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# The first year of ACS/TGO ExoMars observations. Overview of results

Oleg Korablev (1), Franck Montmessin (2), Anna A. Fedorova (1), Alexander Trokhimovskiy (1), Mikhail Luginin (1), Nikolai I. Ignatiev (1), Aurelien Stcherbinine (2), Denis A. Belyaev (1), Kevin S. Olsen (2), Lucio Baggio (2), Sandrine Guerlet (3), Ronald M. B. Young (3), Francois Forget (3), Juan Alday (4), Colin F. Wilson (4), Franck Lefèvre (2), Jean Loup Bertaux (1, 2), Alexei Shakun (1), Andrew Patrakeev (1), Alexei V. Grigoriev (1)  
(1) Space Research Institute (IKI RAS) Moscow, Russia, [korab@iki.rssi.ru](mailto:korab@iki.rssi.ru), (2) LATMOS, UVSQ Université Paris-Saclay, Sorbonne Université, CNRS, France, (3) LMD CNRS Jussieu, Paris, France, (4) Physics Department, Oxford University, Oxford, UK,

## Abstract

ACS (the Atmospheric Chemistry Suite) [1] instrument onboard the ESA-Roscosmos ExoMars Trace Gas Orbiter (TGO) is dedicated to measurements of the Martian atmosphere, in particular implementing the solar occultation technique for sensitive measurement of trace atmospheric gases. TGO has started science observations from April 2018 ( $L_s=162^\circ$ ; MY34), and has observed two major perihelion dust events, the global dust storm 2018A in June till August 2018, and the regional storm in the beginning of 2019. Here we will give a status update of the ACS results, obtained from the data collected during the first year of observations in the orbit of Mars.

## 1. Introduction

ACS consists of three infrared spectrometers featuring a high accuracy, a high resolving power, and a broad spectral coverage (0.7 to 17  $\mu\text{m}$ ). The mid-infrared (MIR) channel is a high dispersion echelle spectrometer dedicated to solar occultation measurements in the 2.3-4.5  $\mu\text{m}$  range. MIR has been conceived to accomplish the most sensitive measurements of Martian trace gases, while simultaneously profiling more abundant compounds such as  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  and their isotopologues. The near-infrared -NIR- (0.7-1.6  $\mu\text{m}$ ) spectrometer, echelle-spectrometer with order-sorting by an acousto-optic tuneable filter. It is used to observe, both in solar occultation and in nadir, water vapor  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , and other gases including molecular oxygen  $\text{O}_2$  in a fundamental state. The third channel, thermal infrared Fourier transform -TIRVIM- spectrometer covers the range from 1.7 to  $\sim 10$   $\mu\text{m}$  when observing the full solar disk in occultation and from  $\sim 6$  to 17  $\mu\text{m}$ ,

measuring the thermal radiation from below in nadir. It enables the characterization of the key meteorological parameters, including the temperature profile of the atmosphere, retrieved from the 15- $\mu\text{m}$   $\text{CO}_2$  band dust, and water ice cloud column opacities. In solar occultation TIRVIM provides multi-wavelength profiling of the optical depth, and gives access to such species as  $\text{H}_2\text{O}$  and  $\text{CO}$ .

The TGO orbit (2 hours, 400-km circular,  $73^\circ$  inclination) is optimised for atmospheric observations, via solar occultations, occurring at various latitudes most of the time, and by providing measurements at a variety of local times in nadir over a 55 Martian day cycle. In solar occultation, ACS MIR pointing has to be alternated with another instrument onboard, NOMAD. Furthermore, we have to share MIR occultations between, for instance, the methane secondary dispersion grating position, on the one dedicated to HDO, or others. Thanks to larger fields of view, NIR and TIRVIM channels can observe together with NOMAD. Also, these channels measure the full useful spectral range at once. In nadir TIRVIM operating pattern allows for optimal both the local time coverage, and for Martian climate model assimilation.

The calibrations and data pipeline are close to the completion for TIRVIM (both occultations and nadir), and NIR (occultations), and are in the advanced state for MIR.

First findings of TGO occultation observations up to October 2018 are recently published, a stringent upper limit of 0.05 ppbv on methane [2], and the effect of dust storm on the vertical profiles of water and HDO [3].

## 2. Main research topics

### 2.1 Search for minor species

An update on more recent methane measurements will be given. An improved processing of MIR data more allows for more accurate assessment, that reported in [2]. Improved upper limits on other potential minor gases, such as ethane, sulfur-bearing, and chlorine-bearing species are also established.

### 2.2 Aerosol profiling

Solar occultations by all the three channels provide information on the aerosol vertical structure at terminator. Broad wavelengths coverage allows to distinguish between dust and water ice aerosols and to obtain their radius and number density profiles.

### 2.3 Water vapor profiles

We have completed one year of observations of the vertical water distribution by NIR channel spanning altitudes from 0 to 100 km. Water vapour mixing ratio is retrieved self-consistently, using atmospheric density and temperature from CO<sub>2</sub> bands. Supported by vertical distribution of dust and water ice clouds this dataset constraints very complex dynamic behaviour of water profiles during the dusty seasons.

### 2.4 Atmospheric temperature

In contrast to MGS and MRO missions, which have provided up to now the reference atmospheric state, TGO for the first time allows for characterizing the diurnal cycle of Mars' atmosphere. TIRVIM measures radiance spectra from which can be retrieved vertical profiles of atmospheric temperature, as well as surface temperatures and vertically-integrated amounts of dust, and water ice, at various local times, latitudes and seasons. Assimilation into LMD GCM shows a significant effect of the dust events on the atmospheric thermal state, and meridional circulation. The diurnal and semi-diurnal tide are also strengthened.

Another aspect of our dataset is the systematic terminator temperature profiling in solar occultations, using the different sensitivity of the CO<sub>2</sub> absorption lines to temperature (rotational temperature), and the hydrostatic temperature, validated against our nadir and MRO/MCS limb measurements

## 2.5 Other topics.

Retrievals of molecular oxygen profiles in the lower atmosphere, carbon monoxide profiles, isotopes of oxygen in CO<sub>2</sub> and water, isotopes of hydrogen in water, are demonstrated, and are subject of more systematic studies. Also, an improved knowledge of the high-spectral-resolution solar spectrum in the range of 1.38  $\mu\text{m}$  is for the first time available from out-of-the-atmosphere measurements by ACS NIR.

## 3. Summary and Conclusions

An overview of the ACS/TGO ExoMars results, obtained from the data collected during the first year of observations in the orbit around Mars is presented. Observational period includes major dust storm events on Mars and reflect the relevant atmospheric feedback. Main results include low upper limits on minor atmospheric constituents, characterisation of the water vertical distribution, atmospheric temperature state, including the diurnal cycle, and other topics. Overall, ACS confirmed expected scientific performance; the instrument is in good health and the measures to ensure its long lifetime on board are undertaken.

## Acknowledgements

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