Continuity of Magnetic Fields across Spatial Scales in Star Formation

Paul Williams (he/him)

July 31, 2023

Outline

- Star Formation
- Comparing B-fields across spatial Scales
- Properties of BLAST J090028
- Indications of a strong magnetic field

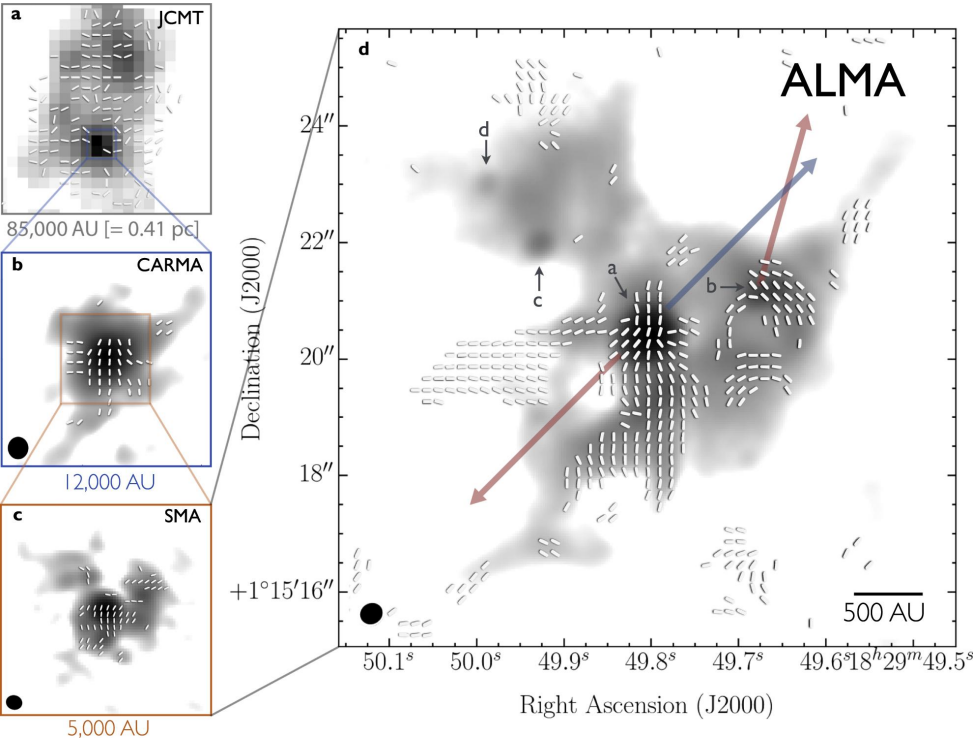
Star Formation

- Nine orders of magnitude in spatial scale involved in star formation (10^{11} to 10^{20} cm) – difficult to simulate
- Very inefficient – only a few percent of the mass in molecular clouds becomes stars
- Roles of magnetic fields, turbulence, feedback are all uncertain
- Influences most areas of astrophysics, including galaxy formation & evolution

