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The 160 mm Fraunhofer-Repsold Transit telescope of 1831 in the Playfair Building on Calton Hill. (Picture by Horst Meyerdierks.)

Society news

For the 2008-06-06 meeting Horst Meyerdierks stepped in at short notice with a talk on digital image processing. On the night it turned out that there was no electricity in the City Dome so that President, speaker, and audience had to squeeze around the telescope pillar in the central room of the Playfair Building. On 2008-07-04 the speaker was Karen Moran, librarian at the Royal Observatory and in charge of the priceless Crawford Collection of old and precious astronomical publications, which makes the ROE library one of the five foremost astronomical libraries in the world. Her talk tied some of these treasures in with the history of astronomy.

The situation with the Calton Hill observatory has turned for the worse again. The City has to be praised for fixing the lead roof of the Playfair building. And with the renovation of the Astronomer's House progressing there is hope that the buildings we use will get their turn sometime. However, the thieves and burglars have been back several times, and we had to have some emergency repairs done for weather protection and had to remove valuable items from Calton Hill altogether.

At the time of writing the Council of the Society is still considering the options and preparing a report to Members for further discussion. Danny Gallacher has initially summarised the issue for the Council. Among the needs of the Society are primarily an adequate venue for the monthly meetings and for council meetings, with an observatory and a library as secondary needs. In the meantime the City Council has carried out emergency repairs and stepped up security on Calton Hill.

Your Editor was unable to attend the meeting on 2008-08-01, where members of the Society will have presented some of their activities.

Telescope for sale

Meade LXD 55, 8 inch diameter Schmidt-Cassegrain telescope, German style Goto mount, 7 eyepieces from 6.4 to 40 mm. Plus Helios 20x80 binoculars and tripod.

£800 o.n.o. Tel. 0131-449.4256

Martin Allan

Why is it dark at night?

Good heavens (sorry)! What a question to ask, especially in an astronomical journal? Most people would answer: 'It's dark because the Sun goes down.' Well, that's not quite true in Scotland in summer, where the Sun is rather reluctant to go away and, instead, makes darkness rather elusive. In winter, it certainly is dark at night (moonlight permitting), if you can get away from artificial lighting.

Nevertheless, the title poses an important question, more precisely expressed as: 'Why, apart from some luminous astronomical objects, is the *night sky* dark?' This question was not even asked until Thomas Digges wrote about it in 1576. Kepler thought about it in 1610, and Edmund Halley and Jean Philippe de Cheseaux discussed it in the 1720s.

The question arises because, assuming that the universe is infinitely large and contains an infinite number of uniformly distributed stars, each with a surface as bright as the Sun, the night sky should be blazing with light from these stars. Even if the farther stars are fainter, their number increases with distance and there should be an enormous amount of the starlight reaching Earth. The result should be a 'wall of light' about as bright and as hot as the Sun. Instead the night sky is practically black. To put the question another way then: 'Why is the night sky not as bright as the Sun?' Of course, in that case, there would be no 'night' – hence my title.

Kepler's explanation was that, because the universe of stars extends only out to a finite distance, once the line of sight passes that boundary, it encounters only empty space. This explanation seemed reasonable, but should not have been accepted after 1687 when Newton published his law of gravitation. For stability, his universe needed to be infinite. Kepler's limited universe would collapse.

Later astronomers proposed various solutions to the problem, which came to be called Olbers' Paradox because the German astronomer Heinrich Olbers stated the problem very clearly.

In 1826, Olbers concluded that the night sky is dark because intervening clouds of dust and gas absorb the starlight from distant sources. However, these clouds would heat up from the collection of light energy and glow brightly. In fact they would radiate as much energy as they absorbed and the problem remains. Even if one objects that, nowadays, we know that stars are collected into galaxies, in an infinite universe every line of sight would end in a galaxy and the sky should be as bright due to them as it would be to just stars.

The first scientifically reasonable answer was given in 1848 by the American poet and writer Edgar Allan Poe. He suggested that the universe is not old enough to fill the sky with light. The universe may be infinite in size, he thought, but there hasn't been enough time since the universe began for starlight, travelling at the speed of

light, to reach us from the farthest reaches of space [1]. I find that an astonishing insight.

