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Left, Sir Patrick Moore and Mike Frost enjoy the sunshine at Patricks Picnic at Selsey. Mike is a member of the *Society for the History of Astronomy* and this year's meeting was at the great man's house.

Bottom Left An Astronomical weathervane.

Below Patrick's well known study from *The Sky at Night* programs.

A Picnic at Patrick's

with Mike Frost

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Is this Pale Blue Dot, as Carl Sagan called it, in danger of becoming a Pale Gray Dot? Is pollution cutting off the clear blue skies with white fluffy clouds I remember from years ago? Over the last 40 or so years I have been flying either on company business or holidays and I always try to get a window seat. Well I like to see where we are going. And over that time I have noticed that I can see less and less of the ground. In the good old days summer flying was great for following the route on the map in the in-flight magazine and spotting the cities and coasts we flew over. At night some cities were spectacular with long ribbons of light stretching away into the distance!

For the last two years we did long haul holiday flights into the USA and this year China. On both of these most of the way was over clouds or in the case of China a fog of low gray mist which looked like industrial smog. During our trip in China we had 4 internal flights, as well as a 5 hour flight to Hong Kong and I don't think I saw much of the ground during any of these flights. Mind you China is in a special case of its own with a quarter of the worlds tower cranes building everything new in city after city.

I would be interested to know what other members have found as they fly around, is the sky getting greyer? Are we getting more polluted and duller skies?

Ivor Clarke

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A Picnic at Patrick's

By Mike Frost

As you probably know, I am a member of the Society for the History of Astronomy. Each summer, we hold a picnic to celebrate the founding of the society. In alternate years, this takes place in Wadham College, Oxford, home of Dr. Allan Chapman, our honorary president. Other years have seen us in Greenwich, and at Isaac Newton's birthplace in Woolsthorpe, Lincolnshire.

This year we had a special invitation by one of our honorary vice-presidents. Sir Patrick Moore invited us to his home in Selsey, on the Sussex Coast. Although I know Sussex well – I studied at Sussex University and my sister lives in Brighton – I had never visited Selsey Bill before and so I was looking forward immensely to the picnic.

Sixty SHA members converged on Patrick's house. Selsey is a small town at the end of a country road winding south from the Chichester bypass. The Moore residence, *"Farthings"*, is some way in from the coast, in a quiet residential area. It's a thatched building with a roofed extension, surrounded by a large garden filled with trees, telescopes and sundials. The roof has a weathervane, featuring an astronomer looking through his scope towards a crescent Moon.

The lower level of the house was open, to allow us to inspect the famous study where *"The Sky at Night"* is filmed, and where Patrick's Corona typewriter has pride of place. Patrick's two cats, Jeannie and Cleopatra, were stowed away upstairs: the front door contained instructions on how to maintain "an airlock" to ensure that no cats escaped!

The great man himself is now very frail, requiring a frame to move around. However the indomitable spirit remains completely unquenched. Shortly after the picnickers arrived, Patrick shuffled his way to a garden seat, parked a bottle or three of wine by his side, and held court there for the rest of the afternoon. One by one we sat ourselves next door to him, accepted a glass of wine and had a chat. After I had enquired about his xylophone, in the room next to the study, he invited me to have a play on his piano (I declined through lack of practice). We also talked about Jeremiah Horrocks and Much Hoole.

I don't think Patrick now does very much observing. However his telescopes are still very much in use. John Fletcher, who gave tours of the scopes, said that observers came round every clear evening. I get the impression that Patrick has a large circle of friends to keep an eye on him. Patrick Moore is no longer as prolific and as active as he used to be, but he still enjoys being the centre of attention!

Gravity: More Than a Simple Attraction

By Paritosh Maulik

Gravity is omnipresent. We have learnt to live with gravity; we do not feel its presence in our everyday life. We have accepted that things fall down and it was Isaac Newton, who suggested why. Albert Einstein came out with a more accurate model of gravity. These we will discuss in general terms. Then we shall have quick look at some experiments are now being carried out to prove certain aspects of gravity. These have taken experimental measurements to the limits

The background

Newton standing on the shoulder of giants came up with some empirical mathematical relationship to show that two objects attract each other. This force of attraction is called gravitation. When one of the objects is the Earth, we call it gravity. According to Newton space, time and absolute space are absolute and need not need defining. Objects, standing still or moving or accelerating, are doing so against the absolute space. Having said that, he was well aware of the fact, that space is somewhat difficult to observe. By the way, the story of falling apple was a spin by one of his admirer and with time Newton began to believe the story.

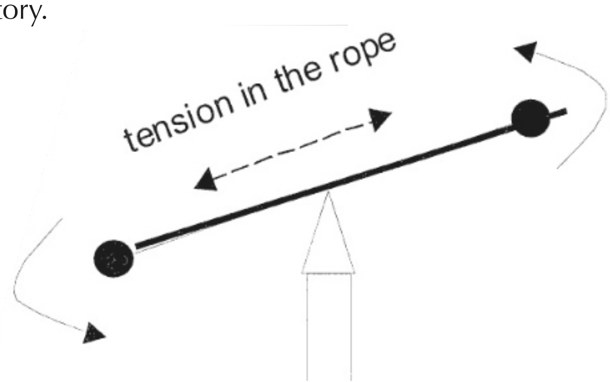

Fig 1. If the stones are rotating the rope is stretched

Let us imagine two stones, as in **Fig. 1** above, tied to the ends of a rope, are rotating. Since the stones are rotating, the direction of velocity is changing and therefore these stones are accelerating; as a result the rope is stretched. This is the view according to a stationery observer. But now if the observer rotates at the same speed as the stones, the stones would appear stationery to the observer. Since the stones are stationary (to the observer) the rope is not expected to be stretched. But our everyday experience tells us that the rope is stretched. Newton argued that what we are seeing is, stones accelerating against the absolute space and the evidence is stretching of the rope.

