



CENTRE OF EXCELLENCE FOR HPC  
ASTROPHYSICAL APPLICATIONS

# RAMSES in SPACE

Tine Colman, Benoît Commerçon (CRAL, CNRS)

RUM 2026



Funded by the European Union. This work has received funding from the European High Performance Computing Joint Undertaking (JU) and Belgium, Czech Republic, France, Germany, Greece, Italy, Norway, and Spain under grant agreement No 101093441.



# SPACE

- Scalable Parallel Astrophysical Codes for Exascale
- 4 year European Center of Excellence project (01/2023 - 12/2026)
- 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

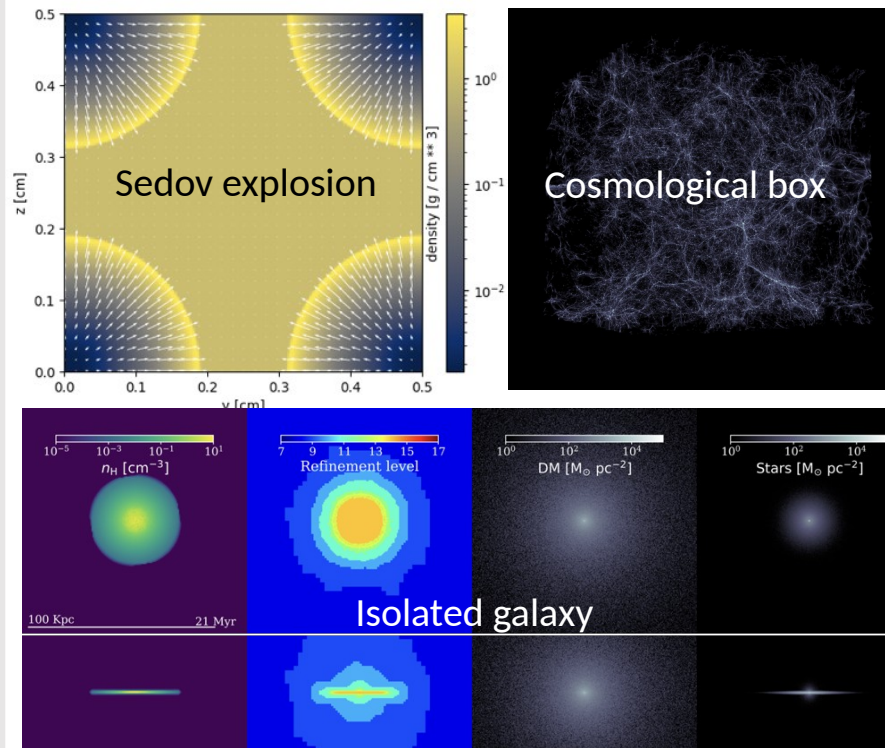


**Goal: improve time-to-solution and scaling**

**Progress:**

- Benchmarking on all EuroHPC machines
- Low level optimisations
  - neighbor searching, godunov solver
- OpenMP
  - sedov, cosmo, galaxy done
- Also tests, doc, code cleaning

**Selected representative use cases:**

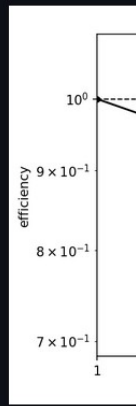
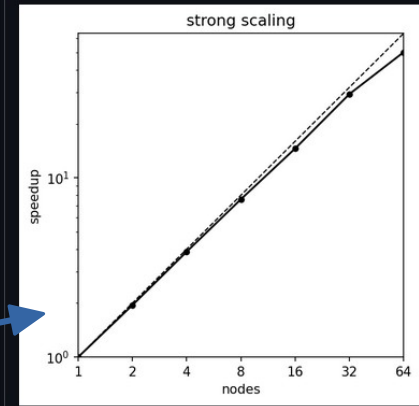


# Benchmarking package

## Benchmark results meluxina

### SEDOV

#### Strong scaling



#### Strong scaling

| nodes | efficiency |
|-------|------------|
| 1     | 100%       |
| 2     | 97%        |
| 4     | 97%        |
| 8     | 95%        |
| 16    | 91%        |
| 32    | 92%        |
| 64    | 79%        |

#### Weak scaling

| nodes | resolution | efficiency |
|-------|------------|------------|
| 1     | 256        | 100%       |
| 8     | 512        | 92%        |
| 64    | 1024       | 86%        |

- RAMSES-BENCHMARKS-PROTOTYPE2
  - analysis
  - doc
  - HPCclusters
  - results
  - setups
  - setups-mini-ramses
  - .gitignore
  - launch\_benchmark\_suite.sh
  - README.md

tinecolman / ramses-benchmarks-prototype2

### Benchmark setups

- SEDOV: classic Sedov explosion in 3D
- COSMO: dark matter-only cosmological box on a uniform grid

