Proton Aurora on Mars: A Dayside Phenomenon Pervasive in Southern Summer

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MAVEN – Mars Atmosphere and Volatile Evolution Mission

EMBRY-RIDDLE Aeronautical University – DAYTONA BEACH, FLORIDA

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

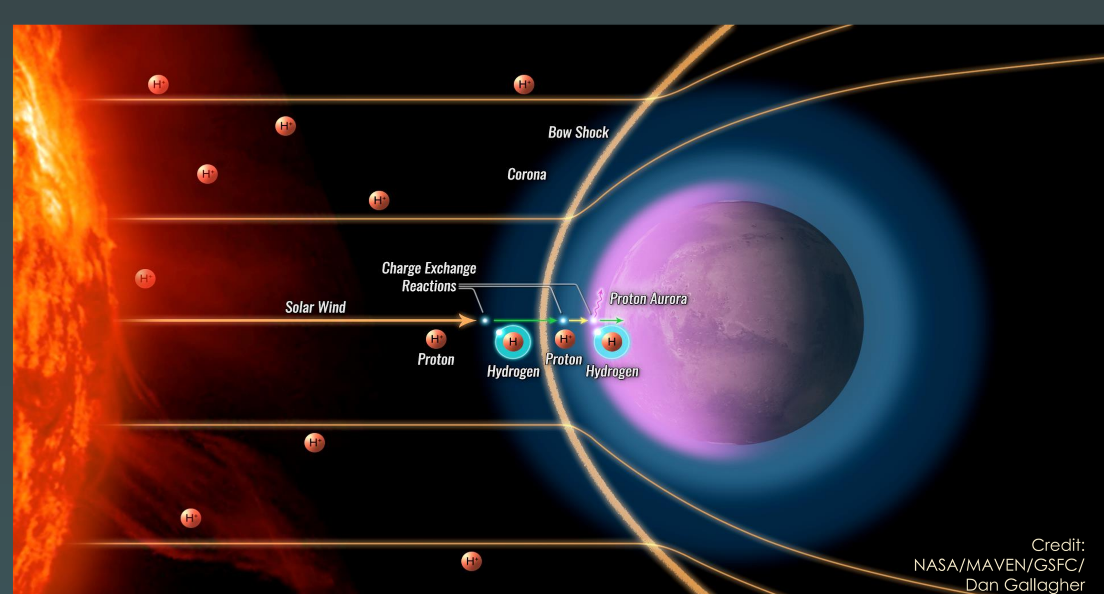


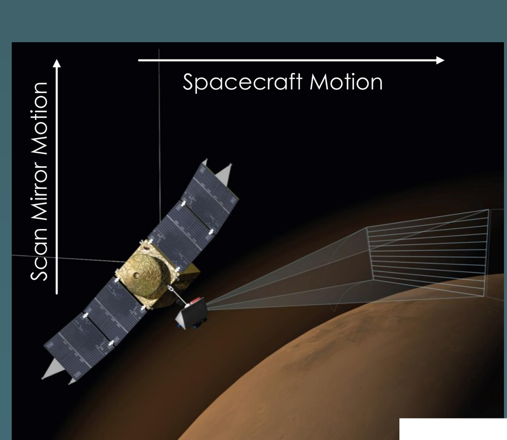
***Figure 1**: Formation Mechanism for Martian proton aurora. Because of Mars' lack of a magnetic field, solar wind protons charge exchange with the H corona to create energetic neutral atoms (ENA) and pass unimpeded through the bow shock then reconvert into protons before depositing their energy.*

