TRANSIT

The May 2014 Newsletter of

Cleveland & Darlington Astronomical Society

FINAL MEETINGS OF THE SEASON, each at Wynyard Planetarium

Friday 9 May 2014, at 7.15 pm

Presidential address: *Great comets of the last century*

Jack Youdale FRAS, *CaDAS honorary president*

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Friday 13 June 2014, at 7.15 pm

AGM + social evening +???

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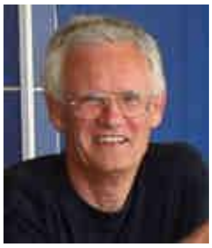
Editorial

Rod Cuff



This month I'm glad to welcome a new contributor to *Transit*, **Alan Kennedy**, who is starrting a series of articles on the people behind the names of some of the craters on the Moon, along with details about the craters themselves. This is rather like a lunar version of my own series (absent for the last couple of months) about deep-space objects well known to amateurs and carrying the names of past astronomers.

The **Ray** double-act continues this month: Mr **Worthy** has a really intriguing piece that might get you to look at Shakespeare in a new light, while Mr **Brown** has another absorbing scientific detective story to relate, this time on the quest for the value of the Universal Gravitational Constant.

Keith Johnson flies the observational flag this month, with another good image of Mars and a bit of hair-tearing about the difficulty of getting it.

We're getting closer to our June meeting, which will consist of the **AGM** and as yet undecided elements of a **social evening**, telescope club, competition and goodness knows what. We hope to be able to say more in the next issue, but to some extent that will depend on you. What would you like to happen during the evening? Emails flying around the committee wonder about such things as a barbecue, food & drink in the planetarium, volunteers collimating and advising on problems with scopes, amateur rocket-building, a quiz …. Drop me or any committee member a quick email to tell us your preferences and your ideas.

And to repeat part of my editorial from last month: CaDAS needs a new **Communications & Information Secretary** to be elected into place at June's AGM. Apart from attending the occasional committee meeting and forwarding information to members from time to time, the Secretary's main activity is editing *Transit*. If you are or might be interested in taking this role on (you can adapt it to suit the time you have, of course), please contact either me or any committee member ASAP. No one has yet indicated they would be interested, so it may be that next month's *Transit* will be the last for a while. That would be a great pity.

Many thanks to all contributors. Please let me have material for the next issue by **28 May**.

Best wishes –

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(01287 638154, mobile 07775 527530)

OBSERVATION REPORTS AND PLANNING

Websites – May 2014

Here are some suggestions for websites that will highlight some of what to look out for in the night sky in May. One of the main attractions this month is Saturn, which reaches opposition on 10 May. It's at magnitude +0.1 with an angular size of about 18 arcsec and has its ring system showing well at 22° to our line of sight. Mars, although past opposition (which was on 8 April), is still a good object for viewing and photographing this month – at the start of May it's at magnitude –1.2 with an angular size of 14.5 arcsec.

- **BAA Sky Notes** for May (I hope – it's still indicating April as at 30 April)
  http://britastro.org/skynotes_render/5402

- **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 this Month (same remark as for the BAA site above):
  www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month
- **Society for Popular Astronomy's** What's Up for May 2014 (sigh … ditto)
  www.popastro.com/youngstargazers/skyguide

Mars – battling our atmosphere

Keith Johnson

Recently, work commitments have not allowed me to take advantage of Mars being at or near opposition this season. However, on Saturday 26 April I managed to obtain a few AVI captures under average seeing conditions.

Mars was a boiling mass of yuck early on in the imaging session, but as the red planet steadily reached the meridian the seeing started to settle down slightly.

Incidentally, while I was waiting for Mars to gain height I slewed the telescope to Saturn, much lower down in the east. But as the gas giant *was* so low down, it too was a boiling mass, with seeing so bad that it was sometimes difficult to make out the shape.

Slewing back to the red planet, I was pleasantly surprised to see that the seeing had settled down enough for me to capture a few AVIs, and I recorded six in total. But almost as soon as I'd started my imaging run, it had to come to an end, as the seeing had deteriorated so much.

One thing I've learned over years of planetary imaging is that no matter how good your collimation, or your knowledge of the software for capturing or processing images, it's the seeing that will determine whether you achieve a good result. I've spent night after night, hour upon hour capturing AVIs when the seeing is poor, and then trying to glean some detail out of the AVIs – but always to no avail.

It's as if the planetary imager is having a constant battle with the atmospheric conditions. More often than not we lose out, but every now and again the conditions are better than most of the other times.

Many are put off planetary imaging simply because on average we get only a handful of good seeing opportunities per year – it just doesn't seem to be worth the expense, time and effort. But when you do get that night of good seeing, then all of a sudden it all seems very worthwhile!

Equipment:

Celestron C9.25" …. 4× ImageMate …. EQ6 Pro mount …. Baader Crayford focuser … Sky-Watcher auto focuser … ZWO ASI 120MC camera … HitecAstro 4-port dew control unit … HitecAstro USB II focus control unit

Processing and display:

A single 4-minute AVI captured at 45 frames per second.

Telescope control: SkyMap Pro 9

Image acquisition: FireCapture v2.3

Focus control: HitecAstro DC Focus v1.2

Aligning and stacking: AutoStakkert! II

RGB alignment, wavelets, histogram stretch, image size increase: Registax v6

GENERAL ARTICLES

Astronomy in the shadow of the gallows

Ray Worthy

In the year 1543, a brilliant mathematician from northern Poland called Nicolaus **Kopernik** put the cat among the pigeons and changed forever the world's understanding of cosmology. Let me take a space to set this statement into context.

Way back around 300 BC, **Eratosthenes** had seen the circular shape of the Earth's shadow on the Moon and had not only deduced that the Earth was spherical, but had accurately measured its size. The world in general, or more particularly our western world, had not chosen to follow this in its world cosmology. The path chosen was that of **Ptolemy**, born four hundred years later, who in turn followed in general terms the teaching of Aristotle.

The world system he described was adopted by medieval western Europe, which persisted with it right up until the 17th century. Those astronomers struggling to develop their new science on a basis of observation found that the world cosmology had been absorbed into a dogma that supported both the Church hierarchy and the reigning political systems of monarchy. If a follower of the 'New Astronomy' even hinted that the system had to be changed, he would find that the establishments of both Church and State would descend on him like a ton of bricks.

So, what was the schematic of world cosmology that held centre stage for all those medieval years? Several woodcuts have survived which, although they span several centuries, have the main theme in common.

Stretching across the base of the picture is the Earth. The Earth is solid and unmoving. Somewhere around the Earth are the other three elements, Air, Fire and Water. Above the Earth are the 'Orbs', crystalline spheres, one after the other. The Moon moves around one orb, the Sun in another. Then comes the orb of the planets. Above all of these is the orb of the stars, where everything is fixed and immutable.

