

Enzo-P/Cello Update (AMR hydrodynamic cosmology on Charm++)

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Motivation for Adaptive Meshes: Gravity Sucks!

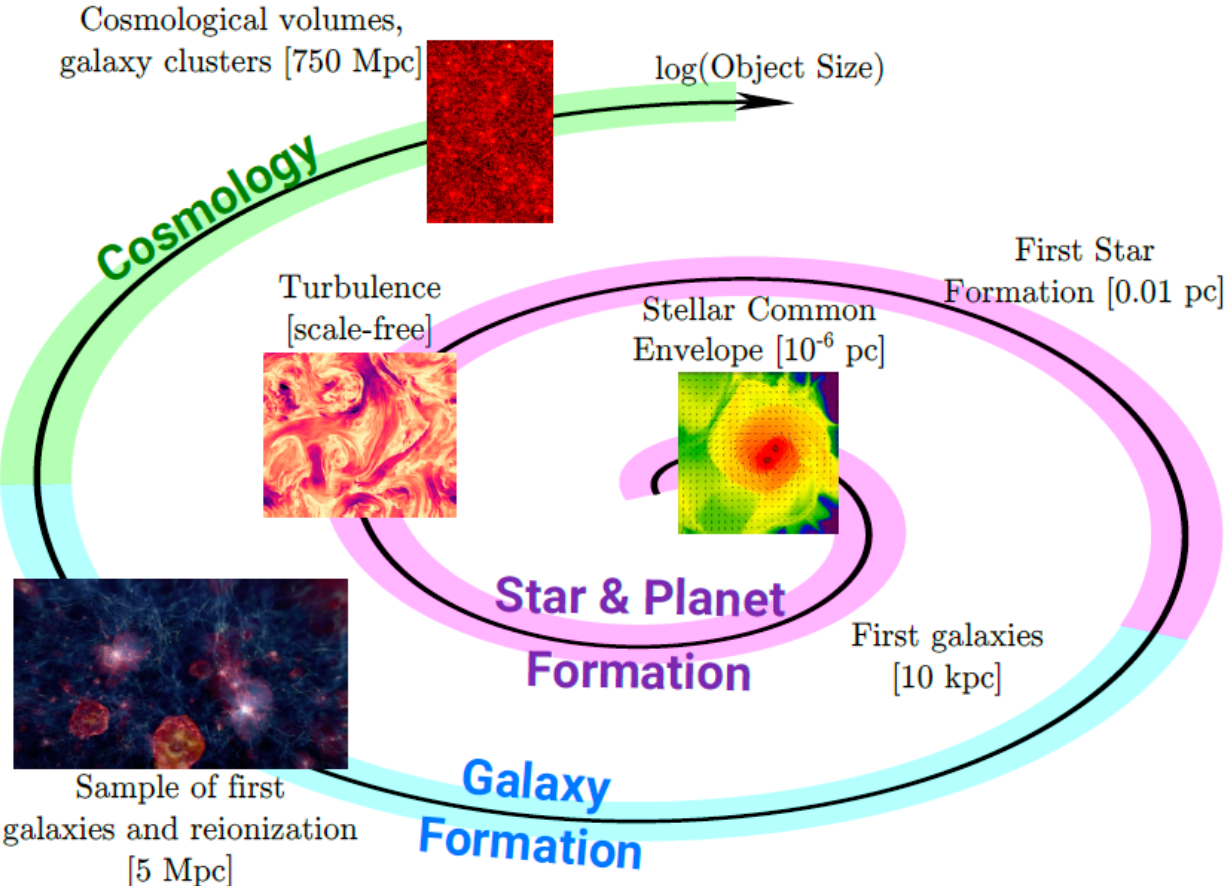


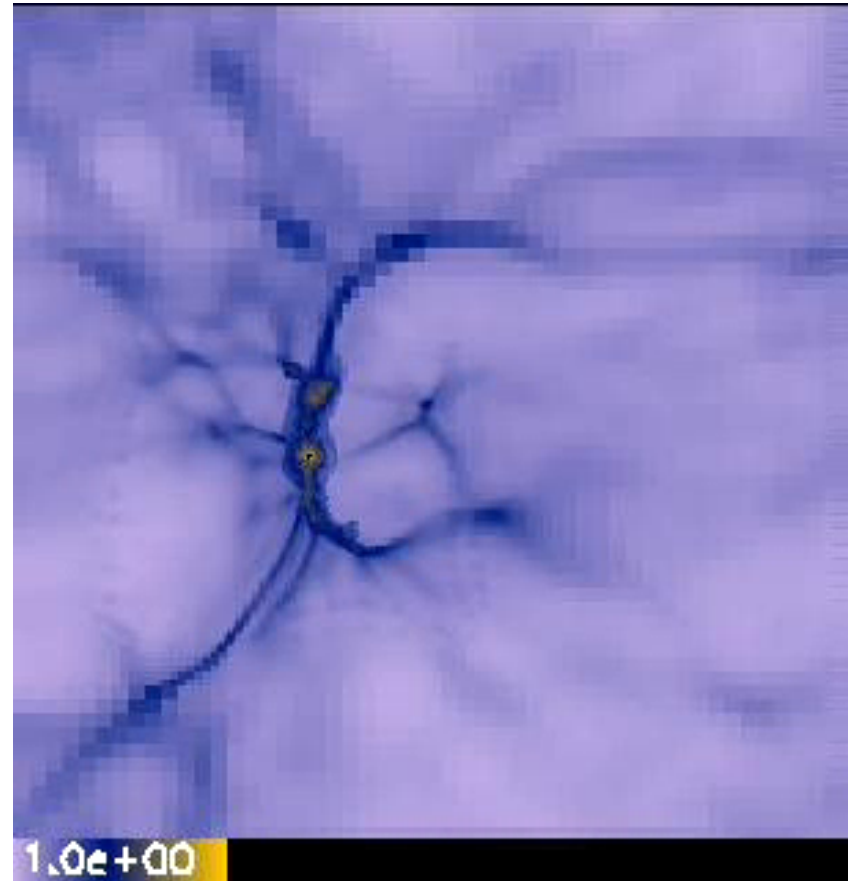
Fig. 1. Astrophysical phenomena can range over extreme scales.

Enzo: AMR Hydrodynamic Cosmology Code

<http://enzo-project.org>



- Enzo code under continuous development since 1994
 - First hydrodynamic cosmological AMR code
 - Hundreds of users
- Rich set of physics solvers (hydro, N-body, radiation transport, chemistry,...)
- Have done simulations with 10^{12} dynamic range and 42 levels

