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Trace gas observations by ACS MIR onboard ExoMars/TGO

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Abstract

The Atmospheric Chemistry Suite (ACS) package is a part of Russian contribution to ExoMars 2016 Trace Gas Orbiter (TGO) ESA-Roscosmos mission for studies of the Martian atmosphere and climate [1]. The design of the middle infrared (MIR) channel was optimized to overachieve the primary science goal of the TGO mission by accomplishing the most sensitive measurements ever of the trace gases present in the Martian atmosphere. Having both, high spectral resolution and signal to noise ratio (SNR) of acquired spectra, ACS MIR channel operates in solar occultation in the spectral range of 2.3-4.24 µm.

1. Introduction

The ExoMars Trace Gas Orbiter (TGO), a mission by the European Space Agency (ESA) and Roscosmos, was launched in March 2016 and started regular observations from Martian orbit in April 2018. On board TGO, the Atmospheric Chemistry Suite (ACS) is a set of three spectrometers, including novel cross-dispersion ACS MIR spectrometer. The most tantalizing goal of ACS MIR is to do sensitive measurements of methane with detection threshold at ppt level. Besides methane, ACS MIR is able to establish new results for a number of minor species having rotational absorption bands within the instrument's wavelength range: C_2H_2, C_2H_4, C_2H_6, HO_2, H_2O_2, H_2CO, HCl, OCS etc. The high aperture of the spectrometer, the ultra-high spectral resolution, and a fast onboard frame processing ensure quality meeting the highest standards.

2. ACS MIR observations and analysis

The latitudes covered in solar occultation range from 88^0 N to 90^0 S and gradually change with time depending on season. For the trace species measurements ACS MIR is operating in the so-called "high-sensitivity" mode, where 200 frames obtained from consecutive 6 ms integration frames are stacked together on-board. One full measurement lasts 2.1 seconds. Depending on orbit a profile of the atmosphere from 0 to 200 km is measured within 3 to 6 minutes depending on orbital parameters. The uppermost part of the occultation corresponds to the clear sun observations, averaged to obtain a reference spectrum.

A "pix-by-pix" data treatment pipeline is being used to calibrated raw frames from the detector. For the upper layers of the atmosphere the standard deviation of the calibrated transmittance spectra calculated for a single detector line is better than 0.02% (SNR > 5000). Moreover, the SNR of transmittances reaches $25*10^3$ for the case of detector lines averaging. The maximum sensitivity of observations is being reached at low tangent altitudes of 5-15 km and for low dust conditions, where and when increasing lines depths and overall decreasing signal intensity are at the optimum ratio.

The synthetic spectra are being computed with spectral line parameters from HITRAN 2016 [2] corrected to account for the CO2 atmosphere. To the date temperature and pressure profiles are extracted from the Mars Climate Database version 5.3 [3], but further analysis will include derived profiles from the MIR or NIR occultation data.

3. Trace species observations

ACS MIR is capable to observe P, Q and R branches of methane absorption simultaneously at different diffraction orders. It was shown [4] that ACS observation show no methane detection at the maximum sensitivity tangent altitudes (5–15 km) with a very good accuracy. Although previous studies report methane background concentrations of an order of 500 ppt [5], for some orbits ACS states an upper limit of 10 ppt from a single occultation.

With a very low upper limit for the methane, the quantities of species like CH2O (the most abundant product of methane oxidation), CH3OH, C2H6 and in general CnHm produced by the methane degradation are too small to be detectable by TGO. If detected, even at the ppt level, those species would be a strong indication of direct outgassing from the subsurface. Our current knowledge of the ethane upper limit is based on works [6, 7] and it is <0.2ppb. There are less ethane lines than methane in our range, but they are stronger, ACS states an upper limit of 10 ppt from a single occultation for ethane in Martian atmosphere.

On Earth the sulfur-bearing species SO2, H2S and OCS are strong indicators of volcanic activity, but those were never detected on Mars. For the H2S and SO2 the MIR performances are inferior to ground-based submillimeter spectroscopy observations [8, 9], but OCS can be well studied from the 3.44 m band. The ACS MIR provides at least an order better knowledge of the upper limit compared to previous observation [9]: 200 ppt upper limit for OCS from a single occultation.

Hydrochloric acid (HCl) is known to be outgassed by volcanoes on Earth and thus may also point to the existence of seepages. Since perchlorate (ClO4) was identified in the Martian soil by Phoenix and Curiosity, an HCl detection could also identify and constrain a cycle of chlorine exchange between the surface and atmosphere. Our current knowledge of the ethane upper limit is based on works [7, 10] and it is <0.3ppb. ACS states an upper limit of 40 ppt from a single occultation for HCl, a seasonal cycle is still to be studied.

With its design, ACS MIR is providing outstanding detection capabilities outmatching by a factor of 10-100 the detection limits of previous attempts for a grand list of trace gases. Ongoing work includes data processing updates, more species study and long-lasting detection campaign. Detailed description of the latest results will be presented.

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