PyMSES Documentation

Release 3.0.0

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CONTENTS

This is the up-to-date (version 3.0.0) online PyMSES manual.

All the examples presented in this manual are based on RAMSES data available here : *RAMSES Data examples*.

CHAPTER

ONE

USER'S GUIDE

1.1 PyMSES : Python modules for RAMSES

1.1.1 Introduction

PyMSES is a set of Python modules originally written for the RAMSES astrophysical fluid dynamics AMR code.

Its purpose :

- provide a clean and easy way of **getting the data** out of RAMSES simulation outputs.
- help you analyse/manipulate very large simulations transparently, without worrying more than needed about domain decompositions, memory management, etc.,
- interface with a lot of powerful Python libraries (Numpy/Scipy, Matplotlib, PIL, HDF5/PyTables) and existing code (like your own).
- be a post-processing toolbox for your own data analysis.

What PyMSES is NOT

It is **not an interactive environment** by itself, but :

- it provides modules which can be used interactively, for example with IPython.
- it also provides an *AMRViewer* graphical user intergace (GUI) module that allows you to get a quick and easy look at your AMR data.

1.1.2 Documentation

- `pdf_manual`
- *Documentation (HTML)*

1.1.3 Contacts

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1.1.4 Indices and tables

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1.2 Installing PyMSES

1.2.1 Requirements

PyMSES has some *Core dependencies* plus some *Recommended dependencies* you might need to install to enable all PyMSES features.

The developpment team strongly recommends the user to install the EPD (Enthought Python Distribution) which wraps all these dependencies into a single, highly-portable package.

Core dependencies

These packages are mandatory to use the basic functionality of PyMSES:

- a gcc-compatible C compiler,
- GNU make and friends,
- Python, version 2.5.x to 2.6.x (*not* 3.x), *including developement headers* (Python.h and such), python 2.6.x is recommended to use some multiprocessing speed up.
- Python packages:
  - numpy, version 1.2 or later
  - scipy
- iPython is not strictly required, but it makes the interactive experience so much better you will certainly want to install it.

Recommended dependencies

Those packages are recommended for general use (plotting, easy input and output, image processing, GUI, ...). Some PyMSES features may be unavailable without them:

- matplotlib for plotting
- the Python Imaging Library (PIL) for Image processing
- HDF5 and PyTables for Python HDF5 support
- wxPython for the AMRViewer GUI
- mpi4py if you want to use the MPI library on a large parallel system.

Delevoper dependencies

You will need this if you intend to work on the source code, or if you obtained PyMSES for an unpackaged version (i.e. a tarball of the mercurial repository, or `hg clone`)

- mercurial for source code management
- Cython
- sphinx for generating the documentation

1.2.2 Installation instructions

For now, the easiest way to install PyMSES from a tarball is:

1. Extract the tarball into a directory, say ~/codes/pymses
2. Run make in the directory
3. Add the make directory to your PYTHONPATH
4. Optional : Add the pymses/bin to your PATH, to quickly start the GUI with the amrviewer command or to launch basic scripts.

For example, using the bash shell:

```
$ cd  ~/codes
$ tar -xvfz pymses-3.0.0.tar.gz
$ cd pymses_3.0.0
$ make
$ export PYTHONPATH=~/codes/pymses_3.0.0:$PYTHONPATH
$ export PATH=$PATH:~/codes/pymses_3.0.0/bin
```

Note that you will need to place the export statements in your `~/.bashrc` or equivalent to set your `PYTHONPATH` and `PATH` for all future shell sessions.

1.3 Get a RAMSES output into PyMSES

Use case

You want to select a specific RAMSES output directory and get somme basic information about it

1.3.1 RAMSES output selection

First, you need to select the snapshot of your RAMSES simulation you would like to read by creating a `RamsesOutput` object :

```
>>> import pymses
>>> ro = pymses.RamsesOutput("/data/Aquarius/outputs", 193)
```

In this example, you are intersted in the files contained in `/data/Aquarius/output/ouput_00193/`

1.3.2 Ouput information

To get some details about this specific output/simulation. Everything you need is in the *info* parameter :

```
>>> ro.info
{'H0': 73.0,
'aexp': 1.0000620502295701,
'boxlen': 1.0,
'dom_decomp': <pymses.sources.ramses.hilbert.HilbertDomainDecomp object at 0x3305e10>,
'levelmax': 18,
'levelmin': 7,
'ncpu': 64,
'ndim': 3,
'ngridmax': 800000,
'nstep_coarse': 9578,
'omega_b': 0.039999999105930301,
'omega_k': 0.0,
'omega_l': 0.75,
'omega_m': 0.25,
'time': 6.2446534480863097e-05,
'unit_density': (2.50416381926e-27 m^-3.kg),
'unit_length': (4.21943976727e+24 m),
'unit_mass': (1.88116596007e+47 kg),
'unit_pressure': (2.50385294276e-13 m^-1.kg.s^-2),
'unit_temperature': (12021826243.9 K),
'unit_time': (4.21970170037e+17 s),
'unit_velocity': (9999379.26156 m.s^-1)}

>>> ro.info["ncpu"]
64

>>> ro.info["boxlen"] / 2**ro.info["levelmax"]
3.814697265625e-06
```

This way, you can easily find the units of your data (see *Dealing with units*).

1.4 Reading particles

1.4.1 Particle data source

If you want to look at the particles, you need to create a `RamsesParticleSource`. To do so, call the `particle_source()` method of your `RamsesOutput` object with a list of the different fields you might need in your analysis.

The available fields are :

- "vel" : the velocities of the particles
- "mass" : the mass of the particles
- "id" : the id number of the particles
- "level" : the AMR level of refinement of the cell each particle belongs to
- "epoch" : the birth time of the particles (0.0 for ic particles, >0.0 for star formation particles)
- "metal" : the metallicities of the particles

```
>>> ro = pymses.RamsesOutput("/data/Aquarius/output", 193)
>>> part = ro.particle_source(["vel", "mass"])
```

Warning

The data source you just created does not contain data. It is designed to provide an *on-demand* access to the data. To be memory-friendly, nothing is read from the disk yet at this point. All the `part_00193.out_*` files are only linked to the data source for further processing.

1.4.2 PointDataset

At the opposite, a `PointDataset` is an actual data container.

Single CPU particle dataset

If you want to read all the particles of the cpu number 3 (written in `part_00193.out_00003`), use the `get_domain_dset()` method :

```
>>> dset3 = part.get_domain_dset(3)
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00003
```

Number of particles

Every `PointDataset` has a *npoints* `int` parameter which gives you the number of particles in this dataset :

```
>>> print "CPU 3 has %i particles"%dset3.npoints
CPU 3 has 157976 particles
```

Particle coordinates

The *points* parameter of the `PointDataset` contains the coordinates of the particles :

```
>>> print dset3.points
array([[ 0.49422911,  0.51383241,  0.50130034],
    [ 0.49423128,  0.51374527,  0.50136899],
    [ 0.49420231,  0.51378629,  0.50190981],
    ...,
    [ 0.49447162,  0.51394969,  0.50146777],
    [ 0.49422794,  0.51378071,  0.50176276],
    [ 0.4946566 ,  0.51491008,  0.50117673]])
```

Particle fields

You also have an easy access to the different fields :

```
>>> print dset3["mass"]
array([  4.69471978e-07,   4.69471978e-07,   9.38943957e-07, ...,
         4.69471978e-07,   4.69471978e-07,   4.69471978e-07])
```

1.4.3 Whole data source concatenation

To read all the particles from all the ncpus `part_00193.out*` files and concatenate them into a single (but maybe not memory-friendly) dataset, call the `flatten()` method of your *part* object :

```
>>> dset_all = part.flatten()
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00001
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00002
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00003
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00004

[...]

Reading particles : /data/Aquarius/output/output_00193/part_00193.out00062
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00063
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00064

>>> print "Domain has %i particles"%dset_all.npoints
Domain has 10000000 particles
```

1.4.4 CPU-by-CPU particles

In most cases, you won't have enough memory to load all the particles of your simulation domain into a single dataset. You have two different options :

- Filter your particles (see *Data filtering*).
- Your analysis can be done on a cpu-by-cpu basis. The `RamsesParticleSource` provides a `iter_dsets()` iterator yielding cpu-by-cpu datasets :

```
>>> for dset in part.iter_dsets():
        print dset.npoints

Reading particles : /data/Aquarius/output/output_00193/part_00193.out00001
254210
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00002
214330
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00003
359648
[...]
Reading particles : /data/Aquarius/output/output_00193/part_00193.out00064
351203
```

1.5 AMR data access

1.5.1 AMR data source

If you want to deal with the AMR data, you need to call the `amr_source()` method of your `RamsesOutput` object with a single argument which is a list of the different fields you might need in your analysis.

When calling the `amr_source()`, the fields you have access to are :

- "rho" : the gas density field
- "vel" : the gas velocity field
- "P" : the gas pressurre field
- "g" : the gravitational acceleration field

To modify the list of available data fields, see *RAMSES AMR file formats*.

```
>>> ro = pymses.RamsesOutput("/data/Aquarius/output", 193)
>>> amr = ro.amr_source(["rho", "vel", "P", "g"])
```

Warning

The data source you just created does not contain data. It is designed to provide an *on-demand* access to the data. To be memory-friendly, nothing is read from the disk yet at this point. All the `amr_00193.out_*`, `hydro_00193.out_*` and `grav_00193.out_*` files are only linked to the data source for further processing.

1.5.2 AMR data handling

AMR data is a bit more complicated to handle than particle data. To perform various analysis, PyMSES provides you with two different tools to get your AMR data :

- *AMR grid to cell list conversion*
- *AMR field point-sampling*

AMR grid to cell list conversion

The `CellsToPoints` filter converts the AMR tree structure into a `IsotropicExtPointDataset` containing a list of the AMR grid *leaf envelope* cells :

- The *points* parameter of the datasets coming from the generated data source will contain the coordinates of the cell centers.
- These datasets will have an additional `get_sizes()` method giving you the size of each cell.

```
>>> from pymses.filters import CellsToPoints
>>> cell_source = CellsToPoints(amr)
>>> cells = cell_source.flatten()
[...]
# Cell centers
>>> ccenters = cells.points
```

```
# Cell sizes
>>> dx = cells.get_sizes()
```

Warning

As a `Filter`, the *cell_source* object you first created is another data provider, it doesn't contain actual data. To read the data, use `get_domain_dset()`, `iter_dsets()` or `flatten()` method as described in *Reading particles*.

AMR field point-sampling

Another way to read the AMR data is to perform a sampling of the AMR fields with a set of sampling points coordinates of your choice. In PyMSES, this is done quite easily with the `sample_points()` function :

```
>>> from pymses.analysis import sample_points
>>> sample_dset = sample_points(amr, points)
```

The returned *sample_dset* will be a `PointDataset` containing all your sampling points and the corresponding value of the different AMR fields you selected.

Note

In backstage, the point sampling is performed with a *tree search* algorithm, which makes this particular process of AMR data access both **user-friendly** and **efficient**.

For example, this method can be used :

- for visualization purposes (see *Slices*).
- when computing profiles (see *Profile computing*)

1.6 RAMSES AMR file formats

1.6.1 Default

The default settings for the AMR data file formats is as follow:

```
>>> from pymses.sources.ramses.octree import RamsesOctreeReader as ROR
>>> ROR.fields_by_file = {
... "hydro" : [ ROR.Scalar("rho", 0), ROR.Vector("vel", [1, 2, 3]), ROR.Scalar("P", 4) ],
... "grav"  : [ ROR.Vector("g", [0, 1, 2]) ]
... }
```

which means that in the `hydro_*.out*` files :

- the first read variable corresponds to the scalar gas **density** field
- the next 3 read variables corresponds to the gas 3D **velocity** field
- the fifth read variable corresponds to the scalar gas **pressure** field

and in the `grav_*.out*` files :

- the 3 read variables corresponds to the 3D **gravitational acceleration** field

1.6.2 User-defined

If you use a nD ($n \neq 3$) or a non-standard version of RAMSES, you might want to redefine this AMR file format to :

- make additional tracers available to your reader
- read nD ($n \neq 3$) data

```
>>> from pymses.sources.ramses.octree import RamsesOctreeReader as ROR

>>> # 2D data format
>>> ROR.fields_by_file = {
... "hydro" : [ ROR.Scalar("rho", 0), ROR.Vector("vel", [1, 2]), ROR.Scalar("P", 3) ],
... "grav"  : [ ROR.Vector("g", [0, 1]) ]
... }

>>> # Read additional tracers : metallicity, HCO abundancy
>>> ROR.fields_by_file = {
... "hydro" : [ ROR.Scalar("rho", 0), ROR.Vector("vel", [1, 2, 3]), ROR.Scalar("P", 4), ROR.Scalar("Z
... "grav"  : [ ROR.Vector("g", [0, 1, 2]) ]
... }
```

To take into effect these settings, make sure you define them before any call to `amr_source()`:

```
>>> from pymses import RamsesOutput
>>> from pymses.sources.ramses.octree import RamsesOctreeReader as ROR
>>> # 2D data format
>>> ROR.fields_by_file = {
... "hydro" : [ ROR.Scalar("rho", 0), ROR.Vector("vel", [1, 2, 3]), ROR.Scalar("P", 4), ROR.Scalar("Z
... "grav"  : [ ROR.Vector("g", [0, 1, 2]) ]
... }
>>> ro = RamsesOutput("/data/metal_simu/run001", 20)
>>> amr = ro.amr_source(["rho", "Z"])
```

1.7 Dealing with units

Need

Okay, I have read my data quite easily. What are the units of these data ? How do I convert them into human-readable units ?
Example : From a RAMSES hydro simulation, I want to convert my density field unit into the H/cc unit.

1.7.1 Dimensional physical constants

In pymses, a specific module has been designed for this purpose : `constants`.

It contains a bunch of useful dimensional physical constants (expressed in ISU) which you can use for unit conversion factors computation, adimensionality tests, etc.

```
>>> from pymses.utils import constants as C
>>> print C.kpc
(3.085677e+19 m)
>>> print C.Msun
(1.9889e+30 kg)
```

Each constant is an `Unit` instance, on which you can call the `express()` method to convert this constant into another dimension-compatible constant. If the dimensions are not compatible, a ValueError will be raised

```
>>> factor = C.kpc.express(C.ly)
>>> print "1 kpc = %f ly"%factor
1 kpc = 3261.563163 ly

>>> print C.Msun.express(C.km)
ValueError: Incompatible dimensions between (1.9889e+30 kg) and (1000.0 m)
```

Basic operations between these constants are enabled

```
>>> unit_density = 1.0E9 * C.Msun / C.kpc**3
>>> print "1Msun/kpc**3 = %f H/cc"%unit_density.express(C.H_cc)
1Msun/kpc**3 = 30.993246 H/cc
```

1.7.2 RAMSES data units

The units of each RAMSES output data are read from the output info file. You can manipulate the values of these units by using the *info* parameter (see *RAMSES output selection*)

```
>>> ro = RamsesOutput("/data/simu/outputs", 10)

>>> ro.info
{'H0': 1.0,
'aexp': 1.0,
'boxlen': 200.0,
'dom_decomp': <pymses.sources.ramses.hilbert.HilbertDomainDecomp object at 0x9df0aac>,
'levelmax': 14,
'levelmin': 7,
'ncpu': 64,
'ndim': 3,
'ngridmax': 1000000,
'nstep_coarse': 1200,
'omega_b': 0.0,
'omega_k': 0.0,
'omega_l': 0.0,
'omega_m': 1.0,
'time': 10.724764558171801,
'unit_density': (6.77025430199e-20 m^-3.kg),
'unit_length': (6.17135516256e+21 m),
'unit_mass': (1.9891e+39 kg),
'unit_pressure': (2.91283226304e-10 m^-1.kg.s^-2),
'unit_temperature': (517290.92492 K),
'unit_time': (4.70430312424e+14 s),
'unit_velocity': (65592.6605874 m.s^-1)}
```

Assuming you already have sampled the AMR density field of this output into a *pdset* `PointDataset` containing all your sampling points (see *AMR field point-sampling*), you can convert your density field (in code unit) into the unit of your choice:

```
>>> rho_field_H_cc = pdset["rho"] * ro.info["unit_density"].express(C.H_cc)
```

Warning

You must take care of manipulating RAMSES data in an unit-coherent way !!!

