CRISIS IN THE COSMOS? Ron Cowen. *Science News*. Oct 8, 2005. Vol. 168, Iss. 15; p. 235 (2 pages)

Galaxy-formation theory is in peril

Imagine peering into a nursery and seeing, among the cooing babies, a few that look like grown men. That's the startling situation that astronomers have stumbled upon as they've looked deep into space and thus back to a time when newborn galaxies filled the cosmos. Some of these babies have turned out to be nearly as massive as the Milky Way and other galactic geezers that have taken billions of years to form. Despite being only about 800 million years old, some of the infants are chock-full of old stars.

These chunky babies may be pointing to a cosmic crisis. They don't seem to fit the leading theory of galaxy formation, which cosmologists have relied on for more than 2 decades to explain an assortment of puzzling features of the universe.

The theory posits that a pervasive, slow-moving, invisible type of matter vastly outweighs the observable matter in the universe. Under the gravitational influence of this unseen material, known as cold dark matter (SN: 4/23/05, p. 264), galaxies start out as small, starry fragments that merge to become much bigger objects. That's usually a gradual process, according to the theory.

The new findings raise the question: Did the universe have enough time during its first 800 million years for infant galaxies to have merged into mature-looking behemoths?

The theory can accommodate a few rare instances of such precocious growth by assuming that the jumbo galaxies reside in a few regions that have an unusually high density of dark matter. There, gravity would have pulled together objects faster than usual, accelerating galaxy growth.

But over the past 18 months, several teams have found so many massive galaxies from this early epoch that the theory is being stretched to its breaking point, several astronomers say.

"Our expectation is that [in the cold dark matter model] when you look back in time, it should be hard to see very massive structures because most galaxies at that early time in the universe are expected to be small," says astronomer Michael Rowan-Robinson of the Imperial College of Science, Technology and Medicine in London. "It would be worrying if this kind of [massive] galaxy is common" at early times.

If too many early, massive galaxies show up, "we might not have the right galaxy-formation scenario," says Bahram Mobasher of the Space Telescope Science Institute in Baltimore.

Even if the theory of cold dark matter survives this onslaught, the new observations of big galaxies in the most ancient of times have important implications. The findings suggest that the earliest galaxies formed stars in a great hurry, much more rapidly than galaxies that were born even a billion years later did. What's more, that first generation of stars might have been rife with heavyweights much more massive, on average, than stars from any later epoch.

BIG BABIES? Over the past few years, researchers have detected several galaxies that were surprisingly massive, given that their measured distance puts them in the early universe (SN: 3/1/03, p. 139). Two of the galaxies, recently found by Andrew Bunker of the University of Exeter in England and his colleagues, are less than a billion years old, which is less than 5 percent of the age of the universe.

Despite their youth, these galaxies contain stars that formed at least 100 million years earlier in time. Furthermore, the galaxies are at least 20 percent as massive as today's typical bright galaxy, which took some 12 billion years to pack on that material.

The team reports several of its findings in an upcoming Monthly Notices of the Royal Astronomical Society.

In a report on Sept. 27, Mobasher and his colleagues describe what appears to be an even more outlandish result. They have evidence of a true whopper of a galaxy-perhaps the most massive ever detected from the early universe. Observations taken at several visible-light and infrared wavelengths suggest that it's likely to be one of the earliest galaxies ever found. It appears to reside 13 billion light-years from Earth. So, the light now reaching our planet left the galaxy when the cosmos was about 800 million years old.

Mobasher's group estimates that the galaxy is six times as massive as the Milky Way. Moreover, the reddish tinge of the galaxy's stars indicates that they're quite mature and must have formed about 200 hundred million years farther back in time.

Bunker's team found a similarly old, red population of stars in the young galaxies they've detected.

In contrast, most galaxies observed at such an early epoch are aglow with the blue light emitted by clumps of hot, newborn stars, notes Richard Ellis of the California Institute of Technology in Pasadena, who is a member of both the Mobasher and the Bunker teams. The observations indicate that in an even earlier epoch, one whose denizens are now too far away and too dim to be seen by existing telescopes, some galaxies were "furiously luminous" and teeming with new stars, says Ellis.

The finding affirms that "there probably was a very luminous early period of [stellar] activity that we haven't yet witnessed," he says.

"That's terrific news for those of us who are working on the James Webb Space Telescope [the proposed successor to the Hubble Space Telescope] and future ground-based telescopes" that will be capable of looking farther back in time, he adds.

However, because Mobasher's team hasn't obtained a spectrum of the galaxy-the only sure way to measure its distance-the researchers can't be positive that the object is as remote and ancient as their images suggest.

Although the team's models deem it unlikely, Mobasher says that it's possible that instead of lying near the edge of the observable universe-and therefore residing far back in time-the galaxy is much closer and looks red merely because it's heavily shrouded in dust.

SEEKING THE YOUNG BUT OLD To find old-looking young galaxies, astronomers combine the sharp eye of the Hubble Space Telescope, which can image faint galaxies in visible and near-infrared light, with the much-longer-wavelength infrared sensitivity of the Spitzer Space Telescope.

