The Large Synoptic Survey Telescope could find more of Earth's transient moons

November 20 2019, by Matt Williams

Artist’s impression of the NEO double asteroid 1999 KW4. Credit: ESO

It is a well-known astronomical convention that Earth has only one natural satellite, which is known (somewhat uncreatively) as "the moon." However, astronomers have known for a little over a decade that Earth also has a population of what are known as "transient moons." These are a subset of near-Earth objects (NEOs) that are temporarily scooped up by Earth's gravity and assume orbits around our planet.

According to a new study by a team of Finish and American astronomers, these temporarily captured orbiters (TCOs) could be studied with the Large Synoptic Survey Telescope (LSST) in Chile, which is expected to become operational by 2020. By examining these objects with the next-generation telescope, the study's authors argue that we stand to learn a great deal about NEOs, and even begin conducting missions to them.

The study, which recently appeared in the journal *Icarus*, was led by Grigori Fedorets, a doctoral student from the University of Helsinki's department of physics. He was joined by physicists from the Luleå University of Technology, the University of Washington's Data Intensive Research in Astrophysics and Cosmology (DIRAC) Institute, and the University of Hawaii.

The concept of TCOs was first postulated in 2006 following the discovery and characterization of RH120, an object measuring two to three meters (6.5 to 10 feet) in diameter that normally orbits the sun. Every 20 or so years, it makes close approaches to the Earth-moon system and is temporarily captured by Earth's gravity.

Subsequent observations of NEOs such as asteroid 1991 VG and meteor EN130114 added further weight to this theory and allowed astronomers to place constraints on TCO populations. This led to the conclusion that temporarily captured satellites come in two populations. On the one hand, there are TCOs, which make the equivalent of at least one revolution around the Earth while being captured.

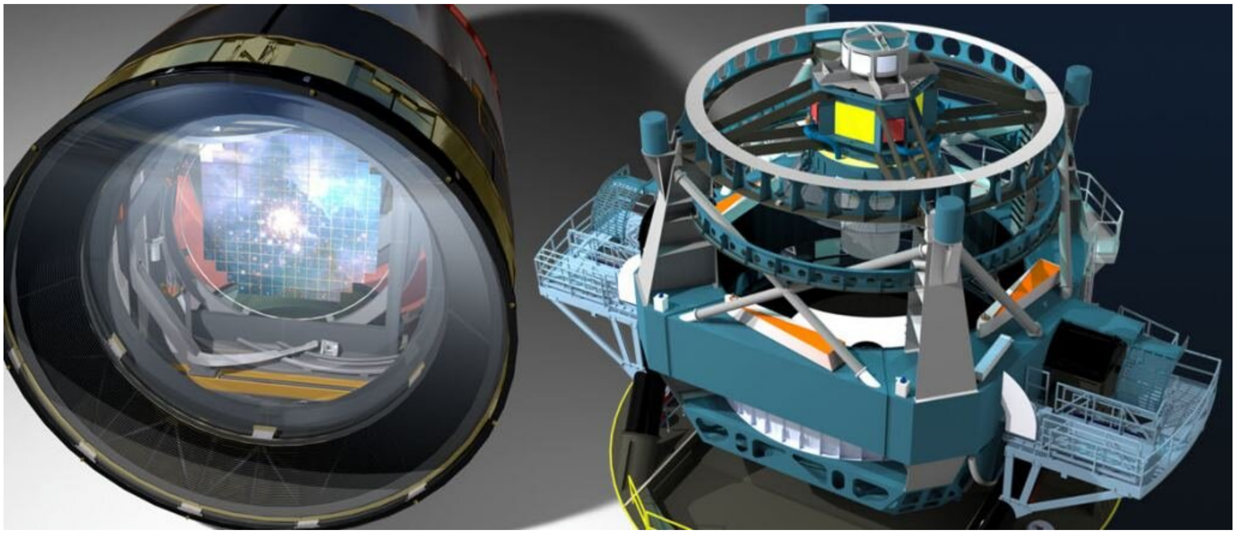
Second, there are temporarily captured flybys (TCFs), which make the equivalent of less than one revolution while being captured. According to Fedorets and his colleagues, these objects are an appealing target for research and rendezvous with spacecraft, either in the form of CubeSat-sized missions or larger spacecraft that could conduct sample-return missions.

