On possibility of visualization of Martian space environment with diffuse aurora: Relations between magnetic field structure and solar energetic electron penetration into the upper atmosphere observed by MAVEN

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MAVEN observations revealed existence of a new type of aurora, diffuse aurora, which illuminates an extended region of Martian upper atmosphere in terms of longitude and latitude and does not related to the crustal magnetic fields [Schneider et al., 2015; 2018]. The diffuse aurora is considered to be caused by the SEP (solar energetic particle) electrons [Gerard et al., 2017]. 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 in December 2014, March 2015, and September 2017. 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. The SEP electron loss into the atmosphere is larger in higher SZA, suggesting the deeper penetration of draped magnetic fields in the nightside than dayside. These results 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. In other words, global diffuse aurora observations can give a new tool to visualize Martian space environment for understanding interaction between the solar wind and Martian upper atmosphere, especially the dynamics of the nightside ionosphere.

References:
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