Cloud top structure of Venus retrieved from Subaru/COMICS mid-infrared spectra

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Venus is completely shrouded by a curtain of dense clouds (50-70 km) with total optical thickness of 20-40 at visible wavelengths. The upper sulfuric acid (H_2SO_4) clouds reflect ~76% of the incident solar radiation back to space [Crisp and Titov, 1997]. Approximately 50% of the solar energy absorbed by Venus is deposited at altitudes higher than 64 km mainly due to unknown UV absorber mixed in the upper clouds [Tomasko et al., 1980]. In addition, infrared radiation from the lower atmosphere is absorbed by the clouds. To elucidate the cloud structure which controls thermal balance of the planet, we analyzed the mid-infrared images obtained by the Cooled Mid-Infrared Camera and Spectrometer (COMICS) mounted on Subaru Telescope [Sato et al., 2014]. We found several important findings near the cloud top altitudes (~70 km), such as the possibility that the westward rotation of the polar features is synchronized between the northern and southern hemispheres, and temporally variable small-amplitude patterns distributed in the entire disk. In order to investigate what atmospheric parameters are responsible for these features seen in the images, we have also analyzed mid-infrared spectra taken on the same date by the same instrument.

A ground-based spectroscopy of Venus was carried out at the solar phase angle of ~90 deg, with the morning terminator in view, using Subaru/COMICS on October 29, 2007 (UT). The entire N-band (8-13 μm) spectra were obtained with a spectral resolving power of R ~ 250, which is equivalent to that of the Fourier Spectrometer onboard Venera 15 [Moroz, 1986]. The slit, which was sufficient to capture the northern and southern limbs of Venus (angular diameter ~25 arcsec), was set to be parallel to the central meridian of Venus just off the nightside limb and Venus was scanned toward the dayside limb. The observed thermal radiation in this wavelength range is emitted mainly from altitudes ~65-70 km.

From slit-scan images composed of a total of 78 spectra, polar hot spots and cold collars in both hemispheres are clearly seen and day-night asymmetry is also found, which are consistent with the characteristics of snapshots at 8.66 μm and 11.34 μm taken by imaging observations on the same date [Sato et al., 2014]. The spectra near 9.6 μm are unavailable due to the contamination of O_3 in the Earth's atmosphere even after the careful data reduction. There are two identifiable CO_2 bands (12.1 μm and 12.7 μm). For both bands, the spectral features appear in absorption for the equatorial region and in emission for the southern cold collar. This qualitative characteristic is consistent with our knowledge obtained from Venera 15 [Moroz, 1986]. Such information as well as overall spectral shape is useful to retrieve atmospheric parameters, for example, cloud top temperature, cloud top altitude, and cloud scale height.

To estimate how accurately atmospheric temperature can be retrieved from 8-13 μm spectra, as a first step, we performed a sensitivity test with VIRA-2 temperatures [Zasova et al., 2006]. The pseudo observed spectra were calculated from several combinations of VIRA-2 temperatures and a cloud model [Zasova et al., 2007; Eymet et al., 2009], and an inversion technique [Smith, 1970] was applied to these spectra while changing the initial guess of the temperature profile. As a result, we found that the temperature in altitudes ~65-70 km can be retrieved with the uncertainty of ~2 K.

In this presentation, we will show the mid-infrared spectra of Venus obtained by Subaru/COMICS and primitive results of atmospheric parameters retrieved from the observed spectra.

Keywords: Venus, cloud structure, ground-based infrared spectroscopy, radiative transfer

