Oxygen airglow emission on Venus and Mars

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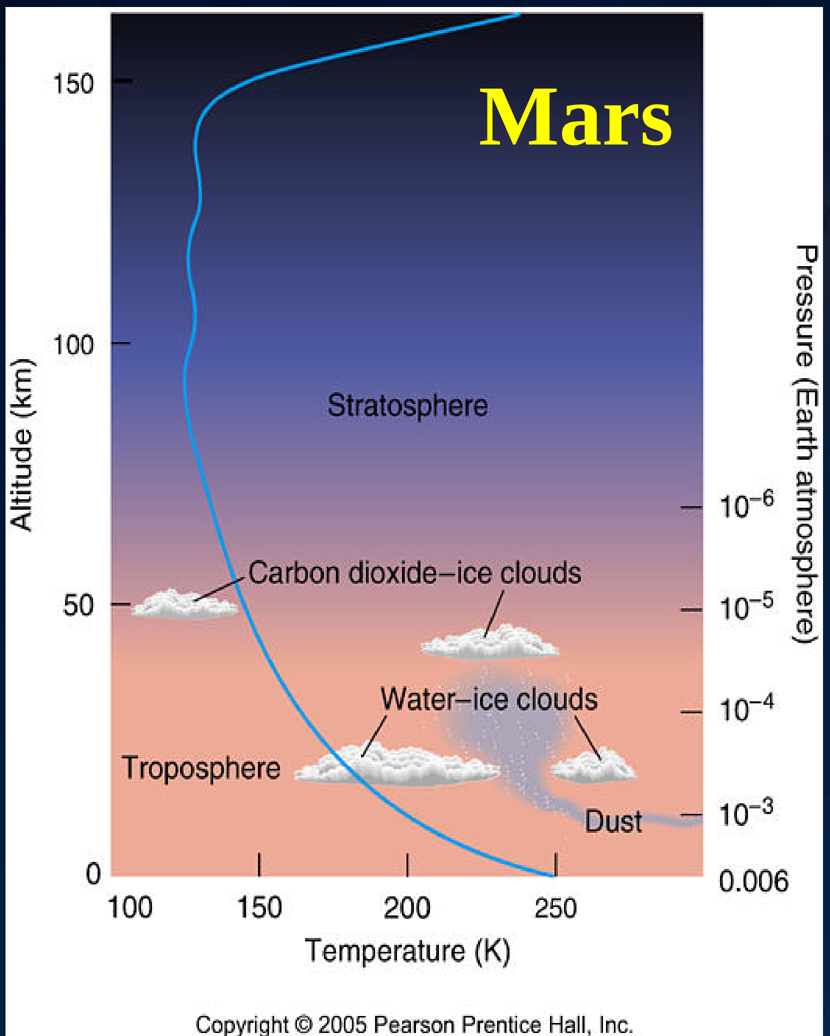
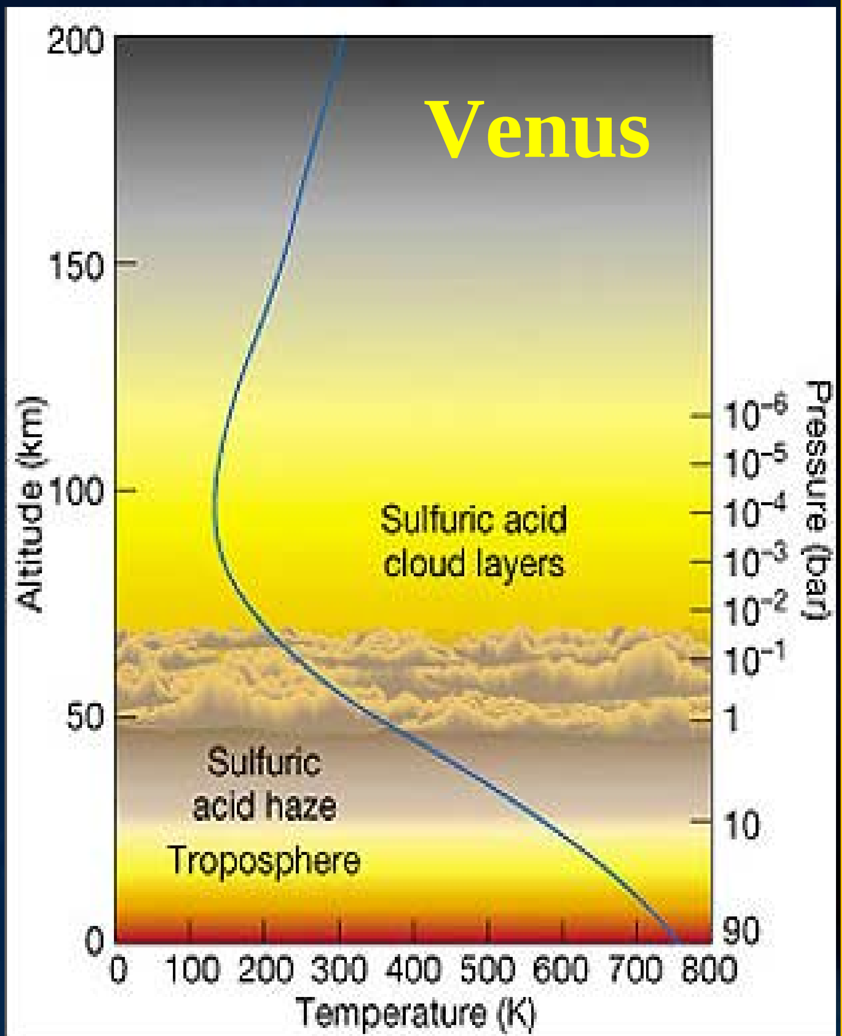
Outline

- ❖ Atmosphere of Venus and Mars
- ❖ Oxygen airglow on Venus and Mars: chemical reactions
- ❖ Spatial and vertical distribution of (0-0) oxygen transition on Venus
- ❖ Seasonal distribution of (0-0) oxygen transition on Mars
- ❖ Wave detection on Mars
- ❖ Summary

Atmosphere on …





Excited oxygen on …

Mars

Mechanism to produce excited $O_2(a)$ on the day side of Mars:

$$O_3 + h\nu \rightarrow O_2(a^1\Delta_g) + O(^1D)$$

while on night, oxygen emission occurs directly from 3-body recombination:

