Summer 2021 Number 32

Kielder Observatory Newsletter

EDITORIAL

It is great to be open to the public again, although be assured that while the pandemic is still ongoing we are taking every precaution for your and our safety. The weather in the North East just about played ball with the partial solar eclipse in June - we have a few photos in the gallery section - and as this newsletter goes out the Perseid meteor shower should be getting into full swing, so left's hope the weather is kind for this too! We have two main articles for you this time - one looking at the James Webb Space Telescope, which is due for launch this year, and one on the planets Uranus and Neptune.

Nigel Metcalfe

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admin@kielderobservatory.org

Kielder Observatory Astronomical Society

Registered Charity No: 1153570.

Kielder Observatory Astronomical Society is a Charitable Incorporated Organisation. Its aims are to

* Promote interest in the science of astronomy to the general public
* Facilitate education of members of the public in the science of astronomy
* Maintain an astronomical observatory in Kielder Forest to support the above aims

https://kielderobservatory.org

KIELDER OBSERVATORY
Infinite Inspiration

E-mail: chairman@kielderobservatory.org
secretary@kielderobservatory.org
admin@kielderobservatory.org

Front cover: looking to the East - Dan Pye.

Rear cover: snow in February - Dan Monk

The trustees are delighted to announce that Cassian Harrison has agreed to join the Board.

Cassian is a highly experienced creative leader. He is currently Senior Vice President Content & Commissioning for BBC Studios, taking a leadership role in developing and launching new BBC services for international audiences.

Before this, Cassian was Channel Editor of BBC4 where he was responsible for maintaining and building the channel's singular and innovative voice, capitalising on its successes across Science, Arts, History, Documentary and International Drama. Under his leadership the channel saw consistent audience growth and won many awards including Broadcast Digital Channel of the Year and Edinburgh TV Festival Specialist Channel of the Year.

He has a passion for extreme astrophysics and a just-about passable bass singing voice.

OBSERVATORY NEWS

Spot the Great Bear!

It's been a wonderful few weeks being open again and welcoming visitors back to the Observatory - lovely to see so many smiling faces! Even though the Government have removed the legal requirements, for everyone's safety we are still operating at reduced capacity and are asking our visitors to be considerate to others by wearing face coverings when indoors. Our rigorous cleaning and sanitisation routines will also continue, to ensure the observatory is as safe as possible.

With our reduced capacity, we would like to stress the important of booking early. At the time of writing, August and September are already pretty full, and October is filling fast. It is also worth keeping an eye on our Facebook page for last minute availability due to cancellations etc.

We are delighted to announce two new additions to our team - Finn Burridge and Guy Haveron. Guy is already well known to some of you as a longstanding volunteer and Finn had a work placement at the Observatory before going to

OBSERVATORY NEWS

Lancaster University to study Physics with Astrophysics and Cosmology.

After a year where most of our education work has had to be online, we are now provisionally booking live school visits from September onwards, and will hopefully be able to resume use of the planetarium.

Our new design, as seen on the tote bag. Available online and at the Observatory.

Project Inspire is all set to go. Mel Bacon has been commissioned as the artist who will be developing a series of creative resources that will help raise awareness, demystify, inspire and engage people in the science and technology of Radio Astronomy.

We have released three new podcasts since the last newsletter - episode 8, "To the Moon", and episode 9, "Back to the Darkness!". Episode 10 has just been released and features an interview with the Rev. Prof. David Wilkinson, astronomer and theologian at Durham University. So tune in to https://podfollow.com/kielderobs/view to catch up, if you haven't already done so!

Our new range of merchandise has arrived and is now available for sale through our website and at the Observatory. The new design has been created by one of the team, Ellie MacDonald. We have t-shirts

Late Night Explorer – 3rd July

"The team members were engaging and approachable (and had a good sense of humour) Just to say: there was zero visibility when we visited, yet despite that, it was still a fantastic experience. Will definitely return."

Daniel, Durham

OBSERVATORY NEWS

and some fantastic new tote bags made with recycled cotton and screen-printed with the new design of the observatory profile. You can also buy a Kielder Observatory notebook featuring our logo, with a pen loop and branded pen included. All proceeds from the shop go to help fund our work in astronomy outreach.

Ah yes, and what was it that was brewing in the last edition? The answer is Kielder Coffee Porter, recently released by Alnwick Brewery.

On a more sombre note we were shocked to hear of the fire which destroyed our fellow observatory, the Scottish Dark Sky Observatory, in late June. At the time of writing they are no longer accepting donations until they have firmed up their plans for the future. Let's hope it won't be too long before they are up and running again.

KIELDER OBSERVATORY
Infinite Inspiration

Guests enjoy some covid-secure observing out on the observation deck.

Return to the Ice Giants

Voyager 2 was launched on the Grand Tour on 20th August 1977, making use of a favourable trajectory utilising gravity assists by Jupiter [flyby 9th July 1979] and Saturn [flyby 25th August 1981] to help it on its way to Uranus [flyby 24th January 1986] and Neptune [flyby 25th August 1989]. It is currently exploring the outer reaches of our Solar System in the Kuiper Belt. It was able to take some detailed images of Uranus and Neptune, but since then no other craft has been able to venture to the Ice Giants.

New Horizons was launched to Pluto on January 19th 2006, making use of a gravity assist by Jupiter [closest approach February 17th 2007], finally arriving at Pluto on July 14th 2015, after a cruise phase between Jupiter and Pluto when the spacecraft was deliberately placed into a hibernation mode to preserve power and the instrumentation.

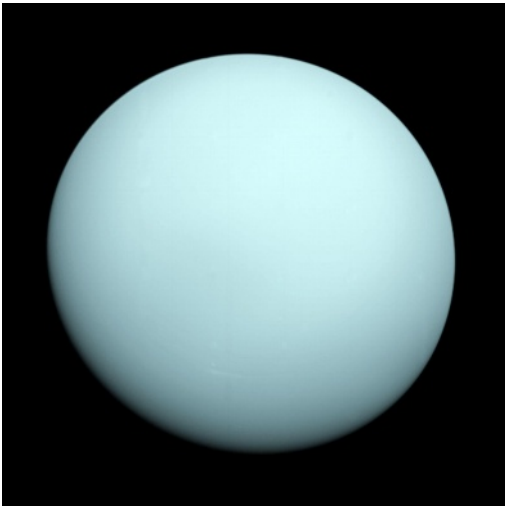
Since the flybys by Voyager 2 of the outer planets, Jupiter has been visited by a number of dedicated probes: 1) Galileo [launched in October 1989, arrived Jupiter December 1995, deliberately de-orbited in 2003] 2) Juno [launched August 5th 2011, arrived July 4th 2016, mission still active]. Scientists have learnt so much from these probes and their success would not have been possible without the assistance from mathematicians who devise the probes' trajectories and are able to envisage the probes' encounters with the planet and moons as the probe flies by.

