Instruments and Imaging Section
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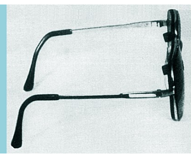

Director: Bob Marriott ram@hamal.demon.co.uk 01604 765190 http://britastro.org/iandi

An astrophotographer tests his home-made fixer

Having been asked occasionally for advice on digital cameras, particularly by new practitioners, I recently consulted Members for opinions on the acquisition of these devices. The appeal related particularly to DSLR cameras, but as I was not very specific the various responses also included advice concerning CCDs and webcams. I am grateful to all those who contributed, and trust that the results presented here provide useful information and guidance. I would be pleased to receive articles on imaging with various types of camera – in particular, the set-up of instrumentation and the techniques employed, with examples of results.

The previous mystery object is the 13.5-metre vertical vacuum spectrograph of the McMath Solar Telescope (now the McMath–Pierce Solar Telescope) being hauled up Kitt Peak in 1962. No-one identified it correctly. And the next mystery object (above) is ... ?

Digital cameras, CCDs, and webcams

Michael Covington

I usually tell my friends (here in the USA) to buy whatever Canon DSLR is currently on offer for $500 at the discount stores. The gain in performance from a more expensive camera is relatively small, and it is definitely not necessary to have an astronomy-modified camera, which has an advantage only for hydrogen nebulae. Having said that, I am not practising what I preach, as I currently own a Canon 60Da (Canon's astronomy-modified model). The astronomy community supports Canon (with special software, and so on) better than the rival brands, though I have also heard many good things about recent Pentax, Nikon, and Fuji DSLRs.

Athens, Georgia astro@covingtoninnovations.com
http://www.covingtoninnovations.com/michael
http://www.dslrbook.com

Cliff Turk

Most of the information I get refers to cameras from the USA, UK, or Australia, and it is difficult to compare one with the other, as each has slightly different features. With a reasonably comprehensive report mainly from one area it will be easier to make comparisons. I will then be able to better assess our local used camera market. At present it seems the Canon 450D is still the best value for money here in South Africa (unless one has unlimited cash to spend), but I for one will be very grateful for independent opinions.

Western Cape cliffturk@absamail.co.za

David Arditti

In my experience, all the Canon EOS line of digital single-lens reflex (DSLR) cameras produce very good results for all astronomical imaging purposes, except for high-resolution imaging of the planets, for which purpose webcams and other fast frame-rate cameras are better. For deep-sky imaging these cameras can be optimised quite cheaply by removing, or paying to have removed, the built-in infrared blocking filter, which greatly increases their sensitivity to the Hα emission of nebulae. They can also easily have light-pollution filters mounted internally; such filters are made to fit these cameras. The uncompressed RAW format data that these cameras can produce is readable by a wide range of image-processing programs, with no loss of information, which is not the case with all makes of DSLR. Early models such as the EOS 350D often now appear very cheaply on second-hand equipment websites, and frequently filter-modified ones as well. The results from these still compare very well, and they are a good bet if something inexpensive is required. Adaptors are also available so that many old film SLR lenses can be used.

Edgeware d@davidarditti.co.uk

Kevin Kilburn

Most of us at Manchester Astronomical Society have Canon DSLRs for general lunar and telephoto sky photography with Canon or old Pentax lenses. These range from the older 350D to the rather expensive 22-Mp 5D Mk2. Most of us have the 18-Mp 550D or 600D. For planetary imaging, the Philips ToUcam or its variants is still popular, though I, and now the MAS, have the Imaging Source DBK21618 colour video cameras.

