Using stellar 'twins' to reach the outer limits of the galaxy

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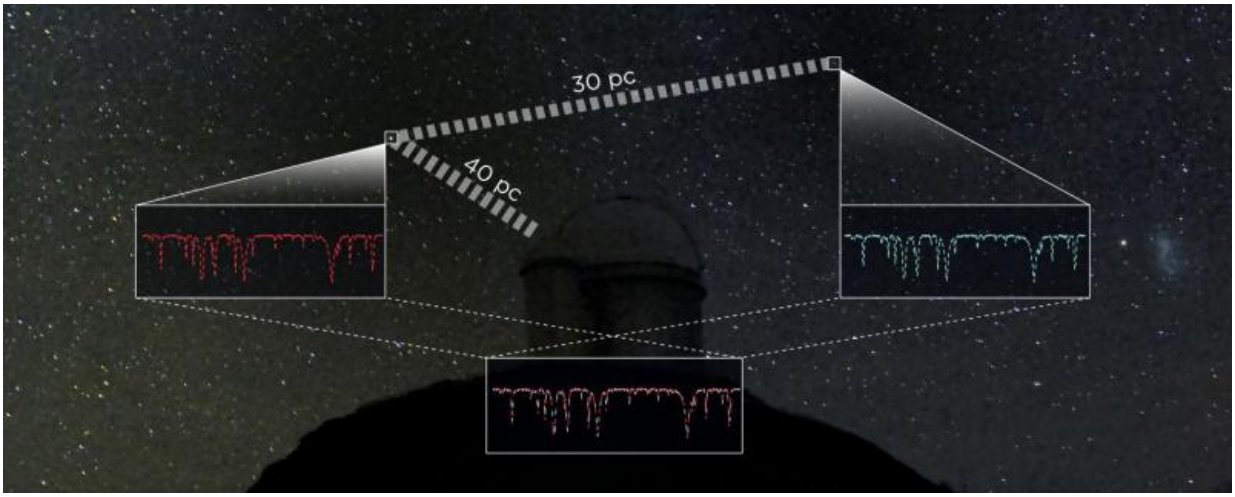

Two 'twin' stars with identical spectra observed by the La Silla Telescope. Since it is known that one star is 40 parsecs away, the difference in their apparent brightnesses allows calculation of the second star's distance. Credit: Carolina Jofré

Astronomers from the University of Cambridge have developed a new, highly accurate method of measuring the distances between stars, which could be used to measure the size of the galaxy, enabling greater understanding of how it evolved.

Using a technique which searches out stellar 'twins', the researchers have been able to measure distances between stars with far greater precision

than is possible using typical model-dependent methods. The technique could be a valuable complement to the Gaia satellite - which is creating a three-dimensional map of the sky over five years - and could aid in the understanding of fundamental astrophysical processes at work in the furthest reaches of our galaxy. Details of the new technique are published in the *Monthly Notices of the Royal Astronomical Society*.

"Determining distances is a key problem in astronomy, because unless we know how far away a star or group of stars is, it is impossible to know the size of the galaxy or understand how it formed and evolved," said Dr Paula Jofre Pfeil of Cambridge's Institute of Astronomy, the paper's lead author. "Every time we make an accurate distance measurement, we take another step on the cosmic distance ladder."

The best way to directly measure a star's distance is by an effect known as parallax, which is the apparent displacement of an object when viewed along two different lines of sight - for example, if you hold out your hand in front of you and look at it with your left eye closed and then with your right eye closed, your hand will appear to move against the background. The same effect can be used to calculate the distance to stars, by measuring the apparent motion of a nearby star compared to more distant background stars. By measuring the angle of inclination between the two observations, astronomers can use the parallax to determine the distance to a particular star.

However, the parallax method can only be applied for stars which are reasonably close to us, since beyond distances of 1600 light years, the angles of inclination are too small to be measured by the Hipparcos satellite, a precursor to Gaia. Consequently, of the 100 billion stars in the Milky Way, we have accurate measurements for just 100,000.

Gaia will be able to measure the angles of inclination with far greater precision than ever before, for stars up to 30,000 light years away.

Scientists will soon have precise distance measurements for the one billion stars that Gaia is mapping - but that's still only one percent of the stars in the Milky Way.

For even more distant stars, astronomers will still need to rely on models which look at a star's temperature, surface gravity and chemical composition, and use the information from the resulting spectrum, together with an evolutionary model, to infer its intrinsic brightness and to determine its distance. However, these models can be off by as much as 30 percent. "Using a model also means using a number of simplifying assumptions - like for example assuming stars don't rotate, which of course they do," said Dr Thomas Mädler, one of the study's co-authors. "Therefore stellar distances obtained by such indirect methods should be taken with a pinch of salt."

The Cambridge researchers have developed a novel method to determine distances between stars by relying on stellar 'twins': two stars with identical spectra. Using a set of around 600 stars for which high-resolution spectra are available, the researchers found 175 pairs of twins. For each set of twins, a parallax measurement was available for one of the stars.

The researchers found that the difference of the distances of the twin stars is directly related to the difference in their apparent brightness in the sky, meaning that distances can be accurately measured without having to rely on models. Their method showed just an eight percent difference with known parallax measurements, and the accuracy does not decrease when measuring more distant stars.

"It's a remarkably simple idea - so simple that it's hard to believe no one thought of it before," said Jofre Pfeil. "The further away a star is, the fainter it appears in the sky, and so if two stars have identical spectra, we can use the difference in brightness to calculate the distance."

Since a utilised spectrum for a single star contains as many as 280,000 data points, comparing entire spectra for different stars would be both time and data-consuming, so the researchers chose just 400 spectral lines to make their comparisons. These particular lines are those which give the most distinguishing information about the star - similar to comparing photographs of individuals and looking at a single defining characteristic to tell them apart.

The next step for the researchers is to compile a 'catalogue' of stars for which accurate distances are available, and then search for twins among other stellar catalogues for which no distances are available. While only looking at stars which have twins restricts the method somewhat, thanks to the new generation of high-powered telescopes, high-resolution spectra are available for millions of stars. With even more powerful telescopes under development, spectra may soon be available for stars which are beyond even the reach of Gaia, so the researchers say their method is a powerful complement to Gaia.

"This method provides a robust way to extend the crucially-important cosmic distance ladder in a new special way," said Professor Gerry Gilmore, the Principal Investigator for UK involvement in the Gaia mission. "It has the promise to become extremely important as new very large telescopes are under construction, allowing the necessary detailed observations of stars at large distances in galaxies far from our Milky Way, building on our local detailed studies from Gaia."

More information: Climbing the cosmic ladder with stellar twins, *Mon. Not. R. Astron. Soc*. 2015.

Provided by University of Cambridge