NWASNEWS

Volume26 Issue 9

MAY 2021

Newsletter for the Wiltshire, Swindon, Beckington, Bath Astronomical Societies

BLACK HOLE EDITION

I'm am sorry I may have confused our speaker topic for this evening, several reasons, but it will not be Black Holes. (Asterisms talk by Martin was booked to replace one about the Big Bang—but during a talk about the Spanish Observatory and memories coming up on Facebook I thought it was asterisms and the speaker replied Big Bang. Either way our speaker is eminently capable, and is awaiting publication of has observational book from Springer about lesser known stellar asterisms, had had taught astronomy of the Big Bang.

To add to my personal confusion whilst putting together the space news section of this bumper 44 page newsletter two topics were coming up through April and May. The fantastic flight of a drone in the thin atmosphere of Mars (lest we forget helicopters can't fly at the height of Everest here on Earth because the height at that altitude is too thin for the blades to achieve enough bite to create lift. At sea level normal is 1013 millibars, on Everest it is about a third of this 310 millibars. Mars is around 6 to 10 millibars. Not a lot.

Even at this pressure the rover Perseverance has managed to extract oxygen from the atmosphere. Please check the news section.

The next topic that kept recurring with different research has been black holes. From their interference when colliding with neutron stars enabling a standard of measurement to be used, spaghettification of stars falling into the event horizon at a black hole, further examination of data that provided the first image of a black hole has been further refined and magnetic streams have been seen around the black hole event horizon. Also discovery of one of the smallest black holes ever detected has been found a mere 1200 light years away (not close enough to affect us).

With this in mind I thought it was time to take a look at where science is with the theories around black holes, hence a special edition, and further confusion for me.

April also saw a few transits of the Sun by the International Space Station. While few April night passes were visible this means it was passing in the day time and close to the Sun's declination. A fabulous set of images were taken and compiled by John Dartnell. See the image on the back page.

On the subject of Space Stations, China has begun launches of a core unit for their own station, and Russia is planning for replacement of the ISS…. More space filling.

Zoom meeting.
Topic Wiltshire AS Zoom Meeting
Speaker Martin Griffiths: Asterisms
Time: May 4, 2021 07:45 PM London
Join Zoom Meeting
https://us02web.zoom.us/j/89153768752?pwd=Syt4TnBsd1RldzZZY081SExXMWNzdz09
Meeting ID: 891 5376 8752
Passcode: 419867

Clear skies

Andy

Messier M101 in Ursa Major (just above the middle star of the handle, Mizar.

Also known as the Pinwheel Galaxy with its face on spiral some 21.8 million light years away and more distant galaxy 103mly away ngc5473

Almost the text book spiral galaxy, though Arp sees the one heavy arm which is very active giving it unusual status.

It almost twice the size of our own Milky Way galaxy.

Nikon D810a, 2 minutes exposure x10 stacked in Sequator.

Andy

Wiltshire Society Page

Wiltshire Astronomical Society

Web site: www.wasnet.org.uk

Facebook members page: https://www.facebook.com/groups/wiltshire.astro.society/

Meetings 2020/2021.

During COVID19 ZOOM meetingd

HALL VENUE the Pavilion, Rusty Lane, Seend

Meet 7.30 for 8.00pm start

SEASON 2020/21

2021

4 May Martin Griffiths Some Lesser Known Asterisms

1 Jun Robert Harvey/Understanding the Universe.

Thank you Peter and those that have helped get a list together in the circumstances.

Membership Meeting nights £1.00 for members £3 for visitors

Wiltshire AS Contacts

Andy Burns Chair, anglesburns@hotmail.com

Andy Burns Outreach and newsletter editor.

Bob Johnston (Treasurer) Debbie Croker (vice Treasurer)

Philip Proven (Hall coordinator) Dave Buckle (Teas)

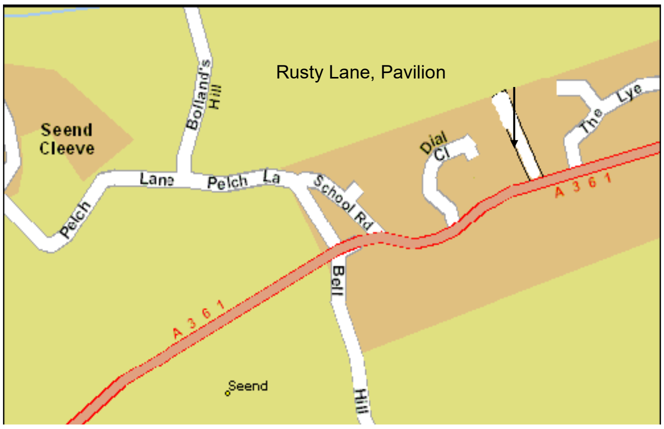
Peter Chappell (Speaker secretary)

Nick Howes (Technical Guru)

Observing Sessions coordinators: Chris Brooks, Jon Gale,

Web coordinator: Sam Franklin

Contact via the web site details.



Observing Sessions see back page

Martin Griffiths

Martin Griffiths BSc. (First Class Honours) MSc. (Distinction) FRAS. FHEA.

Martin Griffiths is an enthusiastic science communicator, lecturer, writer and professional astronomer utilizing astronomy, history and science fiction as tools to encourage greater public understanding of science.

He was a founder member of NASA's Astrobiology Institute Science Communication Group, active between 2003-2006 and managed a multi-million pound ESF programme in Astrobiology for adult learners between 2003-2008. Martin has written and presented planetarium programmes for key stages 1, 2 and 3 and has been an adviser to several museum projects

Martin continues to promote cross-disciplinary links between science and culture that reflect his educational background and interests. He has written monographs on the science communication of the proto-feminist Margaret Cavendish, Duchess of Newcastle; and the 18th century scientist, assay master and political adviser Joseph Harris of Breconshire. He is also a regular contributor to the online science journal LabLit: the culture of science in fiction and fact. Recently he assisted the Brecon Beacons National Park in surveying the darkness of the night sky for their successful bid for the International Dark Sky Association's Dark Sky Reserve Status – the first such reserve in Wales.

Martin is a Fellow of the Royal Astronomical Society; a Fellow of the Higher Education Academy; a member of the British Astronomical Association; the Webb Deep-Sky Society; the Society for Popular Astronomy, The Astronomical Society of the Pacific and the Astronomical League. He is also a local representative for the BAA Campaign for Dark Skies. Martin broadcasts regularly on BBC Wales radio and has appeared on science programmes for the BBC, Einstein TV, Granada TV and the Discovery Channel. He is also a member of the Honourable Society of Cymmrodorion, dedicated to promoting the science, arts and literature of Wales.

He is now working for Dark Sky Wales in their outreach work to schools and adult learning groups. He has now written four books in the Springer Astronomy Series. And completed another book on the myths in the skies.

Swindon Stargazers

Swindon's own astronomy group

Physical meetings suspended

Due to the Covid crisis our meetings, like many other physical meetings have been suspended and replaced with Zoom meetings.

Next Zoom Meeting: Gary Poyner

Our next meeting will be held on Friday, 21 May when the speaker will be Gary Poyner.

Gary Poyner joined the British Astronomical Association in 1978, and served as Director of the Variable Star Section for five years - 1995 to 1999. He was also Variable Star editor for 'The Astronomer' magazine from 2000-2018. He is primarily a visual observer, and has been observing Variable Stars since 1975 following 10 years of general observing (mainly Jupiter). His main interests are Cataclysmic and Eruptive Variables, which he observes at every opportunity with his 51cm and 22cm reflectors from his observatory in North Birmingham.

On the local society side of things, he was a junior member at the Birmingham AS in the early 1970's, past President of Wolverhampton AS and is currently chairman of the Heart of England AS, where he has been a member for over 40 years.

His talk: Variable Stars and the Double Cluster

Ad-hoc viewing sessions postponed

All ad-hoc meetings are currently cancelled until further notice.

Regular stargazing evenings are being organised near Swindon. To join these events please visit our website for further information.

Lately we have been stargazing at Blakehill Farm Nature Reserve near Cricklade, a very good spot with no distractions from car headlights.

We often meet regularly at a lay-by just outside the village of Uffcott, near Wroughton. Directions are also shown on the website link below.

Information about our evenings and viewing spots can be found here:

http://www.swindonstargazers.com/noticeboard/noticeboard06.htm

For insurance reasons you need to be a club member to take part. If you think you might be interested email the organiser Robin Wilkey (see below). With this you will then be emailed regarding the event, whether it is going ahead or whether it will be cancelled because of cloud etc.

We are a small keen group and I would ask you to note that you DO NOT have to own a telescope to take part, just turn up and have a great evening looking through other people's scopes. We are out there to share an interest and the hobby. There's nothing better than practical astronomy in the great cold British winter! And hot drinks are often available, you can also bring your own.

Enjoy astronomy at it's best!

Meetings at Liddington Village Hall, Church Road, Liddington, SN4 0HB – 7.30pm onwards

The hall has easy access from Junction 15 of the M4, a map and directions can be found on our website at:

http://www.swindonstargazers.com/clubdiary/directions01.htm

Meeting Dates for 2021

Friday 21 May Meeting or Zoom

Programme: Gary Poyner: Variable Stars and the Double Cluster

Friday 18 June 19.30 Meeting or Zoom

Programme: Graham Bryant: Pluto: from Myth to a Voyage of Discovery

July & August - No Meetings

Friday 17 September 19.30 onwards - Meeting or Zoom

Programme: Dr Elizabeth Pearson: Planetary Rovers

Friday 15 October 19.30 onwards - Meeting or Zoom

Programme: Charles Barclay: Oldest GOTO telescope in the World (Provisional)

Friday 19 November 19.30 onwards - Meeting or Zoom

Programme: TBA

Friday 10 December 19.30

Programme: Christmas Social

Website:
http://www.swindonstargazers.com

Chairman: Robin Wilkey

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BECKINGTON ASTRONOMICAL SOCIETY

Society Details & Speakers programme can be found on our Website www.beckingtonas.org

General enquiries about the Society can be emailed to chairman@beckingtonas.org.

Our Committee for 2016/2017 is

Chairman: Steve Hill (email chairman@beckingtonas.org)
Treasurer: John Ball
Secretary: Sandy Whitton
Ordinary Member: Mike Witt

People can find out more about us at www.beckingtonas.org

Meetings take place in Beckington Baptist Church Hall in Beckington Village near Frome.

See the location page for details of how to find us on our website…………

Post Code for Sat Nav is BA11 6TB.

Our start time is 7.30pm

STAR QUEST ASTRONOMY CLUB

This young astronomy club meets at the

Sutton Veny Village Hall.

Second Thursday of the Month.

Meet at Sutton Veey near Warminster.

BATH ASTRONOMERS

Bath Astronomers are holding webinar sessions linking in with Stargazers web sight.

Feb24
Talk by Nora Eisner, Planet Hunters TESS: discovering exoplanets using citizen science
24 Feb - Zoom
Wednesday 24th February – Monthly meeting. This month's talk will be given by Nora Eisner, Department of Physics, University of Oxford. She is a PhD student at the University of Oxford where her research focuses on citizen-powered exoplanet discoveries using NASA's TESS (Transiting Exoplanet Survey Satellite) data. She is working under the supervision of Professor Chris Lintott and Professor Suzanne Aigrain. The talk is entitled "Planet Hunters TESS: discovering exoplanets using citizen science". Nora's research focuses on citizen-powered exoplanet discoveries using TESS data via Planet Hunters TESS. As the leader of this exciting project she collates the returns from the citizen science campaigns, analyse them, and follows-up on the most promising detections using ground based facilities. The analysis of the extremely large time-series data sets has a strong emphasis on applying various statistical processes, as well as using machine learning in order detect exciting new planet systems that were missed by the main pipelines and other teams of professional astronomers. Abstract: Since the first unambiguous discovery of an exoplanet in 1995, over 4,000 more have been confirmed, and studies of their characteristics have unveiled an extremely wide range of planetary properties in terms of their mass, size, system architecture and orbital periods. While dedicated planet detection algorithms are able to identify the vast majority of planets in data obtained with spaced satellites, they miss certain types of planets that are key to the further development of our understanding of how these systems form and evolve. In this talk, I will discuss how we can harness the power of citizen science, and in particular Planet Hunters TESS, to find these more elusive planets with the help of tens of thousands of volunteers. I will present some of our exciting findings, including both planets and exotic stellar systems, and show that human classification still plays a vital role in a world that is becoming increasingly automated. Bath Astronomers monthly meeting for all members and new comers to meet up, enjoy perhaps a new topic and a cup of tea and a biscuit. Held on the last Wednesday of every month online or at the Herschel Museum of Astronomy, 19 New King Street.

May26
Talk by Pete Williamson FRAS
26 May - Herschel Museum of Astronomy
Wednesday 26th May – Monthly meeting. Topic: From Herschel to Hawkwind
Jun30
Talk by Chris Starr, Cassini and Saturn
30 Jun - Herschel Museum of Astronomy
Wednesday 30th June – Monthly meet

BLACK HOLES

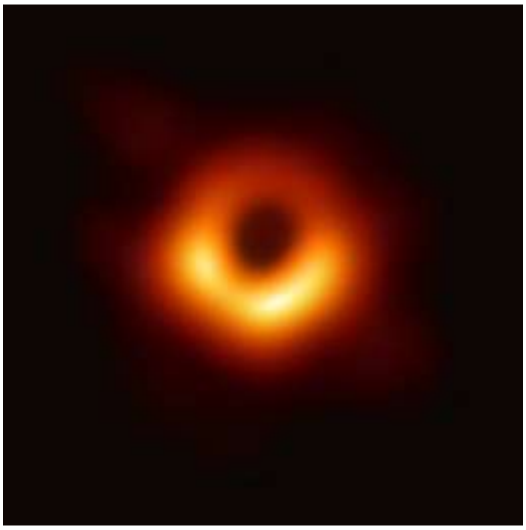
A **black hole** is a region of **spacetime** where **gravity** is so strong that nothing—no **particles** or even **electromagnetic radiation** such as **light**—can escape from it.[1] The theory of **general relativity** predicts that a sufficiently compact **mass** can deform spacetime to form a black hole.[2][3] The boundary of no escape is called the **event horizon**. Although it has an enormous effect on the fate and circumstances of an object crossing it, according to general relativity it has no locally detectable features.[4] In many ways, a black hole acts like an ideal **black body**, as it reflects no light.[5] [6] Moreover, **quantum field theory in curved spacetime** predicts that event horizons emit **Hawking radiation**, with **the same spectrum** as a black body of a temperature inversely proportional to its mass. This temperature is on the order of billionths of a **kelvin** for **black holes of stellar mass**, making it essentially impossible to observe directly.

Objects whose **gravitational fields** are too strong for light to escape were first considered in the 18th century by **John Michell** and **Pierre-Simon Laplace**. The first modern solution of general relativity that would characterize a black hole was found by **Karl Schwarzschild** in 1916, and its interpretation as a region of space from which nothing can escape was first published by **David Finkelstein** in 1958. Black holes were long considered a mathematical curiosity; it was not until the 1960s that theoretical work showed they were a generic prediction of general relativity. The discovery of **neutron stars** by **Jocelyn Bell Burnell** in 1967 sparked interest in **gravitationally collapsed** compact objects as a possible astrophysical reality. The first black hole known as such was **Cygnus X-1**, identified by several researchers independently in 1971.

Black holes of stellar mass form when very massive stars collapse at the end of their life cycle. After a black hole has formed, it can continue to grow by absorbing mass from its surroundings. By absorbing other stars and merging with other black holes, **supermassive black holes** of millions of **solar masses** ($M_\odot$) may form. There is consensus that supermassive black holes exist in the centres of most **galaxies**.

The presence of a black hole can be inferred through its interaction with other **matter** and with electromagnetic radiation such as visible light. Matter that falls onto a black hole can form an external **accretion disk** heated by friction, forming **quasars**, some of the brightest objects in the universe. Stars passing too close to a supermassive black hole can be shred into streamers that shine very brightly before being "swallowed." If there are other stars orbiting a black hole, their orbits can be used to determine the black hole's mass and location. Such observations can be used to exclude possible alternatives such as neutron stars. In this way, astronomers have identified numerous stellar black hole candidates in **binary systems**, and established that the radio source known as **Sagittarius A***, at the core of the **Milky Way** galaxy, contains a supermassive black hole of about 4.3 million solar masses.

On 11 February 2016, the **LIGO Scientific Collaboration** and the **Virgo collaboration announced the first direct detection** of **gravitational waves**, which also represented the first observation of a black hole merger.[11] As of December 2018, eleven **gravitational wave events** have been observed that originated from ten merging black holes (along with one binary **neutron star merger**). On 10 April 2019, the first direct image of a black hole and its vicinity was published, following observations made by the **Event Horizon Telescope** (EHT) in 2017 of the supermassive black hole in **Messier 87**'s **galactic centre**. In March 2021, the EHT Collaboration presented, for the first time, a **polarized-based image** of the black hole which may help better reveal the forces giving rise to **quasars**.



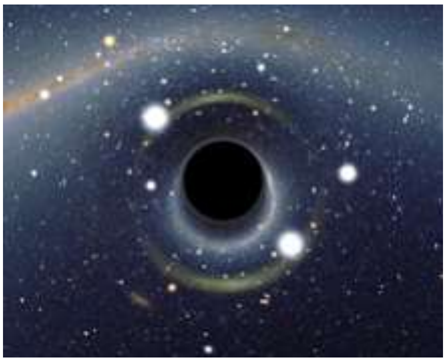
The **supermassive black hole** at the core of **supergiant elliptical galaxy Messier 87**, with a mass about 7 billion times that of the Sun, as depicted in the first **false-colour** image in radio waves released by the **Event Horizon Telescope** (10 April 2019). Visible are the crescent-shaped emission ring and central shadow, which are gravitationally magnified views of the black hole's photon ring and the photon capture zone of its **event horizon**. The crescent shape arises from the black hole's **rotation** and **relativistic beaming**; the shadow is about 2.6 times the diameter of the event horizon.

Simulation of **gravitational lensing** by a black hole, which distorts the image of a **galaxy** in the background

Gas cloud being ripped apart by black hole at the centre of the **Milky Way** (observations from 2006, 2010 and 2013 are shown in blue, green and red, respectively).

As of 2021, the nearest known body thought to be a black hole is around 1500 **light-years** away (see **List of nearest black holes**). Though only a couple dozen black holes have been found so far in the **Milky Way**, there are thought to be hundreds of millions, most of which are solitary and do not cause emission of radiation, so would only be detectable by **gravitational lensing**.

History



Simulated view of a black hole in front of the **Large Magellanic Cloud**. Note the **gravitational lensing** effect, which produces two enlarged but highly distorted views of the Cloud. Across the top, the **Milky Way** disk appears distorted into an arc.

The idea of a body so massive that even light could not escape was briefly proposed by astronomical pioneer and English clergyman **John Michell** in a letter published in November 1784. Michell's simplistic calculations assumed such a body might have the same density as the Sun, and concluded that such a body would form when a star's diameter exceeds the Sun's by a factor of 500, and the surface **escape velocity** exceeds the usual speed of light. Michell correctly noted that such supermassive but non-radiating bodies might be detectable through their gravitational effects on nearby visible bodies. Scholars of the time were initially excited by the proposal that giant but invisible stars might be hiding in plain view, but enthusiasm dampened when the wavelike nature of light became apparent in the early nineteenth century.

If light were a wave rather than a "**corpuscle**", it is unclear what, if any, influence gravity would have on escaping light waves. Modern physics discredits Michell's notion of a light ray shooting directly from the surface of a supermassive star, being slowed down by the star's gravity, stopping, and then free-falling back to the star's surface.

General relativity

*See also: **History of general relativity***

In 1915, **Albert Einstein** developed his theory of **general relativity**, having earlier shown that gravity does influence light's motion. Only a few months later, **Karl Schwarzschild** found a **solution** to the **Einstein field equations**, which describes the **gravitational field** of a **point mass** and a spherical mass.[29] A few months after Schwarzschild, Johannes Droste, a student of **Hendrik Lorentz**, independently gave the same solution for the point mass and wrote more extensively about its properties. This solution had a peculiar behaviour at what is now called the **Schwarzschild radius**, where it became **singular**, meaning that some of the terms in the Einstein equations became infinite. The nature of this surface was not quite understood at the time. In 1924, **Arthur Eddington** showed that the singularity disappeared after a change of coordinates (see **Eddington–Finkelstein coordinates**), although it took until 1933 for **Georges Lemaître** to realize that this meant the singularity at the Schwarzschild radius was a non-physical **coordinate singularity**. Arthur Eddington did however comment on the possibility of a star with mass compressed to the Schwarzschild radius in a 1926 book, noting that Einstein's theory allows us to rule out overly large densities for visible stars like Betelgeuse because "a star of 250 million km radius could not possibly have so high a density as the Sun. Firstly, the force of gravitation would be so great that light would be unable to escape from it, the rays falling back to the star like a stone to the earth. Secondly, the red shift of the spectral lines would be so great that the spectrum would be shifted out of existence. Thirdly, the mass would produce so much curvature of the spacetime metric that space would close up around the star, leaving us outside (i.e., nowhere)."

In 1931, **Subrahmanyan Chandrasekhar** calculated, using special relativity, that a non-rotating body of **electron-degenerate matter** above a certain limiting mass (now called the **Chandrasekhar limit** at 1.4 $M_\odot$) has no stable solutions.[35] His arguments were opposed by many of his contemporaries like Eddington and **Lev Landau**, who argued that some yet unknown mechanism would stop the collapse. They were partly correct: a **white dwarf** slightly more massive than the Chandrasekhar limit will collapse into a **neutron star**, which is itself stable. But in 1939, **Robert Oppenheimer** and others predicted that neutron stars above another limit (the **Tolman–Oppenheimer–Volkoff limit**) would collapse further for the reasons presented by Chandrasekhar, and concluded that no law of physics was likely to intervene and stop at least some stars from collapsing to black holes. Their original calculations, based on the **Pauli exclusion principle**, gave it as 0.7 $M_\odot$; subsequent consideration of strong force-mediated neutron-neutron repulsion raised the estimate to approximately 1.5 $M_\odot$ to 3.0 $M_\odot$ Observations of the neutron star merger **GW170817**, which is thought to have generated a black hole shortly afterward, have refined the TOV limit estimate to ~2.17 $M_\odot$.

Oppenheimer and his co-authors interpreted the singularity at the boundary of the Schwarzschild radius as indicating that this was the boundary of a bubble in which time stopped. This is a valid point of view for external observers, but not for infalling observers. Because of this property, the collapsed stars were called "frozen stars", because an outside observer would see the surface of the star frozen in time at the instant where its collapse takes it to the Schwarzschild radius.

Golden age

In 1958, **David Finkelstein** identified the Schwarzschild surface as an **event horizon**, "a perfect unidirectional membrane: causal influences can cross it in only one direction" This did not strictly contradict Oppenheimer's results, but extended them to include the point of view of infalling observers. Finkelstein's solution extended the Schwarzschild solution for the future of observers falling into a black hole. A **complete extension** had already been found by **Martin Kruskal**, who was urged to publish it.

These results came at the beginning of the **golden age of general relativity**, which was marked by general relativity and black holes becoming mainstream subjects of research. This process was helped by the discovery of **pulsars** by **Jocelyn Bell Burnell** in 1967, which, by 1969, were shown to be rapidly rotating neutron stars Until that time, neutron stars, like black holes, were regarded as just theoretical curiosities; but the discovery of pulsars showed their physical relevance and spurred a further interest in all types of compact objects that might be formed by gravitational collapse.

In this period more general black hole solutions were found. In 1963, **Roy Kerr** found **the exact solution** for a **rotating black hole**. Two years later, **Ezra Newman** found the **axisymmetric** solution for a black hole that is both rotating and **electrically charged**. Through the work of **Werner Israel**, **Brandon Carter**, and David Robinson the **no-hair theorem** emerged, stating that a stationary black hole solution is completely described by the three parameters of the **Kerr–Newman metric**: **mass**, **angular momentum**, and electric charge.

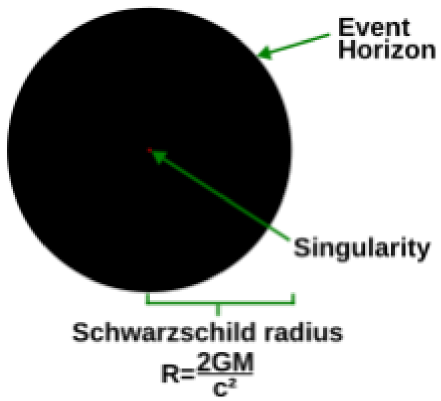
At first, it was suspected that the strange features of the black hole solutions were pathological artifacts from the symmetry conditions imposed, and that the singularities would not appear in generic situations. This view was held in particular by **Vladimir Belinsky**, **Isaak Khalatnikov**, and **Evgeny Lifshitz**, who tried to prove that no singularities appear in generic solutions. However, in the late 1960s **Roger Penrose** and **Stephen Hawking** used global techniques to prove that singularities appear generically. For this work, Penrose received half of the 2020 **Nobel Prize in Physics**, Hawking having died in 2018. Based on observations in **Greenwich** and **Toronto** in the early 1970s, **Cygnus X-1**, a galactic **X-ray** source discovered in 1964, became the first astronomical object commonly accepted to be a black hole.

Work by **James Bardeen**, **Jacob Bekenstein**, Carter, and Hawking in the early 1970s led to the formulation of **black hole thermodynamics**. These laws describe the behaviour of a black hole in close analogy to the **laws of thermodynamics** by relating mass to energy, area to **entropy**, and **surface gravity** to **temperature**. The analogy was completed when Hawking, in 1974, showed that **quantum field theory** implies that black holes should radiate like a **black body** with a temperature proportional to the surface gravity of the black hole, predicting the effect now known as **Hawking radiation**.

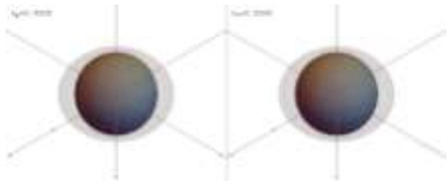
Etymology

John Michell used the term "dark star", and in the early 20th century, physicists used the term "gravitationally collapsed object". Science writer Marcia Bartusiak traces the term "black hole" to physicist **Robert H. Dicke**, who in the early 1960s reportedly compared the phenomenon to the **Black Hole of Calcutta**, notorious as a prison where people entered but never left alive.
The term "black hole" was used in print by ***Life*** and ***Science News*** magazines in 1963, and by science journalist Ann Ewing in her article "'Black Holes' in Space", dated 18 January 1964, which was a report on a meeting of the **American Association for the Advancement of Science** held in Cleveland, Ohio.
In December 1967, a student reportedly suggested the phrase "black hole" at a lecture by **John Wheeler**;[66] Wheeler adopted the term for its brevity and "advertising value", and it quickly caught on, leading some to credit Wheeler with coining the phrase.

