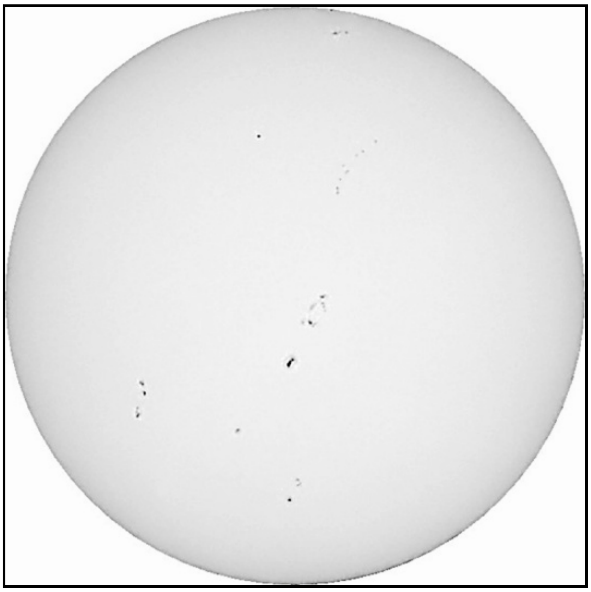


Figure 4: Example drawing of Sunspots

You can either make a drawing of the whole solar disk or draw individual sunspots. Use a fairly soft pencil (HB) to draw the sunspot penumbrae and a very soft pencil (2B or 4B) for drawing in their umbrae. You can either shade in the sunspot penumbra or draw the outline, whichever you find easier. The sunspot umbra are best drawn as dots, start small and increase the size of the "dots" so they match the shape and size that you can see in the solar image.

You can use the Zurich Index ($R_z = k(10g+f)$ to record your counts on the days you observe. This can then be used to calculate your frequency for the month. I use these in my activity graphs so it's worth doing. As you make your observations they will build up over time and then you will start to see the change in sunspot activity over time. You will be able to see for yourself the rise and fall of the sunspot cycle.

Explaining the International Sunspot Number:

- International Sunspot Number: $R_i = k(10g+f)$
  - Belgium's estimates were made with a k-factor value of 1.0, presenting a departure from the Zurich value of 0.6. Since that time, it has varied from that value and is currently approximately 0.9. It is designated by the International Astronomical Union (IAU) to be one of the "official" relative sunspot numbers computed today. Therefore the value of ***k* = 1.**
  - The value of ***g* = the total number of groups of sunspots**.
  - The value of ***f* = the total number of individual sunspots**.
  - ***10*** is the weight assigned value to the cluster of groups (According to the Wolf Index (R)).
    - E.g: Remember *k* = 1 as above. If a total of 7 groups of sunspots (*g*=7) and a total 34 individual sunspots (*f*=34) are observed, the formula will look as follows:
      - $R_i = k(10g+f)$
      - $R_i = 1.0((10)7+34)$
      - $R_i = 1.0(70+34)$
      - $R_i = 1.0(104)$
      - $R_i = 104$
    - *The total count will then be 104. Note that this is not the total number of Sunspots observed.*

Using the Sunspot Observation Sheet (see p.13):

In the section "**Observer's Details**" complete your Name; Location; Co-ordinates (if you have these available); the date and time of your observation.

In the section "**Instrument Used**" complete the type of Instrument Used; Eye Piece Diameter; Field of View; Magnification and Focal Length.

In the section "**Sky Conditions**" write what the Weather Conditions are like, i.e. clear, partly cloudy, cloudy, etc. Also note the Air Transparency, i.e. Excellent, Good, Moderate, Poor. It is also helpful to indicate if there is any Air Pollution, i.e. Smoke; Smog, Mist/Fog etc.

In the section "**International Sunspot Number**" you record the total count as explained above under the heading: "***Explaining the* International Sunspot Number**"

On your "**Drawing Sheet**" you draw the Sunspots and Groupings of Sunspots so that it corresponds as you've observed them through your instrument used. You also record the Date and Time in the space provided. Remember the Time is recorded in Universal Time (UT) which is -2 hours for South Africa.

There is also space provided where you can record the number of groups and individual Sunspots observed. These are divided between the Northern and Southern Hemisphere on the Sun's disc. Then you add up all the Groups in both Northern and Southern Hemisphere and write it in the TOTAL Column and you do the same for the Sunspots. The figure in the Total Column you will use to calculate the count according to the Internationa Sunspot Number.

