Astronomy La Société Guernesiaise Sagittarius

The Newsletter of the Astronomy Section of La Société Guernesiaise

2023

Forthcoming Events

Talks for Members - For details see page 6.

17th January – Intro to Sensors, Noise and Raw Data *Jean Dean*

31st January - Von Kármán Lecture: Near Earth Objects

14th February - How to Photograph the Milky Way *Jacques Loveridge*

28th February - Are we alone in the Solar System? *Jean Dean*

Public Open Days

We will be running public open evenings during 2023, although the exact format and timing of these is still to be decided. We will also be running more daytime solar open days, which due to the nature of the event will be advertised only a few days before they take place. It is likely there will also be a Halloween themed event in October as there has been in previous years. Our events will be announced via the media, on the Astronomy Section website, www.astronomy.org.gg, and on the Section's Facebook pages.

Contents

Section meetings

The Section meets at the Observatory every other Tuesday evening at 8.00 pm, sometimes with a lecture to watch. The currently planned lectures are givenon page 8. Also the last Saturday evening of each month, if clear, except summer, for observing and photography.

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www.astronomy.org.gg

Material for, and enquiries about Sagittarius should be sent to the Editor: tharvey303@gmail.com

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Astronomy Section Officers, 2023

Secretary	Jean Dean
Hon. Treasurer	Steve Bougourd
Membership	Anthony Nel
Editor	Tom Harvey
Equipment mtce.	Allan Phillips
IT/Website	Owain Catton

Introduction from the Editor

Welcome to the 2023 edition of Sagittarius! The last year has been very busy for the Section, and I would like to take this opportunity to thank our Secretary, Jean Dean, for all the work she does keeping the Observatory running. Jean volunteers a lot of time to manage the Section and organise events for members and outreach for schools and the public. Last year saw the successful opening of our new observatory, the David le Conte Astronomical Observatory, which has replaced the previous building. This was an enormous undertaking and I want to thank everyone who helped.
If you'll indulge a little personal news from the editor, I am now studying for my PhD in Astrophysics at the University of Manchester. See the last two articles if you're interested in what I've been doing! This year's Sagittarius is packed full of interesting articles, from some of the great astrophotography that our members have taken to exciting news about NASA's next mission to Titan!

As always, 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 2023

Last year at this time we had a partially constructed telescope building that still required considerable work to finish it and we were rapidly running out of money as the price of timber had increased three-fold. It took another 7 months for members to finish the build and we were very grateful to receive extra financial assistance from La Société Guernesiaise for the second-fix electrics, the Social Investment Fund for the 55" monitor and Skipton Community Fund for the floor covering. In addition, we would also like to thank the builder, Damian Crocker, who made sure we had all the materials we needed to finish the structure and who very generously donated the external cladding.

I would also like to thank all those members who gave their time to the project. Particularly: Anthony, Stephanie, Jill, George, Allan, Owain, Jason and Kieran who all gave many hours of their free time.

The final costs for the new telescope building were:

La Société Guernesiaise	£15,763
Social Investment Fund	£1,038
Skipton Community Fund	£802
Astronomy Section funds	£2,554
TOTAL	£20,157

We combined the official opening with our first public open solar day which took place on 31st July. We also took the opportunity to rename the observatory the David Le Conte Astronomical Observatory. Courtesy of the Charlie Bates Solar Astronomy Project we had free solar eclipse glasses and spectral peepholes to give out to children which proved very popular. It was a very successful event with excellent weather and over 100 members of the public attending. You can find more about the opening day here: https://guernseypress.com/news/2022/08/01/la-societe-opens-new-observatory/

Over the summer we had some excellent clear night skies, albeit very short in length and members were able to do some astrophotography, imaging the East and West Veil Nebula, Elephants Trunk Nebula, Cygnus Wall and the Milky Way.

We held an impromptu solar observing event at Candie Museum which attracted a lot of interest, giving out solar eclipse glasses and spectral peepholes. We also attended the end of summer Nature Guernsey event at Pleinmont Headland.

As the evenings drew in and the planets were visible in the early evening we held a couple of public open evenings, however, on both occasions the weather was cloudy and wet. Jason gave a talk on the Solar system and its Ocean Worlds and Stephanie on the Artemis program that will send humans back to the Moon and eventually much further to Mars.

We also welcomed the return to group outreach with visits from the 12th Guernsey Beavers, Monkey Puzzle Playgroup and the Head and Neck Cancer Group.

Membership

In 2022 the Astronomy Section Committee made the difficult decision to raise the membership rate to £15 because the running and maintenance costs for the observatory site and equipment have increased significantly over the last few years.

You may renew your membership through the La Société Guernesiaise (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. Please remember you need to be a member of LSG to join the Astronomy Section.

There have been some committee changes in 2022, Jill Barnicoat stepped down as Treasurer and Activities Coordinator, and Jason Hill as Treasurer and Research Officer. I would like to thank Jill and Jason for their contributions over the last few years. We welcome a new Treasurer, Steve Bougourd who is the accountant for Marine and General, I am sure our finances will be safe in his experienced hands.

Committee for 2023

Following the Annual Business Meeting on 3rd January 2023 the new Astronomy Section Committee is:

Secretary	Jean Dean
Treasurer	Steve Bougourd
Membership Secretary	Anthony Nel
Equipment Officer	Allan Phillips
IT/Website Officer	Owain Catton
Sagittarius Editor	Thomas Harvey

Bi-weekly meetings and activities
I would like to remind members that we have modern, computerised GOTO telescopes that they can learn to use, including a complete astrophotography setup. Once proficient they may use the facility whenever they wish. For those that have not visited the site, it is very dark and ideal for observing or astrophotography. It has plenty of onsite parking, a toilet, warm meeting room with kitchen area where hot drinks can be made. If you would like to learn to use the equipment, then please come along to our bi-weekly Tuesday night meetings.

To stay in touch with activities see our website: https://www.astronomy.org.gg and members only Facebook group: https://www.facebook.com/groups/557188241419877. Details of activities will also be sent out via email to members.

Equipment Purchase
We made one major equipment purchase in 2022, it was a cooled deep space colour astrophotography camera – a ZWO ASI 533. It saw first light in late summer with the Cygnus Wall which is part of the larger North America Nebula, NGC 7000 in the constellation of Cygnus, which is approximately 2,590 light years away. The picture on the next page shows the capabilities of this camera. The 'W' shaped wall is about 20 light years in length and is a region of new star formation. The image is a stack of 5 x 15 minute exposures with a Ha narrow band filter. It was taken with the Section's 80mm diameter Skywatcher Esprit refracting telescope and Skywatcher HEQ5 tracking mount.

If you have an interest in learning astrophotography then come along to the bi-weekly meetings. There will be some astrophotography-specific lectures.

Jean Dean

Image credit: Jean Dean

Committee Members Reports

Owain Catton – IT/Website Officer

Apart from the normal updates and corrections we have continued to try and expand the available content on the website to cover all our member interests from experienced to new members. We have continued to keep adding articles from our extensive back catalogue from the old website as well as those published by David le Conte and we hope to continue this as and when we can. All the articles are available to be read directly online or offline as a printable PDF.

The galleries utilised across the website have been overhauled, previously they used a couple of different methods, but they all now have they been implemented using the same technique so we have a consistent look across the whole site.

Also, the website content which is managed using the backend CMS interface has been upgraded by exploiting the Gantry5 Framework plugin. This allows via a visual editor for end users to configure and structure page layouts via an easy-to-use drag-n-drop system to create page content.