Leek, Staffordshire kevinkilburn@sky.com

Graham Relf

I have been using Canon DSLR cameras for astrophotography since 2001. I started with the 3-Mp D30, and have traded up five times since then. My main reason for upgrading was that the maximum ISO sensitivity has been increasing with successive models. It has been quite obvious that at the same time the noisiness (in film terms, grain) has been decreasing. Particularly noticeable with current cameras is that the fixed-pattern noise has reduced to the point where dark frames are hardly required any more, making life easier for beginners. For this reason I certainly advise buying the most recent model affordable. My current camera is a 20-Mp 5D MkII, which I bought in 2009. I am very happy with it, and so far feel hardly any temptation to upgrade further. It has now taken about 28,000 exposures, as shown in the EXIF metadata. The shutter is rated (MTBF) for 150,000 exposures, and I assume that this is probably typical of today's cameras. So, stacking large numbers of exposures is not a worry from this point of view. My main interest is deep sky and comet photography. I typically stack exposures taken at ISO 6400, which is the maximum non-extended ISO setting in the 5D2. I say 'non-extended' because the higher sensitivities available through the camera's menus (H1 and H2, going up to ISO 25600 in my case) use software to amplify after digitisation, which is counter-productive for our purposes. The DSLR ISO setting is effectively an amplification factor for the analogue voltage signal read out from the chip, amplified just before it is digitised (which is why I always try to use maximum ISO). Marketing specifications may show the maximum extended ISO, so be careful. I suggest that details should be compared for each model on dpreview.com – an excellent camera review site. The full-frame aspect of the 5D2 is very useful for deep sky and for comets with substantial tails. It provides a wide field of view of 1°.7 x 1°.2 degrees at the prime focus of my 254-mm aperture f/4.8 Newtonian (f = 1200 mm). Of course, the edges of that suffer from coma, so a corrector lens is desirable when the subject covers most of the field. Most consumer DSLR cameras have a frame factor of about 1.6, which means that in my set-up the prime field of view would be 1°.1 x 0°.7 degrees. See the Computing Section's field-of-view calculator at:

http://britastro.org/computing/applets_fovtrail.html

Effectively, it is more magnification for a smaller view but also less need for coma correction. From my fairly unpolluted observing site in the North Pennines, exposures of up to 1 min at ISO 6400 are possible (at my telescope's f/4.8 prime focus) without the background level becoming excessive. From suburbia I have found that only about 5 sec is possible at that ISO. I stack a large number of such exposures, so the random noise averages out. Do not be tempted to use in-camera noise reduction, which is not designed for our purposes. I believe it would tend to remove faint detail just above the background level, which is exactly what we are looking for. So, ignore such features when comparing models. Although I am a confirmed Canon user, I suspect there is very little to choose between different DSLR makers except that there is more support in software for the Canon models. to control my exposure sequence via USB, I use AstroPhotography Tool (APT) from

http://www.ideiki.com/astro/

Until last year, APT was only for Canon cameras, but it now controls CCDs too (and it interfaces to PHD guiding software). APT sets the camera's clock from the PC, which can be useful except that it uses the local time zone, and at the time of writing here in the UK that is BST, not UT – so again, be careful. There is (at my request) an option in APT to switch this time-setting off. I use Canon's DPP software, which comes free with their DSLRs, to batch-convert from Raw to Tiff before stacking. I believe that Canon are in the best position to do this conversion optimally, correcting bad pixels before Bayer interpolation, and so on. Third parties may not know enough about Canon's RAW format, and I think the same would apply for other manufacturers: they tend to keep some details to themselves. Tiff files are about five times the size of Raw files, so I delete them after stacking and just archive the Raw version. APT uses Canon's SDK (software development kit) so, again at my request, it can optionally convert from Raw to Tiff using Canon's own code after capturing each image in a sequence. I have found the APT developer to be very responsive to my feedback.

Whitley Bay,Tyne and Wear gr@grelf.net

Steve Hubbard

I am a visual observer probably at an intermediate level, but wanted to try out some imaging with no real intention of following the full 'CCD guided' route. I have a Mewlon 210 and a WO FLT98 side by side on an EQ6 in a Pulsar dome. I took the advice from my friends at Norwich Astronomical Society, and now have a Canon 1000D and use APT and Deep Sky Stacker software. Having Pentax XW eyepieces I acquired an adapter from Tom Ryan at House of Optics so that they can be attached to the camera as an alternative to using prime focus. I have had lots of fun, and have not yet scratched the surface of what can be done! My key points would be: buy a Canon DSLR (probably any model), because it seems that that is what 'everybody' uses for astronomical work, and use the same software as your friends so that you can help each other.

