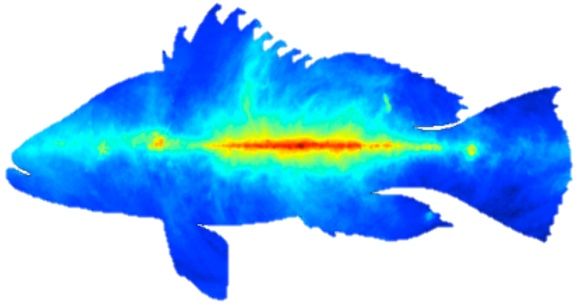
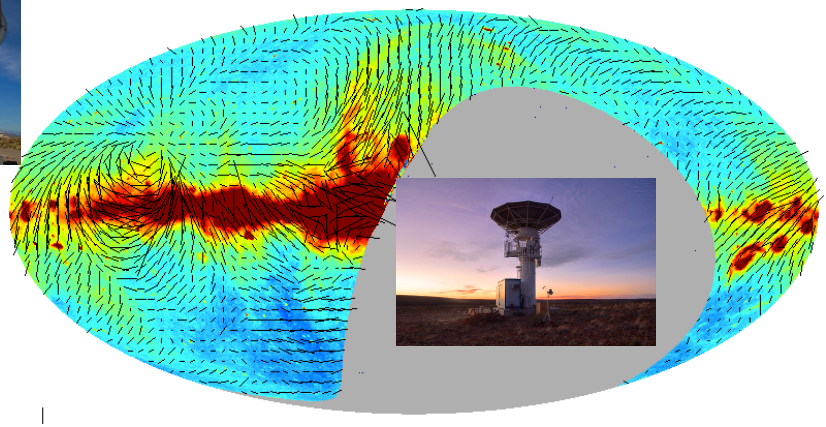


http://www.astro.caltech.edu/cbass

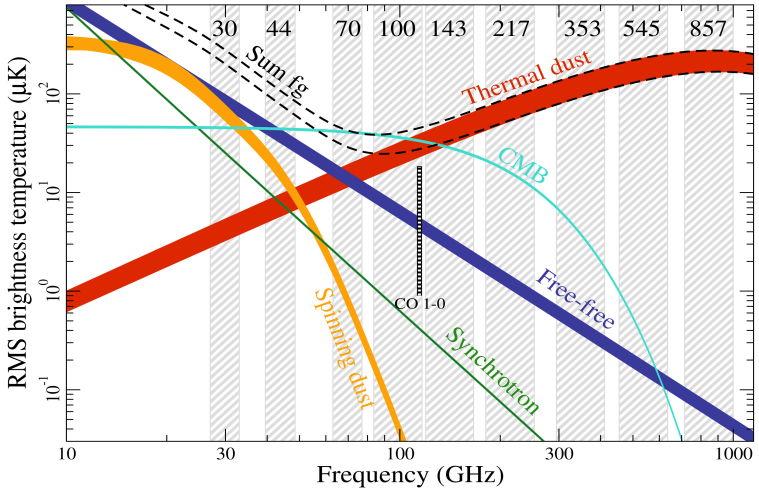
THE C-BAND ALL SKY SURVEY

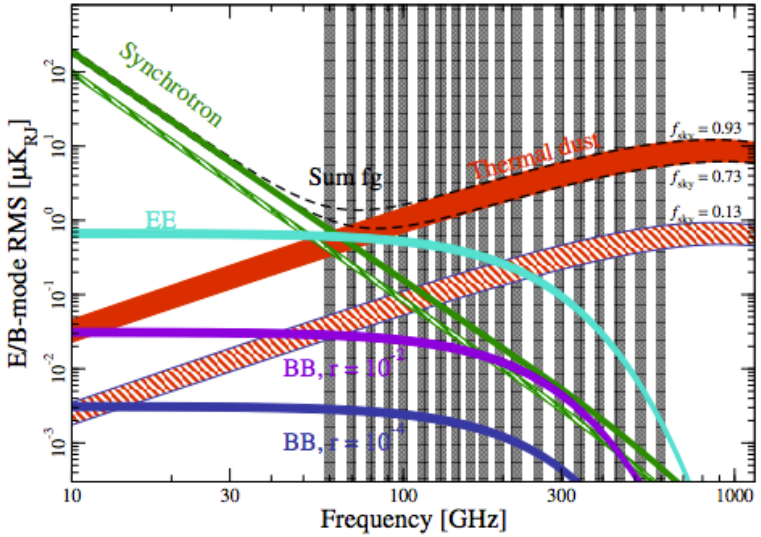
Moumita Aich, University of KwaZulu-Natal, South Africa
*for the **C-BASS** collaboration*



