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Lee Macdonald convinced the Winchester audience that anyone can photograph the Sun

Solar photography with a small telescope

Workshop No. 2:
The 2003 BAA Winchester Weekend
2003 April 26

by Lee T. Macdonald

The Sun is one of the most fascinating targets in the sky for the amateur astronomer and also one of the easiest objects to observe. It is intensively monitored night and day by professional astronomers, so the amateur is very unlikely to make a major discovery on the Sun, as is possible in other fields, such as supernova hunting. But the amateur solar photographer can still make him or herself useful and have a great deal of fun recording the ever-changing panorama of sunspots and other solar features.

Solar photography has several advantages over other areas of astronomy. Firstly, solar work is ideal for those who like their creature comforts. Being a daytime pursuit, solar observing does not involve exposure to cold night-time temperatures, loss of sleep or fumbling for lost equipment in the dark. The Sun can be observed, to some extent, all year round – unlike the planets and most deep sky objects. Also, light pollution poses no problems for the solar photographer. You can observe the Sun from the town as effectively as in the country.

You do not need a big telescope to photograph the Sun. This is partly because, unlike most astronomical objects, the Sun has no shortage of light. Also, when the Sun heats the ground up during the day, convection currents are generated in the atmosphere, causing atmospheric turbulence to be worse during the day than at night. From most observing sites it is rarely possible to resolve solar details smaller than 1 or 2 arcseconds across. 1 arcsecond is the resolution limit for a 100mm (4-inch) telescope and so any instrument larger than this is of no advantage. My main telescope for solar photography is an 80mm (3.1-inch) refractor (Figure 1). Neither does your telescope need to have a drive or even an equatorial mount. Exposures for solar photography are typically the same length as 'snapshot' daytime exposures – too short for the Earth's rotation to show up.

Photographs show what the Sun and its features actually look like more realistically than drawings ever can. For this reason, solar images are good for demonstrating recent solar activity to astronomy clubs. They also have good educational value, as they can be used for showing what the Sun looks like to the public and to schools. Indeed, amateur photographs can sometimes be better in this regard than professional images, because the latter tend to be taken with special instruments that show a drastically different Sun than that visible with an amateur's telescope.

The solar photography skills presented in this article are also useful in photographing transient events involving the Sun – such as the partial phases of solar eclipses and the very rare transits of Venus in 2004 and 2012. I will mainly discuss my own methods and do not claim that the article covers all techniques for photographing the Sun, but it will, I hope, give some suggestions and encourage readers to 'have a go'.

Cameras and films

Had I been writing this 10 years ago, the subject of cameras would have been very simple: I would have stated that the 35mm single-lens reflex (SLR) is the best type of camera for solar photography. But in recent years electronic imaging devices – digital cameras and webcams, as well as dedicated astronomical CCD cameras – have come within amateurs' budgets and have assumed an important role. I have a digital camera, purchased from a local camera shop, and have used it with some success to photograph the Sun, but my main medium for solar photography is still 35mm film.

Given the popularity of digital imaging, why do I use 35mm film nowadays? Digital imaging has two great advantages over traditional photography. First, you can see the results straightaway, either on a computer monitor or on the camera's built-in LCD screen, and so you can learn from your mistakes quickly. Secondly, you can do all your image processing and printing 'in house', using a home computer and printer. There is no need to send films away for processing or to possess a darkroom and chemicals to do the job yourself.