For starters, the study of these objects would allow astronomers to constrain the size and frequency of NEOs that range in size from one-10th of a meter to 10 meters in diameter, which are not well-understood. Typically, these objects are too small and too faint for most telescopes and techniques to observe effectively.

Monitoring and studying this special class of NEOs is where the LSST comes into play. Because of its high-resolution and sensitivity, the LSST is expected to become one of the primary facilities for the discovery of NEOs and potentially hazardous objects that are otherwise very difficult to detect. As Fedorets told universe Today via email:

"[E]ven for LSST, the vast majority of the transient moons will be too faint to discover. However, it will be the only survey capable of discovering any transient moons on a regular basis… The features of LSST that are particularly suitable for TCO detection include: a large field of view; limiting magnitude V=24.7, allowing detections of faint objects; operational mode with back-to-back observations and rapid follow-up of the same field initially on the same night, helping to identify fast-moving trailed objects."

Once it is up and running, the LSST telescope will conduct a 10-year survey that will address some of the most pressing questions about the structure and evolution of the universe. These include the mysteries of dark matter and dark energy and the formation and structure of the Milky Way. It will also dedicate observation time to the solar system in the hopes of learning more about minor planet populations and NEOs.



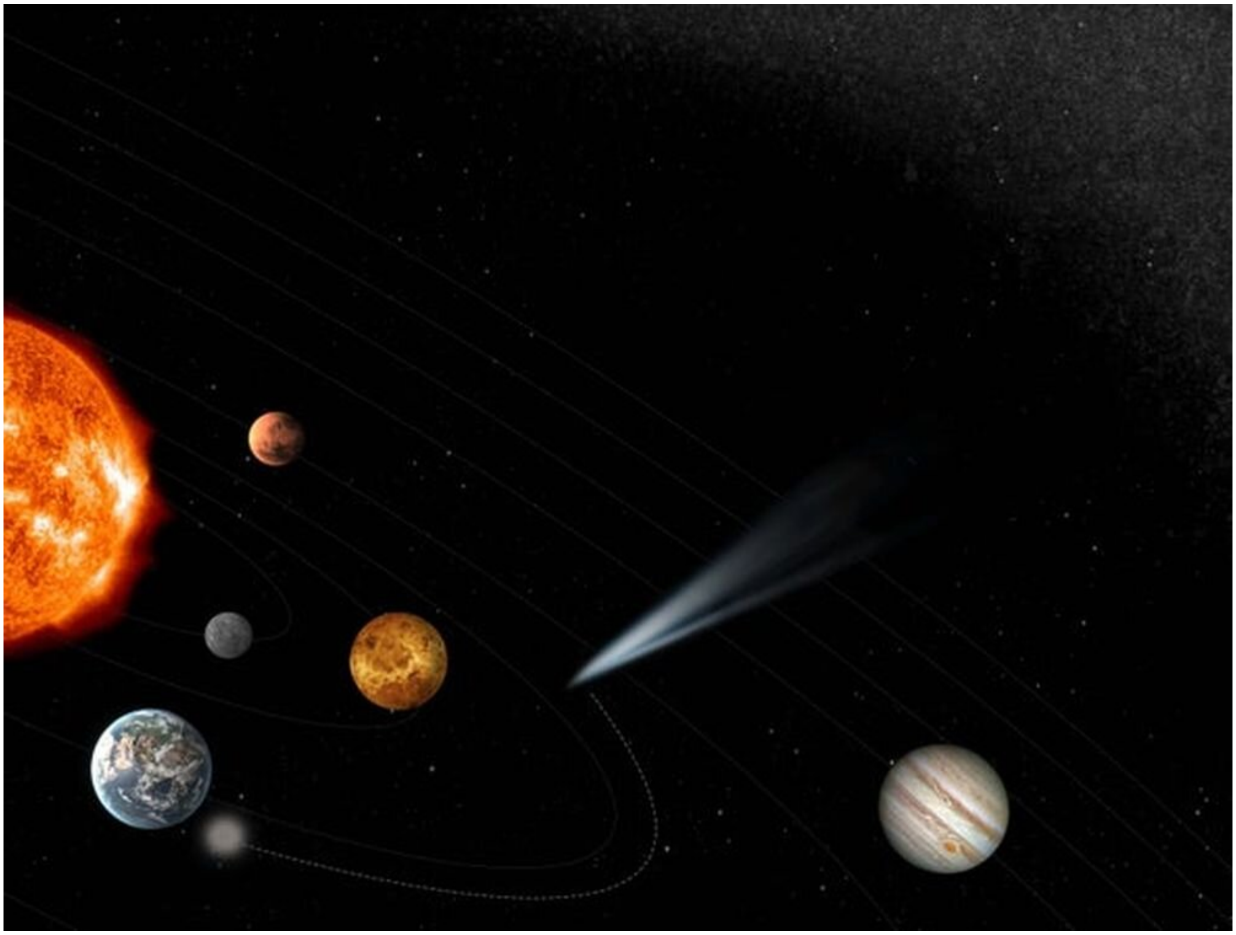
Artist's impression of the Large Synoptic Survey Telescope. Credit: lsst.org

