Phenomenology of Proton Aurora at Mars as Observed by MAVEN/IUVS

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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

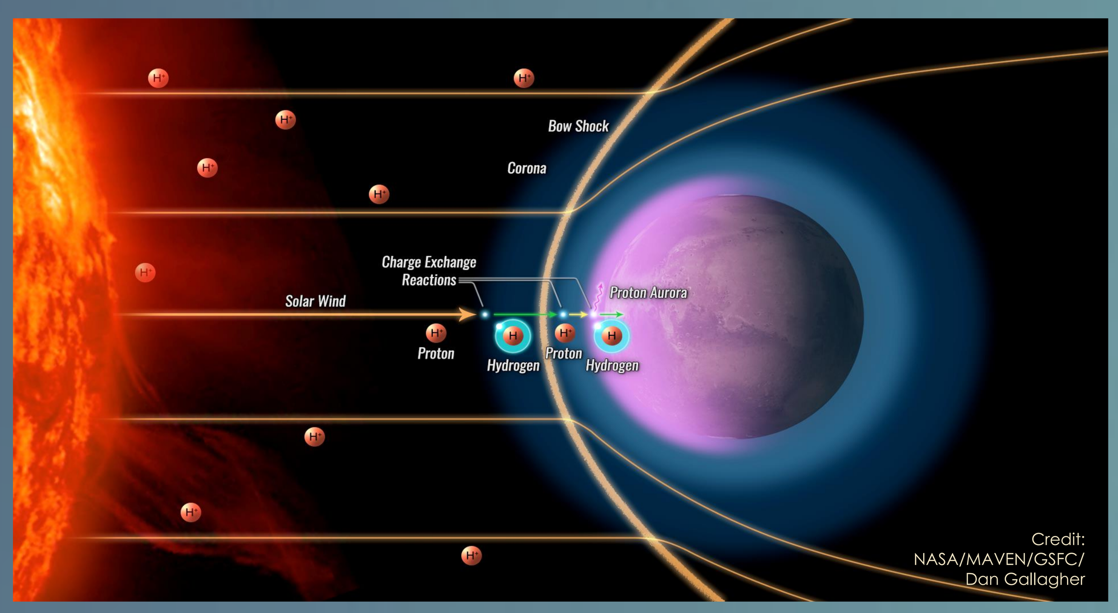


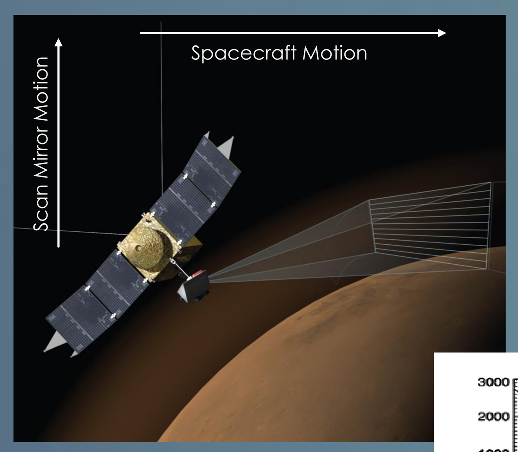
***Figure 1**: Formation Mechanism for Martian proton aurora. Because of Mars' lack of a magnetic field, solar wind protons charge exchange with the H corona to create energetic neutral atoms (ENA) and pass unimpeded through the bow shock then reconvert into protons before depositing their energy.*

