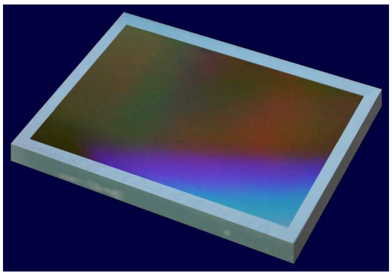
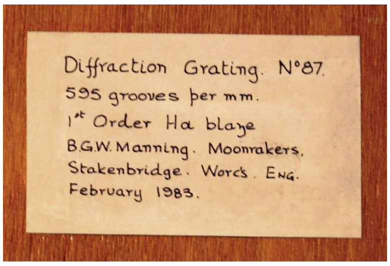
I & I News

New Series No. 3 | Newsletter of the Instruments and Imaging Section | 26 November 2011

On 10 November the Association lost one of its most skilled ATMs and observers: Brian Manning, of Kidderminster. He was aged 85. Brian built several telescopes, and was also the first amateur to make diffraction gratings with a ruling engine that he constructed himself. Beginning in the mid-1950s, this project occupied him for two decades. In his observational work he specialised in the astrometry of comets and asteroids, and in the late 1980s he discovered several asteroids – the first discovered from England for more than 80 years. Brian was a recipient of the Association's Horace Dall Award, and received an honorary PhD from the University of Birmingham.

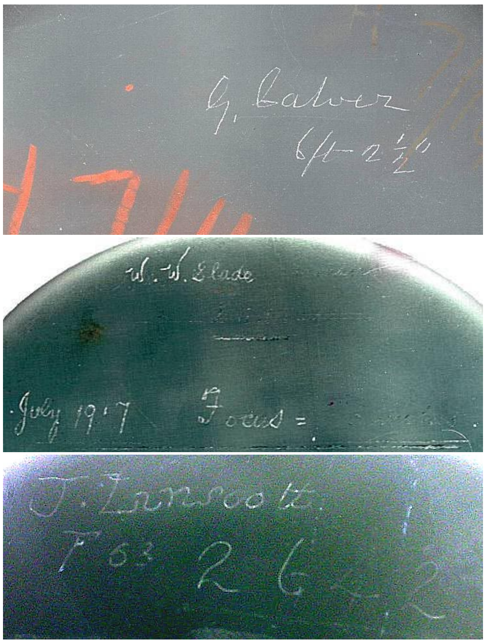




The grating at right, which I acquired several years ago, has a ruled area measuring 76 x 56 mm.

A video of Brian's talk on the construction of his ruling engine, presented at the AGM of *The Astronomer* in 1998, is now available. http://www.youtube.com/watch?v=5buW1oWhCQY

Bob Marriott, *Director*



Signatures on mirrors: a 7-inch by George Calver (the orange markings date from later), a 9¼-inch by W. W. Slade, and a 6½-inch by J. Linscott.

A home-made solar telescope

Brian Mitchell

This solar telescope consists of a 50-mm lens (acquired from Ian Poyser), with a Baader filter and a Coronado Hα filter – either of which can be placed in the open tube at the objective end. The tube is Osma drain-pipe, and eyepieces are used with a very compact version of the Crayford eyepiece mount made from aluminium tubes that I happened to have to hand. (The eyepiece mount is a modified form of the original Crayford eyepiece mount invented and designed by John Wall around forty years ago.) The diagonal is built around an old 90-degree prism, and the RA and declination bearings are large-diameter fine screw fittings from an old lens system. A simple hand-screw provides short-time drive in RA. The wedge is welded from 2-mm steel plate, and is attached to a tripod designed and built to be rigid but light. The diagonal struts linking the legs provide the rigidity, and the top-end leg-attachment clamps can be loosened to allow the struts to slide upwards so that the legs of the tripod can be folded. The instrument is used in conjunction with a heliostat, a 6-inch reflector, and a C8.

Norwich b.mitchell678@btinternet.com

A wooden Crayford focuser

John Wall

This focuser is made from hardwood plant-support stakes available from a garden centre. The wood is very good quality, rather like mahogany, and the focuser has a very smooth action – just right for beginners to make without using machine tools.

Coventry wallporritt@madasafish.com

A flat-field Schmidt camera for CCD imaging

Mike Harlow

1 Introduction

In an article written in 2006 for Orwell Astronomical Society, ‘CCD Imaging with a Schmidt Camera’, I described the upgrade of my 1985-built Schmidt camera from film to CCD imaging. In the present article I describe a further upgrade involving the addition of a field-flattening lens and a larger CCD detector.

2 The field-flattener

2.1 Lens design

For large CCDs, or short focal lengths, the field curvature of the Schmidt camera blurs images significantly at the edges of the flat field of the CCD. In this case a field-flattening lens is required just in front of the CCD. This lens is typically plano-convex with the convex side (facing the mirror) having a radius of curvature, R, given by:[1]

$$R = F(n-1)/n$$

where F is the focal length of the Schmidt camera, and n is the refractive index of the glass used for the field-flattening lens. More generally, for any shape of field-flattening lens, the focal length of the lens, flens, is given by:[2]

$$f_{lens} = F/n$$

where again, F is the focal length of the Schmidt camera, and n is the refractive index of the glass used for the field-flattening lens. Note that the first equation is just a special case for plano-convex lenses derived from the second, general equation.

The detailed theory of the Schmidt camera is provided by Linfoot in his book *Recent Advances in Optics*.[3] In Chapter 3 Section 5 of this book, the field-flattened Schmidt is fully discussed. Equations are given showing how chromatic aberration and coma introduced by the field-flattening lens can be minimised by modifying the shape of the corrector plate and moving it towards the mirror. For the modestly sized camera discussed here, these modifications are unnecessary.

2.2 Making the field-flattening lens

The plano-convex lens for the field-flattener is the smallest optical component I have made (so far). The glass substrate used was the plane-parallel clear window from my first, 1992 vintage, CCD camera, and was just 2 mm thick at the start of grinding. It was ground against a preformed template of the correct curvature, both to minimise the amount of glass removed and to make measuring the radius of curvature easier.

The radius of curvature of the convex side of the lens is derived from the first equation given above. In this case the focal length of the Schmidt is 400 mm and the refractive index of the glass is 1.52. Therefore, R is given by:

The 6-inch Schmidt camera with the 4-inch finder/guidescope

$$R = F(n-1)/n$$
$$R = 400\ \text{mm}(0.52)/1.52$$
$$R = 137\ \text{mm}$$

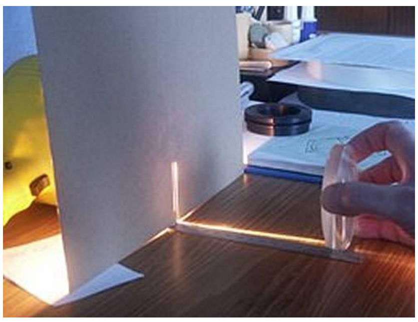
This curvature will result in a lens with a focal length of ~263 mm, or about +3.8 dioptre in terms of lens power.[4]

The glass template was ground, as illustrated below, against a spare piece of glass – the central core from my 36-cm Cassegrain mirror. This very thick piece of glass was ideal, as good clearance was required to prevent the top piece of glass – the template – from grounding on the top of the grinding stand.

The curvature was measured in the early stages of grinding using curves of different radii cut from pieces of card. Curves from 130 mm to 170 mm in 10-mm intervals were cut out and placed against the ground-glass surface to check progress. In this way the curvature could be estimated to within 5 mm of the desired value. Once the curve on the template had been generated with 80-grade carborundum it was smoothed with 180 grade, and final measurements were made of the curvature. These were made using an illuminated slit and a ruler, as illustrated below. The ground surface was sufficiently smooth when wetted to form a good image of the slit, allowing measurements of the curvature to within 1 or 2 mm.

