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Determining thermal dust emission from Planck HFI data using a sparse, parametric technique

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ABSTRACT

Context. The *Planck* 2015 data release provided the community with high frequency ($\nu > 100$ GHz) observations of the full-sky at unprecedented resolutions. These maps contain a wealth of information on the cosmic microwave background (CMB), cosmic infrared background (CIB), extragalactic point sources and diffuse thermal dust emission.
Aims. We aim to determine the modified black body (MBB) model parameters of thermal dust emission and produce all sky maps of pure thermal dust, having separated this Galactic component from the CMB and CIB.
Methods. This separation is completed using a new, sparsity-based, parametric method which we refer to as `premise`. The method comprises of three main stages: 1) filtering of the raw data to reduce the effect of the CIB on the MBB fit. 2) fitting an MBB model to the filtered data across super-pixels of various sizes determined by the algorithm itself and 3) refining these super-pixel estimates into full resolution maps of the MBB parameters.
Results. We show .....
Conclusions. We believe...

Key words. Cosmology: Cosmic Microwave Background – ISM: dust, extinction – Methods: Data Analysis

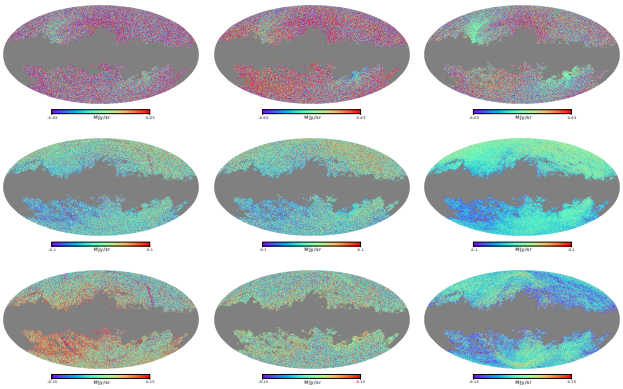

Fig. 1. CIBA plus instrumental noise maps at original resolution made by (*Left:*) $\text{premise}_{\text{MBB}}$, (*middle:*) $\text{GNILC}_{\text{MBB}}$ and (*right:*) 2013_{MBB} at 353, 545 and 857 GHz (*top to bottom).*

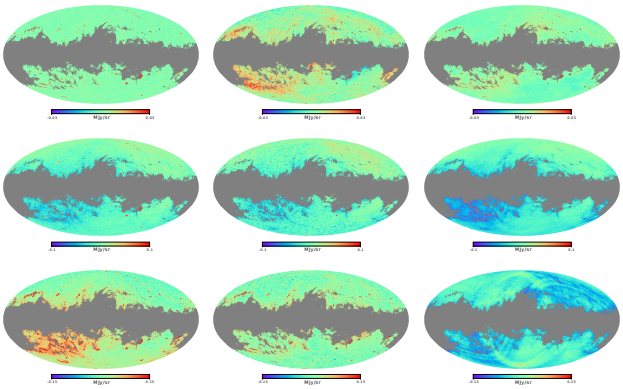

Fig. 2. CIBA plus instrumental noise maps at 1° resolution made by (*Left:*) $\text{premise}_{\text{MBB}}$, (*middle:*) $\text{GNILC}_{\text{MBB}}$ and (*right:*) 2013_{MBB} at 353, 545 and 857 GHz (*top to bottom).*

0.1. CIB maps

Subtracting the thermal dust estimates from the total flux maps (after the G-MCA estimate of the CMB has been removed), then subtracting of the large-scale CIB offsets results in maps of the CIBA plus instrumental noise.

0.1.1. CIB: reconstructed MBB parameters

Fig. 1 shows the CIB plus instrumental noise maps created by subtracting the MBB thermal dust estimates from the total, CMB subtracted, flux maps. The expectation is for these maps to resemble Gaussian noise as the Poisson term of the CIBA only starts to dominate at angular scales smaller than the *Planck* HFI resolutions. We create a Galactic plane mask based on the `premise` τ_{353} estimate, choosing to mask out the regions where τ_{353} is more than 1.3 times greater than the median value. This mask leaves 57 per cent of the sky still visible. The CIBA plus instrumental noise maps (residual maps) are presented at 5 arcmin resolution for 2013_{MBB} and $\text{premise}_{\text{MBB}}$ and various resolutions across each pixel for $\text{GNILC}_{\text{MBB}}$. In Fig. 2 we smooth the maps to one degree FWHM.

