Astrophysix

Release 0.5.0

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DOCUMENTATION

CHAPTER

ONE

INTRODUCTION

The purpose of the `astrophysix` Python package is to provide computational astrophysicists a generic tool to document their numerical projects, **independently** of :

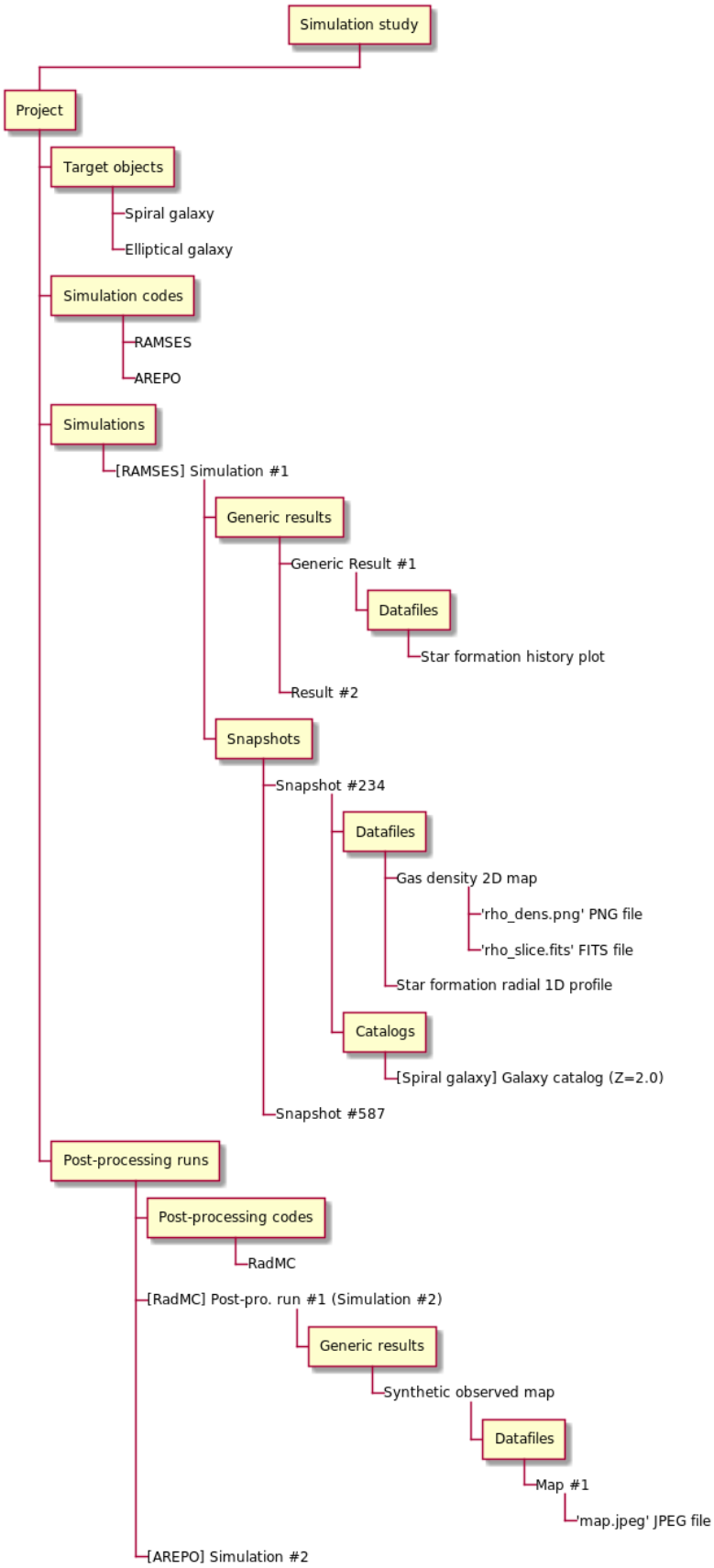
- the astrophysical code they used (RAMSES, AREPO, GADGET, ASH, PLUTO, MAGICS, etc),
- the hardware/software parameters of their numerical setup,
- the post-processing software/library they perform their scientific analysis with (Yt, Osyris, PyMSES, RADMC-3D, SAODS9, Paraview, etc.),
- the type of their scientific analysis (2D column density maps, 3D power spectrum, PPV cubes, statistical analysis, etc.).

`astrophysix` contains :

- the `astrophysix.simdm` package follows the *Simulation Datamodel* (SimDM documentation) standard documented by the International Virtual Observatory Alliance.

- the `astrophysix.units` package provides a more generic-purpose physical quantity and units management tool. The most common physical constants used in astrophysics are defined in this module.

With this package, users can create a *`SimulationStudy`* in which a single numerical project can be fully documented and all the reduced datasets (PNG plots, FITS files, object catalogs, etc.) can be attached. It follows the hierarchical structure :


Simulation study
Project
Target objects
Spiral galaxy
Elliptical galaxy
Simulation codes
RAMSES
AREPO
Simulations
[RAMSES] Simulation #1
Generic results
Generic Result #1
Datafiles
Star formation history plot
Result #2
Snapshots
Snapshot #234
Datafiles
Gas density 2D map
'rho_dens.png' PNG file
'rho_slice.fits' FITS file
Star formation radial 1D profile
Catalogs
[Spiral galaxy] Galaxy catalog (Z=2.0)
Snapshot #587
Post-processing runs
Post-processing codes
RadMC
[RadMC] Post-pro. run #1 (Simulation #2)
Generic results
Synthetic observed map
Datafiles
Map #1
'map.jpeg' JPEG file
[AREPO] Simulation #2

CHAPTER

TWO

GALACTICA DATABASE INTEGRATION

Fig. 1: http://www.galactica-simulations.eu

These studies can be saved in persistent and portable HDF5 files and then distributed to other members of the scientific collaboration to be updated. `SimulationStudy` HDF5 files can be uploaded with a single-click on the Galactica simulation database to automatically deploy web pages for your astrophysical simulation project.

`SimulationStudy` HDF5 files can be uploaded on the Galactica simulation database several times in order to :

- Create new project web pages on the web application (creation),
- Update pages for an existing project (update).

Warning: When you upload a `SimulationStudy` HDF5 file, the Galactica server will **NEVER** take the responsibility of deleting any entry from the database related to an item that is missing in your `SimulationStudy` HDF5 file. In other words, deleting an object from your local `SimulationStudy`, saving the study into a HDF5 file and uploading the file on Galactica won't delete the object from the database (only the *creation* and *update* behaviours are enabled).

If you wish to remove items from the web application, you **MUST** do so by hand (it must be an explicit user action) in the Galactica administration interface.

2.1 Galactica validity checks

Prior to uploading any Simulation study HDF5 file on the Galactica web application, it is advised to perform some preliminary validity checks on your project to make sure the deployment online will go smoothly. To do so, you may use the *galactica_validity_check()* method or enable the galactica_checks option in the *SimulationStudy.save_HDF5()* method. For more details, see *How can I check validity for Galactica ?*

2.1.1 Installation

astrophysix can be installed in you local Python environment (virtualenv, conda, ...) with **pip**.

Latest stable releases

Using **pip**, you can easily download and install the latest version of the astrophysix package directly from the Python Package Index (PyPI):

```
> pip install astrophysix
Collecting astrophysix
    Downloading astrophysix-0.5.0-py2.py3-none-any.whl (101 kB)
Collecting h5py>=2.10.0
    Using cached h5py-2.10.0-cp36-cp36m-manylinux1_x86_64.whl (2.9 MB)
Collecting Pillow>=6.2.1
    Using cached Pillow-7.2.0-cp36-cp36m-manylinux1_x86_64.whl (2.2 MB)
Collecting numpy>=1.16.4
    Using cached numpy-1.19.2-cp36-cp36m-manylinux2010_x86_64.whl (14.5 MB)
Collecting future>=0.17.1
    Using cached future-0.18.2.tar.gz (829 kB)
Collecting six
    Using cached six-1.15.0-py2.py3-none-any.whl (10 kB)
Installing collected packages: numpy, six, h5py, Pillow, future, astrophysix
    Running setup.py install for future ... done
Successfully installed Pillow-7.2.0 astrophysix-0.5.0 future-0.18.2 h5py-2.10.0 numpy-
↪1.19.2 six-1.15.0
```

Unstable releases

If you wish to use a specific beta release of astrophysix, you can select which version to install :

```
> pip install astrophysix==0.5.0ra1
Collecting astrophysix
    Downloading astrophysix-0.5.0a1-py2.py3-none-any.whl (101 kB)
Collecting h5py>=2.10.0
    Using cached h5py-2.10.0-cp36-cp36m-manylinux1_x86_64.whl (2.9 MB)
Collecting Pillow>=6.2.1
    Using cached Pillow-7.2.0-cp36-cp36m-manylinux1_x86_64.whl (2.2 MB)
Collecting numpy>=1.16.4
    Using cached numpy-1.19.2-cp36-cp36m-manylinux2010_x86_64.whl (14.5 MB)
Collecting future>=0.17.1
    Using cached future-0.18.2.tar.gz (829 kB)
Collecting six
    Using cached six-1.15.0-py2.py3-none-any.whl (10 kB)
Installing collected packages: numpy, six, h5py, Pillow, future, astrophysix
```

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```
    Running setup.py install for future ... done
Successfully installed Pillow-7.2.0 astrophysix-0.5.0a1 future-0.18.2 h5py-2.10.0␣
↪numpy-1.19.2 six-1.15.0
```

2.1.2 Quick-start guide

This quick-start guide will walk you into the main steps to document your numerical project. If you want to skip the tour and directly see an example, see *Full example script*.

Project and study

Creation and persistency

To create a *Project* and save it into a *SimulationStudy* HDF5 file, you may run this minimal Python script :

```
>>> from astrophysix.simdm import SimulationStudy, Project, ProjectCategory
>>> proj = Project(category=ProjectCategory.Cosmology, project_title="Extreme␣
↪Horizons cosmology project")
>>> study = SimulationStudy(project=proj)
>>> study.save_HDF5("./EH_study.h5")
```

Loading a study

To read the *SimulationStudy* from your HDF5 file, update it and save the updated study back in its original file :

```
>>> from astrophysix.simdm import SimulationStudy
>>> study = SimualationStudy.load_HDF5("./EH_study.h5")
>>> proj = study.project
>>> proj.short_description = "This is a short description (one-liner) of my project."
>>> # Saves your updated study back in the same file './EH_study.h5'
>>> study.save_HDF5()
```

Study information

A *SimulationStudy* object contains details on when it has been created (*creation_time* property) and last modified (*last_modification_time* property) :

```
>>> study.creation_time
datetime.datetime(2020, 9, 4, 14, 05, 21, 84601, tzinfo=datetime.timezone.utc)
>>> study.last_modification_time
datetime.datetime(2020, 9, 18, 15, 12, 27, 14512, tzinfo=datetime.timezone.utc)
```

Full project initialization example

To initialize a *Project*, you only need to set *category* and *project_title* properties. Here is a more complete example of a *Project* initialization with all optional attributes :

```
>>> proj = Project(category=ProjectCategory.StarFormation, alias="FRIG",
...                project_title="Self-regulated magnetised ISM modelisation",
...                short_description="Short description of my 'FRIG' project",
...                general_description="""This is a pretty long description for my␣
↪project spanning over multiple lines
...                if necessary""",
...                data_description="The data available in this project...",
...                directory_path="/path/to/project/data/")
```

Warning: Setting the *alias* property is necessary only if you wish to upload your study on the Galactica simulation database. See *Why an alias ?* and *How can I check validity for Galactica ?*

See also:

- *SimulationStudy*, *Project* and *ProjectCategory* API references.

Simulation codes and runs

To add a simulation run into your project, the definition of a *SimulationCode* is mandatory. Once defined, you can create a *Simulation* based on that simulation code:

```
>>> from astrophysix.simdm.protocol import SimulationCode
>>> from astrophysix.simdm.experiment import Simulation
>>> ramses = SimulationCode(name="Ramses 3.1 (MHD)", code_name="RAMSES")
>>> simu = Simulation(simu_code=ramses, name="Hydro run full resolution")
```

To add the simulation to the project, use the *Project.simulations* property (*ObjectList*):

```
>>> proj.simulations.add(simu)
>>> proj.simulations
Simulation list :
+---+---------------------------+-----------------------------------------+
| # |           Index           |                  Item                   |
+---+---------------------------+-----------------------------------------+
| 0 | Hydro run full resolution | 'Hydro run full resolution' simulation |
+---+---------------------------+-----------------------------------------+
| 1 | Hydro run full resolution | 'MHD run full resolution' simulation   |
+---+---------------------------+-----------------------------------------+
```

See also:

- *Simulation*, *SimulationCode* API references,
- *Protocols* detailed section.
- *Experiments* detailed section.
- *ObjectList* API reference.

Post-processing runs

Optionally, you can add *PostProcessingRun* into a *Simulation* using the *Simulation.post_processing_runs* property (*ObjectList*). To create a *PostProcessingRun*, you must first define a *PostProcessingCode* :

```
>>> from astrophysix.simdm.protocol import PostProcessingCode
>>> from astrophysix.simdm.experiment import PostProcessingCodeRun
>>>
>>> radmc = PostProcessingCode(name="RADMC-3D", code_name="RADMC-3D", code_version="2.
↪0")
>>> pprun = PostProcessingCodeRun(ppcode=radmc, name="Synthetic observable creation␣
↪of pre-stellar cores")
>>>
>>> # Add post-pro run into the simulation
>>> simu.post_processing_runs.add(pprun)
```

See also:

- *PostProcessingRun*, *PostProcessingCode* API references,
- *Protocols* detailed section.
- *Experiments* detailed section.
- *ObjectList* API reference.

Results and snapshots

Experiment-wide

You can add results into any simulation or post-processing run. If it is an experiment-wide result, create a *GenericResult* and use the *Simulation.generic_results* or *PostProcessingRun.generic_results* property (*ObjectList*) to add it into your run :

```
>>> from astrophysix.simdm.results import GenericResult
>>>
>>> res1 = GenericResult(name="Star formation history", directory_path="/my/path/to/
↪result",
...                       description="""This is the star formation history during the␣
↪2
...                                      Myr of the galaxy major merger""")
>>> simu.generic_results.add(res1)
```

Time-specific

Otherwise, if it is time-specific result, create a *Snapshot* and use the *Simulation.snapshots* or *PostProcessingRun.snapshots* property (*ObjectList*) to add it into your run :

```
>>> from astrophysix.simdm.results import Snapshot
>>> from astrophysix import units as U

>>> sn34 = Snapshot(name="Third pericenter", time=(254.7, U.Myr),
...                 directory_path="/my/path/to/simu/outputs/output_00034")
>>> simu.snapshots.add(sn34)
```

See also:

- *GenericResult*, *Snapshot* API references,
- *Experiments* detailed section.
- *Results and associated datafiles* detailed section.
- *ObjectList* API reference.

Object catalogs

New in version 0.5.0

You can add object catalogs into any result (*GenericResult* or *Snapshot*), using the *catalogs* property :

```
>>> from astrophysix.simdm.catalogs import TargetObject, ObjectProperty, Catalog,␣
↪CatalogField,\
...                                     PropertyFilterFlag
>>> from astrophysix.simdm.utils import DataType
>>> from astrophysix import units as U
>>>
>>> cluster = TargetObject(name="Galaxy cluster")
>>> x = tobj.object_properties.add(ObjectProperty(property_name="x", unit=U.Mpc,
...                                                filter_flag=PropertyFilterFlag.
↪BASIC_FILTER))
>>> y = tobj.object_properties.add(ObjectProperty(property_name="y",  unit=U.Mpc,
...                                                filter_flag=PropertyFilterFlag.
↪BASIC_FILTER))
>>> z = tobj.object_properties.add(ObjectProperty(property_name="z",  unit=U.Mpc,
...                                                filter_flag=PropertyFilterFlag.
↪BASIC_FILTER))
>>> # You may group properties in a property group
>>> pos = ObjectPropertyGroup(group_name="position")
>>> pos.group_properties.add(x)
>>> pos.group_properties.add(y)
>>> pos.group_properties.add(z)
>>>
>>> m = tobj.object_properties.add(ObjectProperty(property_name="M500", unit=U.Msun,
...                                                filter_flag=PropertyFilterFlag.
↪BASIC_FILTER))
>>>
>>> # Define a catalog
>>> cat = Catalog(target_object=tobj, name="Galaxy cluster catalog")
>>> # Add the catalog fields into the catalog (100 clusters)
>>> cat.catalog_fields.add(CatalogField(x, values=N.random.uniform(size=100)))
>>> cat.catalog_fields.add(CatalogField(y, values=N.random.uniform(size=100)))
>>> cat.catalog_fields.add(CatalogField(z, values=N.random.uniform(size=100)))
>>> cat.catalog_fields.add(CatalogField(m, values=N.random.uniform(size=100)))
>>>
>>> # Add the catalog in the snapshot
>>> sn34.catalogs.add(cat)
```

See also:

- *Catalog* and *CatalogField* API references,
- *TargetObject*, *ObjectProperty* and *ObjectPropertyGroup* API references,
- *Target objects and object catalogs* detailed section.

- *ObjectList* API reference.

Datafiles

You can add Datafile objects into any *Snapshot* or *GenericResult*, or even (*new in version 0.5.0*) in an object *Catalog* :

```
>>> from astrophysix.simdm.datafiles import Datafile
>>>
>>> # Add a datafile into a snapshot
>>> imf_df = Datafile(name="Initial mass function",
...                   description="This is my IMF plot detailed description...")
>>> sn34.datafiles.add(imf_df)
```

And then embed files from your local filesystem into the Datafile (the file raw byte array will be imported along with the original file *name* and *last modification date*):

```
>>> from astrophysix.simdm.datafiles import image
>>> from astrophysix.utils.file import FileType
>>>
>>> # Attach files to datafile
>>> imf_df[FileType.PNG_FILE] = os.path.join("/data", "io", "datafiles", "plot_image_
↪IMF.png")
>>> jpg_fpath = os.path.join("/data", "io", "datafiles", "plot_with_legend.jpg")
>>> imf_df[FileType.JPEG_FILE] = image.JpegImageFile.load_file(jpg_fpath)
>>> imf_df[FileType.HDF5_FILE] = os.path.join("/data", "io", "HDF5", "stars.h5")
```

Anyone can reopen your *SimulationStudy* HDF5 file, read the attached files and re-export them on their local filesystem to retrieve a carbon copy of your original file:

```
>>> imf_df[FileType.JPEG_FILE].save_to_disk("/home/user/Desktop/export_plot.jpg")
File '/home/user/Desktop/export_plot.jpg' saved
```

See also:

- *Datafile* API references,
- *Results and associated datafiles* detailed section.

Full example script

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-
# This file is part of the 'astrophysix' Python package.
#
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#
from __future__ import print_function, unicode_literals
import os
import numpy as N

from astrophysix.simdm import SimulationStudy, Project, ProjectCategory
from astrophysix.simdm.catalogs import TargetObject, ObjectProperty, PropertySortFlag,
↪ PropertyFilterFlag, \
    ObjectPropertyGroup, Catalog, CatalogField
from astrophysix.simdm.experiment import Simulation, AppliedAlgorithm,␣
↪ParameterSetting, ParameterVisibility,\
    ResolvedPhysicalProcess
from astrophysix.simdm.protocol import SimulationCode, AlgoType, Algorithm,␣
↪InputParameter, PhysicalProcess, Physics
from astrophysix.simdm.results import GenericResult, Snapshot
from astrophysix.simdm.datafiles import Datafile, PlotType, PlotInfo
from astrophysix.utils.file import FileType
from astrophysix import units as U

# ------------------------------------------------ Project creation -------------------
↪-------------------------------- #
# Available project categories are :
# - ProjectCategory.SolarMHD
# - ProjectCategory.PlanetaryAtmospheres
# - ProjectCategory.StarPlanetInteractions
# - ProjectCategory.StarFormation
# - ProjectCategory.Supernovae
# - ProjectCategory.GalaxyFormation
# - ProjectCategory.GalaxyMergers
# - ProjectCategory.Cosmology
proj = Project(category=ProjectCategory.StarFormation, project_title="Frig",
               alias="FRIG", short_description="Short description of my 'FRIG' project
↪",
               general_description="""This is a pretty long description for my project
↪""",
```

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```
                data_description="The data available in this project...", directory_
↪path="/path/to/project/data/")
print(proj)  # "[Star formation] 'Frig' project"
# ------------------------------------------------------------------------------------
↪-------------------------------- #


# ---------------------------------------- Simulation code definition -----------------
↪-------------------------------- #
ramses = SimulationCode(name="Ramses 3 (MHD)", code_name="Ramses", code_version="3.10.
↪1", alias="RAMSES_3",
                        url="https://www.ics.uzh.ch/~teyssier/ramses/RAMSES.html",
                        description="This is a fair description of the Ramses code")
# => Add algorithms : available algorithm types are :
# - AlgoType.StructuredGrid
# - AlgoType.AdaptiveMeshRefinement
# - AlgoType.VoronoiMovingMesh
# - AlgoType.SpectralMethod
# - AlgoType.SmoothParticleHydrodynamics
# - AlgoType.Godunov
# - AlgoType.PoissonMultigrid
# - AlgoType.PoissonConjugateGradient
# - AlgoType.ParticleMesh
# - AlgoType.NBody
# - AlgoType.FriendOfFriend
# - AlgoType.HLLCRiemann
# - AlgoType.RayTracer
# - AlgoType.RadiativeTransfer
# - AlgoType.RungeKutta
amr = ramses.algorithms.add(Algorithm(algo_type=AlgoType.AdaptiveMeshRefinement,␣
↪description="AMR descr"))
ramses.algorithms.add(Algorithm(algo_type=AlgoType.Godunov, description="Godunov␣
↪scheme"))
ramses.algorithms.add(Algorithm(algo_type=AlgoType.HLLCRiemann, description="HLLC␣
↪Riemann solver"))
ramses.algorithms.add(Algorithm(algo_type=AlgoType.PoissonMultigrid, description=
↪"Multigrid Poisson solver"))
ramses.algorithms.add(Algorithm(algo_type=AlgoType.ParticleMesh, description="PM␣
↪solver"))

# => Add input parameters
ramses.input_parameters.add(InputParameter(key="levelmin", name="Lmin",
                                           description="min. level of AMR refinement
↪"))
lmax = ramses.input_parameters.add(InputParameter(key="levelmax", name="Lmax",
                                                  description="max. level of AMR␣
↪refinement"))

# => Add physical processes : available physics are :
# - Physics.SelfGravity
# - Physics.ExternalGravity
# - Physics.Hydrodynamics
# - Physics.MHD
# - Physics.StarFormation
# - Physics.SupernovaeFeedback
# - Physics.AGNFeedback
# - Physics.SupermassiveBlackHoleFeedback
```

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```
# - Physics.StellarIonisingRadiation
# - Physics.StellarUltravioletRadiation
# - Physics.StellarInfraredRadiation
# - Physics.ProtostellarJetFeedback
# - Physics.Chemistry
# - Physics.AtomicCooling
# - Physics.DustCooling
# - Physics.MolecularCooling
# - Physics.TurbulentForcing
# - Physics.RadiativeTransfer

ramses.physical_processes.add(PhysicalProcess(physics=Physics.StarFormation,␣
↪description="descr sf"))
ramses.physical_processes.add(PhysicalProcess(physics=Physics.Hydrodynamics,␣
↪description="descr hydro"))
grav = ramses.physical_processes.add(PhysicalProcess(physics=Physics.SelfGravity,␣
↪description="descr self G"))
ramses.physical_processes.add(PhysicalProcess(physics=Physics.SupernovaeFeedback,␣
↪description="SN feedback"))
# ------------------------------------------------------------------------------------
↪-------------------------------- #


# ------------------------------------------- Simulation setup ----------------------
↪-------------------------------- #
simu = Simulation(simu_code=ramses, name="My most important simulation", alias="SIMU_1
↪", description="Simu description",
                  execution_time="2020-03-01 18:45:30", directory_path="/path/to/my/
↪project/simulation/data/")
proj.simulations.add(simu)

# Add applied algorithms implementation details. Warning : corresponding algorithms␣
↪must have been added in the 'ramses'
# simulation code.
simu.applied_algorithms.add(AppliedAlgorithm(algorithm=amr, details="My AMR␣
↪implementation [Teyssier 2002]"))
simu.applied_algorithms.add(AppliedAlgorithm(algorithm=ramses.algorithms[AlgoType.
↪HLLCRiemann.name],
                                             details="My Riemann solver␣
↪implementation [Teyssier 2002]"))

# Add parameter setting. Warning : corresponding input parameter must have been added␣
↪in the 'ramses' simulation code.
# Available parameter visibility options are :
# - ParameterVisibility.NOT_DISPLAYED
# - ParameterVisibility.ADVANCED_DISPLAY
# - ParameterVisibility.BASIC_DISPLAY
simu.parameter_settings.add(ParameterSetting(input_param=ramses.input_parameters["Lmin
↪"], value=8,
                                             visibility=ParameterVisibility.BASIC_
↪DISPLAY))
simu.parameter_settings.add(ParameterSetting(input_param=lmax, value=12,
                                             visibility=ParameterVisibility.BASIC_
↪DISPLAY))

# Add resolved physical process implementation details. Warning : corresponding␣
↪physical process must have been added to
```

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```
# the 'ramses' simulation code
simu.resolved_physics.add(ResolvedPhysicalProcess(physics=ramses.physical_
↪processes[Physics.StarFormation.name],
                                                  details="Star formation specific␣
↪implementation"))
simu.resolved_physics.add(ResolvedPhysicalProcess(physics=grav, details="self-gravity␣
↪specific implementation"))
# ------------------------------------------------------------------------------------
↪---------------------------------- #


# ------------------------------------ Simulation generic result and snapshots -----
↪---------------------------------- #
# Generic result
gres = GenericResult(name="Key result 1 !", description="My description", directory_
↪path="/my/path/to/result")
simu.generic_results.add(gres)

# Simulation snapshot
# In one-line
sn = simu.snapshots.add(Snapshot(name="My best snapshot !", description="My first␣
↪snapshot description",
                                 time=(125, U.kyr), physical_size=(250.0, U.kpc),␣
↪directory_path="/path/to/snapshot1",
                                 data_reference="OUTPUT_00056"))
# Or create snapshot, then add it to the simulation
sn2 = Snapshot(name="My second best snapshot !", description="My second snapshot␣
↪description", time=(0.26, U.Myr),
               physical_size=(0.25, U.Mpc), directory_path="/path/to/snapshot2", data_
↪reference="OUTPUT_00158")
simu.snapshots.add(sn2)
# ------------------------------------------------------------------------------------
↪---------------------------------- #


# ------------------------------------------------- Result datafiles --------------
↪---------------------------------- #
# Datafile creation
imf_df = sn.datafiles.add(Datafile(name="Initial mass function plot",
                                   description="This is my plot detailed description
↪"))

# Add attached files to a datafile (1 per file type). Available file types are :
# - FileType.HDF5_FILE
# - FileType.PNG_FILE
# - FileType.JPEG_FILE
# - FileType.FITS_FILE
# - FileType.TARGZ_FILE
# - FileType.PICKLE_FILE
# - FileType.JSON_FILE
# - FileType.CSV_FILE
# - FileType.ASCII_FILE
imf_df[FileType.PNG_FILE] = os.path.join("/data", "io", "datafiles", "plot_image_IMF.
↪png")
imf_df[FileType.JPEG_FILE] = os.path.join("/data", "io", "datafiles", "plot_with_
↪legend.jpg")
imf_df[FileType.FITS_FILE] = os.path.join("/data", "io", "datafiles", "cassiopea_A_0.
↪5-1.5keV.fits")
```

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```
imf_df[FileType.TARGZ_FILE] = os.path.join("/data", "io", "datafiles", "archive.tar.gz
↪")
imf_df[FileType.JSON_FILE] = os.path.join("/data", "io", "datafiles", "test_header_
↪249.json")
imf_df[FileType.ASCII_FILE] = os.path.join("/data", "io", "datafiles", "abstract.txt")
imf_df[FileType.HDF5_FILE] = os.path.join("/data", "io", "HDF5", "study.h5")
imf_df[FileType.PICKLE_FILE] = os.path.join("/data", "io", "datafiles", "dict_saved.
↪pkl")

# Datafile plot information (for plot future updates and online interactive␣
↪visualisation on Galactica web pages).
# Available plot types are :
# - LINE_PLOT
# - SCATTER_PLOT
# - HISTOGRAM
# - HISTOGRAM_2D
# - IMAGE
# - MAP_2D
imf_df.plot_info = PlotInfo(plot_type=PlotType.LINE_PLOT, xaxis_values=N.array([10.0,␣
↪20.0, 30.0, 40.0, 50.0]),
                            yaxis_values=N.array([1.256, 2.456, 3.921, 4.327, 5.159]),
↪ xaxis_log_scale=False,
                            yaxis_log_scale=False, xaxis_label="Mass", yaxis_label=
↪"Probability", xaxis_unit=U.Msun,
                            plot_title="Initial mass function", yaxis_unit=U.Mpc)
# ------------------------------------------------------------------------------------
↪--------------------------------- #


# ------------------------------------------------------ Result products --------------
↪--------------------------------- #
# Target object properties have filter/sort flags to display them in various␣
↪configurations on Galactica. Available
# flag values are :
# - PropertyFilterFlag.NO_FILTER
# - PropertyFilterFlag.BASIC_FILTER
# - PropertyFilterFlag.ADVANCED_FILTER

# - PropertySortFlag.NO_SORT
# - PropertySortFlag.BASIC_SORT
# - PropertySortFlag.ADVANCED_SORT
tobj = TargetObject(name="Spiral galaxy", description="Disk-like galaxy with spiral␣
↪arms and sometimes bars")
vx = tobj.object_properties.add(ObjectProperty(property_name="v_x", sort_
↪flag=PropertySortFlag.ADVANCED_SORT,
                                                unit=U.km_s, filter_
↪flag=PropertyFilterFlag.BASIC_FILTER,
                                                description="Galaxy global velocity␣
↪coordinate along x-axis"))
vy = tobj.object_properties.add(ObjectProperty(property_name="v_y", sort_
↪flag=PropertySortFlag.NO_SORT,
                                                unit=U.km_s, filter_
↪flag=PropertyFilterFlag.BASIC_FILTER,
                                                description="Galaxy global velocity␣
↪coordinate along x-axis"))
vz = tobj.object_properties.add(ObjectProperty(property_name="v_z", sort_
↪flag=PropertySortFlag.NO_SORT,
```

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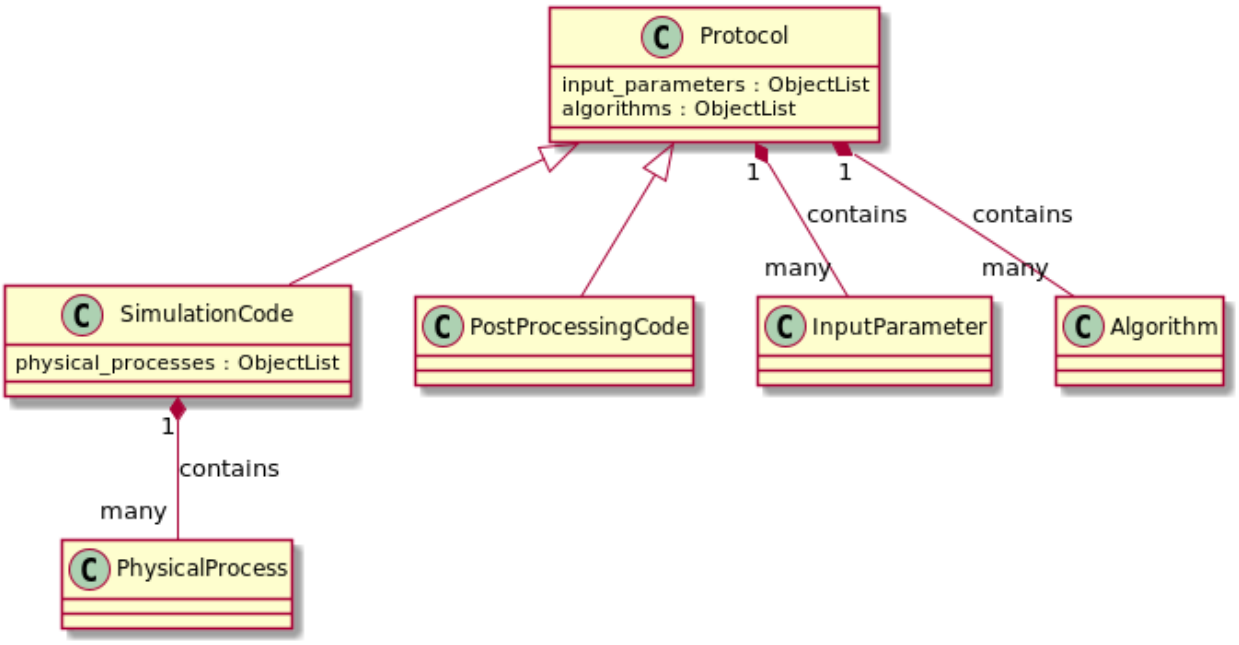
```
                                                    unit=U.km_s, filter_
↪flag=PropertyFilterFlag.BASIC_FILTER,
                                                    description="Galaxy global velocity␣
↪coordinate along x-axis"))
# Property group (optional)
vg = tobj.property_groups.add(ObjectPropertyGroup(group_name="v", description="galaxy␣
↪velocity"))
vg.group_properties.add(vx)
vg.group_properties.add(vy)
vg.group_properties.add(vz)

# Target object catalog + field value arrays
cat = sn.catalogs.add(Catalog(target_object=tobj, name="Spiral galaxy filtered catalog
↪",
                              description="Full description of my catalog containing␣
↪200 spiral galaxies."))
fvx = cat.catalog_fields.add(CatalogField(obj_prop=vx, values=N.random.
↪uniform(size=200)))
fvy = cat.catalog_fields.add(CatalogField(obj_prop=vy, values=N.random.
↪uniform(size=200)))
fvz = cat.catalog_fields.add(CatalogField(obj_prop=vz, values=N.random.
↪uniform(size=200)))

# Add datafiles to the catalog if required.
cdf1 = cat.datafiles.add(Datafile(name="My datafile", description="---"))
cdf1[FileType.PNG_FILE] = os.path.join("/data", "io", "datafiles", "plot_image_IMF.png
↪")
cdf2 = cat.datafiles.add(Datafile(name="My datafile (2)", description="---"))
cdf2[FileType.JPEG_FILE] = os.path.join("/data", "io", "datafiles", "plot_with_legend.
↪jpg")
# ------------------------------------------------------------------------------------
↪-------------------------------- #

# Save study in HDF5 file
study = SimulationStudy(project=proj)
study.save_HDF5("./frig_study.h5", galactica_checks=True)

# Eventually reload it from HDF5 file to edit its content
# study = SimulationStudy.load_HDF5("./frig_study.h5")
```

2.1.3 Protocols

Numerical codes used to produce simulation data or post-process them are called *Protocols* in the `Simulation Datamodel` vocabulary. They can be of two types :

- *`SimulationCode`* to run simulations,
- *`PostProcessingCode`* to post-process simulation data.

Any *Protocol* contains a set of *`Algorithm`* and a set of *`InputParameter`*. In addition, a *`SimulationCode`* contains a set of *`PhysicalProcess`* :



Simu/Post-pro codes

To initialize a *SimulationCode*, you only need to set *name* and *code_name* properties. Here is a more complete example of a *SimulationCode* initialization with all optional attributes :

```
>>> from astrophysix.simdm.protocol import SimulationCode
>>> ramses = SimulationCode(name="Ramses 3 (MHD)", code_name="RAMSES", code_version=
↪"3.10.1",
...                         alias="RAMSES_3", url="https://www.ics.uzh.ch/~teyssier/
↪ramses/RAMSES.html",
...                         description="This is a fair description of the Ramses code
↪")
```

The same applies to the initialization of a *PostProcessingCode*.

Warning: Setting the `SimulationCode.alias` and `PostProcessingCode.alias` properties is necessary only if you wish to upload your study on the Galactica simulation database. See *Why an alias ?* and *How can I check validity for Galactica ?*

See also:

- *SimulationCode* API reference,
- *PostProcessingCode* API reference,
- *Experiments* section.

Input parameters

To add *InputParameter* objects into any *Protocol*, use :

- *SimulationCode.input_parameters* for a *SimulationCode*,
- *PostProcessingCode.input_parameters* for a *PostProcessingCode*.

```
>>> from astrophysix.simdm.protocol import InputParameter
>>> # One-liner
>>> lmin = ramses.input_parameters.add(InputParameter(key="levelmin", name="Lmin",
...                                                   description="min. level of AMR␣
↪refinement"))
# Or
>>> lmax = InputParameter(key="levelmax", name="Lmax", description="max. level of AMR␣
↪refinement")
>>> ramses.input_parameters.add(lmax)
```

To initialize an *InputParameter*, only the *InputParameter.name* property must be set :

```
>>> # Input parameters should be initialised with at least a 'name' attribute.
>>> rho_min = InputParameter()
AttributeError : Input parameter 'name' attribute is not defined (mandatory).
```

See also:

InputParameter API reference.

