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Simulations of preferential heavy ion acceleration resulting from ULF wave drift-bounce resonance: MMS observations

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A general aspect of the recovery phase of geomagnetic storms is the appearance of ULF pulsations and their association with energetic electrons and ions across a range of energies. High-m poloidal mode waves excited by internal plasma instabilities within the ring current region are frequent on the dayside, while Pc5 waves of intermediate wavenumbers on the nightside are much less common. In this study, we perform test particle simulations of drift and bounce resonance wave-particle interactions observed by the ARASE and MMS spacecraft during the recovery phase of the 27 March 2017 storm. At this time, Pc 5 waves of solar wind origin were observed by ARASE in the post-midnight region between L∼5.4-6.1 along with oscillations of differential particle flux at energies greater than 56.3 keV for both H+ and O+, and less than 18.6 kev in the case of O+. Oimatsu et al. [Geophys. Res. Lett., 45, 7277-7286, 2018] attributed the energy range of these flux oscillations to ULF wave drift and bounce resonance processes, respectively, and found that acceleration of O+ at energies less than 18.6 keV was much more efficient than for H+.

Analysis of observations of drift-bounce resonance usually proceeds by making use of the resonance condition, which provides the resonance energy given the wave frequency, azimuthal wavenumber and bounce period. Here, we solve the full equations of motion for ions in the fields of a model of ULF waves and reconstruct the phase space density for O+ and H+ as a function of energy and pitch angle at a virtual satellite position. The simulated distributions are then binned in energy and pitch angle as in the ARASE MEP-i particle detector and compared with observed differential flux for the 27 March 2017 storm. As this procedure makes no apriori use of the resonance condition, it enables hypotheses postulated in the data analysis of the 27 March 2017 storm to be quantitatively evaluated. By comparing our quantitative analysis of drift-bounce resonance with ARASE and MMS spacecraft observations, our simulations offer essential insight into the dynamics of light and heavy ions that interact with ULF waves, as well as improving our understanding of various energetic particle populations that form in the inner magnetosphere.