LIO Institut des Origines de Lyon
UNIVERSITE DE LYON

CRAL
CENTRE DE RECHERCHE ASTROPHYSIQUE DE LYON

RASCAS

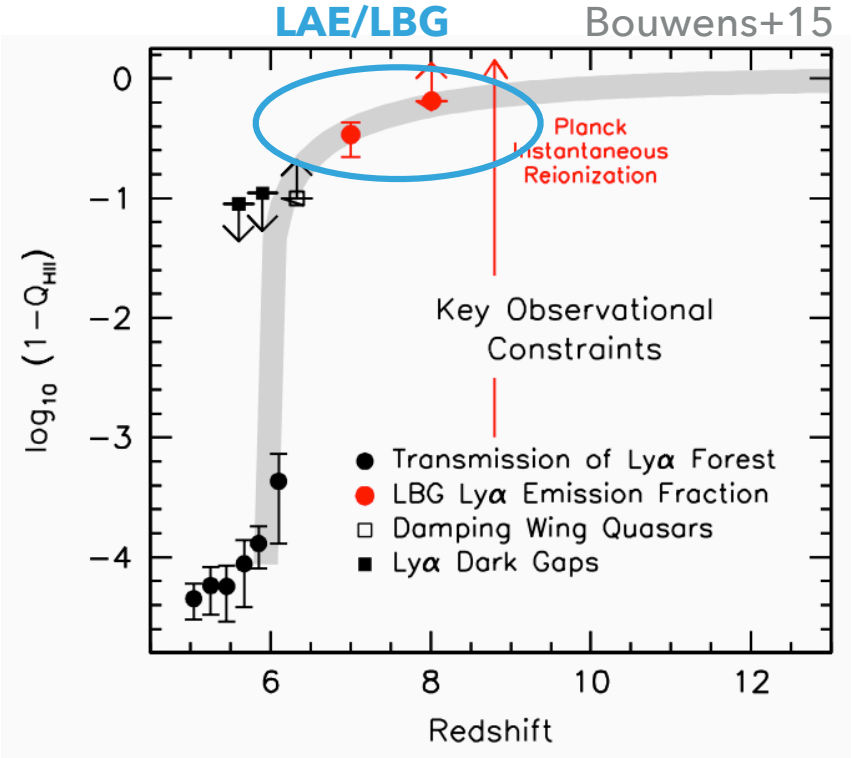
(aka MCLya v.2.0)

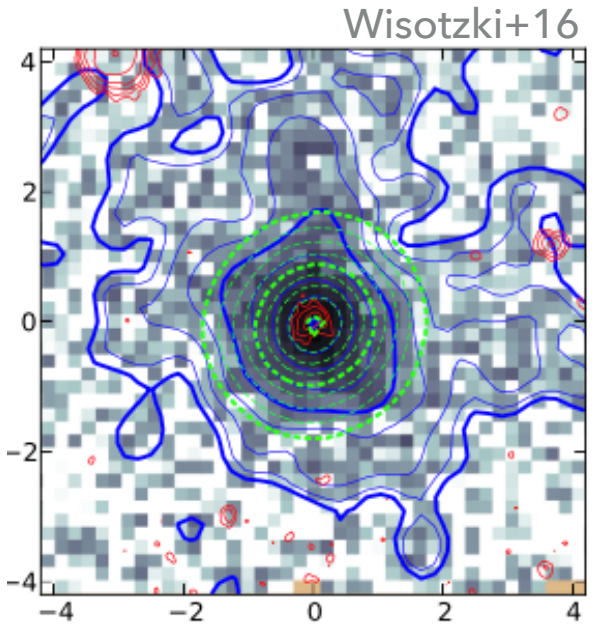
A massively parallel code for line transfer in AMR simulations.

LEO MICHEL-DANSAC, JEREMY BLAIZOT, THIBAULT GAREL, ANNE VERHAMME

SCIENCE MOTIVATIONS

- LAEs, EoR, LABs, … (MUSE, JWST, …)
- CGM in general (Lya, metal line absorption, fluorescence, …)

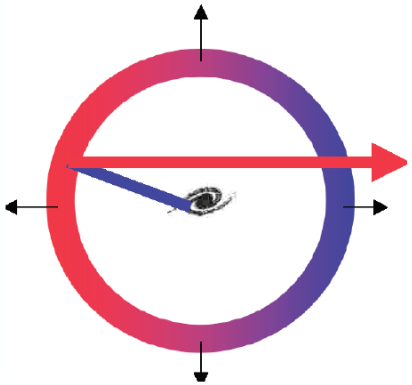


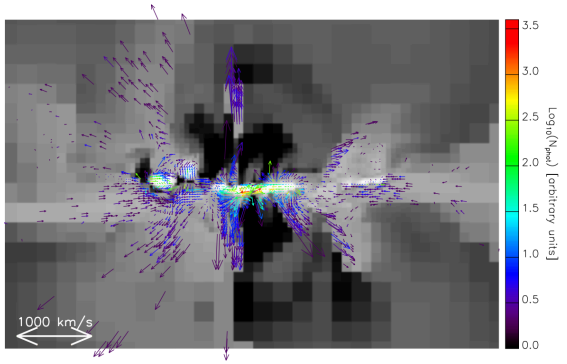


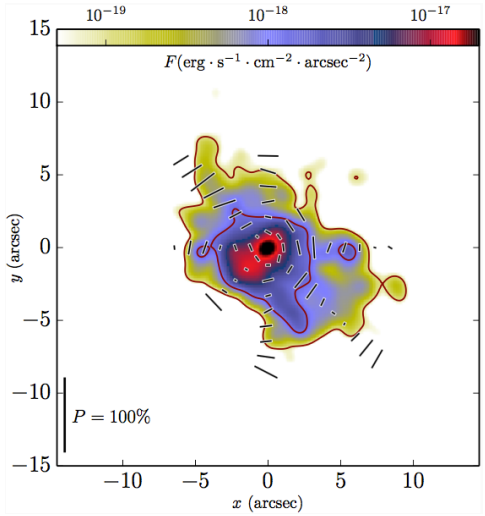
MCLYA (VERHAMME+06,+12, TREBITSCH+16)

A Monte Carlo code for resonant line transfer

- Geneva (Verhamme, Schaerer, Maselli): code development & first application on models of expanding shells (regular mesh)
- Oxford (Verhamme, Dubois): ability to post-process RAMSES simulations (AMR, some level of MPI)
- Lyon (Verhamme, Blaizot, Garel, Trebitsch): optimisation, memory cuts, load balancing (MPI queue), polarisation.







