JANUS
THE NEWSLETTER OF EWELL ASTRONOMICAL SOCIETY

September 2025

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Important Reminder:

To allow sufficient time to compile Janus and place it on the EAS Website by the 1st of the month any submissions for publication are required at least 3 days before the end of the month. Any items received after this date will be held over until the following month.

Editorial

Welcome to the September edition of Janus. With August now gone, we enter meteorological Autumn and embark on a "New Year" for the Society. The first event to look forward to is our annual picnic on Saturday 6 September, starting at 5pm at Headley Heath. Provided the hoped for fine weather materialises, with good viewing conditions, it could go on until 11pm! Our first lecture of the new season will be on Friday 12 September when Dr Steven Banham from Imperial College London will talk about the NASA Curiosity rover mission. There will also be the usual presentation on the sky at night for the coming month.

Amongst his collection of observations and thoughts Gary Walker highlights the tendency of the media – as he sees it - to overemphasise the significance/rarity of events such as a "Blue Moon" or a "Black Moon". The second of these is, perhaps, less talked about than the first, although they occur with equal frequency – typically once every two or three years, perhaps not sufficiently infrequent to be deemed "Rare". Although Blue Moons normally occur about every two or three years, it's possible to have two in the same year. This occurs when a February with no full moon allows for a second full moon to fall within two other months (January and March). The last of these was in 2018 - and one was also a lunar eclipse! The next time we will get two blue moons in a year will be 2037. In case you're wondering, it's not possible to have more than one black moon in a year.

As to the idiom "once in a blue moon", this appears to have originated in the 16th century from the idea of a literal "blue moon" being impossible or absurd – like "when pigs fly". It evolved in the mid-19th century to mean "rarely" or "very seldom" after astronomical explanations or a physically blue in appearance moon following volcanic eruptions (Krakatoa 1883) or forest fires (Canada 1951) provided a real-world phenomenon that was indeed rare. Some people may be disappointed when an advertised ("regular") blue moon doesn't look like a rare (blue coloured) one, but does it really matter?!

John

In this edition:

The Solar System September

MERCURY: begins the month soon passing behind the Sun and will be difficult to see as it will reach its highest point in the sky during daytime and be no higher than 6° above the horizon at dawn. Visibility does not improve and by the end of the month, having recently passed behind the Sun at superior solar conjunction, it is not observable, reaching its highest point in the sky during daytime and being 1° below the horizon at dusk.

VENUS: remains just about visible as a morning object, now well past greatest elongation W and returning closer to the Sun. It begins the month visible in the dawn sky, rising at 03:12 BST – 2 hours and 58 minutes before the Sun – and reaching an altitude of 22° above the E horizon before fading from view as dawn breaks at around 05:49. By the end of the month, still visible in the dawn sky, it will rise at 04:35 BST – 2 hours and 22 minutes before the Sun – and reach an altitude of 18° above the E horizon before fading from view as dawn breaks at around 06:36.

MARS: will soon pass behind the Sun at solar conjunction. Throughout the month, it will not be observable – it will reach its highest point in the sky during daytime and be below the horizon at dusk.

JUPITER: recently passed behind the Sun at solar conjunction and begins the month visible in the dawn sky, rising at 01:25 BST and reaching an altitude of 38° above the E horizon before fading from view as dawn breaks at around 05:49. By the end of the month, emerging from behind the Sun, it is visible in the dawn sky, rising at 23:54 BST and reaching an altitude of 56° above the SE horizon before fading from view as dawn breaks at around 06:36.

SATURN: begins the month approaching opposition, and is visible in the morning sky, becoming accessible around 21:46, when it reaches an altitude of 11° above the E horizon. Reaching its highest point in the sky at 02:21, 36° above the S horizon, it will be lost to dawn twilight around 05:27, 23° above the SW horizon. By the end of the month, having recently passed opposition, it becomes accessible at around 19:50, when it rises to an altitude of 11° above the E horizon. Reaching its highest point in the sky at 00:19, 35° above the S horizon, it will become inaccessible at around 04:49 when it sinks below 11° above the W horizon.

URANUS: is currently emerging from behind the Sun. It begins the month visible in the dawn sky, rising at 22:20 BST and reaching an altitude of 54° above the SE horizon before fading from view as dawn breaks at around 04:45. By the end of the month, visible in the morning sky, it becomes accessible around 22:56 when it reaches an altitude of 21° above the E horizon. Reaching its highest point in the sky at 04:19, 58° above the S horizon, it will be lost to dawn twilight around 05:38, 55° above the SW horizon.

NEPTUNE: is currently approaching opposition. Visible as a morning object in the morning sky, it begins the month accessible around 22:57, when it reaches an altitude of 21° above the SE horizon. It will then reach its highest point in the sky at 02:24, 37° above the S horizon, and will be lost to dawn twilight around 04:45, 29° above the SW horizon. By the end of the month, now past opposition, it will become accessible at around 21:02, when it rises to an altitude of 21° above the SE horizon. Reaching its highest point in the sky at 00:27, 37° above the S horizon, it will become inaccessible at around 03:53 when sinks below 21° above the SW horizon.

