Binary Neutron Stars
&
The Peta-scale Challenge

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Collaborators

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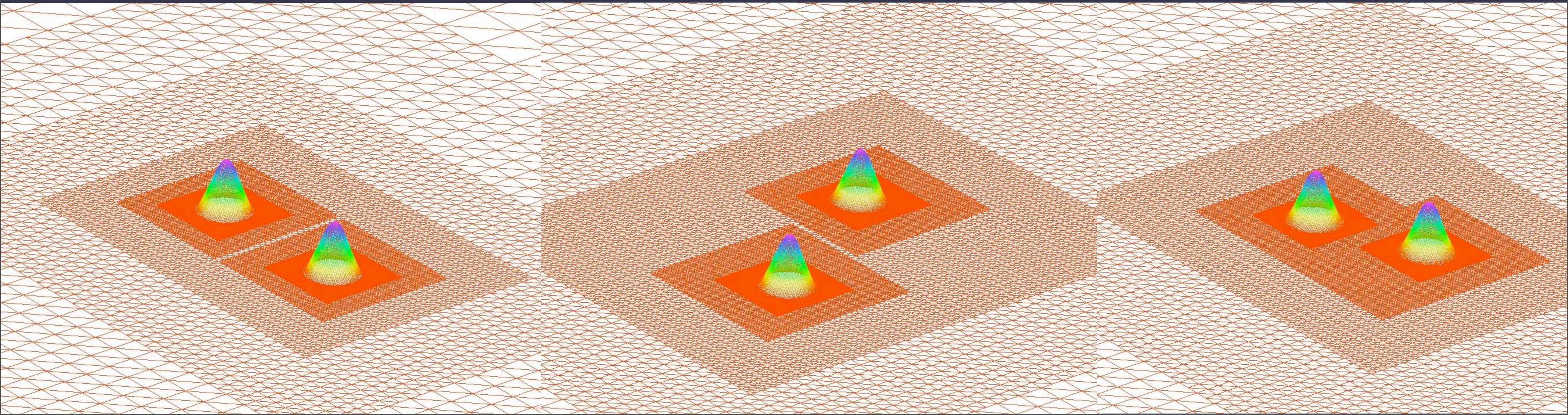
Outline

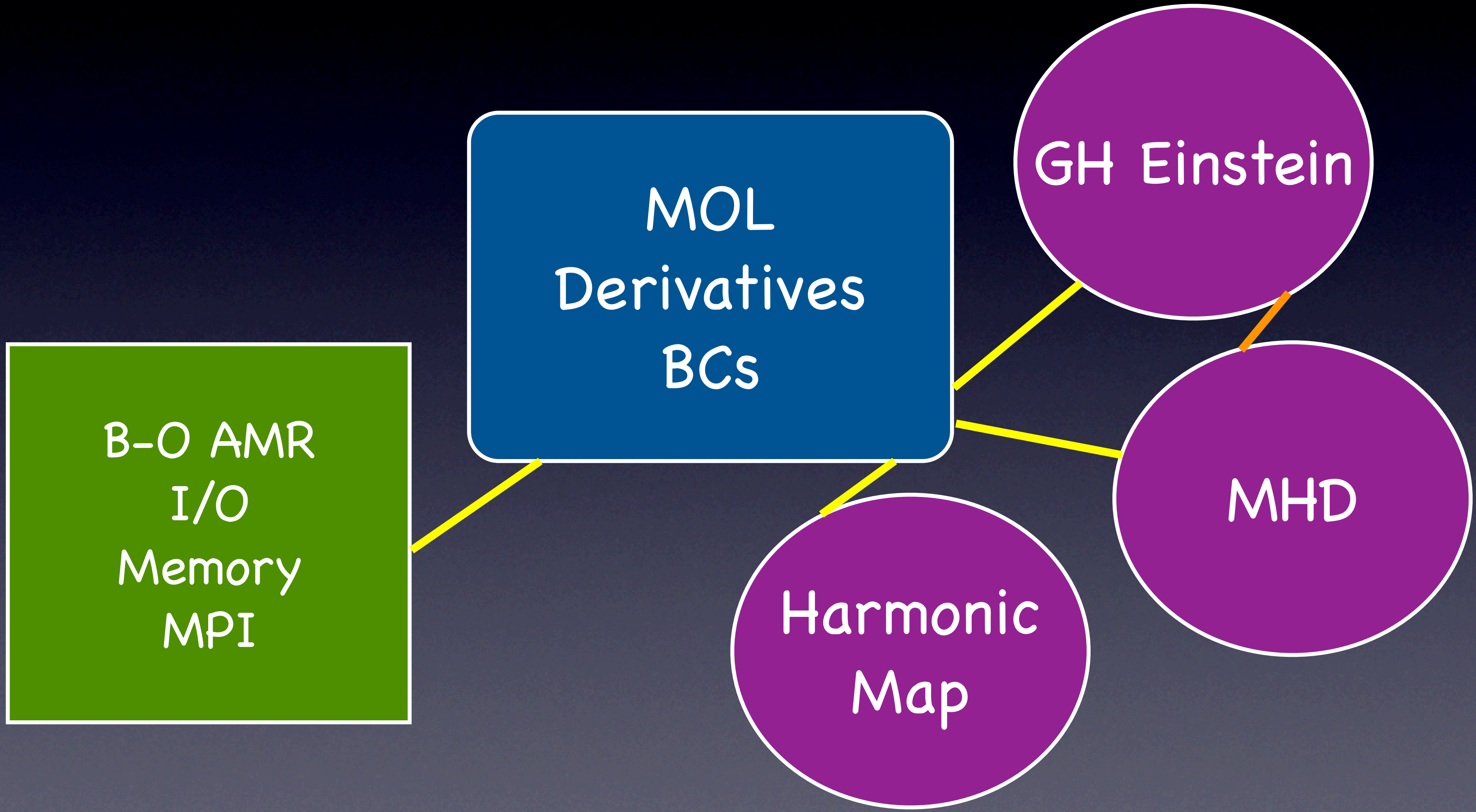
- Introduction to our GRMHD code
  - HAD
  - GRMHD
- Initial tests
- Binary neutron stars
- Binary mergers & magnetic fields

