Einstein Toolkit summer school 2021

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2021-07-26

ILLINOIS

National Center for Supercomputing Applications
University of Illinois at Urbana–Champaign

NCSA

Logistics

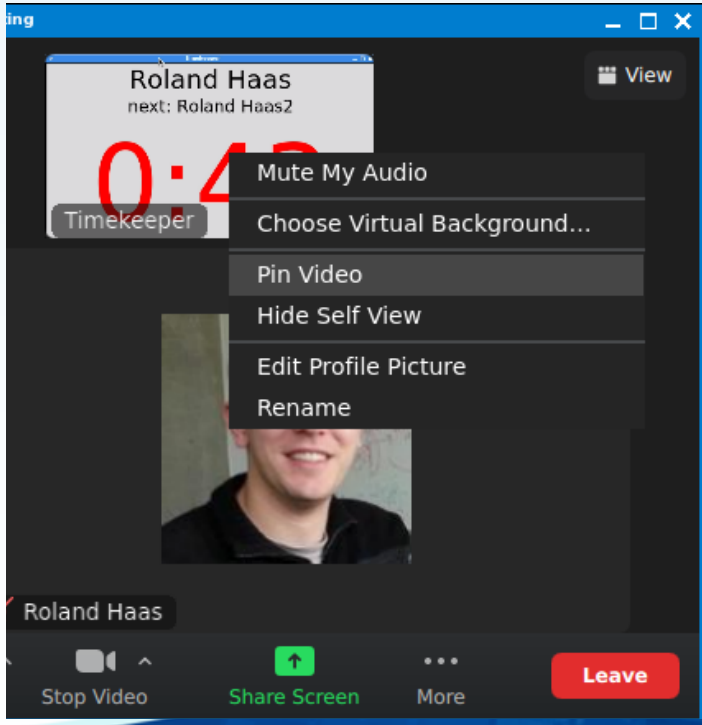
- all virtual summer school
  - 29X registered participants
  - spanning 14 time zones
- connecting
  - via Zoom: information contained in welcome emails to registered participants. Please **do not share** the included link..
  - YouTube stream (active each day): https://go.illinois.edu/et2021uiuc Please **do share** as much as possible.
    - **30 second delay** to Zoom stream
- participate!
  - if on Zoom, please unmute and ask questions
  - or via chat, moderator will read questions to speaker
    - Zoom
    - Gitter: https://gitter.im/EinsteinToolkit/workshop
    - YouTube chat
- recordings
  - we are recording the presentations
  - will be available after the workshop
  - slides will be made available if possible

link

Program

- available on school website: https://einsteintoolkit.github.io/et2021uiuc/program.html
  - scroll down to “Per-day schedules” for detailed time and speaker information
  - presentation pages contain links to recordings, slides, extra material (if available)
- 20min break at around 11am CDT
- tutorial server is https://etk1.cct.lsu.edu signup code will be shared in Zoom chat and on screen during lunch break

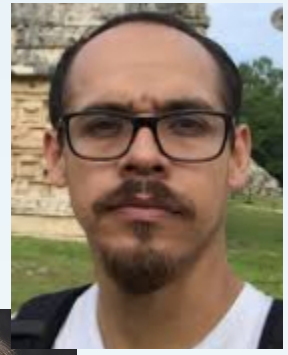
- timekeeper
  - keeps time, may tells you if you are out of time
  - can “Pin” to keep in view, useful for speakers
- help sessions
  - before and after each day
  - same Zoom meeting
  - ask anything you like

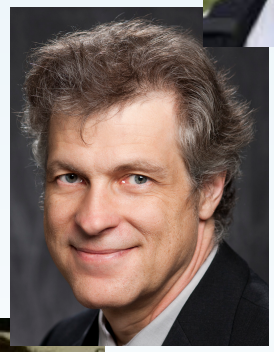


If you are a speaker

- thank you!
- expect questions
- please stay on time, we have no way of creating fresh seconds to make up for lost minutes
  - your allocated time slot includes setup and question time, no extra time is provided for either one of these
  - your session chair will give you updates about your remaining time during your presentation
  - you **will** be muted and your screen share stopped when your time is up
- lightning talks
  - 9 minutes per talk, **including setup and questions** at the end
  - if you encounter technical problems you can ask to be moved to the end of the session and use your **remaining** time then
  - you will receive warnings at the 7, 8, 8:30 minute mark (and when you are muted)
- recordings
  - will be available after the workshop
  - slides will be made available if possible