Yet, everyone can see that the stars move around the sky in 24 hours, so something has to be devised to move them across the heavens. In many of the drawings, one can see angels blowing the stars around. Above the angels is a depiction of God.

In some of the later pictures, the scheme is extended below the Earth to show the Underworld, Purgatory and, lower still, Hell itself.

Unfortunately for any mathematician and astronomical observer wanting to work out a solid base of mathematical explanation, there was one great stumbling block, and that was the retrograde motion from time to time of the outer planets. Mars in particular shows periods in which it appears to stop and then go backwards before resuming its apparent forward motion. From Ptolemy onwards, mathematicians had to attempt to fit epicycles into the grand picture, but the idea never quite fitted the bill.

Because the human race was held to be the most important entity in the Universe, it must therefore be at the centre of the cosmos. Not only that, but the movements of the planets must have a bearing on the affairs of people.

The retrograde motion of the outer planets at conjunction was not the only difficulty the mathematicians faced. They noticed that Mercury and Venus never moved very far from the Sun.

Then, in 1543, on to the world's stage came Kopernik, or **Copernicus**[1] as he was known to the Latin-speaking fraternity. His mathematical ability was second to none and this gave him great confidence. He realised that if he put the Sun at the centre and moved the Earth to the third orbit from the Sun, the explanation for the retrograde motions became obvious. The Earth on its inner orbit was travelling at a greater angular velocity than Mars was and so, viewed from the Earth, Mars appeared to be going backwards.

A statue of Copernicus -- see footnote!

The epicycles problem was reduced and made the preparation of the almanacs so much easier. However, he was no fool. He wrote his world-shaking book *De revolutionibus orbium coelestium* but held off its publication until he knew he was reaching the end of his life. Strangely enough, it was not until seventy years later that the book was proscribed by the Roman Catholic Church. One of the reasons for this delay is put down to the efforts of his publisher and some astronomers from the University of Wittenberg (more about this later) who placated the Church authorities by hinting that the changes were merely a method of making the almanac calculations easier.

Then came the amazing event of 1572. Suddenly, without warning, a bright new star appeared in the constellation of Cassiopeia. It showed itself very brightly in November, remained visible for 18 months, gradually fading and changing colour, and then finally disappeared from view.

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[1] *[I apologise to Ray for the intrusion into his article of this peculiar photo of a statue of Copernicus. My wife and I recently spent a few days in Kraków in Poland and visited the amazing Wieliczka salt mine nearby. Copernicus was much in my mind, as he was educated at the university in Kraków and an understandable fuss is made of him there. I was delighted, then, to discover this roughly life-size statue of him, made entirely out of rock salt, several hundred feet down in the mine, and have been itching to give it a home in* Transit *ever since. The light was weird and I make no claims for artistry or even competence in the quality of the picture! – Ed.]*

Cassiopeia appears circumpolar from northern Europe, which means that it never disappears below the horizon. The new star was a great sensation to all thinking people in the northern hemisphere. Historians digging into the archives recalled that the ancient astronomer Hipparchus had written that a new star had shown itself in the sky in 134 BC. In the interim, most astronomers had paid little attention to the tale, commenting that Hipparchus must have mistaken a comet for the star. They failed to explain how an astronomer whose work was so accurate that he discovered the precession of the equinoxes could mistake a nova with its fixed position for a comet that changed its position every night.

This brilliant new star, which could not be hidden from anyone, shook the established world to its core. The orb that held the fixed stars was way up near Heaven and that was believed to be immaculate, unchanging, was shown not to be so. It was acknowledged at the time that a Danish nobleman astronomer owned the best and most accurate instruments in the world. His name was **Tycho Brahe**, and he it was who assembled a report of all the best observations of the new star. It even became known as 'Tycho's Star'.

In preparation for my previous article ('Let's finish this game of bowls', *Transit*, April 2014) my search led me from the Danish Embassy in London, through the Danish Cultural Office in Edinburgh, to a museum in Sweden and finally to the Royal Library in Copenhagen. The result was that I turned up the names of not just the two Digges, but eleven British astronomers and mathematicians whose very existence had gone unnoticed by me – that is, all except for John Dee. Here are their names in order of when they were born.

Robert Recorde 1512
Leonard Digges 1518
John Field 1520
John Dee 1528
Thomas Digges 1546
Thomas Harriot 1560
Henry Percy 1564

Robert Recorde: No lightweight, he. A brilliant polymath from Tenby, he obtained a maths degree from Oxford, then an MD in Medicine from Cambridge.

He then lectured in Maths in Oxford and in the same period attended Queen Mary in her hours of need. He became Comptroller of the Royal Mint. In his spare time he published books about maths and astronomy and (making a great mistake) extolled the new astronomy of Copernicus. You would think that, with his background, he would be part of the Establishment, but no. He was taken to court for traducing someone's reputation and thrown into King's Bench, a debtor's prison, where he died.

Leonard Digges: If you have read the previous article, you will know something about Leonard Digges from Kent: another brilliant mathematician. He became a noted surveyor and is credited with inventing the theodolite. I am convinced he made a telescope some 30 years before its supposed and published invention. He was imprisoned in the Tower of London but this time for political reasons. He was freed, to live only one more year in freedom.

In 1557, **John Field**, another Oxford mathematician, from Ardsley in West Yorkshire but working in London, published *Ephemeris Anni*. With a foreword by John Dee, it showed the future positions of the planets for navigational purposes. It created a sensation because it was the first book in English that was based on the Copernican New Astronomy. Field retired back to Yorkshire and had a quiet life.

John Dee, possibly the most colourful character of them all, was invited to become the Professor of

Algebra in the University of Paris at the age of 24, and went on to become an advisor to Queen Elizabeth. In his later years, he was consumed with occult ideas and even walked the streets of London dressed as a wizard. There has even been a pop opera written about him by Damon Albarn.

Thomas Digges was the son of Leonard, who whilst in prison arranged for his friend John Dee to take over the education of Thomas. Dee must have done a good job because Thomas became one of the leading mathematicians in the country. He it was who tried to find a parallax for Tycho's Star and opened up a lengthy correspondence with the Dane. It was his book about his father's surveying that convinced me that Leonard had made a telescope.

Henry Percy, the ninth Earl of Northumberland and one of the richest men in the land, was so taken up with astronomy, astrology and alchemy that he was nicknamed the 'Wizard Earl'. The family owned Syon House with its large estate next to the Thames opposite Kew. Here, he gave support to most of the astronomers on my list.

