White Dwarf Mergers as Supernova Progenitors

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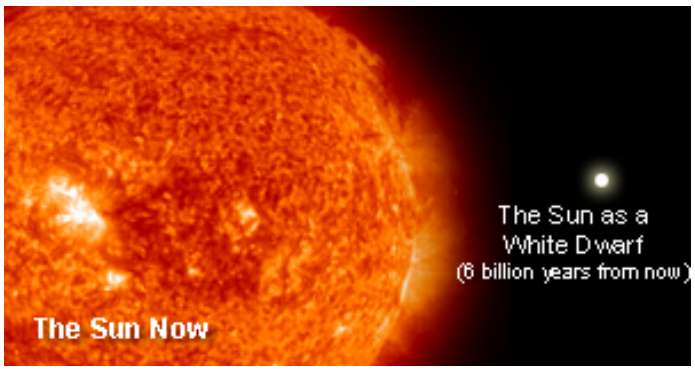
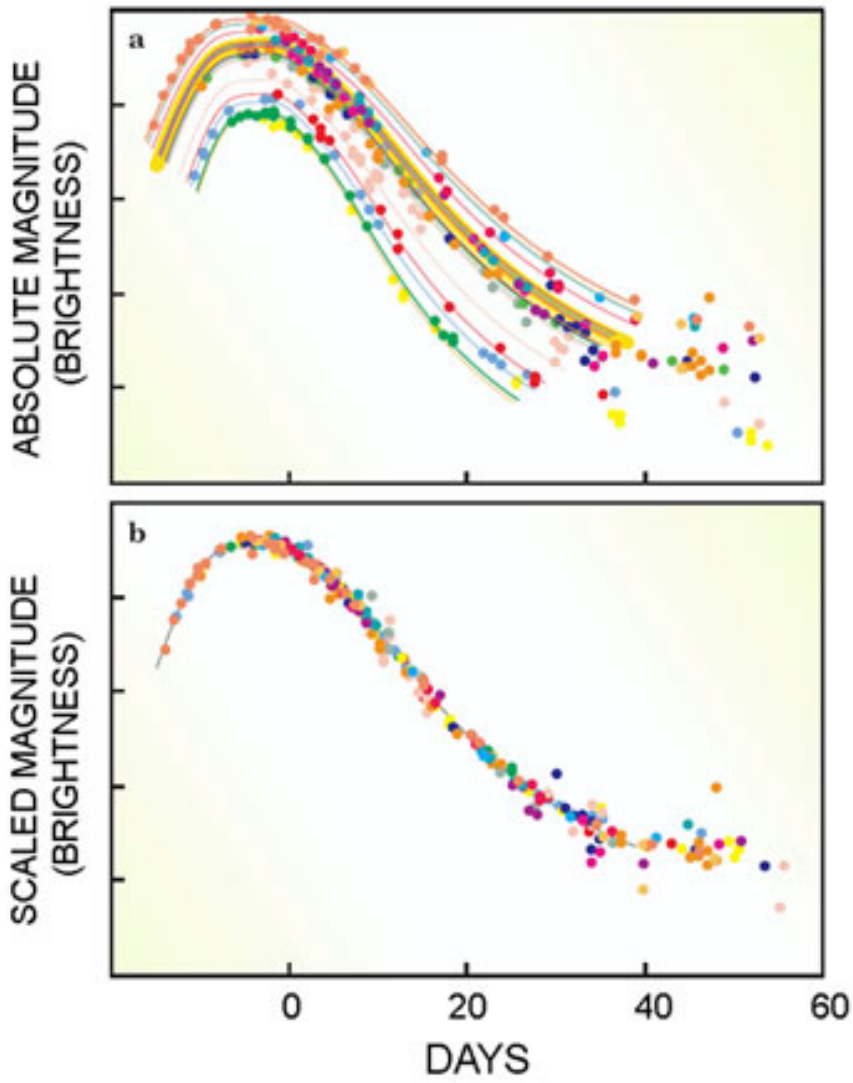
Beacons in the cosmic dark

- Brilliant bursts of light that can outshine galaxies
- Nearly uniform brightness
- Dark energy discovery (1998) due to Type Ia supernovae
- Caused by explosions of white dwarfs, but how?



