In-depth measurements of the interstellar asteroid ‘Oumuamua unveil its turbulent past and verify previous reports

‘Oumuamua is the first astronomical object known to science to have entered the Solar System from the interstellar space, having been ejected from its original planetary system. Using the giant Gemini North telescope in Hawaii, a team of scientists led by astronomers from the Jagiellonian University in Kraków conducted an in-depth study of the body. Among other findings, the study revealed that ‘Oumuamua is “tumbling” through space, consistent with a collision in the distant past, as well as verified and expanded upon a number of previous reports. The results have just appeared in the latest issue of *Nature Astronomy*.

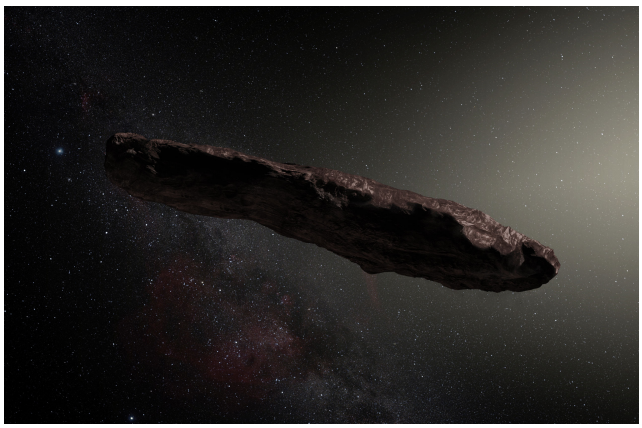

Illustration 1. *Artist’s impression of ‘Oumuamua. Credit: ESO / M. Kornmesser.*

‘Oumuamua is Hawaiian for “scout.” This unique body was discovered with the Pan-STARRS telescope on 19 October 2017 and became a scientific sensation nearly immediately after. For astronomers, however, the visit of ‘Oumuamua was hardly a surprise. They have been expecting for a long time already that darting unnoticed among the countless comets and asteroids that formed together with the Sun and planets, there are small objects born on orbits around other stars, from where they escaped to the interstellar space due to various gravitational pulls. In fact, most of the original comets and asteroids that originated in the Solar System met a similar fate in the remote past.

“*‘Oumuamua is the long-awaited first bridge between extrasolar planetary systems and our own Solar System*,” said Michał Drahus from the Astronomical Observatory of the Jagiellonian University in Kraków, one of the main authors of the study. “*Obtaining detailed information about this object is of fundamental significance to planetary research and astronomy as a whole*,” Drahus added.

The scientists began their study shortly after the Pan-STARRS team announced their discovery. “*Observations of ‘Oumuamua were very demanding: not only was ‘Oumuamua relatively dim, it also moved rapidly away from the Earth and Sun, becoming even dimmer every day*,” said Piotr Guzik, a PhD student at the Astronomical Observatory of the Jagiellonian University and another of the main authors of the study. “*We knew from the beginning that we would need the most powerful telescopes in the world to be able to get valuable measurements*,” Guzik added. The team was granted 12 hours of observation time on the Gemini North telescope in Hawaii, one of the largest and most advanced astronomical instruments on the planet. The 12 hours were also the longest time ever allocated to observations of ‘Oumuamua on a telescope of this class. “*This translated directly into the most extensive and top-quality observational data*,” said Michał Drahus.

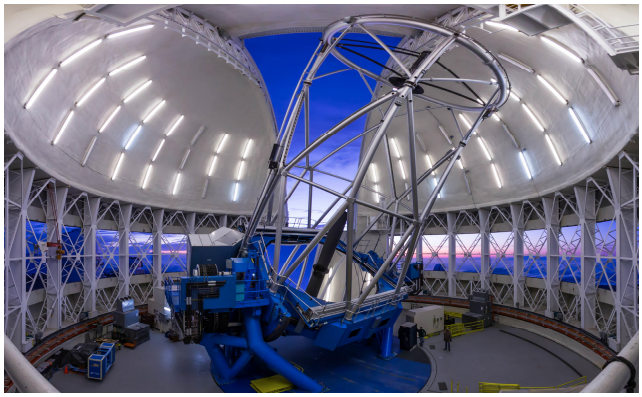

Illustration 2. *Gemini North telescope. Credit: Gemini Observatory / AURA.*

In two nights of observations, the scientists took over 400 accurate photographs of the object that, combined together, allowed them to create the most detailed image of the object’s immediate surroundings. They found that ‘Oumuamua lacks a tail and coma, which are typical for comets, thus providing the most compelling evidence that the object is physically an asteroid. “*This is a very important result, as we expected most of newly-discovered interstellar objects to be comets. But now it turns out that asteroids might be more common*,” explained Piotr Guzik.