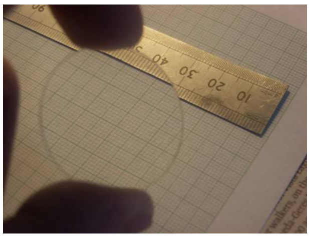
Grinding the template curve

Large curvature requires good clearance

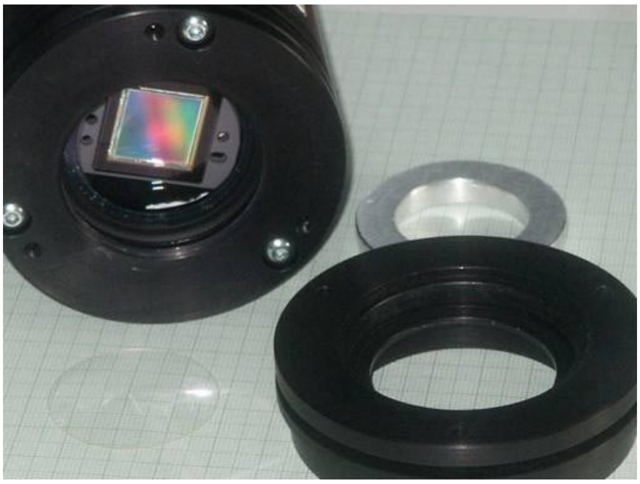


Measuring the radius of curvature

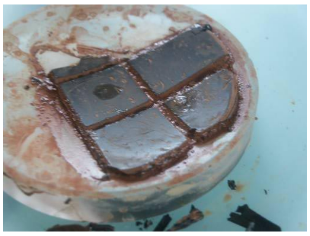
The field-flattening lens during grinding with 280-grade abrasive



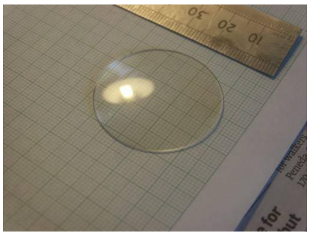
The field-flattening lens – polished



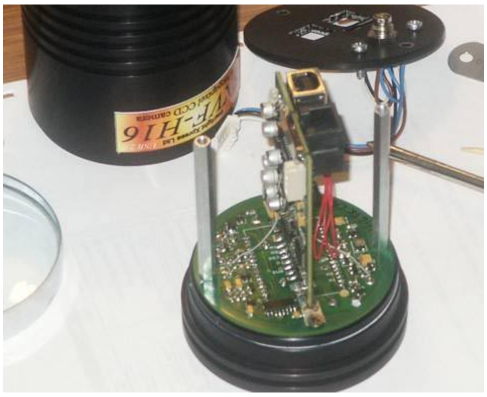
The SXV-H16 camera, the spare front-end adaptor ring, and the field-flattening lens



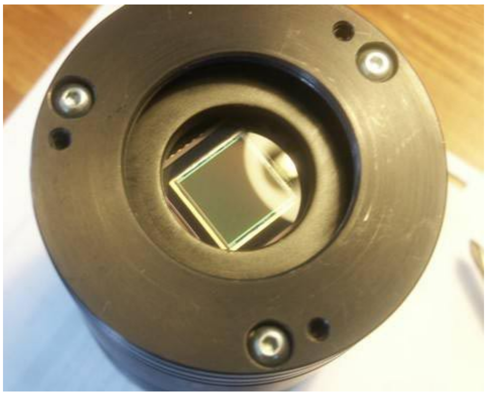
The polisher (believe it or not)



Another view



The partly dismantled camera



The field-flattened camera assembled and ready for action

Once the curvature of the template was as close as possible to the required 137 mm, grinding of the field-flattening lens was started. The lens was mounted on the cap of a 35-mm film canister with double-sided tape to make handling easier and to prevent scratching the already flat, polished back surface. The lens was easily demounted between abrasive grades using nail varnish remover (acetone).

Because of the small size of the lens – just 35 mm diameter by 2 mm thick – and the relatively small amount of glass to be removed, grinding was started with 280-grade carborundum. Changing the surface from flat to the desired curvature took just nine wets, illustrating how fast grinding is on such small lenses. After every three wets grinding the field-flattening lens, the template was reground against its grinding tool to preserve the correct radius and spherical shape. Grinding was completed with 400, 600, and 1000-grade abrasives, and polishing was carried out with a conventional, if rather small, polishing lap. As can be seen in the picture above, it only just survived the polishing process. The pitch was very hard, so adhesion to the glass template was rather poor. After polishing, the focal length of the lens was measured and found to be 268 mm – within 2% of the required value.

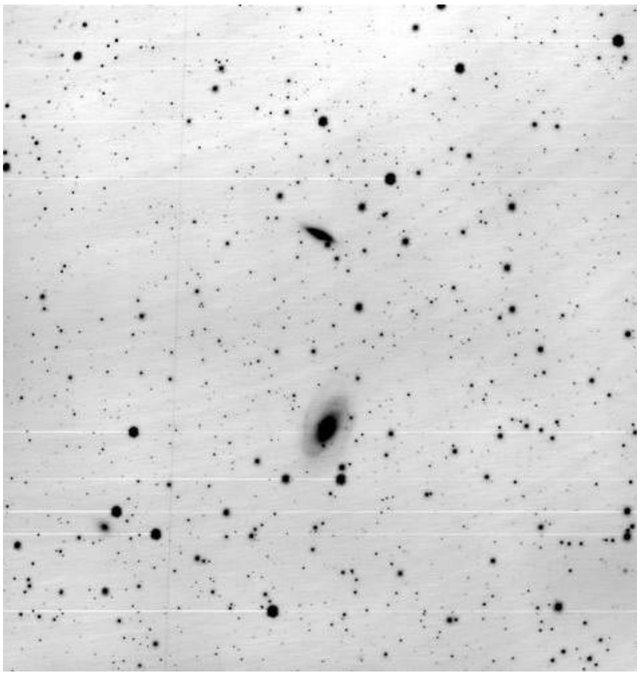
2.3 Mounting the field-flattening lens in the CCD camera head

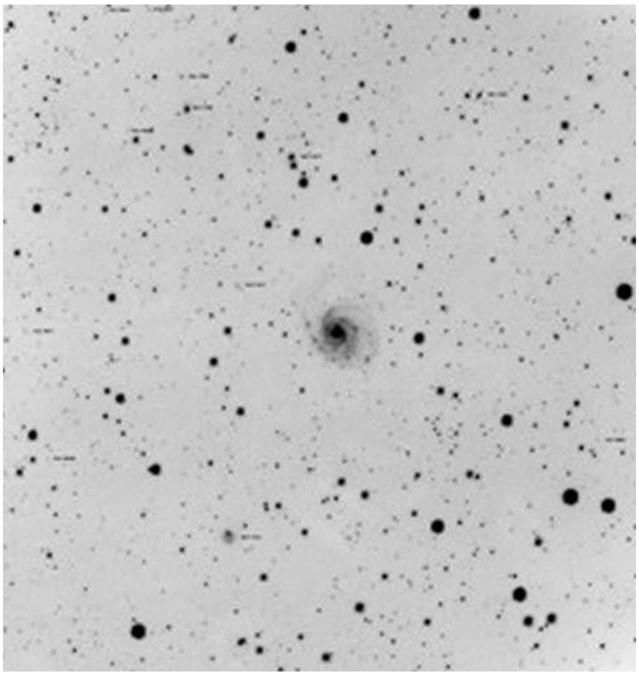
The CCD used with the field-flattened Schmidt is the Starlight Xpress SXVF-H16. This is a monochrome camera with 2048 x 2048 pixels each 7.4 µm square. This produces a chip size of just over 15 x 15 mm, with a diagonal dimension of just over 21 mm. The optical window in the original camera is replaced by the field-flattening lens as follows. An aluminium adaptor ring was made to fit into the recess in the spare front plate of the CCD head. This was sealed in place using silicone sealant and then spray-painted on the outside with matt black paint. The field-flattening lens was then sealed onto the back of the adaptor ring, again using silicone rubber sealant. This new front-end assembly was then swapped with the front-end supplied with the camera. When assembled, the field-flattening lens was within 2 mm of the front surface of the CCD chip.

3 First test images: before and after

The images below show the effect of adding a field-flattening lens. Blurring at the edge of the 2.1 x 2.1-degree field of the H16 CCD is completely eliminated by adding the simple plano-convex lens. (Focusing still had to be perfected to achieve the ultimate image quality.)

