The Jeety Starn
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Welcome to Issue 8 of *The Jeety Starn*, the quarterly newsletter of the Stirling Astronomical Society. This issue includes articles on the Torquetum, early Dutch astronomers and the UK National Space Centre, a story on sunspots, and updates on the ispace mission and on the Society's telescope mirror, as well as our regular ration of literary morsels. We start with an account of an interstellar visitor.

New Comet Coming In

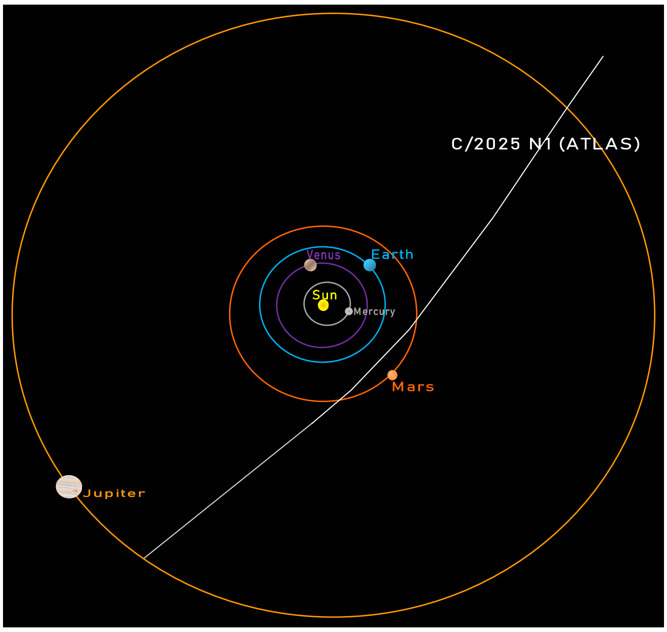
By Sandi Cayless

A new visitor from interstellar space is on its way through our Solar System. On 1st July 2025, the ATLAS (Asteroid Terrestrial-impact Last Alert System) * survey telescope in Rio Hurtado in Chile, observed a comet travelling in from the direction of the constellation Sagittarius (NASA 2025). This interstellar visitor, officially named 3I/ATLAS, but also known as C/2025 N1 (ATLAS) and formerly as comet A11pl3Z, was at a distance of 4.5 AU (670 million km or 420 million mi) from the Sun and with a relative speed of 61 km/s (38 mi/s), and travelling in an eccentric hyperbolic orbit (MPC 2025). Since then pre-discovery observations have been noted in the archives of three other ATLAS telescopes and the Zwicky Transient Facility at Palomar Observatory, California that go back to 14th June 2025, and many other telescopes have observed the comet since. For current data see The Sky Live (2025).

3I/ATLAS is an active comet enclosed in a reflective dust shell and with a nucleus of uncertain size, although it has been estimated at between 0.8 and 24 km (0.5-14.9 mi) diameter, though a size toward the lower end of the range is more likely (Seligman *et al.* 2025; Jewitt & Luu 2025). The velocity of 3I/ATLAS suggests that it originated in the thick galactic disk (a structural component of about 67% of disk galaxies, including the Milky Way); this structure contains numerous older stars, implying that the comet may be water-rich and over 7 billion years old (Hopkins *et al.* 2025).

3I/ATLAS will come to perihelion on 29 October 2025, at a distance of 1.358 ± 0.002 AU (203.15 ± 0.30 million km; 126.23 ± 0.19 million mi) from the Sun and will be observable through early September 2025, and then again in late November 2025 (NASA 2025, Seligman *et al.* 2025).

* ATLAS is a robotic astronomical survey/early warning system made to detect smaller NEOs (near-Earth objects) in weeks to days before they impact Earth. ATLAS is funded by NASA, and developed and operated by the Institute for Astronomy, University of Hawaii. The system currently has 4 operational 0.5-metre telescopes: two in the Hawaiian islands, at Haleakala and Mauna Loa and 160 km apart; one at the Sutherland Observatory in South Africa; and one at the El Sauce Observatory, Rio Hurtado, Chile. A fifth system, at Teide Observatory in Spain (ATLAS-Teide), commissioned February 2025 (Team Baader Planetarium 2025) and consisting of 4 specially-made PlaneWave L-550 mounts each with 4 Celestron RASA 11 in. telescopes (16 units), has already produced its first results (Licandro *et al.* 2025).



The trajectory of interstellar comet 3I/ATLAS on its way through the solar system. It will make its closest approach to the Sun in October. Graphic based on an original by NASA/JPL-Caltech.

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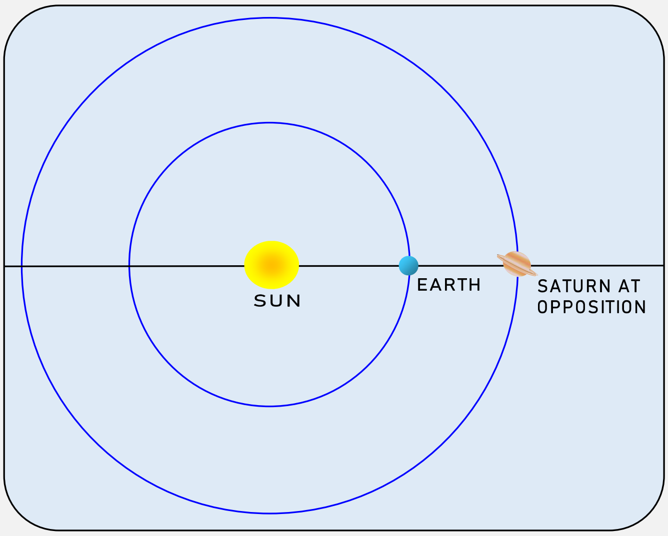
Saturn at Opposition

A very good time to observe and image a planet is when it is at *opposition*, the point at which the Earth is directly between the Sun and that planet.



The planet Saturn reaches opposition on 21st September 2025 and will shine at magnitude 0.6, in the constellation Pisces. At opposition, Saturn is at its shortest distance, 71 light-minutes (~8.55 au), from Earth for 2025. From there, Saturn will cross Pisces to Aquarius by the end of the month.

Saturn's disk appears largest around opposition, at 19.4 arcseconds diameter. The planet's ring tilt at opposition is 2 degrees relative to observers on Earth, which means that they appear very narrow, almost edge-on. Observers may recall that earlier this year, in March, when Earth crossed the plane of the rings, they seemed to disappear for a short time. See the *Happy Observing* section for more on the best view of Saturn at opposition from Stirling!

Update on the High School Telescope Mirror

By Alan Cayless FRAS

On the 6th May this summer, the primary mirror from our Society's historical Newtonian reflecting telescope in the Highland Hotel in Spittal Street, Stirling, was taken for refurbishment to the coating lab of Orion Optics, in Staffordshire. The mirror was last recoated 21 years ago. Refurbishment meant removing the old reflective layer, and applying a new coating. The mirror was eventually shipped home on 14th July, and reinstalled in the telescope by society members on the 22nd of July.


Mirror after recoating. Image credit: Alan Cayless

Dutch Astronomers 2

By Sandi Cayless

Astronomy is among the oldest sciences in the world and boasts many talented and famous figures, but the Netherlands, for so small a country, has contributed an extraordinary number of brilliant minds that have made their marks on the science.

Harlow Shapley (said with reference to Jacobus Kapteyn): "*Holland? Oh, that's the place where they grow tulips and astronomers for export!*"

In the second part of a series that looks at some well-known Dutch astronomers and their work, we consider two that have expanded our knowledge of the universe: John Goodricke and Jacobus Kapteyn.

John Goodricke (1764-1786)

John Goodricke FRS, a pioneer in variable star observing, was born in the city of Groningen, in the province of Groningen in north-east Netherlands, where his father Henry was in the diplomatic service, though he lived for most of his short life of 21 years in England. John was named for his great-grandfather Sir John Goodricke (1617–1670), Baron of Ribston, Yorkshire. A severe illness in early childhood, possibly scarlet fever, left him profoundly deaf (French, 2010, 2012a). His supportive parents thus sent him to Thomas Braidwood's Academy for the Deaf and Dumb in Edinburgh, the first school of its kind in Britain and a progressive establishment focusing on speech and using an early form of sign language (Lee 2015). The excellent grounding available there, which was commented upon by Samuel Johnson (French 2012a), stood him in good stead for his further schooling. From 1778 to 1781 he attended Warrington Academy, an advanced Dissenting Academy (Parker 1914) that focussed on bringing out the best in its students and was known for its teaching of mathematics (which included astronomy) and science (French 2012a).

French (2010) notes that a school report from Warrington describes John Goodricke as an excellent mathematician, and a preserved mathematics notebook of his (held in the Goodricke collection of York City Archives) includes a drawing of several constellations including Orion, Taurus, Auriga and Gemini and their principal stars, as well as the Milky Way, the Moon and the ecliptic, with notes describing these and various star positions either side of the meridian. These positional notes date the drawing to late November 1779, when John was 15 years old. He was thus already studying the sky at this time. Although probably well qualified for university he returned home to York in 1781 (he was 17 years of age), where he met often with the young astronomer Edward Pigott, a distant cousin and son of astronomer and Royal Society Fellow Nathaniel Pigott (Clerke 1896). The return home was possibly due to illness, as in his journal and in Edward Pigott's diary there are references to his being unwell. The first entry in John's observing journal in early November 1781 reads: "Last evening at 9 p.m. Mr. E. Pigott discovered a comet". The entry also includes notes of Edward's communications with William Herschel and Astronomer Royal Nevil Maskelyne (French 2010). A letter exists in the Huntington Collection of Herschel to Pigott, dated November 21st, 1781, with additions that he saw the comet reported by Pigott and on November 22nd noted its location, his estimate of its size, and that he estimates it will be out of sight in two weeks (Huntington Library 2025). However, the only comet listed as discovered in November 1781 is comet C/1781 T1 Méchain (=1781 II) and credited to avid comet-hunter Pierre Méchain, although Edward Pigott would have a comet to his name in 1783 (226P/1783 W1 Pigott-LINEAR-Kowalski).

It was probably Edward Pigott who interested John in variable star observing. Edward was an accomplished astronomer with many discoveries to his credit over his lifetime. He and John often observed together in the private observatory in York built by his father Nathaniel Pigott (Pigott 1781, French 2010, 2012b), but he had earlier noted variations in the reported positions and brightnesses of stars from one star catalogue to another (French 2012b). In Autumn 1782, the two began observations of stars which were, or believed to be, variable. The list in John's diary included Algol (β Persei), which had been observed to vary as far back as 1672 by Montanari (Ashworth 2020). John at first put his observations of Algol's rapid variation down to an optical effect or a defect in his own eyesight, but after being joined by Edward in continued observations on every clear night, the dimming was clearly obvious to both in December. Their possible explanations were an eclipse by an orbiting body (John's favoured theory) or a spot or spots covering part of the star's surface (Edward's view). John's subsequent observations concentrated mostly on Algol, whilst Edward's mainly took in other variable stars, and by observing every eclipse into April 1783, John worked out that the period between successive minima of Algol's light was 2.8646 days, a calculation that remains accepted today (Jetsu 2021). Although Edward had no doubt contributed to the research, it was the convention that one person communicate the results to a member of the Royal Society of London to be read at a Society meeting. John thus sent a letter of the results (omitting the word 'planet' to describe the hypothetical body orbiting Algol) to Dr. Anthony Shepherd, Plumian Professor of Mathematics at Cambridge. It was published in the Society's *Philosophical Transactions* in May 1783 (Goodricke 1783). A number of members of the Royal Society and others were able to confirm the accuracy of Algol's period of light diminution but most astronomers did not accept that the dimming was due to an eclipsing body – indeed William Herschel preferred the spotted star explanation (French 2010, 2012b). Nevertheless, in August 1783, at the age of 19, John Goodricke was awarded the Copley Medal of the Royal Society for his work.

