NOMAD ON EXOMARS TRACE GAS ORBITER: OBSERVATIONS, CALIBRATION, AND PUBLICLY AVAILABLE DATA

I. R. Thomas, **L. Trompet, Y. Willame, A. Piccialli, J. T. Erwin, A.C. Vandaele, B. Ristic, S. Robert, Z. Flimon, F. Vanhellemont, F. Daerden, L. Neary, S. Viscardy, C. Depiesse,** *Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium (ian.thomas@aeronomie.be)*, **S. Aoki**, *University of Tokyo, Tokyo, Japan,* **M.R. Patel**, *Open University, Milton Keynes, U.K., and STFC Rutherford Appleton Laboratory, Oxfordshire U.K,* **J.J. Lopez Moreno**, *Instituto de Astrofisica de Andalucia (IAA/CSIC), Granada, Spain,* **G. Bellucci**, *Istituto di Astrofisica e Planetologia Spaziali (IAPS/INAF), Rome, Italy,* **and the NOMAD Team**

Introduction:

NOMAD is a suite of three spectrometers onboard the ExoMars 2016 Trace Gas Orbiter, designed to measure the constituents of the Martian atmosphere in unprecedented detail [1]. The three channels observe gas species in the 200-650 nm and 2.2-4.3 μm spectral regions, in nadir, limb and solar occultation modes [2]. NOMAD has been operating continuously since April 2016 and has already generated a wealth of data about the atmospheric constituents and processes on Mars.

Observations:

SO channel: Typically, the SO channel operates in the infrared in solar occultation mode, measuring six spectral regions ~30 cm^{-1} wide at a resolution of ~0.15 cm^{-1} in each occultation [3]. The spectral regions are chosen based on the desired molecules/atmospheric constituents, isotopologues and altitude ranges, where the lines are strong enough to be observable but not saturated.

The channel can also operate in 'fullscan' mode, where any number of spectral regions are measured consecutively, covering the full spectral range of the channel or a selected region, for example [4].

Absorption lines of H_2O [5], CO [6], CO_2 [7] and their isotopologues, plus aerosols [8], are measured in almost every occultation, with searches for HCl [9], CH_4 [10] and other trace gases and clouds made regularly.

LNO channel: This channel measures primarily in nadir, measuring 2-6 spectral regions ~30 cm^{-1} wide at a resolution of ~0.2 cm^{-1} [3] in each nadir pass over the dayside of Mars when operating. The spectral range is limited to 2.2-3.8 μm [1] and it typically observes in nadir on one-out-of-four orbits for thermal and lifetime considerations.

Absorption lines of H_2O [11] and CO [12] are measured in almost every nadir observation, with searches for HDO and CH_4 made regularly.

The channel occasionally operates in 'fullscan' mode, to probe a wider spectral range in nadir mode; the channel can also operate in solar occultation mode and has made some fullscans during solar occultations like the SO channel [13].

LNO also observes the nightside of the planet occasionally, plus the Mars' limb on both the dayside and nightside to search for non-LTE CO_2 emissions.

Recently, observations have been made of Phobos and Deimos: Phobos is certainly observable by LNO; however Deimos is potentially too small and too distant from TGO to be observed. Optimisation of these observations is ongoing: systematic noise removal, FOV pointing direction and the trade-off between the SNR and the number of spectral regions measured are all under investigation.

UVIS channel: This channel operates in the same modes as SO and LNO, measuring solar occultations, dayside + nightside nadirs and dayside + nightside limbs, in the ultraviolet and visible spectral region from 200-650 nm. Unlike SO and LNO, the full spectral range is typically measured on every observation, with a spectral resolution of ~1.5 nm [14] when operating in unbinned mode for nadirs and limbs. For solar occultations, spectral binning is normally performed, giving a spectral resolution of ~12nm [14].

In solar occultation and nadir modes, the channel observes O_3 [15] and dust/aerosols [16]. In limb-pointing mode, airglow is observed: the green [17] and red [18] lines have both been measured and we are currently searching for auroral emissions in the nightside limb observations.

