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Time evolution of the O_2 IR Atmospheric nightglow: VIRTIS observations and comparison with a 2-D model

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Abstract

The $O_2\,(a^1\Delta)$ emission at 1.27 µm results from three-body recombination of O atoms produced on the day side and transported to the night side by the global solar to antisolar circulation. It is variable in brightness and shows a peak generally located between 95 and 100 km. In this study, we present individual nadir images of the O_2 $(a^1\Delta)$ nightside airglow emission [1,2] obtained with VIRTIS IR on board Venus Express [3]. A total of 460 VIRTIS images lasting several hours are used to determine the spatial and temporal variations of regions of enhanced excited O_2 $(a^1\Delta)$ density.

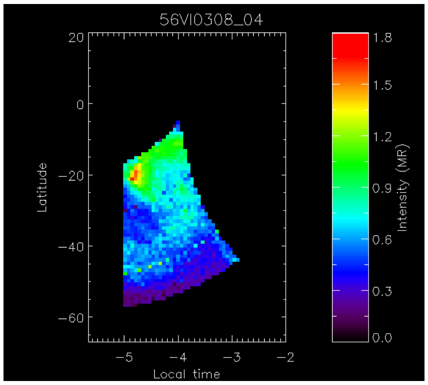

Figure 1: example of a region of enhanced O_2 infrared airglow emission.

The intensity may either increase or decrease during the observation period. Intensity drop is expected as a result of three competing processes: (1) the radiative lifetime of the $O_2\,(a^1\Delta)$ metastable state of 75 min, (2) the effective lifetime of oxygen atoms versus chemical recombination and (3) changes in the local downward flux of O atoms carried by dynamical processes (diffusion, advection).

From the intensity variations, we determine the characteristic rate of change of the bright airglow spots. Their e-folding times have been calculated. The mean decay time is in good agreement with the previous study by [4] who calculated O and CO_2 density profiles using VIRTIS and SPICAV observations. Indeed, if quenching of O_2 $(a^1\Delta)$ is neglected:

$$\frac{d[O]}{dt} = -k[O]^2[CO_2] = -\frac{1}{\tau}[O] \qquad \Rightarrow \tau = \frac{1}{k[O][CO_2]}$$

where $k=3.1\times10^{-32}$ cm^6 s^{-1}, $[CO_2]=7.2\times10^{14}$ cm-3 and $[O]=(2/0.5)/2\times2\times10^{11}=4\times10^{11}$ cm^{-3} at 97 km. In this case, we find a value of $\tau\sim1900$ min, which is in very good agreement with the value deduced from observations.

We compare these results with those of a two-dimensional model of the oxygen chemistry and dynamics [5]. In this model, a time and space varying flux of O atoms is prescribed through the upper boundary and a free boundary condition is used on the lateral boundary. The spot brightness evolution has been simulated with a 2-D model by imposing a localized increase of the oxygen flux at the upper boundary. The evolution of the $O_2(a^1\Delta)$ volume emission rate is represented in Figure 2.

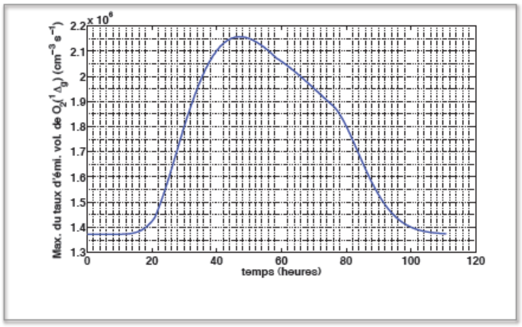

Figure 2: two-dimensional simulation of the volume emission rate at 1.27 µm with a horizontal wind of 25 m s^{-1}.

The horizontal motion of the spots is used to determine the wind speed in the 95-100 km region. Values are in the range of 25 to 150 m s^{-1}, in good agreement with an earlier study.

A statistical study of the location of the brightest region of emission in each picture frame indicates that their locations on the Venus nightside are very variable. However, a concentration of peak detection is observed at low latitude around the midnight, in agreement with earlier results based on a statistical map.

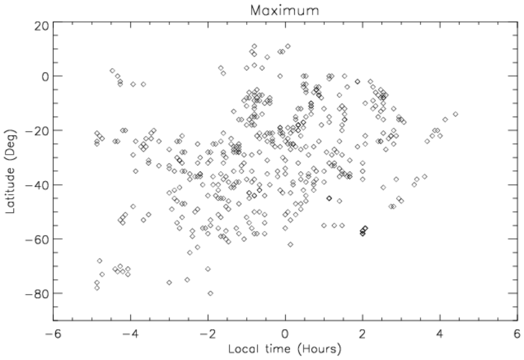

Figure 3: variable position of the centers of the 1.27 μm bright patches

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