Notable Events:

Some observations will require a telescope, others will be visible with the naked eye. More information at: *https://in-the-sky.org*

September

1 Aurigid meteor shower 2025
Close approach of Venus and M44

5 The Moon at aphelion

6 Uranus enters retrograde motion

7 Full Moon
Total lunar eclipse

8 Close approach of the Moon, Saturn and Neptune
Conjunction of Moon and Saturn

9 September ε-Perseid meteor shower 2025

10 The Moon at perigee

12 Close approach of Moon and M45

13 Mercury at superior solar conjunction

14 Moon at Last Quarter
Lunar occultation of Beta Tauri

16 Conjunction of Moon and Jupiter
Close approach of the Moon and Jupiter

19 Conjunction of the Moon and Venus
Close approach of the Moon and Venus
Lunar occultation of Venus

21 Saturn at opposition
Partial solar eclipse
New Moon

22 September equinox

23 Neptune at opposition

24 Conjunction of the Moon and Mars
The Moon at perihelion
NGC 55 is well placed

26 The Moon at apogee

27 Daytime Sextantid meteor shower 2025
Lunar occultation of Antares
47 Tuc is well placed

30 Moon at First Quarter

October

2 Venus at perihelion
1 Ceres at opposition
Andromeda Galaxy is well placed

3 NGC 253 is well placed

4 136472 Makemake at solar conjunction
The Moon at aphelion
Small Magellanic Cloud is well placed

5 October Camelopardalid meteor shower 2025
NGC 300 is well placed

6 Close approach of the Moon and Saturn
Conjunction of the Moon and Saturn

7 Full Moon
NGC 362 is well placed

8 The Moon at perigee
Draconid meteor shower 2025

10 Close approach of the Moon and M45
Southern Taurid meteor shower 2025
Mercury at aphelion

11 δ-Aurigid meteor shower 2025
Lunar occultation of Beta Tauri

14 Close approach of Moon and Jupiter

15 The Triangulum Galaxy is well placed

18 136199 Eris at opposition
ε-Geminid meteor shower 2025

19 Conjunction of the Moon and Venus

21 Conjunction of Mercury and Mars
Orionid meteor shower 2025
New Moon

23 Conjunction of the Moon and Mars
Conjunction of Moon and Mercury

24 The Moon at apogee
The Moon at perihelion
Leonis Minorid meteor shower 2025

25 Lunar occultation of Antares
136108 Haumea at solar conjunction

26 The Perseus Double Cluster is well placed

29 Comet 3I/ATLAS passes perihelion
Moon at First Quarter
Mercury at greatest elongation east

Collected Observations (and thoughts) – Gary Walker

The coming Autumn Sky – Posted 6 August

You can always tell that Autumn is approaching when the Pleides start appearing in the Sky. In addition, for some time, M31 has also been visible (in binoculars). This is at the end of the late evening sky, and after Midnight!

Of course, The "Summer Triangle ", as the late Sir Patrick Moore named it, is easily visible, high up in the sky, with Vega and Deneb virtually overhead, and Altair somewhat lower down in the South. They do, indeed, form a triangle!

Like last Summer, there is currently a lack of Planets in the sky. Mars is still (technically) visible, but so low down as to be lost in the sunset glow. Saturn, however, is now rising at a reasonable time, and is visible in the late evening.

I have not managed to see any more Notilucent Clouds since about June.

The Planetary Parade (Again) – Posted 9 August

Once again, I am seeing posts online from newspapers, etc about the "Planetary Parade", appearing this month in the morning sky!

Six planets are (theoretically) visible, before dawn, including Saturn (now actually visible in the late evening), Jupiter and Venus, (which do form a close conjunction in mid-August), Uranus, Neptune, and Mercury.

As is often the case, this event is overhyped by the media with, for example, the Bournemouth Echo, showing a totally unrealistic diagram of the planets all squashed up next to each other. The planets may be shown at their correct sizes, but they won't be visible anything like that. Some people who don't know much about Astronomy could therefore be disappointed!

Like the previous "Planetary Parade" earlier this year, only the bright planets will be obvious to the naked eye - i.e. Venus, Jupiter, and Saturn - whilst Uranus and Neptune need a telescope in order to be seen. Mercury is also visible, but very low down and elusive.

If the weather is clear, I will be looking out for the Venus - Jupiter Conjunction. Being as these two planets are the brightest, they appear spectacular at a close conjunction, even with the naked eye.

Venus – Jupiter Conjunction – Posted 10-12 August

I saw the Venus - Jupiter Conjunction in the early morning of 10 August at about 3.50am. They were about 2.5 degrees apart and made a spectacular sight with both the naked eye and binoculars!

Venus is, of course, always brighter than Jupiter, which made Jupiter look a bit insignificant in comparison. The night was completely clear, cloudless, and dead calm, with a Full Moon low in the South, all night. I noticed, however, that it was significantly higher in the sky than the last two Full Moons.

