Violent cosmic explosion revealed by ALMA: The merging of massive protostars?

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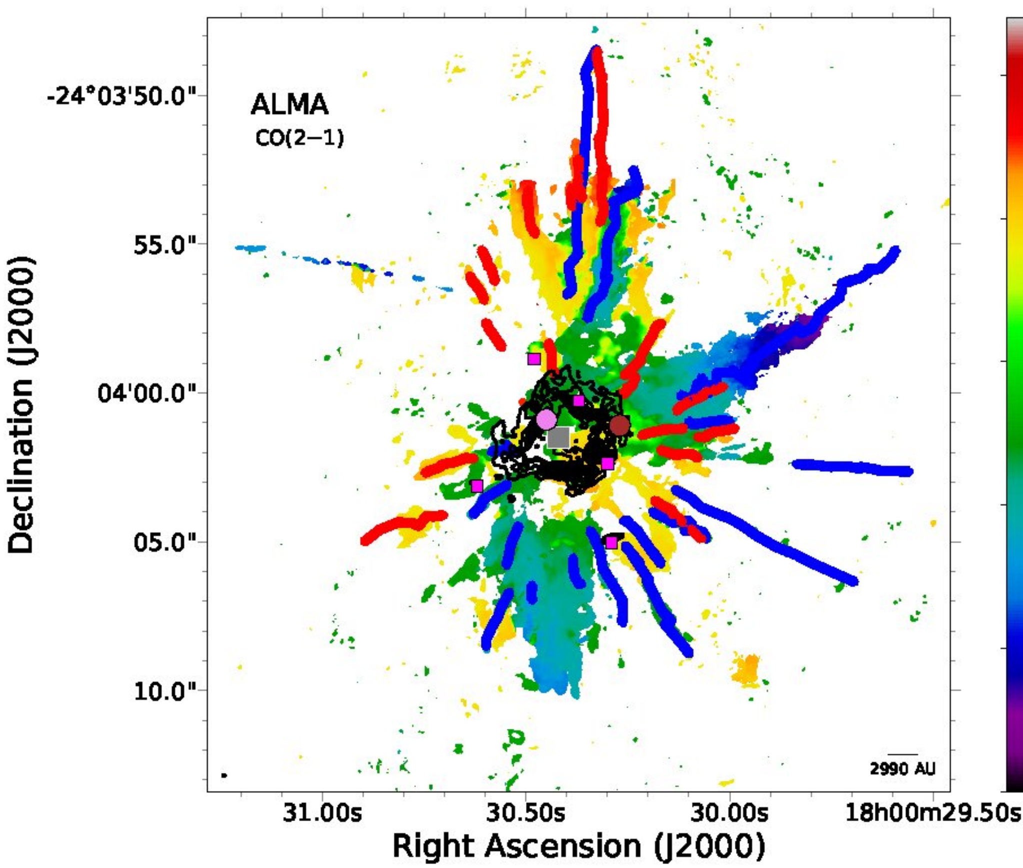
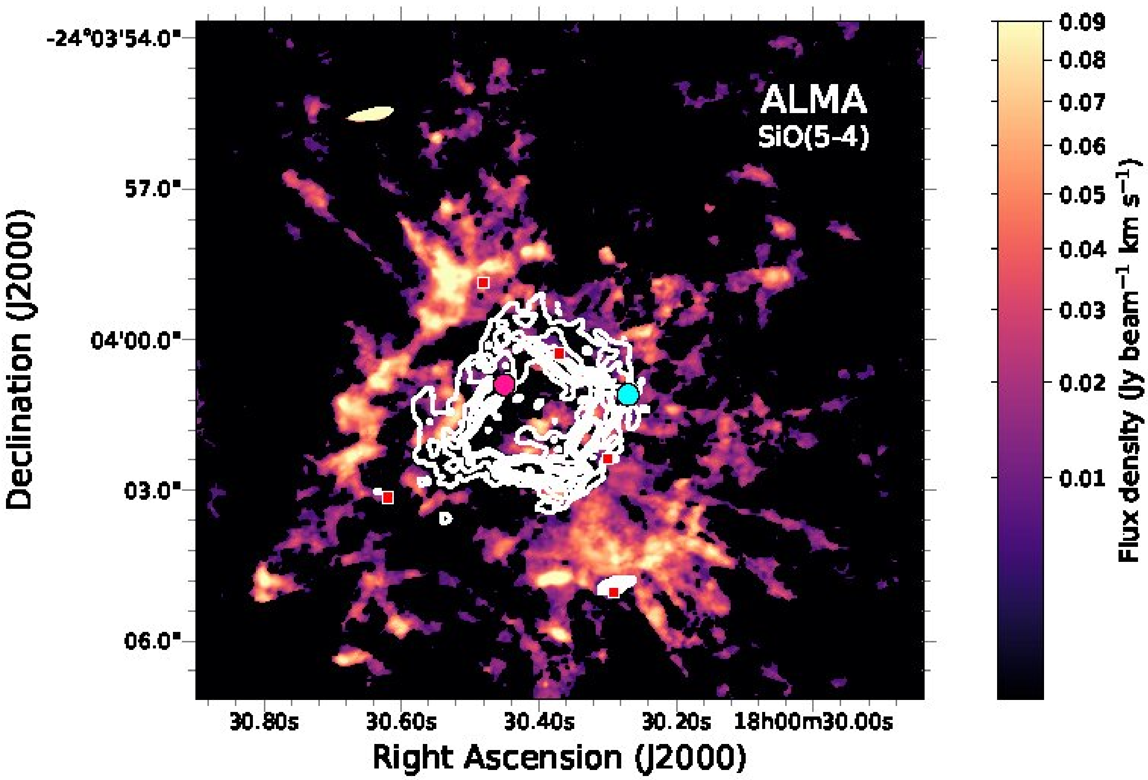


