

Singularity replacement for black hole evolutions

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Background

- Arbona et al. (1997): Stuffed black holes
- Alcubierre et al. (1999): Puncture evolutions
- Bona et al. (2004): Free black hole initial data
- Campanelli et al., Baker et al. (2005):
Moving punctures



The Turducken (a Louisiana speciality)

- Replace singularity in initial data by something non-singular (smoothing), or invent excised initial data
- Accept constraint violation inside horizon
- Ensure constraints do not propagate out
- Ensure discretisation is stable and consistent



Characteristic Speeds

- There are several versions of BSSN; we choose a specific “typical” system
- Main system (BSSN itself) is strongly hyperbolic almost everywhere
- Subsidiary system (constraints) is symmetric hyperbolic: constraints propagate along the light cone, *even if the constraints are violated*



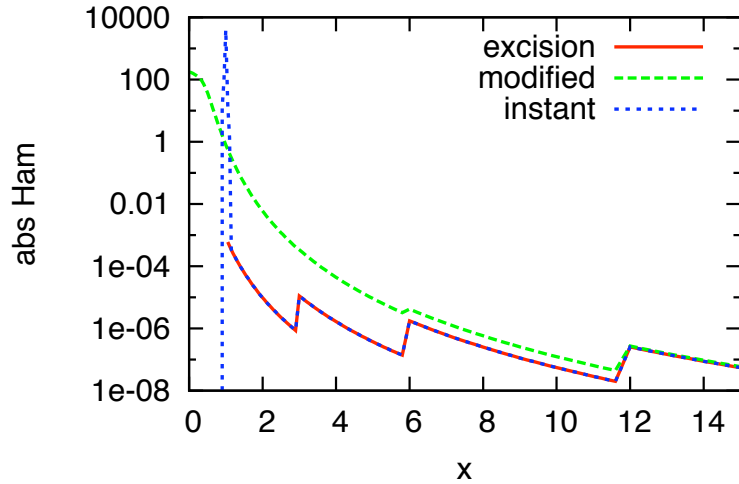
Magic

- Some artificial dissipation necessary (not much)
- Avoid large initial dynamics: e.g., start with a small lapse inside the horizon
- Often, initial data need not be smooth
- Check convergence inside and outside of horizon separately
- Note: A spike near the origin appears / remains

