Three-dimensional GRPIC Simulation of Jets from Accretion Disks

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Abstract

We report on some preliminary results of the three dimensional general relativistic particle-in-cell (GRPIC) code, Accrete3D. This code is used to simulate jet formation from accretion disk interactions with large scale magnetic fields. The disk-jet system is solved self-consistently. The preliminary investigation of the relevant instabilities indicate the growth of the |m| = 4 mode. Because of the low resolution of the simulation, some instability modes may not be fully expressed. Currently, simulations with higher resolution are being conducted.

Background

Accrete3D was developed to study the self-consistent evolution of the jet from the accretion disk. How does particle interaction generate the jet?

GRPIC Considerations

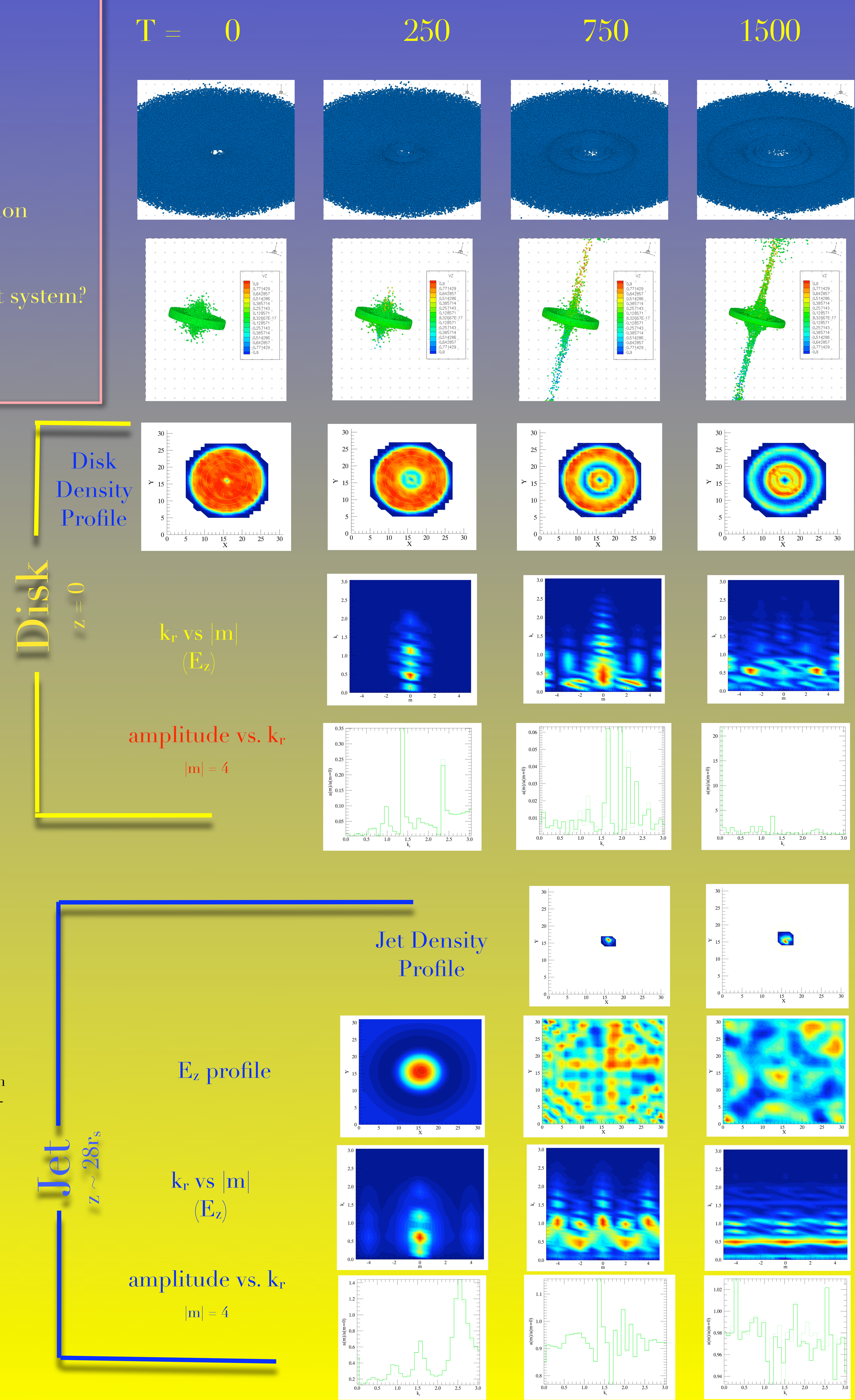
- Particle motion is self-consistent
- Dynamics of charged particle separation
- GRMHD is a fluid approximation

Questions in Disk-Jet Dynamics/Simulation

- What is the acceleration mechanism?
- Why is the jet collimated?
- What is the long-term evolution of the disk-jet system?
  - steady state, state transitions, etc.

Accrete3D

- General relativistic extension of particle-in-cell code
- Tensor form of Maxwell's equations
- Tensor form of Newton-Lorentz equation
- $B_z = -6\times10^4$, 4×10^5 electron/positron particles, 32x32x64 grids
- Free falling corona with Keplerian disk



Disk Instabilities

- We have conducted a preliminary analysis on the plasma mode and density structure within the disk.
- The first row is the density profile within the disk. The density structure develops waves as the jet develops.
- The second row shows the growth of |m| = 4 for the z-component of the electric field . As the jet fully develops the instabilities grow within the disk.
- The third row shows the mode amplitude.
- There is no electric field at T = 0.

Jet Instabilities

- We have conducted a preliminary analysis on the plasma mode and density structure associated with the development of the jet.
- The first row is the density profile within the jet. There is very little structure within the jet. At most, there are only ~20 particles in a plane cutting the jet.
- The second row shows the profile of the z-component of the electric field. The field at T = 250 is focused. This "beamed" field arrives before the jet particles, but is quickly washed out as the jet particles arrive in T = 750 and 1500.
- The third row clearly shows the growth of |m| = 4 . As the jet fully develops the instabilities grow.
- The fourth row shows the mode amplitude.
- There is no electric field at T = 0. There is no density structure at T = 0 and 250.

Conclusion/Further Development

- There appears to be mode coupling between the disk and the jet within the simulation. We see some of the same instabilities within the disk electric field within the jet region.
- The low grid resolution prevents an in-depth analysis of the density modes.
- Spherical and cylindrical versions of the code are being developed.
- We will increase the number of particles study the density fluctuations and test the correspondence with the field modes.
- We will include studies of the particle heating and work done by the field on the particles.
- Using MPI, we will make the code parallel.

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