Transit
The Newsletter of the Cleveland and Darlington Astronomical Society
September 2014

Header picture: The Sombrero Galaxy (M104) **Cover Picture:** The Horsehead Nebula (In Infrared)
Source: hubblesite.org

Contents:

Next Meeting:

Friday 12th September
7:15pm
At Wynyard Planetarium

Future Extremely Large Telescopes

By Prof. Richard Myers
Durham University

Editorial

Welcome to the September issue of Transit (and my first as editor). Our meetings secretary, Neil Haggath, has yet again lined up a great set of speakers for the coming season (listed on the last page).

This year the Thomas Wright Trophy will be contested on Friday 17th October and hosted by Durham University Astronomical Society.
Any volunteers for the CaDAS team would be most welcome, so if you fancy yourself as a bit of a mastermind, or would just like to have a go for a bit of fun, please get in touch with Neil Haggath.
(You can email him at neil.haggath@ntlworld.com)

This month we have another great article by Ray Brown "Getting there by Gravity Assistance" that is definitely well worth a read and very apt with the recent news about the ESA's Rosetta mission.

As you can obviously see I have decided to try a new format for the newsletter and would welcome your comments - both good and bad (hopefully not too many bad ones).
Any suggestions for things that you would like included in future issues would also be nice to receive.

I would also like to extend a request to all members for any images they may have taken that we could feature in forthcoming issues. Why not use this publication to show everyone else what you have imaged?
To start things off I have included two of my own shots of our nearest neighbour (and probably one of the easiest things to image), though I am sure there are a great many more impressive images out there.

If you have an astronomy related question, then why not ask it here.? Hopefully we could then publish any answers the following month.

Any articles for publication would also be most welcome.

Regards
Jon Mathieson
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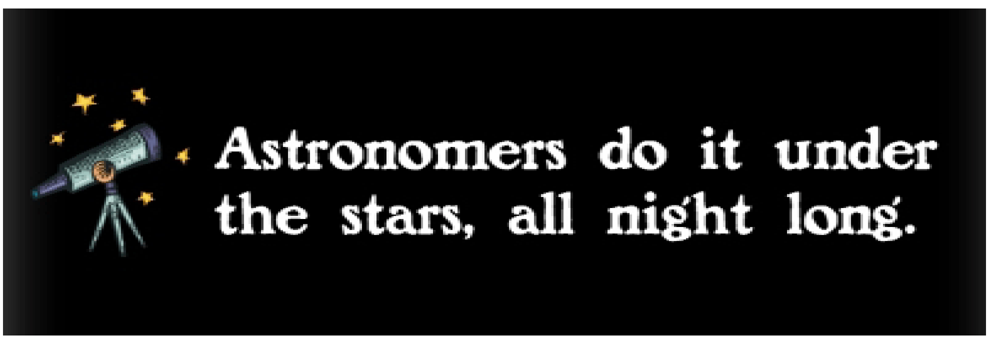


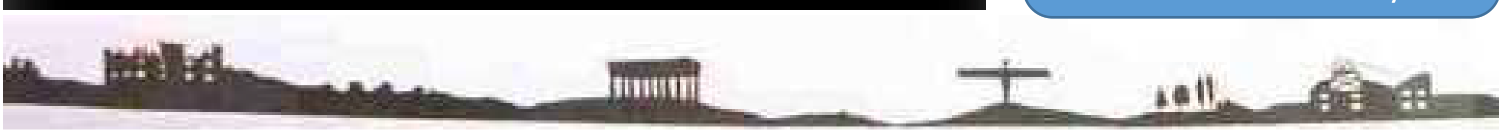
Member's Photos

The moon
Taken by: Jon Mathieson
Camera: Olympus EPL-1
Telescope: Celestron C8 SCT
Notes: Both Images were taken using simple eyepiece projection direct onto the CCD of the Camera, with the camera set to automatic.
(Just goes to show how easy modern DSLR camera's can make things)

Thomas Wright Trophy

Friday 17th October

The Bransden Room
Department of Physics
Durham University



Letters

In Ray Brown's article on pressure, in the June issue, he stated the well-known fact that a woman's stiletto heels exert a greater pressure on the ground than the feet of an elephant. This has reminded me of something I once read, written by a dim-witted journalist who didn't know the difference between force and pressure.