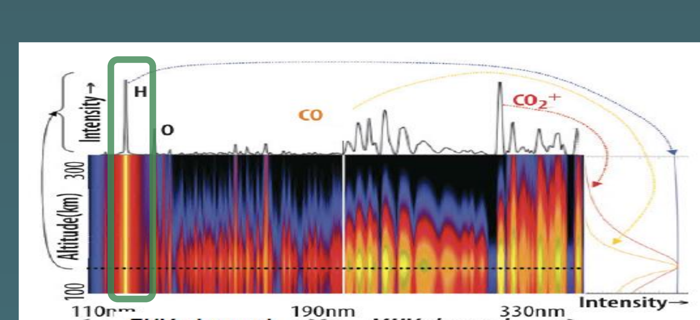
2. Data and Methods

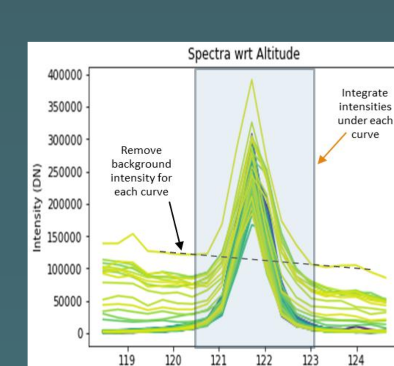
Using data from the Imaging UltraViolet Spectrograph (IUVS) onboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft, we create and assess altitude-intensity profiles of the hydrogen Lyman-alpha (Ly-α) emission (121.6nm) **(Fig. 2)**.

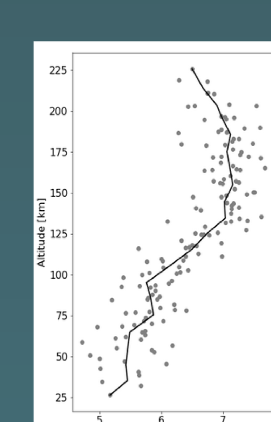
Data Collection & Reduction:

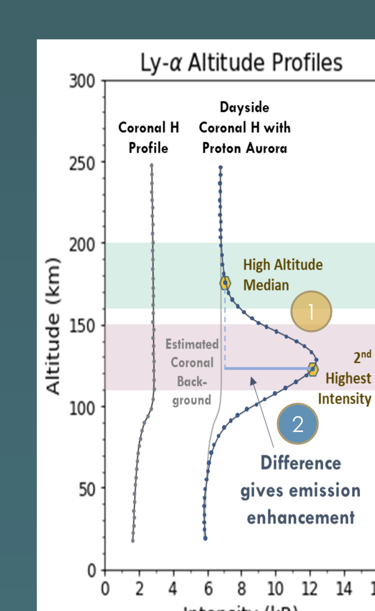
1. IUVS limb scans taken during orbit periapse
2. FUV and MUV spectral and spatial data collected; spectral intensity profiles created
3. Data corrected to remove background Ly-α intensity & converted to kR
4. Altitude profile created by integrating under Ly-α curve (one point for each mirror & slit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











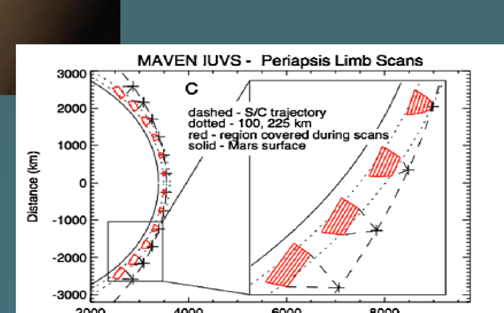
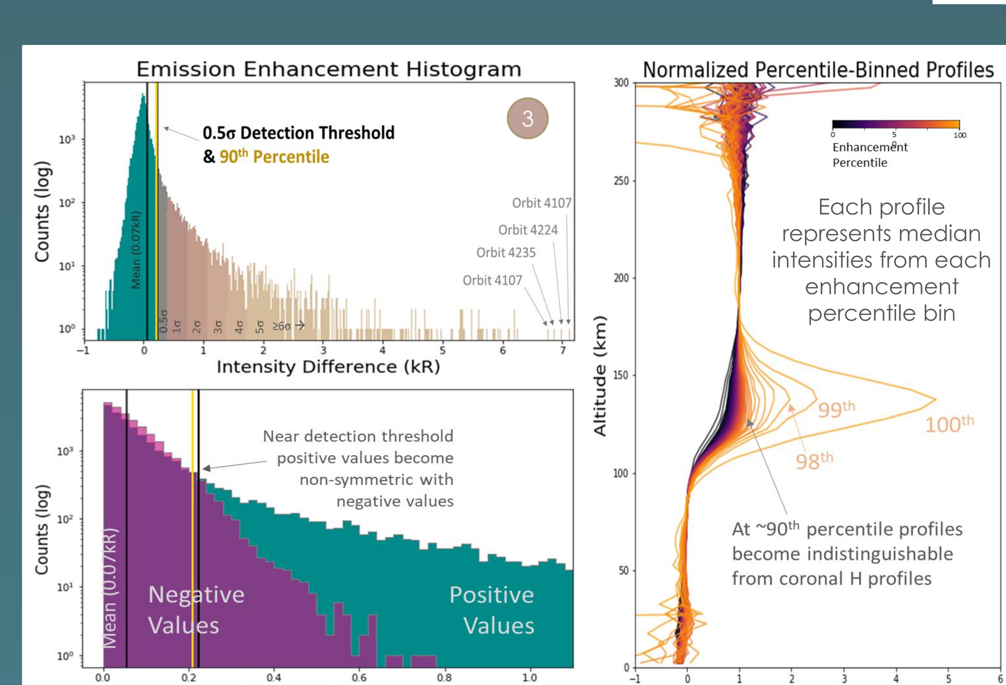


