THE NOMAD SPECTROMETER SUITE ON THE EXOMARS 2016 ORBITER: CURRENT STATUS

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Introduction:

NOMAD, short for "Nadir and Occultation for MArs Discovery", is a suite of three spectrometers onboard the ExoMars 2016 Trace Gas Orbiter [1], designed to measure the constituents of the Martian atmosphere in unprecedented detail [2]. The three channels will observe gas species in the 200-650 nm and 2.2-4.3 µm spectral regions, in both nadir-pointing and solar occultation modes [3, 4], with a spectral resolution typically an order of magnitude better than the instruments currently orbiting Mars [5].

The satellite, now that the descent module Schiaparelli has been released, is currently in an elliptical orbit around Mars, awaiting aerobraking. The primary science mission is expected to begin in late 2017, once aerobraking is complete and the satellite is in its nominal 400km circular orbit.

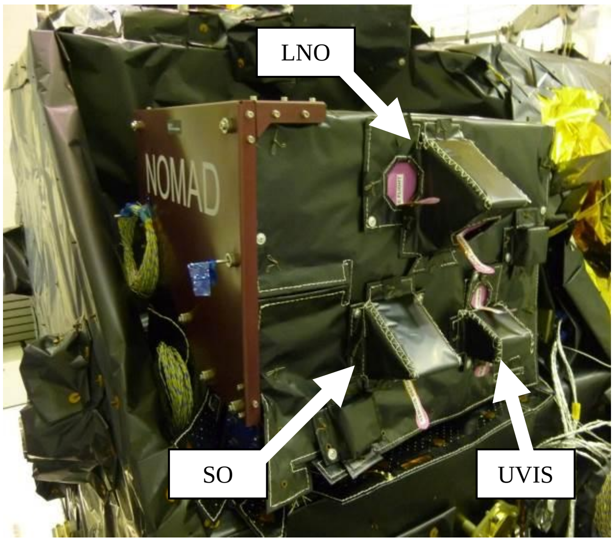

Figure 1: NOMAD after mounting on the payload deck of the spacecraft. The 3 triangular periscopes, through which the occultation boresights pass, can be seen protruding from the main instrument. The NOMAD radiator is hidden by the red cover on the left.

In addition to ground calibration, NOMAD has been switched on for three inflight calibration sessions since launch; two of which occurred during the cruise and one after Mars orbit insertion. During these phases, many calibration and some scientific measurements were made in preparation for the science mission. Results from these observations and the current status of NOMAD will be presented.

Channels:

Solar Occultation (SO) channel: The solar occultation channel operates in the infrared (IR), from 2330 to 4540 cm^{-1} (2.2-4.3 µm) at a resolution of ~0.15 cm^{-1}. It is an improved copy of the SOIR instrument, an occultation instrument onboard Venus Express [6, 7]. The channel contains an echelle diffraction grating in combination with an Acousto-Optic Tunable Filter (AOTF), which acts as a passband filter, selecting the desired diffraction order [3]. The final element of the optical chain is an infrared detector cryo-cooled to maximize the signal-to-noise ratio (SNR) as much as possible.

Limb, Nadir and Occultation (LNO) channel: This channel operates in a similar way to the SO channel, with an AOTF, diffraction grating and cryo-cooled IR detector. The spectral range of LNO is slightly reduced compared to SO, spanning the 2630 to 4540 cm^{-1} (2.2-3.8 µm) range, and with a slightly lower resolution (~0.5cm^{-1}). Both of these changes help to maximize the SNR in nadir mode, by increasing throughput to the detector whilst reducing thermal noise [3]. This channel primarily points nadir, but is capable of making limb and solar occultation measurements if desired using a flip mirror to change the boresight pointing direction. In this way, the LNO channel also functions as a backup to SO.

UltraViolet-Visible (UVIS) channel: This channel operates in the 200-650 nm range with a resolution of ~1.2-1.6 nm. The design uses a diffraction grating illuminated by optical fibres from two telescopes; one for solar occultations and one for limb and nadir observations. It has heritage from the proposed ExoMars Humboldt lander [4].

Science Objectives:

NOMAD will be able to identify many trace gases with absorption features present within the instrument's spectral range. 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 [2, 5, 8].

