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Electron energization by dispersive Alfvén waves in planetary magnetospheres

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Two classes of aurora, defined by the characteristics of the associated electron energization, are defined as mono-energetic and broadband. The latter of these is generally associated with dispersive scale Alfvén waves - that is Alfvén waves with perpendicular scale lengths on the order of the electron inertial length (inertial Alfvén waves), ion gyroradius or ion acoustic gyroradius (kinetic Alfvén waves). Generally, electron inertial effects dominate at high latitudes while kinetic Alfvén waves are dominant in equatorial regions. Both limits support parallel electric fields that are important for electron energization. In planetary magnetospheres these waves may be sourced from such varied processes as the breaking of fast flows in magntotail reconnection, shear flow driven instabilities and moon-magnetosphere interactions (e.g. Io).

In this presentation we use recent results of a gyrofluid-kinetic electron simulation model in curvilinear coordinates [1, 2], in comparison with observations [e.g. 3, 4, 5, 7] to present an overview of the characteristics of the electron energization in these waves both in the context of the terrestrial and giant planet magnetospheres. We discuss the limit of both dispersive scale travelling [2, 6, 8] and standing Alfvén waves [7], both of which peak at substorm onset from the auroral zone into the inner magnetosphere [9]. As an example of the latter, Figure 1 presents results from a simulation of a kinetic scale field line resonance in the inner magnetosphere illustrating the formation of asymmetric field-aligned distributions commonly associated with the electron trapping in kinetic Alfvén waves and loss cones that are evidence of soft electron precipitation. In comparison, Figure 2 presents the result of a simulation of high-latitude electron energization by travelling inertial Alfvén waves for parameters relevant to the Jupiter magnetosphere. As the wave signature arrives close to the ionospheric boundary, the increase in parallel current is accompanied by the formation of beam-like highly field-aligned electron distributions associated with the observed broadband energization.

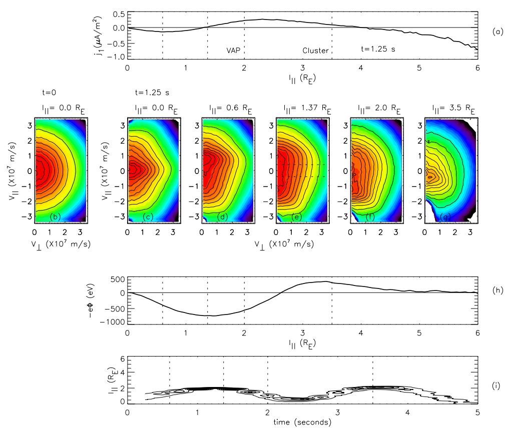

Figure 1: (a) Parallel current density as a function of distance along the field line. (b) Initial Maxwellian distribution function at t = 0. (c)–(g) Electron distribution functions at t = 1.25 s and the indicated values of $l_{||}$. (h) Effective potential at t = 1.25 s. (i) Evolution of an ensemble of trapped electrons taken from core of distribution evident in panel f (from [7]).

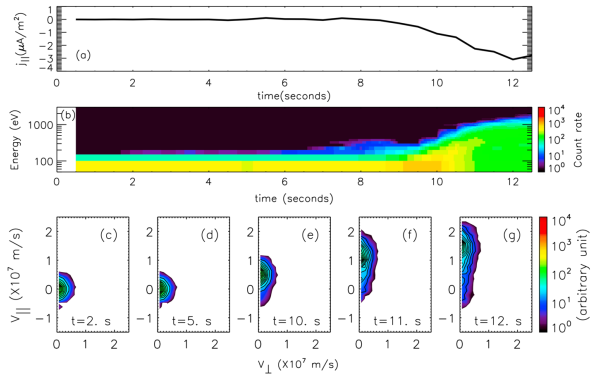

Figure 2: (a) Parallel current above the ionospheric boundary as a function of time. (b) Electron energy spectrogram above the ionospheric boundary. (c–g) Corresponding electron distribution functions at the indicated times (from [8]).

We also briefly discuss the role kinetic Alfvén waves may play in regulating the high latitude energization [2, 6] and how the characteristics of the energizations vary with parameters such as the driving Alfvén Mach number, the presence of heavy ions and the fractions of hot and cold ambient electron populations.

References

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