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Mike Frost was at the unveiling on January 16th, 2020, of a plaque in South Kilworth, a village in the south of Leicestershire to commemorate Revd Dr William Pearson. L to R: Carolyn Bedwell of the Society for the History of Astronomy, Mrs Richardson of Leicestershire County Council, Professor Emma Bunce of Leicester University & Mike Frost with the new plaque.

Below, The Armagh Observatory was founded in 1790 by Archbishop Richard Robinson. Picture by David Arditti. Read about both visits by Mike Frost.

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A Visit to Armagh

By Mike Frost

Every September, the British Astronomical Association holds an away week-end. I'm not always able to attend, but I make a particular effort to get to the meeting if it's held somewhere I've never been before. I've enjoyed trips to Jersey and Aberdeen, and this year I wanted to make my first ever visit to Northern Ireland.

So I caught the 6:45 AM flight from Birmingham to Belfast City Airport – George Best airport, no less. I picked up a hire car but my first port of call was only a mile from the airport. The Titanic was built at the Harland and Wolff shipyard in the heart of Belfast, and next to its dock the city has built an excellent museum, the Titanic Experience. Just outside the museum is a dry dock, containing the last remaining ship of the White Star line, Titanic's tender Nomadic. Behind the museum is "Titanic Studios", where Game of Thrones was filmed – a Northern Ireland success story. Harland and Wolff, however, has fallen on hard times, and there are pickets outside the gates.

The Titanic Experience museum.

After a quick snack I headed south on the motorway to Armagh. The city is in the south-west of Northern Ireland, only five miles from the border with the Republic, but in Ulster everywhere is pretty close to everywhere else, so it took me just over an hour to arrive in town.

I spent Friday afternoon wandering around the city. Armagh is not large, with a population of fourteen thousand, but it owes its city status to its long history and its status as the ecclesiastical capital of Ireland. It was founded by St Patrick, and both the cathedrals in the city, Church of Ireland (Protestant) and Catholic, are named for him. The Church of Ireland building is undergoing restoration, which detracts from its view, but it's surrounded by some lovely gardens. Both cathedrals are on hills; I reckon the catholic cathedral has more steps. St Patrick is reputed to have rescued a fawn which was about to be slaughtered, a story featured in its stained glass windows.

I met up with fellow members of council for a meal before our first talk. Dr Meg Schwamb, latterly of Hawaii and now at Queen's University Belfast, gave us a talk, "Exploring Mars with 150 000 Earthlings", about her Citizen Science initiative to find Spiders on Mars. No, not real spiders, or indeed anything to do with David Bowie, but curious features found close to the Martian poles, which appear to be geyser-driven fractures of the polar ice cap. Galaxy Zoo-style investigations of Martian images have found many examples of these, allowing astronomers to make statistical investigations.

I woke up slightly hung-over on Saturday, but ready for a day's worth of talks, with a loose theme of "Comets and other small Solar System objects". There were some excellent lectures: Nick James and Callum Potter gave section director talks; Terry Mosely, who I had corresponded with but never met, gave an entertaining presentation on close comet approaches, with the claim that one such approach might be recorded in Irish mythology; Mark Burton, the current director, gave us the history of the Armagh Observatory. My favourite talks were by Janice McClean on Agnes Mary Clerke, the great historian of science, from Skibbereen in County Cork; and Professor Alan Fitzsimmons, who was on great form, as usual, analysing the continuing role of the amateur in comet discovery. I didn't follow Yorick Vink's arguments about the formation of the solar system, perhaps because I fell asleep (but it's good to meet someone called Yorick!), and I found Mark Bailey's talk on great comets a little powerpointy – too many bullet points!

After the afternoon session I headed to the bar to catch some of the England football team's match against Bulgaria, then joined the delegates for the conference dinner. The meal was followed by a public lecture by the irrepressible Dr John Mason, who told us how the analysis of Meteor Streams had allowed us to predict meteor showers with ever-increasing accuracy. I was knackered by the end of the proceedings, having been up for much of the previous forty-two hours, but against my better judgement I was dragged off to "The Hole in the Wall", where we supped Guinness and listened to a very good father-daughter musical duo. Suddenly it was 1am, and I really was ready for bed.

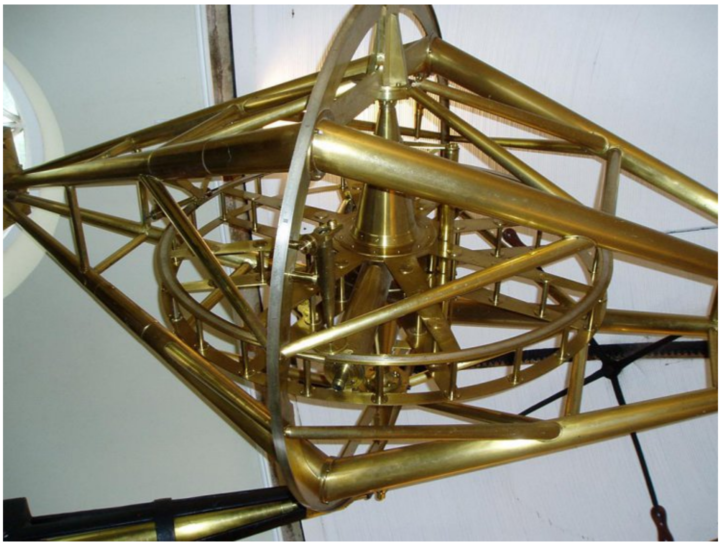
The reason why we met in Armagh, of course, was so that we could visit the Observatory and the Planetarium, so that was the plan for Sunday morning. We split into two groups; one visiting the planetarium and the other joining Michael Burton for a historical tour. Armagh Observatory was founded in 1790 by Archbishop Richard Robinson, who

Armagh Observatory. Pic David Arditti

was determined to give the Catholic Church a place in the age of enlightenment. The church no longer funds the observatory but still takes an interest in its running, albeit with a completely hands-off approach.

The first transit telescope purchased by the observatory is still in place in the dome on top of the astronomer's house – it's claimed to be the oldest telescope in the world still in its original location. It was built by legendary instrument maker Edward Troughton; one of his first telescopes. It's an extraordinary instrument; unlike most transit scopes, which can only point north or south, this one was mounted at two points on an equatorial axis. Unfortunately this meant that it flexed, so it was never used to its full potential.