I write about this now because Horst Meyerdierks referred to the matter in a recent article. He wrote: 'it is dark because the universe is quite empty and not infinitely old' [2]. I queried this, explaining that my understanding was that the night sky is dark because the universe is expanding and that, as a consequence, light from distant, receding galaxies has its light red shifted by the Doppler effect so that it becomes invisible infra-red or radio waves [3].

Horst disagreed, claiming that the paradox is about a lack of stars and a lack of starlight in the night sky. He pointed out that there are few stars (he meant stars in other galaxies) at high red shift; consequently the expansion red shift does little to reduce the amount of starlight we have in the night sky. The paradox is solved, he claimed, by there being no stars more than 13 Gyr ago.

I also quoted a claim by someone in a website that, from this paradox, Olbers could have predicted the expansion of the universe. Horst rejected that idea, claiming that, if the one and only universe we are talking about here has all of the properties of being infinite, eternal, homogeneous and static, then the night sky must be as bright as the Sun. Since the night sky is dark, it follows that one or more of these properties does not apply to the actual universe. However, Horst allowed that the expansion red shift does help with the dark sky 'after all'; the faintness of the cosmic background radiation is due to red shift.

Strangely the paradox has not been discussed before in the pages of this *Journal*.

Confused, I looked for opinions on the web. Wikipedia, whose page on this matter contains a graphic illustration of the sky filling with light, discusses what it calls 'the mainstream explanation' together with alternatives [4]. The former is based on Edgar Allan Poe's idea that not enough time has elapsed for all the starlight to have reached us (since the Big Bang), modified by adding the effect of red shift. The website goes on to claim (confusingly) that the Big Bang model would by itself explain the darkness of the night sky, even if the universe were infinitely old. This is a reference to the Steady State model of the universe, which it points out, cannot explain the detailed behaviour of distant starlight and the microwave background (CBR). The CBR 'requires a continuous transformation of the former into the latter at decreasing frequencies; this transformation is not observed'. So an alternative explanation for the paradox is the finite lives of stars. There is also reference to Charlier's idea of fractal star distribution (1908), which allows for a dark sky even if there had been no Big Bang.

I also looked at several websites dealing with the problem. Explanations varied greatly, as follows:

- 'two explanations are surely correct: the universe is expanding, so distant stars are red-shifted into obscurity and the universe is too young for distant light to have reached us'. [5]
- 'the number of stars in existence at any one time is simply not enough to fill the volume of the Universe with enough light to light the night sky.' [6]
- 'the night sky is very bright with stars shining all over the place. It is just the way our eyes have evolved that makes it seem dark. We are a daylight animal that needs to see in the daytime. The tremendously powerful light from the sun, being so close to Earth is just too powerful and simply overwhelms the starlight during the day.' [7]
- 'At present the most widely accepted resolution of Olber's [sic] paradox is based on denying the infinite age of the universe. Along with this, some authors also mention the expansion of the universe with the consequent red-shifting, but if the universe is closed and destined to enter a collapsing phase, would those authors claim the sky will shine brightly during that phase?' [8]
- because 'the universe is not old enough to fill the sky with light ... that means we can only see the part of it that lies within 12 to 15 billion light-years from us. There may be an infinite number of stars beyond that cosmic horizon but we can't see them because their light has not yet arrived. And the observable part of the universe contains too few stars to fill up the sky with light ... that is not the whole solution to the paradox. Most stars, like the Sun, shine for a few billion years or so before they consume their nuclear fuel and grow dark. Dying stars spew gas and dust back into space, and this material gives birth to new generations of stars. But after enough generations, all the nuclear fuel in the universe is eventually exhausted, and the formation of luminous stars must come to an end. So even if the universe were infinitely old as well as infinitely large, it would not contain enough fuel to keep the stars shining forever and to fill up all of space with starlight. And so the night sky is dark.' [9]
- The paradox was solved by the Big Bang Theory of the origin of the universe: 'an expanding universe continually increases its volume, which accommodates the increasing quantity of energy produced by stars, therefore the temperature of the universe does not increase. In fact, in some forms of the Big Bang theory, the universe's expansion causes an overall decrease in average temperature.' [10]

- 'the universe is not infinitely old, and therefore the light from many stars has not yet had time to reach us ... as the universe expands, it gets steadily cooler (because of the 'stretching' of light to longer wavelengths) and less dense, so in the past it was denser and hotter ... this provides a second possible resolution of Olbers' Paradox: light from very distant objects would have been stretched, so that its apparent temperature would be much less than 3000 K'. [11]

Evidently some of these explanations are wrong. Yet it is surprising that this should be so and that there should be so much disagreement.