The Grand Tour came about as a concept by NASA in the mid 1960s. Originally scheduled as a 4-probe set [2 probes to Jupiter, Saturn and Pluto; two to Jupiter, Uranus and Neptune], budget overruns resulted in a scaled-down plan for two probes to visit each planet in turn but having to miss out on Pluto, because of

scheduling delays. Early planning for Voyagers 1 and 2 began in 1969, with a planned launch of Voyager 1 in 1977 followed by Voyager 2 in 1979. The reason for this plan was due to a fortuitous identification of a coincidental gravity assist, identified by mathematician Gary Flandro of the Jet Propulsion Laboratory (JPL) in 1964. This alignment happens once every 175 years.

The first concept was put together by James Van Allen of the University of Iowa and Gordon JF MacDonald of the University of California at Santa Barbara. It received consent by President Nixon in early March 1970. Due to the introduction of the Space Shuttle, the Grand Tour was further cut back in 1972 to a more streamlined mission. Two trajectories were identified; Jupiter-Saturn-Titan and Jupiter-Saturn with a potential add-on to visit Uranus and Neptune if all went well with the first probe. Both probes were an undoubted success but since then no other mission has visited either Uranus or Neptune.

Unlike Jupiter and Saturn, both Uranus and Neptune are perceived to be of limited public interest. This is probably the main reason why there is little momentum for a dedicated mission in the same vein as Galileo and Juno to Jupiter, or Cassini to Saturn (both of which have other missions planned in the next 10-20 years). With Uranus and Neptune being so distant from Earth and with current technology – a gravity assisted mission is presently the only way to get there, with a New Horizons type plan. However it is doubtful – though not completely unlikely – that a flyby would gain any more information than Voyager 2 did, other than better images and perhaps a greater understanding of the evidence gathered by Voyager. In May 2021, both Uranus and Neptune are 'leading' – i.e. further around in their orbits than either Jupiter or Saturn by a significant angle



Uranus seen by the Voyager 2 spacecraft from a distance of 12.7 million km.

Credit: NASA/JPL

[Uranus by ~90º, Neptune by ~45º from Jupiter]. See, e.g.,
3D Diagram of the Solar System (https://in-the-sky.org/solarsystem.php).
This means that another Grand Tour type trajectory is not currently possible. This situation will not resolve itself for another ~130 years [i.e. 1977+175 years]. Another consideration is that to plan a flyby trajectory [V1, V2, NH] is much easier than to plan a capture orbit [Galileo to Jupiter and Cassini to Saturn] whereby the probe can slow down using the gravity of Uranus or Neptune in conjunction with an orbital insertion burn by the spacecraft.

Even so there are a number of things that can be done:
By simulating the solar system it is possible to map out the exact locations of the planets for any time in the future. This may afford opportunities to use better rocket technology to get to Uranus and – separately – Neptune much quicker than even New Horizons' trip to Pluto, which, though it travelled at ~100,000 km/hour, still took over 9 years to get to its target. New Horizons subsequently went on to flyby KBO 486958 Arrokoth and KBO 15810 Arawn. On December 5, 2017, New Horizons surpassed its own record, imaging the Kuiper belt objects 2012 HZ84 and 2012 HE85 from a distance of 0.50 and 0.34 AU, respectively.

The big question is – why should we want to visit Uranus or Neptune again?
Put simply, terrestrial telescopes and even the Hubble Space Telescope cannot give us a clear and detailed enough view of these two remote worlds. In any case the HST will be de-orbited sometime between 2028 and 2044 (although there is a possibility of another servicing mission, using SpaceX Dragon hardware, sometime this decade). Also, the soon-to-be-launched James Webb Space Telescope is not really designed to image

Introduction to Astronomy – 7th July

"The astronomers giving the talks were great and very charismatic. You can tell they are very passionate about their specialist topics and it really makes the difference for the listeners engagement. Fantastic event and would like to visit again."

Ellie, Durham

SOLAR SYSTEM SLOT

Uranus or Neptune. Scientists are beginning to realise that to understand our place in the Solar System we have to understand the whole of the Solar System. Currently there are many probes to the other planets and with future planned missions we are still increasing our knowledge-base. But Uranus and Neptune are down the pecking order.

So what do we know about these two worlds?
Uranus is classified as an Ice Giant, being substantially different to Jupiter or Saturn. Its atmosphere is similar to Jupiter in being composed of Hydrogen and Helium. However it contains substantially more 'ices' [of water, ammonia, methane etc.] and it is the coldest of the Ice Giants with an average temperature of -224ºC or 49 K, as a result of having no internal heat source. Unlike Jupiter, its cloud system is bland and almost featureless. It has a magnetosphere, which is displaced/off-set from the gravitational centre of the planet, it has a faint ring system and a number of very small moons. So it is very unlike Jupiter or Saturn. Its significant feature is that its axial tilt is 97.8º – i.e. it rotates on its side – probably as a result of an ancient collision with a sizeable body. Put simply, it is 'weird' – and in chemists'-speak, if Uranus was an element, then we would want to investigate why it is so weird.

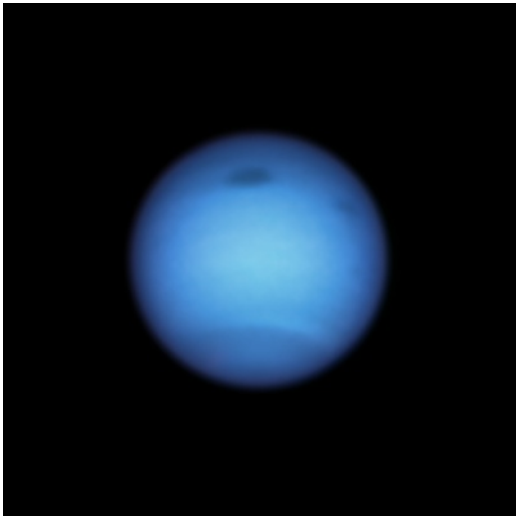
So let's take a more in-depth look at Uranus. It was confirmed by Sir William Herschel, when in the constellation of Taurus on 13th April 1781, having been miss-identified as a star on a number of previous occasions by other observers. He received a payment of £200 per year from King George III as a thank you for his work. Uranus orbits the Sun once every 84 years, so it has completed almost 3 full orbits - due in 2033 - since its discovery. Its orbit is 20 AU from the Sun with a slight eccentricity of 0.046. Its orbit was pinned down by Pierre Laplace in 1783. Its radius of ~25300 km is around four times that of

Uranus's largest moon, Titania, as seen by Voyager 2.