Unfortunately, the All Sky Camera while has been re-installed on a new bracket on the exterior of the new observatory building is still offline. We have had a hardware failure of the Windows PC which runs it and the Meade telescope. This means the committee will be looking at replacing this as well as upgrading the other computer facilities on offer at the observatory for members.

If you have an article you would like to be put onto the website or spot something that needs correcting, please get in contact via the contact form on the website.

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.

17th January

Talk: Beginners guide to digital sensors, raw data and calibration.

Description: This talk addresses the following questions: How do digital sensors work? What is genuine raw data and what is calibration and stacking. This is an introductory talk for those who are new to astrophotography.

Speaker: Jean Dean

31st January

Talk: Von Kármán Lecture: Near Earth Objects - Opportunities for Discoveries.

Description: Comets and asteroids offer clues to the chemical mixture from which the planets formed some 4.6 billion years ago. If we wish to know the composition of the primordial mixture from which the planets formed, then we must determine the chemical constituents of the leftover debris from this formation process - the comets and asteroids. In this talk, we'll discuss with how Near Earth Objects are opportunities for discovery.

Speaker: Dr Davide Farnocchia, Navigation Engineer, NASA/JPL

14th February

Talk: How to Photograph the Milky Way

Description: This is an introduction on how to photograph the Milky Way with a digital camera. It looks at the equipment required, including small portable trackers, typical camera settings and introduces some of the software that can be used for processing the images.

Speaker: Jacques Loveridge

28th February

Talk: Are we alone in the Solar System?

Description: What evidence is there for life, either past or present, within our solar system? There are over 200 worlds in our backyard and evidence is mounting to suggest some may contain life. In 2023 the European Space Agency will launch the JUICE mission which is in part, designed to look evidence of life on some of Jupiters icy moons.

Speaker: Jean Dean

14th March

Von Kármán Lecture - NuStar - Studying the Universe in X-Ray.

Description: The Nuclear Spectroscopic Telescope Array, or NuSTAR, is the first space telescope capable of taking focused high-energy X-ray observations of the cosmos, providing unprecedented information on the dynamics of black holes, exploding stars, and the most extreme active galaxies. Join us to learn how NuSTAR has expanded our knowledge of the universe after almost a decade of operation.

Speaker: Dr Brian Grefenstette, NuSTAR Principal Mission Scientist, Caltech

28th March

Talk: An overview of planetary imaging.

Description: How to image the planets with emphasis on using the Astronomy Section's Celestron Nexstar 8SE and ZWO planetary camera. What software is available? Examples of how to image the Moon.

Speaker: Owain Catton

Members Image Gallery

There are some truly fantastic astrophotographers on the island, and so this section is dedicated to showing off some of the best astrophography of 2022. All images are provided courtesy of the respective photographers. If you're viewing this on a computer, make sure you zoom in to get all the details!

The Veil Nebula, part of the Cygnus Loop found in the outer reaches of the Cygnus constellation, is a supernova remanent, the result of supernova star 200 times more massive than the Sun, exploding between 10,000 and 20,000 years ago. At the time of the explosion the supernova would have appeared brighter than Venus and been visible in daytime.

Image credit: Astronomy Section Member

The image is of the Western Veil, also known as the "Witches Broom", with "Pickering's Triangle" below to the left. It was taken over 2 nights in July after waiting for the First Quarter moon to set, using a Sky Watcher Esprit 80 ED pro and Canon 60Da DSLR. The total integration time was just over 4 hrs, combining 35 x 420s light frames along with dark, flat and bias frames, stacked and processed using Nebulosity and Affinity software.

Image shows Image credit: Jacques Loveridge.

Image showing the Pleiades. Image credit Jacques Loveridge.

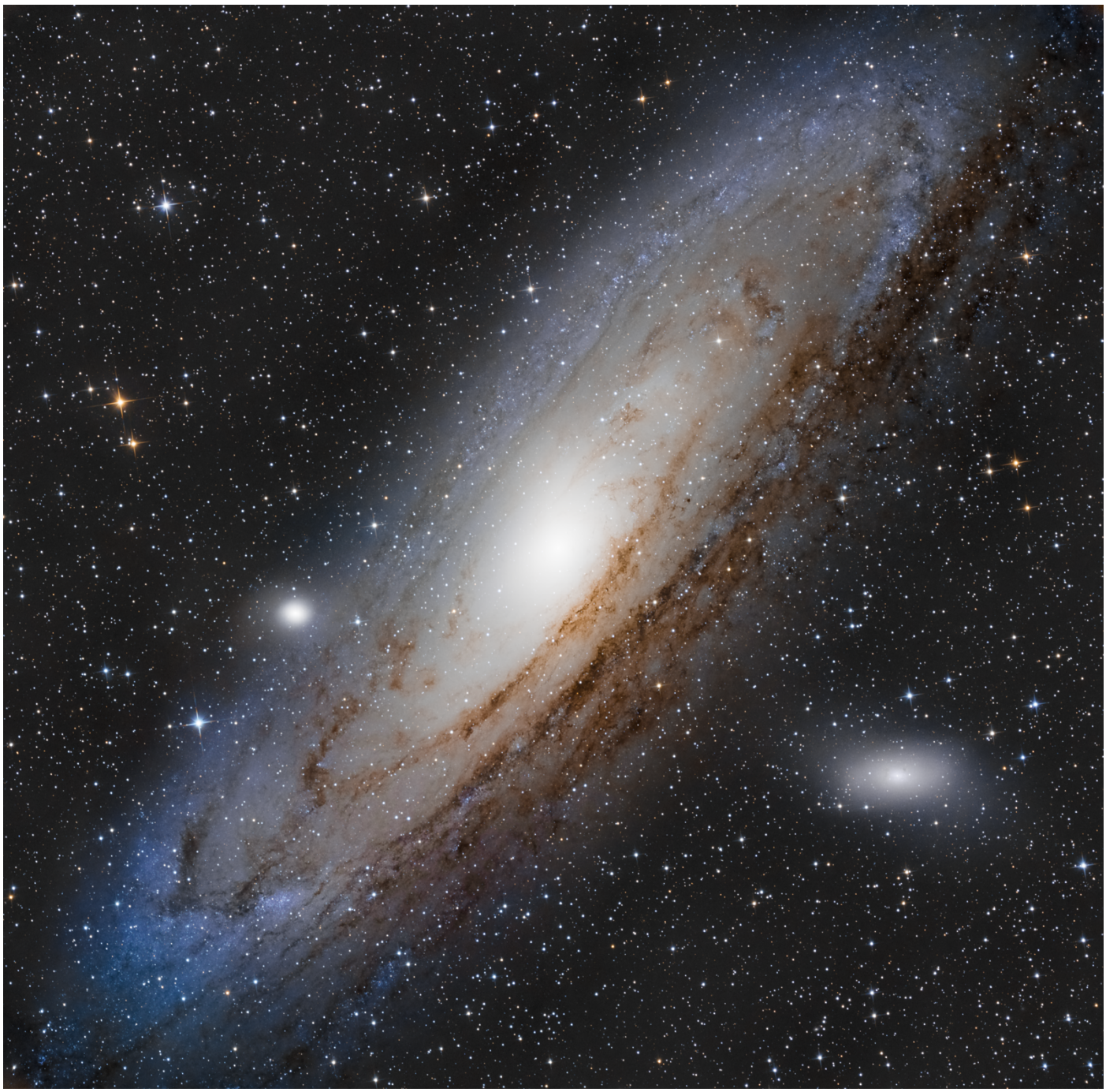


Image showing the Andromeda Galaxy. 2 Panel mosaic, 2hrs per panel with a Sony A7iii, Sky Watcher 10" f/4.7 Newt and EQ6-R Pro. Image credit Jacques Loveridge.

