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Evaluation of the atmospheric extinction on Venus at different wavelengths

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Abstract

In this work the extinction resulting by radiation originated at different heights of the Venusian atmosphere is measured using nightside VEX-VIRTIS data. In particular a statistical method is applied to the spectral windows in the Near InfraRed.

1. The Extinction Factor

In order to study the extinction experienced by the thermally emitted radiation passing through the Venus atmosphere, a parameter named Extinction Factor has been introduced, defined as:

$$EF_{\lambda} = 1 - \frac{I_{\lambda}(\theta *)}{I_{\lambda}(0)} \qquad (1)$$

where $I_{\lambda}(\theta^{*})$ is the thermally emitted radiance coming out from the atmosphere at a defined emergence angle θ^{*} (i.e. angle between the direction of observation and the normal to the surface) and $I_{\lambda}(0)$ is the thermally emitted radiance at Nadir ($\theta°=0$).

EF=0 means that radiation emerging from atmosphere is observable only if emergence angle is lower than θ^{*}, i.e. atmosphere strongly absorbing, while EF=1 indicates independence of radiance coming out from atmosphere on emergence angle, and hence a completely transparent (or absent) atmosphere.

EF has been calculated at five wavelengths, corresponding to emission originating at different heights: 1.03 μm, characterised by the surface emission [1], 1.31 μm, 1.74 μm and 2.30 μm, characterised by the emission originated below the clouds deck (0-30 km, 15-35 km and 25-45 km respectively [2]), and 3.72 μm, characterised by the upper clouds emission (62-73 km [3]).

2. Retrieval of I(θ) function

In advance to the Eq. (1), it has been necessary to compute the I(θ) function at different wavelengths. The Eddington equation, according to which radiance depends linearly on emergence angle, provides a very good approximation for atmospheres with a high reflectivity (close to 1) and a high optical depth (at least 20) [4]. On Venus, this condition is verified only for wavelengths lower than 2.6 μm [3]:

$$I_{\lambda}(\cos\theta) = a_{\lambda} + b_{\lambda}\cos\theta \qquad (2)$$

where a_{λ} and b_{λ} depend only on optical depth in the case in which emission is generated in the atmosphere, and on both optical depth and surface emission otherwise.
In particular, if the emission source is placed in the upper atmosphere, the dependence of I_{λ} on cosθ is quadratic [5]:

$$I_{\lambda}(\cos\theta) = a_{\lambda} + b_{\lambda}\cos\theta + c_{\lambda}\cos^{2}\theta \qquad (3)$$

A statistical analysis on the VIRTIS data [6] made it possible to retrieve the parameters of Eq. 2 at 1.03 μm, 1.31 μm, 1.74 μm and 2.30 μm and those of Eq. 3 at 3.72 μm. For each wavelength, the average values of a_{λ}, b_{λ} and (at 3.72 μm) c_{λ} have been obtained, and then $I_{\lambda}(\theta *)$ has been computed and inserted into Eq. 1 to retrieve EF_{λ}.

3. Results

From this analysis EF has been found to show a strong dependence on altitude where emission is originated (Table 1). In particular, EF is maximum at 1.03 μm, where emission is originated at the surface, and slowly decreases at increasing wavelength (i.e. at increasing height of radiation origin). This is not an obvious result, since the cloud deck optical depth grows from 1.03 μm to 1.74 μm [7, 8].

Table 1: Extinction Factor as function of height of radiation origin.

Wavelength (μm)	Height (km)	EF
1.03	0	0.48
1.31	0-25	0.46
1.74	15-35	0.43
2.30	25-45	0.40
3.72	62-73	0.32

In fact, we can identify two factors affecting the EF: the cloud deck extinction and the atmospheric thickness traversed. The cloud deck optical depth becomes larger from 1.03 μm to 1.74 μm and then decreases [7, 8], while the atmospheric thickness traversed decreases at increasing wavelength. Since the found EF values decrease from 1.03 μm to 1.74 μm, it is possible to conclude that, within these wavelengths, the extinction suffered in the lowest atmospheric layers is more important than the extinction suffered in the cloud deck.

This result could indicate the presence of a cloud layer located near the surface, as proposed by [9], and a haze particles population starting from 30 km, as suggested in [10].

Moreover, we found that the curve better fitting the behavior of EF with the height H of radiation origin is a straight line (Fig. 1):

$$EF=EF_0-\Gamma H \,, \qquad (4)$$

where EF_0 is the Extinction Factor for H=0 and Γ indicates the decrease rate of EF with the height. Extrapolating the height H* where EF vanishes, we found H*=200±30 km, that is considered the upper boundary of ionosphere [11]: this represents the height above which atmosphere is completely transparent and hence could be considered an ideal limit of the Venusian atmosphere.

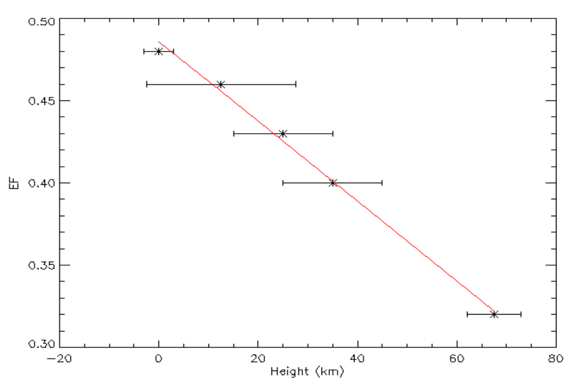

Figure 1: EF as function of height of radiation origin. The red line is the best linear fit.

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