The AAVSO Solar Observing Guide

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1. Introduction and purpose

The sun is our closest variable star and is extremely interesting to observe in many aspects. The main activity of the AAVSO Solar Section is the monitoring of sunspots from which the American Relative Sunspot Numbers (RA) are computed. This program was started in 1944 when the Solar Committee was first formed in response to the difficulty in obtaining formal sunspot counts from Switzerland during World War II. The AAVSO American Relative Sunspot Program produces an independent sunspot index for the use of solar researchers world-wide.

The purpose of the program is to maintain a long-running and consistent database of visual solar observations of sunspot activity. Continuity with older records requires using white-light filters and visual estimates.

The intention of this guide is to instruct the reader on how to make daily observations of sunspots. The main objective is to encourage and maintain a dedicated group of properly trained and skilled solar observers to ensure consistency in the long-term database. Another objective is to encourage safe practices.

Acknowledgements

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Rodney Howe, Solar Section Chair
Dr. Kristine Larsen
Dr. B. Ralph Chou *(for recommendations regarding safe solar observing)*
Tom Fleming *(for information included in the appendicies)*

2. Cautionary note - PLEASE READ

Observing the sun, especially with a telescope, is a dangerous activity that demands strict adherence to safety protocols. The sun is unique among the objects that AAVSO observers pursue because it is so bright. The most important guideline for solar observing is observe safely. This cannot be stressed enough, and if you are uncertain about any of the following equipment and safety recommendations, please request assistance before making any observations of the Sun with your equipment.

The consequence of direct viewing of the image of the sun through an unfiltered telescope, even just briefly, is potential loss of vision in the eye.

The safest method for observing the sun's photosphere with a telescope is by the projection method of the unfiltered image, using a refractor (described in Section 3).

Never look directly at the sun without the protection offered by a filter specifically designed for the purpose.

The very high risk of looking at the sun through a telescope can be reduced to acceptable levels of risk by the placement of a proper solar filter in front of the aperture of the telescope (as described in Section 3), which prevents most of the ultraviolet, visible and infrared radiation from entering the telescope. Solar filters must be *securely* fastened to the front of telescopes.

If you plan to observe the sun directly, place a full-aperture filter over the objective of your scope or, if you have reduced the normal aperture with a stop, place the filter over the effective aperture ("hole"). There are many materials currently on the market, such as aluminum-coated mylar, nickel-glass composites and special films intended for solar use that work well in this application. A Herschel wedge must be used following manufacturers' recommendations. *Do **not** use older devices such as a "solar filter" that is fitted into the eyepiece.*

Remember that the heat from the sun also presents a danger to your equipment, particularly to finder scopes and eyepieces with cemented elements. If you plan to observe by projection, set the focus well outside of where you would require it for direct viewing and then slowly refocus onto the projection surface. You may prefer to use older style eyepiece designs such as the Ramsden and Huygenian instead of modern multi-element designs because the former typically do not employ adhesives in their construction. Finally, place a cap(s) over your finder scope(s), or remove finder(s) altogether if you are dedicating a telescope to solar observing.

3. Methods for observing the sun

Two ways of observing the sun's surface with a telescope are by direct viewing through the telescope with a proper filter (manufactured specifically for this purpose) covering the front of the telescope, and by projection of the unfiltered image onto a screen. Other solar observation methods, not applicable to the visual estimates for the AAVSO solar section, include CCD and webcam imaging in the eyepiece position of a direct-viewing telescope, and specialized monochromatic solar telescopes such as H-alpha telescopes.

For direct viewing, a white-light filter is required to cover the aperture of the telescope. A filter must protect the eye from intense ultraviolet, visible and infrared radiation, and protect the telescope from heat. The filter attenuates the incoming light to allow only a small fraction to pass into the telescope. New solar filters will be compliant with the new ISO standard ISO 12312-2: *2015 Eye and face protection — Sunglasses and related eyewear — Part 2: Filters for direct observation of the sun.*

Direct viewing through a solar aperture filter is the most common method of solar viewing. Advantages over the projection method include the ability to discern fine details, elimination of heat in the telescope, and ability to evaluate seeing conditions.

Caution: always remember that the filter must be securely fastened to the front of the scope and can't be removed accidentally while the telescope is pointed at the sun. In addition, the filter must be examined for flaws before each observing session (as described in Section 4).

Solar filter fits snugly over the aperture.

For projection viewing, two methods of solar projection are by eyepiece projection through the unfiltered telescope onto a shielded projection screen, and by use of the "Sunspotter" device. Projection avoids the risk of looking directly at the sun through a telescope and has the advantage of allowing a number of observers to view the sun simultaneously.

Eyepiece projection through a refractor using a Hossfield pyramid.

Caution: Using an unfiltered telescope for projection requires the extra caution that the projected image must never be allowed to point toward the eyes of yourself or anybody that could be in the way. Keep hands and other body parts out of the light path at all times, as burns may result.

Generally, an image of 6 inches (150 mm) in diameter is the best compromise between image brightness and resolution (since too large of an image may be faint and of low contrast, while an image that's too small could make it too difficult to clearly distinguish small spots).

A useful formula for calculating the distance (in mm) between eyepiece and projection screen needed to have an image of 150 mm is:

$$\text{Distance} = f(16050/F + 1)$$

where f is the eyepiece focal length and F is the telescope focal length in millimeters.

(Source: "Observing the Solar System: the modern astronomer's guide" by G. North)

Note that because the apparent diameter of the sun varies during the year (owing to the ellipticity of the Earth's orbit) the calculated distance is only approximate and should be adjusted to bring the solar image to the appropriate diameter.

4. Equipment

What type of telescope?

You may already have a refractor, reflector, or compound lens-mirror telescope (e.g. SCT or Maksutov). All kinds are fine for direct viewing with a solar aperture filter. Actually, refractors are slightly better and deliver sharper and higher-contrast images than reflectors, which have small diffraction effects caused by obstructions in the light path, but any telescope equipped with a proper solar filter is appropriate to start using for sunspot observations.

For solar projection, refractors are best due to minimum obstruction in the focussed light path and for mechanical mounting of a projection screen. Newtonian reflectors are not recommended for projection. Reflectors are generally bigger than most small refractors used for solar observations and concentrate much more heat in the focal plane and pose a higher risk of damage to the telescope than smaller refractors. Many good solar filters are available for the front of reflectors and they should be used for direct viewing rather than projection. The SCT and other compound telescopes should not be used because the closed tubes may get hot and risk damaging the cement bond holding the secondary mirror and its support onto the corrector plate, and internal baffles or stops may also get damaged. Eyepieces with cemented elements may be damaged by the heat passing through the eyepiece. Also, avoid using an eyepiece with cross hairs, which could melt in the intense focussed image of the sun.

What aperture?

You don't need much aperture. Apertures in the range of 50-80 mm are sufficient. It may be interesting to note that the telescope used for the daily sunspot counts at Zurich for many years by Rudolf Wolf and his successors was an 80 mm refractor. Apertures larger than about 100-125 mm are generally limited by atmospheric turbulence effects. If you experience arc second seeing conditions (or better) at your observing location during daytime, then an aperture of 125 mm or larger could be justified to view the sun at arc second resolution. Apertures smaller than 125 mm have resolution limited by theoretical limitations to greater than an arc second, but most observers probably have daytime seeing conditions worse than an arc second. Whatever telescope an amateur astronomer already has, will most likely work well. AAVSO Solar Section observers that contribute sunspot counts use apertures in the range from about 40 mm to 200 mm.

