Bruno Giacomazzo

www.brunogiacomazzo.org

Einstein Toolkit
einsteintoolkit.org

- Set of publicly available tools for relativistic astrophysics
- Latest release on June 28 2024 (codename “Landau”)
- More than 150 users on 6 continents
- Tested on several HPC infrastructures around the world
- Includes over 100 Cactus thorns, including:
  - McLachlan and Baikal (space-time evolution)
  - GRHydro and IllinoisGRMHD (GRMHD equations)
  - Several initial data and analysis routines
- Data can be read and visualized by open source codes (e.g., Kuibit, Visit)

References

- Einstein Toolkit Webpage: http://einsteintoolkit.org
- Main Publications presenting the toolkit:
  - Loeffler et al 2012: http://arxiv.org/abs/1111.3344
  - Moesta et al 2013: http://arxiv.org/abs/1304.5544
  - Zilhao and Loeffler 2013: http://arxiv.org/abs/1305.5299
- Visualization Tools:
  - Kuibit: https://sbozzolo.github.io/kuibit/
  - Visit: https://visit-dav.github.io/visit-website/
  - YT: http://yt-project.org/
- Every year workshops and (sometimes) schools are organized in EU and USA:
  - EU – 8-12 July 2024 at the University of Amsterdam, Netherlands
  - USA – 3-7 June 2024 at the Louisiana State University, Baton Rouge, Louisiana (hybrid)

- Open source framework
  - Decentralized code development
  - Active and friendly user community
  - Module based approach

- Infrastructure modules
  - Parameter file handling
  - Parallelization (MPI + OpenMP)
  - Adaptive Mesh refinement (Carpet)
  - IO (ASCII and HDF5) + checkpointing

