Astronomy La Société Guernesiaise Sagittarius

The Newsletter of the Astronomy Section of La Société Guernesiaise

2024

Forthcoming Events

Talks for Members - For details see page 4.

23rd January – How to identify bats in flight *Laura Harrison*

6th February - Von Kármán Lecture: Spacecraft Assembly and Launch

20th February - Von Kármán Lecture: The Universe of Very Cold: JWST, MIRI and the Cryocooler

5th March – Light: A User's Manual *Jason Hill*

Public Open Days

Evening and daytime public viewing will be arranged on an impromptu basis so we can be sure of good weather. They will be advertised on our Eventbrite page, by email and media.

Contents

Section meetings

The Section meets at the Observatory every other Tuesday evening at **8.30 pm**, sometimes with a lecture to watch. The currently planned lectures are given on page 3. Additional events may be organised on an impromptu basis; members will be notified of these by email.

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Astronomy Section Officers, 2024

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Introduction from the Editor

Welcome to the 2024 edition of Sagittarius! You're in for a treat this year, as we have a fantastic selection of articles, news, and images in this year's edition. Learn about upcoming telescopes, dig into the details of Newton and Einstein's theories of gravity and marvel at beautiful images taken by our members in the last year. There's also lots of astronomical events to watch out for,

As ever, I'd like to thank everyone who contributed to this newsletter and reiterate that I'm always looking for new articles, so if you'd like to submit something for the next edition please get in touch.

Thomas Harvey

Astronomy Section Secretaries Report 2024

Changes to the Committee

Towards the end of 2023 there were some changes to the committee. I would like to thank our outgoing Treasurer, Steve Bougourd for his time during 2023 and welcome Stephanie Le Tissier, whose experience in finance will benefit the Section. Jacques Loveridge, who recently won the Sovereign Art Foundation Global Student Prize in 2023 has very kindly agreed to be imaging officer and we look forward to expanding our knowledge of astrophotography. I would also like to thank Allan Phillips for tirelessly maintaining our equipment and helping members with their equipment over the last few years, and dealing with the numerous equipment-related public enquiries; he will be taking a short break from this role.

Members and group events for 2023

It has been a busy year for the Astronomy Section, we have had 25 members' activities through the year which have been well attended. In addition, we have held 22 outreach events, many of which have been youth group visits, others have been adult groups and seven have been ticketed Eventbrite events. In total, through our outreach, we engaged with nearly 500 people and raised about £1,430. I would like to thank all those who have helped with the events from the organising and timetabling, catering, lecturing and manning the telescopes.

Maintenance

We have also been busy doing some maintenance and finishing off small jobs associated with the new telescope building. Again, I would like to thank all those members that have donated many hours, including cutting the grass and keeping the edges strimmered. Unfortunately, during the recent gales we lost half the roofing felt from the telescope building and rain found its way into the building, luckily though, no permanent damage was done to the telescopes. I am very grateful to Festung who made some emergency repairs. However, we will need to get the roof re-felted in the coming months. Another priority early in 2024 will be to cut the pine trees to the south-east boundary, at a cost of £960.

Audio-visual upgrades
The main focus through 2023 has been to replace our aging audio-visual equipment and associated software. Towards the end of 2022 we were very fortunate to receive a grant of £6,086 from the Community Foundation. This has allowed us to purchase a new projector, two desktop PC's – one for the meeting room and one for the telescope building and one laptop. The total cost was £6,254.76. We are also grateful to Steve Bougourd for kindly donating a new monitor for the meeting room PC.

Other equipment purchases
Other equipment purchases include an Optolong 3nm dual band filter for the ASI533 camera for £220.83. This will be particularly useful for outreach and will allow us to show the public star forming regions, rich in molecular hydrogen, even under a full moon. It will also allow members to do narrow-band and HaRGB imaging with the deep space camera. In addition, for those interested in astrophotography we have purchased an iOptron SkyGuider Pro package and aluminium tripod for £480, which members when trained may use with their own camera and lenses.

Finally, we have sold the HEQ5 equatorial mount and replaced it with an iOptron GEM 45 mount which cost £1,856. The new mount will be significantly easier to set up and use with the laptop. We are particularly looking forward to using this for upcoming outreach.

Security upgrades
The observatory site has had a complete security overhaul. The locks on the meeting room and store room doors have been changed. Keys are restricted to committee members; and should it be required, then others will be given access through the digital key-safe on the meeting room wall. Periodically, for compliance with insurance requirements to maintain security, the number will be changed and all current persons with access will be notified of the new number. Likewise for the telescope building which is a digital lock. Members are reminded not to give out the numbers to anyone else. The cost of the security upgrade was £133.

Other general items
Weekly meetings – There is a calendar for 2024 which shows the dates for Tuesday gatherings. There will be no formal meetings during the summer months, although outreach will continue. The calendar was attached to the latest Bulletin and can also be found on our website. If anyone would like another copy, please let me know and I will email it. Topics for meetings will be advertised as normal through the Bulletins. On occasion, we might hold an impromptu talk or observing. These are often announced at the last minute, so please check your email.

Membership is now due. The rate for the Astronomy Section will remain the same at £15, or £15.50 through the La Société Guernesiaise (LSG) website. The LSG membership however, has risen slightly to £35 for a single and £40 for a family. You must be a member of LSG to join the Astronomy Section. You may renew your membership through the LSG website: https://societe.org.gg/wp/join-renew/ or by direct payment to the Section's bank account at: NatWest Sort Code: 60-09-20, a/c number 70602964, for a reference please give "membership" and your name.

Honesty box for drinks and biscuits – there is generally milk, tea, coffee, cold drinks and biscuits available in the kitchen. Members who make use of this are asked to put money into the honesty box. Alternatively, you may contribute by purchasing drinks and/or biscuits for others to share.

I wish everyone a very Happy New Year with clear skies.

Jean Dean

Upcoming Talks

Club nights start at 8pm, or 8:30 pm for new or prospective members, who are very welcome to come along to any club nights. The first half hour is reserved for discussions on committee matters, outreach and other logistical matters. A list of club nights for the next few months is given below.

These talks are a mixture of live events and recordings. Generally, recordings are played on the club projector in the meeting room for members to watch and discuss.

23rd January

Talk: How to identify bats in flight

Description: If you are up late at the observatory in the spring-summer months you might have noticed something flying around in the darkness. We are very lucky to have bats in the vicinity. We welcome to the observatory Laura Harrison, Secretary of the Bat Section, who will be giving a brief talk on some of Guernsey's bats and how to identify them.

Speaker: Laura Harrison

6th February

Talk: Von Karman Lecture: Spacecraft Assembly, Test, and Launch Operations (ATLO)

Description: What does it take to build a spacecraft? It's up to the Spacecraft Assembly, Test, and Launch Operations (ATLO) team to assemble it, bake it, shake it, get it to the pad and launch it.

Speakers: Michelle Tomey Colizzi, Mechanical Engineer, NASA/JPL

Luis A Dominguez, ATLO Electrical & Dep. Systems Lead, NASA/JPLASA/JPL

20th February

Talk: Von Karman Lecture: The Universe of Very Cold: The James Webb Space Telescope, MIRI, and the Cryocooler

Description: The James Webb Space Telescope (JWST) takes incredible images using infrared light. The optics and science instruments must be incredibly cold, especially JWST's Mid-Infrared Instrument (MIRI), which needs to be at a temperature of less than 7 kelvins, or -447 F. This is not possible without the Cryocooler, which keeps MIRI's detectors cool.

Speaker: Dr. Konstantin Penanen, JWST/MIRI Cryocooler Lead, NASA/JPL

5th March

Talk: Light: A User's Manual

Description: In this talk we explain how we came to understand the nature of light. It starts by looking at what the ancients thought about light and how we came to realise that light has a finite speed. It looks at Newton's work in his book "Opticks" and the wave theory of light. Then we explain how various sorts of "invisible" light came to be discovered and then extend this idea to the whole of the electromagnetic spectrum. We look briefly at the particle theory of light, wave-particle duality and the photoelectric effect. Then we examine how the James Webb Space Telescope is going to revolutionise astronomy in the years to come.

Speaker: Jason Hill

19th March

Talk: Von Karman Lecture – How do missions get formed?

Description: We'll talk to one of our robotics engineers about project formulation and demonstration, looking at the process of generating ideas - from napkin sketch to prototype to development and testing. We'll also look at how they figure out the right questions to ask in order to understand what technologies are needed to get the job done using real life experiences and stories about the Mars Rovers and Mars Sample Return Mission.

Speaker: Paulo Younse, Robotics Engineer, NASA/JPL

Member's Photo Gallery

In this section I've collected a few of the great images taken by our members in 2023!

