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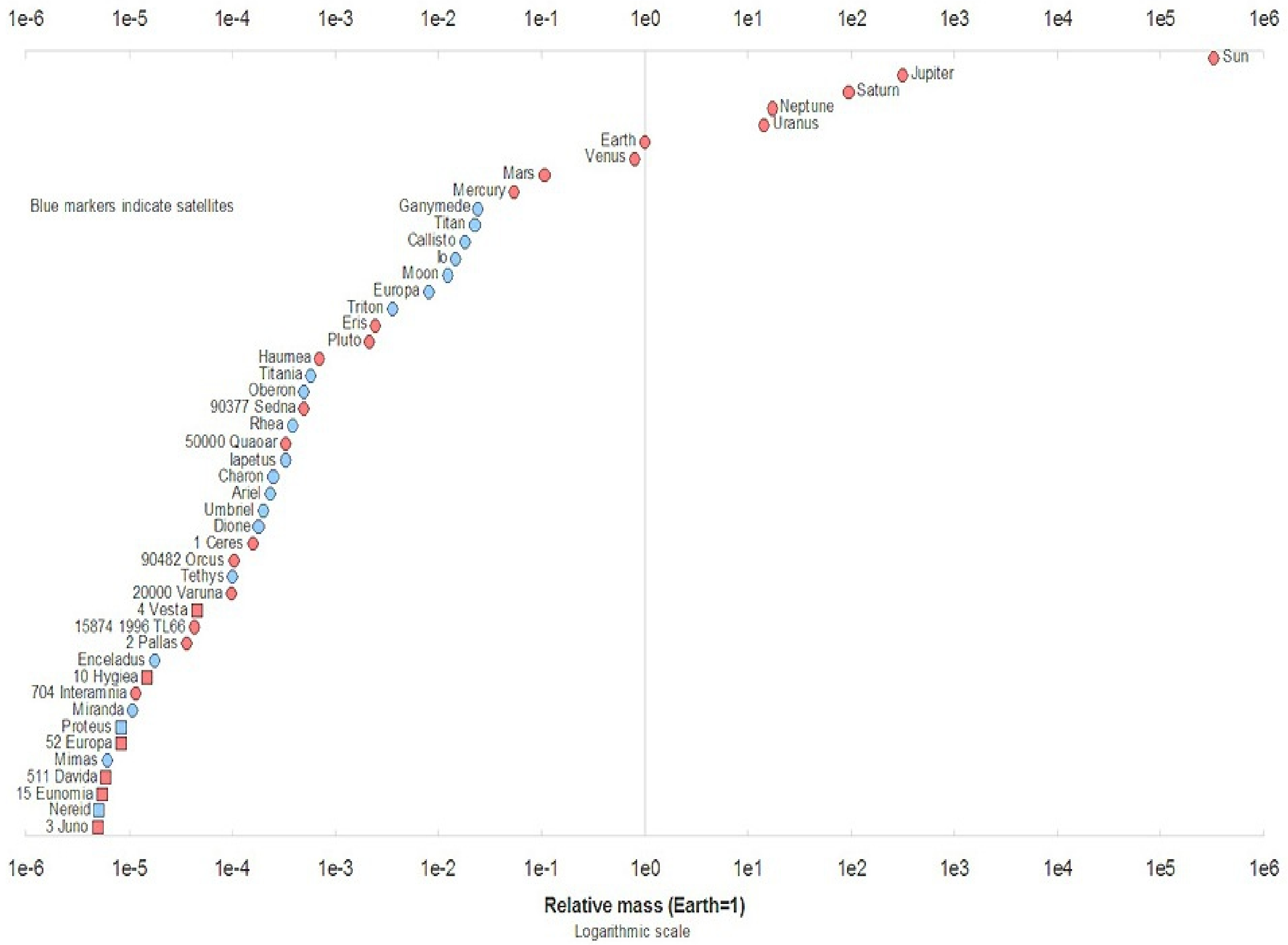
Relative Masses of the Heaviest Solar System Objects



This graph shows where all the "stuff" in the Solar System resides. As you can see most of it is in the Sun over to the far right side. The line through the centre shows where the Earth is and as you can see nearly all other "stuff" is well to the left! This shows the importance of our planet in the solar system, and how all the other bodies we could land on are smaller than us. The scale is a logarithmic one so every mark is a 10 times increase or reduction in mass. When we look at other exoplanet systems how will they rate in size? See *Life on Exoplanets Moons* on page 2. So how does the total mass of asteroids, or meteors, or comets, of which there are properly billions in the outer reaches of the Solar System, compare with the total mass of planets (of which there are only a few) or the Sun (of which there is but one)?
In Mike Frost's article *An Inventory of the Solar System* on page 4, the answer to all these questions is suggested.

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Life on Exoplanets Moons?

By Ivor Clarke

How times change, 20 years ago we didn't know of any planetary systems but our own. Now we know of hundreds, thanks to new technology, dedicated spacecraft and all the new massive telescopes now in use across the globe. The number of candidate exoplanets is approaching 4,000 (going up daily) and the number of planetary systems is approaching 1000. The latest guess on the number of planets in the Milky Way galaxy is over 100 billion!

We do seem to have found a lot of large gas giants, these are the easiest to find owning to their large size and mass, most are a lot larger than Jupiter, most close into their star, often spinning around it in a few days. Not like our home system at all. One or two of these are smaller rocky worlds, most larger than Earth, Super Earths, and do lie in the "Goldilocks Zone". The habitable zone around a star were water would be liquid on the surface of an orbiting body. This implies that the body is large enough to have a reasonable amount of gravity to hold on to an atmosphere or the water will evaporate and be lost to space. Also that the temperature rises above freezing some time during the day. Most of the smaller exoplanets found so far orbit their star very closely and would be extremely hot one side and cold on the other as most would be tidally locked with one side always pointing towards the star. Our planet Mercury, which lies about 36 million miles (70 to 46 million kilometres) from the Sun, does spin slightly faster, three rotations for two every orbits, a 3 / 2 resonance, so it shows most of its surface to the Sun over about 176 days (see Mike Frost's stories in MIRA 53 and 54). It is possible that some of the exoplanets found could have spin resonances of different ratios. Only Mercury has this strange spin resonance with the Sun in our solar system, Venus for some reason spins backward in 243 days which is 20 days longer than its orbital year! Most of the smaller exoplanets found so far whizz round their star in hours or days far inside the orbit where Mercury resides.