***Figure 2**: IUVS periapsis limb scan data collection, example spectral data products, and reduction pipeline (Left three figure credits: MAVEN/IUVS Team & McClintock et al., 2014)*

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.*, 0.5σ in this study) **(Fig. 3)**.



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.

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.

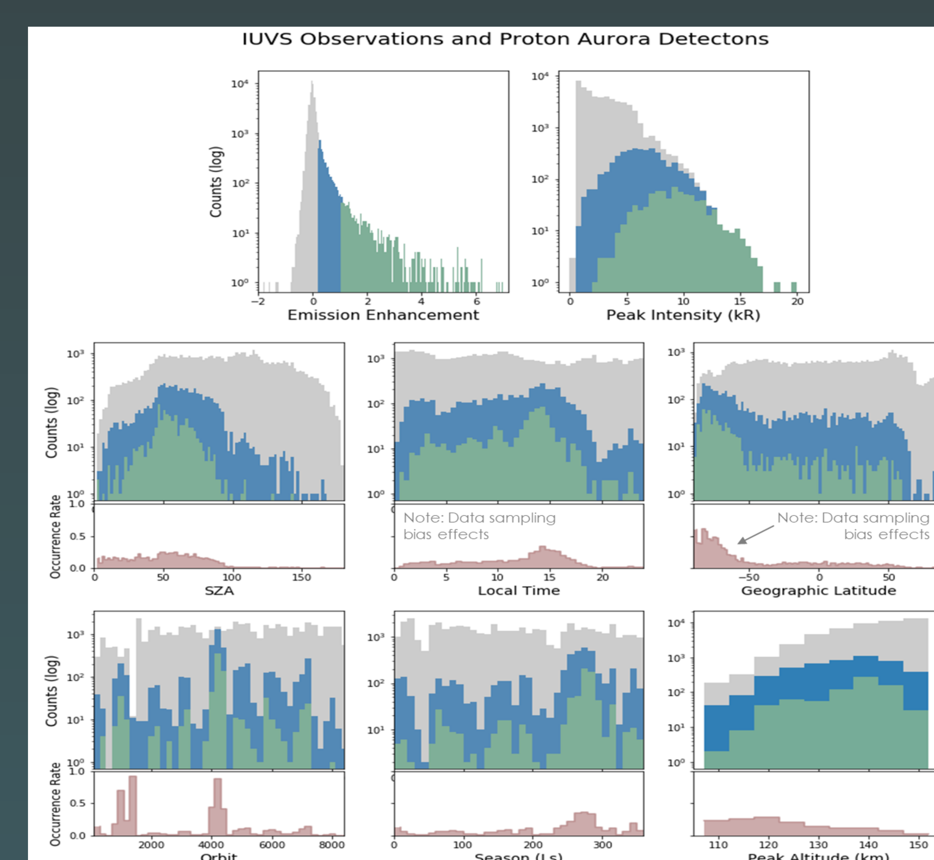


***Figure 4:** Histograms of all IUVS data (grey) and proton aurora detections using 0.5σ threshold (blue) and 3σ threshold (green) as a function of different observational variables. Normalized proton aurora detections (pink) represent occurrence rates (normalization done by dividing detection counts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

- The highest occurrence rates, enhancements, intensities, and peak altitudes are observed around dayside southern summer solstice (L_s ~270).

