C-BASS: The C-band all-sky survey

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for the C-BASS collaboration

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

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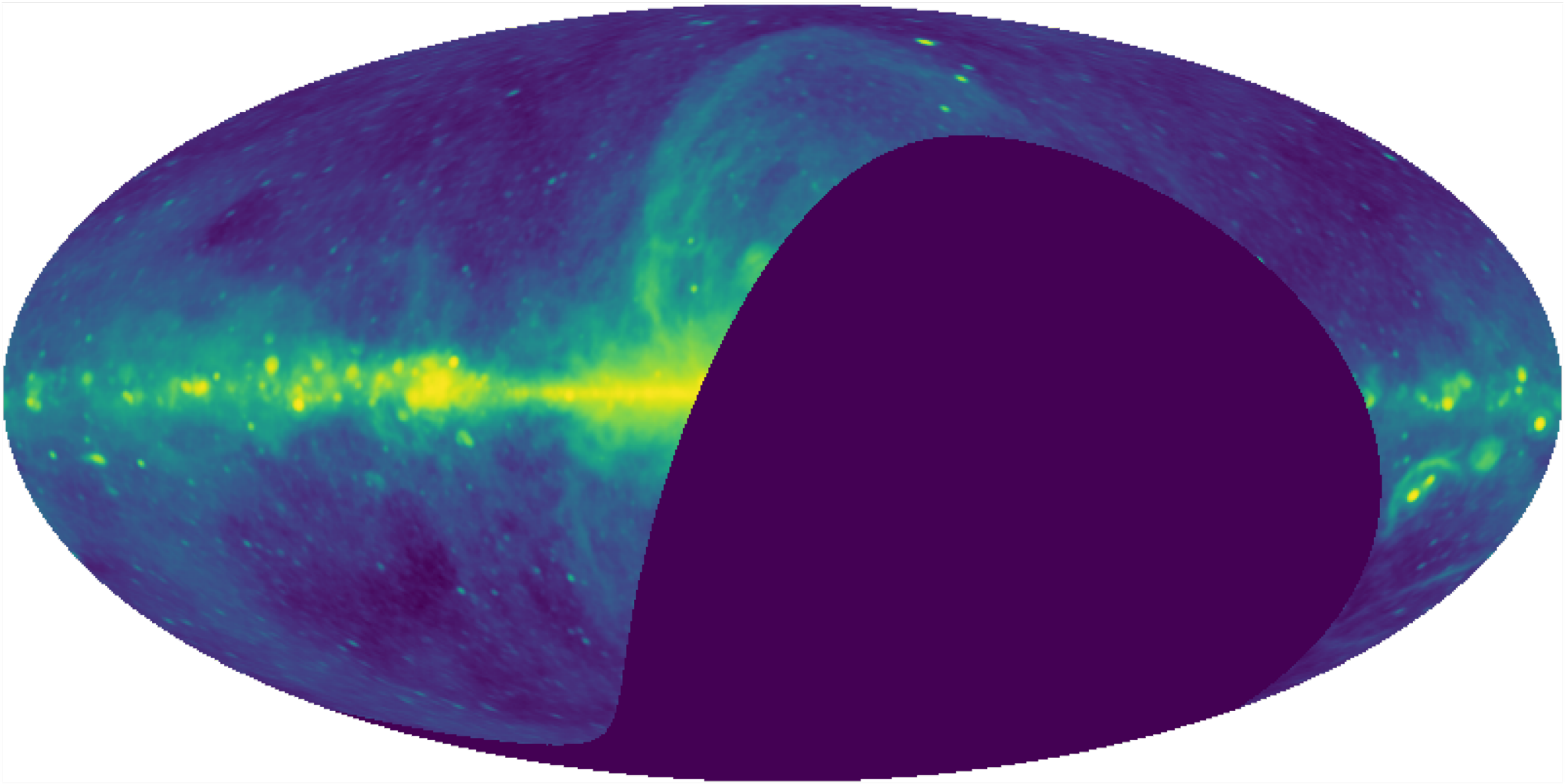
- The C-Band All-Sky Survey (C-BASS) is a project to produce high signal-to-noise all-sky maps at a central frequency of 5 GHz in intensity and linear polarization (Stokes I, Q, and U).
- C-BASS uses two telescopes, one in the northern hemisphere at the Owens Valley Radio Observatory in California, and one close to the South African SKA site. Angular resolution 0.73°.
- Novel optical design to minimize sidelobes.
- Nominal bandwidth 1 GHz.
- Thermal noise sensitivity is ~3 mK√s in I and ~2 mK√s in Q/U, with a target survey thermal noise level of 0.1 mK.
- Maps at this frequency are dominated by synchrotron radiation and largely uncorrupted by Faraday rotation.

Two Telescopes

OVRO California

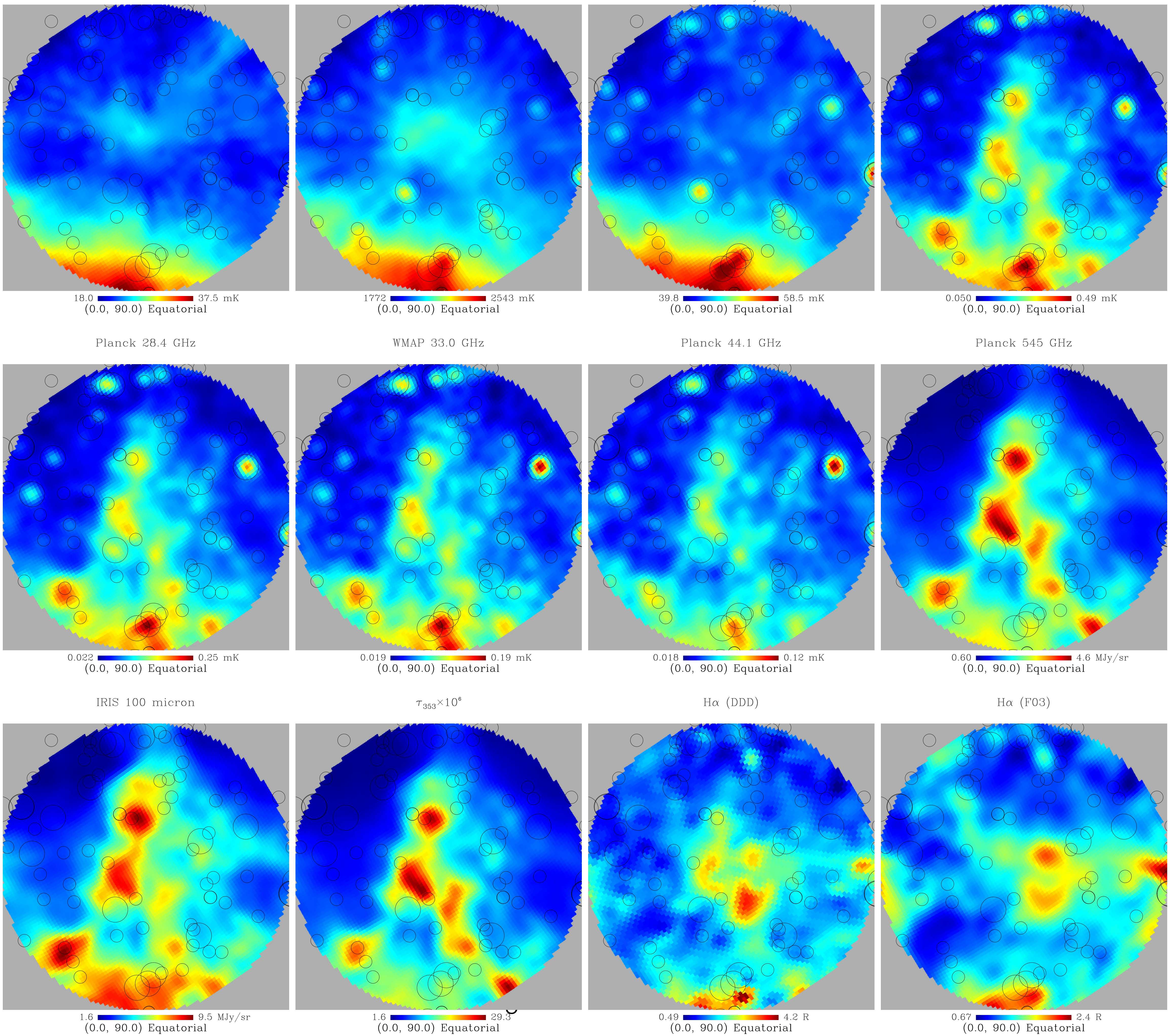
Klerefontein South Africa (SKA site)