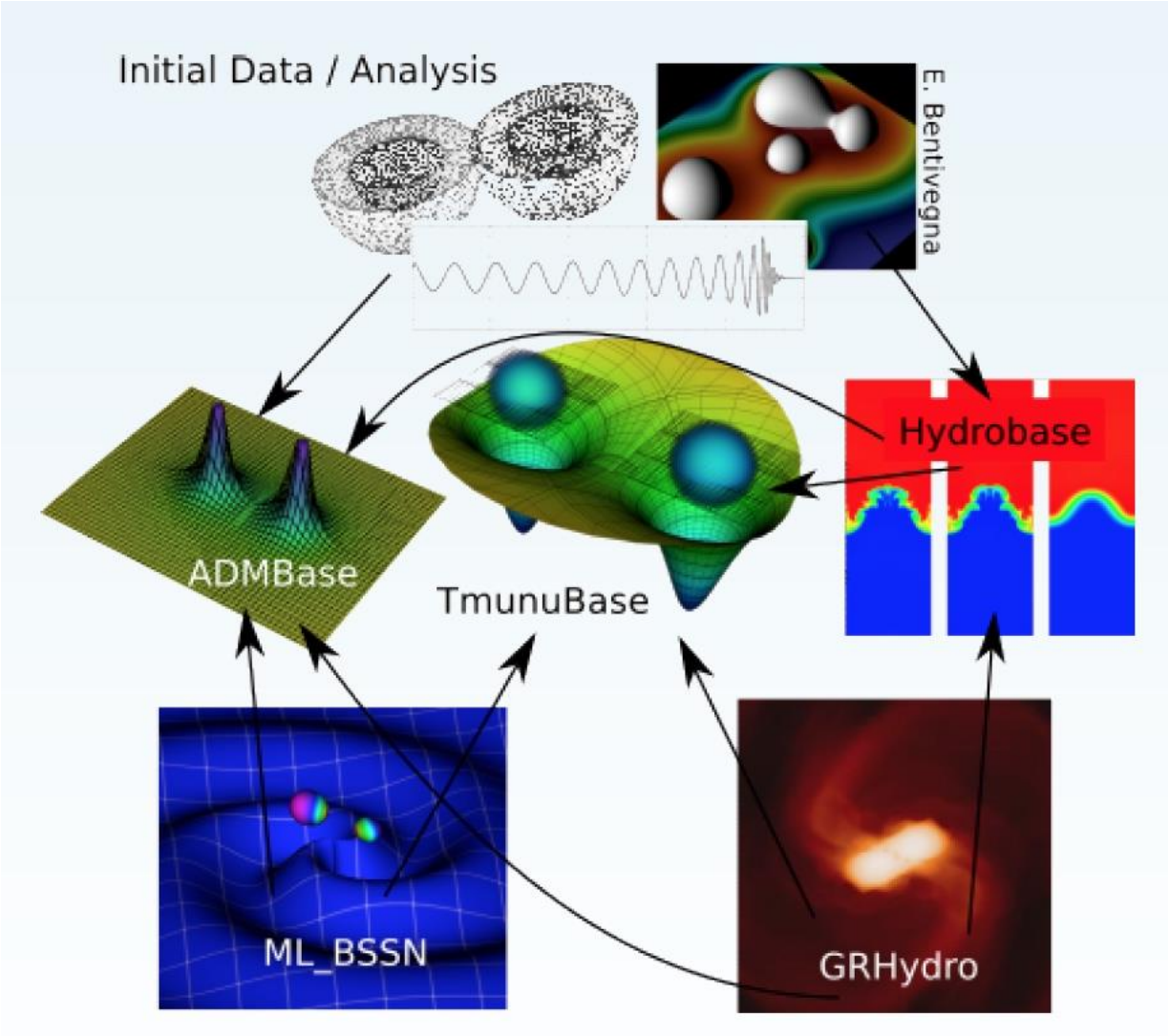
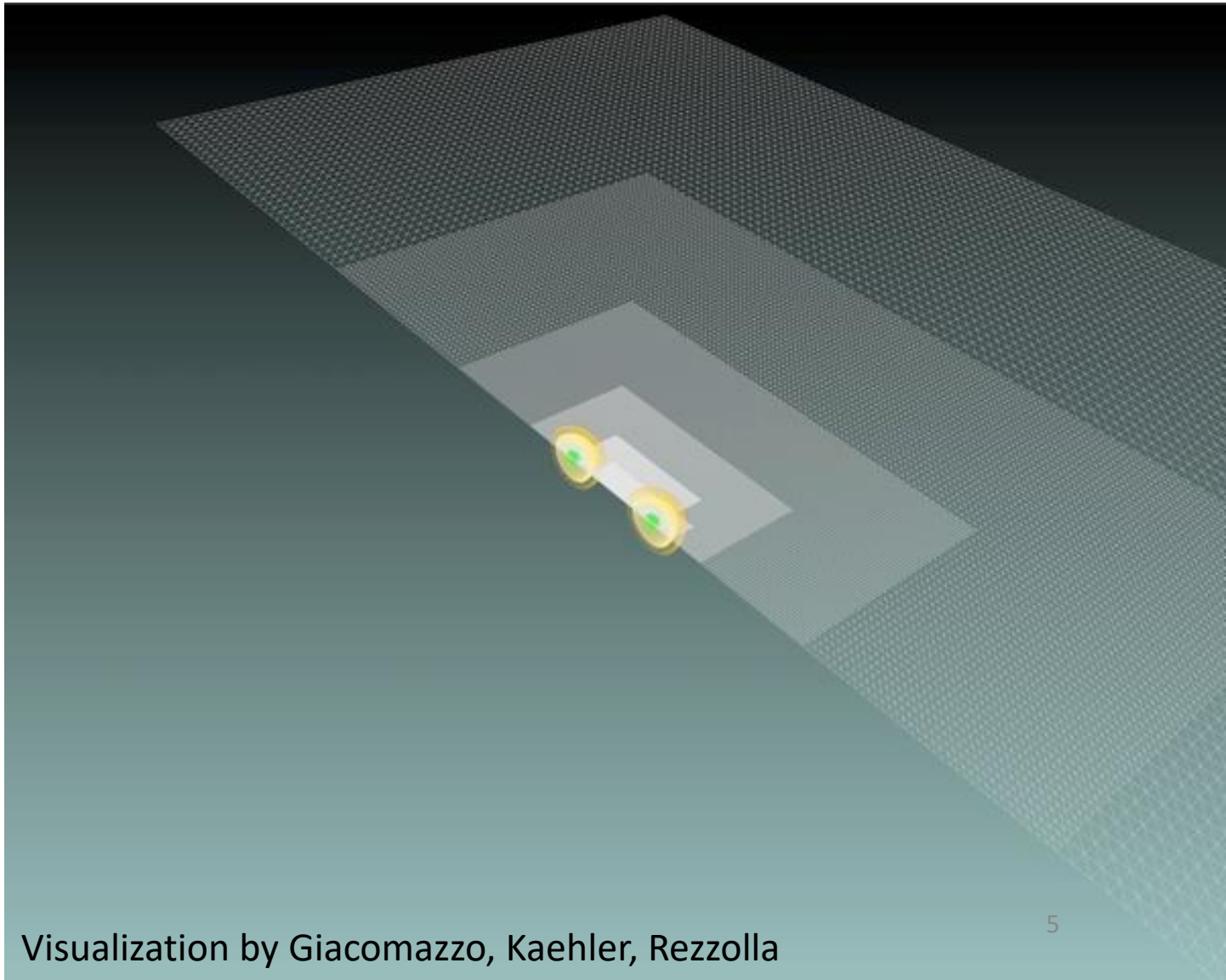


