THE MARTIAN 3 MICROMETERS NORTHERN RING: A SPECTRAL WITNESS OF RECENT SURFACE ALTERATION PROCESSES UNDER POLAR LATITUDES.

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Introduction: The OMEGA experiment is a visible and near-infrared imaging spectrometer onboard the ESA Mars Express orbiter [1], that had observed the Martian surface in the 0.38 – 5.1 µm spectral range from 2004 to 2010. This pre-2010 dataset corresponds to 9646 hyperspectral cubes that cover most of the Martian surface with a typical spatial sampling of 1 km, varying between 350 m and 5 km depending on the position of MEx on its elliptical orbit. Repeated observations of the same region have been frequently obtained over the mission, especially in the high latitudes where time sampling can be about 10° of L_s [2].

One of the main IR spectral features on Mars is a wide absorption band located around 3 µm, mainly associated with the presence of OH/H_2O, and that have been used to map the surface water content [3-6]. This signature has been first associated with adsorbed water [5], but a re-analysis using an extended dataset favored the role of more strongly bounded water [6]. Previous studies using OMEGA data have revealed an overall poleward increase of the strength of this surface hydration absorption [5,6]. The exact nature of this water enhancement is not yet fully understood.

Methods: Here we have reanalyzed OMEGA IR spectra acquired during Northern spring/summer (L_s = 98° – 132°) of Martian year (MY) 27 to look at the 3 µm band shape variability. In addition to the already known overall increase of the 3 µm absorption poleward [3-6], we have identified for the first time a new signature specific to the northern bright regions around the perennial north polar cap. This signature is characterized by a narrow absorption band in spectral ratios, centered on 3.03 µm (hereafter referred as the "narrow 3 µm band"), that comes along with a wider absorption around 4 µm [7]. This specific signature is shown as the red spectrum in figure 1 and significantly differs from the typical latitudinal evolution of the 3 µm band represented by the black spectrum.

Thus, we defined a specific criterion to trace this component, hereafter referred as the *narrow* 3 µm Band Depth (BD), which corresponds to the absorption at 3 µm computed relatively to a continuum whose reference points are taken at 2.9 and 3.2 µm [7].

We have also compared our characteristic spectrum of the narrow 3 µm signature with laboratory spectra of various species to constrain the nature of the origin of this spectral signature observed in the northern regions.

All the OMEGA data were processed (reduction & removal of the thermal and atmospheric components) using the Python module *OMEGA-Py*.

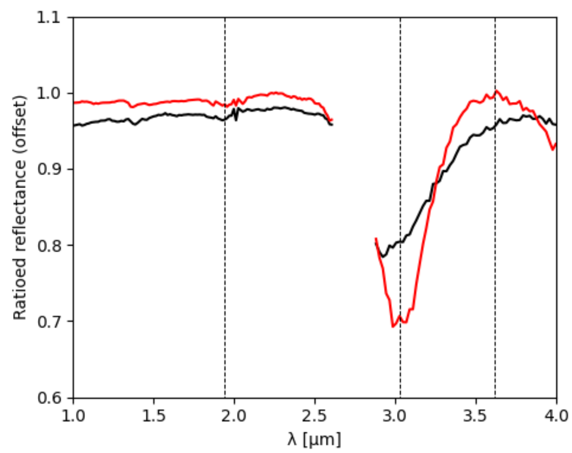

Figure 1 *– Typical averaged spectral ratio associated with the 3 µm northern ring (~70°N / 63°N, red) compared to a spectrum of the standard evolution outside the ring (60°N / 50°N, black). Adapted from [7].*

Results: We compute our 3 µm narrow BD criterion over the entire pre-2010 OMEGA dataset, i.e., all the observations conducted with the 3 spectral channels operating. As it can be observed in figure 2, the narrow 3 µm band (associated with the 4 µm feature) is only observed over a near-annular area around the perennial north polar cap (latitudes between ~ 68°N and 76°N, and longitudes between ~ 0°E and 270°E), hereafter referred as the "3 µm northern ring". One can note that this area includes the Phoenix landing site location. We observe that the transition to the ring region occurs without any significant change in terms of surface albedo between ~ 115°E and 270°E.