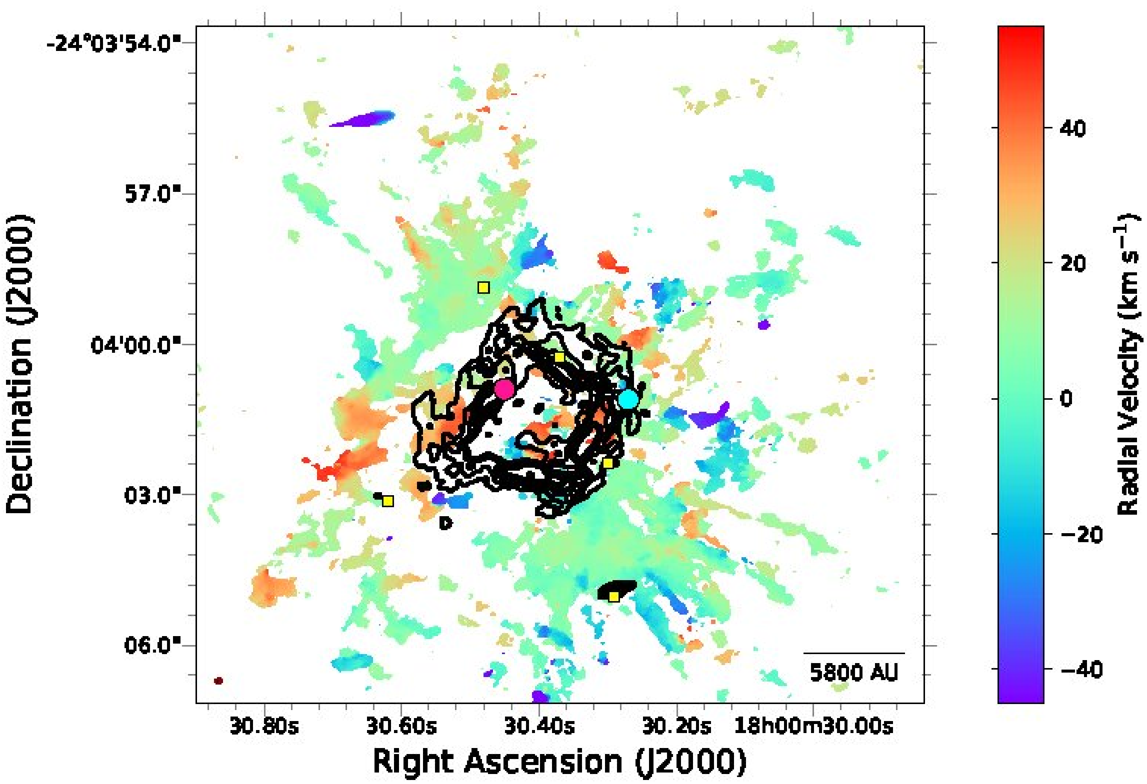
ALMA CO map overlaid with the approaching (blue) and receding (red) explosive filaments in the G5.89–0.39 outflow. The locations of the sources named Feldt's star (pink circle) and Puga's star (brown circle) are shown at the center of the explosive outflow. The gray square marks the origin of the outflow. Credit: Institute of Astrophysics and Astronomy, Academia Sinica

The phenomenon of molecular outflow was first discovered in the 1980's. Very high velocity motions were detected in the line wings of the carbon monoxide (CO) molecule, seen towards young forming stars. The high velocity motions obviously could not be gravitationally bound motions (such as infall or rotation) because of the required large gravitating masses. The first detections were in fact in the extremely bright CO lines in the center of the Orion nebulae, which were already seen when CO was first detected in the interstellar medium.

With the subsequent detection of the molecular outflows in many sources, they became recognized as a ubiquitous and necessary stage in star formation. Excess angular momentum was carried outwards by the molecular outflow, which allowed the remaining material to fall onto the stellar core. These outflows were then associated with the building of the star itself. However, it turns out that the typically bipolar molecular outflows in low mass stars are not likely the same as the outflow in Orion. The new results reported here, is a second example of an outflow like Orion, after some 40 years.