However if there was no acceleration, (the stones are moving with a linear motion), the observer can make the stones *appear* to be stationery by moving at the same velocity as that of the stones. Therefore we have a problem; absolute space can detect acceleration but not velocity. According to Newton always there will be some kind of reference point against which we can measure velocity and acceleration.

Mach (velocity of sound fame) suggested that in a hypothetical space, if everything is removed, it would not be possible to determine if an object is stationery or accelerating. In such an Universe, we cannot say, if the stones of above example are moving and the rope may well be slack. According to Mach, the force felt by the rocks will depend on the total amount of matter in the Universe. If there is x amount of material in the Universe and the force felt by the stones is F, then in an Universe with $2x$ amount of material, the force felt would be $2F$. However Mach did not provide any clear physical model how his concept would work. It is not clear if a distant heavy object or a near by, but not so heavy object, would have similar effects and also how these forces are communicated to objects, stones in our case.

Faraday suggested that there is something called magnetic and electric field. A magnet does not have to touch to attract. It has an area of influence as shown by arrangement of iron filings around a magnet. Similarly static electricity can attract from a distance. He also showed that these two are interlinked.

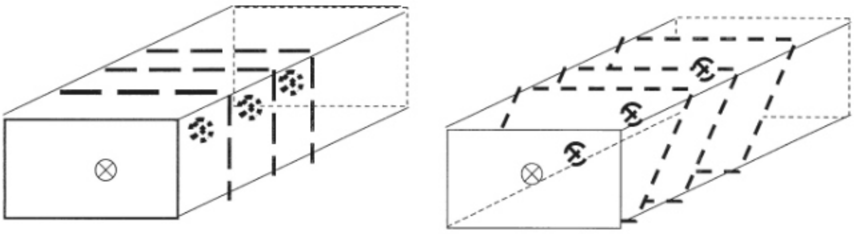

Fig 2. Same object will appear in different location depending on the position of the observer

Critics argue that the original experiment was correct and the new experiments doubting the original result have experimental flaws. New experiments are now being planned to verify the issue.

Maxwell connected these two fields mathematically and showed that any disturbance in the electro-magnetic field will travel at a velocity of about $3x10^9$ km/sec like a wave. Since it is a wave, it was thought that like any other wave, it travels through a medium and this medium was called ether (Aether). Soon Michelson and Morley showed that the velocity of light is about $3x10^9$ km/sec and it does not depend on the direction of motion of the light with respect to the motion of Earth, i.e. the motion of ether is not influenced by the motion of the Earth. To put it another way, light does not need ether to travel.

Lateral thinking of Einstein

Einstein picked up this idea and said that the velocity of light is constant and this is true for both static and moving bodies. Velocity = distance ÷ time, the only way the velocity of light to be constant for a moving body is, to have a different scale of measurement of distance and time compared to a stationary object. This is a simple description of special theory of relativity. Both time and velocity are relative to the observer. We can appreciate this by imagining three objects, one stationery and two moving with different velocities. Velocity of the other measured by each will differ. Time is not fixes as well. Here is an example. A supernova explodes, an observer at 100 light years away, will see the light 100 year earlier than an observer at 200 light years away. No one can agree with absolute time, when the explosion occurred.

A note of caution: Apparently the interference of light experiment by Michelson and Morley to show that the velocity of light does not depend on the direction of the travel of light with respect to the motion of the Earth (and hence ether), has rarely been successfully reproduced. If this is the case, then one can not rule out the presence of "ether" to carry light.

Spacetime

Let us imagine a block of wood in **Fig. 2**. We cut it into slices like that of a sliced bread or at an angle. Let us imagine it takes same amount of time to cut each slice in both cases. Each slice looks different, but when the slices are put together, it becomes the whole block of wood again. On its own, depending on the slice examined, each individual slice represents a relative space and relative time. Thus space and time are relative, but sapcetime is absolute. The stones in **Fig.1** are;

1) with respect to the absolute space; Newton
2) not moving in an empty space; if the space is empty, there is no reference point; Mach
3) moving with respect to the spacetime; Einstein.

This concept is called relativity of simultaneity, because, an incidence recorded simultaneously by two observers will depend on their relative situations, velocity and position. If something is moving through spacetime in a straight line, it has to move in a straight line though the space and at a steady rate in time. This is the case of moving with a constant velocity. An object moving through spacetime will travel

1) in a straight line, if it moves with a constant velocity
2) in a straight spiral. like a cork screw, if it moves in a circle
3) curved line, if it accelerates.

Thus if we know the exact path of an object through spacetime, we can determine if it is moving with a constant velocity or accelerating. **Fig. 3.**

The velocity of light is the highest speed allowed in the Universe. It takes about eight and half minute for a Sun's ray to reach the earth. So if the Sun is to disappear now, it will take about eight and half minutes for the sky to darken, but according to the classical Newtonian model, the earth would be free from the gravitational influence of the Sun instantaneously. But gravity can not move faster than light and hence the earth would still continue to feel

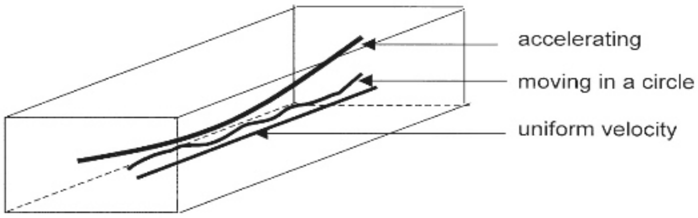

Fig 3. Path of an object in space time, uniform velocity - straight line, moving in a circle - spiral motion / corkscrew, accelerating - curved path

the diminishing influence of gravity for eight and half minute. More about it latter.

