Spring 2019 Number 23

Kielder Observatory Newsletter

EDITORIAL

Well, summer is fast approaching and the nights are getting rather short, but there is still plenty to see in the sky above Kielder. It has been a good year for publicity so far, and we were delighted to see the Observatory feature in the May edition of the Sky at Night magazine. Meanwhile, did you know that the Periodic Table is officially 150 years old this year? Robert Williams takes a look at how astrophysics has shaped the elements. And, in recognition of the publication of the first image of a black hole, we have a bonus science article on black holes! Finally, we are all looking forward to the 50th anniversary of the first Moon landings in July, and we are planning a couple of special events at the Observatory on 20th July to celebrate this special occasion.

Nigel Metcalfe

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Kielder Observatory Astronomical Society

Registered Charity No: 1153570.

Patron: Sir Arnold Wolfendale 14th Astronomer Royal

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

http://www.kielderobservatory.org

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KIELDER OBSERVATORY™
Infinite Inspiration

The main news from the trustees is that at the KOAS AGM in April a Special Resolution was passed to convert the constitution from an 'association' model, where there can be many voting members, to a 'foundation' model, where the only voting members are the trustees. This was mainly done for pragmatic reasons - over the years since our formation we have simply struggled to attract enough members to guarantee our AGMs were quorate. Under the new constitution, the only voting members are the trustees. As they will meet quite regularly, there is no requirement for an AGM and the problem has been solved! The new constitution has now been accepted by the Charity Commission. Although active volunteers will no longer be voting members, the current rewards scheme will continue.

Sadly, we are saying goodbye for now to Peter Sharpe. Peter has been a trustee since KOAS became a CIO but decided to step down at the AGM. Peter has been involved with the Observatory in some form or other ever since it started and he will be a big miss. He is not disappearing entirely though, as he has agreed to serve on a steering group that we have set up to guide the development of our Gillian DIckinson Astro-imaging Academy.

We are now advertising nationally for our new senior management roles - Chief Operating Officer (closing date June 4th) and Observatory Manager (closing date June 30th). Details can be found on the Guardian on-line jobs pages (https://jobs.theguardian.com/jobs/charities/?Keywords=Kielder#browsing) or on the KOAS website (https://kielderobservatory.org/observatory/careers). In the meantime, our Treasurer, Trevor Robinson, has taken over from trustee Stuart Kitching as Interim Chief Operating Officer, but Stuart will continue to cover some of the Observatory Manager functions on an interim basis. They will both step down from these interim positions when the permanent appointments are made.

OBSERVATORY NEWS

Some of our guests enjoying the view from our external decking at the Late Night Dark Skies event on May 3rd.

On the personnel front, we were sad to see our Science Communicator Becki Cooper moving on to pastures new in recent weeks. Becki had been with us since 2015, so she will be quite a miss. Becki's last item for the newsletter was an article on Norwegian Aurora in the Autumn 2018 edition, which brings us on nicely to report that all the back issues of the KOAS newsletter are now available on-line at https://kielderobservatory.org/newsletters.

Some of you may have spotted that we featured prominently in the May 2019 edition of the Sky at Night magazine, with an excellent six page article about the Observatory. I suspect fewer of you will have spotted that we are now on Google street view! Next time you are browsing Google maps, select street view and take a look at the Observatory. You will find you can select some 360 degree panoramas both inside and outside the buildings (in daylight!). If you are coming up for the first time and want some idea of

what to expect, then do take a look. You can also find the tour on our website (https://kielderobservatory.org/when-you-arrive-2).

In June and July, in collaboration with the Calvert Kielder (http://visitkielder.com/visit/calvert-trust-kielder) we will be running a Space & Adventure residential programme for schools. This innovative and exciting programme combines challenging and adventurous outdoor activities with an enlightening dark skies experience. The programme is aimed at primary and secondary schools (Key Stages 1-4) but can be tailored/adapted to accommodate further and high education groups.

Back in March, Dan Pye and Becki Cooper paid a visit to the Natural History Museum's collection of Meteorites. Here is Dan holding a piece of the Moon!

The Observatory will be assisting Beacon Films to produce a video art presentation called 'The Comic Unknown'.
This audio/visual work will be created through a curatorial and commissioning partnership with Great North Museum (GNM), Newcastle University and ourselves, resulting in a ‘full-dome film’ that will premiere in the Great North Museum’s Planetarium and then go on to be part of the Observatory’s pop-up planetarium offer to schools around the North East.

On the events front, we still have places left on May 16th when guest speaker Raman Prinja, Professor of Astrophysics at University College London (UCL) and Head of the Physics and Astronomy Department there, will be giving an overview of our modern understanding of stellar evolution, from the dusty birth of stars, and their nuclear-burning lives, to ultimate demise including supernova detonations, and the bizarre end-states that include neutron stars and black holes. Bookings can be made at

OBSERVATORY NEWS

The Milky Way seen at the Late Night Dark Skies event on May 3rd. This is a stacked image of 23 individual 10 second exposures.

https://kielderobservatory.org/index.php?option=com_virtuemart&view=productdetails&virtuemart_category_id=6&layout=event&virtuemart_product_id=5352. This should be a fascinating talk. The event starts at 20:30 and there will be a tour of the telescopes afterwards and some observing, should weather permit!

Looking further ahead, why not book in for our special celebration of the 50th anniversary of the first Moon landing on July 20th (https://kielderobservatory.org/index.php?option=com_virtuemart&view=productdetails&virtuemart_category_id=6&layout=event&virtuemart_product_id=5428)? We will examine how spaceflight progressed from Sputnik to the Saturn V, and look at the challenges facing the USA's space efforts as they competed for supremacy with the Soviet Union. We will also see how the technologies developed for the Apollo missions trickled down into everyday use

and how modern spaceflight aboard the International Space Station is still developing technologies to improve life down here on Earth.
Although not advertised on our booking site yet, we should also be running a family-oriented event earlier on the same evening, so look out for announcements about that.

Also towards the end of July, we will be running our ever popular Space Kids events again. These sell out quickly, so be sure to book your place well in advance. In fact, details of our events are now available up to the end of December 2019, so you can book your Christmas treat now!

Last but not least, we are now available as a charity which you can support through Smile Amazon. If you use the Smile Amazon site and purchase certain items, Amazon will donate 0.5% of the price to KOAS. So get shopping!

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Not been to Kielder Observatory yet?
Then why not book one of our events for you or your family?
Advanced booking is essential. Weekend events can fill up several weeks in advance. Please book online at http://www.kielderobservatory.org/our-events/ or call us on 0191 265 5510. We can also be contacted at admin@kielderobservatory.org

Universe Full of Stars – 13th April

"This was a treat for my son's birthday and in his words "this was the best night of my life Mam". He was cold but had a fantastic time. Out of this world if you pardon the pun!!"