Star Formation

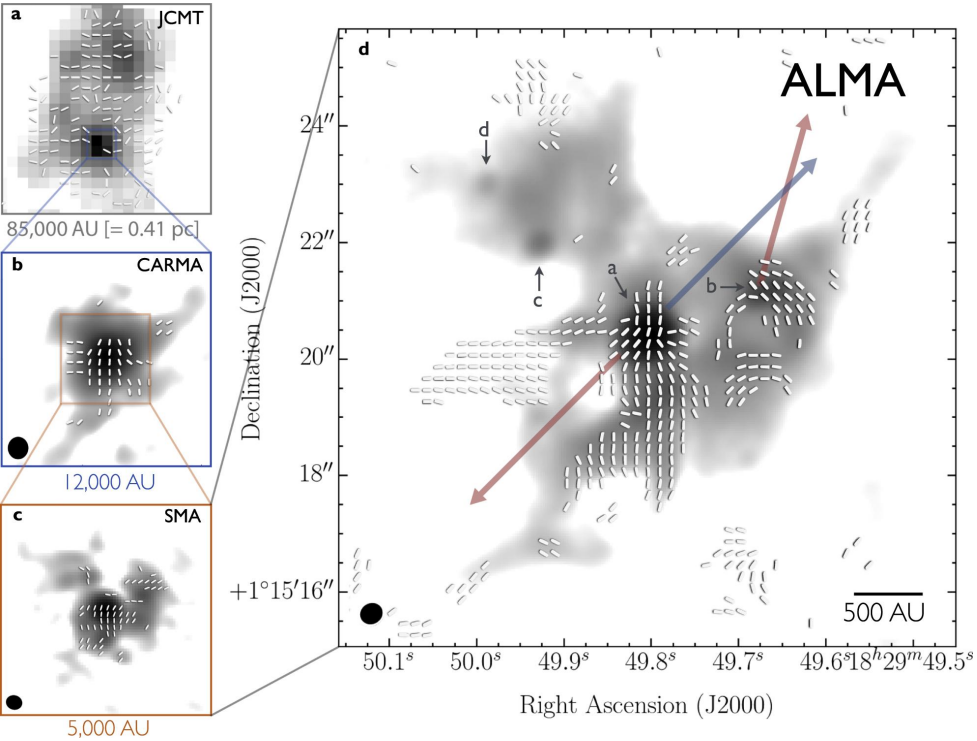
- Nine orders of magnitude in spatial scale involved in star formation (10^{11} to 10^{20} cm) – difficult to simulate
- Very inefficient – only a few percent of the mass in molecular clouds becomes stars
- Roles of magnetic fields, turbulence, feedback are all uncertain
- Influences most areas of astrophysics, including galaxy formation & evolution
- In GMCs, spinning dust grains align themselves with the local magnetic field
- They emit polarized light in the sub-mm
- Polarized emission from dust is the primary CMB foreground at high frequencies

