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Numerical Studies of High-Energy Neutrino Emission from a Radiatively Inefficient Accretion Flow with a 3D GRMHD Simulation

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High-energy neutrino emission from black hole accretion flows is a promising probe of extreme plasma environments and cosmic-ray acceleration in active galactic nuclei (AGNs). While many previous studies have relied on simplified single-zone models, the influence of large-scale plasma inhomogeneity and turbulence remains poorly understood. In this study, we perform the first global simulations of cosmic-ray acceleration and high-energy neutrino production via hadronuclear (pp) interactions in radiatively inefficient accretion flows (RIAFs) and outflows surrounding a supermassive black hole (Kawashima & Asano 2025, ApJ in press). Our calculations are based on three-dimensional general relativistic magnetohydrodynamic (GRMHD) simulation data. To describe turbulent acceleration, we solve the Fokker-Planck equation for cosmic-ray protons using a sub-grid energy diffusion model. The resulting particle energy distributions reflect the highly complex, time-dependent nature of the flow. Compared to the single-zone approximation, the resulting neutrino spectra are flatter and predominantly originate from cosmic rays transported with outflows rather than inflows. These findings suggest that low-luminosity AGNs and quiescent galactic nuclei can act as efficient sources of cosmic rays and may significantly contribute to the observed high-energy neutrino background.

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