Principle of Equivalence

We can easily appreciate that movement of an object A with respect to the object B, is same as B's movement with respect to A. Velocity is relative. Now imagine someone is moving in a car or a coach or whatever, the ride is the smoothest possible and the windows are closed i.e. no external reference. The traveler can not distinguish if the vehicle is moving or stationary. But if the traveler is suddenly forced to lean to one side, the conclusion would be, the vehicle is turning. Similarly a sudden push to the back tells that the vehicle is accelerating forward. Such movement is called acceleration. To be precise, acceleration is the rate of change of velocity. Now this sudden push to the back can also occur, if a heavy object behind the traveler exerts a gravitational pull. Reasoning this way Einstein concluded that force acting on something during acceleration is the same as the force exerted by gravity and hence gravity and acceleration are equivalent.

According to Einstein, if something is accelerating, it must feel the gravity. We are under the influence of gravity of the Earth, whether we are sitting down or standing up. By the act of sitting down or standing up, we are acting against the gravity. We feel the weight and we are accelerating. When we fall freely, we are giving in to the gravity and not resisting against the gravity; we do not feel any force and we are not accelerating. Only such an object can act as the reference for motion. This is how Einstein described gravity.

Curving of Space(time)

Our path is spacetime straight or curved, depends on how we are traveling, with a constant velocity or accelerating. In **Fig. 2** we have seen that we can cut up space in slices and the shape of the slice or its orientation depends on the position of the observer. If we combine these two facts, moving on a curved path (i.e. accelerating) we will have a set of slices and if we join these slices up, it becomes a curved surface. The conclusion being an accelerating observer sees that spacetime as a curved surface and since gravity and acceleration are the two sides of the same coin, gravity also makes the spacetime curved or wrapped. If we take a flat net and put a heavy ball on it, the net droops in the middle. Gravity is like a heavy ball warping the spacetime.

We are to remember that gravity wraps both space and time i.e. spacetime. It is somewhat easier to visualise wrapping of space, but wrapping of time is somewhat difficult to picture. Here is an attempt.

In **Fig. 4** above we have a merry-go-round; A is at the edge and B is somewhere in the middle. Both of them are part of the same system (for the time being let us not worry about linear or rotational velocity). For an outsider A, travels a longer path, than B. According to A's

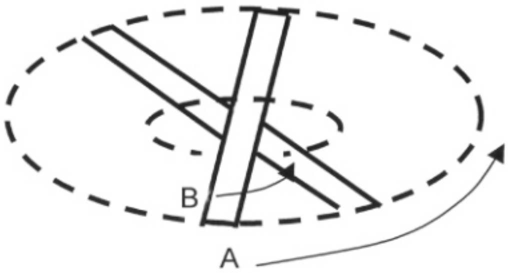

Fig 4. A travels a longer path than B

stopwatch it will take longer to complete one rotation, 360°, the path being longer than the path covered by B. We can say A's watch is slower than B's. In a curved space, time slows down. So things are not quite straightforward in a curved space compared to the flat space. This is the realm of non-Euclidian geometry; sum of angles of a triangle is not 180°.

Mach believed that if there is no other object in the Universe; we can not feel the acceleration. In such an empty Universe, there would not be any gravity and hence no acceleration; special theory of relativity does not deal with acceleration. According to the general theory of relativity, a free falling body is under the combined influence all of the matter and energy present in the Universe and is not under the influence of a local gravity field. Only such a body can act as a bench mark for acceleration.

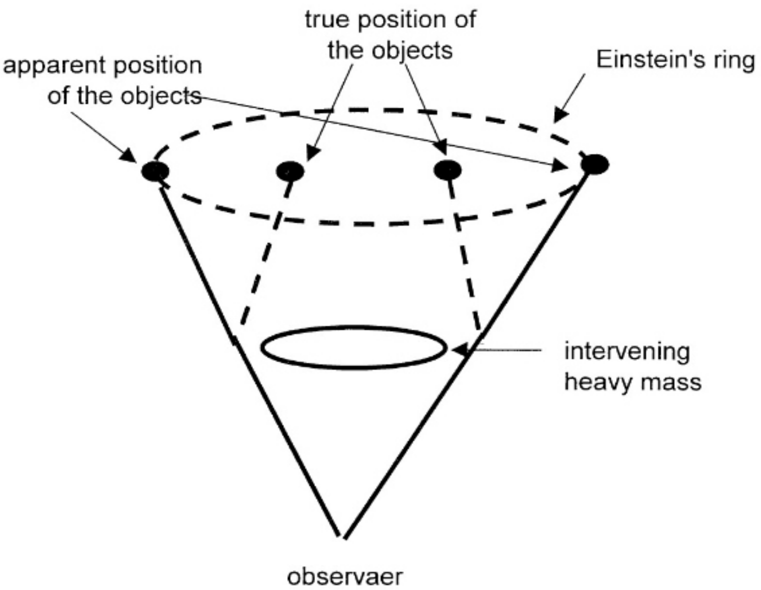

Fig 5. Gravitation lensing happens when a large intervening mass like a galaxy bends the light rays gravitational from a distant object and these appear to be further apart and may seem to move faster than light

Did Gravity really pull the Apple?

