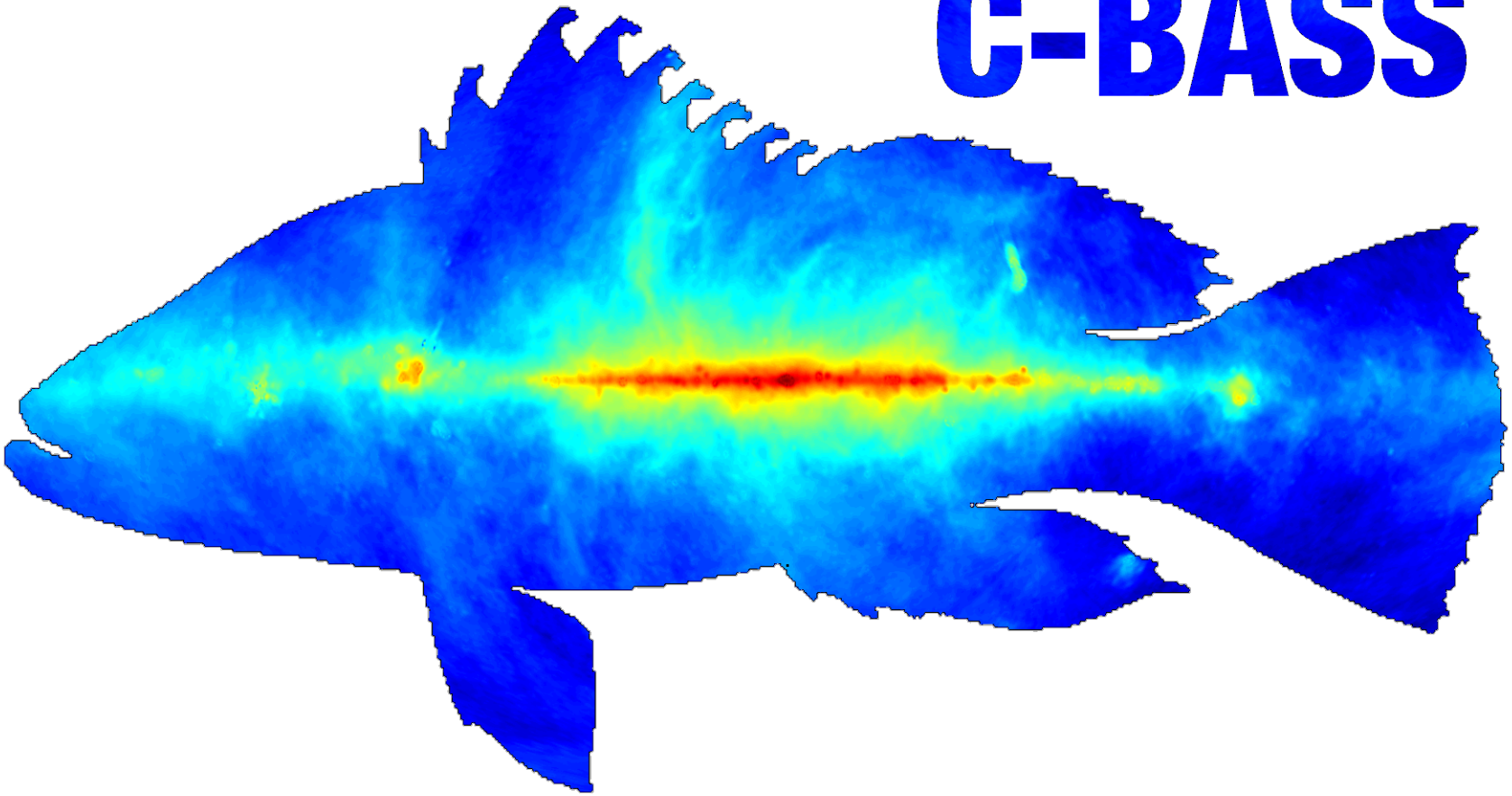
…Early Results from

C-BASS



Stephen Muchovej
Caltech - Owens Valley Radio Observatory

Planck 2014 - Ferrara

The C-Band All Sky Survey (C-BASS)

* **Caltech/JPL/OVRO**
* **Oxford University**
* **Manchester University**
* **SKA-SA/Rhodes/UKZN**
* **KACST**

NSF

STFC

UNIVERSITY OF OXFORD

MANCHESTER 1824 The University of Manchester

JPL Jet Propulsion Laboratory California Institute of Technology

CALIFORNIA INSTITUTE OF TECHNOLOGY 1891

SKA AFRICA SQUARE KILOMETRE ARRAY

UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI

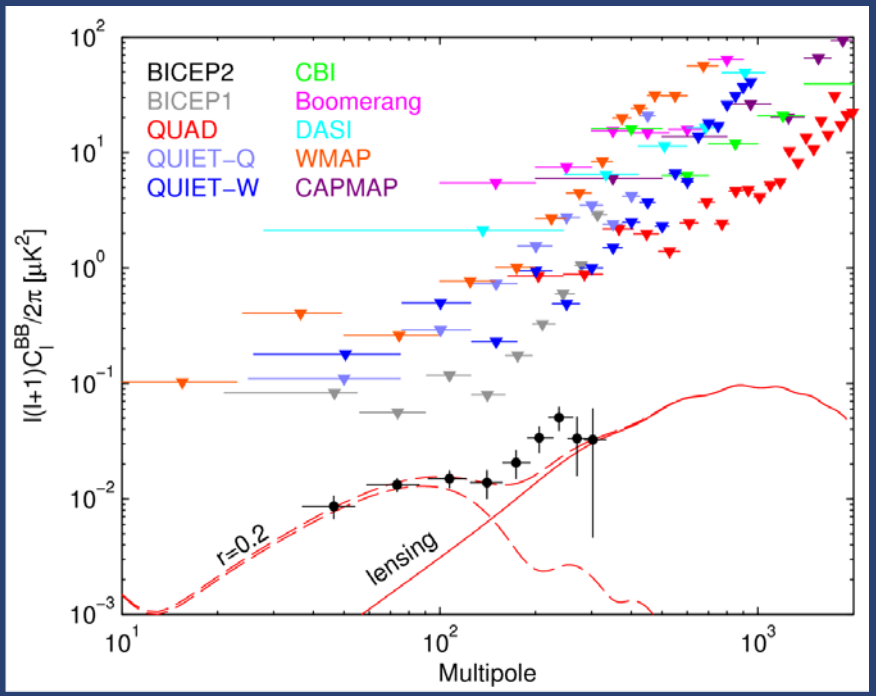
مدينة الملك عبد العزيز للعلوم و التقنية KACST

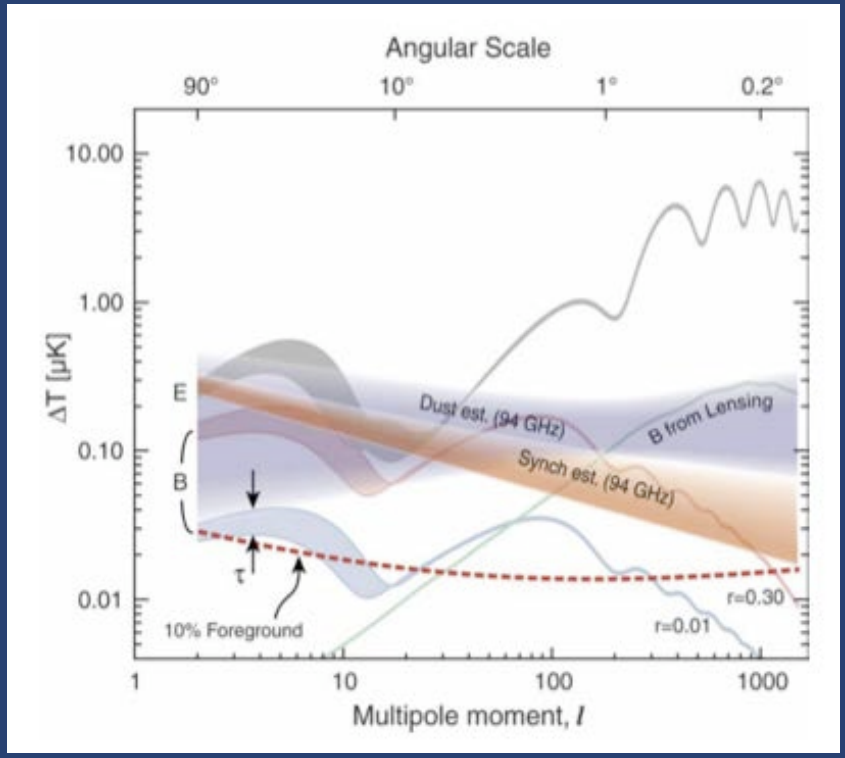
THE ROYAL SOCIETY

Why do C-BASS? FOREGROUNDS!!

•Dearth of all-sky high SNR maps in the decades of frequency space above a GHz.

• CMB Task Force (2005): "Continued support for ground-based efforts to produce 3-15 GHz large-scale maps of the polarized Galactic foreground"





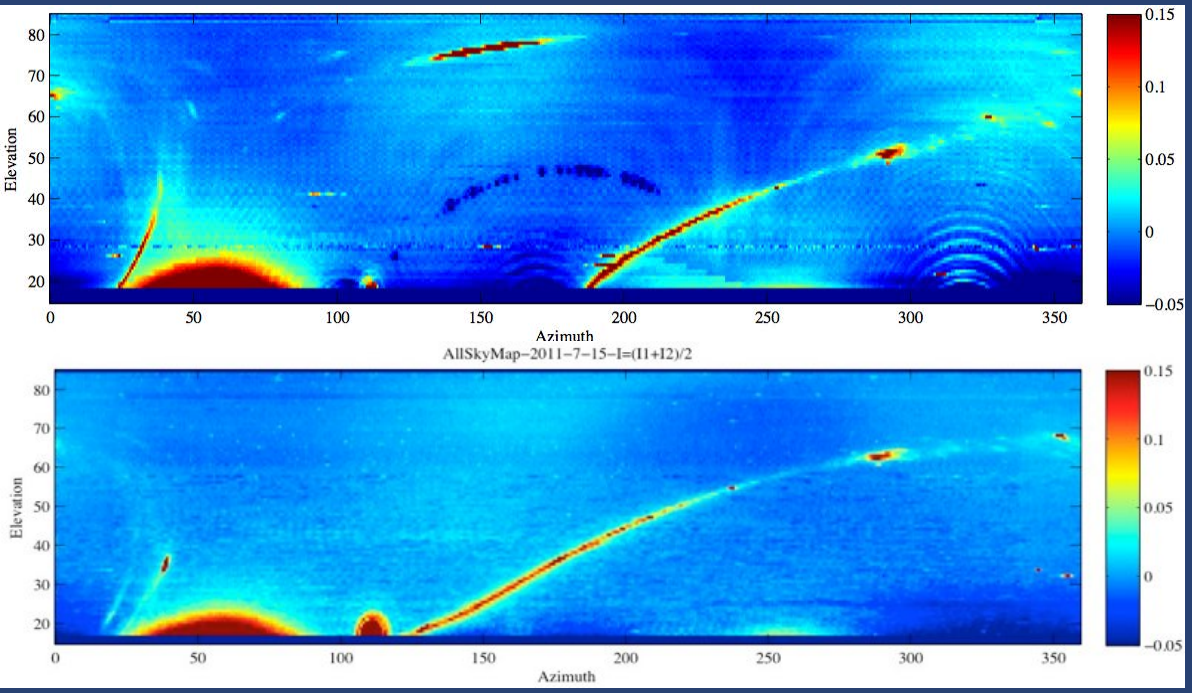
• Lyman Page (yesterday): "We need more sensitive low-frequency measurements of synchrotron: WMAP just isn't sensitive enough"

• To counter Lyman: We won't have the sensitivity for r < 0.001, but at least we'll start lowering those error bars on the synchrotron spectral index. ;-)

What is C-BASS?

