CMBP Galactic Science

Slides for Telecon 2: 9/20/17

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Science Traceability Matrix (STM)

		Scientific Measurement Requirements			Instrument		
Science Goals	Science Objectives	Model Parameters	Physical Parameters	Observables	Instrument Functional Requirements	Projected Performance	Mission Functional Requirements (Top Level)
Explore how the universe evolved (magnetic fields)	Connect the small scale fields in SFR to the Galactic magnetic field		Magnetic field maps of molecular clouds	Linear polarization at frequencies > 300GHz over the entire sky	Angular resolution < 1 arcmin		
Explore how the universe evolved (magnetic fields)	Test models of galactic magnetic fields in a statistically significant sample of external galaxies		Magnetic field maps of nearby external galaxies	Linear polarization at frequencies > 300GHz over the entire sky	Angular resolution < 1 arcmin		
Explore how the universe evolved (magnetic fields)	Test models of the magnetic field turbulence in the diffuse ISM		Magnetic field maps of the diffuse ISM	Linear polarization at frequencies > 300GHz over the entire sky	Sensitivity: A_v <0.1(need to convert to Jy/sr)		
Explore how the universe evolved (magnetic fields)	Test grain alignment models, specifically RAT alignment theory.		Polarization spectra	Linear polarization at many frequencies > 300GHz over the entire sky	Combination of number of bands and angular resolution?		

-Part of the final report
-Also being used to determine instrument trades

Sensitivities for the design under consideration

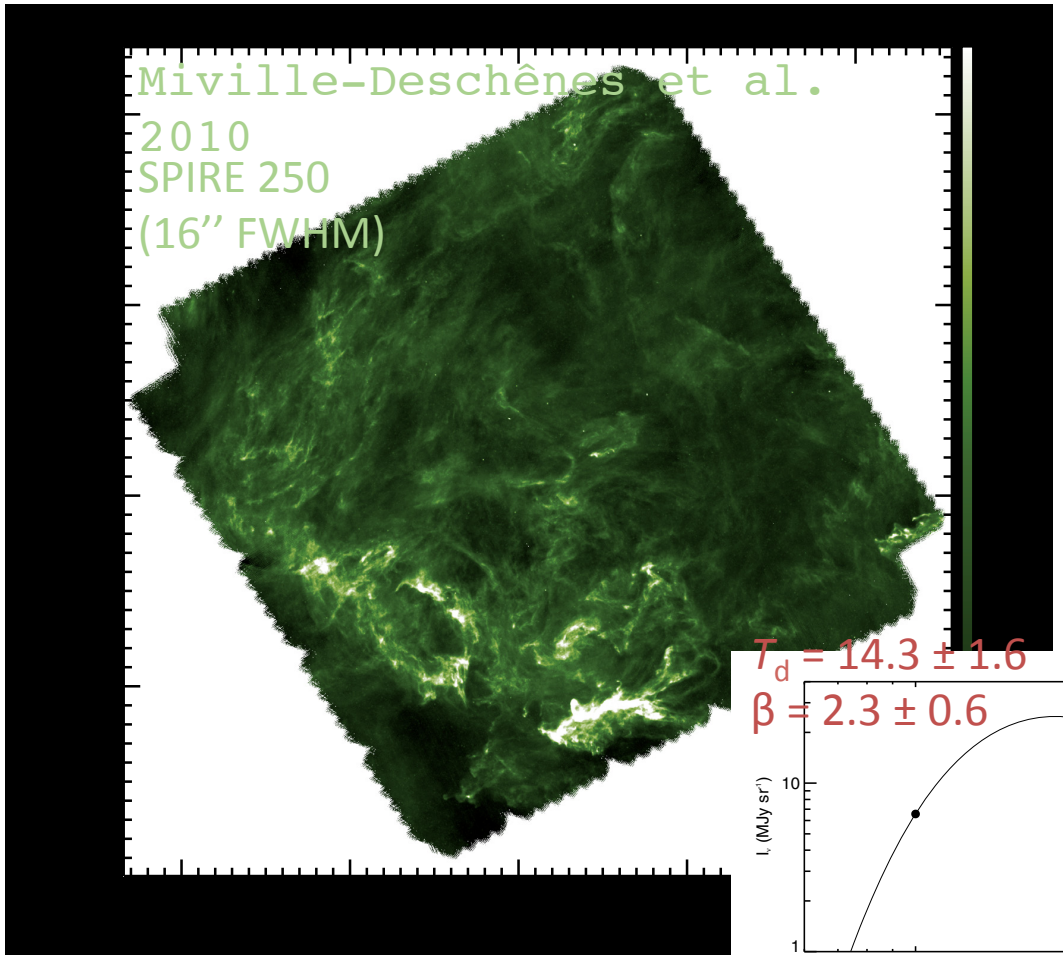
f (GHz)	FWHM (arcmin)	uK	uK arcmin	Jy/sr	uJy/beam
25	34.1	0.97	33	18.29	112.45
30	28.4	0.79	22.4	21.31	90.9
36	23.7	0.63	15	24.37	72.4
43	19.7	0.46	9.1	25.02	51.36
52	16.4	0.43	7	33.08	47.06
62	13.7	0.36	5	39.07	38.78
75	11.4	0.35	4	52.55	36.11
90	9.5	0.34	3.2	68.29	32.59
107	7.9	0.37	2.9	96.87	31.97
129	6.6	0.41	2.7	138.43	31.89
155	5.5	0.47	2.6	194.19	31.07
186	4.6	0.78	3.6	364.51	40.79
223	3.8	1.39	5.3	674.11	51.48
267	3.2	2.81	9	1259.99	68.23
321	2.7	5.93	16	2119.58	81.72
385	2.2	14.55	32	3472.44	88.88
462	1.8	41.67	75	5308.23	90.96
555	1.5	146.67	220	7565.15	90.02
666	1.3	846.15	1100	12820.87	114.59
799	1.1	9090.91	10000	27444.06	175.62