Methods: HAD

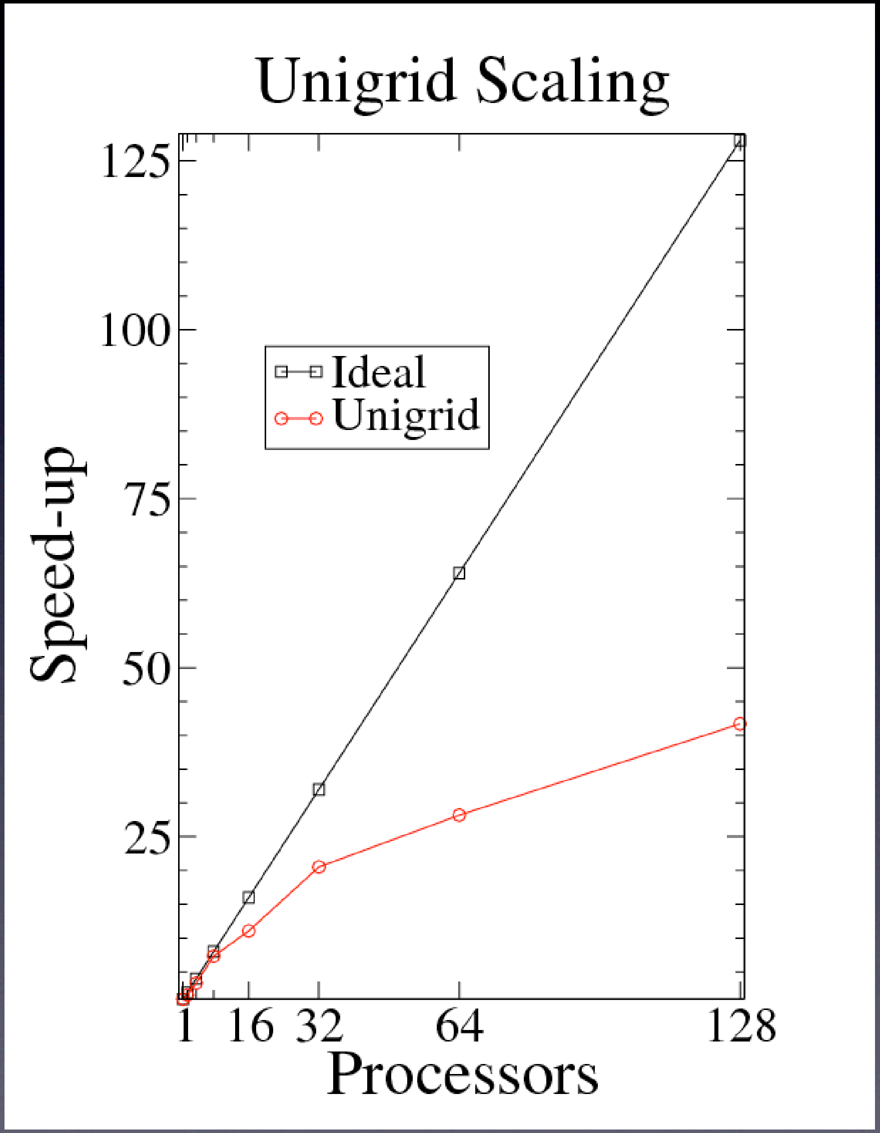
- Distributed parallelism with MPI
- Berger-Oliger AMR
- Hyperbolic & Elliptic equations
- Finite Difference & Finite Volume
- Tapered Boundary Conditions
- Arbitrary accuracy (3rd, 4th order)
- Refinement using Shadow Hierarchy or user-defined criteria
- F77 (with an assist from Perl) ... *fast*

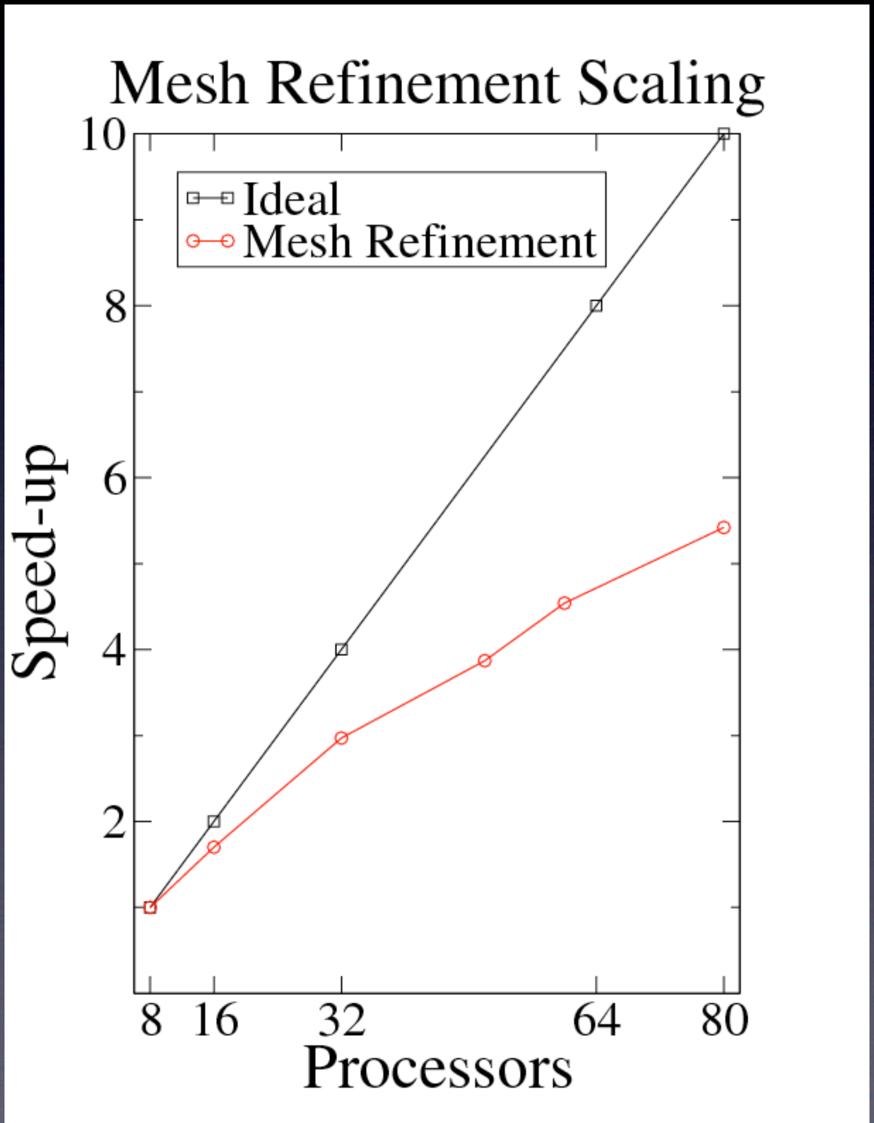


HAD (cartoon form)