MOTIVATIONS FOR A NEW VERSION

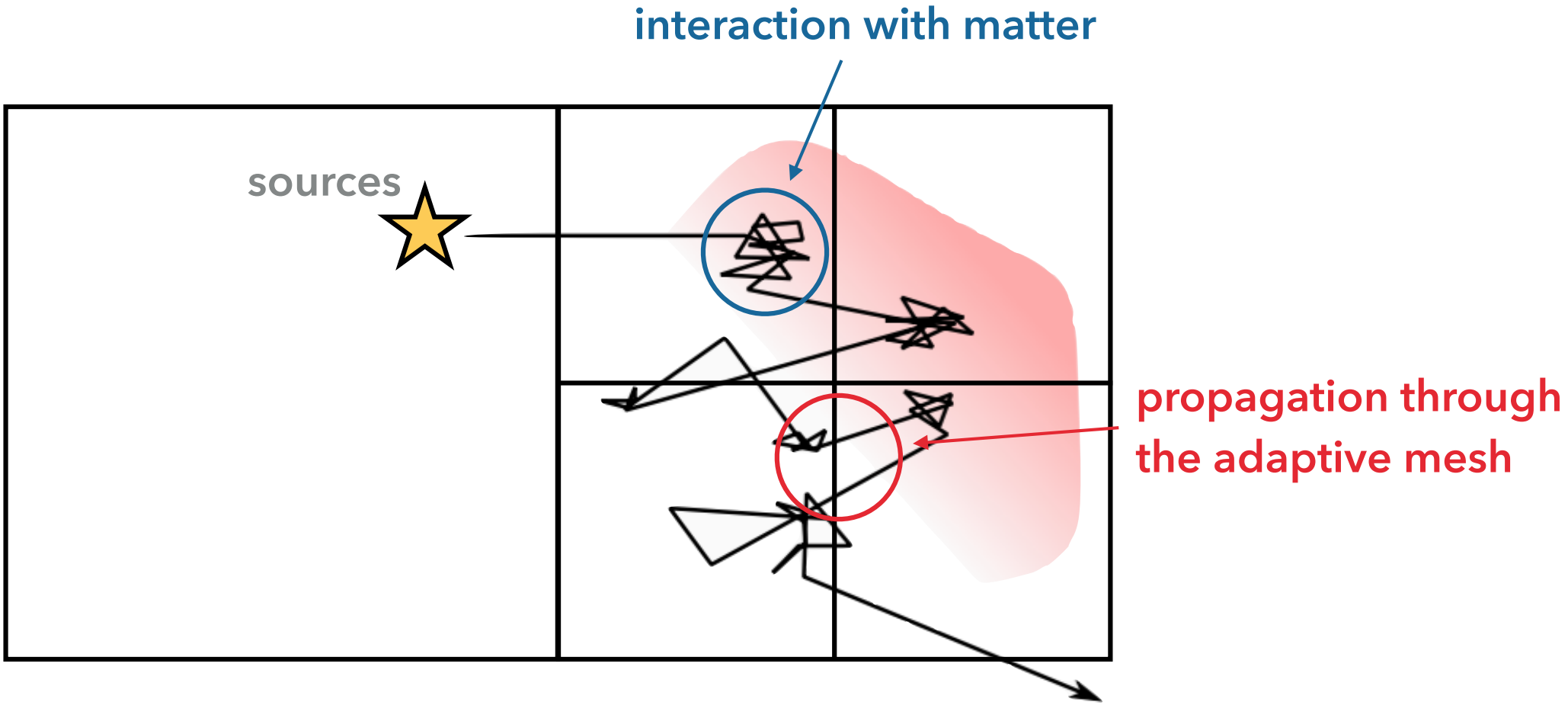
Memory footprint : we need to process large, high-resolution volumes (e.g. haloes of LAEs, giant LABs, HII bubbles at reionisation, ...) on numerous cores (little RAM/core) -> domain decomposition & distributed parallelism.

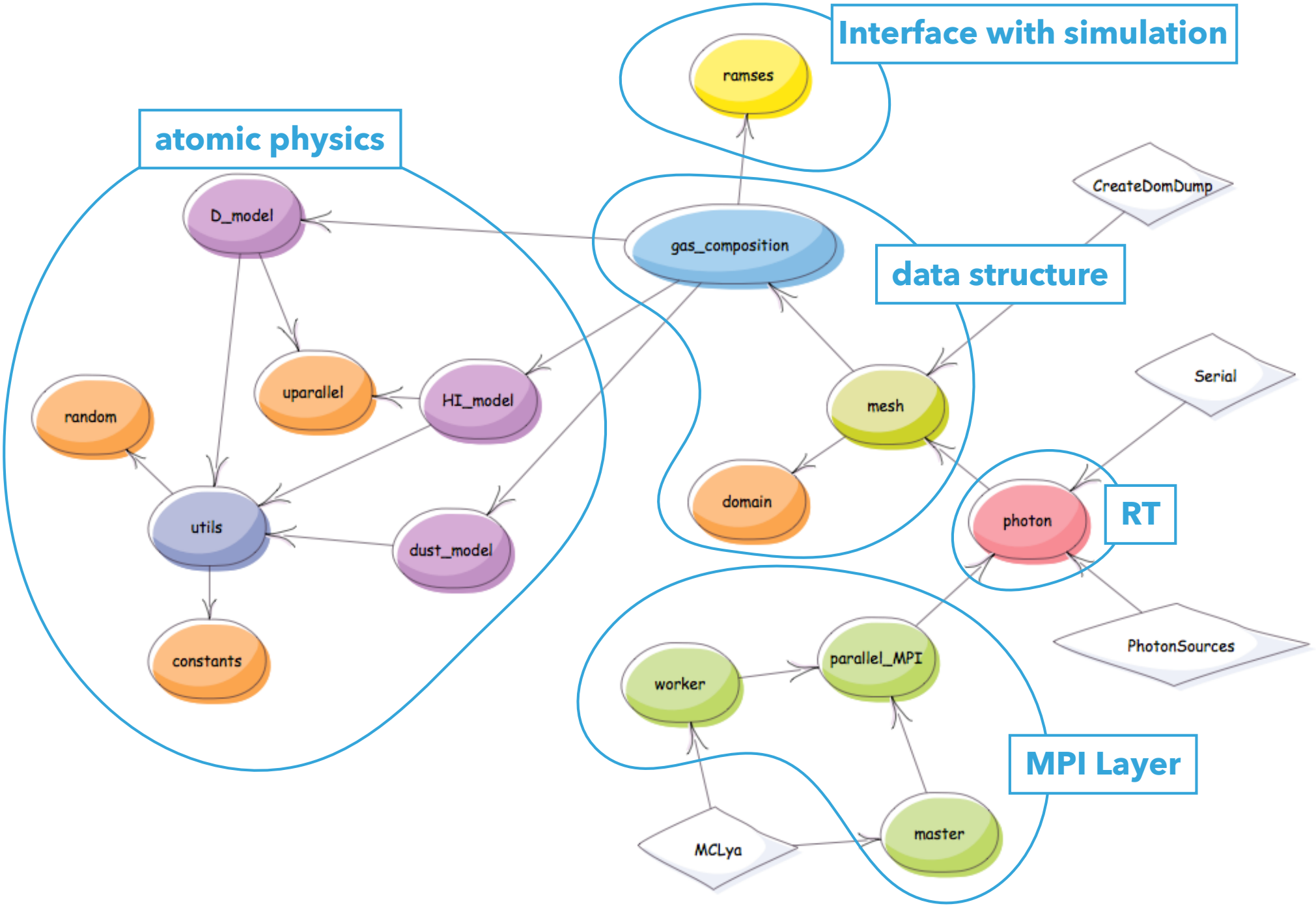
Load balancing: manage the huge diversity of photon effective speeds from low-density IGM to high-density ISM regimes. Balance domain loads.

Modularity/community development: Simple add-ons should allow transfer of any line, or processing the outputs of any simulation (other than RAMSES) -> some level of object oriented design / encapsulation.

Some elements of RASCAS should be usable as a toolbox to manipulate RAMSES outputs.

