1
Imaging Star Trails

In the days of film, capturing star trails used to be a relatively easy project. In the classic example, one simply pointed the camera at the Pole Star and took a single long exposure. With digital cameras, things are not quite so easy due to the 'dark current' produced in the sensor which greatly increases the noise level and overwhelms the image for very long exposure times. Thus the long exposure required to show star trails has to be made up of many short (~30 seconds) exposures which must then be combined to give the final image. This used to be a very complex business, but happily a wonderful program written by Marcus Enzweiler and called *StarStax* has become available to freely download and this takes away all the hard work. It may be downloaded from the Softpedia.com website – just search for 'StarStax Softpedia'.

But first one has to find a suitable location to take the multiple images. If one looks at similar star trails images on the Internet, those that stand out have interesting foregrounds – in one, the lamp housing of a lighthouse covers the Pole Star; in another, an attractive church lies in the foreground. So it is well worth trying to find such a location. To take the classic view of stars trailing around the North Celestial Pole one also needs an unobstructed view towards the north. I have often taken astronomy groups to a parking place on the south side of a mere (lake) near my home in Cheshire. This is about as dark a location as one can easily find in east Cheshire and has an open view to the north. I hoped that the lake would provide an interesting foreground but knew that there would be significant light pollution towards the north as one is looking over Manchester. I went there on a still evening with a transparent sky overhead (so reducing the effects of light pollution), equipped with a sturdy tripod on which to mount my Nikon D7000 camera and Sigma 10–20 mm lens. Wide angle lenses tend to give the most impressive views.

By the lakeside and alongside a convenient bench (as seen in Figure 1.1) I set up the camera pointing towards the Pole Star and set the Sigma 10–20 mm zoom lens to 10 mm (15 mm equivalent focal length) and at its full aperture of f/3.5. I sat beside the camera, wearing several layers of clothing and beneath a duvet cover (the air temperature was four degrees Celsius as I arrived and dropped to zero degrees Celsius as time went by) and manually took a series of 30-second exposures at ISO 800: stored as JPEGs to minimise the post-processing. To reduce the effect of any camera shake as

Figure 1.1 Looking north from the south side of Redesmere lake from where the star trails image was taken

the shutter was pressed, a delay of two seconds was used prior to taking the exposure. It is important that the 'long exposure noise reduction' function of the DSLR is switched off. This takes a second 'dark frame' with the shutter closed so that any amplifier glow or hot pixels can be removed by subtraction from the image. If used, there would thus be 30 second gaps between each exposure – absolutely not what is wanted when taking a star trails image. Every so often I checked the image displayed on the rear screen for signs of dewing. Cassiopeia was directly above and, when fully dark adapted, I could faintly make out the band of the Milky Way arching overhead. The imaging session ended after 50 minutes as the camera lens, perhaps not surprisingly, had dewed up!

As will be seen, 50 minutes was long enough to produce an attractive image. But should the total imaging time required be significantly longer, further steps need to be taken to both prevent the lens dewing up and provide a continuous power supply to the camera. To achieve the former is both cheap and easy. An old sock can simply have its toe removed so that it can be pulled over the lens and two hand warmers placed within it. Once activated, these will supply heat for many hours. A more sophisticated, but expensive, approach is to buy a 'LensMuff' produced by Kevin Adams in the USA (www.kadamsphoto.com). Be warned though, if importing them into the UK, one may well have to pay VAT (not excessive) but also a Post Office handling fee (which is). However, they can also be used to prevent dew forming on the objective of small refractors and so can make a useful and far less expensive alternative to using a dew strap with its associated power supply and controller.

Figure 1.2 A 'LensMuff' to hold two or three hand warmers which will prevent dewing up of the camera lens

To provide a continuous power supply to the camera one can purchase an AC power adapter kit that provides a dummy battery powered from an external AC supply. These are available for virtually all DSLR cameras. As these are mains powered there is a further problem when using one at a dark site such as would usually be chosen for a star trails image. A 12 volt battery will be required as well as a 12 to 220 volt DC to AC power inverter. Many astronomers use SkyWatcher Power Tanks, which are available with capacities of 7 or 17 Ah, but there are several alternatives, such as jump-start batteries, which will often have a 12 volt socket to take the plugs normally used by the inverters for their 12 volt supply. (A very similar setup is used when imaging meteor trails and is shown in Figure 17.1.)

