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Spectral study of scattered light by interstellar dust grains

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Abstract. Interstellar dust is traced by not only thermal emission but also scattered light. The scattered light spectrum observed from ultraviolet (UV) to near-infrared (IR) is useful to constrain some dust properties, such as size distribution, albedo, and composition. Milky Way Galaxy is a unique environment to observe the diffuse scattered light because we can extract it by removing the contribution of starlight. We have observed the UV to near-IR scattered light with space instruments, including Diffuse Infrared Background Experiment (DIRBE), Hubble Space Telescope (HST), and Multi-purpose Infra-Red Imaging System (MIRIS). The scattered light spectrum is marginally consistent with prediction from a recent dust model including carbonaceous and silicate grains with polycyclic aromatic hydrocarbon (PAH). Based on the MIRIS observation of a diffuse cloud, we compare the scattered light color with the dust model with or without grains larger than 1 micrometer. The result shows that the color is consistent with the model without the large grains, which is consistent with recent simulations of dust growth in low-density regions. However, some observations have shown the spectral excess at ~ 0.6 micrometer wavelength, suggesting the presence of extended red emission (ERE) which cannot be explained by the conventional dust model.

Keywords. scattering, dust, extinction, infrared: ISM

1. Introduction

Properties of interstellar dust grains can be studied by spectral observations of extinction curve, thermal emission, and scattered light by starlight. From ultraviolet (UV) to near-infrared (IR), the scattered light has been observed toward different regions with various instruments (e.g., Ienaka *et al.* 2013; Arai *et al.* 2015; Sano *et al.* 2015; Kawara *et al.* 2017).

Spectral shape of scattered light is expected from models of interstellar dust and interstellar radiation field. Brandt & Draine (2012) provide a model of scattered light spectrum by assuming the dust models of Weingartner & Draine (2001) and Zubko *et al.* (2004). Both models consist of sub-micrometer-sized carbonaceous and silicate grains. The observed spectrum of scattered light is marginally consistent with the prediction from these models.

Several observational studies suggest a flat extinction curve in the mid-IR, which cannot be explained by the dust models including grains less than 1 μm (e.g., Indebetouw *et al.* 2005; Nishiyama *et al.* 2009). Wang *et al.* (2015) explain this problem by adding some micrometer-sized carbonaceous grains to the dust model of Weingartner & Draine (2001). A more precise observation of scattered light is expected to constrain grain distribution of interstellar dust.

2. Overview

We present new observations of scattered light with Multi-purpose Infra-Red Imaging System (MIRIS) at 1.1 and 1.6 μm by utilizing its large field of view of $3.67° \times 3.67°$ (Han *et al.* 2014). Observing a diffuse region in the edge of the molecular cloud MBM32, we found a precise linear correlation between near-IR scattered light and thermal dust emission at 100 μm (Schlegel *et al.* 1998).

On the basis of the dust models of Weingartner & Draine (2001) and Wang *et al.* (2015), we predict the spectrum of scattered light. The result shows that the observed near-IR color of scattered light prefers the model of Weingartner & Draine (2001), suggesting little contribution of very large grains of >1 μm in the region. Combined with the implication of flat extinction curve, grain size may depend on the density of the regions because the present observation of scattered light is toward an optically thin region.

At the wavelength of $\sim$0.6 μm, we find an excess contribution in addition to the scattered light, which is the so-called extended red emission (ERE). The ERE might originate from interaction between far-UV photons and nm-sized grains (e.g., Li & Draine 2002), though not all the observations suggest the presence of ERE.

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