Credit: Chandra



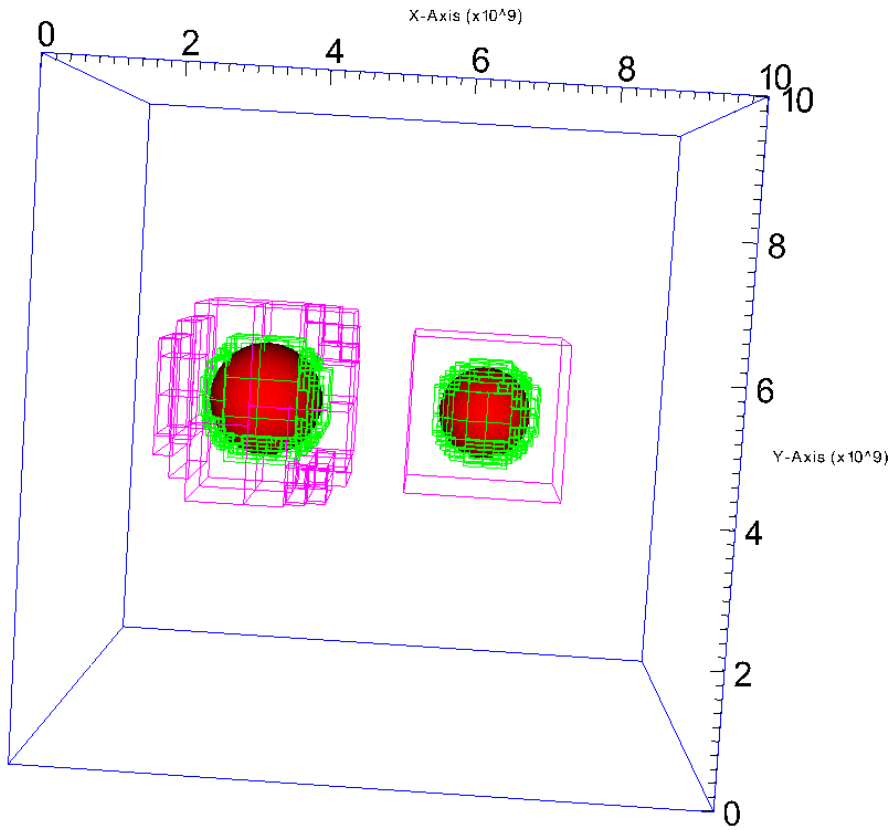
Credit: Science@Berkeley Lab

Mergers of white dwarfs

Credit: NASA / CXC / A. Hobart

Simulating mergers of white dwarfs

- Install equilibrium stellar model on three-dimensional grid or particles
- Apply damping to simulate gravitational radiation
- See if it gets hot enough to cause a nuclear detonation
- If so, does the explosion look like what we see?



