How a speck of light becomes an asteroid

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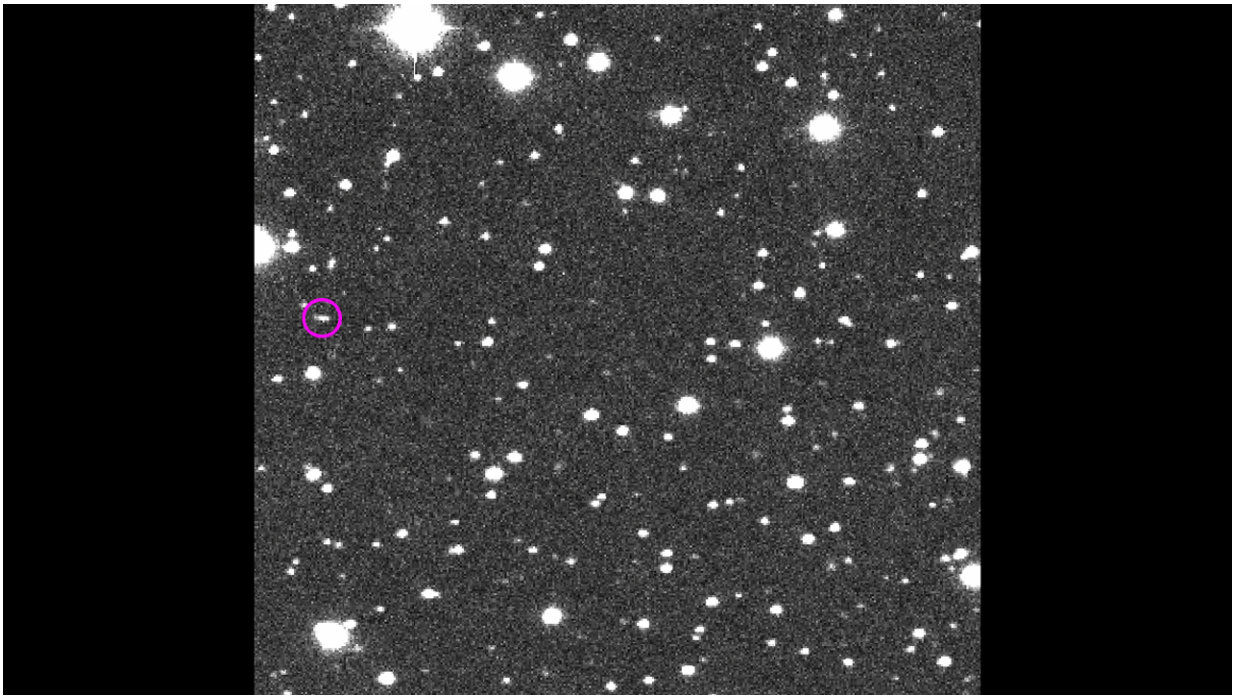

In this sequence of four images taken during one night of observation by the Catalina Sky Survey near Tucson, Arizona, the speck of light that moves relative to the background stars is a small asteroid that was, at the time, about as far away as the moon. Credit: NASA/JPL-Caltech/CSS-Univ. of Arizona

On the first day of the year 1801, Italian astronomer Gioacchino Giuseppe Maria Ubaldo Nicolò Piazzi found a previously uncharted "tiny star" near the constellation of Taurus. The following night Piazzi again observed this newfound celestial object, discovering that the speck had changed its position relative to the nearby stars. Piazzi knew that real

stars were so far away that they never wandered—that they always appeared in the sky as fixed in location relative to each other. Due to the movement of this new object, the astronomer to the king of the two Sicilies suspected he had discovered something much closer—something within our solar system. Piazzi made history's first asteroid discovery. He named it after the Roman goddess for agriculture: Ceres.

While astronomers of Piazzi's era eventually understood there were many more small rocky bodies to be found, for decades after the Ceres discovery, asteroid detections were few and far between. Even a half-century after Ceres' detection, there were only 15 known asteroids. But as time marched on, so did astronomers' equipment, techniques and interest in hunting asteroids. By 1868 the number of known asteroids had reached 100. By 1923 it was 1,000. Today, it is more than half a million.

As a nod to the importance of these objects, the United Nations has declared June 30 International Asteroid Day.

Most asteroids are farther from the sun than Mars is—more than 1.5 times farther from the sun than Earth's orbit is. Asteroids that come closer to the sun than about 1.3 times Earth's distance from the sun are called near-Earth asteroids. The term "near" in near-Earth asteroid is actually a bit of a misnomer, since most of these bodies do not come close to Earth at all. As of this month, more than 16,000 of them are known. Near-Earth asteroids and comets that come within the neighborhood of Earth's orbit are, together, classified as near-Earth objects, or NEOs.

