Gaia turns its eyes to asteroid hunting

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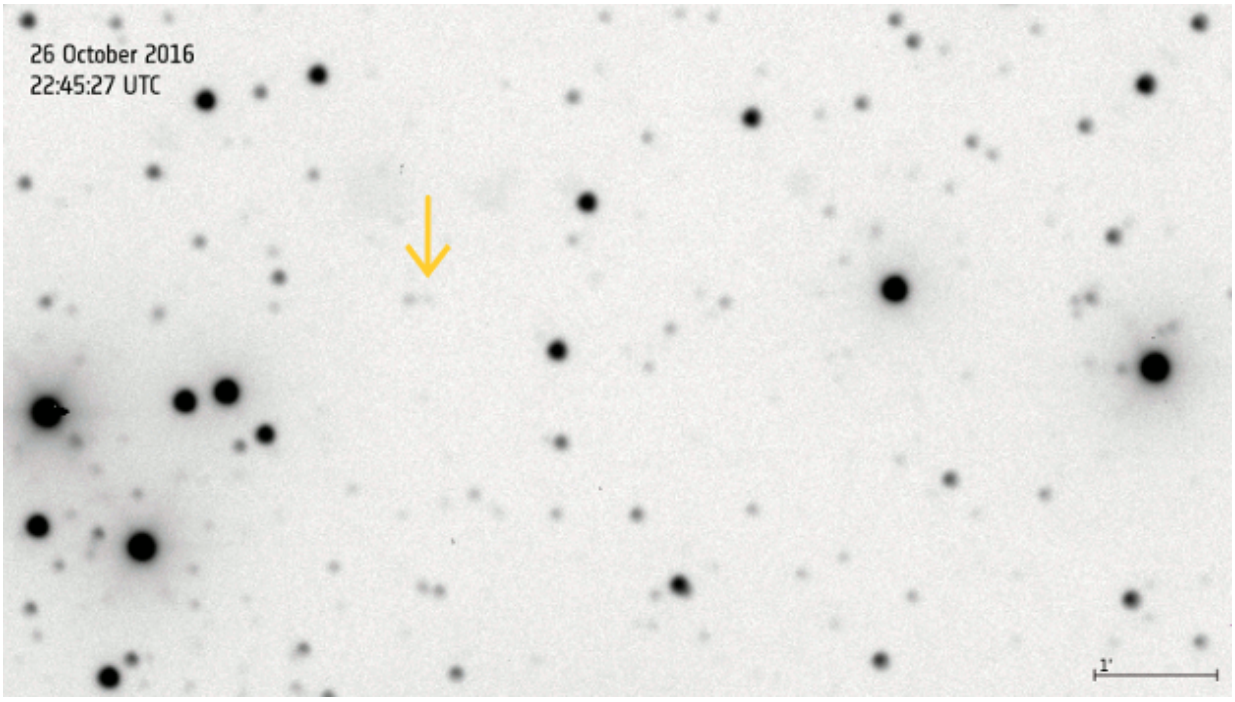


These six images show the asteroid Gaia-606 (indicated by an arrow) on 26 October 2016. The images, spanning a period of a little more than 18 minutes, were taken at the Observatoire de Haute Provence in southern France by William Thuillot, Vincent Robert and Nicolas Thouvenin (Observatoire de Paris/IMCCE). Credit: Observatoire de Haute-Provence & IMCCE

While best known for its surveys of the stars and mapping the Milky Way in three dimensions, ESA's Gaia has many more strings to its bow. Among them, its contribution to our understanding of the asteroids that litter the solar system. Now, for the first time, Gaia is not only providing

