



Publication Year	2017
Acceptance in OA	2020-07-24T08:45:01Z
Title	Sensitive search of CH ₄ on Mars by SOFIA/EXES
Authors	Aoki, S., Richter, M. J., DeWitt, C., Boogert, A., Encrenaz, T., Sagawa, H., Nakagawa, H., Vandaele, A. C., GIURANNA, MARCO, Greathouse, T. K., Fouchet, T., Geminale, A., Sindoni, G., McKelvey, M., Case, M., Kasaba, Y.
Handle	http://hdl.handle.net/20.500.12386/26607

Sensitive search of CH₄ on Mars by SOFIA/EXES

S. Aoki (1,2,3), M. J. Richter (4), C. DeWitt (4), A. Boogert (5), T. Encrenaz (6), H. Sagawa (7), H. Nakagawa (3), A. C. Vandaele (1), M. Giuranna (8), T. K. Greathouse (9), T. Fouchet (6), A. Geminale (8), G. Sindoni (8), M. McKelvey (5), M. Case (4), and Y. Kasaba (3)

1 Planetary Aeronomy, Belgian Institute for Space Aeronomy, 3 av. Circulaire, B-1180 Brussels, Belgium

(E-mail: shohei.aoki@aeronomie.be)

2 Fonds National de la Recherche Scientifique, rue d'Egmont 5, B-1000 Brussels, Belgium

3 Department of Geophysics, Tohoku University, Sendai, Miyagi 980-8578, Japan

4 Physics Department, University of California, Davis, CA 95616, USA

5 Universities Space Research Association, Stratospheric Observatory for Infrared Astronomy, NASA Ames Research Center, MS 232-11, Moffett Field, CA 94035, USA

6 LESIA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, 92195 Meudon, France

7 Faculty of Science, Kyoto Sangyo University, Motoyama, Kamigamo, Kita-ku, Kyoto 603-8555, Japan

8 Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, Via del Fosso del Cavaliere 100, 00133 Roma, Italy

9 Southwest Research Institute, Div. #15, San Antonio, TX 78228, USA

Abstract

We present the results of our sensitive search of CH₄ on Mars using the Echelon-Cross-Echelle Spectrograph (EXES) onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA).

Discovery of CH₄ in the Martian atmosphere has led to much discussion since it could be a signature of biological/geological activities on Mars [1,2,3]. However, the presence of CH₄ 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 CH₄ signal and showed strong variability of the amount (0-9 ppb), sensitive remote-sensing observation is still important to search for the source since TLS can measure CH₄ variation only on the Gale crater.

SOFIA/EXES has unique capabilities to perform a sensitive search for CH₄ 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 CH₄ lines because it reduces the impact of telluric CH₄ on Martian CH₄, and allows us to use CH₄ lines in the 7.5 μ m band which has less contamination.

We performed sensitive measurements of Martian CH₄ by using SOFIA/EXES on 16 March 2016 and 25 January 2017, which corresponds to summer ($L_s = 123.2^\circ$) and winter ($L_s = 305.2^\circ$) in the northern hemisphere on Mars (see Table 1). We selected the 1325-1340 cm^{-1} (7.45 - 7.55 μ m) interval considering the availability of multiple strong CH₄ lines, and used the high-spectral resolution mode ($R \sim 90,000$) to improve the possibility of detecting the narrow Martian CH₄ 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.

We have analyzed the data taken on 16 March 2016 [6]. We confined our analysis to three CH₄ lines at 1327.074219, 1327.409783 and 1332.546743 cm^{-1} because they have no contamination from other lines (i.e., terrestrial CH₄ and H₂O, and Martian CO₂ and H₂O lines) and stronger intensities than the other CH₄ lines. Table 2 summarizes the retrieved CH₄ volume mixing ratios (the weighted averages using the ones retrieved from three CH₄ lines independently), and the corresponding locations (latitude and longitude) and local times. As shown in this Table, there are no definitive detections of CH₄. The Martian disk was spatially resolved into 3 x 3 areas, and the upper limits on the CH₄ volume mixing ratio range from 1 to 6 ppb, which are more stringent than those by the previous remote-sensing observations.

In the presentation, the results from the other data taken on 25 January 2017 will be discussed as well.

