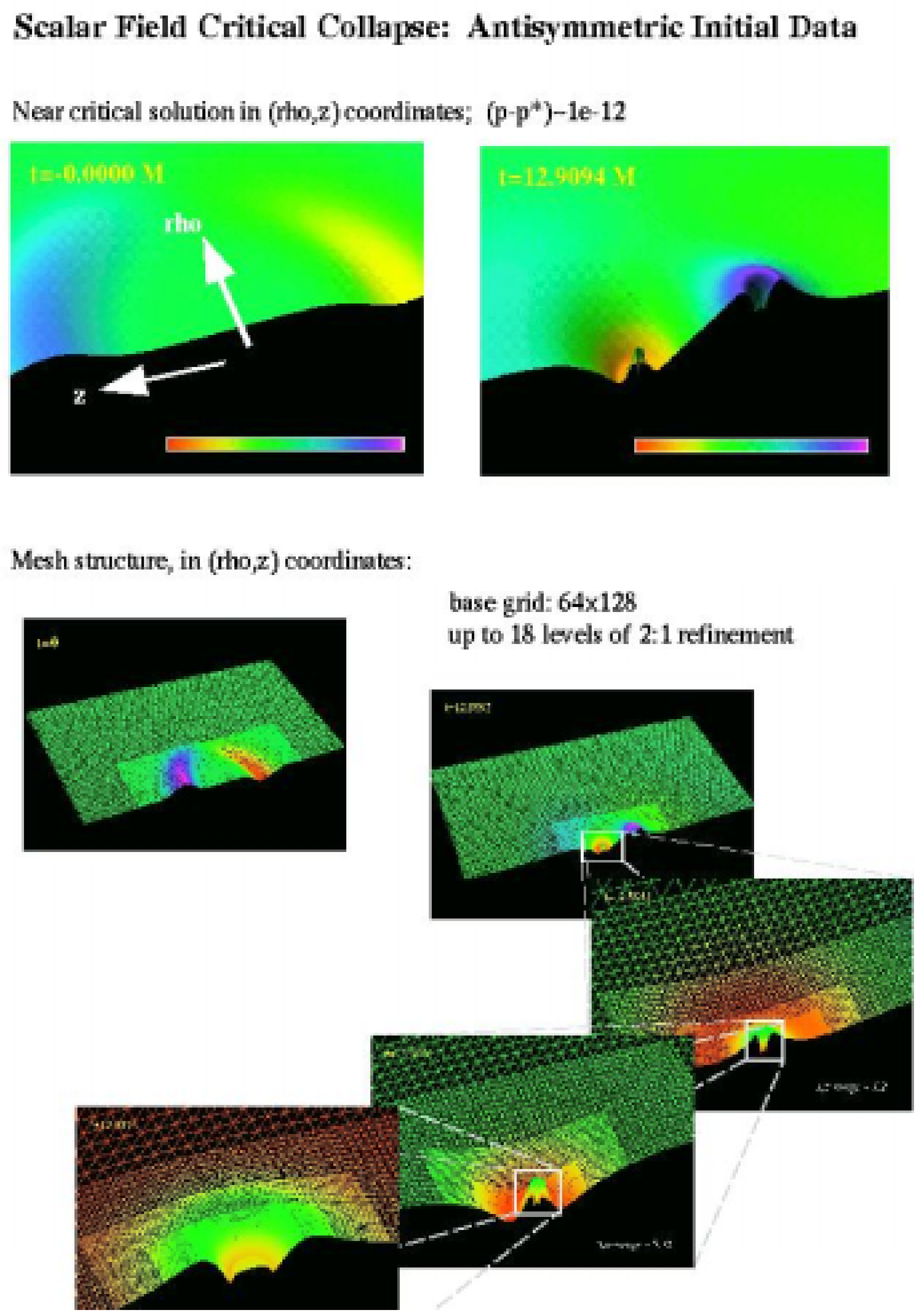
# UBC

*(words from the 2D trenches…)*

- AMR
- EXCISION
- VISUALIZATION (esp. AMR motivated)
- MATTER CODE – AXYSIM
- DISSIPATION
- COMPACTIFICATION
- MATTER CODE –CHARACT (3D)