Digital imaging, however, has several problems. The best digital cameras and astronomical CCD cameras are quite expensive (although prices are dropping all the time). Unlike 35mm SLRs, most popular digital cameras do not have removable lenses, which can cause

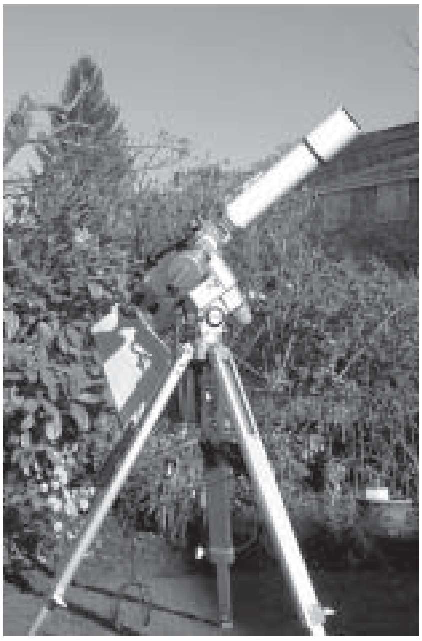

Figure 1. The author's 80mm refractor, used to take the solar images in this article. All illustrations with this article are by the author.

problems in attaching them to a telescope and constrain you to photographing the Sun using just one optical arrangement. Digital cameras also lack through-the-lens viewfinders, making it necessary to use the LCD screen to frame and focus the image through a telescope. It can be difficult to focus the image accurately using these screens and they consume battery power voraciously. If you use a webcam or a dedicated CCD camera to image the Sun you need a laptop computer to focus and control the camera and the whole system requires a lot of setting up if you do not possess an observatory. Digital SLR cameras with removable lenses and through-the-lens viewing are available, but their prices are mostly in four figures and they can be rather bulky when attached to a small telescope.

The main disadvantage with film is that, however you get the film processed, you cannot see the results of your efforts straightaway, and so it takes longer to learn from your mistakes and develop new techniques. However, in my opinion this disadvantage is outweighed by film's many advantages. 35mm cameras are cheap and reliable, tried and tested after many years of use. They require little or no battery power. A computer or LCD screen is not needed to compose and focus the image. It is much easier to focus accurately with the through-the-lens viewfinder of a 35mm camera than it is with a digital LCD screen. The best 35mm films also have a higher resolution than even the most expensive digital systems. You can still enhance and print your developed 35mm images at home, as scanners capable of producing high-resolution digital files from 35mm negatives and slides are now available for less than £300.

If you have a 35mm SLR, the chances are that you can use it for solar photography. Unless you plan to use it for night-sky photography as well, your camera does not have to be fully mechanical. The batteries in electronic cameras are quickly drained by long exposures and cold temperatures at night, but this does not apply in solar photography, in which exposures are short and temperatures are (usually!) benign. The most sophisticated electronic SLRs are usable, provided that the exposure and focus can be manually set.

Ideally, your SLR should be capable of taking exposures down to 1/1000-second. To reduce vibration when the camera is attached to the telescope, the camera should have a smooth shutter release and, if possible, some way of locking up the internal mirror – the main cause of camera vibration – well before the exposure. This can be either a lever to lift the mirror out of the light path or a self-timer device that flips up the mirror a few seconds before the shutter is released. Another useful feature is the ability to change the focusing screen in order to substitute the standard ground-glass screen with a clear screen, which allows you to focus more accurately. My main camera for solar photography is an Olympus OM-1, a model no longer made but often obtainable second-hand in camera shops. It has an very smooth shutter release mechanism, including a mirror-locking lever, and interchangeable focusing screens. The OM-1 is fully mechanical, so I can also use it for night-sky photography.

It is important to use a cable release, in order to avoid shaking the camera when you fire the shutter. This is another area where the 35mm SLR scores over most digital cameras, as the latter usually have no facility to take a cable release.

You can photograph the Sun on black-and-white film just as well as you can in colour, as the Sun has very little true colour and black-and-white emulsions have finer grain than colour films of the same sensitivity. The main aim in solar photography is to capture as much detail as possible, so the finer the grain of the film the better. By far the best black-and-white film is Kodak Technical Pan 2415, which has high contrast and exceedingly fine grain. It is however expensive to get good prints made from black-and-white negatives. For this reason I normally use slow colour slide film (though I may return to black-and-white with the advent of affordable film scanners). My films of choice over the last three years have been Kodak Elite Chrome 100 and Fujichrome Velvia (50 ISO). Slide processing involves only one step and so is economical. Colour print film should not be used for solar photography. Not only is it difficult to get commercial laboratories to print astronomical negatives properly (or print them at all), but these films typically have a low contrast and delicate solar features can appear washed out.