Algorithms

To add *Algorithm* objects into any *Protocol*, use :

- *SimulationCode.algorithms* for a *SimulationCode*,
- *PostProcessingCode.algorithms* for a *PostProcessingCode*.

```
>>> from astrophysix.simdm.protocol import Algorithm, AlgoType
>>> # One-liner
>>> voronoi = arepo.algorithms.add(Algorithm(algo_type=AlgoType.VoronoiMovingMesh,
...                                          description="Moving mesh based on a␣
↪Voronoi-Delaunay tesselation."))
# Or
>>> voronoi = Algorithm(algo_type=AlgoType.VoronoiMovingMesh,
...                     description="Moving mesh based on a Voronoi-Delaunay␣
↪tesselation.")
>>> arepo.algorithms.add(voronoi)
```

To initialize an *Algorithm*, only the *Algorithm.algo_type* property must be set :

```
>>> # Algorithm should be initialised with at least an 'algo_type' attribute.
>>> algo = Algorithm()
AttributeError : Algorithm 'algo_type' attribute is not defined (mandatory).
```

Available algorithm types are :

- *AlgoType.StructuredGrid*
- *AlgoType.AdaptiveMeshRefinement*
- *AlgoType.SmoothParticleHydrodynamics*

- *AlgoType.VoronoiMovingMesh*
- *AlgoType.SpectralMethod*
- *AlgoType.Godunov*
- *AlgoType.PoissonMultigrid*
- *AlgoType.PoissonConjugateGradient*
- *AlgoType.ParticleMesh*
- *AlgoType.NBody*
- *AlgoType.FriendOfFriend*
- *AlgoType.HLLCRiemann*
- *AlgoType.RayTracer*
- *AlgoType.RadiativeTransfer*
- *AlgoType.RungeKutta*

See also:

Algorithm and *AlgoType* API references.

Physical processes

Note: For *SimulationCode* only.

To add *PhysicalProcess* objects into a *SimulationCode*, use the *SimulationCode.physical_processes* property.

```
>>> from astrophysix.simdm.protocol import PhysicalProcess, Physics
>>> # One-liner
>>> sf = ramses.physical_processes.add(PhysicalProcess(physics=Physics.StarFormation,
...                                                    description="Conversion of gas␣
↪into massive star particles."))
# Or
>>> sf = PhysicalProcess(physics=Physics.StarFormation, description="Conversion of␣
↪gas into massive star particles.")
>>> ramses.physical_processes.add(sf)
```

To initialize a *PhysicalProcess*, only the *PhysicalProcess.physics* property must be set :

```
>>> # PhysicalProcess should be initialised with at least a 'physics' attribute.
>>> process = PhysicalProcess()
AttributeError : PhysicalProcess 'physics' attribute is not defined (mandatory).
```

Available physics are :

- *Physics.SelfGravity*
- *Physics.ExternalGravity*
- *Physics.Hydrodynamics*
- *Physics.MHD*
- *Physics.StarFormation*

- *Physics.RadiativeTransfer*
- *Physics.AGNFeedback*
- *Physics.SupernovaeFeedback*
- *Physics.SupermassiveBlackHoleFeedback*
- *Physics.StellarIonisingRadiation*
- *Physics.StellarUltravioletRadiation*
- *Physics.StellarInfraredRadiation*
- *Physics.ProtostellarJetFeedback*
- *Physics.DustCooling*
- *Physics.MolecularCooling*
- *Physics.AtomicCooling*
- *Physics.Chemistry*
- *Physics.TurbulentForcing*

See also:

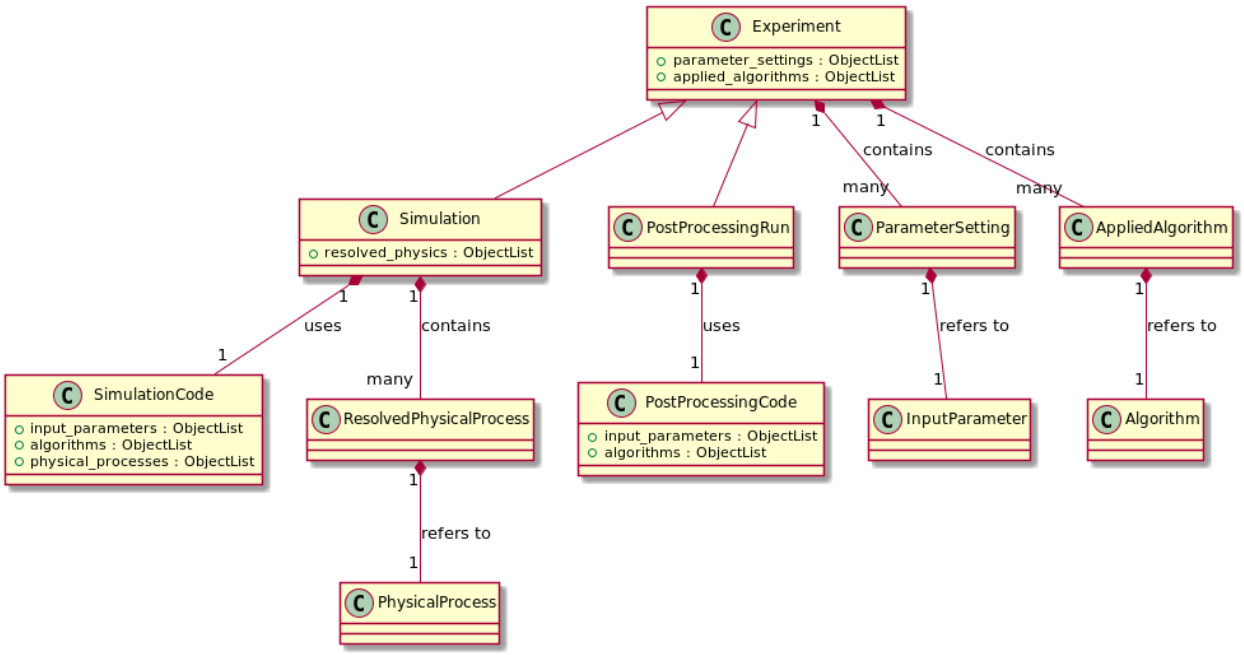
PhysicalProcess and *Physics* API references.

2.1.4 Experiments

In the `Simulation Datamodel` vocabulary, a numerical *Experiment* produces or post-processes scientific data. It can be of two types :

- *Simulation* (using `SimulationCode` as *Protocols*),
- *PostProcessingRun* (using `PostProcessingCode` as *Protocols*).

Any *Experiment* contains a set of *AppliedAlgorithm* and a set of *ParameterSetting*. In addition, a *Simulation* contains a set of *ResolvedPhysicalProcess* :



A strict binding is enforced between :

- an *Experiment*'s `ParameterSetting` and its *Protocol*'s `InputParameter`,
- an *Experiment*'s `AppliedAlgorithm` and its *Protocol*'s `Algorithm`,
- a `Simulation`'s `ResolvedPhysicalProcess` and its `SimulationCode`'s `PhysicalProcess`.

For more details, see *Strict protocol/experiment bindings*.

Simulation

To define a `Simulation`, only two attributes are mandatory :

- **name** : a non-empty string value,
- **simu_code** : a `SimulationCode` instance, (used to initialize the `Simulation.simulation_code` property).

a `Simulation` has an `execution_time` property that can be set to any string-formatted datetime following the `%Y-%m-%d %H:%M:%S` format.

Here is a more complete example of a `Simulation` initialization with all optional attributes :

```
>>> from astrophysix.simdm.protocol import SimulationCode
>>> from astrophysix.simdm.experiment import Simulation
>>>
>>> enzo = SimulationCode(name="", code_name="ENZO", code_version="2.6", alias="ENZO_
↪26,
...                       url="https://enzo-project.org/",
...                       description="This is a fair description of the ENZO AMR code
↪")
>>> simu = Simulation(simu_code=enzo, name="Cosmological simulation",
...                   alias="SIMU_A", description="Simu description",
...                   execution_time="2020-09-15 16:25:12",
...                   directory_path="/path/to/my/project/simulation/data/")
```

Warning: Setting the *Simulation.alias* property is necessary only if you wish to upload your study on the Galactica simulation database. See *Why an alias ?* and *How can I check validity for Galactica ?*

Post-processing run

Once a *Simulation* has been defined, you can add a *PostProcessingRun* into it, to initialize one, only two attributes are mandatory :

- **name** : a non-empty string value,
- **ppcode** : a *PostProcessingCode* instance, (used to initialize the *PostProcessingRun.postpro_code* property).

Here is a more complete example of how to initialize a *PostProcessingRun* with all optional attributes and add it into a *Simulation* :

```
>>> from astrophysix.simdm.protocol import PostProcessingCode
>>> from astrophysix.simdm.experiment import PostProcessingRun
>>>
>>> hop = PostProcessingCode(name="Hop", code_name="HOP")
>>> pprun = PostProcessingRun(name="Overdense structure detection", ppcode=hop,
...                           alias="HOP_DETECTION"
...                           description="This is the description of my HOP post-
↪processing " \
...                                       "run to detect overdense gas structures in
↪" \
...                                       "the star-forming ISM.",
...                           directory_path="/path/to/my/hop_catalogs")
>>> simu.post_processing_runs.add(pprun)
```

Warning: Setting the *PostProcessingRun.alias* property is necessary only if you wish to upload your study on the Galactica simulation database. See *Why an alias ?* and *How can I check validity for Galactica ?*

Parameter settings

To define the value you used for an input parameter of your code in a given simulation (or post-processing) run, you can define a *ParameterSetting*. To do so, you must :

- make a reference to the associated code *InputParameter* : **input_param** attribute,
- give a value (`float`, `int`, `string`, `bool`) : **value** attribute,
- Optionally, you can set a **visibility** flag : *ParameterVisibility* (default to *BASIC_DISPLAY*), only used by the Galactica web app., for display purposes.

Available parameter setting *visibility* options are :

- *ParameterVisibility.NOT_DISPLAYED*,
- *ParameterVisibility.ADVANCED_DISPLAY*,
- *ParameterVisibility.BASIC_DISPLAY*.

Finally, use the *parameter_settings* property to add it into your run. Here is an example :

```
>>> from astrophysix.simdm.experiment import ParameterSetting
>>>
>>> set_levelmin = ParameterSetting(input_param=ramses.input_parameters['levelmin'],
...                                 value=8,
...                                 visibility=ParameterVisibility.ADVANCED_DISPLAY)
>>> simu.parameter_settings.add(set_levelmin)
>>> set_levelmax = simu.parameter_settings.add(ParameterSetting(input_param=lmax,
...                                                             value=12))
```

Warning: A *ParameterSetting* is strictly bound to its *Experiment*'s *Protocol*'s *InputParameter* instance, see *Strict protocol/experiment bindings* for details.

Applied algorithms

To define which algorithms were enabled in a given simulation (or post-processing) run and what were their implementation details, you can define a *AppliedAlgorithm*. To do so, you must :

- make a reference to the associated code *Algorithm* : **algorithm** attribute,
- optionally provide an implementation details (`string`) : **details** attribute.

Finally, use the *applied_algorithms* property to add it into your run. Here is an example :

```
>>> from astrophysix.simdm.experiment import AppliedAlgorithm
>>>
>>> app_amr = AppliedAlgorithm(algorithm=ramses.algorithms[AlgoType.
↪AdaptiveMeshRefinement.name],
...                            details="Fully threaded tree AMR implementation␣
↪[Teyssier 2002].")
>>> ramses_simu.applied_algorithms.add(app_amr)
```

Warning: A *AppliedAlgorithm* is strictly bound to its *Experiment*'s *Protocol*'s *Algorithm* instance, see *Strict protocol/experiment bindings* for details.

Resolved physical processes (for Simulation only)

To define which physical processes were resolved in a given simulation run and what were their implementation details, you can define a *ResolvedPhysicalProcess*. To do so, you must :

- make a reference to the associated *SimulationCode*'s *PhysicalProcess* : **physics** attribute,
- optionally provide an implementation details (`string`) : **details** attribute.

Finally, use the *resolved_physics* property to add it into your run. Here is an example :

```
>>> from astrophysix.simdm.experiment import ResolvedPhysicalProcess
>>>
>>> res_sf = ResolvedPhysicalProcess(physics=ramses.physical_processes[Physics.
↪StarFormation.name],
...                                  details="Star formation specific implementation
↪")
>>> simu.resolved_physics.add(res_sf)
>>> res_sgrav = ResolvedPhysicalProcess(physics=ramses.physical_processes[Physics.
↪SelfGravity.name],
```

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```
                                                details="Self-gravity implementation (gas +␣
↪particles)"))
>>> simu.resolved_physics.add(res_sgrav)
```

Warning: A *ResolvedPhysicalProcess* is strictly bound to its *Simulation*'s *SimulationCode*'s *PhysicalProcess* instance, see *Strict protocol/experiment bindings* for details.

Strict protocol/experiment bindings

When you manipulate *Experiment* class objects (*Simulation* or *PostProcessingRun*) and *Protocol* class objects (*SimulationCode* or *PostProcessingCode*) and when you link objects together, `astrophysix` makes sure for you that your entire study hierarchical structure remains consistent at all times :

- upon object creation,
- upon object addition into another object,
- upon object deletion from another object.

Upon object creation

You are free to create any kind of `astrophysix` object, even those *linked* to another object :

```
>>> from astrophysix.simdm.protocol import InputParameter
>>> from astrophysix.simdm.experiment import ParameterSetting
>>>
>>> lmin = InputParameter(key="levelmin", name="Lmin", description="min. level of AMR␣
↪refinement"))
>>> set_levelmin = ParameterSetting(input_param=lmin, value=9))
```

There is no risk of breaking your study hierarchical structure consistency.

Upon object addition

To avoid *dangling* references into the study hierarchical structure, `astrophysix` will prevent you from :

- Adding a *ParameterSetting* object into the *parameter_settings* list of an *Experiment* if its associated *InputParameter* does not **already** belong to the *Experiment*'s *Protocol*'s *input_parameters* list,
- Adding a *AppliedAlgorithm* object into the *applied_algorithms* list of an *Experiment* if its associated *Algorithm* does not **already** belong to the *Experiment*'s *Protocol*'s *algorithms* list,
- Adding a *ResolvedPhysicalProcess* object into the *resolved_physics* list of a *Simulation* if its associated *PhysicalProcess* does not **already** belong to the *Simulation*'s *SimulationCode*'s *physical_processes* list.

I know it is a bit convoluted, let's see an example :

```
>>> from astrophysix.simdm.protocol import SimulationCode, InputParameter, Algorithm,␣
↪\
                                          PhysicalProcess, AlgoType, Physics
```

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```
>>> from astrophysix.simdm.experiment import Simulation, ParameterSetting, \
                                             AppliedAlgorithm, ResolvedPhysicalProcess
>>>
>>> amr_code = SimulationCode(name="My AMR code", code_name="Proto_AMR")
>>> simu = Simulation(simu_code=amr_code, name="My test run")

>>> # ------------------- Input parameters -----------------------------
>>> lmin = InputParameter(key="levelmin", name="Lmin")
>>> set_levelmin = ParameterSetting(input_param=lmin, value=9)
>>> simu.parameter_settings.add(set_levelmin) # => Error
AttributeError: Simulation '[Lmin = 9] parameter setting' does not refer
to one of the input parameters of '[My AMR code] simulation code'.
>>>
>>> # Add first the input parameter into the code,
>>> amr_code.input_parameters.add(lmin)
>>> # THEN add the parameter setting into the simulation.
>>> simu.parameter_settings.add(set_levelmin) # => Ok
>>> # ------------------------------------------------------------------
>>>
>>> # ------------------- Applied algorithms ---------------------------
>>> amr_algo = Algorithm(algo_type=AlgoType.AdaptiveMeshRefinement)
>>> app_amr = AppliedAlgorithm(algorithm=amr_algo)
>>> simu.applied_algorithms.add(app_amr) # Error
AttributeError: Simulation '[Adaptive mesh refinement] applied algorithm'
does not refer to one of the algorithms of '[My AMR code] simulation code'.
>>>
>>> # Add first the algorithm into the code
>>> amr_code.algorithms.add(amr_algo)
>>> # THEN add the applied algorithm  into the simulation
>>> simu.applied_algorithms.add(app_amr)
>>> # ------------------------------------------------------------------
>>>
>>> # ---------------- Resolved physical processes ---------------------
>>> sf_process = PhysicalProcess(physics=Physics.StarFormation)
>>> res_sf = ResolvedPhysicalProcess(physics=sf_process)
>>> simu.resolved_physics.add(res_sf) # Error
AttributeError: Simulation '[Star formation] resolved physical process'
does not refer to one of the physical processes of '[My AMR code] simulation code'.
>>>
>>> # Add first the physical process into the code
>>> amr_code.physical_processes.add(sf_process)
>>> # THEN add the resolved physical process into the simulation
>>> simu.resolved_physics.add(res_sf)
>>> # ------------------------------------------------------------------
```

Upon object deletion

To avoid missing references into the study hierarchical structure, `astrophysix` will also prevent you from :

- Deleting a *`InputParameter`* object from a *Protocol*'s *`input_parameters`* list if any *Experiment* associated to that *Protocol* contains a *`ParameterSetting`* that refers to the input parameter to be deleted,
- Deleting a *`Algorithm`* object from a *Protocol*'s *`algorithms`* list if any *Experiment*'s associated to that *Protocol* contains a *`AppliedAlgorithm`* that refers to the algorithm to be deleted,
- Deleting a *`PhysicalProcess`* object from a `SimulationCode`'s *`physical_processes`* list if any

Simulation associated to that *SimulationCode* contains a *ResolvedPhysicalProcess* that refers to the physical process to be deleted.