Judith, Prudhoe

NIGHT SKY

MAY 2019 (times in BST)

Lunar phases

New moon	04/05/2019	23:45
First quarter	12/05/2019	02:12
Full moon	18/05/2019	22:11
Last quarter	26/05/2019	23:18

PLANET SUMMARY

Mercury and Venus are both in near conjunction with the Sun and not visible this month. Mars will be visible low in the west in the dusk twilight. Jupiter is a morning object visible from around 0030 until 0300. Saturn is a morning object visible in the dawn twilight, but a challenge to spot being quite close to the Sun. Uranus is near solar conjunction and not visible this month.

THE STARS AT 10PM (BST)

North – Perseus, Cassiopeia and Cepheus are nicely placed. Andromeda, Cygnus and Lacerta are near the horizon.
East – Bootes, Hercules and Lyra are nicely placed, with Ophiuchus and Serpens near the horizon along with Libra containing Jupiter in the south east
South – Coma Berenices, Leo and Cancer are high up, Virgo is nicely placed. The southerly constellations of Crater – the Cup, Corvus the Crow, Sextans and Hydra the Water Snake hug the horizon.
West – Cancer, Gemini and Auriga are nicely placed, along with Perseus. Orion skirts the horizon.

METEOR SHOWERS

There are no bright meteor showers this month.

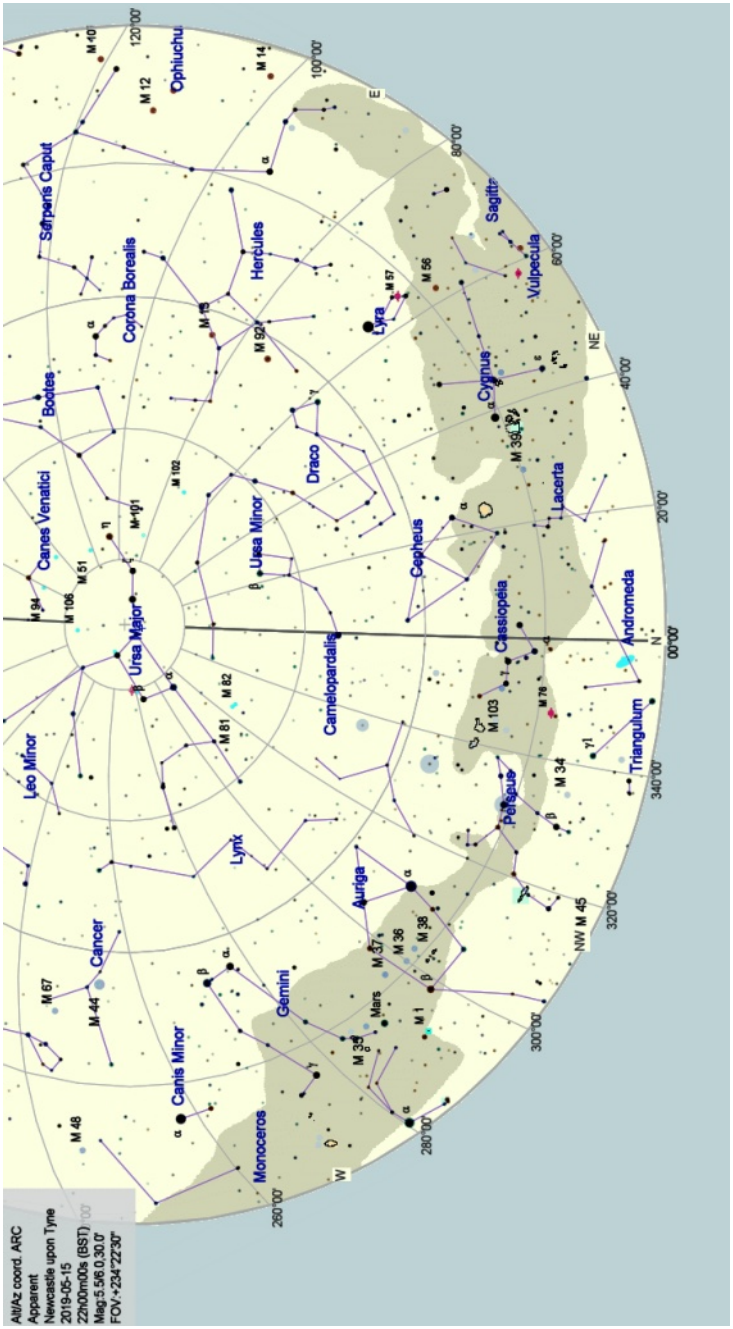
COMETS

There are no comets brighter than about 11th magnitude visible this month.

The Planets 15/05/2019

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	04:58	16:40	04:51	04:26	06:43	23:19	01:14	04:24
Set	21:04	04:20	20:15	18:29	00:21	06:42	08:50	18:57

May 15th night sky at 10pm, looking north from Newcastle-upon-Tyne.



NIGHT SKY

JUNE 2019 (times in BST)

Lunar phases

New moon	03/06/2019	11:01
First quarter	10/06/2019	06:59
Full moon	17/06/2019	09:30
Last quarter	25/06/2019	10:46

PLANET SUMMARY

Mercury will be visible low in the west after sunset. Venus will not be visible this month. Mars will be a difficult object in the evening twilight. Jupiter is near opposition and visible for most of the hours of darkness [from around 2330 until 0230]. Saturn will be visible from around 0030 until 0230. Uranus will be a challenging object to locate in the morning twilight.

THE STARS AT 11PM (BST)

North – Cepheus is nicely placed with the two Bears high up. Near Cepheus are the not-well-known constellations of Lynx and Camelopardalis. Auriga, Perseus and Andromeda skirt the horizon.

East – Hercules, Lyra and Cygnus are nicely placed. Ophiuchus along with both parts of the Serpent are nicely placed in the south-eastern sky.

South – Hercules, Bootes and Coma Berenices are nicely placed along with Ophiuchus, Libra – with Jupiter - and Virgo. To the lower LHS of Libra can be found the claws of the Scorpion.

West – Virgo, Leo , Cancer and Gemini cut a swathe across this view. Auriga is low in the north west.

METEOR SHOWERS

There are no major meteor showers in June.

COMETS

There are no bright comets this month.

