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Seasonal Variation of Martian Pick-up Ions

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Abstract

Statistics of Mars Express (MEX) ion mass analyser (IMA) data shows that ion production from exospheric hydrogen depends more on the Sun-Mars distance than the solar cycle phase or winter-summer hemispheric difference. This indicates that the EUV is not the only driver of the production of cold, exospheric-origin ions, and that the extension of the exosphere is strongly influenced by total irradiance that carries the majority of the solar energy to the Martian atmosphere

1. Introduction

Mars Express (MEX) has operated for more than 10 years in the environment of Mars, providing solar wind ion observations by the Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) experiment's ion mass analyzer (IMA). In the region just outside the bow shock of Mars, IMA frequently observes ring-like distributed ions that include both pick-up ions of exospheric origin and reflected solar wind by the bow shock [1]. These observations have limitations on the detected angular distribution due to the limited field-of-view (FOV), on the low-energy proton detection due to sensor capability, and on the lack of the upstream magnetic field knowledge due to the absence of a magnetometer.

2. Analyses

Despite the lack of magnetic field data, the length and quality of the IMA data (nearly no degradation of the sensor efficiency) is sufficient to statistically diagnose the seasonal (defined by the Sun-Mars distance, and we call "summer" when the Mars is at perihelion) and solar cycle variation of the pick-up ions of exospheric origin. Two methods are employed for such statistical analyses: the automated method [2] and manual (eye-identified) method [3]. The automated method is used to obtain the general distribution whereas the manual method is used to obtain fine (2-months resolution) temporal variation, as shown in Figure 1. Both methods are applied to eight years of MEX/IMA data during 2005-2012.

3. Results

The statistics revealed that the occurrence rate of the pick-up ions varies with Sun-Mars distance, i.e., sharply increases during the Martian summer (Mars perihelion). This seasonal variation is dominant over the solar cycle variation that has a much longer time scale, and the occurrence probability is different for the same level of EUV flux, e.g., between the summer of the solar minimum and winter of solar maximum, results in different probabilities. The automated method further revealed that the variation is mainly driven by the Sun-Mars distance rather than the season of the (southern) hemisphere that possesses large magnetic anomalies. The temporal variation obtained by manual method also revealed that the peak occurrence rate is recorded slightly (1-2 month) after the perihelion.

4. Conclusion

The result indicates that the EUV is not the only driver of the production of cold, exospheric-origin ions, and that the extension of the exosphere is controlled more by the Sun-Mars distance than the EUV. One possibility is that the atmospheric condition (e.g., temperature or existence of dust) might strongly influence the exosphere.

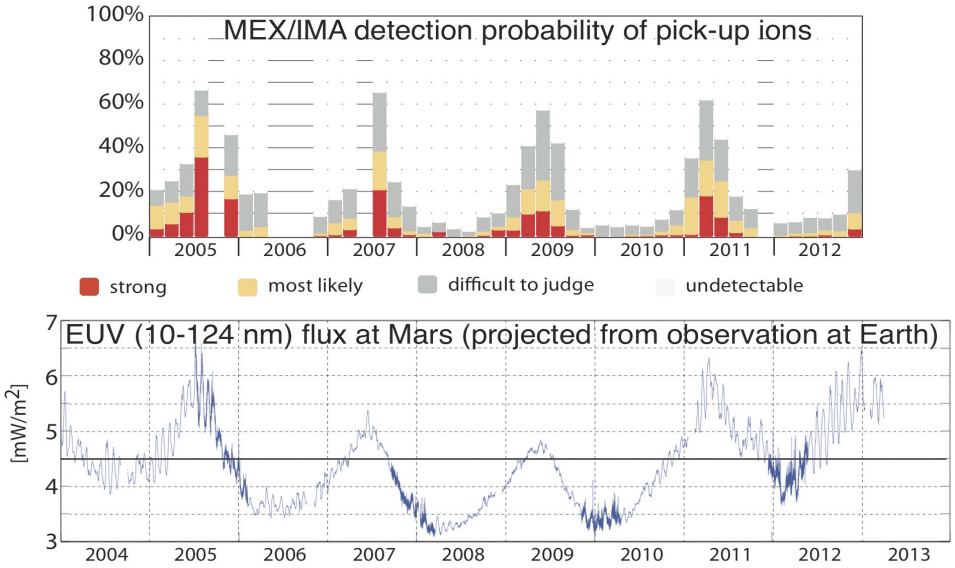

Figure 1: Temporal variation of (a) observation rate of the pick-up ions determined using the manual method, and (b) the estimated EUV flux at Mars from the measured value at the Earth by TIMED/SEE instrument [4]. There are about 7500 inbound or outbound traversals during 2005-2012 with the medium mass-resolution mode. Note that the total number of hours under a specific mass-resolution mode of IMA varies from time to time, and MEX is sometimes completely downstream of the bow shock for about one month. Therefore, taking monthly average is not appropriate. However, data becomes rather smooth if two months time intervals are integrated.

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