

Hydrogen peroxide on Mars: observations, interpretation and future plans

T. Encrenaz (1), T. Greathouse (2), F. Lefèvre (3) and S. Atreya (4)

(1) LESIA, Observatoire de Paris, France, (2) SwRI, San Antonio, TX, USA, (3) LATMOS/IPSL, Paris, France, (4) DAOSS, University of Michigan, USA (therese.encrenaz@obspm.fr/ Fax: +33 1 45 07 28 06)

Abstract

The abundance and spatial distribution of hydrogen peroxide on Mars has been monitored since 2001 using the TEXES instrument at the Infrared Telescope Facility (IRTF). Mixing ratios have been found to range from <10 ppb to 40 ppb as a function of time and location. Comparison with a GCM shows that the observations favor a photochemical model taking into account heterogeneous chemistry (Lefèvre et al., 2008). Delory et al. (2006) and Atreya et al. (2006, 2007) have suggested that large amounts of H₂O₂ could be produced by triboelectricity when dust devils or dust storms are present. The observability of such possible events is discussed using present and future instruments.

1. Introduction

Since the 1970s, following the negative results of the Viking mission regarding the presence of organics on Mars, hydrogen peroxide has been suspected to be responsible for oxidizing the martian surface. After several decades of unsuccessful search, H₂O₂ was detected in 2003 by two ground-based investigations, in the submillimeter range (Clancy et al., 2004) and in the infrared range (Encrenaz et al., 2004). Using the TEXES high-resolution imaging spectrometer (Lacy et al., 2002) at 8 μ m, with a resolving power of about 8×10^4 , we have obtained maps of H₂O₂ for different seasons on Mars.

2. The data set

Our observations are summarized in Table 1. In all cases, the 8 \times 1.1" slit was aligned along the celestial North-South axis and moved from west to east by 0.5" steps. We concentrated on the H₂O₂ doublet at 1241 cm^{-1} which brackets a weak CO₂ transition.

Spectra were fit using a radiative transfer model and a map of the estimated abundances was obtained from the line depth ratio of H₂O₂ and CO₂ transitions.

Our first attempt to detect H₂O₂ led to an upper limit which was lower than the predictions of the photochemical models (Encrenaz et al., 2002). In contrast, the 2003 detection agreed very well with the models. Later, our measurements have been generally lower than the expectations (Encrenaz et al., 2004, 2008, 2009). As demonstrated by Lefèvre et al. (2008), a comparison of the seasonal behavior of H₂O₂ with the models shows that a better agreement is reached when heterogeneous chemistry is taken into account (Fig. 1). However, near equinox, there is still a disagreement which remains to be understood.

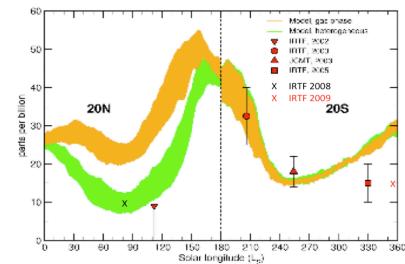


Figure 1: Observed and simulated H₂O₂ seasonal evolution on Mars. Models: Yellow, homogeneous chemistry; green, heterogeneous chemistry (after Lefèvre et al., 2008).

3. Possible localized sources of H₂O₂

The observed range of H₂O₂ abundances is in general agreement with photochemical models but it is not

sufficient for H_2O_2 to oxidize the surface at the level observed by Viking. According to Mancellini (1989), the required abundance would be in the range of 25-250 ppm. However, another possible source of H_2O_2 has been proposed by the electrochemical model of Delory et al. (2006) and Atreya et al. (2006). H_2O_2 could be produced by triboelectricity in dust devils and dust storms. For example, with the maximum pre-discharge electrostatic fields of 25 kV/m, the H_2O_2 production may be enhanced up to a factor 10^4 compared to the photochemical values. For a mean temperature of 225 K, its diffusion into the soil would limit the maximum instantaneous increase to a factor of 200 in the near-surface atmosphere. While the atmospheric lifetime of H_2O_2 in the gas phase is less than a day, its lifetime in the regolith could be quite long, up to millions of years depending on the depth of sequestration. Thus, if this formation mechanism is at work on Mars, hydrogen peroxide could indeed be responsible for the oxidation of the Martian surface (Atreya et al., 2007).

Table 1: The TEXES data set

Obs. date	Ls (°)	Mars diam. (arcsec)	Max H_2O_2 (ppb)
Feb 2001	110	6	< 10
Jun 2003	206	15	40
Dec 2005	335	17	15
May 2008	80	5	10
Oct 2009	352	6	15

During southern spring and summer, the surface temperature is locally above 300 K, which could possibly result in a H_2O_2 enhancement factor by as much as a factor 10^4 in the gas phase. The infrared signature of such an event could be detectable, even with a moderate resolving power ($R = 10^3$), if a sufficient spatial resolution is achieved; however, the event would last for a short time (possibly less than a day). The most favorable season should be southern summer when most of the dust storms take place. Hydrogen peroxide would be best studied in 3 different spectral ranges: (1) at 8 μm with TEXES on a 8-m class telescope; later, the use of EXES on SOFIA will give access to stronger H_2O_2 ν_6 -lines at 1285-1290 cm^{-1} (contaminated by the terrestrial methane in ground-based observations); (2) in the 350-400 cm^{-1} range (ν_4 -band) using PFS aboard Mars Express; the spectral resolution of PFS (1.3 cm^{-1}) is very marginal, however, for detecting H_2O_2 at the

level of 30 ppb but localized sources might be detectable, provided the spacecraft flies over the sources at the right time; and (3) in the submillimeter range with ALMA, using high-frequency H_2O_2 transitions.

Acknowledgements

We are grateful to B. Bézard, T. Fouchet, M. Richter, J. Lacy, F. Forget, and S. Lebonnois for their contribution to the data acquisition, analysis or interpretation. We are grateful to the members of the IRTF staff for their support.

References

Atreya, S. K. et al., Oxidant enhancement in dust devils and storms: implications for life and habitability, *Astrobiology* 6, pp. 439 - 450, 2006

Atreya, S. K. et al., Methane and related trace species on Mars: Origin, loss, implications for life, and habitability, *Plan. Space Sci.* 55, pp. 358 - 369, 2007

Clancy, R. T., Sandor, B. J. and Moriarty-Schiven, G. H., A measurement of the 362 GHz absorption line of Mars atmospheric H_2O_2 , *Icarus* 168, 116 - 121, 2004

Delory, G. T. et al., Oxidant enhancement in dust devils and storms: storm electric fields and electron dissociative attachment, *Astrobiology*, 6, 451 - 462, 2006

Encrenaz, T. et al., A stringent upper limit of the H_2O_2 abundance in the Martian atmosphere, *Astron. Astrophys.* 396, 1037 - 1044, 2002

Encrenaz, T. et al., Hydrogen peroxide on Mars: spatial distribution and seasonal variations, *Icarus* 170, 424 - 429, 2004

Encrenaz, T. et al., Simultaneous mapping of H_2O and H_2O_2 on Mars from infrared high-resolution imaging spectroscopy, *Icarus* 195, 547 - 556, 2008

Lacy, J. H. et al., TEXES: a sensitive high-resolution grating spectrograph for the mid-infrared, *Pub. Astron. Soc. Pacific* 114, 153 - 168, 2002

Lefèvre, F. et al., Heterogeneous chemistry in the atmosphere of Mars, *Nature* 454, 971 - 975, 2008

Mancellini, R. L., Peroxides and the survivability of microorganisms on the surface of Mars, *Adv. Space Res.* 9, 191 - 195, 1989.