NOCTILUCENT CLOUDS

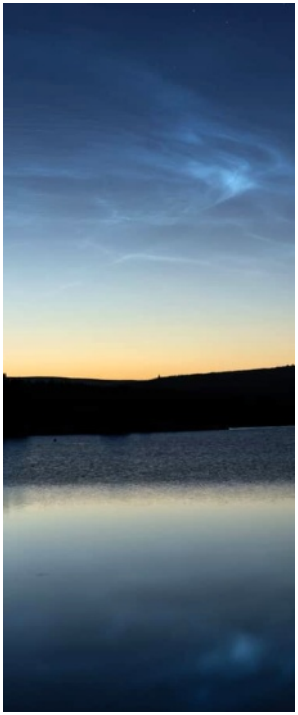
During the Summer months, on clear nights and only if the conditions are right, Noctilucent Clouds may become visible. They are created by a combination of extreme cold in the Earth's high atmosphere – in the Mesosphere at altitudes of about 50km to 100km, trapped water vapour and – it is suggested – the influence of other factors such as shooting stars and dust from, for example, the

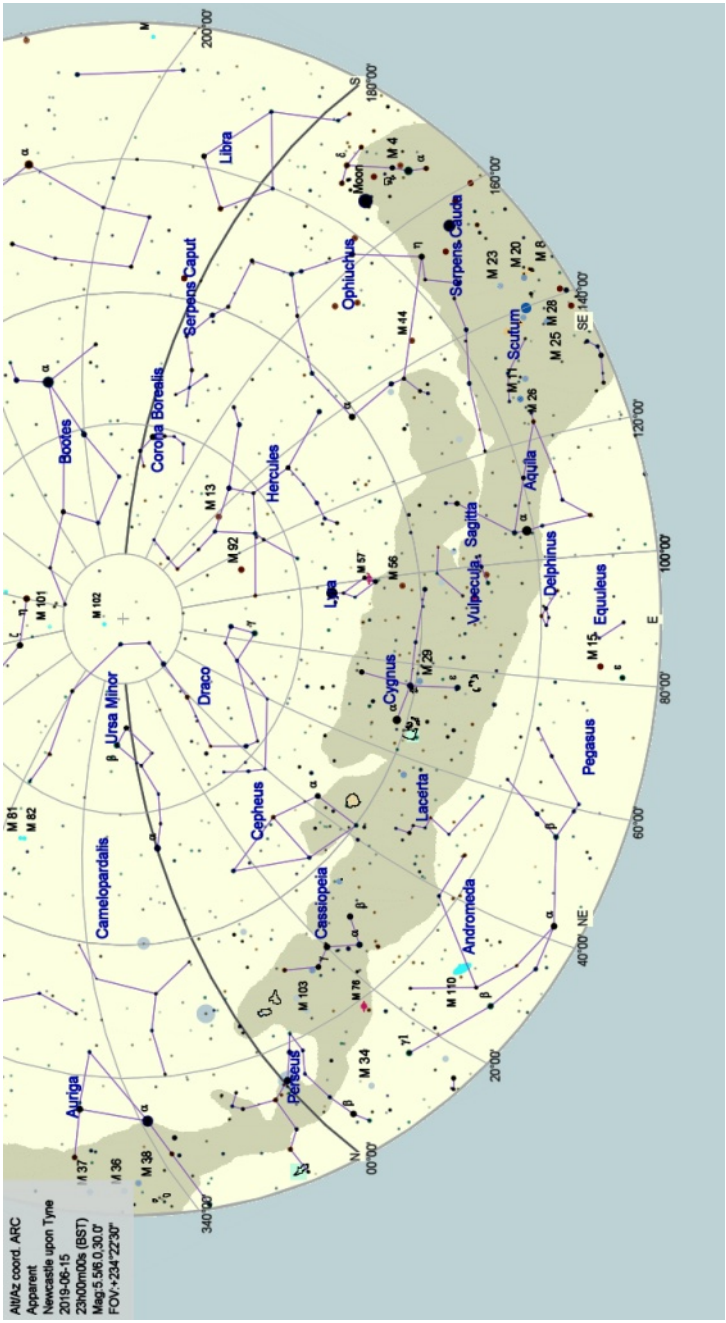
The Planets 15/06/2019

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	04:26	19:38	06:03	03:40	06:19	20:59	23:04	02:25
Set	21:45	03:44	23:31	20:12	23:32	04:26	06:40	17:04

June 15th night sky at 11pmBST, looking east from Newcastle-upon-Tyne.

Sahara Desert. They appear as bright blue streaks, nets and flows and look nothing like any other type of cloud. They tend to appear just after sunset and before sunrise, but can also be seen late at night too.





NIGHT SKY

JULY 2019 (times in BST)

Lunar phases

New moon	01/07/2019	20:16
First quarter	07/07/2019	18:30
Full moon	15/07/2019	13:29
Last quarter	23/07/2019	15:56

PLANET SUMMARY

Mercury and Venus are not visible this month as they are too close to the Sun. Mars is also too close to the Sun to see this month. Jupiter will be visible from around 2230 until 0100. Saturn is visible for most of the hours of darkness – 2230 until 0230.

THE STARS AT 10PM (BST)

North – Corona Borealis and Bootes are high up, with Coma Berenices and Canes Venatici nicely placed. Virgo and Leo are close to the horizon.

East – The Milky Way cuts a swathe across the sky at this time. From Perseus in the east, through Cassiopeia, Cepheus, Cygnus, in the south, into Sagitta and Vulpecula, towards Aquila, Scutum and Sagittarius in the west. Low down are Andromeda and Pegasus.

South – Cygnus, Lyra, Hercules and Bootes are nicely placed with Aquila, Ophiuchus and Virgo still worth a look. You may see the body of Sagittarius and the head of the Scorpion near the horizon.

West – The two Bears, Corona Borealis and Hercules are well placed. Libra (with Jupiter), Virgo and Leo are still visible, with Cancer setting. Venus, the Moon and Mercury make a nice group close to the horizon, in the constellation of Leo.

METEOR SHOWERS

There are no major meteor showers in July.

COMETS

No comets are expected to be bright than 11th magnitude in July.

