火星からの大気イオン流出：MHDシミュレーションによる新しい評価方法

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Critical estimation of ion escape rate from Martian ionosphere using a new estimation method in MHD simulation

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The total rate of ion escape from the Martian atmosphere/ionosphere is an important factor when we consider the loss of atmospheric ions in the total history of Mars during which the solar wind pressure may have varied by many orders of magnitude.
The ion escape rate is usually estimated by numerically integrating the escaping ion flux at a plane placed perpendicular to the solar wind at some distance behind the planet. In the case of MHD simulation, however, we found that this method tends to give a value significantly larger than the value independently estimated from the chemical balance of the total ion production and loss rates estimated for the whole ionosphere. The reason is twofold:

(1) In MHD simulations, artificial viscosity should be included to avoid numerical oscillations. Such artificial diffusion tends to be large at a sharp boundary which is produced between the stagnant ionospheric plasma and the flowing solar wind plasma. We found that, for the special resolution usually employed in the MHD simulations (on the oreder of 100x100x100 spatial meshes around Mars, for example), the escape flux due to artificial diffusion is on the same order of magnitude as the total escape rate discussed in the past papers.

(2) Total escape flux should be evaluated when the system has reached a steady state. However, we found that part of the escaping ion flux is trapped in the flow vortices which are produced in the wake of the planet. The chemical equilibrium in these vortices takes a long time to be attained, and actually the time needed is considerably longer than the time employed in the past papers.

In order to avoid these drawbacks, we developed a new method to estimate a total ion escape rate at Mars. We first obtain plasma flow lines for all the regions around Mars including the ionosphere and the solar wind. Then we estimate the escape flux only for those flow lines that are connected to the downstream solar wind region, avoiding the closed flow lines belonging to the flow vortices in the wake. As a double check, we integrate the total ion production and loss rate on those field lines that are connected to the downstream solar wind, to see if the obtained values are mutually consistent.

The simulation results obtained so far suggest that, for average solar wind conditions at the solar minimum period, the total ion escape rate is very low, less than 10ˆ23 ions/s, especially when the IMF is weak. We are now examining the cases with stronger IMF magnitude, and the results will reveal the reliable estimate for the effect of magnetic field tension-assisted ion escape at Mars.