

The Fighting Temeraire tugged to her Last Berth to be broken up, 1838 by Joseph Mallord William Turner. This famous painting by one of the greatest English painters of the 19th century shows one of the old fighting ships of the Navy being taken to the brokers yard with the setting sun and moon in the sky. But as Mark Edwards explains in his story "The £20 Puzzle" on page 2, not all is well with their positions in this painting. The lower left painting from 1840 shows the moon at the same phase as in the Temeraire painting and right hand painting shows how Turner painted over older canvases. Is this what happened with the Temeraire?



The New Moon, or I've lost my boat, you won't have your hoop, 1840



View of the Beach at Margate (the Phantom Ship) c. 1840

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The £20 puzzle

By Mark Edwards

This article forms part of a talk I gave to the Historical Section of the BAA on *'The Astronomy in Turner's Paintings'* which included many more such intriguing puzzles...

There is no doubt that when the new plastic £20 note is introduced in 2020 it will be controversial. Not because of its plastic nature (as I am sure by then we will be well used to such notes), but because of the painting on its reverse. This painting is 'The Fighting Temeraire tugged to her Last Berth to be broken up, 1838' and must be the most famous of Joseph Mallord William Turner's paintings (who also appears on the note).

So why should that cause controversy and constant discussion? The problem lies in the inconsistencies in the painting. - The ship itself was towed in a westerly direction along the River Thames from Sheerness to Rotherhithe over two days, the 5th and 6th of September 1838, but the positions of the Sun and Moon depict a sunset in the west, not as it should be, a sunrise in the east.

Worse than that, the funnel and mast of the tug have been reversed from real life, so much so that when James Tibbits Willmore produced an engraving of the painting in 1845 he moved them back again (much to Turner's annoyance), although he had a change of heart in 1849 and reversed them again to match the painting.

It is also said that when the Temeraire was being towed it had had its masts and rigging removed, however there is a contemporary sketch by Edward Duncan showing both masts and rigging still there (all be it with the yardarms tilted) when it was being towed up river by two steam tugs.

One thing you can be sure of is that no-one (except me!) will point out that the date given by the phase of the Moon and the relative positions of the Sun and Moon is also incorrect. There was a full Moon on the 4th September, so the Moon would still appear almost

full, not a crescent, on the following two days. It was also said that a sunset was not visible on the days in question.

So if the positions and phase of the Moon are incorrect for the two days in September, were they ever correct for a day in 1838? The answer to this question is yes. There is a good match for 7:52pm on June 26th 1838.

This date is interesting on two counts, firstly the artist John Linnell had seen Turner the previous evening (June 25th) at dinner in the Rev E.T. Daniell's house in London. Secondly, the Temeraire fired her guns for the last time two days later (June 28th) to celebrate the coronation of Queen Victoria. At that time the Temeraire still had her masts and rigging as the dismantling of the ship was only started by Captain Sir John Hill on July 4th.

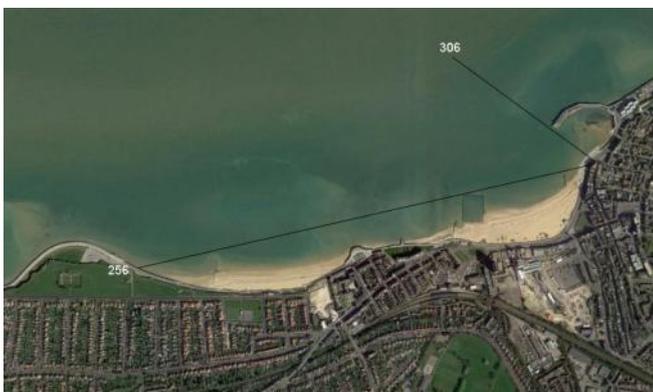
So Turner could have travelled to Sheerness on the 26th to paint the Temeraire complete with masts against the sunset.

There is a major problem with this theory in that on the extreme right of the picture we can see some buildings on a shore. These could be Admiralty House and behind it the tower of the dockyard church, both in Sheerness, but unfortunately this view is looking towards the south east, not north west. It is therefore impossible to have a setting Sun in that position.

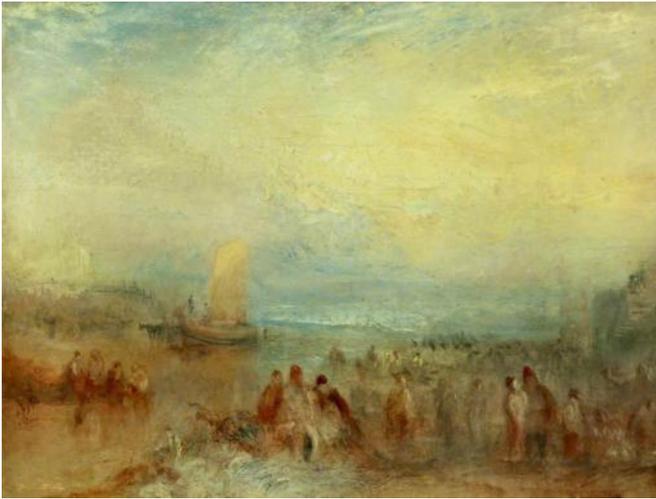
When examining any painting we always have to remember that it is not a photograph, the artist can paint whatever they like, wherever they like on the canvas, but is there any evidence that Turner could have seen the sunset he painted and if he did where was it?

