Magnetized Neutron Stars

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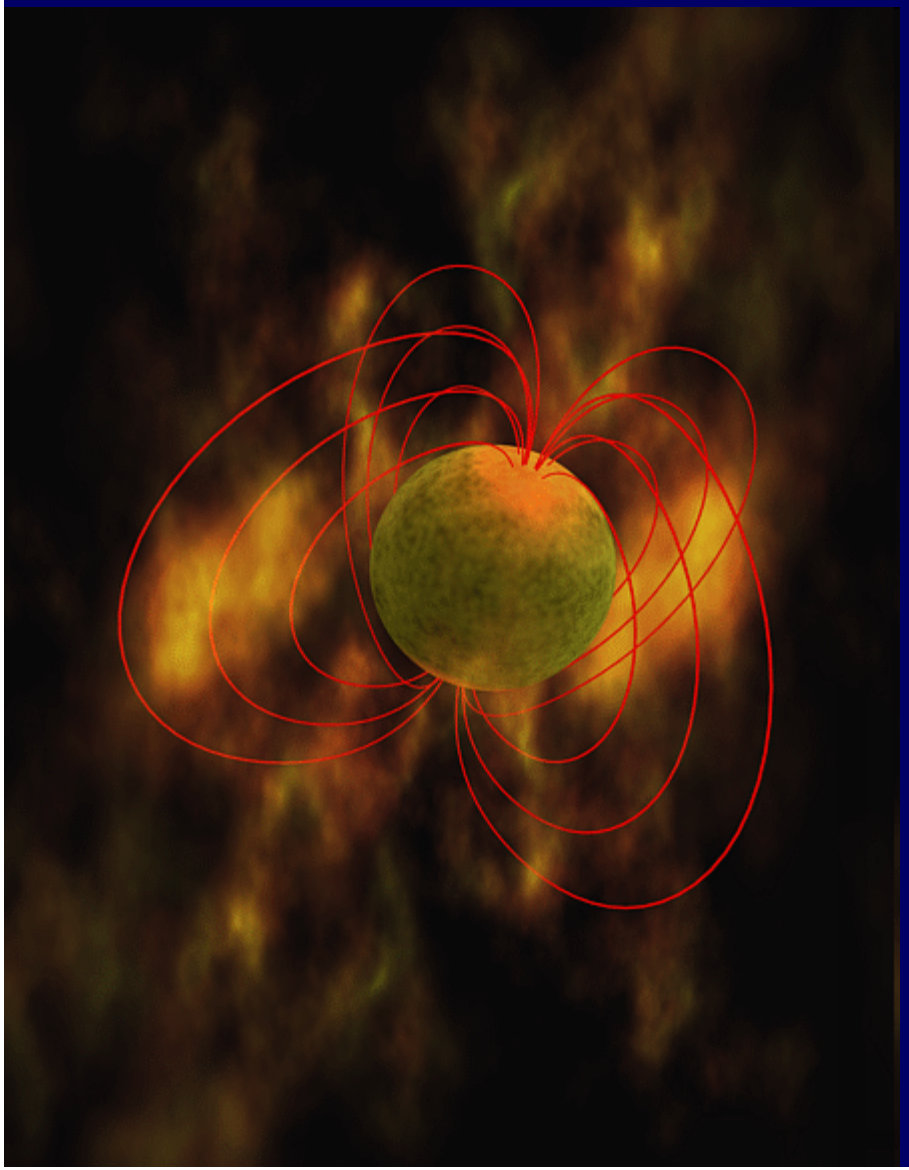
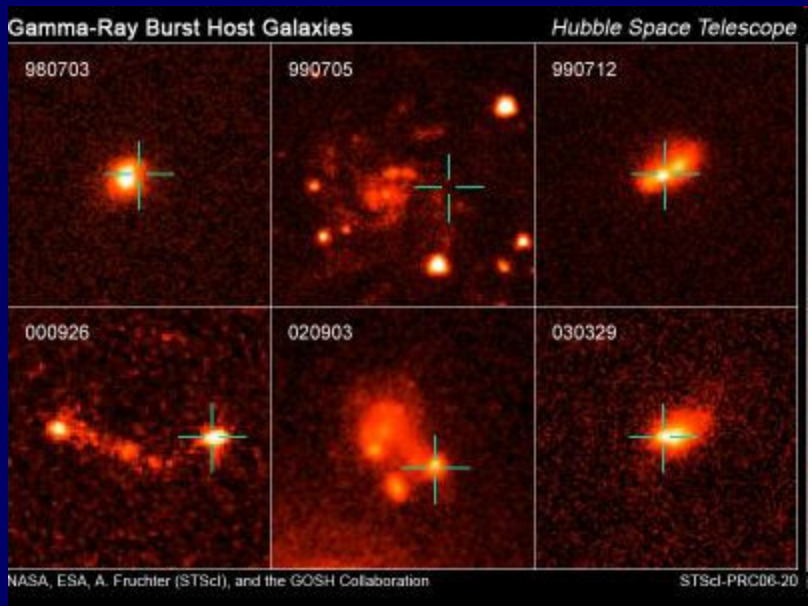
David Neilsen (BYU)
Carlos Palenzuela (AEI)
Joel Tohline (LSU)

