The Response of Photoelectrons in the Martian Atmosphere to Variable Solar Input

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The MAVEN Mission

The Mars Atmosphere and Volatile EvolutioN Mission
Launch Date: November 2013
Orbit Period: 4.5 Days

The Question: Geological evidence indicates that liquid water used to exist on the surface of Mars. This indicates that at some point, a heavier atmosphere was present.

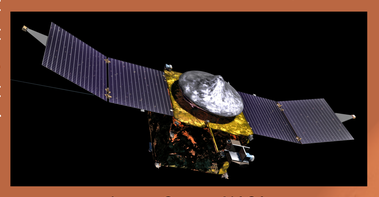


IMAGE CREDIT: NASA

The Goal: The purpose of MAVEN is to understand the processes that control atmospheric loss and the timescales over which they occur.

The Method: A variety of instruments collect data from atmospheric and solar inputs. MAVEN's highly elliptical orbit allows data to be taken from a large portion of the Martian atmosphere. Understanding the different layers of the atmosphere is crucial because different processes dominate at different altitudes.

The Ionosphere

The ionosphere is a layer of the Martian atmosphere that has a high concentration of ions and electrons. Neutral CO_2 and O are both present in the ionosphere. We focus on the double ionization of these in this research. The ionosphere overlaps the exobase and the homopause; their definitions are helpful in understanding why the ionosphere is critical in understanding atmospheric escape.

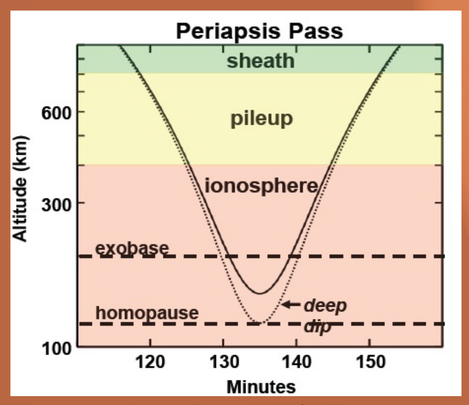
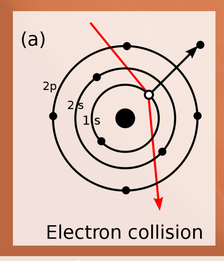


Image Credit: NASA/LASP

Exobase: Where the mean free path becomes larger than the scale height
Homopause: The boundary at which particles adapt individual scale heights. Below this the atmosphere is well mixed.
Left: The orbit of MAVEN

Scale Height: The height at which the density of a ceratin species falls by a factor of e
Mean Free Path: The average distance travelled by a particle before a collision

One process that occurrs in the ionosphere is **the Auger Effect:** A high energy photon hits an atom, knocking off an electron from the inner shell and leaving a vacancy. An upper electron drops to fill this vacancy and to conserve energy, another electron is ejected. This second electron is the auger electron. We can detected Auger electrons because they are produced with a characteristic energy



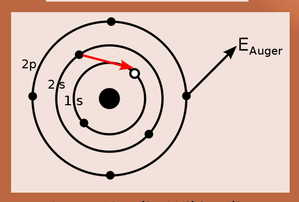
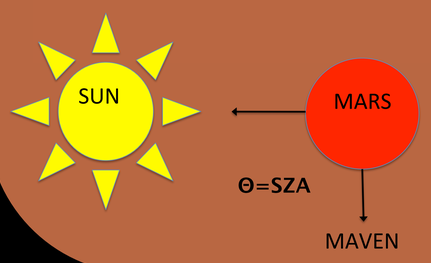


Image Credit: Wikipedia



Filtering Data: In order to isolate Auger electrons, we only look at data that is below 250 km to ensure we are in the ionosphere. To ensure we are observing the sun, we only look at solar zenith angles (SZA) below 90 degrees. (See left)

Instruments

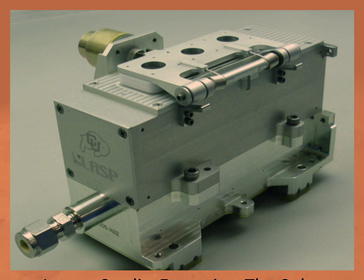


Image Credit: Eparvrier, The Solar Extreme Ultraviolet Monitor for MAVEN

Extreme Ultraviolet Monitor
EUVM Measures changing solar input of soft x-rays and extreme ultra violet. High energy irradiance is a big driver of atmospheric escape. EUVM Channel B measures radiation that is of interest to us (0.1-7 nm).

Solar Wind Electron Analyzer
SWEA measures the energy distribution of photoelectrons in the atmosphere. We isolate the electrons that are around the known Auger energy for CO2.

