The Einstein Toolkit

Frank Löffler

Center for Computation and Technology
Louisiana State University, Baton Rouge, LA

May 22th 2011

einstein toolkit

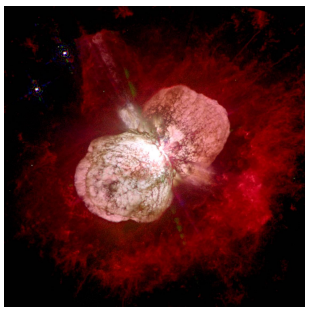
Supported by NFS grants 0903973/0903782/0904015 (CIGR)

LSU CENTER FOR COMPUTATION & TECHNOLOGY

The Einstein Toolkit

einstein toolkit

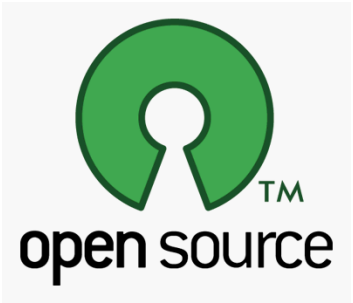
- Collection of software components and tools
- Targeted at simulating and analyzing general relativistic astrophysical systems
- Freely available as open source
- See http://einsteintoolkit.org



LSU CENTER FOR COMPUTATION & TECHNOLOGY

Guiding Principles

- Open, community-driven software development
- Separation of **physics** software from **computational science** infrastructure
- Well thought out and stable interfaces
- Providing core computational tools to
  - facilitate interdisciplinary research
  - enable new science
  - broaden community
  - take advantage of emerging Petascale computers and advanced cyberinfrastructure



LSU CENTER FOR COMPUTATION & TECHNOLOGY

Current State

einstein toolkit

- Last release on April 21, 2011
- New releases roughly every six months
- Atm. mostly Cactus (framework), Carpet (AMR)
- Production quality features (Ninja, NRAR)
- Not all new - grown from other projects

LSU CENTER FOR COMPUTATION & TECHNOLOGY

People

- About 50 contributors over the past decade, both physics and CS
- Currently 62 registered users from 23 research groups worldwide
- 9 maintainers from 6 different institutions
- $>$ 200 publications, $>$ 30 theses building on these components

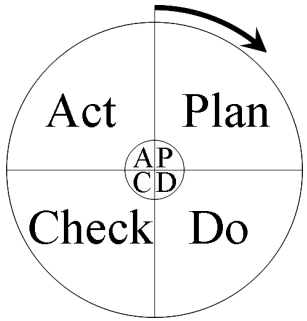
LSU CENTER FOR COMPUTATION & TECHNOLOGY

Science Capabilities

- McLachlan (BSSN, up to 8th order)
- GRHydro (formerly based on WhiskyCode; Valencia formulation)
- BH/NS initial data (TwoPunctures, Lorene)
- Turduckening
- MoL + e.g., Runge-Kutta
- Carpet (Adaptive Mesh Refinement)
- Black hole horizon finder (AHFinderDirect)
- Gravitational wave extraction
- Parallelization: MPI, OpenMP
- Tools: e.g., EOS reader, HDF5 output, Visualization import

LSU CENTER FOR COMPUTATION & TECHNOLOGY

Quality Control



- Open source $\neq$ offering download
- Requirements for (new) Einstein Toolkit components:
  - sufficient quality (actually being used)
  - documentation (e.g. publication)
  - community interest (maintained)
- Regular, tested releases
- Providing easy step-by-step instructions for first-time users

Einstein Toolkit testsuite status

einstein toolkit

TESTSUITE STATUS OF EINSTEINTOOLKIT.TH

Show all information.

Totals		amarok-intel		bluedrop		datura		hopper		kraken		lonestar-intel		minkowski-gcc45		numrel-gcc		numrel-intel		pandora-xl		philip-intel		queenbee-intel		ranger-intel		redshift		topf-gcc	
		1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t
		diener 04/20	diener 04/20	bcmundim 04/05	bcmundim 04/05	ianhiin 04/04	ianhiin 04/04	schnette 04/21	schnette 04/21	hinder 04/09	hinder 04/09	tg459479 04/20	tg459479 04/20	rhaas3 04/20	rhaas3 04/20	knarf 04/20	knarf 04/20	knarf 04/20	knarf 04/20	diener 04/20	diener 04/20	knarf 04/20	knarf 04/20	knarf 04/20	knarf 04/20	tbode 04/21	tbode 04/21	eschnett 04/21	eschnett 04/21	knarf 04/20	knarf 04/20
		0/131	0/124	4/133	18/127	3/133	16/127	4/129	1/122	8/130	18/124	0/131	0/124	0/131	0/124	0/131	0/124	0/131	0/124	8/131	11/124	0/129	0/122	0/131	0/124	2/131	1/124	3/131	4/124	0/131	0/124
	Failing																														
	Succeeding																														