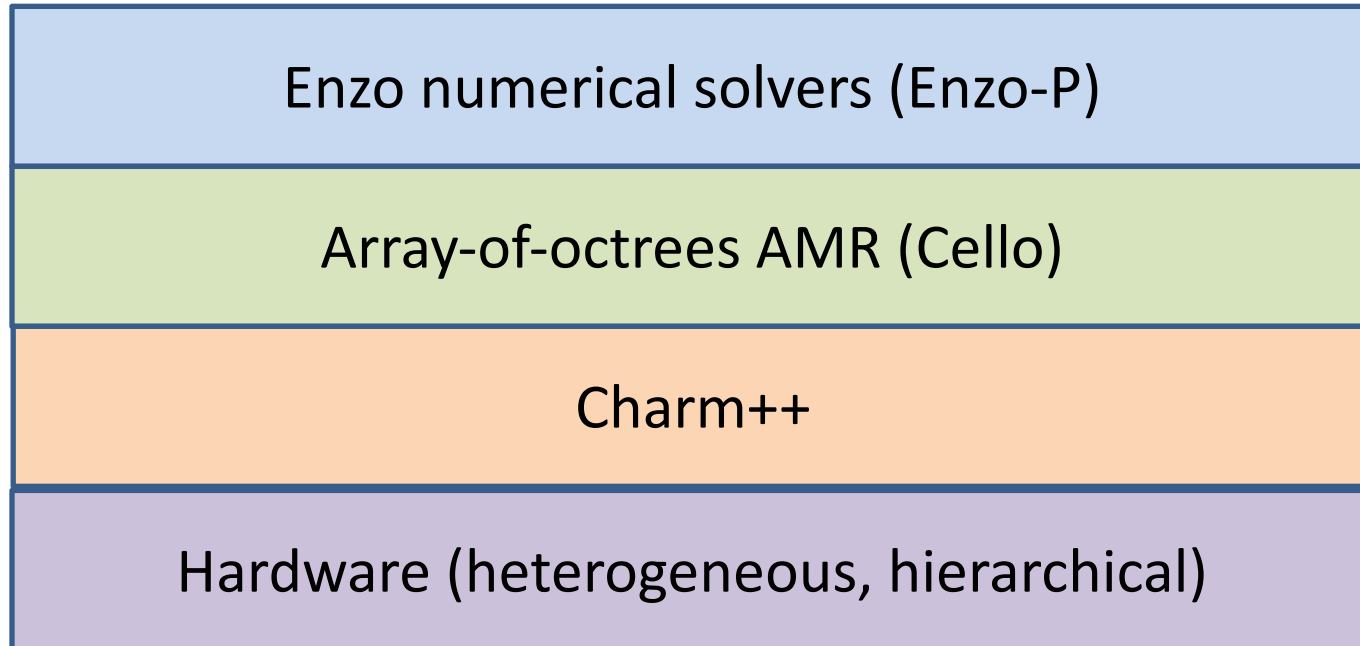


Bryan, Abel & Norman (2001) – Gordon Bell Prize Finalist

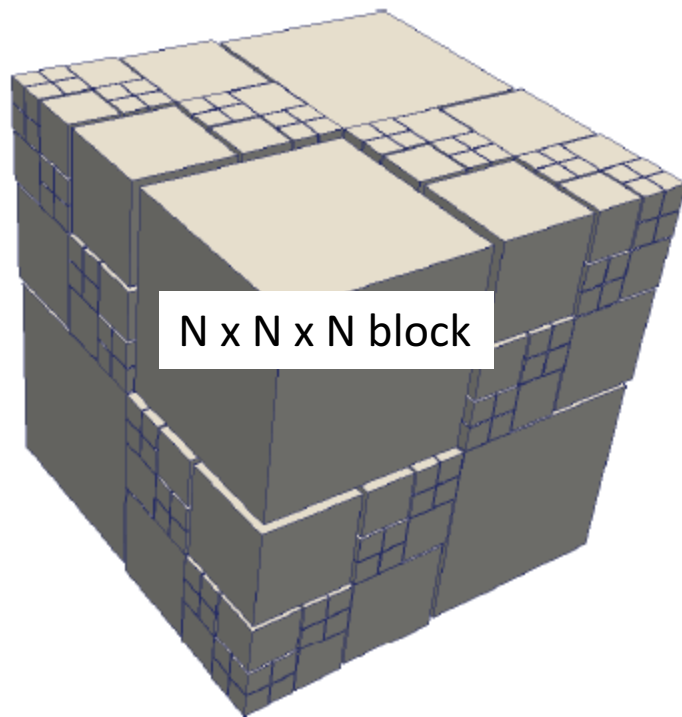
Adopted Strategy

- Keep the best part of Enzo (numerical solvers) and **replace the AMR infrastructure**
- Implement using modern **OOP best practices** for modularity and extensibility
- Use the best available **scalable AMR algorithm**
- Move from bulk synchronous to **data-driven asynchronous execution** model to support patch adaptive timestepping
- Leverage **parallel runtimes** that support this execution model, and have a **path to exascale (Charm++)**
- Make **AMR software library application-independent** so others can use it

Software Architecture



How does Cello implement AOT?