Credit: NASA/JPL

Earth and its day is 17 hrs 14 min long. It has an overall density of 1.27, slightly less than Jupiter. Whereas the axial tilt of the Earth is ~23º, the tilt for Uranus is ~97º. This gives rise to extreme seasons, with each pole being in direct sunlight [1/400th of that hitting Earth] for 42 years at a time. As a result of its distance, the visual magnitude of Uranus is ~5.6, meaning that it is just visible to the unaided eye as a blue star-like object in good seeing with light pollution free skies. Hence the reason why it took a while to be identified as a planet in the 18th century.

Presently, Uranus is thought to comprise of a triple layered sphere, with a rocky core of about one-half Earth mass, a temperature of 9000K and 0.8Re, with a significant icy mantle extending out to about 2Re composed of liquefied gases comprising a clathrate type structure – gases [e.g. Ammonia] dissolved under pressure into a warm electrically conductive liquid, probably water - and a gaseous outer layer. Uranus was found to radiate only about 40% of the heat that Neptune emits. It is possible – using a Diamond Anvil machine – for scientists to simulate the internal structure of Uranus to discover why Uranus behaves differently from Neptune. Whilst the atmosphere of Uranus is mostly Hydrogen and Helium, the simple hydrocarbons, such as Methane, Ethane, Propane, Acetylene, Propyne, and Diacetylene were found by Voyager 2, in conjunction with ground based telescopes. Voyager 2 also discovered unusual radio bursts and this was followed up by the HST discovering that Uranus has faint auroral activity, indicating the presence of an ionosphere of charged atoms. By far the strangest discovery was that Uranus' magnetosphere is displaced from its centre of rotation by about 0.3Ru and it is tilted by 59º to the rotation axis. Uranus



A giant storm is currently visible on Neptune as seen in this shot by the Huble Space Telescope.

Credits: NASA, ESA, STScI, M.H. Wong (University of California, Berkeley), and L.A. Sromovsky and P.M. Fry (University of Wisconsin-Madison)

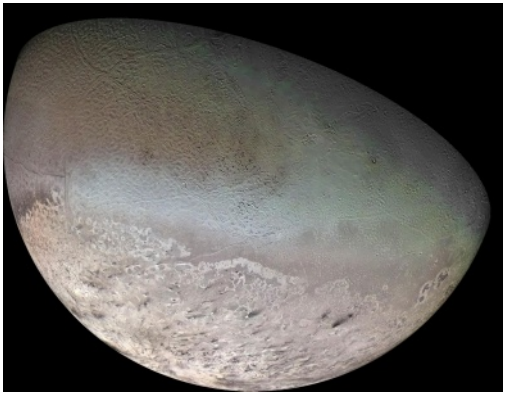
has a bow shock at ~23Ru and a magnetopause at ~18Ru.

The moons of Uranus are an eccentric bunch. To date 27 have been discovered. The largest are Miranda, Ariel, Umbriel, Oberon and Titania, which is the largest at just 788 km in diameter. Compared to those of Jupiter [Ganymede at 5268 km] and Saturn [Titan at 5178 km], these moons are very different and are mostly likely captured KBOs (Kupier Belt Objects), rather than moons formed during the accretion of their parent planet. Even so, there is evidence that some of these moons have 'active' surfaces, such as Ariel, which is much less cratered than the others. Miranda has its own 'grand canyon' about 20 km long, which may have been caused by tidal heating [similar to Europa around Jupiter] due to resonant orbits in the past. There are two KBO-like objects trapped in the L3 Sun-Uranus Lagrange point – 83982 Crantor and 2010 EU65.

Voyager 2 found a series of faint planetary rings around Uranus. These have been further examined by the HST. They may have been identified as early as 1781 by Herschel. A number of these rings have embedded co-orbiting satellites [e.g. Portia in the ν ring and Mab in the μ ring] – just as with the Saturnian system – which act to control and manipulate the ring particles.

We now move out to Neptune. This is the last of the planets and is ranked 4th by size and 3rd by mass. It is more dense than Jupiter and is seventeen times more massive by weight than Earth. It orbits the Sun at 30.1AU and its year is 164.8 Earth years. With an apparent magnitude of 7.67 it is not visible without the use of binoculars or a telescope. Neptune was the first object to be discovered using mathematics. In the early 1840s, anomalies in the orbit of Uranus were found and this led to a search by British and French astronomers. The French got there first and this quest is one of the most interesting stories available.

Neptune has a mass of 1.024×10^{26} kg, some seventeen times that of Earth but only 1/19th that of Jupiter, and a radius of just under 25000 km. Discoveries by Voyager 2 indicated that its internal structure is similar to that of Uranus, with a solid core and hot icy mantle under immense pressure, topped off by a thick gaseous phase. The big difference from Uranus is that Neptune radiates a significant amount of heat and as a consequence with its fast rotation [16hr 6m 6s] this generates supersonic winds in its



Neptune's largest moon, Triton, as seen by Voyager 2 in 1989.

Credit: NASA/JPL/USGS

atmosphere. Like Uranus, its magnetosphere is both highly inclined [47º], offset [0.55Rn] and very dynamic and complex. It has a bow shock extending to ~35Rn and a magnetopause extending to ~25Rn. The climate on Neptune is extreme, with high winds of ~2000 km/hr. Unusually, the wind varies from 350 m/s westerly to 20 m/s easterly. There are also up to 200x more hydrocarbons at the equator than at its poles. This seems to be because of a thermal upwelling at the poles drawing up gases from the equatorial regions. Occasionally colourful storms, for example the 'Scooter', appear in the cloud-tops. These only last a few years before dissipating.

Neptune is known to have a significant effect on the Kuiper belt objects as a result of its large gravitational presence. Objects that are in resonance with Neptune will get cleared out or moved away over time. A number of Neptunian Trojans have been found at the Sun-Neptune-L4 and L5 Lagrange points. For example, 2008 LC18. Neptune – like Earth – also has a number of quasi-satellites, occasional visitors that slip in and out of the Neptunian system.