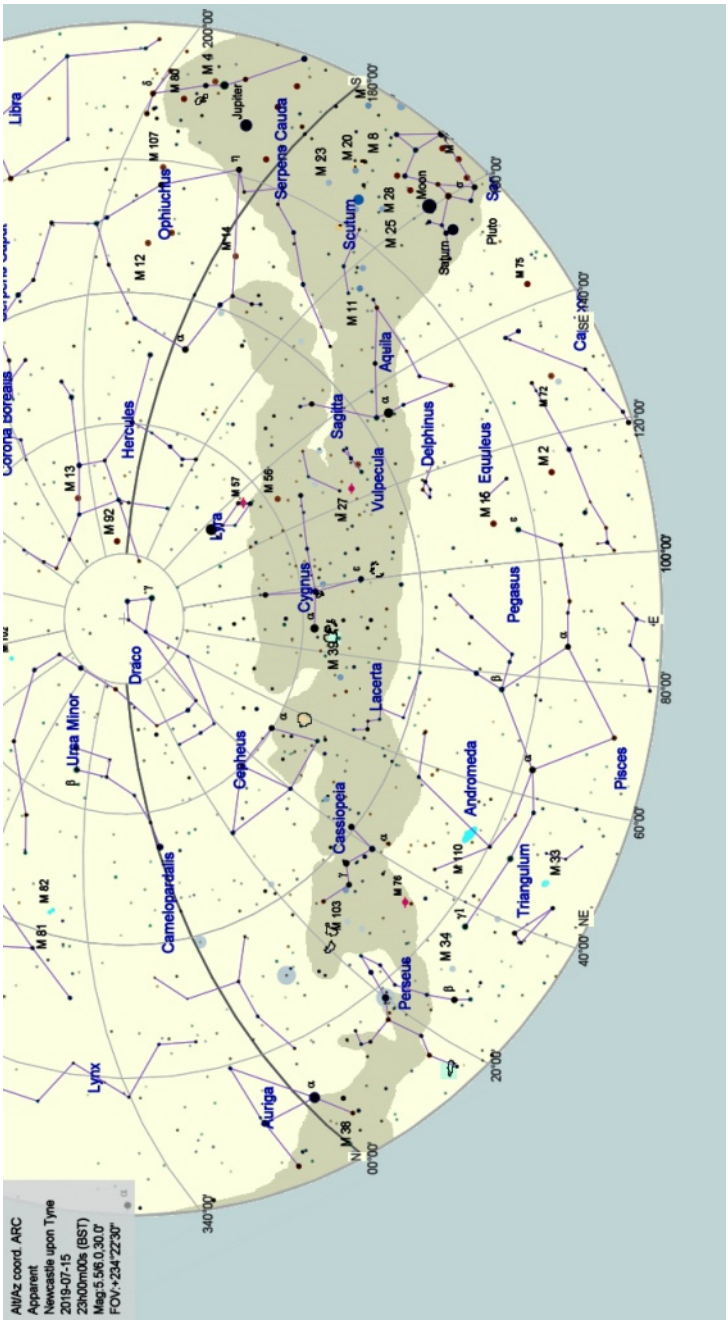
Night Sky credits:

Data sourced from Cybersky 5, https://www.timeanddate.com/moon/phases/ and https://in-the-sky.org/ .

The Planets 15/07/2019

	Sun	Moon	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Rise	04:46	20:42	06:09	04:01	06:13	18:45	21:00	00:28
Set	21:36	03:22	21:24	21:11	22:33	02:16	04:10	15:12

July 15th night sky at 11pm BST, looking east from Newcastle-upon-Tyne.



SCIENCE SLOT

Nucleosynthesis

2019 is the International Year of the Periodic Table ...

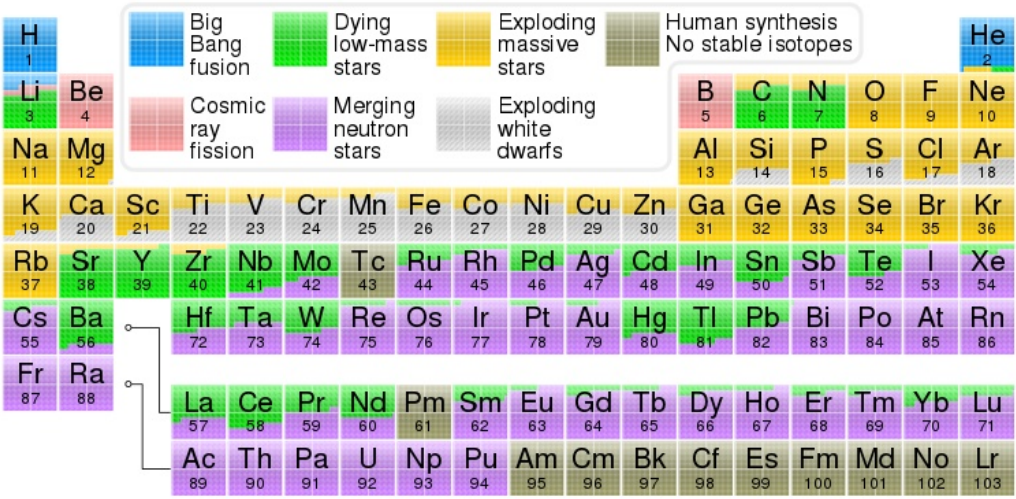
In the beginning there was the Big Bang, which happened some 13.6 billion years ago. Once everything had cooled off, some 300,000 years later, only 3 elements – Hydrogen 95+%, Helium, less than 5% and Lithium, less than 0.5%, were created. Since then stars have taken a central role in creating more Helium, Lithium and the other 89 stable elements in the Periodic Table. So, if you have any mobile device, car or other appliance that uses Lithium ion batteries, you can be reassured that the metal may be up to 13,599,700,000 years old!

The story of how these elements are created in stars – and other astrophysical objects – is collectively known as nucleosynthesis – put simply, welding simple elements into more complex ones inside the nuclear crucibles of stars and other objects such as neutron stars, black holes and supernovae.
Nucleosynthesis was a phrase first coined by Sir Arthur Eddington in 1920, with his ideas elaborated by Hans Bethe, in the same decade. In the 1940's Fred Hoyle weighed in with more ideas. The 1950's saw the biggest investigation of this subject by Burbidge and Burbidge. Since then numerous well known scientists have made further discoveries in this field, such as Carl Sagan, who famously coined the phrase 'We are made from star stuff'.

Let us take you on a journey of discovery amongst the stars ...

Most stars similar to our Sun, and those smaller and a little larger, spend millions or billions of years converting Hydrogen to Helium. Our Sun has been doing this for 5 billion years or so and will continue for about the same amount of time into the future. At the end of its life, it will evolve into a Red Giant star and – for a brief period of time, perhaps only 100 million years - it will then convert the Helium into Carbon, creating a White Dwarf at the centre of a Planetary Nebula as it does so. Look at Messier 57 in Lyra or Messier 27 in Vulpecula – and you are seeing what the Sun may look like in the autumn of its life.