Advances in Theoretical Cosmology in light of data
Stockholm
17 July 2017

Galactic foregrounds in Planck bands

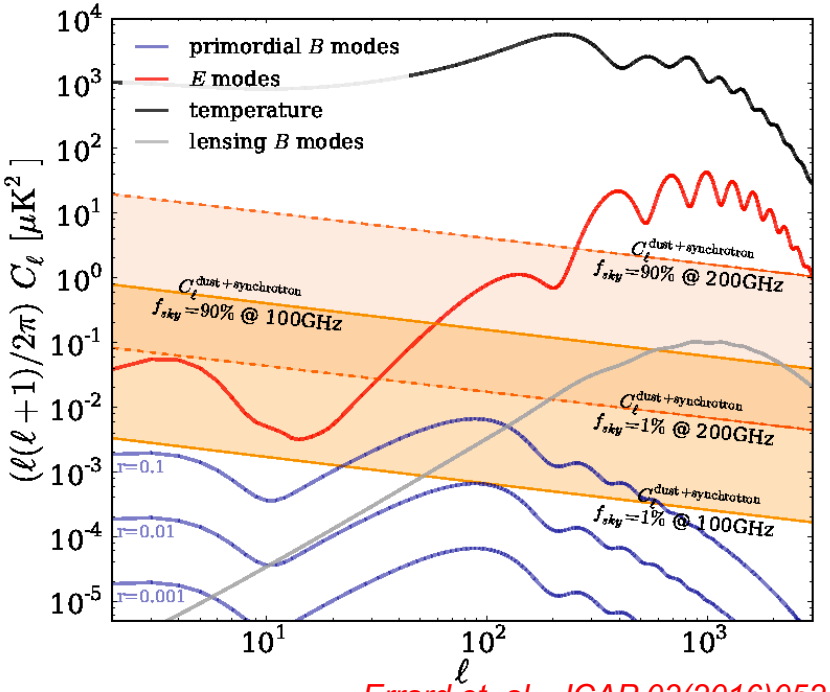




Temperature and polarisation foreground spectra

Planck Collaboration, 2015, arXiv:1502.01588, CORE arXiv: 1704.04501

- Total intensity appear to be more complicated than polarisation!
- Foreground minimum at ~80 GHz
- Polarisation might be less complicated but requires higher precision (CMB weaker)
- Foreground minimum at ~70 GHz



Errard et. al., JCAP 03(2016)052

Need for a synchrotron dedicated study

- Low frequency temperature foreground spectrum consists of free-free, synchrotron and anomalous microwave emission – degenerate in the narrow band 23-70 GHz
- Break degeneracy - extend to lower frequency
- Sky maps where low-frequency foregrounds are clearly detected in each pixel
- Ground based – for wavelengths much longer than 1 cm
- Polarised foreground components synchrotron emission and thermal dust emission are spatially correlated (WMAP 23 GHz and Planck 353 GHZ)[1,2]
- Synchrotron has same 'color' as CMB in 200-400 GHz range; the same level as BB at r=0.01

[1] *Steve K. Choi, Lyman A. Page, JCAP12(2015)020*
[2] *Planck intermediate results. XXII, A&A Volume 576, April 2015*

Low-frequency ground-based surveys

Survey	Frequency (GHz)	Angular Resolution (deg.)	Sky Coverage	Status
GEM: Galactic Emission Mapper	0.4/1.4/2.3/5/10	~0.5 (10GHz)	Full-sky	Low frequencies noisy 10 GHz on-going
S-PASS: S-band Parkes All-Sky Survey	2.3	0.1	Southern Sky	First results out Observations complete Analysis on-going
C-BASS: C-Band All-Sky Survey	5.0	0.75	Full-sky	First results out Northern obs complete Southern obs have begun
QUIJOTE: Q-U-I JOint Tenerife Experiment	11,13,17,19	~1	Northern sky	First results out Obs on-going Possibility of full-sky in future

C-Band All Sky Survey (C-BASS)

Sky coverage	All sky
Angular resolution	0.73 degree (43.8 arcmin)
Sensitivity	0.1 mK rms
Stokes coverage	I, Q & U
Frequency	4.5 - 5.5 GHz (centered at 5 GHz)

- Primary goal: a **synchrotron template** for use in CMB foreground subtraction, **inflationary B-mode searches.**
  - 5 GHz - dominated by synchrotron radiation and largely uncorrupted by Faraday rotation; polarisation angles and fractions can be extrapolated to higher frequencies.
  - A 'low frequency channel' for Planck and future experiments; constrain synchrotron spectral index and its variation across the Galaxy

- Secondary goals:
  - understand emission mechanisms in the diffuse **interstellar medium** and **magnetic fields**
  - study distribution of **AME**, constrain models of **Galactic structure**
  - to help understanding of the **Galactic Haze**

