TRANSIT

The February 2014 Newsletter of

Cleveland & Darlington Astronomical Society

NEXT TWO MEETINGS, each at Wynyard Planetarium

Friday 14 February 2014, at 7.15 pm

A year with a large-aperture Dobsonian

Ian Morris, *CaDAS*

o – o – o – o – o

MONDAY 10 MARCH 2014 at 7.00 pm

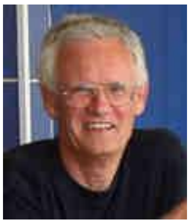
Extraordinary General Meeting

To discuss & vote on involvement in the Planetarium's future

Content

Editorial

Rod Cuff



First of all, a warm welcome to members who've joined us in the past month or so – Ian Rudd; Alex, Helen & Megan Dudiak; Lynne, Peter & Sam Critchley; and Brian Rowland.

The most important thing to note this month is this **FORMAL NOTICE** of an **Extraordinary General Meeting of CaDAS on MONDAY 10 MARCH at 7pm in Wynyard Planetarium**. Members of the CaDAS committee have been negotiating with officers of Stockton Borough Council over whether, and if so on what terms, an independent body could lease and take over the running of the Planetarium, preferably with CaDAS as a major player on the new body's board. It seems almost certain that both sides now agree on a positive way forward, and SBC's legal team are drawing up a proposed lease. We shall give CaDAS members further information on this as soon as we can, which will probably be the first week in March. The EGM will then follow on the 10^{th}, when there will be a presentation of the full facts, including pros and cons of formal CaDAS involvement, and debate and comment will be welcome. The meeting will be asked to vote yes or no to a specific question, along the lines of 'Do you want CaDAS to have at least one representative on the board of the new body?' (precise wording is still to be decided). If you are (or will be by then) a paid-up member of CaDAS, please put the date in your diary and do your best to come and listen and/or take part.

Back to the contents of this issue of *Transit* …

Ray Brown continues his series on gravity, this time dealing with the paradigm shift in physics as Einstein upset the Newtonian applecart. There were some nice positive reactions to the first 'A life in the sky' article on E.E. Barnard in January's magazine, and so the second in the series appears here, and I'll try to include a new one as often as I can.

There are more than the usual number of members' astrophotographs and drawings this month, which is *almost* entirely a good thing in my book, especially if it encourages others to observe and/or submit images. The 'almost' is because Peter Hanna, who very kindly prints and mails out the half-dozen or so copies of *Transit* that go to established members who don't have an internet connection, has pointed out that having many largely black images uses up a lot of ink, makes the paper wrinkly and can bleed through to the other side. So for some issues, such as the current one, I'll also produce a variant in which some images are displayed as negatives, and this is what will be mailed out. I'll ask our webmaster, Don Martin, to make both versions available on our website, starting with the current one.

Finally, either the end or the beginning of an era, depending on how you look at it. Starting with this issue, Neil Haggath is taking over as the *Transit* quizmaster. I've set a quiz in the magazine virtually every month for more than five years, but am very happy to hand the responsibility over to the most experienced quiz setter in the north of England, bar none!

Many thanks to contributors for this issue. Please let me have material for the next issue by 2 March. I may be pushed for editing time, so it probably won't be as long an issue as this one!

Best wishes –

Rod Cuff, info@cadas-astro.org.uk *1 Farndale Drive, Guisborough TS14 8JD*
(01287 638154, mobile 07775 527530)

PS – There's a free telescope on offer on page 18 …

Letter

Ken Mattingley visit

from Pat Duggan

Ken Mattingley, the Command Module Pilot for Apollo 16, is visiting Pontefract in April to give a lecture and speak at a dinner –The dinner places have sold out, but there are some lecture tickets left for Saturday 12 April. I have alerted the friends I went with to the Alan Bean meeting last year, but wondered whether anyone else from CaDAS might be interested.

More information at www.space-lectures.com/intro_10.html.

Cheers, Pat D

OBSERVATION REPORTS AND PLANNING

Websites – February 2014

Here are some suggestions for websites that will highlight some of what to look out for in the night sky in February. Jupiter, Mercury and supernovae feature prominently this month.

- **BAA Sky Notes** for February/March had not appeared online at the time of writing here, but presumably will eventually, linked from the public BAA YouTube Channel. I'd said last month that a PDF of the Notes is also always available from the BAA website, but on checking up it appears that the latest PDF is two years old!
- **HubbleSite**: a **video** of things to see each month (a transcript can be downloaded from the site as well):

  http://hubblesite.org/explore_astronomy/tonights_sky
- **Night Sky Info's** comprehensive coverage of the current night sky:

  www.nightskyinfo.com
- **Jodrell Bank Centre for Astrophysics** – The night sky:

  www.jodrellbank.manchester.ac.uk/astronomy/nightsky
- **Telescope House** monthly sky guide:

  http://tinyurl.com/pzzpmsx
- **Orion's** What's in the Sky – February:
  www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month
- **Society for Popular Astronomy's** monthly Sky Diary:

  www.popastro.com/documents/SkyDiary.pdf

CaDAS astrophotographic gallery

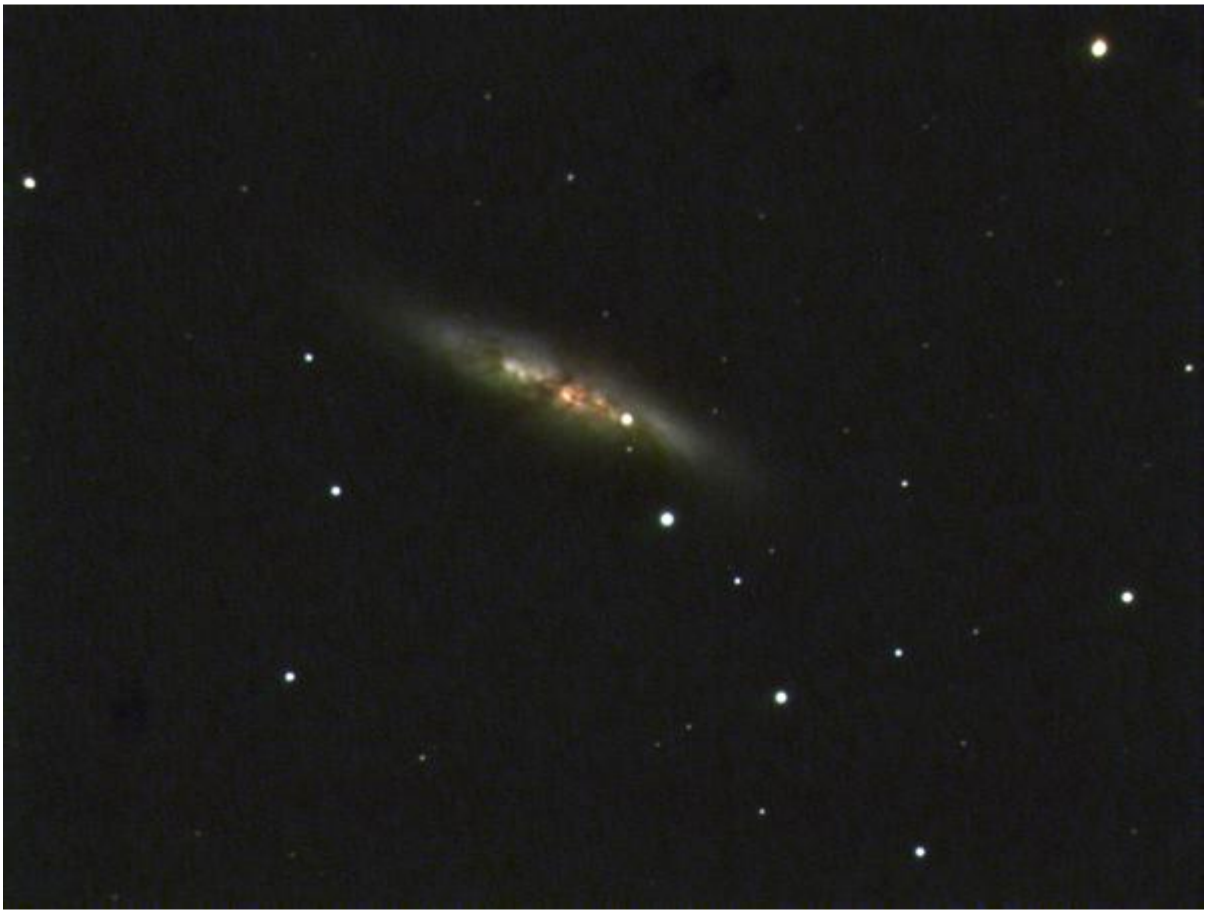
Mark Swinbank, Keith Johnson, Jürgen Schmoll, Rod Cuff

There have been some good opportunities and celestial targets this month. Here's a selection of images and drawings from CaDAS members and friends. Further hardware & software details are available from the editor on request.

M82 and its supernova SN2014J

Dr Mark Swinbank, *Institute for Computational Cosmology, U of Durham*

I obtained the image below on 26 January from one of the 14" telescopes on top of the Physics Department in Durham (1hr integration in total, 20mins each in B,V,R in (lousy) ~3.5" seeing). I've got the level-3 undergraduates monitoring the SNe to derive the light curve.



M82 and SN2014J from Mark Swithinbank – excellent detail

Keith Johnson

The first cropped image below was captured at Dalby StarFest in August 2013, showing M81 and M82 as they then were. The other image, also cropped, was captured at Derwent Reservoir on 25 January 2014 and clearly shows the M82 supernova.

Keith's image of M82 (left) and M81 (right) in August 2013…

… and in January 2014, complete with SN2014J in M82

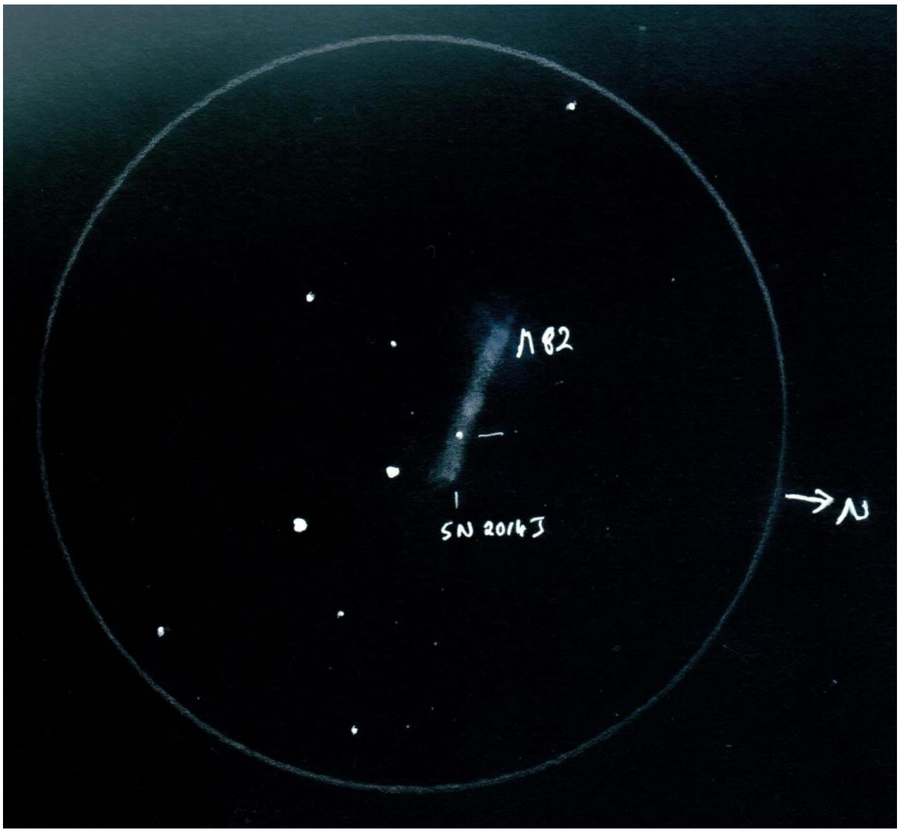
Jürgen Schmoll

I took 6 × 5min subs before high-altitude clouds screwed everything up. 250/2000mm, EOS40Da with CLS filter autoguided on EQ6 pro. (*Image on next page*.)

Jürgen's image from the early hours of 24 January

Rob Peeling

Hi, everyone – Managed to spot supernova SN2014J in M82 visually with my 12” ‘scope last night (25 January). Dead easy to see against the galaxy and a star that definitely wasn’t there before – I know M82 well. I’d guess brightness around 11th magnitude – so, well out of range of binoculars. You might see with something as small as a 6”.



