# PyMSES Documentation

***Release 3.1.0***

**Thomas GUILLET, Damien CHAPON, Marc LABADENS**

November 16, 2012

# CONTENTS

This is the up-to-date (version 3.1.0) online PyMSES manual.

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

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 Downloads

- `downloads`

### 1.1.3 Documentation

- *Documentation (HTML)*

### 1.1.4 Contacts

**Authors** Thomas GUILLET, Damien CHAPON, Marc LABADENS

**Contact** marc.labadens@cea.fr

**Organization** Service d'astrophysique, CEA/Saclay

**Address** Gif-Sur-Yvette, F91190, France

**Date** November 15, 2012

### 1.1.5 Indices and tables

- *genindex*
- *modindex*
- *search*

## 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.output import *
>>> RamsesOutput.amr_field_descrs_by_file = {
... "hydro" : [ Scalar("rho", 0), Vector("vel", [1, 2, 3]), Scalar("P", 4) ],
... "grav"  : [ 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.output import *

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

```
>>> # Read additional tracers : metallicity, HCO abundancy
>>> RamsesOutput.amr_field_descrs_by_file = {
... "hydro" : [ Scalar("rho", 0), Vector("vel", [1, 2, 3]), Scalar("P", 4), Scalar("Z", 5), Scalar("H
... "grav"  : [ Vector("g", [0, 1, 2]) ]
... }
```

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

```
>>> from pymses.sources.ramses.output import *
>>> # 2D data format
>>> RamsesOutput.amr_field_descrs_by_file = {
... "hydro" : [ Scalar("rho", 0), Vector("vel", [1, 2, 3]), Scalar("P", 4), Scalar("Z", 5) ],
... "grav"  : [ 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:

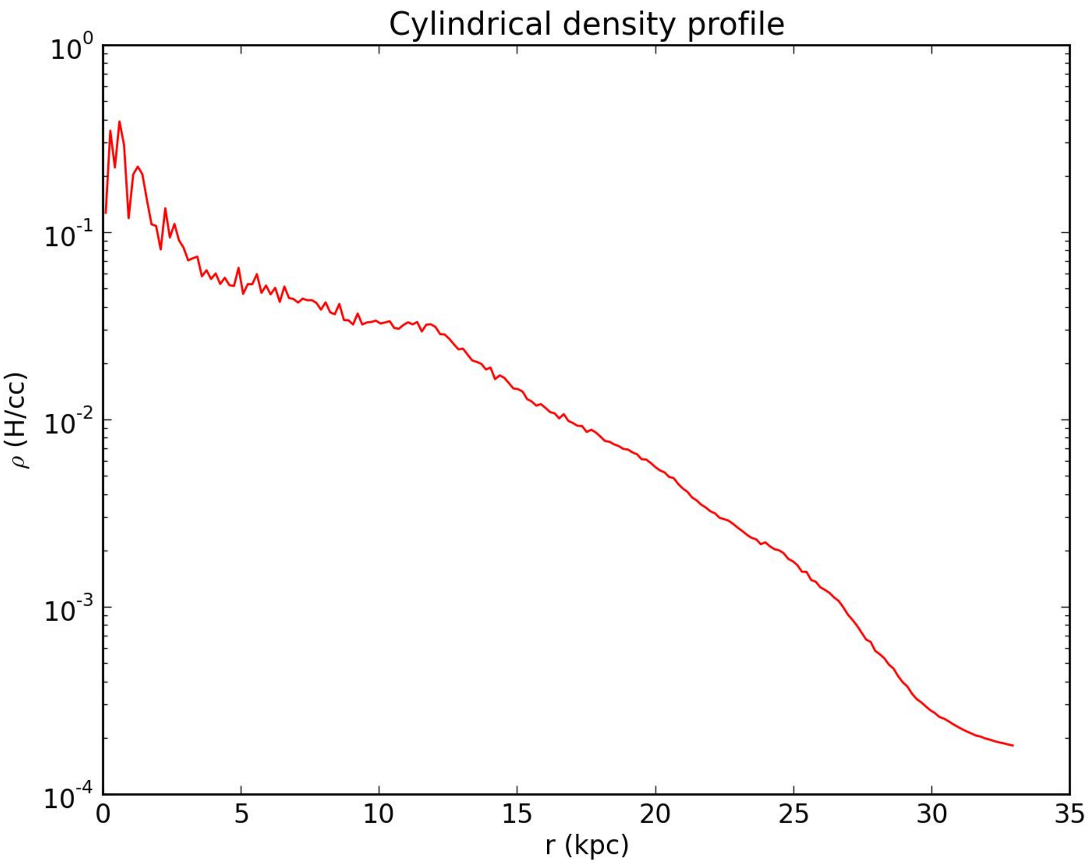
```
>>> import numpy
>>> rho_weight_func = lambda dset: dset["rho"]
>>> r_bins = numpy.linspace(0.0, gal_radius, 200)
```

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)
```

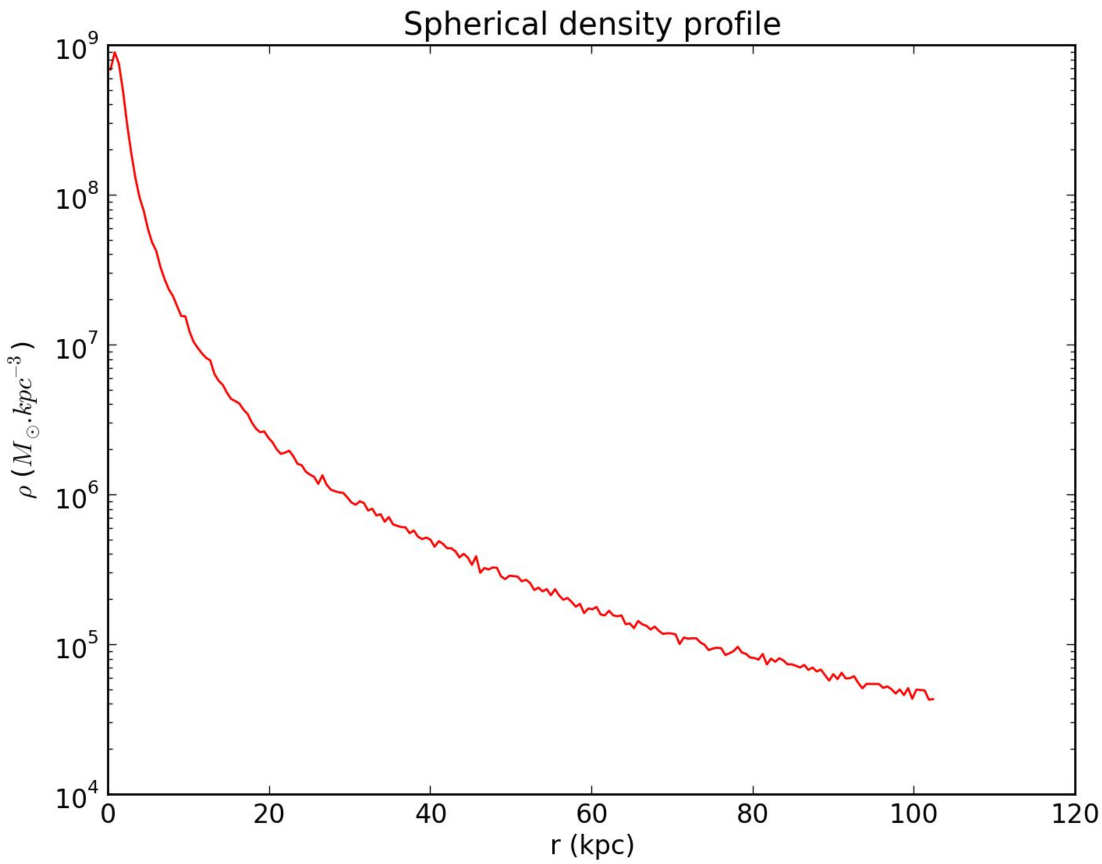
Now we compute the profile `bin_spherical()` function.

