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A Search in the COBE Data for Resonant Structure in the Kuiper Disk

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Abstract. We conduct an observational search in the 60 μm COBE DIRBE data for the Kuiper disk, which is predicted to be, at most, a few percent of the brightness of the zodiacal cloud. By removing emission due to the background zodiacal cloud and the dust bands, we expect to see the trailing/leading signature of Earth's resonant ring. However, when subtracted from the data, we find that none of the empirical background zodiacal cloud models give the ring residuals predicted by theory. We conclude that a dynamical two-component (both inner and outer) zodiacal cloud model must be created to complete the search.

1. Introduction

The Diffuse Infrared Background Experiment (DIRBE) on the Cosmic Background Explorer (COBE) was designed to search for the Cosmic Infrared Background (CIB) radiation. Kelsall et al. (1998) constructed an empirical, parameterized model of the brightness contribution from the zodiacal cloud in the COBE wave bands, which consisted of a combination of models for (1) the background zodiacal cloud, (2) three asteroidal dust bands, and (3) Earth's resonant ring. The goal of this paper is to subtract the best total zodiacal cloud model in order to search for emission from a possible Kuiper disk.

2. COBE Data and Zodiacal Cloud Models

The COBE DIRBE data is organized into 41 Weekly Sky Maps which provide average intensities for each pixel for a specific week corresponding to a particular longitude of Earth, $\lambda_\oplus$. Shown in Figure 1 (left), is 60 μm COBE Weekly Sky Map data for Week 33 ($\lambda_\oplus = 287°$). The left side of the sky map corresponds to lines of sight trailing the Earth in its orbit, while the right side corresponds to leading lines of sight. The S-shaped feature is due to galactic emission. The oval-shaped feature is primarily due to emission from the zodiacal cloud, but could mask the signature of the Kuiper disk.

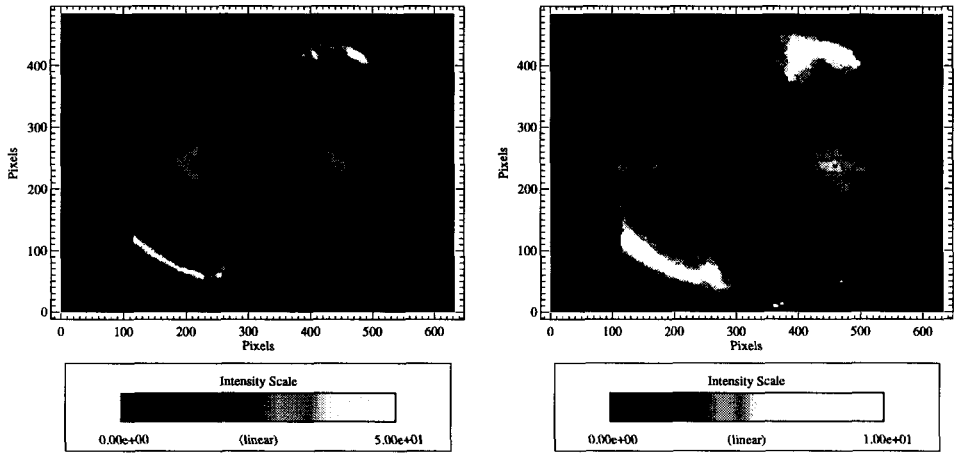

Figure 1. Week 33: (left) 60 μm COBE data. (right) Residuals.

We could successfully reconstruct the Kelsall empirical background zodiacal cloud model to $\sim$ 1%. However, our attempts to reconstruct the dust band model produced a model that, although qualitatively similar to the results from Kelsall et al. (1998), differed from the published brightnesses. We chose not to use either the Kelsall dust band or circumsolar ring model, in favor of using dynamical models for the dust bands (Grogan, Dermott, & Durda 2001) and the resonant ring (Dermott et al. 1994).