Goodricke would change his mind over the eclipse hypothesis in favour of the sunspot one, possibly as this was favoured by senior astronomers such as Pigott, Maskelyne and Herschel, but we now know that Algol is a multiple-star system of three confirmed and at least five suspected companion stars (Jetsu 2021). The primary is a hot, luminous B8 main-sequence star, the secondary a larger, cooler and fainter K2-type subgiant, and the third a very faint F1 main-sequence star orbiting the inner pair every 1.86 years. As he continued to study and report on Algol (Goodricke 1784), John Goodricke also worked out the period of β Lyrae (or Sheliak, a multiple star system of six components) in 1784, his results being published by the Royal Society the following year (Goodricke 1785). Also during 1784, Goodricke observed and determined the period of variation of δ Cephei (the prototype of the Cepheid class of variable stars, a quadruple star system), his results being published by the Royal Society (Goodricke 1786). The period-luminosity relationship of the Cepheids would allow later astronomers to use them as "cosmic yardsticks" to work out the distances to remote galaxies (Bhardwaj 2020).

In 1786, John Goodricke was nominated for membership of the Royal Society by Nathaniel Pigott, and sponsored by seven other members. He was elected to membership on 6 April 1786, at the age of 21, but sadly died 14 days later, on 20 April in York.

"This worthy young man exists no more; he is not only regretted by many friends, but will prove a loss to astronomy, as the discoveries he so rapidly made sufficiently evince…" (Pigott 1786).

Asteroid 3116 Goodricke is named for John Goodricke (MPC 2025a), as is the University of York's Goodricke College (University of York 2025). The Goodricke-Pigott Observatory (GPO) in Tucson, Arizona, privately founded by the late Roy Tucker, was named for both John Goodricke and Edward Pigott, formally dedicated on 26 October 1996 and used, *inter alia*, for asteroid hunting and variable star observation (Craine 2022).

Jacobus Cornelius Kapteyn (1851-1922)

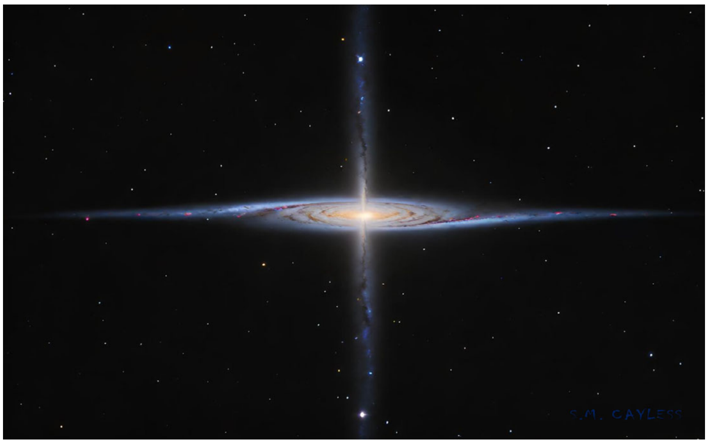
Jacobus Cornelius Kapteyn, a pioneer in the study of the Milky Way, was the tenth of fifteen children (van der Kruit 2014), and was born in Barneveld, in the Dutch province of Gelderland. He grew up in a boarding school that his parents ran, and showing early promise, he entered the University of Utrecht at 17 years old (van Berkel *et al.* 1999). Kapteyn gained his Ph.D. in 1875 with a dissertation entitled: *Onderzoek der trillende platte vliezen* (A Study of Vibrating Flat Membranes) (Kapteyn 1875). He worked first as an observer at the Leiden Observatory, and then in 1877 at the early age of 27, he was appointed to the new chair of astronomy at the University of Groningen. His inaugural lecture in 1878 was titled *The Parallaxes of the Fixed Stars* (van der Kruit 2015).

Denied a well-equipped observatory at Groningen, he entered into a huge project with the Scottish astronomer and pioneering astrophotographer

David Gill at the Royal Observatory, Cape of Good Hope, to compile an index of the brightness and position of almost half a million southern stars (van Berkel *et al*. 1999). In Groningen, Kapteyn would measure the plates made by Gill's staff in their photographic star catalogue of the southern skies. For this work, Kapteyn developed a new method of parallactic measurement, designed precision instruments, and organized an astronomical laboratory (Zuidervaart 2008). The work began in 1885 and the resulting positions of the 454,875 southern stars measured was published as *Cape Photographic Durchmusterung* in three volumes between 1896 and 1900 (these are available as NASA reprints).

In 1898, while Kapteyn was reviewing star charts and the *Durchmusterung* photographic plates, he noted that a star earlier catalogued in 1873 by B. A. Gould as C.Z. V 243, appeared to be missing. However, Scots-born South African astronomer Robert T. A. Innes (discoverer of Alpha Centauri) found an uncatalogued star 15 arcseconds away from where the star should have been, and worked out that because it had a very large proper motion (> 8 arcseconds/year), it had moved significantly over the time interval. Listed as CPD-44 612, the class M1 red subdwarf star became known as Kapteyn's Star, although equal credit should go to Robert Innes (for more on Kapteyn's Star, see Cayless 2025). At the time of its discovery, CPD-44 612 had the highest proper motion of any known star, although Barnard's Star later overtook it.

Kapteyn's key aim in his life's work was to decipher the structure of the visible part of the universe and the distribution of the stars within it, and to this end he first supposed that stellar motion had no specific direction, but was random (van Rhijn 1922). Around 1902, the realisation that this was false and star motion was non-random led Kapteyn to his discovery of opposing Star Streams, whereby there were two preferred directions in space, roughly opposite, and for the Milky Way these were in the direction of the Galactic centre and anti-centre (van der Kruit 2015). He announced his findings in 1904 at a large conference and in 1905 at a meeting of the British Association at Cape Town. His results were quickly confirmed by other astronomers (including the young Arthur Stanley Eddington), the two streams being shown to move at a relative velocity of about 40km/s. The discovery of Star Streams still held observationally, (although some disputed their existence, e.g. Charlier 1924), but ten years on, although the vertical dynamics was shown to be largely correct, Karl Schwarzschild provided the correct explanation of cause: in the plane of the Milky Way, the phenomenon is an anisotropic velocity distribution (van der Kruit 2015; Griv *et al.* 2001), the directions of the Star Streams corresponding to the long axis of the velocity ellipsoid. Although Eddington preferred Kapteyn's explanation (Eddington 1912), Jan Hendrik Oort (one of Kapteyn's students) extended Kapteyn's work in the vertical with his discovery of galactic rotation and the Oort constants (Oort 1928), and the Oort limit (Oort 1932).



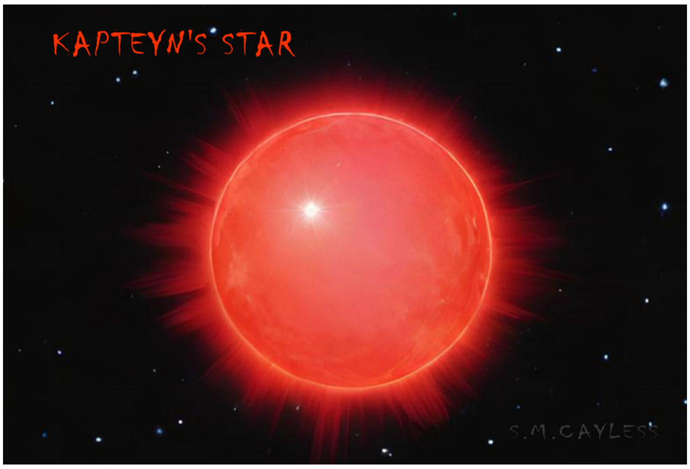
Artist Impression of Kapteyn's Star Streams: S. Cayless

Realising that the data needed for confirming and improving his work was enormous, by 1906 Kapteyn had organised the international cooperative *Plan of Selected Areas*, in which the work of logging the stars in 206 sample areas was divided amongst 30 observatories (van der Kruit 2015), a work that was not finished until almost half a century after his death (van Berkel *et al*. 1999). The data was to cover as many parameters of as many stars as possible, and included apparent brightness, proper motion, radial motion and colour. Edward Pickering at Harvard agreed to carry out a *Durchmusterung* (star catalogue) of Selected Areas across the whole sky as long as Kapteyn widened *his* Plan to include Pickering's *Special Plan*, which focussed on areas in the Milky Way. The photographic plates were sent to Groningen to provide positions and magnitudes, and the work resulted in Harvard-Groningen Durchmusterungs that provided positions, and magnitudes down to 16, in the Selected Areas (later published between 1918 and 1924). But more was needed, and Kapteyn realised that the use of George Ellery Hale's new 60-inch telescope at Mount Wilson as part of the Plan was vital – it was used spectroscopically, to determine radial velocities. Hale insisted on Kapteyn's personal involvement, and this resulted in Kapteyn being appointed a research associate of the Carnegie

Institution, and from 1908 to 1913 he travelled annually to Mount Wilson to work, getting to know many of the American astronomers of the time personally (van Rhijn 1922).

By around 1920 the data gathered and Kapteyn's analysis of it was revealing the Milky Way to be disk-like, about six times as wide as thick, with the Sun near the centre (Kapteyn & van Rhijn 1920). An explanation of the system equilibrium as a precise balance between the stars' gravitational forces and their random motions and organised rotation followed (Kapteyn 1922). Although the vertical aspect of this *Kapteyn Universe*, a lens-shaped island universe becoming increasingly star-dense towards the centre, was proved largely correct, the findings of differential rotation and interstellar extinction in the plane of the Milky Way showed it to be wrong (van der Kruit 2015). Kapteyn knew of the problem of extinction (absorption of starlight by interstellar matter) but was unable to measure it, and according to van der Kruit, he worried over it, writing four papers on the subject (Kapteyn 1904; 1909a; 1909b; 1914). The Kapteyn Universe was therefore altered when absorption was demonstrated: its size had to be increased, although not as much as Harlow Shapley advocated (Oort 1928) and the position of the Sun was determined, as argued by Shapley, to be eccentric (Shapley & Cannon, 1923). Kapteyn and van Rhijn (1922) had argued that Shapley's distances were too large because the short-period local Cepheids used to calibrate had high proper motions and so must be close and hence fainter than Shapley's globular cluster variables. Kapteyn's program, however, retained its validity and was pursued by his successors. His study also showed that there were preferred motions of stars in the solar neighbourhood, which showed relative motions of two groups of stars: this was important evidence that the Milky Way had a spiral structure and that our Sun was in one of the spiral arms (van Berkel *et al*. 1999).