HAD: Strong Scaling Tests

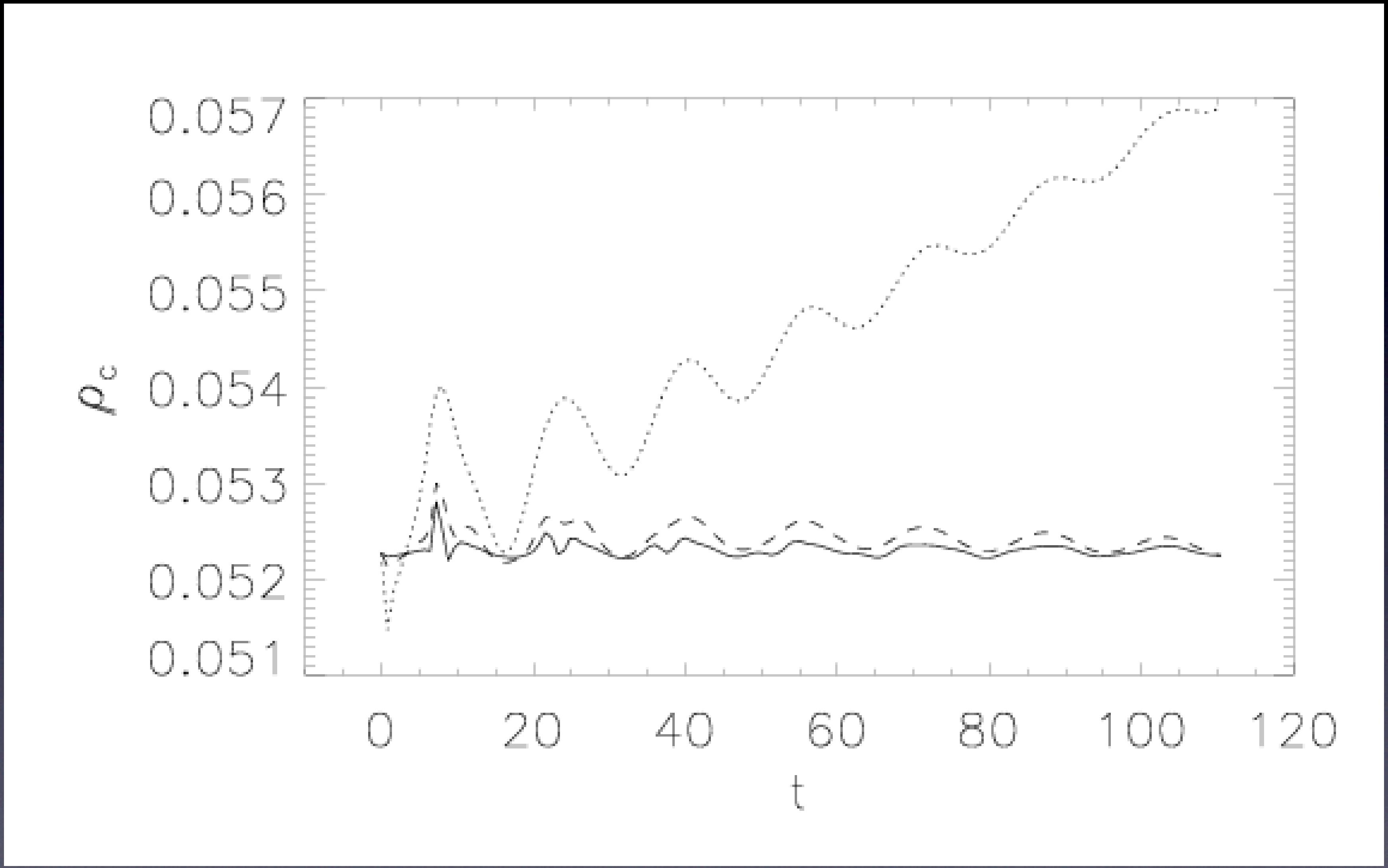




Methods: GRMHD

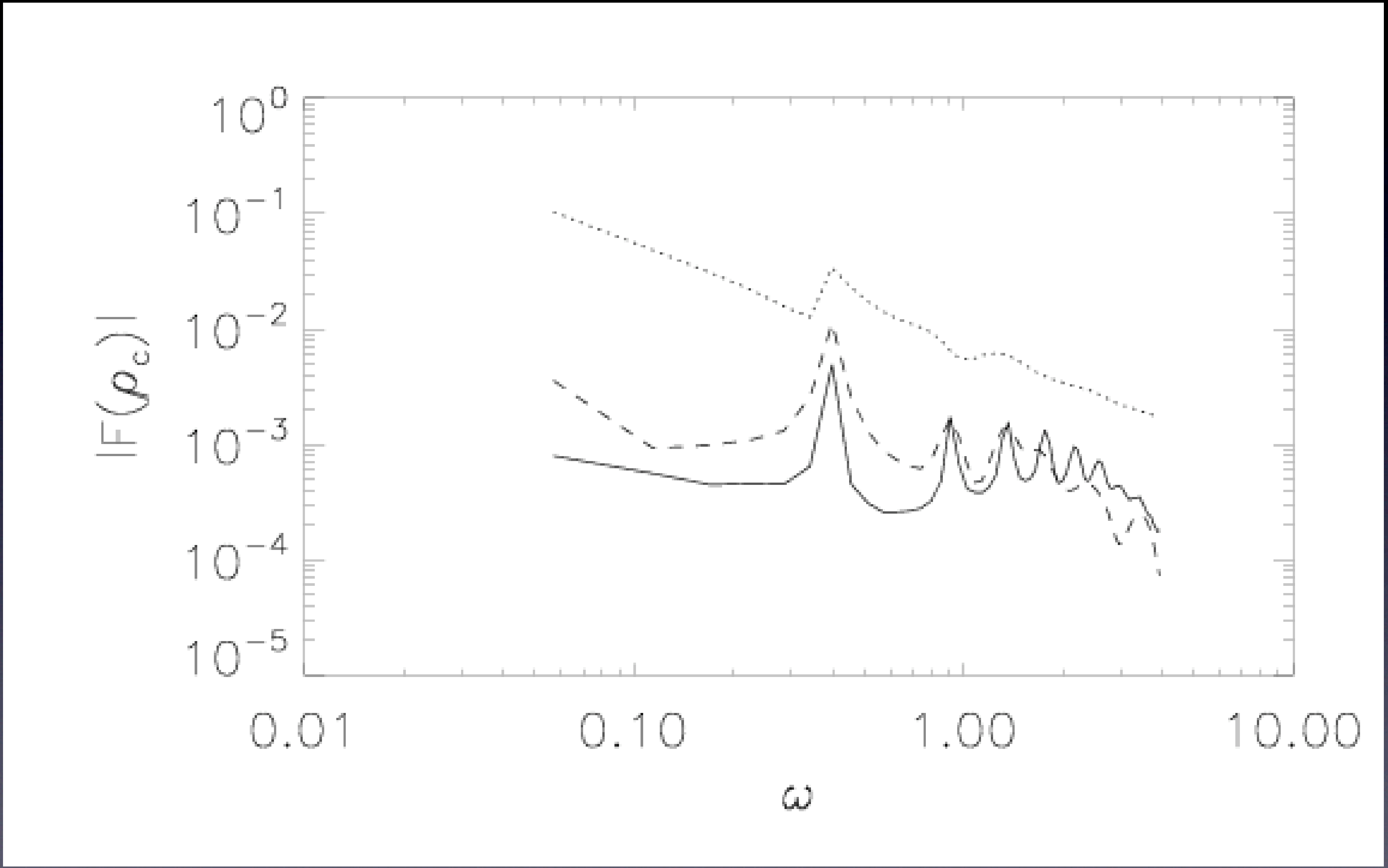
- MHD
  - CENO (FD, central-upwind) & Method of lines
  - HLLE numerical flux
  - PPM reconstruction
  - WENO interpolation for AMR
  - Hyperbolic divergence cleaning
  - Polytropic equation of state
- GR
  - Generalized Harmonic formulation
  - First order form
  - Constraint preserving boundary conditions
  - Difference operators satisfy Summation By Parts
  - Kreiss-Oliger dissipation

