



## TRANSIT

The March 2014 Newsletter of



### **NEXT THREE MEETINGS, each at Wynyard Planetarium**

**MONDAY 10 MARCH 2014 at 7.00 pm**

***Extraordinary General Meeting***

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

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**Friday 14 March 2014, at 7.15 pm**

***The battle for galaxies***

**Rod Hine, *Bradford A.S.***

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**Friday 14 March 2014, at 7.15 pm (*change of speaker & subject*)**

***Astro-imaging: An introduction, including historical and practical aspects***

**Dr Jürgen Schmoll, *CaDAS chair.***

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## Editorial

*Rod Cuff*



First of all, a warm welcome to new members Rhona & Callum McMahon!

Second, and very important this month, if you see this note in time, please remember the **Extraordinary General Meeting on MONDAY 10 MARCH at 7pm in Wynyard Planetarium.**

The telly has some astronomically interesting things that have recently started or are about to get going. There's the relaunched [Sky at Night](#) series, of course, but also Channel 4's [Live from Space](#) season and, for those who can receive the National Geographic Channel, [Cosmos: A Spacetime Odyssey](#), the 'remake' of the groundbreaking Carl Sagan 1980 series, which starts on Sunday 16 March at 7 pm.

You may remember my remarking in last month's editorial that March's issue might be smaller than February's (because I was going to be on holiday until early March). That just shows my anti-Nostradamus tendencies – instead, this issue is even fuller, with fine written material from Keith Johnson, Ray Brown, Ray Worthy and Neil Haggath.

It was going to have an enthusiastic article from me about the wonderful Northern Lights that I anticipated seeing on the Norwegian cruise that was to constitute the holiday for my wife and me, but the cruise ship we were booked on was the one whose restaurant windows were smashed in a couple of days beforehand by a giant wave, killing an unfortunate passenger. Given the storms that were still rolling across the Atlantic, we decided to cancel our trip, and instead had four excellent days in Kraków in Poland. And got back the day *after* millions in the UK saw the best auroral display for decades ... sigh. We have some of 'guest' astrophotographer Dave Thompson's stunning pictures of the event in this issue.

Many thanks to all contributors. Note the free books on offer on page 21! Please let me have material for the next issue by 28 March.

Best wishes –

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(01287 638154, mobile 07775 527530)*

## Letters

### Measuring the speed of light

*from Neil Haggath*

In his article last month, Ray Brown mentioned that the speed of light in vacuum was 'first accurately determined by James Bradley in 1729'. This is a little unfair on Ole Rømer, who deserves the historical credit for making the first measurement of the speed of light, 54 years earlier.



I guess it depends on how you define 'accurately'; I don't know what the accuracy of Bradley's measurement was. Rømer's value was within about 7% of the correct value; while we would in no way regard that now as accurate, we have to consider that

- a. it was the first time it had been measured at all, and no one had previously had the slightest idea what the value was;
- b. his method depended on knowing the value of the Astronomical Unit – the mean radius of the Earth's orbit – which was itself known at the time to an accuracy of only about  $\pm 3\%$ . (The

purpose of the worldwide Transit of Venus expeditions in 1761 – 86 years later – was to refine the measurement of the AU.)

Given that restriction, Rømer's work was a highly creditable effort.

This has inspired me to write, just for the fun of it, a short piece on how Rømer measured it, which appears in this issue.

*Best wishes – Neil*

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### Chris Lintott's Durham lecture

*from Ray Worthy*

In response to an email request, Dr Chris Lintott of Oxford University, who lectured on 'Is the Milky Way special?' at Durham on 4 February, sent me a page reference – [www.eso.org/public/usa/news/eso1332](http://www.eso.org/public/usa/news/eso1332) – which shows animations of clouds being spaghettified by a black hole. Dr Lintott commented: 'The cloud heading into the black hole is known as G2, and the animation I showed was from this page.'



Others might be interested in seeing this.

*Best wishes -- Ray*

## OBSERVATION REPORTS AND PLANNING

### Websites – March 2014

Here are some suggestions for websites that will highlight some of what to look out for in the night sky in March.

- **BAA Sky Notes** for February/March (the BAA has just completely reworked its website, which now has various interesting nooks and crannies on it. You can browse around it if you go to the Sky Notes link below and later click on the Home tab):

[http://britastro.org/skynotes\\_render/3832](http://britastro.org/skynotes_render/3832)

- **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](http://hubblesite.org/explore_astronomy/tonights_sky)

- **Night Sky Info's** comprehensive coverage of the current night sky:

[www.nightskyinfo.com](http://www.nightskyinfo.com)

- **Jodrell Bank Centre for Astrophysics** – The night sky:

[www.jodrellbank.manchester.ac.uk/astronomy/nightsky](http://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:

[www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month](http://www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month)

- **Society for Popular Astronomy's** What's Up for March 2014:

[www.popastro.com/youngstargazers/skyguide](http://www.popastro.com/youngstargazers/skyguide)



## Aurora-gazing Live

**Dave Thompson (Durham A.S.)**

*[The night of Thursday 27 February 2014 is going to stay in the memory of a lot of people in the UK as featuring what seems to have been the best auroral display visible across the UK for many years – some people say for up to 20 years or more. I was out of its range (Kraków is further south than Plymouth – who knew?!), which was terrible timing. I've been anticipating a flurry of images from CaDAS members, but none has materialised. I didn't want the occasion to go unmarked in these pages, so **Dave Thompson** of our sister Society in Durham has agreed that I can include a couple of the excellent pictures that he took from somewhere in Co. Durham of what he says was the best display he's seen this far south, 'like a crown of thorns at brightest ... red and green visible to the naked eye, better than some of the displays I saw in Iceland'. Great pics, Dave, and many thanks!]*

*I'm also grateful to **Pat Duggan**, who has alerted me to yet another good website for forecasting possible auroral visibility. There are quite a few of these sites around, several of which will email you when there is a possibility of seeing the Northern Lights at your location; but **Service Aurora** at [www.aurora-service.eu/aurora-forecast](http://www.aurora-service.eu/aurora-forecast) is about the most informative I've seen. Check it out. – Ed.]*





## Getting into planetary imaging

**Keith Johnson**

*[Keith wrote an excellent four-part series for Transit (available on our [website](#) in issues from September to December 2009) called A beginner's guide to imaging solar system objects. Much of what he wrote then is still perfectly valid, and is more detailed than what follows below; but since then new planetary imaging cameras, software and useful websites have appeared; Keith has got even more experienced and his images more impressive; and many new people have joined CaDAS. So it seemed a good time to ask him to write a fresh introductory article for anyone wanting to try imaging the major planets and/or the Moon. Keen readers may want to add the earlier Transit series to their reading list as well. – Ed.]*



Readers of *Transit* will no doubt have seen images of Jupiter displayed on the internet, on *The Sky at Night* or in an astronomical magazine; but how difficult is it to produce such images?

Surprisingly, it isn't very difficult if you know what equipment you need and how to use it. As with any other pastime, the amount that you spend on equipment has a bearing on the results that you'll achieve, and so it's good to be aware what equipment would be best suited for your budget. In addition, there are a few skills to be mastered.

The picture below is the stacked result of images captured in a seven-second video sequence using a ToUCam Pro II webcam and a 150mm f/5 Newtonian non-motorised reflector, proof indeed that you don't need to break the bank to achieve success!





So when it comes to imaging the planets and the Moon, you can achieve results no matter what telescope you own, and you don't even have to own a motorised (automatically driven) mount to achieve amazing results either!