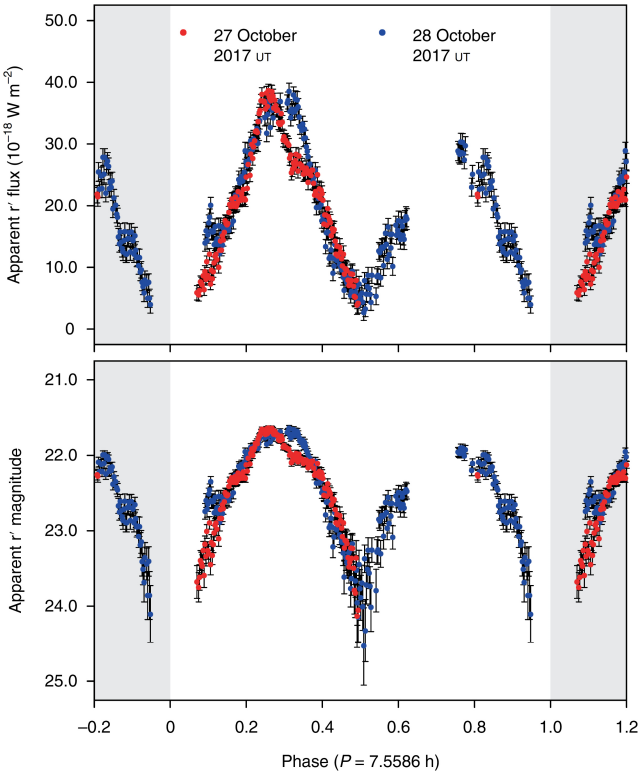

Illustration 3. *Changes in 'Oumuamua's brightness over two subsequent nights. The top panel shows the brightness in the linear flux scale and the bottom panel shows the brightness in the logarithmic magnitude scale. Credit: the Authors.*

The scientists also used the individual photographs of 'Oumuamua to monitor changes in its brightness. Such changes occur naturally when an irregularly-shaped object rotates around its axis and thereby reflects a constantly changing amount of sunlight. "*Already during our observations, we noticed that the range of changes in 'Oumuamua's brightness was very high. However, it took precise measurements before we could learn the true scale of the phenomenon*," said Guzik. The scientists found out that 'Oumuamua's brightness changed as much as eleven-fold during a full rotation, which was higher than previously thought and never seen among Solar System bodies. The observed oscillations in brightness can provide valuable information about the shape of the object, but unravelling this information is far from easy. It was time for advanced computer modelling, performed by Wacław Waniak from the Astronomical Observatory of the Jagiellonian University, co-author of the study. "*If the changes in brightness are caused by the shape of the object, then the object must be highly elongated, though not necessarily as much so as the previous, simplified, calculations suggested*," said Waniak. "*Even an elongation ratio of 5:1 is enough to explain the observed oscillations*." The team also determined that a day on 'Oumuamua lasts about 7.5 hours, the equivalent size of the object is only 150 meters, and its density – contrary to previous reports by other teams – may not be different from the typical density of Solar System's asteroids.

The high-quality observational data indicated an imperfect repeatability of the changes in brightness between the subsequent rotations of the body. "*Once we excluded other possibilities, we concluded that 'Oumuamua does not rotate smoothly, but rather, it 'tumbles' through space*," said Michał Drahus. "*Such a state can last hundreds of millions or even billions of years, and indicates that 'Oumuamua most likely underwent a collision in its original planetary system in the ancient past*," he added. The "Scout" tells us that collisions in extrasolar planetary systems might be quite common, as was the case during the very beginnings of the Solar System.

The visit of 'Oumuamua has opened a completely new chapter in planetary astronomy. "*We are extremely grateful to the Gemini observatory for granting us such a generous amount of observation time, which gave us an opportunity to take part in this groundbreaking research*," said Piotr Guzik.

The results of the team's study were published on 1 May this year in the journal *Nature Astronomy*. The study was conducted with significant financial support from the Polish National Science Centre as part of the SONATA BIS program (Project No. 2016/22/E/ST9/00109). The project is part of research conducted at the Department of Stellar and Extragalactic Astronomy of the Jagiellonian University's Astronomical Observatory.

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