Great Yarmouth dr.s.hubbard@ntlworld.com

John Kemp

Do not dismiss Sony! Take a look at the Sony DSLR range – especially those that have just left the market. I have two identical Sony A580 DSLR bodies – an APS format 16-Mp model. I used to use Olympus OM film cameras, and was late converting to digital. My first DSLR was a Konica/Minolta Dynax 5D – a 6-Mp APS format model, and a *de facto* precursor of the Sony range (the same factory and tooling up, I believe). I chose it for two reasons: (1) image stabilisation in the camera body, so it works with all lenses; (2) I could use the whole range of ancient Minolta lenses due to retention of the mount, the design of which was extraordinarily prescient and future-proof. I now use a very old Minolta film camera lens – the famous 'beer can' 70–210mm f/4 zoom – on my modern Sony DSLR with *all* features available! Posts from the excellent veteran Norwegian astrophotographer Nordstjernen revealed up a plus: the Hα sensitivity was natively *much* better than Canon or Nikon. Furthermore, I considered that 6 Mp was quite enough pixels for astrophotography: the pixel size was better matched to resolution than the models with many more pixels, and led also to relatively low noise. The Dynax 7D was very similar. Be careful buying the 5D second-hand, as early serial numbers had a design fault in a shutter cam, leading to a rare but serious fault ('first frame black'), which was usually intermittent but sometimes serious enough to trash the camera. Minolta and later Sony repaired these free until there were no spares. I cannot remember whether the 7D was similarly affected. When Sony brought out Konica/Minolta they had the common sense to retain the ancient Minolta mount and rebrand it as the Sony Alpha mount. Models in this range of DSLRs had varying Hα sensitivity. One of the better ones is the A580. This camera has several unusual features: a plethora of viewfinder and focusing options; a true DSLR optical viewfinder; an alternative of electronic live view, with a large LCD screen on the back, which is articulated (very useful at the telescope); and a special focus-check magnified live view mode using its own dedicated sensor, which is especially helpful for Hα solar photography. It also has full HD video. Sadly, Sony have all but abandoned true DSLRs, and are following their semi-transparent mirror route, with an electronic viewfinder. I will not touch these models, as I hate electronic viewfinders (even if I welcome them as an option for very specific circumstances), and there are ghosting problems that rarely impinge on everyday normal photographic use but are unacceptable for astrophotography.

When cameras reach end-of-line the price usually either decreases or, rarely, increases, and I had to pay over the odds for my A580 when I picked up one of the last few new ones from Germany. Then I waited until the second-hand price dropped to the usual of about two thirds the best discounted price new (which took a while), and have now snapped up a second body as insurance. I am now in my 70s, and intend to keep these until I drop. I do not have time to seek out my original research, but the following link to Nordstjernen provides a guide:

http://www.dpreview.com/forums/post/51429112

The competition for the A580 is the much more expensive Canon 60Da, and I very nearly opted for one. However, I am not one of the very serious astrophotographers for whom the even better Hα sensitivity will decide the matter. There are so many other reasons for choosing the Sony, especially if it doubles up as an everyday camera, and it is worth serious consideration. There are, I believe, one or two small businesses that will upgrade the infrared filters on DSLRs other than Canon or Nikon, though I do not know whether this includes the A580. Three final points should be considered. (1) The A580 is still being offered new (£724) from Germany on Amazon, from where I acquired mine – a decent firm holding out for a high price for their last few. (2) Ignore any new entrants into the market, with prices too good to be true. There have been several scam websites. I was nearly caught by one of them, though what saved me was that my credit card was rejected by a ‘technical fault’. (3) If Hα sensitivity is an important consideration, find the specific camera. The very similar A550, for example, is not as good as the A580 in this respect.