However, his wealth did nothing to help him when he fell foul of the new king, King James I. A cousin of Henry was implicated in the Gunpowder Plot and Henry was hauled in and imprisoned in the Tower of London. He was there for 17 years. In that time he organised regular visits from his followers, most of the men on this list.

Thomas Harriot had escaped my attention, much to my shame even though I taught astronomy for all those years. Another Oxford scholar, he was taken up by Sir Walter Raleigh and taught Raleigh's captains the latest navigation techniques. He went at least twice to help start a colony in America. When James ascended the throne, Harriot published a horoscope for the new king and was put in prison for his pains. A political rival accused him of casting a spell or contriving to alter the King's destiny. It was Harriot who turned a telescope to the Moon and showed details of its mountains. There is evidence that he knew of sunspots as well.

Other astronomers or mathematicians whose names I uncovered included **Nathaniel Tarporly**, **Nicholas Hill**, **Robert Hues** and **Walter Warner**. They all regularly visited the 'Wizard' Earl in the Tower.

A reader living in the 21st century should bear in mind the fact that, some 70 years later than all this, the greatest scientist who ever lived, Sir Isaac Newton, spent much more of his time on occult matters than he did on his earth-shaking discoveries. Astrological predictions were in great demand and the casting of horoscopes was the province of astronomers. For this work, they needed an accurate forecast of the positions of the planets against the background of the fixed stars. Navigators required the same data for their position finding and time keeping.

Most of the astronomers on my list met up regularly, thanks to the Wizard Earl, and shared their knowledge. They all supported the New Astronomy, which claimed that the Sun was one of many stars in the sky and was at the centre of the Solar System. They believed the stars were not just to be found on a thin skin of a crystalline sphere, but went on and on into infinity. I am convinced that this last idea is evidence that every one of them had been looking through the Digges' telescope.

They kept a low profile, but disseminated their ideas through their navigational publications. It has to be remembered that in Italy, not long into the next century, their beliefs cost the life of one astronomer, Giordano Bruno, who was burned at the stake in a marketplace, and threatened the life of the more celebrated Galileo.

The most astonishing revelation emanating from this investigation is that there was a social link between Thomas Digges and **William Shakespeare**. It has been suggested that the Bard lived near Thomas Digges and that they talked often. Shakespeare was imbued with the whole ethos of the New Astronomy and embarked on a dangerous enterprise. It is suggested that the whole of *Hamlet* is an allegory for the New Astronomy.

Every point is hidden from the casual playgoer, but a knowledgeable person can find the astronomically significant points.

- Tycho Brahe lived on an island in the waters between Denmark and Sweden. The King of Denmark's castle, Elsinore, is in the same stretch of water.
- The first place of learning to take up the new Copernican ideas was Wittenberg University. When Hamlet's father was murdered, Hamlet himself was a student at Wittenberg.
- Two of the students with him were called Rosencrantz and Guildenstern. Two ancestors of Tycho had these names and appeared on his coat of arms.
- In the play itself, Hamlet's uncle, the new king, stands for the old Earth-centred universe and was named Claudius after Claudius Ptolemy, whereas Hamlet stands for the New Astronomy.
- There are various places in the play where astronomical references can be picked up when you deliberately look for them. At one point it is hinted that, at close approach, Venus shows a crescent. Another speech comments that the stars are not on a thin skin of a crystalline sphere, but go on into infinity. These points could only be known by someone who had looked through a telescope and, personally, I am now convinced that Thomas Digges had such an instrument and had given private shows to his friends.

Just why William Shakespeare undertook such a dangerous course I have no idea. However, since I began working on this article, there has appeared on BBC TV a programme entitled *The Very British Renaissance* in which it suggested that, at this time, artists and architects were leaving coded messages all over the place.

To read more detail on this theme, go to Wikipedia and track down Professor Peter Usher of Penn State University.[2] He positively bubbles over with promoting the idea. Professor Usher makes a convincing case. I have tried out his ideas on four teachers of upper-school English; it was the names Rosencrantz and Guildenstern that tipped the balance and persuaded them to accept the idea.

Finding G

Ray Brown

In a recent series we looked at some of the effects of gravity, the dominant force of interaction between celestial bodies. We recall that it all began in the early 1680s with Isaac Newton's brilliant realisation (following correspondence with Robert Hooke) that the force F of gravitational attraction between any pair of masses m_1 and m_2 whose centres of mass are separated by a distance r is

$$F = Gm_1m_2/r^2$$

Here G is the Universal Gravitational Constant which, so far as we know, has had the same value throughout the entire universe and throughout history. But what is the value of G and how was it measured?

Newton decided that any experimental determination of the value of G was impossible at the time, as he thought the gravitational force to be immeasurably small on a laboratory scale. Indeed, he even rejected the idea of observing the deflection of a pendulum by a nearby large mountain. Newton

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[2] [*Or go to* 'Shakespeare's support for the new astronomy' *at* www.shakespearedigges.org/ox2.htm. – *Ed.]*

believed gravitational effects to be detectable only between masses as great as those of celestial bodies.

Four centuries ago, absolute values for the masses of stars and planets, even of Earth itself, were unknown. However, many masses were known as *relative ratios* to the mass of Earth, so there was much interest in measuring Earth's mean density and thus determining its mass. Some at the time even thought our planet might be hollow!

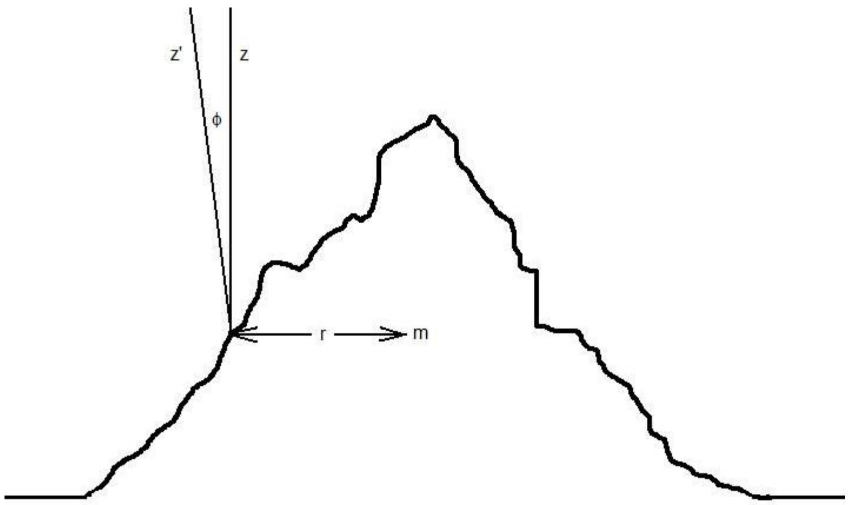
A quantitative comparison with a huge object of known mass was attempted first in 1738 by Pierre Bouguer and Charles Marie de La Condamine, who were already in equatorial South America for other purposes. Chimborazo in the Ecuadorian Andes is, in terms of distance from the centre of Earth, the highest mountain on the planet (Mt Everest losing out because it is at higher latitude on our oblate planet). At altitudes of some 15,000 feet the French astronomers reported the deflection of a pendulum caused by the mountain of some 8 arc seconds. They used an astronomical measurement reference for the zenith but could only estimate the mass of the mountain from crude surveying and density data. The only firm conclusion they were able to make was that the Earth is *not* hollow.

