Auroral Particle Acceleration Due to Nonlinear Interaction of Alfvén Wave Packets

Yan Song and Robert L. Lysak

School of Physics and Astronomy, University of Minnesota, USA

In auroral acceleration regions, the parallel and perpendicular electric fields ($E_{\|}$, $\mathbf{E}_{\perp}$), which are often structured as U-shaped potentials, double layers or charge holes, play a crucial role in the energization of charged particles. From a complete set of dynamical equations, which include Newton's law for ions and electron and Maxwell's equations including the displacement current, it has been found that the generation and maintenance of $E_{\|}$ and potential drops are related to the local enhancement or release of mechanical and/or magnetic stresses. Such stresses are mainly transmitted by Alfvén wave packets; therefore, the nonlinear interaction between the incident and reflected Alfvén wave packets in the auroral acceleration region can release these stresses leading to auroral particle acceleration.

A localized breakdown of the frozen-in condition during the nonlinear interaction enables the perpendicular vortex motion and twisted magnetic field carried by the Alfvén wave packets to be irreversibly reorganized, keeping an approximate conservation of the total magnetic helicity and angular momentum. As a result, either the perpendicular vortex motion of the wave packet or the twist in the magnetic field is enhanced, and the other property is reduced, in the wave packet interaction. When the perpendicular vortex motion is reduced and the magnetic twist is enhanced, parallel potential drop is formed, while an enhanced vortex motion with reduced twist in the magnetic field leads to the formation of charge holes. This process may lead to an enhanced low density region on auroral field lines, which may further amplify $E_{\|}$ on the field lines.

Similarly, during the impinging of fast mode wave packets on the current sheets on the magnetopause and in the tail, the nonlinear interactions between fast mode wave packets and the current sheets can cause the localized breakdown of the frozen-in condition, generating the Alfvén wave packets that can drive auroral processes.