CASTRO

CENTER FOR COMPUTATIONAL SCIENCES AND ENGINEERING

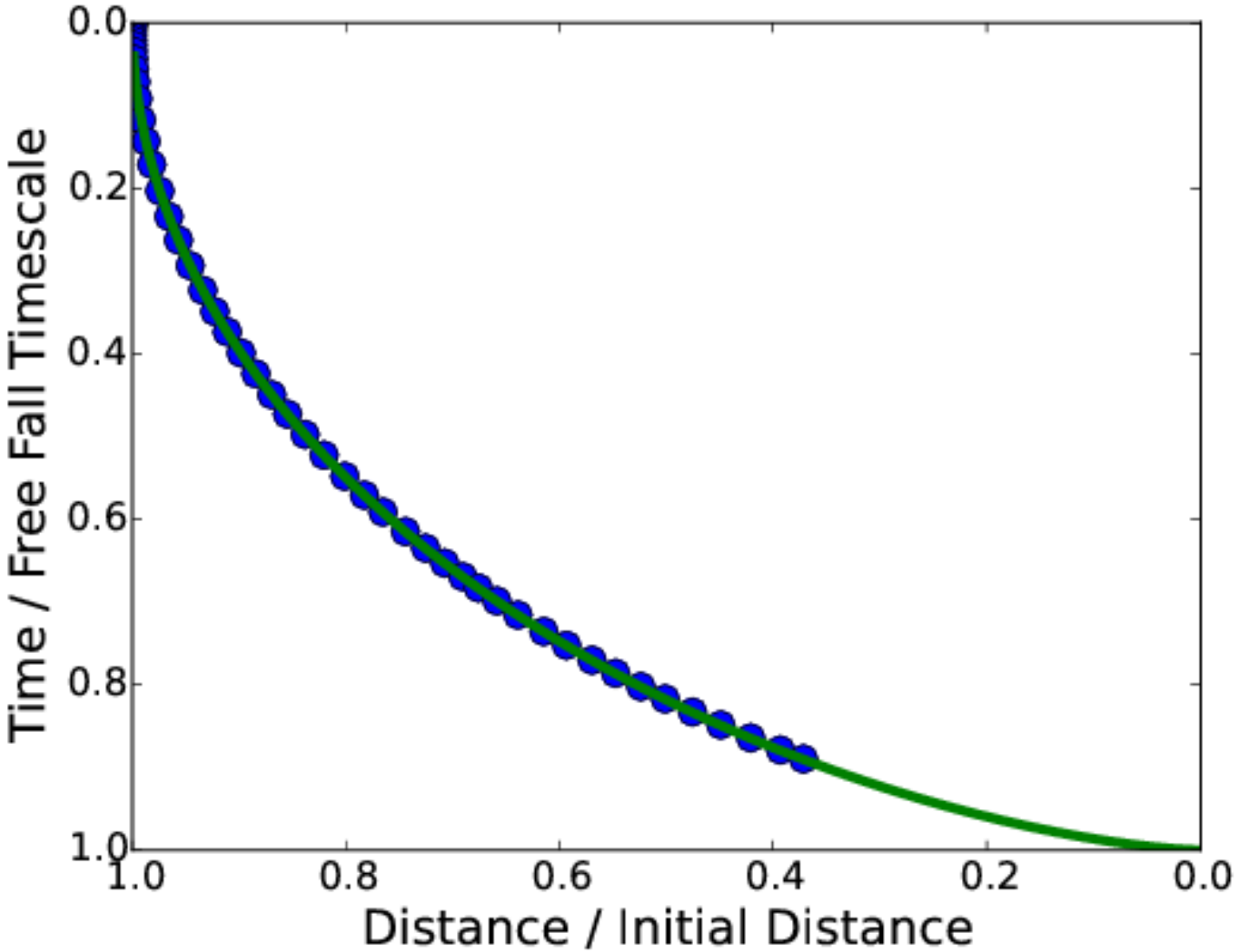
- Euler equations for compressible hydrodynamics
- Self-gravity and realistic equation of state
- Nuclear reaction network and radiation transport included
- BoxLib framework for adaptive mesh refinement with subcycling in time
- Hybrid parallelism: MPI between grids, OpenMP within grids
- Freely available online

