



Current Notes

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Editorial

Recent years have seen a rapid rise of the profile of astronomy in the public eye, it seems. Ever increasing numbers of astronomical space probes are planned and launched, new telescopes are commissioned, and bold new missions announced. This makes for what has been fairly described by popular commentators as a golden age of astronomy. Clearly, this is a fascinating time for those who pursue an interest in the subject. However, the renewed attention lavished upon planetary astronomy by professional astronomers could, to some extent, leave the amateur astronomer thinking that those unanswered questions which remain within the capacity of the amateur astronomer to answer, are no longer worth asking, since the answers are surely now soon to come. This is no better illustrated than by the perception quite reasonably held by many, that the Moon has been a “done and dusted” object for amateur enquiry ever since the Apollo programme concluded last century.

This perception would be mistaken, I believe. While it may be that the answers to many questions have been, and will continue to be, convincingly put by the professional community, one must not forget that those answers relate only to the questions that were asked at the time. They do not relate to questions that were not, or could not have been, anticipated. Similarly, interesting and important questions may well have been ignored due to limited resources, or due to having seemed irrelevant (or even unfashionable) at the time. For these reasons I am fully supportive of the aims and views expressed in Kevin Kilburn’s article regarding the Moon. I hope that you, the reader, might entertain a similar view.

Dr Andrew Fearnside
Editor of Current Notes

Letters and News

Harold Hill (1920–2005)

It is with great sadness that we record the passing of Harold Hill, the famous lunar, planetary and solar observer. Harold worked tirelessly as a visual observer all his life. His detailed renditions of the subjects he observed have been an inspiration for many. The Moon was his favoured subject; his book *A Portfolio of Lunar Drawings*, published in 1991, remains a timeless classic. His lesser known planetary work is a benchmark of visual observation, and he continued to observe Mars during the current opposition, amassing 52 drawings of the planet up until he was taken into hospital on 23 October 2005. After a short illness he passed away on 30 October 2005.

I have had the pleasure of corresponding with Harold since 1984 and, although sporadic at times, my letters always resulted in a flurry of wonderful drawings and reports of his latest work. He was always helpful and encouraging in his comment of others’ work, and freely took those with similar interest under his wing. Because of the nature of his work it is easy to refer to him as a link to the past, which he undoubtedly was, but to those who knew him he was so much more: a sage of the present, and an icon of the future. His memory will live on and he will be sadly missed.

Nigel Longshaw

The Eye of the Beholder

After a Thursday meeting at the Godlee Observatory in November last year, a group of us took the opportunity to take advantage of the clear skies that had appeared over Manchester during the course of that evening. The planet Mars blazed high in a clear but unsteady sky, and presented us with a view both fascinating in the planetary detail it surrendered, yet tantalizing in the detail we all knew it withheld.

Amongst the group was Nigel Longshaw, well known to all within the Manchester Astronomical Society (MAS) as an expert in lunar and planetary observing and drawing. Nigel had come armed with drawing materials that evening, and duly set about recording his view of Mars by hand. Also present was Anthony Jennings, webcammer and aficionado of Registax image processing software. Anthony’s superb planetary and lunar images need no introduction to MAS members. This, it seemed, was a poignant conjunction of expertise in the old and the new ways of recording planetary features. I set each the challenge of producing their best record of Mars viewed through the same telescope (the Godlee 8” refractor) and under the same conditions (within minutes of each other). How would the human eye and brain – expert though they may be – fare when set against the ruthless objectivity of the silicon eye and brain? Would the spectre of Martian canals return to haunt a suggestible human mind, or would the discretion and judgement of a well-trained hand triumph over the mindlessness of the computer?

Judge for yourselves! The results are presented together as Figures 1 and 2 in the Picture Gallery of this issue of Current Notes. A reference image (Figure 3) is provided in the form of a simulated rendition of the unobscured features of Mars presented to both observers that evening at the time they observed. The reference image was produced by Messrs M Adachi and T Ikemura and can be found at <http://www.kksystem.co.jp/Alpo/Latest/..MS2005/MSmenu.htm>. The simulated view appears to correspond well with the rather blurred webcam

image of Mars, at least in terms of global albedo features, yet lacks the colour contrast and shading details of the drawing.

Dr Andrew Fearnside

Chopsticks

Many of you will be aware that there are currently two popular software packages freely available on the Internet and designed to convert video clips into high-resolution images of planets and the like. One such package is known as *Registax*, while the other is known as *K3CCD Tools*.

Although I have been using both the *K3CCD Tools* and the *Registax* imaging packages for three or four years now, I am, when using PCs, a bit like a man playing Chopsticks on a piano. I struggled when using both software packages but found the *K3CCD Tools*' "planetary wizard" to be more user friendly than *Registax*. So, over the last year I have tended to stick with *K3CCD Tools*. Of course, when one looks at all of the fancy amateur images published in astronomy magazines, one finds that all of the top planetary imagers seem to use *Registax*.

Having previously used *K3CCD Tools* to process my own Philips ToUcam Pro images, I decided to be a bit more adventurous and use *Registax* instead and compare the results. *Registax* is well known to many, but *K3CCD Tools* is perhaps less well known. Much like *Registax*, the *K3CCD Tools* package automatically runs through the individual frames of a video clip (e.g. of a planet) and arranges them into a list of descending-quality order. Generally speaking, one finds that the most poorly focused frames are dumped at the end of the list. However, this automatic procedure is not always accurate – or so it seems – and an image frame considered by the software to be the best frame of the video clip may, on closer inspection, be total rubbish.

For example, a speck of dust caught in the optics of the telescope/camera will tend to show up clearly in an image frame. This seems to fool the software into thinking that a poorly focused frame is the best one, simply because the speck of dust is sharply defined even though the rest of the image is not. Nevertheless, the software allows the user to look through all of the frames in the frame list one by one, and to dump the bad ones. However, this manual process can be very time-consuming, and it can be difficult to know where to draw the line. The user can select to use a specific number of frames or a percentage of them. Alternatively, one can simply use all frames, although, sometimes, *K3CCD Tools* seems to reject what it considers to be the very worst, e.g. frames in which the image subject is halfway off the edge of the CCD chip. I use whichever method suits my

whim – pretending I know what I am doing, when I don't! Generally speaking, I cannot claim that, when I individually select the frames to be stacked, my frame choices improve things. For this reason, I usually permit the software to do the frame selection process and I typically opt to use the best 66 per cent of the frames for stacking.

Recently, I reprocessed a video clip I took of Mars using a Philips ToUcam Pro webcam. The webcam video clip was taken on 11 November 2005 at 23:42 UT using a 214 mm Newtonian at f22.

Figures 4 and 5, reproduced in the Picture Gallery of this issue of *Current Notes*, show what was produced by processing the same ToUcam video clip of Mars using *K3CCD Tools* and *Registax*, respectively. I used 434 frames when stacking with *K3CCD Tools* and 1100 frames when using *Registax*. It occurred to me that, ideally, to make a true comparison of the two techniques it would be better to stack the same number of frames in each case. Nevertheless, I think it possible that if I were to reprocess the same Mars video clip in *K3CCD Tools* by stacking all of the 1100 frames of the clip, rather than selecting only the 434 used presently, I might get a worse final result than the one I present here. Irrespective of the infinity of processing variations possible using either *K3CCD Tools* and *Registax*, I have found that the results produced by the two packages, when processing the same video clip, differ quite considerably.

At this stage I am trying to keep an open mind about the relative merits of *K3CCD Tools* and *Registax*, and any other imaging software for that matter. I am not sure I like to say it, but on the face of it *Registax* appears to run rings round *K3CCD Tools*. I think *K3CCD Tools* does a very good job, but I am inclined to think that *K3CCD Tools* is less rigorous than *Registax*. Of course, it might be easy to take things too far and overprocess planetary images (or anything else for that matter) using *Registax*. Indeed, I recently studied an image of Mars produced via a webcam and *Registax*, and published in *Sky & Telescope*. The image presented linear features which I also found in an old Percival Lowell map of Mars as having been identified as canals! I must say, it made me think that if we did not have the benefit of space probes we might still be thinking that there are Martian canals.

Cliff Meredith

Audio Recording of MAS Lectures

It occurred to me some time ago that each time we have a public lecture at MAS, very little of the content of the lecture is recorded. While Minutes of the lecture are produced, with copies kept in the Society Minute book, and some being put on our website, these Minutes only summarize the content of the lectures. We each have our individual memory of lectures we have attended of course, but, alas, how many of us can boast remembering many details. As each lecture passes, a little bit more history is created and then it is promptly partially lost again. So why not make recordings of these lectures so that all of their content is recorded for the Society? There are two methods of recording: video or just audio. So far, except for the occasional special lecture, none of the lectures has been recorded by video camera, and those that have been recorded were recorded by John Mitchell, who is no longer a member of the Society. To my knowledge, nobody else has made any form of lecture recordings, video or audio. As I have been building up audio equipment over the past few months, I thought it would be a good idea to use what I have available to me to make high-quality audio recordings of MAS lectures. I have tried to make audio recordings in the past with a portable hard disk recorder (an Archos AV420); however, the quality of the recordings was poor since a built-in microphone was used. The equipment I now have consists of a very good dual pre-amplifier and two quality studio condenser microphones, which feed into the same Archos AV420 recorder to produce recordings of very high quality.