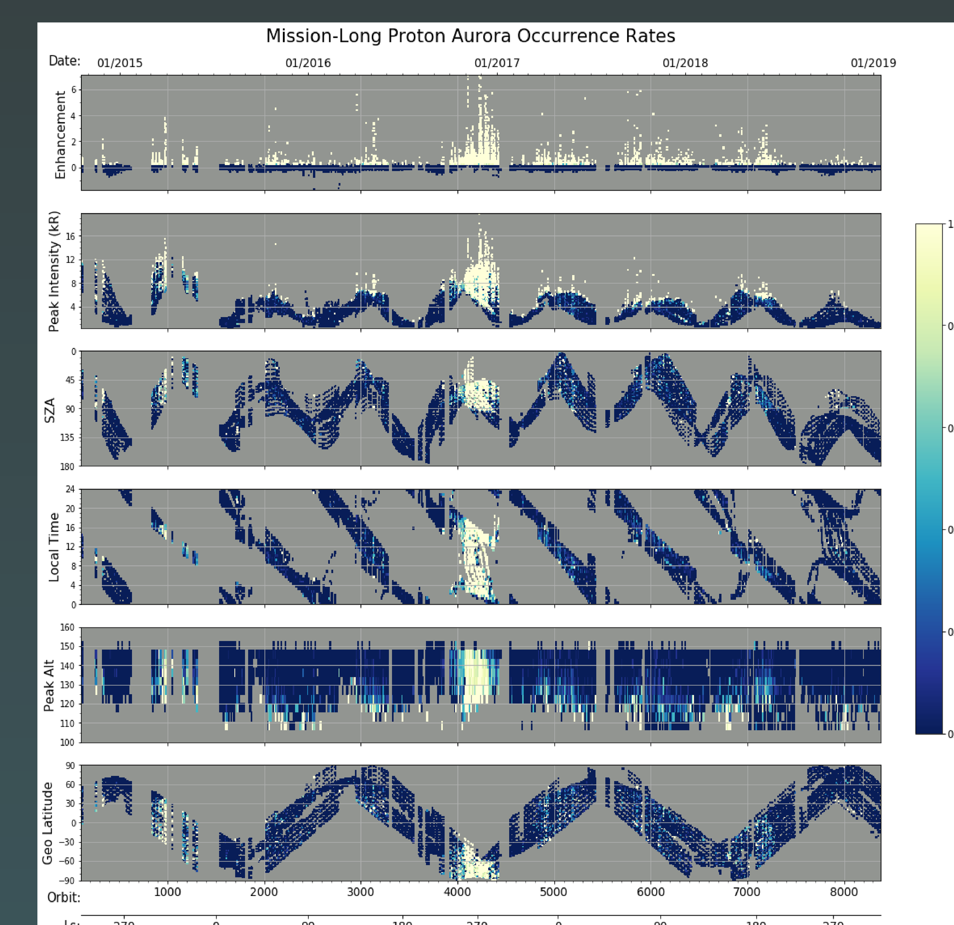


***Figure 5:** Normalized 2-D histograms showing proton aurora occurrence rates as a function of different observational variables and MAVEN orbit (normalization same as in Fig. 4).*