Neptune has 14 known permanent moons, of which Triton is the largest, most active and most interesting. It makes up 99.5% of the mass of all of the moons of the Neptunian system. Unusually it orbits retrograde, indicating that it was a captured object and not created at the birth of Neptune. It is, or has been, geologically active with strong evidence of Nitrogen geysers some time in the recent past. Neptune also has a series of rings, similar in many ways to those of Uranus. Like those of Uranus these rings are likely to be somewhat ephemeral – i.e. short-lived.

The challenge is that to get a probe to Uranus or Neptune quickly needs a start on new engine technology now. Already there have been a few technology

SOLAR SYSTEM SLOT

demonstrations of ion-drive in missions, such as Dawn to the Asteroid Belt, as well as Hayabusa and Beppi-Collumbo to Mercury. These are/were inner solar system missions relying on SEP [Solar Electric Propulsion], which uses solar panels to generate electricity to power the drive. Going to Uranus or Neptune, SEP will not be efficient enough to provide enough thrust, due to the increased distance from the Sun, so a different technology will be needed – NEP, Nuclear Electric Propulsion. NEP will also have the advantage that its very high ISP [Inertial Specific Impulse] will allow a heavy craft to be sent, and that excess thermal heat generated will keep the spacecraft warm or at least defrosted during its 10-year voyage and while in orbit for 5+ years.

There is already another technology which could be a possible alternative in the not-too-distant future. The holy grail of rocket propulsion in the 21st century and probably for a while thereafter, will be TNR [Thermo-Nuclear Rocket] – essentially harnessing the power of a miniature Sun. Whilst this may seem rather sci-fi, in the past few weeks a small but important breakthrough has been announced. See Fuel for world's largest fusion reactor ITER is set for test run (https://www.nature.com/articles/d41586-021-00408-1).
and, more importantly,
Mast Upgrade: UK experiment could sweep aside fusion hurdle (https://www.bbc.co.uk/news/science-environment-57232644).

Sadly, in the last couple of months NASA have rejected a proposed conventional satellite called 'Trident' which would have visited Neptune's moon, Triton. This would have launched in 2025, taking the opportunity of a once-in-13-year alignment between Earth and Jupiter to slingshot

Origins of the Universe – 7th July

"Great talk by Natasha, who was very engaging and made cosmology accessible to the layperson, and a really interesting and personable guide to the stars/planets that night by Liam. That said, the whole team were great."

Kirstin, Macclesfield

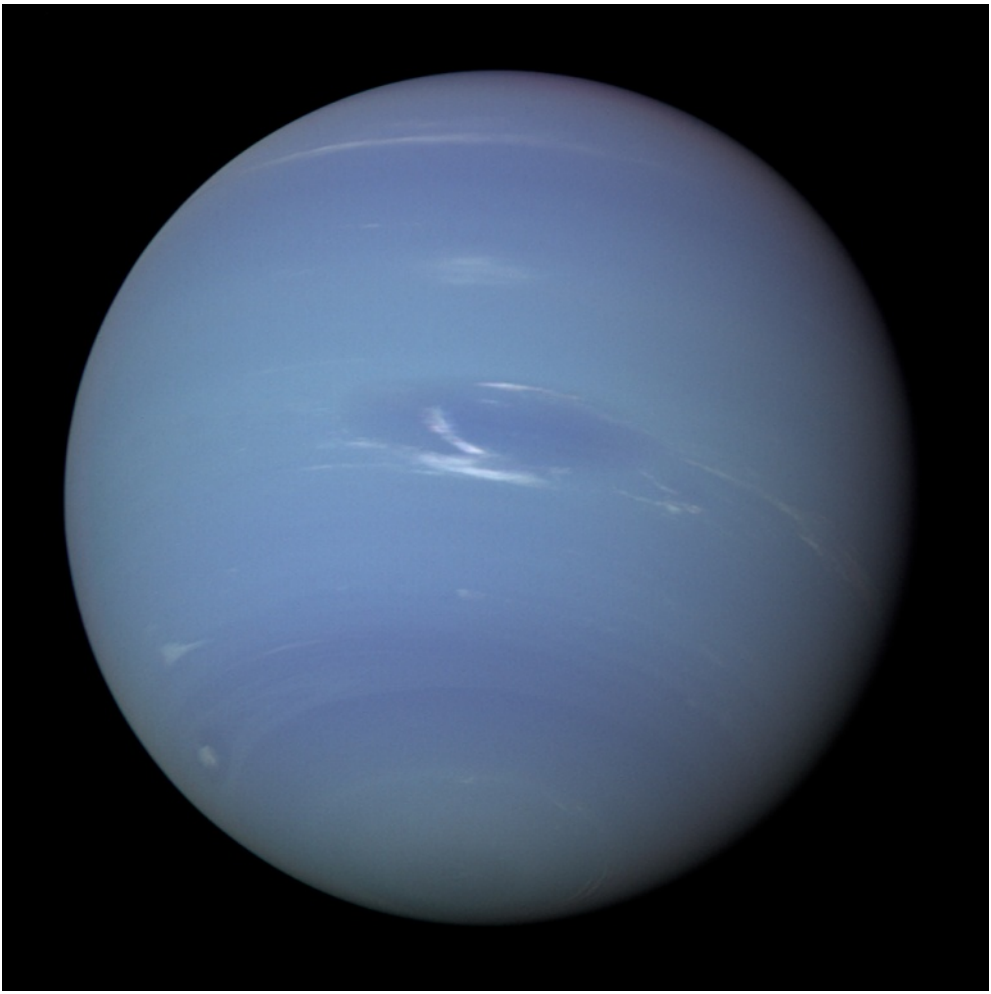
towards Neptune. It would have arrived at its destination in 2038.

Are the Ice Giants just out of reach? …. maybe for now, but perhaps not for much longer.

Robert Williams

Voyager 2 narrow angle camera image of Neptune taken on August 20th 1989. The Great Dark Spot, flanked by cirrus clouds, is at center. A smaller dark storm, Dark Spot Jr., is seen at the bottom left. Above this is a patch of white cirrus clouds, named "Scooter" for its rapid motion relative to other features.

Credit: NASA / JPL / Voyager-ISS / Justin Cowart



NIGHT SKY

AUG 2021 (times in BST)

Lunar phases

New moon	08/8/2021	14:50
First quarter	15/8/2021	16:19
Full moon	22/8/2021	13:01
Third quarter	30/8/2021	08:13

PLANET SUMMARY

Mercury is too close to the Sun to observe. Venus will be the evening star low in the west after sunset. Mars is too close to the Sun to observe. Jupiter is close to opposition and will be visible in fairly dark skies between 2300 and 0300. Saturn is also close to opposition and will be visible from 2300 until 0200. Uranus is a morning object visible from about 0100 until 0330.

