Nvwa Code and Its Future

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GRMHD

$$ds^2 = -(\alpha^2 - \beta_i\beta^i)dt^2 + 2\beta_i dx^i dt + \gamma_{ij} dx^i dx^j$$

$$(\rho u^\mu)_{;\mu} = 0 \qquad (T^{\mu\nu})_{;\nu} = 0$$

$$({}^*F^{\mu\nu})_{;\nu} = 0$$

$$\frac{\partial \mathbf{U}}{\partial t} + \nabla \cdot \mathbf{F} = 0$$

$$\mathbf{U} = (\rho\gamma, \vec{S}, \tau, \vec{B})$$

- Non-strictly Hyperbolic
- Riemann Solver

Nvwa

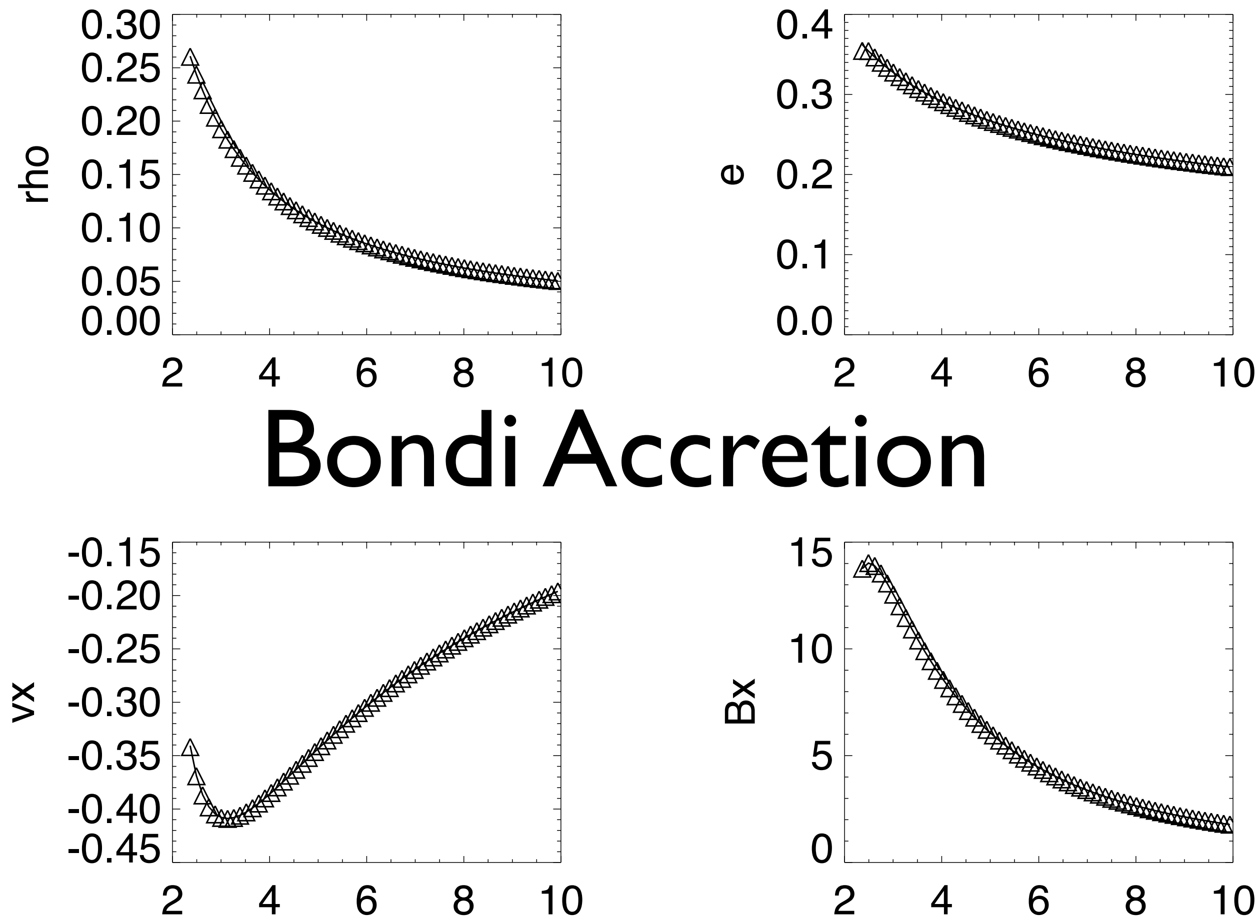
- GRMHD with fixed metric
- Conservation law form with source terms
- Runge-Kutta for Time Stepping
- Piecewise Linear Method for Interpolation
- HLL Riemann solver: only the fast wave
- Constrained Transport
- Boyer-Lindquist & Kerr-Schild

Geometrical Source Terms (Coordinates and Gravity)

- Spherical coordinates:

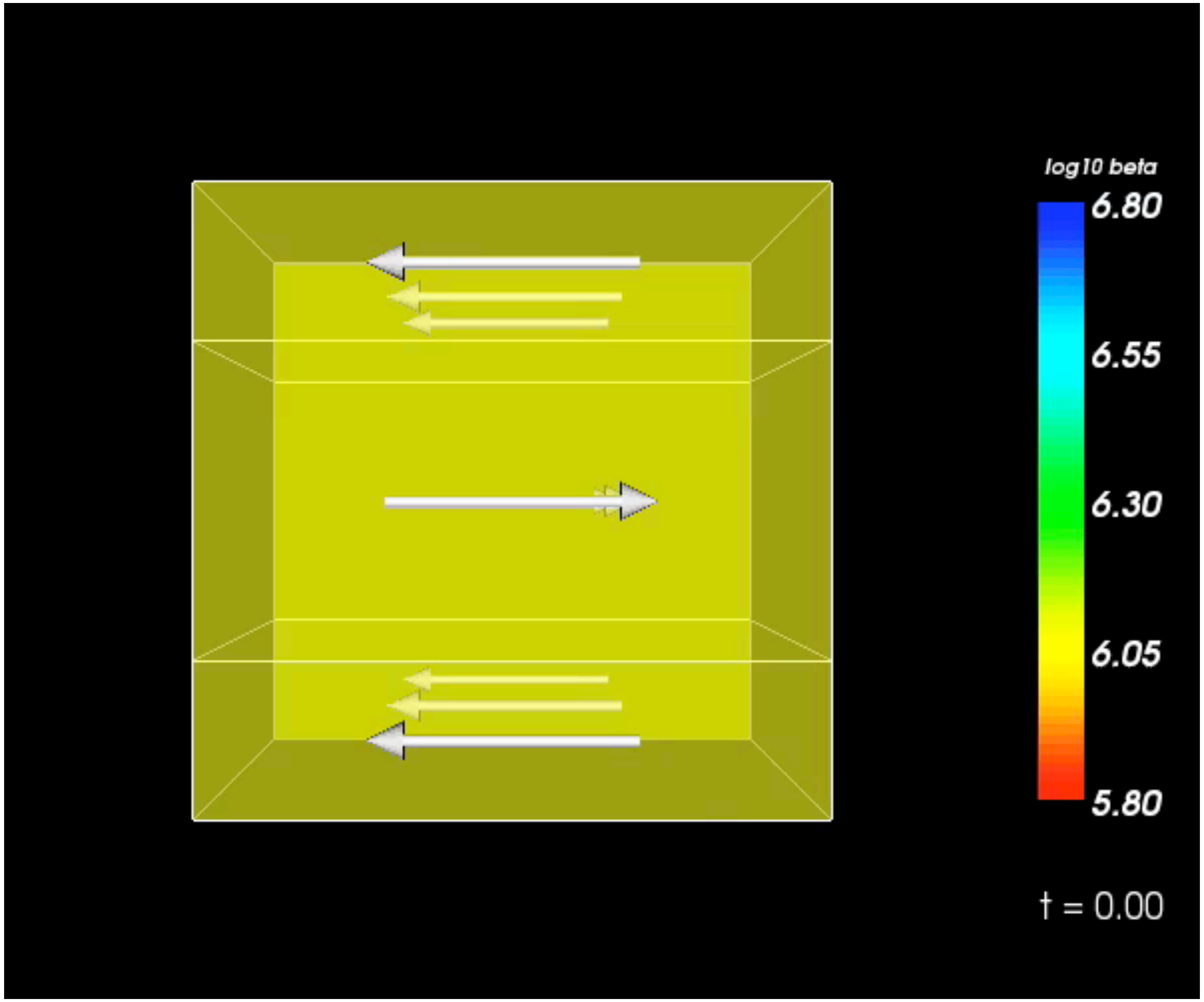
$$\ldots\ldots\frac{1}{r^2}\frac{\partial}{\partial r}(r^2 P) = \frac{2}{r}P$$

- Averaging source terms (using Simpson's rule)



It did not crash for beta = 10^-9 at the event horizon.

3D SRMHD Simulations



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Turbulent Dynamo

Its Future

Discussing Military Tactics on Paper 纸上谈兵

- AMR (CASTRO)
- Unsplit PPM so that it naturally fits into CASTRO
- SRMHD
- GRMHD
- Resistive MHD
- Radiation

div B = 0

$$\partial_t \vec{B} = -\nabla \times \vec{E} \Longrightarrow \partial_t \nabla \cdot \vec{B} = 0$$

- Projection (Brackbil & Barnes 1980)
- 8-wave (Powell et al. 1999)
- Damped diffusion (Dedner et al. 2002)
- Constrained Transport (CT) (Evans & Hawley 1988)

Project Scheme

$$\vec{B} = \nabla \times \vec{A} + \nabla\phi$$ Unphysical

$$\nabla^2\phi = \nabla \cdot \vec{B}$$

Expensive!

