Acceleration of Planetary Ions by Different Electric Field Terms in an Induced Magnetosphere

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We report the preliminary results of a hybrid simulation to differentiate and quantify the energy gain due to different electric field terms in the acceleration of planetary ions escaping from an induced magnetosphere.

The planetary ions gain energy from the electric field formed in the induced magnetosphere. The electric field is not directly measurable and thus has to be expressed by the generalized Ohm’s law with measurable quantities:

\[ E = -V_e \times B - \nabla P_e / (q_e n_e) + j \times B / (q_e n_e) \]

Where \( V_e \) is the velocity of the electrons that freeze the magnetic field \( B \), \( P_e \) is the thermal pressure tensor, and \( j \) is the Hall current. The three terms on the right-hand side describe the three different mechanisms of ion acceleration: the motional term, the pressure gradient term, and the Hall term. All these terms contribute to the energization of escaping ions, while they dominate in different positions in an induced magnetosphere, and play different roles in the dynamics of an escaping ion.

We will quantify the energy gain due to each electric field term of escaping ions depending on the birthplaces of the ions. Our tool is AMITIS, a GPU-based 3-D hybrid code (ions as particles and electrons as a fluid) to model the plasma interaction with a planet (Fatemi et al., 2017). For a test, we simulated the solar wind interaction with Mars at nominal space environment conditions until a quasi-steady state. We calculated different electric field terms and compared them with the MAVEN measurements. The simulation results show good agreement with measurements in both magnitude and spatial distribution.

We further launched test particles from different positions in the ionosphere and tracked the energy gain/loss due to different electric field terms along their escaping trajectories. The energization history of an ion depends on its trajectory, which further partly depends on the birthplace of the ion. Ions produced outside of the IMB are accelerated or “picked up” totally by the motional electric field. Ions produced in the induced magnetosphere in the dayside may be accelerated by the thermal pressure gradient of the ionosphere, while those produced in the nightside are driven more by the Hall electric field.