Aurorae on Mars

B. Ritter[1], J.-C. Gérard[1], B. Hubert[1], and L. Gkouvelis[1]
[1]ILPAP, Université de Liège, Quartier Agora, 19c allée du 6 août, Liège, Belgium

Introduction: Three kinds of UV aurora have been detected on Mars: the discrete aurora [1], the diffuse aurora [2], and the proton aurora [3]. The discrete and the diffuse aurora are seen on the Martian nightside and result from electron impact on the upper atmosphere. Figure 1 shows an electron excited auroral spectrum extended into the visible using laboratory measurements. The proton aurora is observed on the dayside and originates from precipitating protons. We present an overview of these aurorae, combining observations of the SPICAM ultraviolet spectrometer on board Mars Express and modeling results, giving an estimate of what we might be able to observe in the future with UVIS-NOMAD [4] on board Trace Gas Orbiter (TGO).

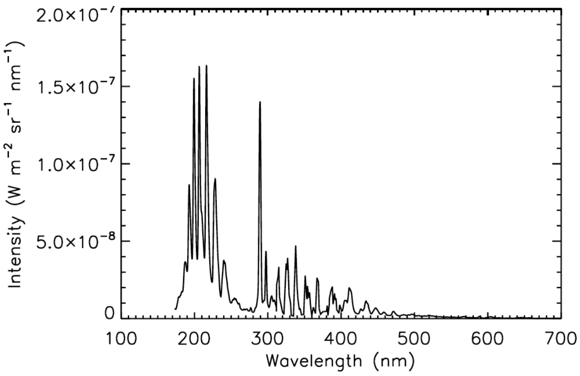

Figure 1: Synthesized electron excited NUV-visible auroral spectrum (from MAVEN observations and laboratory experiments).

Discrete aurora: The discrete aurora was first observed as spatially confined auroral feature in a limb scan of SPICAM [1]. Subsequently, limb and nadir observations of the discrete aurora were reported, revealing that these aurorae are linked to the topology of the crustal magnetic field of Mars [5,6,7] (Fig. 2).
Employing a Monte Carlo code that models the emission arising from energetic electron precipitation on the Martian atmosphere, the electron energies causing this aurora have been deduced to range from 50 to 1000 eV. This interaction produces UV auroral emission at altitudes of about 110 to 150 km, in agreement with observations [7].
As part of the auroral emission falls into the visible part of the auroral spectra, we expect that UVIS-NOMAD will be able to detect the discrete aurora.

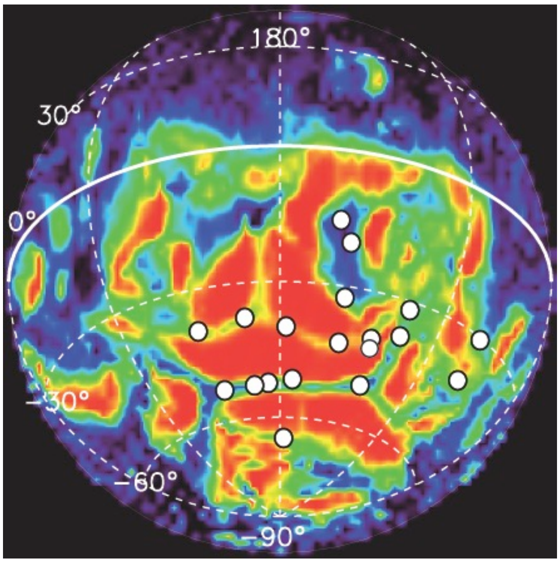

Figure 2: Discrete aurora observations on a Martian magnetic field map [6].

Diffuse aurora: The diffuse aurora was observed by the IUVS ultraviolet spectrograph on board the MAVEN spacecraft [2]. This auroral type is neither restricted in location nor linked to the Martian magnetic field. Instead, it is thought to be globally extended and is closely correlated to solar wind activity.
SPICAM was not sensitive enough to observe this type of aurora, but we modeled ultraviolet and visible auroral emission lines [8]. Among these is the oxygen 297.2 nm oxygen emission (Fig. 3) that will be observable with UVIS/NOMAD on board TGO.