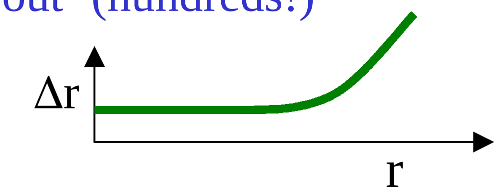
# Critical phenomena in 2D: *Excision*, *AMR*

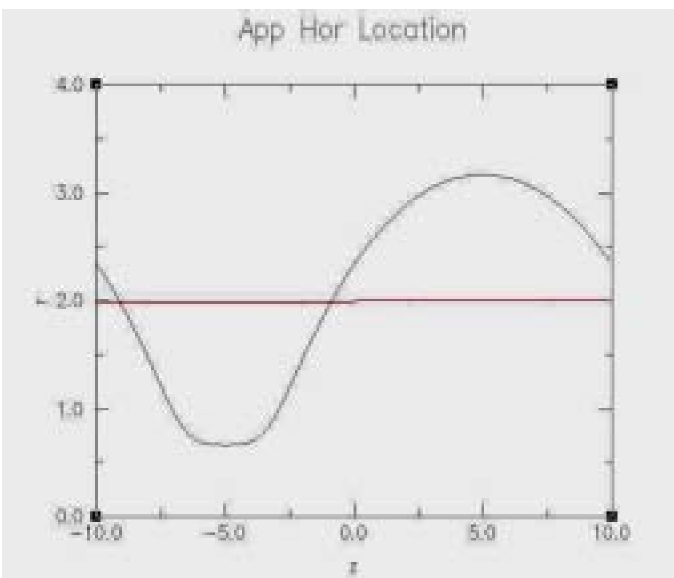
partially constrained multigrid & AMR



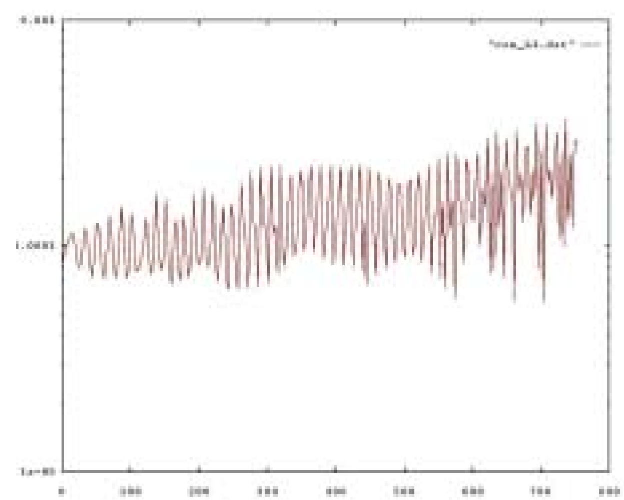
# *Black strings*

- Black hole analogue in higher dimensions. However, could be unstable & lead to naked singularity depending on string length (Gregory-Laflame 94)
- Exponential behavior of metric vars if $L > L_{crit}$
- Needs excision, good resolution and *no-boundary influence!*
  - Using ‘weighted-shift’ interpolation for points ‘popping-out’ (hundreds!)
  - Compactified slices (boundaries at infinity)
  - RHS modified with constraints for stability
  - ‘unperturbed’ and short strings, evolved for $T > 10^4 M$




