Multi-block systems in numerical relativity

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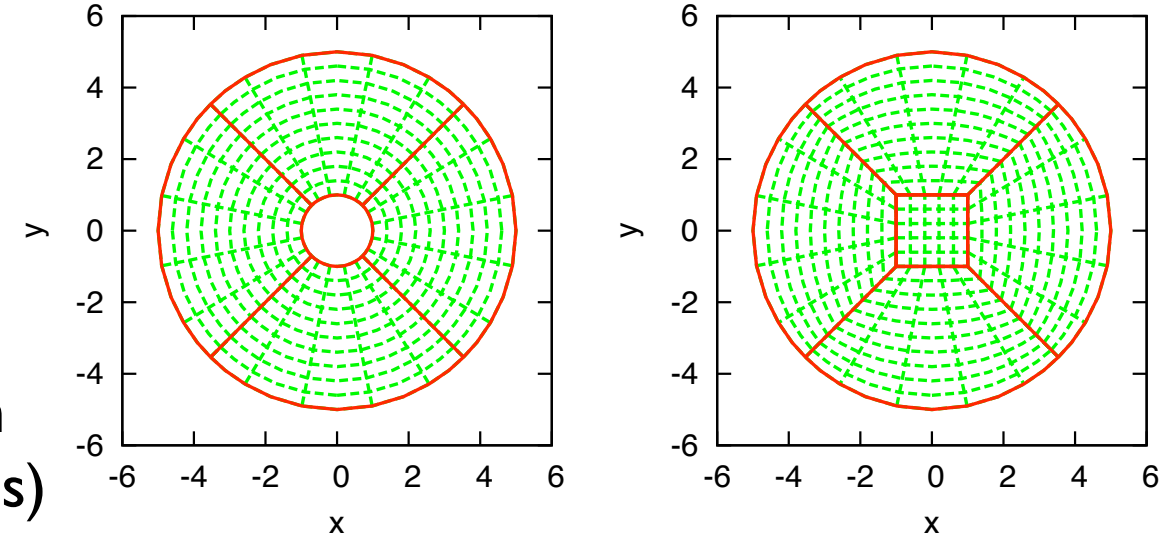
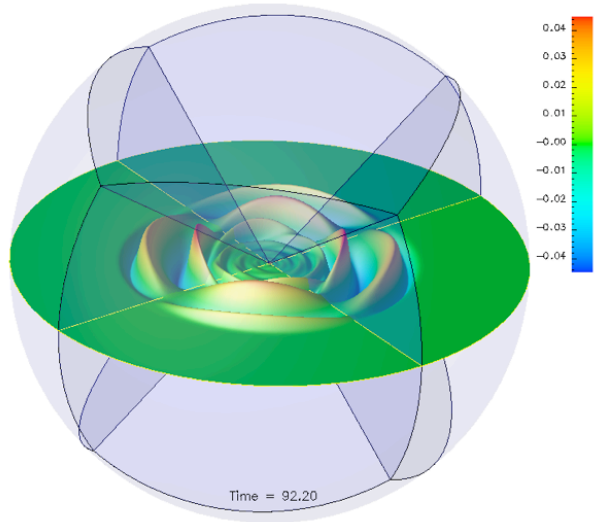
Multiple Blocks

- Cover domain with multiple blocks
- Each block is 3D Cartesian (see 6-patch and 7-patch prototypes)
- Using Cactus Toolkit and Carpet Driver