THE STARS AT 10PM

North – Lyra will be overhead with the two Bears nicely placed along with Cepheus. Auriga will be close to the horizon.
East – Andromeda and Pegasus will be nicely placed. Perseus and Cassiopeia are rising. Cygnus is high up.
South – Aquilla, Serpens Cauda and Ophiuchus are nicely placed.
West – Hercules is nicely placed with Bootes.

METEOR SHOWERS

August is well known for the Perseid Meteor Shower which is visible for most of the whole month. You should see around 50 meteors per hour. The Moon is almost first quarter in 2021 for this shower so hopefully good conditions once it has set at around 0100 on the 13th with Perseus nicely placed in the sky. Expect around 50 to 100 shooting stars per hour.

COMETS

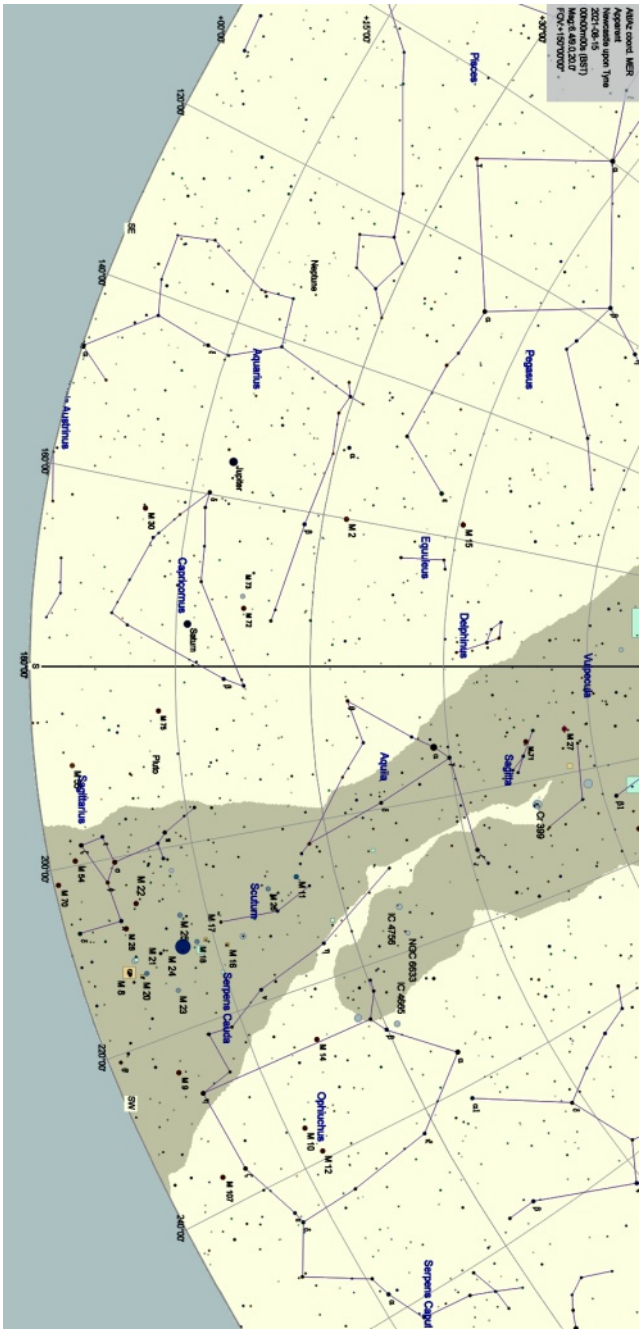
There are no comets brighter than 10th magnitude expected to be visible this month.

Night Sky credits:
Data sourced from Cartes du Ciel,
https://www.timeanddate.com/moon/phases/
and https://in-the-sky.org/ .

The Planets 15/8/2021

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	05:40	14:32	06:58	09:16	07:26	20:49	20:12	22:42
Set	20:44	23:12	21:09	21:37	21:16	06:18	04:30	14:01

The sky chart for Newcastle looking S at midnight on 15/8/2021.



NIGHT SKY

SEPT 2021 (times in BST)

Lunar phases

New moon	07/9/2021	01:51
First quarter	13/9/2021	21:39
Full moon	21/9/2021	00:54
Last quarter	29/9/2021	02:57

PLANET SUMMARY

Mercury, Venus and Mars are too close to the Sun to view this month. Jupiter is near opposition and will be visible from about 2100 until 0100. Saturn is quite close to Jupiter and will be visible at similar times. Uranus is a morning object visible from 2300 until 0430.

THE STARS AT 9PM

North – Lyra and Cygnus will be overhead with the two Bears nicely placed along with Cepheus. Auriga will be close to the horizon.

East – Andromeda and Pegasus will be nicely placed. Perseus and Cassiopeia are rising. Cygnus is high up.

South – Aquilla, Serpens Cauda and Ophiuchus are nicely placed.

West – Hercules is nicely placed with Bootes.

METEOR SHOWERS

There are no major meteor showers in September.

