Vox

SCIENCE

Astronomers spotted something perplexing near the beginning of time

Monsters lurk in the background of James Webb Space Telescope images. Scientists are scrambling to make sense of them.

The James Webb Space Telescope can produce “deep field” images that reveal the history of the cosmos.
NASA, ESA, CSA, I. Labbe (Swinburne University of Technology) and R. Bezanson (University of Pittsburgh). Image processing: Alyssa Pagan (STScI)

By Brian Resnick@B_resnickbrian@vox.com Jan 17, 2024

***Brian** is Vox’s science and health editor, and is the co-creator of Unexplainable, Vox's podcast about unanswered questions in science. Previously, Brian was a reporter at Vox and at National Journal.*

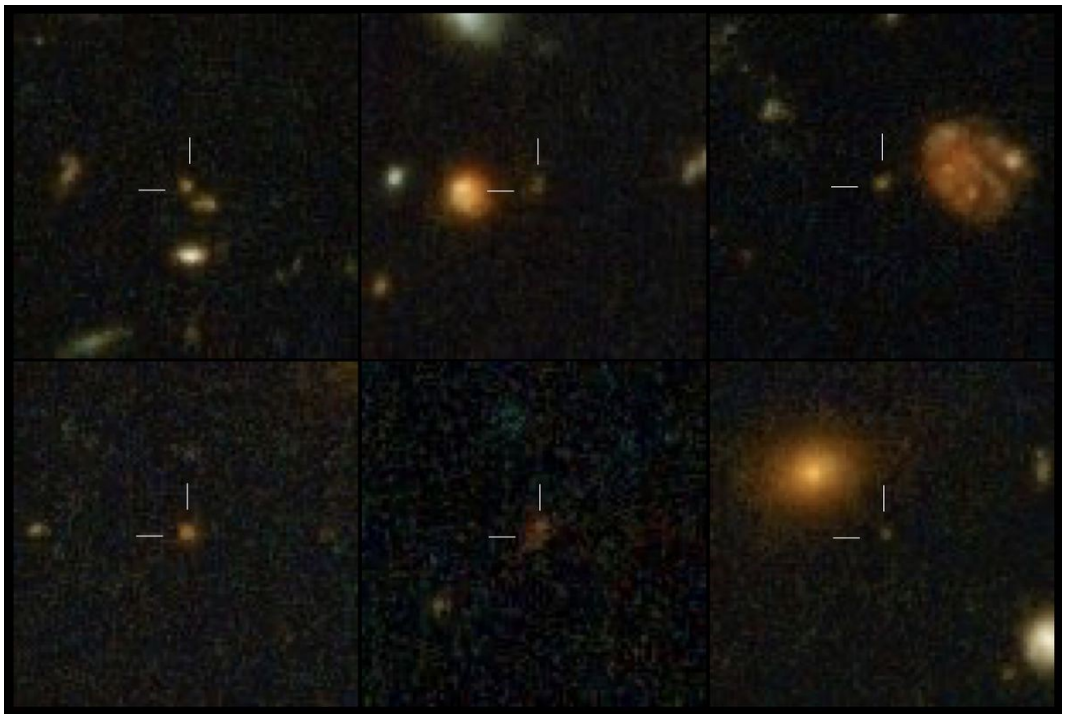
Not long after the James Webb Space Telescope came **online in 2022**, astronomers’ jaws hit the floor.

“I remember thinking, *This just can’t be right!*” says **Mike Boylan-Kolchin**, a University of Texas Austin astronomer.

The observations he’s referring to would, to you and me, seem like little smudgy red blobs among a field of other smudges and blobs. But in his eyes, they represented a potential challenge to the story scientists have painstakingly constructed about the formative years of our universe. That is, sometime after the Big Bang, around **12-plus billion years ago**, when the universe **went from a dark, diffuse place**

full of gas to a light-filled universe populated by stars and galaxies. This is the era that laid the foundation for everything to come – including our solar system, and you and me.

Scientists had some theories about what happened during this crucial period, but the new telescope put them to the test by observing regions of space humans have never seen before.



In the crosshairs: These blobby sources of light are causing a stir among astronomers.
Caitlin Casey, Max Franco, Jeyhan Kartaltepe, and the COSMOS-Web Team

And if the observations were correct, Boylan-Kolchin thought, "everything we know about cosmology is wrong at some level." Cosmology is the study of how our universe evolved from the earliest times onward. So, the potential to be wrong about it "was pretty unpalatable," he says.

Boylan-Kolchin was agog, but not alone in his thoughts. "I cannot even get across how mind-boggling the past year has been of looking at JWST [James Webb Space Telescope] data," says Caitlin Casey, also an astronomer at UT Austin. "We have been seeing all sorts of wild, wild things in the early universe."

