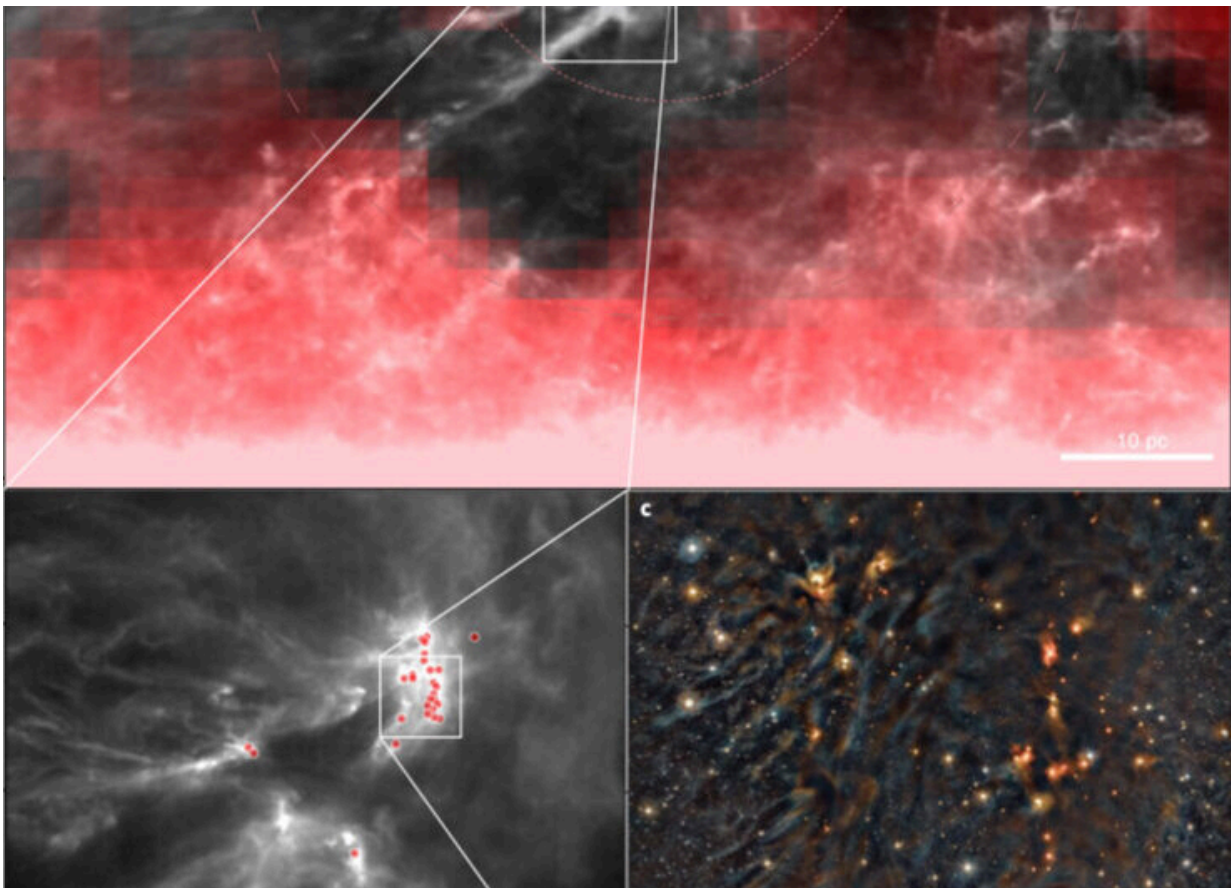


Nearby star-forming region yields clues to the formation of our solar system

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Multi-wavelength observations of the Ophiuchus star-forming region reveal interactions between clouds of star-forming gas and radionuclides produced in a nearby cluster of young stars. The top image (a) shows the distribution of aluminum-26 in red, traced by gamma-ray emissions. The central box represents the area covered in the bottom left image (b), which shows the distribution of protostars in the Ophiuchus clouds as red dots. The area in the box is shown in the bottom right image (c), a deep near-infrared color composite image of the

L1688 cloud, containing many well known prestellar dense-gas cores with disks and protostars. Credit: Forbes et al., *Nature Astronomy* 2021

A region of active star formation in the constellation Ophiuchus is giving astronomers new insights into the conditions in which our own solar system was born. In particular, a new study of the Ophiuchus star-forming complex shows how our solar system may have become enriched with short-lived radioactive elements.