$$2O + CO_2 \rightarrow O_2 + CO_2$$

Venus

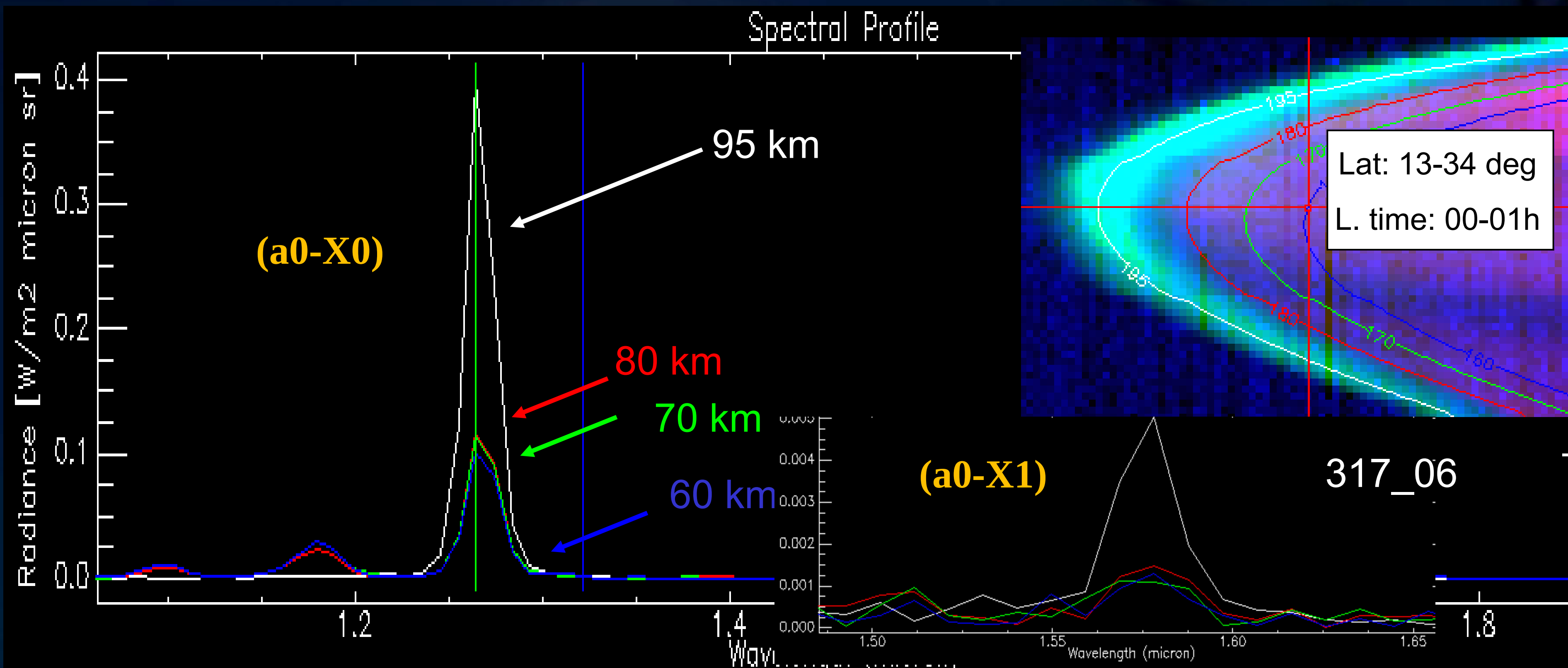
Mechanism to produce excited $O_2(a)$ on the night side of Venus:

$$2O + M \rightarrow O_2^* + M$$
$$O_2^* + M \rightarrow O_2(a) + M$$

which decade from the a-state, emitting photons around 1.27µm and 1.58µm.

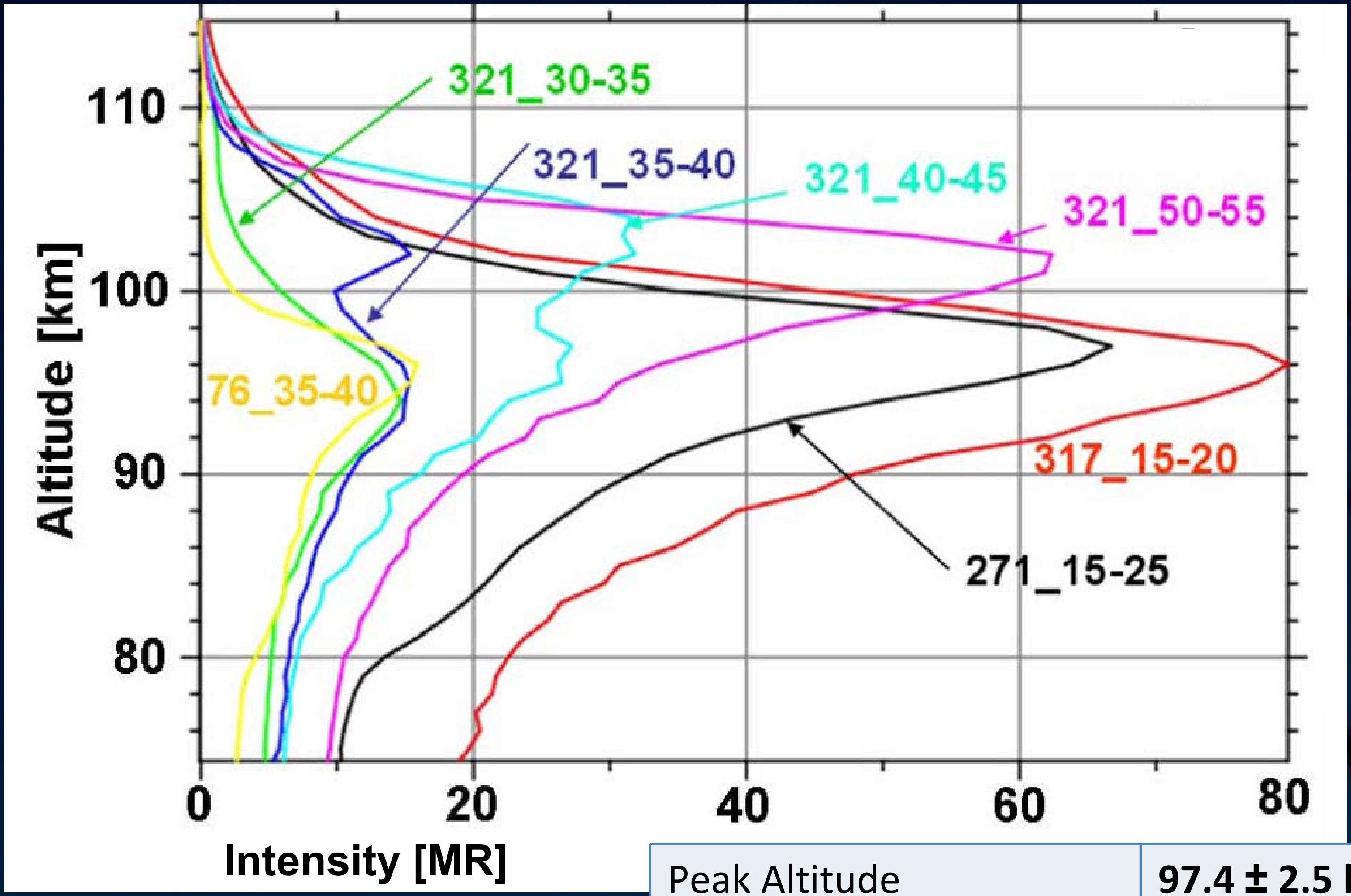
VIRTIS/Venus Express observations of O_2 on Venus

VIRTIS is the imaging spectrometer on board Venus Express mission, which operates in the visible and IR specral ranges, using two channels, one with mid resolution (10nm in the IR), and one with high resolution (3nm). The scientific objectives of the instrument are related to atmospheric composition, structure and dynamics as well as study of the Venus' surface.



On limb mode, the airglow can be spatially separated from the clouds contribution, as the latter becomes important below 85km. Spectra in the altitude range from 90 to 100km are averaged, in order to increase the S/N ratio.

