

# Can Organic Molecules Survive a Supernova Explosion?

— First Detection of Hot Cores in a Supernova Remnant —

## Abstract

For the first time, astronomers have discovered stellar cocoons rich in complex organic molecules within a supernova remnant. A research team from Niigata University, Gifu University, RIKEN, and Kyoto University in Japan used the Atacama Large Millimeter/submillimeter Array (ALMA) to observe the remnant of a massive star that exploded about 1,600 years ago. The team discovered warm, dense cocoons of molecular gas surrounding newborn stars, known as hot cores, marking the first detection of such objects within a supernova remnant. The discovery suggests that newborn stars can remain protected within their natal cocoons, allowing their rich molecular composition to survive even under intense supernova feedback. The findings were published in *The Astrophysical Journal* on July 1, 2026.

## Background

Our Solar System may have formed in a region strongly influenced by a nearby supernova explosion. This possibility is suggested by the analysis of primitive Solar System materials, which are thought to retain a record of the environment in which the Solar System was born.

Stars more than about ten times the mass of the Sun end their lives in spectacular explosions known as supernovae. These events are among the most energetic phenomena in the Universe, forging elements heavier than iron, accelerating cosmic rays (high-energy charged particles), and potentially triggering the formation of the next generation of stars. Yet one important question remains unanswered: How do the powerful shock waves and energetic particles produced by a supernova affect the chemical ingredients from which stars and planets are formed? In such environments, supernova feedback may either destroy organic molecules or promote the formation of new molecular species.

## Research Overview and Results

To address this question, the research team targeted the supernova remnant RX J1713.7–3946 using ALMA. Their goal was to search for newborn stars surrounded by warm molecular gas within this extreme environment. Such objects are known as hot cores, and they provide unique laboratories for investigating the chemistry of star- and planet-forming material.

ALMA's exceptional sensitivity and angular resolution enabled the team to discover two hot cores in the supernova remnant—the first such detections ever in supernova remnants (Fig.1 & 2). Both hot cores exhibit rich molecular emission, including a wide variety of organic molecules. The team also found that the relative abundances of complex organic molecules in one of the newly discovered hot cores are remarkably similar to those measured in ordinary star-forming regions that have not experienced nearby supernova explosions.

*"These observations indicate that even in the harsh environment of a supernova remnant, newborn stars can remain well protected within their natal cocoons, preserving their rich molecular composition,"* says Takashi Shimonishi, an astronomer at Niigata University, Japan, and the paper's lead author. *"The environments capable of harboring complex organic molecules—potential building blocks of prebiotic chemistry—may be more diverse than previously recognized,"* Shimonishi adds.

The authors discuss possible explanations for this surprising resilience. One possibility is that the hot cores have only recently begun to experience the effects of the supernova, leaving insufficient time for energetic particles to significantly alter their chemistry. Another possibility is that strong magnetic fields, thought to be amplified by the supernova shock, suppress the penetration of cosmic rays into the dense molecular gas, thereby shielding the hot cores and preserving their molecular inventory.

## **Future Prospects**

Although the hot cores discovered in this study have retained their molecular richness despite residing within a supernova remnant, it remains unclear whether this is the typical outcome of supernova feedback. Future observations are expected to provide a much more comprehensive picture of the physical and chemical properties of star- and planet-forming regions that have been influenced by supernova explosions. Such observations will provide new insights into whether the environment in which our Solar System formed was typical or exceptional.



Figure 1. Artist's impression of a hot core—a warm cocoon of molecular gas surrounding a newborn star—discovered in a supernova remnant. Blue represents high-energy regions produced by the supernova explosion, while brown indicates the surrounding molecular clouds.

Credit: T. Shimonishi (Niigata University). Artwork created with assistance from Google Gemini and ChatGPT based on the observational results presented in this study.



Figure 2. Two hot cores discovered in the supernova remnant RX J1713.7–3946. The background image is a multiwavelength composite of the region: blue shows high-energy X-ray emission, green shows the distribution of stars observed at 4.6  $\mu\text{m}$ , red indicates warm dust traced by 22  $\mu\text{m}$  infrared emission, and white contours show the distribution of cold interstellar gas. The two newly discovered hot cores are marked by green boxes. The upper-left and lower-right panels present ALMA observations of the two hot cores, revealing emission from various molecular species. The X-ray image is based on observations with XMM-Newton; the infrared image uses data from WISE; and the cold gas distribution is derived from CO and H I observations obtained with the NANTEN, NANTEN2, ATCA, and Parkes telescopes.

Credit: ALMA (ESO/NAOJ/NRAO), T. Shimonishi et al.

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