I've talked to several astronomers about these findings and not all agree that they will lead to a wholesale rewriting of the history of time. At least not until more observations are made, and more follow-up work is done.

But most agreed there's something big to be learned here. And it is these moments in science, when observations don't match predictions, that are the exciting ones. They often pave the way for fundamental new insights. And the more unexplainable, the more exciting they are.

We've experienced these exciting chapters in science before. In the 1960s and '70s, when Vera Rubin observed galaxies rotating at unexpected rates, it opened the door for the "discovery" of dark matter – a hugely important, deeply mysterious substance that makes up 85 percent of all matter and acts as the scaffolding of the universe. And then an unexpected observation in the orbit of Mercury in the 19th century could only be resolved when Albert Einstein reconceptualized our understanding of gravity in the 20th century.

These moments of “this can’t possibly be right!” often lead scientists to uncover deeper truths, or reveal new, uncharted depths of their collective ignorance.

“The thing I think we can all agree on is that [the observations] are weird in the sense that they’re not easily explainable,” says **Erini Lambrides**, an astrophysicist working on a **NASA** fellowship. “It’s monumentous regardless, because I’ve never seen so many people from so many different subfields of astronomy caring.”

So enough teasing! What have astronomers observed that’s caused their jaws to drop?

JWST spotted galaxies scientists didn’t think should exist

To start, it’s helpful to recall what the **James Webb Space Telescope** – often called JWST – was built for.

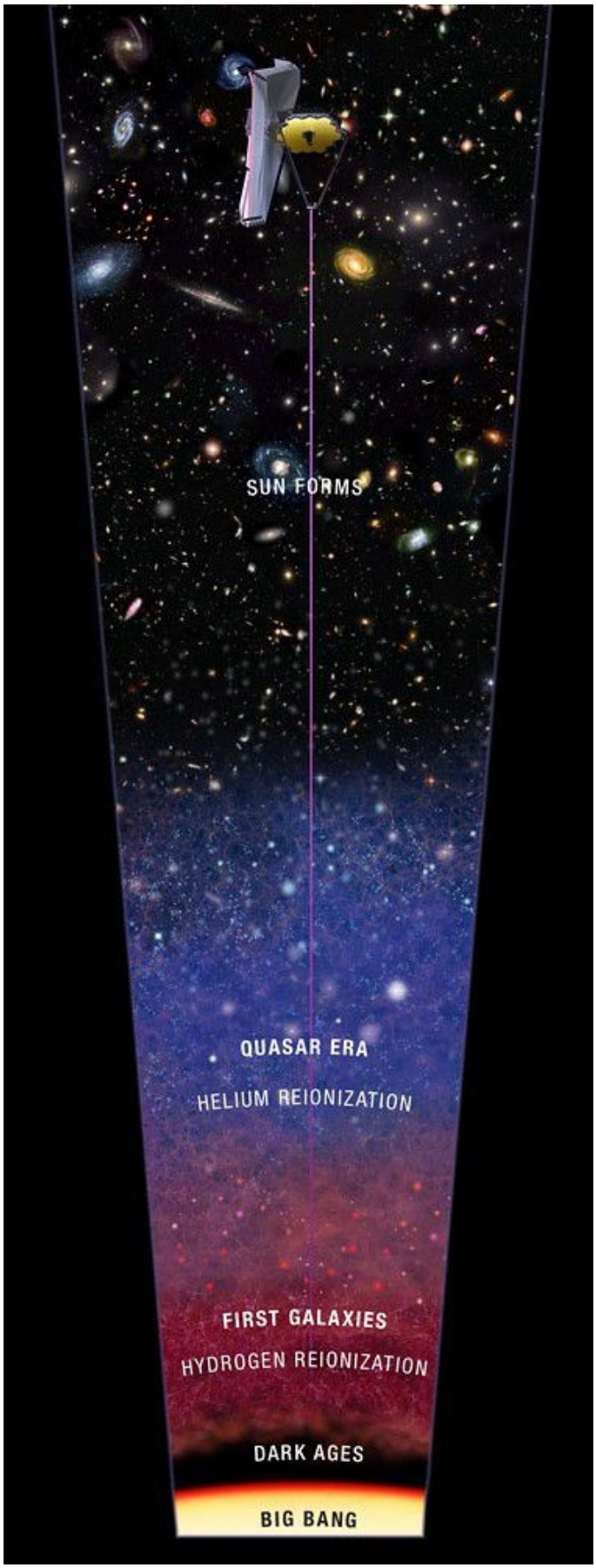
On Earth, astronomers often build telescopes on mountaintops and in remote deserts for an unobstructed view of the sky. But the Earth’s atmosphere still mars the view. Space is “**the ultimate mountaintop**,” as NASA explains.

