

Watching the blink of a star to size up asteroids for NASA's Lucy Mission

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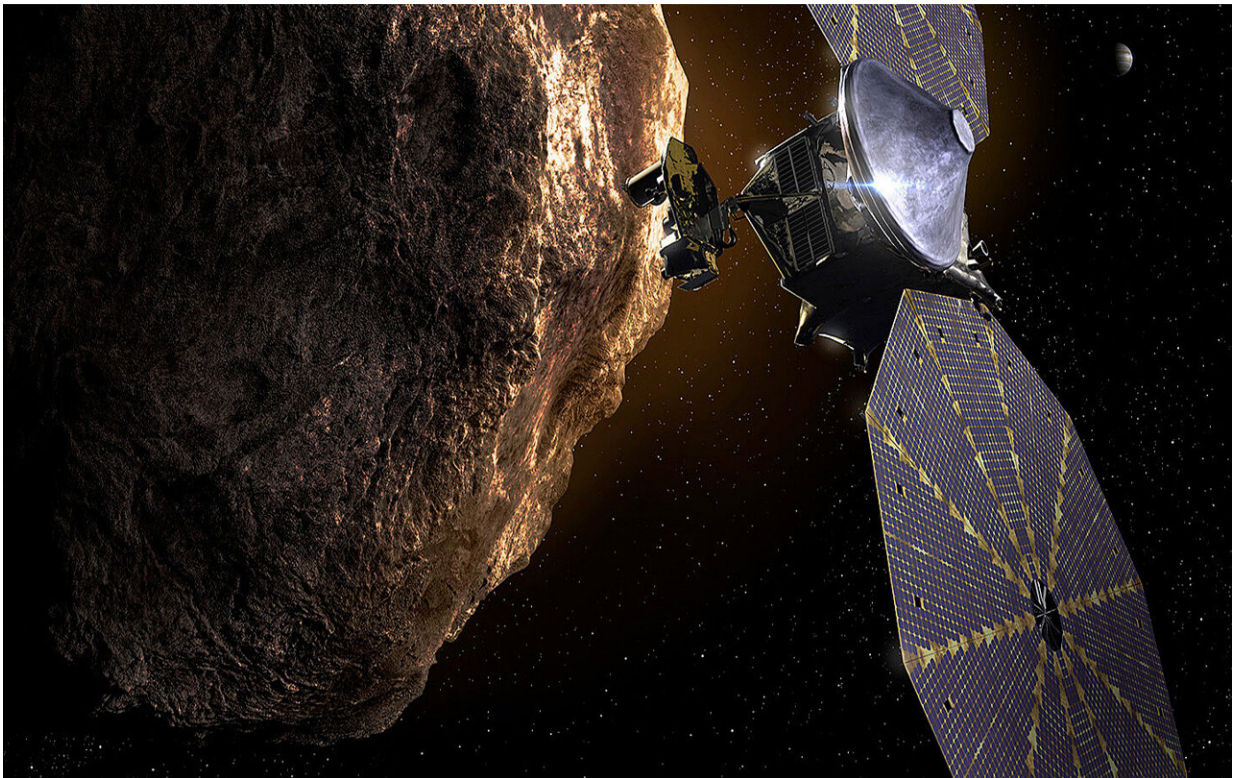


Illustration of the Lucy spacecraft near a large asteroid with Jupiter visible in the distant background. Credit: Southwest Research Institute.

Gathering near Las Vegas recently, dozens of astronomers spread throughout the region, pointed their telescopes at the sky and waited for the moment on Oct. 20 that the light from a faraway star blinked out.

It was an event so miniscule it would have been easy to miss. Yet the data gathered in those few seconds will contribute to the success of NASA's Lucy mission, which launched from Cape Canaveral Space Force Station in Florida on Oct. 16.

The star appeared to briefly blink out because the asteroid Eurybates had passed in front of it. Eurybates is one of a handful of asteroids Lucy will visit over the next 12 years.

As Eurybates eclipsed the star, a phenomenon scientists call an "occultation," a 40-mile- (300-kilometer-) wide shadow the size of the asteroid passed over the region. By spreading out inside the shadow's predicted path across Nevada, astronomers sought to measure the width of Eurybates down to several hundred feet, or a couple hundred meters, and to ascertain its shape. This information will be used by Lucy researchers to supplement data gathered by the Lucy spacecraft's close flyby of Eurybates in 2027, which is designed to determine what the asteroid is made of and where in the solar system it formed billions of years ago.

Why occultations?

An occultation is any event where one celestial object passes in front of another, blocking the latter object from an observer's view. The best-known example is a solar eclipse, which occurs when the Moon passes between the Sun and Earth, blocking the Sun from our view.