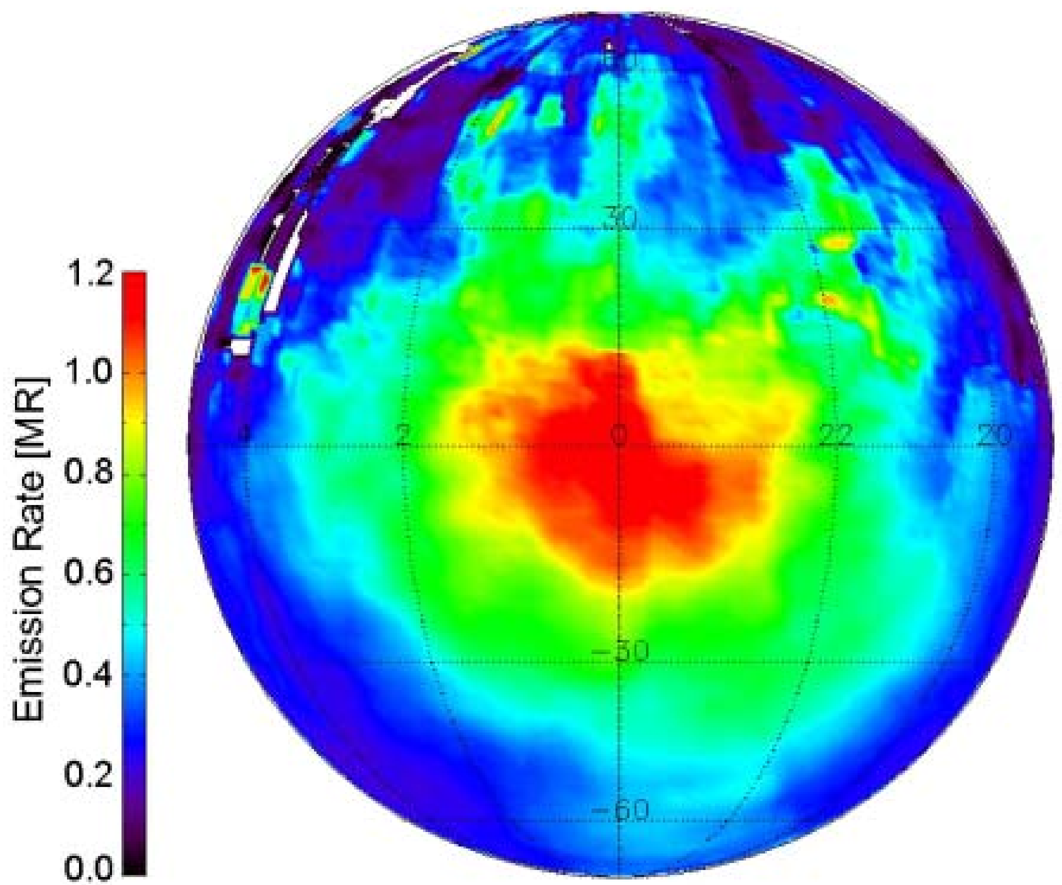
Vertical profiles and FWHM



Piccioni, et al., JGR, 2009

Peak Altitude	**97.4 ± 2.5 km**
FWHM	**7.6 ± 2.2 km**
Tot vertical emission rate	**0.52 ± 0.4 MR**

Spatial distribution on Venus

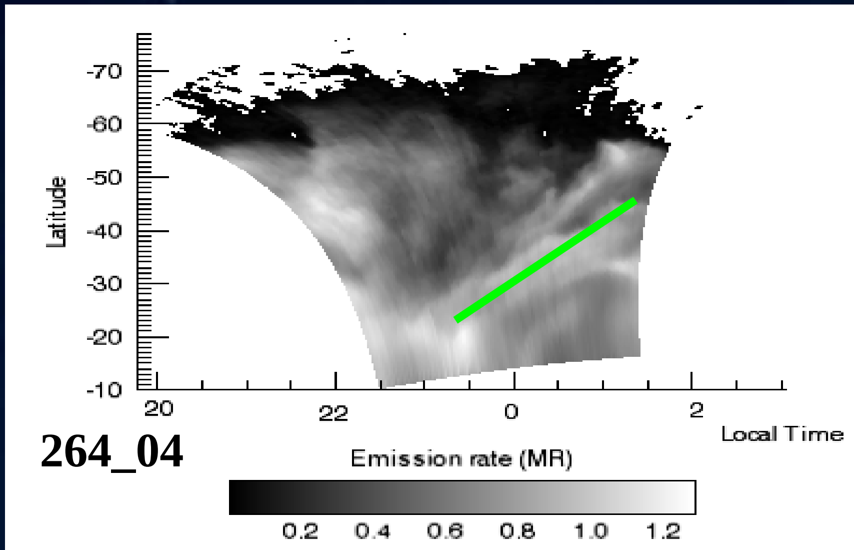


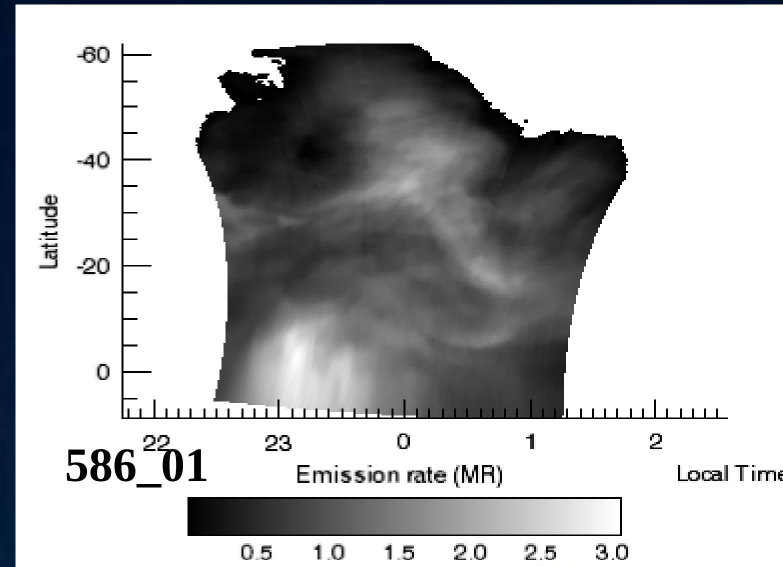
Mean global map of the (0,0) oxygen nightglow

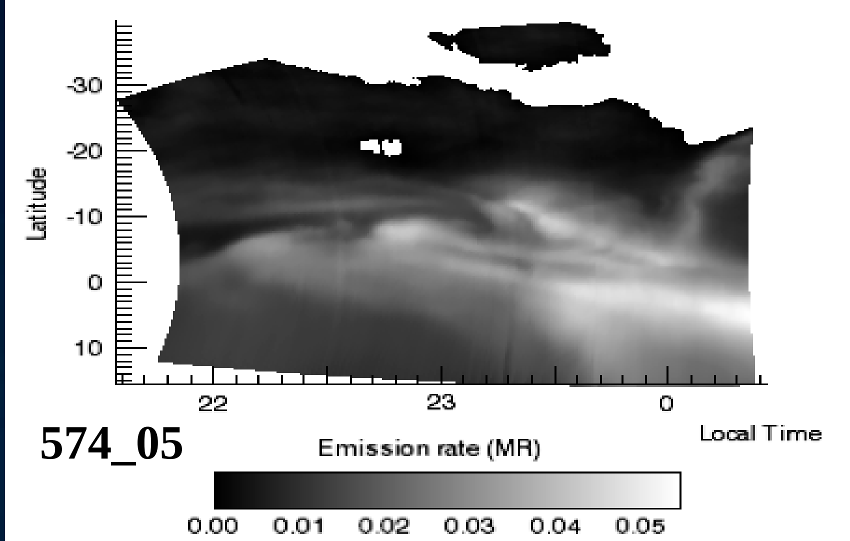
Piccioni, et al., JGR, 2009

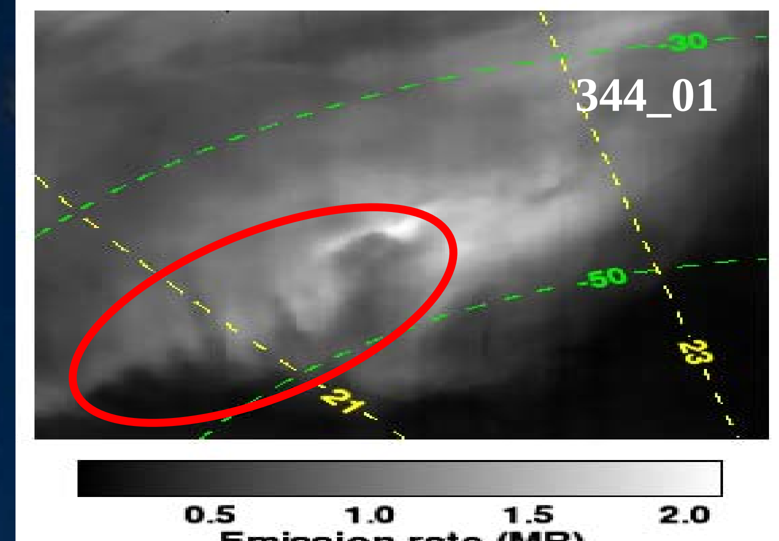
Average of data acquired on 880 orbits in Nadir mode, with VIRTIS, with an exposure time greater than 0.3 sec in the period April 2006 to September 2008. Thermal contribution is estimated from the 1.18μm CO_2 window. Emission rate has a maximum value of 1.2MR, and it is slightly asimmetric with respect to the anti-solar (AS) point, placed about 5°S wrt the AS point.

