Publications of the Korean Astronomical Society
32: 059 ∼ 061, 2017 March

pISSN 1225-1534
eISSN 2287-6936
https://doi.org/10.5303/PKAS.2017.32.1.059

MODELING OF THE ZODIACAL LIGHT FOR THE AKARI MID-IR ALL-SKY DIFFUSE MAPS

Toru Kondo[1], Daisuke Ishihara[1], Hidehiro Kaneda[1], Shinki Oyabu[1], Tomoya Amatsutsu[1],
Keichiro Nakamichi[1], Hidetoshi Sano[1], Takafumi Ootsubo[2], and Takashi Onaka[3]
[1]Graduate School of Science, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan
[2]Graduate School of Arts and Sciences, The University of Tokyo, Meguro-ku, Tokyo 153-8902, Japan
[3]Graduate School of Science, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan
E-mail: kondo@u.phys.nagoya-u.ac.jp

(Received June 17, 2016; Revised Novemer 4, 2016; Accepted Novemer 4, 2016)

ABSTRACT

The AKARI 9 and 18 μm diffuse maps reveal the all-sky distribution of the interstellar medium with relatively high spatial resolution of $\sim 6''$. The zodiacal light is a dominant foreground component in the mid-infrared. Thus, removal of the zodiacal light is a critical issue to study low surface brightness Galactic diffuse emission. We carried out modeling of the zodiacal light based on the Kelsall model which is constructed from the COBE data. In the previous study, only a time-varying component of the zodiacal light brightness was used for determination of the model parameters. However, there remains a residual component of the zodiacal light around the ecliptic plane even after removal with the model. Therefore, instead of using a time-varying component, we use the absolute brightness of the zodiacal light and we find that the new model can better remove the residual component. As a result, the best-fit model parameters are changed from those in the previous study. We discuss the properties of the zodiacal light based on our new result.

Key words: surveys; zodiacal dust; infrared: diffuse background

1. INTRODUCTION

The AKARI 9 and 18 μm maps reveal the all-sky distributions of polycyclic aromatic hydrocarbons and hot dust grains, respectively, with relatively high spatial resolution of $\sim 6''$. However, the zodiacal light, which is the thermal emission from the interplanetary dust (IPD) in our Solar System, is a dominant foreground component in the mid-infrared (IR). The top panels of Figure 1 show the AKARI mid-IR all-sky maps, in which bright zodiacal emission is seen along the ecliptic plane. In order to study Galactic diffuse emission of low surface brightness especially at high Galactic latitudes, we need to remove the zodiacal light accurately. Kelsall et al. (1998) made an IPD cloud model based on the COBE 10 photometric band data (hereafter the Kelsall model). This model has been used for removal of the zodiacal light from IR maps such as the IRAS, COBE, and AKARI maps (Miville-Deschênes & Lagache, 2005; Kelsall et al., 1998; Pyo et al., 2010). However, the Kelsall model does not fully reproduce the distribution of the IPD cloud; for example, there remains a residual component of the zodiacal light ($\sim$1 MJy sr^{-1}) around the ecliptic plane in the COBE 12 and 25 μm maps (Figure 2c in Kelsall et al. 1998). For studies of faint Galactic diffuse emission at $\sim$1 MJy sr^{-1} levels, we need an IPD cloud model which can remove the zodiacal light component more accurately.

2. MODELING OF THE ZODIACAL LIGHT

We determine the model parameters in the Kelsall model to fit the AKARI data. In the Kelsall model, the IPD cloud is decomposed into the following three components: a smooth cloud, asteroidal dust bands, and a resonance component. The resonance component is composed of a circumsolar ring and a blob trailing the

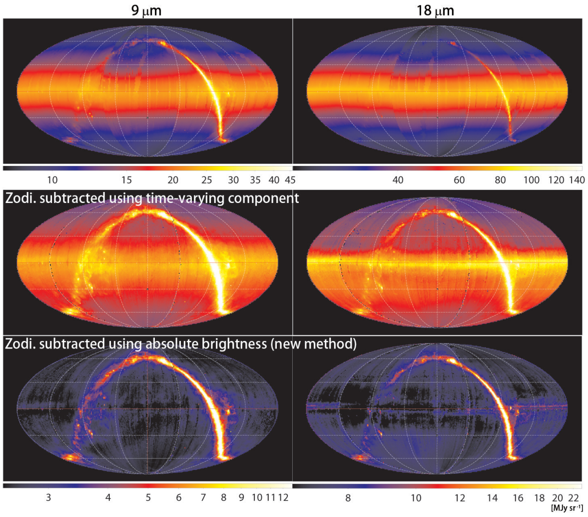

Figure 1. AKARI 9 and 18 μm all-sky diffuse maps, shown in ecliptic coordinates. The top panels show the original maps before subtraction of the zodiacal light. The middle and bottom panels show the maps after subtraction of the zodiacal light modeled by using only a time-varying component and the absolute brightness of the zodiacal light, respectively.