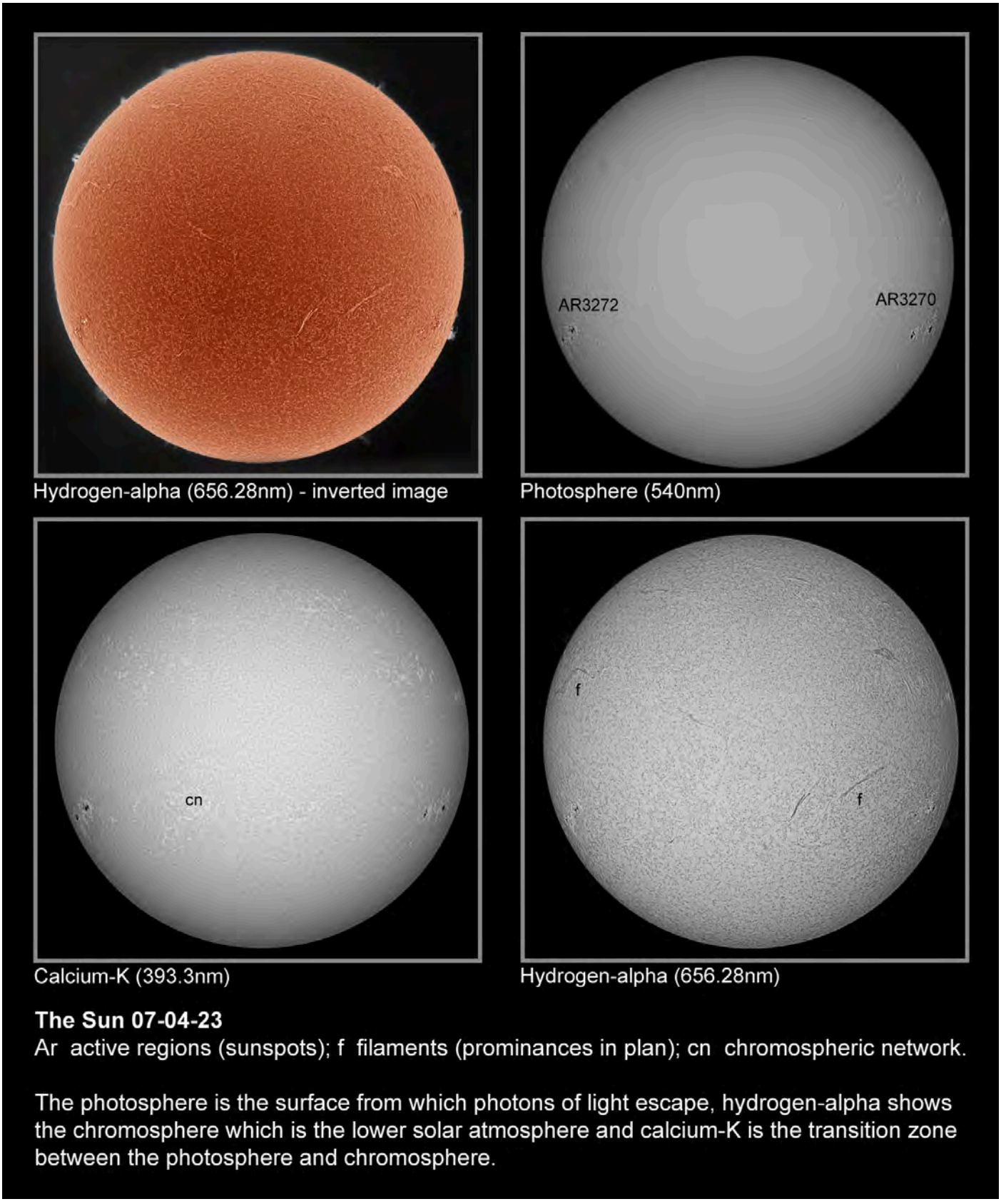
David's Mantra

LOOK UP

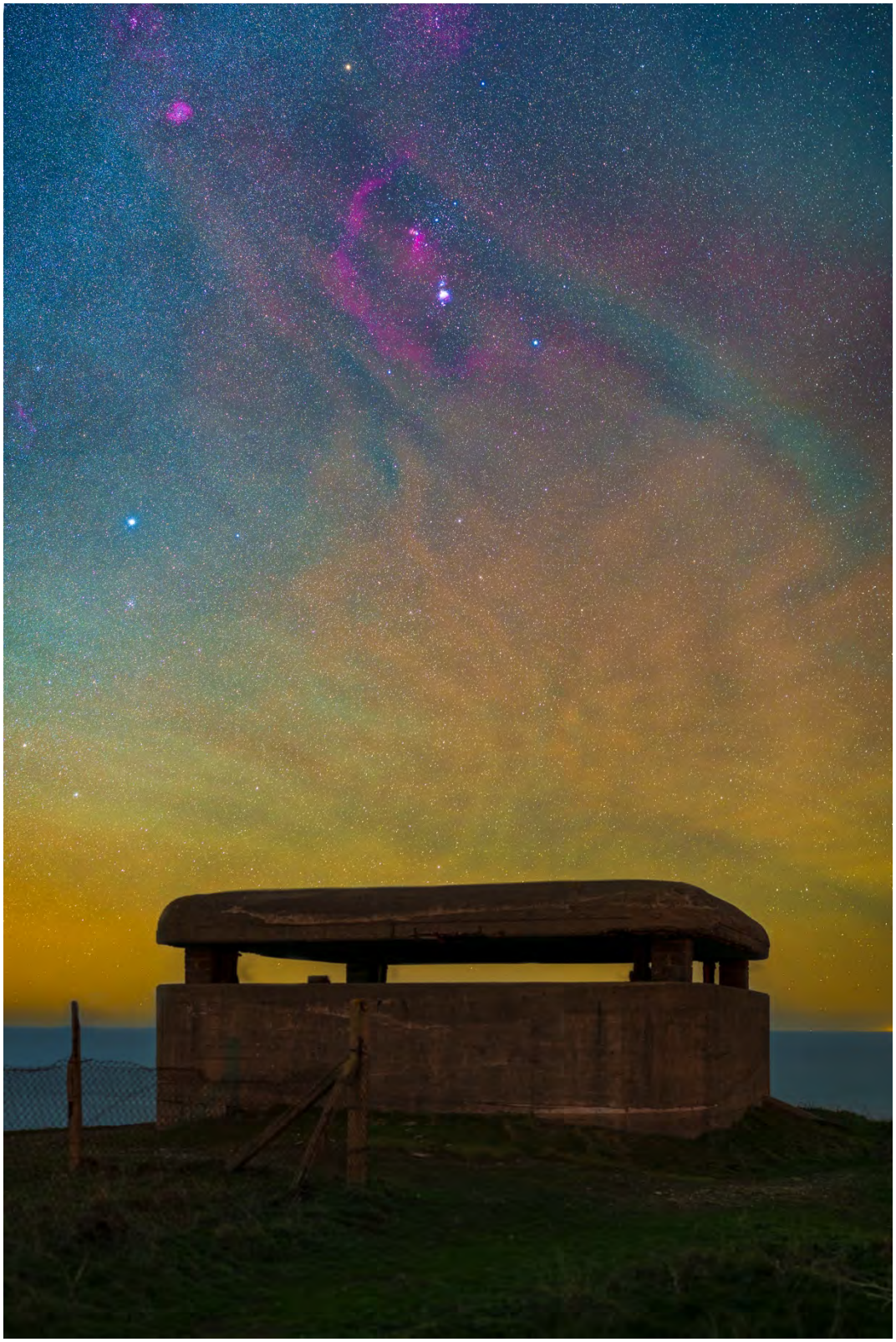
LOOK HARDER
LOOK LONGER
KEEP LOOKING

David Le Conte (Courtesy of Dorothy Le Conte)

Messier 101, commonly called the Pinwheel Galaxy is a face on grand design spiral galaxy, located 21 million light-years away within the constellation of Ursa Major. The spiral disk is 170,000 light-years across and contains around 1 trillion stars, making it about twice the size of our Milky Way galaxy. M101 has high levels of star formation caused by gravitational interactions with neighbouring galaxies; these regions can be seen as red speckles which are rich in hydrogen, the basic element of a star.
This Image was taken using an unmodified Sony A7iii camera attached to a Sky Watcher 250PDS Newtonian reflecting telescope and an EQ6-R Pro equatorial mount. There is a total of 11 hours of 6 minute exposures for broadband data and 7 hours of 10 minute exposures using an Optolong L-enhance filter to capture hydrogen regions. All the data was acquired in May of 2023.
During the process of collecting the data over multiple nights, a bright supernova SN 2023ixf (arrow), occurred in one of the galaxy's spiral arms. This is when a massive star runs out of fuel and gravitational forces dominate, leading to the almost instantaneous collapse of the star (imagine something 1 million times the mass of Earth collapsing in just 15 seconds!). SN 2023ixf was one of the brightest supernovae visible in the last decade and was observed for several months after.
Jacques Loveridge



Imaging of the solar photosphere and Hydrogen-alpha and Calcium-K emission lines from the Sun, taken by Jean Dean.



This image of the upper observation level of the Battery Dollmann command bunker at Pleinmont shows parts of the winter Milky Way, and the constellations of Orion and Monoceros with Barnard's loop, Lambda Orionis ring and many deep sky objects that make up the Orion Molecular Cloud Complex: this is one of the closest stars forming regions to Earth, as close as just 1,400 light-years away. Most of these objects are rich in hydrogen and shown in magenta in this image. Also visible in the image is an atmospheric phenomenon known as airglow, that takes place after atoms recombine after being ionized and broken down by the sun and cosmic rays. Depending on the altitude and chemical element the airglow can take on many different colours and form many different patterns.

This image is a 3-panel panorama with a single 4 minute exposure per panel taken with a Sigma 40mm Art lens at f/2, unmodified Sony A7iii and Sky Watcher Star Adventurer. It was stitched together and edited in Adobe Lightroom and Photoshop.

Jacques Loveridge

Astronomical Events 2024

Welcome to the Astronomy Sections guide for what and when to observe in 2024!

