

Astronomers unveil observational evidence of how cosmic dust grains line up with the Galaxy's magnetic field

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Scientists have long believed that just like dust particles dancing in a ray of light, tiny cosmic particles floating between stars in the Milky Way act as storytellers of the universe.

Now a team of astronomers, has just uncovered the strongest observational evidence yet of how these interstellar dust grains align themselves with magnetic fields in our Galaxy.

Dust grains, typically a few micrometers in size and composed primarily of silicates and carbonaceous material, are found throughout the interstellar medium in the Milky Way and other galaxies. These tiny particles play a crucial role in a wide range of astrophysical processes, including the formation of stars and planets. In 1949, light from certain stars was discovered to be linearly polarized or the electric field vibrations in light are restricted to one specific direction or plane.

This starlight polarization caused by interstellar dust, and the later detection of polarized thermal dust emission revealed that non-spherical silicate grains align with magnetic fields that thread the interstellar medium. However, the exact physical mechanisms behind this alignment have remained an area of investigation in astrophysics for decades.

A team of astronomers led by the Indian Institute of Astrophysics (IIA), Bengaluru, an autonomous institute of the Department of Science and Technology (DST) and their collaborators has made a breakthrough in understanding how these dust grains behave. Their work provides the strongest observational evidence yet for the long-theorized ways in which dust aligns itself with magnetic fields in our Galaxy.

They focused on the massive star-forming infrared dark cloud G34.43+0.24, located around 12,000 light-years away in the Milky Way. This high-mass star-forming filament contains several dense cores at various evolutionary stages. Hidden within this cloud are embryonic stars—protostars—still wrapped inside dense cocoons of dust and gas. Among them are MM1 and MM2 in the central region, fiery newborn giants in the making, MM3 in the north, another hot young star-to-be.

Using the POL-2 polarimeter on the James Clerk Maxwell Telescope in Hawaii, the researchers mapped how dust in this star forming nursery aligned with magnetic fields.

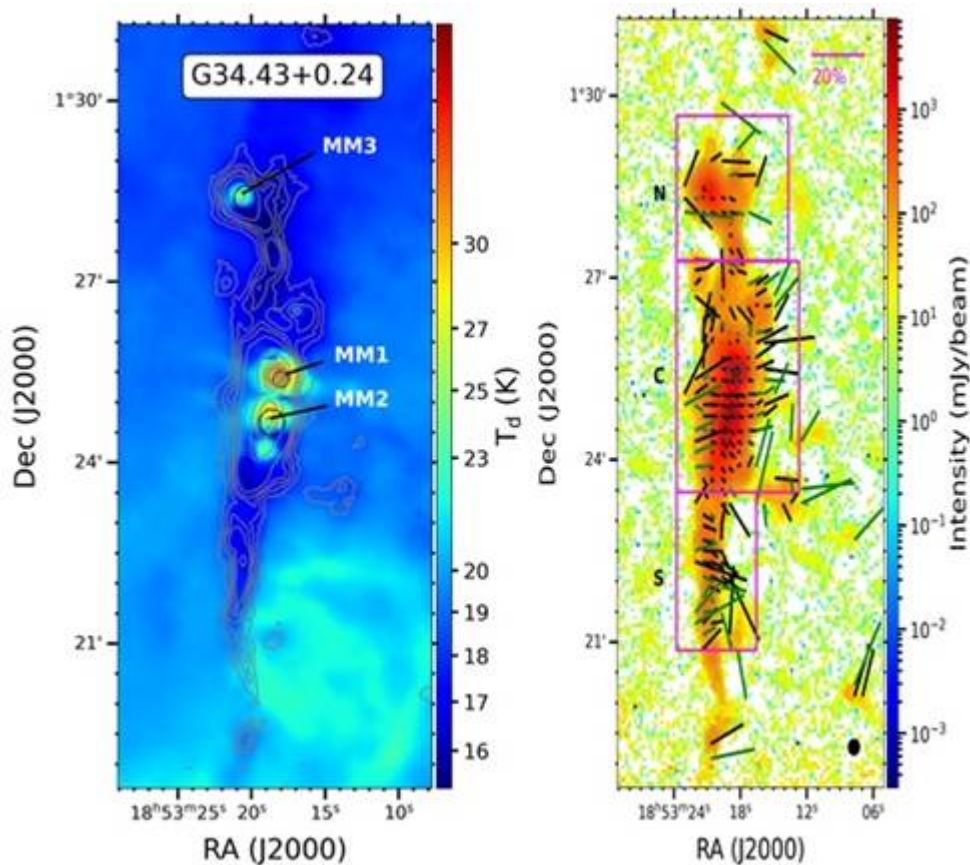


Fig: Dust temperature map that clearly shows high values in the protostellar cores MM1, MM2 in the Central region and MM3 in the Northern region of the G34.43+0.24 filament and lower values outside the core regions (left panel). Total dust emission intensity map is shown in the right panel and polarization vectors are overplotted on it with the length proportional to the polarization fraction and orientations determining the magnetic field orientations. A significant decrease in polarization fraction is observed in the dense regions of the filament.

The study found observational evidence for three different alignment mechanisms acting in a single cosmic cloud namely RAT-A, RAT-D and M-RAT.

RAT-A, implies RAdiative Torque Alignment in which non-spherical grains exposed to anisotropic radiation fields experience RAdiative Torques—RATs, that cause them to spin up and align with the direction of the surrounding magnetic fields. RAT-D is Radiative Torque Disruption in which large dust grains spin so rapidly under strong radiation from the massive and luminous protostars embedded inside the cores that they are disrupted into smaller fragments, reducing the grain alignment efficiency and thereby lowering the polarization fraction. M-RAT implies Magnetically-enhanced RAdiative Torque alignment mechanism in which alignment efficiency of grains is enhanced by strong magnetic relaxation strength of grains, resulting in higher polarization percentages.

This shows that the grains respond differently depending on their environment—sometimes aligning perfectly, sometimes shattering under stress, and sometimes becoming super-efficient at tracing magnetic fields.

By proving how these mechanisms play out in real space, astronomers now have stronger tools to map magnetic fields across the galaxy. Since magnetic fields influence everything from star birth to the structure of galaxies, this study brings us a step closer to understanding how the universe builds itself.

“This work strengthens the observational support for the well-established popular grain alignment theories and makes a significant contribution to the long-standing quest to understand the exact grain alignment mechanisms,” says Saikhom Pravash, lead author and PhD researcher at IIA and Pondicherry University.

As co-author Archana Soam of IIA adds, understanding dust alignment is crucial: “It’s the key to tracing interstellar magnetic fields and exploring their influence on star formation.”

The research has been published in *The Astrophysical Journal*.

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