Whitstable john.e.g.kemp@btopenworld.com

Patrick O’Donnell

Your request came just a few months too late to help me, since I had been going through the process earlier this year of choosing a DSLR for astrophotography. I am pleased to be able to share my experience for the benefit of others on the same path. My requirement was for a DSLR to use both with a 200-mm Schmidt–Cassegrain and stand-alone to photograph the sky, Moon, and planets, but especially deep-sky objects, starting with the Messier and Caldwell listings. I am relatively new to astronomy (15 months), and have never used a DSLR before. As a start, I bought Michael Covington’s excellent book, *Digital SLR Astrophotography*, which provided a good basic understanding of the options available. I soon narrowed the choice to a Canon 60D, which has a good specification: 18 Mp, live view with x5 and x10 magnification for easy focusing, and a very nice touch – a swivel LCD screen which is invaluable when the telescope is pointing at awkward angles. This matched my price range but left me with the decision between the standard or modified (60Da) version. The Canon 60Da features a modified low-pass filter with increased Hα sensitivity that is approximately three times higher than that of a normal DSLR camera. After much soul-searching and viewing of photographs taken with and without this feature, I decided that the extra £300 or for the 60Da version was not justified. My early photographs of M42, and so on, confirm that the standard 60D is quite capable of capturing good colour representation. Although the weather has not been kind since I purchased the camera, I have obtained some nice images of the globular clusters M3 and M13, the Orion, nebula, M42, and the Ring nebula, M57. My experience to date confirms that an autoguider is necessary for exposures longer than about 30 seconds, and this is the next item on my wish list. Many of these DSLRs are available at cut-down prices on the Internet, but I decided to buy from a reputable dealer to avoid warranty problems. John Lewis offers a two-year warranty, which seems to me to be well worth it.

Salisbury patod666@hotmail.com

Sheridan Williams

Important features are:

- Full manual over-ride.
- A screen that can be swivelled so that it can be seen when the camera is pointed at high elevations.
- Live view for focusing.
- Automatic dark-frame subtraction.
- High ISO settings.
- Controllable from a laptop.
- T-mount available.

Useful features are:

- Filters that fit inside the body (Canon DSLRs).
- High-definition video capability.

Leighton Buzzard sheridan@clock-tower.com

Tim Haymes

Digital Cameras (less than £400). I have six cameras, two of which – the DSI-I and WATEC 120N+ – were bought new, while the others are second-hand.

Canon 20D A low-cost, old model with large pixels (good sensitivity), which can be set at 3200 ISO if required. I have one with the filter removed and plain glass added. The Astronomic CLS-CCD filter does the infrared cut. The screen at the back is small by today’s standards but is perfectly usable. If required, the camera can be controlled from a PC (as most of them are). I have had very pleasing results with an f/4 Newtonian. The 40D (which I do not have) has live view and a larger screen, so this is probably a better starting point for DSLR imaging. Images are collected as RAW and then stacked. Flat frames should be used for best results at f/4, and good results can also be obtained with a wide field (18–100 mm focal length).

Meade Deep Sky Imager I and II (mono) I have not yet graduated from these, but they produce pleasing results on a fast OTA. I reach to mag. 18/19 with a 30-cm f/4 (20 min), without cooling. Dark-frame subtraction is automatic, and the images add (stack) on the fly, so the detail can be seen growing as each image is added. I use 21-sec subs, or 1 min if autoguiding (FITS output). I would not recommend these for LRGB as they are not sufficiently sensitive, but results can be achieved with planetary nebulae where the colour contrast is higher.

WATEC 120N+ A great video camera with integration. I use it for occultations and other time-dependent phenomena. It is an ‘industry standard’, now discontinued, though a new near-equivalent is being developed.

Image Source I have the mono and colour DMK21, which I purchased with a lower budget it mind. They work well on bright objects such as the Moon (mono), Jupiter, and Saturn (colour). However, they are only 8-bit, which I feel limits the overall quality, though it was a fair upgrade from the ToUcam.