Planets

Mercury will be visible in the periods around its greatest elongations:

Date	Elongation	Direction	Time
12 January	23.5º Western	Low in East	Before sunrise
24 March	18.7º Eastern	Low in West	After sunset
9 May	26.4º Western	Low in East	Before sunrise
22 July	26.9º Eastern	Low in West	After sunset
5 September	18.1º Western	Low in East	Before sunrise
16 November	22.5º Eastern	Low in West	Before sunset
25 December	22º. Western.	Low in East	Before sunrise

Jupiter will be visible in the evening throughout, January, February and March, but setting earlier as the year progresses. Jupiter reaches opposition on December 7th, when it will be at its brightest point of the year. Jupiter will be visible in the early morning from May, rising earlier throughout the year. Jupiter reaches the perigee of its 12 year orbit of the Sun on December 6th, and will be optimally placed for observation throughout the evening from September onwards.

Mars will be visible in the west in the evening until June, setting earlier throughout the year. From early May, Venus will be visible around dusk, as the “Evening Star” in the western sky.

When Jupiter is visible, we will have good views of the four Galilean moons, atmospheric bands on the planet’s disc, and the Great Red Spot. Transit, shadow and occultation events involving Jupiter’s moons can be calculated using www.skyandtelescope.com/wp-content/observing-tools/jupiter_moons/jupiter.html on the *Sky & Telescope* website. (They can also be found in the 2023 BAA Handbook. They can be simulated on software such as StarryNight (http://www.starrynightstore.com/), and some of the many astronomy apps, some of which also gives the transit times of the Great Red Spot. The Spot’s transit times are also available at http://www.skyandtelescope.com/observing/celestial-objects-to-watch/transit-times-of-jupiters-great-red-spot/ (again using the US date format).

Saturn reaches opposition on September 8th, when it will be at its brightest point of the year. The rings will be almost edge-on. and its brightest moons, especially Titan, should also be visible. Saturn will be visible in the early evening throughout January. It will be visible in the early morning from around June, rising earlier as the year progresses and becoming an evening object by July.

Uranus will be at opposition in Taurus on November 17th. Neptune will be at opposition in Pisces on September 21st.

Phases of the Moon

New Moon	First Quarter	Full Moon	Last Quarter
			Jan. 4
Jan. 11	Jan. 18	Jan. 25	Feb. 2
Feb. 9	Feb. 16	Feb. 24	Mar. 3
Mar. 10	Mar. 17	Mar. 25	Apr. 2
Apr. 8	Apr. 15	Apr. 23	May 1
May 8	May 15	May 23	May 30
June 6	June 14	June 22	June 28

July 5	July 13	July 21	July 28
Aug. 4	Aug. 12	Aug. 19	Aug. 26
Sept. 3	Sept. 11	Sept. 18	Sept 24.
Oct. 2	Oct. 10	Oct. 17	Oct. 24
Nov. 1	Nov. 09	Nov. 15	Nov. 23
Dec. 1	Dec. 08	Dec. 15	Dec. 22
Dec. 30			

Supermoons

So-called ‘supermoons’ occur when the Full Moon happens to coincide with the Moon’s closest approach to Earth (‘perigee’), and therefore appear larger than usual. In 2024 there will be three such moons: on the 18th of September, 16th of October, and 15th of November. As well as a supermoon, September 18th will host a partial lunar eclipse that will be visible in Guernsey!

Dwarf planets and asteroids

Pluto will reach opposition on the 23nd of July, at magnitude 15, around midnight low in the South. It will appear star-like and requires a telescope to observe. The other three dwarf planets (Eris, Makemake and Haumea) are too faint to be seen in most amateur telescopes, although Makemake does reach opposition on the 30th March.

Ceres, the largest asteroid in the Asteroid Belt, will reach opposition on July 06st, at magnitude 7.3, visible low in the South in the evening.

Eclipses

As usual a poor year for eclipses with only one partial lunar eclipse, being visible from Guernsey. The partial lunar eclipse will be visible on the 18th September, peaking at 02:45am UTC.

There will be a total solar eclipse visible across much of North America on the 08 April. Watch out for livestreams and photos of the event!

Occultations

There is a lunar occultation of Saturn on the 21st August, which should be visible from Guernsey in the early morning. Saturn will disappear at 03:25 UTC and reappear at 04:22 UTC.

Lunar conjunctions

The best conjunctions of the Moon and the bright planets, with their positions and separations are:

14 Jan	Saturn	South in evening	2°08’
18 Jan	Jupiter	Southwest in evening	2°46’
06 Apr	Mars	South in morning	1°58’
03 May	Saturn	South in morning	0°50'
05 May	Mars	South in morning	0°11'
31 May	Saturn	Southwest in early morning	0°22’
24 July	Saturn	South in the morning	0°23’
21 August	Saturn	Southwest in the morning	0°27’
17 Sept	Saturn	South in evening	0°18’
20 Nov	Mars	South in morning	2°26'
04 Dec	Venus	South around lunchtime	2°15'
08 Dec	Saturn	South in evening	0°18'
18 Dec	Mars	West in evening	0°54'

Planetary conjunctions

The best observable planetary conjunctions, with their positions and separations, are given below. A planetary conjunction is when two objects appear close together in the sky.

15 July	Mars and Uranus	South, morning	0°33'
14 Aug	Mars and Jupiter	South, early morning	0°18'

Meteors

The Perseids will peak on the night of 12/13 August, with some 140 per hour. The moon will set at 22:08, so observations after this will hopefully have dark skies. The richest annual shower, the Geminids**,** will peak on the night of 13/14 December. The Moon however will be almost full, and so will interfere with observations.

There are, of course, minor meteor showers during the year, and sporadics may be seen at any time. For shower details see the 2023 BAA Handbook.

Comets

There are two bright-comets likely visible in 2024. The first, 2023-A3 (Tsuchinshan-ATLAS), is a long period comet which reaches a perihelion of 0.3 au in September 2024. The predictions are uncertain at the time of writing, but there is a possibility a tail will become visible in October.

The second is a returning comet, known as 12P/Pons-Brooks. It was discovered by Jean-Louis Pons, a French astronomer famous for discovering the most comets (37!). It may be visible in binoculars in late February, and possibly the naked eye by late March. It will disappear into the Southern Hemisphere by late April.

Detailed comet predictions for 2024 are available on the website of the British Astronomical Association's Comet Section: https://people.ast.cam.ac.uk/~jds/preds24.pdf. Also check the Heavens-Above website (heavens-above.com) for star charts showing comet positions, and use programs such as StarryNight for detailed location charts.

The Sun

We are moving towards a solar maximum in 2025, where solar activity, including sunspots, should be most active. There can be outbursts of activity, not only of sunspots but also of coronal holes and coronal mass ejections, which can result in displays of the aurora borealis (and australis) at high latitudes. Details of sunspot numbers are at www.ips.gov.au/Solar/1/6, and real-time views of the Sun are at https://umbra.nascom.nasa.gov/newsite/images.html. Auroral alerts, with lots of other information, are at www.spaceweather.com.

Equinoxes and solstices

The following are the dates and times of the equinoxes and solstices in 2024:

Vernal Equinox	20 March	03:04 UTC
Summer Solstice	20 June	20:49 UTC
Autumnal Equinox	22 September	12:42 UTC
Winter Solstice	21 December	09:20 UTC

Satellites

The International Space Station (ISS) is regularly visible from Guernsey, looking like a very bright star crossing our skies from west to east. With the decommissioning of Iridium satellites flashes from them are now quite rare. Many other, fainter, satellites appear every night. Details of the times and directions of visibility (together with sky charts and much more) can be obtained from www.heavens-above.com, linked from our webpage www.astronomy.org.gg/iss.htm.

Courses

From time to time the Astronomy Section offers public lectures, courses and events for children, please follow our Eventbrite page to receive details.

https://www.eventbrite.co.uk/o/la-societe-guernesiaise-astronomy-section-31040695447

References

General: http://www.seasky.org/astronomy/astronomy-calendar-2021.html
http://astropixels.com/ephemeris/astrocal/astrocal2021gmt.html
http://www.timeanddate.com/
https://www.calendar-12.com/moon_phases/2021
https://www.nakedeyeplanets.com/
https://in-the-sky.org/
Equinoxes, etc: https://www.weather.gov/media/ind/seasons.pdf

The Orion Nebula

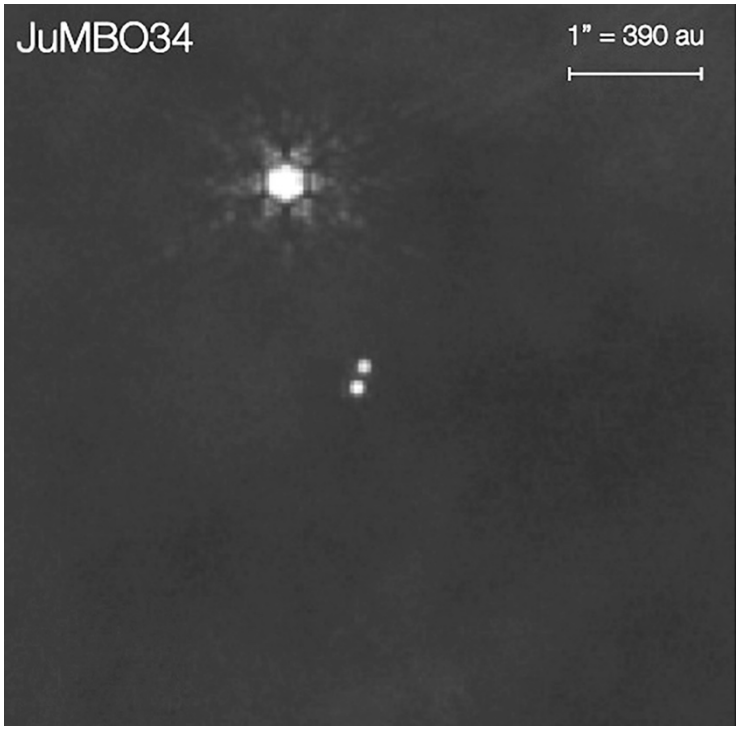
The winter constellation of Orion the Hunter is the most striking constellation in the northern hemisphere. Visible with the naked eye, the brightest region is the Orion Nebula in the sword which lies approximately 1,300 light-years distance from Earth.