Recording equipment: based around a Joemeek TwinQ pre-amp.

One such recording was made (with a different single amplifier) of the lecture delivered by Professor David Hughes. This has been edited and placed on a stock of CD-ROMs which have been placed in the MAS library. The previous recordings I have made, of much lower quality, are also now on CD-ROMs. In December 2005 I visited Salford Astronomical Society for their Christmas Lecture, delivered by Dr Allan Chapman. My recording of his lecture is also in the MAS library and well worth listening to. Allan's talk is entitled *Light from Antiquity to Hubble*. By placing these recordings in the MAS library, any member who has missed a lecture can borrow a recording of that lecture



Produced CD-ROMs

and listen to it at home, in a car, or elsewhere. The recordings can also be used as reference material, or just as a reminder, to anyone who was present, of the contents of the lecture. The fact that an audio recording does not allow you to see any images that were presented during the course of the lecture does not usually spoil the listening. The CD-ROMs will also be available by post to any MAS member who does not visit the Godlee Observatory or the lectures. This will allow such members to keep in touch with what is happening in the Society and, importantly, they will be made to feel more a part of the Society, as the CD-ROMs will also contain discussion of MAS business and the Minutes from the previous meeting, i.e. the preamble before the main lecture. It is unlikely that postal requests will be made very often, so the cost to the Society in postal charges should be low and can be considered a benefit of membership. There would be no need to return the CD-ROMs if posted, but those in the library must be returned for others to borrow. It may also be possible for MP3 files to be made available to members by downloading from the Internet, thereby saving on postage. MP3 files would be of lower sound quality with a typical total data size of about 35 Mb (at 48 kbps) for a 1.5 hour recording. This would of course need splitting into smaller files.

I would welcome any of your thoughts on the method of distribution to members. I will endeavour to record as many of the lectures as I can. It is very rare that I miss one. The lecturer is approached prior to the meeting to gain permission to make and use the recordings for the membership. It is hoped that these recordings will become a valuable asset to the Society. Anyone interested in borrowing a lecture recording (or having one posted, if not able to get to the Observatory) should contact Michael Oates (me@mkeoates.org) or Jerry Grover (jerryg@globalnet.co.uk), Librarian at the Godlee Observatory.

Michael Oates, MSc, FRAS

Introduction to Observing the Moon

Introduction

The Moon is often considered an ideal target for the beginner to study. It is large, bright, easy to locate, and presents a wealth of visible surface detail. However, beginners often ultimately abandon the Moon, believing that there is nothing new to see. It is often assumed that "it's all been done before", and that the amateur observer cannot contribute anything in the way of "serious" observations. Whilst this, in the main, is true, the Moon still has a great deal to offer the amateur observer who is gifted with true enthusiasm.

History Lesson

The Moon has been under observation from the first moment intelligent beings gazed skywards. Even the layman appreciates the mystical aspects of our satellite in terms of so-called "blue Moons" and "harvest Moon" etc., and it is difficult to ignore the influence that the Moon has had on mankind. However, it was not until the first telescopes were turned towards the Moon that we can truly say we "observed" its surface. Whilst Galileo and others depicted what they saw in their early instruments, they were limited to the depiction of the phases of the Moon and the sketching of vague surface features. It was not until the telescope had evolved into more complex, optically superior designs that detailed observations of the Moon's surface were compiled. The work of Johann Schroeter, resulting in the publication of his observations in 1791 and 1802, can be considered as the true birth of selenology (the study of the Moon). Schroeter departed from the tradition of whole disc lunar mapping, and instead he concentrated on smaller areas and details of the surface which were visible in his quality instruments.

The publication of Beer and Madler's *Der Mond (The Moon)* in 1837 provided the most detailed map of the surface of the Moon of the period. Along with a detailed description of all of the surface features of the Moon, the work included height measurements, carried out by both men using a modest 3.75" refractor. *Der Mond* remained the standard reference for the lunar observer for many years. The English observer E. Neison published *The Moon: the condition and configuration of its surface* in 1876. Neison basically took *Der Mond*, expanded and revised the work, using observations made by himself, and created what is generally regarded as the first of the English classics. Neison's work somehow resurrected interest in the Moon and many observers published their own charts, observing guides and observations. Although some of these works are now over 100 years old they are still of great value, and interest, to the amateur observer. Observing the Moon

continued with the emergence of the British Astronomical Association (BAA) and with regional societies leading the way in the collation and publication of observations, which many do to this day. During the Moon missions, NASA collaborated with amateurs who were observing the Moon during the landings, looking for any unusual activity which could have been checked by the Command Module as it circled the Moon.

Following the lunar landings, most of the interest in the Moon came from geologists, and the many books which were published during this period concentrated on the geological aspects of lunar study, and rightly so. However, these books relied little on contributions from amateur observers. There has been a resurgence of interest in observing the Moon in recent years, and several excellent books have been published. A number of these books incorporate both the latest views of the professional scientists in relation to the geological formations of the Moon, and also incorporate amateur observations and images.

Equipment and Programmes

Even humble binoculars will enable the amateur lunar observer to take part in a number of specialized observing programmes currently being led by the relevant sections of the BAA, the Society for Popular Astronomy (SPA) and the Association of Lunar and Planetary Observers (ALPO). One project currently being run jointly by the BAA and the ALPO is the observation of lunar rays: the light streaks which cross the lunar surface and emanate from the younger craters. There is also work being carried out to monitor for impact flashes on the unilluminated section of the Moon caused by meteorites striking the surface. These are usually looked for during times of meteor showers, and the Moon must be at the correct phase for the work to be successful. However, there are accounts of this type of phenomenon being observed.

It is fair to say the prospective student of the Moon will want to observe with a telescope before too long and in this regard even the smallest 60 mm refractor will reveal a wealth of detail. A 100 mm telescope will probably reveal most of the features shown on any of the widely available charts under the best conditions. A 6" or 8" telescope will allow a full programme of observations to be undertaken, to the extent that the committed observer will probably never exhaust the potential of an 8" telescope. However, as with the observation of any astronomical object, it's very often the person "at the small end" who makes the difference; there is no substitute for the dedication of the committed observer.



Figure 1

The two instruments shown in Figure 1 are typical of the type of telescope suitable for lunar observing. On the upper left is a 6" Maksutov-Cassegrain of long focal length and mounted on the tripod is a 3" refractor. These two instruments are of excellent optical quality, and this is much more important for the resolution of fine, low contrast detail. If you intend to concentrate on lunar observing, it's much better to invest in the finest optics one can afford, preferably in a long focal length instrument, even if this means settling for a smaller aperture telescope. Remember, Beer and Madler carried out most of the observations for their monumental work using a 3.75" refractor of excellent optical quality.

"Seeing"

So how can we begin to really observe the Moon, and how should observations be recorded. To begin with, spend a few months getting to know the Moon. Observe as often as possible, with an outline chart showing named features, craters, etc. It is not necessary, at this stage, to commit to making drawings of the features which are observed; however, brief written notes will serve as a good reference in the future. This process will provide a good grounding and in a short time you will be ready to move on to the next level, namely, recording your observations in greater detail.

First, there are a few basics to get to grips with, and, as with anything in astronomy, a little maths and geometry to digest before any serious work can commence. First, most amateurs will be aware that the Moon has a synchronous or captured rotation – it rotates once on its axis in the same period it takes to orbit the Earth – and consequently the Moon keeps the same face towards the Earth during its monthly orbit. It would be nice to be able to see the dark side of the Moon (i.e. the face

which is never orientated towards the Earth); nevertheless, I think we are fortunate in that the surface we can observe is probably the most varied and interesting. However, as the Moon makes its way around the Earth it appears to rock on its axis and allows us to glimpse areas along the limb which would otherwise be hidden from view. These motions give rise to what is known as librations, and these are so well known that it is possible to predict which areas of the averted lunar hemisphere will be visible from month to month. Therefore, we can plan our observations to coincide with these favourable librations, and record features which may otherwise be out of view.

The second point relates to the ability to predict and measure where the lunar terminator will fall on any given night. Anyone who has observed the Moon will know that the most detailed views are available along the terminator, the division between the illuminated and unilluminated portions of the Moon. We can see therefore that if we can predict where this line will fall, by reference to a chart of the Moon we can determine which features will be best placed for observation on any given night. We can therefore plan an observing session or confirm dates when repeat observations can be made under similar conditions of illumination.

The value we calculate for the lunar terminator is known as the solar colongitude. This value can be calculated from the tables published by the BAA or by computer programs such as Mooncalc. This type of program usually involves simply filling in the required date, time and location, and the computer will calculate the colongitude value. These values generally relate to 270 deg at new Moon, 0 deg at first quarter, 90 deg at full Moon and 180 deg at last quarter, and give the terminator's position in relation to lines of longitude on the Moon.

It is imperative that this information is recorded for any observation or image taken of the Moon, as it enables other observers to compare observations, and future observations to be made under exactly the same conditions of illumination. There are other data that can be referenced to ensure exact repeat observing conditions, but recording the colongitude is sufficient for most purposes.

