# Beginner's Guide to Observing the Sun

*Lee Macdonald*

The Sun can easily be observed by amateur astronomers with simple and inexpensive equipment. But before we begin, I must emphasise that observing the Sun is potentially very dangerous. **NEVER look directly at the Sun with a telescope or binoculars, even for a quick glance. NEVER use any solar filter until it has been checked out by an experienced solar observer.** Failure to heed this warning can easily cause permanent eye damage and even blindness. Even staring at the Sun with your naked eye for more than a second or two can damage your eyes.

A filter is not necessarily safe to use because it makes the Sun look dark. The Sun is dangerous not so much because of its brilliant light as the invisible infra-red and ultra-violet radiation that it emits. A filter that reduces the visible light to a comfortable level may still let through dangerous amounts of infra-red and ultra-violet. For this reason, you must never use sunglasses, over-exposed photographic film and other home-made plastic materials as solar filters, because they let through far too much infra-red. Dangerous for a different reason are Sun filters designed to screw into the telescope eyepiece. They sometimes come with very small, cheap telescopes of the sort found in high-street stores. When the filter is used in the eyepiece and the telescope pointed at the Sun, the intense solar heat is focused on the dark glass of the filter. The heated glass naturally expands, but this expansion is checked by the metal ring surrounding the filter, causing the glass to crack and thus instantly allow unchecked solar radiation to pass through to the eye of the unsuspecting observer.

The only safe type of solar filter is one *specifically designed for observing the Sun through a telescope.* These are always 'aperture' filters – that is, filters designed to fit over the front aperture of the telescope, *not* over the eyepiece. A filter must be mounted securely over the aperture, so that it does not fall off accidentally or get blown off by a sudden gust of wind. It is best to order a filter for your make and model of telescope, so that it comes in a suitable mount.

Aperture filters are of two types: Mylar and glass. Much the least expensive is the Mylar type, which takes the form of a sheet of polyester film coated on each side with a thin layer of aluminium. The wrinkled appearance of Mylar filters belies their optical quality; indeed, they should not be stretched too tight, as this can damage them. A good example of a Mylar-type filter is the material produced by the German company Baader Planetarium. Baader filters are available ready-mounted to suit specific models of telescope, or it is possible to buy an A4-sized sheet of the material and make your own mount – though if you choose to do the latter, follow the manufacturer's instructions carefully and ensure that it fits your telescope tightly. Mylar type filters tend to give a bluish cast to the Sun's image, but this is barely noticeable in Baader filters. Glass solar filters are much more expensive, but they are more durable and give a more natural, yellow tint to the solar image.

Telescopes for amateur astronomers come in three types: refractors, which use lenses to focus the light; reflectors, which use mirrors; and catadioptrics, which use a combination of lenses and mirrors. A small telescope, such as an 80mm (3.1-inch) refractor or a 90mm (3.5-inch) catadioptric is ideal for most amateurs living in the British Isles, because during the day shimmering of the solar image due to atmospheric turbulence (what astronomers call 'seeing') is usually so bad that a large aperture is of no advantage. Small telescopes have the added advantage that they are very portable and can be used on short notice – important in Britain's changeable climate.

Another important safety point: if your telescope has a finderscope, always remove it before observing the Sun, especially if young children are present. The Sun is just as dangerous to look at through a finderscope as it is through the main telescope, and curious children could easily pull the lens caps off the finderscope and look through it, with disastrous results. Indeed, you should never leave a telescope unsupervised during the day when the Sun can potentially be observed.

**Sunspots**

On most days, it is possible to see at least one or two sunspots, which are cooler patches on the Sun's gaseous surface, the *photosphere*, caused by magnetic fields preventing energy from emerging out of the solar interior. Don't be disappointed if you fail to see any sunspots, however. The number of sunspots varies over an 11-year period known as the *sunspot cycle*, which is the most visible manifestation of a more general cycle of solar activity known as the *solar cycle*. At the time of writing (Autumn 2008), we are at the minimum of the sunspot cycle, when periods of many days or weeks go by without any spots being visible. The current minimum is proving to be an especially deep one; some two months have now elapsed since I last saw any sunspots, and during 2007 and 2008 there have already been several lengthy periods without spots. Towards the maximum of the sunspot cycle (usually known as sunspot maximum), spots become more numerous, so that around maximum sunspots are almost always present to some degree. The next solar maximum is predicted for 2012.

Sunspots come in many shapes and sizes, ranging from small, simple spots barely large enough to be resolved in a small telescope to huge complexes several times the diameter of the Earth (12,756 kilometres, or 7,800 miles). Sunspots tend to occur in clusters of several spots known as 'sunspot groups'. The largest such groups can contain over a hundred individual small spots and show complex, intricate detail even in small telescopes. The largest and most complex groups tend to occur around sunspot maximum; at minimum, what sunspots there are generally tend to be small and simple. Most sunspot groups show a 'bipolar' structure, based around two principal spots, the westernmost of which is known as the 'leader' and the easternmost the 'follower'. The leader and follower spots have opposite magnetic polarities. Sunspots change their position noticeably from day to day due to the Sun's rotation, which carries them from east to west. As seen from Earth, a complete revolution of the Sun takes about 27 days, and occasionally a large sunspot group survives long enough to come back into view at the eastern limb of the Sun after having rotated around the western limb two weeks before.