Low-Frequency, ground-based all-sky survey

Frequency	4.5-5.5 GHz
Sensitivity	< 0.1 mK/beam rms
Resolution	44’ (matches Haslam/Planck)
Bandwidth	Limited by RFI (~700 MHz)

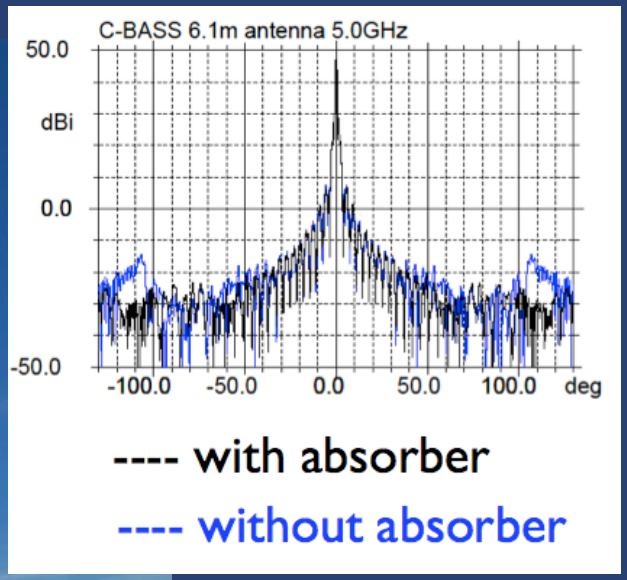


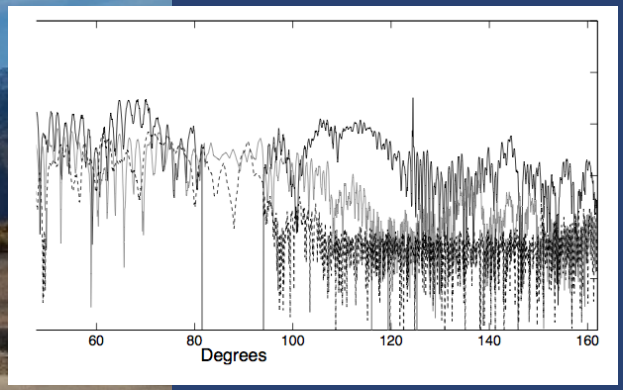
Controlling Systematic Errors

- Balanced receiver architecture: 1/f knee frequency - 100 mHz (I) 10 mHz (P)
- Digital filtering of mains
- Rapid, constant elevation scanning, with many crossing angles
- Novel beam design

Two Telescopes

- Northern Telescope is 6.1 m dish located at Owens Valley Radio Observatory.
- Southern Telescope is 7.6 m dish located at Klerefontein, near the South Africa SKA site
- Novel optical design matches the beam and suppresses sidelobes

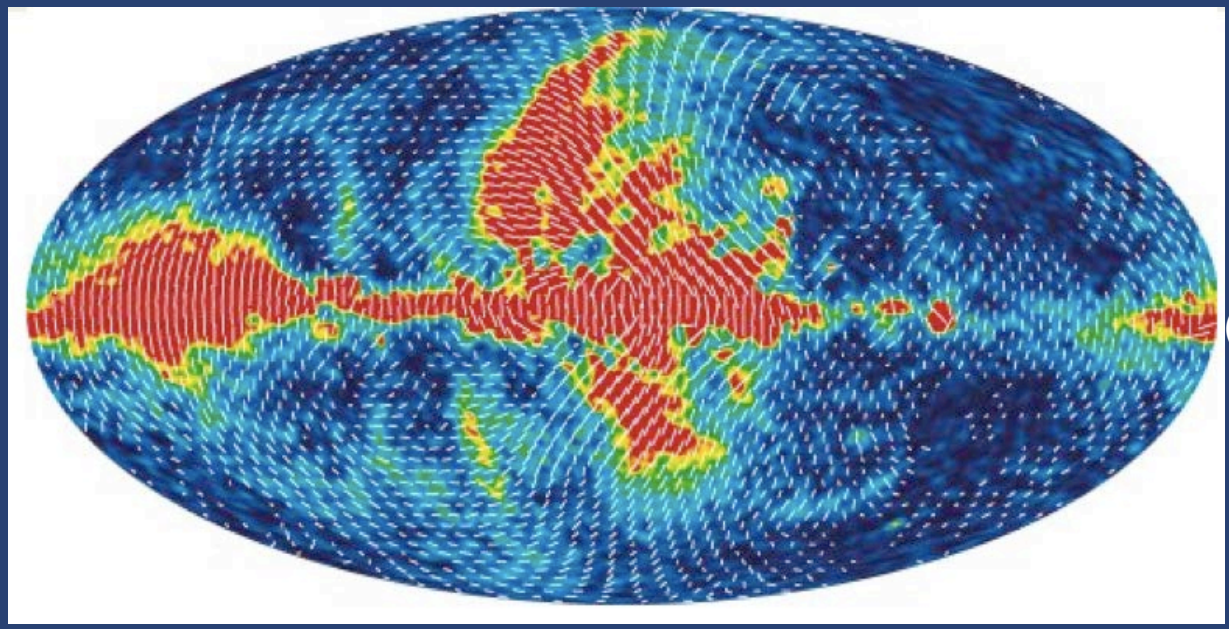




Holler et al., 2012

Scientific Goals

• As it is largely uncorrupted by Faraday Rotation, it'll be the first synchrotron survey whose polarization angles and fractions can be reliably extrapolated to higher frequencies.



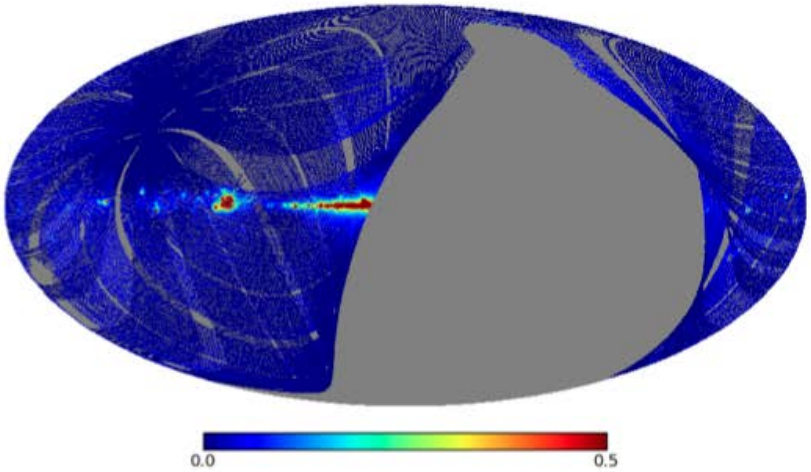
(WMAP 23GHz)

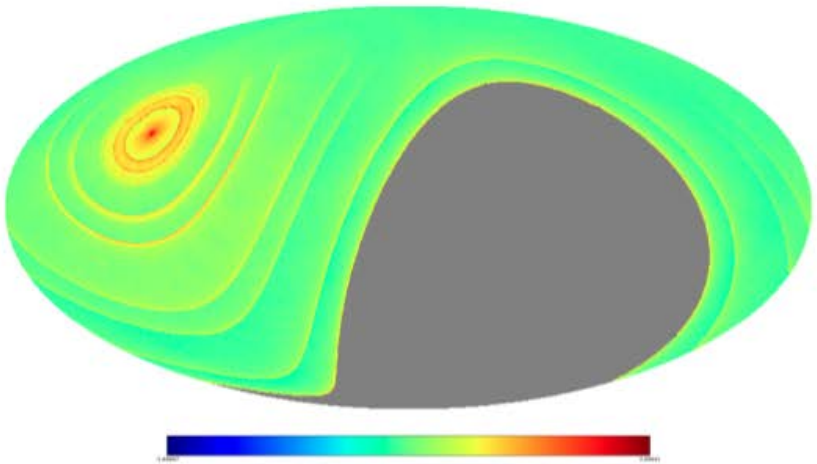
• Enable more accurate subtraction of foreground contaminating signals from high-frequency CMB polarization sky surveys including WMAP and Planck

• Characterization of the interstellar medium
  - Variation on synchrotron spectral index across the Galaxy
  - Template of polarized synchrotron emission
  - Characterization of free-free emission in the Galactic Plane
  - Improved understanding of anomalous microwave emission (AME)
  - Studying of the Galactic magnetic field

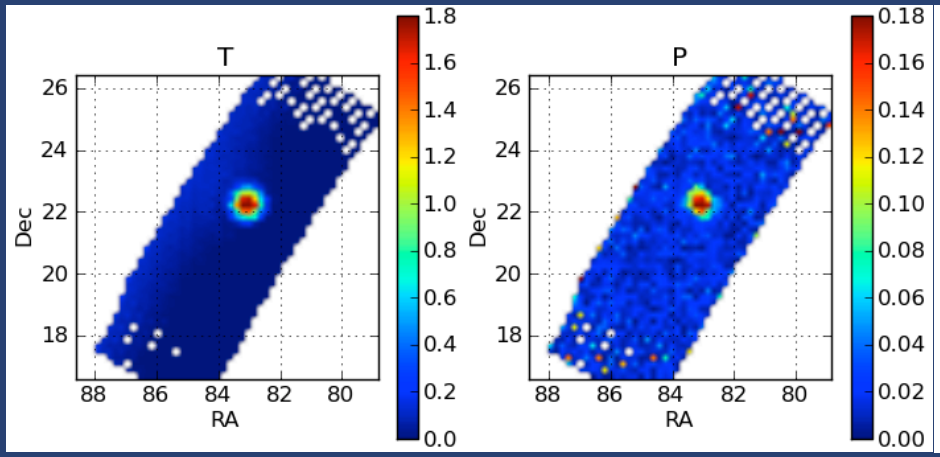
Scan Strategy

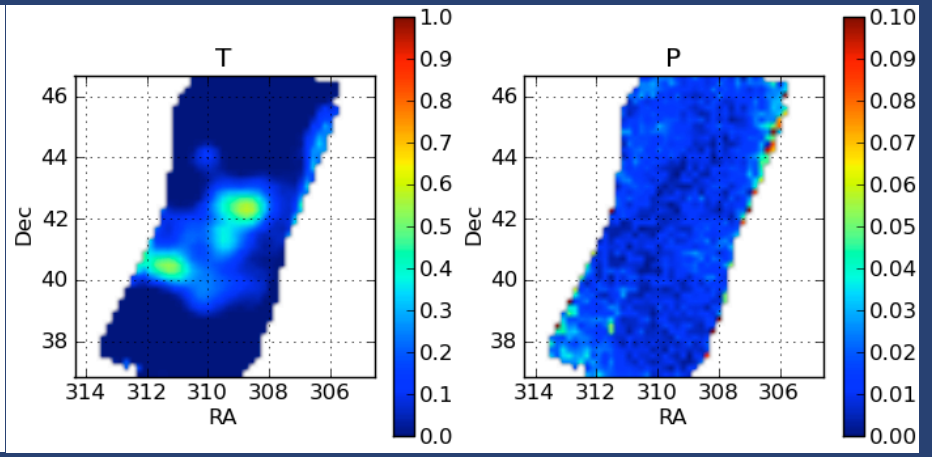
- Rapid scanning (4°/s)
- Highly-redundant coverage at a variety crossing angles