If buying a refractor for observing by projection or through a Herschel wedge, the user must ensure that the instrument doesn't have any plastic parts close to the objective focus, as is common in many cheap refractors sold in department stores. Generally, 100 mm achromat refractors have decent optics and no plastic parts, while apochromatic refractors in smaller sizes are even better made and will also be good for solar observing. For solar projection, an aperture larger than 80-100 mm may allow an excessive amount of heat to pass through the image plane of the telescope and blur the image.

How much magnification?

The magnification used for counting sunspots is important but seeing conditions may limit the maximum usable power, while very steady seeing allows high power. Too much magnification in the telescope may cause observers to count short lived pores (which should not be counted) rather than larger sunspots. Pores are random intergranular blemishes that appear as very small spots without a penumbra which change rapidly (with lifetimes typically less than an hour and dictated by granulation dynamics) and may mark positions of newly forming sunspots. The sunspot observer should become familiar with pores in order to avoid confusing them with sunspots.

Pores have a fuzzy appearance, low contrast, no clearly defined shape, and are not really black, while a true sunspot has a sharp outline, high contrast, and a dark core. If magnification is too low, it may be difficult to define these characteristics. The illustration below shows an example of sunspots and pores. The higher the magnification, the more clearly small spots and pores are resolved in good seeing conditions, but there is the risk of counting a pore as a spot. On the other hand, medium to high magnifications are needed to clearly discriminate between them.

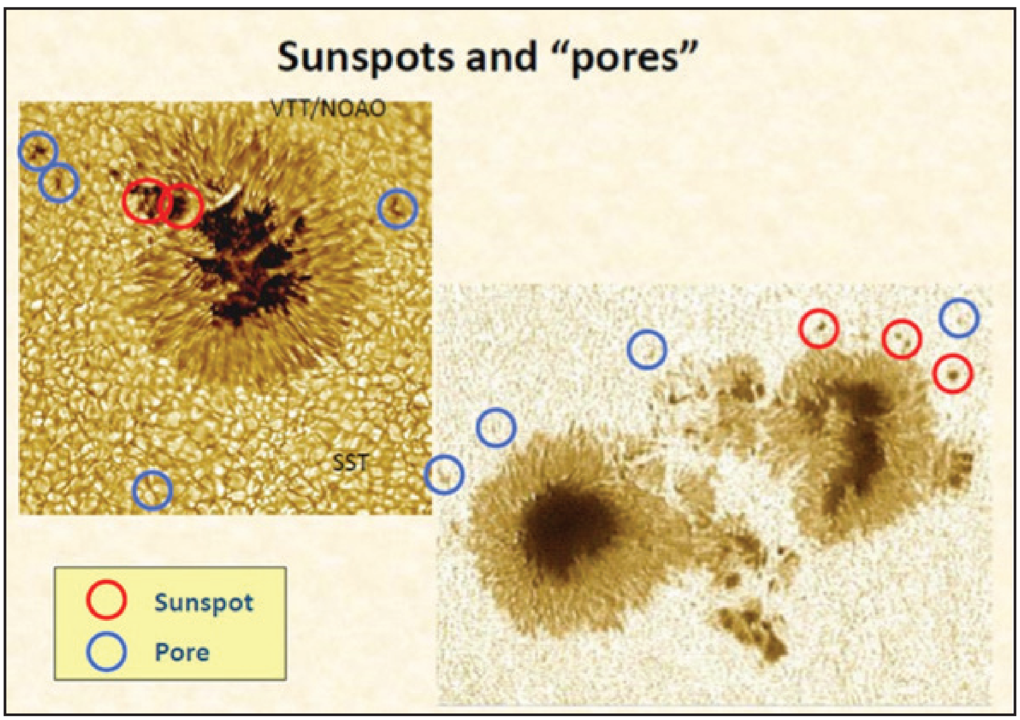


Illustration of sunspots and pores. (Image courtesy of Frédéric Clette.)

A good guideline is to scan the disk at several different powers. Use low power (40x-50x) and medium power (60x-70x) to see the entire disk and to identify the major groups and their structures. If seeing conditions permit, use high power (80x-90x) to aid in identifying tiny groups and achieving an accurate count of spots while identifying and excluding pores.

As a guideline, the resolving magnification that allows us to see all of the details in the telescopic image is equal to half the aperture in mm, but in practice something more is required, say 1.5 times that value, or 60x for an 80 mm aperture, which is a typical value for sunspot counting. If we assume that the smallest resolvable spot has an apparent size of 3 arcsecs, then spot counting is not significantly influenced by aperture because an 80 mm refractor is already capable of resolving 1.5 arcsecs, which is less than the average seeing (typically about 2 arcsec).

How do you calculate magnification?

The magnification is calculated by dividing the focal length of the objective by the focal length of the eyepiece, or in equation form,

power = (focal length of the objective) / (focal length of the eyepiece).

For example, using a telescope with focal length 1000 mm and an eyepiece with focal length 20 mm, the magnification will be power = (1000 mm) / (20 mm) = 50.

Or, using the aperture of the objective and its focal ratio, magnification is calculated as

power = [(aperture) x (focal ratio)] / (focal length of the eyepiece).

For example, using a telescope with aperture 80 mm, focal ratio f/8, and an eyepiece with focal length 10 mm, the magnification will be [(80 mm) x 8] / (10 mm) = 64.

A useful online calculator is available at: http://www.skyandtelescope.com/observing/skyandtelescope-coms-scope-calculator/

What filter?

Solar filters are manufactured as metallic coatings on glass or mylar substrate. Filters in widespread use are generally manufactured by Baader Planetarium (AstroSolar Safety Film) or by Thousand Oaks Optical. Earlier, reliable solar filters were also made by Roger Tuthill Co., named Solar Skreen, and some of these may still be in use. A priority when using a filter is to ensure a proper and secure fit over the aperture of the telescope before each use. Some helpful information about choosing a solar filter may be found at the website http://oneminuteastronomer.com/999/choose-solar-filter/.

Caution: Never use solar filters that fit into the eyepiece! These were distributed with department store-grade telescopes in earlier years and some still exist. They are dangerous because they can crack in the intense focussed sunlight. They should be broken and discarded in order to avoid being used by an unsuspecting future owner.