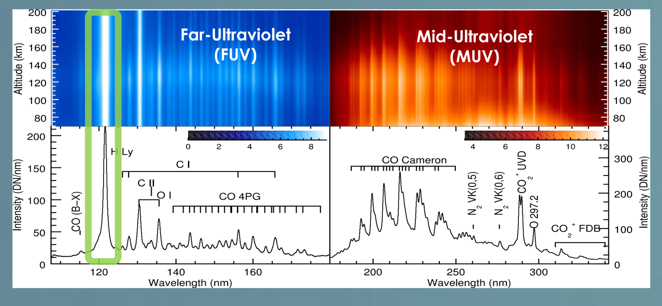
2. Data and Methods

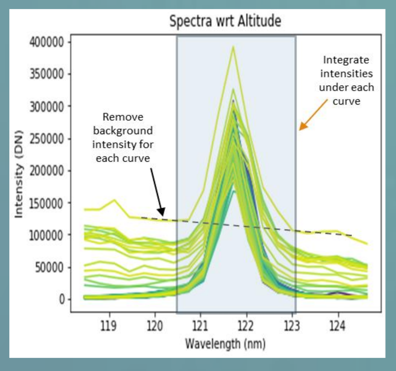
We use altitude-binned periapsis limb scan data from the Imaging UltraViolet Spectrograph (IUVS) onboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft to observe the hydrogen Lyman-alpha (Ly-α) emission (121.6nm), and create/assess Ly-α altitude-intensity profiles **(Fig. 2)**.

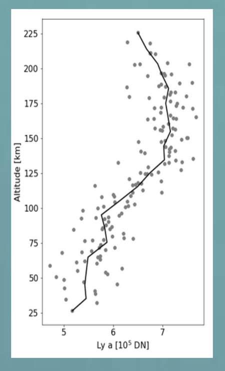
Data Collection & Reduction:

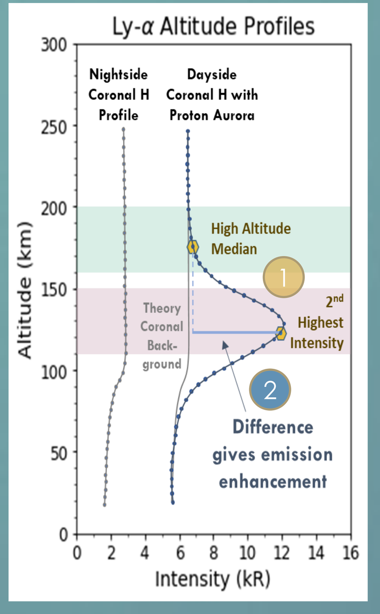
1. IUVS limb scans taken during orbit periapse
2. FUV and MUV spectral and spatial data collected; spectral intensity profiles created
3. Data corrected to remove background Ly-α curve (one point for each mirror & slit position); data binned by 5km altitude bins
4. Altitude profile created by integrating under Ly-α intensity & converted to kR.











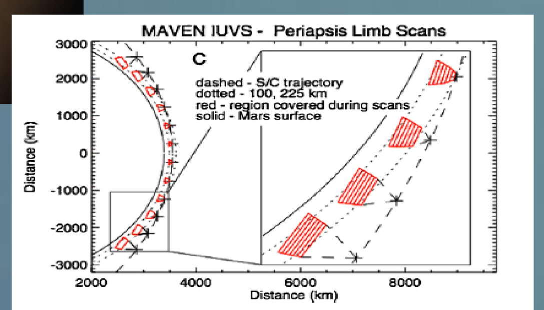
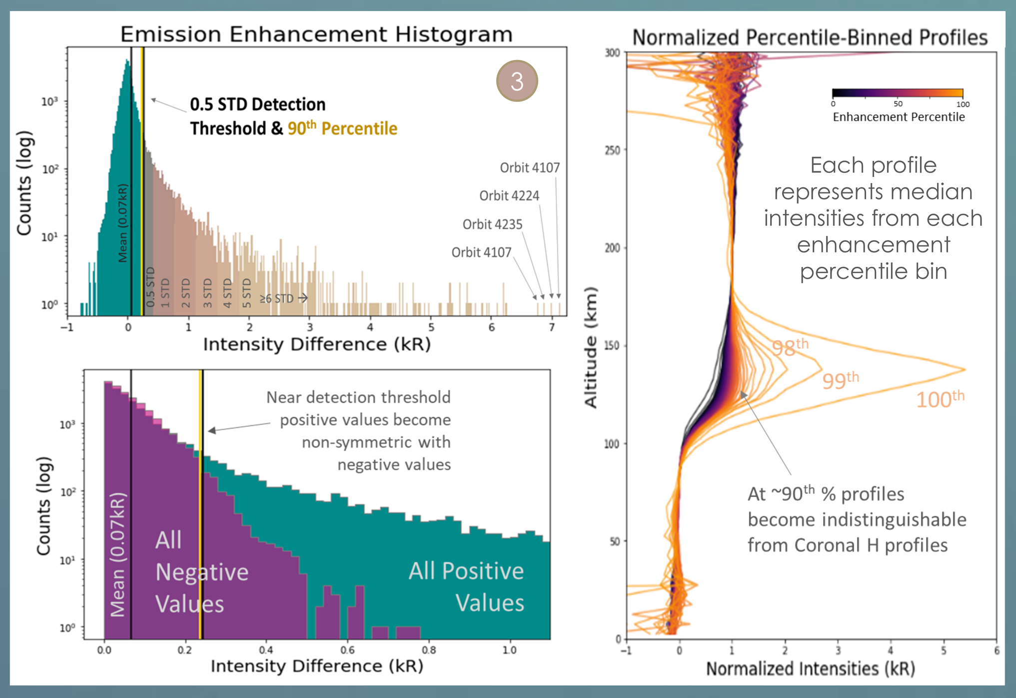