Calibration



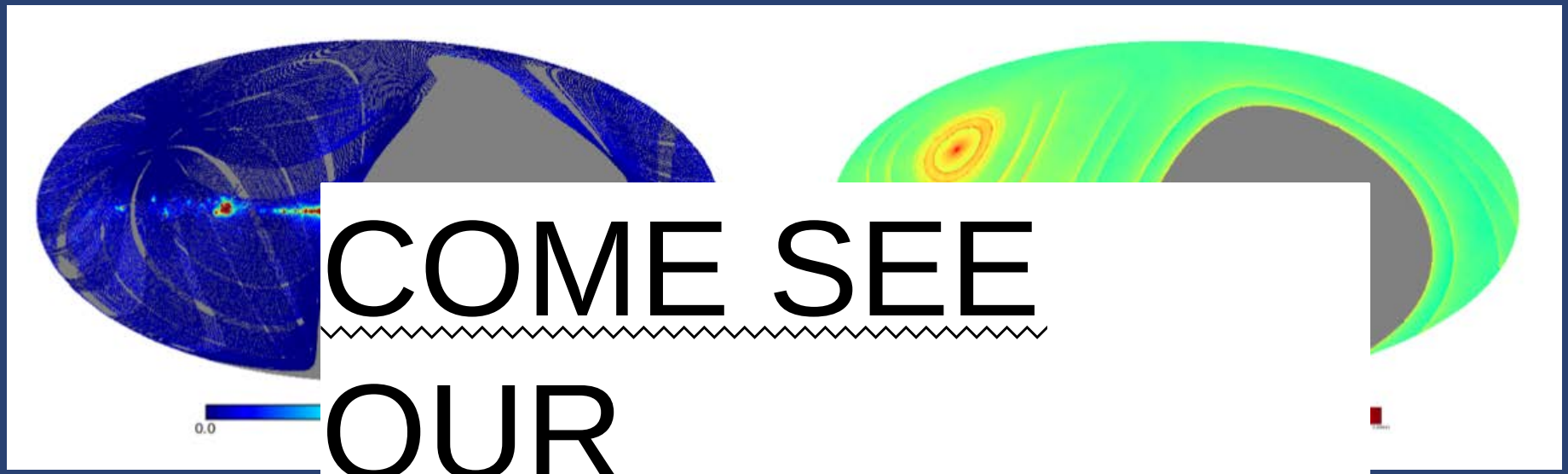


•TauA -- Polarized

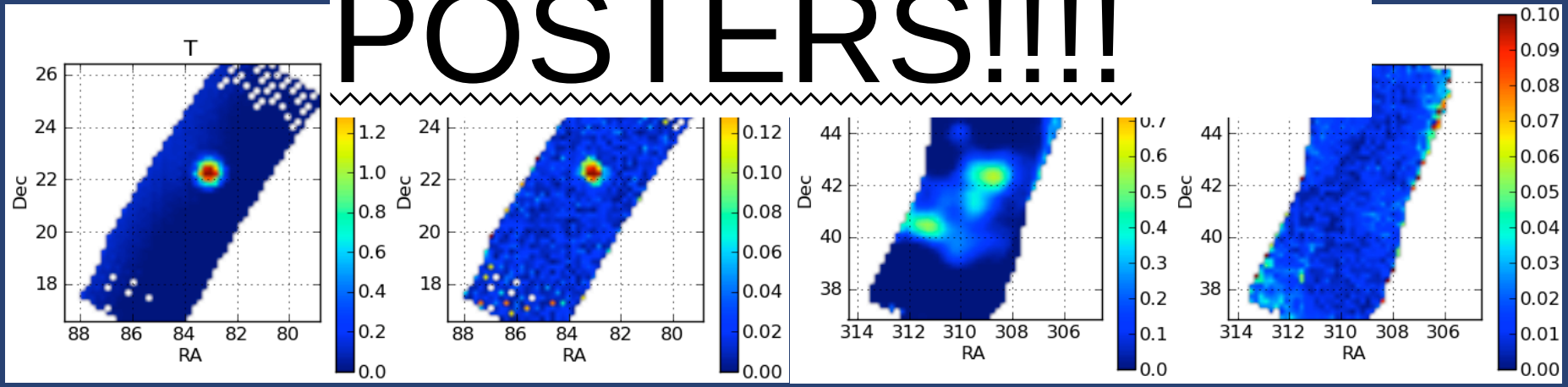
•DR21 -- unpolarized

Scan Strategy

- Rapid scanning (4°/s)
- Highly-redundant coverage at a variety crossing angles



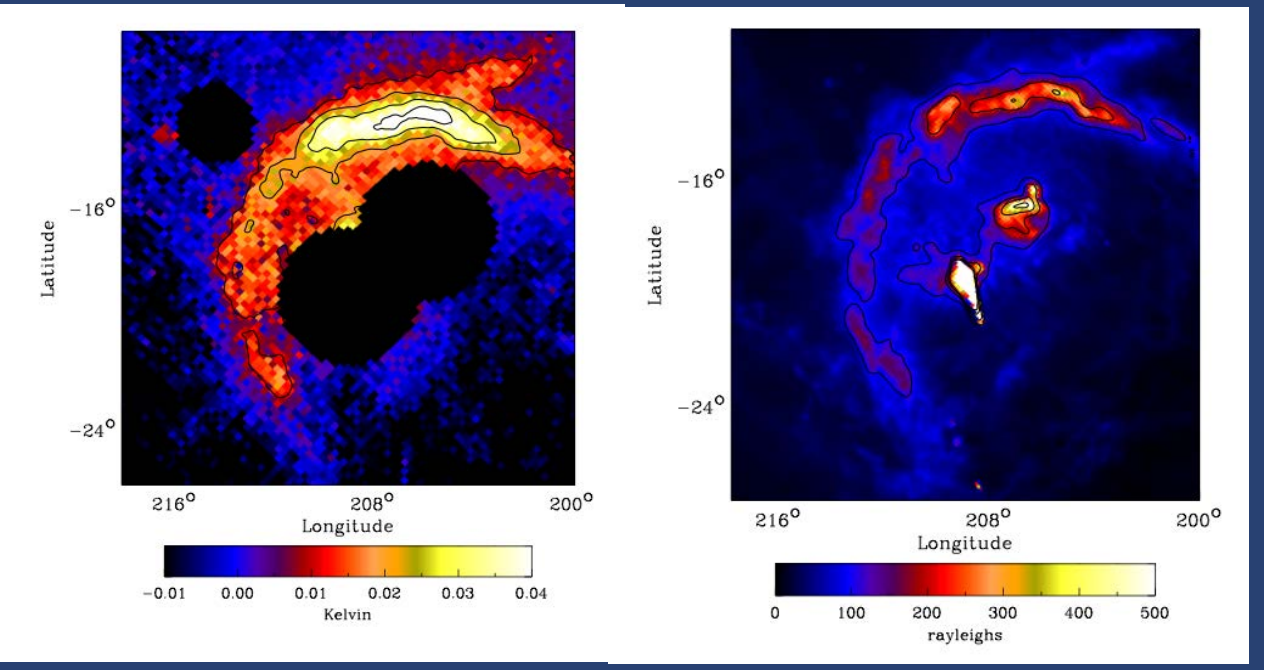
COME SEE OUR POSTERS!!!!

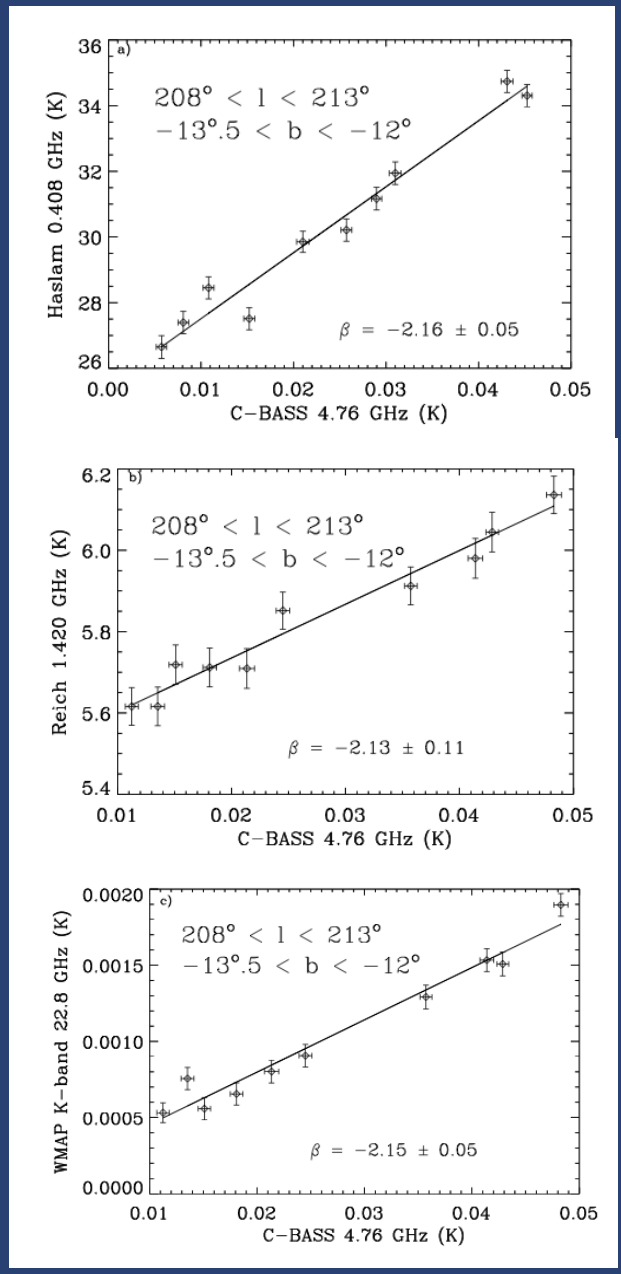


Data Validation

•Barnard's loop: A region known to be dominated by free-free emission.

• Expect a spectral index of -2.1 for free-free.

