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PRESS RELEASE (2026/08/03)

Inter-filamentary diffuse gas flows replenish dense filaments and sustain gas accretion onto hubs, promoting massive star formation

Researchers reveal that diffuse gas surrounding dense filaments significantly contributes to the growth of star-forming hubs

Fukuoka, Japan— Researchers from Kyushu University have discovered that diffuse gas surrounding dense filaments in a nearby stellar nursery plays a much larger role in star formation than previously recognized. By tracking the movement of gas in the Monoceros R2 hub–filament system, the team found that low-density gas contributes to hub growth both through direct inflow and by replenishing nearby dense filaments. Their findings show that overlooking this diffuse gas could substantially underestimate the amount of material available to build massive stars.

Stars form inside interstellar clouds of gas and dust, but the process is far from being well understood. Within these clouds, long, thread-like structures known as filaments often converge into dense central regions called hubs, where clusters of stars and the most massive stars are born. Previous studies have shown that dense gas travels along these filaments into the hub. However, much less is known about the lower-density gas that fills the spaces between the filaments, leaving an incomplete picture of how these stellar nurseries gather enough material to sustain star formation.

In the present study, published in *The Astrophysical Journal Letters* on June 10, 2026, a team led by Assistant Professor Jihye Hwang of Kyushu University's Institute for Advanced Study worked with Associate Professor Doris Arzoumanian to investigate gas motions in the Monoceros R2 hub–filament system. Using observations of the carbon monoxide isotopes ^{13}CO and C^{18}O from Nobeyama 45-m radio telescope operated by Nobeyama Radio Observatory, a branch of National Astronomical Observatory of Japan, the researchers identified three dense filaments and three inter-filament regions and measured gas motions toward the hub and neighboring filaments.

The analysis showed that gas within dense filaments flows toward the hub much faster than gas in the surrounding inter-filament regions. At the same time, the team found that at least 30% of the gas in the inter-filament regions appears to move sideways into nearby filaments, replenishing them with fresh material before continuing toward the hub. When the researchers accounted for both dense and diffuse gas, the estimated amount of material flowing onto the hub increased by approximately 50% compared with estimates based only on dense filaments.

"Previous studies mainly focused on the dense filaments because complementary observations tracing the diffuse gas were not included in their analysis," says Hwang. "Our combined analysis based on observations tracing both the dense gas (using C^{18}O) and the diffuse gas (using ^{13}CO) shows that the inter-filamentary diffuse gas

also contributes significantly to feeding the hub, either directly or by first replenishing the dense filaments."

The team also examined the distribution of dense cores—the compact structures that eventually collapse under gravity, giving rise to stars. They found that cores inside the hub are generally more massive and warmer than those outside it, consistent with the hub providing favorable conditions for the formation of higher-mass stars. These observations support the idea that the continuous inflow of gas helps build up the dense environments where massive stars preferentially form.

"Our results indicate that understanding star formation requires accounting for the entire gas reservoir, not only that of the dense filaments," Hwang explains. "Future studies extending this analysis to additional hub–filament systems and comparing the observations with numerical simulations will help determine how widespread these gas-flow patterns are."

Overall, this study provides new observational evidence that diffuse inter-filament gas is an active component of hub–filament systems rather than merely passive gas between dense structures. By showing that lower-density gas feeds dense filaments and contributes directly to the hub, the research provides a more complete picture of how stellar nurseries accumulate material needed to form massive stars, highlighting the importance of considering the full gas reservoir.

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For more information about this research, see "From Interfilamentary Gas to Filaments and Hubs: Gas Flows in the Monoceros R2 Hub–Filament System" Jihye Hwang, Doris Arzoumanian, Yoshito Shimajiri, Masahiro N. Machida, Shu-ichiro Inutsuka, M. S. N. Kumar, Shingo Nozaki, and Kazuki Tokuda, *The Astrophysical Journal Letters*, https://doi.org/10.3847/2041-8213/ae6f0f.

About Kyushu University
Founded in 1911, Kyushu University is one of Japan's leading research-oriented institutions of higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World Rankings. Located in Fukuoka, on the island of Kyushu—the most southwestern of Japan's four main islands—Kyushu U sits in a coastal metropolis frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Its multiple campuses are home to around 19,000 students and 8,000 faculty and staff. Through its VISION 2030, Kyushu U will "drive social change with integrative knowledge." By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society's most pressing issues.

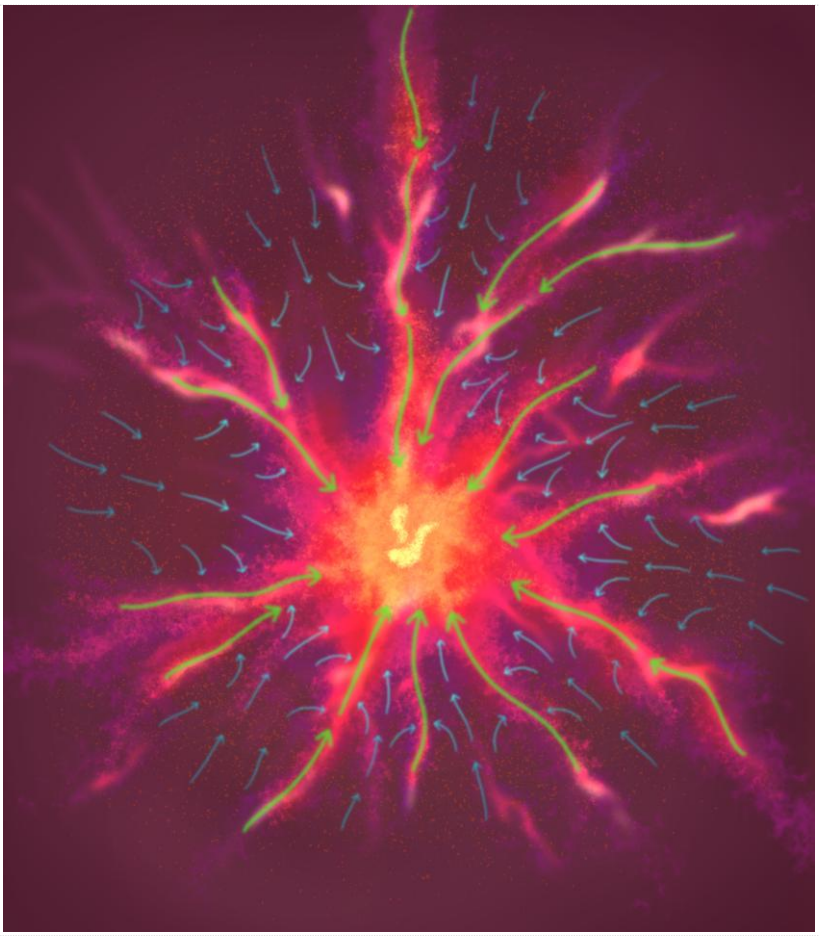

Fig. 1. From inter-filamentary gas to filaments and hubs: gas flow in the Monoceros R2 star-forming hub-filament system.
Illustration of the Monoceros R2 hub–filament system showing how the gas flows along the filaments (green arrows) and in the inter-filament regions (blue arrows) towards the central hub.
The analysis showed that gas within dense filaments flows toward the hub much faster than gas in the surrounding inter-filament regions. At the same time, a fraction of the gas in the inter-filament regions moves sideways into nearby filaments, replenishing them with fresh material before continuing toward the hub, supporting star formation. (Yurika Nakamura and Jihye Hwang/Kyushu University)

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