The simple equation of the Sun is: 4 x [Hydrogen] → 1 x [Helium], plus a lot of energy, a few neutrinos and gamma



The Periodic Table of the Elements is 150 years old this year.

rays. This is a 3-stage process, via Deuterium [Hydrogen-2] and Helium-3, liberating 2 positrons, 2 neutrinos and 4 gamma rays. In the Sun the gamma rays produced are converted to visible light – mostly – with some ultra-violet and infra red radiation as well. This is the story of most stars.

Another reaction in the Sun takes place much more slowly and with less certainty. A Helium nucleus interacts with neutrons, one of which transmutes to a proton and electron [p+e=n], to make the next stable element – Lithium-7. This reaction can go into reverse as well.

In larger stars, a new reaction takes place. Helium is squeezed together to form Beryllium-8: 2 x [Helium] → ← Beryllium-8. This requires energy – obtained from gravity. However Beryllium-8 is somewhat unstable and can fall apart quite easily to recreate Helium-4. However, over a long period of time, the effect of gravity is to slowly build up Beryllium-8. Then comes a tipping point. As the star evolves, Helium-4 is forced to interact with Beryllium-8, at higher temperatures, to form Carbon-12 – one of the most stable elements of the periodic table. This manifests itself as a 'flash', much in the same way as in a nova, as the Beryllium converts to Carbon.

SCIENCE SLOT

If you put a bigger fuel tank in a car it will travel much further/last longer. If you put more fuel in a star, something rather different happens. It will burn up that fuel exponentially faster, hotter, more violently and with a more devastating outcome.

In stars of about 5 to 10 times the mass of the Sun the next phase of nucleosynthesis takes place. At core temperatures of upwards of 50 million degrees, Carbon-12 and Hydrogen-1 form Nitrogen-13 – an unstable form of this element – plus a gamma ray photon. Nitrogen-13 then transmutes into Carbon-13 [fairly stable] releasing a positron, an electron neutrino and more energy. Carbon-13 captures a proton [H-1] forming Nitrogen-14 – which is stable again. This is good, because not only are we made from Carbon but Nitrogen makes up a good portion of our atmosphere! Next, Nitrogen-14 captures a proton to make Oxygen-15 [unstable] plus a gamma ray, which then transmutes to Nitrogen-15 [fairly stable] and a gamma ray and electron neutrino, N-15 captures more Hydrogen [H-1] and transmutes to Oxygen-16 – stable – even better as we breathe that to live! This is collectively known as the CNO process.

In even heavier stars – 10-20 solar masses – a new process kicks in once the Oxygen is made in significant quantities and at temperatures above 50 million degrees. Oxygen-16 reacts with Hydrogen [H-1] to generate Fluorine-17, plus a gamma ray. F-17 transmutes to Oxygen-17 releasing a positron and electron neutrino. O-17 reacts with another proton to generate Nitrogen-14 [stable] and Helium-4 [stable]. Nitrogen-14 reacts with H-1 to give Oxygen-15, which decays to N-15 and a gamma ray. In even heavier stars, and at higher temperatures, Oxygen-17 reacts with H-1 to produce various unstable isotopes of Nitrogen, Oxygen and Fluorine in a cyclical reaction that converts 4 protons [H-1] into a Helium nucleus [He-4].

In still hotter stars, the 'Hot CNO' process takes place, whereby different isotopes of Nitrogen, Oxygen, Fluorine and now Neon [element 10] act as carriers to convert protons into Helium, releasing energy, positrons, neutrinos and gamma rays as they do so.

So, what about the rest of the periodic table?

Stable Beryllium and Boron [element-5]

are created by cosmic ray fission – where heavier elements (see later) are cracked open by high energy cosmic rays. These may have energies in the range of billions [GeV] or trillions [Tev] of times larger than visible light [just plain eV]. Some Lithium is also created by this process.

Low-mass stars also create a whole list of elements as they die.... Li, C, N, Sr, Y, Zr, Nb, Mo, Pd, As, Cd, In, Sn, Sb, Te, Xe, Cs, Ba, Hf, Ta, W, Hg, Tl, Pb, La, Ce, Pr, Nd + small amounts of the other Rare Earth group elements.
Massive star supernovae create small amounts of Carbon and Nitrogen, with larger amounts of O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca, Sc, transition metals, Ga, Ge, As, Se , Br, Kr, Rb.
Exploding White Dwarfs, cataclysmic variables and 'Black Widow' stars can create small amounts of Si, S, Cl, Ar, K, Ca and transition metals, as they die.
Merging Neutron stars (see later) create Nb, Mo, second row transition metals, Cs, Ba, 3rd row transition metals, Fr, Ra, and Uranium row metals. All of these except Fr are essential for our daily lives.

Within the periodic table there are a few 'interesting' elements. Technetium, element 43, is a very rare element on Earth. It should not be, because its neighbours Molybdenum [armour plating steel] and Ruthenium [exotic metal alloys for metal cutting] are quite stable, but it is. Technetium has to be artificially created on Earth. It is used in a special form – Technetium-99 metastable [Tc-99m*] – for Positron Emission Tomography in hospitals. If you have this therapy please don't go on holiday as you are actually quite radioactive for about a week after the injection of Tc-99m*! In nature, Tc-99m* is made in high luminosity asymptotic giant branch [AGB] red giant stars, from Zirconium, by the process Zr-96 + H-1 → Nb-97 [Niobium – rare on Earth]. Nb-97 + H-1 → Mo-98. Mo-98 + H-1 → Tc-99m*. By this process 3 protons are converted to 3 neutrons with a significant release of energy. In the mid-1980s, another isotope of Technetium – Tc-98, which has a half-life of about 4.2 million years, was discovered, using spectroscopy, in a handful of AGB stars. These are highly evolved stars about to go supernova. Because Tc-98 is unstable these stars must be continually re-creating it from simpler elements in the thermonuclear process. One such star – R-Geminorum, is an S-class star in the winter constellation of Gemini. It is currently converting Helium to heavier

elements at a prodigious rate and will go supernova in a few million years or so. If you want to find it, R-Gem is located to the south [right] of Delta-Gem, Wassat, and above Zeta-Gem, Mekbuda.

Over time, massive stars build up a layered structure – similar to an onion – comprising discrete layers of heavier elements towards the core. So long as the inner-most layer at the core is Manganese [element-25] or lighter, the star is 'safe' and thermonuclear reactions generate energy. However the moment Iron – element 26 – is formed the star is doomed, because this requires energy. The balance between thermonuclear energy pushing the star 'up and out' and gravity trying to 'crush' the star down tips in favour of the latter. The outer layers of the star – containing elements such as Be, C, O, Ne, Mg, Si, S, Ar, Ca and Ti – fall towards the core releasing gravitational energy crushing the Iron core, triggering a supernova, resulting in the rapid expansion of the blast wave from the Iron transmuting into much heavier elements. This releases high quantities of neutrinos.