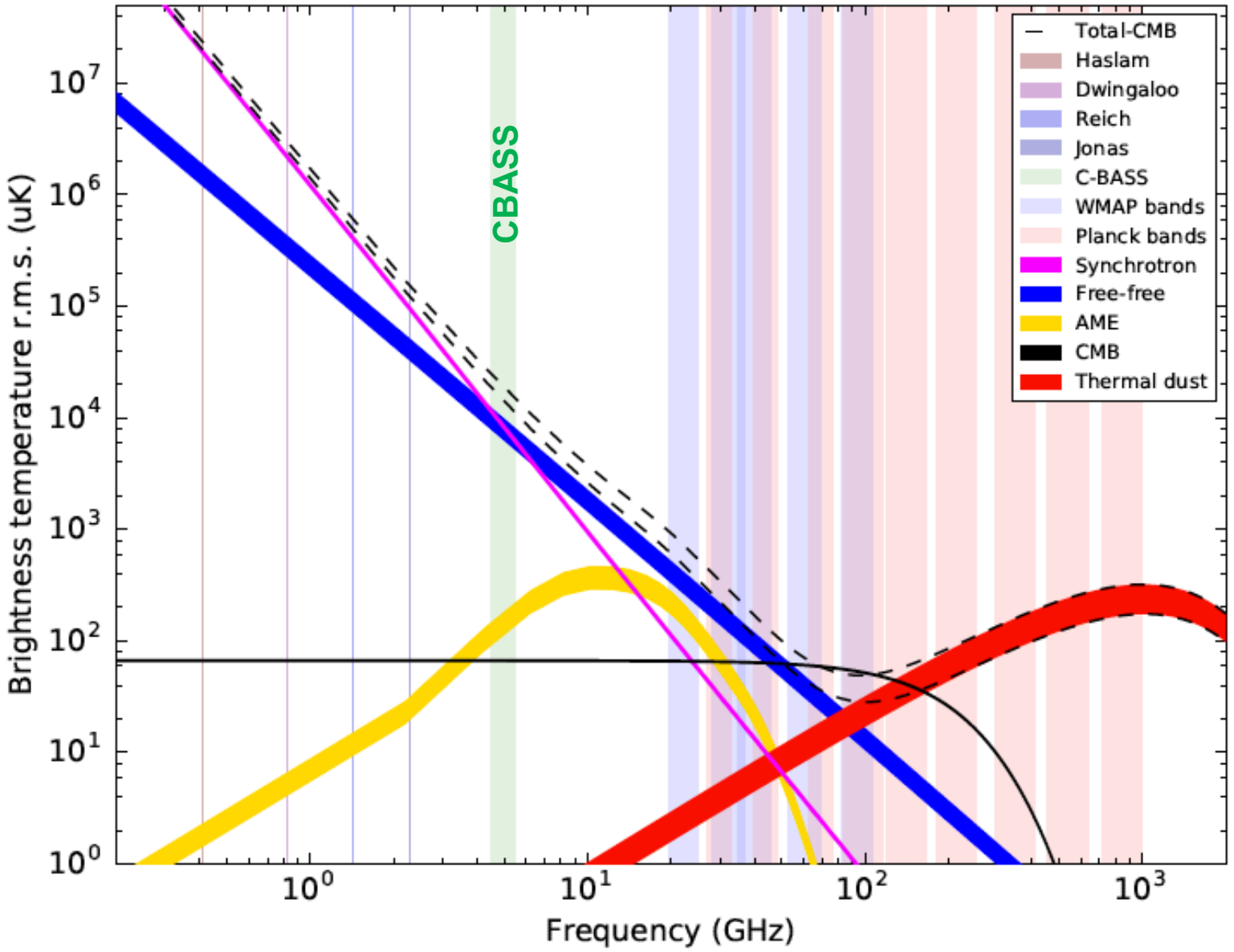
To observe the entire sky, C-BASS uses two different ground based radio telescopes.

C-BASS North vs South

	North	South
Location	Owens Valley Radio Observatory	SKA Support Base in Klerefontein
Bandwidth	4.5 – 5.5 GHz across 1 channel	4.5 – 5.5 GHz across 128 channels
Backend	Analogue	Digital
Dish Diameter	6.1 m with absorbing baffles	7.6 m under-illuminated
Optical Configuration	Gregorian	Cassegrain
Angular Resolution	0.73 degrees	0.73 degrees
Sensitivity	0.1 mK per beam	0.1 mK per beam
Start of Observations	Nov 2012	Late 2015
End of Observations	Early 2015	

