Proton Aurora on Mars: A Dayside Phenomenon

Pervasive in Southern Summer

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1. Introduction and Background

We observe and characterize Martian proton aurora, a third type of aurora (in addition to diffuse and discrete) recently identified at Mars (e.g., Deighan *et al.*, 2018, Ritter *et al.*, 2018).

Project Goals:

- Create a comprehensive catalog of Martian proton aurora detections and characterize based on phenomenology
- Identify statistical trends and abnormalities in detections
- Better understand solar wind's interaction with Mars hydrogen corona

Figure 1: Formation Mechanism for Martian proton aurora. Because of Mars' lack of a magnetic field, solar wind protons charge exchange with the H corona to create energetic neutral atoms (ENA) and pass unimpeded through the bow shock then reconvert into protons before depositing their energy.

2. Data and Methods

Using data from the Imaging UltraViolet Spectrograph (IUVS) onboard the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft, we create and assess altitude-intensity profiles of the hydrogen Lyman-alpha (Ly- α) emission (121.6nm) (Fig. 2).

Data Collection & Reduction:

1. IUVS limb scans taken during orbit periapsis
2. FUV and MUV spectral and spatial data collected; spectral intensity profiles created
3. Data corrected to remove background Ly- α intensity & converted to kR
4. Altitude profile created by integrating under Ly- α curve (one point for each mirror & slit position); data binned by altitude

Figure 2: IUVS periapsis limb scan data collection, example spectral data products, and reduction pipeline (Left three figure credits: MAVEN/IUVS Team & McClintock *et al.*, 2014)

Proton aurora are identified as an enhancement in UV data in Ly- α intensity (compared to coronal H intensities) between ~110-150 km altitude (Fig. 2, Right).

Figure 3: Detection methodology & threshold selection criteria. Using two independent criteria we establish a rigorous detection threshold.

- Detection Methodology:**
1. Separate data into peak and high altitude regions (Fig. 2, Right)
 2. Difference: 2nd highest peak altitude intensity – median high altitude intensity (Fig. 2, right)
 3. Detection threshold: standard deviation of differences of entire dataset (i.e., 0.5 σ in this study) (Fig. 3).

3. Proton Aurora Variability and Phenomenology

- Proton aurora exhibit high emission enhancements and peak intensities, and occur on the planet's dayside (i.e., low SZAs).
- Because proton aurora form via interactions between the solar wind and H corona, seasonal variations (e.g., in dust and temperature) lead to inflation of the corona further beyond the bow shock, increasing occurrence rates, intensities, and peak altitudes.
- The highest occurrence rates, enhancements, intensities, and peak altitudes are observed around dayside southern summer solstice ($L_s \sim 270$).

Figure 4: Histograms of all IUVS data (grey) and proton aurora detections (blue) using 0.5-sigma threshold (blue) and 3-sigma threshold (green) as a function of different observational variables. Normalized proton aurora detections (pink) represent occurrence rates (normalization done by dividing detection counts by all data counts in each histogram bin).

Figure 5: Normalized 2-D histograms showing proton aurora occurrence rates as a function of different observational variables and MAVEN orbit (normalization same as in Fig. 4).

Figure 7 (right): Schematic explanation of seasonal trends in Martian proton aurora.

Figure 6: Seasonal and latitudinal variations for proton aurora. Top plots: all IUVS data (grey) and proton aurora detections (blue); Bottom subplots: Normalized proton aurora occurrence rates (pink) (normalization same as Fig. 4). Beige areas represent bins with ≤ 10 total counts. (Note: latitudinal data sampling bias due to geographic location of MAVEN periapsis during this season, e.g., Fig. 5.)

4. Summary, Conclusions, and Future Work

Summary and Conclusions:

- Using current detection constraints we observe proton aurora in >9% of periapsis profiles and >26% of orbits (i.e., 4705 individual profiles and 1225 unique orbits).
- Proton aurora occur in ~15% of dayside profiles (SZA<105) in our dataset, varying significantly with season.
- Proton aurora are most active around S. summer solstice when atmospheric temperatures and dust content are high: occurring >80% of the time in dayside summer observations.
- Proton aurora events are far more common than originally thought, and are actually the most commonly observed type of aurora on Mars.
- Proton aurora therefore have an unexpected direct link to MAVEN's study of Mars' loss of atmosphere and water!

Outstanding Questions/Future Work:

- What are the locations (geographic, temporal, etc.) of proton aurora events at Mars? Is there any interaction with an upstream magnetic field?
- Compare selected altitude profiles to model predictions via a modeling challenge.

Acknowledgments:

Many thanks to coauthors, collaborators, and funding sources, including:
 • MAVEN/IUVS Team
 • NASA Astrobiology Early Career Collaboration Award
 • Florida Space Grant Consortium
 • John Mather Nobel scholarship
 • AGU and UCAR/CEDAR Travel Grants