JANUS
THE NEWSLETTER OF EWELL ASTRONOMICAL SOCIETY

August 2025

Editor: ewellastro.editor@gmail.com

Email: ewellastro@gmail.com

Website: https://www.ewellastronomy.org

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 August edition of Janus. As members will be aware, there is no monthly meeting in August, so the next meeting – marking the start of our "New Year" – will be in September. Before that event, however, we can look forward to our annual picnic on Saturday 6 September, starting at 6:30pm at Headley Heath – fine weather requested please!

A significant event occurred on 30 July with the announcement of the appointment of Professor Michele Dougherty as the 16th Astronomer Royal. The role of Astronomer Royal dates from the time of Charles II and his creation of the Royal Observatory in Greenwich in 1675. John Flamsteed from Derby was the first person to fill the role and held it for over 40 years. Back then, the job was mostly to advise the king on using the stars to improve navigation at sea – it's expanded a bit since then!

Professor Dougherty succeeds Martin Rees (The Lord Rees of Ludlow) and is the first ever female to occupy the position of Astronomer Royal in its 350-year history. By coincidence, Professor Catherine Heyman has held the equivalent post of Astronomer Royal for Scotland at the Royal Observatory of Scotland since 2021.

Professor Dougherty is a prominent space physicist at Imperial College London, currently holding the positions of Professor of Space Physics and Head of the Department of Physics. Her research focuses on planetary magnetospheres, particularly those of Jupiter and Saturn. She was the Principal Investigator for the magnetometer instrument on board the CASSINI-HUYGENS mission to Saturn and its moons and is the Principal Investigator for the magnetometer instrument for ESA's JUpiter ICy moons Explorer (JUICE) mission currently enroute to Jupiter and its moons. Very much a practicing (and world leading) space scientist, I'm told she gave lectures to our society in 1998, 1999, 2001 and 2002 – I suspect she might be a bit too busy to give a repeat performance!

John

In this edition:

The Solar System August

MERCURY: begins the month having recently passed in front of the Sun at inferior solar conjunction. It will not be visible reaching its highest point in the sky during daytime and being 16° below the horizon at dawn. It remains a difficult target throughout the month and, by the end of the month, soon to pass behind the Sun, will be barely visible, reaching its highest point in the sky during daytime and being no higher than 7° above the horizon at dawn.

VENUS: is visible throughout the month as a morning object, having recently passed greatest elongation W. It begins the month visible in the dawn sky, rising at 02:16 BST – 3 hours and 6 minutes before the Sun – and will reach an altitude of 22° above the E horizon before fading from view as dawn breaks at around 04:57. By the end of the month, still just about visible in the dawn sky, but now well past greatest elongation W and returning closer to the Sun, it will rise at 03:09 BST – 3 hours before the Sun – and reach an altitude of 22° above the E horizon before fading from view as dawn breaks at around 05:47.

MARS: begins the month as an early evening object, now receding into evening twilight and is difficult to see, reaching its highest point in the sky during daytime and being no higher than 2° above the horizon at dusk. By the end of the month, it will soon pass behind the Sun at solar conjunction and will not observable, reaching its highest point in the sky during daytime and being on the horizon at dusk.

JUPITER: recently passed behind the Sun at solar conjunction. It begins the month visible in the dawn sky, rising at 02:56 BST – 2 hours and 26 minutes before the Sun – and will reach an altitude of 15° above the E horizon before fading from view as dawn breaks at around 04:57. By the end of the month, still visible in the dawn sky, it will rise at 01:28 BST and reach an altitude of 37° above the E horizon before fading from view as dawn breaks at around 05:47

SATURN: begins the month visible as a morning object in the morning sky. Becoming accessible around 23:51, when it reaches an altitude of 11° above the E horizon, it will reach its highest point in the sky at 04:29, 36° above the S horizon, before being lost to dawn twilight around 04:30, 36° above the S horizon. By the end of the month, approaching opposition, it remains visible in the morning sky, accessible from around 21:50, when it reaches an altitude of 11° above the E horizon. Reaching its highest point in the sky at 02:25, 36° above the S horizon, it will be lost to dawn twilight around 05:25, 24° above the SW horizon.

URANUS: is currently emerging from behind the Sun and begins the month visible in the dawn sky. Rising at 00:20 BST and reaching an altitude of 28° above the E horizon, it will fade from view as dawn breaks at around 03:36. By the end of the month, still visible in the dawn sky, it will rise at 22:24 BST and reach an altitude of 53° above the SE horizon before fading from view as dawn breaks at around 04:43.

NEPTUNE: begins the month visible as a morning object in the dawn sky. Rising at 22:28 BST, it will reach an altitude of 36° above the S horizon before fading from view as dawn breaks at around 03:36. By the end of the month, still a morning object, but now approaching opposition, it becomes accessible around 23:01, when it reaches an altitude of 21° above the SE horizon. Reaching its highest point in the sky at 02:28, 37° above the S horizon, it will be lost to dawn twilight around 04:43, 30° 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*

August

1 Mercury at inferior solar conjunction
Moon at First Quarter
The Moon at apogee

3 Asteroid 63 Ausonia at opposition

4 Lunar occultation of Antares

6 Conjunction of Saturn and Neptune

7 The Moon at aphelion

9 Full Moon

10 Asteroid 2 Pallas at opposition
Asteroid 89 Julia at opposition

12 Close approach of Venus and Jupiter
Conjunction of Venus and Jupiter
Close approach of the Moon, Saturn and Neptune
Conjunction of the Moon and Saturn
Perseid meteor shower 2025