Early the following morning, the two planets were about 1 degree apart. They appeared in a N-S straight line, and resembled a pair of car headlights!

I could not quite fit them into the same field of view, at 62X, but it wasn't far off. Venus was now at gibbous phase, but due to its bright glare in a dark sky, the phase wasn't that easy to see.

Being as they are the brightest of the planets, Venus and Jupiter make the best of planetary conjunctions.

Like the previous night, the sky was perfectly clear and cloudless, with a bright waning gibbous Moon in the South.

Of course, Murphy's Law states that the closest night of any Conjunction is ALWAYS going to be cloudy, whereas the two nights either side of it, ARE clear!

It seemed as if this would be the case on the morning of 12 August, when Venus and Jupiter would be at their closest. This was because a weak weather front moved in during the previous evening, with cloudy skies, (although the Moon was intermittently visible via small breaks in the cloud). To add to the fun, there were intermittent brief rain showers throughout the night! It was, however, very warm and humid, so very pleasant to be out.

The situation was still the same when Venus and Jupiter arose that morning, although, later, Venus and Jupiter started to appear. Annoyingly, they only appeared momentarily, and, to make matters worse, one would appear, but the other would still be hidden by cloud, so it was very difficult to assess their degree of separation! In addition, they disappeared again into the cloud for long periods of time.

The sky started to clear from the SW, but as the planets were in the NE part of the sky, they were in the worst possible place, as the breaks took for ever to get to them! This wasn't helped by the fact that the clouds were moving extremely slowly; altogether, it was really frustrating, waiting, and hoping that I would be able to see Venus and Jupiter, properly. The Dawn was also approaching, but eventually the planets were finally clear of the clouds!

I found that with a magnification of 62X I still couldn’t quite fit them into the same field of view in my telescope, indicating they were now just over half a degree apart. In this case, the best views were with the naked eye, and with binoculars.

Planetary Conjunctions are of no scientific value but, like this one, they can be spectacular to see - and, for once, the weather has cooperated!

I saw a lot of social media posts advertising this event, and the Perseid meteor shower. Sadly, many of them are headed up by a totally unrealistic image, which vastly exaggerates what can be seen. In the case of the Perseid meteor shower, the title images make it look as if it will appear just like a fireworks display. On seeing the real thing, newcomers to Astronomy could well be disappointed!

Herstmonceux Observatory Saved – Posted 18 August

It has just been announced by Bader College and Science Projects, that they have given Herstmonceux Observatory Science Centre the go-ahead for the Observatory to continue operating on a 10-year agreement on this site!

This is welcome news as anxiety over the future of the Herstmonceux Observatory has been dragging on for over a year now.

Some members of our Society will remember visiting the observatory 7 years ago in August 2018. It has been threatened with closure ever since the Science and Engineering Research Council officially closed it in 1989, and moved most of the staff to Cambridge, in a typical cost cutting exercise. Even the Cambridge site was expected to be closed later on although, fortunately, the site was saved for astronomy.

Unfortunately, although the September issue of Astronomy Now magazine carried an article on the Herstmonceux Observatory, the good news of another 10 years on the lease, arrived too late to make it in this issue. Of course, what we really need is a longer, long term lease, for the future security of this Observatory.

Astronomy Now magazine changes Editor – Posted 23 August

As of September 2025, the wonderful Astronomy Now magazine has changed editors from Keith Cooper, under the Pole Star Publication, with Steven Young, to Stuart Clark, under his own Nebula Press.

Thus, we will likely see some changes seen in the magazine.

Since its launch in 1987, the magazine has gone from strength to strength, and it has to be the best British Astronomical magazine, available! Sir Patrick Moore was heavily involved in its early days, but the magazine nearly went bust in late 1994, before being saved by being taken in by the Pole Star Publications.

Coincidentally, the Sky at Night magazine also celebrates its 20th anniversary this year, being first published in June 2005, at the instigation of Sir Patrick Moore. It too is still going strong!

Unfortunately, I had to stop getting the Irish Astronomer magazine, as it proved impossible to get reliably – either editions never arrived, or were very late! They, too, were really useful, as they described astronomical events from our part of the World, unlike American magazines such as Astronomy, and Sky and Telescope, which are not quite so useful for us in the UK.

The "Black Moon" and other "coloured" Moons – Posted 23 August

There have been a number of posts on social media about a "Rare Black Moon", today, with some even claiming that the sky will go dark!

A Black Moon is not an official astronomical term, but a popular name for the second New Moon in a calendar month or, less commonly, the third New Moon in a season (i.e. Spring, Summer, Autumn, or Winter) with 4 New Moons.

Unfortunately, social media or, even worse, the main news, can get excited about various Full Moons, most notoriously the so called "SuperMoons". Historically, each Full Moon bears a name originally given to it by Native Americans, the majority of which are, perhaps, of little relevance to the rest of the World, although, in the UK, the autumn Full Moons DO have the commonly known names, of the Harvest Moon, and the Hunters Moon In June, it was the "Strawberry Moon", and some people expected it to be pink in colour, whilst others actually claimed that they saw it as a pink Moon. There are also "Blue Moons", which are analogous to Black Moons in that they are extra Full Moons in a certain month! The point is, however, none of these Moons are "special".