Caution: Be sure to point the aperture of the telescope away from the sun before removing the dust cover and attaching the solar filter. The solar filter must be examined for defects before attaching to the telescope. This should be done before each observing session. A three-step process is recommended:

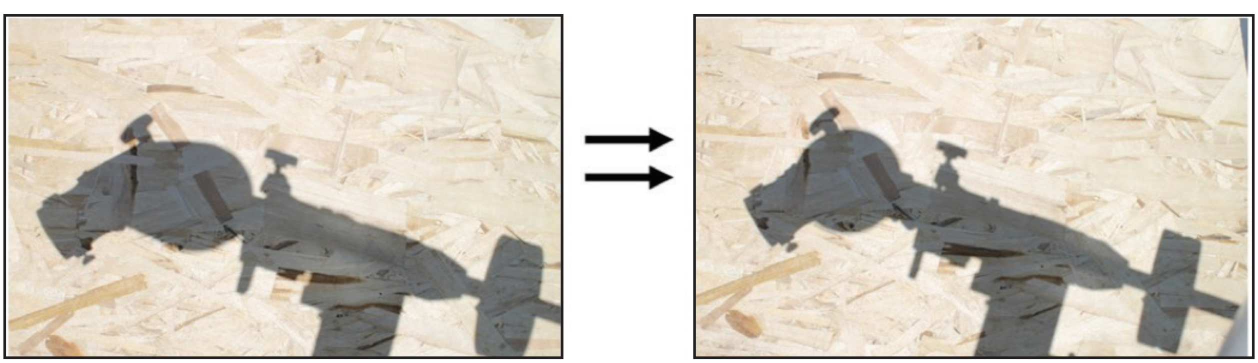
1. Visually inspect the filter for any cracks or chips in the reflective coating.
2. Hold the filter up in the direction of the sun and look through it with your eyes. Be sure that the filter is held between your eyes and the sun. If unfiltered sunlight can be seen through the filter in anything larger than a tiny pinprick, the filter should be discarded. Tiny pinprick holes may be fixed. Some maintenance tips may be found on the Thousand Oaks website (http://www.thousandoaksoptical.com/tech.html).
3. Once the filter is attached and the telescope is pointed toward the sun (see below), look through the diagonal before inserting the eyepiece. Potential defects in the filter will show up as bright spots in this unfocussed image.

Caution: Cover or remove the finder scope when the telescope is pointed at the sun, whether in direct or projection viewing.

How do I align the telescope with the sun?

Aligning the telescope to the sun can be done fairly easily by minimizing the shadow of the telescope on the ground or on a flat surface such as a wall or simply your hand. Start with the telescope pointed generally toward the sun (with the filter over the aperture if using a filter) and move the scope around with small movements until the shadow is minimized; if using the projection method, an image should appear on the screen once the proper alignment is achieved. If a solar filter is used, look through the eyepiece tube (with the solar filter safely attached over the aperture) without the eyepiece and fine-tune the position until the unfocussed, filtered image of the sun is near the middle of the eyepiece tube. Then the image of the sun should be somewhere in the field of view of a low-power eyepiece.

Some observers also find a pinhole projection finder very useful (e.g. Tele Vue's Sol-Searcher).



Alignment of telescope onto the sun by minimizing the shadow.

What type of telescope mount is required?

Any mount that holds the telescope steady for a few moments is fine. Mounts can be alt-azimuth, camera tripods, or equatorial with or without tracking. Non-tracking mounts can be adjusted so that the sun drifts across the field of view, and then nudged every moment. This gets more difficult with higher magnification, but with practice becomes easy. Non-tracking mounts are fine for beginners, but tracking mounts may make the task easier, particularly when using higher magnification, and make it much easier to assign groups and spots to N or S hemispheres. Solar tracking rates available on some computer-controlled drives are optional but not required during the few minutes of the daily observation.

The Sunspotter

Sunspotter telescope
(Image credit: https://www.scientificsonline.com/product/sunspotter)

Provided by Learning Technologies, Inc., this wooden, folded-path, Keplerian telescope provides a safe and convenient way to view the Sun. By using a series of mirrors, the device projects a bright 85 mm diameter solar image onto a viewing screen through a 62 mm diameter objective lens (stopped down to 57 mm). Magnification is 56x. The Sunspotter is fairly easy and quick to align with the sun and consists of two sections. A triangular assembly containing the optical components pivots to provide altitude adjustment inside of an arc-shaped cradle which provides azimuth adjustment (while resting on a flat, horizontal surface). After positioning the cradle toward the sun's azimuth, the triangular assembly may be adjusted upward or downward within the arc of the cradle until the optical axis points to the sun. A gnomon at the front allows approximate alignment and then fine adjustment is provided by adjusting the telescope so that sunlight passing through two small holes (on either side of the objective) aligns as dots within the two "bull's-eye" circles located on either side of the first mirror. For more information about use and application of the Sunspotter, see the reference by Larsen (2013). The Sunspotter is a good introductory instrument for observing sunspots, but telescopes provide more options for different magnifications and more detailed observations can be obtained with a telescope.

5. Observation and recording guidelines and notes

The process is to count the numbers of sunspots and groups of spots. Record these along with the date, time and seeing conditions.

First, the significance of groups or clusters of sunspots should be emphasized for the observer preparing to count sunspots. Numbers of groups are much higher in importance than number of sunspots, and are weighted with a factor of 10 in the Wolf Number (W) used in the calculation of the American Relative Sunspot Numbers. Groups are more closely related to the area of the sun covered by active regions. In contrast to the importance of groups, tiny sunspots or pores that are tiny and only visible at high magnification should not be counted. The Wolf number for each daily observation is calculated from the number of individual spots (s), and numbers of groups (g), as:

$$W = 10g + s$$

Therefore correctly estimating the number of groups is much more important than counting each tiny spot.

The orientation of the sun's equator should be determined before the sunspot observation, so that the observer may correctly assign groups to northern or southern hemisphere. This is not essential, and the monthly sunspot report can be submitted without hemisphere assignment of the observed sunspots, but more experienced observers should be aware of the preferential E-W orientation of sunspot groups, and that they have preceding and following spots. Otherwise, novice observers may make errors in group counting. Details about finding the orientation of the sun are in Appendix D.

Start the observation by scanning the disk at several different powers. Use low power (40x–50x) and medium power (60x–70x) to see the entire disk and to identify the major groups and their structures. If seeing conditions permit, use high power (80x–90x) to aid in identifying tiny groups and achieving an accurate count. 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 condition. Carefully check any faculae for small spots.

Make your best estimate of the number of groups, even though the decision of which spots are in a group may be somewhat arbitrary some days. Some strategies to help with deciding the number of groups are to use Internet resources to follow progression of groups, and observe daily to maintain familiarity with the groups. When you are just starting out, you can consult such images to see if you are taking sufficient care to see small spots. Resources on the Internet are a great way to follow sunspot and group evolution since major satellites and solar observatories are tracking the sun constantly and in many wavelengths, but should not be used to prejudice your observations or “scale” your visual estimates, since the purpose of the program is to maintain a long-term set of sunspot counts by trained visual observers. Some websites with updated solar photosphere images include https://sohowww.nascom.nasa.gov/sunspots/ and https://sdo.gsfc.nasa.gov/, and http://solarham.net.

It’s worthwhile for the observer to understand and recognize the rotation of the sun and the apparent motion of sunspots. As a first approximation, sunspots moving across the sun’s disk mark the rotation of the sun and you may see active sunspot groups reappear at the same position after one solar rotation of about 27 days. In more detail, the rotation rate of the sun is found to be faster at the equator (about 24.5 days) and slower at higher latitudes (more than 30 days in polar regions). The differential rotation rate is noticeable, but an approximate rotation period of 27 days is commonly quoted and is the period at a latitude of 26 degrees north or south of the sun’s equator, which is a typical latitude for sunspots and significant solar activity. The rotation rate varies with latitude because the sun is a gaseous plasma. After observing through a solar cycle, you may notice that sunspots tend to develop at mid-latitudes in the early years of a solar cycle and then appear in a widening latitude band that gradually moves toward the equator as the solar cycle progresses. This results in the so-called Butterfly diagram (https://solarscience.msfc.nasa.gov/SunspotCycle.shtml). Solar observers may discover that solar physics and astronomy is completely fascinating, and that the sun is a very exciting variable star! The NASA website (see the Resources section) is one of many good sources of further information about solar rotation and other factors that may affect the solar observer.