The Brits decided to have a go on home turf 35 years later. A Munro, Schiehallion, was preferred to Whernside and various Lakeland mountains by having a more suitable size and wedge-shape and being thought far enough from neighbouring hills. There's a detailed account in Wikipedia at http://en.wikipedia.org/wiki/Schiehallion experiment, which states:

> *Astronomical instruments included a 12-inch (30 cm) brass quadrant from Cook's 1769 transit of Venus expedition, a 10-foot (3.0 m) zenith sector, and a regulator (precision pendulum clock) for timing the astronomical observations. They also acquired a theodolite and Gunter's chain for surveying the mountain, and a pair of barometers for measuring altitude. Generous funding for the experiment was available due to underspend on the transit of Venus expedition, which had been turned over to the Society by the King.*

A further interesting account can be found at www.sillittopages.co.uk/schie/schie90.html .

The Astronomer Royal, Neville Maskelyne, assembled an expert team and built two observatories, one on each side of the East–West ridge, where he rigorously and meticulously performed a whole series of measurements, in effect to find the deflection angle Φ between and the true zenith *z* and the apparent zenith *z'* indicated by a plumb line.



The vertical force downwards on the plumb bob as a result of Earth's gravity is

$$F = Gm_BM/R^2$$

where m_B is the mass of the plumb bob, M the mass of Earth and R the radius of Earth. The horizontal force sideways on the bob caused by the gravitational pull of Schiehallion is

$$f = Gm_Bm/r^2$$

where m is the mass of the mountain and r is the distance to its centre of mass.

By resolution of forces, $f \div F = \tan \Phi = mR^2/Mr^2$.

So the mass of Earth $M = mR^2/r^2 \tan \Phi$.

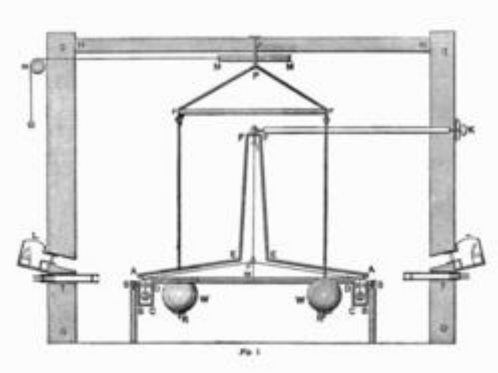
Maskelyne needed to measure Φ and to estimate m and r. R was already known.

In practice, the measurements extended over a period of four months, being made first from the south of Schiehallion and later from the north. The telescope could move in a north–south plane and recordings were taken as a chosen reference set of stars moved across the meridian. The difference in latitude between the two observatories meant that in the absence of any gravitational pull from the mountain there should have been a difference in values of the meridian distance of 42.9", but the average value found was 54.6". The discrepancy of 11.6" was attributed to the expected attractions of the bob by the mountain; so Φ = 5.8".

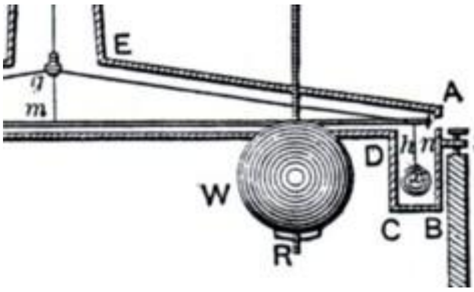
The lack of GPS or aerial photography in those days meant that determination of the difference in latitude between the two stations was difficult. Uncertainties about the value of r were reduced by using the two observatories instead of one, but the greatest source of error lay in the value for m. It was almost a case of 'think of a number' for the density of the rock within Schiehallion (2.5 kg dm^{-3} was chosen). Nevertheless the calculated results for the mass of Earth, for its density as 4.5 kg dm^{-3} and for the gravitational constant were all within 20% of today's accepted values. Remarkably, this first crude value for G was more accurate than had been the first proposed value for the speed of light *in vacuo* calculated from Roemer's data, referred to in the March 2014 issue of *Transit* (and see www.speed-light.info/measurement.htm).

Over the centuries there have been several revisits to Schiehallion, especially to reassess the geology to provide a more accurate value for the mountain's density. The most recent study in 2007, while still accepting Maskelyne's astronomical data, led to a value of 5.48 kg dm^{-3} for Earth's mean density, which compares with the accepted value of 5.515 kg dm^{-3}. This appears dramatically to vindicate the quality of Maskelyne's work, but all determinations of G involving mountains subsequent to 1774 benefited from hindsight; in 1798 Cavendish had made the first accurate determination of G, and he did it in a laboratory. The 'mountain' method is destined to be inaccurate because of the irregular morphology, the uncertain density and the inevitable influences from neighbouring hills.

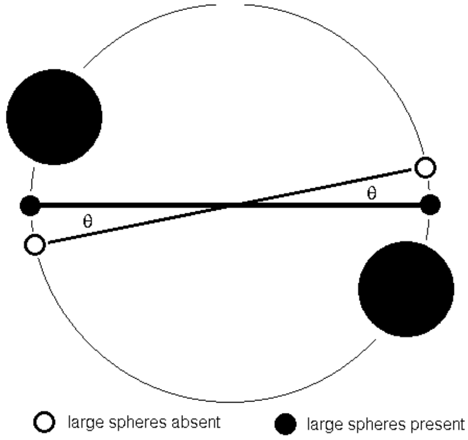
Cavendish used a torsion balance that could measure miniscule forces by their ability to twist a fine wire. A lead sphere (diameter 51 mm, mass m = 0.73 kg) was attached to each end of a uniform wooden rod (length d = 1.8 metres) which was suspended at its mid-point by a thin wire. A pair of much larger lead spheres (each diameter 300 mm, mass M = 158 kg) was held by a separate suspension system, each sphere being brought to a distance r (= 230 mm) from its respective small sphere. The centres of all spheres lay in the same horizontal plane and the whole arrangement had two-fold rotational symmetry about a vertical axis. The whole apparatus was isolated in a sealed housing to avoid the effects of draughts.



