The Einstein Toolkit

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August 09, 2022

https://www.einsteintoolkit.org/

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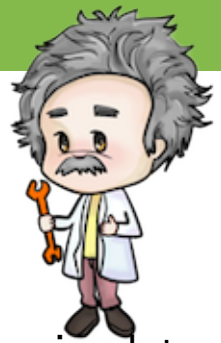
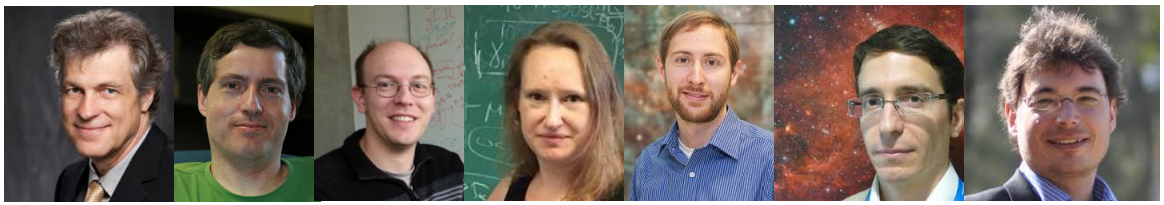
Einstein Toolkit



- Collection of scientific software components and tools to simulate and analyze general relativistic astrophysical systems
- Freely available as open source at http://www.einsteintoolkit.org
- Supported by NSF 1550551/1550461/1550436/1550514, NSF 1212401/1212426/1212433/1212460, NSF 0903973/0903782/0904015 (CIGR), 0701566/0855892 (XiRel), 0721915 (Alpaca), 0905046/0941653(PetaCactus/PRAC)
- State-of-the-art set of tools for numerical relativity, open source
- Currently 364 members from 253 sites and 44 countries
- $>$ 396 publications, $>$ 53 theses building on these components (as of June 2022)
- Regular, tested releases
- User support through various channels



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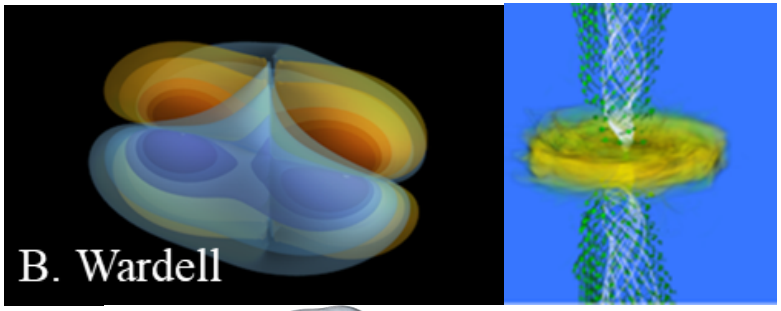
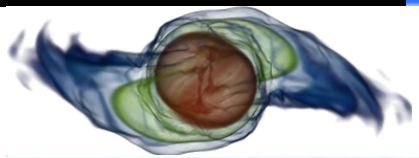
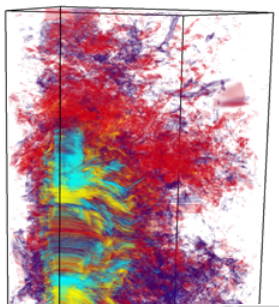
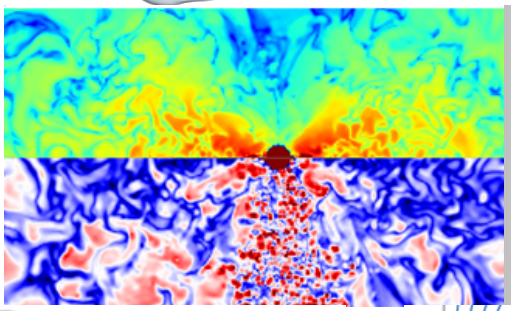
Science

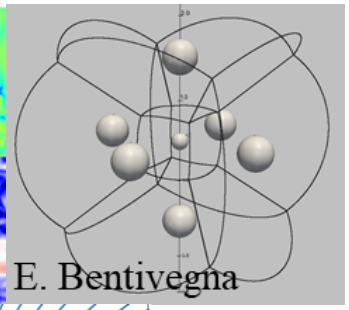
- Binary Black Hole Mergers
- Neutron Star Mergers
- Supernovae
- Accretion Disks
- Boson Stars
- Hairy Black Holes
- Black Hole Binaries in beyond-GR theories
- Cosmic Censorship

