Update SPACE project

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RAMSES SNO meeting 2025

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EuroHPC Joint Undertaking

SPACE

- Scalable Parallel Astrophysical Codes for Exascale
- 4 year European Center of Excellence project
- Goal: prepare state-of-the-art astro codes to efficiently use exascale computation resources
- 7 codes: OpenGadget, ChaNGa, PLUTO, iPIC3D, RAMSES, FIL, BHAC
- Collaboration: research institutes, computing centers, vendors

RAMSES in SPACE

Goal: improve time-to-solution and scaling

Progress:

- benchmarking on all EuroHPC machines

  (see Benoît's talk tomorrow)

- Low level optimisations

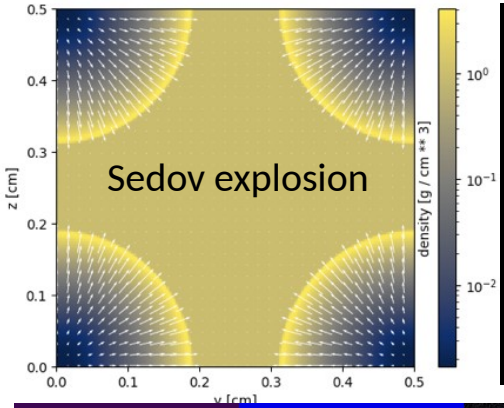
  neighbor searching, godunov solver

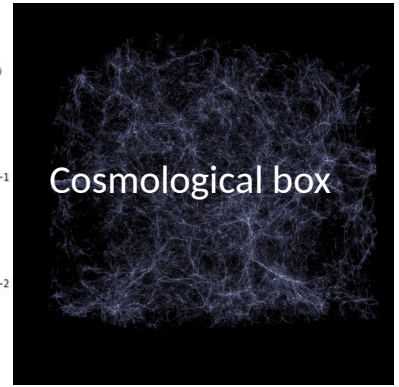
- OpenMP

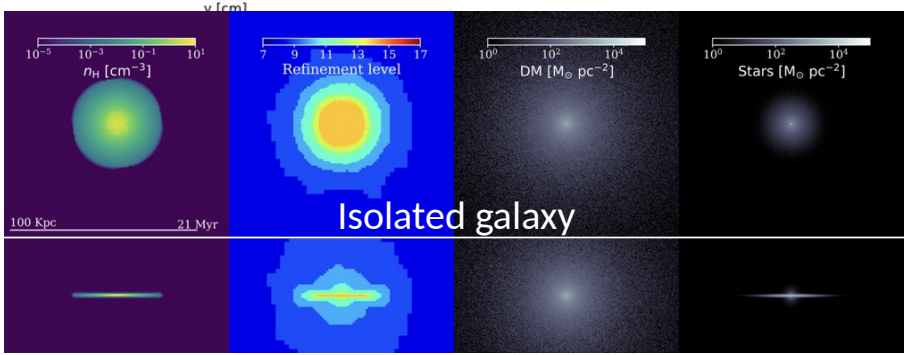
  sedov & cosmo done, amr wip

- Also tests, doc, code cleaning

Selected representative use cases:







1 Open ✓ **48 Closed** Author Label Projects Milestones

- **Overhaul of compiler flags in Makefile** ✓ SPACE
  #185 by tinecolman was merged 3 days ago • Approved
- **Combine hydro, mhd and rhd versions of hydro_parameters.f90** ✓ code quality SPACE
  #184 by tinecolman was merged 5 days ago • Approved
- **Combine hydro and mhd versions of output_hydro.f90** ✓ code quality SPACE
  #183 by tinecolman was merged 5 days ago • Approved
- **further document the order of hydro variables** ✓ documentation SPACE
  #178 by tinecolman was merged last week • Approved
- **combine the hydro and mhd versions of init_flow_fine.f90 into one** ✓ code quality SPACE
  #174 by tinecolman was merged last week • Approved
- **fix after merge** ✗ openmp SPACE
  #171 by tinecolman was merged on Jul 15
- **change slope_type in imhd-tube and imhd-tube-nener tests** ✓ CI SPACE
  #169 by tinecolman was merged 5 days ago • Approved
- **Add 1D advection test** ✓ SPACE test case
  #166 by tinecolman was merged on Jul 9 • Approved
- **Improvements to parameter sweep of sod-tube test** ✓ CI SPACE
  #165 by tinecolman was merged on Jul 9 • Approved
- **regenerate reference solution for stellar-HII with 2 cpus** ✓ CI SPACE
  #160 by tinecolman was merged on Jul 1 • Approved
- **optimizations for hydro solver on uniform grid** ✓ performance SPACE
  #159 by tinecolman was merged 4 days ago • Approved
- **Optimize ctoprim** ✓ performance SPACE
  #158 by tinecolman was merged 5 days ago • Approved

