

# Hydrogen peroxide on Mars: observations, interpretation and future plans

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## 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  $H_2O_2$  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,  $H_2O_2$  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  $8\ \mu m$ , with a resolving power of about  $8 \times 10^4$ , we have obtained maps of  $H_2O_2$  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  $H_2O_2$  doublet at  $1241\ cm^{-1}$  which brackets a weak  $CO_2$  transition.

Spectra were fit using a radiative transfer model and a map of the estimated abundances was obtained from the line depth ratio of  $H_2O_2$  and  $CO_2$  transitions.

Our first attempt to detect  $H_2O_2$  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  $H_2O_2$  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.

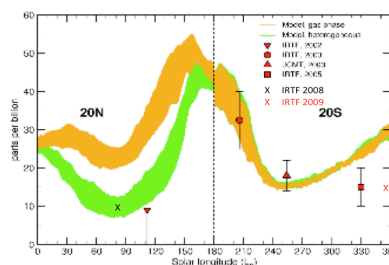


Figure 1: Observed and simulated  $H_2O_2$  seasonal evolution on Mars. Models: Yellow, homogeneous chemistry; green, heterogeneous chemistry (after Lefèvre et al., 2008).

## 3. Possible localized sources of $H_2O_2$

The observed range of  $H_2O_2$  abundances is in general agreement with photochemical models but it is not

sufficient for  $\text{H}_2\text{O}_2$  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  $\text{H}_2\text{O}_2$  has been proposed by the electrochemical model of Delory et al. (2006) and Atreya et al. (2006).  $\text{H}_2\text{O}_2$  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  $\text{H}_2\text{O}_2$  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  $\text{H}_2\text{O}_2$  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 $\text{H}_2\text{O}_2$ (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  $\text{H}_2\text{O}_2$  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  $8\text{ }\mu\text{m}$  with TEXES on a 8-m class telescope; later, the use of EXES on SOFIA will give access to stronger  $\text{H}_2\text{O}_2$   $\nu_6$ -lines at  $1285\text{--}1290\text{ cm}^{-1}$  (contaminated by the terrestrial methane in ground-based observations); (2) in the  $350\text{--}400\text{ cm}^{-1}$  range ( $\nu_4$ -band) using PFS aboard Mars Express; the spectral resolution of PFS ( $1.3\text{ cm}^{-1}$ ) is very marginal, however, for detecting  $\text{H}_2\text{O}_2$  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  $\text{H}_2\text{O}_2$  transitions.

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