In 2009, as the 40th anniversary of Apollo 11 approached, that apology for a newspaper, the Daily Mirror, insisted on dredging up the whole "Moon landings were faked" conspiracy drivel yet again. (Note that I don't actually read that rag; the article was brought to the attention of Phil Plait, who commented on it on his Bad Astronomy blog.) Needless to say, I wrote to them, and told them in no uncertain terms what I thought of their irresponsible piece of garbage.

Most of it consisted of raking over the same old arguments, which have been comprehensively demolished many times over. (Some wit has coined a wonderful term for such arguments – Points Refuted A Thousand Times, or PRATTs.) but its author came up with one of his own, which I hadn't come across before – and which proved only his own ignorance of the most elementary physics.

As we all know, the astronauts' boots typically sank a few centimetres into the lunar regolith, leaving distinct footprints. This fellow's argument was along the lines of: "The Lunar Rovers, used on the last three missions, were far heavier than an astronaut, so why didn't they sink much deeper into the soil and get stuck?" (He actually claimed that the Rovers weighed ten tons; I can't imagine where he got *that* absurd bit of misinformation from! The mass of the entire Lunar Module was only 17 tons; for the record, that of the Rover was a mere 750 kg.)

He followed this with, "NASA will sigh wearily, as if trying to educate the dullest kid in class in the simplest physics" - well, there is a very good reason for that… because it *is* the simplest physics! – and claimed that they will tell you that "an astronaut's boot exerts a greater force on the ground than a large wheel", as if claiming that it's NASA who don't know their basic physics!

My response to this was as follows: "No-one has *ever* said that 'an astronaut's boot exerts a greater force on the ground than a large wheel', or any such thing. It does, however, exert a greater **pressure** – which is what determines the depth of tracks or footprints! The **force** which an object exerts on the ground is equal to its weight; the **pressure** is equal to the force divided by the **area** through which it acts. The four wheels of the Lunar Roving Vehicle, or Rover, had several times the area, in contact with the ground, of the soles of a pair of boots." (In the images of the landing sites taken by the Lunar Reconnaissance Orbiter, the rovers' wheel tracks are indeed less distinct than the trails of disturbed soil due to the astronauts' boots.)

I then responded to his claim about the weight of the Rovers: "For his information, the weight of the Rover was in fact about three quarters of a ton. That is, its weight on Earth was about 750 kg, so it weighed only 125 kg on the Moon. I should say that its **mass** was 750 kg – but as Mr. ... is apparently ignorant of even such elementary physics as the relation between force and pressure, I guess the distinction between mass and weight is also beyond him."

Neil Haggath

GETTING THERE BY GRAVITY ASSISTANCE

By Ray Brown

The rendezvous of space probe Rosetta with the comet 67P-Churyumov-Gerasimenko on 6th August 2014 was the impressive achievement of an awesome technological and scientific project. The 3000kg probe had to be launched and then powered, guided and controlled to draw alongside the comet, initially with a separation distance of only 100km, soon to be further decreased. The rendezvous took place at a distance from the Sun of more than twice the orbital radius of Mars as the comet hurtled towards its perihelion with the Sun (due to occur one year hence) at 5.5×10^4 km hr^{-1} (over 34000 mph) and steadily increasing.

The precise guidance of Rosetta towards the tryst seems to the layman a particularly formidable challenge when it is realised that sighting information from Rosetta would take some 22 minutes to reach the control centre on Earth and then any consequent information for course correction and speed adjustment would need a further 22 minutes to have effect. Imagine piloting an aircraft or driving your car when your reaction time is, at best, ¾ hour!

