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The Hydroxyl Nightglow Emissions on Earth, Venus and Mars

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1 – Introduction

The hydroxyl emission in the Earth atmosphere has been extensively studied. Lately, Migliorini et al. (2015, AS24-A001) estimated the relative population of the vibrational levels of the OH nightglow emission. They analyzed the observations by the VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) instrument on board the Rosetta mission during an Earth flyby . A similar VIRTIS instrument was also present on board the Venus Express spacecraft. Despite its low intensity, the hydroxyl emission has been detected in the Δv=1 and Δv=2 Meinel sequences on the Venus nightside (Piccioni et al., 2008). This is an interesting result since the Earth and the Venus atmospheres are very different: their major constituent are respectively N_2 (78%) and CO_2 (96.5%). Soret et al. (2012) performed a detailed quantitative study of these Meinel emissions based on the entire VIRTIS/VEx database, from April 2006 to October 2008. These results will be described here: intensity and altitude of the Meinel emissions, CO_2 quenching scheme modeling and derived relative population levels. The recently observed sequences of the Meinel bands in the Mars atmosphere will also be presented.

2 – OH airglow observed on Earth with VIRTIS

The Rosetta spacecraft performed a flyby suitable to observe the Earth nightside on November 2009. The VIRTIS imaging spectrometer on board was especially adapted to study the hydroxyl nightglow emissions in the infrared spectral range. Migliorini et al. (2015, AS24-A001) analyzed two limb spectra that simultaneously measured both the OH Δv=1 and Δv=2 sequences (Figure 1).

The PGOPHER code (http://pgopher.chm.bris.ac.uk) was used to generate the line intensities of the rotational transitions for each vibrational band at a temperature of 200 K. The synthetic spectrum was then convolved at the VIRTIS resolution. Both sequences of this synthetic spectrum were simultaneously adjusted by a least-square fit, which yielded to the determination of the relative populations of the v=1 to 9 vibrational levels (Table 1).

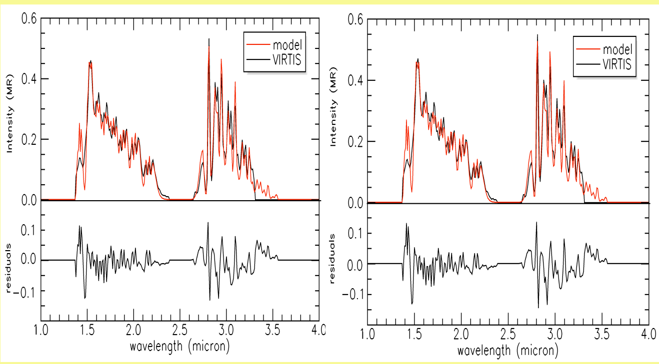


Figure 1: VIRTIS (black) and synthetic (red) spectra for two limb scans. Residuals are shown at the bottom (Migliorini et al., 2015)

Table 1: Relative populations of the OH vibrational levels (from Migliorini et al., 2015)

Vibrational levels	Relative populations
1	5.10 ± 0.5
2	2.80 ± 0.36
3	2.47 ± 0.29
4	1.00 ± 0.14
5	0.67 ± 0.09
6	0.49 ± 0.07
7	0.40 ± 0.06
8	0.38 ± 0.05
9	0.25 ± 0.05

For the first time, the OH infrared nightglow emission was observed from space. Vibrational populations down to *v* =1 could have been deduced. No correction for telluric absorption was needed so that the populations deduced for the 1 to 9 vibrational levels can be considered as quite reliable.

Results have been compared with ground-based observations and theoretical models. A satisfactory agreement is found with the model proposed by *Xu et al.* (2012), assuming a $H+O_3 \rightarrow OH^*+O_2$ (Bates and Nicolet, 1950) production and multi-quantum vibrational relaxation by O_2 and single-quantum relaxation by N_2.

3 – OH airglow on Venus

Piccioni et al. (2008) detected for the first time the OH (Δv=1) and (Δv=2) Meinel sequences emissions on the Venus nightside with the same VIRTIS instrument on board Venus Express (Figure 2).