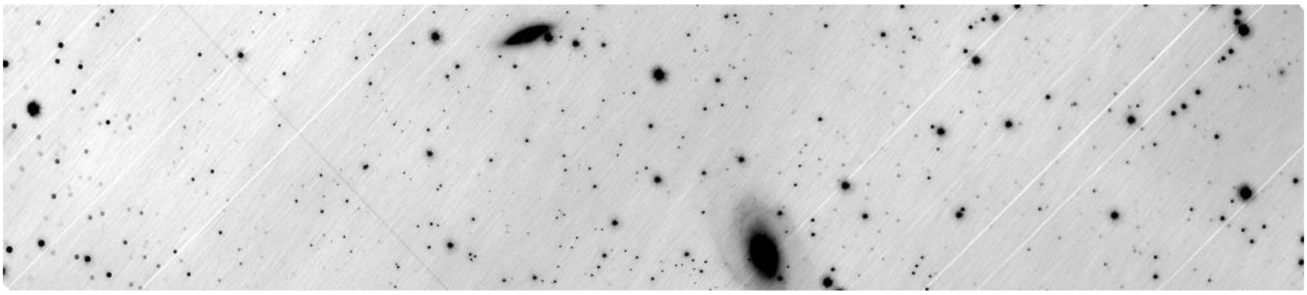
The first terrestrial image to set focus: without the field-flattening lens



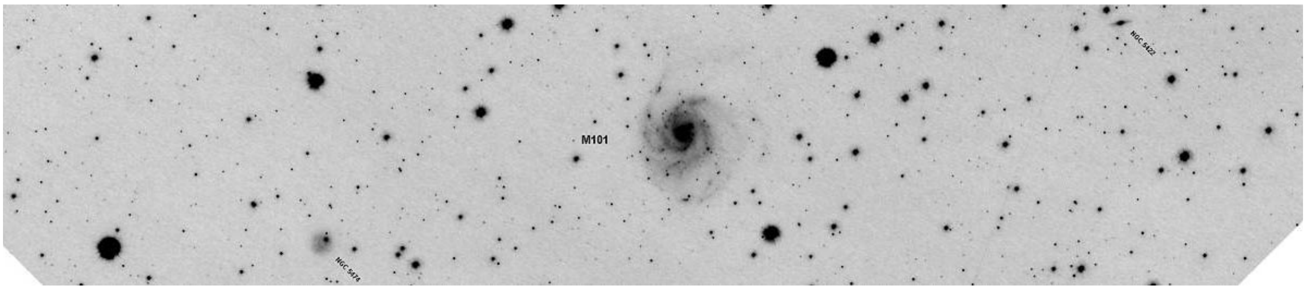


The field of M81 and M82 without the field-flattening lens

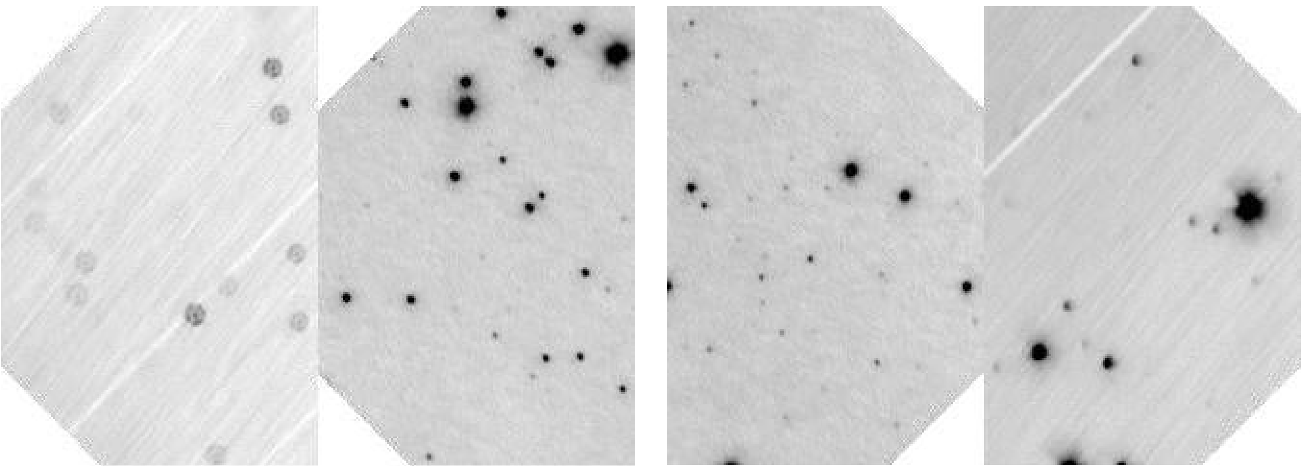
The field of M101 with the field-flattening lens



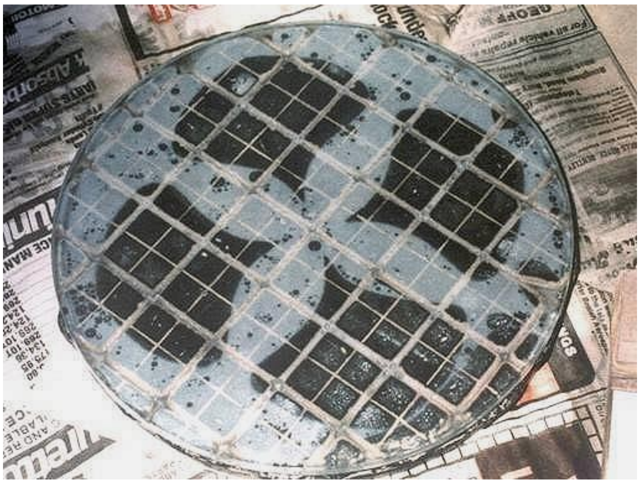
A slice of the above field of M81 and M82 without the field-flattening lens (the white lines are due to a fault in the CCD)



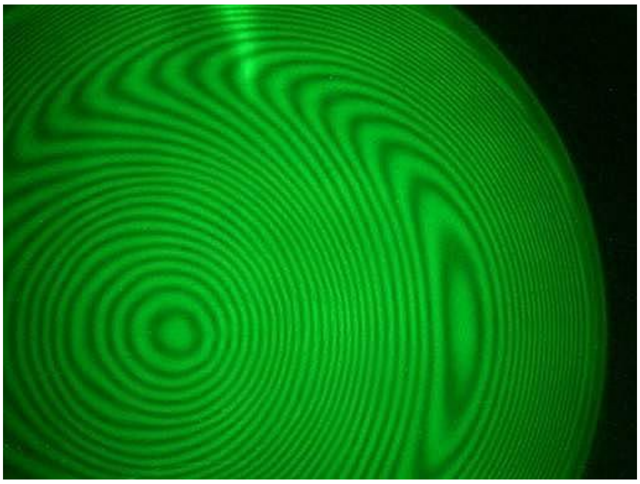
A slice of the above field of M101 with the field-flattening lens



The corners compared



One of the petal polishing laps for generating the corrector profile



Interference test of the corrector plate

Appendix : The Schmidt corrector plate

In my original 1986 article for Orwell Astronomical Society, ‘Construction of a Schmidt Camera’, I mentioned using a petal-shaped polishing lap but did not show any pictures of it. Above is shown one of the petal laps used to generate the corrector profile where the amount of pitch in contact with the corrector at a given radius is proportional to the amount of glass to be removed. The lap is made by hot-pressing a template of the desired profile, made of thin card, into a flat polishing lap. After cooling, the card is easily removed by soaking it in soapy water.

Conventional techniques were initially used to make the corrector plane-parallel with flat surfaces on both sides. Only then was figuring attempted with the petal lap using very short strokes across the centre of the corrector to polish in the aspheric curve. Regular testing was carried out by placing the corrector on an optical flat and illuminating it with monochromatic light. The resultant interference patterns were checked against the theoretical profile, and figuring continued until they matched to within ¼ wavelength. Half the correction was placed on each side of the corrector plate. The interference pattern of the completed corrector, shown above, was produced by a green laser pointer used as the monochromatic source at a wavelength of 532 nm. A small residual wedge between the corrector and the optical flat produces the slightly asymmetric profile.

Note: The corrector has a shape factor A = 1.0, producing a neutral zone at ~71% of the radius.

References

1 Buchroeder, R., private communication.
2 Rutten, H. and van Venrooij, M., *Telescope Optics*. Willmann-Bell, 1988, p. 77.
3 Linfoot, E. H., *Recent Advances in Optics*. Oxford University Press, 1955, ch. 3.
4 Longhurst, R. S., *Geometrical and Physical Optics* (third edition). Longman, 1976, p. 12, eqn. 1.7.

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INSTRUMENTS TAKEN IN EXCHANGE.

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Advertisements, 1906. Following the paper by O’Donoghue, Goulding, and Allen, ‘Consumer Price Inflation since 1750’ (2004), which studies British inflation since 1750, 1906 prices should currently be multiplied by 91. For example, the 6-inch Grubb refractor for £105 is the equivalent of £9,555, the 4½-inch Cooke refractor for £85 is the equivalent of £7,735, and the 3-inch ‘Student’ refractor for £6 10s is the equivalent of £590.