Filters

If you use the projection method to view the Sun's image visually, it is possible to photograph the projected image using any kind of camera. This method is not suitable for serious solar photography, however, for two reasons. First, you have to place the camera to one side of the telescope's optical axis, leading to a distorted image in the final photograph. Also, photographs of projected images usually have a very poor contrast. To take high-quality images of the Sun, you need to shoot directly through the telescope, which must be fitted with a solar filter to protect the camera and – most importantly of all – your eyesight.

Choosing and using filters for solar photography requires the same level of caution as for visual observing, because an inadequately-filtered image of the Sun is just as dangerous when seen in a camera viewfinder as it is when viewed through an eyepiece. It is the Sun's *invisible* radiation, from the infrared and ultraviolet, that is most harmful to the eyes. For this reason, you must never use makeshift filters made from materials such as compact discs, floppy discs, tinfoil or photographic film. They may dim the solar image enough for you to look at it comfortably, but they transmit far too much infrared. Another very dangerous filter is that designed to screw into an eyepiece, like a lunar or planetary filter, and sometimes found with cheap, imported telescopes. These filters are placed very close to the telescope's prime focus where the Sun's light and heat is most strongly concentrated, and they can crack without warning under the intense heat.

Figure 2. Whole-disk image, 2002 August 17, showing a very large sunspot. 80mm refractor with ×2 teleconverter, Baader AstroSolar Photo Film and light yellow filters, exposure 1/500 second on Fujichrome Velvia (50 ISO).

The only safe solar filters are 'aperture filters' – i.e. filters designed to go over the front of the telescope. These are of two types, both employing thin layers of metal to reject the Sun's light and heat. The cheapest is the Mylar type, which consists of a sheet of thin Mylar or other plastic substance coated on both sides. You can buy Mylar filters in ready-made mounts to fit a variety of commercially-available telescopes, or you can buy the material in sheets and mount it yourself. In my experience, the best filter of this type currently on the market is known as 'AstroSolar Safety Film', manufactured by the German firm Baader Planetarium and available in the UK from David Hinds Ltd. It gives sharp, high-contrast images and the colour of the image is a very pale bluish-purple – a big improvement on the strong blue colour cast produced by older filters of this type. An A4 sheet of this material is currently available for just £13, making it very good value for money indeed.

Glass solar filters consist of a thin glass disc, made flat and polished to optical quality, resulting in them being more expensive, typically £70–100 for those designed to fit small telescopes. On the plus side, these filters produce a pleasing, realistically-coloured yellow image of the Sun and are more durable than Mylar-type filters.

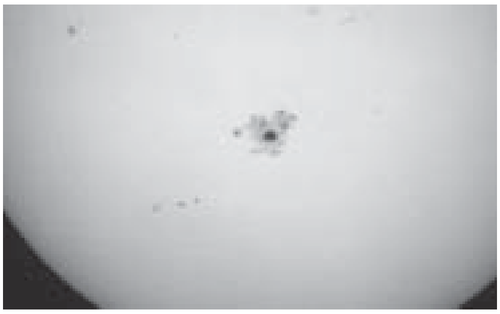

Figure 3. Close-up of the large sunspot shown in Figure 2, 2002 August 17. 80mm refractor with eyepiece projection (effective f/ratio = f/80, effective focal length = 6,400mm), Baader AstroSolar Photo Film and light yellow filters, exposure 1/125 second on Fujichrome Velvia (50 ISO).

