New nuclei can help shape our understanding of fundamental science on Earth and in the cosmos

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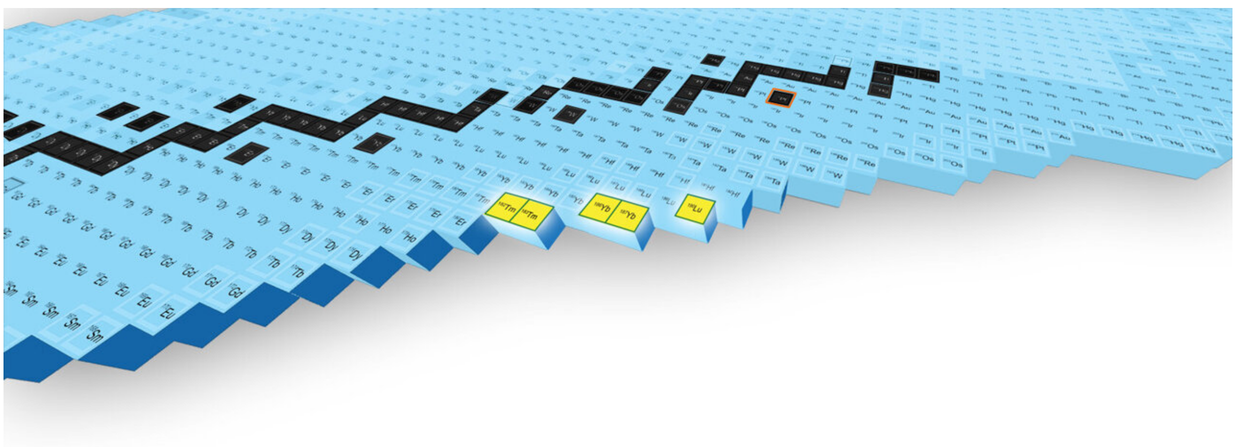

In making the new isotopes, reported in the journal *Physical Review Letters*, scientists are a step closer to being able to more directly probe natural processes that make new elements in stars. The new isotopes also can help inform and refine our understanding of fundamental nuclear physics. Credit: FRIB/MSU

In creating five new isotopes, an international research team working at the Facility for Rare Isotope Beams (FRIB) at Michigan State University has brought the stars closer to Earth.

The isotopes—known as thulium-182, thulium-183, ytterbium-186, ytterbium-187 and lutetium-190—are reported in the journal *Physical*

Review Letters.

These represent the first batch of new isotopes made at FRIB, a user facility for the U.S. Department of Energy Office of Science, or DOE-SC, supporting the mission of the DOE-SC Office of Nuclear Physics. The new isotopes show that FRIB is nearing the creation of nuclear specimens that currently only exist when ultradense celestial bodies known as neutron stars crash into each other.

"That's the exciting part," said Alexandra Gade, professor of physics at FRIB and in MSU's Department of Physics and Astronomy and FRIB scientific director. "We are confident we can get even closer to those nuclei that are important for astrophysics."

Gade is also a co-spokesperson of the project, which was led by Oleg Tarasov, senior research physicist at FRIB.

The research team included a cohort based at FRIB and MSU, along with collaborators at the Institute for Basic Science in South Korea and at RIKEN in Japan, an acronym that translates to the Institute of Physical and Chemical Research.

"This is probably the first time these isotopes have existed on the surface of the Earth," said Bradley Sherrill, University Distinguished Professor in MSU's College of Natural Science and head of the Advanced Rare Isotope Separator department at FRIB.

For an explanation as to what "advanced" means in this context, Sherrill said that researchers needed only a couple individual particles of a new isotope to confirm its existence and identity using FRIB's state-of-the-art instruments.

With researchers now knowing how to make these new isotopes, they can start making them in greater quantities to conduct experiments that were never possible before. The researchers are also eager to follow the path they've forged to make more new isotopes that are even more like what are found in the stars.

"I like to draw the analogy of taking a journey. We've been looking forward to going somewhere we've never been before and this is the first step," Sherrill said. "We've left home and we're starting to explore."

Almost star stuff

Our sun is a cosmic atomic factory. It's powerful enough to take the cores of two hydrogen atoms, or nuclei, and fuse them into one helium nucleus.

Hydrogen and helium are the first and lightest entries on the periodic table of the elements. Getting to the heavier elements on the table requires even more intense environments than what's found in the sun.

Scientists hypothesize that elements like gold—about 200 times as massive as hydrogen—are created when two neutron stars merge.

Neutron stars are the leftover cores of exploded stars that were originally much larger than our sun, but not so much larger that they can become black holes in their final acts. Although they're not black holes, neutron stars still cram an immense amount of mass into a very modest size.

"They're about the size of Lansing with the mass of our sun," Sherrill said. "It's not certain, but people think that all of the gold on Earth was made in neutron star collisions."

By making isotopes that are present at the site of a neutron star collision, scientists could better explore and understand the processes involved in making these heavy elements.

The five new isotopes are not part of that milieu, but they are the closest scientists have come to reaching that special territory—and the outlook for finally reaching it is very good.

To create the new isotopes, the team sent a beam of platinum ions barreling into a carbon target. The beam current divided by the charge state was 50 nanoamps. Since these experiments were performed, FRIB has already scaled its beam power up to 350 nanoamps and has plans to reach up to 15,000 nanoamps.

In the meantime, the new isotopes are exciting in and of themselves, presenting the nuclear research community new opportunities to step into the unknown.

"It's not a big surprise that these isotopes exist, but now that we have them, we have colleagues who will be very interested in what we can measure next," Gade said. "I'm already starting to think of what we can do next in terms of measuring their half-lives, their masses and other properties."

Researching these quantities in isotopes that have never been available before will help inform and refine our understanding of fundamental nuclear science.

"There's so much more to learn," Sherrill said. "And we're on our way."

More information: O. B. Tarasov et al, Observation of New Isotopes in the Fragmentation of Pt198 at FRIB, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.072501

Provided by Michigan State University

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