A lot of these exoplanets are orbiting stars smaller and dimmer than our Sun so the stars gravity will be less and the habitable zone will be closer in and with a smaller radius. With a small red dwarf star the habitable zone may be only a couple million kilometres wide and it may be only 10 to 20 million kilometres from the star, so if a planet has an eccentric orbit it may be bobbing in and out of this zone. One thing in the small / dwarf star favour is their long lives. All the red dwarf stars ever created are still around, their life spans are far greater then the present age of the universe, so any planet in the habitual zone has an amazingly long time to let life get going. It is doubtful that the first stars would have any planets but gas giants as planets are made from the ash of novas. The planets around red dwarfs would need to made from recycled material like the solar system which comes from the explosions of countless supernova in the early universe.

The only way that the universe makes and re-cycles heavy elements, that is elements heaver than hydrogen, helium and lithium which all formed in the Big Bang, is in the giant stars of the past when they explode. So how long before there's enough material to make a planet which can support life? To quote Sir Patrick *"Frankly, we just don't know."* So the earliest red dwarf stars would not have formed with any planetary systems. It was perhaps a billion years before enough material had been formed to condense into gas clouds which then shrank under the pull of gravity and pressure of shock waves from nova and the magnetic fields of the galaxy to form new stars with planets. Only when sufficient raw material have formed into gas clouds with a full quoter of heavy elements could there be a mix of all the elements needed for life. The universe was already nearly 9 billion years old by the time our Sun formed, so plenty of time to collect the chemistry needed.

As most of the exoplanet gas giants found have no chance of supporting life, what about their moons? As yet we can't detect any of the moons that may orbit these planets, also many of them will be small, rocky, icy and airless. Many will be like the moons around the gas giant planets we have, cold and icy or hot and volcanic if near their host.

What must be remembered is that we live on the fifth largest planet in our solar system and only Venus is near our size. Mars is about half our size but because it has no seas or oceans has about the same surface area as Earth (Earth is 70% covered in water). Venus now lies just inside the habitual zone, too close to the Sun, but was just inside it when the Sun was a young star and was 20% dimmer than now. As the solar energy increased and the Sun got hotter and more luminous, the borders of the habitual zone slowly move outwards and eventually Venus was left behind getting hotter all the time. So now all the water has now evaporated away and the Sun's UV light has broken up the water molecules and let the hydrogen escape into space. The only way life could survive on a cold moon outside the habitual zone would be if it was cold enough to have a thick icy crust like Europa with a ocean underneath warmed by gravity flexing the moon during each orbit.

Can we begin to imagine a water world like a mini earth around a gas giant in the stars habitual zone? What would it be like?

First of all it would have to be big. Bigger than any moon in the solar system. Jupiter's moon Ganymede is the largest moon in the solar system and lies about one million kilometres from Jupiter. This moon is 5,275 km in diameter and is larger than Mercury which is 4,880 km. But is it large enough to hang on to an atmosphere if it were nearer the Sun? The answer is no: for its mass would not be high enough if it was warm enough for liquid water on the surface to hold on with such a weak gravity of 2.75 km/s escape velocity. Slowly all the gasses would escape into space leaving it a dry rocky dead moon. Ganymede is a cold frozen world were the surface temperature is around 100°K, so ice would be as hard as rock. This is not to say that under the ice deep down, a water ocean exists.

So what we need is at least a Mars size moon. Mars is 6,795 km in diameter and has an escape velocity of just over 5 km/s, just under half Earth's and we know that long ago it had plenty of water on its surface for perhaps a billion years. Everywhere the Mars rovers look they seem to find evidence of water. But Mars is now a cold world just on the outside edge of the Sun's habitual zone. If we could increase the atmosphere pressure to say a 50 mb level, water would again flow on the surface. But would it last long enough for life to get going?

So we need a moon body say 8,000 km diameter (Earth's is 12,756 km) with a surface gravity about 3/4 of Earth, inside the stars habitual zone and far enough away from the gas giant so that its not fried in the radiation belts that all gas giants seem to have. If we had radio eyes we would see Jupiter when it's near opposition to us as about the size of the Moon! The radiation belts of Jupiter are the most powerful of all the solar system planets and Ganymede orbits inside Jupiter's magnetosphere, the tail of which gets blown away by the Sun's solar wind to reach past the orbit of Saturn. Jupiter's magnetosphere reaches out past all the Galilean satellites and is 14 times more powerful than Earth's, so a moon would need to be in a large orbit in the outer reaches of the system. Jupiter's Callisto, the outer most of the four large satellites lies 1,883,000 km from Jupiter, outside the magnetosphere of Jupiter and has over 300 times less radiation then Europa, so if moon was at least 2 - 2.5m km from the planet, it would be safe on the surface for most of its orbit. Having a magnetic field of its own to ward off stray radiation from the gas giant would also help.

To have a magnetic field implies that the moon has a molten iron core and properly plate tectonics with volcanos too. If the moon had other large moons in resonances like the Galilean's, 1.7 : 3.5 : 7 : 16.5 day orbits, heat would be generated with gravitational interaction as the moons swing past each other: this is what keeps Jupiter's Io so hot and maybe an ocean under Europa's icy crust. If the gas giant is several times Jupiter's mass, it is reasonable to suppose that its radiation belts will be in proportion too. Does this mean that its moons would be larger? We have a small amount of background radiation to contend with on Earth but how much more could life withstand. Low life forms, plants and insects can withstand radiation that would disrupt the DNA on larger complicated life.