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 standard isometric (parallel rays) 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

- 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:

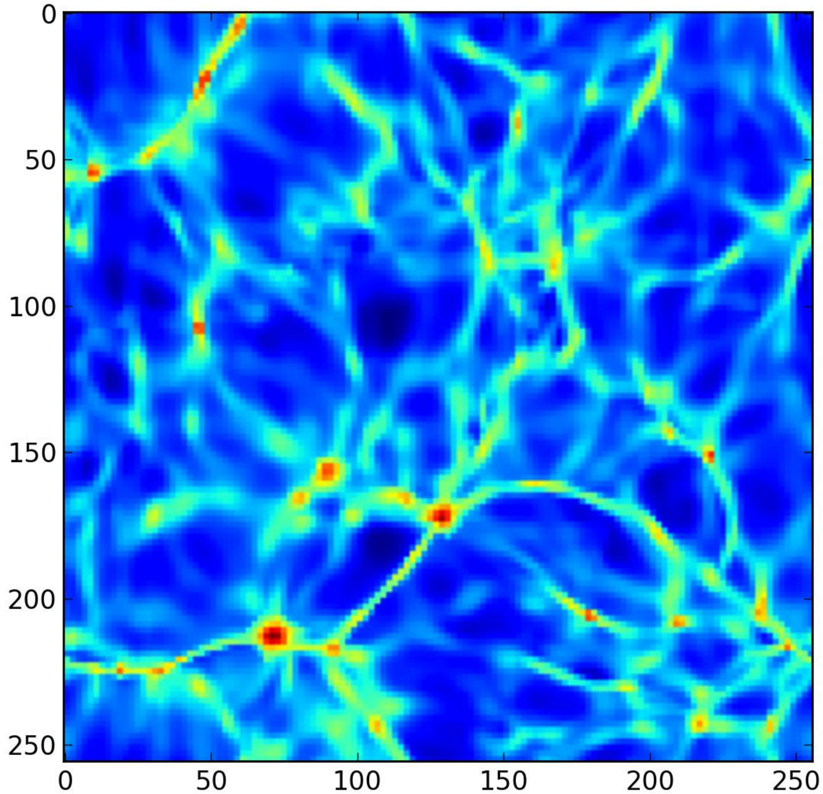
```
>>> from pymses.analysis.visualization import Camera
>>> cam  = Camera(center=[0.5, 0.5, 0.5], line_of_sight_axis='z', region_size=[1., 1.],\
... up_vector='y', map_max_size=512, log_sensitive=True)
```

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**

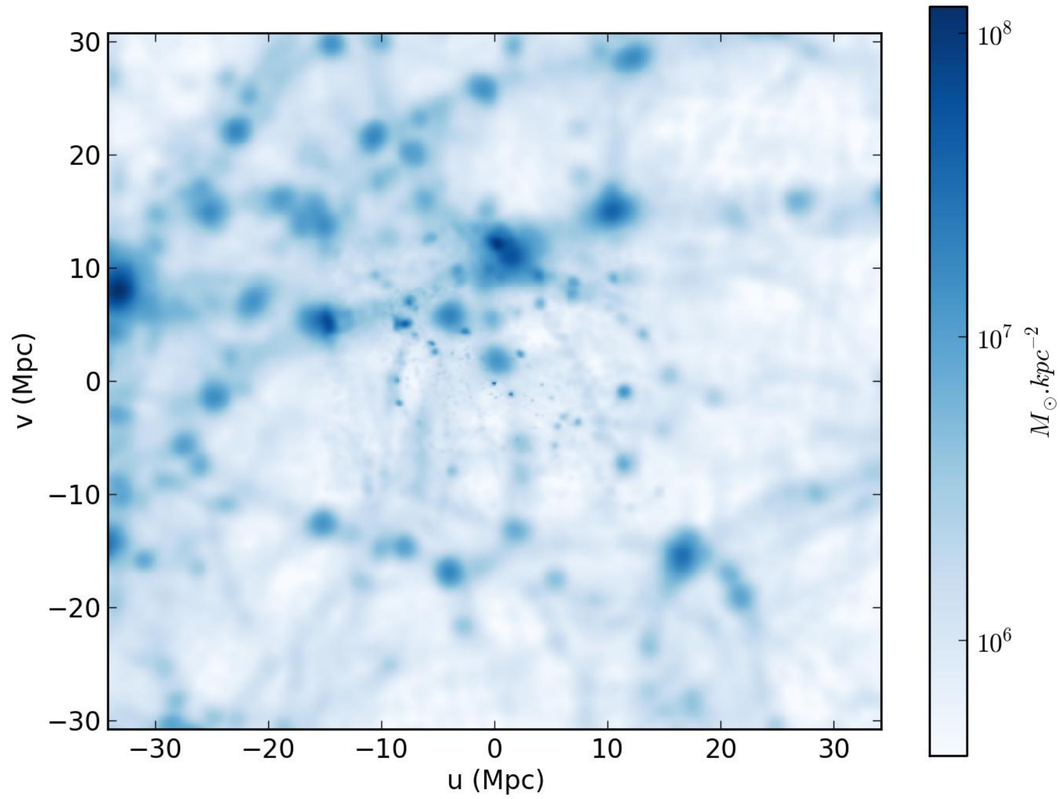
You must keep in mind that any $X$ `Operator` you use with this method must describe an **extensive** physical variable since this method compute a summation over particle/AMR quantities :

