# Spiral pattern gives clue to how high-mass stars form

February 28 2023

Map of material distribution in the disk around protostar G358-MM1. The white "+" marks the location of the protostar. The contour lines indicate signal strength. The colors represent the line-of-sight velocities. Movement away from the viewer is shown in red/orange and movement towards the viewer is shown in blue/green, indicating that the disk is rotating. Overlaid gray lines indicate the spiral arms identified though data analysis. Credit: R. A. Burns

New observations have revealed a spiral pattern in a disk of material around a still forming, but already high-mass, baby star. This indicates that there is gravitational instability in the disk, which has important implications for how high-mass stars form.

As a star forms, a protostellar disk helps to feed material to the nascent "protostar" at its center. For high-mass protostars already exceeding 8 times the mass of the sun and still growing, it is believed that, rather than a continuous flow, clumps of material from the disk occasionally fall on to the protostar causing short, episodic bursts of growth.

An international research team led by Ross A. Burns at NAOJ used VLBI techniques combining radio telescope arrays around the world to map the maser emissions in the disk around a high-mass protostar known as G358-MM1. This high-mass protostar is the third ever case of an observationally confirmed growth burst, and was intensely studied by the maser monitoring organization. The team was able to investigate the phenomenon in detail for the first time. They published their findings Feb. 27 in the journal *Nature Astronomy*.

The observational results show clear rotation around the central protostar and a spiral pattern with four arms. Spiral arms in rotating protostellar disks are a sign of instability, a characteristic which was long theorized to be associated with massive star formation, but had yet to be proven observationally. This discovery not only revealed the first spiral driven accretion disk in a high-mass protostar but also links spiral arm instabilities with the episodic growth bursts that are central to high-mass star formation theory.

This research used a new technique known as "heat-wave mapping." When a clump of material falls from the disk on to the protostar, it releases a burst of energy that heats the inner part of the disk, exciting methanol maser emission. This heat wave then moves outward, heating increasingly more distant parts of the disk as time passes. By observing the regions that ignited maser emission caused by this heating it was possible to map the surface of the disk in G358-MM1. The team, comprising a collaboration of more than 90 astronomers from across the globe, now hopes to apply this technique to observe the disks of other high-mass protostars which undergo growth bursts in the future.

**More information:** R. A. Burns et al, A Keplerian disk with a four-arm spiral birthing an episodically accreting high-mass protostar, *Nature Astronomy* (2023). DOI: 10.1038/s41550-023-01899-w

Provided by National Astronomical Observatory of Japan