One other problem is tidal locking to the parent body. As we have seen this applies to orbiting planets as well as moons. Our own Moon is tidally locked to Earth's so it always shows us one side. All of the Galilean satellites are synchronous locked to Jupiter, always showing the same face to Jupiter. Is this a problem for life? Ganymede orbits in 7 days 4 hours and Callisto the outer most moon in 16 days 18 hours. What this means is that all parts of the moons face the star during each orbit. OK the days are long but so are the nights. I'm sure life would find a way to cope with long 4 or 8 days of light and 4 or 8 day long nights of dark, and night time may not be so dark if other moons are visible. The planet facing side would have a bright night sky with the sun reflecting off the cloud tops and the view would be many times brighter than our full moon light. The rear facing half would have equal long days and nights but on the gas giant facing side an eclipse of the sun would happen on every day as the orbit takes it behind the planet and into its shadow for a few hours depending on the size of the planet the distance of the moon is and its orbital speed. During this eclipse the whole of the moon is likely to be in darkness with an amazing spectacle in the sky of the black planet surrounded by a ring of sunlight poring through the upper atmosphere. And if the planet had a ring system like Saturn. . . What a sight that would be. The temperature would drop during the eclipse but depending on the thickness of the atmosphere and the distance of the star it could be a glad rest from the bright sunlight or a freezing midday.

As the moon orbited the planet the far side would never know what the other side was like unless there was a way to travel around the moon either on land or sea. Living on the far side would be the side to do astronomy as they looked outward from the planet into space. While on the facing side the ever changing view in their sky would be the gas giant. At night the sky would be filled with a full gas giant giving off lots of light so the only time it got darker would be when the star was eclipsed! Even then it wouldn't be completely dark as we have seen. A fascinating world that could exist somewhere.

What would intelligent beings living on such a moon make of it? One side worshipping the giant planet and the other side wide eyed observers of the universe?

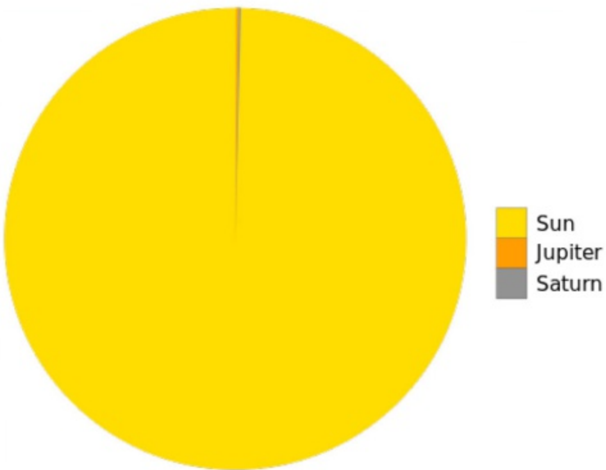
An Inventory of the Solar System

By Mike Frost

Where does all the "stuff" in the Solar System reside? Does the total mass of asteroids, or meteors, or comets (of which there are lots) outnumber the total mass of planets (of which there are a few) or the Sun (of which there is one)? If not mass, how about angular momentum?

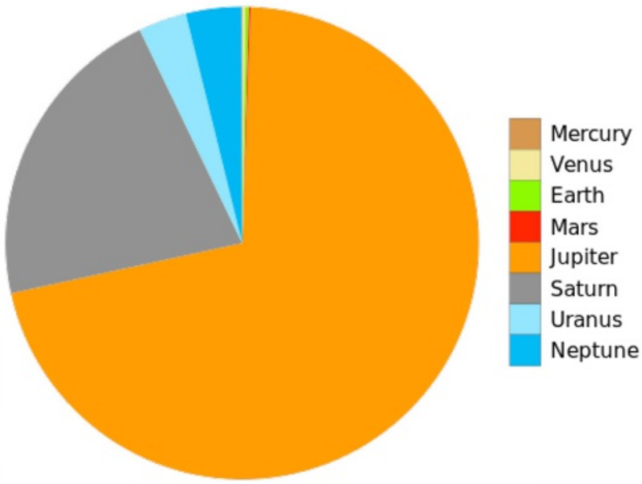
I don't claim to know the answer to all these questions, but at least I can try. Let's start with mass. I started to put together a spreadsheet containing the masses of the larger bodies in the solar system, with the intention of creating some pie-charts to compare their relative sizes. Then I discovered the very useful Wikipedia page which did the job for me, with non-copyright ("commons") illustrations (see links at end).

So the first illustration shows the relative masses of the Sun and the two biggest planets, Jupiter and Saturn – nothing else in the solar system has a mass big enough to show up. Here is how the mass of the solar system divvies up:



You can see that almost all the mass of the solar system is held in the Sun. That probably shouldn't come as a surprise – to a good approximation, the planets orbit round the Sun, rather than vice versa. To be more precise, the barycentre, or centre of gravity of the solar system, is always close to the centre of the Sun.

So, let's put the Sun to one side, so to speak. How is the mass of the rest of the solar system distributed between the planets and other objects? Here are the relative masses of the planets:



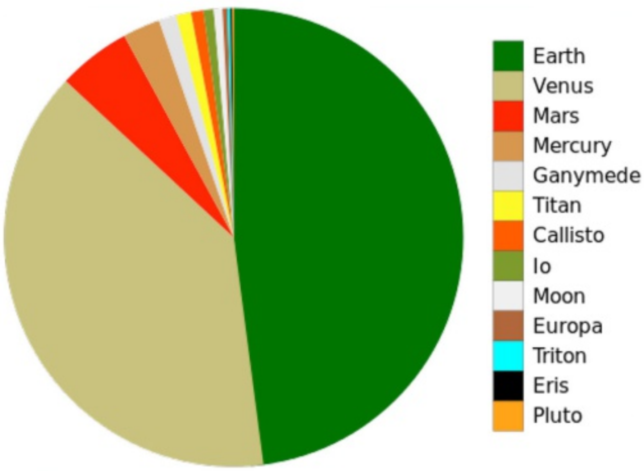
You can see that Jupiter dominates. Most of the mass of the Solar system is concentrated in the Sun; most of the remainder in Jupiter; most of the remainder after these two in Saturn. The rocky planets barely feature at all.

What about the other components of the solar system? I can think of three which, viewed in their entirety, might rival the masses of the planets. First there is the asteroid belt, primarily contained within the orbit of Jupiter, of which we have currently mapped about half-a-million members. There remain millions more asteroids to be discovered, but with our current telescope surveys, we are reasonably certain that we have discovered all the larger asteroids. So there are diminishing returns from the remaining asteroids, and we can, with some certainty, estimate the total mass of the asteroid belt. It's about 3.3×10^{21} kg. How big is that? Be prepared to be surprised – it's about one two-thousandth of the mass of the Earth! The asteroid belt wouldn't even begin to feature on the pie chart above.