Motivation



- Stellar dynamics… magnetars, collapse to BH
- Compact object mergers
- Gamma ray bursts & AGNs
- Supernovae



Ingredients

- Physics
  - Gravity
  - Fluid
  - Electromagnetic Field
  - Photons, neutrinos, temperature, microphysics
- Computation
  - Gravitational Wave extraction in wave zone
  - No symmetry assumptions in space nor on radiation transport
  - Strong AMR Scaling up to 65,000 cores

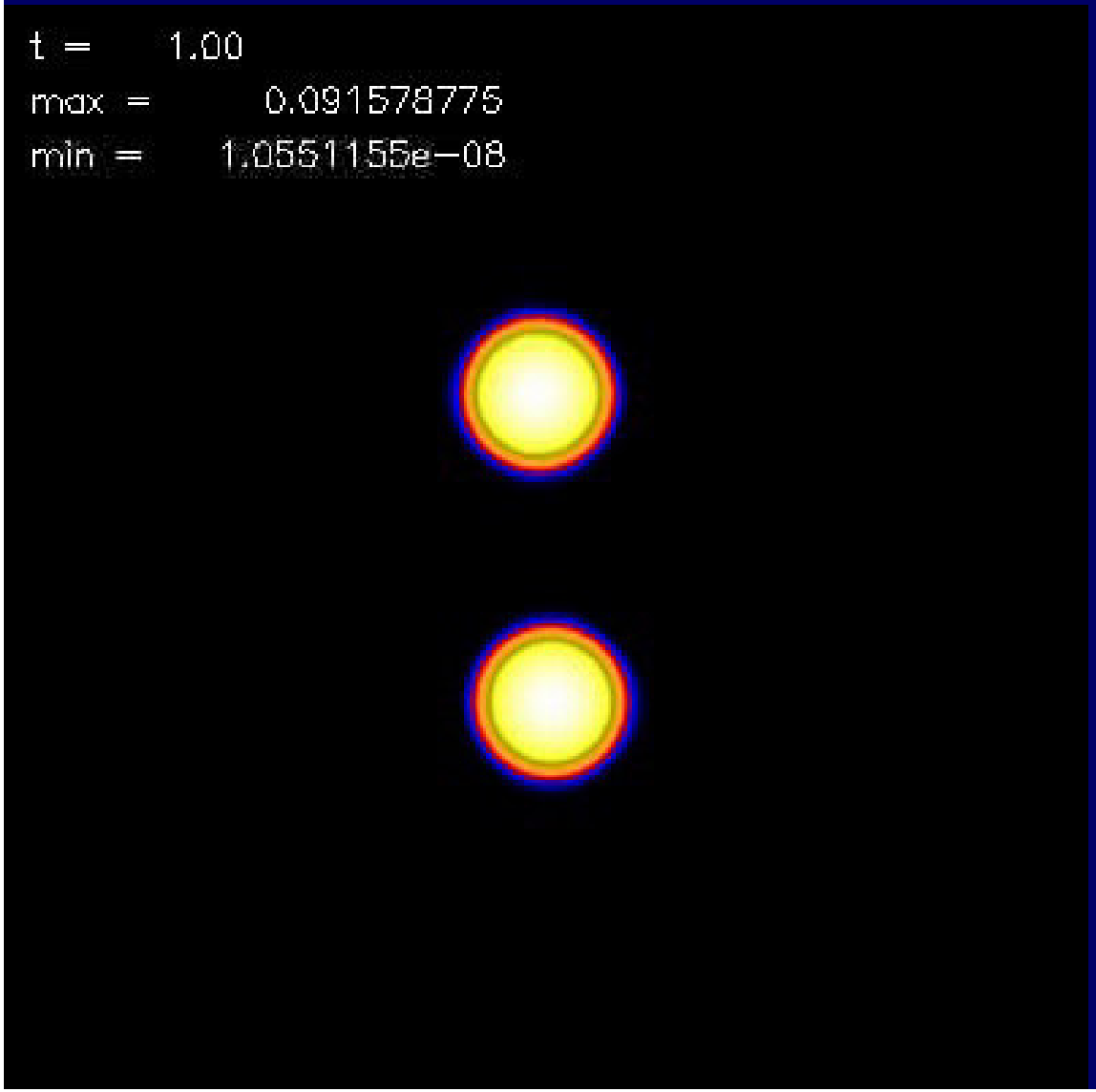
Current Ingredients

- Physics
  - Gravity— harmonic coordinate scheme
  - Fluid— perfect fluid
  - Electromagnetic Field— relativistic MHD
  - ~~Photons, neutrinos, temperature, microphysics~~
- Computation
  - Gravitational Wave extraction in wave zone
  - No symmetry assumptions in space ~~nor on radiation transport~~
  - Strong AMR Scaling up to ~~65,000~~ ~250 cores

Features

- CENO HLLE HRSC w/ PPM
- Hyperbolic divergence cleaning
- SBP derivative operators
- Tapered AMR boundaries w/ shadow
- BH Excision

Binary Mergers



Matt Anderson

Magnetic field effects on gravitational waves from binary neutron stars

Session R10