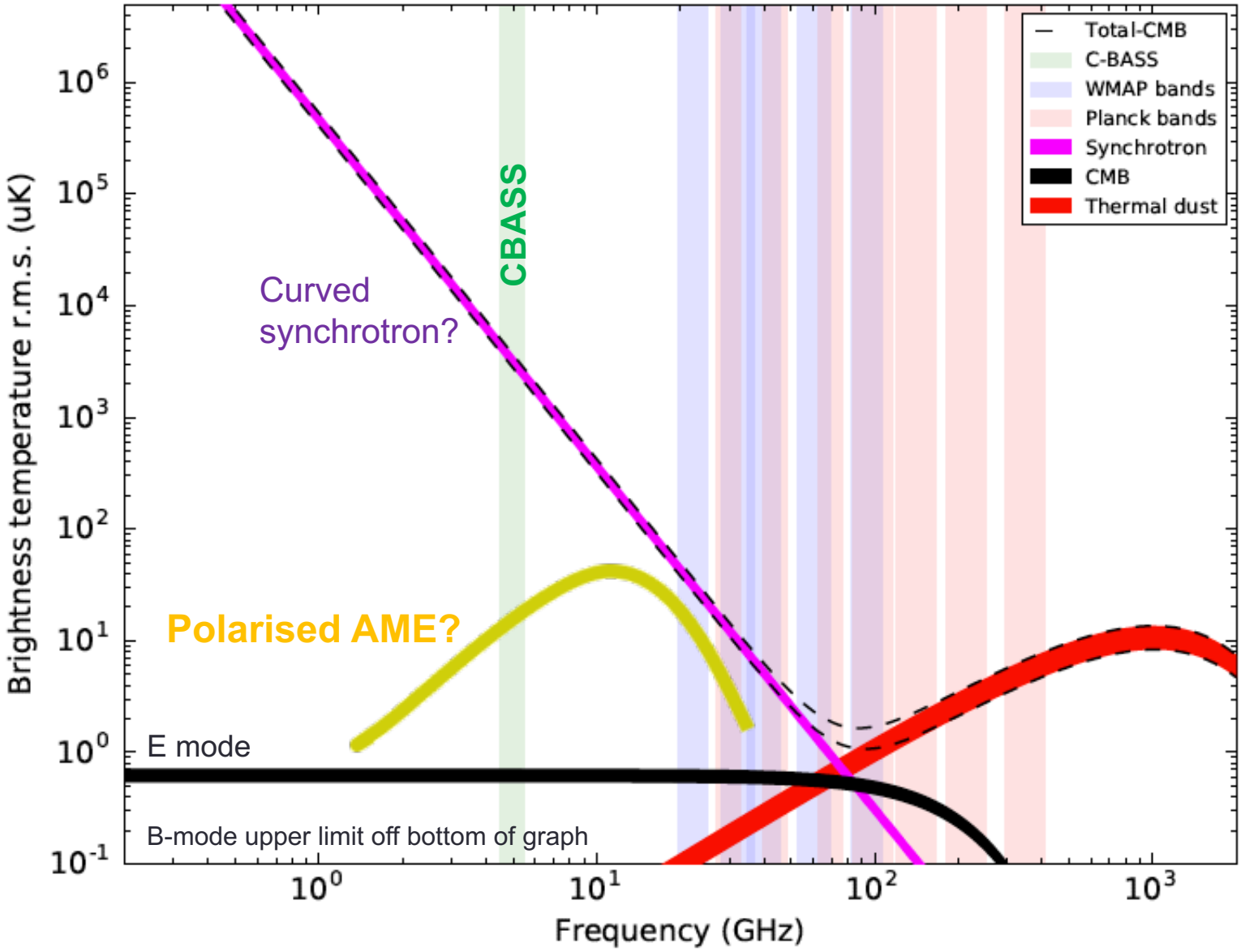
Table courtesy: Heiko Heilgendorff

Observations at 5 GHz - temperature



The C-Band All-Sky Survey: Design and capabilities.
Jones, M.E., et al. 2017, In preparation

