EPSC Abstracts
Vol. 13, EPSC-DPS2019-725-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Strong seasonal and diurnal variability of water D/H on Mars as revealed with ExoMars/NOMAD

Geronimo L. Villanueva (1), Giuliano Liuzzi (1,2), Matteo J. Crismani (1), Shohei Aoki (3), Ann Carine Vandaele (3), Michael J. Mumma (1), Michael D. Smith (1), Frank Daerden (3), Lori Neary (3), Sebastien Viscardy (3), Ian R. Thomas (3), Miguel Angel Lopez-Valverde (4) Bojan Ristic (3), Manish R. Patel (5), James H. Holmes (5) Giancarlo Bellucci (6), Jose Juan Lopez-Moreno (4) and the NOMAD team.

(1) NASA Goddard Space Flight Center, USA, (2) Department of Physics, American University, USA, (3) Royal Belgian Institute for Space Aeronomy, Belgium, (4) Instituto de Astrofísica de Andalucía, Spain, (5) Open University, UK, (6) Istituto di Astrofisica e Planetologia, Italy.
(e-mail : geronimo.villanueva@nasa.gov)

Abstract

We present the first complete dataset of retrievals of water and D/H vertical profiles derived from the Nadir and Occultation for MArs Discovery (NOMAD) instrument, onboard ExoMars Trace Gas Orbiter (TGO). These retrievals cover the entire nominal science phase so far, which started on April 21st, 2018. The water isotopic ratio can be used to test for water loss and ancient water reservoirs, yet climatological and short-term processes (e.g., condensation, Rayleigh distillation) can hide and mask the true evolutionary signature of escape isotopic fractionation. This first comprehensive study of the seasonal and diurnal processes affecting this key signature allows us to better separate evolutionary from climatological processes, providing a strong quantification of water loss impressed in the D/H of water on Mars.

1. NOMAD instrument

NOMAD is a spectrometer operating in the spectral ranges between 0.2 and 4.3 μm onboard ExoMars TGO [1]. NOMAD has 3 spectral channels: a solar occultation channel (SO – Solar Occultation; 2.3-4.3 μm), a second infrared channel capable of nadir, solar occultation, and limb sounding (LNO – Limb Nadir and solar Occultation; 2.3-3.8 μm), and an ultraviolet/visible channel (UVIS – UV visible, 200-650 nm). The infrared channels (SO and LNO) have high spectral resolution (λ/dλ~10,000-20,000) provided by echelle grating in combination with an Acousto Optic Tunable Filter (AOTF) which selects diffraction orders [2]. The concept of the infrared channels are derived from the Solar Occultation in the IR (SOIR) instrument onboard Venus Express. The sampling rate for the solar occultation measurement is 1 second, which provides unprecedented vertical resolution (less than 1 km) spanning altitudes from the surface to 200 km. Thanks to the near-instantaneous change of the observing diffraction orders achieved by AOTF, the SO channel is able to measure five or six different diffraction orders per second in solar occultation mode.

Deuterated water (HDO) is primarily quantified by probing the ν_1 band at 3.7 μm, corresponding to the orders 119-124 of the NOMAD/SO channel. We used information from all of these orders to quantify HDO. Water is measured with NOMAD at different diffraction orders across the whole SO wavelength range. Some strong bands, such as the ν_1 and ν_3 of water at 2.7 μm (orders 166-174), allow to probe high altitudes where the atmosphere is thin, yet these bands become too optically thick at lower altitudes (<30 km). We therefore complement the water measurements by also probing weaker bands, such as the $2\nu_2$ at 3.3 μm (orders 133-136 and 140) and lines in the 3 μm region (orders 145-149). At altitudes when different orders provide similar sensitivities, we verified that the retrievals of water were consistent between the orders. This multi-order quantification strategy ensures maximum altitude coverage and self-consistency across the database.

2. D/H vertical profiles

Measurements of water vapor vertical profiles are a key diagnostic to the escape processes acting on water on Mars. Since the start of the nominal science phase on April 21st 2018, the ExoMars/NOMAD instrument suite has regularly conducted solar occultation measurements that are able to provide water vapor vertical profiles with unprecedented vertical resolution (< 1 km). So far, more than 2500 occultations have been acquired. The occultations sample the dawn and dusk terminators, allowing us to investigate diurnal changes, while the broad range of dates (April/2018 – September/2019) spans almost a full Mars year, and permits the investigations of the seasonal cycle on the D/H. For the retrieval analysis, we employed the Planetary Spectrum Generator (PSG) [3], and similar techniques as reported in [4].

