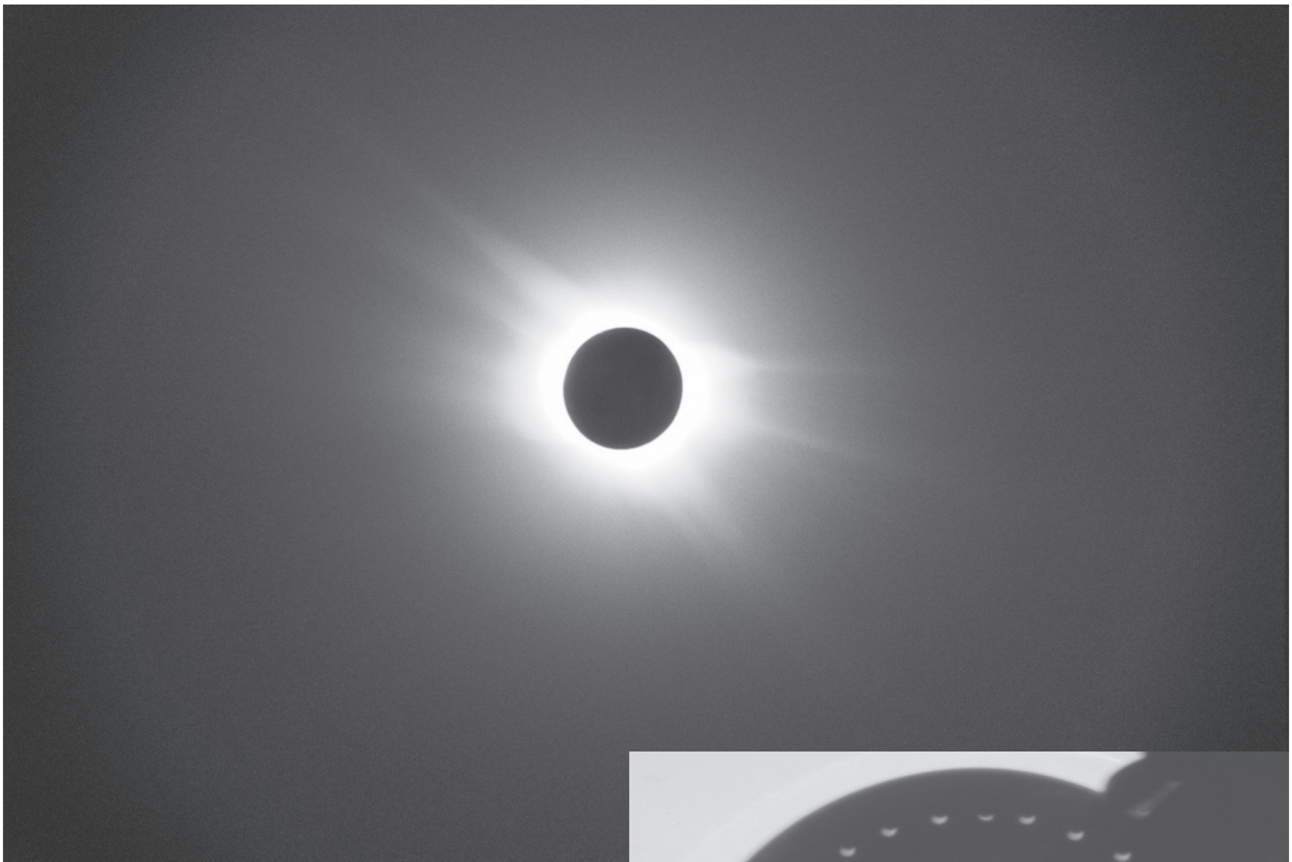
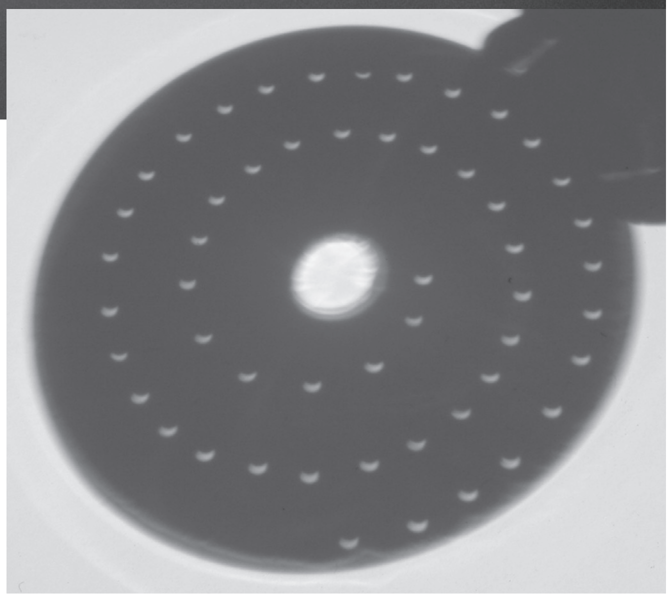
MIRA

Spring 2006
Number 75
Price 50p

The Journal of the
Coventry and Warwickshire Astronomical Society
http://members.fortunecity.com/cawas/





Total Solar Eclipse of 29th March 2006 taken by Geoffrey Johnstone from the Sahara Desert

The CD spiral photo was obtained by projecting images from a CD that I had drilled with a series of 1mm holes in a spiral pattern. The Total eclipse photo was with a 35 mm camera attached to a 60 mm telescope FL 360 mm. The exposure was 1 second on Kodak Portra 160 professional colour negative film. I think the total eclipse photos were reasonable as I have never done anything similar, and you don't get much opportunity to practice!

CONTENTS

A few weeks ago it was my birthday, the life-changing one where the government starts to give you a pay cheque and you don't seem to have to go to work everyday to get money. Its very strange and I've not got used to it yet. Anyway for my birthday my son decided to buy me a bit of the Moon!!!