3. Residuals

Figure 1 (right) shows the residuals obtained by subtracting both the dynamical dust band model and the empirical Kelsall background model from the COBE data in the 60 μm wave band for Week 33. The left side of the image corresponds to lines of sight trailing the Earth in its orbit, while the right side corresponds to leading lines of sight. The brightest feature, aside from the S-shaped galactic emission, should be due to Earth's resonant ring (since it is the closest structure that has not been removed) and in fact, there is a brightness enhancement in the ecliptic, with the *leading* side of the enhancement brighter than the trailing side. However, both COBE observations (Reach et al. 1995, Dermott et al. 1996) and the dynamical resonant ring model shown in Figure 2 (left) exhibit an enhancement in brightness *trailing* the Earth in its orbit.

One possibility for the discrepancy is that the offset of the Kelsall background cloud model from the Sun is incorrect. When the variation of the average north (N) and south (S) polar brightness with longitude of Earth of the COBE data is compared with that of the Kelsall model in the 25 μm wave band (since there is less interference due to the galaxy at this wavelength), we find that the maximum of the curves, a measure of the direction of the offset, are significantly different. The maximum of the (N+S)/2 variation is located at 43.8° $\pm$ 3.0 for the COBE data and at 90.7° $\pm$ 0.1 for the Kelsall model (Holmes 2002). We modify the offset in the Kelsall model so that the maximum of the (N+S)/2 variation is in agreement with the COBE data. The residuals (for Week 33)

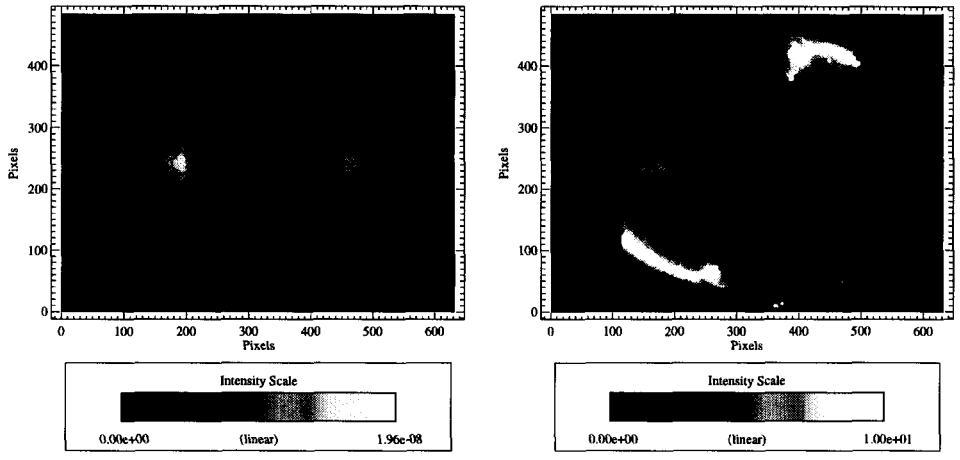

Figure 2. Week 33 in the 60 μm wave band: (left) Earth's resonant ring model (Dermott et al. 1994) (right) Residuals with corrected offset. Trailing lines of sight appear on the left.

resulting from the subtraction of the modified Kelsall background model and the dynamical dust band model from the COBE data are shown in Figure 2 (right) and exhibit a *trailing* brightness enhancement that is in agreement with observations and predictions (Holmes 2002). However, the residuals for some of the other weeks (e.g., Week 5) do not exhibit the trailing/leading asymmetry, casting doubt on the empirical Kelsall model and providing justification for the development of a dynamical background cloud model.

3.1. Dual-Component Dynamical Background Cloud Model

The (N+S)/2 scan of the COBE data reveals the offset at approximately 1 AU, but different parts of the cloud could have different offsets. Perhaps the background zodiacal cloud is best modeled as a combination of an inner and outer cloud, each having a unique offset. We subtracted a trial outer cloud model from the COBE data but the residuals were still dominated by the inner background cloud (Holmes 2002). Building an inner cloud model, which would be dominated by the dynamics of large particles (100 - 500 μm), will be crucial to completing the search for the Kuiper disk.

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