# Disentanglement of Small-Scale Structures from the Zodiacal Dust Cloud

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**ABSTRACT**

The zodiacal light (ZL) is the dominant diffuse radiation in the mid-infrared wavelengths from the interplanetary dust. Although the zodiacal dust cloud has a relatively smooth distribution, it has many small-scale structures, such as asteroidal dust bands and a circumsolar resonance ring. A number of models for the zodiacal dust cloud have been developed, in particular, using the infrared satellite data, such as *IRAS* and *COBE*/DIRBE, thus far. Although the DIRBE ZL model (e.g. Kelsall et al. 1998) reproduces the observed infrared sky well, there are still uncertainties in the model parameters. Since *IRAS*, *COBE*/DIRBE, and *AKARI* were the sun-synchronous orbit satellites, they observed the infrared sky through the circumsolar ring in the Earth's orbit. *SPICA* will be launched onto a halo orbit around L2 point, which is 0.01 AU away from the Earth. In this orbit, we may be able to observe the small-scale structures more clearly. The asteroidal dust bands contribute to the ZL brightness most in the 25–100 $\mu$m region. *SPICA* can cover this wavelength region, whereas *JWST* can observe shorter than 28 $\mu$m.

## 1. BACKGROUND AND MOTIVATION

The zodiacal light (ZL) is the dominant diffuse radiation in the mid-infrared wavelengths due to thermal emission from the interplanetary dust. The interplanetary dust originates mainly from comets and asteroids, and it spreads over the solar system. This "zodiacal dust cloud" has a relatively smooth distribution as a whole. It has, however, many small-scale structures, such as asteroidal dust bands and a circumsolar resonance ring, generated by interactions and resonances with the large bodies in the Solar System (Low et al. 1984; Dermott et al. 1984, 1994; Reach et al. 1995). Many efforts have been devoted to describing the structure of the zodiacal dust cloud so far. A number of models have been developed, in particular, using the infrared satellite data, such as *IRAS* and *COBE*/DIRBE. The ZL model most commonly used to date is the one based on the DIRBE data (e.g. Kelsall et al. 1998; Wright 1998). 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 and extra-solar system sciences but also for the study of the Galactic/extragalactic objects and cosmology.

Although the DIRBE ZL model reproduces the observed infrared sky well, there are still uncertainties in the model parameters. Based on the *AKARI* data, Pyo et al. (2010) found that the DIRBE ZL model underestimates the Earth's resonant ring component. The DIRBE model also cannot reproduce the real fine structure of the asteroidal dust band component, because the DIRBE had the large $42' \times 42'$ beam. Based on the *IRAS* observation, Nesvorný et al. (2010) present a zodiacal cloud model based on the orbital properties and lifetimes of comets and asteroids, and on the dynamical evolution of dust after ejection. They found that 85%–95% of the observed mid-infrared emission is produced by particles from Jupiter-family comets and < 10% by dust from long-period comets. Asteroidal dust is found to be present at < 10%. Since *IRAS*, *COBE*/DIRBE, and *AKARI* were the sun-synchronous orbit satellites, they observed the infrared sky through the circumsolar resonance ring in the orbit of the Earth. It is difficult to evaluate the contribution of these dust components in the model precisely, if the model is based on the data of these satellites.

*SPICA* will be launched onto a halo orbit around L2 point, which is about 0.01 AU away from the Earth in the direction opposite to the Sun (Nakagawa et al. 2011). In this orbit, the contribution from the Earth's circumsolar ring dust will decrease and we may be able to observe the small-scale structures in the zodiacal cloud more clearly. The comparison of the results with *AKARI* and *COBE*/DIRBE is expected to give us a new insight into the structure of the zodiacal dust cloud.

## 2. SCIENTIFIC GOALS

Main scientific goals and objectives of the *SPICA* observations regarding the zodiacal dust cloud are as follows:

- Observe the ZL cloud less contaminated with the Earth's resonant ring. Estimate the contribution of the circumsolar ring and the Earth trailing blob component more precisely.

- Compare the spectrum of the asteroidal dust band, which is not contaminated with the circumsolar ring component, with smooth cloud component. Clarify the contribution of cometary and asteroidal dust to the total ZL more precisely.
- Discover faint small-scale structures originate from distant objects, such as Centaurs and trans-Neptunian objects (TNOs).

## 3. OBJECTIVES OF ZL OBSERVATIONS

### 3.1. Observations of the ZL Cloud from Different Angles

*SPICA* will observe the zodiacal dust cloud from the different position from *IRAS*, *COBE*/DIRBE, and *AKARI*, which is 0.01 AU away from the Earth in the direction opposite to the Sun. In this orbit, the contribution from the circumsolar ring will slightly decrease and the observational data will not be affected by the moon and the South Atlantic Anomaly (SAA). The change of the detector response due to the moon and SAA passage is significant, and it makes the precise observation of faint diffuse emission very difficult, especially near the ecliptic plane (Kondo et al. 2013, this volume). We may be able to observe the small-scale structures in the zodiacal cloud more clearly with *SPICA*. Since the asteroidal dust bands originate from the collision in the main asteroid belt, the dust grains in the dust bands show the lower temperature than the circumsolar ring at 1 AU, and contribute to the ZL brightness most in the 25–100 $\mu$m region (Kelsall et al. 1998). Thus, mid-infrared observations at longer than 25 $\mu$m are very important for the precise construction of the zodiacal dust cloud model. *SPICA* can cover this wavelength region with MCS/WFC and SAFARI, although *JWST* can only observe shorter than 28 $\mu$m.

### 3.2. Comparison of the Spectrum of the Asteroidal Dust Band with the Smooth Cloud

Based on the *IRAS* observation, Nesvorný et al. (2010) found that 85%–95% of the observed mid-infrared emission is produced by particles from Jupiter-family comets. Mid-infrared spectroscopic observations with *AKARI* suggest that spectra of the major mineral phases in collected anhydrous chondritic porous interplanetary dust particles, which are of probable cometary origin, have features at the same wavelengths as the ZL spectrum (Ootsubo et al. 2009). However, there may be the difference in the spectral features between near ecliptic plane and high ecliptic latitude regions (Figure 1 in Ootsubo et al. 2009). *SPICA* can obtain the observational evidence for the supply source of the interplanetary dust cloud.

### 3.3. Discover Faint Small-scale Structures Originate from Distant Objects

There is a possibility that *SPICA* can detect the small-scale structures which originate from the Edgeworth-Kuiper Belt (EKB). Yamamoto & Mukai (1998) examine the thermal emission from the EKB dust cloud produced by the mutual collisions of TNOs within the EKB and by the interstellar dust impacts on TNOs. The EKB dust cloud farther than the main asteroid belt is expected to have lower temperatures than the dust in the asteroidal dust bands. The maximum case of thermal emission from the EKB dust cloud becomes to be comparable to that of foreground zodiacal emission at the wavelength of about tens of $\mu$m to hundreds of $\mu$m (Yamamoto & Mukai 1998). When the EKB dust cloud has a narrow spatial band structure with a thickness of about 10 degree around the ecliptic, the detailed observations with *SPICA* may reveal the contribution of the EKB dust to the foreground zodiacal dust cloud.

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