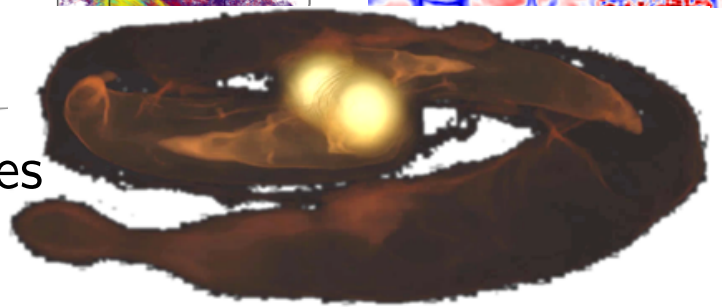


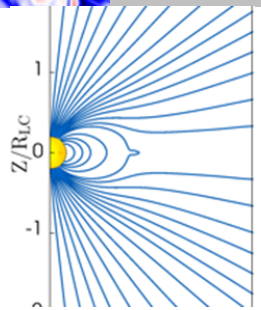












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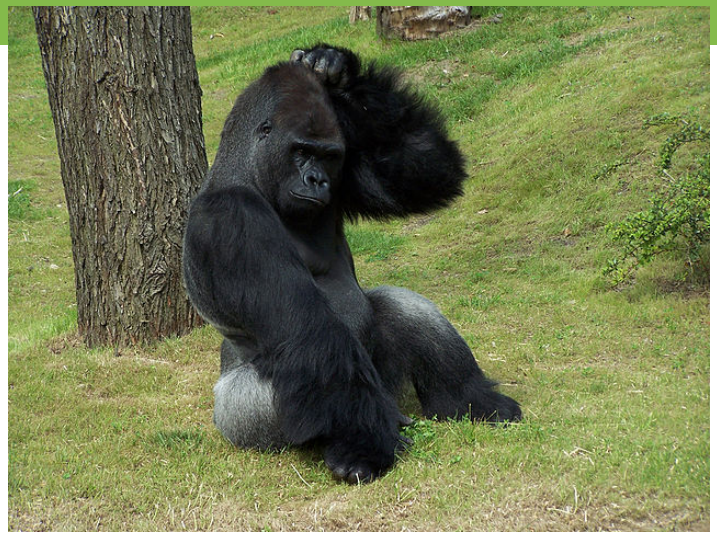
Computational Challenges



- Simulate cutting edge science
- Use latest numerical methods
- Make use of latest hardware
  - Vector (Kranc, NRPy+)
  - Scale to many cores (OpenMP multi-threading)
  - Scale to many nodes (Message Passing Interface, Carpet, CarpetX)
  - Adaptive Mesh Refinement (Carpet, CarpetX)
  - GPU (CarpetX)
  - Machine learning?
  - FPGA?
  - ASIC?
  - Neuromorphic processor?
  - Q-bits?

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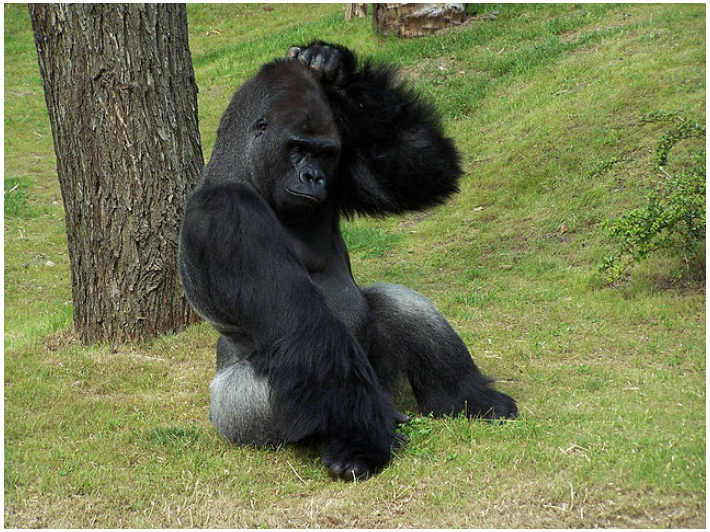
Computational Challenges

More Mundane Challenges

- Efficient I/O
- HDF5
- Checkpoint/Restart
- Parameter Parsing
- Visualization
- Analysis
- Steering



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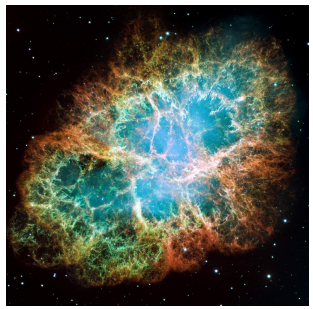
problem



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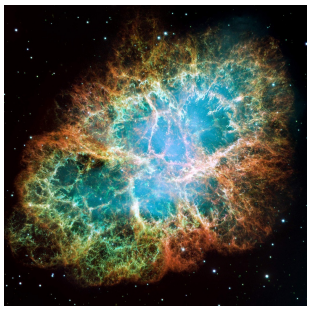
community