CBASS-N intensity

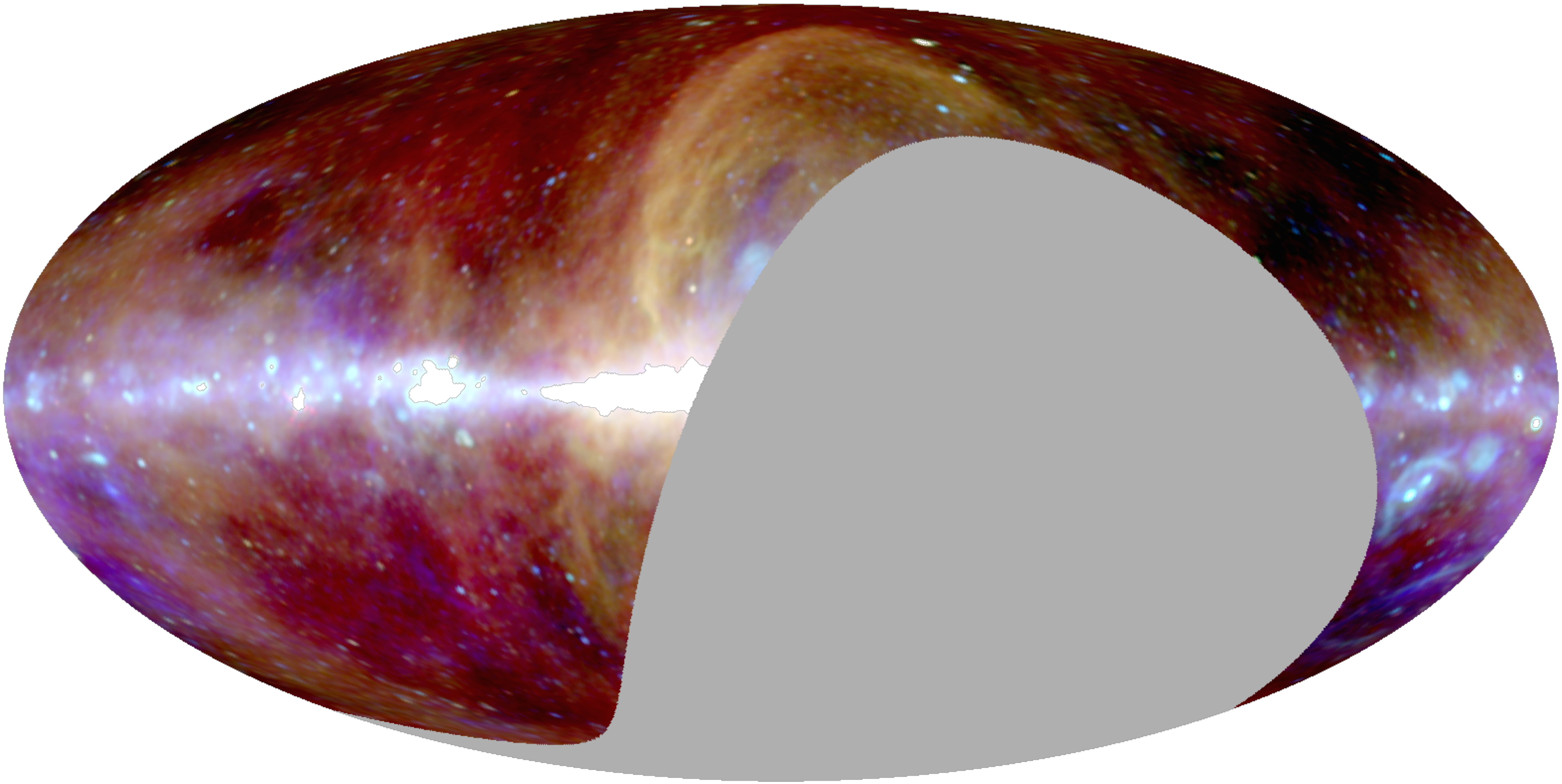


C-BASS northern survey: intensity (nonlinear scale).