COMETS

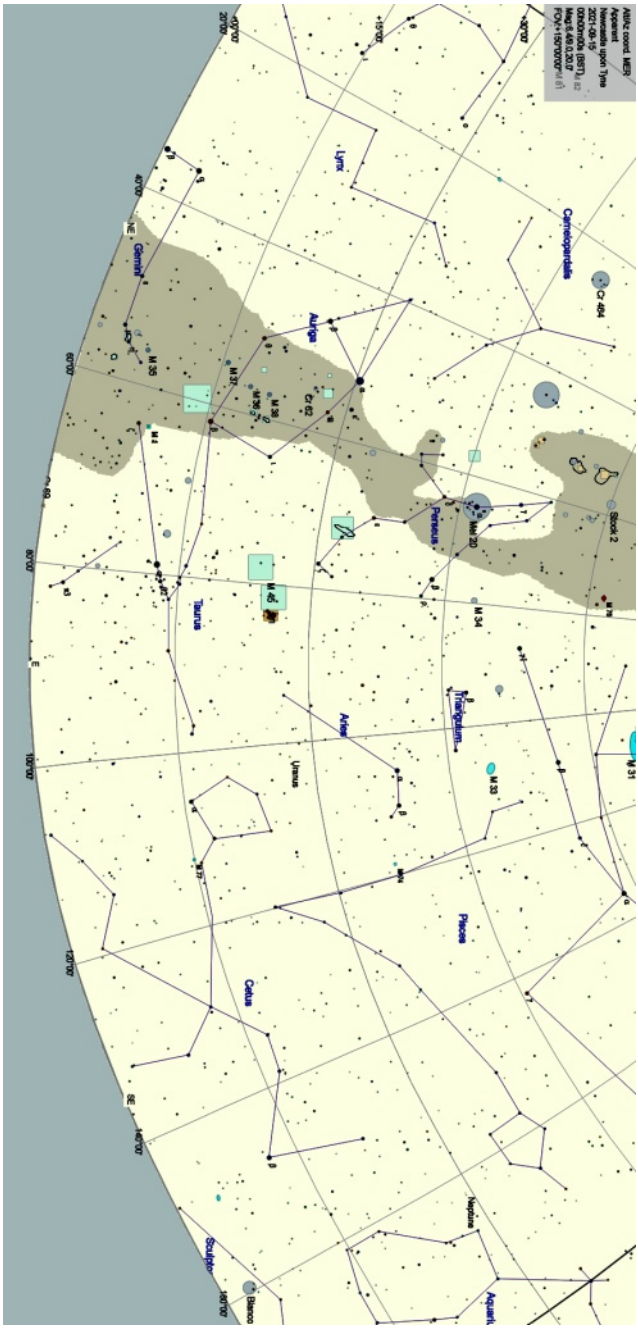
There are no comets brighter than 10th magnitude expected to be visible this month. However, there are a few just fainter than this which might be worth keeping an eye on.

Weekly comet updates can be found at http://aerith.net/comet/weekly/current.html or https://in-the-sky.org/data/comets.php .

The Planets 15/9/2021

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	06:38	17:36	09:31	10:59	07:23	18:36	18:01	20:40
Set	19:26	00:05	19:42	20:18	19:39	02:48	02:11	11:59

The sky map looking E from Newcastle at midnight on 15/9/2021.



NIGHT SKY

OCT 2021 (times in BST)

Lunar phases

New moon	06/10/2021	12:06
First quarter	13/10/2021	04:25
Full moon	20/10/2021	15:56
Full moon	28/10/2021	21:05

PLANET SUMMARY

Mercury, Venus and Mars are too close to the Sun this month. Jupiter and Saturn will be visible from about 2000 until 2230, in fairly dark skies. Uranus is close to opposition and will be visible from about 2000 until 0600.

THE STARS AT 10PM

North – Cepheus will be overhead with the two Bears nicely placed along with Cepheus. Auriga will be close to the horizon.

East – Andromeda and Pegasus will be nicely placed. Perseus and Cassiopeia are rising. Cygnus is high up. Capricornus will be low down.

South – Aquilla, Serpens Cauda and Ophiuchus are nicely placed.

West – Cygnus, Lyra and Hercules are nicely placed with Bootes low down.

METEOR SHOWERS

The major meteor showers of October are:

a) Around 8th October – the Draconids – a minor show but can still put on a show – visible all night in the North – the Moon is thin crescent so the sky could be reasonably dark to spot the components of this relatively minor shower

b) Around 20th October – the Orionids – a major shower of the year. In 2021 there will be a Full Moon, so making it difficult to spot this shower.

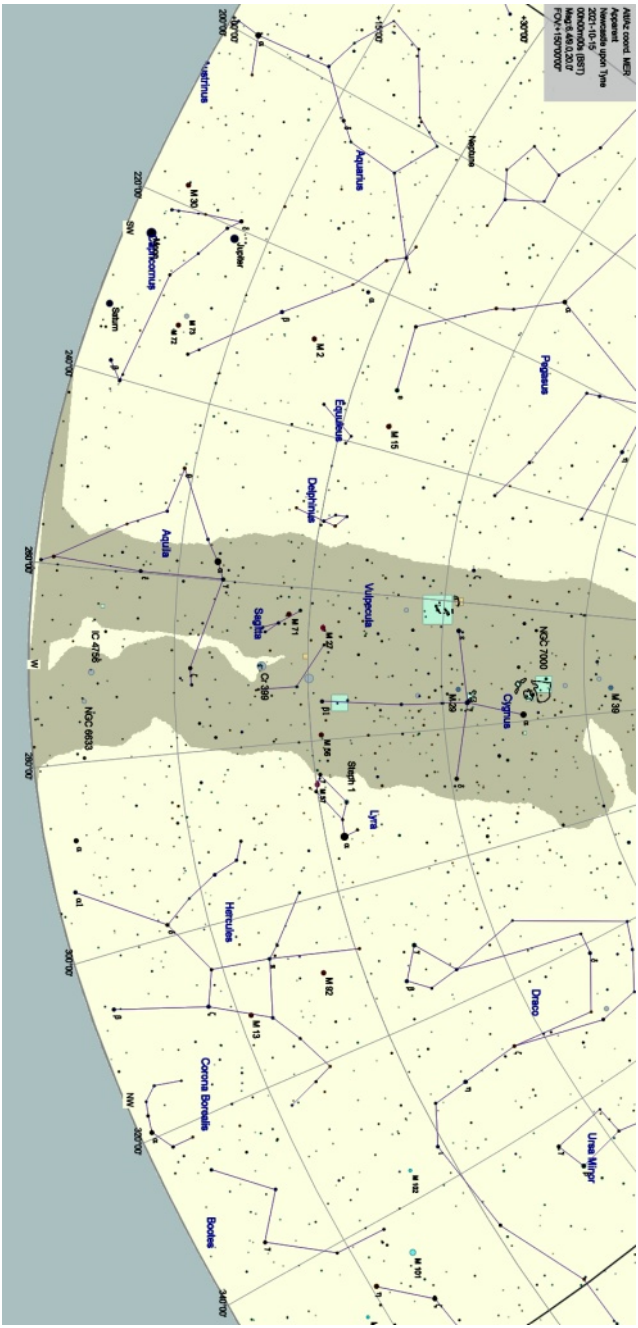
COMETS

There are no comets brighter than 10th magnitude expected to be visible this month.

The Planets 15/10/2021

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	07:35	17:17	06:32	12:31	07:20	16:38	16:02	18:39
Set	18:11	01:59	17:51	19:14	18:06	01:44	00:10	09:54

The sky map looking W from Newcastle at midnight on 15/10/2021.