Thorn	Test	amarok-intel		bluedrop		datura		hopper		kraken		lonestar-intel		minkowski-gcc45		numrel-gcc		numrel-intel		pandora-xl		philip-intel		queenbee-intel		ranger-intel		redshift		topf-gcc	
		1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t	1p, 1t	2p, 2t
ADM	all tests passed (4)																														
ADMConstraints	all tests passed (4)																														
AHFinder	all tests passed (2)																														
AHFinderDirect	Kerr	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√
	Kerr-Cartoon	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	2 missing. 0/0	√	√	√	√	√	√	√	√	√	√
	Kerr-definition-expansion	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-definition-expansion-product	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-definition-inner-expansion	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-definition-mean-curvature	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-modification-radius	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-rotating-180	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-rotating-90	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-selection-areal-radius	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-selection-areal-radius-definition-expansion-product	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Kerr-selection-mean-coordinate-radius	√	√	√	2/2	√	2/2	√	√	√	2/2	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	checkpointML	√		√	7/7	√	7/7	√		√	7/7	√		√		√		√		√		√		√		√		√		√	
	misner1.2-025	√		√	2/55	√	2/55	√		√	2/55	√		√		√		√		√		√		√		√		√		√	
	recoverML	√		√	5/5	√	5/5	√		√	5/5	√		√		√		√		√		√		√		√		√		√	
CarpetIOHDF5	all tests passed (2)																														
CarpetReduce	nonstaggered	√		√		√		√		1/5		√		√		√		√		√		√		√		√		√		√	
	staggered	√		√		√		√		1/5		√		√		√		√		√		√		√		√		√		√	

Tutorial for New Users

einstein toolkit

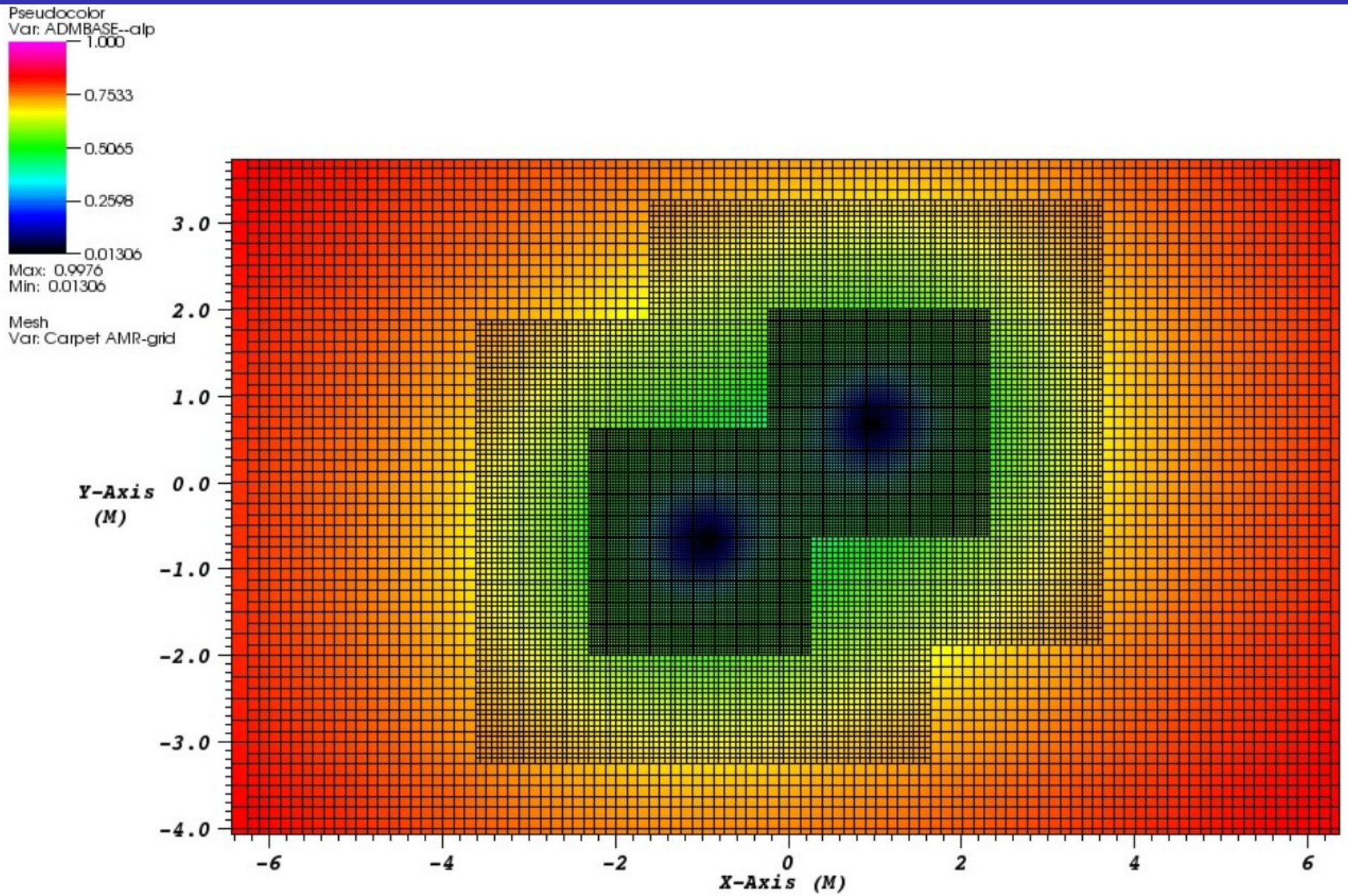
http://docs.einsteintoolkit.org/et-docs/Tutorial_for_New_Users