NCP

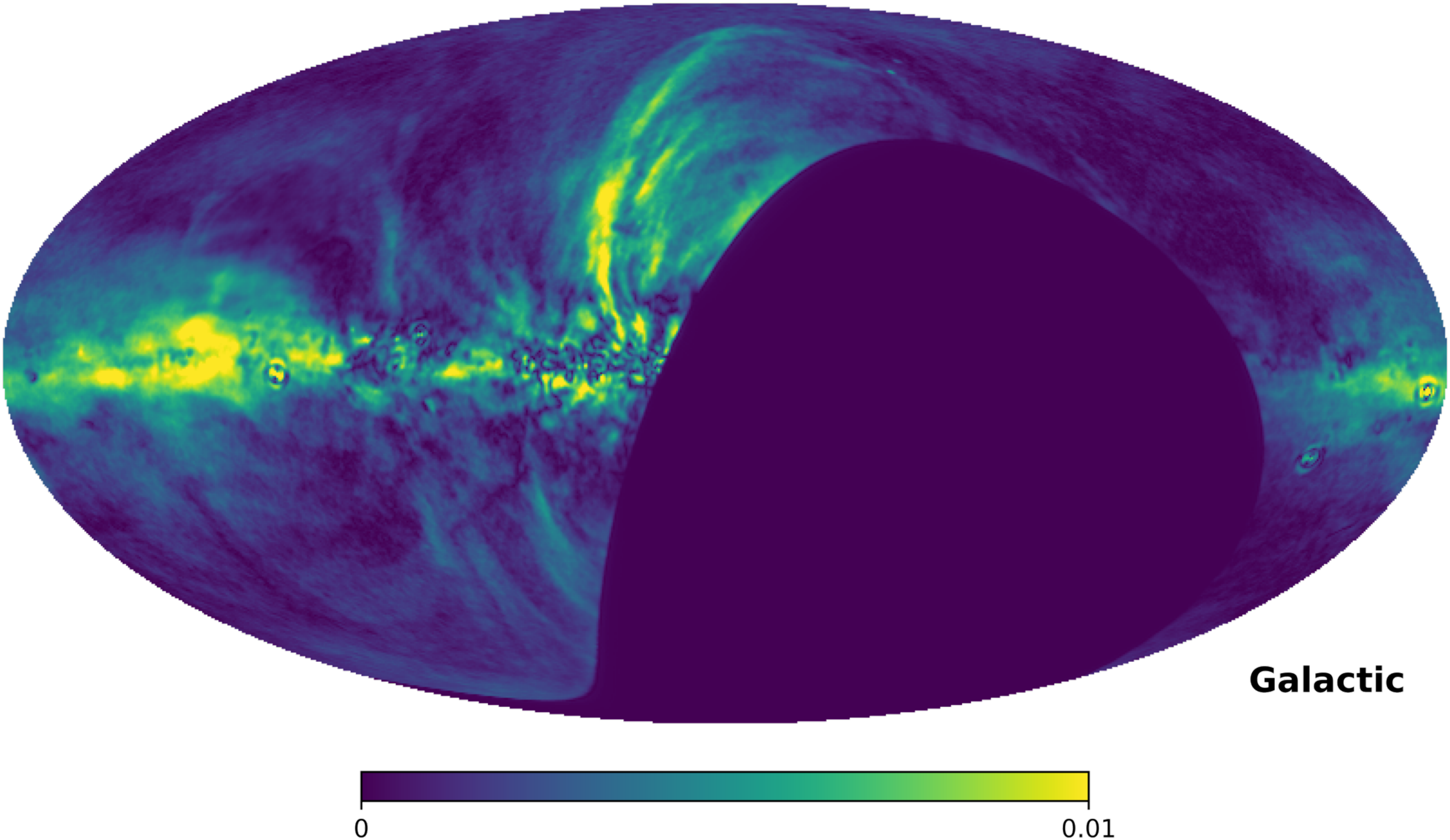

18.0 37.5 mK
(0.0, 90.0) Equatorial
1772 2543 mK
(0.0, 90.0) Equatorial
39.8 58.5 mK
(0.0, 90.0) Equatorial
0.050 0.49 mK
(0.0, 90.0) Equatorial
Planck 28.4 GHz
WMAP 33.0 GHz
Planck 44.1 GHz
Planck 545 GHz
0.022 0.25 mK
(0.0, 90.0) Equatorial
0.019 0.19 mK
(0.0, 90.0) Equatorial
0.018 0.12 mK
(0.0, 90.0) Equatorial
0.60 4.6 MJy/sr
(0.0, 90.0) Equatorial
IRIS 100 micron
$\tau_{353}\times10^{6}$
Hα (DDD)
Hα (F03)
1.6 9.5 MJy/sr
(0.0, 90.0) Equatorial
1.6 29.3
(0.0, 90.0) Equatorial
0.49 4.2 R
(0.0, 90.0) Equatorial
0.67 2.4 R
(0.0, 90.0) Equatorial

408 MHz – 5 GHz – 23 GHz

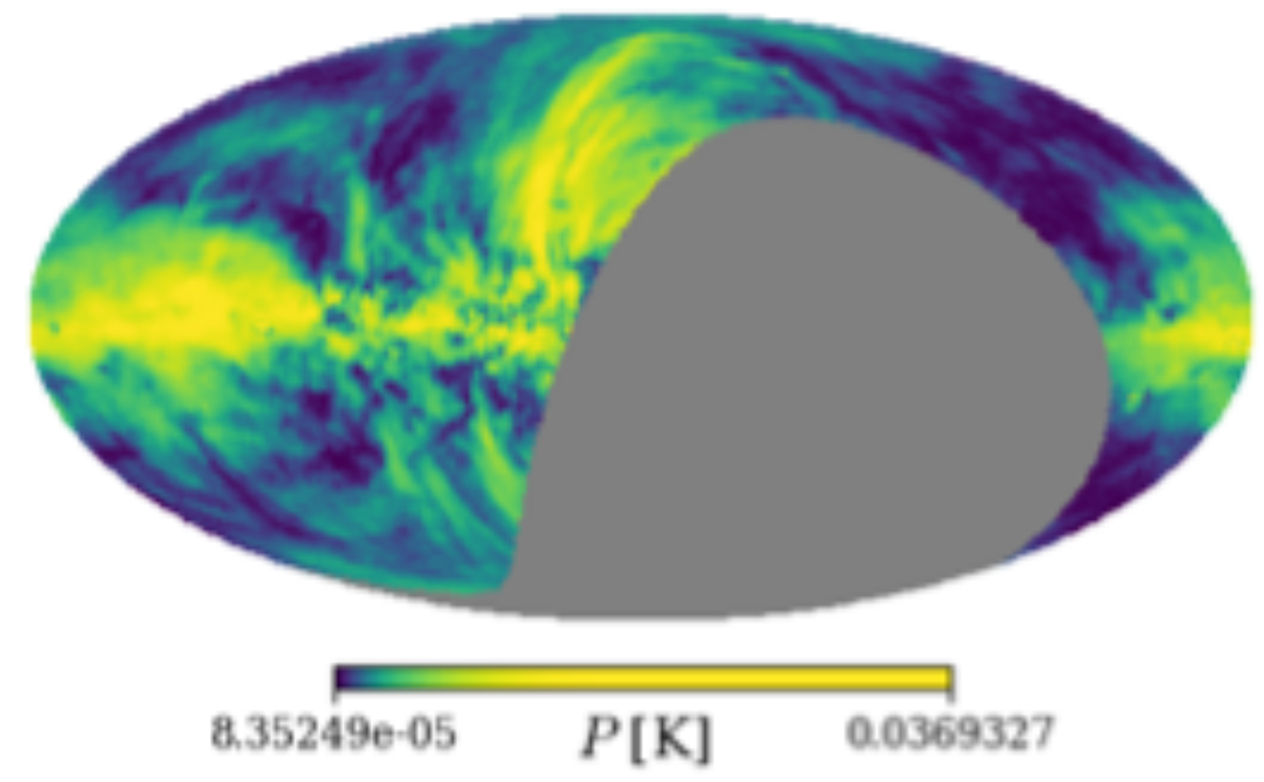


C-BASS northern survey (green), Haslam (red), WMAP *K*–*V* (blue).
A spectrum with temperature index β = 2.7 is white.

