# Determining the Relation Between Electron-Neutral Collisions and Thermal Electron Temperature Profiles in the Mars Ionosphere

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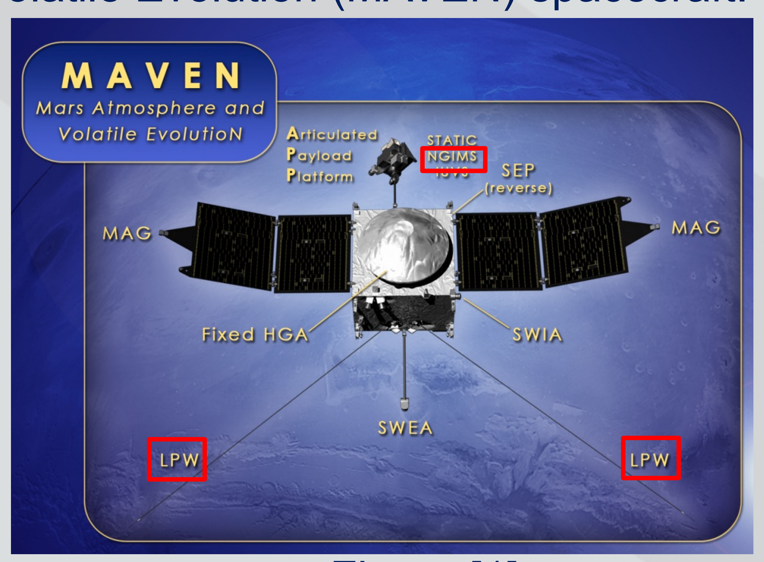
## 1. Introduction

- This project utilizes data from the Langmuir Probe and Waves (LPW) and Neutral Gas and Ion Mass Spectrometer (NGIMS) instruments of NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft.



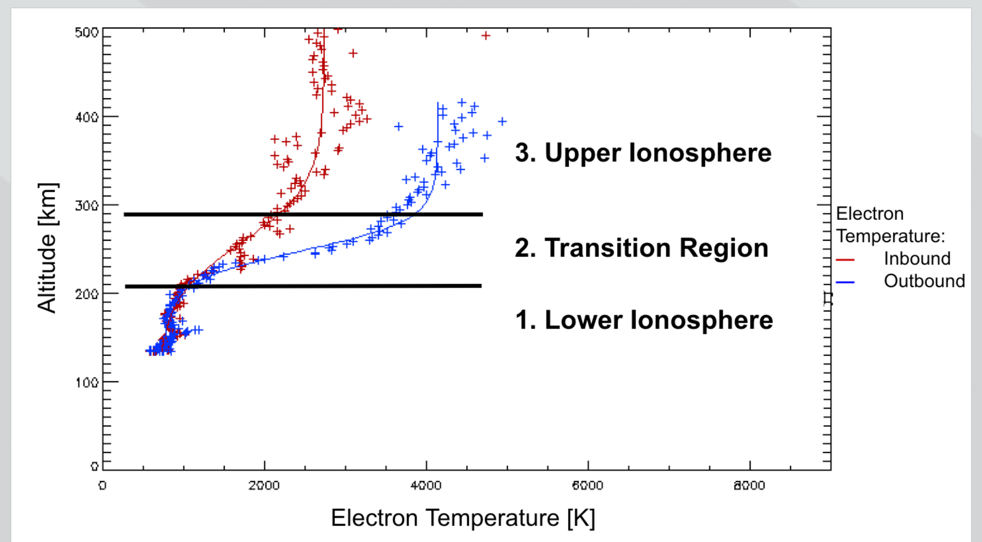




Figure [1]

- Mars's Ionosphere can be divided into three regions dominated by distinct driving processes and trends:
  1. Lower Ionosphere- Dominated by collisions in the neutral atmosphere
  2. Transition Region- Region investigated in this study
  3. Upper Ionosphere- Driven by external transport processes
- Why investigate the transition region?

  The transition from low to high electron temperature ($T_e$) drives the ambi-polar electric field, which can be significant on Mars due to its weak gravity. This field pulls ions through the transition region and can accelerate them to near escape energy.