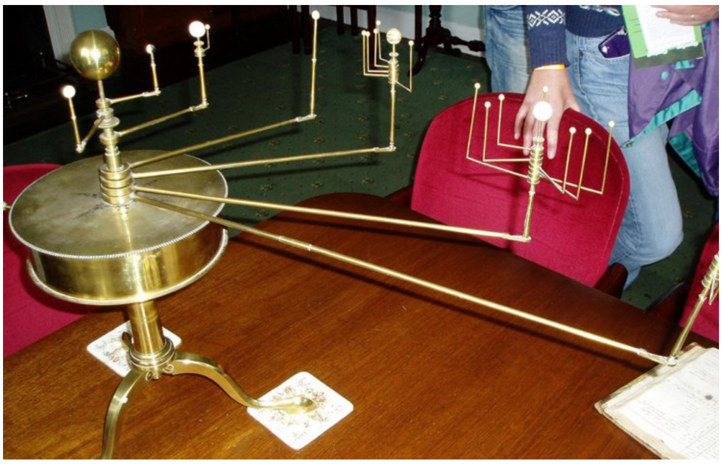
Things did not go well in the early years of the observatory. It was funded by tithes, which were resented



The transit telescope built by Edward Troughton

by the payers, and money was always short. The second director, William Davenport, was unable to cope and shot himself. Things began to turn around under the directorship of the remarkable tenure of Thomas Romney Robinson, who held the post for a remarkable 59 years, another record. Romney is still observing! A model of him is crouched at the eyepiece of another, more conventional, transit scope. Among many other accomplishments, Robinson introduced daily meteorological measurements, which continue to this day. To measure wind speed he invented a 4-cup anemometer, an example of which sits atop the observatory.

The staff had laid on a display of some of the



The orrery, a clockwork model of the solar system

The Grubb refractor gear drive used to compile the NGC, (New General Catalogue) of deep sky objects. Pic D Arditti

instruments and logbooks. I enjoyed seeing the observations of spectacular aurorae, following the Carrington event (a huge solar flare) in 1859. One particularly interesting exhibit was the orrery, a clockwork model of the solar system. All the known moons in the solar system orbit their host planets – so why are there five moons around Jupiter? The orrery had no moons around Mars, so it pre-dated their discovery in 1877, and no Neptune, so it was before 1846. But the fifth moon to be discovered around Jupiter, Amalthea, was found by Edward Emerson Barnard in 1896. A curiosity.

Our final stop on the tour was the dome containing the Grubb telescope from the later part of the nineteenth century. On Romney's death he was succeeded as director by Jean Louis Dreyer, who had been an observer at Lord Rosse's telescope, then the largest in the world, at Birr Castle. Dreyer successfully applied for public funds, 2000 pounds, to purchase a new telescope, beginning the shift away from the church towards becoming a national observatory. Dreyer used the Grubb refractor to compile the New General Catalogue of clusters, galaxies, nebulae and other deep sky objects. If you've ever observed an NGC object, it got its catalogue number at Armagh.

Amongst Dreyer's successors was Ernst Opik; a famous name in his own day but perhaps better-known today as the grandfather of Lembit Opik, politician and dater of Cheeky-Girls. The present status of the Observatory is as a national observatory for Northern Ireland, independent of other academic institutions, and employing around twenty-five astronomers. In recent years it has merged with Armagh's other astronomical institution, the planetarium next door.

Armagh Observatory's website tells us that the Planetarium was opened in 1968, through the efforts of Eric Lindsay. Which is odd, because Patrick Moore was the director from 1965 to 1968, and did run Planetarium shows before the official opening. Sir Patrick seems to have been airbrushed out of the official history – his stay in Armagh was not successful. He was involved with the scout movement and objected to catholic-only and protestant-only troupes, which did not endear him to some. And a prank he pulled off probably didn't help; he and Terry Moseley wrote to the Belfast News-Letter under the guise of a Mrs Hackett, who claimed to tie up her budgerigar's swing on a Saturday evening, so that it could not disport itself on a Sunday. This

big as the piece in Rosario planetarium, of course). Next to it is a fragment of the Bodevy meteorite which fell on Northern Ireland in 1969.

The final item on the tour was a Planetarium show – "The Edge of Darkness", a 2016 show featuring some of the major space probes of 2015 (including Rosetta, Dawn and New Horizons) narrated by Hayley Atwell. I enjoyed the show, although the regular, portentous intoning of *"… to the Edge of Darkness"* was a little annoying.

Before I left Armagh and returned to Belfast, I had one more port of call – the Navan "fort". This is a circular iron-age habitation on a hill two miles to the west of the city. It was long-called a fort but excavations in recent years have revealed a more subtle history. Navan is now thought to have held religious rather than military significance – perhaps Armagh has been a spiritual centre for some time before the arrival of St Patrick. And perhaps there was an early astronomical connection here too.

So, that was my week-end in Armagh. Very enjoyable.

provoked a lively debate; I think some people didn't see the joke.

The staff had laid on tea and scones for us. I then had a wander round the planetarium exhibits; very good, with a strong bias towards space travel. Like many other astronomical museums, it has a piece of the Campo del Cielo ("Field of Heaven") meteorite from Argentina (not a

When the Dust Settles

By Mike Frost

A recent article on the BAA website got me thinking. It's by Gerry Gilmore and Gudrun Tausch-Pebody of the Institute of Astronomy, Cambridge, and it's called *"Why have we all heard of Einstein?"* Gerry Gilmore, who is a superb speaker, will be giving the Alfred Curtis Lecture at the BAA Winchester Weekend in April, entitled *"Eddington, Einstein, 1919: truth and consequences"*, and I imagine it will cover the same subject.

The article appeared on the website on Nov 6th 2019, one hundred years to the day after perhaps the most significant meeting ever to be held by the Royal Astronomical Society. On Nov6th 1919, at Burlington House, Arthur Eddington presented the results of the observations he and others had made of the solar eclipse of May 1919. Eddington viewed the eclipse from Principe, off the west coast of Africa, and another party observed from Recife in Brazil.

Why was this eclipse so significant? Albert Einstein had recently published his general theory of relativity, a comprehensive overhaul of gravity, and his theory made the prediction that light would bend in a gravitational field. The magnitude of the effect is small, and so in 1919 could only be observed close to the most massive body in the solar system, the Sun, which is of course overwhelmingly bright. So the only time any meaningful observations could be made was during the brief minutes of totality during a solar eclipse. The eclipse of 1919 was the first to occur after the devastating disruption of the Great War.

I suspect most readers of this article will be aware of the results of the observations. Einstein was right! The positions of the stars closest to the blocked-out sun had shifted, by a tiny but measurable amount, consistent with Einstein's predictions. The endorsement of Einstein's theory by Eddington, perhaps the leading astronomer of the day, sealed Einstein's reputation, and (with a little help from the press) propelled him to the celebrity status he enjoyed for the rest of his life.