Figure by R. Haas

Adaptive Mesh Refinement Driver (Carpet)

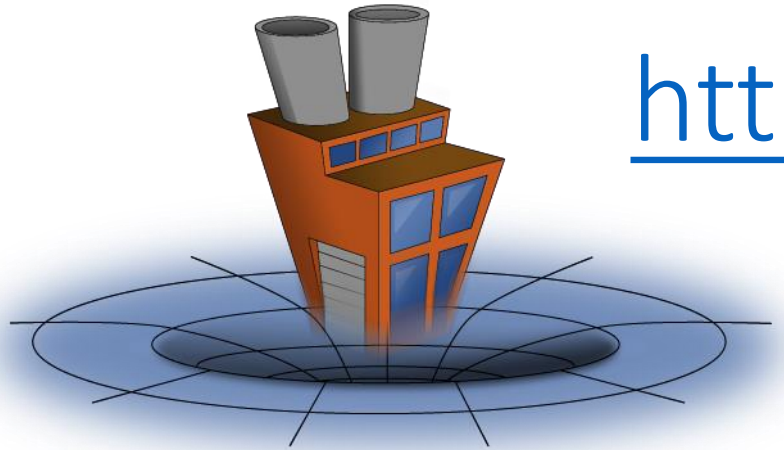
- Carpet provides box-in-box mesh refinement
- It is included in the toolkit



Visualization by Giacomazzo, Kaehler, Rezzolla

SimFactory

http://simfactory.org



Command-line tools for setting up Cactus distribution and managing simulations on a variety of supercomputers, including PRACE machines.

