Search of CH_4 on Mars using EXES aboard SOFIA

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Abstract: We present the results of our sensitive search of CH_4 on Mars using the Echelon-Cross-Echelle Spectrograph (EXES) onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA).

Discovery of CH_4 in the Martian atmosphere has led to much discussion since it could be a signature of recent biological/geological activitie on Mars [1,2,3]. However, the presence of CH_4 and its temporal and spatial variations (0-60 ppb) are under discussion because of the large uncertainties embedded in the previous remote-sensing observations [4]. Although Tunable Laser Spectrometer onboard Curiosity rover detected CH_4 signal and showed strong variability of the amount (0-9 ppb), sensitive remote-sensing observations are still important to search for the source since TLS can measure CH_4 variation only at Gale crater.

SOFIA/EXES has unique capabilities to perform a sensitive search for CH_4 from Earth. The high altitude of SOFIA (~12-14 km) enables us to significantly reduce the effects of terrestrial atmosphere. Thanks to this, it improves the chance to detect Martian CH_4 lines because it reduces the impact of telluric CH_4 on Martian CH_4, and allows us to use CH_4 lines in the 7.5 μm band which have less contamination.

We performed sensitive measurements of Martian CH_4 by using SOFIA/EXES on 16 March 2016 and 25 January 2017, which corresponds to summer (Ls = 123.2°) and winter (Ls = 305.2°) in the northern hemisphere on Mars (see Table 1). We selected the 1325-1340 cm^{-1} (7.45 - 7.55 μm) interval considering the availability of multiple strong CH_4 lines, and used the high-spectral resolution mode (R~90,000) to improve the possibility of detecting the narrow Martian CH_4 lines. We observed the planet at three separate slit positions (center, right, and left of the Martian disk with an offset of 2.5") on 16 March 2016, and two positions (right and left of the Martian disk with an offset of 1") on 25 January 2017. The narrowest slit-width (1.44") was used to maximize the spectral resolving power that provided an instrumental resolving power of 90,000.

We first performed the data analysis on 16 March 2016 [6]. We confined our analysis to three CH_4 lines at 1327.074219, 1327.409783 and 1332.546743 cm^{-1} because they have no contamination from other lines (i.e., terrestrial CH_4 and H_2O, and Martian CO_2 and H_2O lines) and stronger intensities than the other CH_4 lines. Table 2 summarizes the retrieved CH_4 volume mixing ratios (the weighted averages using the ones retrieved from three CH_4 lines independently), and the corresponding locations (latitude and longitude) and local times. As shown in this Table, there are no definitive detections of CH_4. The Martian disk was spatially resolved into 3 x 3 areas, and the upper limits on the CH_4 volume mixing ratio range from 1 to 9 ppb, which are more stringent than those by the previous remote-sensing observations. We also have performed the analysis of the data taken on 25 January 2017 [7]. Table 3 shows the results. As shown in this table, we do not detect CH_4 from the data taken on 25 January 2017. The upper limits are slightly higher (7-14 ppb) than those on 16 March 2016 because of shorter integration time, lower flying altitude of SOFIA, and smaller Doppler Shift between Mars and Earth.

Non-detection of CH_4 could be due to its strong temporal variation, similar to that measured by Curiosity/TLS over Gale crater, or to localized spatial distribution. Our results emphasize that release of CH_4 on Mars is sporadic and/or localized if the process is present. We will continue to perform the sensitive search of CH_4 on Mars by EXES in April and October 2018.

Table 1: Overview of the EXES observations.

Observation Date (UT)	16 March 2016	25 Jan. 2017
Observation Time	9:59-10:32	1:40-2:11
Martian Year	33	33
Doppler shift (km/s)	-16.2	11.7
Diameter of Mars (″)	10.0	5.2
Aircraft Altitude (km)	13.7	11.9
Sub Earth Lon (°W)	247-253	347-353
Spectral range (cm^{-1})	1326.57 -1338.66	1325.87 -1337.96

Table 2: CH_4 volume mixing ratio (VMR) on Mars retrieved from the SOFIA/EXES observation carried on 16 March 2016 (*Ls* = 123.2°) [6]. The Martian disk was spatially resolved into 3 x 3 areas, and the upper limits on the CH_4 volume mixing ratio range from 1 to 6 ppb. Note that EXES spectra were spatially binned over ~2.7 arcsec, which a corresponds latitudinal/longitudinal resolution of about ±27° at the sub-Earth point.

Slit position	Lat (°)	Lon (°W)	LT	CH_4 VMR (ppb 3σ)
Mars Center #1	-17	181	16	2 ± 3
Mars Center #1	13	211	14	1 ± 1
Mars Center #1	40	247	12	1 ± 2
Mars Left	-42	205	15	1 ± 5
Mars Left	-8	237	13	0 ± 3
Mars Left	13	270	11	1 ± 2
Mars Right	0	168	18	3 ± 6
Mars Right	30	189	16	0 ± 2
Mars Right	66	218	14	0 ± 1
Mars Center #2	-17	188	16	1 ± 4
Mars Center #2	13	217	14	0 ± 1
Mars Center #2	40	253	12	0 ± 2

Table 3: CH_4 volume mixing ratio (VMR) on Mars retrieved from the SOFIA/EXES observation carried on 25 January 2017 (*Ls* = 305.2°). The Martian disk was spatially resolved into 2 x 2 areas, and the upper limits on the CH_4 volume mixing ratio range from 7 to 13 ppb. Note that EXES spectra were spatially binned over ~2.5 arcsec, which a corresponds latitudinal/longitudinal resolution of about ±43° at the sub-Earth point.

Slit position	Lat (°)	Lon (°W)	LT	CH_4 VMR (ppb 3σ)
Mars Left	-3	327	11	0 ± 7
Mars Left	-67	336	10	2 ± 8
Mars Right	4	19	8	1 ± 11
Mars Right	39	54	5	0 ± 13

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