As for this month's "Black Moon", it is a particular "non-event" as,'being a New Moon, it wouldn't be visible to anyone! The only time that a New Moon IS visible to us, is during a solar eclipse, when the New Moon, covers part or all of the Sun.

The only time that a Moon is coloured, is because of a lunar Eclipse (and these are now, inevitably, known as "Blood Moons", every time one occurs). Either that, or the Moon is turned Blue, or Red/Orange, due to forest fires and smoke!

Whilst these social media posts may get people looking up at the night sky, it's important to recognise that, in many cases, they can be totally misleading, and are not real astronomy!

Quantum alternative to GPS navigation will be tested on US military spaceplane

Acknowledgement: This article was written by Samuel Lellouch, Assistant Professor in Digital Twinning, School of Physics and Astronomy, University of Birmingham and was first published in THE CONVERSATION on 14 August 2025. It is republished in full under a Creative Commons Licence. The original article, with additional links and images can be found here: https://theconversation.com/quantum-alternative-to-gps-navigation-will-be-tested-on-us-military-spaceplane-262967

A US military space-plane, the X-37B orbital test vehicle, is due to embark on its eighth flight into space on August 21, 2025. Much of what the X-37B does in space is secret. But it serves partly as a platform for cutting-edge experiments.

One of these experiments is a potential alternative to GPS that makes use of quantum science as a tool for navigation: a quantum inertial sensor.

Satellite-based systems like GPS are ubiquitous in our daily lives, from smartphone maps to aviation and logistics. But GPS isn't available everywhere. This technology could revolutionise how spacecraft, airplanes, ships and submarines navigate in environments where GPS is unavailable or compromised.

In space, especially beyond Earth's orbit, GPS signals become unreliable or simply vanish. The same applies underwater, where submarines cannot access GPS at all. And even on Earth, GPS signals can be jammed (blocked), spoofed (making a GPS receiver think it is in a different location) or disabled – for instance, during a conflict.

This makes navigation without GPS a critical challenge. In such scenarios, having navigation systems that function independently of any external signals becomes essential.

Traditional inertial navigation systems (INS), which use accelerometers and gyroscopes to measure a vehicle's acceleration and rotation, do provide independent navigation, as they can estimate position by tracking how the vehicle moves over time. Think of sitting in a car with your eyes closed: you can still feel turns, stops and accelerations, which your brain integrates to guess where you are over time.

Eventually though, without visual cues, small errors will accumulate and you will entirely lose your positioning. The same goes with classical inertial navigation systems: as small measurement errors accumulate, they gradually drift off course, and need corrections from GPS or other external signals.

Where quantum helps

If you think of quantum physics, what may come to your mind is a strange world where particles behave like waves and Schrödinger's cat is both dead and alive. These thought experiments genuinely describe how tiny particles like atoms behave.

At very low temperatures, atoms obey the rules of quantum mechanics: they behave like waves and can exist in multiple states simultaneously – two properties that lie at the heart of quantum inertial sensors.

The quantum inertial sensor aboard the X 37B uses a technique called atom interferometry, where atoms are cooled to the temperature of near absolute zero, so they behave like waves. Using fine-tuned lasers, each atom is split into what's called a superposition state, similar to Schrödinger's cat, so that it simultaneously travels along two paths, which are then recombined.

Since the atom behaves like a wave in quantum mechanics, these two paths interfere with each other, creating a pattern similar to overlapping ripples on water. Encoded in this pattern is detailed information about how the atom's environment has affected its journey. In particular, the tiniest shifts in motion, like sensor rotations or accelerations, leave detectable marks on these atomic "waves".

Compared to classical inertial navigation systems, quantum sensors offer orders of magnitude greater sensitivity. Because atoms are identical and do not change, unlike mechanical components or electronics, they are far less prone to drift or bias. The result is long duration and high accuracy navigation without the need for external references.

The upcoming X 37B mission will be the first time this level of quantum inertial navigation is tested in space. Previous missions, such as Nasa's Cold Atom Laboratory and German Space Agency's MAIUS-1, have flown atom interferometers in orbit or suborbital flights and successfully demonstrated the physics behind atom interferometry in space, though not specifically for navigation purposes.

By contrast, the X 37B experiment is designed as a compact, high-performance, resilient inertial navigation unit for real world, long-duration missions. It moves atom interferometry out of the realms of pure science and into a practical application for aerospace. This is a big leap.

This has important implications for both military and civilian spaceflight. For the US Space Force, it represents a step towards greater operational resilience, particularly in scenarios where GPS might be denied. For future space exploration, such as to the Moon, Mars or even deep space, where autonomy is key, a quantum navigation system could serve not only as a reliable backup but even as a primary system when signals from Earth are unavailable.

