First Detection of Deuterium on Mars with the FTS

In January 1987, the FTS was set up to search for deuterated molecules in the atmospheres of Mars and Venus, a joint proposal made by Toby Owen (Stony Brook), Catherine de Bergh (Paris-Meudon Observatory), Barry Lutz (Lowell Observatory) and Jean-Pierre Maillard (Institut d'Astrophysique de Paris). The purpose was to make measurements of the D/H ratio in these two planets and to obtain new information about the evolution of their atmospheres since their formation by trying to detect HDO on Mars and DCl on Venus.

The detection of HDO on Mars was successful after inspection of a 2–hour integrated spectrum. The observing time was requested when the relative velocity of Mars with respect to Earth was about 15 km/s, allowing enough Doppler shift to separate the Martian lines from their telluric counterparts. For this reason the planet had to be observed during the day, far from opposition. That was made possible by the adjunction in the Cassegrain Bonnette of a dichroic plate built by CFH staff to pick off a few percent of the visible light for guiding directly on the object. The observed band of HDO, centered at 3.67 μm (2720 cm^{-1}), is the fundamental band ν_1. A resolution of 9×10^4 was required to detect the narrow Martian lines.

A lunar spectrum at almost the same airmass was recorded on the same night for comparison. The detection was definitely aided by the low amount of precipitable water on Mauna Kea at the time of the observations: 0.3 mm. Twenty-two lines of HDO belonging to the P and Q-branch of the band, over the 200 wavenumbers of the filter bandpass, were suitable for a determination of the HDO column density. To obtain a value of the D/H ratio, one must know the amount of H_2O that is present, since the Martian water vapor varies with season. Another portion of the Mars spectrum was recorded a few days later with the FTS, at 1.1 μm, in order to detect H_2O lines. Paradoxically, this detection was more difficult to secure, because only a few faint lines can be well separated from the strong telluric water vapor lines or the solar lines. In addition, the amount of precipitable water vapor was higher. However, after careful selection, detection of H_2O was possible, leading to the first determination of a D/H ratio on Mars. It was found to be enriched compared to Earth by a factor of 6.

This new and unexpected result has important consequences for the hydrogen escape process from the planet at origin, which should have been more efficient than assumed. As a preliminary conclusion, the high value of D/H on Mars provides evidence for a wetter and hence warmer epoch in the planet's early history.

The observation of Venus was also successful, since high-resolution spectra in the 4.8μ window were obtained after sunrise during the same run. However, the spectra are crowded with every possible CO_2 isotopic species so that it will take several months to construct a complete synthetic spectrum, in order to conclude if Deuterium is detected in Venus as well.

J. P. Maillard

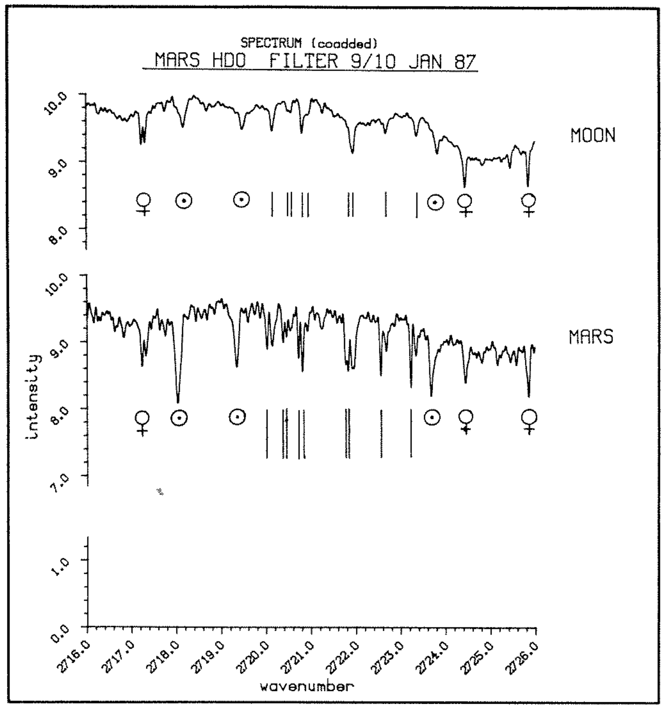

Figure 11: A portion of the spectrum of Mars compared to that of the Moon in the Q-branch of the ν_1 band. The HDO lines from the Martian atmosphere are marked with long bars. Their telluric counterparts are indicated by slightly-shifted short bars in the comparison lunar spectrum. Other telluric lines common to both are due to CH_4. The solar lines look deeper on Mars than on the Moon because of the lower emitting temperature of Mars.

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Questions and comments about the Bulletin should be sent to the attention of Dr. R.A. Crowe at CFHT.

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