Our initial analysis of two D/H profiles measured with NOMAD reveal strong variability before and after the dust storm of 2018 [5], indicative of a strong effect of the climatology on the water cycle and isotopic signatures. In this paper, we advance these pioneering measurements to the whole planet and a broad range of seasons. Our latest results show dramatic variability of the D/H across seasons and over short time scales. The D/H is expected to vary due to the Vapor Pressure Isotope Effect (VPIE), which produces an isotopic fractionation at condensation (e.g., cloud formation and frost/ground fog formation), yet the observed localized (in time and space) anisotropies are certainly higher than was predicted by current atmospheric models. In this presentation, we will discuss different possible scenarios that may explain this variability and will discuss how these short-term processes impact our ability to estimate water loss from atmospheric D/H measurements.

Acknowledgements

This research is supported by NASA, under grant number GSFC-604796. Crismani is supported under NASA Postdoctoral Program, managed by USRA. 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 MICINN through its Plan Nacional and by European funds under grants PGC2018-101836-B-I00 and ESP2017-87143-R (MINECO/FEDER), as well as by UK Space Agency through grant ST/P000886/1 and Italian Space Agency through grant 2018-2-HH.0. The IAA/CSIC team acknowledges financial support from the State Agency for Research of the Spanish MCIU through the 'Center of Excellence Severo Ochoa' award for the Instituto de Astrofísica de Andalucía (SEV-2017-0709). This work was supported by the Belgian Fonds de la Recherche Scientifique – FNRS under grant numbers 30442502 (ET_HOME) and T.0171.16 (CRAMIC) and BELSPO BrainBe SCOOP Project.

References

[1] Vandaele, A. C. et al. NOMAD, an integrated suite of three spectrometers for the ExoMars Trace Gas mission. Space Sci. Rev. 214, 80, 2018.

[2] Neefs, E., et al. NOMAD spectrometer on the ExoMars trace gas orbiter mission: part 1, *Applied Optics*, Vol. 54 (28), pp. 8494-8520, 2015.

[3] Villanueva, G. L., et al., Planetary Spectrum Generator: An accurate online radiative transfer suite, *JQSRT*, 217, pages 86–104, 2018.

[4] Villanueva, G. L.., et al., Strong water isotopic anomalies in the Martian atmosphere, *Science*, 348 (6231), pages 218-221, 2015.

[5] Vandaele, A.C., et al. Martian dust storm impact on atmospheric H_2O and D/H observed by ExoMars Trace Gas Orbiter, *Nature*, 568, pages 521–525, 2019.

The NOMAD Science Team

Ann Carine Vandaele, Jose-Juan López-Moreno, Giancarlo Bellucci, Manish R. Patel, Gustavo Alonso-Rodrigo, Shohei Aoki, Francesca Altieri, Sophie Bauduin, David Bolsée, Giacomo Carrozzo, R. Todd Clancy, Edward Cloutis, Matteo Crismani, Frank Daerden, Fabiana Da Pieve, Emiliano D'Aversa, Cédric Depiesse, Justin T. Erwin, Giuseppe Etiope, Anna A. Fedorova, Bernd Funke, Didier Fussen, Maia Garcia-Comas, Anna Geminale, Jean-Claude Gérard, Marco Giuranna, Leo Gkouvelis, Francisco Gonzalez-Galindo, James Holmes, Benoît Hubert, Nicolay I. Ignatiev, Jacek Kaminski, Ozgur Karatekin, Yasumasa Kasaba, David Kass, Armin Kleinböhl, Orietta Lanciano, Franck Lefèvre, Stephen Lewis, Giuliano Liuzzi, Manuel López-Puertas, Miguel López-Valverde, Arnaud Mahieux, Jon Mason, Michael J. Mumma, Hiromu Nakagawa, Lori Neary, Eddy Neefs, Robert E. Novak, Fabrizio Oliva, Arianna Piccialli, Etienne Renotte, Birgit Ritter, Séverine Robert, Frédéric Schmidt, Nick Schneider, Giuseppe Sindoni, Michael D. Smith, Nicholas A. Teanby, Ed Thiemann, Ian R. Thomas, Alexander Trokhimovskiy, Loïc Trompet, Jean Vander Auwera, Geronimo L. Villanueva, Sébastien Viscardy, James Whiteway, Valerie Wilquet, Yannick Willame, Michael J. Wolff, Paulina Wolkenberg, Roger Yelle.