Through very high resolution solar occultation and nadir observations, detection and mapping of isotopologues of methane and water will be possible, providing important measurements of the Martian D/H and methane isotope ratios globally. Sensitivity studies [5,8] have shown that in occultation mode, using expected SNR values [9,10], NOMAD should have the ability to measure methane concentrations down to ~25 parts per trillion (ppt) in solar occultation mode, and 11 parts per billion in nadir mode. This sensitivity level could be increased to 10 ppt in occultation mode by averaging spectra together sufficiently [8]. Using SO and LNO in combination with UVIS, aerosol properties such as optical depth, composition and size distribution will be also derived, as has been performed for Venus [11]. The surface UV radiation environment can be determined by observing reflected light in nadir mode.

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. Global datasets of CO_2, H_2O, O_3, CO etc. will be invaluable to monitoring changes in the atmosphere of Mars. The measurements made by NOMAD will be interpreted with 1D [12] and general circulation models for Mars [13], and will contribute to identify and understand atmospheric processes, including constraining the sources of methane, if present [14].

Results:

A variety of measurements have already been completed, both on the ground and in space. At the time of writing, only calibration measurements have been performed so far, however the first nadir measurements of Mars were expected to be made at the end of November 2016, after insertion into an elliptical orbit around Mars. Figures 2 and 3 show the results of some calibration measurements made during Near-Earth Commissioning in April 2016 and Mid-Cruise Checkout in June 2016. These show that the channels are working well in occultation mode, and that the spectral calibration and boresight pointing directions are now well known. Similar results were also found for the UVIS channel.

Conclusion:

After the final calibration session in November 2016 and analysis of the data taken, NOMAD will be ready to begin the science mission, generating a huge global dataset of atmospheric observations of trace gases and major atmospheric constituents in unprecedented detail. Such data will be instrumental in improving our knowledge of Mars, including mapping sources and sinks of methane and isotopes, and measuring variations in the D/H ratio across the planet. Monitoring of carbon, ozone, water and dust cycles will also be performed, continuing previous datasets into the next decade.

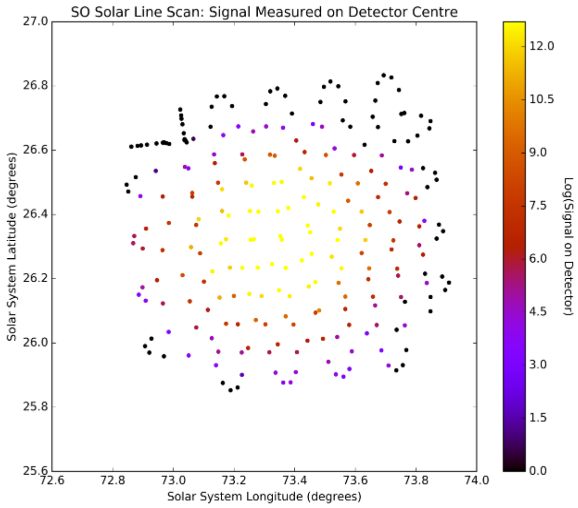

Figure 2: Line of sight calibration measurements were performed to measure the pointing direction of all solar occultation channels, as this information will be crucial for all solar calibration and occultation measurements. To achieve this, the spacecraft performs a series of slews, moving the boresight around the sun whilst data is being recorded. The exact pointing direction can be determined by finding the positions where the sun centre was observed by the channels.

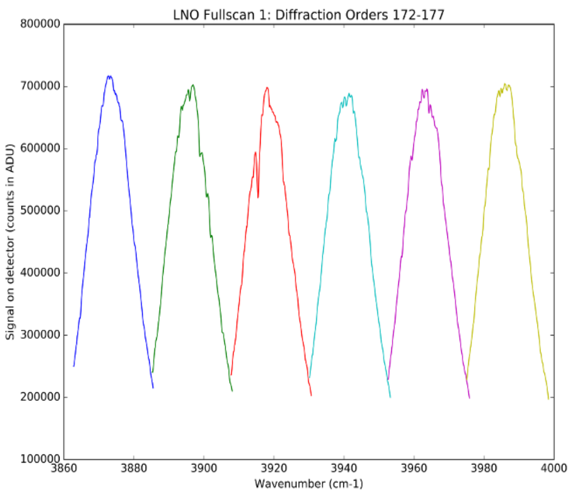

Figure 3: Sun calibration of the NOMAD LNO channel. Here the raw signal has been plotted for six consecutive diffraction orders, from order 172 to 177. The absorptions visible are Fraunhofer lines in the solar spectrum, which can be used to spectrally calibrate the instrument and AOTF.

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