14 The Moon at perigee
Messier 15 is well placed
Venus at highest altitude in morning sky

15 Messier 2 is well placed

16 Moon at Last Quarter
Close approach of the Moon and M45

18 κ-Cygnid meteor shower 2025
Lunar occultation of Beta Tauri

19 Mercury at greatest elongation west
Conjunction of Moon and Jupiter
Close approach of Moon and Jupiter

20 Conjunction of the Moon and Venus

21 Mercury at dichotomy
Mercury at highest altitude in morning sky
Conjunction of the Moon and Mercury

23 New Moon

25 The Moon at perihelion
Asteroid 6 Hebe at opposition

26 Close approach of the Moon and Mars
Conjunction of the Moon and Mars

27 Mercury at perihelion
Lunar occultation of Spica

29 The Moon at apogee

31 Moon at First Quarter
Lunar occultation of Antares

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 the Moon and Saturn

9 September ε-Perseid meteor shower 2025

10 The Moon at perigee

12 Close approach of the Moon and M45

13 Mercury at superior solar conjunction

14 Moon at Last Quarter
Lunar occultation of Beta Tauri

16 Conjunction of the 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

Collected Observations (and thoughts) – Gary Walker

New Interstellar Comet –Posted 11 July

According to a report on the BBC News, the third interstellar comet has been discovered this month, which has been labelled as 31/ATLAS. It apparently originates from the Thick Disk in our Galaxy, and is over 7 billion years old, which means that it formed 3 billion years before our Sun did!

You will notice that it is yet another ATLAS comet; that is because the ATLAS telescopic system discovers so many of them! Thus, it can get a bit confusing with all the ATLAS names comets about - the same is true with PANSTARS comets, discovered by the PANSTARS telescopic system. I have seen a number of them over the years, as will be true for many in our Society!

My Telescope – Posted 12 July

My Telescope has not been feeling very well for the past month! When the previous batteries died, I changed them as usual, only to find that there was now no power coming through anywhere. Being as it happened so suddenly, I presume that it must be a broken wire, or a loose contact. Whatever the cause, I found the sudden failure extremely frustrating and depressing.

As members may be aware, the telescope is a Meade 8' SCT instrument. So, I contacted this Society to see if anyone could find the problem and fix it. They put it on the group WhatsApp and, at the July meeting, Anita asked me to come up to the front and explain the problem. Some members came up with useful suggestions and Stephen Roebuck offered to try his 12V battery with it. Hopefully, between us it will be possible to solve the problem.

The Full Moon is still very low – Posted 12 July

The Moon is still in its Major Lunar Standstill, so it still appears very low in the Southern sky. Despite this, over the past few nights, it has been visible from my garden, albeit very low down!

Due to this fact, the celebrated "Moon Illusion" is visible whenever the Moon is visible; it doesn't really rise, essentially it just slides along low down in the Southern sky. That said, it cannot be denied that it makes a very beautiful sight in the sky!

During the recent heatwaves, it has also been very pleasant being able to sit out late at night, watching the sky!

Saturn – Posted 12 July

Saturn is now starting to rise in time to be seen after midnight. Early this morning, I saw it again, with the rings clearly visible, but nearly edge on. The right-hand ring, appeared to be detached from the globe of Saturn, but the opposite ring appeared to be joined properly to the globe!

As Adam stated in last night's lecture, Galileo had a problem with Saturn. His telescope could see that there was something unusual about Saturn, in 1610, and he thought that it was two satellites either side of Saturn. However, Saturn then went through one of its ring plane crossings, and these "satellites" disappeared, only to reappear later on causing Galileo to remark "Has Saturn devoured his children"?.

Unfortunately, his telescope was just not good enough to resolve the ring system, (which, incidentally, even my little 40X40mm refractor COULD do!).

It was not until 1655 that Christian Huygens, with a better telescope, realised that it was a ring system. However, it is not unreasonable that earlier astronomers failed to discover them, as nobody expected a system of rings, as they had never been seen before!

Update on my Telescope – Posted 17 July

As reported earlier, when the batteries in my Meade 8"SCT ran out and the scope's GOTO stopped working, I replaced them with new batteries only to find that there was no power in the telescope, and the red power light had gone off. Since this had happened before, I suspected it was probably due to a broken wire, rather than the Handset. As promised, Steve Roebuck came to my house, confirmed that it WAS a broken wire, and fixed it quite quickly. Unfortunately, over time, these wires are becoming increasingly brittle and keep on breaking.

As members will know, the GOTO system won't work without a power supply. My telescope broke down on the night of 19 June, so, for the past month, I have only been able to use it manually. Consequently, I have been unable to find many Deep Sky Objects, which GOTO is so good at doing. Fortunately, however, it is possible to do a lot with my telescope, manually, (I did check that when I originally bought it, as some like the Celestron telescopes, cannot be used manually!). I can still observe planets, the Sun and the Moon, as well as brighter Deep Sky Objects.

Having said it is possible to cope without a GOTO, it is amazing how difficult it is to find any Deep Sky Objects manually, even the brightest and easiest to find. I hate manual star hopping, as it always goes wrong for me, although many amateur astronomers really get great satisfaction out of doing it, becoming familiar with the night sky in the process. I much prefer GOTO, as I can quickly get to what I want to see, without a lot of frustrating searching. Also, GOTO will keep something in the field of view, which is especially useful when using high magnifications. As Shakespeare would have said, "To GOTO, or not GOTO, that is the question"!

Perversely, since it has been working again, the skies have been cloudy. Nonetheless, a great Thank You to Steve Roebuck, again!

Coming Solar Eclipses – Posted 27/28 July

The next two years will be a good time for Total Solar Eclipses, as there are two of them, a year apart, in August 2026 and August 2027.

I have seen adverts in the newspapers for the one in 2026 since last October last and, this year, one for a cruise to Greenland and Norway, etc. The 2026 Eclipse is total over Greenland and part of Spain.