- **Good**:

```
>>> info = ro.info

>>> # Density
>>> rho_H_cc = rho_ramses * info["unit_density"].express(C.H_cc)

>>> # Mass
>>> part_mass_Msun = part_mass * info["unit_mass"].express(C.Msun)

>>> # Kinetic energy
>>> factor = (info["unit_mass"] * info["unit_velocity"]**2).express(C.J)
>>> kin_energy_J = part_mass * part_vel**2 * factor
```

- **Not so good**:

```
>>> info = ro.info

>>> # Density
>>> factor = (info["unit_mass"] / info["unit_length"]**3).express(C.H_cc)
>>> rho_H_cc = rho_ramses * factor

>>> # Mass
>>> factor = (info["unit_density"]*info["unit_length"]**3).express(C.Msun)
>>> part_mass_Msun = part_mass * factor

>>> # Kinetic energy
>>> factor = (info["unit_pressure"] * info["unit_length"]**3).express(C.J)
>>> kin_energy_J = part_mass * part_vel**2 * factor
```

1.8 Data filtering

In PyMSES, a `Filter` is a data source that :

- filter the data coming from an origin data source.
- provides a new data source out of this filtering process.

1.8.1 Region filter

For a lot of analysis, you are often interested in a particular region of your simulation domain, for example :

- spherical region centered on a dark matter halo in a cosmological simulation.
- cylindrical region containing a galactik disk or a cosmological filament.
- ...

```
>>> # Region of interest
>>> from pymses.utils.regions import Sphere
>>> center = [0.5, 0.5, 0.5]
>>> radius = 0.1
>>> region = Sphere(center, radius)
```

To filter data source with a region, use the `RegionFilter`:

```
>>> from pymses.filters import RegionFilter
>>> from pymses import RamsesOutput
>>> ro = RamsesOutput("/data/Aquarius/output/", 193)
>>> parts = ro.particle_source(["mass"])
>>> amr = ro.amr_source(["rho"])

>>> # Particle filtering
>>> filt_parts = RegionFilter(region, parts)

>>> # AMR data filtering
>>> filt_amr = RegionFilter(region, amr)
```

Note

The region filters can greatly improve the I/O performance of your analysis process since it doesn't require to read all the cpu files (of your entire simulation domain) but only those whose domain intersects your region of interest.
The filtering process occurs not only at the cpu level (as any other `Filter`) but also in the choice of required cpu files.

1.8.2 The CellsToPoints filter

see *AMR grid to cell list conversion*.

1.8.3 Function filters

You can also define your own function filter. Here an example where only the particles of mass equal to $3 \times 10^3 M_\odot$ are gathered :

```
>>> from pymses.filters import PointFunctionFilter
>>> from pymses.utils import constants as C

>>> part_source = ro.particle_source(["mass"])

>>> # Stellar disc particles filter : only keep particles of mass = 3000.0 Msun
>>> part_mass_Msun = 3.0E3 * C.Msun
>>> part_mass_code = part_mass_Msun.express(ro.info["unit_mass"])
>>> st_disc_func = lambda dset: (dset["mass"]==part_mass_code)

>>> # Stellar disc particle data source
>>> st_disc_parts = PointFunctionFilter(st_disc_func, part_source)
```

1.8.4 Randomly decimated data

You can use the PointRandomDecimatedFilter filter to pick up only a given fraction of points (randomly chosen) from your point-based data:

```
>>> from pymses.filters import PointRandomDecimatedFilter
>>> part_source = ro.particle_source(["mass"])

>>> # Pick up 10 % of the particles
>>> fraction = 0.1
>>> dec_parts = PointRandomDecimatedFilter(fraction, part_source)
```

1.8.5 Combining filters

You can pile up as many filters as you want to get the particular data you're interested in:

```
>>> # Region filter
>>> reg_parts = RegionFilter(region, parts)

>>> # Stellar disc filter
>>> st_disc_parts = PointFunctionFilter(st_disc_func, reg_parts)

>>> # 10 % randomly decimated filter
>>> dec_parts = PointRandomDecimatedFilter(fraction, st_disc_parts)
```

In this example, the *dec_parts* data source will provide you 10% of the stellar particles contained within a given *region*

1.9 Analysis tools

1.9.1 Profile computing

In this section are presented 2 examples of profile computing. The first is based on AMR data and the second on particles data.

Cylindrical profile of an AMR scalar field

Use case

You want to compute the cylindrical profile (for example, the surface density of a galactic disk) of a scalar AMR field (here, the `rho` density field). We assume that we know beforehand the configuration of the disk (center, radius, thickness, normal vector).

We take the configuration of the galactic disk to be:

```
>>> gal_center = [ 0.567811, 0.586055, 0.559156 ]        # in box units
>>> gal_radius = 0.00024132905460547268                  # in box units
>>> gal_thickn = 0.00010238202316595811                  # in box units
>>> gal_normal = [ -0.172935, 0.977948, -0.117099 ]      # Norm = 1
```

Reading AMR data from the RAMSES output

As already explained in *Get a RAMSES output into PyMSES* and *AMR data access*, we create the AMR data source from the RAMSES output we are intersted in, reading only the density field:

```
>>> from pymses import RamsesOutput
>>> output = RamsesOutput("/data/Aquarius/output", 193)
# Prepare to read the density field only
>>> source = output.amr_source(["rho"])
```

Random sampling of the AMR data fields in a given region of interest

Now we build the `Cylinder` that will define the region of interest for the profile:

```
>>> from pymses.utils.regions import Cylinder
>>> cyl = Cylinder(gal_center, gal_normal, gal_radius, gal_thickn)
```

Generation of an array of 10^6 random points uniformly spread within the cylinder (`random_points()` function), and then sampling of the AMR fields at these coordinates (see *AMR field point-sampling*):

```
>>> from pymses.analysis import sample_points
>>> points = cyl.random_points(1.0e6) # 1M sampling points
>>> point_dset = sample_points(source, points)
```

Computing the profile from the point-based samples

As we are interested in the density profile, we use the data field `rho` as the weight function. We also take 200 linearly spaced radial bins within the cylinder radius:

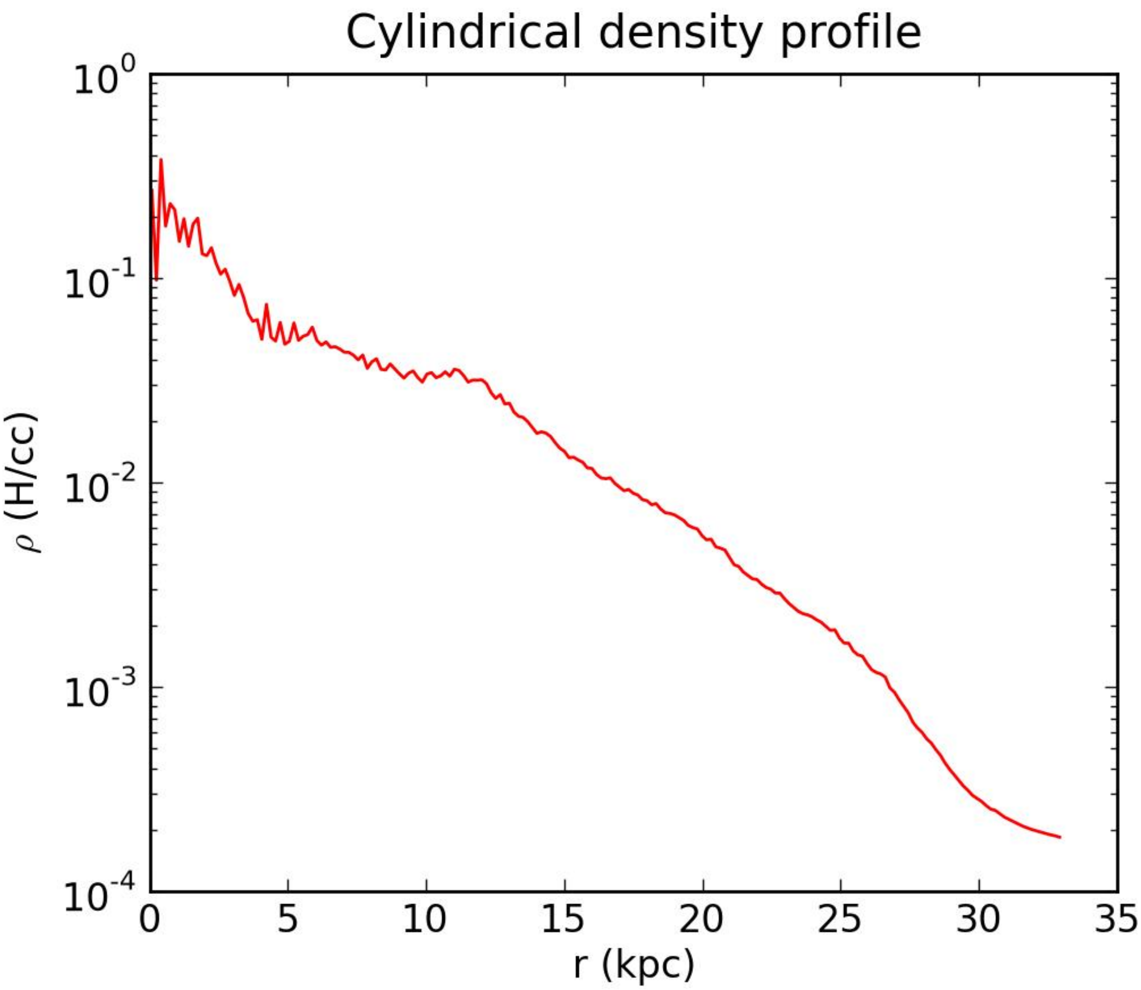
```
>>> import numpy
>>> rho_weight_func = lambda dset: dset["rho"]
>>> r_bins = numpy.linspace(0.0, gal_radius, 200)
```

Now we compute the profile of the resulting `PointDataset` using the `bin_cylindrical()` function.

We set the *divide_by_counts* flag to `True`, because we're averaging the density field in each cylindrical shell:

```
>>> from pymses.analysis import bin_cylindrical
>>> rho_profile = bin_cylindrical(point_dset, gal_center, gal_normal,
... rho_weight_func, r_bins, divide_by_counts=True)
```

Finally, we can plot the profile with Matplotlib:



Spherical profile of a set of particle data

> **Use case**
>
> You want to compute the spherical radial profile of a given particle data field.
> **Example** : From a RAMSES cosmological simulation, you want to compute the radial density profile of a dark matter halo. You already know the position and the size of the halo.

We take the location and spatial extension of the dark matter halo to be:

```
>>> halo_center = [ 0.567811, 0.586055, 0.559156 ]        # in box units
>>> halo_radius = 0.00075                                  # in box units
```

Reading particle data from a RAMSES output

As already explained in *Get a RAMSES output into PyMSES* and *Reading particles*, we create the particle data source from the RAMSES output we are intersted in, reading only the *mass* and *epoch* fields:

```
>>> from pymses import RamsesOutput
>>> ro = RamsesOutput("/data/Aquarius/output", 193)
# Prepare to read the mass/epoch fields only
>>> source = ro.particle_source(["mass", "epoch"])
```

Filtering all the initial particles within a given region of interest

See *Data filtering* for details.

Now we build the `Sphere` that will define the region of interest for the profile:

```
>>> from pymses.utils.regions import Sphere
>>> sph = Sphere(halo_center, halo_radius)
```

Then filter all the particles contained in the sphere by using a `RegionFilter`:

```
>>> from pymses.filters import RegionFilter
>>> point_dset = RegionFilter(sph, source)
```

Filter all the particles which are initially present in the simulation using a `PointFunctionFilter`:

```
>>> from pymses.filters import PointFunctionFilter
>>> dm_filter = lambda dset: dset["epoch"] == 0.0
>>> dm_parts = PointFunctionFilter(dm_filter, point_dset)
```

Computing the profile

As we are interested in the density profile, we use the data field `mass` as the weight function. We also take 200 linearly spaced radial bins within the sphere radius:

```
>>> import numpy
>>> m_weight_func = lambda dset: dset["mass"]
>>> r_bins = numpy.linspace(0.0, halo_radius, 200)
```

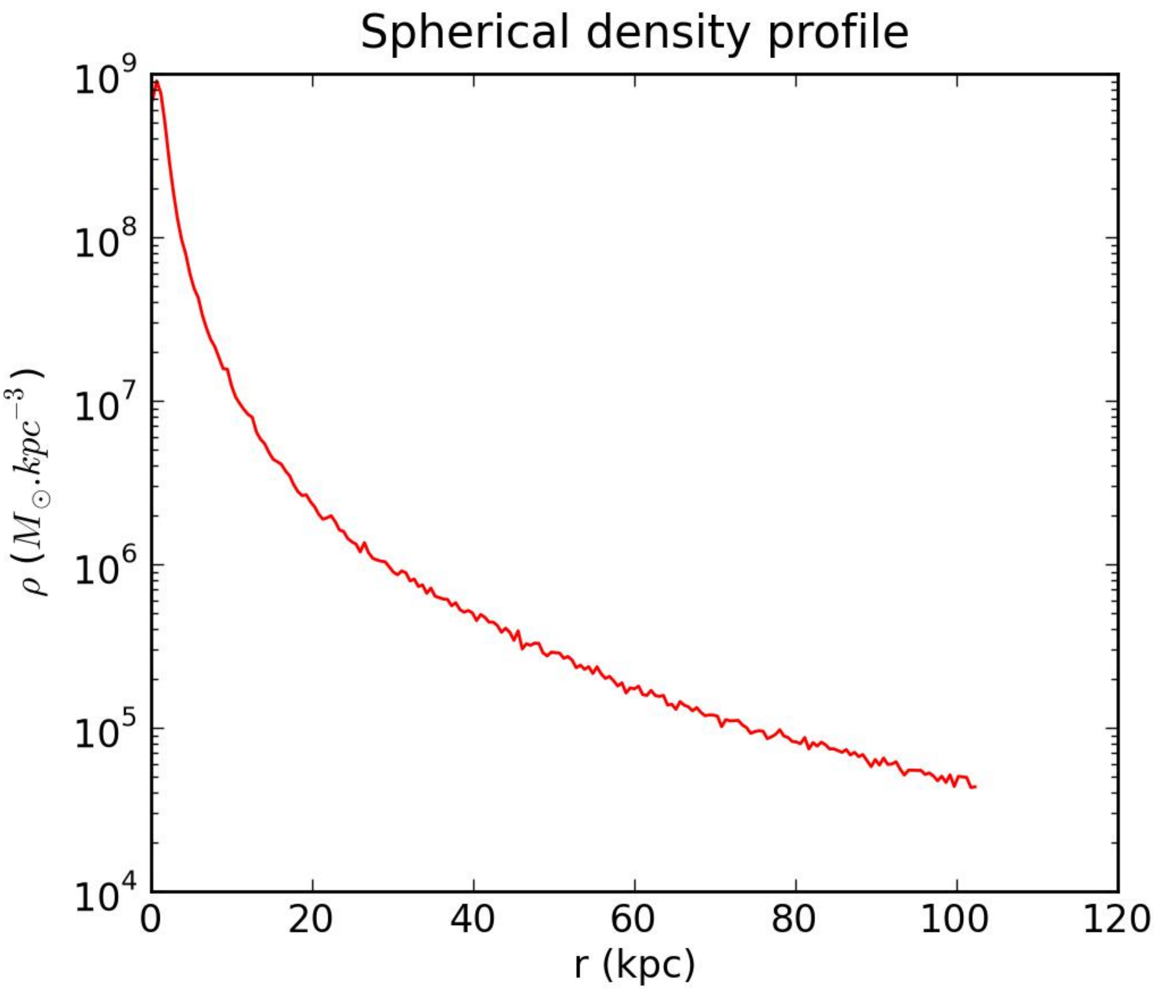
Now we compute the profile `bin_spherical()` function.