Methods of Recording Observations

The classical method of recording observations is to make detailed observational drawings and descriptions of a particular feature under observation, and this method has been favoured since Schroeter's work in the late 18th century. However, modern methods of recording detailed images digitally have certainly increased the potential for serious work by amateurs. The most important consideration, if observations are to be recorded by making drawings, is to ensure that the rendition is accurate. It is much better to

produce an accurate outline drawing than it is to make an artistic rendition, which may not be accurate.

I have found that one of the best ways to practise drawing at the telescope is to draw star clusters. In the eyepiece, these appear to be a simple pattern of dots. When making a drawing, the important thing is to get the dots in the right place and in the right orientation with respect to each other. Making drawings in this way will give the observer practice with respect to positional accuracy without being overburdened with complex details.

It will also help to practise drawing at the telescope, which is altogether different than drawing at a table indoors! This process will assist in attaining positional accuracy in your drawings and make you more comfortable working at the eyepiece. Unless a low-power eyepiece is used, the view at the telescope will be filled with a view of the lunar surface. This view is in the most part overwhelming, particularly for the novice observer. However, we must ask ourselves one question when looking into the eyepiece – do we want to draw the whole view?

The answer is invariably no. We wish to concentrate on a small area of interest, and in this way we section off an area in our mind, and concentrate on this. Once selected, spend a few minutes viewing the area to familiarize yourself with what is on view. Concentrate on the details which are visible, how they relate to each other, and note if there is anything unusual.

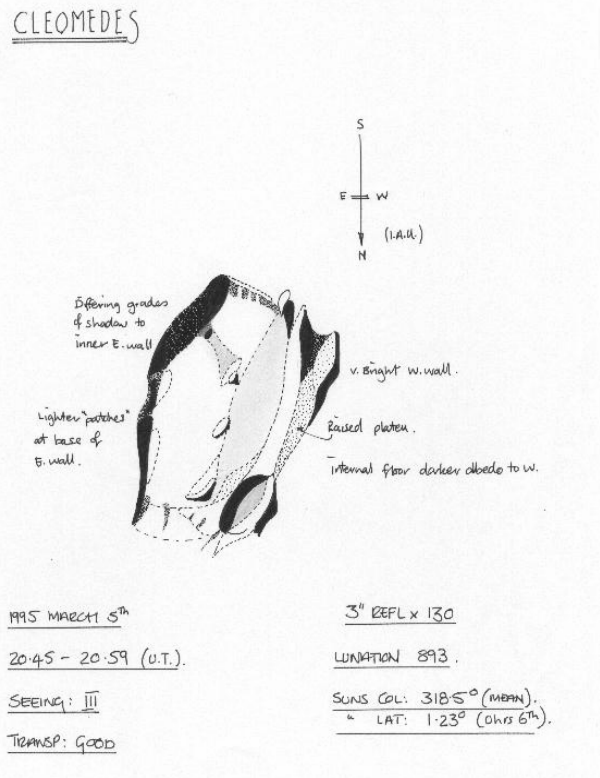
Commence by sketching in the main details in outline, giving careful consideration to their relative positions, then work over the whole of the area chosen, filling in each small area at a time. By doing this, working from one section of the drawing to the other, you will soon build up a picture of the area under observation.

This process can take a considerable amount of time, especially if the area is a complex one, or you have to wait continually for the better moments of seeing to capture the finer details. In this regard, it is better to block in the shadows of the area first, as these are constantly changing. Finally, note down the start and completion times of the observation, the telescope used, the date, and seeing conditions.

The all important colongitude values can be calculated indoors and added to the drawing later. Do not forget to calculate the colongitude for the start and finish of the drawing, as this value is changing all the time as the Sun rises over the lunar surface. The change equates to around half a degree an hour, so if the drawing has taken a considerable time to complete, which some do, then the colongitude value will

have changed from the start to the finish of the drawing.

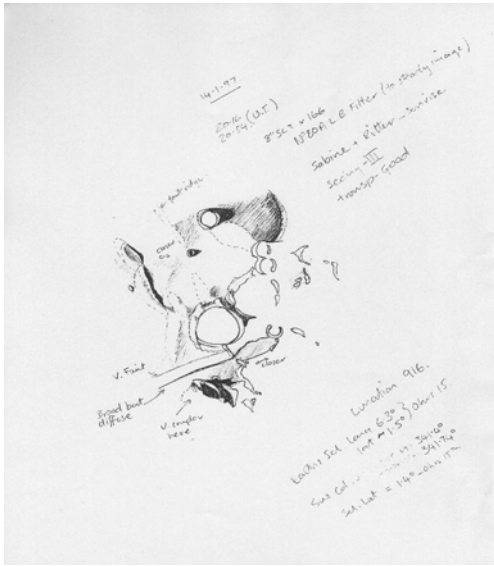
This drawing can then be redrafted indoors to give a neater finished drawing if required. Initially, it is fine to present one's work as a simple line drawing, such as the one of Cleomedes shown here.



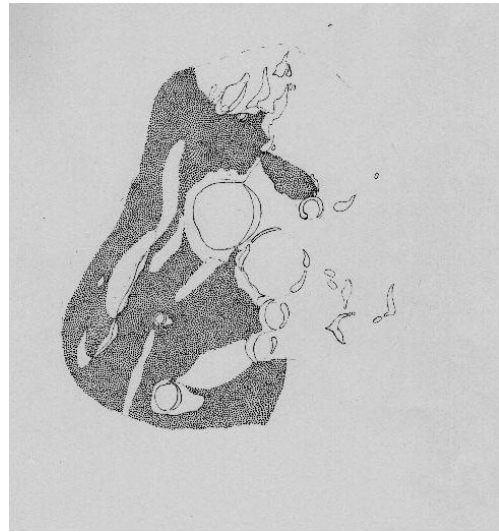
Observations can also be worked up to give a shaded relief drawing. These can give a more lifelike impression of the lunar surface; however, accuracy is always of the utmost importance. A favoured method is to use the stipple technique, not only because it gives a good rendition of the lunar surface but also because it copies so well on modern photocopy machines, which is very important if you are to submit your work to others.

What follows is an example of the sequence of steps for producing a finished observational drawing using this method. However, it does take practice and is very time-consuming.

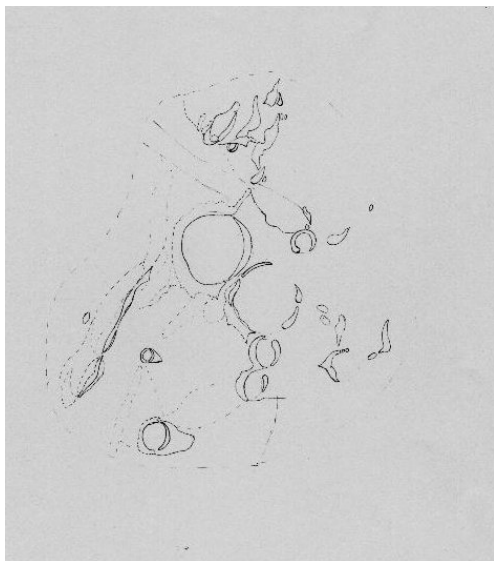
1. First, a sketch is drawn at the telescope, including the time, date and other relevant details.



3. Subsequently, the main areas of the pencil outline of the surface are blocked in, leaving out the lighter areas of surface.



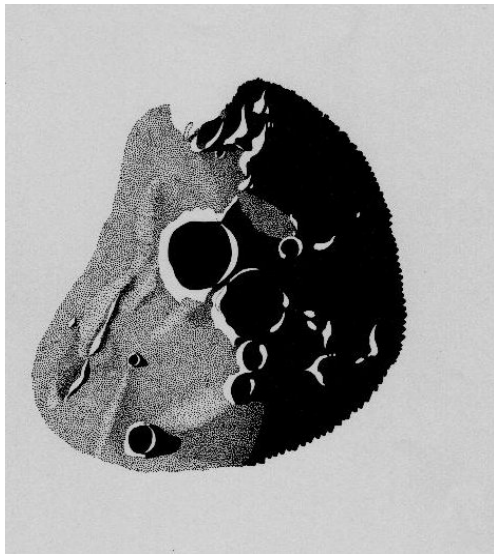
2. Next, a pencil draft outline is made, which you will note has been rectified to the I.A.U. convention with south at the top of the drawing.



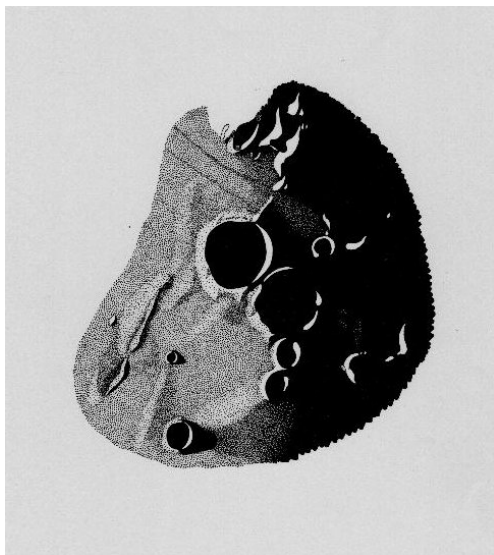
4. Next, areas of the lunar surface are added by working over the relevant parts of the drawing with a thicker pen. Lighter areas of surface are blended/toned down with a thinner pen.