Understanding the Zurich and McIntosh classification systems of sunspot groups (see the Appendices) may help to better understand and recognize the evolution of sunspot groups.

Estimate the seeing conditions

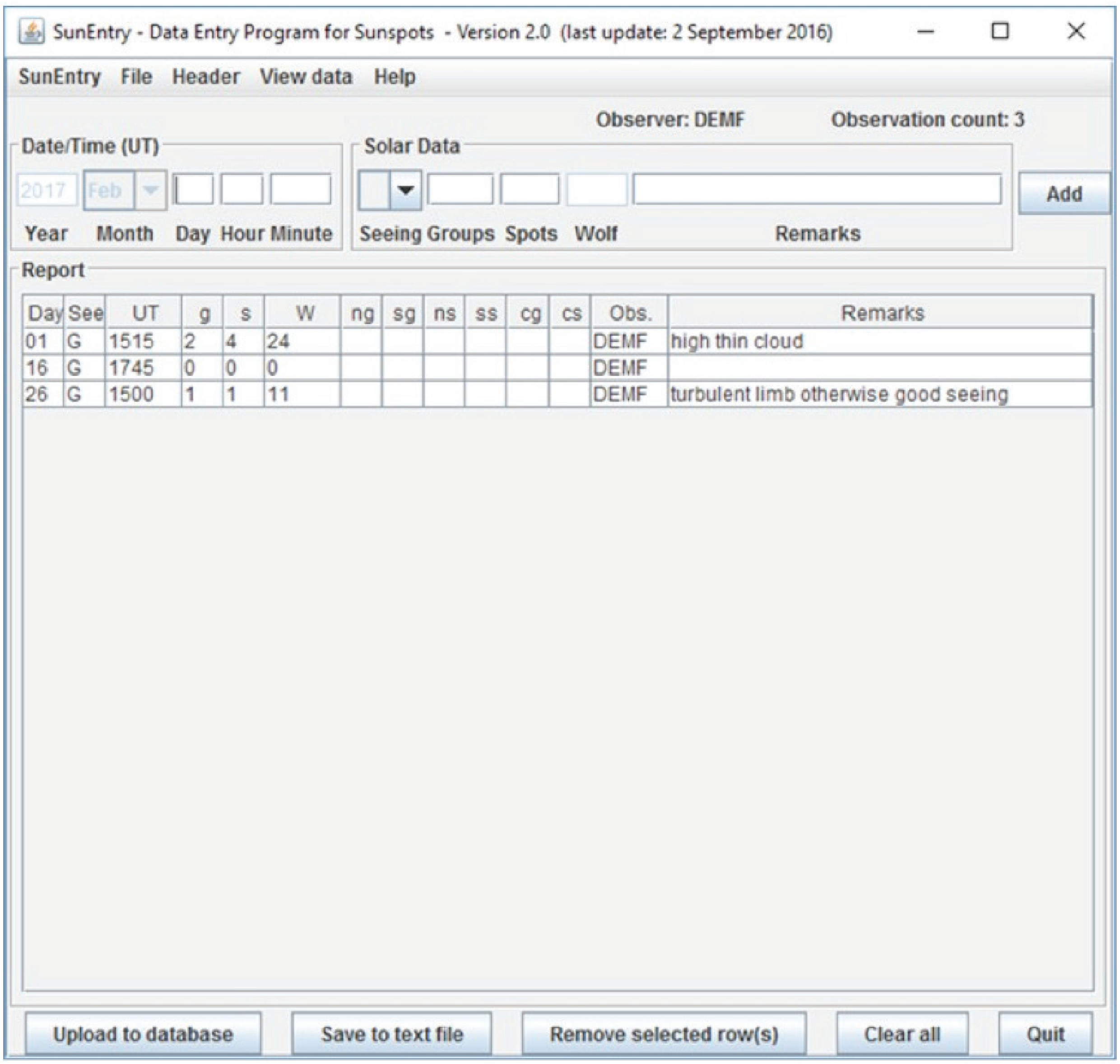
“Seeing condition” is a term that describes the degree of shakiness in the image, caused by turbulence and variations in density of the air in Earth’s atmosphere. Good seeing conditions result in fairly steady images while fair or poor conditions result in turbulent or blurry solar images. The seeing condition needs to be recorded and reported with each observation, and so you need to estimate the seeing condition as excellent, good, fair or poor. Of course you should strive to observe under excellent seeing conditions, but these may not occur often. Since the solar observation would be more accurate under excellent seeing conditions, the factors affecting seeing may be worth some discussion which appears in Appendix A of this guide.

When to observe

Observing at the same time every day would be ideal, especially when seeing conditions are good or excellent. Observing when the sun is high in the sky minimizes absorption and distortion by Earth's atmosphere, but heating of the ground and nearby buildings may cause degraded seeing conditions. Many observers find that the best seeing conditions occur in the morning after sunrise, before seeing degrades. For more information, see the discussion of seeing conditions in Appendix A.

6. Reporting the observations

Use the AAVSO software SunEntry to upload your observations to the AAVSO. After entering your observer code and password (or registering as a solar observer first), the report software requires the date, time, seeing condition, and numbers of groups and spots. The screenshot below illustrates the input section. Optionally, count and report the numbers of northern and southern groups. This requires finding the orientation of the sun and its equator. Some information is provided in Appendix D. (Note: to register as an AAVSO solar observer, follow the instructions on the website https://www.aavso.org/sun-entry).



When preparing a sunspot report for submission to the AAVSO, check to be sure that you have calculated the Wolf number (10g + s) correctly. Your calculated number must agree with the value calculated by the SunEntry software, which automatically checks arithmetic, and this check is one level of quality assurance. As usual, carefully check your observations before submitting them, and don't report questionable observations. The Remarks column might include comments such as "observed through high clouds", "hazy", "hazy and turbulent", or "limb turbulent" as some examples.

Submit your reports in a timely fashion. Remember that, to have your results included in the Solar Bulletin for a given month, your report must be received by the chair of the Solar Section by the 10th of the month following the month of observations. If you wish, you may submit your observations on a daily basis as you make the observations rather than sending them in one report at the end of the month.

7. Sunspot classification

Various classification schemes for sunspots and groups have been developed in order to classify the stages of development and evolution of sunspots. The Zurich sunspot classification system was used for visual observations for many years until communication and spacecraft operations led to requirements for better capability to predict solar flares. A revision of the Zurich system was devised by Patrick McIntosh that included the penumbra of a group's largest spot and the distribution of spots in the groups. This more detailed system provided the information useful for predicting flares. More classification schemes are described in Solar Astronomy Handbook, by Beck et. al. (see Resources) and some further information is available at the website https://www.aavso.org/sites/default/files/SemSunspotsClassV3s.pdf. While not necessary for AAVSO sunspot observers, the Zurich and McIntosh classification schemes may help the observer to understand the position of a sunspot in its life cycle, and both are shown in Appendices B and C below.

The AAVSO has used the Zurich classification system since 1924 and since the main purpose of the AAVSO Solar Section sunspot counts is maintaining the valuable long-term consistent record of sunspot counts, novice solar observers should start out with the Zurich system and become familiar with it before studying other classification systems. While some other amateur astronomy groups use the McIntosh classifications, AAVSO observers need to follow the Zurich classifications for long-term continuity. More information about the historical long-term value of the AAVSO sunspot observations may be found at the link https://www.aavso.org/dances-wolfs-short-history-sunspot-indices and in the references at the end of that article.