$$map[i,j] = \sum_{\text{particles/AMR cells}} X$$

### Examples

#### Particles map

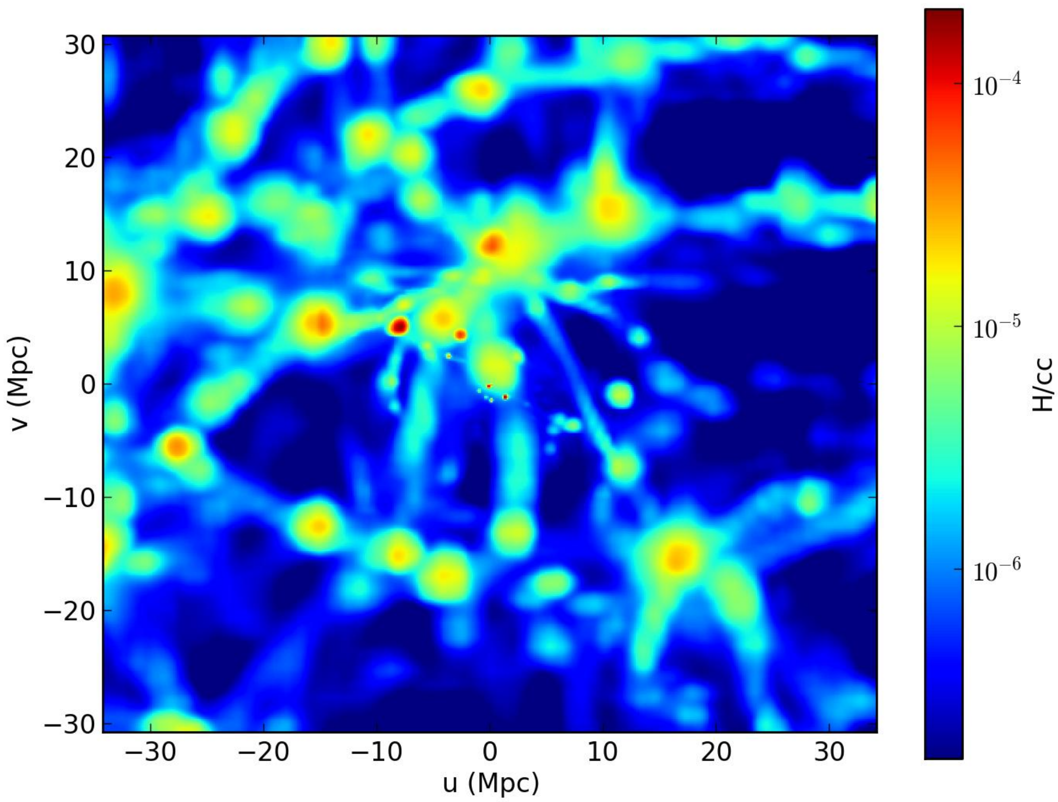
```
from numpy import array, log10
import pylab
from pymses.analysis.visualization import *
from pymses import RamsesOutput
from pymses.utils import constants as C

# 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)
        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 :

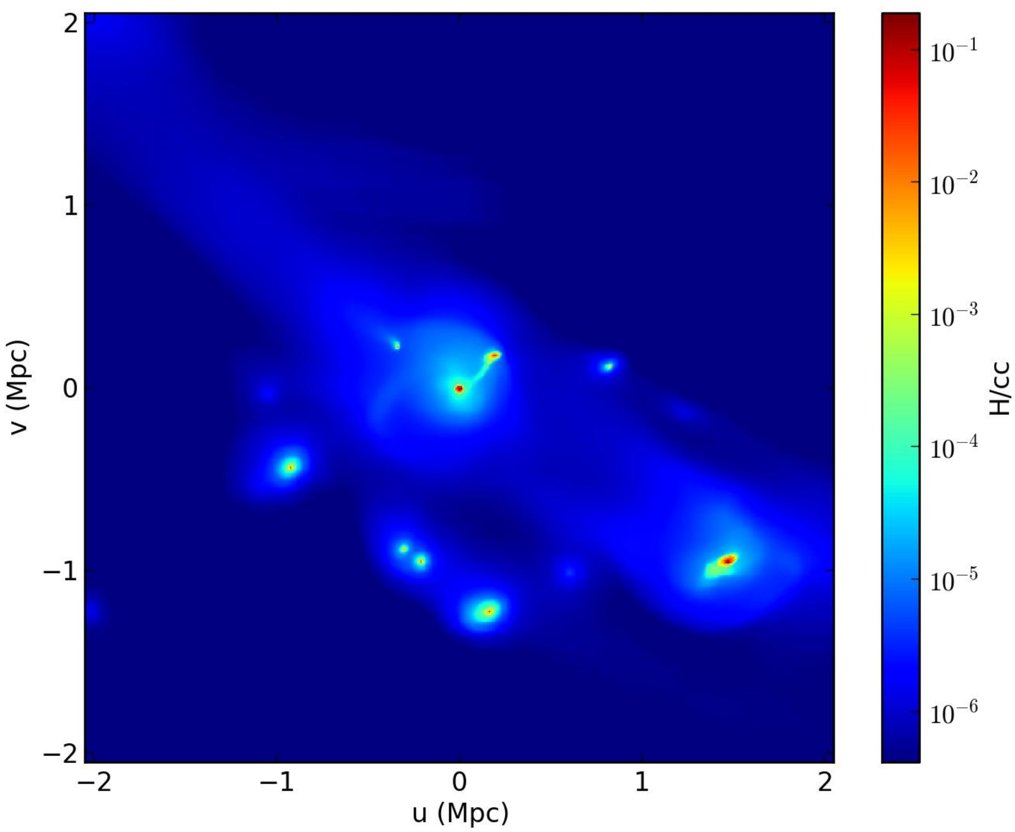
$$map[i,j] = \int_{z_{\mathrm{min}}}^{z_{\mathrm{max}}} X \mathrm{d}S_{\mathrm{pix}} \mathrm{d}z$$

### 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)
```

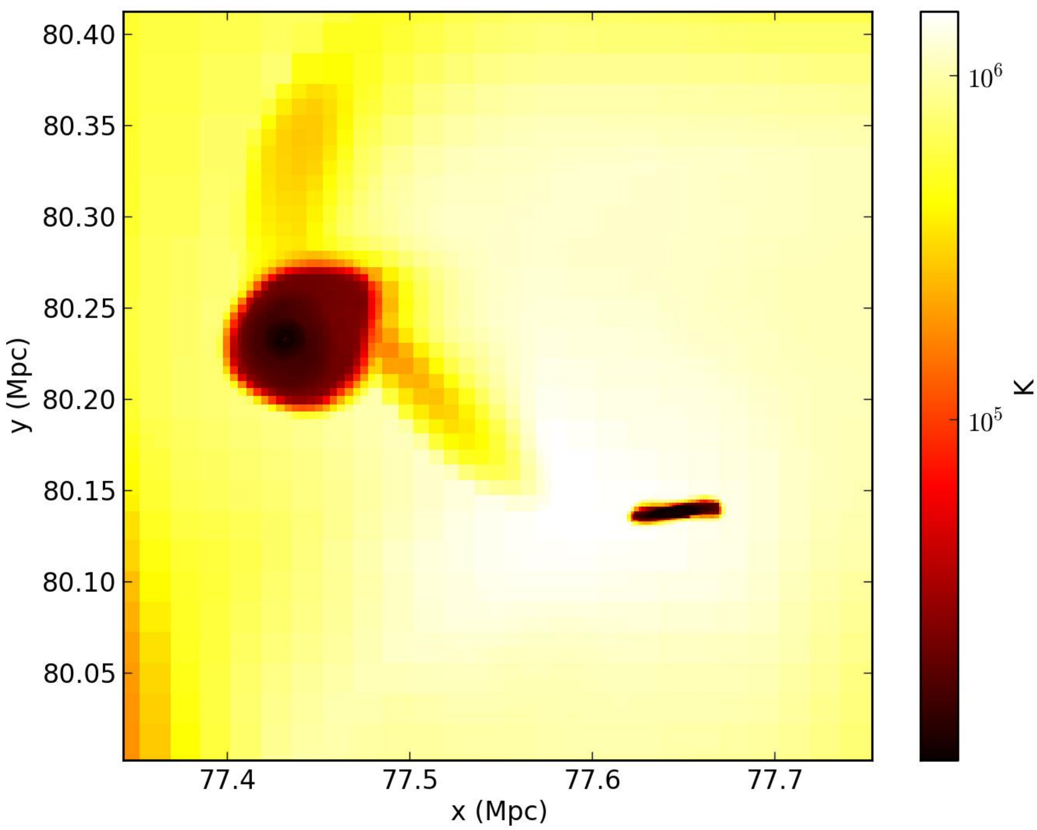
```
        # Plot map into Matplotlib figure/PIL Image
        fig = save_HDF5_to_plot(h5fname, map_unit=("H/cc",factor), axis_unit=("Mpc", scale), cmap="je
#        pil_img = save_HDF5_to_img(h5fname, cmap="jet")

        # 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):
```