I have also, already, been seeing some social media posts for the August 2027 one, sadly, with the usual media hyperbole. Some posts claim that it won't be seen again in our lifetimes or for 100 years! They also seem to indicate that the eclipse is this year, so it is typical "Clickbait", again!

The 2027 event is total over parts of the Mediterranean, Including Egypt, and has one of the longest totalities at 6 minutes and 54 seconds, at maximum.

Still more social media posts are saying about a Total Solar Eclipse on 2 August, THIS YEAR, when it won't actually occur for another 2 years! Even more stupidly, some posts claim that the whole World will go dark when, of course, Total Eclipses only cover a small and narrow area across the World, which is the main reason why they are so difficult to experience!

There is also the repeated claim that this won't occur again for another 100 years. As I have said before, media is always obsessed with big numbers - often, ironically, making an astronomical event seem to be even RARER than it actually is!

Little going on in the sky this month – Posted 29 July

Surprisingly, there have been very few astronomical events occurring this month, in the sky, or with Space Missions, which is why I haven't been able to write so much for Janus, this month!

Photographing Constellations with a DSLR and lens - Martin Howe

Although we are all in awe at the stunning deep sky astrophotos that amateurs produce these days, there is no denying that you could easily spend a couple of thousand pounds on even fairly modest equipment to emulate these images. However you can also take some great photos with relatively basic equipment – a DSLR, camera lens, and a standard camera tripod. Moonrises in front of iconic foreground features are one aspect, and another, which I will look at here, is to image constellations as a whole.

For the photos in this article, the only equipment I used comprised of a Canon 80D DSLR, a camera lens, and a standard fixed camera tripod.

Although the camera equipment is relatively basic there are quite a few hints and tips to help get a decent image of the constellations.

First is to have a lens with an appropriate focal length (magnification) to image your target – some constellations are quite large, and a 50mm lens will work, whereas for others you might need a 135mm lens or longer. Having a zoom lens that covers a range of focal lengths can help you find the optimum focal length for a range of targets.
Another aspect of the lens is how “fast” they are, essentially meaning how fast they are at collecting light, and this is governed by the aperture (diameter) of the lens in proportion to the focal length. This is known as the f-ratio, usually written as something like f/2.8 or f/11. The smaller the f-number that a lens can operate at, the faster it is. Lenses have a built-in mechanism to change the aperture to let in more or less light to help attain the right exposure. This is clearly important in ‘normal’ photography, for example, when shooting on a cloudy day versus a bright sunny day, and so allows you to control the amount of light entering the camera. Clearly for astrophotography though we need as much light as possible, and generally speaking we use the widest possible aperture (although as we will see later, this is not always the case).

We are all familiar with the fact that the stars appear to rotate above our heads as the Earth turns. As a result, to take very long exposures, you need an equatorially driven mount – one that tracks the stars across the sky. Clearly a standard fixed tripod will not do that, so we need to keep the exposures long enough to gain enough light in the dark skies, and yet short enough to ‘freeze’ the motion of the stars. But how short is short? This depends on the magnification you are using – the higher the magnification, the shorter the exposure you have to use to stop the stars trailing across your image. There is a rule of thumb used by astrophotographers called the 500 rule – your maximum exposure in seconds is equal to 500 divided by the focal length you are using. So, for a 50mm lens, the maximum exposure you could use is 500/50 = 10 seconds. This rule is for a full-frame sensor camera. If your DSLR has a cropped-frame sensor, then you also need to divide through by the crop factor. So if you had a 1.6x crop factor sensor, such as with the Canon 80D, then the maximum exposure should be about 10/1.6 = ~ 6 seconds.

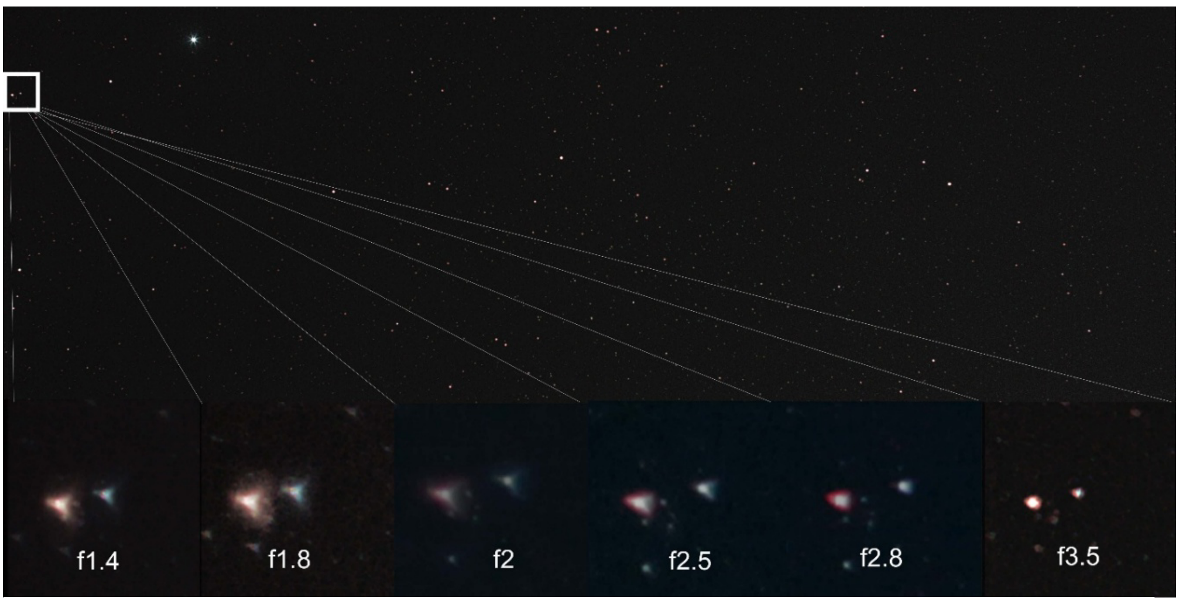
With this information to hand we are ready to set the controls on the camera. First set the camera to fully manual mode and set a high resolution (RAW). Set your lens to manual focus. Now set your ISO to a reasonably high value, such as 1600; your exposure, based on the focal length of your lens by applying the 500 rule; and your aperture wide open depending on the quality of your lens.