8. Resources

Books and Articles:

Guidelines for the Observation of White Light Solar Phenomena (A Handbook of the Association of Lunar and Planetary Observers Solar Section), edited by Jenkins, J., 2010. (also available online at http://www.alpo-astronomy.org/solarblog/wp-content/uploads/wl_2010.pdf).

How to Observe the Sun Safely (2nd edition), Macdonald, L., Springer-Verlag New York, 2012, ISBN: 978-1-4614-3824-3.

Monitoring Solar Activity Trends With a Simple Sunspotter, Larsen, K., 2013 JAAVSO Vol. 41

Observer's Handbook of the RASC 2017, Royal Astronomical Society of Canada, Webcom Inc., 2016.

Observing the Solar System: the modern astronomer's guide, North, G., Cambridge University Press, 2012. ISBN: 978-0521897518.

Observing the Sun, Taylor, P., Cambridge University Press, 1991. ISBN: 978-0-52105-636-6.

Solar Astronomy Handbook, Beck, Hilbrecht, Reinsch and Volker, Willmann-Bell Inc., 1995. ISBN: 978-0-94339-647-7.

Solar Sketching: A Comprehensive Guide to Drawing the Sun, Rix, E., Hay, K., Russell, S. and Handy, R., Springer Publishing, 2015. ISBN: 978-1-49392-900-9

The Sun and How to Observe It, Jenkins, J., Springer Publishing, 2009. ISBN: 978-0-38709-497-7.

Websites:

NASA solar science website: https://solarscience.msfc.nasa.gov/SunspotCycle.shtml

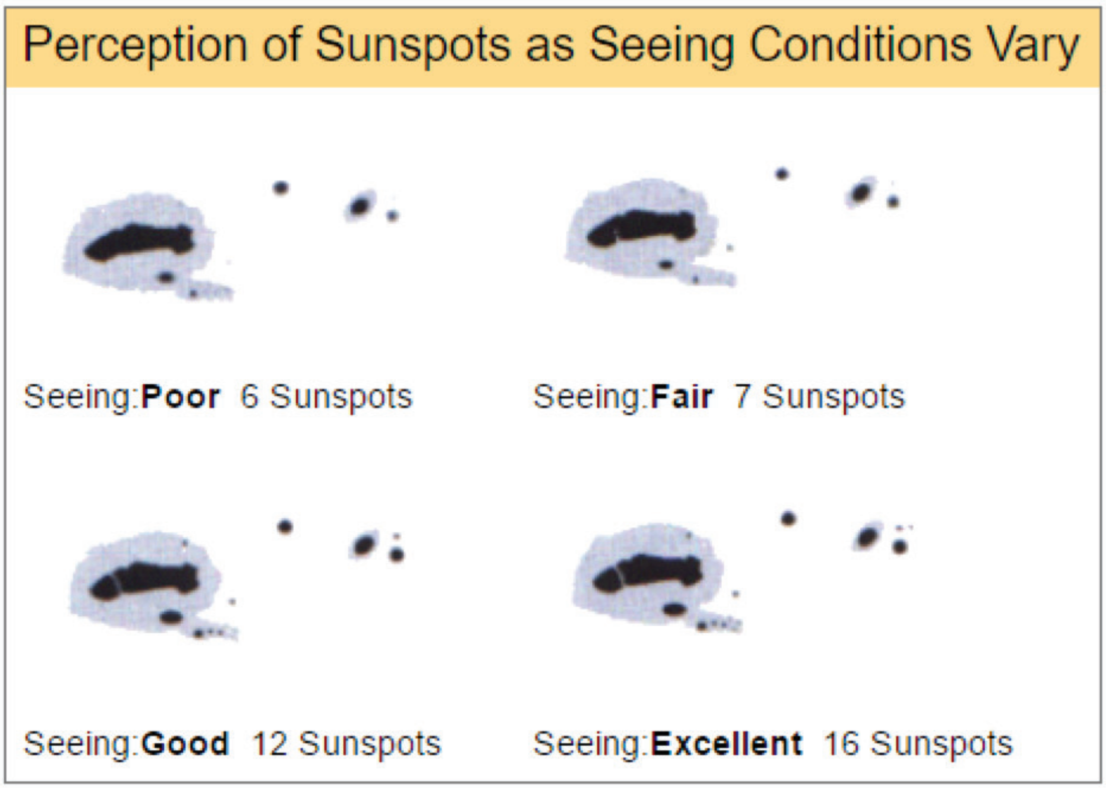
Appendix A – Seeing conditions

(Note: the following is from https://www.aavso.org/atmospheric-seeing-conditions-solar-observing)

Atmospheric Seeing Conditions - *Contributed by Tom Fleming (FLET)*

Reports and observations submitted to the AAVSO use the following ratings for atmospheric turbulence (Seeing): Poor, Fair, Good and Excellent.

The illustration below shows the same sunspot group as it would appear under these four conditions. Of course a still image on a printed page cannot represent accurately the rippling turbulence of the atmosphere when conditions merit a 'Poor' rating. So, the images for Poor Seeing and Fair Seeing represent an image averaged over several seconds.



The Poor Seeing image shows three sunspots within the large penumbral area. Three more sunspots are to the right. There are hints of a few more but turbulence will prevent these from being verified. As conditions improve to 'Fair', another sunspot just to the right of the large penumbral area is revealed. Under 'Good' Conditions several smaller spots are revealed—four in the large penumbral area (the largest spot has resolved into two as there is a complete break—any bridging of that gap and the sunspot would be counted as a single instead of two) and lastly another near the smaller sunspot with the penumbra. Finally, under excellent conditions all is revealed.

In general, Poor and Excellent seeing conditions are less frequent with Fair and Good conditions making up the majority of your observing experience. Observing the rippling of the limb of the sun is a common barometer for judging the quality of the seeing. If you are inexperienced, you may wonder how you will recognize Excellent seeing conditions. The experience is similar to peering at a quarter through 4 feet (1 meter) of swimming pool water. You can see it there but the ripples prevent you from seeing whether it is head or tails. Excellent seeing is akin to putting on a face mask and breaking through the surface. Not only will you see the face on the coin you can read its date and see the reflections off of the scratches. The detail in the penumbral regions of large sunspots, for example, will be amazing. An extended sunspot under average conditions may show itself to be three or more individual spots under excellent conditions and so on.

In the following section you will find a detailed discussion of conditions that impact seeing and how to optimize them.

A Detailed Discussion of Seeing Conditions

Seeing turbulence is the result of volumes of atmosphere of unequal temperature mixing. The conditions that cause unequal temperature are many and varied. Some are within your control and others totally beyond your ability to control.