If you need help





- workshop@einsteintoolkit.org
- Miguel Gracia, who handles the website
- Steve Brandt, who maintains the tutorial cluster
- Samuel Cupp, who beta-tested the tutorials
- the scientific organization committee: Steven R. Brandt, Zachariah Etienne, Roland Haas, Philipp Moesta, Helvi Witek, Yosef Zlochower

- general ET questions
  - the ET mailing list users@einsteintoolkit.org
  - the tutorial help sessions
- on lectures
  - the tutorial help sessions, we will ask the speakers to hang around
  - email the speakers
- about Zoom
  - please test your system before joining
  - please make sure you are logged in to a Zoom account

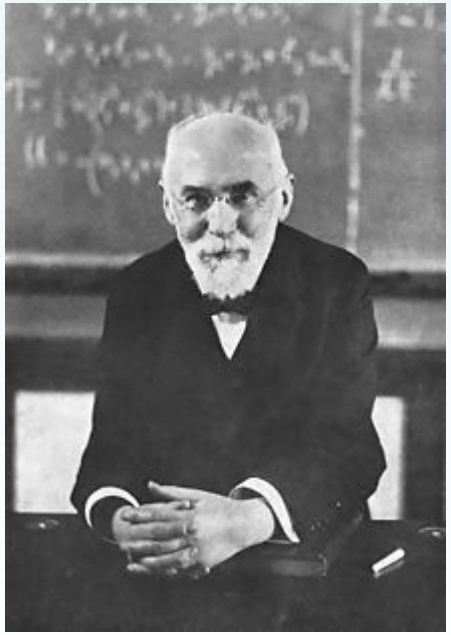
Einstein toolkit

- Goals
  - community-driven
    - mailing list
    - wiki, bug tracker
  - build and enable an active community of user-developers
  - core computational tools for relativistic astrophysics and gravitational physics
- Components
  - Cactus thorns for GW science
  - Simulation factory
  - GetComponents component retrieval tool
  - Kranc
  - Waveform analysis

- Guiding principles
  - Open, community-driven software development
  - Well thought out and stable interfaces
  - Separation of physics software from computational science infrastructure
  - complete working production codes
- does not itself develop codes
  - codes are proposed for inclusion, then reviewed
  - must be of current interest for the community

“Lorentz” release

- named after Hendrik Lorentz
- 21[1st] release on 2021-05-31
- release team:
  - Zachariah B. Etienne
  - Roland Haas
  - Steven R. Brandt
  - William E. Gabella
  - Peter Diener
  - Atul Kedia
  - Miguel Gracia
  -



- first release with Zachariah Etienne as release manager
- POWER, a Python package to post-process the data products of simulations to compute the gravitational wave strain at future null infinity.
- Simfactory fully compatible with Python 2 or 3.
-

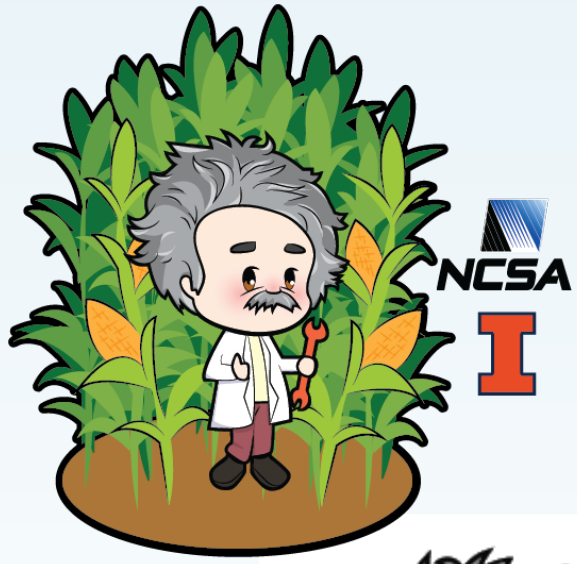
```
In [ ]: %cd ~/

In [ ]: !curl -kLO https://raw.githubusercontent.com/gridaphobe/CRL/E
        !chmod a+x GetComponents
```