Quantum navigation is just one part of the current, broader wave of quantum technologies moving from lab research into real-world applications. While quantum computing and quantum communication often steal headlines, systems like quantum clocks and quantum sensors are likely to be the first to see widespread use.

Countries including the US, China and the UK are investing heavily in quantum inertial sensing, with recent airborne and submarine tests showing strong promise. In 2024, Boeing and AOSense conducted the world's first in-flight quantum inertial navigation test aboard a crewed aircraft.

This demonstrated continuous GPS-free navigation for approximately four hours. That same year, the UK conducted its first publicly acknowledged quantum navigation flight test on a commercial aircraft.

This summer, the X 37B mission will bring these advances into space. Because of its military nature, the test could remain quiet and unpublicised. But if it succeeds, it could be remembered as the moment space navigation took a quantum leap forward.

Voyager 1 Still Operating after more than 40 years – John Davey

First launched in 1977, NASA's Voyager 1 is the most distant human-made object in space and is now over 15 billion miles from Earth (about 167 AU).

Remarkably, it carries only 69 KB of memory - less than the average size of a single photo on your mobile phone - yet it's still sending valuable data from interstellar space.

In 2024, a failed memory chip scrambled its transmissions. With signals taking over 22 hours each way, NASA engineers pulled off a remarkable feat: rewriting and relocating code to by-pass the damaged area restoring the spacecraft's ability to send engineering and science data.

Voyager 1 carries instruments that study cosmic rays, magnetic fields, and plasma waves, helping us understand the edge of the Sun's influence and the nature of interstellar space.

It's expected to keep operating until at least 2030, running on a power source no bigger than a household toaster.

The Bubble Nebula - Martin Howe

The constellation of Cassiopeia contains a few beautiful deep sky emission nebulae that are in relatively easy reach of astro-imagers living in London. A lot of the light pollution in London can be reduced by utilising narrow-band filters (so-called because these block a lot of the wavelengths of light, and just pass through a very narrow bandwidth in the region of certain atomic emission wavelengths). The wavelength known as hydrogen-alpha (commonly abbreviated Ha or Hα) is a common occurring wavelength in emission nebulae. These emissions are due to the release of photons at specific wavelengths as a result of electrons of the excited hydrogen atoms dropping down from higher level energy states. The Ha line is at 656 nanometres, which sits in the red part of the visible spectrum (which is why the images you often see of emission nebulae that are dominated by hydrogen-alpha transitions are usually predominantly red in colour).

Cassiopeia, as seen from London, also has the advantage of being circumpolar, so never sets (subject to local horizon limitations caused by buildings or trees!). It is also easy to spot, as it has a very distinctive shape, and usually described as a (slightly wonky) “W”. At this time of year, Cassiopeia is rising in the north east, culminating about 2am by mid-September.

Cassiopeia contains four of my favourite imaging targets, all within easy reach of a relatively small refractor. These include the Pacman nebula, heart nebula, soul nebula, and the one featured here, the bubble nebula. (The heart nebula is actually so large, that to capture the full extent of it, you need to use something like a 100mm focal length camera lens!)

The bubble nebula clearly gets its moniker from the lovely looking ‘bubble’, which is formed by the shock front of stellar winds generated by a hot massive star. It is over 7,000 light years away, which, despite this large distance, with the nebula being so large (about 7 light years across), it means that at its widest part it still appears to be about half the size of the full Moon.

The image below was the result of 10x10 minute exposures in Ha, OIII and SII, using a 102mm refractor and ATIK 314L CCD camera. You can see the dominance of the hydrogen-alpha emission by the red colour of the nebula.

The bubble nebula (NGC 7635). Image: Martin Howe

Sweet Ryugu – John Pillar

Asteroids Ryugu and Bennu are like playground ball-pits – and each ball tells a secret about the early solar system. Let's jump in…

Pristine samples of Ryugu and Bennu asteroids were returned to earth by the Japanese Hyabusa2 (2020) and NASA Osirus Rex (2023) missions and have yielded fascinating insights into the conditions and evolution of the solar system

Ryugu sample collection

The Hyabusa2 spacecraft arrived at Ryugu mid-2018 and orbited the asteroid for over a year, mapping the asteroids surface features, topography, boulders and chemical composition. Two sampling sorties were completed – for the first, the spacecraft touched down and fired a projectile into the surface, dislodging rocks and rubble into a sample collection bin. The second sample collection was a two-stage operation – a projectile was fired into the asteroid to create a small crater and expose fresh unweathered material which was later sampled by Hyabusa2. In total about 5.4g of material was returned to earth.