Commits from SPACE

46 PRs merged on dev

+ 9 PRs merged on openmp

Various stuff in development on

https://github.com/tinecolman/ramses

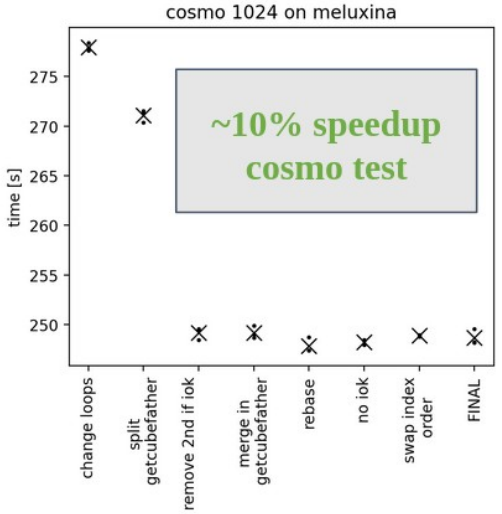
Optimization of neighbor searching

Elementary routine used in many parts of the code

Identified as bottleneck in COSMO use case

=> refactor for efficiency

cosmo profiling Name	Inclusive Time w.r.t. Wall Time(s)	
	old	new
gauss_seidel_mg_fine	15.31	15.17
interpolate_and_correct_fine	12.08	12.15
move1	9.89	9.75
sync	9.32	9.60
mca_btl_vader_poll_handle_frag	9.32	7.83
get3cubefather	17.86	0.28
cic_amr	6.92	6.64
cmp_residual_mg_fine	6.23	6.15
gauss_seidel_mg_coarse	4.16	4.03
check_tree	4.19	3.97
get3cubepos	3.85	3.79