Unregular distribution





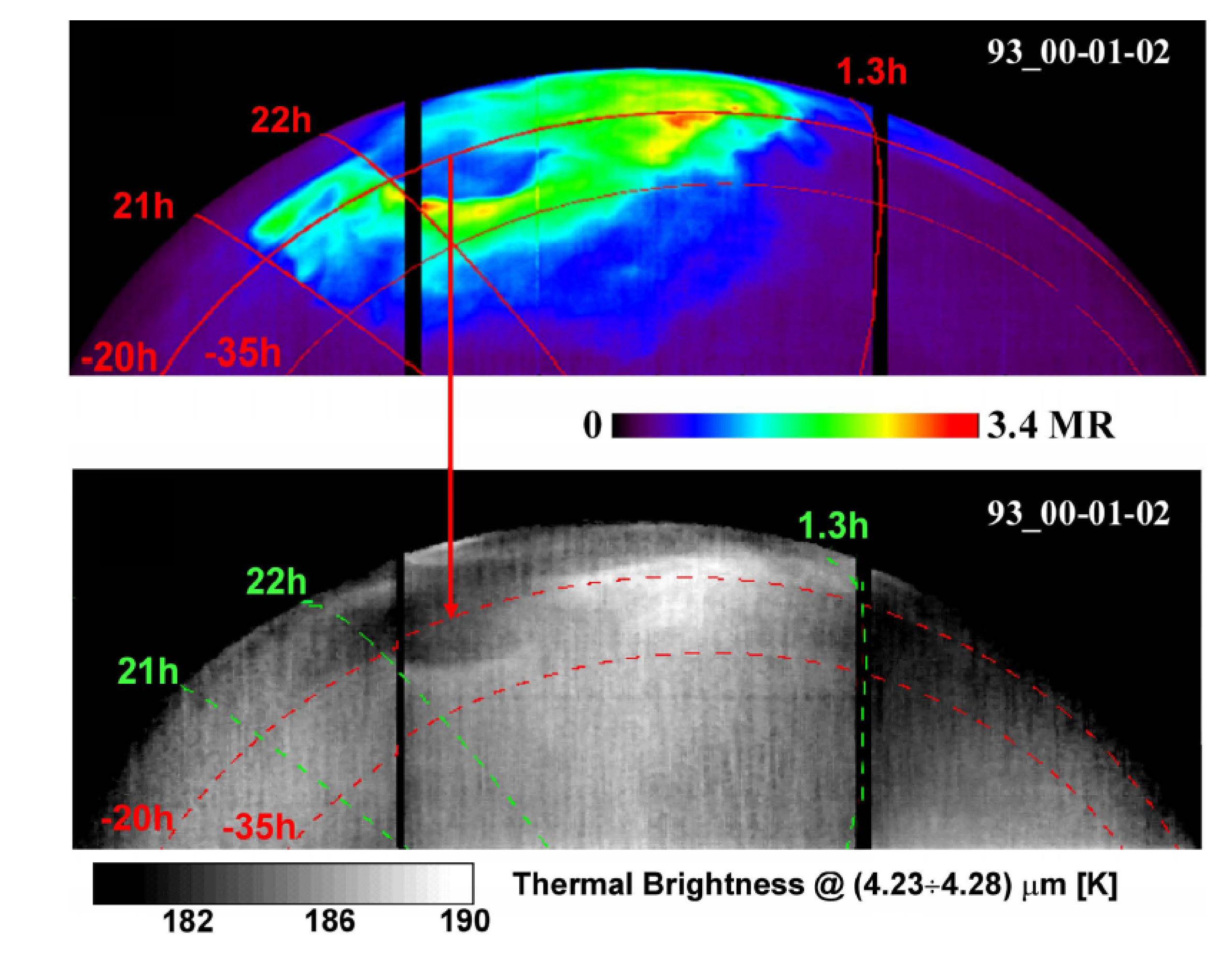




On single images, stripes or elongated shapes are observed. They are sometimes 1700-2300km wide, with no peculiar trend with latitude. Wave patterns are also observed.

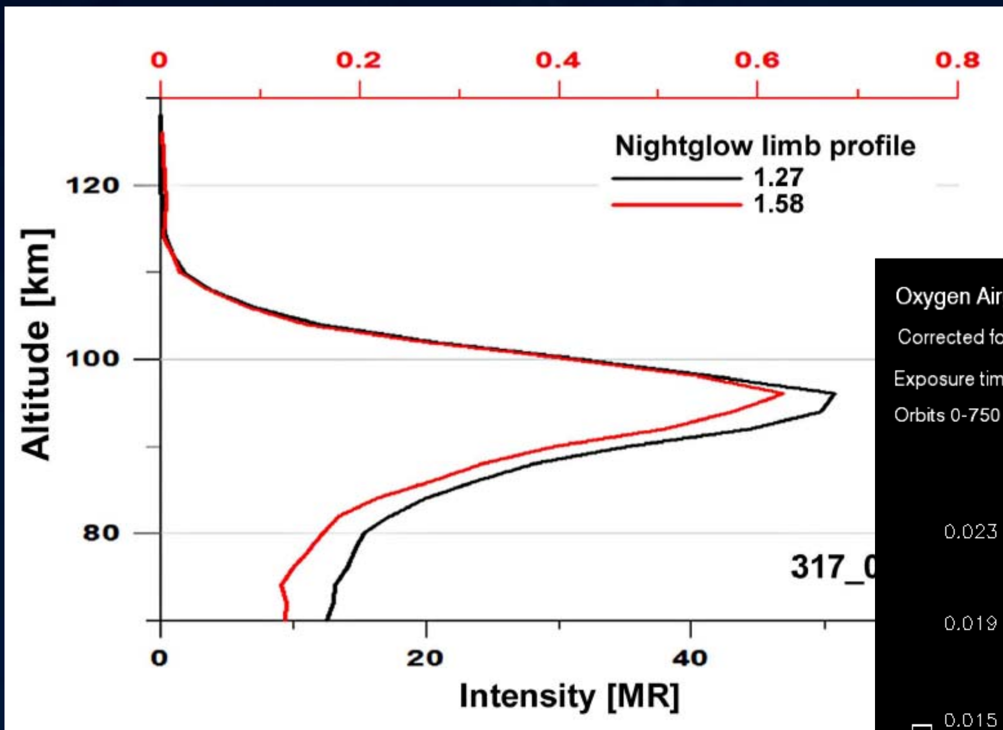
Comparison with thermal brightness

Mosaic of images acquired during orbit 93 (2006-06-22).
A strong correlation between airglow distribution and thermal brightness is observed: the higher the airglow intensity, the warmer the temperature at about 90km height (calculated using the spactral region around 4.26μm). This indicates a strong correlation between airglow and dynamics.



