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Magnetospheric Current Sheets in M87*: Pair Enrichment and Ultra-High Energy Proton Acceleration

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Recent progress in numerical simulations of magnetically arrested accretion onto supermassive black holes has provided significant insights into the formation and dynamics of magnetospheric current sheets near the black hole horizon. Focusing on M87* and by treating the pair magnetization in the upstream region and the mass accretion rate as free parameters, we estimate the magnetic field strength and construct numerical models. These models, inspired by recent 3D particle-in-cell simulations, describe the populations of relativistic electrons and positrons (pairs) within the reconnection region. We compute the non-thermal photon spectra for different magnetization values. Our findings indicate that pairs, accelerated to the energy limit set by synchrotron radiation while traversing the current sheet, can generate MeV flares, regardless of magnetization. Additionally, pairs trapped in transient current sheets can produce X-ray counterparts to these MeV flares, with durations of about a day for current sheets of a few gravitational radii. We also show that photon-photon pair creation can enrich the upstream plasma, leading to a new equilibrium magnetization. Furthermore, we investigate the capability of magnetospheric current sheets to accelerate protons to ultra-high energies. Despite limitations from various loss mechanisms, such as synchrotron and photopion losses due to non-thermal emissions from pairs, we find that protons can achieve maximal energies in the range of a few EeV in these sheets around supermassive sub-Eddington accreting black holes.

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