2 x 2 x 2 tree

- **Array of octrees** of arbitrary size $K \times L \times M$
- An octree has leaf nodes which are **blocks** ($N \times N \times N$)
- Each block is a **chare** (unit of sequential work)
- The entire FOT is stored as a **chare array** using a bit index scheme
- Chare arrays are **fully distributed data structures** in Charm++

Largest
AMR
Simulation
in the
world

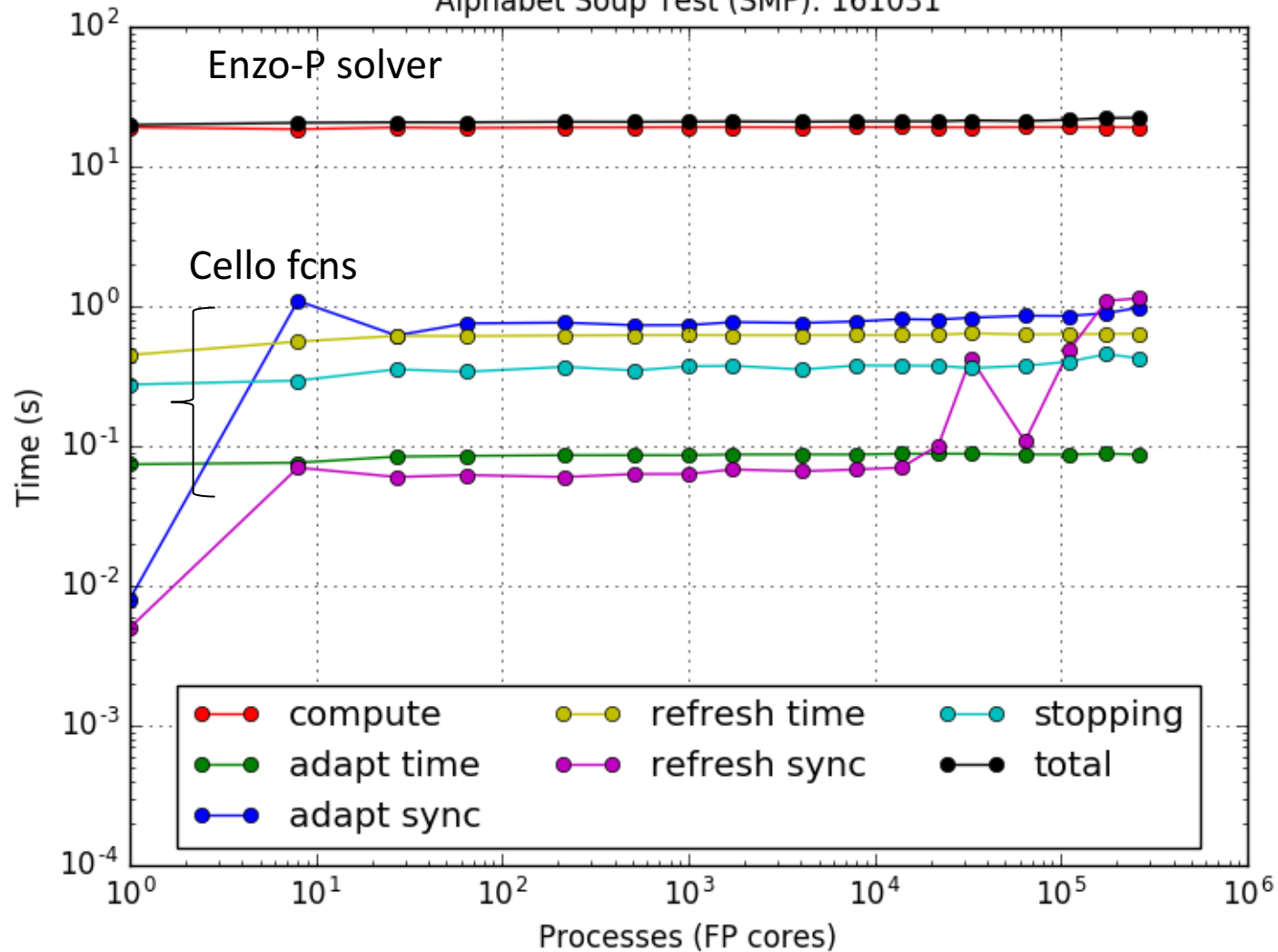
1.7 trillion