We set the *divide_by_counts* flag to `False` (optional, this is the default value), because we're cumulating the masses of the particles in spherical shells:

```
>>> from pymses.analysis import bin_spherical
>>> # This triggers the actual reading of the particle data files from disk.
>>> mass_profile = bin_spherical(dm_parts, halo_center, m_weight_func, r_bins, divide_by_counts=False
```

To compute the density profile, we divide the mass profile by the volume of each spherical shell:

```
>>> sph_vol = 4.0/3.0 * numpy.pi * r_bins**3
>>> shell_vol = numpy.diff(sph_vol)
>>> rho_profile = mass_profile / shell_vol
```



1.10 Visualization tools

1.10.1 Camera and Operator

Camera

To do some data visualization, the view parameters are handled by a `Camera`:

```
>>> from pymses.analysis.visualization import Camera
>>> cam  = Camera(center=[0.5, 0.5, 0.5], line_of_sight_axis='z', region_size=[0.5, 0.5], distance=0
... far_cut_depth=0.5, up_vector='y', map_max_size=512, log_sensitive=True)
```

This object is then used in every PyMSES visualization tool to render an image from the data.

The camera is :

- centered around **center**
- oriented according to a **line_of_sight_axis** pointing towards the observer and an **up_vector** pointing upwards (in the camera plane)

- delimited by a **region_size** in the directions perpendicular to the camera plane.
- delimited by front/background cut planes at position **distance/far_cut_depth** along the line-of-sight axis
- log-sensitive or not (**log_sensitive**)
- built with a virtual CCD-detector matrix of max. size **map_max_size**

Saving / loading a Camera

Camera can be saved into an HDF5 file:

```
>>> import tables
>>> from pymses.analysis.visualization import Camera
>>> cam  = Camera(center=[0.5, 0.5, 0.8], line_of_sight_axis='y', region_size=[0.5, 0.8], distance=0
>>> file= tables.openFile("my_cam.hdf5", "w")
>>> cam.save_HDF5(file)
```

It can also be loaded from a HDF5 file to retrieve a previous view:

```
>>> import tables
>>> from pymses.analysis.visualization import Camera
>>> file= tables.openFile("my_cam.hdf5", "r")
>>> cam = Camera.from_HDF5(file)
```

Other utility functions

The camera definition can be used to know the maximum Ramses AMR level up needed to compute the image map:

```
>>> level_max = cam.get_required_resolution()
```

To do further computation we can also get the pixel surface from the camera object:

```
>>> pixel_surface = cam.get_pixel_surface()
```

We can get some camera oriented slice points directly from the camera (see *Slices*):

```
>>> slice_points = cam.get_slice_points(z)
```

Operator

For every PyMSES visualization method you might use, you must define the physical scalar quantity you are interested in.

For example, you can describe the kinetic energy of particles with the `ScalarOperator`:

```
>>> import numpy
>>> from pymses.analysis.visualization import ScalarOperator
>>> def kin_en_func(dset):
...     m = dset["mass"]
...     v2 = numpy.sqrt(numpy.sum(dset["vel"]**2, axis=1))
...     return m*v2
>>> Ek = ScalarOperator(kin_en_func)
```

You can also define `FractionOperator`. For example, if you need a mass-weighted temperature operator for your AMR grid (FFT-maps):

```
>>> from pymses.analysis.visualization import FractionOperator
>>> M_func = lambda dset: dset["rho"] * dset.get_sizes()**3
>>> def num(dset):
...     T = dset["P"]/dset["rho"]
...     M = M_func(dset)
...     return T * M
>>> op = FractionOperator(num, M_func)
```

If you want to ray-trace the max. AMR level of refinement along the line-of-sight, use `MaxLevelOperator`.

1.10.2 Maps

Slices

Intro

A quick way to look at data is to compute 2D data slice map.

Here is how it works: It first gets some sample points from a camera object, using a basic 2D Cartesian grid. Then those points are evaluated using the pymses point_sampler module. A sampling operator can eventually be applied on the data.

Example

We first need to define a suitable camera:

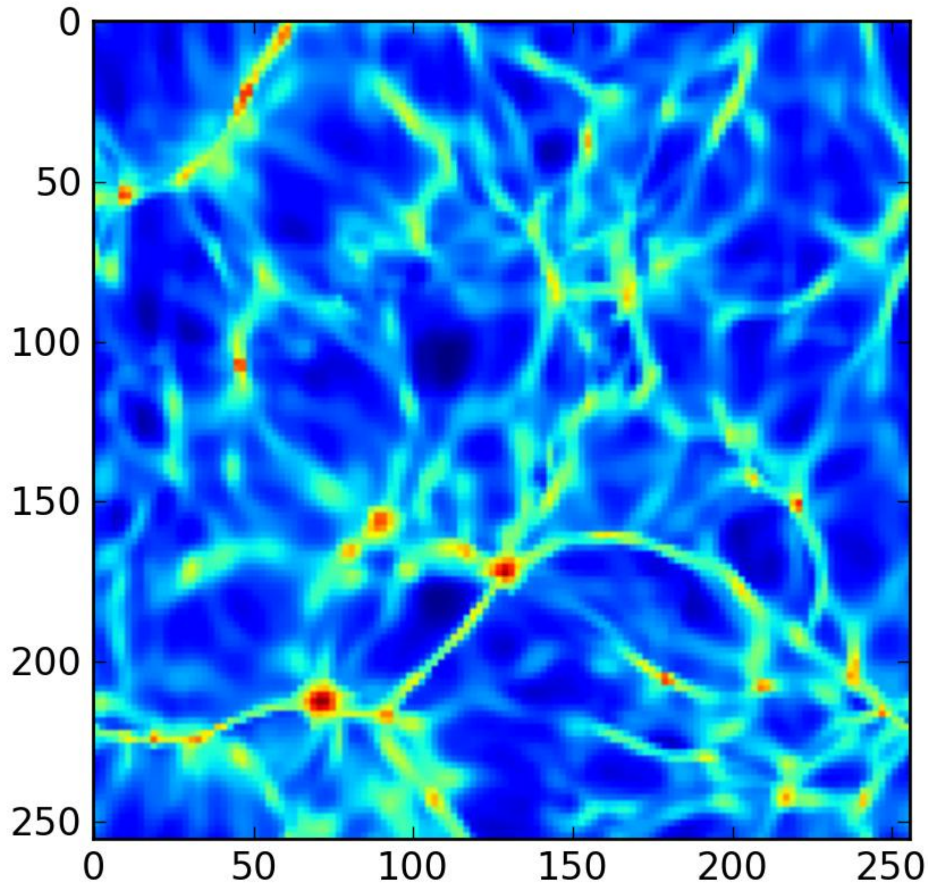
```
>>> from pymses.analysis.visualization import Camera
>>> cam  = Camera(center=[0.5, 0.5, 0.5], line_of_sight_axis='z', region_size=[1., 1.],\
... up_vector='y', map_max_size=512, log_sensitive=True)
```

Using the amr data previously defined in *AMR data access*, we can get the map corresponding to the defined slice view. A logarithmic scale is here applied as it is defined in the camera object.

```
>>> from pymses.analysis.visualization import SliceMap, ScalarOperator
>>> rho_op = ScalarOperator(lambda dset: dset["rho"])
>>> map = SliceMap(amr, cam, rho_op, z=0.4) # create a density slice map at z=0.4 depth position
```

The result can be seen using the matplotlib library:

```
>>> import pylab as P
>>> P.imshow(map)
>>> P.show()
```



FFT-convolved maps

Intro

A very simple, fast and accurate data projection (3D->2D) method : each particle/AMR cell is convolved by a 2D gaussian kernel (*Splatter*) which size depends on the local AMR grid level.

The convolution of the binned particles/AMR cells histogram with the gaussian kernels is performed with FFT techniques by a `MapFFTProcessor`. You can see two examples of this method below :

- *Particles map*
- *AMR data map*

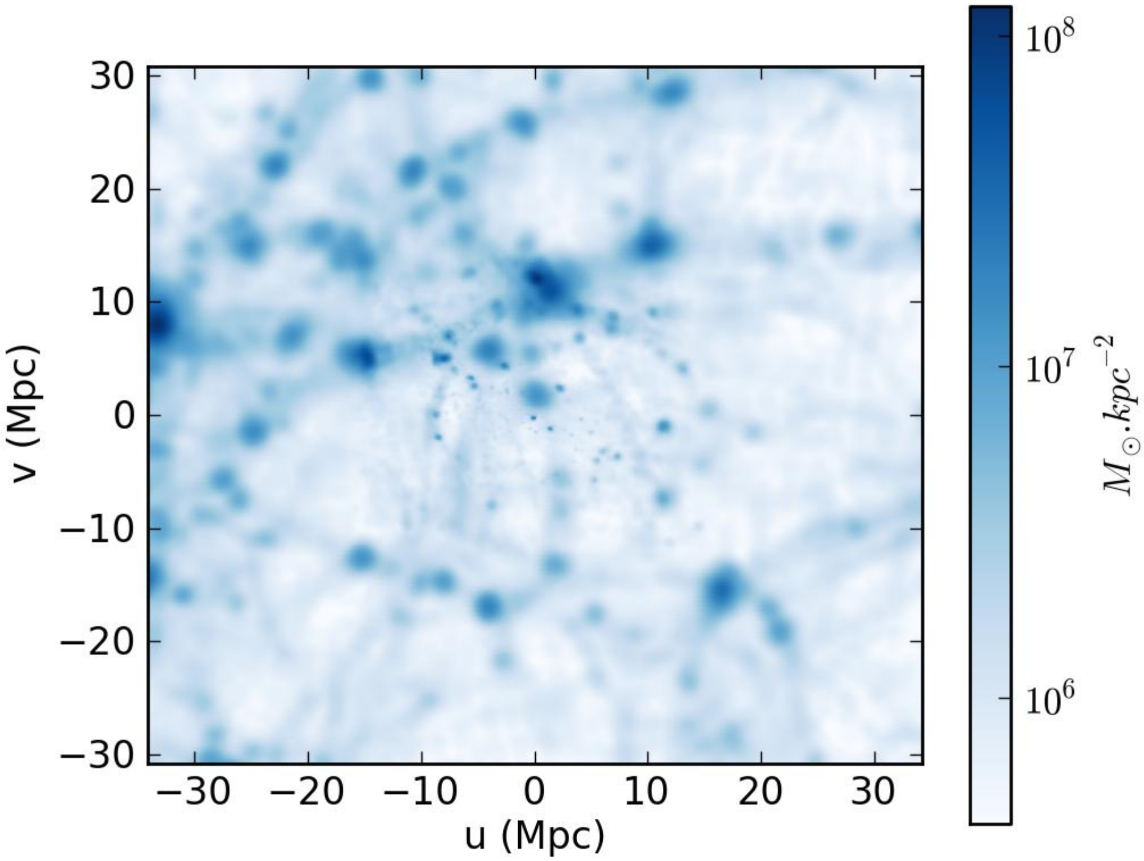
Important note on operators

You must keep in mind that any X `Operator` you use with this method must describe an **extensive** physical variable since this method compute a summation over particle/AMR quantities :
$map[i,j] = \sum_{\text{particles/AMR cells}} X$

Examples

Particles map

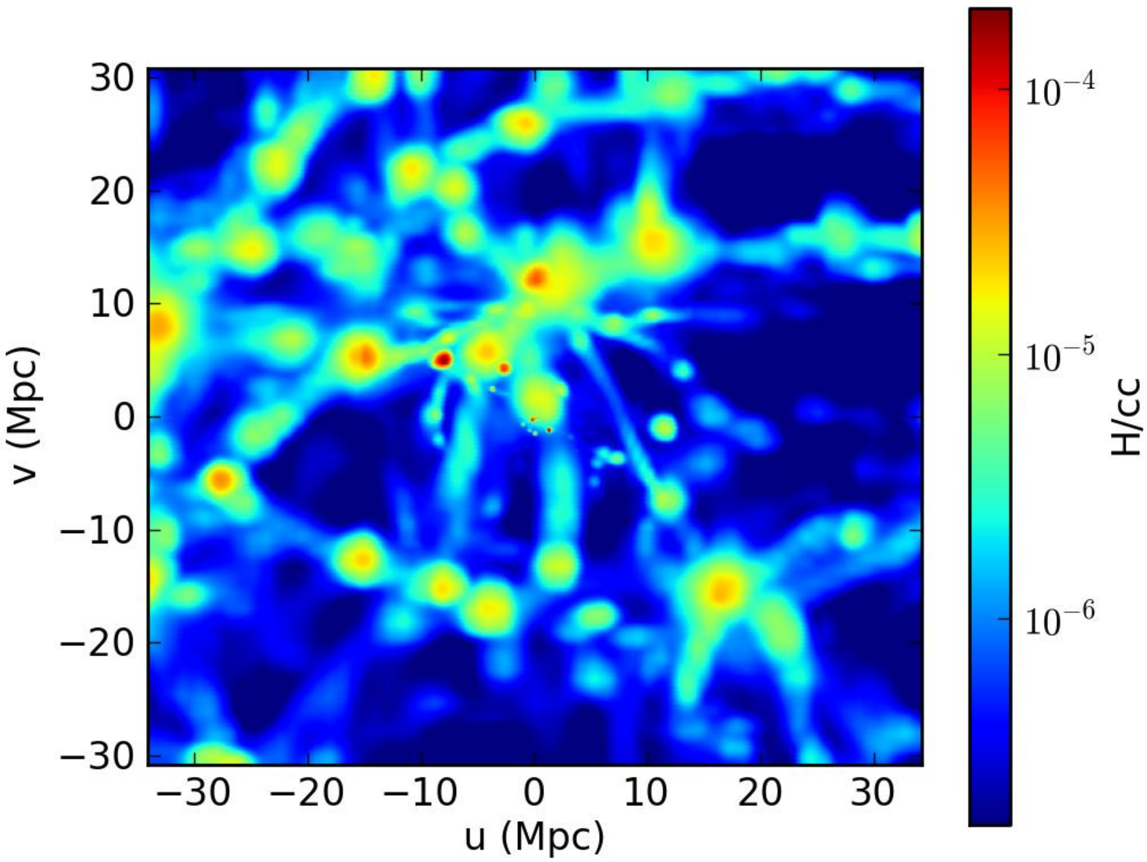
```
from numpy import array, log10
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# Ramses data
ioutput = 193
ro = RamsesOutput("/data/Aquarius/output/", ioutput)
parts = ro.particle_source(["mass", "level"])

# Map operator : mass
scal_func = ScalarOperator(lambda dset: dset["mass"])

# Map region
center = [ 0.567811, 0.586055, 0.559156 ]
axes = {"los": array([ -0.172935, 0.977948, -0.117099 ])}

# Map processing
mp = fft_projection.MapFFTProcessor(parts, ro.info)
for axname, axis in axes.items():
        cam  = Camera(center=center, line_of_sight_axis=axis, up_vector="z", region_size=[5.0E-1, 4.5
                        distance=2.0E-1, far_cut_depth=2.0E-1, map_max_size=512)
        S = cam.get_pixel_surface()
        map = mp.process(scal_func, cam, surf_qty=True)
        factor = (ro.info["unit_mass"]/ro.info["unit_length"]**2).express(C.Msun/C.kpc**2)
        scale = ro.info["unit_length"].express(C.Mpc)

#        pylab.imshow(map)
#        pylab.show()
        # Save map into HDF5 file
        mapname = "DM_Sigma_%s_%5.5i"%(axname, ioutput)
        h5fname = save_map_HDF5(map, cam, map_name=mapname)

        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("$M_{\odot}.kpc^{-2}$",factor), axis_unit=("Mpc",
#        pil_img = save_HDF5_to_img(h5fname, cmap="Blues", fraction=0.1)

        # Save map into PNG image file
#        save_HDF5_to_plot(h5fname, map_unit=("$M_{\odot}.kpc^{-2}$",factor), \
#                        axis_unit=("Mpc", scale), img_path="./", cmap="Blues", fraction=0.1)
#        save_HDF5_to_img(h5fname, img_path="./", cmap="Blues", fraction=0.1)

# pylab.show()
```