Using CASTRO for mergers

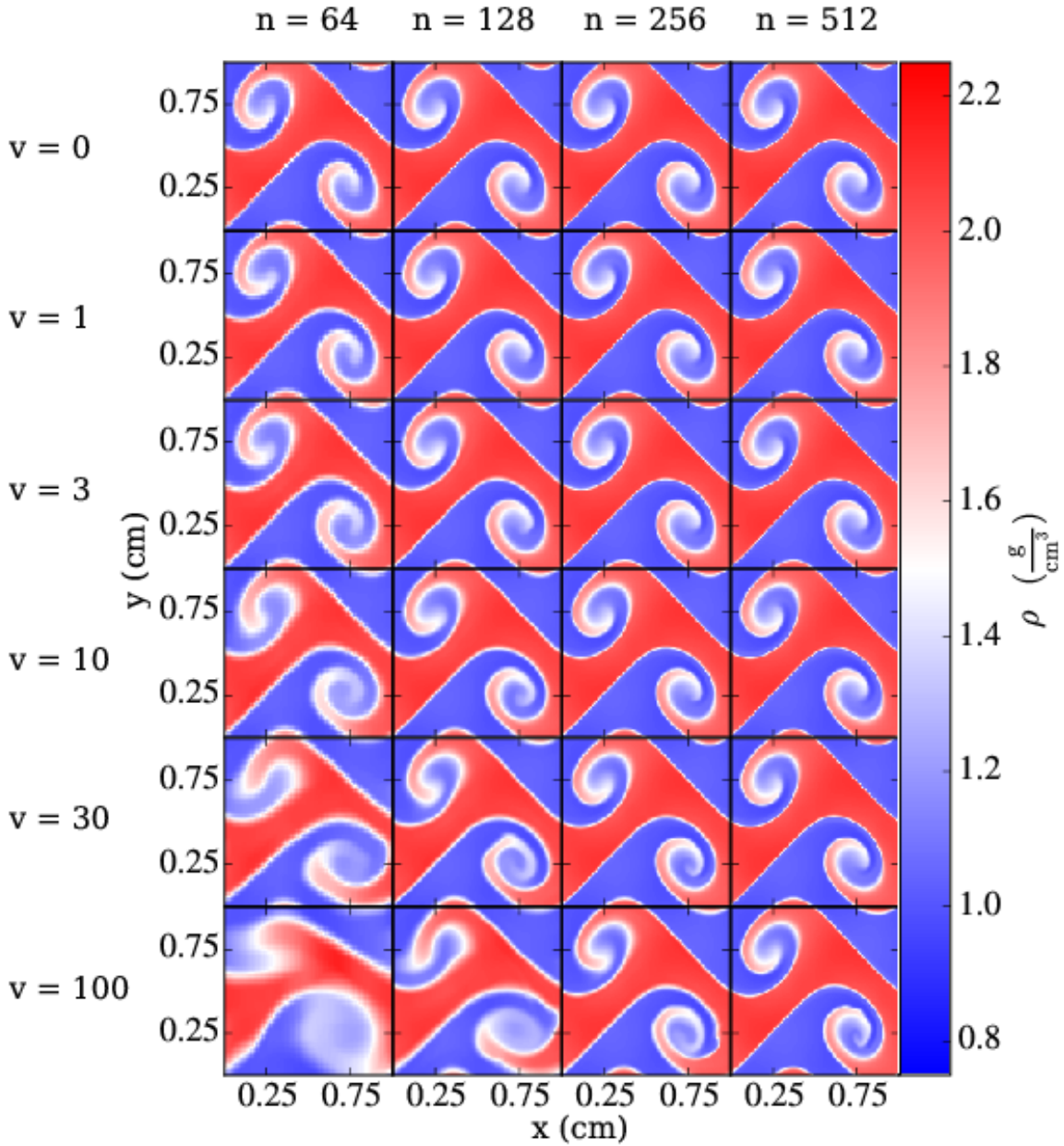
Changes we've made to the code

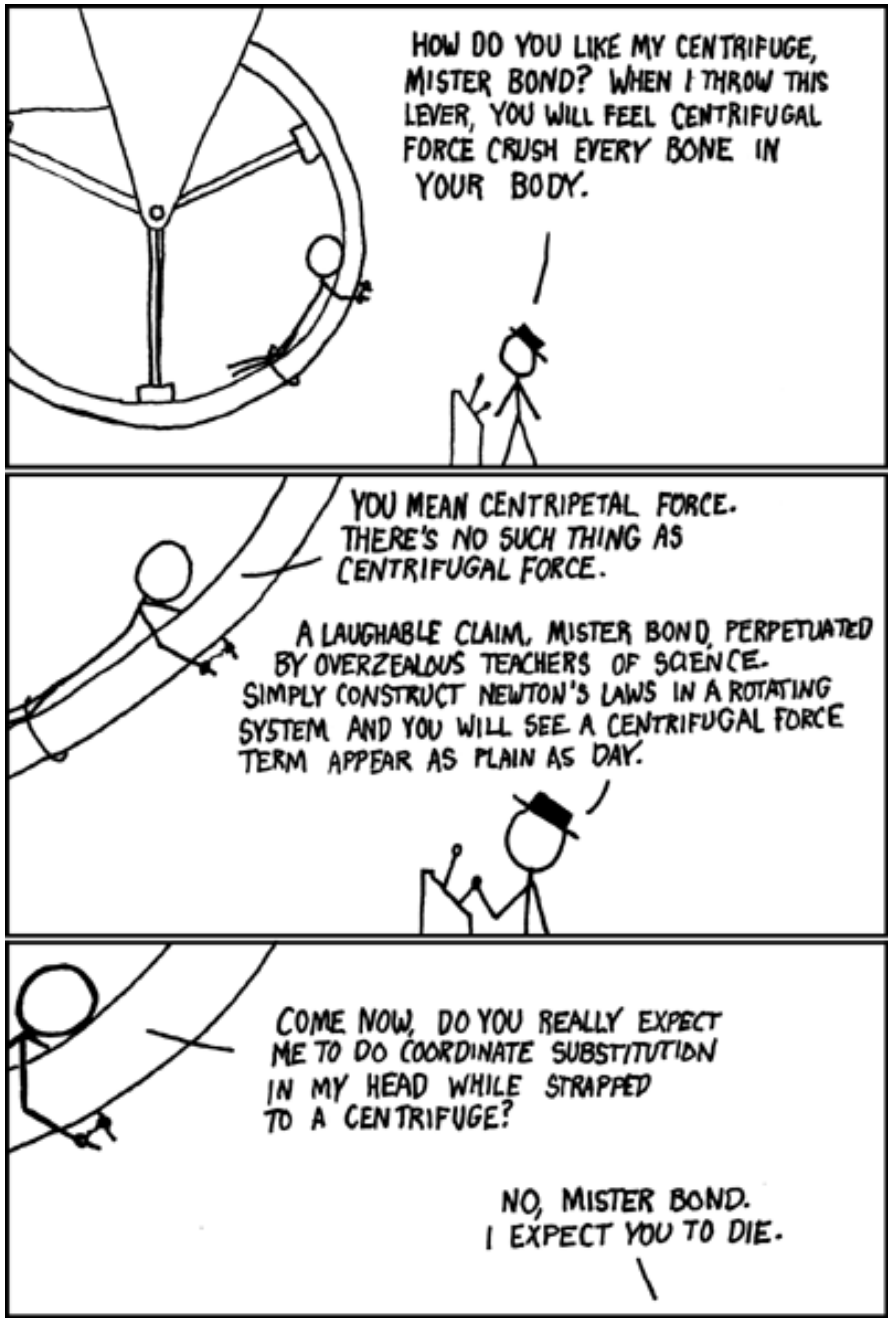
- Gravity, especially boundary conditions and energy coupling
- Hydrodynamics, especially the core piecewise-parabolic method
- Equation of state (including work in progress on GPUs)