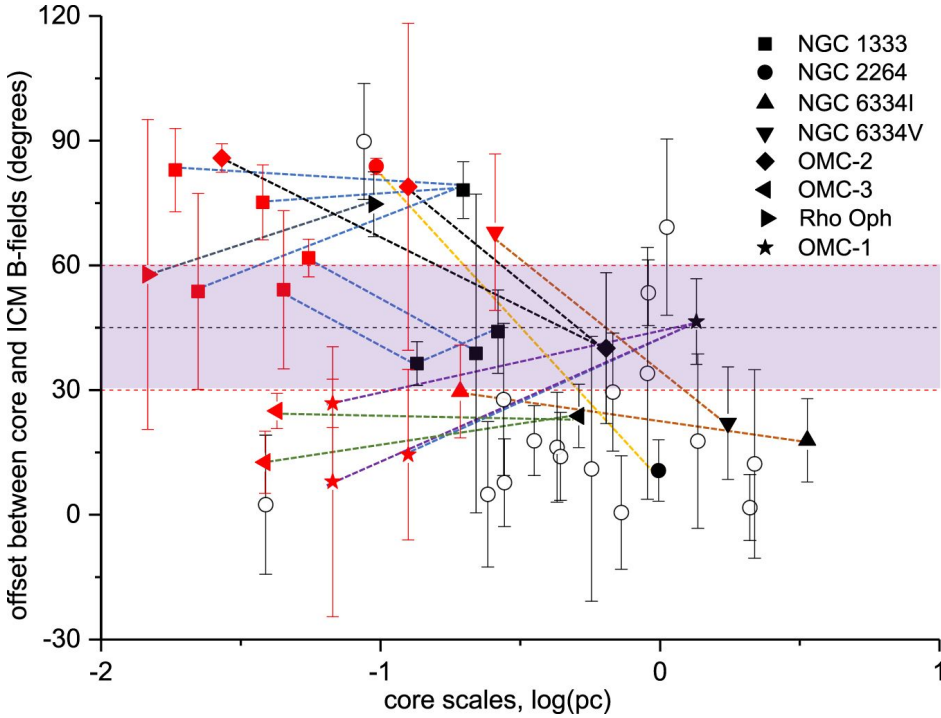
Magnetic Fields Across Scales



Hull+ 2017

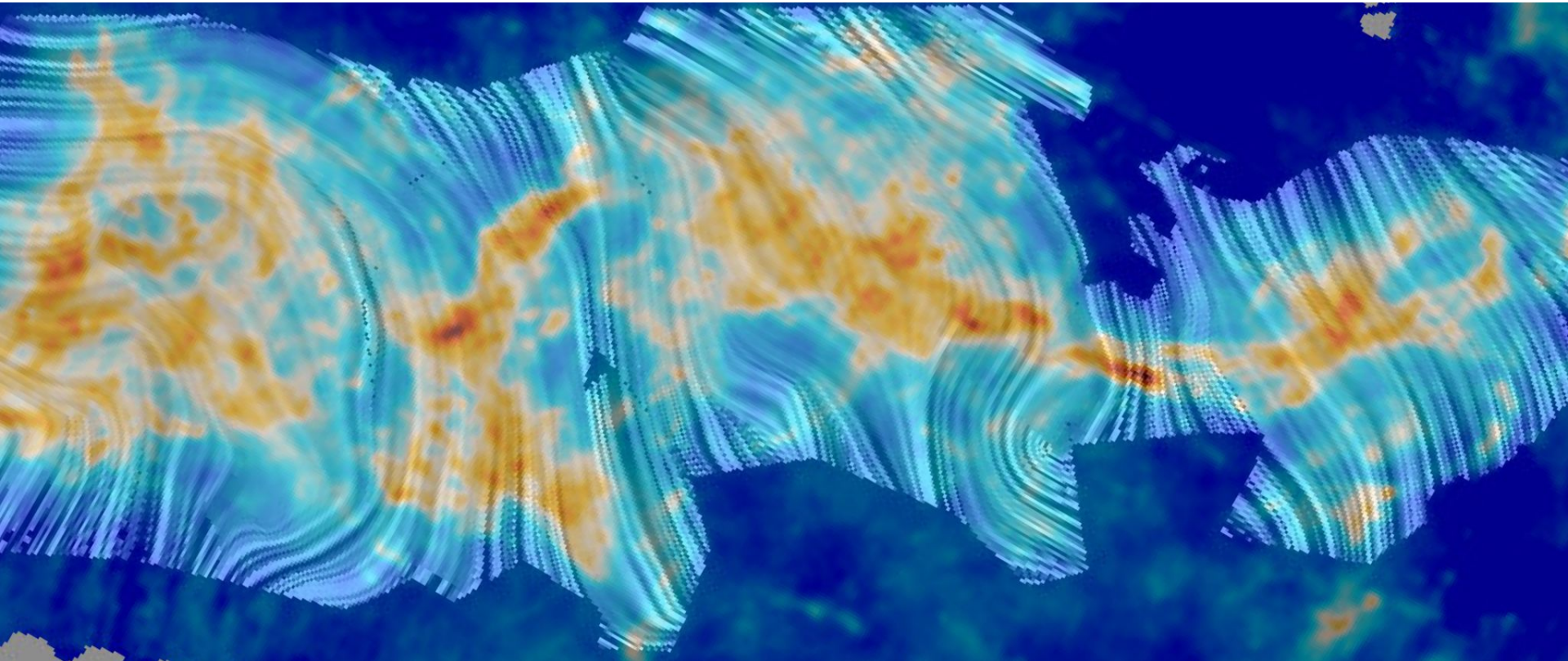
Magnetic Fields Across Scales



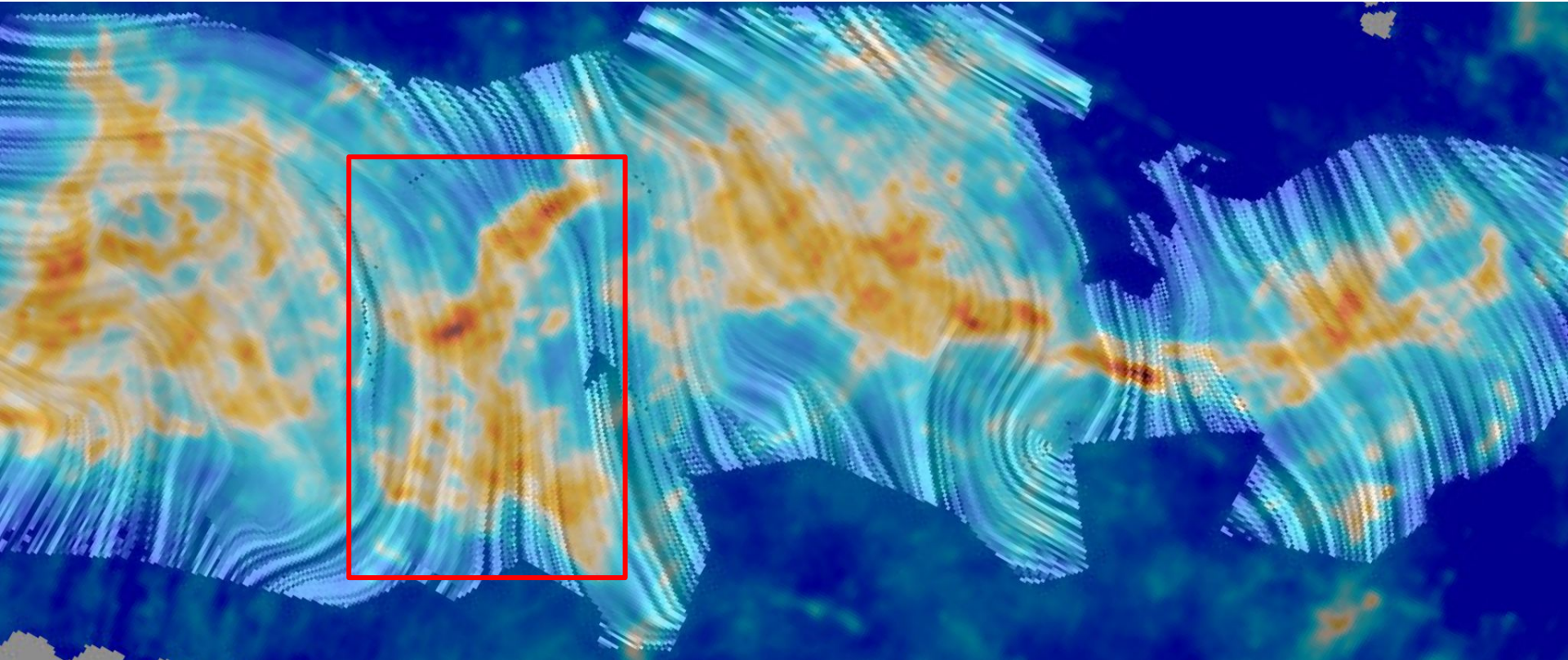