Single Stars: Central Density



TOV star, domain [-10,10], R=1.01, M=0.09, Gamma=2, K=1
Resolutions: 20, 40 & 80 points/star

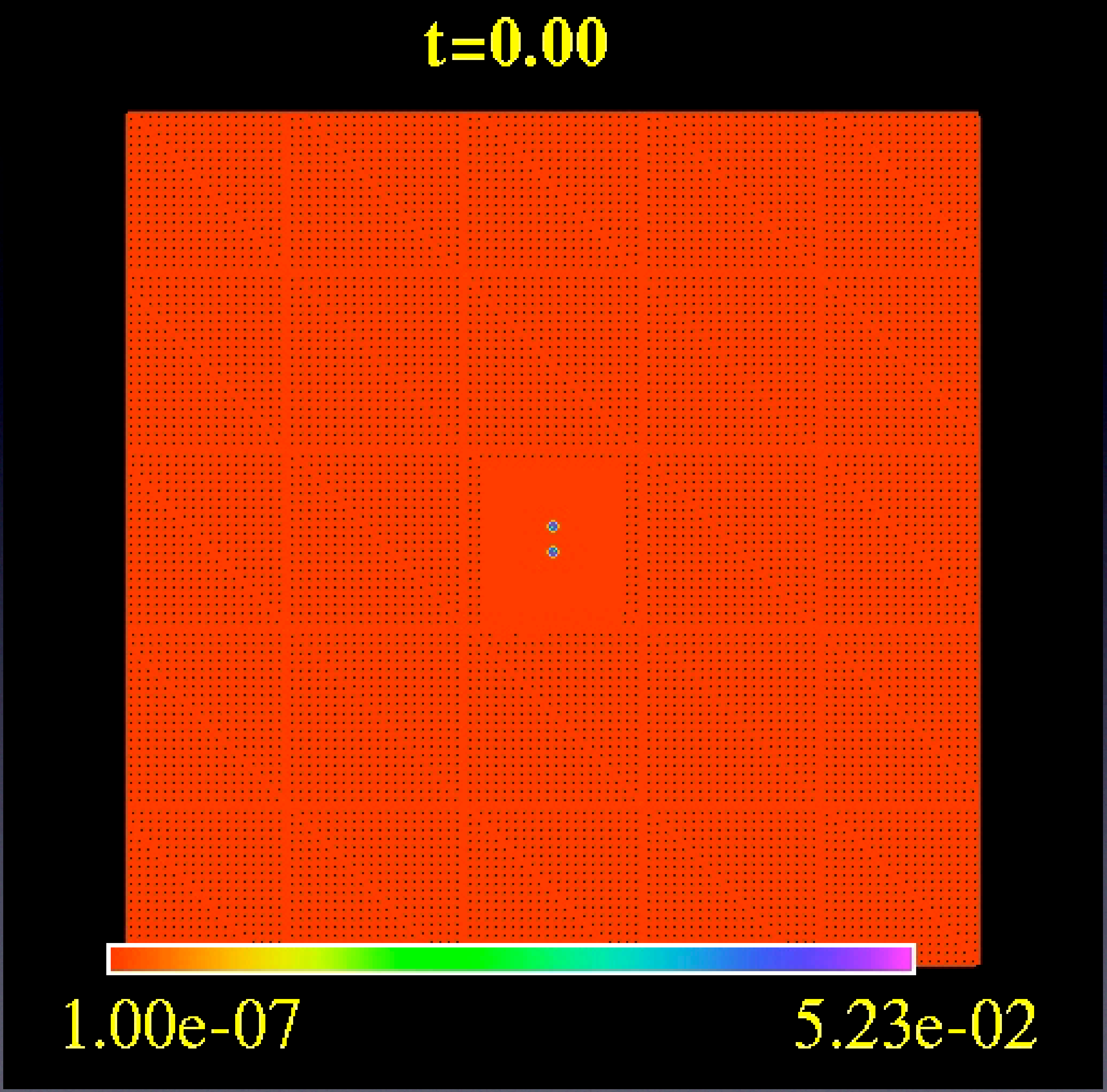
Single stars: Fourier modes

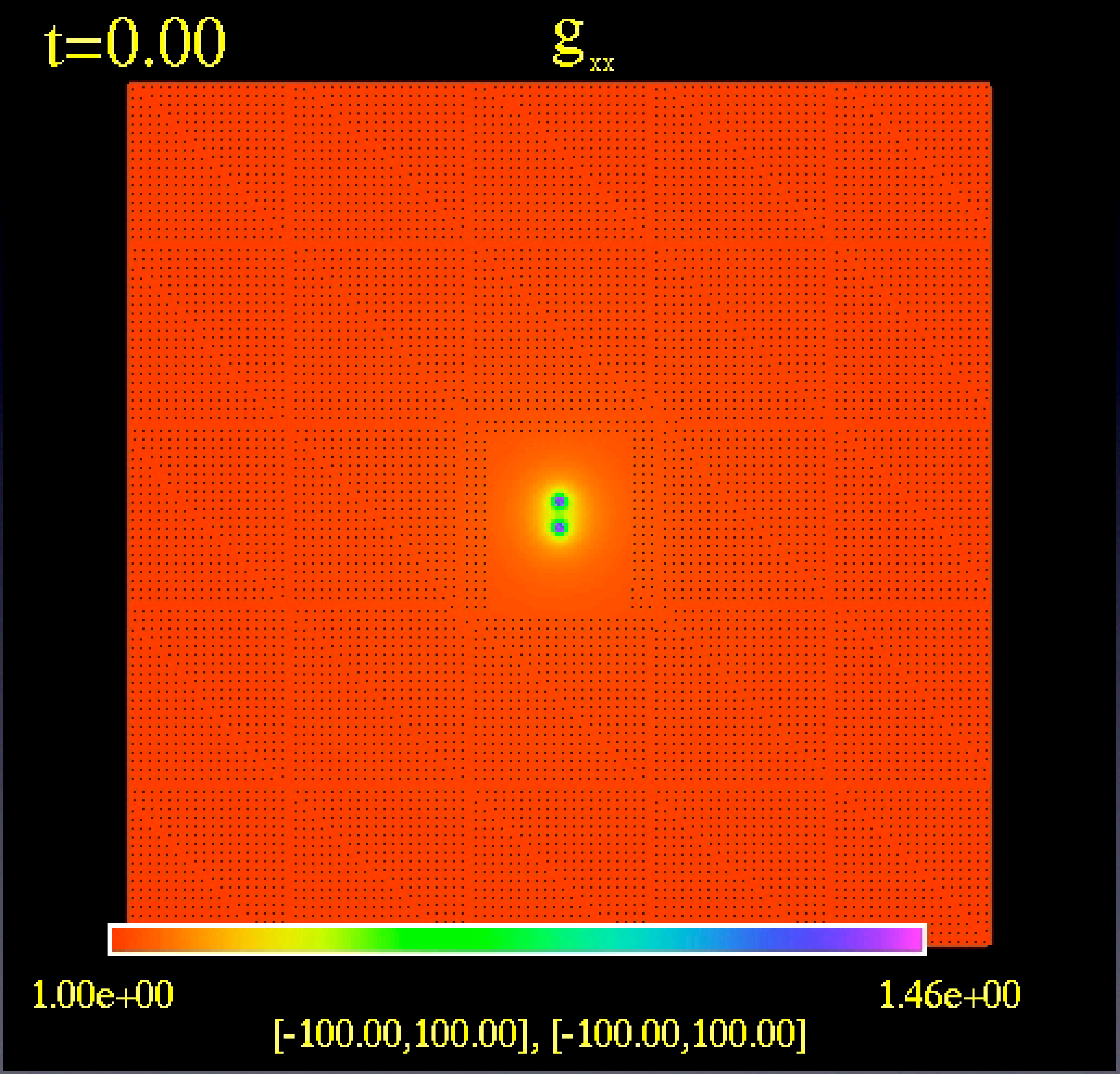


Fundamental: 14,400 Hz (Gamma=2, K=1)