I know it is a bit convoluted, let's see an example :

```
>>> from astrophysix.simdm.protocol import SimulationCode, InputParameter, Algorithm,␣
↪\
                                        PhysicalProcess, AlgoType, Physics
>>> from astrophysix.simdm.experiment import Simulation, ParameterSetting, \
                                          AppliedAlgorithm, ResolvedPhysicalProcess
>>> amr_code = SimulationCode(name="My AMR code", code_name="Proto_AMR")
>>> simu = Simulation(simu_code=amr_code, name="My test run")
>>>
>>> # ------------------- Input parameters -----------------------------
>>> lmin = InputParameter(key="levelmin", name="Lmin")
>>> amr_code.input_parameters.add(lmin)
>>> set_levelmin = ParameterSetting(input_param=lmin, value=9)
>>> simu.parameter_settings.add(set_levelmin)
>>> del amr_code.input_parameters[lmin]
AttributeError: '[levelmin] 'Lmin' input parameter' cannot be deleted, the following␣
↪items depend
on it (try to delete them first) : ['My test run' simulation [Lmin = 9] parameter␣
↪setting].
>>>
>>> # Delete the parameter setting from the simulation first,
>>> del simu.parameter_settings[set_levelmin]
>>> # THEN delete the input parameter from the code.
>>> del amr_code.input_parameters[lmin] # => Ok
>>> # ------------------------------------------------------------------
>>>
>>> # ------------------- Applied algorithms ---------------------------
>>> amr_algo = Algortihm(algo_type=AlgoType.AdaptiveMeshRefinement)
>>> amr_code.algorithms.add(amr_algo)
>>> app_amr = AppliedAlgorithm(algorithm=amr_algo)
>>> simu.applied_algorithms.add(app_amr)
>>> del amr_code.algorithms[amr_algo]
AttributeError: ''Adaptive mesh refinement' algorithm' cannot be deleted, the␣
↪following items depend
on it (try to delete them first) : ['My test run' simulation [Adaptive mesh␣
↪refinement] applied algorithm].
>>>
>>> # Delete the applied algorithm from the simulation first,
>>> del simu.applied_algorithms[app_amr]
>>> # THEN delete the algorithms from the code
>>> del amr_code.algorithms[amr_algo] # => Ok
>>>
>>> # ------------------------------------------------------------------
>>>
>>> # ---------------- Resolved physical processes ---------------------
>>> sf_process = PhysicalProcess(physics=Physics.StarFormation)
>>> amr_code.physical_processes.add(sf_process)
>>> res_sf = ResolvedPhysicalProcess(physics=sf_process)
>>> simu.resolved_physics.add(res_sf)
>>> del amr_code.physical_processes[sf_process]
AttributeError: ''Star formation' physical process' cannot be deleted, the following␣
↪items depend
on it (try to delete them first) : ['My test run' simulation [Star formation]␣
↪resolved physical process].
```

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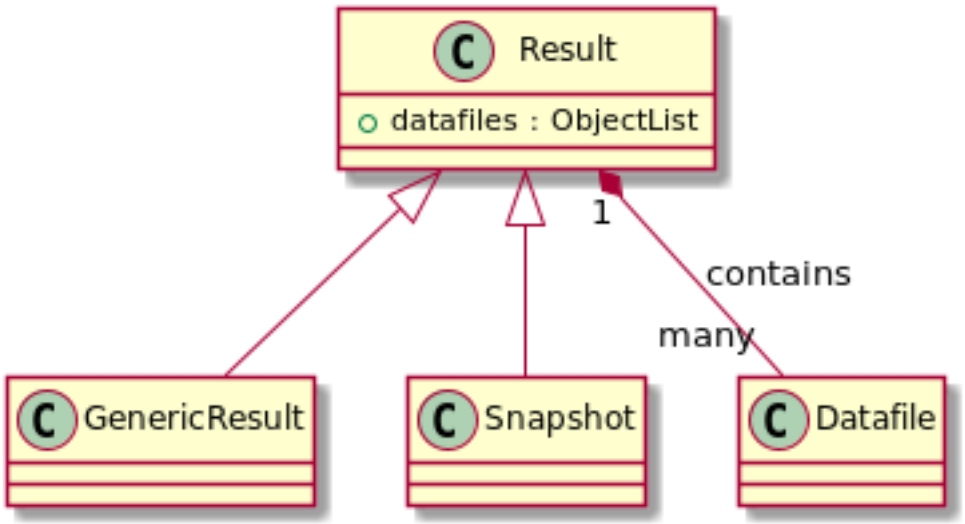
```
>>>
>>> # Delete the resolved physical process from the simulation first
>>> del simu.resolved_physics[res_sf]
>>> # THEN delete the physical process from the code
>>> del amr_code.physical_processes[sf_process] # => Ok
>>> # ------------------------------------------------------------------
```

2.1.5 Results and associated datafiles

To any *Experiment* (*Simulation* or *PostProcessingRun*), you can attach results of your scientific analysis. There are two kinds of result available in astrophysix:

- *GenericResult* : result **not strictly related to a particular instant** in the dynamical evolution of your numerical experiment (e.g. star formation history, solar activity cycles, planetary orbital decay, etc.),
- *Snapshot* : result **corresponding to a specific moment** during the numerical experiment (galactic pericentric passage, solar activity peak, star formation burst, etc.).



Generic result

Here is a full example on how to create a *GenericResult* object with all optional parameters and add it into an *Experiment*, using the *Simulation.generic_results* or *PostProcessingRun.generic_results* property :

```
>>> from astrophysix.simdm.results import GenericResult
>>>
>>> res1 = GenericResult(name="Star formation history",
...                      directory_path="/my/path/to/result",
...                      description="""This is the star formation history during
...                                     the 2 Myr of the galaxy major merger""")
>>> simu.generic_results.add(res1)
```

Snapshot

A *Snapshot* derives from a *GenericResult* object but with additional optional properties :

- *time*,
- *physical_size*,
- *data_reference*.

Here is a full example on how to create a *Snapshot* object and add it into any *Experiment*, using *Simulation.snapshots* or *PostProcessingRun.snapshots* property :

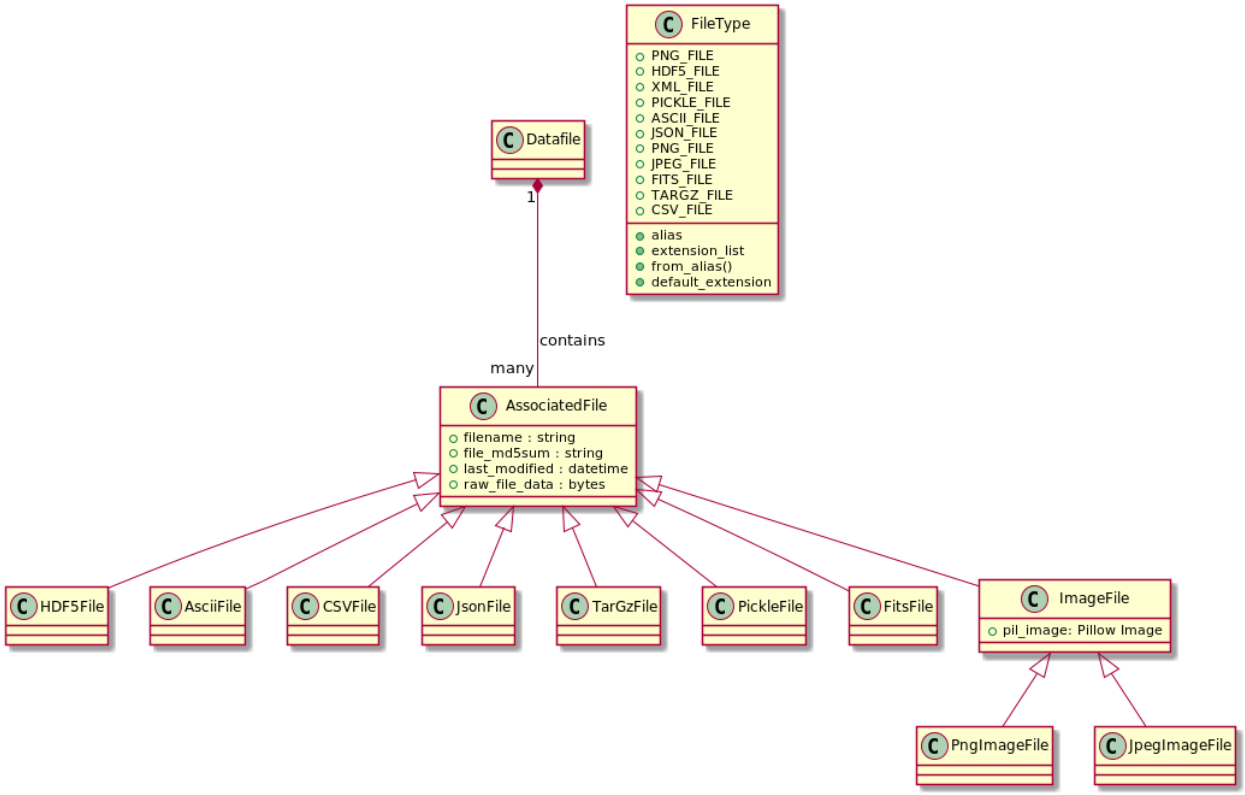
```
>>> from astrophysix.simdm.results import Snapshot
>>> from astrophysix import units as U

>>> sn34 = Snapshot(name="Third pericenter",
...                 time=(254.7, U.Myr),
...                 physical_size=(400.0, U,kpc),
...                 decription="""This snapshot corresponds to the third pericentric
...                               of the galactic major merger simulation, occurring
...                               around $t\simeq255 \; \\textrm{Myr}$.""",
...                 data_reference="34;Big_endian",
...                 directory_path="/my/path/to/galactic_merger/simu/outputs/output_
↪00034")
>>> simu.snapshots.add(sn34)
```

Note: The *Snapshot.data_reference* property is only used by the Galactica web application to provide a reference on your raw simulation data files to the on-demand post-processing services (see Terminus documentation.

Datafiles

One of the most important feature implemented in the `astrophysix` package is the possibility to insert documents into a *SimulationStudy* and to describe each one of them with meta-information.



To do so, you must create a *Datafile* (the *name* attribute is the only one mandatory) and then add it into your *Snapshot* (or *GenericResult*) using the *Snapshot.datafiles* (or *GenericResult.datafiles*) property :

```
>>> from astrophysix.simdm.datafiles import Datafile, PlotType, PlotInfo, image, file
>>> from astrophysix.utils.file import FileType, FileUtil
>>>
>>> imf_df = Datafile(name="Initial mass function",
...                   description="This is my IMF plot detailed description...")
>>> snapshot_100.datafiles.add(imf_df)
```

Attached files

Once created, a single *Datafile* can contain different files, but **at most one per** *FileType*. The available *FileType* values are :

- *FileType.HDF5_FILE*
- *FileType.PNG_FILE*
- *FileType.JPEG_FILE*
- *FileType.FITS_FILE*
- *FileType.TARGZ_FILE*
- *FileType.PICKLE_FILE*
- *FileType.JSON_FILE*
- *FileType.CSV_FILE*

- *FileType.ASCII_FILE*
- *FileType.XML_FILE*

To add files from your filesystem in a *Datafile*, you can do it in 2 steps (create first a *AssociatedFile* and then put it in the *Datafile*):

```
>>> import os
>>> from astrophysix.simdm.datafiles import image, file
>>>
>>> # JPEG image
>>> jpeg_filepath = os.path.join("/data", "path", "to", "my", "plots", "IMF_plot.jpg")
>>> jpeg_image_file = image.JpegImageFile.load_file(jpeg_filepath)
>>> imf_df[FileType.JPEG_FILE] = jpeg_image_file
>>>
>>> # HDF5 file
>>> hdf5_filepath = os.path.join("/data", "path", "to", "raw", "datasets", "all_stars.
↪h5")
>>> hdf5_file = file.HDF5File.load_file(hdf5_filepath)
>>> imf_df[FileType.HDF5_FILE] = hdf5_file
```

or if you are in a hurry, you can do it in a single one :

```
>>> import os
>>> from astrophysix.simdm.datafiles import image, file
>>>
>>> imf_df[FileType.JPEG_FILE] = os.path.join("/data", "path", "plots", "IMF_plot.jpg
↪")
>>> imf_df[FileType.HDF5_FILE] = os.path.join("/data", "path", "datasets", "all_stars.
↪h5")
```

To delete a file from a *Datafile* use the `del` Python operator:

```
>>> del imf_df[FileType.HDF_FILE]
```

The *AssociatedFile* contains your file raw byte array and has information on the original file (filename, last modification time). It can be used to re-export your file from your *SimulationStudy* to save it on your local filesystem (it even preserves the *last modification time* of the original file):

```
>>> jpeg_image_file = imf_df[FileType.JPEG_FILE]
>>> jpeg_image_file.last_modified
datetime.datetime(2020, 9, 22, 10, 42, 18, tzinfo=datetime.timezone.utc)
>>> saved_path = os.path.join("/home", "user", "Desktop", jpeg_image_file.filename)
>>> jpeg_image_file.save_to_disk(saved_path)
File '/home/user/Desktop/IMF_plot.jpg' saved
>>>
>>> import filecmp
>>> # Is the file saved identical to the original one ?
>>> filecmp.cmp(saved_path, jpeg_filepath, shallow=False)
True
>>>
>>> from astrophysix.utils.file import FileUtil
>>> from astrophysix.utils import DatetimeUtil
>>> # Was the file 'last modification time' preserved ?
>>> last_mod_tms = FileUtil.last_modification_timestamp(fpath)
>>> last_mod_dt = DatetimeUtil.utc_from_timestamp(last_mod_tms)
>>> last_mod_dt == jpeg_image_file.last_modified
True
```

Note: Since you can embed all your reduced data files into a *SimulationStudy*, you can safely remove your datafiles from your local filesystem and use the *SimulationStudy* HDF5 file as a self-contained, portable filesystem that you can exchange with your scientific collaborators.

Plot information

A *Datafile* can also have additional meta-information on a scientific plot for which you may already have attached PNG files (or JPEG, etc.). This meta-information can be used by other users to reproduce your plot or by the Galactica web application to display an interactive version of your plot online.

```
>>> from astrophysix.simdm.datafiles import PlotType, PlotInfo
>>> from astrophysix import units as U
>>>
>>> imf_df.plot_info = PlotInfo(plot_type=PlotType.LINE_PLOT, title="My plot title",
...                             xaxis_values=N.array([10.0, 20.0, , 22.0, 24.2, 30.
↪0]),
...                             yaxis_values=N.array([1.2, 35.2, 5.2, 21.2, 14.9]),
...                             xaxis_log_scale=False, yaxis_log_scale=True,
...                             xlabel="x-axis label", ylabel="y-axis label",
...                             xaxis_unit="Myr", yaxis_unit=U.kpc)
```

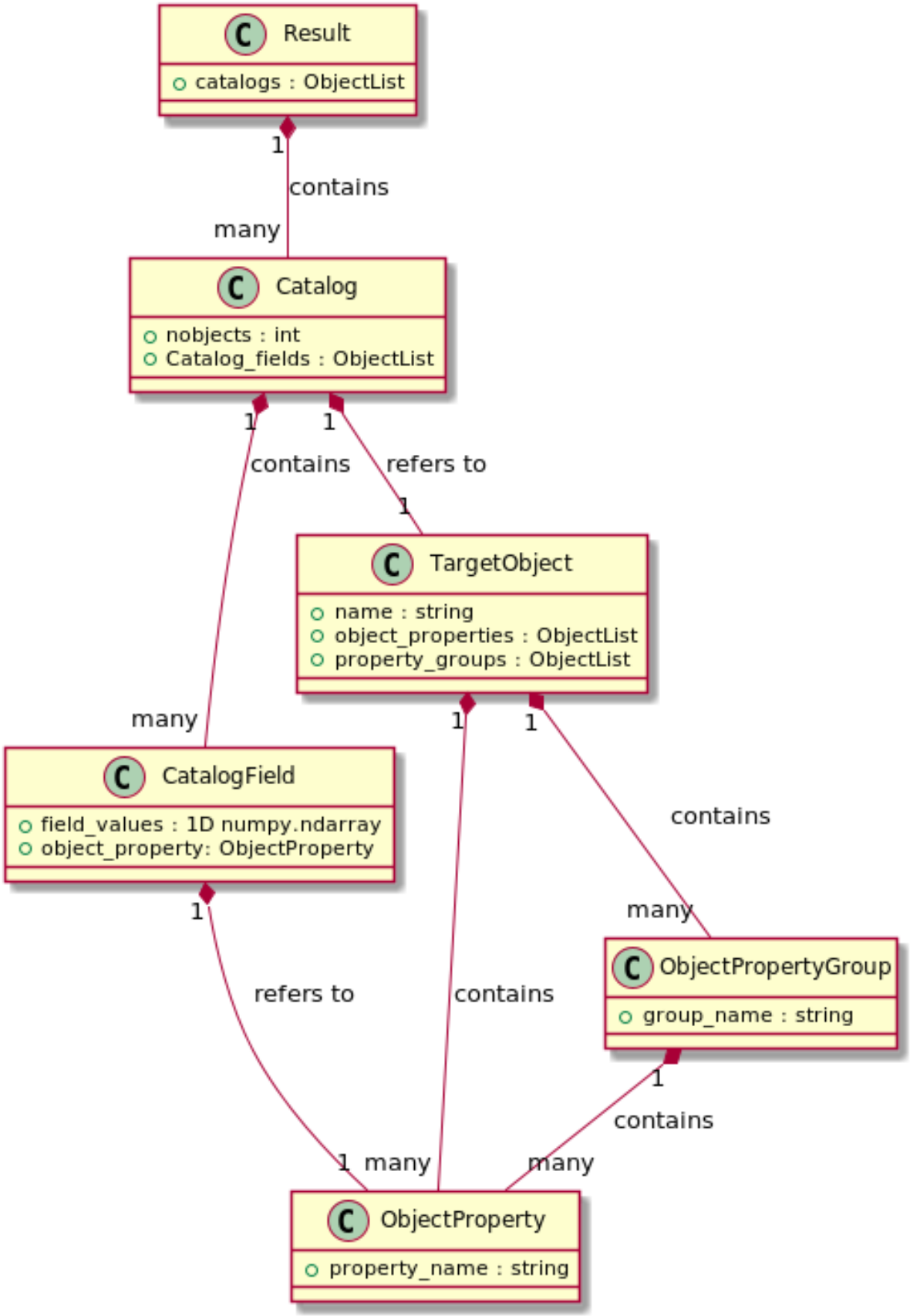
2.1.6 Target objects and object catalogs

New in version 0.5.0

Introduction

To any *Result* (*GenericResult* or *Snapshot*), you can attach catalogs of objects identified into your simulation data. The object types identified in any *Catalog* are described as *TargetObject* :

- Each *TargetObject* is qualified with a set of properties (*ObjectProperty* instances) that are optionally grouped in property groups (*ObjectPropertyGroup* instances) ,
- a *Catalog* gather a list of fields (*CatalogField* objects), each one referring to an *ObjectProperty* of the associated *TargetObject*.