However the purpose of this little piece is to consider the means by which space probes are powered towards the outer reaches of the Solar *S*ystem. Energy must be supplied for a space vehicle to overcome the Earth's gravitational pull and then further energy is required to move against the gravitational field of the Sun.

The famous equation of Newton, which has appeared *ad nauseam* in my earlier articles, expresses the attractive force *F* between two point masses *m* and *M* separated by a distance *r.*

$$F = \frac{GmM}{r^2}$$

G is the Universal Gravitational constant which has the value

$$G = 6.7 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$$

A bit of simple maths allows us to deduce from this equation another equation which expresses the energy *E* needed to transfer a small mass *m* from a stationary initial position, a distance *r* from a large mass *M*, to a final stationary position at a distance *R* from *M*.

$$E = GmM(\frac{1}{r} - \frac{1}{R})$$

Clearly if *R* is infinite then this equation reduces to

$$E = \frac{GmM}{r}$$

We can plug into this equation values for the mass *M* and radius *r* of Earth together with the mass *m* of Rosetta in order to calculate the minimum amount of energy E_1 needed to launch Rosetta on a hypothetical first stage of its mission (i.e. to orbit the Sun following the Earth's path at a sufficiently large and constant distance from Earth so as to be essentially free from Earth's gravitational influence)

$$E_1 = 6.7\times10^{-11} \text{ x } 3000 \text{ x } 6\text{x}10^{24} / 6.37\text{x}10^6 = 1.89\text{x}10^{11} \text{ joules} = 5.2 \text{ x } 10^4 \text{ kw hr}$$

The *kinetic* energy of an body orbiting in a circle increases with the radius, so the first equation given above, which involves only *potential* energy terms, must be modified in order to calculate the *total* energy required to transfer a space vehicle of mass *m* from an inner orbit (radius *r*) to an outer orbit (radius *R*).

$$E = \frac{GmM}{2}(\frac{1}{r} - \frac{1}{R})$$

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Here M is the mass of the Sun. So E_2, the minimum amount of energy needed to take Rosetta from an Earth orbit to the outer circular orbit for its rendezvous with comet 67P would have been

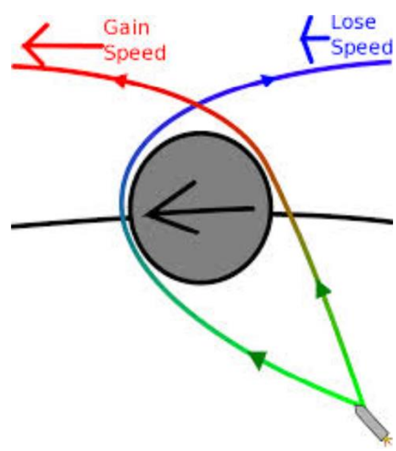
$$E_2 = 6.7\times10^{-11} \times 3000 \times 2\times10^{30} / [1/(2 \times 1.5\times10^{11}) - 1/(2 \times 5.7\times10^{11})] = 1.0\times10^{12} \text{ J}$$
$$= 2.8 \times 10^5 \text{ kw hr}$$

By comparing the values of E_1 and E_2 we see that the energy needed to get Rosetta clear of the Earth's gravitational field into an Earth orbit around the Sun is much smaller than that required subsequently to take it to a circular orbit at the distance from the Sun at which it eventually met up with Comet 67P. The launch from Earth was accomplished by means of an Ariane 5 two-stage rocket weighing 777 metric tonnes. And this was just the easy bit! How was the energy for the main part of the journey to be supplied? Bearing in mind that the 3 tonne payload of the Ariane was less than 0.5% of its total mass, it is clear that the energy content of the fuels carried and used by the rocket was vastly greater than our estimate of E_1 given above. Had it been necessary for Rosetta to rely solely upon rocket propulsion for its entire journey then the original launch would have been impractical and probably impossible as a result of huge increases in the amounts of propellant required. Of course the probe module does have its own booster rockets to permit course corrections and a final deceleration as it would approach comet 67P, but their size and propellant requirements are much less than those which would have been needed to take the craft to its outer orbit.