So now I'm the proud owner of an acre of the Mare Imbrium and I have a LUNAR DEED to prove it. It is located in Area E-5, Quadrent Foxtrot. Lot number 141 / 0648. This is recorded at the Lunar Embassy located in Gardnerville, Nevada, USA. (Where else?) On the Deed it says that this property has been purchased from "The Head Cheese" and filed with the United Nations. (Who thinks up all this stuff?) I also have / own all the mineral rights on the property, wow!

This area is a very nice one, classy with nice neighbours and with good views of Earth nearly overhead as the property lies at 25°N 31°W not far from a small wrinkle ridge crossing the Mare at 45°. 50 km to the south east lies the crater Euler (28 km dia) while 500 km south lies the magnificent famous crater Copernicus (93 km). This will make a great day out to see the terraced walls and central mountains which stand 1200 m above the floor which lies nearly 4km below the mean lunar surface. Map 19 in Rükl's *Atlas of the Moon* shows the area, it is a smooth area, so a landing is easy and when I've got the ranch ready all members of the C&WAS will be welcome. (Please bring your own oxygen and water as its a long way to go to collect it from the North Polar Refining Facility in Peary crater. And the prices they charge. . .).

I've been looking at the Clementine Moon orbiter data of the area, one of the major scientific goals of the mission was to map the Moon in 11 different wavelengths in the visible and near-infrared parts of the spectrum. The filter colours of the Clementine cameras were carefully chosen to differentiate types of lunar surface material. By looking at the global colour, each Clementine image made by the UV/VIS camera was reduced to its average value, producing a picture of the Moon at low resolution (about 50 kilometres per pixel). I can see that the colour pictures shows that very high titanium lavas (in deep blue and cyan colours) appear to be largely confined to the Oceanus Procellarum, Mare Imbrium, and Mare Tranquillitatis areas (all near side mara). These views of the Moon in three colours, only hint at the scientific richness contained within the Clementine global data, which will be investigated for years to come. Of cause I expect that the titanium mine will be environmentally friendly and not spoil the view and it certainly will not cause any of my neighbours to complain about the noise and smells.

Looking on the web site of the Moon Estates Corporation I see that not only are they flogging pieces of the Moon but also Mars and Venus! At least I can keep an eye on my property most of the time from about the 12th day after new moon for the next fortnight. But if it's on Mars or Venus you have no hope of even finding the planet for months on end, let alone seeing if all's well. And even when Mars is near opposition you still need Hubble to spot the area unless you can spy it with one of the orbiters. As for buying a place on Venus. . . forget it.

All this is fun I know, but safer than just "Buying a Star" which lies in a far southern constellation and is only 18 mag and far from the fashionable constellations of the zodiac. Also how do we know if the star has already got habitable planets and so is already "owned"? And what if it has already been sold by some other aliens who will take us to the Galactic Government Court of Supreme Justice for breach of ownership?

It's a great talking point at dinner parties to say you have a lunar ranch and when you mention what you building on your acre of lunar mare and the cost of transport and how you just can't get the qualified workers now-a-days and the price of everything. . .

Now one more thing, what name shall I call my ranch??

Ivor Clarke

These issues of MIRA are now produced on an Apple G5 iMac using a new (to me) DTP program. So if it looks different from the older MIRA's I did on my old Acorn RISC-PC that's why. Now I can't use floppy discs, so please e-mail me with your stories and pictures or give them to me on a CD or DVD. The iMac can read all PC discs and Word files so I can reformat them for MIRA.

The Neptune Conspiracy

By Mike Frost

During my course on *"Great Astronomers of History"* I did a lot of research on the discovery of the planet Neptune. There is a popular version of the story, involving a race between British and French astronomers, that is well known and often repeated (for example in the books by Littmann and Standage listed in my bibliography). To my surprise, however, I found that recent discoveries have given the story a completely different complexion. Leading astronomers of the nineteenth century now stand accused of retrospectively making the British case for the discovery of Neptune much stronger than it actually was.

The background to the story is complicated. Let me begin with the discovery of Uranus by William Herschel in 1781. Herschel had built himself the best telescope in the world at the time, and used it for a thorough mapping of the sky. On March 13^{th}, 1781, he spotted an object, right at the limits of naked eye visibility, which moved slowly through the stars from night to night.

Herschel initially thought that he had discovered a comet rather than a planet. It wasn't until Anders Lexell computed the orbit of Herschel's object that anyone realised that the object was further away from the Sun than any other object previously discovered in the Solar System, and therefore had to be much larger than any known comet to give as bright an image as Herschel observed. The orbit of Uranus was also nearly circular, unlike most comets, which have strongly elliptical orbits that approach the Sun closely and then recede.

The discovery of a new planet made Herschel very famous. Nobody had expected the Solar system to contain a previously undiscovered planet. After the triumphs of Galileo, Kepler and Newton, it was further proof that astronomy had moved on from the fixed system of the ancient world.

As a result of Herschel's spectacular discovery, many people conjectured that there might be further planets beyond the orbit of Uranus. But where should astronomers start to look? One starting point was suggested by a curious piece of numerology called Bode's Law, which had been lent credibility by the discovery of Uranus.

In 1772, Johann Bode publicized a curious numerical relationship first pointed out by Johann Daniel Titius in 1766. The distances from the Sun to each of the planets could be summarized as follows;

Mean Distance from the Sun in astronomical units = $(4 + 3*2^{n-1}) / 10$

(The Astronomical Unit or AU is the distance from the Earth to the Sun, 92,955,807 miles, 149,597,870 km).