MC LYA RT, TECHNICALLY




Interface with simulation
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atomic physics
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CreateDomDump
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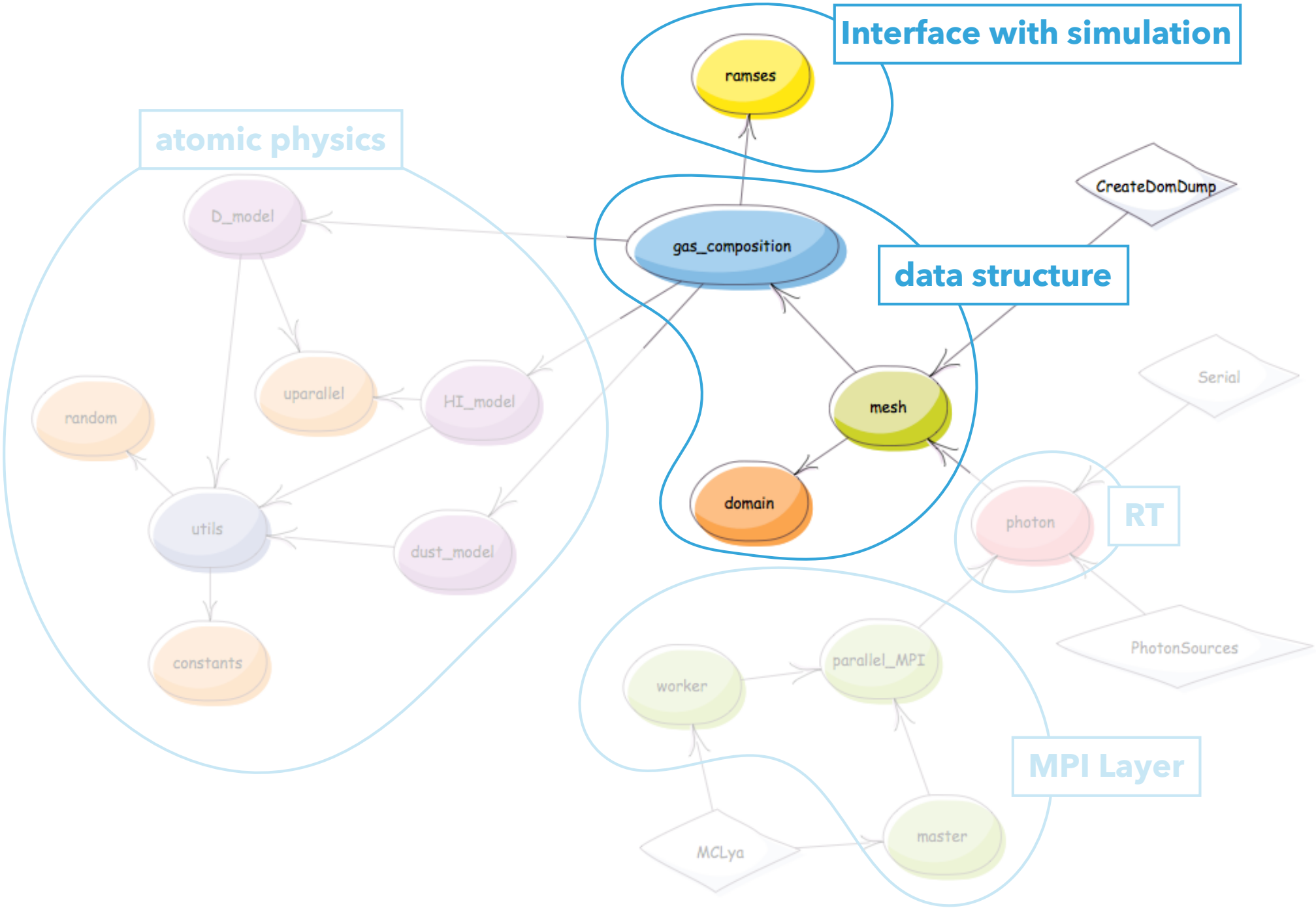
MCLya
master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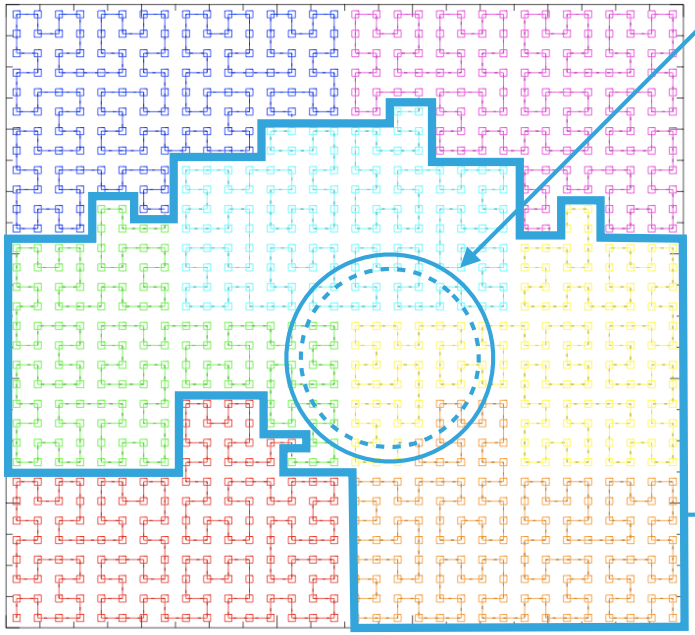
DOMAIN (RE)CONSTRUCTION

RAMSES output

Region for RT

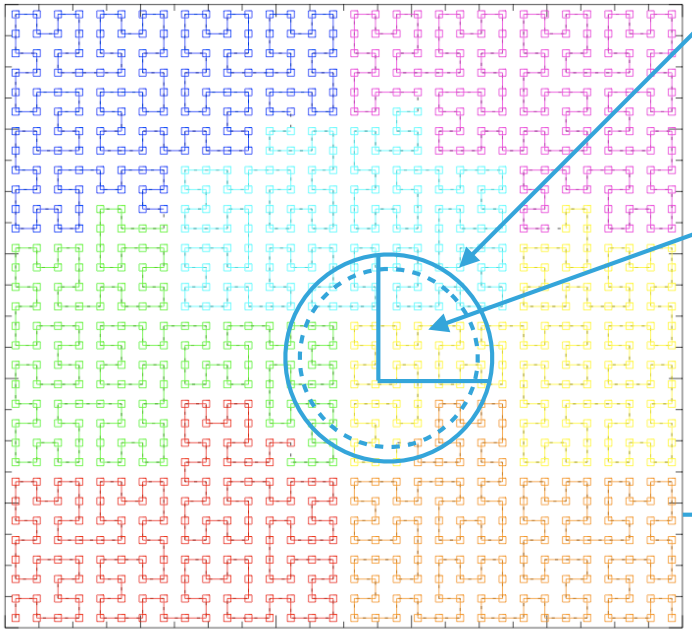


MCLya v1.0 : load all cpu-domains overlapping with zone of interest into memory.

domain-specific indexes
(oct-cell relation, nbor, son, father)

DOMAIN (RE)CONSTRUCTION

RAMSES output



domain-specific indexes
(oct-cell relation, nbor, son, father)

Region for RT

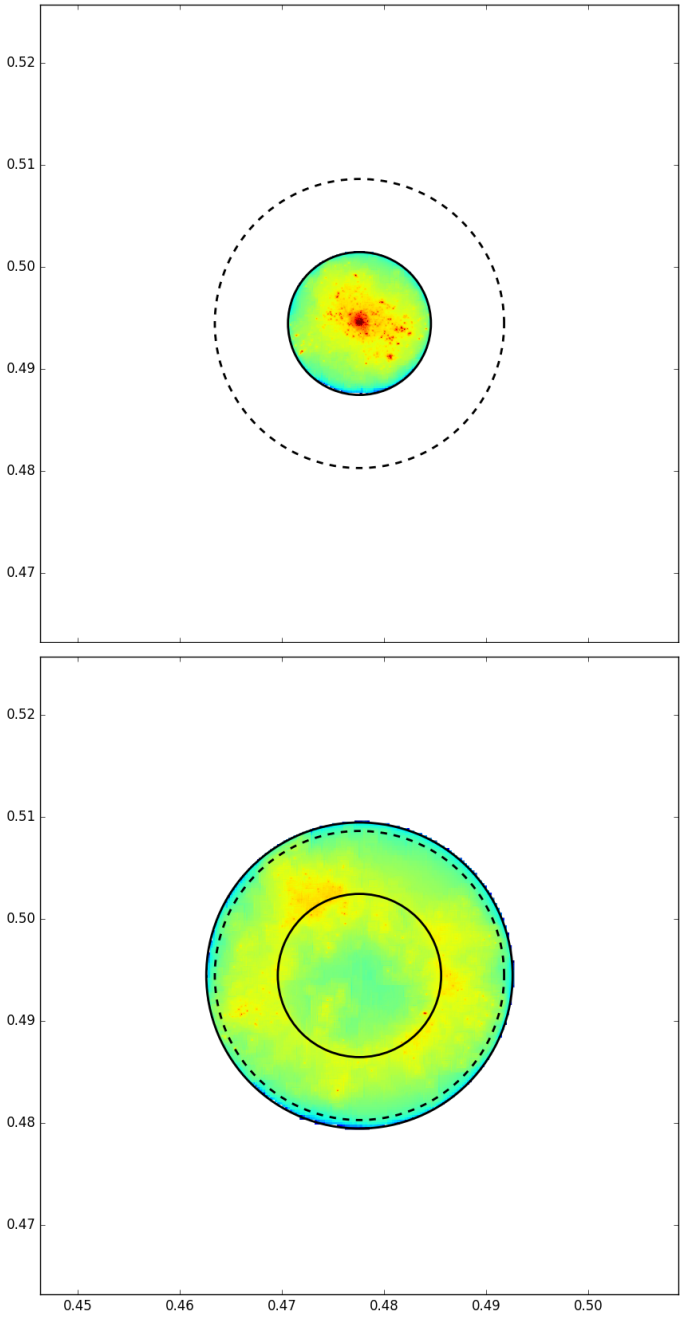
RASCAS: Select an arbitrary collection of leaf cells and re-construct all ramses indexes (oct-tree).
Keep minimal information.

