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Oblique instabilities driven by pickup ion ring-beam distributions in the outer heliosheath

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The energetic neutral atom (ENA) ribbon observed by the Interstellar Boundary Explorer (IBEX) spacecraft is believed to originate from the pickup ions in the outer heliosheath. The outer heliosheath pickup ions generally have a ring-beam velocity distribution at a certain pickup angle, α, the angle at which these ions are picked up by the interstellar magnetic field. The pickup ion ring-beam distributions can drive unstable waves of different propagation angles with respect to the background interstellar magnetic field, θ. Previous studies of the outer heliosheath pickup ion dynamics were mainly focused on ring-like pickup ion distributions with $\alpha \approx 90^\circ$ and/or the parallel- and anti-parallel-propagating unstable waves ($\theta = 0^\circ$ and 180°). The present study carries out linear kinetic instability analysis to investigate both the parallel and oblique unstable modes ($0^\circ \leq \theta \leq 180^\circ$) driven by ring-beam pickup ion distributions of different pickup angles between 0° and 90°. Our linear analysis reveals that ring-beam pickup ions can excite mirror waves as well as oblique left-helicity waves and their harmonics. The maximum growth rate of the mirror mode increases with increasing α. On the other hand, the wavenumber and growth rate of the most unstable oblique left-helicity modes are consistent with the unstable modes of 0° and 180° examined in our earlier work.