The second contender is the Kuiper belt – the asteroids outside the orbit of Neptune. We have only just started to discover these, from the late 1980's onwards, although it now appears that Pluto, discovered in 1930, is simply a larger Kuiper belt member rather than a fully-fledged planet. Because we have only discovered a few Kuiper belt objects, we don't yet have a strong estimate of the total mass. The Internet contains estimates for the total mass of all Kuiper Belt objects as 3.0×10^{23} kg, one hundred times the mass of the asteroid belt, but still only about one twentieth of the mass of the Earth, and still not enough to register on the planetary mass chart. And remember, that 3.0 x 10^{23} kg includes the mass of Pluto (1.3 x 10^{21} kg).

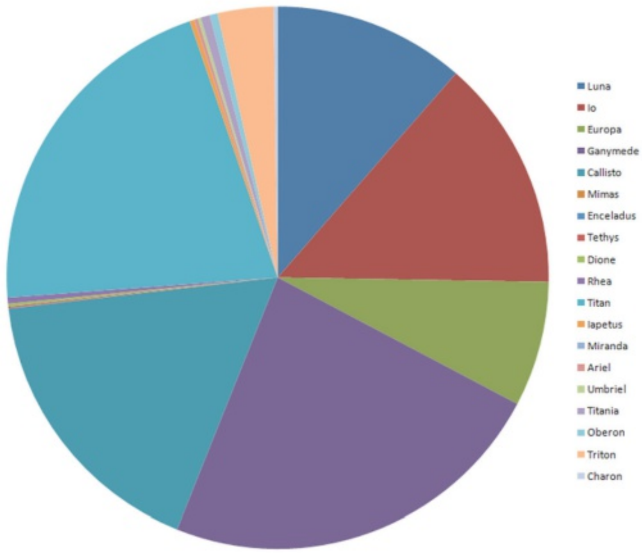
The final contender is the Oort Cloud; the reservoir of comets thought to extend a light year or more from the Sun. Any estimates of the mass of the Oort Cloud have to be approximate for the simple reason that we have never directly observed a single member of it. All we can do is observe Oort Cloud comets, such as the recently deceased Comet ISON, whose orbits were perturbed so that they entered the inner solar system, where they could be observed. A 1988 paper by Marochnik, Mukhin and Sagdeev gives an estimate of the total mass of the Oort Cloud of one thirtieth that of the Sun, but other sources give a much smaller mass, between that of the Earth and that of Uranus.

We have much more accurate estimates for the masses of the rocky bodies of the solar system. Let's see how these compare (if you are reading this in black and white, the bodies are distributed around the pie chart as the same order as the index on the right-hand side):



Earth dominates here, along with Venus. Mars and Mercury are an order of magnitude smaller, but still bigger than any of the Moons in the solar system. The really noteworthy entry on the pie chart is Pluto, which has the tiniest slice of the pie. By mass, Pluto is the eighteenth largest body so far discovered in the solar system – less massive than seven moons, including our own. Why did anyone ever think that Pluto deserved to be a planet? Because, when it was first discovered, it was thought to be much larger. Throughout the twentieth century, the estimated mass of Pluto was revised steadily downwards (we now know it to high accuracy). I think there was an element of wishful thinking about the mass of Pluto – Percival Lowell was expecting to find a planet the size of Neptune, so that was how its size was first reported.

Let's take a look at the relative size of the moons of the solar system (again, Moons in order of index):

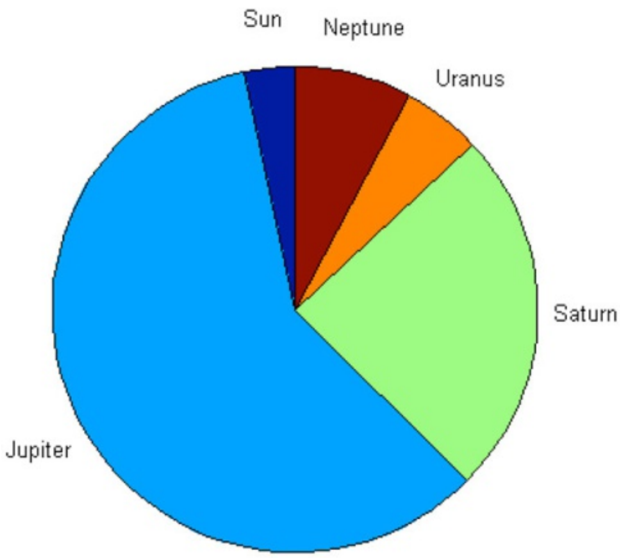


For the first time, there isn't a clear hierarchy. Ganymede is the most massive moon, but it isn't substantially more massive than Callisto or Titan. Perhaps this is telling us something about the formation of moons within solar systems in general. Similarly, both Ganymede and Titan are physically bigger in size than Mercury, the smallest planet, but noticeably smaller in mass. Again, this tells us something interesting about the solar system – Mercury, like Venus, Earth and Mars, is rocky, whereas Ganymede and Titan seem to be made up at least partially of much less dense ice.

Let's move on to angular momentum. This is a little complicated to define, as it comes in two flavours. First there is the orbital angular momentum of the planets. For a given planet, this is defined as its distance from the Sun multiplied by its speed around the Sun multiplied by its mass (it's a little more subtle than that - for example it's actually a vector quantity - but let's not complicate things). Angular momentum is conserved, meaning that an object in an elliptical orbit speeds up as it gets closer to the Sun, and slows down again as it recedes.

You can see that, by this definition, the gas giants, which are massive, and a long way from the Sun, have large angular momenta. The inner planets move a lot more quickly but their mass and closeness to the Sun give smaller angular momenta. You can also see that the Sun has no orbital angular momentum at all. However, there is a second type of angular momentum – rotational angular momentum, the angular momentum intrinsic to a spinning body. To calculate this you have to sum up (speed x distance from the centre x mass) for all the plasma in the Sun. There is a similar calculation for all the other planets but it turns out that the Sun, because of its huge mass, has far more rotational angular momentum than any other object in the solar system.