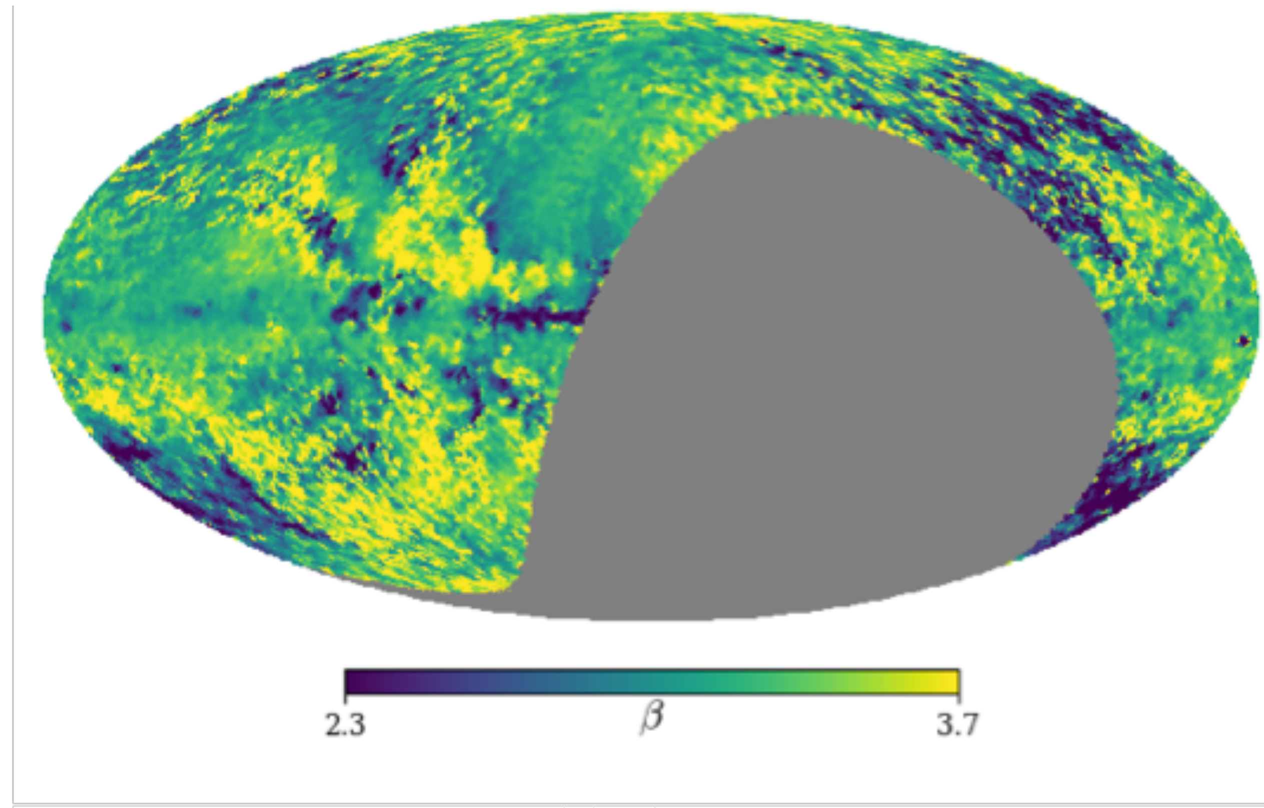
CBASS-N polarized intensity



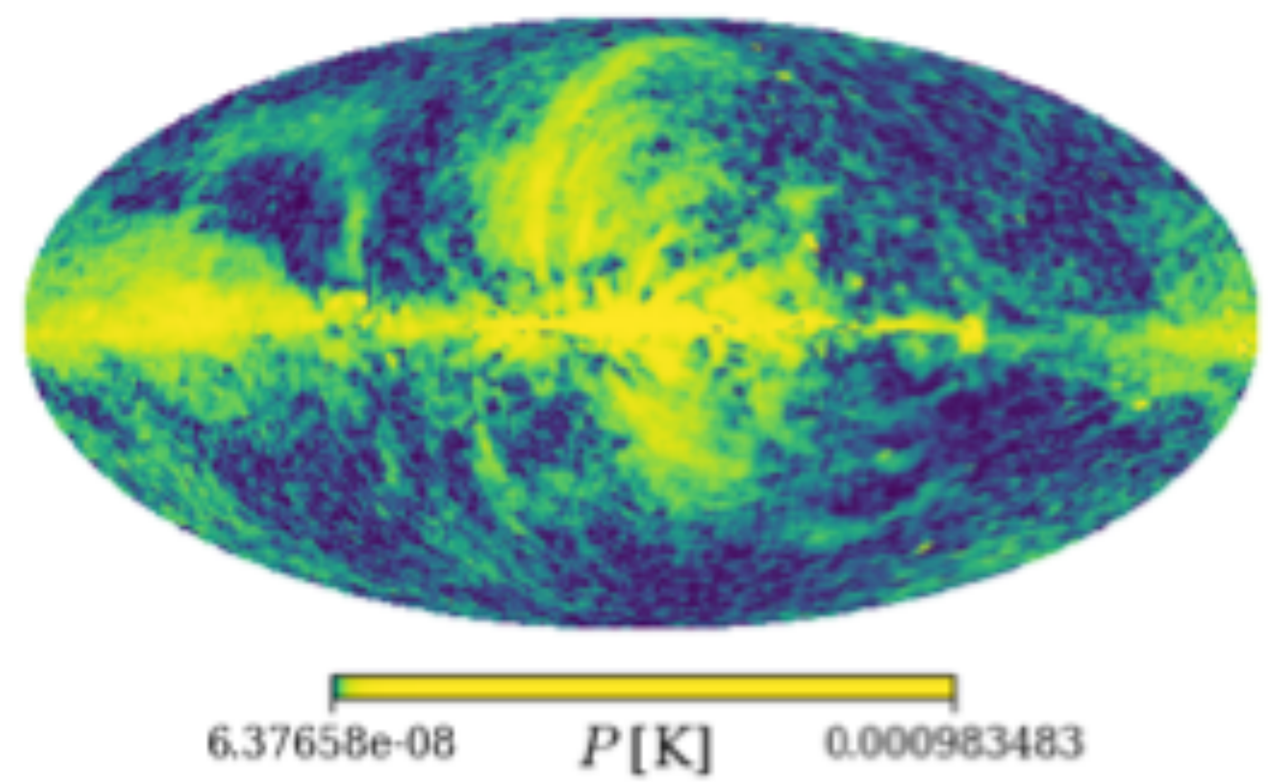
Polarized spectral indices 5 – 30 GHz



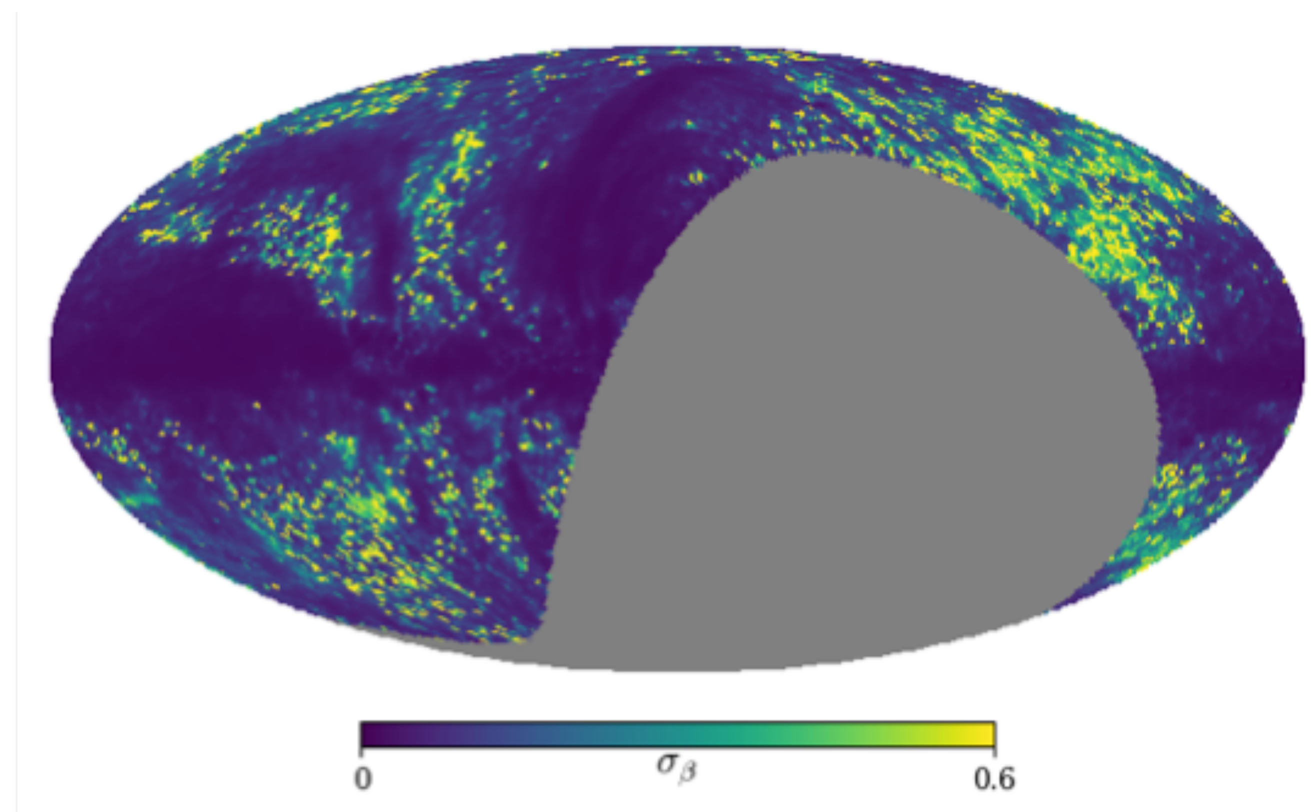
(a) C-BASS P map



Spectral index map

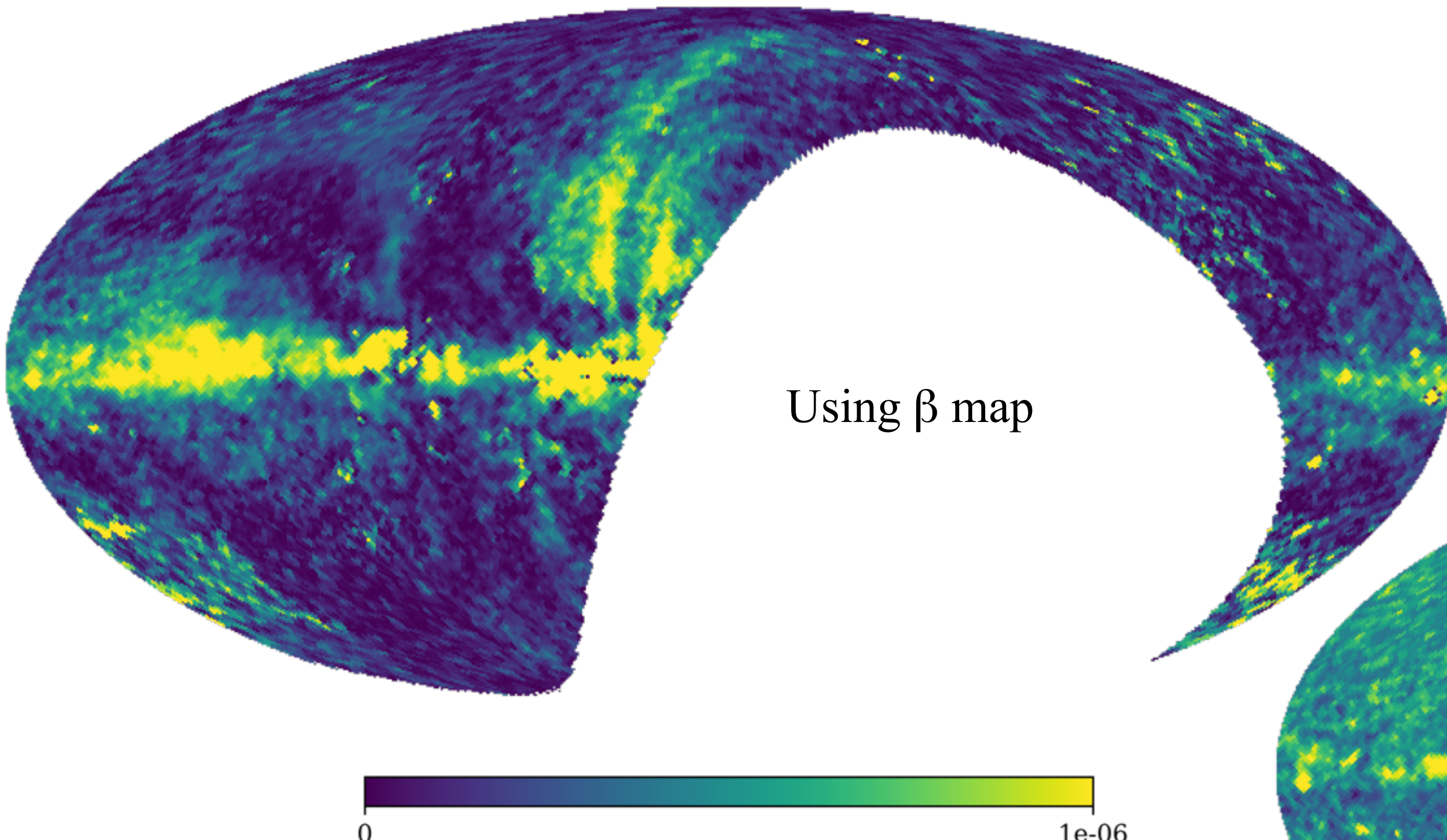


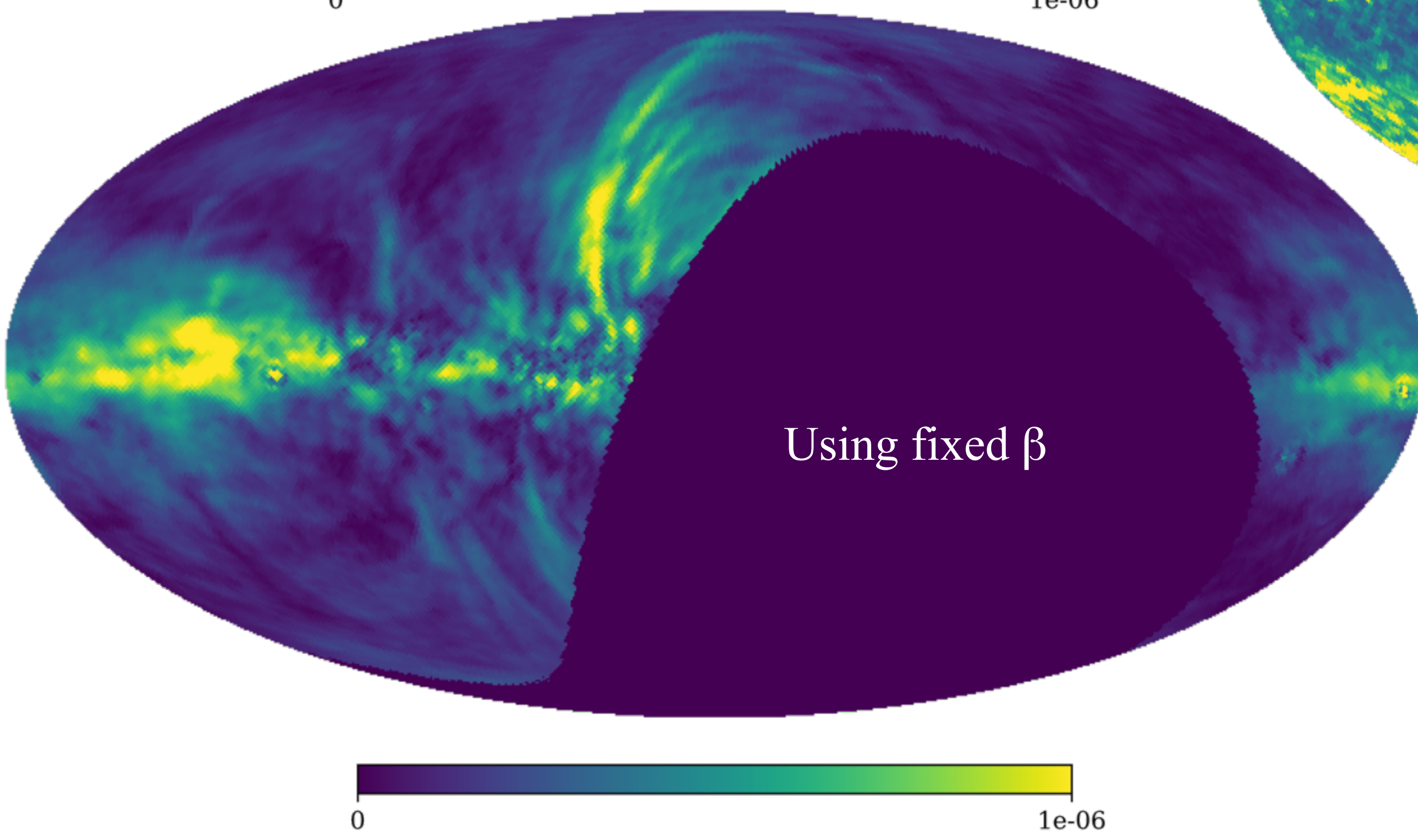
(c) *Planck* 30 GHz P map

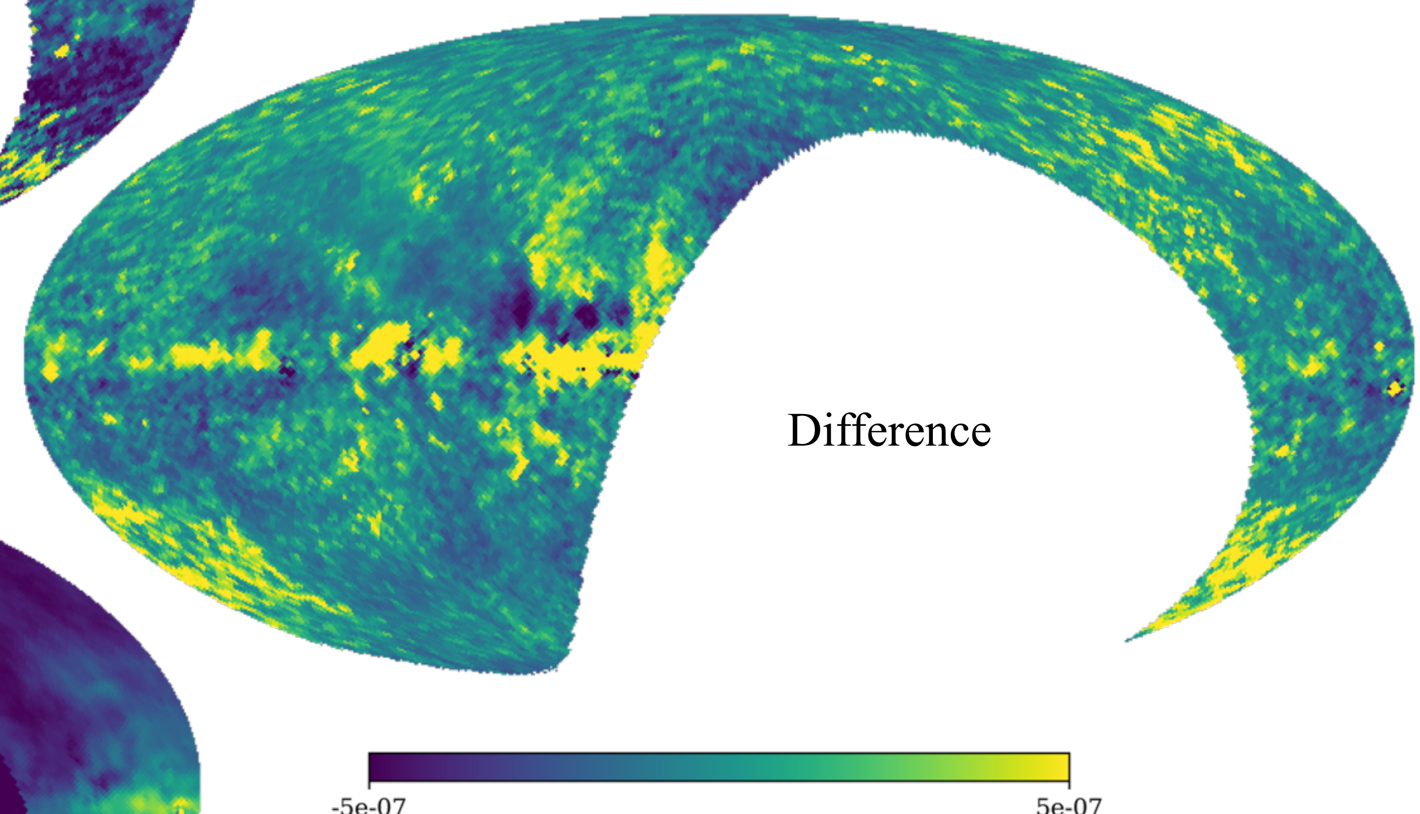


Spectral index error map

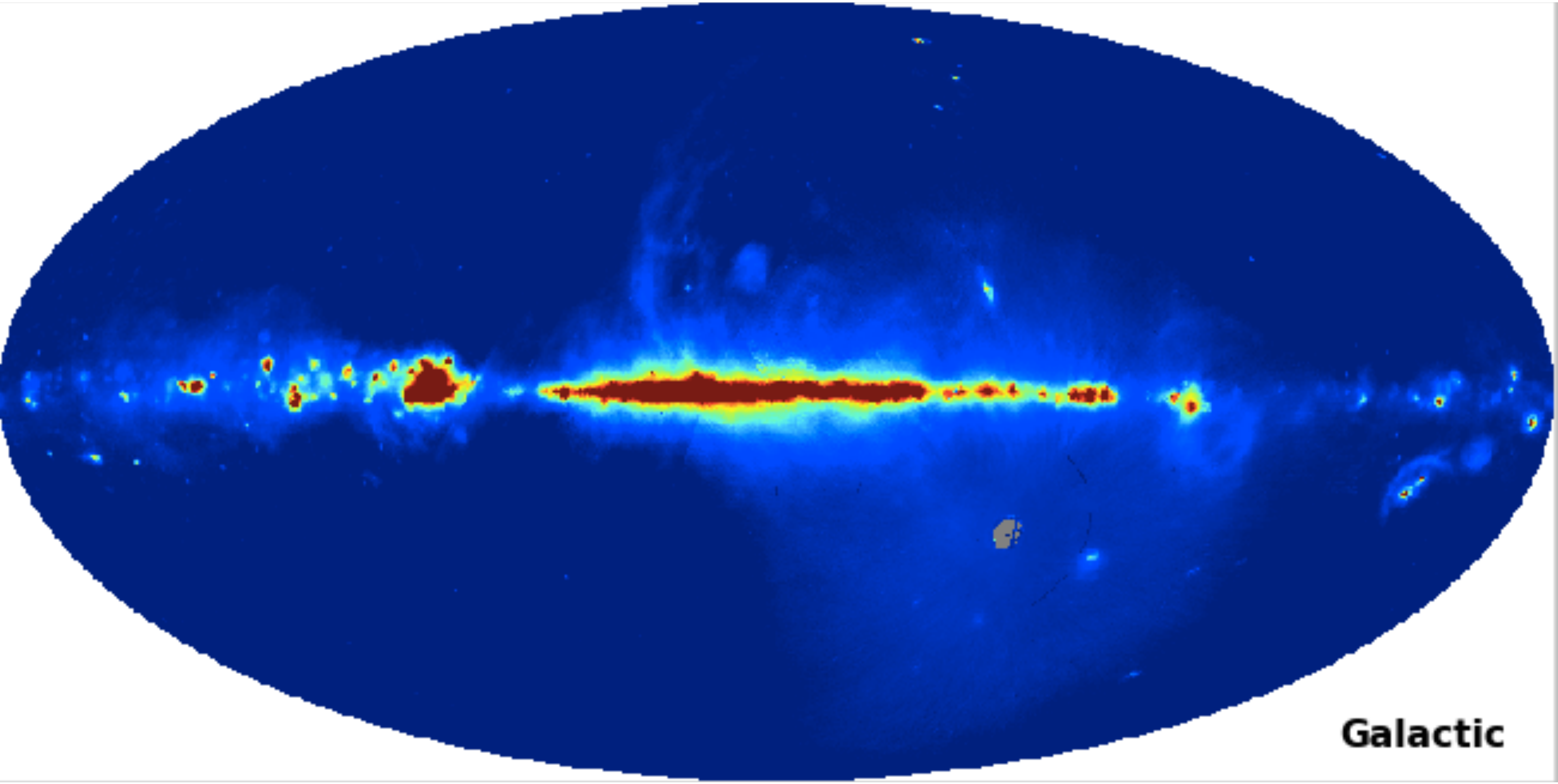