Ham. const



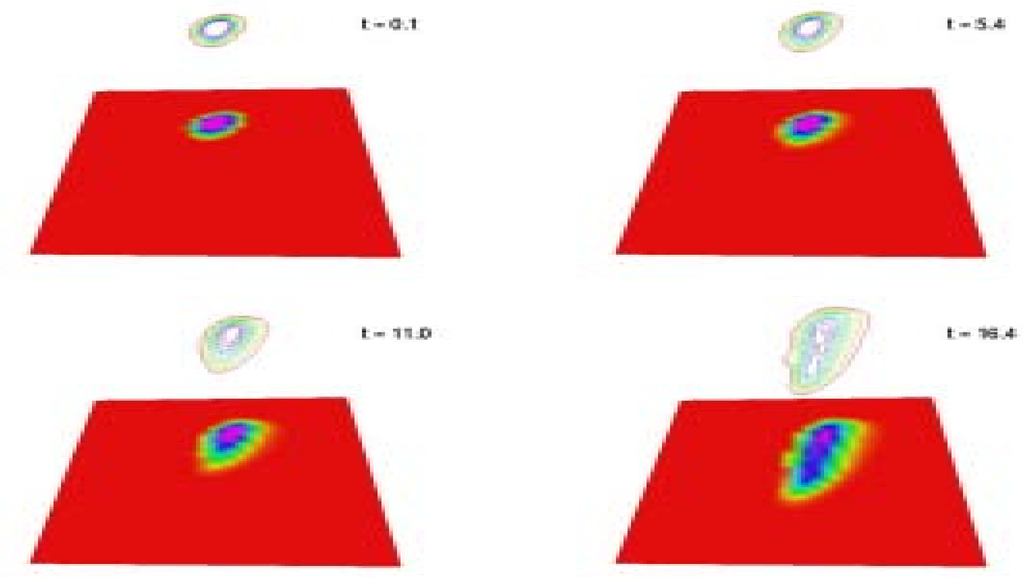
# *2D but generic conclusions/results...*

- Dissipation crucial (beyond ‘built in’)
- Boundary conditions huge role.
- Multi-grid and AMR
- Stable excision implemented *(in free & constrained evolutions)*
  - Points ‘in and out’ without problems
- Physics?
  - Head-on collisions, Critical phenomena in 2D
  - Rotating stars *(under development)*
  - Resolution (?) of the black string problem

# *Characteristic BH-NS problem*

- Initial data minimizing spurious radiation
- (almost) co-moving coordinates

Density(r,q=const,p)

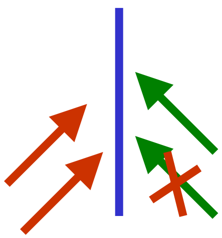


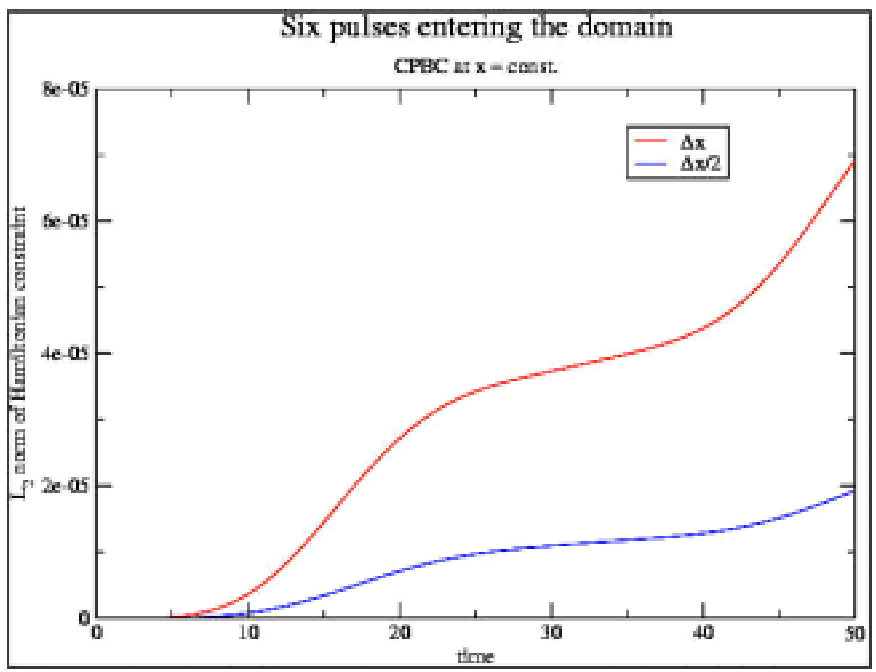

- Problems/missing links:
  - Lack of resolution/speed!
  - Working on parallelization and AMR [both quite different from usual]
  - Need to ‘match’ appropriately to early stages.