Properties and structure



Simple illustration of a non-spinning black hole
The no-hair theorem postulates that, once it achieves a stable condition after formation, a black hole has only three independent physical properties: mass, electric charge, and angular momentum; the black hole is otherwise featureless. If the conjecture is true, any two black holes that share the same values for these properties, or parameters, are indistinguishable from one another. The degree to which the conjecture is true for real black holes under the laws of modern physics is currently an unsolved problem.
These properties are special because they are visible from outside a black hole. For example, a charged black hole repels other like charges just like any other charged object. Similarly, the total mass inside a sphere containing a black hole can be found by using the gravitational analogue of **Gauss's law** (through the **ADM mass**), far away from the black hole. Likewise, the angular momentum (or spin) can be measured from far away using **frame dragging** by the **gravitomagnetic field**, through for example the **Lense-Thirring effect**.
When an object falls into a black hole, any information about the shape of the object or distribution of charge on it is evenly distributed along the horizon of the black hole, and is lost to outside observers. The behavior of the horizon in this situation is a **dissipative system** that is closely analogous to that of a conductive stretchy membrane with friction and **electrical resistance**—the **membrane paradigm**. This is different from other **field theories** such as electromagnetism, which do not have any friction or resistivity at the microscopic level, because they are **time-reversible**. Because a black hole eventually achieves a stable state with only three parameters, there is no way to avoid losing information about the initial conditions: the gravitational and electric fields of a black hole give very little information about what went in. The information that is lost includes every quantity that cannot be measured far away from the black hole horizon, including **approximately conserved quantum numbers** such as the total **baryon number** and **lepton number**. This behavior is so puzzling that it has been called the **black hole information loss paradox**.



Gravitational time dilation around a black hole

Physical properties

The simplest static black holes have mass but neither electric charge nor angular momentum. These black holes are often referred to as Schwarzschild black holes after Karl Schwarzschild who discovered this **solution** in 1916. According to **Birkhoff's theorem**, it is the only **vacuum solution** that is **spherically symmetric**. This

any other spherical object of the same mass. The popular notion of a black hole "sucking in everything" in its surroundings is therefore correct only near a black hole's horizon; far away, the external gravitational field is identical to that of any other body of the same mass.
Solutions describing more general black holes also exist. Non-rotating **charged black holes** are described by the **Reissner–Nordström metric**, while the Kerr metric describes a non-charged rotating black hole. The most general **stationary** black hole solution known is the Kerr–Newman metric, which describes a black hole with both charge and angular momentum.
While the mass of a black hole can take any positive value, the charge and angular momentum are constrained by the mass. In **Planck units**, the total electric charge *Q* and the total angular momentum *J* are expected to satisfy

$${\displaystyle Q^{2}+\left({\tfrac {J}{M}}\right)^{2}\leq M^{2}\,}$$

for a black hole of mass *M*. Black holes with the minimum possible mass satisfying this inequality are called **extremal**. Solutions of Einstein's equations that violate this inequality exist, but they do not possess an event horizon. These solutions have so-called **naked singularities** that can be observed from the outside, and hence are deemed *unphysical*. The **cosmic censorship hypothesis** rules out the formation of such singularities, when they are created through the gravitational collapse of **realistic matter**.[2] This is supported by numerical simulations.
Due to the relatively large strength of the **electromagnetic force**, black holes forming from the collapse of stars are expected to retain the nearly neutral charge of the star. Rotation, however, is expected to be a universal feature of compact astrophysical objects. The black-hole candidate binary X-ray source **GRS 1915+105** appears to have an angular momentum near the maximum allowed value. That uncharged limit is

$${\displaystyle J\leq {\frac {GM^{2}}{c}},}$$

allowing definition of a **dimensionless** spin parameter such that

$${\displaystyle 0\leq {\frac {cJ}{GM^{2}}}\leq 1.}$$ [80][Note 1]

Black hole classifications		
Class	**Approx. mass**	**Approx. radius**
Supermassive black	10^5–10^{10} $M_\odot$	0.001–400 **AU**
Intermediate-mass black	10^3 $M_\odot$	10^3 km ≈ R_{Earth}
Stellar black	10 $M_\odot$	30 km
Micro black hole	up to M_{Moon}	up to 0.1 mm

Black holes are commonly classified according to their mass, independent of angular momentum, *J*. The size of a black hole, as determined by the radius of the event horizon, or Schwarzschild radius, is proportional to the mass, *M*, through

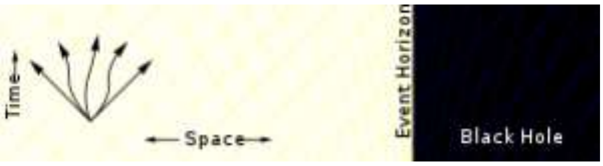
$$r_{\mathrm {s} }={\frac {2GM}{c^{2}}}\approx 2.95\,{\frac {M}{M_{\odot }}}~\mathrm {km,}$$

where r_s is the Schwarzschild radius and $M_\odot$ is the **mass of the Sun**. For a black hole with nonzero spin and/or electric charge, the radius is smaller, until an extremal black hole could have an event horizon close to

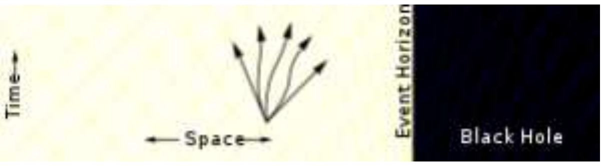
$$r_{\mathrm {+} }={\frac {GM}{c^{2}}}.$$

Event horizon

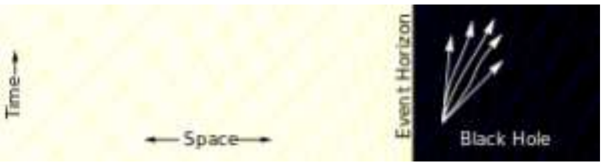
Main article: ***Event horizon***



Far away from the black hole, a particle can move in any direction, as illustrated by the set of arrows. It is restricted only by the speed of light.



Closer to the black hole, spacetime starts to deform. There are more paths going towards the black hole than paths moving away.[Note 3]



Inside of the event horizon, all paths bring the particle closer to the center of the black hole. It is no longer possible for the particle to escape.

The defining feature of a black hole is the appearance of an event horizon—a boundary in **spacetime** through which matter and light can pass only inward towards the mass of the black hole. Nothing, not even light, can escape from inside the event horizon. The event horizon is referred to as such because if an event occurs within the boundary, information from that event cannot reach an outside observer, making it impossible to determine whether such an event occurred.

As predicted by general relativity, the presence of a mass deforms spacetime in such a way that the paths taken by particles bend towards the mass. At the event horizon of a black hole, this deformation becomes so strong that there are no paths that lead away from the black hole.

To a distant observer, clocks near a black hole would appear to tick more slowly than those further away from the black hole Due to this effect, known as **gravitational time dilation**, an object falling into a black hole appears to slow as it approaches the event horizon, taking an infinite time to reach it. At the same time, all processes on this object slow down, from the viewpoint of a fixed outside observer, causing any light emitted by the object to appear redder and dimmer, an effect known as **gravitational redshift** Eventually, the falling object fades away until it can no longer be seen. Typically this process happens very rapidly with an object disappearing from view within less than a second.

On the other hand, indestructible observers falling into a black hole do not notice any of these effects as they cross the event horizon. According to their own clocks, which appear to them to tick normally, they cross the event horizon after a finite time without noting any singular behaviour; in classical general relativity, it is impossible to determine the location of the event horizon from local observations, due to Einstein's **equivalence principle**.

The **topology** of the event horizon of a black hole at equilibrium is always spherical. For non-rotating (static) black holes the geometry of the event horizon is precisely spherical, while for rotating black holes the event horizon is oblate.

Singularity

Main article: ***Gravitational singularity***

At the centre of a black hole, as described by general relativity, may lie a **gravitational singularity**, a region where the spacetime curvature becomes infinite. For a non-rotating black hole, this region takes the shape of a single point and for a rotating black hole, it is smeared out to form a **ring singularity** that lies in the plane of rotation. In both cases, the singular region has zero volume. It can also be shown that the singular region contains all the mass of the black hole solution. The singular region can thus be thought of as having infinite **density**.

Observers falling into a Schwarzschild black hole (i.e., non-rotating and not charged) cannot avoid being carried into the singularity once they cross the event horizon. They can prolong the experience by accelerating away to slow their descent, but only up to a limit.[106] When they reach the singularity, they are crushed to infinite density and their mass is added to the total of the black hole. Before that happens, they will have been torn apart by the growing **tidal forces** in a process sometimes referred to as **spaghettification** or the "noodle effect".

In the case of a charged (Reissner–Nordström) or rotating (Kerr) black hole, it is possible to avoid the singularity. Extending these solutions as far as possible reveals the hypothetical possibility of exiting the black hole into a different spacetime with the black hole acting as a **wormhole** The possibility of traveling to another universe is, however, only theoretical since any perturbation would destroy this possibility. It also appears to be possible to follow **closed time-like curves** (returning to one's own past) around the Kerr singularity, which leads to problems with **causality** like the **grandfather paradox**. It is expected that none of these peculiar effects would survive in a proper quantum treatment of rotating and charged black holes.

The appearance of singularities in general relativity is commonly perceived as signalling the breakdown of the theory. This breakdown, however, is expected; it occurs in a situation where **quantum effects** should describe these actions, due to the extremely high density and therefore particle interactions. To date, it has not been possible to combine quantum and gravitational effects into a single theory, although there exist attempts to formulate such a theory of **quantum gravity**. It is generally expected that such a theory will not feature any singularities.

Photon sphere

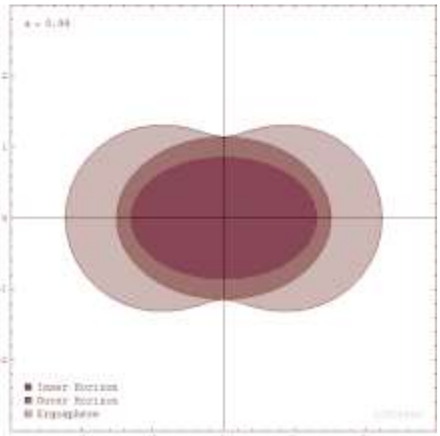
Main article: ***Photon sphere***

The photon sphere is a spherical boundary of zero thickness in which **photons** that move on **tangents** to that sphere would be trapped in a circular orbit about the black hole. For non-rotating black holes, the photon sphere has a radius 1.5 times the Schwarzschild radius. Their orbits would be **dynamically unstable**, hence any small perturbation, such as a particle of infalling matter, would cause an instability that would grow over time, either setting the photon on an outward trajectory causing it to escape the black hole, or on an inward spiral where it would eventually cross the event horizon.

While light can still escape from the photon sphere, any light that crosses the photon sphere on an inbound trajectory will be captured by the black hole. Hence any light that reaches an outside observer from the photon sphere must have been emitted by objects between the photon sphere and the event horizon.[115] For a Kerr black hole the radius of the photon sphere depends on the spin parameter and on the details of the photon orbit, which can be prograde (the photon rotates in the same sense of the black hole spin) or retrograde.

Ergosphere

Main article: ***Ergosphere***



The ergosphere is a region outside of the event horizon, where objects cannot remain in place.

Rotating black holes are surrounded by a region of spacetime in which it is impossible to stand still, called the ergosphere. This is the result of a process known as **frame-dragging**; general relativity predicts that any rotating mass will tend to slightly "drag" along the spacetime immediately surrounding it. Any object near the rotating mass will tend to start moving in the direction of rotation. For a rotating black hole, this effect is so strong near the event horizon that an object would have to move faster than the speed of light in the opposite direction to just stand still.

The ergosphere of a black hole is a volume bounded by the black hole's event horizon and the *ergosurface*, which coincides with the event horizon at the poles but is at a much greater distance around the equator.

Objects and radiation can escape normally from the ergosphere. Through the **Penrose process**, objects can emerge from the ergosphere with more energy than they entered with. The extra energy is taken from the rotational energy of the black hole. Thereby the rotation of the black hole slows down. A variation of the Penrose process in the presence of strong magnetic fields, the **Blandford–Znajek process** is considered a likely mechanism for the enormous luminosity and relativistic jets of **quasars** and other **active galactic nuclei**.

Innermost stable circular orbit (ISCO)

Main article: ***Innermost stable circular orbit***

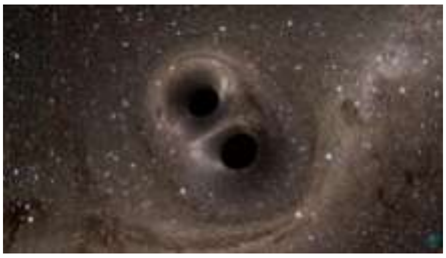
In **Newtonian gravity**, **test particles** can stably orbit at arbitrary distances from a central object. In general relativity, however, there exists an innermost stable circular orbit (often called the ISCO), inside of which, any infinitesimal perturbations to a circular orbit will lead to inspiral into the black hole. The location of the ISCO depends on the spin of the black hole, in the case of a Schwarzschild black hole (spin zero) is:

$$r_{\rm {ISCO}}=3\,r_{s}={\frac {6\,GM}{c^{2}}},$$

and decreases with increasing black hole spin for particles orbiting in the same direction as the spin.

Formation and evolution

Given the bizarre character of black holes, it was long questioned whether such objects could actually exist in nature or whether they were merely pathological solutions to Einstein's equations. Einstein himself wrongly thought black holes would not form, because he held that the angular momentum of collapsing particles would stabilize their motion at some radius. This led the general relativity community to dismiss all results to the contrary for many years. However, a minority of relativists continued to contend that black holes were physical objects, and by the end of the 1960s, they had persuaded the majority of researchers in the field that there is no obstacle to the formation of an event horizon.



Simulation of two black holes colliding

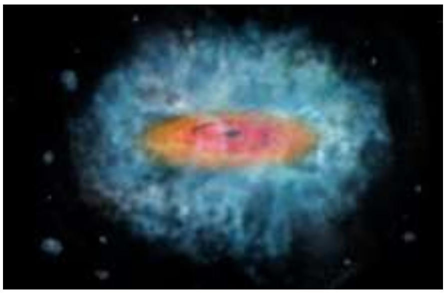
Penrose demonstrated that once an event horizon forms, general relativity without quantum mechanics requires that a singularity will form within. Shortly afterwards, Hawking showed that many cosmological solutions that describe the **Big Bang** have singularities without **scalar fields** or other **exotic matter** (see "**Penrose–Hawking singularity theorems**").The **Kerr solution**, the no-hair theorem, and the laws of black hole thermodynamics showed that the physical properties of black holes were simple and comprehensible, making them respectable subjects for research. Conventional black holes are formed by **gravitational collapse** of heavy objects such as stars, but they can also in theory be formed by other processes.

Gravitational collapse

Main article: ***Gravitational collapse***

Gravitational collapse occurs when an object's internal **pressure** is insufficient to resist the object's own gravity. For stars this usually occurs either because a star has too little "fuel" left to maintain its temperature through **stellar nucleosynthesis**, or because a star that would have been stable receives extra matter in a way that does not raise its core temperature. In either case the star's temperature is no longer high enough to prevent it from collapsing under its own weight.[128] The collapse may be stopped by the **degeneracy pressure** of the star's constituents, allowing the condensation of matter into an exotic **denser state**. The result is one of the various types of **compact star**. Which type forms depends on the mass of the remnant of the original star left if the outer layers have been blown away (for example, in a **Type II supernova**). The mass of the remnant, the collapsed object that survives the explosion, can be substantially less than that of the original star. Remnants exceeding 5 $M_\odot$ are produced by stars that were over 20 $M_\odot$ before the collapse.

If the mass of the remnant exceeds about 3–4 $M_\odot$ (the Tolman–Oppenheimer–Volkoff limit[, either because the original star was very heavy or because the remnant collected additional mass through accretion of matter, even the degeneracy pressure of **neutrons** is insufficient to stop the collapse. No known mechanism (except possibly quark degeneracy pressure, see **quark star**) is powerful enough to stop the implosion and the object will inevitably collapse to form a black hole.



Artist's impression of supermassive black hole seed

The gravitational collapse of heavy stars is assumed to be responsible for the formation of **stellar mass black holes**. **Star formation** in the early universe may have resulted in very massive stars, which upon their collapse would have produced black holes of up to 10^3 M☉. These black holes could be the seeds of the supermassive black holes found in the centres of most galaxies. It has further been suggested that massive black holes with typical masses of ~10^5 M☉ could have formed from the direct collapse of gas clouds in the young universe. These massive objects have been proposed as the seeds that eventually formed the earliest quasars observed

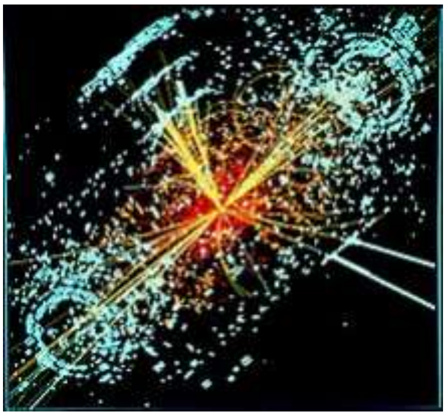
already at redshift {\displaystyle z\sim 7} Some candidates for such objects have been found in observations of the young universe.

While most of the energy released during gravitational collapse is emitted very quickly, an outside observer does not actually see the end of this process. Even though the collapse takes a finite amount of time from the **reference frame** of infalling matter, a distant observer would see the infalling material slow and halt just above the event horizon, due to gravitational time dilation. Light from the collapsing material takes longer and longer to reach the observer, with the light emitted just before the event horizon forms delayed an infinite amount of time. Thus the external observer never sees the formation of the event horizon; instead, the collapsing material seems to become dimmer and increasingly red-shifted, eventually fading away.

Primordial black holes and the Big Bang

Gravitational collapse requires great density. In the current epoch of the universe these high densities are found only in stars, but in the early universe shortly after the Big Bang densities were much greater, possibly allowing for the creation of black holes. High density alone is not enough to allow black hole formation since a uniform mass distribution will not allow the mass to bunch up. In order for **primordial black holes** to have formed in such a dense medium, there must have been initial density perturbations that could then grow under their own gravity. Different models for the early universe vary widely in their predictions of the scale of these fluctuations. Various models predict the creation of primordial black holes ranging in size from a **Planck mass** ($m_P=\sqrt{\hbar c/G} \approx 1.2\times10^{19}$ **GeV/c^2** $\approx 2.2\times10^{-8}$ kg) to hundreds of thousands of solar masses. Despite the early universe being extremely **dense**—far denser than is usually required to form a black hole—it did not re-collapse into a black hole during the Big Bang. Models for the gravitational collapse of objects of relatively constant size, such as **stars**, do not necessarily apply in the same way to rapidly expanding space such as the Big Bang.

High-energy collisions



Simulated event in the CMS detector: a collision in which a micro black hole may be created

Gravitational collapse is not the only process that could create black holes. In principle, black holes could be formed in **high-energy** collisions that achieve sufficient density. As of 2002, no such events have been detected, either directly or indirectly as a deficiency of the mass balance in **particle accelerator** experiments. This suggests that there must be a lower limit for the mass of black holes. Theoretically, this boundary is expected to lie around the Planck mass, where quantum effects are expected to invalidate the predictions of general relativity This would put the creation of black holes firmly out of reach of any high-energy process occurring on or near the Earth. However, certain developments in quantum gravity suggest that the minimum black hole mass could be much lower: some **braneworld** scenarios for example put the boundary as low as 1 TeV/c^2. This would make it conceivable for **micro black holes** to be created in the high-energy collisions that occur when **cosmic rays** hit the Earth's atmosphere, or possibly in the **Large Hadron Collider** at **CERN**. These theories are very speculative, and the creation of black holes in these processes is deemed unlikely by many specialists. Even if micro black holes could be formed, it is expected that they would **evaporate** in about 10^{-25} seconds, posing no threat to the Earth.

Growth

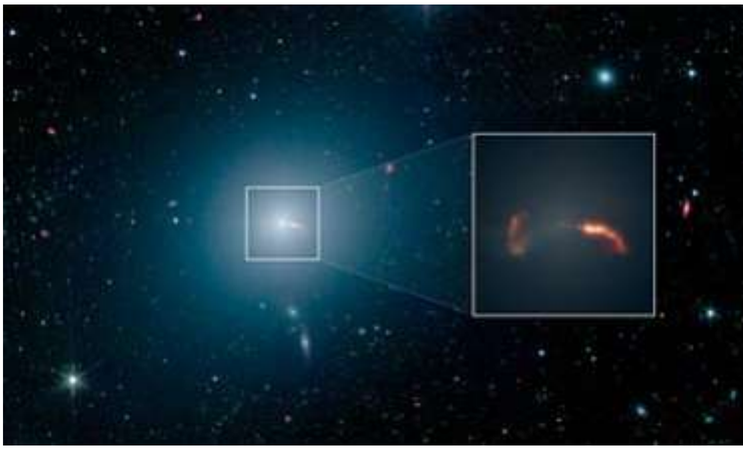
Once a black hole has formed, it can continue to grow by absorbing additional **matter**. Any black hole will continually absorb gas and **interstellar dust** from its surroundings. This growth process is one possible way through which some supermassive black holes may have been formed, although the **formation of supermassive black holes** is still an open field of research. A similar process has been suggested for the formation of **intermediate-mass black holes** found in **globular clusters**.] Black holes can also merge with other objects such as stars or even other black holes. This is thought to have been important, especially in the early growth of supermassive black holes, which could have formed from the aggregation of many smaller objects. The process has also been proposed as the origin of some intermediate-mass black holes.

Evaporation

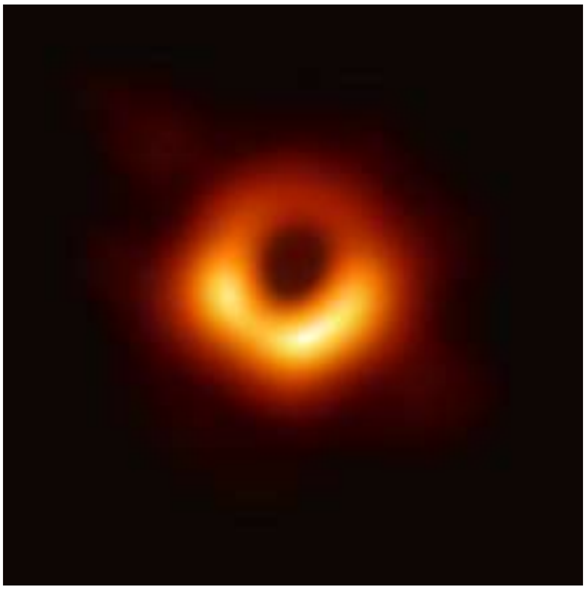
Main article: ***Hawking radiation***

In 1974, Hawking predicted that black holes are not entirely black but emit small amounts of thermal radiation at a temperature $\hbar c^3/(8 \pi G M k_B)$; this effect has become known as Hawking radiation. By applying quantum field theory to a static black hole background, he determined that a black hole should emit particles that display a perfect **black body spectrum**. Since Hawking's publication, many others have verified the result through various approaches. If Hawking's theory of black hole radiation is correct, then black holes are expected to shrink and evaporate over time as they lose mass by the emission of photons and other particles The temperature of this thermal spectrum (**Hawking temperature**) is proportional to the surface gravity of the black hole, which, for a Schwarzschild black hole, is inversely proportional to the mass. Hence, large black holes emit less radiation than small black holes.

A stellar black hole of 1 $M_\odot$ has a Hawking temperature of 62 **nanokelvins**. This is far less than the 2.7 K temperature of the **cosmic microwave background** radiation. Stellar-mass or larger black holes receive more mass from the cosmic microwave background than they emit through Hawking radiation and thus will grow instead of shrinking To have a Hawking temperature larger than 2.7 K (and be able to evaporate), a black hole would need a mass less than the **Moon**. Such a black hole would have a diameter of less than a tenth of a millimeter.
If a black hole is very small, the radiation effects are expected to become very strong. A black hole with the mass of a car would have a diameter of about 10^{-24} m and take a nanosecond to evaporate, during which time it would briefly have a luminosity of more than 200 times that of the Sun. Lower-mass black holes are expected to evaporate even faster; for example, a black hole of mass 1 TeV/c^2 would take less than 10^{-88} seconds to evaporate completely. For such a small black hole, quantum gravity effects are expected to play an important role and could hypothetically make such a small black hole stable, although current developments in quantum gravity do not indicate this is the case.
The Hawking radiation for an astrophysical black hole is predicted to be very weak and would thus be exceedingly difficult to detect from Earth. A possible exception, however, is the burst of gamma rays emitted in the last stage of the evaporation of primordial black holes. Searches for such flashes have proven unsuccessful and provide stringent limits on the possibility of existence of low mass primordial black holes. NASA's **Fermi Gamma-ray Space Telescope** launched in 2008 will continue the search for these flashes.
If black holes evaporate via Hawking radiation, a solar mass black hole will evaporate (beginning once the temperature of the cosmic microwave background drops below that of the black hole) over a period of 10^{64} years. A supermassive black hole with a mass of 10^{11} $M_\odot$ will evaporate in around 2×10^{100} years. Some monster black holes in the universe are predicted to continue to grow up to perhaps 10^{14} $M_\odot$ during the collapse of superclusters of galaxies. Even these would evaporate over a timescale of up to 10^{106} years.



closeup



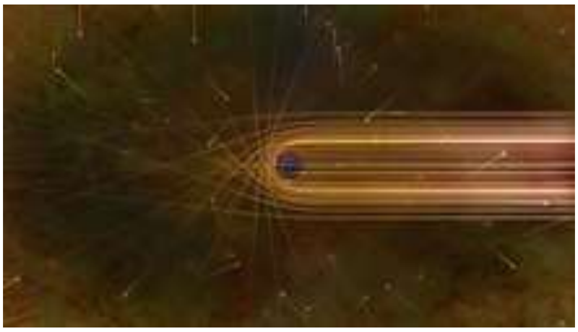
supermassive black hole

Observational evidence

Messier 87 **galaxy – home of the first imaged black hole**

context

magnetic radiation other than the hypothetical Hawking radiation, so astrophysicists searching for black holes must generally rely on indirect observations. For example, a black hole's existence can sometimes be inferred by observing its gravitational influence upon its surroundings.
On 10 April 2019 an image was released of a black hole, which is seen in magnified fashion because the light paths near the event horizon are highly bent. The dark shadow in the middle results from light paths absorbed by the black hole. The image is in **false color**, as the detected light halo in this image is not in the visible spectrum, but radio waves.



This artist's impression depicts the paths of photons in the vicinity of a black hole. The gravitational bending and capture of light by the event horizon is the cause of the shadow captured by the Event Horizon Telescope.
The **Event Horizon Telescope** (EHT), is an active program that directly observes the immediate environment of the event horizon of black holes, such as the black hole at the centre of the Milky Way. In April 2017, EHT began observa-

tion of the black hole in the centre of Messier 87.[154] "In all, eight radio observatories on six mountains and four continents observed the galaxy in Virgo on and off for 10 days in April 2017" to provide the data yielding the image two years later in April 2019. After two years of data processing, EHT released the first direct image of a black hole, specifically the supermassive black hole that lies in the centre of the aforementioned galaxy. What is visible is not the black hole, which shows as black because of the loss of all light within this dark region, rather it is the gases at the edge of the event horizon, which are displayed as orange or red, that define the black hole.
The brightening of this material in the 'bottom' half of the processed EHT image is thought to be caused by **Doppler beaming**, whereby material approaching the viewer at relativistic speeds is perceived as brighter than material moving away. In the case of a black hole, this phenomenon implies that the visible material is rotating at relativistic speeds (>1,000 km/s), the only speeds at which it is possible to centrifugally balance the immense gravitational attraction of the singularity, and thereby remain in orbit above the event horizon. This configuration of bright material implies that the EHT observed **M87*** from a perspective catching the black hole's accretion disc nearly edge-on, as the whole system rotated clockwise. However, the extreme **gravitational lensing** associated with black holes produces the illusion of a perspective that sees the accretion disc from above. In reality, most of the ring in the EHT image was created when the light emitted by the far side of the accretion disc bent around the black hole's gravity well and escaped; this means that most of the possible perspectives on M87* can see the entire disc, even that directly behind the "shadow".
Prior to this, in 2015, the EHT detected magnetic fields just outside the event horizon of Sagittarius A*, and even discerned some of their properties. The field lines that pass through the accretion disc were found to be a complex mixture of ordered and tangled. The existence of magnetic fields had been predicted by theoretical studies of black holes.

