高次精度MHDシミュレーションコードCANS+の開発と応用

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High-resolution Magnetohydrodynamic Simulation Code CANS+: Assessments and Applications

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We developed a new MHD simulation code with the aim of providing accurate numerical solutions to astrophysical phenomena where discontinuities, shock waves and turbulence are inherently important. The code implements the HLLD approximate Riemann solver, the fifth-order, monotonicity preserving interpolation scheme, and the hyperbolic divergence cleaning method for the magnetic field. This choice of schemes greatly improved numerical accuracy and stability, and therefore saved computational costs in multi-dimensional problems.

In one-dimensional benchmark tests, including linear Alfven wave propagation and shock tube problems, adopting the spatially fifth-order scheme gave superior results as compared with the second-order scheme even additional computational costs arising from the higher order reconstruction were considered. In two-dimensional tests of the K-H turbulence, the Orszag-Tang vortex problem, and the magnetic reconnection, it was shown that CANS+ code enables to solve discontinuities including shock waves and turbulence at the same time with high accuracy and stability. The test problem of the Parker instability also showed a high capability of solving very low-beta (~10^{-3}) plasma in which the numerical divergence errors of the magnetic field maintained within reasonably low levels.

As an application of CANS+ code, we present global simulations of the accretion disk around a black hole. With a given initial set up and grid resolutions, CANS+ code could follow a long-term evolution of the accretion disk in which the MRI and resulting mass accretion into the black hole sustained for 50 rotational periods. The long-term evolution characterized by compressible MHD turbulence clearly benefited from adoption of the fifth-order scheme, while they quickly decayed in the results from the second-order scheme owing to the strong numerical damping effects of the TVD property.