HYDROGEN PEROXIDE ON MARS DURING NORTHERN SUMMER: OBSERVATIONS AND MODELS

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Introduction:

Hydrogen peroxide is an important tracer of Martian photochemistry, possibly responsible for the absence of organics at the surface of Mars (Oyama et al. 1977; Bullock et al. 1994). 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 favored the model developed by Lefèvre et al. (2008) based on heterogeneous chemistry (Encrenaz et al. 2012, 2015).

In this abstract, we present a new observation of Mars obtained on May 7, 2016, near opposition, under an especially favorable geometry. The disk diameter was 17″ and the solar longitude was 148.5°. Combining this observation with previous data obtained in 2014 (Ls = 96° and Ls = 156°, Encrenaz et al. 2015) allows us to monitor the evolution of H_2O_2 on Mars from northern summer solstice to mid-northern summer, at a time of rapid evolution.

Observations:

Our observation was performed using the TEXES (Texas Echelon Cross Echelle Spectrograph; Lacy et al. 2002) imaging spectrometer 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 East/West 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 choose the 1230-1238 cm^{-1} spectral interval that contains an H_2O_2 doublet (at 1234.00 and 1234.05 cm^{-1}), well separated from terrestrial atmospheric lines, with nearby weak CO_2 transitions. This H_2O_2 doublet was already observed in our 2003 observations (Encrenaz et al. 2004).

As in our previous analyses, our H_2O_2 map was obtained by dividing the line depth of the H_2O_2 doublet by that of a nearby weak CO_2 line. We carefully analyzed the CO_2 line depth maps corresponding to different weak CO_2 transitions, because some of them (including the 1233. 93 cm^{-1} transition close to the H_2O_2 doublet) were contaminated by the terrestrial atmospheric opacity. We finally chose the CO_2 transition at 1233.20 cm^{-1}. 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, as well as a model of the terrestrial atmospheric transmission. It can be seen that the H_2O_2 doublet at 1234.0 cm^{-1} is barely detectable on the disk-integrated spectrum.

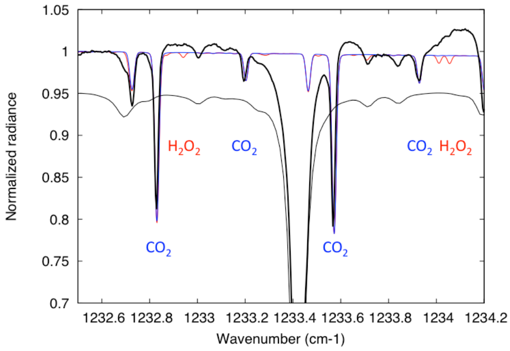

Figure 1: The disk-integrated TEXES spectrum between 1232.5 and 1234.2 cm^{-1} (thick black line). Models: CO_2 (blue), H_2O_2 with a mixing ratio of 60 ppbv (red). Thin black line: standard atmospheric opacity at Maunakea Observatory, shifted by 0.01 for clarity.

Results:

Figure 2 shows the H_2O_2 map retrieved by this method.

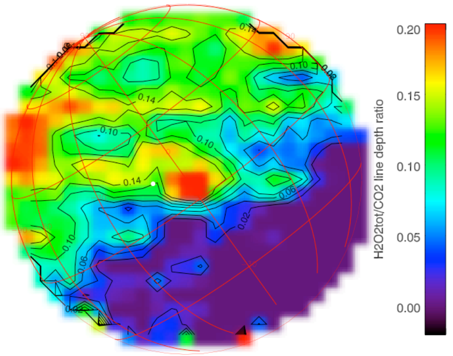

Figure 2: Map of the H_2O_2/CO_2 line depth ratio, using a summation of the two H_2O_2 doublet lines at 1234.0 cm^{-1} and the CO_2 transition at 1233.2 cm^{-1}. The CO_2 transition at 1233.86 cm^{-1} was not used due to terrestrial contamination. A line depth ratio of 0.12 corresponds to a H_2O_2 mixing ratio of about 40 ppbv. In the region where the line depth ratio is zero,

the H_2O_2 lines are too weak to be detected.

Because we are close to opposition, the whole disk of Mars is observed on the dayside and the CO_2 line depth can be measured everywhere; as a result, in contrast with our 2014 observations, the H_2O_2/CO_2 line depth ratio can be retrieved on the whole disk. The map shows a clear dichotomy between the northern and southern hemispheres.

We have isolated northern and southern regions (centered on the Central Meridian, at latitudes of 35N and 25S respectively) and have determined the mean H_2O_2 mixing ratios in these two regions. Results are shown in Figures 3 and 4. We find a H_2O_2 mixing ratio of 45 +/- 10 ppbv in the northern hemisphere, and less than 10 ppbv in the southern hemisphere.