Predicted appearance of non-rotating black hole with toroidal ring of ionised matter, such as has been proposed] as a model for **Sagittarius A***. The asymmetry is due to the **Doppler effect** resulting from the enormous orbital speed needed for centrifugal balance of the very strong gravitational attraction of the hole.

Detection of gravitational waves from merging black holes

On 14 September 2015 the **LIGO** gravitational wave observatory made the first-ever successful **direct observation of gravitational waves**. The signal was consistent with theoretical predictions for the gravitational waves produced by the merger of two black holes: one with about 36 solar masses, and the other around 29 solar masses. This observation provides the most concrete evidence for the existence of black holes to date. For instance, the gravitational wave signal suggests that the separation of the two objects prior to the merger was just 350 km (or roughly four times the Schwarzschild radius corresponding to the inferred masses). The objects must therefore have been extremely compact, leaving black holes as the most plausible interpretation.
More importantly, the signal observed by LIGO also included the start of the post-merger **ringdown**, the signal produced as the newly formed compact object settles down to a stationary state. Arguably, the ringdown is the most direct way of observing a black hole. From the LIGO signal it is possible to extract the frequency and damping time of the dominant mode of the ringdown. From these it is possible to infer the mass and angular momentum of the final object, which match independent predictions from numerical simulations of the merger. The frequency and decay time of the dominant mode are determined by the geometry of the photon sphere. Hence, observation of this mode confirms the presence of a photon sphere; however, it cannot exclude possible exotic alternatives to black holes that are compact enough to have a photon sphere.
The observation also provides the first observational evidence for the existence of stellar-mass black hole binaries. Furthermore, it is the first observational evidence of stellar-mass black holes weighing 25 solar masses or more.
Since then many more **gravitational wave events** have been observed.

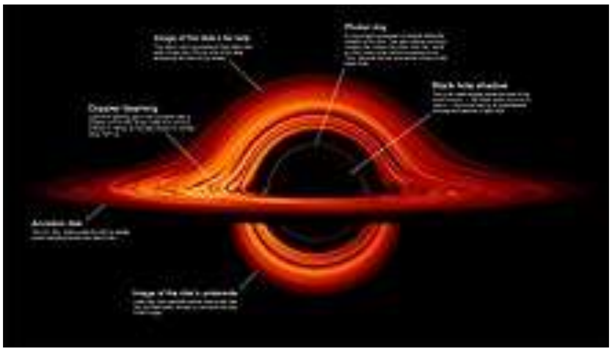
Proper motions of stars orbiting Sagittarius A*

The **proper motions** of stars near the centre of our own **Milky Way** provide strong observational evidence that these stars are orbiting a supermassive black hole.[169] Since 1995, astronomers have tracked the motions of 90 stars orbiting an invisible object coincident with the radio source Sagittarius A*. By fitting their motions to **Keplerian orbits**, the astronomers were able to infer, in 1998, that a 2.6×10^6 $M_\odot$ object must be contained in a volume with a radius of 0.02 **light-years** to cause the motions of those stars. Since then, one of the stars—called **S2**—has completed a full orbit. From the orbital data, astronomers were able to refine the calculations of the mass to 4.3×10^6 $M_\odot$ and a radius of less than 0.002 light-years for the object causing the orbital motion of those stars.[169] The upper limit on the object's size is still too large to test whether it is smaller than its Schwarzschild radius; nevertheless, these observations strongly suggest that the central object is a supermassive black hole as there are no other plausible scenarios for confining so much invisible mass into such a small volume. Additionally, there is some observational evidence that this object might possess an event horizon, a feature unique to black holes.

Accretion of matter

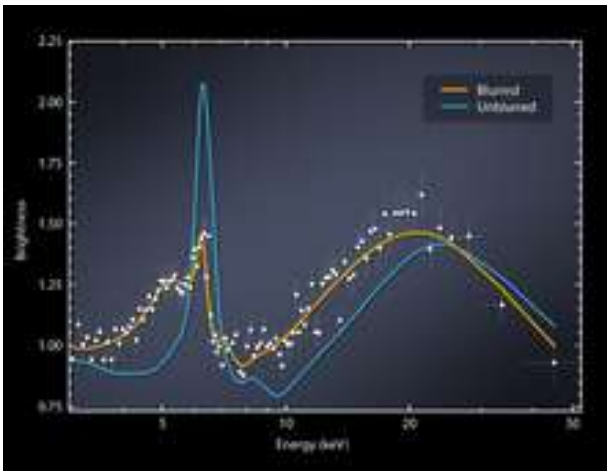
*See also: **Accretion disk***

Black hole with corona, X-ray source (artist's concept)
Due to **conservation of angular momentum** gas falling into the **gravitational well** created by a massive object will typically form a disk-like structure around the object. Artists' impressions such as the accompanying representation of a black hole with corona commonly depict the black hole as if it were a flat-space body hiding the part of the disk just behind it, but in reality gravitational lensing would greatly distort the image of the accretion disk.



NASA simulated view from outside the horizon of a Schwarzschild black hole lit by a thin accretion disk.

Within such a disk, friction would cause angular momentum to be transported outward, allowing matter to fall farther inward, thus releasing potential energy and increasing the temperature of the gas.



Blurring of X-rays near black hole (**NuSTAR**; 12 August 2014)

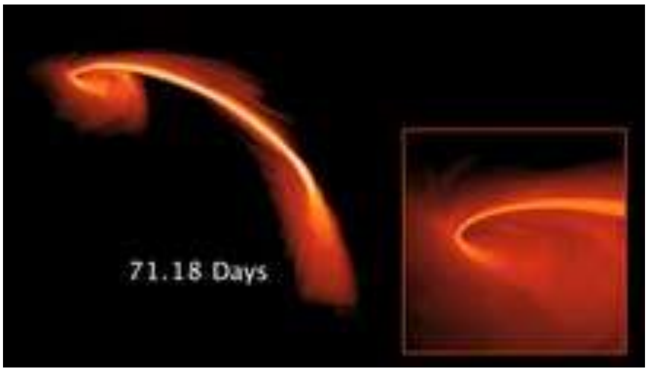
When the accreting object is a neutron star or a black hole, the gas in the inner accretion disk orbits at very high speeds because of its proximity to the **compact object**. The resulting friction is so significant that it heats the inner disk to temperatures at which it emits vast amounts of electromagnetic radiation (mainly X-rays). These bright X-ray sources may be detected by telescopes. This process of accretion is one of the most efficient energy-producing processes known; up to 40% of the rest mass of the accreted material can be emitted as radiation.[1] (In nuclear fusion only about 0.7% of the rest mass will be emitted as energy.) In many cases, accretion disks are accompanied by **relativistic jets** that are emitted along the poles, which carry away much of the energy. The mechanism for the creation of these jets is currently not well understood, in part due to insufficient data.

As such, many of the universe's more energetic phenomena have been attributed to the accretion of matter on black holes. In particular, active galactic nuclei and **quasars** are believed to be the accretion disks of supermassive black holes. Similarly, X-ray binaries are generally accepted to be **binary star** systems in which one of the two stars is a compact object accreting matter from its companion. It has also been suggested that some **ultraluminous X-ray sources** may be the accretion disks of intermediate-mass black holes.

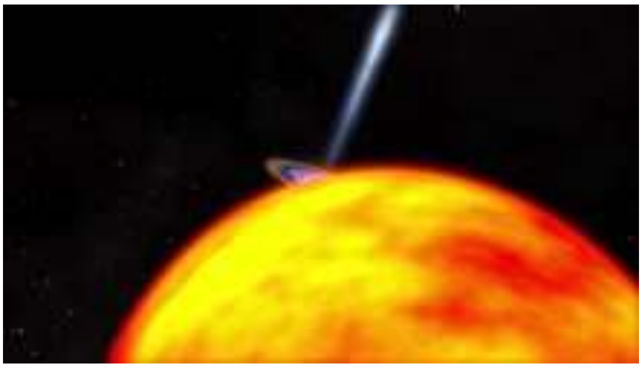
In November 2011 the first direct observation of a quasar accretion disk around a supermassive black hole was reported.

X-ray binaries

*See also: **X-ray binary***



Computer simulation of a star being consumed by a black hole. The blue dot indicates the location of the black hole.



This animation compares the X-ray "heartbeats" of GRS 1915 and IGR J17091, two black holes that ingest gas from companion stars.

A **Chandra X-Ray Observatory** image of **Cygnus X-1**, which was the first strong black hole candidate discovered

X-ray binaries are binary star systems that emit a majority of their radiation in the **X-ray** part of the spectrum. These X-ray emissions are generally thought to result when one of the stars (compact object) accretes matter from another (regular) star. The presence of an ordinary star in such a system provides an opportunity for studying the central object and to determine if it might be a black hole.

If such a system emits signals that can be directly traced back to the compact object, it cannot be a black hole. The absence of such a signal does, however, not exclude the possibility that the compact object is a neutron star. By studying the companion star it is often possible to obtain the orbital parameters of the system and to obtain an estimate for the mass of the compact object. If this is much larger than the Tolman–Oppenheimer–Volkoff limit (the maximum

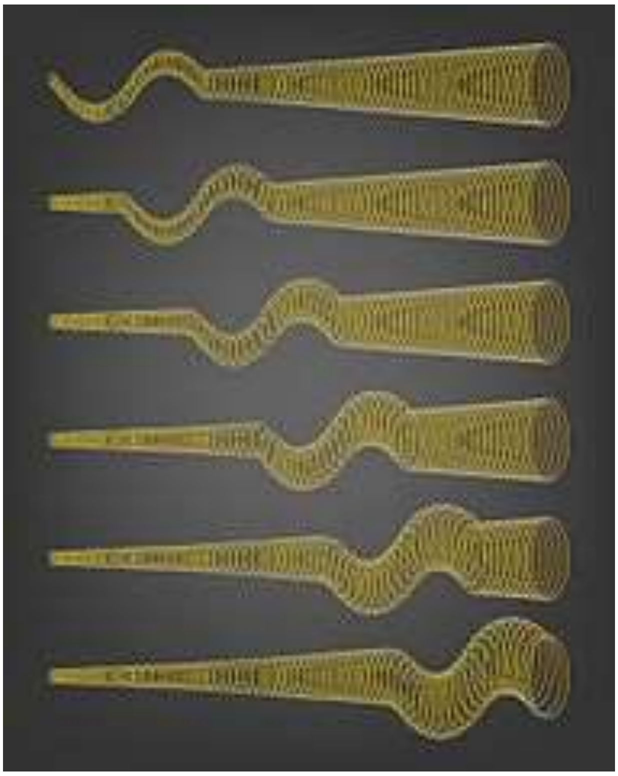
mass a star can have without collapsing) then the object cannot be a neutron star and is generally expected to be a black hole.
The first strong candidate for a black hole, **Cygnus X-1**, was discovered in this way by **Charles Thomas Bolton**,[181] **Louise Webster**, and **Paul Murdin**[182] in 1972. Some doubt, however, remained due to the uncertainties that result from the companion star being much heavier than the candidate black hole. Currently, better candidates for black holes are found in a class of X-ray binaries called soft X-ray transients. In this class of system, the companion star is of relatively low mass allowing for more accurate estimates of the black hole mass. Moreover, these systems actively emit X-rays for only several months once every 10–50 years. During the period of low X-ray emission (called quiescence), the accretion disk is extremely faint allowing detailed observation of the companion star during this period. One of the best such candidates is **V404 Cygni**.

Quasi-periodic oscillations

Main article: ***Quasi-periodic oscillations***
The X-ray emissions from accretion disks sometimes flicker at certain frequencies. These signals are called **quasi-periodic oscillations** and are thought to be caused by material moving along the inner edge of the accretion disk (the innermost stable circular orbit). As such their frequency is linked to the mass of the compact object. They can thus be used as an alternative way to determine the mass of candidate black holes.[185]

Galactic nuclei

See also: ***Active galactic nucleus***



Magnetic waves, called **Alfvén S-waves**, flow from the base of black hole jets.
Astronomers use the term "active galaxy" to describe galaxies with unusual characteristics, such as unusual **spectral line** emission and very strong radio emission. Theoretical and observational studies have shown that the activity in these active galactic nuclei (AGN) may be explained by the presence of supermassive black holes, which can be millions of times more massive than stellar ones. The models of these AGN consist of a central black hole that may be millions or billions of times more massive than the **Sun**; a disk of **interstellar gas** and dust called an accretion disk; and two **jets** perpendicular to the accretion disk.

Detection of unusually bright **X-Ray** flare from Sagittarius A*, a black hole in the center of the **Milky Way** galaxy on 5 January 2015
Although supermassive black holes are expected to be found in most AGN, only some galaxies' nuclei have been more carefully studied in attempts to both identify and measure the actual masses of the central supermassive black hole candidates. Some of the most notable galaxies with supermassive black hole candidates include the **Andromeda Galaxy**, **M32**, **M87**, **NGC 3115**, **NGC 3377**, **NGC 4258**, **NGC 4889**, **NGC 1277**, **OJ 287**, **APM 08279+5255** and the **Sombrero Galaxy**.
It is now widely accepted that the center of nearly every galaxy, not just active ones, contains a supermassive black hole. The close observational correlation between the mass of this hole and the velocity dispersion of the host galaxy's **bulge**, known as the **M-sigma relation**, strongly suggests a connection between the formation of the black hole and that of the galaxy itself.
Simulation of gas cloud after close approach to the black hole at the centre of the Milky Way.
Microlensing (proposed)

Another way the black hole nature of an object may be tested in the future is through observation of effects caused by a strong gravitational field in their vicinity. One such effect is **gravitational lensing**: The deformation of spacetime around a massive object causes light rays to be deflected much as light passing through an optic **lens**. Observations have been made of weak gravitational lensing, in which light rays are deflected by only a few **arcseconds**. However, it has never been directly observed for a black hole. One possibility for observing gravitational lensing by a black hole would be to observe stars in orbit around the black hole. There are several candidates for such an observation in orbit around Sagittarius A*.

Alternatives

The evidence for stellar black holes strongly relies on the existence of
pends on the assumptions made about the properties of dense matter
free **quarks** at high density might allow the existence of dense quark s
[195] Some extensions of the **standard model** posit the existence of **pr**
thetically form **preon stars**. These hypothetical models could potentia
it can be shown from arguments in general relativity that any such obj

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Since the average density of a black hole inside its Schwarzschild radius is inversely proportional to the square of its mass, supermassive black holes are much less dense than stellar black holes (the average density of a 10^8 $M_\odot$ black hole is comparable to that of water).] Consequently, the

physics of matter forming a supermassive black hole is much better understood and the possible alternative explanations for supermassive black hole observations are much more mundane. For example, a supermassive black hole could be modelled by a large cluster of very dark objects. However, such alternatives are typically not stable enough to explain the supermassive black hole candidates.[177]
The evidence for the existence of stellar and supermassive black holes implies that in order for black holes to not form, general relativity must fail as a theory of gravity, perhaps due to the onset of **quantum mechanical** corrections. A much anticipated feature of a theory of quantum gravity is that it will not feature singularities or event horizons and thus black holes would not be real artifacts. For example, in the **fuzzball** model based on **string theory**, the individual states of a black hole solution do not generally have an event horizon or singularity, but for a classical/semi-classical observer the statistical average of such states appears just as an ordinary black hole as deduced from general relativity.
A few theoretical objects have been conjectured to match observations of astronomical black hole candidates identically or near-identically, but which function via a different mechanism. These include the **gravastar**, the **black star**, and the **dark-energy star**.

Open questions

Entropy and thermodynamics

Further information: ***Black hole thermodynamics***
$S = 1/4\, c^3k/G\hbar\, A$
The formula for the Bekenstein–Hawking entropy (S) of a black hole, which depends on the area of the black hole (A). The constants are the **speed of light** (c), the **Boltzmann constant** (k), **Newton's constant** (G), and the **reduced Planck constant** ($\hbar$). In Planck units, this reduces to $S = A/4$.
In 1971, Hawking showed under general conditions that the total area of the event horizons of any collection of classical black holes can never decrease, even if they collide and merge This result, now known as the **second law of black hole mechanics**, is remarkably similar to the **second law of thermodynamics**, which states that the total entropy of an isolated system can never decrease. As with classical objects at **absolute zero** temperature, it was assumed that black holes had zero entropy. If this were the case, the second law of thermodynamics would be violated by entropy-laden matter entering a black hole, resulting in a decrease in the total entropy of the universe. Therefore, Bekenstein proposed that a black hole should have an entropy, and that it should be proportional to its horizon area.
The link with the laws of thermodynamics was further strengthened by Hawking's discovery that quantum field theory predicts that a black hole radiates **blackbody radiation** at a constant temperature. This seemingly causes a violation of the second law of black hole mechanics, since the radiation will carry away energy from the black hole causing it to shrink. The radiation, however also carries away entropy, and it can be proven under general assumptions that the sum of the entropy of the matter surrounding a black hole and one quarter of the area of the horizon as measured in Planck units is in fact always increasing. This allows the formulation of the **first law of black hole mechanics** as an analogue of the **first law of thermodynamics**, with the mass acting as energy, the surface gravity as temperature and the area as entropy.
One puzzling feature is that the entropy of a black hole scales with its area rather than with its volume, since entropy is normally an **extensive quantity** that scales linearly with the volume of the system. This odd property led **Gerard 't Hooft** and **Leonard Susskind** to propose the **holographic principle**, which suggests that anything that happens in a volume of spacetime can be described by data on the boundary of that volume.
Although general relativity can be used to perform a semi-classical calculation of black hole entropy, this situation is theoretically unsatisfying. In **statistical mechanics**, entropy is understood as counting the number of microscopic configurations of a system that have the same macroscopic qualities (such as mass, charge, pressure, etc.). Without a satisfactory theory of quantum gravity, one cannot perform such a computation for black holes. Some progress has been made in various approaches to quantum gravity. In 1995, **Andrew Strominger** and **Cumrun Vafa** showed that counting the microstates of a specific supersymmetric black hole in string theory reproduced the Bekenstein–Hawking entropy.[204] Since then, similar results have been reported for different black holes both in string theory and in other approaches to quantum gravity like **loop quantum gravity**.

Information loss paradox

Main article: ***Black hole information paradox***
Unsolved problem in physics:
Because a black hole has only a few internal parameters, most of the information about the matter that went into forming the black hole is lost. Regardless of the type of matter which goes into a black hole, it appears that only information concerning the total mass, charge, and angular momentum are conserved. As long as black holes were thought to persist forever this information loss is not that problematic, as the information can be thought of as existing inside the black event horizon in accordance with the holographic principle. However, black holes slowly evaporate by emitting Hawking radiation. This radiation does not appear to carry any additional information about the matter that formed the black hole, meaning that this information appears to be gone forever
The question whether information is truly lost in black holes (the **black hole information paradox**) has divided the theoretical physics community (see **Thorne–Hawking–Preskill bet**). In quantum mechanics, loss of information corresponds to the violation of a property called **unitarity**, and it has been argued that loss of unitarity would also imply violation of conservation of energy, though this has also been disputed. Over recent years evidence has been building that indeed information and unitarity are preserved in a full quantum gravitational treatment of the problem.
One attempt to resolve the black hole information paradox is known as **black hole complementarity**. In 2012, the "**firewall paradox**" was introduced with the goal of demonstrating that black hole complementarity fails to solve the information paradox. According to **quantum field theory in curved spacetime**, a **single emission** of Hawking radiation involves two mutually **entangled** particles. The outgoing particle escapes and is emitted as a quantum of Hawking radiation; the infalling particle is swallowed by the black hole. Assume a black hole formed a finite time in the past and will fully evaporate away in some finite time in the future. Then, it will emit only a finite amount of information encoded within its Hawking radiation. According to research by physicists like **Don Page** and Leonard Susskind, there will eventually be a time by which an outgoing particle must be entangled with all the Hawking radiation the black hole has previously emitted. This seemingly creates a paradox: a principle called "**monogamy of entanglement**" requires that, like any quantum system, the outgoing particle cannot be fully entangled with two other systems at the same time; yet here the outgoing particle appears to be entangled both with the infalling particle and, independently, with past Hawking radiation In order to resolve this contradiction, physicists may eventually be forced to give up one of three time-tested principles: Einstein's equivalence principle, unitarity, or local quantum field theory. One possible solution, which violates the equivalence principle, is that a "firewall" destroys incoming particles at the event horizon In general, which—if any—of these assumptions should be abandoned remains a topic of debate.

SPACE NEWS MAY 2021

Mars helicopter Ingenuity goes faster and farther than ever on 4th flight

By Mike Wall 3 days ago

Ingenuity aced its latest hop after a one-day delay.

NASA's Mars helicopter Ingenuity keeps pushing the aerial exploration envelope.

The 4-lb. (1.8 kilograms) chopper lifted off from the floor of Mars' Jezero Crater today at 10:49 a.m. EDT (1449 GMT), kicking off its fourth flight on the Red Planet.

Ingenuity achieved all of its main technology-demonstrating goals on flights one through three — which occurred on April 19, April 22 and April 25 — so the helicopter's handlers let it off the leash today. Ingenuity covered 872 feet (266 meters) of ground and reached a top speed of 8 mph (13 kph) during the 117-second jaunt, NASA officials said.

The previous highs, set on sortie number three, were 330 feet (100 m) of lateral distance, a 4.5 mph (7.2 kph) maximum speed and an 80-second flight time. (The maximum altitude attained — about 16.5 feet, or 5 m — has remained the same on the three most recent flights.)

If all went according to plan, Ingenuity also took 60 photos with its downward-facing navigation camera and five with its 13-megapixel color imager while aloft today, helicopter team members said.

We don't yet know if Ingenuity's robotic partner, NASA's Perseverance rover, will be in any of those shots. Ingenuity managed to spot the rover from the air during flight number three, capturing an image unprecedented in the history of exploration.

Perseverance carries two onboard microphones, and the rover attempted to record sound of Ingenuity's flight today for the first time, mission team members said. Again, we'll have to wait until more data comes down to see if that did indeed happen.

Showing what's possible

Ingenuity and Perseverance landed together Feb. 18 inside the 28-mile-wide (45 kilometers) Jezero, which hosted a big lake and a river delta in the ancient past. Ingenuity deployed from the rover's belly on April 3 and began prepping for its flight campaign, which is designed to show that aerial exploration is possible on Mars.

And now we know that it is.

"Future Mars exploration missions can now confidently consider the added capability an aerial exploration may bring to a science mission," Lori Glaze, director of NASA's Planetary Science Division, said in a statement Wednesday (April 28). Indeed, members of the Ingenuity team are already thinking about the next generation of Mars helicopters — bigger craft that could gather lots of data on the Red Planet and serve as scouts for rovers or human explorers.

A one-day delay

NASA's Mars rover Perseverance captured this view of the ingenuity helicopter flying on April 30, 2021. (Image credit: NASA/JPL-Caltech)

Ingenuity was supposed to fly yesterday (April 29), but the solar-powered copter didn't manage to get off the ground. Ingenuity's debut Martian flight was also delayed, after the chopper didn't transition to flight mode as required to perform a high-speed rotor spin test. The mission team tweaked the command sequence beamed from Earth and got Ingenuity aloft on April 19, about a week later than originally planned.

That fix gets Ingenuity into flight mode about 85% of the time, mission team members determined. And it appears that yesterday was just one of those relatively rare occasions where it didn't work.

A mission extension

Ingenuity's flight campaign was initially capped at five hops over a one-month stretch from the deployment date. That deadline was imposed to allow Perseverance to start focusing on its own mission, which involves hunting for signs of long-gone Mars life and collecting samples for future return to Earth.

(Perseverance has been documenting and supporting Ingenuity's work; for example, communications to and from the helicopter must go through the rover.)

But Ingenuity's success to date has earned it a mission extension. NASA officials announced today that the chopper will soon move into a new "operations demonstration phase," which will last for at least 30 additional days on the Red Planet.

"It's like Ingenuity is graduating," mission project manager MiMi Aung, of NASA's Jet Propulsion Laboratory in Southern California, said during a news conference this morning.

In the new phase, "we can show how a rotorcraft can be used and show products that only an aerial platform, from an aerial dimension, can give," Aung said.

Flights four and five serve to transition Ingenuity to the new phase, which will kick off at an entirely new locale. The helicopter will fly to that to-be-determined new site on sortie number five, which is expected to take place in about a week, Aung said.

Ingenuity will fly less frequently during the new phase — likely once every two to three weeks as opposed to the tech-demo cadence of once every three days or so, NASA officials said. This will give Perseverance time to really dig into its science work. The rover also won't capture video of those coming flights, which will also free up considerable time, Perseverance team members said.

The newly granted extension does not come with a hard deadline; team members will assess how Ingenuity performed after the 30 days are up and decide whether or not to keep flying. But Ingenuity will definitely be grounded for good by late August, NASA officials said.

"That timing will allow the rover team time to wrap up its planned science activities and prepare for solar conjunction — the period in mid-October when Mars and Earth are on opposite sides of the sun, blocking communications," NASA officials wrote in an update today.

Mike Wall is the author of "Out There" (Grand Central Publishing, 2018; illustrated by Karl Tate), a book about the search for alien life. Follow him on Twitter @michaeldwall. Follow us on Twitter @Spacedotcom or Facebook.

Russia wants to build its own space station to replace the ISS, state officials say

By Brandon Specktor 5 days ago

Russian officials called the 23-year-old space station a 'catastrophe' waiting to happen, according to state TV.

The International Space Station was launched into low Earth orbit in 1998. Russia's space agency may withdraw from the station in the next four years, officials say. (Image credit: NASA)

The 23-year partnership between the United States and Russia that has kept the International Space Station (ISS) in orbit could soon come to an end, Russian officials suggested this week.

