

Ion acceleration by fast magnetosonic waves and their role in ring current radiation belt coupling

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Abstract

During the main phase of geomagnetic storms ions are transported across the geomagnetic field towards the Earth from the outer magnetosphere. Convective (and inductive) electric fields transport low energy ions of a few tens of keV through dawn towards the dayside while higher energy ions are transported through dusk by curvature and gradient drift. The higher energy ions can be trapped by the magnetic field to form the partial, and total, ring current. Recent observations show that the ion distribution function on the dayside magnetosphere often has a ring type distribution as a result of different ion drift paths, and as a result of ion loss processes. These ring distribution can excite fast magnetosonic waves that propagate across the magnetic field at frequencies between the proton cyclotron frequency and the lower hybrid frequency. Here we present wave data from the CLUSTER spacecraft with very high frequency resolution which shows magnetosonic waves with a line structure that has frequency spacing comparable to the local proton cyclotron frequency. We present results from the Ring current Atmosphere Model (RAM) to simulate the development of the ring current during a storm and find that ion ring distributions are predicted by the model and that they can generate fast magnetosonic waves with multiple spectral peaks. By modelling the multiple peaked spectra, we show that these waves diffuse ring current ions at energies between 10 and 100 keV, and that energy diffusion rates are up to two orders of magnitude higher than pitch angle diffusion. Since diffusion does not extend into the loss cone we show that these waves are not an effective loss process. We solve the Fokker Planck equation to obtain the evolution of the ion distribution function and show that although the waves diffuse ions to lower energies the ion ring distribution still remains even after a period of 5 hours, suggesting that ion ring distributions are remarkably robust. More significantly, we show that the waves can accelerate ions up to 100 keV or so and increase the ion flux at 100 keV by an order of magnitude or more. Thus we suggest that magnetosonic waves could be an effective means of producing the high energy part of the ion ring current. Finally, we show that the waves produce a highly anisotropic ion distribution which can help excite electromagnetic ion cyclotron (EMIC) waves. Since EMIC waves cause loss of radiation belt electrons we suggest that magnetosonic waves can couple the ring current to the electron radiation belts via ion diffusion and the excitation of EMIC waves.

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