MCLya v1.0 : load all cpu-domains overlapping with zone of interest into memory.

EXAMPLE

Example on a zoom simulation (~14pc resolution, 1E11 Msun halo @ z=3)

- RAMSES output = 18GB
- hydro+AMR data = 9.7GB
- mesh data rebuilt from cells inside Rvir = 1.2GB (4.2GB inside 5*Rvir)
- Can be split further with custom domain decomposition.
- Domains should overlap to avoid photons moving back and forth

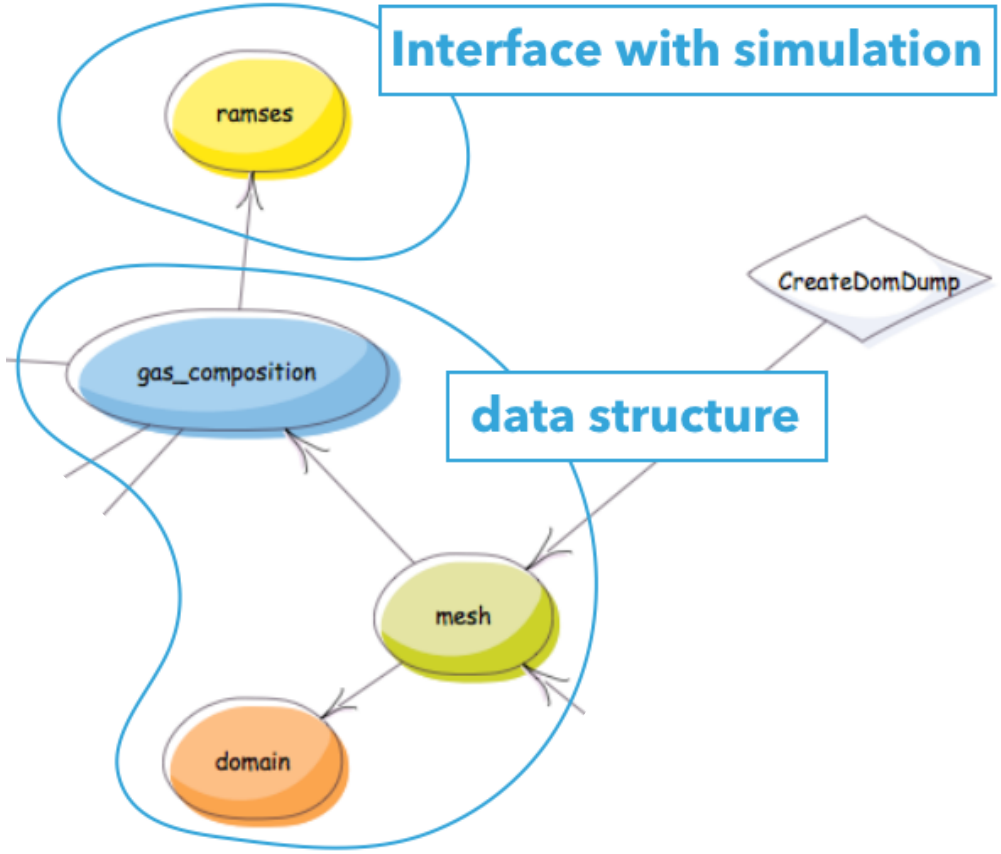


DOMAIN (RE)CONSTRUCTION

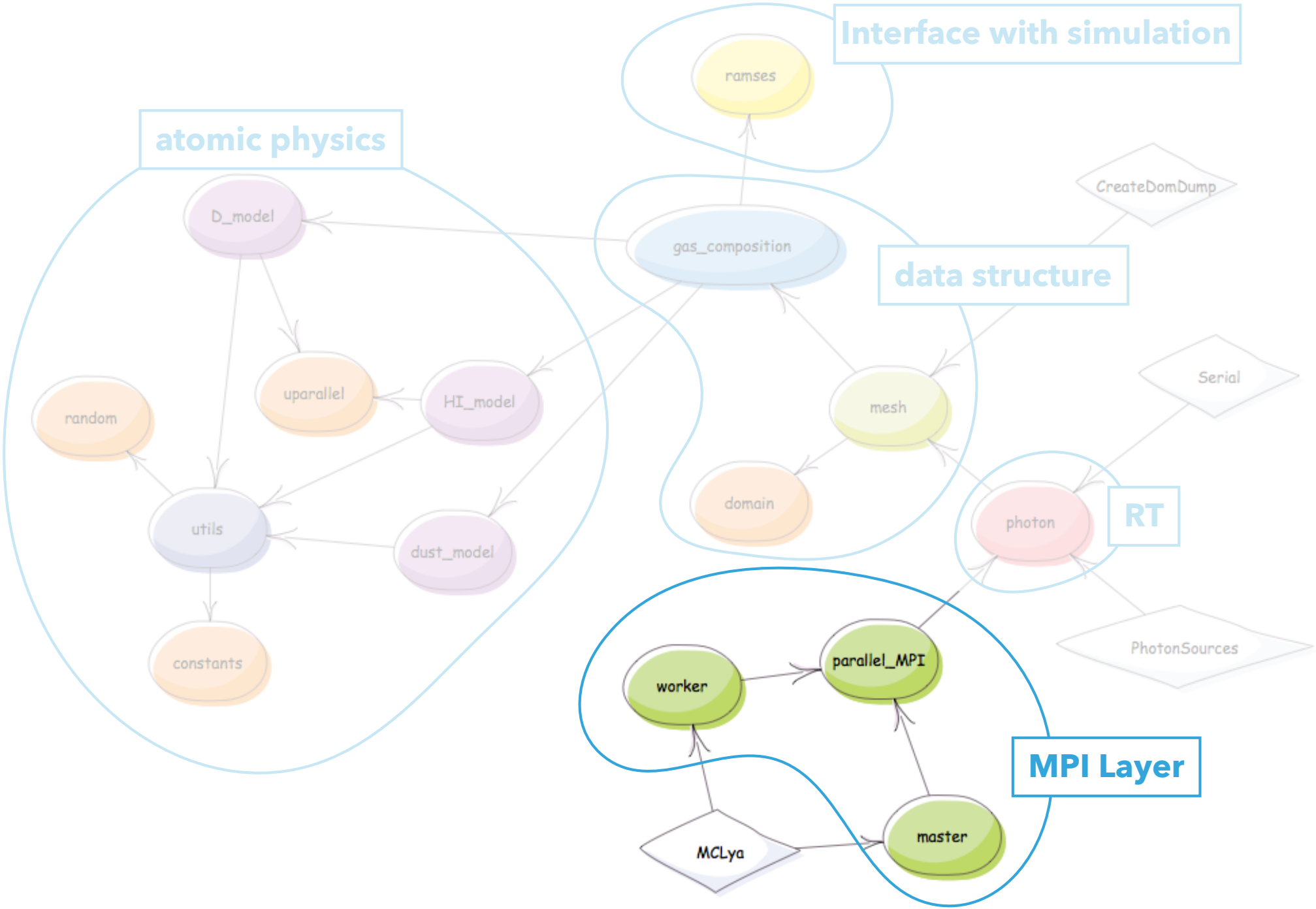
Stand-alone code to build custom domains which contain:

- an AMR mesh with all the oct-tree indexes (son, father, nbor, ...)

- a gas mixture (e.g. HI, Deuterium, and dust) with relevant properties (density, velocity dispersion) for each species.