Astronomical Events 2023

Welcome to the Astronomy Sections guide for what and when to observe in 2023! This year looks to be a good year for meteor showers, with both the Perseids and Geminids coinciding with a New Moon. The dark skies should allow your eyes to see more meteors than normal.

There are also reports that a comet discovered last year C/2022 E3, will become visible in the night skies above Guernsey in late January and early February. It's too early to tell if the comet will continue to brighten, but this could be the best comet since NEOWISE in 2020.

Planets

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

Date	Elongation	Direction	Time
30 January	25º Western	Low in East	Before sunrise
11 April	19.5º Eastern	Low in West	After sunset
29 May	24.9º Western	Low in East	Before sunrise
10 August	27.4º Eastern	Low in West	After sunset
22 September	17.9º Western	Low in East	Before sunrise
4 December	21.3º Eastern	Low in West	Before sunset

Jupiter will be visible in the evening throughout, January, February and March, but setting earlier as the year progresses. Jupiter reaches opposition on November 3rd, 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 and becoming an evening object by September.

Mars will be visible in the west in the evening until July. It will be lost into the solar glare around November, before re-emerging in December. On the 18th of November it will be at its furthest from Earth, around 2.5 AU.

From early May, Venus will be visible around dusk, as the "Evening Star" in the western sky. It will reach its greatest eastern elongation, when it is highest in the sky, on June 4th.

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 August 27th, when it will be at its brightest point of the year. The rings are still at a good angle for observation, 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 August.

Uranus will be at opposition in Aries on November 13th. Neptune will be at opposition in Aquarius on 19 September.

Phases of the Moon

New Moon	First Quarter	Full Moon	Last Quarter
		Jan. 6	Jan. 15
Jan. 21	Jan. 28	Feb. 5	Feb. 13
Feb. 20	Feb. 27	Mar. 7	Mar. 15
Mar. 21	Mar. 29	Apr. 6	Apr. 13
Apr. 20	Apr. 27	May 5	May 12
May 19	May 27	June 4	June 10
June 18	June 26	July 3	July 10
July 17	July 25	Aug. 1	Aug. 8
Aug. 16	Aug. 24	Aug. 31	Sept. 6
Sept. 15	Sept. 22	Sept. 29	Oct. 6
Oct. 14	Oct. 22	Oct. 28	Nov. 5
Nov. 13	Nov. 20	Nov. 27	Dec. 5
Dec. 12	Dec. 19	Dec. 27	

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 2023 there will be four such moons: on 3 July, 1 August, 31 August, and 29 September.

Dwarf planets and asteroids

Pluto will reach opposition on the 22nd of July, at magnitude 14.9, around midnight 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 March 21st, at magnitude 7.1, visible in the South in the evening.

Vesta, one of the largest asteroids in the Asteroid Belt, will reach opposition on the 21st December, around midnight, in the South, at an altitude of 21 degrees. It should be visible as a reddish dot in a small telescope.

Eclipses

I seem to say this every year, but this is a very poor year for eclipses one partial lunar eclipse, being visible from Guernsey. The partial lunar eclipse will be visible on the 28th October, peaking at 20:14pm UTC.

There is a hybrid solar eclipse on the 23rd April visible only from Australia and neighboring countries. There is also an annular solar eclipse on the 14th October, but from Guernsey the Sun will set before the eclipse begins.

Occultations

There is a lunar occultation of Venus on the 9th November, which will theoretically be visible during the day, around 10am from Guernsey. Venus will disappear at 09:52 GMT and reappear at 10:45 GMT.

Lunar conjunctions

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

31 Jan	Mars	Southwest in evening	0°06’
22 Feb	Jupiter	Southwest in evening	1°11’
28 Feb	Mars	South in evening	1°04'
24 March	Venus	West in evening	0°06’
14 June	Jupiter	East in the Dawn Sky	1°30’
09 November	Venus	Southeast in the dawn sky	1°00’
17 Dec	Saturn	Evening sky in the South	2°28’

Planetary conjunctions

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

02 March	Venus and Jupiter	South, early evening	0°32'

Meteors

The Perseids will peak on the night of 12/13 August, with some 80 per hour, and with the Moon only 3 days from New will hopefully be favourable. The richest annual shower, the Geminids**,** will peak on the night of 13/14 December. The New Moon is the day before, so this should be the best time of the year to see a meteor shower.

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

A comet discovered last year, 2022 E3, might be the brightest comet of the year, making a closest approach to the Earth of 0.3 au. It will be visible in the morning sky throughout January, at about 9th magnitude.

Detailed comet predictions for 2023 are available on the website of the British Astronomical Association’s Comet Section: http://www.ast.cam.ac.uk/~jds/preds23.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 2023:

Vernal Equinox	20 March	21.17 UTC
Summer Solstice	21 June	04.39 UTC
Autumnal Equinox	23 September	06:43 UTC
Winter Solstice	22 December	03:21 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

Details are on our website (www.astronomy.org.gg) and Facebook page (https://www.facebook.com/AstronomyGuernsey).

Additional courses may be run during the year, including astrophotography courses.

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

A Year of JWST: What have we learned?

On Christmas Day 2021, after years of delays, the James Webb Space Telescope (JWST) finally launched. JWST is the long-awaited successor to the Hubble Space Telescope, designed to enable astronomy that has never before been possible. Looking back at the results over the last year, it is safe to say that the long-awaited observatory has not disappointed. It would be far too long an article to look at all the amazing things that have been discovered, but I would like to highlight my 5 favourite JWST discoveries. JWST has revolutionised astronomy at all scales, from what we know about our own solar system all the way out to the most distant galaxies ever discovered.

The first discovery is (relatively) close to home – JWST has been successfully used to observe the outer planets of our solar system, particularly the gas giants and their moons. This has led to new discoveries, such as the observation of clouds on the largest moon of Saturn, Titan. Titan was observed with both the imaging camera aboard JWST, called NIRCam, which can take very high-resolution photographs in infrared light, as well as by

the spectrograph known as NIRSpec, which lets scientists analyse the composition of gases in Titan's atmosphere. Titan has seas of liquid methane so it is likely that these clouds are also made of methane vapor, in a similar fashion to how the water cycle works here on Earth! JWST also observed the gas giant Neptune, re-discovering an inner ring that was last seen by the Voyager 1 probe in 1989.