Hydro test: gravitational free fall



Kelvin-Helmholtz Instability and Galilean Invariance



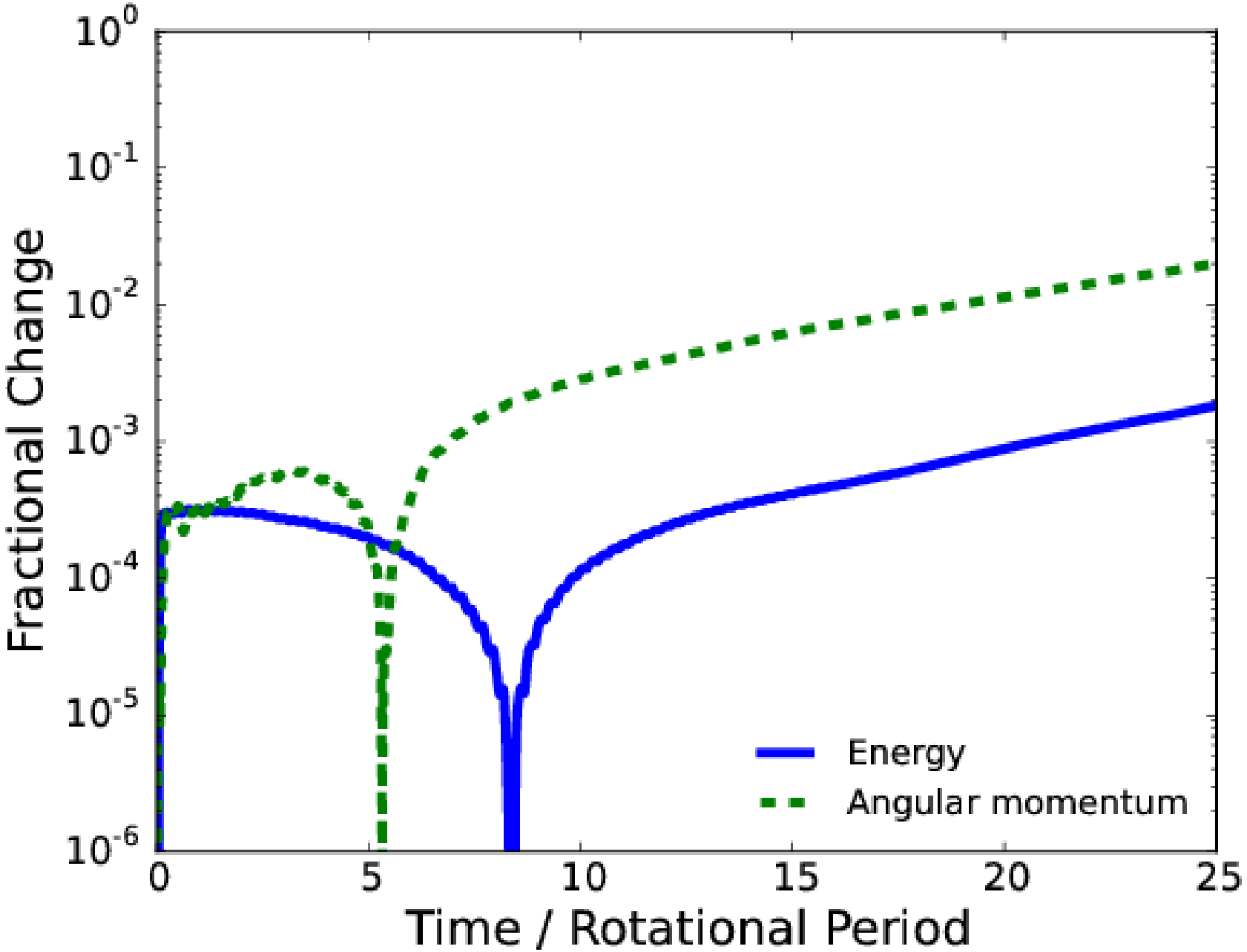

HOW DO YOU LIKE MY CENTRIFUGE, MISTER BOND? WHEN I THROW THIS LEVER, YOU WILL FEEL CENTRIFUGAL FORCE CRUSH EVERY BONE IN YOUR BODY.
YOU MEAN CENTRIPETAL FORCE. THERE'S NO SUCH THING AS CENTRIFUGAL FORCE.
A LAUGHABLE CLAIM, MISTER BOND, PERPETUATED BY OVERZEALOUS TEACHERS OF SCIENCE. SIMPLY CONSTRUCT NEWTON'S LAWS IN A ROTATING SYSTEM AND YOU WILL SEE A CENTRIFUGAL FORCE TERM APPEAR AS PLAIN AS DAY.
COME NOW, DO YOU REALLY EXPECT ME TO DO COORDINATE SUBSTITUTION IN MY HEAD WHILE STRAPPED TO A CENTRIFUGE?
NO, MISTER BOND. I EXPECT YOU TO DIE.