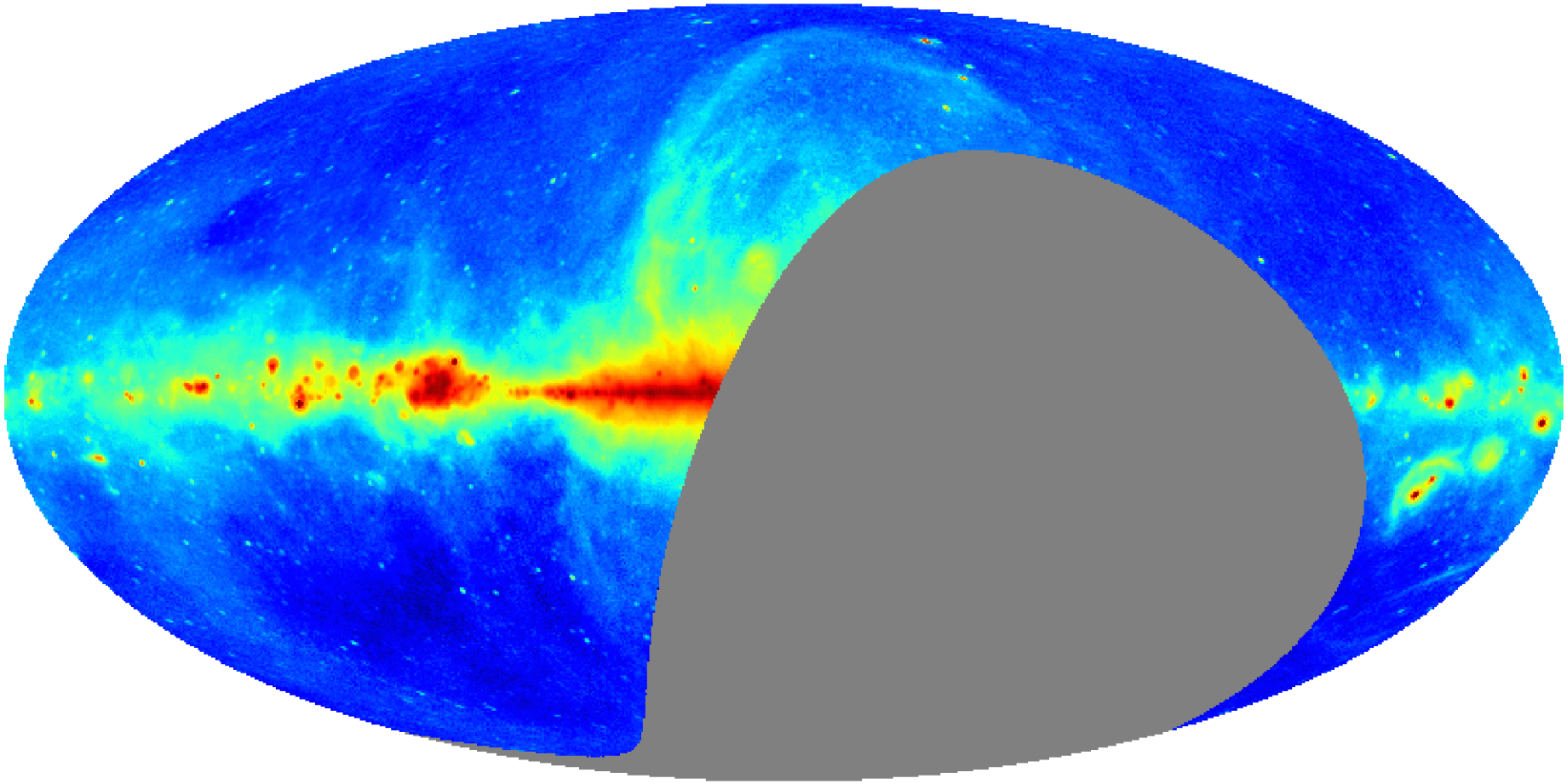
Observations at 5 GHz - polarisation



Polarised AME, *if any* (*Dickinson et al. 2011*, *Rubino-Martin et al. 2012*, QUIJOTE results – *Genova-Santos et al. 2016*)