Rob's drawing of M82 and SN2014J

Jupiter

Jürgen Schmoll

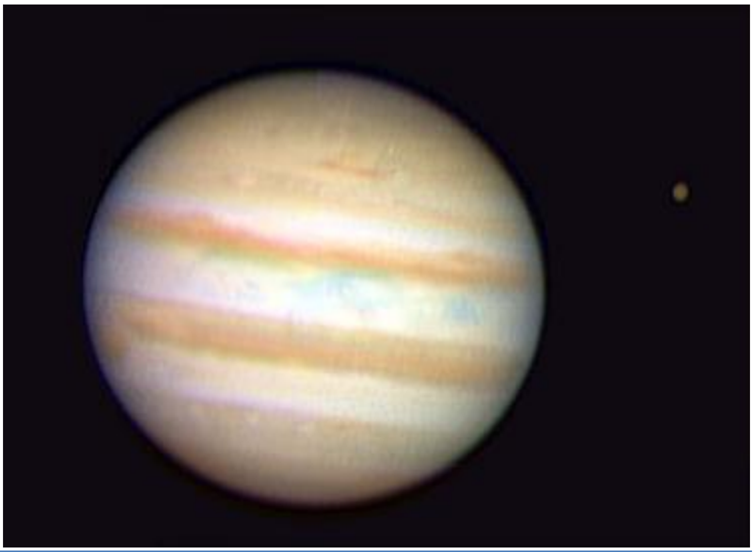
19 January 2014, between about 8pm and 10pm.

(*This is one of five images that Jürgen provided from the same night. – Ed.*)

Rod Cuff

12 January 2014. The satellite is Callisto, with an angular diameter of about 1.6 arcsec. The Great Red Spot on Jupiter is just rotating into view at bottom left.

These three images show how just much astro-photographical processing depends on personal choice!



Keith Johnson

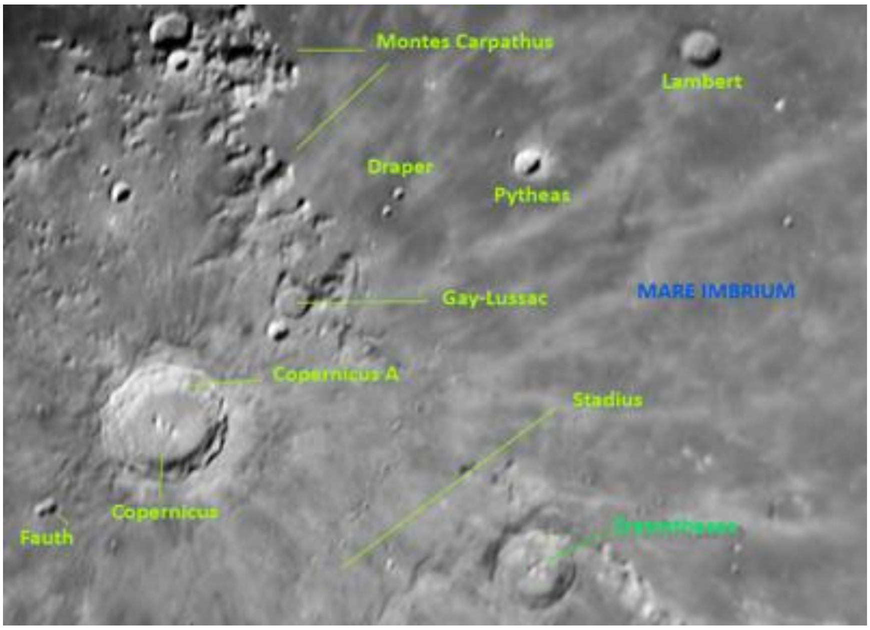
5 January 2014 at 00:46 UT.

The Moon

Rod Cuff

The main picture below shows the region around Copernicus, 12 January 2014, 01:03 UT.

The labelled mini-version on the right identifies some of the features – it's a fascinating part of the Moon.



A life in the sky: a postscript on E.E. Barnard

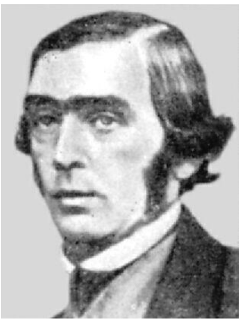
Rod Cuff

The first article in the *A life in the sky* series (*Transit*, Jan 2014) concerned Edward Emerson Barnard (1857–1923), a gifted and largely self-taught observational astronomer and pioneering astro-photographer. Here's a (verbatim) anecdote from one of his obituaries. Think on this the next time the clouds roll in as you've just finished setting up ….

> In the early days of the [Yerkes] observatory the unkindly elements at times made observing a matter of great difficulty. During the second winter there had been a very heavy storm, bringing nearly two feet of snow. This had been followed by rain which froze as it fell. About dark the rain stopped and it turned suddenly cold, and by 10 o'clock it was 10° below zero, Fahrenheit.
>
> Suddenly, without warning, the skies cleared. It was Barnard's night with the 40-inch. He first aroused the night engineer (for electric power was not then kept on all night), and then he went to the 40-inch dome in order to begin observing. By this time the skies were completely clear, and the stars looked crisp and small, as if the seeing must certainly be of the finest.
>
> But, alas! When attempting to open the dome, the shutters were so caked with ice that nothing would budge. The average astronomer might resign himself to his fate, after finding no method of opening the shutters until morning, and then go to bed, inwardly thanking his stars that he did not have to work on such a bitter night. But not Barnard! It was his night to work, and work he would or know the reason why.
>
> The only thing to do was to find a ladder, go outside the dome from the balcony about 75 feet above the ground, and chop away the ice. And this on a night without Moon, and the thermometer 10° below zero! Unfortunately the only ladder long enough was one at the YMCA camp, a half-mile away, and down a hill 200 feet high.
>
> The astronomer and the night engineer trudged through the heavy snow and secured the ladder. Both were nearly exhausted when they again reached the observatory building. Then it was the work of an hour in a bitter wind, with the imminent danger of a disastrous fall to the ground. At last the ice was chopped away, the dome was opened, and the astronomer went happily to start his work. But, before the telescope was even pointed at the first star, the clouds had shut in again; and although a vigil was kept until daylight, not a break occurred in the unkindly clouds!

A life in the sky – 2: J.R. Hind

Rod Cuff



Things to observe

Hind's Variable Nebula … Hind's Crimson Star … asteroids.

Who was Hind?

John Russell Hind (1823–95) was one of the early discoverers of asteroids and variable stars, and discovered the first nova of modern times.

