GLOBAL STRUCTURE AND VARIABILITY OF THE INNER HOT OXYGEN CORONA AS IMAGED BY EMM/EMUS

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Introduction:

The hot atomic oxygen corona of Mars is composed of a hyper-thermal population (energies of order ~ 1 eV) resulting from solar EUV driven photochemistry in the planet's upper atmosphere. A fraction of this population has sufficient velocity to escape from the planet, representing a mechanism for loss of atmosphere that has driven planetary evolution over the history of the solar system. The gravitationally bound portion of the corona extends to many planetary radii, but is mostly confined within the first couple radii of the planet. At distances within ~1/2 Martian radius above the surface, the structure of corona is expected to retain the strongest imprint of any spatial variations in the photochemical source around the globe. At more distant altitudes of multiple Martian radii the corona is expected to become more uniform as spatial variations become more globally averaged.

Previous Work:

The hot oxygen corona is directly observable via remote sensing in the far ultraviolet by measuring solar resonant fluorescence of the O I 130.4 nm emission line. However, the signal is quite dim (1-10 Rayleighs within the first Martian radius), and very sensitive instrumentation is required for a detection, let alone sampling profiles or capturing images. Detection at a few select altitudes at the base of the corona was first accomplished by the ALICE instrument aboard the Rosetta mission during a Mars flyby (Feldman et al. 2011). The MAVEN IUVS instrument has been orbiting Mars since 2014, and has been collecting vertical 1D profiles of hot oxygen within the first Martian radius at a roughly daily cadence (Deighan et al. 2015). Interpretation of the IUVS data has three key complicating factors (1) the 1D profiles are obtained while MAVEN is deeply embedded within the hot oxygen corona structure, (2) the roughly daily sampling cadence makes longitudinal information sparse, and (3) the local time sampling varies with the MAVEN orbit precession over the course of months, during which time there can be significant variations in season and solar activity. These factors present challenges in deconvolving the drivers of the observed O I 130.4 nm brightness in order to reconstruct a global 3D description of the hot oxygen.

Current Work:

We report here on an extensive new set of data for studying the Martian hot oxygen corona that is now available from the Emirates Mars Ultraviolet Spectrometer (EMUS) aboard the Emirates Mars Mission (EMM). The EMUS instrument was designed with a driving requirement for high sensitivity and low background in order to obtain comprehensive 2D images of the inner Martian corona (Holsclaw et al. 2021). In addition, the EMM spacecraft orbit (19,970 km periapse altitude, 42,650 km apoapse altitude, 25° inclination, 54.5 hour period) is configured to allow imaging of the planet from outside the majority of the corona across a wide range of positions around the planet with a full image set cadence of at least once per week (Amiri et al. 2022, Almatroushi et al. 2021). These key features enable major advancements in our understanding of the structure and variability of the hot oxygen corona, giving insight to its drivers and its connection to atmospheric loss.

Data:

Here we present results from the EMUS UOS-2 observations which image the inner corona out to at least 1800 km from at least six points of view around a single EMM orbit in order to provide 3D information about the structure of the corona. These image sets are obtained at least once per week (approximately 3 orbits), and occasionally on every orbit during a "high cadence" week every 15° of L_S in order to look for short term variability. With the nominal science mission beginning 23 May 2021, there are now multiple Mars seasons of data available and a modest range of solar activities to examine as Solar Cycle 25 begins ramping up.

Method:

Due to the highly sensitivity nature of the measurement, faint background stars in the sky represent a major nuisance. Affected data are identified and removed from the analysis by interrogating the spectrum for continuum signal at 133–161 nm.

To examine spatial structure we compare the EMUS images to a simple 3D model of the hot oxygen corona density that includes an inverse radial power law dependence and a cosine power law dependence in solar zenith angle. This two parameter model captures the most basic structure of the photochemically generated corona and allows for a reference point by which asymmetries and trends can be identified. The density model is integrated through for every line of sight in the observations in order to provide a direct comparison to the measured brightnesses.

To examine temporal variability we average the dayside corona (SZA > 70°) across altitudes of 700-1500 km for each observation to provide a consistent geometry for sampling across time. This criterion ensures good signal and also avoids the denser thermal oxygen corona that dominates at lower altitudes.

Results:

We find while that the simple reference model of the inner hot oxygen coronal density can reproduce the gross structure of the observations, it tends to systematically under predict the brightness in the dimmer areas of the EMUS images, both at higher altitudes and on the nightside of the planet. Interrogation of the spectra confirm the presence of O I 130.4 nm signal and not a spurious background. We interpret this behavior as a foreground contribution of the hot oxygen population residing in the extended middle corona (1.6-6 Martian radii), a region through which the EMUS line of sight must pass when observing the inner corona (< 1.6 Martian radii) from the elevated orbit of EMM.

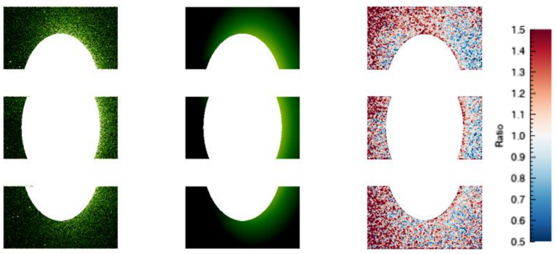

Figure 1. Data/Model/Ratio comparison for the three swaths of a UOS2 observation.

In terms of temporal variability, we find that that the hot oxygen coronal brightness has generally increased over the EMM mission to date, due to a combination of the Mars-Sun distance and increase solar activity. This is consistent with other indicators for airglow variability measured on the disk of the planet, namely O I 130.4 nm reflecting from the thermospheric cold atomic oxygen population and C I 128.0 nm emission from CO_2 dissociation. It is also well correlated with direct measurements of solar activity as recorded by the MAVEN EUVM instrument (Eparvier et al. 2015).

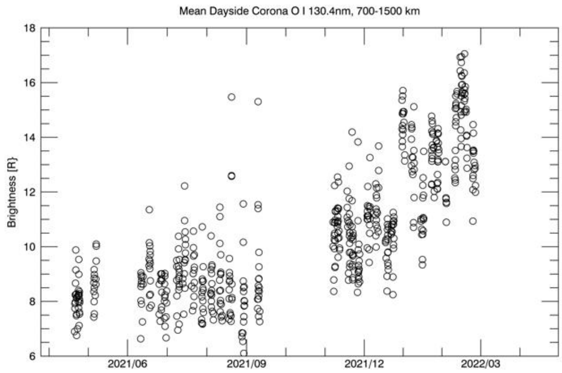

Figure 2. Timeline of average dayside inner hot oxygen brightness measured by EMM/EMUS.

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