The far-infrared polarization spectrum of Rho Ophiuchi A from HAWC+/SOFIA observations

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Magnetic Fields and Star Formation

- Role of magnetic fields in star formation

- Interstellar polarization from dust emission

- How to interpret polarization maps? Indirectly traces magnetic fields
  - Grain alignment

**Magnetic** fields in the Milky Way mapped through observations of interstellar polarization
• Rho Oph A: ~130 pc
• Warmed up by Oph S1 - massive B3 star
Rho Oph A – HAWC+ Observations

HAWC+ Observations:
- Band C: 89 µm
- Band D: 155 µm

Main Goal: combine pol. bands C and D
- Slope of polarization spectrum – probe grain alignment efficiency
- Test Radiative Torques (RATs)

Column density map (based on Herschel)
- Peak extinction $A_V > 100$ mag

Credits: Spitzer, JPL, Caltech
Magnetic fields in Rho Oph A

HAWC+ polarization map band D - 155 µm, ~13.6” beam size

Comparison of polarization angles bands C & D

HAWC+ polarization map band C - 89 µm, ~7.8” beam size

Oph S1

B-field inferred

Rho Oph A

Magnetic fields in Rho Oph A

• Slope of polarization spectrum: $R_{DC} = \frac{P_D}{P_C}$

Good probe of grain alignment efficiency
Far-IR polarization spectrum

Map of $R_{DC} = P_D / P_C$

- More diffuse $R_{DC} > 1$
- Dense $R_{DC} < 1$

- Systematic dependence of polarization spectrum slope with cloud density

- Hypothesis: differences in grain alignment efficiency
  - outer (warm) grains, well aligned
  - inner (cold) grains, poorly aligned


Zooming in on Star Formation - June 2019 – Nafplio, Greece
Far-IR polarization spectrum

• Very simple model:
  • Spherical dense core embedded in uniform background
  • Fit 7 model parameters based on *Herschel* data

• Transition radius $R_T$:
  • $r < R_T$: no polarized flux (no grain alignment) – free parameter
  • Test for RATs
Comparing model with observations:

- Calculate $R_{DC}$ vs. $\log N$ for different $R_T$ values: 0.3 R, 0.6 R, and 0.9 R
Rho Oph A Molecular Cloud

• The observed decrease of \( \sim 50\% \) in \( R_{DC} \) can be reproduced with the simple model

• Decrease in grain alignment efficiency likely responsible for trends in polarization spectrum slope – support for RATs
Final remarks

• First conclusive observation of systematic variations of the far-infrared polarization spectrum within an interstellar cloud.

• Consistent with reduced grain alignment efficiency in the core, based on very simple modeling of the cloud.

• New method to probe grain alignment efficiency. Grain alignment theory: critical connection between interstellar polarization and magnetic fields – crucial to understand star formation.

Thank you!