Kapteyn in later years linked his two great investigations, star streams and stellar system formation, to work out that if the masses, positions and velocities of all stars at a specific time point are given, it should be possible to work out the future form of the universe using the laws of mechanics. His dynamic conception has star streams as a circular movement parallel to the plane of the Milky Way, with stars moving clockwise and anti-clockwise. Jacobus Kapteyn retired in 1921 and died in Amsterdam on 18 June 1922 after a lifetime devoted to advancing astronomy. His work was recognised by several honours: the Gold Medal of the Royal Astronomical Society (1902); the James Craig Watson Medal "In recognition of his bold and penetrating researches in the problem of the structure of the stellar universe" (1913); and, the Bruce Medal, for his outstanding contributions to astronomy (1913).



As well as Kapteyn's Star, the Kapteyn Astronomical Institute at the University of Groningen is named for him, as is the J.C. Kapteynlaan, a street in the city of Groningen, and the Jacobus Kapteyn Telescope (JKT), one of the Isaac Newton Group of Telescopes on La Palma (Canary Islands). The lunar impact Kapteyn Crater (10.79°S 70.59°E) near the Moon's eastern limb was named in his honour, as was Main Belt Asteroid 818 Kapteynia, discovered by Max Wolf in 1916 (MPC 2025b). His daughter Henriette (1881-1956) was married to astronomer Ejnar Hertzsprung.

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John Goodricke (1629-95) Portrait attributed to James Scouler (1740–1812), painted 1785/86; original pastel in the possession of the Royal Astronomical Society, London; public domain.
Jacobus Cornelius Kapteyn (1851-1922) Dutch astronomer. Painting by Jan Veth (1864–1925) made in 1921 on the occasion of the 40th anniversary of Kapteyn's professorship and on view in the Kapteyn Institute, Groningen; public domain.

> "I feel the deepest obligation to the astronomers who have helped me in my task by permitting me to use their observations."
>
> J. C. Kapteyn
> Groningen, 1914

A Quote or Two...

Galileo, Galilei (1564-1642)
The sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else in the universe to do.

The Milky Way is nothing else but a mass of innumerable stars planted together in clusters.

Measure what can be measured, and make measurable what cannot be measured.

To command their professors of astronomy to refute their own observations is to command them not to see what they do see and not to understand what they do understand.

Gell-Mann, Murray (1929-2019)
Our planet doesn't seem to be the result of anything very special.

Glenn, John (1921-2016)
The most important thing we can do is inspire young minds and to advance the kind of science, math and technology education that will help youngsters take us to the next phase of space travel.

Haldane, John B. S. (1892-1964)
If one could conclude as to the nature of the Creator from a study of his creation it would appear that God has a special fondness for stars and beetles.

It is my supposition that the Universe in not only queerer than we imagine, is queerer than we can imagine.

Halley, Edmond (1656-1742)
Scarce any problem will appear more hard and difficult, than that of determining the distance of the Sun from the Earth very near the truth: but even this... will without much labour be effected.

This sight... is by far the noblest astronomy affords.

In the year 1456… a Comet was seen passing Retrograde between the Earth and the Sun… Hence I do venture to foretell, that it will return again in the year 1758.

Hanks, Tom (1956-)
From now on we live in a world where man has walked on the Moon. It's not a miracle; we just decided to go.

Hawking, Stephen (1942-2018)
The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe. Why does the universe go to all the bother of existing?

We are just an advanced breed of monkeys on a minor planet of a very average star. But we can understand the Universe. That makes us something very special.

We are very, very small, but we are profoundly capable of very, very big things.

One of the basic rules of the universe is that nothing is perfect. Perfection simply doesn't exist… Without imperfection, neither you nor I would exist.

Nothing is fool-proof to a sufficiently talented fool.

We only have to look at ourselves to see how intelligent life might develop into something we wouldn't want to meet.

Heinlein, Robert A. (1907-1988)
The universe never did make sense; I suspect it was built on government contract.

When a place gets crowded enough to require IDs, social collapse is not far away. It is time to go elsewhere. The best thing about space travel is that it made it possible to go elsewhere.

Herschel, William (1738-1822)

I have tried to improve telescopes and practiced continually to see with them. These instruments have play'd me so many tricks that I have at last found them out in many of their humours.

Not this one, Mr. Herschel…

The National Space Centre

By Graem Farland

The National Space Centre (NSC) is a national public facility situated on Exploration Drive, Space City, two miles north of the city centre of Leicester (NSC 2025). The NSC is a museum and educational resource devoted to space science and astronomy, and in partnership with Leicester University, it runs a space research programme. It is also a registered charity. It was opened to the public on 30th June 2001 by former NASA astronaut Jeffrey A. Hoffman (University of Leicester 2021), where it was the base for over sixty scientists and astronomers working on projects in a Space Science Research Unit.

The Centre contains an outstanding collection of artefacts that tells the past, present and future stories of space exploration and science. Its many attractions include interactive galleries with hands-on sensory and other activities, exhibitions, and a Planetarium that holds, amongst other shows, Tours of the Night Sky.

National Space Centre   Image Credit: Pick Everard; ©ESA

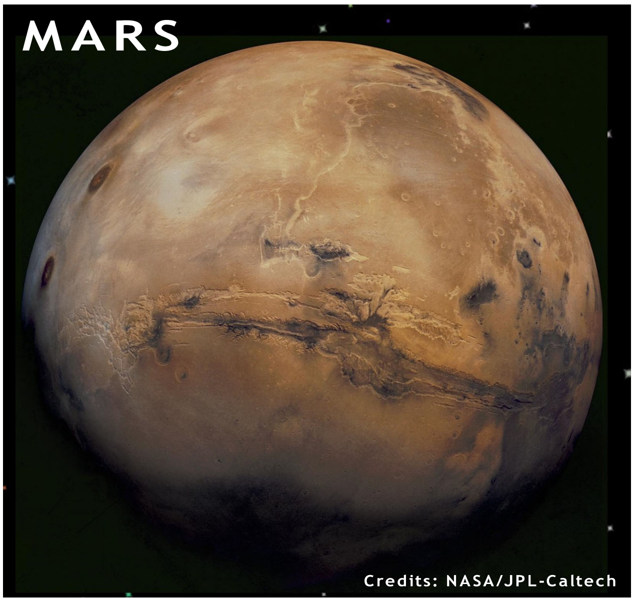
The activities are drop-in so that visitors can come and go. The NSC also hosts live events, movie nights and much more, and caters for all ages (NSC 2025). Younger visitors can paint pictures or visit the sensory space, which has moving stars and sensory toys and other items to use. The live events include evening musical performances, and interactive science talks on subjects such as the Moon, space research and exploration and astronomy from the earliest times to the present day. The access facilities are very good all through the Centre, with plenty of wheelchair space, and assistance dogs are welcome. There are also disabled parking bays in the (pay and display) car park and wheelchair spaces are available in the Planetarium. There is seating all around the Centre and a café (called Boosters, where you can sit under a rocket!) and a large shop that sells all kinds of space-themed articles such as T-shirts and mugs.

The exhibitions feature showcases and models that are contained in six Galleries. These are Home Planet; Into Space; Space Oddities; Our Solar System; The Universe; and, Live Space.

The **Home Planet Gallery** shows how satellites monitor the Earth's health in terms of air, water and land, how humans can live more sustainably, the habitats there are and how to look after them. There is a giant 3-metre Earth globe and a Meteosat geostationary satellite as well as artistic pieces depicting a giant wave and water pollution, and a marble run, where a marble is launched on a track down through various channels and wheels. Visitors are also encouraged to make a pledge to help the Home Planet.

The **Into Space Gallery** includes a walk through a mock-up of the Columbus Module from the International Space Station and also shows you how to use a space toilet. There are displays including astronauts, spacesuits and 'our journey into space'. Astronauts that have visited the NSC include Buzz Aldrin, part of the Apollo 11 crew that landed on the Moon. On display are Helen Sharman's Kazbek-UM Shock Absorbing launch couch and PK-14 Cosmonaut flightsuit, from her journey as the first British person in space. Also displayed are her training Sokol KV-2 Rescue Spacesuit and Mir hygiene kit. Helen launched on 18th May 1991 on Project Juno, aboard the Soyuz TM-12 craft, on an eight-day mission orbiting the Earth, mostly on the Mir space station. There she carried out medical and agricultural tests, investigated crystal growth in microgravity and talked to British schoolchildren over amateur radio (Maciel, 2017).

The **Space Oddities Gallery** displays objects that relate to less well-known stories in space history, and has an interactive touch-table, to explore objects more fully. Included in the displays are: scale models of Ganymede, Callisto, Io and Europa; a fake Roswell alien head; emergency food rations; graphics of ExoMars landing sites Mawrth Vallis and Oxia Planum; a Gemini 9A Model Astronaut Manoeuvring Unit (AMU); a Gemini Recovery Training Beacon; an Omega Speedmaster Professional X-33 Calibre 1666 watch; many space mission patches; and early space books by H.G. Wells and Jules Verne.



The **Our Solar System Gallery** explains the neighbouring planets, moons and dwarf planets in our solar system. On a walk through the gallery, visitors can stop off at Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune. The Mars Rover Challenge workshop is a group event where students work in teams to use coding and programming to control Lego Spike rovers and carry out a number of challenges like some of those met by NASA robotic engineers. A piece of rock from Mars is in a display cabinet and visitors can drive a tiny Martian rover on a model landscape of Mars.

In the **Universe Gallery**, visitors can explore the wonders of the Universe, journey through a wormhole, watch the Big Bang, look up to see the space technology that is observing the Universe and visit the Stellarium, which shows how the Sun fits into the Universe. You can also take your picture to become an alien and see an Alien Autopsy Roswell head.

The **Live Space Gallery** is a drop-in space and is a talks stage. There are regular science shows over school holidays where visitors can watch the latest videos, and hear news stories and live updates. There are also interactive talks and demonstrations by experts, guest lecturers, science communicators and the NSC's Discovery team.

The **Sir Patrick Moore Planetarium** is the largest fulldome planetarium in the UK. The planetarium was renamed in honour of the British astronomer and broadcaster, and launched by Sir Patrick in 2012 (Bramley 2012). It is used to host spectacular and immersive musical-visual shows (some shows are age-restricted), as well as tours of the night sky. Other shows are educational, such as The Apollo Story, or immersive, such as Astronaut, that allows visitors to feel what it is like to be launched from a rocket, or to float around in the International Space Station; or at a microscopic scale, feel what it would be like to navigate through the human body. The themes change regularly and there are also opportunities for young visitors to find out about aliens, the early days of the universe, climate change, and what astronomers do.

The **Tetrastar Spaceport** is an immersive (and bumpy) experience that includes a low Earth orbit cruise on the **Tharsis** spacecraft, which is a crewed ship and where you can operate the controls and then take a seat to ride off on a journey to the stars. (**Tharsis** is a massive volcanic plateau in the western hemisphere of Mars that contains three of the largest volcanoes in the Solar System (Arsia Mons, Pavonis Mons and Ascraeus Mons). The largest volcano in the Solar System is Olympus Mons, which is located is off the western edge of Tharsis.)