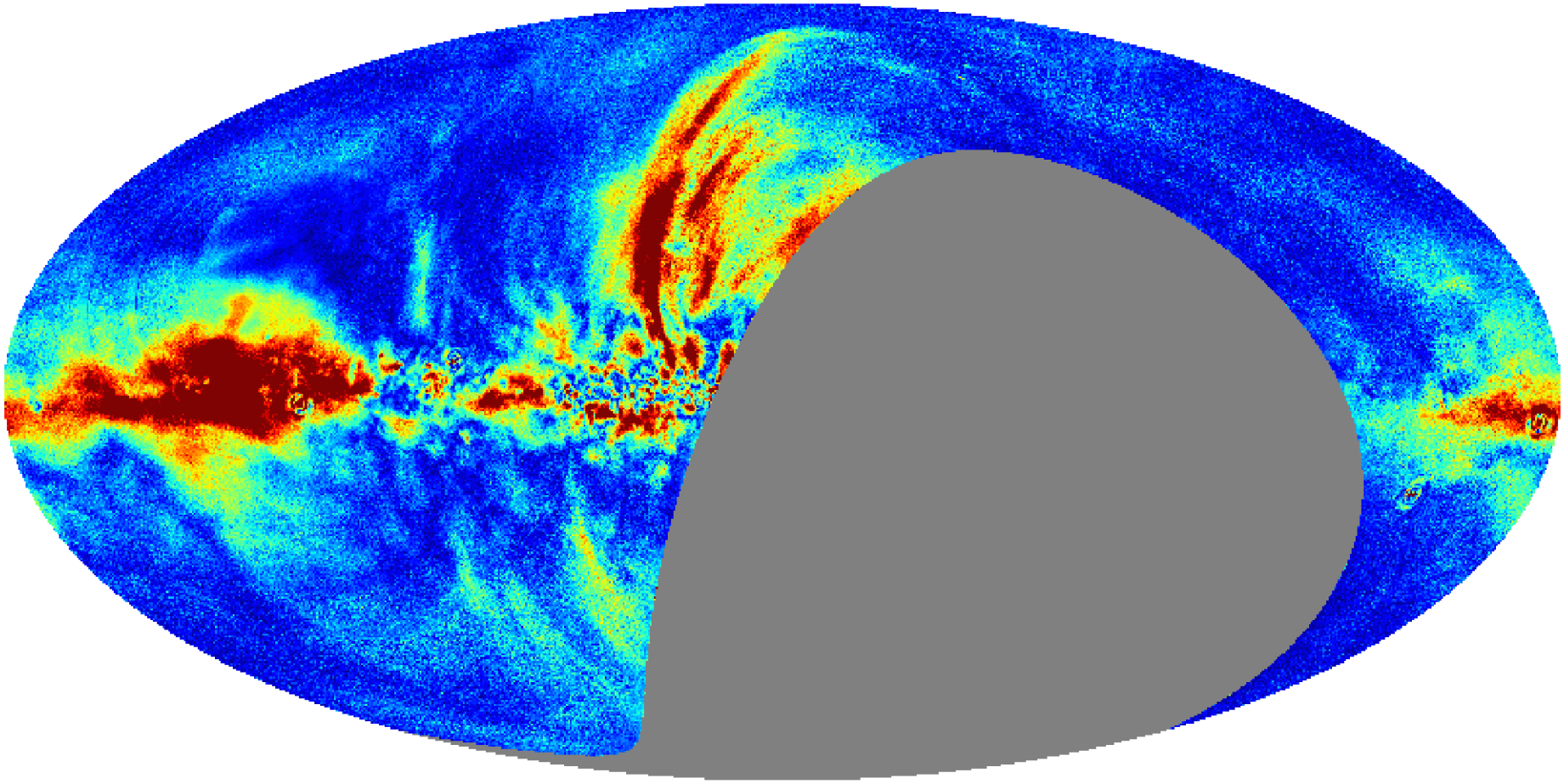
The C-Band All-Sky Survey: Design and capabilities.
Jones, M.E., et al. 2017, In preparation

Preliminary full season temperature map from C-BASS north



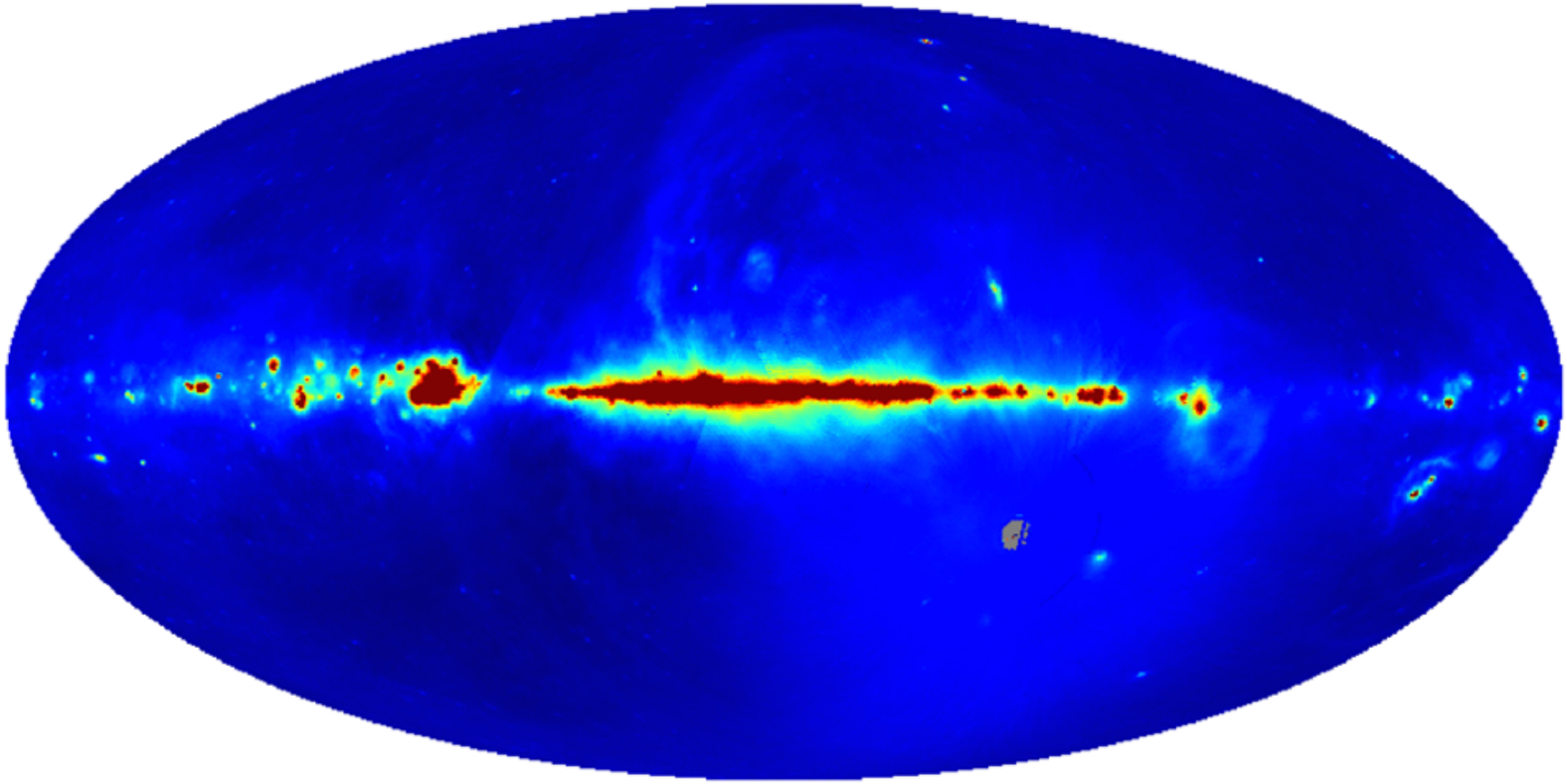
These are not the final maps as work is continuing on calibration and removal of systematic effects such as ground-spill, atmospheric 1/f noise and instrumental cross-polarisation. This map is of Stokes I and is presented with a highly non-linear colour scale to show features at all brightness levels – the ratio of brightest pixel to thermal noise level in the map is over 10,000:1.