Add together orbital and rotational angular momentum and you get total angular momentum. Let's see how that is distributed around the solar system. This time I had to construct my own pie chart:



Things are a lot different now. Most of the angular momentum in the solar system resides in the orbit of Jupiter; most of the remainder in Saturn's orbit.

This isn't just playing with figures. Angular momentum is one of the fundamental quantities of physics. Its conservation leads to some interesting consequences – for example, the slingshot effect, where a spacecraft can pick up speed by a close approach to a planet, in effect stealing some of its angular momentum. Similarly, the fact that Jupiter has the lion's share of the solar system's angular momentum means that it bosses the rest of the solar system – any smaller body that comes close to Jupiter tends to get pulled into the same plane that Jupiter orbits in. So it is unlikely that there are any major bodies in the inner solar system whose plane of rotation is tilted substantially to the ecliptic.

And what about those three zones – the asteroid belt, Kuiper belt and Oort cloud – which we talked about earlier. Where would they feature in the pie chart of angular momentum? The asteroid belt, being at about the same distance as Mars, but with considerably less mass, has less total angular momentum than Mars, so barely features. The Kuiper belt, being at about the same distance as Neptune, but with less mass, has less total angular momentum than Neptune, so is a minor player.

But the Oort cloud…? Well, as we don't know the mass of the Oort cloud, we can only guess at its angular momentum. But the estimates are astonishing. The paper by Marochnik, Mukhin and Sagdeev suggests that "angular momentum [of the Oort cloud] may exceed the present angular momentum of the whole planetary system by one order of magnitude". The conclusions of this paper were re-evaluated three years later in a paper by Weissman who decided that an order of magnitude was a little high, but still estimated that the total momentum of the Oort cloud was somewhere between 2 and 4 times as great as the rest of the solar system put together.

So, perhaps, the angular momentum of the Oort cloud exceeds the angular momentum of the rest of the solar system by a factor of between 2 and 10! The comets in the reservoir may not be massive, and they may not move quickly, but their distance from the Sun, and the sheer number of them, means that they carry the better part of the solar system's angular momentum. This probably tells us something profound about the way the solar system formed – but quite what, I don't know.

This is the way astronomy works. You think you have an inventory for what's out there, and suddenly something unexpected crops up which completely alters the big picture. Returning to mass, for example – how much dark matter is there is in the Solar system? There can't be too much in the inner solar system, otherwise we would notice its effects. But if there was a halo of dark matter around the solar system, like the Oort cloud, it would be difficult to detect. The gravitational pull we'd feel from an evenly distributed spherical halo of dark matter on the inner solar system would be – zero.

It's a continuing challenge to astronomers to figure out how to prove, or disprove, the existence of entities that could dwarf the structures that we already know about. Think dark energy (postulated to be 75% of the mass-energy in the universe, but never observed), neutrinos (billions passing through every one of every second, almost completely unhindered), gravitational waves, Higgs bosons …

It's what makes astronomy so much fun!

Links to Wikipedia and other web pages

1 Sizes of Solar System bodies
`en.wikipedia.org/wiki/List_of_Solar_System_objects_by_size`

2 Mass of Oort Cloud
`http://www.ncbi.nlm.nih.gov/pubmed/17815893`

`http://adsabs.harvard.edu/abs/1991Icar...89..190W`

Cataclysmic Variables

By Paritosh Maulik

Earlier we have seen that the eclipsing of a star by its binary companion or starspots can cause the changes in the light output of a star. Sometimes high energy processes can cause sudden flaring of a star. These high energy processes occur with binary star systems and due their nature, are called Cataclysmic Variables. The outbursts can occur in optical to gamma ray range. New stars (nova) or guest stars sometime make unannounced appearance in the sky. These are not really new stars, but were too dim for nakedeye observation and as nova these become bright enough to be visible to the eye.

Before we go to the Cataclysmic Variables a brief discussion:

Red Giant Star

In a star, hydrogen in converted into helium by thermonuclear process and as result, the star radiates energy. Helium being heavier than hydrogen; it sinks to the centre of the star; the star develops a hydrogen shell and helium rich core. Gravitational collapse heats up the star and fusion of hydrogen to helium occurs in the shell just outside the core. Higher temperature increases the reaction and the luminosity of the star increases by a factor of 1,000 – 10,000 times; the outer layer increases in size and as a result the overall temperature of the star drops. The spectrum of the star shifts to the red end, but in reality the colour appears to be orange.

White Dwarf

The nuclear reaction in the star, hydrogen -> helium -> carbon -> oxygen has ceased; the star is just a ball of gas. It continues to collapse under its own gravity. If density reaches to $5*10^8$ kg/m3; further collapse is prevented by electron degeneracy (high density causes electrons to pack more tightly). The heat leftover from the earlier nuclear reactions causes the surface temperature to rise to about 10,000 k. The highest mass of white dwarf is about 1.45 solar mass, and the luminosity of the star is a thousand to ten thousand times less than that of the Sun and therefore these are not very easy to detect. With time, the white dwarf cools.

Sometimes a red giant and a white dwarf occur as a binary pair. The white dwarf accretes gases, mainly hydrogen from the red giant. Accumulation of this gas, forms an accretion disc around the white dwarf. Frictional heating due to swirling of gases causes the temperature to be high enough to produce ultraviolet and x-rays. The star brightens up; the invisible star becomes visible and it is called a nova.

If the white dwarf has accreted enough material and its mass has increased more than 1.45 times the solar mass, the Chnadrashekhar limit, the white dwarf explodes as type 1a supernova. This is the end of the star. Supernova explosion occurs at the centre of the star, whereas nova is a surface phenomenon. During the nova outburst, temperature can be high enough to synthesise radioactive fluorine. Formation of this element can be studied in the laboratory particle accelerators. It is hoped that the better understanding of such processes would lead to the better understanding of supernova explosions.

The strong magnetic field of the white dwarf may interfere with the accretion process. The magnetic field may stop the formation of the disc. The magnetic field may cause polarisation of the optical light. These variables are called polars.

There are some variations on the theme. These systems are named after the star, in which the phenomenon was first observed.