Planet	***n***	***Predicted Distance (AU)***	***Actual Distance (AU)***
Mercury	0	0.55	0.39
Venus	1	0.7	0.72
Earth	2	1.0	1.00 (by definition)
Mars	3	1.6	1.52
??	4	2.8	
Jupiter	5	5.2	5.20
Saturn	6	10.0	9.52
Uranus	7	19.6	19.18
??	8	38.8	

You can see that Uranus's distance from the Sun is not far from the prediction given by Bode's Law. (You can also see that Mercury doesn't really fit the Law, a fact that most accounts gloss over - the best value of n for Mercury is actually n = -∞

You might notice that there is a gap in the series for n=4. Johann Schroter decided to look for a planet, which would lie between the orbits of Mars and Jupiter and so fill the gap. He called a meeting of astronomers in Lillienthal, Germany, in September 1800. The "Lilienthal Detectives" or "Celestial Police" divided up the ecliptic between them, but within a few months Giuseppi Piazzi, in Sicily, beat them in their search by finding a new object, Ceres, at roughly the distance from the Sun predicted by Bode's Law. Ceres, the first of the minor planets or asteroids, was rapidly followed by Pallas, Juno and Vesta. So, the search for a planet between Mars and Jupiter, suggested by the gap in Bode's Law, had led to the discovery, not of one new major planet, but four new minor planets. Extrapolating the Law for n=8 suggested that if, there was another planet to be found, it could be at roughly twice the distance from the Sun of Uranus.

Moreover, there was other evidence that the discovery of Uranus did not complete the inventory of the outer Solar System. Try as they might, mathematicians could not fit an orbit to the existing observations of Uranus that would accurately predict subsequent motion — the planet always ended up straying from its predicted path. In an attempt to resolve the discrepancies, astronomers searched back though observing records to see if anyone had recorded Uranus without realizing they had seen anything special (in much the same way as Kowal and Drake discovered that Galileo had managed to observe Neptune, as I recounted in MIRA 72, Autumn 2005). It transpired that several astronomers, starting with John Flamsteed in 1690, had recorded stars that were there no longer there, but were explainable as inadvertent observations of Uranus.

However, these pre-discovery observations did not clear up the orbit of Uranus, which still stubbornly continued to diverge from its predicted orbit. Moreover, around the year 1822, the nature of the orbital discrepancies changed. Prior to 1822 Uranus seemed to surge ahead of orbital predictions, but after 1822 it seemed to be held back in its orbit.

A number of theories were put forward to explain Uranus's motion. It was suggested that a collision with a comet had changed the orbit of Uranus - although the longer discrepancies built up, the harder it became to explain them with a single event. Likewise, an unseen satellite of Uranus might have explained discrepancies over a short period, but became an untenable explanation in the long run. Some people, including George Biddell Airy, the Astronomer Royal, contended that Newton's Law of gravity might not hold so far from the Sun; others that there was some sort of fluid medium modifying the path of the planet.

All these theories found it difficult to explain the quantitative discrepancies in the orbit of Uranus, in particular the change that occurred around 1822. Only one theory withstood critical analysis - the suggestion that the orbit of Uranus was being modified by the gravitational pull of a yet more distant, undiscovered planet. The significance of events in 1822 under this theory was that 1822 would be the year when Uranus "overtook" the outer planet in its orbit. Prior to 1822, the pull of the outer planet would speed up Uranus in its orbit, after 1822 the pull would hold it back.

This account simplifies what was in reality a fiercely difficult problem. Observations of Uranus had to be converted to accurate positions, and from these an orbit had to be inferred. In particular, the distance of Uranus from the Sun, or "radius vector" could only be implied, not calculated directly. Direct observations of Uranus were only available from 1781, not yet one complete orbit around the Sun. Older observations were of questionable accuracy and validity. Experienced astronomers such as Airy suggested that it might still be possible to fit an accurate orbit to Uranus without invoking unknown neighbours. Above all, the mathematics needed to predict the position of a new planet from discrepancies in the orbit of Uranus was at the limits of knowledge, and the calculations required were daunting and tedious.

Nevertheless, two young astronomers, anxious to make their names, decided to attempt to calculate where an outer planet might be, so that an attempt could be made to search for it. These two astronomers were the Frenchman, Urbain Le Verrier, and John Couch Adams of St. Johns' College, Cambridge. Both astronomers started off by assuming that the outer planet lay at the distance predicted by Bode's Law, 38.8 astronomical units. Adams was first to make his predictions. In 1843 his interest had been piqued when he read a report by Airy on the discrepancies in Uranus's orbit, and he resolved to attempt to find the location of a perturbing planet. He was able to hone his mathematical skills by computing the orbits of several comets, discovered at Cambridge University's observatory. The director of the Observatory, the Revd. James Challis, wrote to Airy on Adams' behalf, asking for detailed observational data on Uranus. Airy was happy to oblige.

It is here that the "Official Version" of events, recently challenged, begins to come to the fore. According to the Official Version, in 1845 John Couch Adams made two uninvited visits to Greenwich, bearing a letter of introduction from Challis, to present his predictions for an undiscovered planet to the Astronomer Royal. On the first occasion, Airy was away on business in France. On the second occasion, in late September 1845, Adams arrived at Airy's house at the Greenwich Observatory. The Airy family was at dinner and unable to receive him. Adams returned some hours later but was not allowed to meet Airy. The family butler instead took his calculations and passed them on to the Astronomer Royal. (It should be noted that Airy also had other things to worry around at this time — on October 27th 1845, Airy had to suspend a senior R.G.O. worker charged with incest and murder, and October 29th 1845 Airy's 7th child was born.)

Airy, it is said, wasn't very impressed with Adams' calculations, and replied some weeks later, asking whether or not Adams could explain the discrepancies in the radius vector of Uranus. Adams was perplexed by this request and did not respond to it. Why not? Much later on he is reported to have told a friend, Galisher, that "I should have done so; but the enquiry seemed to me to be trivial". The result was that Airy took no further action until another mathematician had produced predictions that matched Adams's.

