Sagittarius

The Newsletter of the Astronomy Section of La Société Guernesiaise

January – March 2010

Forthcoming Events

Observatory

Observatory is now operational!

Annual Business Meeting

early February - tba

WEA Course

Thursdays 8.00 pm at the Observatory

11th February – 18th March

La Société Guernesiaise Junior Section

Friday 26th February
6.45 pm at the Observatory

In addition, the Section meets at the Observatory every Tuesday evening, and Friday if clear for observing.

Inside

Inserts

Star chart

Sunset, sunrise, moonset and moonrise times

Section News

We are pleased to announce that the Observatory is fully operational following necessary building works to the main building. The building has been completely refurbished and is now in tip top condition and our thanks go to our landlord for undertaking this.

We have a busy few months with a large number of group visits (note particularly the Société Junior Section on 26th February at 6.45 pm) as well as the annual WEA Star Gazing course running on Thursday evenings from 11th February until 18th March.

Currently there is no date set for the Annual Business Meeting but it is likely to be early February as visits allow.

Colin Spicer

International Year of Astronomy, 2009

The International Year of Astronomy, 2009, has come to a conclusion. Building works at the Observatory forced it to close for many months, so the Astronomy Section could only mark the year in a limited way. Public open evenings and some group visits had to be cancelled, and the Foucault pendulum at the Town Church had to be suspended (excuse the pun!) because of building works there. Nevertheless we did run a number of events. We accommodated Houguette School children, a scout group, a Vale wives group, and a class of Elizabeth College students studying optics. We hosted the visit of Cambridge astronomical historian Dr Michael Hoskin, and, following his public lecture, showed telescopic views of Saturn and the Moon. There was a lecture about black holes by Dr David Falla, and we ran the annual WEA course.

There were also several activities beyond our own premises. We made several broadcasts on BBC Guernsey, especially about the 40th anniversary of the Moon landing which included a televised interview. I was invited to speak to groups at Galaad Methodist Church, St Peter's Church, Torteval Church, and the Mare de Carteret WI. I also made presentations to school assemblies at the Ladies' College, St Sampson's High (twice), Melrose, and St Andrew's Primary. And, at the request of the Houguette School PTA, I laid out a new analemmatic sundial (human shadow clock) in the playground.

So, despite not having an Observatory base for much of the year, we still managed to mark the 400th anniversary of the telescope in an appropriate way.

David Le Conte

Astronomical Events in 2010

Mars reaches opposition, the Perseid meteor shower makes a favourable appearance, and there should be a good binocular comet this year.

PLANETS

The dates of maximum elongations of **Mercury** are as follows. It can usually be seen about ten days before and after these dates. The best time to observe it will be the first week of April.

27 January	Morning
08 April	Evening
26 May	Morning
07 August	Evening
19 September	Morning
01 December	Evening

Venus will appear as the 'Evening Star' in the western sky in April, and will be visible for the next few months, reaching greatest eastern elongation on 20 August. It will achieve maximum brilliance a month later, on 23 September (magnitude -4.5). However, by then it will have moved rapidly south, and its low declination will place it too near the horizon for observation after sunset. It will not then be seen until early November, when it will dramatically reappear before dawn in the south-east, reinvented as the 'Morning Star' until March next year.

Mars will be the planet of most interest to observers at the beginning of the year, as it will reach opposition in the constellation Cancer on 29 January. It will then shine at magnitude -1.3, have an angular diameter of 14 arc-seconds, a distance of 62 million miles (99 million km), and will be visible all night. Although not anything like as close as it can be, its high declination (+22°) makes it well-placed for observation high in the sky, and a good subject for the Observatory's WEA course. The last Martian opposition was in December 2007, and the next will be in March 2012. The next reasonably close one will not be until July 2018. This year it will remain visible, although getting fainter, in the evening sky until June, passing within a degree of Regulus on the nights of 6 / 7 June. For a couple of days around 16 April it will be close (1°) to the Beehive Cluster.

