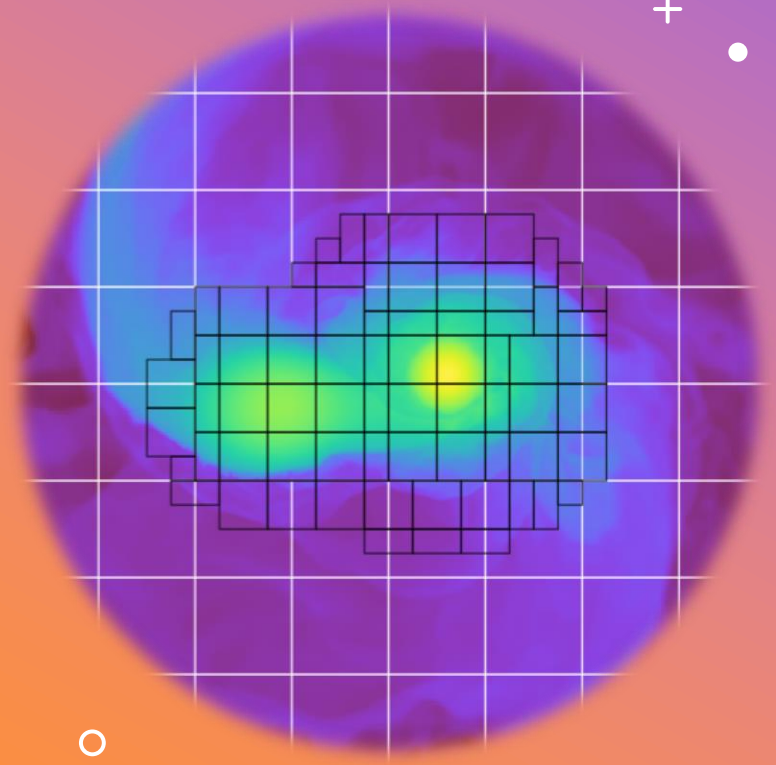
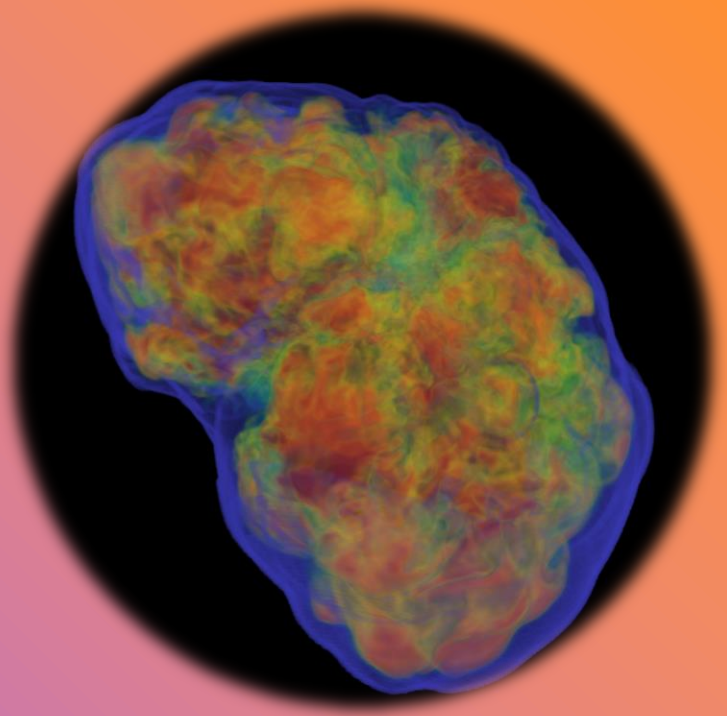


HPC AND ASTROPHYSICS

CS 455 - Introduction to High Performance Computing

Eddie Federmeyer

ASTROPHYSICS



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

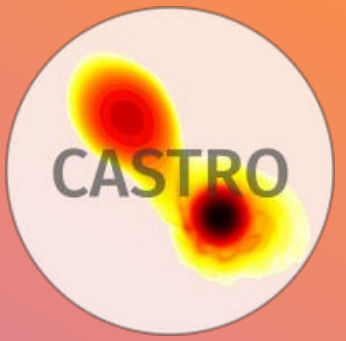
HPX – A MODERN ALTERNATIVE

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:

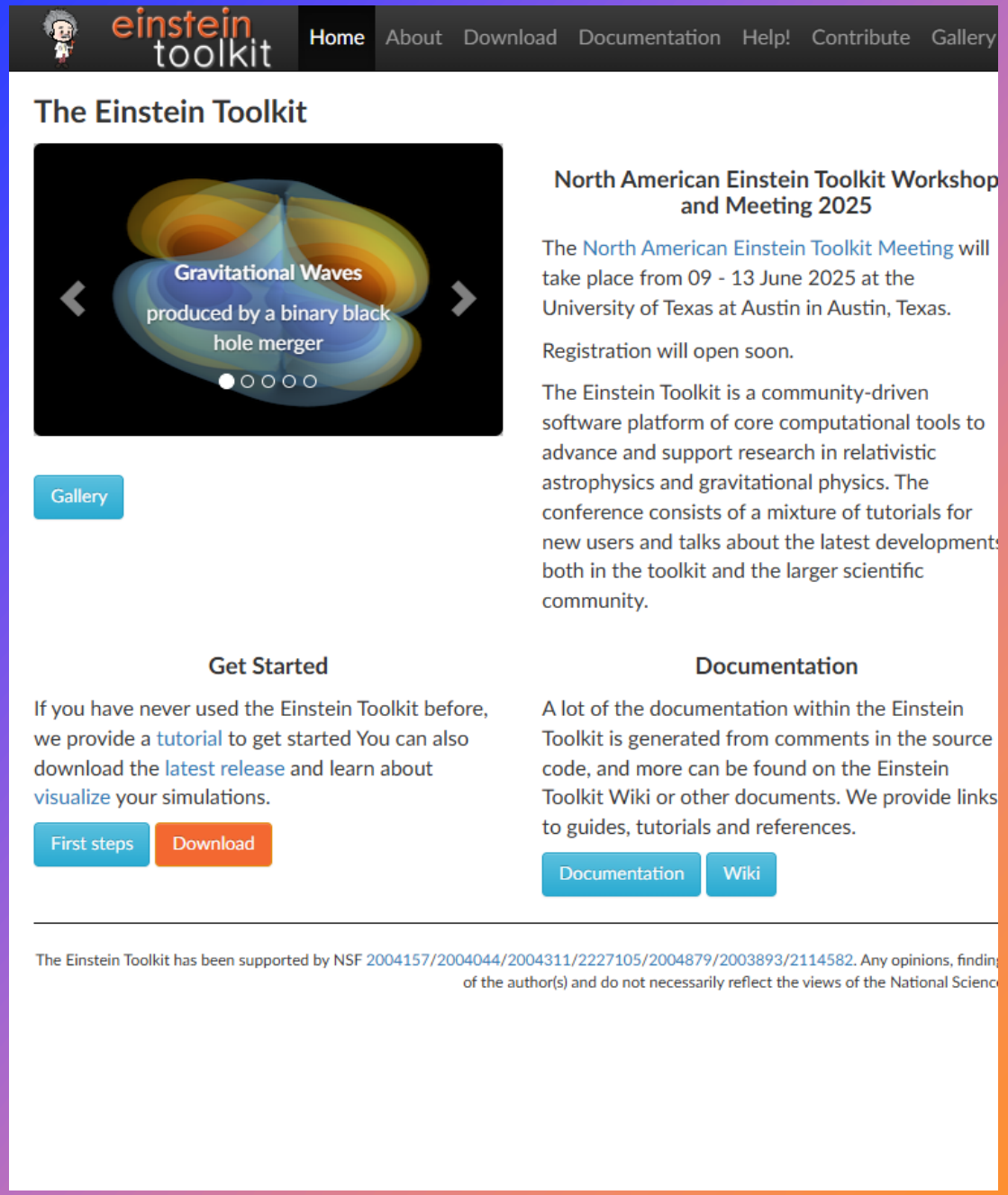
- Steeper learning curve compared to MPI
- Less mature ecosystem and smaller user base
- May not always outperform MPI for regular workloads
- Debugging asynchronous tasks can be more complex