II. DYNAMICAL LOAD-BALANCING

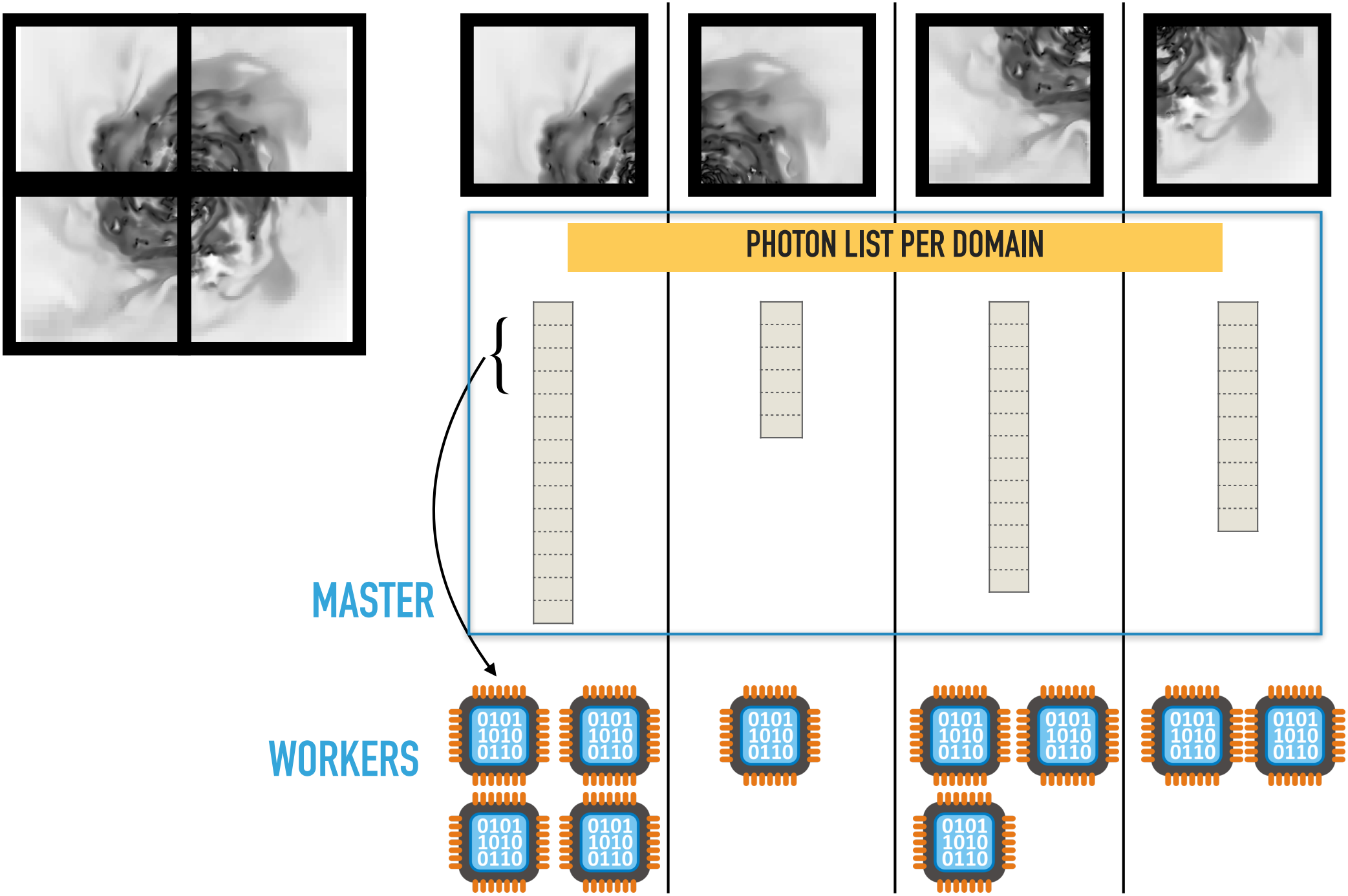


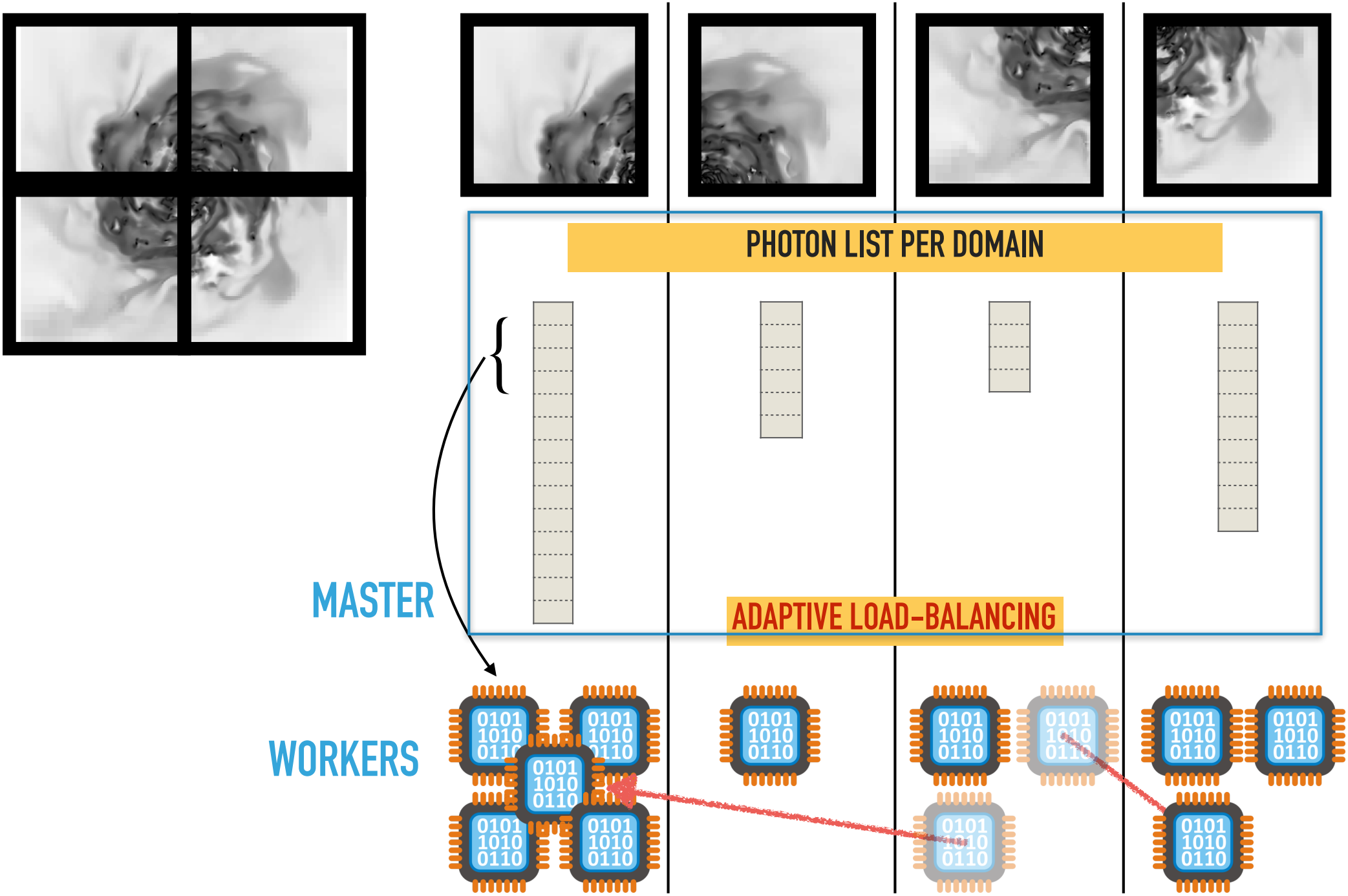
PARALLELISM STRATEGY

Master-slaves scheme, where :

- A slave CPU receives photons from the master, propagates photons through a given domain, and sends them back (when they escape the domain, when the are absorbed, or when the escape the computational volume boundary).

- The master manages **photon queues** (dynamically) and adjusts the ***load per domain*** by assigning more or less CPUs to a given domain.


