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Field-aligned particle acceleration on auroral field lines by interaction with transient density cavities stimulated by kinetic Alfven waves

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We consider the field-aligned acceleration of energetic ions and electrons which takes place on auroral field lines due to their interaction with time-varying density cavities stimulated by the strong oscillating field-aligned currents of kinetic Alfven waves. It is shown that when the field-aligned current density of these waves increases, such that the electron drift speed exceeds the electron thermal speed, ion acoustic perturbations cease to propagate along the field lines and instead form purely-growing density perturbations. The rarefactions in these perturbations are found to grow rapidly to form density cavities, limited by the pressure of the bipolar electric fields which occur within them. The time scale for growth and decay of the cavities is much shorter than the period of the kinetic Alfven waves. Energetic particles traversing these growing and decaying cavities will be accelerated by their time-varying field-aligned electric fields in a process that is modelled as a series of discrete random perturbations. The evolution of the particle distribution function is thus determined by the Fokker-Planck equation, with an energy diffusion coefficient that is proportional to the square of the particle charge, but is independent of the mass and energy. Steady-state solutions for the distribution functions of the accelerated particles are obtained for the case of an arbitrary energetic particle population incident on a scattering layer of finite length along the field lines, showing how the reflected and transmitted distributions depend on the typical “random walk” energy change of the particles within the layer compared to their initial energy. When this typical energy change is large compared to the

initial energy, the reflected population is broadly spread in energy about a mean which is comparable with the initial energy, while the transmitted population has the form of a strongly accelerated field-aligned beam. We suggest that these processes are responsible for the occurrence of accelerated field-aligned beams of ions and electrons that are commonly observed on auroral field lines in planetary magnetospheres.