Vertical section drawing of Cavendish's torsion balance instrument including the building in which it was housed. The large balls were hung from a frame so they could be rotated into position next to the small balls by a pulley from outside. Figure 1 of Cavendish's paper.



*Detail showing torsion balance arm (*m*), large ball (*W*), small ball (*x*), and isolating box (*ABCDE*).*



Attraction of the small spheres by the large spheres caused the wooden rod to swing through an angle ϑ until the gravitational forces were counterbalanced by the torsion in the wire. If F was the attractive force between each small sphere-large sphere pair, then

$$F = GmM/r^2$$

So the turning couple $Fd = GdmM/r^2 = k\vartheta$.

The torsional coefficient k of the wire was obtained from the natural oscillation period t (about 20 minutes) of the balance rod with its small lead spheres when it was allowed freely to twist to and fro:

$$t = 2\pi(I/k)^{1/2}$$

where I is the moment of inertia of the rod with small spheres (easily calculated, but for details see http://en.wikipedia.org/wiki/Cavendish_experiment .)

Cavendish obtained the result of 5.448 kg dm^{-3} for the mean density of Earth, leading to a value for G of 6.754 × 10^{-11} m^3 kg^{-1} s^{-2}.

In 2007 a measurement by atomic interferometry gave the value for G as

G = 6.693 ± 0.027 × 10^{-11} m^3 kg^{-1} s^{-2}.

Cavendish's experiment has been repeated, notably by C.V. Boys in 1895, who used a much smaller apparatus that employed small gold spheres (5 mm diameter), small fixed lead spheres (115 mm diameter) and, instead of the torsion wire, a quartz fibre; but the results were not a significant improvement over the 1798 original.

Lunar craters – who are they named after?

Alan Kennedy

Craters on the Moon are named after famous people, from Ancient Greeks to present-day Nobel Prize winners. In this series I'll take a look at who they were or are, and what the lunar features named after them are like.

The first two craters I've chosen to start with are close together on the Moon: Eratosthenes and Wallace. The scholars after whom these craters are named are separated by over 2000 years of history, yet each has had an impact on our lives today.

Eratosthenes the crater

Eratosthenes is almost central on the face of the Moon. It's on the bottom south-east corner of **Mare Imbrium**, just east of the large rayed crater **Copernicus**, and is best observed one day after first quarter or one day after last quarter. This almost circular crater lies at the southern extremity of **Montes Apenninus**; it has very high terraced walls, a multiple central peak and a flat crater floor with wrinkle ridges, hills and rilles.

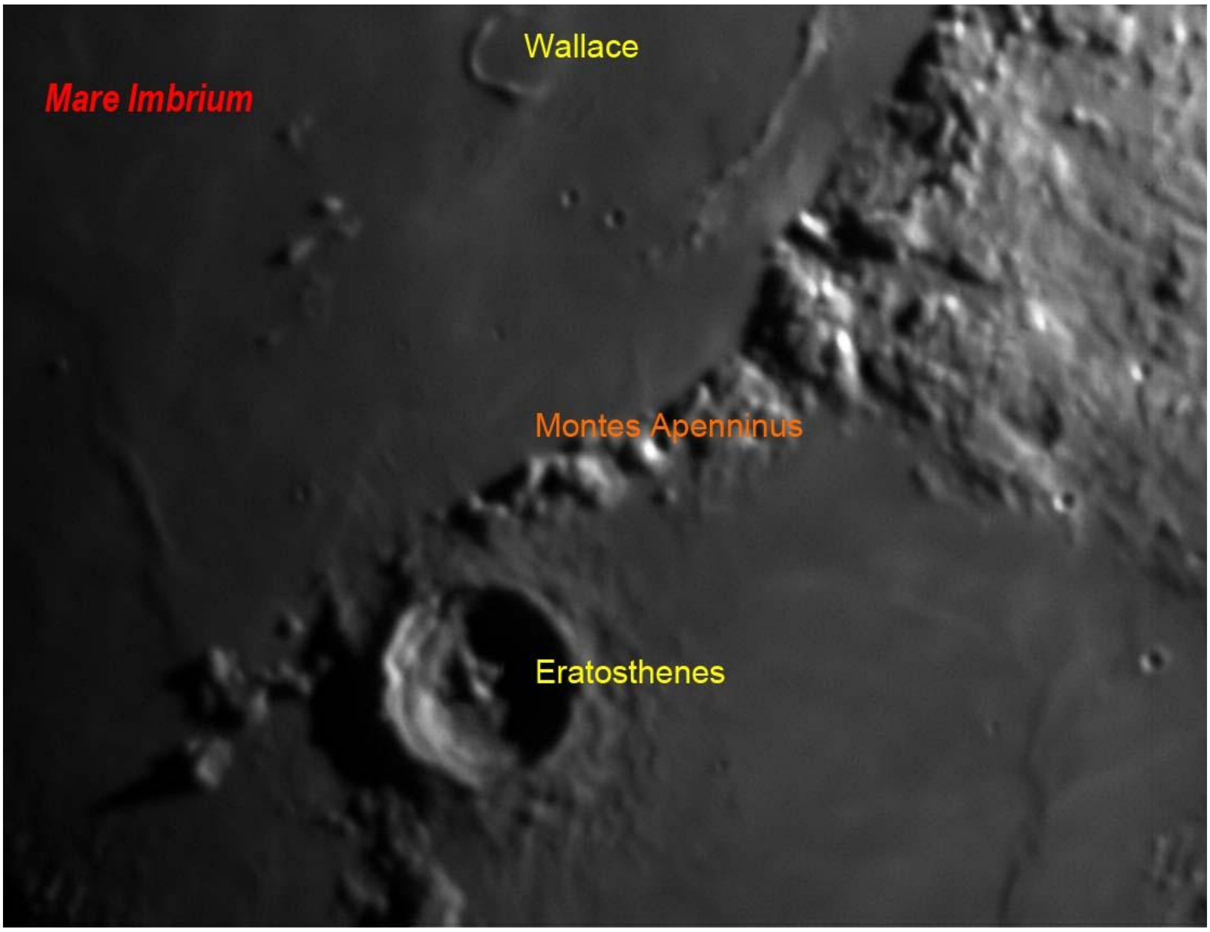


Image taken with an 8" SCT and ZWO ASI120MC camera (by Alan Kennedy)

Wallace the crater

Wallace is the remains of a lunar crater that has been flooded by lava. It also lies in the south-eastern part of Mare Imbrium, to the north-east of Eratosthenes. The crater rim forms a somewhat polygonal outline, and is broken in the south-east. The floor is flat and devoid of significant features, but is overlain by ray material from Copernicus to the south-west. The rim rises to an altitude of 0.4 km above the lunar mare.