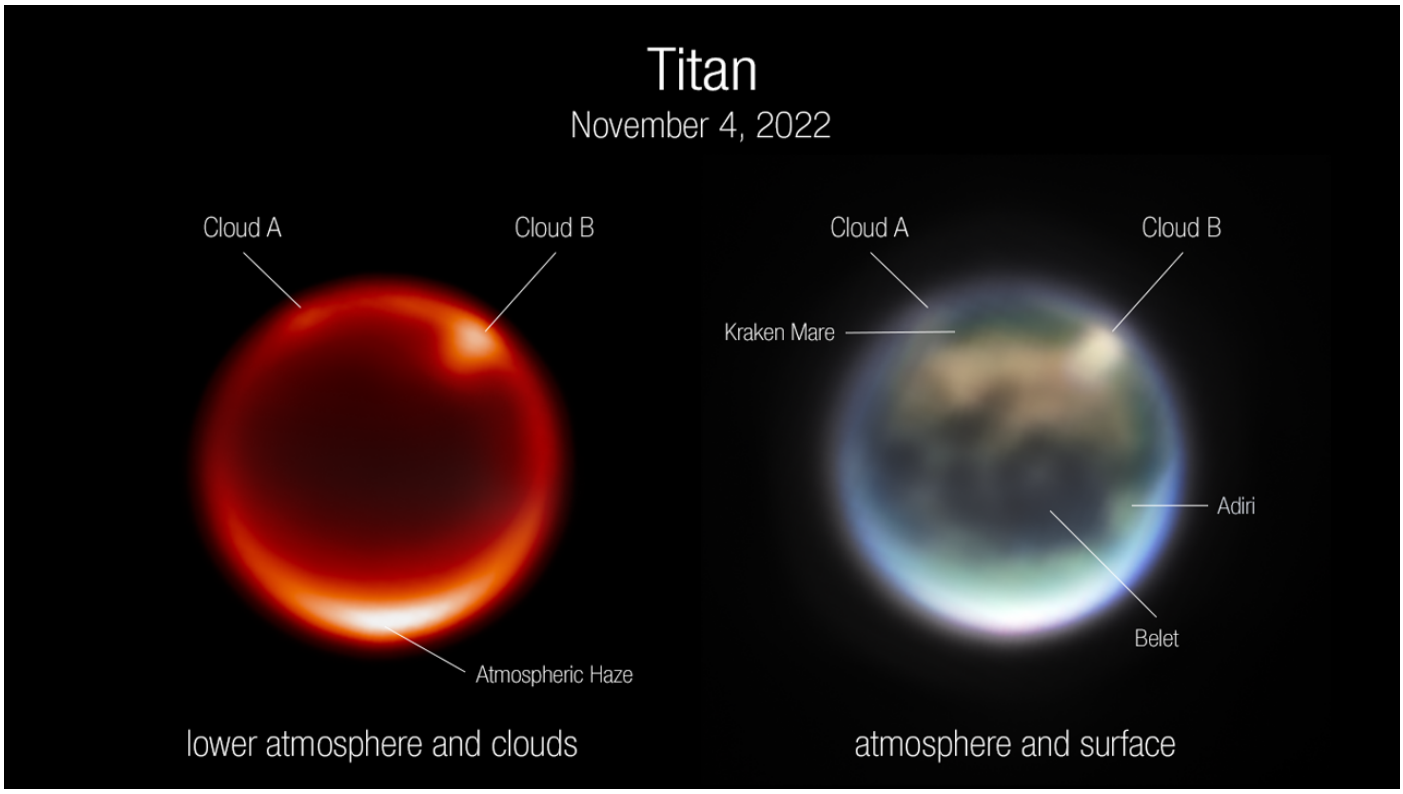


Image of Saturn's largest Moon, Titan. (Image credit: NASA, ESA, CSA, Webb Titan GTO Team/Alyssa Pagan (STScI))

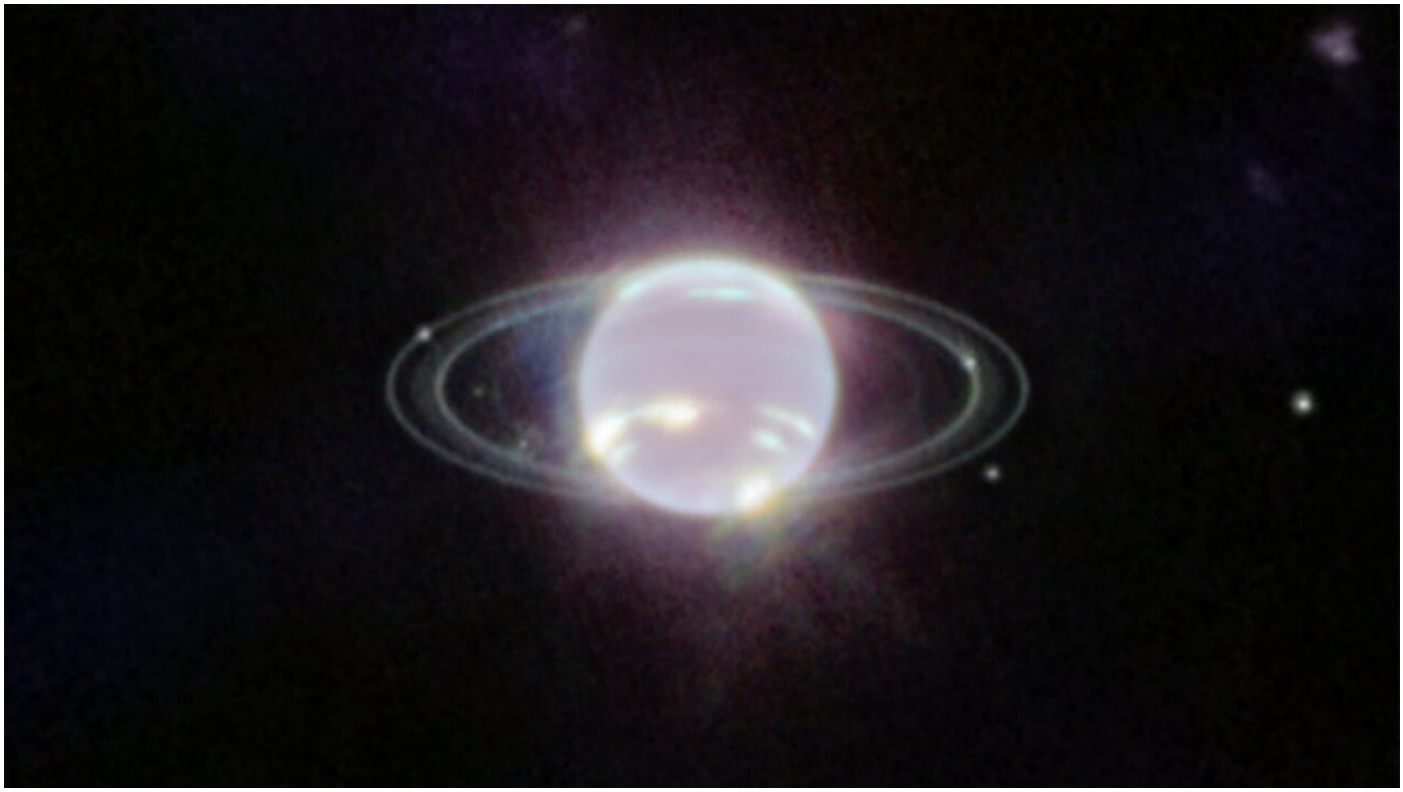


Image of Neptune and rarely seen rings. Image credit: NASA, ESA, CSA and STScI

Moving a bit further from us, but still within our local galactic neighbourhood, the second discovery of the year is the discovery of hidden star formation and young stars in NGC 3324, known as the Cosmic Cliffs. Observation with NIRCam in the infrared allow us to see through the thick clouds of molecular gas that make up the Cosmic Cliffs, and observe the formation of very young stars. The image below shows powerful outflows of gas from dozens of these young stars, some extending many light years. Many of these young stars have masses like our Sun, and it is likely our own Sun formed in a similar molecular cloud.