Most solar filters of glass and Mylar type are designed primarily for visual observing and are coated to a neutral density of 5 – that is, they let through 10^{-5} or 1/100,000th of the Sun's light. Such filters are adequate for photographing the whole solar disc at low magnification, but for close-ups of individual sunspot groups the image becomes very faint and it is necessary to increase the exposure time, resulting in blurred images. To shoot at high magnification you need to use a filter designed specifically for photography. These are coated to a neutral density of 4 (letting through 1/10,000th of the Sun's light), allowing short exposures even at high magnifications. Examples of such photographic filters include Baader's Mylar-type 'AstroSolar Photo Film' and the Type 3+ filter produced by Thousand Oaks Optical. If you are serious about solar photography with 35mm film you should consider buying one of these. Note, though, that you must not look at the Sun through one of them, even for focusing, as they may let through unsafe levels of light and heat. Always focus using a standard visual filter and then switch over to the photographic filter. It may not be necessary to purchase a photographic filter if you plan to do digital imaging, as the high sensitivity of CCD chips may allow you to use visual filters even at high magnifications.

Whatever the type of filter used, always check that it is safe before using it. If you are new to solar observing or are unsure about a filter's suitability, get an experienced solar observer to look it over for you.

Photographic techniques

The simplest type of solar photography involves imaging the whole solar disk, showing the principal sunspot groups. The best method is the 'prime focus' method, in which the telescope acts like a telephoto lens and the camera is attached with a standard camera adapter. In a small telescope, though, this method can make the image too small to show much detail. For example, my 80mm refractor has a focal length of 910mm, which gives a solar image on the film just 8mm across using this method. It is quite easy to magnify the image using a teleconverter lens in front of the camera. A 2× teleconverter gives my 80mm refractor an effective focal length of 1,820mm, resulting in a 16mm-diameter solar image that fills up a good part of the 35mm frame and shows plenty of detail (Figure 2). Using a standard visual Baader AstroSolar filter over the aperture, I have found that exposures of 1/125 or 1/250 second on 100 ISO film give good solar images with this method.

One accessory I have found to be useful is a light yellow filter, screwed into the front of the camera adapter and used *in addition to* the main aperture filter. This replaces the slight bluish-purple cast produced by the main filter with a more natural yellow tint. It also increases the contrast of sunspots and sharpens the image slightly, perhaps by eliminating some of the false colour inherent in my achromatic refractor.

To take close-ups of sunspots you need to magnify the image much more. The main objective when taking such close-ups is to capture as much fine solar detail as possible, including the umbrae and penumbrae of the main spots and other details within sunspot groups. To capture these details on 35mm film it is necessary to use an effective focal length of at least 5,000mm.

The easiest method of achieving such long focal lengths is eyepiece projection. This involves inserting an eyepiece in front of the camera body so that it projects a magnified image onto the film, rather like the lens in a projector throwing a magnified image of a slide onto the screen. The further the film is behind the eyepiece, the longer the effective focal length and the higher the magnification. Alternatively, an eyepiece of shorter focal length will have the same effect. To take photographs with this method you need an eyepiece projection camera adapter into which an eyepiece can be inserted. If your telescope is an SCT this is known as a *tele-extender*. The best type of adapter or tele-extender is the variable type, which allows you to use a range of magnifications with a given eyepiece by varying the distance between the eyepiece and film.

To work out how powerful your eyepiece projection setup is, first find the effective focal ratio from the following relation:

$$\text{Effective focal ratio} = [F\,(D - f)]\,/\,f$$

where F is the telescope's original f/ratio, D is the distance between the eyepiece and the film and f is the focal length of the eyepiece used. For example, to take sunspot close-ups with my 80mm refractor (whose f/ratio is f/11.4), I typically use a 15mm Plössl eyepiece and an eyepiece-to-film distance of 120mm. (You cannot measure this distance precisely, because you cannot see the eyepiece inside the adapter, but you can usually make a rough estimate.) Inserting these numbers into our formula, we obtain:

$$[11.4 \times (120 - 15)]\,/\,15 = 79.8$$

Because our measurement of D is not precise, it is as well to round off the f/ratio to the nearest whole number, in this case f/80. To obtain the effective focal length, multiply the effective focal ratio by the telescope's aperture. In this example, my telescope's aperture is 80mm. Multiplying 80 by 80 gives 6,400mm – easily long enough to reveal fine solar detail.