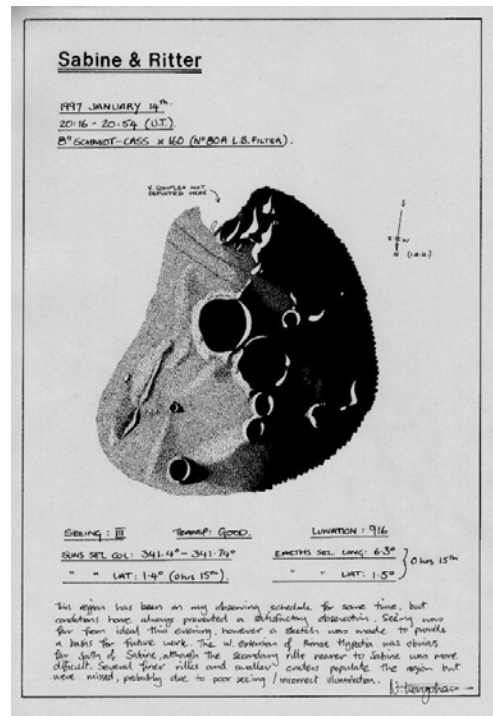
5. The main areas of shadow are then blocked in using a wide-tipped felt pen.



6. Then, with a fine pen, further work is done to the drawing to darken the regions to bring in line with the shadow areas, to soften shadow edges, to add details of rilles etc., and to tone down crater walls.



7. Finally, relevant details and observational notes are added to the drawing to complete it. See the Picture Gallery for a full view.



Equipment

Suitable pens for use in carrying out this type of drawing are fine felt tip technical drawing pens. Using ordinary photocopy paper, a drawing with this amount of detail can take around two to three hours to complete, along with the time taken at the telescope of around an hour. A completed drawing can equate to four hour's work, or more. Needless to say, never send original drawings in the post – photocopies should always be made for distribution.

There is of course increasing opportunity to record the lunar surface on film or in digital format. However, it's important not to get too carried away simply trying to obtain the best image. At the end of the day, images should be observations too. If imaging is your chosen method of observing, then it is much better to prepare a programme of work, much as the visual observer does, and take advantage of the power of the latest technology to make a real contribution to the observing programmes currently being undertaken by the likes of the BAA, and work in tandem with the visual observers.

What To Do With Your Observations

One of the most gratifying aspects of serious lunar observing is being able to sift through the many publications and huge amount of reference material available, trying to track down comparative observations. Very often,

features will be observed which do not appear on the usual maps and charts, and these can be verified by comparison with past observations or images. Sometimes, however, this is not the case and anything which is considered to be unusual can be noted down for future observation, checking the available dates with similar colongitude values. It is also important to carry out observation under opposite illumination, as this can sometimes shed new light on a previously disputed feature.

The ability to verify observations in this manner, or to carry out new lines of enquiry, is one of the reasons lunar observing can be so rewarding. A major factor in any amateur's decision to observe a particular object should be the desire to record what is observed, and to share these observations with others of similar interests. In this regard, the Moon is no exception and the BAA, the SPA and the ALPO all have active Lunar Sections. They give advice on observing projects and all produce a regular circular or magazine, which is an excellent forum for the publication of observations.

Reference Material

The list of reference material is almost endless. In addition to recent publications available through the recognized book sellers, there are many second-hand book dealers who generally have a stock of books relating to the Moon. Whilst the theory in many of the older volumes will of course be out of date, those including maps, charts and descriptions of the lunar surface are still excellent sources of reference material. Examples of older books (some of which are very difficult to get hold of) and some of the more modern publications are shown as follows.

Older Works (clockwise from the top)



At the top is the *Times Atlas of the Moon*, which is a large format book covering most of the lunar surface. However, it excludes the majority of the limb areas. Based on the results of the Orbiter missions, and the maps created by NASA, the book was published in 1969 and is

now extremely rare, copies being advertised on the Internet for \$500. On the right is Neison's *The Moon*, the first of the English classics, published in 1876, and now very rare. It contains charts of the lunar surface in sections, with a complete description of its surface. At the bottom is Patrick Moore's book *Survey of the Moon* containing charts of the Moon with a description of its surface. Published in 1963, this useful book is generally widely available on the second-hand market at reasonable cost. Finally, on the left, published in 1895, is *The Moon*, by Gwyn Elger, Director of the BAA Lunar Section and ex-president of the Liverpool Astronomical Society. Elger's descriptions of the features of the Moon are wonderful; however, this work is now unfortunately rather rare.

Modern Works (clockwise from the top)



At the top is the *Hamlyn Atlas of the Moon* by A. Rukl. This standard modern atlas has been out of print for a number of years. It has recently been updated and reprinted, and is now available from Sky & Telescope Publishing. On the right is *Observing the Moon* by G. North, still available and an excellent guide to lunar observing and imaging. At the bottom is *The Modern Moon* by C. Wood, published recently and available from Sky & Telescope Publishing. This book is an excellent guide to the geology of the Moon, which it manages to convey in an easy to read format. On the left is the *Moon Observer's Guide* by P. Grego. Recently published by Philip's, this little book is available in most bookshops and is an excellent introduction to observing and imaging the Moon. There are of course numerous sources of reference material on the Internet, one of the best being the *Consolidated Lunar Atlas* and the *Lunar Orbiter Atlas*, accessible through the NASA website and other websites. The latter contains images taken by the various Lunar Orbiter spacecraft, which carried out detailed imaging of the Moon prior to the Apollo missions. The last comprehensive mapping mission to the Moon was carried out by the Clementine Orbiter. However, most of these images were taken when the surface was illuminated by the Sun from above and there is

little detail shown in the way of shadow relief. They are of little use to the amateur.

Conclusion

There is much more to lunar observing than casually scanning the Moon's surface and identifying features on a map. As an observing target, for the beginner or more experienced observer alike, the Moon is unique. No other object in the night sky offers the amateur the opportunity to observe such fine details, even with modest equipment. The most detailed amateur observations made under low illumination often show features of low relief which question the maps and charts. Until the Moon is mapped in greater detail, by radar, giving heights of features to a few tens of metres, then there remains real opportunity for the amateur to contribute to our knowledge of lunar topography.

Nigel Longshaw

A Trio of 3" Refractors

Introduction

When my interest in astronomy began some twenty years ago one of my earliest recollections was scanning the night sky with my 10x50 binoculars and reading *The Observers Book of Astronomy* by Patrick Moore.

Whilst the binoculars I had were adequate for my first steps in the hobby, I soon longed for a telescope. The advice given in Patrick's book was to obtain a refractor with nothing less than a 3" aperture or a reflector with an aperture of no less than 6". I suspect that, like many beginners, I completely ignored that advice and, in my eagerness to obtain a telescope, I ended up buying a 2" refractor with a table top stand from a local camera shop.

I had my first view of Saturn's rings through this instrument, and watched a total eclipse of the Moon in January 1982. Luckily the wobbly stand, small field of view, and rather dim image did nothing to dampen my enthusiasm for the subject. During these first years I was able to observe through several instruments, and at a local star party I viewed Jupiter through a Vixen 80 mm refractor. The image produced by this achromatic blew away my 2" refractor, and I vowed one day to own such an instrument.

However, circumstances presented a different opportunity, and the 2" refractor was sold to help purchase a second-hand 6" reflector. To the present day, I have owned a number of instruments, some of which have been sold on, and some I have retained. I now have a collection of instruments which suit my

circumstances and observing requirements, and in one way or another I have ended up with three refractors, each of 3" aperture.



Lower left: TeleVue Ranger. Middle: Takahashi FS78. Rear: Solomon 3" refractor.

The Solomon 3" Refractor

In the recent past I have become interested in the history of astronomy through Alan Chapman's wonderful books and lectures on the subject. His books include lengthy text notes and bibliographies which have led me to numerous other contemporary works. Having recently purchased an antique refractor, at a reasonable price, I was keen to explore the night sky as some of the characters in Alan's books might have done.

One of my favourite books is *The Victorian Amateur Astronomer*, in which Alan refers to the "Solomon £5 telescope". In this regard he refers to the scrapbook of the Leeds Astronomical Society (LAS), among other works, as his reference material. As the case for my telescope bears the trade label of Solomon, and the instrument is of rather simple design, I wondered if my telescope might be one of these "five pounders" (as they came to be known).

After contacting Ray Emery of the LAS with my query in relation to information contained in the scrapbook, Ray kindly supplied me with digital images of the pages in question. This information comprises various cuttings from periodicals such as *The English Mechanic* from around 1876, some of which appear to have been collated by Walter Barbour, who I understand was later secretary of the LAS. These clippings made for fascinating reading

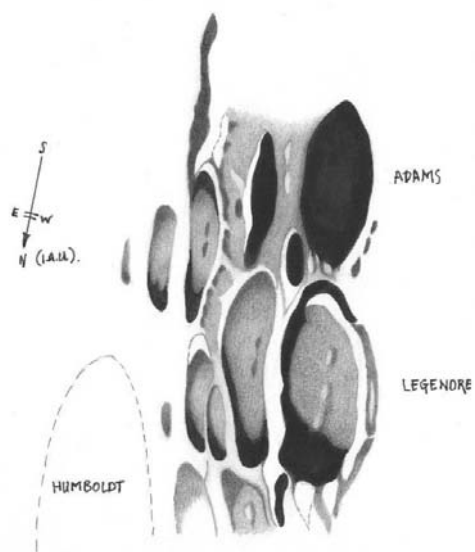
and appear to be a discourse, in letter form, as to the virtues, or not as the case may be, of the £5 telescope. It appears that in around 1876 a number of companies were offering such instruments, these telescopes having either 2.25" or 3" (stopped down) objectives, supplied with two eyepieces and a pillar-and-claw stand for the sum of £5. The former seemed to be the better quality type, with the latter, in the most, appearing to have inferior optics.