The formation of massive stars, that is, those with a mass ten or more times that of our Sun, is still far from being clearly understood. For a long time, many astronomers think that this kind of giant stars may be formed in a similar fashion as their smaller cousins, stars with masses similar to our Sun. In this picture, the massive stars grow up in quiet environments gaining mass via accretion from large circumstellar disks and peacefully reaching their final masses. However, this seems not to be the rule.

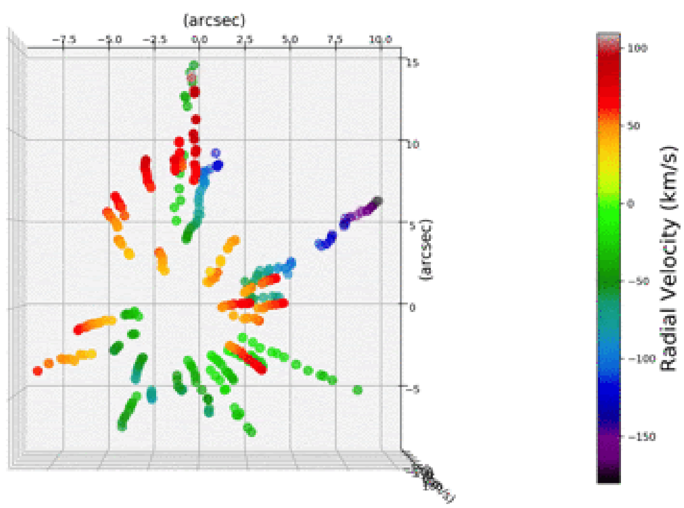

ALMA
SiO(5-4)
-24°03'54.0"
57.0"
04'00.0"
03.0"
06.0"
Declination (J2000)
30.80s
30.60s
30.40s
30.20s
18h00m30.00s
Right Ascension (J2000)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Flux density (Jy beam^{-1} km s^{-1})


-24°03'54.0"
57.0"
04'00.0"
03.0"
06.0"
Declination (J2000)
5800 AU
30.80s
30.60s
30.40s
30.20s
18h00m30.00s
Right Ascension (J2000)
40
20
0
−20
−40
Radial Velocity (km s^{-1})

ALMA SiO(5-4) moment-zero (upper panel) and moment-one (lower panel) overlaid with the 1.3 mm continuum emission in white contours that are tracing the star formation region. The location of the sources named Feldt's star (pink circle) and Puga's star (cyan circle) are shown at the center of the explosive outflow. Credit: Institute of Astrophysics and Astronomy, Academia Sinica

Using the Atacama Large Millimeter/submillimeter Array (ALMA), astronomers captured a violent explosion from a region in the sky that is forming massive stars and that the astronomers named as G5.89-0.39 because of its galactic coordinates. Such an explosion was identified using the millimeter wave emission from two simple molecules, carbon monoxide (CO) and silicon monoxide (SiO). These molecules are known to trace shocks, with supersonic motions, in dense and dark regions of gas where the formation of the stars is taking place. But the explosive high velocity motions are fundamentally different from the molecular outflows in low mass stars.

The explosion appears to have occurred some 1,000 years ago and has liberated a large amount of energy. Although the released energy is less than that produced by the supernovae that occur at the end of the life of massive stars, this explosion was unexpected in these very early stages. The ALMA observations revealed about thirty molecular "bullets," radially flowing outwards. The motions appear to be impulsive in nature, occurring at a single instant, and they point back in time to an ionized region possibly formed by the high temperatures due to the explosion. "What is intriguing is that there are no known massive young stars at the center of the explosion," says Masao Saito an astronomer at NAOJ. The young massive stars probably migrated from their birthplace after a violent dynamical interaction. As the massive stars are always formed in clusters, such interactions may be quite common. The impulsive explosive nature of this outflow is very different fundamentally from the steady molecular outflow from sun-like stars.



Three-dimensional animation of the explosive event in G5.89−0.39. The radial blue shifted and red shifted velocities are shown from blue to red colors. The animation starts with a view from up to down and then left to right. The duration of the animation is about 10s. Credit: Institute of Astrophysics and Astronomy, Academia Sinica

"This kind of explosive outflows are suggested to be powered by the liberation of gravitational energy associated with the formation of a close-by stellar massive binary or maybe even a protostellar merger," explains Paul Ho, Distinguished Research Fellow, Academician of Academia Sinica. This outflow is similar in nature to the case in Orion. G5.89-0.39 is the second clear example of this new family of molecular flows related with the formation of a cluster of massive stars.

The impulsive nature of this explosive outflow, and the short duration of this outflow phase, may make their detection a rare phenomenon. "If enough of these outflows can be detected in the future, the merging of cluster of stars may be an important formation mechanism of massive stars," says Luis Zapata, the director of the Institute of Radio Astronomy and Astrophysics in Mexico.

More information: "Confirming the Explosive Outflow in G5.89 with ALMA," Luis Zapata (Universidad Nacional Autónoma de México) et al., 2020, to appear in the *Astrophysical Journal Letters*, arxiv.org/abs/2010.13835

Provided by Institute of Astrophysics and Astronomy, Academia Sinica

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