AMR data map

```
from numpy import array
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# Ramses data
ioutput = 193
ro = RamsesOutput("/data/Aquarius/output/", ioutput)
amr = ro.amr_source(["rho", "P"])

# Map operator : mass-weighted density map
up_func = lambda dset: (dset["rho"]**2 * dset.get_sizes()**3)
down_func = lambda dset: (dset["rho"] * dset.get_sizes()**3)
scal_func = FractionOperator(up_func, down_func)

# Map region
center = [ 0.567811, 0.586055, 0.559156 ]
axes = {"los": array([ -0.172935, 0.977948, -0.117099 ])}
```

```
# Map processing
mp = fft_projection.MapFFTProcessor(amr, ro.info)
for axname, axis in axes.items():
        cam  = Camera(center=center, line_of_sight_axis=axis, up_vector="z", region_size=[5.0E-1, 4.5
                        distance=2.0E-1, far_cut_depth=2.0E-1, map_max_size=512)
        map = mp.process(scal_func, cam)
        factor = ro.info["unit_density"].express(C.H_cc)
        scale = ro.info["unit_length"].express(C.Mpc)

#        pylab.imshow(map)
        # Save map into HDF5 file
        mapname = "gas_mw_%s_%5.5i"%(axname, ioutput)
        h5fname = save_map_HDF5(map, cam, map_name=mapname)

        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("H/cc",factor), axis_unit=("Mpc", scale), cmap="je
#        pil_img = save_HDF5_to_img(h5fname, cmap="jet")

        # Save into PNG image file
#        save_HDF5_to_plot(h5fname, map_unit=("H/cc",factor), axis_unit=("Mpc", scale), img_path="./
#        save_HDF5_to_img(h5fname, img_path="./", cmap="jet")

# pylab.show()
```



Ray-traced maps

Intro

Ray-traced maps are computed in PyMSES by integrating a physical quantity along *rays*, each one corresponding to a pixel of the map. Ray-tracing is handled by a `RayTracer`. You can see two examples of this method below :

- *Density map*
- *Min. temperature map*
- *Max. AMR level of refinement map*

Important note on operators

You must keep in mind that any X `Operator` you use with this method must describe an **intensive** physical variable since this method compute an integral of an AMR quantity over each pixel surface and along the line-of-sight :

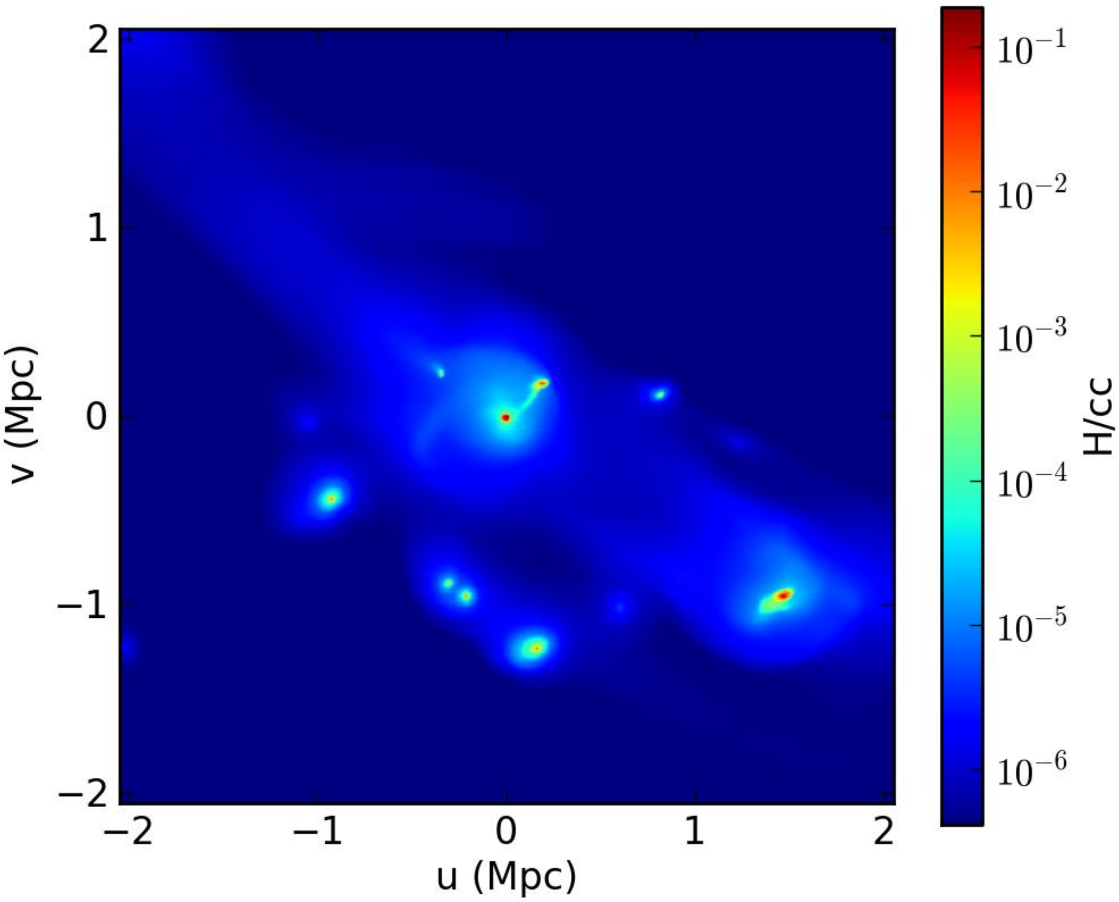
$$map[i,j] = \int_{z_{\rm min}}^{z_{\rm max}} X \mathrm{d}S_{\rm pix} \mathrm{d}z$$

Examples

Density map

```
from numpy import array
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# Ramses data
ioutput = 193
ro = RamsesOutput("/data/Aquarius/output/", ioutput)

# Map operator : mass-weighted density map
up_func = lambda dset: (dset["rho"]**2)
down_func = lambda dset: (dset["rho"])
scal_op = FractionOperator(up_func, down_func)

# Map region
center = [ 0.567811, 0.586055, 0.559156 ]
axes = {"los": array([ -0.172935, 0.977948, -0.117099 ])}

# Map processing
rt = raytracing.RayTracer(ro, ["rho"])
for axname, axis in axes.items():
        cam  = Camera(center=center, line_of_sight_axis=axis, up_vector="z", region_size=[3.0E-2, 3.
                        distance=2.0E-2, far_cut_depth=2.0E-2, map_max_size=512)
        map = rt.process(scal_op, cam)
        factor = ro.info["unit_density"].express(C.H_cc)
        scale = ro.info["unit_length"].express(C.Mpc)

        # Save map into HDF5 file
        mapname = "gas_rt_mw_%s_%5.5i"%(axname, ioutput)
```

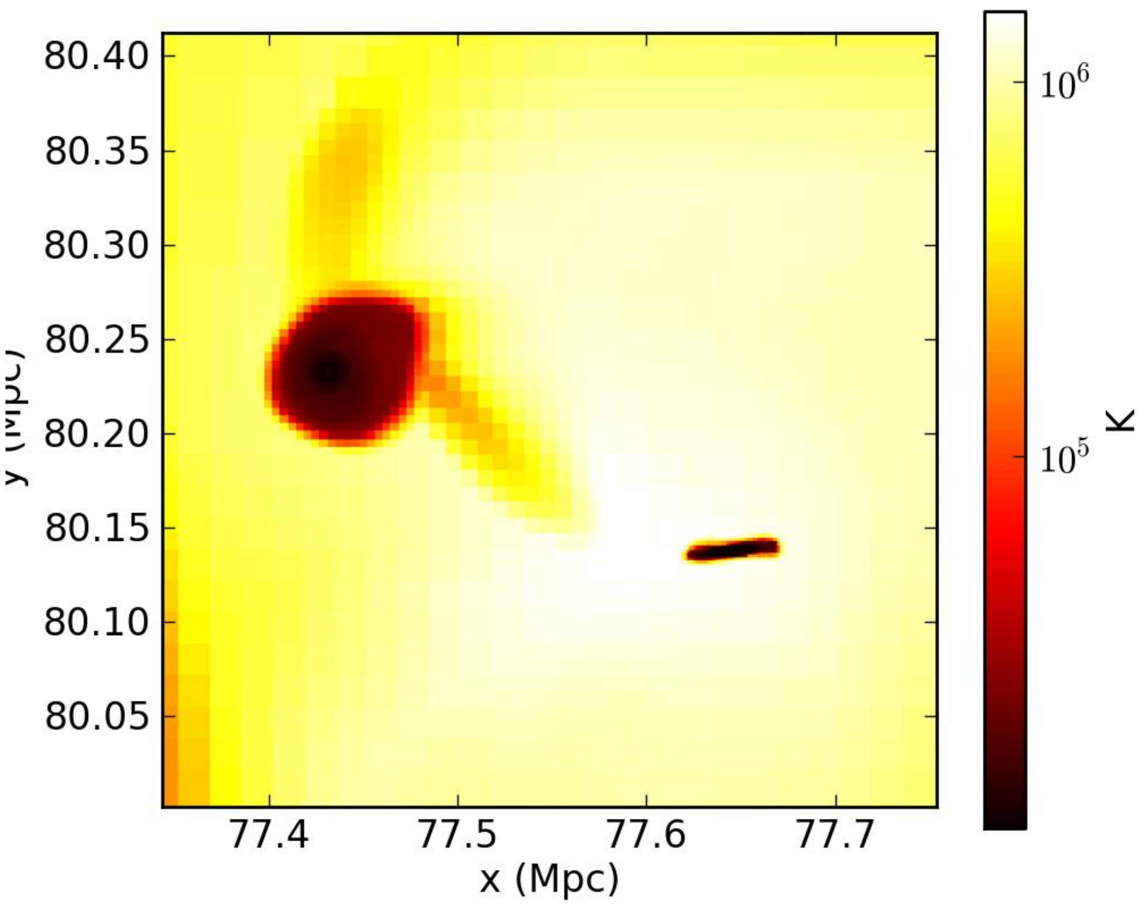
```
        h5fname = save_map_HDF5(map, cam, map_name=mapname)

        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("H/cc",factor), axis_unit=("Mpc", scale), cmap="je
#        pil_img = save_HDF5_to_img(h5fname, cmap="jet")

        # Save into PNG image file
#        save_HDF5_to_plot(h5fname, map_unit=("H/cc",factor), axis_unit=("Mpc", scale), img_path="./
#        save_HDF5_to_img(h5fname, img_path="./", cmap="jet")

#pylab.show()
```



Min. temperature map

```
from numpy import array, zeros_like
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# Ramses data
ioutput = 193
```

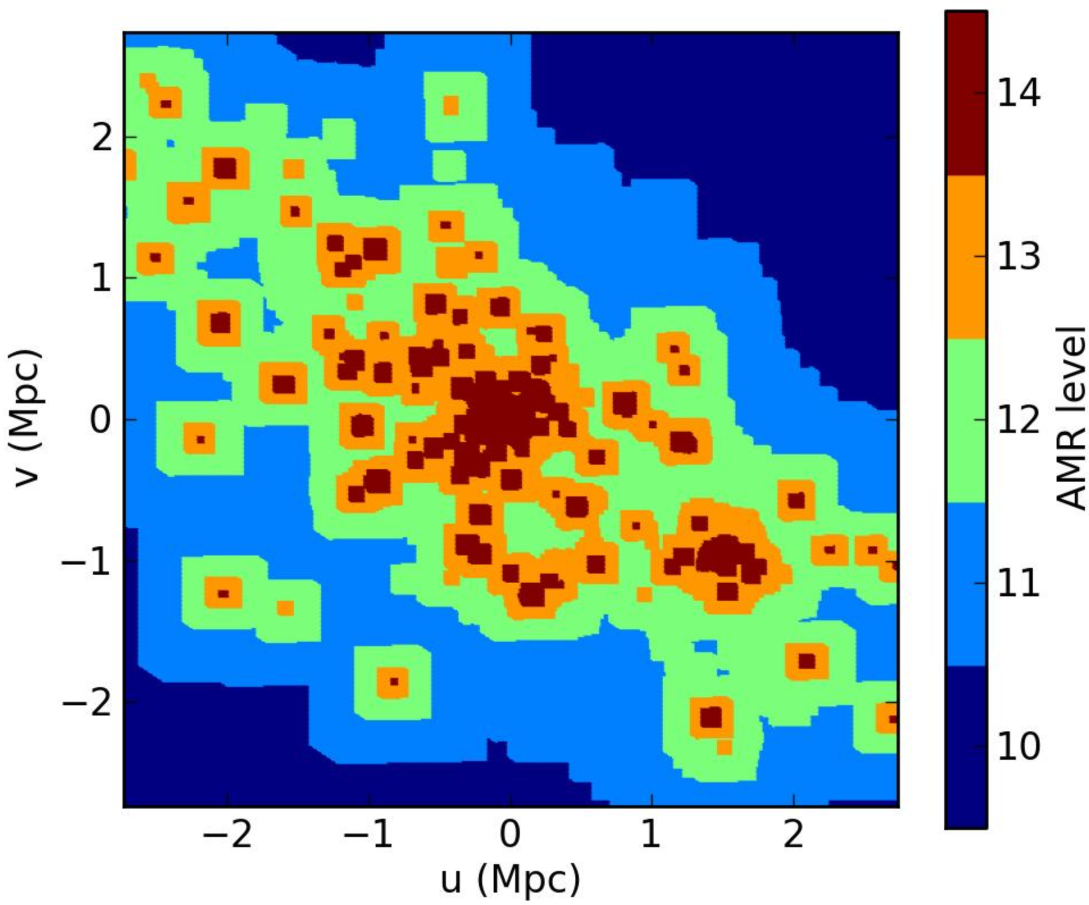
```
ro = RamsesOutput("/data/Aquarius/output/", ioutput)

# Map operator : minimum temperature along line-of-sight
class MyTempOperator(Operator):
        def __init__(self):
                def invT_func(dset):
                        P = dset["P"]
                        rho = dset["rho"]
                        r = rho/P
#                        print r[(rho<=0.0)+(P<=0.0)]
#                        r[(rho<=0.0)*(P<=0.0)] = 0.0
                        return r
                d = {"invTemp": invT_func}
                Operator.__init__(self, d, is_max_alos=True)

        def operation(self, int_dict):
                        map = int_dict.values()[0]
                        mask = (map == 0.0)
                        mask2 = map != 0.0
                        map[mask2] = 1.0 / map[mask2]
                        map[mask] = 0.0
                        return map
scal_op = MyTempOperator()

# Map region
center = [ 0.567111, 0.586555, 0.559156 ]
axes = {"los": "z"}

# Map processing
rt = raytracing.RayTracer(ro, ["rho", "P"])
for axname, axis in axes.items():
        cam  = Camera(center=center, line_of_sight_axis=axis, up_vector="y", region_size=[3.0E-3, 3.(
                        distance=1.5E-3, far_cut_depth=1.5E-3, map_max_size=512)
        map = rt.process(scal_op, cam)
        factor = ro.info["unit_temperature"].express(C.K)
        scale = ro.info["unit_length"].express(C.Mpc)

        # Save map into HDF5 file
        mapname = "gas_rt_Tmin_%s_%5.5i"%(axname, ioutput)
        h5fname = save_map_HDF5(map, cam, map_name=mapname)

        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("K",factor), axis_unit=("Mpc", scale), cmap="hot",
#        pil_img = save_HDF5_to_img(h5fname, cmap="hot")

        # Save into PNG image file
#        save_HDF5_to_plot(h5fname, map_unit=("K",factor), axis_unit=("Mpc", scale), img_path="./", c
#        save_HDF5_to_img(h5fname, img_path="./", cmap="hot")

#pylab.show()
```



Max. AMR level of refinement map

```
from numpy import array
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# Ramses data
ioutput = 193
ro = RamsesOutput("/data/Aquarius/output/", ioutput)

# Map operator : max. AMR level of refinement along the line-of-sight
scal_op = MaxLevelOperator()

# Map region
center = [ 0.567811, 0.586055, 0.559156 ]
axes = {"los": array([ -0.172935, 0.977948, -0.117099 ])}

# Map processing
rt = raytracing.RayTracer(ro, ["rho"])
for axname, axis in axes.items():
```

```
        cam  = Camera(center=center, line_of_sight_axis=axis, up_vector="z", region_size=[4.0E-2, 4.(
                        distance=2.0E-2, far_cut_depth=2.0E-2, map_max_size=512, log_sensitive=False)
        map = rt.process(scal_op, cam)
        scale = ro.info["unit_length"].express(C.Mpc)

        # Save map into HDF5 file
        mapname = "gas_rt_lmax_%s_%5.5i"%(axname, ioutput)
        h5fname = save_map_HDF5(map, cam, map_name=mapname)

        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("AMR level",1.0), axis_unit=("Mpc", scale), cmap="
#        pil_img = save_HDF5_to_img(h5fname, cmap="jet", discrete=True)

        # Save into PNG image file
#        save_HDF5_to_plot(h5fname, map_unit=("AMR level",1.0), axis_unit=("Mpc", scale), img_path="
#        save_HDF5_to_img(h5fname, img_path="./", cmap="jet", discrete=True)

#pylab.show()
```



Multiprocessing

If you are using python 2.6 or higher, the RayTracer will try to use multiprocessing speed up. You can desactivate it to save RAM memory and processor use by setting the multiprocessing option to False:

```
>>> map = rt.process(scal_op, cam, multiprocessing = False)
```

1.10.3 AMRViewer GUI

Starting the GUI

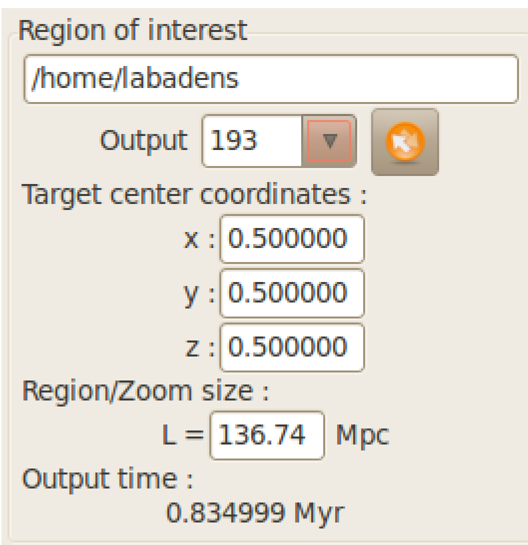
PyMSES has a Graphical User Interface (GUI) module which can be used to navigate into AMR data. Once installed as described in *Installing PyMSES*, the GUI can be started with the following python prompt commands:

```
>>> from pymses.analysis.visualization import AMRViewer
>>> AMRViewer.run()
```

Loading AMR data

To load some data, a Ramses outputs folder has to be selected via the toolbar button or the menu.