That mathematician was Urbain Le Verrier, who had begun working on his own calculations for the position of the perturbing planet, encouraged to do so by Francois Arago, director of the Paris Observatory. In late 1845, Le Verrier presented the first of three papers to the Paris academy. This was a review of the existing observations of Uranus, re-iterating the opinion that there was no known orbit that satisfactorily fitted all the known observations, both pre- and post- discovery.

However, his first prediction of an undiscovered planet's position was not until June 1st 1846, in his second presentation to the Paris academy. Le Verrier sent this prediction to George Airy, reaching him on June 23rd. Airy replied in generally encouraging terms, but, intriguingly did not mention that he had already received similar predictions from another mathematician. Airy posed to Le Verrier the same question about the radius vector that he had asked Adams. Le Verrier was non-plussed by the query in much the same way as Adams had been, but sent a reply in which he indicated that further calculations, published as his third paper at the end of August 1846, explained both radius vector and angular errors.

Airy was, it is said, convinced enough by the two sets of predictions, to announce to a meeting of the board of visitors to the Royal Greenwich Observatory (probably including Revd. William Pearson, who I wrote about in Mira 71), that it was quite possible that a new planet would be discovered soon.

In July 1846, Airy visited Cambridge, and met Adams accidentally and briefly on the "Bridge of Sighs" in St. Johns' College. No mention was made of Adams' work on an undiscovered planet. However, a week later Airy wrote to the Revd. James Challis, director of the Cambridge Observatory, asking that he commence a search for the new planet, at the positions predicted by Adams, and suggesting that Challis might require an assistant. Cambridge possessed a much larger telescope than any at Greenwich, the 11.75 inch Northumberland equatorial.

Adams prepared a fresh ephemeris of predictions, and Challis began a half-hearted search for the new planet. The director of the observatory declined the suggestion that an observing assistant was required, deciding that he could search alone for the new planet at night, whilst continuing his reduction of cometary data during the day time. The planet search began on July 29th 1846. Night by night Challis noted down star positions, returning days later to re-sweep the same area of sky and then look for objects that moved. On August 12th, Challis made his first check, comparing the positions of the first 39 stars observed on both July 30th and August 12th. No stars had moved, and Challis was satisfied that he had a workable procedure. Unknown to Challis, star 49 on his list had moved - it was Neptune.

John Couch Adams had still not published any predictions at all for the position of the undiscovered planet. He decided to present his predictions to the British Association, meeting in Southampton on September 16th 1846. Unfortunately, he misunderstood the details of the event, and turned up a day late for the relevant session.

Unlike Adams, Le Verrier had failed to persuade anyone in France to act on his predictions, so on September 18th 1846 he wrote to Johann Galle at the Berlin Observatory in Germany. This letter was received on September 23rd. Galle was enthusiastic, and asked the observatory director, Encke, if he could search straight away for it. The director was celebrating his birthday that evening and so did not object. A young student named Heinrich D'Arrest begged to join the search.

Galle and D'Arrest had a lucky break. Karl Bremiker, the observatory mathematician, had just published a new star catalogue for this part of the sky, as part of a mapping project being undertaken by the German observatories. Although James Challis was receiving copies of the same charts, his copy of the relevant part of the sky had not yet arrived in Cambridge. Galle began sweeping the skies around the position of Le Verrier's predictions, with D'Arrest checking star positions as Galle called them out. After just half an hour D'Arrest cried - "that star is not on the map!" Closer observation revealed a hint of a disk - the new planet had been found!

Galle and D'Arrest needed to observe the new planet for a few days, to verify its motion. There was still the opportunity for Challis in Cambridge to make an independent discovery. Alas, Challis squandered his remaining opportunities. On the 29th September there is a brief note in his observing book - "that star looks like it has a disk" - as he looked, unknowingly, at Neptune. And the Reverend William Towler Kingsley arrived at the Cambridge Observatory on September 30th, intent on assisting Challis with his search. Mrs. Challis insisted on making tea for the visitor, and the sky had clouded over by the time refreshments were finished.

On October 3rd, Le Verrier announced to the observatories of Europe that he had found a new planet at his predicted position. Two days later, Sir John Herschel, William Herschel's son, wrote to the *Athenaeum* magazine pointing out that there was an English astronomer, Adams, who had made similar predictions. Later in October, James Challis also wrote to the *Athenaeum*, pointing out that he had commenced an observing program, several weeks before Galle and D'Arrest's observations, which had already picked up Neptune, although regrettably this fact had not been noticed. Furthermore, Challis had made these observations as a result of predictions by Adams, though unfortunately these predictions had never been published. *"Some may be of the opinion"*, Challis wrote, *"that in placing before the first astronomer of the kingdom results which showed he had completed the problem, and by which he was, in a manner, pledged to the production of calculations, there was as much publication as was justifiable on the part of a mathematician whose name was not yet before the world"*. To top it off, Challis proposed that the new planet be called Oceanus.

The French reaction was predictable. Le Verrier had triumphantly announced the discovery of a new planet, from predictions widely published some months earlier. Now suddenly here were British astronomers, who claimed to have been searching, in secret, using the unannounced and unpublished predictions of a hitherto unknown astronomer - and even had the cheek to propose their own name for the new planet. What was going on?! The French newspapers were in no doubt - the British astronomers were seeking to steal their planet. One newspaper, *L'Illustration*, had a cartoon that showed Adams using his telescope to spy on Le Verrier's calculations across the English Channel.

There was a stormy meeting of the French Academy on October 19th. Arago attacked Adams. *"Le Verrier is called upon today to share the glory, so loyally, so rightly earned, with a young man who has communicated nothing to the public and whose calculations, more or less incomplete, are totally unknown in the observatories of Europe. No! No! The friends of science will not allow such a crying injustice to be perpertrated"*

At a meeting of the Royal Astronomical Society on November 13th, Adams, Airy and

Challis put their cases. Airy spoke first, presenting correspondence and defending his own position strongly. Challis's speech was much less impressive; he seemed to be apologizing for missing opportunities. Adams gave the best speech, sticking primarily to the technicalities of discovery, without seeking to lay blame.

