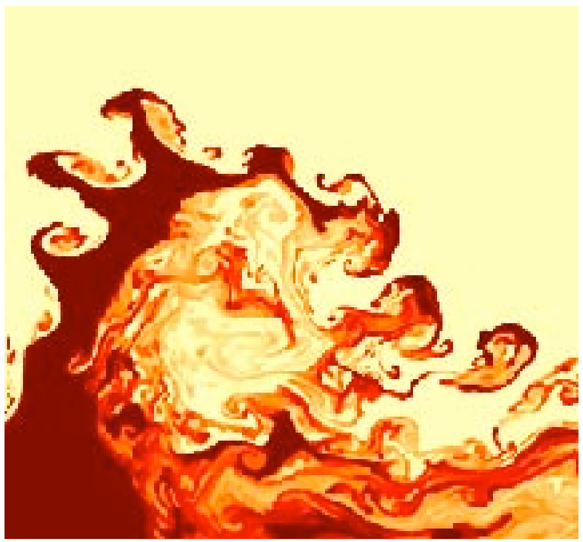
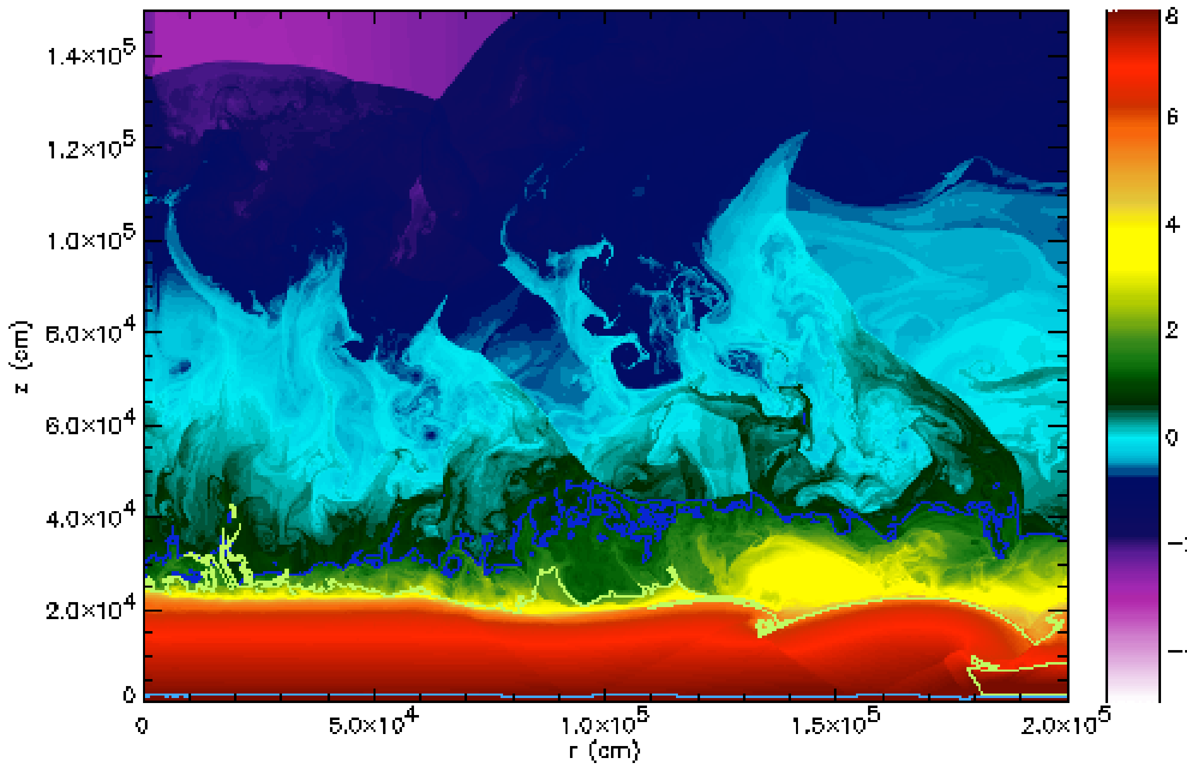
Tom Theuns
ICC
Durham University

Ascona 2008

Durham University

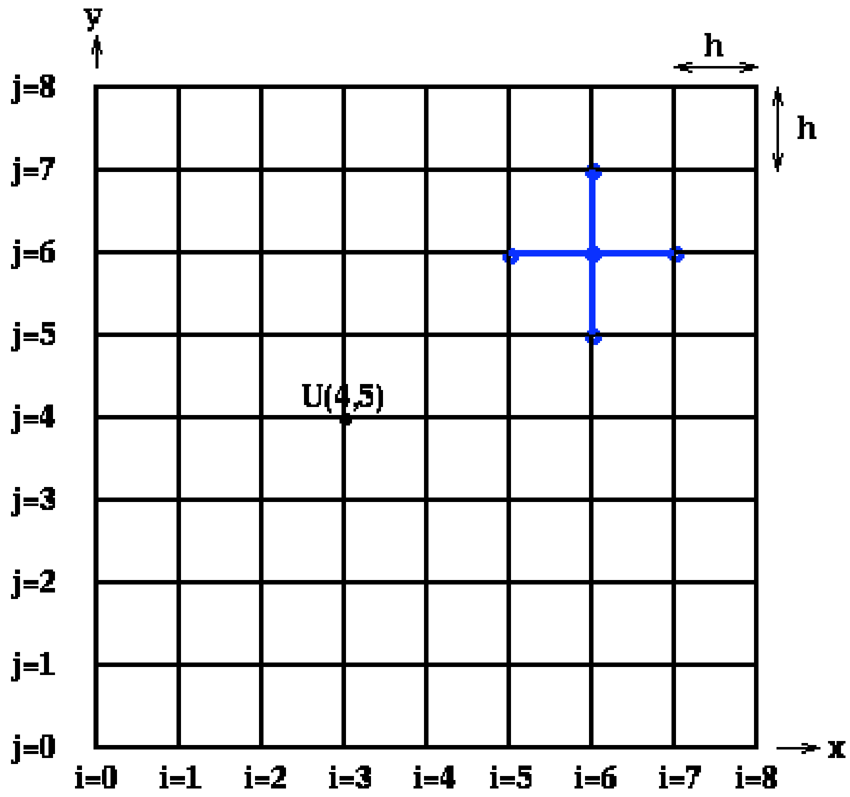
1. An FFT (Ooohh no, another :(Poisson solver for Flash
2. Gadget vs Flash in clusters (Ooooh no, the entropy thingy again :(





$$\nabla^2\phi(x) = \frac{\phi(x+\Delta) + \phi(x-\Delta) - 2\phi(x)}{\Delta^2}$$

Discretization of the 2D Poisson Equation



4*U(i,j) – U(i–1,j) – U(i+1,j) – U(i,j–1) – U(i,j+1) = b(i,j)

$$\nabla^2 \phi = \rho$$

$$\nabla \phi(x + \Delta/2) \approx \frac{\phi(x+\Delta) - \phi(x)}{\Delta}$$

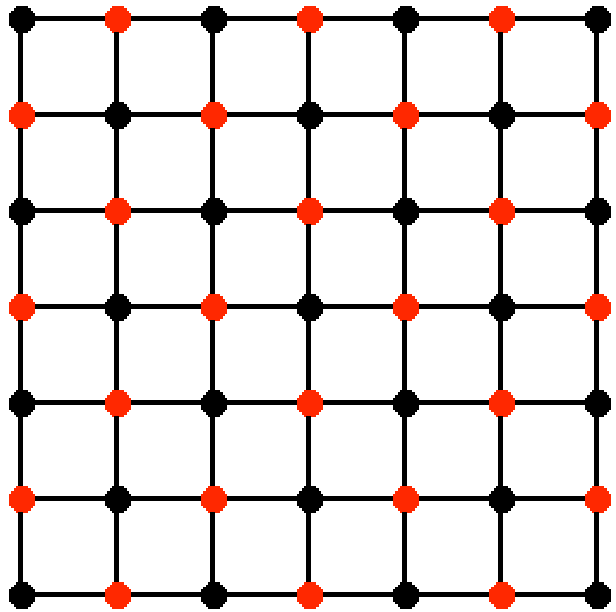
$$\begin{aligned}
\nabla^2 \phi(x) &= \frac{(\phi(x+\Delta) - \phi(x))/\Delta - (\phi(x) - \phi(x-\Delta))/\Delta}{\Delta} \\
&= \frac{\phi(x+\Delta) + \phi(x-\Delta) - 2\phi(x)}{\Delta^2}
\end{aligned}$$

$$\phi(x) = \frac{\phi(x+\Delta) + \phi(x-\Delta)}{2} - \frac{\rho(x)}{2\Delta^2}$$