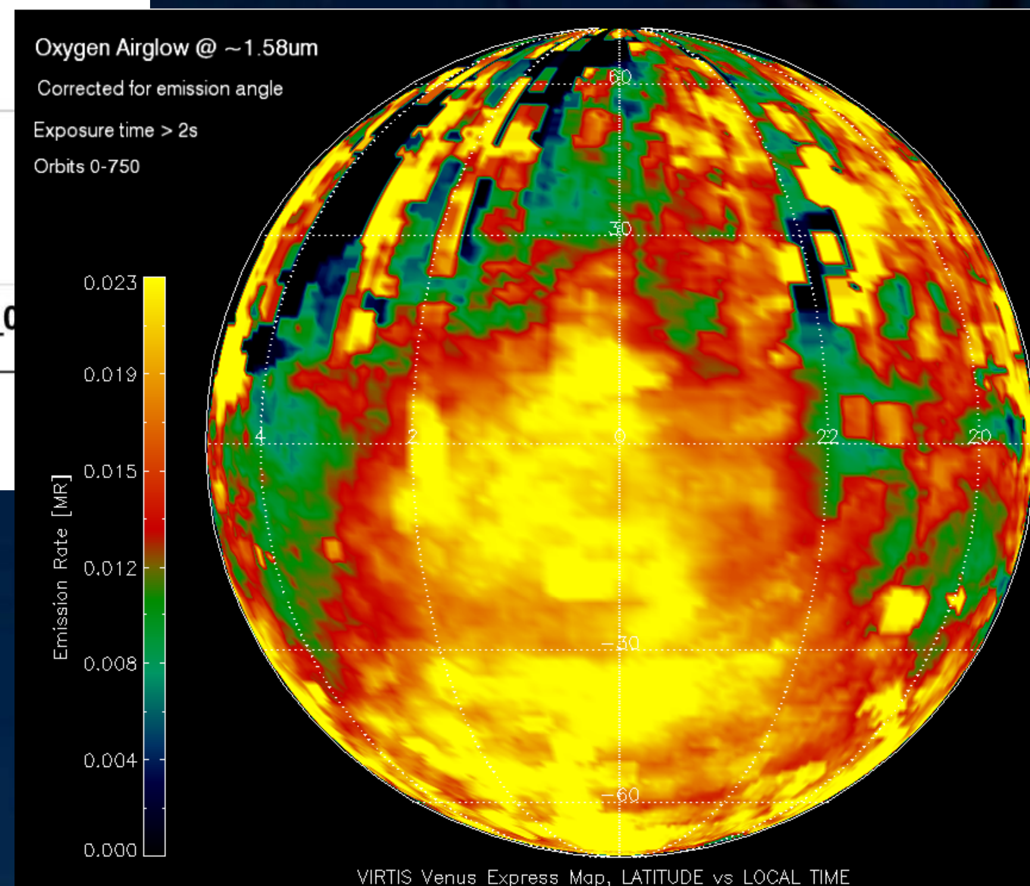
Piccioni, et al., JGR, 2009

(0-1) Oxygen emission on Venus



Piccioni, et al., JGR, 2009

Vertical profiles for (0-0) and (0-1) peak at about the same altitude (approx 97km)

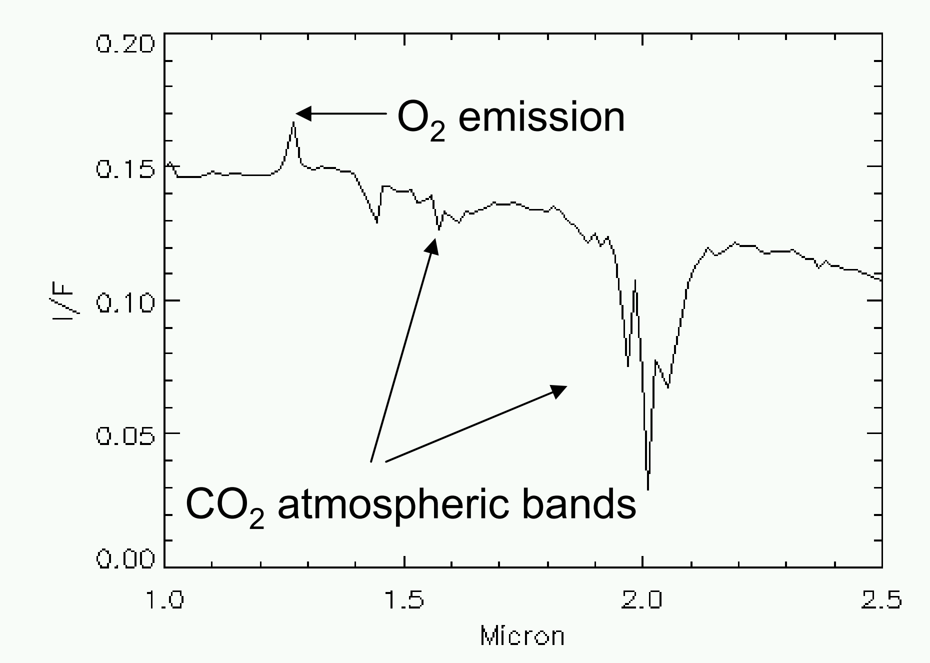


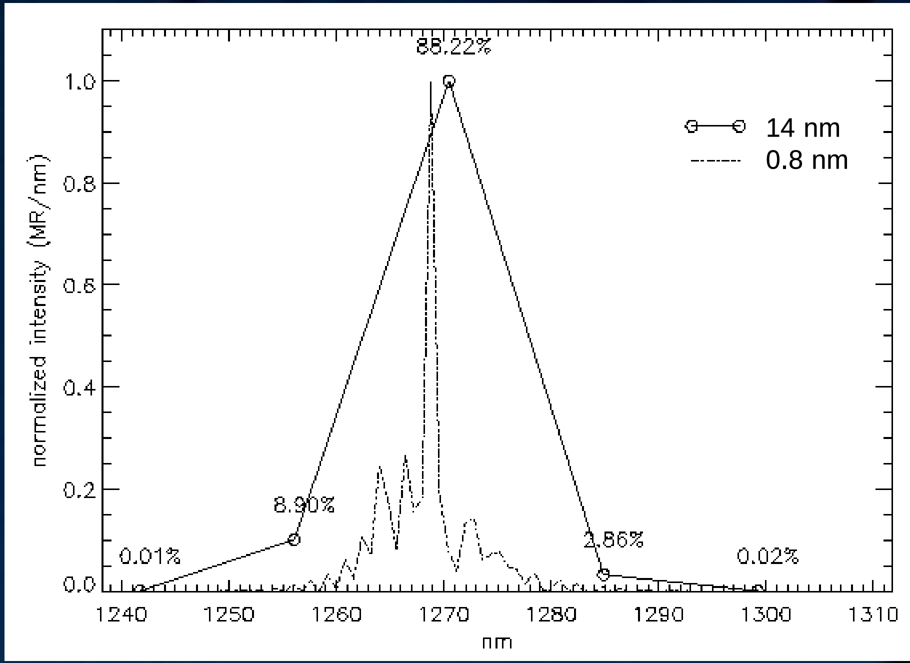
The spatial distribution of (0-1) is quite similar to the (0-0), and the emission rate is about 0.02MR in the anti-solar point.

Mars: O_2 emission as seen by OMEGA

OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité, Bibring et al. 2004) is the imaging spectrometer on board the ESA mission Mars Express in orbit around Mars since December 2003, dedicated to the study of Martian surface and atmosphere. Although spurious spikes can appear in the OMEGA spectra, the O_2 emission a t 1.27 µm is well observed at OMEGA spatial resolution of 14 nm with a detection limit of **4 MR.**

OMEGA presents the advantage of acquiring bi-dimensional maps, allowiong to study longitudinal and latitudinal variations with a spatial resolution of about 1-5 km/px (IFOV = 1.2 mrad, images size: 64 or 128 px) , depending on the position of MEx on its elliptical orbit.