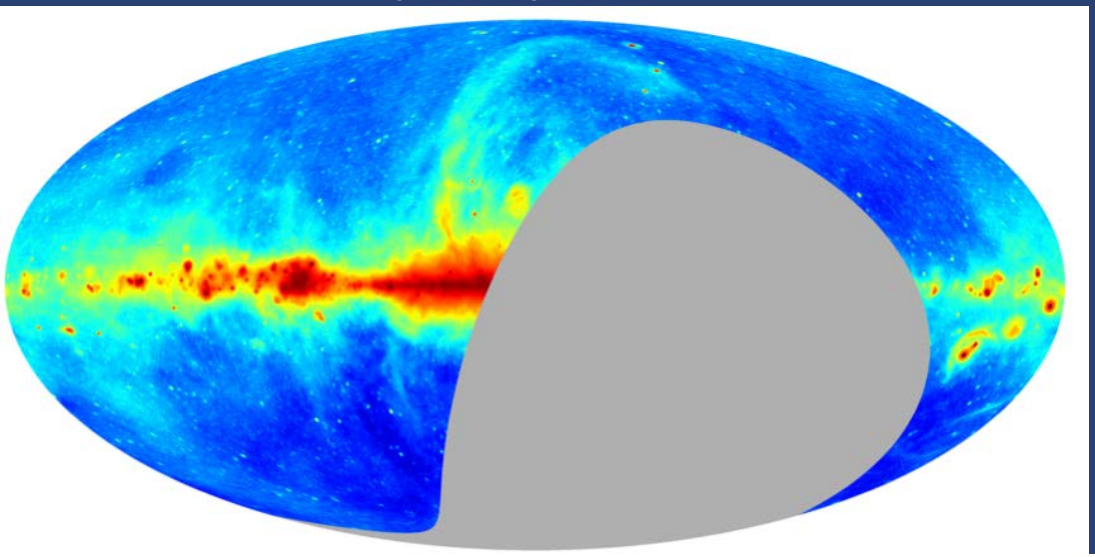




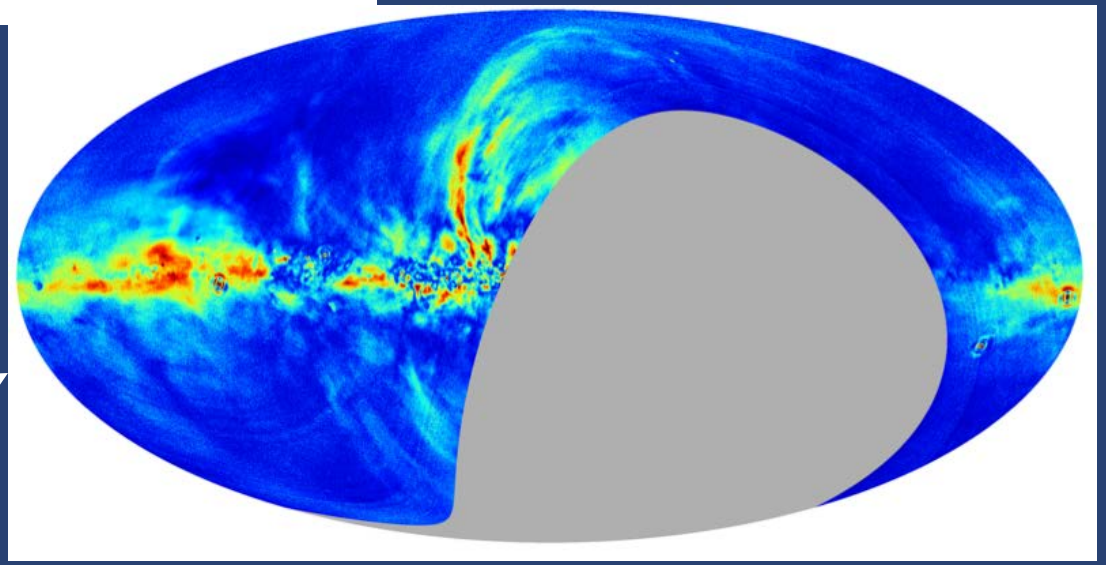
Irfan et al., 2014

CURRENT STATUS

- Northern Survey mostly complete



Total Intensity (I)

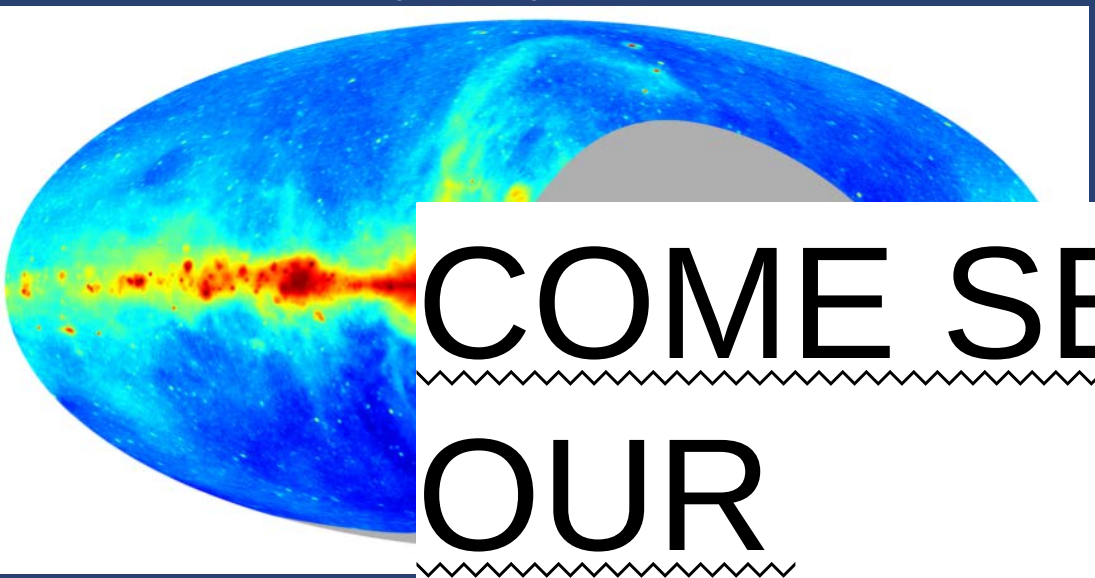


Polarization Intensity (P)

- Southern Telescope being commissioned

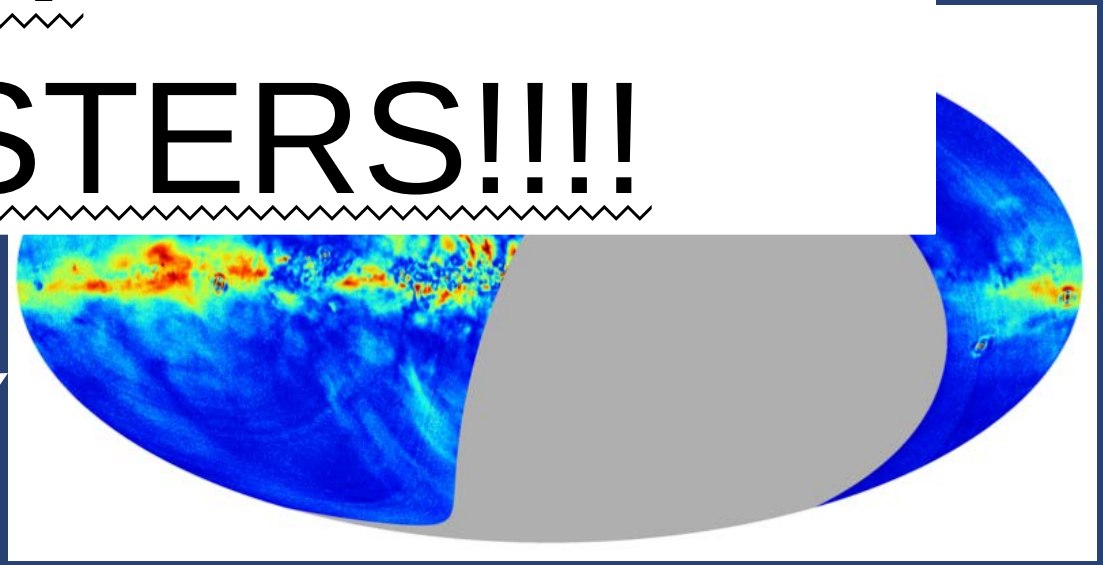
CURRENT STATUS

- Northern Survey mostly complete



Total Intensity (I)

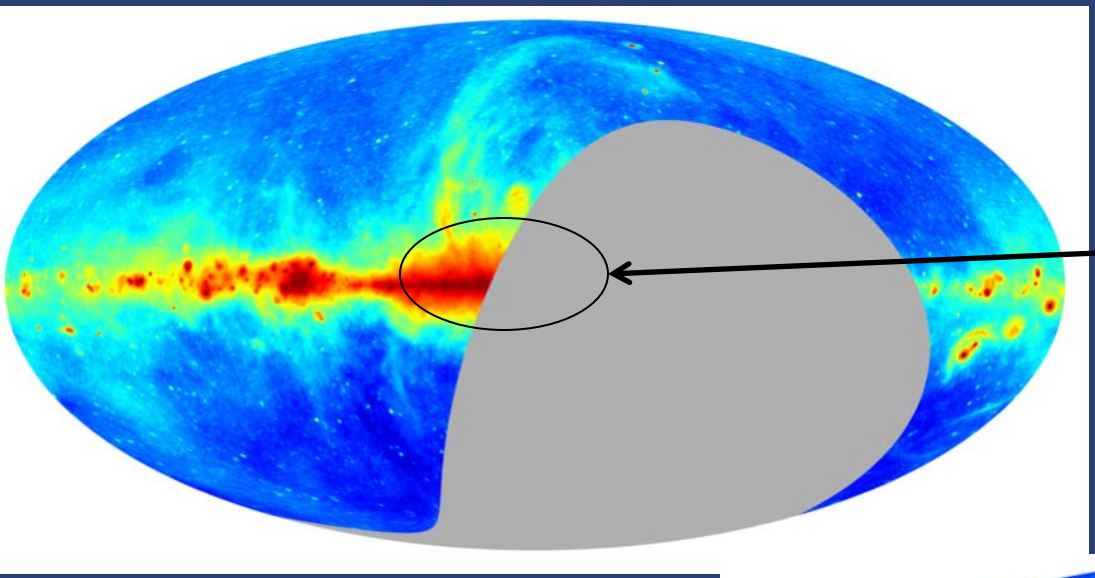
COME SEE OUR POSTERS!!!!



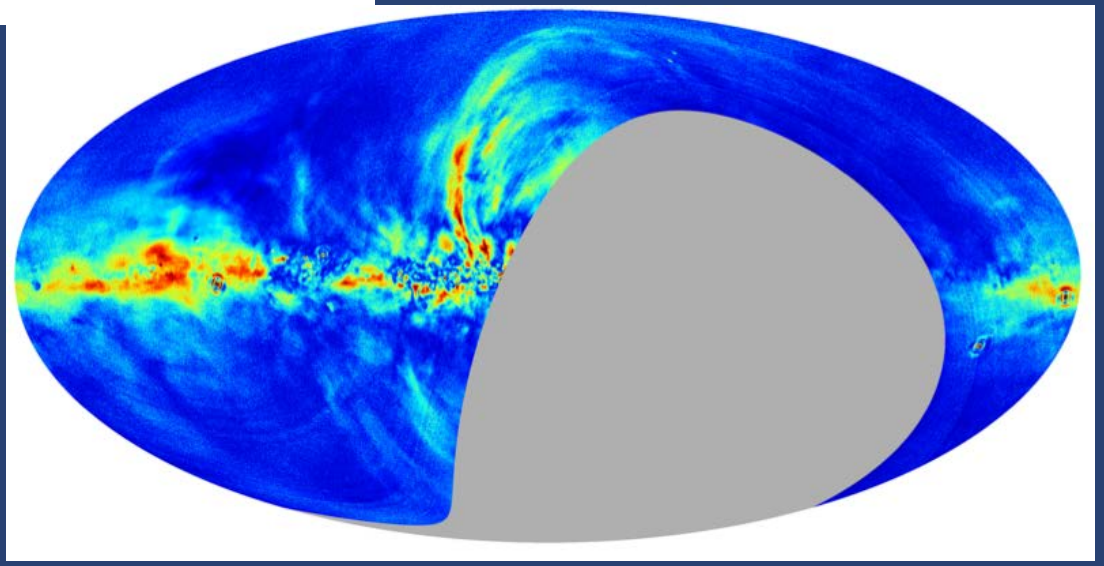
Polarization Intensity (P)

