Heat wave signals the growth of a stellar embryo

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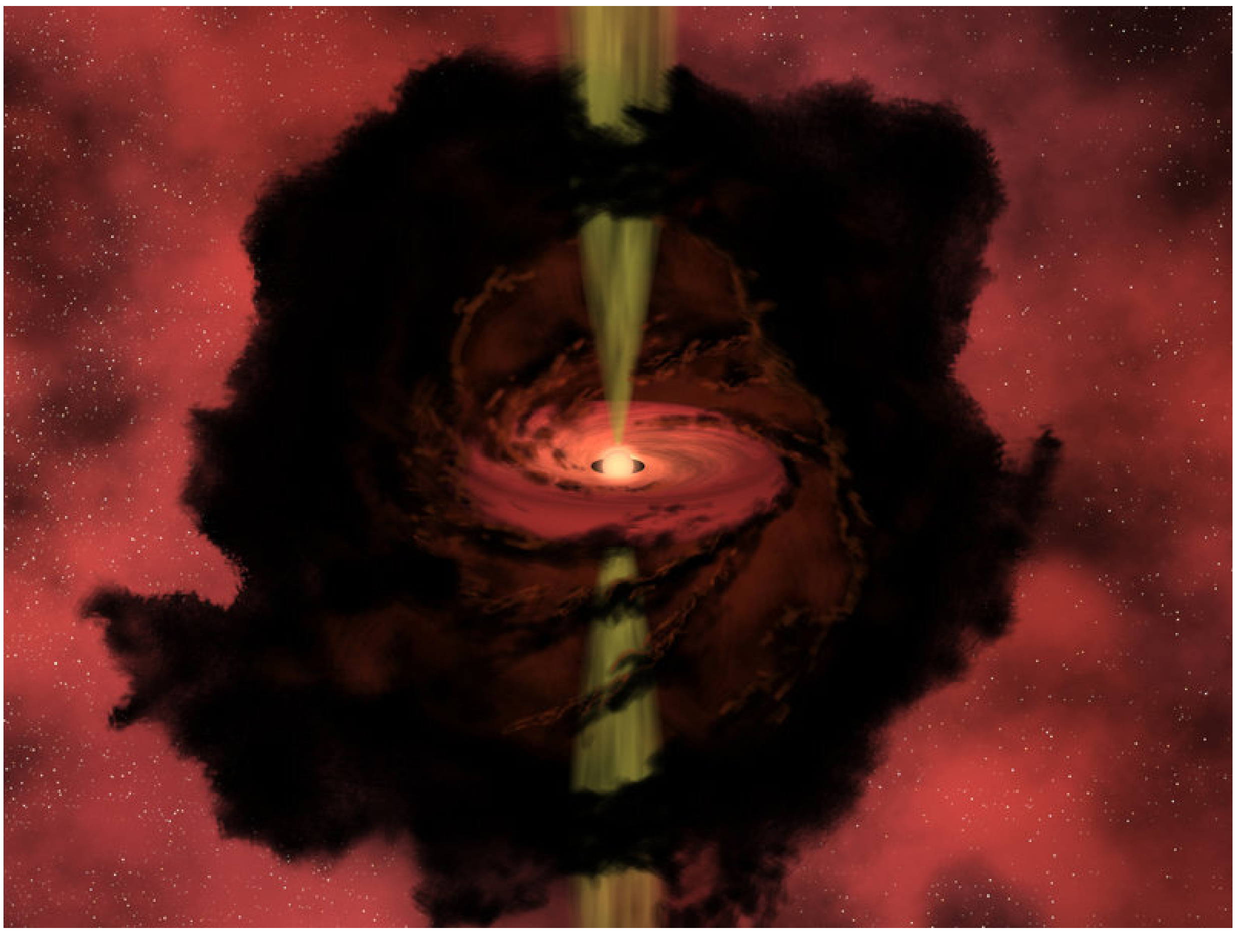

Artistic impression of a protostar that accretes gas from a circumstellar disk and grows. Part of the material is ejected by jets perpendicular to the plane of the disk. Gas continues to fall from the outer shell onto the disk. This can produce instabilities, which occasionally lead to increased infall onto the protostar. Since protostars are deeply embedded in dense clouds, they are difficult to observe directly. Credit: NASA/JPL-Caltech/R. Hurt (SSC)

An international research team with the Max Planck Institute for Astronomy (MPIA) participating has detected a propagating heat wave near a massive protostar. It confirms the scenario that such objects grow in bursts. This wave became visible by observing naturally generated microwave lasers, whose spatial arrangement changed unexpectedly rapid.