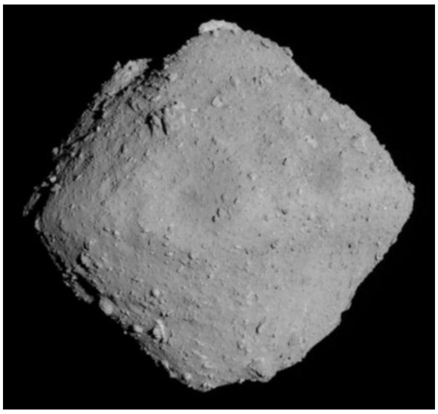

Figure 1: Asteroid Ryugu. JAXA, U. of Tokyo. Kochi U., Rikkyo U., Nagoya U., Chobatech, Meijii U., U. of Aizu AIST

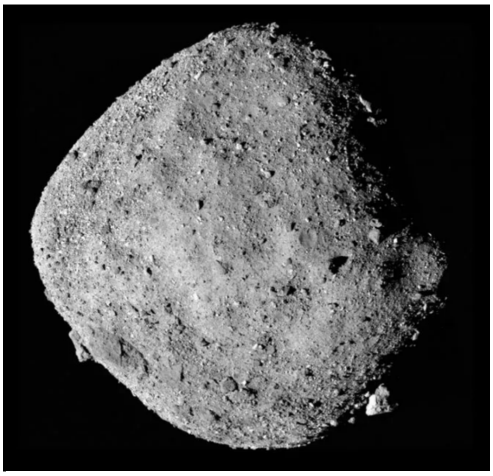

Figure 2: Asteroid Bennu. NASA/Goddard/University of Arizona/Edited by The Planetary Society

Bennu sample collection

A sample from Bennu was obtained by touching down on the surface with a 3.4 meter long 'pogo-stick' sample collection arm. The sampling arm sank 0.5 metres into the rubbly surface and retrieved 127g of pristine samples. The sampling arm found the Bennu surface so soft and unconsolidated that it would have continued sinking into the surface were it not for the spacecraft thrusters firing and reversing the downward movement - the unconsolidated dust and rubble of the asteroid surface behaved **like balls in a ball-pit**, simply moving away as the probe entered.

Rubble pile asteroids: Ingredients

Because Ryugu's return preceded Bennu's return by a few years there is more information available about Ryugu, so most of the description below relates to Ryugu. However, Bennu appears to be very similar, and there some are indications that Bennu and Ryugu are siblings, born from the same parental material in the outer solar system.

Images of Ryugu show its surface to be a jumble of rocks, the majority greater than 5m, approximately one per 50km^2 that is greater than 20m long, and the largest at 160m in length. Very little dust occurs on the surface of Ryugu. The boulders are mostly very angular – indicating that they haven't been jumbled together to 'round off any sharp edges'. Also, the size range and variation rule out their origin as ejecta from Ryugu's craters. The overall density of Ryugu is very low, indicating the rubble is very loosely consolidated throughout the asteroid body – calculations suggest that Ryugu is 50% empty space! (for comparison, a ball-pit is about 35% empty space).

The samples brought back from Ryugu are predominantly clay as a fine-grained matrix, plus minor amounts of organic matter, magnetite, carbonates and Fe-sulphides. Clay contains substantial amounts of water locked in its crystal lattice.

Laboratory analysis of the samples reveals that Ryugu has a bulk chemistry that is very similar to a standard CI (that's C1) carbonaceous chondrite. CI chondrites are a class of meteorites that have a very primitive chemical composition - characterised by a high proportion of water and volatile elements, including amino acids and hydrocarbons. Carbonaceous chondrites like Ryugu typically contain several weight percent carbon as small blebs of organic matter dispersed throughout the rock matrix.

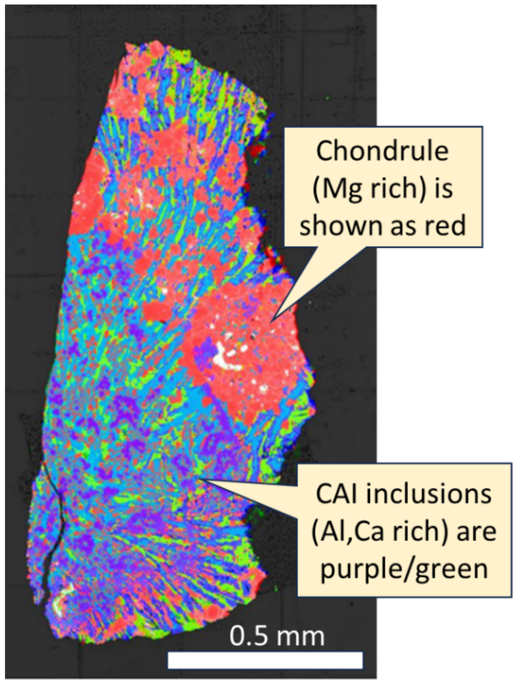

Figure 3: Fragment of the chondritic Allende meteorite, about 1mm size. False colour. Shows welded chondrule and CAI inclusion.
From Russell et.al, 44th Lunar and Planetary Science Conference (2013) 2062.pdf

The earliest mineral condensates from the protoplanetary disk essentially come in two varieties – chondrules and CAInclusions (calcium/aluminium inclusions) - Figure 3 shows a false colour image of a tiny fragment of welded CAI and chondrule.