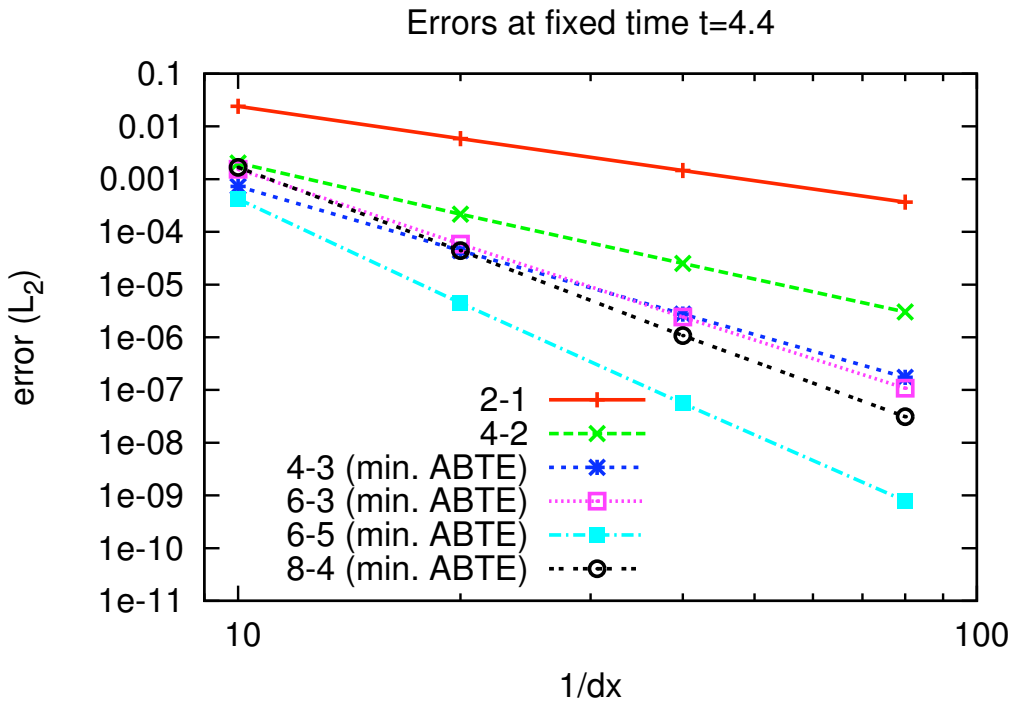


Advantages (MB meets AMR)

- Outer boundary location: MB cost scales with O(R) [AMR: $O(R^3)$]
- Radial resolution: MB cost scales with $O(1/h^2)$ [AMR: $O(1/h^4)$]
- MB is well adapted to almost-spherical systems (stars, single BH, binary BH from far away)
- MB allows smooth outer boundaries
- Well-posed excision easily possible
- Co-rotating coordinates possible (no CFL reduction)

Our Ingredients

- Non-overlapping blocks, SAT (penalty) boundaries for characteristic variables
- Finite differences, SBP operators
- Generalised Harmonic formulation
- Outer boundaries: freeze incoming characteristics



Simpler than Mesh Refinement

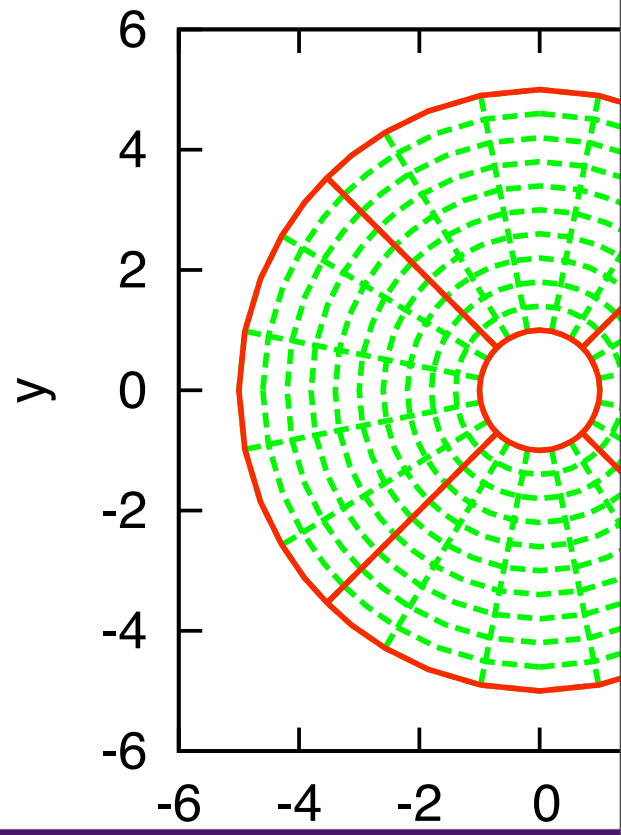
- Use global tensor basis (same variable gxx as before)