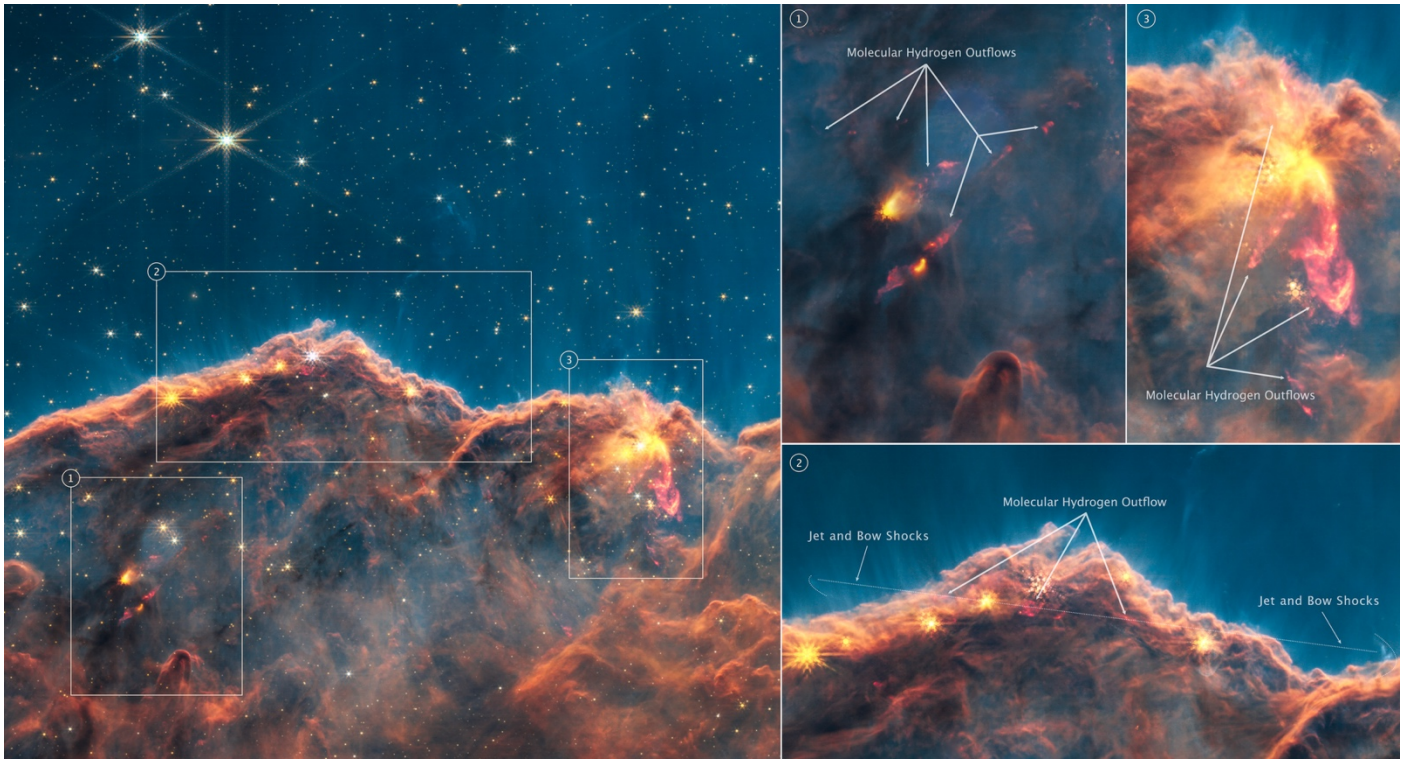


Image credit: NASA, ESA, CSA, and STScI. Image processing: J. DePasquale (STScI).

JWST has also enabled new discoveries in one of the fastest growing areas of astronomy – the discovery and study of planets orbiting other stars, known as exoplanets. JWST is not designed to discover new planets, as its small field of view is designed for targeted operations rather than observing millions of stars in the hope of catching the dip in light as the planet passes in front of the star. Other missions, such as the Transiting Exoplanet Survey Satellite, or TESS, are designed for that kind of mission. We have now discovered over 5000 exoplanets, and JWST is the perfect tool for detailed followup study of the most interesting. JWST can directly observed gas giants orbiting close to nearby stars using a clever device called a coronagraph – essentially a very small movable mask which is used to block the light from the star so we can observe the nearby planets, which would otherwise be invisible. One of the most interesting planets is Wasp-39b – a gas giant the size of Jupiter but the mass of Saturn, which orbits 4x closer to its star than Mercury. Completing an orbit every 4 days, the atmosphere of WASP39b reaches temperatures of 900 °C. JWST has analysed the composition of this planets atmosphere and found evidence of molecules and even clouds. The spectroscopy using NIRSpec shows evidence for sodium, potassium, water vapour, carbon dioxide and sulphur dioxide. The presence of these elements hints at complex chemical reactions occurring in this extreme energy-rich environment. The quality of the results from these observations are also very promising for JWSTs capabilities to observe smaller and more earth like exoplanets.

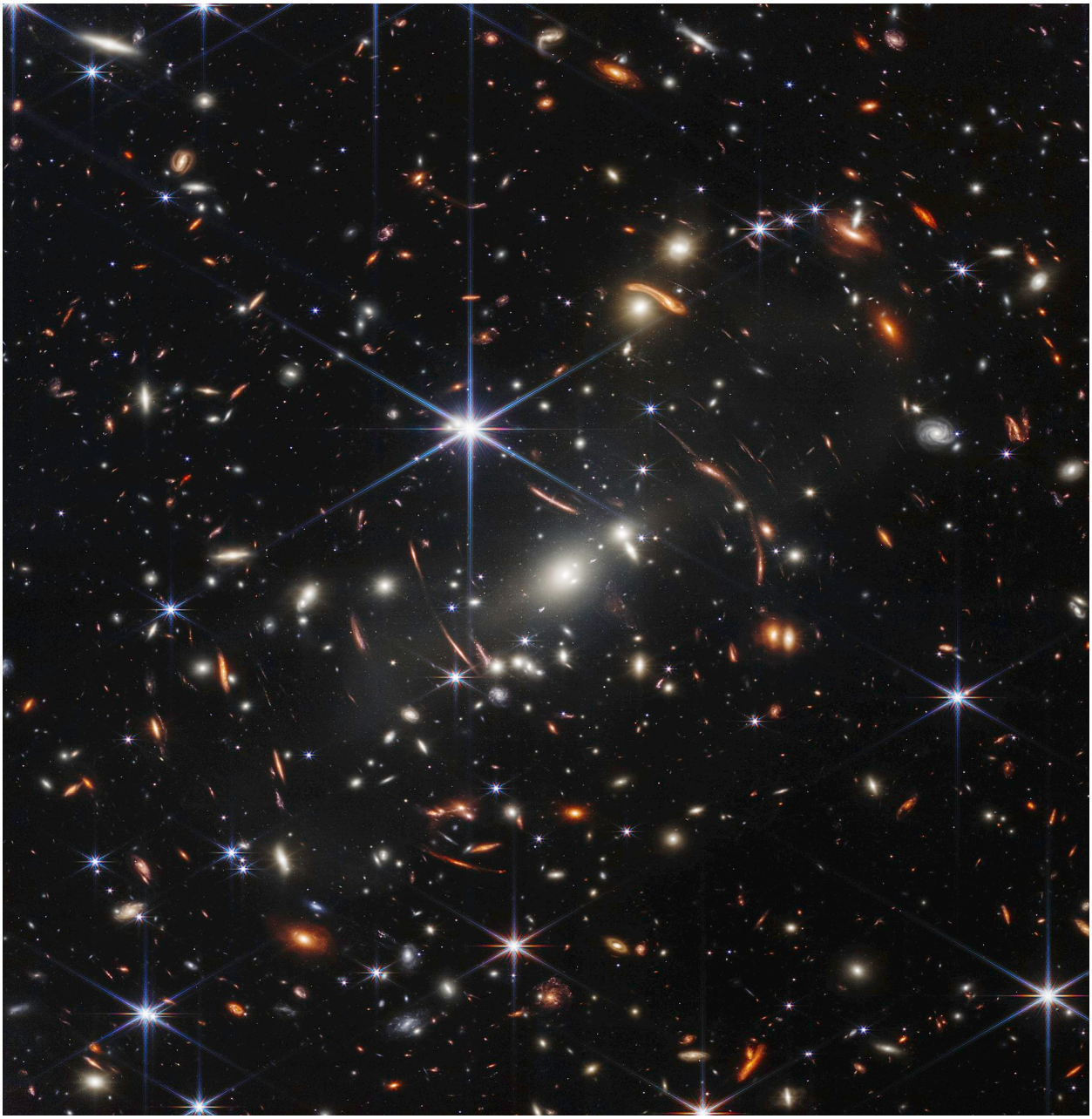
The fourth object is something completely unexpected which took astronomers by surprise. They were observing a Wolf-Rayet binary, which is a pair of stars orbiting each other. One of the stars is a special type of high mass star (more than 25x as heavy as our Sun) that is approaching the end of its life. These stars are unusual because we can see a lot of heavy elements in their atmospheres, whereas most stars have atmospheres made up of hydrogen. Wolf-Rayet stars are thought to have already lost their hydrogen envelopes, exposing the inner layers of the star to observation. The other star is also massive, known as an O-type star, but is younger. As these stars orbit each other, approximately once every 8 years, they pass close to each other and the gravitational influence of the stars produces a ring from the collision of the strong stellar winds produced by each star. This event happens on a regular cycle, which is why the below image shows such uniform concentric rings.