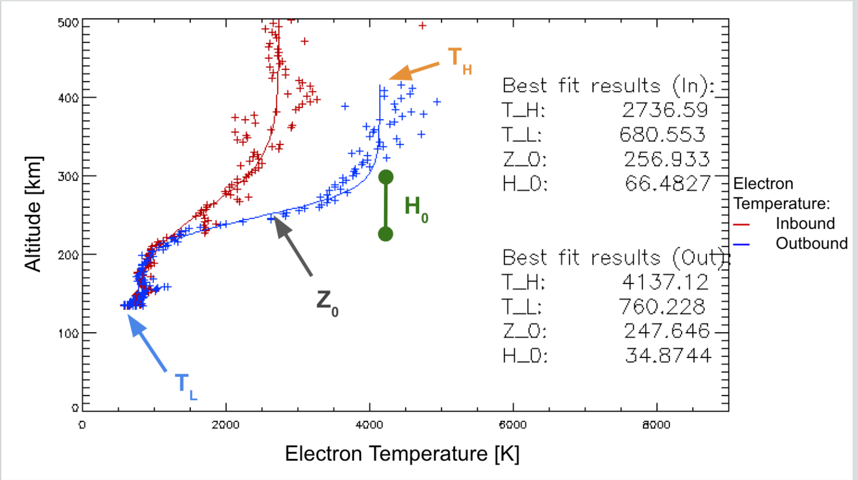
$$E_{||} = -\frac{\nabla_{||} P_e}{e n_e} \qquad P_e = n_e k_b T_e$$

- By understanding how the transition region changes in response to various drivers, we can understand which physical processes control $E_{||}$.

## 2. Background

- Fitting an analytical function to $T_e$ profiles gives a description of shape and amplitude of the transition region with 4 variables. Analysis can be done with other MAVEN instruments to determine underlying physics.
- This can be done using this equation [1]

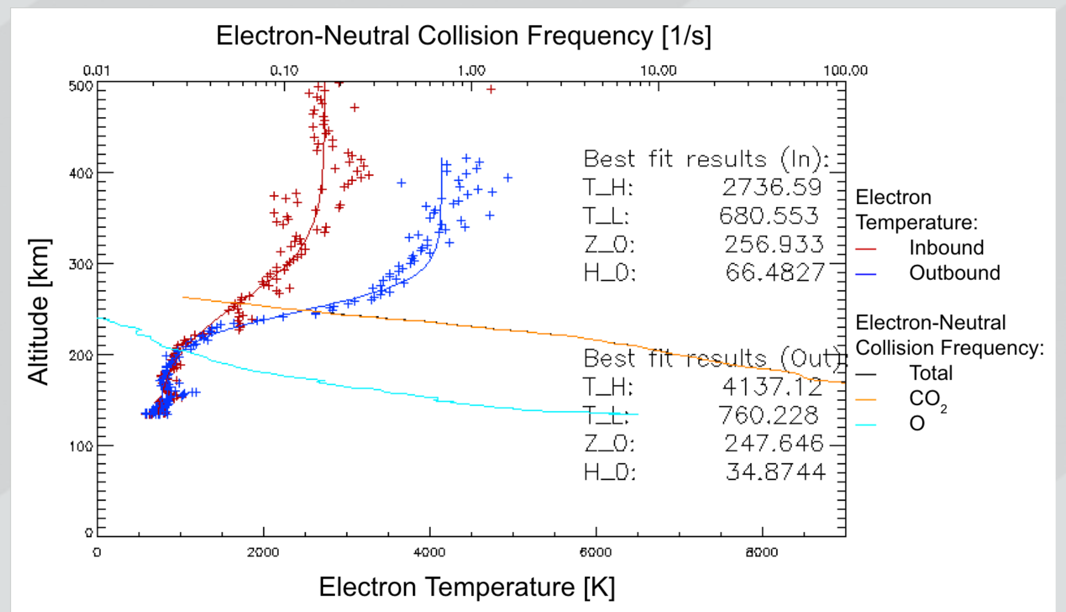
$$T_e = \frac{T_H + T_L}{2} + \frac{T_H + T_L}{2} \tanh\frac{z - Z_0}{H_0}$$




- 4 variables describe the transition region:
  - $T_H$: Highest electron temperature of the fit
  - $T_L$: Lowest electron temperature of the fit
  - $Z_0$: Average altitude of the transition region
  - $H_0$: Altitude range of the transition region
- Each plot shows one periapsis pass where descending into the ionosphere is depicted in red and ascending out of the ionosphere is in blue.