***Figure 2**: IUVS periapsis limb scan data collection, example spectral data products, and reduction pipeline (Left three figure credits: IUVS Team & McClintock et al., 2014)*

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 identified in UV data as an enhancement 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 Phenomenology and Variability

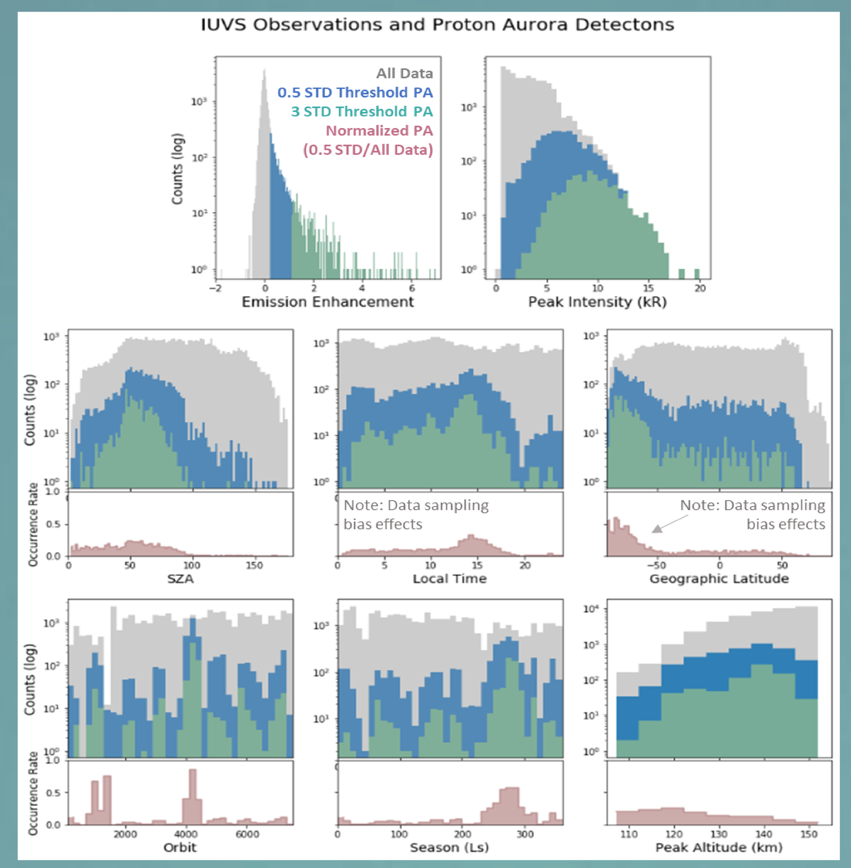


***Figure 4:** Histograms of all IUVS data (grey) and proton aurora detections using 0.5σ threshold (blue) and 3σ threshold (green) as a function of different observational variables. Normalized proton aurora detections (pink) correspond to occurrence rates (normalization done by dividing detection counts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

- *Proton aurora correspond with large emission enhancements, high peak intensities, low SZAs, and daytime occurrence (**Fig. 4 & Fig. 5A-C**); there are notable seasonal variations in intensity, enhancement, and peak altitude (**Fig. 5D-F**).*