One of the amazing sights at the NSC is the 42-metre high **Rocket Tower**. It holds the huge Blue Streak and Thor Able rockets, and is a semi-transparent tower covered on the outside with high-tech ETFE (ethylene tetrafluoroethylene) *pillows*, which are cushions made from layers of ETFE foil that are filled with air and are transparent and lightweight for insulation and structural support (Fauchon & Hovraluck 2014). The Tower was specially designed to contain the NSC's largest exhibits and as well as the rockets, it includes the Gagarin Experience, Apollo Lunar Lander and a piece of real Moon rock brought back to Earth from one of the Apollo missions. A glass lift takes you up the four exhibition decks; these tell the stories of the Space Race, the history of rocketry, and the British Space Race.

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The Home Planet: © S.M. Cayless
Galaxy: © S.M. Cayless

September Aurora

By Arryll Idrennis

As cold September nights unfold,
And chill winds cut a deeper cold –
The sky's dark canvas, clear, sublime
Lights soft with stars as old as time.

Then softly stirs a spectral gleam
In symphony of red and green.
The pulsing curtains' rhythmic glow
Cross starlit skies and earth below.

A sweep of stars speck tinted veils –
The Hunter shines through lucent sails…
Orion's belt and sword of stars,
Blaze clear within auroral bars.

The dark skies glow in silent show,
As colours ebb and pulse and flow;
The fleeting streamers span the night –
Unearthly sylphs in cloaks of light.

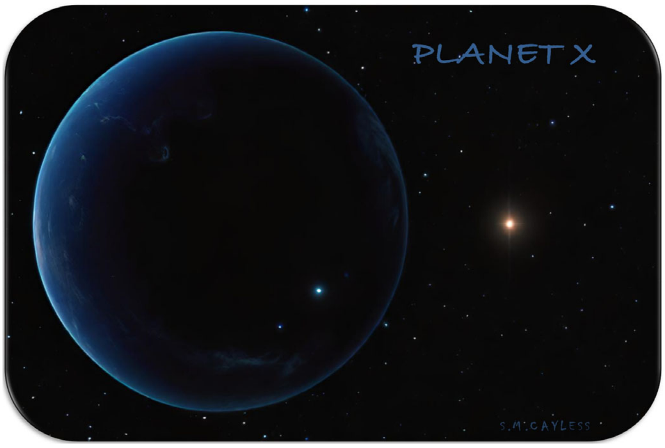
On cold September's midnight face
The dancers wash the skies with grace…
Auroral shades of rippling light
That send all lesser stars to flight…

Finding Pluto

By Sandi Cayless

In the 1920s, the search was underway to find 'Planet X', or the ninth planet that was expected to exist in the Solar System. The idea of Planet X was put forward by Percival Lowell (1855-1916), who was convinced of its existence because he (and others) argued that the orbit of Uranus was being affected by a planet beyond Neptune (NASA 2025). Percival Lowell came of a wealthy American family from Boston, and after graduation at Harvard in 1876, where he had excelled in mathematics and graduated *magnum cum laude*, he entered business in Boston and held various prestige positions (Agassiz 1917). Later he went travelling to the Far East, mostly Japan, but he was also appointed as foreign secretary to the Special Mission of Korea to the USA. He also wrote four well-received books on Oriental culture, but he had always been interested in Giovanni Schiaparelli's work on Mars. In the early 1890s the colour-blind Schiaparelli's eyesight failed (Sheehan 1997) and Lowell decided to take up the Italian astronomer's work where he had left off.

Lowell first searched for a site to build an observatory for this work, and as well as the USA he searched in France, Algiers, the Mexican Plateau and the Andes. He settled on Flagstaff, Arizona, on the edge of a high tableland, as the height would help observation. He founded Lowell Observatory in 1894, mainly for studying the planets, particularly Mars, but work also covered comet composition, the spectra and velocity of nebulae, and stellar photography – the rotations of Venus and Uranus were both established by the Doppler Effect there (Agassiz 1917). Lowell and his staff also carried out mathematical investigations over many years, and in his work *Memoir on a Trans-Neptunian Planet*, he analysed the disturbances on the outer planets of a mysterious Planet X using celestial mechanics, although he could never verify the results visually or photographically. His *Memoir on Saturn's Rings* investigated the probable internal constitution of Saturn, worked out from the relationship of the positions of the ring divisions to the Saturnian satellites. But it was for his work on Mars that Lowell was best known. By 1917 his accumulated data on Mars was said to be very much greater than the results of all the other observers combined, and as Agassiz (1917) says, his theory on Mars being inhabited might seem fanciful, but it *was* deduced by logical reasoning from observed facts. [Although Campbell (1896), in a review of Lowell's book on Mars, wrote that the observations covered only a quarter of a Martian year and Lowell ignored other evidence sources.] The Observatory was a productive source of scientific papers nevertheless, as well as Lowell's popular works on astronomical subjects.



Despite the attention surrounding his Mars work, Lowell continued to spend time in the search for Planet X and began an initial research programme that ran from 1905 to 1909 to do this (Schindler 2023). He employed a team of 'computers' under astronomer Elizabeth Williams to calculate regions where X might be (Tombaugh 1946, Schindler 2023). A 5-inch (13 cm) aperture camera (a Brashear) was used first to record thousands of star positions for comparisons, and about 250 plates were made of 3-hour exposures (by E.C. Slipher and K.P. Williams) along the plane of the solar system at every 5° of longitude. But despite hand-magnifier examination by Lowell of pairs of plates set one on top of the other, X was not found (because of its orbital eccentricity). The next set of plates was made using a 42-inch (110 cm) reflector but it had a small field of view and was not practical for the search, though a blink comparator was used to help (DeVorkin 2015).

Lowell accelerated his search in 1910 as his former associate Pickering of Harvard (who was now a rival in the search for Planet X) had published orbital and positional data for a hypothetical trans-Neptunian planet. This second phase of the Observatory programme ran from 1910 to Lowell's unexpected death in 1916 (Schindler 2023). The search *had* picked up in 1914 as Sproul Observatory had loaned Lowell a 9-inch (23 cm) telescope, and until 1916, many plates were made and checked using the blink comparator (Tombaugh 1946). In 1915, Percival Lowell published his *Memoir on a Trans-Neptunian Planet*, in which he had calculated that Planet X had a mass of 1/50,000 of the sun (i.e. x7 bigger than Earth) and was at an average 43 astronomical units

(AU) distance, with a high albedo and low density, comparable to the outer planets. Unfortunately, Lowell died suddenly at his Observatory on the 12th of November 1916. He was buried close by it (McKim 1995), and left his fortune to maintain it, but the search was interrupted for 13 years, as his widow Constance contested his will. It was thus left to others at the Observatory to find Planet X.

Pickering was still working on the task to find the mysterious planet, and irregularities in Neptune's movements had led him in 1919 to deduce that there was a planet in the same part of the sky as Neptune, and predicted it would be 15th magnitude. Four photographs of the patch of sky were taken using the 10-inch Mount Wilson telescope, but nothing was found. Later, at Lowell, preparations were being made to continue the search for Planet X with the purchase in 1925 of glass disks for a 13-inch photographic telescope (Tombaugh 1946). In 1927, A. Lawrence Lowell, Percival Lowell's younger brother and president of Harvard University, gave $10,000 to fund the construction of a 13-inch wide-field astrograph (the Lawrence Lowell telescope) and its dome, and Percival's nephew Roger Lowell Putnam, became the Observatory's sole trustee. One of Putnam's main tasks was to restart the search for Planet X and prove his uncle's predictions (Schindler 2023). The facility was completed in February 1929 and the third and final phase of the search for Planet X began again on 6th April 1929.

Meanwhile, in January 1929, a young amateur astronomer from a farming background and with no formal training had begun work as an assistant and groundskeeper at Flagstaff. Born in 1906, Clyde Tombaugh's family could not afford a college education for their son; he thus studied astronomy on his own, using a 2¼-inch telescope purchased jointly by his father and his amateur astronomer uncle, Lee (Tombaugh & Moore 1980). He taught himself to grind and test optics and then designed and built another two telescopes (also one for Uncle Lee). He used his 9-inch Newtonian reflector (built 1928) to observe and make drawings of Mars and Jupiter and sent these to several observatories for comment. Their detail impressed Vesto Slipher, then director of Lowell Observatory, so much that he hired him (Adams 2024). A few weeks later, the objective for the 13-inch astrograph arrived and was installed. Tombaugh (1946) noted that the 66-inch focal length and a plate scale of 30 mm per degree of the Lawrence Lowell telescope gave good images over the plate area (14 x 17 in) and covered a 12° x 14° area of sky. He also wrote that every plate was tested to make sure it was of the standard curvature needed for identical focussing, and every plate pair matched carefully to help in their scrutiny under the blink comparator ("laborious work at best"). To ensure accuracy, many factors had to be right: plates of similar age and sensitivity; the sky's transparency and light; equal exposure times; same guide star, steadiness of seeing and hour angle; careful guiding; and, consistent plate development. Avoiding moonlight was also a priority. A 7-inch refractor was used as the guide scope to make sure the guide star was in the centre of the plate, and an exposure time of one hour used. About 300,000 stars were caught on each plate.

Clyde W. Tombaugh at the door of the Pluto discovery telescope, Lowell Observatory, Ariz. Credit: Lowell Observatory Archives.

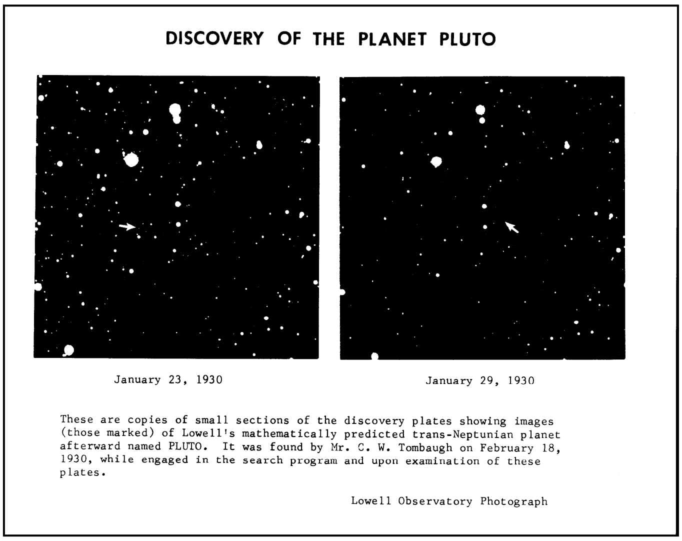
During the hour of exposure, Tombaugh kept the telescope centred on the relevant guide star so that star images were not distorted. He obtained a few photographs each evening, and developed them the next day. The tough and time-consuming part of the work was examining the star fields for points that moved over time. He used the blink comparator to compare the same star fields taken several days apart. The twin plates were aligned and blinked back and forth – non-stellar objects could be picked out as points of light that moved against the relatively fixed starfield. It took 10 months of repetitive work ("the long, hard, tedious task"), with various improvements built-in along the way (Tombaugh

1946). One was photographing each region near its opposition point (180° from the Sun) where apparent retrograde for a planet beyond Earth is maximum, making the planet's daily shift roughly inversely proportional to its distance; this meant that asteroids in the images shifted about 7 mm per day and showed short trails over an exposure of an hour, but Pluto moved only 0.5 mm per day. This was started in September 1929. The next great improvement was taking three plates inside a week of each area, although this increased the workload by 50%. A lot of planet-suspects were very faint and practically every plate had one or two – many turned out to be plate defects. With a third plate used to compare against the plate with the suspects, only a few passed the test, meaning that only a few regions had to be re-photographed. Tombaugh (1946) noted that it took three days to thoroughly examine a pair of plates. Three plates had been taken on January 21st, 23rd and 29th that centred on Delta Geminorum: Tombaugh would later begin to scan these with the blink comparator.