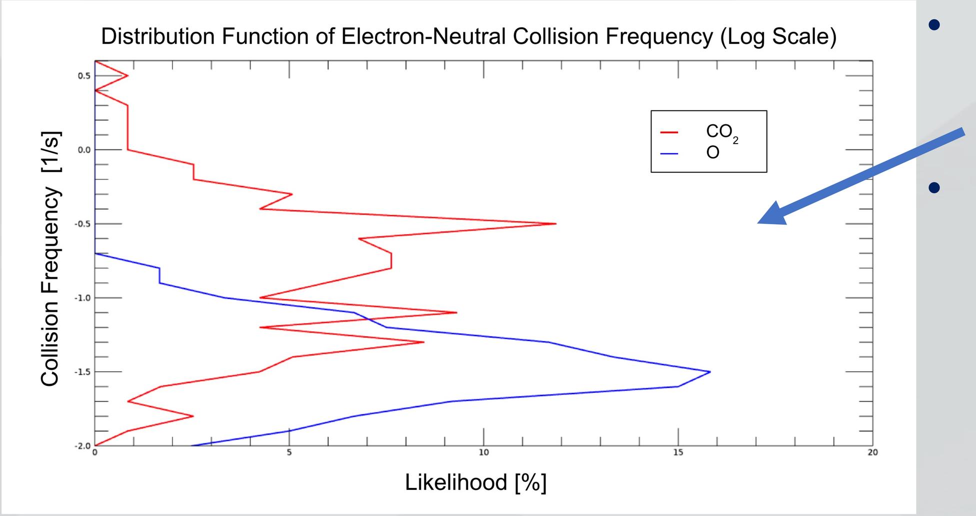
## 3. Preliminary Statistics

- By analyzing the Electron-Neutral Collision Frequencies ($\nu_{en}$) from the dominant neutral species at Mars ($CO_2$ and O), obtained from NGIMS data, we can identify trends between transition region shape and driving processes in the lower ionosphere
- Analyzed 60 days (~270 orbits) and are working to increase this. Only dayside observations have been extracted.

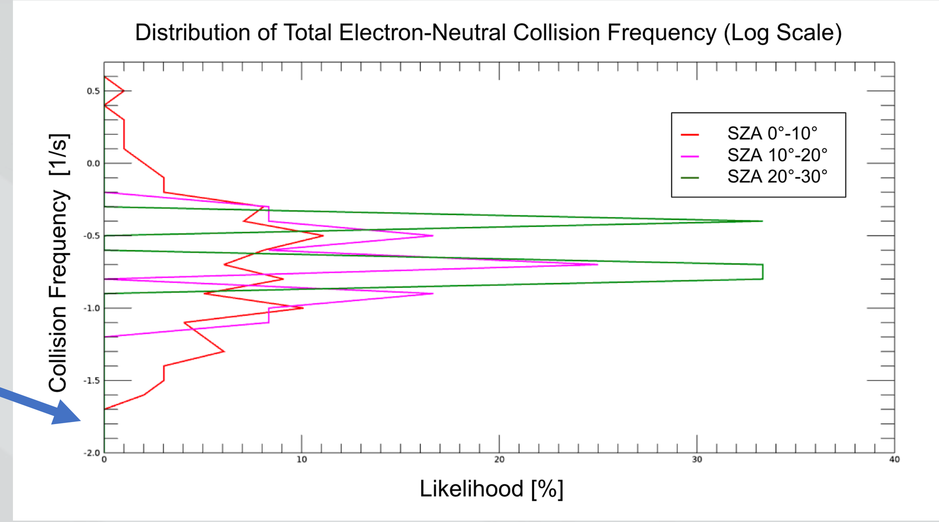



- Electron-temperature profile fits provide values for the average transition region altitude ($Z_0$) and the width of the transition region in altitude($H_0$).
- $\nu_{en}$ can be calculated within the transition region using measured densities and $T_e$.
- At these low altitude values $CO_2$ densities, and $\nu_{en,\,CO2}$ by extension, dominate. O becomes more important at higher altitudes, typically above the transition region.

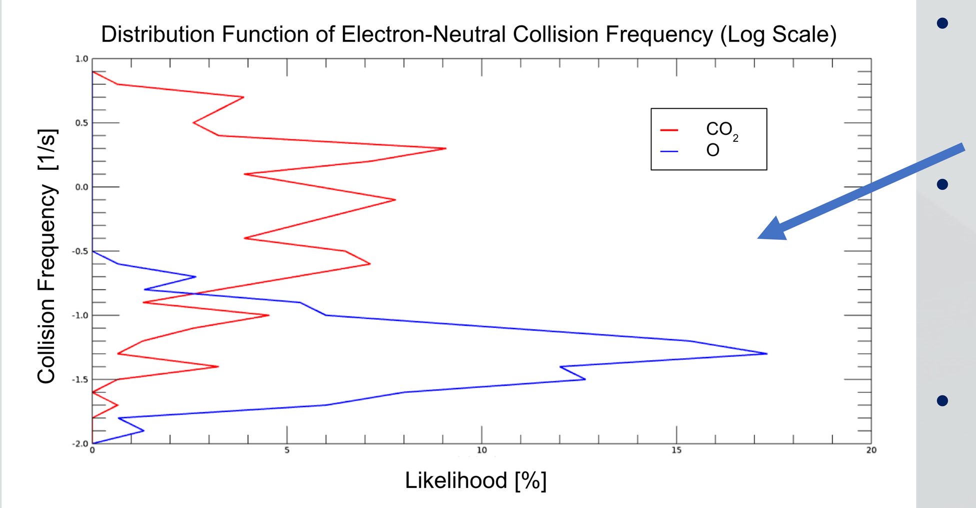
- Top of Transition Region (at $Z_0$+½ $H_0$):