10:45am Monday

Luis Lehner

Neutron stars in binaries, status and a bright future

Session W5
10:45am Tuesday

Previous Work

- Shapiro, Shibata, Duez, Stephens, Liu: astro-ph/0503420, astro-ph/0510653, astro-ph/0511142, astro-ph/0610840, astro-ph/0605331, 0802.0200
- Zink, Stergioulas, Hawke, Ott, Schnetter, Mueller: astro-ph/0611601
- Rezzolla and collaborators: gr-qc/0701109
- Us: gr-qc/0801.4387, gr-qc/0708.2720, gr-qc/0702035, gr-qc/0605102

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- Us: gr-qc/0801.4387, gr-qc/0708.2720, gr-qc/0702035, gr-qc/0605102

Also work with the gravity part w/ boson stars: gr-qc/0706.2435, gr-qc/0612067

Initial Data

- Polytropic Stars (n=1) from RNS initial data solver
  - TOV
  - Rigidly/uniformly rotating
    - Constant angular momentum
    - Spun up to mass shredding limit (Keplerian equatorial velocity
  - Differentially rotating
- Divergence-less B field (poloidal) :
  - Define azimuthal vector potential

$$A_\phi = A\left[x^2 + y^2\right]\left(P - P_{vac}\right)$$

  - Free to tilt resulting B field in x-z plane
- Perturb:

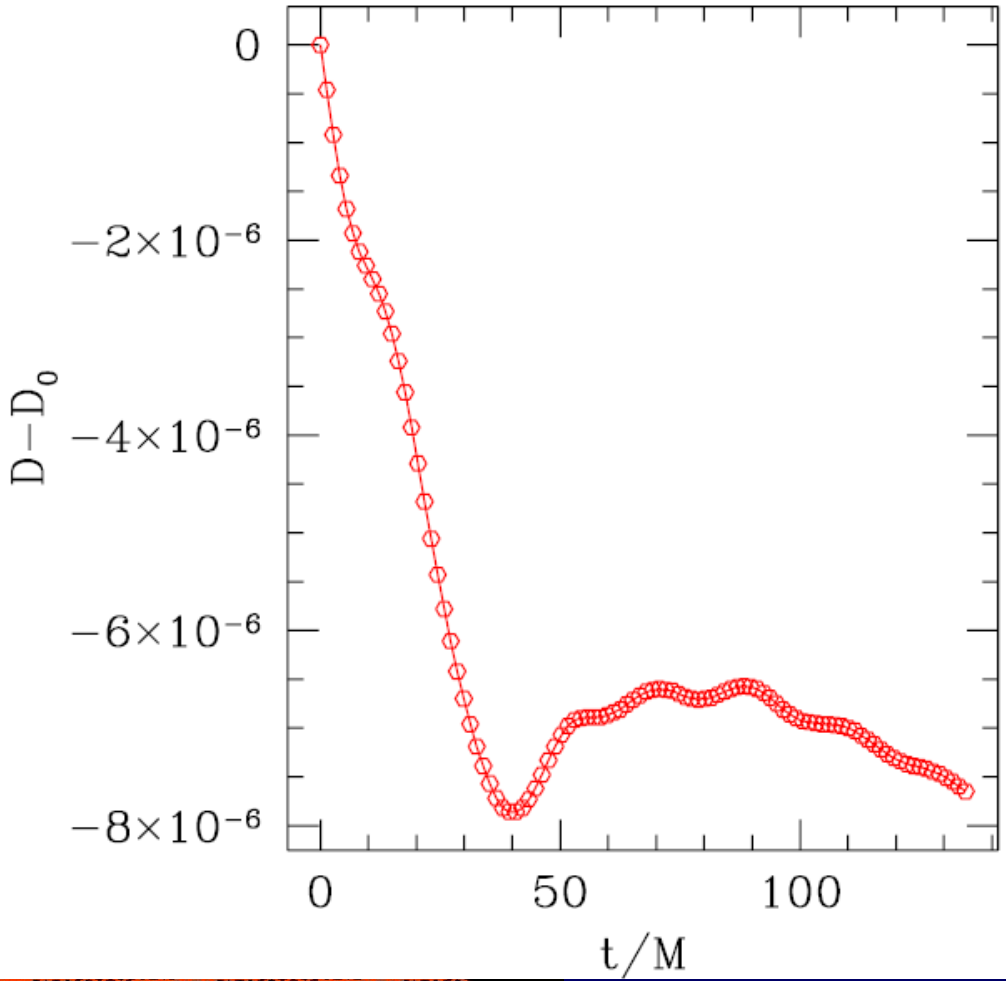
$$P \rightarrow P\left[1 - A\sin^2\left(m\varphi\right)\right]$$

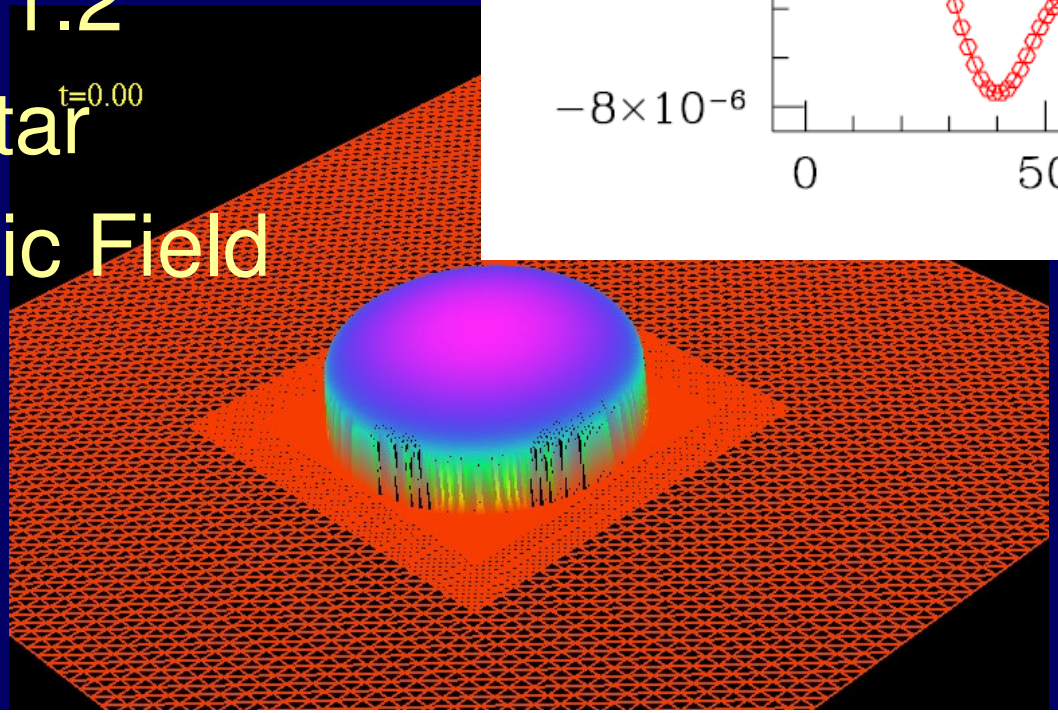
Large Parameter Space

- Polytropic Index (or other EOS parameters)
- Central density
- Angular momentum
- Strength of B-field
- Degree of “differential”
- Perturbation

