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A new survey of exocomet belts is changing what we know about planetary systems

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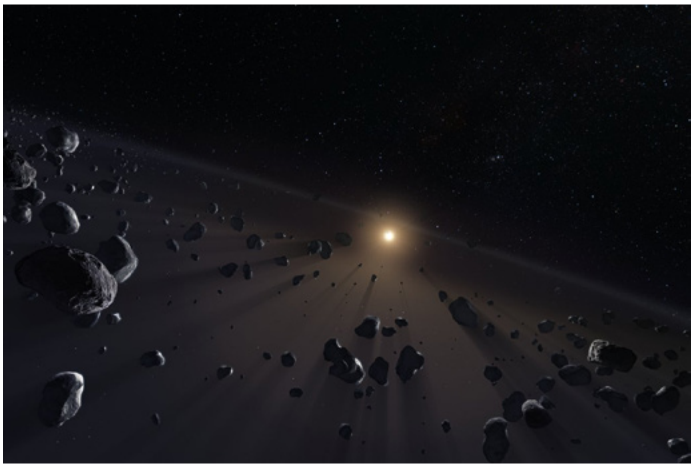
Ready to rock: discover what mysterious belts of dust, ice, and rock around distant stars can tell us about the formation of planetary systems.

The following was adapted from an ESO blog article.

Saturn, Uranus, Neptune, and... Those of you that continued the sentence with 'Pluto' already know it: there are other objects lurking beyond the orbit of Neptune. Hundreds of thousands of objects encircle our solar system in the so-called Kuiper Belt. Now, a one-of-a-kind survey has revealed a total of 74 other similar belts surrounding planetary systems close to our own. Astronomers are realizing that studying this collection of belts of different shapes, ages, and sizes can teach us a lot about the formation and evolution of planetary systems, including our own.



Artist's impression of the Kuiper belt, a disc full of icy and rocky objects beyond the orbit of Neptune
Image: M. Kornmesser/ESO, CC BY 4.0

From dust to belt

The Edgeworth–Kuiper Belt (or, simply, Kuiper Belt)[1] is a huge structure full of icy and rocky objects that extends between 30 to 50 times the distance from the Earth to the Sun. Larger objects in the belt are often called 'trans-Neptunian objects'. It's named after the Dutch astronomer Gerard Kuiper, who hypothesized its existence based on models for the formation of the solar system, but the Irish astronomer Kenneth Edgeworth had already also speculated about this structure, and the idea actually predates both astronomers. But where does it come from?

About 4.5 billion years ago, the Sun, its planets, and everything else we find in the solar system now, were just a giant rotating cloud of gas and dust. Much like making a pizza from a ball of dough, by rotating over time, the cloud eventually became a flat disc, called a protoplanetary disc, with a very dense structure in its centre that formed into a protostar and eventually became the Sun.

Grains of dust collided and fused into increasingly large structures within the disc, and once they reached a kilometre in size their own gravity started to attract more objects, fuelling their growth even further. This is – in a very summarized form – how we think planets formed. We have actually seen this process taking place in other planetary systems beyond our own. However, we also know that not all dust ended up forming planets.

Astronomers think that the influence of large planets like Neptune could have prevented dust beyond its orbit from creating new planets, leaving us with just a belt of debris. This debris, though, is actually a hidden space treasure.

Today, the Kuiper Belt is a collection of dusty and icy space rocks, ranging from dust grains and pebbles to comets and dwarf planets. From a few millimetres to kilometres in diameter, many of these objects have changed little since their formation. Frozen (literally) in time, these are remnants of the early stages of the solar system, and tell us a lot about its initial properties.

Belts of debris like the Kuiper Belt exist in other planetary systems too. They are broadly known as 'planetesimal belts', since the objects within them have the potential to come together to form planets, or 'exocomet belts', since they are usually hiding comets (icy planetesimals) within them. But how can we observe these belts?

Exocomets

An exocomet, or extrasolar comet, is a comet that orbits a star other than the Sun or that travels through outer space without being bound to a star. The HARPS instrument at the European Southern Observatory's (ESO) La Silla Observatory in Chile has been used to make the most complete census of comets around another star and found nearly 500 individual comets orbiting the star Beta Pictoris.

Artist's impression of exocomets orbiting the star Beta Pictoris
Image: L. Calçada/ESO, CC BY 4.0

A journey in search of other belts

At first glance, finding exocomet belts should be easy given how large they are. However, these belts have been difficult to observe and image.

The reason behind this is their temperature. The objects within an exocomet belt are very far from their host star, and thus they are extremely cold. In the Kuiper Belt, for example, temperatures range from –250 to –150°C. At these low temperatures, exocomet belts only shine at long wavelengths, making them difficult to observe for most – but not all – telescopes. One telescope that can observe them is the Atacama Millimetre/submillimetre Array (ALMA). Operated by the ESO and its partners, this array of 66 antennas in the Atacama desert in northern Chile is specifically designed to detect long-wavelength radiation from cold astronomical sources, like exocomet belts.