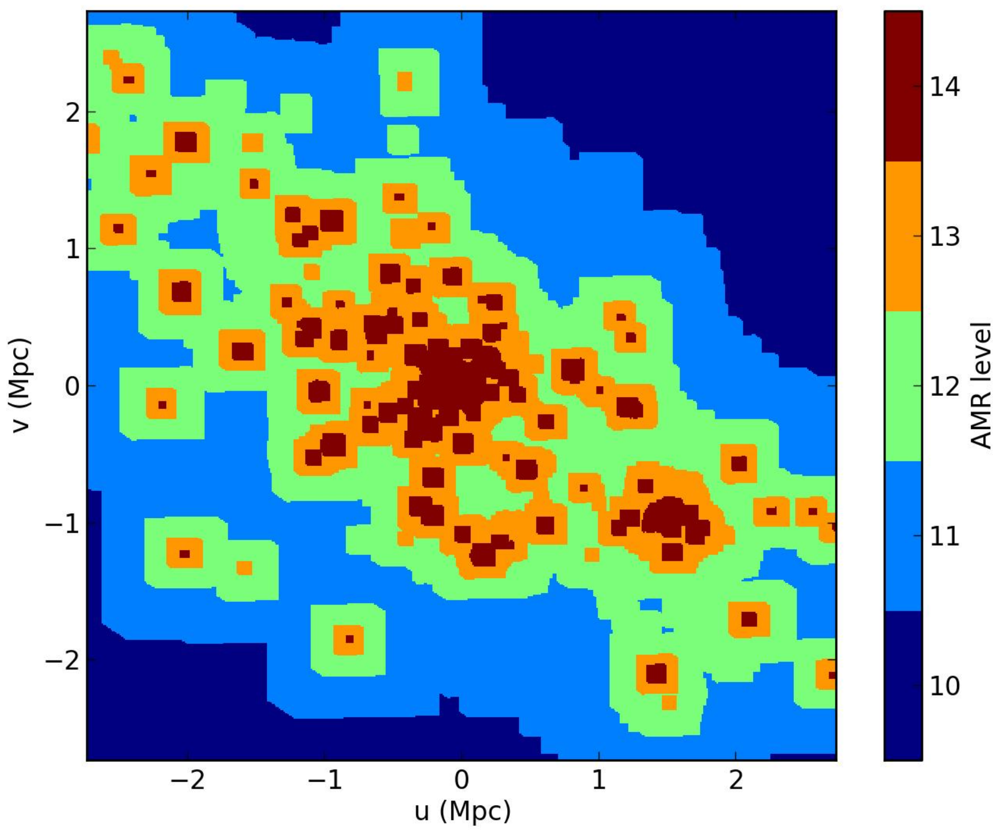
```
                def invT_func(dset):
                        P = dset["P"]
                        rho = dset["rho"]
                        r = rho/P
#                        print r[(rho<=0.0)+(P<=0.0)]
#                        r[(rho<=0.0)*(P<=0.0)] = 0.0
                        return r
                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

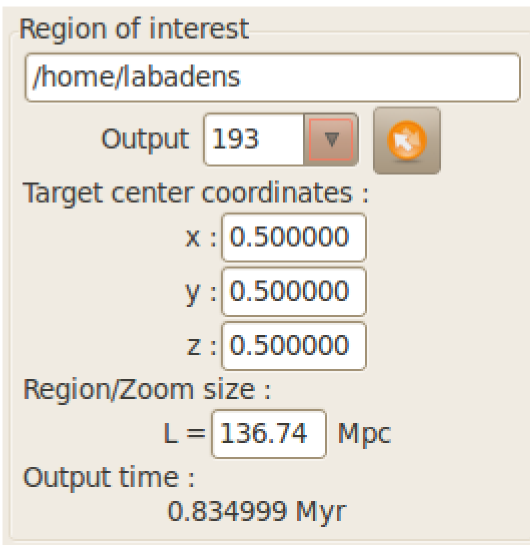
PyMSES has a Graphical User Interface (GUI) module which can be used to navigate into AMR data. Once installed as described in *Installing PyMSES*, the GUI can be started with the following python prompt commands:

```
>>> 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.

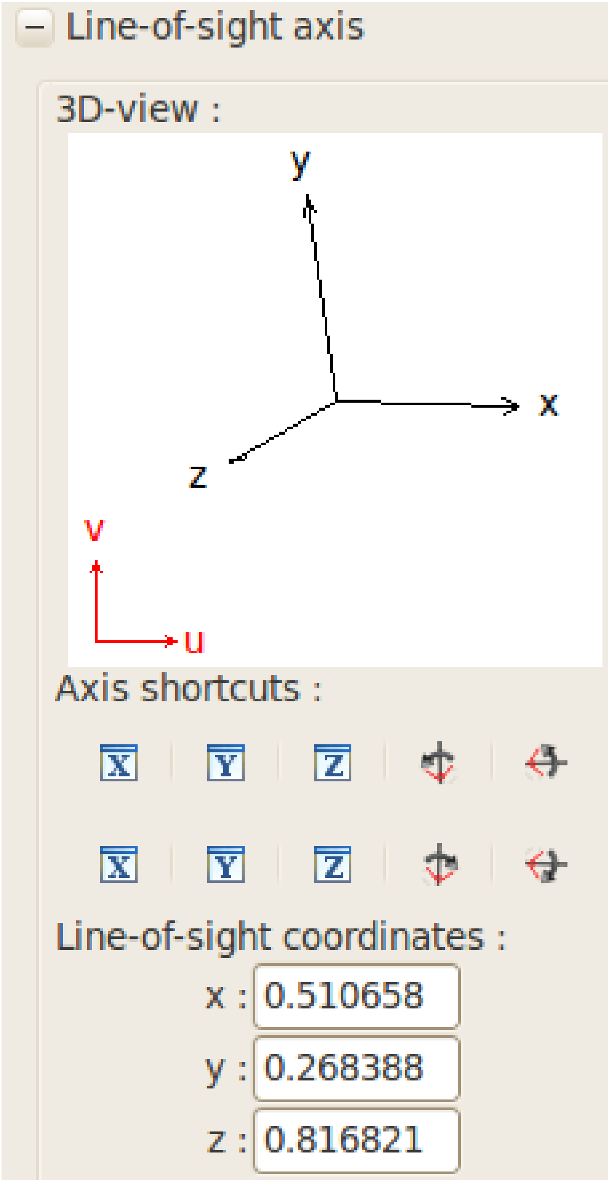
The required output number can be specified with the output number list on the left of the main window



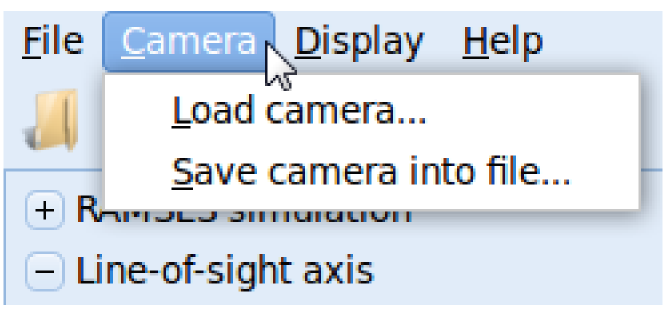

#### Playing with the camera

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.

