Using the GCFE to study the "ringing" of a Schwarzschild black hole

Jörg Frauendiener

joint work with Chris Stevens

Department of Mathematics and Statistics, University of Otago
and
Centre for Mathematics in Applications, University of Oslo

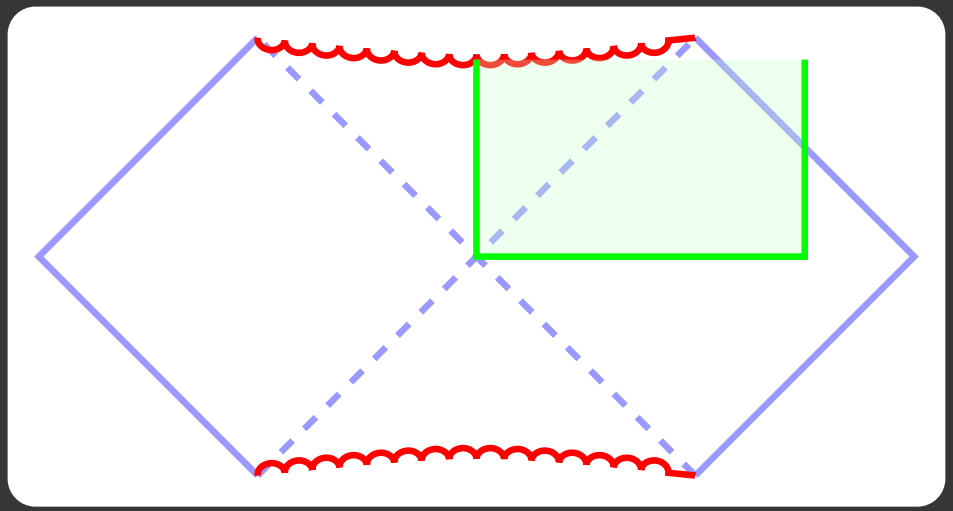
New York, 12. July 2016

Conformal field equations

- implement Penrose's conformal approach, developed by H. Friedrich
- system of equations equivalent to standard Einstein equations
- determine a space-time in a conformally covariant way
- equations for
  - frame
  - (Weyl) connection
  - Ricci tensor
  - Weyl tensor
- conformal Gauß gauge:
  - based on congruence of time-like conformal geodesics
  - yields mostly advection equations along conformal geodesics
  - spin-2 equation for Weyl tensor is symmetric hyperbolic

Setup

Schematic diagram of computational domain



- Schwarzschild initial data (note, not spatially compactified)
- left boundary inside horizon
  - isometry condition
- finite outer boundary
  - data with $\Psi_0 \neq 0$, (axi-symmetrically) 'distorted' black hole
- reach the singularity and null-infinity on the same grid
- read off Ψ_4 on $\mathscr{I}$ and compute the Bondi mass

Results and issues

Results

- constraints propagate (numerical observation)
- IBVP is (numerically) well-posed
- reproduce Schwarzschild (and S-dS and S-AdS)
- distorted black hole loses energy, Bondi mass loss

Issues

- $t = const$ hyper-surfaces tilt upwards, become null outside $\mathscr{I}$
- variable number of incoming modes at the outer boundary
- 'ringing' not (yet) seen
  - lack of resolution (?)
  - magnitude (?)
  - inner boundary condition (?)
- work in progress

Outlook

- approach seems to be ideal to study global properties of space-times
- currently work on improving the code to run higher resolutions
- can be used also when initial data surface is compactified
- allows the setup of a scattering problem
  - ingoing wave data given on $\mathscr{I}^-$ read
  - outgoing wave data read off on $\mathscr{I}^+$
- should also be applicable to Kerr black holes