Adams, indeed, was first to compute an accurate orbit for Neptune. Intriguingly, the planet was NOT at the distance given by Bode's Law - its mean distance from the Sun is only 30 AU. This perhaps explains why both Adams' and Le Verrier's calculations came up with highly eccentric orbits.

The scientific dispute between Britain and France rumbled on for some time. However, the two major proponents, were able to rise above it. Once Le Verrier and Adams met in person, in Oxford in June 1847, they got on well immediately. The Royal Astronomical Society awarded Le Verrier their annual medal, and some kind of peace descended on the proceedings.

****

That, then, is the Official Version. John Couch Adams is cast as the brilliant but diffident mathematician who had Neptune in his grasp but lost it because of Challis's failure to act. Airy is an honest broker, who might have saved the day if only Adams had been more forward with his calculations. Le Verrier retains his authority as mathematician, but the primacy of his calculations is challenged - Adams essentially got there first. Galle and D'Arrest are relegated to lucky bystanders.

The problem with this reading of the history is that there was little evidence to either support or contradict the British point of view (Le Verrier, of course, ensured that his predictions were widely disseminated before Neptune's discovery). The primary archive of astronomical history in the U.K. is held by the Royal Greenwich Observatory (now as part of Cambridge University Library). For much of the latter part of the twentieth century, anyone requesting files pertaining to the discovery of Neptune would have been told that they were "unavailable".

Where were they? The R.G.O. librarians were not generally forthcoming, but they turned out to have been in the ownership of Olin Eggen, who had been deputy director of the R.G.O. during the 1960's. Eggen had taken the Neptune Files, ostensibly to write biographies of Airy and Challis for the Dictionary of National Biography, but had held on to the documents, even when he moved to Mt. Stromlo in Australia, and then to Chile.

The problem was that Eggen denied that he had the files. The R.G.O. librarians were reluctant to press Eggen, for fear that he would destroy the files rather than acknowledge that he had still had them in his possession. So the status of the Neptune Files remained unclear for decades, until Eggen died in 1998. The astronomers in Chile rang the R.G.O. to alert them. The R.G.O. was in the process of moving from Herstmonceux to Cambridge, and the phone call came in the final week before the phones were cut off permanently in Herstmonceux.

The Chilean astronomers shipped 105 kg of missing material back to the R.G.O. - not only pertaining to Neptune, but also other rarities, including a manuscript by Jeremiah Horrocks. The Neptune files were entrusted to Nick Kollerstrom, a historian of Astronomy from University College London. Nick is a council member of the Society for the History of Astronomy, of which I am a member. For the last few years, funded by a grant from the Royal Society, he has been carefully sifting through the documents. At the same time, he has uncovered new material, from, among others, the St. Johns' College Archives in Cambridge and even from descendents of John Couch Adams.

Most of the primary source matrial, and Kollerstrom's analysis of it, is on Nick Kollerstrom's website at
`www.ucl.ac.uk/sts/nk/neptune`

I don't always recommend websites, particularly those that hint at a conspiracy theory, but I have no hesitation in this case. [If you don't trust me, Scientific American recommend the site too]

Here are some of Kollerstrom's findings:

There is an eye-witness account of Adams' second visit to the Airy household, by Airy's wife Richarda. By her recollection Airy did not snub Adams; he was simply not at home at the time, either out walking or in London on business. Richarda had no recollection of Adams returning.

There is no copy of the document Adams presented to Airy in Sep 1845. One piece of paper does exist, with a Sep 1845 date added

by a different hand. This paper does not contain predictions for the location of an outer planet, rather, its orbital elements, listed in great numerical detail - hardly a hurried note.

There is no copy of the ephemeris presented by Adams to Challis. Another piece of paper does exist with calculations on it; this has been supposed to be the ephemeris, but it is undated and there is no proof that it was written before Neptune's discovery.

There are several other calculations by Adams dating from 1845-1846. These give widely differing predictions for the location of an outer planet. Adams' calculations, unlike Le Verrier's, did not seem to be converging on a definitive position.

At the meeting of the R.G.O. board of visitors meeting in June 1846, the official minutes are not at all clear that the imminent discovery of a new planet was announced.

There is an astonishing letter from Airy to Sedgwick at Cambridge, in which Airy blows his top about the inability of Cambridge students to stand up for themselves intellectually.

Although Challis did not have the chart that Galle and D'Arrest used to locate Neptune, he did have the neighbouring chart, which featured an area of sky in which Neptune was moving during the whole of August, the early part of Challis's search for it.

For me, a number of things stand out from Kollerstrom's analysis. Adams' predictions, although "in the right ballpark", did not settle down to a final definitive value. Morevover, it isn't clear which predictions were passed on to Airy and Challis. Le Verrier, on the other hand, had a consistent set of figures, which were published and then passed on to Galle in Berlin. The claim that Adams' predictions, were "within one degree" (i.e. as close as Le Verrier) were highly dubious. It's difficult to decide on exactly how much Adams was in error. Kollerstrom suggests four degrees, which would have made Challis's search very difficult.

The role of Adams in the "Official Version" becomes more and more untenable. For example, did he really turn up to the British Association and not tell anyone about his predictions? If he had strong predictions, surely he would have told many people. But if his predictions had not yet converged, his reluctance would have made much more sense.

On his web site, Kollerstrom hints at a conspiratorial explanation for events. In the article he wrote with William Sheehan and Craig Waff in Scientific American, the conspiracy is spelt out explicitly. The British astronomers, the authors claim, greatly overstated the British case after the event. Airy and Challis cherry-picked the best of Adams' predictions and claimed, retrospectively, that this was the one and only prediction Challis had used for his search. Whilst acknowledging that John Couch Adams was a brilliant mathematician, Kollerstrom, Sheehan and Waff claim that he never came up with a coherent set of predictions.