Altieri et al. Icarus, submitted paper

Method

$$(I_{1.271} - I_c) / F_{Sun,1.271} =$$

$$[IF_{1.271} / T_{1.271} - 0.5 \times (IF_{1.256} / T_{1.256} + IF_{1.285} / T_{1.285})]$$

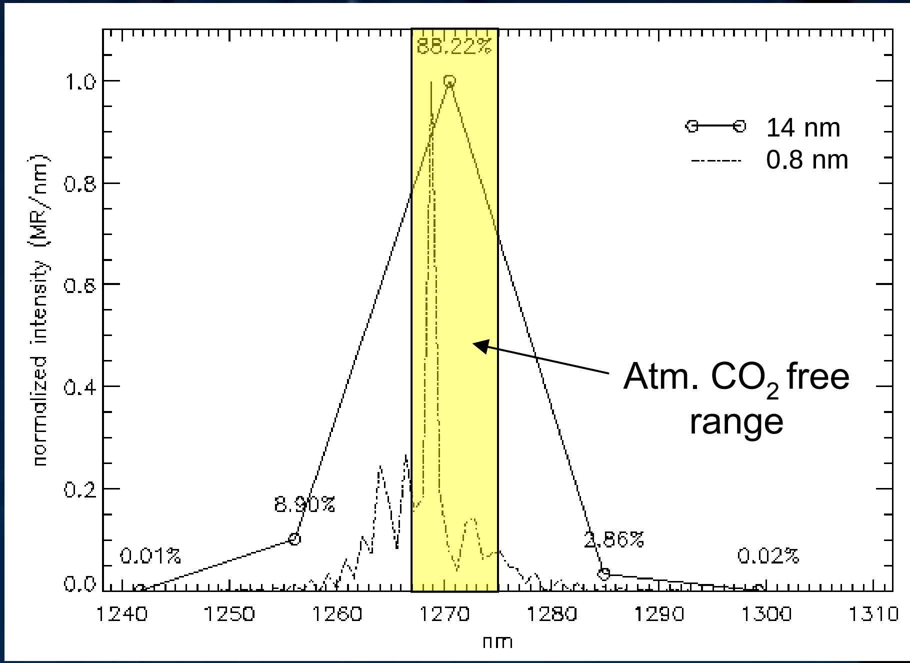
I_c = continuum averaged between 1.256 μm and 1.285 μm

In this way only the **82.3 %** of the emission can be retrieved

Airs mass and surface reflectance correction: method in Krasnapolsky (2003) and Fedorova et al. (2006).

At OMEGA spectral resolution, the continuum (taken at 1.256 μm and 1.285 μm) as well as the spectral channel at 1.271 μm (where most of the emission occurs) are affected by the atmospheric CO_2 and solar absorptions.

- Atmospheric CO_2 → T (Langevin et al. 2005)
- Solar lines → Δ in the IF spectrum
- CO_2 ice band at 1.31 μm (affecting continuum at 1.285 μm) → continuum at 1.256 μm



Altieri et al. Icarus, submitted paper

Vertical distribution of the O_2 dayglow

During the day O_2 ($a^1\Delta_g$) molecules are produce by photolysis of O_3 with an efficency of 90%

$O_3 + h\nu \rightarrow O_2(a^1\Delta_g) + O$, $0.20 < \lambda < 0.31$ µm

Then, from the excited state, the $O_2(a^1\Delta_g)$ can be deactivated through emission or by collision with atmospheric CO_2 molecules.

Emission occurs at two wavelengths:

$O_2(a^1\Delta_g) \rightarrow O_2(X^3\Sigma_g, v''=0) + h\nu$, $\lambda = 1.27$ µm

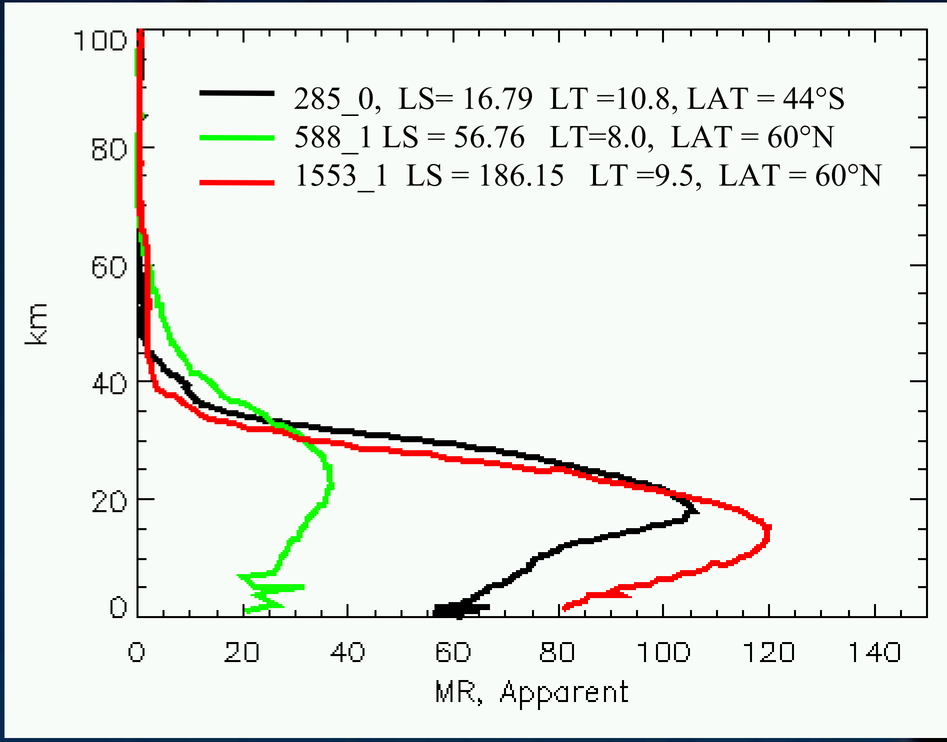
$O_2(a^1\Delta_g) \rightarrow O_2(X^3\Sigma_g, v''=1) + h\nu$, $\lambda = 1.58$ µm

The local amount of ozone on Mars is controlled by the abundance of in odd hydrogen species (H, OH, $HO_2 - HO_x$ family) produced by photolysis of water vapor and its reaction with O(1D)

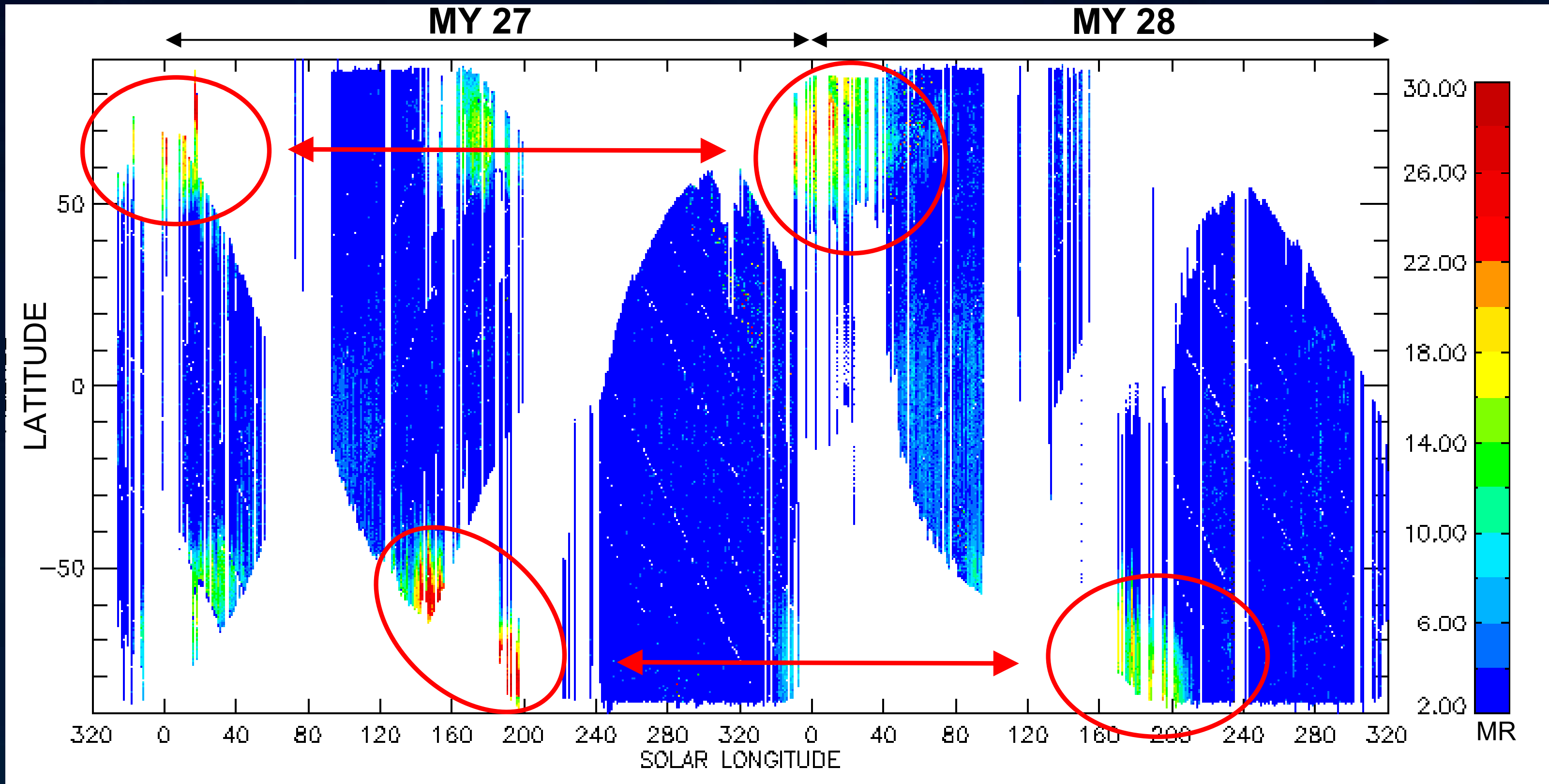
De-excitation through collisions with CO_2 molecules occurs by the following reaction

