

Numerical Relativity using Cactus



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www.CactusCode.org



What is Cactus?

Cactus is a freely available, modular, portable and manageable environment for collaboratively developing high-performance multidimensional simulations



Cactus for Numerical Relativity?

- Many astrophysics groups already using and developing modules for Cactus
 - Albert Einstein Institute, Washington University, NCSA, Pittsburgh, Penn State, U. of Texas, E.U. Network, ...
- Common code base, common language, much experience, access to large support network
- New modules often made public, can use straight away
- Easy to work on one part of a problem (apparent horizon, initial data, gauge conditions, ...)
- Easy to collaborate, share your work with others
- Standard stuff ... portability, parallelism, latest software technology, parallel IO, visualization, support, (AMR), lots of new funded projects in physics/computer science



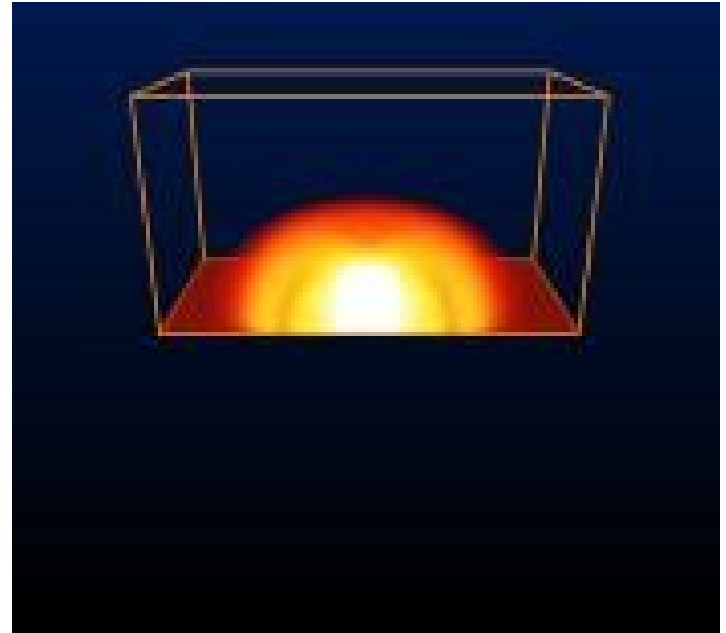
Cactus Relativity ToolKit

- ADM
 - Evolution of 3+1 quantities, staggered leapfrog, iterative Crank Nicholson, standard leapfrog. Lapse evolution: geodesic, static, harmonic family, algebraic, external
- ADMConstraints
- AHFinder
 - 3D minimisation and flow algorithms, well tested (paper)
- Einstein
 - Sets up variables, handles slicing choices, evolve conformal quantities.
 - Calculate $\text{tr}K$, $\text{det}g$
- Extract
 - Calculate gauge invariant waveforms, masses
- IDAnalyticBH
 - Initial data for black holes in various slicings. Schwarzschild, Misner, Kerr, Brill-Lindquist
- IDAxBrillBH
 - Initial data for black hole perturbed by a Brill wave
- IDBrillData
 - Vacuum Brill wave



Cactus Relativity ToolKit (2)

- IDLinearWaves
 - Plane waves and Teukolsky waves
- PsiKadelia
 - Neumann Penrose quantities, Ψ_0 , ..., Ψ_4 , etc.
- TimeGeodesic
 - Integrate timelike geodesics through spacetime (can be streamed for visualisation)





Also Available:

- **BAM_Elliptic**
 - Multigrid solver for e.g. Maximal slicing
- **BosonStar**
 - Initial data and evolver of source terms in ADM equations
- **Maximal**
 - Maximal slicing
- **Various other initial data thorns.**
- **AEI Group working on:**
 - More stable evolvers
 - BH Excision
 - Shift conditions
- **CactusZeus**
 - Port of Zeus package to Cactus
- **Relativistic Hydrodynamics**
 - Developed at Wash U.
 - Solvers
 - Initial data
 - Equations of State



Einstein Thorn

Global Variables

- Metric group:
`gxx, gxy, gxz, gyy, gyz, gzz`
- Extrinsic curvature group:
`kxx, kxy, kxz, kyy, kyz, kzz`
- Gauge groups:
 - `alp`
 - `betax, betay, betaz`
- Conformal Factor groups:
 - `psi`
 - `psix, psiy, psiz`
 - `psixx, psixy, psixz, psiyy, psiyz, psizz`
- Scalars
 - `conformal_state`
 - `shift_state`

Main parameters (restricted)

- `use_conformal`
- `initial_data`
- `evolution_system`
- `initial_lapse`
- `slicing`
- `shift`

Analysis

- metric, curvature in spherical polar coords
- `tr(K), det(g)`



Tutorial Aims

- Overview of Cactus
- Example application: Scalar Wave Equation in 3D
- A review of a few of the external software packages which can be used with Cactus, and a look at some of the newest and coolest features which are available now
- Hands-on-session tomorrow ...



More Information

At our web site www.CactusCode.org

- A detailed tutorial working through the WaveToy application, explaining the code and the concepts behind it.
- Recent published papers about some of the computational science issues.
- Downloadable and online slides from the first Cactus Workshop, held last year at the NCSA.
- Downloadable slides from complete tutorial.
- Cactus User's Guide.
- Details of projects we are involved in.
- Relativity: For questions about relativity modules, cactusmaint@cactuscode.org
- Talk to me at the hands on session tomorrow