The Hubble images were recorded as part of the Ultra Deep Field, the deepest survey of the heavens ever conducted in visible light. Between September 2003 and January 2004, Hubble stared at a patch of sky about one-tenth the diameter of the full moon for a total of 11 days, recording distant galaxies in unprecedented detail (SN: 05/15/04, p. 309).

[Photograph]
YOUNG ODDITY - Astronomers located an old-but-young galaxy among some 10,000 others in a patch of sky called the Hubble Ultra Deep Field (left). An enlargement of one section of the field (upper right) shows the galaxy's location in visible light (green circle). The galaxy shows up only faintly at near-infrared wavelengths (center right) but appears much brighter (bottom right) at the longer infrared wavelengths recorded by the Spitzer Space Telescope. The infrared brightness indicates that the galaxy is quite massive.

A distant galaxy typically shows up at about the same brightness in near-infrared and visible-red wavelengths but vanishes at shorter wavelengths. That's because clouds of hydrogen gas absorb far-ultraviolet light, and the most distant galaxies have the largest amount of hydrogen gas between them and Earth (SN: 2/24/96, p. 120). The expansion of the universe shifts light from the remote galaxies to longer wavelengths, so the galaxies drop out of sight not in the far-ultraviolet but at longer wavelengths-blue visible light.

Once astronomers identify a galaxy as a distant dropout, they turn to the infrared Spitzer telescope to estimate the mass and age of its constituent stars. An infrared telescope is a prerequisite because the majority of stars in any galaxy glow strongest in the infrared. The infrared-brightest stars are also the oldest ones. Therefore, the brighter a galaxy appears in Spitzer images, the older its stars.

With Spitzer, notes Bunker, "we can attempt to age-date the stars." The observations indicate that some of the youngest galaxies in the universe are prematurely old. The stars in these infrared-bright distant galaxies formed a mere half-billion years after the Big Bang.

SIFTING THROUGH Nonetheless, theorists who study galaxy formation maintain that the cold dark matter model isn't yet in peril. Simon White of the Max Planck Institute for Astrophysics in Garching, Germany, says that the would-be spoilers have yet to demonstrate that massive galaxies in the early universe are common enough to pose a problem.

Mobasher told Science News that his team is currently studying several other galaxies within the Ultra Deep Field data that might be nearly as massive and as distant as the galaxy that his team has just announced.

"There could be a problem with the theory," says theorist Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. "Any additional examples of [young] massive galaxies would be very useful for theorists attempting to figure out the implication."

If cold dark matter does run into trouble, the theory won't be salvaged with just a small bit of tinkering, Loeb warns. It's possible that the universe is populated by a type of dark matter different from that which cosmologists have considered most plausible, he adds.

Another idea, Loeb notes, harks back to the notion that chance, microscopic fluctuations in the density of the primordial cosmic soup gave birth to galaxies. Perhaps, he says, those fluctuations aren't uniformly distributed but are skewed to make the formation of rare, massive galaxies more likely than researchers had supposed.

If the galaxy found by Mobasher's team turns out to be too small to challenge current theory, it may nonetheless reveal the nature of the first generation of stars in the universe. The finding would add to the evidence that stars, not the black hole-powered beacons known as quasars, were the first objects to light up the cosmos after the Big-Bang.

To gauge the galaxy's mass, Mobasher's team observed the brightness at several infrared wavelengths. The infrared glow comes from the galaxy's predominant stellar population-low-mass stars. Using the ratio of low-mass to high-mass stars measured in galaxies today, the team estimated the young galaxy's total stellar mass.

When researchers make such estimates, they assume that the ratio has remained the same throughout cosmic history. If that ratio was lower in the past, the galaxy would weigh less than Mobasher's team has estimated. It would also indicate, as some simulations suggest, that stars of the first generation were heftier than those in later generations.

The prospect of determining the nature of the first stars is thrilling, says Ellis, because their characteristics will reveal whether they were critical for ending the era known as the cosmic dark ages.

This dark era began some 300,000 years after the birth of the universe, when the radiation left over from the Big Bang streamed freely into space and faded.

The dark ages continued even as the first stars and quasars emerged from the murk because their light was quenched by hydrogen atoms. Only when those first objects generated enough ultraviolet light to break these atoms apart into protons and electrons could starlight flood the cosmos.

Cosmologists aren't sure whether quasars, stars, or both first lit up the universe. But the heftier the first generation of stars, the more important they would have been in switching on the cosmos. That's because the more massive a star is, the more ultraviolet light it can produce, breaking apart atoms and lighting the cosmos.

Indirectly, then, the galaxy discovered by Mobasher's group may be unusually illuminating. It might point to the group of stars that generated the cosmic dawn.

[Sidebar]
"We might not have the right galaxy-formation scenario."
- BAHRAM MOBASHER, SPACE TELESCOPE SCIENCE INSTITUTE