Understanding the the magnetic field in the BHR 71 protostellar binary

High-resolution ALMA observations reveal enhanced polarization along outflow cavity walls

Summary. We present 1.3 mm ALMA observations of polarized dust emission toward the wide-binary protostellar system BHR 71. While IRS1 seems to have an hourglass-shaped magnetic field that is not obviously affected by its outflow, IRS2 exhibits strongly enhanced polarization along its outflow cavity walls. The origin of the enhanced polarization in IRS2 is most likely the irradiation of the outflow cavity walls, which enables the alignment of dust grains with respect to the magnetic field—but only to a depth of ~300 au, beyond which the dust is cold and unpolarized. Our combined dust-polarization and spectral-line observations tell the story.

Observations of dense gas tracers help us better understand the magnetic field morphology in BHR 71. Below we find a clear anti-correlation between $^{13}$CO and N$_2$D$^+$. The latter of these is also anticorrelated with the dust polarization, suggesting that it, and similar species like N$_2$H$^+$, are good tracers of conditions in the ISM that are not favorable for dust-grain alignment via Radiative Torques (RATs).

Dense gas tracers toward BHR 71. The color scales show integrated emission from N$_2$D$^+$ (J=3→2) [left] and $^{13}$CO (J=2→1) [right] toward BHR 71. The line segments are the inferred magnetic field orientation.

Conclusions. After analyzing the inferred magnetic field morphology toward both BHR 71 IRS1 and IRS2 alongside maps of their bipolar outflows and dense-gas tracers, we draw several conclusions in addition to those listed above.

1. In the case of the polarization along the IRS2 outflow cavity, we find polarization to a depth of ~300 au. In order to align grains deep enough in the cavity walls, the aligning photons are likely to be in the mid- to far-infrared range, which implies a degree of grain growth beyond what is typically expected in very young, Class 0 sources.

2. Enhanced polarization along outflow cavity walls is common, having also been seen in several other Class 0 sources.

3. Even more common are narrow, highly polarized features that are not associated with outflow cavities e.g., the NE arm of the IRS1 hourglass pictured above, as well as features in many other sources. We speculate that these features may be magnetized accretion streamers; however, this scenario has yet to be confirmed by kinematic observations of dense-gas tracers.

References