Flow of material observed for the first time around a young eruptive star

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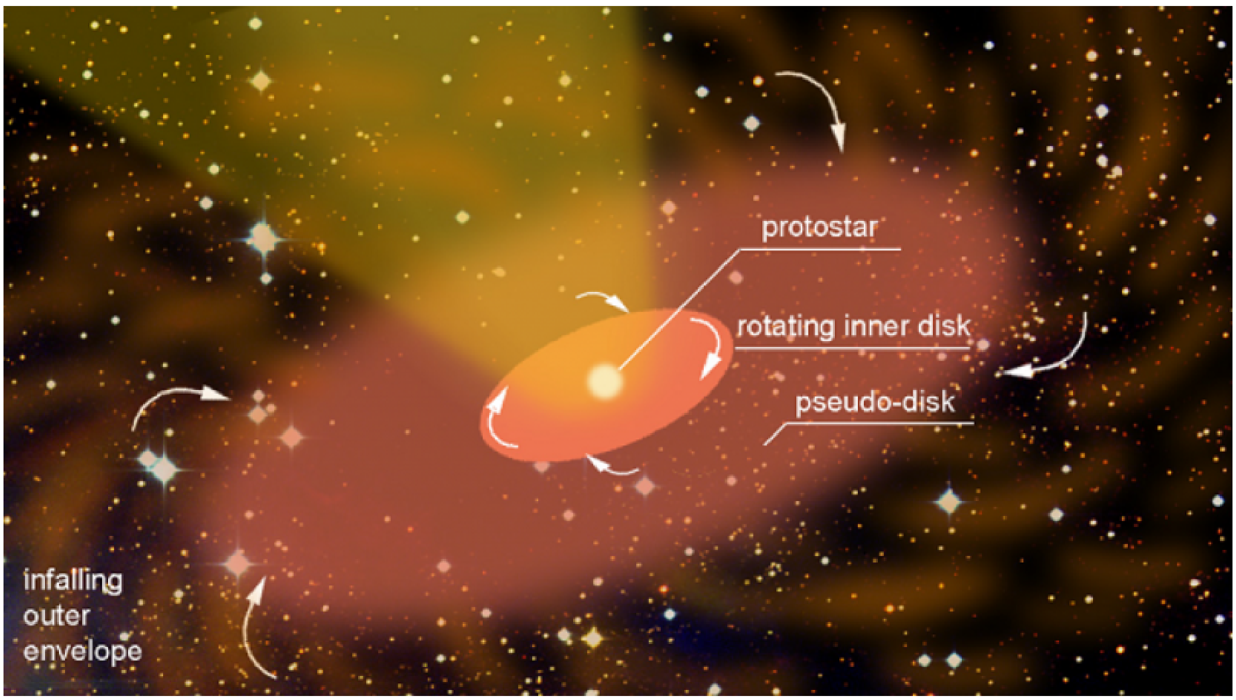

Artist's conception of the V346 Nor system. Credit: MTA CSFK

Every year, about two Earth masses of material flows to the disk of the young star V346 Nor from its surroundings, to end up on the star causing brightening. The hard-to-see phenomenon was captured by a Hungarian-led research group using ALMA, the largest astronomical telescope on Earth. The observation helps in the understanding of a key phenomenon: how circumstellar disks evolve and ultimately form planets.

New planets are born in the universe every second. The most interesting ones are those similar to Earth, especially if they have the possibility to harbor life.

Until a few decades ago, only estimates and model predictions were available to outline where and how habitable planets or uninhabitable planets are born.

Nowadays, thanks to the largest telescopes, the situation is different: Astronomers can glimpse the details of star and planet formation and are learning more about the circumstances of their birth.

Important advances have been made in this field by a team coordinated by Hungarian researchers. The latest issue of the *Astrophysical Journal* published an article by Ágnes Kóspál and collaborators, in which they study the young star V346 Nor and its environment. V346 Nor is a protostar only a few hundred thousand years old of 0.1 solar mass, but it is still growing. It is possible that planets are currently forming around it. It is an ideal target for analyzing what factors determine the properties of the forming planets and their surroundings. For this, it is important to know the composition, temperature, and grain size of the disk where the planets are growing.

