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Distant galaxies

The race for the furthest galaxy

The James Webb Space Telescope keeps breaking its own record for the most distant galaxy ever found, reports **Leah Crane**

AS THE James Webb Space Telescope (JWST) has begun sending back its first science data, researchers around the world have reported new galaxies, each more distant than the last.

The distance to a cosmic object is denoted by what is known as redshift. This works a bit like the Doppler effect, in which a sound seems to change in pitch depending on whether it is moving towards or away from the listener. The faster a galaxy is moving away from the Milky Way, the higher its redshift – and because of the expansion of the universe, the more distant a galaxy is, the faster it moves away from us and the redder it looks.

We knew JWST would spot incredibly distant objects, with correspondingly high redshifts, but the immediate cascade of such distant galaxies it has revealed was surprising to many astronomers. "I don't think any of us really expected to see quite this many sources at such high redshifts," says Guido Roberts-Borsani at the University of California, Los Angeles. "We all expected to be surprised in some way or another, but not so quickly or so drastically."

Before JWST, the most distant object spotted had a redshift of about 11, meaning it formed within about 400 million years of the big bang. JWST has now been used to identify several galaxies with apparent redshifts of 13 and even higher, meaning they formed within 300 million years of the big bang (arxiv.org/abs/2207.12474).

So far, we don't know much about these galaxies, and most of their redshifts haven't yet been confirmed. "Right now, we're just grabbing all the fruit. We still have to figure out which are the good ones and which are the rotten ones, but right now, it's just gimme gimme gimme," says Jane Rigby at NASA's Goddard Space Flight Center in Maryland. "We're still in the initial harvest stage, and we don't really know what's important yet."

"We all expected to be surprised in some way or another, but not so quickly or so drastically"

"It's really quite an amazing mess right now, but it's been this sudden lurch forward and then we'll take some time and take a breath," says Rohan Naidu at the Harvard-Smithsonian Center for Astrophysics. After a whirlwind of new findings, the tough task of double-checking everything will begin, generally by taking more detailed measurements of the objects' light in a process called spectroscopy.

That will be particularly important for the most distant candidates. For example, a team led by Haojing Yan at the University of Missouri claims to have found a galaxy at a redshift of 20, so it would have to have formed within 180 million years of the big bang – far earlier than we expect galaxy formation to have begun (arxiv.org/abs/2207.11558).

"Our results are completely unexpected and are at odds with all previously favoured predictions," says Yan, who declined to comment on the details of his team's work before it is peer-reviewed.

"That, essentially, would break galaxy evolution," says Roberts-Borsani. If there really is a galaxy at a redshift of 20, it could mean that we have deeply misunderstood the physics of galaxy and star formation in the early universe.

