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MUCH BIGGER?
According to new findings, the Milky Way Galaxy is at least 50 per cent larger than is commonly estimated.

Unravelling the mystical stars

CELESTIAL MARVEL In a bid to discover hydrogen-deficient stars, a scientist and his student stumbled upon a new discovery, writes Nityanand Rao

Twinkling stars, whether little or giant, are rich in hydrogen. But astronomers who spend their days wondering what stars are, know that there exist many stars that barely have any hydrogen in them. Now, it turns out the sky has a small middle class too.

"We don't expect hydrogen-deficient stars, but we see them in nature," says Dr Gajendra Pandey of the Indian Institute of Astrophysics, Bengaluru, whose student BP Hema reports this discovery in a paper published in the *Astrophysical Journal Letters*. "This kind of star was not discovered earlier," says Hema.

A typical star derives its energy from the fusion of hydrogen nuclei to form helium, the next higher element in the periodic table. When the hydrogen in its core runs out, it begins to fuse helium to form higher elements. It also swells in size to become what's called a red giant. But its atmosphere, the outer layer, will still have hydrogen, the most abundant element in the universe. There are some stars, however, that may not have much hydrogen in their atmospheres. Finding out how such a star forms and how it evolves would require knowing its surface, temperature and its luminosity. While the effective temperature of a star can be found from its spectrum, luminosity can be found only if you know the distance to it.

To find such specimens with almost no hydrogen, Hema used the Vainu Bappu Observatory in Kavalur, Tamil Nadu, to survey the globular cluster Omega Centauri. Although it's the largest and brightest such aggregation in our galaxy, it's far enough that light takes about 16,000 years to make a trip. "These are very faint stars," says Hema. If the stars in a globular cluster formed from the same material, one would expect them to have similar composition: the same proportions of hydrogen, helium, and metals. The presence, and relative amount, of any element or molecule in a star's atmosphere

similar temperature and gravity, their spectrum should be exactly the same, if they have the same metallicity," says Gajendra. If they're not, it means they have different amounts of the elements.

The molecule whose lines Hema and Gajendra chose to examine, was one containing hydrogen – magnesium hydride, or MgH2. They also looked at the lines of the element magnesium, a triplet called Mgb2. If these lines are intense, and the MgH2 lines which form a band, are not, it must mean that the star is relatively hydrogen-deficient.

They found that the stars they surveyed fell into three groups. One group had intense Mg lines and some MHG bands too, meaning they were metal-rich. A second group had weak Mg lines and no MgH band, meaning they were metal-poor. A third group had strong Mg lines, but no MgH band. Within each group, the spectra of stars having similar effective temperatures and surface gravities were compared with each other, in order to eliminate the influence of these factors.

Four stars stood out. Two of them, from the first group, had MgH bands that were weak compared to that of the average star having the same characteristics. The other two, from the third group, had no MgH at all, which was unexpected for some stars. Overall, it seemed that all four were hydrogen deficient.

To confirm this, the researchers determined what the spectra of these stars should have been, based on their known characteristics and data from previous studies. To ensure that the theoretical model they used was valid, they compared the generated spectrum of a well-known red giant with its observed spectrum.

By adjusting the Mg abundance in the model used, the theoretical spectrum could be made to agree with the observed one for each of the stars surveyed. The Mg abundance at which this happens for a star should be a good estimate of its actual Mg abundance. For most stars surveyed, be found only if you know [illegible] it.

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On a starry search

So, to see if a star has abundant hydrogen, the obvious thing to do would be to look at its hydrogen lines. "But the hydrogen lines are strong and saturated. So, you cannot distinguish between normal-hydrogen stars and slightly-less-hydrogen stars," says Gajendra.

But there's another way. Gajendra suspected that some stars appear more metal-rich than they really are because of their hydrogen deficiency, which leads to their atmospheres being more transparent to light at visible wavelengths. So, to detect hydrogen-poor stars, you have to search for metal-rich ones.

But the stars in Omega Centauri don't have the same metallicity – the proportion of metals they contain, which is unusual for a globular cluster. "The range in the metallicity is the main reason why we selected this cluster," says Hema. Among the metals, the lines of neutral and ionised iron, along with the broadening of the hydrogen lines can be used to find how strong the gravitational pull at the outer layers of a star is. "If you pick two stars of the Omega Centauri cluster, which are of drogen deficient.

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By adjusting the Mg abundance in the model used, the theoretical spectrum could be made to agree with the observed one for each of the stars surveyed. The Mg abundance at which this happens for a star should be a good estimate of its actual Mg abundance. For most stars surveyed, this theoretical Mg abundance was within the typical range of values expected for stars in Omega Centauri. However, the model predicted that the two stars from the third group had much lower amounts of Mg. This should mean a very weak MgH band. Accordingly, observations showed they hardly had any MgH. But it should also have resulted in weak Mg lines. Here, the observations disagreed – they showed strong Mg lines. "So we actually went to look for stars which are hydrogen-deficient, with almost no hydrogen, but ended up discovering stars which are relatively hydrogen-poor than what's normal. This is the first detection of such kind of stars," adds Gajendra.

The discovery of these relatively hydrogen-deficient stars may have broader implications too. All stars in a globular cluster are thought to have the same age, having formed at the same time. "But this discovery means that maybe there was a burst of star formation and after some time, another set of stars formed from the material again, which was enriched by the earlier star formation. We thought there is one single population in the globular cluster. But this study suggests that it may have multiple populations," concludes Gajendra.

ASTRAL SPECTACLE Stars shine by burning hydrogen into helium in their cores.