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PLASMA SIMULATOR FOR ROTATING ASTROPHYSICAL OBJECTS

K. E. Nakamura,[1,2] R. Matsumoto,[2] M. Machida,[2] and W. Chou[3]

RESUMEN

Estamos desarrollando un simulador de plasmas astrofísicos con rotación, que consiste de módulos manejados por un código tridimensional magneto-hidrodinámico. Los módulos que hemos diseñado incluyen difusión magnética, conducción térmica, enfriamiento radiativo y autogravedad. Estamos desarrollando módulos para hacer la visualización. El código está paralelizado y optimizado para computadoras vectorizadas y paralelas.

ABSTRACT

We are developing an astrophysical rotating plasma simulator, which consists of reusable modules plugged-in to a platform of a 3-dimensional magnetohydrodynamical code. Modules incorporating magnetic diffusion, thermal conduction, radiative cooling, self-gravity, and so on, have been designed. We are also developing modules to visualize the numerical results. The code is parallelized and optimized for vector-parallel computers.

Key Words: **ACCRETION DISKS — METHODS: NUMERICAL — MHD**

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1. INTRODUCTION

Rotating plasma, such as accretion disks or galactic gas disks, is one of the most interesting objects in astrophysics and is present in a variety of astrophysical phenomena. Accretion disks have been studied intensively for more than three decades. Theoretical models of accretion disks have successfully explained the observations of active galactic nuclei, X-ray binaries, and dwarf novae. However, fundamental problems such as the origin of the viscosity, which transports the angular momentum, and the formation mechanism of jets and outflows remain to be solved.

A wealth of evidence shows that magnetic fields play an important role in accretion disks. Non-linearity of the interaction between the plasma and the magnetic field makes it hard to understand the nature of the active phenomena in accretion disks. Computer simulations are helpful for understanding the physics of such non-linear and complex phenomena. In the early 1990s, computational experiments were done using simplified models because the machine power was not enough. Recently, we have been able to apply computer simulations to more realistic models. The use of computer simulations has become a powerful research tool.

Our simulation code is designed for rotating plasma such as accretion disks. We include the following physics: ideal magnetohydrodynamics, magnetic diffusion, self-gravity, radiative cooling, and thermal conduction.

2. CODE

We are developing modules which incorporate each physical mechanism. Selected modules are plugged-in to a main platform of a 3-dimensional magnetohydrodynamic code. The Cartesian and cylindrical coordinate codes are ready. The time-evolving integrator is coded by a modified Lax-Wendroff scheme with artificial viscosity. However, a Lax-Wendroff scheme based on the conservation form is not appropriate for calculating low β regions ($\beta = p_{\rm gas}/p_{\rm mag} < 1$). We are now incorporating the CIP-MOCCT scheme (Kudoh, Matsumoto, & Shibata 1999).

[1]Japan Science and Technology Corporation.
[2]Department of Physics, Chiba University, Japan.
[3]Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan.

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To achieve high performance in a large scale simulation the codes should be parallelized. Our codes are parallelized by using MPI and tuned for vector-parallel computers like FUJITSU VPP300. We achieved high parallel performance in both the platform of the MHD engine and in modules plugged-in to the platform.

We will provide the graphical user interface (GUI) of the simulator which enables manipulation without entering command lines or editing the source program (see Fig. 1). The initial conditions, boundary conditions and parameters are set up through the GUI console. We are able to analyze the numerical results and visualize them on the GUI console. Results under calculation can be monitored. We will provide modules which automatically create animations of the numerical results.

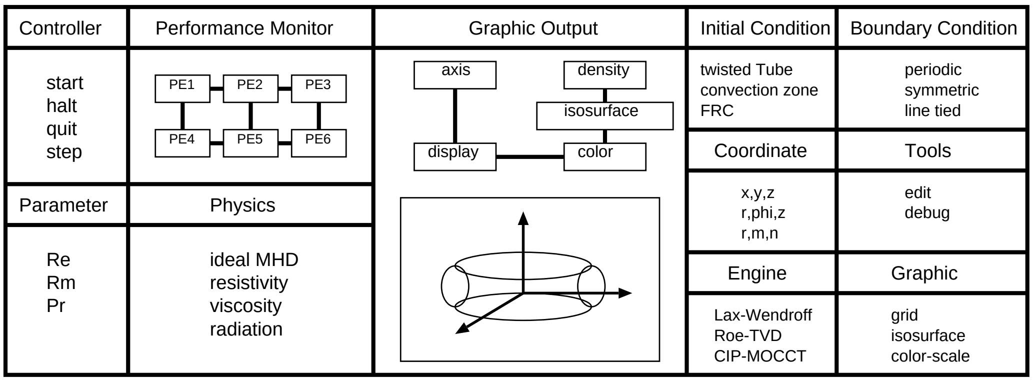

Fig. 1. Conceptual design of GUI.

3. APPLICATION

We have already applied our codes to accretion disks. Through 3-dimensional MHD simulation, jet formation is studied assuming an initial torus threaded by a vertical magnetic field (Matsumoto 1999). The jet emanates from the accretion disk along the twisted magnetic field due to magnetic acceleration. Machida, Hayashi, & Matsumoto (2000) simulated a torus threaded by toroidal magnetic fields. They clearly showed the amplification of the magnetic field by the magneto-rotational instability, and efficient angular momentum transport consistent with conventional accretion disk theory.

We are now developing the self-gravity, radiative cooling, and thermal conduction modules. In addition to accretion disks other rotating objects such as galactic disks and stars will be investigated with our simulator in the future.

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REFERENCES

Kudoh, T., Matsumoto, R., & Shibata K. 1999, Comput. Fluid Dynamics, 8, 56

Machida, M., Hayashi, M. R., & Matsumoto, R. 2000, ApJ, submitted (astro-ph/9911291)

Matsumoto, R. 1999, in ApSS Vol. 240, Numerical Astrophysics, ed. S. M. Miyama, K. Tomisaka & T. Hanawa (Boston: Kluwer Academic), 195

K. E. Nakamura: Japan Science and Technology Corporation, Japan (kenji@c.chiba-u.ac.jp).

R. Matsumoto and M. Machida: Department of Physics, Faculty of Science, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 2638522, Japan.

W. Chou: Institute of Astronomy and Astrophysics, Academia Sinica P.O. Box 1-87 Nankang, Taipei 11529, Taiwan.