If you already own a telescope, the only bit of extra kit required to get started is of course a camera. Choosing an appropriate one can be a minefield, but with a little knowledge and some helpful advice you can soon be capturing amazing results from solar system objects.

So let's start with the **camera**. There are a wide variety of suitable cameras on the market from £100 upwards, but if you know where to look you can often pick one up for around half that price – and what's more, you couldn't have picked a better time to look!

Webcams can still be seen for sale in classified ads on various astronomical websites. The one to look out for is the ToUCam Pro II pictured here, often for sale between £40 and £60. Sadly, ToUCam cameras are no longer made, but they do come up for sale now and again. Why not put a 'Wanted' ad on [UK Astronomy Buy & Sell](#)? Someone may have one that they don't use anymore.



So when is the best time to look? Right now Jupiter is a couple of months past opposition but still very high and prominent in the night sky, and this just happens to coincide with a new series of cameras out in the marketplace – the [ASI series](#) from a company called ZWO. Every man and his dog are buying it (ZWO's website says 'As amateur astronomers ourselves, we believe that we can design better products for other amateur astronomers'), which means that a lot of second-hand cameras are being sold on sites such as UK Astronomy Buy & Sell. Cameras on offer there as a result of the appearance of the ASI range include models such as [The Imaging Source DMK](#)

[and DFK cameras](#); and the QHY5 (originally from the [QHY company](#)) is a popular camera too. All the cameras I've mentioned are very good quality and will give appealing results on the Moon and planets.

To achieve sufficient detail on the planets, especially Jupiter and Saturn, I would suggest a telescope aperture size of at least 200mm and a focal length of at least f/6 – the higher the focal ratio, the better. There's an old saying of 'bigger is better' when choosing a telescope for visual observing, or deep-sky or indeed planetary imaging, but there's also another and perhaps wiser saying: 'a good telescope is one that gets used'! Larger telescopes are far heavier and subsequently more difficult and time consuming to set up, so do bear this in mind when choosing your telescope.

Most makes of planetary imaging cameras are available in either **colour or mono**. For beginners I'd recommend a colour camera, for which the learning curve is not as steep as that for a mono camera. The latter must have additional accessories such as red, green and blue filters to enable images to be captured in colour; to record each colour channel, these filters have to be selected in turn by means of a filter wheel. A good set of RGB filters and wheel costs anywhere from about £300 upwards. Although this approach gives better resolution (captures more detail), it is often better left until you have gained more experience with planetary imaging.

Colour cameras can and do give outstanding results, and brand-new cameras now come supplied with a 1.25" adaptor to allow them to be fitted to the telescope in place of an eyepiece. If you're using a refracting telescope or a [Schmidt-Cassegrain](#) (SCT), I recommend removing the [star diagonal](#); this is because we want to gather as much light as possible, and having a diagonal in place will reduce the amount of light received at the camera and so result in a poorer-quality image.

Planetary imaging cameras capture what is known as an **AVI** (short for Audio Video Interleave), a movie format comprising hundreds or even thousands of frames, with the number depending on the time the camera is set to record. The reason we use this method rather than taking a 'single shot' is down to the randomly warping effect of the Earth's atmosphere on light passing through it. When observing or imaging the planets and Moon, we often use the term '[seeing](#)'. The analogy I use when explaining why the quality of seeing is important is this. Imagine you are on holiday abroad, and during the daytime you walk past a swimming pool with lots of swimming and splashing going on. If you see a small object on the pool floor, you'll find it very difficult to make out its proper shape, owing to turbulence created by the movement of the water. However, if you return later that evening when no one is in the pool, the water will often be still and calm; you can now see the object on the pool floor more clearly, probably making out its shape and detailed features.

This is similar to how the position of the [jet stream](#) high in our atmosphere (and much in the news recently) can affect the stability of the image we see when we look through a telescope at an object in our solar system. It has a fundamental effect on how well your images or visual observing will turn out, and looking at the jet stream forecasts can help immensely when preparing to image the Moon or planets. One of the many websites I regularly check beforehand is the [jet stream forecast at netweather.tv](#), where you can view the forecasted jet stream as a red and yellow pattern. Ideally you should plan your imaging session when neither the red nor yellow is covering the UK.

Now that you've chosen the camera and fitted the adaptor, what additional hardware is required? You could increase the magnification by adding a [Barlow lens](#), and it would be worthwhile buying a clear-glass 1.25" screw filter, which will protect the CCD chip from **dust bunnies**, minute particles of dust that can settle on the CCD chip and show on the capture software screen as dark spots. These can have a profound effect on the quality of the image, and can be awkward to remove; great care should be taken when trying to do so. A little trick I use at night time is to remove the 1.25" adaptor, switch on the camera and point it (unfocused) at a street light. The light looks diffuse, but any dust bunnies are clearly visible on the capture-software screen. I then turn the camera to face downwards

and use an air brush to blow air over the CCD chip. I point the camera towards the street light again, and if necessary repeat the process until all the dust bunnies have been removed. *Under no circumstances* should you apply any chemical to the CCD when the camera is switched on; doing so will cause it to short out and irreparable damage will result.

Now let's turn to [software](#). You'll be pleasantly surprised to learn that there are many free software programs available on the internet that will help you with image capturing and image processing.

Time and experience will eventually enable you to choose your particular favourite capture software, but if you are a beginner I suggest you choose one that is basic and simply does what you need, which is to capture AVI files. [Sharpcap](#) ticks these boxes. It's free, easy to use and a popular program, so there is a wealth of knowledge out there on the internet if you need advice.

I suggest starting off by capturing images of the Moon, because it's big and bright – big enough that you can easily place its image onto the camera-capture screen, and bright enough that hopefully you won't struggle to achieve focus and adjust the camera settings correctly.

The nature of the object you wish to image will affect the length of the AVI you would be advised to capture. For example, as shown in the image above, you don't need to capture for long periods of time to create an image of the Moon. For Jupiter, 90 seconds is recommended if you're using high magnification (which delivers a relatively large image), because Jupiter's fast rotation means that a longer capture would result in blurred images when the AVI is processed (see below).

We now need to process our recorded AVI file. Capturing many thousands of frames allows us to filter out the frames taken at moments of poor seeing and retain the ones during periods of good seeing. However, each of these good-seeing frames will include random visual [noise](#), which will vary from frame to frame although the underlying basic [signal](#) (the features we want to enhance) remains the same. We need to take these noisy but good frames and align them exactly on top of one another so that the 'signal' parts of each frame match in position. It's as if they were a transparent pack of cards all of the same hand, tightly stacked upon each other.

We use software to [stack](#) all of these frames to create a better signal-to-noise ratio. The program favoured by most is [AutoStakkert II](#). I first became aware of it when visiting Sir Patrick Moore for a private function celebrating the 55<sup>th</sup> year of *The Sky at Night*. The 50 or so friends and guests who had taken part in the program over the years included planetary imaging gurus Damian Peach and Dave Tyler, and during the evening the three of us chatted about planetary imaging. For aligning and stacking, both Damian and Dave had moved from an earlier favourite, Registax (see below), to AutoStakkert II. One of the handy aspects of the latter program is that you can load many AVI files into it at one time and batch-process them. Since each AVI can take up to 15 minutes or more to process, by loading all of your night's imaging sessions you can simply let the software do all of the processing while you go to bed for the night. When you wake up the next morning, all the stacked images have been processed!

