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Astronomy

A delightful deluge of stars

The first set of science images from the James Webb Space Telescope is an incredible feast for the eyes, mind and heart

IT HAS been just over a week since we got our first glimpse of the power of the James Webb Space Telescope (JWST), with a sneak peek unveiled by US president Joe Biden on 11 July ahead of a presentation from NASA and its partners on 12 July.

Despite technical hitches – streaming video around the world is somehow more difficult than capturing starlight from across the universe, it seems – astronomers took visible glee in being able to share their new views of the cosmos with everyone else.

"JWST has produced images worthy of the history books in just six months since it launched"

The reaction to these images has almost universally been one of wonder and excitement. They are all the more impressive for how quickly JWST has got to work, producing images worthy of the history books in just six months since its launch in December 2021. In contrast, while the Hubble Space Telescope was launched in 1990, it wasn't until 1995 that NASA released its most iconic picture, the Pillars of Creation, in part due to problems with the telescope that had to be rectified by astronauts.

In this special report, we highlight some of the best pictures released so far, detail the science that astronomers have already teased out of data collected by the telescope (see "A glimpse of chemistry in a distant galaxy", right, and page 13) and answer questions from *New Scientist* readers who have been wowed by the imagery (see page 10).

In a world so often filled with hardship, it is good to have something that we can all look up to. ■ Jacob Aron

NASA, ESA, CSA, AND STSCI

One of the brightest nebulae in the sky, the Carina Nebula is a huge cloud of gas and nascent stars. It is about 7600 light years from Earth in the direction of the constellation Carina. The top part of the image is full of huge, hot stars, shining onto the stellar nursery at the bottom of the picture.

"Today, for the first time, we're seeing brand new stars that were completely hidden from our view," said JWST scientist Amber Straughn at the 12 July release of the telescope's first images. "We see examples of bubbles and cavities and jets that are being blown out by these newborn stars. We even see some galaxies sort of lurking in the background up here. We see examples of structures that honestly we don't even know what they are."

The orange ridges in the so-called cosmic cliffs of this image are up to 7 light years high, jutting into a cavity in the nebula. The cavity was carved out by the intense radiation and stellar winds of the young stars at the top of the image, a process that continues to chip away at the gas and dust. The streamers of gas and dust in the centre of the picture are in the process of being heated and blown away from the denser, cooler area below.

As JWST observes in infrared wavelengths instead of visible light, it peers through the cosmic clouds to see young stars that were blocked from previous observations. Leah Crane

Early universe

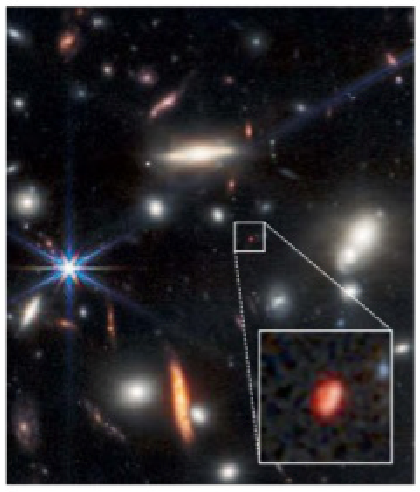
A glimpse of chemistry in a distant galaxy

Will Gater

THE spectrum of light from an inconspicuous red galaxy in JWST's "deep field" image (see page 13) has set astronomers' hearts aflutter. Produced by the telescope's NIRSpec instrument, which uses tiny windows to isolate and analyse the light from objects within the telescope's field of view, it is an unprecedented insight into a galaxy present in the early universe.

Such had been the secrecy around the capture and release of the first JWST observations that some of the NIRSpec team weren't even aware of the existence of the spectrum until the public announcement on 12 July. But there was one feature of the data that NIRSpec team member Andrew Bunker, at the University of Oxford, saw was "a real step [forward] within minutes of the data being released".