$O_2(a^1\Delta_g) + CO_2 \rightarrow O_2(X^3\Sigma_g) + CO_2$

It dominates for altitude < 20 – 26 km depending on the season and latitude.

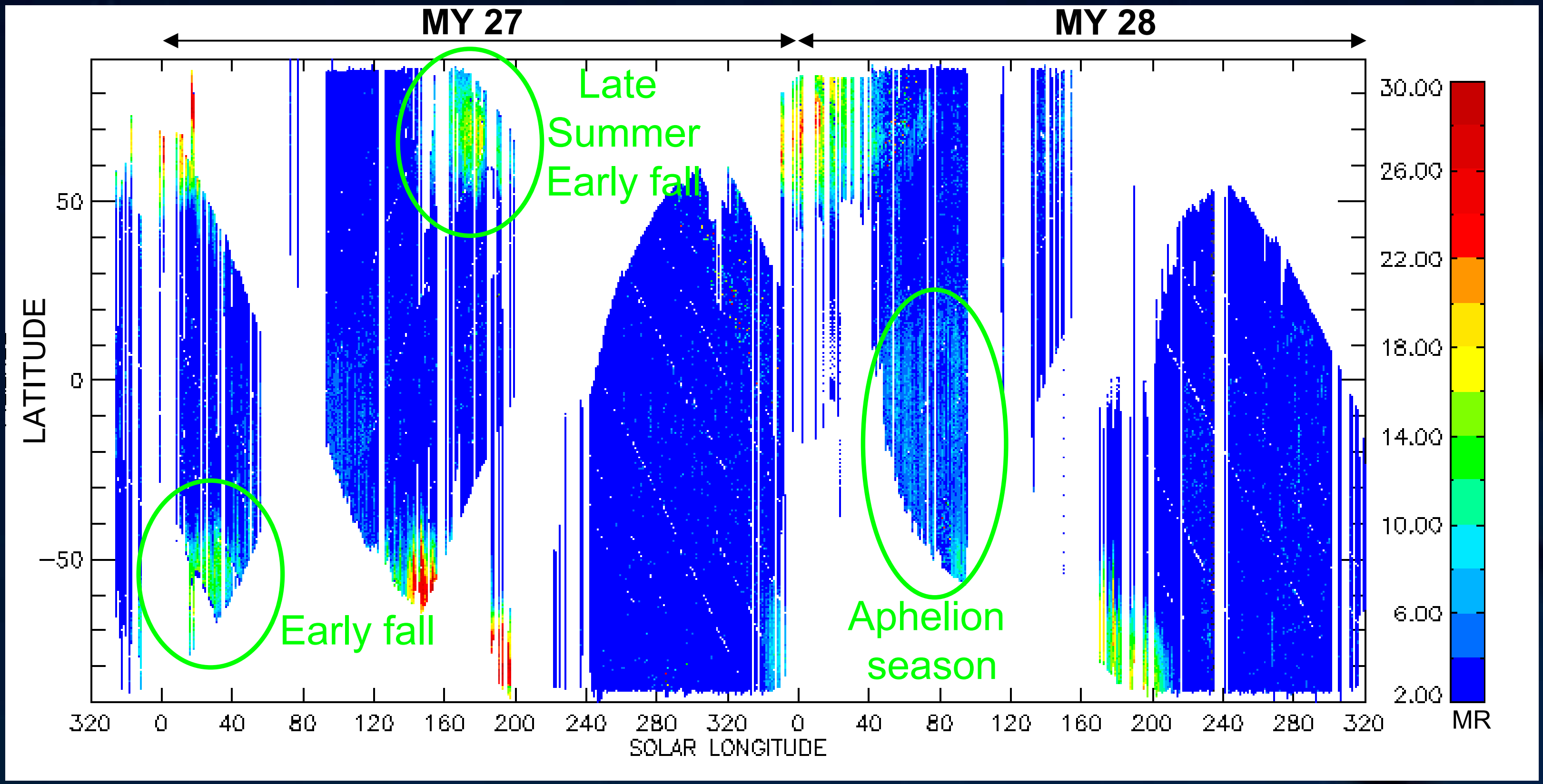


Seasonal map



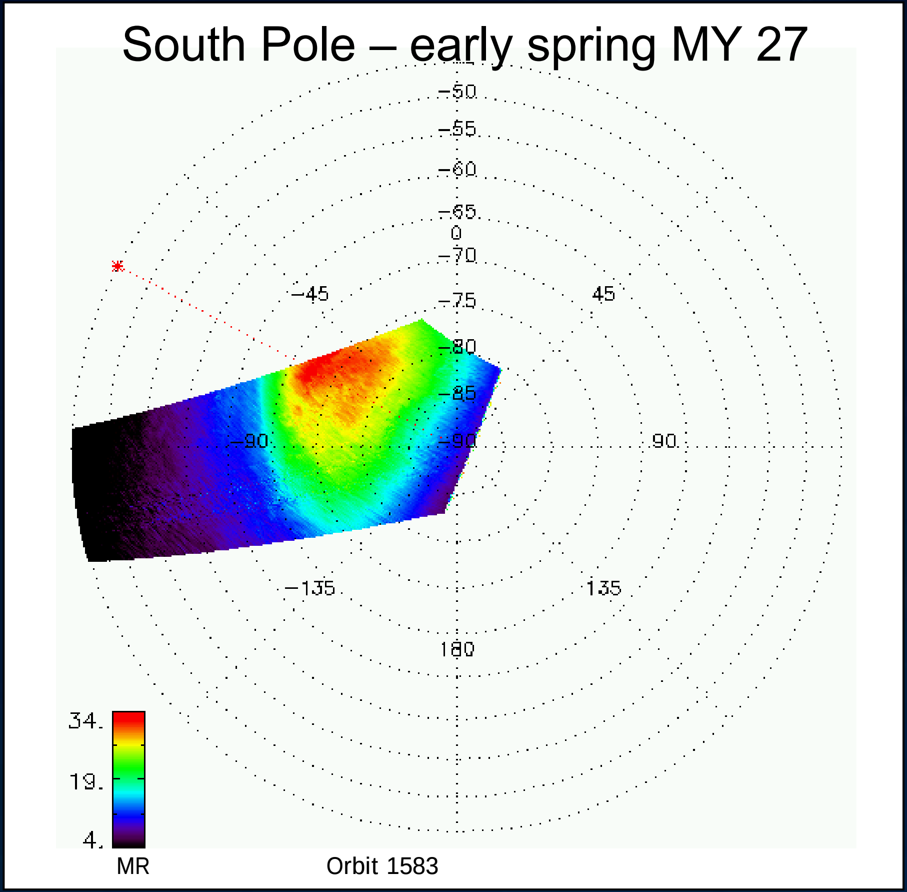
Data acquired in the period Jan 2004-Oct 2007, which corresponds to approx 2 Martian yrs. O_2 intensity is higher at high latitudes, in the region 60-85deg, with a slight asymmetry between Northern and Southern hem. The highest value in the Southern hem is 31MR, while in the Northern is 24MR. The distribution is driven by two factors: H_2O abundance, decreasing with latitude, and with the solar illumination. Maxima are found during the late winter/spring on both hemispheres (before the polar night).