SPACE SLOT

An update on the James Webb Space Telescope

In Astronomy there are many things worth waiting for, such as clear skies, the Aurora Borealis, or any one of a huge list of astronomical events, such as Lunar/Solar Eclipses, Meteor Showers or – just occasionally – a really bright comet.

In the field of Observatories, some of the larger professional observatories take many years or even decades of planning from concept to 'first light'.

The Hubble Space Telescope took – depending on your point of view – 67 years from original idea – in 1923 by Hermann Oberth – to launch in 1990. Since then it has given over 30 years of amazing views, punctuated along the way by initial disappointment and frustration with faulty optics, to amazing repair missions and upgrades at regular intervals and the many ground-breaking and news-making images and information from its cameras and spectrographs. Hopefully the HST will be with us for another 5 years or so before it is de-orbited safely.

By then its replacement – the James Webb Space Telescope – will have had a few years under its belt to carry on the legacy of the HST well into the 2040s and hopefully beyond.

The Hubble Space Telescope started life in early 1970 with two NASA committees asked to establish a brief of its design and capabilities. In 1974, due to budget cuts, it almost got cancelled but at the same time there was a ground-swell of support to keep the project going, by the many scientists who stood to gain most from the data it would provide.

Launched on April 24 1990, when first light came shortly afterwards it was immediately apparent that the optical system was flawed. The subsequent investigation discovered a fleck of paint in the testing device was – probably – the cause of the main 2.4 m diameter mirror being ground fractionally too 'flat' – by about 2 μm, but that is huge in the field of optics where an hill/valley in the mirror of 100 nm [λ/5] is considered reasonable for amateur optics and professional optics are ground to a tolerance of something like 10 nm [λ/50] or less.

Luckily, the HST was built around a modular design and NASA had the Space Shuttle available to service the telescope. There have been 5 repair missions in total – worn out parts have been replaced and upgrades installed – but the most important was the first, the COSTAR mission, which installed a set of corrective optics to cure the mirror problem.

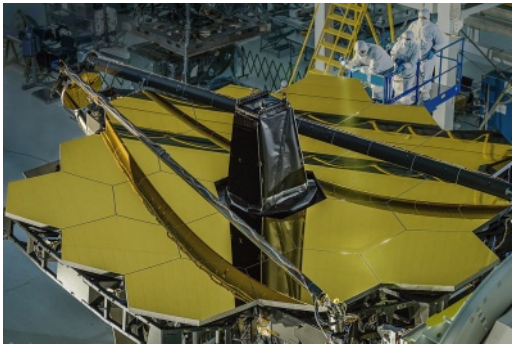
That was the HST which orbits the Earth. Now the world is getting ready for its successor, the James Webb Space Telescope (JWST), to be launched in October 2021 – hopefully!

JWST has been designed to do a different job from HST. HST was planed around a light-window from near infra-red to near-UV, around 1000 nm to 250 nm [visible light is ~700 nm to 400 nm]. In this region it could see about 80-90% of the astrophysical objects in the Universe. JWST is optimised to see in a different window – from 600 nm to 28000 nm – the 'mid-Infra Red'. In this region it will view cooler [T<=50 K] objects and – perhaps most importantly – objects with high red-shift [Z>=5] to try to see the earliest light from the Universe, almost back to the Big Bang itself.

To do this, JWST is a radically different design to HST. Let's compare the two:

a) HST – 2.4 m diameter quartz mirror - classical Cassegrain design with an f-ratio of f/24. Fully enclosed tube with door closing off the aperture during launch. Mostly made from aerospace-grade metal and carbon fibre composites.

b) JWST – 6.5 m diameter multi-mirror - 18 segments arranged in 3 sets for folding during launch. Each mirror constructed from Beryllium metal coated with gold – about 48 g of gold used as the coating. There are two further mirrors with complex curvature in the light path. The entire space chassis is being fabricated from carbon fibre, with exotic alloy components. JWST will also have a number of layered sunshields [also Earth-shield!], made from coated aluminised Kapton, each of which will be the size of a tennis court. Each of the main mirror segments sits on micro-actuators so that the optical path can be fine-tuned regularly and image stabilisation is built in as well.



Engineers inspect the JWST mirrors. The secondary mirror can be seen to the top left in its folded position for launch.

Credit: NASA/Chris Gunn

The really significant detail is that JWST will orbit at L2 – approximately 1.5 million km from Earth – on the far side from the Sun. As a consequence – unlike Hubble – once it is launched it will be too far away from Earth to be serviced.

SCIENCE SLOT

So what else makes JWST special...
JWST is a joint venture between NASA, ESA and the Canadian Space Agency and is being fabricated by the established Space Engineering firm Northrop Grumman, who have constructed many of NASA's leading investigative missions such as SWIFT [2004], IBEX [2008] and TESS [2018].
The instrumentation that JSWT carries comes in the form of:
a) NIRCam – imaging between 5000 nm and 600 nm, built by a team at Arizona University. This instrument also facilitates the adaptive optics system.

b) NIRSpec – Infra Red Spectrograph – built by ESA in Holland, it will obtain spectra in the same wavelength range as NIRCam. It will use a combination of a prism and two gratings to obtain spectra in three separate wavebands. Each instrument being selected by a filter-wheel type arrangement. These are generational instruments based on those flown in ISO [1995-99]. Each spectrograph is designed to observe many hundreds of sources at the same time.

c) MIRI – Mid InfraRed Instrument – will observe in the range 5 μm to 27 μm and contains both a camera and a

The view from the HST of the Pillars of Creation in the optical (left) is very different from that in the infrared (right).

Credit: NASA, ESA/Hubble and the Hubble Heritage Team

spectrograph. It is a joint development between NASA and ESA. Again using a filter-wheel type arrangement this instrument is the most demanding, being the 'coolest' onboard JWST, as it is designed to operate at <=6 K [-267º C], using a Helium Gas regenerative cooler.
d) FGS/NIRISS – Fine Guidance Sensor / Near Infrared Imager and Slit-less Spectrograph, fabricated by the Canadian Space Agency. As its name suggests this is designed to lock onto a target and maintain positional accuracy during an observation. It also interacts with the image stabilisation mechanism of the secondary and tertiary mirrors. The second part of this instrument will undertake imaging and spectroscopy in the 0.5 to 8 μm waveband.
The other major hardware is the truss system – made of carbon fibre and weighing 350 kg, supporting the JWST [total weight 6.5 tons] including mirrors, sunshield and instrumentation etc. It supports other infrastructure such as computers, communication antennae, coolers and alignment jets. There is also the onboard science module that interprets the data from the instruments and sends it to the communication hub for transfer to earth-based receiving stations. All of these being controlled by a sizeable computer package.