Let me quote their conclusions. *"... Adams utterly failed to communicate his results forcefully to his colleagues and to the world. A discovery does not consist merely of launching a tentative exploration of an interesting problem and producing some calculations; it also involves realizing that one has made a discovery and conveying it effectively to the scientific world"*.

So this is the latest thinking from (some) historians of astronomy. Urbain Le Verrrier should take sole credit for predicting the position of Neptune; Galle and D'Arrest for acting on his predictions and spotting the new planet. The British astronomers failed either to predict the location with anything like enough accuracy, or to search for it with any great diligence. However that didn't stop the British astronomical establishment, principally Airy and Challis, from an audacious claim to co-discovery, based on selective evidence that was then effectively hidden from scrutiny for over 150 years.

Of course, things have now changed. You wouldn't find senior British civil servants sexing-up important documents these days, would you....

Bibliography

"Planets Beyond - Discovering the Outer Solar System", M.Littmann (Wiley, 1988)

"The Neptune File - A Story of Astronomical Rivalry and the Pioneers of Planet Hunting", T.Standage (Walker, 2000)

"The Case of the Pilfered Planet", W.Sheehan, N.Kollerstrom and C.B.Waff, Scientific American Vol 291 Number 6 (pp.68-75)

"Finding Neptune", University of Central Lancashire course notes, Chapter 10, for course AA1066

"Great Astronomers of History" (UCL, 2004-5)

Nicholas Kollerstrom's website
www.ucl.ac.uk/sts/nk/neptune

The Fibonnaci Series and the Golden Ratio

By Mike Frost

I wanted to say something about the mathematics of the Da Vinci Code (see MIRA73, Christmas 2005). Of great significance to the plot is the Fibonnaci series – a series of numbers, starting 1 and 1, where each number is the sum of the previous two. The Fibonnaci series goes: -

1 1 2 3 5 8 13 21 34 55 89 etc.

It's also interesting to look at the ratio of successive terms in the series: -

1/1 = 1.000 2/1=2.000 3/2=1.500 5/3=1.667 8/5=1.600 13/8=1.625

The ratio of successive terms quickly converges to a value of 1.618… This is the Golden Ratio, ϕ or phi, which has a long history in the theory of aesthetics. A rectangle who's sides are in the ratio ϕ:1 is said to be particularly pleasing to the eye. Perhaps more interestingly, both the Fibonnaci series and phi turn up in nature. In the Da Vinci Code, Dan Brown's hero Robert Langdon cites occurrences of the golden ratio in the ratios of successive chambers of nautilus seashells, in the ratio of females to males in beehives, and in the ratios of sunflower spirals, pinecones and leaf segmentation.

Some people might think that the prevalence of ϕ is evidence of "intelligent design" in some form. This is not a view I subscribe to – it's my opinion that mathematics is everywhere in the natural world. I'd like to demonstrate to you how both the Fibonacci Series and the Golden Ratio can arise quite naturally from a straightforward process that could easily occur biologically.

I'd like you to consider an idealized rectangular organism made up of square cells, which grows in the following manner: -

Take the largest dimension of the rectangle, and add a square of that size.

For example, if we start with a unit square, the above instruction requires us to add another unit square, and then a square of size two, size three, and so on (See Figures 1 and 2). The illustrations show successive stages of growth of the organism. In fact, you should be able to see that successive cells are in the sizes of the Fibonnaci series. You can also see that the organism grows in a spiral fashion. Sea-shells and plants grow in a similar fashion – that's to say, adding an extension similar to what is already there - without ever knowing anything about the Fibonnaci series.

If you start with different shapes, you'll see that the initial shape doesn't really matter. The organism rapidly settles down to a Fibonnaci-style growth. Ultimately the organism size approaches the golden ratio. That is to say, adding a unit square to an existing rectangle produces a new rectangle with the same ratio of sides.

In other words, the ratio of x:1 is the same x+1:x

This is easy to turn into an equation, namely $x^2 = x + 1$

This equation has two solutions,

$x = (1 + \mathrm{sqrt}(5))/2$ and $x = (1 - \mathrm{sqrt}(5))/2$ where sqrt is the square root.

These two numbers work out to be 1.618033988… and –0.618033988…

The first of these is the golden ratio, ϕ, which I spoke of earlier. The second, let's call it η, is as you can see related to ϕ but negative.

ϕ and η have fascinating properties:

$\phi^2 = \phi + 1;$ $\eta^2 = \eta + 1;$

$1 / \phi = \phi - 1;$ $1 / \eta = \eta - 1;$

Every number F_n in the Fibonacci series is the sum of powers of ϕ and η.

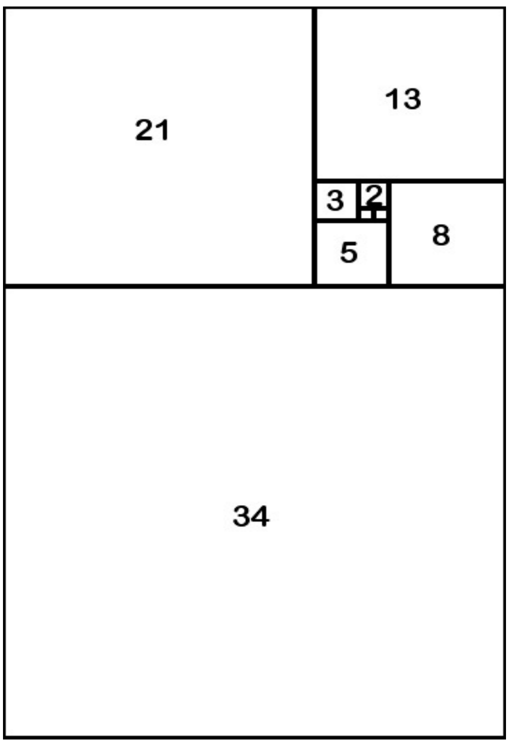
$F_n = (\phi^n + \eta^n) / \text{sqrt}(5)$

Some of the claims made for the golden ratio are very dodgy. From the Da Vinci Code, "*[Da Vinci] was the first to show that the human body is literally made of building blocks whose proportional ratios* always *equal PHI ... Measure the distance from the tip of your head to the floor. Then divide that by the distance from your belly button to the floor. Guess what number you get...*" Do you really measure a ratio of 1.618033988 for every single human being? Try it at home! In reality the ratio around about 1.6, varying from person to person. And is it of any significance anyway?