Jupiter has enhanced the evening sky for many months, but now we are losing it as it moves behind the Sun. We will have to wait until May to see it again, and then in the morning sky, in the south-east before dawn. It will reach opposition on 21 September, when it will shine all night at magnitude -3. It will then remain as a prominent evening object for the remainder of the year. Transit, shadow and occultation events involving Jupiter's moons will be found on the Sky and Telescope website (see www.skyandtelescope.com/observing/objects/planets/3307071.html?page=2&c=y), or simulated on software such as Starry Night (www.starrynightstore.com).

Saturn will initially be visible in the morning sky. It will soon rise earlier and earlier, reaching opposition in Leo on 22 March, the rings starting to open again. It will then be visible in the evening until July, remaining in Virgo all the time.

Uranus will be at opposition in Pisces on 21 September at magnitude 5.7. **Neptune** will be at opposition in Capricornus on 20 August at magnitude 8.

DWARF PLANETS

Pluto reaches opposition in Sagittarius on 25 June, at magnitude 14. **Ceres** reaches opposition on 18 June, also in Sagittarius, at magnitude 7. The other three dwarf planets (Eris, Makemake and Haumea) are too faint to be seen in most amateur telescopes.

ASTEROIDS

The brightest asteroid, **Vesta**, at magnitude 6, is at opposition on 20 February in the head of Leo. NASA's Dawn probe is due to arrive at Vesta in August 2011, and Ceres in 2015.

ECLIPSES

Last year was not a good one for Guernsey eclipses, and this year is not much better. The best we can look forward to is a rather poor total lunar eclipse on the morning of 21 December. The Moon will start entering the penumbra of the Earth's shadow at 05.32. The interesting part starts at 06.32, when the partial phase will start, with the Moon entering the umbra, being totally eclipsed at 07.40. Unfortunately, it will then be just 3° above the western horizon, and the Sun will be about to rise, at 08.04, the Moon setting just afterwards, at 08.11. So the total phase of the eclipse, as seen from Guernsey, will be very short-lived. Totality actually ends at 08.53, but the Moon will by then be well below the horizon, and the Sun well above it.

On 15 January there will be an annular solar eclipse, passing across Africa, southern India, northern Sri Lanka, Burma, and ending in China.

On 26 June a partial lunar eclipse will be visible from the Americas, the Pacific Ocean and Australasia.

On 11 July a total solar eclipse crosses the south Pacific.

OCCULTATIONS AND CONJUNCTIONS

There are no lunar occultations of note this year.

The following are planetary conjunctions, 3° or closer:

17 February	Venus and Jupiter (0.5°)
08 August	Venus and Saturn (3°)
20 August	Venus and Mars (2°)
14 December	Mercury and Mars (1°)

and conjunctions of the planets with the Moon, 3° or closer:

15 April	Mercury (1°)
16 May	Venus (0.1°)
12 August	Mercury (2°)
11 September	Venus (0.3°)
05 November	Venus (0.2°)
07 December	Mercury (2°)

and:

15-17 April	Mars and Beehive Cluster
06-07 June	Mars and Regulus
08-09 October	Comet Hartley and the Double Cluster

METEORS

The **Quadrantids** shower peaks on 03 January, with up to 80 per hour but the maximum is shortly after Full Moon and so not very favourable. Conditions for the **Perseids**, however, are excellent, as their peak on 12 August, is just two days after New Moon. The **Leonids** peak on 17 November, but will be badly affected by the bright Moon. The **Geminids** peak on the morning of 14 December, with up to 100 per hour, after the first-quarter Moon has set.

COMETS

Comet predictions for 2010 are available at the excellent website of the British Astronomical Association's Comet Section (www.ast.cam.ac.uk/~jds/preds10.pdf). The highlights should be: **Wild** (81P) in the spring, **McNaught** (2009R1) in June, and **Hartley** (103P) in the autumn. None of these will be very bright, but should be visible in binoculars or just naked-eye visibility. The best is likely to be periodic Comet Hartley, which may reach magnitude 5 in October, when it comes within 11 million miles of the Earth. On 08/09 October it will pass the Double Cluster. NASA's *Deep Impact* spacecraft (now renamed *Epoxi*) is to fly past it on 04 November. Check the www.heavens-above.com for star charts showing comet positions. It is, of course, always possible that a new comet may make an unexpected bright appearance.