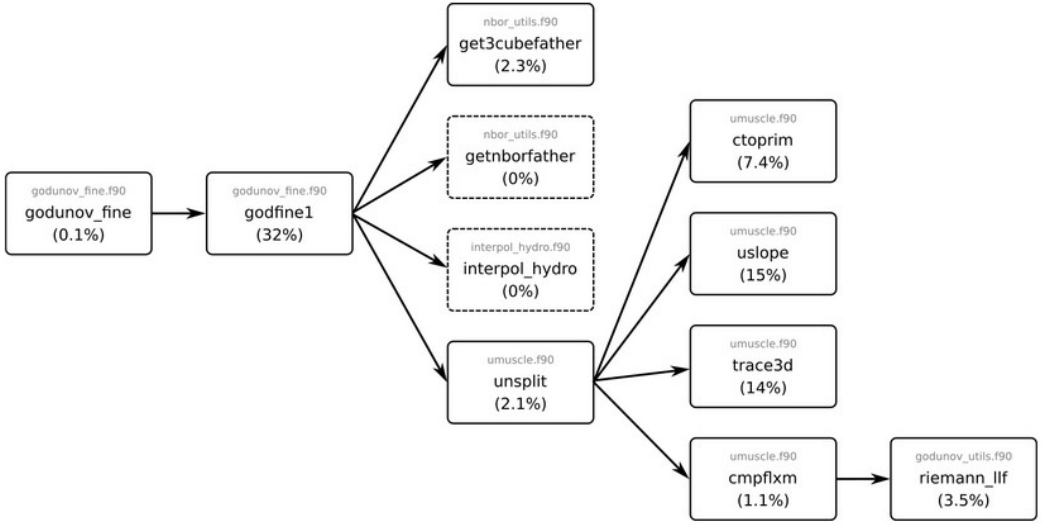


[SPACE] Optimize and document nbor utils ✓

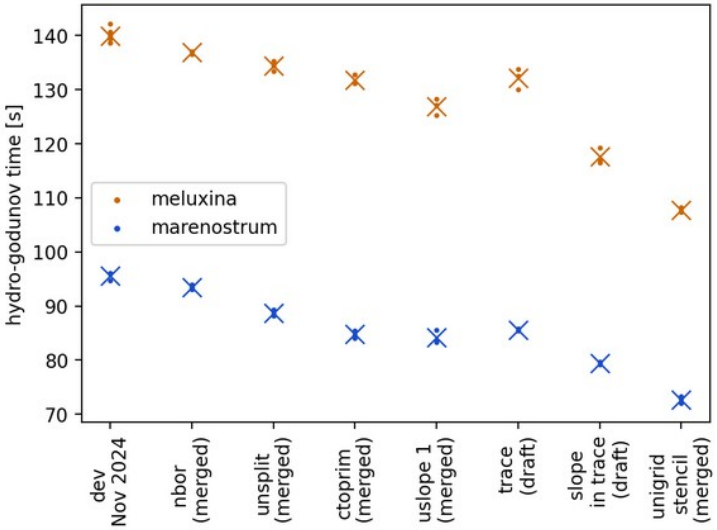
#108 by tinecolman was merged 3 weeks ago • Approved

Optimization of Godunov solver

Initial profiling of sedov use-case



Progress



23% speedup for sedov test

MPI + OpenMP implementation

Shared memory parallelism with OpenMP inside nodes

=> reduce number of MPI domain

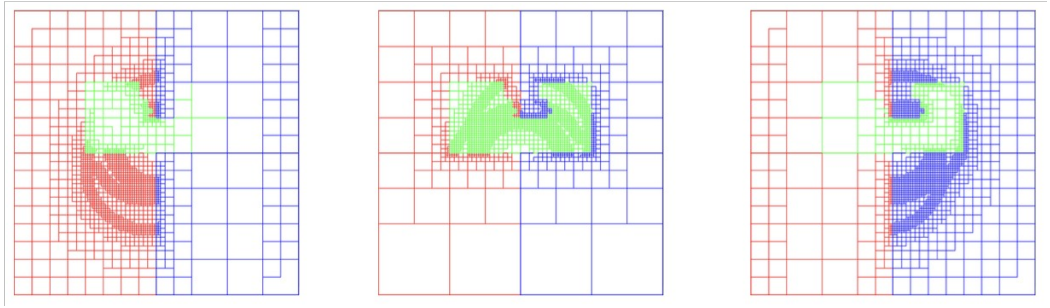
=> decrease communication &

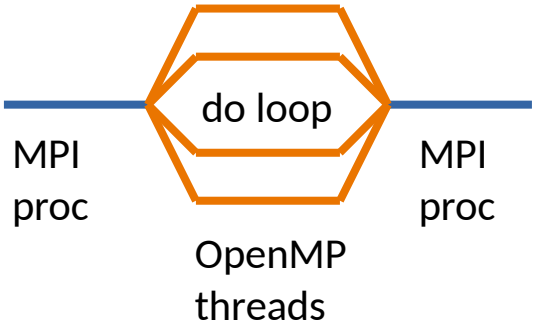
reduced memory imprint ghost zones

=> less time spent communicating

=> **improved scalability**

Starting from RAMSES-yOMP





openmp branch

NEW BRANCH on vanilla ramses

Done:

- Hydro on uniform grid (SEDOV)
- DM-only on uniform grid (COSMO)

WIP:

- Refinement
- MHD
- RT & cooling (STROMGREN)

Working version of OpenMP in particles for COSMO (part2) openmp SPA
ramses-organisation/ramses#213 · by tinecolman was closed yesterday · ✓ 16/18

adjust omp for set_uold/unew to allow for more than 8 threads openmp
ramses-organisation/ramses#207 · by tinecolman was closed on Oct 17 · ✓ 8/8

