Unusual meteorite unlocks treasure trove of solar system secrets

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An unusual meteorite that fell on a frozen lake in Canada five years ago has led a Florida State University geochemist to a breakthrough in understanding the origin of the chemical elements that make up our solar system.

Professor Munir Humayun of the National High Magnetic Field Laboratory and the geological sciences department at FSU and Alan Brandon of NASA discovered an isotopic anomaly in the rare element osmium in primitive meteorites. The anomalous osmium was derived from small stars with a higher neutron density than that which formed our solar system. The findings of the researchers, who also included colleagues from the University of Maryland and Bern University in Switzerland, were recently published in the journal Science.

"Our new data enabled us to catch a glimpse of the different star types that contributed elements to the solar system, the parental stars of our chemical matter," Humayun said. "It opens a treasure trove of prospects for exploring the formation of the elements."

For about 50 years, scientists have known that all the elements beyond iron in the periodic table were made in stars by up to three nuclear processes. Osmium is mainly formed by two of those processes, the so-called s-process in which neutrons are slowly added to nuclei over a period of perhaps thousands of years in aging, medium-size stars and the r-process that occurs in supernovae in which neutrons are pumped into nuclei at a rate of hundreds of neutrons in a few seconds.

The new data gathered by Humayun's team not only shows the different star types that contribute elements to the solar system, it also will be used to test astrophysical models of production of the chemical elements at a more sophisticated level than previously possible, he said.

Humayun and colleagues studied samples from an extremely fragile meteorite that fell on Tagish Lake on Jan. 18, 2000. Unlike iron meteorites, primitive meteorites like this one are not preserved long on the Earth's surface because they disintegrate and form mud when exposed to water. This one was retrieved within 48 hours of its fall in the dead of an Arctic winter.

Most meteorites have a uniform osmium isotopic distribution, but Humayun's team found that osmium extracted from the Tagish Lake meteorite was deficient in s-process osmium. They are the first to report an anomaly in the isotopic makeup of the element osmium from meteorites.

Other researchers have found isotope anomalies in several other elements in some primitive meteorites, but not in others. Because of the disparity, scientists believed that the ashes of stars that preceded the solar system must have been sprinkled in a non-uniform way into the solar nebula, the disk of gas and dust that formed the sun, planets and meteorites. Scientists had hypothesized that some of the dust could have been created by an active nearby star.

Humayun's findings challenge that explanation. He believes that the anomaly is an expression of presolar stardust that survived the homogenization that affected nearly all other meteorites. Typically, stardust accretes to form meteorites and is then heated by radioactivity - a process that destroys the silicon carbide grains that are the carriers of the anomaly. But in the case of the meteorites with osmium isotopic anomalies, the heat was not significant enough to destroy the silicon carbide.

"The previous interpretation of incomplete mixing of different sources of dust at the scale of the solar nebula no longer seems tenable," he said. "We now interpret those anomalies as incomplete dissolution of silicon carbide grains that carried traces of molybdenum, ruthenium and osmium. These anomalies reveal that the raw materials from which our solar system was built are preserved in a few exceptional meteorites, from which we can now recover the prehistory of our solar system."

Source: Florida State University

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