P maps extrapolated to 100 GHz







First full-sky C-BASS map



Uncalibrated intensity map

Impact of C-BASS: intensity

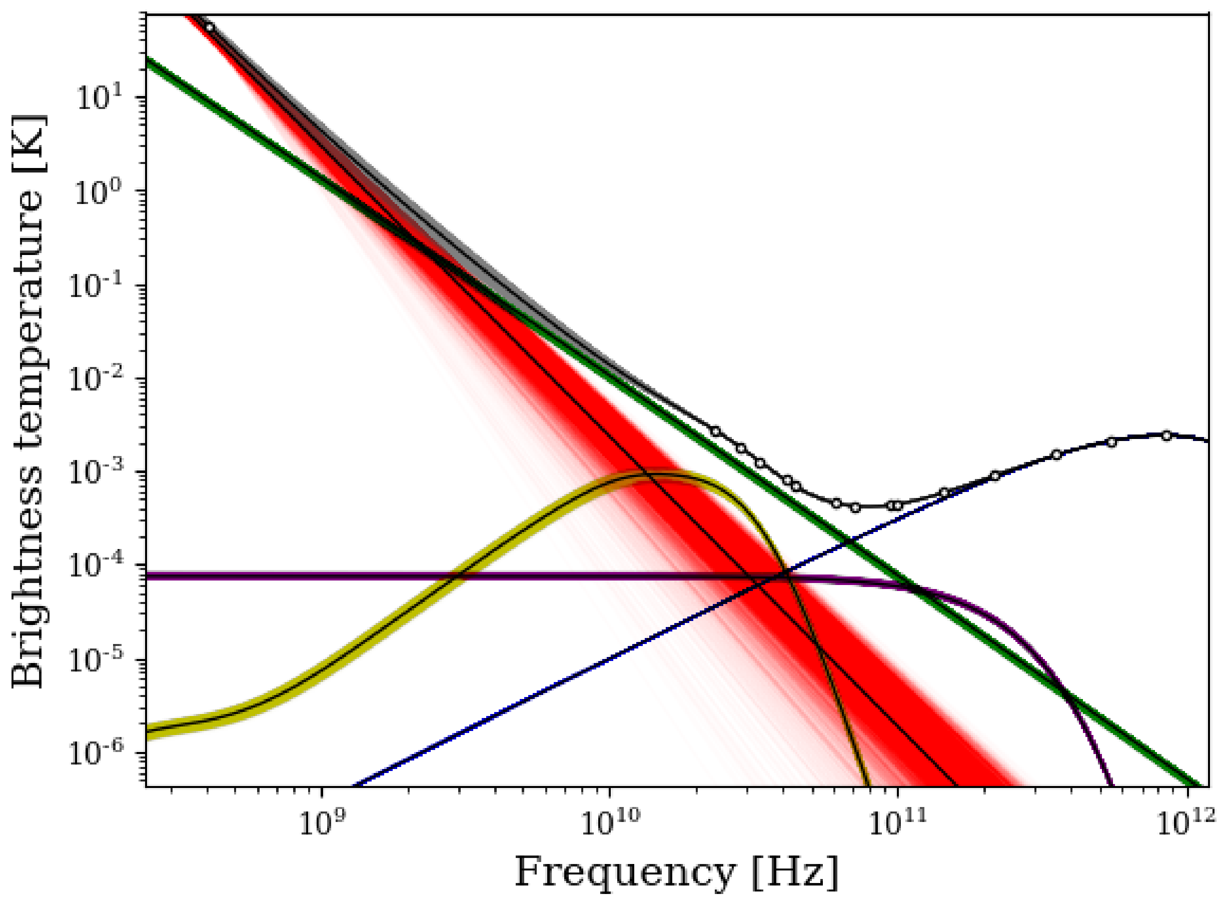


Figure 7. Total intensity frequency spectra for a 1° pixel in a sky region with significant foreground contamination. The *solid black lines* are spectra of the true simulated foreground components. The coloured lines are the frequency spectra of the sky components of 