$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

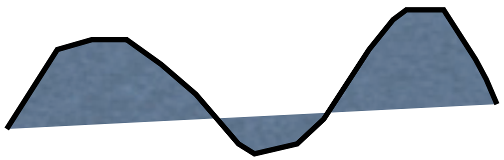
Red-Black Ordering of Grid Points



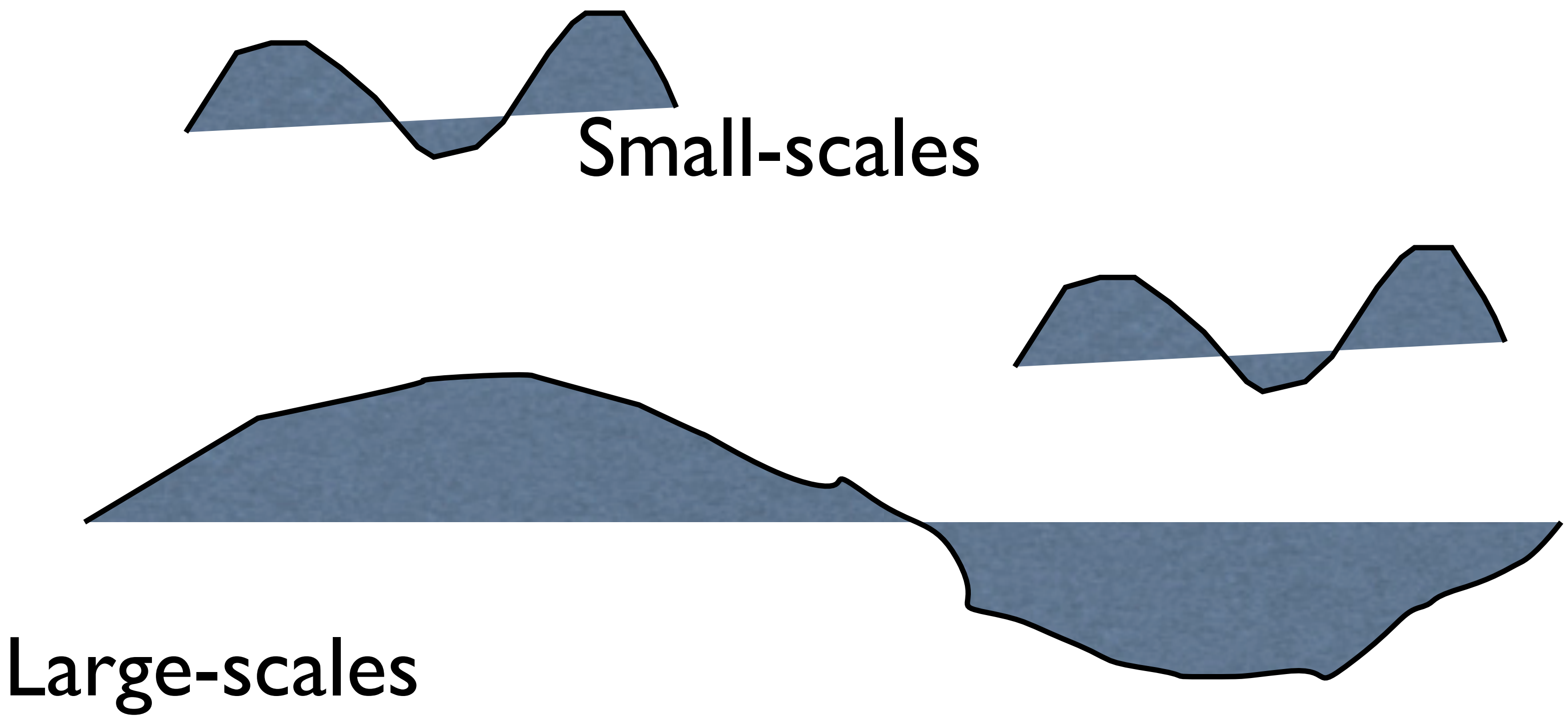
Black points have only Red neighbors

Red points have only Black neighbors

$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

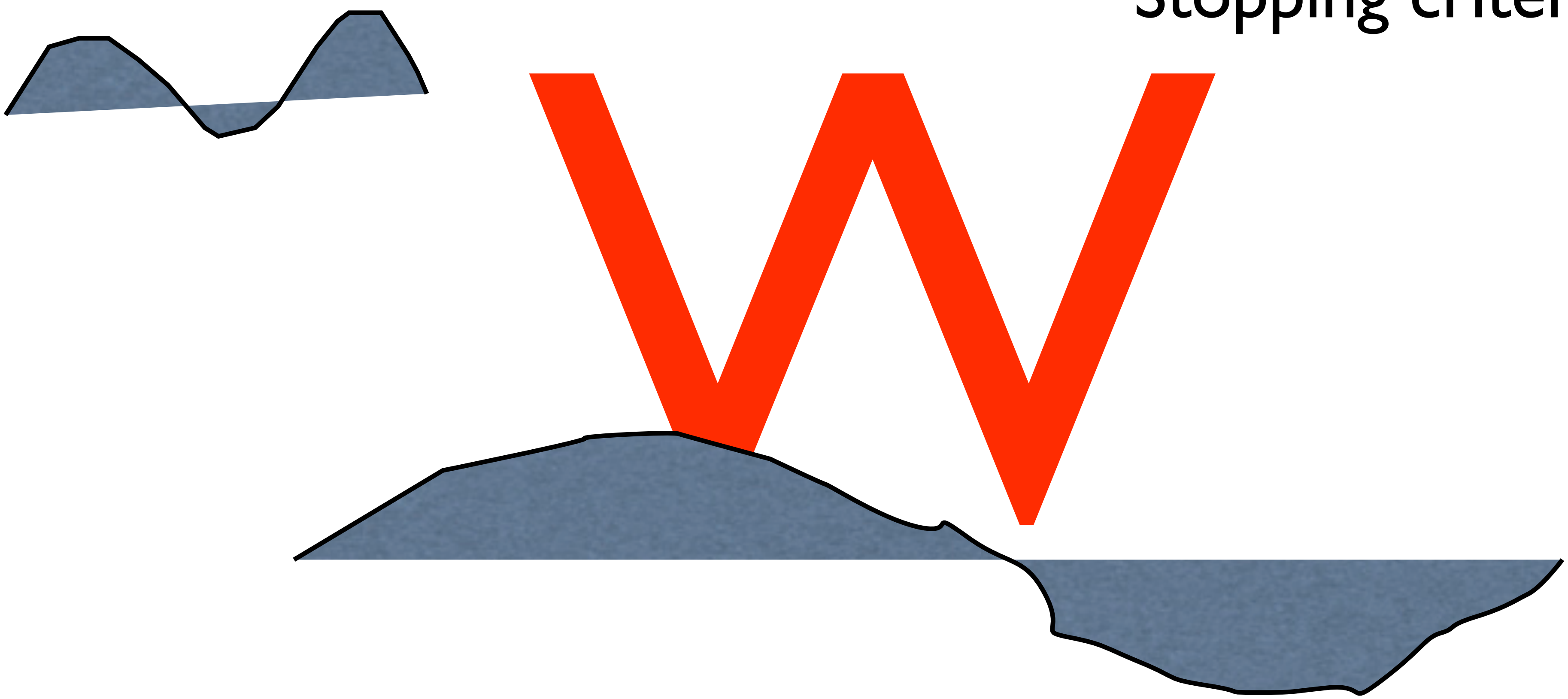


$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

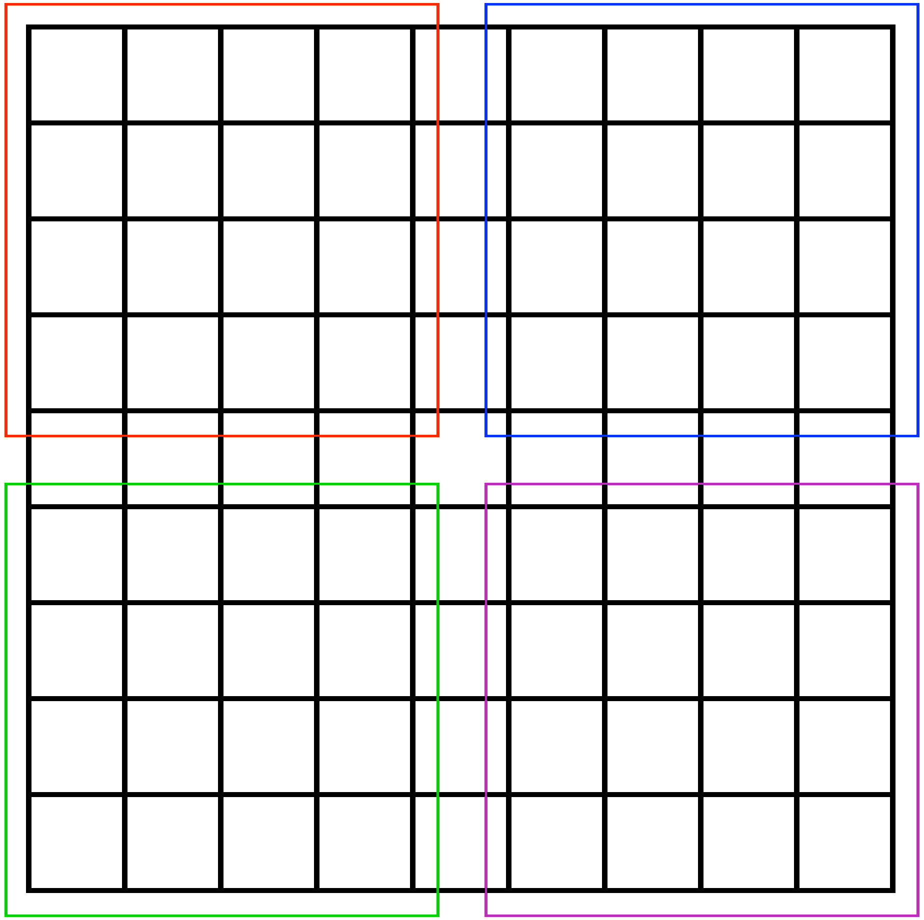


$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

Stopping criterion?



Partitioning of the 2D Poisson Equation



Boundary conditions need to be exchanged between processors every step

Issues:

- Updating of BCs expensive
- Parallelization

Dominates time

Few blocks at coarse level

FFTs?

New Implementation:
•use FFTs on mesh
•use GS on further refinements

✓*Works well* Tasker et al; Frazer's talk
✓*Mapping of particles to mesh takes >80 % of CPU time*

$$\phi(x) = \frac{\phi(x+\Delta) + \phi(x-\Delta)}{2} - \frac{\rho(x)}{2\Delta^2}$$

$$\begin{aligned} \phi(x) &= \sum_k \hat{\phi}(k) \exp(ikx) \\ \rho(x) &= \sum_k \hat{\rho}(k) \exp(ikx) \end{aligned} \qquad (8)$$

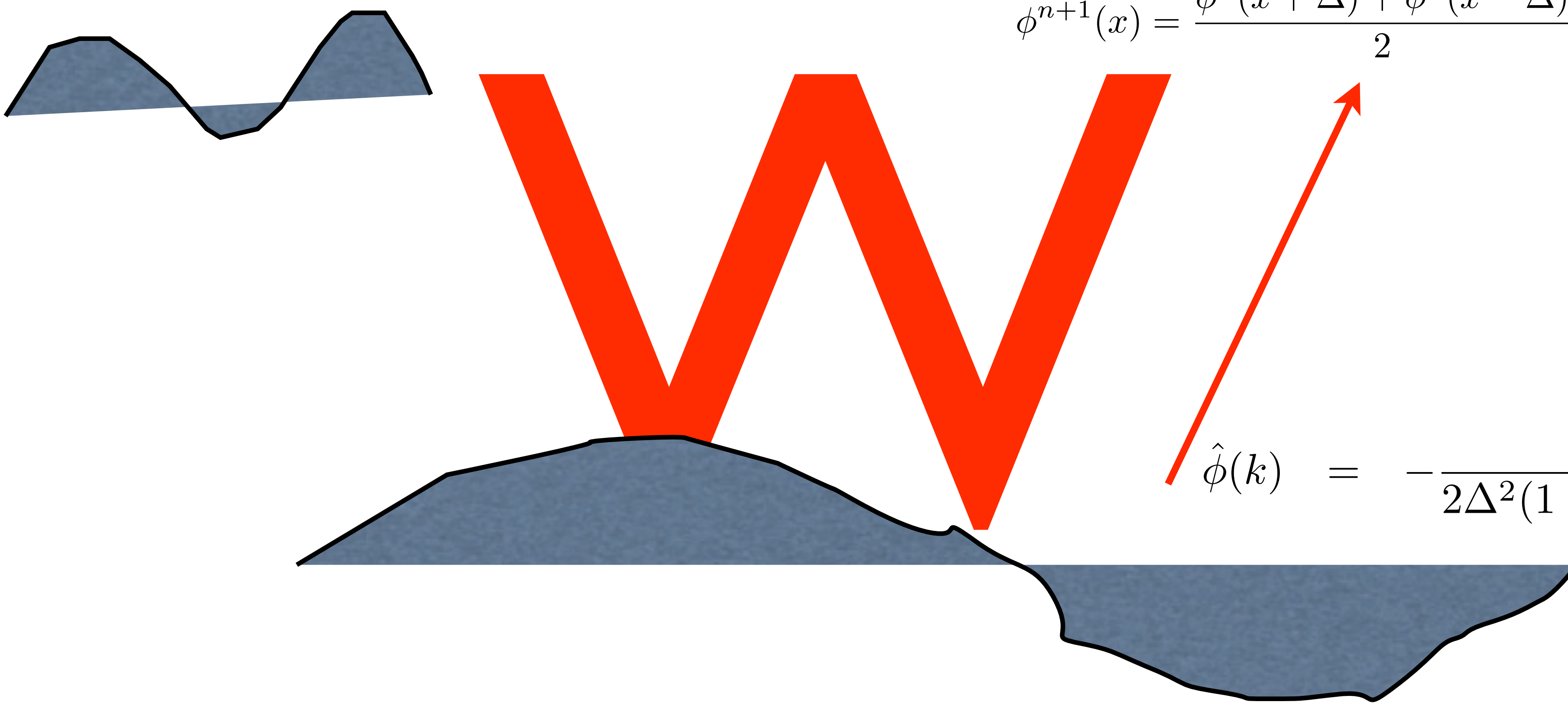
$$\begin{aligned} \sum_k \hat{\phi}(k) \exp(ikx) &= \sum_k \hat{\phi}(k) \frac{\exp(ik(x+\Delta) + \exp(ik(x-\Delta))}{2} - \sum_k \hat{\rho}(k) \exp(ikx)/2\Delta^2 \\ &= \sum_k \hat{\phi}(k) \exp(ikx) \frac{\exp(ik\Delta) + \exp(-ik\Delta)}{2} - \sum_k \hat{\rho}(k) \exp(ikx)/2\Delta^2 \\ &= \sum_k \exp(ikx)(\hat{\phi}(k)\cos(k\Delta) - \hat{\rho}(k)^2\Delta^2) \end{aligned} \qquad (9)$$

$$\hat{\phi}(k) = -\frac{\hat{\rho}(k)}{2\Delta^2(1-\cos(k\Delta))} \approx -\frac{\hat{\rho}(k)}{k^2}$$