Eratosthenes the person (*276 –194 BC*)

Eratosthenes was a Greek mathematician, geographer, librarian, poet, inventor, philosopher, astronomer and music theorist. He was born in Cyrene in Greece and died in Alexandria in Egypt.

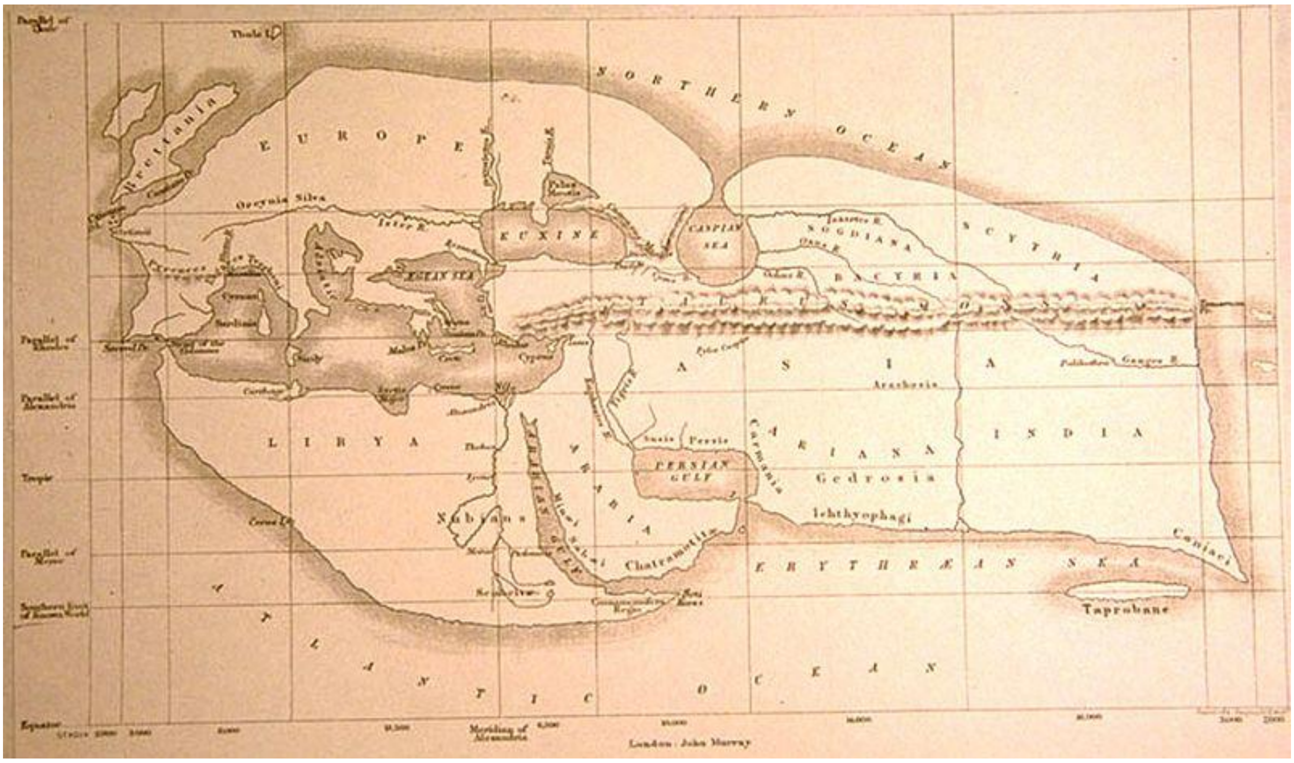
He produced many works in philosophy and grammar and tutored the son of the pharaoh Ptolemy III Euergetes. He became the chief librarian at the library of Alexandria and invented the discipline of geography, including much of the terminology used today.

But he is best known for being the first person to calculate the circumference of the Earth, which he did using a measuring system using stadia (the *stadion*, Latinized as *stadium* and anglicized as *stade*, is an Ancient Greek unit of length. Modern scholarship has concluded that a stadion was somewhere between 174 and 179 metres). His result was remarkably accurate.

He was also the first to calculate the tilt of the Earth's axis, again with remarkable accuracy.

Further, he may have accurately calculated the distance to the Sun (now called the **astronomical unit**) at 804,000,000 stadia and invented the leap day!

He created the first map of the world that incorporated parallels and meridians, based on the available information of the then known world, from the British Isles to Ceylon, and from the Caspian Sea to Ethiopia.



9th-century reconstruction of Eratosthenes' map of the known world, 194 BC

He also compiled a star catalogue containing 675 stars, which has not survived.

In mathematics he introduced Eratosthenes' sieve, an efficient method of identifying prime numbers. Eratosthenes made several other important contributions to mathematics and science, and was a friend of Archimedes.

Around 255 BC, he invented the armillary sphere which is a model of objects in the sky (in the celestial sphere), consisting of a spherical framework of rings, centred on Earth, that represent lines of celestial longitude and latitude and other astronomically important features such as the ecliptic. As such, it differs from a celestial globe, which is a smooth sphere whose principal purpose is to map the constellations. The armillary sphere was introduced to Western Europe via Al-Andalus in the late 10th century with the efforts of Gerbert d'Aurillac, the later Pope Sylvester II (r. 999–1003). Pope Sylvester II applied the use of sighting tubes with his armillary sphere in order to fix the position of the pole star and record measurements for the tropics and equator.

Further advances in the instrument were made by Tycho Brahe (1546–1601), whose elaborate armillary spheres passing into astrolabes are figured in his *Astronomiae Instauratae Mechanica.*

