Galactic Science and Magnetic Fields

Team members: Laura Fissel, Susan Clark, Sarah Sadavoy
(additional collaborators welcome)
Session Outline

• Introduction: Laura Fissel
• Magnetic Fields Galactic and Diffuse ISM (Susan Clark):
  • What can we learn about the magnetic fields and turbulence in the diffuse ISM with the planned CCAT prime surveys
  • Suggested additional survey: Studying magnetic fields in extremely nearby galaxies.
• Multi-scale study of the role of magnetic fields in star formation (Laura Fissel):
  • Extending the planned CMB wide scale surveys to cover the Galactic Plane.
  • Additional Targeted deep surveys of magnetic fields.
• Discussion
## Sensitivity Estimates

**Based on Choi et al Table 1**

<table>
<thead>
<tr>
<th>freq</th>
<th>df</th>
<th>Res ['&quot;]</th>
<th>Beam area [deg2]</th>
<th>NEI</th>
<th>NEPI</th>
<th>NET</th>
<th>N detectors</th>
<th>I source</th>
<th>sig_p full resolution (%)</th>
<th>%p need for 3 sigma detections smooth to [arcsec]</th>
<th>%p needed for 3 sigma detection after smoothing</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>56</td>
<td>57</td>
<td>0.00028328</td>
<td>3700</td>
<td>7400</td>
<td>7.6</td>
<td>0.00732</td>
<td>0.4</td>
<td>1.8%</td>
<td>5.5%</td>
<td>60</td>
</tr>
<tr>
<td>280</td>
<td>60</td>
<td>45</td>
<td>0.00017656</td>
<td>6100</td>
<td>12200</td>
<td>14</td>
<td>0.01530</td>
<td>1.4</td>
<td>1.1%</td>
<td>3.3%</td>
<td>60</td>
</tr>
<tr>
<td>350</td>
<td>35</td>
<td>35</td>
<td>0.00010681</td>
<td>16500</td>
<td>33000</td>
<td>54</td>
<td>0.05321</td>
<td>2</td>
<td>2.7%</td>
<td>8.0%</td>
<td>60</td>
</tr>
<tr>
<td>410</td>
<td>30</td>
<td>30</td>
<td>7.8472E-05</td>
<td>39400</td>
<td>78800</td>
<td>192</td>
<td>0.14825</td>
<td>4</td>
<td>3.7%</td>
<td>11.1%</td>
<td>60</td>
</tr>
<tr>
<td>850</td>
<td>97</td>
<td>14</td>
<td>1.709E-05</td>
<td>6.00E+07</td>
<td>1200000000</td>
<td>3.00E+0</td>
<td>5</td>
<td>16600</td>
<td>3.75501</td>
<td>150</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

Assumes 1 hr spent mapping 1 deg^2

860 GHz is the most sensitive to dust

assumed \( \sigma_p = 2 \sigma_i \), where \( P = \sqrt{Q^2 + U^2} \):

- Half the KIDs measure horizontal, half vertical poln: factor of \( \sqrt{2} \)
- Half the array measures Q, half U: factor of \( \sqrt{2} \)
For polarization sensitivity equates to the maximum resolution to detect polarization.
BLAST-TNG/BLASTPol

Stratospheric balloon-borne polarimeters that fly >35km altitude (>99.5 of the atmosphere).

- **BLASTPol**
  - similar NTE detectors to Herschel SPIRE
  - flew in 2010, 2012 from Antarctica

- **BLAST-TNG**
  - mKIDs (NIST manufactured, ROACH2 readout)
  - first flight January 2020
    - flight was only 16 hours due to a launch anomaly, so we likely won’t achieve the polarization science we’d hoped

BLAST-TNG at the Columbia Scientific Balloon Facility July 2018
Comparing CCAT 860GHz and BLAST-TNG Poln Sensitivity Pre-flight estimates

\[ l_{\text{min}}: \text{Total intensity the dust would need to have to get } \sigma_p = 0.5\%. \text{ In molecular clouds } p_{\text{mean}} \sim 2\% \]