But, if you have heard the story of Eddington's observations, you will likely know that they were not without controversy. Eddington had to compare the positions of stars on two sets of photographic plates; one set taken at night, the other during the daytime, during an eclipse, when conditions vary wildly over very short timescales. Moreover, the observations from Recife were inferior in quality, because of the weather, and Eddington chose to ignore some of these.

Almost immediately, there were claims that Eddington's reduction of data was suspect. As Gilmore and Tausch-Pebody explain, even in the 1980's, analysis cast doubt on the veracity of the reduction. However, the authors have reanalysed the original plates, and confirm that Eddington's reduction was valid and his conclusions hold.

Yet the story persists – Eddington's reduction of data was flawed, his conclusions invalid; relativity suspect; Einstein wrong. This is certainly the mantra of many a crank scientist, but the first assertion, flawed reduction, has had some decidedly non-crank supporters. For example, in an essay in 1968, Arthur C. Clarke claimed that *"One of the world's leading astrophysicists (he may have changed his mind now, so I will not identify him beyond saying that his name begins with Z) once shook me by remarking casually, as we were on the way up Mount Palomar, that he regarded all three proofs of the general theory as disproved"*. Evidence elsewhere suggests that "Z" was Fritz Zwicky, the man who posited both neutron stars and dark matter; not someone to be taken lightly.

So why didn't astronomers just repeat the observations? This turns out to be more difficult than one might expect. Total solar eclipses only happen every eighteen months or so, and not always in accessible parts of the world (I know this well!). Moreover, the Sun's location in the sky for the 1919 eclipse was serendipitous; the Sun was crossing through the Hyades Cluster, and so in a region of the sky rich with stars; not many succeeding eclipses had sufficiently bright stars so close to the Sun.

But of course attempts were made to repeat the observations. In 1922, for example, Lick Observatory organised an expedition to near Broome on the remote north-western coast of Australia. John Evershed, director of the Kodaikanal observatory in India arranged to join them, accompanied by his wife Mary, an accomplished solar observer in her own right (and of course my predecessor as director of the BAA historical section). Tracy Daugherty's recent biography of Mary details the expedition, which for the Eversheds was beset by technical difficulties. The Americans declared that they had confirmed Eddington's observations – but, notably, John Evershed remained unconvinced through his life.

Technology moves on, and there have been many more attempts to repeat the observations. Most notably, in the last few years the wide availability of CCD/CMOS technology has allowed amateurs to contribute accurate and measurable images of totality, and in 2017 the Great American Eclipse allowed observers along a long track of totality to submit observations. Once again the claim was that Einstein had been confirmed – but, to play devil's advocate, the size of the measurement to be taken was typically less than a pixel on most cameras, and so the data reduction relied on the averaging of many observations.

However, in the professional field, the accuracy of measurement is reaching jaw-dropping levels, enabling us to see the bending effects of the Sun's gravitational field a long way away from the bright disk. Gerry Gilmore also works on the Gaia satellite, and another of his talks is about that staggeringly successful mission. Gaia is so accurate at measuring star positions that the gravitational bending of starlight by the Sun can be seen even looking at right angles to the Sun.

Another technique of taking relevant observations is to observe in different parts of the electro-magnetic spectrum. The Sun, overwhelmingly bright in visual wavelengths, is a relatively quiet emitter in radio wavelengths, and so can be studied continuously. When the Sun passes in front of a distant radio source such as a quasar, the bending of light is clear and easily measurable.

Moreover, the effects of gravitational bending of light can now be seen with many other astronomical objects. Einstein could only have dreamed of being able to see multiple images of a distant quasar, lensed gravitationally by an intervening cluster of galaxies, yet such observations are now commonplace.

So the gravitational bending of light by the Sun, and other astronomical bodies, is now proven by multiple observations, multiple techniques, and multiple contexts. Yet the suspicions of the bending of light round the Sun remain in some quarters. Why?

I think it's to do with the way in which we report scientific advances. As a society, we favour the new and the sensational. We crave the big news stories and the announcement of groundbreaking advances. I remember being at Astrofest a few days before the announcement of the first observation of gravitational waves (another prediction of Einstein, of course). The excitement was palpable. Every speaker at Astrofest knew something huge was about to be announced, and none of them was allowed to tell us – except for Stuart Clark, who as a science journalist had accurate sources and knew exactly what was going to be announced.

But, for every groundbreaking discovery - gravitational waves, black hole images, Higgs Bosons – there's a discovery that turns out to be not quite what it seemed. Who can forget the announcement of cold fusion? Microbe life in Martian meteorites? Faster-than-light neutrinos? These turned out not to be valid discoveries.

I think that the headlines given to all these extraordinary announcements, followed by scepticism and then, in some cases, retraction, gives the general public a sense that all such announcements are provisional and therefore suspect. We do not do a good enough job reporting successful confirmation. I remember the scepticism over black hole mergers, when people realised that the interferometers could also record tremors and even be set off by passing traffic. Couldn't the tiny, brief patterns recorded, near-simultaneously, in Washington and Louisiana states, simply be co-incidental tremors? Well, probably not, but even if the first observation was a co-incidence (it wasn't), what about all the follow-ups? We're up to eleven detections now, but do any of the others get a mention? And other detectors have come online, making the odds against simultaneous chance events large. But does this ever get reported?

The bending of light by the gravitational field of the Sun is an extreme case. It's a technically challenging observation which for decades could only be carried out on the rare occasion of a solar eclipse. Yet during these decades steadily improving observational technology, and alternative modes of observation, enabled multiple confirmations of the hypothesis, few of which received much attention.

In one sense science is always provisional. Observations can always come along which force us to overturn, or at least modify, our theories as to how the universe works. But I simply don't think that we do enough to explain that what was once new and untested is now canonical, sitting comfortably within an interconnected web of evidence.

To begin with, a theory such a General Relativity might only have provisional and tentative evidence in support of it. But when the dust settles, and the evidence becomes overwhelming, someone needs to be able to point out that the evidence is no longer provisional.

And that should be the job of the science historians.

Sources:

"Why have we all heard of Einstein?" Gerry Gilmore and Gudrun Tausch-Pebody
https://www.britastro.org/node/19749

"Possible, That's All", by Arthur C Clarke, appeared in the Oct 1968 edition of the Magazine of Fantasy and Science Fiction, as a riposte to Isaac Asimov's *"Impossible, That's All"* in the Feb 1967 edition of the magazine. The essay was reprinted in *"Greetings, carbon-based bipeds"* (Voyager, 1999) and another essay in the same collection reveals that Zwicky gave Clarke a tour of Palomar in 1962.

Chapter 18, *"Wallal"* of *"Dante and the Early Astronomer"* by Tracy Daugherty (Yale 2019) tells the story of the 1922 eclipse expedition to Australia.

