# Galactic Science and Magnetic Fields

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

Planck Int XXXV 2016

# 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

Source intensity based on Planck Cold Clump SEDs (Juvela et al. 2015)

Based on Choi et al Table 1

| freq | df | Res [''] | Beam area [deg2] | NEI | NEPI | | NET | N detectors | | I source | sig_p full resolutio n(%) | %p need for 3 sigma detection at full resolution | smooth to [arcsec] | %p needed for 3 sigma detection after smoothig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jy/sr-1 sqrt(s) | | | mK sqrt(s) | | dP Mjy/Str | Mjy/Sr | | | | |
| 220 | 56 | 57 | 0.00028328 | 3700 | 7400 | | 7.6 | | 0.00732 | 0.4 | 1.8% | 5.5% | 60 | 5.2% |
| 280 | 60 | 45 | 0.00017656 | 6100 | 12200 | | 14 | | 0.01530 | 1.4 | 1.1% | 3.3% | 60 | 2.5% |
| 350 | 35 | 35 | 0.00010681 | 16500 | 33000 | | 54 | | 0.05321 | 2 | 2.7% | 8.0% | 60 | 4.7% |
| 410 | 30 | 30 | 7.8472E-05 | 39400 | 78800 | | 192 | | 0.14825 | 4 | 3.7% | 11.1% | 60 | 5.6% |
| 850 | 97 | 14 | 1.709E-05 | 6.00E+07 | 120000000 | | 3.00E+05 | 16600 | 3.75501 | 150 | 2.5% | 7.5% | 60 | 1.8% |