Chondrules are millimetre-sized spheres cooled from molten micro-droplets of rock to form tiny spheres of primary minerals including olivine, pyroxene, calcite, spinel, and pyrrhotite (a hydrated form of pyrite – maybe familiar as 'fools-gold', an iron-sulphide mineral).

The 'chondrite' term relates to the occurrence of chondrules in the matrix of the meteorite or asteroid rock. Confusingly, Ryugu, as a CI-chondrite, doesn't have any chondrules because they've all been replaced by other minerals (mostly clay) by chemical reactions in the presence of water.

CA Inclusions are rich in aluminium and calcium and are believed to be the earliest condensate (freezing at >1300^o C) from the protoplanetary disk. CAIs are dated using radiometric dating to 4568.3 Ma – an age used to define the age of the Solar System...'CAI-time-zero'. Characteristic minerals in CAI's include plagioclase feldspar, melilite (calcium/aluminium silicate), perovskite (a calcium/titanium silicate – the key component of solar-panels to make electricity), and spinel (commonly used as a gemstone).

Chondrules and CAI particles are believed to have undergone many flash-melting events as they swirled in the hot proto-planetary disk… pressure waves of heat washed through the system causing momentary melting and re-solidification.

The chondrules/CAIs were subsequently dispersed by turbulent processes toward the outer region of the protoplanetary disk where they mixed with water/CO_2 ice and carbon compounds (outside the frost line, Figure 4).

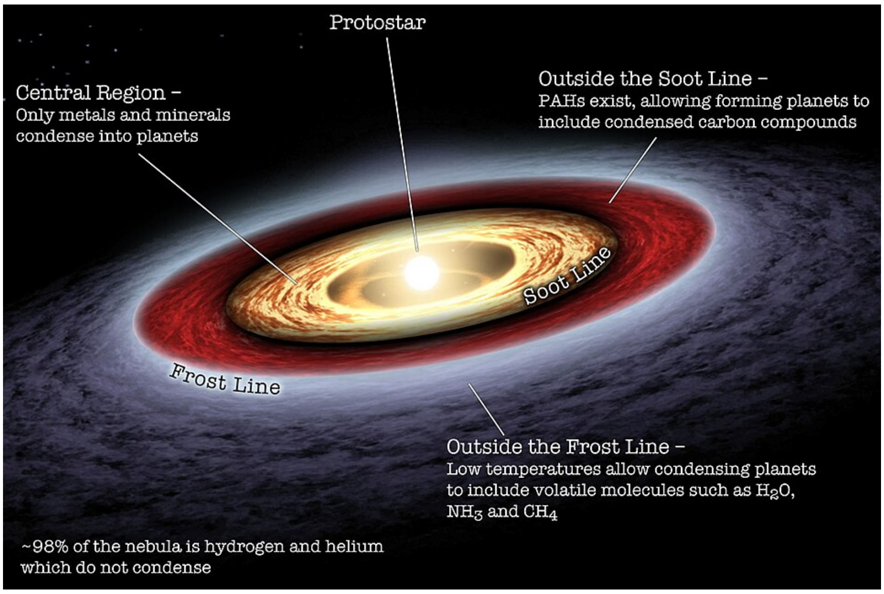

Figure 4: Artists' impression of the protoplanetary disk. CAIs/chondrules form inside the 'soot' line, are transported by turbulent mixing outside the 'frost' line and aggregated into asteroidal bodies. PAHs are 'polycyclic aromatic hydrocarbons'… organic compounds. NASA/JPL-Caltech edited by Invader Xan https://supernovacondensate.net/2012/07/19/between-fire-and-ice/

The primary chondrules/CAIs have almost completely been replaced in the Ryugu samples by pervasive reaction and alteration by chemical reactions in an alkaline, salty water fluid, plus CO_2 – the mineral matrix has been 'steam cooked' to form a second-generation mineralogy comprising clays, carbonates, magnetite and iron-sulphides plus organic matter. Fluid inclusions (tiny bubbles locked in the mineral crystalline matrix) record a CO_2 rich fizzy water fluid (cosmic Perrier 😊) and indicate a temperature of less than ~50^{o} C at the time of formation (when the primary minerals were altered to form clays, carbonates etc). Bennu samples also indicate that it experienced alteration by reactions with water, but more of the original refractory minerals remain than in Ryugu.

The carbon content characteristic of a carbonaceous chondrite is found in mainly carbonate minerals (($(Ca,Mg,Fe)CO_3$, graphite and abiotic organic matter (not related to life). The origin of the organic matter is complex and debated… its deuterium and ^{15}N isotopic compositions indicate formation at very low temperatures, maybe even in the pre-solar molecular cloud or interstellar region. After incorporation in a planetesimal body the organic matter subsequently underwent further reactions, some mediated by the rock matrix clay mineralogy, to form amino acids and more complex organic matter.

Rubble Pile

Ryugu and Bennu are known as ‘rubble pile’ asteroids – loose bodies of angular boulders, large and small, with lots of empty space between. They literally are … rubble piles … debris from a huge collision.