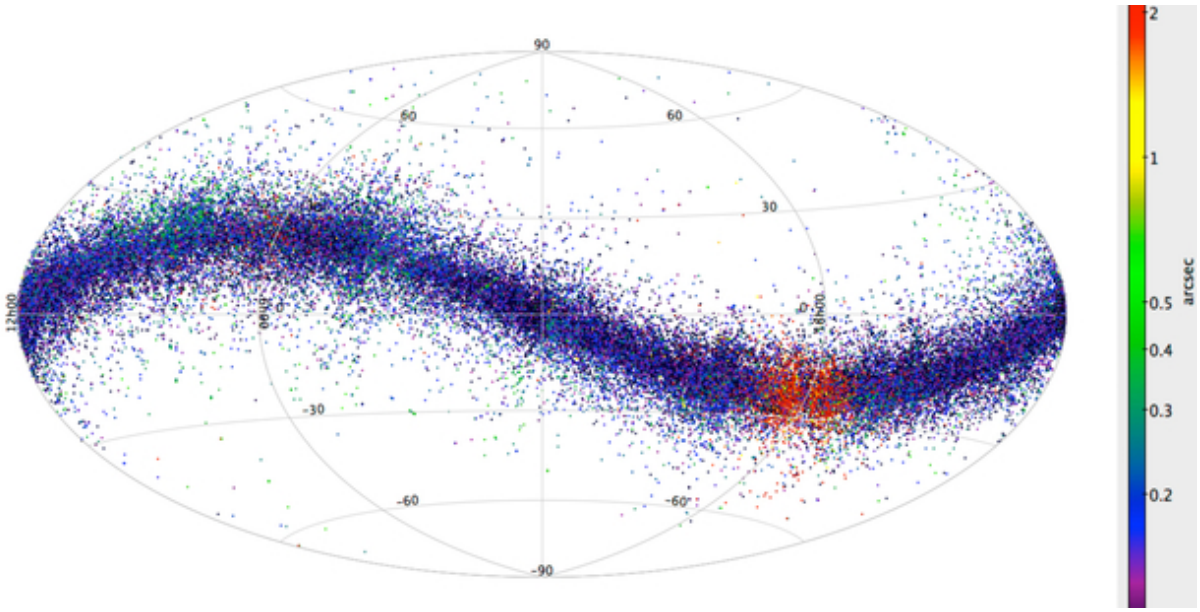
information crucial to understanding known asteroids, it has also started to look for new ones, previously unknown to astronomers.

Since it began scientific operations in 2014, Gaia has played an important role in understanding solar system objects. This was never the main goal of Gaia – which is mapping about a billion stars, roughly 1% of the stellar population of our galaxy – but it is a valuable side effect of its work. Gaia's observations of known asteroids have already provided data used to characterise the orbits and physical properties of these rocky bodies more precisely than ever before.

"All of the asteroids we studied up until now were already known to the astronomy community," explains Paolo Tanga, Planetary Scientist at Observatoire de la Côte d'Azur, France, responsible for the processing of solar system observations.

These asteroids were identified as spots in the Gaia data that were present in one image and gone in one taken a short time later, suggesting they were in fact objects moving against the more distant stars.

Once identified, moving objects found in the Gaia data are matched against known asteroid orbits to tell us which asteroid we are looking at. "Now," continues Tanga, "for the first time, we are finding moving objects that can't be matched to any catalogued star or asteroid."



As it scans the sky surveying stars in the Milky Way galaxy, Gaia has also detected a wealth of asteroids, the small rocky bodies that populate our solar system, mainly between the orbits of Mars and Jupiter. Because they are relatively nearby and orbiting the Sun, asteroids appear to move against the stars in astronomical images, appearing in one snapshot of a given field, but not in images of the same field taken at other times. Credit: ESA/Gaia/DPAC/CU4, L. Galluccio, F. Mignard, P. Tanga (Observatoire de la Côte d'Azur)

The process of identifying asteroids in the Gaia data begins with a piece of code known as the Initial Data Processing (IDT) software – which was largely developed at the University of Barcelona and runs at the Data Processing Centre at the European Space Astronomy Centre (ESAC), ESA's establishment in Spain.