JWST launched in December 2021 as the successor to the Hubble Space Telescope, and it improves on its predecessor in several ways. For instance, because of its **huge golden mirrors** and **infrared cameras**, it can make **better observations of planets** orbiting stars other than our sun.

But for this discussion, what matters is how it **can observe farther back in time** than the Hubble telescope.

In astronomy, the farther away an object is in a telescope’s mirror, the older it is, because light needs time to traverse such large distances. Some of the light JWST captures is almost as old as the universe itself, dating back to **100 million to 250 million years after the Big Bang** – the relatively infant days of our universe, which is believed to be **13.77 billion** years old. That light is so far away it has been traveling nearly the age of the universe to reach us.

So, when JWST focuses its mirrors on a particular patch of sky, it can see through time.



An illustration of how JWST captures a huge span of the age of the universe in its images. *STSci/NASA*

The farthest objects in the image are the oldest. Those in the foreground are more current. The images that contain this rich history are called “deep field” observations. And while they appear in two dimensions to us, in them, scientists can see how the universe has evolved.

Before JWST, the Hubble Space Telescope gave humanity **its deepest look** into the evolution of space. And in the Hubble images, scientists saw a pattern. As they peered farther back in time, there were fewer and fewer galaxies, and they were smaller and smaller.

“The Hubble Deep Field,” the 1995 image that helped astronomers determine the number of galaxies in the universe. *Hubble Deep Field/NASA*

This makes intuitive sense. Just like fossils in the oldest layers of the Earth’s crust represent more primitive forms of life, the oldest galaxies in a deep field image ought to represent more primitive galaxies. And they differ from modern galaxies – because they had the shortest amount of time to assemble. They were like teenagers, compared to the large adult galaxies of today.

When JWST went online, astronomers were eager to peer a bit more deeply into the past. They thought the pattern from the Hubble images would just continue.

“We thought we would maybe see a couple of more distant galaxies, but they would be very, very rare,” Casey says. “We really didn’t think there was much going on there.”

But that’s not what they saw.

“When JWST turned on,” Boylan-Kolchin says, “it was apparent that there was a lot more light [back then] and a lot more galaxies.”

Even though the galaxies appear to our eyes as smudgy blobs, scientists can study the quality of light coming from them and make inferences about their size and age.

Early analyses revealed many of these galaxies were apparently huge – full-fledged adults, not teens. “We have found really mature, large, bright galaxies back even farther than we expected,” Casey says. To further the fossil metaphor, it would be like finding evidence of advanced life forms in layers of the Earth when life ought to have been just starting out.

In more fun terms, Casey explains it’s like “at the earliest times, the universe was having a party. And we had no idea it was happening.”

Okay, you might be thinking, so what? We got big, bright, plentiful galaxies way back near the beginning of time. Unexpected, perhaps, but it’s not like it’s violating the laws of physics, right?

Well, the problem is *time*. “We’re really starting to butt up against the age of the universe itself,” Casey says. “They’ve had very, very little time to assemble.”

It’s kind of like if you were flipping through a family photo album, and came to the realization that your grandmother grew to be an adult from an infant in just a couple of months. Such a finding might make you wonder if we’re missing a big piece of understanding human development. Or, somehow, the pace of human development worked differently in the past.

If these galaxies contain the number of stars implied by these early observations, it should be nearly impossible for them to exist.

It would require, Boylan-Kolchin says, “all of the gas in the system being converted into stars, which is something you *never* see kind of anywhere in the universe at all. So, even in the galaxies that are really intensely forming stars, we see more gas than stars.” Gas is always left over in the process of forming stars out of it.

Which is to say, even more simply: These JWST observations, on their face, make no sense.

What the heck is going on?

So … what explains these bright, large galaxies?

In short: They don’t yet know. Though most of the astronomers I spoke to said they believed there is indeed something odd about these galaxies, a note of caution: It is still early, and more observations need to be done to confirm their age and size.

“I think we don’t have enough data yet,” says **Christina Williams**, an astronomer at NOIR Lab. “We have to keep in mind that the amount of data JWST has produced is actually just probing the tiniest fraction of the universe right now. We have very small areas in the sky that we’ve looked at.”

(There are a couple of other sources of uncertainty, Williams adds. One is that a lot of the galaxies still need their masses and ages verified by more extensive follow-up. Two, Williams also told me it’s possible that some of the formulas scientists use to make inferences about the size of galaxies might

need tweaking when it comes to the early days of the universe. “Stars in the early universe were different than they are today,” she says. They had less heavy metals in them, for instance.)

Some of the excitement around these galaxies might dim with more time. But if they are verified, scientists need to figure out why they are there.

The scientists I spoke to outlined a few possibilities, ranging from small tweaks to our understanding, to, as Boylan-Kolchin calls them, the “most disruptive” options.