Surprisingly, some dictionaries carry an entry for the paradox. Chambers says that it is 'now explained by postulating a finite expanding universe'. *Encyclopedia Britannica*'s Micropedia claims that:

> 'if the assumptions [infinite universe] are accepted, then the simplest resolution is that the average luminous lifetime of stars is far too short for light to have yet reached the Earth from very distant stars. In the context of an expanding universe, it can be argued similarly: the universe is too young for light to have reached the Earth from very distant regions.'

However, in EB's Macropedia, Prof. Frank H Shu, noting that it used to be believed that the solution lay in red shifts, reports that the consensus now is that the finite age of the universe is far more important. He points out that there are too few galaxies within the spherical 'cosmic event horizon' which surrounds us to make the night sky bright.

Lastly, I looked for Stephen Hawking's explanation. He states that 'the only way of avoiding ... [the paradox] would be to assume that the stars had not been shining forever but had turned on at some finite time in the past. In that case, the absorbing matter might not have heated up yet or the light from distant stars might not yet have reached us' [12]. Evidently, he does not consider red shift to be relevant.

It is clear that my opinion was influenced by the out-of-date notion that the explanation lies in red shifts. I have had to revise my view.

It appears that Edgar Allan Poe was right. It's dark at night because all the light in the universe has not yet reached us. In fact, much of it will never reach us because it is outside the 'cosmic event horizon', the limit of the observable universe; its sources are receding faster than the speed of light. More fundamentally, it is dark at night because the universe is expanding from an origin some 13.7 billion years ago.

In a way, Kepler was right: the observable universe reaches a limit, beyond which there are no more stars (galaxies), because it is also a limit in time, the time before

any stars shone. Horst's notion that the explanation is partly because the universe is relatively empty seems irrelevant. If the universe were infinite, even a relatively empty one would be a blaze of light.

In short, it is dark at night because the universe is finite in size and began a finite time ago. This solution to Olbers' paradox only emerged a century after he outlined it. In 1927, Georges Lemaitre, trying to explain the recession of the galaxies discovered by Edwin Hubble, proposed that the cosmos originated from what he called 'a primeval atom', as Edgar Allan Poe had suggested. Only in 1948 did Ralph Alpher and George Gamow develop the Hot Big Bang Theory.

Notes and references

1. *Eureka: A Prose Poem* (Subtitled: 'An Essay on the Material and Spiritual Universe'). It is based on a lecture he gave in New York and includes a cosmological theory that anticipated the Big Bang theory by 80 years. He contended that the universe filled with matter after a single, high-energy particle exploded and that, since the energy of the explosion is pushing matter outward, the universe must be expanding (see *Eureka*, an annotated edition by Stuart and Susan F Levine, University of Illinois Press, 2004).
2. 'Atmospheric Extinction' in *Journal* 56, June 2008.
3. Isaac Asimov in *The Universe* (1966), Ritchie Calder in *Man and the Cosmos* (1968), Iain Nicolson in *Astronomy – a dictionary of space and the universe* (1977) and Nigel Henbest in *The Exploding Universe* (1979).
4. http://en.wikipedia.org/wiki/Olber%27s_paradox
5. http://math.ucr.edu/home/baez/physics/Relativity/GR/olbers.html
6. http://physics.uwstout.edu/deptpages/physqz/olber.htm#Question
7. http://pages.prodigy.com/suna/olber.htm
8. http://www.mathpages.com/home/kmath141/kmath141.htm
9. http://www.amnh.org/education/resources/rfl/web/essaybooks/cosmic/cs_paradox.html
10. http://www.arachnoid.com/sky/index.html
11. http://www.shef.ac.uk/physics/teaching/phy111/summary10.html
12. *A Brief History of Time* (1988).