Which brings me on to distortions in the lens, specifically coma. This is where the lens cannot bring the stars into sharp focus across the entire flat plane of the sensor (this is also a common issue in fast Newtonian reflecting telescopes). The solution to this is to close the aperture down by a couple of f-stops. To see just how much of an issue this can be, the image below was taken with a Canon 80D and a 50 mm lens. This shows a magnified image of some stars on the very edge of the frame, and how these show extremely bad coma when the lens is wide open at f/1.4, but much better when stopped down to f/3.5. This will be a matter of experimentation with your lenses to see what works best.
Having dialled in the settings we are now ready to focus on our target. Framing and focusing with a wide-angle lens with the small back screen of a DSLR can be very tricky, and some trial and error may be required. The best method to obtain focus is to find the brightest star in the sky and use that to focus on. Zoom into the star using the camera's live view and manually change the focus until the star is as sharp as possible, and then recompose your target in the frame as required.

Then it is a case of simply releasing the shutter button. However to avoid shaking the camera, you must use some sort of remote shooting mechanism – such as a shutter release cable, or the camera's built-in self-timer. Finally, review the image and zoom in to check the focus and to see that any star trails are of an acceptably short length so as to be virtually unnoticeable.

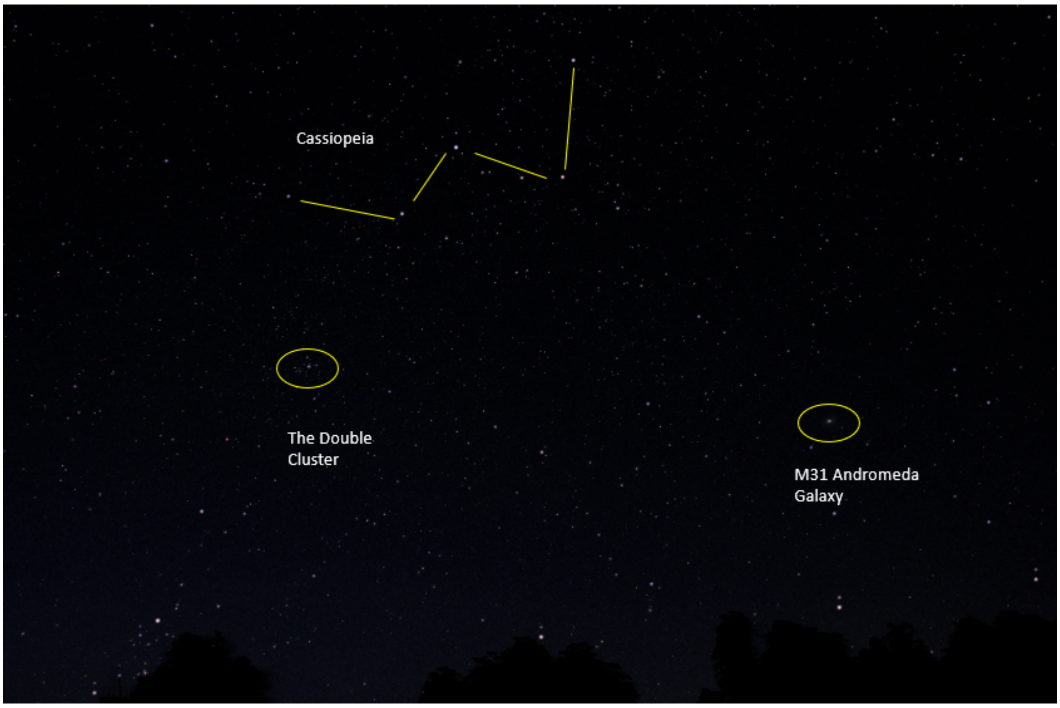
Then you should take many further shots so as to stack them later into a single image. Using multiple images will create a better final result by improving the signal-to-noise ratio.

Once you have captured your images you can then process them – stacking, gradient removal (if necessary), and cosmetic tweaks such as cropping and contrast. Although this part can be very time consuming it is rewarding to see the results, and there is a lot of free software available to do these tasks. These include DeepSkyStacker or Sequator for stacking, and Graxpert for gradient removal. There are a huge range of software packages to make cosmetic tweaks from expensive packages such as Photoshop, lower-cost options such as Photoshop Elements, as a well as many free packages such as Siril and Gimp.