Although the basic principles of star formation are generally well understood, the existence of massive stars is still puzzling in some details. Due to the enormous gravitational pressure inside a massive protostar, nuclear fusion starts while it is still growing. Further growth is made more difficult by the radiation pressure of the young star. In order to overcome this resistance, the accretion of material from a circumstellar disk might occur in phases of single large packets. During this process its brightness increases strongly for a short time. However, such fluctuations are difficult to observe because protostars are deeply embedded in dense clouds.

An international network of astronomers, the Maser Monitoring Organisation (M2O), in which the Max Planck Institute for Astronomy (MPIA) is involved, has now detected a heat wave propagating in the vicinity of the massive protostar G358-MM1 through observations with several radio telescopes. Subsequent observations have confirmed that it was caused by a temporary increase in accretion activity.

The heat wave was revealed by the activity of masers. Masers are the equivalent of lasers, which, however, emit microwave radiation—or radio waves—instead of visible light. They occur in massive star formation regions as natural, very bright and compact sources of radiation. Both the comparatively high temperatures and densities as well as the richness of complex chemistry in such environments favour their formation. In the present case, it is methanol (methyl alcohol) that is excited by the intense radiation of the protostar and causes masers.

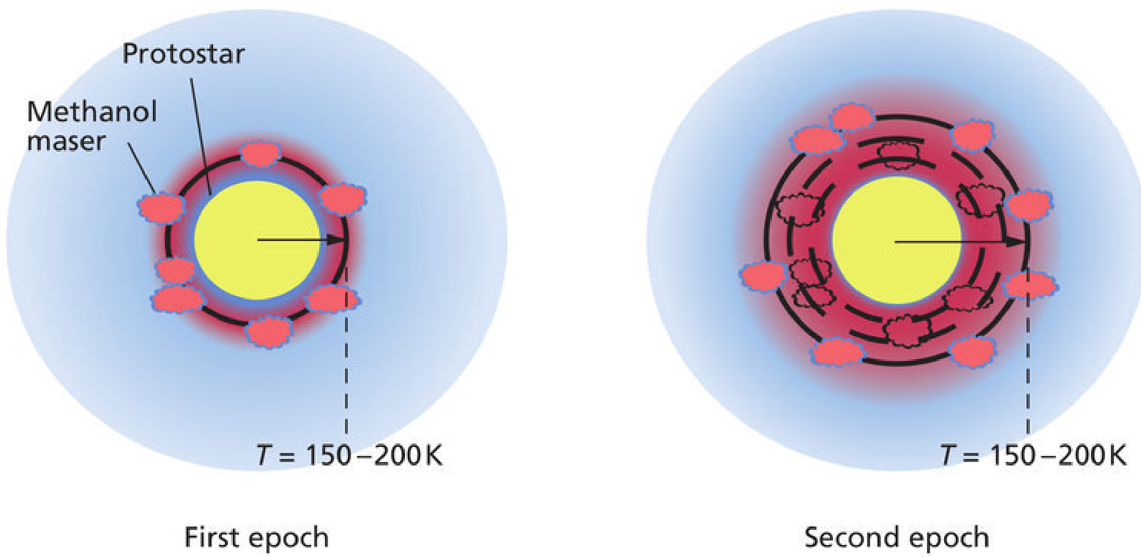

Illustration of the mechanism by which the propagating heat wave stimulates maser activity in the material surrounding the protostar. The wave locally increases the temperature of the gas for a short time. In this region the characteristic radiation of methanol masers is emitted. As the wave propagates, the positions of the maser emission change. Credit: R. A. Burns/MPIA

The scientists, who recorded radio-interferometric data with a high spatial resolution of 0.005 arc seconds (1 angular degree = 3600 arc seconds) at intervals of several weeks, discovered that the masers appeared to propagate outwards. However, the determined velocity of up to 8% of the speed of light was too high to be compatible with the movement of gas. Instead, astronomers concluded that a wave traversing the surrounding medium caused maser activity on its way. This heat wave has its origin in the accretion of gas on the protostar.

"The M2O observations are among the first to provide detailed evidence of the immediate effects of an accretion burst in a massive protostar in sufficient detail to support the episodic accretion theory of massive star formation," explains Ross Burns of the National Astronomical Observatory of Japan, who heads the research group.

Hendrik Linz from MPIA adds: "To observe the actual heat wave directly in the thermal infrared would be very complicated. As strong radiation sources in an easily accessible wavelength range, masers are excellent observation tools for indirectly tracing the passage of such a heat wave on small spatial scales, and thus on short time scales after an outburst."

The partners in the M2O project will continue to monitor masers in many star formation regions to learn more about the growth of massive protostars.

More information: R. A. Burns et al. A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar, *Nature Astronomy* (2020). DOI: 10.1038/s41550-019-0989-3

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