



**HAL**  
open science

## Three Martian Years of Searching for Methane on Mars with ACS Aboard the Trace Gas Orbiter

Franck Montmessin, Oleg Korablev, A V Trokhimovskiy, Kevin Olsen, Franck Lefèvre, Lucio Baggio, Anna Fedorova, Abdanour Irbah, Gaetan Lacombe, Andrey Patrakeev, et al.

► **To cite this version:**

Franck Montmessin, Oleg Korablev, A V Trokhimovskiy, Kevin Olsen, Franck Lefèvre, et al.. Three Martian Years of Searching for Methane on Mars with ACS Aboard the Trace Gas Orbiter. Tenth International Conference on Mars, Jul 2024, Pasadena, United States. pp.LPI Contribution No. 3007, id.3145. insu-04673595

**HAL Id: insu-04673595**

**<https://insu.hal.science/insu-04673595v1>**

Submitted on 20 Aug 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

### THREE MARTIAN YEARS OF SEARCHING FOR METHANE ON MARS WITH ACS ABOARD THE TRACE GAS ORBITER. F. Montmessin<sup>1</sup>, Oleg Korablev<sup>2</sup>, A.V. Trokhimovskiy<sup>2</sup>, Kevin Olsen<sup>3</sup>, Franck Lefèvre<sup>1</sup>, Lucio Baggio<sup>1</sup>, Anna Fedorova<sup>2</sup>, Abdanour Irbah<sup>1</sup>, Gaetan Lacombe<sup>1</sup>, Andrey Patrakeev<sup>2</sup>, Natalia S. Duxbury<sup>4</sup>

<sup>1</sup>Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Guyancourt & Paris, France, franck.montmessin@latmos.ipsl.fr, <sup>2</sup>Space Research Institute (IKI) RAS, Moscow, Russia, <sup>3</sup>AOPP, Oxford University, Oxford, UK, <sup>4</sup>George Mason University, Fairfax, VA, US

**Introduction:** Since 2004, studies have probed Martian methane, theorizing its continuous presence or replenishment. Detection efforts from Mars' surface and orbit, including by Curiosity rover, Mars Express, and Trace Gas Orbiter (TGO), yield conflicting measurements. TGO's Atmospheric Chemistry Suite (ACS) [1] searches for methane using solar occultation, showed its global absence above a level of 50 pptv [2], then 20 pptv [3], contrasting with higher concentrations reported elsewhere [5,6,7,8,9]. The update presented here integrates data until spring 2024, aiming to illuminate Martian methane's presence and mechanisms.

For decades, methane on Mars has captivated scientists due to its potential implications for ongoing geophysical or biogenic activity on a planet traditionally viewed as inert. Despite a history of both failed attempts and positive detections between 2004 and 2019 [4,5,6,7,8,9,21,22], the Trace Gas Orbiter (TGO) commenced its mission in April 2018, marking a significant step forward in the quest to understand Martian methane.

Equipped with two cutting-edge infrared spectrometers designed for outstanding detection capabilities, TGO embarked on its mission with the primary objective of confirming the presence of methane on Mars or establishing the most stringent upper limits possible. Among these instruments, the Atmospheric Chemistry Suite (ACS), developed by IKI with support from CNES, stands out. Alongside NOMAD, ACS offers comprehensive coverage across the entire wavelength spectrum, from UV to thermal IR [1,10]. Both instruments observe the mid-IR range, providing redundant and reliable exploration of various trace gases.

Noteworthy achievements of these instruments include the simultaneous observation of HDO and H<sub>2</sub>O [11,12], the discovery of HCl [13,14,15], the close monitoring of water and ozone dynamics [16,17,18], as well as the first profiles of CO on Mars [19].

**Method:** The mid-infrared range, particularly the vicinity of the fundamental 3.3  $\mu\text{m}$  band of the C-H bond, offers unparalleled sensitivity for detecting methane and higher-order hydrocarbons (see Fig. 1). Over the past four years, the Atmospheric Chemistry Suite (ACS) has extensively surveyed this spectral

region around Mars, revealing an absence of methane above a limit of 20 pptv. Concurrently, NOMAD has similarly established such a limit at 60 pptv [20].

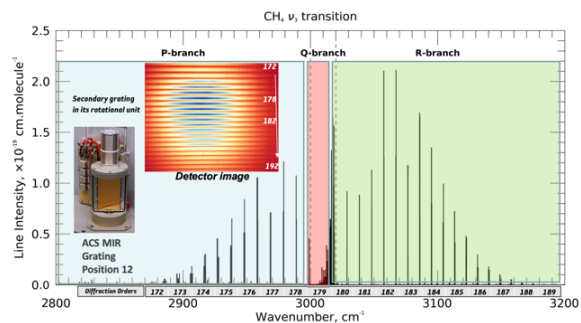


Figure 1: From [3]. The  $\sim 200$  nm wide wavelength range sampled by ACS, discretized in diffraction orders, covers the entire CH<sub>4</sub> band at 3.3  $\mu\text{m}$  (3030  $\text{cm}^{-1}$ ).