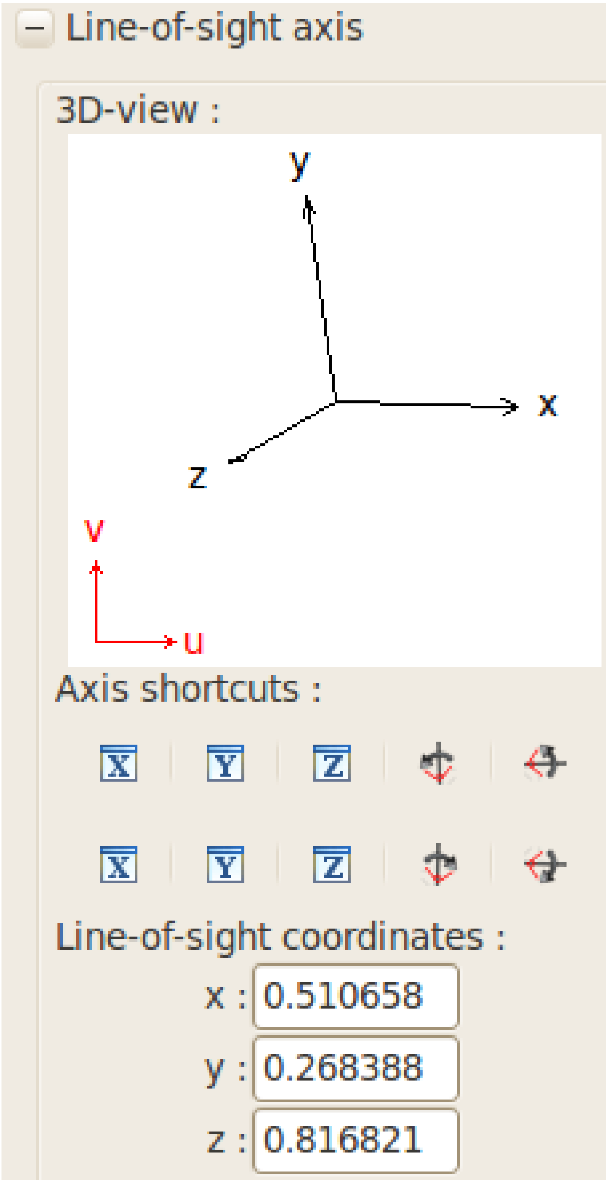
The required output number can be specified with the output number list on the left of the main window



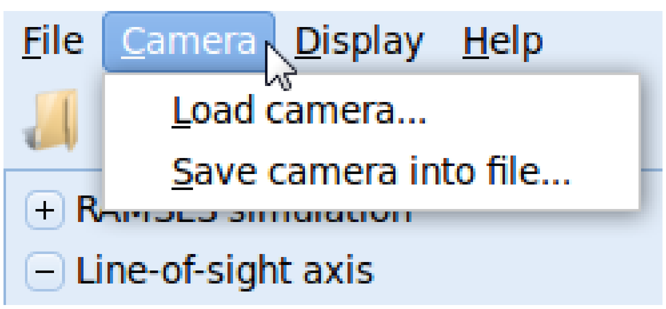
Playing with the camera

The camera parameters can be adjusted with the line-of-sight axis expander. You can drag-and-drop the line-of-sight axis to modify it interactively. You can also press `Ctrl` while dragging the axes to perform a rotation around the line-of-sight axis.

A few convenient shortcuts have been added to this menu.

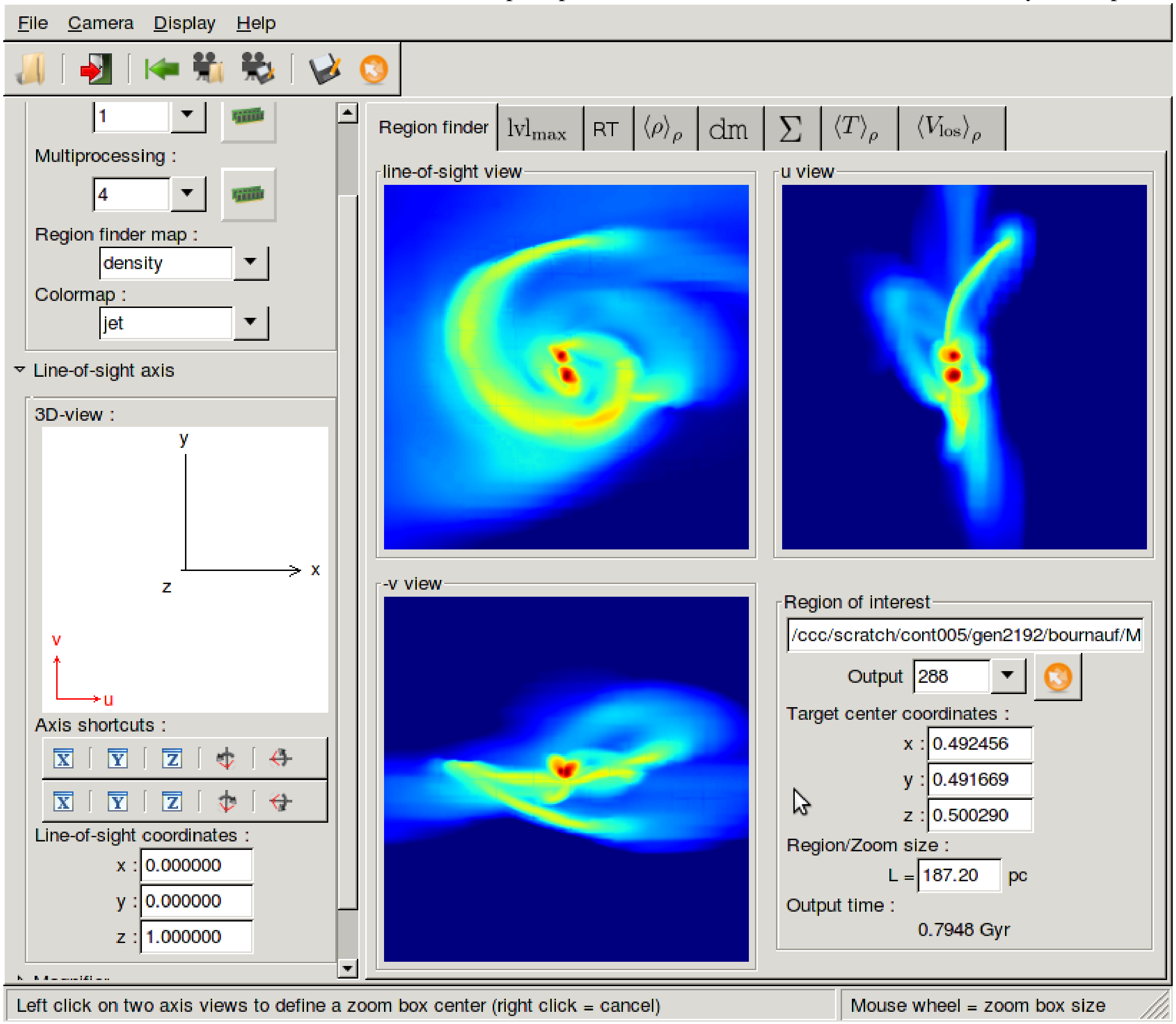


There is a possibility to save and load camera parameter via the `Camera` menu bar.



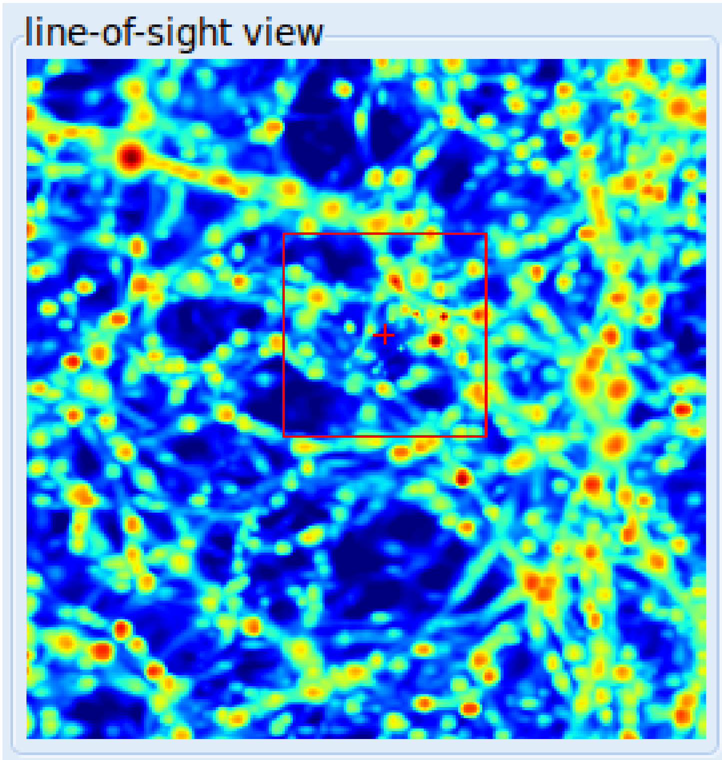
The Region Finder

The *update view* button is the trigger to actually read and process the data. Progress can then be seen in the command prompt, until the view has been totally computed.



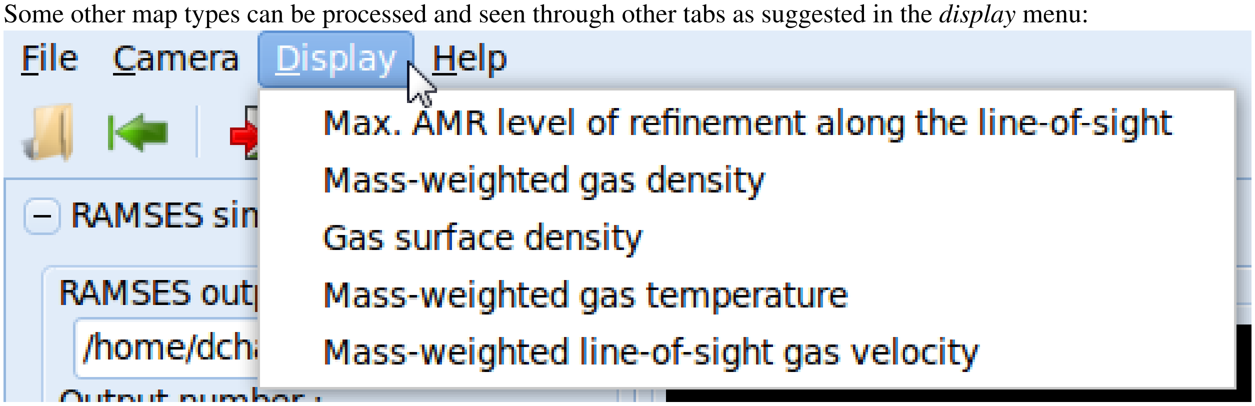
Navigation

The AMRViewer Region finder is made to navigate through data. Left clicks set the zoom center/zoom box size while right clicks unset them. Mouse wheel let you adjust the zoom box size.

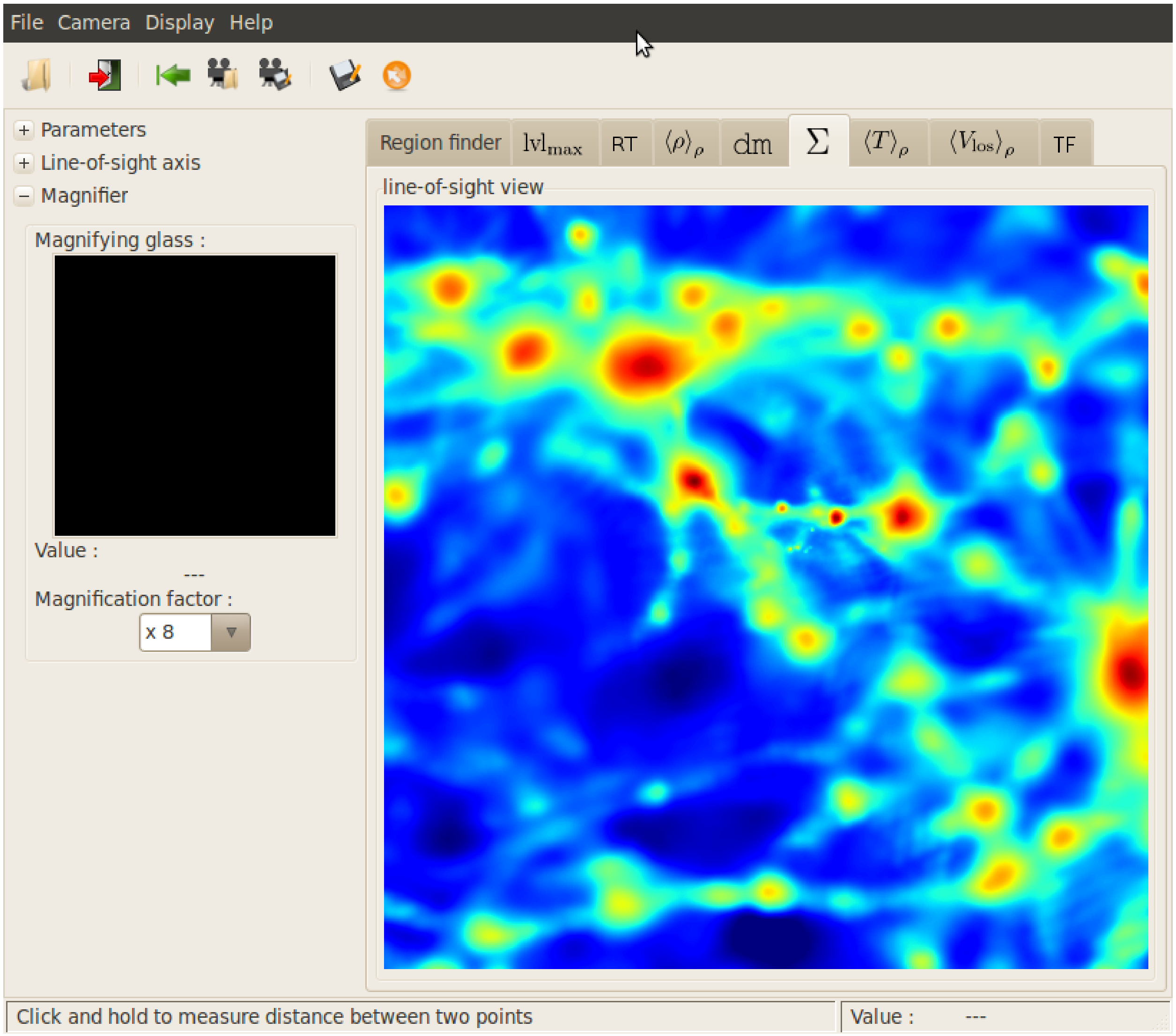


Other map types, other tabs

Some other map types can be processed and seen through other tabs as suggested in the *display* menu:

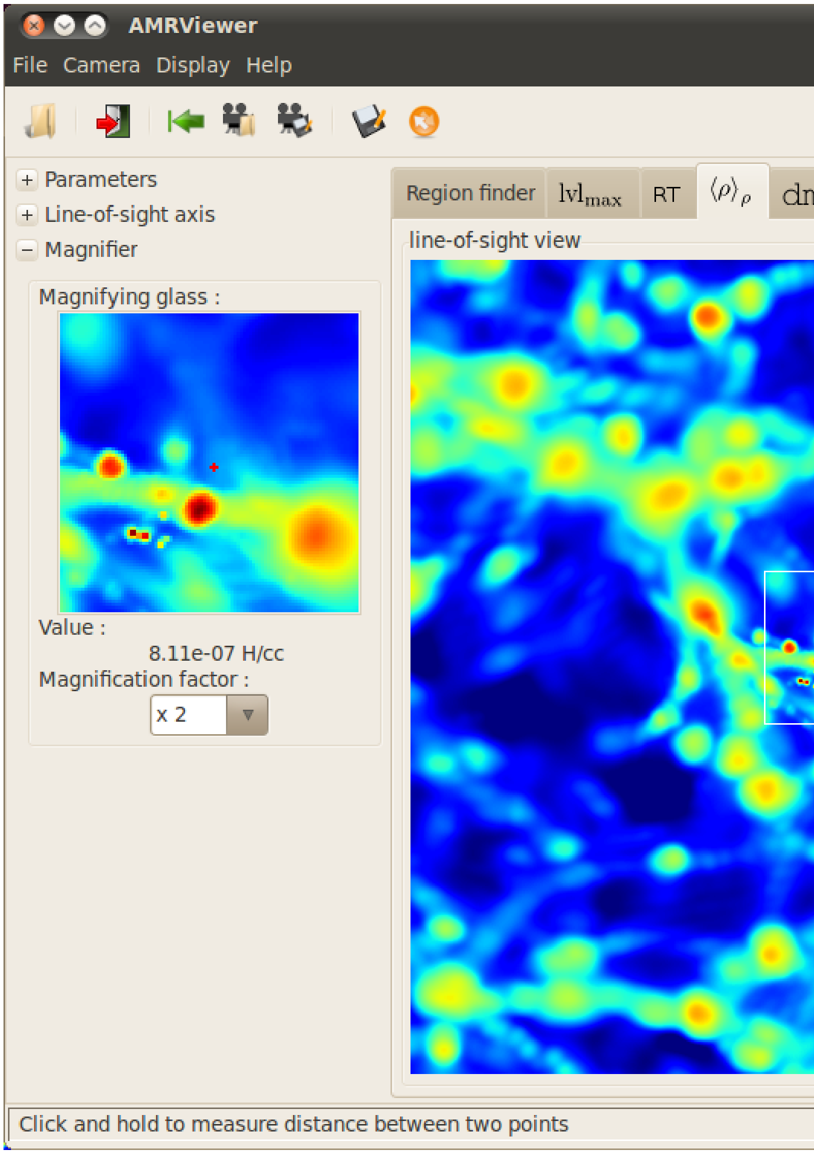


For example, gas surface density projected map (see *FFT-convolved maps*):

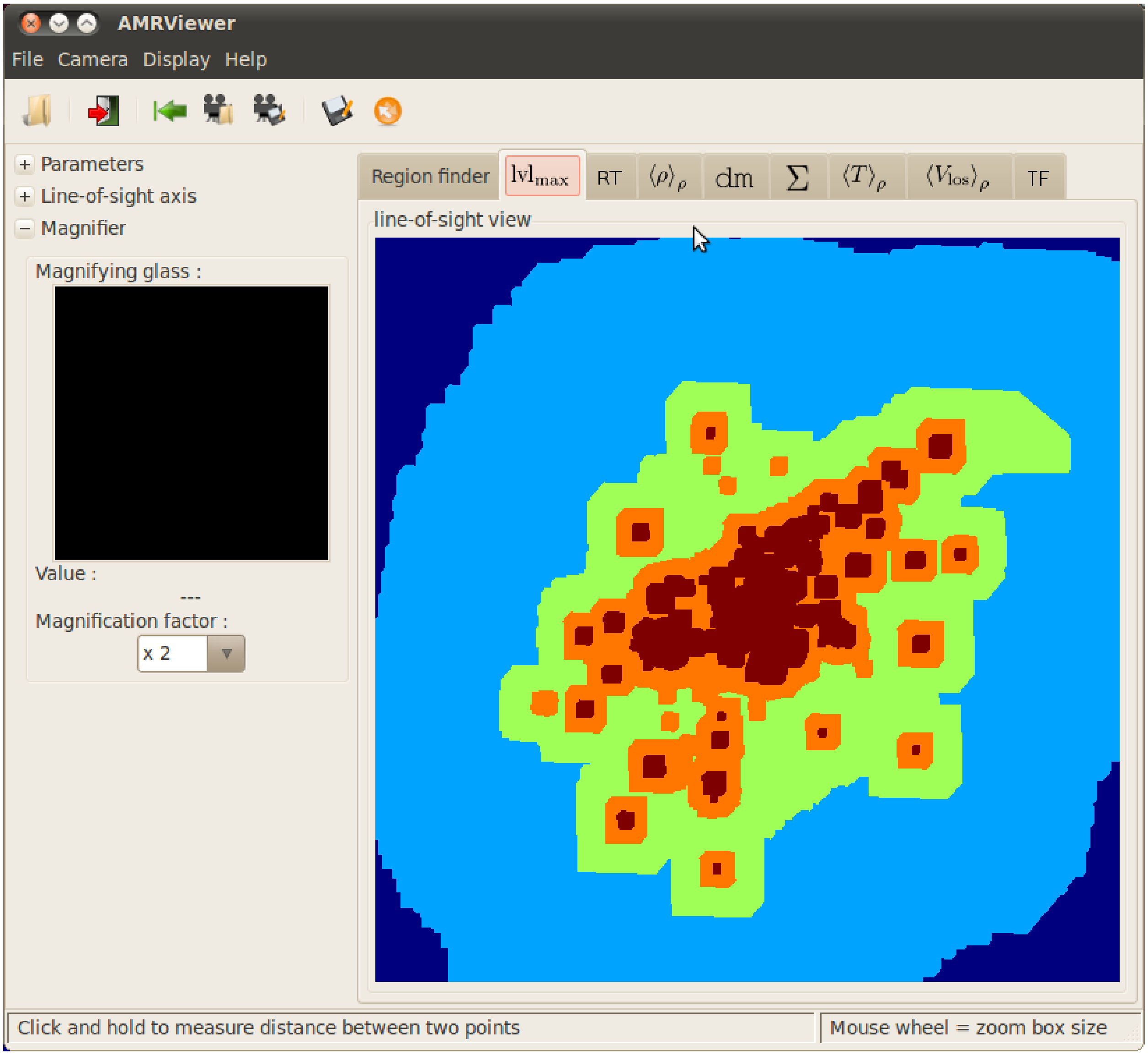


File Camera Display Help
Parameters
Line-of-sight axis
Magnifier
Magnifying glass :
Value :

Magnification factor :
x 8
Region finder
$\text{lvl}_{\max}$
RT
$\langle\rho\rangle_\rho$
dm
Σ
$\langle T\rangle_\rho$
$\langle V_{\text{los}}\rangle_\rho$
TF
line-of-sight view
Click and hold to measure distance between two points
Value : ---



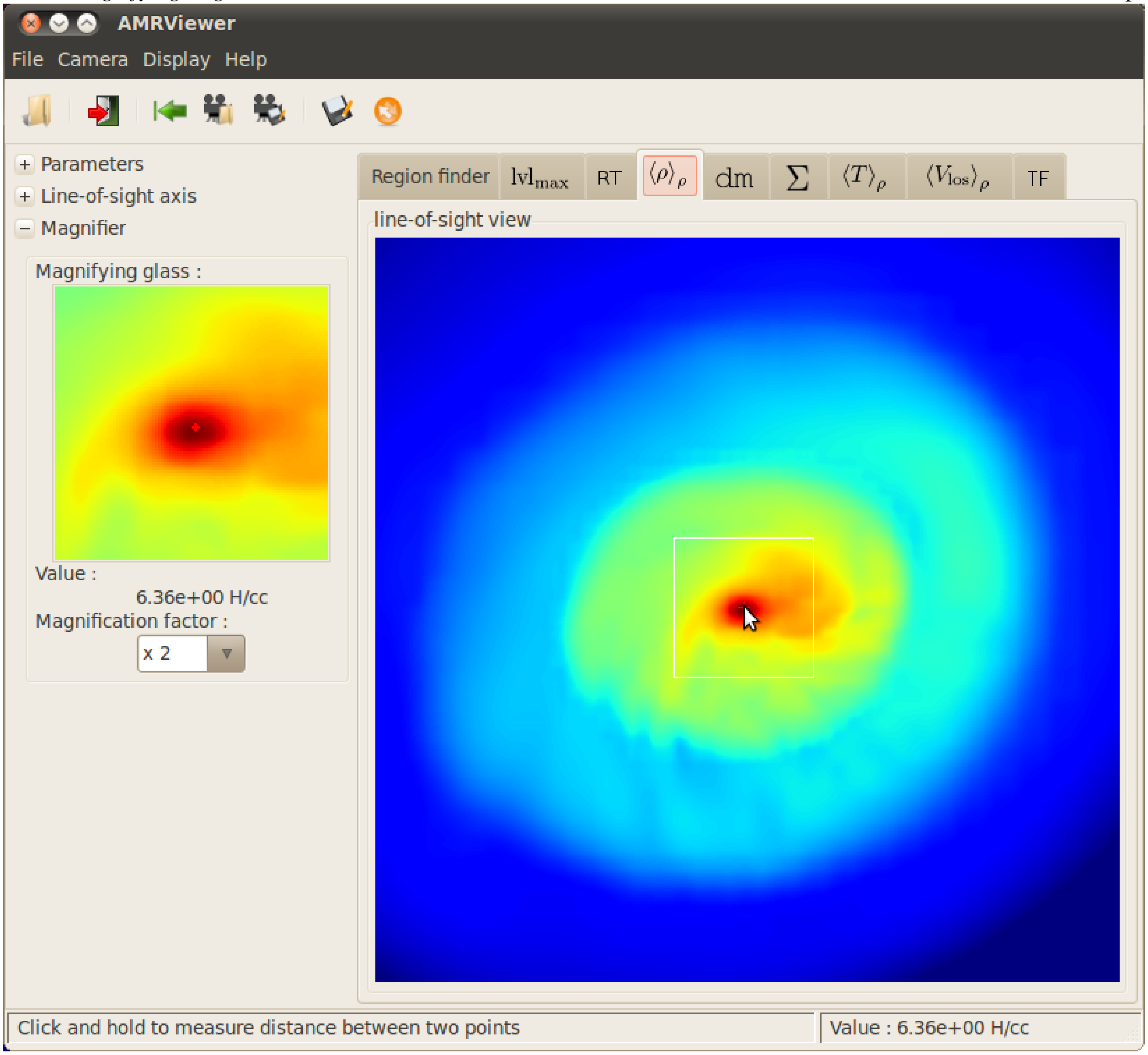
Mass weighted gas density map (see *FFT-convolved maps*):
Max. AMR level of refinement along the line-of-sight map (see *Ray-traced maps*):


AMRViewer
File Camera Display Help
Parameters
Line-of-sight axis
Magnifier
Magnifying glass :
Value :

Magnification factor :
x 2
Region finder
$\mathrm{lvl}_{\mathrm{max}}$
RT
$\langle\rho\rangle_\rho$
dm
Σ
$\langle T\rangle_\rho$
$\langle V_{\mathrm{los}}\rangle_\rho$
TF
line-of-sight view
Click and hold to measure distance between two points
Mouse wheel = zoom box size

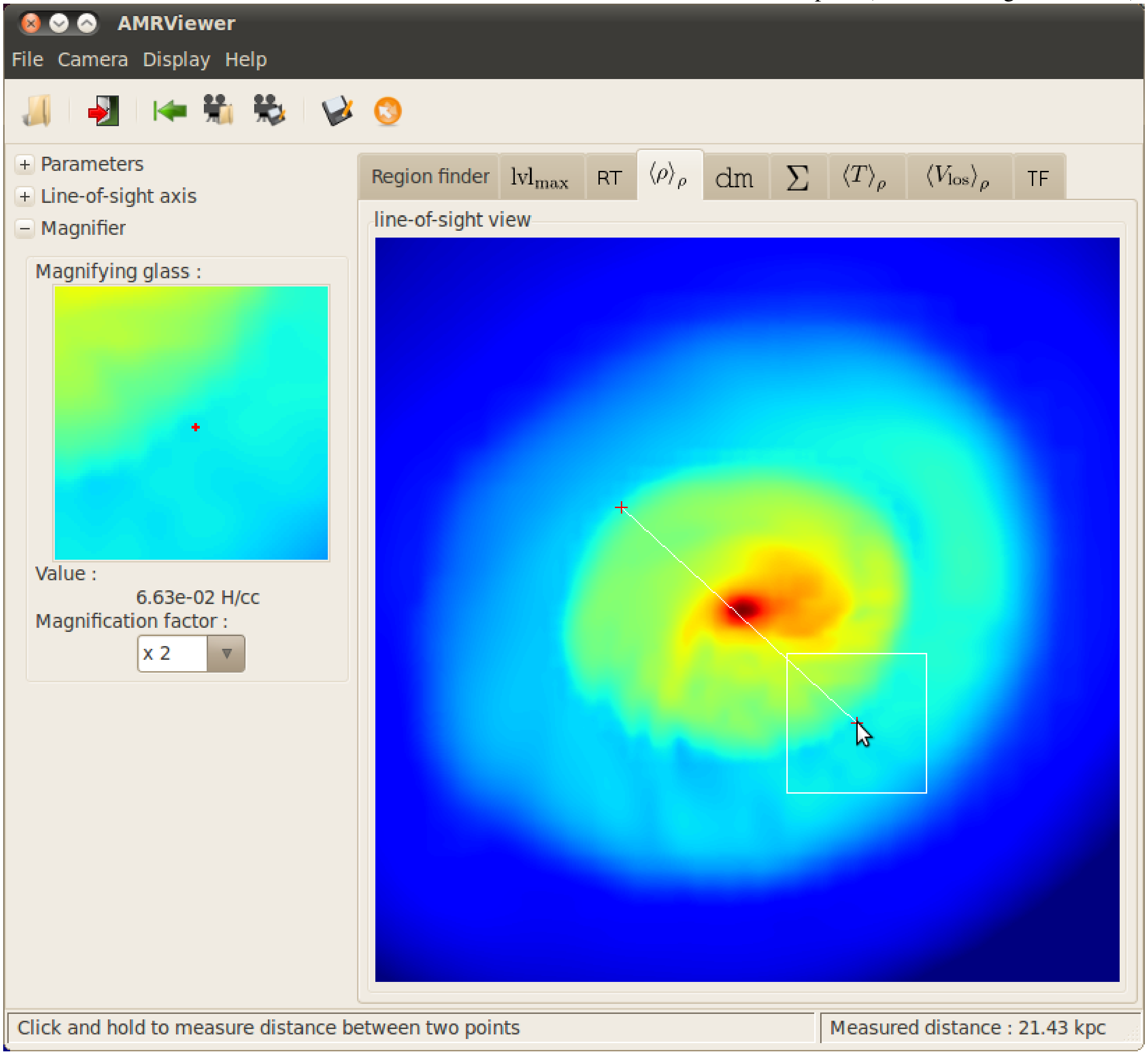
Magnifier

The *magnifying glass* tool can then be used to see the exact value on the map:



Rule

The *rule* tool can be used to measure distances on the maps (click-and-drag behavior):



CHAPTER

TWO

SOURCE DOCUMENTATION

2.1 Data structures and containers

2.1.1 `pymses.core.sources` — PyMSES generic data source module

class `Source`()

Bases: `object`

Base class for all data source objects

`flatten`()

Read each data file and concatenate resulting dsets. Try to use multiprocessing if possible.