The main key to obtaining good solar close-ups, however, is to *keep your exposures short*. If you shoot with shutter speeds slower than around 1/125 second, the image begins to blur, partly due to atmospheric turbulence but mostly because of camera shake. The vibrations caused by the camera's shutter release and reflex action can be enough to blur the image in a telescope projecting a highly magnified image. But if you use a shutter speed of 1/125 second or faster there is not enough time for camera shake to register. With a full-aperture filter made from Baader AstroSolar Photo Film and eyepiece projection giving an effective focal length of 6,400mm at f/80 on my 80mm refractor, I can take close-ups of sunspots using exposures of 1/125 or 1/250 second on 100 ISO slide film (Figures 3 and 4).

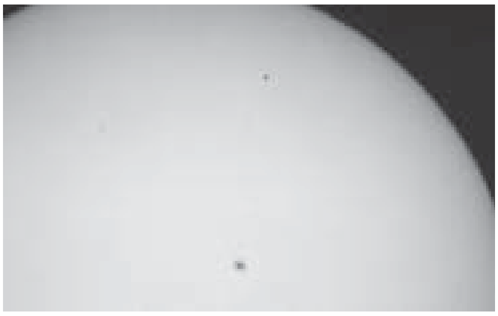

Figure 4. Transit of Mercury, 2003 May 7. 80mm refractor with eyepiece projection (effective f/ratio = f/87, effective focal length = 7,000mm), Baader AstroSolar Photo Film and light yellow filters, exposure 1/125 second on Kodak Elite Chrome 100.

Photography in hydrogen-alpha

Thanks to modern filter technology, it is possible to image part of the Sun's

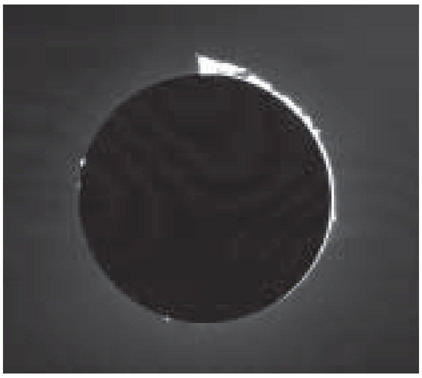

Figure 5. Prominences around whole solar disk, 2002 October 12. 80mm refractor with Baader coronagraph, exposure 1/30 second on Fujichrome Velvia (50 ISO).

atmosphere as well as the photosphere. The corona, the outer part of the atmosphere so prominent during a total eclipse, emits a continuous spectrum and so unfortunately cannot be photographed even with filters. Just above the surface, however, is the *chromosphere*, a thin layer of hydrogen which emits strongly in the hydrogen-alpha (H-alpha) line, located in the red part of the visible spectrum. Filters are now available which use sophisticated coatings to isolate the H-alpha line and allow amateurs to view and photograph activity in the chromosphere.

The most spectacular features visible through an H-alpha filter are *prominences* – large, flame-like clouds of hydrogen around the Sun's limb, which are visible with ordinary instruments during a total eclipse but are otherwise overwhelmed by scattering of sunlight by the Earth's atmosphere. Prominences come in all shapes and sizes and some change their appearance in a matter of minutes, although many stay the same for much longer periods.

