Galactic 'gold mine' explains the origin of nature's heaviest elements

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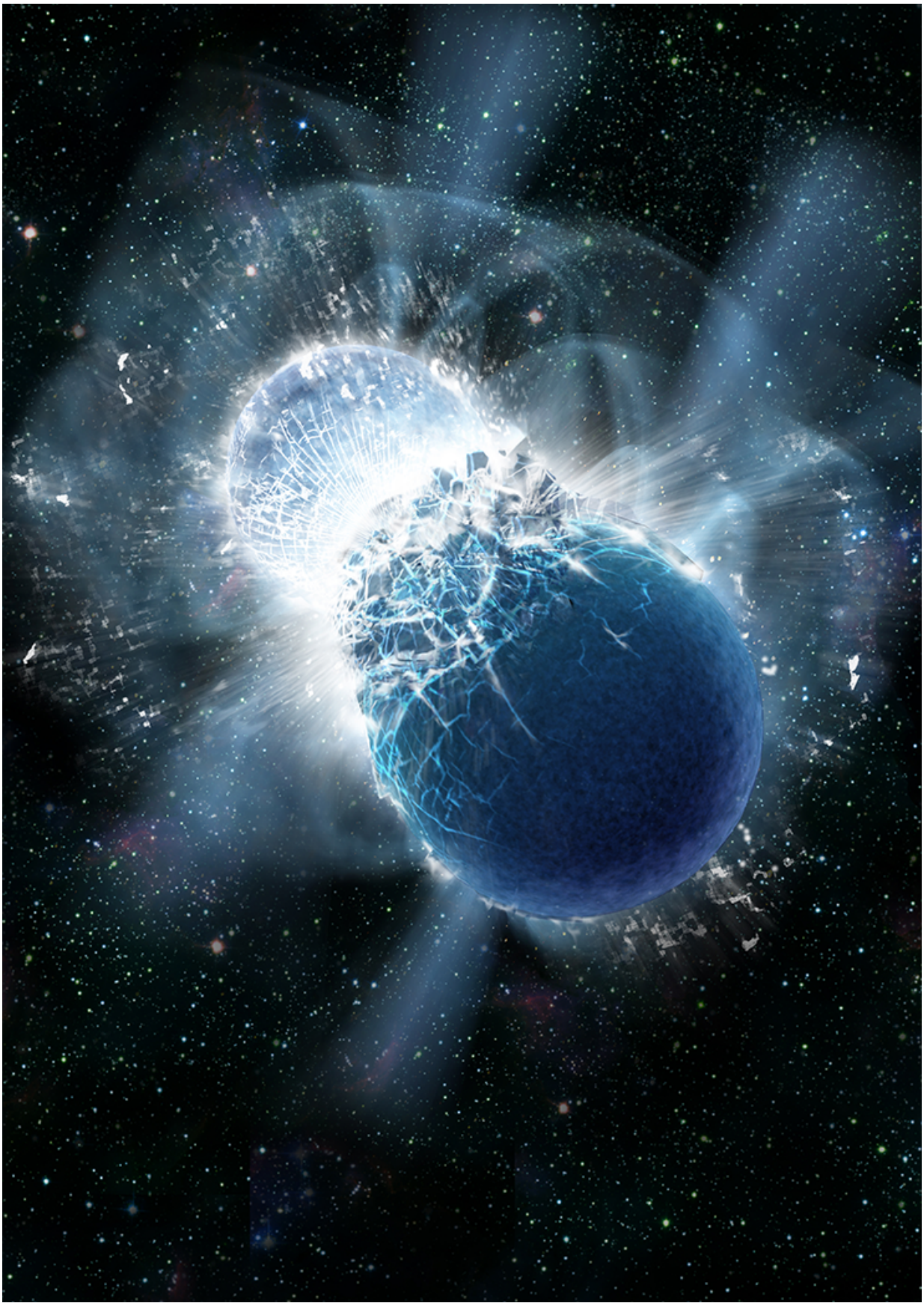

An artist's impression of two neutron stars colliding. Credit: Dana Berry / Skyworks Digital, Inc./The Kavli Foundation

The origin of many of the most precious elements on the periodic table, such as gold, silver and platinum, has perplexed scientists for more than six decades. Now a recent study has an answer, evocatively conveyed in the faint starlight from a distant dwarf galaxy.

In a roundtable discussion, published today, The Kavli Foundation spoke to two of the researchers behind the discovery about why the source of these heavy elements, collectively called "r-process" elements, has been so hard to crack.

"Understanding how heavy, r-process elements are formed is one of hardest problems in nuclear physics," said Anna Frebel, assistant professor in the Department of Physics at the Massachusetts Institute of Technology (MIT) and also a member of the MIT Kavli Institute for Astrophysics and Space Research (MKI).

"The production of these really heavy elements takes so much energy that it's nearly impossible to make them experimentally," Frebel continued. "The process for making them just doesn't work on Earth. So we have had to use the stars and the objects in the cosmos as our lab."

The findings also demonstrate how determining the contents of stars can shed light on the history of the galaxy hosting them. Nicknamed "stellar archaeology," this approach is increasingly allowing astrophysicists to learn more about conditions in the early universe.

"I really think these findings have opened a new door for studying galaxy formation with individual stars and to some extent individual elements," said Frebel. "We are seriously connecting the really small scales of stars with the really big scales of galaxies."

In the late 1950s, nuclear physicists had worked out that extreme conditions somewhere in the cosmos, full of subatomic particles called neutrons, must serve as the forges for r-process elements, which also include familiar substances such as uranium and lead. The explosions of giant stars and the rare mergings of the densest stars in the universe, called neutron stars, were the most plausible sources. But observational evidence was sorely lacking.

Researchers at the MKI have now filled this observational gap. An analysis of the starlight from several of the brightest stars in a tiny galaxy called Reticulum II, located some 100,000 light years from Earth, suggests these stars contain whopping amounts of r-process elements.

Since the stars could not have made the heavy elements on their own, some event in Reticulum II's past must have "seeded" and enriched the matter that grew into these stars. The abundances of elements in the stars squarely implicates the collision of two neutron stars.

Frebel's graduate student Alexander Ji discovered the enriched stars in Reticulum II while using the Magellan telescopes at the Las Campanas Observatory in Chile. He is first author on a paper about the findings, published March 31 in the journal *Nature*.

"When we read off the r-process content of that first star in our telescope, it just looked wrong, like it could not have come out of this galaxy!" said Ji, in the roundtable. "I spent a long time making sure the telescope was pointed at the right star."

Ji further commented on how the discovery helps to finally tell the tale of how r-process elements come to exist. "Definitely one of the things that I think attracts people to astronomy is understanding the origin of everything around us."

Enrico Ramirez-Ruiz, a professor of Astronomy and Astrophysics at the University of California, Santa Cruz, joined Ji and Frebel for the roundtable.

"I've been working on neutron star mergers for a while, so I was extremely excited to see Alex and Anna's results," said Ramirez-Ruiz, who was not involved in the research. "Their study is indeed a smoking gun that exotic neutron star mergers were occurring very early in the history of this particular dwarf galaxy, and for that matter likely in many other small galaxies. Neutron star mergers are therefore probably responsible for the bulk of the precious substances we call r-process elements throughout the universe."

More information: Alexander P. Ji et al, R-process enrichment from a single event in an ancient dwarf galaxy, *Nature* (2016). DOI: 10.1038/nature17425

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