Reading tvh.observatory@btinternet.com

Tony Rodda

I use two cameras – SBig and Starlight Xpress - mainly for photometry, so I have a particular bias. Usually, the first question is: ‘What does the user want to do with the camera?’ Some of the cheap ‘planetary’ CMOS and video cameras are ideal, but a good second-hand cooled camera can be acquired for the same price. Many good-quality earlier-generation cooled/USB models are now available second-hand, so there are bargains to be had. Cooled cameras are better than non-cooled, and again, good second-hand bargains are available. Setpoint cooling is better than 'just' cooling, and it is easier to acquire calibration frames. Monochrome cameras are better than one-shot colour cameras due to better (and linear) sensitivity, but involve more work, less convenience, usually greater cost, and the need for filter wheels and filters. If the targets are very faint nebula, lengthy exposure times versus sensitivity might be a consideration. Other consideration include fields of view and image scale, based on an instrument's aperture and focal ratio. A useful program is Ron Wodaski's CCD Calc, by which the user selects different telescopes and cameras to derive the field of view of commonly known objects. Then there is the simple statement that the camera's results will be only as good as the mount allows. If you are chasing 'faint fuzzies' you will need a good mount for longer exposures and probably guiding. Options include off-axis guiders with another guide camera, a second guide camera with its own guidescope, or a more expensive dual-chip camera. In addition, a more expensive camera might be acquired that will accommodate a close coupled filter wheel so that automated filter runs can be performed. I have to use photometric filters, short (2 or 3-minute) exposures, and long, multi-filter, runs, so I need to automate as much as possible with a low-noise, good-quality, sensitive camera. If you want none of the above, but simply want to take pictures with a large-format camer without the use of a PC, want portability, and are not concerned about any photometry or particularly noisy frames, then just buy an ordinary SLR camera, as they are cheap enough these days. Buying a camera for astronomical purposes impacts just about everything else you do or own! Do not buy one in isolation.

Newcastle upon Tyne tonyrodda@btconnect.com

Peter Woolliams

For solar, lunar, and planetary imaging you cannot go wrong with the Imaging Source DMK series – the 21 lower-cost model for planetary imaging (the colour version if you do not like using filters). I use a 41 model for lunar and solar imaging, as I can grab larger areas and so reduce the need for mosaicing. All are 8-bit, which may be a limitation, as it limits the dynamic range acquirable, so multiple exposures may be needed (for instance, for capturing the solar disk and prominences). However, more bits tends to involve fancy interfaces, which most people do not have on their computers. I have had two images published in *Astronomy Now*, so my camera and my solar telescopes are perfectly adequate. Processing, of course, is as important as the hardware, with Registax, AutoStakkert, and others being regulars. Once stacked, wavelet and dynamic range corrections can bring out fine detail and produce the final result.

Hampton, Middlesex woolliams@googlemail.com

John Mallett

I have had many good results with the SXVR-H18 – a really great camera from a great company: Starlight Xpress. The shutter is a really valuable feature, enabling automated dark-frames and subtraction on the fly or storage for processing later. The large-format chip is also great for deep-sky objects, and binning modes are good for automated variable-star image collection. The cooler is able to maintain the chip temperature low enough to avoid significant noise. It is an all-round camera – and I want another one! Feel free to use any images available on my website: http://www.astro.me.uk

Hewelsfield, Gloucestershire john@astro.me.uk

Ray Taylor

I use a Canon 350D, and am very pleased with the results so far. It has been used in some terrible weather, often being covered in mist, and more than once by a thin film of frost, though it appears to be not adversely affected. I made my own dew heater, which I run off a 12V car battery (charged by a solar panel) which also provides power for the equatorial mount, the laptop, the CCD camera, and low-power red lights. The camera has a good range of ISO ratings, though ISO 1600 is useful. It supports up to a 2Gb flash card, which is rather limiting when shooting in manual with the B shutter and the raw data settings activated, but this was solved with additional flash cards. The standard manual hand shutter release was limiting, but thanks to Bev Ewen-Smith at COAA I acquired one which provided automatic timer settings with control over start time, number of exposures, length of exposures, and delays between exposures. With a Yongnuo Digital MC-36b remote control (from www.hkyongnuo.com) it works really well. I had to search for a different T fitting because the normal Canon T fitting was too thick and so did not provide sufficient focus range, but I managed to find a slim-line fitting which I then matched to the standard 1¼-inch adapter for use with my Konus 1,000-mm focus reflector. This fitting has served me well for at least three years.