There is another painting which was exhibited in 1840, the year after the Fighting Temeraire was exhibited at the Royal Academy, called 'The New Moon, or I've lost my boat, you won't have your hoop!'. The depiction of the Moon is the same as in the Fighting Temeraire. The Sun is unfortunately absent, but the scene is obviously one around sunset. This was painted from the beach in Margate and the position of the Moon on June 26th is consistent with this view. Certainly, it looks like a summer scene, with people paddling in the sea and wearing summer clothes.

This opens the intriguing possibility that Turner might have travelled from London to Margate on that day arriving in the evening in time to paint the sunset, which he later used in both paintings. There is also a piece of circumstantial evidence - where are Turner's paintings of Queen Victoria's coronation? There are



Aerial view of Margate Seafront showing the positions of the moon and sun on June 26th from a point near the harbour



Margate Harbour 1335-40



X-ray of The Fighting Temeraire

not any! If he was at Margate on the 26th June, he might still have been there two days later and not in London to see it.

If we assume then that he painted the scene in Margate, do the positions of the Sun and Moon match the topography of Margate? At 7:52pm the Sun was at an azimuth of 306° and that of the Moon 256°, these angles are consistent with a view from the seafront of Margate Harbour, just west of the harbour wall and not far from where Turner's friend Mrs. Booth lived.

This would mean that the boat on the far right of the painting could be next to the harbour wall and the headland on the left could be that of Westbrook.

Turner produced a number of paintings from the

seafront at Margate, amongst them one of Margate Harbour.

In this painting there is a boat with a large white sail which is in exactly the same position as a sail which appears on an X-ray of the Fighting Temeraire.

So this opens the intriguing possibility that Turner had painted a picture of a boat on the sea at Margate which included the Sun and Moon, but he then over painted it with the Temeraire when he heard that it was about to be broken up. He certainly was known to re-use his canvases as a recently authenticated painting known as 'The Phantom Ship' shows a sailing ship half over painted by a view of the sea from Margate beach.

In the Footsteps of Henry Miller

By Mike Frost

To everyone's surprise, I ended up giving the lecture to the February meeting, when the scheduled speaker was unable to attend. I reprised an old and popular talk of mine, "The Arms of Buddha", which I had previously given to the society in the mid 1990's.

I hope you enjoyed listening to the talk as much as I enjoyed giving it. But there was one small drawback to presenting the talk at short notice. My talks don't stay still – I am forever finding out new things, or being sent new material, which I can incorporate into my presentation. In this case, the version of the talk which was on my memory stick didn't include photographs from a trip I made in the summer of 2016: to Big Sur in California, the home of Henry Miller, one of the fascinating characters who play roles in the "Arms of Buddha". Indeed, it's a quote from one of Miller's books which gives the talk its enigmatic title.

Henry Miller is by no means an obvious subject for a science-based talk. He was born (so the venerable Wikipedia tells us) in 1891 in New York. He married

his first wife, Beatrice Wickens, whilst working for Western Union in human resources, a job he took whilst trying to establish himself as a writer. He had an affair with an exotic dancer, June Mansfield, who then became his second wife. Miller tried to pass off one of his early novels as having been written by her. In 1930 Miller headed to Paris, where he spent the next nine years, supported financially by the writer Anaïs Nin, with whom he had an affair. His stream-of-consciousness account of these years, "*Tropic of Cancer*", achieved notoriety for its priapic content and language. It was banned in both America and Britain, which only increased its popularity.

As war approached, Miller had to leave Paris, returning to America via Greece. He settled in California with his third wife, Janina Lepeska, in the then remote settlement of Big Sur, in the Santa Lucia Mountains south of San Francisco. He wrote an entertaining account of his life there in his book "*Big Sur and the Oranges of Hieronymus Bosch*". It's not for



The Big Sur Post Office

me to analyse where he got his title from, but, having read the book, my understanding is that he thought, in some sense, that Hieronymus Bosch conveyed the sense of “orange” in his paintings better even than California oranges do.

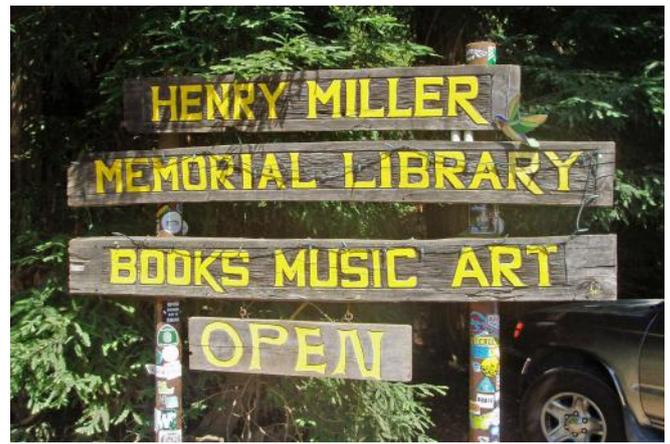
The reason I know about this book is because of a quote from it which appeared at the start of an article I read in Scientific American magazine. Miller is writing about walking at dawn on the hills to the south of Big Sur.

“If it be shortly after sunup of a morning when the fog has obliterated the highway below, I am then rewarded with a spectacle rare to witness. Looking up at the road towards Nepenthe... the sun rising behind me throws an enlarged shadow of me into the iridescent fog below. I lift my arms as in prayer, achieving a wingspan no god ever possessed, and there in the drifting fog a nimbus floats about my head, a radiant nimbus such as the Buddha himself might proudly wear. In the Himalayas, where the same phenomenon occurs, it is said that a devout follower of the Buddha will throw himself from a mountain peak into the arms of Buddha”.