Steuart Campbell

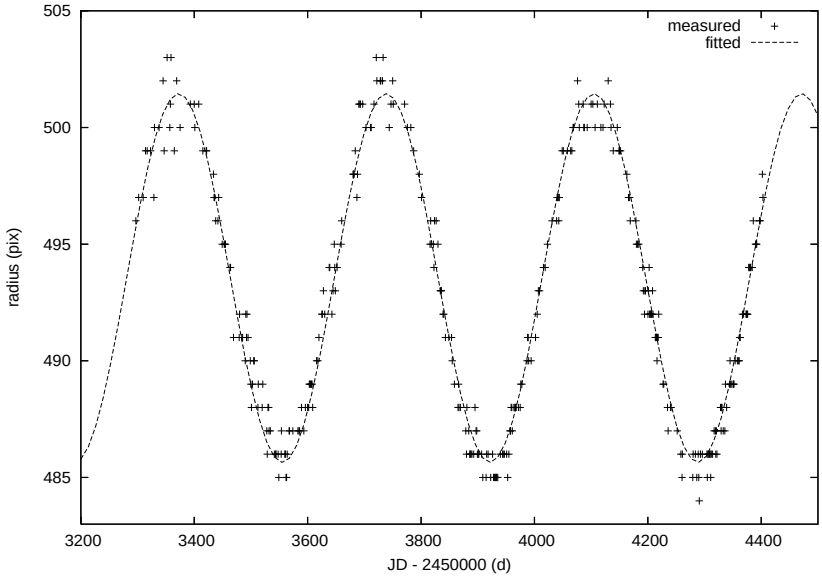


Fig. 1: *The apparent radius of the Sun in pixels plotted against the Julian Date. Crosses show the measurements. The curve is a sine curve fitted "by hand".*

Backyard astrophysics:

Kepler's laws

For a number of years the idea of "backyard astrophysics" has been in the back of my mind. What observations can we as amateur astronomers make to demonstrate astronomical knowledge? One kind of observation I make quite frequently is to take an image of the Sun to count sunspots and measure their positions. Previously [1], I had shown how the brightness of the Sun depends on its altitude above the horizon, and what this tells us about the Earth's atmosphere.

If you make full-disc drawings of the Sun yourself, you know that you have to adjust the projection such that the solar image is not only in the right place, but also of the right size to fit the standard drawing template. Similarly, When I measure sunspot positions in my digital images I have to determine the centre and radius of the solar image. Since my focal length is fixed, I measure the size of the solar image rather than adjust it to fit a prepared template.

When I reduced the images day after day and week after week, I noticed that the measured size of the Sun did not merely vary at random by a pixel or two. There

seemed to be a systematic change over the weeks. I had serendipitously re-discovered Kepler's laws of planetary motion, in the first instance that the Earth does not revolve in a perfect circle around the Sun. Scientists call it serendipity when they discover something by accident. The term derives from an old Persian tale of the three Princes of Serendip – a country we today call Sri Lanka; the legendary princes seemed to have a knack for finding out things they had not set out to discover.

Plotting about three years' worth of data one can very clearly see a sine curve (Fig. 1). This is a very small modulation of 8 pixel (average to extreme) on top of a large solar radius of 494 pixels. One of the instances when the radius has the average value can be read to be JD 2453648. From these starting guesses it takes a few attempts at plotting data minus fit to find that the period is 2π times 58 days.

With a spreadsheet it is then possible to calculate the root-mean-square (rms) of the deviations of data from fit: For each data point the difference between measured and fit value is squared, all those squares are averaged, and the root of the average is taken. This is a measure of how well the curve fits the data. We vary the fit parameters to improve the fit, i.e. to reduce the rms. The best fit for the data here is when the rms is 0.83 pixel, and the fitted curve for apparent radius ρ in image pixels as a function of Julian Date then is:

$$\rho/\mathrm{pix} = 493.55 + 7.9\ \sin[(JD/\mathrm{d} - 2453647.0)/58.3]$$

Nice curve, but what does it mean? How does this relate to Kepler's laws [2]:

1. The planets move in ellipses with the Sun in one of their focal points.
2. The radius vector of a planet encompasses equal areas in equal time intervals.
3. The squares of the revolution periods of two planets relate to each other like the cubes of their orbits' semi major axes.