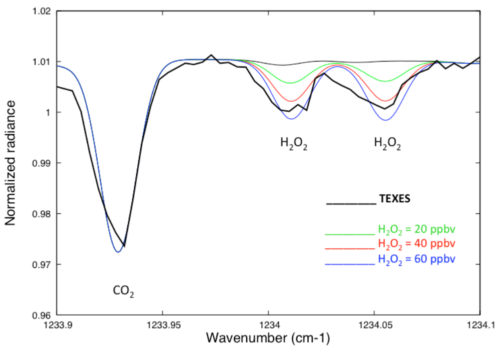

Figure 3: The TEXES spectrum of Mars integrated over the northern region centered on the Central Meridian and 35N latitude, compared with different synthetic models. Green: H_2O_2 = 20 ppbv; red: H_2O_2 = 40 ppbv; Blue: H_2O_2 = 60 ppbv.

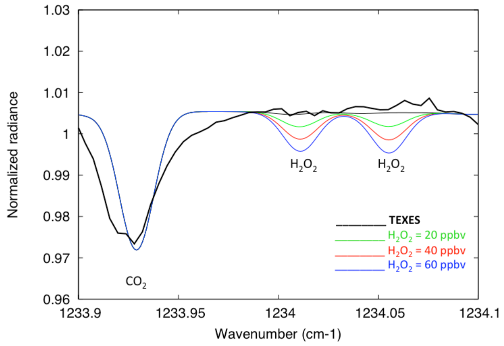

Figure 4: The TEXES spectrum of Mars integrated over the southern region centered on the Central Meridian and 25S latitude, compared with different synthetic models. Green: H_2O_2 = 20 ppbv; red: H_2O_2 = 40 ppbv; Blue: H_2O_2 = 60 ppbv. It can be seen that the CO_2 line at 1233.93 cm^{-1} is poorly fitted, which is possibly due to a contamination by the terrestrial absorption or to an instrumental artifact.

Figure 5 shows the GCM simulation of the H_2O_2 mixing ratio using the model developed by F. Lefèvre including heterogeneous chemistry. The north-south dichotomy is well reproduced and the observed H_2O_2 abundance is in good agreement with the prediction; however, we do not see the longitudinal variations expected by the model at 30N latitude.

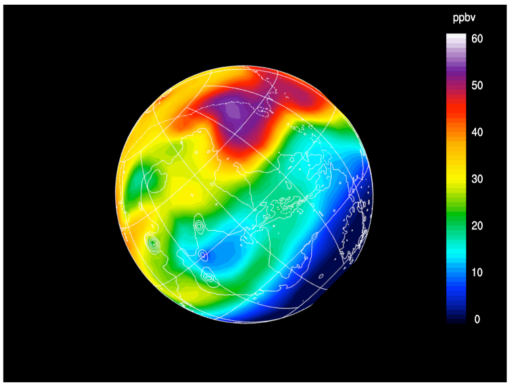

Figure 5: GCM simulation of the H_2O_2 map for Ls = 148.5°, under the same geometry as the TEXES observations of May 2016.

It is interesting to compare these new results with previous H_2O_2 observations (Encrenaz et al. 2015), obtained in March and July 2014, respectively before (Ls = 96°) and after (Ls = 156°) our present observation (Ls = 148.5°). Because the geometry of the planet was different, with a significant part of the disk on the night side for Ls = 156°, we could only observe a small part of the disk (Encrenaz et al. 2015). Still, we can confirm the H_2O_2 evolution predicted by the GCM, with a high H_2O_2 (above 30 ppbv) content above 60N for Ls = 96°, a constant high value of about 40 ppbv above 10N for Ls = 148.5° and a H_2O_2 maximum of about 35 ppbv at 20N-30N for Ls = 156°. This trend, shown in Figure 6, is well reproduced in our 2014 and 2016 datasets. In the future, observing Mars at Ls = 120° would allow us to test the prediction of a strong H_2O_2 maximum around the North pole at this season.

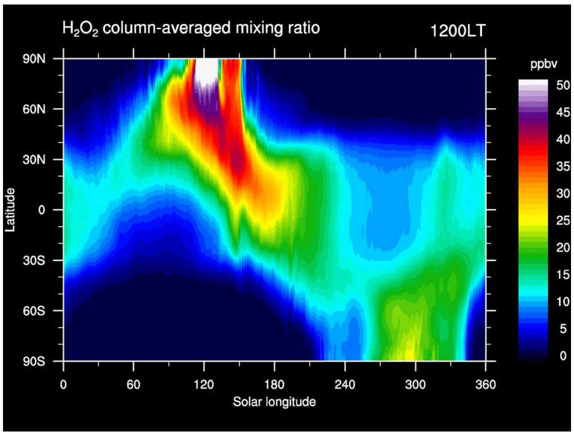

Figure 6: Variations of the longitude-averaged mixing ratio of H_2O_2 as a function of solar longitude and latitude, as predicted by the GCM of Lefèvre et al. (2008) including heterogeneous chemistry.

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