Much of this hardware is already 6+ years old so lets hope it will last!.
In its orbit the spacecraft will encounter temperatures of about 80º C [350 K], so the massive sunshield will play a key role in keeping the JWST cool enough to function properly. Unlike HST which goes into Earth's shadow for ~20 minutes of every orbit, JWST will be in the full glow of the Sun 24/7/365.25.
To preserve the onboard chiller, the sun-shield is designed to drop the local ambient temperature to close to 50 K or below. This is in stark contrast with previous IR observatories which used solid or liquid Helium [T<=5 K] at launch to preserve the instruments. Then when this ran out the mission ended or – as with Herschel, JWST's predecessor – went on to undertake other observations not reliant on having an ultra-cold detector.

History of its development

1989-1994 – Hi-Z concept – 4 m mirror telescope orbiting at 3 AU from the Sun [near the orbit of Mars!].
1996 – JWST inaugurated as the NGST [Next Gen Space Telescope], renamed in 2002 after James Webb – NASA administrator in the years during the early Apollo missions [1961-68].
1995 – Faster, Cheaper, Better policy led to a re-design of a larger instrument

located at 2 AU from the Sun, with a cost estimate of $500 million.
2003 – contract awarded for the NGST [~$825 million] 6.1 m mirror, launch date 2010.

Mission development

2005 costs starting to spiral led to a review, launch now delayed until 2013
April 2006 - 2nd project review – new budget of $4.5 billion.

Construction

2007 – First peer review of the technical systems required for NGST
March 2008 - 1st design review passed .
2010 – Mission Critical design review passed.
2011 – most of JWST hardware in final construction and pre-flight testing.
2015 – start of fabrication of the beryllium mirror segments [completed in February 2016].

Pre-Launch

2018 – NASA delayed launch of JWST until earliest 2020 as a result of a failure of the sunshield during a test deployment.

Budget reviews

Between 2006 and 2019 there have been many design reviews which have had consequent budget reviews both by NASA and the US Government. One of the principal supporters in Congress was Sen. Barbara Mikulski, who was at the forefront of support for the HST during its troubled early life in space.
At present the total cost of the project is ~$10 billion.
So, what will JWST actually do for scientists.....

The Science behind JWST

Four cornerstone projects:
a) The very early Universe – following on from Hubble to see even further back in time to the era no more than 100 Myr after the Big Bang when the earliest 'stars' were forming.
b) Galaxies over time – observing how the morphology of galaxies has changed since the Big Bang.
c) The Lifecycle of stars – to view into the dusty clouds that are the nurseries of Stars
d) Other Worlds – the atmosphere of extra-stellar Planets and the search for the building blocks of life.

Hopefully JWST will be as successful as the HST! For more details check this link out.....
https://www.bbc.co.uk/news/science-environment-57078657
For news about the JWST check this out.....
James Webb Space Telescope (https://www.jwst.nasa.gov/index.html)

Robert Williams

GALLERY

We would love to display your images here, whether they are taken up at Kielder or not. Please send them to

admin@kielderobservatory.org

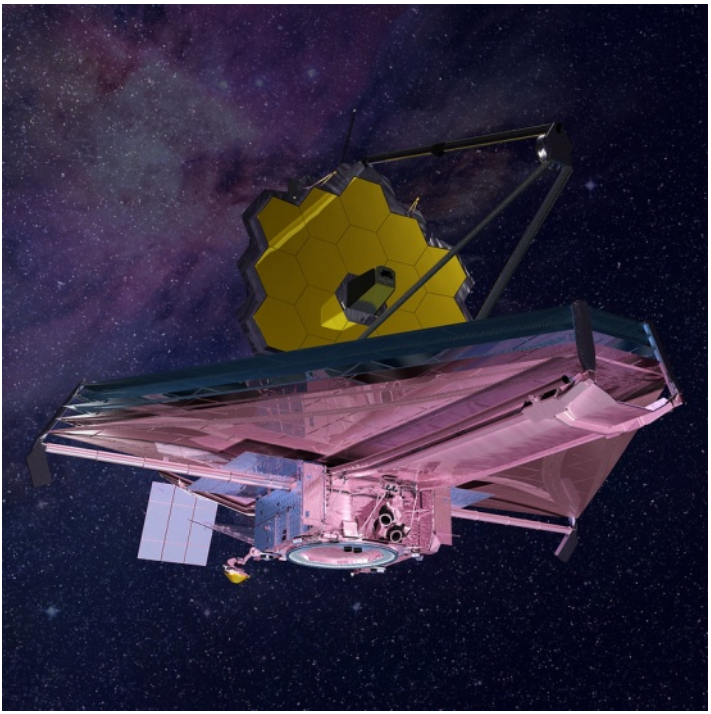
along with a brief description of how and when they were taken.

KIELDER OBSERVATORY
Infinite Inspiration

The partial solar eclipse of June 10th seen from Seaton Carew. This was taken using a 25mm Pocket Borg Refractor, 32 mm Celestron eyepiece, Baader Solar Film and Google Pixel 3a phone mounted as the camera.

Credit: Kevan Hubbard

GALLERY



We didn't have room for this in the JWST article, so we have sneakily slipped it into the Gallery! An artist's impression of what the JWST will look like once unfolded in space.

Credit: Northrop Grumman

Another view of the partial solar eclipse. Taken from Co. Durham using a Celestron Nexstar 102SLT telescope and eyepiece projection onto a sheet of paper. Photographed with a simple digital camera.

Credit: Nigel Metcalfe

The moon seen from Seaton Carew on May 21st. This was taken using a 25mm Pocket Borg Refractor, 25mm Kelner eyepiece and Google Pixel 3a mounted as the camera.

Credit: Kevan Hubbard

GALLERY

A couple of shots taken on our reopening night (May 17th) by one of our guests.

Credit: Michele Parker

Noctilucent clouds seen over Seaton Carew in the early morning of June 21st. Taken with a Google Pixel 3a phone.

Credit: Kevan Hubbard

Aurora Night – 12th July

"Learnt such a lot from enthusiastic staff. Their passion for the Observatory and night skies was so obvious. Although we couldn't use the telescope because of cloud cover Guy's talk about it was so interesting. The Observatory felt like a very special place to be at night - in the deep forest in the darkness - wonderful. After thinking beforehand what are we going to do for three hours? - it flew past!"

Sue, Thirsk

Kielder Observatory - a beacon for dark skies

https://kielderobservatory.org

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