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Venusian atmospheric O^+ escape rate dependence on the upstream solar wind conditions

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Abstract

We use the Venus Express ASPERA-4/IMA data to characterize the ion escape rate through the Venusian magnetotail and its dependence on the upstream conditions of the solar wind. We find a clear dependence of the escape rate on the solar wind dynamic pressure that is consistent with previous results of the escape rate measurements at Venus. By binning the measured data into several groups of different upstream condition ranges, we formulate the escape rate as a function of upstream parameters.

1. Introduction

The Venusian ionosphere interacts directly with the incoming solar wind and creates an induced magnetosphere. Even though the Venusian atmosphere is capable of balancing the solar wind dynamic pressure, energy is still transferred from the solar wind to the atmospheric particles. This energy is enough to power escape of atmospheric particles. A main escape channel for the atmospheric ions is the induced magnetotail, where the escape rate is (3-6) $\cdot 10^{24}$ s^{-1} under the typical condition [4]. However, several studies indicate that the escape rate is dependent on upstream conditions, such as dynamic pressure [3], extreme ultraviolet (EUV) flux [5] and the solar cycle [6, 7]. As the solar wind and solar EUV was stronger in the earlier history of the solar system [1, 9], an empirical model of the escape rate as a function of the upstream conditions is needed in order to properly extrapolate the escape rates backwards in time. The extrapolation is important to understand the effect of the solar-wind driven atmospheric erosion on the evolution of the Venusian atmosphere. In addition, by comparing the atmospheric escape rates with similar studies made for Mars [8] and Earth [10], we can investigate the effects on the atmospheric escape rates from different characteristics of the planets, such as gravity, an intrinsic magnetic field, and atmospheric content.

2. Data

We use all available data measured during 2006-2014 by the Ion Mass Analyser (IMA), part of the ASPERA-4 instrument package [2] on board the Venus Express mission [11]. The 8.5 years of operation, providing more than 3000 orbits, enables us to formulate a statistically-confident empirical formulation. The IMA instrument provides measurements of ion fluxes in the energy range 0.01-36 keV/q, with a 90x360° field-of-view, every 192 s. The mass-separation capability of IMA allows us to confidently determine the flux of heavy ions.

3. Method

We created average distribution functions of O^+ in the Venusian magnetotail [7]. The average distributions were then used to calculate the total flux and total escape rate of O^+ through the Venusian magnetotail for different upstream parameter ranges (e.g. solar wind dynamic pressure and EUV flux). We then find empirical functions to the escape rates with respect to the upstream conditions. The upstream plasma parameters are derived from the Venus Express mission itself using the inbound and outbound orbit paths just outside of the Venusian bow shock.

4. Preliminary results

We find a significant escape rate dependence on solar wind dynamic pressure. A higher solar wind dynamic pressure gives a higher escape rate through the Venusian magnetotail. This is in agreement with previous studies, where the increase in dynamic pressure during space weather events was shown to increase the escape rate by a factor 1.9 [3]. When the solar wind dynamic pressure is higher, there is more energy in the solar wind that can potentially transfer to the Venusian atmospheric particles. This allows for a larger acceleration of the atmospheric particles, pushing more particles above the escape velocity of

~10 km/s and the total escape rate increases. We will represent the dependence empirically with an analytical form. The different upstream parameters will be used in the empirical expression.

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