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▶ **To cite this version:**

Thérèse Encrenaz, Thomas K. Greathouse, Franck Lefèvre, Franck Montmessin, Thierry Fouchet, et al.. Seasonal and interannual variations of H2O2 on Mars. European Planetary Science Congress 2017, Sep 2017, Riga, Latvia. pp.EPSC2017-175. insu-01669346

**HAL Id: insu-01669346**

**https://insu.hal.science/insu-01669346**

Submitted on 20 Dec 2017

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EPSC Abstracts
Vol. 11, EPSC2017-175, 2017
European Planetary Science Congress 2017
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# Seasonal and interannual variations of $H_2O_2$ on Mars

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## Abstract

Following a long-term monitoring campaign on the abundance and distribution of hydrogen peroxide on Mars, we present a new observation near summer solstice which corresponds to a maximum of the seasonal abundance of $H_2O_2$. Our result is in full agreement with GCM predictions (Lefèvre et al. 2008; [1]). We also analyse previous measurements of $H_2O_2$ in the vicinity of aphelion which seem to indicate the existence of interannual variations, and we discuss their possible origin.

## Introduction

Hydrogen peroxide is an important tracer of Martian photochemistry, possibly responsible for the absence of organics at the surface of Mars [1, 2]. For over ten years, we have been monitoring its abundance and distribution over the disk of the planet along the seasonal cycle using ground-based high-resolution imaging spectroscopy. Comparison with global climate models has favoured the GCM model of the Laboratoire de Météorologie Dynamique based on heterogeneous chemistry [3, 4, 5].

In this abstract, we present a new observation of Mars obtained on May 7, 2016, near opposition, under an especially favourable geometry. The disk diameter was 17″ and the solar longitude was 148.5°.

## 1. Observations

Our observation was performed using the TEXES instrument (Texas Echelon Cross Echelle Spectrograph; [6]) at the IRTF (InfraRed Telescope Facility), at Maunakea Observatory. As for our previous observations, we aligned the slit of the spectrograph along the North-South celestial axis and we moved the slit in the East-West direction from one limb to the other. As the slit length is about 10″, the northern and southern hemispheres of Mars were recorded sequentially. The observations took place on May 07, 2016, starting from 08:31:25 UT and lasting for 30 minutes. We used the 1230-1238 $cm^{-1}$ spectral interval (previously observed in 2003) that contains an $H_2O_2$ doublet (at 1234.00 and 1234.05 $cm^{-1}$) with nearby weak $CO_2$ transitions. As in our previous analyses, our $H_2O_2$ map was obtained by dividing the line depth of the $H_2O_2$ doublet by the line depth of a nearby weak $CO_2$ line.

## 2. The $H_2O_2$ map for Ls = 148°

Figure 1 shows the TEXES disk-integrated spectrum between 1232.5 and 1234.2 $cm^{-1}$, with a nominal synthetic model including $CO_2$ and $H_2O_2$. It can be seen that the $H_2O_2$ doublet at 1234.0 $cm^{-1}$ is barely detectable on the disk-integrated spectrum.

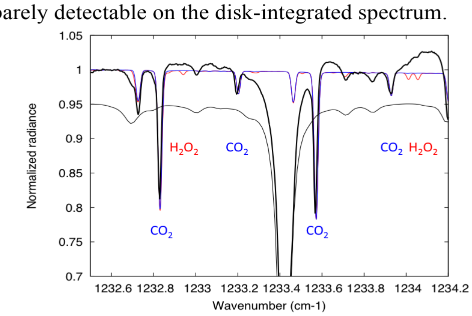


*Figure 1: The disk-integrated TEXES spectrum between 1232.5 and 1234.2 $cm^{-1}$ (rest frequencies, thick black line). Models: $CO_2$ (blue), $H_2O_2$ with a mixing ratio of 60 ppbv (red). Thin black line: standard atmospheric opacity at Maunakea Observatory, shifted vertically by 0.01 for clarity.*

Figure 2 shows the $H_2O_2$ map retrieved from our observation, compared with the GCM prediction. It can be seen that, as expected by the model, there is a clear dichotomy between the northern and southern hemispheres, even stronger in the TEXES data than predicted by the GCM.

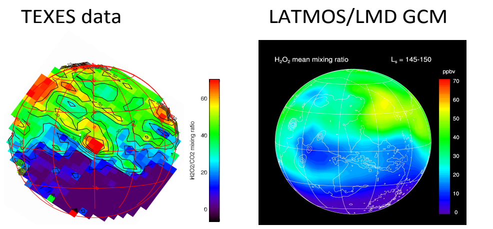


*Figure 2: (left)Map of the $H_2O_2$ mixing ratio, in ppbv, inferred from the $H_2O_2/CO_2$ line depth ratio, using a summation of the two $H_2O_2$ doublet lines at 1234.0 $cm^{-1}$ and the $CO_2$ transition at 1233.2 $cm^{-1}$. (right) GCM model corresponding to the same observing conditions. The Martian North pole is at the top of both figures.*

Figure 3 shows the observed seasonal variations of $H_2O_2$ on Mars including all published measurements, compared with several models. It can be seen that the present TEXES measurement is the highest value ever measured, and is in good agreement with both GCM models (homogeneous and heterogeneous).

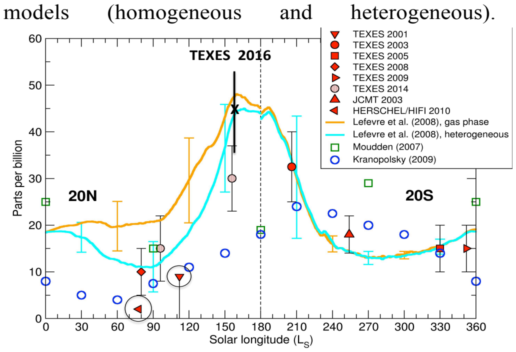


*Figure 3: Seasonal variations of $H_2O_2$ on Mars (observations and models), for a mean latitude of 20N for Ls = 0 -180°, and 20S for Ls = 180-360°.The figure is adapted from [7].*

## Possible interannual variations around aphelion

A special situation appears in the region of Ls = 70 – 120°, i.e. in the vicinity of northern summer and near aphelion. There are two upper limits, measured in 2001 by TEXES and in 2010 by Herschel/HIFI, that are significantly below the expected values, while two other TEXES measurements, in 2008 and 2014, are in good agreement with the GCM. In contrast, all measurements corresponding to other seasons are consistent with the model. This anomaly suggests that interannual variations might be present at the time of aphelion.

At the time of the first $H_2O_2$ detection by Clancy et al. (2004), at Ls = 256°, the authors suggested that the absence of detection by TEXES in 2001 (Ls = 110°) might be due to the fact that the height of the hygropause is known to be very low near aphelion [8, 9], because of a combination of a large water vapour content and a low temperature. Indeed, in 1995 and 1997, the altitude of the hygropause, measured from millimetre observations, was found to be only a few kilometres [9, 10]. This might affect the $H_2O_2$ formation process which is expected to take place at higher levels. While the $H_2O$ column density has been well monitored and is known to show little interannual variations, the height of the hygropause is less well known and might be more variable, due possibly to different dust conditions. Such variations would have little effect on the total $H_2O$ column density. In order to test this hypothesis, it will be interesting to investigate whether a correlation exists between the $H_2O_2$ content and the altitude of the hygropause. This can be tried using different means: the $H_2O$ vertical profiles of SPICAM/Mars Express [11,12], the millimetre and submillimetre spectra of $H_2O$ and HDO [13], or the OMEGA/Mars Express data showing the altitude of the $H_2O$ cloud.

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