However, [Registax v6](#) is the most popular program for the next (and more or less final) stage: applying what are known as [wavelet functions](#) (adjustments of varying levels of contrast), which enable us to tease out details in our image. Many people then use Photoshop or similar software to tinker further, but if you've gone carefully through all the points in this article, you'll already have an image that you can be proud of. Why not publish it in *Transit*?

Below is an image I captured using the tools & techniques described in this article, at 20:19 UT on 27 February. It shows the Great Red Spot on Jupiter itself, the satellite Europa off to the right, and the shadow of Europa transiting across the planet.

The hardware I used was a Celestron C9.25" SCT on a Sky-Watcher EQ6 Pro mount, using a ZWO ASI120MC camera and a 4× ImageMate (a type of superior Barlow lens).



I captured a single, 90-second AVI, recording at 45 frames per second (this is *fast* and requires an up-to-date camera! With the ToUCam II, for instance, you would be limited to 10 frames per second, because that camera cannot download full frames to your laptop at a faster rate, and instead compresses the data, causing detail to be lost).

At various stages in capturing and processing, the software I used was SkyMap Pro 9 (star-charting software), AutoStakkert II and Registax v6.

I put most of my astrophotographic images on a [Flickr site](#), which you are very welcome to browse through!

*[**Postscript:** Stephen Carr, an astrophotographer in the very active Sunderland A.S., posted the following on Facebook recently (thanks for permission to repeat it, Stephen!). – Ed.]*

*You've probably noticed I've been taking and posting quite a lot of planetary images right now. The reason is I'm trying to get lots of practice with the new camera on Jupiter, so that I can get the best out of Mars and Saturn when they are at opposition this year.*

*The reason for the big rush on these planets is that over the next few years both Saturn and Mars are going to get lower and lower in our sky at each opposition, making it harder to image and view them.*

*By 2018, viewed from the North East, Saturn will only reach 12° altitude, not starting to rise again until 2019. It will take until 2022 before it gets back to 18° altitude as it is now.*

*Mars has quite an eccentric orbit compared to Earth. Its closest encounter with Earth will be the July 2018 opposition, when Mars will be only 57,596,372 km from us. However, at this opposition, it will only be 9° above the horizon, viewed from the North East.*

*So the basic point I'm making is whether you want to view or image them, do it this year, as it's only going to get harder!*



## Some thoughts on gravity and tides

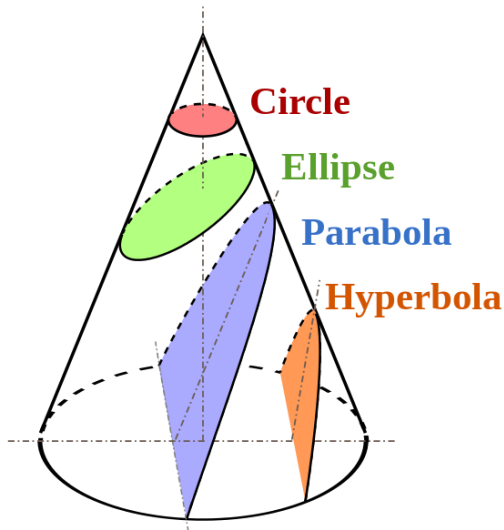
### Part 6: The three-body problem, orbital resonances and binary exoplanets

Ray Brown

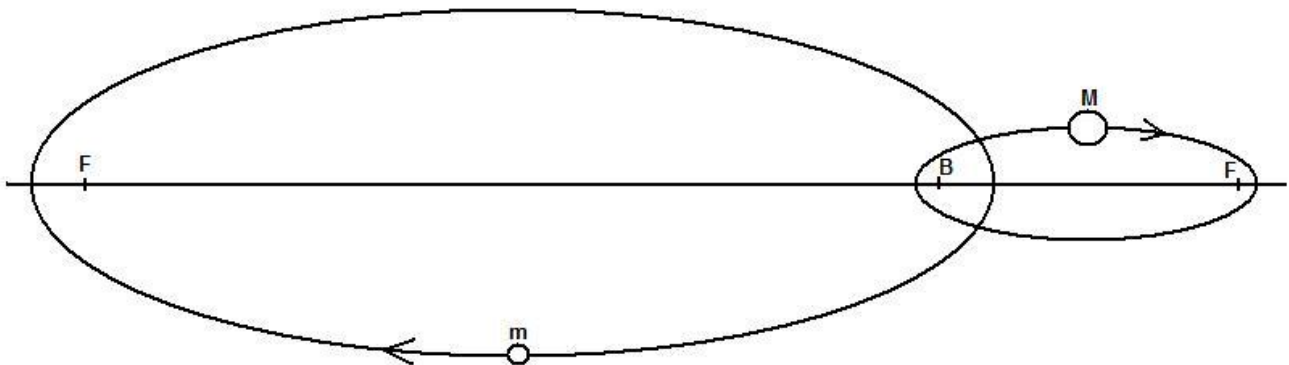
Earlier parts of this series were mainly concerned with gravitational attractions between pairs of masses, in particular celestial bodies. For any pair of masses

moving relative to one another but remote from all other masses, Newton showed that each of their trajectories follows the perimeter of a **conic section**.

A conic section is a surface formed by the intersection of a right-circular cone by a plane; it can be an ellipse, a parabola or a hyperbola.



If the gravitational attraction between the pair is sufficiently strong and their angular momenta about the **barycentre** (centre of mass) are sufficiently small, each trajectory will be an ellipse (a circle is simply an ellipse with zero eccentricity) with one of its two foci at the barycentre. Both orbits are closed loops with a regular period.



A pair of gravitationally-attracted masses,  $m$  (smaller) and  $M$  (larger) in elliptical orbits (foci at  $F$ ) around barycentre  $B$

By contrast, if the angular momenta around the centre of mass are large and the gravitational attraction is weak, then both trajectories will be hyperbolic, in which case the encounter is a non-repeated event from which the bodies go their separate ways for ever. (Some comets are periodic, whilst others follow hyperbolic paths.) Parabolic behaviour is the boundary between ellipsoidal and hyperbolic behaviours – the orbital period is infinite and the aphelion is at an infinite distance from the barycentre.

These analytical results for the treatment of the two-body problem by Newtonian mechanics are simple, deterministic and exact, but never precisely represent an actual astronomic circumstance; the Universe contains many billions of billions of celestial bodies, not just a single pair. Fortunately it is often possible to calculate approximately the behaviour of real planets, satellites and stars to a high level of accuracy by recognising that the effects of a third body are almost insignificant if its mass is relatively small and it is located far from the pair of interest. This is called **the two-body**

**approximation.** For example, the orbit of every planet in the Solar System is essentially elliptical because its gravitational attraction is dominated by the Sun, which is so massive as to dwarf the effects of other planets. But orbital movement of the Sun itself, in any case relatively small, cannot be treated as that of one of a pair of masses because *all* the planets, especially the gas giants, affect it.

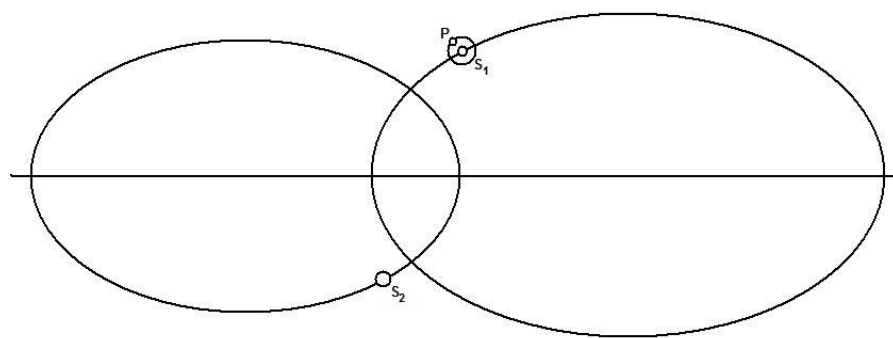
Early astronomers and mathematicians sought an exact analytical description for the general three-body problem. Newton himself made a preliminary effort but it was not until two centuries later that Poincaré showed that such a solution for three or more interacting bodies is impossible. There are special exceptions (the **restricted three-body problem** for the case where one of the masses is incomparably smaller than the other two was long ago solved for the co-linear case and for Lagrangian points). Also, approximate solutions can be made with high accuracy, especially by computer application of numerical techniques.

