Mind the gap: filling in the missing pieces for star clusters

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My colleagues and I have confirmed the existence of a new type of star cluster – as published recently in Monthly Notices of the Royal Astronomical Society.

But what are star clusters, and why do they matter?

When you look up at the night sky you see individual stars belonging to our galaxy, the Milky Way. But you may also see satellites of the Milky Way. The most famous of these are the clouds of Magellan, named after the Portuguese explorer Ferdinand Magellan.

Under good conditions, you might also see a compact cluster of stars – a globular cluster.

Globular clusters are dense, spherical collections of stars that orbit around the Milky Way like moths around a light bulb. They are over 10 billion years old and thought to have formed just after the Big Bang.

In this sense they are the fossils of the astronomical world providing clues to the early universe and the process of galaxy formation.

In the almost 350 years since the discovery of the first cluster by German amateur astronomer Abraham Ihle, we now know of almost 200 globular clusters orbiting around the Milky Way.

Missing mass

Globular clusters around the Milky Way, and indeed other galaxies, have a range of mass from a few thousand to a few million times the mass of our sun. However, they are all, to first order, of the same size – a few light years across.

Globular Star Cluster 47 Tuc. NASA

In the past decade, astronomers had discovered star clusters around other galaxies that are of similar mass to globular clusters but several times larger in size – for some reason such clusters are not made in the Milky Way.

By 2011, it was known that the universe made star clusters with a large range in mass and size, but a gap existed: none were known with an intermediate mass and a large size. Did such objects not form or do they remain to be discovered?

My colleagues and I were keen to know the answer.

What we found

The existence of a gap in star cluster properties suggested to some that there are distinct types, or families, of star cluster. Filling the gap, with intermediate mass clusters, would show that star clusters are made with a continuous range of sizes and masses.

Either situation had interesting implications for ideas of how star clusters might form. For example, star clusters with large masses and sizes have been suggested to be the remnant core of a small galaxy that has been stripped of its outer stars.

But this scenario would have difficulty explaining the intermediate mass (gap) clusters if they exist.

We began the process by using the Hubble Space Telescope to identify a number of candidates around three elliptical galaxies, all located a few tens of millions of light years away (that's nearby by astronomical standards).

An example of the new type of star cluster discovered (left), and an example of a previously known globular star cluster (right). The images were taken with the Hubble Space Telescope and their distances from Earth confirmed by the Keck II Telescope. Monthly Notices of the Royal Astronomical Society

To confirm their distance, and hence their physical properties, we needed to obtain a spectrum of each cluster. They are very faint and getting a spectrum of their light is out of the reach of most telescopes.

For this task we turned to the world's largest optical observatory and the Keck II telescope. The Keck telescope, with its 10m diameter mirror, has more than 15 times the collecting area of the Hubble Space Telescope.

Using the Deimos instrument on the Keck telescope with long exposures we were able to obtain high signal-to-noise spectra of several candidate star clusters.

We thus confirmed their intermediate masses and large sizes filling the gap in star cluster properties for the first (and last) time.

We now know that in terms of the fundamental properties of mass and size, star clusters are rather continuous. But this continuity also suggests that the current ideas for star cluster formation will need to be revisited.

Why? Because no single model can explain the wide range of properties now observed.