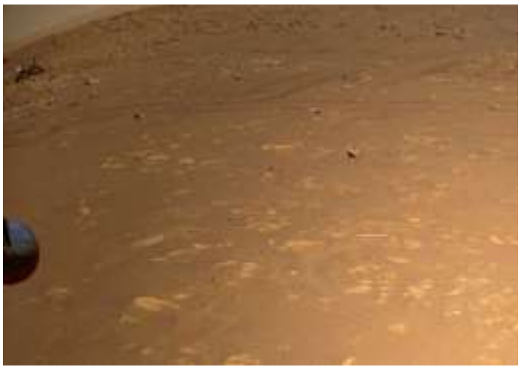
Yury Borisov, the Russian Deputy Prime Minister, reportedly said in a government meeting that the nation might withdraw

from the ISS in 2025, according to a state TV news report on April 18. Borisov cited the deteriorating condition of the space station — which was launched in 1998 by NASA and the Russian space agency Roscosmos — as the primary reason for the potential departure.
"We can't risk the lives [of our cosmonauts]," Borisov said, according to the BBC. "The structure and the metal [are] getting old, [and] it can lead to irreversible consequences — to catastrophe."
Later that day, Borisov released a statement partially walking back the 2025 departure date, saying, "a technical inspection is needed, and then we can make a decision and inform our partners," according to Science magazine.
Meanwhile officials with Roscosmos announced that work has already begun on a national space station, which would serve as a successor to the country's Salyut and Mir stations, launched into low Earth orbit in the 1970s and 80s. Dmitry Rogozin, head of Roscosmos, posted a video to the messaging app Telegram saying, "the first core module of the new Russian orbital station is in the works" and could be complete by 2025, the BBC reported.
Rogozin added that Russian would not depart from the ISS until that potential new station was completed. Still, even with ample notice Russia's potential departure could put a hefty strain on NASA and the other agencies that rely on the ISS.
"ISS partners would have a really hard time keeping the station functional without Russia," Vitaly Egorov, an industry observer and former spokesperson for Russia's Dauria Aerospace company, told Science magazine. Cargo and crew services provided by SpaceX could potentially help fill the gaps left behind by Roscosmos, the magazine added.

Mars helicopter Ingenuity spots Perseverance rover from the air (photo)

By Mike Wall 5 days ago
We've never seen a Mars rover from this vantage point before.
Here's something you've never seen before.
NASA's Mars helicopter Ingenuity managed to snap a photo of the agency's Perseverance rover from the air on Sunday (April 25), providing an unprecedented view of a robotic explorer on the surface of another world.
"Oh hey, there I am! Never thought I'd be the subject of another photographer on Mars. Great capture by the #MarsHelicopter team," Perseverance's handlers said via the rover's official @NASAPersevereTwitter account on Tuesday evening (April 27), when the photo was released.
NASA's Pathfinder lander photographed the first-ever Mars rover, Sojourner, on the Red Planet back in 1997. But both of those robots were firmly on the ground.

A zoomed-in view of Perseverance, as seen by Ingenuity on April 25, 2021. (Image credit: NASA/JPL-Caltech)
The 4-lb. (1.8 kilograms) chopper was about 279 feet (85 meters) from Perseverance when it took the photo, flying at an altitude of about 16.5 feet (5 m), NASA officials said in a photo description.
The milestone occurred during Ingenuity's third flight on Mars, its most ambitious sortie to date. Ingenuity traveled much faster and farther on Sunday than it had previously, covering about a total distance of about 330 feet (100 m).



NASA's Mars helicopter Ingenuity captured this photo of the Perseverance rover and its tracks from the air on April 25, 2021. (This photo has been cropped so that the rover is more clearly visible.) (Image credit: NASA/JPL-Caltech)
Ingenuity is a technology demonstration designed to show that aerial exploration is possible on Mars. The rotorcraft carries no science instruments but is paving the way for future Mars helicopters that could gather lots of data on their own and also serve as scouts for rovers and human pioneers on the Red Planet, NASA officials have said.
Ingenuity and Perseverance landed together inside Mars' 28-mile-wide (45 kilometers) Jezero Crater on Feb. 18. The helicopter deployed from the car-sized rover's belly six weeks later and took to the skies for the first time on April 19, performing the first-ever powered, controlled flight by an aircraft on a world beyond Earth.
The Ingenuity team aims to pack two more flights into the helicopter's month-long flight window, which closes in early May. And there won't be an extension of that window; Perseverance, which has been documenting and supporting Ingenuity's work, needs to start focusing on its own life-hunting, sample-gathering mission soon.
Those final two hops will likely be even more complex and ambitious than Sunday's sortie, for the team wants to push the little robot's limits. Ingenuity project manager MiMi Aung, of NASA's Jet Propulsion Laboratory in Southern California, said earlier this month that she'd like the helicopter to travel about 2,000 feet (600 m) on its fifth and final flight, if possible.
That would be quite a journey — one that Ingenuity would hopefully document with many more gorgeous photos from the air.

Astronomers ask UN committee to protect night skies from megaconstellations

By Tereza Pultarova - Senior Writer 6 days ago
A United Nations committee will discuss whether pristine night sky should be protected against Starlink trains.

(Image credit: Victoria Girgis/Lowell Observatory)

The International Astronomical Union is calling for the pristine night sky to be protected by the United Nations as astronomers struggle with exposures ruined by trains of Elon Musk's Starlink satellites.

At first, they provided a new type of heavenly spectacle. But Space's Starlink internet satellite trains traveling across the sky in neat formations after the launch of each batch of the megaconstellation's spacecraft have long annoyed astronomers.

The IAU has now decided to take the issue to the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), according to Thomas Schildknecht, the deputy director of the Astronomical Institute of the University of Bern, Switzerland, who represents Switzerland in the IAU. The organization of astronomers is requesting that UN COPUOS protect the sky's darkness for the sake of future advancements in astronomy.

"These trains are nice and impressive, but do we really want to see them everywhere?" Schildknecht said on April 20 in a news conference organized by the European Space Agency (ESA) during the 8th European Space Debris Conference held virtually from Darmstadt, Germany, April 20 to 23. "Do we want to see them in the Australian outback? In Antarctica? Or in the very dark regions of Chile? Probably not."

Astronomers have complained about the streaks ruining their observations ever since SpaceX, Starlink's operator, started lofting the Internet-beaming megaconstellation into low Earth orbit in 2019. SpaceX currently has approval to launch 12,000 satellites, but the company's plans call for launching as many as 30,000 spacecraft. The launches are coming thick and fast, up to four a month, each injecting up to 60 satellites into orbit.

"It's not just the streaks but also the diffuse background light and the radio noise from these satellites that may prevent us from accessing the sky," Schildknecht said. "It may cut us off from accessing knowledge about our universe."

SpaceX has acknowledged the problem and tried to reduce the amount of light reflected by the satellites. Astronomers, however, said the mitigation measures so far have been insufficient.

The IAU, Schildknecht said, asks UN COPUOS to create regulations that would restrict the brightness of the satellites in megaconstellations and request operators to share data about their satellites' orbits with astronomers so that they could more easily avoid streaks in their observations.

The efforts of SpaceX, as well as other aspiring megaconstellation developers like Amazon and OneWeb, which launched 36 new satellites for its own constellation on Sunday, concern the global space community not only because of the impact on astronomical observations but also because of the hazards these satellites pose to the already cluttered orbital environment.

Operators at the European Space Operations Centre in Darmstadt, Germany, have to conduct avoidance maneuvers on average every two weeks over the fleet of 20 ESA spacecraft controlled from the center, said Holger Krag, the head of ESA Space Safety Program, during the news conference. But many more events generate alerts and have to be evaluated, even though an avoidance maneuver is at the end not conducted.

Nearly half of all of these alerts involve objects in large constellations or small satellites, the agency added in a written statement to Space.com. "These two classes are those that increased most in the past few years and are forecast to continue increasing," ESA said.

Related: This is what SpaceX's Starlink satellites first looked like in the sky

Space debris experts have long warned about the deteriorating orbital environment. Regulations, they say, were drawn up long ago when there were far fewer satellites hurtling around the Earth. What is worse, the guidelines, such as the requirement to deorbit a spacecraft within 25 years of a mission's end, are not always observed. According to ESA, only about 20% of satellites in low Earth orbit are successfully deorbited at the end of their mission.

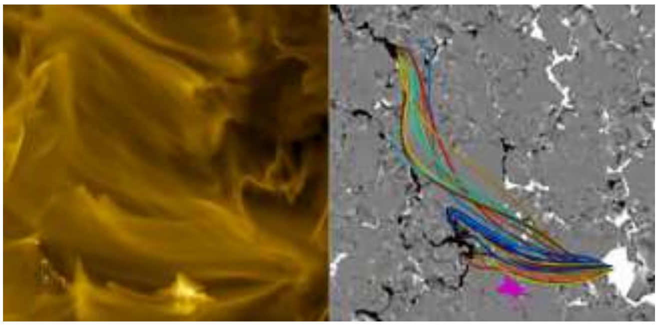
According to ESA, about 11,370 satellites have been launched since 1957, when the Soviet Union successfully orbited a beeping ball called Sputnik. About 6,900 of these satellites remain in orbit, but only 4,000 are still functioning. Starlink, with its monthly rate of over a hundred launched satellites, might wreak havoc in the already perilous orbital environment.

"Within one month, hundreds of satellites are being launched, and that is much more than we used to launch during an entire year," Schildknecht said. "Even with post-mission disposal, if we want to ensure long-term sustainable use of space, we will come to a point in certain orbital regions when we have to decide about the maximum capacity. We will need to decide whether we can safely launch another 10,000 new satellites."

Mysterious heating of sun's corona powered by solar 'campfires,' study suggests

By Tereza Pultarova - Senior Writer 6 days ago

One of the sun's strangest behaviours might be caused by 'campfires' on the star's surface.



The evolution of a solar campfire and its magnetic field as generated by a computer simulation. (Image credit: Chen et al)

The mysterious heating of the sun's corona might be powered by miniature solar flares dubbed 'campfires,' discovered by the European-US Solar Orbiter mission last year, a new study suggests.

The temperature of the sun's outer atmosphere, the corona, has puzzled scientists for decades. Extending millions of kilometers into space, it is unimaginably hot - more than 1.7 million degrees F (1 million degrees C). The solar surface, on the other hand, is a 'pleasant' 9,900 degrees F (5,500 degrees C). The difference defies logic: in most circumstances, material closer to a source of heat is hotter than anything more distant. Scientists have long known some unknown mechanism must be at play.

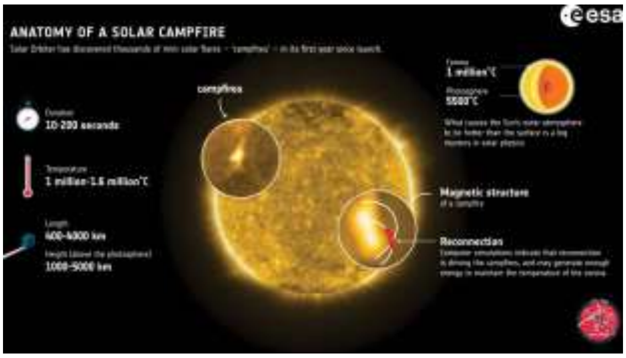
Now, a new study has found that the heat released by the recently discovered campfire mini solar flares could be enough to sustain the enormous coronal heating. The research was presented at the European Geosciences Union (EGU) General Assembly on Tuesday, April 27, 2021 and accepted for publication in the journal Astronomy and Astrophysics.

The study used computer simulations to model emissions of energy from the sun, hoping to generate flares like those measured in reality by scientific instruments. As the team ran the simulation, they saw brightenings similar in scale to the campfires observed by Solar Orbiter, said Professor Hardi Peter of the Max Planck Institute for Solar System Research in Germany, in a statement released by the European Space Agency (ESA). The scientists then looked more closely at magnetic disturbances around seven of the brightest simulated campfires, which were about the same size as the brightest events detected by Solar Orbiter.

"[The model] traces out the magnetic field lines, allowing us to see the changes of the magnetic field in and around the brightening events over time," Hardi said.

Tracing these magnetic lines revealed that a process called reconnection seems to be taking place, Hardi added. Scientists hypothesize that magnetic reconnections trigger large scale solar flares and coronal mass ejections. The visible disruptions on the sun's surface occur when two magnetic field lines of opposite direction break and reconnect, releasing a massive amount of energy in the process.

"Our model shows that the energy released from the [campfires] through component reconnection could be enough to maintain the temperature of the solar corona predicted from observations," said Yajie Chen, a PhD student from Peking University of China and lead author of the paper in the ESA statement.



Campfires, the miniature solar flares discovered in the first images by the ESA-NASA Solar Orbiter mission last year, are driven by the process of magnetic reconnection, which could be responsible for the mysterious heating of the sun's outer atmosphere. (Credit: ESA) (Image credit: ESA)

The campfires, some 250 and 2500 miles (400 to 4000 km) in diameter, might seem large from the human perspective. But they're actually tiny compared to the better known but rarer solar flares that cause magnetic storms on Earth, as well as beautiful aurora borealis displays.

What gives these campfires significance is their abundance. In the first Solar Orbiter images, released in July 2020, scientists could observe those campfires all over the sun's disk, each flickering like a candle for ten seconds to a few minutes before disappearing.

The idea that miniature solar flares could be responsible for the mysterious coronal heating was first put forward in the 1980s by U.S. physicist Eugene Parker, the namesake of another ground-breaking solar science spacecraft, NASA's Parker Solar Probe.

The new study suggests that Parker, now 93 years old, may have been right.

"Our mission is lucky to be building on the incredible groundwork of those that have flown before, and the theories and models already put forward over the last decades," Daniel Müller, ESA's Solar Orbiter Project Scientist, said in the statement. "We're looking forward to seeing what missing details Solar Orbiter – and the solar community working with our data – will contribute to solving open questions in this exciting field."

The results are especially impressive since Solar Orbiter is not yet in its official science phase. The spacecraft, which is meant to take the closest ever images of the sun, is still in a period of validation and orbital adjustments known as the cruise phase. It will officially commence its scientific exploration of the star at the center of our solar system in November of 2021.

The images that revealed the campfires were taken in June 2020 around the spacecraft's first perihelion, the point in its orbit closest to the sun. At that time, the spacecraft was about 48 million miles (77 million kilometres) away from the star's surface, about half of the average distance between the sun and Earth. But Solar Orbiter controllers continue to tighten its orbit around the sun, which will ultimately bring the spacecraft to the distance of only 42 million kilometers.

During its closest passes, the Parker Solar Probe dives way deeper into the sun's environment, passing closer than 10 million miles from its surface. But the spacecraft doesn't carry cameras for imaging the surface of the sun, instead making other measurements of the near-solar environment.

Later in its mission, operators will tilt Solar Orbiter's orbit around the sun out of the ecliptic plane in which planets orbit, allowing the spacecraft to take the first ever high-res images of the star's poles. Studying the activity around the poles, the scientists say, will help advance our understanding of the sun's magnetism and understand what drives the solar cycle, the periodical ebb and flow of the star's flares and sunspots.

Black Hole-Neutron Star Collisions Could Finally Settle the Different Measurements Over the Expansion Rate of the Universe

If you've been following developments in astronomy over the last few years, you may have heard about the so-called "crisis in cosmology," which has astronomers wondering whether there might be something wrong with our current understanding of the Universe. This crisis revolves around the rate at which the Universe expands: measurements of the expansion rate in the present Universe don't line up with measurements of the expansion rate during the early Universe. With no indication for why these measurements might disagree, astronomers are at a loss to explain the disparity.

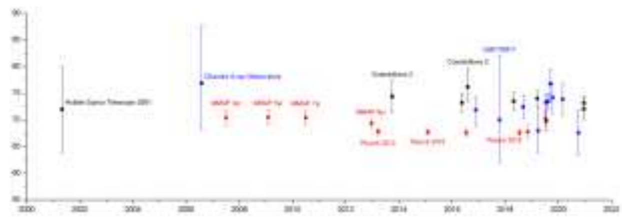
The first step in solving this mystery is to try out new methods of measuring the expansion rate. In a **paper** published last week, researchers at University College London (UCL) suggested that we might be able to create a new, independent measure of the expansion rate of the Universe by observing black hole-neutron star collisions.

Let's back up for a minute and discuss where things stand right now. When we look out into the Universe, galaxies that are further away appear to be moving away from us faster than closer ones, because space itself is expanding. This is expressed by a number known as the Hubble constant, which is usually written as the speed (in kilometers per second) of a galaxy one megaparsec (Mpc) away.

One of the best ways to measure the Hubble constant is to observe objects known as Cepheid Variables. Cepheids are stars that brighten and dim regularly, and their brightness just happens to line up with their period (the time it takes to dim and brighten again). The regularity of these objects makes it possible to estimate their distance, and a survey of many Cepheids gives us a Hubble constant of about 73km/s/Mpc.

Type 1A supernovae are another common object with a known brightness, and they also give a Hubble constant hovering around 73km/s/Mpc.

On the other hand, you can measure the expansion of the Universe during its earliest phase by observing the afterglow of the big bang, known as the cosmic microwave background radiation (CMB). Our best measurement of the CMB was taken by the European Space Agency's Planck spacecraft, which released its final data in 2018. Planck observed a Hubble constant of 67.66km/s/Mpc.



Estimated values of the Hubble constant. Black represent measurements from Cepheids/Type 1A Supernovae (73 km/s/Mpc). Red represents early universe CMB measurements (67 km/s/Mpc). Blue shows other techniques, whose uncertainties are not yet small enough to decide between the two. Credit: Renerpho (Wikimedia Commons).

The difference between 67 and 73 isn't enormous, and at first, the most likely explanation for the difference seemed to be instrument error. However, through subsequent observations, the error bars on these measurements have been narrowed down enough that the difference is statistically significant. A crisis indeed!

Here is where the UCL researchers hope to step in. They propose a new method of measuring the Hubble constant, which does not rely in any way on the other two methods. It begins with a measurement of gravitational waves: the ripples in spacetime caused by the collision of massive objects like black holes. The first gravitational waves were detected only recently, in 2015, and they haven't yet been associated with any visible collisions.

As lead researcher Stephen Feeney **explains**, "we have not yet detected light from these collisions. But advances in the sensitivity of equipment detecting gravitational waves, together with new detectors in India and Japan, will lead to a huge leap forward in terms of how many of these types of events we can detect."

Gravitational waves allow us to pinpoint the location of these collisions, but we need to measure light from the collisions too if we want to measure their speed. A black hole-neutron star collision might be just the type of event that would produce both.

If we see enough of these collisions, we could use them to produce a new measurement for the Hubble constant.

The LIGO Gravitational Wave detector in Louisiana. Image Credit: Caltech/MIT/LIGO Laboratory.

The UCL team used simulations to estimate how many black hole-neutron star collisions might occur in the next decade. They found that Earth's gravitational wave detectors might pick up 3000 of them before 2030, and of these, about 100 of them will probably also produce visible light. That would be enough. As such, by 2030 we just might have a brand-new measurement of the Hubble constant.

We don't know yet whether the new measurement will agree with the CMB measurement, or with the Cepheid/Type 1A measurement, or disagree with both. But the result, whatever it turns out to be, will be an important step in unraveling the puzzle. It could either put the crisis in cosmology to rest, or make it more serious, forcing us to look closer at our model of the Universe, and admit that there is more we don't know about the Universe than we thought.

Learn More: "**Black hole-neutron star collisions may settle dispute over Universe's expansion**." UCL.

Instead of Betelgeuse, Keep Your eye on AG Carinae, Another Star That's About to go Supernova

Astrophotography is one of the most gratifying parts of space exploration, and there's nothing better at it than **Hubble**. Recently, it celebrated the 31st anniversary of its launch by taking a spectacular image of one of the most impressive stars in the sky – **AG Carinae**. In the not too distant future, Hubble, or a successor, might be able to capture an even more spectacular display from the star when it goes supernova.

AG Carinae, located appropriately in the constellation **Carina**, is one of the most luminous stars in the sky, though its apparent brightness on Earth is somewhat diminished give its 20,000 light year distance from Earth. The star is famous for a number of reasons, including that it is one of only 50 known **luminous blue variable stars**.

Video showing AG Carinae in all it's glory.
Credit: NASA / ESA / STScI, Leah Hustak (STScI) Alyssa Pagan (STScI), Joseph DePasquale (STScI), Greg T. Bacon (STScI)

Luminous blue variables are extremely short lived and violent, barely balancing between exploding into a supernova and collapsing under its own weight into a black hole. As part of their life cycle, they occasionally emit a spectacular outburst that creates a kind of glowing shell around them, as can be seen in the Hubble image of AG Carinae.

Outbursts like the one in the picture only happen once or twice in a luminous blue variable's lifetime. They occur when radiation pressure from the interior of the star expands it out to such an immense size that it pushes material out of itself, then collapses back into a more stable state for potentially millions of years.

An older image of AG Carinae pulled from Hubble's Legacy archives and processed by Judy Schmidt.
Credit: Judy Schmidt / Hubble

In the case of AG Carinea, that outburst took place about 10,000 years ago, and ejected about 10 times the Sun's mass and is approximately 5 light years across, a little more than the distance from the Sun to the Alpha Centauri system. Material from the explosion is then subjected to the immense solar winds coming from the supermassive star, which itself is still approximately 70 times the mass of the Sun.

Traveling at up to 670,000 miles an hour, that solar wind is about 10 times faster than the ejecta, creating a "snowplow" effect that clears away some of the area directly around the star. At points around the star, the wind broke through the shall of material and dispersed it even more, as can be seen in the faint red glow in the upper left part of the Hubble image.

Eta Carinae is another luminous blue variable in the same general direction as AG Carinae and has the spectacular Homunculus Nebula surrounding it.
Credit: Jon Morse (University of Colorado) & NASA Hubble Space Telescope

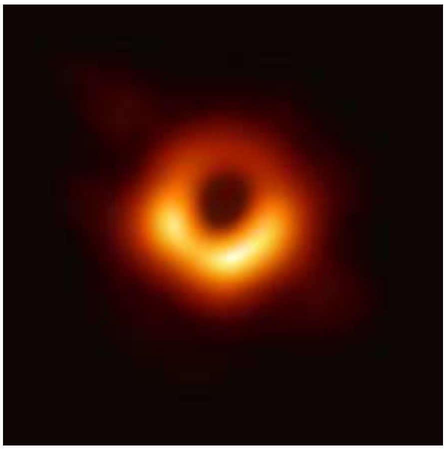
Other prominent features of the Hubble image include "tadpoles" and "bubbles" that can be seen highlighted in blue. These features are dust clumps that are denser than the rest of the ejecta material, and partially caused by interactions with the same stellar wind.

The image itself was taken in both visible and ultraviolet light, which allows for a clearer view of the filaments of material surrounding AG Carinae. Hubble isn't only taking pictures just for dramatic effect though. Its in the middle of the largest program in its history, known as the Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES), which focuses on young stars such as the blue luminous variables. With luck, the program might catch one of these ultra-rare stars at its expected end – a shocking supernova blast. If there's one current observational platform capable of capturing such an event in all its glory, its Hubble.

Are we Seeing a Star That Just got Spaghettified?

Sometimes astronomers come up with awesome names for certain phenomena and then feel like they can't use them in formal scientific contexts. **Tidal Disruption Events** (TDEs) are one of those – colloquially they are known as "**spaghettifications**" where a star is pulled apart until its constituent matter looks like a string of spaghetti.

Astronomers have long known of this process, which takes place when a star gets too close to a black hole, but most of that knowledge has come through studying radiation bursts emitted by the blackhole as it devoured the star. Now, a team led by Giacomo Cannizzaro and Peter Jonker from **SRON**, the Netherlands Institute for Space Research, and **Radboud University** now think they have captured the first glimpses of a star actively being spaghettified around the pole of a black hole.



An image of the accretion disk of the supermassive black hole as the center of M87.
Credit: EHT Collaboration

Those filaments of material have never been imaged before, as most images instances of an "**accretion disk**", as the disks of material surrounding black holes are known, have been seen from edge on, meaning they appear as a band of material in front of the black hole, much as Saturn's rings would appear if they were viewed edge on. What the SRON team did for the first time was capture information about the accreditation disk while looking at one of the poles of the black hole.

Accretion disks emit **X-ray** radiation, but do not do so edge-on, so when the SRON team saw that they had captured X-ray signatures in their spectra, they realized they were looking at the accretion disk of a black hole from a new perspective. That perspective would be like looking down at Saturn's rings from far above the pole of the planet, finally be able to truly appreciate how many there are.

UT Video describing the process of falling into a black hole.

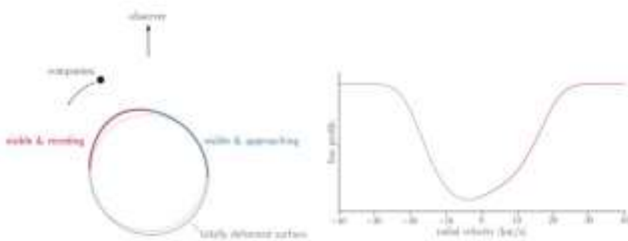
And there truly are many strands of material wrapped around this observed black hole – the team captured separate absorption lines that would indicate there are multiple strings of material wrapped around the star multiple times. That ball of yarn pattern is similar to what would be expected to happen in a spaghettification process. Additionally, there was no Doppler shift in the data, indicating that the material was not rotating, again hinting at the underlying cause of the disk.

While the spectral data hasn't yet been translated into a pretty picture for public consumption, it does put another feather in the cap of the TDE theory of how stars interact with black holes. Let's hope astronomers can come up with some other unique names for more esoteric processes – doughification perhaps?

Smallest, Closest Black Hole Ever Discovered is Only 1,500 Light-Years Away

In theory, a black hole is easy to make. Simply take a lump of matter, squeeze it into a sphere with a radius smaller than the **Schwarzschild radius,** and poof! You have a black hole. In practice, things aren't so easy. When you squeeze matter, it pushes back, so it takes a star's worth of weight to squeeze hard enough. Because of this, it's generally thought that even the smallest black holes must be at least 5 solar masses in size. But a recent study shows the lower bound might be even smaller.

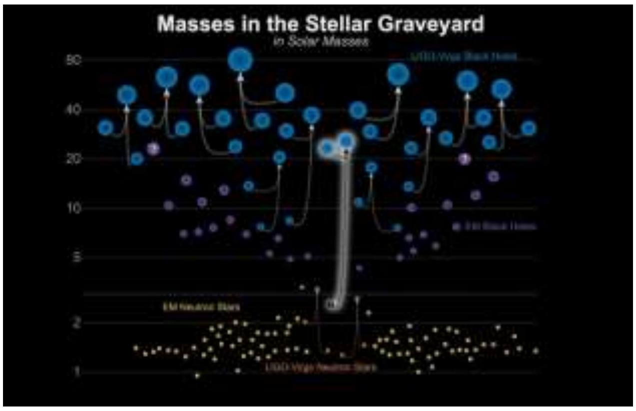
The work focuses red giant star known as V723 Monoceros. This star has a periodic wobble, meaning it's locked in orbit with a companion object. The companion is too small and dark to see directly, so it must be either a neutron star or black hole. Upon closer inspection, it turns out the star is not just wobbling in orbit with its companion, it's being gravitationally deformed by its companion, an effect known as tidal disruption.



How the distorted shape of V723 Mon affects its light curve.
Credit: K. Masuda and T. Hirano

Both the orbital wobble and the tidal disruption of V723 Mon can Doppler shift the light coming from it. Since both of these effects depend on the mass of the companion, you can calculate the companion mass. It turns out to be about 3 solar masses.

This is odd because it falls into what's known as the [mass gap](/blog/dark-edge/ mass gap) for compact bodies. According to our understanding of nuclear physics, a neutron star shouldn't be more than 2.5 solar masses. the largest neutron star we've observed is about 2.24 solar masses. Since black holes should be greater than 5 solar masses, there is a gap where don't expect to see compact bodies. And this object is right in the middle of it.