APPLICATIONS

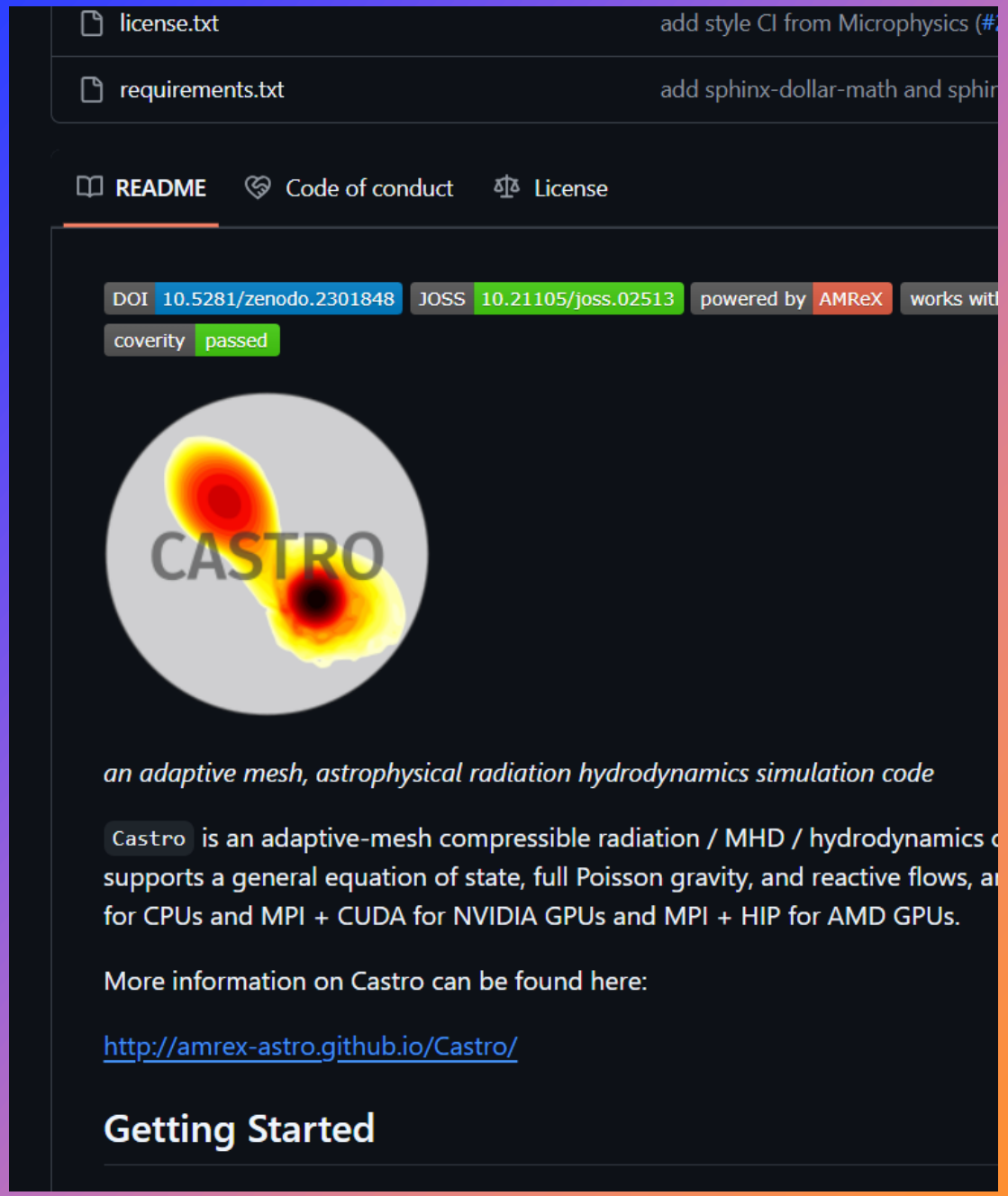
NEUTRON STAR MERGERS

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



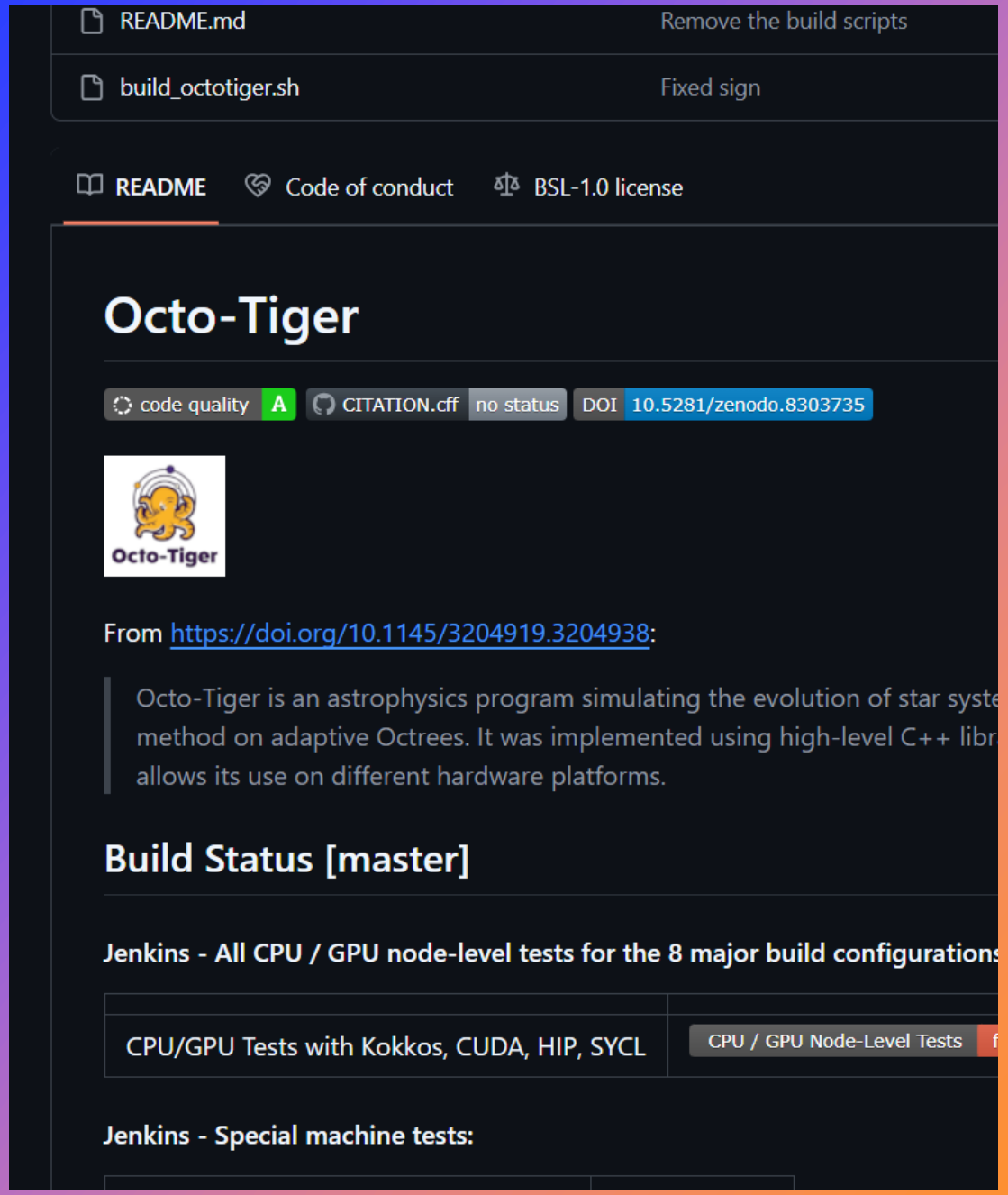
SUPERNOVA & MHD

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



