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The magnetohydrodynamic-particle-in-cell module in ATHENA ++

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We present a new magnetohydrodynamic-particle-in-cell (MHD-PIC) code integrated into the \texttt{Athena++} framework.
It treats energetic particles as in conventional PIC codes while the rest of thermal plasmas are treated as background fluid described by MHD, thus primarily targeting at multi-scale astrophysical problems involving the kinetic physics of the cosmic-rays (CRs).
The code is optimized toward efficient vectorization in interpolation and particle deposits, with excellent parallel scaling.
The code is also compatible with curvi-linear coordinates, static/adaptive mesh refinement, with dynamic load balancing to further enhance multi-scale simulations. In addition, we have implemented a compressing/expanding box framework which allows adiabatic driving of CR pressure anisotropy, as well as the δf method that can dramatically reduce Poisson noise in problems where distribution function f is only expected to slightly deviate from the background.
The code performance is demonstrated over a series of benchmark test problems including particle acceleration in non-relativistic parallel shocks. In particular, we measure the CR scattering rate at the saturated state in the balance between the CR gyro-resonance instabilities and ion-neutral damping, from the first princeple, to calibrate the CR feedback effeciency in galaxy evolutions.

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