From Iron, Nickel is formed – as Ni-56 [element 28] – as a remnant of the blast, along with Copper-58 [element-29], Cobalt-60 [element 27] and Zinc-62 [element 28]. These isotopes are very unstable and decay rapidly [releasing gamma rays] generating even more energy.

Other heavier elements such as Gallium, Germanium, Arsenic and Selenium are minor constituents of supernovae explosions and are somewhat toxic to humans. More useful elements such as Bromine are also formed. The heavy stuff – Strontium, Yttrium and Zirconium – is only formed in the atmospheres of red giant stars, as oxides which are present in the form of 'grains' and can be detected using infra-red sensitive cameras on [Space] telescopes such as Spitzer. S-class stars, such as R. Geminorum, R and Chi Cygni, W Aquilae and R, RR and X Andromidae are all stars of this class. These are pulsating (very) Red Super- and Hypergiant stars. They are capable of synthesising elements such as the metals including Silver, Mercury and Lead.

Most of the heavy elements, such as Gold, Platinum, Samarium – important in high field magnets for electric cars – are created by neutron star mergers. Neutron stars – with masses of about 20 solar

masses – often occur in pairs, because of how they are created in clusters of massive stars. As time goes by they begin to interact gravitationally, in a 'dance of death'. With sizes of only a few tens of kilometres, once they get as close as about 20km, gravitational tides force them to merge over timescales of a few tens of milliseconds. Releasing massive quantities of gravitational potential energy as they merge, this is the crucible to form the really heavy stuff – elements such as the Lanthanide series of rare Earths [e.g. Samarium and Lanthanum – important for super-conducting magnets] and Lanthanides – e.g. Thorium, Uranium and Plutonium and beyond. These then decay by nuclear fission generating a second 'pulse' or pulses of energy, almost completely destroying the stars and creating a black hole in the process, and releasing typically 20 to 50 solar masses of energy [$E=mc^2$ and all that].

As Carl Sagan says – We are made from star stuff.

Robert Williams

For more details of IYPT please look here.... https://www.iypt2019.org/

Oxygen	65%	Important in all physiological processes
Carbon	18.5%	Proteins [muscles etc.] , Enzymes[metabolism]
Hydrogen	9.5%	Important in all physiological processes
Nitrogen	3.2%	Proteins [muscles etc.] , Enzymes[metabolism]
Calcium	1.5%	Bones and Enzymes[metabolism]
Phosphorus	1.0%	Bones and Enzymes[metabolism]
Potassium	0.5%	Brain function and nerves
Sulphur	0.3%	Proteins [muscles etc.] , Enzymes[metabolism]
Sodium	0.2%	Blood chemistry, brain function and nerves
Chlorine	0.2%	Blood chemistry
Magnesium	0.1%	Many bodily functions
14 trace elements	0.1%	Enzymes, metabolic process

This table shows the constituents of the human body and what they are used for - see if you can work out which stars they all came from!

SCIENCE SLOT 2

The Supermassive Black Hole in Galaxy M87

Using the Event Horizon Telescope, scientists obtained an image of the black hole at the center of galaxy Messier 87 (M87), outlined by emission from hot gas swirling around it under the influence of strong gravity near its event horizon.

Credit: Event Horizon Telescope collaboration

Many if not most people have heard of black holes, astronomical objects that are so dense that even light cannot escape their huge gravitational field. Fewer people perhaps have heard of supermassive black holes (SBHs). Astronomers have believed for many years that these objects, with a typical mass equivalent to 1000 million times the mass of our own Sun, lie at the heart of most galaxies. In fact, this year marks the 50th anniversary of the publication of the scientific paper that first proposed that there are SBHs at the centre of galaxies. For anyone who is interested, and has access to a scientific research library, that paper is

D. Lynden-Bell, “Galactic nuclei as collapsed old quasars”, Nature 223 (5207), pp. 690-694, 1969.

There are thought to be three types of black holes, which form in different ways:

• Primordial black holes – these are around the size of an atom, but with the mass of a large mountain, and are

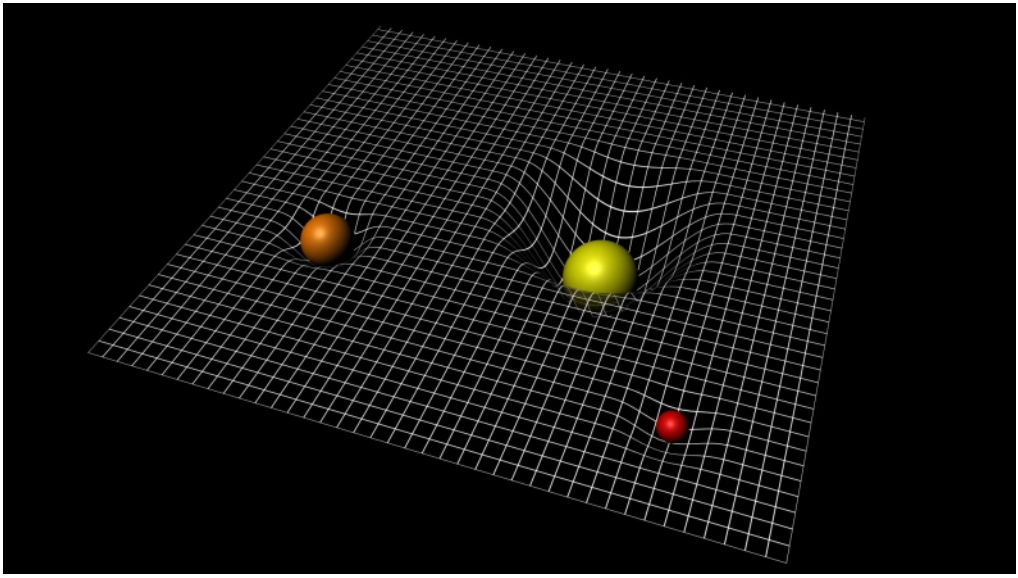
believed to have been formed very early in the life of the universe, very soon after the Big Bang;

• Stellar black holes – these form when the center of a massive star collapses in upon itself;

• Supermassive black holes – it is believed these form at the same time as the galaxy in which they are located, and their size is related to the size and mass of that galaxy.

This article is about supermassive black holes, and in particular, the photograph of the SBH which was published by the scientific team that obtained it on 10th April 2019.