At 353 GHz, in the original resolution maps, the dipole produced by the *Planck* scanning strategy can be seen. The

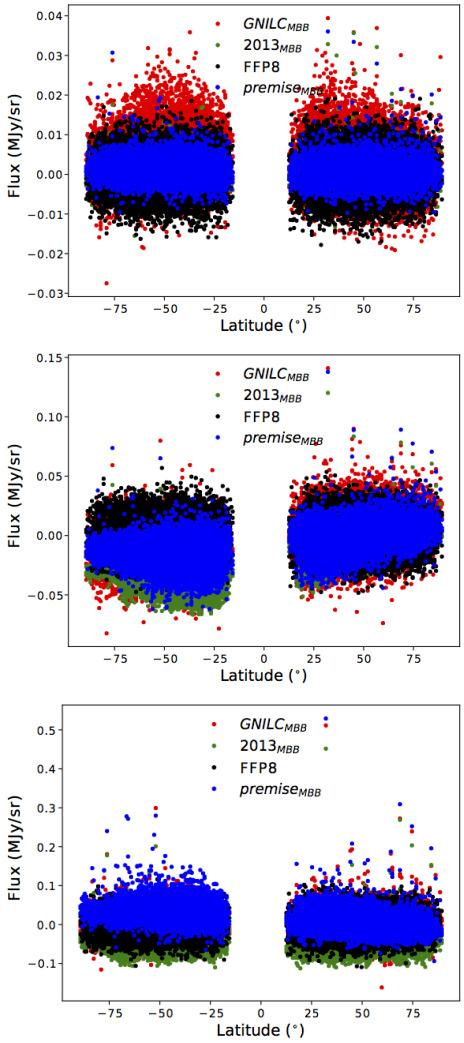

Fig. 3. Comparison of the CIBA plus instrumental noise estimates with the FFP8 simulations at 353, 545 and 857 GHz (*top to bottom).*

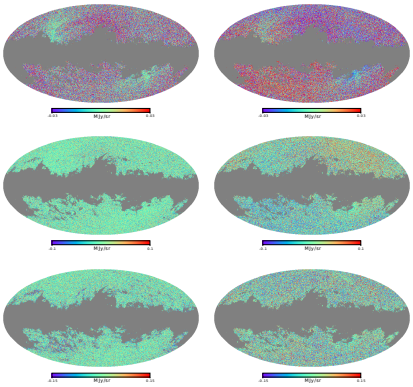

Fig. 4. CIBA plus instrumental noise maps at original resolution made by (*Left:*) premise$_{\rm filt}$ and (*Right:*) GNILC$_{\rm filt}$, 353, 545 and 857 GHz (*top to bottom).*

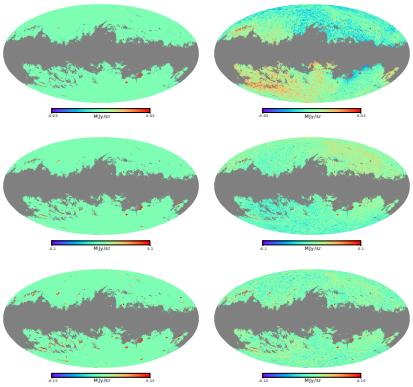

Fig. 5. CIBA plus instrumental noise maps at 1° resolution made by (*Left:*) premise$_{\rm filt}$ and (*right:*) GNILC$_{\rm filt}$ at 353, 545 and 857 GHz (*top to bottom).*

353 GHz GNILC$_{\rm MBB}$ residual map shows a high intensity feature to the south-west, which is more obvious in the one degree smoothed maps. At 545 GHz the IRAS streaks become visible in the premise$_{\rm MBB}$ original resolution residual map. The 2013$_{\rm MBB}$ shows strong thermal dust contamination towards the south-west but otherwise is visibly clean across the poles. The GNILC$_{\rm MBB}$ and premise$_{\rm MBB}$ estimates show comparable contamination around the Galactic plane, both at a lower level then 2013$_{\rm MBB}$.