Fittingly, believed to be the cosmic fire of creation by the Maya of Mesoamerica, it is an enormous cloud of gas and dust where vast numbers of new stars are being forged. The brightest, central region is the home of four massive, young stars arranged in a trapezoidal pattern (T), unleashing their ultraviolet light, carving a cavity within the nebula and disrupting the growth of hundreds of smaller stars.

Recent James Webb Space Telescope near-infrared studies of the Trapezium Cluster by Samuel G. Pearson and Mark J. McCaughrean have revealed free-floating pairs of planet-like objects with masses between 0.6 and 13 times the mass of Jupiter, that are still quite young – about 1 million years old and thus luminous and warm. They have been dubbed Jupiter Mass Binary Objects, or JuMBOs. To date 40 pairs and two triple systems have been found. Their origin is presently a mystery and new observations are currently scheduled for early 2024 – this discovery could lead to a revised model for stellar and/or planetary formation.

The Orion (top-centre) and Running Man (lower-left) Nebulae. The image covers an area 38 x 38 light-years, T is the Trapezium Cluster. Reds are hydrogen gas, browns are dust and blues are reflected blue/white light from young stars. Image credit: Astronomy Section members.

Inner Orion Nebula and Trapezium Cluster covering an area 4 x 2.75 light-years, made using the NIRCam instrument on the James Webb Space Telescope. The centre cavity is mostly filled with ionised gas, seen here in purple, while the surroundings have a mix of dust and molecular gas seen in reds, browns, and greens. The bright area is being eroded by the massive stars at the centre of the region and there are many pillars of gas and dust which are being carved. Image credit: NASA/ESA/CSA.

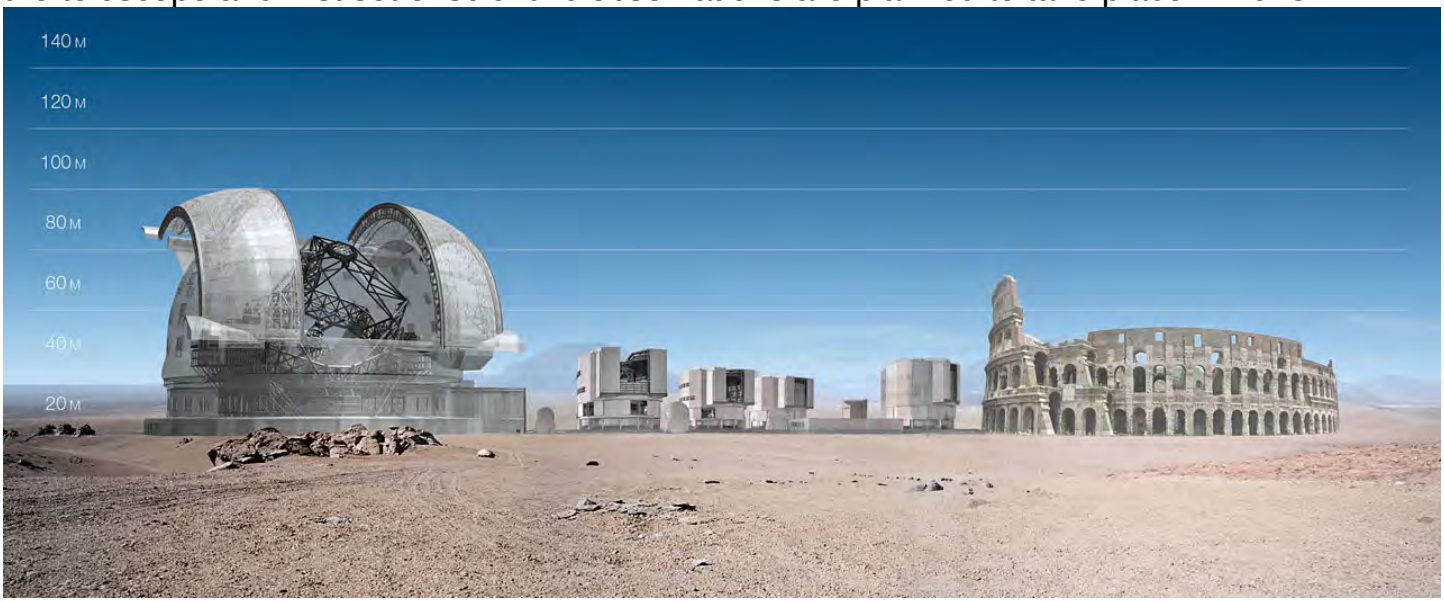


JuMBO 034 – 5 Jupiter-mass binary free-floating planetary-like objects. Image credit: NASA/ESA/CSA/ Pearson and McCaughrean.

Jean Dean

The Extremely Large Telescope

In 2012 the ESO (European Southern Observatory) approved the programme for construction of the ELT, short for the Extremely Large Telescope. With a primary mirror of a diameter of 39 metres, this will be the largest telescope ever constructed to gather observations in the visible and near-infrared wavelengths of light. Currently the first light for the telescope and first set of scientific observations are planned to take place in 2028.



An image comparing a 3D Render of what the telescope will look like compared to other large ground-based telescopes and the Colosseum in Rome. *Image Credit: ESO*

As a ground-based telescope, it is possible to construct a telescope larger than would be possible for a space telescope such as The Hubble or James Webb Space Telescopes. However, being located on Earth creates other challenges that space telescopes do not have to contend with. In order to combat many of the challenges facing a ground-based telescope, the ESO selected Cerro Armazones, a mountain at an altitude of about 3 kilometres, in Chile's Atacama Desert. The height at which the telescope is situated will minimise the amount of atmospheric turbulence that the telescope will have to contend with. Additionally, the location that was chosen has low amounts of rainfall (over 320 clear nights per year) and low average wind speeds allowing the telescope to collect as much data as possible. Furthermore, due to the remote location, the ELT will have access to some of the darkest skies on Earth.

Despite the ideal location of the telescope minimising the disadvantages of being a ground-based telescope, the telescope will still experience amounts of atmospheric turbulence, affecting the observations of the telescope. To further reduce the effect of atmospheric turbulence on the telescope's observations, the telescope itself will contain adaptive optics. Having adaptive optics means that a telescope's mirror will be able to make real time minute adjustments for atmospheric turbulence, allowing the telescope to deform its mirrors in order to compensate for the blurring effects caused by Earth's atmosphere.

An image of the current progress of the construction taken in September 2023
Image Credit: ESO/G. Vecchia

Currently the construction of the telescope has passed the milestone of being 50% complete. As of the 12th January 2024 the first 18 hexagonal mirror segments (out of 796) for the telescope's primary mirror have arrived at the ESO's Paranal Observatory in Chile. After arrival, the segments were examined to ensure that they did not suffer any damage during the process of being transported from Europe.