The outer part of the system consists of a large, tenuous envelope from which gas and dust flows towards the center. In the middle, there is a flattened disk, where the newborn star captures material from the inner edge of the disk. The outer part of the disk is being replenished by the infalling envelope. The rate of this latter flow was measured precisely by the Hungarian-led team for the first time, and turns out to be about a millionth solar mass (or two Earth masses) per year.

The largest telescope to capture the smallest details

The ALMA (Atacama Large Millimeter/Submillimeter Array) radio antenna system is located in the dry Atacama Desert at an elevation of 5000 meters above sea level.

When complete, it will consist of 66 radio telescopes with 12 and 7 meter diameter dishes, most of which are already in place and operational.

The instrument can detect electromagnetic radiation from the sky with wavelengths between 350 micrometers and 3 millimeters. This spectral range enables the study of the densest parts of star-forming regions and the environment of young stars, which are unobservable in optical light.

Experts from the Research Centre for Astronomy and Earth Sciences of the Hungarian Academy of Sciences took images of the young star V346 Nor and its environment at a spatial resolution of one arcsecond and analyzed the structure and movement of the gaseous material. The target is a young eruptive object, a pre-main-sequence star that is still growing by capturing material from its surroundings. The energy output of such objects varies with time, depending on the actual flow of material from the disk onto the star. Due to the uneven transport of material, sometimes spectacular eruptions happen. During these times, the disk heats up and its material is transformed as the dust grains crystallize, as the Hungarian researchers discovered a few years ago.

Although many details are uncertain in this process, Ágnes Kóspál and her colleagues identified and studied an even less well-known phenomenon in the system.

We know that the disk gives material to the protostar, but how the disk receives material from the surrounding diffuse envelope has been unknown.

The infall rate onto the disk is much higher than the rate from the disk onto the star, so the disk retains the material for a while. The disk-to-star mass transport is usually quite slow, and it increases only occasionally, when it causes a brightening. The Hungarian researchers demonstrated quantitatively for the first time how much material falls from the envelope onto the disk, where it accumulates and falls onto the star at an uneven rate.

The researchers mapped the location and movement of the disk material using measurements of the spectral line of the carbon monoxide molecule and the 1.3 millimeter emission of the dust. The gas and dust is the densest in the central 350 AU region around the central star. Here, the rotational movement of the disk material is determined by the gravitational field of the central star. Further out, there is a flattened, disk-like structure, a so-called pseudo-disk, whose movement is a combination of infall and rotation, conserving the angular momentum of the surrounding envelope.

According to the new ALMA measurements, the pseudo-disk receives two Earth masses of material every year, which is significantly larger than the mass collection rate of the central protostar.

The observations give the first direct evidence that the eruptions of such young stellar objects happen when so much material accumulates in the inner disk that it becomes unstable and the mass flow to the star becomes much faster for a while.

Hungarian-led international team

"This is the first direct measurement of a mismatch between the envelope-to-disk and the disk-to-star mass flow in a young eruptive star," says Ágnes Kóspál. The Hungarian-led international group took advantage of the unprecedented spatial resolution and sensitivity of

ALMA in their discovery. The background knowledge for the study was in large part supplied by the MTA CSFK Disk Research Group, a team that formed in 2014 at the Konkoly Observatory to study the dynamics of circumstellar disks as well as star and planet formation in the ALMA era. This project gave the framework in which the analysis methods were developed for this study.

This topic is promising, because the eruptions of young stars are supposed to have a direct effect on the disk material. In the V346 Nor system, there may already be planetesimals that will eventually form exoplanets, although most of them will fall into the star or will be destroyed by the eruptions. In the coming decades, Ágnes Kóspál and her collaborators plan to understand these dynamical disks and shed light on the steps leading to planet formation and the factors influencing it.

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