$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$

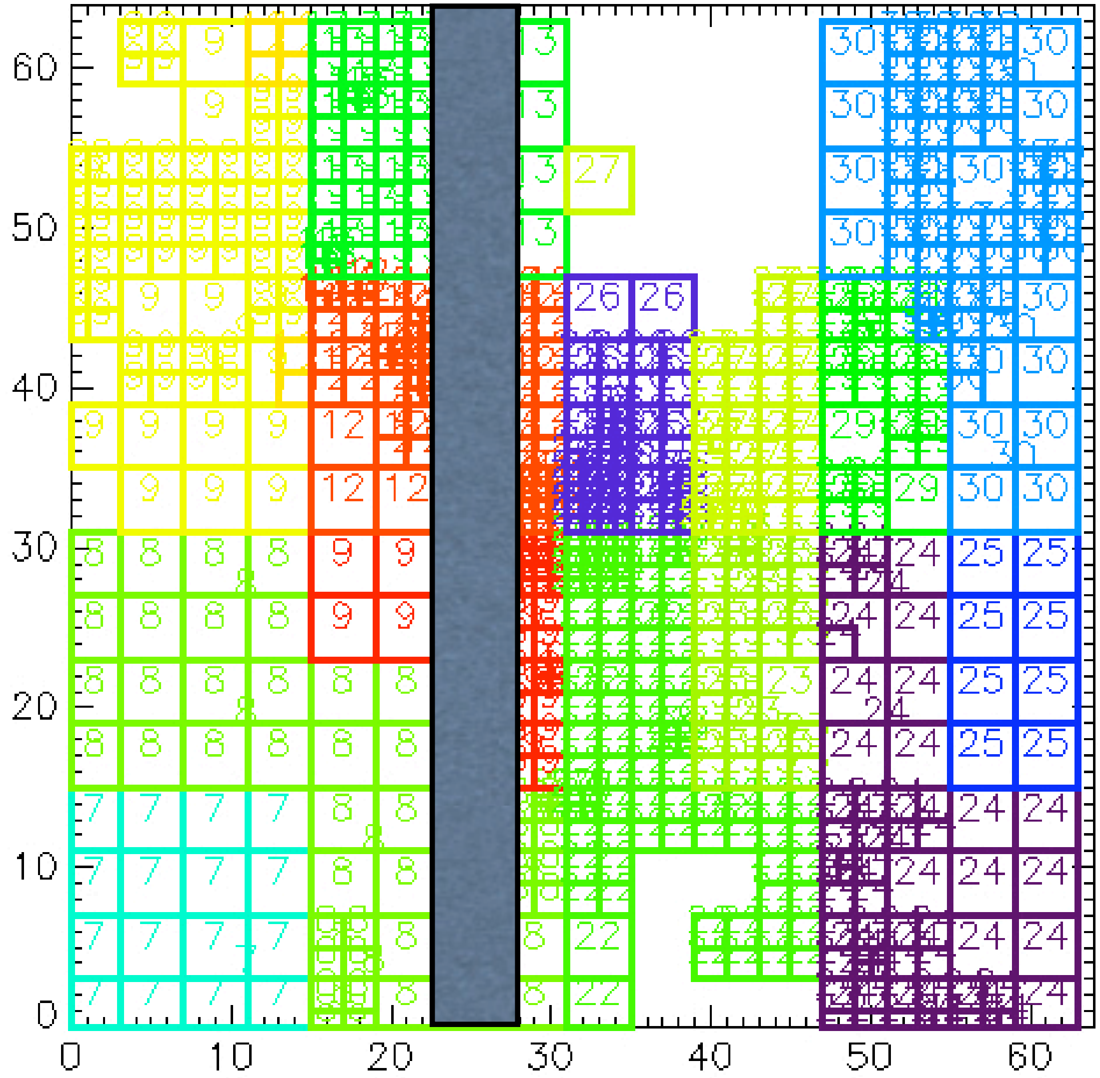
$$\hat{\phi}(k) \quad = \quad -\frac{\hat{\rho}(k)}{2\Delta^2(1-\cos(k\Delta))}$$

$$\phi^{n+1}(x) = \frac{\phi^n(x+\Delta) + \phi^n(x-\Delta)}{2} - \frac{2\rho(x)}{\Delta^2}$$



$$\hat{\phi}(k) = -\frac{\hat{\rho}(k)}{2\Delta^2(1-\cos(k\Delta))}$$

FFT-plane



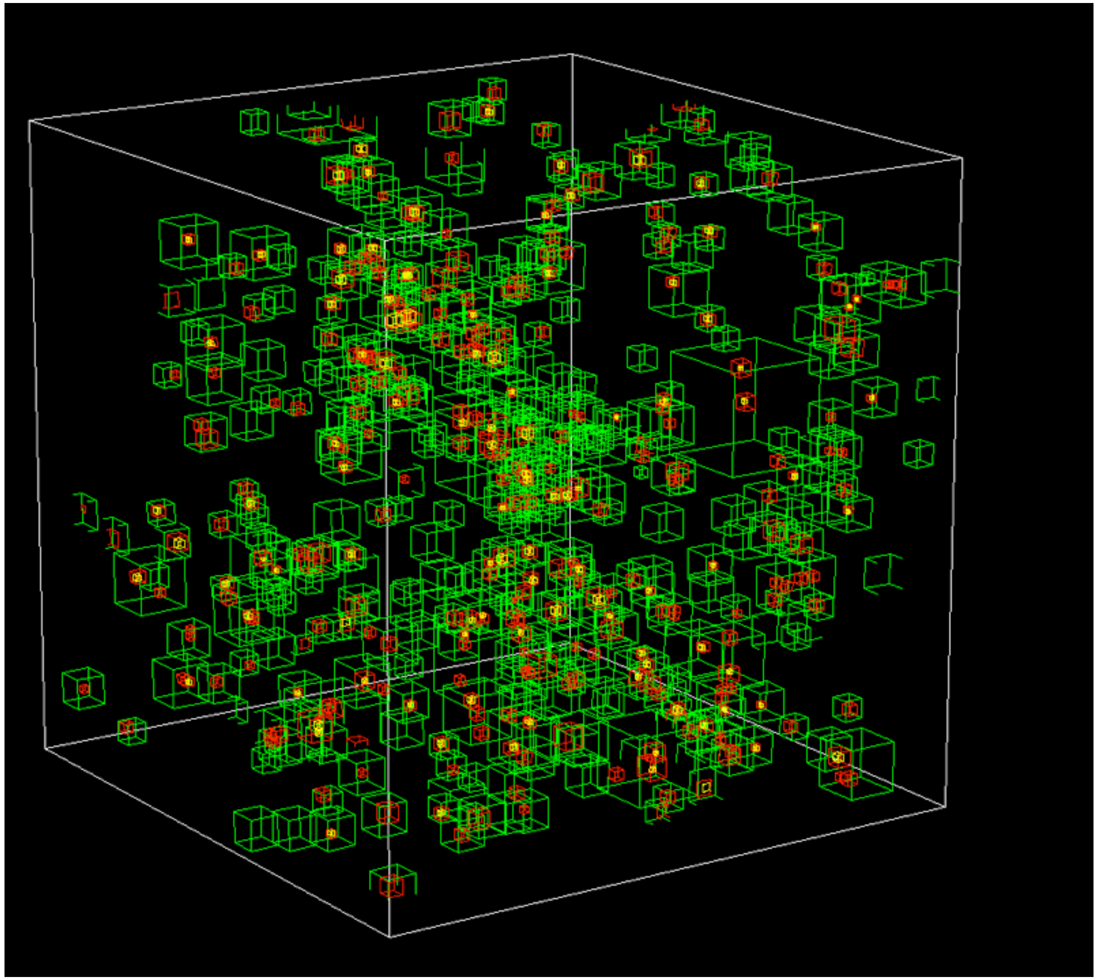
AMR-blocks

- Compute density on AMR block
- Set-up FFT planes (FFTW, pFFT) Pick FFT level
- Copy AMR density to FFT density
- Perform FFT
- Multiply with Green's function
- Perform inverse FFT
- Copy potential to AMR potential May need to restrict.
- Prolong potential to finer AMR blocks
- Iterate fine potential

Stopping criterion?