U Geminorum stars

Again we have a white dwarf and a red giant. Incoming material from the red giant has filled its Roche lobe and it accretes around the white dwarf. A hot spot forms somewhere inside the accretion disc, surrounding the white dwarf. The light from this system is from both of the stars, accretion disc and the hot spots. From time to time excess flow of incoming material occurs on the surface of the white dwarf and this can lead to a nuclear reaction on the surface of the white dwarf. The magnitude increases by several times and eventually drops to the normal level over days to months.

There are two suggested explanations for this phenomenon.

Mass-transfer burst model

An instability occurs on the surface of the cooler star. The reason for this instability is not very clear. Excess material is dumped on the disc may cause the disc to collapse. This excess material triggers off a fusion reaction.

Disc – transfer model

The material flow from the cooler dwarf is constant; the material piles up on the accretion disc and eventually the thermal instability sets in leading to an outburst. This model does not require any mechanism to account for the possible increase in the output from the cooler star and simulation studies also give better corroborations.

Recurrent novae

These have outbursts of about 4 to 9 magnitudes, repeating every 10 to 80 years. Examples include T

Pyxidis and RS Ophiuchi.

T Pyxidis, the brightening interval is about 7 years and the mechanism is similar to above. Despite the earlier eruptions, the mass of the white dwarf is increasing close to Chandrashekhar limit and may end as a supernova. The last eruption was in 2011. This was somewhat later than expected. The system is in the centre of a dust shell and the outburst causes changes in the dust shell. The nature of the dust has been studied by examining changes in the shell following eruptions.

Z Camelopardalis

There are two types of Cataclysmic Variables; periodic smaller blasts and classical massive explosion. Classical nova can make the star 10^4 – 10^6 times brighter and after the explosion a shell of shocked gas is the remnant. Z Camelopardalis (Z Cam) is one of the earliest known dwarf nova. It is known to have brightened up about 40 times around every 20 days. This is due to thermal instability at the surface of the white dwarf and the eventually, the white dwarf accumulates enough material to undergo thermonuclear reaction. In 2007, NASA's Galaxy Evolution mission images showed a shell of matter surrounding the star in the ultraviolet image. Further examination confirmed the material to be a shell of ionised gas from a previous classical nova explosion a few thousand years previously. As things stand now, although the white dwarf had ended its life in a supernova, a binary system is still operative with smaller eruptions. This shell is easier to see in ultraviolet range than in the optical range and therefore escaped previous detection.

SU Ursae Majoris Stars

These show "superoutbursts" which are brighter than the average.

As the name suggests, this type of cataclysmic variable was first observed in the Great Bear constellation. Like other variables, the star goes through periodic increase in brightness, but then it goes into superdrive and becomes brighter than the normal bright state. This additional rise in brightness is called Superoutburst and the increase in the magnitude is called a Superhump. From this periodic increase in the additional brightness, it has been possible to calculate the orbital period of similar systems. In all such systems it appears that the orbital period is less than 2 hours.

The suggested mechanism for such a phenomenon is Thermal – Tidal instability. We have seen earlier that hot spots developing in the accretion disc can produce periodic fluctuation in brightness, but in the SU Umajoris type of system, there is an additional component Tidal instability, which causes the pre-existing eccentric disc to expand and at a critical size of the disc, the system goes into super outburst state. Following the additional outburst the disc come back to the normal state.

SS Cygni stars

Outburst from these stars occur in two distinct lengths.

Cataclysmic variables from this group are quiet or quiescence during most of the time, but without prior warming, the star brightens up within a day or so and then it continues cyclic outbursts in two modes, one is narrow and the other is wide and there is no well-defined pattern.

In such systems, the stars are very close about 0.16 million km (100,000 miles) and the orbital time may be as short as 6 1/2 hours.

Magnetic and X-ray variable

The primary star, the white dwarf, has a strong magnetic field. The emissions from these stars are polarised. Magnetic field prevents the formation of accretion disc. The in falling material from the secondary red dwarf enters the white dwarf via the magnetic pole, like a bar magnet. The speed of the

This composite image shows Z Camelopardalis, or Z Cam, a double-star system featuring a collapsed, dead star, and a companion star, as well as a ghostly shell around the system.
Image credit: NASA/JPL-Caltech

in falling material can be as high as 3,000 km/sec. As the material meets the white dwarf, the high kinetic energy is converted into x-rays. Sometimes the magnetic field is tilted such that material it points towards the direction of the incoming material. In such cases the accreted material enters preferentially along one pole. About half of the emission from the system comes from the this hot spot and the system appears to flicker; rest of the radiation is somewhat diffused.

If the magnetic field is strong, the x-ray emission is powerful. If the magnetic field is not so strong, x-ray emission is still possible due to frictional heating. X-rays produced this way are not very powerful. However, if the is nuclear synthesis takes place on the surface of the white dwarf, it also generates x-rays.

In addition to the x-ray output, the red dwarf can get distorted by the white giant and as result the optical output from the red giant becomes variable. The x-ray from the white giant can heat the surface of the red dwarf. The secondary periodically obscure the hot spot.

The space telescopes are also gathering new information about the processes occurring in variable star systems.

XXM Newton, the x-ray telescope of the European Space agency, has been observing zeta Puppis a massive star in the constellation of Puppis in the southern hemisphere over ten years. Some of the findings have been recently announced. It showed stable x-ray emission lasting over a few hours. But over several days, the x-ray output was variable. The explanation of this phenomenon is something like this. Massive stars lose a lot of mass as stellar wind driven off by the light from the star. This wind can collapse to form new stars or just get blown away by the stellar light. As the clumps of stellar wind collide the temperature of the clumps can get over a few million degrees to emit x-rays. If the number of the clumps is large, variation of x-ray emission from one given clump is less important and the overall x-ray emission is more stable over a few hours.

However when observed over a few days, the x-ray output appeared to be unstable. This suggests a fragmented non-uniform distribution of clumps possibly caused by spiral arm like features interfering with the stellar wind.

Gravity Field and Steady State Ocean Circulatory Explorer: GOCE a brief update

By Paritosh Maulik

In 2009, European Space Agency launched a mission for the very accurate measurement of the gravity of the Earth. We have discussed it in an earlier issue of MIRA 85 (2009.2).