The spatial and temporal stability of the signature (across Ls, Martian years, and local time) leads us to favor the interpretation of a stable superficial surface component. In addition, spectral investigations also

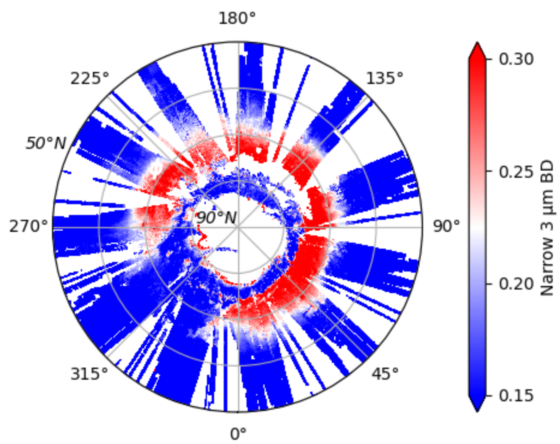

Figure 2 *– Composite OMEGA map of the distribution of the narrow 3 µm band depth in the Martian north polar regions during the northern summer of MY 27 (Ls = 98° – 132°). Adapted from [7].*

exclude the possible implication of water ice as the source of the signature. The distribution of the ring area over various geologic terrains dated from the Amazonian era [8] suggest that the signature is the result of a recent (and possibly still ongoing) process.

Comparisons with terrestrial samples spectra from public libraries suggest a possible role of sulfates (and maybe perchlorates), through a change of hydration and/or grain size with the latitude. Thus, we have identified two possible scenarios to explain the formation of the 3 µm northern ring (see figure 3), which are briefly described below.

Scenario 1. Sulfates are known to be present under North polar latitudes [9], above the northern limit of the 3 µm northern ring, and have essentially been interpreted as gypsum, a hydrated Ca-sulfate. Previous studies have shown the role of wind transportation in the observed distribution of these polar sulfates [10]. Thus, as the spectral signature observed over the ring could be caused by a superficial layer of low-hydrated sulfates, one possibility is that these sulfates come from polar gypsum deposits. After desiccation and fracturation, small grains could have been transported further away by winds, compared to the larger gypsum grains (figure 3.a).

Scenario 2. On the other hand, low amounts of poorly hydrated/anhydrous salts have been detected by in-situ measurements either by the Phoenix lander in the polar regions [11] and by the Curiosity rover under equatorial latitudes [12]. Thus, a second scenario could be envisaged, in which a superficial layer of anhydrous salts is widely present over the northern hemisphere. Here, the southern extent of the ring corresponds to a latitudinal hydration threshold (figure 3.b), related to the poleward increase of the surface hydration [5,6].

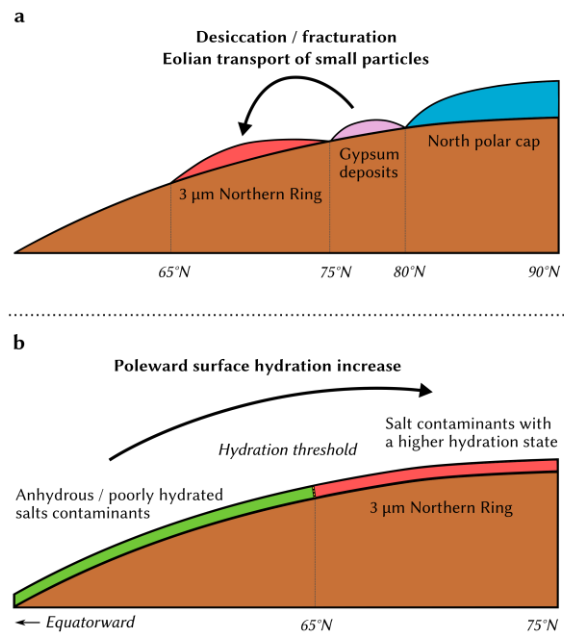

Figure 3 *– Schematic drawings of two possible scenarios for the formation of the 3 µm northern ring. Adapted from [7].*

Conclusion: To conclude, we report here the detection of a new spectral signature specific to a near-annular region around the perennial north polar cap, probably related to some recent modification of the physical and/or chemical properties of the ice-free soils. If the exact nature of the signature is not yet fully explained, first comparisons with laboratories data lead us to propose two plausible hypothetical scenarios to explain this observation.

Acknowledgments: The OMEGA/MEx data are freely available on the ESA PSA at https://archives.esac.esa.int/psa/#!Table%20View/OMEGA=instrument. The source code of the *OMEGA-Py* Python module is freely available on GitHub at https://github.com/AStcherbinine/omegapy.

References: [1] Bibring et al. (2004) *ESA Publication Division, 1240*, 37-49. [2] Langevin et al. (2007) *JGR, 112*, E08S12. [3] Milliken and Mustards (2005) *JGR, 110*, E12001. [4] Pommerol et al. (2009) *Icarus, 204*, 114-136. [5] Jouglet et al. (2007) *JGR, 112*, E08S06. [6] Audouard et al. (2014) *JGR Planets, 119*, 1969-1989. [7] Stcherbinine et al. (2021) *Icarus, 369*, 114627. [8] Tanaka et al. (2005) *USGS, 2888*, 32. [9] Langevin et al. (2005) *Science, 307*, 1584-1586. [10] Massé et al. (2012) *EPSL, 317-318*, 44-45. [11] Boynton et al. (2009) *Science, 325*, 5936. [12] Bish et al. (2013) *Science, 341*, 6153.