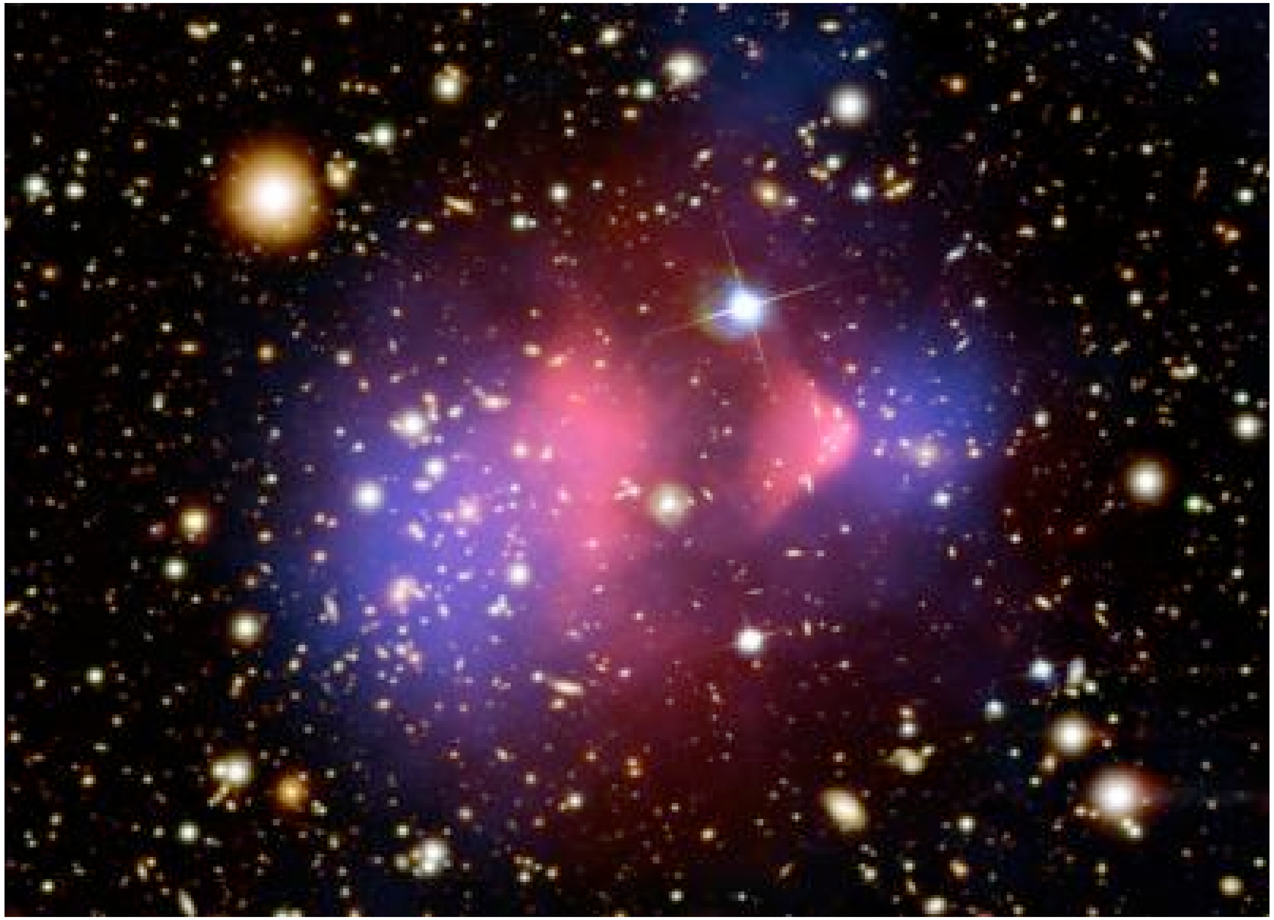
Wish list / issues

- Massive particles in small cells?
- PP-step for particles
- Isolated BCs
- Isolated FFTs (Refinements)

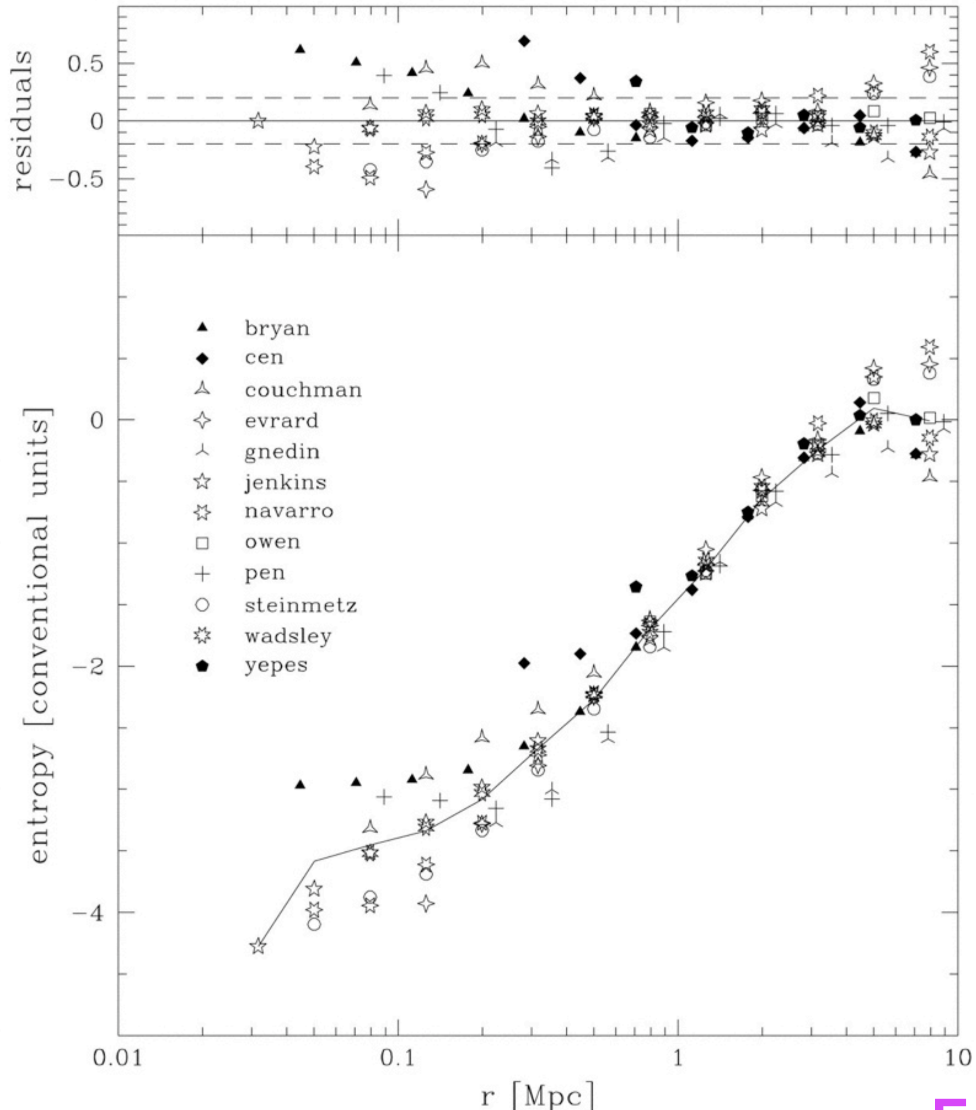


Multiple timesteps?

And now for something completely different ...

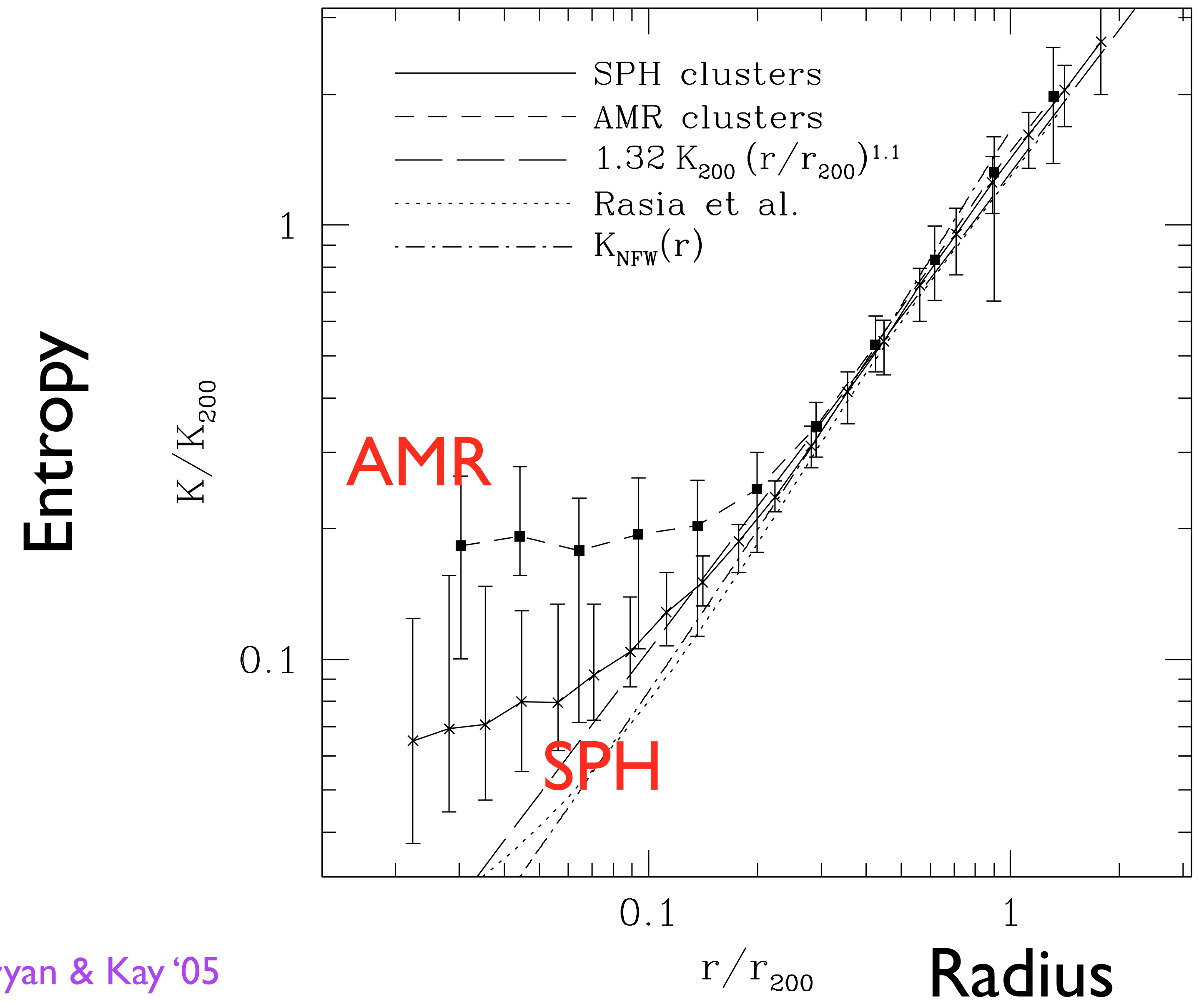


The Santa Barbara Cluster Comparison Project: A Comparison of Cosmological Hydrodynamics Solutions