Anthony Nel

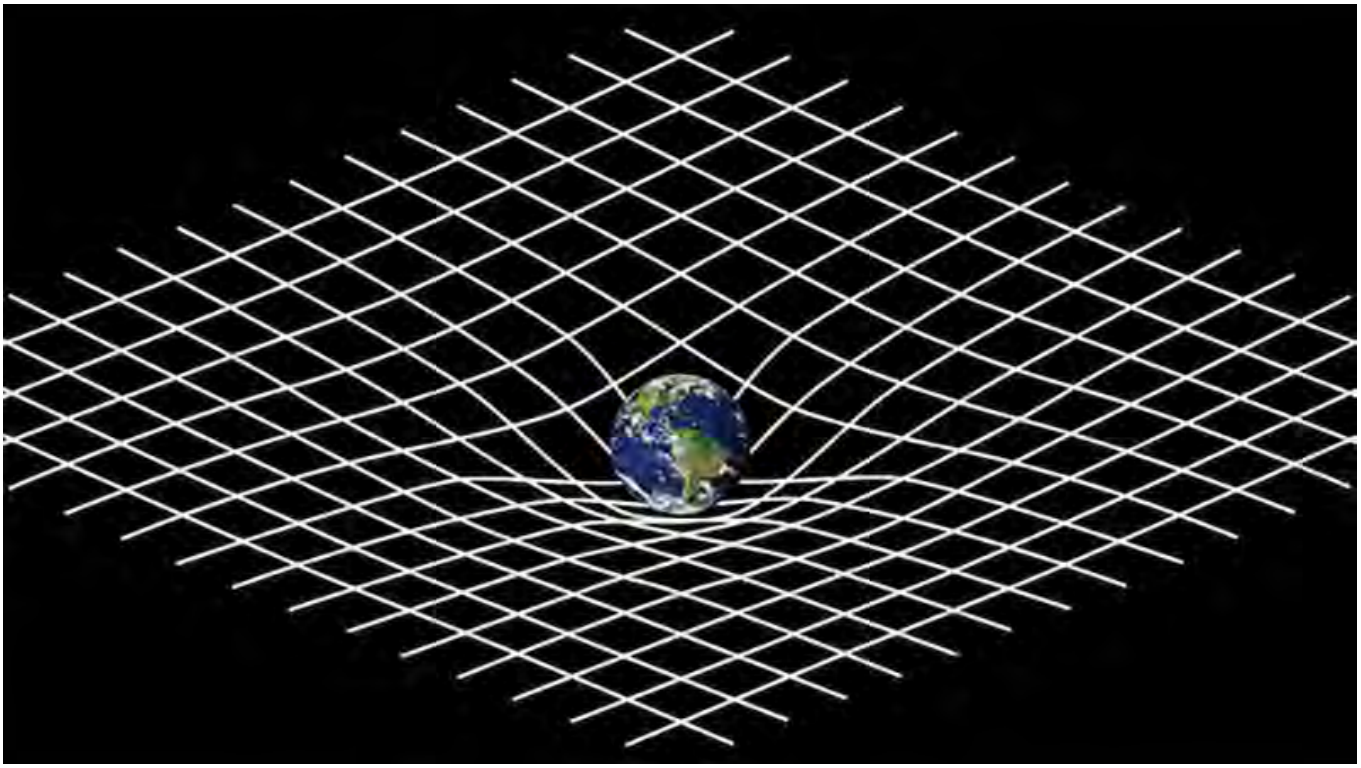
Earth's Gravity

Newton was not the first person to observe that apples fall to the ground but he was the first to come up with a good explanation. He postulated that gravity was a force and it was the same force that not only causes an apple to fall but also keeps the Moon in it's orbit. His triumph was to come up with mathematical equations and laws of motion to make those ideas explicit. It is an experimental fact that, in the absence of air resistance, all objects fall to Earth with an acceleration of 9.8 m/s^2. Given the mass and radius of the Earth, along with Newton's gravitational constant, you can use Newton's formulae to calculate that figure.

Newton's idea of gravity as a force seemed to explain everything. It was therefore a great surprise when, 200 years after Newton, Einstein came up with a radically different explanation. His idea is neatly summed up by John Archibald Wheeler's quote: "Spacetime tells matter how to move, matter tells spacetime how to curve". The idea is often illustrated by a picture of a heavy ball, representing say a star or planet, which is placed on a rubber sheet and makes the sheet sink in the middle. (You have to assume you are in in a gravitational field for the model to work). Then when you roll a small object across the sheet it's path does not follow a straight line but deviates because of the sheet's curvature. In this article I'd like to explore this model in the context of the gravity we experience here on Earth.

The first thing we have to do is shrink down the Earth to more or less a point while keeping the mass (about 6 x 10^{24} kilograms) the same. In fact this is just what one does to calculate the Newtonian gravitational force, though Newton did go to some trouble to show that the gravitational effect of a spherically symmetric body was the same as if it's entire mass was concentrated at it's centre. From that picture Newton could calculate the force of gravity on an object. What is required is the way it looks from Einstein's point of view. That was provided by Karl Schwarzschild.

Karl Schwarzschild was a contemporary of Einstein and within a short time of Einstein publishing his theory of general relativity in 1915 Schwarzschild came up with an equation describing the curvature of space and time around a point mass. Remarkably he came up



with his equation while serving on the front in the First World War. Using his equation one can calculate the motion of freely-falling objects in the vicinity of what we would now call a non-rotating black hole. Unlike in Newton's version Schwarzschild's equations showed the existence of an event horizon from within which nothing can escape and other curious things happen. If we did shrink the Earth down to a point mass it's event horizon radius would be a tiny 0.9 cm.

We can use Schwarzschild's equation to explore the curvature of space for our rubber sheet model. The radius of the Earth is some 6,400 km, many orders of magnitude larger than the event horizon. In fact, as we shall see, we are well away from any significant distortion, out in the region where our rubber sheet is almost flat. Not entirely flat however. A freely-falling particle follows a path called a geodesic and if we apply Einstein's geodesic equations to the slightly curved space-time of Schwarzschild's equation we get that an object will accelerate at a rate of 9.8 m/s^2, just as observed and calculated using Newton's methodology.

So far so good. The rubber sheet model suggests that space is distorted, but by how much? If we plug the numbers for the mass and radius of the Earth into Schwarzschild's equation we find that if you take a vertical distance of 1 km at 10 km above the Earth's surface and then bring it vertically down to the ground the length will increase by about 1 nanometre. That's an imperceptible increase. If the stretch factor was very much larger we might have to start taking into account the difference between our horizontal inches and our vertical inches. We can ignore that and for all intents and purposes our local space is flat.

Space however is not the the only thing that is distorted by the Earth's mass. Time is distorted too, by a factor of about 9 nanoseconds per day per kilometre of height. Clocks run a little bit slower as you descend and a little bit faster as you go up. The difference in daily life is imperceptible. If it was greater then you might find after spending some time at altitude on a plane journey that when you come down to the ground you'd need to adjust your watch back to Earth Surface Time as well as to the local time zone.

The difference may be small but the altitude effect has in fact been measured by highly accurate atomic clocks taken on plane journeys. GPS satellites are at a much higher altitude and there the difference in clock rates is definitely important. A clock on a GPS satellite would gain some 45 microseconds a day due to gravitational effects. A different relativistic effect causes the clock to run slower but the two don't cancel out so a net adjustment has to be made to synchronise with clocks on the ground.

So we have two gravitational distortions, space and time. Which is the most important? For Newton time and space were separate and independent. In Einstein's theory they are combined into a single entity, space-time. To use them together requires a conversion factor between space and time, which is 299,792 km for 1 second (the speed of light). A very small amount of time is equivalent to very large distance. Our time distortion of 9 nanoseconds per day per km is equivalent to about 27 cm. In the geodesic equations it is the time factor that is overwhelmingly important for the gravity we experience here on Earth. Things fall because time runs slower lower down.

Where does that leave our rubber sheet model? As an illustration of the way space stretches as you approach a massive object it does its job. As an explanation of gravity, because it ignores the curvature of time, it is completely misleading.

Peter M Langford, November 2023 ©2023 PM Langford

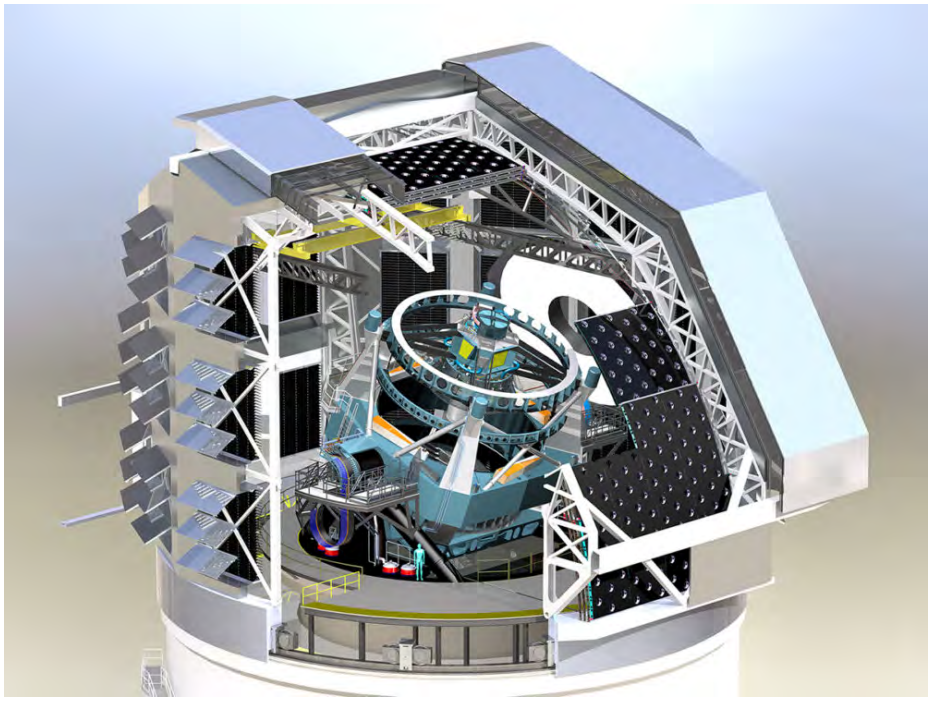
Further reading: "Exploring Black Holes, Introduction to General Relativity" by Edwin F Taylor and John Archibald Wheeler, Addison Wesley Press, 2000

First Light from the Vera C. Rubin Observatory

Generally, when people think of telescopes, Hubble or James Webb comes to mind, both of which are space telescopes. However, there are approximately 50 ground-based telescopes in world-wide operation with several more currently under construction. Each new telescope is more sensitive, delving deeper into the cosmos, seeking to answer many fundamental questions such as how the Universe began and what is the nature of dark matter and dark energy.

Vera C. Rubin Telescope Observatory under construction on Cerro Pachón, in Chile. Image credit: Rubin Obs/NSF/AURA.

One new observatory due to see first light this year is the Vera C. Rubin Observatory, which houses a uniquely designed reflecting telescope. What makes this telescope special is its optical configuration which features a unique three-mirror design, giving it a wide-field of view of 3.5˚ (7 x 7 full moons), covering a 64 cm diameter flat focal plane, while maintaining a compact shape that allows it to move quickly across the sky. The primary mirror is 8.4 metres diameter with a 4.42 metre convex secondary mirror – the largest ever made and a 5 metre tertiary mirror. It is optically very fast at F/1.2 and is fitted with a 3.2 gigapixel camera which is cooled to -100˚ C and an automated data processing system.