GetComponents accepts a thorn list as an argument. To check out the needed components:

Einstein Toolkit workshops

- Summer school at UIUC, 2021
  - this meeting
  - 290+ workshop participants
  - diverse program and tutorials and contributed talks
  - many international participants
- Summer school at LSU, 2020
  - 160 participants
  - first all virtual Einstein Toolkit summer school
  - all presentations available on YouTube
- Presentations on CarpetX and NRPy+ at ICERM summer school, 2021



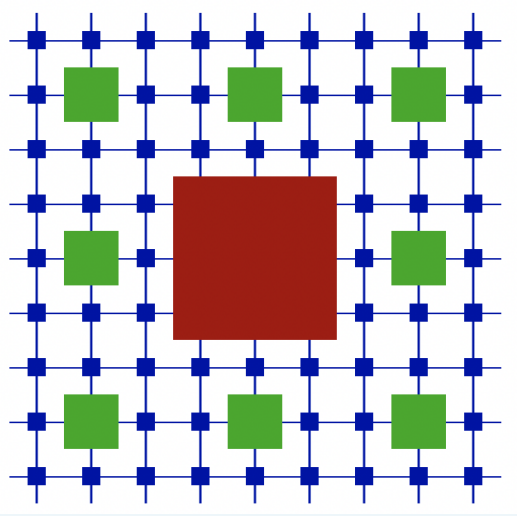
einstein toolkit

A community-driven software platform supporting astrophysics and gravitational physics

NCSA

Current and future developments

CarpetX – a new mesh refinement driver for numeric relativity



- Designed for the Einstein Toolkit
- True adaptive mesh refinement based on local error estimate
- High-order prolongation/ restriction operators
- Vertex/cell/face/edge-centred variables
- Refluxing for exact conservation in (M)HD
- can currently run a qc0 BBH merger
- see presentations by Don Willcox and Erik Schnetter

- Uses AMReX
- for Exascale scalability
- Much improved multi-threading
- Much improved I/O speed (ADIOS2, openPMD)
- Improved SIMD vectorization
- Works with GPUs (CUDA)

NRPy+ code generation

- NRPyLaTeX provides a robust LaTeX interface for sympy, enabling easy input of complex tensorial expressions relevant to general relativity anddifferential geometry.
- LaTeX = typesetting language; thus not designed to resolve ambiguities in mathematical expressions
  - To address, NRPyLaTeX implements configuration interface defines variables/keywords and assigns properties/attributes to them.
  - Config. commands appear as LaTeX comments, enabling NRPyLaTeX-compatible mathematical expression notebooks to fit seamlessly into scientific papers source codes
- See presentation by Leo Werneck

- Adopts NRPy's tensor syntax, enabling NRPyLaTeX->optimized C-code kernels with NRPy+
- Robust and user-friendly error-handling, catching common tensor indexing errors and enabling quick resolution of math ambiguities

```
\begin{align}
    % keydef basis [t, r, \theta, \phi]
    % vardef -const 'G', 'M'
    % vardef -zero 'gDD' (4D)  %% initialize every component of gDD to zero
    g_{t t} &= -\left(1 - \frac{2GM}{r}\right) \\ %% g_{t t} = g_{0 0}
    g_{r r} &=  \left(1 - \frac{2GM}{r}\right)^{-1} \\
    g_{\theta\theta} &= r^2 \\
    g_{\phi\phi} &= r^2 \sin^2\theta \\
    % assign -metric 'gDD'  %% inverse gUU, determinant det(gDD), and connection GammaUDD
    R^\alpha{}_{\beta\mu\nu} &= \partial_\mu \Gamma^\alpha_{\beta\nu} - \partial_\nu \Gamma^\
        alpha_{\beta\mu} + \Gamma^\alpha_{\mu\gamma} \Gamma^\gamma_{\beta\nu} - \Gamma^\alpha_
        {\nu\sigma} \Gamma^\sigma_{\beta\mu} \\
    R_{\beta\nu} &= R^\alpha{}_{\beta\alpha\nu} \\
    R &= g^{\beta\nu} R_{\beta\nu} \\
    G_{\beta\nu} &= R_{\beta\nu} - \frac{R}{2} g_{\beta\nu} \\
    K &= R^{\alpha\beta\mu\nu} R_{\alpha\beta\mu\nu} %% automatic index raising & lowering
\end{align}
```