The solution is, with hindsight, embarrassingly obvious. Yet it was only in 1961, four years after Sputnik 1, that the method of gravity-assist, or slingshot, was proposed to accelerate a space vehicle using the kinetic energy of a planet it was passing by. It is based upon the long-established facts that
the Solar System is dynamic.
energy transfer between moving bodies is possible through gravitational interaction without any contact being required. In any elastic collision kinetic energy, as well as momentum, is conserved.
When a small body such as a probe is sufficiently close to a planet, the gravitational field exerted on it by the planet far exceeds and dominates the gravitational field of the Sun. Thus, when close to the planet, a probe will follow a hyperbolic path around the planet, much as a non-returning comet passes around the Sun.

Consequently both the speed and direction of travel of a space vehicle are affected by its proximity to a massive body. The speed and direction of the massive body are also affected, but to a much smaller, indeed imperceptible, extent.

The position-time profile (and therefore the velocity-time profile) *relative to the planet* following the periapsis is the mirror image of that before the periapsis. However, as the planet is itself moving in an orbit relative to the Sun, then the position-time profile (and velocity-time profile) of the probe *relative to the Sun* is *not* symmetrical before and after its encounter with the planet.



If, after the periapsis, the velocity vector ***V*** of the probe relative to the planet points in the same direction as the velocity vector ***U*** of the planet relative to the Sun more closely than it did before the periapsis, then the effect of the encounter will be to accelerate the speed of the probe within the Solar System. Conversely the probe will lose speed whenever that inequality is reversed.

Put more simply, the probe will accelerate if it flies with the planet and will decelerate if it flies in the opposite direction

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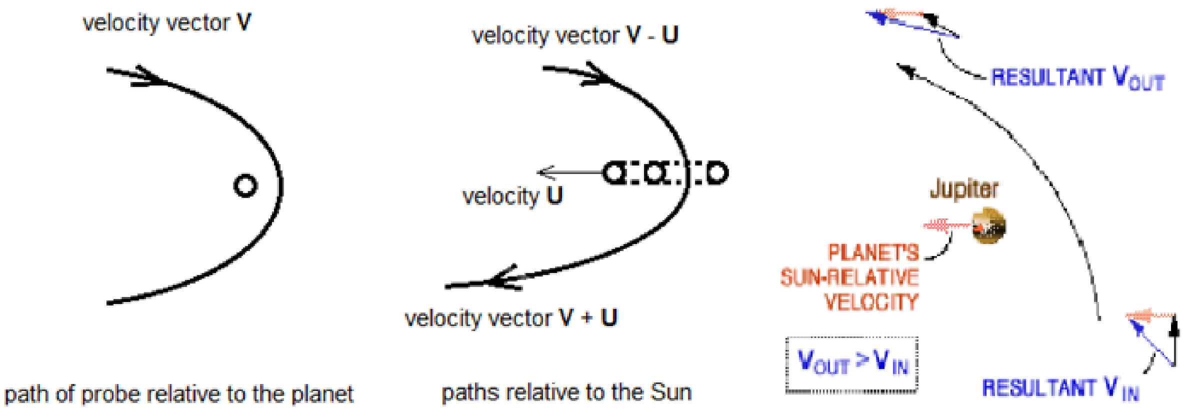
If that still sounds incomprehensible, we can use the analogy of another type of elastic collision. Imagine a tennis ball being driven at 30 mph directly into the path of an oncoming truck travelling at 60 mph. The speed of the ball, *relative to the truck* before impact is 30 + 60 = 90 mph. If the bounce off the front of the truck is fully elastic then the ball will rebound at 90 mph *relative to the truck*. But this is equivalent to 90 + 60 mph = 150 mph as witnessed by a bystander. The impact with the truck has increased the speed of the tennis ball from 30 mph to 150 mph. Kinetic energy has been transferred from the truck to the ball, but the loss in energy by the truck is such a small fraction of its total energy that its speed appears unaffected. In this example the ball and the truck collided head-on. More generally collisions are glancing, so the speed increase is smaller.