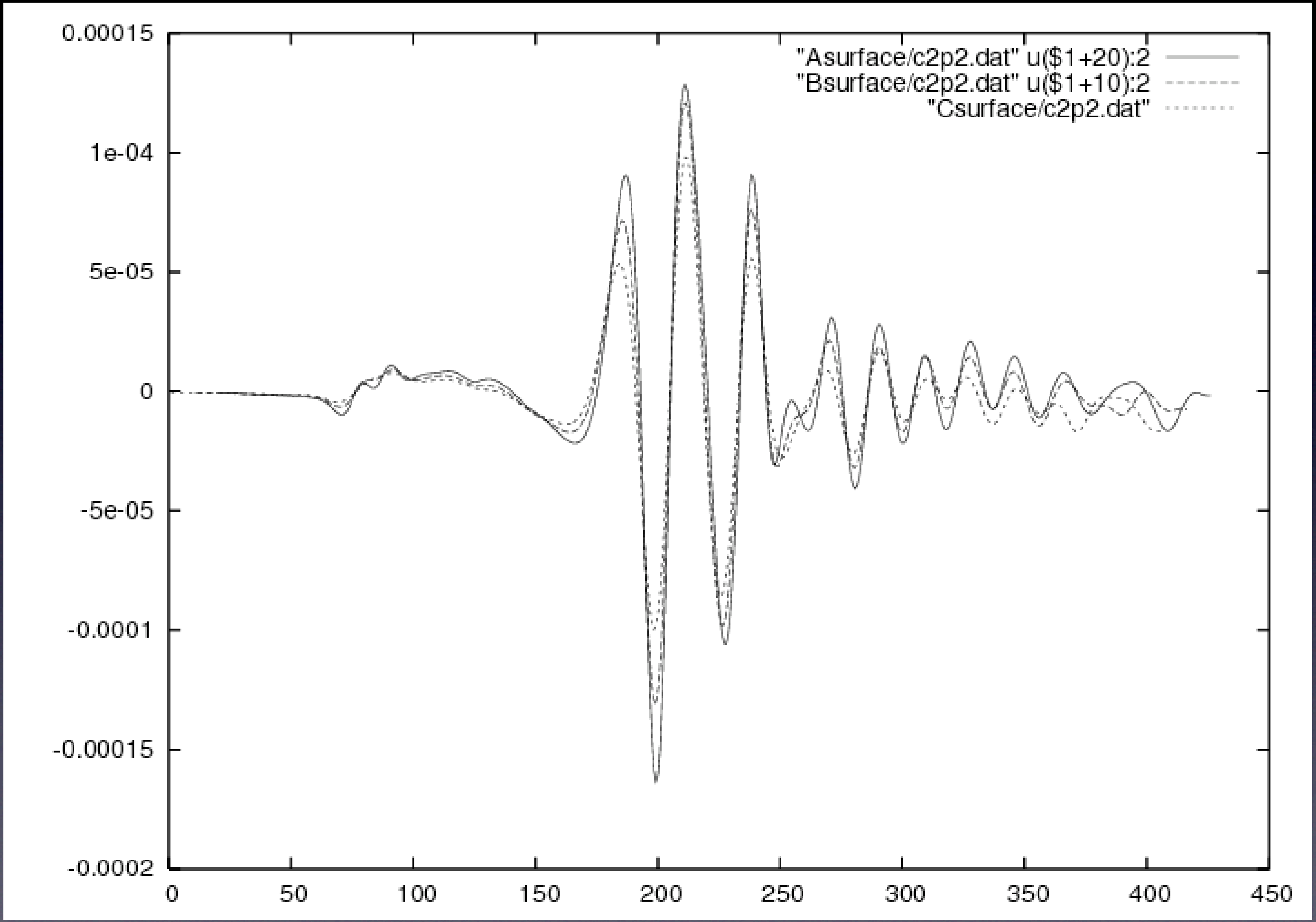
Orbits

- Initial data using Kerr-Schild superposition
- M=0.09, R=1
- Domain [-100,100], d = 6, v=0.09
- Resolution: 32 pts/star
- GW extraction at 50, 60, 70


t=0.00
1.00e-07
5.23e-02


t=0.00
g_{xx}
1.00e+00
1.46e+00
[-100.00,100.00], [-100.00,100.00]

