

# There could be meteors traveling at close to the speed of light when they hit the atmosphere

February 19 2020, by Matt Williams

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Artist's concept of the meteorite entering Earth's atmosphere. Credit: University of Oxford

It's no secret that planet Earth is occasionally greeted by rocks from space that either explode in the atmosphere or impact on the surface. In addition, Earth regularly experiences meteor showers whenever it passes

through clouds of debris in the solar system. However, it has also been determined that Earth is regularly bombarded by objects that are small enough to go unnoticed—about 1 mm or so in size.

According to a new study by Harvard astronomers Amir Siraj and Prof. Abraham Loeb, it is possible that Earth's atmosphere is bombarded by larger meteors—1 mm to 10 cm (0.04 to 4 inches) – that are extremely fast. These meteors, they argue, could be the result of nearby supernovae that accelerate particles to sub-relativistic or even relativistic speeds—from several thousand times the [speed](#) of sound to a fraction of the speed of light.

Their study, titled "Observational Signatures of Sub-Relativistic Meteors", recently appeared on the arXiv pre-print server and has been submitted to the *Astrophysical Journal*. Their work addresses an ongoing mystery in astrophysics, which is whether or not the ejecta created by a supernova can be accelerated to relativistic speeds and travel through the interstellar medium to reach Earth's atmosphere.

The existence of these kinds of meteors, which would measure about 1 mm in diameter (0.04 inches), has been proposed by several astronomers in the past, including Lyman Spitzer and Satio Hayakawa. The question of whether or not they could survive the trip through interstellar space has also been studied at length. As Siraj explained to Universe Today via email:

"Empirical evidence indicates that at least one supernova has rained heavy elements on Earth in the past. Supernovae are known to release significant quantities of dust at sub-relativistic speeds. We also see evidence of clumpiness or 'bullets' in supernova ejecta. The fraction of mass contained in small clumps is unknown, but if just 0.01% of the dust ejecta is contained in objects of millimeter size or larger, we would expect one to appear in the Earth's atmosphere as a sub-relativistic

meteor every month (based on the rate of supernovae in the Milky Way galaxy)."



Meteors are pieces of comet and asteroid debris that strike the atmosphere and burn up in a flash. A brilliant Perseid meteor streaks along the summer Milky Way as seen from Cinder Hills Overlook at Sunset Crater National Monument—12 August 2016 2:40 A.M. (0940 UT). It left a glowing ion trail that lasted about 30 seconds. The camera caught a twisting smoke trail that drifted southward over the course of several minutes. Credit: Jimmy Westlake

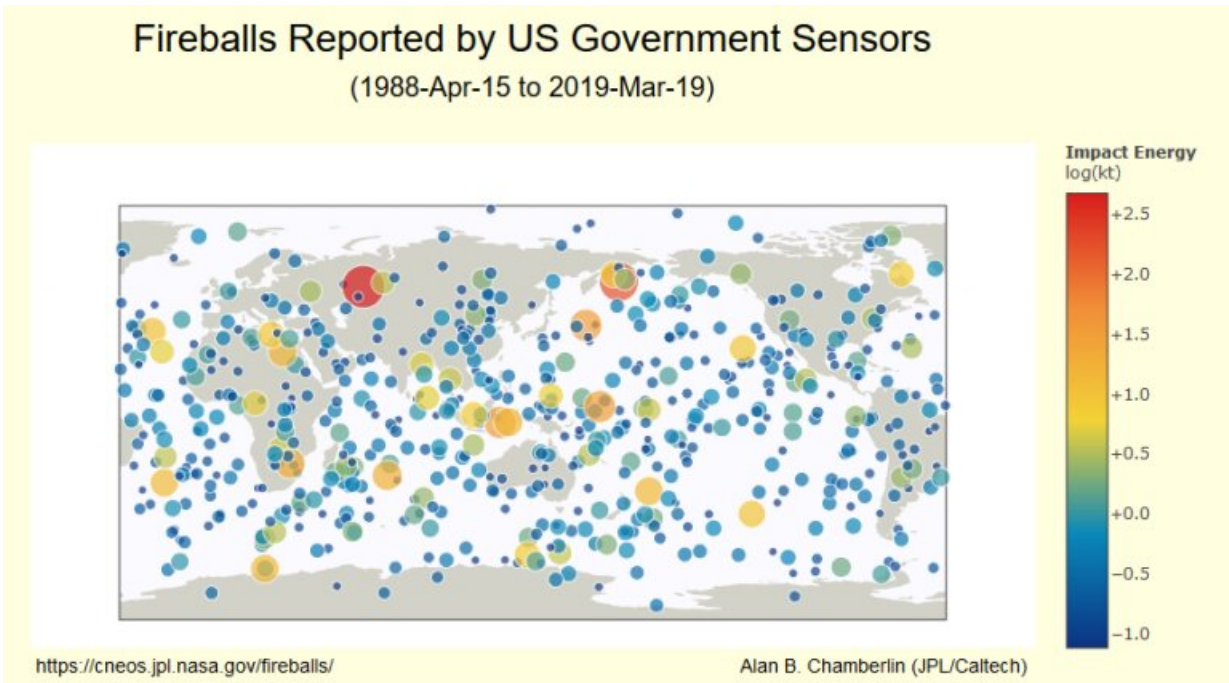
Despite having a sound theoretical basis, the question remains as to whether or not meteors larger than a grain of dust enter Earth's