Visual observation of double stars

Bob Marriott

After William Herschel's study of the motions of double stars between 1780 and 1815 – proving the extension of Newton's theory of gravity to the sidereal system – the first systematic survey of double stars was carried out by F. G. Wilhelm Struve, using Fraunhofer's 9¼-inch f/19 refractor at Dorpat Observatory, Estonia. The result was a catalogue of 3,212 objects: *Mensurae Micrometricae*, published in St Petersburg in 1837. In the 1840s Struve's son Otto continued this work at Pulkowa Observatory, St Petersburg, including many wide doubles in his survey. Wilhelm Struve chose the Greek capital Σ to denote his name, while Otto symbolised his discoveries with OΣ for his first catalogue, OΣΣ for his catalogue of 256 wide pairs, OΣI for the first appendix, and OΣII for the second appendix. (The Struve family included nine astronomers in five generations – the first of them being F. G. W. Struve, and the last of them Otto Struve, Director of Mount Wilson and Palomar Observatories, who died in 1964.) During 1913–18, W. S. Franks – using the 6⅛-inch Cooke refractor at F. J. Hanbury's observatory at Brockhurst, near East Grinstead – remeasured all the pairs in Otto Struve's catalogues, the results being published in *Monthly Notices of the Royal Astronomical Society*. During the 1980s the Webb Society began a new survey of the 256 wide pairs, named the Franks Programme.

After Wilhelm Struve's initiative, many other double-star observers (mostly amateurs) added to the proliferation of discoveries and micrometric measurements – a vestige of traditional positional astronomy, but encompassing the new physical astronomy and utilising more accurate and more refined instruments. The first collection of the results of eighty years was Sherburne W. Burnham's monumental two-volume catalogue and analysis of about 16,000 pairs: *A General Catalogue of Double Stars within 121° of the North Pole*, published by the Carnegie Institution of Washington in 1906.

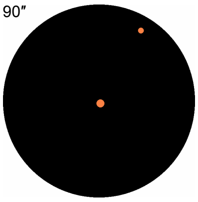
Most Struve objects can be found and observed with modest instruments (assuming that observational skills are being utilised), and some of the less well known doubles and multiples are equally accessible. For example, many of John Herchel's discoveries (prefixed with h) are bright and attractive, and are always worth investigating. However, if you are new to double stars avoid Burnham objects (prefixed with β), most of which were discovered by S. W. Burnham using the Dearborn 18-inch, the Lick 36-inch, and the Yerkes 40-inch refractors. They are either exceedingly close (a fraction of an arcsecond) or, if acceptably wide, have a very faint companion – sometimes down to magnitude 16. They can be observed, but attempts to split them will result in severe frustration. Also avoid Aitken pairs (prefixed with A), which were discovered by Robert G. Aitken between about 1900 and 1930 – again using the Lick 36-inch refractor. Many of them are spectroscopic binaries – orbiting pairs that can be neither split nor measured visually.

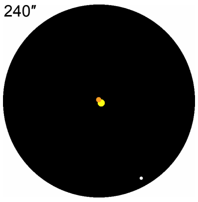
Observing skills can be enhanced by abstaining from the use of a 'goto' facility, thereby providing an incentive to refer to catalogues and charts, encouraging 'star-hopping', and leading to increased knowledge of the telescopic sky. Estimation of the position angle and separation of double-star components is also a good observing discipline. Position angle is measured anticlockwise from north – N = 0°, E = 90°, S = 180°, and W = 270° – and separation requires knowledge of the size of the field of view, which can be easily deduced by timing the transit of a star. For simplicity, it can be stated that a star on the celestial equator takes 1 hour to traverse 15°. Therefore, if it transits the eyepiece field in 1 minute, the field is 15 arcminutes... if it takes 20 seconds, the field is 5 arcminutes... and so on. It is preferable not to choose a star too far from the celestial equator, but if it is necessary the timing result should be multiplied by the cosine of the declination. It should also be remembered that with an equatorial mount the orientation of the field is retained when the instrument is moved, but with an altazimuth mount the field rotates. Double stars can also be used to test (with good seeing) an instrument's optical quality and resolving power.

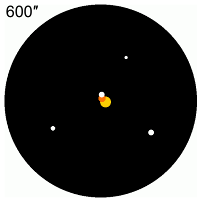
Due to contrast, colours of double stars can seem more enhanced than those of single stars, and should be recorded whenever possible. The doyen of star-colour description was W. H. Smyth, who in his 'Bedford Catalogue' (the second volume of *A Cycle of Celestial Objects*, published in 1844) utilises 114 colours, including sixteen shades of white. One colour description which has never been surpassed, however, is Struve's *olivaceasubrubicundae*.

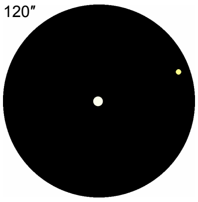
The illustrations below show a few examples of double and multiple stars (with the discs and colours exaggerated) that can be easily found and observed. In each case, south is at top, although the field sizes differ. Also included below is the Greek alphabet, which is worth learning.

Further details of the Association's double-star programme can be obtained from the Deep Sky Section's double-star coordinator, John McCue: john.mccue@ntlworld.com.

90″

15 Aquilae

240″

38 Geminorum

600″

η Cassiopeiae

120″

β Cephei

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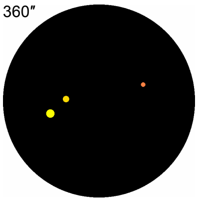
λ Arietis

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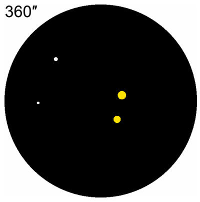
ψ Draconis

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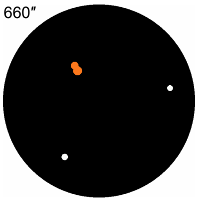
61 Cygni

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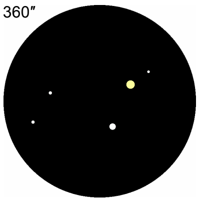
39 Draconis

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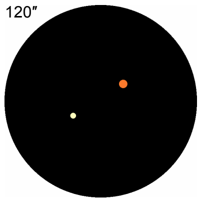
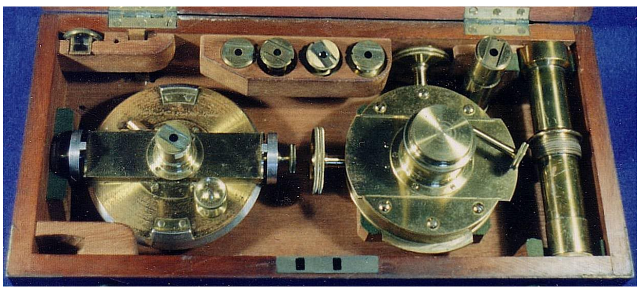

β Cygni

alpha	α	Α	iota	ι	Ι	rho	ρ	Ρ
beta	β	Β	kappa	κ	Κ	sigma	σ	Σ
gamma	γ	Γ	lambda	λ	Λ	tau	τ	Τ
delta	δ	Δ	mu	μ	Μ	upsilon	υ	Υ
epsilon	ε	Ε	nu	ν	Ν	phi	φ	Φ
zeta	ζ	Ζ	xi	ξ	Ξ	chi	χ	Χ
eta	η	Η	omicron	ο	Ο	psi	ψ	Ψ
theta	θ	Θ	pi	π	Π	omega	ω	Ω

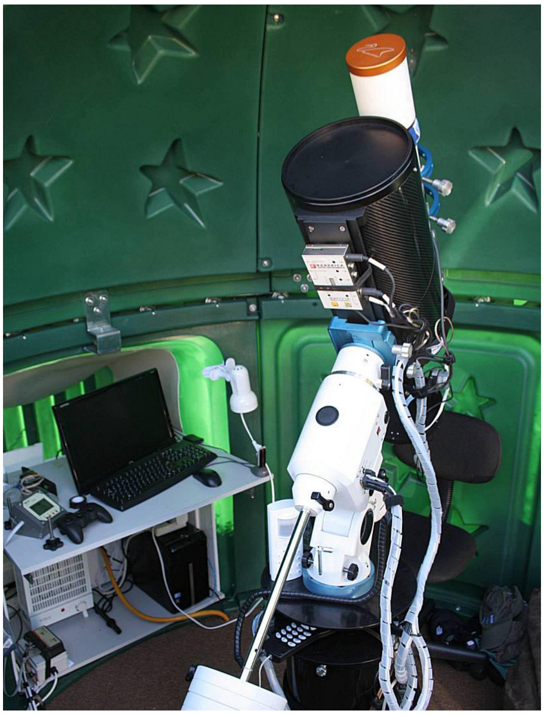

A fine example of a late-nineteenth-century micrometer.