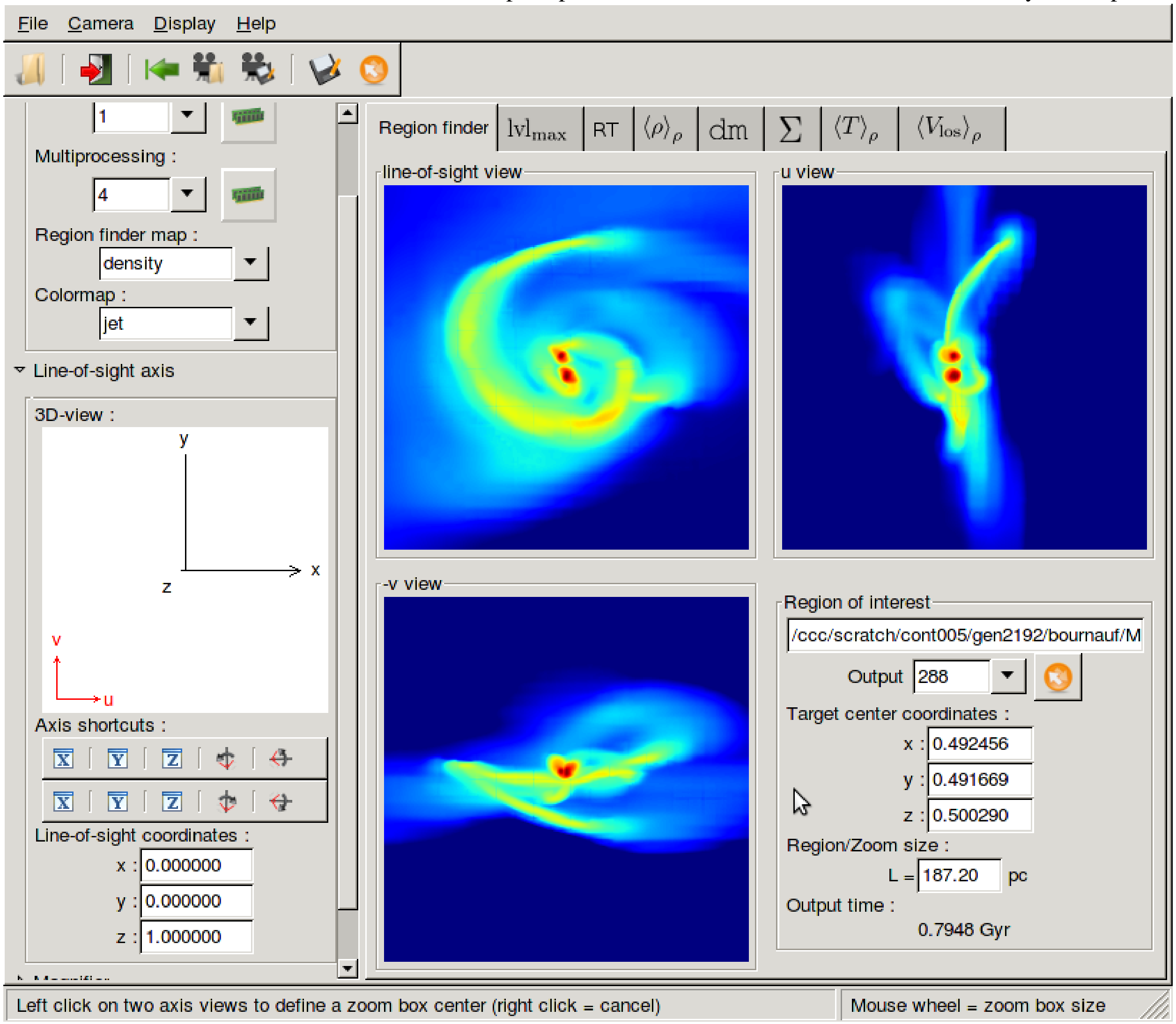



There is a possibility to save and load camera parameter via the `Camera` menu bar.



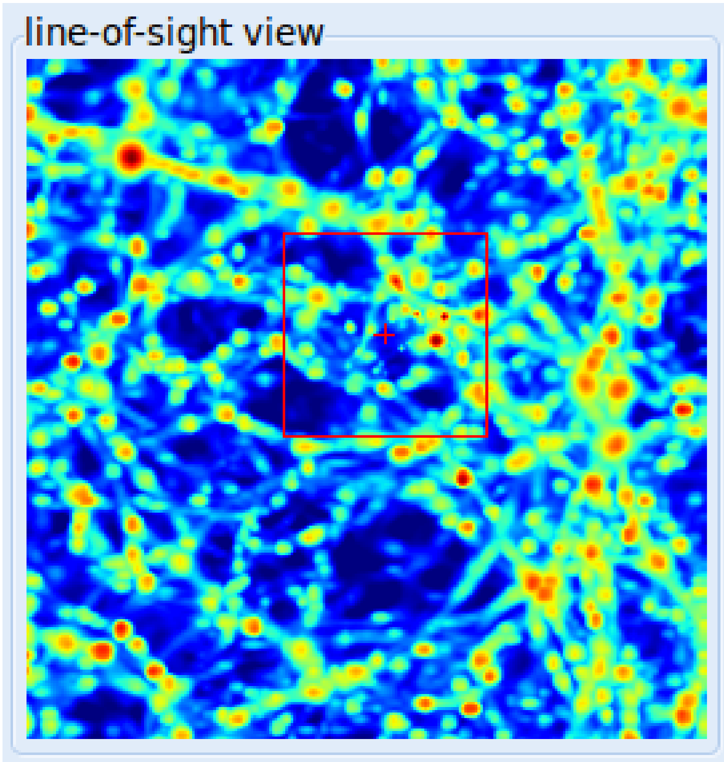
### The Region Finder

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.



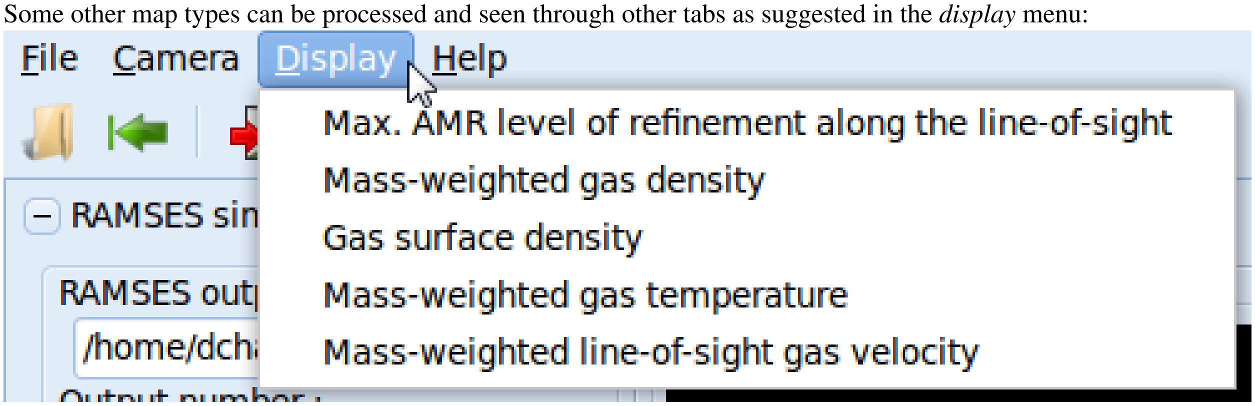

**Navigation**

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.