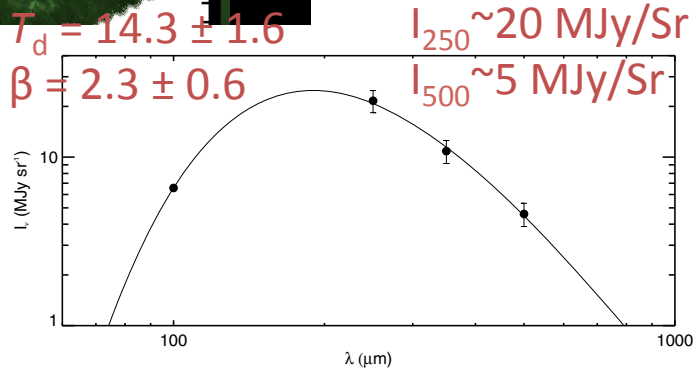
We have also been asked to consider the effects of:

- Resolution Trade-offs:
  - 2x better resolution
  - 2x worse resolution
- Sensitivity Trade-offs:
  - 2x better sensitivity
  - 2x worse sensitivity
  - 4x worse sensitivity
- Frequency Coverage Trade offs:
  - 555 GHz maximum frequency (detector technology changes for f > 600 GHz)

Magnetic Fields in Star Formation Sensitivity Goal: resolve the HI to H_2 transition

High Latitude Cirrus Cloud, distance ~150 pc





- Base sensitivity estimates on Polaris Flare Cloud
- Intensity of diffuse emission ($A_V < 1$) at 500 microns: ~5 MJy/Sr.
- To resolve the HI to H2 transition we want a 3-sigma detection of 2% polarized dust.
- Assume T_d = 14.3, β = 2 and scale 5 MJy/Sr to CMB Probe bands (I_{ref})