Result
catalogs : ObjectList
1
contains
many
Catalog
nobjects : int
Catalog_fields : ObjectList
1
1
contains
refers to
1
TargetObject
name : string
object_properties : ObjectList
property_groups : ObjectList
many
1
1
CatalogField
field_values : 1D numpy.ndarray
object_property: ObjectProperty
contains
1
many
ObjectPropertyGroup
group_name : string
refers to
contains
1
contains
1 many
many
ObjectProperty
property_name : string

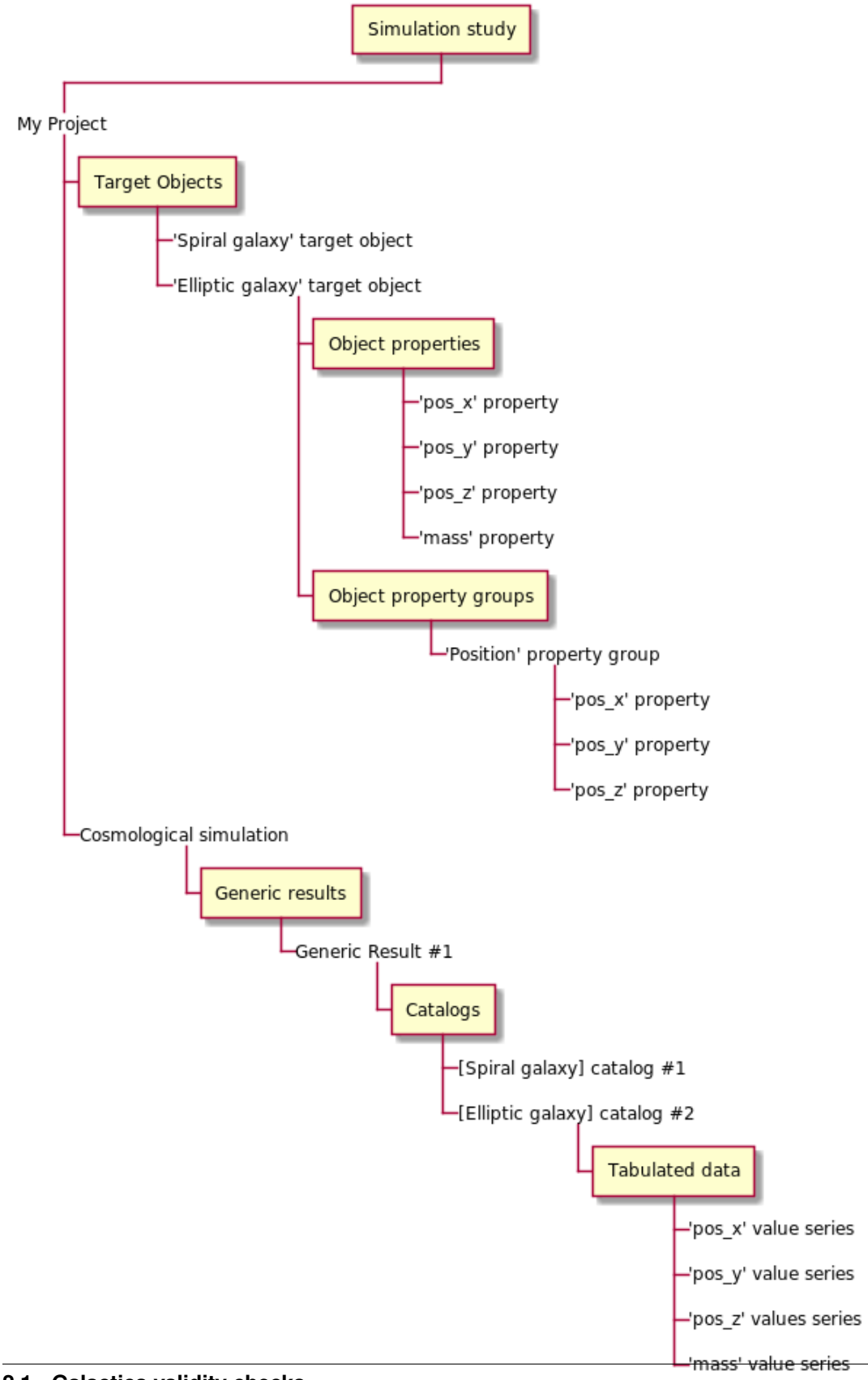
A strict binding is enforced between a *Catalog*'s *CatalogField* and its *TargetObject*'s *ObjectProperty*, see *Strict target object/catalog bindings* for more details.

The content of a *Catalog* can be represented as a table where :

- the **rows** correspond to the collection of *TargetObject* instances,
- the **columns** correspond to the different *CatalogField* objects.

As a consequence, a *Catalog* can be quite naturally converted into a pandas.DataFrame, using the *Catalog.to_pandas()* method.

Example study structure



Target object definition

Target objects define the type of items you will be able to characterize into a *Catalog*. To initialize a *TargetObject*, you only need to set its *name* property. Here is a more complete example of a `TargetObject` initialization with all optional attributes :

```
>>> from astrophysix.simdm.catalogs import TargetObject
>>> cluster = TargetObject(name="Galaxy cluster", description="My cluster object full␣
↪description")
```

See also:

- *TargetObject* API reference.

Target object properties

You can insert *ObjectProperty* into a *TargetObject* using its *object_properties* attribute :

```
>>> from astrophysix.simdm.catalogs import ObjectProperty
>>> # One-liner
>>> pos_x = cluster.object_properties.add(ObjectProperty(property_name="pos_x",
...                                                      description="x-axis position␣
↪of the cluster center of mass"))
# Or
>>> pos_x = ObjectProperty(property_name="pos_x",
...                        description="x-axis position of the cluster center of mass
↪")
>>> cluster.object_properties.add(pos_x)
```

To initialize an *ObjectProperty*, only the *ObjectProperty.property_name* property must be set :

```
>>> # Object properties should be initialised with at least a 'property_name'␣
↪attribute.
>>> unknown = ObjectProperty()
AttributeError : ObjectProperty 'property_name' attribute is not defined (mandatory).
```

Other optional *ObjectProperty* attributes are :

```
>>> from astrophysix.simdm.catalogs import PropertyFilterFlag, PropertySortFlag
>>> from astrophysix.simdm.utils import DataType
>>> from astrophysix import units as U
>>>
>>> mass = ObjectProperty(property_name="$M_{500}$", description="Cluster mass",
...                       filter_flag=PropertyFilterFlag.BASIC_FILTER,
...                       sort_flag=PropertySortFlag.BASIC_SORT,
...                       dtype=DataType.REAL, unit=1.0e9*U.Msun)
```

Available property filter flag enum values are :

- *PropertyFilterFlag.NO_FILTER*,
- *PropertyFilterFlag.BASIC_FILTER*,
- *PropertyFilterFlag.ADVANCED_FILTER*

and available property sort flag enum values are :

- *PropertySortFlag.NO_SORT*,

- *PropertySortFlag.BASIC_SORT*,
- *PropertySortFlag.ADVANCED_SORT*

Warning: Only *CatalogFields* associated to *ObjectProperty* instances with :

- *filter_flag* set to *PropertyFilterFlag.BASIC_FILTER* or *PropertyFilterFlag.ADVANCED_FILTER* will appear as *filter fields* in the online Galactica object catalog search form.
- *sort_flag* set to *PropertyFilterFlag.BASIC_SORT* or *PropertyFilterFlag.ADVANCED_SORT* will appear as *sortable fields* in the online Galactica object catalog search form.

See also:

- *ObjectProperty* API reference,
- *PropertyFilterFlag*, *PropertySortFlag* and *DataType* API references.

Object property groups

Optionally, you can group *ObjectProperty* instances in groups for better clarity in your workflow or enhanced display on the Galactica web application. You can insert *ObjectProperty* objects into a *ObjectPropertyGroup* with the *ObjectPropertyGroup.group_properties* attribute and include the *ObjectPropertyGroup* into your *TargetObject* using its *TargetObject.property_groups* attribute :

```
>>> from astrophysix.simdm.catalogs import ObjectPropertyGroup
>>>
>>> # Additional object properties (positions along y/z axes)
>>> pos_y = cluster.object_properties.add(ObjectProperty(property_name="pos_y"))
>>> pos_z = cluster.object_properties.add(ObjectProperty(property_name="pos_z"))
>>>
>>> # Velocity properties along x/y/z axes
>>> v_x = cluster.object_properties.add(ObjectProperty(property_name="v_x"))
>>> v_y = cluster.object_properties.add(ObjectProperty(property_name="v_y"))
>>> v_z = cluster.object_properties.add(ObjectProperty(property_name="v_z"))
>>>
>>> # Position property group
>>> pos = ObjectPropertyGroup(group_name="position", description="Cluster position")
>>> pos.group_properties.add(pos_x)
>>> pos.group_properties.add(pos_y)
>>> pos.group_properties.add(pos_z)
>>> cluster.property_groups.add(pos)
>>>
>>> # Veloicity property group
>>> vel = ObjectPropertyGroup(group_name="velocity", description="Cluster velocity")
>>> vel.group_properties.add(v_x)
>>> vel.group_properties.add(v_y)
>>> vel.group_properties.add(v_z)
>>> cluster.property_groups.add(vel)
```

To initialize an *ObjectPropertyGroup*, only the *ObjectProperty.property_name* property must be set :

```
>>> # Object property groups should be initialised with at least a 'group_name'␣
↪attribute.
>>> unknown = ObjectPropertyGroup()
```

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```
AttributeError : ObjectPropertyGroup 'group_name' attribute is not defined␣
↪(mandatory).
```

See also:

ObjectPropertyGroup API reference.

Catalog construction

To define a *Catalog*, only two attributes are mandatory :

- **name** : a non-empty string value,
- **target_object** : a *TargetObject* instance.

Here is a more complete example of a *Catalog* initialization with all optional attributes :

```
>>> from astrophysix.simdm.catalogs import TargetObject, Catalog
>>>
>>> cat = Catalog(target_object=cluster, name="Galaxy cluster catalog at $Z \simeq 2$
↪",
...               description="This is the catalog of all galaxy clusters identified␣
↪in the "
...               "simulation at redshift $Z\simeq 2$")
```

Setting catalog fields

Once the *Catalog* has been created, you can insert *CatalogField* objects in it, using the *Catalog.catalog_fields* property. To define a *CatalogField*, you must set :

- **obj_prop** : catalog's *TargetObject*'s *ObjectProperty* instance quantified in the field,
- **values** : 1D `numpy.ndarray` (numeric type) containing the values of the field for each object.

```
>>> from astrophysix.simdm.catalogs import CatalogField
>>>
>>> cat.catalog_fields.add(CatalogField(obj_prop=pos_x, values=N.random.
↪uniform(size=200))
>>> cat.catalog_fields.add(CatalogField(obj_prop=pos_y, values=N.random.
↪uniform(size=200))
>>> cat.catalog_fields.add(CatalogField(obj_prop=pos_z, values=N.random.
↪uniform(size=200))
>>> cat.catalog_fields.add(CatalogField(obj_prop=mass, values=N.array([...]))
```

Warning: Once the first *CatalogField* is inserted into a *Catalog*, it sets the number of objects contained in the *Catalog* (*values* 1D `numpy.ndarray` size). Every subsequent *CatalogField* addition into that *Catalog* **MUST** contain the same number of objects :

```
>>> cat.catalog_fields.add(CatalogField(obj_prop=vel_x, values=N.random.
↪uniform(size=300))
AttributeError: Cannot add a catalog field with 300 item values in a catalog␣
↪containing
200 items.
```

See also:

- *Catalog* and *CatalogField* API references,
- *How to add/remove objects in an existing Catalog ?*

Strict target object/catalog bindings

When you manipulate *TargetObject* and their *ObjectProperty* and *ObjectPropertyGroup*, and you link them to a *Catalog* and its list of *CatalogField* objects), astrophysix makes sure for you that your entire study hierarchical structure remains consistent at all times :

- upon object creation,
- upon object addition into another object,
- upon object deletion from another object.

Upon object creation

You are free to create any kind of astrophysix object, even those *linked* to another object :

```
>>> from astrophysix.simdm.catalogs import ObjectProperty
>>> from astrophysix.simdm.catalogs import CatalogField
>>>
>>> posy = ObjectProperty(property_name="pos_y")
>>> field_posy = CatalogField(obj_prop=posy, values=N.array([0.5, 0.6, 0.48, 0.65, 0.
↪49]))
```

There is no risk of breaking your study hierarchical structure consistency.

Upon object addition

To avoid *dangling* references into the study hierarchical structure, astrophysix will not let you :

- add a *CatalogField* object into the *catalog_fields* list of a *Catalog* if its associated *ObjectProperty* does not **already** belong to the *Catalog*'s *TargetObject*'s *object_properties* list,
- add an *ObjectPropertyGroup* into the *property_groups* list of a *TargetObject* if all the *ObjectProperty* it contains does not **already** belong to the *TargetObject*'s *object_properties* list.
- add a *ObjectProperty* object into a *ObjectPropertyGroup* contained in the *property_groups* list of a *TargetObject* if the *ObjectProperty* does not **already** belong to the *TargetObject*'s *object_properties* list.

Here are the examples :

```
>>> from astrophysix.simdm.catalogs import TargetObject, ObjectProperty, CatalogField,
↪ \
                                        Catalog
>>> # ------------------------------------------------------------------------------
↪ #
>>> tobj = TargetObject(name="Spiral galaxy")
>>> x = tobj.object_properties.add(ObjectProperty(property_name="pos_x"))
```

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```
>>> y = tobj.object_properties.add(ObjectProperty(property_name="pos_y"))
>>> z = ObjectProperty(property_name="pos_z")  # z not added in target object
>>> cat = Catalog(target_object=tobj, name="Spiral galaxy catalog")
>>> # Tries to add a catalog field with z property => error
>>> cat.catalog_fields.add(CatalogField(z, values=N.random.uniform(size=5))) # =>␣
↪Error
AttributeError: Cannot add catalog field. 'pos_z' target object property
is not a property of 'Spiral galaxy' target object.
>>>
>>> # Add first the 'pos_z' property into the 'Spiral galaxy' target object,
>>> tobj.object_properties.add(z)
>>> # THEN add the catalog field into the catalog
>>> cat.catalog_fields.add(CatalogField(z, values=N.random.uniform(size=5))) # => Ok
>>> # ------------------------------------------------------------------------------
↪ #
>>>
>>> # ------------------------------------------------------------------------------
↪ #
>>> alpha = ObjectProperty(property_name='alpha')
>>> delta = ObjectProperty(property_name='delta')
>>> beta = ObjectProperty(property_name='beta')
>>> g = ObjectPropertyGroup(group_name="Group1")
>>> # Tries to add properties to a group and then insert the group before the property
>>> # have been added to the TargetObject property list => raises an error
>>> g.group_properties.add(alpha)
>>> g.group_properties.add(delta)
>>> tobj.property_groups.add(g)
AttributeError: 'alpha' target object property does not belong to this TargetObject
object property list.
>>> # Add the properties in the TargetObject first
>>> tobj.object_properties.add(alpha)
>>> tobj.object_properties.add(delta)
>>> # THEN add the group
>>> tobj.property_groups.add(g)  # => Ok
>>> # ------------------------------------------------------------------------------
↪ #
>>>
>>> # ------------------------------------------------------------------------------
↪ #
>>> # Tries to add a property to an already registered group in the TargetObject
>>> # property group list while the property has not added yet to the TargetObject
>>> # property list => raises an error
>>> g.group_properties.add(beta)
AttributeError: 'beta' target object property does not belong to this TargetObject␣
↪object
property list.
>>> # Add the property in the TargetObject first
>>> tobj.object_properties.add(gamma)
>>> # THEN insert it into the group
>>> g.group_properties.add(gamma)  # Ok
>>> # ------------------------------------------------------------------------------
↪ #
```

Upon object deletion

To avoid missing references into the study hierarchical structure, `astrophysix` will also prevent you from deleting an *ObjectProperty* from a *TargetObject.object_properties* list if :

- the *ObjectProperty* is included in one of the *ObjectPropertyGroup* of the *TargetObject.property_groups*,
- any *Catalog* associated to that *TargetObject* contains a *CatalogField* that refers to the *ObjectProperty* to be deleted.

Here are the examples :

```
>>> from astrophysix.simdm.protocol import SimulationCode, InputParameter, Algorithm,␣
↪\
                                        PhysicalProcess, AlgoType, Physics
>>> from astrophysix.simdm.experiment import Simulation, ParameterSetting, \
                                          AppliedAlgorithm, ResolvedPhysicalProcess
>>> tobj = TargetObject(name="Pre-stellar core")
>>> x = tobj.object_properties.add(ObjectProperty(property_name="pos_x"))
>>> y = tobj.object_properties.add(ObjectProperty(property_name="pos_y"))
>>> z = tobj.object_properties.add(ObjectProperty(property_name="pos_z"))
>>> pos = tobj.property_groups.add(ObjectPropertyGroup(group_name="position"))
>>> pos.group_properties.add(x)
>>> pos.group_properties.add(y)
>>> pos.group_properties.add(z)
>>>
>>> # ------------------------------------------------------------------------------
↪-- #
>>> # Tries to delete x, while it is in 'position' group
>>> del tobj.object_properties[x.property_name]
AttributeError: ''pos_x' target object property' cannot be deleted, the following␣
↪items
depend on it (try to delete them first) : ['Pre-stellar core' target object -
↪'position'
property group - 'pos_x' target object property].
>>>
>>> # Delete property from 'position' group first
>>> del pos.group_properties[x.property_name]
>>> # THEN delete 'pos_x' property from TargetObject => Ok
>>> del tobj.object_properties[x.property_name]
>>>
>>> # ------------------------------------------------------------------------------
↪-- #
>>> cat = Catalog(target_object=tobj, name="Core catalog")
>>> fy = cat.catalog_fields.add(CatalogField(y, values=N.random.uniform(size=10)))
>>> # Tries to delete 'pos_y' property, while it is linked to fy catalog field
>>> del tobj.object_properties[y.property_name]
AttributeError: ''pos_y' target object property' cannot be deleted, the following␣
↪items
depend on it (try to delete them first) : ['Core catalog' catalog 'pos_y' catalog␣
↪field].
>>>
>>> # Delete CatalogField from Catalog first
>>> del cat.catalog_fields[y.property_name]
# THEN delete Property from TargetObject => Ok
del tobj.object_properties[y.property_name]
```

2.1.7 Physical units and constants module

The `astrophysix` package also provides a *`Unit`* helper class to handle physical constants and units. In addition, a large set of *physical quantities* and *constants* are defined in this module.

See also:

- The *`Unit`* API reference.