On the afternoon of 18th February 1930, Tombaugh spotted a point of light on the two plates taken on 23rd and 29th January that moved at the speed deduced for a trans-Neptunian planet. It was about 2 magnitudes brighter than the faintest stars. Examination by hand-lens confirmed the images, as did a check of the 21st January plates. The Director of the Observatory and other staff were told. The night of February 18th was cloudy but the 19th was clear: the Delta Geminorum region was re-photographed and within a minute, the movement of the new planet, now 3 weeks along on its path, was spotted where it should be. The 24-inch refractor and later the 42-inch reflector were then used to verify, and the rate of motion was confirmed as expected.

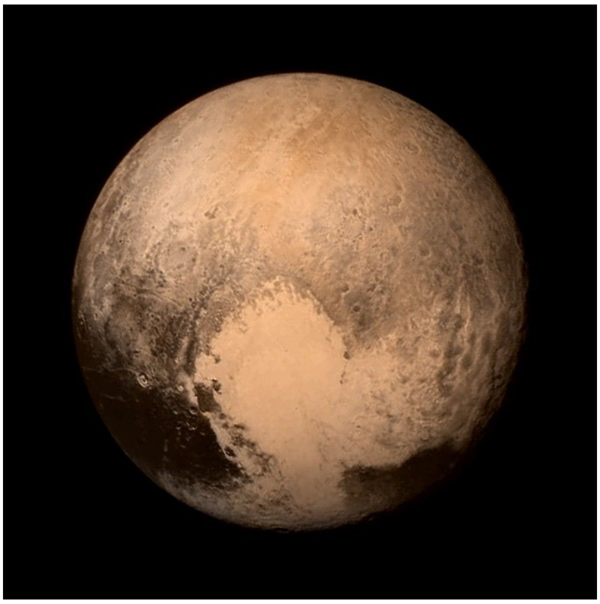
The news was telegraphed to the Harvard College Observatory on 13th March 1930, from where the new planet was revealed publicly. That day would have been Percival Lowell's 75th birthday. The next day The New York Times ran the headline: *Ninth Planet Discovered on Edge of Solar System: First Found in 84 Years* (Adams 2024). However, Pluto was too small to be Planet X.

The credit of naming the new planet went to an 11-year old Oxford girl, Venetia Burney. On hearing the news, she suggested 'Pluto', the Roman god of the underworld, to her grandfather. He told an Oxford astronomer, who sent a telegram with the proposal to Lowell Observatory on 16th March. Several names had been put forward, but Pluto was chosen as appropriate for the new planet on 1st May 1930. The first two letters of Pluto are also the initials of Percival Lowell, and a planetary symbol was created to represent the letters PL. It was later replaced by another but neither are used routinely in astronomy.



Copies of the glass plates used by Clyde Tombaugh when he discovered Pluto. Taken 6 days apart with the 13-inch telescope, the arrows show Pluto's movement across the sky over time. Credit: Lowell Observatory Archives.

Pluto continued to be a mystery until the New Horizons mission in 2015 took detailed images in its flypast of the planet. Clyde Tombaugh had died in 1997 and some of his ashes were carried aboard the New Horizons spacecraft on the road to and beyond Pluto (Stern 2006). The large heart-shaped region of the planet (see image below) was named Tombaugh Regio in his honour.


The first images of Pluto from New Horizons revealed the dwarf planet's icy heart. Credit: NASA/JPL - NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute.

Clyde Tombaugh's career continued at Lowell and elsewhere, and he made other important discoveries: the SU-Ursae Majoris cataclysmic variable *TV Corvi* (now known as *Tombaugh's Star*) and other variables; Comet 274P/Tombaugh-Tenagra (Levy 1999, 2015); many asteroids (see Table below); and, various star clusters, galaxy clusters and a galaxy supercluster (Academy of Achievement 2022). Other places named for him are: Tombaugh Crater, Mars (3.5°N 198.2°W); and, Tombaugh Cliffs (71°5'S 68°18'W), ice-free cliffs at the north side of the mouth of Pluto Glacier on Alexander Island in Antarctica. However, Clyde W. Tombaugh will always be remembered as the astronomer who found Pluto.

Minor planets discovered by Tombaugh

Designation	Discovery
2839 Annette	October 5, 1929
2941 Alden	December 24, 1930
3310 Patsy	October 9, 1931
3583 Burdett	October 5, 1929
3754 Kathleen	March 16, 1931
3775 Ellenbeth	October 6, 1931
3824 Brendalee	October 5, 1929
4510 Shawna	December 13, 1930
4755 Nicky	October 6, 1931
5701 Baltuck	November 3, 1929
6618 Jimsimons	September 16, 1936
7101 Haritina	October 17, 1930
7150 McKellar	October 11, 1929
(8778) 1931 TD3	October 10, 1931
134340 Pluto	January 23, 1930

Data: Minor Planet Centre

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Image Credits

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Image of Clyde Tombaugh: Clyde W. Tombaugh at the door of the Pluto discovery telescope, Lowell Observatory, Ariz. Credit: Lowell Observatory Archives. http://www.jhuapl.edu/newscenter/pressreleases/2006/images/ClydeTombaugh_lg.jpg

Pluto: The first images of Pluto sent back from New Horizons revealed the dwarf planet’s icy heart. Credit: NASA/JPL - NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute. https://solarsystem.nasa.gov/resources/855/color-pluto/.

Solar Cycle 25 has Passed its Peak

By Alan Cayless FRS

Last year (2024) was a good year for solar activity with several spectacular auroral displays, most memorably in May and October. There have also been large numbers of sunspots in the first part of this year, continuing over the summer.

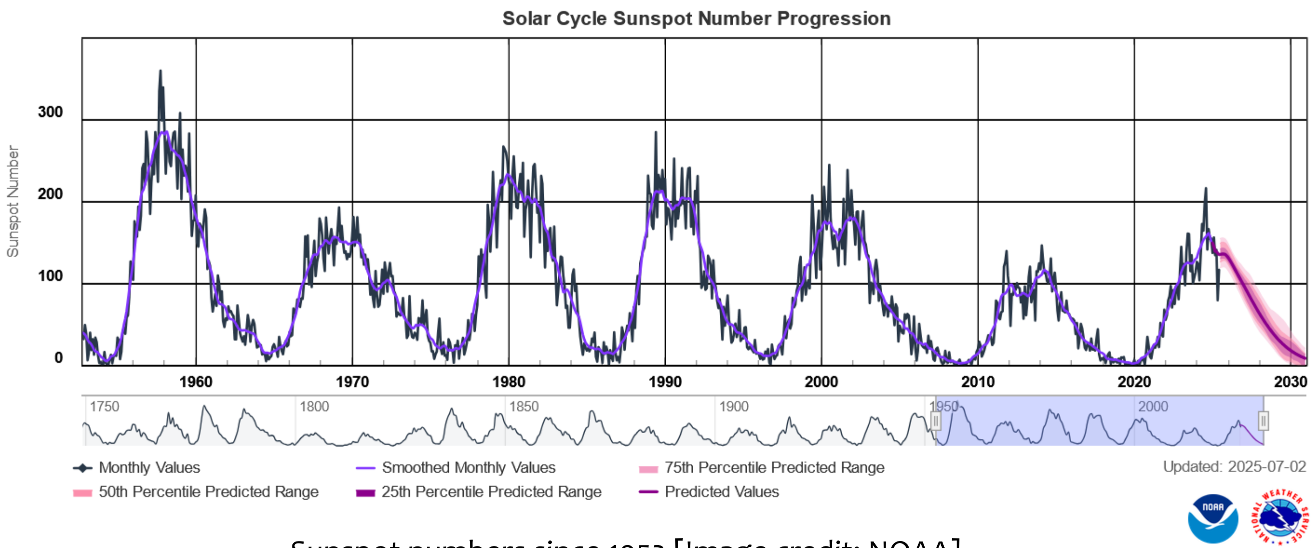
Both sunspots and aurorae are signs of solar activity. Sunspots are formed when the Sun’s magnetic field penetrates the surface of the Sun and the aurora is caused by charged particles from the solar wind entering the Earth’s atmosphere. Solar activity is usually tracked by monitoring the sunspot number and follows an 11-year cycle, which was first established in 1844 by German astronomer Heinrich Schwabe (Schwabe 1844). This 11-year cycle in overall activity is part of a longer 22-year cycle which also takes into account reversals of the Sun’s magnetic field.

The sunspot number itself is based on a calculation involving both numbers of spots and numbers of groups and is best thought of as an index, rather than a simple count of individual spots (Spaceweather.com 2025).

Sunspots tend to appear in bands spaced approximately equally above and below the equator. As each solar cycle progresses, these bands move closer to the equator. At the start of the next cycle, spots begin to appear again at higher latitudes. Recent images in the Society Gallery show this effect quite clearly.

While the Sun remains very active there are signs that the current solar cycle has now passed its peak, with sunspot numbers beginning to decline in 2025 (Space.com, 2025). The National Oceanic and Atmospheric Administration (NOAA) publishes regular updates and predictions of sunspot numbers and recent figures confirm that numbers have started to fall from their peak in late 2024.

This chart from NOAA summarises the last seven solar cycles. While the peak of just over 200 in the sunspot number is higher than the previous cycle (which peaked in early 2014), it is significantly lower than the three cycles before that (1980 – 2003) each of which reached the mid-200s. Cycle 19 was even higher, reaching a peak of well over 300 in 1957 (NOAA, 2025).



Sunspot numbers since 1952 [Image credit: NOAA]

Although we have now passed the maximum, solar activity will remain high until the end of the year so it will be worth keeping a look out for sunspots and aurorae this autumn. With any luck we will be treated to at least one more auroral display before the end of this cycle.

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Betelgeuse: A Stellar Companion

By Sandi Cayless

It has long been predicted that our closest M-supergiant neighbour, and the 10th brightest star in our night sky, Betelgeuse (α Ori A), has a companion star, and recent results by Howell et al. (2025) give the strongest evidence yet that this is the case. Changes in brightness and measured velocity had suggested a companion star, and recent analyses of over 100 years of Betelgeuse observations produced predictions of the star's location and brightness. These latest data and diffraction-limited optical speckle imaging, by means of the 8.1 m Gemini North telescope in Hawaii paired with a high-resolution imaging camera built by NASA, was used to potentially directly observe the companion star, despite atmospheric blurring. Howell's team detected signs of the faint companion at the predicted locus, orbiting very close to Betelgeuse's outer edge (NASA 2025).