Among the various hallmarks of different elements within the galaxy was a particular fingerprint – what astronomers call an emission line – of glowing oxygen gas, with a wavelength of 436.3 nanometres. The NIRSpec team had hoped to observe this emission line in extremely distant galaxies, says Bunker, but anticipated having to search "dozens or hundreds" of targets to uncover it. "I don't think we really dreamt that within the first, essentially publicity, snap that it would be there. That's really quite incredible," he says. It is all so sudden that the galaxy doesn't even appear to have a name.



NASA, ESA, CSA, AND STSCI

The distant red galaxy occupies just a handful of pixels in JWST's image

The oxygen line is important because astronomers use it to calibrate their measurements of the compositions of galaxies. If you can see this line with your instruments, and are able to compare it with other oxygen emission lines in a galaxy's light, you unlock a way to translate the apparent prominence of different chemical fingerprints in a spectrum into how much of those chemicals are really in the galaxy. Scientists have done this for nearby galaxies before, says Bunker, but not for far-off ones.

Future JWST spectra will allow researchers to explore how the proportion of elements heavier than helium in distant galaxies has changed over time. "It gives you data points on that evolution," says Emma Chapman, an astrophysicist at the University of Nottingham, UK.

Insights like these have the potential to revolutionise what we know about the early universe. "There is a missing billion years in our understanding of the evolution of our universe," says Chapman. "From around 380,000 years after the big bang to about a billion years after, we have very little information. Now, JWST is being able to dive right back into that era." ■

7600
Distance in light years to the Carina Nebula

7
Height of the "cosmic cliffs" of dust and gas in light years

Space exploration

Collision risk may limit Webb's view

SCIENTISTS may have to avoid pointing the James Webb Space Telescope (JWST) in certain directions too often for fear of damage from space rocks.

During the six-month period of instrument testing called commissioning, JWST was struck by at least six micrometeoroids, pieces of space dust that orbit the sun. Space is full of these tiny rocks, and the team expected a single collision per month, but one that struck a segment of the telescope's mirror in May was larger than anything anyone predicted before its launch.

According to a report on JWST commissioning released on 12 July, that strike "caused significant uncorrectable change in the overall figure of that segment. However, the effect was small at the full telescope level." Thanks to the precise control mechanism needed to align the 18 segments of the mirror, engineers were able to tweak their positions to mostly mitigate the effects of the micrometeoroid strike (arxiv.org/abs/2207.05632).

Nevertheless, too many of these strikes could seriously degrade the segments. The JWST team is now working on new models to figure out how common events like this should be and how to deal with any damage they might cause. That might even mean avoiding pointing the telescope in the direction in which it is travelling to stave off head-on collisions. ■ LC

Q&A

Cosmic questions answered

New Scientist space reporter **Leah Crane** explains what the first images from the James Webb Space Telescope can tell us and what it will look for in the future

ON 12 July, the first set of full-resolution science images from the James Webb Space Telescope (JWST) was released. This set included astonishingly sharp pictures of the Carina Nebula (see page 8); the Eight-Burst Nebula, also known as the Southern Ring Nebula (below); a group of galaxies called Stephan's Quintet (far right); and a deep-field image showing a galaxy cluster called SMACS 0723 (see page 13) stretching the light of the objects behind it. There was also an analysis of the composition of an exoplanet named WASP-96b.