The UVIS channel has also successfully observed Phobos and Deimos; calibration and observation optimisation of these observations is ongoing.

Calibration:

Recently, several calibration papers have been published for all three channels:

- *Calibration of NOMAD on ESA's ExoMars Trace Gas Orbiter: Part 1 – The Solar Occultation channel* [4]
- *Calibration of NOMAD on ESA's ExoMars Trace Gas Orbiter: Part 2 – The Limb, Nadir and Occultation (LNO) channel* [13]
- *Calibration of NOMAD on ExoMars Trace Gas Orbiter: Part 3 - LNO validation and instrument stability* [19]
- *Calibration of the NOMAD-UVIS data* [14]
- *Removal of straylight from ExoMars NOMAD-UVIS observations* [20]

- *The deuterium isotopic ratio of water released from the Martian caps as measured with TGO/NOMAD (supporting information)* [21]

These papers describe in detail the latest calibration analysis, giving data users insight into how the instrument was calibrated and important information for understanding how NOMAD's three channels function for further analysis of the spectra.

Availability of Data:

At the time of writing (April 2022), work is ongoing to convert almost all NOMAD data into the NASA PDS4 format [22]. This data will then be available to everyone via the ESA PSA interface [23]. The observations that will be available are as follows:

- SO + UVIS occultations (figure 1)
- SO + LNO occultation fullscans (figure 2-3)
- LNO + UVIS day nadir (figure 4)
- UVIS night nadir
- UVIS day limb (figure 5)
- UVIS night limb

The other remaining observation modes (LNO night nadirs; LNO day + night limbs; LNO day nadir fullscans and LNO + UVIS Phobos/Deimos) will be delivered to the PSA when the respective calibrations are ready.

Each observation on the PSA has an associated thumbnail image: examples of these can be found in figures 1-5.

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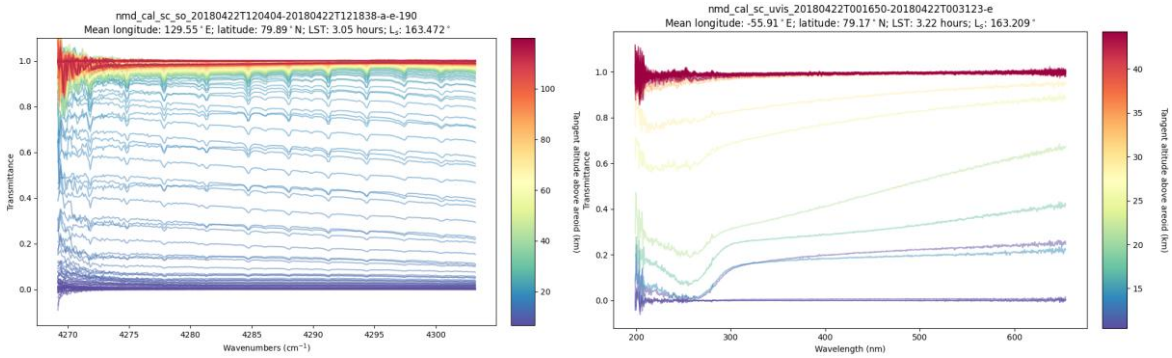

Figure 1: SO (left) and UVIS (right) solar occultation spectra. Thumbnail images available on the ESA PSA.

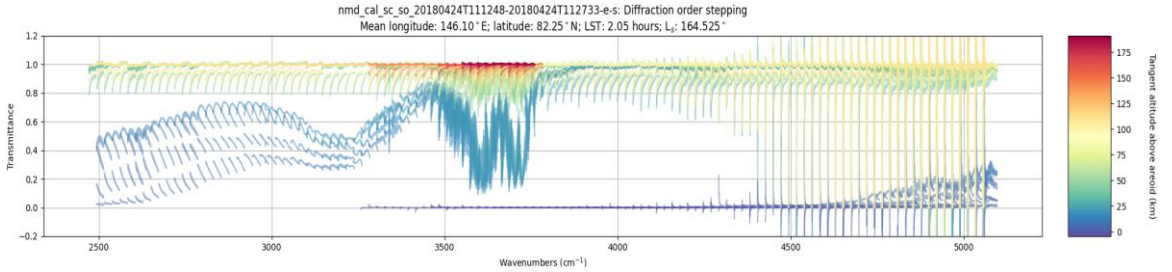

Figure 2: SO solar occultation fullscan spectra. Thumbnail images available on the ESA PSA.