Gravity is omnipresent in this real Universe, which is full of matter. Unlike electromagnetic shield, we can not put up an anti-gravity screen. Having said all that, gravity is a weak force The ratio of two forces, gravitational attraction between two protons and the electrical repulsion between these two protons, are very very small. In fact it is so small that it is perhaps not possible to determine the ratio. Both electrical forces and gravity follow the similar equations connecting the force with distance and mass. In most of the objects the positive and negative charges balance out and we do not feel the effect of electrical force, but the gravitational force depends only on mass, hence a large body can exert a large gravitational force. The proverbial apple only fell to the earth when its electrical energy (chemical bond) became weaker than the gravitational force due to all the combined matter on the Earth. A fridge magnet stays on the door rather than on the floor.

The gravitational force of the Earth may not be high enough to pluck the apple from the tree, but if the object is heavy enough such as a galaxy or a cloud of dark matter, it can bend light. The situation is somewhat similar to the refraction of light. When particles of light, photons, moves from one medium to another, it interact with the electrons and this causes a change in its energy. This leads to the change in the direction of travel, called refraction.

Similarly the gravity field can alter the direction of traveling of light. It is called gravitational microlensing. Eddington used this phenomenon to verify one of the aspects of the general theory of relativity. Under suitable circumstances, gravitational bending of light can produce multiple images as shown in **Fig. 5**. This has been observed with both optical and radio images.

Gravity controls Shape

Size to mass ratio of a living organism is controlled by gravity. If an elephant is not large enough in size, i.e. the bones and muscles, it would not be able to carry its own weight. On heavenly matters, lighter objects like asteroids or smaller moons, the gravity is too weak to draw matter into an uniform shape; these remain irregular in shape. Somewhat heavier bodies like our Moon and most of the planets are not rigid enough; under the influence of own gravity these become near round in shape, but can distort under the gravitational influence of another body. But if the mass is high enough, well over the mass of Jupiter, under right circumstances it can collapse on itself triggering a nuclear reaction as in a star

Now we have a physical picture of gravity. Like the electromagnetic field, gravity has its own sphere of influence. We do not need physical contact to feel the gravity. Gravity bends or warps spacetime and this is what we feel. We can predict how fast it moves. We can not hide from it and it controls how we look, well the mass to shape ratio.

Over the years theoretical works on gravity have made some predictions about its behavior. Verification of these needed high precision measurements and had to wait advances in technology. We shall look at some of these next.

Experimenting with Gravity

One of the predictions of the General Theory of Relativity is, gravity travels with a speed as that of light. Light is of dual existence, as electromagnetic wave and as a particle called photon. Theory suggests that gravity can spread like a wave and can exist as a particle as well called, a graviton. Some aspects of this theoretical prediction are now being put to test. The effects we are trying to measure are very small and only recently have we had the technology to measure these small changes. Let us first see how the speed of gravity (wave) has been measured and then we shall consider gravity waves.

Speed of Gravity

Maxwell's equation predicts when a charge moves in an electromagnetic field, it creates waves and this is what we see as light. This equation does not involve detection of electromagnetic wave. A similar set of equations now does exist to calculate the speed of gravity due to a moving body, which is producing a gravity field. All we need to know is the mass and velocity of this moving body and the shift of the electromagnetic wave from a source passing through this field. Like Maxwell's equations, this new equation does not need the detection of gravity waves. Shift is electromagnetic waves due to the gravity field of a moving body was known; remember, Eddington's experiment during the total solar eclipse. But this new equation allows us to calculate the change in gravity field due to a moving and rotating body.

The moving and rotating body was chosen was Jupiter. Its mass and orbit is known very precisely. The electromagnetic source chosen was a quasar, **Fig. 6** below. Radio telescopes in the US, Hawaii and Germany formed a Very Long Baseline Array ranging over 10,000 km to achieve high resolution of about 10 microarcsecond, about 5 billionths the diameter of the full Moon. The sources of errors were i) possible change in the position of telescopes due to continental drift, ii) change in the rotation of earth, iii) variation of magnetic field of Jupiter, iv) variable radio output from the quasar, v) adverse weather condition affecting signal received by a telescope. After years of planning and several days of measurements, the answer was the speed of gravity is (1.06 ± 0.25) times the speed of light; the conclusion being gravity travels with a finite speed and not instantaneously.

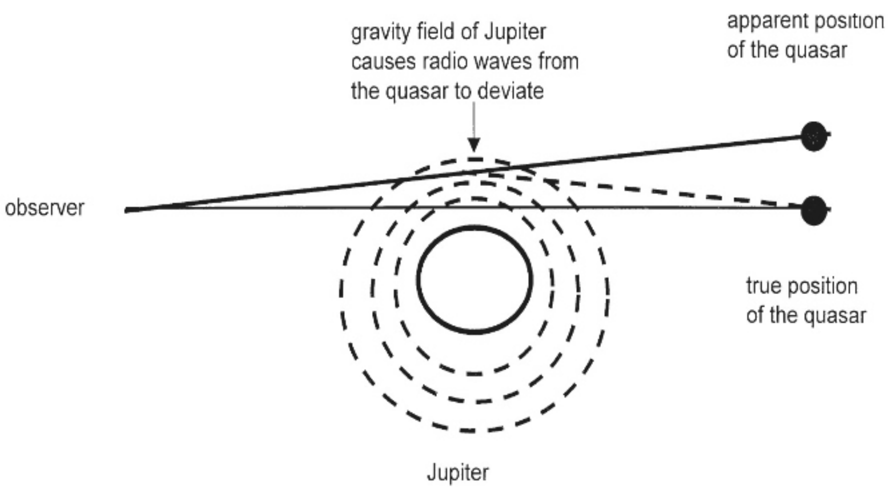

Fig 6. Rotating and moving Jupiter produces an oscillating gravity field. The radio signal from the quasar is gravitational shifted by the gravity field and is picked up by the receiver

Dragging of Spacetime

As gravity wraps spacetime like a heavy ball on a net, a rotating body drags the spacetime around it. If a light object comes under the influence of a rotating heavy object, the rotating spacetime around the heavy object will set the light body down a distorted path. This is the view of an outsider. The frame of the light object has been distorted. It is called frame dragging. But to the light object, it is descending just as before, no change in path.