Skirlaugh, East Riding of Yorkshire mygtrvdc@hotmail.com

Alan Clitherow

The problem of which camera to buy is a complex one, and depends on the purpose for which it is intended, as well as the budget. For occasional snaps of the Moon taken via eyepiece projection, almost any digital camera and a number of smartphones will do the job well enough to show friends and family, but other than that one needs to specialize.

For the solar system – particularly the planets – then one really needs a high frame-rate video recording device, as the smallest detail on view tends to be lost, in many exposures, due to atmospheric distortion. Capturing a video stream allows software to later pick out the few 'steady' frames in the stream and combine them into a high-resolution final image. Simple webcams have done well in the past but were limited by the amount of data they could squeeze through the computer bottle-neck caused by the early USB connections. The later USB2 standard helped, and the development of USB3 may well bring about a renaissance of simple webcam use; but for now, the best results come from specialized monochrome devices such as those supplied by The Imaging Source, Point Grey Research, or Baasler. These companies, and others, produce versions of industrial cameras for the planetary photographer with various high-speed connections to a computer. The idea is to grab a video stream of the target and then use software such as Registax or AutoStakkert to sort through the hundreds or thousands of image frames and produce a mosaic of the best of them, least blurred by atmospheric turbulence. Colour cameras are inherently less sensitive than monochrome versions, but are more convenient to use, and the best results are obtaine with monochrome cameras matched with filter wheels so that final colour-composite images can be built up from the results of imaging through coloured filters. Many imagers, however, find that colour cameras are good enough for their purposes, and much less post-processing is required to produce an acceptable final image.

Due to the problem of the rate of data transfer, chip size tends to be small for planetary cameras, as perhaps several thousand images need to be captured in a relatively short time – typically 4 minutes maximum for fast-rotating planets such as Jupiter and Saturn. Targets that change minimally on a scale of minutes can be imaged with larger-chipped slower transfer-rate cameras – relating particularly to solar or lunar, though Mars is also a suitable target. In addition, very-narrow-band filters used to view and image the Sun tend to rule out the use of colour cameras for that target. The chip itself is often of the CCD type which, as a generalization, usually produces better results than CMOS-type chips for this application. Technology is changing continually, however, and at least two specialist planetary cameras have recently arrived that use one particular small CMOS chip from Aptina, giving excellent sensitivity and resolution for planetary imaging. These are the QHY 5L-II and the ASI-120M – both available in colour and monochrome versions. Modern DSLR cameras are now also being used for planetary imaging, as they often have a built-in high-definition video capture mode or, even better, can be used to capture at full resolution (the camera chip has many more rows of sensors than are needed for just HD video capture) direct to a computer hard-drive via third-party software. One example is the program BackYardEOS for the popular Canon range of DSLR cameras. All these cameras use CMOS chips, and while the results are not up to the standard of the specialist CCD planetary cameras, they allow DSLR camera owners to achieve acceptable results without extra investment.

I use a number of cameras – all monochrome versions – for solar-system imaging. For the Sun and Moon I have a DMK41, which has a relatively large field of view and good resolution. It is not a highly sensitive camera, but does not need to be for these bright targets. For the planets I have a DMK21 using the highly sensitive, if very small, Sony ICX-618 sensor. This chip is available in a number of specialist cameras, and has been the gold standard for planetary imaging for the last two years or so, though as always, changing as technology advances. I recently acquired one of the QHY5L-II cameras, and while it is somewhat quirky in use it seems to be acceptably sensitive and of slightly higher resolution than my own DMK21, and will probably be my camera of choice for the next couple of years.