SUNSPOT OBSERVATION SHEET

Observer details:

Name: ______________________

Location: ______________________

Co-ordinates: ______________________

Date: ______________________

Time: ______________________

Instrument Used:

Instrument: ______________________

Eyepiece diameter: ______________________

Field of View: ______________________

Magnification: ______________________

Focal length: ______________________

Sky Conditions:

Weather Conditions: ______________________

Air Transparency: ______________________

Light Pollution: ______________________

International Sunspot Number: $R_i = k(10g+f)$:

R_i = 1.0 ((10) +)

R_i = 1.0 (+)

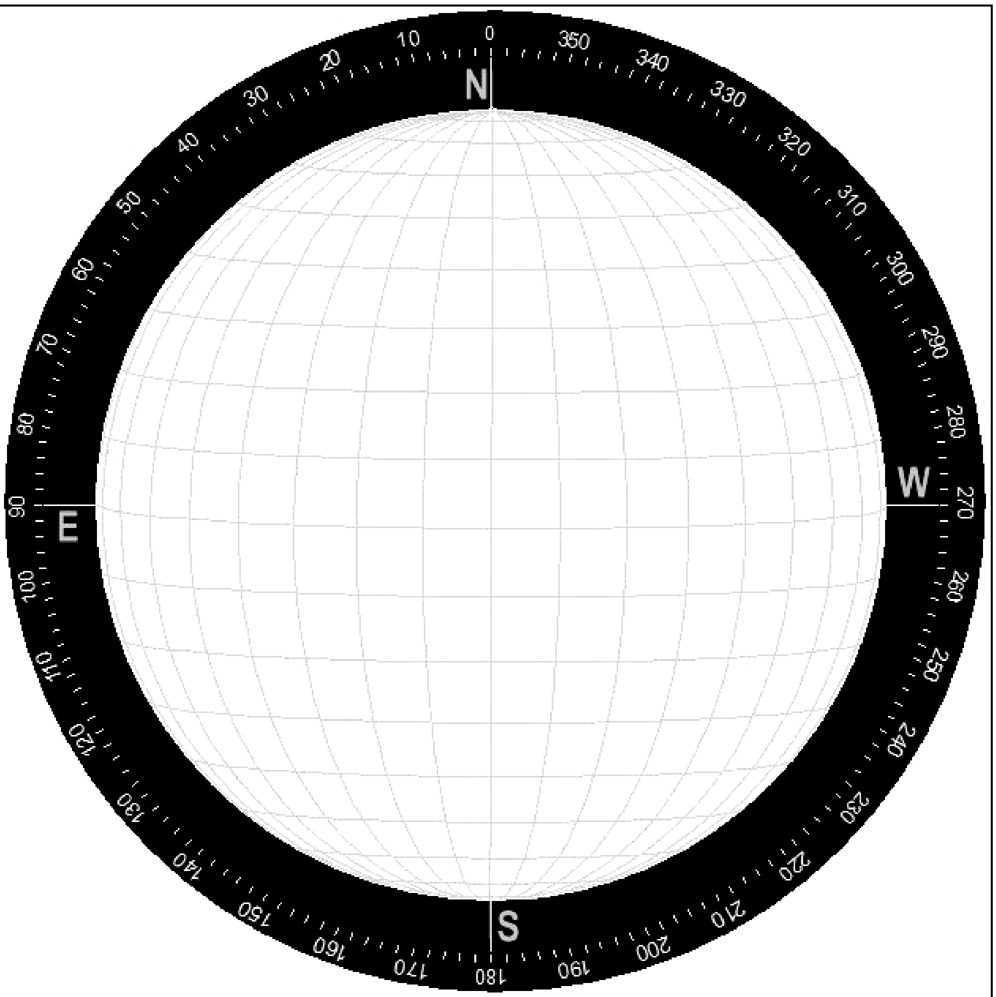
R_i = 1.0 ( )

R_i = ______________________

Drawing Sheet

Date:	
Time:	

	TOTAL	North	South
Groups:			
Spots:			



Safety First

Solar observing is the one time that astronomy poses a real risk of physical injury. Viewing the Sun provides an enjoyable way to supplement the usual nighttime observing activities, but you should be aware of the potential for serious injury and take precautions to ensure your safety and the safety of others. Viewing the Sun also demands extra vigilance when it comes to equipment. Never leave a telescope or binoculars unattended, especially when children are about. It takes only a moment of inattentiveness to create a dangerous situation.

The danger is obvious: its disk is so bright that prolonged, direct exposure can cause permanent damage to the retina, leading to loss of vision or blindness. To observe the Sun safely, you need to filter out more than 99% of the Sun's light before it reaches your eyes.