### Benchmark results per cluster

| Cluster     | Benchmark results |
|-------------|-------------------|
| Meluxina    | SEDOV             |
| MareNostrum |                   |

### How to do your own benchmarking

- How to use the benchmark script
- How to process the results
- How to add a setup
- How to add a cluster

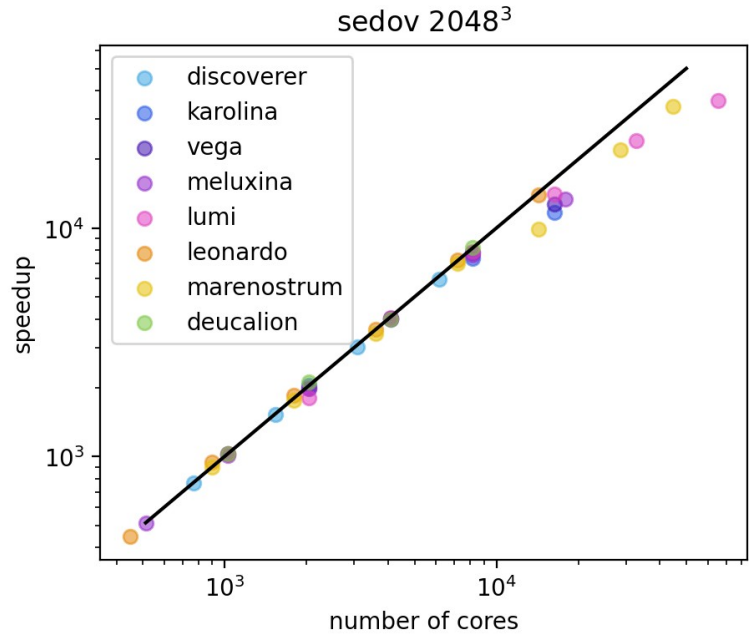
<https://github.com/tinecolman/ramses-benchmarks-prototype2>

# Using the benchmark script



```
$ ./launch_benchmark_suite.sh -c meluxina -l "1" -h refactor_3cube_nbor_utils -t 1,2 -a p200525 -i 3
```

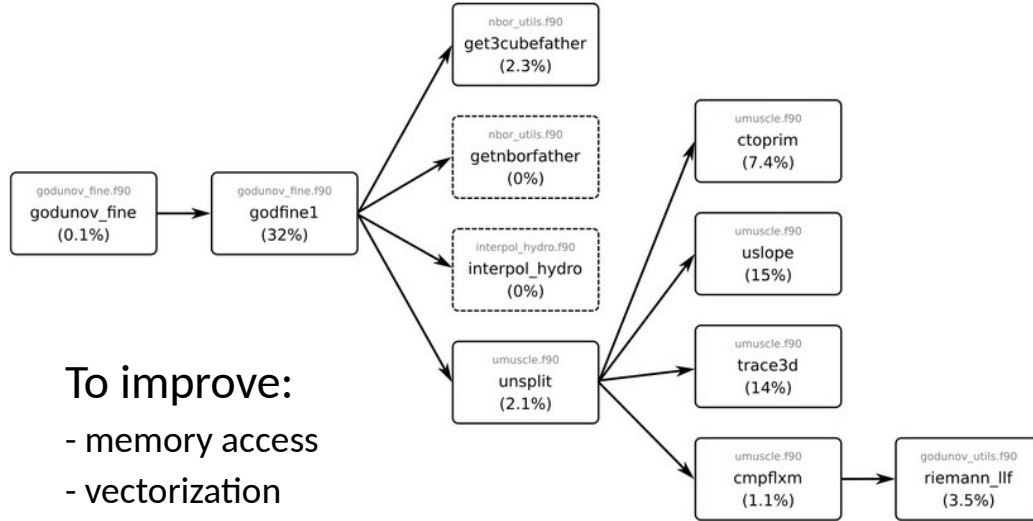
```
Switched to branch 'openmp_hydro_unigrid'  
Your branch is up to date with 'origin/openmp_hydro_unigrid'.  
#####  
# Launching RAMSES performance benchmarks #  
#####  
Multiple projects found. Please select one:  
1) nocredit  
2) p200525  
#? 2  
You selected allocation ID: p200525  
Will launch the following benchmarks:  
 [ 2] setups/sedov  
-----  
Test 1/1: sedov  
Compile job submitted with Job ID: 2577666  
Waiting for compile job to finish...  
Compile job completed successfully.  
Launched benchmark sedov on 1 nodes [JOB ID 2577669]  
Launched benchmark sedov on 1 nodes [JOB ID 2577670]  
Launched benchmark sedov on 1 nodes [JOB ID 2577671]  
Launched benchmark sedov on 2 nodes [JOB ID 2577672]  
Launched benchmark sedov on 2 nodes [JOB ID 2577673]  
Launched benchmark sedov on 2 nodes [JOB ID 2577674]  
Launched benchmark sedov on 4 nodes [JOB ID 2577675]  
Launched benchmark sedov on 4 nodes [JOB ID 2577676]  
Launched benchmark sedov on 4 nodes [JOB ID 2577677]  
Submitted batch job 2577678
```



