The C-Band All Sky Survey

Point Source Detection and Zero-Level

Richard D.P. Grumitt

Contents

- Point Source Detection
  - Second Order Spherical Mexican Hat Wavelet filters.
  - C-BASS source catalogues.
- C-BASS Zero-Level
  - Matching C-BASS zero-level to S-cubed sources and ARCADE.
  - Polarisation fraction estimates.

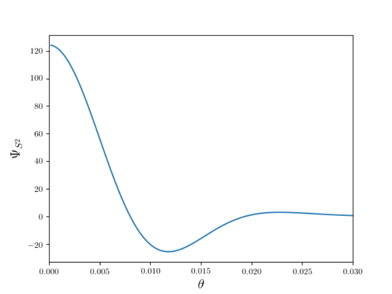
Point Source Detection: Spherical Mexican Hat Wavelet

- Employ similar algorithm to that used in producing the Planck Catalogue of Compact Sources (PCCS).
- We use a second order Spherical Mexican Hat Wavelet filter (SMHW2), given by,

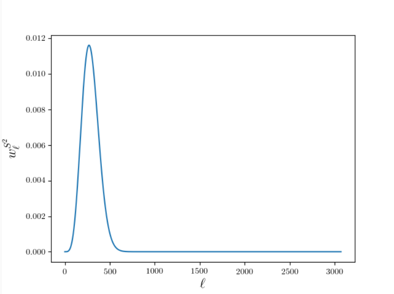
$$\Psi_{S^2}(\theta, R) = \frac{\mathcal{N}(R)}{\cos^4\theta/2}\left[(R\sigma)^4 - 4(R\sigma)^2\tan^2\frac{\theta}{2} \right. \\ \left. + 2\tan^4\frac{\theta}{2}\right]\exp\left(-\frac{2\tan^2\theta/2}{(R\sigma)^2}\right). \quad (1)$$

- In general, we obtain the order n SMHW by taking the inverse stereographic projection of the corresponding MHW on $\mathbb{R}^2$ (Antoine and Vandergheynst 1999).

Point Source Detection: Spherical Mexican Hat Wavelet



(a) The SMHW2 filter for $\sigma = 1^\circ/(2\sqrt{\ln 2})$ and $R = 1$.



(b) The SMHW2 window function for $\sigma = 1^\circ/(2\sqrt{\ln 2})$ and $R = 1$.

Point Source Detection: Algorithm

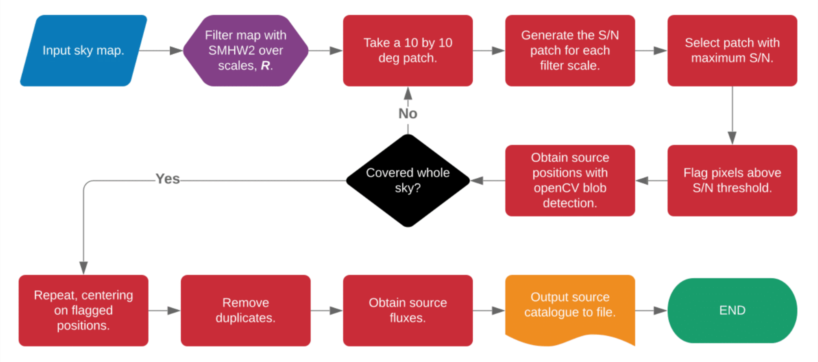


Figure 2: Source detection algorithm flowchart.

Point Source Detection: Input Sky

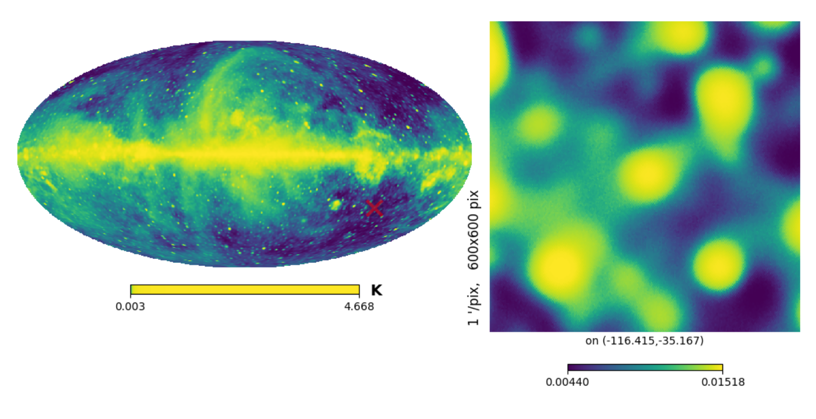


Figure 3: An input sky - generated by taking a simulation of diffuse emission from PySM and adding in a source population (produced using the GB6 and PMN catalogues).