Around this period, commercial instrument suppliers tended to have instruments made to their specifications in outside workshops, the instruments then being labelled up by the retailer. The trade label in my telescope case puts S & B Solomon at 39 Albemarle Street, London, where they were between 1840 and 1875. The specification of my instrument, being a 3" objective of f20 focal ratio, suggests that in fact it would probably have been a rather more expensive purchase than the "five pounders". The information supplied by Ray Emery indicates my instrument may have retailed around the £10–12 mark, still around three months wages for a railway porter.

Rather simple in design, the telescope has a terrestrial and astronomical eyepiece, giving magnifications of around x40 and x80, respectively. There is no finder 'scope supplied and the tube is mounted on the infamous pillar-and-claw table top stand.

Luckily the cast iron pillar unbolts from the legs of the mount, so I was able to fashion a tall portable wooden pier and stand. The original cast iron pier simply bolts to the top of the pier, which is much more satisfactory for prolonged observing sessions. However, the whole does suffer a little in windy conditions due to its height and the length of the telescope tube.

I was expecting a rather poor view from an instrument of around 150 years old, but on the first night of use I was rather surprised. Using the astronomical eyepiece the field of view is rather narrow, but the image is quite good compared to modern instruments. There is a certain amount of stray light in the field of view, but Saturn and Jupiter appeared sharp and remarkably free from false colour, a product of the long focal length no doubt. The Moon was again sharply defined, and unusually the stray light tended to disappear when the terrestrial eyepiece was used. This eyepiece has an additional element to correctly orientate the image for viewing terrestrial objects, but works fine on night-time objects. However, it takes a little getting used to after using astronomical telescopes for many years.



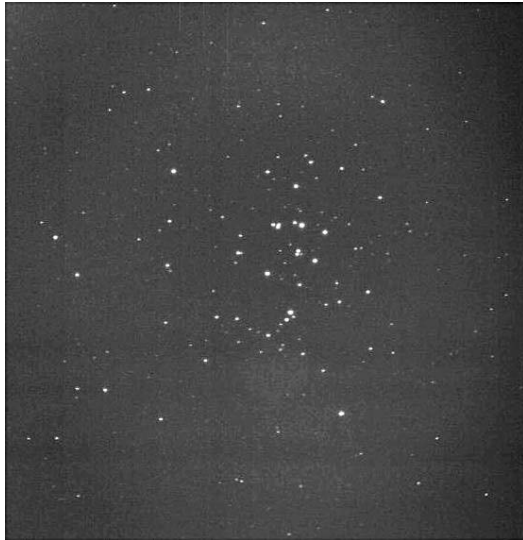
Craters East of Petavius via the Solomon 3" refractor at x80 magnification, Seeing conditions: Antoniadi III

I have had some excellent views of well-known double stars and have had no problems splitting Alpha Geminorum (Castor) and Gamma Leonis (Algieba) with the astronomical eyepiece. Without a finder 'scope and due to the rather narrow field of view given by the eyepieces (non-standard fit), deep sky objects are a little difficult to locate and observe. This could be one reason why this type of object was neglected by amateurs until the advent of short focal length, large aperture silver on glass mirrors.

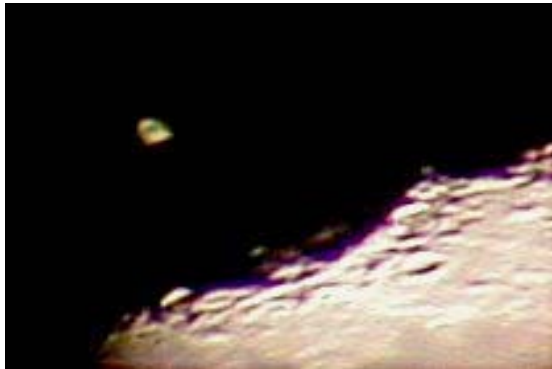
TeleVue Ranger 70 mm

My TeleVue Ranger was purchased a number of years ago, as a special offer which included the TeleVue carry bag, quick point "red dot" finder and lens shield, all for less than the price of the telescope alone from other retailers at the time. I had decided to fulfil my desire for a quality portable instrument.

The TeleVue has become quite a favourite; its semi-apochromatic lens gives pinpoint star images, but also performs adequately for detailed views of the Moon and planets. I use this instrument to make routine observations of my favourite Solar System objects. I have also imaged some of the rarer astronomical phenomena, such as the transit of Venus, using a Meade Electronic Eyepiece, and an occultation of Saturn by the Moon. In the latter case, I simply hand held my digital camera up to a wide field eyepiece.



M44 via a 5 min exposure on 400 ASA black and white film using TeleVue Ranger on a driven equatorial mount

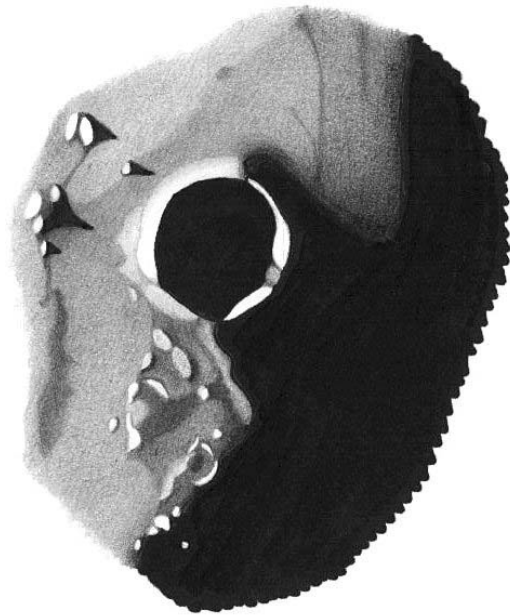


Occultation of Saturn by the Moon on 3 November 2003: Olympus 1.3 Megapixel Camera and TeleVue Ranger

Mounted on a simple camera tripod, the Ranger makes a first class "grab and go" 'scope with sufficient aperture to provide pleasing views of the night sky.

Takahashi FS 78

The current trend for high-quality refractors whetted my appetite for such an instrument. The recent price drops on the FS series, a good year at work and a now dissolved bonus scheme, persuaded me that it would be a good time to make an investment. At 78 mm the aperture of the Takahashi is a little larger than the TeleVue, and with a focal ratio of f8, the telescope feels more substantial than the Ranger. Mounted on a TeleVue Telepod alt-az mount, the Takahashi is almost as portable as the TeleVue Ranger, a feature which is important to me as my instruments are stored indoors, and I have limited observing space outside.



Lunar crater Kunowsky on 1 March 2004 via a Takahashi FS78 at x252 magnification. Seeing conditions: Antoniadi II

The similarities end here though; the Takahashi's Fluorite front doublet lens gives superior views of my favourite night-time objects: the Moon and planets. The rendition of planetary colours is among the best I have seen, and lunar views are very contrasty with little or no scattered light. Under the best seeing conditions the objective will take between x50 and x80 per inch of aperture.

Conclusion

I have been pleasantly surprised by the performance of the Solomon telescope. It would appear that the trailblazers of amateur astronomy, many of who were no doubt members of the Leeds and Manchester Astronomical Societies, may not have been at such a disadvantage as one might assume, in terms of the instruments which were available to them. I think Patrick's advice from all those years ago is essentially sound; however, I have no regrets in relation to the way my collection of instruments has developed. The 3" refractor is indeed an excellent all round telescope, and I would not be without any of my current instruments.

Nigel Longshaw

Colour on the Moon

Introduction

At the last MAS meeting in the Godlee Observatory, before we closed for the Christmas break in December 2005, Anthony Jennings showed some new digital pictures he had taken of the Moon. I was intrigued to notice slight colour differences between certain lunar formations and I asked him to digitally increase the colour saturation, using image-processing software. The result was startling. It showed a picture of the Moon that closely matched that in the *Larousse Encyclopaedia of Astronomy* (1967) as drawn by the French astronomer, L. Rudaux. This is, to my knowledge, the only map of the Moon that attempts to show colour on the lunar surface – colour so subtle that very few observers have attempted to describe it.

[Editor's Note. A facsimile copy of Rudaux's drawing is reproduced in Figure 2 of this article for the purposes of criticism or review within the meaning of Section 30(1) of the Copyright, Designs and Patents Act 1988. By comparing the drawing with a digital photograph produced by the author, one can see clear correspondences between the two in terms of the extent and hue of coloured regions, attesting to the accuracy of the drawing.]

Two years ago, I discussed lunar colouration with expert Moon observer, Nigel Longshaw. That evening we spent some time looking at the full Moon with the 8" Godlee refractor and, slowly, we started to see that certain areas of the Moon did indeed have some colouration. The observing technique is straightforward and can be done by anyone with a small telescope. Ask yourself how the Moon could be painted or drawn in colour. Is the lunar surface presented simply in shades of grey, black and white, or are there regions of the Moon where browns, blues, yellows, greens and even purple tints are detectable?

