ONE YEAR OF ACS/TGO OBSERVATIONS OF THE MARS ATMSOPHERE. O. I. Korablev[1], F. Montmessin[2], A. A. Fedorova[1], A. Trokhimovskiy[1], M. Luginin[1], N. I. Ignatiev[1], F. Lefèvre[2], A. Shakun[1], A. Patrakeev[1], D. A. Belyaev[1], J. L. Bertaux[1,2], K. S. Olsen[2], L. Baggio[2], J. Alday[4], C. F. Wilson[4], S. Guerlet[3], R. M. B. Young[3], E. Millour[3], F. Forget[3], A. V. Grigoriev[1], I. Maslov[1], D. Patsaev[1], G. Arnold[5], Davide Grassi[6]

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Introduction: 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 (Ls=162°; 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. 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]. Here we will give a status update of the ACS results, including the first year of occultation observations on the orbit of Mars, and nadir observations.

The instrument: ACS consists of three infrared spectrometers featuring a high accuracy, a high resolving power, and a broad spectral coverage (0.7 to 17 μm). The mid-infrared (MIR) channel is a high dispersion echelle spectrometer dedicated to solar occultation measurements in the 2.3-4.5 μm range. MIR has been conceived to accomplish the most sensitive measurements of Martian trace gases, while simultaneously profiling more abundant compounds such as CO_2, H_2O and their isotopologues. ACS MIR is a crossed dispersion spectrometer which measures spectra dispersed onto a cryogenic 512×640 CdHgTe infrared array. For each acquired frame, MIR measures ≥20 adjacent diffraction orders, covering an instantaneous spectral range of 0.15 to 0.3 μm wide. To achieve the full spectral coverage, a secondary dispersion grating can be rotated to one out of 12 distinct positions. The near-infrared -NIR- (0.7-1.6 μm) spectrometer, echelle-spectrometer with order-sorting by an acousto-optic tunable filter (AOTF) with InGaAs infrared array. It is used to observe, both in solar occultation and in nadir, water vapor H_2O, CO_2, and other gases including molecular oxygen O_2 in a fundamental state. The third channel, thermal infrared Fourier transform -TIRVIM- spectrometer with a cryogenic CdHgTe detector covers the range from 1.7 to ~10 μm when observing the full solar disk in occultation and from ~6 to 17 μm, 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-μm 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 H_2O and CO.

Observations: The TGO orbit (2 hours, 400-km circular, 73° inclination) is designed to favorize atmospheric observations, via solar occultations, occurring at various latitudes most of the time (short gaps occurred at Ls~175°, 207°270°, 330°, and 360°), and providing measurements at a variety of locals 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 occultations, TIRVIM is operated mostly in "climatology" mode, measuring a spectrum every 0.4 s with spectral resolution ≤1 cm^{-1}. In nadir TIRVIM operating pattern allows for optimal both the local time coverage, and for Martian climate model assimilation.

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

Major research topics:

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.

Aerosol profiling. Solar occultations by all 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.

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_2 bands. Supported by vertical distribution of dust and water ice clouds this dataset constraits very complex dynamic behaviour of water profiles during the dusty seasons.

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 [4] 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_2 absorption lines to temperature (rotational temperature), and the hydrostatic temperature, validated against our nadir and MRO/MCS limb measurements

Other topics. Retrievals of molecular oxygen profiles in the lower atmosphere, carbon monoxide profiles, isotopes of oxygen in CO_2 and water, isotopes of hydrogen in water, are demonstrated, and are subject of more systematic studies.

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