Using ALMA, the Hawaiian Submillimeter Array (SMA), and archival data, a team led by Luca Matrà, an associate professor at the University of Dublin, has embarked on a mission to image as many exocomet belts as possible, in all stages, from newly formed to very mature. The survey, named REASONS, is the largest of its kind to date.

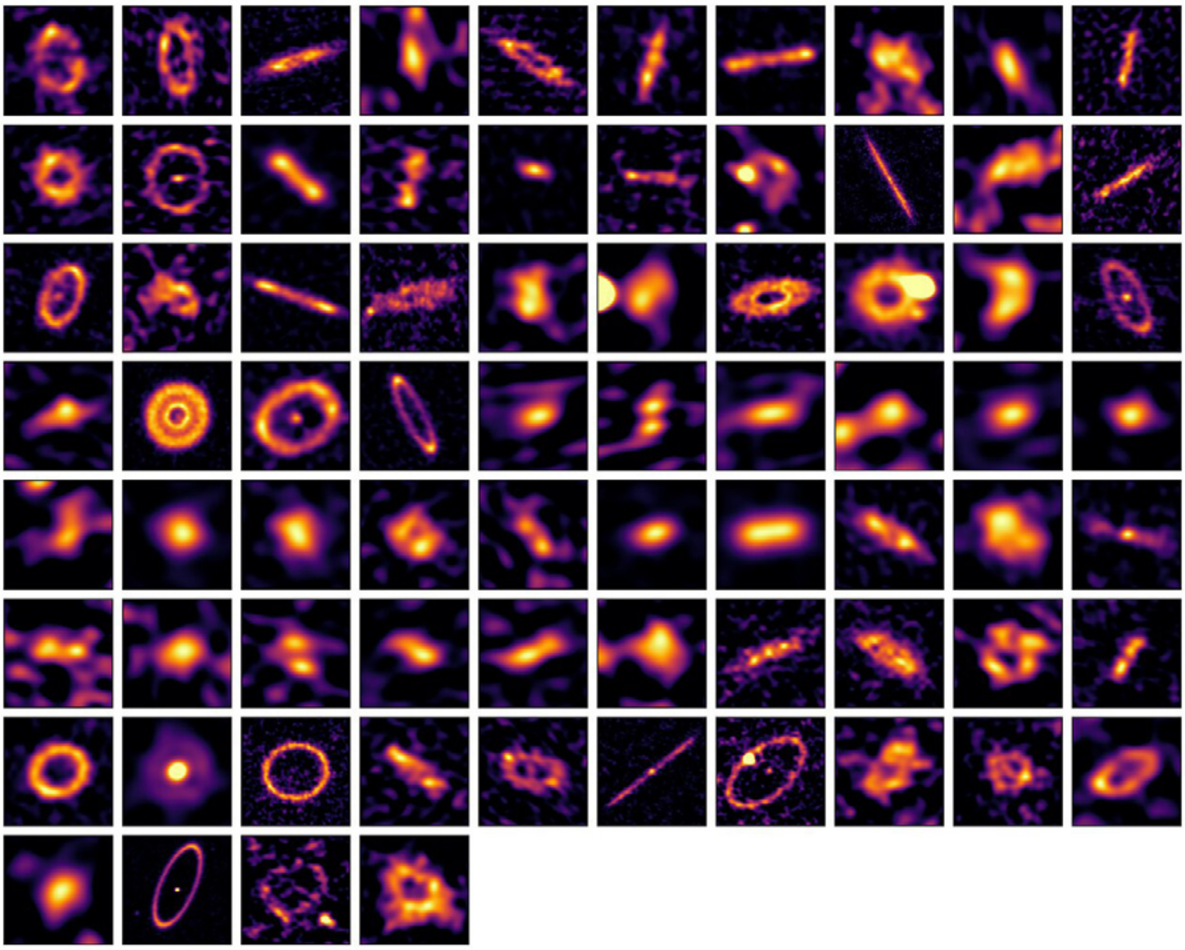
The survey contains images of 74 exocomet belts around nearby planetary systems (within 500 lightyears from Earth). These results have now published in the scientific journal *Astronomy and Astrophysics*[2,3] and they are already challenging the ideas astronomers had about these structures.

The ALMA antennas observing the night sky in the Chajnantor Plateau in Chile

Image: Y. Beletsky (LCO)/ ESO, CC BY 4.0

Where did all the small, thin belts go?

Not all belts are equal. The REASONS survey has revealed that exocomet belts come in all shapes, sizes, and ages, but within this variation, scientists are starting to see some patterns.