5000 randomly drawn samples from the converged MCMC chains. *Left* is the result from only including Haslam, WMAP and *Planck* data points. *Right* is with the addition of a C-BASS data point. Synchrotron is *red*; thermal dust is *blue*; AME is *yellow*; free-free is *green*; and CMB is *purple*.

Impact of C-BASS: polarization

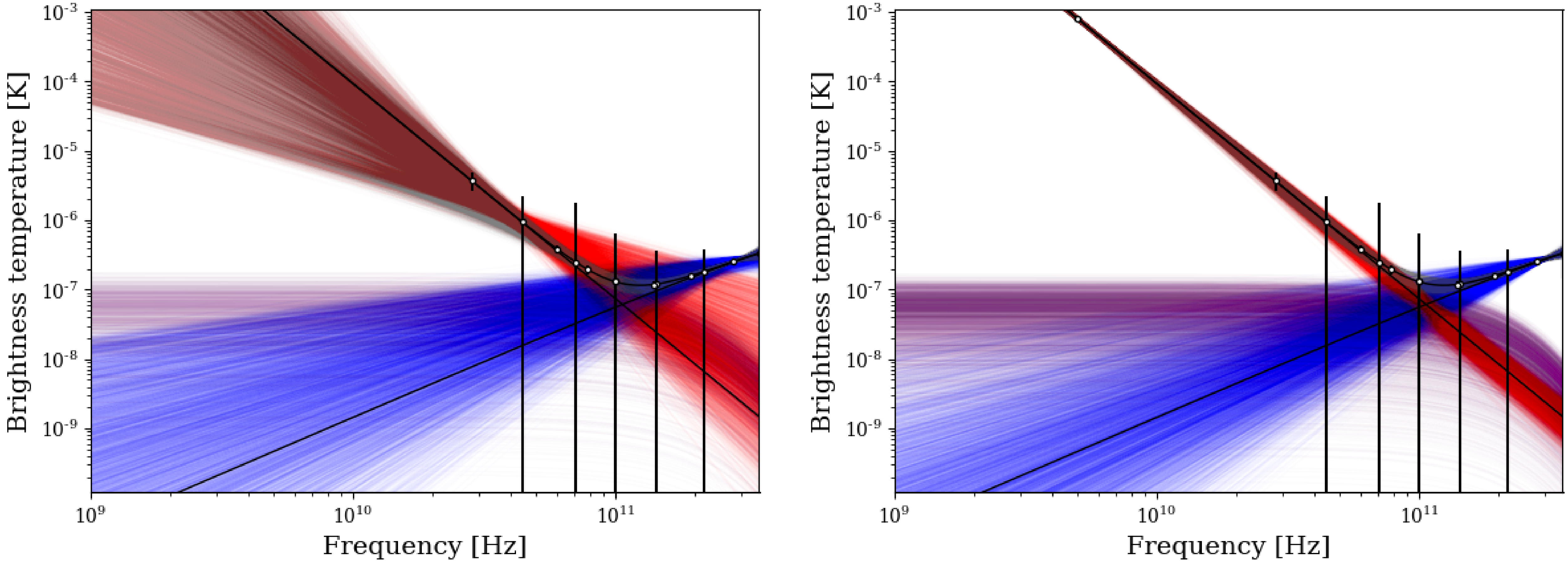


Figure 9. B-mode polarization frequency spectra for a 3° pixel in a sky region with low foreground emission. The *solid black lines* are spectra of the true simulated foreground components. The coloured lines are the frequency spectra of the sky components of 5000 randomly drawn samples from the converged MCMC chains. *Left* is the result from only including *Planck* and *LiteBIRD* data points. *Right* is with the addition of the C-BASS data point. Synchrotron is *red*; thermal dust is *blue*; and CMB is *purple*.