Born in Nottingham, the son of a lace manufacturer, he went to Nottingham Grammar School before moving to London at seventeen with the intention of becoming a civil engineer. But by then he had become an enthusiastic amateur astronomer contributing notes for local newspapers; and within months he secured a post at the Royal Observatory, Greenwich, under the Astronomer Royal of the time, George Biddell Airy (of **Airy disk** fame).

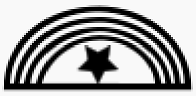
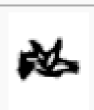
Airy was a notoriously hard taskmaster, often exhausting his staff, and after four years in the Magnetical and Meteorological Department Hind 'escaped' to succeed **William Dawes** (*see sidebar*) as the salaried observer at South Villa in Regent's Park. This was a serious and successful observatory privately owned by a businessman, George Bishop, who later became successively the Treasurer, Secretary and President of the Royal Astronomical Society (RAS) and was elected a Fellow of the Royal Society.

'Eagle-eye Dawes' (1799–1868) is probably best known to amateur observers for the **Dawes limit**. This formula expresses the maximum resolving power of a telescope – the angle R in arcseconds subtended by the smallest detail it can distinguish:

$R = 11.6 / D$, where D is the diameter in centimetres of the aperture or objective lens.

The nine years that Hind spent at the South Villa Observatory made his name as a discoverer: he found ten asteroids, three comets and many variable stars and nebulae. The Royal Society, the RAS, the King of Denmark and the French Academy of Sciences awarded him Gold Medals, and in 1852, at the age of 29, he was granted an annual pension of £200 (about £18,500 in today's terms) from the Civil List 'in consideration of his contribution to astronomical science by important discoveries'. (In recent times the Civil List was reduced to just supporting the official expenses of various members of the Royal Family, and was abolished in 2011.)

Here are the names, Hind's discovery dates and, for the earlier asteroids, the icons that were used for them in early texts and star maps, before astronomers adopted a different approach by showing each as a number inside a circle.

Name	***Discovery date***	***Icon originally used***	
		Graphic	***Meaning***
7 Iris	August 13, 1847		A rainbow (*iris*) and a star
8 Flora	October 18, 1847		A flower (*flora*) (specifically the Rose of England)
12 Victoria	September 13, 1850		The laurels of victory and a star
14 Irene	May 19, 1851		A dove carrying an olive branch (symbol of *irene* 'peace') with a star on its head, or an olive branch, a flag of truce, and a star
18 Melpomene	June 24, 1852		The dagger of Melpomene, and a star
19 Fortuna	August 22, 1852		The wheel of fortune and a star
22 Kalliope	November 16, 1852	—	—
23 Thalia	December 15, 1852	—	—
27 Euterpe	November 8, 1853	—	—
30 Urania	July 22, 1854	—	—

The number of asteroids between Mars and Jupiter is now known to be so vast (one estimate at space.com suggests more than 750,000 larger than a kilometre in diameter) that it's difficult today to realise the level of interest aroused by discoveries through Hind and others in the middle of the nineteenth century. The first four asteroids had been discovered in the very early 1800s – in fact, 1 Ceres was found on the very first day of the century, 1 January 1801 – but there was a nearly 40-year gap before a Dresden postmaster, **Karl Hencke**, discovered 5 Astraea after 15 years of patient searching, and 6 Hebe nineteen months later. In the next year, 1847, Hind made *his* first asteroidal discoveries, of Iris and Flora.

However, in between Hencke's pair of discoveries, **Johann Galle** had discovered the planet Neptune, based on **Urbain Le Verrier**'s calculations. Further, as is well known, the British astronomer **John Couch Adams** had (possibly!) also correctly predicted where the new planet would be found, but had been unable to persuade British astronomers to conduct a search. (After Galle's announcement, Hind became the first person to knowingly observe Neptune from Britain.) These events were all causes, naturally enough in the mood of the astronomical times, for celebrations and medals. But this left the RAS enmired in fierce controversy over how their annual Gold Medal should be awarded.

And so there arose a splendid British compromise whereby twelve Testimonials were awarded instead, including one to Hind. The roll call of his co-recipients illustrates the level of the astronomical company in which he was now classed: it included Hencke, Adams, Airy (!), Galle, Le Verrier and **Sir John Herschel**. Also honoured was Hind's employer at South Villa, George Bishop.

In 1853 Hind was appointed Superintendant of the Nautical Almanac (in preference to Adams), a position he held for the next 38 years until his retirement in 1891. His immediate successor at South Villa Observatory was **Norman Pogson**, a skilled observer who proposed the modern logarithmic system of stellar magnitudes (*see* sidebar).

John Russell Hind continued to supervise the observers at Bishop's observatory, even after it moved to the darker skies of Twickenham (!). He died of heart disease at Twickenham on 23 December 1895, and is buried in Twickenham Cemetery.

In 1856 Pogson noted that the stellar magnitude system due to the Ancient Greek astronomer Hipparchus had resulted in 'first magnitude' stars being about 100 times as bright as 'sixth magnitude' stars (so, five magnitudes apart). He proposed to put this on a firm mathematical basis involving constant ratios, so that a first-magnitude star is $100^{1/5}$ or about 2.512 times as bright as a second-magnitude star. This is known as **Pogson's ratio**. To be precise, if m_1 and m_2 are the magnitudes of two stars and L_1 and L_2 their luminosities, then **Pogson's formula** declares that $m_1 - m_2 = -2.5 \log_{10} (L_1 / L_2)$.

Hind for today's observer

- **HIND'S VARIABLE NEBULA (**NGC 1554/5**)** was the first variable nebula to be discovered, and quite a sensation in the astronomical world for several years after Hind first recorded its presence on 11 October 1852. He had been scanning near the ecliptic for asteroids when he came across a tenth-magnitude star, later to be designated as T Tauri, near the Hyades, and a small nebula just to its south-west. So far, so routine: but then a few years later it began fading, could no longer be seen visually at all by 1868, and stayed out of sight until 1890 when (who else?!) E.E. Barnard and a colleague barely detected it using the 36-inch Lick refractor. After it was photographically retrieved at the very end of the 19th century, it has stayed visible and indeed has steadily brightened since the late 1930s – but has switched to being to the *west* of T Tauri!

A near-infrared image of Hind's Variable Nebula and T Tauri.

