What gives meteorites their shape? New research uncovers a 'Goldilocks' answer

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as 'mock meteorites' that erode while moving through water. Credit: NYU's Applied Mathematics Laboratory

Meteoroids coming from outer space are randomly shaped, but many of these, which land on earth as meteorites, are found to be carved into cones. Scientists have now figured out how the physics of flight in the atmosphere leads to this transformation.

The progression, discovered through a series of replication experiments in New York University's Applied Mathematics Lab, involves melting and erosion during flight that ultimately results in an ideal shape as meteoroids hurl through the atmosphere. The findings are reported in the journal *Proceedings of the National Academy of Sciences (PNAS)*.

"Slender or narrow cones flip over and tumble, while broad cones flutter and rock back and forth, but we discovered between these are cones that fly perfectly straight with their point or apex leading," explains Leif Ristroph, an assistant professor in NYU's Courant Institute of Mathematical Sciences, who led the study. "Amazingly, these 'Goldilocks' cones of the 'just right' angles exactly match the shapes of eroded clay resulting from our experiments and of actual conical meteorites."

"By showing how the shape of an object affects its ability to fly straight, our study sheds some light on this long-standing mystery about why so many meteorites that arrive on Earth are cone shaped," he adds.

The forces behind the peculiar shapes of meteorites, which are meteors or "shooting stars" that survive the fiery flight through the atmosphere and land on Earth, have long been a mystery.

"The shapes of meteorites are not as they are in space, since they are actually melted, eroded, and reshaped by atmospheric flight," explains Ristroph. "While most meteorites are randomly shaped 'blobs,' surprisingly many—some say about 25 percent—are 'oriented meteorites,' and complete samples of these look almost like perfect cones."

To explore the forces that produce cone-shaped meteorites, the researchers, who included Jun Zhang, a professor of physics and mathematics at the Courant Institute and NYU Shanghai, replicated meteoroids traveling through outer space: clay objects, attached to a rod, served as "mock meteorites" that erode while moving through water.

The clay objects held in the water current were eventually carved into cones of the same angularity as conical meteorites—not too slender and not too broad.

However, the researchers recognized the limitations of this experimental design: unlike the clay objects, actual flying meteoroids are not held in a fixed position and can freely rotate, tumble, and spin. This distinction raised the following question: what allows meteorites to keep a fixed orientation and successfully reach Earth?

The team, which also included Khunsa Amin and Kevin Hu, both NYU undergraduates, and Jinzi Huang, an NYU doctoral student at the time of the work, then conducted additional experiments in which they examined how different shaped cones fell through water. Here they discovered that narrow cones flip over while broad cones flutter. However, in between these two are "just right" cone shapes that fly straight.

"These experiments tell an origin story for oriented meteorites: the very aerodynamic forces that melt and reshape meteoroids in flight also

stabilize its posture so that a cone shape can be carved and ultimately arrive on Earth," observes Ristroph. "This is another interesting message we're learning from meteorites, which are scientifically important as 'alien visitors' to Earth whose composition and structure tell us about the universe."

More information: Khunsa Amin el al., "The role of shape-dependent flight stability in the origin of oriented meteorites," *PNAS* (2019). www.pnas.org/cgi/doi/10.1073/pnas.1815133116

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