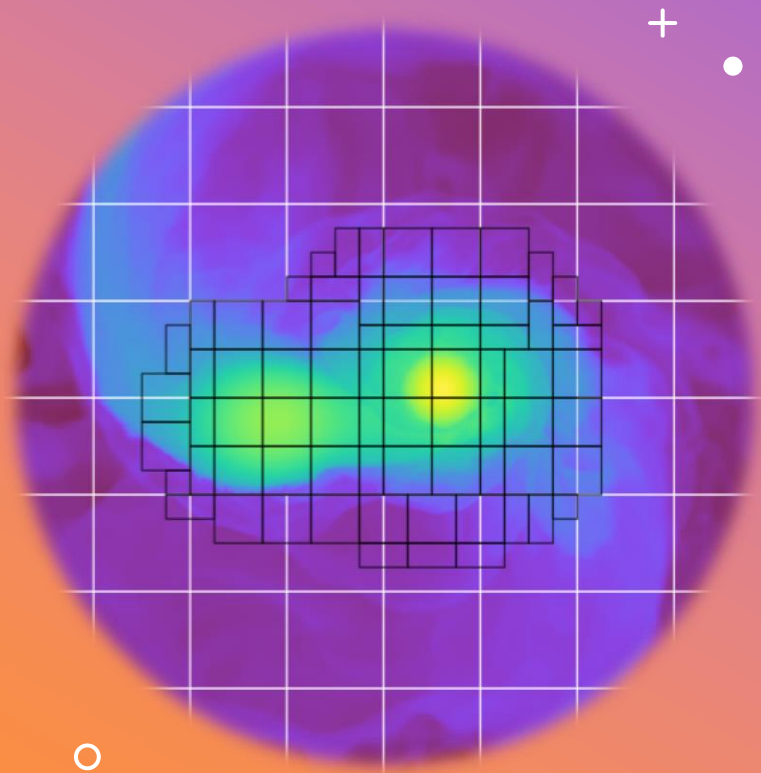
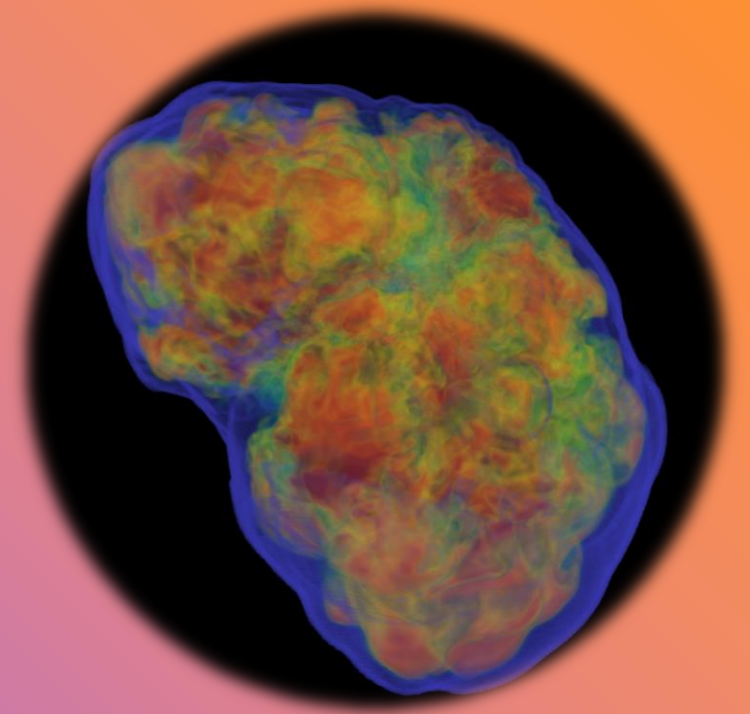


HPC AND ASTROPHYSICS

CS 455 - Introduction to High
Performance Computing
Eddie Federmeyer



ASTROPHYSICS



A vertical bar on the left side of the slide with a gradient from orange at the top to blue at the bottom.