Fig. 2 shows an extreme ellipse like a comet might use for an orbit. Perihelion – when the planet is closest to the Sun – and aphelion – when it is furthest from the Sun – both occur on the major axis, top right and

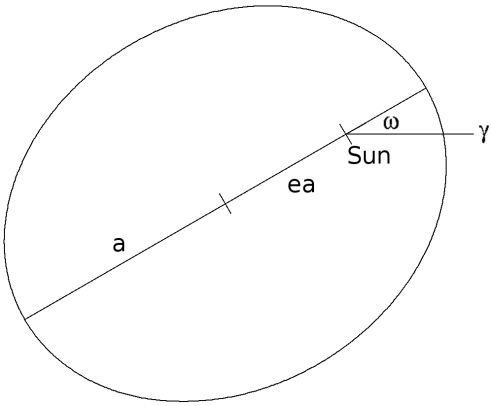


Fig. 2: *An elliptic orbit around the Sun. The size of the ellipse is measured by the semi-major axis a, its shape is measured by the numeric eccentricity e. The ellipse has two focal points, with the Sun in one of them. The ellipse shown here has an eccentricity of 0.6.*

bottom left in Fig 2. The Sun is not in the centre of the ellipse, but in one of its foci, a distance e (the numeric eccentricity between 0 and 1, 0.6 in Fig. 2) times a (the semi major axis) from the centre. For $e = 0$ the ellipse becomes a circle, as e approaches 1 it turns into a parabola.

Our primary results was that the apparent size of the Sun is changing between two extremes, perihelion and aphelion. The ratio of these two extremes can be expressed as a ratio of the sine of the Sun's apparent radius. Fortunately, the apparent radius is so small at 0.27° that the sine function can be approximated in a very simple manner, and the numeric eccentricity is simply the ratio of the size modulation divided by the size:

$$e = 7.9/493.55 = 0.016$$

This is a tiny eccentricity, but it translates to a difference of 6.5 % in the brightness of the Sun between perihelion and aphelion. Looking at the real orbit of the Earth in Fig. 3 you cannot tell the difference from a circle. But the small separation between the centre and the focus, the small offset of the Sun from the centre can just be seen.

Our sine curve fit to the apparent radius of the Sun reaches a maximum a quarter period after the fitted reference date. That is to say, the Earth went through perihelion at

$$T = 2453739 \text{ d} = 2006\text{-}01\text{-}03$$

Our data do not say very much about Kepler's second law. It is a statement about how the planet moves faster when it is closer to the Sun. We would have to measure the position of the Sun over the year to confirm this.

But we can talk a little bit about the third law, because we have measured the revolution period of the Earth, what we call a year. We find that the length of the year and the mean daily motion of the Earth around its orbit are:

$$P = 2\pi\, 58.3 \text{ d} = 366.3 \text{ d}$$
$$n = 360^\circ/P = 0.983^\circ/\text{d} = 1.987\, 10^{-7} \text{rad/s}$$

Kepler wrote down his laws before Newton had told us all about force and counterforce, and how the gravitational force diminishes with the square of the distance. Kepler's second law is a consequence of the balance between the attractive gravitational force and the centrifugal force. Knowing the law of gravity we can write Kepler's second law in terms of the gravitational constant G and the combined mass of the Sun (M) and the planet (m):

$$n^2\, a^3 = G\,(M+m)$$

Wow! If we plug in the astronomical unit and the universal constant G, we have in effect weighed the Sun! It is not a weight, but a mass; and it is not the mass of the Sun but the combined mass of Sun plus Earth (and Moon). But it is still amazing that we can do this just by measuring how long a year is. With [3]

$$a = 149.59787\ 10^9\,\mathrm{m}$$
$$G = 6.672\ 10^{-11}\,\mathrm{m}^3/(\mathrm{kg\,s}^2)$$

we find

$$(M+m) = 1.98\ 10^{30}\,\mathrm{kg}$$

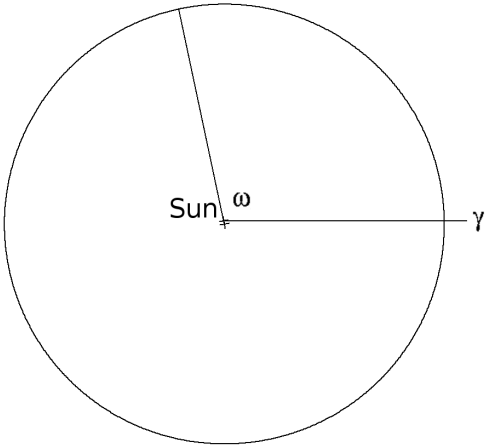


Fig. 3: *The Earth's orbit around the Sun according to my measurements. Note the extra cross at the centre of the orbit just below the Sun. At the time of vernal equinox the Earth is on the left. The Earth moves counterclockwise once a year. At summer solstice it is at the bottom, at autumn equinox on the right and at winter solstice at the top. Shortly after that it passes through perihelion (the point closest to the Sun), indicated by the line from the Sun pointing just left of upwards. This happens in early January.*