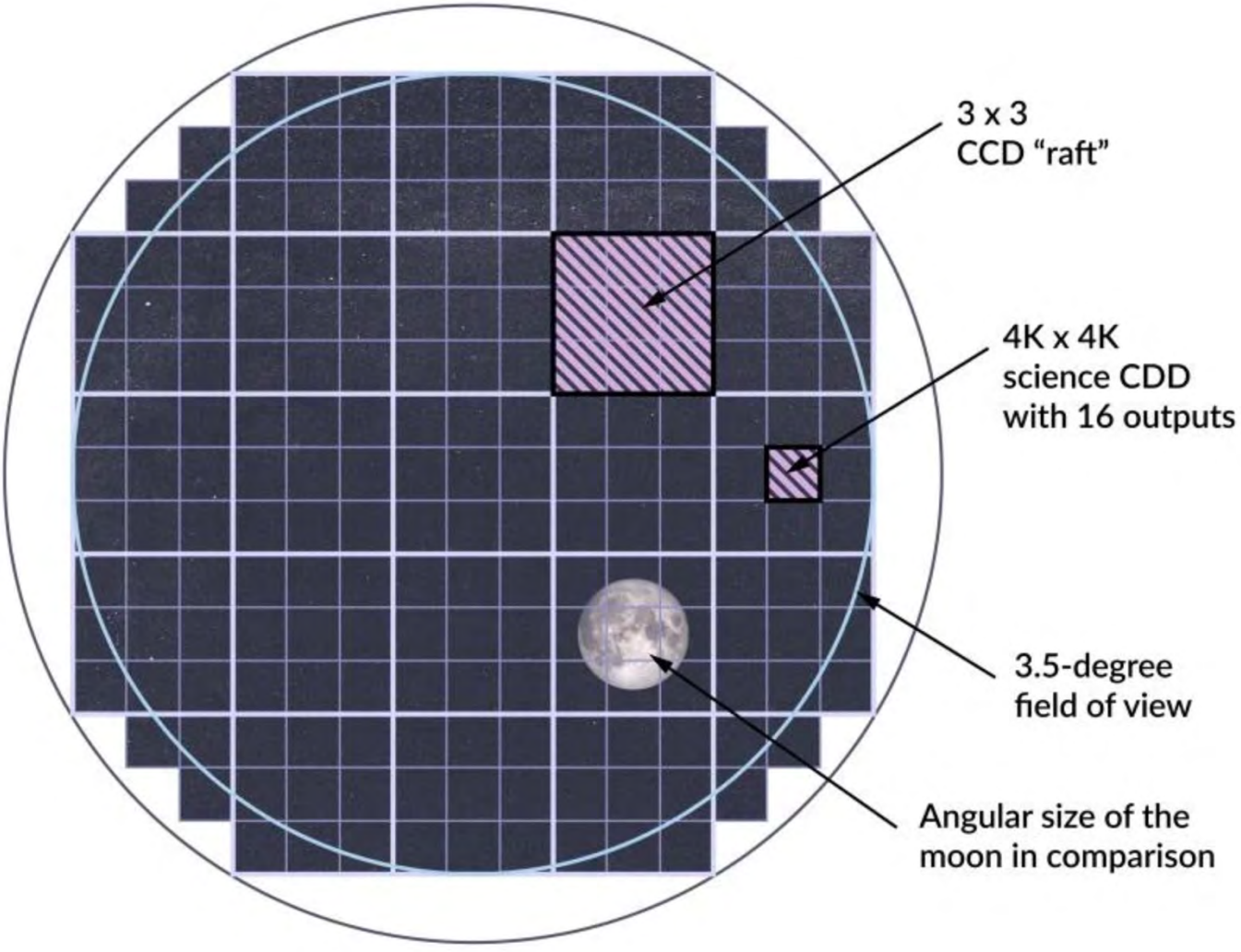


Schematic showing the dome and Simonyi Survey Telescope. Image credit: Rubin Obs/NSF/AURA.

The Rubin Observatory's mission is to continue with the long tradition of sky surveys. These started as visually compiled catalogues such as Tycho Brahe's *Thousand Star Catalogue*, Johannes Bayer's *Uranometria* and even the well-loved Messier list of objects produced by Charles Messier. With the advent of photography everything changed as surveys were then recorded on photographic plates, starting with

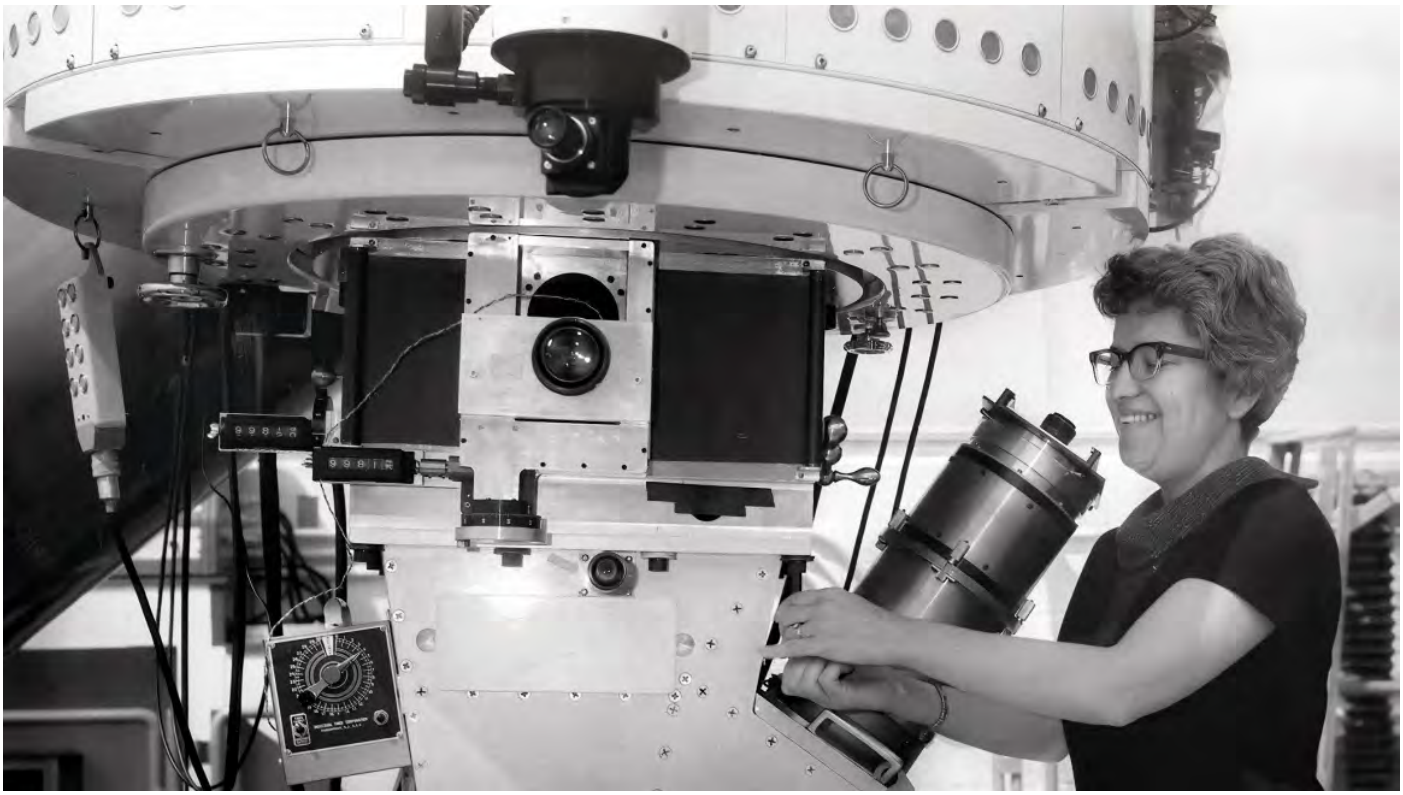
Carte du Ceil (lit. Map of the Sky) which was a vast and unprecedented international star-mapping project initiated in 1887 by the Paris Observatory, that contains 22,000 glass plates collected over nearly six decades. An even larger collection of some 500,000 photographic plates is the *Harvard Plate Collection*. Early photographic surveys provide an invaluable base-line comparison for modern astrometric surveys.

The Legacy of Space and Time (LSST) collaboration will survey the entire available southern sky every few days, taking 15-second exposures every 20 seconds, for the next ten years. To repoint any telescope within 5 seconds is quite a task, to repoint a 60 tonne telescope with an 8.4 metre primary mirror is an exceptional achievement. The camera is a mosaic of 189 CCD sensors with 16 megapixels each and a 0.2 arc-second sampling resolution. The camera is expected to take over 200,000 images per year; this is a staggering 1.28 petabytes of uncompressed data - a petabyte of computer data is 8×10^{15} bits of information.



Camera focal plane comprising 3 x 3 CCD "rafts". Image credit: LSST Collaboration.

The sheer volume of data is far more than humans can review, so an automated processing system has been designed which issues alerts on three different timescales: *prompt*, *daily* and *annually*. The *prompt* produces alerts, issued within 60 seconds about objects that have changed brightness or position when compared to archive data. This allows near-real time identification of changes, such as supernovae, asteroids and comets. It is estimated that as many as 10 million alerts might be generated per night, which will be further sub-sampled and finally, forwarded on to interested parties.



Dr Vera C. Rubin operating the 2.1 metre telescope and spectrograph at Kitt Peak national Observatory. Image credit: NSF's Optical-Infrared Astronomy Research Laboratory/ KPNO/AURA.