Digitally enhanced imaging answered the question in one go. This short article summarizes what I have learned since mid December, less than a month ago as I type these words.

Imaging the Moon

My Christmas present to myself was a 127 mm Maksutov–Cassegrain telescope, part of an arsenal of new equipment for digital astrophotography in which I am investing. I am on a learning curve that I hope to share with our more experienced digital astrophotographers, and benefit from them. Digital Moon imaging is new to me but, compared with "normal" photography, it is much quicker and the results are better. Digital images contain much more extractable information than 35 mm photochemical pictures.

To date, I have digitally processed whole-disc prime focus images, taken in December 2005, using Adobe Photoshop 5.5 as follows. With one button (denoted "Autolevels") I adjusted the contrast and brightness of the images, and I then increased the colour saturation to +70 (whatever that means) and finished the job. An example is presented as Figure 1 of this article and again confirms Rudaux's view, presented as Figure 2 of this article. The Moon is colourful. Other digital images provided by Jerry Grover confirmed exactly what had already been learned.

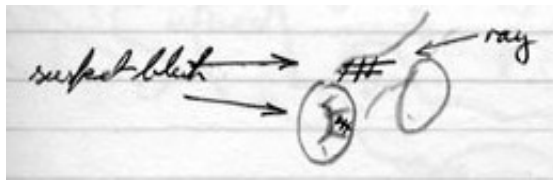
Lunar Colour

The lunar Maria show shades of brown and blue. They are definitely not grey. Mare Tranquillitatis is blue and this overlaps into a band of colour flowing into and along the eastern edge of Mare Serenitatis, whose central area is a yellow–brown. The eastern corner of Mare Imbrium is brown and there are patches of brown north of Sinus Iridium on the otherwise bluish floor of the Imbrium basin. Remote sensing and narrow-band colour imaging from NASA's Galileo spacecraft confirm this. The blue colouration of the maria basalts is put down to their high titanium content. The brown colouration is due to the later outflowing of iron-rich lava. This explanation has been asserted following comparisons of remotely sensed surface colorimetry with ground truth Apollo mineral samples and laboratory calibrated mineral colorimetry.

The most colourful region is found to be an area known as Wood's Spot, adjacent to the crater Aristarchus. In 1912, Professor R. W. Wood recorded this area as having a spectral reflectivity similar to the sulphurous deposits around volcanic regions on Earth. Visually, Wood's Spot is vaguely yellowish. Colour enhanced digital images show it as a dirty yellow, and it presents by far the strongest colour shade on the earthward face of the Moon. Furthermore, a distinct bluish area is shown in digital images produced by Portuguese astronomer Alves, of the area between Aristarchus and neighbouring crater Herodotus. Alves has published an article on lunar colour and digital remote sensing in *Sky & Telescope*, July 2005.

Transient Lunar Phenomena

In late December 1969, I recorded two uncorroborated observations of so-called transient lunar phenomena (TLPs) between Aristarchus and Herodotus. These appeared as blue–violet abnormalities. Previously, in January 1967, Patrick Moore, Terrance Moseley, Mike Duckworth, Peter Sartory and I had reported a small red abnormality on the outer wall of Gassendi (see NASA Technical Report R-277, available at <http://www.mufor.org/tlp/1965.html>).



Observation of possible TLP activity between the craters Aristarchus and Herodotus on 26 December 1969. Kevin Kilburn

TLPs are confined almost exclusively to the edges of the maria and are most often observed at or shortly after sunrise on that part of the Moon. One suggestion has been that they are associated with out-gassing from dawn-warmed regions where subsurface gas has accumulated during the cold lunar night.

Here is another possible explanation for TLPs. They may be mineral rich coloured areas of the Moon that brighten under certain, specific, solar illumination angles and become just detectable with the naked eye or through simple alternating red and blue filters, as were employed in the 1960s under the "Moon-blink" project run by the Lunar Section of the BAA. Visual colour detection is a function of the brightness and intrinsic colour saturation of the target. If these quantities are at a low level, colour cannot be sensed with the naked eye. The red and blue filters employed in Moon-blink apparatus may have made surface colour more detectable by blinking the colour contrast effect. Blue areas would appear bright in blue filters and dark in red. Conversely, red areas would appear light in red filters and dark in blue. Digital image enhancement may bring lunar surface colour above that otherwise just-detectable threshold and hold the key to explaining TLPs.

Observing Programme

We now need a coordinated programme of observation. Whole-disc digital imaging has already confirmed the visual appearance seen by colour-acute observers and narrow-band remote sensing technology. We need to collect high-resolution digital images of the Moon. Target areas are the maria and basalt filled craters. Historically documented TLP targets will be imaged and compared with previously recorded observations. We also need to know how the coloured areas of the Moon react to increasing and decreasing Sun angles.

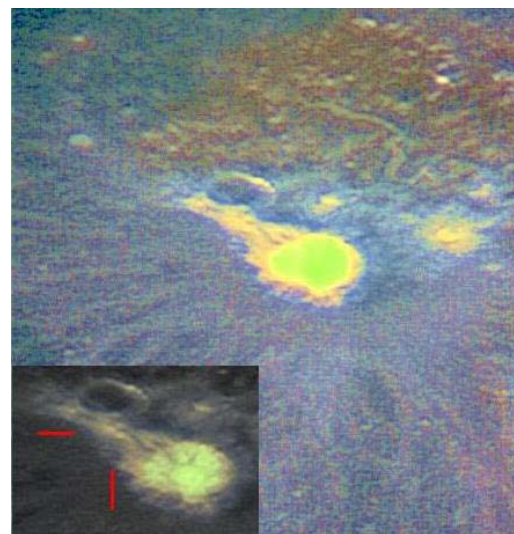
This new project may provide answers to questions still to be asked. Moon colour is visually subjective, yet instrumentally demonstrable. How it relates to the vexed question of TLPs still needs to be addressed.

Kevin J Kilburn, FRAS

Wood's Spot

Also known as the Aristarchus Plateau, Wood's Spot is a roughly diamond-shaped island (hardly a "spot") of ancient lunar highland material measuring about 170 × 200 km and elevated by up to about two kilometres above the younger mare basalt of Oceanus Procellarum which surrounds it. A sinuous rille wends its way across the plateau, in the form of Schroeter's Valley, and extends from a volcanic crater measuring nine kilometres in diameter and known as the Cobra Head. Both the plateau and the rille predate the very bright, young crater Aristarchus. A reddish hue was attributed to the plateau by Hevelius in 1647, and has been similarly described by subsequent observers. Professor R. W. Wood photographed the plateau in ultraviolet light in 1912, and found the plateau to be the darkest region on the Moon at that wavelength; a consequence attributed to the presence of sulphur. Thence came the appellation Wood's Spot.

Presented below is an image of Aristarchus, Herodotus and Wood's Spot made by myself on 13 November 2005 using a 125 mm Maksutov-Cassegrain telescope, with a x2 Barlow lens and a Philips ToUcam Pro webcam. The main image shows all three of the above-named formations in exaggerated brightness and colour. This has been done for the purposes of illustrating the regions of differing colour, and Wood's Spot in particular; this being the broad red-brown region at the top right of the image. Inset is a section taken from the original image, without adjustment to colour or brightness, with the suspected TLP region, referred to by Kevin Kilburn, generally indicated by red markers.



Aristarchus, Herodotus and Wood's Spot
By Andrew Fearnside

Dr Andrew Fearnside

Colour on the Moon



Figure 1



Plate I. GENERAL MAP OF THE MOON drawn by L. Rudaux.
(South is at the top.)

Figure 2

Picture Gallery

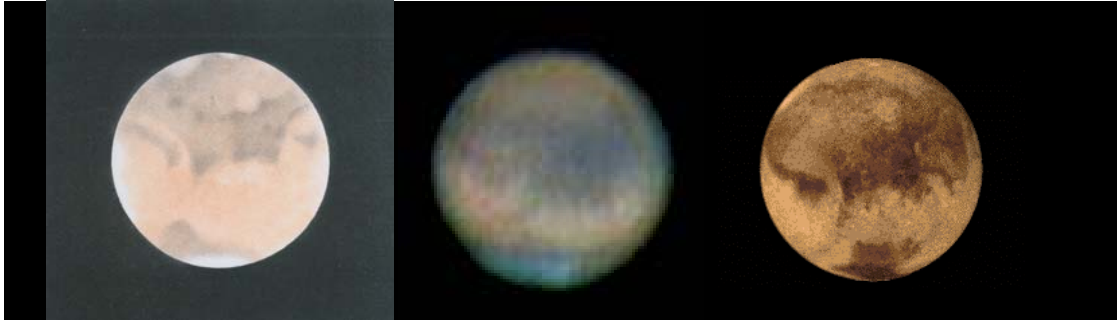


Figure 1: By Nigel Longshaw.

Figure 2: By Anthony Jennings.
See "The Eye of the Beholder" in Letters and News.

Figure 3: By M Adachi and T Ikemura.