The stellar disk of Betelgeuse was spatially resolved in both 2020 and 2024 observations, but the 2024 observations with the optical speckle imaging camera show the probable direct-imaging detection of Betelgeuse's companion star (α Ori B), as well as the properties of the star. They suggest it is around 6 magnitudes fainter at 466 nm than α Ori A, and is possibly a young, pre-main-sequence F dwarf. However, Howell *et al.* (2025) stress that their results cannot be claimed as definitive, as detection is at the limit of instrument capabilities, but they do show the most direct and substantive evidence for the existence of the stellar companion thus far. As Betelgeuse means *Hand of the Giant*, the *Elgeuse* being a historical Arabic name for Orion and a female name in Arabic legend, the authors have suggested that the orbiting α Ori B be named *Siwarha*, or *Her Bracelet*.

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The Colour of Betelgeuse

The red colour of Betelgeuse has been observed since ancient times; Ptolemy described it as hypókirrhos (orange-tawny), and other authors have referred to it as rich topaz, or as having ruddiness (Allen 1963). The 19th century astronomer-priest Angelo Secchi counted Betelgeuse as an example of his Class III (orange to red) stars, although Hyginus of Rome and Chinese astronomer Sima Qian two millennia ago saw the star as yellow 'like Saturn'. If true, this suggests that Betelgeuse was then in a yellow supergiant phase, which is possible, as historical study allied to recent research into the complex evolutionary track of such stars indicates a rapid colour evolution (Neuhäuser *et al.* 2022).

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ispace Resilience mission update

By Alan Cayless FRAS

Following the successful landing of the Blue Ghost mission in Mare Crisium earlier this year (Banks 2025), the ispace Resilience lander made its final approach to the Moon in June.

Both spacecraft had left Earth together in January, launched from Kennedy Space Center on a Falcon 9 rocket (Space.com 2025a). Once separated from the launch vehicle, the two missions took different routes to the Moon with the ispace mission, carrying the Resilience lander and Tenacious rover, following a longer, but more energy-efficient trajectory.

The ispace spacecraft entered lunar orbit on 28 May, orbiting 100 km above the lunar surface and circling the Moon every two hours. While in orbit, the spacecraft carried out pre-landing checks and sent back detailed pictures of the lunar surface below.

One of the last images received from Resilience while in orbit shows the Earth highlighted above the lunar surface [Image credit: ispace]

Resilience was intended to land in Mare Frigoris on 6 Jun 2025. Once on the surface, it would deploy the Tenacious micro-rover – a four-wheeled vehicle approximately the size of a microwave oven with a mass of just 5kg – to explore and sample the lunar surface. The main Resilience lander itself carried a number of scientific instruments aimed at measuring radiation, electrolysing water found on the Moon, and cultivating algae (Space.com 2025b).

On the day of the landing the first phase of the descent appeared to be going well, with the main engine firing successfully on schedule at an altitude of approximately 20 km. However contact with the spacecraft was lost as it approached the landing site and no signals were subsequently received from the surface. Later that day, ispace issued a notice confirming that the spacecraft had been lost (ispace 2025a).

Following analysis of telemetry received during the descent phase, ispace issued a Technical Cause Analysis on 24 June (ispace 2025b). This report identified a fault in the laser range finding system (LRF) as the most probable cause of the accident. Although descending correctly in a vertical attitude during the later stages of the approach, without accurate height information from the LRF the lander was not able to decelerate in time and most likely impacted the lunar surface in what the report describes as a "hard landing". The site of the impact has been imaged by NASA's Lunar Reconnaissance Orbiter with signs of debris in the image appearing to confirm that the craft was destroyed (NASA 2025).

In a concluding statement to the report Takeshi Hakamada, Founder and CEO of ispace, praised the efforts and dedication of the Resilience team and confirmed the company's commitment to reaching the Moon on future missions (ispace 2025b).

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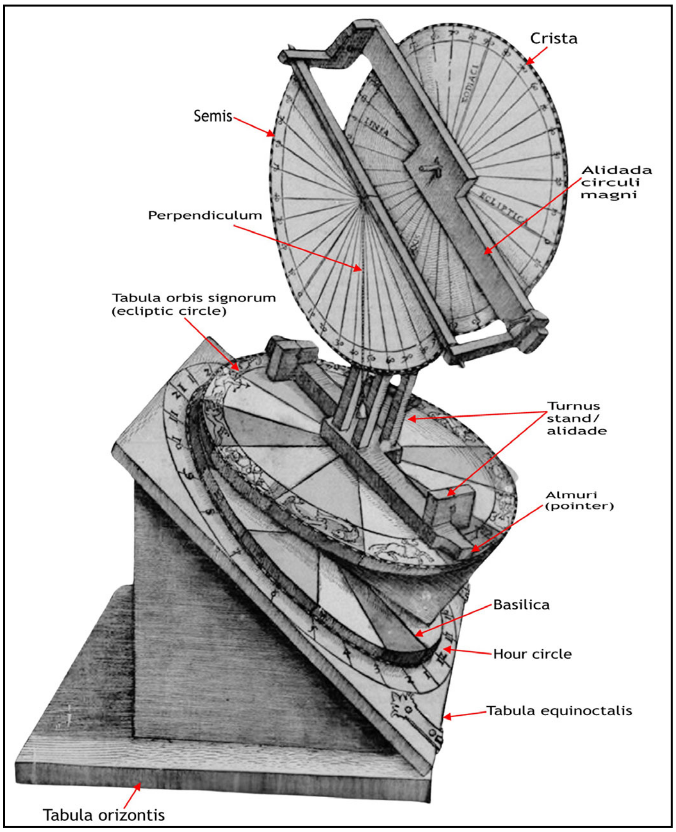
The Torquetum: an Ancient Astronomical Instrument

By Sandi Cayless

The torquetum (turketum or turquet) is generally believed to date to the medieval period. An astronomical instrument from about the late 13th century in Europe, it was used to measure in three sets of coordinates: horizontal (altazimuthal), equatorial and ecliptic (Dekker & Lippincott 1999; Paselk 2024). The origin of the instrument is unknown, although there was a claim by the 15th century astronomer Johannes Regiomontanus that it is earlier, Arabic, and associated with Jābir ibn Aflaḥ (known as Geber) of Seville, a 12th century astronomer. However, Arabic sources make no mention of this (Dekker & Lippincott 1999). Likewise, a few researchers believe it, or a precursor of it, may be much older (Hecht 1999; Rommel 1999; Sanders 2001), but this view is not widely accepted.

The complex construction of the torquetum *is* known, as there are extant descriptions, illustrations and artefacts, although its degree of utility is unknown according to Włodarczyk (2022), as the only significant existing set of observations made with one is a catalogue of 58 stars compiled in Kassel between 1560 and 1563. Opinion is divided amongst modern researchers on the uses of the torquetum, and as well as an observational device, it has been called an analogue computer because it provided a mechanical way to interconvert between altazimuthal, equatorial and ecliptic coordinates without using calculations, or a demonstration piece, as it could show the relationships between these sets of coordinates (Poulle 1964; Dekker & Lippincott 1999; Paselk 2024). According to Latin authors Franco de Polonia (of Poland) and Bernard de Verdun at the end of the 13th century, the torquetum *was* used to ascertain altitude- azimuth, and equatorial or ecliptic coordinates (Włodarczyk, 2022), and Dekker and Lippincott (1999) list several sources that support the use of the torquetum primarily for observational astronomy. The examples given include: Franco of Poland's advice for its use in finding star and planet positions to verify the Toledan tables (astronomical tables used to predict the motions of the Sun, Moon and planets relative to the fixed stars, completed ca. 1080 by Arabic astronomers at Toledo, Spain); John of Murs' 1318 defence of observational astronomy; Paolo Toscanelli's use for observing Halley's comet in 1456; Johannes Schōner's building of one for viewing Halley's comet in 1531; and, Peter Apian's possible use of a torquetum for observing the comets of 1531, 1532 and 1533. Early misunderstandings about the use of the torquetum may, however, be down to its evolution of design, for during the mid-16th century, several structural changes were made, the chief one by instrument-maker Erasmus Habermel, which enabled astronomers to make observations in all three of the scales (see Dekker & Lippincott 1999).

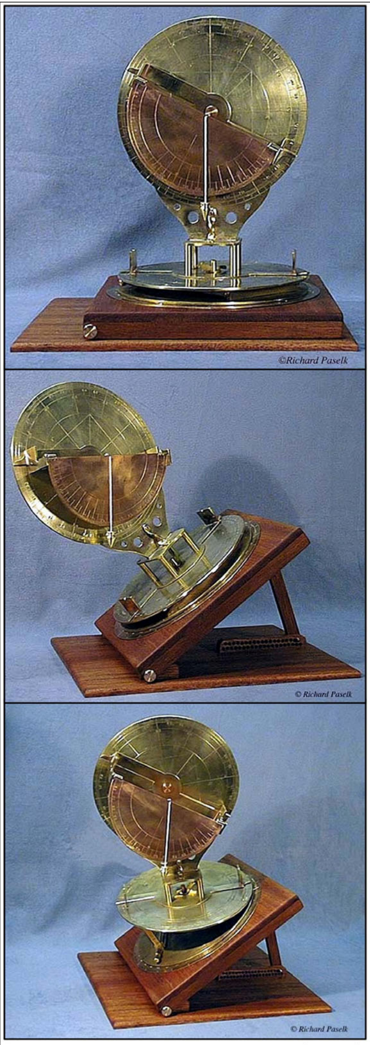
Parts of a Torquetum



A torquetum has several parts, listed below (Dekker & Lippincott 1999; Włodarczyk, 2022; Paselk 2024), where the various plates and circles represent the circles of the celestial sphere. The figure above is based on the 1540 engraving by Peter Apian (Petrus Apianus), from his book *Astronomicum Caesareum*.

The first part, a horizontal plate (*Tabula orizontis*), places the torquetum in the horizontal and meridional planes and represents the Earth's horizon relative to the point of measurement. Hinged to this, the *Tabula equinoctialis* (equatorial plate) is a plate representing the celestial equator and holds a circle graduated in hours. The triangular wedges supporting the tabula equinoctalis shown in the figure consist in other designs of a prop (*stilus*) that pins to a series of slotted holes on the tabula orizontis to allow tilting to the observer's latitude or, folded flat, to rest the tabula equinoctialis on top of the tabula orizontis. Attached above, the *Basilica* rotates on a pin representing the axis of the Earth. The *Tabula orbis signorum* (ecliptic circle) is a disc fixed to the basilica which may be locked at an angle of 23.5° to represent the plane of the ecliptic. It has a zodiacal calendar and degree scales inscribed. The *Almuri*, a pointer, connects to the basilica beneath the zero point of Capricorn. The *Turnus* rotates around the axis of the ecliptic circle and works as an *alidade* (a tool to view a distant object and use the line of sight to carry out a task).

