Characteristic features in Venus' cloud-top temperature obtained by Akatsuki/LIR

T. Fukuhara[1], M. Taguchi[2], M. Futaguchi[2], T. Imamura[3], and Akatsuki TIR Team, [1]Hokkaido University, (North-10, West-8, Sapporo, Japan, tetsuyaf@ep,sci,hokudai.ac.jp), [2]Rikkyo University, Tokyo, [3]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA).

Introduction: The Japanese Venus Climate Orbiter called Akatsuki was designed to study the meteorology of the Venusian atmosphere, which differs to that of the Earth in composition, density and circulation. Akatsuki was to orbit around Venus in an elongated equatorial orbit with almost the same angular velocity during most of the orbital period as that of the super rotation of the atmosphere at the cloud top altitudes, like a geosynchronous satellite. A 3-D structure of the atmosphere was to be reconstructed by multi-depth imaging using four cameras operating in the mid-infrared to near ultraviolet regions and using the radio occultation technique [1].

The Longwave Infrared Camera (LIR), which mounts an uncooled micro-bolometer array (UMBA), is one of a suite of cameras onboard Akatsuki, designed to take mid-infrared images of Venus with a single bandpass filter of 8–12 μm [2]. LIR detects thermal radiation emitted from the layer where the cloud optical depth equals unity. The noise equivalent temperature difference (NETD) of LIR is 0.3 K and absolute temperature can be determined with an accuracy of 3K. In addition, the horizontal wind vector field at the cloud-top height could be retrieved by a cloud tracking technique.

Unfortunately, Akatsuki failed to enter the orbit because trouble occurred with the propulsion system on December 7, 2010. However, while Akatsuki was traveling away from Venus, LIR acquired a few mid-infrared images of almost the entire nightside hemisphere on December 9, the first mid-infrared images of Venus obtained by a spacecraft at a distance of about 600,000 km. We report the characteristic features found in the temperature distributions retrieved from those images and compares them with vertical temperature distributions and cloud-top temperatures obtained by past spacecraft.

Observation results: Brightness temperature distributions have been obtained from images by using calibration data which acquired in the labolatory before the launch. Because Akatsuki conducted an attitude control maneuver for pointing the cameras toward Venus in a somewhat unusual manner during this observation, the attitude control system could not keep the attitude of the spacecraft completely still with respect to the reference frame during the sequence of acquiring the 32 intermediate images that should be accumulated to reduce a noise. Therefore, the line-of-sight of LIR slowly drifted by about 3 pixels in both the horizontal and vertical directions in the image field during the accumulation time, and consequently scanned the Venus disk at an almost constant rate of about 0.1 pixel/(intermediate image interval). The 32 intermediate images, which are usually not downloaded to the ground in order to reduce the downlink data volume, were downloaded and the brightness center position of the Venus disk was determined for each image. The 32 intermediate images were then stacked after correction for the attitude variation. Since the instantaneous spatial resolution determined by the imaging performance of the optical system of LIR is better than that determined by the pixel size of the image sensor, the scanning by attitude drift during the sequence of acquiring the intermediate images resulted in an image with finer spatial resolution than that of the original intermediate image.

Several remarkable features are observed in the temperature distributions. The temperature decreases in both polar regions, especially in the northern polar region. A slightly lower temperature belt is identified in the northern middle latitudes. The equatorial region exhibits the highest temperature exceeding 240–245 K. An extremely low temperature belt and a slightly higher temperature region, which must correspond to the polar collar and the polar dipole, respectively, are identified in the northern high latitudes. Other zonal structures can be seen in the middle and low latitudes, and they may correspond to the Y- structures seen by ultraviolet imaging in past Venus missions. Moreover, patchy temperature structures or quasi-periodic streaks extending in a north–south direction with horizontal scales of several hundred to a thousand kilometers are identified in the northern middlelatitude belt and in the southern low latitudes. The zonal structures, though they do not appear in the same latitudinal regions, could have the same origin as those seen in the UV images. The origin of the Y-shape in the UV images has not yet been identified, though it is likely to be absorption of UV irradiation by an unidentified material. On the other hand, the zonal structure seen in the mid-infrared arises from the difference in temperature and/or cloud optical depth. The UV absorber may be stratified at a layer which is sometimes covered by the upper cloud, or it may have accumulated at the altitude of the upper cloud-top by convection in the cloud.

The temperature distribution was compared with the meridional temperature fields obtained by the Venera 15 IR spectrometer [3]. The temperature obtained by LIR varies from 243 K in the low latitudes to 237 K in the polar collar. These temperatures correspond to altitudes of 63 km in the low latitudes down to 58 km in the polar collar. The cloud optical depth at 1218 cm-1 (8.21 μm) has been retrieved and the cloud-top altitudes defined by the altitude of unit optical depth have been plotted in the meridional temperature distributions. It reaches 66 km in the low latitudes and decreases to less than 60 km in the polar region. The cloud-top temperatures obtained by LIR are significantly higher than those obtained by Venera 15. The wavenumber of 1218 cm-1 corresponds to the most transparent range of cloud in the mid-infrared in the Venus atmosphere, while the 8–12 μm band includes weak absorption bands associated with CO2, SO2, H2O and H2SO4. The absorption due to the gaseous constituents makes the peak altitude of the weighting function for the passband of LIR a little higher than that at 1218 cm-1, though this is the opposite to what is required to explain the temperature difference. CO2 has the widest equivalent width and its variation in equivalent width above the cloud-top may result from the variation in the cloud-top altitude, though this has little effect on outgoing radiation compared to the associated temperature variation. It has been confirmed by radiative transfer analysis that the outgoing radiation power in the passband of LIR would decrease by only 2% if the concentrations of SO2 and H2O were doubled. Therefore, the temperature difference between the previous and LIR measurements ought to be attributed not to variations in the absorption due to the gaseous constituents but to the temperature change itself and/or changes in the cloud-top altitudes.

References: [1]Nakamura, M. et al., 2007. Space Sci. 55, 1831–1842. [2]Fukuhara, T. et al., 2011. Earth Planet Space 63, 1009–1018. [3]Zasova, L.V., Ignatiev, N., Khatuntsev, I., Linkin, V., 2007. Planet. Space Sci. 55, 1712–1728.