Revealing Secret of Lithium-rich Stars by Monitoring Their Heartbeats

Lithium is an ancient element that is almost as old as the universe itself. As one of the building blocks of our present-day universe though, the context of lithium observed in many celestial bodies often disaccord with predictions of classic theories.

Lithium-rich stars, accounting for only 1% of the total number of the low-mass evolved stars, are one example of such conflict. They preserve up to thousands of times more lithium than the normal stars that account for the rest 99%. Astronomers are wondering what these stars really are and why.

A recent study from an international team led by Prof. ZHAO Gang, Prof. SHI Jianrong, and Dr. YAN Hongliang from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) provides new insights to lithium-rich stars. The study was published online in *Nature Astronomy* on Oct. 5, 2020.

By monitoring their "heartbeats", they found that most lithium-rich stars are so-called "red clumps" rather than "red giants" as previously thought.

"The 'red clumps' and 'red giants' are names for different stages of the senile stars," said Prof. ZHAO, co-corresponding author of this paper, "though they look alike on the H-R diagram, a tool for mapping the evolutionary stage of a star over its lifetime."

"Imagine you are looking at two grey-haired elders," he added, "it is very hard to tell who is older just by their appearances."

Traditionally, the convective movement in the "red giants" was thought to be a favorable environment for

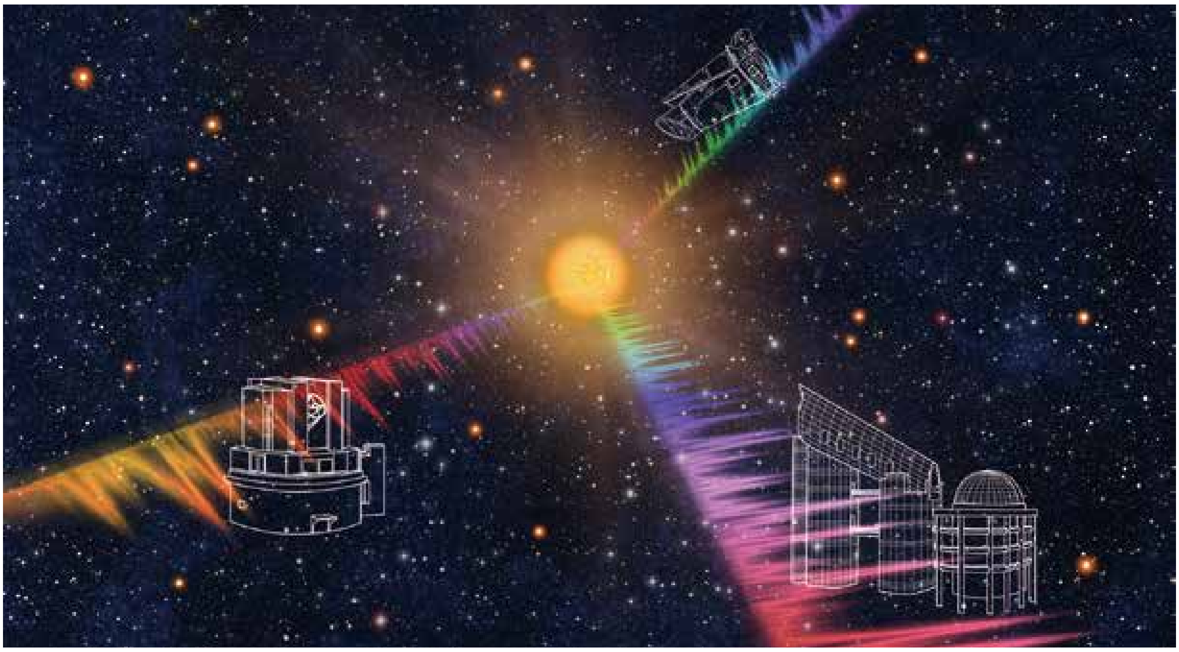

Figure 1: Astronomers reveal the secrets of the lithium-rich low-mass evolved stars by monitoring their heartbeats and analyzing their spectra. (Credit: YU Jingchuan, Beijing Planetarium).

creating lithium in stars. That partly explains why most of lithium-rich stars were thought to be "red giants" at the very beginning.

"The key problem was," said Dr. YAN, the lead author of this study, "we didn't exactly know what the lithium-rich stars really are – not until now."

The game changer here is the combination of spectroscopy and the asteroseismology, a technique that measures the feature of a star's oscillation by monitoring their light variations from a space satellite, Kepler, run by NASA. "We are monitoring the heartbeats, taking the cardiogram for stars," said Dr. YAN. "Although the 'red giants' and 'red clumps' are alike in appearances, they have different hearts, thus beat diversely."

Most lithium-rich stars in this study were found by the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST), a special quasi-meridian reflecting Schmidt telescope with active optics technique, located at Xinglong Station, north China. Some of these stars were also observed by other telescopes worldwide using different resolutions, such as Subaru telescope operated by Japan, to confirm that the information derived from LAMOST data are correct. "The spectra can tell us the physical parameters of the stars, and how much lithium are kept in their atmospheres," said Prof. ZHAO. "So, spectra are equally important as the 'heartbeats' of stars in our study."

The research shows that over 80% of lithium-rich stars are "red clumps". Importantly, it reveals a bunch of new signatures for "heartbeats" of lithium-rich stars helpful for classifying individual stars into "red clumps" or "red giants". "All of these signatures are hard to explain using the current scenarios," said Prof. SHI, co-corresponding author of the paper. "There are still some unknown processes that could significantly affect surface chemical compositions in low-mass stellar evolution, but this is an exciting opportunity for us astronomers to find out how lithium is created in stars."

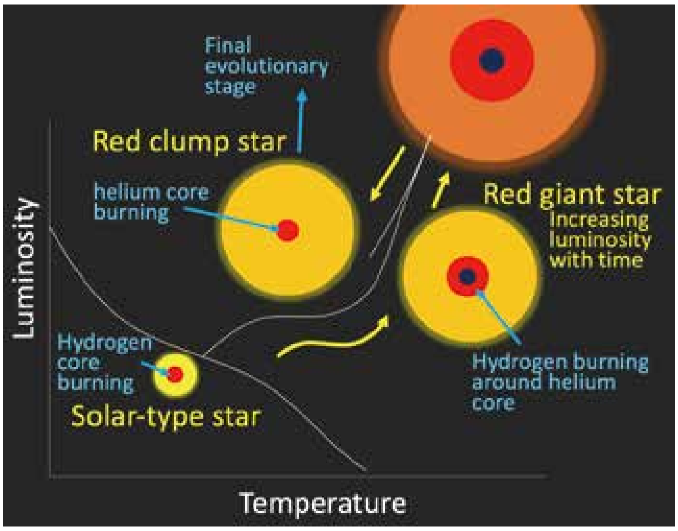

Figure 2: Internal structure and evolution of low-mass stars. The internal structure of red clump stars is different from red giants with hydrogen nuclear burning around the central core, but the temperature and luminosity of clump stars are indistinguishable from some red giants (Credit: Wako Aoki, NAOJ).

The research is done by an international team with scientists from institutes worldwide, including China, Japan, France, the Netherlands, the United States, Australia, and Denmark. Besides LAMOST, Subaru, and Kepler, four other telescopes also contributed to the data, including the 3.5-meter telescope at Apache Point Observatory, the Automated Planet Finder telescope at Lick Observatory, the 2.4-meter and 1.8-meter telescope at Lijiang Observatory.

The paper can be accessed at https://www.nature.com/articles/s41550-020-01217-8

(NAOC)