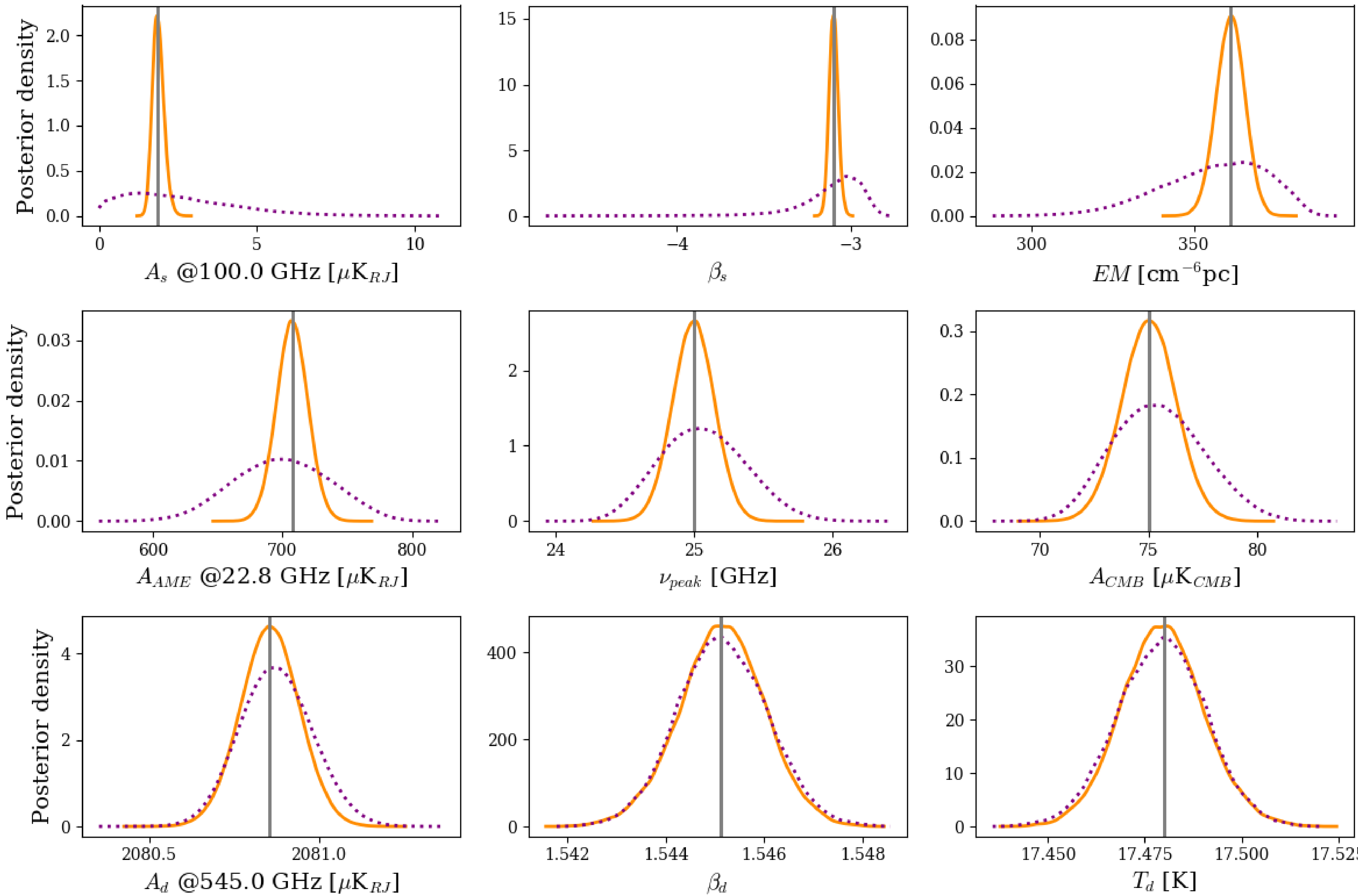


Figure 6. PDEs of the total intensity component parameters for a typical 1° pixel in a sky region with significant foreground contamination. The *dashed lines* are the PDEs when only including Haslam, WMAP and *Planck* data points in the fit. The *solid lines* are the PDEs when the C-BASS data point is included. The vertical lines are at the true parameter values used to simulate the data.

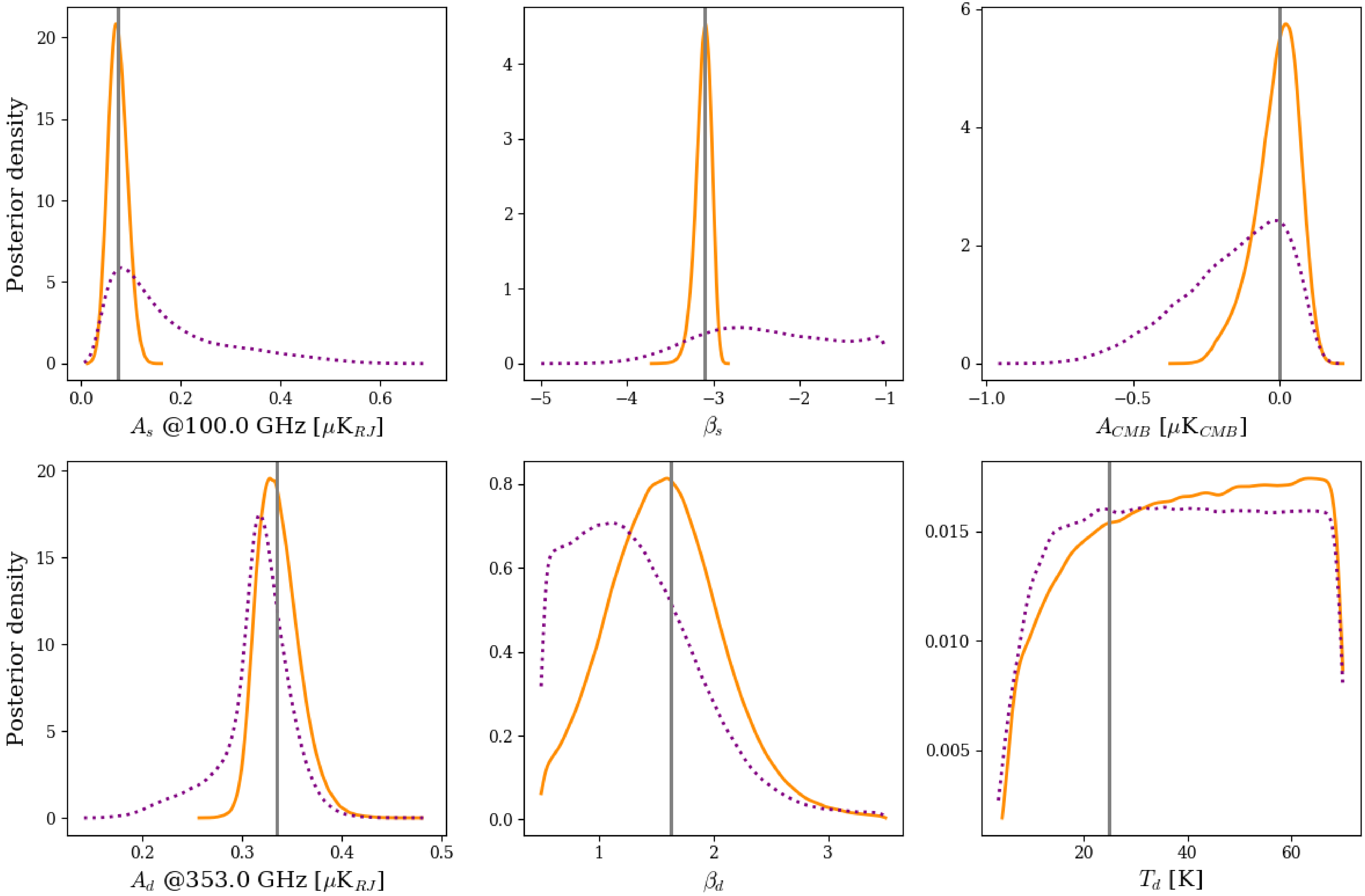


Figure 8. PDE of the *B*-mode polarization component parameters for a typical 3° pixel in a sky region with low foreground emission. The *dashed lines* are the PDEs when only including *Planck* and *LiteBIRD* data points. The *solid lines* are the posterior density estimates when the C-BASS data point is included. The vertical lines are at the true parameter values used to simulate the data.

Issues for the future

- We need maps at many frequencies to fully characterize foregrounds even in the cleanest areas of sky
- We will need maps like C-BASS, only better, at multiple frequencies, with higher resolution than C-BASS, and (ideally) matched beams
- Problems to be tackled:
    - Ground pickup (need good ground screens)
    - RFI (radio frequency interference) – getting worse
    - Sun and other sources in far sidelobes
    - Instrumental stability (easier in space?) and control of systematics
    - Polarization calibration (C-BASS is tied to Tau A, which is uncertain at ~ 1% or 1 deg)
    - Zero level (cf. ARCADE)

C-BASS: The C-band all-sky survey

- *C-BASS is a collaborative project between:*
- Oxford University (UK) *supported by Oxford University, STFC, and the Royal Society*
  - Angela Taylor, Mike Jones, Jamie Leech, Luke Jew, Richard Grummit
- Manchester University (UK)
  - Clive Dickinson, Paddy Leahy, Stuart Harper, Adam Barr, Mel Irfan, Rod Davies, Richard Davis, Mike Peel, Joe Zuntz
- California Institute of Technology (USA) + OVRO + JPL *supported by NSF and NASA*
  - Tim Pearson, Stephen Muchovej, Tony Readhead, Oliver King, Erik Leitch, Matthew Stevenson, Sebastian Kiehlmann
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  - Justin Jonas, Charles Copley, Cynthia Chiang, Jon Sievers, Moumita Aitch, Heiko Heiligendorff
- KACST: King Abdulaziz City for Science and Technology (Saudi Arabia)
  - Yaser Hafez