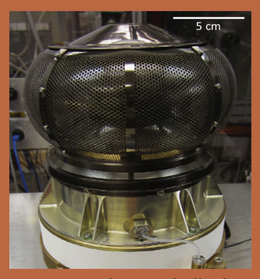
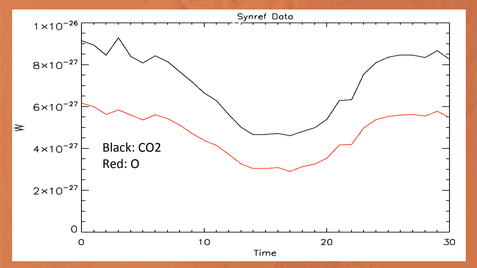


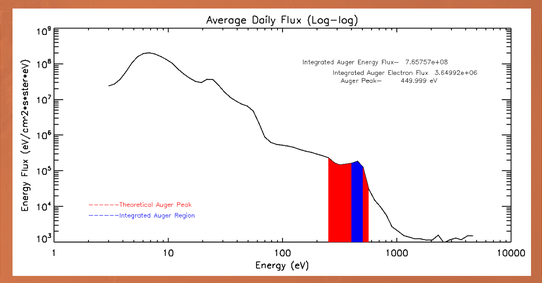
Image Credit: Mitchell, The MAVEN Solar Wind Electron Alayzer

Data Analysis: October 2015

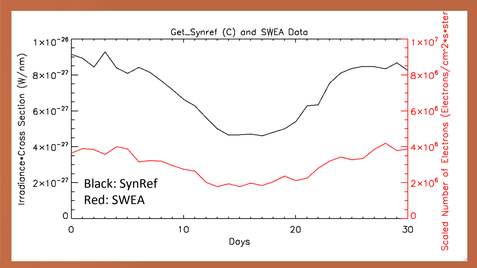
I. Create Cross Section/Irradiance convolutions from Models
Cross Section: A qualification of how likely it is that a particular molecule will absorb radiation



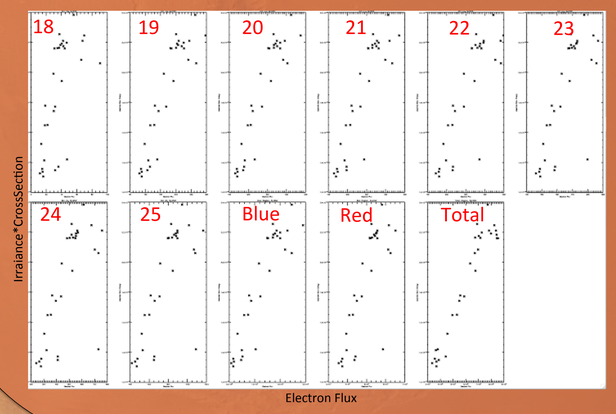
II. Find Energy Distribution from SWEA: We find the integrated electron flux for energy bins surrounding the Auger peak



III. Plot SWEA and Model data together



IV. Plot the two Variables against each other:
If SWEA and model data were perfectly correlated, the scatter plot would be a straight line. Each plot to the right corresponds to integrating over a different range of energy bins



V. Pearson Correlations:
A Pearson correlation of 1 means that two variable are perfectly positiviley correlated

red=max, blue=min, green=peak

SYNREF					FISM				
alt (km)	200	250	180	200	alt (km)	200	250	180	200
sza (degrees)	90	90	90	70	sza (degrees)	90	90	90	70
Bin(s)	Correlation with SWEA	Correlation with SWEA	Correlation with SWEA	Correlation with SWEA	Bin(s)	Correlation with SWEA	Correlation with SWEA	Correlation with SWEA	Correlation with SWEA
18	0.683845	0.683845	0.638655	0.654726	18		0.65978	0.623587	0.640211
19	0.923751	0.923751	0.908152	0.919146	19		0.909285	0.89713	0.90799
20	0.936938	0.936938	0.925728	0.935274	20		0.927415	0.918509	0.927104
21	0.901001	0.901001	0.873045	0.897011	21		0.89359	0.869282	0.891273
22	0.852452	0.852452	0.805242	0.84368	22		0.847679	0.805603	0.840915
23	0.779056	0.779056	0.707566	0.768809	23		0.776093	0.71189	0.769613
24	0.717674	0.717674	0.625654	0.707248	24		0.714127	0.630102	0.707645
25	0.749037	0.749037	0.665677	0.740579	25		0.747452	0.672055	0.743148
blue	0.924437	0.924437	0.907729	0.9213	blue		0.914244	0.900567	0.913077
red	0.812154	0.812154	0.749851	0.803652	red		0.811117	0.756011	0.806484
total	0.941417	0.941417	0.930094	0.939224	total		0.956686	0.947641	0.958062

Conclusion

- Both models (FISM and SynRed), are able to predict the behavior of Auger electrons with decent accuracy
- FISM, a coarser model, shows slightly higher correlation than SynRef when it comes to integrating over multiple energy bins
- SynRef correlates higher at the Auger peak, and therefore, as suspected, is better at predicting fine details
- Regarding the two statements above, the small difference in correlation coefficients between the two models may not be significant

Future Research

Short term:
- Fit slopes to the correlation plots
- Compute correlations with more combinations of SZA and altitude

Long Term:
- Adjust models (change assumed temperature of the sun) to find higher correlations