論文内容の要旨

論文題目

CIBER Observation of the Near-Infrared Spectrum of the Zodiacal Light

（CIBER による黄道光の近赤外線分光観測）

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Zodiacal light (ZL) is the scattered sunlight by the interplanetary dust (IPD) in the near-infrared wavelength region and a major constituent of the celestial diffuse brightness. Continuous supply of IPD is necessary because IPD is falling into the sun due to the Poynting-Robertson effect. Possible sources for this supply are asteroid collisions and cometary ejections, but relative contribution from these two sources is still unknown. Spectroscopic observation of ZL in the near-infrared wavelength region is important in deriving composition of IPD, because there are distinct spectral features in the near-infrared to distinguish the material of IPD. However, there are little spectroscopic observations of ZL to study the composition of ZL since it is difficult to conduct the spectroscopic observation of the diffuse emissions such as ZL. In this thesis, I show a new observational result of the spectrum of ZL with the Low Resolution Spectrometer (LRS) boarded on the Cosmic Infrared Background ExpeRiment (CIBER).

CIBER is a rocket-borne mission designed for measuring the absolute spectrum and fluctuation of the diffuse emission in the near-infrared wavelengths. The CIBER instrument consists of four optics and they are cooled with liquid nitrogen to reduce thermal emission from the optics. LRS is one of the CIBER optics and it observed the absolute spectrum of the sky in the 0.75-2.1μm spectral region. This wavelength

region has not been much explored by previous space missions for the study of the diffuse emissions. LRS consists of a 5-cm aperture refractive system with five spectral slits providing 2.8 arcminute by 5.5 degree long fields on the sky. A prism disperses the incident light perpendicular to the slits and the spectra are imaged with a 256×256 PICNIC detector array. Depending on the wavelength, a spectral resolution between 15 and 30 is achieved.

Prior to the launch, we have curried out many laboratory experiments for performance evaluation and calibration of the CIBER instruments, and we achieved calibration accuracy better than 10% in the flight configuration.

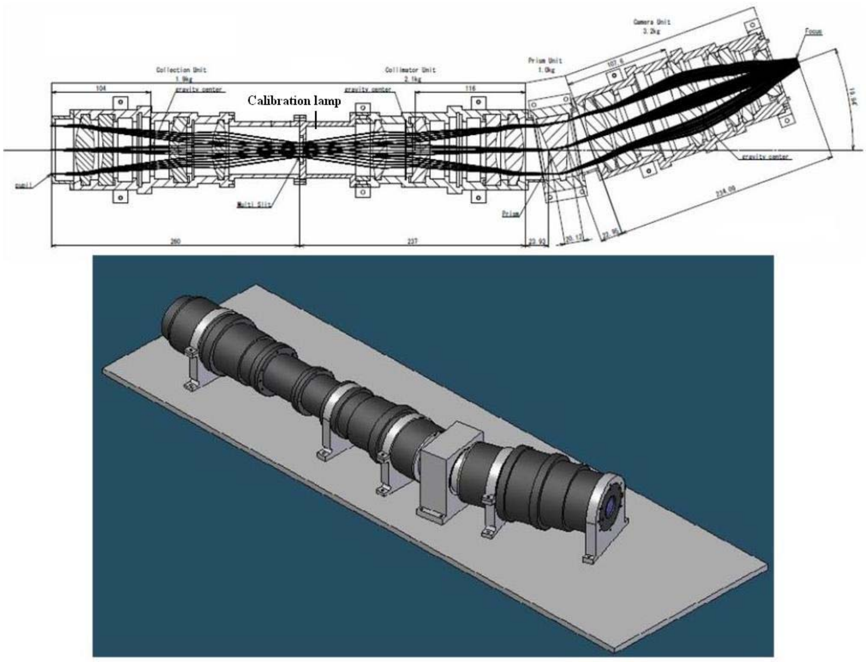

Fig.1 Design and appearance of LRS, which uses a prism to disperse radiation through five slits onto the 256×256 array.