Credit: 2MASS/NASA

A partial explanation for this apparently odd behaviour is that the nebula is reflecting radiation from T Tauri, which turns out to be a variable star with magnitude ranging from 9.3 to 14, and now has an entire class of variability named after it. T Tauri stars are young, and have not yet settled down to join the main sequence. Their radiative energy comes from gravitational energy released as they contract – the centre of the star is not as yet hot enough for hydrogen fusion to begin. They probably have many big starspots, and certainly have very strongly variable emissions across all wavelengths. That having been said, it's only a partial explanation for the odd behaviour of Hind's Variable Nebula, since the changes in brightness levels in the nebula are not synchronised with those in T Tauri, and of course there's that small matter of the centre of reflected radiation moving around …

Observing notes: The nebula and star are at RA 04^h 21.8^m, Dec +19° 32' – in our skies at the moment, along of course with the rest of Taurus. An article by Nick Hewitt in the *BAA Journal* from 2003 comments that the star itself is worth monitoring, as it has an irregular period and varies by a few tenths of a magnitude almost daily. Building a light graph (the usual term 'light curve' would seem odd for such an unpredictable object) could be quite rewarding for CCD astrophotographers wanting to hone their skills in astrometry (measuring the brightness of stars).

The nebula is 30 arcseconds across, so pretty small. Because it's a reflection nebula and not an emission nebula, so-called 'nebular filters' will be of no use. Capturing it with a CCD camera is likely to require a 10-inch (?) telescope and dark skies, and visual chances are iffy at best. There's a cracking image of the whole fascinating region at http://annesastronomynews.com/annes-image-of-the-day-hinds-variable-nebula/.

- **HIND'S CRIMSON STAR** (R Leporis) was found by Hind in 1845 at RA 4h 59m 36s, Dec –14° 48' 23" – just south of the constellation of Orion, which means it never rises above about 25° altitude in our part of the world. It's at its best in November–February. It's a carbon star – a type of cool giant (in this case, with a surface temperature of only 2250 K) that has left the main sequence and where internal convection has dredged up huge amounts of carbon towards the surface. The resulting carbon-based molecules absorb almost all light except at red wavelengths, resulting in a star that either is visible only in the infra-red or, as in this case, has a vivid deep red colour. Hind described it as like 'a drop of blood on a black field'.

Hind's Crimson Star (attribution unknown).

Observing notes: The left (Saif) and right (Rigel) 'feet' of Orion make an isosceles triangle with R Leporis. Like all carbon stars, it's a variable:

its magnitude ranges between 5.5 and 11.7 with a period of about 427 days, and the star is reddest when at its dimmest. For part of that range it's a binocular object, but it would really come into its own in a CCD image – any takers?

- **ASTEROIDS:**

  Observing notes: The *Handbook of the BAA* for 2014 gives ephemerides (including RA, Dec and apparent magnitude) at 10-day intervals during observable periods for **12 Victoria** (June–Nov, mag. 9.0–10.5), **18 Melpomene** (Jan–March, 9.4–10.7) and **23 Thalia** (Oct–Dec, 9.3–10.7). All these are well within the normal observing range for amateur observers – checking observations with a good planetarium program a few days apart for each of those would make a rewarding 'Hind project' on its own.

  I'm surprised to find that 7 Iris isn't in the list, since it's the fourth brightest asteroid, with a mean opposition magnitude of 7.8; probably it's not well positioned for us this year. The same goes for 8 Flora (seventh brightest, mean opposition magnitude 8.7).

Other Hind discoveries

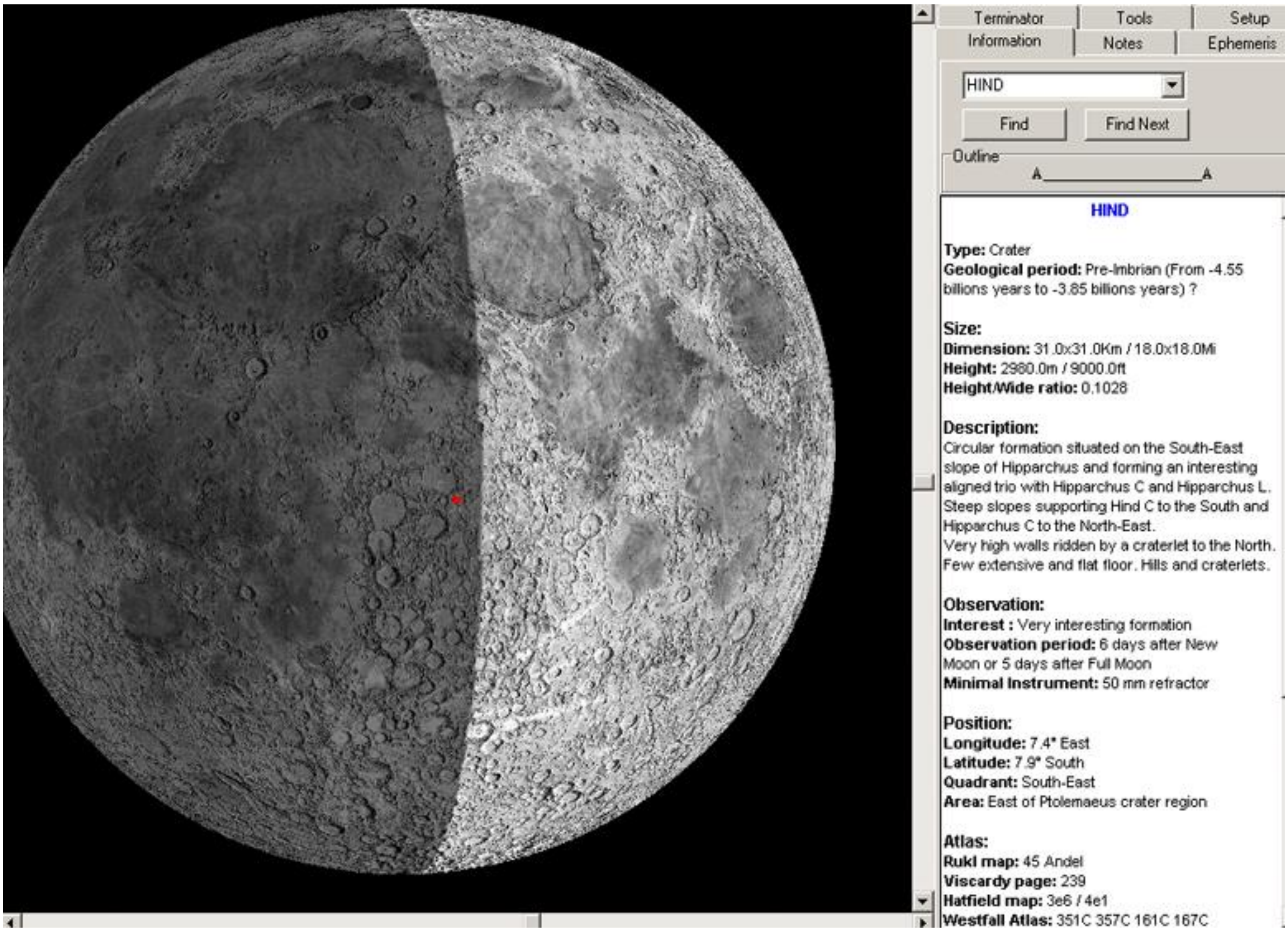
- Hind discovered **Nova Ophiuchi 1848** (now V841 Ophiuchi), on 27 April 1848 – the first nova or supernova to be identified since Kepler's Supernova in 1604. At the time Hind observed it, it was strongly red, of magnitude 4 or 5; it had not been visible when he had last looked at that region on 5 April. By the end of July it had faded to 8th magnitude, and by the time it was re-observed by (sorry, this may be getting boring …) E.E. Barnard in 1921 it was about magnitude 12.5. SkyTools gives its present magnitude as 13.5, and its position as RA 16h 59m 30.4s, Dec –12° 54' 27" (epoch 2000).
- Hind discovered or co-discovered **two comets**: C/1847 C1 (Hind) and C/1846 O1 (de Vico–Hind). The C/ prefix means that the comets are not (thought to be) periodic, or have periods of more than 200 years. C1 signifies that the comet was the first to be discovered in the third half-month of the year (i.e., the first half of February), and O1 that it was the first to be discovered in the 15th half-month (i.e., the first half of August).
- In 1783 William Herschel had noted that the star **Mu (μ) Cephei** was 'a very fine deep garnet colour', and it has come to be known as Herschel's Garnet Star. **Hind discovered in 1848 that it is a variable star**, and it is now the prototype of the class of Mu Cephei irregular variables. It's one of the largest stars visible to the naked eye, and indeed in the whole galaxy – if it were to replace our Sun, its radius would reach midway between Jupiter and Saturn. It's about 350,000 times as luminous as the Sun, and one of the most luminous stars we know of. Like Hind's Crimson Star, it too is a carbon star.