"It really does look like a star just vanished," said Marc Buie, occultation science lead for the Lucy mission at the Southwest Research Institute, which is headquartered in San Antonio. Buie helped coordinate the Eurybates observations in Nevada. "It's kind of a weird thing to see, but an occultation gives us really valuable information."

Observing occultations is one of the tools scientists have for gathering precise information about the size and shape of Lucy's target destinations, known as "Trojan" asteroids. These Trojans are clustered in two swarms that orbit the Sun at about the same distance as Jupiter (though they're as far away from Jupiter as they are from the Sun). Trojan asteroids are remnants of the early solar system, with the largest ones named after characters from Greek mythology. The Lucy mission, for the first time, will analyze seven of them up close, helping scientists hone the theory of how the planets formed and ended up in their current locations.

While scientists can spot Trojan asteroids using powerful observatories such as NASA's Hubble Space Telescope (and in fact discovered a moon of Eurybates this way in 2018), the asteroids appear only as small points of light, so it's challenging to precisely determine their true sizes and shapes.

"Occultations are one way for us to learn as much as we can about the objects before Lucy gets there, so that we can make the most of the brief opportunity we'll get when the spacecraft is super close to each target," said Brian Keeney, an occultation specialist for the Lucy mission at the Southwest Research Institute.

After Lucy reaches each asteroid, scientists will be able to measure each asteroid's mass. That information, combined with size and shape data from flybys, occultations, and other Earth-based techniques, will help reveal the density of each asteroid. Density tells scientists about composition, or whether an asteroid is made mostly of ice or of rock. Scientists hope to compare the compositions of the Trojan asteroids to figure out if they came from the same or different parts of the solar system about 4.5 billion years ago, and how the Trojans relate to other asteroids in the solar system.

"Lucy will see each asteroid's surface, but we need to learn more about the interior, which is where occultations can help," Keeney said.

Watching a star disappear

To prepare for an occultation, astronomers predict a shadow's path across Earth, based on the known orbit of the asteroid and the precise position of the star to be occulted. Then they set up dozens of telescopes along a line perpendicular to that path and wait for the asteroid to eclipse a specific star. They count the seconds that starlight blinks out as the asteroid passes in front of it and then use the asteroid's known velocity to calculate its width.

Since the occultation time, and thus width, is different at each point on the line where telescopes are stationed—with each telescope station corresponding to a different line across the asteroid—scientists can also determine the shape of an asteroid's silhouette by combining data from each telescope. By observing multiple occultations of the same asteroid, scientists can catch different sides of the asteroid and combine their two-dimensional silhouette projections into a three-dimensional shape model.

"Occultations have proven to be an excellent technique to maximize the science return of missions such as Lucy," said Adriana Ocampo, program executive for the Lucy mission based at NASA Headquarters in Washington.

Accurate predictions of future occultation times and locations rely on impeccable information related to star and asteroid locations. When Buie started tracking occultations in the 1980s, the data available left him with huge areas of uncertainty, meaning his team could end up miles outside an asteroid's shadow. To catch an occultation of a 10-mile- (20-kilometer-) wide asteroid, for instance, Buie would have spread telescopes out along a 190-mile (300-kilometer) path. Today, that area is

six times smaller.

Astronomers' predictions have improved dramatically thanks to Hubble and ESA's (the European Space Agency) Gaia satellite, which help pin down the precise locations of nearly 2 billion stars. Additionally, the trajectories of Lucy's fast-moving target asteroids are constantly monitored and refined using ground-based telescopes and occasionally Hubble.

How to catch an occultation

Buie calls occultation events "mega campaigns," as they require large teams, precise location predictions for each telescope, and many telescopes for successful data collection. In Nevada, for instance, professional and amateur astronomers from across the country, including teachers and high school students, used 37 telescopes to observe Eurybates.

But occultations happen all over world, from Argentina to South Africa, Senegal and Spain. Buie and other Lucy scientists must coordinate travel to these destinations, find observation volunteers locally, and train them.

"Occultations provide an important international collaborative factor of scientific advancement for the good of humanity, excitement, engagement and inspiration which is at the core of NASA's mission," said Ocampo, who participates in observation campaigns.

On top of the logistical challenges of organizing occultation campaigns, scientists must contend with unpredictable weather. Successful campaigns depend on clear skies. As observers waited for Eurybates occultation in Nevada, they saw clouds moving toward them.

"If that Eurybates [occultation](#) had been an hour later, nobody would've

seen anything," Buie said. "The clouds would have wiped us out."

The team will continue to observe occultations until Lucy's last flyby of Trojan asteroid Patroclus in 2033, even in the face of bad weather.

Provided by NASA's Goddard Space Flight Center

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