Point Source Detection: Filtered Sky

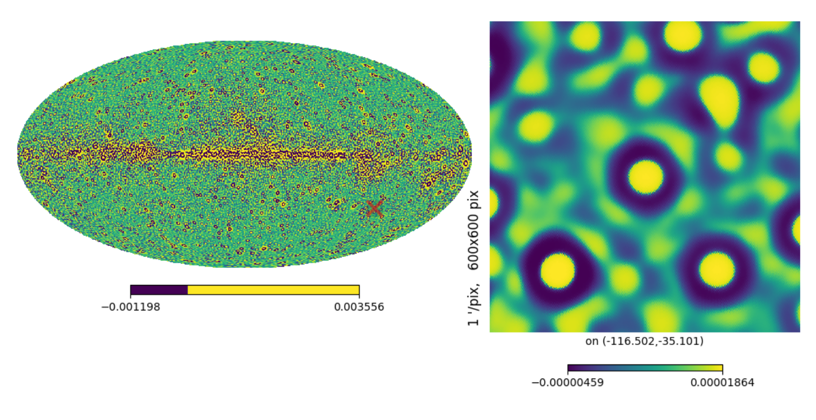


Figure 4: The corresponding filtered sky, at some filter scale.

Point Source Detection: Filtered Sky Patch

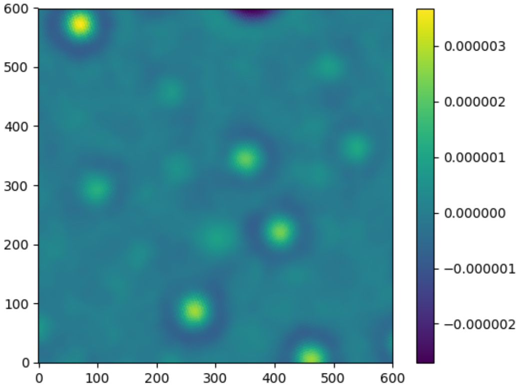


Figure 5: Filtered sky patch, using the filter scale that maximises the S/N.

Point Source Detection: S/N Patch

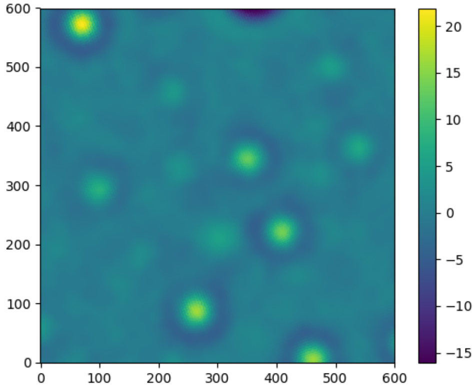


Figure 6: S/N map for the filtered sky patch.

Point Source Detection: Flagged Pixels

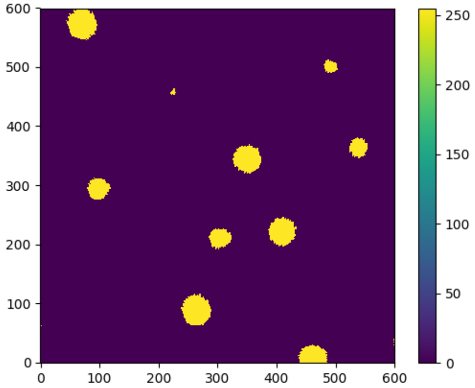


Figure 7: Thresholded map, flagging pixels with $S/N > 4$.

Point Source Detection: OpenCV Detections

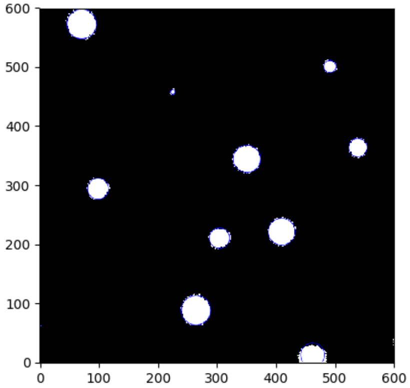
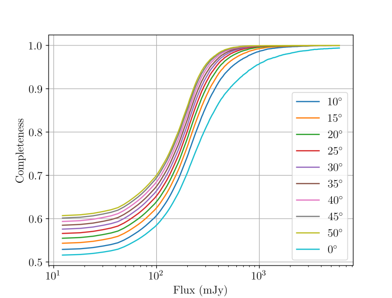


Figure 8: OpenCV blob detections, shown as blue circles.