There is one further very useful accessory that can be used so that manual initiation of each exposure is not required and that is an intervalometer. This will automatically initiate each exposure and not cause any camera shake. When, say, a 30-second exposure is set in the camera's manual mode, the interval between exposures would be set to 31 seconds and a long sequence of exposures programmed. The Viltrox MC Series 'Digital Timer Remote Controller' that I have used can initiate a sequence of up to 399 exposures. It is important that the unit has the correct connector for the camera to be used. Some cameras have built-in intervalometers but I have found these to be somewhat fiddly to use, especially in the dark, and much prefer to use an external unit. They are not expensive and can also be used as a remote shutter release when single exposures are to be taken.

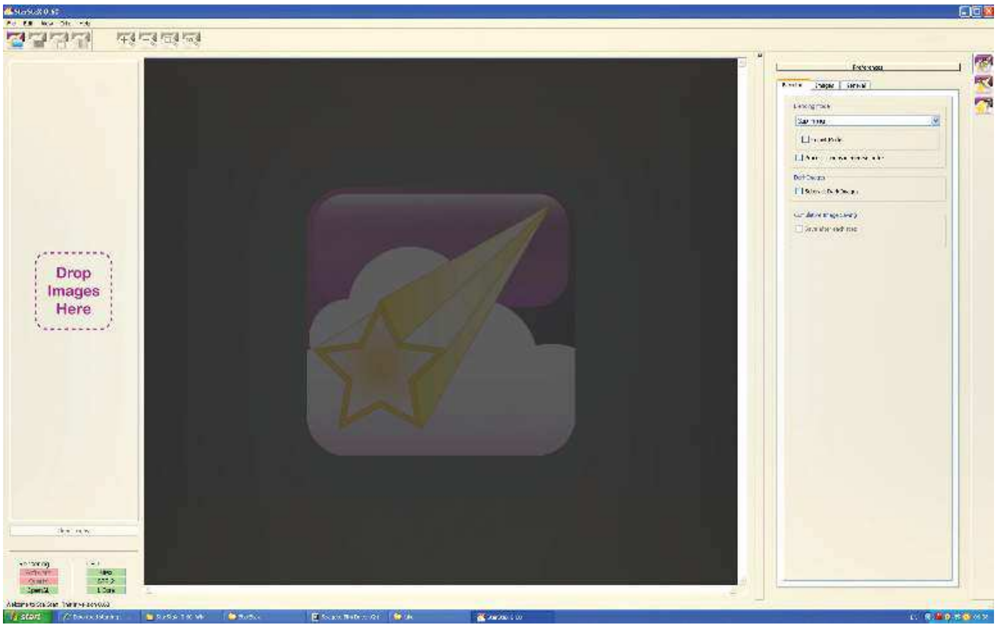

Figure 1.3 The *StarStax* opening screen

Back at home, the images were downloaded into a folder on the PC, and *StarStax* opened up as seen in Figure 1.3. The image processing was amazingly simple: first the 100 JPEG images were selected and dropped into the image box (seen on left in Figure 1.4) and then the ‘Gap Filling’ blending mode was selected in the preferences box, which was opened by clicking the ‘gear wheel’ icon at the top right of the screen. This mode fills in any gaps in the trails caused by the short breaks between exposures.

Though the images were heavily light polluted, the stars making up the Plough could be seen at the bottom of the first image and Polaris was very close to the image centre. The bright star at the upper left is Vega and the star just above the tree is Capella. The constellation Cassiopeia lies near the top of the frame.

The ‘Start processing’ icon (fourth from the left at the top left of the screen) was clicked and, as the program ran, the star trails gradually became apparent, taking a few minutes to build up the complete picture as seen, partly through the process, in Figure 1.5.

As I had seen in the camera rear screen display of individual images, the sky was an orange-red colour owing to light pollution from the Manchester area. The effect was not too unpleasant but more prominent than I wanted. I simply loaded the image produced by *StarStax* into *Adobe Photoshop*, opened the Levels box, selected the red level slider (rather than the overall RGB slider) and moved the ‘black point’ over to the right, so reducing the amount of red in the image. To avoid the railings in front of my camera, I had not included the lake when capturing the star trails, but to capture it, took a single 30-second exposure with the camera above the railings and tilted