[OpenMP] Progress of openmp for cosmo box: poisson multigrid solver
ramses-organisation/ramses#200 · by tinecolman was closed on Sep 30 · ✓ 8/8

Openmp virtual_boundaries openmp SPACE
ramses-organisation/ramses#196 · by tinecolman was closed on Sep 23 · ✓ 8/8

fix after merge openmp SPACE
ramses-organisation/ramses#171 · by tinecolman was closed on Jul 15 · ✗ 8/10

OpenMP: hydro on unigrid openmp SPACE
ramses-organisation/ramses#119 · by tinecolman was closed on Jun 6 · Approved · ✓ 8/10

OpenMP: add variables for nthr + fix openmp SPACE
ramses-organisation/ramses#118 · by tinecolman was closed on Jun 5 · ✓ 8/10

Use the communicator active instead of the linked list openmp SPACE
ramses-organisation/ramses#103 · by tinecolman was closed on Apr 14 · Approved · ✓ 8/10

OpenMP: make saved variables threadprivate openmp SPACE
ramses-organisation/ramses#96 · by tinecolman was closed on Apr 1 · ✓ 8/10

OpenMP: compile and launch test suite with threads openmp SPACE
ramses-organisation/ramses#84 · by tinecolman was closed on Mar 19 · ✓ 15/15