Hence “The Arms of Buddha”! I loved the idea of a sky phenomenon so powerful that someone seeing it would throw themselves into oblivion off the top of a mountain. A few years ago, I had some correspondence with a Californian divinity student, Justin O’Jack, whose dissertation was on this very subject. He assures me that there is at least a grain of truth to the legend – there have been cases of devout Buddhists throwing themselves from mountain-tops which are known for this very phenomenon.

Why do the rings appear around the head of the observer? Such a personal location! Surely your divinity has chosen you! Well, maybe she has, but the shadow of your head is also the anti-solar point; and so my talk is an investigation of anti-solar phenomena – things you can see in the sky in exactly the opposite direction to the Sun.

What Henry Miller saw, though he may not have known it, was a phenomenon called the Spectre of the Brocken, where the shadow of the observer, projected at low angle onto cloud, appears to loom in the mist in



distorted fashion (it’s common on the Brocken mountain in central Germany). The rings of light are a related phenomenon called the Glory, an interference effect appearing in light which passes through very small water drops. As I explained in my talk, although the the physics of the Glory (Mie scattering) is well-understood, and can predict what we see, there isn’t a model which explains the phenomenon intuitively in quite the same way as there is for, say, the rainbow.

So, in what sort of location did Henry Miller see this memorable sight? In the summer of 2016, my girlfriend and I took two weeks of holiday to California. She wanted to see Los Angeles and visit a friend at Stanford University; I wanted to visit Yosemite and drive the Pacific Highway. We were able to meet these requirements by making a big circular tour of central California: Los Angeles and Long Beach, then Yosemite National Park, a few days in San Francisco and San Jose, then back down the coast through San Luis Obispo and Santa Barbara before flying out of Los Angeles. An excellent holiday.

For me, one of the highlights had to be driving Route One south from Monterey Bay, taking lunch in Carmel-by-the-Sea, and then hitting the winding road through Pfeiffer Big Sur State Park. Big Sur is a small village on the highway, with a post office that doubles as a general store and brewpub (I had a swift half). From Big Sur we could see plumes of smoke rising from forest fires inland; indeed, all roads except the coast road were closed off by firefighters.

About five miles south of Big Sur is the Henry Miller Memorial Library, which cheerfully announces itself as “A place where nothing much happens”. There’s a book store, where you can purchase editions of his many works or admire the watercolours which he painted whilst living in Big Sur. There’s a short exhibition about Miller’s life, but the Library definitely isn’t a museum; rather a place to celebrate his life. The library hosts arts events from time to time – Laurie Anderson performed there a few weeks after our visit. The advertised cat didn’t seem to be around; but there was a dog who was delighted to chase ad infinitum the Frisbee which I threw. It was a friendly place to while away time.



Sea mist along the Pacific coast



Nepenthe, a restaurant and souvenir shop that was "just up the hill" hiding in the trees

Of course I made enquiries about Nepenthe, and was delighted to be told that it was literally "just up the hill". In Henry Miller's day Nepenthe was an artists' colony; these days it's a restaurant and souvenir shop which trades on tremendous views over the Pacific from commanding height.

I was surprised to find that Nepenthe was so close to the sea; I had envisaged it as being up in the mountains. I'm sure that the mists into which Miller's shadow was projected are sea mists; this portion of the coast is renowned for them. San Francisco has them too – we never managed to see the entire Golden Gate Bridge, from top to bottom, in any of our visits to the city.

I'd love to be able to tell you that I re-created

Henry Miller's view of the Arms of Buddha from Nepenthe. Truth be told, however, it was the wrong time of day. And although we encountered much mist on the drive south on the Pacific Highway, it wasn't around when I most needed it!

I would certainly recommend the Pacific Highway – one of the world's great drives. But check before you set off – the road was breached in floods the winter after we visited, and the through route didn't open for over a year. Considering it's in populous California, Big Sur is surprisingly remote.

References

"The Big Sur and the Oranges of Hieronymus Bosch" - Henry Miller (Flamingo, 1993)

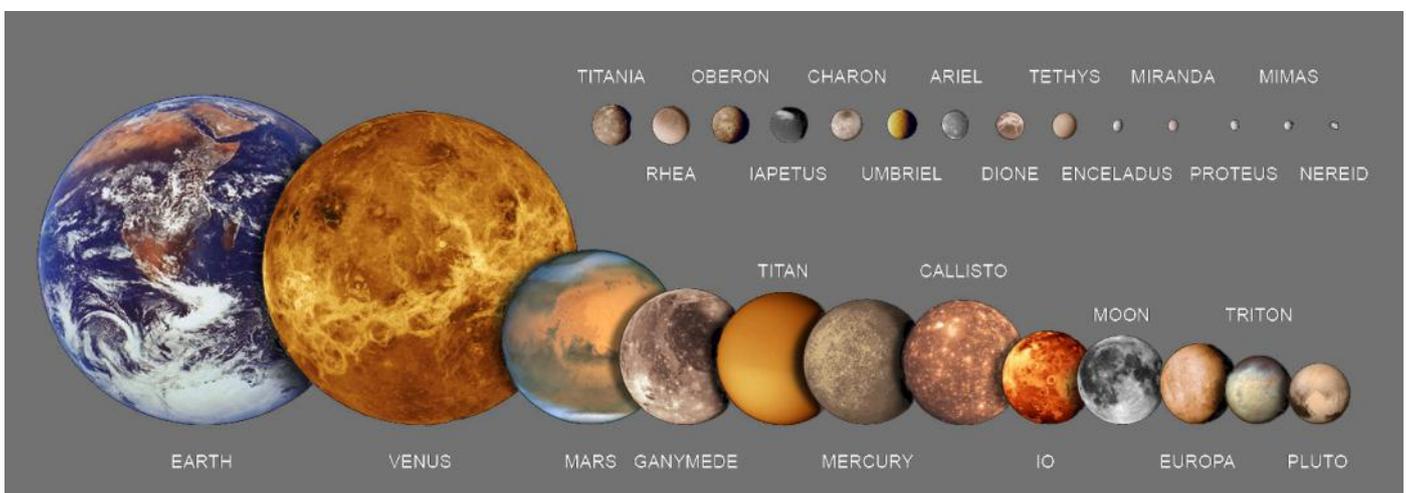
The article I read in Scientific American is "The Glory" - HC Bryant and N Jarmie, Scientific American (231,60 1974). This was referenced from "Rainbows, Haloes and Glories" - RH Greenler (C.U.P. 1980) – one of my all-time favourite books.