Evidence of this enrichment process has been around since the 1970s, when scientists studying certain mineral inclusions in meteorites concluded that they were pristine remnants of the infant solar system and contained the decay products of short-lived radionuclides. These [radioactive elements](#) could have been blown onto the nascent solar system by a nearby exploding star (a supernova) or by the strong stellar winds from a type of massive star known as a Wolf-Rayet star.

The authors of the new study, published August 16 in *Nature Astronomy*, used multi-wavelength observations of the Ophiuchus star-forming region, including spectacular new infrared data, to reveal interactions between the clouds of star-forming gas and radionuclides produced in a nearby cluster of young stars. Their findings indicate that supernovas in the star cluster are the most likely source of short-lived radionuclides in the star-forming clouds.

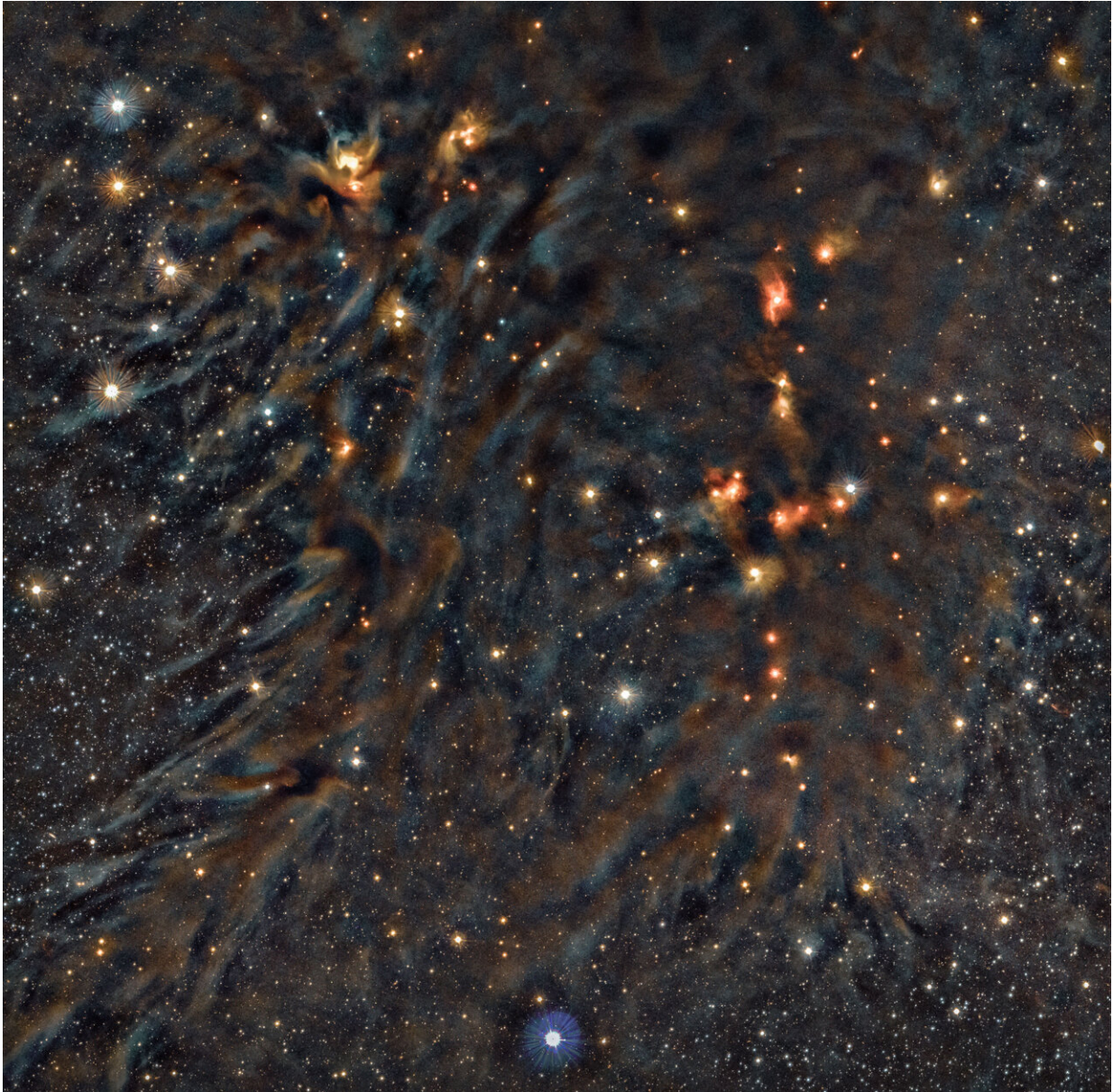
"Our solar system was most likely formed in a giant molecular cloud together with a young stellar cluster, and one or more supernova events from some massive stars in this cluster contaminated the gas which turned into the sun and its planetary system," said coauthor Douglas N. C. Lin, professor emeritus of astronomy and astrophysics at UC Santa Cruz. "Although this scenario has been suggested in the past, the strength