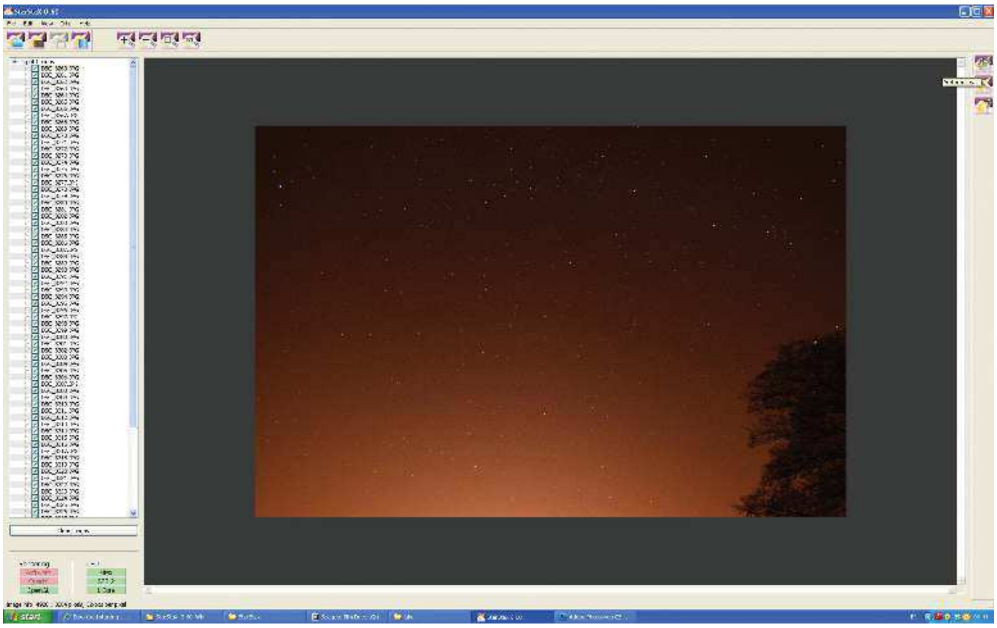

Figure 1.4 The 100 JPEG images have been loaded into *StarStax*, which then shows the first image

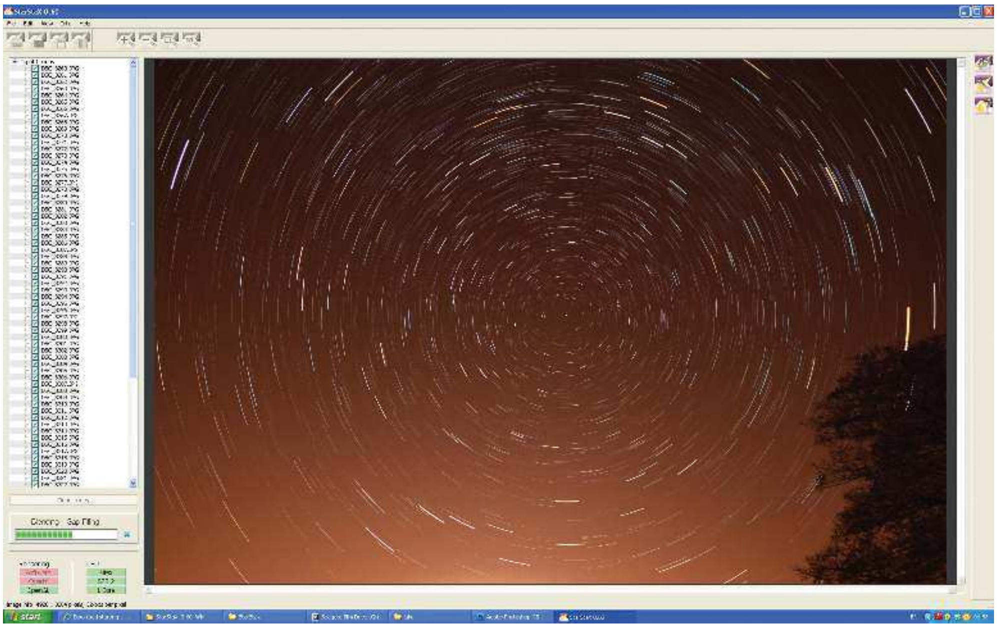

Figure 1.5 *StarStax* has combined half of the 100 individual images

Figure 1.6 Star trails over Redesmere taken with a Nikon D7000 camera and Sigma 10 mm, f/3.5, wide angle lens

a little lower. *Photoshop* was then used to merge the star trails and lake images. The star trails and lake images were opened up together and the canvas size of the star trails image increased downwards using a black background. By opening the 'Clone Stamp' tool and suitably clicking, with the Alt key pressed, on a defined point in the lake image (this was a point at the far end of the lake), the star trails image was opened and the lake image cloned over the black extension on the star trails image to give the result seen in final image shown in Figure 1.6.

