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A sensitive search for methane and ethane on Mars

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Abstract

Extraction of methane on Mars from IRTF/CSHELL spectra has been significantly improved by comparison with the similar spectra of the Moon. Observations in February 2006 at L_S = 10° along the central meridian at 63-93°W show ~8 ppb at 0-40°S and ~3 ppb outside this region. Observations in December 2009 at L_S = 20° and 0-30°W reveal no methane with an upper limit of 8 ppb. No methane with the same upper limit was seen in March 2010 at L_S = 70° on the martian disk in the scanning mode from 30°W to 90°E and along the central meridian. The measured methane abundances and upper limits are smaller than those in the PFS and TES maps. Our search for ethane at 2977 cm^{-1} results in an upper limit of 0.3 ppb on Mars, with improvement of the previous limit by three orders of magnitude. The observed ethane abundance in the Earth's atmosphere is 0.17 ppb and corresponds to CH_4/C_2H_6 = 12,000.

1. Introduction

A long-slit high-resolution spectrograph CSHELL at NASA IRTF is currently the best instrument for ground-based search for methane on Mars. Methane is observed using its R0 and R1 lines at 3028.752 and 3038.498 cm^{-1} that are Doppler-shifted relative to the very strong telluric lines. The instrument resolving power is 4×10^4, and 90% of the line absorption is in an interval of 0.1 cm^{-1}. According to our calculations, statistical uncertainty for a 20-minute exposure is 0.5% in this interval and corresponds to 2.5 ppb of methane. However, the signal on the steep wing of the strong telluric line varies within this interval by a factor of 3 (Fig. 1), and it is very difficult to extract a deviation of ~1% from this signal. Our retrievals using synthetic spectra resulted in systematic errors that exceed the calculated statistical uncertainty. Comparison of the Mars spectra with those of the Moon measured with the same instrument may significantly improve detection of methane.

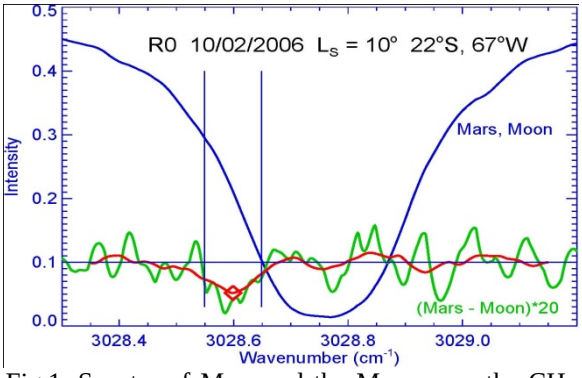

Fig.1. Spectra of Mars and the Moon near the CH_4 R0 line are similar in the figure. Their difference scaled by a factor of 20 is shown below (green). The difference smoothed within 0.1 cm^{-1} is red. It shows absorption at the expected Doppler-shifted position of the martian methane between the vertical lines.

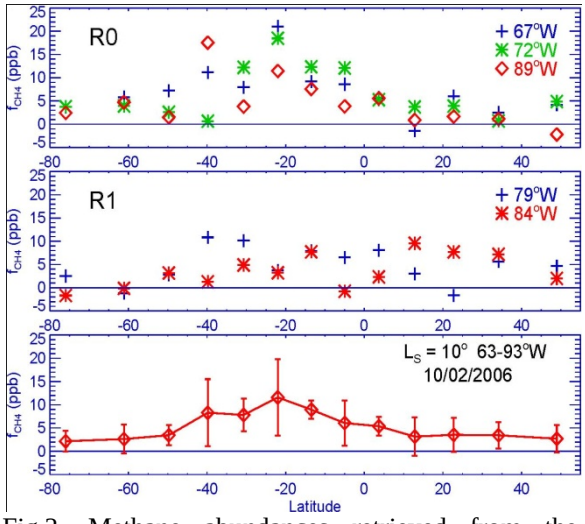

Fig.2. Methane abundances retrieved from the observations of the R0 and R1 lines along the central meridian in February 2006. Longitudes of the central meridian are given. Mean mixing ratios and their uncertainties are shown in the lower panel.

2. Observations and their results

We have developed a method to adjust a spectrum of the Moon and subtract it from a spectrum of Mars. This is shown in Fig. 1, where the spectrum was

observed at a point with a maximum CH_4 ~20 ppb. The methane absorption is well seen in Fig.1.

Results of our observations on February 10 2006 at L_S = 10° are shown in Fig. 2. The retrieved line equivalent widths were converted to the CH_4 mixing ratios using the MGS/TES temperatures and pressures for the observed regions, the line strengths from HITRAN, and two-way airmasses. Methane is ~8 ppb at 0-40°S near the deepest canyon Valles Marineris and ~3 ppb outside this region.

