Solar energetic electron penetration into the Martian upper atmosphere observed by MAVEN

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Discovery of diffuse aurora at Mars caused by the SEP (solar energetic particle) electrons [Schneider et al., Science, 2015] sheds a new light on the high-energy particle environment at Mars. Since Mars has no global intrinsic magnetic field, direct interaction between the solar wind and Martian upper atmosphere results in the draping of the interplanetary magnetic field (IMF) around Mars and forms the induced magnetosphere. The diffuse aurora observation in the northern hemisphere, where the crustal field is absent, indicates penetration of the high-energy electrons of ~100 keV down to the altitudes around 70 km most likely along the draped IMF around the planet. However, to what extent the draped magnetic field configuration around Mars controls the SEP electron penetration to the atmosphere is far from understood.
In this study, we investigated three SEP events observed by MAVEN from December 2014 to March 2015. The pitch angle (PA) distributions of the high-energy (30-210 keV) electrons observed in the Martian ionosphere are analyzed in details. In order to achieve a good coverage in the 2-D (PA-energy) phase space, data obtained during a SEP event is accumulated and binned. Using the elevation angle of the local magnetic field, we also sorted the data so as to investigate the SEP electron loss below the MAVEN periapsis (~150 km altitude). The obtained PA distributions in the ionosphere are compared with the distributions of the source electrons in the magnetosheath. The results show that the field-aligned component is pronounced for the penetrating electrons and it does not significantly depend on the initial PA distributions in the magnetosheath. The observation also indicates that the highest energy of the SEP electrons lost into the Martian atmosphere depends on the magnetic field configuration draped around the planet. During the aurora event reported by Schneider et al. [2015], electrons with energy less than ~130 keV were lost into the atmosphere. These SEP observations thus support the scenario that the solar energetic electrons penetrate into the ionosphere along the draped magnetic field and the altitude to which they can penetrate depends on the magnetic field configuration.

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