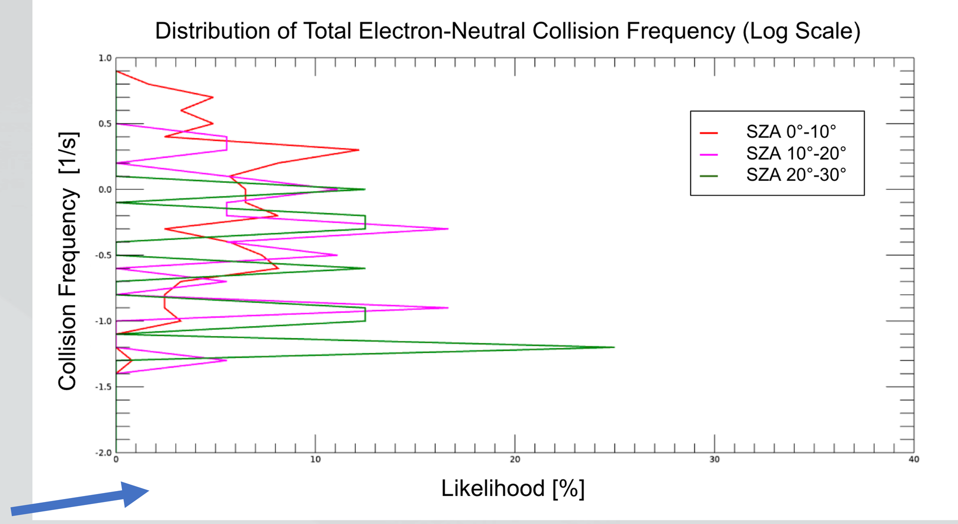

- $\nu_{en\,,\,O}$ values are lower than $\nu_{en,\,CO2}$, as expected.
- Potential trends driven by solar zenith angles, but more data is needed.



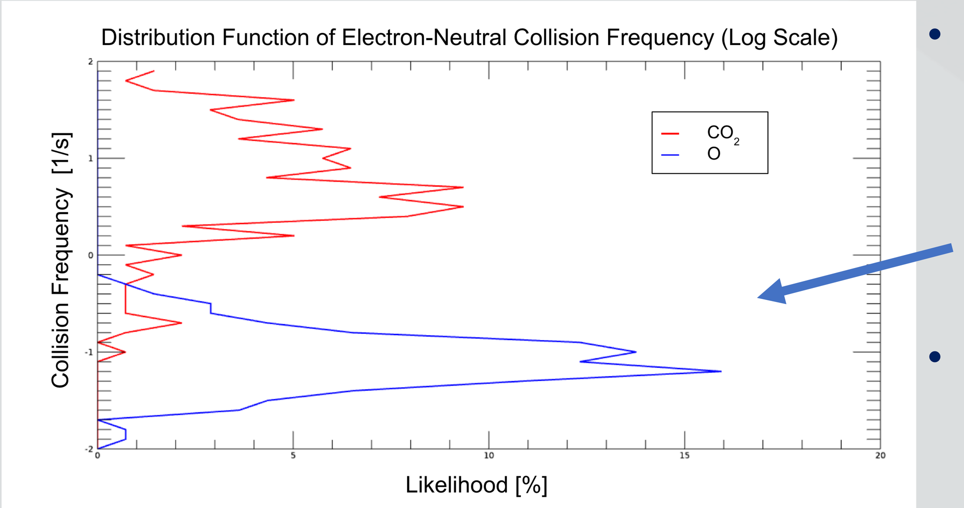

- Average Value of Transition Region (at $Z_0$):