How well have we done compared to current best knowledge [3]? Our eccentricity of 0.016 is 4 % smaller than the real value of 0.0167 (for 2000). The 2006 perihelion was actually on 2006-01-02, one day earlier than we figured. The year we have measured is the anomalistic year (perihelion to perihelion). Its true length is 365.259635 d, our value is 1 d (0.3 %) too long. The mass of the Sun is 1.9891 10^{30} kg, the mass of the Earth plus Moon is about 330,000 times less and hence insignificant. Our value for the solar mass is then 0.5 % low.

The accuracy of our values is remarkable. Historically, much depends on the accurate measurement of the astronomical unit and of the gravitational constant. Our length of the year and time of perihelion are not terribly accurate, but it is clear that perihelion is in the middle of northern winter. Hence, summer and winter must be determined mostly by factors other than proximity to the Sun.

The Sun radiates away energy at a rate of 3.846 10^{26} W [2]. If it made heat like I do at home, it should be a mix of 20 % methane and 80 % molecular oxygen (by mass).

This could burn to carbon dioxide and water, releasing 6.12 10^{30} kWh. That seems a lot to the domestic consumer, especially when converted to £ or € at current prices. Indeed it would last the high-demand consumer Mr. Sun for 1800 years. But our recorded history is longer than that and life on Earth has existed for over 3500 million years. So the Sun must be doing something much, much more efficient to make heat and light. The processes known to atomic physics (aka chemistry) are not sufficient, it took insight into nuclear physics to understand how the Sun manages to shine for as long as it has. The Sun does not have enough uranium to use nuclear fission and plutonium does not occur naturally anyway. But hydrogen – which makes up most of the universe – happens to be a good fuel for nuclear fusion. The result is a substance we call helium, because it was first detected in the spectrum of Helios, the Sun.

References

1. Horst Meyerdierks, 2008, Atmospheric extinction, *ASE Journal*, **56**, 9
2. Albrecht Unsöld, Bodo Baschek, 1999, *Der neue Kosmos, 6. Auflage*, Springer
3. 1998, *Astronomical Almanac for the year 2000*, United States Naval Observatory and Rutherford Appleton Laboratory

Horst Meyerdierks

BAA variable star observing workshop

The BAA Variable Star Section is organising a Variable Star Observing Workshop in Edinburgh on Saturday 18th October 2008. The workshop will be held at the Royal Observatory Edinburgh. It will last from 10.30am to 4pm. There will be a £ 10 charge, which will include lunch. Included in the day will be a short presentation by the ROE of its Crawford Collection.

All BAA members and variable star observers are welcome. Also welcome are members of astronomical societies and interested members of the public.

I would be grateful if you could let me know if you intend to come to the workshop. Nearer the date I will forward a full programme. The workshop is aimed at those who are thinking of observing variable stars or are new to it, and will provide information on current observing campaigns which will be of interest to more experienced observers.

Des Loughney,
Secretary, BAA Variable Star Section,
<desloughney@blueyonder.co.uk>

Kielder Forest autumn star camp

The 6th Kielder Forest Star Camp will be staged over five nights from 29 October to 2 November 2008 in the spectacular Border countryside between England and Scotland. The event is being staged by the Kielder Observatory Astronomical Society, which has been formed to exploit an exciting new £480,000 observatory built 1270 feet above England's remotest village and which is now fully operational.

The Star Camp will be based at Kielder campsite and for the fifth year in succession we have kept pitch fees at £12 per night with an electric hook-up and £10 without (per pitch). There's also a minimum two night stay and fees must be paid up front.

The main day will be on Saturday 1 November at the 18th century Kielder Castle. We will have top speakers and a full line-up of the nation's leading astronomy vendors. Activities on the main day will be free of charge.