Hull+ 2017, Zhang+ 2019

Vela C Cloud at 250 micron, with inferred B-field direction

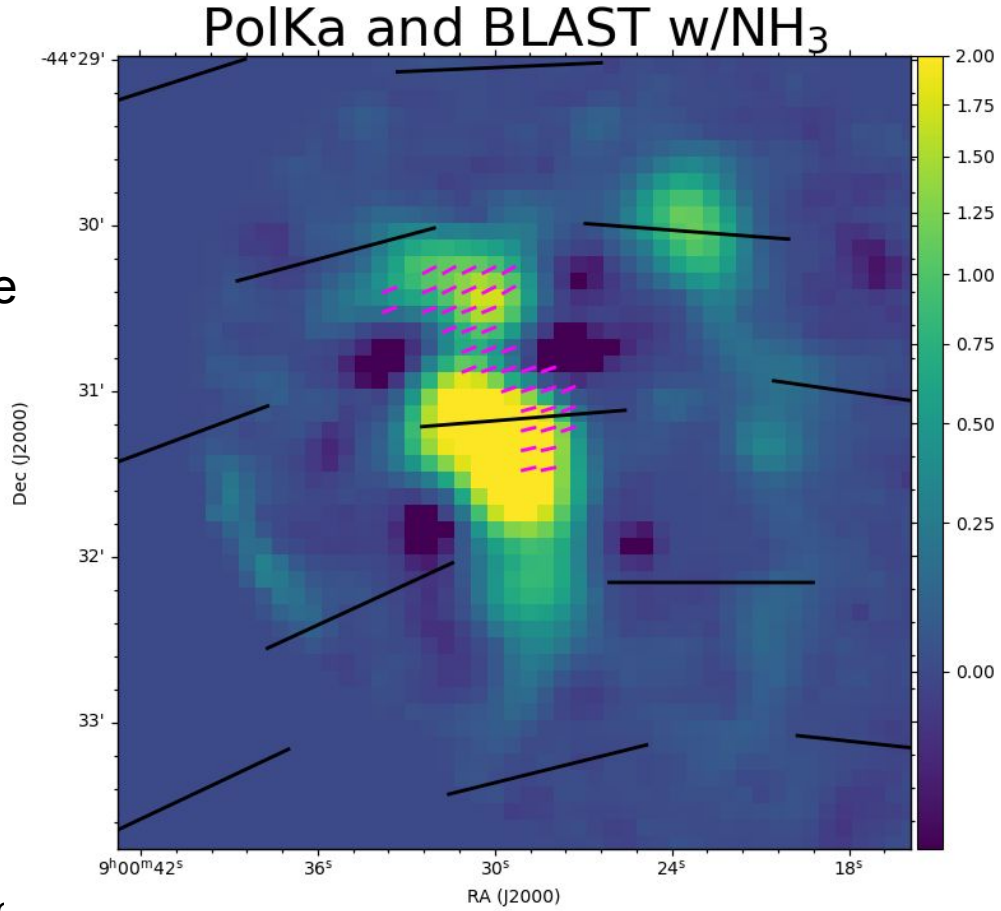


Vela C Cloud at 250 micron, with inferred B-field direction