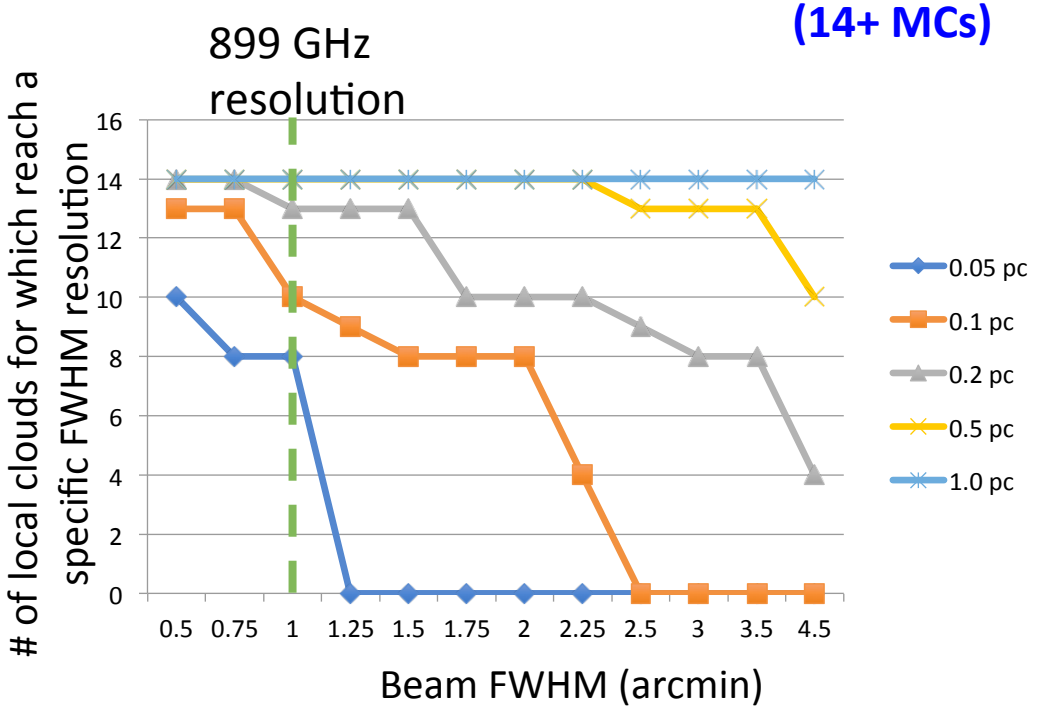
Freq	lamda	sigma_I	I_ref	p_min
[GHz]	[microns]	[MJy/Sr]	[MJy/Sr]	(3-sigma)
107	2803.7	0.00010	0.0083	7.0%
129	2325.6	0.00014	0.0178	4.7%
155	1935.5	0.00019	0.0373	3.1%
186	1612.9	0.00036	0.0770	2.8%
223	1345.3	0.00067	0.1566	2.6%
267	1123.6	0.00126	0.3117	2.4%
321	934.6	0.00212	0.6178	2.1%
385	779.2	0.00347	1.1839	1.8%
462	649.4	0.00531	2.2035	1.4%
555	540.5	0.00757	3.9560	1.1%
666	450.5	0.01282	6.7335	1.1%
799	375.5	0.02744	10.7565	1.5%

Goal #2: Resolve Magnetic Fields in Cores and Filaments in a Large Sample of nearby clouds

Linear Scales: Cores ~ 0.05pc, Filament widths ~0.1pc, resolve cloud field structure ~ 1 pc

For 1 arcmin FWHM: **(8 MCs)** **(10 MCs)** **(14+ MCs)**

Assumed Beam FWHM [arcmin]		0.5	1	1.5	2
Molecular Clouds	distance (pc)	Res [pc]	Res [pc]	Res [pc]	Res [pc]
Taurus	140	0.020	0.041	0.061	0.081
Perseus	300	0.044	0.087	0.131	0.175
Chameleon	160	0.023	0.047	0.070	0.093
Lupus	155	0.023	0.045	0.068	0.090
Ophiuchus	140	0.020	0.041	0.061	0.081
Orion	450	0.065	0.131	0.196	0.262
Aquila	260	0.038	0.076	0.113	0.151
Musca	160	0.023	0.047	0.070	0.093
Pipe	150	0.022	0.044	0.065	0.087
Corona Australis	170	0.025	0.049	0.074	0.099
Cepheus	440	0.064	0.128	0.192	0.256
Coalsack	150	0.022	0.044	0.065	0.087
Vela	700	0.102	0.204	0.305	0.407
IC 5146	400	0.058	0.116	0.175	0.233