# Optimization of Godunov solver



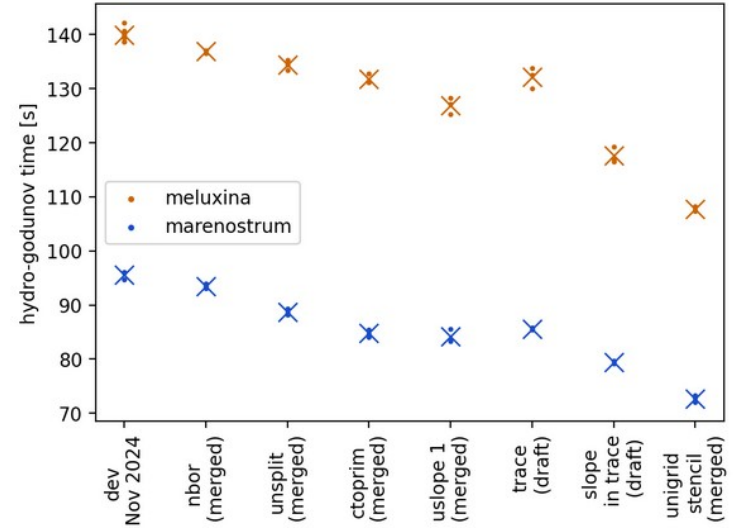
## Initial profiling of sedov use-case



To improve:

- memory access
- vectorization

## Progress



23% speedup for sedov test

- [\[OpenMP\] dynamic scheduling for particle loops](#) ✓ openmp SPACE  
#251 by tinecolman (Member) was merged on Feb 24
- [Openmp misc](#) ✓ openmp SPACE  
#247 by tinecolman (Member) was merged on Feb 20
- [OpenMP for the galaxy benchmark](#) ✓ openmp SPACE  
#246 by tinecolman (Member) was merged on Feb 19
- [Openmp for MHD collapse test](#) ✓ openmp SPACE  
#244 by tinecolman (Member) was merged on Feb 18
- [OpenMP for RT \(without refinement\)](#) ✓ openmp SPACE  
#243 by tinecolman (Member) was merged on Feb 17
- [Openmp make tree fix](#) ✓ bug openmp SPACE  
#216 by tinecolman (Member) was merged on Nov 27, 2025
- [Openmp in flagging for refinement](#) ✓ openmp SPACE  
#215 by tinecolman (Member) was merged on Dec 11, 2025
- [Working version of OpenMP in particles for COSMO \(part2\)](#) ✓ openmp SPACE  
#213 by tinecolman (Member) was merged on Nov 20, 2025
- [adjust omp for set\\_uold/unew to allow for more than 8 threads](#) ✓ openmp  
#207 by tinecolman (Member) was merged on Oct 17, 2025
- [\[OpenMP\] Progress of openmp for cosmo box: poisson multigrid solver](#) ✓  
#200 by tinecolman (Member) was merged on Sep 30, 2025
- [Openmp virtual\\_boundaries](#) ✓ openmp SPACE  
#196 by tinecolman (Member) was merged on Sep 23, 2025

# MPI + OpenMP



Shared memory parallelism inside nodes

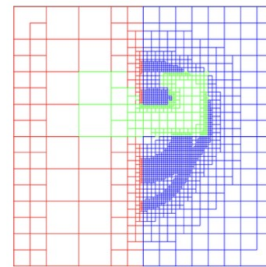
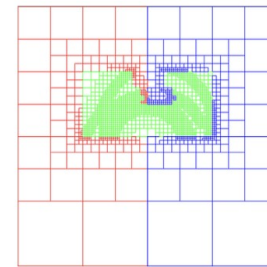
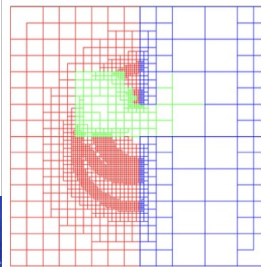
=> reduce number of MPI domain