PHOTON LIST PER DOMAIN
MASTER
WORKERS
0101
1010
0110


PHOTON LIST PER DOMAIN
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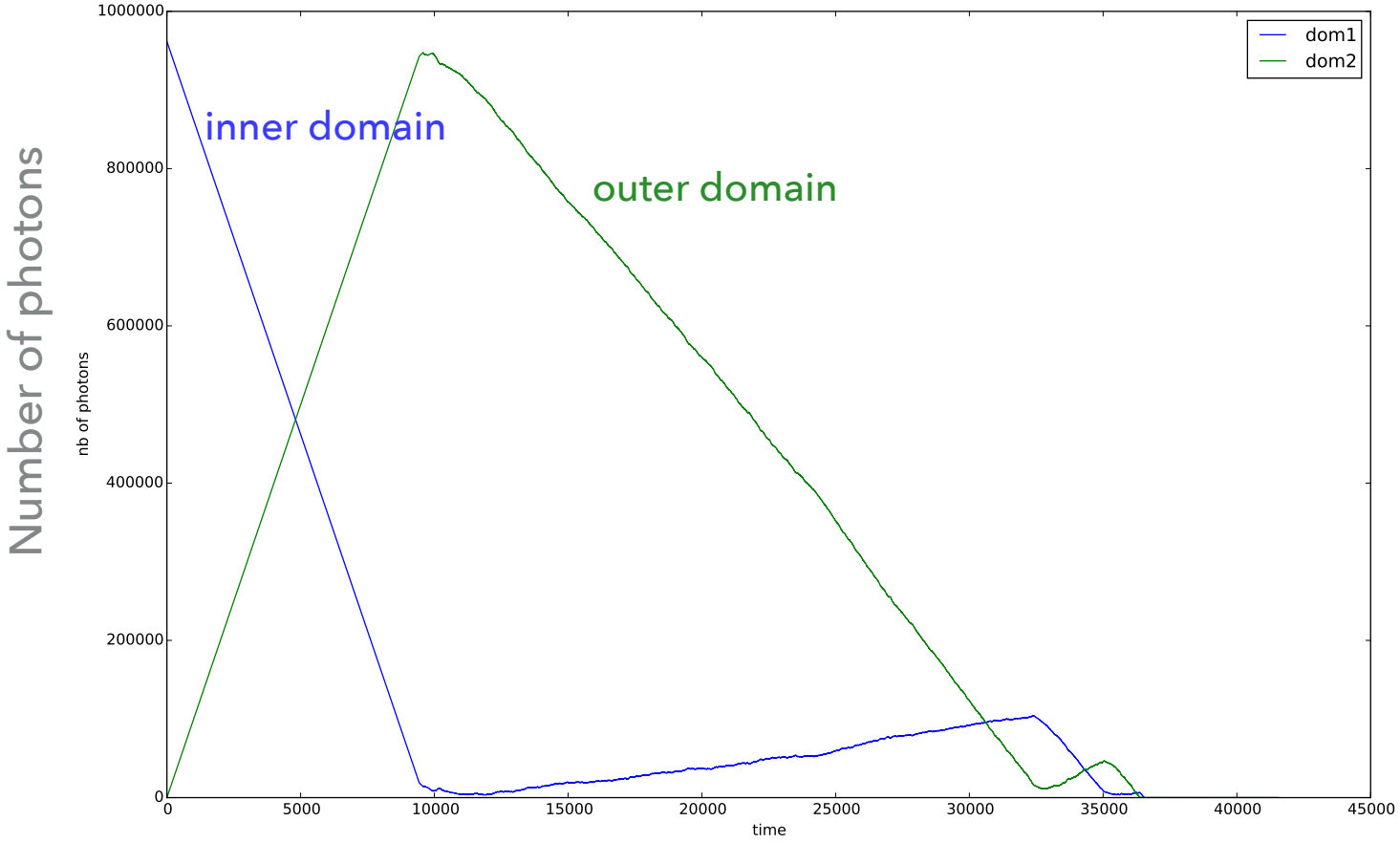
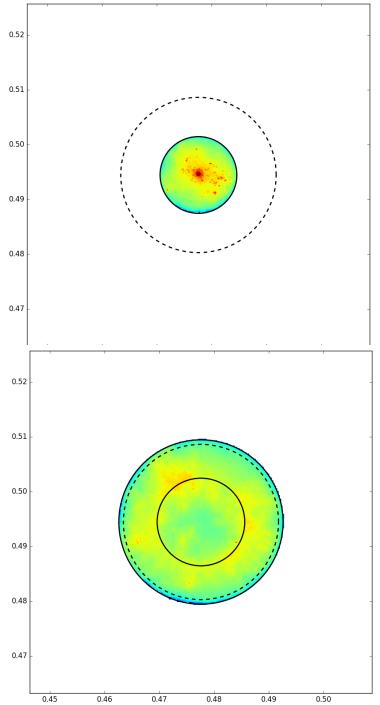
0110