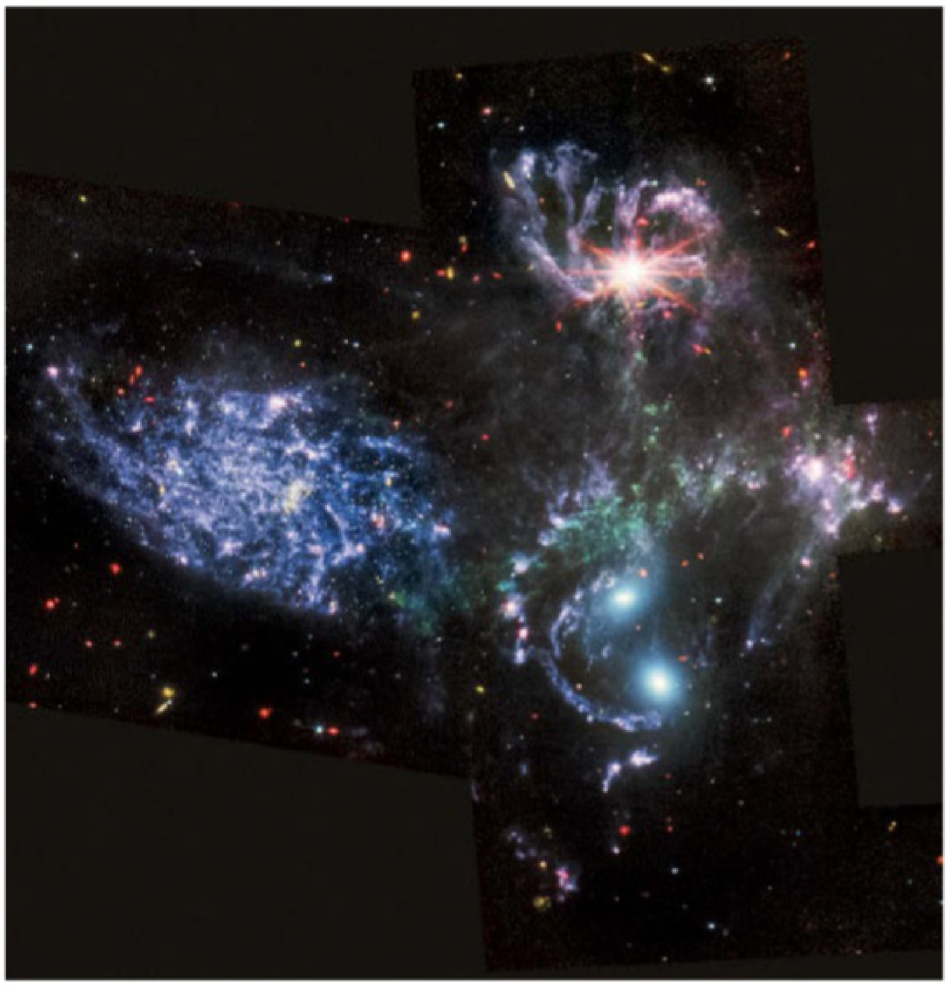
"The capabilities of Webb are such that it could observe a redshift-20 thing if it were there, but there's a lot of scepticism whether it could be there," says Nathan Adams at the University of Manchester in the UK. "Something that extreme needs a closer look and validation from multiple people."

How did it all begin?

It might take a while to get that closer look. JWST's schedule is booked far in advance, and so is the other telescope big enough to do the necessary spectroscopy, the Atacama Large Millimeter/submillimeter Array in Chile. So unless researchers can convince the directors of those telescopes to let them skip the queue, these observations will have to wait.

Even before the necessary checks, it is clear that there are at least some galaxies that are brighter and more distant than expected. "If even 20 per cent of the galaxies reported in the last week turn out to be at the redshifts that they are reported to be at, it's strong evidence that these things form very early and very quickly, and get very massive and very bright very early," says Naidu.

Once we know which of these galaxies are real and formed in the extremely early universe, we can start studying them in more detail. "In the big picture, we're asking, how did it all get started?" says Rigby. "How quickly do galaxies stop being boring places of just hydrogen, helium and dark matter and start actually making the rest of the periodic table that we're made of?"



NASA, ESA, CSA, STSCI

A grouping of galaxies called Stephan's Quintet as seen by JWST

Exoplanets

New telescope could tell us what exoplanet surfaces are made of

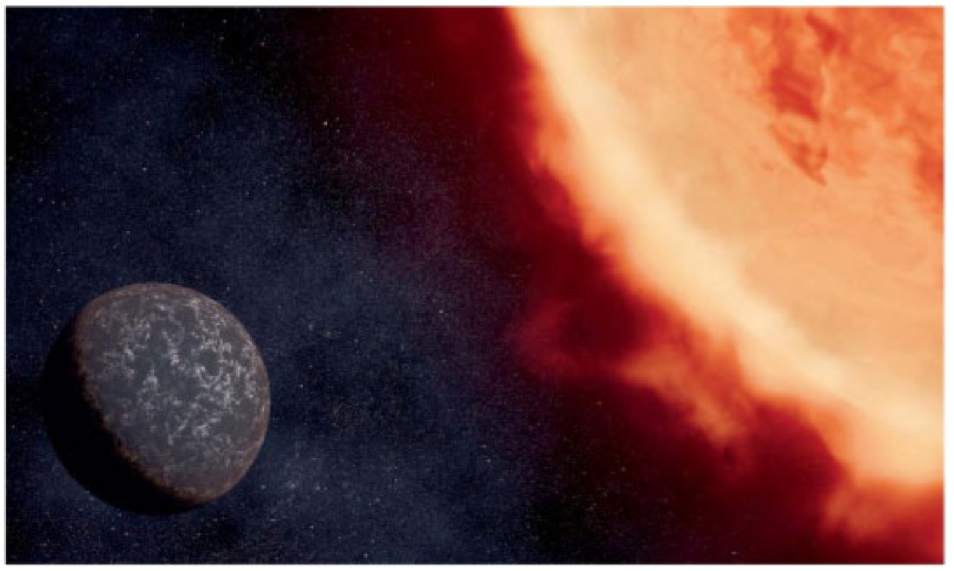
Alex Wilkins

THE James Webb Space Telescope (JWST) may be able to give us a glimpse of the surfaces of rocky planets outside our solar system, as well as their atmospheres.

