EPSC Abstracts
Vol. 12, EPSC2018-654, 2018
European Planetary Science Congress 2018

The NOMAD Spectrometer Suite on ExoMars Trace Gas Orbiter: Data Products, Format and Availability in the ESA Planetary Science Archive

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Introduction

NOMAD, one of four scientific instruments on the ExoMars Trace Gas Orbiter (TGO), is a suite of three spectrometers operating in the UV-visible and infrared spectral ranges [3]. It was launched 2 years ago and, at the time of writing (May 2018), has begun making measurements as part of the TGO nominal science phase.

Data taken by NOMAD will be made available to the public and Mars community in NASA PDS4 format (pds.jpl.nasa.gov/), the current standard for space science missions, via the ESA Planetary Science Archive (archives.esac.esa.int/psa/). At the time of writing this abstract, the data is still under embargo - though this will be lifted soon, and therefore now is an opportune time to present the dataset to the scientific community.

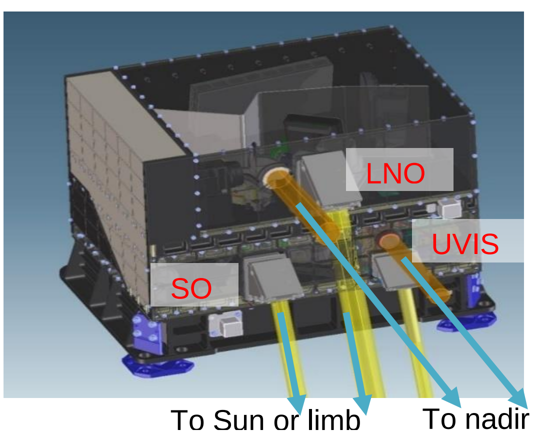

Figure 1: The NOMAD spectrometer suite.

There are three spectrometers within NOMAD, performing two main types of observations:

Solar occultations, where the sun is continually observed as the field of view passes through the atmosphere, have extremely high signal to noise ratios, but can only be performed when the orbital position of the spacecraft allows it. On some occultations, the field of view never reaches the surface – these are known as grazing occultations.

Nadir observations, where the field of view is pointed to the ground directly below the spacecraft, and reflected sunlight is observed by the spectrometer. These can be measured regularly, but the trade-off is a lower signal to noise ratio.

The three channels are as follows:

SO (2.2-4.3um, resolving power ~20000 and SNR>1000) which operates in solar occultation mode.

LNO (2.2-3.8um, resolving power ~15000), which operates in nadir mode but can also measure in occultation and/or limb mode also.

UVIS (200-650nm), which operates in both solar occultation and nadir mode, and potentially in limb mode in future.

Both SO and LNO do not typically measure their entire spectral range every observation (though it is possible to do so). Instead, the range is split into ~100 diffraction orders, a selection of which are measured in an observation [1]. An acousto-optic crystal (AOTF) acts as a pass-band order-sorting filter, allowing radiation for the desired diffraction order to enter the spectrometer for a measurement, before the crystal driver frequency is changed to shift the pass-band onto another diffraction order [1]. Typically, up to 12 diffraction orders are measured during a solar occultation, and 2, 3 or 4 are measured during a nadir pass, however these values can be adapted depending on the observation conditions e.g. surface solar illumination angle. The choice of diffraction orders, the speed through which the diffraction orders are cycled, the detector readout rows (which affects the FOV direction), integration time, and many other parameters can also be varied – meaning that SO and LNO data can be complex to understand.

UVIS typically returns a full spectrum for each observation [2] (though a limited spectral range is also possible), and therefore no AOTF or diffraction order options exist. Multiple observation modes are possible, such as un-binned mode, where each pixel is read out individually (increasing SNR) rather than onboard binning if sufficient data volumes are available, and the nadir integration time depends on the surface illumination for a given observation.

Data Products

The data products in the PSA are grouped as follows:

Raw products: these contain only uncalibrated housekeeping and science data.

Partially processed products: these contain a mixture of calibrated and uncalibrated datasets. The housekeeping (e.g. temperatures, voltages, etc.) are converted into SI units while the detector and observation parameters (e.g. AOTF driver frequency) remains in a raw format.

Calibrated products: these contain calibrated housekeeping, science and ancillary data. The process for calibrating the data is described in the next section.

Derived products: these are higher-level products created from single or multiple observations e.g. atmospheric densities or gas species maps.

Data Pipeline

The three channels and multiple observation modes makes it very difficult to describe all possible variations. In general terms though, the nominal science data is calibrated as follows:

1. Housekeeping and observation parameters converted to SI units.

2. Geometry parameters added e.g. latitude, longitude, occultation tangent height, L_s, sub-solar and sub-TGO parameters, etc.

3. Spectral calibration (including temperature dependency and AOTF for SO/LNO).

4. Detector data corrections e.g. dark subtraction and/or vertical binning of detector rows (if applicable), correction/detection of bad pixels and other anomalies.

5. Straylight correction (UVIS only).

6. Radiometric calibration. For solar occultations by both UVIS and SO, the data is converted to transmittance (where 1=top of atmosphere and 0=no signal). For nadir and limb observations, UVIS data is converted to radiance and LNO data is converted to either radiance factor or radiance. The resulting datasets will form the basis of the PSA calibrated products.

Data Format

The NOMAD PSA collection is comprised of .xml label files which reference tabulated data stored in ASCII in .tab files. Metadata, such as observation parameters (e.g time, diffraction order, start/end geometry) will be included here, allowing the searching and filtering of specific datasets using the PSA interface.

The tabulated data products contain one spectrum per line, including housekeeping, geometry, spectral calibration (e.g. wavelengths (UVIS) or wavenumbers (SO/LNO), AOTF function (SO/LNO), etc.), radiometric calibration (e.g. radiance), and radiometric calibration error (e.g. uncertainty in radiance).

Acknowledgements

The authors would like to thank everyone who has contributed to the design, construction, testing, operations and management of NOMAD and TGO. The NOMAD experiment is led by the Royal Belgian Institute for Space Aeronomy (IASB-BIRA), assisted by Co-PI teams from Spain (IAA-CSIC), Italy (INAF-IAPS), and the United Kingdom (Open University). This project acknowledges funding by the Belgian Science Policy Office (BELSPO), with the financial and contractual coordination by the ESA Prodex Office (PEA 4000103401, 4000121493), by the Spanish Ministry of Economy, Industry and Competitiveness, by FEDER funds under grant ESP2015-65064-C2-1-P (MINECO/FEDER), and by the UK Space Agency through grant ST/P000886/1 and Italian Space Agency through grant 2018-2-HH.0.

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