EXAMPLE WITH 2 DOMAINS

CPUs start switching to domain #2



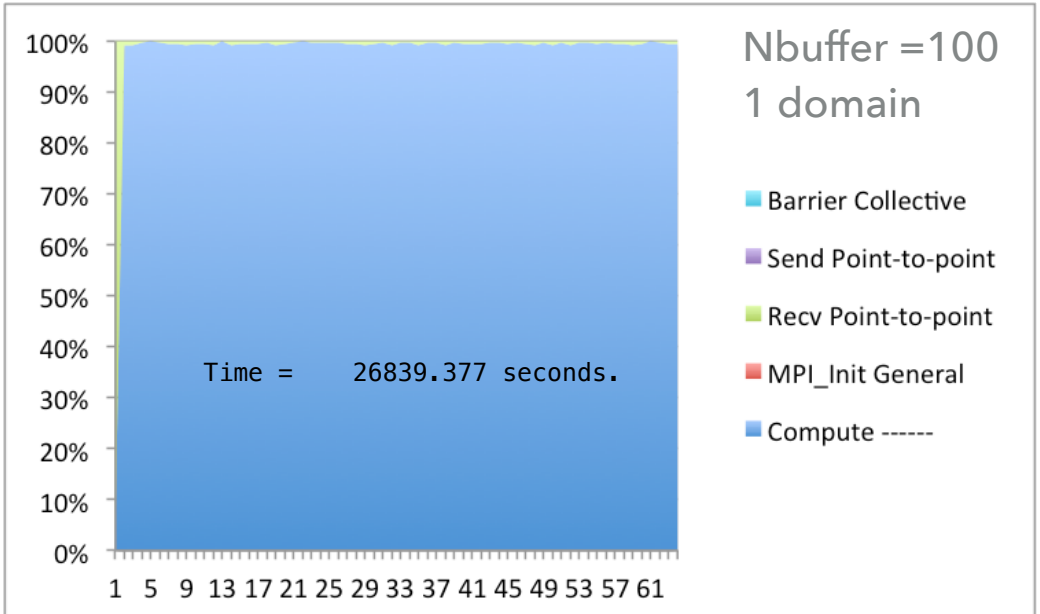


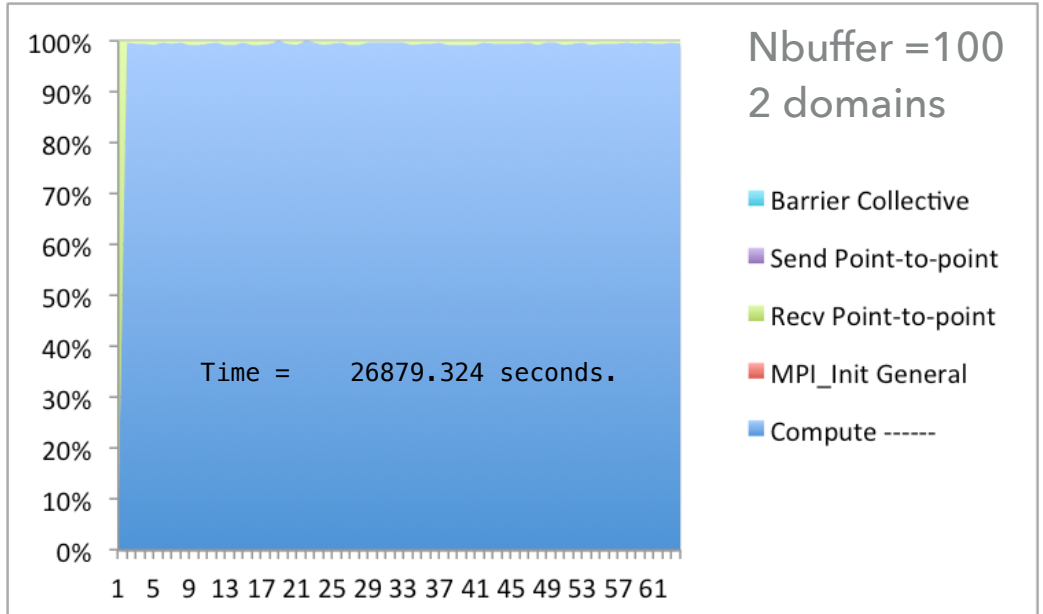
All CPUs on domain #1

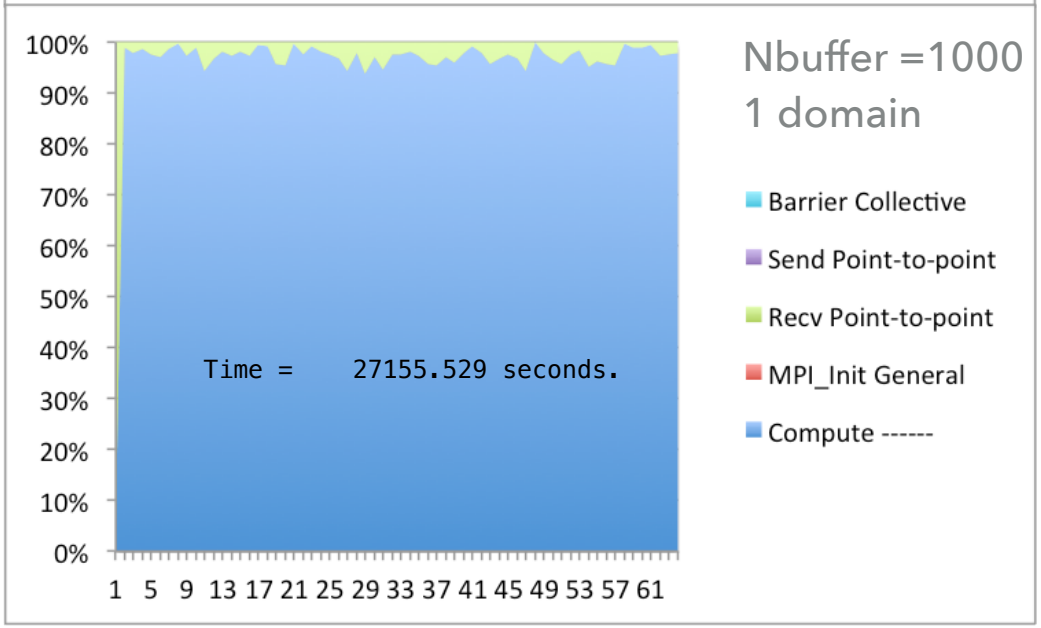
PROFILING MPI

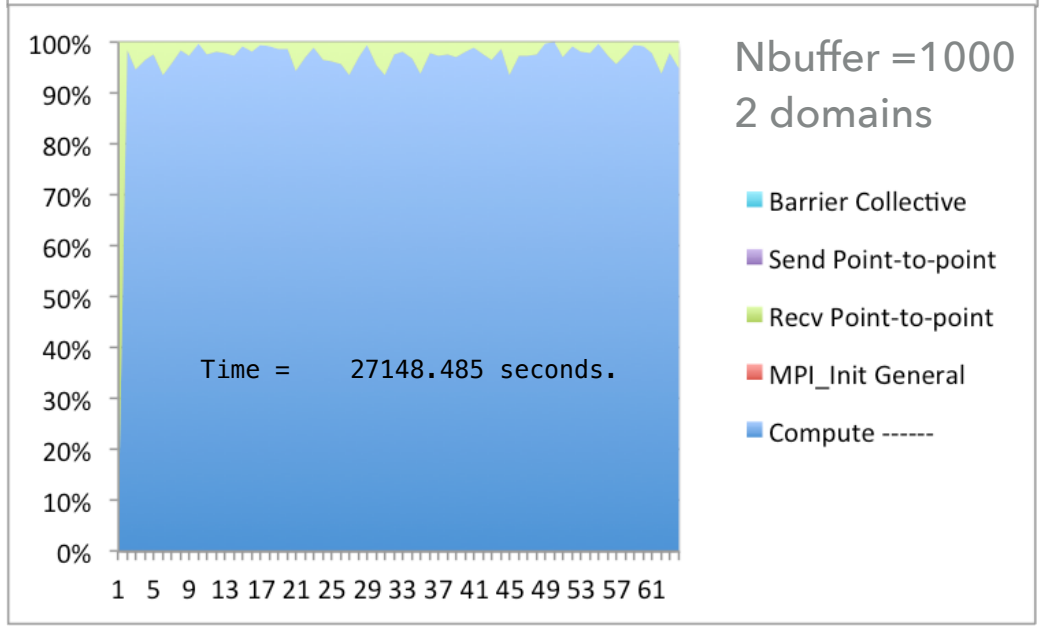
10^6 photons

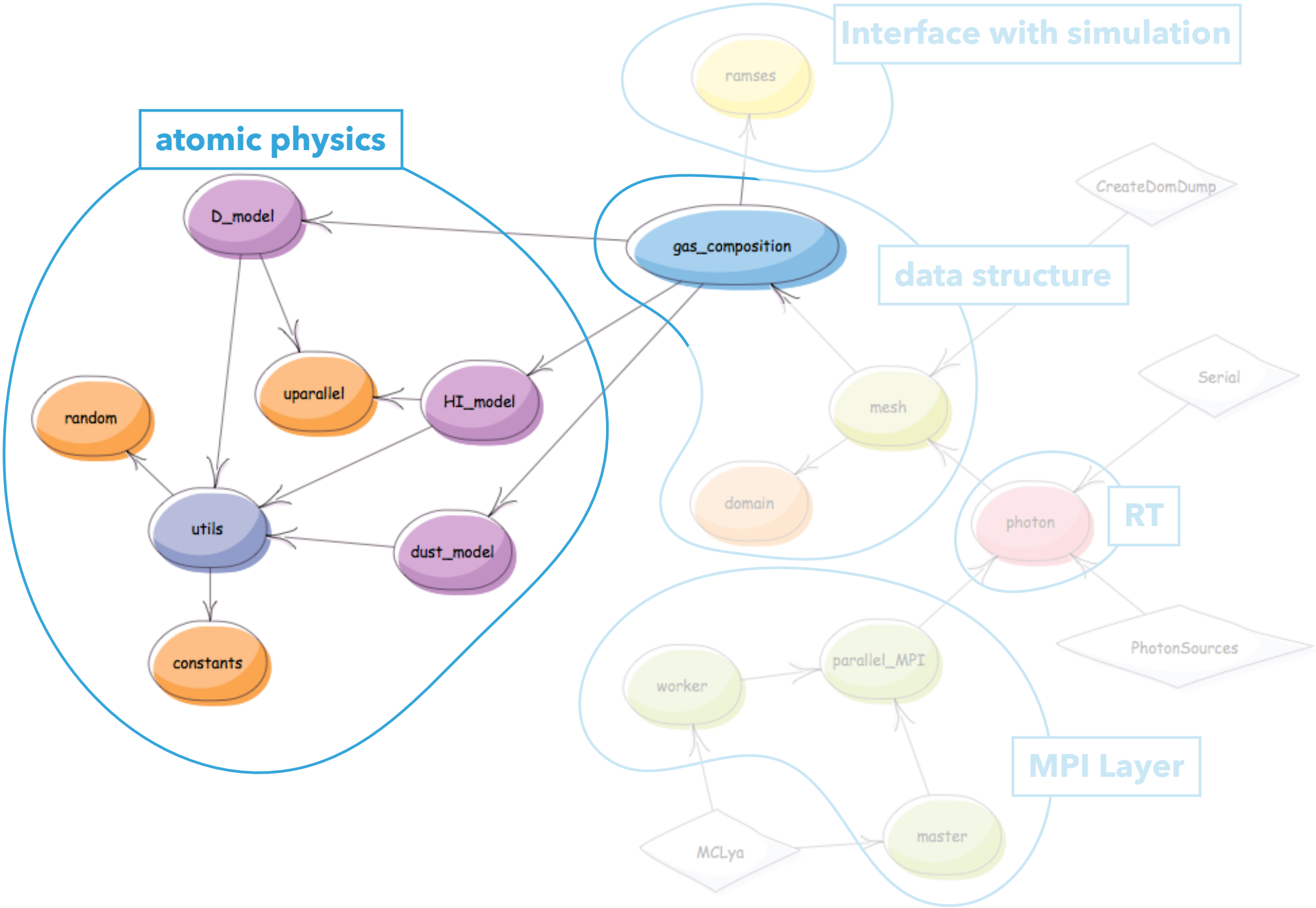
64 threads MPI







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ATOMIC PHYSICS

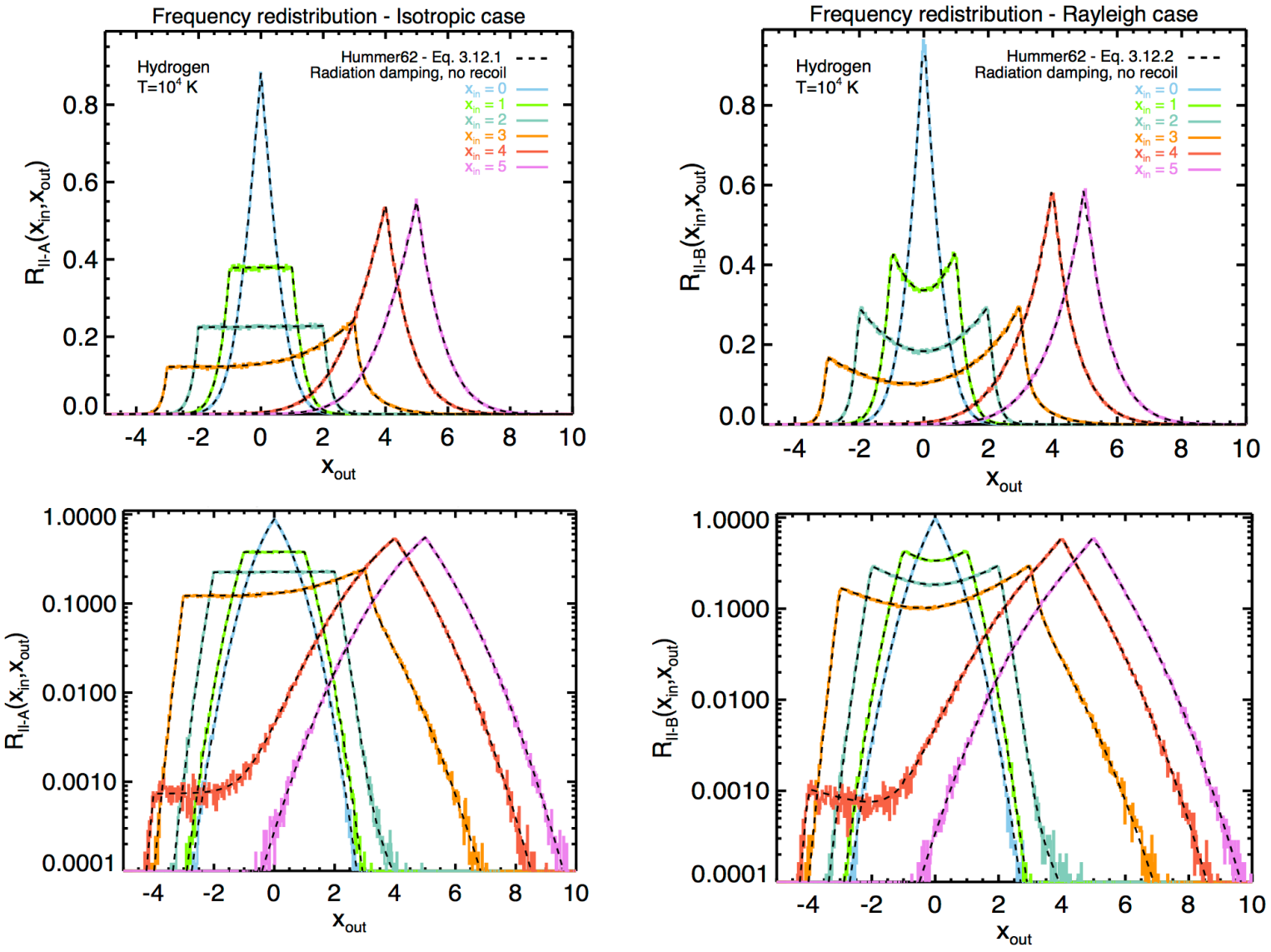
Module “gas composition” asks each scatterer’s module for optical depth and outcome of an interaction.

Scatterer modules (e.g. HI) contain all the atomic physics.