Later named for Hind

Two solar system objects have been named after Dr Hind:

- **ASTEROID 1897 HIND**, discovered on 26 October 1971 by the extraordinarily prolific Luboš Kohoutek, who discovered a further five asteroids the same night, and a total of 75 in his career. His name may be familiar from his cometary discoveries, especially 'Comet Kohoutek' (C/1973 E1), another much-anticipated 'comet of the century' that didn't quite make the splash that the media wanted – although it *was* a naked-eye object.

- **CRATER HIND** on the Moon. A British amateur astronomer, William Radcliffe Birt, along with his friend John Lee, prepared an outline map of the entire Moon in 1865 that included 85 new names, many of them later adopted by the International Astronomical Union. Hind's name was one of the latter, given to a 30 km crater near the visual centre of the Moon. Here are some more details from [Virtual Moon Atlas](#):



Please send in images, drawings, measurements, light-curves or comments you may have relating to this article, or indeed to the earlier article on Barnard.

Kiruna in Swedish Lapland

Pat Duggan

I watched the sunspots approach, and spaceweather.com was warning of the possibility of an X-class flare from AR1944.

I had long wanted to go to the Ice Hotel and perhaps this was a good time? I asked a few friends if they would like to come with me on this exciting trip – and they all said I was mad! So I booked myself a room there first and a warm hostel room in Kiruna town itself for the nights before and after, and also Heathrow Airport rooms for the nights either side of my SAS flights.

Everything went like clockwork and I landed in –17°C, the mid-afternoon high for that far north! The nice bus driver dropped me right outside the hostel and I was able to leave my big suitcase there even though I would be away for the middle night, which was really helpful.

The Ice Hotel encases you in a sort of astronaut suit with boots, gloves and balaclava as soon as you check in. This was fortunate because they then cheerfully told everyone their own restaurant was fully booked for the evening, so there would be a one-kilometre walk to the nearest place for a hot meal! I'm not at all certain the staff of youngsters who seem to run the place have ever heard of 'customer care training', or 'health and safety' for that matter!

All belongings are left in an allotted cubicle in the warm. My thermal ski under-layer (bought from Lidl the day I left home) was a necessity. The trip around the hotel was just beyond description. The internet photos do not do it justice and words could not describe the atmosphere inside. The corridors to the art-carved rooms had misty magic clouds below knee height and the lights were multifaceted, hand-carved chandeliers of ice. The Bar was carved to house a huge fish, ice chairs, tables and the glasses too. The lighting shone through the clear and frosted walls and furniture. Plaques of writing, done with ice, explained the fish and told stories and ideas that had brought the Ice Hotel to be an annual reality. I think it was those incandescent blues that brought tears to my eyes – and I was not the only one!

I had gone to see the Northern Lights. Just to assure myself that the trip would not be a waste of effort, I had booked into a room called 'The Northern Lights Room', where an artist's impression of the blues and greens shimmered all night across the walls and ceiling made of sparkly ice. The 'furniture' was made of clear ice – yes, that included the bed! But it was covered with a foam pad and skins of reindeer. The temperature was kept below at most –5 degrees. It was so pretty that I didn't want to go to sleep when the time came!

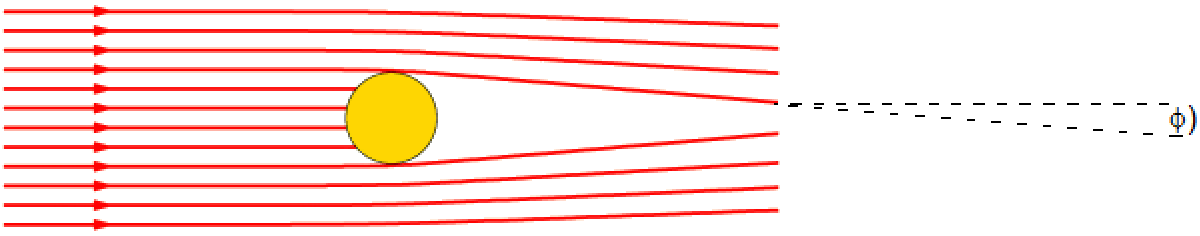
The one-kilometre walk back from the restaurant was along (on) the frozen river where the huge ice building blocks are cut from. The sight of a rippling green aurora, spreading and wavering low to the north was what I had come for and I was, for that short time, a part of its own strange world. I should like to say I have photographs of it; but, as I brought my simple camera out of my padded suit, the battery froze and so did my fingers! But what a memory.