This graphic shows the latest merger compared to known black holes and neutron stars. Credit: LIGO-Virgo/ Frank Elavsky & Aaron Geller (Northwestern)

This isn't the first time we've observed an object in the mass gap. In 2019 LIGO and Virgo detected gravitational waves from a **merger between a 23 solar mass and 2.6 solar mass object.** While the merger object might have been a large neutron star, this new object seems too large for that. Right now the evidence strongly points to it being a black hole. If that's true, it is the smallest black hole we've discovered.

It would also be the closest black hole we've discovered, at only 1,500 light-years away. Astronomers have nicknamed this object The Unicorn, partly because of its unique properties, and partly it is in the constellation Monoceros. While we can't yet confirm The Unicorn is a black hole, we can with further studies. So, I guess you could call these future studies a Unicorn Chaser.

Reference: Masuda, Kento, and Teruyuki Hirano. "**Tidal Effects on the Radial Velocities of V723 Mon: Additional Evidence for a Dark 3 M? Companion.**" The Astrophysical Journal Letters 910.2 (2021): L17.

Reference: Jayasinghe, T., et al. "**A Unicorn in Monoceros: the 3 M? dark companion to the bright, nearby red giant V723 Mon is a non-interacting, mass-gap black hole candidate**." arXiv preprint arXiv:2101.02212 (2021).

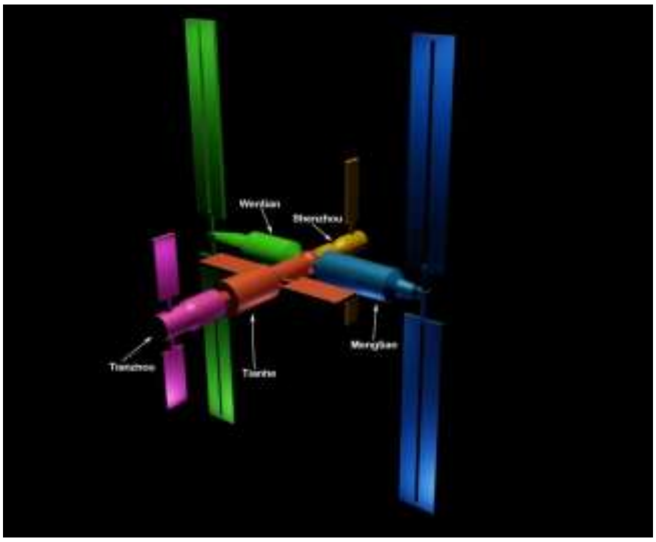
China Launches the Core Module of Its New Space Station

Early on Thursday, a Long March 5B rocket – currently the most powerful of China's space launch vehicles – blasted off from Wenchang, carrying the first major component of an ambitious new modular space station.

The station module, dubbed Tianhe (Harmony of the Heavens), marks the next big step in China's human spaceflight program in Low Earth Orbit (LEO). Barred from participating in the International Space Station (ISS) by US law, which forbids cooperation in space between the two countries, China has been developing its own LEO capabilities for over a decade now.

It launched its first spacefarers (called taikonauts) in 2003 and 2005 under the Shenzhou program, with a vehicle based on the Russian Soyuz design. A technology sharing agreement with Russia also enabled China to launch their first space station in 2011: a small, single-module space base known as Tiangong-1. A similar platform, Tiangong-2, followed in 2016. Both have since **deorbited**.

Tianhe is a big upgrade from these small predecessors. The core module houses life support for three taikonauts, as well as power and propulsion systems. A series of docking ports will enable crewed spacecraft to visit the station, but also make room for future modules (two other large laboratory sections, named Mengtian and Wentian, are planned). When complete, the modular station will weigh around sixty-six tons – smaller than the ISS, but much more capable than the prototype Tiangong stations. Tianhe also includes an extra-vehicular activity (EVA) airlock and hatch, allowing taikonauts to perform spacewalks.



Artist's impression of the completed station, showing the 3 core modules, a crewed vehicle (Shenzhou), and a cargo vehicle (Tianzhou). Credit: Saggittarius A (Wikimedia Commons)

Tianhe is currently orbiting at an altitude of approximately 360 kilometers at its lowest, and 400 kilometers at its highest, though further orbit-raising maneuvers will likely occur in the coming days to bring the station to its operational position. Like the ISS, it will require regular boosts to keep atmospheric drag from pulling the station back towards Earth.

Despite the political barriers that prevent cooperation with the US, other countries are keen to work with the Chinese space program on the station. Several European experiments are already planned to fly in the coming years, and back in 2019, nine experiments from seventeen countries **were selected to fly on the station** under the auspices of the United Nations Office for Outer Space Affairs (UNOOSA).

The first taikonauts will arrive at Tianhe in June, to begin construction and operations during a three-month stay in orbit. Three more construction missions are planned between now and 2022, which will be followed by longer-duration science missions. The completed station is expected to last at least ten years.

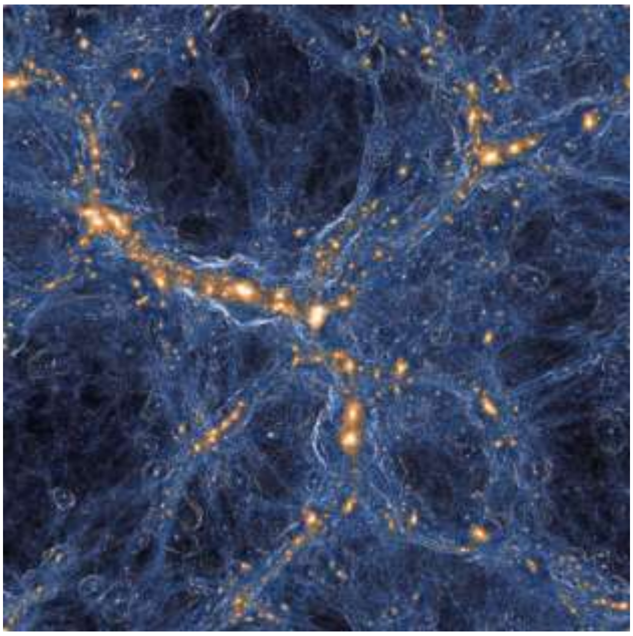
Tianhe's launch site, in Wenchang on the island of Hainan, is one of China's newest spaceports, hosting its first liftoff in 2016. Located closer to the equator than any other Chinese launch site, it provides access to orbital trajectories unavailable to the more northerly sites (although taikonauts visiting the station will launch from the Jiuquan launch center in the Gobi desert instead). The station's other modules will also launch from Wenchang, which is upgraded to support the newest variants of the Long March family of rockets: those designed as heavy-lift vehicles for interplanetary missions. China's first robotic Mars mission, Tianwen-1, launched from Wenchang last year.

Featured Image: Tianhe before launch. Credit: CNS (Wikimedia Commons).

11-Sigma Detection of Dark Energy Comes From Measuring Over a Million Extremely Distant Galaxies

After galaxies began to form in the early universe, the universe continued to expand. The gravitational attraction between galaxies worked to pull galaxies together into superclusters, while dark energy and its resulting cosmic expansion worked to drive these clusters apart. As a result, the universe is filled with tight clusters of galaxies separated by vast voids of mostly empty space.

The scale of these clusters and voids is based upon the rate at which the universe has expanded over time. The effect is similar to the way air molecules are clustered together by the varying pressure of sound waves, so the effect is known as **baryon acoustic oscillation (BAO).** Through this effect, astronomers can study dark energy by measuring the position and redshift of more than a million galaxies. Gathering and analyzing galaxies was first done by the **Baryon Oscillation Spectroscopic Survey (BOSS).** It was then extended to eBOSS, which has released its first results.



A Visualization of the Laniakea supercluster of which our galaxy is a part. Credit: Tsaghkyan / Wikimedia Commons

This new survey analyzed galaxies ranging from 0.7 – 1.8 billion light-years away, studying the BAO effect just as the early BOSS studies did. But eBOSS also looked at an effect known as redshift space distortions (RSD). This allowed the team to take into account the motion of a galaxy within space as well as cosmic expansion.

Within the standard model of cosmology, the distance of a galaxy can be determined by its redshift. Because the universe is expanding everywhere, the more distant a galaxy is, the greater the expansion of space between us, and the greater the redshift. But galaxies also move through space, and their relative motion can also contribute a redshift or blueshift. As a result, the overall redshift could be skewed, making our measurements of BAO less accurate. Through RSD, the team could account for this statistically, making their overall results much more accurate.

By combining BAO and RSD, the team confirmed the existence of dark energy to a stunning confidence level of 11-Sigma. Typically, a scientific result to 5-Sigma is taken as confirmation. A result at 11-Sigma is so strong it is about as close to certainty that we can get. Dark energy and the accelerating expansion it drives is definitely real.

Of course, we still don't know what dark energy actually is. One idea is that dark energy is an inherent property of space and time. A cosmological constant that causes the universe to expand. Another is that dark energy is an energy field that fills the universe, like a fifth fundamental force. To distinguish between these conflicting models, we must not only confirm the existence of dark energy, but also whether it changes over time, or varies depending on the direction we look. Studies such as eBOSS will give us the data we need to understand the cosmic mystery of dark energy.

"Put LUCKY on My Tombstone." Apollo 11 Astronaut Michael Collins Dies at 90

We bid a reluctant but truly fond farewell today to Michael Collins. The NASA astronaut passed away at the age of 90 on April 28, 2021. Collins flew on the historic Apollo 11 mission in 1969, and also on Gemini 10 in 1966.

As Command Module Pilot, Collins was the lone member of the Apollo 11 crew who remained in orbit while his fellow astronauts became the first to land and walk on the Moon. But his endearing nature means he will be most remembered for his wit and humor, his passion and humbleness, his unflappable demeanor, his thoughtful contemplations, and the inspiring words he left behind as a writer of several books.

Apollo 11 astronaut Michael Collins. Credit: Geekout-NewYork

Collins always felt he was one of the luckiest people to ever live. "Usually, you find yourself either too young or too old to do what you really want," he said in **an interview he did with himself in 2009,** "but consider: Neil Armstrong was born in 1930, Buzz Aldrin 1930, and Mike Collins 1930. We came along at exactly the right time. We survived hazardous careers and we were successful in them. But in my own case at least, it was 10 percent shrewd planning and 90 percent blind luck. Put LUCKY on my tombstone."

Collins passed away after a battle with cancer, according to **statement issued by his family:**

"We regret to share that our beloved father and grandfather passed away today after a valiant battle with cancer. He spent his final days peacefully, with his family by his side. Mike always faced the challenges of life with grace and humility, and faced this, his final challenge, in the same way. We will miss him terribly. Yet we also know how lucky Mike felt to have lived the life he did. We will honor his wish for us to celebrate, not mourn, that life. Please join us in fondly and joyfully remember his sharp wit, his quiet sense of purpose, his wise perspective gained both from looking back at Earth from the vantage of space and gazing across calm waters from the deck of his fishing boat."

Apollo 11 astronauts Neil Armstrong, Michael Collins and Buzz Aldrin examine film taken of their mission. Credit: NASA

NASA remembered Collins as a "true pioneer and lifelong advocate for exploration," said acting NASA Administrator Steve Jurczyk **in a statement,** and a "a tireless promoter of space…. There is no doubt he inspired a new generation of scientists, engineers, test pilots, and astronauts."

During the Apollo 11 flight, Collins was described as the "loneliest man in history" as he flew by himself, orbiting to the far side of the Moon, cut off even from radio communications with Earth. But he said he felt very much a part of the mission the entire time.

"I don't mean to deny a feeling of solitude," he said. "It is there, reinforced by the fact that radio contact with the Earth abruptly cuts off at the instant I disappear behind the moon, I am alone now, truly alone, and absolutely isolated from any known life. I am it. If a count were taken, the score would be three billion plus two over on the other side of the moon, and one plus God knows what on this side."

Collins was an Air Force pilot before being chosen as an astronaut in 1963. He never flew again after Apollo 11, but he didn't lament his lack of chance to walk on the lunar surface.

"As an astronaut I always thought I had the best job in the world and I still think that," he said, "but for me when it was over, it was over."

But still, he said he would look up and see the Moon, and think, "'Oh my God! I've been there!' I was up there, you see. Kind of takes me by surprise despite all these years."

Astronaut Michael Collins in a mockup of the Apollo 11 spacecraft during training. Credit: NASA

Collins left NASA in 1970 and joined the State Department, and then became director of the Smithsonian Air and Space Museum. He also began writing about his experiences. "Carrying the Fire: An Astronaut's Journeys" was a best seller and is often considered one of the best astronaut autobiographies.

He also wrote "Flying to the Moon and Other Strange Places (1976) a children's book on his experiences, "Liftoff: The Story of America's Adventure in Space," (1988) a history of the American space program, "Mission to Mars," (1990), a non-fiction book on human spaceflight to Mars. Collins was also an artist, painting watercolor landscapes.

Astronaut Michael Collins photographed inside the Gemini 10 spacecraft during the mission in Earth orbit. Credit: NASA

In addition to considering himself lucky, Collins never missed an opportunity to express his gratitude for the hundreds of thousands of people who worked during the early days of the US space program, who ultimately made it possible to send astronauts to the Moon.

"This trip of ours to the Moon may have looked, to you, simple or easy," he said in a transmission to Mission Control on the trip back to Earth from the Moon in 1969." I'd like to assure you that has not been the case…. This operation is somewhat like the periscope of a submarine. All you see is the three of us, but beneath the surface are thousands and thousands of others, and to all those, I would like to say, thank you very much."

Official crew photo of the Apollo 11 Crew. From left to right are astronauts Neil A. Armstrong, Commander; Michael Collins, Command Module Pilot; and Edwin E. Aldrin Jr., Lunar Module Pilot. Image Credit: NASA

Personally, I have always been inspired by Mike Collins and feel we have now lost a true national treasure. A few years ago, I wrote a song about him, called "Who Flies the Ship When Mike Collins Goes to Sleep." **You can listen to it here.** The song is a retrospective, if not whimsical look at the Apollo 11 mission through the eyes of the young girl I was in 1969, sitting in front of the television set, watching history.

A Recent Megaflare Shows that Proxima Centauri is not a Nice Place to Live

Proxima b, the closest exoplanet to our Solar System, has been a focal point of scientific study since it was first confirmed (in 2016). This terrestrial planet (aka. rocky) orbits Proxima Centauri, an M-type (red dwarf) star located 4.2 light-years beyond our Solar System – and is a part of the Alpha Centauri system. In addition to its proximity and rocky composition, it is also located within its parent star's habitable zone (HZ).

Until a mission can be sent to this planet (such as **Breakthrough Starshot**), astrobiologists are forced to postulate about the possibility that life could exist there. Unfortunately, an international campaign that monitored Proxima Centauri for months using nine space- and ground-based telescopes recently spotted an extreme flare coming from the star, one which would have rendered Proxima b uninhabitable.

The campaign was led by **Meredith A. MacGregor**, an assistant professor of astrophysics from the University of Colorado Boulder, and included members from the **Carnegie Institution for Science**, **Sydney Institute for Astronomy** (SIfA), **CSIRO Astronomy and Space Science, Space Telescope Science Institute** (STScI), the **Harvard-Smithsonian Center for Astrophysics** (CfA), and multiple universities.

This artist's impression shows the planet Proxima b orbiting the red dwarf star Proxima Centauri, the closest star to the Solar System. Credit: ESO/M. Kornmesser

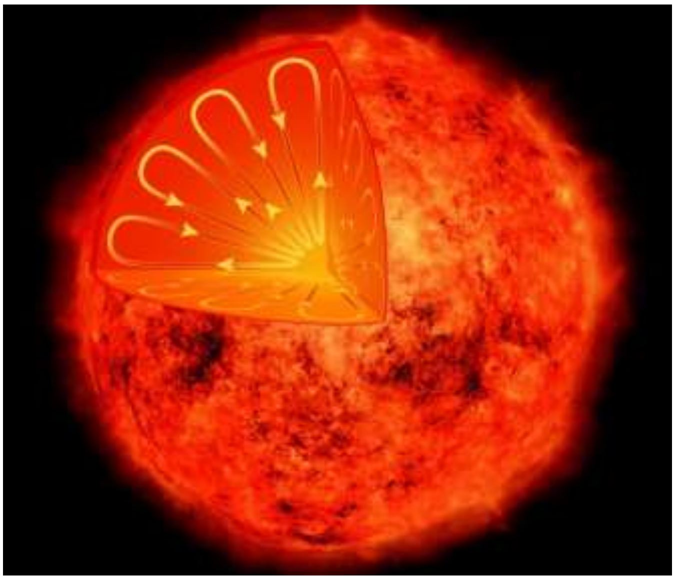
M-type stars like Proxima Centauri are a class of low-mass, low-luminosity stars that are known to be variable and unstable compared to other classes. In particular, these stars are prone to flare-ups, which occur when there's a shift in their magnetic fields that accelerates electrons to near light-speed (NLS). These electrons interact with the star's plasma, causing an eruption that produces emissions across the entire electromagnetic (EM) spectrum.

To determine how much Proxima Centauri flares, the research team observed the star for 40 hours over the course of several months in 2019. This included the **Australian Square Kilometre Array Pathfinder** (ASKAP), **Atacama Large Millimeter/submillimeter Array** (ALMA), **Hubble Space Telescope** (HST), **Transiting Exoplanet Survey Satellite** (TESS), and the **du Pont Telescope**.

These telescopes recorded a massive flare on May 1st, 2019, capturing the event as it produced a wide-EM spectrum of radiation and tracing its timing and energy in unprecedented detail. As MacGregor explained in a recent Carnegie Science **press release**:

"The star went from normal to 14,000 times brighter when seen in ultraviolet wavelengths over the span of a few seconds… If there was life on the planet nearest to Proxima Centauri, it would have to look very different than anything on Earth. A human being on this planet would have a bad time."

Since red dwarfs are rather dim compared to other types of stars, flare-ups are not likely to produce much in the way of visible light. Ordinarily, astronomers consider themselves lucky if they can observe flares of this kind with just two instruments. This campaign was the first time that astronomers were able to get multi-wavelength coverage of a stellar flare, which allowed them to observe the huge surges in ultraviolet and millimeter-wave radiation.



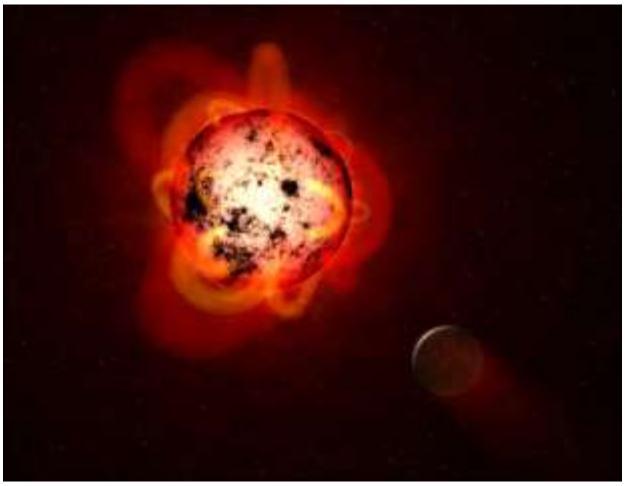
Artist's depiction of the interior of a low-mass star, such as the one seen in an X-ray image from Chandra in the inset. Credit: NASA/CXC/M.Weiss

The team's findings, which appeared in The Astrophysical Journal Letters on April 21st, constitute one of the most in-depth anatomies of a flare from any star in our galaxy. In the future, these signals could help researchers gather more information about how stars generate flares, which could have immense implications for exoplanet and habitability studies. Unfortunately, it does not bode well for planets like Proxima b.

This research is the latest in a series of papers and studies conducted since Proxima b was discovered that indicate how the system is not suitable for life. As the closest exoplanet to Earth, and located in the star's HZ, Proxima b is the most likely candidate for follow-up observations and astrobiological surveys. But according to this latest study, the flares it emits would have likely rendered the planet sterile a long time ago. As Weinberger **explained**:

"Proxima Centauri is of similar age to the Sun, so it's been blasting its planets with high energy flares for billions of years. Studying these extreme flares with multiple observatories lets us understand what its planets have endured and how they might have changed. Now we know these very different observatories operating at very different wavelengths can see the same fast, energetic impulse."

Beyond Proxima Centauri, the findings could also have implications for all planets that orbit within the HZs of red dwarf stars. M-type dwarfs are the most common type of stars in our galaxy and account for about 70% of stars in the entire Universe. Of the over **4,375 exoplanets** that have been confirmed to date, a statistically significant number of the "Earth-like" planets have been found orbiting M-type dwarfs.



An artist's illustration of a hypothetical exoplanet orbiting a red dwarf. Image Credit: NASA/ESA/G. Bacon (STScI)

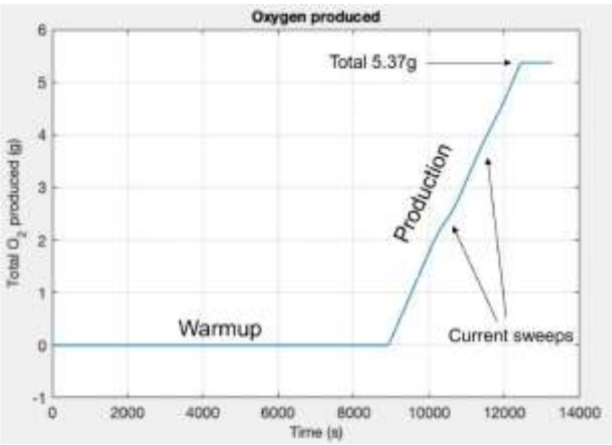
This has led many astronomers to speculate that the best place to find potentially habitable rocky planets is in red dwarf star systems. For this to be true, most of these stars would have to be significantly less active than Proxima Centauri. On a more positive note, the research suggests that our closest stellar neighbor could have more surprises in store for astronomers, like previously unknown types of flares that demonstrate exotic physics.

This research was conducted with support provided by the NASA Goddard Space Center.

Perseverance Successfully Extracts Oxygen From the Martian Atmosphere. About 10 Minutes of Breathing Time for an Astronaut

Humanity achieved an incredible series of new milestones on Mars this week. It began on Monday April 19th, when the Ingenuity helicopter demonstrated the **first-ever powered, controlled flight** on another world. And now, for the first time, the Perseverance rover has used ingredients from the Martian atmosphere to create breathable oxygen, in a test that might pave the way for future astronauts to 'live off the land' on the Red Planet.

The feat was achieved by the Mars Oxygen In-Situ Resource Utilization Experiment (**MOXIE**), a gold-colored cube bolted to the rover's belly. Over the course of an hour on April 20th, MOXIE produced 5.4 grams of oxygen, enough to keep an astronaut breathing for about ten minutes.

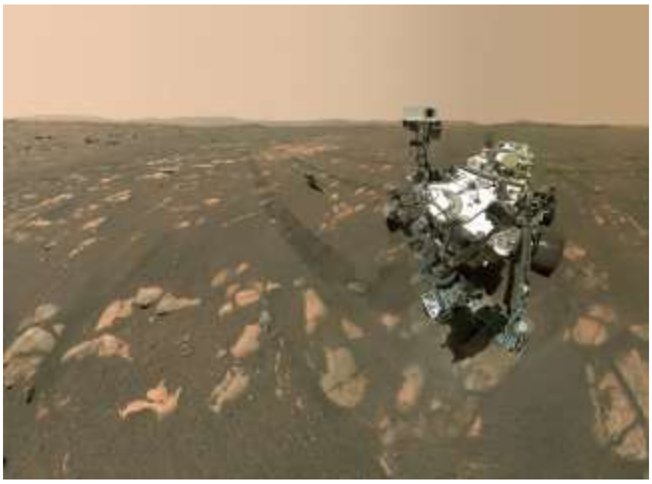


Data from MOXIE's first oxygen production test. The two minor reductions in oxygen production, labelled 'Current sweeps', were carried out purposefully to assess the instrument's status. Credit: MIT Haystack Observatory

MOXIE works by sucking in carbon dioxide (which makes up about 96% of Mars' thin atmosphere) while filtering out unwanted particles. The compressed carbon dioxide is then heated, breaking the molecules into oxygen and carbon monoxide. Further heating is required to separate the two new gasses, releasing the unwanted carbon monoxide back into the atmosphere, and leaving behind the breathable oxygen. MOXIE's gold plated exterior is designed to protect the other instruments on the rover from the process's extreme heat, which reaches over 800 degrees Celsius/1470 Fahrenheit.

Like Ingenuity, MOXIE is a technology demonstration: neither has any impact on Perseverance's primary science goals. Instead, they are meant to provide proofs of concept for future missions. Future Ingenuity-like drones might be able to explore places a rover can't go, like a cliff edge or a fissure, for example. Similarly, future missions could use MOXIE-like technology to enable long-term exploration.

Creating a breathable atmosphere for humans isn't the only application. It could also be used to refuel a rocket for its return journey home. As MOXIE's principal investigator Michael Hecht **explains**, "To get four astronauts off the Martian surface on a future mission would require 15,000 pounds (7 metric tons) of rocket fuel and 55,000 pounds (25 metric tons) of oxygen…The astronauts who spend a year on the surface will maybe use one metric ton between them to breathe." In other words, most of the oxygen created by future MOXIE-like gadgets won't be for life-support, but rather for propulsion.



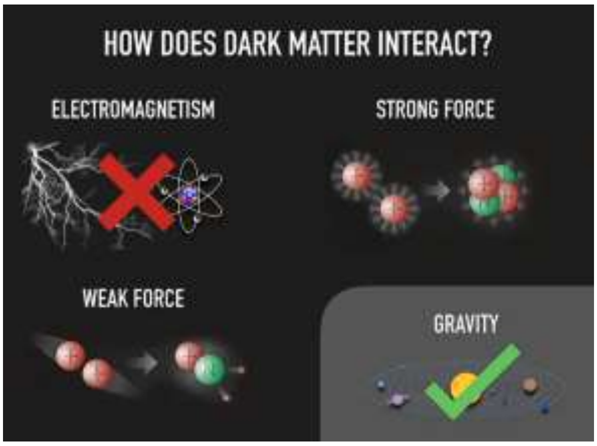
NASA's Perseverance rover, with MOXIE on board, takes a selfie next to the Ingenuity helicopter on 6 April 2021. Credit: NASA/JPL-Caltech/MSSS.

Future tests will push the limits of MOXIE's capabilities. It should be able to double its output to 12 grams of oxygen per hour, and over the next two years it will be tested at least nine more times in different conditions (different seasons and times of day). The team is also currently analyzing the purity of the oxygen produced: preliminary results show near-perfect success.

In the meantime, Ingenuity has about a week and a half left in its test period, in which it will make progressively more complicated flights. When it's done, Perseverance will rove away on its own mission – bringing MOXIE with it – to collect samples of Martian soil and rock. The samples will be picked up by a future sample-return mission, bringing them home to Earth for a close-up examination.