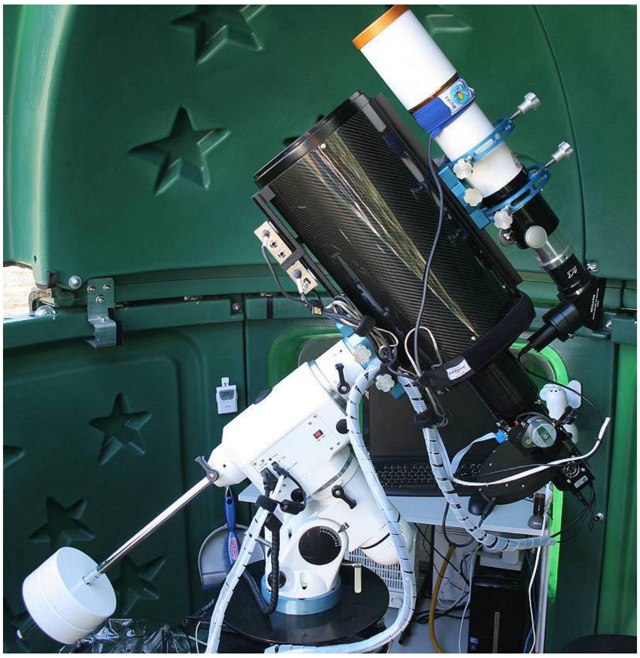
Observing from an AONB

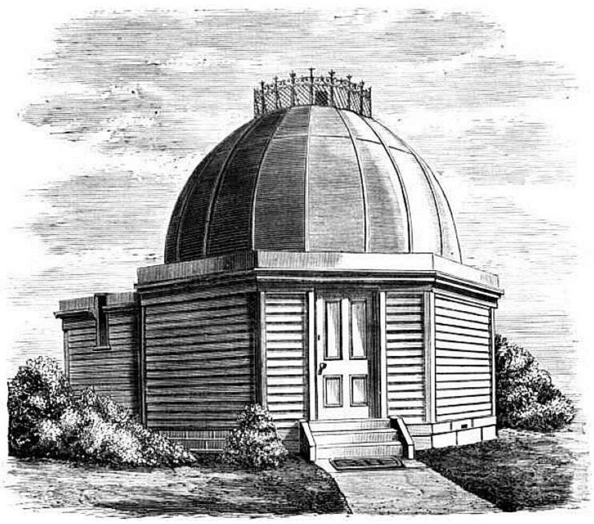
John Mallett

I first gained an interest in astronomy from watching *The Sky at Night*, and also by using stars as a back-up when navigating at sea and in the mountains. I have been taking a more active interest over the last twenty years, my first telescope being a Meade LX90. I now have a good portable Skywatcher set-up for star parties and outside events, so I have sold the LX90. My observatory is located at 700 feet above the Wye Valley, and has quite a few natural obstructions: trees. But this is a designated Area of Outstanding Natural Beauty, so cutting a few of them down is not an option (although, as a consolation, the nearest street-light is 7 miles away). The dome is a Skyshed Pod, which has proved very good in the location, which is very exposed to the wind, rain, and snow. The pier-mounted telescopes are an 8-inch Ritchey–Chrétien astrograph and an 80-mm Williams Optics apochromatic refractor. The camera, guider, and filters are all Starlight Xpress: SXVR-H18, Lodestar, and filter wheel. The mount is an NEQ6 Pro driven by EQMOD software, with Observation Manager (my own software) and Script Generator driving AstroArt 5.0. The software for these tools, which is under constant development, is available free on my website at http://www.astro.me.uk.

Hewelsfield, Gloucestershire john@astro.me.uk







Astronomical Observatory T. Cooke & Sons, York, 1886

The form is octagonal, the overhanging eaves and iron rail upon which the dome revolved being supported in the interior at each angle by cast iron pillars which are let into the stone work surrounding the basement of the building, the foundation of which is brick. The sides are constructed of redwood boards; the framework of the dome is also of redwood, which is covered with canvas thoroughly painted to withstand the weather; this covering has the advantage of being light, and thus renders the dome, which rests upon seven cast iron wheels working on a circular rail, capable of being turned round with comparative ease. The shutter of the dome is divided longitudinally through the centre, and the two halves move on rails equably from the centre by means of a pinion and double rack... It being almost impossible to give estimates for observatories without previously knowing the apertures of the telescopes for which they are required, we have refrained from publishing a series of estimates, feeling that however large we might make the series it would at best be unsatisfactory. We shall be glad, however, to send specifications and estimates to anyone upon being furnished with the necessary particulars.

The 10-inch Cooke refractor of the Mills Observatory, Dundee

Ken Kennedy

The Mills Observatory was built at the top of Balgay Hill in Dundee in 1935. It was the legacy of John Mills who, on his death in 1889, left a bequest to construct a 'building equipped with astronomical and other instruments suitable for the study of the wonder and beauty of the works of God in creation.' The original telescope housed in the 8-metre dome was an 18-inch Newtonian reflector constructed by Grubb Parsons. After the Second World War, negotiations between Dundee City Council and Professor E. Finlay Freundlich, of St Andrews University, resulted in the 18-inch being replaced by a 19-inch Schmidt–Cassegrain telescope which was a pilot model for a 37-inch planned for St Andrews Observatory.

After three years of trials, in February 1951 the 19-inch was transferred back to St Andrews, and in exchange, Mills Observatory received a 10-inch Cooke refractor which had previously been used by students. This telescope had become surplus to requirements, and seemed a most suitable instrument for a public observatory, being robust, and requiring little maintenance.

The 10-inch was made by Thomas Cooke and Sons of York in 1871. It is not known who first purchased the instrument, nor where it was used, but in 1912 J. H. Worthington bought it second-hand from Baker's of Holborn. It was established at Four Marks, near Winchester, and over several years it was used by well-known observers such as W. H. Steavenson and R. L. Waterfield. Records of observations include not only those of Jupiter but of details on the discs of Jupiter's major satellites – though possibly the best-known observation is the drawing of Uranus, showing a bright equatorial band, made by Steavenson in 1915.

The telescope was next owned by the Director of the BAA Lunar Section, Walter Goodacre, who used it for the compilation of his lunar atlas, published in 1931. (His final notes to the publisher were presented to Mills Observatory by Patrick Moore in 1972.) Following Goodacre's death in 1938, the telescope was purchased by St Andrews University as a teaching instrument.

The dome of Mills Observatory is 8 metres in diameter, and was constructed to house the original 18-inch Newtonian reflector. Therefore, because of the height of the column and the length of the tube of the 10-inch Cooke, it fits very closely, and the dew cap has had to be discarded to allow the dome to close.

The drive of the 10-inch is the original clockwork motor, and despite receiving very little in the way of maintenance it has continued to function well to this day. The first major maintenance carried out for many years was completed in 2010, and showed that there were no mechanical problems in the motor and gears.

Given clear skies, from Monday to Friday between the months of October and March, the telescope is used for showing visitors the 'wonder and beauty' of the objects in the heavens. In addition, members of Dundee Astronomical Society collaborate with the trust which now administers the observatory to provide events such as Family Fun Nights and lunar and solar observing sessions. Busy nights can see more than 100 visitors entertained and enlightened by viewing through the Cooke, and John Mills would surely have been pleased to see his observatory being used for the purpose he intended, so many years after his generous gift to the city.

Further information on the observatory can be found in Harry Ford's article 'The Mills Observatory, Dundee', in the Association's *Journal*, **93** (1983), 251, and Tom Flood's *The Mills Observatory: A Historical Survey* (1986).

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Ken Kennedy is Director of the Association's Aurora Section, and is currently Vice Chairman of the Mills Observatory Advisory Group, which liaises with Dundee City Council. At left is Dr Bill Samson, a former Astronomer (the official title of the person in charge of the observatory).

The 10-inch Cooke in its full glory. (Note the Coronado PST at lower left.)

Imaging the Sun with Coronado PSTs

Mick Nicholls

My interest in astronomy first developed when I was aged 6, in 1976. Over the years I was primarily a visual observer, and in 1996 I decided to try my hand at imaging. I was always interested in observing the Sun, so it was a natural progression for me to begin imaging first in white light, then in Hα, and finally in calcium light. The most economical way to proceed was to purchase two 40-mm f/10 Coronado PSTs (Personal Solar Telescopes) – one for Hα, and the other for calcium. These are the 'babies' of the Coronado range. In March 2011 I purchased an Imaging Source DMK21 USB monochrome camera and an HEQ5 Pro SynScan mount for night-time use, but they are also very useful for imaging the Sun and for producing solar animations. It should be noted, however, that a laptop with a fair-sized hard drive is required, especially for solar animations, as gigabytes of data can be collected. It is also worth marking the position of the tripod legs at night, so that they can be repositioned for solar imaging. This will help prevent field rotation, as even with a tracking mount, if it is not accurately set up, the Sun will drift – which is undesirable when acquiring data for animations over a period of an hour or so.