Returning to the probe and the planet



Here the interaction with the planet is seen to increase the speed of the probe, as well as changing the direction of flight. The increase is less (and normally much less) than twice the speed of the planet (2 x U). In effect each planetary encounter is intended to give the probe a shove on towards the next stage in its odyssey. Of course the whole process depends on there being a planet travelling in the right direction at the right time so, whilst the flight path based on gravity-assist propulsion is energy-efficient, it is highly indirect and so of long duration. The gravity-assist method requires that the entire flight scenario be mapped out in advance; crucial planning and complex calculations must be performed accurately and to sufficiently high precision so that the probe's booster motors can cope with any corrections *en route*.

An instructive video of the Rosetta flight path is available at
http://www.esa.int/Our_Activities/Space_Science/Rosetta/The_long_trek

This video shows us that the initial launch on 4th March 2004 sent Rosetta into an orbit slightly more eccentric than Earth's but with a similar period so that it swung first inside and later outside Earth's orbit before returning for the first slingshot, centred on its first birthday. This quite gentle shove increased both the period and eccentricity of Rosetta's second orbit of the Sun so that on 25th February 2007, early in its third orbit, it was able to receive its second accelerating slingshot, this time by passing within 250 km of Mars. This shove again increased the eccentricity, propelling Rosetta back towards Earth's orbit where its third gravity-assist (the second delivered by Earth) occurred on 13th November 2007, towards the end of its third orbit. As a result both the size and eccentricity of Rosetta's orbit were again increased. Towards the end of its fourth orbit, on 13th November 2009, Rosetta received its final and most powerful slingshot from Earth, sending it out on its fifth lap almost to the orbit of Jupiter before returning on a flight path which brought it gradually to coincide with the orbit of 67P, approaching from the inside of the orbit and from the rear of the comet.