There is also another interesting version of frame dragging. If the rotating heavy object is a huge hollow sphere, the space inside the sphere will be set in motion as seen by an outsider. If the rotating sphere is sufficiently heavy it will prevent any information getting inside the sphere.

Let us consider the first simple case of frame dragging. If frame dragging is a real phenomenon, the Earth should be dragging spacetime around it and therefore it could be verified as follows. Send a rotating gyroscope round the Earth with its axis pointing to a fixed direction. If Newtonian view is correct i.e. no effect on spacetime, the gyroscope would continue to point towards the fixed direction and if spacetime dragging according to Einstein is correct, the gyroscope should change its orientation. This concept was suggested as early as 1960, but it had to wait till 2004 to get the necessary funding. Here is a brief description of the setup called Gravity Probe B, designed by Stanford University.

The satellite is orbiting the earth at an altitude about 600 km (400 mile). Housed in the satellite are four near perfect spheres. These spheres are, about 38 mm (1.5 inch) and round to within 7.62 nm ($7.62x10^{-9}$ m; three 10 million of an inch**).** These spheres form the gyroscope and are kept in a vacuum, at about 5K (-270°C), pointing to one given star. The gyroscope is encased in a shield, protected from, any magnetic, electric or solar forces. If frame dragging is real, the gyroscope should change its orientation by about 1/100,000 of a degree in a year. The satellite is expected to orbit the Earth 7000 times and during that period the gyroscope would rotate by about 2 billion times.

Gravity can cause Waves

So far we have seen gravity can warp and drag the spacetime. Now imagine the common picture of warping of space, ball on a net causing the net to droop. If the ball is not static on the net, but it is oscillating, we can expect waves or ripples passing through the net, starting from the centre, traveling to the edge. As the changes in electric charge can send an electromagnetic wave such as radio wave, any disturbance in gravity field should cause gravity waves and these would be carried by particles called gravitons. These gravity waves move within the spacetime disturbing the geometry, electromagnetic field on the other hand travels through spacetime. The theory also suggests that the object causing the disturbance of the spacetime and sending gravity waves, should loose its energy. This aspect of the theory has been shown to be correct, by long term monitoring two binary pulsars orbiting round each other. These neutron stars move very fast and emit radio waves with very reproducible time interval. From all these, it is possible to calculate the rotational speed of these stars. Results show that in fact these two stars are loosing energy and slowing down as predicted by the theory. But the direct evidence of the presence of gravity wave is yet to be verified.

A set up is now running in the US to measure the gravity waves named Laser Interferometry Gravity wave Observatory (LIGO) since 2002. It is essentially a laser interferometer on a giant scale. There are two L shaped arms of about 4 km (2.5 mile) long. At the ends of each of these arms, there is a near perfect mirror. A beam from an ultrastable laser light bounce several hundred times between these two mirrors in a vacuum and create an interference pattern. The total light distance traveled is around 300 km (180 mile). This interference pattern essentially measures the length of the arm. If somewhere two neutron stars collide or two black holes merge, there will be ripple in the fabric of spacetime and gravitational waves will travel to the LIGO setup causing a differential change in the lengths of the arms. The only problem is, the change is miniscule (one one-hundred-millionth the diameter of a hydrogen atom, or 10 to the negative 21st power). This is why the set up has to be extremely sensitive. In fact there are two setups, about 3,000 kilometers (2,000 mile) apart, to confirm the observation. Once the gravity waves have been detected and analysed, the identity of source of the waves can from the determined.

A joint ESA/NASA mission named **L**aser **I**nterferometry **S**pace **A**ntenna (LISA) is scheduled for 2012 – 2013, foresees to go one step ahead of LIGO. In this mission the aim is not only to measure the gravitational wave but polarization of the wave as well. There will be three spacecraft about 500,000 km apart forming an equilateral triangle. Each spacecraft has three arms. Each of these two arms has a reference mirror and a telescope assembly. The entire system works like two giant Michelson interferometers. Light from a laser traveling between the mirrors forms an interference pattern. If a gravity wave happens to be passing by, it would alter the light path one arm with respect to the other. The instrument is shielded from solar flairs and cosmic radiation. The precision of measurement is $4x10^{-11}$m (averaged over 1 second) and taking into consideration of the fact that these telescopes are widely spaced, the instrument is capable of estimating a change in the interference path corresponding to change in the gravity wave length of $10^{-23.}$

Questioning Newton?

Newton theoretically showed that the strength of gravity decreases with the square of the distance, known as inverse squire law. For most of the normal distant objects around us and most of the astronomical bodies obeys the inverse square law very well. But is there a limit, below which the inverse square law breaks down? We do not know.

By now, we all have heard that three spatial and one time dimension are not enough to explain the Universe. A better model of the Universe requires more dimensions; the reason we not feel these dimensions is that these are very small.