In general in a system of three or more masses, it is not possible to predict exactly the future positions and velocities of the bodies; their trajectories will not follow repeatable orbits. Poincaré introduced the concept of deterministic chaos, now familiar in many areas of science such as meteorology, turbulence and (arguably!) human actions. It is sometimes referred to as the 'butterfly effect' where the slightest change in the initial conditions can cause increasingly profound changes in subsequent behaviour.

Exoplanets associated with binary star systems are a particularly interesting three-body situation, the subject of a recent article in a popular science magazine (*Scientific American*, November 2013, pp 28–33). In recent years astronomers have found that:

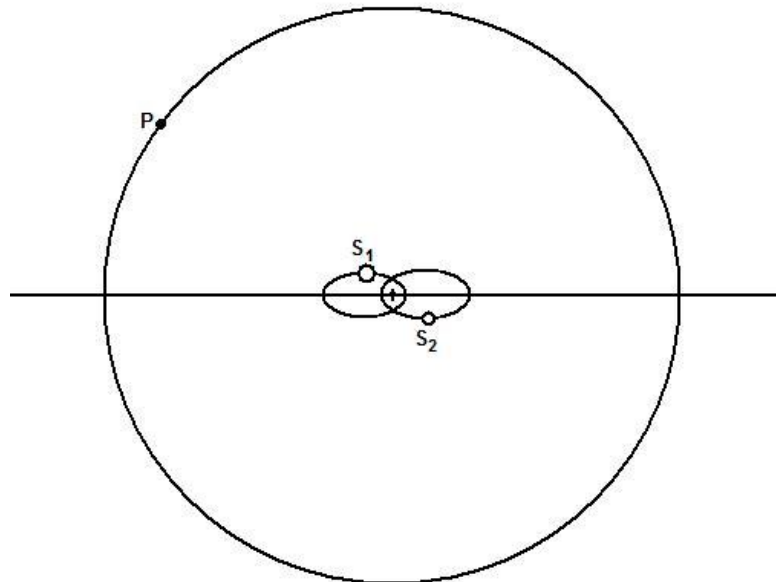
- 1) Sun-like lone stars that are not in orbital systems with other stars are likely to be the exception rather than the rule, and
- 2) many, if not most, stars possess associated planets – i.e., the Solar System, previously expected by some (possibly those of a religious inclination) to be unique, is commonplace.

It is reasonable, then, to suppose that exoplanets might exist in multiple star systems, and indeed several have been reported for binary- and triple-star arrangements and one in the quadruple star system Kepler 64. Exoplanets in binary stars are of two types.



A circumbinary planet P orbiting star  $S_1$  in a binary system with star  $S_2$

- a) Some exoplanets, said to be **circumbinary**, are closely attracted to one star  $S_1$  and are relatively distant from, and unaffected by, its partner  $S_2$  – i.e., the planetary orbit is much smaller than the separation of the stars at their mutual perigee. These are binaries with long stellar orbital periods, perhaps hundreds of years.



A circumbinary planet P orbiting around binary stars  $S_1$  and  $S_2$

- b) By contrast, **circumbinary** planets have wide orbits that sweep around both stars, as though they were a single mass at their barycentre. To date, 17 circumbinary planets have been confirmed ([http://en.wikipedia.org/wiki/Circumbinary\\_planet](http://en.wikipedia.org/wiki/Circumbinary_planet)). For stability, the orbital radius of a circumbinary exoplanet must exceed the separation of the binary pair by a factor of about 2 or 3. Most of such planets so far discovered orbit just beyond this limit. It has also been noticed that, of the thousand eclipsing binary star systems examined by the Kepler mission, half have orbital periods of less than 2.7 days, yet those with exoplanets all have periods exceeding 7.4 days.

Situations intermediate between a) and b) are three-body systems that cannot be approximated to two-body systems. It is to be expected that multiple star systems are less accommodating hosts for planets than are lone stars, and that instabilities in the three-body systems are more likely to eject planets to become unattached rogues in the galaxy. No exoplanets have yet been discovered associated with those binary stars located closest to our Solar System.

Another particularly interesting result of (three or more)-body interactions is the phenomenon of **orbital resonance**, which occurs when two **orbiting** bodies exert a regular, periodic **gravitational** influence on each other, usually due to their **orbital periods** being related by a ratio of two small **integers**. The mutual gravitational attraction between the moons depends on the distance between them, and that distance varies with time. If moon 1 has an orbit period  $P_1$  and moon 2 an orbit period  $P_2$ , then the distance between the moons varies over time with a period  $P_{12}$ , where

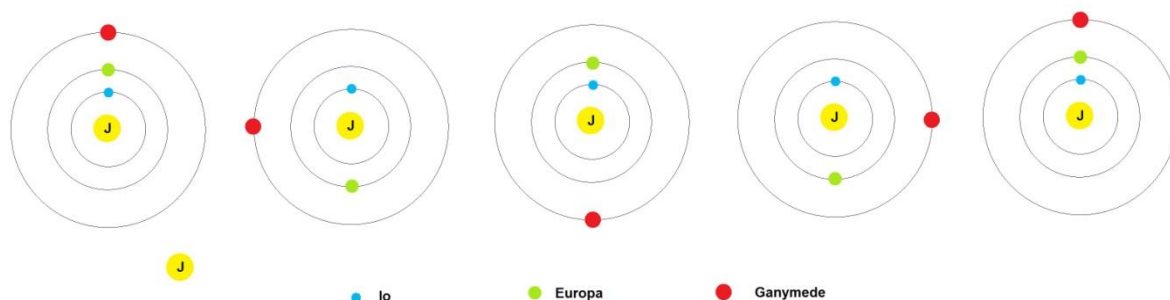
$$1/P_{12} = (1/P_1 + 1/P_2) = (P_1 + P_2)/P_1 P_2$$

If  $P_{12}$  is a multiple of the period of one of the moons, the gravitational tugs from one moon on the other occur at the same point in the moons' orbits, allowing small perturbations to build up. Thus strong resonances correspond to cases where  $P_{12} = nP_1$ , with  $n$  being any non-zero whole number. This corresponds to the condition  $(n-1)P_1 = nP_2$ . Hence the strongest resonances occur where the period ratio is 2/1, 3/2, 4/3, 5/4 etc. These are known as **first-order resonances**, and are usually represented as follows: 2:1, 3:2, 4:3 etc.

There are several stable resonances in the Solar System. Pluto completes 2 orbits of the Sun for every 3 orbits by Neptune. Three pairs of Saturn's moons are in stable resonances. During each orbit of Saturn, Dione is lapped once by Enceladus. For every 3 orbits of Saturn by Hyperion, Titan does an extra one. Tethys and Mimas return to their same relative positions following 2 orbits by Tethys and 4

by Mimas (n.b. a 2:4 resonance differs from a 1:2 resonance because the two orbits are neither perfectly coplanar nor circular).