The safest way to look at the Sun through your own telescope is **NOT** to! Not only could you damage your eye(s), but you can also damage the lenses in the telescope. The safest practical way to see the Sun is by eyepiece projection. Line up your telescope with the Sun, but **DO NOT LOOK THROUGH THE EYEPIECE!**

If you want to observe the Sun, there are many options. You can easily and safely observe the Sun by projecting it through a tiny hole onto a white sheet of paper. This simple device is called a "pinhole camera". You'll need:

- 2 sheets of stiff white paper
- A pin
- A sunny day
- Perhaps a friend to help

With the pin, make a hole in the centre of one of your pieces of paper. Go outside, hold the paper up and aim the hole at the Sun. (**DON'T LOOK AT THE SUN EITHER THROUGH THE HOLE OR IN ANY OTHER WAY!**) Now, find the image of the Sun which comes through the hole. Move your other piece of paper back and forth until the image looks best. What you are seeing is not just a dot of light coming through the hole, but an actual image of the Sun!

Don't forget to make sure that your telescope's finderscope is capped at the objective end or, better yet, removed completely. Aiming the telescope without a finder might seem problematic but it is quite simple. Just move the telescope around until its shadow is minimized, at which point the Sun should be within the field of a low-power eyepiece.

Because binoculars and telescopes concentrate the Sun's blazing light, it's even more crucial to use safe filters. Make sure to avoid any filter that is placed at the eyepiece end of the scope. The concentrated sunlight will probably destroy such a filter, followed shortly thereafter by your vision.

There are also specialist solar telescopes. This shows just one wavelength of light – the most active – that's given off by hydrogen atoms. This will reveal features such as prominences and filaments – solar activity that is invisible when projecting the view or using solar filters.

Be aware that some telescopes have internal plastic parts and these can be damaged by heat by projecting the Sun's image through them.

You can also get safe solar views through reflectors and refractors by fitting a solar filter over the front, objective end of the telescope. These cut out all of the ultraviolet and infrared radiation (heat) from the Sun and also 99.9 per cent of its brightness, so the internal workings don't heat up. Solar filters are made from materials such as aluminum-coated Mylar, or coated glass. Such filters offer safe white-light views of the Sun, revealing a host of features.

When it comes to outfitting optical instruments for solar viewing, a number of excellent options are available. However, there is one type of filter that is very dangerous: the eyepiece ***"Sun Filter"***. These were once commonly supplied with telescopes and consist of a piece of dark glass mounted in a cell which screws into the bottom of an eyepiece. The heat from the Sun concentrated by a telescope can shatter these filters without warning.

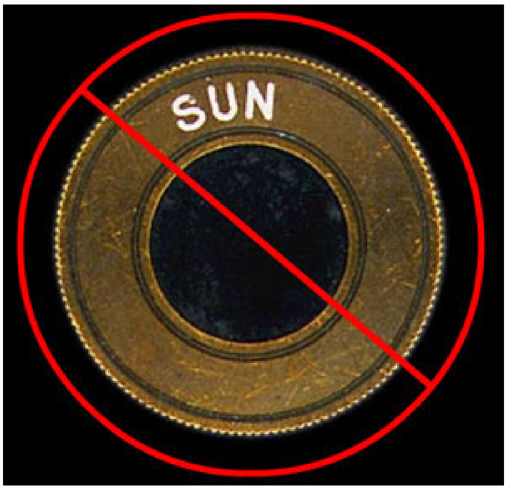


Figure 5: DESTROY THESE FILTERS TO ENSURE THEY CAN CAUSE NO HARM

But no matter what, do **NOT** use "filters" such as smoked glass, stacked sunglasses, polarized filters, camera filters, candy wrappers, or compact discs. They might reduce the Sun's glare, but enough harmful radiation can sneak through to damage your eyes. Only use materials specifically manufactured for safe solar viewing or No. 14 arcwelder's glass.

It's possible to get great, close-up views of our star with the right equipment, but it's really important to realise that the Sun's intense heat and light can be very dangerous if not treated with respect. Don't use sunglasses or layers of photographic film – it's just not worth the risk.

Never observe the Sun with any optical apparatus that has not been fitted with a proper solar filter.

Baader Astro Safety Solar Film is about the best solar filter you can get. It is very safe and gives excellent views of sunspots. Personally, I believe it to be better than Mylar as it gives clearer, sharper, views of sunspots. It must be handled with care but is "pin-hole" resistant as it is usually coated on both sides of the film. It can be purchased in flat A4 sheets or comes pre-mounted in purpose-made filter mounts.

Observing the Sun can be dangerous. **NEVER** look at the Sun directly through a telescope – you could be blinded. Do not assume that a filter which makes the Sun look dark is safe to look through: it may let through infra-red and/or UV. Only use filters intended for solar observing.

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