GENERAL ARTICLES

Some thoughts on gravity and tides
Part 5: How Einstein changed the scene

Ray Brown

The Newtonian concept of gravity was a massive contribution (pardon the pun) to science and to the Enlightenment. It was consistent with almost all astronomical observations in the solar system. However, Newton's view of gravity simply as a force of one mass acting on another was unable to answer a few subtle questions, which were to be addressed more than two centuries later by Albert Einstein's **General Theory of Relativity**. The extent to which light rays are deflected when they pass by a massive object of mass M and radius R was first calculated in 1801 by J.G. van Soldner, using Newtonian mechanics. He predicted a maximum deflection angle of $2GM/Rc^2$ radians, where G is the universal gravitational constant and c is the speed of light in a vacuum, first accurately determined by James Bradley in 1729. For the case of the Sun, this result corresponded to a maximum deflection angle ϕ of 0.87 arc seconds, but such a small value could not be verified experimentally at the time.

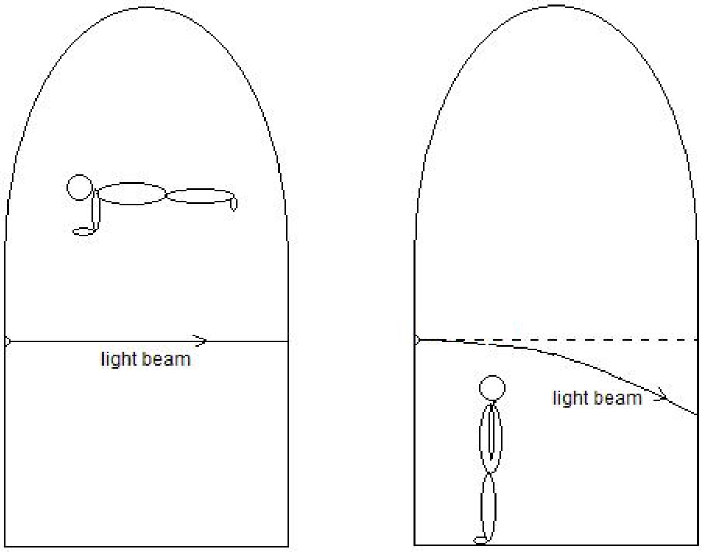


Newton, who recognised that light might consist of 'corpuscles' (i.e. particles), had himself mentioned in passing that such deflection should occur. During the 19th century the **corpuscular theory of light**, and of electromagnetic radiation in general, lost ground and interest in favour of the **wave theory**. At the beginning of the 20th century Max Planck realised that electromagnetic radiation consists of packets (**quanta**) of energy E, which are proportional in magnitude to the wave frequency v of the radiation ($E = hv$ where h is the universal Planck's constant). Einstein's **Special Theory** a few years later (1905) drew attention to the equivalence of mass and energy ($E = mc^2$). Einstein recognised that light rays consist of particles (photons) that must have effective masses ($m = hv/c^2$) and therefore, according to Newton's law of gravitation, are attracted by other masses, leading to deflection of the rays. The **dual nature of light** as wave *and* particle was finally established.

Remarkably, in 1911 Einstein, in agreement with van Soldner's result, also concluded the maximum angle of light deflection by a massive object to be $2GM/Rc^2$ radians, but he acknowledged a fault in the reasoning; a photon already travelling at the speed of light would be accelerated whilst being attracted radially towards the mass, thereby increasing its speed – impossible! Later, after developing his General Theory of Relativity in 1916, he included the effect of **gravitational time dilation** (see below) and revised his result to $4GM/Rc^2$ radians, i.e. twice the previous estimate of the deflection. The General Theory introduced a completely new view of gravity; instead of a pair of masses exerting an attractive force on one another, each is instead influenced (accelerated) by the **warping of space–time** caused by the other. So whilst Newtonian mechanics treats gravity as a force (successfully for most purposes), it is only an *imaginary* force in much the same way as a 'centrifugal force' is *fictitious*. When we are thrown to one side as we travel in a car rapidly negotiating a steep bend, we are said to experience centrifugal force pulling us outwards, but in fact our body mass is simply being prevented by an (inward) centripedal force (effective through the tyres) from continuing in the straight line it would otherwise follow in accordance with the Law of Conservation of Momentum.

However, in a framework of curved space–time the shortest distance between two points, known as the **geodesic**, a path always followed by a light ray, is not necessarily a straight line. By analogy, on the spherical surface of Earth, the shortest distance between, say, Darlington and Sydney is the Great Circle route and not a straight line. Only members of the Flat Earth Society and possibly Jules Verne might demur! The effect that we call gravity is equivalent to acceleration in a space–time framework.

This **equivalence principle** is usually illustrated by a beam of light being shone from one wall of a spaceship to the opposite wall; the beam strikes the far wall at the same height from the floor as the light source *only* so long as the spaceship is not accelerating (and the crew are feeling weightless). But when the ship accelerates, the crew are sent to the floor and the light beam now strikes the opposite wall at a point lower than the source; the ship is moving on whilst the photons travel across the cabin. The light beam has been 'deflected' by the acceleration, whilst the crew, now no longer weightless, experience what feels like gravity.



zero gravity, zero acceleration

acceleration upwards

Famously, during the total solar eclipse of 1919 Arthur Eddington measured the deflection of light rays from distant stars as they passed by the Sun on their way to Earth, obtaining a value in approximate agreement with Einstein's revised prediction.[1] In the six decades that followed, increasingly refined measurements progressively confirmed the general validity of this aspect of the General Theory and nowadays **gravitational lensing** by galaxies and galaxy clusters has become a major feature in astronomy; a distant light source is seen as a ring around the intervening massive object. Gravitational time dilation arises because events (such as a clock ticking) occur more slowly in a high gravitational field than in a low field. So a person who works on the ground floor of a skyscraper ages slightly more slowly than her twin who works on the top floor, further from Earth. Likewise, an astronaut who experiences acceleration of his spaceship will return younger than his twin who stayed at home. Karl Schwarzschild famously solved Einstein's field equations to obtain an expression that quantifies gravitational time dilation:

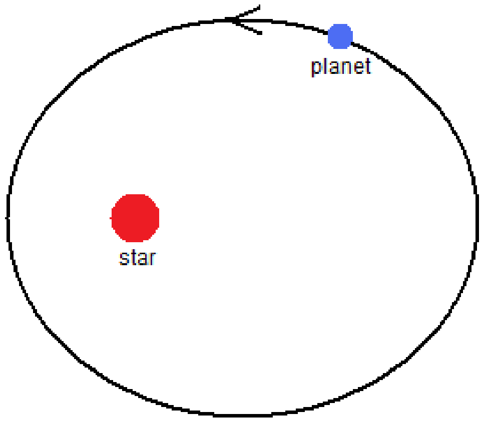
$$t_0 / t = (1 - 2Gm/rc^2)^{½}$$

Here t_0 is the so-called *proper* time taken for an event to occur at a distance *r* from a centre of mass *m* as measured by an observer at the scene of the event, whereas *t* is the duration measured for exactly the same event but timed by a second observer located outside the gravitational field. Clearly *t* must always be greater than t_0, so the clock inside the gravitational field runs more slowly than that outside. In the extreme case of a mass so large that $m = rc^2/2G$, then t_0 becomes zero and for the local observer time stands still. This is how it must be at a **black hole**.

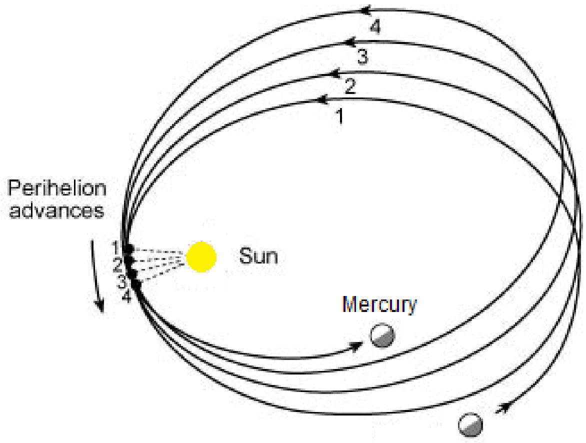
The classical Newtonian view of forces is that their effects are immediate, yet the Special Theory argued that nothing can move faster than light travelling through a vacuum; the nearer the velocity of an object approaches to the speed of light, the more closely does its mass approach an infinite value. It follows that the gravitational force cannot have instantaneous effect. So, should the Sun explode in a supernova, we would not immediately be blown to smithereens; instead the orbit of Earth around the Sun would continue as before unperturbed for another 8½ minutes, assuming that the gravitational effect can be transmitted at the speed of light. Just time for a cuppa!

---

[1] [*Wikipedia says, using a well-referenced source: 'When asked by his assistant what his reaction would have been if general relativity had not been confirmed by Eddington and Dyson in 1919, Einstein famously made the quip: "Then I would feel sorry for the dear Lord. The theory is correct anyway."' – Ed.*]



Two-body system – elliptical orbit with a fixed periapsis



Precession of elliptical orbit with advancing perihelion

The first major success of the General Theory of Relativity had been its explanation of the extent of precession of the orbit of the planet Mercury. Precession of an orbit is caused usually by the gravitational effects of third bodies, in this case the other planets. As early as 1859 Urbain le Verrier found a discrepancy between the rate of precession obtained from the recorded times for the transits of Mercury over the previous two centuries and the rate he calculated for the effects of the other planets using Newtonian mechanics. The anomaly remained unresolved until Einstein showed that it was explicable by the effect of the curvature of space–time caused by the mass of the Sun. The observed precession rate of 574 arc seconds per century is made up of a 532 arc seconds contribution from attraction by other planets and 43 arc seconds from the effect of general relativity.

Next month: Part 6, truly the last in this series (Ray added the article above only a few weeks ago!), will discuss ***the three-body problem, orbital resonances and binary exoplanets.***

FREE OFFER!

Telescope needs a good home

Jon Mathieson

Having just replaced my more than 20-year-old telescope, I wondered if anyone would be able to make use of it. It's been a good scope, though has some wear and tear, and a few paint splashes on the outer case. I'm not looking for anything for it, if anyone can make use of it.

It came from a commercial manufacturer rather than being home-built, but I can't remember the company. It's a Newtonian with a tube 39" long and 9.5" in diameter. The mirror is approx. 8". The mount is a clockwork manual one. Included in the offer are a 5mm eyepiece, finder scope, tripod, etc.

Regards, Jon (jon.mathieson@jonm.net)

[*Please contact Jon directly. – Ed.*]

Answers to January's quiz

Every answer starts with the letter L. The questions are in very rough order of increasing difficulty.

1. An oscillation of a celestial object around some mean position. **Libration.**
2. Celestial body containing the Tarantula Nebula. **Large Magellanic Cloud.**
3. A period of intense cratering during the final stages of Solar System planetary formation about 3.8–4 billion years ago. **Late heavy bombardment.**
4. A galaxy with a central bulge and disk, but no spiral arms. **Lenticular galaxy.**
5. Generally accepted as the inventor of the telescope. **Hans Lipperhey (c.1570–1619).**
6. M76. **Little Dumbbell Nebula.**
7. The two Soviet Moon vehicles that were the first automated rovers to operate on another world. **Lunokhods.**
8. The first site occupied by the European Southern Observatory (ESO). **La Silla, in the Chilean Atacama Desert. There is now a second site on Mount Paranal, where the Very Large Telescope (VLT) is situated.**
9. Discoverer of the period–luminosity relation for Cepheid variable stars. **Henrietta Swan Leavitt (1868–1921).**
10. Constellation whose 'alpha' star is Zuben el Genubi. **Libra.**

February's quiz

Neil Haggath

Every answer starts with the letter M. The questions are in very rough order of increasing difficulty.

1. The first star that was known to be variable.
2. A small constellation, named after a very small creature.
3. The body on which is found the highest cliff in the Solar System.
4. A major observatory, operated by the University of Texas.
5. The only feature on Venus named after a man!
6. The man who didn't fly on Apollo 13.
7. A curved string of galaxies within the Virgo Cluster.
8. The man who discovered about half as many 'Messier objects' as Messier himself.
9. The astronomer who discovered the variability of Algol.
10. The unofficial name given by astronaut Gus Grissom to his Gemini 3 spacecraft.