Perhaps the best-known example of orbital resonance concerns the moons Io, Europa and Ganymede, which orbit Jupiter with orbital periods of respectively 1.769, 3.551 and 7.155 days. These periods are in the ratios 1 : 2.0 : 4.0. Whereas the orbit of each of these moons can be regarded mainly as a two-body interaction (the moon and Jupiter) with a regular period akin to a pendulum or a child on a swing, each moon is *also* influenced periodically and regularly by its fellow moons. 'Nothing special about that,' you might say, 'it's similar to the Solar System planets orbiting the Sun.' However, the periods of the orbits of moons around Jupiter are essentially simple multiples (1:2:4) of one another and therefore the moon–moon interactions around Jupiter are periodic and regular. The net effect is that the shape of each individual 'two-body' orbit that a moon would have around its parent planet is being modified somewhat by two other moons.



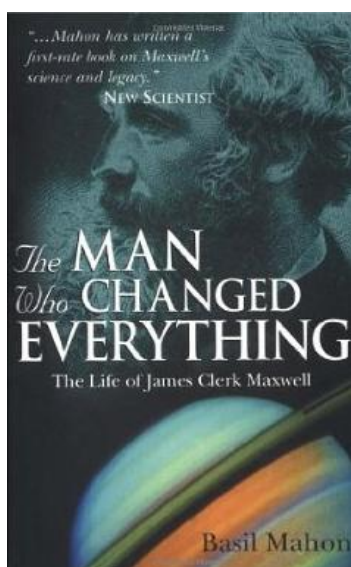
**Positions of three moons of Jupiter during successive orbits by Io**

This case of **Laplace resonance** is an example of a stable resonance. Likewise, the red dwarf star Gliese 876 is believed to have three of its exoplanets in a 1:2:4 stable resonance. We are able to witness these phenomena precisely because they are stable, but most resonant effects are unstable and leave either no evidence that they ever existed or voids such as the gaps between Saturn's rings from which material has been and is being ejected. Orbital resonance is a complex and fascinating subject on which there is a vast literature, especially concerning Saturn's moons and rings.



**We'll go sailing, we'll go sailing... or will we?**

**Ray Worthy**



Since my seeing ability went AWOL several years ago, my studying has been through the medium of talking books and various scientific podcasts. Because of this, I find it difficult, if not impossible, to follow detailed mathematical arguments. That needs a certain amount of visual input. At least, that is my excuse, because in this article I am going to expose some limitations in my understanding. I am referring to the idea of sending sailing vessels out into space on 'cheapo' missions. The more I think of it, the more and more questions pile up in my brain. So, as this article develops, with points to be answered, I hope some of you young mathematical geniuses, (or is it genii?) might be stimulated to get tapping on your keyboards with some answers.

What started me off on this theme was that the RNIB's Talking Book service had sent me a disc, *The Man Who Changed Everything*, by Basil Mahon, about the life of James Clerk Maxwell. He of course was the



Scottish mathematician who, after years of brilliant conjecture and calculation, finally derived a set of equations that united the fields of Electricity and Magnetism theory. One consequence was that he forecast the existence of the whole of the electro-magnetic spectrum, whose waves were propagated at the speed of light and did not need the mythical 'ether' as a medium in which to travel. I had studied Maxwell's life on other occasions before, of course, but what caught my eye, or rather my ear, this time was that these equations allowed him and his followers to put a figure on the 'weight of light', as it were. What it meant was that if one spread out in space a mirror the size of one hectare to face the sunshine, the sunshine would push at the rate of seven grams. What astonished me was that this calculation was made as early as 1864. It had never occurred to me before that here was someone actually equating mass with energy forty years before Einstein came up with his famous equation. No wonder Einstein placed Maxwell on a pedestal up there with Isaac Newton.

This information chimed in my mind with something I had come across earlier in the year about a new development in the pursuit of achieving cheap travel in space. I won't give details of this until later, if you don't mind, and I'll bring it into the text at the appropriate point.

As long ago as the time of the first telescopes, Johannes Kepler, who had been Tycho Brahe's assistant for many years, was writing to Galileo that he had been studying a very bright comet and had been struck by the brilliance of the comet's tail. Kepler put forward the idea that the very sunshine might be exerting a pressure that drove the tail directly away from the Sun.

Naturally, the idea of using this pressure of sunlight as a means of propulsion in space had to remain just speculation until the first initial and crude stages of space travel had been negotiated. A space sail craft could not launch itself from the Earth's surface. It must, perforce, be constructed and launched from a base that is itself already in space. In other words, the space sail had to wait for the International Space Station to be placed in orbit.

I understand that there is a movement afoot to explore the possibility of using so called 'nano' sailcraft, with micro-instruments as payloads, but for the purposes of this article I shall put comment on that idea to one side and concentrate on a craft with sails a kilometre across.

A space sail can only be assembled in space. There is no way it can be folded up and opened out once in orbit. The problem of constructing the masts, the support structure for such large sails, in space has always presented the planners with almost insurmountable difficulty. However, in 2013 some bright spark put forward an idea that just might do the trick. The plan is to use the new technology of 3D printers to extrude the masts alongside the Space Station. Out there, the masts will be weightless and will require little support as the mast leaves the printer. The plans already being put forward envisage a radial structure like a spider of eight limbs which, in turn, will carry triangular sails.

When I heard about this idea, here in my ivory tower, it took my breath away. The vision of the idea, the simplicity. I was gobsmacked. It was during the late Christmas period that I was brought back down to Earth. One of my daughters-in-law is the head teacher of a large secondary school on the Medway in Kent.

'Oh yes,' she said casually, when I brought up the subject, 'We have 3D printers on our curriculum.'

'On your curriculum?' I asked, astonished.

'Oh yes,' she replied, as if it were nothing special, 'Some of the older pupils visit the University of Greenwich, where they use the apparatus regularly.'

And later, in the early New Year, I was visited by a nephew who is on the staff of a school in Redcar, and he told me that they had their own 3D printer which the pupils used regularly. He also mentioned that they no longer use hammers and saws and such like, but use computer-programmed laser cutters.

I realised just how out of touch I had become. It puts the old woodwork and metalwork at the Billingham Campus in their place. What a turn-up.

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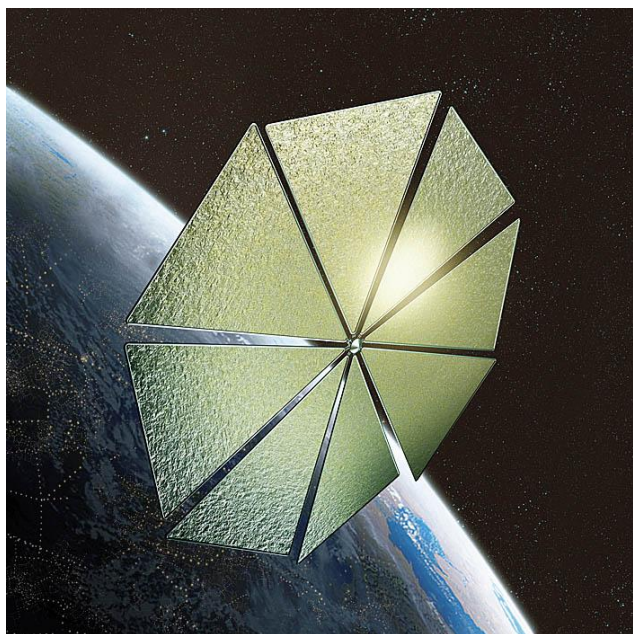
So, having been brought abruptly up to date, we can assume that the concept of making a space sail might soon be brought to reality. Some time in your life, but probably not in mine, you will find something growing within easy binocular reach, at the side of the Space Station.