WHY ASTROPHYSICS NEEDS HPC

- Simulations involve billions of particles and millions/billions of years
- Includes physics like gravity, thermodynamics, and radiation
- Observational data (e.g., from James Webb Telescope) provide massive datasets
- HPC enables feasible computation + rich visualizations



MPI – THE TRADITIONAL BACKBONE

Advantages:

- Suited for distributed memory systems
- Widely adopted and used by major codebases:
 - FLASH
 - CASTRO
 - GAMRA

Challenges:

- Synchronization overhead
- Load imbalance in adaptive simulations



HPX – A MODERN ALTERNATIVE

Advantages:

- No global synchronization barriers
- Dynamic task scheduling gives better load balancing
- Global address space simplifies distributed programming
- Scales well for irregular, adaptive workloads

Challenges:

- Steeper learning curve compared to MPI
- Less mature ecosystem and smaller user base
- May not always outperform MPI for regular workloads
- Debugging asynchronous tasks can be more complex




APPLICATIONS



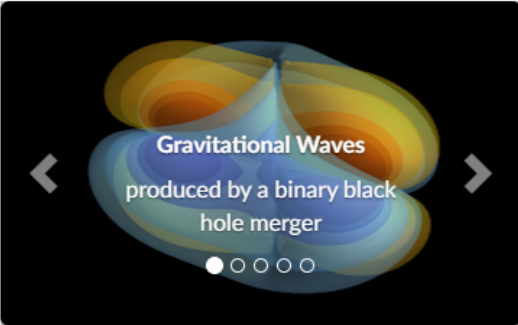
NEUTRON STAR MERGERS

- Extremely dense stellar remnants
- Mergers emit gravitational waves
- HPC simulations help interpret data from LIGO, Virgo
- Requires modeling nuclear densities & relativistic physics

 **einstein toolkit**

Home About Download Documentation Help! Contribute Gallery

The Einstein Toolkit



Gravitational Waves
produced by a binary black
hole merger

Gallery

Get Started

If you have never used the Einstein Toolkit before, we provide a [tutorial](#) to get started. You can also download the [latest release](#) and learn about [visualize](#) your simulations.

First steps Download

Documentation

A lot of the documentation within the Einstein Toolkit is generated from comments in the source code, and more can be found on the Einstein Toolkit Wiki or other documents. We provide links to guides, tutorials and references.

Documentation Wiki

North American Einstein Toolkit Workshop and Meeting 2025

The [North American Einstein Toolkit Meeting](#) will take place from 09 - 13 June 2025 at the University of Texas at Austin in Austin, Texas.