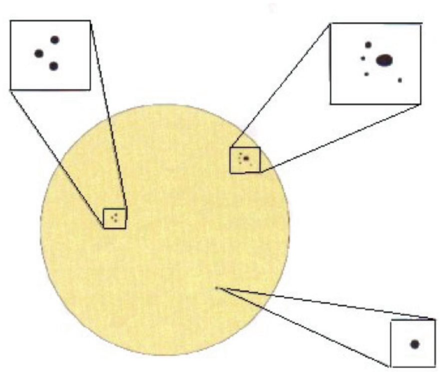
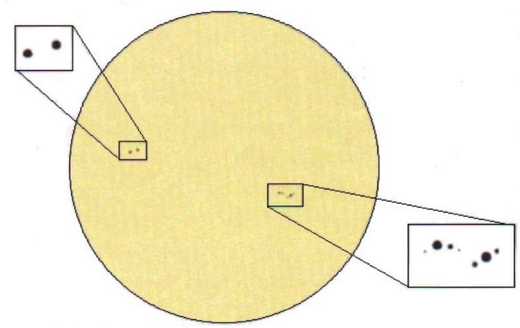
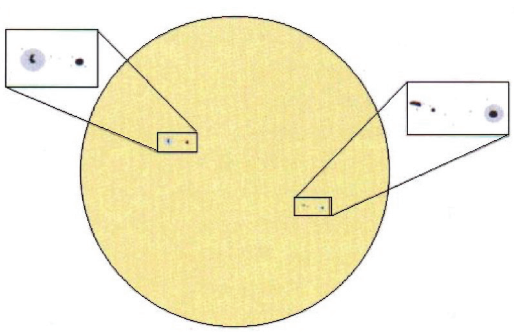
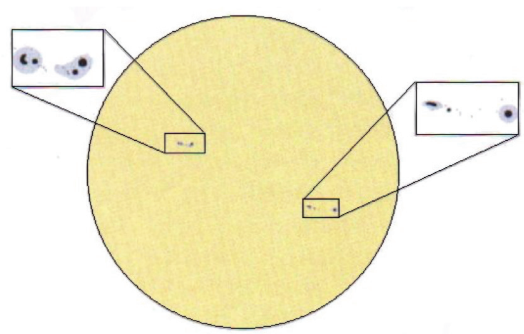
Local conditions: Turbulence may occur within the light path of your telescope. Before observing, allow time for your telescope to adjust to the local temperature. Select your observing location with the following factors in mind: Beware of nearby walls and fences, these vertical faces will receive maximum heating from the sun when the sun is near the horizon (this is generally a favored time to observe). Avoid observing over roof lines or pavement when possible. In general, nearby areas with trees or grass will help stabilize the air in your light path. Observing over a body of water generally provides the most stable air (note Big Bear Observatory). If your location is at an altitude in excess of 5000 ft (1500 m) this is also a big help. Frontal passages regularly bring turbulence as existing warm air is replaced by cool or cold air. However, there is a brief time shortly after the front has passed. When the last clouds no longer interfere with your view of the sun, you may experience good seeing before conditions degrade. The window of opportunity is about 10 to 15 minutes.

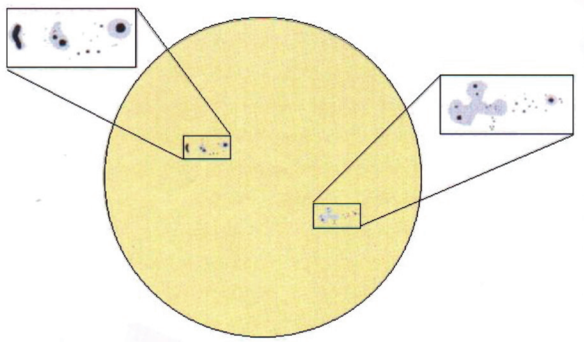
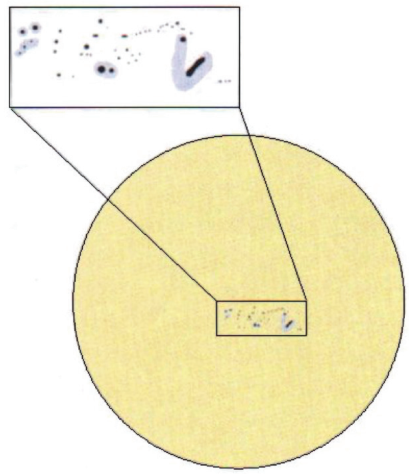
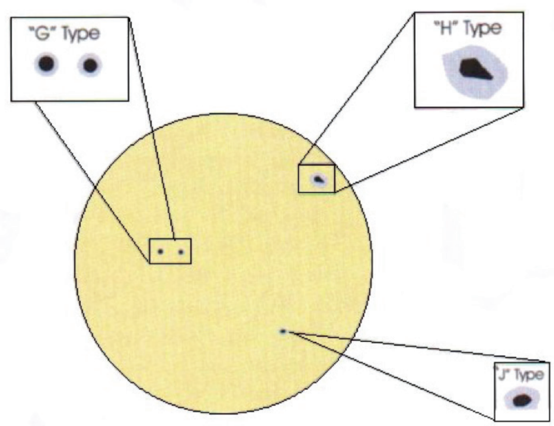
Observing the limb of the sun will give you some clues as to the type of seeing you will encounter for your observing session. Large scale ripples that traverse the sun in fractions of a seconds can be attributed to local conditions - these indicate unfavorable conditions at your selected site that you may be able to adjust. Rippling evident along the limb that exhibits a more random motion is due to turbulence at higher altitudes. If you are observing the sun at a low angle this type of turbulence occasionally improves as the sun rises above a layer of disturbed air. However, daytime heating of the Earth's surface and adjoining air is your biggest enemy. This is why observing the sun at low altitude rather than near local noontime is recommended. For this same reason, it is important to be ready to observe as clouds clear your area before surface heating begins to affect the air.

More than once in this manual you will see references to recommended methods of observing the Sun and collecting your data. Multiple scans at different magnifications, for example, is recommended. Experienced observers have noted remarkable variations in seeing conditions over time spans lasting from a few seconds or even a few minutes. A patient observer who is ready to exploit improved seeing conditions will be rewarded with better quality data.