Before we get into more detail, we should take a step back and consider the characteristics of a Black Hole. To understand this you must first get to grips with General Relativity – but only in a very basic way! Einstein's Theory says that space (or more accurately the space-time continuum) curves in the presence of mass. This is illustrated on the diagram below, but remember this is a 2-dimensional representation of a 3-dimensional effect. It can be difficult to

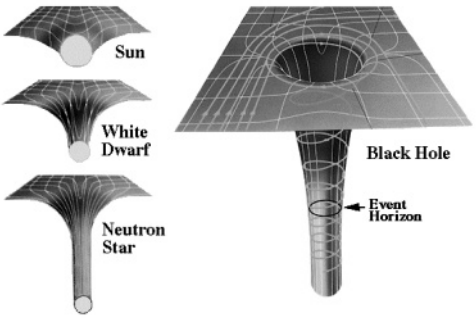


The diagram illustrates how a mass, such as a planet or a star, will distort space-time. A real-life example in 2-D would be where a large but extremely thin sheet of rubber suspended horizontally in mid-air would be distorted by, say, a few heavy snooker balls resting upon it.

SCIENCE SLOT 2

get your head around space becoming curved, whereas it is easy to visualise a 2-dimensional surface becoming curved, which is why this analogy is very often used.

Einstein's Theory of General Relativity predicts that a sufficiently compact mass can deform space-time to form a black hole, with a gravitational field so strong that nothing, not even light, can escape from it. Black holes of stellar mass are formed when stars with a mass of more than around 3 times the mass of our Sun collapse at the end of their life cycle. A



The figure illustrates the impact that a Black Hole has on the space-time continuum, and compares it to 2-D representations of the distortions associated with the Sun, a White Dwarf star and a Neutron Star. The Black Hole's Event Horizon is shown – nothing can escape from beyond this point, not even any form of electromagnetic radiation, including visible light, X-rays and Gamma rays.

black hole has a gravitational pull so intense that nothing, not even light, can escape it once inside a certain region called the event horizon.

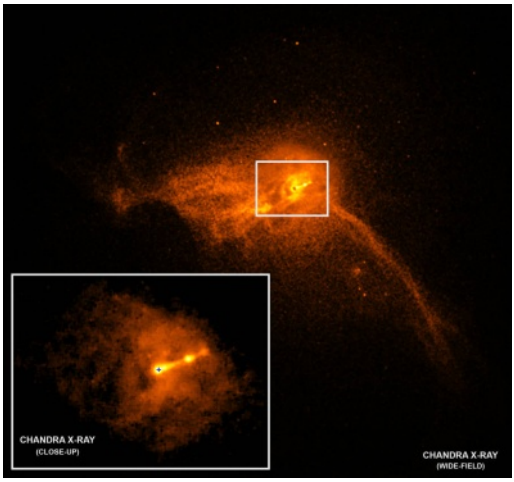
The diagrams shown opposite are based on stellar size black holes, but the same principles apply for SBHs. As gas and dust are sucked in, the material is accelerated and heated to very high temperatures, which results in the emission of X-ray light. A SBH produces huge amounts of X-ray radiation. By its very nature, a Black Hole cannot be seen. The hot disk of material that encircles it shines bright, however, and against a bright backdrop, such as this disk, a black hole appears to cast a shadow, and this is what we see in the image at the top of this article. It shows the shadow of the SBH in the center of M87, which is an elliptical galaxy some 55 million light-years from Earth. The SBH is 6.5 billion times the mass of the Sun, which even by the standards of SBHs is very large; in fact, it is considered to have one of the highest known masses for such an object.

This SBH is also physically large, with a radius equal to around 120 times the Earth-Sun distance. The rotating disk of ionized gas surrounding the SBH has

a maximum diameter of 25,000 times the Earth-Sun distance, which also equates to around 640 times the radius of the Solar System. It is this massive size that helps to make the environs of the SBH visible, even at a distance from Earth of 55 million light-years.

The SBH image was captured by scientists working in the Event Horizon Telescope (EHT) collaboration (https://eventhorizontelescope.org). Eight ground-based radio telescopes around the globe were made to work together as if they were one giant telescope the size of the Earth. This was a huge scientific undertaking, involving highly synchronized observations and petabytes of data (note – one petabyte is one thousand million Gigabytes, so we are talking about a massive amount of data here).

There is a wide range of scientific questions that scientists hope this continuing research will help to answer. For example, it is uncertain at the moment why particles get such a huge energy boost around black holes, becoming very large jets that rush away from the Black Hole poles at almost the speed of light. When material falls into the Black hole, where does the energy go? This is a topic of research that is at the forefront of modern astrophysics, covering the whole range of black holes. For example, there is a huge body of scientific research based on jet formation in X-ray binary stars, to name just one area of activity. It is hoped that the EHT and associated work will take a further step forward in understanding these phenomena.



Running in parallel with the EHT work, several NASA platforms were part of a wider effort to observe the SBH using different light wavelengths. The purpose of this work was to use data from these missions to match up with any changes in the SBH observations made by the EHT. One of these, the Chandra X-ray Observatory, obtained this image of the core of the M87 galaxy.

Credit:NASA/CXC/Villanova University/J. Neilsen

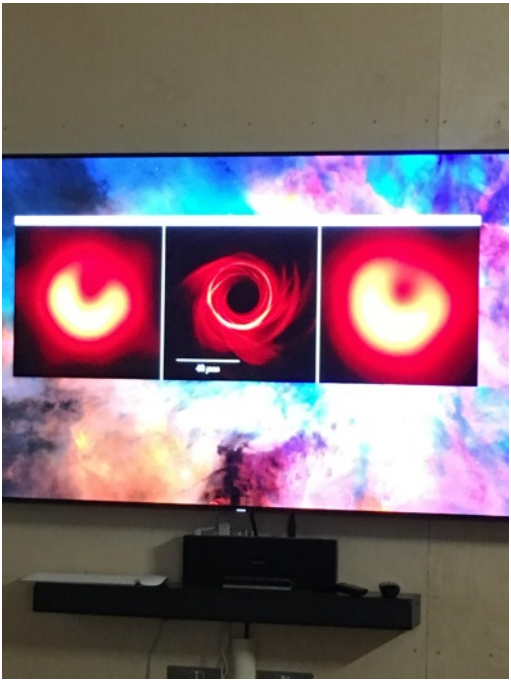
SCIENCE SLOT 2

And finally – earlier in this article there was a reference to a 50th anniversary. 2019 is also the 100th anniversary of the first confirmation of Einstein's Theory of General Relativity. During a total solar eclipse in 1919, Sir Arthur Eddington observed the location of stars close to the edge of the eclipse, demonstrating that they appeared to be at a slightly different position to where the observers would have expected them to be seen. The light from these stars had in fact been bent as it passed by the Sun, thus proving the curvature of space-time by the Sun's gravity. This made Einstein famous and the story appeared on the front page of most major newspapers. As did the M87 photographs 100 years later!