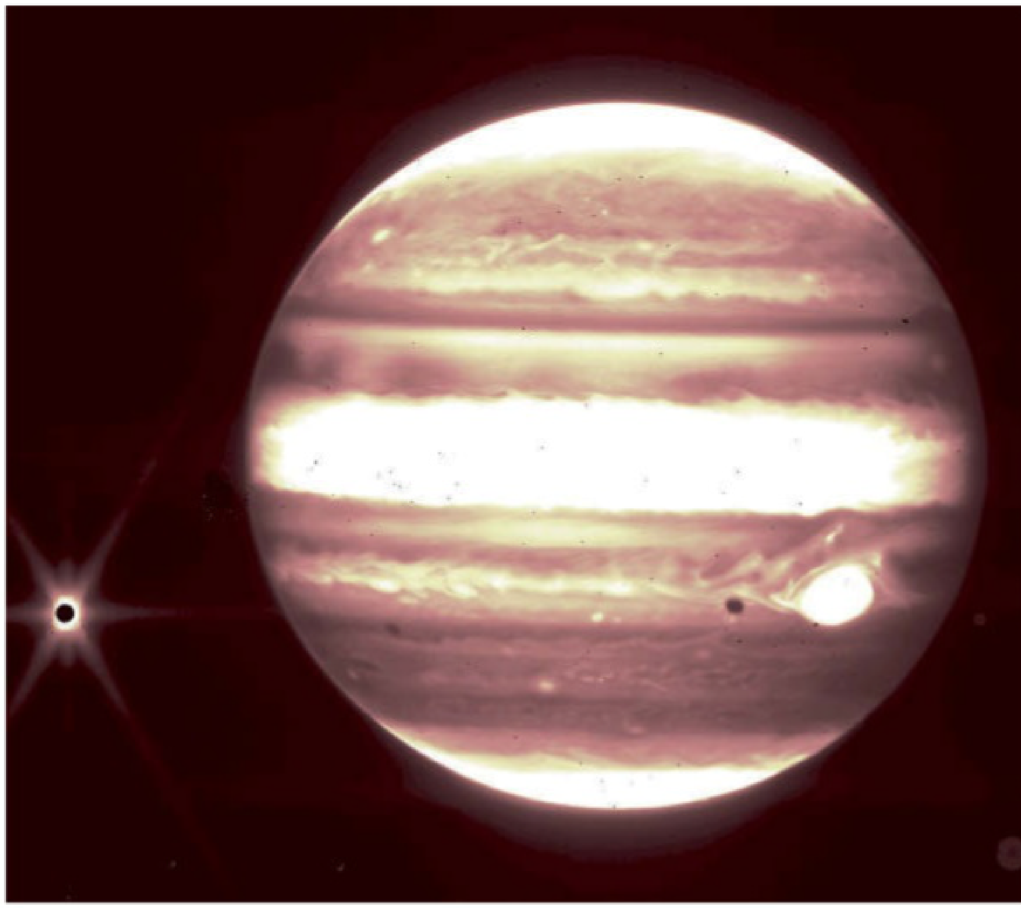
These images are the culmination of decades of work by scientists and engineers – and they are just the beginning of JWST's exploration of the universe. They have also inspired dozens of questions from *New Scientist* readers, from queries about the telescope itself to what it might be able to do next. Here is a round-up of our favourite questions, along with their answers.

What is so special about these images? Didn't we have the Hubble Space Telescope before the James Webb Space Telescope?
We did and do have Hubble, which delivers so many gorgeous images of space. But JWST is much bigger, so its pictures are more detailed.

It also observes in different wavelengths than Hubble, which allows it to see things – particularly extremely distant things – that Hubble can't.

How close to the edge of the observable universe will JWST be able to see? Official releases have said the telescope can see 13.5 billion years back in time – that seems very close to the age of the universe at about 13.8 billion years.
JWST should be able to see back to between 100 million and 250 million years after the big bang. But while that is up to about 13.5 billion years ago, it isn't 13.5 billion light years away – it is much further than that, because the expansion of the universe has stretched space as light travelled to us, causing it to cross much longer distances.

13.5bn
Age in years of the oldest light the James Webb Space Telescope can see


NASA, ESA, CSA, AND B. HOLLER AND J. STANSBERRY (STSCI)

Will the James Webb Space Telescope study supermassive black holes? Can it produce an image similar to the one from the Event Horizon Telescope?
JWST can't make an image of a supermassive black hole like the Event Horizon Telescope did – that's a different kind of telescope – but it will study them. In fact, the picture of Stephan's Quintet (far right), a galaxy cluster nearly 300 million light years from Earth, is providing insight on one already.

Is it possible for gravitational lensing, like that seen in JWST's first deep-field image, to be strong enough to see yourself? As in light does a U-turn?
Yes! Black holes can have a feature called a photon sphere, where gravity's pull is so strong that light orbits the black hole. So if you aim a light just outside the photon sphere, you could, in theory, see that light come around the other side of the black hole. Depending on the distance to the black hole, it could take a really long time, though – the most laborious selfie ever.

