Efficient non-thermal particle acceleration mediated by the kink instability in jets

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Jets emanating from active galaxies are among the most powerful particle accelerators in the universe. They shine across the entire electromagnetic spectrum, and are candidate sources of ultrahigh-energy cosmic rays. Yet, the dominant mechanisms responsible for particle acceleration in these systems are not well understood. Global magnetohydrodynamic simulations suggest that the development of the current-driven kink instability (KI) can play an important role in the dissipation of the jet's internal magnetic field near recollimation regions, but it remains unclear if such process could lead to efficient non-thermal particle acceleration. We have performed large-scale 3D particle-in-cell simulations to investigate the self-consistent particle acceleration dynamics associated with the development of the KI in conditions relevant to magnetized relativistic jets. We find that the development of the KI mediates the efficient conversion of the magnetic energy into high-energy particles. We show that non-thermal particles are accelerated by a large-scale inductive electric field that develops throughout the unstable region during the nonlinear stage of the KI. The acceleration process is made efficient by the highly tangled magnetic field structure that arises in the nonlinear phase, which enables rapid curvature drifts across magnetic field lines and along the inductive electric field. This results in the development of a power-law energy tail that contains 50% of the initial magnetic energy, and that extends to the confinement energy of the jet. By scaling our results to the conditions of bright knots in AGN jets, such as HST-1 and Knot A in M87, we show that this mechanism can account for the spectrum of synchrotron radiating particles, and offers a viable means for accelerating ultra-high energy cosmic rays.

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