Preliminary full season polarisation amplitude map from C-BASS north



This map is polarized intensity (Stokes $(Q^2 + U^2)^{1/2}$) and is on a linear intensity scale.

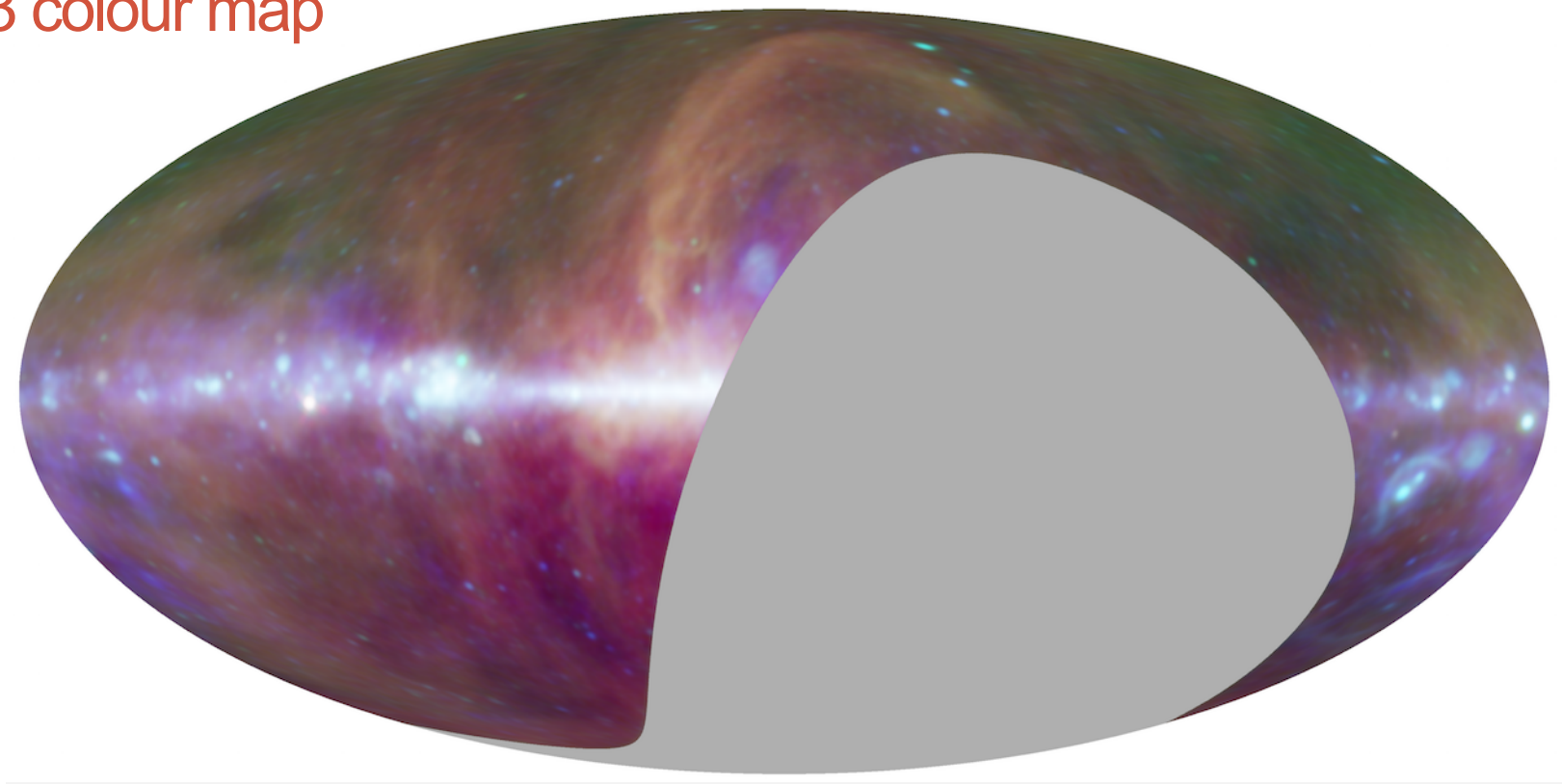
Preliminary all-sky intensity map from C-BASS