At 857 GHz the 2013$_{\rm MBB}$ residual map shows the highest level of contamination, followed by premise$_{\rm MBB}$, then GNILC$_{\rm MBB}$. The premise$_{\rm MBB}$ residual map is cleaner than the GNILC$_{\rm MBB}$ residual at 353 GHz, comparable at 545 GHz and worse at 857 GHz because the 3000 GHz total flux map is used to recover our τ_{353}. This map contains CIB at 3000 GHz, which although almost negligible when scaled to 353 GHz, becomes more and more detrimental to the estimation of thermal dust as the scaling frequency increases.

The FFP8 CIBA and instrumental noise simulations provide estimates against which the premise$_{\rm MBB}$, GNILC$_{\rm MBB}$ and 2013$_{\rm MBB}$ residual maps can be compared. In Fig. 3 we present the various CIBA plus instrumental noise estimates as a function of latitude. We downgrade the maps to N$_{\rm side}$ 64 to provide clearer plots. At 353 GHz the GNILC residual appears to overestimate the level of the CIB, implying an underestimation in their thermal dust estimate at 353 GHz. At 545 GHz we seem to still have a dipole. At 857 GHz the GNILC residual provides the closest replication of the FPP8 CIBA and instrumental noise estimate.

0.1.2. CIB: filtered maps

The filtered residual maps (CIBA plus instrumental noise) are shown Fig. 4 at their original resolution. The filtered residual maps shown in Fig. 5 have been smoothed to one degree. It should be noted that the large-scale CIB offsets are included within the GNILC filtered thermal dust estimates and so the GNILC$_{\rm filt}$ residual map does not need to have any offsets removed from it. The only feature of note is the high intensity patch within the GNILC$_{\rm filt}$ residual map, towards the south-west. Comparison with the FFP8 CIBA plus instrumental noise estimates, Fig. 6, confirms that the `premise` filtering is less conservative than the GNILC filtering, allowing more CIB into the filtered thermal dust maps. This does not effect our final parameter estimates as the quadtree, super-pixel fit allows us to average out the effect of the CIBA. we seem to still have a dipole

1. Conclusions

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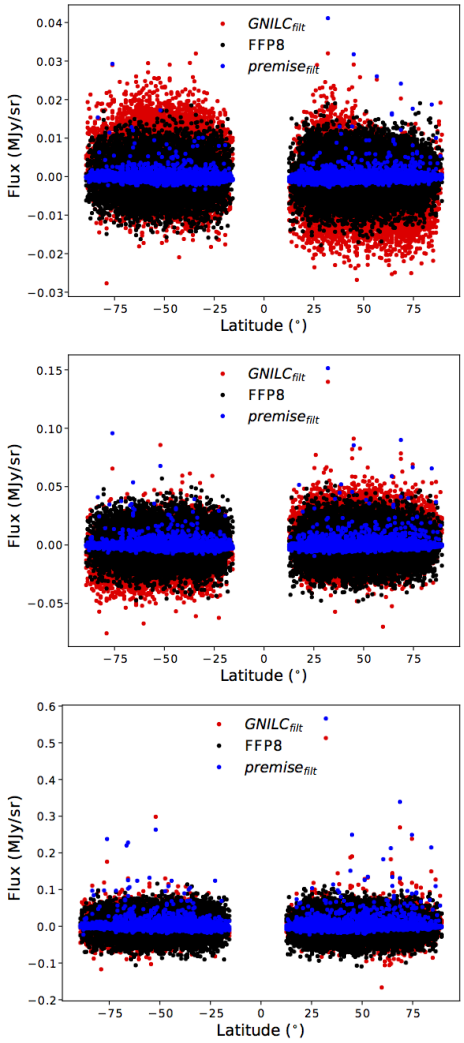

Fig. 6. Comparison of the CIBA plus instrumental noise estimates with the FFP8 simulations at 353, 545 and 857 GHz (*top to bottom).*

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