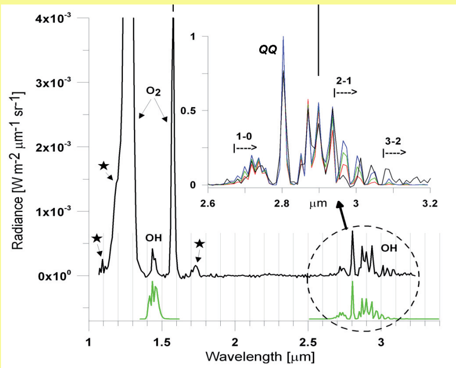


Figure 2: First detection of the OH (Δv=1;2) Meinel sequences in the Venus atmosphere. The (2-0), (1-0), (2-1) and (3-2) bans were identified. The OH synthetic spectrum is shown in green. (Piccioni et al., 2008)

Soret et al. (2012) analyzed two years of VIRTIS-VEx data. They show that the peak intensity and altitude of the two sequences are significantly correlated (Figure 3). The mean intensity ratio of the two sequences is 0.38±0.37, and the Δv=2 emission is located ~1 km lower than the Δv=1.

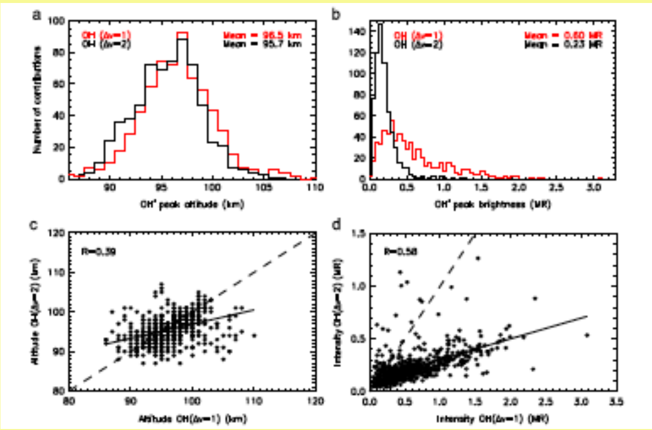


Figure 3: A very good correlation is observed both in altitude and intensity for the OH(Δv=1) and OH(Δv=2) (Soret et al., 2012)

Soret et al. (2012) also produced a non-LTE model of OH vibrational populations to evaluate the CO_2 quenching scheme occurring in the Venusian atmosphere. Figure 4 shows that a Single Quantum quenching process provides a much better agreement in the Venus atmosphere than a Sudden Death collisional relaxation.

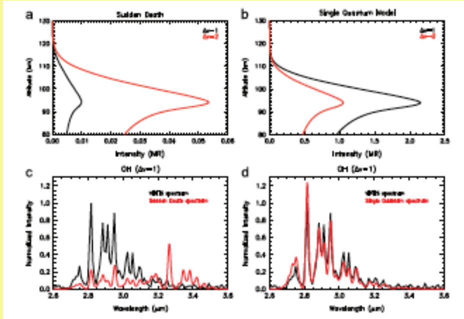


Figure 4: Observations (in black) are better reproduced with a Single Quantum quenching process than a Sudden Death collisional relaxation (Soret et al., 2012)

As Migliorini et al. (2015), a synthetic spectrum has been adjusted to fit the Venus OH(Δv=1) spectrum and relative population levels have been deduced (Table 2).

Table 1: Relative populations of the OH vibrational levels deduced from VIRTIS-Vex observations

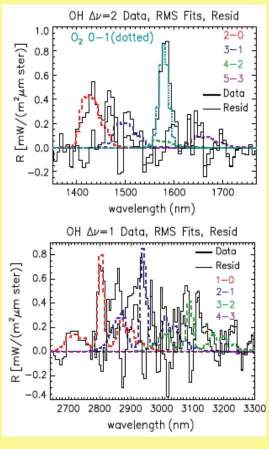
Levels	Relative populations
1	5.94
2	3.64
3	1.82
4	1.00

Important differences can be observed between Earth and Venus. Although the Bates-Nicolet mechanism is the source of OH for both planets, they probably stem from the difference of the atmosphere compositions: CO_2 is the dominant quencher on Venus, while O_2 and O play the major role on Earth to deactivate vibrationally excited OH. Also, quenching by CO_2 seems to occur with collisional cascades on Venus while Earth models favor sudden death deactivation by atomic oxygen as the major process controlling the vibrational population.

4 – OH airglow on Mars

The OH nightglow has been detected for the first time in the Mars atmosphere by Clancy et al. (2013). Average limb intensities of (1–0), (2–1), and (2–0) Meinel bands of 990 ± 280, 1060 ± 480, and 200 ± 100 kR have been determined for 70–90 NS polar winter latitudes over altitudes of 40–56 km.

As for Venus, the Mars atmosphere is dominated by CO_2 and model simulations conclude as well that a Bates-Nicolet production combined with collisional-quenching of the OH vibrational population is more realistic than a Sudden Death quenching scheme.



5 – References

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