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Scientist refines cosmic clock to determine age of Milky Way

June 29 2005

The University of Chicago's Nicolas Dauphas has developed a new way to calculate the age of the Milky Way that is free of the unvalidated assumptions that have plagued previous methods. Dauphas' method, which he reports in the June 29 issue of the journal *Nature*, can now be used to tackle other mysteries of the cosmos that have remained unsolved for decades.

"Age determinations are crucial to a fundamental understanding of the universe," said Thomas Rauscher, an assistant professor of physics and astronomy at the University of Basel in Switzerland. "The wide range of implications is what makes Nicolas' work so exciting and important."

Dauphas, an Assistant Professor in Geophysical Sciences, operates the Origins Laboratory at the University of Chicago. His wide-ranging interests include the origins of Earth's atmosphere, the oldest rocks that may contain evidence for life on Earth and what meteorites reveal about the formation of the solar system.

In his latest work, Dauphas has honed the accuracy of the cosmic clock by comparing the decay of two long-lived radioactive elements, uranium-238 and thorium-232. According to Dauphas' new method, the age of the Milky Way is approximately 14.5 billion years, plus or minus more than 2 billion years.

That age generally agrees with the estimate of 12.2 billion years-nearly as old as the universe itself-as determined by previously existing methods. Dauphas' finding verifies what was already suspected, despite the drawbacks of existing methods: "After the big bang, it did not take much time for large structures to form, including our Milky Way galaxy," he said.

The age of 12 billion years for the galaxy relied on the characteristics of two different sets of stars, globular clusters and white dwarfs. But this estimate depends on assumptions about stellar evolution and nuclear physics that scientists have yet to substantiate to their complete satisfaction.

Globular clusters are clusters of stars that exist on the outskirts of a galaxy. The processes of stellar evolution suggested that most of the stars in globular clusters are nearly as old as the galaxy itself. When the big bang occurred 13.7 billion years ago, the only elements in the universe were hydrogen, helium and a small quantity of lithium. The Milky Way's globular clusters have to be nearly that old because they contain mostly hydrogen and helium. Younger stars contain heavier elements that were recycled from the remains of older stars, which initially forged these heavier elements in their cores via nuclear fusion.

White dwarf stars, meanwhile, are stars that have used up their fuel and have advanced to the last stage of their lives. "The white dwarf has no source of energy, so it just cools down. If you look at its temperature and you know how fast it cools, then you can approximate the age of the galaxy, because some of these white dwarfs are about as old as the galaxy," Dauphas said.

A more direct way to calculate the age of stars and the Milky Way depends on the accuracy of the uranium/thorium clock. Scientists can telescopically detect the optical "fingerprints" of the chemical elements. Using this capability, they have measured the uranium/thorium ratio in a single old star that resides in the halo of the Milky Way.

They already knew how fast uranium and thorium decay with time. If they also know the ratio of uranium and thorium when the star was formed-the production ratio-then calculating the star's age becomes a problem with a straightforward solution. Unfortunately, "this production ratio is very poorly known," Dauphas said.

Dauphas solved the problem by combining the data from the uranium/thorium observations in the halo star with measurements of the uranium/thorium ratio that other scientists had made in meteorites. "If you measure a meteorite, you ultimately have the composition of the material that formed the sun 4.5 billion years ago," he said. And this material included debris from many generations of other stars, now long dead, that still contains information about their own uranium/thorium composition.

"We have very good instruments in the laboratory that allow us to measure this ratio with very, very good precision," Dauphas said.

Following the change in amount of two sufficiently long-lived radioactive elements is a sensitive way of measuring the time since they were formed, Rauscher said. "The problem is to set the timer correctly, to know the initial amounts of uranium and thorium. By clever combination of abundances in stars and meteorites, Nicolas provides the important starting value for the uranium/thorium clock," he said.

Scientists can now use that clock to determine the age of a variety of interstellar objects and particles, including cosmic rays, Rauscher said. These subatomic scraps of matter continually bombard the Earth from all directions. Where they come from has baffled scientists for almost a century.

Dauphas' work may also lead to a better understanding of how stars produce gold, uranium and other heavy elements that play an important role in everyday life, Rauscher said.

Source: University of Chicago

Citation: Scientist refines cosmic clock to determine age of Milky Way (2005, June 29) retrieved 24 April 2024 from https://phys.org/news/2005-06-scientist-refines-cosmic-clock-age.html