# LSU *(words from a new front)*

- *INSTABILITIES…*
  - Bound conditions
    - Developed constraint preserving boundary conditions, tested in 1D, extending to 3D.
      - Key: (I) Hyperbolic formulation to decide what to give

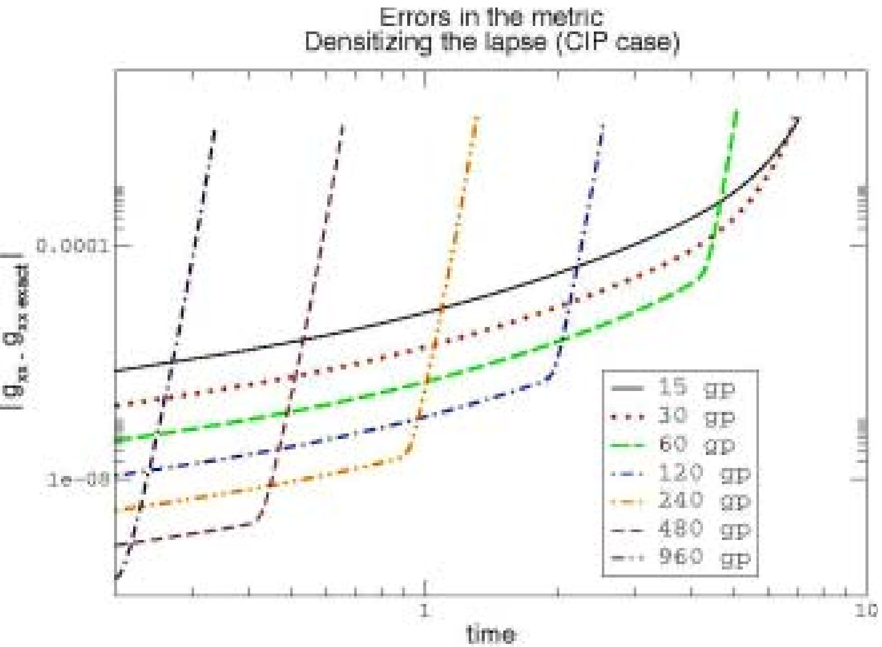
        (II) Above not enough. Demand constraint induced evolution preserve constraints → not all from (I) are freely specifiable