THE SUN

Solar activity is expected to increase as the Sun heads towards solar maximum in 2013. During 2010 the sunspot number is predicted to change from 20 to almost 90. Updates are available at www.ips.gov.au/Solar/1/6.

EQUINOXES AND SOLSTICES

The following are the dates and times of the equinoxes and solstices in 2010:

Vernal Equinox	20 March	17.32 UT
Summer Solstice	21 June	12.28 BST
Autumnal Equinox	23 September	04.09 BST
Winter Solstice	21 December	23.38 UT

SATELLITES

The International Space Station is regularly visible from Guernsey. Also of interest are flashes from the Iridium satellites, and periodic launches of the Space Shuttle. Many other, fainter, satellites appear every night. Details of the times and directions of visibility (together with sky charts and much more) can be obtained from www.heavens-above.com website.

WEA COURSE

The Astronomy Section is again running its annual six-week "Star Gazing" course at the Observatory in February and March. It runs on Thursdays from 8.00 to 10.00 pm, starting on 11 February. At the time of writing (early December 2009) there are still a few spaces available. Enrolment is through the Workers Education Association (www.wea.org.gg).

OPEN DAYS
The Observatory will be open again on a number of Tuesday evenings during the year. Details will appear in the Astronomy Section newsletters, and on the website.

David Le Conte

References

SkyMap Pro and *Starry Night Pro* software
RAS diary
BAA Comet Section
Astronomy magazine

CALENDAR OF ASTRONOMICAL EVENTS

Month	Date	Time	Event
January		Morning	Saturn visible
January	03		Quadrantid meteor shower (unfavourable)
January	15		Conjunction of Venus and the Moon
January	15		Annular solar eclipse (not from Guernsey)
January	27	Morning	Mercury at greatest elongation
January	29		Mars at opposition
February	11	20.00 UT	WEA course starts
February	17	Evening	Conjunction of Venus and Jupiter
February	20		Vesta at opposition
March	18	20.00 UT	WEA course – final class
March	20	17.32 UT	Vernal Equinox
March	22		Saturn at opposition
March	28	01.00 UT	BST starts
April		Evening	Venus appears as the ‘Evening Star’
April		All night	Comet Wild (81P) visible
April	08	Evening	Mercury at greatest elongation
April	15	Evening	Mercury conjuction with the Moon
April	15-17	Evening	Conjunction of Mars with Beehive Cluster
May		Morning	Jupiter reappears
May	16	Evening	Venus conjunction with the Moon
May	26	Morning	Mercury at greatest elongation
June			Comet McNaught (2009R1) visible
June	06-07	Evening	Conjunction of Mars and Regulus
June	18		Ceres at opposition
June	21	12.28 BST	Summer Solstice
June	25		Pluto at opposition
July			Saturn disappears
July	11		Total solar eclipse (not from Guernsey)
August	07	Evening	Mercury at greatest eastern elongation
August	08	Evening	Conjunction of Venus and Saturn
August	12		Perseid meteor shower (favourable)
August	12	Evening	Conjunction of Mercury with the Moon
August	20	Evening	Conjunction of Venus and Mars

August	20		Neptune at opposition
August	20	Evening	Venus at greatest eastern elongation
September		Evening	Venus disappears
September	11	Evening	Conjunction of Venus and the Moon
September	19	Morning	Mercury at greatest elongation
September	21		Jupiter at opposition
September	23	Evening	Venus at maximum brilliance (mag -4.5)
September	21		Uranus at opposition
September	23	04.09 BST	Autumnal Equinox
October		Evening	Comet Hartley visible
November		Morning	Venus reappears
November	05	Morning	Conjunction of Venus and the Moon
November	07	Evening	Conjunction of Mercury with the Moon
November	17		Leonid meteor shower (unfavourable)
December	01	Evening	Mercury maximum elongation
December	13		Geminid meteor shower (favourable)
December	14	Evening	Conjunction of Mercury and Mars
December	21	06.32-08.11 UT	Total lunar eclipse
December	21	23.38 UT	Winter Solstice

Light, Gravity and Black Holes

Before we even begin to think about black holes we have to consider the nature of light and the effect that gravity has upon it.