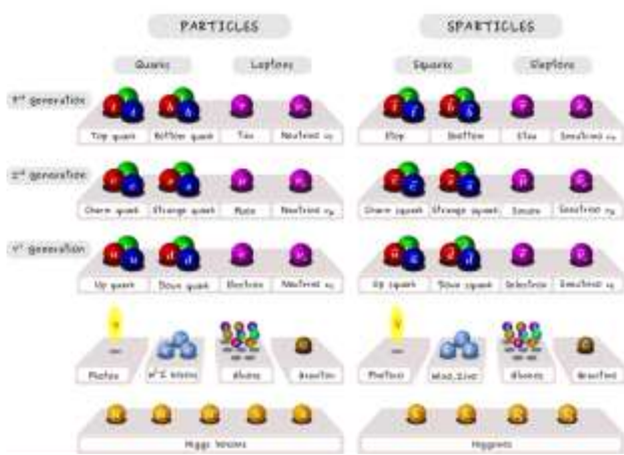
One Idea to Explain Dark Matter – Ultralight Bosons – Fails the Test

Dark matter continues to resist our best efforts to pin it down. While dark matter remains a dominant theory of cosmology, and there is lots of evidence to support a universe filled with cold dark matter, every search for dark matter particles yields nothing. A new study continues that tradition, ruling out a range of dark matter candidates.



What we know about dark matter interactions. Credit: Perimeter Institute

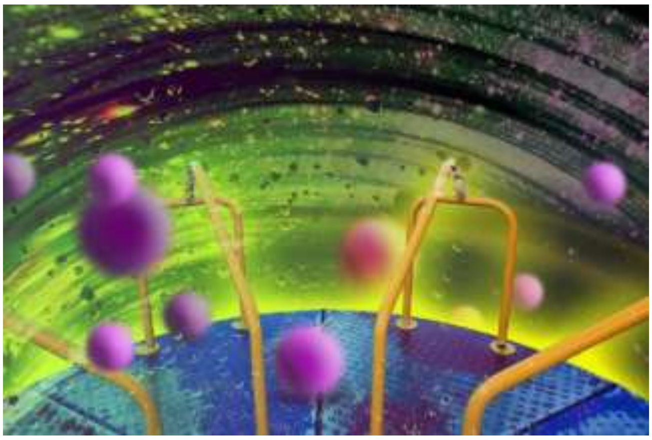
If dark matter particles exist, we know they can't interact strongly with light. They must interact gravitationally, and they might interact via the strong and weak nuclear forces as well. We also know they can't be highly massive particles. If they were, they'd decay over time into lighter particles, and we see little evidence of this. This leaves three broad candidates: small black holes, **sterile neutrinos,** or some type of light boson. This latest work focuses on the third option.



A table of supersymetric particles. Credit: Claire David / CERN

Known elementary particles of matter can be placed in one of two categories: fermions and bosons. So, electrons, quarks, and neutrinos are fermions, while photons and gluons are bosons. Within the standard model of particle physics, there are no bosons that would fit the bill for dark matter. But some alternative models predict particles that could be dark matter. Supersymmetry models, for example, predict that every known fermion must have a corresponding boson and vice versa. Thus, the electron would have a counterpart boson known as the selectron, the photon would have a counterpart fermion known as the photino, and so forth. Another possibility are **axions,** which were proposed in 1977 to address subtle aspects of how quarks interact.

Both axions and supersymmetry particles could be low-mass bosons and would satisfy the needs of dark matter. But if either exists, they haven't been found thus far. Still, these light bosons would interact with regular matter gravitationally, hence this latest study.



Bosons can slow down a black hole like kids jumping on a merry-go-round. Credit: Jose-Luis Olivares, MIT

If dark matter is made of light bosons, then these particles would be spread across the universe, including near black holes. A black hole would gravitationally capture nearby bosons, thus increasing its mass. If a black hole is rotating, the capture of dark matter particles would also tend to slow down its rotation. You can imagine children at a playground that has a merry-go-round. If children jump onto the merry-go-round as it is spinning, the merry-go-round will slow down slightly because of the added mass. The same would be true for black holes.

In other words, dark matter bosons would limit the rate that black holes rotate. The team realized that heavier bosons would limit black holes more, and lighter bosons would constrain them less. So they looked at the LIGO and Virgo data of black hole mergers, which tells us the rotation rate of black holes before they merge. It turns out that some of these black holes rotated so quickly that it rules out the existence of ultra-light dark matter bosons. Based on this study, dark matter can't be axions or light supersymmetry particles.

So once again, a search for dark matter has shown us not what dark matter is, but what it isn't. It's extremely frustrating, and potentially exciting because we are quickly running out of options for dark matter.

Reference: Ng, Ken KY, et al. "**Constraints on Ultralight Scalar Bosons within Black Hole Spin Measurements from the LIGO-Virgo GWTC-2**." Physical Review Letters 126.15 (2021): 151102.

NASA Picks SpaceX to Land Astronauts on the Moon!

As part of the Artemis program, NASA is gearing up to send the "first woman and next man" to the Moon by 2024. Central to this is the development of the ***Space Launch System*** (SLS), the most powerful rocket since the Saturn V that took the Apollo astronauts to the Moon, and the ***Orion*** spacecraft. But after these elements transport astronauts to Lunar orbit, they will need a lander to take them to and from the surface.

For this reason, NASA contracted a number of commercial partners to develop a **Human Landing System** (HLS). After much consideration, NASA announced on **Friday, April 16th**, that they had selected SpaceX to continue developing their concept for a lunar lander. When American astronauts return to the Moon for the first time in fifty-two years, it will be a modified version of the Starship that will bring them there.

The SpaceX concept was **one of three finalists** selected by NASA in April of 2020 to develop an HLS proposal as part of **Appendix H: Human Landing System** of the **Next Space Technologies for Exploration Partnerships (NextSTEP-2)** program. Along with Blue Origin and Dynetics, the finalists were awarded contracts worth $967 million for the 10-month base period. With this latest award, SpaceX has earned a firm and fixed-price milestone-based contract worth a total of $2.89 billion.

SpaceX's HLS concept calls for a fully-integrated vehicle similar in design to the Starship – the orbiter element of a fully-reusable two-stage super-heavy launch system the company is currently developing. During the HLS base period of performance, SpaceX engineers have been working closely with NASA experts to create a lander design that meets NASA's performance requirements and human spaceflight standards.

The HLS Starship takes advantage of the company's tried and true **Raptor** engine design, as well as the company's experience with launch vehicles and spacecraft – the ***Falcon 9*** and ***Falcon Heavy*** rockets and the ***Dragon*** vehicles. The HLS Starship design also includes a spacious cabin for the four astronauts and two airlocks to accommodate extra-vehicular activities (EVAs) – aka. "moonwalks."

As Kathy Lueders, NASA's associate administrator for **Human Exploration and Operations Mission Directorate** (HEOSM), said in a NASA **press release**:

"With this award, NASA and our partners will complete the first crewed demonstration mission to the surface of the Moon in the 21st century as the agency takes a step forward for women's equality and long-term deep space exploration. This critical step puts humanity on a path to sustainable lunar exploration and keeps our eyes on missions farther into the solar system, including Mars."

When the Artemis III mission launches (currently scheduled for October of 2024), the SLS and Orion will send four astronauts on a multi-day journey to lunar orbit. At this point, two crew members will transfer to the SpaceX HLS to make the final leg of the journey and descend to the lunar surface. After about a week spent exploring the surface, the astronauts will launch aboard the lander to rendezvous with Orion and head back to Earth.

This will be a historic event, and not just because it will be the first time that boots are placed on the lunar surface since the last mission of the Apollo Era. This was ***Apollo 17***, which took place in December of 1972, and saw astronauts Eugene Cernan and Harrison Schmitt spend three days on the lunar surface and conduct the longest "moonwalk" to date (also the longest).

This time around, at least one of the two astronauts to land on the Moon will be a woman. Another goal of the Artemis program includes having the first person of color walk on the lunar surface. **Said** Lisa Watson-Morgan, the program manager for HLS at NASA's Marshall Space Flight Center:

"This is an exciting time for NASA and especially the Artemis team. During the Apollo program, we proved that it is possible to do the seemingly impossible: land humans on the Moon. By taking a collaborative approach in working with industry while leveraging NASA's proven technical expertise and capabilities, we will return American astronauts to the Moon's surface once again, this time to explore new areas for longer periods of time."

Illustration of Artemis astronauts on the Moon. Credits: NASA

Alongside the Appendix H award, NASA plans to implement a competitive procurement for the development of crewed lunar transportation services. In keeping with their goal of creating a program of "sustained lunar exploration" that will continue well beyond the Artemis program, this service will provide human access to and from the lunar surface using the Lunar Gateway.

Earlier this year, NASA announced that it had **contracted with SpaceX** to provide launch services for the Gateway's core elements. These include the **Power and Propulsion Element** (PPE) and the **Habitation and Logistics Outpost** (HALO), both of which are scheduled to launch from **Launch Complex 39A** at NASA's Kennedy

Roman Space Telescope Will Also Find Rogue Black Holes

In the past **we've reported** about how the **Roman Space Telescope** is going to potentially be able to detect hundreds of thousands of exoplanets using a technique known as "**microlensing**". Exoplanets won't be the only things it can find with this technique though – it should be able to find solitary black holes as well.

Solitary black holes are unique, as most black holes that scientists have "found" are those that are directly interacting with another object. However, those that are relatively small that could be roving around the galaxy by themselves which would be almost impossible to find since they absorb all electromagnetic wavelengths.

UT video describing microlensing

Usually these small black holes weigh around 10 times the weight of the sun. They form when a star dies and either goes supernova or collapses directly into a black hole, depending on its weight. If the black hole isn't surrounded by any gas or dust to absorb, it would then become essentially invisible to almost all instruments.

So far scientists have found 20 of these "stellar mass" black holes, but only because they are next to a different astronomical object, making their gravitational force apparent in the way that companion object moves.

NASA Video describing how to use gravitational lensing to detect black holes.

Credit: NASA

The neat thing about the microlensing technique that Roman will use to detect planets is that any large gravitational field will cause the microlensing effect. So if Roman sees what appears to be a microlensing effect around something where there is not an obvious source of mass, it is likely to be a black hole causing it.

In order to find the slight disturbances that would cause the microlensing, Roman will have to stare at hundreds of millions of stars for a very long time. But that is exactly what it is designed to do. With this additional data, scientists will be able to answer questions such as why solitary black holes only seem to mass around 10x what the sun does, or exactly how many stellar-mass black holes there are in the galaxy. The current estimate is around 100 million.

UT video discussing the prevalence of black holes.

No matter the answers to these questions, Roman will provide more data to inform conclusions on these questions and many others when it launches around 2025.

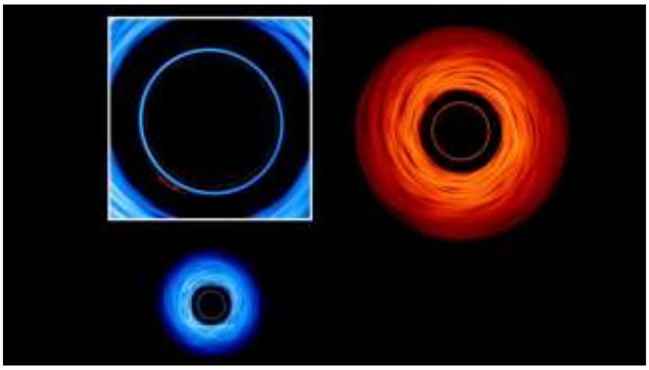
You Thought Black Hole Event Horizons Looked Strange. Check out Binary Black Hole Event Horizons

One of the strangest predictions of general relativity is that gravity can **deflect the path of light.** The effect was first observed by Arthur Eddington in 1919. While the bending effect of the Sun is small, near a black hole light deflection can be significant. So significant that you need a powerful supercomputer to calculate how light will behave.

Recently the NASA Goddard Media Studios released a few videos showing us how a binary black hole system might look under gravitational lensing. The simulation traces the paths of light coming from the accretion disks of two close-orbiting black holes. One with a mass of 200 million Sun, the other with half that mass. The simulation was run on the Discover supercomputer at the NASA Center for Climate Simulation and took about a day to complete.

Check out NASA Goddard's video to see the latest simula-

tion.
This new simulation takes into account **some of the more subtle effects.** For example, near a rotating black hole, light coming from the side rotating toward us will appear brighter, while light from the side rotating away from us would appear dimmer. This effect is known as Doppler boosting. Another strange effect is known as relativistic aberration, where black holes appear smaller when moving toward the viewer, and larger when moving away.



Each accretion disk holds a reflection of the other. Credit: NASA's Goddard Space Flight Center/Jeremy Schnittman and Brian P. Powell

Perhaps the biggest computational challenge is that you can't just do a simple first-order simulation of the lensing. When two black holes are visually close to each other, light from black hole A can be distorted by black hole B to the point that it is twisted back to black hole A. It can then be lensed again before it has a chance to head our way. Light paths can be so distorted at times that it is difficult to determine which accretion disk the light came from. To make this effect easier to see, the visualization uses a bright red color for the larger black hole's accretion disk and a bright blue color for that of the smaller black hole. In the video and images, you can see reflections of one black hole accretion disk in that of the other. The proximity of the black holes also distorts the visual shape of the accretion disks, making them appear more oval than they actually are.
Even though this isn't a simulation of an actual black hole system, it tells us a great deal about how binary black holes can appear. This is particularly important as we discover more binary black holes by their gravitational waves. Although black holes themselves don't emit light as they merge, their accretion disks do. As we better understand how this light is distorted by gravity, we can better combine optical and gravitational data to give us a detailed understanding of real black hole mergers.
Reference: GMS N. GMS. "NASA Visualization Probes the Doubly Warped World of Binary Black Holes." **https://svs.gsfc.nasa.gov/13831.** Published April 15, 2021.

Biden Administration is Looking for a 6.3% Increase in NASA's Budget for 2022

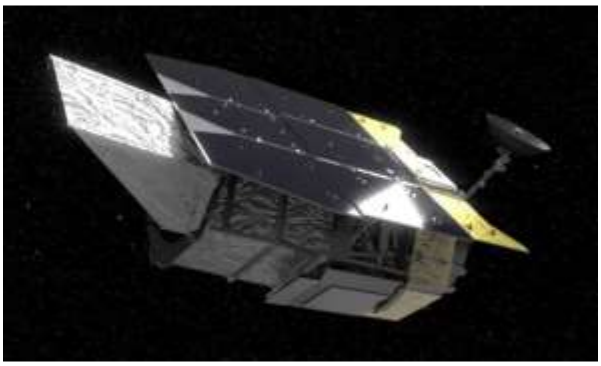
Space research, like much else in capitalist societies, is driven by funding. The biggest source of that funding for that space research is usually the US government. Which is why, when US presidents release their budget proposals, the space community takes notice. Especially because that budget affects NASA, the largest space funding agency in the world. With a new year and new administration comes a new budget and with the 2021 proposed budget comes a nice funding increase for NASA.
The **proposed budget** was released on April 9th, and, at 58 pages, goes into high level details about almost every part of federal spending. The section regarding NASA is only about a page long, but has some useful hints at how the new administration views the role of its space exploration arm. In order to fulfill that role, the administration plans to spend $24.7 billion on the agency, an increase of 6.3% over the funded level last year.

Banner from a NASA Facebook account showing its interest in climate change science.
Credit: NASA

Some of that money will go to one of the administrations biggest focal points – **climate change**. The administration had already released an **infrastructure plan** that focused on alleviating climate change. NASA is also being roped into the effort, as it is well placed to help contribute to this priority through it's combination of satellite monitoring and Earth Science research. $2.3 billion is earmarked to go directly towards understanding and alleviating climate change, a 10% increase over the prior year.
The biggest chunk of the budget ($6.9 billion) will go to the **Artemis program**, the US's effort to land astronauts on the moon again. The program reached a deal with **SpaceX** today to provide it's lunar landing module. While this funding level is an increase of $325 million over the previous year, in that previous year NASA had asked for almost double the current amount provided for this program. It's unclear whether the current funding level is capable of supporting the program's mission to land a person on the moon by 2024.

The Artemis program selected three commercial landers for its first phase, pictured above from left to right are the Peregrine by Astrobotic, Nova-C by Intuitive Machines, and Z-01 by OrbitBeyond
Credit : NASA GSFC

Although a specific funding number wasn't mentioned for any individual project, various robotic missions were mentioned as part of the budget proposal. These include the **Europa Clipper**, **Dragonfly**, and **Mars Sample Return** mission that is the follow-up to **Perseverance**. Also the budget specifically calls out the **Roman Space Telescope**, supporting a project that had previously been on the **chopping block**.



Artist's depiction of the Roman Space Telescope, which is explicitly funded as part of the new NASA proposed budget.
Credit – NASA WFIRST Project and Dominic Benford
Other funding categories specifically called out in the proposal were Space Technology R&D, STEM workforce training, and **ISS** support. The research and development NASA will fund for will focus on providing technologies to empower the commercial space industry as well as create more efficient aerospace tools in order to fight climate change.
At $20 million, the educational side of NASA might seem like a drop in the bucket in terms of the overall cost of the program. However, its increase at 16% was actually the highest specifically called out in the NASA part of the budget, and again marks a sharp departure from the previous administration's efforts to defund the educational outreach efforts of the space organization. The ISS is also still in good stead, with $3 billion going towards its continual operation and research performed on the space station.
This Week at NASA is one of the programs sponsored by the Educational Outreach arm of the space research organization. It also happened to do a video on the details of the proposed budget.
Credit: NASA YouTube Channel
Other aerospace related agencies would also benefit from increased budgets in the new proposal. These include the **National Science Foundation**, which funds a significant amount of planetary science, which has a requested increase of 20% to bring it's funding to $10.2 billion.
The **National Oceanographic and Atmospheric Association** (NOAA) would also get a $500 million boost to bring it's total budget to $2 billion. NOAA has its own array of Earth-observing satellites that would also be useful in the fight against climate change.
There are other space-facing parts of agencies that aren't specifically called out in the budget, such as the FAA's Office of Commercial Space Transportation. However, given the general theme of the budget, those programs would be seemingly well supported.
As with all things to do in US politics, however, this budget is no sure thing. It will still have to get through Congress, which is notorious for their fights over budgets. While the increases mentioned above might not survive political realities, it at least points to what the new administration values in space exploration, and proves that they are willing to fund it in order to achieve their goals.

Earth Gains 5,200 Tons of Dust From Space Every Year

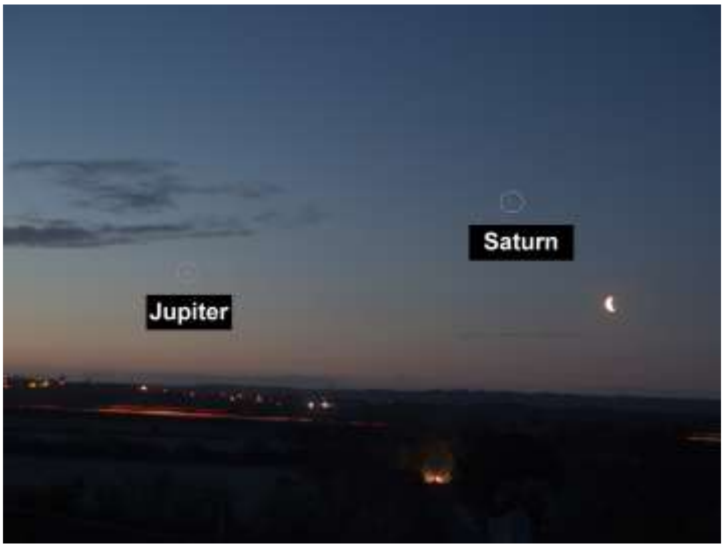
Whenever I wipe the dust off my coffee table or catch a glimpse of dust motes floating in sunlight, my spacey mind always wonders, is any of that cosmic dust?
It just might be. But the amount of space dust that lands on our planet every year might surprise you.
Scientists have long known that there is annual flux of extraterrestrial material deposited on Earth, which mainly comes in the form of tiny particles, primarily from comets and asteroids. These sub-millimeter-sized dust grains are the ones that can make it down through our atmosphere unscathed. But the exact amount has never been calculated, due to the difficulty in collecting and monitoring this dust. The biggest issue is that Earth itself and the atmosphere are dusty places, so if you're collecting dust, how do you discern between Earth dust and space dust?
For the past 20 years, a group of scientists have collected dust in the least dusty place on Earth: the plains of central Antarctica, which are always covered with snow and ice.

Dome C Antarctica station. Credit: Stephen Hudson, Public Domain, via Wikimedia Commons.
An international collaboration of researchers from France, the United States and the United Kingdom conducted six expeditions over two decades to the Franco-Italian Concordia station, called Dome C, located 1,100 kilometers from the coast in of Antarctica. The Dome C area is considered ideal for the study of micrometeorites because of the near absence of terrestrial dust and low rates of accumulation of snow.
Using a calculated system of extracting samples of snow in 2-meter deep trenches, the researchers collected extraterrestrial particles, ranging in size from 30 to 200 micrometers. They were able to collect enough samples over the years to measure an annual flux, which corresponds to the mass accreted on Earth per square meter per year.
The team reports that if their results are applied to the whole planet, the total annual flux of micrometeorites represents 5,200 tons per year.

Collecting micrometeorites in the central Antarctic regions, at Dome C in 2002. Snow sampling. Credit and copyright: Jean Duprat/ Cécile Engrand/ CNRS Photothèque
"This is the main source of extraterrestrial matter on our planet, far ahead of larger objects such as meteorites, for which the flux is less than ten tons per year," according to lead researcher Jean Duprat from the French National Centre for Scientific Research (CNRS).
To determine how much cosmic dust falls in my nearby surroundings per year, a quick back-of-the envelope calculation yields about 9 grams per square kilometer or .85 ounces per square mile.
In other words, we don't have to worry about a Pompeii-type event of cosmic dust covering us each year.
The **team's paper** also explains how small particles of space dust make it through our atmosphere without burning up:
The degree of heating experienced by the particles during their atmospheric entry depends on various factors including the initial mass of the particles, their entry angle and velocity. The ablated metallic vapours oxidize and the resulting metal oxides, hydroxides and carbonates condense into nm-sized particles termed meteoric smoke (Plane et al., 2015). These particles are transported by the general atmospheric circulation until eventually deposited at the surface, where their flux can be evaluated by elemental or isotopic measurements (Gabrielli et al. (2004).

E Mails Viewings Logs and Images from Members.

Hi Andy,
Here are my submissions for the WAS May 2021 newsletter.
06/04/2021
Jupiter, Saturn and 30% Lit Waning Crescent Moon



Canon G16, ISO 200, F2.8, 1 sec.

06/04/2021
30% Lit Waning Crescent Moon
Canon Powershot SX50HS 1200mm, ISO 1000, F6.5, 1/30 sec
80 raw images converted to tiff in Canon DPP, cropped and centred in Pipp, stacked and wavelet in Registax 6 and post processed in Affinity Photo.

14/04/2021
6.5% Lit Waxing Crescent Moon
Canon SX50HS 1200mm, ISO 125, F6.5, 1/25 sec

80 raw images converted to tiff in Canon DPP, cropped and centred in Pipp, stacked and wavelet in Registax 6 and post processed in Affinity Photo.

And see back page! Ed.
Clear Skies,
John

Hi Andy,

Two viewing logs and pictures for the magazine.

Managed to find Venus very low in the western sky on the 22nd, was due to set about 20 minutes later?

The Moon taken with a Canon 70D attached to the Meade telescope, tech details: shutter speed of 1/10th of a second, ISO 200 at f10. Moon phase was 6.79 days old or 36.3 % lit and 394,262 km away (all info from Virtual Moon Atlas)

Pete

Viewing logs:

Viewing Log for 14th of April

After playing golf in the late afternoon and early evening, plus a beer at the 19th, I did not get home until around 20:30! With the skies clear and no wind around I thought I would go out and do a late viewing session! By the time I had finished my evening meal, loaded the car and got out to my usual viewing position near Uffcott (first time this year due to our friend Covid-19 and lockdown 1.3) just south of Swindon and off from the A4361. After using my EQ mounts at home and having some problems with them I decided I would use my trusted Meade LX90 8 inch (203 mm) GOTO telescope with a 14 mm Pentax XW eye piece, set up was complete by 21:47 and a starting temperature of 4 °C. before doing the three star alignment I noticed the power lead jack that goes into the control panel was on the loose side and would need to be attached to the hand controller jack which was right beside this jack, only item I could use was a plaster from the car first aid kit to tie the two jacks together and stop any looseness from the power supply!

First target would be the waxing crescent Moon which was just above the hedge row as I viewed it, it was 2.77 days old or 6.7 % lit and 405,562 km away according to Virtual Moon Atlas and 2.51 days old and 18.3 % lit according to the Meade hand controller, a big differences between them? With the Moon being so low I would not need any filters to save my eye sight, I noticed four large craters on the terminator, namely (from the north) Bernoulli, Langrenus, Petavius and Furnerius plus of Mare Humboldtianum (Sea of Humboldt) and Mare Crisium (Sea of Crises). With the Moon due to set by 22:35 there would be no light pollution from it only the odd car which could go pass me! Only solar system target on view was Mars, being 1.5 AU away and only 4 arc seconds in diameter no detail could be made out? As it is around the time of year to do the Messier marathon I thought I would have a go at it. Being a late start I had already missed M 77, 74, 33, 31, 32 and 110 due to the glow in the western sky or they were too low to view?. First target was M52, a dim, small open cluster (O C), it did have a few bright stars within this cluster. While viewing this cluster a Hercules from RAF Brize Norton flew over, after looking at the plane for a few minutes it was on to my next target and M 103, the other O C in Cassiopeia, this was also dim and small to look at, I did notice a triangle of stars within this cluster? Next object should be M 76 but I decided I would go for M 42 and 43 in Orion as they were between branches in a nearby tree! Could hardly make out the any detail due to the lowness? Other object in this constellation M 78 was a faint fuzzy blob (F F B) to look at? M 41 was in the hedge and M 79 had already gone! So it was back to the order and M 76, this planetary nebula (P N) had a bright core but nothing else to report? Again I decided I would jump again and look at M 45 as it was just above that hedge, could make out the main seven stars with the aid of the finder scope, main scope was looking thru this O C! Back to order again and M 34, this O C was dim and fairly loose to look at, did not help as I was looking thru branches of a tree! Rest of the evening should be done in order from now? M 1 the only supernova remnant on the whole list was next, a large F B with some detail? Now there would be a cluster of O C's to view, starting with M 35, large O C that filled the eye piece with stars (now the skies had darken a bit)? Same comment could also be said about M 37 but I would add the word dense to the statement? M 36 was a large and loose for an O C, M 38 was similar but had more stars to look at than M 36? Next five objects I would be looking at are not normally on my radar set, starting with M 50 a dim with not many stars in this O C? M 47 was large and very loose for an O C, not far away is M 46, this also large but dim and very loose to look at? Could not make out M 93, the glow from Devizes killed this O C as it was starting to get low! M 48 was a very large and loose O C? Another cluster that is better seen with the finder scope is M 44 about a third of this scope had starts in it? Finally O C would M 67, this had a good number of stars in it? Time to go over head and view Ursa Major starting with M 81, this galaxy had a bright core. Nearby is M 82 a long and thin galaxy often called the Cigar galaxy? M 108 was an F F B to look at, classic spiral galaxy even though it had an elevation of 85 °, one degree higher was M 97 formally my nemesis this P N looked like a large F B? Both M 109 and 106 were F F B to look at even at this angle with little atmosphere to affect their light coming to me? As for M 40, well! The only double star on this whole list, enough said? Back to Leo and M 95, an F F B and easy to miss even with GOTO equipment! Nearby was M 96, this galaxy had a brighter core than M 95? M 105 was an F B and I noticed another galaxy in the eye piece, checking Stellarium later on it turns out to be NGC 3389? Onto M 66 and 65, both of these galaxies could be seen in the same field of view, I would say M 66 is the brighter of the two?