Theory suggests that gravity leaks out

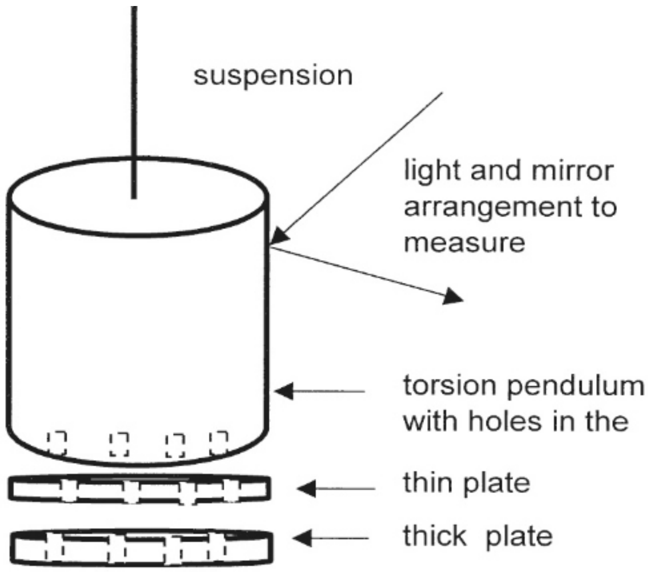

Fig 7. Torsion pendulum to measure the force of gravity with distance

though these small dimensions, which causes gravity to be weak. The explanation goes something like this. The surface area of a sphere is proportional to its

(radius)^2 for three dimensional space
(radius)^3 four dimensional space
(radius)^4 five dimensional space;

and so on.

Hence, more dimensions, the larger is the surface area of the sphere, the strength of the gravity will be progressively weaker. However there is no agreement on how small are these dimensions. These dimensions could be theoretically between as small as Planck's length, (10^{-35} m) to as large as 1 mm. Planck's length is the distance, when relativistic spacetime breaks down and quantum phenomenon takes over. Experiments are now being carried out to determine the shortest distance, over which the inverse square law holds good and this can also give us some idea about the sizes of these extra spatial dimensions.

The setup in **Fig. 7** is a twentieth century version of the torsion balance used by Lord Cavendish to measure the gravitational constant. A hollow metal cylinder is suspended by a wire. There are 10 equally spaced holes at its base. Below this pendulum, there are two discs called attractors. One of the discs is thicker than the other. These two discs also have equally spaced 10 holes, but the size and the spacing of all these three sets of holes do not match. The thin attractor is rotated. As it rotates under the cylinder, its holes create an effect of moving "positive and negative" mass near the cylinder. This causes the cylinder to rotate. The lower thicker attractor is also rotated in a way to counterbalance the rotation of the cylinder; thus the cylinder is kept stationary. An optical lever monitors the rotation of the cylinder. Now by changing the distance, between the attractors and the cylinder, the effect of distance on gravity can be measured.

The set up is housed in vacuum and electrically shielded. Variation of localized gravity has to be taken into account. In one experiment the difference between the summer and winter results turned out to be due to rain soaking the ground, increasing the weight. It has been reported that the inverse square law hold good to about 160 μm (1.6 mm) and unofficially to about 70 μm (0.07 mm).

There are other experiments being carried out to examine the distance over which the inverse square law is still applicable. Some of these involve manipulation of a few molecules. Critics argue that in such experiments quantum forces may interfere with gravitational forces.

Conclusion

Understanding of gravity has come a long way since Newton published his calculations in 1684 and Cavendish experimentally verified the results in 1798. Einstein came up with physical model of how gravity works and within a few years some aspects of his theory was proven to be correct. However to prove some of Einstein's theory on gravitation needed more technological developments and these are becoming available only now. Hopefully within the next few years we shall know more about gravity waves, dragging of spacetime and why gravity is so weak.

Further reading

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The lighter side of gravity, Janyant V Narlikar, Cambridge University Press, 1996
Seven Wonders of the Cosmos, Janyant V Narlikar, Cambridge University Press, 1999
Just Six Numbers, Martin Rees, Widenfeld and Nicholson, 1999
The New Scientist, 11 January, 2003, p 32
The New Scientist, 19 February, 2005, p 55
The New Scientist, 2 April, 2005, p 30

See Over ➡

Note added later

Chandra X-ray Observatory has located a periodic x-ray binary at a distance of about 1,600 light years from the Earth, separated by only 80,000km (about one fifth of Earth – Moon distance) and rotating around each other every 5.36 minutes. The rotation is speeding up and its orbits are closing in at about 2.5 cm per hour. This system is loosing its energy in the form of gravity waves. This has been identified as a suitable candidate for the detection of gravity waves by LISA.

The gravitational waves from the above source will be of a frequency of about 5.36 minutes. This is too small to be detected by ground based LIGO detectors. However LIGO can detect pulsars with frequency of the order of milliseconds. New born pulsars rotate very fast initially and then slow down. But there are some millisecond pulsars. These accrete mass from a binary source and pick up spin later. If the neutron stars are irregular these should send gravity waves which could be detected by LIGO; but the loss of energy in the form of gravity waves would prevent further speeding up of these objects.

A Quick Trot to Turkey

By Mike Frost

In October 1996, I had the unexpected pleasure of seeing a sunset eclipse of the Sun. I was on holiday in Olu Deniz, Turkey, and was able to observe the partially eclipsed Sun setting into the Mediterranean Sea. I wrote an account of this eclipse, "Turkish Delight", which appeared in Mira No 42 and in the BAA Journal

Just under ten years later, I returned to Turkey for the total solar eclipse of March 29th 2006. Initially, this was an eclipse that I was expecting to have to miss, due to work commitments in North America. However, the start date for my trip to Indiana went back from the beginning of March to the beginning of April, and so I looked around for a short trip to the totality zone, which stretched from just off the Brazilian coast, across north-west Africa, Libya and Egypt, then into Asia to conclude in Mongolia.