Regarding the nature of light, there is one great question which has remained for at least two centuries: does light consist of particles or is it wave-like in nature? Sir Isaac Newton, as shown in his famous treatise 'Opticks' (1704), believed that a beam of light consisted of a stream of minute material particles, or 'corpuscles', which was an apparently commonsense view based on the fact that light travels in straight lines. Its actual speed (c) of travel had been measured in 1676 by Ole Romer, from observations of Jupiter. Later, in the eighteenth century, Thomas Young and Christiaan Huygens provided evidence which advanced the alternative theory, that light is wave-like in nature: this could be deduced from the results of optical experiments which showed that it could be diffracted and could also show the phenomenon of interference, when one wavetrain interacts with another. The wave properties of light had remained unknown until it was realised that light has a very short wavelength (about one half of a thousandth of a millimetre), which means that these properties do not normally show up when light interacts with objects on an everyday scale; in practice, special optical experiments have to be devised in the physics laboratory.

In 1900, Max Planck proposed that light is made up of small packets of energy, or 'quanta'. Each quantum carries an energy hf where f is the frequency of the light (related simply to its wavelength) and h became known as Planck's Constant. It was natural to assume that these packets of energy were associated with some kind of particle, which later became known as the 'photon'. This idea was further advanced by Albert Einstein (1905) in his theory of the photoelectric effect, which is shown by light when it interacts with electrons in solid materials.

The dilemma of 'particles versus waves' cannot easily be resolved. We could try to approach the problem in a simple-minded way, by thinking of light in terms of a wavetrain in which energy is carried in the form of a 'wave packet' which exists only over a limited region of space: it could look something like:

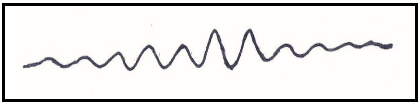

Figure 1: Wavepacket

which resembles a simple wave in some respects but, if the packet were sufficiently short, would also show an important property associated more with particles, namely that its energy is localised to a small region of space. Unfortunately, this does not give a full representation of the properties of the photon which, as later experiments showed, is more of an enigma than was first supposed.

The next historic step was also taken by Einstein, in his Special Theory of Relativity (1905), in which he proposed the relationship between energy and mass, as expressed in the famous equation $E = mc^2$. Applied to photons of light, this means that a photon of energy E (given by $E = hf$) should have a mass associated with it: this mass is obtained by putting together the two foregoing formulae for E, to give the result that a photon for which the frequency is f has a mass hf/c^2. Our conclusion from this is therefore that photons, which carry mass, are inevitably affected by the force that affects all masses in the Universe, and that force is gravity.

Newton's Universal Law of Gravity, which includes the well-known inverse-square law, states that the attractive force F between any two masses, $m(1)$ and $m(2)$, is given by the equation $F = m(l) \,.\, m(2) \,.\, G/r^2$, where r is the distance between them and G is the universal constant of gravitation. Newton also put forward, in 'Opticks', an important further concept, which is expressed there as 'Query I': ***"Do not Bodies act upon light at a distance, and by their action bend its Rays, and is not this action (other things being equal) strongest at the least distance?"*** It was much later (1916) that Einstein put forward his General Theory of Relativity (GTR), which is essentially a theory of gravity (ie an explanation, more than a description expressed in a Law), explaining how a mass can cause distortion of the space in which it is located, and that it is this distortion which causes other masses in the vicinity to experience 'the force of gravity'. Since the force of gravity is very weak, a very large mass would be required for its effect on light, which has photons of very small mass, to be detectable. Such a large mass is the Sun, which could perhaps affect light in the way that the GTR predicted. Physicists therefore looked to astronomers, not only to suggest, but also to carry out, observations that would demonstrate the effect of gravity on light.