The Henry Miller memorial library website is

<https://henrymiller.org/>

Nepenthe restaurant website is www.nepenthe.com

25 of the Solar System objects smaller than Earth



Earth is the largest rocky planet in our solar system and with the highest gravity, on page 6 is an article about the gravity of the other planets and moons

G r a v i t y

By Ivor Clarke

It's hard to believe but it's nearly 50 years since the Apollo missions to the Moon, when some of us older ones watched the B&W TV pictures of the first lunar landing. The first blurry pictures from the surface TV camera, with its slow scan rate of the TV camera and relay made the astronauts move in a fascinating bouncy way as they bounded slowly across the dusty surface kicking up showers of dust: all in slow-motion. On the Moon with its one sixth gravity the best way to walk seemed to be to hop! And the way things fall so slowly is fascinating to watch. As we go on to explore the many other planets and their satellites, we will find that we live on a high gravity planet!

We in fact live in the gravitational pull of the largest body in our solar system that its possible to walk on. Earth's diameter of 12,756 km, with an escape velocity of 11.2 km/s makes it the giant of the rocky worlds in the solar system. All the other larger planets, with higher gravity, Jupiter, Saturn, Uranus and Neptune are gas giants with no solid surface unless its thousands of miles under their cloud tops. Down in the depths of their atmospheres where the pressure will be hundreds of Bars and temperatures of 1000's of K. only a few hardened probes may ever go.

With the Moon's diameter at 3,474 km and its gravity only one sixth of Earth's it will be easy to build large structures on the surface and the effort of digging and mining will be less. The escape velocity of 2.4 km/s and lack of atmosphere helps making landing and getting off the surface relatively easy. One aspect of low moon gravity that now seems to have caught on with film makers is that on the Moon astronauts move sloowwly in their spacesuits on the lunar surface. But when they get inside the base or back to the ship they all seem to be back in "normal" gravity! But of cause they are still in a low gravity environment and will bounce around even more when they get the space suites off inside a large base and dropping an object takes 6 times longer for it to hit the floor than on Earth. And when we get to some of the smaller moons things will take a lot longer to reach the floor in almost every case.

Our next target will be Mars, here the force of gravity is just over a third of Earth's, with an escape velocity of 5 km/s. This makes its pull quite interesting as it would be enough to keep you fit and you would feel light enough to enjoy the experience of a lower gravity. The only other body with a similar pull is Mercury, which is a bit less than a third Earth's, with an escape velocity of 4.3 km/s, it has a diameter 4878 km to Mars 6794 km. This shows how a density of a body

reflects its gravitational pull, with Mars being a third larger than Mercury yet having only slightly more gravity owing to the large iron core at Mercury's heart. Even a large moon such as Ganymede, orbiting Jupiter, the largest moon in our solar system at 5268 km diameter, has less gravitational pull than Mercury, (it is only a little more than our Moon) because its composition is mostly ice with a small rocky core, whereas Mercury's iron core is denser. The other major moons in the Jupiter system, Callisto, Europa and Io are similar in size to our Moon so have similar gravity. Io may be far to dangerous to ever get too close to, as it lies in the intense radiation belts surrounding Jupiter.

The only other two large moons are Titan orbiting Saturn and the distant Triton at Neptune. Titan has a diameter of 5,152 km and an escape velocity of 2.7 km/s making it just smaller than Ganymede, with only a seventh of Earth gravity, while Triton is only 2706 km in diameter with 1.5 km/s escape velocity is even less at a twelfth. By now there are only Pluto at 2,380 km and the other dwarf planets out in the outer reaches of the solar system, Haumea, Makemake, Eris and a couple of others that will be over a 1,000 km in diameter. Pluto's moon Charon is in a family with Titania, Oberon and Ariel in orbit around Uranus and Rhea, Iapetus, Umbriel, Dione and Tethys orbiting Saturn. All these are between 1580 km and 1000 km in diameter and all with an escape velocity well under 1 km/s makes them low gravity worlds. With Titania at only a twenty-fifth of Earth's gravity, one of the strongest in this family.

When we get to the asteroids, there is only Ceres at 975 km diameter which is nearly round. Its escape velocity is only 0.5 km/s, a fifth of our Moon's and with a gravitational pull only a thirty-fifth of Earth's. All the rest, Pallas, Vesta and Hygiene and all the smaller asteroids and smaller moons are not fully round as their gravity is not strong enough to pull them into a sphere. Most of the smaller ones we have seen from space probes resemble potatoes with lots of craters covering their surface. So the gravity on most will be just about strong enough to stop you drifting off into space.

