INVERSION OF THE DIRBE PHOTOMETRY TO DERIVE THE THREE DIMENSIONAL DISTRIBUTION OF THE INTERPLANETARY DUST

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ABSTRACT

The Diffuse Infrared Background Experiment (DIRBE) on board NASA's *Cosmic Background Explorer* (*COBE*)[1] satellite has surveyed the entire sky in ten photometric bands covering the wavelength range from 1 to 240 μm at an angular resolution of 0.7°. The spin of the spacecraft, in combination with its orbital motion, allowed the DIRBE instrument to sample redundantly each celestial direction from multiple orientations within the interplanetary dust cloud. The variation in viewing aspect gives rise to time-dependent changes in the observed intensity which are only associated with the changing brightness contributions from the interplanetary dust. We present a three-dimensional, semi-physical model for the emission and scattering of interplanetary dust and describe the techniques employed to optimize the model to match the temporal variations of the infrared sky brightness as observed by DIRBE along selected lines of sight. We then show the accuracy with which the optimized model is able to reproduce the apparent temporal and angular variation of sky brightness associated with the interplanetary dust over the entire sky.

1. INTRODUCTION

Over the period of one day, the DIRBE instrument measures approximately one half the sky at a range of elongation angles between 64° and 124°. Due to the orbital motion of the Earth, this 60° viewing swath shifts by one degree per

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day, allowing the DIRBE to sample redundantly each line of sight from multiple orientations within the interplanetary dust (IPD) cloud. The change in viewing aspect gives rise to temporal variations in the dust density and temperature distribution along the line of sight due to variations in distance from the Sun, solar elongation angle, and location of the spacecraft with respect to the peak of the dust density distribution, which is inclined with respect to the ecliptic plane. The inversion procedure exploits these effects to separate the zodiacal light from the brightness contributions associated with stellar and interstellar sources by imposing an analytical form for the dust density distribution, thermal characteristics, and scattering phase function, and then optimizing the model to match the observed temporal variations to selected directions.

2. THE MODEL

The analytical form of the model is fully described by Reach et al. (1995). Briefly, it consists of the integral along the line of sight of the product of an emissivity function and a density distribution function. The emissivity function includes both a thermal component and a scattering component, and the density distribution includes a smooth cloud component (Good 1994), two pairs of asteroidal dust bands (Reach 1992), and a circumsolar dust ring based on the numerical model of Dermott et al. (1994).

3. THE OPTIMIZATION PROCEDURE

The optimization procedure makes use of approximately 200,000 weekly-averaged photometry measurements consisting of about two thousand uniformly distributed lines-of-sight (pixels) in ten wavebands over forty-one weeks. The key to fitting the zodiacal light while ignoring the brightness contributions associated with stellar and interstellar sources is to constrain the fit using only the observed time variation along independent lines-of-sight, while ignoring the pixel-to-pixel variations. This is achieved by including an arbitrary constant along each line-of-sight which forces the mean of the model over all time samples to match the mean of the data. In this way, the optimization procedure only has enough information to match the amplitude and phase of the temporal variation for each pixel. The disadvantage to this approach is that low contrast structure associated with the interplanetary dust (e.g., the asteroidal dust bands) is difficult to fit. This difficulty is overcome by allowing the angular variations to influence the fit in the 12 and 25 μm wavebands at high Galactic latitudes ($|b| > 30^\circ$), where it is reasonable to assume that the pixel-to-pixel variations are dominated by the zodiacal brightness contribution.

4. FINAL RESULTS

Following the optimization procedure, the zodiacal light model was removed from each weekly-averaged photometry map, and the residual maps were combined to form the mission-averaged maps with zodiacal light removed. Figure 1 shows the observed mission-averaged sky brightness at 1.25, 3.5, 12, and 60 μm, and Figure 2 presents the final, mission-averaged maps after zodiacal light removal. The 1.25 μm residual brightness shows no indication of structure with an ecliptic latitude dependence, which suggests that the zodiacal light contribution to the angular variation has been removed correctly. At 3.5 μm, the map does show weak evidence of positive residuals near the ecliptic plane. This waveband contains a mixture of scattered light and thermal emission, and there is reason to believe that it sees a hot dust component which is not supplied by the model (Reach et al. 1995, Berriman et al. 1995). The 12 μm residuals clearly show ecliptic longitudinal banding structure which is most likely associated with shape errors in the band model and/or smooth cloud component. The model tends to oversubtract near the ecliptic plane at 12 μm, while it undersubtracts at 60 μm. This disparity may be a result of the assumption that the particle properties of the dust bands and circumsolar ring are identical to those of the smooth cloud (Reach et al. 1995). In general, the apparent angular variations associated with the IPD in the mission-averaged residual maps are at the few percent level in all bands relative to the observed sky brightness.