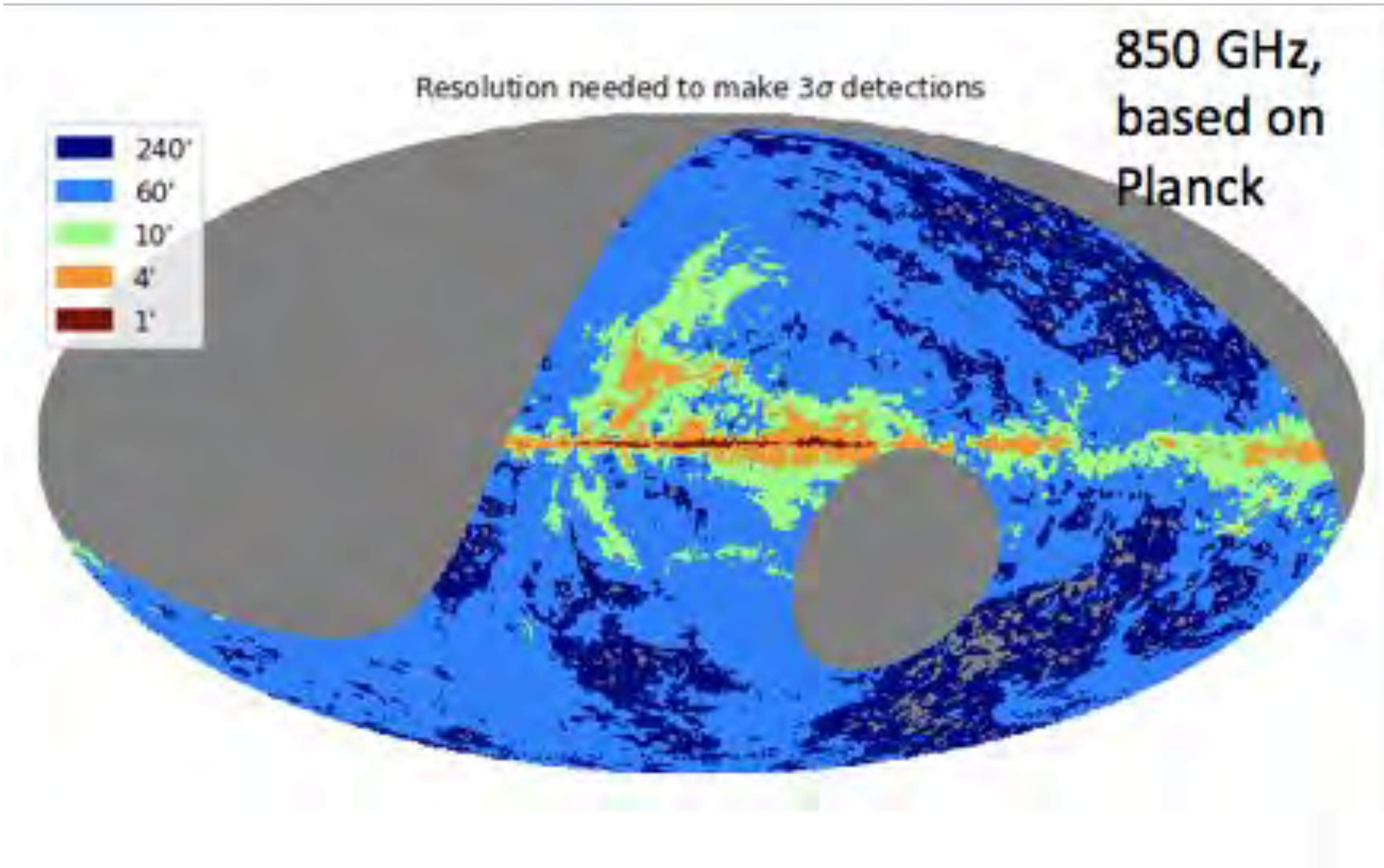
Assumes 1 hr spent mapping 1 deg^2

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 sfqrt(2)

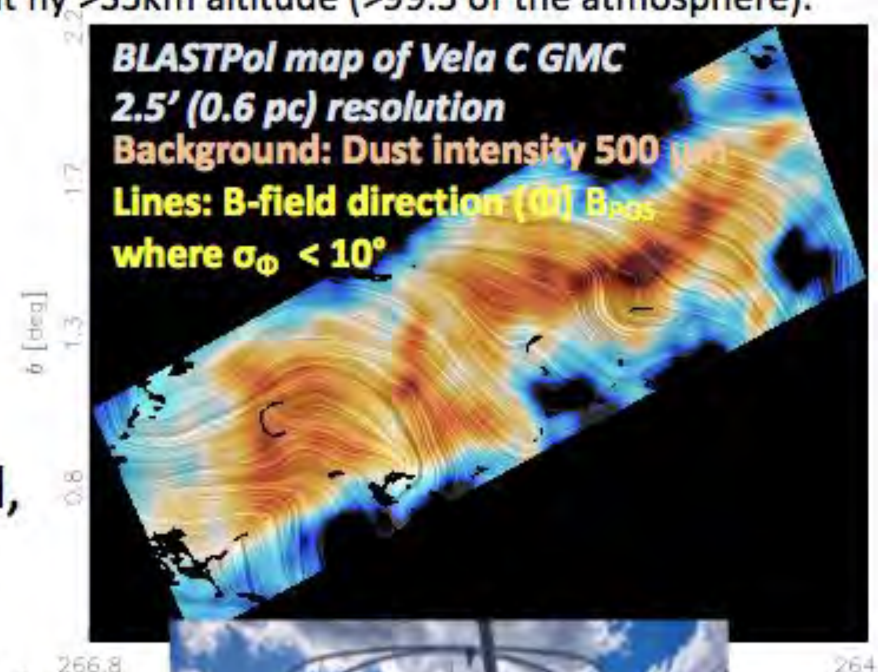
# For polarization sensitivity equates to the maximum resolution to detect polarization.



# 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

$I_{min}$: Total intensity the dust would need to have to get $\sigma_p$ = 0.5%. In molecular clouds $p_{mean}$ ~2%

| Survey | Band Wlen microns | FWHM arcsec | dP (860 GHz) mJy/beam | dP (860 GHz) Mjy/Sr | I_min (dp=0.5%) Mjy/Sr | I_min [60"FWHM] Mjy/Sr | Area deg^2 | Time hr | Depth hrs/deg^2 |
|---|---|---|---|---|---|---|---|---|---|
| EOR-CCATp | 350 | 14 | 0.589 | 0.11314387 | 22.62877488 | 5.280047472 | 10 | 2400 | 240 |
| SFH-CCATp | 350 | 14 | 5 | 0.96047432 | 192.0948632 | 44.82213474 | 36 | 120 | 3.33333333 |
| CMB-CCATp | 350 | 14 | 15.8 | 3.03509884 | 607.0197676 | 141.6379458 | 12000 | 4000 | 0.33333333 |
| BLAST-TNG | 250 | 31 | | | 188.7 | 97.495 | 1 | 5 | 5 |
| BLAST-TNG | 350 | 41 | | | 113.4 | 77.49 | 1 | 5 | 5 |
| BLAST-TNG | 500 | 59 | | | 42.4 | 41.69333333 | 1 | 5 | 5 |

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"

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

- 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 ~60deg$^2$, Musca 4deg$^2$
  - Observational cadence: not important
  - Other requirements: maximal crosslinking (some observations near transit)

Assume: ~4000 hours, 2 broadband modules + EoR-spec & 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

# Full Science (Additional Requests)

Assume: ~4000 hours, up to Choi et al. Instrument or variations (e.g. more EoR modules), & CHAI

- Notional titles of paper(s)
  - A comparison of magnetic fields and turblence 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.