JINA: Center for the Evolution of the Elements

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Using the Gaia satellite to study the environment of the r-process

Understanding the origin of the elements is one of the major challenges of modern astrophysics, and the r-process is one of the fundamental ways that stars produce the heavy elements. In the last few years, astronomers have found new ways to understand the r-process by observing its impact on the surrounding environment. This could be observed directly, as in the case of the "kilonova" electromagnetic counterpart associated with the merger of two neutron stars detected in gravitational waves (GW170817; [1, 2]). It could also be observed indirectly, as in the case of the r-process-rich dwarf galaxy Reticulum II, where the yield of a single r-process event can be estimated because other properties of the galaxy are known ([3, 4, 5]).

To help answer this question, JINA-CEE researcher Ian Roederer and his colleagues Kohei Hattori and Monica Valluri at the University of Michigan recently published [6] a new technique to assess the impact of the r-process on its environment.

This technique studies the orbits and other kinematic properties of highly r-process-enhanced stars in the Milky Way field population. Earlier this year, the European Space Agency's Gaia satellite released a catalog of astrometric data for 1.3 billion stars, including many of the known r-process-enhanced stars. Using these data, the team was able to calculate the shapes and sizes of the orbits of these stars and look for similar properties among them for the first time.

The results suggest that virtually all highly r-process-enhanced stars known are members of the Galactic halo population, and they just happen to be passing through the Solar Neighborhood right now. The results also suggest that these stars were likely born long ago in dwarf galaxies, which were later disrupted through tidal interactions with the Milky Way. If so, the study suggests that the birth environment, rather than the nature of the r-process site, may be the key factor contributing to creating the highly r-process-enhanced stars that are frequently studied by astronomers.

As the Gaia satellite continues to collect data on billions of stars in the Milky Way, larger and more distant samples of r-process-enhanced stars will be available for studies like this one.

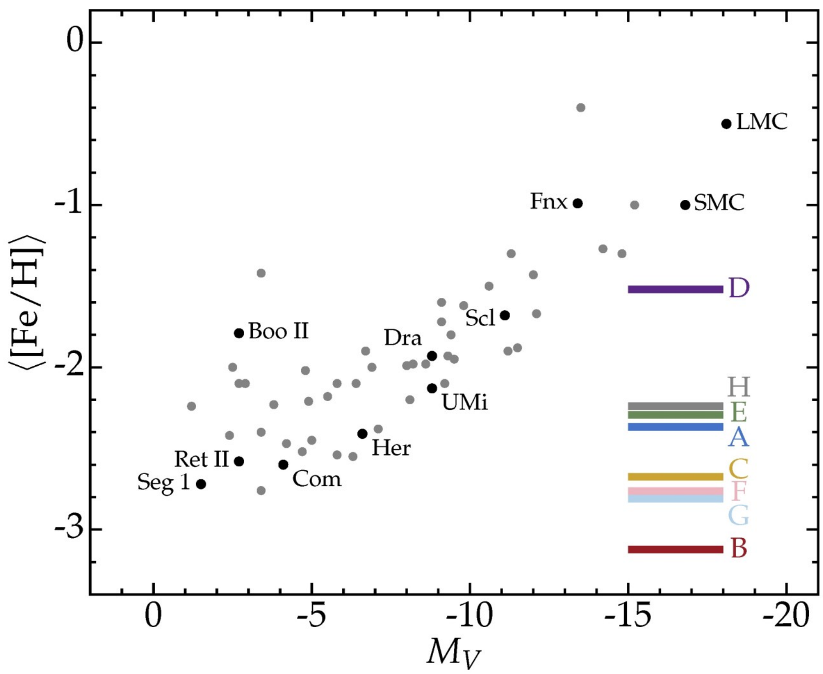

Figure: The average metallicities of kinematically-similar groups of r-process-enhanced stars (horizontal lines labeled A-H), compared with the dwarf galaxy luminosity-metallicity relation. The low average metallicities of these groups suggest the r-process-enhanced stars were born in dwarf galaxies similar in mass or luminosity to today's so-called ultra-faint dwarf galaxies.

Further reading: "Kinematics of Highly r-process-enhanced Field Stars: Evidence for an Accretion Origin and Detection of Several Groups from Disrupted Satellites" ApJ, 156, 179 (2018). We acknowledge support by NSF grants PHY 14-30152 (JINA-CEE), AST 16-13536, AST 18-15403 (to I.U.R.), and NASA-ATP award NNX15AK79G (to M.V.).

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