General relativistic particle-in-cell simulations of compact neutron star magnetospheres

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Magnetospheres of compact objects such as neutron stars and black holes are complex systems where quantum electrodynamic (QED) processes, kinetic-scale pair plasma physics and general relativity (GR) play all an important role. To study such intricate and exotic systems, advanced simulation techniques are required. In this work, we present a GR module recently developed for the particle-in-cell (PIC) code OSIRIS [1]. PIC simulations treat the plasma as particles and capture the self-consistent coupling between particles and fields down to the plasma kinetic scales. All algorithms in this GR-PIC module of OSIRIS (field solver, particle pusher and current deposit) support Minkowski, Schwarzschild or the slow-rotation limit of the Kerr metric. We present two-dimensional simulations of isolated neutron star magnetospheres, where QED processes are mimicked by injecting plasma at the stellar surface. We find that GR effects induce a region of unscreened electric field near the pulsar magnetic poles, in agreement with previous analytical estimates [2, 3]. We characterize the plasma distribution function in this region in simulations with and without GR effects.

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