Earth, both of which have dust grains trapped into the Earth's resonance orbits near 1 AU. The brightness of the zodiacal light at wavelength λ for the celestial position p at time t is calculated by integrating the thermal emission along the line of sight s, summing IPD cloud components c as

$$Z_\lambda(p,t) = \sum_c \int n_c(\mathbf{R}) E_{c,\lambda} B_\lambda(T) ds, \qquad (1)$$

where $n_c(\mathbf{R})$ is the dust density in each component at the heliocentric position $\mathbf{R}$, $E_{c,\lambda}$ is the emissivity modification factor, which represents deviations from the Planck function $B_\lambda(T)$. We assume that the dust temperature T varies with distance from the Sun, R in units of AU, as $T(R) = T_0 R^{-\delta}$, where T_0 is 286 K, the dust temperature at 1 AU.

The zodiacal light brightness observed with the telescope varies with time, because the telescope moves relative to the IPD cloud, depending on the orbital phase of the Earth. In order to determine the model parameters, Kelsall et al. (1998) used only a time-varying component of the zodiacal light brightness to separate the zodiacal light from the Galactic component. Following the previous study, we carried out model fitting using the time variation of the sky brightness in half a year. The middle panels of Figure 1 show the result of removal of the zodiacal light. The map shows large offsets in the intensity, since this method cannot estimate the component that does not vary with time. In addition to the offsets, there still remains a residual component around the ecliptic plane, whose level is ~8% of the original brightness of the zodiacal light. It is likely that we cannot reproduce the precise distribution of the zodiacal light only by a long-term variations (half a year). We therefore change our strategy; we carried out model fitting using the absolute brightness of the zodiacal light. In order to avoid the Galactic emission, we do not use Galactic plane regions, which are defined as those with brightness ≥7 MJy sr^{-1} in the IRAS 100 μm map.

Table 1
Changes of the best-fit model parameters which affect the physical properties of the IPD cloud

Kelsall model COBE	Our new model AKARI
Temperature power-law index δ	
0.47	0.37
Density of the circumsolar ring at 1 AU (AU^{-1})	
1.8×10^{-8}	4.5×10^{-8}
Density of the trailing blob at 1 AU (AU^{-1})	
1.9×10^{-8}	6.7×10^{-8}

3. RESULTS

The bottom panels of Figure 1 show the AKARI mid-IR all-sky diffuse maps after subtraction of the zodiacal light with our new method, obtained by using the absolute brightness of the zodiacal light. We significantly improve the removal of the zodiacal light. There are no significant brightness gradients from the ecliptic plane to the ecliptic poles in these maps, which are seen in the COBE maps in Kelsall et al. (1998). The residual component level is ~1% of the original brightness of the zodiacal light.

Most of the best-fit model parameters are changed from those in Kelsall et al. (1998). Table 1 summarizes the changes of the parameters which significantly affect the physical properties of the IPD cloud. The power-law index (δ) of the dust temperature distribution becomes 10% smaller, while the dust densities in the circumsolar ring and the trailing blob become about three times larger.

4. DISCUSSION

We discuss the causes of the changes in the model parameters. As shown in Table 1, the Kelsall model showed $\delta = 0.47$, which is close to the theoretical value of 0.5, estimated by assuming the blackbody radiation from large dust grains in radiative equilibrium. On the other hand, our new model shows $\delta = 0.37$, which is ∼20% smaller than the previous value. This result indicates that the IR emissivity of IPD grains is lower or the grain size is smaller than the previous understanding. For the changes of the dust densities in the resonance component, it is possible that the Kelsall model underestimated the densities. Alternatively, there is a possibility that the size or spatial distributions of the IPD grains were changed in a time span of ∼16 years between COBE and AKARI.

5. SUMMARY

We carried out modeling of the zodiacal light for the AKARI mid-IR all-sky survey data based on the Kelsall model. By changing a fitting method from the previous study, we have successfully improved the zodiacal light subtraction process. As a result, the model parameters are significantly changed. These changes can be explained by the change of the model or a temporal variation of the distribution of the IPD cloud.

ACKNOWLEDGMENTS

We thank all the members of the AKARI project. T.K. is financially supported by Grants-in-Aid for JSPS Fellows No. 25002536.

REFERENCES

Kelsall, T., Weiland, J. L., Franz, B. A., et al., 1998, The COBE Diffuse Infrared Background Experiment Search for the Cosmic Infrared Background. II. Model of the Interplanetary Dust Cloud, ApJ, 508, 44

Miville-Deschênes, M. -A. & Lagache, G., 2005, IRIS: A New Generation of IRAS Maps, ApJS, 157, 302

Pyo, J., Ueno, M., Kwon, S. M., et al., 2010, Brightness map of the zodiacal emission from the AKARI IRC All-Sky Survey, A&A, 523, A53