Composition	14 lenses, 2 filters, 1 prism, 5 slits
Aperture	50 mm
F number	2
FOV	5.5 degrees along a slit
Pixel size	1.4 arcminutes×1.4arcminutes
Slit	2 pixels×236 pixels
Wavelength range	750-2100nm
Wavelength resolution	$\lambda/\Delta\lambda$=15-30
Optics efficiency	0.8
Detector	256×256 substrate removed 2.5μm cutoff PICNIC
Detector QE	0.9
Dark current	$< 0.6[e^-/s]$
Read-out noise	$< 26[e^-]$ CDS

Table.1 Low-Resolution Spectrometer Specifications

The rocket with the CIBER instruments was successfully launched at the White Sands Missile Range in New Mexico, USA in February 25th 2009, achieved an apogee of 330 km, and allowed us to obtain more than 400 seconds of astronomical data. As a result of the CIBER/LRS observation, we obtained a good quality spectrum of the diffuse emission of the sky at various ecliptic latitudes.

During the flight, we observed large emission for wavelengths greater than 1.8μm. This emission is evidently due to scattered thermal emission from the sounding rocket skin, which was heated by air friction on ascent. There is no evidence this emission affects results presented here at shorter wavelengths and we simply omit data at wavelengths larger than 1.8μm. There was another component observed with exponential time dependence but the contribution is almost negligible except in the fields at the beginning of the observations at low altitude, Elat-10 and Elat-30. This terrestrial emission was mainly due to atmospheric airglow and dissociated water vapor outgassed from the payload early in the flight. Based on its spectrum, with prominent emission features at 1.1 and 1.6μm, we attribute this component to mainly OH molecules. We subtracted this component based on its time dependence.

The obtained sky brightness is consistent with previous observations with the infrared astronomical satellites COBE/DIRBE and IRTS. The spectral shapes of the sky brightness for a variety of ecliptic latitudes are very similar to each other. This is consistent with the fact that the sky brightness is dominated by zodiacal light and the spectral shape of zodiacal light is approximately isotropic.

The ZL spectrum was derived by using its ecliptic latitude dependence. The obtained ZL spectrum is redder than the solar spectrum in the observed wavelength region, and its spectral shape is isotropic within measurement error over a wide range of the ecliptic latitude. In addition, the spectrum clearly shows a broad absorption feature, previously unreported, centered at approximately 0.9μm, indicating the existence of silicates in IPD material. The IPD reflectance spectrum, including the extended wavelength range to 2.5μm using IRTS data, is similar to the reflectance of S-type asteroids. This result suggests that fragments of S-type asteroids dominate the composition of IPD near Earth's orbit.

The recent dynamical analyses favor cometary origin to explain the observations of ZL in the mid-infrared, where ZL is brightest. The mid-infrared observations of ZL is biased by the low-albedo dust (i.e. dust from C-type asteroids and comets), while ZL in the near-infrared is biased by the high-albedo dust (i.e. dust from S-type asteroids). Therefore, our result can be consistent with the resent result favoring a cometary origin if the asteroidal dust concentrated near the earth according to the asteroid distribution in the solar system. In addition, the distribution of S- and C-type asteroids in the asteroid belt naturally explain that dust from S-type is more dominated than dust from C-type asteroids. Consequently, I concluded that the observed ZL spectrum in the near-infrared is explained mainly by dust from S-type asteroids, and this is the first evidence from the ZL spectrum in the near-infrared wavelengths to show the existence of the asteroidal dust in IPD.