Credit: xkcd

Unequal Mass Binary: Inertial Frame

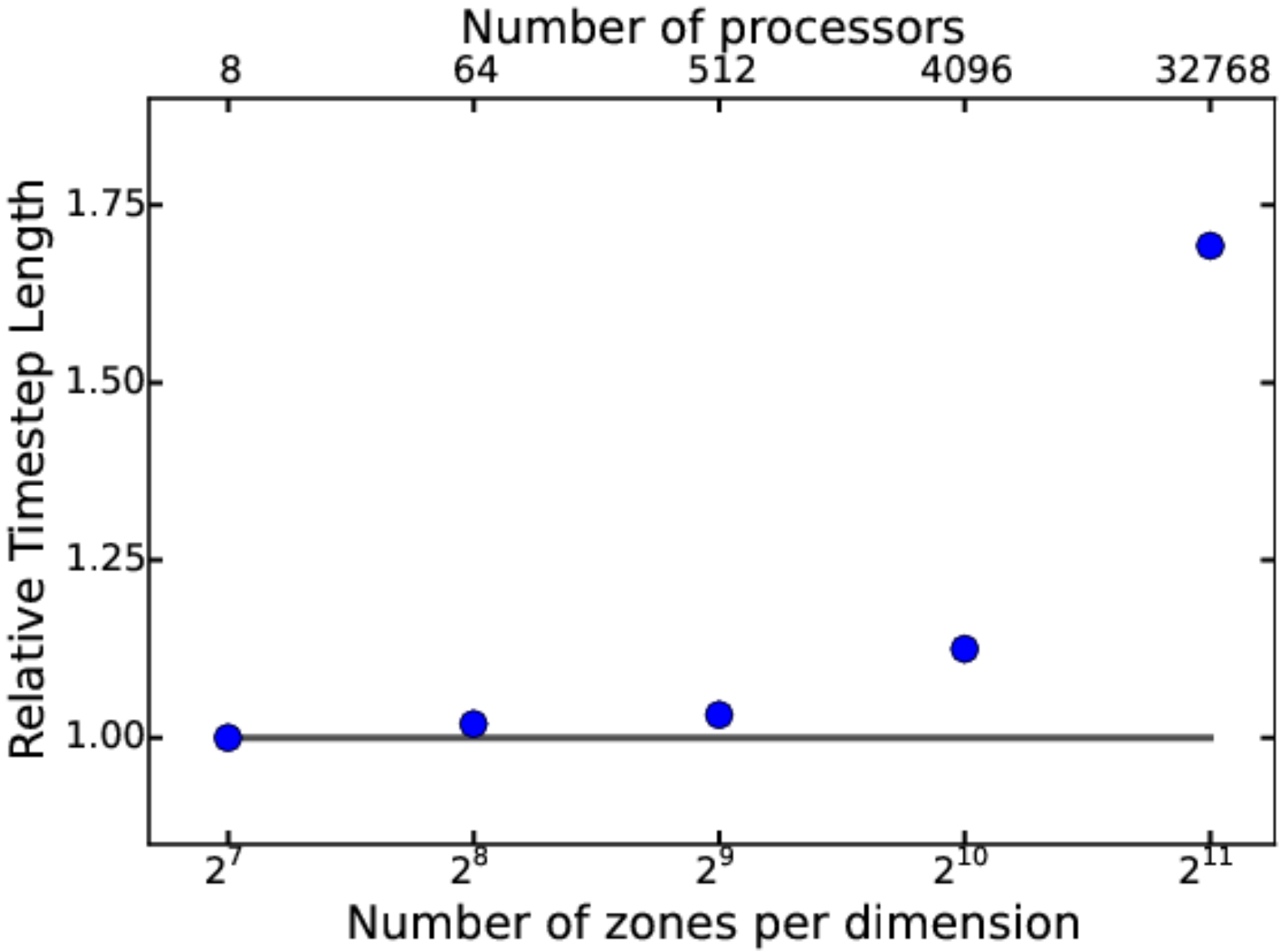
Unequal Mass Binary: Rotating Frame

Energy and angular momentum conservation

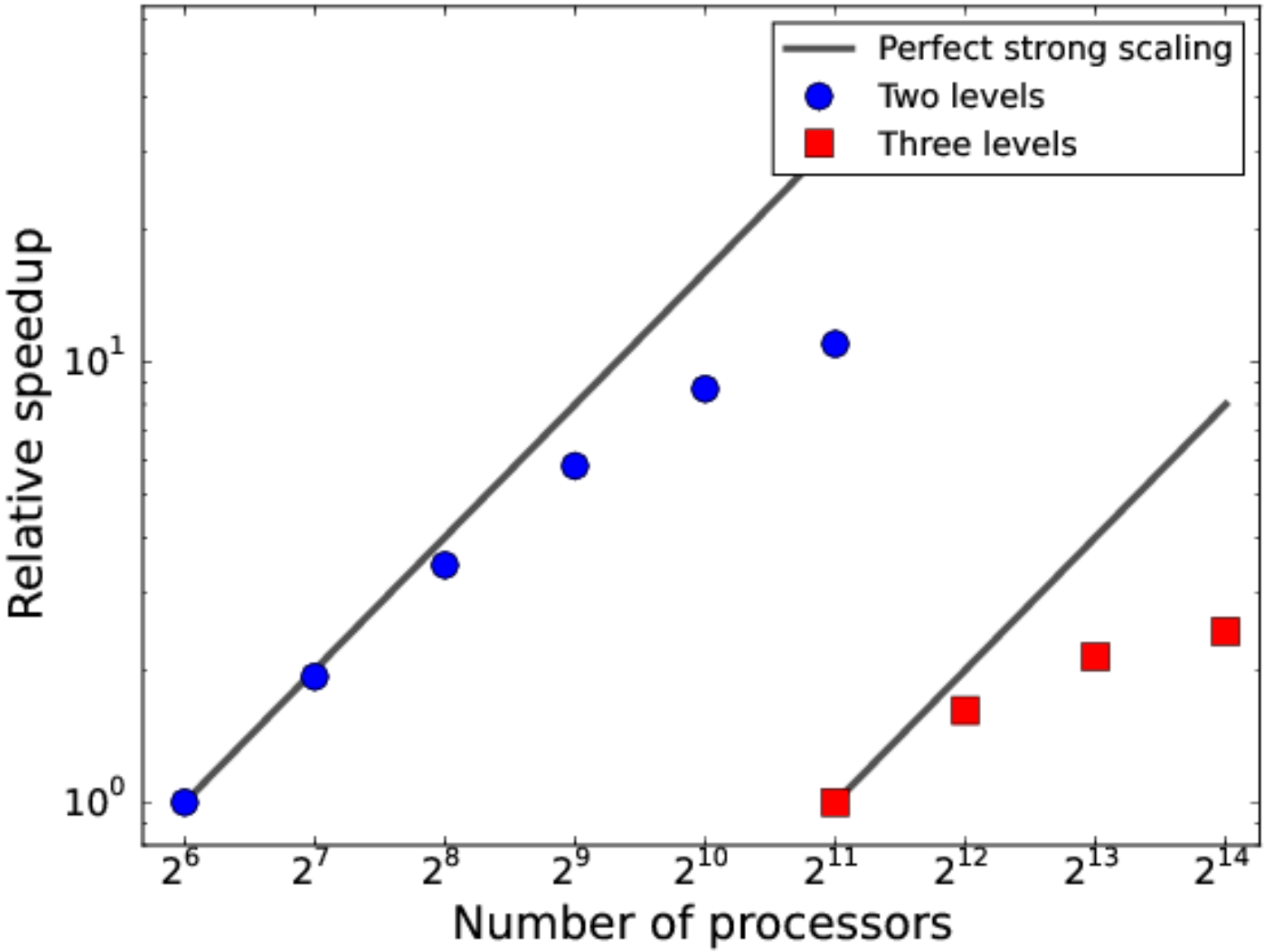


Collision

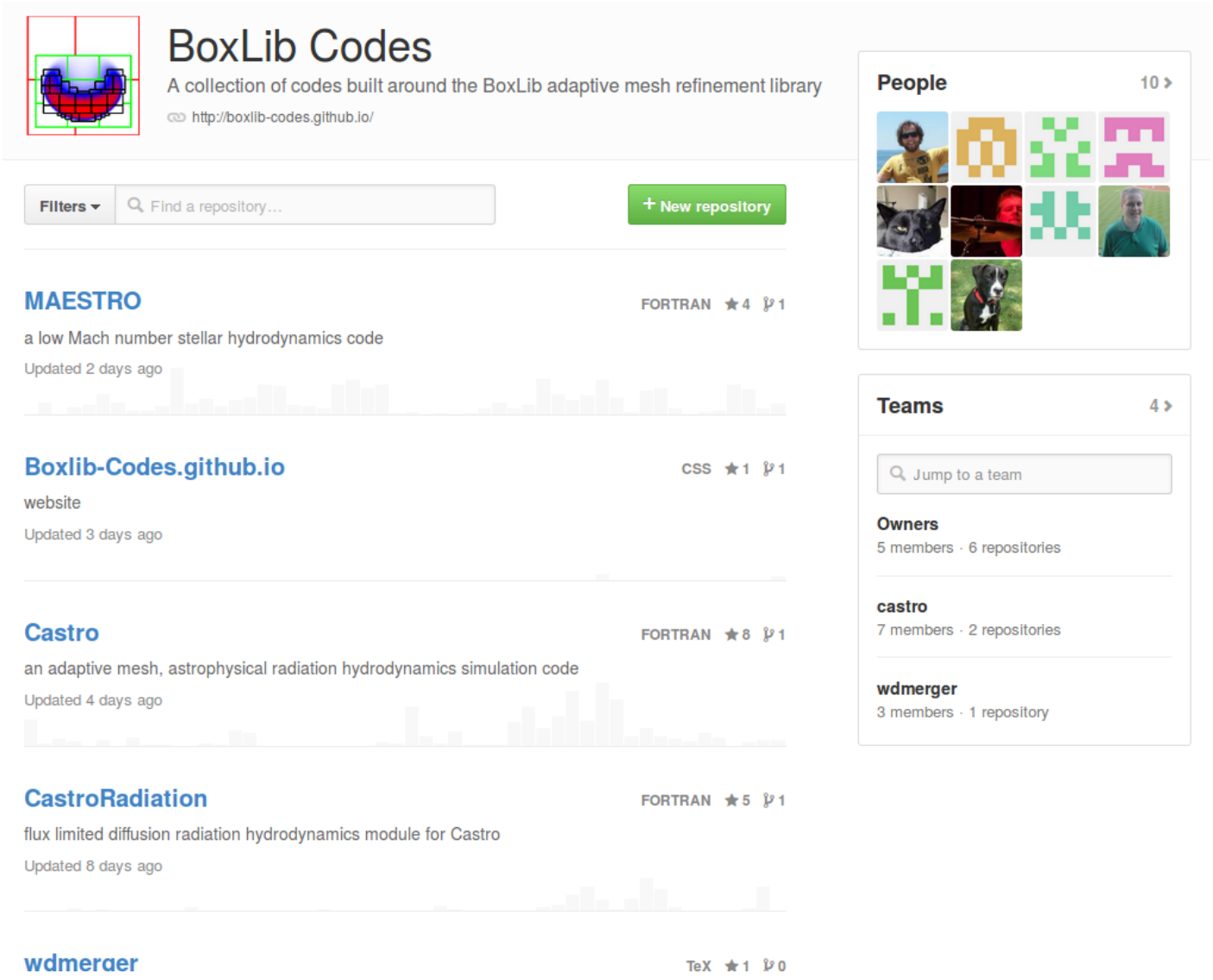
Weak scaling on Blue Waters



Strong scaling on Blue Waters



Download our codes!



github.com/BoxLib-Codes

Summary

- We are using the compressible hydro code CASTRO to simulate the mergers of WDs
- Our goal is to determine whether the conditions for a detonation form robustly
- We have made good progress on the verification front and have made numerous updates to the algorithms (Zingale & Katz 2015, ApJ; Katz et al. 2015 in prep)

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