One way of measuring the atmosphere of a distant planet is to watch as it passes, or transits, in front of its star. As light passes through the gases that envelop a world, molecules absorb certain wavelengths of light, helping astronomers figure out the composition of its air.

Measuring the surface of a planet is trickier. Light reflecting off it will also carry information on its make-up, but it has to pass through the atmosphere, making it hard to figure out what they are both made from. The reflected light will also be weak, so noise can be a problem. So far, no one has managed to accurately determine the make-up of an exoplanet's surface – but this could be about to change.

"With JWST, hopefully, the noise floor should be low enough that we'll be able to disentangle which of those features are coming from the surface of the planet and which are coming from the atmosphere," says Emily Whittaker at the University of California, Los Angeles.



NASA, ESA, CSA, DANI PLAYER (STSCI)

Illustration of the exoplanet LHS 3844b and its host star

In an effort to prepare for JWST's exoplanet observations, Whittaker and their team have practised with data taken by the Spitzer Space Telescope of LHS 3844b – a planet that is hot like Mercury – as it passed in front of its host star. The heat means the planet's surface produces a strong signal, one that is unaffected by its sparse atmosphere.

The researchers created artificial signals from a variety of different surface and atmosphere compositions and then compared them with the telescope data to work out the make-up of the surface. The most likely scenarios involved rocky ground dominated by iron, with varying amounts of other metals like magnesium and calcium in different forms (arXiv, doi.org/h6vk).

"What we can already say just looking at this planet is yes, JWST will be able to characterise some surfaces, but what we're finding is that the surfaces that we will be able to characterise are the more reflective ones," says team member Matej Malik at the University of Maryland.

The planets we can observe might share similarities with bodies in our solar system such as Mercury or the moon, which have dark surfaces, but with brighter, spotty regions, says Malik.

The TRAPPIST-1 planetary system, which is around 40 light years from Earth, could be a prime target for this technique. "It's not something that's only applicable to LHS 3844b," says Raymond Pierrehumbert at the University of Oxford. "TRAPPIST-1b is a hot planet which is certainly rocky, and potentially a nearly bare rock with a wisp of atmosphere."

This ability to potentially distinguish the signatures of atmospheres and surfaces is innovative, says Pierrehumbert, and makes observing some exoplanet surfaces within the "margins of feasibility". ▮

Galaxies

JWST spots a weird galaxy with almost no heavy elements

THERE is a strange, metal-poor galaxy lurking in the distant universe. The very first image released by the James Webb Space Telescope (JWST) team revealed a galaxy with far fewer heavy elements than we would expect, which may mean it is sucking up pristine hydrogen gas from intergalactic space.

Mirko Curti at the University of Cambridge and his colleagues examined the light from three galaxies shown in JWST's first deep-field image to measure the abundance of elements that astronomers call metals, meaning anything heavier than hydrogen. These heavy elements are formed in stars, which distribute them throughout space when they die.

Two of the galaxies the team examined were about 29.4 billion light years away from Earth, while the third was around 30.2 billion light years away. The nearer galaxies had fewer metals than galaxies in our part of the universe, as expected, but the further one had almost no metals at all – just 2 per cent of the metal content of the sun (arxiv.org/abs/2207.12375).

"This is one of the most extremely metal-poor objects that we have ever seen," says Curti.

Spotting such an odd galaxy so soon into JWST's observation run was a surprise. "No one was expecting to immediately see evidence for this extremely metal-poor galaxy in the very first data," says Curti.

"This galaxy is one of the most extremely metal-poor objects we have ever seen"

In the local universe, a galaxy's metal abundance is closely linked to its mass and rate of star formation, but this galaxy seems to buck the trend. That probably means it recently underwent some sort of dramatic change, says Curti, possibly swallowing up hydrogen gas from the space between galaxies.

As we get more detailed observations of other distant galaxies, researchers will be able to figure out whether such metal-poor galaxies are common or if this one is an anomaly. ▮ LC