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SMALL-SCALE STRUCTURE OF THE ZODIACAL DUST CLOUD OBSERVED IN FAR-INFRARED WITH AKARI

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ABSTRACT

The zodiacal light emission is the thermal emission from the interplanetary dust and the dominant diffuse radiation in the mid- to far-infrared wavelength region. Even in the far-infrared, the contribution of the zodiacal emission is not negligible at the region near the ecliptic plane. The AKARI far-infrared all-sky survey covered 97% of the whole sky in four photometric bands with band central wavelengths of 65, 90, 140, and 160 μm. AKARI detected the small-scale structure of the zodiacal dust cloud, such as the asteroidal dust bands and the circumsolar ring, in far-infrared wavelength region. Although the most part of the zodiacal light structure in the AKARI far-infrared all-sky image can be well reproduced with the DIRBE zodiacal light model, there are discrepancies in the small-scale structures. In particular, the intensity and the ecliptic latitude of the peak position of the asteroidal dust bands cannot be reproduced precisely with the DIRBE models. The AKARI observational data during more than one year has advantages over the 10-month DIRBE data in modeling the full-sky zodiacal dust cloud. The resulting small-scale zodiacal light structure template has been used to subtract the zodiacal light from the AKARI all-sky maps.

Key words: surveys — interplanetary medium — zodiacal dust — infrared: diffuse background

1. INTRODUCTION

The zodiacal light (ZL) emission is the thermal emission from the interplanetary dust (IPD) and the dominant diffuse radiation in the mid- to far-infrared (IR) wavelength region. Even in the far-IR, the ZL contribution is not negligible at high galactic latitude regions where Galactic radiation is relatively low. The IPD originates mainly from comets and asteroids, and it spreads over the solar system. The zodiacal dust cloud has a relatively smooth distribution. However, from the results of the IRAS observations, it was found that there are many small-scale structures in the ZL distribution, such as asteroidal dust bands and a circumsolar resonance ring (Low et al., 1984; Dermott et al., 1984). It was also found that the sky brightness near the ecliptic plane observed with the IRAS and COBE/DIRBE is brighter towards the direction that trails the Earth's motion than towards the leading direction (Dermott et al., 1994; Reach et al., 1995), and this is confirmed with the AKARI mid-IR observations (Pyo et al., 2010).

Observations with IRAS and COBE/DIRBE were used for constructing the IPD cloud model by many authors (e.g., Kelsall et al., 1998; Wright, 1998; Gorjian et al., 2000). Since ZL is the nearest and forefront diffuse source to the Earth, it is extremely important to understand the nature of the zodiacal dust cloud not only for the solar system sciences.

2. SMALL-SCALE STRUCTURE OF THE ZL IN FAR-IR

We have made an all-sky multi-band photometric observation at 65, 90, 140, and 160 μm with AKARI/FIS (Doi et al., 2012). The AKARI far-IR all-sky survey covered 97% of the whole sky in about one year and a half. Although the most part of the ZL structure in AKARI far-IR images can be well reproduced with ZL model based on the DIRBE data (Kelsall et al., 1998; Wright, 1998), there are discrepancies in the small-scale structures. In particular, the intensity and the ecliptic latitude of the peak position of the asteroidal dust bands cannot be reproduced precisely with these models. The DIRBE model cannot reproduce the real fine structure of the asteroidal dust band components, because the DIRBE had the large $42' \times 42'$ beam and only small fraction of the DIRBE data were used to construct the DIRBE ZL model (Kelsall et al., 1998; Wright, 1998).

To extract the small-scale structures in the AKARI far-IR all-sky maps, at first, we only subtracted the smooth cloud component of the ZL based on the Gorjian model (Gorjian et al., 2000). To investigate the small-scale structures in the ZL cloud, we constructed two separate maps: one for the leading and the other for the trailing direction to the Earth's motion (Figure 1).

