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Contrasts in near-IR images of the Venus clouds (VMC/VEx) and their probable causes

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1 Introduction

The Venus Monitoring Camera (VMC) onboard the Venus Express (VEx) spacecraft, successfully operated in orbit around Venus since April 2006 until November 2014. It has been imaging Venus in four narrow spectral channels centered at the wavelengths of 0.365 µm (UV), 0.513 µm (VIS), 0.965 µm (NIR1), and 1.010 µm (NIR2) [1]. It took around 350 000 images in four channels covering almost all the latitudes, including night and day sides.

The clouds of Venus scatter radiation in the visible and near infrared wavelengths nearly conservatively and the planet disk has very little contrast. However, many features are observed in UV. The contrast in UV, which is partly caused by SO_2 (in the range between 0.20 and 0.32 µm) and partly by the so-called "unknown UV absorber" (at about 0.365 µm) reach 20 – 30 % [2, 3], while the contrasts in NIR and VIS channels do not exceed 2 – 4 %. Though they are not as numerous and pronounced as the usually considered UV-contrast patterns characteristic of the appearance of the Venus upper cloud deck in UV, their causes remain unclear. So, to study such cases was the aim of the current work.

2 Method

To retrieve the properties of cloud particles from the images of clouds, the phase profiles of brightness obtained from these images taken at small phase angles are used. The shape of the glory feature observed at small phase angles allows the size of scattering particles and, sometimes, their refractive index to be determined. In our previous works it was shown that there is a strong connection between the positions of glory minimum and maximum and particles' sizes [4–7], and ese positions do not change when we compare the single-scattering phase function of particle (red curve in fig. 1), and the phase profiles retrieved for the optically thick layer (see fig. 1).

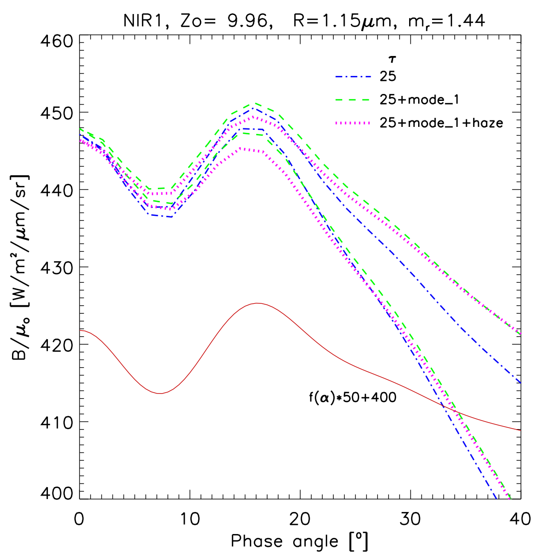

Figure 1: The angular position of glory on the upper deck of the optically thick layer (three sets of the curves) is determined by the single-scattering phase function of the particles f(α) that dominate the scattering in this layer (lower curve; $\lambda = 0.965$ μm, $R_{eff} = 1.15$ μm, $m_r = 1.44$). The brightness coefficient of the plane-parallel layer (the optical thickness $\tau = 25$) with the presence of small submicron particles (mode 1, 95% of the total number of particles in the cloud) and the upper haze of such particles ($\tau_h = 0.05$) was calculated with the radiative transfer code described by [8]. The solar zenith angle is fixed at approximately 10°, while the zenith angleof observations Z_0 is changing, which provides the change in the phase angle α; two branches of the curves correspond to the azimuths 0° and 180°.

Due to the technical reasons, the VEx observations at small phase angles were rare, and such near-IR images, containing contrast features, were obtained in less than a dozen of orbits. The phase profiles of the NIR-dark and NIR-bright features seen in these images are analyzed. They are also compared to the phase profiles obtained from the simultaneously taken UV or visible images (if available). No unambiguous correlation between the brightness of the considered features at different wavelengths has been found: sometimes the contrasts of the same or opposite signs (the feature that is seen as bright (or dark) object in one channel is seen as bright (or dark) in the other one) are observed at the other wavelengths, sometimes not. This may be caused by the fact that different cloud levels are sounded at different wavelengths.

3 Results

The comparison of the measured phase profiles to the single-scattering phase functions of particles with different sizes and refractive indices and the phase profiles of clouds modeled with the radiative-transfer code has shown that

- in most cases, the sizes of particles in the NIR-dark and NIR-bright features are the same;
- in the NIR images (as well as in the visible ones) the higher brightness may be caused by a higher refractive index of particles in the clouds or/and the higher optical depth of the clouds; the effect of the higher refractive index on the UV profiles is opposite due to absorption;
- the presence of small submicron particles in the clouds and, especially, above them produces a considerable effect on brightness in UV and visible, while its influence on the NIR brightness is very weak.

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