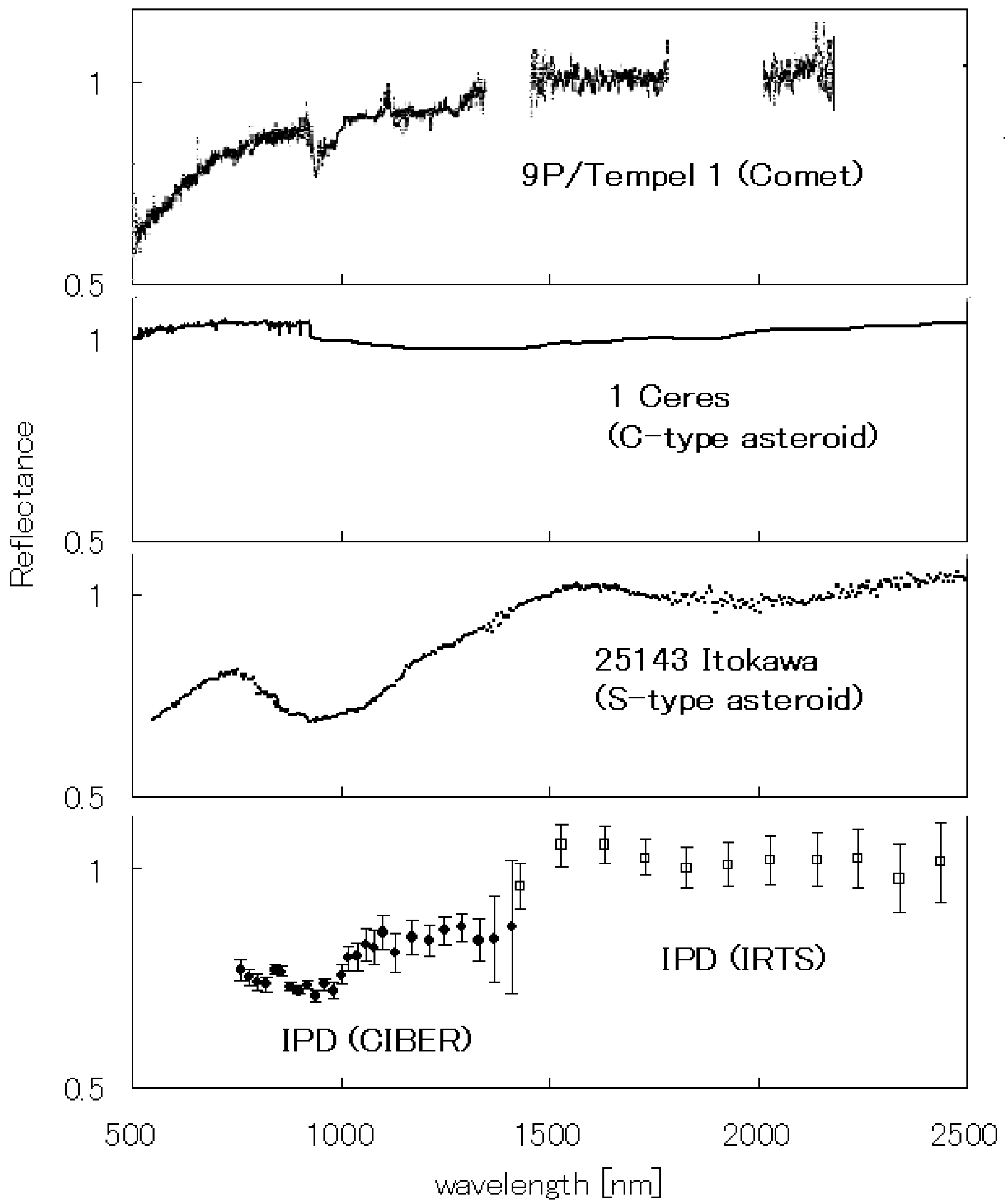

Fig.2 The reflectance of IPD normalized at 1.83μm. CIBER/LRS and IRTS results are plotted together with those of comet and asteroids. Note that the absorption at 0.95-1μm in the spectrum of 9P/Tempel-1 was caused by the atmosphere in the earth.