Howsoever this may be, I am still filled with question after question. In the early 1960s I lived for two years in the beautiful holiday resort of Weymouth and owned a small sailing dinghy. It was a ten-foot-six Lymington pram with two sails – a jib at the front and a mainsail that dipped around the mast when changing tack. I loved it and became quite proficient sailing it single-handed, and by dint of operating the jib and the rudder I could turn the boat completely round a hundred and eighty degrees in its own length. It was a delight.

The standing rigging comprised a single mast, which was stayed at each side and down to the bow with the forestay. In the centre of the boat was a narrow well down which a removable keel, called a dagger board, was fitted. This was important, because it provided resistance against sideways drift and was the swivel around which the craft turned. Without this dagger board the dinghy would drift to one side rather than rotate around the fulcrum.

The jib, the front of which ran up and down the forestay, could be used to accelerate a turn across the wind. It was controlled by two sheets, one at either side, which were guided through two rings fixed to the sides of the boat. If I pulled the jib tight to one side, it acted as a rudder in the air and pushed the bow around very quickly as required until the boat was laid on the other tack. The mainsail did not come into its own until the dinghy was well and truly laid over. Because the front edge of the mainsail on its own yard dipped like a curtsey around the mast, it practically looked after itself during the manoeuvre and all I had to do was to adjust its sheet on the appropriate side and away we would go. It is a memory full of sunshine.

With this experience as a background, I intend to compare and contrast it with what I have gleaned about sailing in space. As I have mentioned before, I am full of questions.



Let us suppose that the sailing vessel has been successfully put together and is tethered to the Space Station. It is huge, with a spider-like arrangement of eight masts. Each mast is something like a thousand metres long. Suspended between each pair of masts is a huge triangular sail of mirror cloth or plastic. I do realise that the planners envisage sailing in nearly all directions, but I wish to start with the idea that the most simple possibility is just that, with the sails pulled tight to the eight masts and aligned to give maximum exposure to the sunlight. How on earth does one get started, launched or whatever?

Here we are in fairly low Earth orbit. Half the time we are in the shadow of the planet, where there will be no thrust whatever, and half the time the sunshine is pushing the craft towards the Earth. It is academic really, because with seven grams thrust per hectare at the start, you are not going anywhere in a hurry.

The solution, of course, is to take it somewhere else and launch from there. But as soon as you make that decision, you will have to use up some precious chemical fuel and the cheap option will not be so cheap after all.

The great attraction of course is the so-called limitless supply of light, so that the resultant acceleration will go on and on, forever if need be. It has to be realised that, if the craft is headed away from the Sun, the supply of energy will be subject to the law of the inverse square. After two astronomical units, you will have only a quarter of the power supply.

Once out in space and away from the Earth, the craft will experience the various and multiple gravitational gradients as the outer planets come around in their orbits. However it is done, sooner or later the craft will have to be steered somehow away from the direct radial direction. How will this be accomplished? There can be no dagger board to thrust down into the water. There will be no resistance to sideways motion to swivel around as the rudder takes hold. All we are left with is the equivalent of the jib, somehow pulled flat against the wind of light. Any such manoeuvre might take months to accomplish.

I can visualise that, at the end of each long mast, there will be some structure built at right angles into the third dimension, with the corner of the jib pulled at 45° into the flow of light to deflect the Sun's rays and give some sort of sideways control. Using the eight sails, I'd bet it would be easy to spin the whole assembly like a mill, but navigation-wise I cannot see any advantage in this design. It is this vision of the whole assembly spinning round and round like a windmill that leads me to think that the eight-section radial configuration might not be the best design for space navigation. The computer-controlled 3D extruder might allow more complex freedom of design, with huge rectangular panels of reflective surface that could be hinged with reference to the main frame.

Now, it is at this point that I really wish to trail my coat, hoping that someone will be stimulated to stand on it and bring me up sharp.

I have read (or heard) that that planners of these sailing trips maintain they will be able to guide their craft upstream against the sunlight and navigate completely without rockets and suchlike, and actually reach the inner planets. I just do not see it. Fundamentally, my gut instinct is to deny the possibility.

To my prosaic and earthbound mind, beating up against the wind requires some form of keel that encounters resistance against sideways drift. In space, where does this resistance come from? Why have they settled on the octagonal configuration? What advantages does the design confer?

I am hoping that CaDAS has been nursing within its bosom some amazing wunderkind to put me to rights and set me on my way.

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Contact with the editor, of course can be by means of the usual route, but I should be happy with a direct e-mail ([rayw43@virginmedia.com](mailto:rayw43@virginmedia.com)) or phone call (01429 268086) to keep me abreast of what is going on.



## How was the speed of light first measured?

*Neil Haggath*

The velocity of light in a vacuum, denoted by  $c$ , is one of the most important and fundamental constants in physics and astronomy. It's the 'speed limit of the Universe', which nothing can exceed, and the fact that it *is* a constant forms the basis of Einstein's Special Theory of Relativity. Its value is now known to fantastic accuracy – to better than one part in a billion – thanks to modern electronic methods. But some may be surprised to learn that it was first measured as early as the late 17<sup>th</sup> century. How it was measured way back then without any sophisticated modern instruments is remarkably simple, and required no more than a good telescope and an accurate clock.

In those days, no one had any idea what the speed of light was, except that it was extremely fast. People had initially tried to measure it in the same way in which they had measured the speed of sound, but had soon realised that it was far too great to measure by any method involving distances on Earth. Any method of determining it would have to involve somehow measuring the travel time of light over astronomical distances.



**Ole Rømer, portrait by Jacob Coning from c. 1700 (Wikipedia)**

In 1675, the Danish astronomer Ole Rømer, who was then working at the Paris Observatory under G.D. Cassini, realised how it could be done, using observations of the satellites of Jupiter. He arrived at an estimate within about 7% of the true value – which wasn't bad for the first attempt!

The four Galilean satellites had been known for decades, and their orbital periods had been measured pretty accurately. We're all familiar with the way the satellites and their shadows periodically transit, or cross, in front of Jupiter itself from our point of view; most of us who own telescopes have observed such transits for ourselves. They were easy to observe, even with the relatively crude telescopes of 1675 – and they were the key to Rømer's measurement of the speed of light.

His method involved observing successive transits of the satellites and accurately measuring the time intervals between them, when the Earth and Jupiter were at different relative positions in their orbits. We'll consider Io, which has an orbital period of roughly 1.6 days, and obviously transits once per orbit.

(Astute readers will realise that, apart from a couple of months around the Winter Solstice, observing two consecutive transits of Io is pretty difficult – but you could easily observe one and then the next but one, 3.2 days later, and thus measure double the time interval.)

Fig. 1 shows the orbits of Earth and Jupiter, though not to scale. For clarity, I've drawn Earth's orbit roughly twice as big as it actually is in relation to that of Jupiter. Each planet travels anticlockwise in its orbit, as seen from above its north pole. The Earth travels with a velocity  $v$ , which can easily be calculated if you know the radius of its orbit. (Of course,  $v$  varies slightly during the year, because the orbit is elliptical – but for simplicity, we'll assume here that it's circular.) In 1675, the Earth's distance from the Sun wasn't known to great accuracy; it had been determined to an accuracy of about  $\pm 3\%$ . This was, in fact, the primary factor limiting the accuracy of Rømer's calculations. At any given point in its orbit, the Earth is moving in a direction tangential to the circle, as indicated by the arrows.