So now we are into the smaller moon zone, there are 175 known satellites and 150 of them fall into the small moon group where the gravity pull is getting weaker and even walking around the surface in a bulky heavy spacesuit may cause problems. getting enough grip to walk will require serious work. One way may be to lean as far forward as necessary to allow you to start to fall and bunny hop! Taking care not to launch yourself into orbit and spend hours trying to get back to the ground.

What about Venus? Well even if you could land how would you get back off the surface? Venus is 12,100 km in diameter, only 640 km less than Earth, not a good place to visit with a 90 bar atmosphere pressure and a ground temperature of around 450°C, it is not a welcoming place to be. It would be possible to parachute down but how could you get back out? With a surface gravity only a little less than here and an escape velocity only a km/s less than Earth's, its thick carbon dioxide atmosphere would stop most rockets getting far off the ground without using a lot of fuel and how would you fuel a takeoff rocket with such high temperatures and pressures that would ignite or vaporise most rocket fuels?

One of the consequences of living on one of these small bodies will be you would have to exercise just as much as the astronauts do now on the ISS if you want to keep fit and healthy. Until folk start living on the Moon and Mars we don't know how their bodies will react to weeks and years in low gravity environments. Will it extend life as the body doesn't have to work so hard to move about or shorten it as we don't need to use much effort and get lazy? Will we need to wear lead weights around our wrists and ankles and around our waists to weigh us down and make our muscles work harder to keep fit? Hopefully in a few more years we may start to find out what living on another body is like.

Rosario Planetarium

By Mike Frost

I spent quite a lot of 2017 working in South America, putting together a control system for a steel mill in San Nicolas de Los Arroyos, Argentina. San Nicolas is a small town, about 150 miles west of Argentina on the Parana River. It's mostly an industrial town, although most famous for the visions of the Virgin Mary which were seen during the 1980s; hundreds of thousands of people descend on the town on the anniversary every September.

San Nicolas sits on the flood-plain of the Parana River; flat agricultural land which extends for hundreds of miles. The nearest city is forty miles to the west. Rosario, in the province of Santa Fe, is the third-largest city on Argentina, home to just over a million people. Like San Nicolas, it overlooks the Parana River; the river, and the railway line and motorway west from Buenos Aires, are the major routes into the west and north-west of Argentina. The city is the birthplace of Lionel Messi and Che Guevara. General Manuel Belgrano created the Argentine flag here, and there is an impressive flag memorial.

I visited Rosario on each of my two visits to San Nicolas – it's the obvious place to go on a day off. Like Buenos Aires, Rosario is an elegant city, especially the parts which overlook the river. To the south of the Flag Memorial, Urquiza Park runs along the riverside. It's named after a nineteenth-century president of the Argentine Confederacy. There's an open-air auditorium, a carillon, many statues (Argentina loves statues) – and a planetarium and observatory.

I spotted the planetarium when I was planning my first visit to Rosario. On this occasion I caught the bus from San Nicolas to Rosario, then caught a taxi to

Urquiza Park. My first impression of the complex was very positive. The City of Rosario planetarium is a very imposing dome-shaped structure. A spur from the main building houses the observatory, on top of a three-storey administrative building.

Of course, I was keen to see inside. There was only one problem – it was shut! I pulled at the doors, to no avail – no-one was around. The Observatory was shut too, but I could at least see a cleaner inside. She came to the door and I explained I was visiting from England and would like to see the observatory. Unfortunately, I spoke English and she spoke Spanish, so not much information was exchanged! I motioned to ask if I could look inside the building, and to my surprise she agreed. I was able to go up to the steps up to the Observatory, but it was locked. On the way out the cleaner told me something – with hindsight, I think this was probably “*come back at four o'clock*”, as this was when the Planetarium opened. But I didn't figure this out at the time.

My second visit to the Planetarium was a little more successful. First of all, some colleagues were around, and we had a hire car to travel in. Second, I was a little more prepared and knew the opening hours. Even though we arrived in Rosario in the morning this time, we parked by the Planetarium, as I knew that there would be space to park here; it was Sunday, and the park was very quiet.

We spent most of the day wandering around the city, returning at 4 PM. To our surprise, the park had filled up in the interim with picnicking families - perhaps they were at church in the morning. To my



The City of Rosario Planetarium, Urquiza Park Rosario. The observatory is to the left. Rosario Observatory. Right

satisfaction, the planetarium was now open, so we purchased tickets for a show, and, while we were waiting, a tour of the science centre which is housed on the second storey of the planetarium.

Despite my lack of Spanish, I quite enjoyed the tour of the science centre. There were demonstrations of polarization and Van der Graaf generators. I was particularly impressed with the meteorite on display from the Campo del Cielo (Field of Heaven) meteorite field. This meteorite fall in antiquity deposited 60 tonnes of iron-rich meteoritic material onto a site in northern Argentina. The largest fragment is 37 tonnes, the second-largest single meteorite ever found (the largest is Hoba West in Namibia). A large fragment was donated to the Science Museum in London, another is on display in Buenos Aires. Rosario has an impressive 11 kg fragment which you can touch.

The planetarium show was equally good, if equally confounded by my lack of Spanish. We got what was clearly a tour of the skies above Rosario, including of course many southern constellations not visible from the UK (Rosario is 33 degrees south, not quite in the tropics).