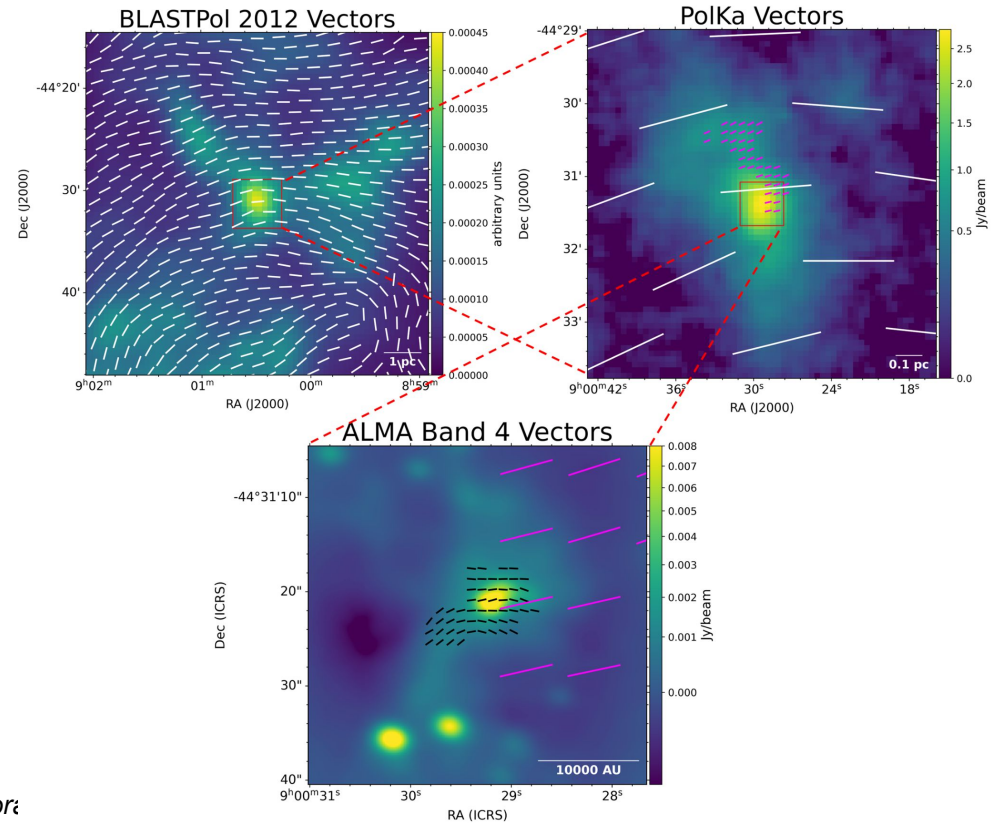
Properties of BLAST J090028

- IR-quiet Massive Dense Core (MDC)
- MDCs are the objects that form one or more massive stars
- This MDC is 200 solar masses