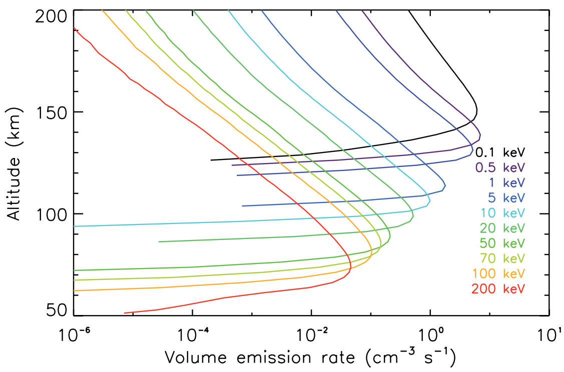

Figure 3: Monte Carlo modeling results of the 297.2 nm OI line [8].

Proton aurora: The proton aurora is seen as intensity enhancement in Lyman-α limb profiles at altitudes between 120 and 150 km (Fig. 4). It has been observed with IUVS [3] and with SPICAM in 6 out of 143 observation sequences and is related to the arrival of coronal mass ejections or corotating interaction regions at Mars [9].
Mote Carlo modeling has reproduced the intensity enhancement at these altitudes and revealed how the Lyman-α line profile and intensity change in the presence of an induced magnetic field [10].
Even though the Lyman-α emission is the strongest emission, the proton aurora manifests as well in the visible (Balmer series), of which the H-β line at 486.1 nm falls into the detection range of the UVIS-NOMAD instrument.

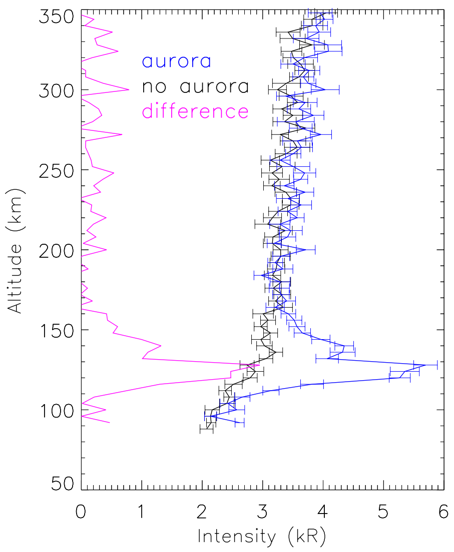

Figure 4: Lyman-α a limb profile of a proton aurora on Mars observed with SPICAM [9].

References:
[1] Bertaux, J.-L. et al., ***Nature****, 435,* 7043, 790–794, 2005.
[2] Schneider, N. et al., ***Science****, 350*, 6261, 0313, 2015.
[3] Deighan, J. et al., ***AGU****, Fall General Assembly*, #P13D-01, 2016.
[4] Vandaele, A.-C. et al., ***PSS****, 119,* 233–249, 2015.
[5] Leblanc, F. et al. ***JGR,*** *113,* A08311, 2008.
[6] Gérard J.-C. et al., ***JGR****, 120*, 8, 6749-6765, 2015.
[7] Soret, L. et al., ***Icarus****, 264,* 398-406, 2016.
[8] Gérard, J.-C. et al., ***Icarus,*** *288,* 284-294, 2017
[9] Ritter, B. et al., submitted to ***GRL***.
[10] Gérard, J.-C. et al., ***EPSC***, EPSC2017-259, 2017.

Acknowledgements: B.R. acknowledges support from the Brain/SCOOP research program of the Belgian Federal Science Policy Office (BELSPO). This research was partly funded by the NOMAD PRODEX program managed by the European Space Agency with help of BELSPO. The authors thank the SPICAM instrumental team for the SPICAM data and calibration and specifically G.Lacombe and L.Baggio for their support.