Basic use cases

Unit information

You can have access to unit parameters with the *`name`*, *`description`*, *`coeff`*, *`dimensions`*, *`latex`* and *`physical_type`* properties :

```
>>> from astrophysix import units as U
>>> mass_unit = U.Msun
>>> mass_unit.name
Msun
>>> mass_unit.dimensions
array([1, 0, 0, 0, 0, 0, 0, 0], dtype=int32)
>>> mass_unit.coeff
1.9889e+30
>>> mass_unit.description
'Solar mass'
>>> mass_unit.latex
'\\textrm{M}_{\\odot}'
>>> mass_unit.physical_type
'mass
```

A summary of any *`Unit`* can be displayed using the *`Unit.info`* method :

```
>>> from astrophysix import units as U
>>> U.ly.info()
Unit : ly
---------
Light year

Value
-----
9460730472580800.0 m

Equivalent units
----------------
 * m            :      1.057e-16 ly
 * um           :      1.057e-22 ly
 * mm           :      1.057e-19 ly
 * cm           :      1.057e-18 ly
 * nm           :      1.057e-25 ly
 * km           :      1.057e-13 ly
 * Angstrom     :      1.057e-26 ly
 * au           :    1.58125e-05 ly
 * pc           :        3.26156 ly
 * kpc          :        3261.56 ly
 * Mpc          :    3.26156e+06 ly
```

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```
 * Gpc           :    3.26156e+09 ly
 * Rsun          :    7.35153e-08 ly
```

Unit retrieval

The *built-in units and constants* defined in the `astrophysix` package are directly accessible as variables of the package :

```
>>> from astrophysix import units as U
>>> U.Msun.description
'Solar mass'
>>> U.kHz.description
'kilo-Hertz : frequency unit'
```

For custom units retrieval, see *Custom Units*

Unit operations

You can create composite units by multiplying or dividing *Unit* objects by `float` values or other *Unit* objects. You can also raise *Unit* objects to a given (integer) power :

```
>>> from astrophysix import units as U
>>> u = U.km/U.s
>>> print(u)
(1000 m.s^-1)

>>> joule = kg*(m/s)**2
>>> joule == U.J
True

>>> my_p = 250.0 * J * m**-3
>>> my_p.physical_type
'pressure'
```

Custom Units

If you want to create your own units and use them elsewhere in your code, you can create a *Unit* instance that will be included in the `astrophysix` unit registry, use *Unit.create_unit* method to add a new unit, and *Unit.from_name* to retrieve it :

```
>>> from astrophysix import units as U
>>> U.km_s == U.km/U.s # Soft equality => same coefficient and same dimensions
True
>>> U.km_s.identical(U.km/U.s)  # Strict equality => they do not share the same names/
↪LaTEX formulae, descriptions
False
# Create a custom Solar mass per square kiloparsec surface density unit
>>> u = U.Unit.create_unit(name="Msun_pc2", base_unit=U.Msun/U.pc**2, descr="Solar␣
↪mass per square parsec",
                           latex="\\textrm{M}_{\\odot}\\cdot\\textrm{pc}^{-2}")
```

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```
>>> u.identical(U.Msun/U.pc**2)
False

>>> # Later in your Python script ...
>>> surf_dens_unit = U.Unit.from_name("Msun_pc2")
surf_dens_unit == U.Msun/U.pc**2
True
>>>surf_dens_unit.description
"Solar mass per square parsec"
```

Unit search

You can browse the units available in the `astrophysix` unit registry using the *`Unit.equivalent_unit_list`* method, the *`Unit.appropriate_unit`* method or the *`Unit.iterate_units`* iterator :

```
>>> # Equivalent units
>>> U.km.equivalent_unit_list()
[m : (1 m),
 um : (1e-06 m),
 mm : (0.001 m),
 cm : (0.01 m),
 nm : (1e-09 m),
 Angstrom : (1e-10 m),
 au : (1.49598e+11 m),
 pc : (3.08568e+16 m),
 kpc : (3.08568e+19 m),
 Mpc : (3.08568e+22 m),
 Gpc : (3.08568e+25 m),
 Rsun : (6.95508e+08 m),
 ly : (9.46073e+15 m)]

>>> # Most appropriate unit
>>> u = 0.3 * U.pc
>>> f, best_unit = u.appropriate_unit()
>>> print("{f:g} {bu:s}".format(f=f, bu=best_unit.name))
0.978469 ly

>>> # Unit iterator
>>> for u in Unit.iterate_units(phys_type="time"):
        print(u.name)
s
min
hour
day
sid_day
year
kyr
Myr
Gyr
```

Unit conversion

Unit conversion can be done with the *Unit.express* method :

```
>>> from astrophysix import units as U
>>> # Basic unit conversion
>>> l = 100.0 * U.kpc
>>> t = 320.0 U. Myr
>>> v = l/t
>>> print("v = {c:g} km/s".format(c=v.express(U.km_s)))
v = 305.56 km/s
```

Built-in quantities and constants

Base units

Name	Description
A	Ampere : electric intensity base unit
K	Kelvin : base temperature unit
cd	Candela: base luminous intensity unit
kg	Kilogram : base mass unit
m	Meter : base length unit
mol	mole: amount of a chemical substance base unit
none	Unscaled dimensionless unit
rad	radian: angular measurement (ratio lengh / radius of an arc)
s	Second : base time unit

See also:

Wikipedia : SI base unit

Constants and common units

Name	Value	Decomposition in base units	Description
Angstrom	1e-10	m	Angstrom: 10**-10 m
C	1	s.A	Coulomb
F	1	kg^-1.m^-2.s^4.A^2	Farad
G	6.67428e-11	kg^-1.m^3.s^-2	Graviational constant
GHz	1e+09	s^-1	giga-Hertz : frequency unit
Gauss	0.0001	kg.s^-2.A^-1	Gauss
Gpc	3.08568e+25	m	Gigaparsec
Gyr	3.15576e+16	s	Gigayear : trillion years
H	2.26855e-18	s^-1	Hubble's constant
H_cc	2.18421e-21	kg.m^-3	Atoms per cubic centimeter
Henry	1	kg.m^2.s^-2.A^-2	Henry
Hz	1	s^-1	Hertz : frequency unit
J	1	kg.m^2.s^-2	Joule : (SI) energy unit
Jy	1e-26	kg.s^-2	Jansky
Lsun	3.846e+26	kg.m^2.s^-3	Solar luminosity

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Table 1 – continued from previous page

Name	Value	Decomposition in base units	Description
MHz	1e+06	s^-1	mega-Hertz : frequency unit
Mearth	5.9722e+24	kg	Earth mass
Mpc	3.08568e+22	m	Megaparsec
Msun	1.9889e+30	kg	Solar mass
Myr	3.15576e+13	s	Megayear : million years
N	1	kg.m.s^-2	Newton : (SI) force unit
Ohm	1	kg.m^2.s^-3.A^-2	Ohm
Pa	1	kg.m^-1.s^-2	Pascal: (SI) pressure unit
Rsun	6.95508e+08	m	Solar radius
S	1	kg^-1.m^-2.s^3.A^2	Siemens
T	1	kg.s^-2.A^-1	Tesla
V	1	kg.m^2.s^-3.A^-1	Volt
W	1	kg.m^2.s^-3	Watt
a_r	7.56577e-16	kg.m^-1.s^-2.K^-4	Radiation constant
arcmin	0.000290888	rad	arc minute: 1/60 of a hour angle
arcsec	4.84814e-06	rad	arc second: 1/60 of an arcminute
atm	101325	kg.m^-1.s^-2	atm: atmospheric pressure (101 3525 Pa)
au	1.49598e+11	m	Astronomical unit
bar	100000	kg.m^-1.s^-2	Bar
barn	1e-28	m^2	barn: surface unit used in HEP
barye	0.1	kg.m^-1.s^-2	Barye: (CGS) pressure unit
c	2.99792e+08	m.s^-1	Speed of light in vacuum
cm	0.01	m	Centimeter
cm3	1e-06	m^3	Cubic centimeter
day	86400	s	Day
deg	0.0174533	rad	degree: angular measurement corresponding to 1/360 of a full rotation
dyne	1e-05	kg.m.s^-2	dyne : (CGS) force unit
e	1.60218e-19	s.A	e : elementary electric charge carried by a proton
eV	1.60218e-19	kg.m^2.s^-2	electron-Volt
erg	1e-07	kg.m^2.s^-2	erg : (CGS) energy unit
g	0.001	kg	Gram
g_cc	1000	kg.m^-3	Gram per cubic centimeter
h	6.62607e-34	kg.m^2.s^-1	Planck Constant
hPa	100	kg.m^-1.s^-2	Hectopascal
hbar	1.05457e-34	kg.m^2.s^-1	Reduced Planck constant
hour	3600	s	Hour
hourangle	0.261799	rad	hour angle: angular measurement with 24 in a full circle
kB	1.38065e-23	kg.m^2.s^-2.K^-1	Boltzmann constant
kHz	1000	s^-1	kilo-Hertz : frequency unit
kPa	1000	kg.m^-1.s^-2	Kilopascal
km	1000	m	Kilometer
km_s	1000	m.s^-1	kilometers per second
kpc	3.08568e+19	m	Kiloparsec
kpc3	2.938e+49	m^3	Cubic kiloparsec
kyr	3.15576e+10	s	kyr : millenium
lm	1	rad^2.cd	Lumen
lx	1	m^-2.rad^2.cd	Lux
ly	9.46073e+15	m	Light year
m3	1	m^3	Cubic meter

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Table 1 – continued from previous page

Name	Value	Decomposition in base units	Description
mGauss	1e-07	kg.s^-2.A^-1	Milligauss
mH	1.66e-27	kg	Hydrogen atomic mass
m_s	1	m.s^-1	Meters per second
min	60	s	Minute
mm	0.001	m	Millimeter
nm	1e-09	m	Nanometer
pc	3.08568e+16	m	Parsec
pc3	2.938e+49	m^3	Cubic parsec
percent	0.01		One hundredth of unity
rhoc	9.2039e-27	kg.m^-3	Friedmann's universe critical density
sid_day	86164.1	s	Sidereal day : Earth full rotation time
sigmaSB	5.6704e-08	kg.s^-3.K^-4	Stefan-Boltzmann constant
sr	1	rad^2	Steradian: solid angle (SI) unit
t	1000	kg	Metric ton
uGauss	1e-10	kg.s^-2.A^-1	Microgauss
um	1e-06	m	Micron
year	3.15576e+07	s	Year

Physical quantities

Quantity	Decomposition in base units
acceleration	m.s^-2
amount of substance	mol
angle	rad
angular acceleration	s^-2.rad
angular momentum	kg.m^2.s^-1
angular velocity	s^-1.rad
area	m^2
dimensionless	
dynamic viscosity	kg.m^-1.s^-1
electric capacitance	kg^-1.m^-2.s^4.A^2
electric charge	s.A
electric charge density	m^-3.s.A
electric conductance	kg^-1.m^-2.s^3.A^2
electric conductivity	kg^-1.m^-3.s^3.A^2
electric current	A
electric current density	m^-2.A
electric dipole moment	m.s.A
electric field strength	kg.m.s^-3.A^-1
electric flux density	m^-2.s.A
electric potential	kg.m^2.s^-3.A^-1
electric resistance	kg.m^2.s^-3.A^-2
electric resistivity	kg.m^3.s^-3.A^-2
energy	kg.m^2.s^-2
energy flux density	kg.s^-3
entropy	kg.m^2.s^-2.K^-1

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Table 2 – continued from previous page

Quantity	Decomposition in base units
force	kg.m.s^-2
frequency	s^-1
inductance	kg.m^2.s^-2.A^-2
kinematic viscosity	m^2.s^-1
length	m
linear density	kg.m^-1
luminance	m^-2.cd
luminous emittence	m^-2.rad^2.cd
luminous flux	rad^2.cd
luminous intensity	cd
magnetic field strength	m^-1.A
magnetic flux	kg.m^2.s^-2.A^-1
magnetic flux density	kg.s^-2.A^-1
magnetic permeability	kg.m.s^-2.A^-2
mass	kg
molar volume	m^-3.mol
moment of inertia	kg.m^2
momentum/impulse	kg.m.s^-1
permittivity	kg^-1.m^-3.s^4.A^2
power	kg.m^2.s^-3
pressure	kg.m^-1.s^-2
radiant intensity	kg.m^2.s^-3.rad^-2
solid angle	rad^2
specific energy	m^2.s^-2
specific volume	kg^-1.m^3
spectral flux density	kg.s^-2
surface density	kg.m^-2
temperature	K
thermal conductivity	kg.m.s^-3.K^-1
time	s
velocity	m.s^-1
volume	m^3
volume density	kg.m^-3
wavenumber	m^-1

2.1.8 Frequently asked questions

Why an alias ?

the *alias* property in the `astrophysix` package is an optional parameter only mandatory within *`SimulationStudy`* HDF5 files that are meant to be uploaded on the Galactica simulation database. This optional property can be found in various classes :

- *`Project`*,
- *`SimulationCode`*,
- *`PostProcessingCode`*,
- *`Simulation`*,

- *PostProcessingRun*.

The *alias* must verify a specific format. For more details, see *Alias formatting*.

These *alias* properties are used to reference in a unique way the projects, protocols and experiments displayed on the web pages and appear in the URL of your web browser when you wish to visit the page of a given project or simulation. These URLs need to be unique. For example, this is the URL of a ORION_FIL_MHD simulation of the ORION project in the STAR_FORM (*ProjectCategory.StarFormation*) project category :

- http://www.galactica-simulations.eu/db/STAR_FORM/ORION/ORION_FIL_MHD/

How can I check validity for Galactica ?

When you try to upload a *SimulationStudy* HDF5 file onto the Galactica web application, the server will check the consistency of the project you are trying to upload against the content of the database. These checks are more stringent than the ones performed by astrophysix upon saving the HDF5 file. In case your project cannot be uploaded, a panel showing error messages will be displayed :

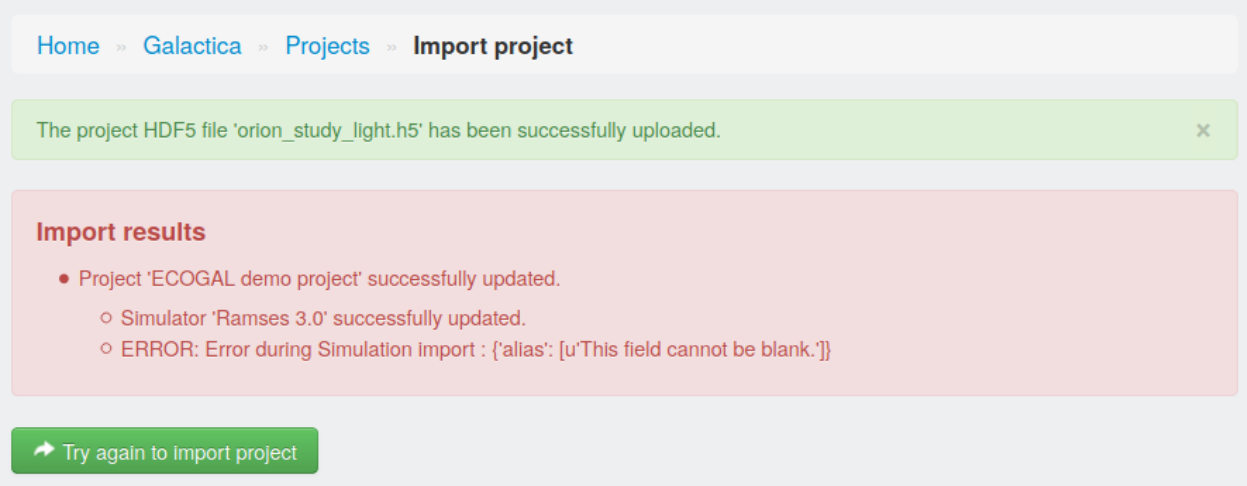

Fig. 2: Galactica admin. interface : an error occurred while trying to upload a *SimulationStudy* HDF5 file on the Galactica web server. The *Simulation* seems to miss its alias parameter.

This example project was created by the following script, running quite silently :

```
>>> from astrophysix.simdm import SimulationStudy, Project, ProjectCategory
>>> from astrophysix.simdm.experiment import Simulation
>>> from astrophysix.simdm.protocol import SimulationCode
>>>
>>> # Project creation + study
>>> proj = Project(category=ProjectCategory.StarFormation, alias="ECOGAL_DEMO",
...                project_title="ECOGAL demo project")
>>> study = SimulationStudy(project=proj)
>>>
>>> # Simulation code definition : RAMSES
>>> ramses = SimulationCode(name="Ramses 3.0", code_name="Ramses",
...                         code_version="3.0.1", alias="RAMSES_3")
>>>
>>> # Simulation setup, with alias missing
>>> simu = Simulation(simu_code=ramses, name="ORION MHD run",
...                   description="MHD simulation description",
```

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```
...                     execution_time="2020-01-01 00:00:00")
>>> # Add simulation into project
>>> proj.simulations.add(simu)
>>>
>>> # Save study in HDF5 file
>>> study.save_HDF5("./orion_study_light.h5")
```

Upon saving your study HDF5 file

You have the possibility to enable *Galactica* validity checks upon saving your HDF5 file by adding a `galactica_checks=True` option to the *`SimulationStudy.save_HDF5()`* method :

```
>>> study.save_HDF5("./orion_study_light.h5", galactica_checks=True)
[WARNING] 'ORION MHD run' simulation Galactica alias is missing.
```

Which tells you that your *`Simulation.alias`* is missing.

SimDM object direct check

You can also directly call the *`galactica_validity_check()`* method of any object of your study to perform those checks even prior to saving your *`SimulationStudy`* HDF5 file :

```
>>> simu.galactica_validity_check()
[WARNING] 'ORION MHD run' simulation Galactica alias is missing.
```

These *validity* checks include, e.g. :

- `alias` format validation,
- missing parameters in an object,
- object name/alias unicity,
- some `string` parameters maximum length,
- minimum number of items in catalogs ($n_{obj} \geq 1$).

Alias formatting

Valid Galactica aliases are non-empty character `string` attributes of maximum length **16** which verify the following regular expression pattern : `^[A-Z]([A-Z0-9_]*[A-Z0-9])?$`.