How much detail you can see in H-alpha depends on the type of filter you use. The cheaper H-alpha filters let through 0.15nm (1.5 Angstroms) or more of the spectrum, centred on the H-alpha line – that is, they have a *passband* of 0.15nm. These filters show prominences but the Sun's disk is featureless, except for sunspots. If your filter has a passband of less than 0.1nm (1Å), you can also observe or photograph chromospheric features on the solar disk, above the photosphere. When viewed through such a filter, the Sun's disk has a strongly granular appearance and it is usually possible to see some *filaments* – dark, sinuous features, which are prominences seen in silhouette against the photosphere. Sunspots are often surrounded by bright *plages* and are sometimes half-hidden by chromospheric activity. Active spot groups sometimes produce *flares* – violent outbursts that are visible as brilliant patches in or near the groups.

Filters transmitting less than 0.1nm of the solar spectrum are known as *sub-angstrom* filters. Only three manufacturers are currently producing these filters for amateur astronomers – the DayStar Filter Corporation, Coronado Instruments and the recently-founded Solarscope. Because of the complexities of their coatings, all H-alpha filters are expensive, usually costing well over £1,000 and sometimes running to £3,000 or more. The price of a filter increases with both its size and the narrowness of its passband. A breakthrough in H-alpha filters came in 2001 when Coronado Instruments introduced their 40mm-aperture 'Solar Max' filter – the first sub-angstrom H-alpha filter to be available for under £1,000.

Unfortunately, H-alpha features have a delicate contrast and are notoriously difficult to capture on 35mm film. An additional problem is the fact that the prominences are much fainter than the disk and so require a longer exposure, making it difficult to image both prominences and disk features at the same time. The best H-alpha photographs of disk features have been taken using Kodak TP2415 film, which has very high contrast and strong red sensitivity, making it very efficient for H-alpha work. One solution to the brightness differences between the prominences and disk is to take two images in quick succession – a short exposure for the disk and a longer one for the prominences – and then to digitally combine them to create a composite image.

Although I possess a Coronado Solar Max filter and have had some beautiful views with it visually, I have made no attempt at 35mm photography through it yet. I have, however, had considerable success at photographing prominences with a *coronagraph* attached to my 80mm refractor. The name 'coronagraph' is rather misleading, as the device does not show the corona, but it blocks out the brilliant solar disk with an occulting disc like the coronagraphs found at professional mountaintop observatories. Behind the occulting disc is an H-alpha filter of 0.15nm passband – too broad to show disk features but narrow enough to reveal prominences. The device is made by Baader Planetarium, the same firm that makes the white light filters, and a 35mm camera can readily be attached to it.

The view through the coronagraph is in many ways like a total solar eclipse – although without the solar corona, of course. Whereas using many sub-angstrom filters requires stopping down the telescope aperture, the coronagraph can be used at the full aperture of my 80mm refractor, giving bright images and showing intricate details in prominences. Also, because the Sun is hidden by the occulting disc, the contrast of the prominences is much higher. Again, Kodak Technical Pan 2415 or Elite Chrome 100 are a good choice of films. I have taken many images showing prominences around the edge of the solar disk using exposures of 1/250 to 1/30 second (see Figure 5).

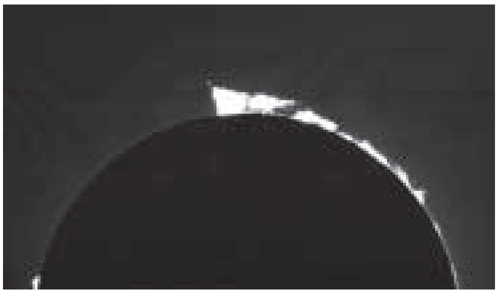

Figure 6. Close-up of the prominence complex shown in Figure 5, 2002 October 12. 80mm refractor with Baader coronagraph and ×2 teleconverter, exposure 1/8 second on Fujichrome Velvia (50 ISO).