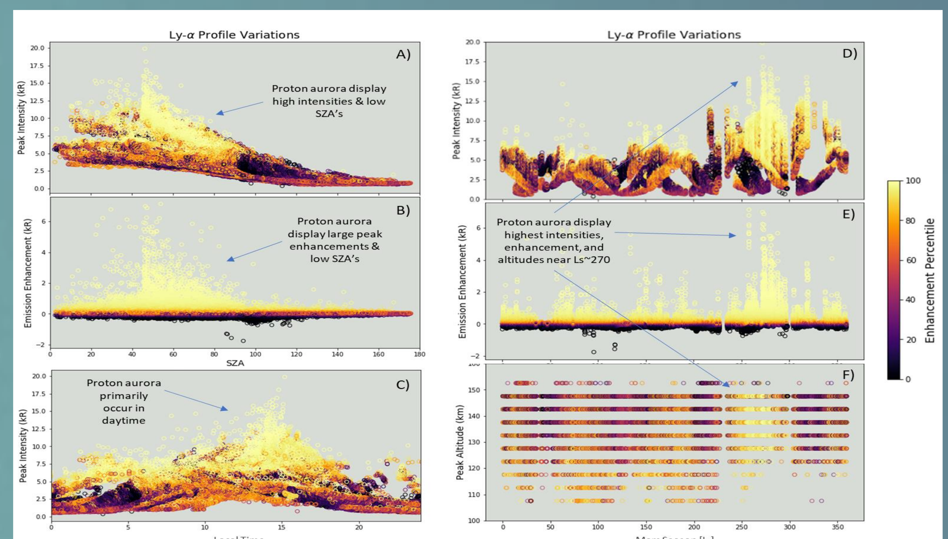


***Figure 5:** Proton aurora variations with respect to SZA (A&B), local time (C), and season (Ls) (D-F). Color represents emission enhancement percentile bin (similar to Fig. 3, Right), and proton aurora detections correspond with percentiles greater then ~90th percentile.*