When observing the Sun, you may notice occasional bright patches, especially in the vicinity of sunspot groups. These are known as *faculae* and are areas of gas slightly hotter than the surrounding photosphere. They are most easily observed near the limb of the Sun, which is slightly darker than the rest of the solar disc, causing the faculae to show up by contrast.

**Tracking Sunspot Activity**

The sunspot cycle can easily be followed with a properly-filtered small telescope. No sunspot cycle is ever the same as the previous one, and it is this unpredictability that makes observing the Sun so exciting.

The easiest way of measuring sunspot activity is to count the number of sunspot groups seen each day and take an average at the end of the month. This monthly average is known as the *Mean Daily Frequency* (MDF). For counting purposes, sunspot groups are known as 'active areas'. A group, however large or small, counts as one active area, provided it is at least ten degrees of solar latitude or longitude from any other group. Even a small, single spot counts as an active area in its own right as long as it is separated by at least ten degrees from any other group. It is not necessary to measure the ten-degree distance exactly for the purposes of demonstrating the solar cycle, and in any case it is usually easy to distinguish as to whether groups should be counted separately, as most of them naturally form at greater separations than this. If you see no sunspots, you should always record the count for that day as zero, as this will affect the monthly average.

To demonstrate how the MDF works, let us use an example from my own solar logbook. My active area counts for the month of July 2007 are tabulated below:-

| **Day** | **No. of Active Areas** |
|---|---|
| 1 | 2 |
| 3 | 1 |
| 6 | 1 |
| 7 | 2 |
| 11 | 1 |
| 17 | 1 |
| 18 | 1 |
| 22 | 0 |
| 24 | 0 |
| 29 | 1 |
| 30 | 1 |
| 31 | 0 |
| **Total** | **11** |

I saw a total of 11 sunspot groups that month. To get the average, we need to divide this figure by the total number of days on which observations were made, in this case 12.

$$\frac{11}{12} = 0.92$$

Therefore my MDF for July 2007 was 0.92 – not a high figure, indicative of the fairly low level of solar activity at the time, as the sunspot cycle was declining towards minimum.

If you measure the amount of sunspot activity in this way over a period of years and plot the results on a graph, it is possible to see the cycle rising and falling. The graph is not smooth, as activity varies markedly from month to month, but a general trend can be detected after a few years.

**The Chromosphere**

The Sun has an atmosphere, but this is not normally visible from Earth, because it is much fainter than the photosphere and scattering of the Sun's light by the Earth's atmosphere drowns it out. The Sun's atmosphere is in two parts. The outermost part is called the *corona*; it is extremely hot (more than a million degrees Kelvin) but very faint, and normally the only time amateur astronomers can see it is when the Sun is masked by the Moon during a total solar eclipse. The innermost layer of the atmosphere is called the *chromosphere*, and this part is visible from ground level using special filters. This is possible because, unlike the corona, the chromosphere emits light in certain discrete wavelengths of the electromagnetic spectrum, and these can be isolated with filters that cut out all wavelengths except the one under observation. The easiest of these discrete wavelengths to observe is the bright red light emitted by hydrogen, known as hydrogen-alpha or H-alpha, and most amateur filters for observing the chromosphere are H-alpha filters.

Unfortunately, H-alpha filters are expensive, but in recent years their price has dropped considerably and some models, at any rate, are within the budgets of amateur astronomers and schools. The cheapest H-alpha instrument on the market is a dedicated H-alpha solar telescope made by the US manufacturer Coronado, known as the Personal Solar Telescope (PST), which currently retails in the UK for around £450. Larger and more sophisticated instruments show more detail in the chromosphere, but most cost well over £1,000.

The most obvious H-alpha features are the *prominences* – dramatic, flame-like structures visible at the Sun's limb, jutting out into what looks like the blackness of space but which is really the unseen corona. Prominences come in all shapes and sizes, from tiny tufts and spikes to huge complexes with shapes resembling rows of trees. Most prominences are 'quiescent', showing only very gradual changes and appearing similar from one day to the next. But if activity is high, you may see occasional 'active' prominences, which change their appearance in as little as a few minutes and sometimes eject material away from the Sun altogether – an amazing sight.

Prominences are not always associated with individual sunspot groups, but their frequency rises and falls in step with the sunspot cycle – although even at sunspot minimum one or two prominences are usually visible, even on days with no spots.

The Sun's disc in H-alpha shows a strongly granulated appearance, a property of the chromosphere. Sunspots are still visible, but they are less conspicuous than they are in white light, because they are partly hidden beneath the chromosphere. Sunspot groups in H-alpha are usually surrounded by bright patches known as 'plages', which are similar to the faculae seen in white light. Plages often form several days before sunspots and remain for a similar length of time after the spots have disappeared, so they can sometimes be indicators of sunspot activity to come. Quite often you may see one or more dark, curved lines on the Sun's disc when you observe in H-alpha; these are known as *filaments* and are simply prominences, which look dark against the bright solar disc.

