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Fossil galaxy may be one of first ever formed

The stars in the nearby Segue 1 dwarf galaxy have low abundances of elements heavier than helium.

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The Magellan Telescopes at Las Campanas Observatory in Chile targeted stars in the Segue 1 dwarf galaxy for 6 to 15 hours each to measure their content of 'metals', or elements heavier than helium.

A tiny galaxy circling the Milky Way may be a fossil left over from the early Universe, astronomers say. A recent study found that the stars in the galaxy, called Segue 1, contain fewer heavy elements than those of any other galaxy known, implying that the object may have stopped evolving almost 13 billion years ago. If true, Segue 1 could offer a window into the conditions of the early Universe and reveal how some of the first galaxies came to be.

Segue 1 is very, very tiny. It appears to contain only a few hundred stars, compared with the few hundred *billion* stars in the Milky Way Galaxy. Researchers led by Anna Frebel of the Massachusetts Institute of Technology in Cambridge collected detailed information on the elemental composition of six of the brightest of Segue 1's stars using the Las Campanas Observatory's Magellan Telescopes in Chile and the Keck Observatory in Hawaii. The measurements, reported in a paper accepted for *Astrophysical Journal* and posted on the arXiv repository, revealed that these stars are made almost entirely of hydrogen and helium, and contain just trace amounts of heavier elements such as iron. No other galaxy studied holds so few heavy elements, making Segue 1 the "least chemically evolved galaxy known."

Complex elements are forged inside the cores of stars by the nuclear fusion of more basic elements such as hydrogen and helium atoms. When stars explode in supernovae, even heavier atoms are created. elements spew into space to infuse the gas that births the next generation of stars, so that each successive generation contains more and more heavy elements, known as metals. "Segue 1 is so ridiculously metal-poor that we suspect at least a couple of the stars are direct descendants of the first stars ever to blow up in the Universe," says study co-author Evan Kirby of the University of California, Irvine.

All supernovae are not created equal. When very massive stars blow up they form a mix of elements such as magnesium and calcium, whereas low-mass star explosions almost exclusively make iron. Frebel and her colleagues measured the content of each of these particular elements in Segue 1's stars and found that they contained the products of high-mass stars but very few products of low-mass stars. Because high-mass stars die much younger than do low-mass ones, this evidence reveals how quickly star formation occurred in the dwarf galaxy. “Segue 1 is the only example that we know of now that was never enriched by these low-mass stars, meaning it formed stars really quickly, in the blink of an eye,” Kirby says. “If it had formed stars long enough those low-mass stars would have to contribute.”

The findings suggest Segue 1 went through one brief bout of star formation long ago, and then stopped forever. “The big question is, why did it stop?” says Irvine astrophysicist James Bullock, who was not involved in the study. “A galaxy like this should have been able to make a million more stars, but it didn’t.”

One possibility is the epoch of reionization. When the Universe was born it was hot and dense, and all gas was ionized, meaning protons and electrons were isolated and could not band together to form atoms. Eventually the Universe cooled enough to allow atoms to form in the gas and the first stars were born from this material. Those stars blasted out radiation, which energized the gas around them and reionized it sometime around 13.2 billion years ago. Because stars cannot form from ionized gas, reionization might have terminated star formation in the existing galaxies at the time. “Maybe Segue 1 was on its way to forming a bunch of stars but reionization turned on and killed all the star formation in the galaxy,” Kirby says. “That could also explain why the star formation lasted such a short time.”

The case is not closed, however. Bullock, one of the main authors of the reionization idea, says the latest theoretical simulations of galaxy formation suggest the shutdown caused by reionization looks to be less sudden than scientists previously thought. “It’s not obvious to me that reionization by itself could have done this,” he says. “Maybe, but I definitely think there are other possibilities.” For instance, perhaps some quirk has caused Segue 1 to be incredibly inefficient at forming stars compared with other galaxies.

Segue 1 may help reveal not just what halts galaxy evolution, but how it gets started as well. “This study is so interesting because I really want to know, can galaxies form this small?” says astronomer Beth Willman of Haverford College, who was not involved in the research. “Can galaxies form and look like Segue 1 when they form or do they have to form larger and then have some mass taken away?” It is possible, after all, that this dwarf was once a much larger galaxy and lost most of its stars, perhaps through disruptions from its close neighbor, the Milky Way. The extremely low metal counts in Segue 1’s stars, however, support the idea that it formed roughly the same size it is now, because disruptions would be unlikely to pull only the metal-rich stars from the galaxy, leaving behind the metal-poor.

If there is no barrier to such puny galaxies forming in the first place, then mini galaxies like Segue 1 could be plentiful, but unseen. Only Segue 1’s close proximity to the Milky Way makes such a small, dim galaxy detectable. “There could be 200 Segue 1-like galaxies around us,” Willman says. “My lifelong goal is trying to understand, are things like this the most abundant in the Universe?”

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