McLachlan

- Produced using the KRANC code: http://kranccode.org

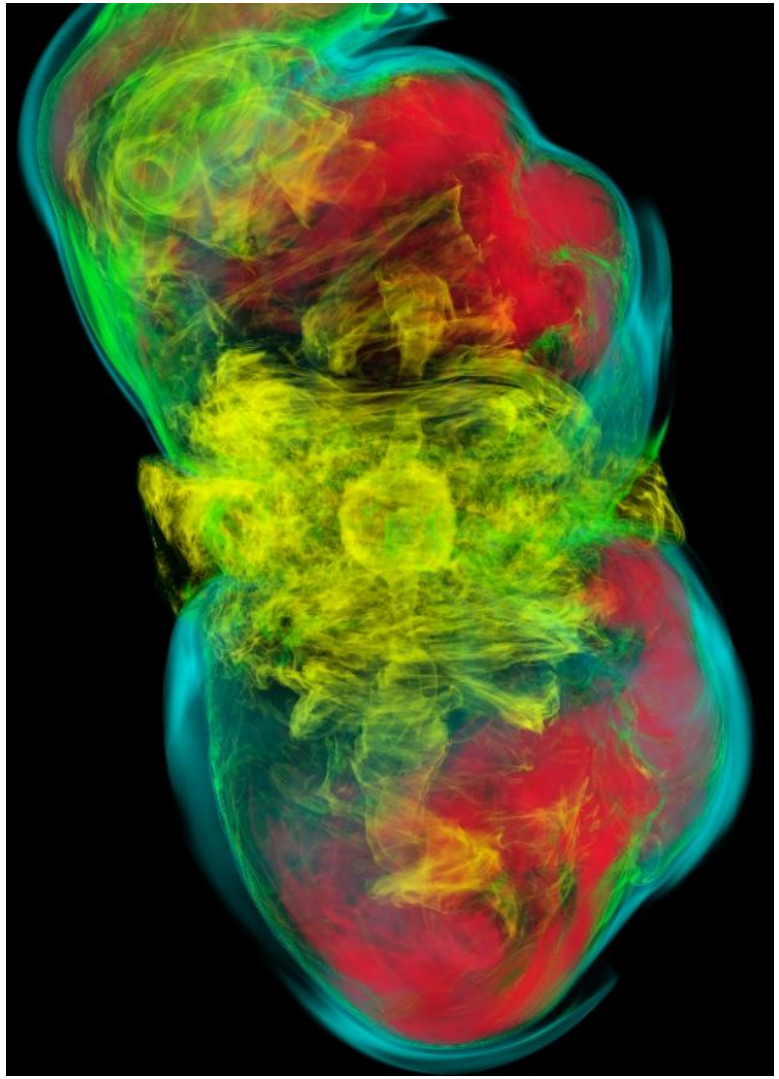
- Can solve Einstein Equations using different formulations (BSSN and Z4)
- Implement finite difference schemes up to 8^{th} order
- Implements singularity-avoiding slicing conditions

Baykal

- a spacetime evolution code using NRPy+ (https://nrpyplus.net/) for code generation

- BaikalVacuum, a version of Baikal optimized for vacuum only simulations

GRHYDRO



Moesta et al 2013: http://arxiv.org/abs/1304.5544

- First publicly available fully GRMHD code
- Based on the public version of the Whisky code
- Fully embedded in the Einstein Toolkit
- Uses Valencia formulation
- Implements up to 5^{th} order reconstruction
- Divergence cleaning and Constrained Transport

IllinoisGRMHD

- First publicly available fully GRMHD code using the vector potential as evolution variable
- Very robust code for GRMHD in AMR
- Implements only PPM+HLLE
- Included in the Einstein Toolkit

http://math.wvu.edu/~zetienne/ILGRMHD/index.html

Spritz

Cipolletta, Kalinani, Giacomazzo, Ciolfi, Sala, Giangrandi, Giudici

- A new GRMHD code based on WhiskyMHD
- Vector potential formulation with staggered Avec
- Support for several EOSs, including tabulated ones, via EOSOmni
- It can be used with ZelmaniLeak for neutrino transport
- It includes the best aspects of WhiskyMHD, IllinoisGRMHD, and GRHydro in one code
- Up to 5^{th} order convergence

REFERENCES

- Loeffler et al 2012, **The Einstein Toolkit**: a community computational infrastructure for relativistic astrophysics, CQG 29, 115001

- Moesta et al 2014, **GRHydro**: A new open source general-relativistic magnetohydrodynamics code for the Einstein Toolkit, CQG 31, 015005

- Etienne et al 2015, **IllinoisGRMHD**: an open-source, user-friendly GRMHD code for dynamical spacetimes, CQG 32, 175009

- Cipoletta et al 2020, Cipolletta et al 2021, **Spritz**: a new fully general-relativistic magnetohydrodynamic code, CQG: https://doi.org/10.5281/zenodo.3689751