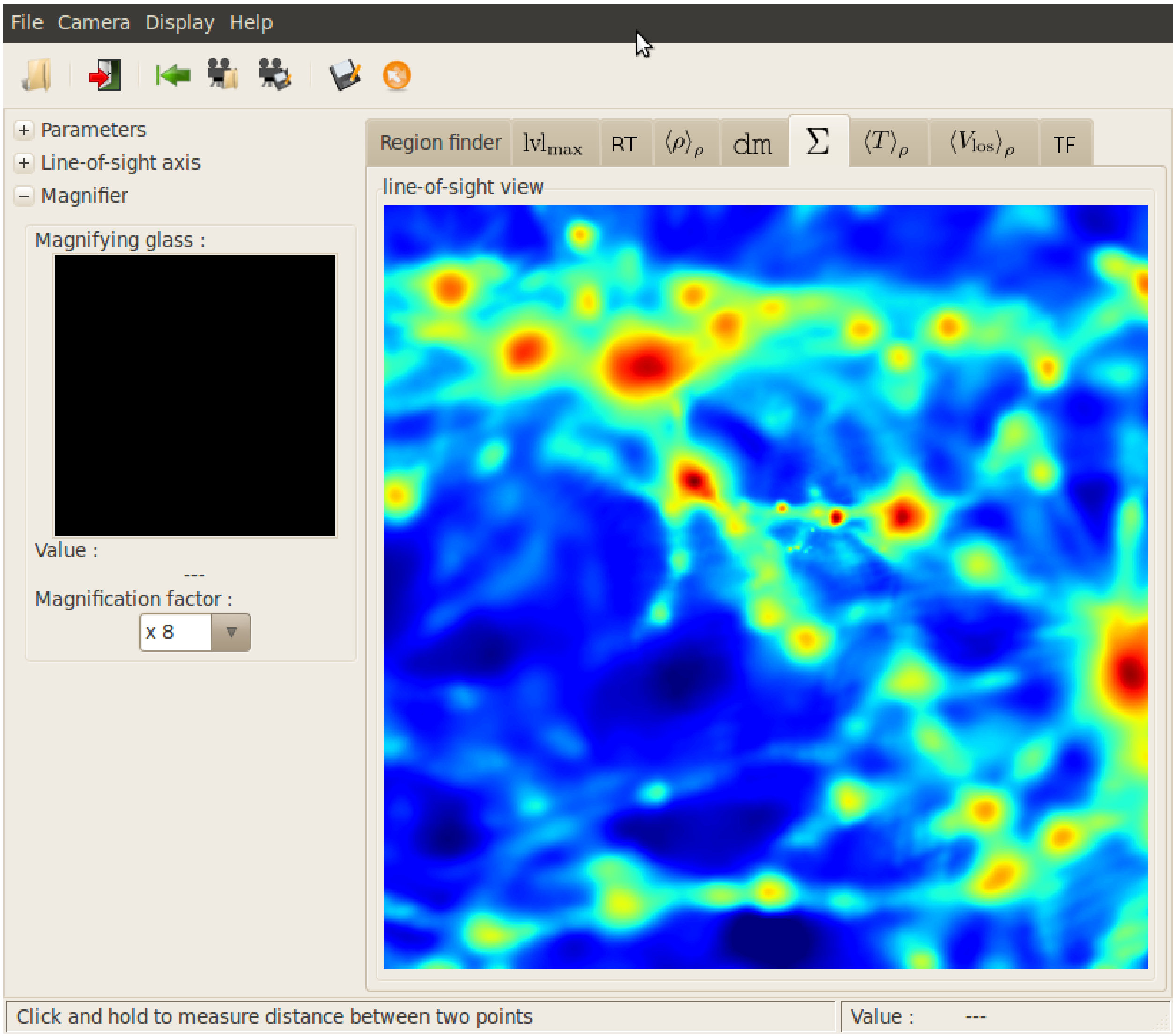


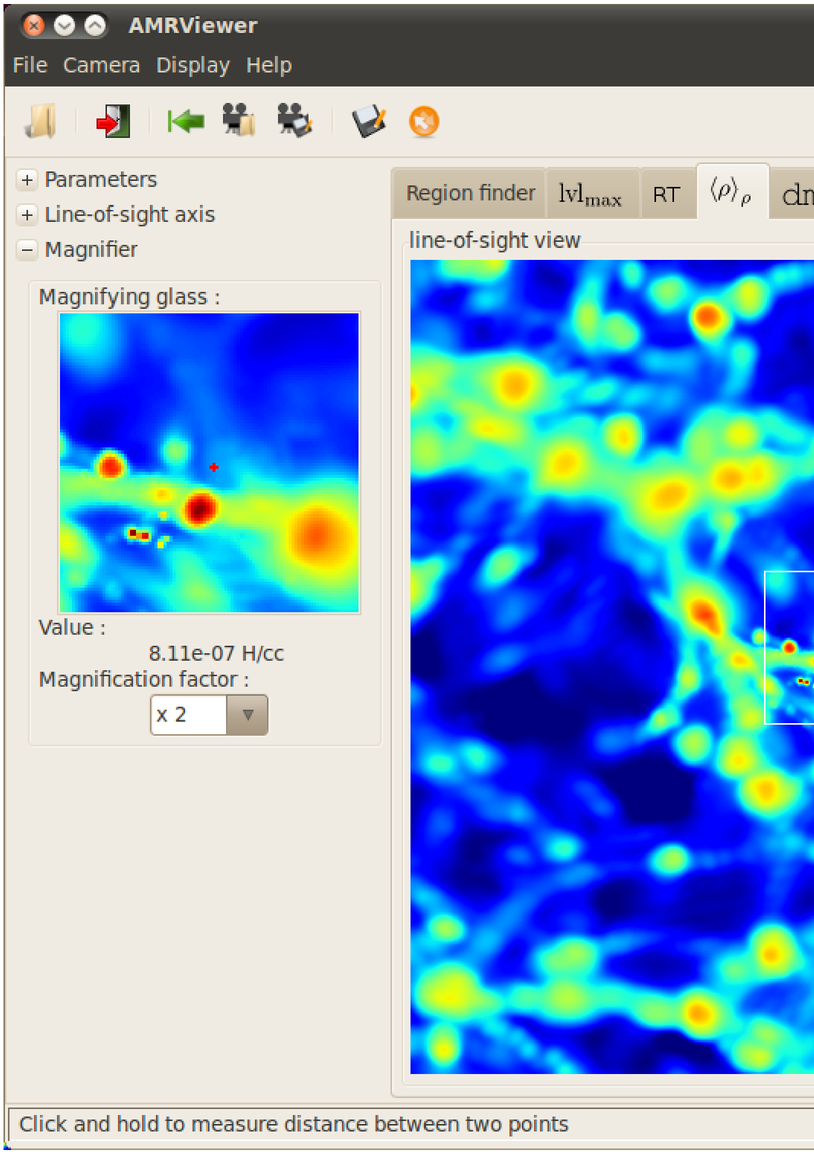

### Other map types, other tabs

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

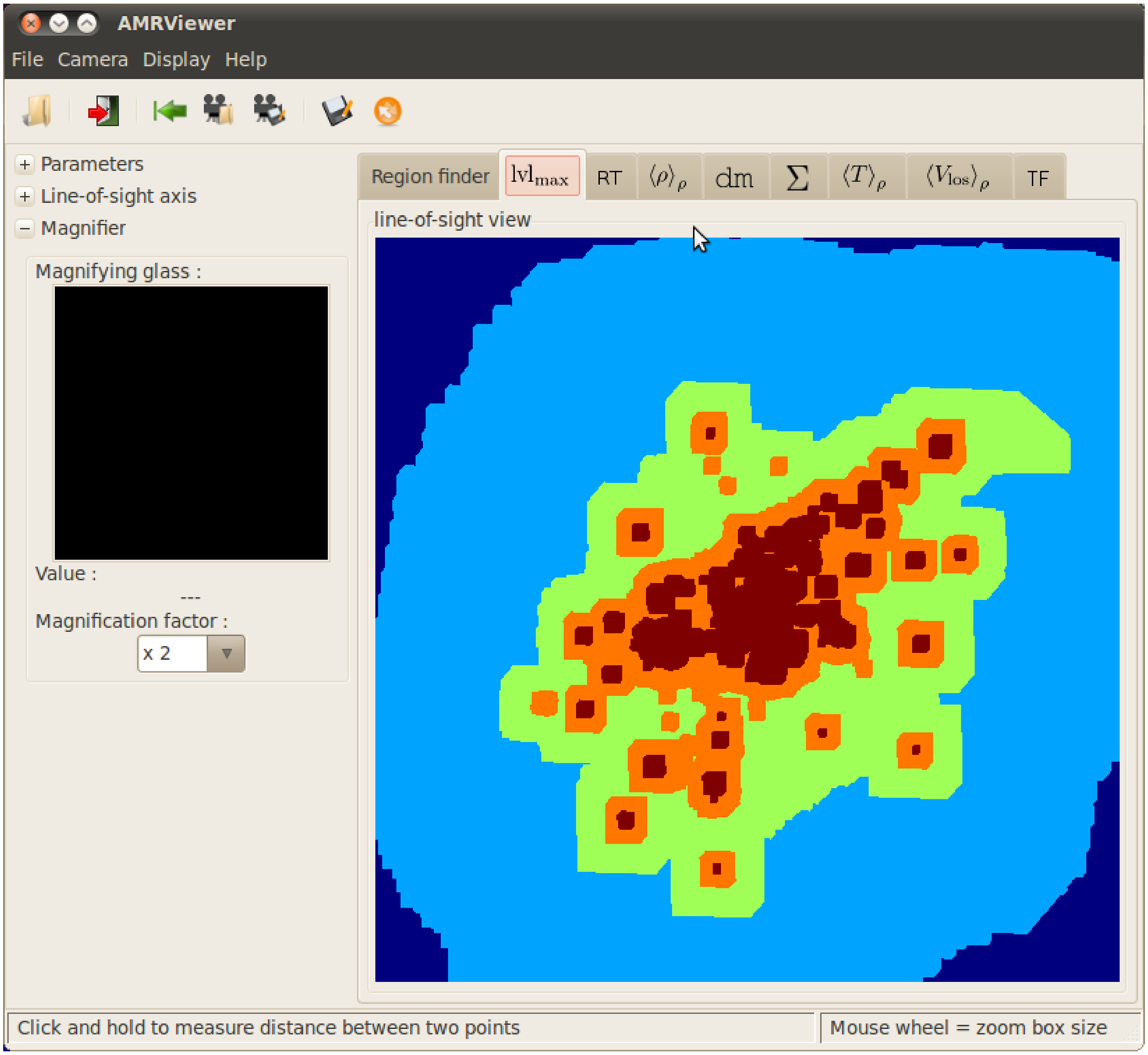



For example, gas surface density projected map (see *FFT-convolved maps*):


File Camera Display Help
Parameters
Line-of-sight axis
Magnifier
Magnifying glass :
Value :
---
Magnification factor :
x 8
Region finder
$\mathrm{lvl}_{\mathrm{max}}$
RT
$\langle\rho\rangle_\rho$
dm
$\Sigma$
$\langle T\rangle_\rho$
$\langle V_{\mathrm{los}}\rangle_\rho$
TF
line-of-sight view
Click and hold to measure distance between two points
Value : ---