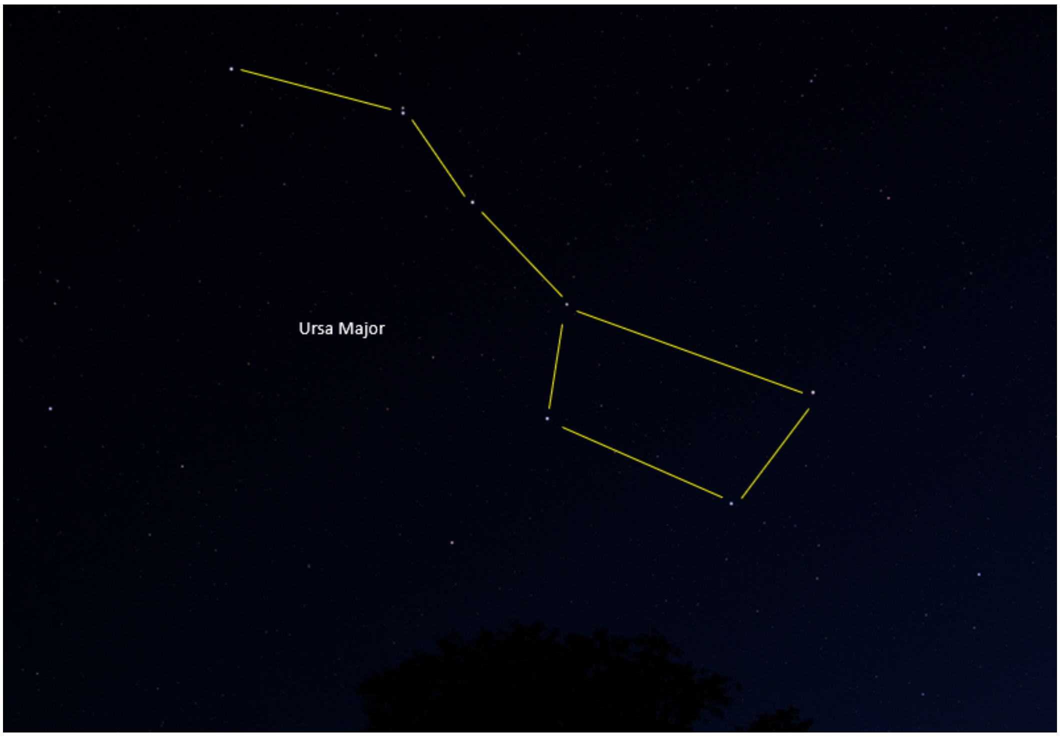
Coma lens distortion at various apertures on a Canon 50 mm lens (Image: Martin Howe)

Two examples of some final images are shown below of the region around Cassiopeia and Ursa Major.



Cassiopeia and the surrounding area. (Image: Martin Howe)

Canon 80D, ISO 1600, 24mm focal length, f/5, 12 x 10-second exposures



Ursa Major. (Image: Martin Howe)

Canon 80D, ISO 1600, 24mm focal length, f/5, 15 x 8-second exposures

Could the first images from the Vera Rubin telescope change how we view space for good?

Acknowledgement: This article was written by Professor Manda Banerji, Professor of Astrophysics, School of Physics & Astronomy, University of Southampton and Dr Phil Wiseman, Research Fellow, Astronomy, University of Southampton and was first published in THE CONVERSATION on 27 June 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/could-the-first-images-from-the-vera-rubin-telescope-change-how-we-view-space-for-good-259857

We are entering a new era of cosmic exploration. The new Vera C Rubin Observatory in Chile will transform astronomy with its extraordinary ability to map the universe in breathtaking detail. It is set to reveal secrets previously beyond our grasp. Here, we delve into the first images taken by Rubin's telescope and what they are already showing us.

These images vividly showcase the unprecedented power that Rubin will use to revolutionise astronomy and our understanding of the Universe. Rubin is truly transformative, thanks to its unique combination of sensitivity, vast sky area coverage and exceptional image quality.

These pictures powerfully demonstrate those attributes. They reveal not only bright objects in exquisite detail but also faint structures, both near and far, across a large area of sky.

Cosmic nurseries – nebulae in detail

Clouds of gas and dust that comprise the Trifid nebula (top) and the Lagoon nebula, which are several thousand light-years away from Earth. Credit: NSF–DOE Vera C. Rubin Observatory

The stunning pink and blue clouds in this image are the Lagoon (lower left) and Trifid (upper right) nebulae. The word nebula comes from the Latin for cloud, and these giant clouds are truly enormous – so vast it takes light decades to travel across them. They are stellar nurseries, the very birth sites for the next generation of stars and planets in our Milky Way galaxy.

The intense radiation from hot, young stars energises the gas particles, causing them to glow pink. Further from these nascent stars, colder regions consist of microscopic dust grains. These reflect starlight (a process known in astronomy as “scattering”), much like our atmosphere, creating the beautiful blue hues. Darker filaments within are much denser regions of dust, obscuring all but the brightest background stars.

To detect these colours, astronomers use filters over their instruments, allowing only certain wavelengths of light onto the detectors. Rubin has six such filters, spanning from short ultraviolet (UV) wavelengths through the visible spectrum to longer near-infrared light. Combining information from these different filters enables detailed measurements of the properties of stars and gas, such as their temperature and size.

Rubin’s speed – its ability to take an image with one filter and then quickly move to the next – combined with the sheer area of sky it can see at any one time, is what makes it so unique and so exciting. The level of detail, revealing the finest and faintest structures, will enable it to map the substructure and satellite galaxies of the Milky Way like never before.

Mapping galaxies across billions of light years

This image captures a small section of NSF–DOE Vera C. Rubin Observatory’s view of the Virgo Cluster, offering a vivid glimpse of the variety in the cosmos. Credit: NSF–DOE Vera C. Rubin Observatory

The images of galaxies powerfully demonstrate the scale at which the Rubin observatory will map the universe beyond our own Milky Way. The large galaxies visible here (such as the two bright spiral shaped galaxies visible in the lower right quarter of the picture) belong to the Virgo cluster, a giant structure containing more than 1,000 galaxies, each holding billions to trillions of stars.

This image beautifully showcases the huge diversity of shapes, sizes and colours of galaxies in our universe revealed by Rubin in their full technicolour glory. Inside these galaxies, bright dots are visible – these are star-forming regions, just like the Lagoon and Trifid nebulae, but remarkably, these are millions of light years away from us.