By great good fortune, a total eclipse of the Sun was due to take place on 29th May 1919. In a total eclipse it would be possible to view stars close to the edge of the Sun's disc, which would be shaded by the Moon from direct view; so the stars' positions in the sky could be measured and compared with their normal positions in the absence of the Sun from that field of view. Again by great good fortune, the Sun at the forecast time of the eclipse would be in the constellation of the Hyades, which contains a rich field of suitable stars. Sir Arthur Eddington organised an expedition, sponsored by the Royal Astronomical Society, to the island of Principe, in the Gulf of Guinea off the west coast of Africa, which would be in the line of totality; a second expedition was at the same time sent to Sobral in Northern Brazil, also suitable in that respect. Several months after the observations were made - a delay inevitably caused by the poor speed of communication in those days - the results on the measured stellar positions were compared and found to be consistent and in good agreement with those predicted by Einstein's GTR. The angle (***a***) of deflection of the light, caused by the Sun's gravity was just 1.74 seconds of arc (Figure 2).

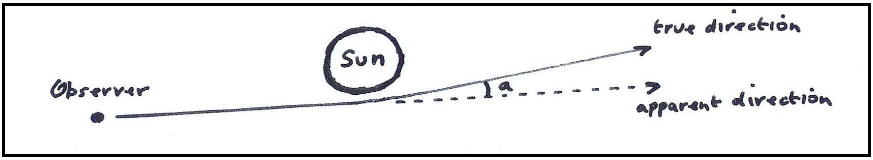

Figure 2: Light deflected by the Sun's mass.

The result was a triumph for Einstein's Theory. Even the popular press showed an interest, with the 'Daily Herald' of the day displaying the headline, 'Light caught bending' (!)

Gravity can also affect photons of light emitted vertically from the surface of a massive stellar body such as the Sun, causing them to lose energy as they ascend through the body's gravitational field. This situation is rather similar to that of a rocket being launched from the Earth's surface, and which requires a certain critical velocity, the 'escape velocity', to be propelled into space, eventually to free itself from the Earth's gravitational attraction. For the Earth, the escape velocity is well known to be 11 km/sec; but it can be calculated for any planet or planetary satellite and for the Moon, for example, it is only 2.5 km/sec.

The escape velocity is dependent on the ratio M/R, where M is the mass of the planet and R its radius. The interesting question that now arises is, could the ratio M/R be so large that the escape velocity exceeds the velocity of light itself? This question was considered in the eighteenth century by the Revd John Michell and by the French mathematician Pierre Laplace. The conclusion drawn by Laplace (1798) has been well expressed by him as follows:

"A luminous body in the Universe of the same density as the Earth, whose density is 250 times larger than the Sun, can, by its attractive power, prevent its light rays from reaching us. Consequently, the largest bodies in the Universe could remain completely invisible".

In rather different terms, Michell (1783) concluded that a body with the same density as the Sun, but with 500 times its radius (that is, with radius about 4 AU), would have the effect of preventing the light emitted from its surface arriving at us so "we could have no information [about them] from sight".

Both of the above similar predictions of the existence of objects which we now call 'black holes' were based on Newton's original idea that light consisted of material corpuscles, that is material particles which could be treated by the same laws of physics that apply to rockets. Photons are not, however, like material particles. When a photon loses energy it cannot slow down because it always travels with the same speed, c; instead, it loses energy by increasing its wavelength (which is the same as decreasing its frequency, because its energy is hf). When a photon emitted from a massive luminous source of radiation like the Sun ascends through the gravitational field of the source it therefore experiences a 'gravitational redshift' (a shift to longer wavelength, that is lower frequency). The exact amount of this redshift for any particular source can be calculated, as a further result of Einstein's GTR. For the Sun, the redshift is about 2 parts per million of the original wavelength of emission; while for radiation emitted from the Earth's surface it is only about a billionth part of that amount. It seems almost incredible that this latter minute redshift was actually measured, in an experiment at Princeton in 1960, using a technique derived from a discovery by the Russian physicist Mossbauer in 1956.

With the idea having been accepted, through experimental verification, that a photon can lose energy by gravitational redshift, it could be argued that in certain circumstances a photon might lose all of its energy. In such circumstances, where the ratio M/R, as previously mentioned, exceeds a certain critical value, again derivable from GTR, a black hole could be formed. It turns out that this critical value of M/R is equal to $c^2/2G$, where G is again the constant of gravitation. Rather remarkably, this is the same formula as that derived from classical physics, and as used by

Michell and by Laplace, nearly two centuries earlier.