As we left, we spotted several more astronomically-themed features. The friends of the Rosario observatory

have their own mini-observatory, also locked up. Nearby, there is a display of facsimile instruments from antiquity – a sundial, a mural quadrant, an armillary sphere, and a reproduction of an Egyptian column. Most amusingly, there was a cycle-proficiency park, where kids could learn the rules of the road. Because it was next door to the observatory, all the “streets” in the park were named after planets.

So, my second visit to Rosario Planetarium was more successful than the first. Perhaps a third visit will allow us to go at night, and actually see something through the telescopes.



An 11kg fragment from the Campo del Cielo meteorite fall on northern Argentina



Rosario Planetarium projector

Not So Universal Gravity

By Mike Frost

Learning and understanding are not the same - there's a difference between learning the facts and understanding what they mean. Sometime the way to gain real insight is to notice the contradictions inherent in what you are being told. My old physics teacher at school, for example, having told us that similar electric charges repel, would go on to describe how the atomic nucleus was made of electrically neutral particles, neutrons, and positively charged particles, protons. How many of his students asked why the protons didn't shoot out of the nucleus because they repelled each other? Not one of them, me included, thought to ask that simple question – yet it would have led directly to the appreciation that there are still-stronger forces holding the nucleus together.

Here's another example. Anyone who studies mathematics or physics to, say, A-level standard, will probably have come across the following statements:

Isaac Newton postulated a Universal Law of Gravity – the force that causes an apple to fall to Earth is the same force which causes the planets to orbit the Sun and the Moon to orbit the Earth.

Johannes Kepler, examining the observations of Tycho Brahe, determined that the planets followed elliptical orbits.

An artificial satellite such as the International Space Station goes round the Earth in a circular orbit.

Ignoring air resistance, a projectile such as a cannonball will follow a path described by a parabola.

But these seem to be four contradictory statements! How does something falling freely under gravity know if it's a projectile (following a parabola), an artificial satellite (a circle) or a planet (an ellipse)? Is the difference decided by the location – parabola close to the Earth, then circles further out, then ellipses? If so, gravity is hardly universal.

The insight to be gained here is that all four statements are true, but reflect different aspects of the theory of gravity.

In fact, for the simplest case of two bodies interacting solely under gravity, four possible types of motion are allowed:

Circular motion of a very small body around a large one

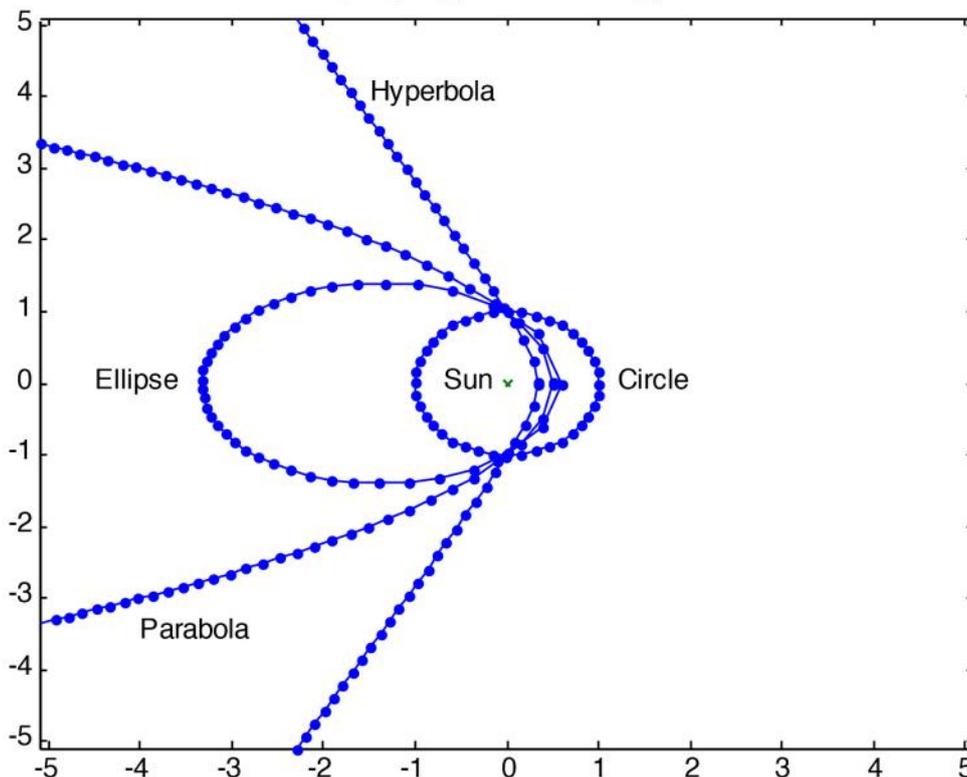
Elliptical motion around the common centre of gravity of the two bodies
Parabolic orbits
Hyperbolic orbits

Two of these are limiting cases. The first two cases are closed orbits, which repeat themselves, the second two cases open orbits.

Let's go back to the four statements. How do they fit in with the deeper insight?

Motion of a projectile – this is the most interesting one. Look at the derivation of projectile motion and you'll notice that the mathematics assumes the Earth is flat! (It isn't.) For a spherical Earth, where the ground drops away, the motion of the projectile becomes elliptical. But it's

Circle, ellipse, parabola and hyperbola



an ellipse which is very close to being a parabola. Putting it another way, when calculating the motion of a cannonball, it's a good approximation to say that the Earth is flat – but for a faster moving projectile such as a rocket an ellipse is a better fit.