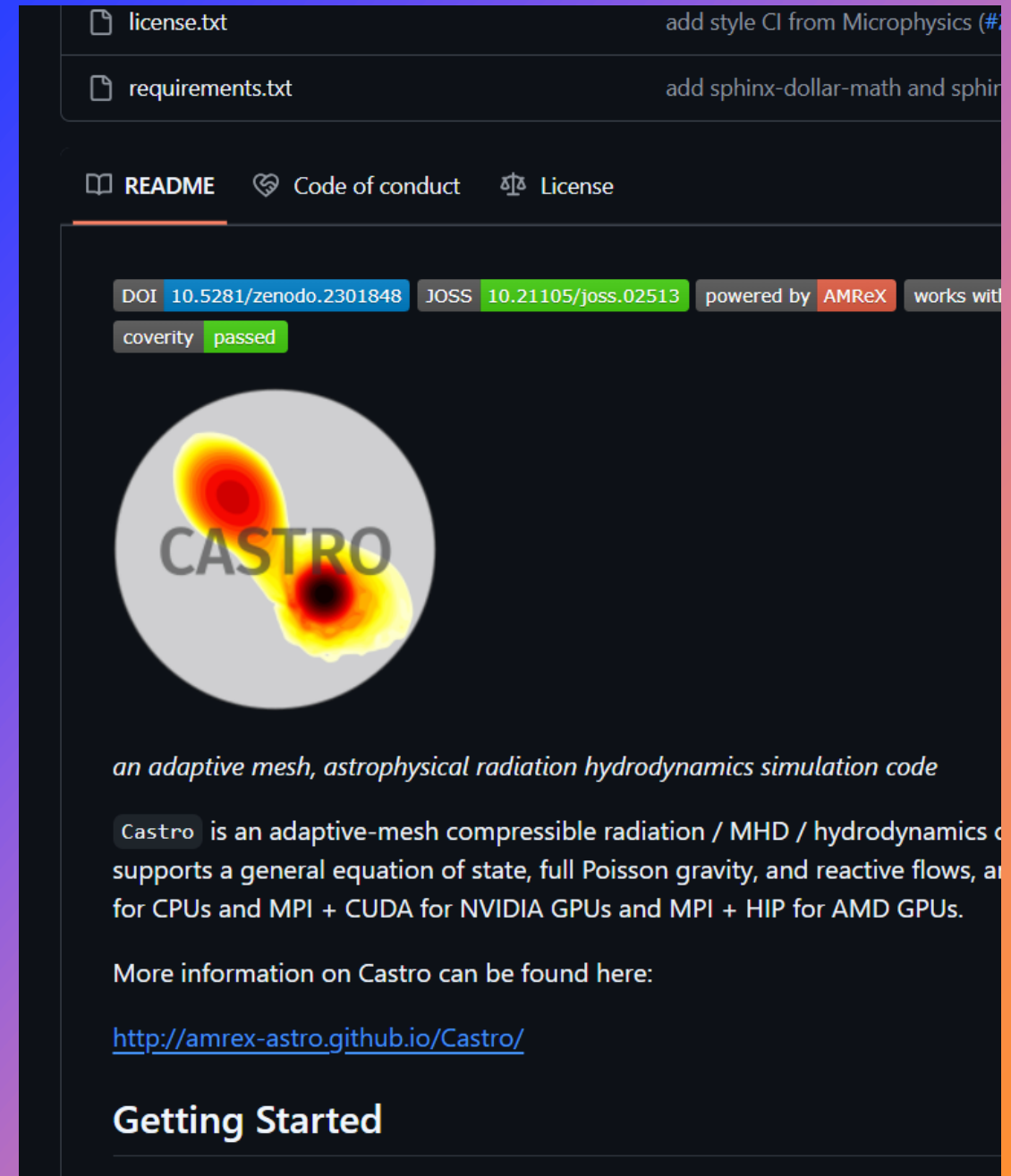
Registration will open soon.

The Einstein Toolkit is a community-driven software platform of core computational tools to advance and support research in relativistic astrophysics and gravitational physics. The conference consists of a mixture of tutorials for new users and talks about the latest developments both in the toolkit and the larger scientific community.

The Einstein Toolkit has been supported by NSF [2004157/2004044/2004311/2227105/2004879/2003893/2114582](#). Any opinions, findings, conclusions, or recommendations of the author(s) and do not necessarily reflect the views of the National Science Foundation.

SUPERNOVA & MHD

- Complex, energetic stellar deaths
- Simulations include:
 - Neutrino transport
 - Magnetohydrodynamics (MHD)
 - General relativity



The screenshot shows the GitHub repository page for the Castro project. At the top, there are links to 'license.txt' and 'requirements.txt'. Below these are links to 'README', 'Code of conduct', and 'License'. A row of badges includes 'DOI 10.5281/zenodo.2301848', 'JOSS 10.21105/joss.02513', 'powered by AMReX', and 'works with'. A 'coverity passed' badge is also visible. The main image is a circular logo featuring a supernova simulation with the word 'CASTRO' overlaid. Below the logo, the text reads 'an adaptive mesh, astrophysical radiation hydrodynamics simulation code'. A paragraph describes Castro as an adaptive-mesh compressible radiation / MHD / hydrodynamics code that supports a general equation of state, full Poisson gravity, and reactive flows, available for CPUs and MPI + CUDA for NVIDIA GPUs and MPI + HIP for AMD GPUs. A link to 'http://amrex-astro.github.io/Castro/' is provided. The section 'Getting Started' is partially visible at the bottom.