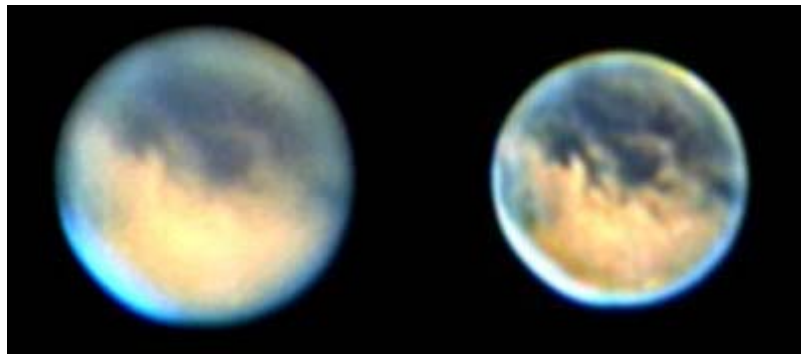


Figure 4 (left) and Figure 5 (right): By Cliff Meredith. See "Chopsticks" in Letters and News.



Figure 6: Winning photograph of MAS photo competition 2005 by Mike Oates. Taken 27 Feb 2005 at 17:39pm, Prestwich, Manchester. Fuji Finepix S7000 f8 at 1/70th sec, ISO 200. The image is of a Sun Pillar, caused by the reflection of sunlight by ice crystals in the atmosphere.

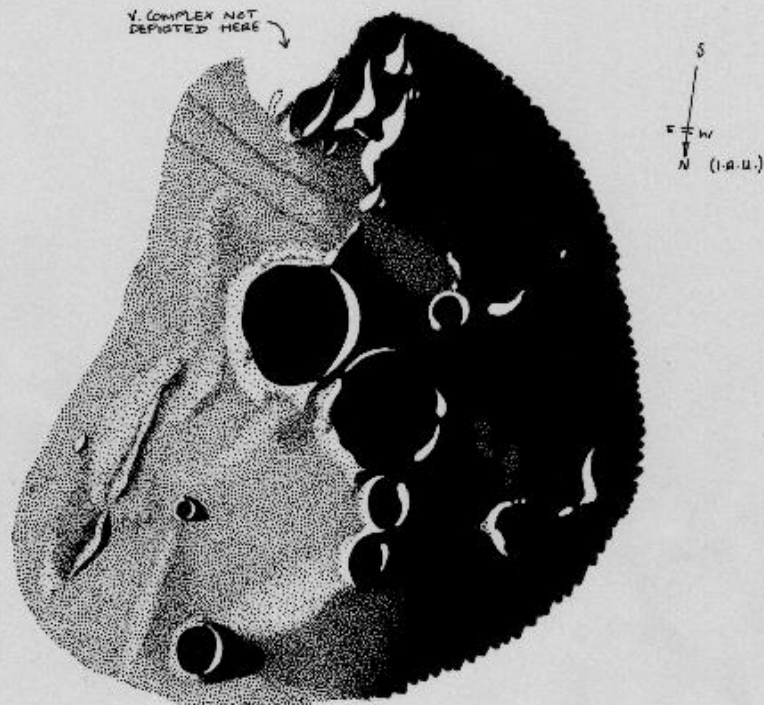
Picture Gallery

Sabine & Ritter

1997 JANUARY 14th.

20:16 - 20:54 (U.T.).

8" SCHMIDT-CASS X 160 (N° 80A L.B. FILTER).



SEEING: III

TRANSP: GOOD.

LUNATION: 9.16

SUN'S SEL COL: 341.4° - 341.74°

EARTH'S SEL LONG: 6.3°

" " LAT: 1.4° (0 hrs 15th).

" " LAT: 1.5°

} 0 hrs 15th

This region has been on my observing schedule for some time, but conditions have always prevented a satisfactory observation. Seeing was far from ideal this evening, however a sketch was made to provide a basis for future work. The w. extension of Rinae Hypatia was obvious far south of Sabine, although the secondary rille nearer to Sabine was more difficult. Several finer rilles and smaller craters populate the region but were missed, probably due to poor seeing / incorrect illumination.

W. Longshaw

Sabine & Ritter. By Nigel Longshaw

Iron Meteorite: Campo del Cielo

Campo del Cielo meteorites are named after the region in which they were first discovered. This area is located in Gran Chaco Gualamba in northern Argentina which is about 500 miles north–north-west of Buenos Aries at latitude 27 degrees 39 minutes south and longitude 61 degrees 44 minutes west.

Campo del Cielo is structurally classified as a coarse octahedrite, type Og, with a Widmanstätten bandwidth of 3.0 ± 0.6 mm. Chemically, it is classed as group IAB, containing 6.68% nickel, 0.43% cobalt, 0.25% phosphorus, 87 ppm (parts per million) gallium, 407 ppm germanium and 3.6 ppm iridium; the remainder being iron.

It has been estimated that this meteorite fell to Earth between 4000 and 6000 years ago. The first record of the Campo was in 1572. A Spanish governor learned of the iron from the Indians who reportedly believed that it had fallen from heaven. The governor sent an expedition under the command of one Captain de Miraval who brought back a few pieces of a huge iron mass he called Meson de Fierro (large table of iron). The location of the find was the Campo del Cielo (meaning: *field of the sky* or *field of heaven*), a fitting name for the location of a meteorite. Since the Indians believed that the irons fell from heaven the name may have come from the meteorites. The area is an open brush-covered plain that has little water and no other rocks – very good country in which to locate meteorites.

The next record of Campo Del Cielo meteorites was made about 200 years later in the late 1770s. The Spanish thought some pieces of the meteorite might be silver ore, but once they tried to process it. They found that it was only iron. A Spanish navy lieutenant excavated one specimen which he believed weighed 14–18 tons. This may have been the Meson de Fierro. He left the mass in place and it was not seen again – or was it?

In the 1800s more, smaller, irons were found. A pair of flintlock pistols, reportedly said to be made from this material, was given to President James Monroe. Later analyses showed that the iron was not meteoritic. In the 1900s, systematic exploration revealed many more large masses. However, the Meson de Fierro remained lost. In 1992, American meteorite dealer Robert Haag was arrested by Argentine authorities while transporting a 37 ton meteorite from the area. Haag had purchased the mass from a local person who claimed ownership. Unfortunately, the authorities disagreed. Haag was released and the huge meteorite remains in Argentina. Whether this is the famous Meson de Fierro remains for speculation. If anyone knows, then send me an e-mail.

The Craters

The larger Campo del Cielo meteorites are found in and around a series of small craters in the south-western part of the strewn field. The largest crater is 78 x 65 metres. A smaller one is 56 metres in diameter and five metres deep. All together, searchers have found at least 12 craters.

The main part of the crater-forming mass was found in each of these craters. This is in contrast to other meteorite falls such as Canyon Diablo and Odessa, where the main crater-forming mass is believed to have vaporized or shattered on impact. In this respect, the field is similar to the Sikhote-Alin fall. Scientists have attempted to date the Campo fall by carbon dating of charred wood found in the craters. Dates of 5800 years (plus or minus 200 years) and 3950 years (plus or minus 90 years) have been obtained. These dates are consistent with an Indian oral tradition that the irons fell from heaven.

The Strewn Fields

Many of the Campo meteorites from the original 1572 strewn field are highly rusted and corroded by terrestrial chlorides. However, some have significant areas of relatively fresh fusion crust. This too is an indicator of a fall in the not-too-distant past.



A Campo iron meteorite

This field is located in a valley and the meteorites have been subjected not only to weathering, as the soil above them was eroded by water and wind, but also to chemical action by the salts dissolved in the water and present in the soil. A more recently discovered strewn field has been found at a higher level, with these specimens exhibiting far less corrosion; most Campo's found for sale today are from this second "new" location. Most of the Campo del Cielo meteorites found are many kilos in weight (compare the size of the meteorite with the size of the shovel) and small examples are quite rare, commanding a premium price. For example, it is possible to find a specimen weighing 51 kg for sale on the Internet at an asking price of £2,200, whilst another piece weighing only 222 g is being offered for \$222 or about £135. Do the maths for yourself!

Regmalypts and Other Features

Most iron meteorites exhibit regmalypts, or "thumbprints", which are caused by ablation (wearing away or melting) during passage through the Earth's atmosphere. These regmalypts may vary in depth depending on the precise structure of the meteorite at any particular point on its surface and the position of the point relative to the trajectory.



Iron meteorite exhibiting regmalypts

Another feature of meteorites is known as fusion crust. This is the part of the object that was subjected to actual entry melting during travel through the atmosphere. As most meteorites tumble as they travel through the atmosphere it is likely that some evidence of fusion crust may be found on any or all surfaces. The image shown below is of a meteorite possessing a fusion crust, showing the shiny metal effect left after cooling.



A meteorite possessing a fusion crust

Rarely, the meteorite may not tumble during passage and the result is shown in the image below of a stony meteorite from the Karakol find, where the melted rock has flowed backwards over the rest of the specimen.



Stony meteorite from the Karakol find

The Campo del Cielo meteorite is described as a polycrystalline coarse octahedrite. At three millimetres, the Widmanstätten bands are thicker than those at Canyon Diablo or Odessa, but still thin enough to have the same coarse octahedrite classification. The mass was composed of large austenite [carbon in solid solution in gamma (i.e. face centred cubic) iron] crystals from five cm to 50 cm in size. On break-up the fragments were cold worked like those at Sikhote-Alin and Gibeon.