What’s so exciting is that each option is its own fork, leading to new questions, new possibilities, and new understandings of our science or the universe.

Option 1: It’s possible that stars and galaxies just formed differently, and perhaps more efficiently, earlier on in the universe.

“If you think about the early universe, it’s a really dark place compared to where we live now,” Casey explains. There were simply fewer stars and galaxies. “And that light actually impacts how stars form out of new gas clouds. It makes it harder sometimes to form stars. In the early universe, those floodlights are not on, and so you could form stars really, really quickly – in a way that can’t happen today, because right now the floodlights are on.”

The idea is that starlight itself impedes the development of other stars. “Maybe,” Boylan-Kolchin says, “that slowing down of star formation didn’t happen in the early universe.” Which then led to these massive galaxies. But exactly how, the scientists aren’t sure. This option, he says, “would be unexpected but wouldn’t require a fundamental sort of revision to everything we know about galaxy formation and cosmology.”

A second option: What if it’s not stars that are making these galaxies appear so bright?

“The alternate explanation is also really confusing,” Casey says. Instead of a huge mass of stars, “maybe we’re looking at some of the most massive, supermassive black holes.”

It’s confusing because, yes, JWST is still observing galaxies. “But there is a situation where the light might not be coming from stars,” Casey explains. “And the alternate option is that light is coming from a very, very hot disc of material that is being sucked into a giant black hole. And that disk of material is so hot that it shines really brightly. It can even, in some situations, outshine the galaxy in which it lives.”

This explanation solves some problems. If you assume all the mass in the galaxies is due to black holes, “you get much more reasonable stellar masses that don’t break the universe,” Lambrides says. You don’t need to account for weirdly efficient star-making. But this solution deviously opens the door to other vexing questions that could break our understanding of the universe in other ways.

Their question: Why the heck are there so many supermassive black holes in the early universe?! Scientists know supermassive black holes play **some role in galaxy development**. But if these JWST observations represent black holes, “it blows our estimates of how many powerful, massive, supermassive black holes at this time should exist out of the water,” Lambrides says. “We do not know how the black holes got so massive so fast.”

Again, the essential problem here is the observations aren’t matching expectations. Which makes scientists think they are missing something in their understanding of the universe – something potentially very big.

Option 3: The most extreme possibility is that scientists are missing a big piece in their understanding of cosmology.

Cosmology is one part recipe, one part narrative for the creation of the universe as we see it today.

Scientists can take the earliest possible observation of the afterglow of the Big Bang, which represents a universe before stars existed. They take that image and, using what they know about the properties of the universe (gravity, electromagnetism), tell the story of how the universe came to look like it does today.

Scientists know the story is incomplete. Huge portions of it – like dark matter (a mysterious form of matter that seems to hold galaxies together) and dark energy (an even more mysterious force behind the acceleration of the expansion of the universe) – are still not fully understood.

But maybe this story is also incomplete in ways they had not previously considered.

This is the most radical option. "It's very hard to see a wholesale revision to our picture of cosmology because it's so successful in so many different ways," Boylan-Kolchin says. Even their incomplete story can explain a lot of why the universe looks the way it does today.

The new JWST observations could be resolved by tweaking the cosmological model. Some of the tweaks could end up changing the estimate of how old the universe is. Or it could be that dark matter and dark energy are more complicated than scientists previously understood. "All of those [options] are disruptive in some way," Boylan-Kolchin says.

"Or …" – and this brings us to option 4: "… there is some other component of the universe that we haven't even accounted for that's out there," he says.

Why does it matter if scientists figure out which option it is?

Finding our place means tracing the history of the cosmos. "If the world around us depends on what it took to get to this world, we need to study that path,'" Lambrides says. "Why Earth? Why the Milky Way? Why the solar system? … Much of that is rooted to the very first beginning of the universe."

It's like humans have been put into a puzzle box of the universe. And the deeper we look into it, the more confounding it often becomes.

It's going to take a lot more careful observations of these galaxies to narrow down the possibilities and figure out why they are so bonkers. And the good news is there will be time to do it: JWST is expected to remain **online for up to 20 years**.

Answers won't come quickly or easily, but to the scientists searching for them, they are simply tantalizing. It's the pure thrill of exploration.

"Imagine, right, the wonder of the first person who set foot on Antarctica and saw penguins there," says **Rohan Naidu**, an MIT physicist. "That's kind of like the vibe that is happening right now."

We're just at the beginning of observing this era of time, which, again, was previously obscured to us. "It took thousands of people to get that telescope launched," Lambrides says. "And I think it's going to take thousands of people to understand the data that came off of it. We've got a ways to go."

Source: https://www.vox.com/science/24040534/jwst-galaxies-big-bright-mystery-black-holes-cosmology