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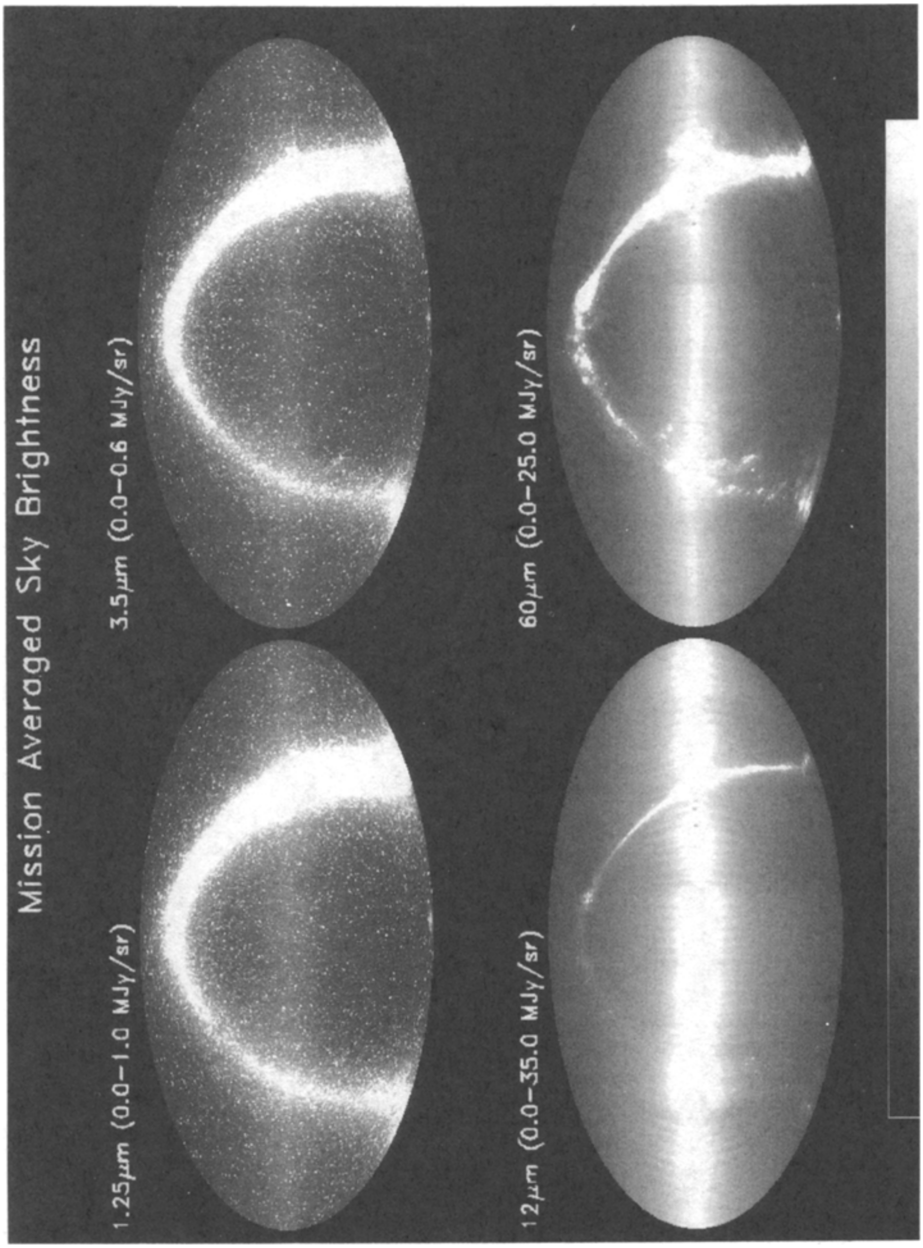
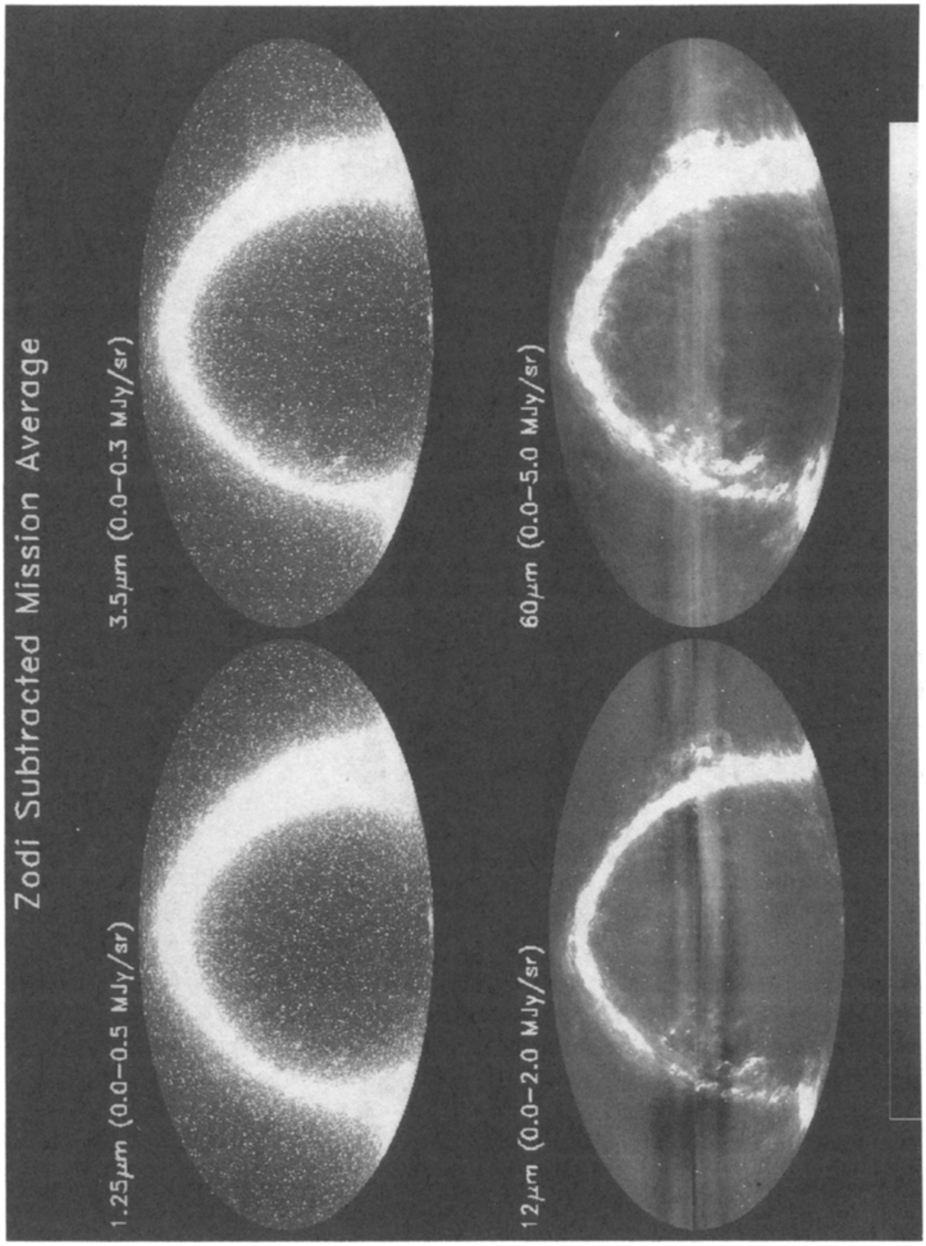
FIGURE CAPTIONS

Figure 1: Average of 41 weekly-averaged sky brightness maps at 1.25, 3.5, 12, and 60 μm in ecliptic Mollweide projection with longitude zero at center.

Figure 2 Average of 41 weekly-averaged maps with zodiacal light removed at 1.25, 3.5, 12, and 60 μm in ecliptic Mollweide projection with longitude zero at center.


Mission Averaged Sky Brightness
1.25μm (0.0–1.0 MJy/sr)
3.5μm (0.0–0.6 MJy/sr)
12μm (0.0–35.0 MJy/sr)
60μm (0.0–25.0 MJy/sr)


Zodi Subtracted Mission Average
1.25μm (0.0–0.5 MJy/sr)
3.5μm (0.0–0.3 MJy/sr)
12μm (0.0–2.0 MJy/sr)
60μm (0.0–5.0 MJy/sr)