The Coronado PST is intended primarily for visual use, and when imaging there are some obstacles to overcome. The main problem is that there is insufficient focus travel. However, there are two solutions. One is to buy a short nosepiece for the DMK camera that does not have a lip at the bottom end near the camera. This is useful, as more than half the Sun's disk can be imaged at once if there is a large area of activity. The second method is the one I use. As the DMK nosepiece is a standard 1¼-inch connection, I simply unscrew the lower lens of a 2x Barlow lens and screw it into the nosepiece. This also helps to improve the image scale, and I can zoom in on regions of interest, which is very useful when collecting data for time-lapse animations.

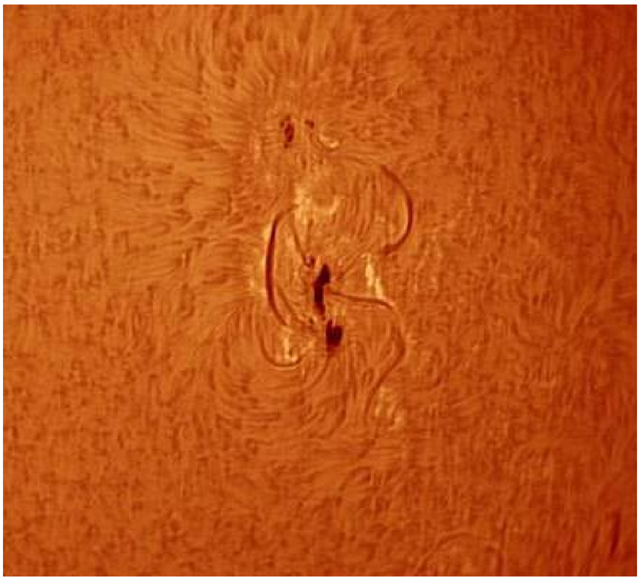
The first task is to focus the DMK camera. Sky conditions can, of course, affect efficiency of focusing, as well as determine what camera settings should be used. However, the object is to capture data, so if the sky conditions change while a series of images is being acquired, I do not adjust the camera settings. This might result in an animation that appears brighter or darker at times, but if the camera settings are repeatedly changed to adjust to sky conditions, the animation *will* have variations in brightness.

As a general rule I normally set the camera at 30 frames per second, reduce the gain to as low as possible, leave the brightness and contrast at their factory settings, reduce the gamma to 60% to reveal the contorted field lines – the dark mottling on the solar surface – and use an exposure of 45th–57th of a second. For one image, I normally capture 500–600 frames.

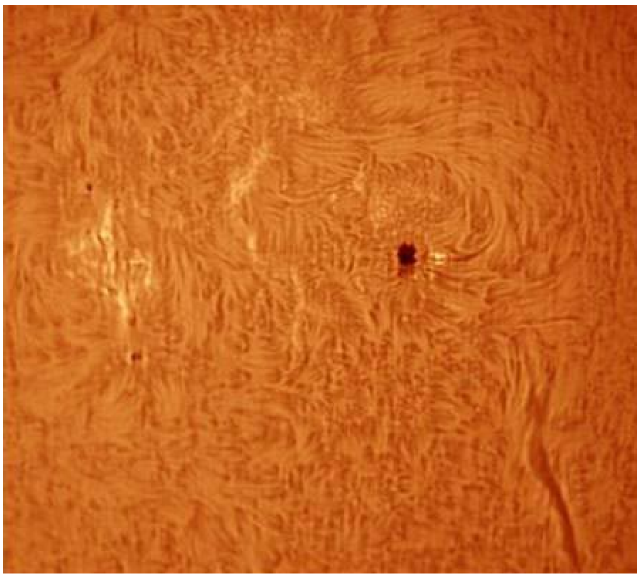
The DMK21 camera is monochrome, but image-processing software can be used to produce colour images and animations. I use Photoshop 6.0, although any software that allows changes of colour, shadow, midtone, and highlight will suffice. The settings I use are as follows:

Shadow	Red channel	+50%
Midtone	Red channel	+83%
	Yellow channel	–100%
Highlight	Red channel	+44%
	Yellow channel	–28%

For time-lapse animations the procedure is to image the same region of the Sun repeatedly at specific time intervals. I usually aim to capture about 20–40 individual video sequences at intervals of about 90–120 seconds, with each video having 500–600 frames. Each sequence is then stacked and processed to obtain 20–40 images.



The Sun in Hα light: 2011 September 29, 0909 UT



The Sun in Hα light: 2011 October 15, 0943 UT

It is important to capture each video with exactly the same camera settings and to process the images with the same settings, else the animation may appear odd or may even be ineffective. I use Registax to process the videos and also to create time-lapse sequences.

To assist with precise centring of the area of interest I have made a little transparent device that fits over my laptop screen. This is essential when compiling animations, and can be used with any of my telescope/camera combinations – including a Dobsonian – to assist with alignment of solar features.

The results of animations can be quite spectacular, and it is very satisfying to see the movement of a flare, a prominence, or a filament.

Calcium-light imaging is also very rewarding, though it is very sensitive to seeing conditions, and even a tiny amount of haze in the air can necessitate considerable adjustment of the camera settings. Overall, it is always worth experimenting in order to obtain the best results.

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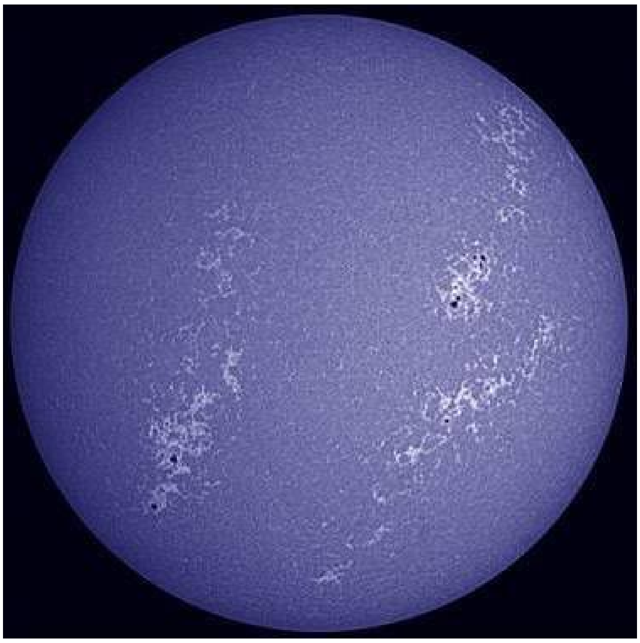


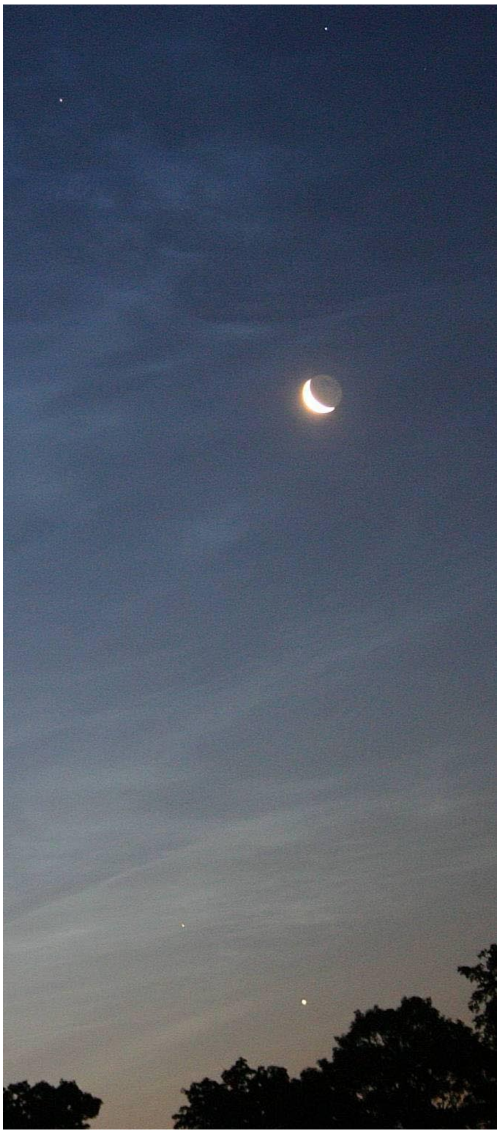
The Sun in calcium light: 2011 March 31, 1313 UT