- Southern Telescope being commissioned

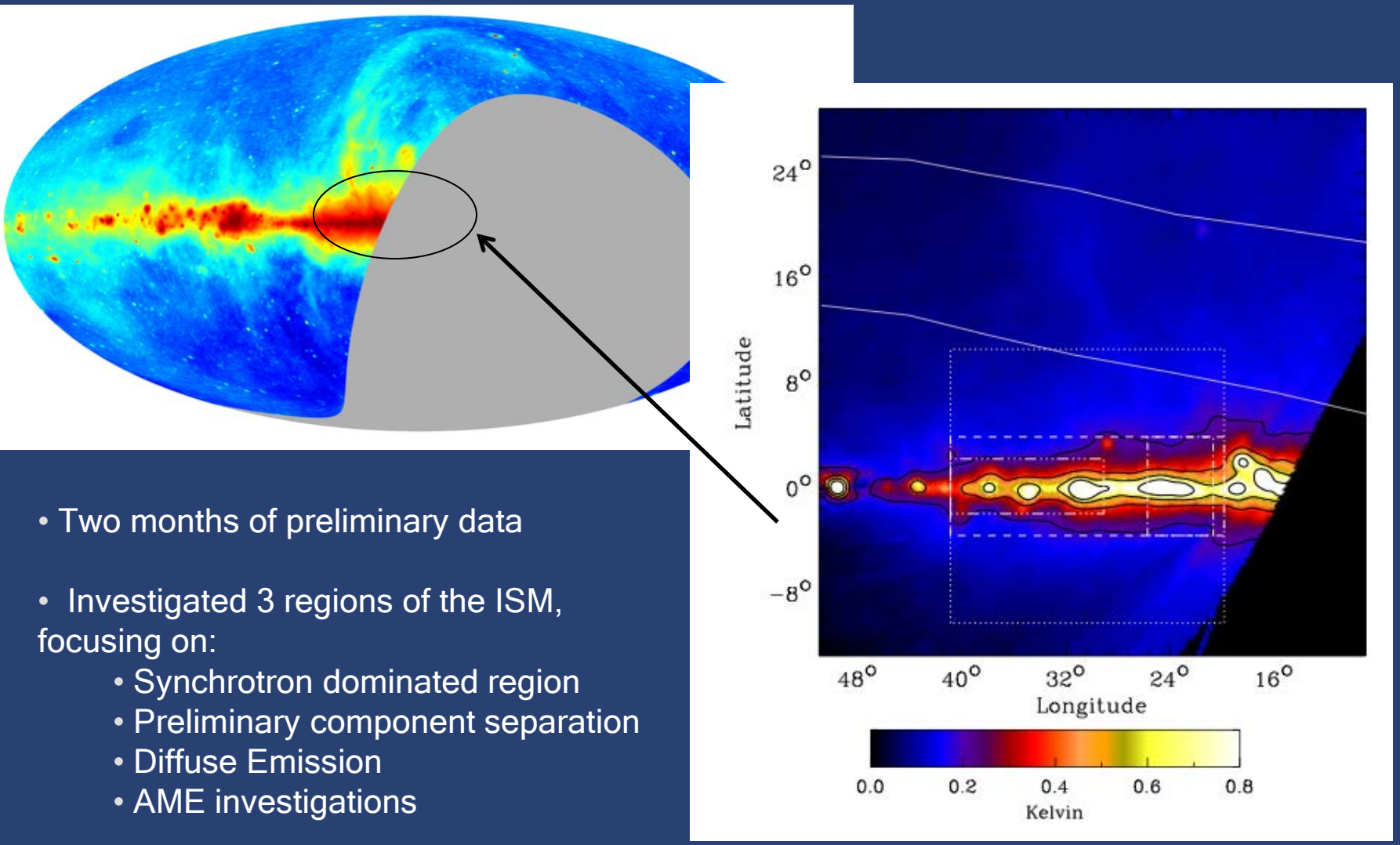
EARLY RESULTS



- Selected Regions of High Signal-to-noise ratio
- HIGH SIGNAL!!!



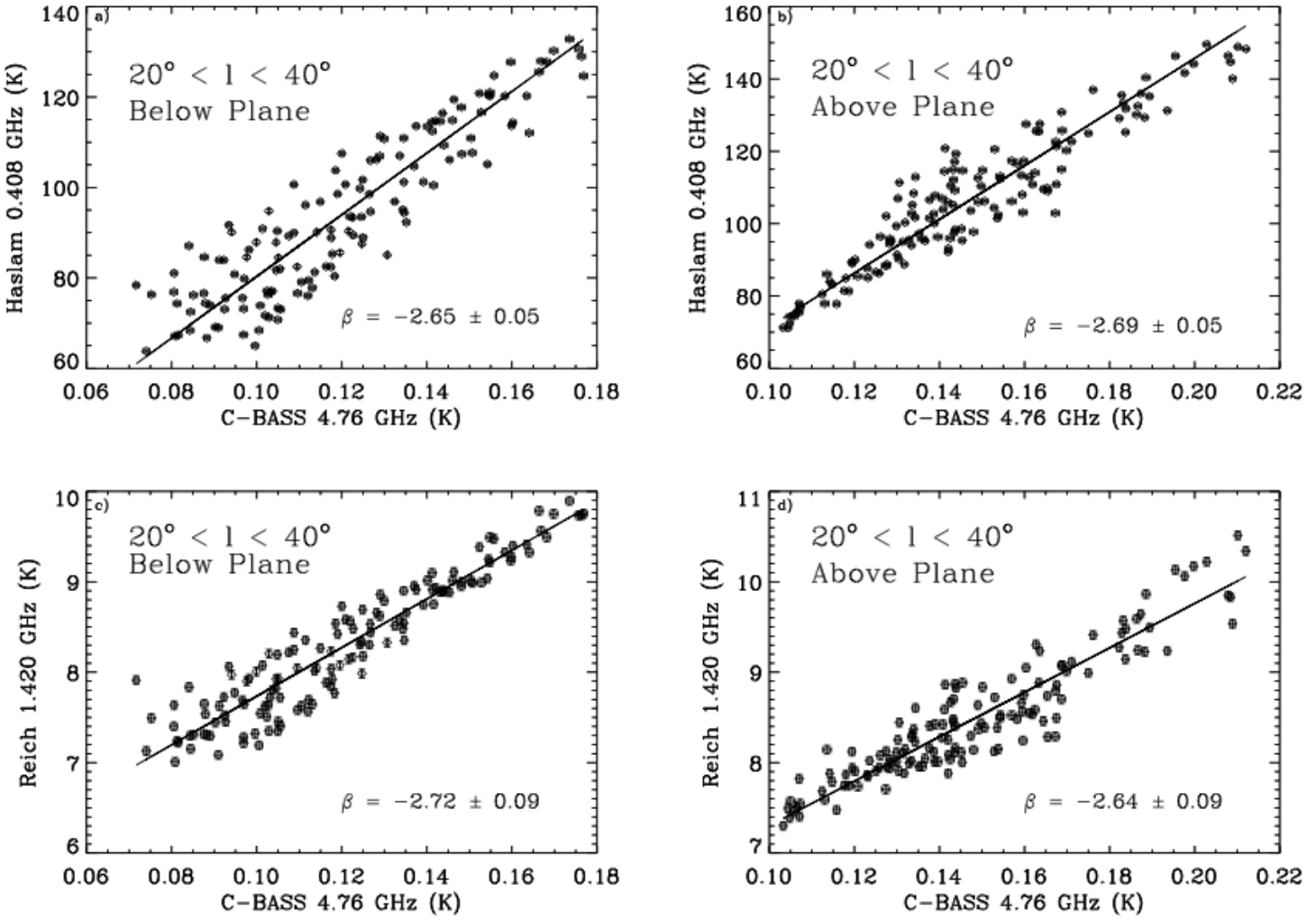
DIFFUSE GALACTIC EMISSION



- Two months of preliminary data
- Investigated 3 regions of the ISM, focusing on:
  - Synchrotron dominated region
  - Preliminary component separation
  - Diffuse Emission
  - AME investigations

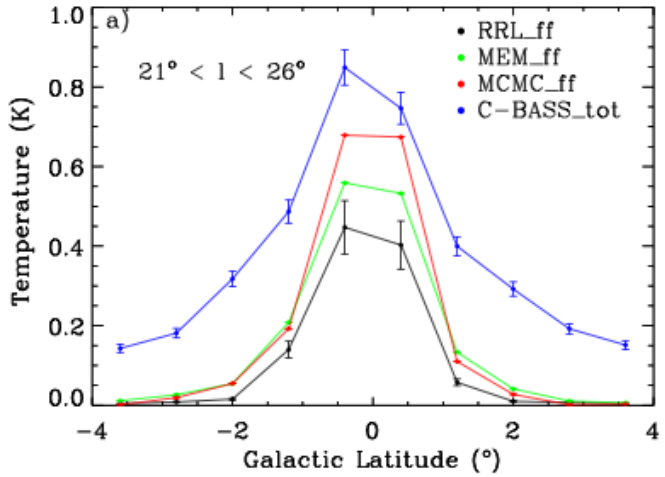
(Irfan et al., 2014)

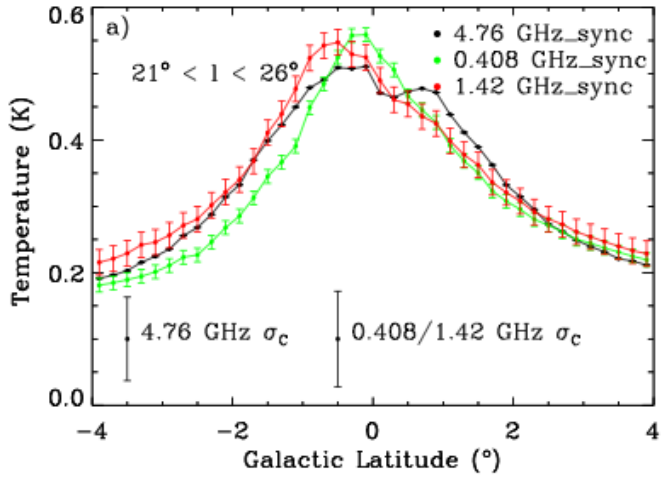
Diffuse Galactic Emission – Synchrotron

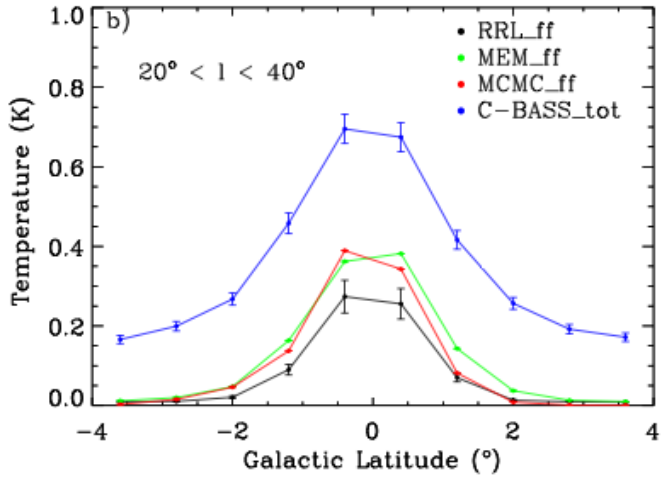


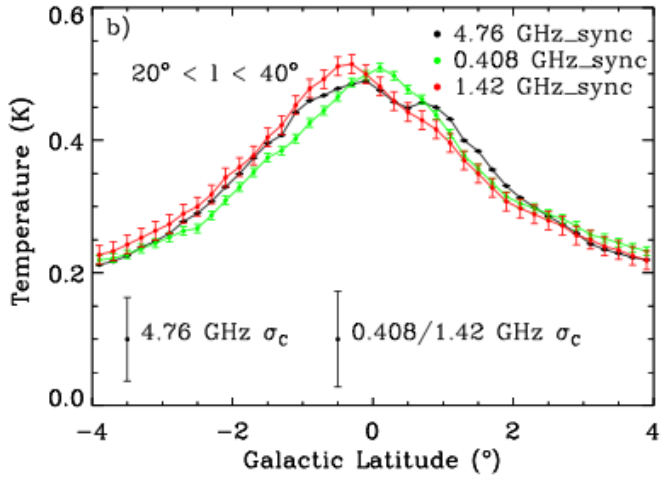
(Irfan et al., 2014)

