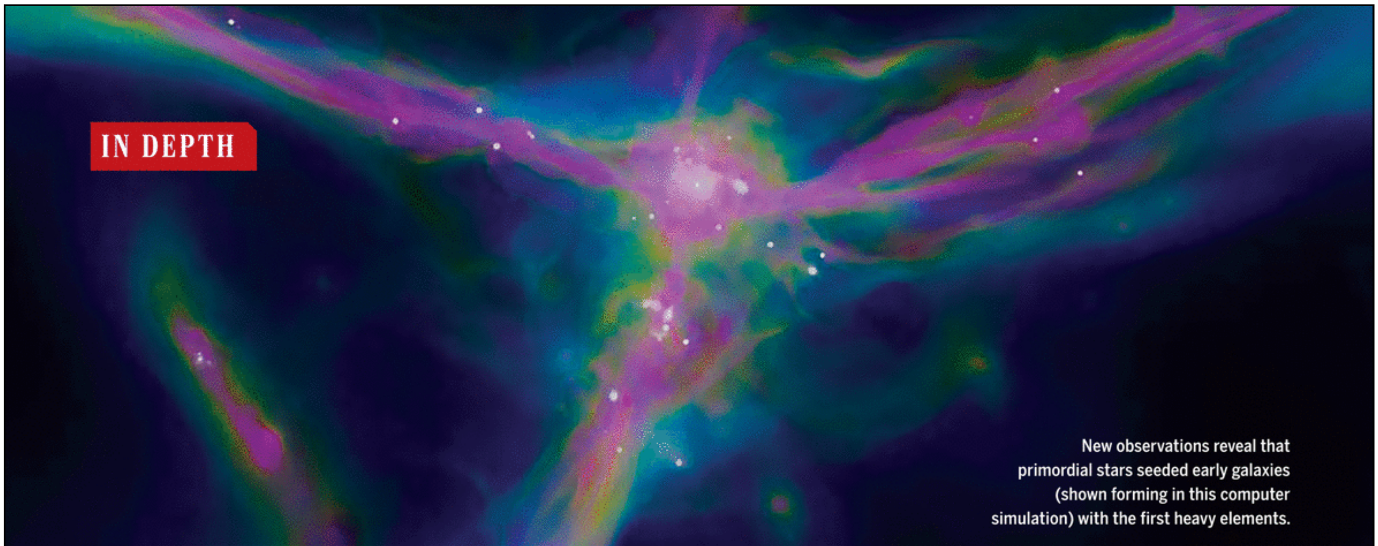

New observations reveal that primordial stars seeded early galaxies (shown forming in this computer simulation) with the first heavy elements.

SPACE

Astronomers see ashes of the first stars

Primordial clouds show how giant stars forged the heavy elements that fill today's universe

By **Daniel Clery**, *in Kissimmee, Florida*

The universe of today is a rich banquet of elements, from the silicon and oxygen in rocky planets to the carbon and nitrogen in our bodies. But in its early days, the cosmic offerings were monotonous: mostly hydrogen, some helium, and a pinch of lithium, all made in the big bang. At a meeting of the American Astronomical Society (AAS) here last week, researchers announced that they have seen signs of how, starting in those early days, truly monstrous stars 100 times as massive as our sun began transforming those simple ingredients into today's feast of elements.

Until recently, says astronomer John O'Meara of Saint Michael's College in Colchester, Vermont, this ancient—hence distant—epoch remained in "the realm of computer simulations." But now, teams using some of the world's biggest telescopes are beginning to probe it by studying light from ancient quasars, superbright galaxy cores that shone in the early universe. As the light passes through clouds of gas en route to Earth, the gas absorbs specific wavelengths, creating an absorption spectrum that reveals what the cloud was made of and how new ingredients were added to the early universe.

These elements were forged in the earliest stars, which formed about 150 million years after the big bang and were unlike any today. They were giant puffballs, made from gas so hot that it was slow to compress to the density needed to ignite fusion in their cores. These unlit protostars kept piling on mass until, finally, their cores became hot and dense enough to ignite. Because they had become so huge, these giants—known as population III stars—burned hot and fast; after only a few million years their cores ran out of fuel, collapsed, and exploded. But in the meantime, their fusion furnaces had forged hydrogen into numerous heavier elements, and their end-of-life explosions—while making still more elements—helped to spread them across the cosmos.

That was the beginning of the process by which the pristine gas clouds from the big bang have become "enriched" with heavier elements (which astronomers call "metals")—a process that continues in stars today and provided the ingredients for planets and life.

In 2011, O'Meara and colleagues used quasar spectra to discover two gas clouds at the very beginning of this process: They appeared completely devoid of elements heavier than hydrogen (*Science*, 2 December 2011, p. 1245). These clouds existed about 2 billion years after the big bang—long after the first population III stars ignited—showing that some pristine clouds survived to that later time. Then last year, a team led by David Sobral of the University of Lisbon detected a bright galaxy just a billion years after the big bang that seemed to have some stars made from hydrogen, helium, and nothing else.

Now, O'Meara and his colleagues at Swinburne University of Technology, Hawthorn, in Australia have found a gas cloud that existed when the universe was 1.8 billion years old and has just a wisp of heavier elements: 1/3000 of the level in our solar system. This suggests that it contains only the remains of population III stars dispersed by their violent deaths.

The team identified the cloud in quasar spectra collected using high-resolution spectrographs on the Keck telescopes in Hawaii and the Very Large Telescope in Chile. They focused on a portion of the spectrum that is so crammed with absorption lines from hydrogen gas clouds that it is known as the Lyman-α forest. "We dared to go down into the weeds and study a few hundred quasars," O'Meara says. It took considerable modeling to derive element abundances from the spectral lines. "This is a prototype of a new avenue of study," he says.

"It's quite exciting," says Sobral, now at the United Kingdom's Lancaster University. "It shows that extremely metal-poor clouds exist even out at [1.8 billion years]." Avi Loeb, chair of Harvard University's astronomy department, says such studies help answer the question of when life could have arisen in the universe. There has to be carbon and oxygen, but at what stage are they abundant enough? "We're getting close to the sensitivity to probe the transition between the formation of massive [population III] stars and those similar to what we have around today."

Teasing the faint fingerprints of the first heavy elements from light that has crossed the universe taxes today's most powerful instruments. Researchers hope to probe deeper into the workings of early stars with the James Webb Space Telescope, due for launch in 2018, and the next generation of giant ground-based telescopes in the 2020s. "This is a really exciting game to play with 30-meter telescopes. There will be no problem doing thousands of spectra," O'Meara says. ■

IMAGE: CEVERINO, DEKEL & PRIMACK