Concentric dust rings around a Wolf-Rayet star. Image credit: NASA/ESA/CSA/STScI/JPL-Caltech

Finally, my favourite discovery of the year (and the most distant by far), has been JWST's discovery of some of the most distant galaxies ever observed. JWSTs large mirror means it can collect a lot more light than previous space-based telescopes, allowing it to peer much deeper into the Universe in less time than before. It can also look further into the infrared than the Hubble Space Telescope, allowing it to spot more distant galaxies that formed in the early Universe. JWST has already done surveys of many of the most famous 'deep' Hubble observations, and many teams from around the world have been rushing to

find the most distant galaxies to date. It is not an exact science, and there are ongoing disagreements between different teams as to whether certain galaxies are as far away as claimed, but there are some galaxies that everyone agrees on, the most distant of which likely formed only 250 million years after the Big Bang, over 13.5 billion years ago. The first image showing these distant galaxies was the now famous SMACS-0723 galaxy cluster, You can read the next article to learn all about how we discover these fascinating objects.

There are many other exciting discoveries I didn't have time to cover here, and the JWST era has only just begun. Highlights to come this year include the deepest JWST observations to date, which will reveal galaxies one hundred times fainter than has been done before. From July we will be in Cycle 2, where the next round of JWST proposals and their exciting new science will begin. I can't wait to see what JWST discovers this year!



The SMACS-0723 cluster. Image credit: NASA, ESA, CSA, and STScI

Return to Titan

On January the 14th 2005 the Huygens probe, named after the Dutch physicist Christiaan Huygens who discovered Saturn's largest moon Titan, made the first and only landing on an outer solar system body. The probe completed a two hour and 27 minute descent, before landing and transmitting data from the surface of Titan.

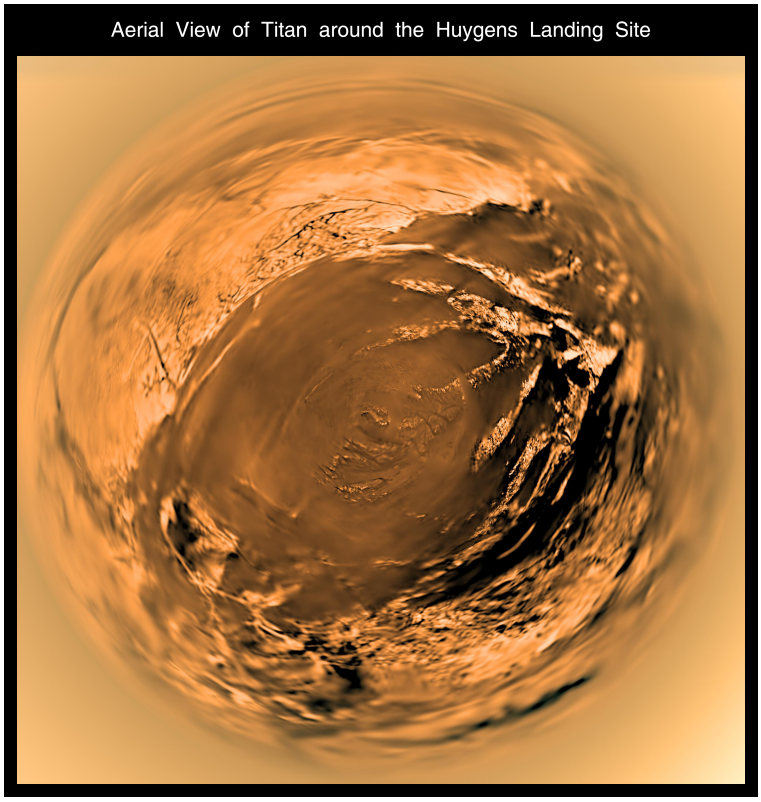


Image taken during Huygens descent from 5 kilometers (3 miles) above Titan's surface.
Image Credit:
ESA/NASA/JPL/University of Arizona

Image taken by Huygens on Titan's surface.
Image Credit:
NASA/JPL/ESA/University of Arizona

NASA has plans to revisit Titan via the Dragonfly mission which is planned to arrive at the moon in 2034, almost 30 years after the Huygens probe landed. The mission is currently set to launch in 2027 and will send a rotorcraft to the moon of Saturn. Due to the moon's weak gravity and dense atmosphere (four times denser than Earth's), the rotorcraft will be able to become the first extra-terrestrial vehicle to transport its own full set of scientific equipment via flight. The baseline mission is planned to last 32 months, with the probe being powered by a radioisotope thermoelectric generator for the duration of the mission. During this time period the rotorcraft is expected to eventually fly more than 108 miles (175 kilometres) – almost twice the distance travelled to date by all the Mars rovers combined.

Once on Titan the Dragonfly rotorcraft will be looking to study the potential habitability of extra-terrestrial environments. The craft will carry a variety of scientific instruments that will

allow it to take measurements of and study the subsurface ocean of the moon and also analyse chemical compounds and molecules that are present on the surface of the moon. It is believed that on certain locations on the moon complex organic materials key for life and liquid water existed together on the surface of the moon for some time in the past. Analysing these areas may help scientists learn about the formation of life on the early Earth.

An artists illustration of the rotorcraft flying on Titan.
Credits: NASA/JHU-APL

Anthony Nel

The First Galaxies – An Inside Perspective

In September last year I started my PhD in astrophysics, focusing on the study of the first galaxies. Most of my research uses the James Webb Space Telescope, NASA's new flagship observatory. Read the previous article to learn more about the first year of JWST!.