Other claims in the Da Vinci Code are certainly valid. Robert Langdon (who clearly studied mathematics with his astronomy classes), points out that the external line segments in the pentacle are in the golden ratio to the internal line segments. This is true, but I won't inflict the proof on you. I'd also point out that the pentacle can be used to generate two fascinating shapes – the so-called Penrose tiles, named for Roger Penrose, the Oxford physicist. These can be used to completely tile an infinite plane, in a fascinating pattern, with five-fold symmetry, which never, ever, exactly repeats itself. The golden ratio and Penrose tiles are inextricably linked.

Finally, I'd point out that the two numbers in the ratios of the orbital periods of Venus and the Earth, 13 and 8, are both Fibonnaci numbers. Weird or what? I think it's simply a co-incidence, but I tend to be on the sceptical side…

Sources: -
"The Da Vinci Code", Dan Brown (Corgi, 2003)
"Penrose Tiles to Trapdoor Ciphers", Martin Gardner, chapters 1 and 2 (Freeman, 1989)



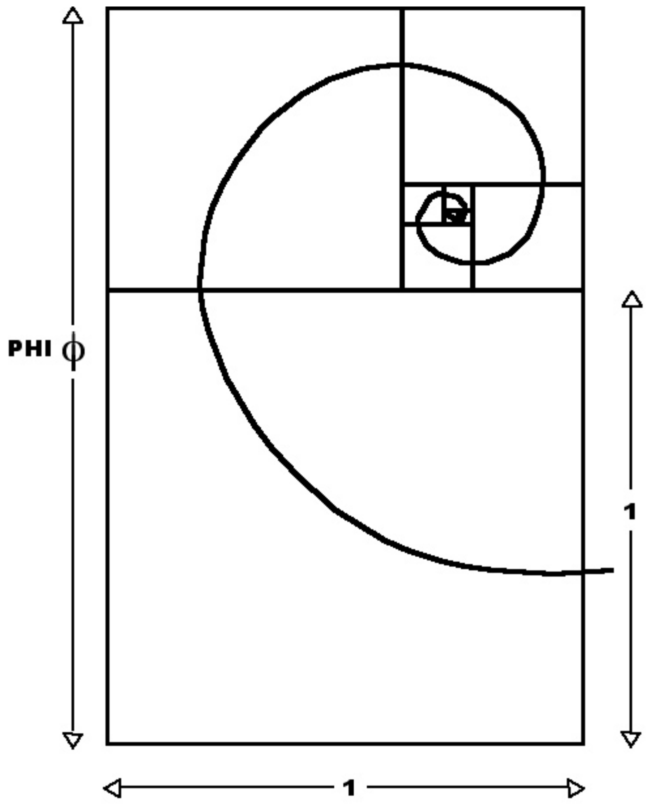


Fig 1, Above, Fibonnaci Square Progression
Fig 2, Right, The Golden Ratio showing also the Fibonnaci Sprial

To Prove: The internal line segments of the pentangle are in the ratio 1:phi with the external line segments.

Proof: Let x be the external line segment length, y the internal line segment. We want to prove that $x/y = \phi$, where ϕ is the golden ratio, which satisfies $\phi^2 = \phi + 1$

From the known properties of ϕ, we also have $y/x = \phi - 1$

By simple trigonometry, the points of the pentangle have angles of 36 degrees.

So $y/2 = x \sin 18$, and the problem reduces to finding the sin of 18 degrees.

We need to prove $\sin 18 = y/2x = (\phi-1)/2$, where $\phi^2 = \phi + 1$

Set $s = \sin 18$, then we need to prove $2s + 1 = \phi$. Substituting this into $\phi^2 = \phi + 1$ gives $4s^2 + 2s - 1 = 0$

We can evaluate sin 18 by noting that $1 = \sin 90 = \sin 5*18$

Repeatedly use the trigonometric identities:

$$\sin (A + B) = \sin A \cos B + \sin B \cos A$$
$$\cos (A + B) = \cos A \cos B - \sin A \sin B$$
$$1 - \cos A \cos A = \sin A \sin A$$

to decompose $\sin 90 = \sin (18 + 72)$, and then 72 degrees into 2*36 and 4*18 degrees.

This procedure eventually gives $16s^5 - 20s^3 + 5s - 1 = 0$

which factorises to $s.(4s^2 + 2s - 1)^2 = 0$

proving that $s = \sin 18 = (\phi-1)/2$, as required

Q.E.D. Mike Frost

Sent in by Geoffrey Johnstone

Detection of gravitational waves promises to allow astronomers to gain new insights into black holes, neutron stars and supernova.

Justin Cunningham reports

Making waves in space-time

The detection of the elusive gravitational wave is the hot topic for physicists at the moment. Its discovery will confirm predictions made by Einstein in his General Theory of Relativity and should lead to greater understanding of space phenomena, the big bang and the universe. So why, would engineers, be interested in the fringes of the theoretical becoming reality? Technology has often followed in the footsteps of scientific breakthroughs. As scientists discover how the world works, engineers produce what has never been before in the form of varying technological innovations. Gravitational waves should open up a new door through which to view the universe.