Frenk et al ‘99

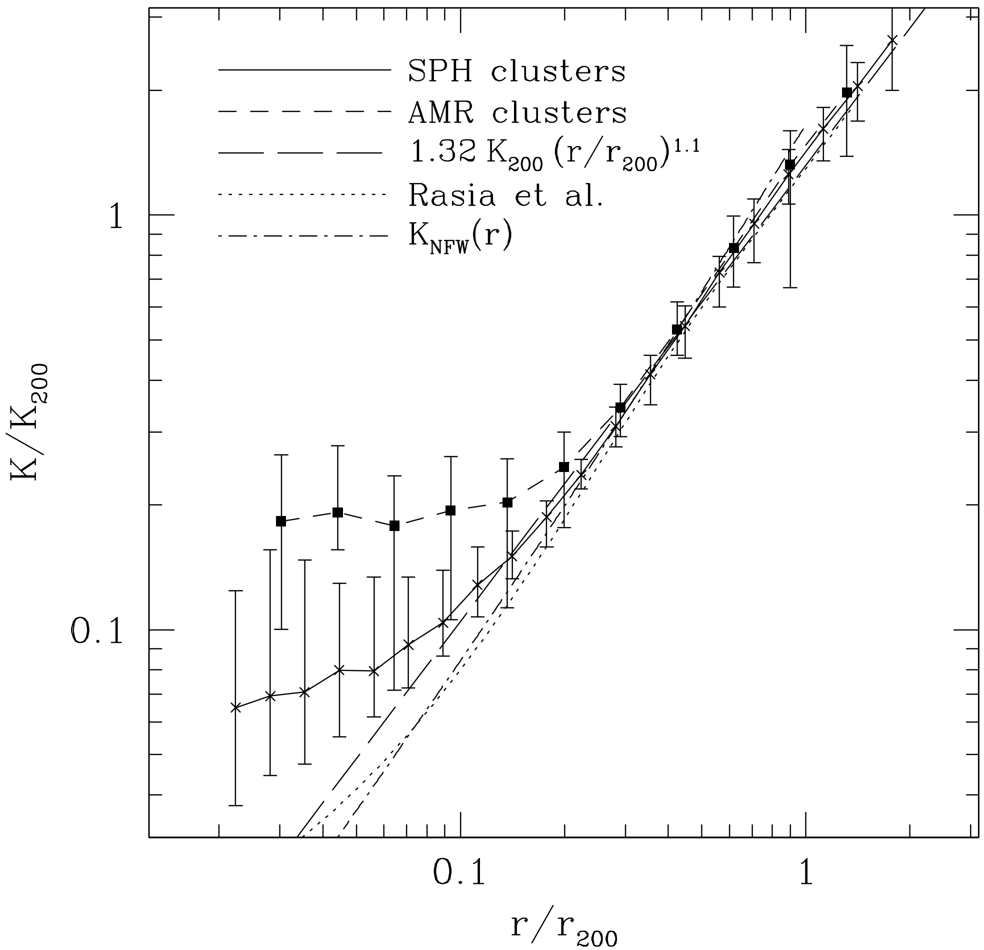
Cluster entropy profiles: SPH vs AMR



Voit, Bryan & Kay '05

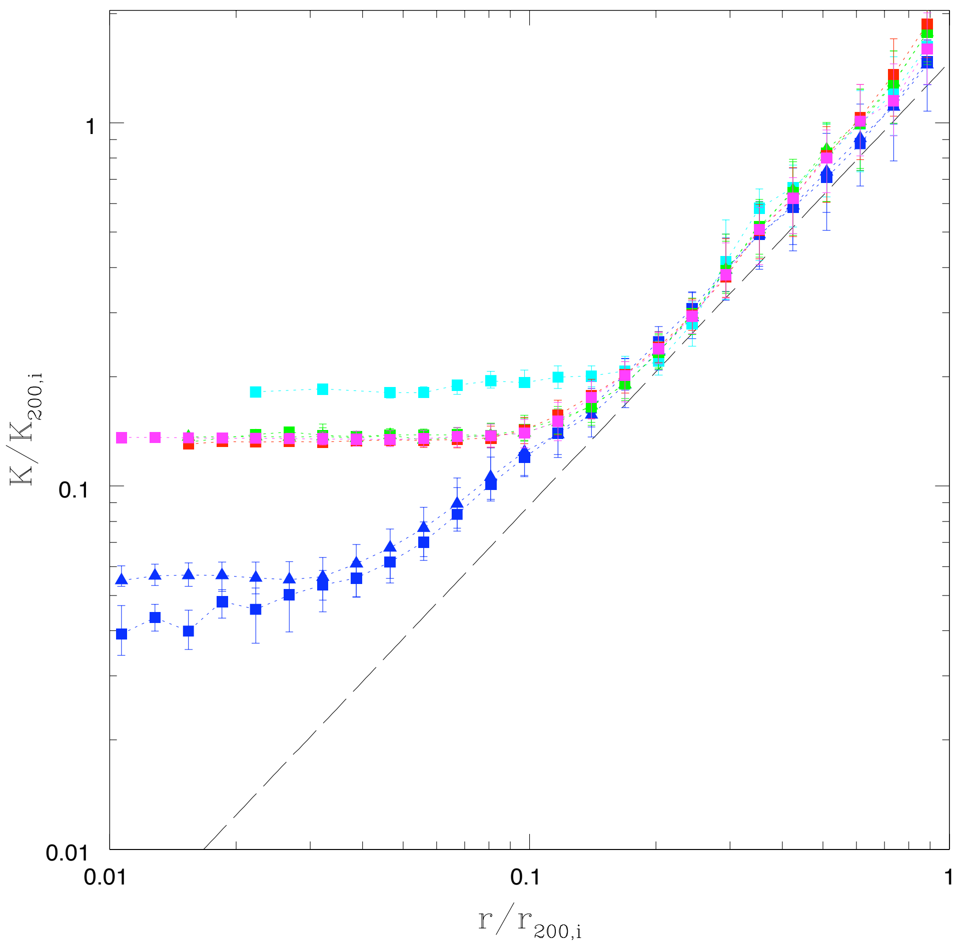
Cluster entropy profiles: *NOT* due to cosmology