Though getting rather cold, sitting still under a dark and cloudless sky for nearly an hour was actually a rewarding experience and I felt that the resultant image had made it very worthwhile. I hope that some of you might try to achieve similar, and hopefully even better, results yourselves.

2
Imaging a Constellation with a DSLR and Tripod

This is a simple project for beginners but, as we will see, to get attractive results does require some effort in processing the images. The chapter introduces a highly important program called *Deep Sky Stacker* and a second, very useful, program called *IRIS*, and so is important even if images are only to be taken using telescopes.

The problem is that DSLR sensors are far better than film. When looking at a constellation image produced by a film camera, the brighter stars are perceived as such not so much by the fact that their images are brighter than others – all but the faintest stars will actually have a very similar brightness – but that their images are larger than those of fainter stars. This is similar to the way that star charts show stars of differing magnitudes. The reason is that film suffers from a problem called 'halation': the light from very bright objects can scatter off the back of the film and expose adjacent areas of the image, so making these regions, in our case bright stars, larger and more prominent. Though DSLR sensors do make the bright star images a little larger than the fainter ones, the effect is far less, and the initial image will not make the constellation patterns stand out. Digital constellation images can thus appear somewhat disappointing. Fear not – image processing programs such as *Adobe Photoshop* can be used to process the sky image to make the brighter stars more prominent and bring out their colours.

Aspects of the Use of DSLRs for Astroimaging

Sensor Size

Some years ago I would never have considered anything but a camera with an APSC (advanced photo system – C) sensor. At that time, the cost of full frame DSLRs having a sensor 36 × 24 mm in size was very high and for the same money one could purchase a cooled CCD camera which would be more worthwhile. However, prices have fallen considerably and it is now possible to purchase both Nikon and Canon full frame (FX) cameras for no more than the cost of my Nikon D7000 with an APSC sized sensor (DX) bought some years ago. The good thing about FX sensors is that they cover more than twice the area of sky as compared to a DX sensor (2.35 times in the case of Nikon APSC sensors and 2.63 times for Canon). This would make them very suitable for imaging meteor trails, as will be discussed in Chapter 17. It is not quite so obvious that they should be used with a telescope. Unless the telescope and field flattener elements (in telescopes termed astrographs) have been designed for use with an FX sensor, it is likely that images will suffer from both vignetting (darkening) and poor stellar images in the frame periphery. In the case of the former, discussed in Appendix E, corrections can be made by the use of flat fields (images of a uniform-brightness white surface) which are loaded along with the light frames (those of the object to be imaged) into the program to align and stack the images. In the case of the latter there are some techniques in *Photoshop* that can be used, which will be described in this and later chapters.

The Use of Raw and/or JPEG Files

A DSLR will typically read the data out from the sensor with a 12- or 14-bit analogue to digital converter (ADC). It may be possible to choose which bit depth is used, in which case choose the higher for astronomical imaging. If the output files are in the form of JPEGs only the most significant 8 bits will be output for each colour channel per pixel. As each pixel is only sensitive to one colour (as determined by the colour filter in the Bayer matrix above the sensor), interpolation is used to provide a colour value for the two colours per pixel that are not measured. The camera processor may well employ some scaling of the data before generating the JPEG file. There will thus be three bytes (8-bit words) saved per pixel. If a raw file is output, then for each pixel a 16-bit word will be saved. These should closely relate to the actual data readout from each pixel, but there may be some scaling. For example, the sensor in the Nikon D7000 is somewhat more sensitive to green light (as are most CCD or CMOS sensors) and so the values read out from the red and blue pixels are multiplied by 1.126 and 1.160 respectively before they are saved in the raw file. The software that processes the raw file has to know the format of the Bayer matrix used above the sensor in order to 'de-Bayer' the data to produce a colour image.

In general, therefore, it is better to save and process raw files, but as each image has to be passed through a raw converter, they can be slow to look through to find images, called light frames, that might suffer from tracking faults (perhaps due to a gust of wind) or have a plane or satellite passing across the field of view. I thus always save both raw and JPEG versions of each frame (though only JPEGs for star trail or meteor imaging as hundreds of frames might then be taken during an imaging session) as these can be easily scanned through to eliminate any poor frames before they are aligned and stacked.