- Includes ~ 3 months of C-BASS south data, uncalibrated, uncleaned, lacks ground subtraction (gives rise to the background slope towards the SCP).
- Currently surveying through the SCP and will be surveying at a variety of elevations as per the north.

Figure courtesy: Angela Taylor

3 colour map

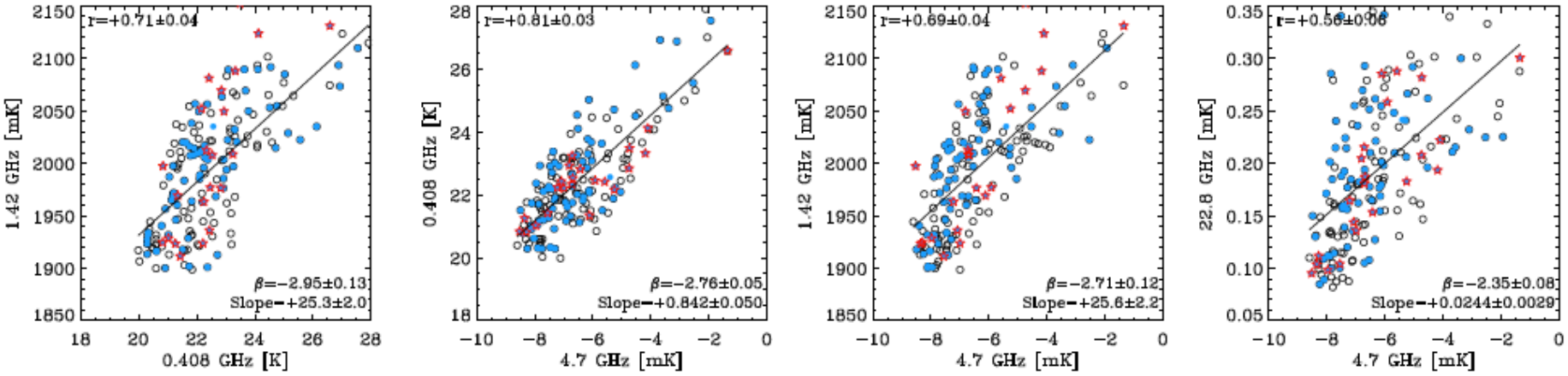


This map is a three-colour image in which

- red channel is the Haslam et al 408 MHz map
- green channel is the C-BASS *I* map, and
- blue channel is WMAP K band − V band, which is an approximation to the high-frequency diffuse emission with the CMB removed.

The colours are balanced such that a temperature spectrum of index **−2.7** would appear white. The intensity scale is highly non-linear.

Preliminary C-BASS T-T plots



T-T plots of the NCP region for various combinations of maps. The circles are for pixels used for template fitting. Blue filled circles are pixels that contain a weak (< 600mJy) extragalactic source from the Mingaliev et al. (2007) survey. Red stars are pixels that contain a bright (> 600mJy) source and are excluded from the analysis. The line is the best-fitting straight line to the masked data (unfilled and filled blue circles).

C-BASS NCP paper, C. Dickinson et al. 2017, In preparation

Figure courtesy: Luke Jew

Survey status

- The **northern** survey observations at Owens Valley, USA are **complete**
- The **southern** survey at Klerefontein, South Africa started in **late 2015**
- Data analysis pipeline is complete: working on optimization of
  - RFI detection
  - Sun contamination (data selection and subtraction)
  - Ground contamination
  - Polarisation calibration
  - Pointing corrections
- Repeat **Planck intensity analysis including C-BASS** using COMMANDER, Gibbs sampling software, performs a pixel based parametric component separation (*Luke Jew* working with *Hans Kristian Eriksen & Ingunn Wehus*)
-
- Aim to have final **northern maps** in **late 2017**
- **Southern survey** should be completed in **2018**, with full-sky maps soon thereafter

Thanks!