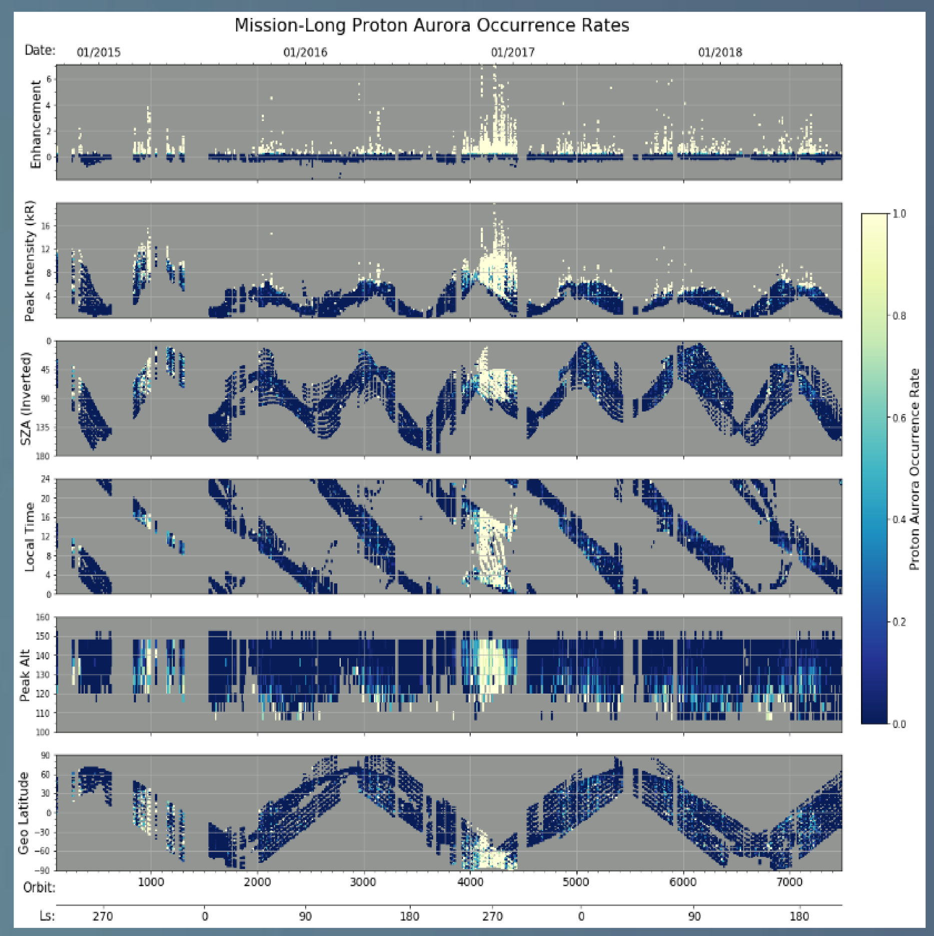


***Figure 6:** Normalized 2-D histograms showing proton aurora occurrence rates as a function of different observational variables and MAVEN orbit (normalization same as in Fig. 4).*

- The highest emission enhancements, peak intensities, peak altitudes, and occurrence rates are observed around southern summer solstice (L_s ~270) (**Fig. 5 & Fig. 6**).
- Proton aurora occurrence rates are highest in dayside southern summer observations, approaching 100% at low solar zenith angles during this time (**Fig. 7**) (note latitudinal data sampling biases, *e.g.*, as in **Fig. 6**).

Because proton aurora form via interactions between the solar wind and H corona, seasonal variations in the H corona (*e.g.*, due to lower atmospheric dynamics and dust activity) inflate the corona further beyond the bow shock, increasing proton aurora occurrence rates and magnitude.

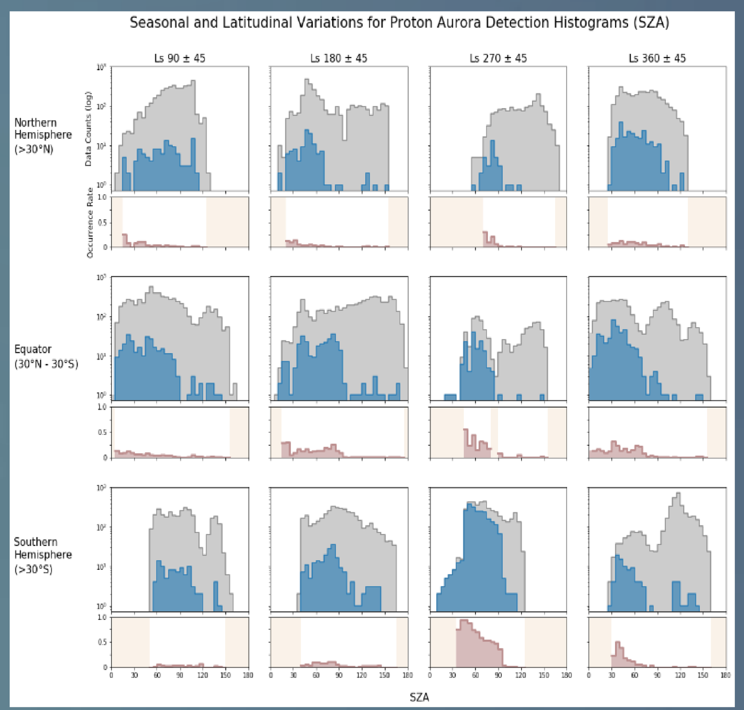


***Figure 7:** Seasonal and latitudinal variations of SZA for proton aurora. Top plots: All IUVS data (grey) and proton aurora detections (blue); Bottom subplots: Normalized proton aurora occurrence rates (pink) (normalization same as Fig. 4). Beige areas on normalized subplots represent bins where the total number of counts is ≤10. (Note: apparent latitudinal dependence is due to geographic location of MAVEN periapsis during this season, e.g., Fig. 6.)*

4. Summary, Conclusions, and Future Work

Summary and Conclusions:

- Using current detection constraints **we observe proton aurora in ~10% of periapsis profiles** and >27% of orbits (*i.e.*, 4254 individual profiles and 1074 unique orbits).
- Proton aurora **occur in ~14% of dayside profiles** (SZA<105) in our dataset, varying significantly with season.
- Proton aurora are **most active near S. summer solstice: occurring >80% of the time** in dayside observations.
- Based on these findings, **proton aurora are found to be the most commonly observed type of aurora at Mars.**

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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