With all of the action I had seen earlier in the day I was starting to feel quite tired, so I decided to call it a day and pack up at 23:27. During this time not one car had gone past me, an advantage to starting later in the evening? With no wind there was very little dew on the car roof but the temperature had dropped to – 1 °C by now. I would still have to dry all equipment used that evening over night to make sure they were dry before putting them away in storage.

Peter

Viewing Log for 18th of April

Another clear night and I was free, so that really only means one thing, a viewing session? With the Moon well over head and just short of half phase, I knew some deep sky objects could well be washed out? Normally I do not do any viewing session between half-moon until at least five days after full.

As usual I went to Uffcott with my Meade LX90 again with the Pentax 14 mm WX eye piece and everything set up and ready by 21:05, starting temperature was 5 °C with no wind and twilight skies out to the west and north. As usual I started with Mars as it is the only planet in the evening sky until Venus and Mercury at the end of the month? Again no details could be made out on the fourth planet from the Sun. Thought I would try and catch a couple of the Messier (M) objects I could not see from the 14th, started with M 41 just below Sirius, this open cluster (O C) I could just make out, sky conditions are not that good currently? On to M 42, I could make out the four trapezium stars and a bit of the nebula surrounding them, I would say M 42 has now been lost until the autumn skies return?

Earlier in the week I had been reading the current issue of Astronomy Now and there was a section about the Caldwell (C) list made up by Patrick Moore, so I thought I would follow their selection starting the winter targets are they were sinking in the western sky if not already gone? First object was C 49 which is part of the Rosette nebula, I could not make out any parts of this emission nebula, Moon and light in the western sky would not help? So onto C 50, the other part of the Rosette, this O C was very loose and large to look at? C 41 does not need any telescope to track down as it is the Hyades O C, this is a very large O C which is best looked at with a finder scope, Aldebaran is not part of this cluster but a fore ground star? The Flaming Star nebula or C 31 was a faint fuzzy blob (F F B) to look at, looks great in pictures but not to the eye! C 39 is a good example of a planetary nebula (P N), it was fairly bright even though it was close to the Moon, might be another target to come back to once the Moon is out of the way?

Onto the spring collection and started with C 59, another P N also known as the 'Ghost of Jupiter' a fussy blob (F B) with a bright centre. The Spindle galaxy or C 53 looks similar to M 82 but a bit smaller and dimmer. C 38 is another looking needle galaxy but much dimmer to look at, a classic F F B, same could be said about C 32, the Whale galaxy in Canes Venatici? As for C 26, could not make it out at all, final object in the spring collection was C 21, the Box galaxy, a large F B similar to M 1 to look at?

Now onto autumn targets and C 13 the Owl cluster an old friend to me, a large and loose O C with two bright stars and fainter ones making out the wings? Another beauty is C 14, the Double cluster, this time I had to view the O C's one at a time as they filled the eye piece, I am surprised that Messier did not add these to his list? C 23 another edge on galaxy was too low to view. That was it for Caldwell objects, the summer collection was either too low or not risen in the eastern skies?

So back to the Messier marathon and carry on from where I had finished five nights before, I had been in Leo but now it was across the sky to the north and M 101, this was an F F B to look at, while viewing this object I noticed thin cloud was rolling in, this had been forecast? Could make out the two galaxies that make up M 51, the Whirlpool. The Sunflower galaxy (M 63) was an F B to look at, again M 94 was also an F B but had a bright core. For globular clusters (G C) M 3 is a nice one to look at even with the cloud around which was getting thicker! I am sure M 53, another G C would be fine to look at if this cloud was not around?

That was about it for deep sky objects as the cloud had now won, time to look at the Moon no filters required! Again some nice features along the day/night line of the terminator.

With the time of 22:37 I started to pack up the equipment used and only three cars past me during this session.

Clear skies.

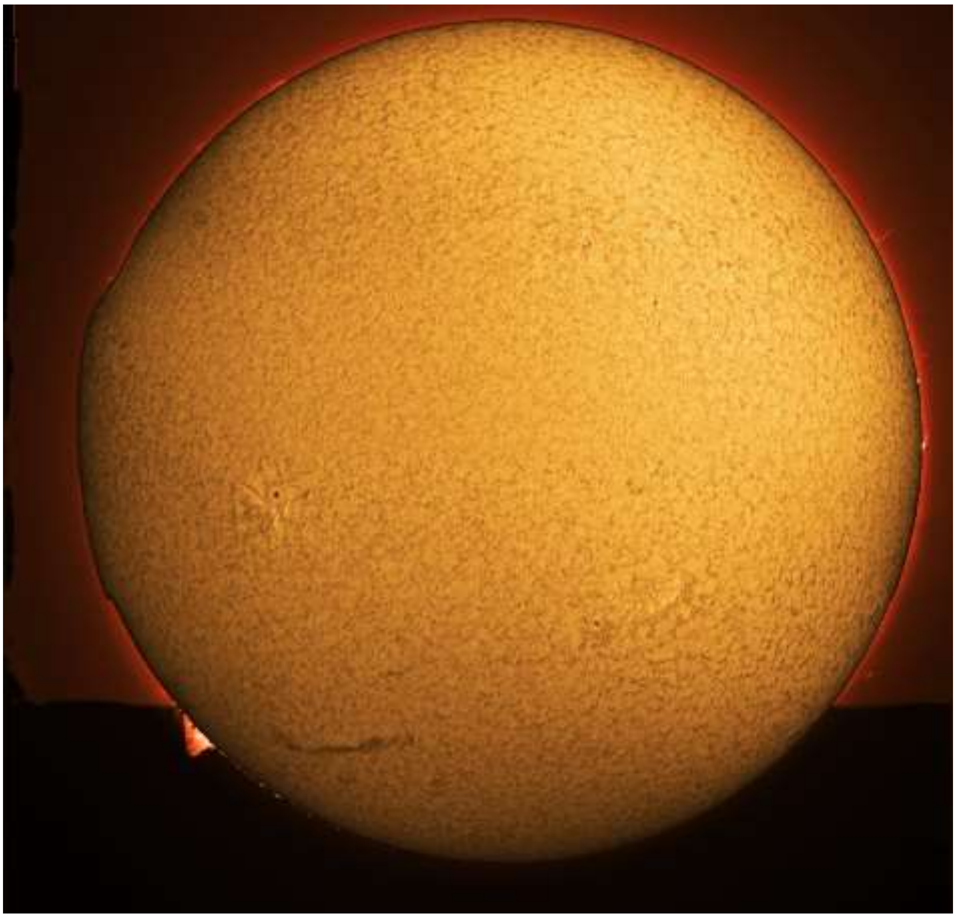
Peter Chappell

Hi Andrew,

this is the first light for Jamie Proven who is Andrew Proven's eldest son and my pride and joy at this moment because of his "first light" A great moment for him and certainly the wonderful moment for me. You'll thank me when is it when he is an adult and a enthusiastic amateur astronomer. Specification of the equipment is the pantograph and

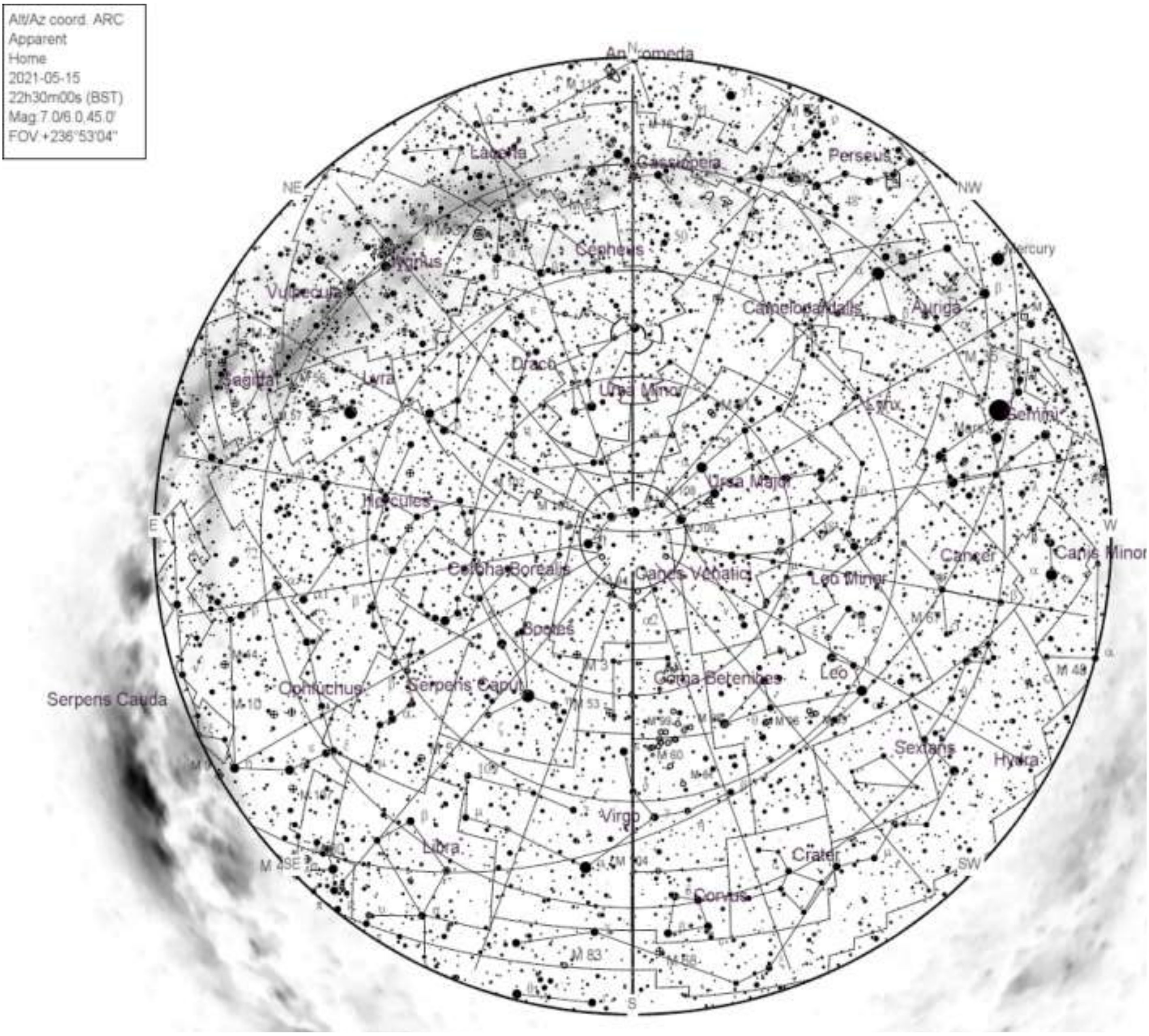
the binoculars are a 10 x 60 which as you know I'm too heavy to hold for any length of time. This was last Saturday evening and the moon was in the south-east I think but I will check that position and come back to you.It might be of interest to the members and you are free to print it if you wish take care old friend and I hope those pesky pains I am lessened.

As ever Philip



The Sun on 21st April, Halpha imaged using mono webcam DMK 52AU. Stacked in registax and coloured in Photoshop. Andy Burns.

WHATS UP, MAY 2021



May 6, 7 - **Eta Aquarids Meteor Shower.** The Eta Aquarids is an above average shower, capable of producing up to 60 meteors per hour at its peak. Most of the activity is seen in the Southern Hemisphere. In the Northern Hemisphere, the rate can reach about 30 meteors per hour. It is produced by dust particles left behind by comet Halley, which has been observed since ancient times. The shower runs annually from April 19 to May 28. It peaks this year on the night of May 6 and the morning of the May 7. The second quarter moon will block out some of the faintest meteors this year. But if you are patient, you should still should be able to catch quite a few good ones. Best viewing will be from a dark location after midnight. Meteors will radiate from the constellation Aquarius, but can appear anywhere in the sky.

May 11 - **New Moon.** The Moon will located on the same side of the Earth as the Sun and will not be visible in the night sky. This phase occurs at 19:01 UTC. This is the best time of the month to observe faint objects such as galaxies and star clusters because there is no moonlight to interfere.

May 17 - **Mercury at Greatest Eastern Elongation.** The planet Mercury reaches greatest eastern elongation of 22 degrees from the Sun. This is the best time to view Mercury since it will be at its highest point above the horizon in the evening sky. Look for the planet low in the western sky just after sunset.

May 26 - **Full Moon, Perigee moon.** The Moon will be located on the opposite side of the Earth as the Sun and its face will be will be fully illuminated. This phase occurs at 11:14 UTC. This full moon was known by early Native American tribes as the Flower Moon because this was the time of year when spring flowers appeared in abundance. This moon has also been known as the Corn Planting Moon and the Milk Moon. This is also the second of three supermoons for 2021. The Moon will be near its closest approach to the Earth and may look slightly larger and brighter than usual.

May 26 - **Total Lunar Eclipse.** A total lunar eclipse occurs when the Moon passes completely through the Earth's dark shadow, or umbra. During this type of eclipse, the Moon will gradually get darker and then take on a rusty or blood red color. The eclipse will be visible throughout the Pacific Ocean and parts of eastern Asia, Japan, Australia, and western North America.

Observing Notes - March 2021

Pottering Around Perseus

Perseus appears highest in the evening sky in the months around November but remains around the 50°above the horizon in the western skies this time of the year, at least for the early part of the evening.

It is quite prominent constellation with 16 stars of fourth magnitude or brighter so observable for us townies to a reasonable degree.

Perseus is perhaps best known for the Perseid meteor shower, one of the best annual meteor showers, however that is in the summer, a good few months away yet, so we will have to wait for that even.

The Milky Way also passes through this area of the sky, where it forms a particularly broad band of deep sky objects, including over a dozen bright open clusters. I can never resists looking in this part of the sky with my 16 x 80 binoculars for a while no matter what my targets for the night are, the rich star fields are amazing. However, the main part of the constellation of Perseus is not quite as spectacular as some of the constellation around it but it has a few nice objects to pick up in binoculars and telescopes.

The Myth

The constellation Perseus represents the hero of the same name and is one of the six constellations associated with the Greek myth and legends. Sit tight is a bit of a long one but I will be as brief as I can.

Perseus was the grandson of King Acrisius who ruled Argos. Before Perseus was born, it was foretold to the King that he would die at the hand of his own grandson. On hearing this he had his daughter, Danaë, locked away in a dungeon. But Zeus (who was a bit of a sucker for maidens in distress, a fell in love with her and so took the form of golden rain to visit her. When the rain fell into her lap, Danaë got pregnant (as you do) but Acrisius found out and once Perseus was born, the king locked both Danae and his grandson into a wooden chest and cast them out to sea (harsh!). The chest washed ashore and a fisherman called Dictys found them and took them home with him where he raised Perseus as his own son.

Dictys had a jealous brother, King Polydectes, who wanted Danaë for himself but Perseus defended her from the king's advances. To get rid of Perseus, Polydectes came up with a story about

▲ Looking West / North West to Perseus

being engaged to another woman (Hippodameia, who was the daughter of yet another King). He asked everyone to give him and his bride horses as a wedding present but Perseus did not have any horses and could not afford to buy one, so Polydectes sent the him to bring the head of the Gorgon Medusa who was one of the three hideous sisters with snake hair, whose gaze could turn anyone who looked at them into stone (we have all seen the film).

Polydectes expected Perseus to die in the attempt to kill the Gorgon, but he underestimated Perseus and with the help the goddess Athena's reflective shield, was able to look at Medusa and cut off her head. Perseus returned to King Polydectes with the Gorgan's head in a bag but on hearing that he had been sent away to his death so that the King could stalk his mother, he pulled the head from the bag and turned him in to stone.

Finding the Constellation

Perseus is bordered by Aries and Taurus to the south, Auriga to the east, Camelopardalis and Cassiopeia to the north, and Andromeda and Triangulum to the west.

If we start with the 5 stars that make up familiar 'W' asterism of Cassiopeia (see September 20 Observing notes) located roughly in the North West at around 20:00, noting that the 'W' is more-or-less on its side this time of the year. We then find the 'V' of the Hyades in the constellation of Taurus (see November 20 Observing notes). The constellation of Perseus is located directly between the two and identified by the brightest star Mirfak.

The Major Stars

There are 19 stars in the constellation's main asterism with the most notable being:

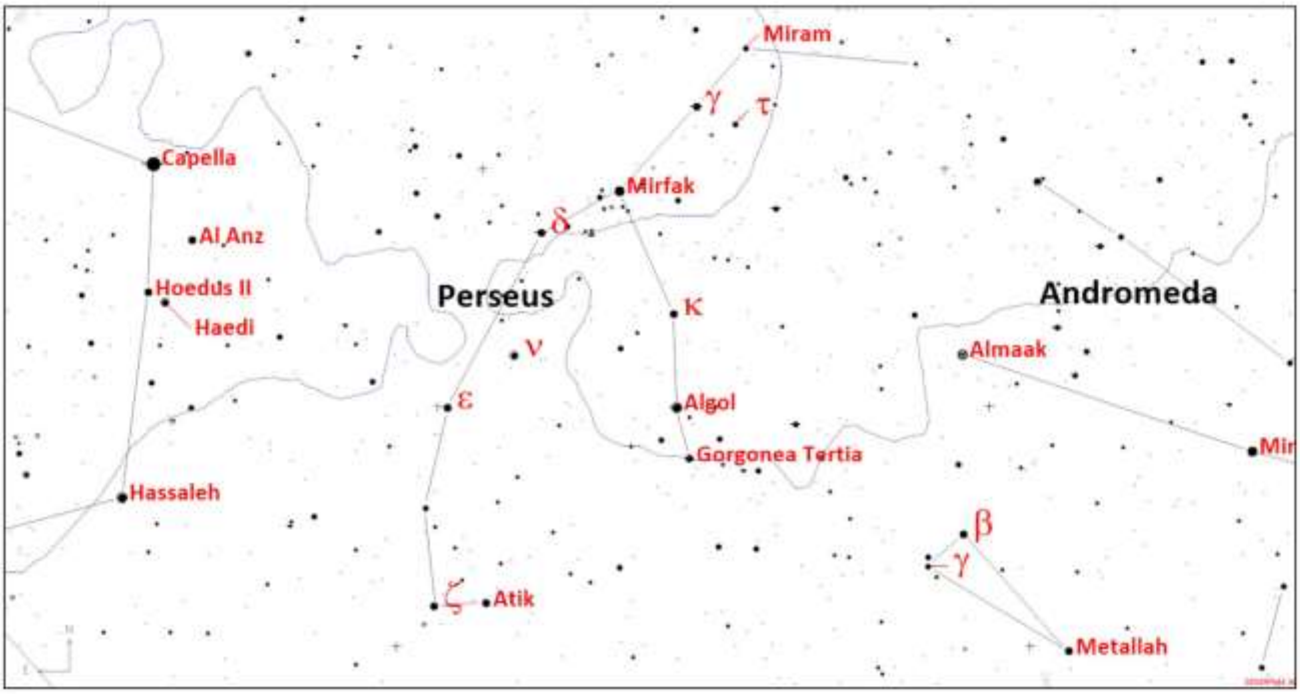
Mirfak – α Persei (Alpha Persei)

Alpha Persei is a supergiant star with a visual magnitude of 1.8 and lying 510 light years distant. It is the brightest star in Perseus constellation and is located in a star cluster known as the Alpha Persei Cluster, which can easily be seen in binoculars.

The star's traditional names, Mirfak and Algenib, mean "elbow" and "flank" or "side" respectively in Arabic.

Algol – β Persei (Beta Persei)

The Demon Star was the first eclipsing binary star ever discovered and one of the first variable stars to be found. Beta Persei is in fact a triple star



▲ Perseus and his main stars

system with an apparent magnitude of around 2.1, but it drops to 3.4 every two days, 20 hours and 49 minutes, and stays dimmer for about 10 hours. Algol is a prototype for a class of stars known as Algol variables.

The star's name is derived from the Arabic phrase *ra's al-ghul* (yes, just like the supervillain in the Batman comics), which means "the demon's head." It was associated with a ghoul in Arabic tradition and with the head of the Gorgon Medusa in Greek mythology.

γ Persei (Gamma Persei)

Gamma Persei is a double star with a combined visual magnitude of 2.9, approximately 243 light years distant from Earth. It is the fourth brightest star in Perseus. The system is a wide eclipsing binary star, with the two stars orbiting each other every 14.6 years.

δ Persei (Delta Persei)

Delta Persei is a binary star with a visual magnitude of 3.0, approximately 520 light years distant. It is seven times more massive than the Sun and a rapid rotator, with a projected velocity of 190 km s−1.

Delta Persei is believed to be a double star, and possibly even a triple star system. Which may be gravitationally bound to the main star and not just an optical double, but this has not been confirmed.

ε Persei (Epsilon Persei)

Epsilon Persei is composed of several stars. The system has a combined visual magnitude of 2.88 and is about 640 light years distant from the Sun.

The two main components in the Epsilon Persei system orbit each other with a period of 14 days but may have a third component, but its existence has not been confirmed.

Atik (Menkhib) – ζ Persei (Zeta Persei)

Zeta Persei is a blue-white supergiant about 47,000 times more luminous than the Sun and 750 light years distant. It has an apparent magnitude of 2.86 and has a 9th magnitude companion located 12.9 arc seconds away. The two stars are suspected to be physically associated as they are on a similar trajectory.

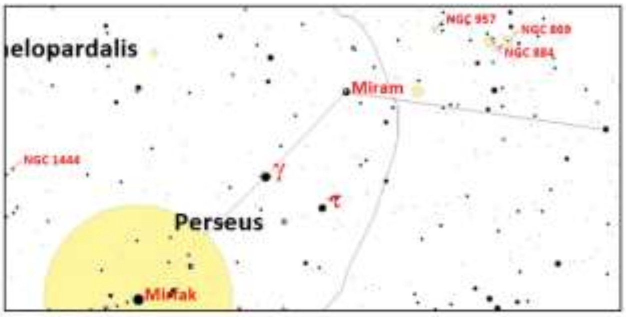
Nova Persei 1901

Nova Persei 1901 is approximately 1500 light years distant from the solar system. Also known as GK Persei, it was a bright nova that occurred in 1901. With a peak magnitude of 0.2, and was the brightest nova of modern times. GK Persei subsequently faded to magnitude 12 or 13, but has occasional outbursts of 2 to 3 magnitudes so visible in larger scopes. In the last 30 years, the outbursts have become pretty regular and last about two months every three years or so, which makes GK Persei resemble not a typical nova, but a dwarf nova-type cataclysmic variable star.

Deep Sky Objects

NGC 869 and NGC 884 - The Double Cluster

These bright open clusters are separated by only half a degree and commonly known as a "Double Cluster" and easily visible to the naked eye and a wonderful sight in binoculars and telescopes. Both clusters have been known since antiquity when the Greek astronomer Hipparchus



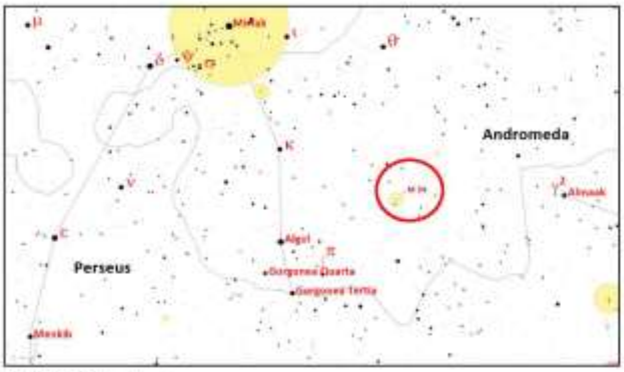
▲ The Double Cluster

first catalogued them around 130 B.C. Early celestial cartographers named them as "h Persei" (NGC 869) and "χ Persei" (NGC 884).

This Double Cluster is located in the far north-western part of Perseus, close to the border with Cassiopeia. To locate the object, draw an imaginary line from Mirfak (α Per - mag +1.8) in a north-westerly direction towards the centre of the "W" of Cassiopeia. The Double Cluster lies just over halfway along this line.

Messier 34 – Open Cluster

The open cluster M34 that may be just about seen with the naked eye and is easily resolved with a small telescope or 10x 50 binoculars. The cluster lies at an approximate distance of 1,500 light years from Earth and has an apparent magnitude of 5.5.



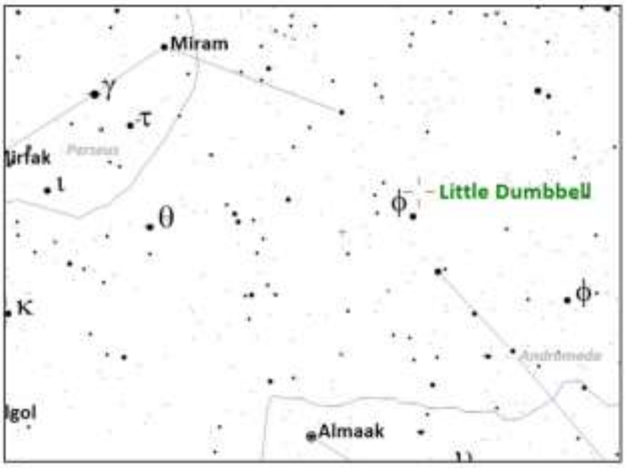
▲ M34 finder chart

The best way to view M34 is in telescopes at low magnifications. Small telescopes will reveal up to 20 stars, while larger telescopes can show as many as 80.

Messier 34 is relatively easy to find located just to the north of the imaginary line drawn from Algol (Beta Persei), to Almach, the third brightest star in the neighbouring constellation Andromeda often referred to as Gamma Andromedae. The cluster lies 5 degrees northwest of Algol.

Messier 76 – The Little Dumbell Nebula

M76 lies at an approximate distance of 2,500 light years from Earth and has an apparent magnitude of 10.1 A planetary nebula that in large binoculars and small telescopes shows as a small, diffuse point of light and so is better seen through a medium-sized telescope. Being regarded as one of the most difficult Messier objects to spot I am going to make it this month's challenge objects.

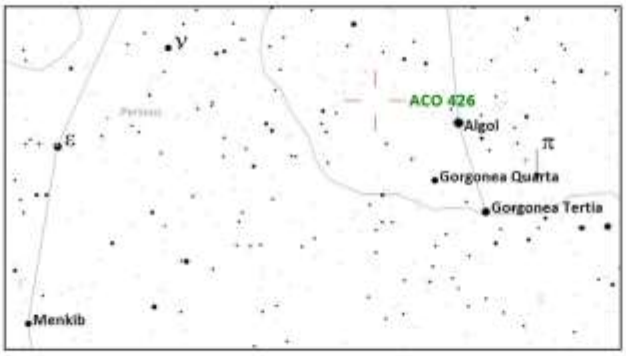


▲ M76 The Little Dumbbell finder chart

Probably the easiest way to find M76 Is to draw an imaginary line between γ Almach (Gamma Andromeda) and δ Ruchbah (Delta Cassiopeia) which is the bottom of the left hand 'V' in the 'W' asterism and M76 lies almost centre between these two stars.