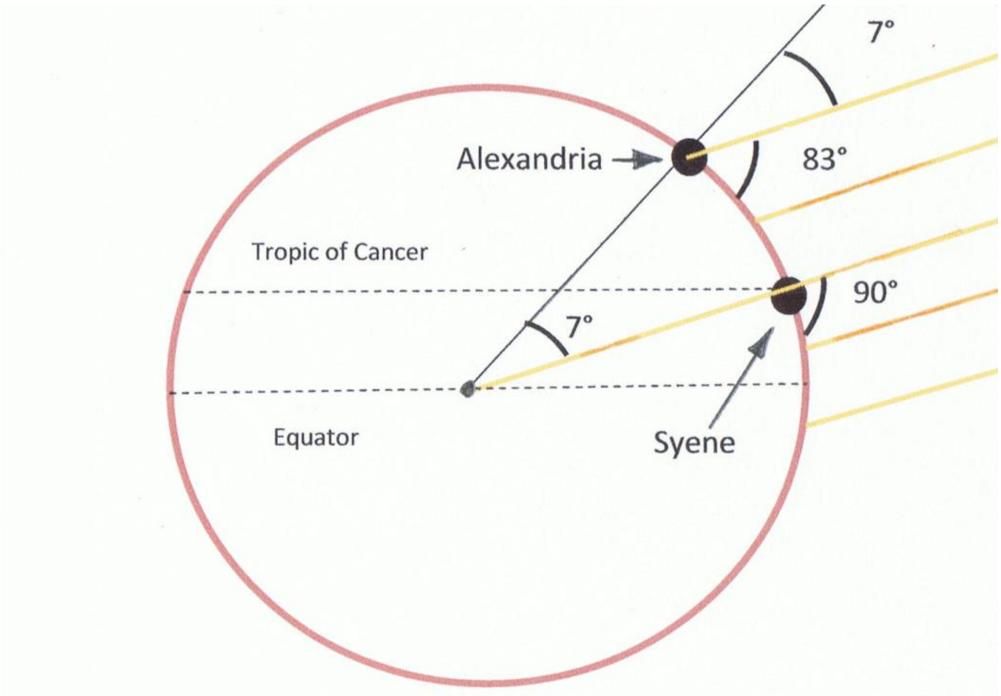
A representation of an armillary sphere is present in the modern flag of Portugal and has been a national symbol since the reign of Manuel I.

As head of the Alexandria library, Eratosthenes expanded the library's holdings: in Alexandria all books had to be surrendered for duplication. It was said that these were copied so accurately that it was impossible to tell if the library had returned the copy or the original. Eratosthenes created a whole section devoted to the examination of Homer, and acquired original works of the great tragic dramas of Aeschylus, Sophocles and Euripides.

As he aged he contracted ophthalmia, becoming blind around 195 BC. Losing the ability to read and to observe nature plagued and depressed him, leading him to voluntarily starve himself to death. He died in 194 BC at the age of 82 in his beloved Alexandria.

Calculating the circumference of the Earth

What mattered for Eratosthenes' experiment is the fact that at the summer solstice, local noon, the Sun's rays are just overhead (at a right angle to the ground) on the Tropic of Cancer.



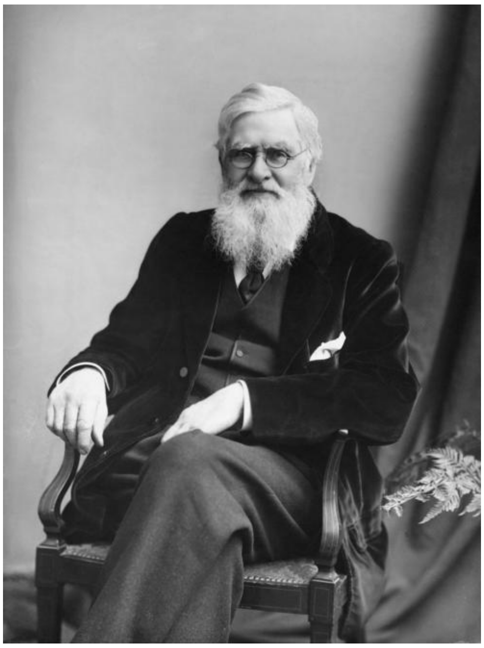
Eratosthenes' experiment

Eratosthenes knew that on the summer solstice at local noon on the Tropic of Cancer, the Sun would appear at the zenith, directly overhead (sun elevation of 90°), although Syene was in fact slightly north of the tropic. He also knew, from using a vertical stick and measuring the cast shadow, that in his hometown of Alexandria the angle of elevation of the Sun at the same time would be 83°, or 7° south of the zenith. Assuming that Alexandria was due north of Syene (Alexandria is in fact on a more westerly longitude) he concluded, using the geometry of parallel lines, that the distance from

Alexandria to Syene must be 7/360 of the total circumference of the Earth. The distance between the cities was known from caravan travels to be about 5000 stadia. He established a final value of 700 stadia per degree, which implies a circumference of 252,000 stadia. The exact size of the stadion he used is no longer known (the common stadion was about 185 m), but it is generally believed that Eratosthenes' value corresponds to between 39,690 km and 46,620 km. The circumference of the Earth around the poles is now measured at around 40,008 km. Eratosthenes' result is not bad at all.

Unfortunately, there are only fragments left of his works after the destruction of the Library of Alexandria.

Alfred Russel Wallace the person

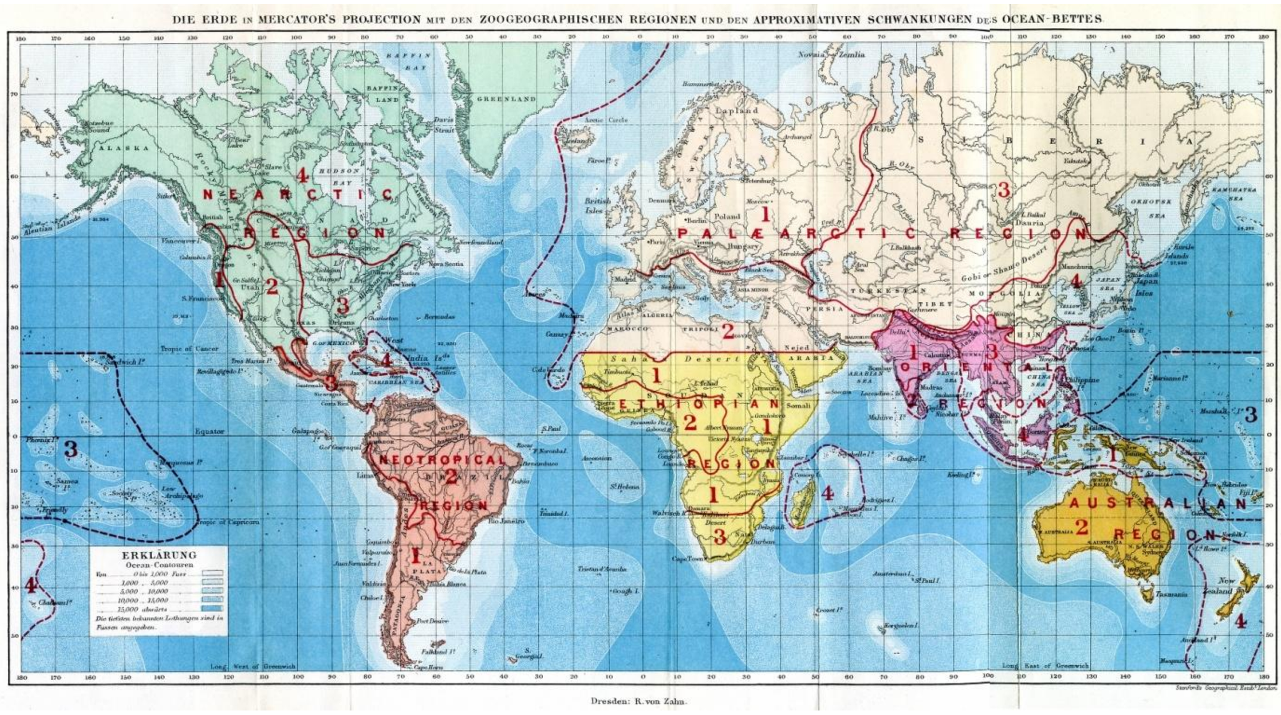


(*8 January 1823 – 7 November 1913*)

Alfred Wallace was born in the Welsh village of Llanbadoc, near Usk, Monmouthshire. He was the seventh of nine children of Thomas Vere Wallace and Mary Anne Greenell.

