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High-frequency waves driven by pickup ion ring-beam distributions in the outer heliosheath

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Scattering of pickup ion ring-beam distributions in the outer heliosheath is a fundamental element in the spatial retention scenario of the energetic neutral atom (ENA) ribbon observed by the Interstellar Boundary EXplorer (IBEX). According to our earlier linear instability analysis, pickup ion ring-beam distributions trigger magnetic field-aligned, right-hand polarized unstable waves in two separate frequency ranges which are near and far above the proton cyclotron frequency, respectively. We have performed hybrid simulations to study the unstable waves near the proton cyclotron frequency. However, the high-frequency waves well above the proton cyclotron frequency are beyond the reach of hybrid simulations. In the present study, particle-in-cell simulations are carried out to investigate the parallel- and anti-parallel-propagating high-frequency waves excited by the outer heliosheath pickup ions at different pickup angles as well as the scattering of the pickup ions by the waves excited. In the early stages of the simulations, the results confirm the excitation of the parallel-propagating, right-hand polarized high-frequency waves as predicted by the earlier linear analysis. Later in the simulations, enhanced anti-parallel-propagating modes also emerge. Furthermore, the evolution of the pickup ion ring-beam distributions of the selected pickup angles reveals that the high-frequency waves do not significantly contribute to the pickup ion scattering. These results are favorable regarding the plausibility of the spatial retention scenario of the IBEX ENA ribbon.