The equation $M/R = c^2/2G$ has important consequences, for it suggests that any object of mass M could, in principle, form a black hole if its radius were sufficiently small. Closer inspection of the equation, however, shows that for objects with small mass M, such as we might encounter every day, the critical radius would require an impossibly large density. Black holes are more likely to be found, beyond the Earth in the wider Universe, by astronomical observation. In general, the critical radius required for black hole formation is given by simple rearrangement of the foregoing equation, to give $R = 2MG/c^2$, referred to as the Schwarzschild radius and denoted by R_S. There is a useful formula for R_S that can now be derived: $R_S = 3(M/M_0)$ km, where M_0 is the solar mass. For the Sun, R_S is therefore just 3 km; while for the Earth, if it could be compressed sufficiently, it is only 9 mm.

We can easily imagine how a black hole might be formed. Suppose that a star is unable to prevent itself from collapsing under the inward force of its own gravity, which is a situation that could arise when it has come to the end of the series of thermonuclear processes which have generated its internal energy. In the 'implosion' of the star, successive shells of material fall inwards towards its centre. Figure 3 shows a partial view, diametrically across the centre of the collapsing star.

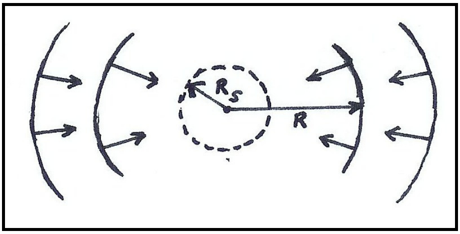

Figure 3: Collapsing Star

When the radius R of an inner shell becomes less than the Schwarzschild radius R_S for the mass of stellar material within the shell, light can no longer emerge from that inner region and a black hole is produced. The critical radius R_S, within which the material disappears, defines what is termed the 'event horizon', from beyond which no knowledge of further events can be extracted.

The astronomical objects most likely to form black holes are the compact remnants of stars at the end of their evolutionary process. There are several different types of stellar remnant, depending on the mass of the star as it attains its final state. For a star with a mass less than $1.4\ M_0$, the Chandrasekhar limit, a white dwarf star is formed. A white dwarf is composed of high-density (about one tonne per cubic centimetre) material and is maintained in a stable state by the internal pressure provided by the electrons trapped within the system. Above that limit, for stars with greater mass, a supernova could occur and produce a neutron star as a final state. Neutron stars have a density even greater than that of white dwarves, and in them the internal pressure is provided by the neutrons which, although they are elementary particles of a quite different type, resemble electrons in this important respect. Neutron stars can be stable for stellar masses up to about $3\ M_0$. For a star above that mass, there is no mechanism at present known whereby it can retain its stability. It is generally believed that it will inevitably collapse under the inward force of its own gravity, to form a black hole.

Because there are many stars, in our own Galaxy and beyond, that have such large masses, black holes must be quite common objects in the Universe. It has been estimated that if all stars with mass greater than $8\ M_0$ end up as black holes then there could be as many as 100 million of them in our Galaxy alone. Black holes, even though invisible from the time of their formation, continue to exert a gravitational influence on their surroundings. They also contribute to the total mass of the astronomical system in which they lie, and they could make a contribution to the well-established 'missing mass' within galaxies. (It has generally been concluded, however, that the solution of the larger problem of 'dark matter' in the Universe will most probably be found elsewhere).

How can black holes possibly be discovered when, by definition, they cannot be seen? Fortunately, the ubiquitous force of gravity, which is responsible for the formation of black holes in the first place, also enables us to detect them. Consider a single black hole surrounded by interstellar gas. This gas will be drawn by the force of gravity towards the black hole, in a process of 'accretion'. As it falls inwards the accreted gas becomes denser, and it also becomes hotter, and can attain a temperature in excess of 100 million degrees Celsius, at which it can radiate X-rays. Before the gas reaches the event horizon and disappears 'down the stellar plughole', it can radiate some of this X radiation outwards, giving rise to an X-ray star.