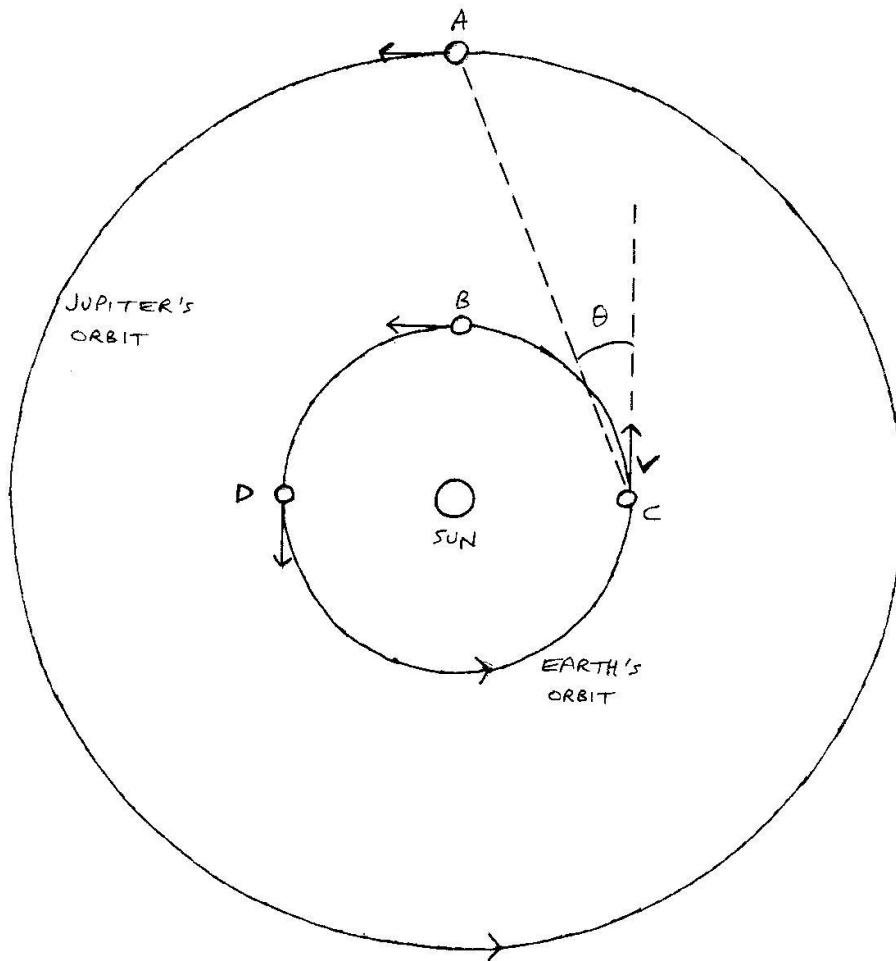


Fig. 1

First, consider what happens when Jupiter is at position A, as shown in the diagram, and Earth at position B – i.e., when Jupiter is at opposition. Both planets are moving very nearly parallel to each other, so the distance between them doesn't change appreciably over a timescale of a few days. We observe successive transits of Io, and measure the time interval between them, which we'll call  $t$ .

Now suppose we do the same when the Earth is at position C, relative to Jupiter. This time, the measured interval between successive transits is slightly shorter than that measured at B, by an amount ' $\delta t$ ', or  $\delta t$  – i.e., it's equal to  $(t - \delta t)$ . Can you see why?

This is because, during the time between the two transits, the Earth has moved slightly closer to Jupiter – so the light reaching us from the second transit has travelled a slightly shorter distance than that from the first transit.

Naturally, when the Earth is at position D, the exact opposite happens, as the Earth is moving away from Jupiter. The measured time interval is longer than that measured at B, by the same amount – i.e. it's equal to  $(t + \delta t)$ . In the case of Io,  $\delta t$  is about eight seconds.

So now we can calculate the speed of light. If we measure the angle  $\theta$  between the direction of the Earth's tangential motion and that of the line of sight to Jupiter, the component of its velocity in the direction towards Jupiter is  $(v \cos \theta)$ . So in the time interval  $t$ , the Earth moves closer to Jupiter by a distance equal to  $(vt \cos \theta)$ .



This distance is also the difference in the path lengths travelled by the light from the two transits. If we call the speed of light  $c$ , we can see that this difference in the light paths is equal to  $(c \delta t)$ .

So we can now say that

$$c \delta t = vt \cos \theta$$

Solve that equation, and *voilà* – we have the speed of light!



## Obituary: John Dobson, 1915–2014

*Neil Haggath*



On 15 January, the world of amateur astronomy lost one of its most influential figures of the last few decades, with the death of **John Dobson**, at the age of 98. Though best known as the inventor of the ultra-low-cost telescope mounting design that bears his name, he also played a major part in astronomy outreach and public education, and pioneered the concept of 'sidewalk astronomy' – in which a couple of our own members have been involved.

John Lowry Dobson was born on 14 September 1915, in Beijing, China, where his father taught at the University. At the age of 12, his parents returned to the United States; thereafter, he spent most of his life in San Francisco, California.

In 1943, Dobson graduated with a master's degree in chemistry from the University of California, Berkeley. Astronomy, however, was to become his lifelong passion.

The following year he became involved with Vedanta, a Hindu religious sect, and joined the Vedanta Society Monastery in San Francisco. He served there as a monk for the next 23 years. One of his responsibilities was to 'reconcile astronomy with the teachings of Vedanta'.

While at the monastery, Dobson began building his own telescopes; it was during this time that he invented the mounting that came to be named after him. He often took his telescopes outside the monastery, and would attract the interest of neighbours and passers-by. He also often corresponded with, and offered assistance to, people outside the monastery in the matter of building telescopes. This work was frowned upon by the order, and he was told to either stop building telescopes or leave the monastery. He chose the former option – but in 1967, he was expelled anyway!

Why he was expelled is not clear; there are various versions. What seems the most likely is that he wrote a paper or essay on astronomy, which the swami interpreted as contradicting the order's teaching on the 'reconciliation' of science and faith. Another version, however, is that too many people kept calling the monastery, not to ask about religious matters, but to ask Dobson's advice on building telescopes!

Having left the monastery, he was free to pursue his hobby. He found that the local society, the San Francisco Amateur Astronomers, was somewhat elitist, and had a frankly ridiculous policy of not permitting children to join! This was anathema to Dobson, who had dedicated himself to 'taking astronomy to the people'. Together with two friends – one of them a 12-year-old boy, who was not eligible to join the aforementioned society, despite having already built his own telescope! – he founded a new group, the San Francisco Sidewalk Astronomers. Instead of holding formal meetings, the group's philosophy was to simply set up telescopes on the sidewalk (pavement to us Brits!), and

show astronomical objects to any passers-by who expressed an interest. Sidewalk Astronomers has since grown into an organisation with members in many countries. For many years, Dobson also gave public classes in telescope making – just like our own esteemed President, who did so a little later!

In 1969, the Sidewalk Astronomers were invited to the prestigious annual Riverside Telescope Makers' convention in California; they took along a 24-inch Dobsonian reflector – a size that was almost unheard of at the time for an amateur instrument. Controversially, the telescope won joint first prize for optics, and second prize for mechanics, despite its design being so simple. This was when the Dobsonian design first became widely known.