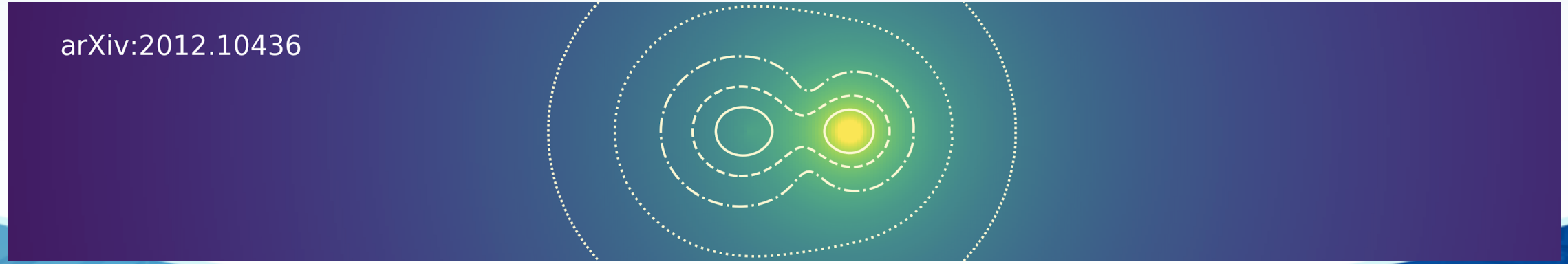
Figure 1: Schwarzschild Solution — Einstein's Equations

Canuda code library

- Open-source library for fundamental physics and strong-field tests of gravity
- Authors: H. Witek, M. Zilhao, M. Elley, G. Ficarra, H. O. Silva

below: Gauss-Bonnet scalar field sourced by a head-on collision of black holes.

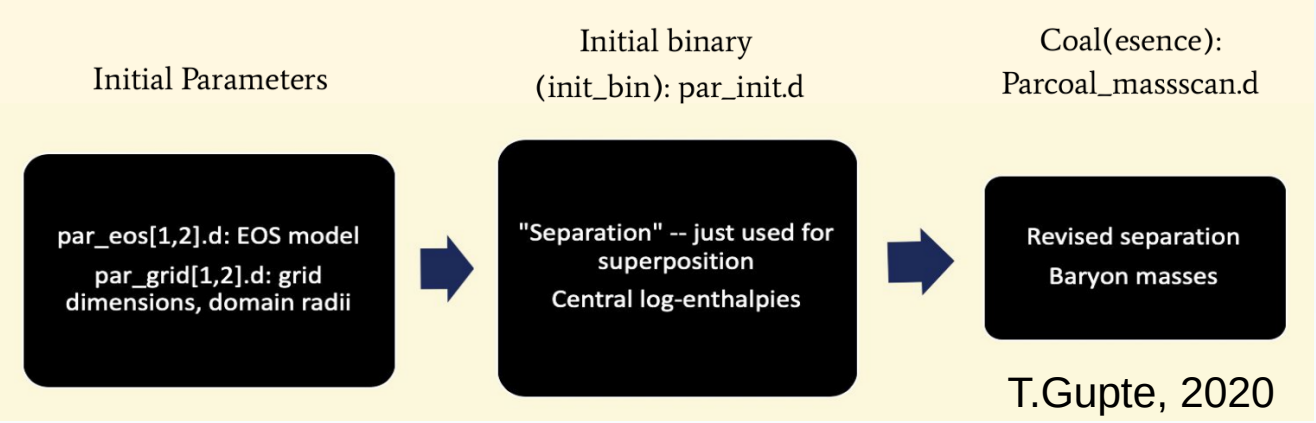
- lean_public (GR Evolution using BSSN, in Einstein Toolkit
- Proca (Massive vector fields, in Einstein Toolkit)
- scalar (Massive scalar fields)
- Canuda_EdGB_dec (Scalar Gauss-Bonnet gravity in decoupling approximation)