3. STRUCTURE OF ASTEROIDAL DUST BANDS

The WIDE-S maps include both the interplanetary and interstellar dust emission, while the WIDE-L maps mainly detect the interstellar dust emission. To reduce the contribution from the Galactic dust and extract the ZL structures, we subtracted 0.3×WIDE-L intensity of leading and trailing maps from the WIDE-S leading and trailing maps, respectively, assuming the interstellar dust in the WIDE-L maps has temperature T$\sim$ 18 K. In these WIDE-S−0.3×WIDE-L maps, we can see the prominent dust bunds near the ecliptic plane and $\pm 10^\circ$. To measure the latitudes of the dust bands and the structure of the circumsolar ring precisely, we fitted vertical slice profiles with Gaussians. A 5-Gaussian fit (2 dust-band pairs and a circumsolar ring) was performed at each ecliptic longitude for each map. We adopt the Gaussian because it is a convenient fitting function and is able to reproduce the profiles adequately. Based on the procedure above, we constructed the template for the small-scale structure of the ZL in far-IR.

4. RESULTS AND FUTREU WORKS

The resultant small-scale structure template is subtracted from the all-sky map for each band. We can reduce the residual component of the ZL to < 1 MJy/sr level around the ecliptic plane, subtracting these templates from the AKARI all-sky maps. We adopted the Gaussian for the fitting, although the Gaussian shape is not theoretically motivated. To improve the ZL model, we will consider a more realistic model for the dust bands that has been proposed on physical grounds (e.g., Sykes & Greenberg, 1986; Reach et al., 1997) in the future analsys.

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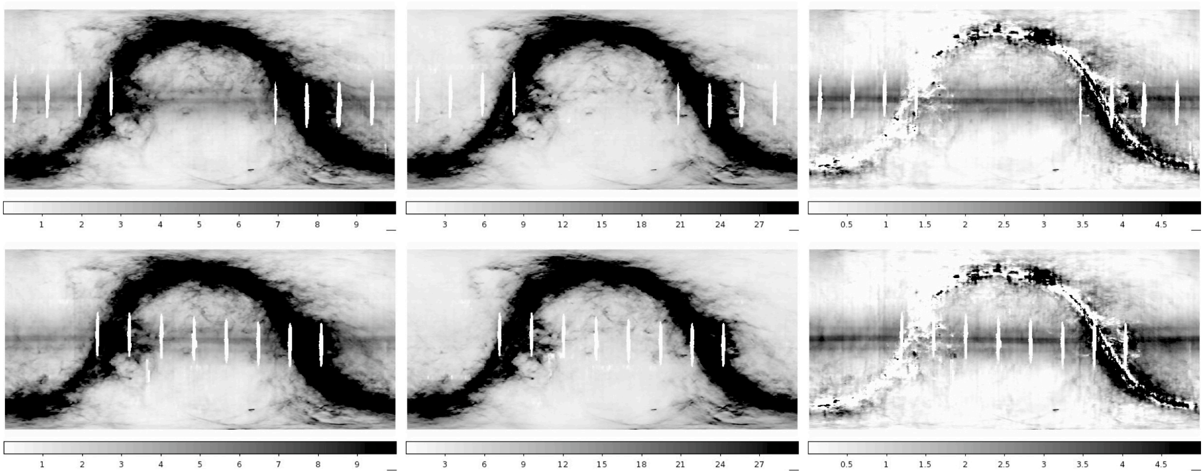

Figure 1. AKARI WIDE-S (90 μm) and WIDE-L (140 μm) all-sky maps for the leading (top panels) and trailing (lower panels) directions, shown in the ecliptic coordinates. The left and middle panels show the WIDE-S and WIDE-L maps, which only ZL smooth cloud component are subtracted, respectively. The right panel shows the difference maps between WIDE-S and WIDE-L. The regions contaminated by the Moon are marked in white and were excluded from the analysis.

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