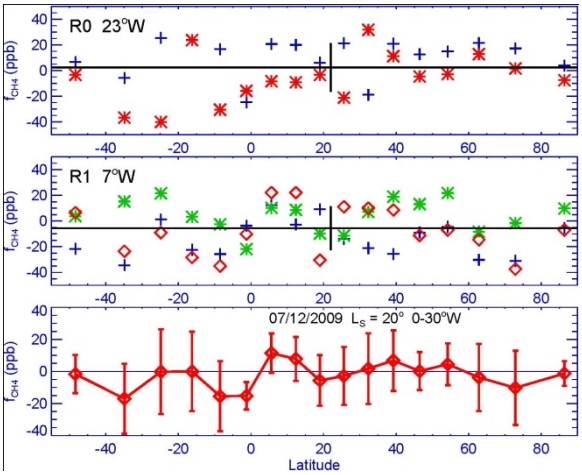

Fig.3. Methane observed in December 2009 at L_S = 20°. Different symbols refer to different spectral frames. Horizontal lines are the mean values, vertical bars are standard deviations. The lower panel shows mean values and standard deviations for each latitude.

Observations on December 7 2009 at L_S= 20° are shown in Fig. 3. The lines are blue-shifted in the observations, and this is less favorable because of contamination by the telluric $^{13}CH_4$ line. No methane is seen with an upper limit of 8 ppb.

Observations on March 30-31 2010 at L_S = 70° were made along the central meridian and in a scanning mode that covered the full martian disk with intervals of 1 arcsec. Observations along the central meridian are shown in Fig. 4. No methane was observed in both modes with an upper limit of 8 ppb. Our observation covers region A that extends from 30°S to 30°N at ~50°E where Mumma et al. (2009) observed maximal methane abundances of 30-45 ppb in 2003.

A search for ethane was made in October 2007 using an absorption feature centered at 2976.79 cm^{-1}. Its strength within an interval of 0.1 cm^{-1} is equal to 4.1×10^{-19} cm at 215 K. A small part of the observed spectrum is shown in Fig. 5. The telluric line gives

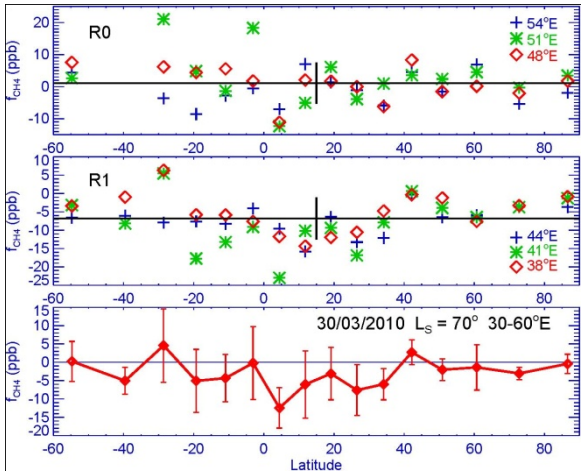

Fig. 4. Methane observed in March 30 2010 at L_S=70°. Mean values and standard deviations are in the lower panel.

the ethane abundance of 0.17 ppb that results in CH_4/C_2H_6 = 12,000. An upper limit to martian ethane is 0.3 ppb with improvement of the previous upper limit by three orders of magnitude.

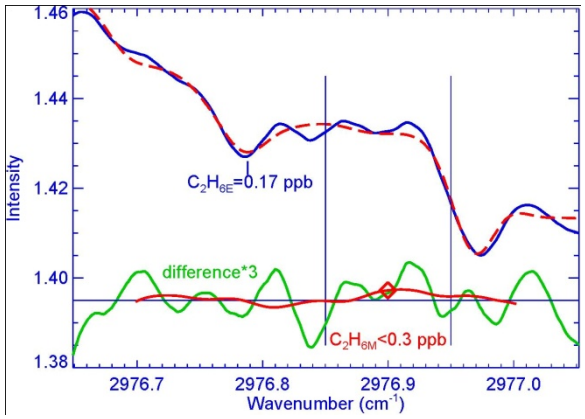

Fig.5. A part of the observed spectrum (blue) near the ethane band. Its Doppler-shifted position is shown by the vertical lines. Synthetic spectrum (dashed) fits the observation for telluric C_2H_6 = 0.17 ppb. The lack of absorption in their difference spectrum gives an upper limit of 0.3 ppb to martian ethane.

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