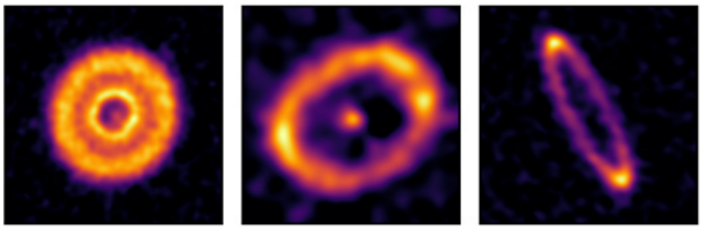
The 74 exocomet belts imaged by ALMA's REASONS survey, showing belts of all shapes, sizes, and ages

Image from Ref.[2]

One of these patterns is that the observed belts are remarkably larger than expected. Smaller belts are closer to their host star, making them hotter, brighter, and theoretically easier to find. However, the new observations indicate that they are very rare. This means that either most belts form further out, or that smaller belts are less massive and, in fact, harder to detect.

The team also confirmed previous findings: as exocomet belts evolve, collisions within them smash their large objects into smaller ones. If this process were to happen faster in belts closer to their stars, it could also explain why the team didn't find small belts.
The observed belts are not only larger than previously thought, but also extend more widely; like a doughnut with a hole, rather than an onion ring. Narrower belts – what we would call 'rings' – are less common in the survey.

One possibility is that exocomet belts broaden out over time. The first results from this survey, though, found that older belts are not necessarily broader, which indicates that this is probably not the case. Another possibility is that wide belts have gaps within them that split them into narrower rings, but we can't resolve that yet.



Details of some of the belts imaged
Image adapted from Ref. [2]

Belts and the Earth: enemies or allies?

This is not the end of the story of exocomet belts, though. Researchers think that future telescopes will be able to uncover substructures within belts, like gaps and rings. They could even be hiding dwarf planets much like Pluto, ready to be discovered.

But studying these belts is more than space treasure hunting, it is also learning about the history of our solar system and our own planet.

Astronomers are always monitoring the Kuiper Belt, which is a big source of asteroids and comets. Many of the asteroids and comets we see may have come from this distant region.

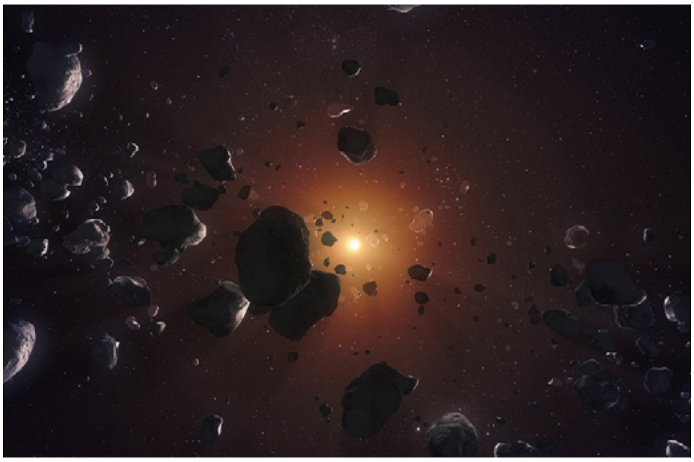


Image: M. Kornmesser/ESO, CC BY 4.0

Some, like this year's Tsuchinshan-ATLAS comet, come from a structure even farther away, called the Oort Cloud, while others, like the mysterious interstellar object Oumuamua, originated from somewhere beyond our solar system. Given that an asteroid caused a major extinction 65 million years ago, it is understandable why we would be concerned. However, one theory suggests that at least some of Earth's water may have also arrived from the Kuiper Belt, which known to be a giant repository of frozen water. Large, far-away planets like Neptune or Uranus may have had a crucial role in propelling water-bearing comets toward us, providing a substance that would otherwise have been quite rare on the primitive Earth. Only time will tell whether we owe our lives to space rocks.

As we get to know more about exocomet belts, we may finally be able to understand the role that belts play in the formation and evolution of planetary systems. «

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[1] An introduction to the Kuiper Belt: https://science.nasa.gov/solar-system/kuiper-belt/facts/

[2] Matrà L (2025) REsolved ALMA and SMA Observations of Nearby Stars (REASONS). *Astronomy and Astrophysics* **693**. doi: 10.1051/0004-6361/202451397

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AUTHOR BIOGRAPHY

Alejandro is an evolutionary biologist from Spain who has been researching the ancestors of shrimps, centipedes, and insects, trying to understand how evolution worked 500 million years ago. He has discovered several strange-looking extinct animals such as the 'Pac-man' crab (Pakucaris) and the 'Cambrian beagle' (Balhuticaris). At ESO, he aims to strengthen his communication skills while re-igniting his childhood passion for the cosmos.