Motion of the planets – Kepler was right, planets do move in ellipses. But he was wrong in saying that they go round the Sun; rather, both Sun and planet orbit the barycenter, the centre of gravity of the solar system, in ellipses. The planet's ellipse is large, the Sun's ellipse much smaller. In our solar system, planets orbit the barycenter in near-circular elliptical orbits. But there are bodies such as comets which have much more elliptical orbits. As the furthest point of the orbit gets further and further from the Sun, the shape of the orbit becomes closer and closer to a parabola. In the limiting case, a comet at rest "at infinity" (in the far reaches of the Oort Cloud, perhaps) drops very slowly into the solar system, describes a parabola around the Sun, and returns to infinity at rest. Visitors to the solar system, such as the recently discovered object 'Oumuamua, enter the solar system at speed, whizz round the Sun in a hyperbolic orbit, and leave at similar speed, never to return.

Artificial satellites – these can describe elliptical orbits, and sometimes do. Sometimes they visit a planet in a hyperbolic orbit – the planetary flybys of Voyager or New Horizons, for example. The important thing about artificial satellites is that their mass is negligible compared with the planet they orbit. Under these circumstances the satellite can describe a circular orbit – the planet doesn't notice its presence and so doesn't make any motion. As the mass of the satellite becomes

noticeable, satellite and planet begin to describe elliptical orbits around their common centre of gravity. (In the exceedingly unlikely case of two identical masses, circular orbits are possible).

What I'm trying to get across is that my A-level teachers weren't trying to mislead me with contradictions – rather, they were presenting different aspects of one, united, universal law of gravity. Some aspects – parabolic and hyperbolic orbits – weren't apparent to Kepler. Other aspects are limiting cases.

I'll finish by posing a little puzzle to you – one I thought up a while ago, puzzled over for a while, and eventually figured out. Once I understood the physics, the answer was obvious – you may figure it out immediately.

Here's the puzzle:- I've already told you that for a body of negligible mass, a circular orbit is possible around a much larger body; but, as the mass of the smaller body gets larger, this motion changes to elliptical motion around the common centre of mass.

Now consider hyperbolic motion. A tiny body entering the solar system from afar will go past the Sun in a hyperbola; the Sun won't notice it and won't move at all. But what happens as the mass of the smaller body become significant? The smaller body will still travel in a hyperbolic orbit around the common centre of mass.

But what orbit will the Sun describe in this case?

Please take time to think about this – with the right insight, it's not a difficult puzzle.

Answer on page 12.



The Kirriemuir Camera Obscura roof top of the cricket pavilion with the mirror of the lens system showing

Kirriemuir Camera Obscura

By Mike Frost



On May 26th 2018 I had the pleasure of running a meeting of the BAA Historical Section in the Smith Art Gallery and Museum, Stirling, Scotland. The meeting was very successful, and the venue ideal; just right for the number of attendees we had, and with helpful museum staff to make the day run smoothly. The museum was small enough to allow a tour during the lunch break; there were some fascinating exhibits, including the world's oldest football, found in the ceiling of Stirling Castle during renovations, and probably dating back to the time of Mary Queen of Scots. Star of the show was Oswald, the museum cat, who is in charge of the museum – he has his own Twitter feed.

The night before the meeting I spoke to Stirling Astronomical Society, who meet in the same location. My lecture on "The Green Flash" is particularly appropriate to Scottish societies as there is such a strong Scottish connection. I was able to tell the audience that Jules Verne had visited Stirling, staying at the Golden Lion hotel on the night of August 30th 1859 – I ate at the same hotel, where the staff didn't seem to know about the Verne connection (Robert Burns stayed at the same hotel on August 26th 1787, and that visit is much more strongly celebrated). On both the Friday and Saturday evenings several of us observed from Stirling AS's observatory on top of the Highland Hotel, which I have written about before in MIRA. Late May is not a great time to observe from Scotland as sunset is very late, but we did manage views of the Moon and Venus.

Of course, Stirling is a beautiful city to stay in, and I took a week's holiday, basing myself at the Highland Hotel. Stirling is very central for lowland Scotland, and I took the train to Glasgow and to Edinburgh for the day. In Edinburgh I climbed up to Arthur's Seat, with fine views over the city, revisited the Museum of Scotland, which had hosted the BAA Exhibition in 2017, and paid a third visit to my favourite location in

Edinburgh, the Outlook Tower camera obscura. Regular readers of my articles will know of my interest in these fascinating examples of Victorian-era technology – I have visited many around the world, and gleefully pointed out that they were using one of my pictures (taken from the Internet) of the camera in Pretoria, South Africa, which I visited in 1998.

Our keynote speaker at the historical section meeting, Dave Gavine, surprised me by revealing that he had been a technical consultant on a short film entitled "*Latin for A Dark Room*", a period drama made in 1994 starring the excellent Siobhan Redmond and Neil Pearson, directed by the poet Liz Lochhead, and set in and around the Outlook Tower. The story starts from the historical fact that the camera's first proprietor was an optician called Maria Short; however the drama then moves into murkier territory of illicit romance, voyeurism and murder. I've seen several films which feature camera obscuras, but this is the first in which the protagonists make love on the camera projection table – as the table is concave, I suspect it would be a little uncomfortable!