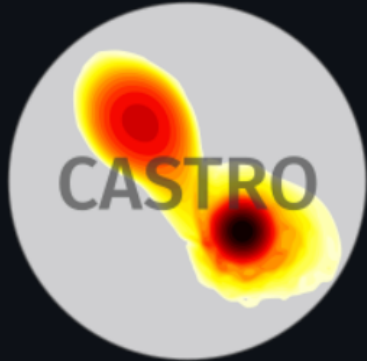
license.txt add style CI from Microphysics (#2

requirements.txt add sphinx-dollar-math and sphin

README Code of conduct License

DOI 10.5281/zenodo.2301848 JOSS 10.21105/joss.02513 powered by AMReX works with

coverity passed



an adaptive mesh, astrophysical radiation hydrodynamics simulation code

Castro is an adaptive-mesh compressible radiation / MHD / hydrodynamics c supports a general equation of state, full Poisson gravity, and reactive flows, an for CPUs and MPI + CUDA for NVIDIA GPUs and MPI + HIP for AMD GPUs.

More information on Castro can be found here:

<http://amrex-astro.github.io/Castro/>

Getting Started

BLACK HOLES & STELLAR MERGERS

- Simulations explore:
 - Accretion disks
 - Binary interactions
 - Gravitational wave emission
- Octo-Tiger uses AMR and **HPX** to simulate stellar mergers

README.mdRemove the build scripts

build_octotiger.shFixed sign


READMECode of conductBSL-1.0 license

Octo-Tiger

code qualityA

CITATION.cffno status

DOI10.5281/zenodo.8303735



From <https://doi.org/10.1145/3204919.3204938>:

Octo-Tiger is an astrophysics program simulating the evolution of star systems using the adaptive Octrees method on adaptive Octrees. It was implemented using high-level C++ libraries that allows its use on different hardware platforms.

Build Status [master]

Jenkins - All CPU / GPU node-level tests for the 8 major build configurations

CPU/GPU Tests with Kokkos, CUDA, HIP, SYCL	CPU / GPU Node-Level Tests
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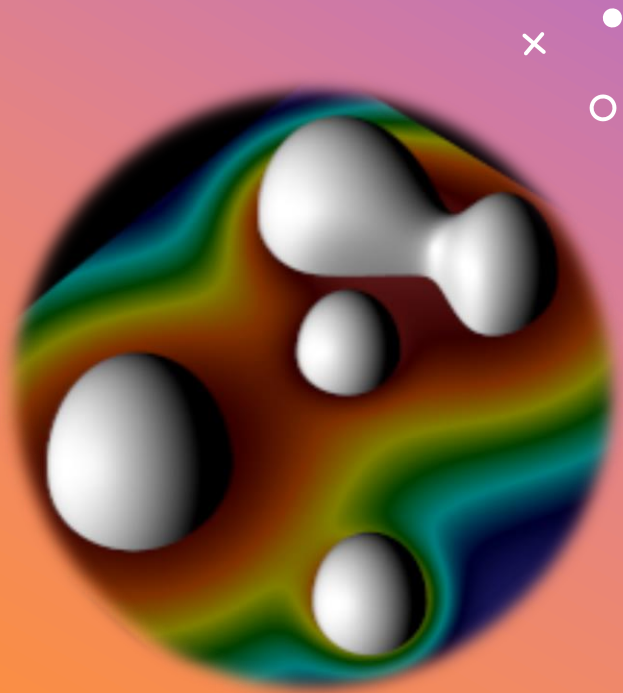
Jenkins - Special machine tests:

+

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○

THE FUTURE



THANK YOU

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[LinkedIn.com/in/eddiefed](https://www.linkedin.com/in/eddiefed)