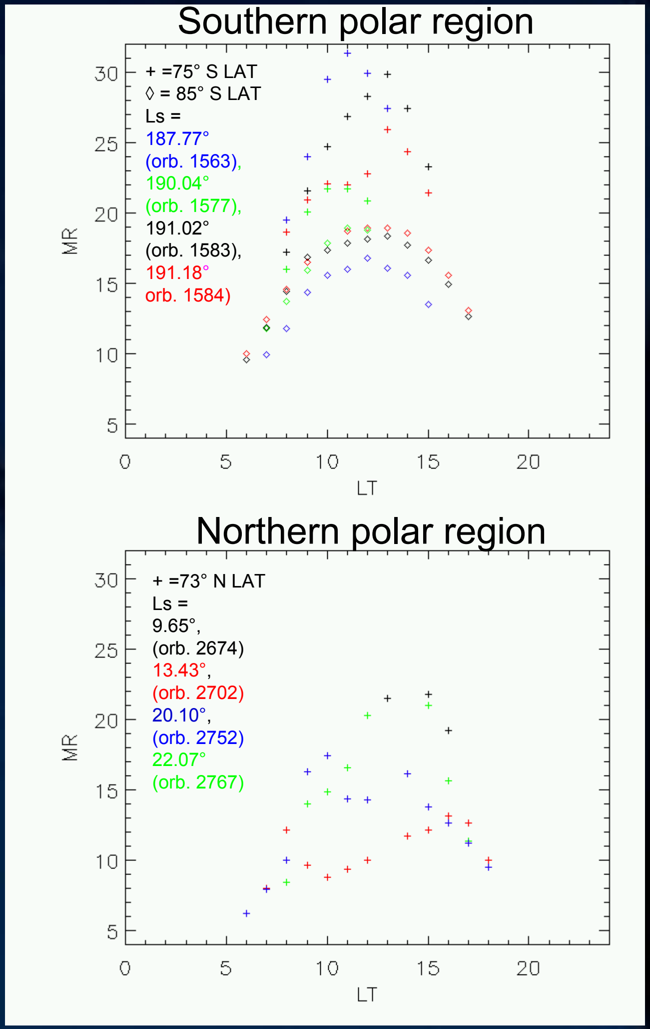
Seasonal map



Fall equinox: increase of O_2 on polar regions on both hemispheres (after the polar night)
Aphelion season: the increase of O_2 (and then of O_3) at mid latitude is due to the decrease of the altitude of the water vapor layer (hygropause).

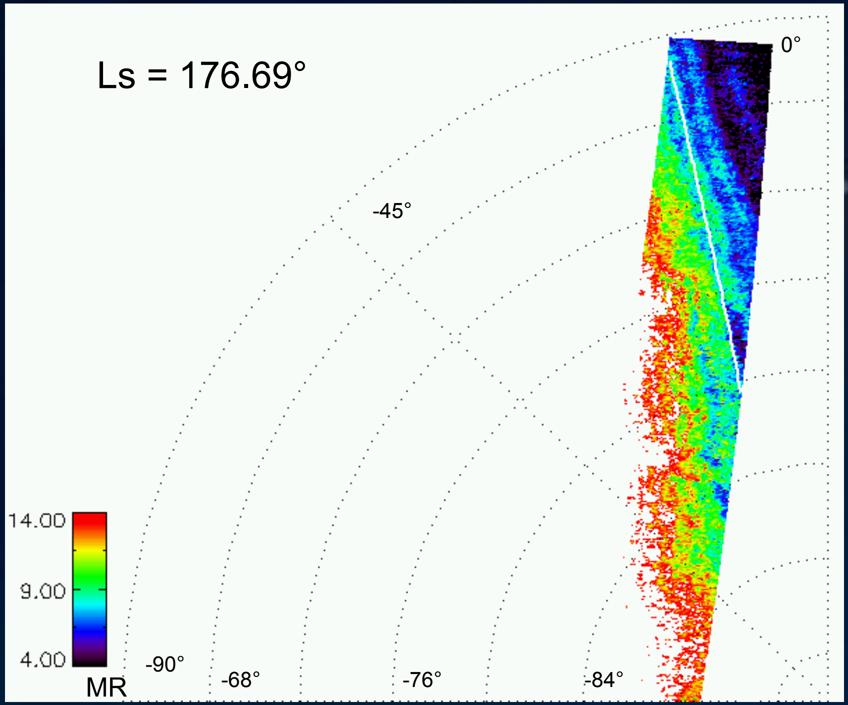
Polar region diurnal profiles

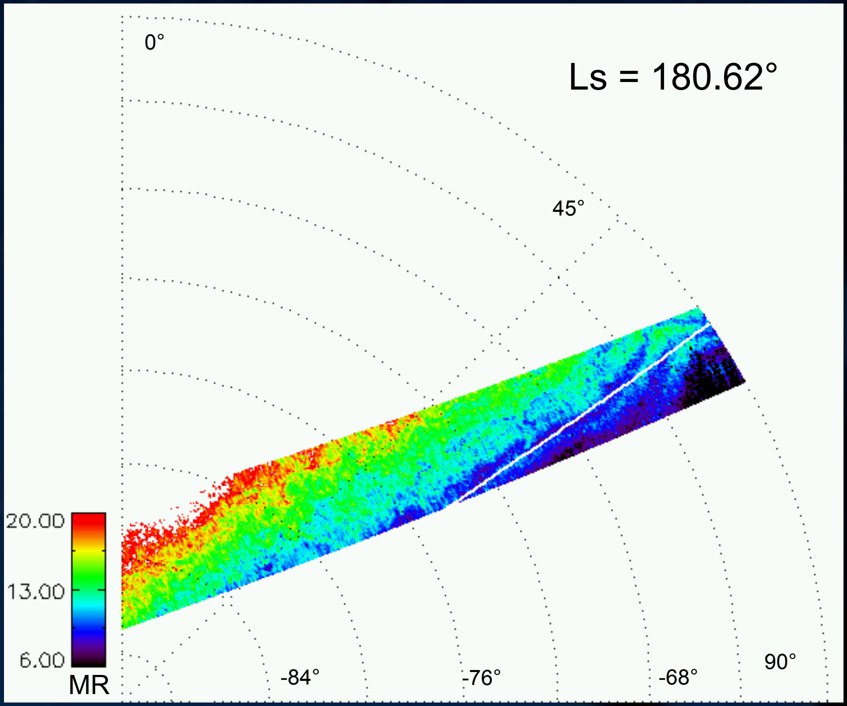




The day by day variability is 30-50% (Perrier et al. 2006) as expected from models (Lefevre et al. 2006)

Martian anomalies: wave patterns traced by O_2 emission





Wave patterns are usually observed at the terminator (white line on the images). They are sometimes parallel to the terminator , sometimes they cross the terminator.
The wave amplitude is about 4MR. The estimated wavelength is variable, being for example 100km for the case on the left and 130km for the case on the right.

Summary

1. Dayglow on Mars and nightglow on Venus are compared, because of instrument sensitivity.
2. On Mars, oxygen dayglow is produced by ozone photodissociation. On Venus, the photodissociation of CO_2 is the most important source for oxygen, on the night side. The predicted amount of ozone is not so high on Venus (estimated value for density product is $[H]*[O_3] = 4\text{-}9 \cdot 10^{15} cm^3$).
3. During day, oxygen is more abundant at the polar region during equinoxes, and it is anti correlated to the water vapor cycle on Mars. On Venus, the O_2 emission is higher close to the anti-solar point.
4. Oxygen airglow is used as a tracer for photochemistry and dynamics in planetary atmospheres. For examples, wave patterns and elongated stripes are observed on both planets.