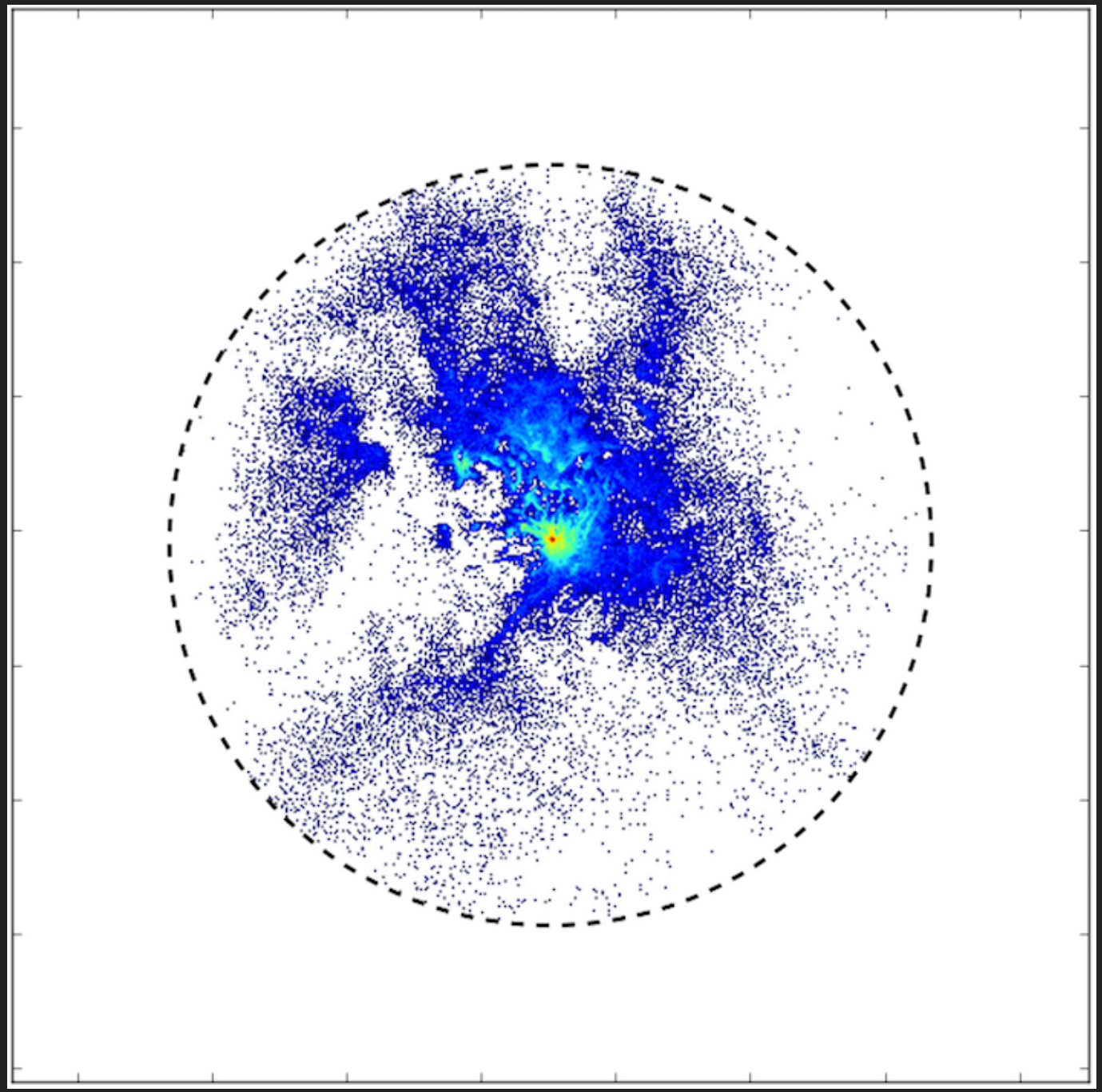
-> easy to add new species/lines (no modification beyond gas composition module).

-> allows to robust testing of each element.

REDISTRIBUTION FUNCTIONS



III. RADIATIVE TRANSFER - EXAMPLE RUN ON A ZOOM SIMULATION



FUTURE DIRECTIONS

- Use for science ! (LAEs, LABs, EoR, …)
- Add more physics (more lines, e.g. SiII, MgII, etc.) to probe CGM.
- Polish some functionalities (restart, random number, …) and explore MPI parameters to get optimal perf.
- Implement some optimisations for Lya.
- Develop interface(s) with other codes ?
- Try GPUs ?

THANK YOU

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