Trevor Robinson
(Trevor is the KOAS treasurer)

Footnote – another scientific paper worth looking at is one published by the EHT team:

The Event Horizon Telescope Collaboration, "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole", The Astrophysical Journal Letters, 875:L1 (17pp), 2019.



To bring all this topical and fascinating scientific activity close to home – the image above is a photograph of the large display screen in our Gillian Dickinson Astro-imaging Academy, taken on the day that the M87 images were published.

The picture on the left of the display screen is an actual image from the EHT observations. The image on the right is derived from a computer simulation of what the photograph might look like, based on theoretical considerations. They are amazingly similar!

GALLERY

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

newsletter@kielderobservatory.org

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

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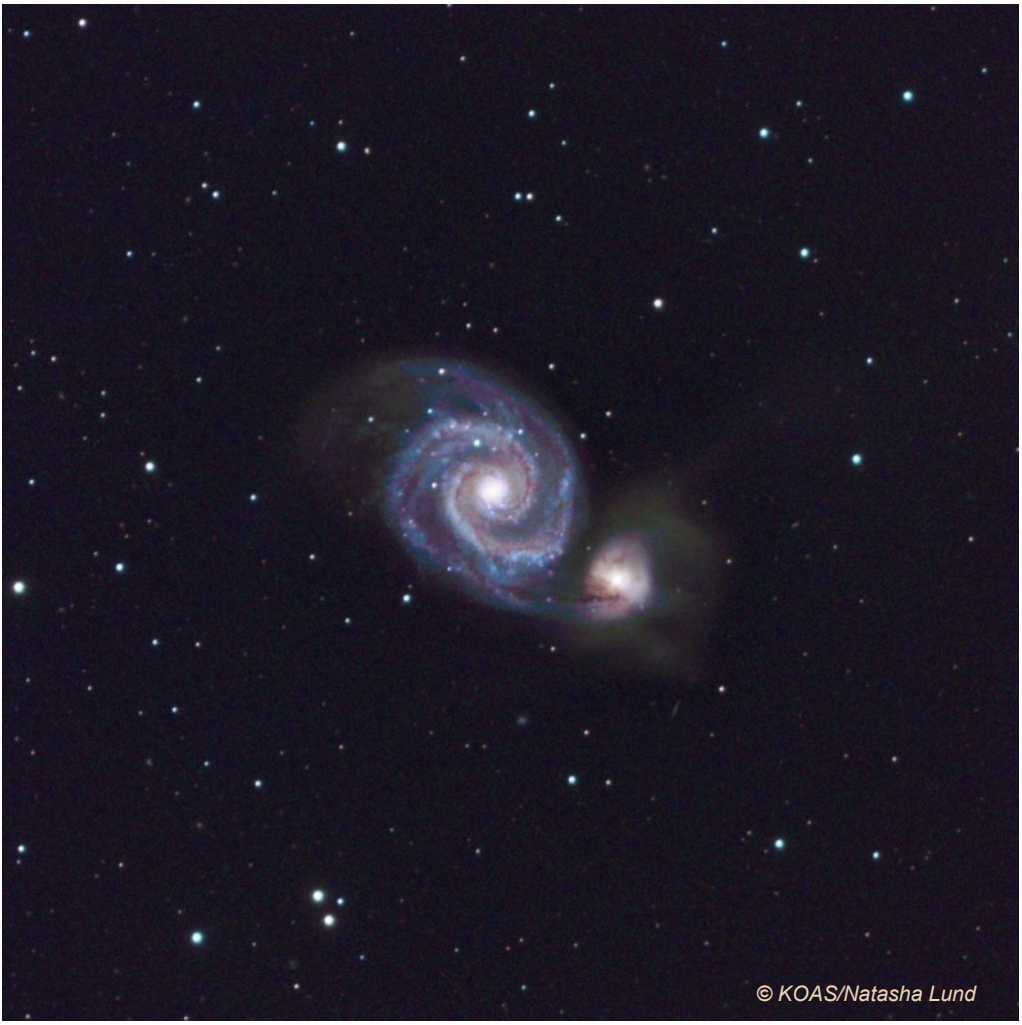
The Pinwheel Galaxy, Messier 101, is high up in the sky in Ursa Major at the beginning of the night at this time of year. Discovered in 1781, it lies about 20 million light-years away, and is one of our nearer galactic neighbours. This image was taken from the Gillian Dickinson Astro-imaging Academy using an Atik 4120EX camera on the 5" Takahashi FSQ106 EDX4 telescope. It is a combination of 12 five-minute exposures.

GALLERY



Also high up, and just over the border from Ursa Major in Canes Venatici, is the Whirpool Galaxy, Messier 51. It is at a similar distance to Messier 101 and is believed to be two galaxies interacting. This image was taken from the Gillian Dickinson Astro-imaging Academy using an Atik 4120EX camera on the 5" Takahashi FSQ106 EDX4 telescope. It is a combination of 9 ten-minute exposures.

This rather spectacular image is a 40-minute star trail over the observatory, taken at the end of March

Late Night Dark Skies – 3rd May

"We arrived at the location early and were greeted with heavy snow. as we sat in the car waiting to go into the late night dark skies event, we were a little disappointed with the weather conditions. However when we went in the team were really geared up and put our minds at rest. after 30 mins the sky cleared to reveal the most spectacular view I have ever seen. the milky way was right above our heads. We looked at planets, nebula, galaxies.....you name it we seen it all. The event team were so relaxed, they set up all the equipment and just let you use everything at your own leisure. This has to be one of the best things I have ever done, If you have not done this then its a must. Thanks for a great night!!!"

Philip, Sunderland

"Fantastic from start to finish, great experience would absolutely come back again. Felt it was done in a humoured way so beginners like myself could even understand the talks. The team were fantastic, made us all feel welcome, great idea to give for a birthday, Christmas or wedding present giving an experience!"

Faith, Hawick

"We thought this was a brilliant event. The knowledge and enthusiasm of all the staff shone through. Jessie was excellent at explaining everything, and we intend to come back again to the late night one in autumn to see if we can see the milky way. Thank you so much to all the staff, they helped to make it such a memorable night. They could not have done anymore to make the night any better :: we will be back!"

Vicki , Whitley Bay