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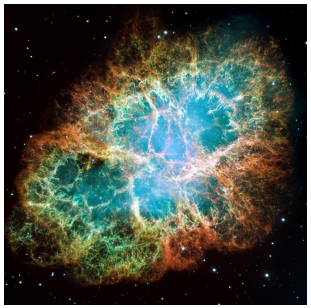
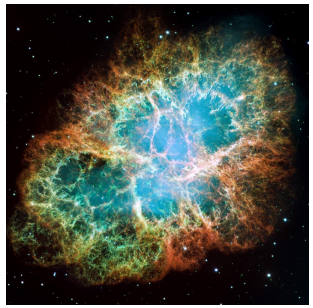
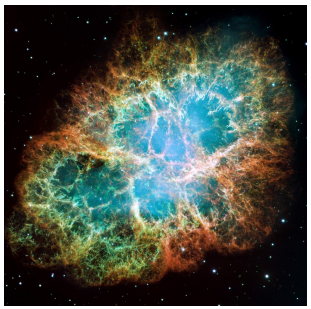
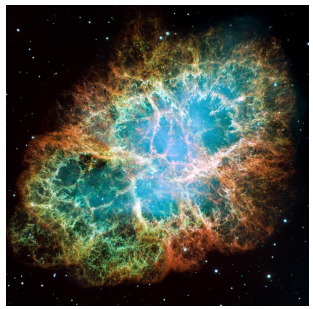

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competition

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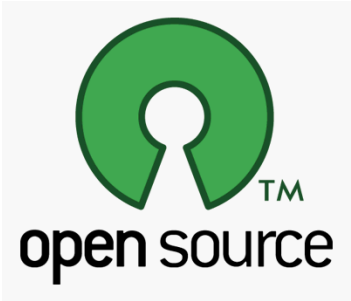
Guiding Principles

- Open, community-driven software development
- Separation of **physics** software and **computational** infrastructure
- Stable interfaces, allowing extensions
- Simplify usage where possible:
  - Doing science >> Running a simulation
  - Students need to know a lot about physics (meaningful initial conditions, numerical stability, accuracy/resolution, have patience, have curiosity, develop a "gut feeling" for what is right ...)
  - Einstein Toolkit **cannot** give that, **however**: Open codes that are easy to use allow to concentrate on these things!



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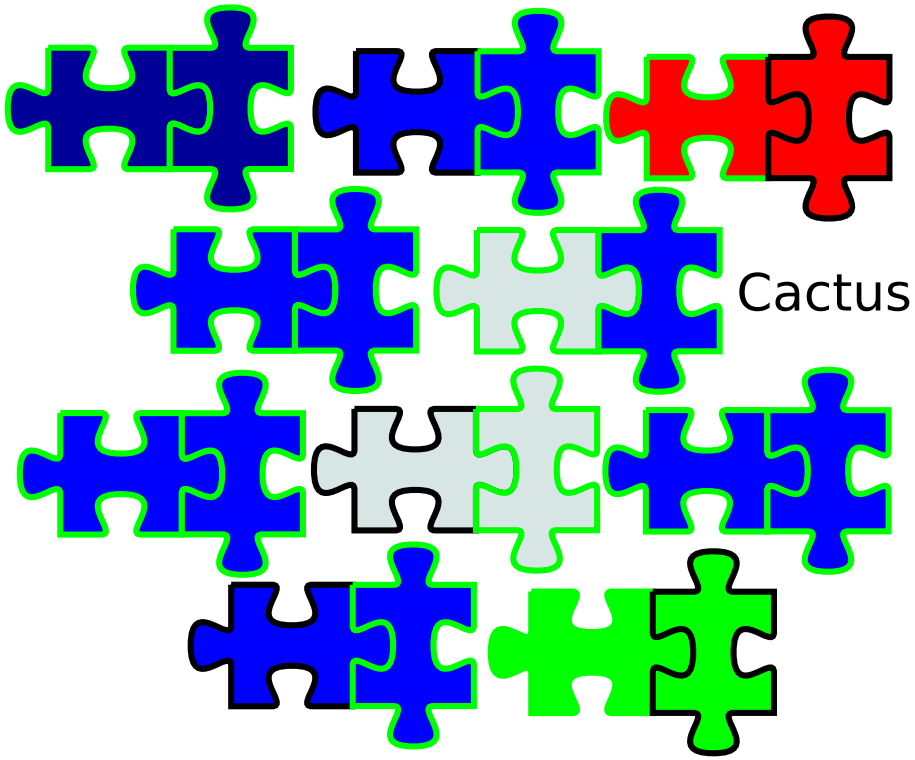
Einstein Toolkit as growing project

- Most modules open-source, but not necessarily all



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Vision

Cutting Edge / Future

- New Driver Thorn: CarpetX
- New Spherical Coordinates Thorn (RIT)
- New Python Code Generator: Full thorn output from NRPy+
- Kerr background support in SelfForce1D

Recent

- PN based initial data and eccentricity reduction
- New Declarative Synchronization: Presync
- Python based simulation analysis: kuibit
- Beyond-GR theories of gravity: Canuda

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Supported By

The Einstein Toolkit is supported by
NSF 2004157/2004044/2004311/2004879/2003893, NSF 1550551/1550461/1550436/1550514 Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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