Distant asteroid revealed to be a complex mini geological world

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Artistic representation of the Trojan system showing the large 250 km dual shape Hektor and its 12 km moon. Credit: H. Marchis & F. Marchis

After 8 years of observations, scientists from the SETI Institute have found an exotic orbit for the largest Trojan asteroid, (624) Hektor—the only one known to possess a moon. The formation of this system made of a dual primary and a small moon is still a mystery, but they found the asteroid could be a captured Kuiper body product of the reshuffling of

giant planets in our solar system. The results are being published today in Astrophysical Letters.

This study, based on W. M. Keck Observatory data and photometric observations from telescopes throughout the world, suggests that the asteroid and its moon are products of the collision of two icy asteroids. This work sheds light on the complex youth of our solar system, when the building blocks that formed the core of Giant planets and their satellites were tossed around or captured during the giant planet migrations.

In 2006, a small team of astronomers led by Franck Marchis, astronomer at the Carl Sagan center of the SETI Institute, detected the presence of a small 12 km diameter moon around the large Trojan asteroid (624) Hektor using the 10 m Keck II telescope atop Mauna Kea, fitted with the NIRC-2 (Near-Infrared Camera 2) instrument behind the adaptive optics and laser guide star system (LGS-AO).

Since then, they collaborated with several researchers from University of California at Berkeley in order to determine the orbit of this moon and understand the origin of the system. Trojan asteroids are those that are temporarily trapped in regions 60 degrees in front or 60 degrees behind the planet Jupiter in its orbit around the Sun. They are difficult to study since they are small and faint.

While the asteroid has been studied for 8 years, there were a couple of significant challenges before a paper could be published, according to Marchis. "The major one was technical: the satellite can be seen only with a telescope like Keck Observatory's fitted with LSG-AO, but time on the mighty Keck's is highly prized and in limited availability," he said. "Secondly, the orbit of the satellite is so bizarre that we had to develop a complex new algorithm to be able to pin it down and understand its stability over time."

The research, conducted with expert assistance from colleagues at the Institut de Mécanique Céleste et de Calcul des Éphémérides (IMCCE) of the Observatoire de Paris, revealed that the 12 km moon orbits the large 250 km asteroid every 3 days at a distance of 600 km in an ellipse inclined almost 45 degrees with respect to the asteroid's equator.

"The orbit of the moon is elliptical and tilted relative to the spin of Hektor, which is very different from other asteroids with satellites seen in the main-belt," said Matija Cuk, coauthor and scientist at the Carl Sagan Center of the SETI Institute. "However, we did computer simulations, which include Hektor being a spinning football shape asteroid and orbiting the Sun, and we found that the moon's orbit is stable over billions of years."

Hektor has been known since the 1970s to be spinning rapidly (less than 7 hours) and extremely elongated. Using the high-angular resolution of the Keck II telescope, combined with a large number of photometric observations taken since 1957, the team built a refined shape hoping to get a clue to the origin of the system.

"We built several models of equal quality from the photometric data, but we favored a model made of two lobes since some of the best adaptive optics observations suggest that the Trojan asteroid has a dual structure," said Josef Durech, co-author and researcher at the Charles University in Prague.

A complex shape for the asteroid and a bizarre orbit for the moon will be matters of discussion for the scientific community. The team speculated that the moon could be ejecta produced by a slow encounter that formed the bi-lobed asteroid, but emphasized the need for robust and accurate simulations.

"We also show that Hektor could be made of a mixture of rock and ices,

similar to the composition of Kuiper belt objects, Triton and Pluto. How Hektor became a Trojan asteroid, located at only 5 times the Earth–Sun distance, is probably related to the large scale reshuffling that occurred when the giant planets were still migrating," said Julie Castillo-Rogez, researcher at the Jet Propulsion Laboratory, California Institute of Technology.

Hektor was discovered in 1907 by August Kopff. The satellite of Hektor, discovered in 2006 by Franck Marchis and his team has not been named yet. The team welcomes any idea for naming the satellite, keeping in mind that the satellite should receive a name closely related to the name of the primary and reflecting the relative sizes between these objects.

The paper entitled "The puzzling mutual orbit of the binary Trojan asteroid (624) Hektor" published today by ApJL is co-authored by F. Marchis (SETI Institute), J. Durech (Charles University), J. Castillo-Rogez (Jet Propulsion Laboratory), F. Vachier (IMCCE-Obs. De Paris), M. Cuk (SETI Institute), J. Berthier (IMCCE-Obs. De Paris), M.H. Wong (UC Berkeley), P. Kalas (UC Berkeley), G. Duchene (UC Berkeley), M. A. van Dam (Flat Wavefronts), H. Hamanowa (Hamanowa observatory)and M. Viikinkoski (Tampere University)

The W. M. Keck Observatory operates the largest, most scientifically productive telescopes on Earth. The two, 10-meter optical/infrared telescopes on the summit of Mauna Kea on the Island of Hawaii feature a suite of advanced instruments including imagers, multi-object spectrographs, high-resolution spectrographs, integral-field spectroscopy and world-leading laser guide star adaptive optics systems.

Provided by SETI Institute