of this paper is to use multi-wavelength observations and a sophisticated statistical analysis to deduce a quantitative measurement of the model's likelihood."

First author John Forbes at the Flatiron Institute's Center for Computational Astrophysics said data from space-based gamma-ray telescopes enable the detection of gamma rays emitted by the short-lived radionuclide aluminum-26. "These are challenging observations. We can only convincingly detect it in two star-forming regions, and the best data are from the Ophiuchus complex," he said.

The Ophiuchus cloud complex contains many dense protostellar cores in various stages of star formation and protoplanetary disk development, representing the earliest stages in the formation of a planetary system. By combining imaging data in wavelengths ranging from millimeters to gamma rays, the researchers were able to visualize a flow of aluminum-26 from the nearby star cluster toward the Ophiuchus star-forming region.

"The enrichment process we're seeing in Ophiuchus is consistent with what happened during the formation of the solar system 5 billion years ago," Forbes said. "Once we saw this nice example of how the process might happen, we set about trying to model the nearby star cluster that produced the radionuclides we see today in gamma rays."



Deep near-infrared color composite image of the L1688 cloud in the Ophiuchus star-forming complex from the VISIONS European Southern Observatory public survey, where blue, green and red are mapped to the NIR bands J ($1.2 \mu\text{m}$), H ($1.6 \mu\text{m}$) and KS ($2.2 \mu\text{m}$), respectively. Credit: João Alves/ESO VISIONS

Forbes developed a model that accounts for every massive star that could

have existed in this region, including its mass, age, and probability of exploding as a supernova, and incorporates the potential yields of aluminum-26 from stellar winds and supernovas. The model enabled him to determine the probabilities of different scenarios for the production of the aluminum-26 observed today.

"We now have enough information to say that there is a 59 percent chance it is due to supernovas and a 68 percent chance that it's from multiple sources and not just one supernova," Forbes said.

This type of [statistical analysis](#) assigns probabilities to scenarios that astronomers have been debating for the past 50 years, Lin noted. "This is the new direction for astronomy, to quantify the likelihood," he said.

The new findings also show that the amount of short-lived radionuclides incorporated into newly forming star systems can vary widely. "Many new star systems will be born with aluminum-26 abundances in line with our solar system, but the variation is huge—several orders of magnitude," Forbes said. "This matters for the early evolution of planetary systems, since aluminum-26 is the main early heating source. More aluminum-26 probably means drier planets."

The infrared data, which enabled the team to peer through dusty clouds into the heart of the star-forming complex, was obtained by coauthor João Alves at the University of Vienna as part of the European Southern Observatory's VISION survey of nearby stellar nurseries using the VISTA telescope in Chile.

"There is nothing special about Ophiuchus as a star formation region," Alves said. "It is just a typical configuration of gas and young massive [stars](#), so our results should be representative of the enrichment of short-lived radioactive elements in star and planet formation across the Milky Way."

The team also used data from the European Space Agency's (ESA) Herschel Space Observatory, the ESA's Planck satellite, and NASA's Compton Gamma Ray Observatory.

More information: A Solar System formation analogue in the Ophiuchus star-forming complex, *Nature Astronomy* (2021). [DOI: 10.1038/s41550-021-01442-9](https://doi.org/10.1038/s41550-021-01442-9), www.nature.com/articles/s41550-021-01442-9

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