Alfred Russel Wallace was a British naturalist, explorer, geographer, anthropologist and biologist. He is best known for independently conceiving the theory of evolution through natural selection.

His paper on the subject was jointly published with some of Charles Darwin's writings in 1858. This prompted Darwin to publish his own ideas in *On the Origin of Species*. Wallace did extensive fieldwork, first in the Amazon River basin and then in the Malay Archipelago, where he identified the faunal divide now termed the ***Wallace Line***, which separates the Indonesian archipelago into two distinct parts: a western portion in which the animals are largely of Asian origin, and an eastern portion where the fauna reflect Australasia.



A map from *The Geographical Distribution of Animals*, showing Wallace's six bio-geographical regions

From the chapter on applying natural selection to humans in Wallace's 1889 book *Darwinism*

In 1864 Wallace published a paper, *The Origin of Human Races and the Antiquity of Man Deduced from the Theory of 'Natural Selection'*, applying the theory to humankind. Darwin had not yet publicly addressed the subject, although Thomas Huxley had, in *Evidence as to Man's Place in Nature*. He explained the apparent stability of the human stock by pointing to the vast gap in cranial capacities between humans and the great apes. Unlike some other Darwinists, including Darwin himself, he did not 'regard modern primitives as almost filling the gap between man and ape'. He saw the evolution of humans in two stages: achieving a bipedal posture freeing the hands to carry out the dictates of the brain, and the recognition of the human brain as a totally new factor in the history of life. Wallace was apparently the first evolutionist to recognize clearly that, with the emergence of that bodily specialization which constitutes the human brain, 'bodily specialization itself might be said to be outmoded'. For this paper he won Darwin's praise.

Wallace was a prolific author. In 2002, a historian of science published a quantitative analysis of Wallace's publications. He found that Wallace had published 22 full-length books and at least 747 shorter pieces, 508 of which were scientific papers (191 of them published in *Nature*). He further broke down the 747 short pieces by their primary subjects as follows. 29% were on biogeography and natural history, 27% were on evolutionary theory, 25% were social commentary, 12% were on anthropology, and 7% were on spiritualism and phrenology. An online bibliography of Wallace's writings has more than 750 entries.

In 1862 Wallace returned to England, where he moved in with his sister Fanny Sims and her husband Thomas. While recovering from his travels, Wallace organised his collections and gave numerous lectures about his adventures and discoveries to scientific societies such as the Zoological Society of London. Later that year, he visited Darwin at Down House, and became friendly with both Charles Lyell and Herbert Spencer. During the 1860s, Wallace wrote papers and gave lectures defending natural selection. He also corresponded with Darwin about a variety of topics, including sexual selection, warning colouration and the possible effect of natural selection on hybridisation and the divergence of species.

In 1866, Wallace married Annie Mitten. Wallace had been introduced to Mitten through the botanist Richard Spruce, who had befriended Wallace in Brazil and who was also a good friend of Annie Mitten's father, William Mitten, an expert on mosses. In 1872, Wallace built the Dell, a house of concrete, on land he leased in Grays in Essex, where he lived until 1876. The Wallace's had three children: Herbert (1867–74), Violet (1869–1945) and William (1871–1951).

Wallace's grave

On 7 November 1913, Wallace died at home in the country house he called Old Orchard, which he had built a decade earlier. His death was widely reported. *The New York Times* called him 'the last of the giants belonging to that wonderful group of intellectuals that included, among others, Darwin, Huxley, Spencer, Lyell, and Owen, whose daring investigations revolutionised and evolutionised the thought of the century'.

Shown here is Wallace's grave in Broadstone Cemetery, Broadstone, Dorset, which was restored by the A.R. Wallace Memorial Fund in 2000. It features a 7-foot tall fossil tree trunk from Portland mounted on a block of Purbeck limestone.

[I acknowledge Wikipedia as the original source of much of the text of this article.]

THE TRANSIT QUIZ *set by Neil Haggath*

Answers to April's quiz

Every answer starts with the letter O.

1. The common name of M97. **The Owl Nebula.**
2. A mechanical model representing the orbital motion of the planets. **Orrery.**
3. The biggest plain, or 'sea', on the Moon. Either the Latin or the English name will do! **Oceanus Procellarum or the Ocean of Storms.**
4. The phenomenon where one astronomical body passes in front of another in our line of sight, and obscures it from view. **Occultation.**
5. The highest mountain in the Solar System. **Olympus Mons, on Mars.**
6. The Solar System's distant realm of comets. **The Oort Cloud.**
7. The constellation that 'holds' the one that is split into two parts. **Ophiuchus, the Serpent Bearer. The constellation split into two parts is Serpens, the Serpent, consisting of Serpens Caput and Serpens Cauda (Head and Tail respectively).**
8. A meteor shower associated with Halley's Comet. **Orionids.**
9. His paradox asks, 'Why is it dark at night?'. **Heinrich Olbers (1758–1840). He popularised the 'paradox', though he wasn't the first to think of it.**
10. An observatory in the Czech Republic. **Ondrejov Observatory.**

May's quiz

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

1. The eighth brightest star.
2. The second asteroid to be discovered.
3. The first space probe to fly by Jupiter.
4. The constellation in which the First Point of Aries is situated.
5. His ratio forms the mathematical basis of the stellar magnitude scale.
6. The answer to Question 4 is a consequence of this phenomenon.
7. For a binary star, the closest point in the secondary's orbit to the primary.
8. Henrietta Leavitt's vitally important discovery.
9. Two astronomer brothers, both long associated with Harvard College Observatory.
10. An amateur astronomer who made a historic observation on Christmas Day 1758. (And give yourself a bonus point if you can spell his name!)

As a bonus, a single 'Q'. Well, you didn't think even I could think of a set of those, did you?

11. A meteor shower named after a non-existent constellation.