cells

262K cores
on NCSA
Blue Waters

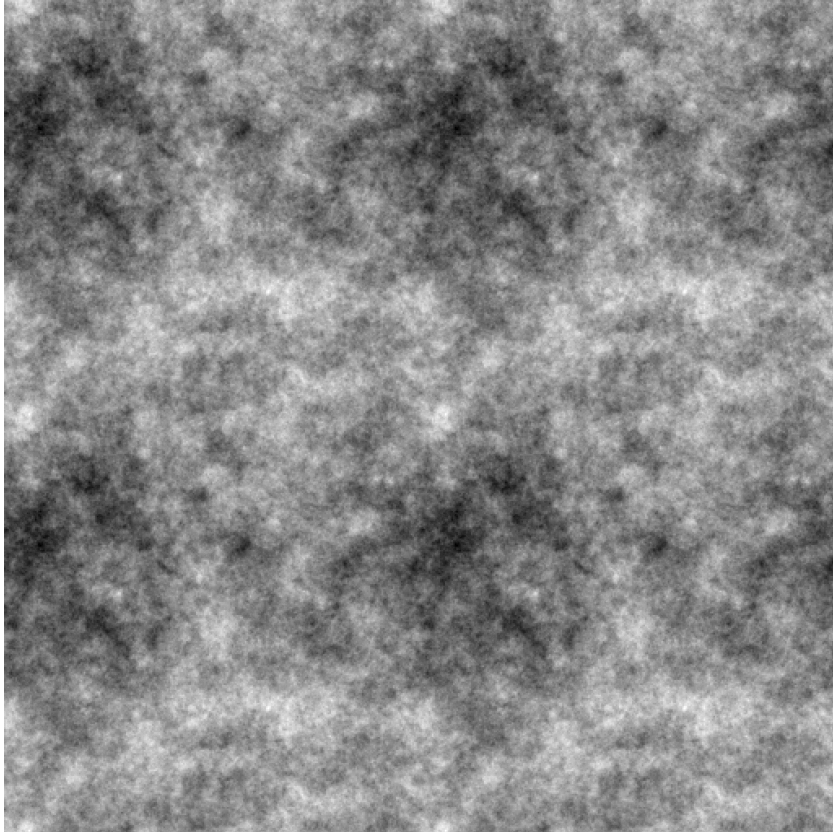


Enzo-P Weak Scaling on Blue Waters: Time

Alphabet Soup Test (SMP): 161031



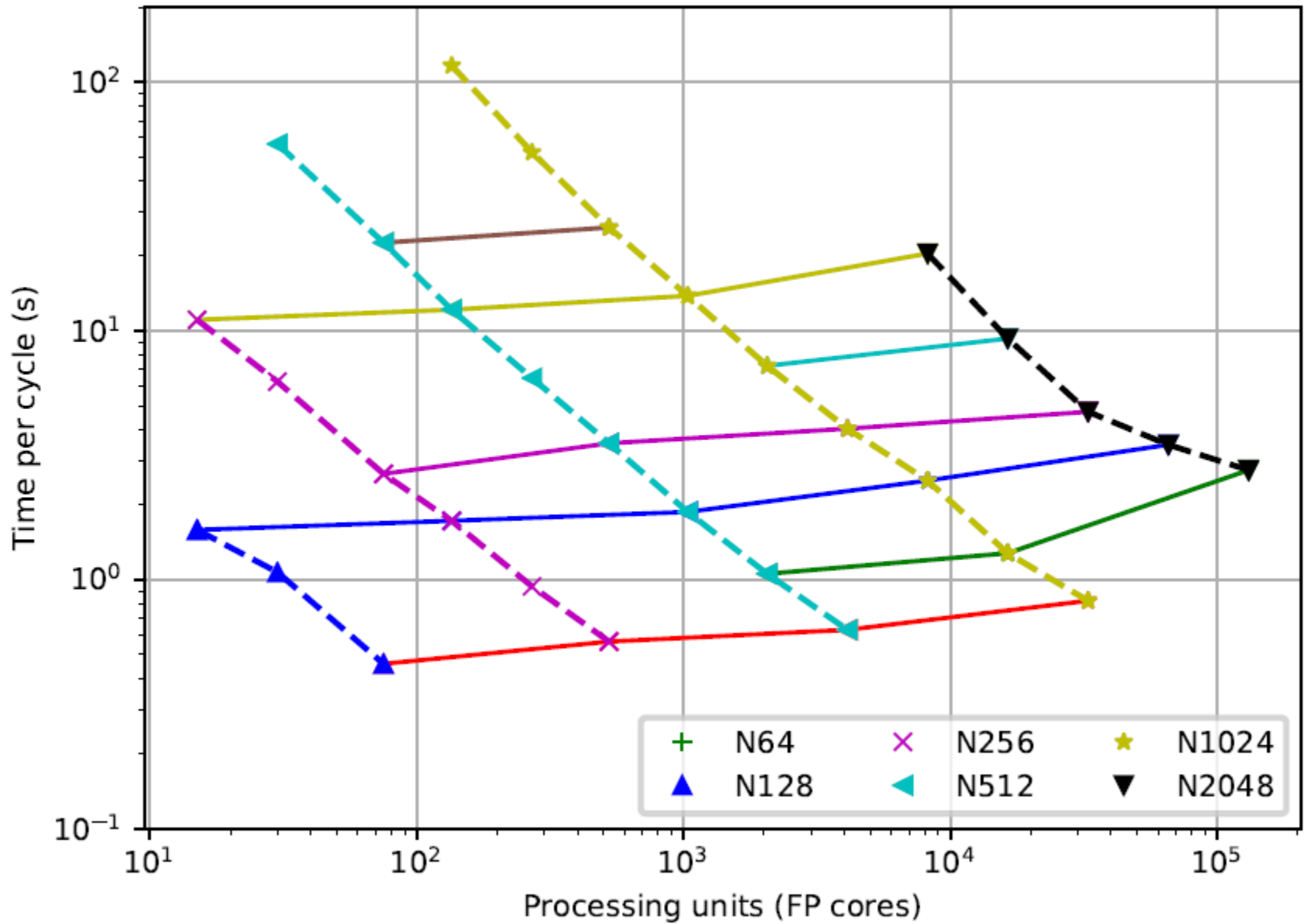
Hydrodynamic Cosmology Scaling Tests



Density projection in 512^3 simulation

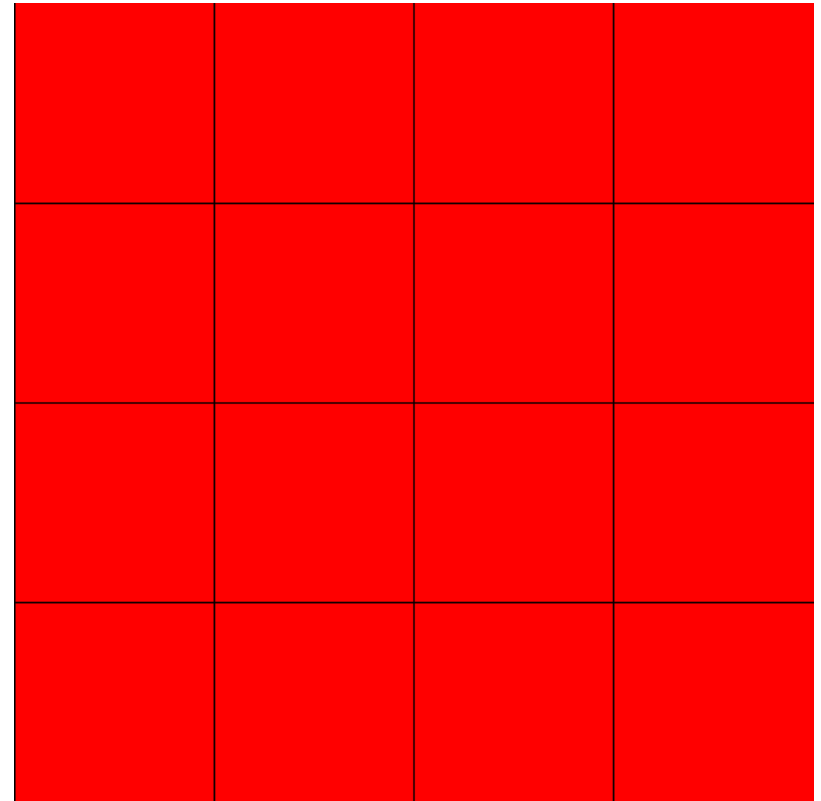
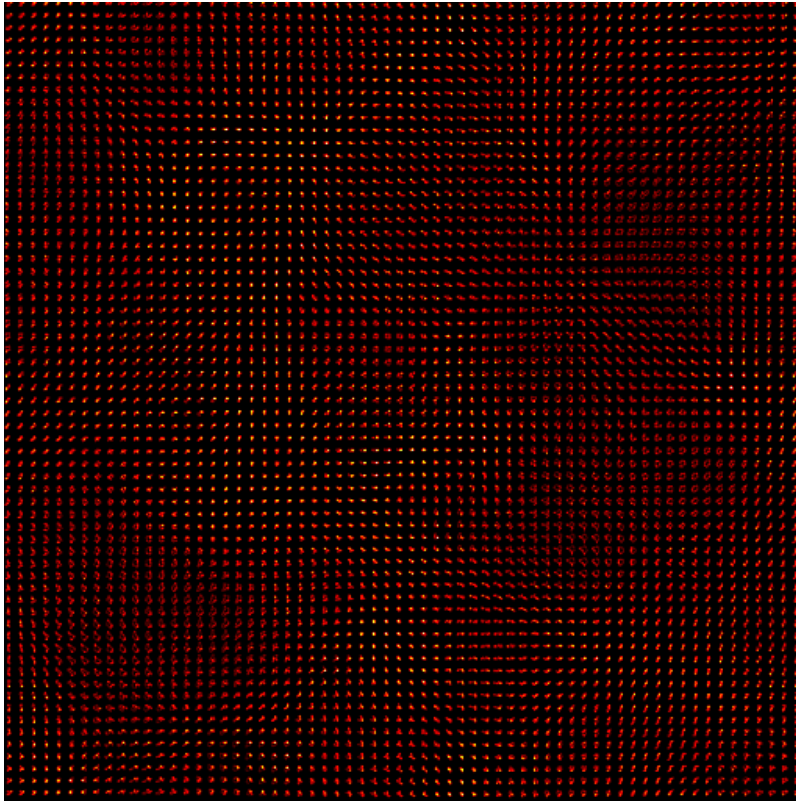
- Uniform grid only
- Weak and strong scaling
- 32^3 blocks/chare
- 1, 8, 64 chares/core
- 64^3 to 2048^3 meshes
- p=8 to 128k cores

Enzo-P Cosmology scaling on Blue Waters



AMR cosmology with HG* solver

64^3 mesh (4^3 array of 16^3 blocks), 4 AMR levels (1024^3 eff.), $pe=8$



* HG = multigrid preconditioned BICGSTAB

NSF CSSI grant (Enzo-E)

- \$1.9M, 3 years
- Goal: feature-complete implementation of Enzo solvers into Enzo-P
- Goal: migration of Enzo community to Enzo-P
- Goal: foster new applications of Cello+Charm++ stack
- Goal: implementations for exascale (accelerators)
- PI team
 - Mike Norman, James Bordner (UCSD)
 - Brian O'Shea (MSU)
 - Greg Bryan (Columbia)
 - John Wise (Georgia Tech)

Enzo-E tasks

- Exa-FMM gravity solver
- Block-adaptive local timestepping
- Adaptive ray tracing radiative transfer
- Cosmic ray transport incl. MHD
- Interfacing to GRACKLE chemistry library
- Lots of scaling/optimization work.....