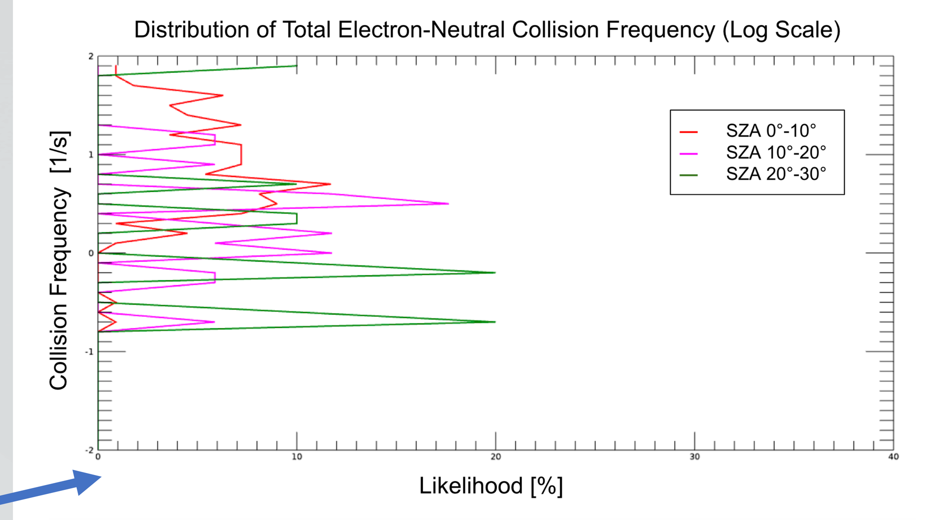

- $\nu_{en\,,\,O}$ values are lower than $\nu_{en,\,CO2}$, as expected.
- $\nu_{en}$ are larger than at $Z_0$+($H_0$/2), as expected since neutral densities are greater at $Z_0$.
- Possible trends driven by solar zenith angles, but more data needed.




- Bottom of Transition Region (at $Z_0$-½ $H_0$):

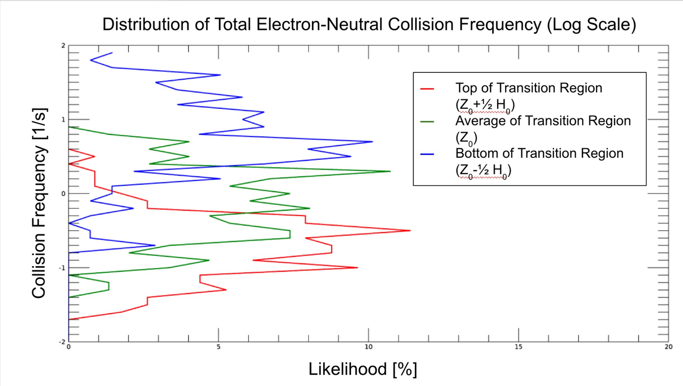



- Collisions are expected to dominate at lower altitudes, leading to $\nu_{en}$ that are an order of magnitude larger than at $Z_0$.
- Possible trends driven by solar zenith angles, but more data needed.




## 4. Conclusions

- Preliminary results show:
  - $\nu_{en}$ values are largest at the lowest altitudes sampled by MAVEN, as expected. The rate-of-change of collision frequencies with altitude may control the width of the transition region.




  - There may be a correlation between SZA and a larger spread in $\nu_{en}$ values.

## 5. Future Work

- Continue improvement and validation of $T_e$ profile fits.
- Use the full MAVEN data set to increase amount of data available.
- Investigate how differences in driving processes in other regions drive the shape of the transition region. For example, comparing fit parameters with collision frequencies in the lower ionosphere, and with the presence of electromagnetic waves in the upper ionosphere.
- Confirm if $\nu_{en}$ span a wider ride at lower SZAs and what that means for the transition region.
- Investigate if the "closeness" in collision frequency values at $Z_0$-($H_0$/2), $Z_0$, and $Z_0$+($H_0$/2) controls the width of the transition region.

## 6. Question for Modelers!

Would a database containing analytical fits of $T_e$ as a function of altitude and SZA be helpful to you? If so, what other parameters would you want present?

## Literature Cited

Figure [1]: NASA. (n.d.). *The Maven Spacecraft*. Retrieved from https://www.nasa.gov/mission_pages/maven/spacecraft/index.html.

[1]: Ergun, R. E., Andersson, L. A., Fowler, C. M., Woodson, A. K., Weber, T. D., Delory, G. T., Andrews, D. J., Eriksson, A. I., McEnulty, T., Morooka, M. W., Stewart, A. I., Mahaffy, P. R., & Jakosky, B. M. (2016). Enhanced $O_2^+$ loss at Mars due to an ambipolar electric field from electron heating. *Journal of Geophysical Research: Space Physics*, *121*(5), 4668–4678. https://doi.org/10.1002/2016ja022349