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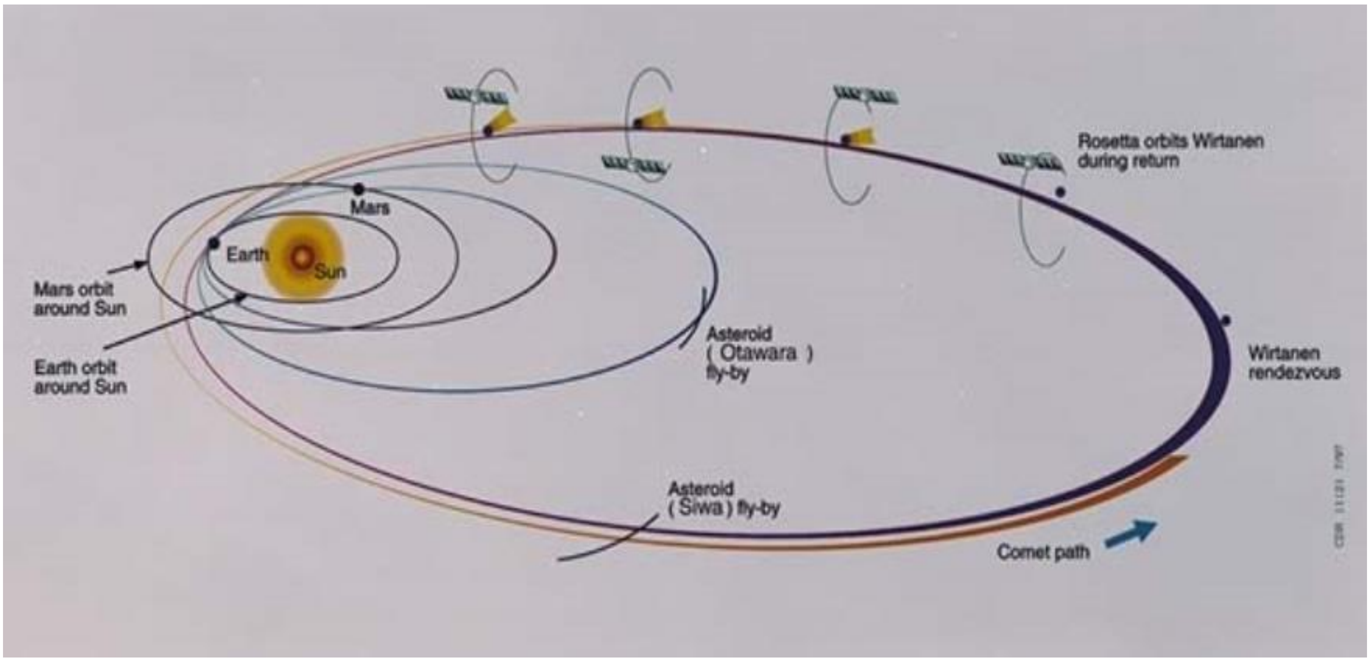
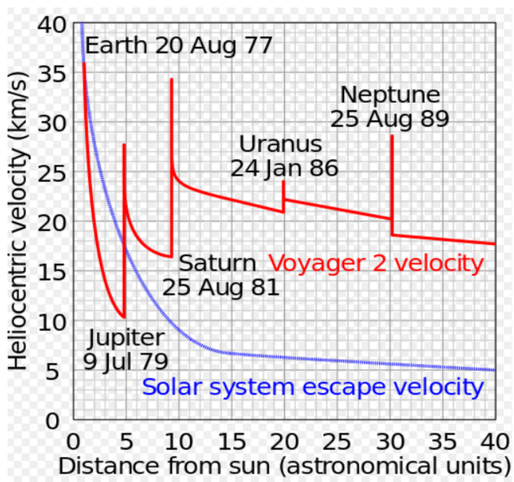


The ESA has to get maximum information value from their missions so, during the 4th and 5th orbits, it flew closely by two asteroids.

Of course Rosetta is not the first space probe to have used the gravity-assist method. The first was Mariner 10 in 1974 although, as its mission was to investigate the inner planets, the slingshot technique was used to decelerate the probe rather than to propel it.

Possibly the most notable examples of gravity-assisted propulsion were the Voyager 1 and Voyager 2 missions which exploited a highly fortunate arrangement of Jupiter and Saturn which will not recur until the mid-22nd century by employing those planets to provide the crucial slingshots to send Voyager eventually completely out of the Solar System. The graph shows that the velocity of Voyager 2 gradually decreased as it pulled away from the Sun but was boosted by its successive encounters with the outer planets, Jupiter and Saturn providing the most impressive slingshots.



The Oberth Effect: the booster rockets of a spacecraft are more effective in imparting acceleration the faster the craft is moving. For a given burn time, the boost force F is applied over a longer distance d when the speed of the craft is higher, so the energy E imparted to it ($E = F \times d$) is greater. The speed of a module undergoing gravity-assist by a planet is highest at the periapsis, so if it is intended to supplement the "natural" slingshot effect with a short rocket burn, then that is the time to use it most efficiently.

I wish to acknowledge my main source of information: the excellent account of the slingshot technique provided by Wikipedia http://en.wikipedia.org/wiki/Gravity_assist

The Transit Quiz

Every Answer starts with the letter “M”