It is of course for his telescope design that Dobson is best known. Strictly speaking, the term 'Dobsonian telescope' is a misnomer, as the telescope itself is simply a Newtonian reflector; his

innovation was the *Dobsonian mount* – a simple alt-azimuth mounting, which can be built from simple materials, such as plywood, formica and plastic pipe fittings. For observers who are not interested in photography, and therefore don't need tracking capability, the Dobsonian design enables amateurs to build a far bigger telescope, for any given budget, than was ever previously possible. Consequently, it is now commonplace for amateurs to build instruments with apertures that were utterly unheard of a few decades ago. For this reason, Dobson can truly be said to have revolutionised amateur astronomy. For those who want their telescope to be simply a 'light bucket' for purely visual work, the Dobsonian has been the design of choice for the last 30 or so years.



For many years, Dobson spent much of his time travelling around the United States – and sometimes abroad – giving talks to societies on astronomy and telescope making. His telescope design was further publicised in such publications as *Sky and Telescope* – where many others, over the years, have published their own innovative variations on the basic Dobsonian. In 1991, he wrote a book, *How and Why to Make a User-Friendly Sidewalk Telescope*. This was published with a unique binding, made from that essential material for most Dobsonian mounts - plywood!

A lesser known aspect of Dobson is that he had his own unorthodox views on cosmology. He opposed the Big Bang Theory, claiming that it has too many problems, and proposed his own 'Steady State' model of the Universe, in which he claimed that it's forever expanding, but that matter is somehow constantly 'recycled' via quantum tunnelling.

It's hardly surprising that Dobson earned a number of awards and distinctions for his astronomy outreach work – but these were not limited to those awarded by astronomical organisations. In 2004, the Crater Lake Institute gave him its Annual Award for Excellence in Public Service, for pioneering sidewalk astronomy in national parks and forests, 'where curious minds and dark skies collide'. The following year, *Smithsonian* magazine named him among 35 'individuals who have made a major difference' during the magazine's lifetime.

I'll end on a personal note. I volunteered to write this obituary because I once had the honour of meeting John Dobson. In 2002, he came to the UK to give a series of talks. He crossed the Atlantic primarily to speak at the Whirlpool Star Party in Ireland, but he also spoke at a couple of events in the UK, with the organisers sharing the costs.

One of those events was the Horncastle Astronomy Weekend, which I've attended every year for the last 25 years. He was there for the whole weekend – during which he celebrated his 87th birthday – and gave two talks. He was accommodated at the home of one of the 'regulars', Barry, who lived

locally and was a good friend of mine. After the end of the event, Barry invited me to his house, so I got to chat with John privately for a while.

The following weekend, John spoke at West Yorkshire A.S., in an event which was combined with the Yorkshire Astromind competition. This was my last time of competing in Astromind – I've chaired it ever since – and John presented me with the trophy.

I consider myself privileged to have met this remarkable man.

### FREE BOOKS ON OFFER

I've been clearing out a few bookshelves to make room for other material, and have some astronomy-related books that I no longer wish to keep. They're each on offer free of charge to anyone who would like them. If there are any titles you want, please email or text me (Rod Cuff – my contact details are at the end of the editorial on page 2), and I'll reserve each for the first person to claim it. Please also tell me if you're planning to be at the EGM on Monday 10<sup>th</sup> and/or our normal monthly meeting on the 14<sup>th</sup>, which might make good opportunities for a handover.

All but two are paperbacks. There's a clickable reference for each, to tell you something about them, but sometimes it may refer to a later edition.

[\*Coming of Age in the Milky Way\*](#), Timothy Ferris (1988)

[\*Philip's Stargazing with a Telescope\*](#), Robin Scagell (2000)

[\*The Transit of Venus\*](#), Peter Aughton (2004)

[\*Genesis – The origins of man and the universe\*](#), John Gribbin (1981)

[\*The Planets\*](#), Dava Sobel (2006)

[\*The Autobiography\*](#), Patrick Moore (2003)

[\*Brilliant Stars\*](#), Patrick Moore (1996 – legitimate ex-library copy)

[\*Eyes on the Universe\*](#), Isaac Asimov (1975?)

[\*The Nature of the Universe\*](#), Fred Hoyle (hardback, 1951)

[\*A New Popular Star Atlas \(Epoch 1950\)\*](#), R.M.G. Inglis (hardback, 1949)

### THE TRANSIT QUIZ *set by Neil Haggath*

#### **Answers to February's quiz**

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

1. The first star that was known to be variable. **Mira (o Ceti).**
2. A small constellation, named after a very small creature. **Musca, the Fly.**
3. The body on which is found the highest cliff in the Solar System. **Miranda, a satellite of Uranus. The cliff, or scarp, is Verona Rupes, an incredible 21 km high!**
4. A major observatory, operated by the University of Texas. **McDonald Observatory.**
5. The only feature on Venus named after a man! **Maxwell Montes, named after James Clerk Maxwell. Apart from the unimaginatively named Alpha Regio and Beta Regio, all other features on Venus are named after goddesses or famous women.**

6. The man who didn't fly on Apollo 13. **Ken Mattingly, who was dropped from the crew and replaced with his backup.**
7. A curved string of galaxies within the Virgo Cluster. **Markarian's Chain.**
8. The man who discovered about half as many 'Messier objects' as Messier himself. **Pierre Méchain (1744–1805). Charles Messier's catalogue includes many objects that he didn't discover himself. His friend Méchain is credited with discovering 30 of them.**
9. The astronomer who discovered the variability of Algol. **Geminiano Montanari (1633–87) in 1669. (Not John Goodricke; he famously *explained* its variability.)**
10. The unofficial name given by astronaut Gus Grissom to his Gemini 3 spacecraft. **Molly Brown.**

Nos 6 and 10 require a little explanation, for those who don't know the history!

**No. 6:** Each Apollo mission had two crews, prime and backup, which trained in parallel so that if any member of the prime crew was unable to fly, he could be replaced by his counterpart from the backup crew. Ken Mattingly was Command Module Pilot of the prime crew.

A few days before launch, Charlie Duke, who was a member of the backup crew, became ill with measles. As the crews had been working closely together, the prime crew had also been exposed to it. Jim Lovell and Fred Haise had had measles as children, and were therefore immune, but Mattingly had not. So there was a risk that he had been infected (it turned out that he had not) and would have become ill during the flight. Therefore he was dropped from the crew, and replaced by his backup, Jack Swigert.

Each backup crew became the prime crew for three missions later – so Mattingly later took Swigert's place on Apollo 16.

**No. 10:** Gus Grissom was the first man to go into space twice. He made the second manned Mercury flight, then commanded the first manned Gemini mission. At the end of his Mercury flight, after splashdown, the hatch accidentally blew open, and his capsule filled with water and sank.

The Gemini spacecraft were not given individual names, as the Mercury ones had been – but Grissom unofficially named his after 'the unsinkable Molly Brown', a survivor of the *Titanic*, who was immortalised in a Broadway musical.

### March's quiz

*Every answer starts with the letter N. As usual, they are in roughly increasing order of difficulty.*

1. He compiled a star atlas in 1910 that is still in print today.
2. The common name of Sigma Sagittarii.
3. The second satellite of Neptune to be discovered.
4. A list of deep-sky objects published by J.L.E. Dreyer in 1888.
5. The 7000<sup>th</sup> object in Question 4.
6. A constellation, which isn't named after Marilyn Monroe!
7. The Large Magellanic Cloud.
8. An extensive canyon system on Mars.
9. The former husband of the first woman in space.
10. The formal name of the facilities at Jodrell Bank.