Returns **fdset** : flattened dataset

`iter_dsets`()

Datasets iterator method. Yield datasets from the datasource

`set_read_lmax`(*max_read_level*)

Sets the maximum AMR grid level to read in the datasource

Parameters **max_read_level** : `int`

max. AMR level to read

class `Filter`(*source*)

Bases: `pymses.core.sources.Source`

Data source filter generic class.

`filtered_dset`(*dset*)

Abstract *filtered_dset()* method

`get_domain_dset`(*idomain, fields_to_read=None*)

Get the filtered result of *self.source.get_domain_dset(idomain)*

Parameters **idomain** : `int`

number of the domain from which the data is required

Returns **dset** : `Dataset`

the filtered dataset corresponding to the given *idomain*

`get_source_type`()

Returns **type** : `int`

the result of the *get_source_type()* method of the *source* param.

set_read_lmax (*max_read_level*)
Source inherited behavior + apply the set_read_lmax() method to the *source* param.

Parameters **max_read_level** : `int`

max. AMR level to read

class **SubsetFilter** (*data_sublist, source*)
Bases: `pymses.core.sources.Filter`

SubsetFilter class. Selects a subset of datasets to read from the datasource

Parameters **data_sublist** : `list` of `int`

list of the selected dataset index to read from the datasource

2.1.2 `pymses.core.datasets` — PyMSES generic dataset module

class **Dataset** ()
Bases: `pymses.core.sources.Source`

Base class for all dataset objects

add_scalars (*name, data*)
Scalar field addition method

Parameters **name** : `string`

human-readable name of the scalar field to add

data : `array`

raw data array of the new scalar field

add_vectors (*name, data*)
Vector field addition method

Parameters **name** : `string`

human-readable name of the vector field to add

data : `array`

raw data array of the new vector field

fields
Dictionary of the fields in the dataset

class **from_hdf5** (*h5file, where='/', close_at_end=False*)

iter_dsets ()
Returns an iterator over itself

write_hdf5 (*h5file, where='/', close_at_end=False*)

class **PointDataset** (*points*)
Bases: `pymses.core.datasets.Dataset`

Point-based dataset base class

class **concatenate** (*dsets, reorder_indices=None*)
Datasets concatenation class method. Return a new dataset

Parameters **dsets** : `list` of `PointDataset`

list of all datasets to concatenate

reorder_indices : `array` of `int` (default to None)

particles reordering indices

Returns dset : the new created concatenated `PointDataset`

`filtered_by_mask`(*mask_array*)
Datasets filter method. Return a new dataset

Parameters mask_array : `numpy.array` of `numpy.bool`

filter mask

Returns dset : the new created filtered `PointDataset`

class **`from_hdf5`**(*h5file, where='/'*)

`reorder_points`(*reorder_indices*)
Datasets reorder method. Return a new dataset

Parameters reorder_indices : `array` of `int`

points order indices

Returns dset : the new created reordered `PointDataset`

`transform`(*xform*)
Transform the dataset according to the given *xform* `Transformation`

Parameters xform : `Transformation`

`write_hdf5`(*h5file, where='/'*)

class `IsotropicExtPointDataset`(*points, sizes=None*)
Bases: `pymses.core.datasets.PointDataset`

Extended point dataset class

`get_sizes`()

Returns sizes : `array`

point sizes array

2.1.3 Dataset transformations

`pymses.core.transformations` Geometrical transformations module

class `Transformation`()
Bases: `object`

Base class for all geometric transformations acting on Numpy arrays

`inverse`()
Returns the inverse transformation

`transform_points`(*coords*)
Abstract method. Returns transformed coordinates.

Parameters:

coords – a Numpy array with data points along axis 0 and coordinates along axis 1+

transform_vectors (*vectors, coords*)
Abstract method. Returns transformed vector components for vectors attached to the provided coordinates.

Parameters:

vectors – a Numpy array of shape (ndata, ndim) containing the vector components

coords – a Numpy array of shape (ndata, ndim) containing the point coordinates

class **AffineTransformation** (*lin_xform, shift*)
Bases: `pymses.core.transformations.Transformation`

An affine transformation (of the type x -> L(x) + shift)

inverse ()
Inverse of an affine transformation

transform_points (*coords*)
Apply the affine transformation to coordinates

transform_vectors (*vectors, coords*)
Apply the affine transformation to vectors

class **LinearTransformation** (*matrix*)
Bases: `pymses.core.transformations.Transformation`

A generic (matrix-based) linear transformation

inverse ()
Inverse of the linear transformation

transform_points (*coords*)
Applies a linear transformation to coordinates

transform_vectors (*vectors, coords*)
Applies a linear transformation to vectors

class **ChainTransformation** (*xform_seq*)
Bases: `pymses.core.transformations.Transformation`

Defines the composition of a list of transformations

inverse ()
Inverse of a chained transformation

transform_points (*coords*)
Applies a chained transformation to coordinates

transform_vectors (*vectors, coords*)
Applies a chained transformation to vectors

identity (*n*)

Returns the identity as a LinearTransformation object :

translation (*vect*)

Returns an AffineTransformation object corresponding to a translation :

of the specified vector :

rot3d_axvector_matrix (*axis_vect, angle*)
Returns the rotation matrix of the rotation with the specified axis vector and angle

rot3d_axvector (*axis_vect, angle, rot_center=None*)
Returns the Transformation corresponding to the rotation specified by its axis vector, angle, and rotation center.

If rot_center is not specified, it is assumed to be [0, 0, 0].

rot3d_euler (*axis_sequence, angles, rot_center=None*)
Returns the Transformation corresponding to the rotation specified by its Euler angles and the corresponding axis sequence convention.

The rotation is performed by successively rotating the object around its current local axis axis_sequence[i] with an angle angle[i], for i = 0, 1, 2.

See http://en.wikipedia.org/wiki/Euler_angles for details.

rot3d_align_vectors (*source_vect, dest_vect, dest_vect_angle=0.0, rot_center=None*)
Gives a `Transformation` which brings a given *source_vect* in alignment with a given *dest_vect*.

Optionally, a second rotation around *dest_vect* can be specified by the parameter *dest_vect_angle*.

Parameters **source_vect** : `array`

source vector coordinates array

dest_vect : `array`

destination vector coordinates array

dest_vect_angle : `float` (default 0.0)

optional final rotation angle around the *dest_vect* vector

Returns **rot** : `Transformation`

rotation bringing *source_vect* in alignment with *dest_vect*. This is done by rotating around the normal to the (*source_vect*, *dest_vect*) plane.

Examples

```
>>> R = rot3d_align_vectors(array([0.,0.,1.]), array([0.5,0.5,0.5]))
```

scale (*n, scale_factor, scale_center=None*)

2.2 Sources module

2.2.1 `pymses.sources` — Source file formats package

2.2.2 `pymses.sources.ramses.output` — RAMSES output package

2.2.3 `pymses.sources.ramses.sources` — RAMSES data sources module

class **RamsesGenericSource** (*reader_list, dom_decomp=None, cpu_list=None*)
Bases: `pymses.core.sources.Source`

RAMSES generic data source

get_domain_dset (*icpu, fields_to_read=None*)
Data source reading method

Parameters **icpu** : `int`

CPU file number to read

fields_to_read : `list` of `strings`

list of AMR data fields that needed to be read

Returns **dset** : `Dataset`

the dataset containing the data from the given cpu number file

class **`RamsesAmrSource`**(*reader_list, dom_decomp=None, cpu_list=None*)

Bases: `pymses.sources.ramses.sources.RamsesGenericSource`

RAMSES AMR data source class

`get_source_type`()

Returns **Source.AMR_SOURCE** :

class **`RamsesParticleSource`**(*reader_list, dom_decomp=None, cpu_list=None*)

Bases: `pymses.sources.ramses.sources.RamsesGenericSource`

RAMSES particle data source class

`get_source_type`()

Returns **Source.PARTICLE_SOURCE** :

2.2.4 `pymses.sources.hop` — HOP data sources package

2.3 Filters module

2.3.1 `pymses.filters` — Data sources filters package

class **`RegionFilter`**(*region, source*)

Bases: `pymses.core.sources.SubsetFilter`

Region Filter class. Filters the data contained in a given region of interest.

Parameters **region** : `Region`

region of interest

source : `Source`

data source

class **`PointFunctionFilter`**(*mask_func, source*)

Bases: `pymses.core.sources.Filter`

PointFunctionFilter class

Parameters **mask_func** : `function`

function evaluated to compute the data mask to apply

source : `Source`

data source

class **`PointIdFilter`**(*ids_to_keep, source*)

Bases: `pymses.core.sources.Filter`

PointIdFilter class

Parameters **ids_to_keep** : `list` of `int`

list of the particle ids to pick up

source : `Source`

data source

class **`PointRandomDecimatedFilter`**(*fraction, source*)

Bases: `pymses.core.sources.Filter`

PointRandomDecimatedFilter class

Parameters **fraction** : `float`

fraction of the data to keep

source : `Source`

data source

class **`CellsToPoints`**(*source, include_split_cells=False, include_boundary_cells=False, include_nonactive_cells=False*)

Bases: `pymses.core.sources.Filter`

AMR grid to cell list conversion filter

`filtered_dset`(*dset*)

Filters an AMR dataset and converts it into a point-based dataset

class **`SplitCells`**(*source, info, particle_mass*)

Bases: `pymses.core.sources.Filter`

Create point-based data from cell-based data by splitting the cell-mass into uniformly-distributed particles

`filtered_dset`(*dset*)

Split cell filtering method

Parameters **dset** : Dataset

Returns **fdset** : Dataset

filtered dataset

class **`ExtendedPointFilter`**(*source*)

Bases: `pymses.core.sources.Filter`

ExtendedParticleFilter class

`filtered_dset`(*dset*)

Filter a PointDataset and converts it into an IsotropicExtPointDataset with a given size for each point

2.4 Analysis module

2.4.1 Visualization module

pymses.analysis.visualization — Visualization module

class Camera (*center=None, line_of_sight_axis='z', up_vector=None, region_size=, [1.0, 1.0], distance=0.5, far_cut_depth=0.5, map_max_size=1024, log_sensitive=True, perspectiveAngle=0*)

Camera class for 2D projected maps computing

Parameters center : region of interest center coordinates (default value is [0.5, 0.5, 0.5],

the simulation domain center).

line_of_sight_axis : axis of the line of sight (z axis is the default_value)

[ux, uy, uz] array or simulation domain specific axis key "x", "y" or "z"

up_vector : direction of the y axis of the camera (up). If None, the up vector is set

to the z axis (or y axis if the line-of-sight is set to the z axis). If given a not zero-normed [ux, uy, uz] array is expected (or a simulation domain specific axis key "x", "y" or "z").

region_size : projected size of the region of interest (default (1.0, 1.0))

distance : distance of the camera from the center of interest (along the line-of-sight

axis, default 0.5).

far_cut_depth : distance of the background (far) cut plane from the center of interest

(default 0.5). The region of interest is within the camera position and the far cut plane.

map_max_size : maximal resolution of the camera (default 1024 pixels)

log_sensitive : whether the camera pixels are log sensitive or not (default True).

perspectiveAngle : (default 0 = isometric view) angle value in degree which can be used to

transfom the standard pymses isometric view into a perspective view.

Examples

```
>>> cam  = Camera(center=[0.5, 0.5, 0.5], line_of_sight_axis='z', region_size=[1., 1.], \
... distance=0.5, far_cut_depth=0.5, up_vector='y', map_max_size=512, log_sensitive=True)
```

deproject_points (*uvw_points, origins=None*)

Return xyz_coords deprojected coordinates of a set of points from given [u,v,w] coordinates : - (u=0,v=0, w=0) is the center of the camera. - v is the coordinate along the vaxis - w is the depth coordinate of the points along the line-of-sight of the camera. if origins is True, perform a vectorial transformation of the vectors described by uvw_points anchored at positions 'origins'

class **from_HDF5** (*h5f*)

Returns a camera from a HDF5 file.

get_3D_right_eye_cam (*z_fixed_point=0.0, ang_deg=1.0*)

Get the 3D right eye camera for stereoscopic view, which is made from the original camera with just one rotation around the up vector (angle ang_deg)

Parameters ang_deg : float

angle between self and the returned camera (in degrees, default 1.0)

z_fixed_point : float

position (along w axis) of the fixed point in the right eye rotation

Returns **right_eye_cam** : the right eye Camera object for 3D image processing

get_bounding_box()
Returns the bounding box of the region of interest in the simulation domain corresponding of the area covered by the camera

get_camera_axis()
Returns the camera u, v and z axis coordinates

get_map_box(*take_into_account_perspective=False*)
Returns the (0.,0.,0.) centered bounding box of the area covered by the camera

get_map_mask()
Returns the mask map of the camera. each pixel has an alpha : * 1, if the ray of the pixel intersects the simulation domain * 0, if not

get_map_size()

Returns **(nx, ny)** : (int, int) tuple

the size (nx,ny) of the image taken by the camera (pixels)

get_pixel_surface()
Returns the surface of any pixel of the camera

get_pixels_coordinates_edges(*take_into_account_perspective=False*)
Returns the edges value of the camera pixels x/y coordinates The pixel coordinates of the center of the camera is (0,0)

get_rays()
Returns ray_vectors, ray_origins and ray_lengths arrays for ray tracing ray definition

get_region_size_level()
Returns the level of the AMR grid for which the cell size ~ the region size

get_required_resolution()

Returns **lev** : int

the level of refinement up to which one needs to read the data to compute the projection of the region of interest with the specified resolution.

get_slice_points(*z=0.0*)
Returns the (x, y, z) coordinates of the points contained in a slice plane perpendicular to the line-of-sight axis at a given position z.

z — slice plane position along line-of-sight (default 0.0 => center of the region)

printout()
Print camera parameters in the console

project_points(*points, take_into_account_perspective=False*)
Return a (coords_uv, depth) tuple where ‘coord_uv’ is the projected coordinates of a set of points on the camera plane. (u=0,v=0) is the center of the camera plane. ‘depth’ is the depth coordinate of the points along the line-of-sight of the camera.

rotate_around_up_vector(*ang_deg=1.0*)

save_HDF5 (*h5f*)
Saves the camera parameters into a HDF5 file

set_perspectiveAngle (*perspectiveAngle=0*)
Set the perspectiveAngle (default 0 = isometric view) angle value in degree which can be used to transfom the standard pymses isometric view into a perspective view.

similar (*cam*)
Draftly test if a camera is roughly equal to an other one, just to know in the amrviewer GUI if we need to reload data or not.

viewing_angle_rotation ()
Returns the rotation corresponding to the viewing angle of the camera

viewing_angle_transformation ()
Returns the transformation corresponding to the viewing angle of the camera

save_map_HDF5 (*map, camera, unit=None, scale_unit=None, hdf5_path='./', map_name='my_map'*)
Saves the map and the camera into a HDF5 file

save_HDF5_to_plot (*h5fname, img_path=None, axis_unit=None, map_unit=None, cmap='jet', cmap_range=None, fraction=None, save_into_png=True, discrete=False, verbose=True*)
Function that plots the map with axis + colorbar from an HDF5 file

Parameters **h5fname** : the name of the HDF5 file containing the map

img_path : the path in wich the plot img file is to be saved

axis_unit : a (length_unit_label, axis_scale_factor) tuple containing :

- the label of the u/v axes unit
- the scaling factor of the u/v axes unit, or a Unit instance

map_unit : a (map_unit_label, map_scale_factor) tuple containing :

- the label of the map unit
- the scaling factor of the map unit, or a Unit instance

cmap : a Colormap object or any default python colormap string

cmap_range : a [vmin, vmax] array for map values clipping (linear scale)

fraction : fraction of the total map values below the min. map range (in percent)

save_into_png: whether the plot is saved into an png file or not (default True) :

discrete : wheter the map values are discrete integer values (default False). for colormap

save_HDF5_to_img (*h5fname, img_path=None, cmap='jet', cmap_range=None, fraction=None, discrete=False, ramses_output=None, ran=None, adaptive_gaussian_blur=False, RT_instensity_dimming=False, verbose=True*)
Function that plots, from an HDF5 file, the map into a Image and saves it into a PNG file

Parameters **h5fname** : `string`

the name of the HDF5 file containing the map

img_path : `string`

the path in wich the img file is to be saved. the image is returned (and not saved) if left to None (default value)

cmap : `string` or `Colormap` object

colormap to use

cmap_range : [*vmin*, *vmax*] `array`

value range for map values clipping (linear scale)

fraction : `float`

fraction of the total map values below the min. map range (in percent)

discrete : `boolean`

whether the colormap must be integer values only or not.

ramses_output : `boolean`

specify ramses output for additional csv star file (look for a "sink_%iout.csv" file with 3D coordinates in output directory) to add stars on the image

ran : `boolean`

specify map range value to fix colormap during a movie sequence

adaptive_gaussian_blur : `boolean`

experimental : compute local image resolution and apply an adaptive gaussian blur to the image where it is needed (usefull to avoid AMR big pixels with ray tracing technique)

RT_instensity_dimming : `boolean`

experimental : if ramses_output is specified and if a star file is found, this option add a ray tracing pass on data to compute star intensity dimming

verbose : `boolean`

if True, print colormap range in console.