Omega Tours were advertising a two-day mini-break to Antalya, so I signed up for it (as it turned out, the Indiana trip drifted back to early May, so I could have joined one of the longer tours). The tour turned out to be an extra-ordinary piece of logistics, involving six separate flights from the UK to Antalya on Tuesday 28th March, in planes which stayed over at the airport before returning the next day. Thirteen hundred eclipse chasers spent one night in Turkey – not an expedition that would have been very easy to book during the high season!

Many of us stayed in the Maritimo Pine Beach Resort, a huge and very plush four-star resort at Belek, almost on the centre line of totality. The Maritimo featured two conference halls, a water park (empty), golf course, crazy golf, gym, Turkish baths, and I'm sure many other facilities which I never managed to find. To the surprise of everyone, including the tour guides, the facilities turned out to be all-inclusive – including the beer!

On the Tuesday evening we started with a presentation in the larger of the two conference halls. Our astronomers, Paul Money and Nigel Bradbury, lectured to an appreciative audience of 650 people. Paul's style is inimitable, of course, and he managed to convey the delights that would await us the next day. I felt Nigel told us more than we probably needed to know about the sky during the eclipse (did anyone really attempt to see the Orion nebula?) but again his enthusiasm carried the day.

On most of my previous eclipse holidays, eclipse day usually started at around 3 AM, with a coach journey to the back of beyond. March 29th started with a lie-in and a leisurely breakfast. The sky was almost completely clear, with a few distant clouds, mostly around the mountains to the north of the coastal plain.

We even had time to grab a plate full of lunch, before the eclipse began at 12:38 local time. The astronomers had spread themselves along the beach and the gardens immediately behind it. I set up in the gardens, with the aim of keeping an eye on the shadows of the foliage, next to the life-guards tower from which Nigel was providing a running commentary on events. We sorted out an umbrella and sun lounger. I had a newly acquired camcorder, which I initially attempted to mount on a tripod, but the mount proved a little fiddly, so I decided to record from hand-held instead.

Over the next hour and a quarter, the Moon steadily worked its way across the solar surface. As usual, there was little change to the quality of light during the first half of this time, but events began to speed up rapidly during the latter portion of partiality. The temperature, which had been a lovely 23 degrees centigrade, began to ease and then drop sharply. As it dropped, we began to see cloud condensing – not enough to block out the Sun, but certainly enough to form a beautiful 22 degree halo around it. There was quite a lot of activity by the sparrows around the resort, who began to swarm prior to roosting. We waved as the helicopter from Turkish TV passed overhead.

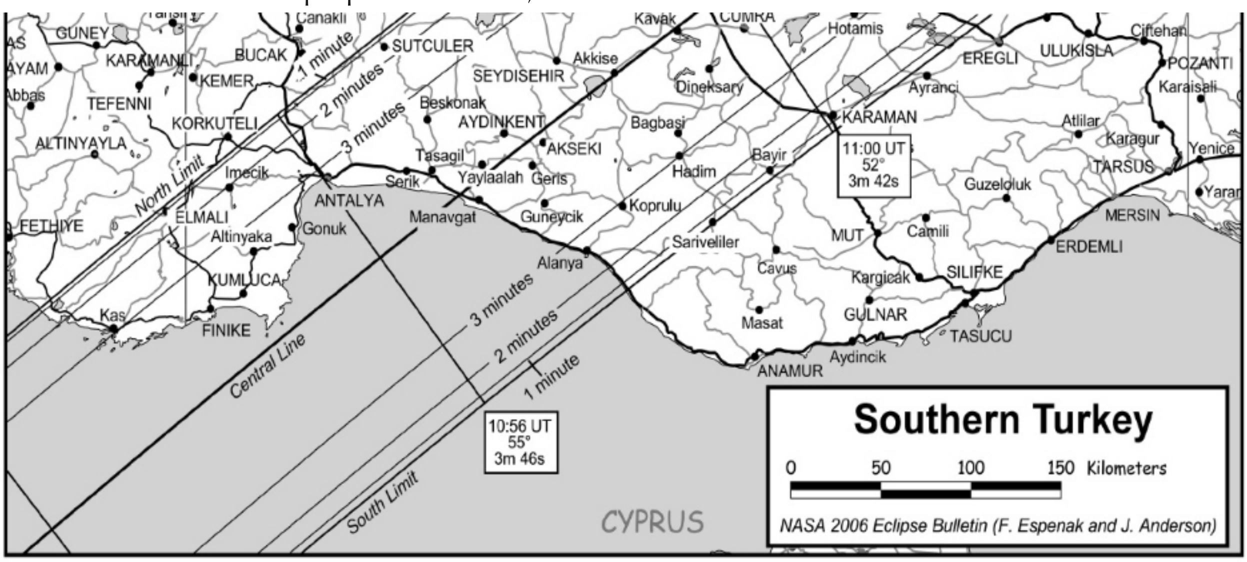
At 13:54, totality began. It came on us as a little of a surprise, I think that our MC wasn't expecting it for another 30 seconds, and so I really didn't see much by the way of Baily's beads. I fiddled with the camcorder, trying to get the best view on the zoom, neglecting to put my finger on the Record button.

