Searching explanations for mysterious structures in protoplanetary disks

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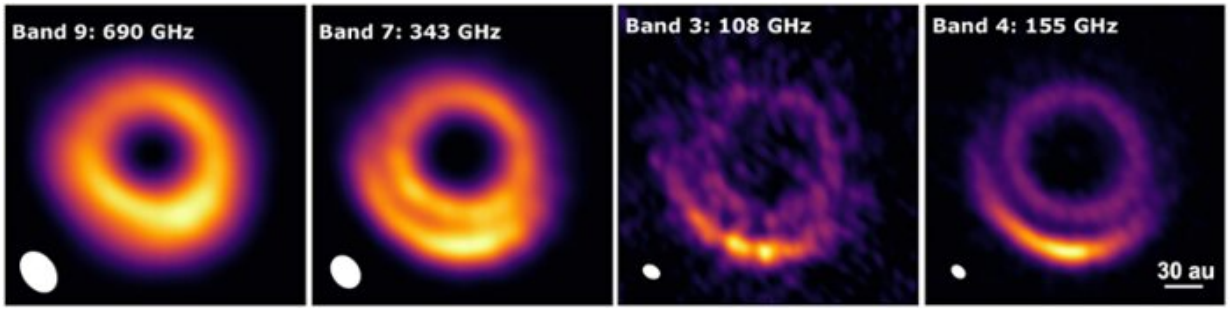

Observations at different wavelengths and resolutions of a horseshoe and a ring-shaped structure in the dust around HD 135344B. Credit: Paolo Cazzoletti

In the discs of dust and gasses around young stars, mysterious structures occur. Together with professor Ewine van Dishoeck, Ph.D. student Paolo Cazzoletti investigate how we can explain these forms, such as rings, spirals and holes. On 12 December, he will defend his thesis.

Since the discovery of the first exoplanet in the '90s, more than 4000 exoplanets have been found. Planets are formed in protoplanetary disks around young stars. "First, the dust clumps together into grains that gradually grow to the size of pebbles and eventually to rocks and planets," Cazzoletti tells. "If they are big and heavy enough, they can attract gas from the disk and in some cases grow into gas giants like Jupiter and Saturn."

Horseshoes and bananas

In the first telescope observations, protoplanetary disks seemed smooth and symmetrical. But this changed about seven years ago. Using the Atacama Large Millimeter/submillimeter Array (ALMA) radio telescope in Chile, astronomers were able to observe the disks in more detail. "These observations showed that they are not symmetrical and smooth," says Cazzoletti. "We saw structures and shapes, such as holes, rings and horseshoe- and banana-shaped substructures. That was a surprise."

The most frequently mentioned explanation for this is the presence of one or more planets. These can interact with the dust and gas in the disc, creating the structures. But fewer planets were found than necessary to explain all the dust and gas structures. Cazzoletti: "This makes the structures more mysterious. We had to look for other explanations."

Dust vortices

In his research into explanations for the structures, Cazzoletti builds on his master's thesis. "I have been interested in these planetary disks for some time now," he says. "And the knowledge from my master's research appeared to fit in well with the first two chapters of my thesis."

For his Ph.D., he studied, among other things, ALMA observations of HD 135344B, a disc around a young star. This disc is not symmetrical. On the southern side is a banana-shaped structure. It looks like a kind of dust vortex. Furthermore, small dust particles in the upper layer of the disc form spiral arms. Astronomers initially thought that these were caused by the presence of planets in the outer area of the disc. But no planets were found. Cazzoletti describes in his thesis how the spiral arms can be created by the asymmetric dust vortex. If that is the case, only one planet, close to the star, is needed to explain the rest of the observed

structure.

Holes or no holes?

In addition to this observational work, Cazzoletti also carried out theoretical research to explain ring-shaped structures in the gas of protoplanetary disks. For this purpose, he focused on cyanide molecules. "There are two possibilities by which we see these ring-shaped gas structures," says Cazzoletti. "It can be caused by a ring-shaped hole in the disk.

Or there is no hole, but there only seems to be a hole because of the chemistry of the cyanide molecules and the way they emit light." By analyzing theoretical models, he discovered that the observed ring shapes are not related to the shape of the dust disc. "They are mainly chemical holes because there is less cyanide in the vicinity of the mother star."

More knowledge about exoplanets

Cazzoletti's Ph.D. research contributes to a better understanding of the way in which structures are created in protoplanetary disks. With this knowledge, astronomers in the future hope to find out how the structures relate to the formation of planets and the diversity of exoplanetary systems that have been observed over the past twenty-five years.

Cazzoletti himself is not continuing this research. Astronomers are very much in demand as data scientists in a whole range of organizations. Since the beginning of November, Cazzoletti has been using his knowledge of data analysis as a data scientist at the Italian company Prometeia.

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