At the heart of the instrument there are three pairs of identical accelerometers set 90° to each other. These accelerometers form the three arms of the Gradiometer. In each accelerometer there is a proof mass. The position of this proof mass is maintained at a fixed position by an electrostatic force. As a proof mass notices a change in gravity, it tries to change its position and from this, the localised change in gravity is calculated. At each position there are two accelerometers to give an average reading. One arm of the gradiometer points towards the satellite trajectory (velocity direction), another arm at 90° to the velocity direction and the third arm points approximately to the centre of the Earth. For an animation see the ESA website, **(1).**

The spacecraft, carrying the instrument, orbited the Earth at an altitude of 255 km, lower than any other major mission. The drag of the Earth is compensated by ion thrusters. The first set of data was published in 2010, **(2).**

The information from the gravity measurement is converted into Geoid. In simple terms Geoid means there are no tides or currents in the oceans and the surface of the oceans is only due to the localised gravity variation. Thus Geoid provides a reference surface for the measurement of sea level change, ocean currents and ice dynamics. All these are becoming more important as we try to model climate change.

A further set of data was published in 2011, **(3)**, the data gathered to date suggests that there are some currents moving a large amount of water, but the signal is poor. It is hoped that the lower altitude measurement will help to the better understanding of small features with strong signals and large features with weak signals.

Now in order to improve the accuracy of measurement further, the GOCE scientists have started to lower the altitude of the satellite. They aim to lower the orbit to 235 km by February 2013. The ion thrusters move the satellite up and down to compensate for the drag on the satellite by the air molecules in near Earth orbit and also the spacecraft must be flown smoothly to keep the noise of measurement to minimum. Additionally, if the Sun becomes more active, it will increase the temperature of the upper atmosphere and this in turn will affect the flight of the spacecraft. The GOCE team thinks that there is enough xenon gas to carry out the lower altitude measurements. But if the control of the satellite cannot be controlled for two days, the craft would be lowered and eventually burn up as it enters the atmosphere. If things go without any problem the mission is expected end around October 2013.

Web Sites mentioned above

(1)http://www.esa.int/esaLP/ESAHTK1VMOC_LPgoce_0.html
(2)http://www.esa.int/esaCP/SEMY0FOZVAG_index_0.html
(3)http://www.esa.int/esaCP/SEM1AK6UPLG_index_0.html

"Observing Basics" – The History of Astronomy

This article by Mike Frost first appeared in the British Astronomical Association's Journal for October 2013. Mike is the Director of the Historical Section of the BAA and many of you will remember reading his accounts of many local astronomers from this area in past editions of MIRA.

I'm sure most of the readers of this article are dedicated observers. But what can you do when the weather is cloudy, or raining, or snowing, or cloudy (again)?

Or put it another way. On a cold, wet day, where would you sooner be? Outside, shivering, at the eye of a telescope? Or in a nice warm library, snuggled up with a book?

Yes, I know. Most of you would prefer observing. But let me try again. Have you ever wondered about your fellow observers from time past; the people you look up to; the pioneers of your discipline? Do you know their stories? – how they came to study the same objects as you, what difficulties they had to overcome, what tales they had to tell.

I am an observer like the rest of you – many of you will have bumped into me on eclipse trips, or observing aurorae or meteors around the world. I even have a Master's degree in astronomy from Sussex University. But these days my main area of research is into the history of the subject. In this guide I'd like to show you how easy it is to research the history of our wonderful subject, and how rewarding this research can be.

I can vividly remember how it was that I came to take up historical research. It was 1985, just after I had graduated, and I had just started a job "in the real world", and joined my local astronomy society, Coventry & Warwickshire AS. Halley's Comet was about to return, and to celebrate, my society had invited Dr Allan Chapman of Oxford University to speak on Edmond Halley.

I was captivated. Allan's talk effectively brought Halley off the pages of the history books and to life as an engaging human being – a convivial soul who once pushed Peter the Great through a hedge in a wheelbarrow, when both were drunk. I realised two things – first, how rich and deep the history of our subject is; and second, that here was an aspect of our subject where I could continue to do research, without the need for world-class telescopes or supercomputers.

Initially my researches concentrated on subjects that I had already studied – the development of understanding of the law of gravity, for example. I also developed an interest in sky phenomena - rainbows, glories, parhelia, setting sun phenomena – where there is a rich and rewarding history, mixing fascinating mythology and outrageous legends with accessible and interesting physics. But whilst this led to a series of very popular lectures which I have given to astronomical societies around the country, I wasn't doing very much original research.

The next step in my commitment to astronomical history occurred in 1997, when one of my friends in Coventry asked how much I knew about the life of Sir Norman Lockyer. I was aware that Lockyer was a solar astronomer who had discovered helium in the Sun's spectrum. I was surprised to discover that he had been born in Rugby, where I live, and astonished to find out that I had been walking past his birthplace for twelve years, without ever once noticing the plaque on the wall commemorating him.

I resolved to find out more about him. Lockyer is well-known for his solar work; and as the founder of the journal *Nature*; for his pioneering researches into archaeo-astronomy, and for the observatories he founded, in central London (now the site of Imperial College) and in Sidmouth (still thriving). There are two biographies of Lockyer; one published after his death by his family, another more recent by Jim Meadows of Leicester University. Yet neither covers Lockyer's early life in Warwickshire in any detail.

Over the next few years I worked quite closely with friends from Rugby local history research group to find out more about Lockyer's childhood, school days, and early adulthood. The result was a paper on *"J.Norman Lockyer – the early years"* which appeared in *"The Antiquarian Astronomer"*, the journal of the Society for the History of Astronomy. I became a founder member of the SHA when it was formed in 2002, and they have been an invaluable support to my researches.

When researching local figures, there are an impressive number of resources which can be utilised. Local libraries are invaluable; for example to consult newspapers or directories for years gone by (for example, Lockyer moved in with an uncle in Kenilworth when his mother died, and I was able to find out his uncle's address and the school Lockyer attended from a contemporary directory). Local history groups are also well worth getting in with – quite often they will have the facts, but not the technical skills to interpret them (a local historian will probably be aware that so-and-so was interested in astronomy, but may not understand what he studied or what instruments he used).