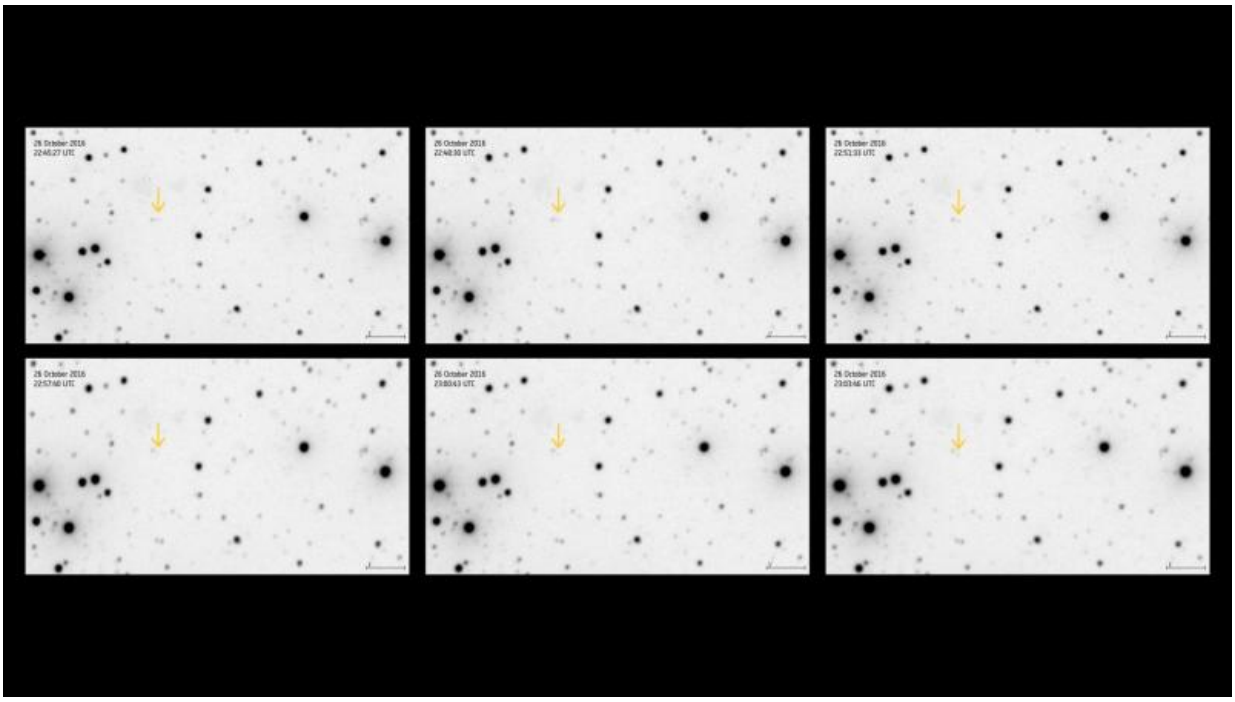
This software compares multiple measurements taken of the same area and singles out objects that are observed but cannot be found in previous observations of the area. These are likely not to be stars but, instead, solar system objects moving across Gaia's field of view. Once found, the

outliers are processed by a software pipeline at the Centre National d'Etudes Spatiales (CNES) data centre in Toulouse, France, which is dedicated to solar system objects. Here, the source is cross matched with all known minor bodies in the solar system and if no match is found, then the source is either an entirely new asteroid, or one that has only been glimpsed before and has never had its orbit accurately characterised.

Although tests have shown Gaia is very good at identifying asteroids, there have so far been significant barriers to discovering new ones. There are areas of the sky so crowded that it makes the IDT's job of matching observations of the same star very difficult. When it fails to do so, large numbers of mismatches end up in the solar system objects pipeline, contaminating the data with false asteroids and making it very difficult to discover new ones.

"At the beginning, we were disappointed when we saw how cluttered the data were with mismatches," explains Benoit Carry, Observatoire de la Côte d'Azur, France, who is in charge of selecting Gaia alert candidates. "But we have come up with ways to filter out these mismatches and they are working! Gaia has now found an asteroid barely observed before."

The asteroid in question, nicknamed Gaia-606, was found in October 2016 when Gaia data showed a faint, moving source. Astronomers immediately got to work and were able to predict the new asteroid's position as seen from the ground over a period of a few days. Then, at the Observatoire de Haute Provence (southern France), William Thuillot and his colleagues Vincent Robert and Nicolas Thouvenin (Observatoire de Paris/IMCCE) were able to point a telescope at the positions predicted and show this was indeed an asteroid that did not match the orbit of any previously catalogued solar system object.