The coronagraph gives my 80mm refractor an effective focal length of 1,365mm at f/17, producing a 12.5mm-diameter image on 35mm film. This will show prominences around the whole Sun, but detail within the prominences is obviously limited at this image scale. A teleconverter will enlarge the image and show much more detail. Beware, though, that doubling the magnification also means doubling the effective f/ratio and thus quadrupling the exposure time (Figure 6).

Digital solar photography

In spite of the disadvantages of digital photography described above, it is possible to take excellent solar images with a digital camera, CCD equipment or a webcam. I have had some success with digital cameras of the type found at a camera shop, and will describe my techniques in the final part of this article.

Practically any of today's digital cameras can be used to some extent for solar photography, but it is a great advantage if the camera has a threaded lens

Figure 7. Sunspots, 2002 September 22, 80mm refractor with Baader AstroSolar Safety Film (visual) filter. Imaged with Nikon Coolpix 900 digital camera coupled to 26mm Plössl eyepiece using ScopeTronix adapter. Self-timer and auto-exposure used.

cell, as the camera can then be clamped directly to the telescope. Because the lens on most digital cameras cannot be removed, we need to image the Sun by pointing the camera into the eyepiece – a method known as the *afocal* method. If the camera has no lens thread, it has to be positioned slightly away from the eyepiece, allowing stray sunlight to enter the picture. This can be eliminated by using a cloth between the camera and eyepiece, but the arrangement is rather cumbersome. The US firm ScopeTronix makes a large variety of adapters that allow many makes and models of digital camera to be clamped to the eyepiece.

The latest digital cameras are quite expensive, around the upper end of the three figures bracket, but many good cameras are coming onto the second-hand market as users upgrade to new models. For example, my (admittedly rather basic) Nikon Coolpix 900 cost just £200 secondhand. If you can afford it, choose a camera with through-the-lens viewing – as noted above, it can be difficult to focus in bright sunlight using the LCD screen found on most cameras. If you have to use the screen, try making a simple sunshade from cardboard or black paper. Another very useful feature is a remote control, enabling you to take exposures without touching the camera and introducing vibration.

Before starting a photographic session, make sure your camera has fresh batteries and an additional supply of batteries on standby, as digital cameras consume power very quickly. As already noted, a normal visual solar filter over the telescope aperture will suffice, as digital cameras are quite sensitive and can cope well even at high magnifications. Point the telescope at the Sun, switch on the camera and focus as well as you can. You may find that the picture on your screen suffers from heavy vignetting – i.e. the outer part of the picture is cut off by the field of view – and you may have to use the zoom feature on the camera to eliminate this. If your camera does not have a remote control, activate the self-timer, which delays the exposure until several seconds after you have pressed the shutter release and so reduces camera shake. Many digital cameras do not allow manual exposure setting, but you can still experiment with various light metering methods and zoom settings (Figure 7).

The resulting images may look washed out when you first download them to the computer. However, basic image processing can improve your pictures drastically. Professional image processing software, such as Adobe *Photoshop*, is very expensive but simpler programs such as *Photoshop Elements* and *PhotoDeluxe* are much cheaper and have all the required features. Such programs often come ‘bundled’ with PCs, scanners and digital cameras. Begin by cropping out unwanted black sky or parts of the Sun dimmed by vignetting. Then adjust the brightness and contrast of the image using the relevant tools in your software. I have found that reducing the brightness value substantially and then increasing the contrast just a little can greatly increase the contrast of the picture. You can also make the image look sharper by applying the ‘sharpen’ feature and sharper still using unsharp mask, although over-use of these tools can make the image look grainy.

Conclusion

Solar photography with a small telescope is not always easy, but the rewards come with practice. You need to get a number of things right – camera, filter, film, focusing and exposure. With my 80mm refractor I have taken many useful images which have supplemented my visual observations and have had a lot of fun in the process. I hope that the techniques outlined above will inspire others to have a go at recording their solar observations photographically.

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Further reading

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