C&WAS Page

Astro Rhymes

Whether the weather be fine or whether the weather be not.
Whether the weather be cold or whether the weather be hot.
We'll whether the weather whatever the weather, whether we like it or not.

Twinkle, twinkle, little star.
I know precisely what you are.
Nuclear furnace in the sky,
you'll burn to ashes by & by.

Twinkle, twinkle, little star.
I don't wonder what you are.
You're the cooling down of gasses,
turning into solid masses.

Twinkle, twinkle, little star.
Do you wonder what we are.
Below we'er nickel-iron bright,
mantled in peridotite.

A great incandescent mass of self gravitating gas.
Far away in outer space, I believe that is the case.
In your thermonuclear core,
proton-proton chains galore.
Fuse together nucelli,
releasing radiant energy.

Scintillate, scintillate bloboe vivific.
Fain would I fathom thy nature specific.
Loftily poised in ether capacious.
Strongly resembling a gem carbonaceous.

Tony Sturgess

Old photograph of some of the original members of the Astro Society

Standing L to R Jack Osbourne, Arthur Lagley, Alan Hancocks, Bill Grey

Seated, David Spearman, Bill ?, Fred Vears, John Pedrick, John ?

If anyone can fill in the other details of who, when and where this would be useful for the C&WAS history records.

February 2020 saw the C&WAS feature in the BBC's *Sky at Night* magazine and also in *Astronomy Now* in the March edition in the Society News section. Both said similar reports of the Society but neither mentioned Alan Hancocks cake cutting skills.

SOCIETY IN FOCUS

The **Coventry & Warwickshire Astronomical Society (CAWAS)** celebrated its 80th anniversary in November 2019. The meeting to mark the occasion opened with some historical comments from chairman John Davis, and was followed by our regular 'Skynotes', a review of forthcoming astronomical events to keep an eye on over the month ahead, given by Society member Mark Edwards. We celebrated our anniversary with three birthday cakes and drinks, followed by an excellent lecture by Dr Julian Onions on galaxies. It was a great evening, enjoyed by all who attended.

CAWAS was originally formed through an association with Coventry Technical College, and a merger in 1974 with Warwickshire AS resulted in the Society we enjoy today. We meet on the second Friday of each month at Earlsdon Methodist Church Hall in Coventry at 7.15pm. Meetings include our Skynotes, a discussion of members' observations and a visiting speaker.

Help is on hand for beginners and encouragement for young astronomers is important. In recent years two younger members, Cameron Watson and Tom Killestein, have won the Patrick Moore Achievement Award, presented annually by the British Astronomical Association.

Observing opportunities are also available at sites around Coventry, including at the local Rugby Cricket Ground. We look forward to meeting any new members.

John Fell, committee member, CAWAS
▸ www.covastro.org.uk

BBC Sky at Night Magazine **February 2020**

HEATHER COUPER, who has died aged 70, was an astronomer and television presenter whose golly-gosh enthusiasm and determination to inform and educate the scientifically illiterate led some to dismiss her as superficial.

Heather Anita Couper was born on June 2 1949 in Wallasey, Cheshire, an only child. She was brought up in Ruislip, where, aged seven or eight, she spotted a bright green meteor in the night sky. She decided to become an astronomer: "My father bought me a series of little telescopes and I used to go out into the garden."

Her contribution was recognised in her election in 1984 as the first woman president of the British Astronomical Association and in her appointment in 1993 to the chair of astronomy at Gresham College, a post which had been held by both Isaac Newton and Christopher Wren. She was the first woman to be selected. She was the author of dozens of books of popular astronomy (with co-author Nigel Henbest) as well as monthly astronomy columns for *The Independent*. Heather Couper first appeared on the nation's television screens in Patrick Moore's *The Sky at Night*. Among other endeavours, she fought hard to get the funding for the National Space Centre in Leicester which opened in 2001. Asteroid 3922 Heather is named in her honour.

From the Daily Telegraph, 21 February 2020

A Plaque for Revd Pearson

By Mike Frost

I've written extensively in MIRA about Revd Dr William Pearson, co-founder of the Royal Astronomical Society, who was the Rector of South Kilworth, a village in the south of Leicestershire. Between 1821 and 1847 he observed from the village, building a new wing for the Rectory, and then an Observatory on the south side of the village.

On 2020 January 16th, we unveiled a plaque in South Kilworth to commemorate him. The RAS had celebrated its 200th birthday 4 days previously. On 1820 January 12th, fourteen men met in the Freemason's Tavern, Lincoln's Inn Fields, London, to found a new astronomical society. There was only one professional astronomer amongst them – a visiting professor from Lithuania – although others, such as Sir John Herschel and Sir Charles Babbage, were amateurs of considerable renown.

The meeting had been suggested and then organised by William Pearson. Pearson was at the time the proprietor of a very successful boys' preparatory school in East Sheen, Surrey, which counted the Duke of Wellington's son amongst its pupils. Pearson became the treasurer of the fledgling London Astronomical Society, and served its council for decades, yet within two years of its foundation, he had sold up his East Sheen school and moved to South Kilworth.

Why did he do this? We can surmise, I think, that he had made enough money to be able to pursue his main aim; a church career which gave him ample time to do serious astronomical work. Pearson added a new wing to the Rectory, with narrow windows facing north and south, through which Pearson timed stars as they crossed the meridian. Pearson's assistants were a South Kilworth villager, Ambrose Clark, and later Thomas Pooley.

Pearson's view was obstructed by smoke from houses in the village, so in 1834 he built a second observatory on the south side of the village. From here he carried out decades of observations, producing a catalogue of stars which could be occulted by the Moon, and an accurate determination of the obliquity of the ecliptic. Pearson also published a book, *Practical Astronomy,* detailing his observational and instrumentation techniques. Practical Astronomy earned Pearson the Royal Astronomical Society's gold medal, putting him in the company of Einstein, Eddington, Caroline Herschel, Hawking, Hubble and Hoyle, to name but a few.

After Pearson's death, the Observatory fell into disrepair, becoming a storehouse and then a cow shed. Fortunately it was renovated to become a private house, and I was invited by the then owners, Sue and David Dilks, to provide provenance for the history of the building. I was greatly assisted in this task by Jacky Harrison, current owner of the Rectory, whose late husband had done much research into Pearson's life in South Kilworth. I published papers on Pearson's life in the village in MIRA and in The Antiquarian Astronomer, the journal of the Society for the History of Astronomy (SHA).

Leicester County Council run a Green Plaque scheme to honour eminent residents of the county. Pearson had already been nominated by Carolyn Bedwell, of the Leicester Astronomical Society, and assistant-librarian of the SHA, who has carried out an extraordinary amount of research into the life of Pearson and his family. Carolyn suggested that I co-nominated him, and we were successful!