Magnetized TOV

- Central Density 0.010
- Mass 0.023
- Radius 1.2
- 77pts/star
- Magnetic Field A=0.1



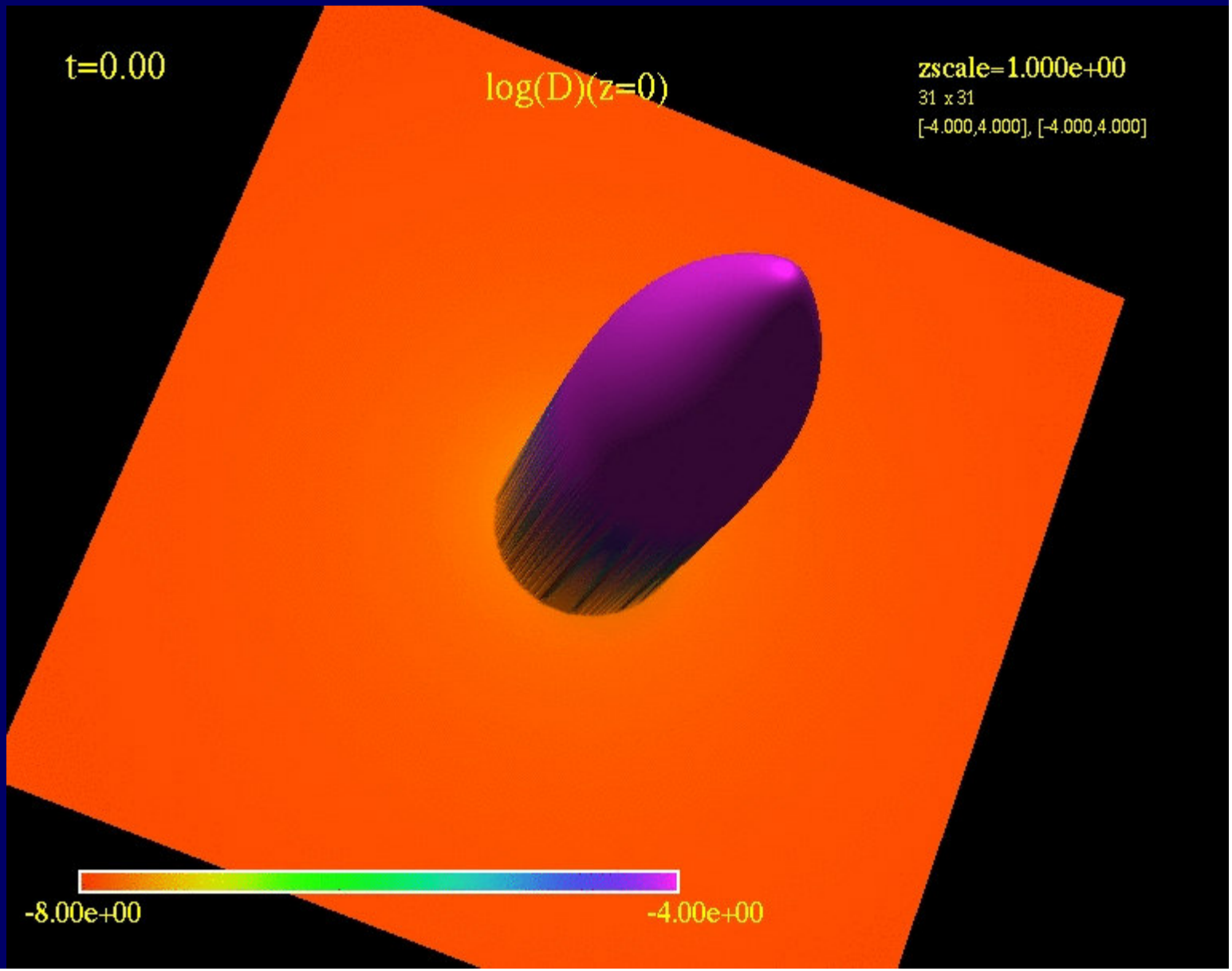


Magnetized Rigidly Rotating Star

- Central energy 0.4
- M=0.188
- Equatorial Radius=0.843
- Angular Velocity=0.4
- J/M^2 = 0.47