If you observe the Sun in H-alpha during high activity, you may be lucky enough to see a solar *flare*. Caused by complex interactions within powerful magnetic fields around an active sunspot, a flare shows up as a brilliant white patch (or more than one patch), which suddenly appears and rises to brilliance in a few minutes. Many flares fade away over a similar period of time, but some last much longer. Flares are particularly likely in large, complex sunspot groups.

**Solar Photography**

The Sun can be photographed quite easily with today's digital cameras, always provided that your telescope is safely filtered as for visual observing. Just about any digital camera can be used to some extent for solar photography. Digital cameras come in two basic types: the fixed-lens variety used for everyday photography and the Digital Single Lens Reflex (DSLR). The DSLR type is much the best for photographing the Sun through a telescope. DSLRs are generally more expensive than fixed-lens cameras, but like some H-alpha filters, their price has dropped dramatically in recent years and several models are now available for under £500.

DSLR cameras have three principal advantages: they are easy to attach to a telescope, they allow full manual control of the exposure and they are easier to focus, because focusing is done through an optical viewfinder and not using an LCD screen as with fixed-lens models. Fixed-lens cameras are cheaper, but they are harder to attach to a telescope because the lens is not removable. For some models of fixed-lens camera it is possible to buy an adapter to attach it to the telescope eyepiece; alternatively, you can make your own adapter, mount the camera on a separate tripod or even simply hold the camera to the eyepiece by hand – the latter can give surprisingly good results. If you use a fixed-lens camera, try to ensure that it is one with some degree of exposure control, such as spot metering or exposure compensation, because the full auto-exposure mode can overexpose the Sun surrounded by black sky, washing out the sunspots and any other detail present.

To attach a DSLR to a telescope, you need a standard camera adapter and a 'T-ring' which matches your model of camera (e.g. Canon, Nikon) to the thread at the rear of the adapter. Both of these accessories are available from telescope suppliers. Coupling a DSLR to the telescope means removing the camera lens and telescope eyepiece, and the lens or mirror of the telescope acts as the camera lens. A consequence of this is that the image scale is somewhat smaller than that obtained by attaching a fixed-lens camera to the eyepiece, but if you wish, you can increase the image scale by using a teleconverter on the camera or an eyepiece inside the camera adapter. These techniques are beyond the scope of this brief article, and in any case it is best to begin with a low magnification that shows the whole solar disc in a single shot.

Even through a filter, the Sun is very bright and you may find that exposures of 1/1000 second or less are required to capture the whole solar disc and sunspots.

Your solar images may look slightly disappointing when you first download them to your computer, with a slightly fuzzy and washed-out appearance, even when correctly exposed. But a few minutes' work with an image processing program can bring out a remarkable amount of detail in solar images. Professional image processing programs such as *Photoshop* are very expensive, but a basic package such as *Photoshop Elements* is very affordable (indeed, it sometimes comes bundled free with a new digital camera) and has all the features you need for enhancing solar images. I have found that by reducing the brightness and increasing the contrast of the image by modest amounts, I can obtain a sharp image with plenty of contrast, with sunspots standing out beautifully.

An important point to bear in mind with image processing is to always work with a copy of the original image, never the original image itself. This is so that if things go wrong, you can start again with the downloaded image.

## Going further

If you are keen on observing the Sun, or any other aspect of astronomy, it is a good idea to join a local astronomical society. Such a society is very likely to have experienced members, who will be able to give you much valuable advice on solar observing. Some societies also give talks and astronomical advice to schools. A search on the Internet or an enquiry at your local library should find the nearest astronomical society to you.

The best national society for beginners is the Society for Popular Astronomy ( www.popastro.com). For more advanced observers, there is the British Astronomical Association (www.britastro.org). Both societies have active solar sections, which will be able to guide you and offer advice on more advanced techniques than have been discussed here.

Below are a few books on the Sun and solar observing which you may find useful:-

Beck, R, Hilbrecht, H, Reinsch, K and Volker, P (eds.), *Solar Astronomy Handbook* (Willmann-Bell Inc., 1995)

Golub, L and Pasachoff, J M, *Nearest Star: The Surprising Science of Our Sun* (Harvard University Press, 2001)

Lang, K R, *Sun, Earth and Sky* (2nd edition, Springer-Verlag, 2006)

Lang, K R, *The Cambridge Encyclopaedia of the Sun* (Cambridge University Press, 2001)

Macdonald, L, *How to Observe the Sun Safely* (Springer-Verlag, 2003)

Phillips, K J H, *Guide to the Sun* (Cambridge University Press, 1992)

Reeves, R, *Introduction to Digital Astrophotography* (Willmann-Bell Inc., 2005)

Spence, P, *Philip's Sun Observer's Guide* (Philip's, 2004)