The unveiling took place on a blustery, wet January afternoon. We started with a short ceremony in St Nicholas'

L to R: A strong presence from the Royal Astronomical Society. Professor Mark Lester, Professor Martin Barstow, Dr Robert Massey, Professor Emma Bunce, Mike Frost and Nick Hewitt with the new plaque to the Revd Dr William Pearson, co-founder of the Royal Astronomical Society, who was the Rector of South Kilworth between 1821 and 1847, a village in the south of Leicestershire.

Church, where there are memorials to Pearson. I gave a short presentation, as did Louise Richardson CC, representing the leader of Leicestershire County Council. Then we all trooped to the centre of the village, where the plaque had been mounted on the gates of the Rectory. The unveiling was done by Louise Richardson and Professor Emma Bunce of Leicester University, the president-elect of the RAS. There was a strong presence from the RAS, including Dr Robert Massey, the deputy CEO of the RAS; Prof Mark Lester, Geophysical Secretary, and past-president Prof Martin Barstow. The BAA was represented by two more fellows of the RAS, Nick Hewitt and myself, and the Society for the History of Astronomy by Carolyn Bedwell and Chairman Gerard Gilligan. The deputy Lord-Lieutenant of Leicestershire was in attendance, as were several local councillors; and there was a strong contingent of South Kilworth villagers, including several pupils from the school, which was founded by William Pearson.

Many of the attendees took a minute to visit Pearson's memorial in the church graveyard. This has recently been renovated with the assistance of grants from the Royal Astronomical Society and the South Kilworth Parish Council.

We hope that we have done justice to a lesser-known figure from the early history of the Royal Astronomical Society.

"Reverend Doctor William Pearson in South Kilworth, Leicestershire", M.A. Frost (The Antiquarian Astronomer (2006) 3, 49–56)
"Revd Dr William Pearson (1767-1847): a Founder of the Royal Astronomical Society", S.J. Gurman and S.R.Harratt (Q.J.R. astr. Soc. (1994) 35, 271–292)
"The Rector of South Kilworth" By M Frost, MIRA 71
"William Pearson's sundial" By M Frost, MIRA 99
"Revd Dr William Pearson and the Foundation of the RAS" By M Frost, MIRA 105

A strong contingent of South Kilworth villagers, including several pupils from the school, which was founded by William Pearson came to see the new plaque.

Mike delivered a short presentation in the church before the unveiling.

The Solar System, a brief description

By Paritosh Maulik

A large gas and dust cloud condensed to form the Sun, planets formed from the left over material. There are four inner rocky planets, Mercury, Venus, Earth and Mars. Then comes the gas giants, Jupiter, Saturn, Uranus and Neptune. Beyond Neptune, there is Pluto with a somewhat unusual orbit; its status as a planet is being debated. Between Mars and Jupiter there is the asteroid belt, the leftover material from the formation of solar system. These contain metallic materials, minerals, organic compounds and these are probably free of volatile material. Beyond Neptune, the Kuiper belt objects contain minerals and volatile materials including water ice. From time to time, both fragments of asteroids and comets come down to Earth as meteorites. These are the earliest building blocks of the solar system and have undergone no change. The ice from the comets might have bought water to the Earth. Asteroids may contain water and could well have bought water to the Earth like comets.

Recent studies suggest that the formation solar system, as we see it today, might not have a fairly neat orderly process and there would have been a lot of movements before everything settled down to the current positions. Could there be another planet, Planet 9 or X, about 10 times heavier than the Earth and is responsible for the movement of objects far way from the Sun? The distinction between the asteroid and comets may not be that clear cut.

In the 1780s William Herschel observed cloud like objects and concluded these to be luminous gas clouds or nebulae. It was suggested that new stars born from such cloud. If this is true, the universe is not static, it is still evolving. Some observers thought they could see stars in the nebulae and no gas. Herschel's telescope was 49.5 inch (125 cm) diameter. William Parson, Earl of Ross, wanted to resolve these issues and built the next large telescope 72 inch (183 cm). One of the members of the Irish observation group, perhaps then the director of Armagh observatory, was a clergyman Thomas Romney Robinson. Considering the fact that, the interpretation was subjected to the opinion the observer and the the recording medium was drawing, often the conclusion was not unequivocal. Earl of Ross thought, he did not see stars, but what he saw turned out to be spiral galaxies. On the other hand, Robinson was confident that he did not see any cloud, but stars and since these stars are not evolving from the gas cloud, there is no evolution, no need to question the origin. Unknowingly, perhaps each had their own agenda. Earl of Ross wanted the project to be building the telescope and running it for the advancement of Irish technology and manufacturing while Robinson wanted to show the never changing universe. All these happened before Darwin and evolution came into the scene in 1859. Herschel confirmed the presence of Planet Uranus in 1781 from his observatory in Bath.

William Huggins took the first spectrum of the Orion nebula in the 1880s and confirmed the spectrum to be similar that from gas, where as the spectrum of Andromeda was typical of stars. Now we have clear images of gas cloud around the newly formed stars (Hubble image of Pillars of Creation for example). Such gas and dust cloud are the birth place of stars and planets. So it is likely that the solar system also formed from the nebula surrounding the young proto-Sun.

Some of the characteristics of the solar system:

1) All planets (and almost all of the moons) rotate in the same anti-clock wise direction as seen from their north poles. The exception being Venus and Uranus. These rotate in clockwise direction.
2) Each planet has its own orbital plane. The tilting of one orbital plane from another is around 6°. Pluto is inclined by about 11°.
3) Terrestrial planets are rocky and small; planets further away are large and gaseous.

About 4.7 billion ($4.7*10^9$) years ago gravitation collapse of a gas and dust cloud (nebula) occurred. The collapse might have been triggered by a nearby supernova explosion or density wave. The size of the nebula was several light years across. The collapse caused the materials to get hot and the heat led to expansion.

Motion of the particles in the cloud was random, but there was an overall rotational motion. As the cloud collapsed more under the effect of gravity, its rotational speed increased. For such a body, most of the collapsing occurs along the spin axis. This results in flattening of the system. The nebula spreads out to a thin disc of about 200 AU in diameter, (twice the Sun – Pluto distance). Thus the solar nebula is born.

The high density region in the centre triggered nuclear fusion, which led to the formation of the Sun. The heat from the young Sun melted the dust. These molten droplets agglomerated into small globules, termed as chondruls (grain, seed in Greek). The sizes of these globules were a few millimetre. This melting process is likely to have occurred many a times. These chondrules got embedded in the pre-solar dust. These ancient rocks come down to Earth as meteorites called chondrites. Thus chondrites gives the best preserved history of the solar system, before the formation of planets.