Magnetized Rigidly Rotating Star

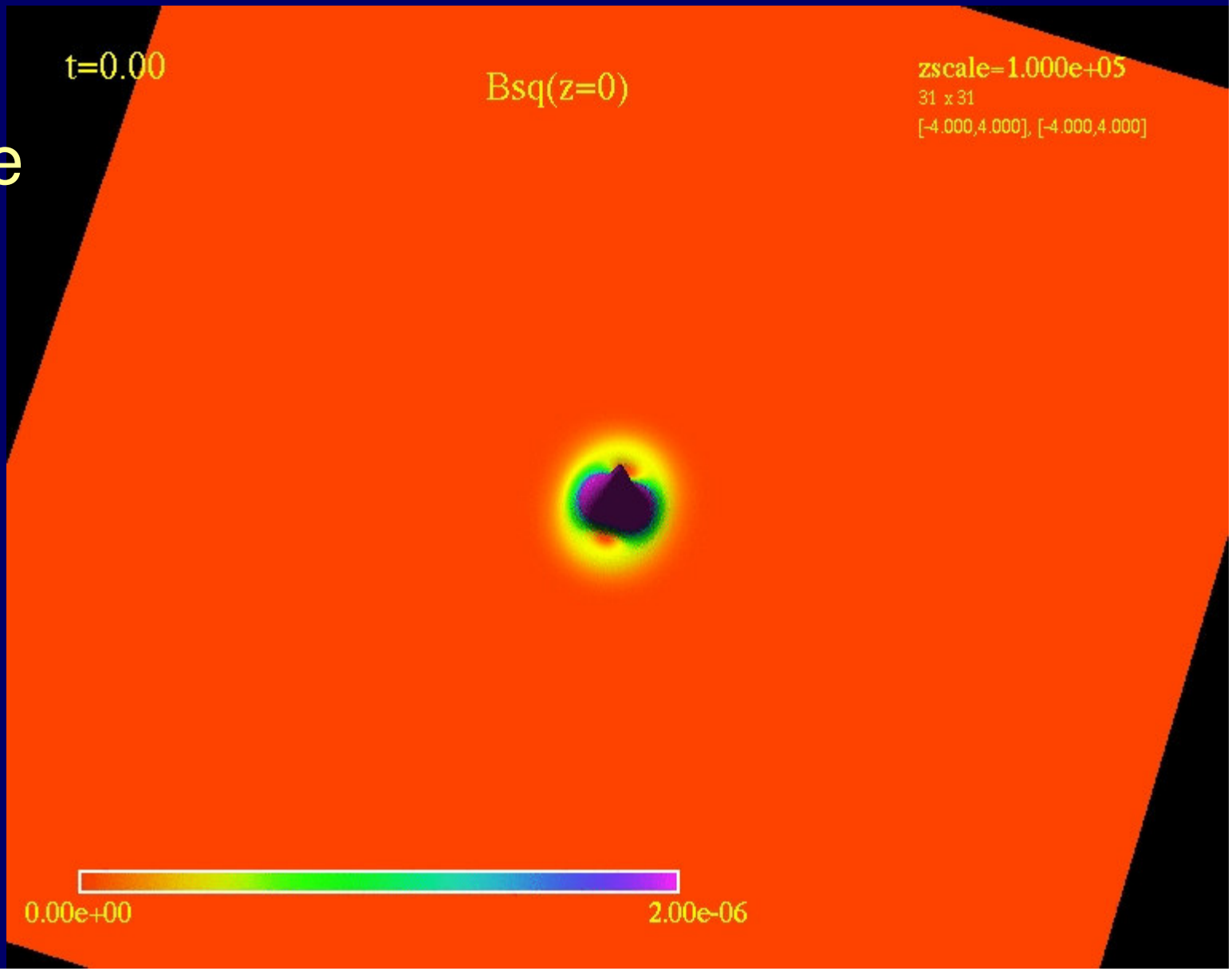
Log(D)