atmosphere at sub-relativistic or [relativistic speeds](#). These would be meteors that measure 1 mm (0.04 in), 1 cm (0.4 in), or 10 cm (4 in) in diameter. Much of the problem has to do with our current search methodology, which is simply not set up to look for these kinds of objects.

"Meteors typically travel near 0.01% of the speed of light," said Siraj. "Therefore, current searches are tuned to find signals from objects moving at that speed. Meteors from supernovae would travel a hundred times faster (around 1% of the speed light), and so their signals would be significantly different from typical meteors, making them easily missed by current surveys."

For the sake of their study, Siraj and Loeb developed a hydrodynamic and radiative model to track the evolution of hot plasma cylinders that result from sub-relativistic meteors passing through the atmosphere. From this, they were able to calculate what kind of signals would be produced, thereby providing an indication of what astronomers should be on the lookout for. As Siraj explained:





Map displaying location and energy of meteor explosions detected by CNEOS.  
Credit: NASA/CNEOS

"We find that a sub-relativistic meteor would give rise to a shock wave that could be picked up by a microphone, and also a bright flash of radiation visible in [optical wavelengths](#)—both lasting for about a tenth of a millisecond. For meteors as small as 1 mm, a small optical detector (1 square centimeter) could easily detect the flash of light out to the horizon."

With this in mind, Siraj and Loeb outlined the kind of infrastructure that would allow astronomers to confirm the existence of these objects and study them. For instance, new surveys could incorporate infrasound microphones and optical-infrared instruments that would be able to detect the acoustic signature and optical flashes created by these objects entering our atmosphere and the resulting explosions.

Based on their calculations, they recommend that a global network of about 600 detectors with all-sky coverage, which could detect a few of these types of meteors per year. There is also the option of searching through existing data for signs of sub-relativistic and relativistic meteors. Last but not least, there is the possibility of using existing infrastructure to look for signs of these objects.

A good example of this, Siraj explained, is to be found in NASA's Center for Near-Earth Object Studies (CNEOS) network and database: "In addition, we note that the U.S. government's global classified network of sensors (including microphones and optical detectors) that provides the CNEOS Fireball and Bolide Database likely comprises a capable existing infrastructure. We urge the U.S. government to declassify broader swaths of the CNEOS data so scientists can search for sub-relativistic [meteors](#) without spending more taxpayer money to develop a new global network—with one already in operation!"

The payoff for this would be nothing less than the ability to study an entirely new set of objects that regularly interact with Earth's atmosphere. It would also provide a new perspective to the study of supernovae by allowing astronomers to place important constraints on the ejecta they produce. With this in mind, a low-cost, [global network](#) of all-sky cameras seems well worth the investment.

**More information:** Observational Signatures of Sub-Relativistic Meteors: [arxiv.org/pdf/2002.01476.pdf](https://arxiv.org/pdf/2002.01476.pdf)

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