=> less time in MPI communications &  
reduced memory imprint ghost zones

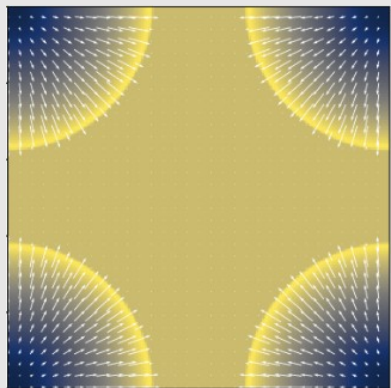
=> **improved scalability**

Starting from RAMSES-yOMP

Dedicated branch on RAMSES GitHub



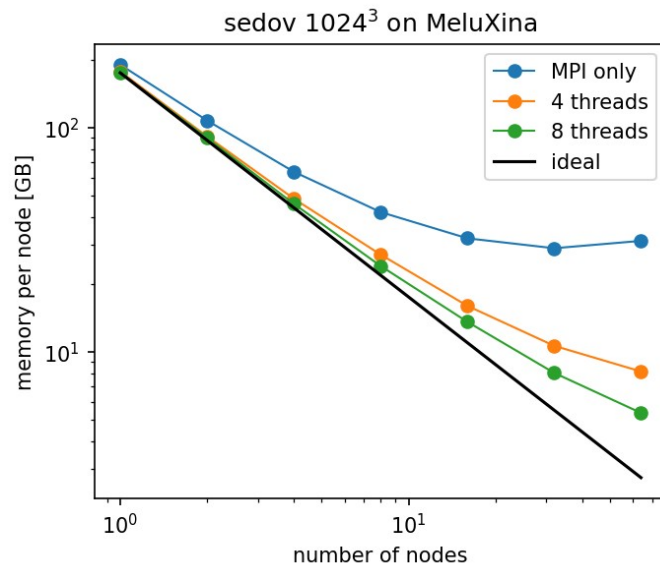
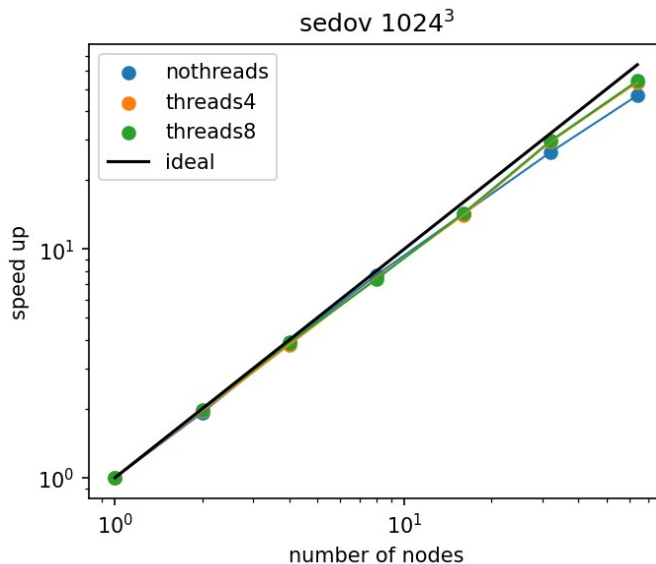
# OpenMP for SEDOV