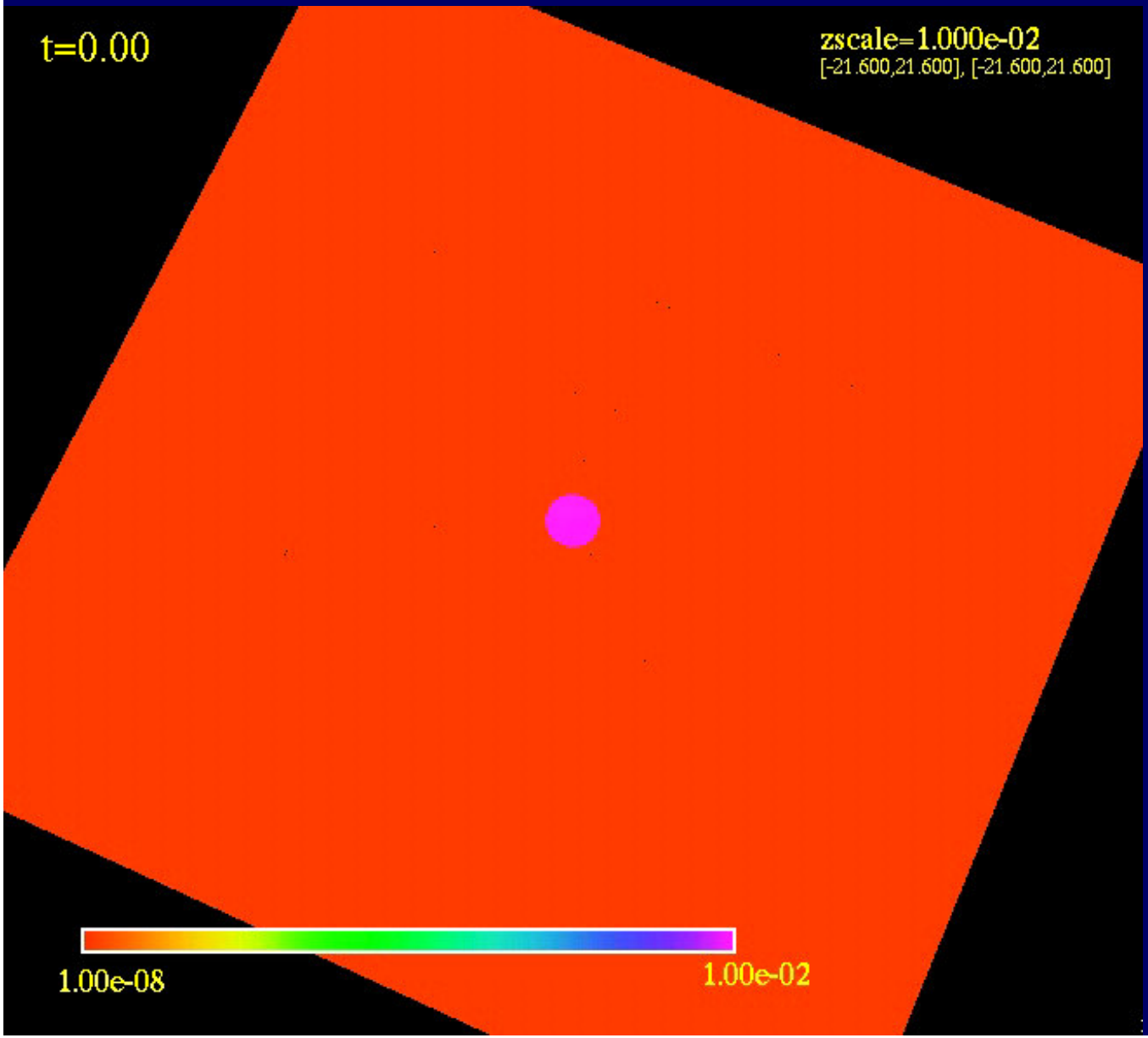
Magnetized Rigidly Rotating Star

B^2

Z=0 plane



Magnetized Differentially Rotating



Summary

- Lots of physics…isolated stars, compact mergers, magnetic fields, accretion, collapse to BH
- Need to go to differentially rotating stars
- Other future work:
  - More realistic EOS
  - Better initial data (quasiequilibrium binaries)
  - Explore parameter spaces