To determine how many TCOs the LSST will detect, the team ran a series of simulations. Their work builds on a previous study conducted in 2014 by Dr. Bryce Bolin of Caltech and colleagues, in which they assessed the current and next-generation astronomical facilities. It was this study that suggested the LSST would be extremely effective at detecting transient moons.

For their study, Fedorets reconsidered the work of Bolin and conducted their own analysis. He wrote, "[A] synthetic population of transient moons was ran through the LSST pointing simulation. The initial analysis showed that the Moving Object Processing System of LSST could recognize only three objects in four years (cadence of three detections over a period of 15 days). This seemed [like] a small number, so we performed additional analysis. We selected all observations with at least two observations, and performed orbit determination and orbital linking with methods alternative to MOPS. This special treatment increased the number of observable transient moon candidates by an order of magnitude."

In the end, Fedorets and his team concluded that using the LSST and modern automatic asteroid identifications software—specifically, a moving-object processing system (MOPS)—a TCO could be discovered once every year. That rate could be increased to one TCO every two months if additional software tools are developed specifically for the identification of TCOs that could complement a baseline MOPS.

Ultimately, the study of TCOs will be beneficial to astronomers for a number of reasons. For starters, there exists a gap between the study of larger asteroids and smaller bolides—small meteors that regularly burn up in Earth's atmosphere. Those that fall in-between, which typically measure between one and 40 meters (~three to 130 feet) in diameter, are currently not well-constrained.



An artist’s overview of the mission concept for the Comet Interceptor spacecraft, which will fly from the vicinity of Earth to rendezvous with a long-period comet or interstellar object inbound from the outer solar system. Credit: ESA

"Transient moons are a good population to constrain that size range, as at those size ranges, they should appear regularly and be detected with LSST," says Fedorets. "Moreover, TCOs are outstanding targets for [in-situ] missions. They have been delivered "for free" to the vicinity of the Earth. Therefore, a relatively small amount of fuel is required to reach them. Potential missions could be designed as in situ flyby missions (e.g., of CubeSat class), or as first steps in asteroid resource utilization."

Another benefit of the study of these objects is that they will help astronomers gain a better understanding of potentially hazardous objects (PHOs). This term is used to describe asteroids that periodically cross Earth's orbit and pose a risk of collision. While they have similar observational characteristics to TCOs, they can be discerned based on their orbits alone.

Of course, Fedorets emphasized that while TCOs spend months in geocentric orbits, a possible mission to study one of them would have to be rapid-response in nature. Luckily, the ESA is developing such a mission in the form of their Comet Interceptor, which will be launched to a stable hibernating orbit and activated once a comet or asteroid enters Earth's orbit.

A greater understanding of Earth's temporary satellites, potentially hazardous objects and near-Earth asteroids is merely one of many benefits that are expected to come from next-generation telescopes like the LSST. These instruments will not only allow astronomers to see farther and with greater clarity, thus expanding our knowledge of the solar system and the cosmos, they could also ensure our long-term survival as a species.

More information: Grigori Fedorets et al. Discovering Earth's transient moons with the Large Synoptic Survey Telescope, *Icarus* (2019). DOI: 10.1016/j.icarus.2019.113517

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