```
>>> simu.alias = "_hydro_RUN_8_"
>>> simu.galactica_validity_check()
[WARNING] 'ORION MHD run' simulation Galactica alias is not valid (The alias can␣
↪contain capital
letters, digits and '_' only. It must start with a capital letter and cannot end with␣
↪a '_'.)
```

See also:

FAQ section : *Why an alias ?*

How to delete object from lists ?

Let us assume that you wish to remove a *Snapshot* from a *Simulation*. Then you can use the standard `del` python operator to remove it :

```
>>> simu.snapshots
Snapshot list :
+---+--------------------------+--------------------------------------+
| # |           Index          |                 Item                 |
+---+--------------------------+--------------------------------------+
| 0 | My best snapshot !       | 'My best snapshot !' snapshot        |
+---+--------------------------+--------------------------------------+
| 1 | My second best snapshot ! | 'My second best snapshot !' snapshot |
+---+--------------------------+--------------------------------------+
>>> del simu.snapshots[1]
>>> simu.snapshots
Snapshot list :
+---+--------------------------+--------------------------------------+
| # |           Index          |                 Item                 |
+---+--------------------------+--------------------------------------+
| 0 | My best snapshot !       | 'My best snapshot !' snapshot        |
+---+--------------------------+--------------------------------------+
```

See also:

ObjectList example in the API reference.

How to delete files from a Datafile ?

To remove a file from a *Datafile*, you can use the standard `del` python operator:

```
>>> from astrophysix.utils.file import FileType
>>>
>>> power_spectrum_datafile.display_files()
[Power scpectrum] datafile. Attached files :
+-----------+-----------------------------+
| File type |          Filename           |
+-----------+-----------------------------+
| PNG       | spectrum_1.png              |
+-----------+-----------------------------+
| JPEG      | spectrum_with_overlays.jpg  |
+-----------+-----------------------------+
>>>
>>> del power_spectrum_datafile[FileType.PNG_FILE]
>>> power_spectrum_datafile.display_files()
[Power scpectrum] datafile. Attached files :
+-----------+-----------------------------+
| File type |          Filename           |
+-----------+-----------------------------+
| JPEG      | spectrum_with_overlays.jpg  |
+-----------+-----------------------------+
```

See also:

- *Datafile* example in the API reference,
- *Attached files* detailed section.

How to add/remove objects in an existing Catalog ?

To modify the size of an existing *Catalog*, you **must first clear it completely** and then reinsert new *CatalogField* instances :

```
>>> # Catalog contained 200 objects, now we want 354 !
>>> new_fields = [CatalogFields(obj_prop=f.object_property, values=N.random.
↪uniform(size=354))
...                for f in wrong_size_cat.catalog_fields]
>>> for i in range(len(wrong_size_cat.catalog_fields)):  # Empty the object list
...     del wrong_size_cat.catalog_fields[0]
>>> # Add new fields (size: 354)
>>> for new_field in new_fields:
...     wrong_size_cat.catalog_fields.add(nf)
```

2.1.9 Changelog

0.5.0 (Feb. 11th, 2021)

in `astrophysix.simdm` package :

- Added *TargetObject*, *ObjectProperty*, *ObjectPropertyGroup* classes, *PropertySortFlag* and *PropertyFilterFlag* enums to describe catalog objects,
- Added *Catalog* and *CatalogField* classes defining object catalogs,
- added *Project.acknowledgement* property,
- Added *Physics* :
  - *Physics.ExternalGravity*,
  - *Physics.SupermassiveBlackHoleFeedback*,
  - *Physics.StellarIonisingRadiation*,
  - *Physics.StellarUltravioletRadiation*,
  - *Physics.StellarInfraredRadiation*,
  - *Physics.ProtostellarJetFeedback*,
  - *Physics.ExternalGravity*,
  - *Physics.DustCooling*,
  - *Physics.MolecularCooling*,
  - *Physics.AtomicCooling*,
  - *Physics.TurbulentForcing*,
  - *Physics.RadiativeTransfer*.
- Added *AlgoType* :
  - *AlgoType.RadiativeTransfer*,
  - *AlgoType.RungeKutta*,
  - *AlgoType.StructuredGrid*,
  - *AlgoType.SpectralMethod*,

  - *AlgoType.NBody*.
- *AssociatedFile* persistency bug fix,
- none *Unit* persistency bug fix,

0.4.2 (Dec. 8th, 2020)

- Galactica validation fully operational.

0.4.1 (Oct. 16th, 2020)

- Set *InputParameter.name* property as index in *Protocol* input parameter list. Set *InputParameter.key* as optional (Galactica simulation database compatibility).

0.4.0 (Oct. 14th, 2020)

Implemented Simulation Datamodel classes :

- *Project* and *SimulationStudy*,
- *Protocols* (*SimulationCode* and *PostProcessingCode*),
- *Experiments* (Simulation and *PostProcessingRun*),
- *Results* (*GenericResult* and *Snapshot*),
- *Datafile*.

2.1.10 Study and projects

SimulationStudy

class astrophysix.simdm.**SimulationStudy**(*project=None*)
HDF5 simulation study file for Project tree structure persistency

Parameters **project** (*Project*) – study main project

property creation_time
Study creation date/time (datetime.datetime).

property last_modification_time
Study last modification date/time (datetime.datetime).

classmethod load_HDF5(*study_file_path*)
Loads a new or existing SimulationStudy from a HDF5 (*.h5) file

Parameters **study_file_path** (string) – SimulationStudy HDF5 (existing) file path

Returns **study** – Study loaded from HDF5 file.

Return type *SimulationStudy*

property project
Study main project

save_HDF5(*study_fname=None*, *dry_run=False*, *callback=None*, *galactica_checks=False*)
Save the SimulationStudy into a HDF5 (*.h5) file

Parameters

- **study_fname** (string) – Simulation study HDF5 filename.
- **dry_run** (bool) – perform a dry run ? Default False.
- **callback** (callable) – method to execute upon saving each item of the study.
- **galactica_checks** (bool) – Perform Galactica database validity checks and display warning in case of invalid content for upload on Galactica. Default False (quiet mode).

property study_filepath
Simulation study HDF5 file path

property uid
Study UUID

Project and ProjectCategory

class astrophysix.simdm.**ProjectCategory**(*value*)
Project category enum

Example

```
>>> cat = ProjectCategory.PlanetaryAtmospheres
>>> cat.verbose_name
"Planetary atmospheres"
```

Cosmology = ('COSMOLOGY', 'Cosmology')

GalaxyFormation = ('GAL_FORMATION', 'Galaxy formation')

GalaxyMergers = ('GAL_MERGERS', 'Galaxy mergers')

PlanetaryAtmospheres = ('PLANET_ATMO', 'Planetary atmospheres')

SolarMHD = ('SOLAR_MHD', 'Solar Magnetohydrodynamics')

StarFormation = ('STAR_FORM', 'Star formation')

StarPlanetInteractions = ('STAR_PLANET_INT', 'Star-planet interactions')

Supernovae = ('SUPERNOVAE', 'Supernovae')

property alias
Project category alias

classmethod from_alias(*alias*)

Parameters **alias** (string) – project category alias

Returns **c** – Project category matching the requested alias.

Return type *ProjectCategory*

Raises **ValueError** – if requested alias does not match any project category.

Example

```
>>> c = ProjectCategory.from_alias("STAR_FORM")
>>> c.verbose_name
"Star formation"
>>> c2 = ProjectCategory.from_alias("MY_UNKNOWN_CATEGORY")
ValuerError: No ProjectCategory defined with the alias 'MY_UNKNOWN_CATEGORY'.
```

property verbose_name
Project category verbose name

class astrophysix.simdm.**Project**(**args*, ***kwargs*)

__eq__(*other*)
Project comparison method

other: *Project* project to compare to.

__unicode__()
String representation of the instance

property acknowledgement
How to acknowledge this project.

New in version 0.5.0.

property alias
Project alias

property category

property data_description
Data description available in this project

property directory_path
Project data directory path

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (*dict*) – keyword arguments (optional)

property general_description
General description of the project

property project_title
Project title

property short_description
Short description of the project

property simulations
Project *Simulation* list (*ObjectList*)

2.1.11 Protocols

Simulation and post-processing codes

`Protocol` is the generic term for a software tool used to conduct a numerical `Experiment`. There are two different types of protocols :

- *SimulationCode*,
- *PostProcessingCode*.

class astrophysix.simdm.protocol.**SimulationCode**(***kwargs*)

Simulation code

Parameters

- **name** (string) – name (mandatory)
- **code_name** (string) – base code name (mandatory)
- **alias** (string) – code alias
- **url** (string) – reference URL
- **code_version** (string) – code version
- **description** (string) – code description

__eq__(*other*)

SimulationCode comparison method

other: SimulationCode simulation code to compare to

__ne__(*other*)

Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()

String representation of the instance

property algorithms

Protocol *Algorithm* list (*ObjectList*)

property alias

Protocol alias

property code_name

Protocol code name

property code_version

Protocol code version

property description

Protocol description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)

Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property input_parameters

Protocol *InputParameter* list (*ObjectList*)

property name
Protocol name

property physical_processes
Simulation code *PhysicalProcess* list (*ObjectList*)

property uid

property url
Protocol code url

class astrophysix.simdm.protocol.**PostProcessingCode**(***kwargs*)
Post-processing code

Parameters

- **name** (string) – name (mandatory)
- **code_name** (*:obj:`string*) – base code name (mandatory)
- **alias** (string) – code alias
- **url** (string) – reference URL
- **code_version** (string) – code version
- **description** (string) – code description

__eq__(*other*)
Protocol comparison method

other: Protocol Protocol to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property algorithms
Protocol *Algorithm* list (*ObjectList*)

property alias
Protocol alias

property code_name
Protocol code name

property code_version
Protocol code version

property description
Protocol description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property input_parameters
Protocol *InputParameter* list (*ObjectList*)

property name
Protocol name

property uid

property url
Protocol code url

Input parameters

class astrophysix.simdm.protocol.**InputParameter**(***kwargs*)
Protocol input parameter

Parameters

- **name** (string) – input parameter name (mandatory)
- **key** (string) – input parameter configuration key
- **description** (string) – input parameter description

__eq__(*other*)
InputParameter comparison method

other: ***InputParameter*** input parameter to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property description
Input parameter description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property key
Input parameter configuration key

property name
Input parameter name

property uid

Algorithms

Algorithm type

class astrophysix.simdm.protocol.**AlgoType**(*value*)
Algorithm type enum

Example

```
>>> t = AlgoType.PoissonMultigrid
>>> t.name
"Multigrid Poisson solver"
```

AdaptiveMeshRefinement = ('AMR', 'Adaptive mesh refinement')

FriendOfFriend = ('FOF', 'Friend-of-friend')

Godunov = ('Godunov', 'Godunov scheme')

HLLCRiemann = ('HLLC', 'Harten-Lax-van Leer-Contact Riemann solver')

NBody = ('nbody', 'N-body method')

ParticleMesh = ('PM', 'Particle-mesh solver')

PoissonConjugateGradient = ('Poisson_CG', 'Conjugate Gradient Poisson solver')

PoissonMultigrid = ('Poisson_MG', 'Multigrid Poisson solver')

RadiativeTransfer = ('rad_transfer', 'Radiative transfer')

RayTracer = ('ray_tracer', 'Ray-tracer')

RungeKutta = ('runge_kutta', 'Runge-Kutta method')

SmoothParticleHydrodynamics = ('SPH', 'Smooth particle hydrodynamics')

SpectralMethod = ('spectr_meth', 'Spectral method')

StructuredGrid = ('struct_grid', 'Structured grid method')

VoronoiMovingMesh = ('Voronoi_MM', 'Voronoi tesselation-based moving mesh')

classmethod from_key(*key*)

Parameters **key** (string) – algorithm type key

Returns **t** – Algorithm type matching the requested key.

Return type *AlgoType*

Raises **ValueError** – if requested key does not match any algorithm type.

Example

```
>>> t = AlgoType.from_key("FOF")
>>> t.name
"Friend-of-friend"
>>> t2 = AlgoType.from_key("MY_UNKNOWN_ALGO_TYPE")
ValuerError: No AlgoType defined with the key 'MY_UNKNOWN_ALGO_TYPE'.
```

property key
Algorithm type indexing key

Algorithm

class astrophysix.simdm.protocol.**Algorithm**(***kwargs*)
Protocol algorithm

Parameters

- **algo_type** (*AlgoType* or string) – AlgoType enum value or AlgoType valid key (mandatory).
- **description** (string) – algorithm description

__eq__(*other*)
Algorithm comparison method

other: ***Algorithm*** algorithm to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property algo_type
Algorithm type (*AlgoType*)

property description
Algorithm description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property name
Algorithm name

property uid

Physical processes

Physics

class astrophysix.simdm.protocol.**Physics**(*value*)

Physics enum

Example

```
>>> ph = Physics.MHD
>>> ph.name
"Magnetohydrodynamics"
```

AGNFeedback = ('AGN_feedback', 'AGN feedback')

AtomicCooling = ('atomic_cooling', 'Atomic cooling')

Chemistry = ('chemistry', 'Chemistry')

DustCooling = ('dust_cooling', 'Dust cooling')

ExternalGravity = ('ext_gravity', 'External gravity')

Hydrodynamics = ('hydro', 'Hydrodynamics')

MHD = ('mhd', 'Magnetohydrodynamics')

MolecularCooling = ('mol_cooling', 'Molecular cooling')

ProtostellarJetFeedback = ('psjet_feedback', 'Protostellar jet feedback')

RadiativeTransfer = ('rad_transfer', 'Radiative transfer')

SelfGravity = ('self_gravity', 'Self-gravity')

StarFormation = ('star_form', 'Star formation')

StellarInfraredRadiation = ('stell_ir_rad', 'Stellar infrared radiation')

StellarIonisingRadiation = ('stell_ion_rad', 'Stellar ionising radiation')

StellarUltravioletRadiation = ('stell_uv_rad', 'Stellar ultraviolet radiation')

SupermassiveBlackHoleFeedback = ('smbh_feedback', 'SMBH feedback')

SupernovaeFeedback = ('sn_feedback', 'Supernovae feedback')

TurbulentForcing = ('turb_forcing', 'Turbulent forcing')

classmethod from_key(*key*)

Parameters **key** (string) – physics key

Returns **t** – Physics matching the requested key.

Return type *Physics*

Raises **ValueError** – if requested key does not match any physics.

Example

```
>>> ph = Physics.from_key("star_from")
>>> ph.name
"Star formation"
>>> ph2 = Physics.from_key("MY_UNKNOWN_PHYSICS")
ValuerError: No Physics defined with the key 'MY_UNKNOWN_PHYSICS'.
```

property key
Physics indexing key

Physical process

class astrophysix.simdm.protocol.**PhysicalProcess**(***kwargs*)
Simulation code physical process

Parameters

- **physics** (*Physics* or string) – Physics enum value or Physics valid key. (mandatory)
- **description** (string) – physics description

__eq__(*other*)
PhysicalProcess comparison method

other: PhysicalProcess physical process to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property description
Physical process description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters kwargs (dict) – keyword arguments (optional)

property name
Physical process name

property physics
Prrocess type (*Physics*)

property uid

2.1.12 Experiments

Simulation and post-processing runs

Numerical `Experiments` can be of two different types:

- *Simulation*,
- *PostProcessingRun*.

class astrophysix.simdm.experiment.**Simulation**(*Simulation data model*)

Parameters

- **name** (string) – Simulation name (mandatory)
- **simu_code** (*SimulationCode*) – Simulation code used for this simulation (mandatory)
- **alias** (string) – Simulation alias (if defined, 16 max characters is recommended)
- **description** (string) – Long simulation description
- **directory_path** (string) – Simulation data directory path
- **execution_time** (string) – Simulation execution time in the format '%Y-%m-%d %H:%M:%S'

EXETIME_FORMAT = '%Y-%m-%d %H:%M:%S'

__eq__(*other*)
Simulation comparison method

other: ***Simulation*** simulation to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property alias
Experiment alias. Can be edited.

property applied_algorithms
Experiment applied algorithm list (*ObjectList*)

property description
Experiment description. Can be edited.

property directory_path
Experiment data directory path. Can be edited.

property execution_time
Simulation execution date/time. Can be edited.

Example

```
>>> simu = Simulation(simu_code=gadget4, name="Maxi Cosmic", execution_time=
↪"2020-09-10 14:25:48")
>>> simu.execution_time = '2020-09-28 18:45:24'
```

property execution_time_as_utc_datetime
UTC execution time of the simulation (timezone aware)

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (*dict*) – keyword arguments (optional)

property generic_results
Experiment generic result list (*ObjectList*)

property name
Experiment name. Can be edited.

property parameter_settings
Experiment parameter setting list (*ObjectList*)

property post_processing_runs
Simulation associated post-processing run list (*ObjectList*)

property resolved_physics
Simulation resolved physical process list (*ObjectList*).

property simulation_code
SimulationCode used to run this simulation. Cannot be changed after simulation initialisation.

property snapshots
Experiment snapshot list (*ObjectList*)

property uid

class astrophysix.simdm.experiment.**PostProcessingRun**(**args*, ***kwargs*)
Post-processing run (Simulation data model)

Parameters

- **name** (string) – post-processing run name (mandatory)
- **ppcode** (*PostProcessingCode*) – post-processing code used for this post-processing run (mandatory)
- **alias** (string) – Post-processing run alias (if defined, 16 max characters is recommended)
- **description** (string) – Long post-processing run description

__eq__(*other*)
PostProcessingRun comparison method

other: **PostProcessingRun** post-processing run to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property alias
Experiment alias. Can be edited.

property applied_algorithms
Experiment applied algorithm list (*ObjectList*)

property description
Experiment description. Can be edited.

property directory_path
Experiment data directory path. Can be edited.

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (*dict*) – keyword arguments (optional)

property generic_results
Experiment generic result list (*ObjectList*)

property name
Experiment name. Can be edited.

property parameter_settings
Experiment parameter setting list (*ObjectList*)

property postpro_code
PostProcessingCode used to run this post-processing run. Cannot be changed after post-processing run initialisation.

property snapshots
Experiment snapshot list (*ObjectList*)

property uid

Parameter settings

Parameter visibility flag

class astrophysix.simdm.experiment.**ParameterVisibility**(*value*)
Parameter setting visibility flag (enum)

Example

```
>>> vis = ParameterVisibility.BASIC_DISPLAY
>>> vis.display_name
"Basic display"
```

ADVANCED_DISPLAY = ('advanced', 'Advanced display')

BASIC_DISPLAY = ('basic', 'Basic display')

NOT_DISPLAYED = ('not_displayed', 'Not displayed')

property display_name
Parameter visibility display name

classmethod from_key(*key*)

Parameters **key** (string) – parameter visibility flag key

Returns **t** – Parameter vsibility flag matching the requested key.

Return type *ParameterVisibility*

Raises **ValueError** – if requested key does not match any parameter visibility.

Example

```
>>> vis = ParameterVisibility.from_key("advanced")
>>> vis.display_name
"Advanced display"
>>> vis2 = ParameterVisibility.from_key("MY_UNKNOWN_FLAG")
ValuerError: No ParameterVisibility defined with the key 'MY_UNKNOWN_FLAG'.
```

property key
Parameter visibility flag key

Parameter setting

class astrophysix.simdm.experiment.**ParameterSetting**(***kwargs*)
Experiment input parameter setting class

Parameters

- **input_param** (*InputParameter*) – protocol input parameter (mandatory)
- **value** (float or int or string or bool) – numeric/string/boolean value of the input parameter (mandatory)
- **unit** (Unit or string) – parameter value unit (or unit key string)
- **visibility** (*ParameterVisibility*) – Parameter setting visibility (for display use only). Default *BASIC_DISPLAY*

__eq__(*other*)
ParameterSetting comparison method

other: ***ParameterSetting*** parameter setting to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (*dict*) – keyword arguments (optional)

property input_parameter
Experiment protocol's *InputParameter*. Cannot be edited after parameter setting initialisation.

property parameter_key
Experiment protocol's *InputParameter* key

property uid

property unit
Parameter value unit (`Unit`). Can be edited.

Example