**Setup:** blastwave  
(unigrid)

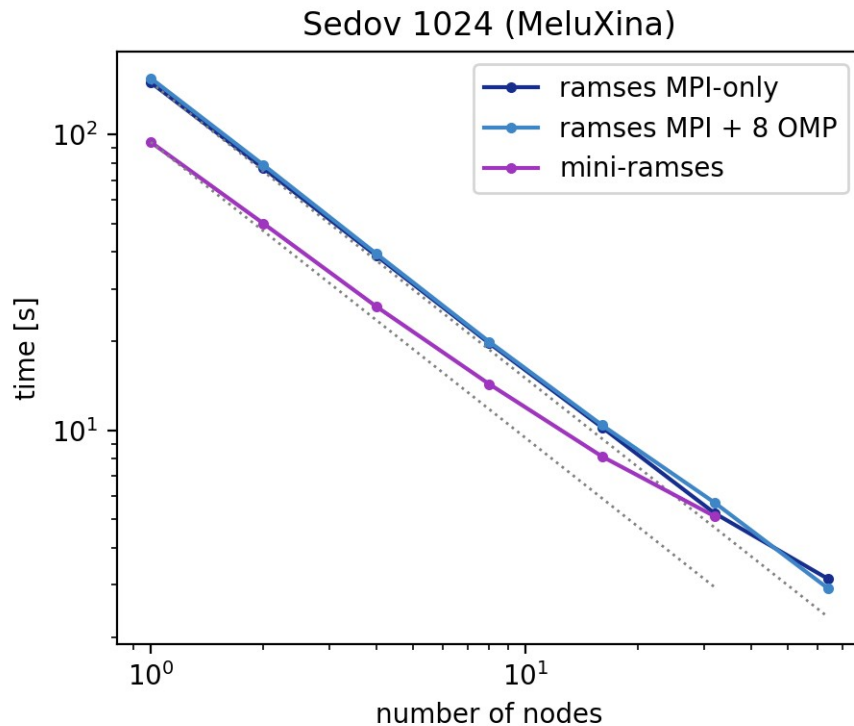
**Module:** hydro

- Godunov solver
- communication



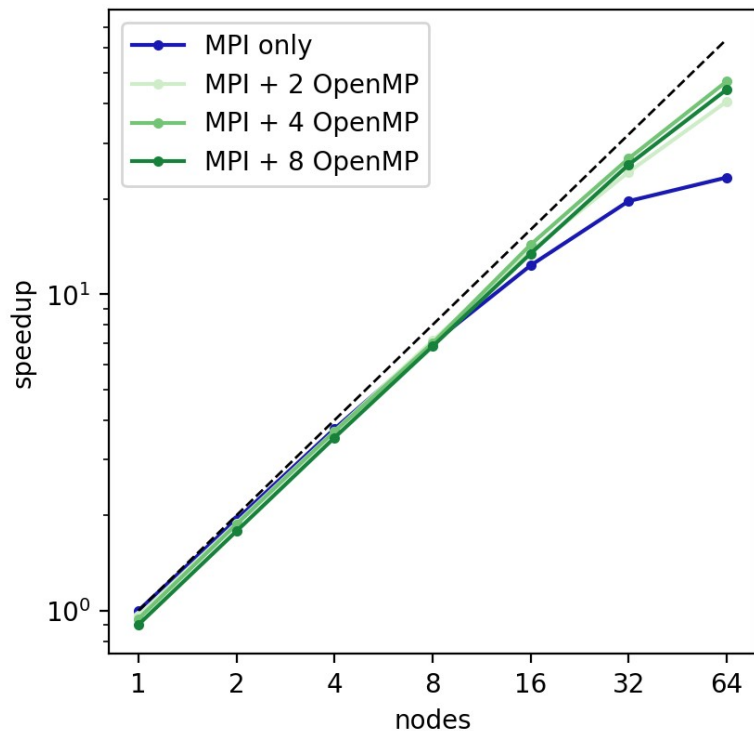
**Results:** small improvement in strong scaling  
factor x4 decrease in memory on 64 nodes

# What about mini-RAMSES?





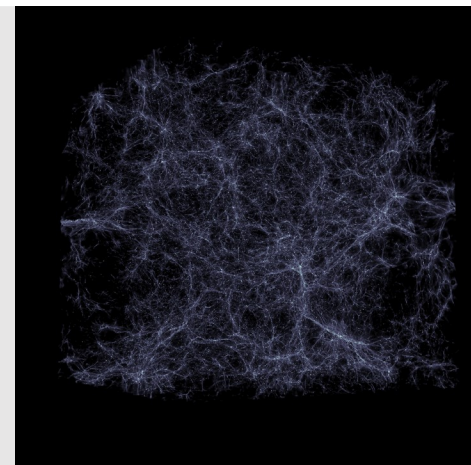
Cosmo on MeluXina



**Setup:** DM-only (unigrid)

**Module:** gravity

- Poisson multigrid solver
- Force calculation
- Particle-mesh (Cloud-in-cell)
- Moving of particles