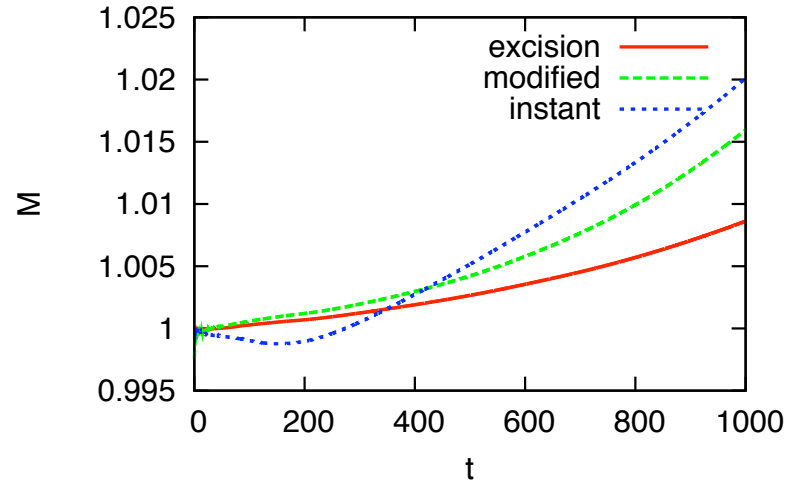


Single black holes

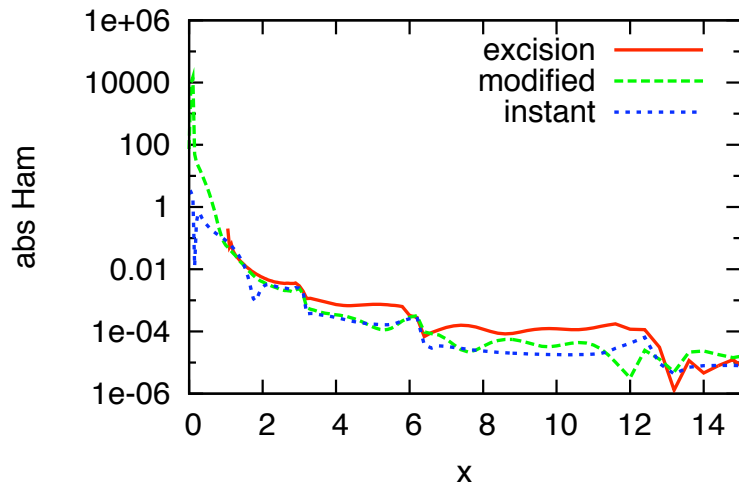
Initial constraint violation



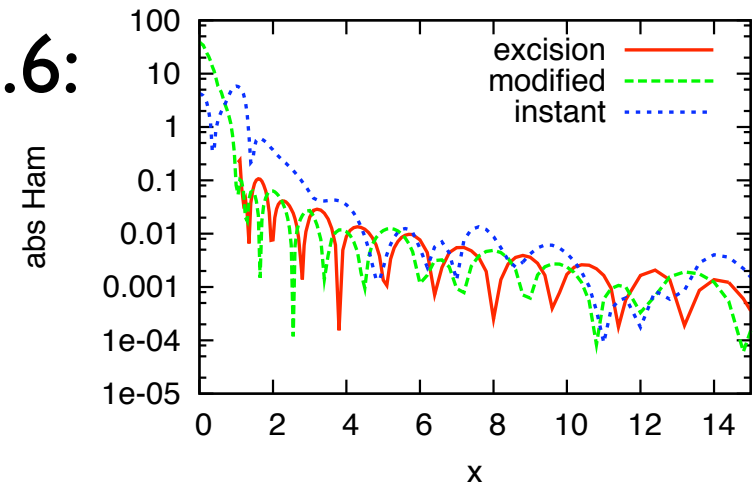
Apparent horizon mass



Constraint violation at $t=1000$



Constraint violation at $t=200$

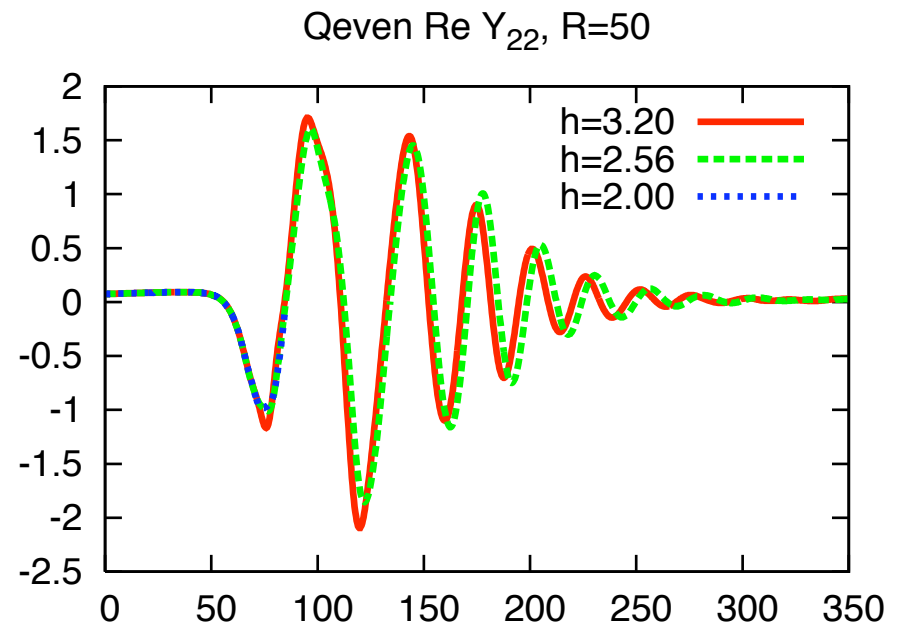
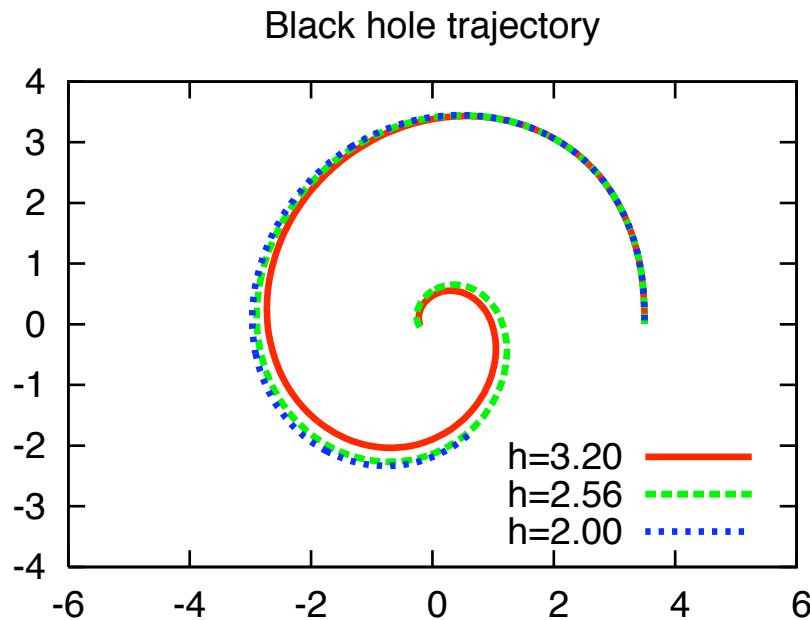


$a=0.6:$



Quasi-equilibrium binary black holes

- Cook-Pfeiffer data sep_07.00_59a
<http://www.black-holes.org/researchers3.html>





Future

- Compare initial data methods: punctures, quasi-equilibrium, helical Killing vector, reconstructed post-Newtonian
- Compare evolution methods: excision vs. no-excision, mesh refinement vs. multi-patch
- Combine evolution methods: spectral accuracy with mesh refinement flexibility