- Get account on cluster "QueenBee" (fill in web form)
- Download (4 shell commands)
- Configure (3 commands) [user name, email address, allocation]
- Build (1 command)
- Run simulation (1 command)

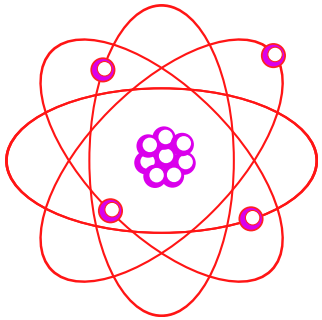
LSU CENTER FOR COMPUTATION & TECHNOLOGY

Linda Holyoke - REU undergraduate student

Linda Holyoke: AMR visualization



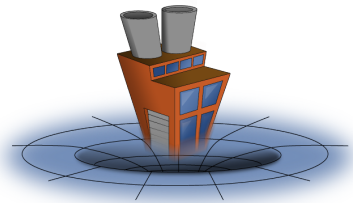
Science vs. Simulation



- Doing science >> Running a simulation
- Need to know about meaningful initial conditions, numerical stability, accuracy/ resolution, have patience, have curiosity, have a "gut feeling" for what is "right"...
- Einstein Toolkit cannot give that!
- But, with open codes that are easy to use, can concentrate on science!

Convenience Tools

GetComponents



Simfactory

Formaline

Tools: GetComponents

Task: Collect software from various repositories at different sites

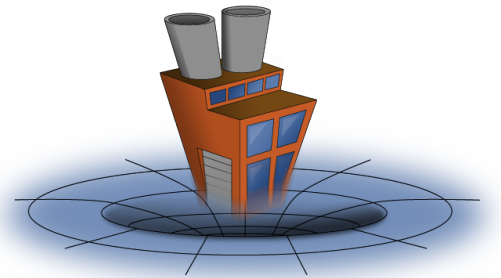
Example simulation assembly:

- Core Einstein Toolkit (svn.einsteintoolkit.org)
- Cactus Flesh and Toolkit (svn.cactuscode.org)
- Carpet AMR (carpetcode.org, hg)
- Tools, Parameter Files and Data (svn.einsteintoolkit.org)
- Group Modules (x.groupthorns.org)
- Individual Modules (x.mythorns.org)

x: cvs, svn, darcs, git, hg, http

LSU CENTER FOR COMPUTATION & TECHNOLOGY

Tools: Simulation Factory



http://www.simfactory.org/

Task: Provide support for common, repetitive steps:

- Access remote systems, synchronize source code trees
- Configure and build on different systems semi-automatically
- Provide maintained list of supercomputer configurations
- Manage simulations (follow "best practices", avoid human errors)

LSU CENTER FOR COMPUTATION & TECHNOLOGY

Tools: Formaline

- Task: Ensure that simulations are and remain repeatable, remember exactly how they were performed
- Take snapshots of source code, system configuration; store it in executable and/or git repository
- Tag all output files

General Guideline

The Einstein Toolkit

- Does not want to provide "the" best code
- Rather wants to offer different codes with are
  - of high quality
  - maintained
  - open source
  - easy to use

$\rightarrow$ Computational General Relativity for the Masses

Support

- Web site http://einsteintoolkit.org
- Mailing list users@einsteintoolkit.org
- Bug tracking system http://trac.einsteintoolkit.org
- Weekly public phone meetings
- Also blog, wiki, code repositories, ...

Acknowledgements

- More than 4 dozen contributors (over past years)
- NSF projects: CIGR, XiRel, Alpaca, PetaCactus (LSU, GA Tech, RIT, Caltech, AEI)
- LONI "loni_cactus" allocation

LSU CENTER FOR COMPUTATION & TECHNOLOGY

Future

- Looking for users and contributions
- Don't want to take over software
- Currently Cactus-centric, want to expand in other directions
- Also looking for analysis tools / scripts
  (e.g. gravitational wave postprocessing tools)
- Working on GRMHD
- Improve existing numerical methods (scaling)
- Investigate alternative methods for GR

LSU CENTER FOR COMPUTATION & TECHNOLOGY