The still image captures just 2% of the area of a full Rubin image revealing a universe that is teeming with celestial bodies. The full image, which contains around ten million galaxies, would need several hundred ultra-high-definition TV screens to display in all its detail. By the end of its ten-year survey, Rubin will catalogue the properties of some 20 billion galaxies, their colours and locations on the sky containing information about even more mysterious components of our universe such as dark matter and dark energy. Dark matter makes up most of the matter in the cosmos, but does not reflect or emit light. Dark energy seems to be responsible for the accelerating expansion of the universe.

The UK's role

These unfathomable numbers demand data processing on a whole new scale. Uncovering new discoveries from this data requires a giant collaborative effort, in which UK astronomy is playing a major role. The UK will process around 1.5 million Rubin images and hosts one of three international data access centres for the project, providing scientists across the globe with access to the vast Rubin data. Here at the University of Southampton, we are leading two critical software development contributions to Rubin.

First of these is the capability to combine the Rubin images with those at longer infrared wavelengths. This extends the colours that Rubin sees, providing key diagnostic information about the properties of stars and galaxies. Second is the software that will link Rubin observations to another new instrument called 4MOST, soon to be installed at the Vista telescope in Chile.

Part of 4MOST's job will be to snap up and classify rapidly changing "sources", or objects, in the sky that have been discovered by Rubin. One such type of rapidly changing source is a stellar explosion known as a supernova. We expect to have catalogued more supernova explosions within just two years than have ever been made previously. Our contributions to the Rubin project will therefore lead to a totally new understanding of how the stars and galaxies in our universe live and die, offering an unprecedented glimpse into the grand cosmic cycle.

The Rubin observatory isn't just a new telescope – it's a new pair of eyes on the universe, revealing the cosmos in unprecedented detail. A treasure trove of discoveries await, but most interesting among them will be the hidden secrets of the universe that we are yet to contemplate. The first images from Rubin have been a spectacular demonstration of the vastness of the universe. What might we find in this gargantuan dataset of the cosmos as the ultimate timelapse movie of our universe unfolds?

Cheese? - Dr John Pillar

What is the moon made of? What was its origin? What are the markings we see across the lunar disc?...

That beautiful moonglade or bright winter moon on a frosty winter's night belies a violent, cataclysmic birth and long tortured history. Stripped of atmosphere and scarred by meteorite impacts – the serene moonscape we observe today is a unique product of nature's cauldron 4.5 billion years ago.

What do we know about the origin of the moon, its early history, and how it came to be our close companion in orbit around our star?

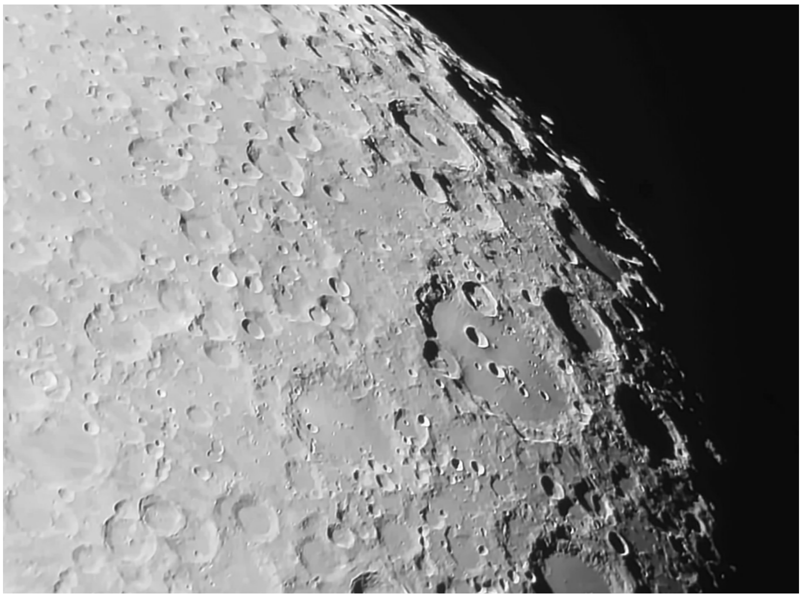


Figure 1: Familiar heavily cratered lunar-scape. Taken with a RaspberryPi HQ camera and Celestron 9.25" SCT

The visual characteristics of the moon are very familiar – the darker "maria", the brighter areas of highlands, and the intensely cratered, pockmarked surface. A lot is known about the moon's surface chemistry from material brought back from Apollo missions, but much less is known about the internal structure and chemistry of the moon, deep below the surface.

When the astronauts set foot on the moon they left footprints in the lunar regolith – a fine grained dusty "soil" a few centimetres thick. One might initially think that the lunar regolith would provide a good insight into the chemistry and lithology (the rocks) on the lunar surface, but in fact, the regolith is a dusty, glassy mix of lunar crust and the meteorites that impacted the moon over a 4-billion-year evolution.

The lunar maria are known to be predominantly tholeiitic basalts – a class of basalts characterised by having a relatively high amount of silica and lower amounts of sodium and potassium. In terms of mineralogy, a tholeiite is comprised of pyroxene $(Ca,Mg,Fe)MgSi_2O_6$, olivine $(MgFe)_2SiO_4$, and plagioclase feldspar $CaAl_2Si_2O_8$. Tholeiitic basalts form the ocean crust on earth and are derived by melting of the mantle at mid-ocean ridges (Iceland is a great place to see tholeiitic basalts… but basically, they're just layered, fine-grained, black, igneous rocks).