Implementation

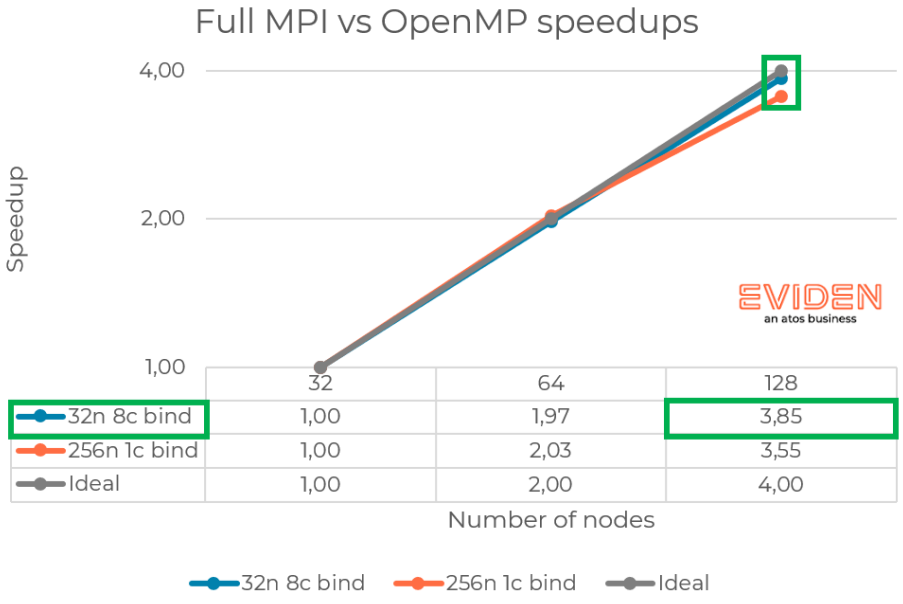
Place !$omp on loops over grids

Beware of updates to neighbors or other levels

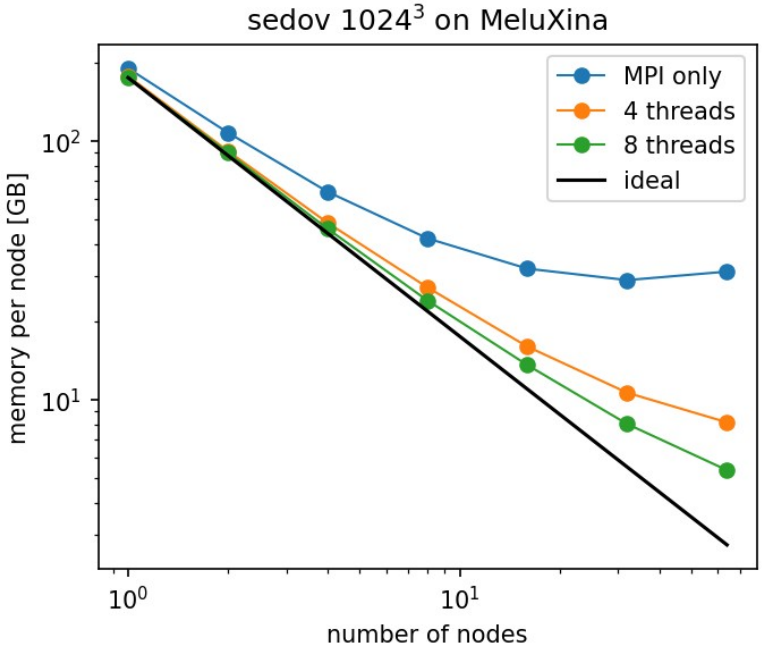
```
  ! Loop over active grids by vector sweeps
  ncache=active(ilevel)%ngrid
!$omp parallel do private(ngrid,i)      You, last mo
  do igrid=1,ncache,nvector
     ngrid=MIN(nvector,ncache-igrid+1)
     do i=1,ngrid
        ind_grid(i)=active(ilevel)%igrid(igrid+i-1)
     end do
     call godfine1(ind_grid,ngrid,ilevel)
  end do
```

```
  ! Update particles position and velocity
!$omp parallel private(ig,ip,jgrid,igrid,npart1,ipart,local_c
  ig=0
  ip=0
  ! Loop over particles that are not tracers
!$omp do
  do jgrid=1,active(ilevel)%ngrid
     igrid=active(ilevel)%igrid(jgrid)
     npart1=numbp(igrid)  ! Number of particles in the grid
     if(npart1>0)then
        ...
        ! Loop over particles in current grid
        do jpart=1,npart1
           ! Save next particle  <---- Very important !!!
           next_part=nextp(ipart)
           ...
           if(ip==nvector)then
              ! send gathered nvector particles to calculatio
              call move1(ind_grid,ind_part,ind_grid_part,ig,i
              ...
           end if
           ipart=next_part  ! Go to next particle
        end do
        ! End loop over particles
        ...      You, yesterday • Uncommitted changes
     end if
  end do
!$omp end do nowait
  ! End loop over grids
  if(ip>0)call move1(ind_grid,ind_part,ind_grid_part,ig,ip,il
!$omp end parallel
```

OpenMP for SEDOV ✅

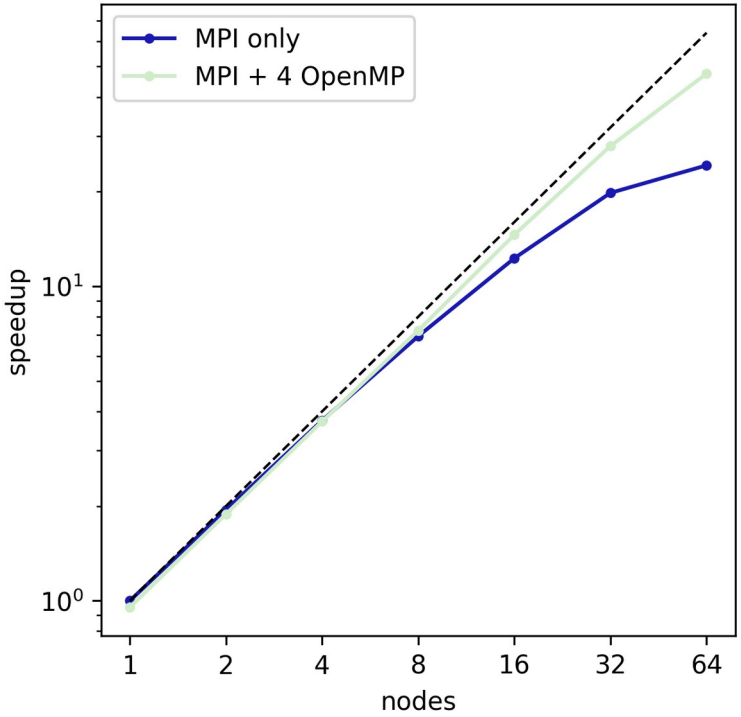


	32	64	128
32n 8c bind	1,00	1,97	3,85
256n 1c bind	1,00	2,03	3,55
Ideal	1,00	2,00	4,00



