# Warped protoplanetary disks reshape existing ideas about how planets form

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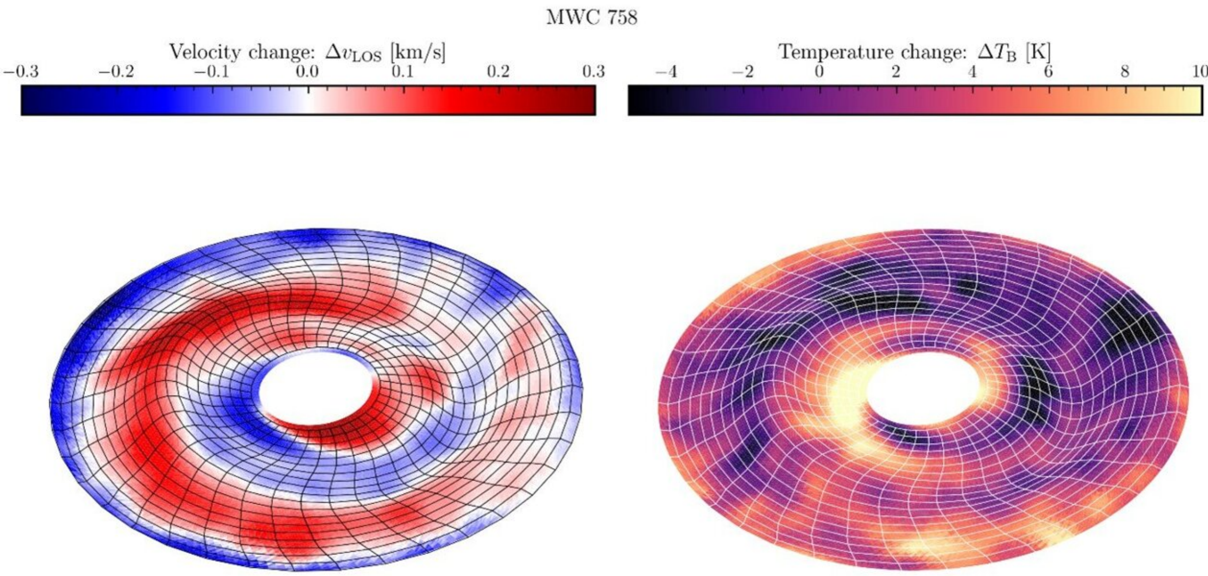


Visualization of the warped disk around the young star MWC 758, with warping exaggerated by a factor four to make it visible. Both panels show properties of the disk inferred from CO emission. On the left-hand side, we see deviations in the line-of-sight velocity from the expected rotation if the disk were flat. The variations in velocity can be used to infer the warp structure. On the right-hand side we see variations in the gas temperature, from which we can see evidence of shadowing in areas of the disk. Credit: Dr. A Winter, Queen Mary University of London

The textbook picture of how planets form—serene, flat disks of cosmic dust—has just received a significant cosmic twist.

New research, published in *Astrophysical Journal Letters*, is set to reshape this long-held view. An international team of scientists, wielding the formidable power of the Atacama Large Millimeter/submillimeter Array (ALMA), has found compelling evidence that many protoplanetary disks, the very birthplaces of planets, are in fact subtly warped.

These slight bends and twists in the disk plane, often just a few degrees, bear a striking resemblance to the subtle tilts observed among the planets in our own solar system. This discovery suggests the initial conditions for planetary systems might be far less orderly than previously thought, with profound implications for how planets grow and settle into their final orbits.

Dr. Andrew Winter, the lead author of the study from Queen Mary University of London, where he is a Royal Society University Research Fellow in astronomy, said, "Our results suggest that protoplanetary disks are slightly warped. This would be quite a change in how we understand these objects and has many consequences for how planets form. Particularly interesting is that the couple of degrees of warping are similar to the differences in inclination between our own solar system planets."

Dr. Myriam Benisty, director of the Planet and Star Formation Department at the Max Planck Institute for Astronomy said, "exoALMA has revealed large-scale structures in the planet-forming disks that were completely unexpected. The warp-like structures challenge the idea of orderly planet formation and pose a fascinating challenge for the future."

To uncover these subtle twists, the team meticulously analyzed Doppler shifts—tiny changes in the radio waves emitted by carbon monoxide (CO) molecules swirling within the disks. These shifts act like a cosmic speedometer, revealing the gas's exact motion. As part of a major ALMA program called exoALMA, researchers used this flagship observatory to map the gas's velocity across each disk in unprecedented detail. By carefully modeling these intricate patterns, they were able to detect when different regions of a disk were slightly tilted, thus revealing the warps.

"These modest misalignments may be a common outcome of star and planet formation," Dr. Winter added, noting the intriguing parallel with our own solar system. The research not only provides a fresh perspective on the mechanics of planet formation but also raises new questions about why these disks are warped—a mystery the team is eager to unravel.

Is it the gravitational pull of unseen companion stars, or perhaps the chaotic dance of gas and dust that twists these stellar cradles? The findings show that these subtle disk warps, often tilting by as little as half a degree to two degrees, can naturally explain many of the prominent large-scale patterns observed in the gas's motion across the disks. They even suggest these warps could be responsible for creating intriguing spiral patterns and slight temperature variations within these cosmic nurseries.

If these warps are a key driver of how gas moves within the disk, it profoundly changes our understanding of critical processes like turbulence and how material is exchanged—ultimately dictating how planets form and settle into their final orbits. Intriguingly, the nature of these warps appears to be connected to how much material the young star is actively drawing in towards its center. This hints at a dynamic link between the disk's innermost regions, where the star is fed, and its outer, planet-forming areas.

This discovery offers a thrilling glimpse into the complex and often surprising realities of planet formation, fundamentally changing our cosmic blueprint and opening new avenues for understanding the diverse worlds beyond our sun.

**More information:** Andrew J. Winter et al, exoALMA. XVIII. Interpreting large scale kinematic structures as moderate warping, *Astrophysical Journal Letters* (2025). iopscience.iop.org/article/10. … 847/2041-8213/adf113

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