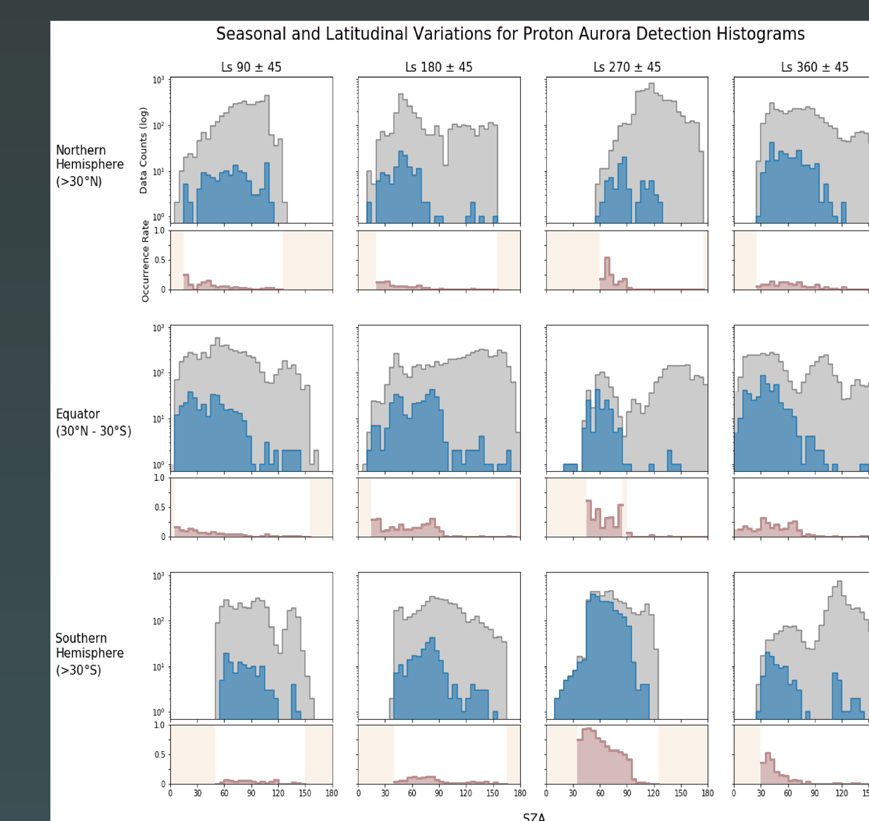
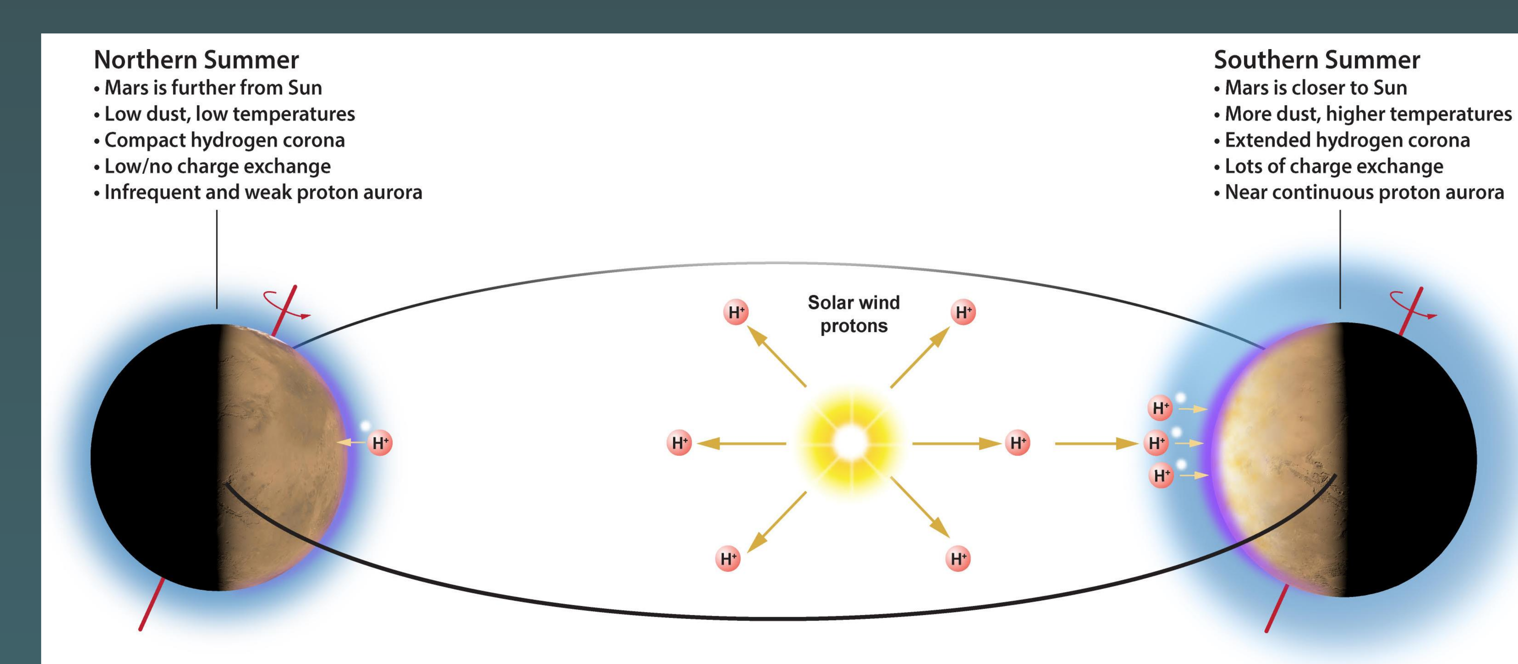


***Figure 6:** Seasonal and latitudinal variations of SZA for proton aurora. Top plots: all IUVS data (grey) and proton aurora detections (blue); Bottom subplots: Normalized proton aurora occurrence rates (pink) (normalization same as Fig. 4). Beige areas represent bins with ≤10 total counts. (Note: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

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



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.

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