Noctilucent clouds

Bob Marriott

2009 June 19, 01:31:50 UT

2009 June 19, 01:36:32 UT



2009 June 19, 01:38:56 UT
(Top) α and β Arietis
(Bottom) Mars and Venus

Visual observing, imaging, and mobility

Grant Privett

Like so many other amateur astronomers I developed an interest when I was very young, and my first observations were made with a 60-mm refractor. I even discovered what might have been Comet Privett, but it proved to be M3. By 1985/6 I was living and working in north London. I acquired some 10 x 50 binoculars from a charity shop, and shortly afterwards began observing variable stars. Eventually, I bought a secondhand 8-inch f/8 Newtonian by Fullerscopes. In 1991, when I moved to Shropshire, where the skies are darker, I dispensed with the Fullerscopes instrument in favour of an 8-inch f/4.5 Newtonian with a mirror by Hinds, on a Super Polaris mount. These days I use a 10-inch f/4.4 Newtonian on an EQ6 mount. It is rather awkward to move, but I have yet to build the structure that will be grandiosely entitled 'the observatory'. I observe with the instrument and mount on three levelled bricks that lie in the gravel at the back of the house. It takes an hour or so to set up, so I rarely observe if the weather report does not forecast at least three hours of clear skies.

These days my main interests are deep sky, so I tend to regard the Moon as light pollution. Despite the mount being a 'goto' I have never used it as such, and instead star-hop from a nearby reference star. This is a traditional method of visual observing, and it helps to develop knowledge of the telescopic sky. I love observing visually, and often take binoculars or a small telescope with me on family holidays. In particular, I like observing with binoculars, and am always surprised how much can be seen with 10 x 50s. Even the Veil Nebula can be seen with normal binoculars and no filter. I find 80-mm binoculars rather too heavy to be hand-held, and have never been comfortable with parallelogram mounts because of an old neck injury (incurred by flying a hang-glider into a tree at 30 mph). I do, however, like the mirror-based systems that allow observation of most of the sky from a seated position, and 60-mm binoculars have always seemed a good compromise. I also occasionally use an 80-mm f/5 Helios refractor. It does not bear much magnification, but it is good for low-magnitude sweeping, as is the 114-mm reflector I sometimes take away from home or use to track the planets into the twilight.

Although I still observe visually, my primary interest these days is imaging. Generally, after locating a target I have a good long look at it with different powers, and then use the camera. I love its accuracy and objectivity. At one time my drawing was fairly good, but when drawing the fainter extremities of nebulae I was never entirely sure what I had seen and what was expectation. It worried me a lot. (Browse various websites, and you will find people claiming that with a 150-mm aperture they have seen the gravitationally lensed portions of Abell 2218. The words 'pigs' and 'fly' can form part of a useful phrase.)

Essentially, my observing programmes involve observing an occasional Local Group galaxy, capturing the brightest Kuiper Belt Objects, imaging extremely dim globular clusters, and experiments such as the polarimetric imaging I tried recently. If the telescope has been indoors for a long time I might pursue a nebula with a Baader 30-nm Hα filter. It is only a low-cost filter, so some sky brightness does leak through, but it can produce quite good results. Alternatively, I occasionally obtain unfiltered images of globular clusters – but not the faint Pal globulars, which tend to need really long integrations to show anything in them that suggests something other than randomly strewn background stars. On darker nights I tend to target reasonably compact nebulae (the sweet spot is hideously small on an f/4.4, and I have yet to buy a coma corrector), and often image just one object a night. Collecting as many photons as possible is all-important, and it is better to obtain one deep image rather than two or more that are underexposed or of poor quality. With the Polaris mount I used to take about 200 45-second exposures, and after disposing of the poor results I obtained beautifully low noise by median-stacking the images in batches of 25 frames and then summing the resultant set of images. These days I tend to acquire as many 2-, 4- or 6-minute images as possible.

The planetary nebula PK 164+31.1 in Lynx

Polarised RGB image of the Crab Nebula – a combination of three images taken with a 0-, 45-, and 90-degree polariser in front of the camera. The alignment is poor, but it indicates what is possible.

I find image processing a very satisfying pursuit on a cloudy night – which is just as well, as it is the sort of thing I do for a living. I also tend to decimate my spare time by writing my own camera-control software for the Starlight Xpress SXV-M7, though it also works with Lodestars and the MX916. I much prefer using my code because, by definition, it is intuitive to me.

I recently carried out some astrometry on a Kuiper Belt Object I had imaged a few days earlier: Eris – one of the easy ones. I have imaged it before, but this time I submitted the astrometry, which I consider as a practise exercise for more challenging quarry. I have never imaged anything of 22nd magnitude, but I intend to attempt it this winter. At some time or other my 10-inch may be replaced by a 12-inch, and the observatory will probably be built next year – though it always seems to be 'next year'.

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The pouring of the 200-inch mirror disc

An eye-witness account

John H. Hindle (1869–1942) was one of the leading optical practitioners of his time. He was the only non-American invited to Corning Glass Works to watch the pouring of the 200-inch Palomar disc in 1935, and he afterwards published an account of this event in the *Journal*, **45**, 5 (1935), 200.

Having been advised by my friend, Mr A. G. Ingalls, Science Editor of the *Scientific American*, that the second 200-inch mirror would be poured sometime during the four weeks following November 25, I sailed for New York on the *Majestic* on 1934 November 14. The Corning people did not wish to fix a definite date in advance, neither was the spectacle to be a public one, as in the former instance, but it was intimated that I might probably have the opportunity of being present.

Shortly after I arrived in New York, the date of Sunday, December 2, was given as *the* day, and I received a very courteous letter of welcome from the Corning Glass Works. As officially only the Press was to be present, I was nominated as the London representative thereof. Strange to say, I was the only visitor from overseas, and the experience was many times worth the little trouble incurred. Corning is in the State of New York, but about 260 miles from the city, and the route, by the Lackawana Railway, is quite a picturesque and romantic one along the Delaware River, calling to mind the Fennimore Cooper thrillers of one's boyhood.

Mr Gage, from the Corning Glass Works, met me at the station on the Saturday afternoon, and we adjourned to the Baron Steuben Hotel. Corning is actually situated in Steuben County, and Baron Steuben was a celebrated German who assisted the Americans to throw off the English yoke. Whilst the nomenclature naturally remains, only the kindliest consideration and expression of goodwill to English people prevails. Early Sunday morning during breakfast, Mr Gage informed me that the pouring had already commenced. Everything had been found in order, and it was consequently decided to carry on without any further delay. Shortly we came to the works, exhibited our credentials, and passed along to where the melting and pouring of the glass was taking place – a scene which it took some little time to fully comprehend. The glare of the molten glass in the semi-darkness, the muffled roar of the innumerable gas- and air-burners under pressure, the little crowd of spectators safely housed on specially prepared galleries, all constituted a most striking ensemble.

After some time devoted to taking in the significance of the scene, one could investigate the methods adopted. The Corning Glass Works apparently have a great advantage in an abundant supply of natural gas, and the main furnace heated by this means contained 30 or 40 tons of glass of a special formula, molten at a temperature of 2,800° F. A few yards away from the furnace was a domed structure built of very light silica brick, a USA commercial product, which answers all the purposes required, *viz*., resistance to heat, sufficient strength, and easy manipulation. There were three main iron doors to this structure, and between each door there were twelve bunsen burners imparting sufficient heat to the casting chamber to keep the glass in a plastic state. The lower part of the chamber had the cores built up to form the geometrically-shaped recesses in the bottom of the disc. A mono-rail was fixed between the main furnace and the casting chamber, with switching points, so that the ladle could be run to each door in succession. The gas and air supply was under the control of one man, who stood by from start to finish. The ladle was provided with an extremely long handle, and was first of all soused in cold water; then the furnace door was opened and the ladle thrust inside and very slowly and deliberately dipped into the glass with a semi-rotation, filling it to the brim. Three or four men bore down on the extreme end of the handle lifting the ladle clear of the molten glass, and it was withdrawn from the furnace. The chief ladleman then scraped away the overflow with a long rod, and another man placed a perforated metal ring slightly larger than the ladle, throwing a shower of cold water upon the outer sides of the ladle itself. This chilled the glass next to the metal, and we now have a glass-lined ladle, preventing impurities from the ladle itself contaminating the casting. The ladle was then run along suspended on the mono-rail to the appropriate door in the casting chamber, thrust inside, and quickly poured. As the flow of glass began to diminish it tended to assume a ribbon-like form, showing its extreme viscosity. The ladle was then quickly returned to an upright position and brought outside. The glass remaining in the ladle, including the temporary lining, was dumped into a wheelbarrow and returned to the main furnace. During the actual operation of pouring, the air and gas were turned off and turned on again immediately the door was closed. The heat of the chamber was sufficient to automatically ignite the gas jets.