Diffuse Galactic Emission – Component Separation



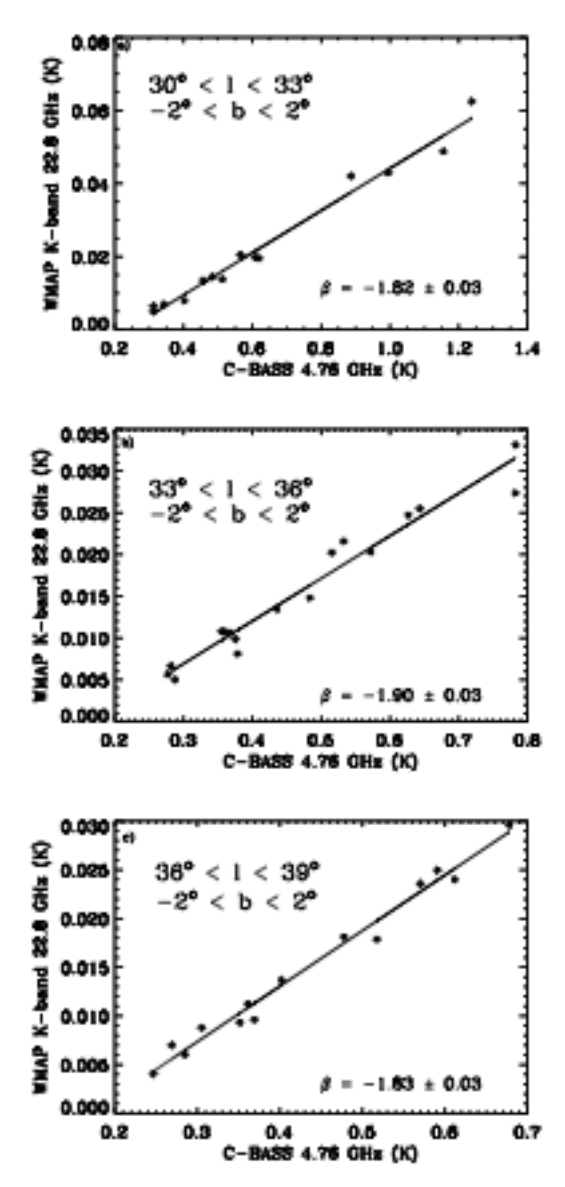


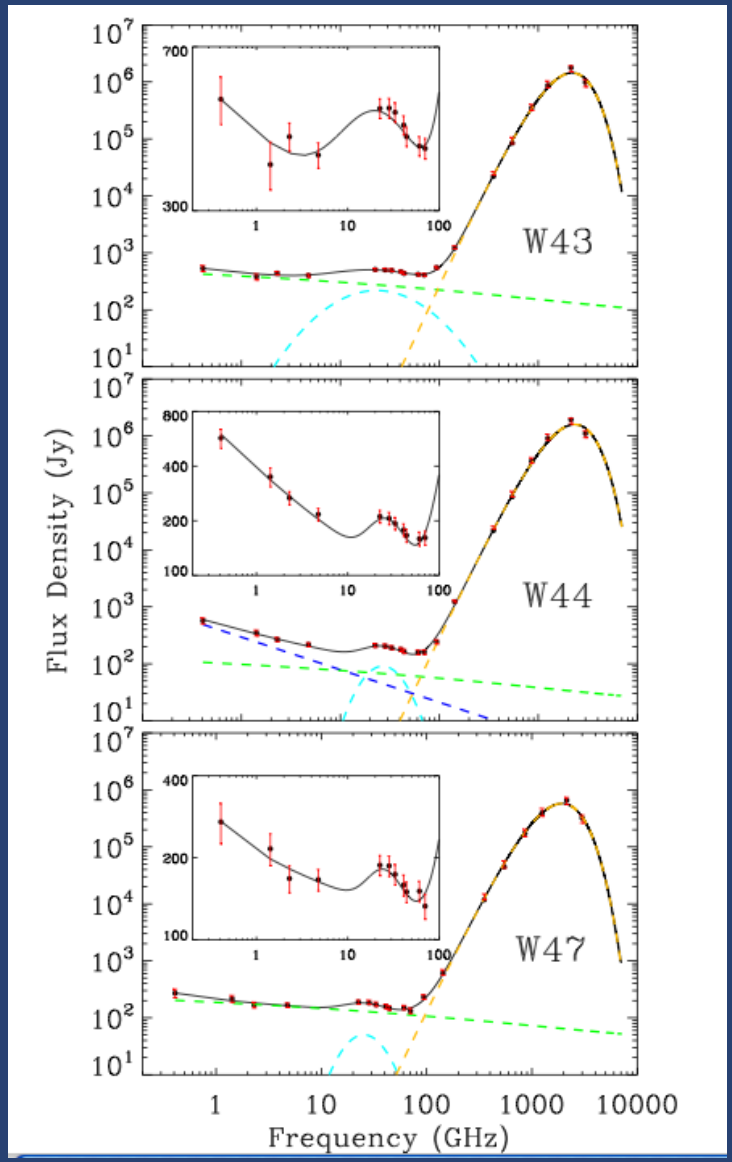




(Irfan et al., 2014)

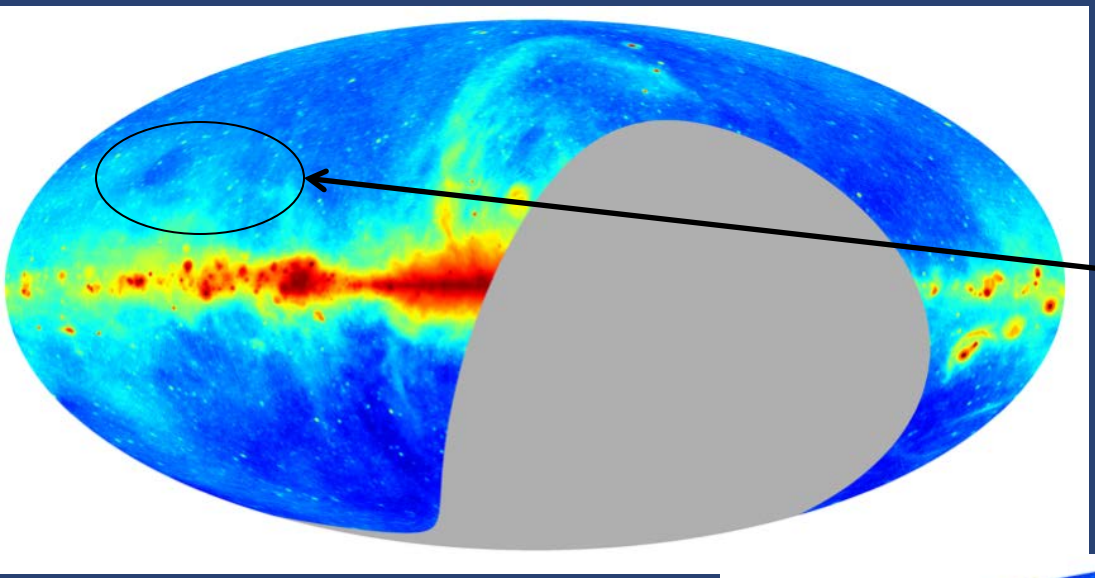
Diffuse Galactic Emission – AME



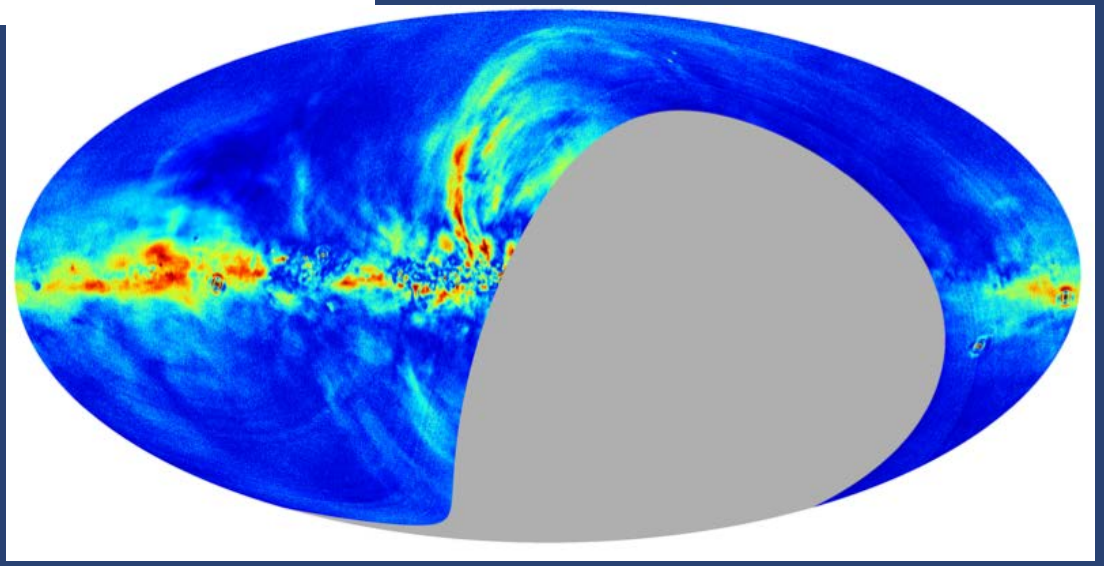


(Irfan et al., 2014)