Solar occultation, the technique used in this study, is reputed to be far more sensitive than nadir observations. This heightened sensitivity arises from the Sun, a source on Mars that is approximately 600,000 times brighter than Mars itself. While atmospheric dust impedes observations of the near-surface region, the combination of high resolving power (30,000) and a high Signal-to-Noise Ratio (SNR, approximately 10,000 at low levels of dust) partly compensates for this limitation.

In [2] and [3], our efforts to detect CH<sub>4</sub> were focused on the R2 region, which features the most intense individual lines of the band system. Additionally, parallel searches in three other spectral regions are conducted to provide confirmation in the event of positive detection. These previous works have been extended to take advantage of the best SNR configuration, while accounting for the nature of the doublet of the instrumental line spread. These changes aim to push back the detection limits and gain a few kilometers towards the surface, where CH<sub>4</sub> is apparently released.

**Results:** With more than three Martian years of survey, the dataset consists of >1500 individual altitude profiles. This updated dataset will be presented, along with its implications regarding other observational studies and attempts to explain and reconcile the various observations.

In our pursuit of methane detection on Mars, special attention has been directed towards the Gale

Crater region, where MSL detected methane. By focusing our detection attempts on Gale Crater and its vicinity (see Fig. 2), we aim to either understand the contrast of reports between TGO and MSL or find methane whenever detectable by our instrument.

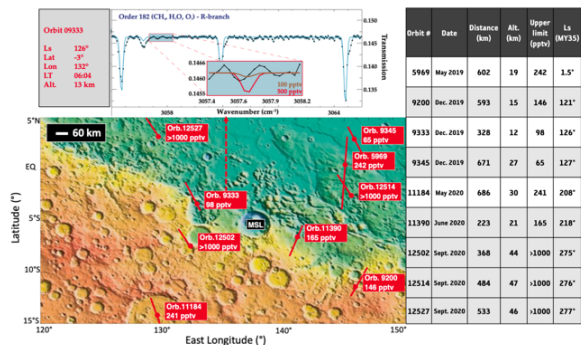


Figure 2: From [3]. Locations of the ACS detection attempts close to Gale crater (from 04/2018 to 11/2020), with their corresponding information given in the right table. Red circles show the location where the upper limit was inferred. The displayed spectrum corresponds to the closest approach to Gale that revealed an upper limit of ~100 pptv and is compared to a synthetic CH<sub>4</sub> signature of 100 and 500 pptv.

However, the equatorial region is more difficult to probe due to the geometrical constraints of TGO's orbit and is additionally veiled by a thicker dust loading (see Fig. 3). This figure shows an evident lack of data points from 30°S to 30°N. These challenging conditions have made it difficult to provide a comprehensive and sensitive survey of the Gale area. However, as the mission unfolds, more and more attempts are enabled, consolidating statistics.

This targeted approach shall enhance our understanding of localized methane emissions and aid in unraveling the complex interplay between geological processes, atmospheric dynamics, and novel chemical pathways.

The talk will also present a rapid overview of all the mechanisms that have been proposed to date to explain methane sporadic behavior.

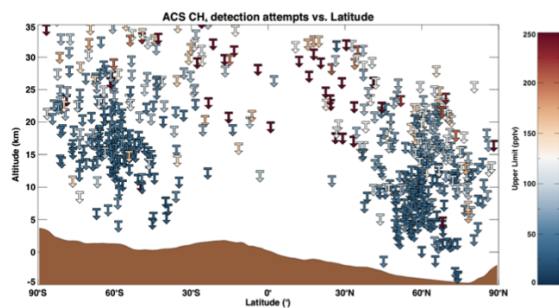


Figure 3: From [3]. Altitude distribution of 1σ upper limits derived by ACS as a function of latitudes (from 04/2018 to 11/2020). Upper limit symbols are coloured depending on

their value. Mars topography or zonal mean elevation vs. MOLA zero datum is indicated with the brown shaded area.

**References:** [1] Korablev, O., et al. 2018. Space Sci. Rev. [2] Korablev, O., et al. 2019. Nature [3] Montmessin, F., et al. 2021. Astron. & Astrophys. [4] Lellouch, E., et al. 2000. Astron. & Astrophys. [5] Formisano, V., et al., 2004. Science [6] Krasnopolsky, V. et al., 2004. Icarus [7] Mumma, M. et al., 2009. Science [8] Webster, C.R., et al., 2015. Science [9] Webster, C.R., et al., 2018. Science [10] Vandaele, A.C., et al. 2018. Space Sci. Rev. [11] Villanueva, G. et al., 2020. Sci. Adv. [12] Alday, J. et al., 2021. Nat. Ast. [13] Korablev, O., et al., 2021. Sci. Adv. [14] Aoki, S., et al., 2021. Geophys. Res. Let. [15] Olsen, K. et al., 2021. Astron. & Astrophys. [16] Fedorova et al., A., et al., 2020. Science [17] Patel, M., et al., 2021, J. of Geophys. Res. [18] Belyaev, D., et al, 2021., Geophys. Res. Let. [19] Olsen, K. et al., 2021. Nat. Geo. [20] Knutsen, E., et al., 2021, Icarus. [21] Villanueva, G. et al., 2013. Icarus [22] Aoki, S., et al., 2017. Astron. & Astrophys.