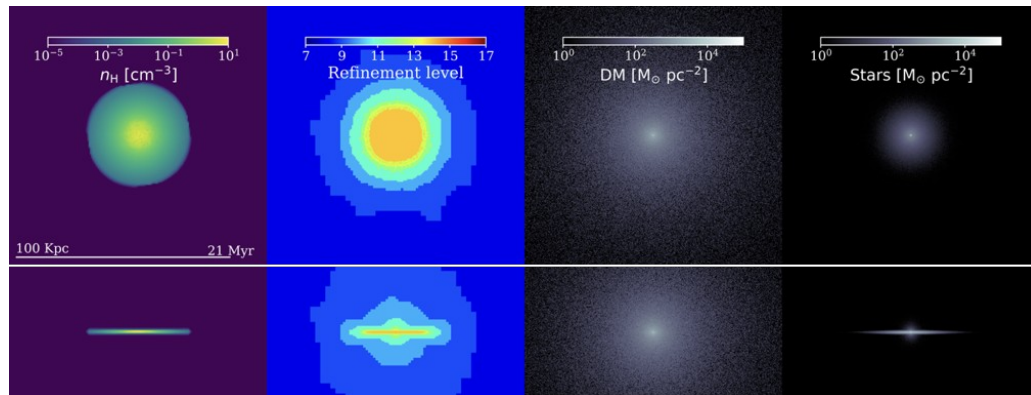
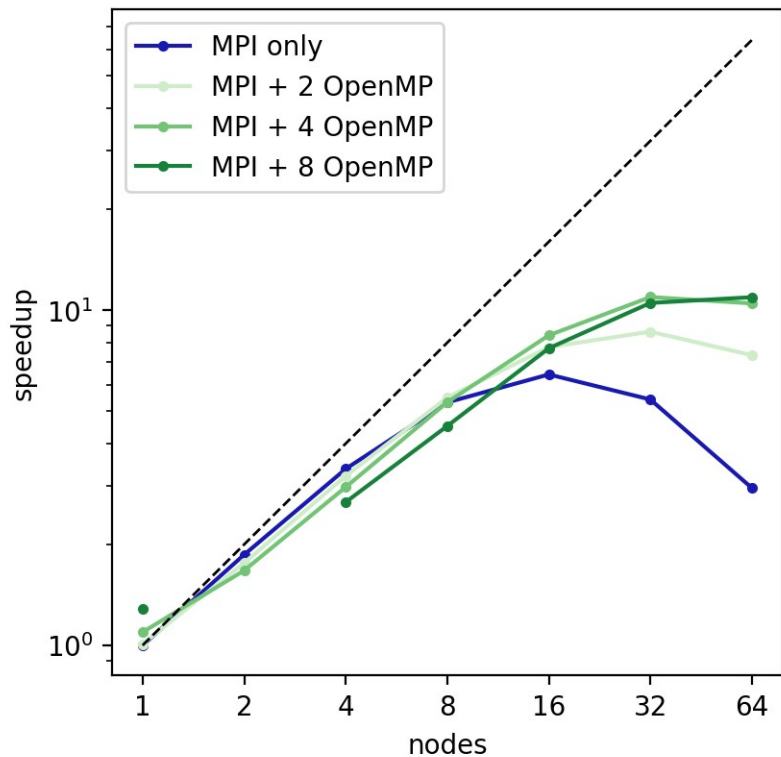


**Results on 64 nodes:**

x2 faster

scaling 37% → 74%

# OpenMP for GALAXY



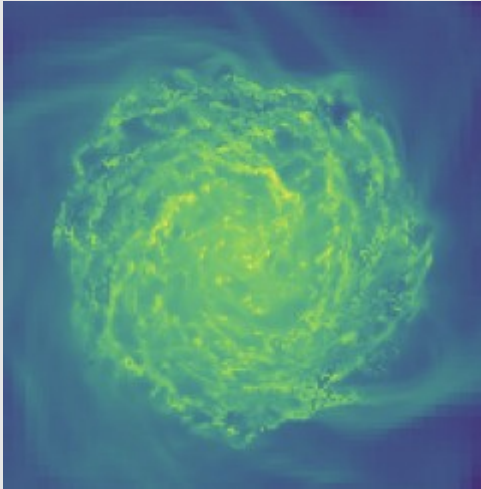
**Setup:** gas, DM & stars particles

**Modules:** hydro + gravity + **AMR**

**Results:** scaling from awful to less bad

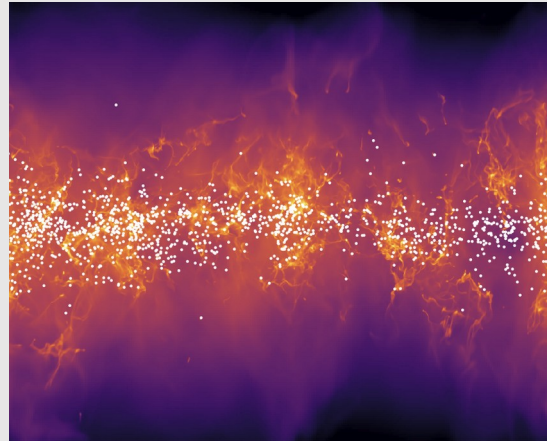
## Star forming galaxy

- Star formation (in test)
- Stellar feedback (WIP)



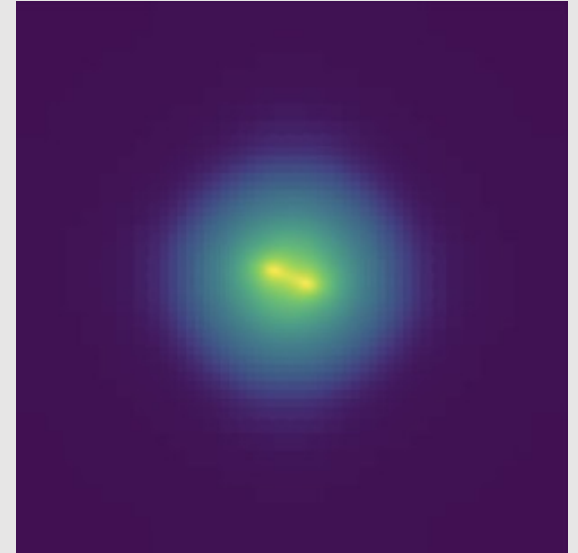
## ISM in kpc box

- Sink formation (to do)
- Sink feedback (to do)
- RT (to test)