Returns img : PIL `Image`

if *img_path* is left to None

ran = (vmin, vmax) :

if *img_path* is specified

`save_HDF5_seq_to_img`(*h5f_iter, *args, **kwargs*)

fraction [fraction (percent) of the total value of the map above the returned vmin value] (default 1 %)

`get_map_range`(*map, log_sensitive, cmap_range, fraction*)

Map range computation function. Computes the linear/log (according to the map values scaling) scale map range values of a given map :

- if a user-defined cmap_range is given, then it is used to compute the map range values
- if not, the map range values is computed from a fraction (percent) of the total value of the map parameter. the min. map range value is defined as the value below which there is a fraction of the map (default 1 %)

Parameters map : 2D map from wich the map range values are computed

log_sensitive : whether the map values are log-scaled or not (True or False)

cmap_range : user-defined map range values (linear scale)

fraction : fraction of the total map values below the min. map range (in percent)

Returns map_range : [`float`, `float`]

the map range values [min, max]

class Operator(*scalar_func_dict, is_max_alos=False, use_cell_dx=False*)
Base Operator generic class

class ScalarOperator(*scalar_func*)
ScalarOperator class

Parameters scalar_func : function

single *dset* argument function returning the scalar data `array` from this *dset* Dataset.

Examples

```
>>> # Density field scalar operator
>>> op = ScalarOperator(lambda dset: dset["rho"])
```

class FractionOperator(*num_func, denom_func*)
FractionOperator class

Parameters up_func : function

numerator function like *scalar_func* (see `ScalarOperator`)

down_func : function

denominator function like *scalar_func* (see `ScalarOperator`)

Examples

```
>>> # Mass-weighted density scalar operator
>>> num = lambda dset: dset["rho"]    * dset.get_sizes()**3
>>> den = lambda dset: dset["rho"]**2 * dset.get_sizes()**3
>>> op = FractionOperator(num, den)
```

$$I = \frac{\int\limits_V \rho \times \rho \mathrm{d}V}{\int\limits_V \rho \mathrm{d}V}$$

class MaxLevelOperator()
Max. AMR level of refinement operator class

SliceMap(*source, camera, op, z=0.0*)
Compute a map made of sampling points

Parameters source : Source

data source

camera : Camera

camera handling the view parameters

op : Operator

data sampling operator

z : float

position of the slice plane along the line-of-sight axis of the camera

Returns **map** : `array`

sliced map

`pymses.analysis.visualization.fft_projection` — FFT-convolved map module

class **`MapFFTProcessor`**(*source*, *info*, *ker_conv=None*, *pre_flatten=False*, *remember_data=False*, *cache_dset={}*)

MapFFTProcessor class Parameters ——— source : `Source`

data source

info [`dict`] RamsesOutput info dict.

ker_conv [:class:'~pymses.analysis.visualization.ConvolKernel'] Convolution kernel used for the map processing

pre_flatten [`boolean`] Option to flatten the data source (using multiprocessing if possible) before computing the map The filtered data are then saved into the "self.filtered_source" source attribute.

remember_data [`boolean`] Option which uses a "self.cache_dset" dictionarry attribute as a cache to avoid reloading dset from disk This uses a lot of memory as it currently remembers a active_mask by levelmax filtering for each (dataset,levelmax) couple

cache_dset : Cache dsets dictionnary reference, used only if remember_data == True, to share the same cache between various MapFFTProcessor

`prepare_data`(*camera*, *field_list=None*)

prepare data method : it computes the "self.filtered_source" source attribute for the process(...) method. Load data from disk or from cache if remember_data option is activated. The data are then filtered with the CameraFilter class This uses multiprocessing if possible. Parameters ——— camera : `Camera`

camera containing all the view params, the filtering is done according to those param

field_list `list of strings` list of AMR data fields that needed to be read

`process`(*op*, *camera*, *surf_qty=False*, *multiprocessing=True*, *FFTkernelSizeFactor=1*, *data_already_prepared=False*)

Map processing method

Parameters **op** : `Operator`

physical scalar quantity data operator

camera : `Camera`

camera containing all the view params

surf_qty : `boolean`

whether the processed map is a surface physical quantity. If True, the map is divided by the surface of a camera pixel.

FFTkernelSizeFactor : `int or float`

allow to change the convolution kernel size by a multiply factor to adjust points size

data_already_prepared : `boolean`

set this option to true if you have already called the prepare_data() method : this method will then simply used it's "self.filtered_source" source attribute without computing it again

Returns map : `array`

FFT-convolved processed map

class ConvolKernel(*ker_func, size_func=None, max_size=None*)
Convolution kernel class

convol_fft(*map_dict, cam_dict*)
FFT convolution method designed to convolute a dict. of maps into a single map

map_dict : map dict. where the dict. keys are the size of the convolution kernel. cam_dict : ExtendedCamera dict. corrsponding to the different maps of the map dict.

get_size(*dset*)

class GaussSplatterKernel(*size_func=None, max_size=None*)
2D Gaussian splatter convolution kernel

class Gauss1DSplatterKernel(*axis, size_func=None, max_size=None*)
2D Gaussian splatter convolution kernel

class PyramidSplatterKernel(*size_func=None, max_size=None*)
2D pyramidal splatter convolution kernel

class Cos2SplatterKernel(*size_func=None, max_size=None*)
2D Squared cosine splatter convolution kernel

`pymses.analysis.visualization.raytracing` — Ray-tracing module

class RayTracer(*ramses_output, field_list*)
RayTracer class

Parameters ramses_output : `RamsesOutput`

ramses output from which data will be read to compute the map

field_list : `list` of `string`

list of all the required AMR fields to read (see `amr_source()`)

process(*op, camera, surf_qty=False, verbose=False, multiprocessing=True, source=None, use_hilbert_domain_decomp=True*)
Map processing method : ray-tracing through data cube

Parameters op : `Operator`

physical scalar quantity data operator

camera : `Camera`

camera containing all the view params

surf_qty : `boolean`

whether the processed map is a surface physical quantity. If True, the map is divided by the surface of a camera pixel.

multiprocessing : `boolean`

try to use multiprocessing (process cpu data file in parallel) to speed up the code (need more RAM memory, python 2.6 or higher needed)

class OctreeRayTracer(**args*)

RayTracerDir class

Parameters **ramses_output** : `RamsesOutput`

ramses output from which data will be read to compute the map

field_list : `list` of `string`

list of all the required AMR fields to read (see `amr_source()`)

process(*op, camera, surf_qty=False, return_image=True*)

Map processing method : directional ray-tracing through AMR tree

Parameters camera : `Camera`

camera containing all the view params

class RayTracerMPI(*ramses_output, field_list, remember_data=False*)

RayTracer class

Parameters **ramses_output** : `RamsesOutput`

ramses output from which data will be read to compute the map

field_list : `list` of `string`

list of all the required AMR fields to read (see `amr_source()`)

remember_data : `boolean` (default False)

option to remember dataset loaded. Avoid reading the data again for each frame of a rotation movie. WARNING : The saved cache data don't update yet it's levelmax and cpu list, so use carefully this if zooming / moving too much inside the simulation box.

process(*op, camera, surf_qty=False, use_balanced_cpu_list=False, testing_ray_number_max=100, verbose=False*)

Map processing method using MPI: ray-tracing through data cube

Parameters **op** : `Operator`

physical scalar quantity data operator

camera : `Camera`

camera containing all the view params

surf_qty : `boolean` (default False)

whether the processed map is a surface physical quantity. If True, the map is divided by the surface of a camera pixel.

use_balanced_cpu_list : `boolean` (default False)

option to optimize the load balancing between MPI process, add an intial dsets testing before processing every rays

testing_ray_number_max : `boolean` (default 100)

number of testing ray for the balanced cpu list option

verbose : `boolean` (default False)

more printout (may flood the console out for big simulation with many cpu)

2.4.2 `pymses.analysis` — Analysis and post-processing package

sample_points (*amr_source, points, add_cell_center=False, add_level=False, max_search_level=None*)
Create point-based data from AMR-based data by point sampling. Samples all available fields of the *amr_source* at the coordinates of the *points*.

Parameters **amr_source** : `RamsesAmrSource`

data description

points : (*npoints*, *ndim*) `array`

sampling points coordinates

add_level : `boolean` (default False)

whether we need the AMR level information

Returns **dset** : `PointDataset`

Contains all these sampled values.

bin_cylindrical (*source, center, axis_vect, profile_func, bin_bounds, divide_by_counts=False*)
Cylindrical binning function for profile computing

Parameters **center** : `array`

center point for the profile

axis_vect : `array`

the cylinder axis coordinates array.

profile_func : `function`

a function taking a `PointDataset` object as an input and producing a numpy array of weights.

bin_bounds : `array`

a numpy array delimiting the profile bins (see numpy.histogram documentation)

divide_by_counts : `boolean` (default False)

if True, the returned profile is the array containing the sum of weights in each bin. if False, the mean weight per bin array is returned.

Returns **profile** : `array`

computed cylindrical profile

bin_spherical (*source, center, profile_func, bin_bounds, divide_by_counts=False*)
Spherical binning function for profile computing

Parameters **center** : `array`

center point for the profile

profile_func : `function`

a function taking a `PointDataset` object as an input and producing a numpy array of weights.

bin_bounds : `array`

a numpy array delimiting the profile bins (see numpy.histogram documentation)

divide_by_counts : `boolean` (default False) if True, the returned profile is the `array` containing the sum of weights in each bin. if False, the mean weight per bin `array` is returned.

Returns profile : `array`

computed spherical profile

`average_point` (*source, weight_func=None, returned=False*)
Return the average point coordinates of a PointDataSource assuming an optional weight function

Parameters source : *PointDataSource*

the *PointDataSource* from which the average point is computed

weight_func : `function`, optional

function used to give a weight for each point of the PointDataSource. Takes a *Dataset* for single argument and returns the weight value for each point

returned : boolean, optional (default False)

if True, the sum of the weights is also returned

Returns av_pos : `array`

coordinates of the barycenter

sow : `float`

returned only if *returned* was True. Sum of the weights

`amr2cube` (*source, var, xmin, xmax, cubelevel*)
amr2cube tool.

2.5 Utilities package

2.5.1 Dimensional physical constants

`pymses.utils.constants` — physical units and constants module

class **`Unit`** (*dims, val*)
Bases: `object`

Dimensional physical unit class

Parameters dims : 5-`tuple` of `int`

dimension of the unit object expressed in the international system units (`m`, `kg`, `s`, `K`, `h`)

val : `float`

value of the unit object (in ISU)

Examples

```
>>> V_km_s = Unit((1,0,-1,0,0), 1000.0)
>>> print "1.0 km/s = %.1e m/h"%(V_km_s.express(m/hour))
1.0 km/s = 3.6e+06 m/h
```

express (*unit*)

Unit conversion method. Gives the conversion factor of this `Unit` object expressed into another (dimension-compatible) given *unit*.

Checks that :

- the *unit* param. is also a `Unit` instance
- the *unit* param. is dimension-compatible

Parameters **unit** : `Unit` object

unit in which the conversion is made

Returns **fact** : `float`

conversion factor of itself expressed in *unit*

Examples

Conversion of a kpc expressed in light-years :

```
>>> factor = kpc.express(ly)
>>> print "1 kpc = %f ly"%factor
1 kpc = 3261.563163 ly
```

Conversion of $1 M_{\odot}$ into kilometers :

```
>>> print Msun.express(km)
ValueError: Incompatible dimensions between (1.9889e+30 kg) and (1000.0 m)
```

list_all ()

Print all available constants list:

`none`, `m`, `cm`, `km`, `pc`, `au`, `kpc`, `Mpc`, `Gpc`, `kg`, `g`, `mH`, `Msun`, `s`, `hour`, `day`, `year`, `Myr`, `Gyr`, `dyne`, `K`, `J`, `W`, `G`, `kB`, `c`, `ly`, `H`, `rhoc`, `H_cc`, `h`, `sigmaSB`

2.5.2 Geometrical region module

`pymses.utils.regions` — Regions module

class **Region** ()

Generic region class

contains (*points*)

Parameters **points** : `float array of 3D points coordinates`

Returns **points** : `boolean array`

True when points coordinates are inside the region

random_points (*npoints, ensure_exact_count=True*)

Generates a set of randomly distrubuted points in the region

Parameters **npoints** : `int`

number of points to generate

ensure_exact_count : `boolean` (default True) whether the exact required number of random points are generated or not

Returns **points** : `array`

ramdom points array

class Sphere (*center, radius*)

Bases: `pymses.utils.regions.Region`

Spherical region class

Parameters **center** : 3-`tuple` of `float`

sphere center coordinates

radius : `float`

radius of the sphere

Examples

```
>>> sph = Sphere((0.5, 0.5, 0.5), 1.0)
```

contains (*points*)

TODO

get_bounding_box ()

TODO

get_volume ()

Returns **V** : `float`

volume of the sphere (radius r) given by $V = \frac{4}{3}\pi r^3$

class SphericalShell (*center, radius_in, radius_out*)

Bases: `pymses.utils.regions.Region`

Spherical shell class

Parameters **center** : 3-`tuple` of `float`

spherical shell center coordinates

radius_in : `float`

radius of the innerr sphere

radius_out : `float`

radius of the outer sphere

Examples

```
>>> sph_shell = SphericalShell((0.5, 0.5, 0.5), 0.5, 0.6)
```

contains (*points*)

TODO

get_bounding_box ()

TODO

get_volume()

Returns V : float

volume of the spherical shell ($r_{in} < r < r_{out}$) given by $V = \frac{4}{3}\pi(r_{out}^3 - r_{in}^3)$

class Box(*bounds*)

Bases: pymses.utils.regions.Region

Box region class

Parameters bounds : 2-tuple of list

box region boundary min and max positions as a (min, max) tuple of coordinate arrays

Examples

```
>>> min_coords = [0.1, 0.2, 0.25]
>>> max_coords = [0.9, 0.8, 0.75]
>>> b = Box((min_coords, max_coords))
```

get_bounding_box()

Returns (min_coords, max_coords) : 2-tuple of list

bounding box limit

get_volume()

Returns V : float

volume of the box given by $V = \prod\limits_{1\leq i\leq \mathrm{ndim}} (\mathrm{cmax}_i - \mathrm{cmin}_i)$

printout()

Print bounding box limit in console

class Cube(*center, width*)

Bases: pymses.utils.regions.Box

Cubic region class

Parameters center : tuple

cube center coordinates

width : float

size of the cube

Examples

```
>>> cu = Cube((0.5, 0.5, 0.5), 1.0)
```

get_volume()

Returns V : float

volume of the cube (size L) given by $V = L^{\mathrm{ndim}}$

class **`Cylinder`** (*center, axis_vector, radius, height*)

Bases: `pymses.utils.regions.Region`

Cylinder region class

Parameters **center** : 3-`tuple` of `float`

cylinder center coordinates

axis_vector : 3-`tuple` of `float`

cylinder axis vector coordinates

radius : `float`

cylinder radius

height : `float`

cylinder height

Examples

```
>>> center = (0.5, 0.5, 0.5)
>>> axis = (0.1, 0.9, -0.1)
>>> radius = 0.3
>>> h = 0.05
>>> cyl = Cylinder(center, axis, radius, h)
```

`contains` (*points*)

TODO

`get_bounding_box` ()

TODO

`get_volume` ()

Returns **V** : `float`

volume of the cylinder (radius r, height h) given by $V = \pi r^2 h$

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