If the James Webb Space Telescope can see 13.5 billion years back, could we one day make a telescope that can "see" further than the beginning of time?
I wish! Unfortunately, there is a fundamental limit to how far back we can see, because up until a little less than 380,000 years after the big bang, the universe was completely filled with hot plasma and was therefore opaque.

This cloud of dust and gas surrounding two stars is called the Southern Ring Nebula, or the Eight-Burst Nebula, imaged here in infrared.

The nebula is about 2000 light years from Earth and nearly half a light year across. The bright cloud that makes up the ring came from the outer layers of one of the stars at the centre of the nebula, which expanded when it reached the end of its lifetime and transformed from a sun-like star into a white dwarf star.

Two images of this nebula were released among the first JWST images, which revealed the two stars in extraordinary detail. They show that the dimmer, redder star – the one that spawned this nebula – is surrounded by dust, whereas the brighter star may one day puff out its own nebula.


NASA, ESA, CSA, AND STSCI

This picture of Jupiter was taken using JWST's near infrared camera, NIRCam, with two different filters to focus on separate wavelengths of light. Jupiter's moon Europa is also visible, as is its shadow just to the left of the planet's Great Red Spot.

The image was taken as part of a test of JWST's scientific instruments to check that the observatory could track objects moving at high speeds through the solar system. Jupiter was the slowest and largest of nine moving targets used for these tests, and it showed that smaller objects like Europa can be tracked even with a bright planet bouncing light into the cameras.

Even if it weren't opaque, though, space and time began simultaneously, so, while this can be hard to wrap your brain around, there is no such thing as "further than the beginning of time". As far as physicists know, there is nothing to see before the big bang.

"These images are the culmination of decades of work by scientists and engineers"

Can we see further back than 380,000 years after the big bang with gravitational waves detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) or the Laser Interferometer Space Antenna (LISA)?
Unfortunately, the answer is no, because gravitational waves come from the motion of masses and there just weren't any structures big enough to create measurable gravitational waves until about 100 million years after the big bang.

The only way we can see that far back in time is by using the cosmic microwave background, which consists of light left over from the extremely early universe, now spread throughout the cosmos.

With the data and imagery collected, is it possible (or even probable) that scientists will revise the currently accepted age of the universe to be much much older than a mere 13.7 billion years?
It is possible that the data from JWST will cause us to revise the age of the universe based on new measurements of its expansion, but, if so, it will probably go down rather than up. This is because there are two estimates of the rate of expansion of the universe, one of which gives us an age of about 13.8 billion years and the other of which gives an age of about 11.4 billion years.

Was there anything unexpected about the spectra of the galaxy and exoplanet obtained so far?
There wasn't anything particularly shocking in the data that has come down so far, aside from the better-than-expected performance of the telescope itself. The images are all of systems that are already very well studied, but we just have far more detail now than ever before. So, we are seeing new things, but I don't think those are very unexpected.

Why did the JWST crew choose WASP-96b as the first exoplanet to analyse the composition of? What was special about it?
What's special about WASP-96b is that it isn't cloudy – the new spectrum shows some evidence of clouds and haze, but not much. That is good because it allows the light from its star to shine right through the planet's atmosphere and for us to analyse it without being blocked by lots of clouds, which would make these observations more challenging.

How will astronomers decide what to take a picture of with JWST next?
The first year of science has actually already been planned out. Researchers made more than 1000 proposals for what to observe and the best options were selected by panels of scientists who get the final say on where to point JWST. The winning proposals include many more exoplanet observations, views of supermassive black holes smashing together, searches for the first stars and galaxies, and analyses of the large-scale structure of the entire universe.

Why is space so pretty?
The fun answer: because it is everything! The physicist's answer: hydrogen. The actual answer: often it is because we assign colours to dust and gas in order to make our space pictures prettier and more informative.

NASA, ESA, CSA, AND STSCI

These five galaxies, called Stephan's Quintet, are about 290 million light years from Earth in the direction of the constellation Pegasus.