Thanks to new technology, better search techniques and a team of professional and dedicated amateur astronomers hunting for them, the number of known NEOs expands by about five every night of the year.

Ever wonder how these small celestial objects are discovered?

"Just as in Piazzi's day, it usually starts with just a speck of light in an astronomer's telescope," said Paul Chodas, manager of the Center for Near-Earth Object Studies (CNEOS) at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "Even with some of the most powerful optical telescopes on the planet tasked with hunting asteroids, they appear as mere specks of light in the sky because they are so small. When an astronomer finds a speck that is moving, that's when the fun begins."

The Planetary Defense Coordination Office at NASA Headquarters in Washington is responsible for finding, tracking and characterizing potentially hazardous asteroids, issuing warnings about possible impacts, and coordinating U.S. government planning for response to an actual impact threat. Almost always, a new asteroid detection is courtesy of telescopes that are sponsored by NASA.

The planetary defense office oversees the Near-Earth Object Observation Program, which in turn funds the Catalina Sky Survey in Arizona and the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) in Hawaii. Both projects upgraded their telescopes in 2015, significantly improving their asteroid and near-Earth object discovery rates.

"Telescopes funded by outside institutions and even some amateurs are also involved with NEO discovery and do other important asteroid-related work," said Chodas. "But, at present, Catalina and Pan-STARRS are our most powerful asteroid detection instruments. Between these two surveys, four telesopes in all, about 90 percent of all new NEO discoveries are made."

At the heart of each one of these survey telescopes is a hyper-upgraded

version of the same kind of camera chip (called a CCD, or charge-coupled device) that is inside our cellphones. With the exception of nights that have too much rain or snow, or several nights surrounding a full moon (when moonlight can drown out the faint light of an asteroid), the dedicated observers of Catalina and Pan-STARRS open up their telescopes every night they can find a hole in the cloud cover and take 30-second exposure after 30-second exposure of the heavens above.

Survey astronomers are on the lookout for points of light that move relative to the more distant and fixed background stars. To find them, they take three or more images of the same region of the sky (called a field), separated by several minutes. On a good night a survey will take several hundred photos of the sky.

When survey astronomers find a point of light that appears to move across the same field in a series of images of the same region of the sky, they check it against the predicted positions of all the known objects in the catalog maintained by the NASA-sponsored Minor Planet Center (MPC) in Cambridge, Massachusetts. If the newfound, moving point of light does not match up with the predicted position and motion of an object in the MPC's database of known asteroids and comets, there is a good chance it's a new discovery—but there is more work to be done.

Computers do much of this detection work, but a prudent astronomer also double checks the work, making sure the points of light are not some kind of reflection of a nearby star, or perhaps a faulty pixel on the CCD. If confident about the potential space-rock discovery, the astronomer ships the discovery's coordinates (known as the "astrometry") to the MPC's NEO Confirmation Page, where it is given a temporary identifier—like YL9E0A0. The MPC also computes an initial (approximate) orbit for the still-to-be-confirmed NEO.

CNEOS has a system called Scout, which actively monitors the MPC

confirmation page, getting the data from each potential new asteroid discovery and automatically computing the possible range of future motions even before these objects have been confirmed as discoveries.

"If our calculations indicate a new discovery could be coming close by Earth, we call in the reinforcements," said Chodas. "NASA has a worldwide network of astronomers who perform follow-up observations. They take the latest astrometry and try to find the new speck of light, too. If they do find it, they measure its coordinates and send their follow-up astrometry back to the MPC, where it is added to a table of information about the object. This follow-up is extremely important. It really helps expand our understanding of a new discovery's orbit."

Usually it takes two to three nights of observations for enough information to be collected on a new discovery for the MPC to verify that a speck of light is indeed a near-Earth object. When that transformation occurs, the MPC removes it from its confirmation page and replaces its temporary tag with a more permanent name, which always starts out with the year it was discovered and then an alphanumeric code indicating the half-month of discovery and the sequence within that half-month. The MPC then generates a Minor Planet Electronic Circular which contains all known astrometry and the preliminary orbit of the object. The MPC announces the new asteroid discovery in an email to those who are interested in that sort of thing.

"We are interested all right," said Chodas. "And we stay interested even after a discovery is announced, because we are in the asteroid- and comet-hunting game for the long run. The more information we get on a celestial object—new discovery or old—the more we refine our knowledge of its orbit."

All the new orbits are automatically picked up by a computer system at JPL called Sentry, where all asteroid and comet orbits, including those

with future close-Earth approaches, are calculated and impact probabilities are assessed daily.

"While NASA is leading the way in near-Earth object survey, we are not resting on our laurels," said Lindley Johnson, NASA's planetary defense officer. "New optical systems are coming on line, new computer programs are being created, and we are exploring new technologies both ground- and space-based that will further accelerate our discovery, characterization and orbital analysis of these potential threats."

Provided by Jet Propulsion Laboratory