The turnus is also the support for the *Crista*, a vertical disc divided into degrees. The crista corresponds to the meridians of the celestial sphere when the ecliptic circle is folded flat. Another alidade (the *Alidada circuli magni*), rotates over the crista to show latitudes with respect to the plane of the ecliptic. Suspended from this are the *Semis*, a semicircle divided into degrees (90-0-90) and at the centre, the *Perpendiculum*, a plumb-line and bob to fix the zenith. Note that both alidades have pinholes either end to aid sighting – the body for which the coordinates are needed is sighted through the pinholes.



Torquetum © Richard Paselk (2024)

Use of a torquetum

As the semis also has an hour-line diagram for unequal hours, it can operate like a quadrant, but as Nothaft (2023) points out, any astronomer who wanted to find celestial altitudes had a choice of simpler and cheaper instruments to do this. However, when all the tables of the torquetum are folded flat (top image by Paselk, 2024, of his self-made torquetum) the alidade on the crista gives the altitude, the plane of the horizon being zero and the zenith at 90°; when the basilica is rotated such that north is at zero degrees, the turnus gives the azimuth, measuring east 0° to 360° like a compass. In this configuration, Paselk (2024) likens it to an altazimuth theodolite (an instrument for measuring horizontal and vertical angles, and used in surveying since the 16th century). Rasing the tabula equinoctialis on the stilus to 90° of latitude (the co-latitude) and aligning its axis with the north pole (centre image) gives the positions of celestial objects in *right ascension* (RA, in hours, minutes, seconds), shown by the almuri (pointer) on the hour circle, and *declination* (degrees) on the crista. The zero for RA is defined as the vernal equinox, the zero for declination the equator, and the north pole is equal to 90°. As Paselk (2024) notes, the torquetum set up this way is similar to a modern telescope on an equatorial mount, where the alidada circuli magni replaces the telescope.

When the tabula orbis signorum (ecliptic circle) is raised and set to the obliquity of the ecliptic (i.e. the earth's tilt, the angle between the plane of the ecliptic (or plane of the earth's orbit) and the plane of the earth's equator) the instrument gives ecliptic coordinates, or celestial latitude and longitude, allowing calculation of the positions of celestial objects (this is the set-up in the annotated figure above). The celestial latitude of an object above (north of) the ecliptic is positive, while that of an object below is negative. The crista is divided 90-0-90 degrees on both sides of the vertical to make the measurement simple. Today, celestial longitude is measured in degrees east of the ecliptic from the vernal equinox. The ancients divided the ecliptic into the twelve signs of the zodiac, each 30°, with the vernal equinox defined as the first point of Aries (see Woolard 1942 for a history of celestial co-ordinate systems). Ecliptic coordinates are useful for planetary observations, since the planets and their satellites follow paths within a few degree of the ecliptic. However, the equatorial coordinate system is better suited to the fixed stars as it follows diurnal motion (Woolard 1942).

Włodarczyk (2022) outlines several practicalities given by early authors in using the instrument, especially its stability in the fully-raised mode. Franco de Polonia stressed that the tabula orizontis should sit on a base of levelled stone or wood that is marked with the local meridian line and be so fixed that it would not move. The connection between the horizontal and equatorial plates also needs to be stable and two metal wedges rather than a rod to connect the two is shown in examples of torqueta by Nicholas of Cusa and Peter Apian. The shaft connection between the tabula equinoctialis and the basilica should be such that the basilica should rotate "stubbornly" according to Franco. For simple observing, the torquetum should be set thus: (i) place the equatorial plate on the horizontal plate; (ii) fasten the zodiacal alidade on the equatorial plate and turn to point east-west; (iii) set the alidade of the crista along the ecliptic line of the crista. If the plumb-line divides the semis into halves, the horizontal and equatorial plates are horizontally parallel. To read off the coordinates of celestial objects, the ecliptic circle must be set to the actual ecliptic using a reference point (during the day, the Sun is the obvious choice) – point the ecliptic alidade to the sun, a ray of which should pass through the two pinholes on the alidade, with the alidade casting no shadow. This is not simple, as Włodarczyk (2022) points out that the joint equatorial and ecliptic plates, and the alidade, have to be turned simultaneously around two different axes. This author gives a full account of the problems, and the means to combat them.

History of the Torquetum

As noted above, the torquetum is mainly considered a medieval instrument, known to be used in the late 13th century and claimed to date back to the 12th, and with an origin largely unknown. With various descriptions, images and examples available, attempts have been made to clarify its age and use. From the evidence, Nothaft (2023) argues that the torquetum, familiar to astronomers in Paris before mid-1284, seems to have been initially designed to combine the observational functions of an instrument of Ptolemy's to measure celestial positions directly in ecliptic coordinates, allied to certain mathematical and horological uses of an astrolabe. Thorndike (1945a, b) ascribes the earliest treatise on the torquetum to Franco of Poland; it seems to date to 1284, and she notes its use by Peter of Limoges in observing the comet of 1299 (later known as Halley's comet). Also in the 13th century, an account of a torquetum appears in the writings of Bernard of Verdun, although the exact date is unclear (Poulle 1964). However, in the treatise entitled *Iṣlāḥ al-Majisṭi* (Correction of the [Ptolemy's] Almagest) by the 12th century mathematician and astronomer Jābir ibn Aflaḥ, an astronomical instrument is described that has been viewed as a precursor of the torquetum (Calvo 2007), and some attribute its invention to him (Lorch 1976). The best known description of the device is perhaps that of Peter Apian (Petrus Apianus), a German humanist, astronomer, mathematician, printer and map-maker (O'Connor & Robertson 2002), in his book *Astronomicum Caesareum* (1540), where he also explains its use for astronomical observations and its manufacturing process (Dekker & Lippincott 1999; Draxler and Lippitsch 2012). However, the most famous illustration of a torquetum is the one in the painting *The Ambassadors* by Hans Holbein the Younger (1497/8-1543), painted in 1533; the subjects were Jean de Dinteville, the French Ambassador to the court of Henry VIII of England, and Georges de Selve, Bishop of Lavaur, and the torquetum is depicted in meticulous detail on the far right of the table next to de Selve (Dekker & Lippincott 1999).

Włodarczyk (2022) provides a detailed account of written sources on the torquetum, including those of Franco de Polonia and Bernard de Verdun, and its various constructions, based on existing torqueta. The oldest of those still extant was made in Nuremberg and bought in 1444 by Nicholas of Cusa, and is preserved in the St. Nikolaus-Hospital in Bernkastel-Kues. The second, constructed in 1487 by Hans Dorn for Martin Bylica of Olkusz, is in the Jagiellonian University Museum Collegium Maius in Cracow. Neither are whole and both have rebuilt elements, but the latter has a sundial on the tabula orizontis set for 50° of latitude (i.e. Cracow) and an attached compass.

The image here is of a torquetum made in 1568 in Nuremberg by Bohemian German astronomer and mathematician Johannes Praetorius. It is held in the German National Museum in Nuremberg.

However, there is a claim that the torquetum, or a precursor of it, has been used since earlier times. There is evidence that the astronomical instruments of Eratosthenes, the Greek scholar and head of the great library at Alexandria, were used to guide ancient mariners at sea (Sanders 2001). Eratosthenes had already measured the Earth's circumference and calculated its axial tilt remarkably accurately, *and* created the first global projection of his known world using lines of latitude and longitude (thus aiding oceanic navigation) by the time (about 232 BCE) that a flotilla of six ships set out from Egypt under the captain, Rata, on a voyage to circumnavigate the globe (Hecht 1999). The group's navigator and astronomer, Maui, was a friend of Eratosthenes. Although no records show that the convoy returned to Egypt (probably being shipwrecked off Pitcairn Island, see LaRouche Jr. 1999), Maui and others left records of the journey in caves along the route, including drawings of instruments and star charts; some have been found in Sosorra, which is in McCluer Bay, Irian Jaya (west New Guinea), and others in a cave near Santiago in Chile, on Pitcairn Island and in Fiji (LaRouche Jr. 1999). One drawing in particular in the "Caves of the Navigators" in Sosorra discovered in 1937-8, with its associated rebus deciphered by epigrapher Barry Fell in the 1970s as a dialect of Ptolemaic Egyptian, portrayed an instrument that was said to function as a torquetum (Rommel 1999). Much of Fell's epigraphic work has been discredited (e.g. Feder, 1984) but from the depiction, the device, Maui's *Tanawa* ("calculator") was reconstructed by Rommel (1999) as a brass model. To test if navigator Maui could have determined his longitude using Eratosthenes' tables brought from Alexandria, and his Tanawa from his current location to read off ecliptic coordinates directly, Sanders (2001) and Cooper (2001) showed in principle that a simple wooden torquetum could measure angular differences of about 0.5 of a degree.

Although the torquetum as an astronomical device has long been superseded, its place in history as a piece of complex (and in some cases highly artistic) astronomical equipment must stand.

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Torquetum (1568), made by Johannes Praetorius in Nuremberg: German National Museum (Nuremberg, Germany, GNM WI 33). Author: Wolfgang Sauber. Licensed under Creative Commons, file licence: https://en.wikipedia.org/wiki/GNU_Free_Documentation_License. See also: https://zeiten-des-wandels.gnm.de/de/natur-und-mensch.

Poetic Licence

Brooke, Henry: Universal Beauty (1735)
One house, one world, one universe divine,
Where countless orbs through countless systems shine;
Systems, which view'd throughout the circuit wide,
Or lost, or scarce the pointed sight abide,
(Through space immense with diminution seen)
Yet boundless to those worlds that roll within;
Each world as boundless to its native race,
That range and wanton through its ample space,
Frequent, through fields, through clouds of fragrance stray,
Or skim the wat'ry or ethereal way.

Mallet, David: The Excursion: a Poem in Two Books (1728)
… this blue profundity of Heaven,
Unfathomable, endless of extent!
Where unknown suns to unknown systems rise,
Whose numbers who shall tell? stupendous host!
Sun beyond sun, and world to world unseen,
Measureless distance, unconceiv'd by thought!

Ramsay, Allan: An Ode to the Memory of Sir Isaac Newton (1727)
The God-like man now mounts the sky,
Exploring all yon radiant spheres;
And with one view can more descry,
Than here below in eighty years.
Tho' none, with greater strength of soul,
Could rise to more divine a height,
Or range the orbs from pole to pole,
And more improve the humane sight.
Now with full joy he can survey
These worlds, and ev'ry shining blaze,
That countless in the Milky Way
Only through glasses shew their rays.

Thomson, James: The Seasons (1730)
. . . amid the radiant orbs,
That more than deck, that animate the sky,
The life-infusing suns of other worlds,
Lo! from the dread immensity of space
Returning, with accelerated course,
The rushing Comet to the Sun descends;
And as he sinks below the shading earth,
With awful train projected o'er the heavens,
The guilty nations tremble…

Prior, Matthew: Solomon on the Vanity of the World, a Poem in Three Books (1718)
And of those stars, which our imperfect eye
Has doom'd, and fix'd to one eternal sky,
Each by a native stock of honour great,
May dart strong influence, and diffuse kind heat,
Itself a sun; and with transmissive light
Enliven worlds deny'd to human sight.

And in that space, which we call air and sky,
Myriads of earths, and moons, and suns may lye
Unmeasur'd, and unknown by human eye.

