



**HAL**  
open science

## Circulation Patterns in the Martian Nightside Upper Atmosphere Revealed by Nitric Oxide Nightglow

Z. Milby, A. Stiepen, N. Schneider, S. Jain, F. González-Galindo, E. Royer, J.-C. Gérard, J. Dieghan, A. I. F. Stewart, F. Forget, et al.

► **To cite this version:**

Z. Milby, A. Stiepen, N. Schneider, S. Jain, F. González-Galindo, et al.. Circulation Patterns in the Martian Nightside Upper Atmosphere Revealed by Nitric Oxide Nightglow. Ninth International Conference on Mars 2019, Jul 2019, Pasadena, United States. pp.LPI Contribution No. 2089, id.6321. insu-04408251

**HAL Id: insu-04408251**

**<https://insu.hal.science/insu-04408251v1>**

Submitted on 21 Jan 2024

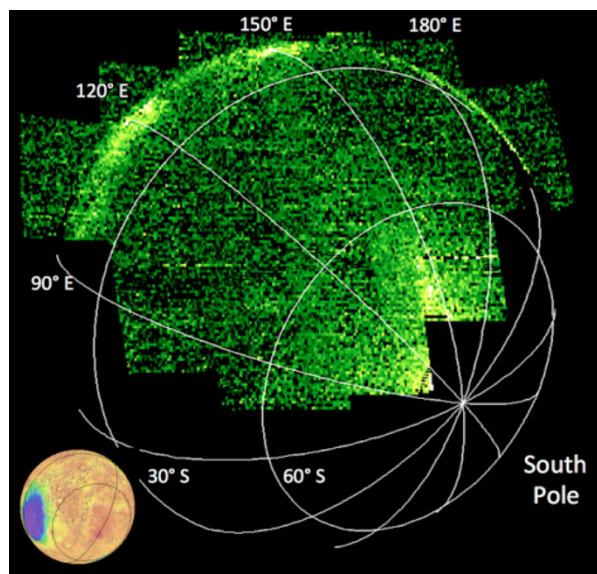
**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## CIRCULATION PATTERNS IN THE MARTIAN NIGHTSIDE UPPER ATMOSPHERE REVEALED BY NITRIC OXIDE NIGHTGLOW EMISSION.

Zachariah Milby<sup>1</sup>, Arnaud Stiepen<sup>2</sup>, Nicholas Schneider<sup>1</sup>, Sonal Jain<sup>1</sup>, Francisco González-Galindo<sup>3</sup>, Emilie Royer<sup>1</sup>, Jean-Claude Gérard<sup>2</sup>, Justin Deighan<sup>1</sup>, Ian Stewart<sup>1</sup>, François Forget<sup>4</sup>, Franck Lefèvre<sup>5</sup>, <sup>1</sup>Laboratory for Atmospheric and Space Physics (zachariah.milby@lasp.colorado.edu), <sup>2</sup>Laboratoire de Physique Atmosphérique et Planétaire, Space Sciences, Technologies and Astrophysics Research (STAR) Institute, University of Liège, Liège, Belgium, <sup>3</sup>Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain, <sup>4</sup>Laboratoire de Météorologie Dynamique (LMD), Paris, France, <sup>5</sup>Laboratoire Atmosphères, Milieux, Observations Spatiales, CNRS, Université Pierre et Marie Curie, Paris, France

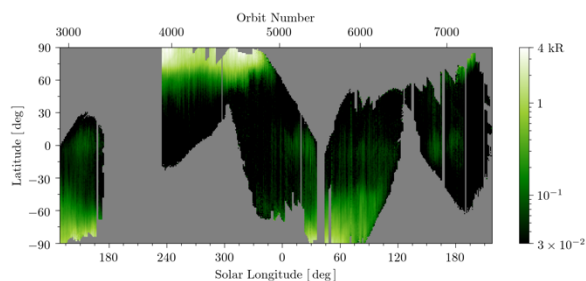
**Introduction:** The nitric oxide (NO) nightglow is a reaction rate which traces flux between from the nightside Martian thermosphere to the mesosphere. The process begins in the dayside thermosphere, where solar extreme ultraviolet radiation photo-dissociates atmospheric CO<sub>2</sub> and N<sub>2</sub> molecules. Upper-atmosphere Hadley circulation transports N and O atoms toward the nightside poles, where descending polar winds bring the atoms down into the mesosphere. The atoms combine to form an excited NO molecule, which nearly-instantaneously relaxes, emitting ultraviolet photons in the distinctive NO  $\delta$  and  $\gamma$  bands. Brighter emission occurs where descending air brings molecules deeper into the mesosphere, so we use the reaction rate as a tracer of the dynamics between Mars' thermosphere and mesosphere [1, 2, 3, 4, 5].



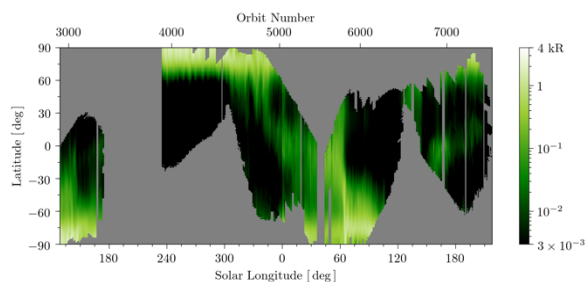
**Figure 1:** Derived NO nightglow observed during MAVEN orbit 3102 on May 4, 2016. We observe the expected enhanced emission near the southern (winter) pole, but also unexpected features near the equator at longitudes 120° E and 150° E.