AMD Milan architecture, 128 cores (256 threads) / node, AOCC compiler

OpenMP for COSMO ✅

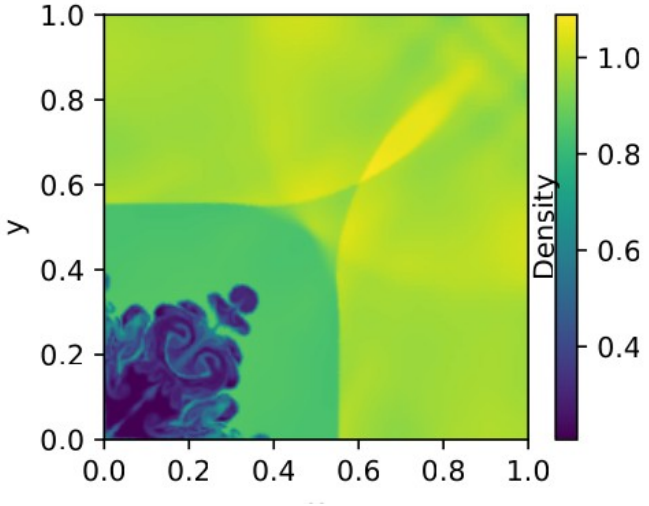


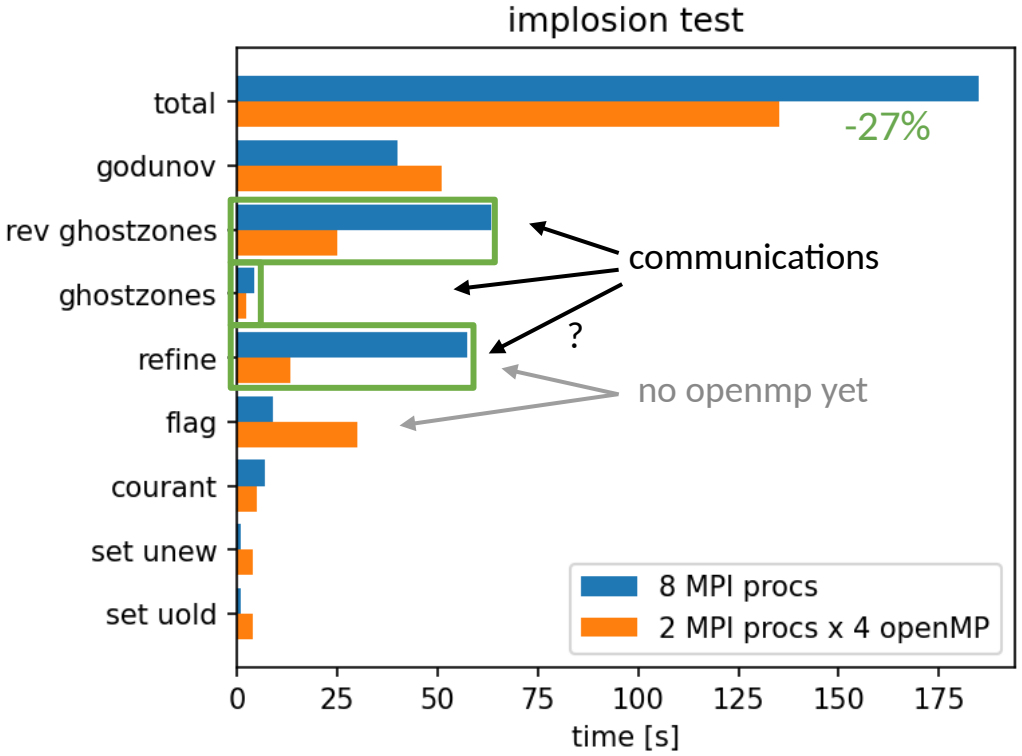
On 64 nodes:

x2 faster

scaling 38% → 72%

WIP: implosion test with AMR





Acknowledgement & Disclaimer

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