The name of the observatory is very fitting. Vera Florence Cooper Rubin (1928-2016) was an American astronomer whose work provided convincing evidence for the existence of unseen "dark" matter in the Universe. Prior to her work, dark matter was a concept that had been introduced but not taken seriously. But when Vera Rubin and her colleague Kent Ford studied more than 60 galaxies and found that the stars at the outer edges were moving just as fast as those towards the centre, they knew for sure that something strange was going on. What they observed didn't obey the laws of physics - if they added up the mass of all of the seen matter, the galaxies should have been flying apart! There had to be some invisible mass holding the galaxies together and causing them to rotate at such high velocities. The work resulting from these observations eventually convinced the science community that dark matter was real. Since then, scientists have calculated that dark matter makes up more than 80% of all the matter in the Universe, while regular matter makes up less than 20%. Learning more about this mysterious unseen matter is one of the main science goals of the LSST collaboration.

Another primary aim will be to unlock the fossil record of galaxy cluster evolution by looking for the exceptionally faint glow of intracluster light. This is the collective glow of innumerable stars stripped from their home galaxies and left to wander the vast intergalactic space. This will be the first astronomical survey to provide scientists with the data they need to detect intracluster light in thousands of galaxy clusters, unlocking clues to the evolutionary history of the Universe on large scales.

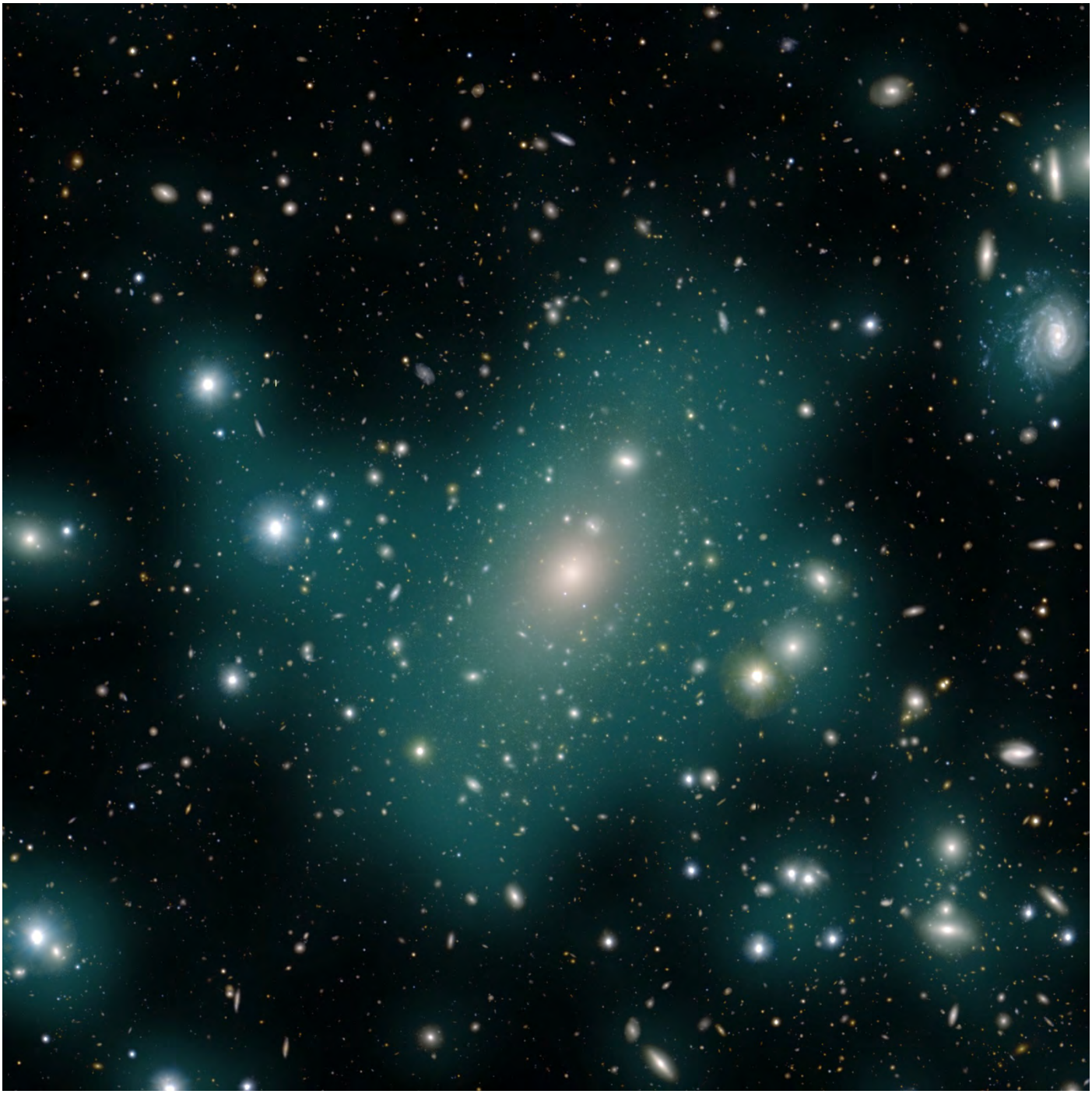


Image of the Abell 85 galaxy cluster, taken by the Hyper Suprime-Cam on the Subaru telescope in Hawaii. The enhanced teal hazy overlay is intracluster light — the collective glow of innumerable stars stripped from their home galaxies and left to wander the vast intergalactic space. Image credit: Astronomical Data/Image: M. Montes (Instituto de Astrofísica de Canarias); Artistic Enhancement: J. Pinto (Rubin Observatory).

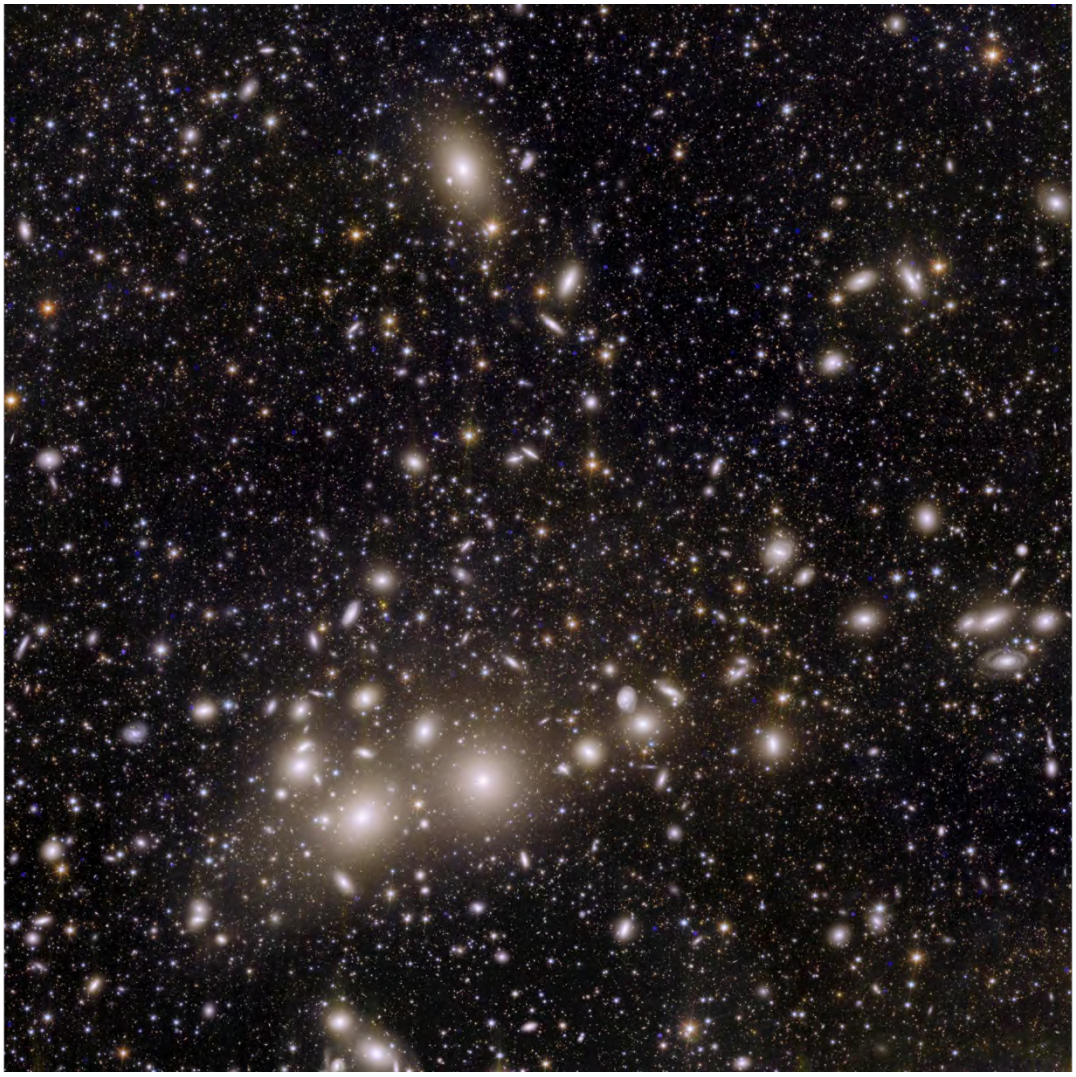
Twenty twenty-four could be as exciting as 2022 when the JWST saw first light.