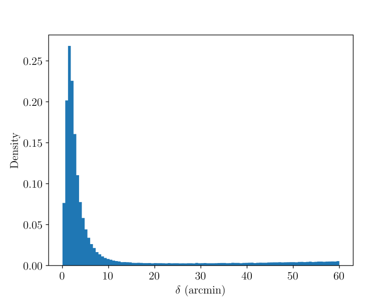
Point Source Detection: Validation

- We generate 100 Monte Carlo simulations of source skies and embed these in a simulation of diffuse emission (generated with PySM).
- We run the SMHW2 algorithm over these simulated skies, comparing detections to the input catalogues.
- We target an 80% true positive rate, and calculate the associated completeness level.

Point Source Detection: Completeness and Accuracy



(a) Catalogue completeness, applying a range of cuts around the galactic plane.



(b) The absolute deviation of the detected source positions from the input source positions.

Point Source Detection: C-BASS Source Catalogue (i)

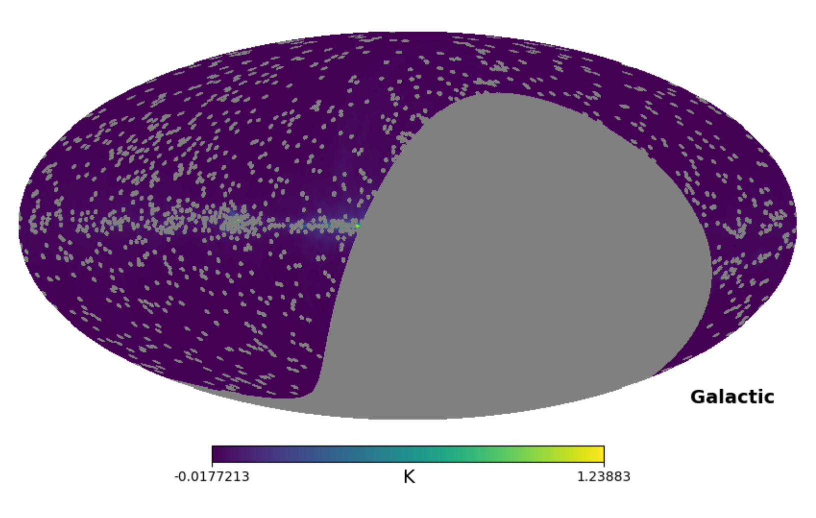


Figure 10: The C-BASS North map, with detected point sources masked. The colour scale has been chosen to make the masked source positions clear.

Point Source Detection: C-BASS Source Catalogue (ii)

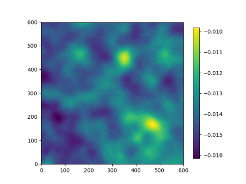
- We have a C-BASS source catalogue in *I*, containing 1149 sources. We can now produce dedicated source masks, and create source subtracted maps.
- The source catalogue will provide us with an important cross-check on our pointing.
- C-BASS data can be used to track source variability by fitting over multiple time periods.
- We will also look to extract polarised fluxes for the brightest sources in our catalogue.

C-BASS Zero-Level: Fitting Procedure

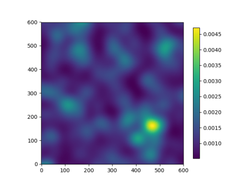
- Fit faint regions of the C-BASS I map to a model of the sky emission plus a constant offset.
- Model point source emission using GB6 sources, and the integrated contribution from faint S-cubed sources (Wilman et al., 2008).
- Also consider diffuse emission (modelled with PySM) and the ARCADE excess monopole.
- Generally, the model consists of our simulated sky plus an offset, with thermal noise and faint source noise contributions i.e.

$$m_{CBASS}(\theta, \phi) = m_{sky}(\theta, \phi) + \zeta + n_{white}(\theta, \phi) + n_{S3}. \qquad (2)$$

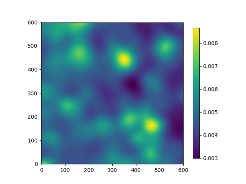
C-BASS Zero-Level: Sky Simulations



(a) A faint C-BASS region at $l = -160°$ and $b = 42°$.



(b) The corresponding source emission model.