We got three minutes and twenty two seconds of totality, but not unexpectedly it seemed like twenty seconds. I was surprised by the shape of the corona; 11 years previously, in India, I remembered a much more tapered shape, and was expecting something similar at the same stage in the solar cycle. For the last few seconds I put down the camcorder altogether and watched the Sun directly; the lower limb was a mass of purple – and then, DIAMOND RING – and everybody started applauding.

I took a quick look down at the beach towel I had spread in front of me. There was just a hint of shadow bands fluttering across the white of the towel, faster but narrower than I remembered them from Curacao in 1998, perhaps a little more like Zimbabwe 2001. Next I ran over to the lookout tower and tried to put the exposed Sun behind the building, in an attempt to see the corona on the side of the Sun which was still covered. I tried and failed to do this in Madrid last year and I failed once more – the sky was just too bright.

I exchanged congratulations and observations with the neighbouring astronomers, then tried the roaming capabilities of my mobile phone by ringing my parents back in Rochdale. The sparrows, who had decided to give up on roosting, gathered on top of the beach umbrella and greedily eyed the remains of my lunch. The temperature shot back up to "very-nice-for-March" and we planned a quick dip in the Med before queueing for the coach back to Birmingham.

In many ways it was quite a surreal visit – we barely had time to acknowledge our surroundings. I didn't change any money, and my only purchases, postcards and some Turkish delight, were made in sterling. There was no time to acquire the local newspaper or watch the excited report on local TV. So there was little sense of absorbing the culture of our host country, which has enriched so many of my previous eclipse trips. Nonetheless it was a lovely eclipse, on a beautiful warm spring day, and I'm glad I got the chance to go.



Collision Course

Target earth: Many believe that an asteroid impact wiped out dinosaurs. Spacecraft could be used to prevent a similar catastrophe occurring to the human species. Sent in by Geoffrey Johnstone

What do we have to do to prevent the Earth being hit by a giant asteroid, wiping out civilization? Normal Hollywood blockbusters such as "Armageddon" and "Deep Impact" have explored the possibility of an asteroid or comet hitting the earth with devastating consequences. How concerned should we be about this potential global terror? Its well documented that most asteroids and comets orbiting our solar system do so far from our planet but a small fraction of them come close to the earth, posing a potential threat. These are referred to as near-earth objects. (NEOs) and range from rocks 5m across to the largest asteroid detected near earth, known as Eros, of 30km diameter. Alan Fizsimmons, a professor of astronomy at Queens University, Belfast, says: *"Although statistically we are not due to be hit by a NEO of notable size for the near future, the distribution of impacts is random, so we should not take this as a certainty. To date only 5% of sub-1km objects are estimated to have been found, so accurate cataloguing of properties and size is vital."*

NEOs over 1km in diameter are much easier to detect owing to their size. Some 90% have been detected, and the aim is to find 100% by 2007. *"Our concern now is finding all the NEOs that are much harder to track and locate,"* says Firzsimrnons. *"These range from 10 to 500m and would have a dramatic effect if one impacted the Earth, so it's a major concern."* A key aspect of attempting to prevent an impact is accurate and thorough observation. Colin McInnes professor of engineering at Strathelyde University says: *"A long 'lead time' is paramount. We are looking at a wide range of NEOs and so multiple solutions need to be explored. If we have 50 years to work out a course of action we would hope to be OK. However, if we are given months we should run for the hills. In reality it is likely to be around 10-20 years but as detections get increasingly thorough this figure is likely to increase, which is good news all round."*

Deflection avoids impact

The engineering challenge is huge but the European Space Agency ESA has already begun to explore various strategies. Andres Galvez, advanced concepts ream manager at ESA, says: *"The technologies I am highlighting are for various lead times as well as for different properties such as stone, metal or a mixture of both."* The prevention method would not have to destroy the NEO. Preferably it would deflect or alter its course so it missed the planet by a minimum of one earth radius. ESA says the solutions need to he flexible and multiple because of the uncertainty involved.

Knocked off course

The most straightforward deflection method is the aptly named kinetic energy transfer. It transfers kinetic energy from one body to another, and it is hoped that this will change the velocity of the NEO enough to prevent an impact. A spacecraft would go into a counter-orbit to the asteroid, gaining the maximum impact speed, and would then slam in to the asteroid. This could prove the quickest solution to procure as it relies on relatively straightforward engineering principles. *"However this is quite an uncertain way of doing things and may be more suitable for smaller objects under a shorter lead rime,"* say's Galvez. The low-thrust deflection concept would see a satellite craft fly to the NEO where it would plant itself on the surface and act as a thruster. This would require a longer lead time and may have extra complications if the asteroid has any rotational movement. Galvez says: *"The planted craft would use a highly efficient and continuous low-thrust propulsion system over many years to alter the asteroid's path."*

There are also some more exotic suggestions on the agenda, such as coating the asteroid in a reflective paint so that over 50-100 years the solar radiation would alter the asteroid's course so much that it would miss the earth. The reflective coating would act much like a solar sail, a technology that is available today. Another solution is to put a giant mirror over and above the asteroid to deflect a beam of sunlight on to the surface. The small heated area of the asteroids surface would create a plume of vaporised exhaust material which over time would act in a similar way to a low-powered thruster. For a small asteroid, a l00m mirror would be needed. These methods are beneficial and advantageous owing to their "clean" nature but may prove less practical to fabricate. To date, more than 2,500 NEOs have been discovered, with around 400 being found each year. Once discovered and tracked, their orbits are calculated so that the risk of a future impact can be assessed. Fitzsimmons says: *"Current detection does show that a collision is likely to occur for an asteroid called 1950DA. It is likely to hit earth on 16th March 2880. So we shouldn't be too worried just yet."*