Jean Dean

2023 in Spaceflight

Thanks in part to the efforts of Elon Musk's SpaceX, commercial spaceflight is in an ongoing boom at the moment. 2023 saw 211 successful rocket launches, the third year running the record has been broken. 98 of these launches, almost half, were by SpaceX. The majority of SpaceX launches this year were carrying Starlink satellites designed to provide global internet coverage. There are now over 5000 Starlink satellites in orbit, which along with other proposed mega-constellations provide an ongoing challenge for ground-based astronomy. 2023 saw several notable launches for astrophysics and planetary exploration.

On the astrophysics side, the European Space Agency launched *Euclid,* a space telescope designed to probe cosmology and the mysteries of dark matter and dark energy. *Euclid* will study the large-scale structure of the Universe and photograph more than one third of the Night Sky, covering thousands of times more area than *Hubble* or *JWST* ever will. Japan successfully launched *XRISM*, a next-generation x-ray telescope which will study distant black holes and energetic galaxy outflows.

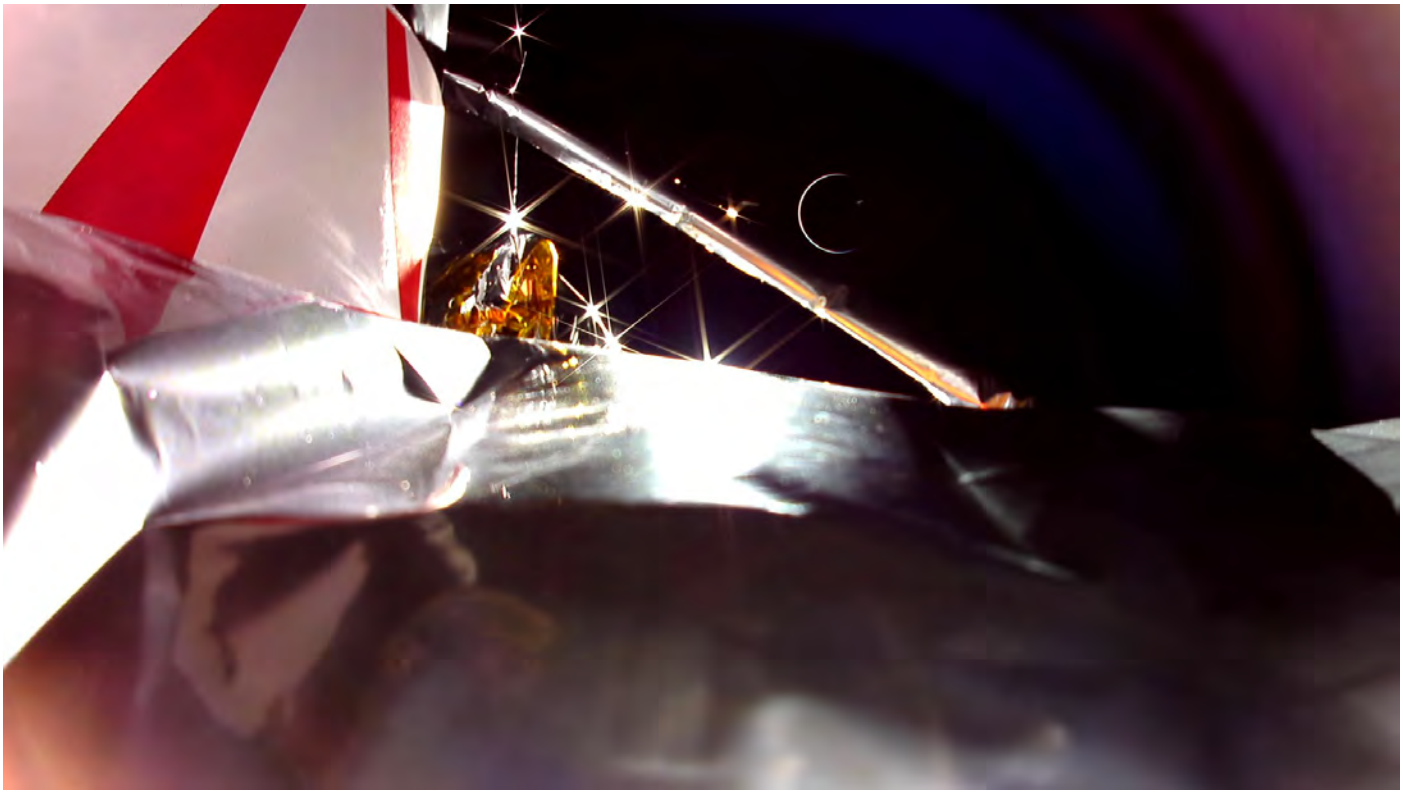


One of the first images taken by Euclid showing the Perseus cluster, revealing faint galaxies which have never been observed before.
ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, CC BY-SA 3.0 IGO

Looking a bit closer to home, 2023 also saw the conclusion of some long-running missions to study our solar system, as well as the launch of exciting new probes we will be hearing about for years to come. *OSIRIS-Rex* successfully returned samples from the asteroid Bennu and collected much more material than scientists were hoping for. These samples will tell us about the formation of our Solar System, as Bennu has been preserved as a 'time capsule' for a few billion years. The presence of any organic molecules may also tell us about how life evolved on Earth. *OSIRIS-Rex* continues its mission and is expected to arrive at the asteroid Apophis in 2029. NASA also launched the *Psyche* mission, to explore the asteroid 16 Psyche, one of the largest in the asteroid belt. 16 Psyche is particularly interesting to scientists because it has an extremely high metal content and is thought to be part of the ejected core of a protoplanet which is leftover from the formation of the solar system.

A closeup of the sample returned from *Osiris-Rex,* which NASA has finally managed to open 4 months after it landed in the Australian Outback. They even had to design and build a special tool to undo the bolts! *NASA/Erika Blumenfeld/Joseph Aebersold*

The *Jupiter Icy Moons Explorer (JUICE)* mission also began its 8-year journey to the gas giant Jupiter, where it will study Jupiter's largest moons, particularly Ganymede, for evidence of subsurface oceans. *JUICE* will also probe Europa for organic molecules, and for the first-time attempt to measure the thickness of the surface ice above the volcanic regions.



A crescent Earth taken from the *Peregrine* lunar lander on its ill-fated mission to the Moon. *Credit Astrobotic.*

Our own Moon hasn't missed out on the fun either, although she is a fickle mistress. There have been several missions, both private and public, in 2023 and the majority have encountered various technical issues. *Luna 25,* the first Russian lunar mission since *Luna 24* in 1974, suffered an engine issue which resulted in the spacecraft crashing into the surface. The third Indian lunar mission, Chandrayaan-3, which consists of an orbiter, lander and rover successfully landed on the lunar surface, making India only the fourth country to successfully land on the Moon. The *Vikram* lander touched down near the South Pole, which is of particular interest as there are permanently shadowed craters that may contain water ice. The Japanese also launched a lunar lander, named *SLIM,* which took a slow route to the Moon over a number of months and successfully landed in early 2024, making Japan the 5th country to land on the Moon. It appears however that *SLIM* fell over on landing, blocking light to the solar panels and only lasted a few hours on the surface before the batteries drained. Astrobotic's private lander, named *Peregrine*, suffered a rupture fuel tank that caused the spacecraft to spin out of control on the way to the Moon. The loss of fuel prevented a landing attempt and the lander burned up in the Earth's atmosphere upon it's return. All is not lost however, as in 2024 there are several more private missions aiming to land on the lunar surface, as well as the NASA *VIPER* rover which will explore those exciting shadowed craters at the lunar south pole.

Other noteworthy accomplishments which I don't have the space to dive into include the launch and fiery explosion (or Rapid Unscheduled Disassembly!) of SpaceX's latest Starship rocket prototype, a number of private missions by Axiom Space carrying tourists to the ISS, the launch of Virgin Galactic's first paying customers on *VSS Unity*, and the heaviest communications satellite ever launched to a geostationary orbit.

Lastly, an honourable mention for *Ingenuity*, The Little Helicopter That Could. Initially expected to make only a handful of flights across a few days of life, *Ginny,* has massively surpassed all expectations by surviving for over 2.5 years and making 72 flights (as of publication). *Ginny* is the first aircraft ever flown on another planet and operates mostly autonomously due to the speed-of-light delay between Earth and Mars. As a technology demonstrator, *Ginny* has paved the way for future aerial exploration of extra-terrestrial worlds, and the promise of future missions that will be able to cover more distance, much faster over inhospitable terrain that would be challenging for a rover like *Curiosity* or *Perseverance.*

2024 also promises to be an exciting year for spaceflight. Highlights include the launch of the *Europa Clipper* mission, which will perform a detailed study of the Jovian moon and its subsurface ocean. The new spaceplane *Dream Chaser* is also scheduled to launch to the ISS, and we have already seen the launch of the new methane powered Vulcan rocket. In April, another private spaceflight from Axiom may perform the first commercial spaceflight in history. At the end of the year, *Rocket Lab* is planning to fling a small satellite towards Venus, the first private mission, to study its atmosphere. Maybe the disputed claims of an organic molecule called phosphine, which could indicate microbial life, will be settled for good?

In summary, 2023 has been an incredible year for spaceflight, and 2024 promises to be better yet. In the longer term, both NASA and the Chinese Manned Space Agency (CMSA) are still aiming for boots on the Moon before 2030, and the new Space Race appears to be heating up.

Tom Harvey

(Editor's Note – if you want to track what's going on in Astronomy this year, the New York Times offers a free calendar at https://www.nytimes.com/explain/2024/astronomy-space-calendar , which you can add to your Google, Apple or Outlook calendar app.)