- Only derivatives are local; use Jacobian to transform:

$$D_i = \frac{\partial x^a}{\partial x^i} D_a$$

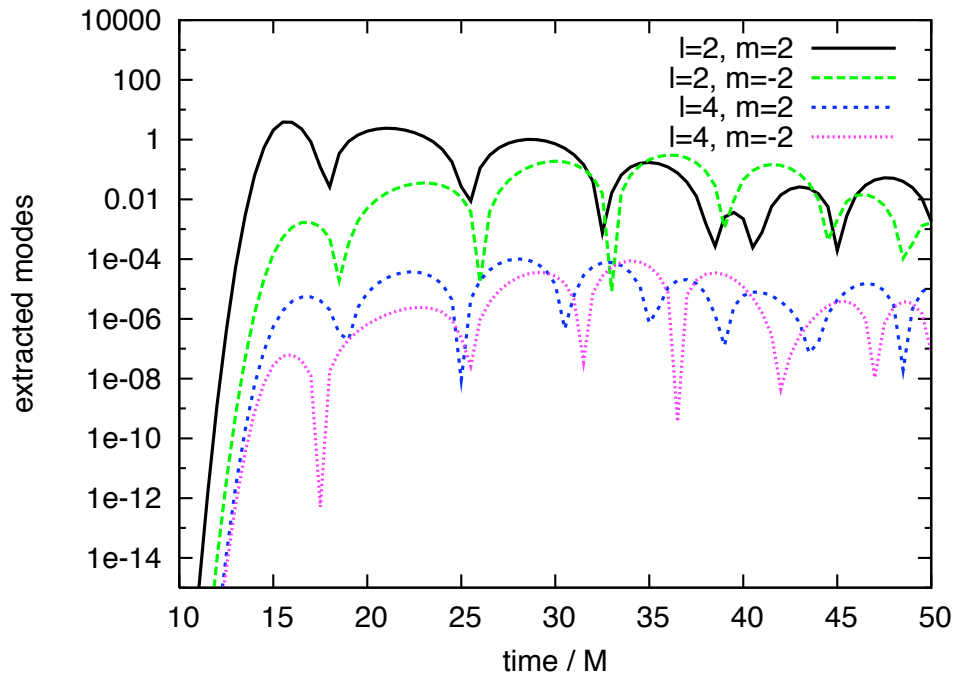
(linear, analytically known, floating point accuracy)

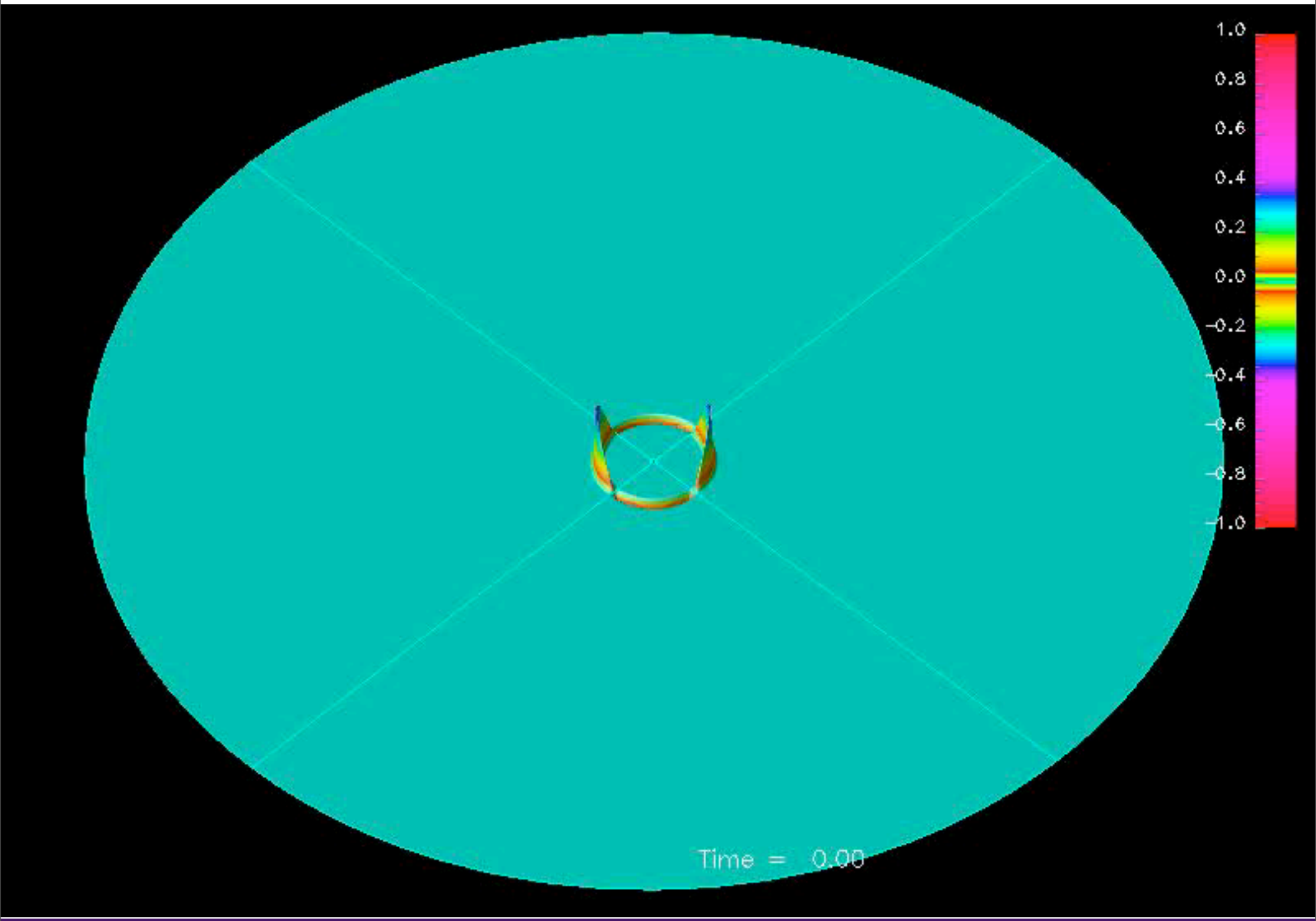
- Use interpolation at inter-patch boundaries, as with AMR



