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Observational study of interplanetary dust based on the mid-infrared spectrum of zodiacal emission

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A recent space mission of the Infrared Telescope in Space (IRTS) provided opportunities of the comprehensive studies of zodiacal emission. The IRTS was the Japanese first satellite-borne infrared telescope. It was launched in March 1995 and surveyed about 7% of the sky with four instruments during its 26 day mission. The Mid-Infrared Spectrometer (MIRS) was one of the focal plane instruments. It was a low-resolution spectrometer with the 8'*8' wide field of view, and covered the spectral range of 4.5-11.7 micron with the resolution of 0.23-0.36 micron. The zodiacal emission spectrum from 4.5-11.7 micron obtained with the IRTS/MIRS provides strong constraints on the composition and size distribution of interplanetary dust.

The observed zodiacal emission brightness has a clear dependence on the ecliptic latitude, indicating that the zodiacal emission dominates in the mid-infrared sky brightness. The MIRS spectrum in the 4.5-8 micron region can be fitted by both of a gray body radiation at 275 K and the three-dimensional DIRBE IPD model spectrum which is the integration of the radiation along the line of sight. The MIRS spectrum and the DIRBE IPD model spectrum are mostly unity but the MIRS spectrum has excess emission at longer than 9 micron compared to the model spectrum. The possible 20% excess emission is seen in the 9-11 micron region.

We have calculated the emission spectra of interplanetary dust for four different constituent materials and two size distributions, and examined the models by comparing with the MIRS spectrum. The most important constraint on interplanetary dust models is the strength of the spectral feature over the continuum. With respect to the dust size distribution, the lunar size distribution is ruled out for all the constituent materials considered in this thesis. As for the strength of the emission feature, only olivine glass could explain the emission feature of the MIRS spectrum (~ 20%) for the interplanetary size distribution, although the shape of the feature is different and the temperature of the continuum spectrum is somewhat cold. The olivine glass with graphite impurity modifies the shape of the 9-11 micron feature and the color temperature. However, none has a correct shape in the 8-12 micron region. It implies that major constituents of the interplanetary dust particles may be carbonaceous materials and silicates of high absorptivity in the visible wavelengths such as glassy olivine, and some materials can explain the spectral feature particularly around 11 micron.

The presence of the 9-11 micron feature in the zodiacal emission spectrum indicates that the particles producing the zodiacal emission are composed of silicates similar to those found in the coma of comets, collected interplanetary dust particles, and the dust around the nearby star beta Pic. The spectrum of the zodiacal emission, augmented by information from laboratory analyses of silicates, allow us to draw some conclusions about the dust particles in the interplanetary space. The 11.2 micron peak in the zodiacal emission spectrum may be due to Mg-rich olivine crystals, which is also seen in cometary spectra. Crystalline olivines probably make a major contribution to the 9-11 micron emission of the zodiacal emission spectrum as well as cometary spectra. Also amorphous, or glassy, silicate particles are probably present in the interplanetary space to explain the width of the emission feature of the zodiacal emission spectrum. There are both crystalline and amorphous silicates in the interplanetary space, which may be originated from comets.