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The stars that time forgot remember the youth of our Milky Way

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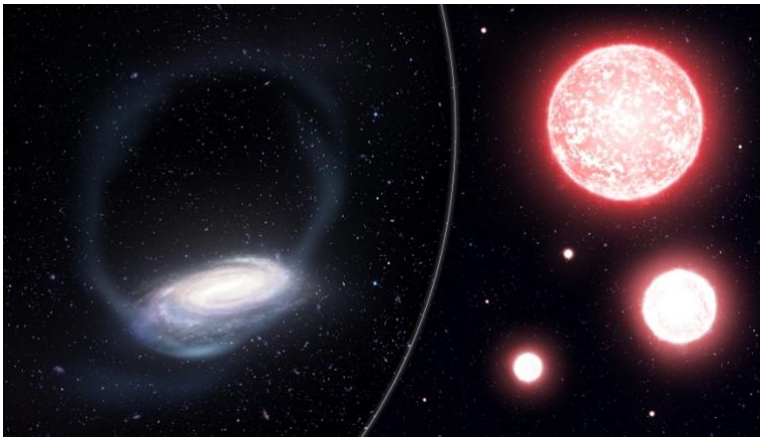
Born more than ten billion years ago, the early life of our Milky Way galaxy remains mysterious. Recently we discovered the Phoenix Stream, the remnants of a cluster of stars on the verge of destruction. The stars of the Phoenix Stream are old, formed in the first instances of the Galaxy, providing a new window on our Milky Way's evolution.



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How did galaxies, like our own Milky Way, arise from the featureless universe after the Big Bang? Through a lot of astronomical detective work, we now know that galaxies expand through consuming smaller systems, tearing them apart through their gravitational forces and assimilating their stars. But the initial stages, with the birth of the first few generations of stars, remain mysterious.

There is a witness to these early times — tight bundles of about a million stars known as globular clusters. Held together by their own gravity, about 150 globular clusters orbit within the tenuous stellar halo of the Milky Way, lying far outside the Galaxy's brightest regions. Their ancient stars reveal that they were formed when the Galaxy was young.

Globular clusters appear to have no dark matter (the dominant mass in the universe), so they must have been formed from immense clouds of collapsing gas, although exactly how they were born remains a mystery. One clue comes from their rich chemical composition, demonstrating that they cannot have been formed only from the pure hydrogen and helium that filled the universe after the Big Bang. These various elements must have been formed in previous generations of stars, which fuse hydrogen and helium into heavier elements at their cores, polluting surrounding gas when the star eventually dies. If we can unravel the formation of globular clusters, we will gain clues to the state of the baby Milky Way.

However, the picture has now become muddier with our discovery of an unusual globular cluster by exploring the stars called the Phoenix stream. This exceptional globular cluster might take our ideas of galaxy evolution back to the drawing-board.

Located about 60,000 light-years away from Earth, the Phoenix Stream was recently discovered in the Dark Energy Survey, a program using the 4-m Blanco Telescope in Chile. The goal of the Dark Energy Survey is to hunt for the elusive energy, which is causing the expansion of the universe to accelerate, but a by-product has been finding stars scattered through the Milky Way's tenuous stellar halo. Some of these appear as long, thin streams, the debris of other star systems that have strayed too close and are now being destroyed by the Galaxy's gravitational forces.

Like a piece of spaghetti, the Phoenix Stream is more than 10,000 light-years long, but barely 200 light-years across. We targeted it as part of the Southern Stellar Stream Spectroscopic Survey (or more simply S5), a program using the 3.9-m Anglo-Australian Telescope to measure speeds and chemistry of individual stars. While this telescope is pretty old, with first-light in 1974, its superb instrumentation, especially the spectrograph that can collect the light from almost 400 objects simultaneously, means that it is still world-beating.

From the rainbow spectrum of light of each star, we measured its speed. This revealed that the progenitor of the Phoenix Stream was a globular cluster that is being disrupted. In a couple of billion years, it will be completely disrupted and merged with the Milky Way. The spectrum of light also revealed the chemical composition of the stars, and this is where the Phoenix Stream became extremely interesting. The progenitor globular cluster of the Phoenix Stream was chemically purer than all the other globular clusters, suggesting that it was not born with the others. Its chemical purity points to it forming from earlier generations of stars, at a time and in an environment very different to the others.

Surely the Phoenix Stream could not have been the only globular cluster to have arisen at this earlier time, so where are its siblings? In the earliest stages of our Galaxy, we would have expected that the Phoenix Stream was a population of similar globular clusters, but the gravitational forces of the Milky Way have steadily ground this population down, steadily disrupting each one and adding their stars to the Galaxy. The Phoenix Stream appears to be the last of its kind, the sole survivor of a population now lost, and, in the blink of a cosmic eye, it will be gone.

Deciphering the origins of the Phoenix Stream is very exciting, giving us a new window on the earliest stages of the Milky Way. But it raises some interesting questions about other possible populations that might have played a pivot role in the Galaxy's early evolution and are now lost to time. A lot more work is needed before we fully understand the history of the Milky Way.