Away from the Sun, as the temperature drops, compounds of aluminium, iron, nickel, titanium froze first. These have higher melting points, about 1600°K (1300°C). These amounted to about 0.2% mass of the solar nebula. Then further away silicates solidified and formed silicate bearing grains. The solidification temperature of the silicate grains varies between 500° to 1300°K (200°–1000°C). These constituted to about 0.4% of the mass of the nebula. Gases with hydrogen containing molecules, such as ammonia, methane, water ice moved further way and froze where the temperature was still lower, about 150°K (–120°C), 1.4% of mass. The rest of the solar nebula, about 98%, consisting of lighter gases hydrogen and helium, remained in the gaseous state. In short, the inner nebula consisted of solid materials and gaseous material at the outskirts.

Formation of Planets

Freely moving solid particles began to collide gently with each other. Gentle collision between particles caused the particles to grow larger. This is the process of accretion. Violent collisions breaks the growing body. Eventually after about a few million years, the the accreted bodies grew to a few kilometre in size. These are called proto-planets.

In the inner solar environment, it was warmer and there was abundance of rock and metal. These accumulated to

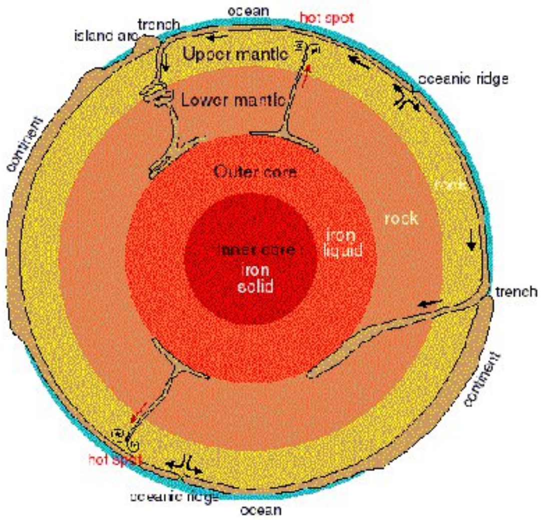


Fig 1. Inner structure of the Earth

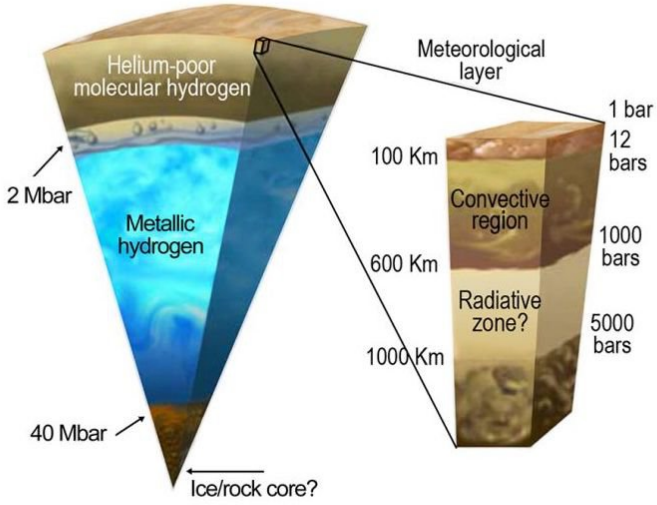


Fig 2. Suggested model of the section of Jupiter

form rocky planets. There were more collisions in this area. So the rocky planets did not grow much bigger. Even if these rocky planets accumulated gases, like hydrogen or helium, solar radiation would have stripped away the gasses. These are the terrestrial planets Mercury, Venus, Earth and Mars. These account for about 2% of the heaver elements (heavier than hydrogen) of the solar nebula.

When the proto-planets grew sufficiently large, the heat from the decay of the radioactive elements resulted the melting and the constituents separated according their densities.

Further away from the Sun, the temperature was lower. There were abundance of ice and gasses. These formed the building blocks of the Jovian planets, Jupiter, Saturn, Uranus and Neptune. The core of the planets were about 15 times bigger than that that of the Earth. These captured hydrogen and helium building the planets with a thick atmosphere. These are now termed as icy giants. Although these are rich in gas, these may have a rocky core. Aurorae occur on all gas giant planets. Occurrent of aurora suggest the presence of magnetic fields. NASA mission Juno (the goddess and wife of god Jupiter who reviled the secrets of Jupiter), left the Earth in 2011 and now carrying out survey of Jupiter. One of the objectives is to study the gravitational and magnetic field of Jupiter, and also the dynamics and composition of its atmosphere. The earlier assumption was the core of Jupiter is 1 to 10 times to that of the Earth or it may not have a core at all. Preliminary results from Juno suggests that the dynamic gas circulation systems are nearly 3000km deep. Further down, the pressure is increasing. Under high pressure hydrogen behaves like metallic solid. However the temperature is high enough to to melt the metallic hydrogen. Metallic hydrogen can conduct charge and the moving electric charge can generate a dynamo effect. This appears to be the origin of the strong magnetic field of Jupiter. Juno gravity mapping data indicates that the core of Jupiter is solid, formed by the minerals of the solar system. After the formation of the planet, it underwent a period of heavy bombardment, which formed a looser dust layer around the core. Now this dust layer is mixed with liquid hydrogen. So the solid core of Jupiter is surrounded by a layer dust and liquid metallic hydrogen mixture. Molten metallic hydrogen surrounds this second layer and the outermost layer is gaseous (mainly hydrogen with some helium) with the circulating patterns. Suggested section of Jupiter is shown in Fig 2.

This is the solar system as we see it today, but the process of evolution of the solar system was somewhat different, to be discussed later.

Asteroid Belt

Between Mars and Jupiter there is the asteroid belt, made from planetesimals of sizes from a few meters to 1000km. Often these collide with each other and debris come under the influence of planets or the Sun. When one of these fragments land on the Earth, we call it meteorite. Some of these can be recovered and examined. These have undergone very little change since the formation of the solar system. Meteorites provide us with information about the early solar building blocks. Since these formed close to the Sun, these are devoid of volatiles. Some of the asteroids have very low density and unlike the spherically shaped planets, most of these are of irregular shape.

Kuiper Belt Objects

Beyond Neptune, the solar nebula is running out of materials. The planetesimals grew only to a few kilometre as lumps of particles and snow. The density is too low to form a near spherical shape like other planets. Some of these objects visit the inner solar system as comets.