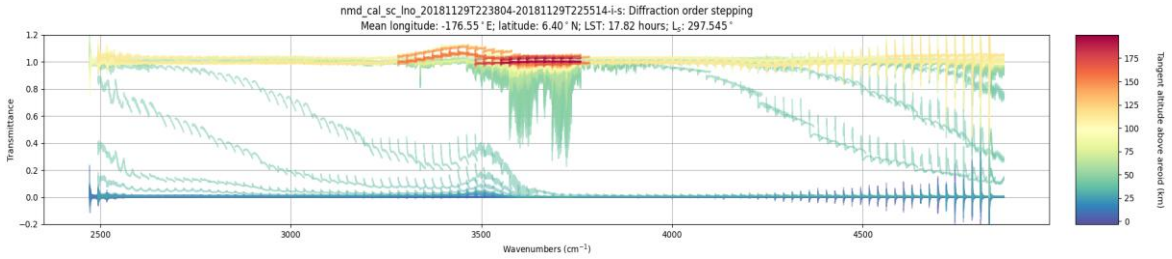

Figure 3: LNO solar occultation fullscan spectra. Thumbnail images available on the ESA PSA.

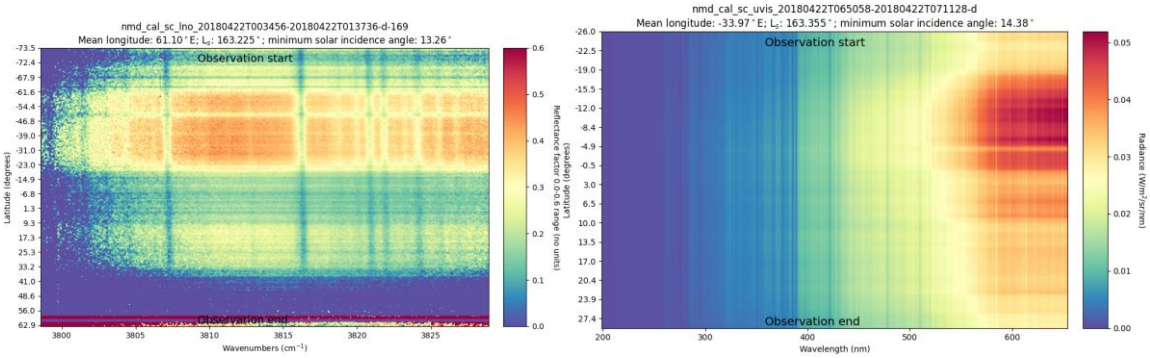

Figure 4: LNO (left) and UVIS (right) day nadir spectra. Thumbnail images available on the ESA PSA.

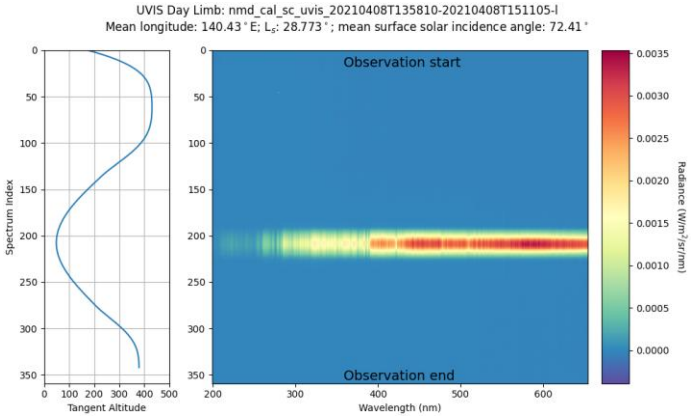

Figure 5: UVIS day limb altitude profile and spectra. Thumbnail images available on the ESA PSA.