Wave Extraction

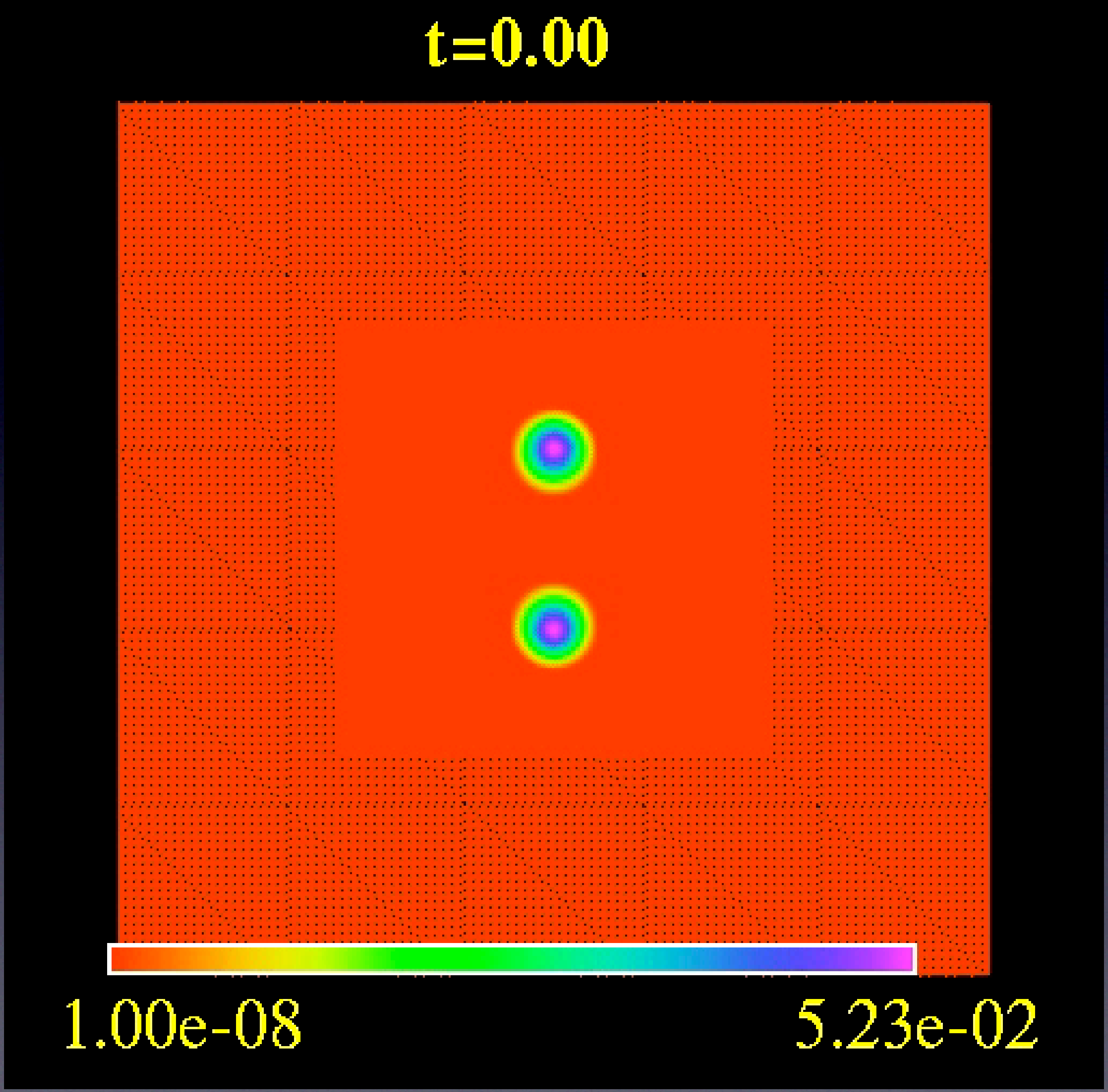


The l=2, m=2 mode. Extraction at R= 50, 60 & 70 R.

Mergers with Magnetic Fields

Sotani, Yoshida, Kokkotas, PRD 75 084015 (2007)