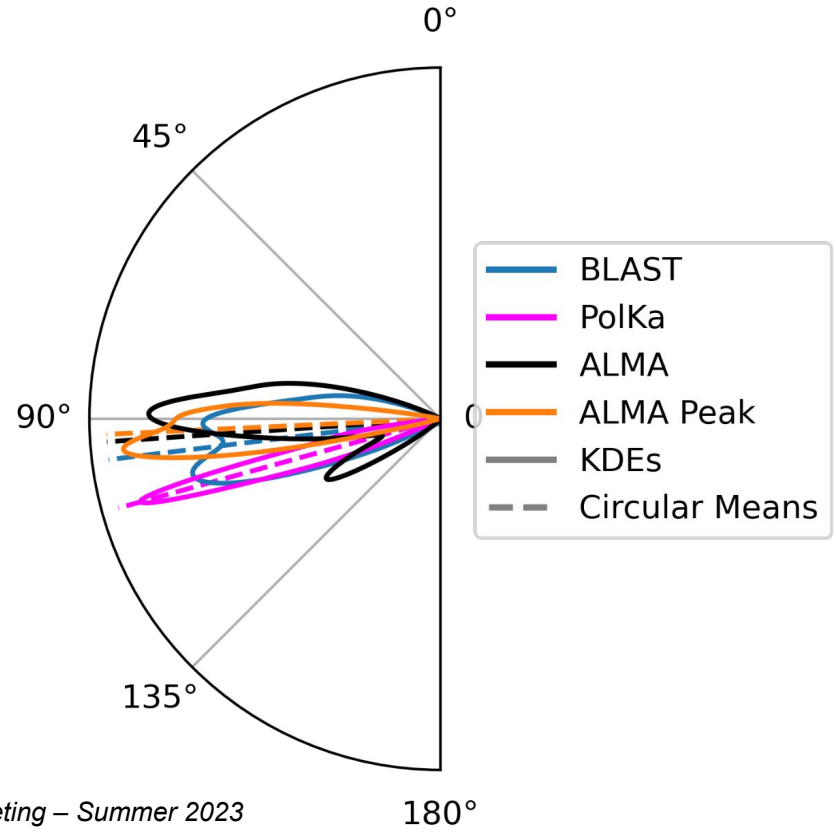
Magnetic Field Continuity Across Spatial Scales

- Indications of a dynamically important magnetic field include:
- Magnetic Field direction continuous from 10 pc to 0.01 pc spatial scales
- Magnetic fields are perpendicular to filamentary structures



Comparing field direction distributions

- Distributions overlap significantly
- PRS > 4 for PolKa and ALMA vectors compared with BLASTPol (PRS from Jow+ 2018)



Conclusions

- In star formation, the length scales at which magnetic fields, turbulence, and gravity are important are uncertain
- This work finds that for BLAST J090028, magnetic fields are dynamically important from 10 pc to 0.01 pc (cloud to core scales)
- Previous studies find a mix of strong and weak magnetic fields
- Upcoming instruments will enable more of these comparisons
    - CMB-S4: ~1’ resolution across 2/3 sky
    - ALMA upgrades: polarimetry with ACA, polarimetry mosaicing
    - BLAST Observatory: Longer flight and higher sensitivity, will map more clouds
    - TolTEC: 5’’ resolution, will reconstruct entire clouds

References

Hull, C. L. H., Girart, J. M., Tychoniec, L., et al. 2017, ApJ, 847, 92

Jow, D. L., Hill, R., Scott, D., et al. 2018, MNRAS, 474, 1018

Williams et al., 2023, in prep.

Zhang, Y., Guo, Z., Wang, H. H., & Li, H. b. 2019, ApJ, 871, 98

Extra Slides

Polarized Dust Emission

- Dust in the interstellar medium (ISM) emits polarized light
- This is the primary CMB foreground at high frequencies
- Dust grains spin

Observations

- BLASTPol
  - 500 μm
  - Cloud scale
  - Spatial scales: 25 pc to 0.67 pc
- PolKa
  - 870 μm
  - Filament scale
  - Spatial scales: 0.67 pc to 0.081 pc
- ALMA
  - 1.8 - 2.4 mm
  - Core scale
  - Spatial scales: 0.059 pc to 0.01 pc (12,000 AU to 2000 AU)