Scaling Information for
"Four Projects in Astrophysical Magnetohydrodynamics"

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In order to quantify the performance and scaling, and to select the number of nodes to use for our jobs, we perform weak scaling studies for each of our four simulations. For each suite of simulations, we perform one fiducial simulation that targets the production physics packages, root grid size, particle count, and approximates the unpredictable adaptive mesh refinement (AMR) structure. We perform a single time step on the root grid, which takes many time steps on the subgrids. Also included in our estimation are reading and writing the data and initialization.

The results can be seen in Figure 1. Shown in the figure is $\mathrm{SU_{zu}}$, the number of service units for the update of one cell, assuming 64 cores per node. Each of our four suites uses a different set of physics modules, which changes the cost between suites. Additionally they have different adaptive mesh refinement (AMR) structure, which changes the overhead. We discuss each suite below.

The quantity $\mu = core - hours/zone - update$, given perfect scaling, is independent of the problem size and number of cores used. It depends only on the combination physics solvers. $\mathrm{SU_{zu}} = \frac{\mu}{\mathrm{Nc/Nn}}$ is then the cost per zone-update, and the total cost $SU = \mathrm{SU_{zu}ZU}$, where Z is the total number of zones, and U is the total number of updates. $\mathrm{SU_{zu}}$ also depends on the number of cores per node. For all runs we use 64 cores per node. Given perfect scaling, SU is independent of processor count. Our scaling is imperfect, and the optimal node number is selected from the Figure.

The blue line shows a set of fiducial simulations that use only the relevant hydro solvers and gravity. The hydro (or MHD) solver and gravity solver are the most expensive part of the code, so we present their timing alone as a baseline. The simulations use either Piecewise Parabolic Method (**?**) for the pure hydro turbulence simulations, or the second order MHD scheme of (**?**) for the other three. The points in the blue line are, bottom to top, PPM, MHD, PPM+Gravity, MHD+Gravity.

The orange line shows the scaling for the fiducial *turbulence* simulations. These simulations will only use PPM and the driving module. The fiducial simulation is, as the production simulations will be, 1024^3 root grid with no AMR. We run on 4, 8, 16, and 32 nodes, 64 cores per node. The result is $\mathrm{SU_{zu}} = 2\times10^{-11}$ on 4 cores, and 4×10^{-11} for 32 nodes. We will run on 32 nodes, as the small increase in cost will be offset by the much shorter run time.

The green curve shows the weak scaling for the fiducial *cores* simulation. This simulation has 512^3 zones and 1024^3 tracer particles. On each of 4 levels, we refine a cubic region with volume identical to the simulations in (Collins et al. 2012). We additionally use the gravity solver and MHD solvers. For this simulation, the density and pressure are uniform, which simplifies the setup but does not affect the timing of the solver. what number I use

The red line shows the scaling for the *foregrounds* simulations. The fiducial simulation is also 1024^3 and driving like the *turbulence* suite, but uses the MHD solver so is slightly more expensive. Due to the increased memory of the extra magnetic fields, we run on 8, 16, and 32 nodes. We find $\mathrm{SU_{zu}} = 2\times10^{-11} - 7\times10^{-11}$. Again, we will use 32 nodes due to the short run times.

The final suite is the *galaxies* suite, shown in purple. This suite employs the most additional physics packages (including star formation, cooling and heating, and chemistry). The AMR structure, outlined in greater detail in the main document, is a nest of refinements, each about 1/8 of its parent by volume (about half the length), that allows us to resolve both the disk and the circumgalactic medium. The fiducial simulations use 5 levels of refinement, rather than the target 9, but the amount of overhead relative to useful work doesn't change much going from 5 to 9 levels We use the same target root grid of 1.3 Mpc in physical size and 256 zones on a side. The AMR structure that Enzo produces is coincidentally 64 grid patches per level, so we run our scaling study from 1 to 5 nodes with 64 cores per node. This scaling is good, rising from 2×10^{-11} to 3×10^{-11}, so we will use 9 nodes for our 9 level production simulations.

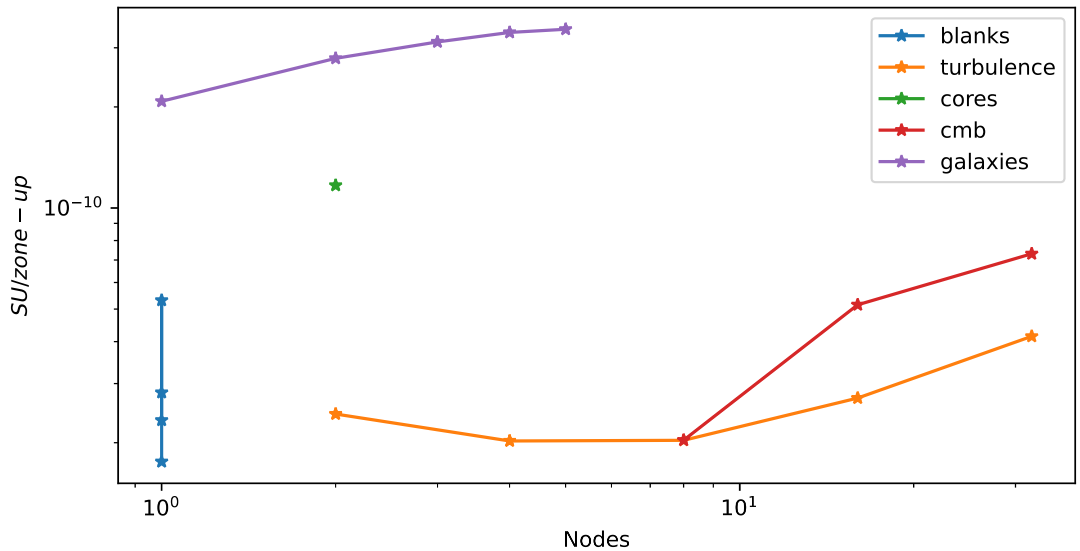

Figure 1: The cost per zone-update for each of our simulation suites. Each fiducial simulation is nearly identical to the target production simulations.

References

Collins, D. C., Kritsuk, A. G., Padoan, P., Li, H., Xu, H., Ustyugov, S. D., & Norman, M. L. 2012, ApJ, 750, 13