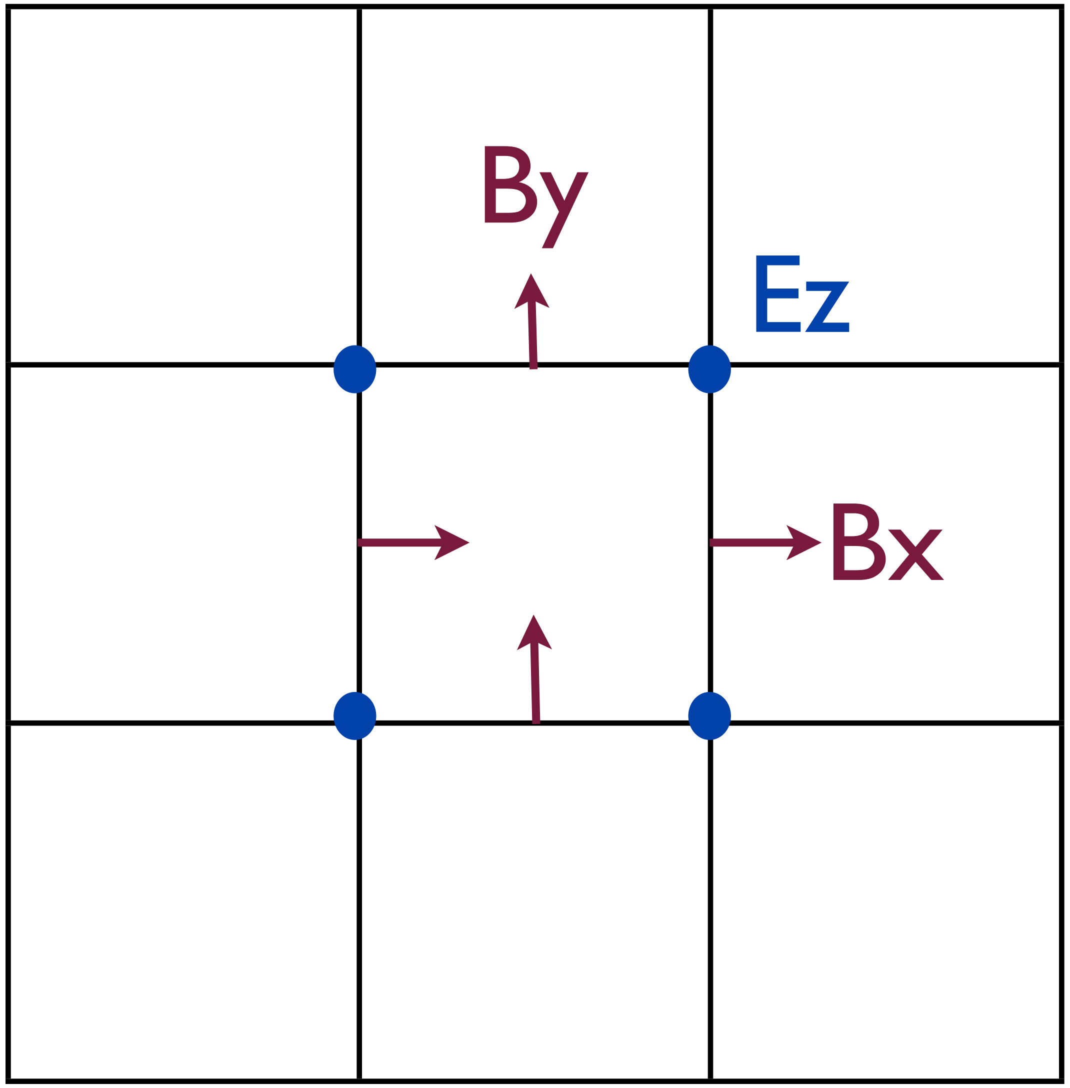
- Well studied in incompressible fluid dynamics (Almgren, Bell & Crutchfield 2000; Howell & Bell 1997)
- An approximate scheme might be enough. (Crockett et al. 2005)

CT

$$\partial_t \int\int \vec{B} \cdot d\vec{S} = -\int \vec{E} \cdot d\vec{l}$$

B: face E: edge Others: Center

- B: Face => Center
- Unsplit PPM (with extra steps (Gardiner & Stone 2005))
- Fluxes => E on edges
- Update B on faces



Advantages of CT

- Much cheaper
- Face-centered is more natural than cell-centered
- Easy for AMR (conservation of flux)
  - Divergence-preserving prolongation and restriction (e.g., Toth & Roe 2002)
  - coarse-fine grid boundary: easy to fix

Publicly Available Relativistic MHD AMR Code