Cosmological clusters



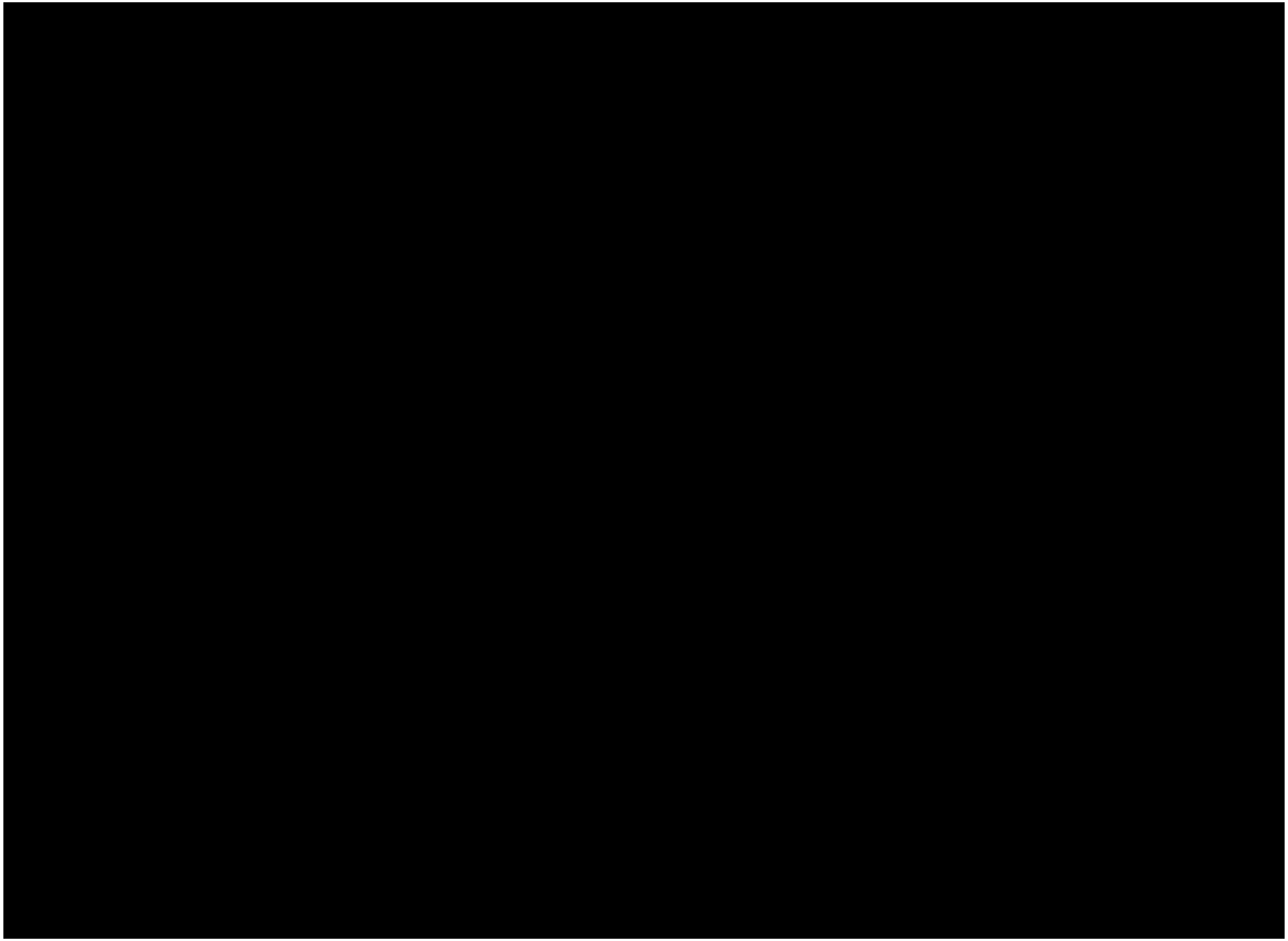
Voit, Bryan & Kay '05

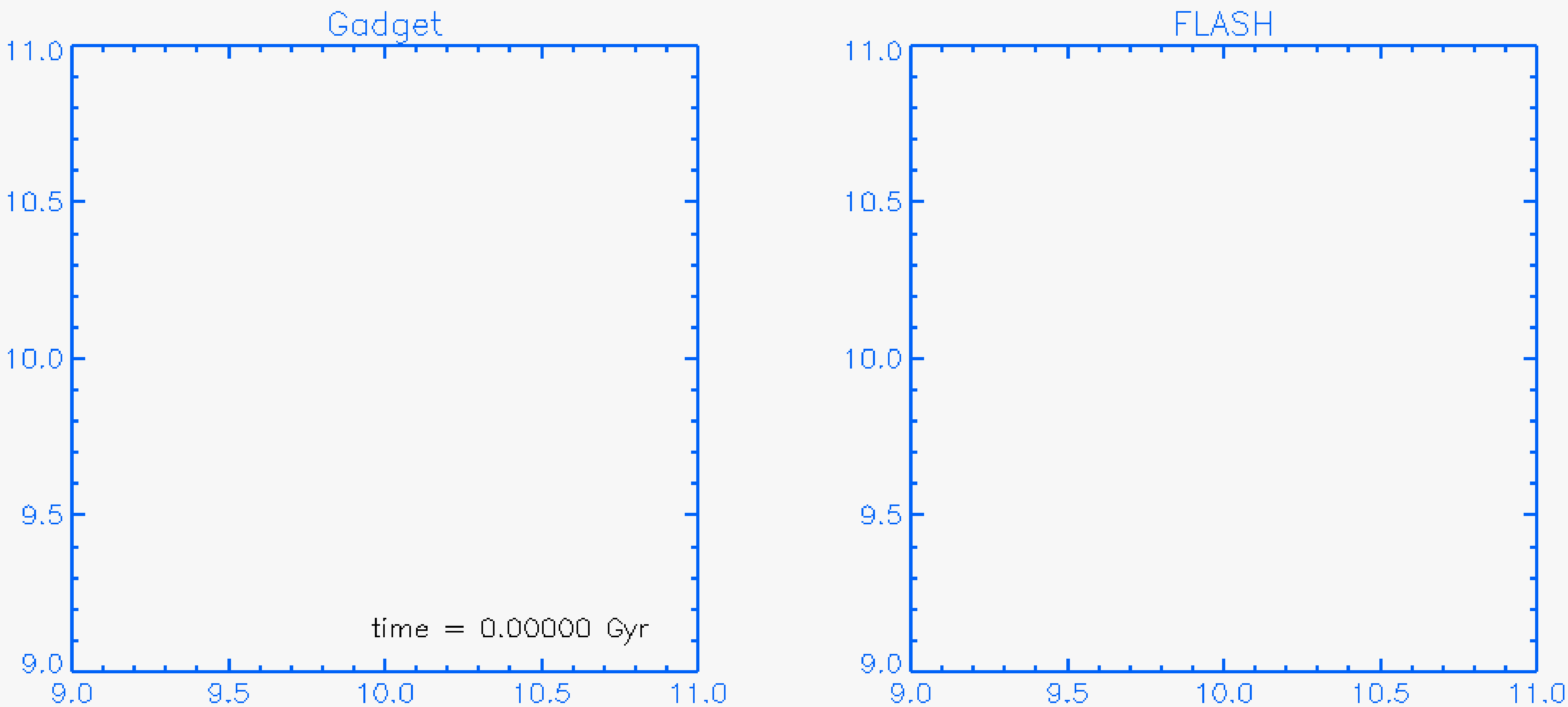
Binary collisions



Mitchell, McCarthy, Bower & TT

SPH AMR





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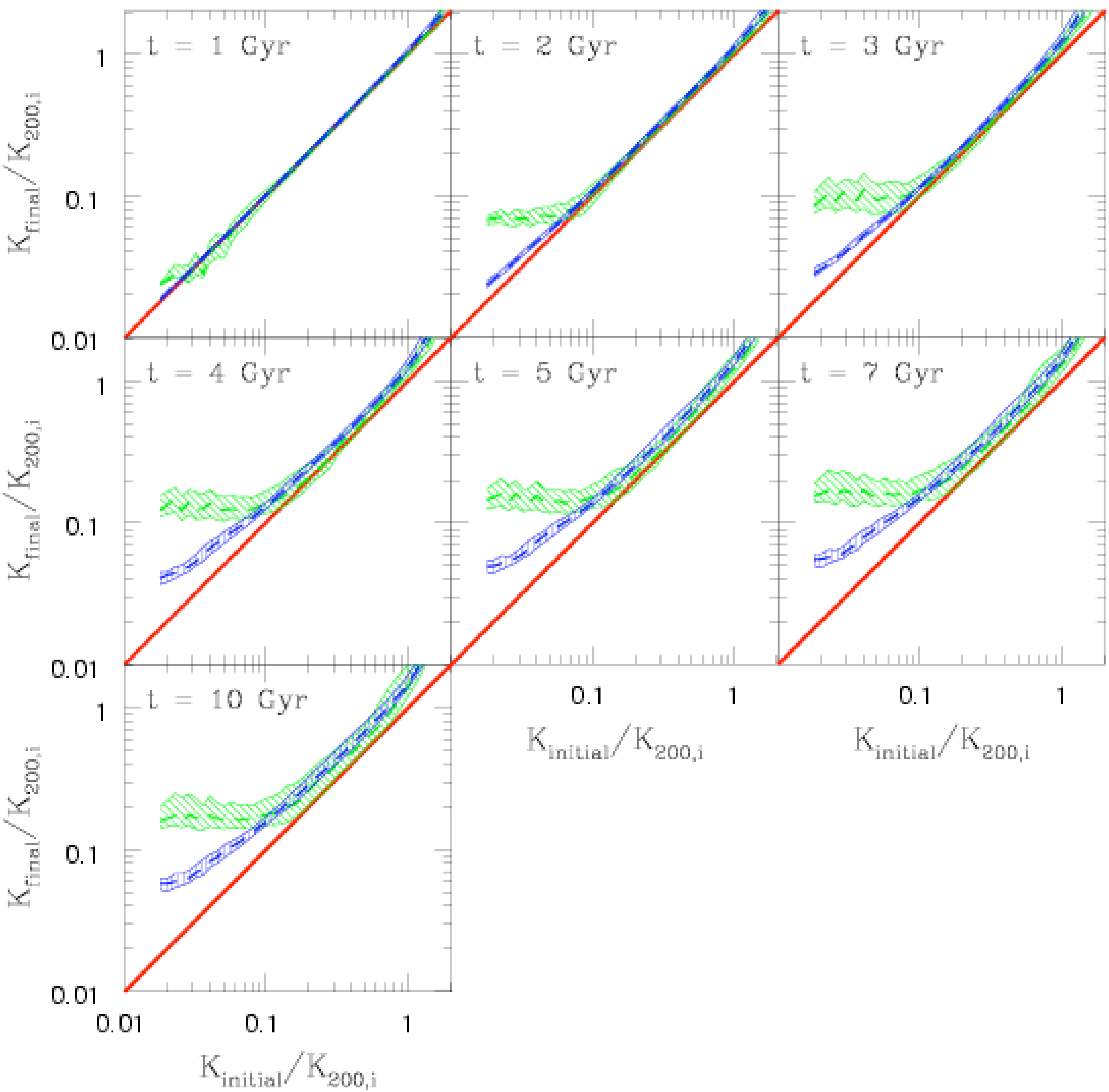
t = 1 Gyr
t = 2 Gyr
t = 3 Gyr
t = 4 Gyr
t = 5 Gyr
t = 7 Gyr
t = 10 Gyr
K_final/K_200,i
K_initial/K_200,i
0.01
0.1
1

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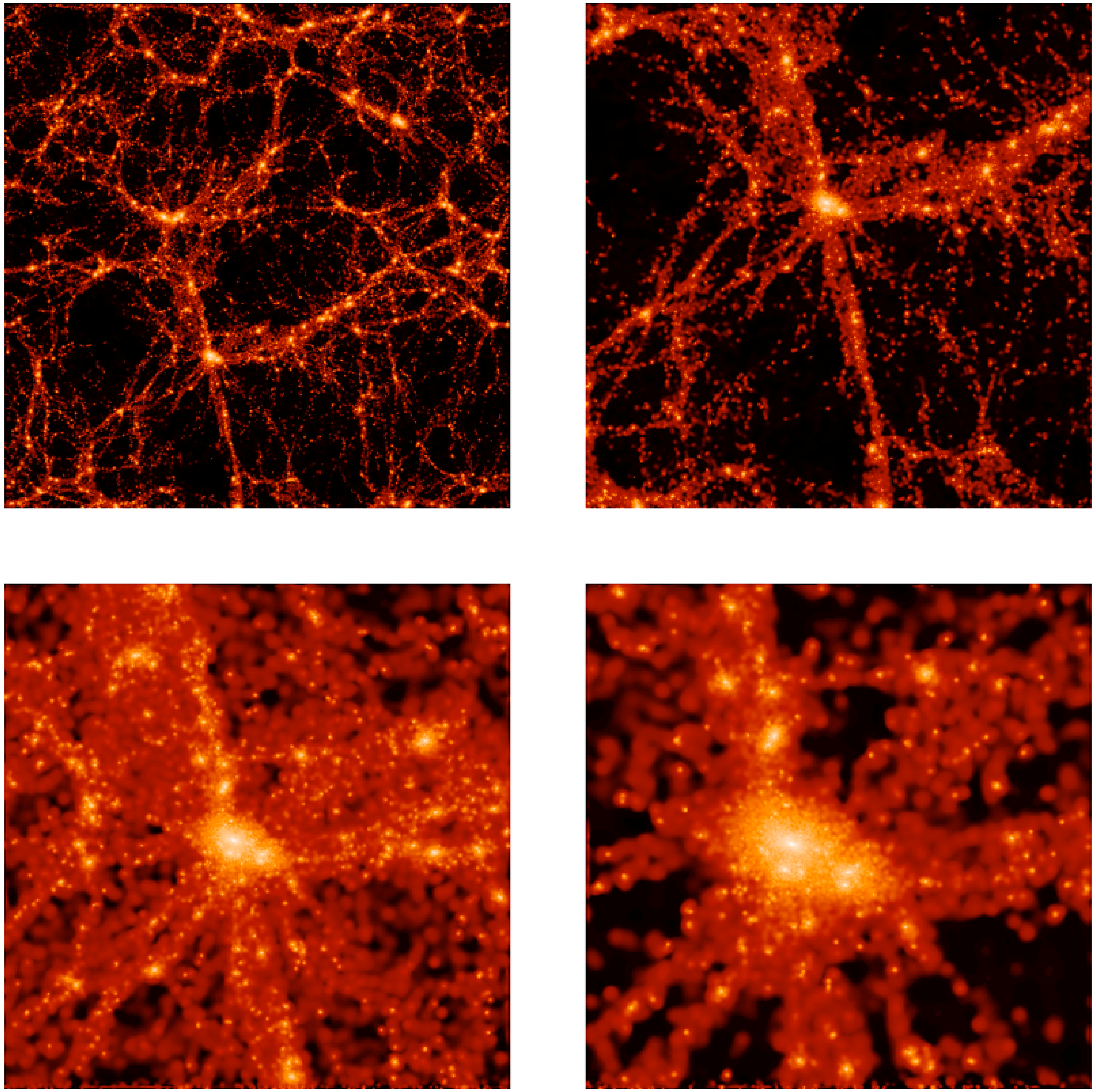
Conclusions:

- Poisson solver
- Entropy generation is real problem



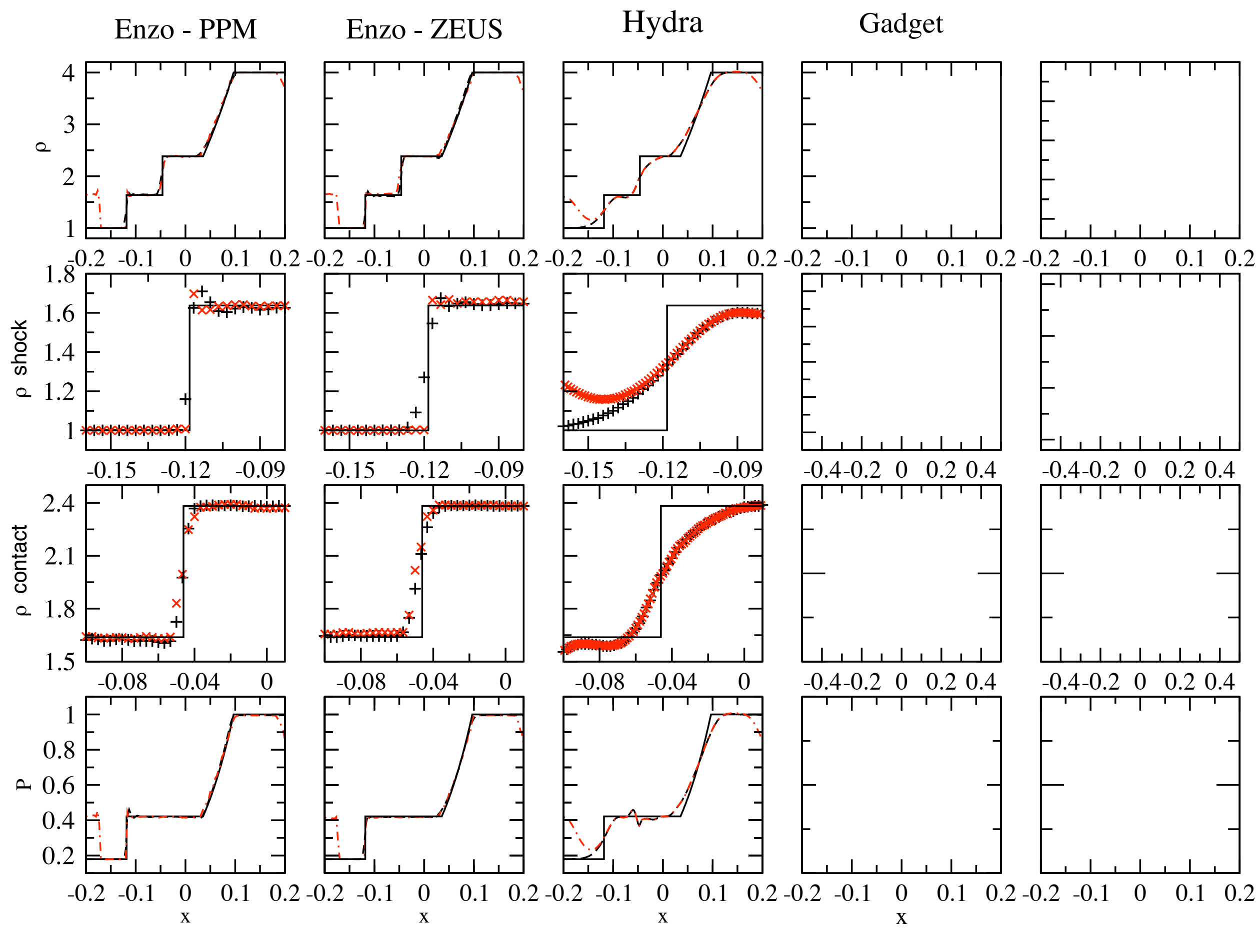


Figure 1: Results from the 3D shock test for each hydro scheme tested. The top and bottom rows of plots shows the density and pressure respectively through the middle of the simulation box. The 2nd and 3rd rows show a close up of the shock wave and contact discontinuity.The analytical solution is given by a solid black line, the [1,0,0] set-up results are shown by a black dashed line or black '+' (for close-ups). The oblique [1,1,1] set-up is shown as a red dot-dash line and red 'x'.

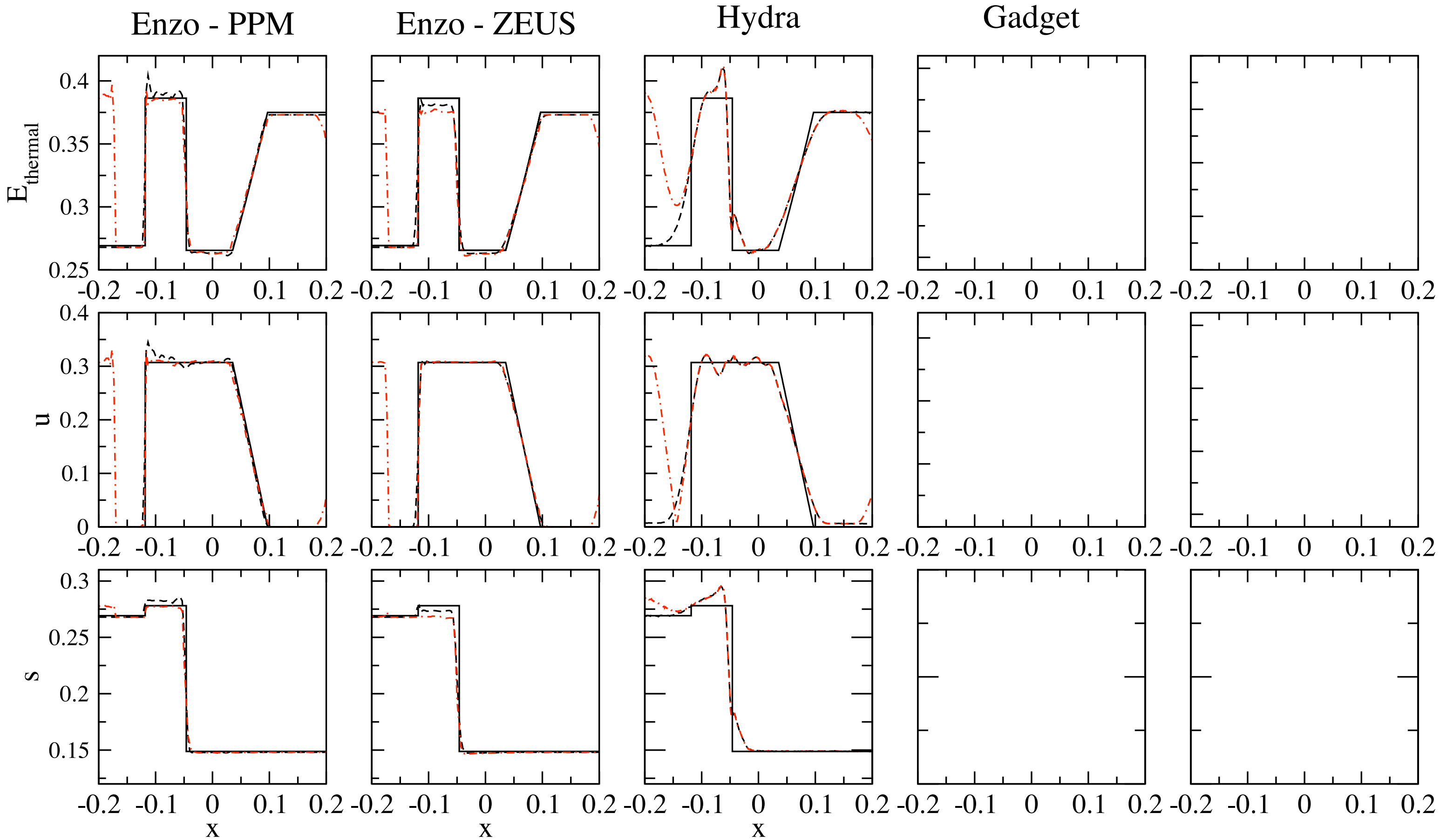


Figure 2: Results for the three-dimensional shock test. Top: thermal energy, middle: velocity and bottom: entropy

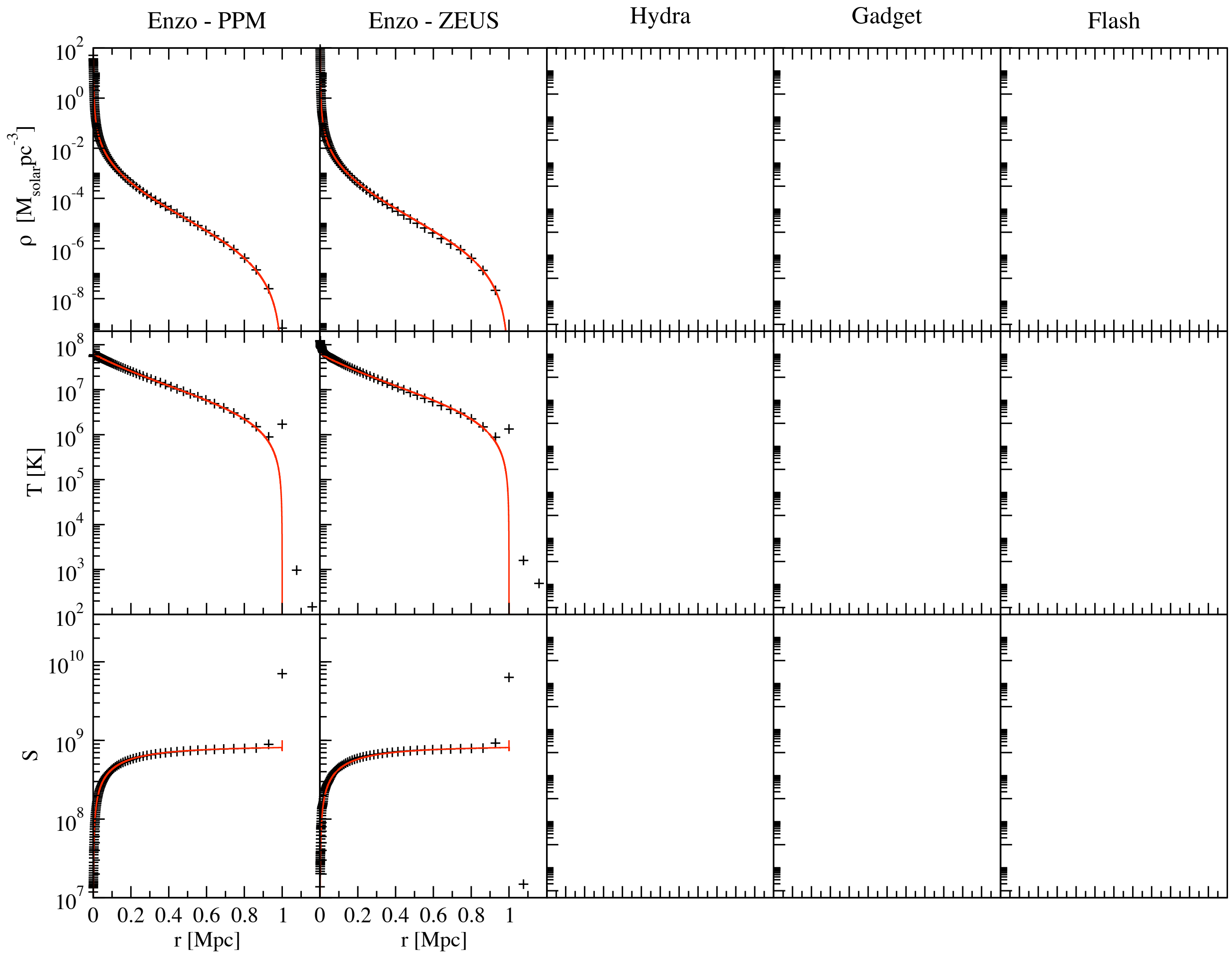
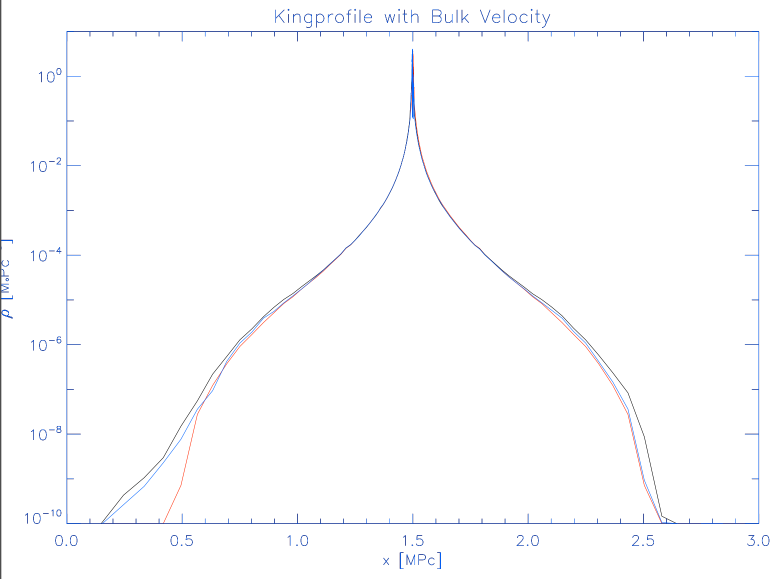
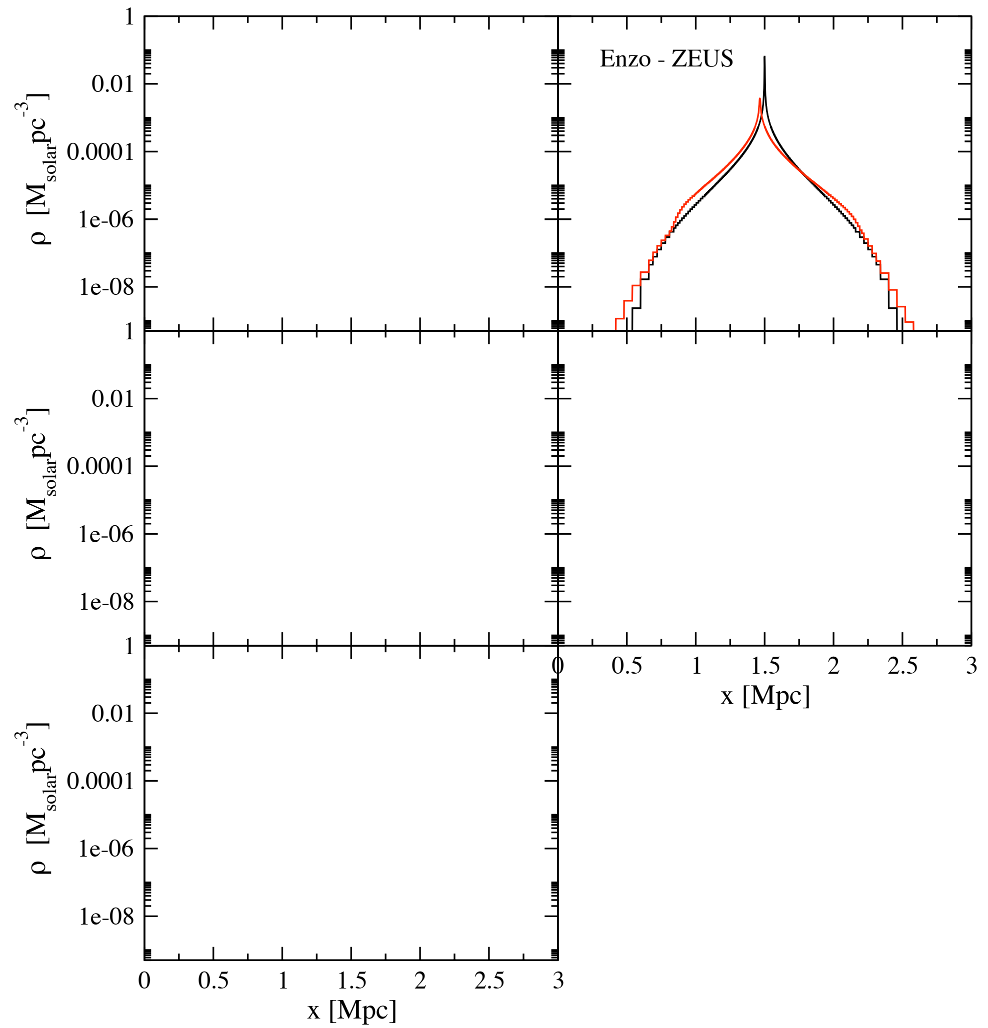