**Observations:** Our data come from the Imaging Ultraviolet Spectrograph (IUVS) [6] on the Mars At-

mosphere and Volatile Evolution (MAVEN) mission [7] spacecraft. Figure 1 shows an example of an observation from a single orbit with brighter pixels indicating enhanced NO emission. Our dataset spans a large range of seasonal conditions and latitudes (figure 2). We also compare to LMD-MGCM simulations of the same data points (figure 3). The broad data span allows us to compare some observations between subsequent Mars years 33 and 34.



**Figure 2:** Climatology map of IUVS observations. Our observations have some overlap of equatorial equinox data between 150° and 180° solar longitude.

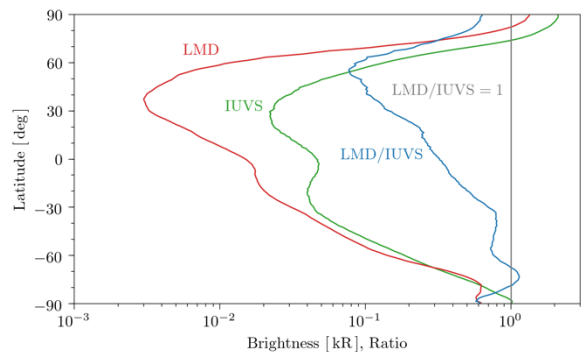


**Figure 3:** LMD-MGCM simulations of the same data points. The model's brightness range covers an additional order of magnitude.

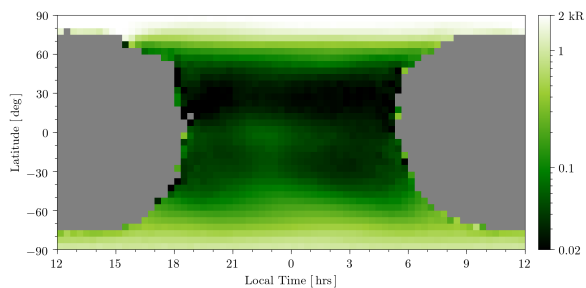
**Results:** In our initial study using vertical limb-scans of the nightside atmosphere, we found a wave-3 structure at equatorial latitudes [7]. We further expanded this study using full-disk images taken at MAVEN's orbital apoapsis with enhanced geographical coverage. Because we only observe poles during winter, we observe the expected latitude gradient from the equator to the poles, but we also see the

equatorial enhancement correlated with the wave-3 structure (figure 4).

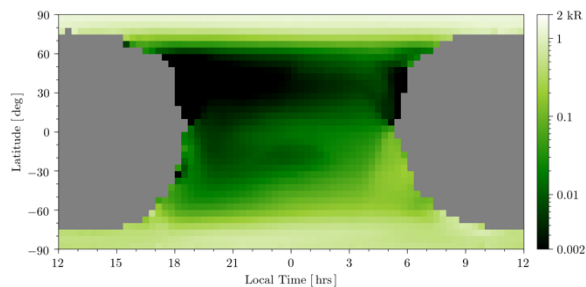
To explore the characteristics of the wave-3 feature, we analyze its local-time behavior. On average, we see the feature peak in brightness in the late evening and decrease in brightness rapidly in the hours just after midnight (figure 5). The LMD-MGCM reproduces the feature, but it steadily increases in brightness over night from evening to late morning (figure 6).



**Figure 4:** Average NO meridional nightglow brightness across our entire dataset. The green curve are the average of the IUVS observations, the red curve are the average of LMD-MGCM simulations of the same data points. The blue curve is the ratio of the two averages, and the grey line shows where they are equal in magnitude.

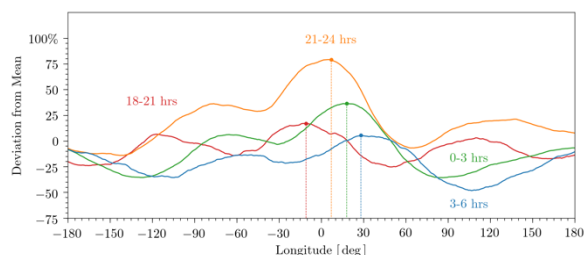


**Figure 5:** Local-time behavior of IUVS observations averaged across the entire disk-image dataset. We see the polar brightness enhancements and magnitude differences between northern and southern winter, and the equinox equatorial enhancement peaking just before midnight.



**Figure 6:** LMD-MGCM simulations of the same data points as the IUVS observations. The model reproduces the polar brightness but at a lower magnitude. It also reproduces the equinox equatorial enhancement, but the brightness increases with local time rather than peaking between 22 and 23 hours as in the observations.

To determine which kind of wave-3 we observe, we analyze how the longitude of the peak changes with local time. We find that the peak moves eastward at an average rate of 4.67 degrees per hour, consistent with a DE2 wave (diurnal, eastward-propagating wave-2) as the dominant contributing wave which produces three peaks in longitude over the course of one day (figure 7).



**Figure 7:** Three-hour averages of IUVS observations between latitudes  $-30^\circ$  to  $30^\circ$  and how they deviate from the mean across the entire dataset. Vertical dashed lines show the longitude of the peaks of the average profiles.

**References:** [1] Bertaux, J.-L et al. (2005) *Science* 307/5709, 566-569. [2] Cox, C. et al. (2008) *JGR*, 113, E08012. [3] Gagné, M.-E. et al. (2013) *JGR*, 118, 2172-2179. [4] Stiepen, A. et al. (2015) *Geophys. Res. Lett.*, 42, 720-725. [5] Stiepen, A. et al. (2017) *JGR*, 122, 5782-5797. [6] Jakosky, B. et al. (2015) *Space Sci. Rev.* 195:1-4, 3-48. [7] McClintock, W. et al, (2015) *Space Sci. Rev.* 195:1-4, 75-124.