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Multi-wavelength limb darkening effect on the Venus nightside from the VIRTIS infrared images

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The limb darkening (LD) is the decrease of the observed radiance when emission angle increases. If this effect is not accounted for, areas on the planet with equivalent thermal energy would appear different, if observed at different emission angles.

Nightside Venus atmosphere in the Near Infrared

The nightside Venus atmosphere is almost completely opaque in the near-infrared, and only nine, narrow, transmission windows at the following wavelengths (in μm) are detectable: 1.0, 1.10, 1.18, 1.27, 1.31, 1.51, 1.55, 1.74 and 2.3 [1, 2]. Only radiance emitted at 1.0 μm is originated almost completely by the surface, while emission in the other windows comes from the cloud deck in the upper troposphere (25-45 km) [1]. Then, at 3.71 μm emission comes from the lower mesosphere (62-73 km) [3].

Algorithms for Venus LD correction

Carlson et al. [4] proposed an algorithm, using a radiative transfer model from [5] and a cloud model from [6]. From these synthetic data, linear relation between radiance emerging from atmosphere (normalised to radiance at zero emission angle) and cosine of emission angle has been found. This relation was obtained only for two windows, at 1.74 and 2.3 μm, and is in good agreement with observed data (NIMS data).

New approach for LD correction

In this work a new algorithm for LD correction, that can be extended to all the windows of the nightside Venus infrared spectrum, is described. We used calibrated VIRTIS-IR spectra [7]. These data have been previously refined in wavelength calibration and corrected for scattered sunlight. From radiative transfer equation and Eddington-Barbier approximation (source function of every atmospheric layer directly proportional to optical thickness), we retrieved the relation $R_\lambda = a_\lambda + b_\lambda \cos\theta$, where R_λ is radiance, at wavelength λ, emerging from the atmosphere, and θ is the emission angle. If radiance comes mainly from the surface (1.0 μm window), a_λ and b_λ depend on surface emissivity, surface temperature and atmospheric coverage. Otherwise, if radiance comes from atmosphere, they depend only on atmospheric coverage. In this case, groups of pixels having the same atmospheric coverage were selected by means of an empirical method. For each group, a_λ and b_λ were calculated and LD-corrected radiance was retrieved. In the 1.0 μm window, groups of pixels having the same LD-corrected 1.31 μm radiance (describing the cloud coverage) and the same surface elevation (furnished by Magellan data), linked to surface temperature, were selected, and it has been possible to calculate a_λ and b_λ, and obtain LD-corrected radiance.

Results

Parameters of the linear relation between normalised radiance emerging from atmosphere and $\cos\theta$ were calculated for the windows at 1.0, 1.31, 1.74, 2.3 μm and for the thermal emission at 3.71 μm. It has been found that they depend strongly on the height of the atmospheric layer where emission is originated. Then, at 1.74 μm and 2.3 μm our results agree with those obtained in [4].

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