So you can guess that, on the day after the historical section meeting, I was determined to visit one of the few British camera obscuras which I had not yet seen, at the little town of Kirriemuir, to the west of Forfar in Angus. I had an enjoyable drive north from Stirling, past Perth and Dundee, and then into the country roads of the Strathmore Valley.

Kirriemuir is a compact little town set in beautiful hilly countryside. From the south, you pass through the town's one-way system and then head uphill out of town to the north-west. Tourist signs directed me to the sports ground, where the camera obscura is located in the roof of the cricket pavilion.

The camera obscura dates from 1929, when it was presented to the town by its most famous son, the writer James Matthew (J.M.) Barrie, author of "*Peter Pan*". Although Barrie was based in London for most of his

career, he often returned to his hometown. He grew up watching cricket on "The Hill" and wrote *"I remember the old matches on the Hill of Kirriemuir; as far as I can recall, Kirriemuir always won. I only played twice in these matches myself. The first time I made one; the second time I was not so fortunate"*. However, the location clearly made an impression on him and he offered to pay for a pavilion to be built there. Barrie wanted *"something for children"* in the pavilion, and the architect, Frank Thomson, suggested a camera obscura.

Cricket is still played on the cricket field and the pavilion is still used as changing rooms, although these days much of the pavilion is taken up with displays explaining the history of the camera obscura. It has been in use more-or-less continuously since 1930, although opening times have varied. For many years recently it was run by the Scottish National Trust, who manned the camera but didn't do very much maintenance. Since 2015, the camera has been run by the local community, through the Kirriemuir Regeneration Group. The camera has been overhauled but it now opens mostly at week-ends.

I had emailed ahead to check opening hours so I was confident the camera would be open, and, indeed, as I arrived at the pavilion, volunteer Rob was welcoming a family who were just about to enter the camera ahead of me. We went to the back of the pavilion, up a few steps, and into the Dark Room.

The view is really rather excellent. Kirriemuir (or, "Kirrie", as everyone calls it) lies a few miles south of the foothills of the Cairngorms. To the south and west are the Sidlaws and Ochils, and on a less hazy day, Ben Ledi, Ben Lui and Ben Lawers. Rather closer to home are the Grampians and the Angus Glens.

The camera lens is a 179mm (7-inch) diameter apochromat, with a focal length of 2667 mm. The table diameter is 1372mm, and the table can be raised or lowered to bring foreground or distant objects into focus – however, intriguingly, Rob preferred to tilt the table, which achieved the same effect on one side of the table. The mechanism to open and close the lens window is part of a car steering mechanism.

After the demonstration I had a look round the pavilion exhibits and then a quick chat with Rob and Morag, who was selling tickets for the camera. I then explored the neighbourhood. To the south of the playing fields, on the downslope towards town, is the cemetery. The most famous gravestone, not surprisingly, is for J.M.Barrie – at his request, his name appears without fanfare amongst others on a family tombstone, however there are other memorials in the vicinity that make clear the esteem in which he is held. Barrie's grave and the camera obscura are stops on a scenic walk, so I continued on that, stopping to admire a bronze-age standing stone; and the woods, planted for the millennium, which have the side effect of spoiling the camera's north-eastern vista.

On my return to the camera I joined John, and Morag, and several other volunteers (Elaine and another Morag and Maggie, if I remember correctly). We chatted inconsequently for a while; I told them about my visits to camera obscuras around the world; they explained what it was like running a community attraction like a camera. I was particularly pleased to hear that they had used the camera obscura to view the solar eclipse of March 2015.

I had one or two more things to see before I returned to Stirling, I drove to the town centre, and went to see the statue of Peter Pan which stands in the very centre of town. Just down the hill is another statue, of Bon Scott, raised in Kirrie, singer with AC/DC, who lived hard and died young.

My final stop was J.M.Barrie's birthplace. It's a small cottage on the Brechin Road out of town, with the next door cottage now attached to form the inevitable shop for the National Trust of Scotland, who run the birthplace. Barrie's life story is interesting. He was the ninth child of ten, and, at the age of six, his elder brother died in an ice-skating accident – he literally became a boy who would never grow up. Barrie always felt that his mother never regarded him as highly as his older brother.

Barrie's first published works were accounts of life among weaving families on the small Scottish town of Thrums, a fictionalised version of Kirrie. He went on to have literary successes with *Quality Street* and *The Admirable Crichton*, but of course is best known for his oft-staged novel *Peter Pan*. He married actress Mary Ansell in Kirriemuir in 1894, but the marriage was childless and ended in divorce, at a time when divorces were rare. When Barrie died in 1937, he left his estate to his secretary, Cynthia Asquith, except for the copyright to *Peter Pan* and associated works, which, famously, was given to Great Ormond Street Hospital, who have benefited from it greatly.

The birthplace museum is fascinating, but small, and for most of the time I was there I was the only visitor. Outside the museum is a small garden, commemorating Barrie, and the family washhouse, which was the staging-place for childhood entertainments, Barrie's first plays.

I enjoyed my visit to Kirrie. I'm delighted to see a camera obscura being run by and for the benefit of the local community. I wish them every success, and encourage you to support them by paying a visit. But check before you go! Their website www.kirriemuircameraobscura.com has details.

Answer to Not So Universal Gravity

The Sun will also describe a hyperbola. The insight is to consider the system from the point of view of the centre of gravity of the two bodies. If the smaller body approaches from infinity, then the Sun, the larger body, also has to arrive from infinity. It may do so very slowly – if the Sun is a trillion times the mass of the smaller body, it is always a trillion times closer to the centre of gravity – but it still ends up at infinity.