Possibility of O^+ acceleration by the local convection electric field: Venus Express observations

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Abstract

Using data from ASPERA-4 (Analyser of Space Plasma and Energetic Atoms) and MAG (magnetometer) experiments onboard Venus Express, we investigate spatial distribution s of O+ fluxes (>100 eV) around Venus for two convection electric fields: solar wind electric field (SWEF; $\mathbf{E}_{SW}$ = -$\mathbf{V}_{SW}$ x $\mathbf{B}_{SW}$) and local convection electric field (LCEF; $\mathbf{E}_L$ = -$\mathbf{V}_L$ x $\mathbf{B}_L$). Comparison between these distributions under two different IMF configurations (namely IMF directs nearly perpendicular to the Venus-Sun line and nearly parallel to it), we find that the spatial distribution of the O+ fluxes depends on the LCEF's direction for both IMF configurations. We conclude that the O+ ions would be accelerated more effectively by LCEF rather than SWEF.

1. Introduction

We have found that spatial distributions of escaping O+ ions (>100 eV) are different between two IMF configurations: IMF directs nearly perpendicular to the Venus-Sun line (perpendicular IMF case) and IMF directs nearly parallel to it (parallel IMF case) [1]. In the perpendicular IMF case, IMF drapes around Venus ionosphere followed by forming a single plasma sheet, and most of O+ ions flow out through it. The energy of O+ fluxes has an energy dependency in the direction of a global convection electric field (SWEF; $\mathbf{E}_{SW}$ = -$\mathbf{V}_{SW}$ × $\mathbf{B}_{SW}$; where $\mathbf{V}_{SW}$ and $\mathbf{B}_{SW}$ are the solar wind's velocity vector and the IMF vector) as seen in a previous study [2]. On the other hand in the parallel IMF case, IMF drapes around the ionosphere complicatedly and forms multiple outflow channels around the terminator. There is no energy dependence on GCEF's direction. These differences between the two IMF cases indicate that in the parallel IMF case O+ ions are not accelerated by GCEF but by local effects, such as a magnetic tension force [3], viscous force [4] or local convection electric field (LCEF; $\mathbf{E}_L$ = -$\mathbf{V}_L$ × $\mathbf{B}_L$; where $\mathbf{V}_L$ and $\mathbf{B}_L$ is the local velocity vector and the local magnetic field).

In this study, we assume there is LCEF and examine if it works for the O+ acceleration by using three dimensional plasma energy spectra and magnetic field data observed by Venus Express.

2. Data selection

In this study, we use data from ASPERA-4 and MAG instruments on board Venus Express. The data is selected for a period between June 25, 2006 and December 31, 2008. As was done in our previous study [1], we classified the data into two different IMF configurations: IMF directs nearly perpendicular to the Venus-Sun line (perpendicular IMF case), and IMF directs nearly parallel to it (parallel IMF case). We obtained 39 perpendicular IMF cases and 26 parallel IMF cases. To ensure which convection electric fields contribute more for acceleration of the O+ ions, we define two electric field reference frames. One is the VSE (Venus-Solar electric) coordinate system where GCEF directs to the z axis and the other is the VLE (Venus-local electric) coordinate system where LCEF directs to the z axis.

3. Observations & Discussion

We statistically investigated positions where O+ fluxes (>100 eV) were detected with respect to the two convection electric fields to examine their contributions for O+ accelerations. Regardless of upstream IMF directions, these spatial distributions of O+ fluxes show a clear asymmetry in the direction of LCEF. More O+ ion fluxes are observed in the $+E_L$ hemisphere (Z>0 in the VLE frame) compared with show a clear asymmetry in the direction of LCEF. More O+ ion fluxes are observed in the $+E_L$ hemisphere (Z>0 in the VLE frame) compared with those in the $-E_L$ hemisphere (Z<0 in the VLE frame) for both IMF cases. Especially in the magnetosheath, O+ ions have clearer dependency on the LCEF's direction. The result indicates that LCEF contribute more on O+ acceleration rather than the GCEF. In the induced magnetosphere, ion detection is often associated with Bx reversal as seen in the plasma sheet [2, 3]. This may suggest that a draped IMF generates a magnetic tension force or viscous force as well as LCEF, and then both of them contribute to O+ accelerations.

4. Summary

Using the data from ASPERA-4 and MAG onboard Venus Express, we examine if LCEF is capable of O+ acceleration. Compared with the different spatial distributions of O+ ions between two convection electric fields, we find that LCEF works for the O+ acceleration. We also find that a draped IMF generates a magnetic tension force and/or viscous force as well as LCEF in the induced magnetosphere, and then these effects might contribute to O+ accelerations. Therefore, O+ acceleration at Venus may depend on the local plasma condition rather than that of upstream solar wind.

References

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