Appendix B – Zurich classification system

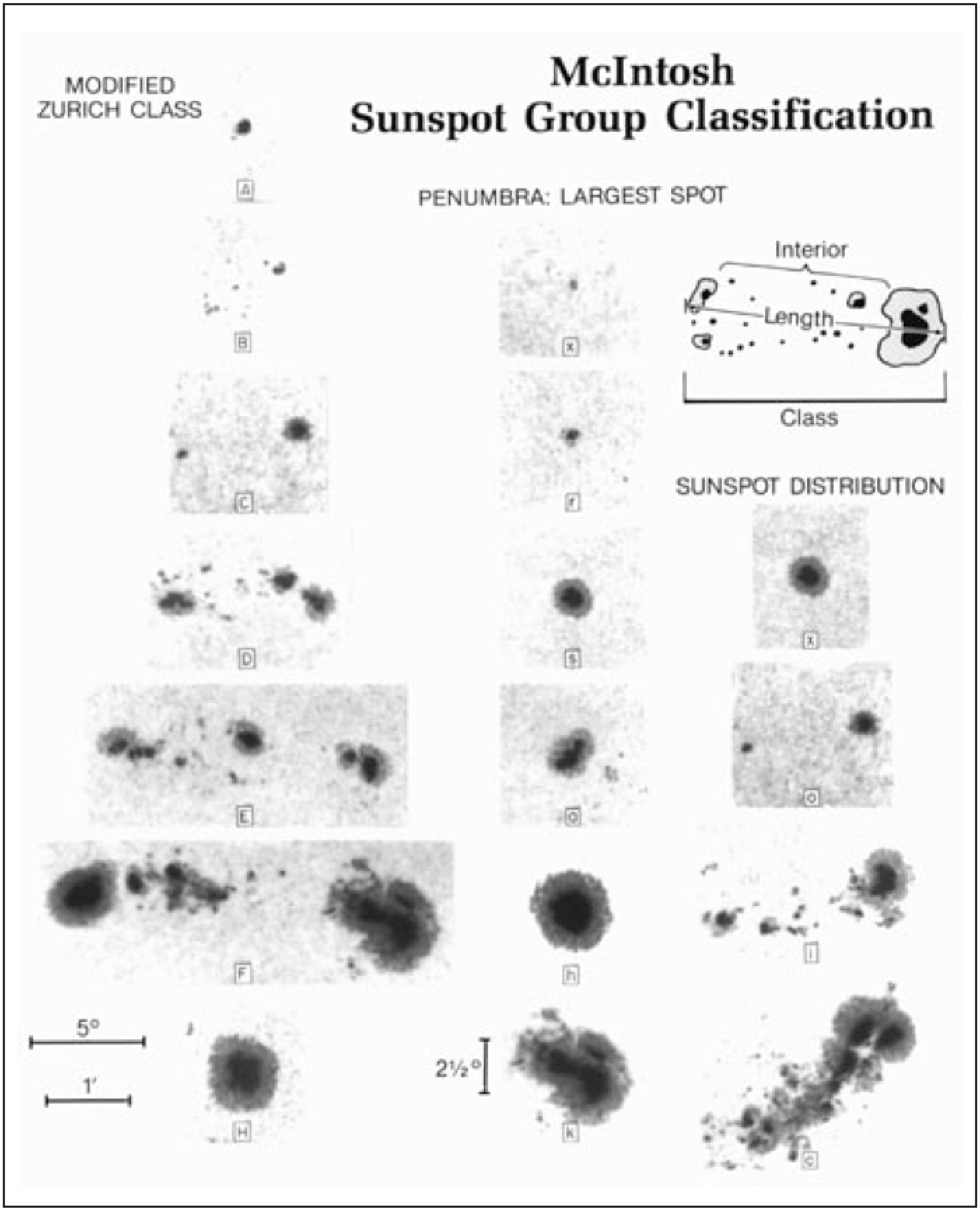
The Zurich Classification System of Sunspot Groups - Contributed by Tom Fleming (FLET)
(Note: the following is from https://www.aavso.org/zurich-classification-system-sunspot-groups)

“A” Type: One or more tiny spots that do not demonstrate bi-polarity or exhibit penumbra.	**“B” Type:** Two or more tiny spots that demonstrate bi-polarity but do not exhibit penumbra.
	
“C” Type: Two or more spots that demonstrate bi-polarity and either the lead spot or trailing spot has a penumbra.	**“D” Type:** Two or more spots that demonstrate bi-polarity and the lead spot and trailing spots display a penumbra. The “D” Type will occupy 10 degrees or less of Solar longitude.
	

<table>
<tr><td>“E” Type: This group type is similar to the “D” type but spreads between 10 and 15 degrees of Solar longitude.</td><td>“F” Type: Largest and most extensive of groups, similar to “E” type but will cover in excess of 15 degrees of Solar longitude.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>“G” Type: The decayed remnant of “D”, “E”, and “F” groups. Demonstrates a bi-polar group with penumbras.</td><td>“H” Type: The decayed remnant of “C”, “D”, “E”, and “F” groups. A single spot group with penumbra. Must be larger than two and one-half degrees in diameter. The “H” type occasionally is accompanied by a few small spots.</td></tr>
<tr><td colspan="2">“J” Type: The same as the “H” type but
has a diameter less than 2½ degrees.</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

Appendix C – McIntosh classification system

(From The Classification of Sunspot Groups by Patrick S. McIntosh, Solar Physics, vol. 125, Feb 1990, p. 251-267)



Appendix D – Orientation and finding the equator of the sun

The orientation of the sun's equator may be found using graphical or mathematical means or by use of software. A good reference for mathematical calculation is *Solar Astronomy Handbook*, by Beck et. al. (see Resources) and a good source for ephemerides of the sun is the NASA JPL website http://ssd.jpl.nasa.gov/horizons.cgi#top or the *Observer's Handbook of the RASC* (see Resources). Stoneyhurst disks, Porter disks and solar grid diagrams can be downloaded from several websites including the BAA Solar Section (http://www.petermeadows.com/html/location.html). Excellent software for calculating solar orientation is *Tilting Sun* (written and developed by Les Cowley, freely available at http://www.atoptics.co.uk/tiltsun.htm).

In order to determine the orientation of the sun's equator, the E-W celestial direction should be established first. In observing by projection one can use a template in which the solar disc is crossed by two perpendicular lines. The template may then be rotated until any spot is seen drifting along one of the lines due to the apparent E-W motion of the sun in the sky, the other line then marking the celestial N-S direction. In observing directly through a solar filter, the E-W direction can be determined in the same way by means of a crosshair eyepiece of the type commonly used for guiding during deep sky photography. The E-W and N-S celestial directions differ from the true solar directions by the quantity P, the position angle of the sun's north pole, as explained below.

The sun's orientation has three key elements that the sunspot observer should understand.

Heliographic latitude (Bo) of the center of the disk results from the inclination of the sun's equator to the ecliptic (which is 7.25 deg). When Bo is positive, the solar equator is south of the center of the solar disk and the sun's north pole is tilted toward the observer. This tilt of the sun's equator results in sunspots following semi-elliptical paths across the solar disk, rather than straight lines.

Heliographic longitude of the center of the sun's disk (Lo) is measured relative to a standard longitude on the sun, known as Carrington's prime meridian and is used for identifying locations of features on the disk.

The position angle (P) between the solar axis and the north-south direction in the sky (or lines of right ascension) results from a combination of the inclination of the ecliptic in the sky (23.43 deg) and the sun's inclination (7.25 deg) to the ecliptic. When P is positive, the north pole of the solar axis is inclined toward the east.

One of the simplest ways for calculating solar orientation is by using the *Tilting Sun* software. An example from *Tilting Sun* is shown below for June 1, 2017 for the coordinates of Cambridge, MA and shows the position of the sun's equator and the east-west drift direction across the sky.

