Examining exploding stars through the atomic nucleus

February 18 2017

Imagine being able to view microscopic aspects of a classical nova, a massive stellar explosion on the surface of a white dwarf star (about as big as Earth), in a laboratory rather than from afar via a telescope.

Cosmic detonations of this scale and larger created many of the atoms in our bodies, says Michigan State University's Christopher Wrede, who presented at the American Association for the Advancement of Science meeting. A safe way to study these events in laboratories on Earth is to investigate the exotic nuclei or "rare isotopes" that influence them.

"Astronomers observe exploding stars and astrophysicists model them on supercomputers," said Wrede, assistant professor of physics at MSU's National Superconducting Cyclotron Laboratory. "At NSCL and, in the future at the Facility for Rare Isotope Beams, we're able to measure the nuclear properties that drive stellar explosions and synthesize the chemical elements - essential input for the models. Rare isotopes are like the DNA of exploding stars."

Wrede's presentation explained how rare isotopes are produced and studied at MSU's NSCL, and how they shed light on the evolution of visible matter in the universe.

"Rare isotopes will help us to understand how stars processed some of the hydrogen and helium gas from the Big Bang into elements that make up solid planets and life," Wrede said. "Experiments at rare isotope beam facilities are beginning to provide the detailed nuclear physics information needed to understand our origins."

In a recent experiment, Wrede's team investigated stellar production of the radioactive isotope aluminum-26 present in the Milky Way. An injection of aluminum-26 into the nebula that formed the solar system could have influenced the amount of water on Earth.

Using a rare isotope beam created at NSCL, the team determined the last unknown nuclear-reaction rate affecting the production of aluminum-26 in classical novae.

They concluded that up to 30 percent could be produced in novae, and the rest must be produced in other sources like supernovae.

Future research can now focus on counting the number of novae in the galaxy per year, modeling the hydrodynamics of novae and investigating the other sources in complete nuclear detail.

To extend their reach to more extreme astrophysical events, nuclear scientists are continuing to improve their technology and techniques. Traditionally, stable ion beams have been used to measure nuclear reactions. For example, bombarding a piece of aluminum foil with a beam of protons can produce silicon atoms. However, exploding stars make radioactive isotopes of aluminum that would decay into other elements too quickly to make a foil target out of them.

"With FRIB, we will reverse the process; we'll create a beam of radioactive aluminum ions and use it to bombard a target of protons," Wrede said. "Once FRIB comes online, we will be able to measure many more of the nuclear reactions that affect exploding stars."

Provided by Michigan State University