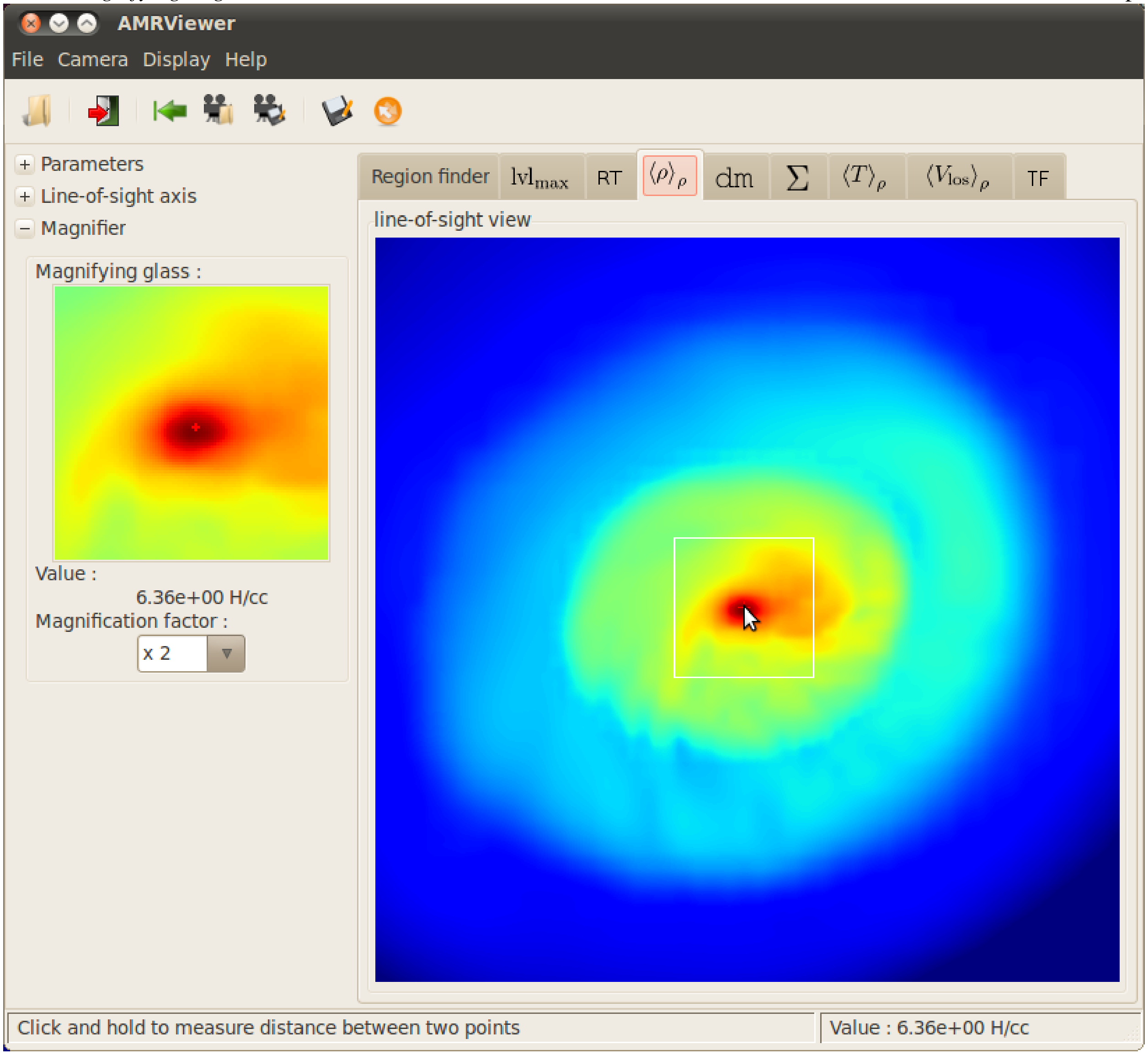



Mass weighted gas density map (see *FFT-convolved maps*):
Max. AMR level of refinement along the line-of-sight map (see *Ray-traced maps*):


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
$\Sigma$
$\langle T\rangle_\rho$
$\langle V_{\mathrm{los}}\rangle_\rho$
TF
line-of-sight view
Click and hold to measure distance between two points
Mouse wheel = zoom box size

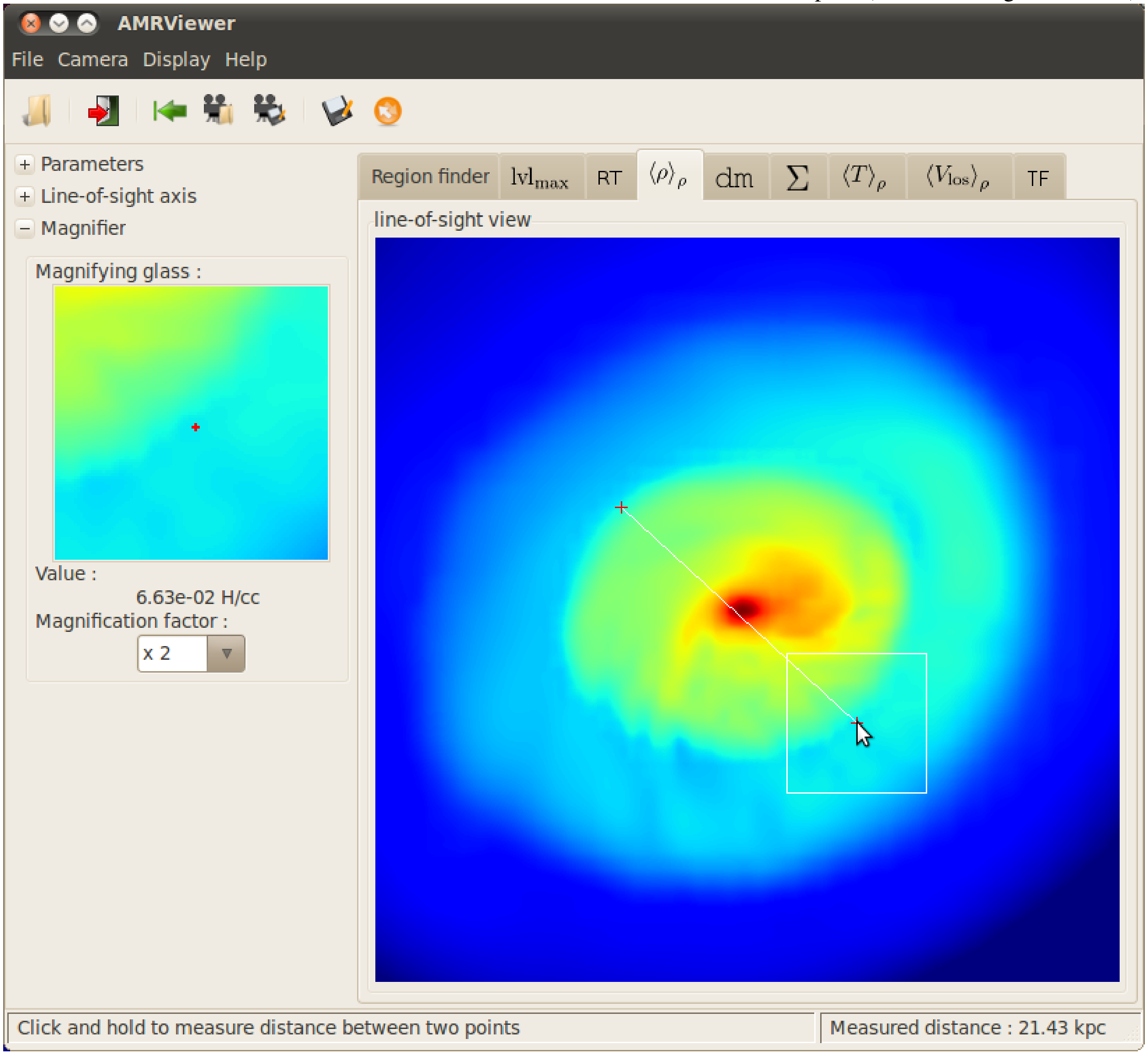
### Magnifier

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

**classmethod 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

**add_random_shift** ()
Add a random shift to point positions in order to avoid grid alignment effect on processed images. The field "size" (from CellsToPoints Filter and IsotropicExtPointDataset) is needed to know the shift amplitude. This method is processed only once, and turn the random_shift attribute to True.