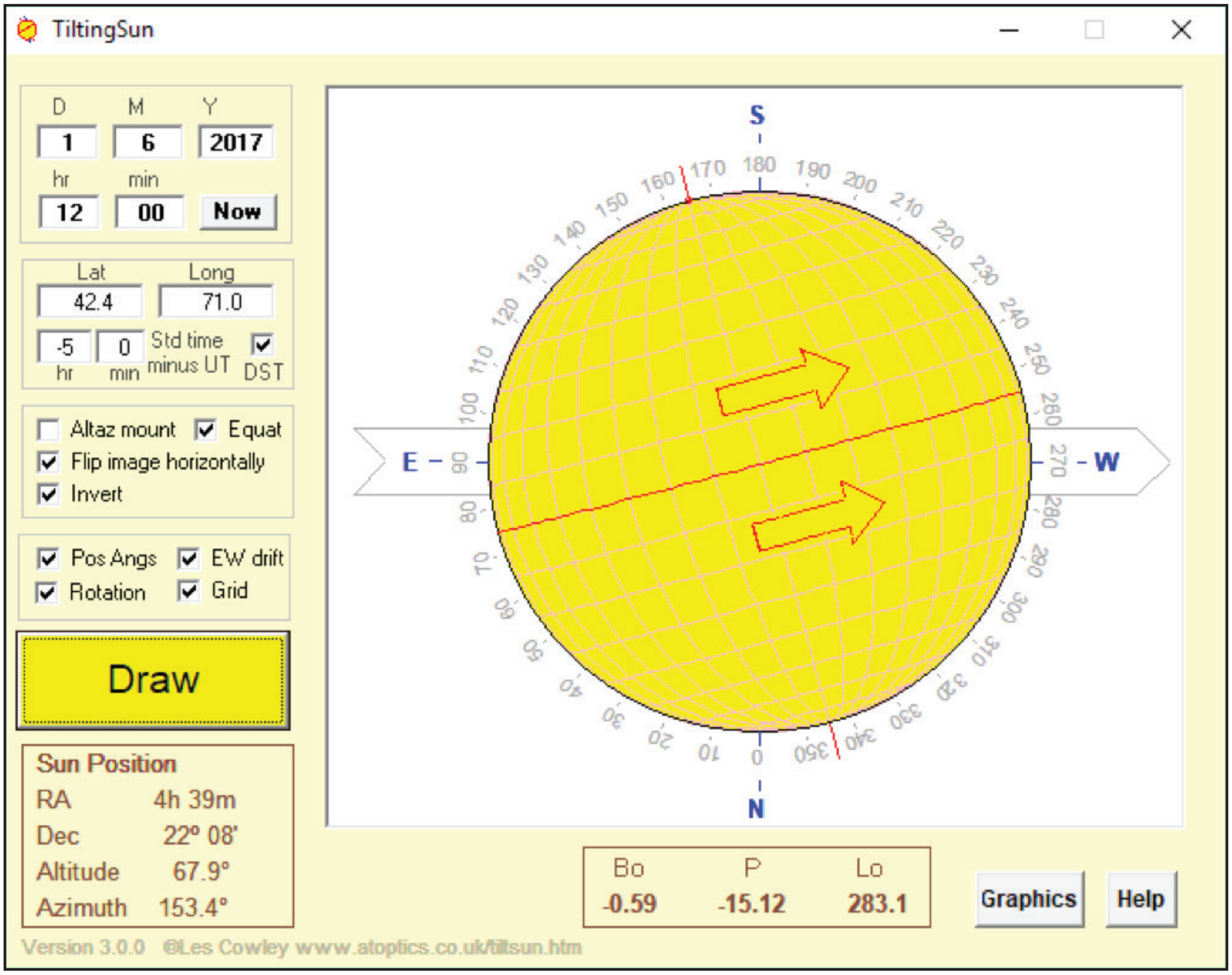
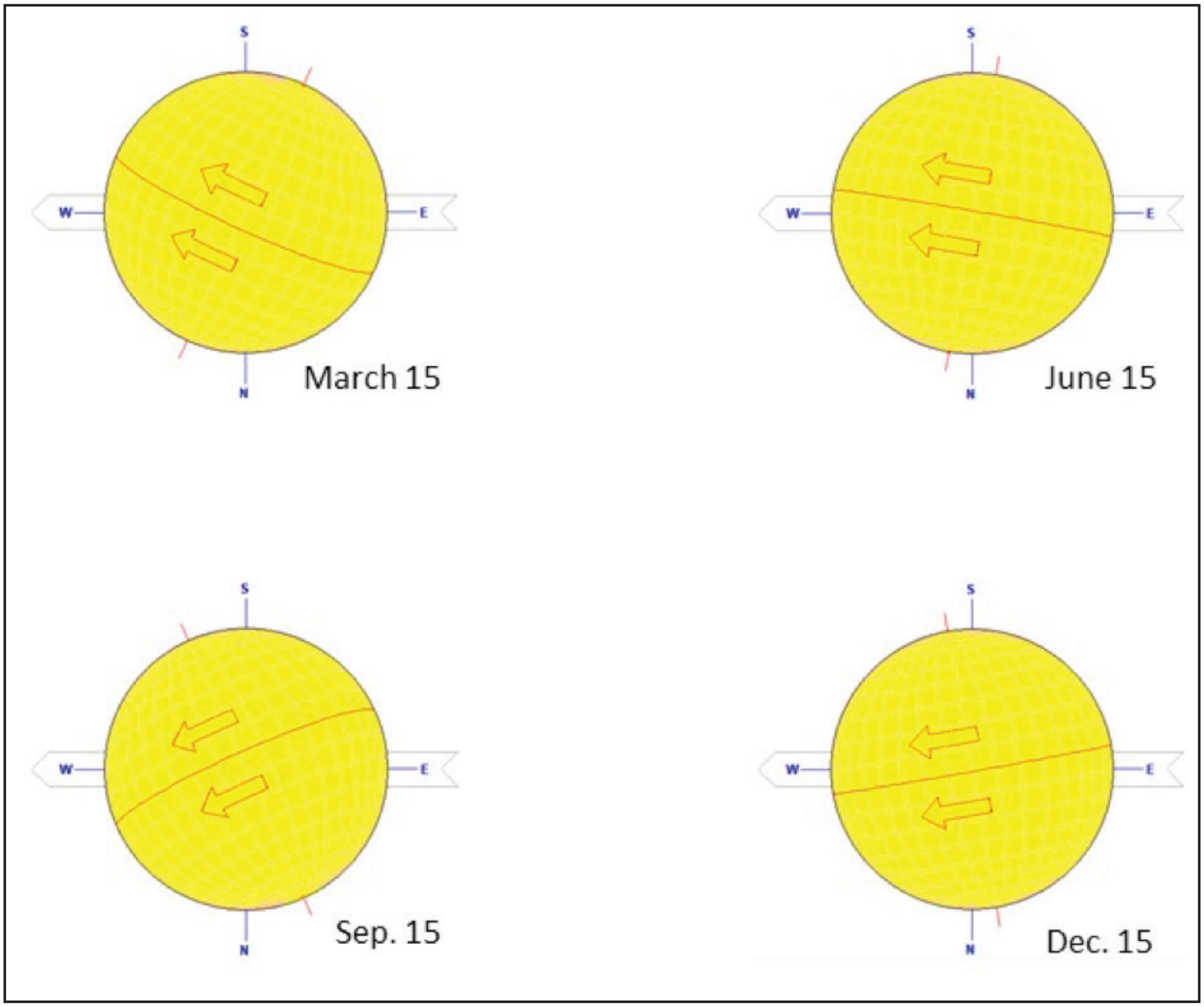


Figure showing an example from Tilting Sun (courtesy of Les Cowley - www.atoptics.co.uk)

An essential detail for the solar observer to realize is that the sun's orientation changes throughout the year as the sun's position progresses along the ecliptic.

The images on the next page show examples from *Tilting Sun* for every third month of the year to illustrate the significant changes in the orientation of the sun's equator with the drift direction across the observer's eyepiece.



Different solar orientations during the year from Tilting Sun
(courtesy of Les Cowley - www.atoptics.co.uk)

While *Tilting Sun* may be very easy to use, orientations may also be found using ephemeris values of Bo, Lo and P.

For example, the solar orientation parameters for January 1, 2017 may be found in the *RASC Observer's Handbook 2017*, p 184, and are given as P = 2.0, Lo = 123.5, and Bo = -3.0.