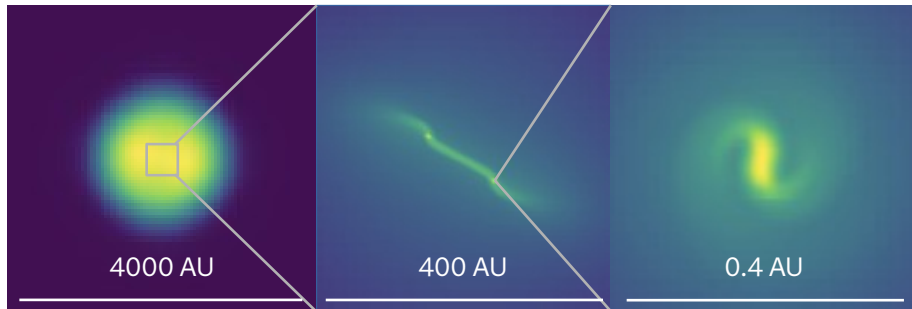


## Collapsing core

- MHD (done)



# OpenMP for collapse simulations

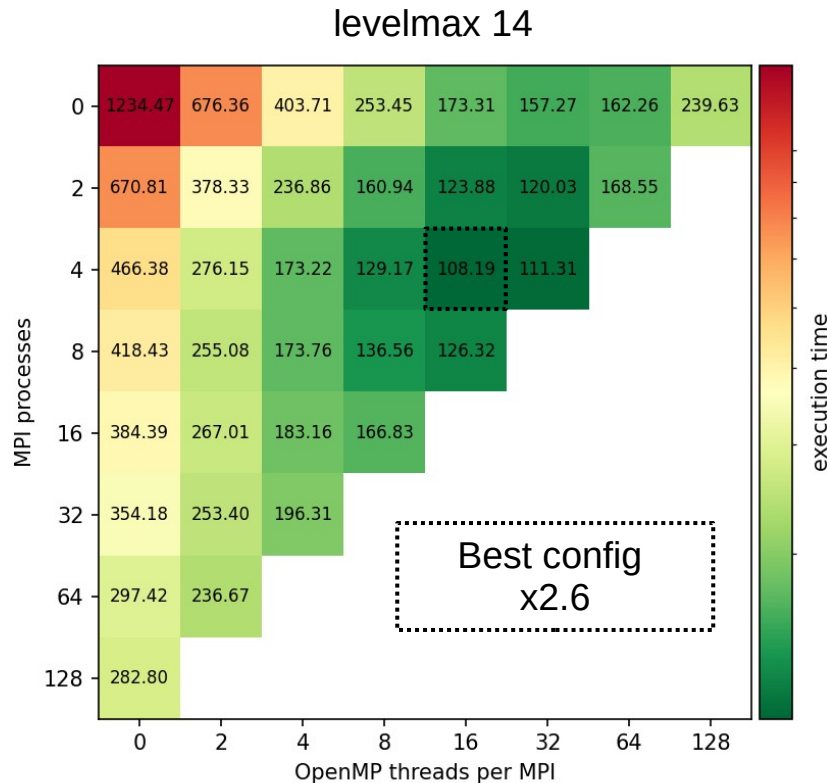


**Physics:** MHD, gravity, EOS

**Challenge:** deep AMR

## Results

- levelmax 14: speedup x2.6
  - levelmax 20: speedup x4-5
- factor 10 - 20 less memory needed