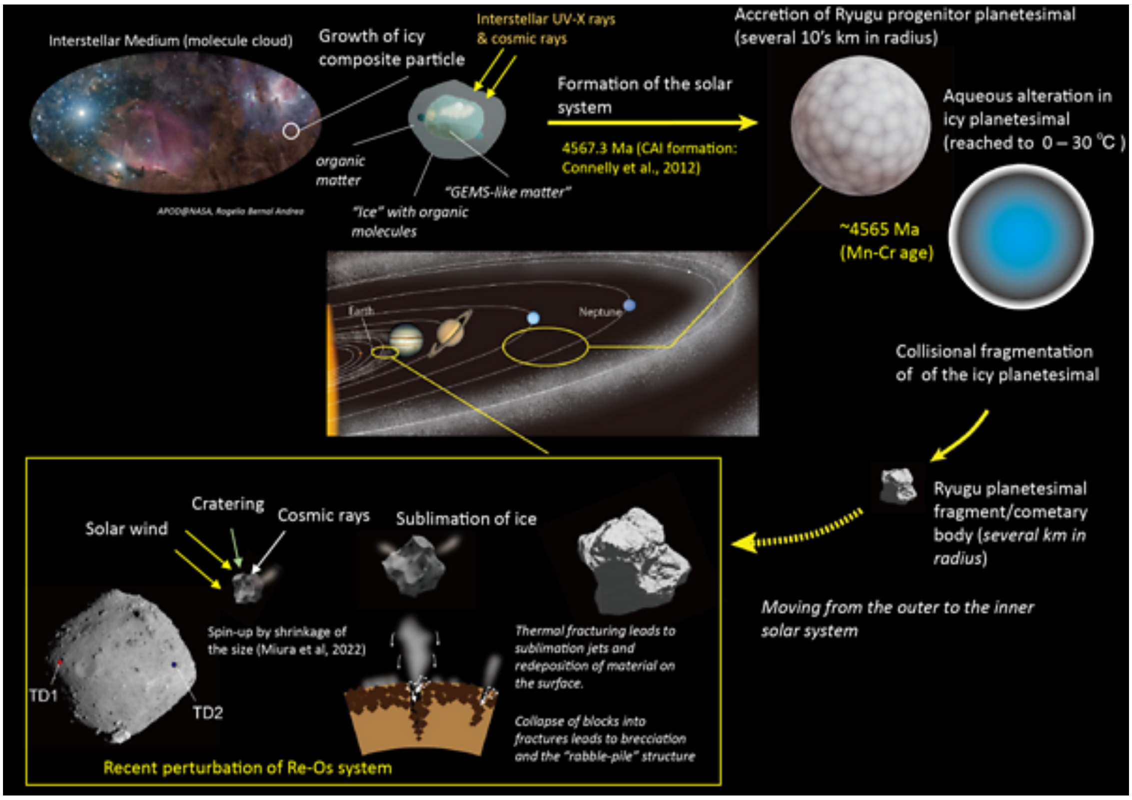

Figure 5. Evolutionary summary of the asteroid Ryugu, from an icy planetesimal, through impact and fragmentation, reaccumulation and then orbital transfer to the inner solar system. Taken from Nakamura et.al., On the origin and evolution of the asteroid Ryugu: A comprehensive geochemical perspective Proc Jpn Acad Ser B Phys Biol, 2022;98(6):227-282.

Figure 5 provides a super summary of the evolution of Ryugu (and similarly Bennu), from the interstellar medium through impact, reassembly and transfer to its present-day orbit within the asteroid belt.

It is believed that a large (100km) parent asteroidal body orbiting in the outer Solar System suffered a violent shattering impact by a smaller body (10km diameter). The rocky debris from the collision slowly and gently re-assembled, each boulder and fragment being drawn to another by weak gravitational attraction. The high proportion of void space (around 40%) in a rubble pile body such as Ryugu is possibly due to their original incorporation of large volumes of ice that has since sublimated away.

It was during the intact lifetime of the parent body that the aggregated dust, chondrules, CAIs, and organic matter were compressed, heated by radiogenic decay (mainly ^{26}Al), and ‘metamorphosed’ in the presence of water and CO_2, transforming from refractory minerals (olivine, feldspar, pyroxene etc) into clay and other secondary minerals.

Up Next:

ANNUAL PICNIC: 5pm Saturday 6 September – Hedley Heath

NEXT MEETING: 8pm Friday 12 September – Nonsuch High School

Dr Steven Banham from Imperial College London will talk about the NASA Curiosity rover mission.

As usual, there will also be a presentation on the sky at night for the coming month.

NEXT USER GROUP:
Suspended until further notice.

NEXT DENBIES OBSERVING SESSION:

The next sessions, allowing for moon rise & set times and cloud conditions, should be sometime around the new moon which is on 21 September.

The precise date and timings of any session will be advised by email and WhatsApp a few days in advance but should be within the period 18 – 24 September.

AD HOC OBSERVING AT WARREN FARM:

These will be at short notice when the weather is favourable, and may replace, or be additional to, sessions at Denbies. Please watch our WhatsApp feed for alerts