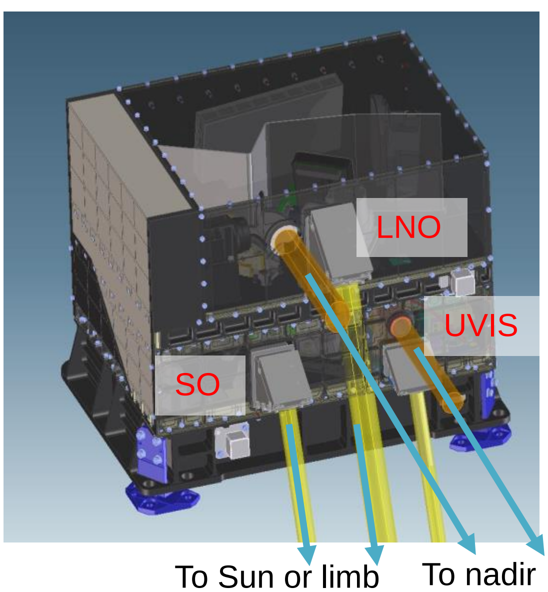
THE NOMAD SPECTROMETER SUITE ON EXOMARS TRACE GAS ORBITER. I. R. Thomas[1], A. C. Vandaele[1], F. Daerden[1], R. Drummond[1], E. Neefs[1], M. R. Patel[2], J.-J. López-Moreno[3], J. Rodriguez Gomez[3], G. Bellucci[4] and the NOMAD team. [1]Belgian Inst. for Space Aeronomy (IASB-BIRA), Avenue Circulaire-2-Ringlaan, Uccle, Brussels, Belgium (Thomas@atm.ox.ac.uk), [2]Open University, Milton Keynes, UK, [3]Instituto de Astrofisica de Andalucia IAA-CSIC, Granada, Spain, [4]Istituto di Astrofisica e Planetologia Spaziali, Roma, Italy.

Introduction: NOMAD consists of three spectrometers for measuring the atmosphere of Mars in the infrared, visible and ultraviolet as part of the ExoMars Trace Gas Orbiter mission, due for launch in 2016. Through observations in solar occultation, limb and nadir modes, it will be able to detect a wide range of trace atmospheric gases, many of which are important markers of geophysical and/or biogenic activity [1].

During the two-year mission, it will both investigate the sources and sinks of trace gas species, to determine the nature of the processes involved, and continue mapping the water, carbon, ozone and other climatologic cycles occurring in the atmosphere of Mars. NOMAD has an order-of-magnitude increase in spectral resolution over previous instruments orbiting Mars: this will allow it to measure isotopic ratios of the major constituents of the atmosphere, in addition to optical properties and particle size distributions of dust and ice aerosols.



NOMAD Channels: The three channels, each of which will generate a complimentary dataset, are as follows: solar occultation (SO); limb, nadir and occultation (LNO); and ultraviolet/visible (UVIS).

SO channel. The solar occultation channel operates in the infrared, from 4540 to 2330cm^{-1} (2.2-4.3μm) at a resolution of ~0.15cm^{-1}, and is an improved copy of the SOIR instrument currently operating on Venus Express [2]. The channel consists of an echelle grating in combination with an acousto-optic tunable filter (AOTF): the dispersive element provides the spectral discrimination, while the filter selects the diffraction order. A cooled infrared detector array is used to maximise the signal-to-noise ratio (SNR) as much as possible.

LNO Channel: This operates in a similar way to the SO channel, utilising an AOTF, echelle grating and cooled infrared detector also, but with a slightly reduced spectral range (4540 to 2630cm^{-1}; 2.2-3.8μm) and resolution (~0.3cm^{-1}) to increase SNR and reduce dark current. This channel primarily points nadir, but is capable of making limb and also additional solar occultation measurements.

UVIS Channel: UVIS operates from 200-650nm with a resolution of 1nm. It is a copy of the miniature grating spectrometer originally designed for the ExoMars lander with an added telescope for orbital measurements, rather than observations from the surface. UVIS can operate in solar occultation, limb, and nadir observational modes.

Observational Modes: NOMAD is a very versatile instrument, allowing many parameters such as integration time, spectral coverage, pixel binning, etc. to be selected in-flight; ideal for optimising the science return, given the limited Mars-Earth downlink rate. This approach enables a multitude of measurement types, depending on the observation mode and atmospheric constituent under investigation. For example, both SO and LNO - when operating in solar occultation mode - can take spectra for 6 different diffraction orders per second. Therefore, 12 slices of spectra, each 20-35cm^{-1} wide (depending on the spectral bandpass of the AOTF at the chosen wavelength) can be measured per second, resulting in a vertical spatial resolution of 1km and horizontal resolution of 10km for typical spacecraft altitudes. UVIS has a resolution of 1km x 1km per second and operates simultaneously.

For detecting trace gases however, integration times can be increased, improving SNR and hence detection ability, though at the expense of reduced vertical resolution. Between solar occultations, both LNO and UVIS can make nadir and/or limb observations to retrieve fractional column densities of gas species, for example O_3 and CO_2, for latitudes between 74°N and 74°S in the chosen orbit.

Aims: When operating nominally, NOMAD has the resolving power to identify many trace gases that exhibit absorption features within the spectral range of the three channels. These include: CO_2 (incl. $^{13}CO_2$, ^{17}OCO, ^{18}OCO, $C^{18}O_2$), CO (incl. ^{13}CO, $C^{18}O$), H_2O (incl. HDO), NO_2, N_2O, O_3, CH_4 (incl. $^{13}CH_4$, CH_3D), C_2H_2, C_2H_4, C_2H_6, H_2CO, HCN, OCS, SO_2, HCl, HO_2, and H_2S.

In particular, spatial and temporal mapping of several isotopologues of potential methane and water will be possible, providing crucial measurements of the Martian D/H and methane isotope ratios. Sensitivity studies [3] have shown that in occultation mode, using the SNR of SOIR [4], NOMAD should have the ability to measure methane concentrations <1 part per billion, with lower levels achievable using increased integration times, potentially as low as 10 parts per trillion if spectra are averaged sufficiently. Using SO and LNO in combination with UVIS, aerosol properties such as optical depth, composition and size distribution will be derivable [5].

In addition to trace gases, NOMAD will also continue to monitor the major seasonal cycles on Mars, extending existing datasets made by successive space missions in the past decade.

GEM-Mars Global Circulation Model: The NOMAD science team will assimilate instrument observations into the GEM-Mars global circulation model [6,7]. This allows modelling of complex atmospheric and chemical processes, such as heterogeneous chemistry, phase transitions, and regolith interaction on both a localised and global scale. Crucially, model results and simulations can then influence the selection of observational modes and spectra acquisition, in order to select the optimum measurement parameters for the available data rate.

References: [1] Daerden, F. (2011) EPSC-DPS Joint Meeting 2011, 6, #1300-1; [2] Vandaele, A.C. et al. (2008), J. Geophys. Res., 113; [3] Drummond, R. (2011) Planetary and Space Science, 59, pg. 292–298; [4] Mahieux, A. et al., (2009) Optics Express, 17, pg. 2005-2014 ; [5] Wilquet, V. et al. (2009) J. Geophys . Res., 114 ; [6] Daerden, F. et al. (2010), Geophys. Res. Lett., 37; [7] Neary, L. et al. (2010), EGU Abstracts, 12, #10472-1.

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