The effect of a spatially varying Galactic spectral index on the maximum entropy reconstruction of Planck Surveyor satellite data

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ABSTRACT We study the effect of Galactic foregrounds with spatially varying spectral indices on analysis of simulated data from the Planck Satellite. We also briefly mention the effect the extra-galactic point sources have on the data analysis and summarise the most recent constraints on Galactic emission at GHz frequencies.

KEYWORDS: Cosmic microwave background: observations: Galaxy: general.

1. INTRODUCTION

The data obtained through observations of the cosmic microwave background (CMB) in the frequency range of 30 to 900 GHz will be contaminated with various foregrounds. These foregrounds must be subtracted before accurate maps of the CMB can be obtained.

A previous paper (Hobson, Jones, Lasenby & Bouchet 1998a, hereafter HJLB98) used a maximum entropy technique to analyse simulated data from the Planck Surveyor satellite that included six different components of emission in 10 × 10-degree fields (Bouchet et al. 1997, Gispert & Bouchet 1997). It was found that faithful reconstructions of five components (CMB, thermal Sunyaev-Zel’dovich effect and Galactic free-free, synchrotron and dust emissions) were possible using only frequency spectral information and faithful reconstructions of all six were possible when spatial information was included (the above five and the kinetic SZ which has the same frequency spectrum as the CMB). A recent update to that paper (Hobson et al. 1998b) also includes the effects of extra-galactic point sources in the data (Toffalatti et al. 1998) and it was found that the reconstructions were not significantly altered. The analysis technique did not subtract the effect of the point sources from individual data pixels but rather treated them as an additional noise term in the covariance matrix.

This proceeding updates the Galactic foreground simulations to relax the assumptions made about the frequency spectra of the Galactic components and includes spatially varying spectral indices.

2. THE SIMULATIONS AND RECENT UPDATES

HJLB98 presented the simulations used to create the data for the Planck Satellite
FIGURE 1. The six input components used for the Planck Surveyor satellite observations. They are shown at 300 GHz in equivalent thermodynamic temperature. The components shown are a) CMB (CDM realisation), b) kinetic SZ, c) thermal SZ, d) dust emission, e) free-free emission and f) synchrotron emission.
FIGURE 2. The spatial variation of the dust spectral index used in the simulated Planck
Surveyor satellite observations.

observations. Here we use the same input maps so that easy comparison can be
made and we do not include the effects of point sources as this was found to have
little effect on the reconstructions. Figure 1 shows the six input components at
300 GHz.

We perform two separate analyses to test the effect of relaxing the assumptions
made about the Galactic foregrounds. The first is simply to assume the incorrect
frequency spectra for the Galactic foregrounds and test the effect that this has on
the reconstructions. The second is to assume a spatially varying spectral index for
the Galactic foregrounds and try to reconstruct the components without knowing
the form of this spatial variation. Figure 2 shows the input spatial variation in the
Galactic dust spectral index.

3. RESULTS FROM THE MEM ANALYSIS

We first assume that the Galactic components contributing to the data do not
have a well known spectral dependence. We therefore need to search over a range of
spectral indices to find the best result. This is done by observing the $\chi^2$ dependence
as a function of spectral index. For the free-free and synchrotron emission it was
found that little difference in the $\chi^2$ value was found when the incorrect spectral
index was used. The reconstructions of the other components were not altered in
this case but the reconstruction of the free-free and synchrotron were lost. However,
in the case of varying both the dust emissivity and temperature a strong minimum
in $\chi^2$ was seen at the input values (Figure 3). Therefore, it is possible to fit for the
dust emission using the data alone whereas more information on the free-free and
synchrotron are needed to be confident in their reconstructions.

The errors in each of the reconstructions, if the point at the $\chi^2$ minimum is used,
are not correlated with the reconstruction itself (see Figure 4) except in the case
of a wrongly assumed spectral index for the free-free and synchrotron where only
the errors on those two components themselves become correlated with the input
signal.
FIGURE 3. The $\chi^2$ for the reconstructions assuming the temperature and emissivity of dust in the plot. The input temperature and emissivity were 18K and 2 respectively. The minimum in $\chi^2$ is seen to lie at the input values.

FIGURE 4. The error in the CMB reconstruction for one of the simulations. It is seen that the errors are uncorrelated with the input maps and indeed have no discernible structure themselves.
We now attempt to reconstruct the six channels in the presence of a spatially varying spectral dependence on the Galactic foregrounds. As previously the free-free and synchrotron emission are not significant enough to allow fitting for the spectral index and so a spatially varying spectrum in these two channels will only worsen their reconstruction and it is very difficult to fit for this variation. However, if the dust has a spatially varying spectrum (as in Figure 2) it is possible to fit for this variation. The simplest way to do this is to assume that the dust channel is made up two or more different templates, each with a separate spectral index which covers the expected range of variation. For example, we present here the analysis using three dust templates. The input spatial variation in the dust emissivity was taken from a Gaussian ensemble with a mean of 2 and a standard deviation of 0.1. So we use three templates with spectral emissivities of 2.1, 2.0 and 1.9. Figure 5 shows the reconstruction of the six channels using this method. As can be seen each of the channels have been reconstructed very well (the dust templates have been added together to allow a comparison with the input maps of Figure 1). Indeed, the error on the CMB reconstruction per pixel is still 6\(\mu\)K which is the same as in the case of a single dust channel with known emissivity (HJLB98). This should be contrasted with the 10\(\mu\)K error obtained by performing the analysis with only one dust template (as in HJLB98) assuming a spectral index of 2.0. The free-free, synchrotron and thermal SZ have been reconstructed to a lower amplitude than the input map (this is because most of the information on these foregrounds occur at the lower frequencies of the Planck Surveyor which have lower resolutions; see HJLB98). The kinetic SZ is not reconstructed to a very high significance and only features associated with strong thermal SZ effects are reconstructed (see HJLB98).

4. CONCLUSIONS

The maximum entropy method was used to reconstruct data in the presence of Galactic foregrounds with uncertain spectral dependencies. It was seen that the Planck Surveyor can fit for a dust spectral index in the case of a single emissivity and temperature and can also reconstruct the foregrounds in the presence of a spatially varying spectral index with little effect on the CMB reconstruction. It was found that the same was not possible for the free-free and synchrotron foregrounds but that assuming an incorrect spectral dependence for these two did not make a significant difference to the reconstruction of the other components in the data.

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FIGURE 5. The reconstruction of the six channels by using three dust channels with different emissivities to model the spatial variation in the dust.
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