**classmethod 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`

**classmethod 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*, *ndim=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*, *ndim=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*, *ndim=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_nonactive_cells=False*, *include_boundary_cells=False*, *include_split_cells=False*, *smallest_cell_level=None*)

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)
```

**contains_camera**(*cam*)

**Parameters** **An other camera object** :

**Returns** **Boolean** : True if data needed for this camera view include all data

needed for the camera view given in argument.

**copy**()

Returns a copy of this camera.

**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'

classmethod **from_HDF5**(*h5f*)

Returns a camera from a HDF5 file.

classmethod **from_csv**(*csv_file*)

Returns a camera from a csv (Comma Separated Values) 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**(*reduce_u_v_to_PerspectiveRatio=False*)
Returns the (0.,0.,0.) centered cubic bounding box of the area covered by the camera Parameters ———- reduce_u_v_to_PerspectiveRatio : `boolean` (default False)

take into account the camera.perspectiveAngle if it is defined to make a perspective projection. This reduce the map u and v (i.e.horizontal and vertical) size with the perspective ratio.

**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. Parameters ———- points : `numpy array of floats`

array of points(x,y,z) coordinates to project

**take_into_account_perspective** [boolean (default False)] take into account the camera.perspectiveAngle if it is defined to make a perspective projection.

**rotate_around_up_vector**(*ang_deg=1.0*)

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

**save_csv**(*csv_file*)
Saves the camera parameters into a csv (Comma Separated Values) 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*, *log_sensitive=None*)
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.

**log_sensitive** : `boolean`

apply logarithmic value, if not precise (default value = None), this code use the hdf5 camera.log_sensitive value to decide

**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=False*, *cmap_range=None*, *fraction=None*)
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]

**apply_log_scale** (*map*)
Used to apply log-scale map if the camera captors are log-sensitive. Takes care of null and negative values warning

**Parameters** **map** : original numpy array of map values

**Returns** **map** : ~ numpy.log10(map) (takes care of null and negative values)

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*, *interpolation=False*, *use_C_code=True*, *use_openCL=False*, *verbose=False*)
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

**interpolation** : boolean (default False)

Experimental : A proper bi/tri-linear interpolation could be great! THIS IS NOT IMPLEMENTED YET : in this attempt we supposed corner cell data while ramses use centered cell data, letting alone the problem of different AMR level...

**use_C_code** : boolean (default True)

The pure C code is slightly faster than the (not well optimized) Cython code, and should give the same result

**use_openCL** : boolean (default False)

Experimental : use "pyopencl" http://pypi.python.org/pypi/pyopencl

**verbose** : boolean (default False)

some console printout...

**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={}*, *use_level_max=True*)
MapFFTProcessor class Parameters ———- source : Source

data source

**info** [`dict`] RamsesOutput info dict.

**ker_conv** [:class:'~pymses.analysis.visualization.ConvolKernel' (default None leads to use a GaussSplatterKernel)] Convolution kernel used for the map processing

**pre_flatten** [`boolean` (default False)] 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` (default False)] 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** [: `python dictionary` (default {})] Cache dsets dictionnary reference, used only if remember_data == True, to share the same cache between various MapFFTProcessor

**use_level_max** [`boolean` (default True)] Limit the transformation of the AMR grid to particles to AMR cells under the camera octree levelmax (so that visible cells are only the ones that have bigger size than the camera pixel size). Set this to False when using directly particle data from ".part" particles files (dark matter and stars particles), so as to get the cache_dset working without the levelmax specification

**`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*, *random_shift=False*, *stars_age_instensity_dimming=False*)

Map processing method

**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.

**multiprocessing** : `boolean` (default True)

try to use multiprocessing to compute both of the FractionOperator's "top" and "down" FFT maps in parallel

**FFTkernelSizeFactor** : `int or float` (default 1)

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

**data_already_prepared** : `boolean` (default False)

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

**random_shift** : `boolean` (default False)

add a random shift to point positions to avoid seeing the grid on resulting image

**stars_age_instensity_dimming** : `boolean` (default False)

**Requires the "epoch" field. Make use of this formula :** if star_age < 10 Million years (Myr) : intensity_weights = operator_weights (young stars are normally bright) else : intensity_weights = operator_weights * [star_age/10**6 Myr]**-0.7 (intensity dimming with years old)

**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=True*, *multiprocessing=True*, *source=None*, *use_hilbert_domain_decomp=True*, *use_C_code=True*, *use_bottom_up=False*)
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` (default False)

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

**verbose** : `boolean` (default False)

show more console printouts

**multiprocessing** : `boolean` (default True)

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)

**source** : class:~*pymses.sources...* (default None)

Optional : The source to process may be specified here if you want to reuse a CameraOctreeDatasource already loaded in memory for example (see pymses/bin/pymses_tf_ray_tracing.py)

**use_hilbert_domain_decomp** : `boolean` (default True)

If False, iterate on the whole octree for each cpu file(instead of iterating on the cpu minimal domain decomposition, which is faster)

**use_C_code** : `boolean` (default True)

Our pure C code is faster than the (not well optimized) Cython code, and should give the same result

**use_bottom_up** : `boolean` (default False)

Force the use of the bottom-up algorithm instead of the classic top-down on the octree. Use the "neighbors" array. DOESN'T WORK YET

**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*, *rgb=True*, *use_C_code=True*, *use_openCL=False*, *dataset_already_loaded=False*, *reload_scalar_field=False*)

Map processing method : directional ray-tracing through AMR tree

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.

**return_image** [`boolean` (default True)] if True, return a PIL image (when rgb option is also True), else it returns a numpy array map

**rgb** [`boolean` (default True)] if True, this code use the camera.color_tf to compute a rgb image if False, this code doesn't use the camera.color_tf, and works like the standard RayTracer. Then it returns two maps : the requested map, and the AMR levelmax map

**use_C_code** [`boolean` (default True)] Our pure C code is faster than the (not well optimized) Cython code, and should give the same result

**use_openCL** [`boolean` (default False)] Experimental : use "pyopencl" http://pypi.python.org/pypi/pyopencl

**dataset_already_loaded** [boolean (default False)] Flag used with use_openCL=True to avoid reloading a dataset on the device

**reload_scalar_field** [boolean (default False)] Flag used with use_openCL=True and dataset_already_loaded=True to avoid reloading the dataset structure on the device while using a different scalar field

**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*, *use_C_code=True*)

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)

**use_C_code** : boolean (default True)

Our pure C code is faster than the (not well optimized) Cython code, and should give the same result

### 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*, *interpolation=False*, *use_C_code=True*, *use_openCL=False*, *verbose=False*)

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 to add a *level* field in the returned dataset containing the value of the AMR level the sampling points fall into

**add_cell_center** : `boolean` (default False)

whether we need to add a *cell_center* field in the returned dataset containing the coordinates of the AMR cell center the sampling points fall into

**interpolation** : `boolean` (default False)

Experimental : A proper bi/tri-linear interpolation could be great! THIS IS NOT IMPLEMENTED YET : in this attempt we supposed corner cell data while ramses use centered cell data, letting alone the problem of different AMR level...

**use_C_code** : `boolean` (default True)

The pure C code is slightly faster than the (not well optimized) Cython code, and should give the same result

**use_openCL** : `boolean` (default False)

Experimental : use "pyopencl" http://pypi.python.org/pypi/pyopencl

**verbose** : `boolean` (default False)

some console printout...

**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 $1M_{\odot}$ 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 $V = \prod_{1\leq i\leq \mathrm{ndim}} (\mathrm{cmax}_i - \mathrm{cmin}_i)$

**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 $V = \pi r^2 h$

# PYTHON MODULE INDEX

## p

# INDEX

## I



## L



## M



## O



## P



## R

## S



## T



## U



## V



## W