Neighbourhood watch: What the mission to map the Milky Way is revealing about satellite galaxies

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Researchers are trying to determine if the Large Magallenic Cloud - the largest of our satellite galaxies - is orbiting the Milky Way or not. Credit: Skatebiker/Wikimedia, licenced under CC BY-SA 3.0

Our Milky Way is not alone in the universe. Surrounding us are numerous satellite galaxies, taking part in a continuous grand dance. But how do these neighbouring galaxies behave, how do they interact with our galaxy, and what does the future hold for them?

To find out, scientists are making use of a vast new trove of data from the European Space Agency's (ESA) Gaia space observatory. This telescope, launched in 2013, has been busy mapping more than a billion stars inside and outside our galaxy—and its latest batch of data has just been released.

On 3 December, the first part of the third batch of data from Gaia—called the Gaia Early Data Release 3 – was made available to scientists. It revealed new positional and velocity data for many stars already in its database, a small portion of which were in these satellite galaxies.

Using this new data, which includes more precise measurements for hundreds of millions of these stars, scientists are planning to probe our galaxy and its surroundings in exquisite detail. And in so doing, we're about to learn more about our satellite galaxies than ever before.

The Milky Way has at least 50 to 60 satellite galaxies, although the exact number is unknown—some are simply too faint to see. The most populated of these contain billions of stars, compared to hundreds of billions in our own galaxy, while the least populated have just hundreds. They range in distances from about 26,000 to a million light years away.

Plane

While they come in different shapes and sizes, most share an odd trait. "Many of the satellites move in a plane, akin to how the planets move around the sun in our solar system," said Dr. Marius Cautun from Leiden

University in the Netherlands. "This is quite puzzling, because (based on current theoretical models) we would expect more random motion."

Dr. Cautun and his team made this discovery as part of a project called DancingGalaxies. Using Gaia's unprecedented and vast data, they have been able to monitor the motion of stars inside these satellite galaxies, and thus track their overall movements.

"Most of the data from Gaia is about stars in the (Milky Way)," said Dr. Cautun. "But you can measure the motion of bright stars as far as 100,000 light years, and maybe even farther, away. And we can average the motion of those stars and obtain the motion of the satellite galaxies."

This revealed the odd motion of these satellite galaxies—and it could provide an insight into the evolution of the Milky Way. "Typically, galaxies grow by accreting (gathering) matter from outside," said Dr. Cautun. "What we think happened in the case of our own Milky Way is the matter, instead of being accreted spherically, was accreted in a plane—including the satellite galaxies. If this is the case, the Milky Way is an extreme example of accretion in a plane." This might make the Milky Way a bit unusual, as other galaxies are thought to have accreted spherically.

Dark matter

Studying the motion of these galaxies has also allowed astronomers like Dr. Cautun to probe dark matter, specifically a halo of dark matter known to surround our galaxy. The atypical motion of our satellites has suggested that, rather than being spherical, the dark matter halo is more shaped like a rugby ball and twisted.

"The puzzling thing is that at some distance, maybe 40,000 to 100,000 light years away from the centre of our own galaxy, the halo undergoes a sudden flip," said Dr. Cautun, a feature that again might mean the Milky Way is unique, as less than one percent of galaxies are thought to have such a flip. "It's like rugby balls on top of each other, but at some point the rugby ball gets flipped by 90 degrees, a twist in the dark matter halo. This is a weird feature that only happens in very, very few galaxies."

In the future it should be possible to use Gaia data to probe some of our faintest satellite galaxies in greater detail than before. "We are going to have more precise measurements for the motion of the faintest satellites," said Dr. Cautun, with at least a factor of ten improvement expected on the known motion of such galaxies. "It will make a big difference."

Two satellite galaxies in particular are of keen interest to astronomers, because they are in the process of interacting both with each other and with our Milky Way. These are known as the Small and Large Magellanic Clouds, or SMC and LMC, located about 200,000 and 163,000 light years away respectively.

Professor Maria-Rosa Cioni at the Leibniz Institute for Astrophysics Potsdam in Germany is the lead on a project called Interclouds that is using the LMC and SMC, the former being the largest of our satellite galaxies, to understand more about how galaxies behave. '(Our) idea is to use these two galaxies to learn about galaxy interactions," she said. Their close proximity to Earth makes them easy candidates to study as even individual stars can be seen.

Pass

To study them, Prof. Cioni and her team have been analysing the populations and motions of the stars in each cloud. Currently, both clouds are moving away from the Milky Way at about 320 kilometres per second, with this being the end of a close pass that began recently in astronomical terms within the last two billion years. A major unanswered question, however, is whether this was their first or second pass.

"It appears they're moving too fast to be on a bound orbit, so we think they just made the first passage to the Milky Way," said Prof. Cioni. "But there are other people that think they are on their second passage, which (would mean) they are already bound to the Milky Way."

If the former is true, it's possible the Magellanic Clouds may continue to move away—and thus might not actually be satellites. To find out we will need to know exactly how their mass compares to the Milky Way to discern if there is a strong enough gravitational pull to bring them back or not, and Gaia's data is vital to come up with that accurate measure of their masses.

"If the Milky Way is not very massive, then the gravitational force that the Magellanic Clouds would feel is not very strong," said Prof. Cioni. '(But) if the mass of the Milky Way is significantly larger than the mass of the Magellanic Clouds, they will slow down tremendously such that they will remain closer."

Prof. Cioni also hopes to probe the ages of the Magellanic Clouds, their chemical compositions, and even their structures—something simply not possible without large-scale datasets like Gaia. "Gaia is allowing us to do that on a level that was not possible before," she said.

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