When deep-sky imaging is considered, requirements change. Instead of fast capture of large numbers of images, what is required is a camera capable of long time-exposures with minimal electronic noise added to the image. Electronic noise is inherent in all electronic imaging devices, but can be minimized in two ways; first, by intelligent design, to insulate the imaging chip and data transfer routes within the camera as much as possible from electronic interference; and second, by cooling of the sensor, which can dramatically reduce the amount of noise picked up in the final image. It is possible to minimize the effects of noise by capturing a large number of images (noise tends to be random in pattern, so can be averaged out by combining several images) and by using techniques such as dark-frame subtraction. This is not the place to discuss these techniques in detail, but they work well enough for modern DSLR cameras to be useful for deep-sky imaging, even though they do not have electronics designed to minimize noise in long exposures, nor any form of cooling. There are limits to these cameras, however. Users of specialist cooled astronomical CCD cameras often point to the lack of sensitivity inherent in DSLR-type cameras. This is true, but only up to a point. DSLR cameras are colour rather than monochrome, so some sensitivity is lost in that way, but they are also designed to produce a colour image that is balanced, at least approximately, to the colour balance as seen by the human eye. This is done by the placement of a series of filters in front of the sensor that cut out infrared light (we cannot see it, so why should the camera?) and curtail the amount of red and blue seen to more closely match our own ocular sensitivity. By doing so, the images produced 'look right' to our eyes. In fact, the DSLR camera sensors are much more sensitive than our eyes across the spectrum, particularly in the far-red end, where many deep-sky objects – particularly Hα-emission objects – emit light.

It is possible to have DSLR cameras modified by the removal of the filter element overlaying the chip. This significantly increases the sensitivity of the camera in the most useful area of the spectrum for deep-sky imaging. It is even possible to buy a filter that fits within the camera body and which mimics the filters removed from the chip, thus allowing the camera to be used both normally for family photographs and for deep-sky work with the filter removed.

These 'modified' DSLR cameras are cheap when compared with specialist astronomical cameras fitted with chips of comparable size, and, as long as colour is compared with colour, are no longer as 'insensitive' as specialist camera users claim. The difference may be as little as 10%, depending on the light-frequency discussed and the particular chips in use. Modified DSLR cameras are not, however, cooled (with one or two highly specialized and somewhat experimental exceptions), so there is a limit to exposure time before the electronic noise level visible in individual images rises and swamps the faint signal from dim deep-sky objects. When that happens it becomes impossible to average-out or dark-subtract the noise; and if the noise is brighter than the signal then the signal is lost irrevocably. This means that DSLRs – especially unmodified ones – will have access to only a limited number of the brighter deep-sky objects. To see the rest requires a well-designed, cooled specialist camera – which can cost serious money. Such cameras tend to use the most sensitive sensors available (currently all CCD rather than CMOS), and the cost tends to increase in line with chip size. The bigger the chip, the larger the field of view in any given telescope set-up. There is a place for small chips in imaging some very small faint objects, but generally, larger chips will be more versatile for object selection. If a small-chipped camera is the first choice, an upgrade will be required sooner rather than later. The options of one-shot-colour versus monochrome plus filters is a personal choice. Colour cameras are less sensitive, so will need longer exposures to capture fainter objects, and may not work well with narrow-band filters used to isolate specific emission bands from certain objects. On the other hand, monochrome cameras will need long exposures through three different filters to obtain a colour image, with all the frustrations imposed by cloudy skies, with limited windows of opportunity for imaging. Prices start from around £1,000 for the (generally cheaper) colour cameras with average-sized chips, and rise dramatically for large monochrome cameras.

I have a modified Canon EOS 500D DSLR camera for wide-field colour work and an Atik 314-L cooled monochrome CCD camera for smaller and fainter objects imaged at longer focal lengths. The Atik is somewhat old now, and has a relatively small chip compared with more modern cameras of around the same price, but is sensitive and exceptionally noise-free. Ultimately, what to buy depends on personal budget and level of interest. For the beginner, a modified DSLR camera provides access to both planetary and deep-sky imaging, but will never be the master of both. Specialist cameras will always be 'better', but this must be balanced against how much is to be paid. If I were starting out I would buy a good colour planetary camera such as the DMK21 with ICX618 (around £380) or the QHY5L-II/ ASI120M (around £290), and obtain a second-hand DSLR such as an EOS 450D (around £200) and have it modified by filter-removal (around another £150). This would give me access to detailed lunar and planetary work, though not solar work without extra expense, and entry to deep-sky imaging including many, if not all, available objects. If the imaging bug were to bite, I would then be thinking about monochrome planetary cameras with filter wheels and a dedicated cooled CCD camera – plus a second mortgage.

Ceres, Fife clitherowclan@supanet.com