Karsten Danzmann, a professor at the Max-Planck Institute for Gravitational Physics in Hanover, Germany, says: *"At present we can only 'see' the universe through the electromagnetic spectrum: light, radio waves,and gamma rays. Although electromagnetic waves are much stronger and hence easier to detect than gravitational waves, they often scatter and corrupt, whereas gravitational waves should not. Their detection should effectively allow astronomers to 'hear' large and catastrophic phenomena, such as black holes, neutron stars and supernova".* It's predicted that gravitational waves should reveal obscure parts of the universe that at present are a mystery. Massive black holes have a gravitational pull so strong that light cannot escape. Bernard Schutz, a professor at Cardiff University, says: *"Advanced detection through the combined effort of both ground and space-based interferometers could yield secrets about the black holes, the big bang and the very existence of the universe"*

Europe's centre for research on this subject is the GEO600 site, located in an unassuming looking field near Hanover. Its interferometer uses a laser and a system of mirrors and optics in an almost dust-free clean room. A laser beam is fired and split at right angles down two 600m vacuumed pipes where it is then deflected backwards by another series of mirrors hanging from a structure. The gravitational waves should make a tiny change to the length of the laser beams, equivalent to detecting a hair width change in the distance between here and Alpha Cenrauri, the next nearest star system, 4.2 light years away. Put another way, that's the equivalent of identifying a change in the distance between the earth and the moon of 100 billionths the width of a human hair.

It is hoped that the innovative technology and development that has gone into this project will have spin-off applications in the future. One breakthrough currently under development is the laser.

The laser is a 200W diode-pumped neodymium YAG laser that will be the most powerful of its kind in the world. The continuous wave infrared laser has unmatched stability and is designed to run for over a year virtually non-stop without deterioration of any component parts or beam quality. The technology is however limited to its position on the earth.

To get an almost guaranteed observation, and to cover a larger range of frequencies, an experiment in space is needed. The European Space Agency and Nasa have now entered the fold and have plans for two joint missions, a procurement mission and a full-scale mission involving three satellites flying in formation. The full-scale mission, Lisa (Laser Interferometer Space Antenna), will cover frequencies not achievable on the ground. The ground-based station GE0600 and its US counterpart will look at a frequency range only above about 10Hz whereas the space-based interferometer will be able to detect lower and longer lived signals emitted from things such as super massive black holes. Danzmann says: *"By detecting a larger range of frequencies it is hoped that not only will we detect one of the elusive gravitational waves but will be able to understand and use this data to view the universe in a way that has never before been possible."*

The procurement mission, called Lisa Pathfinder, is due for launch in 2008-09. It will test the technology and general concept. The spacecraft's operational orbit will be the sun-earth Lagrangian points where the gravitational pull of the sun is equal to the pull of the earth. A spacecraft placed here will be in near perfect gravitational freefall. Two test masses, each measuring $10cm^3$, will comprise part of the Lisa test package payload. The surrounding spacecraft will, like its successor Lisa, protect the masses from solar winds and other forces so they will effectively be undisturbed. The spacecraft will not be in contact with the masses but will measure with unprecedented accuracy their movement while in freefall. The craft's own position will be adjusted to allow the masses to move freely in space. Any changes in distance relative to one another can then possibly be attributed to gravitational waves

Assuming the Pathfinder mission is a success, Lisa should launch in 2013 and will again need technology never used before. The plan is to fly three satellites in a triangular formation trailing earth's orbit. The satellites will be 5 million km apart and will be able to detect a mm drift in formation. The aim is that Lisa will become operational at the same time as advanced Ligo. Ligo (Laser Interferometer Gravitational Wave Observatory) is the current US gravitational wave detection site. The US researchers are due to start installing the more advanced technology of GEO600 at their larger and more powerful site in early 2007. Detection from this site would then become a British-German-US collaboration.

The US site has received funds of upwards of £350 million, and will use technology developed by GEO600 that is estimated to have cost £15 million. Place your bets Scientists at GEO600 plan to start early next year an observational run that will last 18 months. Strain says: *"Although the chance of detections is slim, if even one observation is made during this time it would mean that expectations of advanced Ligo and the Lisa mission would be 10 observations a day."* Jim Hough, also a professor at Glasgow, says: *"I will stick my neck out and say we will make a detection by 2010."* Hough placed a bet at 500-1 and stands to win £12,500 if his prediction is correct. Ladbrokes has since slashed its odds to 2-1 in response to *"a rush of interest from punters."*

Precision engineering pursues the miniscule

Gravitation waves are ripples in the fabric of space-time. They are caused by the movement of masses, but only ripples from seismic events around the universe, such as the collapse of stars, formation of black holes, and other huge astronomical events. would be detectable at present. There wavelength is araound 10-18m, miniscule compared to any other wavelength detected.

Imagine two points in a perfectly still lake. The flat surface of the water represents the fabric of space-time and the shortest distance between two points is a straight line along the surface of the water. If a mass collides with that surface, such as a ball hitting the water, waves will propagate outwards. Now if we follow the contours of the surface of the water, the distance between the two points will change if we measure while the waves move through our two points. This is metaphorically sending ripples through space-time.

Now imagine the principle on a much smaller scale with a much stiffer object like a sheet of steel. If the sheet is struck with a hammer this will send tiny ripples through the sheet and change the distance between the two points fractionally as the surface is no longer straight, but follows the curves of the waves. The distance will be slightly shorter then longer as the vibration occurs. This stretches and squeezes the distance between the two points on a minute scale and over a very short time. Space-time can be thought of as a very stiff sheet of material. When a massive astronomical event happens it will have a similar effect as hitting a very stiff sheet with a hammer or throwing a ball in a lake. Waves will propagate outwards and these will change the distance between two given points as they move through - but only very slightly and for a very short period. This is why precision engineering has been required to detect such minute discrepancies.

Article from *"Professional Engineer"* by Justin Cunningham