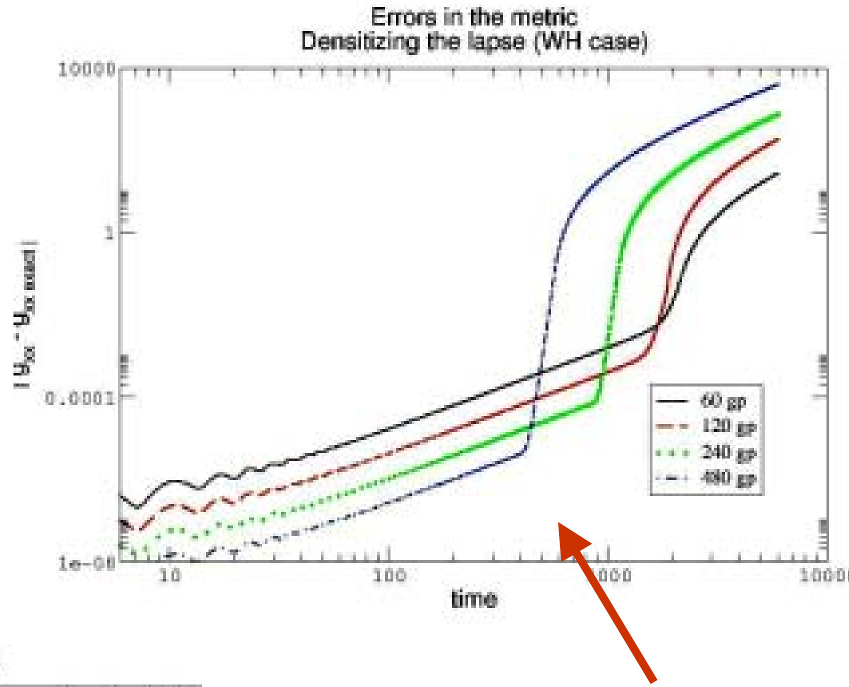


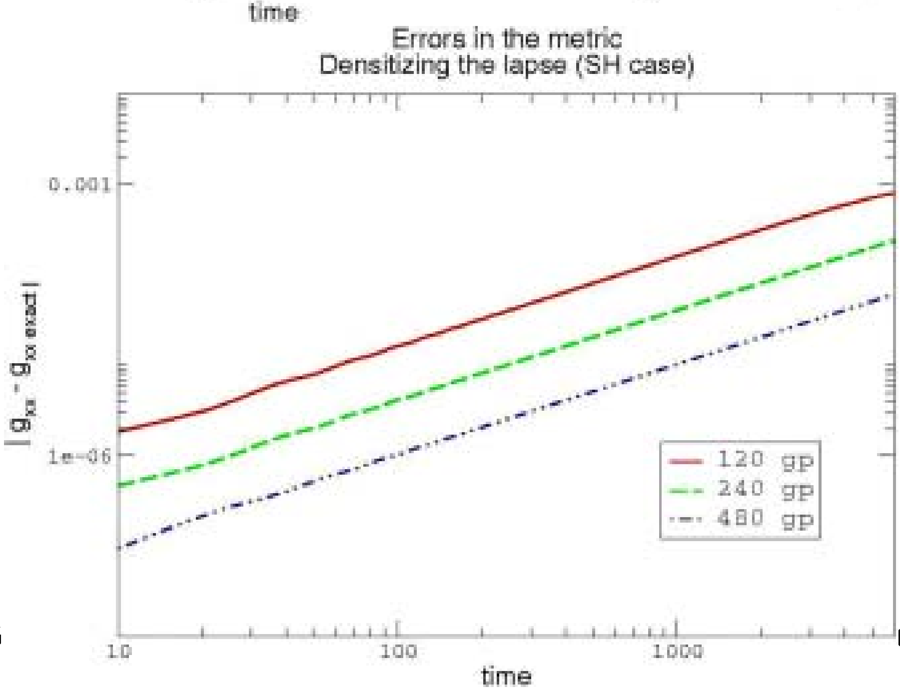


- Formulation?: The usual + analysis of non-principal terms
  - On fixed backgrounds
  - Von-Neuman type analysis of Fourier modes

- NUMERICAL *(can algorithms for wave eqns be used for weakly hyperbolic problems?)*
  - Observation: ‘standard’ algorithms: developed for *symm. hyperbolic eqns and linear*
  - What happens in weakly hyperbolic cases (and worse ones?)




When disisipation added

LIG

er

# *Conclusion & future*

- Lots of 'heat' on constraint behavior… but:

  *do we know for sure they're the cause and not the effect?*

  Eg.: Not a significant issue in 2D with bdries at infinity
- Boundary conditions.  Beyond accuracy, crucial for
  - Resolution (OB,T~500M, CC~$10^8$TFlops with uniform grid)
  - Stability (constraint violating modes fed in there)
- Watch out for 'off-the-shelve' algorithms

What's next?

- New code
  - Incorporating what's been learned from different analysis
  - And 2D black string