Figure 2: Basalt, and the main constituent minerals. Taken from Wikipedia images

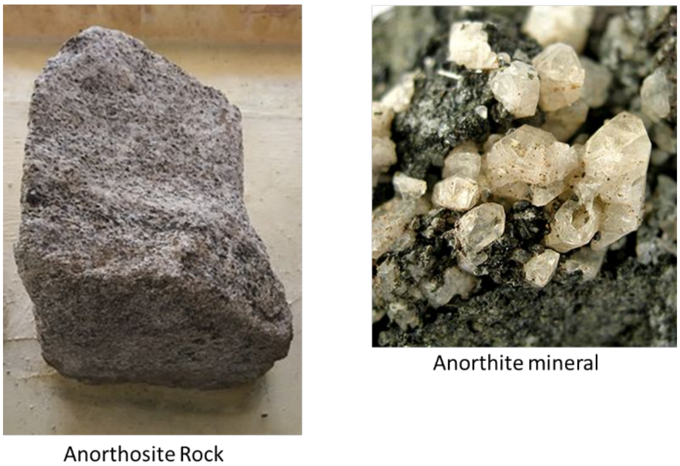


Figure 3: The lunar highlands are composed predominantly of anorthosite, rich in the mineral anorthite with minor amounts of pyroxene and other minerals..

The lunar highlands are composed predominantly of anorthosite. This rock, as its name suggests, is comprised of a high proportion of a feldspar called anorthite, plus minor amounts of pyroxene and other minerals. Anorthosites are found on earth in ancient, 1 to 3.2 billion years old, continent forming areas (e.g. interior US and Canada) and are believed to have been formed by large scale melting of the mantle and slow crystallisation.

The most widely accepted theory for the formation of the earth-moon system proposes that 4.25 billion years ago, the proto-earth, a planetary body 90% of the present earth, was impacted by another body of the diameter of Mars (half the terrestrial diameter and 10% of its mass). The impacting body is referred to as Theia.

Theia is believed to have collided with a glancing blow (resulting in an earth-moon system with angular momentum observed today), causing a large amount of material to shear off from planet earth in a stretchy gloop of vaporised molten rock and debris, 100,000s of km long. Most of this material fell back to earth, but the outer portions remained in orbit around earth and consolidated to form the moon – a body 1.2% of the mass of the earth (that's approximately $1/80^{th}$ of the earth's mass) and ¼ of the earth's diameter.

The energy released in the collision was immense, sufficient to melt planet earth and form a magmatic ocean 2000km deep. The earth and moon then orbited together in the early solar system – two fiery, glowing balls of red-hot molten lava and rock, each cooling and consolidating a crystalline metallic core and thin crust above a seething magmatic mantle.

Because the earth and moon were formed from the same immense "blob" of molten rock following the Theia collision they share similar chemical "building blocks"..

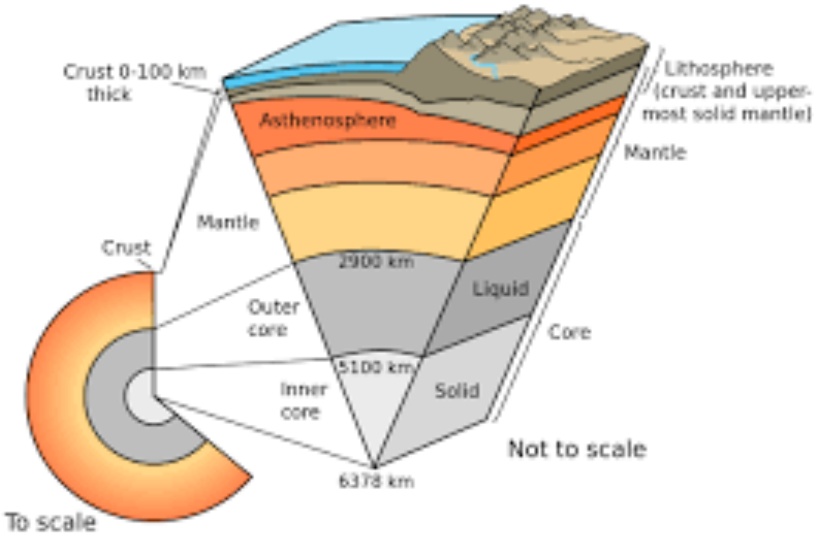


Figure 4: Internal structure of the earth, showing the crust, mantle (2900km deep) and core. A plausible theory is that the Theia collision ejected significant volume of mantle material into low earth orbit, which ultimately became the moon. Source USGS

The moon's surface geology doesn't give much away regarding the overall composition and internal geology. The surface is either predominantly anorthosite (in the highland regions), or basaltic (in the maria). Anorthosite is found on earth as a very evolved crystalline rock – it doesn't directly represent the magma composition it originated from. Basalt, likewise, is known on earth as a product of partial melting of rocks of mantle chemical composition.

A coincidence that may have some significance is that the overall average density of the moon is similar to that of the earth's mantle: 3.3g/cm^3.

The earth's mantle sits below the crust (the continental crust and the ocean crust) and is about 2900km thick – it is a dominant 84% of the earth's total volume. The mantle is comprised dominantly of olivine, pyroxene (a calcium/sodium rich variety) and plagioclase feldspar, and typically is a dark, crystalline rock, exposed in the cores of mountain belts on earth where it has been thrust to the surface by tectonic movements.

A plausible hypothesis proposes that the majority of the molten plume ejected by the Theia collision was of earth mantle material.

But how did a 'ball' of molten mantle material cool and evolve to form the dominant rock types observed on the moon: the anorthosites forming the lunar highlands and the basalts forming the lunar maria?