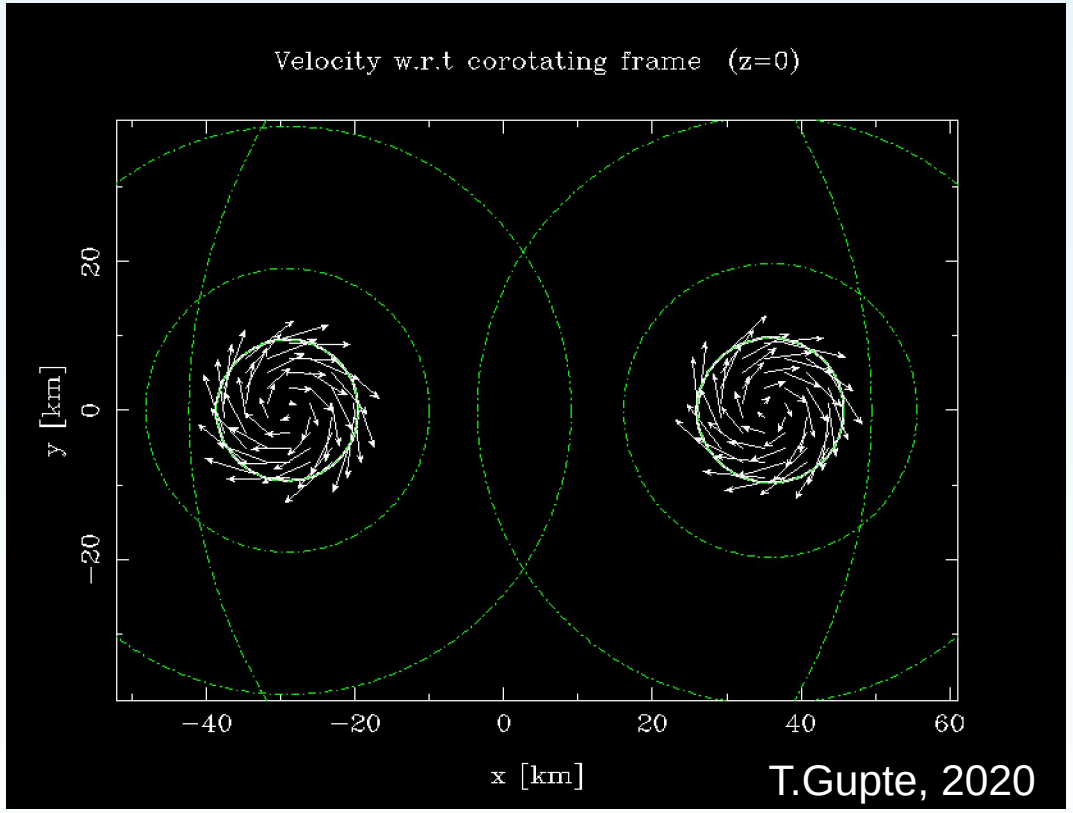


H. O. Silva, H. Witek, M. Elley and N. Yunes,
Phys. Rev. Lett. 127 (2021) no.3, 031101

Binary neutron star initial data library

- Tanmayee Gupte and Joshua Faber (both RIT) are continuing to release data and documentation into a public BNS initial data library





- See presentation by Joshua Faber and Atul Kedia

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