Early galaxies not as massive as initially thought, study finds

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This is a small portion of the field observed by NASA's James Webb Space Telescope's NIRCam (Near-Infrared Camera) for the Cosmic Evolution Early Release Science (CEERS) survey. It is filled with galaxies. The light from some of them has traveled for over 13 billion years to reach the telescope. Credit: NASA, ESA, CSA, Steve Finkelstein (University of Texas at Austin)

When astronomers got their first glimpses of galaxies in the early universe from NASA's James Webb Space Telescope, they were expecting to find galactic pipsqueaks, but instead they found what appeared to be a bevy of Olympic bodybuilders. Some galaxies appeared to have grown so massive, so quickly, that simulations could not account for them.

Some researchers suggested this meant that something might be wrong with the theory that explains what the universe is made of and how it has evolved since the big bang, known as the standard model of cosmology.

According to a study in *The Astrophysical Journal* led by University of Texas at Austin graduate student Katherine Chworowsky, some of those early galaxies are in fact much less massive than they first appeared. Black holes in some of these galaxies make them appear much brighter and bigger than they really are.

"We are still seeing more galaxies than predicted, although none of them are so massive that they 'break' the universe," Chworowsky said.

The evidence was provided by Webb's Cosmic Evolution Early Release Science (CEERS) Survey, led by Steven Finkelstein, a professor of astronomy at UT and study co-author.

Black holes add to brightness

According to this latest study, the galaxies that appeared overly massive probably host black holes rapidly consuming gas. Friction in the fast-moving gas emits heat and light, making these galaxies much brighter than they would be if that light emanated just from stars. This extra light can make it appear that the galaxies contain many more stars, and hence are more massive than we would otherwise estimate.

When scientists remove these galaxies, dubbed "little red dots" (based on their red color and small size), from the analysis, the remaining early galaxies are not too massive to fit within predictions of the standard model.

"So, the bottom line is there is no crisis in terms of the standard model of cosmology," Finkelstein said. "Any time you have a theory that has stood the test of time for so long, you have to have overwhelming evidence to really throw it out. And that's simply not the case."

Efficient star factories

Although they've settled the main problem, a less thorny one remains: There are still about twice as many massive galaxies in Webb's data of the early universe as expected from the standard model. One possible reason might be that stars formed more quickly in the early universe than they do today.

"Maybe in the early universe, galaxies were better at turning gas into stars," Chworowsky said.

Star formation happens when hot gas cools enough to succumb to gravity and condenses into one or more stars. But as the gas contracts, it heats up, generating outward pressure. In our region of the universe, the balance of these opposing forces tends to make the star formation process very slow.

But perhaps, according to some theories, because the early universe was denser than it is today, it was harder to blow gas out during star formation, allowing the process to go faster.

More evidence of black holes

Concurrently, astronomers have been analyzing the spectra of "little red dots" discovered with Webb, with researchers in both the CEERS team and others finding evidence of fast-moving hydrogen gas, a signature of black hole accretion disks.

This supports the idea that at least some of the light coming from these compact, red objects comes from gas swirling around black holes rather than stars—reinforcing the conclusion of Chworowsky's team that the stars are probably not as massive as astronomers initially thought. However, further observations of these intriguing objects are incoming and should help solve the puzzle about how much light comes from stars versus gas around black holes.

Often in science, when you answer one question, that leads to new questions. Although the researchers have shown that the standard model of cosmology probably is not broken, their work points to the need for new ideas in star formation.

"And so, there is still that sense of intrigue," Chworowsky said. "Not everything is fully understood. That's what makes doing this kind of science fun, because it'd be a terribly boring field if one paper figured everything out, or there were no more questions to answer."

Other UT authors are Michael Boylan-Kolchin, Anthony Taylor and Micaela Bagley. They, Finkelstein (as its director) and Chworowsky are members of UT's Cosmic Frontier Center, which seeks to improve our understanding of the early universe.

More information: Evidence for a Shallow Evolution in the Volume Densities of Massive Galaxies at z = 4 to 8 from CEERS, *The Astrophysical Journal* (2024). DOI: 10.3847/1538-3881/ad57c1

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