Figure 5: Results from the static cluster test at 1.5 Gyrs. From top to bottom, plots show the density, temperature and entropy profiles.

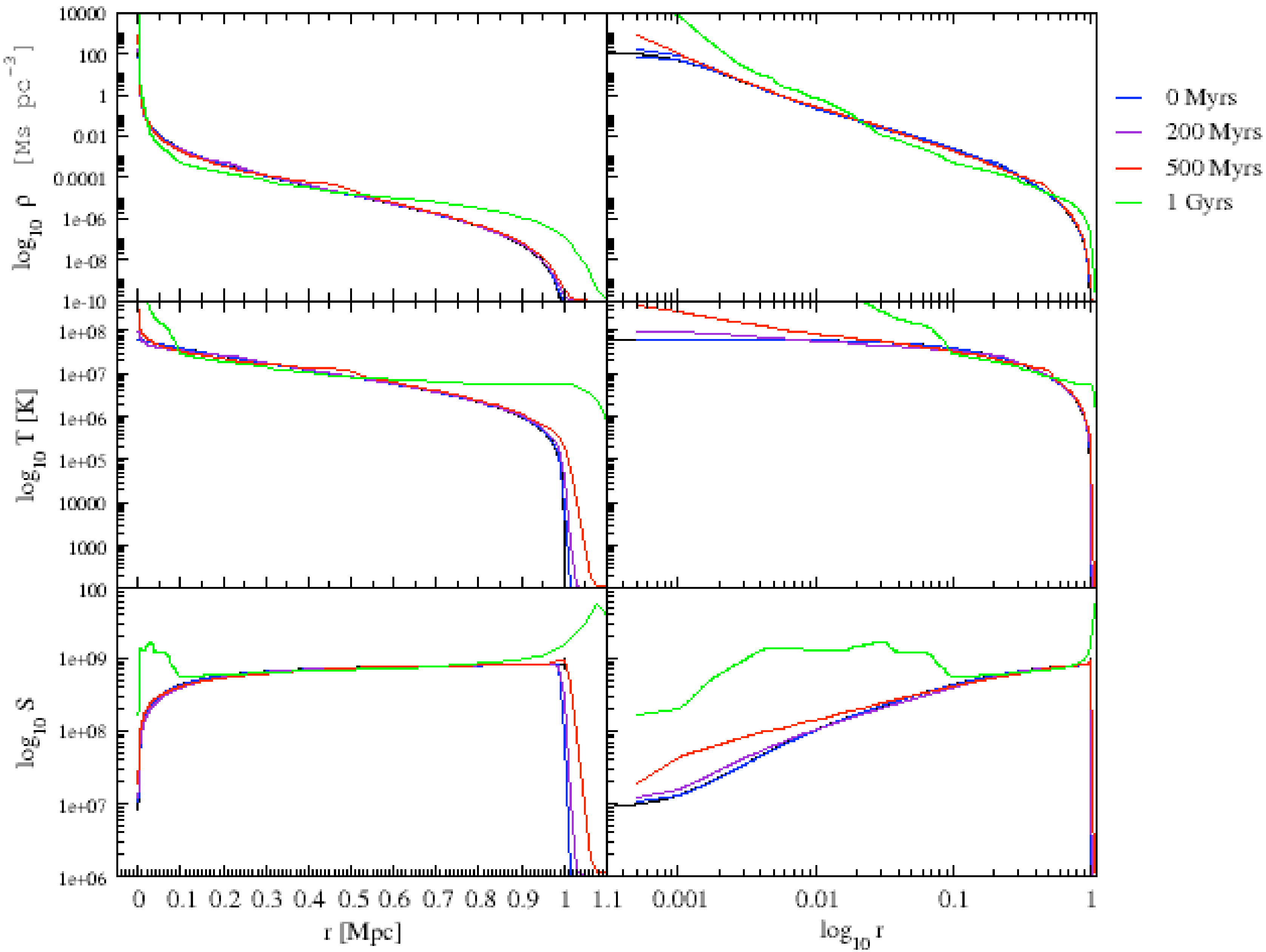




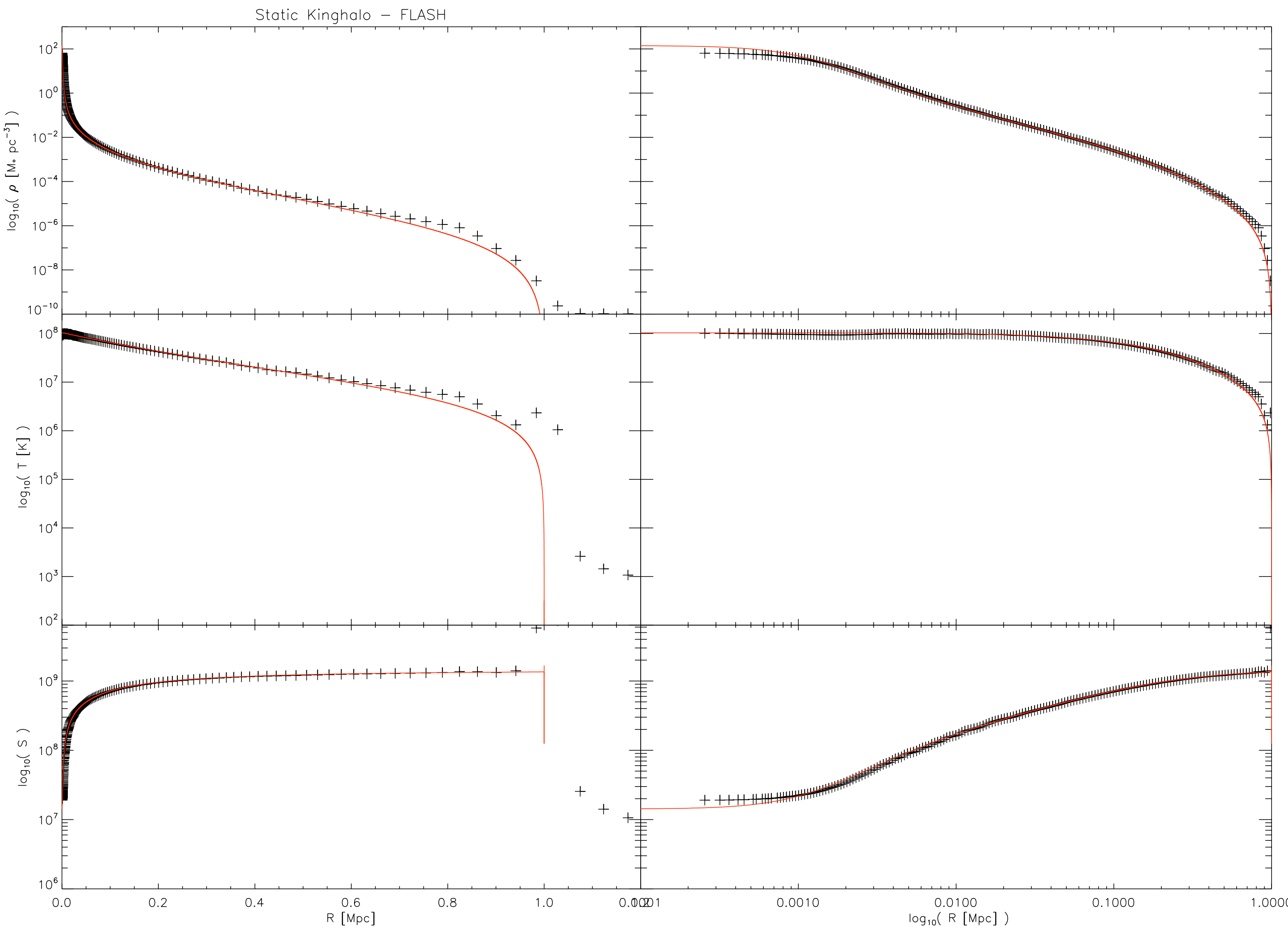
King profile with bulk velocity of 3000 km/s

Figure 7: Plots of the projected density through the centre of the simulation box. Shown in black is the profile at the start of the run and in red is the profile 1 Gyr later.

Parallel ENZO ("static cluster")



Flash (Parallel, 1Gyr)



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Institute for Computational Cosmology