Choice of ISO

An important difference between the ASA of a film and the ISO used by a digital camera when imaging is that a film with a high ASA (say 400) is actually more sensitive than one of low sensitivity (say 50). The silver halide crystals are larger in a high ASA film and so are more sensitive to light, but with the consequence that high ASA images will show more grain. In contrast, the sensitivity of a camera sensor is fixed and will depend on the size of the pixels and the technology employed. Modern camera sensors are far more sensitive than they were, partly because of the use of microlenses above each pixel which capture more light to focus into the pixel well, which is smaller than the overall size of the pixel owing to the supporting electronics surrounding the well.

When the ISO is increased, the gain of the amplifiers reading out the pixel data is increased, so making it appear that the sensitivity of the sensor is increased. This will tend to introduce more noise into the image, so high ISO images will naturally be noisier. The effect is often mitigated by the use of in-camera noise reduction – which is probably best turned off if JPEG files are to be used. Beyond some ISO value, which is thought to be 800 for my Nikon D7000 camera, the data readout (exactly as it would be at ISO 800) is simply multiplied by 2, 4, and 8 for ISOs of 1600, 3200 and 6400 respectively. As fewer effective bits are used, with the least significant bits containing more zeros as the ISO is increased, the noise level is bound to increase. So if raw files are to be saved – as will usually give the best results – there is little point in using ISOs greater than ~800.

When long exposures, of say 30 seconds, are made with a DSLR, the default mode is that 'long exposure noise reduction' will be applied. When the image (light frame) has been taken, a second exposure of the same length is taken with the shutter closed (a dark frame). The two images are then differenced in order to remove hot pixels and any amplifier glow that can sometimes be seen at the edge or corner of the image. This will obviously halve the effective exposure time, so it is probably best to turn off this camera mode. Hot pixels can easily be cloned out if they have not been removed by the stacking software. In general, the more photons detected from the sky, the better the final image.

Avoiding Camera Shake

Pressing the camera shutter will tend to cause a little tremor in the imaging system, which when imaging stars is surprisingly obvious if short exposures are being made. One can either use a remote release as discussed in Chapter 1 or employ a two second delay prior to each exposure. The lifting of the mirror in a DSLR can also cause a very slight tremor and a one second delay following its lifting can also be employed. However, if the camera is in 'Live View' mode, the mirror is always raised. (Live view is also an excellent aid to focusing.)

Taking a Constellation Image

First a suitable sky image must be taken and it is sensible to choose an area of the sky with some prominent stars making up one or more constellation patterns. For this chapter's examples, I chose to image the region encompassing Cassiopeia and Perseus from a dark sky site in Wales.

Choosing a Lens

The sensitivity of a camera to stars depends only on the effective area of the aperture of the chosen lens. As fully discussed in Chapter 17, that of a 50 mm, f/1.8 lens is several times greater than that of a 24 mm, f/2.5 lens. But, of course, the shorter focal length covers a greater area of sky. So a lens, preferably with a wide aperture (low f number) that will just cover the chosen area should be used. Prime lenses tend to give somewhat better image quality and have wider apertures than zoom lenses, though with the superb anti-reflection coatings now in use, the image quality difference is not as great as it once was. Most, but not all, lenses perform better when stopped down by one or two stops and the optimum f-stop to use can often be found by searching for lens reviews on the Internet.

Focusing

Most current DSLR cameras have a 'Live View' mode, which provides a continuous display of the scene being imaged, which is a very great help when focusing the lens. The camera must be in 'Manual Focus' mode (usually a switch beside the lens mount) and the focus initially set to the infinity mark on the lens. Using Live View, increase the magnification of the image whilst observing a bright star and make any fine adjustments if required. If the camera does not have Live View, one will have to take some test exposures and inspect the captured images at high magnification.

Imaging Cassiopeia and Perseus

I chose to use an excellent 40 mm equivalent, f/2.8 prime lens, stopped down to f/4. When using a fixed tripod, the Earth's rotation causes the stars to become elongated unless the exposures are very short. This effect is greatest when using a long focal length lens near the Celestial Equator and least when using a short focal length lens near the North Celestial Pole. So, when using a fixed tripod, it is best not to use a full frame equivalent focal length greater than ~50 mm (so 35 mm for an APSC sensor). With such a lens, exposures of 10 seconds will be about right for Orion at declination zero, on the Celestial Equator. Imaging nearer the pole and using shorter focal lengths will allow longer exposures: up to about 30 seconds when using a 24 mm equivalent lens to image Ursa Major. To acquire good images it is important to use a sturdy tripod, then select a mid-range ISO, say 800, and give a 2-second delay between triggering the camera and taking the exposure (or use a remote release such as an intervalometer, as described in