When a large body of molten rock cools we know that minerals crystallise from it in a known, predictable sequence – it doesn't just freeze 'all at once' to form a solid rock. The sequence

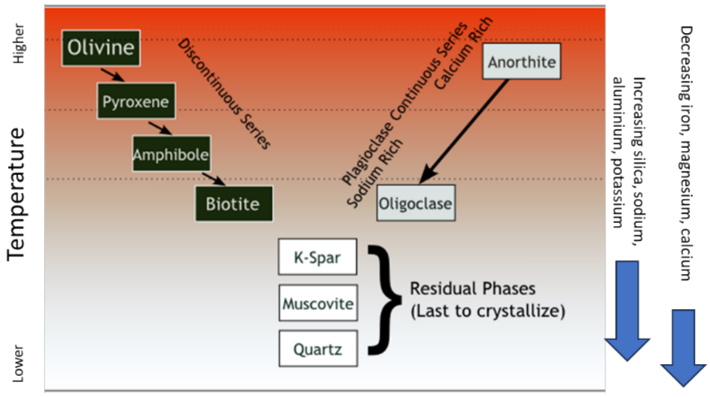


Figure 5: Bowen's reaction series - the typical order in which minerals crystallise from a magma of molten rock, from high temperature to low, from olivine to quartz.

is documented as "Bowen's reaction series" (Figure 5) and describes the order in which minerals crystallise out of a typical basaltic magma. Minerals with high melting/freezing points crystalise out of the melt first, and as temperature cools, minerals with a lower 'freezing' point crystalise, and so on. Commonly the last minerals to form are rich in quartz (SiO_2) and elements that don't 'fit' very well into normal crystal lattices, such as rubidium, uranium, and the rare-earth elements. These are known as 'incompatible' elements, typically found on earth in granites where they concentrated as the last stage of a cooling magma body.

The immense "blob" of molten rock and debris ejected into near earth orbit by the Theia collision would have formed a thin crust of basaltic material over a thick "ocean" of magma which then gradually cooled and crystalised over many millions of years. As a magma of

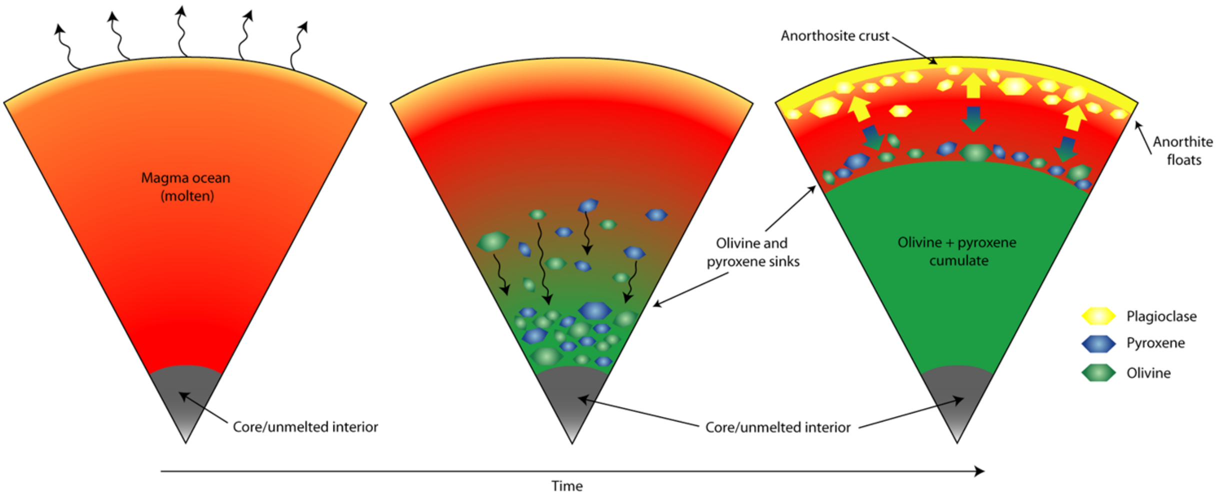


Figure 6: Cooling and crystallisation sequence of the molten Moon, starting from the left, through olivine/pyroxene crystallisation, and ultimate formation of the anorthositic crust. From Crystallising the Lunar Ocean http://www.psrd.hawaii.edu/Aug11/LMO-crystallization.html

mantle composition cools the first minerals to crystalise out of the melt are olivine and pyroxene. These crystals are denser than the magma from which they cool, so tend to sink under gravity and concentrate into a dense basal layer of the cooling moon. Olivine and pyroxene are rich in magnesium and iron and as they crystalise they leave behind a liquid that becomes increasingly poor in these elements and conversely richer in silica, aluminium and sodium.

Ultimately, after about 80% of the melt had crystallised, the chemistry and temperature of the melt (now with high concentration of aluminium, calcium and sodium) had evolved to the point that feldspar was stable, and anorthosite feldspar started to crystalise. Feldspar crystals are relatively light (low density) and tend to float upward in the remaining melt - ultimately forming a thick feldspar rich (anorthosite) layer – the primordial crust of the moon.

Late in the crystallisation sequence the remaining melt (actually, probably a crystal mush) would be very enriched in the incompatible elements and formed a layer below the anorthositic crust. These rocks, known as KREEP because they are rich in potassium (K), rare-earth (REE) and phosphorous (P) are known from areas on the moon that have been deeply exposed by meteorite impacts, such as Mare Imbrium.

The lunar maria, or dark seas, are younger than the anorthositic highlands and are formed from basaltic lava flowing into large impact basins. The majority of the basins were filled around from 3-4 billion years ago, but volcanic activity is believed to have continued to around 1 billion years ago. The chemistry of the basalts is consistent with them being formed from partial melts of the lunar mantle (the thick layer rich in olivine, pyroxene plus the late residual KREEP rock below the anorthositic crust). The reason for the melting event is debated, but a consensus is that the lunar mantle melted as a result of heating by a major impact event plus heat built up from the radioactive decay of elements in the KREEP layer below the continents. The major impact event, late heavy bombardment (4.1-3.8 billion yrs ago), was the same event that may have destroyed the Martian atmosphere and desiccated the planet.

Up Next:

ANNUAL PICNIC: 6:30pm 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 23 August.

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 20 – 27 August.

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