Goal #3: Resolve cloud field structure in a large sample size of molecular clouds

Use BGPS sample of clouds with well characterized kinematic distances (49%), typical size ~10 pc

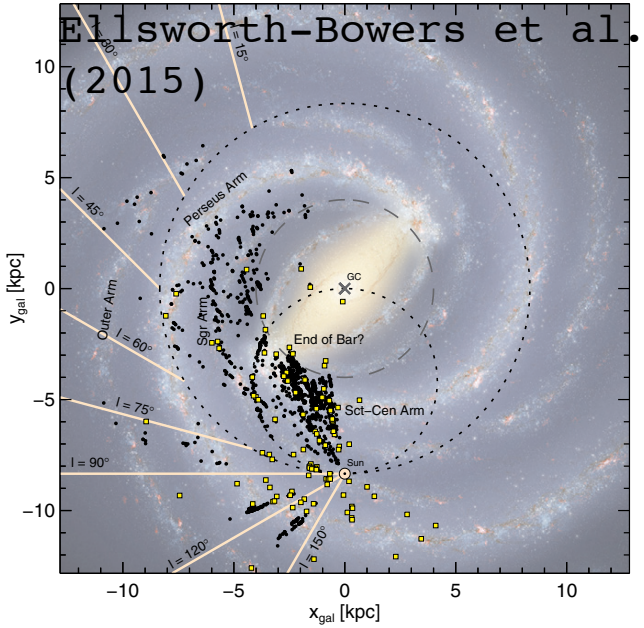
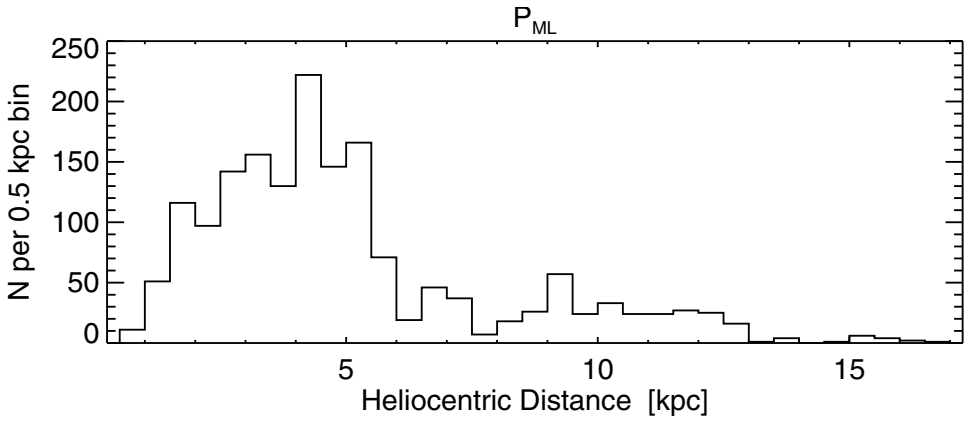


Figure 15. Face-on view of the Milky Way for sources with well-constrained distance estimates (black circles), plotted atop an artist's rendering of the Milky Way (R. Hurt: NASA/JPL-Caltech/SSC) viewed from the north Galactic pole. Yellow squares mark the locations of masers with trigonometric parallaxes (Reid et al. 2014, Table 1). The image has been scaled to match the R_0 used for calculating kinematic distances. The outer dotted circle marks the solar circle, and the inner dotted circle the tangent point as a function of longitude. The dashed circle at $R_{gal} = 4$ kpc outlines the region influenced by the long Galactic bar where the assumed flat rotation curve breaks down (Benjamin et al. 2005; Reid et al. 2014). Various suggested Galactic features are labeled. For clarity, distance error bars are not shown.

