A Fast Apparent Horizon Finder for 3-D Cartesian Grids in Numerical Relativity

Jonathan Thornburg (AEI Golm)

Motivation:

gravitational waves $\Rightarrow$ binary BH coalescence
$\Rightarrow$ numerical relativity
$\Rightarrow$ want to **find apparent horizons** (BH surfaces) **at each time step** of a numerical evolution

existing AH finders are very slow (minutes) $\Rightarrow$ want a faster AH finder

Main Ideas:

- assume AH is a Strahlkörper ("star-shaped region"), parameterize by $r = h(\text{angle})$ for some single-valued $h : S^2 \to \Re^+$
- AH equation becomes **elliptic PDE** for h on S^2
  $\Theta(h, \partial_u h, \partial_{uv} h; g_{ij}, K_{ij}, \partial_k g_{ij}) = 0$
- **finite difference** in angle on S^2 (N_{ang} angular grid points)
- multiple grid patches to avoid z axis singularities
- solve by **Newton's method** in N_{ang} dimensions
- use "**symbolic differentiation**" to compute Jacobian matrix
- interpolate g_{ij} and K_{ij} to AH surface points, **compute $\boldsymbol{\partial_k g_{ij}}$** at AH surface points **as part of (Hermite) interpolation**

Results:

- **very fast: finds AHs in a few seconds**
- Cactus thorn AHFinderDirect
- code will be freely available (GNU GPL) starting in summer 2003