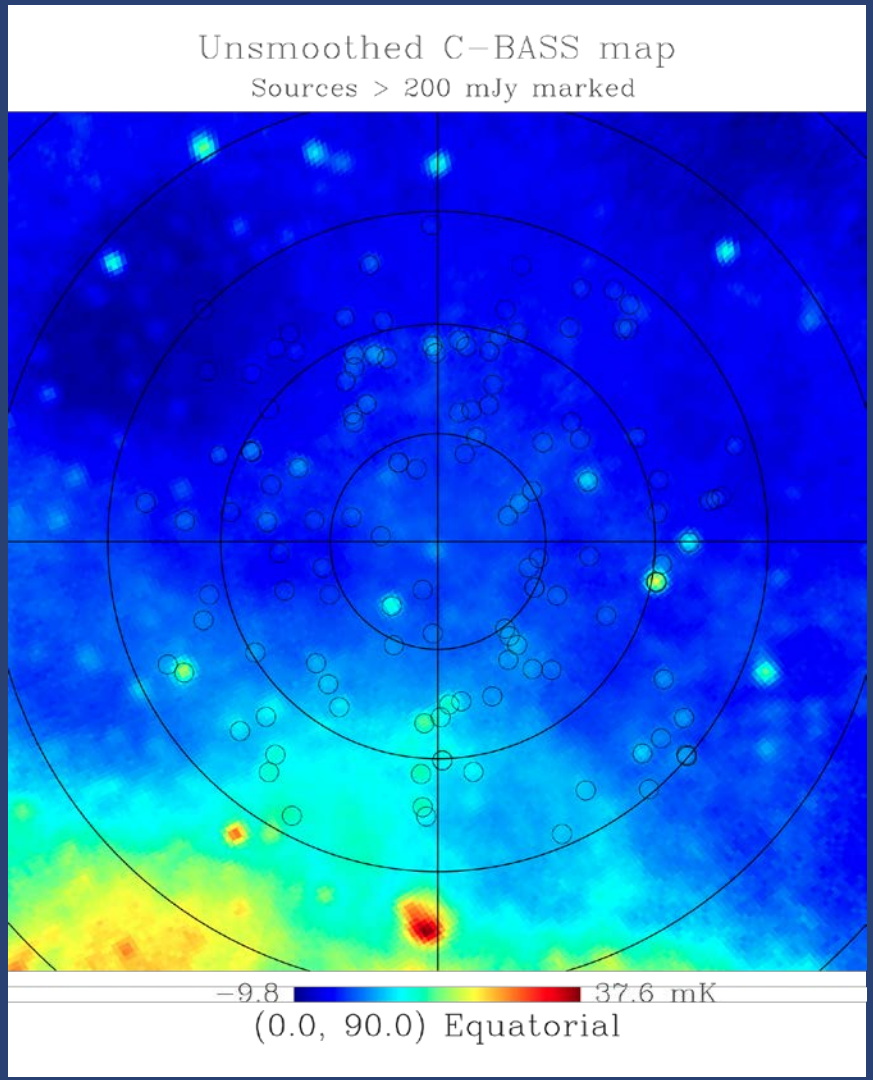
EARLY RESULTS

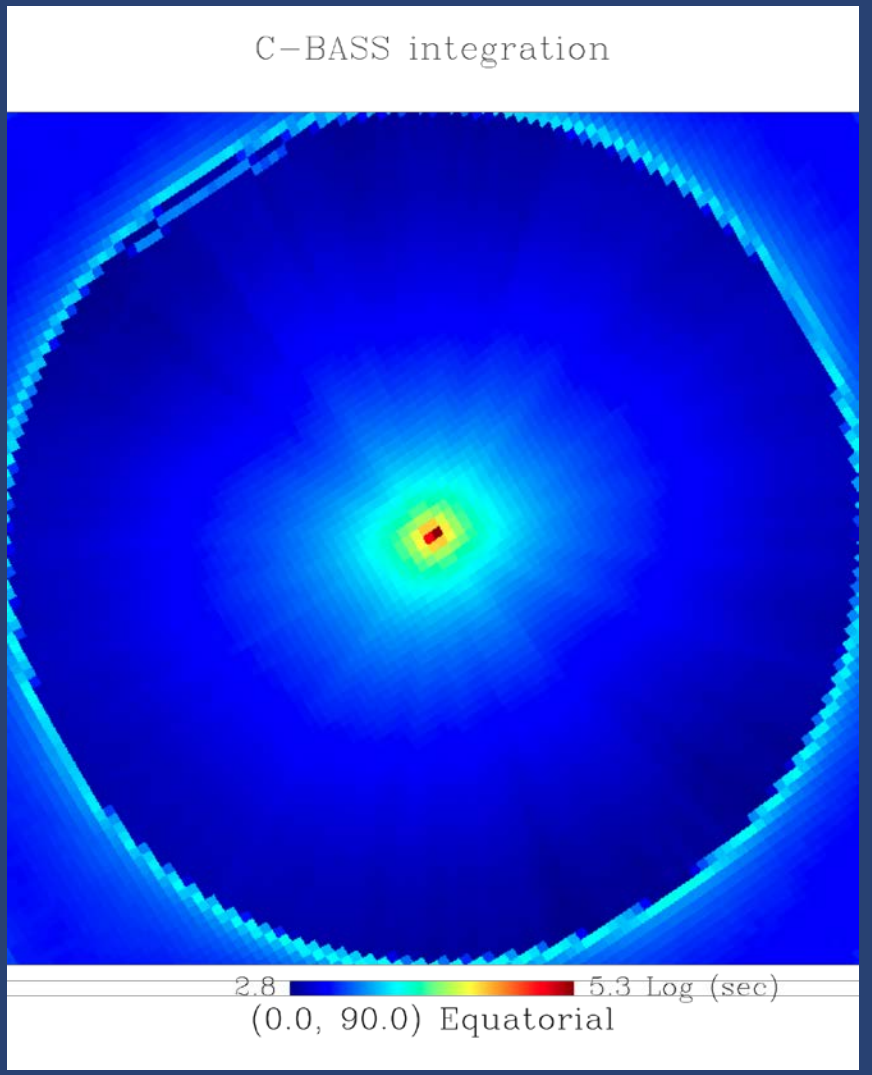


- Selected Regions of High Signal-to-noise ratio
- LOW NOISE!



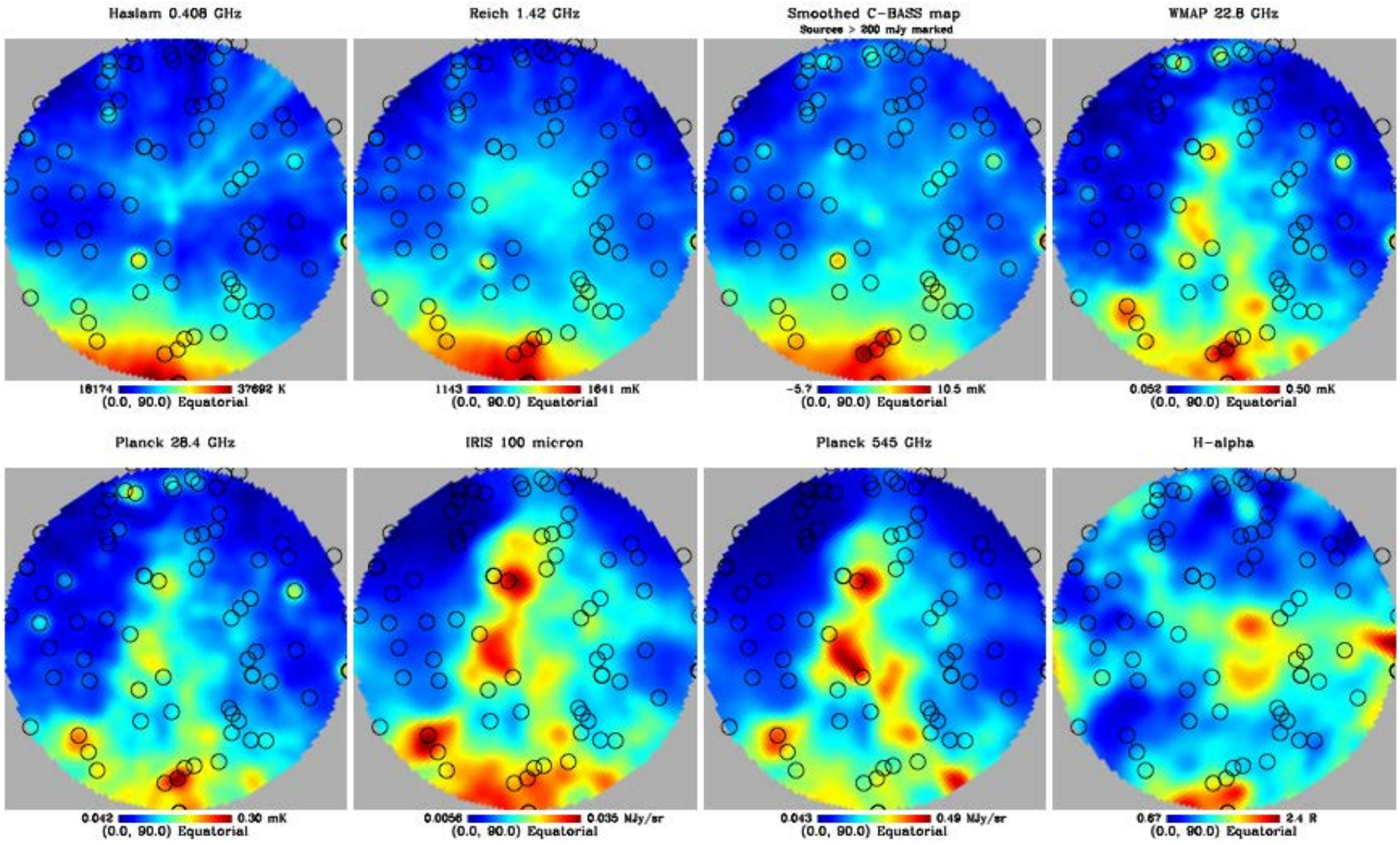
North Celestial Pole – Observations





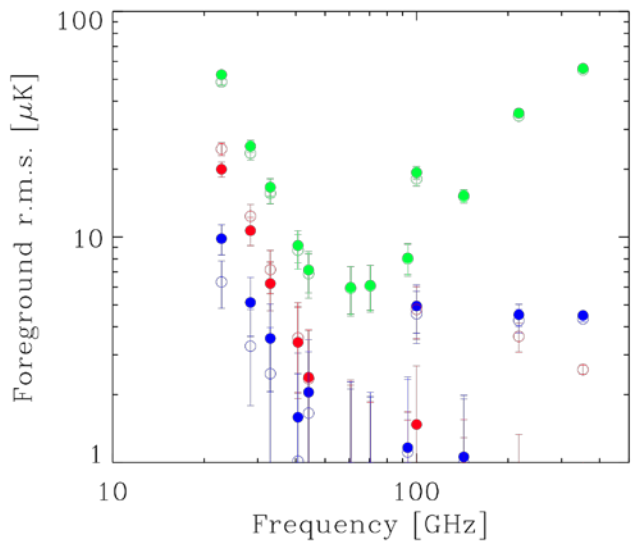
(Dickinson et al., in prep)

North Celestial Pole – Multi-Band Analysis



(Dickinson et al., in prep)

North Celestial Pole – Template Fitting



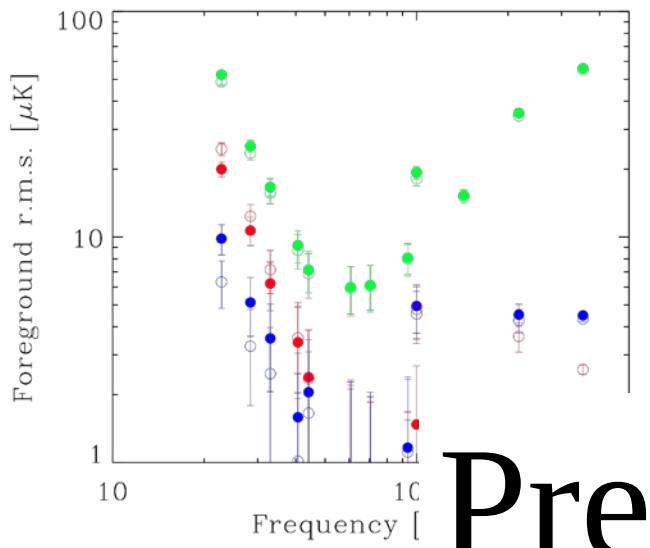
- Synchrotron Template: CBASS or Haslam
- Free-free template: H-alpha
- Dust template: IRIS 100 micron