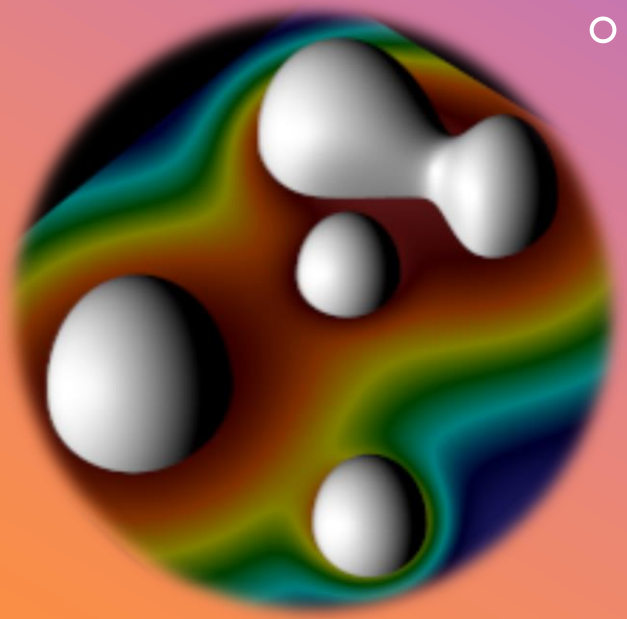
BLACK HOLES & STELLAR MERGERS

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



THE FUTURE

THANK YOU



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