In the beginning, there was nothing. And then suddenly there was everything. We think the Universe began as a rapidly expanding ball of superheated plasma, known as the Big Bang. This was so hot that no atoms could exist, but as it expanded (initially much faster than the speed of light), it cooled. Atoms and other subatomic particles were continuously spontaneously coming into existence and then being destroyed. After about 10 seconds atoms were able to form – this is when all the hydrogen and helium was created. It is still far too hot for these atoms to hold onto their electrons, so they are all ionised. Nothing much happened for a while and then eventually, around 400,000 years later, the plasma cooled enough that the electrons could combine with atoms to form neutral atoms. Suddenly all these electrons, which had been flying round everywhere and blocking all the light from travelling anywhere, disappeared into the atoms and the universe was finally

transparent. Not that there was much to see at this point. This was the beginning of the dark ages.

During that period of superfast expansion I mentioned earlier, the Universe went from being microscopic, where spooky quantum processes had a large impact, to being gigantic (about 600 lightyears across 15 minutes after the Big Bang). Luckily for us, this rapid expansion meant that the small quantum fluctuations which happen all around us all the time, expanded as well. This led to regions of plasma which were slightly denser that the surrounding regions. This caused a small net uniform gravitational attraction towards the overdense regions, particularly in the form of dark matter. Dark matter is still a bit of a mystery, but it only interacts with our regular matter through gravity. There also seems to be a lot more of it than normal matter. This let to these overdense regions attracting more matter, causing them to become even more dense, attracting more matter and so on. You can see where this is going. It probably took at least 150,000,000 years, before the first of these gas clouds had condensed enough for the pressure and temperature at its core to start nuclear fusion, becoming the first star in the otherwise dark and lonely Universe.

This first generation of stars were probably quite different from those we see today. They were likely much more massive, reaching hundreds of times the mass of our Sun, and would have lived comparatively short lives of 10 million years or less before dying in energetic explosions known as supernova. These stars were made up of only hydrogen and helium, which we call Population III stars. When these first stars died in supernovae, they spread the new elements they had created into the environment, changing the chemical makeup of the gas. All the stars that are around today contain traces of heavy elements from previous generations of stars.

These first stars would have formed in groups, making up the very first proto-galaxies. These galaxies started a new age, which we call the Cosmic Dawn, and began the Epoch of Reionisation. Over the next billion years or so, the new galaxies would re-ionize almost all the gas in the observable Universe.

My PhD aims to find and characterise these early galaxies, so we can learn more about when and how they formed. JWST is the perfect tool for this for several reasons. Firstly, its large mirrors make it extremely sensitive, allowing it to see light from faint galaxies that was emitted when the Universe was less than 2% of its current age. This light has travelled an incredibly long way, meaning it is both exceptionally faint and has also been ‘redshifted’ in wavelength. The universe hasn’t stopped expanding, and indeed a lot of the expansion happened when the light from these galaxies was on its long journey to us. If you imagine this light as a wave travelling through space, the expansion of the universe acted to pull on the wave, stretching it out and increasing the distance between the peaks. This redshifting means that the light that was emitted in one colour, say **blue,** now looks **red** (it shifted towards the red, hence the name). These galaxies are in fact so distant that the light they visible they emitted has been shifted beyond what our eye can see and into the infrared. Infrared light is blocked by the Sun’s atmosphere, which is why we needed to put the telescope in space, and it is also annoyingly emitted by **everything.** This meant that the telescope has to be reeeeallly cold so that it can see the infrared light from space, and not just the infrared light emitted by its own mirror.

Now, how exactly do we look at a set of images taken by JWST and distinguish between the blobs (galaxies) that are really far away, and those that are nearby? Nearby faint

galaxies can look further away, and distant bright galaxies can look closer. Astronomers have developed a clever technique, where we look for what are called Lyman-break galaxies. The technique involves taking pictures of the same patch of sky in a number of different wavelengths (colours), and then looking through the pictures overlaid on top of each other.

We take advantage of the fact that the space between us and these distant galaxies is in fact not empty, but filled with a very diffuse neutral hydrogen gas. The electrons in this hydrogen gas will absorb all the light from the galaxy which has enough energy to move them between energy levels. The energy of a light particle is directly related to its wavelength, so this means that photons with more energy than the 'Lyman' limit, are all absorbed and we don't see them. These galaxies will then 'drop out' – where we can see a galaxy in a red filter, we wouldn't be able to see it in a blue filter. Depending on what color filter the galaxy 'drops out' in, tells us how far away it is. The further away the galaxy, the further into the infrared this break occurs. JWST can detect more distant galaxies than the Hubble Space Telescope because it's camera and filters work at longer wavelengths.

The below image shows a real example I made from a JWST program called the *Cosmic Evolution Early Release Science* Survey, or CEERS. The top left panel shows the measurement of the brightness of the galaxy at different wavelengths, which corresponds to the 7 images underneath. They correspond to 7 JWST filters of different wavelengths, and the first 3 images are all just noise, showing there is no detection until somewhere between the 3rd and 4th images where we can clearly see the galaxy. This is what tells us how far away the galaxy is, which you can see in the two plots on the right. This gives the probability of the galaxy being at different redshifts (or distances). Two different tools show that there is a very high chance this galaxy really is the most distant galaxy ever observed. Spectroscopic observations to confirm the distance were actually taken on Christmas Eve, so we should soon know!