Tables

Table 1: Overview of the SOFIA/EXES observations.

Observation Date (UT)	16 March 2016	25 January 2017
Observation Time (UT)	9:59-10:32	1:40-2:11
MY	33	33
Doppler shift (km/s)	-16.2	11.7
Diameter of Mars (")	10	5.2
Aircraft Altitude (km)	13.7	11.9
Sub Earth longitude (°W)	247-253	347-353
Spectral range (cm ⁻¹)	1326.57-1338.66	1325.87-1337.96

Table 2: CH₄ volume mixing ratio (VMR) on Mars retrieved from the SOFIA/EXES observation carried on 16 March 2016 ($L_s = 123.2^\circ$) [6]. The Martian disk was spatially resolved into 3 x 3 areas, and the upper limits on the CH₄ volume mixing ratio range from 1 to 6 ppb. Note that EXES spectra were spatially binned over ~ 2.7 arcsec, which corresponds latitudinal/longitudinal resolution of about $\pm 27^\circ$ at the sub-Earth point.

Slit position	Lat (°)	East Lon (°)	LT	CH ₄ VMR (3 σ)
Mars Center #1	-17	179	16	2 $\pm$ 3 ppb
Mars Center #1	13	149	14	1 $\pm$ 1 ppb
Mars Center #1	40	113	12	1 $\pm$ 2 ppb
Mars Left	-42	155	15	0 $\pm$ 4 ppb
Mars Left	-8	123	13	0 $\pm$ 3 ppb
Mars Left	13	90	11	2 $\pm$ 4 ppb
Mars Right	0	192	18	0 $\pm$ 2 ppb
Mars Right	30	171	16	0 $\pm$ 2 ppb
Mars Right	56	126	13	0 $\pm$ 1 ppb
Mars Center #2	-17	172	16	1 $\pm$ 3 ppb
Mars Center #2	13	143	14	0 $\pm$ 1 ppb
Mars Center #2	40	107	12	1 $\pm$ 3 ppb

Acknowledgements

This work has been supported by the FNRS “CRAMIC” project under grant agreement n° T.0171.16 and based on observations made with the NASA/DLR Stratospheric Observatory for Infrared Astronomy (SOFIA). SOFIA is jointly operated by the Universities Space Research Association, Inc. (USRA), under NASA contract NAS2-97001, and the Deutsches SOFIA Institut (DSI) under DLR contract 50 OK 0901 to the University of Stuttgart. MJR, CD, and MC of the EXES team are supported by NASA award NNX13AI85A. YK and NH are supported by a Grant-in-Aid for Scientific Research (15H05209; 16K05566) from the Japanese Society for the Promotion of Science (JSPS). HN was supported by the Astrobiology Center Program of National Institutes of Natural Sciences (NINS) (Grant Number AB281003).

References

- [1] Formisano, V., Atreya, S.K., Encrenaz, T., Ignatiev, N., Giuranna, M., 2004. Detection of methane in the atmosphere of Mars. *Science* 306, 1758–1761.
- [2] Mumma, M.J., Villanueva, G.L., Novak, R.E., Hewagama, T., Bonev, B.P., DiSanti, M.A., Mandell, A.M., Smith, M.D., 2009. Strong release of methane on Mars in northern summer 2003. *Science* 323 (5917), 1041–1045.
- [3] Atreya, S.K., Mahaffy, P.R., Wong, A., 2007. Methane and related trace species on Mars: Origin, loss, implications for life, and habitability. *Planet. Space Sci.* 55, 358–369.
- [4] Zahnle, K., Freedman, F.S., Catling, D.C., 2010. Is there Methane on Mars?, *Icarus*, 212, 493–503.
- [5] Webster, C.R., et al, 2015. Mars methane detection and variability at Gale crater, *Science*, 347, 415–417.
- [6] Aoki, S., Richter, M.J., DeWitt, C., Boogert, A., Encrenaz, T., Sagawa, H., Nakagawa, H., Vandaale, A.C., Giuranna, M., Greathouse, T.K., Fouchet, T., Geminala, A., Sindoni, G., McKelvey, M., Case, M., Kasaba, Y., Stringent upper limit of CH₄ on Mars based on SOFIA/EXES observation, *Astron. Astrophys. submitted*.