Comets contain volatile materials including water ice. As the comets come near the Sun, the volatile matters sublimate and form ion and dust trails. Ion tail is the result of ionisation of the volatiles by the ultraviolet rays of the Sun and the solar wind sweeps the ionised gas to form the ion tail. The ion tail could be 100 million km ($100*10^6$ km) long. Strong magnetic field associated with the ion tail forms complex structure of the tail. The magnetic interaction can rip the tail off as it happened with comet Enke, in 2017 as it came within the orbit of Mercury.

The dust tail is off white, pinkish to yellowish in colour, caused by the reflection of the sunlight. It is slightly curved, due to the motion of individual particles. These particles are often very small about 1μm (0.000,001 mm; $1*10^{-6}$ m).

Comets reside in the Kuiper belt or Oort Cloud. Computer simulation of the formation of solar system, suggests that there were a lot of movement and repositioning of materials during the formation of solar system, and comets could well have formed in the inner region of the early solar system.

The orbit of asteroids are generally shorter and more circular, where comets have highly elliptical orbits with very long periods.

Asteroids do not have tails, but the presence of tails have been seen with some asteroids. It is believed that this is dust plume was caused by the collision between two asteroids. Both asteroids and comets may contain high levels of carbonaceous compounds called, Tholins, reddish in colour, “sepia pink” and often observed on the objects of outer solar system and on the atmosphere of the outer planets and their moons. These form by the interaction of ultraviolet solar radiation or cosmic rays with simpler compound like carbon dioxide, methane, ethane. These compounds often contain nitrogen and do not occur on the Earth.

Pluto seems to be halfway between the terrestrial planets and the Jovian planets. It is small, density is low. It has 5 moons, but, there are neighbouring Kuiper belt objects as well. Pluto is classed as a dwarf planet and a Kuiper belt object. Recently NASA's New Horizon Mission has just completed observation of Pluto. Recently the VLT, in Chile, has reported the observation of an asteroid/dwarf planet Hygiea about 430 km in diameter.

However there always a but-
Asteroids sometime break up during their travel.

An object named 133P/Elst-Pizzaro was initially thought to be an asteroid. It periodically showed a cometary tail. This periodic event ruled out the possibility that this was due to an impact event and the likely explanation is, it is outgassing more like a comet. It does contain ice and the period of rotation prevents from continuous evaporation to form a tail, typical of a comet.

Then there is asteroid 24 Themis. Ground based observations identified water and organic molecules. 1999 RE70 has a nearly circular orbit like an asteroid, but it outgasses forming tails. P/2013 P5 (PANSTARRS) shows clear evidence of outgassing, i.e. coma and tail. These objects are now classified as main belt comets (near circular orbit as asteroids). The distinction between the comet and asteroid may not be that clear cut. Asteroids may contain ice, and the new evidence tends to suggest that the water on the Earth was not carried only by the comets; asteroids might have played a role as well.

Moons

The orbit of the some of the moons of the giant planets are highly irregular. These are likely to have been captured via a three body interaction. Jovian planets accreted materials and formed moons around the planets. Jupiter had a proto-lunar disc similar to the solar nebula. With Jupiter, there were several stages of moon formation. These moons eventually got attracted and fell into the planet. The present generation of moons is probably its fifth generation of moons. From the past history, it is expected these moons also to spiral into the planet, but the resonance of their motion may be the likely reason that these moons do not fall into Jupiter. The very outer moons are probably captured asteroids by Jupiter's proto-lunar disc. Some of these broke apart under stress exerted during the process of capture and some during collisions. Today there are about 79 moons around Jupiter.

The rings of Saturn are made from asteroids, comets and broken up moons. These consist of rocks and ice covered with dust. The size of the particles vary widely. Some of the particles accreted to form moons. These moons maintain the shape of the rings via gravitational interaction. One of the images from the Cassini probe has been interpreted as the process of formation or breakdown of a moon via the ring–moon interaction. As the moons form, the there is depletion of particles and it may eventually lead to the end of formation of moons. The number of moons orbiting Saturn is now reported to be as high as 82.

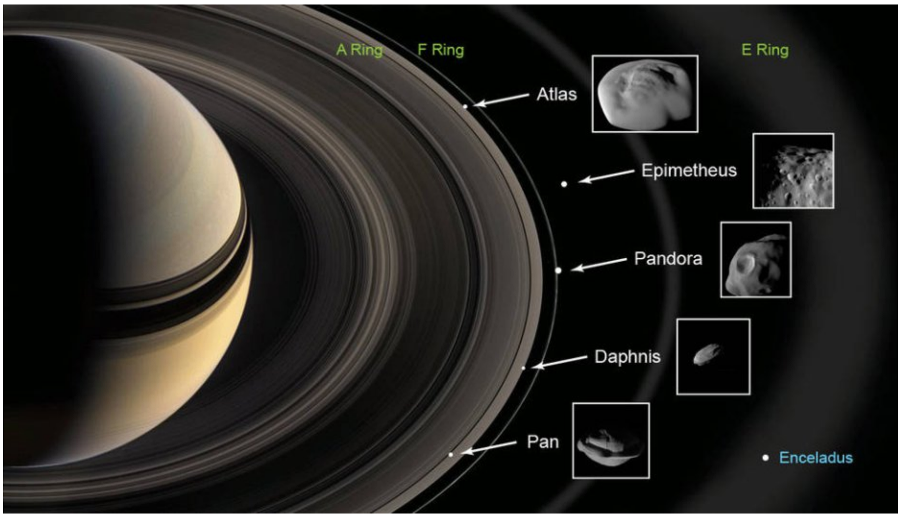


Fig 3. Some of the inner moons of Saturn

Some of the moons were captured objects by the planets. For example the moons of Mars are probably captured asteroids.

The Moon

Moon formed as a result of collision of a large body with Earth. The ejected mass eventually formed Moon. The evidences in support of this theory are:

1) The minerals on Earth and moon show presence of similar elements, however there are certain noticeable differences.

2) Moon does not contain any easily volatile elements like carbon, nitrogen, sulphur, hydrogen. The ejected mass that became the moon was too hot and these evaporated. On Earth there are clay minerals which are absent in the Moon. Clay minerals form in presence of water. It is likely due to the absence of water in bulk of the Moon, but presence of water has been confirmed in the south polar region.

3) Had the moon formed from the same gas cloud as that of the Earth, we would have expected composition of Earth and Moon to be different, as we find the case with Earth and other planets. However Earth and Moon are very similar in composition, but the density of Moon is much lower. The core of the Earth accounts for about 30% of its weight, where as for Moon, the core is about 3%.

4) Oxygen isotopes ratio found on the Earth and Moon are very similar. This indicates a common origin. The ratio of oxygen isotopes has been found to depend on the distance of the object from the Sun.