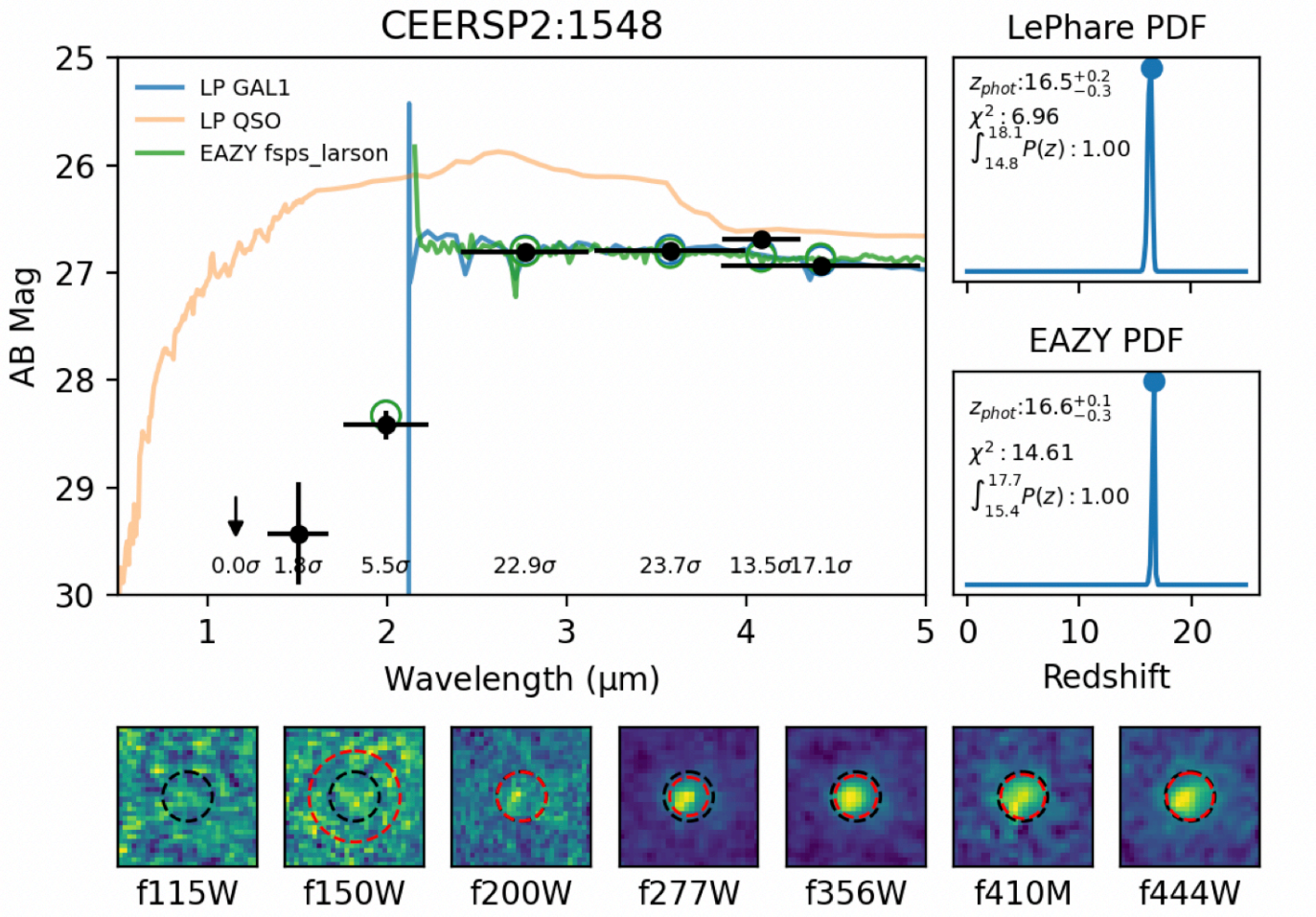


Image showing a redshift 16 galaxy candidate. Image credit: Thomas Harvey

This technique is how almost all of the most distant galaxies have been found, but it isn't foolproof. There are other astronomical sources which can look like dropouts, such as brown dwarfs (very low mass failed stars), or very dusty nearby galaxies. To confirm a high redshift galaxy, we must look at it with spectroscopy, where specific features like emission lines can be used to confirm its distance much more precisely.

In its first year, JWST has resulted in a slew of dozens of new 'high-redshift' galaxy candidates. There seem to be many more than were predicted, and they also contain many more stars than expected. This may have big implications for our understanding of how the Universe formed! The figure below shows four new JWST confirmed high-redshift galaxies, including one at redshift 13.2, which means the light was emitted only 400 million years after the Big Bang! The highlighted galaxies in this image are forming stars at a much faster rate than nearby galaxies, meaning that lots of young hot stars are being born and emitting UV photons, contributing to the 'reionisation' I mentioned earlier. My current research project involves testing methods of weighing these galaxies to determine how many stars there are, and whether their existence does cause problems for our cosmological theories! (Spoilers: It probably doesn't, our current methods for estimating the masses of these galaxies use assumptions which probably aren't true in the early universe.)

This is just the start of the discoveries that will be made with JWST, and I am expecting the record for most distant confirmed galaxy to be broken very shortly. The deadline for

proposals for the next year of JWST science closes at the end of the month, and many groups including my own will be submitting new ideas to build on the first year of discovery with JWST. It's an exciting time to be doing a PhD and I can't wait to see what we find.

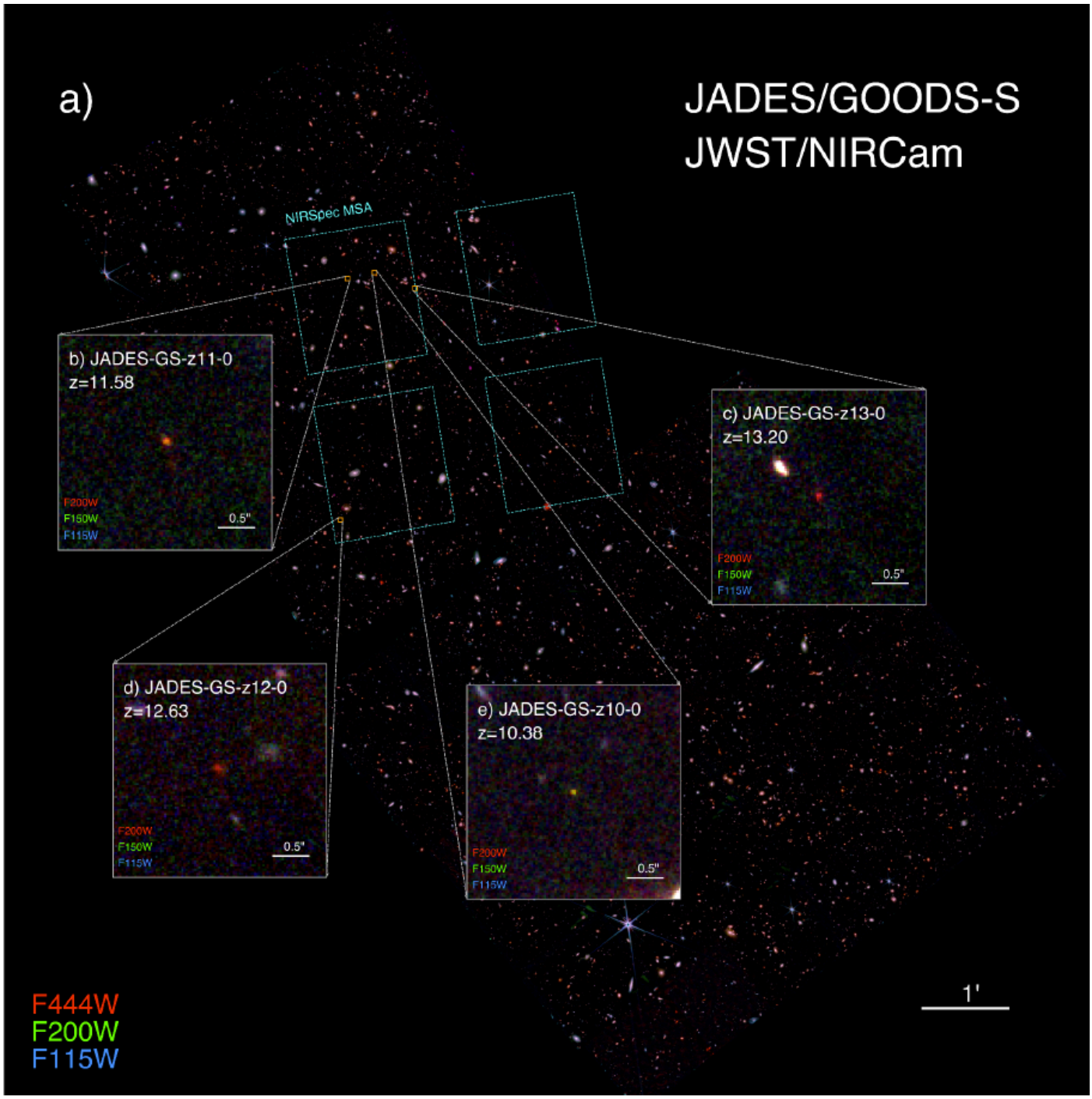


Image shows JWST NIRCam image of the GOODS-South field. b-e) are spectroscopically confirmed high-redshift galaxies. Image credit JADES team, NASA, ESA, CSA, and STScI