Multi-Band Far-Infrared Polarization as a Means of Recovering 3D Information on Interstellar Magnetic Fields and Grain Alignment

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The polarization of far-infrared (FIR) dust emission is one of the most important tracers of interstellar magnetic fields, as well as dust properties themselves. This because interstellar dust grains are generally non-spherical and their major axes tend to orient perpendicularly to magnetic field lines. Since emission is preferentially polarized along a grains' longer axis, the polarization angle of dust emission contains information on the magnetic field's projected direction on the plane of the sky. Furthermore, the polarization fraction is often used to estimate magnetic field disorder and grain alignment efficiency. Polarimetry is therefore central to many astrophysical fields, including star formation and galaxy evolution on cosmic times.

Unfortunately, there are two major limitations to the efficiency of polarization as a tracer. The first is that it can only provide information on the projected magnetic field, with a loss of information on the 3D structure of the magnetic field. Secondly, polarization fraction is degenerate: in typical observations, one cannot separate the effects of magnetic field structure, grain alignment and dust optical properties, so that the polarization fraction provides limited information by itself.

Both of these problems can be alleviated by using multi-band FIR polarimetry, as opposed to single-band. In environment with strong temperature gradients on the line of sight – such as molecular clouds – different bands are sensitive to dust at different temperature, and therefore in different cloud regions. In environment with relatively uniform temperatures, such as the diffuse interstellar medium, it can be shown that the effects of magnetic fields on polarization are at first approximation independent of wavelength: the shape of the polarization spectrum is then a good constraint on the dust properties and alignment.

I will present our team's results for a pilot study of multi-wavelength polarization in the star-forming region NGC 2071. The analysis combined 850 μm data from POL-2 at JCMT (observed as part of the BISTRO survey) with 154 and 214 μm data from HAWC+ on SOFIA. We detect a wavelength dependence of the polarization angles on a significant fraction of the target; this is most likely caused by a rotation of the magnetic field lines within the cloud. On those regions where the observed polarization angle is constant, the polarized spectrum shape suggests heterogenous grain alignment within the cloud. Overall, the analysis shows the potential of multi-band polarimetry for tracing the 3D structure of magnetic fields, as well as grain alignment.

I will also discuss the planned follow-ups to this analysis, including the selection of new polarimeters and databases following the decommissioning of SOFIA, the challenge of combining data from different telescopes, and the techniques we developed to improve our inter-telescope comparison.