The four at the top of this image are engaged in a deadly game of chicken, swooping past one another closer and closer until, someday in the distant cosmic future, they will probably smash together and merge. We have seen them before – in fact, the group of four is the most thoroughly studied compact group of galaxies – but this image is far more detailed than any of the previous ones. It is a mosaic of almost 1000 pictures, making it JWST's biggest image to date.

That detail allows us to see the area around a supermassive black hole, the brightest part of the top galaxy. "We cannot see the black hole itself, but we see the material sort of swirling around and being swallowed by this cosmic monster," said JWST researcher Giovanna Giardino during a 12 July press conference. This area is 40 billion times as bright as our sun, she said.

Gravitational lensing

Unscrambling the cosmos

Astronomers are already using the images from the James Webb Space Telescope to reveal a new understanding of the objects they depict, says **Leah Crane**

JUST days after the first full-resolution image from the James Webb Space Telescope (JWST) was released on 11 July, two groups of researchers have already analysed the data to recreate the structure of the cluster of galaxies in the image.

The cluster, called SMACS 0723, is so massive that it warps space-time, bending and magnifying the light from the galaxies behind it in a process called gravitational lensing. JWST's image of it is the deepest picture of the cosmos ever created.

"I've been preparing for this since 2005, when I started working on JWST, and when the image came out, it's like I had been going through life without any glasses on and I finally got my first pair of prescription glasses," says Brenda Frye at the University of Arizona. The day the deep-field picture was released, she assembled a team across as many time zones as possible so they could analyse the data around the clock, and then got to work.

A similar tale was unfolding in the UK, where Guillaume Mahler at Durham University and his colleagues began to examine the same observations. "I expected to see galaxies that we'd never seen, so I was ready for new discoveries, but what I was amazed by was how many there were," says Mahler. "At first, it was a bit overwhelming, like: what do we do with all of this?"

The teams began by searching for background galaxies that appeared to repeat, being cloned by the effects of gravitational lensing. This is a common effect of the phenomenon. Mahler's team found 16 repeated galaxies (arxiv.org/abs/2207.07101) and Frye's team found 13 (arxiv.org/abs/2207.07102). Both teams used them to reconstruct SMACS 0723 and calculate where dark matter is lurking within the cluster.

NASA, ESA, CSA, AND STSCI

The first image released by the James Webb Space Telescope team

"It's like I had been going through life without any glasses on and I finally got my first pair"

10bn

Number of stars in every galaxy seen in this JWST image

"What we're seeing, which is so spectacular, is this rich tapestry with so many colours and textures. But what you see is the tip of the iceberg," says Frye. "Every single blob that you see is a galaxy with 10 billion stars, but most of the cluster's mass we can't see because it's invisible dark matter, just like most of an iceberg is underwater."

The researchers found that the cluster is more elongated than we had realised from previous observations with other telescopes. This oblong shape is most likely due to mergers with other large galaxy clusters.

"All of this faint, diffuse light emission from the cluster that we see, this is completely new and unexpected," says Mahler. "It's telling us something about the history of the cluster – all those stars come from destroyed galaxies." As SMACS 0723 devoured other galaxy clusters, it ripped them apart, leaving stars and other matter strewn in a bright streak across the cluster's centre.

Frye's team also spotted an unexpected gap in that faint light. If the cluster finished destroying all those other galaxies a long time ago, we would expect the light to be smoothly distributed, but this strange void indicates that a huge merger may still be going on, says Frye.

One next step among many is to take a closer look at the background galaxies themselves. JWST's resolution is so high that researchers can not only tell which ones are repeated images, but they can also spot bursts of star formation – and maybe even individual stars – in galaxies halfway across the universe.

Anything but boring

SMACS 0723 has been thoroughly studied for years using other telescopes. "For the first release, they tried to find a boring cluster... but JWST is so good that it turned this 'boring' cluster with nothing to learn into this amazing treasure," says Mahler. "We are really seeing galaxies and star formation at the dawn of the universe."

Frye also leads a group that will use JWST to look at seven more galaxy clusters and their gravitationally lensed background galaxies over the course of the next month. Hers is one of several programmes designed to take incredibly deep images of the cosmos, so the coming months are sure to provide a surge of new insights on the earliest stars and galaxies, and the dark matter that sits between them and us.