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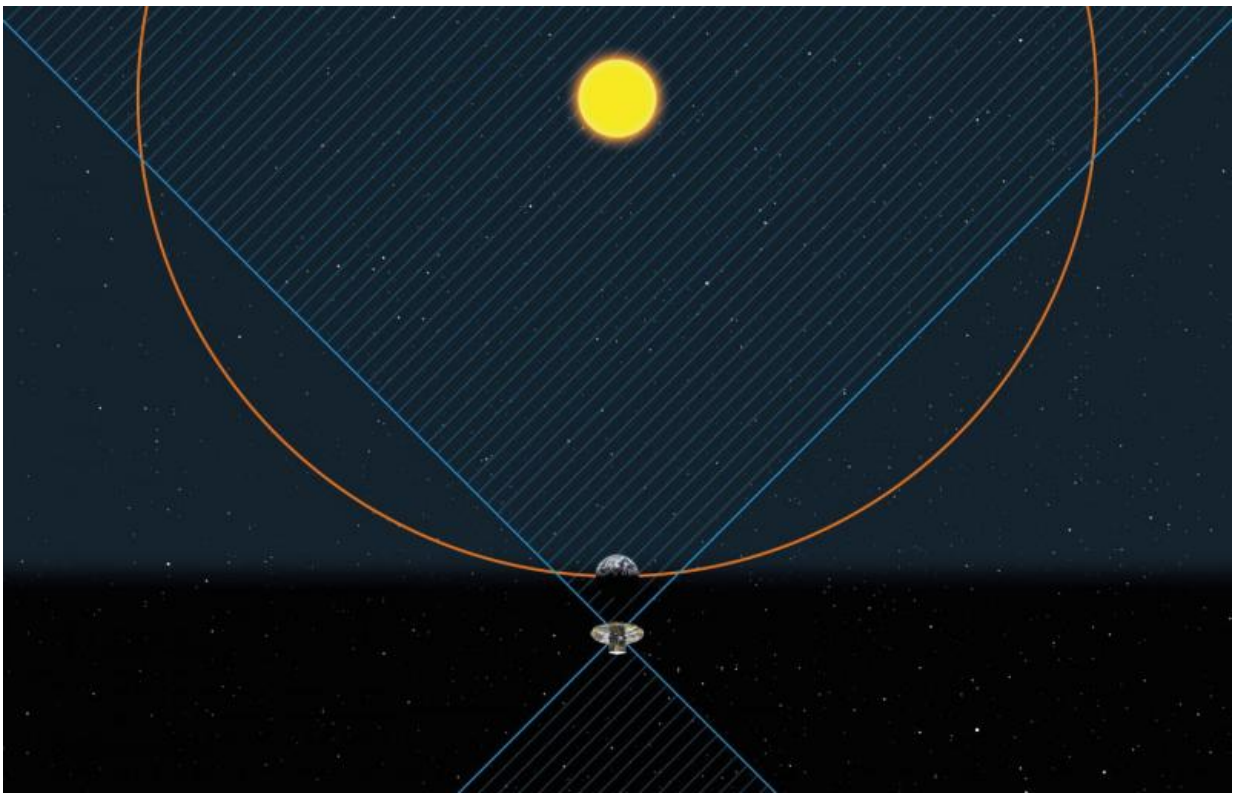
However, despite not being present in any catalogue, a more detailed mapping of the new orbit has shown that some sparse observations of the object do already exist. This is not uncommon with new discoveries where, as with Gaia-606 (now renamed 2016 UV56), objects that first appear entirely new transpire to be re-sightings of objects whose previous observations were not sufficient to map their orbits.

"This really was an asteroid not present in any catalogue, and that is an exciting find!" explains Thuillot. "So whilst we can't claim this is the first true asteroid discovery from Gaia, it is clearly very close and shows

how near we are to finding a never-before-seen solar system object with Gaia."

Gaia-606 was found in the main asteroid belt, which is not surprising given how many asteroids exist there. However, Gaia also provides data from swathes of the sky not extensively observed by existing ground-based surveys giving it the potential to find asteroids in areas where others would not look. One such area is a region close to the sun as seen from Earth. Observations are made from the Earth during the night when the angle between any source and the sun is fairly large, whilst Gaia can make observations at any time and so observe objects much closer to the sun. This gives Gaia the exciting potential to observe asteroids that orbit within Earth's orbit – these are known as Atira asteroids and only sixteen are currently known.



During the course of its five-year nominal mission Gaia is expected to observe several hundred thousand asteroids. Many of these will be in the main asteroid belt, located between Mars and Jupiter. One of the strengths of Gaia is that it will also observe regions that are not extensively observed by existing ground-based surveys – this gives it the potential to find asteroids in areas where others would not, or could not, look. Ground-based observations are made during the night when the angle between a source and the Sun is fairly large. Gaia can make observations at any time and hence observes objects much closer to the Sun. In particular, Gaia is ideally situated to probe the region between the Sun and Earth. This is where the Atira asteroids are found, orbiting inside Earth's orbit. To date, only 16 of these asteroids have been discovered. The dashed lines indicate regions of the sky that are unobservable by Gaia. All other regions are accessible to Gaia, including swathes within Earth's orbit. Credit: ESA

Gaia also has the potential to make discoveries at high ecliptic latitudes. Not because ground-based surveys of solar system objects cannot observe there, but because they tend not to. The vast majority of asteroids exist in the ecliptic plane and, as a result, it is here that most surveys concentrate their efforts. Gaia has no such prejudices and scans the entire sky, giving it the potential to discover new asteroids in the less crowded areas missed by other surveys.

"Whilst Gaia's primary role in solar system science remains its ability to characterise the movement and physical properties of known asteroids, it has now shown that it can also play a role in finding new ones, adding to its ever expanding catalogue of solar system objects," concludes Tanga.

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