Details and a booking form can be found at http://www.richard.demon.co.uk/starcamp. For further information contact me at <starcamp@richarddarn.demon.co.uk>, or call 01226-246.351. We hope to see you under Kielder's dark sky!

Richard Darn,
Kielder Observatory Astronomical Society

Forthcoming events

2008-09-05	20:00	Gerry Taylor, ASE **Twenty bright stars**
2008-10-03	20:00	*speaker TBD* **Title TBD**
2008-11-07	20:00	*speaker TBD* **Title TBD**
2008-12-05	20:00	*speaker TBD* **Title TBD**

Our meetings are open to the public (unless otherwise stated). We are always happy to see new faces. Ordinary meetings take place at 20:00 (Civil Time) in the City Dome of the City Observatory, Calton Hill (usually on the first Friday of the month). Any changes to our meeting arrangements will be put on our website http://www.astronomyedinburgh.org

Recent observations

Noctilucent cloud

Doubt has been cast over the early-May noctilucent cloud mentioned in the previous issue of the *Journal*. Dave Gavine, Iain McEachran and Frank Howie report a number of nights with NLC in June and July. Frank took this picture across the Forth to Fife 2008-07-03/04.

Sun

Horst Meyerdierks takes an image of the Sun whenever possible and averages his spot counts in 30-day intervals. He reports the following R numbers (number of spots plus ten times the number of spot groups):

2008-04-04 / -05-03	0.0	2008-06-03 / -07-02	5.5
2008-05-04 / -06-02	4.2	2008-07-03 / -08-01	1.1

Solar eclipse

The solar eclipse of 2008-08-01 was partial in Edinburgh with a deepest phase of 35 % of the solar diameter, but the weather was no good. Frank Howie caught a brief glimpse, while Falkirk may have had a five minute interval near maximum phase

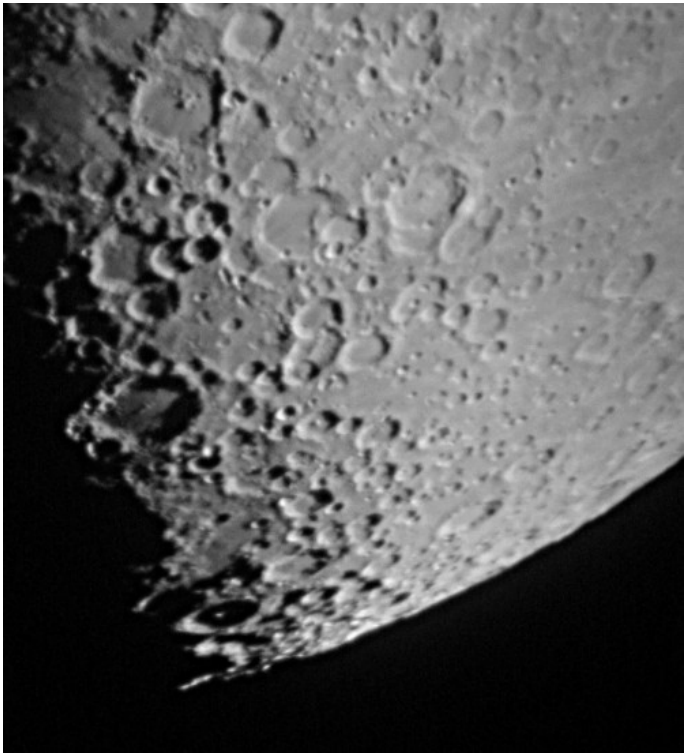
to see the event. The eclipse was total in parts of Canada, Russia and China. Des Loughney travelled to China and had very good conditions; we look forward to his report and images.

Moon

Prompted by the talk on digital imaging, Angus Self dug out some pictures he had taken of the Moon some five years earlier.

> It is the most simple and basic method one could possibly use. In 2003 I held my 2-megapixel Canon Ixus to the eyepiece of my Tal 1 reflector and went click ... click ... click ... and eventually found some quite decent pictures when I put them on the PC. The close-up is pretty neat for such a Heath-Robinson affair, with the crater Walter showing central uplift (near the top left).

His close-up of 2003-02-09 is shown here with an unsharp mask applied.



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About the ASE Journal

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