It has been hypothesized that the original body was tabular in shape and broke up on entry into the atmosphere. This would account for the finds at two widely separated strewn fields. Some of the lumps would also have broken up on impact to leave sharp edges.

Graham Hodson, FRAS

Variable Stars

Introduction

Variable stars are stars with a brightness which varies over time. These stars are classed into two types. The first type is known as Extrinsic: in which the variation in brightness is due to an eclipse of one star by another star in orbit around it. The pair forms an eclipsing binary star system. The second type is known as Intrinsic: in which the variation in brightness is due to pulsation of the star itself. When the star expands it brightens, and when it shrinks it dims.

Eclipsing Binary Stars

Classes of eclipsing binaries include what is referred to as the E Class. This class relates to binary systems having orbital planes very close to the line of sight of the observer, and in which both stars of the pair eclipse each other. Specific details are as follows.

- i. **EA, Algol Type.** In this type of binary star, the light received from the system remains almost constant between eclipses, or varies only slightly during those periods as a result of light from one star of the pair reflecting from the other. A secondary minimum may be absent. The stars in the pair are typically slightly ellipsoidal in shape, and eclipse periods cover a wide range from about two days to 10,000 days or more. The variation in brightness of different examples of such systems ranges widely, and may reach several magnitudes in value. An example of such a binary is Beta Persei.
- ii. **EB, Beta Lyrae Type.** The apparent brightness of binaries of this type changes continuously between eclipses. The result is that the beginning and end of eclipses cannot be identified from the light curves. A secondary minimum is always observable, its depth usually being considerably less than that of the primary minimum. Periods are usually greater than one day, although some periods are as short as 0.4 of a day.
- iii. **EW, W Ursae Majoris Type.** Exemplified by Beta Lyrae, the beginning and end of the eclipse of such stars cannot be identified from their light curves. Primary and secondary are similar in depth, but periods are less than one day.

Eruptive Variables

Classes of these intrinsic variable stars, whose nature is self-evident to some extent from their appellation, are as follows.

- i. **BE Stars.** These stars show small-scale variations in brightness over time. There are at least 50 types of this class of intrinsic.
- ii. **FU Orionis Stars.** Stars of this type are similar to so-called Orion variables, but differ in displaying a gradual increase in

brightness amounting to about six magnitudes over several months. This period of brightening is followed by a constancy at maximum brightness typically for decades.

- iii. **GCAS Stars.** Gamma Cass. being the prototype star, these variables comprise rapidly rotating giant stars. Variability is associated with the formation of an equatorial disc, or rings, of matter around the star resulting in a temporary fading of the starlight reaching us. Brightness reductions of as much as 1.5 magnitudes may occur, which equates to nearly a fourfold drop in brightness.
- iv. **ECB Stars.** The prototype star being R. Coronae Borealis, these stars are of spectral type Bpe. Consequently, they are poor in hydrogen and rich in carbon and helium. The stars are simultaneously eruptive and pulsating variables. Slow non-periodic fades in brightness occur, so close scrutiny is essential. Brightness fades of one to nine magnitudes have been observed over durations of months to a few years.
- v. **SDOR Stars.** These stars have high luminosity, being in the range one to seven magnitudes. They are amongst the most luminous stars in the Milky Way. The prototype star is S Doradus.
- vi. **Cepheid Variables.** These fascinating stars are relatively young pulsating variable stars which have left the main sequence. Cepheid variables famously obey the Cepheid period–luminosity relation, which states that the period of the variable brightness is proportional to the maximum brightness of the star. These stars have periods of one to 135 days. They occupy the spectral class F at maximum brightness and spectral class G–K at minimum brightness.
- vii. **RR Lyrae Stars.** These rapidly pulsating giants stars occupy the spectral class A–F. They exhibit a brightness variation typically ranging from 0.2 to two magnitudes, and periods of 0.2 to 1.2 days.

Cataclysmic Variables

Examples of cataclysmic variables include the following.

- i. **AM Herculis Stars.** These are close binary systems consisting of two dwarf stars. They form a compact object possessing a strong magnetic field. Brightness typically varies by four to five magnitudes.
- ii. **N (Novae) Stars.** Close binary systems, these systems possess orbital periods from 0.05 days to about 230 days. One star of the pair is a hot dwarf star. These systems typically increase in visual brightness suddenly over days, weeks or months, followed by a gradual return to its original state over months or years. Brightness

- increases of seven to 19 magnitudes may occur.
- iii. **NA (Fast Novae) Stars.** Fast Novae display a rapid brightness increase reaching a maximum brightness which subsequently typically fades by about three magnitudes in 100 days or so.
 - iv. **NL Nova Stars.** Resembling Novae in light variation or spectra, these stars are insufficiently studied.
 - v. **Recurrent Novae Stars.** These stars differ from Novae stars in that they have had two or more outburst.
 - vi. **SN (Supernovae).** Examples include B Cass. and CM Tau. These stars increase in brightness by 20 magnitudes or more, and fade slowly thereafter. Subclasses include Type 1 having spectral lines associated with doubly-ionised elements, absorption lines of calcium and silicon etc, but no hydrogen spectral lines. Such stars typically fade by 0.1 magnitudes per day, this rate of dimming decreasing to about 0.014 per day thereafter, for 20 to 30 days after maximum brightness. The Type 2 subclass of stars display spectral lines of mainly hydrogen Helium, and other elements to a lesser degree.
 - vii. **UG (U Geminorum) Dwarf Novae.** U Geminorum Stars are close binary systems including a dwarf star or a subgiant of K–M spectral class. These systems display rapid increases in brightness by several magnitudes, returning to normal brightness after a few days or weeks.
 - viii. **BL Lac Objects.** These objects are in fact variable *galaxies*, but appear star-like.
 - ix. **Mira Stars or Long-period Variables.** Variable stars of this type display brightness which varies typically by 3.0 to 9.5 magnitudes over periods of e.g. 331 days. However, the maximum brightness of such variables rarely attains second magnitude.
 - x. **Short Period Variables.** I briefly mention these variables under the “Extrinsic” heading, but they can just as well be classified as “Intrinsic”. Examples are RV Tauri Stars, which can display either short or long variation periods as previously mentioned.
 - xi. **Irregular Variables.** These stars are of late spectral class K and M and, as a rule, they are giant stars. They show brightness changes in the range less than 2.5 magnitudes. Periods of 35 to 1200 days are observed. Examples include CO Cygni.
 - xii. **SR (Semiregular).** Having spectral class M and C, these stars have periods of 20 to 2000 days. The stars are subclassed into subclasses A, B, C or D. Subclass A stars vary in brightness by less than 2.5 magnitudes; an example is Z Aquila. Subclass B stars have periods of 20 to 2300 days or alternating periods. Subclass C stars have periods of 30 to several thousand days, and only one magnitude of brightness variation. Finally, subclass D

stars vary in brightness from 0.1 to four magnitudes, an example being SX Herculis.

xiii. **Rotating Variable Stars.** These stars have a non-uniform surface brightness, or an elliptical shape. Their apparent variation is due to starspots such as seen on the Sun.

Stars to Observe

Table 1 lists stars suitable for observing in one of three ways, namely with the naked eye, using binoculars, or using a telescope.

Table 1

Star	Magnitude range
Naked eye	
Gamma Cass. (Irregular)	1.6–3.0
Rho Per	3.3–4.0
Epsilon Aurigae (EB)	2.9–3.8
Eta Geminorum (SR)	3.2–3.9
Zeta Geminorum (Cepheid)	3.6–4.2
Alpha Herculis (SR)	2.7–4.0
Binocular variables	
V341 Carinae (Type LP)	6.2–7.1
Eta Carinae	–0.8–7.9
Z Ursae Majoris (SRB)	6.2–9.4
RY Ursae Majoris (SRB)	6.7–8.3
RS Canes Venatici (EA)	7.9–9.1
IQ Herculis (SRB)	7.0–7.5
CH Cygni (SR)	5.6–8.5
Telescopic variables	
R Ursae Majoris (LP)	6.7–13.5
R Andromedae Mira	6.0–14.9
R Aquilae	6.9–12.0
3c 273 (Irregular)	12.4–13.2
T Herculis	7.8–12.8

Conclusion

To summarize, variable star observing is very rewarding. We have available to us some 50,000 known variable stars deserving of continued study, and I have identified a few of the different types of variable star in this article. Variable star astronomy is one of a few fields where the amateur can still make a valuable contribution by supplying their observational data to suitable organizations to enable the professional to determine what mechanisms are responsible for making these stars variable. If this article has encouraged you to take up the challenge of observing variable stars, more information for the beginner can be found at The Society for Popular Astronomy (<http://www.popastro.com/join.htm>).

Dennis Keith Jones, FRAS

Manchester Astronomical Society Officers and Council, 2005–2006

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Floor G, Sackville Building, Sackville Street,
Manchester, M60 1QD
Answerphone (24 hrs): 0161 200 4977
Fax: 0161 228 7040

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currentnotes@manastro.co.uk

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**Manchester Astronomical Society
Godlee Observatory
University of Manchester
Sackville Building, Sackville Street
Manchester
M60 1QD**