- Initially no differential rotation
- Domain [-10,10]
- R = 1.01, M=0.1
- Initial separation, d=4
- Initial boost, v=0.08
- 20 pts/star
- Gamma=2, K=1
- 2 levels of refinement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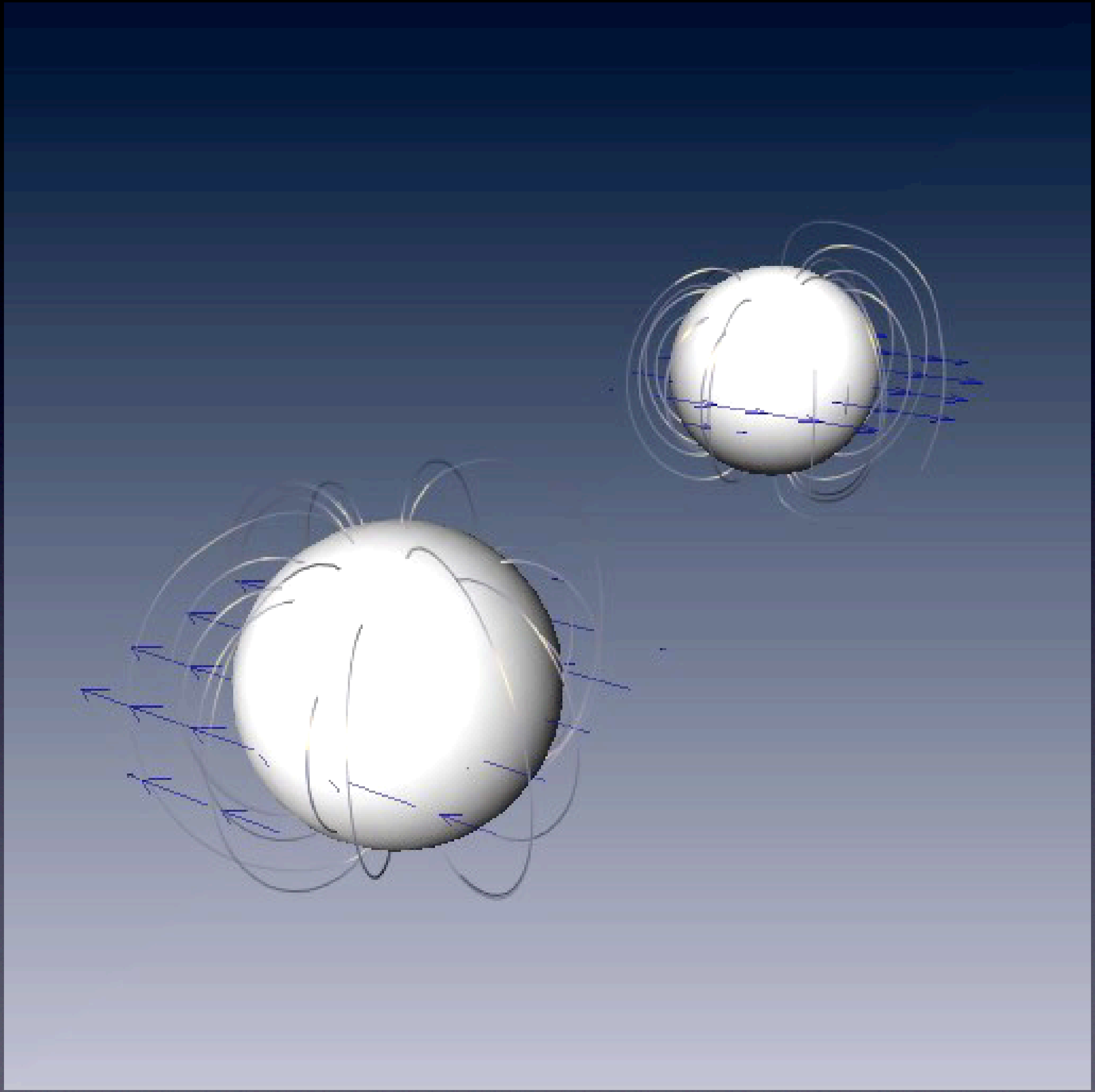
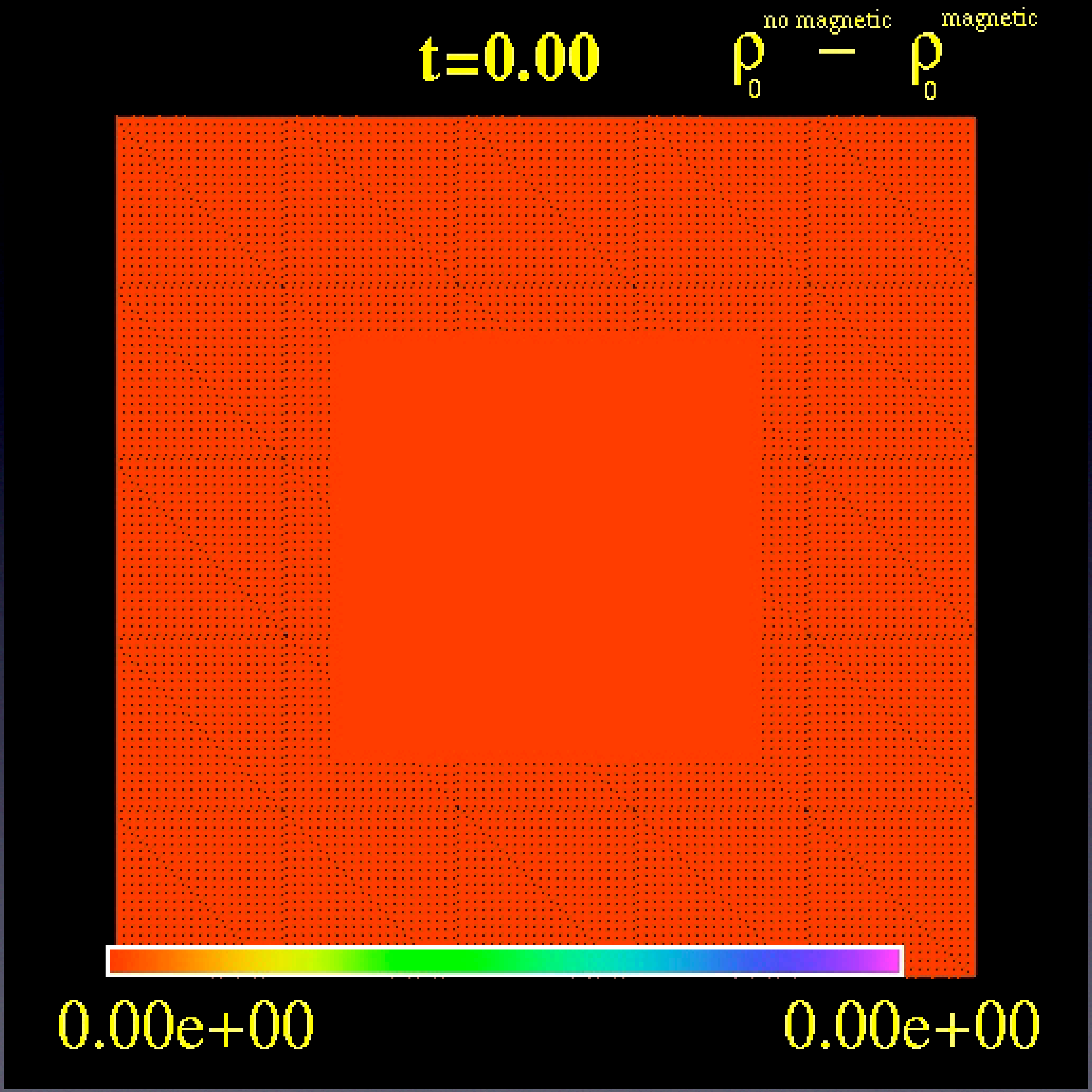
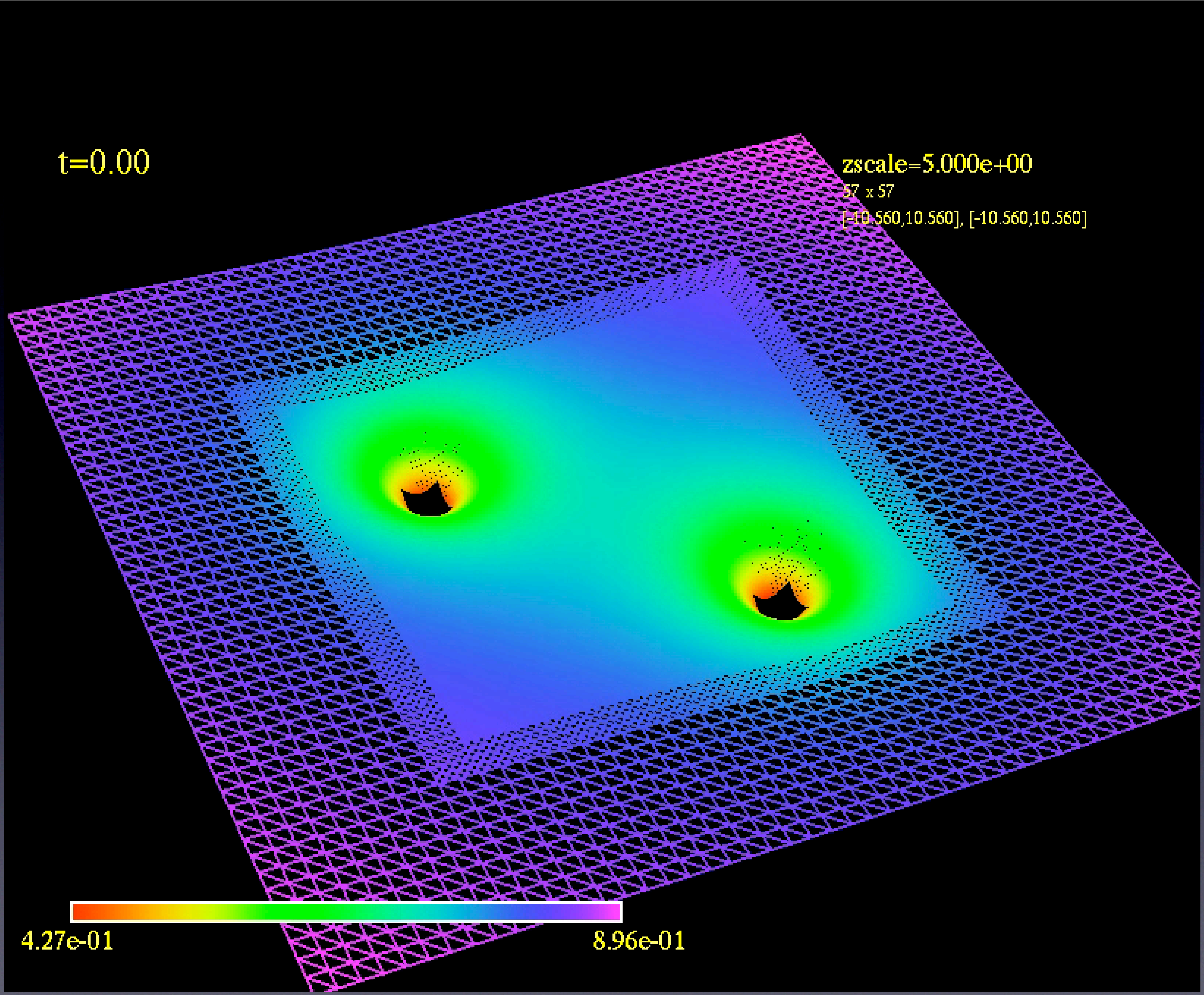
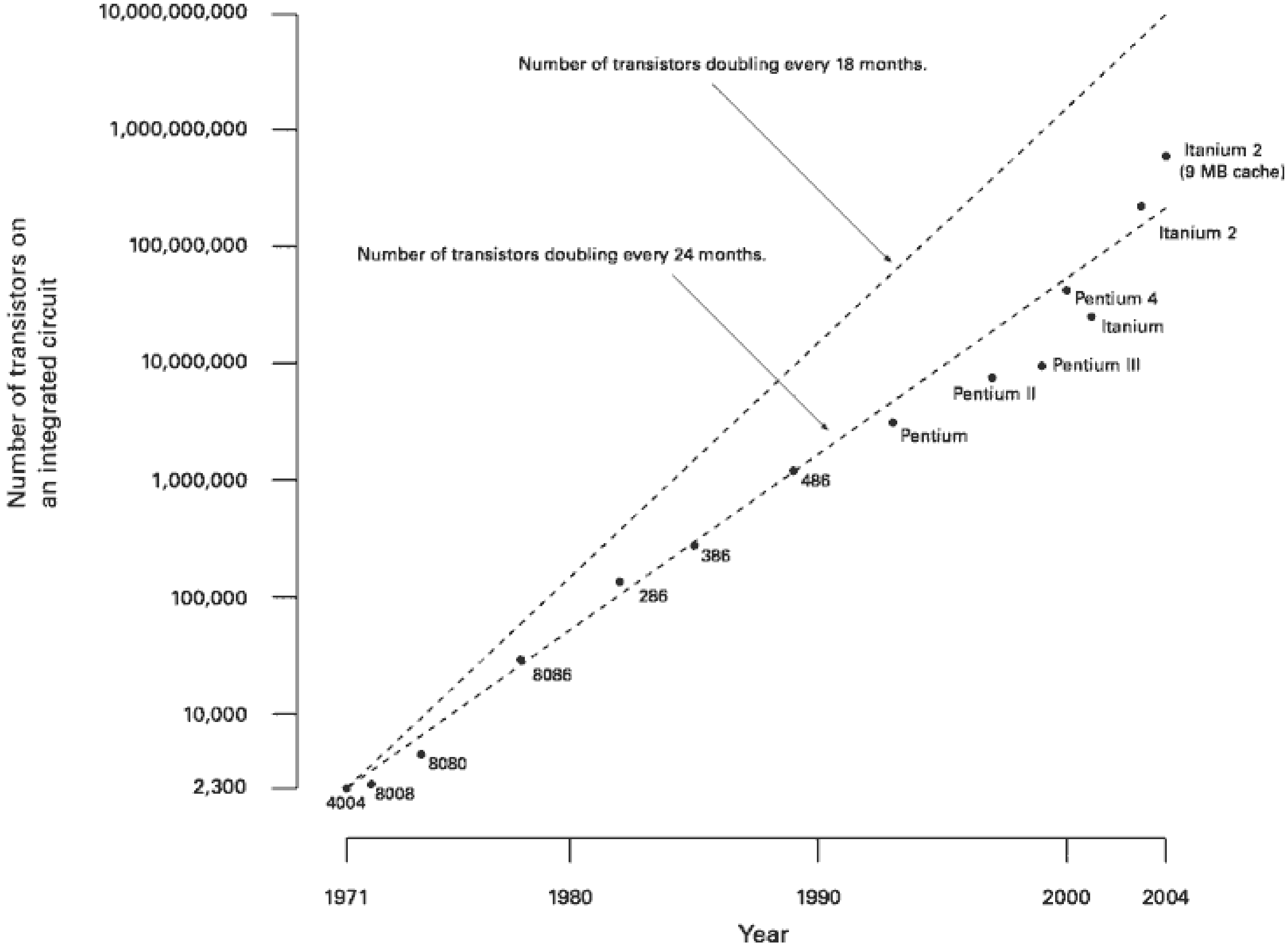



t=0.00
$\rho_0^{\text{no magnetic}} - \rho_0^{\text{magnetic}}$
0.00e+00
0.00e+00


t=0.00
zscale=5.000e+00
57 x 57
[-10.560,10.560], [-10.560,10.560]
4.27e-01
8.96e-01

Moore's Law



Number of transistors on an integrated circuit
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
Number of transistors doubling every 18 months.
Number of transistors doubling every 24 months.
Itanium 2
(9 MB cache)
Itanium 2
Pentium 4
Itanium
Pentium III
Pentium II
Pentium
486
386
286
8086
8080
8008
4004
1971
1980
1990
2000
2004
Year

Petascale in 2010(?)

Challenges with the current message passing model

- Heterogeneous computing components
  - Multicore, GPUs, Clearspeed SIMD, IBM Cell
- Latency
- Overhead
- Starvation
- Resource contention
- Fault tolerance

ParalleX Model for future computation

Thomas Sterling, CCT, LSU

- Locality (synchronous local resources)
- System wide global name space
- Multithreaded
- Parcels
- Local Control Objects
- Percolation
- Echo

Future directions

- Role of magnetic field in collapse
- General equations of state
- BH-NS
- Move towards petascale platforms
- Radiation hydrodynamics