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The Mars InfraRed Trace Gas Investigation Spectrometer (MIRTIS) for the 2016 Exomars Trace Gas Orbiter

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Abstract

MIRTIS is dual spectrometer aimed at characterizing trace gases in the atmosphere of Mars. It operates in the near- and mid- infrared and shall provide unprecedented sensitivity for the detection of trace gases with geophysical and/or biological origin.

1. Instrument description

The Mars InfraRed Trace Gas Investigation Spectrometer (MIRTIS) is a compact, high-heritage instrument that has been designed to comprehensively address the three Science Objectives of the 2016 ExoMars Trace Gas Orbiter (TGO), whose announcement of opportunity has recently been released jointly by ESA and NASA. The MIRTIS instrument is the combination of a mid-infrared (MIR, see figure 1) and a near-infrared (NIR) channel that both operate in nadir and solar occultation modes. The MIR channel is a cross-dispersion spectrometer that covers simultaneously the 2.3-3.8 µm range with a mean spectral resolution of 11,000 and a signal- to-noise ratio (SNR) of 500 (per 6 second exposure) in nadir and 3,800 (per second) for solar occultation. The NIR channel is based on Acousto-Opto Tunable Filter (AOTF) technology that sequentially scans the 0.7-1.7 µm range at a spectral resolution of 1,300 and with a SNR ranging between 400 (nadir) and 800 (occultation). Leveraging high heritage from experiments currently flying on Mars and Venus Express, Rosetta, MIRTIS is dedicated to the following scientific objectives:

1) Detection and inventory of trace gases on Mars

The recent detection of CH4 has reignited interest in the possibility of past or extant life even though an abiogenic origin is also plausible. Regardless of origin, this discovery suggests that Mars is still an active planet, contrary to common perception. An intriguing aspect of the observations is that CH4 appears to be locally enhanced, up to 45 ppbv, and to change with seasons. Owing to its supposed 300-year lifetime, this short-scale variability is at odds with the current understanding of chemistry and physics87. Furthermore, Earth-based and PFS/MEX measurements show very different CH_4 maps and variability. A first priority is therefore to confirm the presence of CH_4 by performing a high-sensitivity search throughout the atmosphere of Mars.
With a detection limit (after co-adding) of 10 pptv in solar occultation and 100 pptv in nadir, MIRTIS is able to quantify the abundance of CH_4 with unprecedented sensitivity. In addition to CH4, MIRTIS will search for and quantify the abundance of a suite of gases listed by the Joint International Definition Team report: $^{13}CH_4$, C_2H_2, C_2H_4, C_2H_6, CH_2O, H_2S, OCS, N2O, HCl, HCN. MIRTIS can improve detection capabilities over previous investigations by at least one and up to several orders of magnitude (figure 2).

2) Characterization of trace gas distributions

The nadir mapping capability of MIRTIS can provide a global view of the spatial and temporal variability of trace gases, with sensitivity all the way down to the surface level, even under conditions of high dust loading (see Figure 3). Concurrent mapping and vertical profiling of standard climatic variables (dust, clouds, temperature) will relate the trace species to their environmental context.

3) Sinks and sources: localization and quantification

MIRTIS has the capability to fulfill the geographical and temporal coverage requirements needed to identify the sinks and sources of trace gases on Mars. The MIRTIS mid-infrared channel allows identification and quantification of all targetable species simultaneously, which is needed to estimate the oxidation rate and the lifetime of chemical species by both homogeneous and heterogeneous processes. Depending on the gases observed, or through ratios with isotopologues, fundamental information on the nature of the source (biogenic vs. abiotic) will be obtained.

2. Figures

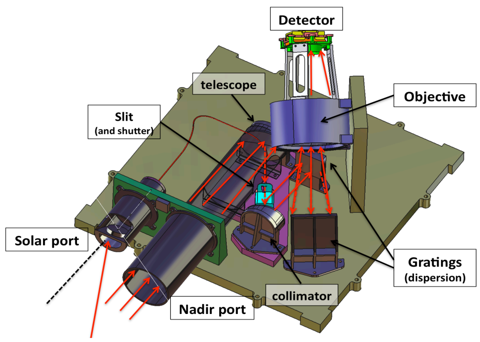

Figure 1: MIRTIS MIR channel layout.

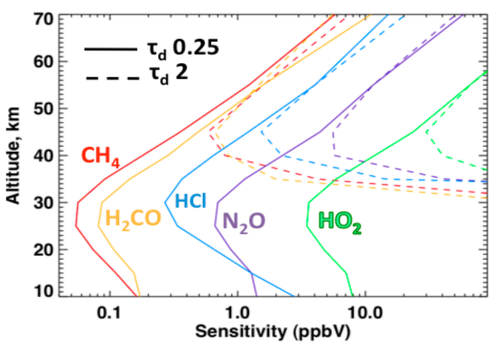

Figure 2: MIRTIS sensitivity in occultation for various gases and different dust backgrounds.

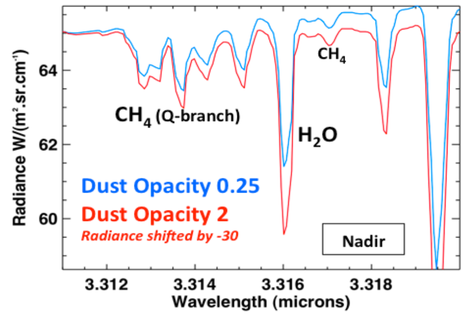

Figure 3: CH4 (10 ppbv) spectral region observed by MIRTIS under various conditions of dust. Dust has negligible effect on methane band strength and structure, making nadir viewing a very robust way to detect methane.