It is also difficult to simulate a process to show that Earth captured a passing body as a satellite to form the Moon. The collision that led to the formation of the Moon, tilted the axis of Earth and the presence of Moon has stabilised the orbit of the Earth. These are some of the primary conditions which allowed life, as we know it, to flourish on the Earth.

Planet 9, X

Some of the Kuiper belt objects show a somewhat unusual orbit, highly elliptical, beyond Neptune and rotate at

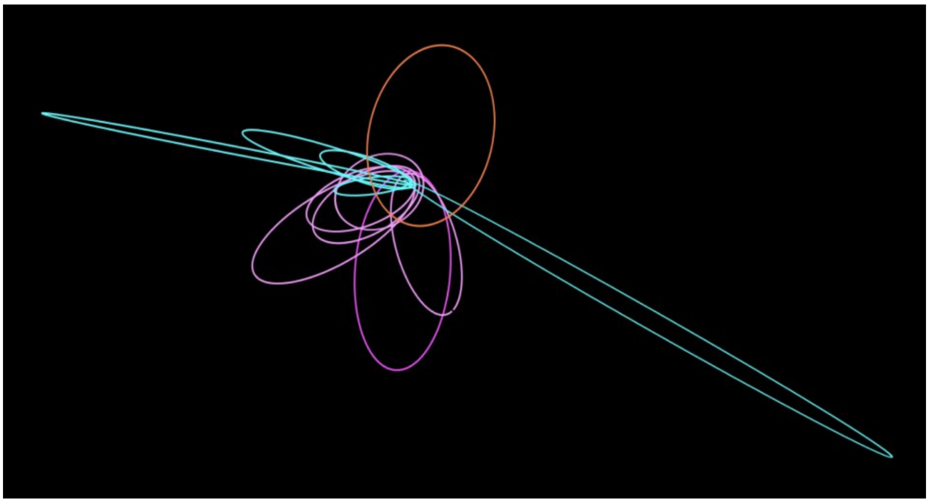


Fig 4. Simulation of some of the trans-Neptunian objects. The orbits of the five objects with high-inclination orbits (nearly perpendicular to the ecliptic) are shown here as cyan ellipses with the hypothetical Planet Nine in orange.

different rates. Their plane of rotation is about 90° downwards from the plane of the 8 planets. Computer simulation suggested that such a system could only be explained by the existent of a planet, with about 10 times the mass of the Earth, and its plane at near 30° to the solar system. The orbit of this object is about 20 times the average Sun-Neptune distance (nearly 4.5 billion km, 30.1 Au) and takes about 10–20,000 years to orbit the Sun. This planet has been named as Planet 9 (X), but its presence is yet to be confirmed.

This is the Solar system as we see it today, but how did it come to being?

Computer simulations suggest that the evolution of the present state of the solar system, has not been that straightforward. According to the simulations, there should be planets within the orbit of Mercury, an Earth like planet where the Mars is and the asteroid belt to be full of Mars size objects.

Jupiter was the first born and formed around 3Au from the Sun. The proto-planetory disc around the Sun was very dense and greater than the weight of the planets. This dense disc altered the behaviour of Jupiter and exerted gravitational drag on Jupiter. This process prevented any formation of planets. Jupiter collected mass and grew nearly to its current size. Jupiter was destined to fall into the Sun. But gasses flew out of the proto-planetary disc and Jupiter migrated to a position 1.5 Au, which is the current position of Mars.

In the mean time, Saturn has formed; it also migrating towards the Sun and reached to about 2Au from the Sun. Then both Jupiter and Saturn stopped their Sun-ward migration and started to retreat away from the Sun. Eventually Jupiter and Saturn settled to their current position 5.2 and 9.5Au respectively from the Sun. During this process a lot of material has been removed from the proto-planetory disc. The leftover material provides the material for the inner rocky planets and the Moon.

The large mass of Jupiter and hence the large gravity field prevented the rocky material from forming a planet. Material stayed as loose collection of icy material. During Jupiter's initial journey towards the Sun, the rocky material was pushed outward and during its outwards motion, some of the rocky materials got moved towards the Sun and gave rise to the asteroid belt between Mars and Jupiter.

Since Mars formed away from Venus and the Earth, it should have been expected to be larger. But during its stay nearer to the Sun, Jupiter scattered a lot of material and less was available for the formation of Mars. This change in the direction of movement of Jupiter has been described to be similar to the change of direction used by sailors, called tacking. Hence the the model is known Grand Tack model. A separate simulation from the Nice observatory (France) also came up with a similar scenario (Nice, Model).

Looking for planet 9

Astronomers from Carnegie Institution while looking for planet 9, spotted a new set of moons of Jupiter. This brings the total number of moons of moons of Jupiter to 79. The observation period was over one year and a wide area of the sky was covered. They took 4 separate images and stitched them together to cover a large field of view.

Two of the moons orbit in prograde direction i.e. the same direction as the planet. These are just outside the orbit of the Galilean moons. These are probably once one large moon and since then has been broken by collision. These take about a year to orbit the planet.

Nine of the new moons orbit further away, in an orbit opposite to the planet i.e. in retrograde motion. These are thought to be larger bodies, broken up by collision with asteroid, comets or other moons. The 12th of the new moons, orbits in prograde motion, but close to the outer 9 set of retrograde moons. This 12th moon is on a potential collision course with its neighbouring moons.

Possible presence of the planet X (or 9) got a boost with the detection of another dwarf planet, named 2015 TG387, affectionately called Goblin. It was first detected in 2015 by Japanese 8.2m Subaru telescope in Hawaii. It is extremely slow moving and has a long orbital period. Its orbit was monitored by other telescopes from 2015 to 2018. The estimated diameter is about 300km with highly eccentric orbit. The Perihelion of some of the dwarf planets are: 2015 TG387, about 65 AU; Sedna, about 76 AU and 2012 VP113 about 80 AU.

Although 2015 TG387 has the third closest perihelion, its orbital semi-major axis is larger than Sedna and 2012 VP113. This means 2015 TG387, travels further (estimated aphelion 2300 AU) than Sedna and 2012 VP113. Since all these are so far out, these three dwarf planets are unaffected by the gravity of the giant planets of solar system Jupiter and Neptune. Such eccentric orbit can only be explained by the presence of another planet X or 9.

Our knowledge of the formation of solar system is far from complete. Missions are being sent to orbit planets, robotic mission to land on the Moon and Mars. Observation of Exo-solar planets has opened up a new avenue to understand the formation of planetary systems.

Asteroid break up see
`www.nasa.gov/feature/goddard/2019/hubble-watches-spun-up-asteroid-coming-apart/`
The moons of Mars
`www.astronomy.com/news/2016/12/captured-moons-of-the-giant-planets`
(Also see, Frost, M; MIRA 105)