- Aim is to look at magnetic field structure and large scale turbulence as a function of cloud age, mass, SF history, turbulent line widths, etc…



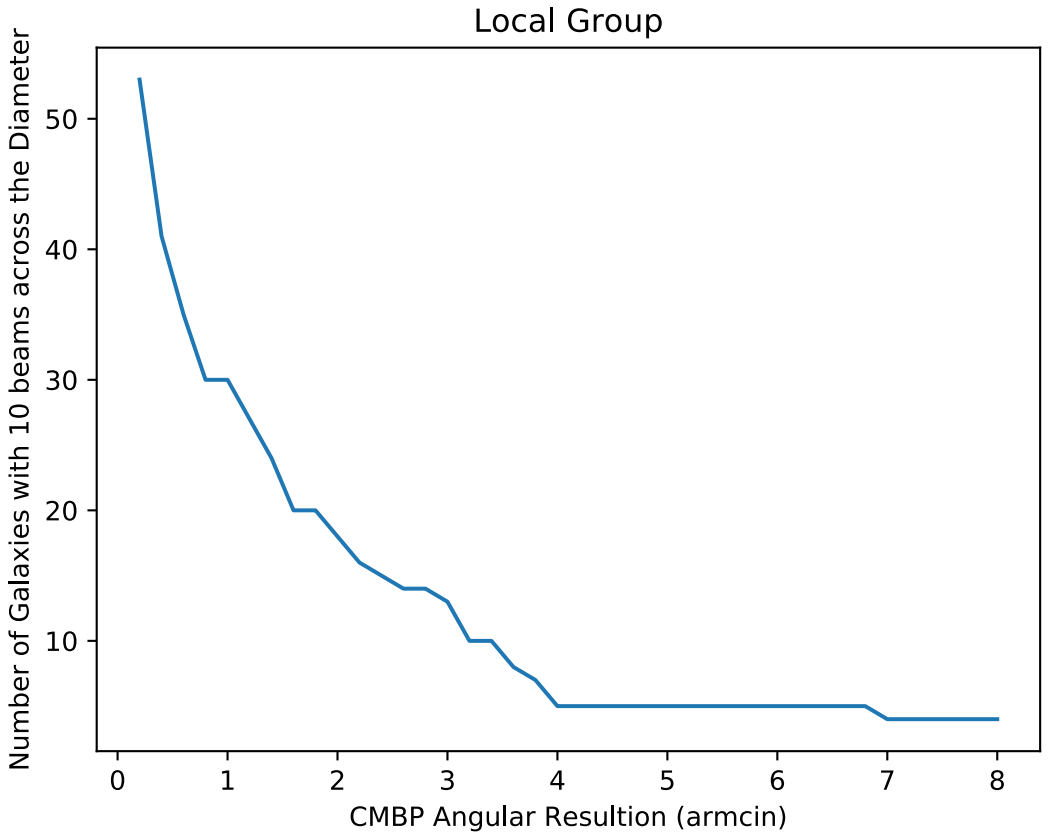
We can resolve 1pc out to:
1' resolution -> 3.4 kpc (700 BGPS sources)
2' resolution -> 1.7 kpc (180 BGPS sources)

- Assume a factor of ~4 increase in the number of clouds for an all sky survey: ~2500 clouds with <1 pc resolution for a 1 arcmin beam.

Magnetic Fields in Star Formation Trade-offs

	Nearby Clouds Studies	Distant Cloud Studies	Polarization Spectrum
2x better sensitivity	could better resolve turbulence in A_V<<1	same as NCS	N/A
2x worse sensitivity	probably require beam smoothing to study B-fields in cloud envelopes	same as NCS	N/A
4x worse sensitivity	definitely require beam smoothing to study B-fields in cloud envelopes	same as NCS	N/A
2x worse resolution (2')	Can't resolve core (0.05 pc) scales for any nearby clouds	Observe 500 clouds at 1pc resolution, instead of 2500	Can't study polarization spectrum of starless cores.
2x better resolution (0.5')	Resolve core (0.05 pc) scales for Perseus, Aquilla	Many more clouds	Detailed studies polarization spectrum/efficiency of starless cores.
max 555 GHz band	Can't resolve core (0.05 pc) scales for any nearby clouds	Observe 2,000 clouds at 1pc resolution, instead of 2500	Farther from polarization spectrum minimum at ~350 microns

External Galaxies



To Do:

1. Extend this to Galaxy catalogs
2. Incorporate sensitivity into the analysis