This process continued, and before very long the molten glass began to rise above the cores and form the substance of the optical portion of the disc. There was no hitch of any sort, and after returning from lunch it could be seen, looking through coloured glass into the apertures of the casting chamber, that the surface was remarkably level and soon settled down after the addition of each ladleful. At 2.10 Dr Macauley, in charge of the operations, walked across to Chief-Ladleman Wilson and shook him by the hand. That signified that an important part of the proceedings was satisfactorily completed. In all, 104 ladlesful of molten glass had been poured. Many of the spectators were particularly impressed by the fact that Chief-Ladleman Wilson was wearing a metal and glass shield over face, head and shoulders, whilst asbestos protected hands and arms. It seems that Wilson used to carry this shield gripped in his teeth, but since the pouring of the first 200-inch his dentition had somehow gone awry, and he wore the shield fastened to a baseball mask, at the same time wearing a cap with the visor reserved in baseball umpire style.

The most important departure from previous practice is the rnethod of building a special casting chamber which is preheated, and may continue to be heated for a considerable period to maintain the molten glass at a temperature at which it can flow and the various pourings mingle completely. Obviously, the technical staff of Corning have very carefully planned the method of casting, and the actual pouring was a splendid example of team work. Returning in the evening before leaving for New York I found Dr Macauley still on the warpath, and the iron doors of the casting chamber were ajar, permitting a certain amount of cooling. A little incident I noticed was that Dr Macauley, with a long iron rod touched the surface of the glass to feel its plasticity. Deciding that the temperature of the surface was falling just a little too quickly, the doors were closed, and the gas jets ignited again, for a little while.

The next process of annealing will be just as carefully attended to. The base of the casting chamber is constructed on the table of a powerful hoist, which, when the glass is cooled sufficiently, is lowered to the floor below; it is then moved sideways and again hoisted up under another chamber, the annealing oven, which is electrically heated and controlled. Heavy bus-bars carry the current around the outside of the chamber and pass through insulating bushes. Thermal couples at various points lead to recording instruments in an adjoining room, and it is arranged that every three hours a reduction of 1° centigrade, at each of ten points in succession, will take place. This diminution of temperature will proceed night and day for a period of nine or ten months until normal temperature is reached, and by which time it is considered certain that the whole of the strain induced in pouring will be entirely removed. There have been prognostications of difficulty on this particular point, and that it would be almost impossible to remove the strains from the rib portions. Dr Young, who was connected with the business, stated that when they cast the first 30-inch disc with ribs it had a preliminary period of annealing, after which optical tests showed only very slight positions of strain; these were at the junction of ribs and were circular shafts only about the thickness of the lead in a lead pencil. 'Obviously,' he said, 'had the annealing process been continued just a little longer, these would have entirely disappeared.' And he thought, moreover, that the authorities for whom they were carrying out the work were quite satisfied on that score. In my opinion, it is definitely certain that there need be no further discussion about cemented mirrors after seeing the result of the present experiment.

It may be as well to recall that not very long ago pessimists were saying that a 200-inch disc was impossible. The failure of the costly experiment with quartz must have damped a lot of enthusiasm. It has been found that the first disc, in which one or two of the cores became detached and floated to the surface, can have the glass removed satisfactorily, and the California Institute of Technology is now in the extraordinary position of having two 200-inch mirror blanks. The glass of the first 200-inch mirror is a turquoise-blue. It will require further annealing, as it was cooled down in about a couple of months. The last 200-inch is of glass of a different formula and will be a clear crystal white. The Corning people express the opinion that they could make much larger discs if necessary, and refuse even to put any limit on the size they would attempt. They could certainly make a 300-inch or even a 400-inch disc, they said.

Pyrex Brand resistant glass seems to be a most desirable material for telescope mirrors. It has an expansion coefficient of 0.0000032. It is said to reach its maximum expansion in bright sunlight in about 20 minutes, and thereafter remain constant. It cannot be produced of optical quality, but that is unnecessary. The blanks are very carefully annealed in an electric furnace for a sufficiently long period to remove all evidence of strain.

I wish to acknowledge the courtesy of Mr Quigley, the New York representative, of Drs Hotstetter and Macauley at Corning, and particularly of Mr Gage, who took care that my short stay in Corning was very pleasant and that I had every facility for acquiring information. I also thank Mr A. G. Ingalls of the *Scientific American* for kindly arranging to make my visit possible.

Photographing minor planets

Max Wolf (1863–1932), operating at Heidelberg Observatory, pioneered the use of astrophotographic techniques for the discovery and recovery of asteroids. This account of his early work was published in the *Journal*, **3**, 1 (1892), 19.

In December 1886 Dr Isaac Roberts first succeeded in photographing with his telescope the minor planet Sappho, estimated to be of the 11th magnitude. The planet described a short trail on the plate amongst the stars near the place of the ephemeris, and from the plate the correction of the ephemeris was immediately obtained.

The difficulty in detecting a minor planet, amongst the enormous number of faint stars, by eye-observation is very great, because it is only by its movement that the planet can be discerned. The observer must, therefore, make a diagram of the region in which he supposes the planet to be. After a time, on comparing the diagram star by star with the sky, he finds that one star – the planet he sought for – has moved, always supposing, that is to say, that he has examined its right place, and not, by mistake, a neighbouring but inaccurate position. Photography holds out two great advantages over that method; it gives a larger field, while the planet marks its trail and therefore immediately distinguishes itself from the surrounding stars.

I commenced photographing minor planets in August 1890, using both a telescope lens of 16.2 cm aperture and 262 cm focal length, and an aplanatic lens of 6 cm aperture and 44 cm focal length. I was seeking for several lost asteroids at the time during several nights, and used ten plates with long exposures. I had no success because I could not employ suitable lenses, the focal length of the first employed being too long, and the aperture of the second too small. To photograph minor planets both a large field and a marked brightness of image is required. For photographing nebulae the brightness has as factor the quantity D/F2, where D is the diameter of the object-glass and F the focal length of the lens employed. But it is quite a different thing with asteroids, of which the area is a 'point'. The brightness of the image on the plate would be the same as from a fixed star of equal intensity. It would have as factor the quantity D2, if we neglect for simplicity's sake the small influence of the focal length. But the asteroids are moving and are drawing a trail amongst the stars on the plate. This trail becomes longer when using a lens of longer focus, and the intensity of a planetary trail drawn by a longer-focus lens is diminished. It therefore results that the brightness has as factor the quantity D/F2. To photograph asteroids, therefore, we need a lens with an aperture as great as possible, with a focal length as short as possible, and giving a large field; as for instance, a large portrait lens.

From this point of view I recommenced the photography of minor planets in November 1891, using my 5¼-inch Kranz aplanatic lens. After some experiments in focusing the plate I succeeded in getting on my plate, on the evening of December 22, the first new minor planet discovered by means of photography. This is no. 323, Brucia. On the same plate I found the lost planet 275, Sapientia, both of the 12th magnitude. Since then I have photographed a great number of old and new minor planets. From 1891 November 28 till 1892 April 25 I obtained 125 different positions of 58 different minor planets, 17 of which were new discoveries.

For the most part the positions were roughly taken from the Argelander charts, but a great number were measured. This measurement is quite simple. A microscope with a long-focus object-lens and supplied with a filar micrometer in the eyepiece is alone required. The distance of the middle of the planetary trail from several known stars on the plate is measured. The distances give, by a simple trigonometric example, the differences in RA and in North Polar Distance from one of the known stars. The accuracy gained by this simple arrangement is within a fraction of one second of arc, and the measures are therefore equivalent to eye observations.

Since May 1892, besides many known planets, several lost and several new planets have been discovered by my photographic lenses, and it has been found necessary since August to introduce a new method of reckoning the newly discovered asteroids.

I hope the fact will be of interest for your members that the new planet 1892C was discovered by my friend, Mr A. Staus, who is a member of your Association.

The success already obtained proves that it is easy to find all the hitherto lost minor planets, and to arrange for a simple and sure watch over all the known asteroids, working with lenses of large field and great light-grasping power, and by means of the self-registering action of the planetary trails on the photographic plates.

The work is very straining and fatiguing, because I have to expose each plate for two hours, controlling without intermission the driving clock by the guiding telescope.