Quasinormal Mode Excitation of Kerr BHs

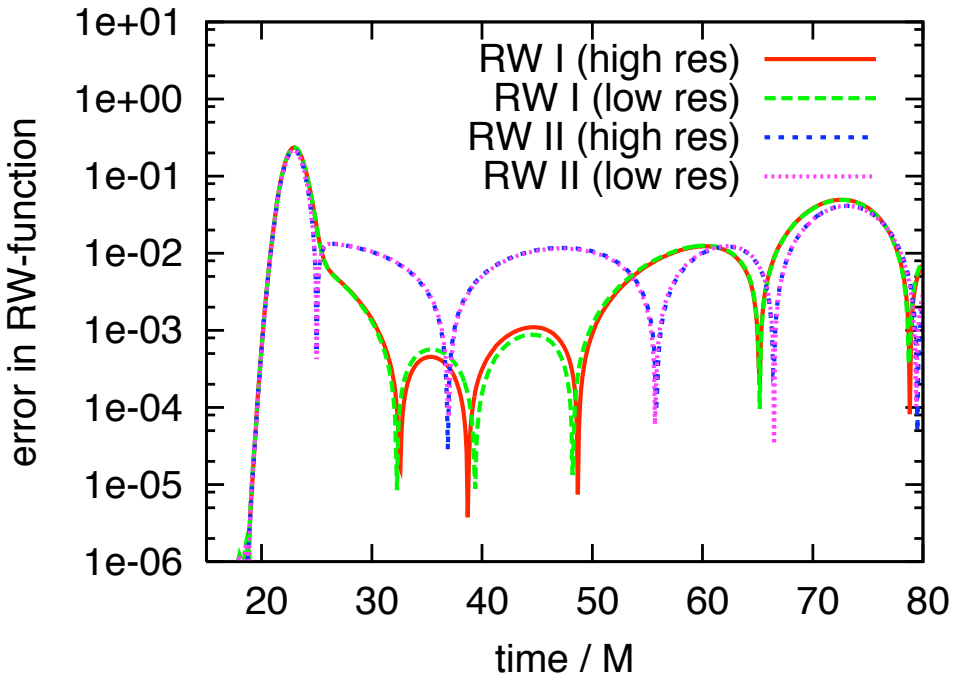
- Mode-mode coupling of a scalar perturbation
- Kerr, M=1, a=0.9
- Initial data:
  Gaussian l=2, m=2
- Extracted at R=5M
- [Thesis of Nils Dorband]




1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Time = 0.00

Systematic Wave Extraction Errors

- Distorted BH, full GR
- Extract waves with Regge-Wheeler-Zerilli formalism at R=80M
- Extracted wave has systematic error when using wrong background
- [Work of Enrique Pazos]



Plans

- Ongoing: Quantitative comparison of efficiency (accuracy vs. cost) of AMR and MB
- Combine AMR and MB for BBH simulations
- GRMHD [Burkhard Zink]
- (BBH with co-rotation and excision, à la Caltech/Cornell)