Abell 426

Abell 426 (ACO 426 in the chart) otherwise known as the 'Perseus Cluster' is a massive group of thousands of galaxies. It lies approximately 2° from Algol. Draw an imaginary line between Algol and Mirfak, go along the line 1.5° from Algol and then turn immediately left 1.5° and the cluster is in this area covering very approximately 1° square.

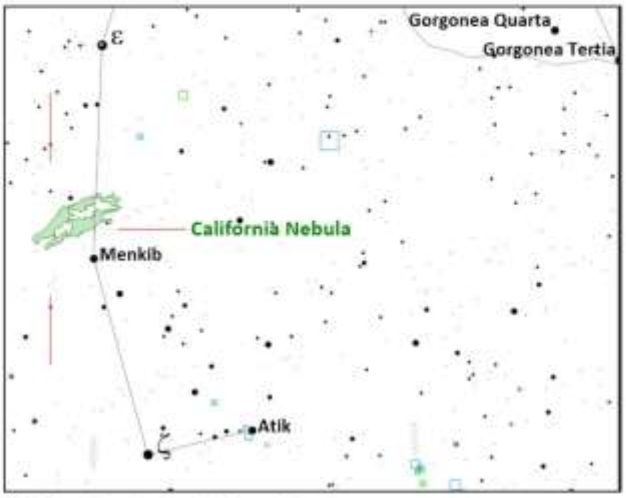


▲ Abell 426 The Perseus Cluster

To be fair there is not a lot to see visually in small telescopes and binoculars. Even in my 4" Refractor which has great contrast, it is difficult to make out much. It looks a little better still in my 10" reflector but still not very exciting. But what actually fascinates me is that when I am staring into this area of space, I are staring into the a cluster of hundreds, if not thousands of galaxies. Most of which I am sure are probably home to other worlds maybe like ours, maybe not. As I sit and look, I just imagine the very likely possibility of others staring back at our own galaxy. Although I have not done so yet I will have a go at photographing this area of space and see if I can capture a handful of the worlds.

California Nebula (NGC 1499)

This is a large and long emissions nebula to the North of Menkib and very hard to observe visually but takes on the shape of the American state when viewed through larger telescopes and binoculars and better still when using an Hbeta filter under darker skies. Jon has seen it in his 8" reflector from Kelling Heath in Norfolk; it is a subtle object and proper dark adaption was required. The Nebula is 2.5° long reflection nebula that is 60 light-years across and roughly 1,500 light-years away from Earth.



▲ Finder Chart for the California Nebula

March 2021 Solar System

Meteor Showers

No meteor showers this month unfortunately.

Moon

The Moon is at last quarter on the 6th March so dark sky viewing is best carried out over the following couple of weeks with the new Moon on the 13th.

There is a good opportunity to observe the Lunar XV on the 20th at around 02:00 GMT.

The Planets

Mercury is poorly positioned morning planet reaching greatest western elongation on 6 March.

Venus reaches superior conjunction on 26 March and is unlikely to be seen this month.

Mars is an evening planet dimming to the naked eye and telescopically small. It can be south of the Pleiades at the start of March.

Jupiter is a morning planet, but badly positioned despite rising 70 minutes before sunrise by the end of the month.

Saturn Morning planet close to Jupiter. Badly positioned for viewing this month.

The *Uranus* observing window is quickly closing as the planet drifts ever closer to the evening twilight.

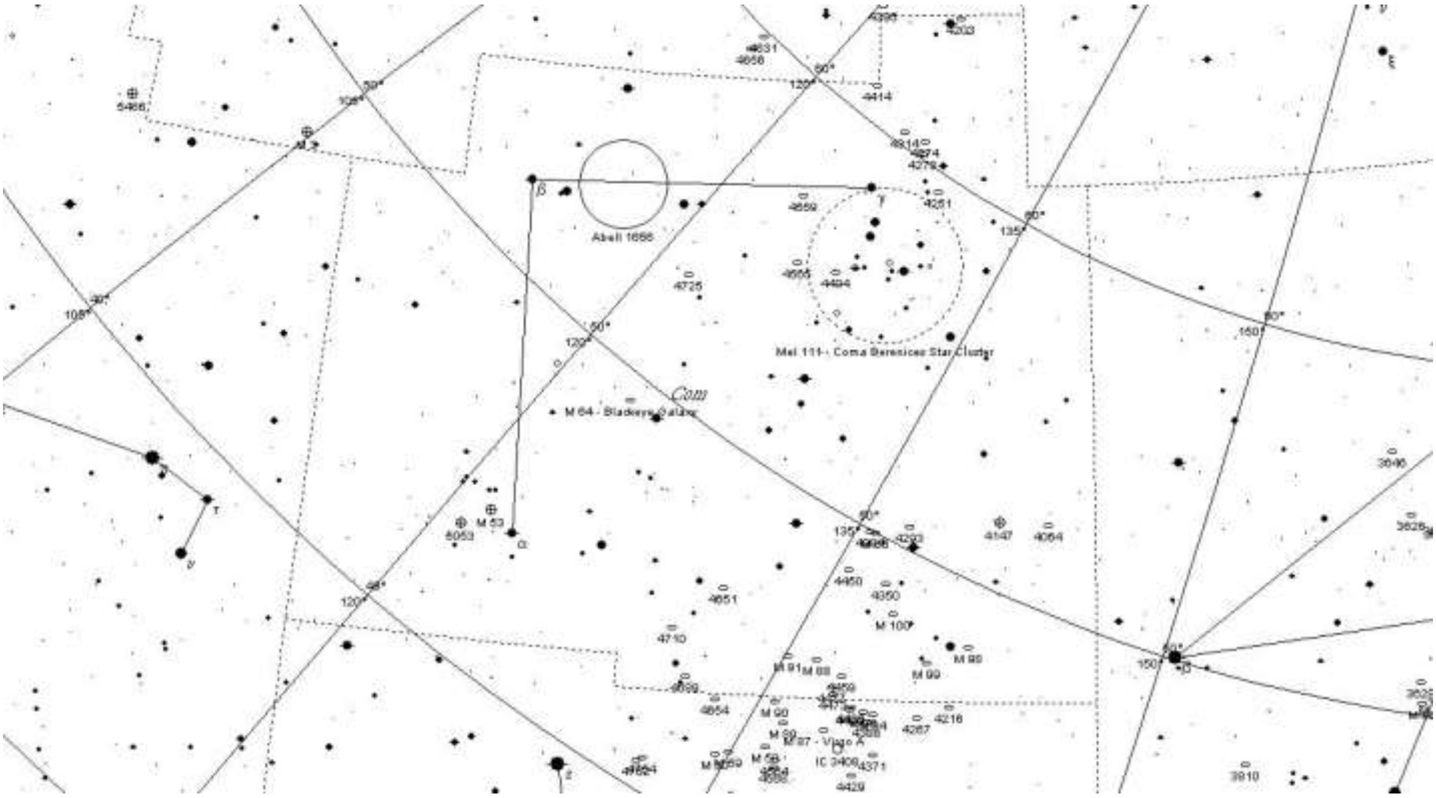
Neptune is in conjunction with the Sun on 10th March and not visible this month.

Don't forget the clocks go forward on the 28th March.

Good observing and stay safe.

Chris Brooks
Jonathan Gale
WAS Observing Team

CONSTELLATIONS OF THE MONTH: COMA BERENICES



The Coma Berenices Constellation

In the 2nd century CE, Greek-Egyptian astronomer Claudius Ptolemaeus (aka. Ptolemy) compiled a list of all the then-known 48 constellations. This treatise, known as the *Almagest*, would be used by medieval European and Islamic scholars for over a thousand years to come, effectively becoming astrological and astronomical canon until the early Modern Age.

One of these is the constellation Coma Berenices, an ancient constellation located in the norther skies. In the *Almagest*, Ptolemy considered the asterism to be part of the constellation Leo. Today, it is one of the 88 constellations recognized by the International Astronomical Union, and is bordered by the constellations of Canes Venatici, Ursa Major, Leo, Virgo and Boötes.

Name and Meaning:

In mythology, it is easy to see why this dim collection of stars was once associated with Leo and considered to be the tuft of hair at the end of the Lion's tail. However, as the years passed, a charming legend grew around this sparkling group of stars. Since the time of Ptolemy, this grouping of stars was recognized and although he didn't list it as one of his 88 constellations, he did refer to is as "Berenice's Hair".

As legend would have it, the good Queen Berenice II of Egypt offered to sacrifice her beautiful long hair to Aphrodite for the safe return of her husband from battle. When she cut off her locks and placed it on the altar and returned the next day, her sacrifice was gone. To save his life, the court astronomer proclaimed Aphrodite had immortalized Berenice's gift in the stars… and thus the Lion lost his tail and the astronomer saved his hide!

History of Observation:

Like many of the 48 constellations recognized by Ptolemy, Coma Berenices traces it routes back to ancient Mesopotamia. To Babylonian astronomers, it was known as *Hegala*, which translated to "which is before it". However, the first recorded mention comes from Conon of Samos, the 3rd century BCE court astronomer to Ptolemy III Euergetes – the Greek-Egyptian king. It was named in honor of his consort, Berenice II, who is said to have cut off her long hair as a sacrifice to ensure the safety of the king.

The constellation was named "*bostrukhon Berenikes"* in Greek, which translates in Latin to "Coma Berenices" (or "Berenice's hair"). Though it was previously designated as its own constellation, Ptolemy considered it part of Leo in his 2nd century CE tract the *Almagest,* where he called it "Plokamos" (Greek for "braid"). The constellation was also recognized by many non-western cultures.

In Chinese astronomy, the stars making up Coma Berenices belonged to two different areas – the Supreme Palace Enclosure and the Azure Dragon of the East. Eighteen of the constellation's stars were in an area known as *Lang wei* ("seat of the general"). To Arabic astronomers, Coma Berenices was known as *Al-Du'aba, Al Dafira* and *Al-Hulba*, forming the tuft of the constellation Leo (consistent with Ptolemy's designation).

Fragment of Mercator's 1551 celestial globe, showing Coma Berenices. Credit: Harvard Map Collection

By the 16th century, the constellation began to be featured on globes and maps produced by famed cartographers and astronomers. In 1602, Tycho Brahe recognized it as its own constellation and included it in his star catalogue. In the following year, it was included in Johann Bayer's famed celestial map, *Uranometria.* In 1920, it was included by the IAU in the list of the 88 modern constellations.

Notable Objects:

Despite being rather dim, Coma Berenices is significant because it contains the location of the North Galactic Pole. It is comprised of only 3 main stars, but contains 44 Bayer/ Flamsteed designated members. Of its main stars, Alpha Comae Berenices (aka. Diadem) is the second-brightest in the constellation.

The name is derived from the Greek word *diádema*, which means "band" or "fillet", and represents the gem in Queen Berenice's crown. It is sometimes known by its other traditional name, *Al-Zafirah*, which is Arabic for "the braid". It is a binary star composed of two main sequence F5V stars that are at a distance of 63 light years from Earth.

The Black Eye Galaxy (Messier 64). Credit: NASA/The Hubble Heritage Team (AURA, STScI)

It's brightest star, Beta Comae Berenices, is located 29.78 light years from Earth and is a main sequence dwarf that is similar to our Sun (though larger and brighter). It's third major star, Gamma Comae Berenices, is a giant star belonging to the spectral class K1II and located about 170 light years from Earth.

Coma Berenices is also home to several Deep Sky Objects, which include spiral galaxy Messier 64. Also known as the Black Eye Galaxy (Sleeping Beauty Galaxy and Evil Eye Galaxy), this galaxy is located approximately 24 million light years from Earth. This galaxy has a bright nucleus and a dark band of dust in front of it, hence the nicknames.

Then there is the Needle Galaxy, which lies directly above the North Galactic Pole and was discovered by Sir William Herschel in 1785. It is one of the most famous galaxies in the sky that can be viewed edge-on. It lies at a distance of about 42.7 million light years from Earth and is believed to be a barred spiral galaxy from its appearance.

Coma Berenices is also home to two prominent galaxy clusters. These includes the Coma Cluster, which is made up of about 1000 large galaxies and 30,000 smaller ones that are located between 230 and 300 million light years from Earth. South of the Coma Cluster is the northern part of the Virgo Cluster, which is located roughly 60 million light years from Earth.

The globular cluster Messier 53 (NGC 5024), located in the Coma Berenices constellation. Credit: NASA (Wikisky)

Other Messier Objects include M53, a globular cluster located approximately 58,000 light years away; Messier 100, a grand design spiral galaxy that is one of the brightest members of the Virgo cluster (located 55 million light years away); and Messier 88 and 99 – a spiral galaxy and unbarred spiral galaxy that are 47 million and 50.2 million light years distant, respectively.

Finding Coma Berenices:

Coma Berenices is best visible at latitudes between +90° and -70° during culmination in the month of May. There is one meteor shower associated with the constellation of Coma Berenices – the Coma Berenicid Meteor shower which peaks on or near January 18 of each year. Its fall rate is very slow – only one or two per hour on average, but these are among the fastest meteors known with speeds of up to 65 kilometers per second!

For both binoculars and telescopes, Coma Berenices is a wonderland of objects to be enjoyed. Turn your attention first to the brightest of all its stars – Beta Coma Berenices. Positioned about 30 light years from Earth and very similar to our own Sun, Beta is one of the few stars for which we have a measured solar activity period – 16.6 years – and may have a secondary activity cycle of 9.6 years.

Now look at slightly dimmer Alpha. Its name is Diadem – the Crown. Here we have a binary star of equal magnitudes located about 65 light years from our solar system, but it's seen nearly "edge-on" from the Earth. This means the two stars appear to move back-and-forth in a straight line with a maximum separation of only 0.7 arcsec and will require a large aperture telescope with good resolving power to pull them apart. If you do manage, you're separating two components that are about the distance of Saturn from the Sun!

Another interesting aspect about singular stars in Coma Berenices is that there are over 200 variable stars in the constellation. While most of them are very obscure and don't go through radical changes, there is one called FK Comae Berenices which is a prototype of its class. It is believed that the variability of FK Com stars is caused by large, cool spots on the rotating surfaces of the stars – mega sunspots! If you'd like to keep track of a variable star that has notable changes, try FS Comae Berenices (RA 13 3 56 Dec +22 53 2). It is a semi-regular variable that varies between 5.3m and 6.1 magnitude over a period of 58 days.

For your eyes, binoculars or a rich field telescope, be sure to take in the massive open cluster Melotte 111. This spangly cloud of stars is usually the asterism we refer to as the "Queen's Hair" and the area is fascinating in binoculars. Covering almost 5 full degrees of sky, it's larger than most binocular fields, but wasn't recognized as a true physical stellar association until studied by R.J. Trumpler in 1938.

Located about 288 light years from our Earth, Melotte 111 is neither approaching nor receding… unusual – but true. At around 400 million years old, you won't find any stars dimmer than 10.5 magnitude here. Why? Chances are the cluster's low mass couldn't prevent them from escaping long ago…

Now turn your attention towards rich globular cluster, Messier 53. Achievable in both binoculars and small telescopes, M53 is easily found about a degree northwest Alpha Comae. At 60,000 light years away from the galactic center, it's one of the furthest globular clusters away from where it should be. It was first discovered by Johann Bode in 1755, and once you glimpse its compact core you'll be anxious to try to resolve it.

The Needle Galaxy (NGC 4565). Credit: ESO

With a large telescope, you'll notice about a degree further to the east another globular cluster – NGC 5053 – which is also about the same physical distance away. If you study this pair, you'll notice a distinct difference in concentrations. The two are very much physically related to one another, yet the densities are radically different!

Staying with binoculars and small telescopes, try your hand at Messier 64 – the "Blackeye Galaxy". You'll find it located about one degree east/northeast of 35 Comae. While it will be nothing more than a hazy patch in binoculars, smaller telescopes will easily reveal the signature dustlane that makes M64 resemble its nickname. It is one of the brightest spiral galaxies visible from the Milky Way and the dark dust lane was first described by Sir William Herschel who compared it to a "Black Eye."

Now put your telescope on Messier 100 – a beautiful example of a grand-design spiral galaxy, and one of the brightest galaxies in the Virgo Cluster. This one is very much like our own Milky Way galaxy and tilted face-on, so we may examine the spiral galaxy structure. Look for two well resolved spiral arms where young, hot and massive stars formed recently from density perturbations caused by interactions with neighboring galaxies. Under good observing conditions, inner spiral structure can even be seen!

Try lenticular galaxy Messier 85. In larger telescopes you will also see it accompanied by small barred spiral NGC 4394 as well. Both galaxies are receding at about 700 km/sec, and they may form a physical galaxy pair. How about Messier 88? It's also one of the brighter spiral galaxies in the Virgo galaxy cluster and in a larger telescope it looks very similar to the Andromeda galaxy – only smaller.

How about barred spiral galaxy M91? It's one of the faintest of the Messier Catalog Objects. Although it is difficult in a smaller telescope, its central bar is very strong in larger aperture. Care to try Messier 98? It is a grand edge-on galaxy and may or may not be a true member of the Virgo group. Perhaps spiral galaxy Messier 99 is more to your liking… It's also another beautiful face-on presentation with grand spiral arms and a sweeping design that will keep you at the eyepiece all night!

There are other myriad open clusters and just as many galaxies waiting to be explored in Coma Berenices! It's a fine region. Grab a good star chart and put a pot of coffee on to brew. Comb the Queen's Hair for every last star. She's worth it.

We have written many interesting articles about the constellation here at Universe Today. Here is What Are The Constellations?, What Is The Zodiac?, and Zodiac Signs And Their Dates.

Be sure to check out The Messier Catalog while you're at it!

For more information, check out the IAUs list of Constellations, and the Students for the Exploration and Development of Space page on Canes Venatici and Constellation Families.

Source:

- *Constellation Guide – Coma Berenices*
- *Wikipedia – Coma Berenices*
- *SEDS – Coma Berenices*

ISS PASSES For April and All May 2021 from Heavens Above website maintained by Chris Peat

Date	Brightness	Start	Highest	End						
	(mag)	Time	Alt.	Az.	Time	Alt.	Az.	Time	Alt.	Az.
01 May	-2.3	04:05:23	18°	S	04:06:59	25°	SSE	04:09:51	10°	E
02 May	-1.9	03:19:43	18°	SE	03:19:49	18°	SE	03:22:14	10°	E
02 May	-3.5	04:52:50	10°	WSW	04:56:11	62°	SSE	04:59:33	10°	E
03 May	-1.0	02:34:00	11°	ESE	02:34:00	11°	ESE	02:34:16	10°	ESE
03 May	-3.3	04:06:57	21°	SW	04:08:54	47°	SSE	04:12:11	10°	E
04 May	-3.0	03:21:13	34°	S	03:21:39	35°	SSE	03:24:47	10°	E
04 May	-3.7	04:54:54	10°	W	04:58:18	88°	SSE	05:01:42	10°	E
05 May	-2.0	02:35:26	22°	ESE	02:35:26	22°	ESE	02:37:20	10°	E
05 May	-3.8	04:08:23	16°	WSW	04:10:58	77°	SSE	04:14:21	10°	E
06 May	-0.9	01:49:38	10°	E	01:49:38	10°	E	01:49:42	10°	E
06 May	-3.7	03:22:34	38°	SW	03:23:39	62°	SSE	03:27:01	10°	E
07 May	-3.3	02:36:44	45°	SE	02:36:44	45°	SE	02:39:39	10°	E
07 May	-3.7	04:09:42	10°	W	04:13:06	86°	N	04:16:31	10°	E
08 May	-1.8	01:50:52	20°	E	01:50:52	20°	E	01:52:15	10°	E
08 May	-3.8	03:23:49	24°	W	03:25:45	88°	S	03:29:09	10°	E
09 May	-3.9	02:37:56	61°	SW	02:38:25	77°	SSE	02:41:49	10°	E
09 May	-3.7	04:11:51	10°	W	04:15:16	89°	N	04:18:39	10°	E
10 May	-3.0	01:52:01	42°	E	01:52:01	42°	E	01:54:27	10°	E
10 May	-3.7	03:24:57	13°	W	03:27:55	85°	N	03:31:18	10°	E
11 May	-1.6	01:06:05	18°	E	01:06:05	18°	E	01:07:06	10°	E
11 May	-3.8	02:39:01	30°	W	02:40:32	86°	N	02:43:57	10°	E
11 May	-3.8	04:14:00	10°	W	04:17:23	68°	SSW	04:20:45	10°	ESE
12 May	-3.9	01:53:00	79°	WSW	01:53:12	88°	S	01:56:36	10°	E
12 May	-3.9	03:26:39	10°	W	03:30:03	82°	S	03:33:27	10°	ESE
13 May	-2.9	01:06:55	40°	E	01:06:55	40°	E	01:09:14	10°	E
13 May	-3.8	02:39:50	14°	W	02:42:42	89°	N	02:46:06	10°	E
13 May	-3.3	04:16:11	10°	W	04:19:23	40°	SSW	04:22:35	10°	SE
14 May	-1.9	00:20:36	21°	E	00:20:36	21°	E	00:21:53	10°	E
14 May	-3.8	01:53:29	25°	W	01:55:20	85°	N	01:58:44	10°	E
14 May	-3.7	03:28:47	10°	W	03:32:06	53°	SSW	03:35:25	10°	SE
14 May	-1.9	21:53:20	10°	SSE	21:55:01	13°	SE	21:56:41	10°	ESE
14 May	-3.6	23:27:57	10°	SW	23:31:14	49°	SSE	23:34:31	10°	E
15 May	-3.8	01:04:35	10°	W	01:07:59	86°	N	01:11:22	10°	E
15 May	-3.9	02:41:25	10°	W	02:44:48	68°	SSW	02:48:10	10°	ESE
15 May	-2.4	04:18:36	10°	W	04:21:14	21°	SW	04:23:51	10°	SSE
15 May	-3.2	22:40:50	10°	SW	22:43:58	36°	SSE	22:47:07	10°	E
16 May	-3.9	00:17:14	10°	W	00:20:37	89°	S	00:24:01	10°	E
16 May	-3.9	01:54:05	10°	W	01:57:28	81°	SSW	02:00:52	10°	ESE
16 May	-2.9	03:31:03	10°	W	03:34:02	29°	SSW	03:37:01	10°	SSE
16 May	-2.8	21:53:51	10°	SSW	21:56:44	26°	SSE	21:59:38	10°	E
16 May	-3.9	23:29:54	10°	WSW	23:33:16	78°	SSE	23:36:40	10°	E
17 May	-3.9	01:06:44	10°	W	01:10:07	89°	N	01:13:32	10°	E
17 May	-3.4	02:43:36	10°	W	02:46:48	39°	SSW	02:49:59	10°	SE
17 May	-3.8	22:42:36	10°	WSW	22:45:57	64°	SSE	22:49:18	10°	E
18 May	-3.8	00:19:22	10°	W	00:22:45	85°	N	00:25:21	16°	E
18 May	-2.7	01:56:13	10°	W	01:58:15	32°	W	01:58:15	32°	W
18 May	-3.5	21:55:22	10°	SW	21:58:39	49°	SSE	22:01:56	10°	E
18 May	-3.8	23:32:00	10°	W	23:35:23	86°	N	23:38:47	10°	E
19 May	-3.8	01:08:51	10°	W	01:11:57	63°	SW	01:11:57	63°	SW
19 May	-3.8	22:44:38	10°	W	22:48:02	89°	SSE	22:51:25	10°	E
20 May	-3.9	00:21:29	10°	W	00:24:53	81°	SSW	00:25:52	43°	ESE
20 May	-1.3	01:58:28	10°	W	01:58:48	12°	W	01:58:48	12°	W
20 May	-3.8	21:57:18	10°	WSW	22:00:41	78°	SSE	22:04:04	10°	E
20 May	-3.8	23:34:08	10°	W	23:37:32	90°	N	23:39:53	19°	E
21 May	-2.3	01:11:00	10°	W	01:12:49	26°	WSW	01:12:49	26°	WSW
21 May	-3.7	22:46:47	10°	W	22:50:10	85°	N	22:53:34	10°	E
22 May	-3.6	00:23:37	10°	W	00:26:53	52°	SSW	00:26:53	52°	SSW
22 May	-3.7	21:59:24	10°	W	22:02:47	85°	N	22:06:11	10°	E
22 May	-3.8	23:36:15	10°	W	23:39:37	67°	SSW	23:40:59	32°	SE
23 May	-1.3	01:13:26	10°	W	01:13:56	12°	W	01:13:56	12°	W
23 May	-3.8	22:48:53	10°	W	22:52:17	80°	S	22:55:07	14°	ESE
24 May	-2.4	00:25:53	10°	W	00:28:03	25°	WSW	00:28:03	25°	WSW
24 May	-3.7	22:01:32	10°	W	22:04:55	90°	NW	22:08:19	10°	E
24 May	-3.2	23:38:24	10°	W	23:41:35	39°	SSW	23:42:12	35°	S
25 May	-3.5	22:51:00	10°	W	22:54:18	52°	SSW	22:56:23	20°	SE
26 May	-1.3	00:28:41	10°	WSW	00:29:20	12°	WSW	00:29:20	12°	WSW
26 May	-3.7	22:03:38	10°	W	22:07:00	66°	SSW	22:10:21	10°	ESE
26 May	-2.1	23:40:50	10°	W	23:43:24	20°	SW	23:43:33	20°	SSW
27 May	-2.5	22:53:15	10°	W	22:56:12	28°	SSW	22:57:47	19°	SSE
28 May	-3.0	22:05:47	10°	W	22:08:58	38°	SSW	22:12:04	10°	SE
29 May	-1.5	22:56:05	10°	WSW	22:57:56	14°	SW	22:59:20	12°	SSW
30 May	-1.9	22:08:13	10°	W	22:10:46	20°	SW	22:13:18	10°	SSE

END IMAGES, OBSERVING AND OUTREACH

.25/04/2021
Double ISS Solar Transit 07:16 BST (06:16 UTC) and 10:28 BST (09:28 UTC)
Transit-Finder.com predicted a double ISS Solar Transit at sites near home. The first was at 07:16 BST (06:16 UTC) duration 3.58 seconds – M4 Motorway Bridge at Dauntsey. The second was at 10:28 BST (09:28 UTC) duration 1.07 seconds – railway bridge Callow Hill, Brinkworth. I think this was quite a rare event – the two locations were only a few miles apart and three hours twelve minutes between transits.
Clear Skies,
John

Fabulous imaging John!

Wiltshire Astronomical Society Observing Suggestion for May 2021 @ 23:00

We have updated the observation target this month for those with binoculars or smaller telescopes have something to look for.

As we can no longer gather as one, for the time being, each month the WAS Observing Team will provide recommended socially distant observing sessions for you to do at home.
This will continue until we can start our group observing again (hopefully) in the new season.
Most target objects can be found around due south between 2300 and Midnight
We have added the observation suggestion in the 'What's Up' link below.
Where To Look This Month: Leo

Upload Link: WAS_May_2021.pdf
Also Wiltshire Astronomical Society will produce the monthly newsletter containing further information, which can be downloaded here: https://wasnet.org.uk/

OUTREACH
Zoom sessions and Google Classroom sessions have kept outreach going to schools. In January I did sessions at Stonar and Westbury Leigh. If anyone else has links to schools who might be interested in ‘in the classroom’ sessions ask them to get in touch with me via anglesburns@hotmail.com.