(c) Emission model with point source and diffuse contributions.

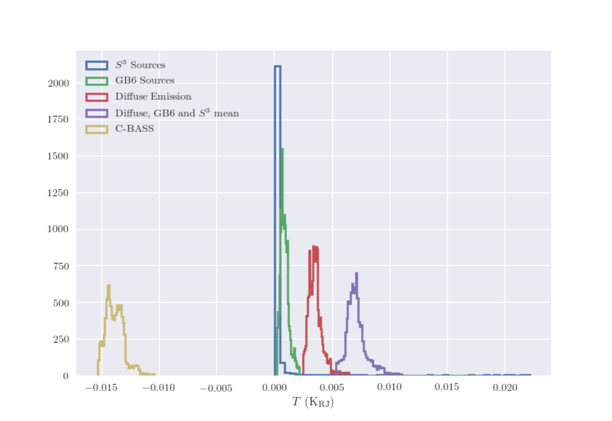


Figure 12: Histogram of the various components involved in the zero-level fits. Matching to source emission gives an offset of $\sim 15\,\mathrm{mK}$. Adding in diffuse emission from PySM gives $\sim 20\,\mathrm{mK}$.

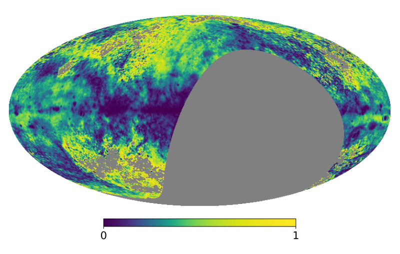
C-BASS Zero-Level: The ARCADE Monopole

- After accounting for synchrotron and free-free emission, ARCADE found an excess monopole of,

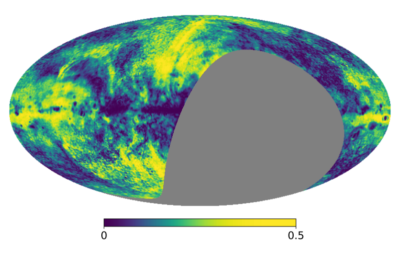
$$T = 24.1 \pm 2.1\,(\mathrm{K}) \left(\frac{\nu}{\nu_0}\right)^{-2.599\pm0.036}, \nu_0 = 310\,\mathrm{MHz}. \tag{3}$$

- At $5\,\mathrm{GHz}$ this gives $T \approx 18\,\mathrm{mK}$, significantly greater than our point source emission levels.
- As it stands, we may consider a lower limit on the C-BASS offset from source emission, and an upper limit from ARCADE.

C-BASS Zero-Level: Polarisation Fraction Maps (i)

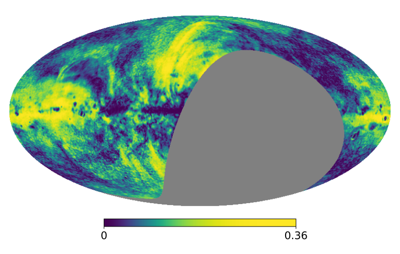


(a) P/I map obtained by shifting C-BASS I to match point source emission.

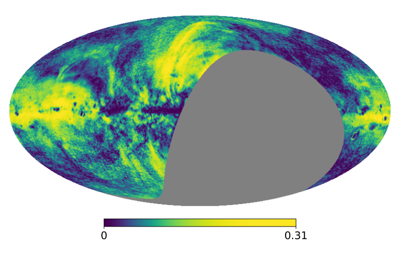


(b) P/I map obtained by shifting C-BASS I to match point source and PySM diffuse emission.

C-BASS Zero-Level: Polarisation Fraction Maps (ii)



(a) P/I map obtained by shifting C-BASS I to match the ARCADE excess monopole.



(b) P/I map obtained by shifting C-BASS I to match ARCADE and PySM diffuse emission.

C-BASS Zero-Level: Next Steps

- We have estimates for the range of possible C-BASS offsets.
- We are currently carrying out a detailed joint analysis using C-BASS, ARCADE and Haslam data.
- In particular, we are looking to properly account for the spatial distribution of diffuse emission.
- Results to follow ...

Summary

- We have obtained a C-BASS point source catalogue containing 1149 sources, employing the SMHW2.
- Full characterisation of the C-BASS catalogue is being completed, and we will also be obtaining polarised fluxes for the brightest sources.
- Lower limits on the C-BASS zero-level have been found by fitting to point source emission.
- More detailed joint analysis with C-BASS, ARCADE and Haslam data is currently underway.