Vesta reveals the childhood of the Solar System

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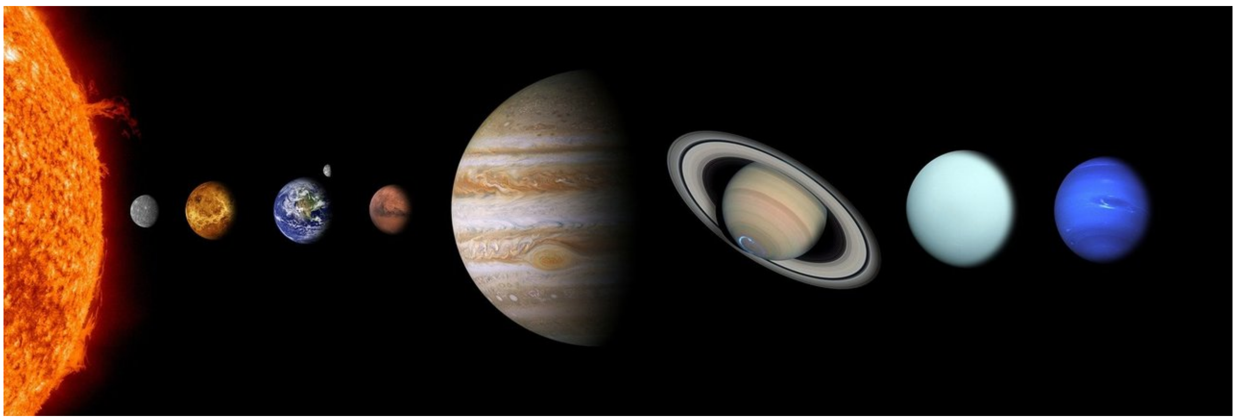

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Investigating the earliest and least-known phases of the history of the solar system, when the young sun was still enveloped by a disk of gas and dust in which the planets began to form, is probably one of the most complex challenges in modern planetary science. The existing celestial bodies that formed at the time are few, and in the majority of cases, evidence of the ancient processes that marked the birth of the solar system has been lost.

For decades, the asteroid Vesta has been a subject of high interest. In particular, the survival of its thin volcanic crust to impacts provided a powerful constraint to the violence of the early solar system. Recently, however, the data collected by NASA's Dawn mission, which is now coming to its end after successfully exploring also asteroid Ceres, raised the possibility that Vesta's memory may not be as good as we thought.

On one hand, the craters produced by impacts on its surface in the last 4 billion years seem to have erased the traces of the much older ones formed in the circumsolar disk. The Dawn mission confirmed that the HED meteorites were fragments of Vesta's crust that landed on Earth. The possible greater thickness of Vesta's crust with respect to what was suggested by the HED meteorites challenges conclusions derived from the crust condition.

The results of an international team of researchers led by Diego Turrini of INAF-IAPS, published in the journal *Icarus*, suggest differently. "It is all about changing our perspective and, instead of focusing only on the destructive effects of impacts as we have done so far, consider the constructive ones too," Diego Turrini explains.

"Each impact removes material from the surface of Vesta, but at the same time, delivers new material," says Vladimir Svetsov, member of the team and co-author of the study. "By balancing the two effects, it is possible to extract more precise information from the data of Dawn and HEDs."

The results of laboratory studies of HED meteorites had revealed in recent years how some of these meteorites present superabundances of water and of siderophilic elements (elements showing affinity to metals and therefore expected to be mainly segregated in Vesta's metallic core) and provided upper limits to their global presence in Vesta's crust.

Depending on its composition (for example a rocky asteroid or a comet), each meteorite can deliver one or both of these materials, modifying the composition of the crust. The team then wondered if it was possible to use the global limits on the presence of these materials set by the HEDs in synergy with the data provided by Dawn to constrain the primordial flow of impacts on Vesta and, consequently, the ancient history of the solar system.

"Instead of focusing on the direct search for the true evolutionary path of the primordial solar system, in our study we use a "Sherlock Holmes" approach, showing how the destructive and constructive effects of impacts can be used to exclude all impossible scenarios, leaving only the realistic ones," explains Guy Consolmagno, also member of the team and co-author of the study. "Sherlock Holmes said to eliminate the impossible, but sometimes it's not so easy to admit what is impossible," says Consolmagno. "The Vesta we found when Dawn arrived was different from what we had expected, but we have to deal with the Vesta that is, not the Vesta that we thought."

Given the large number of parameters that can be varied in this type of investigation, the team focused on a case study based on the formation and migration of Jupiter. Scientists now believe that the giant planet formed in a different region of the solar system than the one it inhabits today and then progressively migrated the its current orbit.

The results obtained by the team indicate how this approach not only establishes whether Jupiter has migrated or not, but also constrains the extent of its migration. "While we could consider only a subset of all proposed migration scenarios, balancing the crust erosion by impacts with water accretion and mass accretion allows us to reject three scenarios out of the four we simulated," explains Svetsov "While a modest migration of Jupiter by about 0.25 au is consistent with the data, larger migrations (up to 1 au) or no migration at all are to be excluded."

"The most innovative aspect of our results is possibly the fact that the joint use of the information provided by Dawn and the HEDs allows us to perform, for the first time, quantitative comparisons between different models," Turrini says. "Our main goal in this study was to provide the planetary science community with a new tool of investigation. The different groups involved all around the world in the study of the origins of the solar system can now use it to verify their models and evolutionary scenarios."

More information: D. Turrini et al. The late accretion and erosion of Vesta's crust recorded by eucrites and diogenites as an astrochemical window into the formation of Jupiter and the early evolution of the Solar System, *Icarus* (2018). DOI: 10.1016/j.icarus.2018.04.004

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