In the case of a stellar binary system where one member of the binary evolves to form a black hole, the black hole can in some circumstances accrete material from the atmosphere of its stellar companion. The life history of a binary-star system, with two stars having different masses, which then evolve at different rates, can be formidably complex, but at some epoch of that history circumstances could favour the process of accretion on to a black hole, with the formation of an X-ray star, as described.

A further important aspect of binary stars is that the stellar masses can be obtained by the application of dynamics to observations of the motion of the two components. The most noteworthy example of a black hole discovered by this means is Cygnus XR 1 (the first X-ray star to be discovered in the constellation of Cygnus), where the calculations showed that the star emitting the X-radiation had a mass between $6\ M_0$ and $10\ M_0$, which supported its identification as a black hole.

There is another and quite different type of black hole, which is not the final state of an individual star**;** sometimes referred to as 'supermassive black holes', these take the form of massive concentrations of material at the centres of galaxies. Infrared astronomy has revealed that an extensive and complex region of great activity exists around the centre of our Galaxy. The association of a large mass with this innermost Galactic region (its 'nucleus') follows from a further application of dynamics. The method employed to obtain this result can be illustrated by the Solar System, where the Earth is gravitationally bound in its orbit by the Sun. If the Earth (E) moves with a speed v around a (presumed circular) orbit of radius r (see Figure 4), a simple formula $M = r \,.\, v^2/G$ for the solar mass can be derived; and since $r = 1\ AU$ (150 million kilometres) and $v = 30$ ***km/sec***, obtained simply from the figure for r and the length of the year in seconds, M can be calculated.

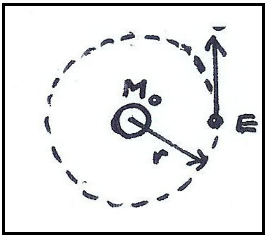

Figure 4: Orbital velocity around centre of mass.

Imagine now that the Solar System is being viewed by an observer from far beyond its furthermost limit. The Earth would then be seen as some kind of satellite (probably without any obviously special characteristics) moving with speed v at a distance r from a centre of gravitational attraction, both of which could be measured by that distant observer. From the same formula, quoted above, the mass at the centre of attraction, which we ourselves know from closer acquaintance to be the Sun, could then be calculated. Exactly the same method can be used to estimate the mass at the centre of our Galaxy.

In the direction of the Galactic Centre, in the constellation of Sagittarius, infrared astronomy has shown that the complex innermost region includes a ring of material 2.6 light years in diameter and circulating with a speed of about 150 km/sec. Application of the same dynamical formula already quoted gives the result that the central mass providing the required gravitational attraction is approximately two million times M_0. Strictly speaking, this is the estimated mass located within the confines of the gaseous ring, but it is tempting to suggest that the mass could be in the form of a supermassive black hole.

Similarly, in the case of the Seyfert galaxy NGC 4151, material moving with a speed measured to be about 3,000 km/sec has been observed in the galactic nucleus, which has a diameter of about 20 light years. Again, the mass required for the gravitational containment of this material within the nucleus can be calculated, and in this case is found to be about a billion times M_0. (A Seyfert galaxy is a type of galaxy with a small bright nucleus. It is thought that quasars, or 'quasi-stellar objects', represent an extreme example of this general type, but are so distant that only their small bright nuclei can be seen.)

The actual size of a black hole with mass of a billion times M can be calculated to be about 3,000 times the radius of the Sun, or 13.5 AU, which is rather larger than the radius of Saturn's orbit. If such a supermassive black hole does exist in the nucleus of NGC 4151 then it must lie deep within the galactic nucleus, which has a radius 50,000 times greater than that of the hypothetical black hole at its centre.

Finally, we refer briefly to the possible existence of black holes of intermediate mass, that is with mass between that of individual stars and that of the hypothetical supermassive black holes at the centres of galaxies. It has been suggested that these black holes, which could have masses of the order of 10,000 times M_0 , may lie in certain globular clusters, for example G1 in the Andromeda Galaxy M31.

As we have seen, evidence for the existence of black holes has come mainly from the application of physics to systems that we observe in astronomy. One of the most remarkable features of astrophysics is that our knowledge of physics, acquired on that speck of the Universe that is the Earth, can be applied quite generally to systems in the wider Universe, to gain some (but never complete) understanding of them.