- Strong Indication for AME in WMAP/Planck 20-40 GHz band

Template	Unit	*WMAP* 22.8 GHz	*Planck* 28.4 GHz	*WMAP* 33.0 GHz	*WMAP* 40.7 GHz	*Planck* 44.1 GHz
Synchrotron (Haslam)	μK/K	12.1 ± 0.93	6.32 ± 0.92	3.76 ± 0.91	2.06 ± 0.90	1.37 ± 0.89
Hα (F03)	μK/R	42.2 ± 6.5	21.5 ± 6.4	15.2 ± 6.4	6.81 ± 6.3	8.37 ± 6.3
Dust (IRIS 100 μm)	μK/(MJy/sr)	38.1 ± 1.1	18.0 ± 1.1	12.1 ± 1.1	6.66 ± 1.1	4.93 ± 1.1
Offset	μK	$-328. \pm 23.$	$-146. \pm 23.$	$-95.6 \pm 23.$	$-48.5 \pm 22.$	$-29.8 \pm 22.$
Synchrotron (C-BASS)	μK/mK	15.8 ± 1.0	7.81 ± 1.0	4.62 ± 1.0	2.30 ± 0.99	1.44 ± 0.98
Hα (F03)	μK/R	27.1 ± 6.5	13.8 ± 6.4	10.6 ± 6.4	4.35 ± 6.3	6.76 ± 6.2
Dust (IRIS 100 μm)	μK/(MJy/sr)	35.3 ± 1.2	16.7 ± 1.1	11.3 ± 1.1	6.34 ± 1.1	4.75 ± 1.1
Offset	μK	-7.75 ± 9.8	20.5 ± 9.8	3.38 ± 9.7	5.03 ± 9.6	5.55 ± 9.5

(Dickinson et al., in prep)

North Celestial Pole – Template Fitting



- Synchrotron Template: CBASS or Haslam
- Free-free template: H-alpha
- Dust template: IRIS 100 micron

- Strong Indication for AME in WMAP/Planck 20-40 GHz band

Preliminary

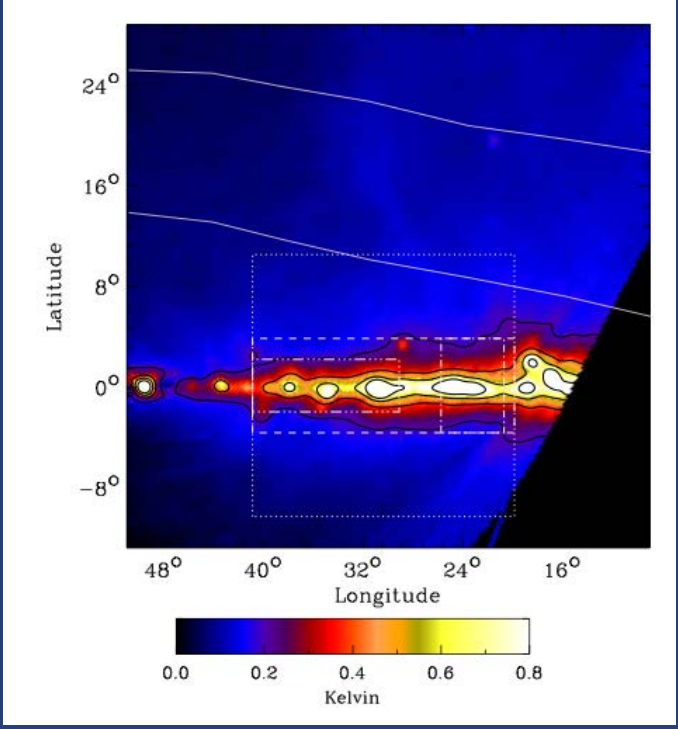
Template	Unit	*WMAP* 22.8 GHz	*Planck* 28.4 GHz	*WMAP* 33.0 GHz	*WMAP* 40.7 GHz	*Planck* 44.1 GHz
Synchrotron (Haslam)	μK/K	12.1 ± 0.93	6.32 ± 0.92	3.76 ± 0.91	2.06 ± 0.90	1.37 ± 0.89
Hα (F03)	μK/R	42.2 ± 6.5	21.5 ± 6.4	15.2 ± 6.4	6.81 ± 6.3	8.37 ± 6.3
Dust (IRIS 100 μm)	μK/(MJy/sr)	38.1 ± 1.1	18.0 ± 1.1	12.1 ± 1.1	6.66 ± 1.1	4.93 ± 1.1
Offset	μK	$-328. \pm 23.$	$-146. \pm 23.$	$-95.6 \pm 23.$	$-48.5 \pm 22.$	$-29.8 \pm 22.$
Synchrotron (C-BASS)	μK/mK	15.8 ± 1.0	7.81 ± 1.0	4.62 ± 1.0	2.30 ± 0.99	1.44 ± 0.98
Hα (F03)	μK/R	27.1 ± 6.5	13.8 ± 6.4	10.6 ± 6.4	4.35 ± 6.3	6.76 ± 6.2
Dust (IRIS 100 μm)	μK/(MJy/sr)	35.3 ± 1.2	16.7 ± 1.1	11.3 ± 1.1	6.34 ± 1.1	4.75 ± 1.1
Offset	μK	-7.75 ± 9.8	20.5 ± 9.8	3.38 ± 9.7	5.03 ± 9.6	5.55 ± 9.5

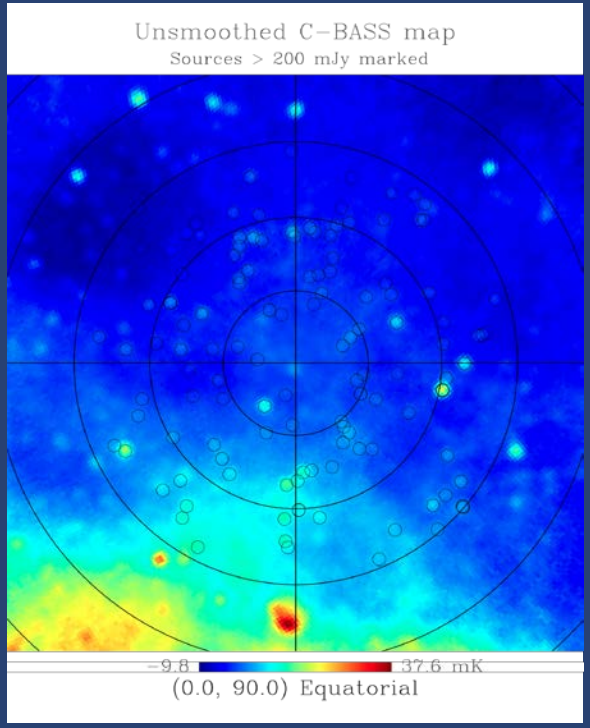
(Dickinson et al., in prep)

Conclusions

- With subset of data, on track to reaching our goals!!!

- Characterization of the interstellar medium:
  - Variation on synchrotron spectral index across the Galaxy
  - Template of (polarized) synchrotron emission
  - Characterization of free-free emission in the Galactic plane
  - Improved understanding of anomalous microwave emission (AME)
  - Studying of the galactic magnetic field



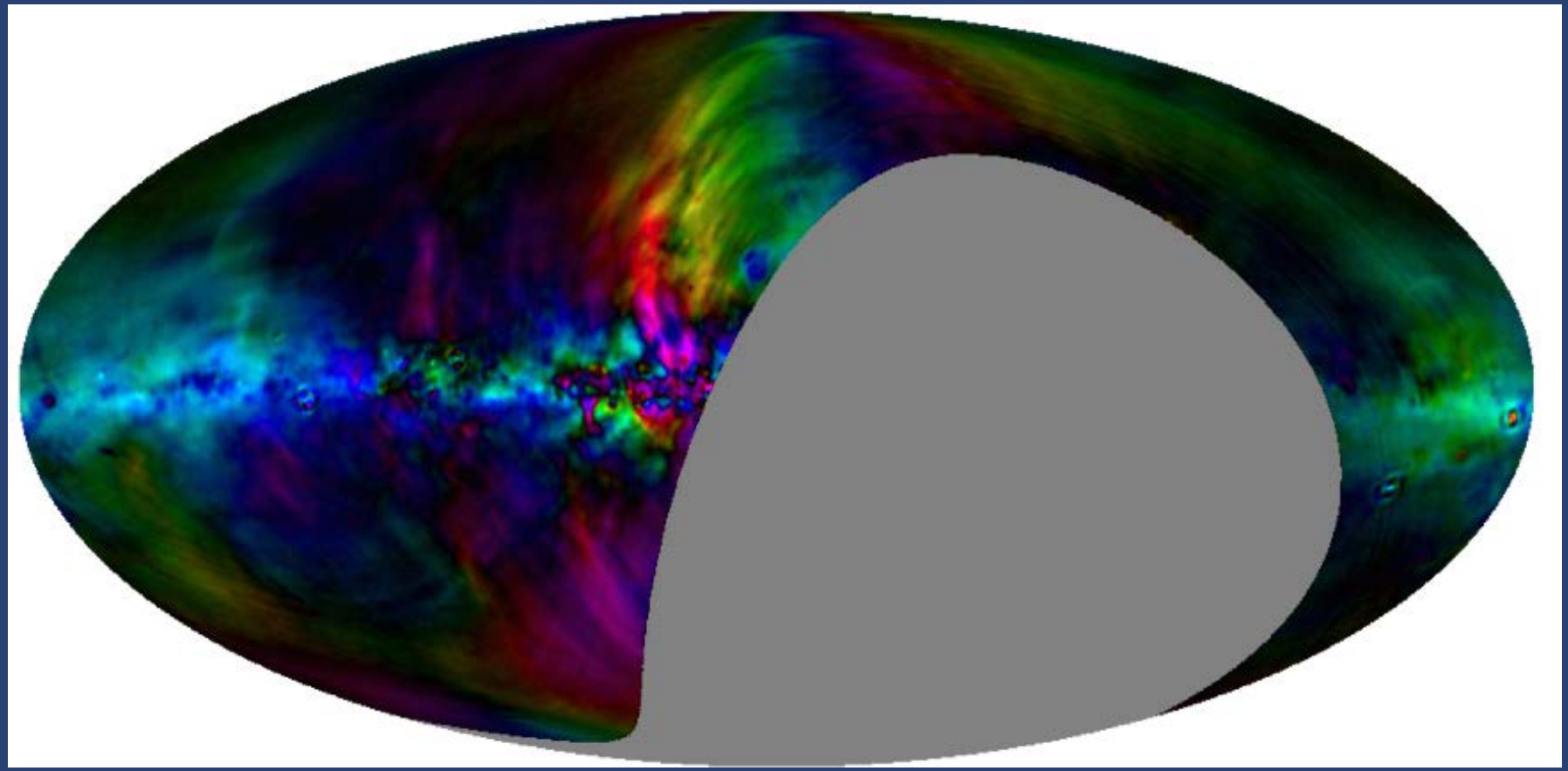


Stay tuned…

- Northern Survey to be completed next month; Southern survey beginning next year.

- Low-level systematics: residual ground spillover, 1.2 Hz contamination, polarization calibration.

- More to come….



Thank you.

Early Results from The C-Band All Sky Survey (CBASS)

Stephen Muchovej
California Institute of Technology

sjcm@astro.caltech.edu