Another vital resource is the city and county archives, who will often have civic or family collections dating back centuries. For example, the Warwickshire county archives, at Priory Park, Warwick, have been of great use to me over the years. Curiously, in the case of Lockyer the county archives were not very helpful; they held one letter signed by him, apologising for being unable to attend a speaking engagement. That day, instead of leaving in disgust, I looked up "astronomy" in the card index, and within minutes came across a chart entitled *"The Sun's eclipse, delineated for Coventry, Feb 18 1736-37"*, prepared by Henry Beighton FRS. Finding out about Beighton, a polymath who played a vital role in the development of the Warwickshire coalfields, has been an ongoing project ever since, and I have a paper on him which will appear in the Journal in the near future.

This illustrates one of the delights of historical research – the serendipitous discoveries which often seem to drop into the researcher's lap. Around the time of the 2004 transit of Venus, I was engaged in research into transits past, which resulted in an article called *"Transit Tales"* which appeared in the Journal in 2004. One of my transit tales was about Jeremiah Horrocks, the first observer of a transit in 1639. Once again, Horrocks has been the subject of much research, and is the subject of a very readable biography by Peter Aughton; I have uncovered one or two snippets about his life, but nothing very much new.

On the other hand, there is still much to be found out about his contemporaries. A single line from Horrocks's biography set me off on another detective story. In the letter he wrote to William Crabtree in Manchester, alerting him to the possibility of a transit, Horrocks wrote *'If this letter should arrive sufficiently early, I beg you will apprise Mr. Foster of the conjunction [Transit of Venus], as, in doing so, I am sure you would afford him the greatest pleasure.'*. Who was "Mr. Foster"? I found out easily that he was Samuel Foster, Gresham Professor of Astronomy in London. To my complete surprise I found out that Foster was from Coventry, on my doorstep, and that in 1638 he had observed from Coventry with his friends John Palmer and John Twysden. All three were accomplished observers who left behind detailed records of their observations, and finding out about their lives in the Midlands and beyond has been a continued source of satisfaction to me ever since.

Once you become known as an astronomical historian, new lines of enquiry sometimes arrive from nowhere. One day in 2005, a friend at work informed me that some friends of his were converting an old observatory into a house. Was I interested in finding out more? Of course, I was, and before long I was finding out about Revd Doctor William Pearson, co-founder of the Royal Astronomical Society, whose portrait hangs in Burlington House. Pearson spent many decades observing from two observatories in South Kilworth, Leicestershire, where he was the Rector. The owners of the two houses he observed from were more than happy for me to add interest to the histories of their dwellings, by detailing the life and achievements of the Rector of South Kilworth.

What I would like to convey to you is what an extraordinarily rich astronomical heritage surrounds us in Britain. All the astronomers I have told you about so far (with the exception of Jeremiah Horrocks) lived or were active within 15 miles of my home. And I know of perhaps half-a-dozen other astronomers within that radius, who I have simply not had time to investigate.

Something else I hope to get across to you is the connectivity of astronomical history. Astronomers interact with each other, and the studies of these interactions can be immensely fruitful. Foster and his circle, for example, were observing during the course of the English civil war. Which side were they on? John Twysden came from a Royalist family, but ended up with living with parliamentarian in-laws in Northamptonshire. What did they talk about over breakfast? Even non-interaction offers clues. In the course of my researches into Samuel Foster I came across another Coventry astronomer, called Nathaniel Nye, who lived at the same time and in the same location as Foster, yet never mentioned or was mentioned by Foster or his friends. And yet Nathaniel Nye, in 1642, claimed, in an almanac for the city of Birmicham [Birmingham], to have seen the 1639 transit of Venus. I don't believe him (his account is inaccurate, incomplete and garbled) and I suspect he had come across Horrocks's unpublished account and was trying to pass it off as his own. But how did he find out? And was Nye's distance from Foster connected to his career as a gunner in the civil war? I started off by studying astronomy but was rapidly drawn into the tumultuous politics of the age.

Looking back on what I've written so far, I realise that my attempts to explain how to study astronomical history have a very personal slant to them. But I think this is one of the attractions of the subject. You do get a close connection to "your astronomers". That's not to say they weren't flawed human beings like the rest of us – Lockyer was famously cantankerous and argumentative; Pearson had a splendid row with (of all people) William Wordsworth, over a boathouse Pearson owned on Grasmere. But when for example John Palmer, rector of Ecton, Northamptonshire, tells us that he observed the deep partial solar eclipse of 1652 *"in the company of ministers and friends"*, I can't help wishing I had been observing with him. And who would not have wanted to join the party, which included Palmer, John Wilkins and Robert Hooke, when in 1654 they visited St Paul's cathedral, hung a 14 lb. weight onto a 200ft rope attached to the dome, and timed the oscillations of the pendulum.

So I would absolutely commend to you the study of astronomical history. Here are some hints as to how to go about doing it:

Pick a subject that interests you – some people might go for astronomers in their field of interest (Jeremy

Shears, for example, has produced an excellent series of papers on variable star observers).
Pick a subject convenient for you to study
Lesser-known characters can often be more rewarding than well-known figures
Be prepared for your research to head off in unexpected directions
The resources available to you are many:
- Local libraries
- City and county archives
- University libraries
- Specialist collections
- The RAS library and BAA book collections
- Online resources

People who can help you:
- The BAA Historical Section (of course!)
- The Society for the History of Astronomy
- Local history groups

A number of universities offer remote study courses in the history of astronomy. I took the University of Central Lancashire's *"Great Astronomers of History"* course and can recommend it.

And finally – if you do find out something interesting, share it! A paper in the BAA Journal will secure the record of your researches for the benefit of the current BAA membership and for future generations. Even the smallest of snippets can be presented to the historical section membership through its bi-annual newsletter (email me at **frostma@aol.com** if you would like to be added to the mailing list). And we are always on the lookout for interesting and engaged speakers for our annual section meetings (as are the SHA).

Good luck with your studies. I look forward to hearing from you!

Some of the many illustrations used by Mike Frost over the years in his historical stories in MIRA.

Top Left: New House Coventry in 1702, Samuel Foster taught at Greasham College, Cambridge and has connections with New House, it was demolished in 1778.
Top Right: The sundial at Cawston House, Rugby, a copy of the 1633 sundial at Holyrood Palace.
Left: Rev. William Pearson's house The Observatory at South Kilworth, Leicestershire today, now a private house.
Right: the Old Rectory in South Kilworth, were the Rev. Pearson once lived.