Astrophysicists regard their subject, however, as more than just a branch of applied physics; for they hope that the study of some of the more exotic objects in the Universe might yield fresh insights into the properties of matter in extreme conditions. Matter in a state of density greater than we can imagine must surely exist within black holes, but it will forever remain beyond the reach of our observations. 'Seeing is believing', as the old saying goes, but although we cannot see black holes directly, most of us are by now fairly well convinced of their existence.

David Falla.

Geoff Falla’s regular roundup of articles from popular Astronomy and Space Journals

NASA's Giant Leap back to the Moon. Two lunar spacecraft were launched on 18th June 2009, in preparation for a return to future manned missions. The spacecraft are a lunar reconnaisance orbiter, to survey the Moon for future landing sites and a base, and a lunar crater impactor and observation satellite, to study the effects of an impact in the Moon's south polar region - a chosen site for the location of water ice. (Astronomy Now, October 2009)

The New Habitable Zones. It is now known that microbial life and other organisms can thrive in the most extreme environments of heat and cold. Astrobiologists now consider that it is not only Sun-like stars which can provide suitable conditions for planetary life. Habitable zones around red dwarf stars and those hotter than the Sun are no longer being dismissed. (Sky and Telescope, October 2009)

Prelude to Disaster. The RS Ophiuchi binary star system is one of a number found to be producing recurrent nova outbursts of major brightening. The most recent of these events was observed in 2006, and it is thought that a much larger stellar explosion may come soon. (Sky and Telescope, October 2009)

The Great 2012 Scare. A summary of some previous end of the world predictions, and the forthcoming one being linked to the date of 21st December 2012. For the Mayan civilisation, who kept a highly accurate calendar, this date marks the end of a cycle of time, each lasting several centuries. The current prediction has been linked with planetary alignments, but it seems that there are no such alignments due at the end of 2012. (Sky and Telescope, November 2009)

Real Potential Disasters. Almost all of the near Earth asteroids which may have posed a threat to the planet have now been identified, but there are other dangers. These include the potential supervolcano under North America's Yellowstone National Park, a possible major tidal wave in the Atlantic, and with a marked decline in Earth's magnetic field being noted in recent years, a magnetic reversal could also be a serious disruption for civilisation. (Sky and Telescope, November 2009)

Exoplanets - an update of discoveries. In the past 15 years, evidence has been found of almost 400 planets in orbit around other stars, from the first discovery in the constellation of Pegasus in 1995. A summary of some of the most interesting findings so far, including multi-planet systems - confirming that our solar system may be far from unique. (Astronomy Now, November 2009)

Water found on the Moon. In what has been announced as being the most important astronomical discovery in recent years, and overturning current ideas, the latest lunar spacecraft findings have revealed that there is widespread water embedded just below the surface of the Moon. Details of this discovery will become of particular importance in establishing a lunar base. (Astronomy Now, November 2009)

Mid-Latitude Ice on Mars. NASA's Mars Reconnaissance Orbiter has revealed that recent meteorite impacts forming small craters at mid-latitudes have uncovered ice, at just a few feet below the surface. It is now thought that the 1976 Viking lander would have also found ice if it had dug just a few inches deeper. (Astronomy & Space, December 2009)

La Société Guernesiaise Junior Section

Friday 26th February
6.45 pm at the Observatory

The Astronomy Section will be holding an open evening for the junior members of La Société Guernesiaise on Friday 26th February 2010 at the Observatory at La Rue du Lorier, St Peters, starting at 6.45 - 7pm. Weather permitting we shall be able to view the Moon and the planet Mars, together with a variety of nebulae and star clusters. We have some small telescopes which will be available for visitors to find stellar objects for themselves. This is not always as easy as it may seem, but we hope that you will have fun trying. The members of the Astronomy Section will be available to point out various naked eye objects and the distinct constellations of the winter skies as well as answer any questions you may have. If you have binoculars, please bring them along as there is a wealth of binocular objects to be seen and we shall be happy to take you on a binocular tour of the skies.

If you would like any information about the open evening, or the Observatory in general, please contact Mrs Debby Quertier on 725760.

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