1. The first star which was known to be variable.

2. A small constellation, named after a very small creature.

3. The body on which is found the highest cliff in the Solar System.

4. A major observatory, operated by the University of Texas.

5. The only feature on Venus named after a man!

6. The man who didn’t fly on Apollo 13.

7. A curved string of galaxies within the Virgo Cluster.

8. The man who discovered about half as many “Messier objects” as Messier himself.

9. The astronomer who discovered the variability of Algol.

10. The unofficial name given by astronaut Gus Grissom to his Gemini 3 spacecraft.

June’s Answers

1. The first American woman to go into space.
   The late Dr. Sally Ride.
2. The common name of Alpha Herculis.
   Rasalgethi.
3. A large emission nebula in Monoceros, composed of NGC2237, 2238 and 2239.
   The Rosette Nebula.
4. The term used to describe Solar System bodies which orbit in the “wrong”direction.
   Retrograde – i.e. those (usually small) bodies which orbit in the opposite direction to that of the orbits of the planets and of most planetary satellites. Some comets have retrograde orbits, as do several small satellites of Jupiter and Saturn, which are probably captured asteroids. The only large body with a retrograde orbit is Triton – probably as a result of some catastrophic event.
5. An amateur astronomer who built the world’s biggest telescope in 1845.
   Lord Rosse – more correctly, Sir William Parsons, Third Earl of Rosse (1800-67) who built the 72-inch reflector known as the Leviathan of Parsonstown, at Birr Castle in Ireland.
6. “The Father of Modern Astrophysics”.
   Henry Norris Russell (1877-1957).
7. The layer of loose pulverised material which covers the surface of the Moon.
   Regolith.
8. The Hubble Space Telescope uses this type of optics, a variation on the Cassegrain design.
   Ritchey-Chrétien.
9. A 17th Century astronomer who established the naming conventions for lunar features, which we are stuck with to this day.
   Father Giovanni Battista Riccioli (1598-1671).
10. The closest distance at which a satellite can orbit a planet, without being torn apart by tidal forces.
    The Roche Limit.

TASC

Teesside Astronomical Science Centre

Wynyard Planetarium & Observatory

Wynyard Planetarium & Observatory

Next Public Show:

Friday 5th September 2014

at 7:30p.m.

(Suitable for adults and children 6 years old and over)

Rosetta

Andromeda

Pleiades

What's Up?'

Explore the splendours of the universe. Find out what stars and planets are in the sky this month, and keep in touch with any special events. Plus: An update on Cassini and Rosetta space probes.

Public Show Charges apply at: £5.00 per adult, £3.00 per child/concession and £13.00 per family (2 adults & 2 children). Please call the Planetarium on (01740) 630544 for further information or to book seats. The Planetarium is accessible to wheelchair users.

The Wynyard Planetarium & Observatory is a joint venture between the Teesside Astronomical Science Centre and the Cleveland and Darlington Astronomical Society, supported by the Durham Astronomical Society. Providing information, education & entertainment in space and science on Teesside and across the northeast.

Cleveland & Darlington Astronomical Society

Durham Astronomical Society

Tel: **(01740) 630544**
e-mail: **info@wynyard-planetarium.net**
web: **www.wynyard-planetarium.net**

Wynyard Woodland Park

Cleveland and Darlington Astronomical Society

Meeting Calendar
2014-2015

12th September 2014	**Future Extremely Large Telescopes** Prof. Richard Myers of Durham University
10th October 2014	**The Decay of the Universe** Prof. Ruth Gregory of Durham University
14th November 2014	Title to be confirmed Dr. Tim Roberts of Durham University
12th December 2014	**Atmospheric Optics** Dave Newton of Sunderland Astronomical Society
9th January 2015	**Your First Telescope** Dr Jurgen Schmoll, CaDAS Chairman
13th February 2015	**Astrophotography** Keith Johnson, CaDAS
13th March 2015	Title to be confirmed Gary Fildes of Kielder Observatory
10th April 2015	Title to be confirmed To be confirmed
8th May 2015	Title to be confirmed Paul Money FRAS, FBIS
12th June 2015	**CaDAS Annual General Meeting and Social Evening** Venue to be confirmed

All meetings are held at the Wynyard Planetarium (with the exception of the AGM).
Doors Open at 19:15 for a 19:30 start