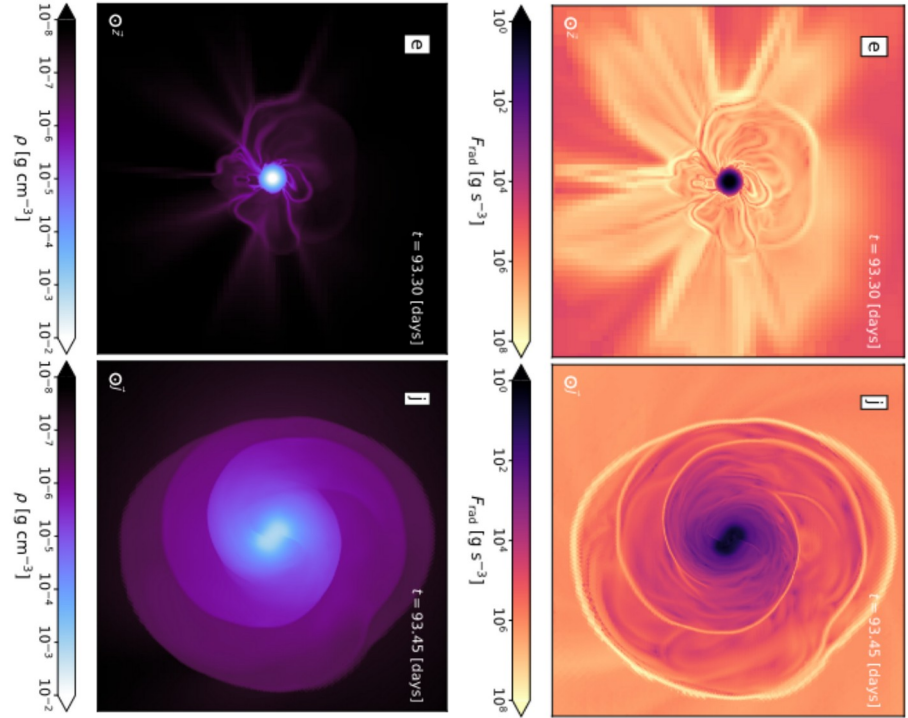


# RAMSES-ISM merge

## Porting key RAMSES-ISM modules:

- Radiation with Flux Limited Diffusion (FLD)  
Commerçon+2011,2014, Gonzalez+2015
- Non-ideal MHD  
Masson+2012, Marchand+2018
- Dust multifluid  
Verrier+2025

=> benefit from optimizations & OpenMP  
in public RAMSES

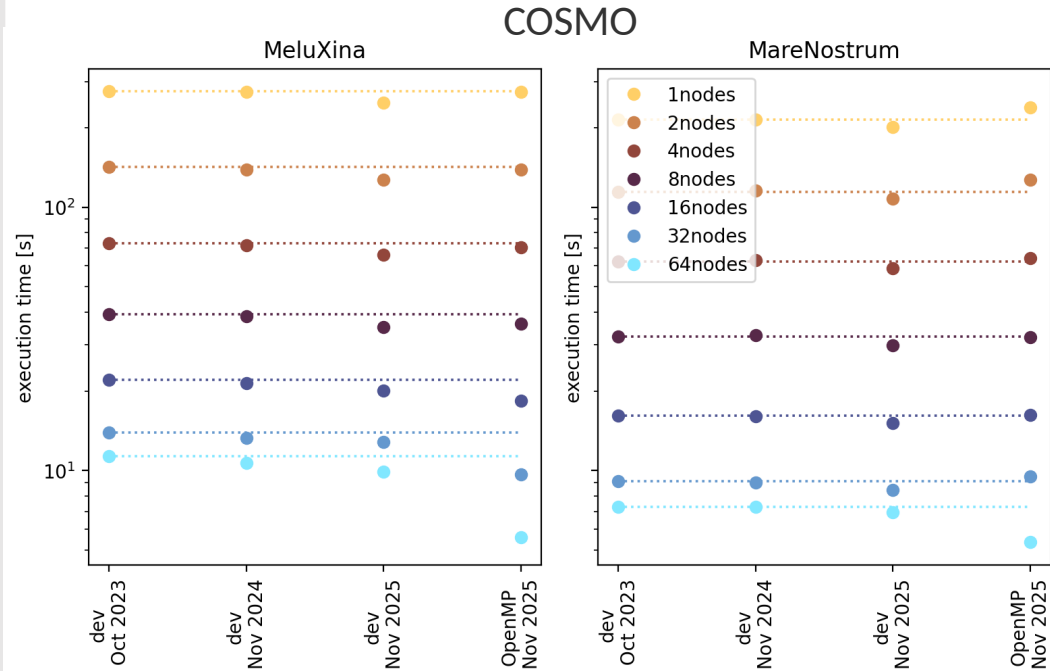


Ahmad+2015

# Summary: RAMSES, now even faster!



- Benchmarking
  - On all EuroHPC systems
  - Development of scripts
  - Gathering scaling for different setups
- Godunov solver optimized: 10-25% speedup
- OpenMP implementation
  - DONE: Hydro/MHD, gravity, particles
  - TODO: Stars & sinks
- RAMSES-ISM community moving to public version



# Acknowledgement & Disclaimer



Funded by the European Union. This work has received funding from the European High Performance Computing Joint Undertaking (JU) and Belgium, Czech Republic, France, Germany, Greece, Italy, Norway, and Spain under grant agreement No 101093441.

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European High Performance Computing Joint Undertaking (JU) and Belgium, Czech Republic, France, Germany, Greece, Italy, Norway, and Spain. Neither the European Union nor the granting authority can be held responsible for them