<table>
<thead>
<tr>
<th>Survey</th>
<th>Band Wlen microns</th>
<th>FWHM arcsec</th>
<th>( dP ) (860 GHz)</th>
<th>( dP ) (860 GHz)</th>
<th>( l_{\text{min}} ) (dp=0.5%)</th>
<th>( l_{\text{min}} ) [60&quot;FWHM]</th>
<th>Area deg^2</th>
<th>Time hr</th>
<th>Depth hrs/deg^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOR-CCATp</td>
<td>350</td>
<td>14</td>
<td>0.589</td>
<td>0.11314387</td>
<td>22.62877488</td>
<td>5.280047472</td>
<td>10</td>
<td>2400</td>
<td>240</td>
</tr>
<tr>
<td>SFH-CCATp</td>
<td>350</td>
<td>14</td>
<td>5</td>
<td>0.96047432</td>
<td>192.0948632</td>
<td>44.82213474</td>
<td>36</td>
<td>120</td>
<td>3.3333333333</td>
</tr>
<tr>
<td>CMB-CCATp</td>
<td>350</td>
<td>14</td>
<td>15.8</td>
<td>3.03509884</td>
<td>607.0197676</td>
<td>141.6379458</td>
<td>12000</td>
<td>4000</td>
<td>0.3333333333</td>
</tr>
<tr>
<td>BLAST-TNG</td>
<td>250</td>
<td>31</td>
<td></td>
<td></td>
<td>188.7</td>
<td>97.495</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>BLAST-TNG</td>
<td>350</td>
<td>41</td>
<td></td>
<td></td>
<td>113.4</td>
<td>77.49</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>BLAST-TNG</td>
<td>500</td>
<td>59</td>
<td></td>
<td></td>
<td>42.4</td>
<td>41.693333333</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Preliminary Conclusion: CCAT-p polarization at 860 GHz would have similar or slightly better sensitivity than BLAST-TNG!
Magnetic Fields and Galactic Science

• Understanding how magnetic fields affect star formation and energy transport in galaxies:
  • How are magnetic fields in the ISM and molecular clouds shaped?
  • How is energy in the magnetic field?
  • How strong are magnetic fields as a function of density molecular clouds?
  • Do magnetic fields affect the formation of dense substructures (filaments, cores, disks) in star forming regions?
"First Light Science"

- Notional titles of paper(s)
  - The Connection between Molecular Cloud and Galactic Scale Magnetic Fields in the LMC (200 hours at reduced mapping speed)
  - A CCATprime Survey of Magnetic Fields in the Musca Filament (160 hours at reduced mapping speed)

- Observing Requirements:
  - Wavelength/frequency bands: Ideally 860 GHz
  - Sensitivity: LMC $\sigma_p = 2.9$ MJy/Sr, Musca $\sigma_p = 0.84$ MJy/Sr
  - Mapping area: LMC $\sim 60$ deg$^2$, Musca 4 deg$^2$
  - Observational cadence: not important
  - Other requirements: maximal crosslinking (some observations near transit)

Assume: 100-400 hours, using 1-2 modules including 270/350/860 GHz + EoR modules and CHAI
Baseline Science

(science that can be done with already planned surveys)

• Notional titles of paper(s)
  • A comparison of magnetic field properties and cloud structure for ~100 molecular clouds.
  • CCATprime measurements of the magnetized turbulence power spectrum in the local ISM.

• Observing Requirements:
  • Wavelength/frequency bands: 860 GHz, though 350 GHz could also be useful
  • Sensitivity: Large Area dP = 9.6 MJy/Sr, Musca dP = 0.24 MJy/Sr
  • Mapping area Large Area 26,000deg$^2$, Deep 4deg$^2$
  • Observational cadence: Not important
  • Other requirements

Assume: ~4000 hours, 2 broadband modules + EoR-spec & CHAI
Full Science
(Additional Requests)

• Notional titles of paper(s)
  • A comparison of magnetic fields and turbulence in the LMC and SMC (100 extra hours on the SMC)
  • Energy dissipation scale in the turbulent ISM (possible 100 hour deep field survey of an intermediate density CNM cloud)
  • CCAT Studies of the role of magnetic fields in setting star formation efficiency, supporting filaments against gravity, and regulating core collapse (surveys of 5 additional molecular cloud fields ~300 hours)

• Observing Requirements:
  • Wavelength/frequency bands: 860 GHz
  • Sensitivity: SMC $\sigma_p = 2.9$ MJy/Sr, Clouds, Diffuse field $\sigma_p = 0.84$ MJy/Sr
  • Mapping area – LMC ~60deg$^2$, Clouds 4deg$^2$ each
  • Observational cadence
Products/Path to Science

• Path to science
  • Observing requirements:
    • 860 GHz band polarization observations of large area and deep surveys
    • Additional 860 GHz maps requested:
      • six 4 deg$^2$ maps of nearby molecular clouds (300-400 hours)
      • maps of the LMC and SMC (200 hours)
      • 1 extremely deep CNM field (100 hours)
  • Reduction plan and requirements (computing & such): We can mostly use the same polarization reduction pipeline as the CMB polarization observations (e.g. TOAST)
  • Model/simulations: Need synthetic observations of star formation simulations to compare with our observations.
  • Foreground removal: Not applicable
  • Data analysis schedule:
  • Personnel needs/plans: TBD, though analysing and producing maps will probably require at least one postdoc, and there is enough science for many, many PhD theses.