Williams, Sarah: The Old Astronomer to his Pupil (1868)
Reach me down my Tycho Brahe, I would know him when we meet,
When I share my later science, sitting humbly at his feet;
He may know the law of all things, yet be ignorant of how
We are working to completion, working on from then to now.

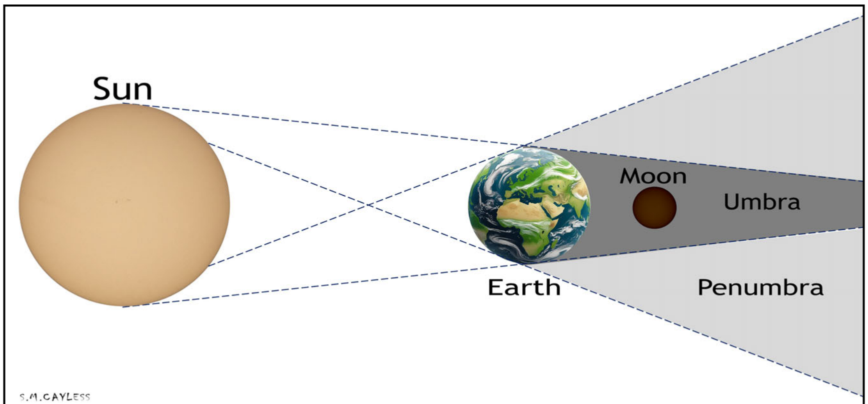
Galaxy NGC 3628, known as the *Hamburger Galaxy*, is nicknamed *Sarah's Galaxy* in tribute to Williams. It is an unbarred spiral about 35 million light years away in Leo and was discovered in 1784 by William Herschel.

Armstrong, John: The Art of Preserving Health (1744)
And all the worlds that roll around the Sun,
The Sun himself, shall die, and ancient Night
Again involve the desolate abyss:
'Till the Great Father thro' the lifeless gloom
Extend his arm to light another world,
And bid new planets roll by other laws.
For through the regions of unbounded space,
Where unconfin'd Omnipotence has room,
Being, in various systems, fluctuates still
Between creation and abhorr'd decay:
It ever did, perhaps and ever will.
New worlds are still emerging from the deep;
The old descending, in their turns to rise.

Happy Observing!

The first of September sees the peak of the Aurigid meteor shower (active 28 Aug-5 Sep), with about 6 meteors per hour (and a waxing gibbous moon). In Stirling, around 04:00 BST is the best time to view, although as the radiant point (in Auriga) is circumpolar, the shower will be active throughout the night. The parent body of the Aurigids is comet C/1911 N1 (Kiess). On 6 September at 06:17 BST Uranus enters retrograde motion and turns west. Visible from Stirling in the dawn sky, it rises at 21:51 to reach 51° above the SE horizon before fading as dawn breaks. Uranus reaches its highest point four minutes earlier each night, to become visible in evening and pre-dawn skies as it nears opposition on November 21.

September 7 brings a total lunar eclipse, with the Moon passing through the Earth's shadow between 17:27 - 20:56 BST [see diagram: not to scale!]. The event will be hard to see from Stirling, as moonrise occurs part of the way through. Local time, the total eclipse will last from 18:31 until 19:53, with the Moon partially eclipsed between 17:27 and 20:56. The Moon will seem red during the eclipse as the light illuminating it has passed through our atmosphere and been refracted back towards it.



The Geometry of a lunar eclipse: within the umbra, the Earth covers the whole of the Sun's disc (as far as the Moon is concerned). Within the penumbral shadow, the Earth covers a part of the Sun's disc. Areas of the Moon's surface that pass through the penumbra look to be darker than usual, as the Earth is blocking some of the sunlight that would normally illuminate them. Areas within the umbra receive no sunlight at all.

The Moon, Saturn and Neptune are close together on 8 September and visible in the morning sky. The trio will climb to 11° above the eastern horizon at 21:45, reaching their highest point at 02:07, 31° above the southern horizon. The epsilon (ε)-Perseid meteor shower (active 5-21 Sep) peaks on September 9, with perhaps 4 meteors per hour, although the Moon will be only 3 days past full… The radiant in Perseus is circumpolar from Stirling, so the shower will be active through the night. The radiant is highest shortly before dawn; the best viewing times will thus be before dawn and after twilight on 9 September. The ε-Perseids come from an unknown parent body in the Oort cloud. On 12 September, the Moon and M45 come close (58.4 arcminutes apart) in Taurus, and on the 16th, there is a Moon-Jupiter conjunction in Gemini. On the 19th, a Moon-Venus conjunction leads to a lunar occultation of Venus. Viewed from Stirling, the planet will disappear behind the Moon at 12:42, to reappear at 14:02 BST. Although daylight, it should be visible. [N.B. Use *extreme* caution if using binoculars or a telescope to view *any* astronomical object when the Sun is above the horizon!] Planet Saturn reaches opposition on September 21 and will be a bright object in Pisces. A good opportunity for our astrophotographers, from Stirling it will be visible between 20:53 - 05:31, with its highest point at 01:12, 30° above the southern horizon. If any members are out New Zealand way, they may be lucky enough to see the partial solar eclipse of September 21, alas not visible from home.

September 22 heralds the Autumnal equinox (19:20 BST), the first day of autumn and the Harvest Moon (in the northern hemisphere – those of our friends under southern skies will see the first day of spring) and everywhere on Earth will have almost exactly 12 hours of day and night. Neptune reaches opposition on the 23rd, and can be seen locally between 22:08 and 04:13. If you spot an odd meteor between 05:00 - 06:30 about September 27, it may be a Daytime Sextantid (shower active 9 Sep-9 Oct), although at a rate of 1 meteor per hour, they are difficult to spot.

On 2 October, Venus is at perihelion and visible from 04:53 BST from Stirling, fading around 06:55, whereas asteroid 1 Ceres is at opposition in Cetus and visible to the south through a telescope between 00:18 and 02:41 as a point of light. This is also a good date to view M31 (the Andromeda Galaxy) as it reaches its highest point about midnight local time. The Camelopardalid meteor shower is active 5-6 October, producing its peak rate of meteors (variable) around midnight. The radiant is in Draco, but as the Moon is close to full, it will interfere with viewing. The Moon and Saturn are in conjunction on

6 October and will be visible between 19:53 - 04:24, the day before the Full Moon (see *The Jeety Starn* issue 5 for an article on the naming of Full Moons). As the Moon is close to perigee, it will appear slightly larger than usual.

In October we are well into meteor season and the 8th brings the peak of the Draconid shower (active 6-10 October). Look soon after dusk to see short, bright trails, but as the Moon is 3 days past full, there will be interference. However, 2 days later on October 10, the Southern Taurids (active 10 Sep-20 Nov, radiant in Cetus) will be at a peak rate of about

5 meteors/hr. From Stirling, the best display should occur around 02:00 BST. The parent of the Southern Taurids is comet 2P/Encke. The δ-Aurigids (active 10-18 Oct) peak on 11th and will be best seen around 06:00 BST, though only 1 meteor/hr is expected.

The Moon and Jupiter are in conjunction on October 13 at 23:30, in Gemini. For our astrophotographers, M33 (the Triangulum Galaxy) reaches its highest point on 15 October at around midnight local time. Although faint (mag 5.8), it can be seen in a small telescope. Dwarf Planet 136199 Eris reaches opposition on 18 October (and is at perigee), and will be visible from Stirling (telescope needed!) between 22:08 and 04:24 in Cetus, rising to an altitude of 33° in the south-east at 01:16. This date coincides with the peak of the ε-Geminid meteor shower (active 14-27 Oct). The best displays of about 2 meteors/hr will be seen at around 06:00 BST. This is followed on the 19th by a conjunction of the Moon and Venus, in Virgo. The pair rise at 05:55.

One of the spectacles of October, the Orionid meteor shower (active 2 Oct-7 Nov), peaks around 21 October, with a maximum rate of about 11 meteors/ hr. Start observing from 22:00 local time, for with a New Moon at the peak, visibility should be good; the best displays will be later, around 06:00, when the radiant point is highest. Orionids tend to be fast, with lasting trails, and their parent body is comet 1P/Halley. On or around 24 October, the Leonis Minorid meteor shower (active 19-27 Oct) peaks – look to Leo Minor shortly before dawn, though only 1 meteor/hr is anticipated. The parent body of the Leonis Minorids is comet C/1739 K1. The Perseus Double Cluster (NGC 869 and NGC 884, aka Caldwell 14) is well placed for viewing, and reaches its highest point on 26 October at close to midnight. A striking duo of open star clusters in Perseus, it makes a great object for astrophotography.

November begins with a conjunction of the 12-day old Moon and Saturn on the second. Visible from 17:22 in the south-east, they reach their highest point at 21:13. The Moon is in Pisces and Saturn in next-door Aquarius. The New Moon of 5 November is the first of the two Supermoons of 2025. This Beaver Moon will be visible most of the night, rising at dusk and setting at dawn. The following day, the Moon and M45 pass within 49.0 arcminutes of each other, reaching their highest point at 01:00. A few days later, on 10 November, the Moon is in conjunction with Jupiter, in Gemini. This occurs just before Jupiter enters retrograde motion, on 11 November.

For asteroid spotters, 471 Papagena is at opposition on November 11 and well placed in Cetus for viewing using a medium-aperture telescope; it reaches its highest point around midnight. The Northern Taurid meteor shower (active 20 Oct-10 Dec), is at its peak around 12 November. Look before dawn or after dusk for about 4 meteors/hr. The parent body creating the Northern Taurids is asteroid 2004 TG10.

One week later, on 17 November, we have the peak of the Leonid meteor shower (active 6-30 November). Start looking after 22:00, although the best show of about 12 meteors/hr will be closer to dawn. As the shower peaks close to New Moon, the sky should be relatively dark. The parent body of the Leonids is comet 55P/Tempel-Tuttle.

November 17 also brings the best placing of possibly the most familiar asterism of the winter sky, the Pleiades, or Seven Sisters. This open star cluster in Taurus is easily visible to the naked eye, and with over one thousand stars, it makes a spectacular object in a telescope. Hawk-eyed stargazers may be able to spot more than the 6 normally visible jewels in the cluster with unaided eyes, but even a small pair of binoculars will show many more of the individual stars.

Uranus at opposition on 21 November will be visible between 18:37 and 05:26. This is also the peak of the α-Monocerotid meteor shower (active 15-25 Nov). The radiant point in Canis Minor rises above the eastern horizon just before 22:00. With a variable hourly rate, the best time to view will be around 04:00 GMT. The parent body of the α-Monocerotids is comet C/1917 F1 Mellish. On 28 November, Saturn ends retrograde motion, and the November Orionid meteor shower (active 13 Nov-6 Dec) reaches its peak rate (2 meteors/ hr) at about 02:00 GMT. The November Orionids have no known parent body. The month ends with a Moon-Saturn conjunction on the 29th. Visible in the early evening sky, the duo reach their highest point at 19:24 and will be observable until 23:31.

Happy observing all!

Many thanks to all our contributors to this quarter's issue of *The Jeety Starn*. Members, please hand submissions to the editor, or any contributions can be sent via the Society's contact email address. Illustrations and snippets also welcome!

S.C.

The Jeety Starn

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