Beads of glass in meteorites help scientists piece together how solar system formed

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A cross-section of a piece of the Allende meteorite. The beads of glass inside these meteorites are called chondrules. Scientists think they are bits of rock left over from the debris that was floating around billions of years ago, which eventually coalesced into the planets we now know and love. Credit: James St. John/CC-BY-2.0.

Ever since scientists started looking at meteorites with microscopes, they've been puzzled—and fascinated—by what's inside. Most meteorites are made of tiny beads of glass that date back to the earliest days of the solar system, before the planets were even formed.

Scientists with the University of Chicago have published an analysis laying out how these beads, which are found in many meteorites, came to be—and what they can tell us about what happened in the early solar system.

"These are big questions," said UChicago alum Nicole Xike Nie, Ph.D.'19, a postdoctoral fellow at the Carnegie Institution for Science and first author of the study. "Meteorites are snapshots that can reveal the conditions this early dust experienced—which has implications for the evolution of both Earth and other planets."

'This question goes back 50 years'

The beads of glass inside these meteorites are called chondrules. Scientists think they are bits of rock left over from the debris that was floating around billions of years ago, which eventually coalesced into the planets we now know and love. These are immensely useful to scientists, who can get their hands on pieces of the original stuff that comprised the solar system—before the constant churn of volcanoes and tectonic plates of Earth changed all the rock we can find on the planet itself.

But what exactly caused the formation of these chondrules remains unclear.

"We have the same theories we had 50 years ago," said study co-author and UChicago postdoctoral researcher Timo Hopp. "Even though there have been advances in many other areas, this one has been stubborn."

Scientists can find clues about the early days of the solar system by looking at the types of a given element in a rock. Elements can come in several different forms, called isotopes, and the proportion in each rock varies according to what happened when that rock was born—how hot it was, whether it cooled slowly or was flash-frozen, what other elements were around to interact with it. From there, scientists can piece together a history of likely events.

To try and understand what had happened to the chondrules, Nie, Hopp and other scientists at the Dauphas Origins Lab at UChicago tried applying a unique angle to the isotopes.

First, Nie took extremely rigorous, precise measurements of the concentrations and isotopes of two elements that are depleted in meteorites, potassium and rubidium, which helped narrow down the possibilities of what could have happened in the early solar system.

From this information, the team pieced together what must have been happening as the chondrules formed. The elements would have been part of a clump of dust that got hot enough to melt, and then to vaporize. Then, as the material cooled, some of that vapor coalesced back into chondrules.

"We can also tell you how fast it cooled, because it was fast enough that not everything condensed," said Nicolas Dauphas, Professor of Geophysical Sciences at UChicago. "That must mean the temperature was dropping at a rate of around 500 degrees Celsius per hour, which is really fast."

Based on these constraints, scientists can theorize what kind of event would have been sudden and violent enough to cause this extreme heating and cooling. One scenario that fits would be massive shockwaves passing through the early nebula. "Large planetary bodies nearby can create shocks, which would have heated and then cooled the dust as it passed through," Dauphas said.

Over the past half-century, people have proposed different scenarios to explain the formation of the chondrules— lightning, or collisions between rocks—but this new evidence tips the balance toward shockwaves as an explanation.

This explanation may be the key to understanding a persistent finding that has bedeviled scientists for decades, involving a category of elements that are "moderately volatile," including potassium and rubidium. The Earth has less of these elements than scientists would expect, based on their general understanding of how the solar system formed. They knew the explanation could be traced to some complex chain of heating and cooling, but no one know the exact sequence. "It's a huge question in the field of cosmochemistry." said Dauphas.

Now, finally, the team is happy to have put a significant dent in the mystery.

"We know other processes happened—this is just one part of the story—but this really solves one step in the formation of planets," said Hopp.

Nie agreed: "It's really cool to be able to say quantitatively, this is what happened."

Other co-authors on the paper were from the Carnegie Institution for Science and the University of Washington.

More information: Nicole X. Nie et al, Imprint of chondrule formation on the K and Rb isotopic compositions of carbonaceous meteorites, *Science Advances* (2021). DOI: 10.1126/sciadv.abl3929

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