A comparison of relativistic particle integrators in a fast magnetized flow (2)

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The particle-in-cell (PIC) method is one of the most important tools to study kinetic processes in space and in astrophysical sites. Basic frameworks and numerical schemes for PIC simulation have long been established. For example, the Boris (1970) integrator to advance particles has long been used in PIC simulation, as it is introduced by several textbooks. Recently, there is a renewed attention to numerical schemes for PIC simulation, in particular in particle integrators, because the classical schemes are incapable of the situations in astrophysics. For example, Vay (2008) and Higuera & Cary (2017) have proposed numerical schemes to preserve the force-free condition, E + V x B = 0, which is ideal to study a magnetized relativistic flow.
In this contribution, we will present a comparison of various particle integrators for PIC simulation in a relativistic plasma flow. Carrying out 80,000 long-term test-particle simulations, we have evaluated particle motions in the electromagnetic field. It is found that many numerical schemes fail to advance particles at the correct speed, because they are unable to satisfy the force-free condition. As a consequence, we observe numerical acceleration/deceleration of particles, whose amplitude is proportional to (delta t)**2. We have developed a second-order theory to predict the numerical acceleration/deceleration. We extend our earlier results in the SGEPSS 2019 meeting, and then we will present a general theory to deal with non-zero parallel velocity.

Keywords: Particle-In-Cell simulation, Numerical scheme, Relativistic motion

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