```
>>> from astrophysix import units as U
>>> psetting = ParameterSetting(input_param=inpp, value=0.5, unit=U.pc)
>>> psetting.unit = U.kpc
>>> psetting.unit = "Mpc"
```

property value
Parameter value.

Can be set to a `bool`, `string`, `int` or `float` value. When set, *value_type* is also set accordingly.

Example

```
>>> psetting = ParameterSetting(input_param=inpp, value=0.5)
>>> type(psetting.value) is float and psetting.value == 0.5 and psetting.
↪value_type == DataType.REAL
True
>>> psetting.value = "true"
>>> type(psetting.value) is bool and psetting.value is True and psetting.
↪value_type == DataType.BOOLEAN
True
>>> psetting.value = "false"
>>> type(psetting.value) is bool and psetting.value is False and psetting.
↪value_type == DataType.BOOLEAN
True
>>> psetting.value = "banana"
>>> type(psetting.value) is str and psetting.value == "banana" and psetting.
↪value_type == DataType.STRING
True
>>> psetting.value = 4.256
>>> type(psetting.value) is float and psetting.value == 4.256 and psetting.
↪value_type == DataType.REAL
True
>>> psetting.value = 58.0
>>> type(psetting.value) is int and psetting.value == 58 and psetting.value_
↪type == DataType.INTEGER
True
>>> psetting.value = "3.584e2"
>>> type(psetting.value) is float and psetting.value == 358.4 and psetting.
↪value_type == DataType.REAL
True
>>> psetting.value = "-254"
>>> type(psetting.value) is int and psetting.value == -254 and psetting.value_
↪type == DataType.INTEGER
True
```

property value_type
Parameter value type (*DataType*)

property visibility
Parameter setting visibility flag (*ParameterVisibility*). Can be edited.

Example

```
>>> psetting = ParameterSetting(input_param=inpp, value=0.5,␣
↪visibility=ParameterVisibility.ADVANCED_DISPLAY)
>>> psetting.visibility = ParameterVisibility.BASIC_DISPLAY
>>> psetting.visibility = "not_displayed"
```

Applied algorithms

class astrophysix.simdm.experiment.**AppliedAlgorithm**(***kwargs*)
Experiment applied algorithm class

Parameters

- **algorithm** (*Algorithm*) – protocol algorithm (mandatory).
- **details** (string) – implementation details.

__eq__(*other*)
AppliedAlgorithm comparison method

other: ***AppliedAlgorithm*** applied algorithm to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property algo_name
Algorithm name. Cannot be edited.

property algorithm
Experiment protocol's *Algorithm*. Cannot be edited after applied algorithm initialisation.

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property implementation_details
Applied algorithm implementation details (string). Can be edited.

property uid

Resolved physical processes

class astrophysix.simdm.experiment.**ResolvedPhysicalProcess**(***kwargs*)
Simulation resolved physical process class

Parameters

- **physics** (*PhysicalProcess*) – simulation code's *PhysicalProcess* instance (mandatory)
- **details** (string) – resolved physical process implementation details

__eq__(*other*)
ResolvedPhysicalProcess comparison method

other: ***ResolvedPhysicalProcess*** resolved physical process to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property implementation_details
Resolved physical process implementation details. Editable.

property physical_process
Simulation code's *PhysicalProcess*. Cannot be edited after instance initialisation

property process_name
Simulation code's *PhysicalProcess* name. Cannot be edited.

property uid

2.1.13 Results

Generic results and snapshots

class astrophysix.simdm.results.generic.**GenericResult**(***kwargs*)

__eq__(*other*)
GenericResult comparison method

other: ***GenericResult*** generic result to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property catalogs
Result `Catalog` list (*ObjectList*)

New in version 0.5.0

property datafiles
Result *Datafile* list (*ObjectList*)

property description
Result description. Can be set to any `string` value.

property directory_path
Result directory.path. Can be set to any `string` value.

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (`dict`) – keyword arguments (optional)

property name
Result name. Can be set to a non-empty `string` value.

property uid

class `astrophysix.simdm.results.snapshot.`**Snapshot**(***kwargs*)
Experiment snapshot class (Simulation data model)

Parameters

- **name** (`string`) – snapshot name (mandatory)
- **description** (`string`) – snapshot description
- **directory_path** (`string`) – snapshot directory path
- **time** ((`float`, `Unit`) `tuple`) – snapshot time info (value, unit) tuple
- **physical_size** ((`float`, `Unit`) `tuple`) – snapshot physical size info (value, unit) tuple
- **data_reference** (`string`) – snapshot data reference (e.g. data directory name, snapshot number) string

__eq__(*other*)
Snapshot comparison method

other: *Snapshot* snapshot to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property catalogs
Result `Catalog` list (*ObjectList*)

New in version 0.5.0

property data_reference
Snapshot data reference (e.g. data directory name, snapshot number). Can be set to any `string` value.

property datafiles
Result *Datafile* list (*ObjectList*)

property description
Result description. Can be set to any `string` value.

property directory_path
Result directory.path. Can be set to any `string` value.

galactica_valid_alias (*alias_value*)

galactica_validity_check (***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (`dict`) – keyword arguments (optional)

property name
Result name. Can be set to a non-empty `string` value.

property physical_size
Snapshot physical size info (value, unit) tuple . Can be set to a `float` value (unitless) or a (`float`, `Unit`) tuple.

Example

```
>>> sn = Snapshot(name="My super snapshot")
>>> sn.physical_size = "0.256"
>>> sn.physical_size = ("0.24", U.pc)
>>> sn.physical_size = ("0.45", "kpc")
>>> sn.physical_size[1] == U.kpc
True
>>> sn.physical_size = 4.46
>>> sn.physical_size = (7.89e2, "Mpc")
>>> sn.physical_size[1] == U.Mpc
True
>>> sn.physical_size = (78.54, U.ly)
```

property time
Snapshot time info (value, unit) tuple . Can be set to a `float` value (unitless) or a (`float`, `Unit`) tuple.

Example

```
>>> sn = Snapshot(name="My super snapshot")
>>> sn.time = "0.256"
>>> sn.time[1] == U.none
True
>>> sn.time = ("0.24", U.year)
>>> sn.time = ("0.45", "Myr")
>>> sn.time[1] == U.Myr
True
>>> sn.time = (7.89e2, "Gyr")
>>> sn.time = (78.54, U.min)
```

property uid

Datafiles

Datafile and AssociatedFile

class astrophysix.simdm.datafiles.**Datafile**(***kwargs*)

Datafile class

Parameters

- **name** (string) – datafile name (mandatory)
- **description** (string) – datafile description

Example

```
>>> from astrophysix.utils import FileType
>>> from astrophysix.simdm.datafiles import JpegImageFile
>>> df = Datafile(name="Pre-stellar cores mass spectrum")
>>> df[FileType.PNG_FILE] = "/data/SIMUS/result_spectrum/mass_spectrum.png"
>>> df[FileType.FITS_FILE] = "/data/SIMUS/result_spectrum/pre-stellar-core-mass-
↪hist.fits"
>>> df[FileType.PNG_FILE] = JpegImageFile.load_file("/data/SIMUS/result_spectrum/
↪hist.jpg")
ValueError: Datafile associated file type mismatch : expected PngImageFile object␣
↪but JpegImageFile was provided.
>>> df[FileType.PNG_FILE] = "/data/SIMUS/result_spectrum/hist.jpg"
AttributeError: Invalid filename for a PNG file (/data/SIMUS/result_spectrum/hist.
↪jpg).
>>> # Removing a file
>>> del df[FileType.FITS_FILE]
```

__delitem__(*ftype*)

Remove associated file given its file type.

Parameters **item** (*FileType*) –

Raises **KeyError** – if the search index type is not a *FileType* instance or if there is no associated file with the required file type.

__eq__(*other*)

Datafile comparison method

Parameters **other** (*Datafile*) – datafile to compare to:

__getitem__(*ftype*)

Get an associated file from the data file, given its file type.

Parameters **ftype** (*FileType*) – Associated file type

Returns **f** – datafile associated file for the required file type.

Return type *AssociatedFile*

Raises **KeyError** – if the search index type is not a *FileType* instance or if there is no associated file with the required file type.

__ne__(*other*)

Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__setitem__(*filetype*, *ass_file*)
Set an associated file with a given file type into the data file.

Parameters

- **filetype** (*FileType*) – Associated file type
- **ass_file** (string or *AssociatedFile*) – Associated file path or instance

__unicode__()
String representation of the data file instance

property description
Datafile description. Can be set to any string value.

display_files()
Show tabulated view of associated files

Example

```
>>> df.display_files()
[My best datafile] datafile. Attached files :
+-----------+----------------------------+
| File type |          Filename          |
+-----------+----------------------------+
| PNG       | CEA.png                    |
+-----------+----------------------------+
| JPEG      | irfu_simple.jpg            |
+-----------+----------------------------+
| FITS      | cassiopea_A_0.5-1.5keV.fits |
+-----------+----------------------------+
| TARGZ     | archive.tar.gz             |
+-----------+----------------------------+
| JSON      | test_header_249.json       |
+-----------+----------------------------+
| ASCII     | abstract.txt               |
+-----------+----------------------------+
| HDF5      | study.h5                   |
+-----------+----------------------------+
| PICKLE    | dict_saved.pkl             |
+-----------+----------------------------+
```

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property name
Datafile name. Can be set to a non-empty string value.

property plot_info
Datafile plot information. Can be set to a *PlotInfo* instance.

property uid

class astrophysix.simdm.datafiles.file.**AssociatedFile**(***kwargs*)

class astrophysix.simdm.datafiles.file.**FitsFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *FITS_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**PickleFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *PICKLE_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**AsciiFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *ASCII_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**HDF5File**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *HDF5_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**JsonFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *JSON_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**CSVFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *CSV_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.file.**TarGzFile**(***kwargs*)
Bases: *astrophysix.simdm.datafiles.file.AssociatedFile*

Datafile associated *TARGZ_FILE* file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.image.**PngImageFile**(***kwargs*)
Bases: astrophysix.simdm.datafiles.image.ImageFile

Datafile associated *PNG_FILE* image file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property pil_image
Pillow image (JPEG/PNG) image property getter. Implements lazy I/O.

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

class astrophysix.simdm.datafiles.image.**JpegImageFile**(***kwargs*)
Bases: astrophysix.simdm.datafiles.image.ImageFile

Datafile associated *JPEG_FILE* image file class.

property filename
Gets associated file name. Cannot be edited.

property last_modified
Returns file last modification time. Cannot be edited.

classmethod load_file(*filepath*)
Loads an *AssociatedFile* object from a filepath

Parameters **filepath** (string) – path of the file to load.

Returns **f** – Loaded associatedfile

Return type *AssociatedFile* instance

property pil_image
Pillow image (JPEG/PNG) image property getter. Implements lazy I/O.

property raw_file_data
File binary raw data. Cannot be edited.

Returns **raw_data**

Return type bytes

save_to_disk(*filepath=None*)
Save associated file to an external file on the local filesystem

Parameters **filepath** (string) – external file path

Plot information

class astrophysix.simdm.datafiles.plot.**PlotType**(*value*)
Plot type enum

Example

```
>>> pt = PlotType.HISTOGRAM_2D
>>> pt.alias
"2d_hist"
>>> pt.display_name
"2D histogram"
>>> pt.ndimensions
2
```

HISTOGRAM = ('hist', 'Histogram', 1, 1)

HISTOGRAM_2D = ('2d_hist', '2D histogram', 2, 1)

IMAGE = ('img', 'Image', 2, 1)

LINE_PLOT = ('line', 'Line plot', 1, 0)

MAP_2D = ('2d_map', '2D map', 2, 1)

SCATTER_PLOT = ('scatter', 'Scatter plot', 1, 0)

property alias
Plot type alias

property axis_size_offset

property display_name
Plot type verbose name

classmethod from_alias(*alias*)
Find a PlotType according to its alias

Parameters **alias** (string) – required plot type alias

Returns **ft** – Plot type matching the requested alias.

Return type *PlotType*

Raises **ValueError** – if requested alias does not match any plot type.

Example

```
>>> pt = PlotType.from_alias("hist")
>>> pt.display_name
"Histogram"
>>> pt2 = PlotType.from_alias("MY_UNKNOWN_PLOT_YPE")
ValuerError: No PlotType defined with the alias 'MY_UNKNOWN_PLOT_YPE'.
```

property ndimensions
Plot type number of dimensions

class astrophysix.simdm.datafiles.plot.**PlotInfo**(***kwargs*)
Datafile class (Simulation data model)

Parameters

- **plot_type** (*PlotType* or string) – Plot type or plot type alias (mandatory)
- **xaxis_values** (numpy.ndarray) – x-axis coordinate values numpy 1D array (mandatory).
- **yaxis_values** (numpy.ndarray) – y-axis coordinate numpy 1D array (mandatory).
- **values** (numpy.ndarray) – plot data values numpy array (mandatory for 2D plots).
- **xlabel** (string) – x-axis label
- **ylabel** (string) – y-axis label
- **values_label** (string) – plot values label
- **xaxis_unit** – TODO
- **yaxis_unit** – TODO
- **values_unit** – TODO
- **xaxis_log_scale** (bool) – TODO
- **yaxis_log_scale** (bool) – TODO
- **values_log_scale** (bool) – TODO
- **plot_title** (string) – Plot title.

__eq__(*other_plot_info*)
PlotInfo comparison method

Parameters **other_plot_info** (*PlotInfo*) – plot info object to compare to:

__unicode__()
String representation of the instance

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (*dict*) – keyword arguments (optional)

property plot_type
Returns the plot type (*PlotType*). Cannot be edited.

set_data(*xaxis_values*, *yaxis_values*, *values=None*)
Set plot data arrays.

Parameters

- **xaxis_values** (numpy.ndarray) – x-axis coordinate array
- **yaxis_values** (numpy.ndarray) – TODO
- **values** (numpy.ndarray) – TODO

property title
Plot title. Can be set to any string value.

property values
Plot values array. Cannot be edited. Implements lazy I/O.

Note: To edit plot values, see *PlotInfo.set_data()* method.

property values_label
plot values label. Can be set to any string value.

property values_log_scale
value log scale boolean flag. Can be edited to any bool value.

property values_unit
TODO

property xaxis_log_scale
x-axis log scale boolean flag. Can be edited to any bool value.

property xaxis_unit
TODO

property xaxis_values
Plot x-axis coordinate array (numpy.ndarray). Cannot be edited. Implements lazy I/O.

Note: To edit plot values, see *PlotInfo.set_data()* method.

property xlabel
x-axis label. Can be set to any string value.

property yaxis_log_scale
y-axis log scale boolean flag. Can be edited to any bool value.

property yaxis_unit
TODO

property yaxis_values
Plot y-axis coordinate array (numpy.ndarray). Cannot be edited. Implements lazy I/O.

Note: To edit plot values, see *PlotInfo.set_data()* method.

property ylabel
y-axis label. Can be set to any string value.

2.1.14 Object catalogs

New in version 0.5.0

Target object and their properties

New in version 0.5.0

class astrophysix.simdm.catalogs.targobj.**TargetObject**(***kwargs*)
Catalog target object class (Simulation data model)

Parameters

- **name** (string) – object name (mandatory)
- **description** (string) – result description

__eq__(*other*)
TargetObject comparison method

other: *TargetObject* target object instance to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property description
Target object description. Can be edited.

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property name
Target object name. Can be edited.

property object_properties
Target object *ObjectProperty* list (*ObjectList*)

property property_groups
Target object *ObjectPropertyGroup* list (*ObjectList*)

property uid

class astrophysix.simdm.catalogs.targobj.**ObjectProperty**(***kwargs*)
Target object property class (Simulation data model)

Parameters

- **property_name** (string) – property name (mandatory)
- **description** (string) – object property description
- **unit** (string or *Unit*) – object property physical unit
- **filter_flag** (*PropertyFilterFlag*) – target object property filter flag. Default *PropertyFilterFlag.NO_FILTER*

- **sort_flag** (*PropertySortFlag*) – target object property sort flag. Default *PropertySortFlag.NO_SORT*

__eq__(*other*)
ObjectProperty comparison method

other: ***ObjectProperty*** target object property instance to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property datatype
Object property datatype (*DataType*)

property description
Object property description. Can be edited.

property display_name
Object property display name. Concatenation of the property name and its unit LaTex formula, if defined.

property filter_flag
Object property filter flag. Can be edited.

Returns **f** – object property filter flag

Return type PropertyFilterFlag

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property property_name
Target object property name. Can be edited.

property sort_flag
Object property sort flag. Can be edited.

Returns **f** – object property sort flag

Return type PropertySortFlag

property uid

property unit

class astrophysix.simdm.catalogs.targobj.**ObjectPropertyGroup**(***kwargs*)
Target object property group class (Simulation data model)

Parameters

- **group_name** (*property group name (mandatory)*) –
- **description** (*property group description*) –

__eq__(*other*)
ObjectPropertyGroup comparison method

other: ***ObjectPropertyGroup*** target object property group instance to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property description
Object property group description. Can be edited.

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property group_name
Object property group name. Can be edited.

property group_properties
Object property group *ObjectProperty* list (*ObjectList*)

property uid

class astrophysix.simdm.catalogs.targobj.**PropertySortFlag**(*value*)
An enumeration.

ADVANCED_SORT = ('advanced_sort', 'Sort in advanced form')

BASIC_SORT = ('basic_sort', 'Sort in basic form')

NO_SORT = ('no_sort', 'Not used for sorting')

property displayed_flag
Object property sort flag displayed name

property flag
Object property sort flag value

classmethod from_flag(*flag*)

Parameters **flag** (string) – property sort flag value

Returns **t** – Property sort flag matching the requested flag value.

Return type *PropertySortFlag*

Raises **ValueError** – if requested flag value does not match any property sort flag.

Example

```
>>> flag = PropertySortFlag.from_flag("basic_sort")
>>> flag.displayed_flag
"Sort in basic form"
>>> flag2 = PropertySortFlag.from_flag("MY_UNKNOWN_FLAG")
ValuerError: No PropertySortFlag defined with the flag 'MY_UNKNOWN_FLAG'.
```

class astrophysix.simdm.catalogs.targobj.**PropertyFilterFlag**(*value*)
An enumeration.

ADVANCED_FILTER = ('advanced_filter', 'Filter in advanced form')

BASIC_FILTER = ('basic_filter', 'Filter in basic form')

NO_FILTER = ('no_filter', 'Not used in filters')

property displayed_flag
Object property filter flag displayed name

property flag
Object property filter flag value

classmethod from_flag(*flag*)

Parameters **flag** (string) – property filter flag value

Returns **t** – Property filter flag matching the requested flag value.

Return type *PropertyFilterFlag*

Raises **ValueError** – if requested flag value does not match any property filter flag.

Example

```
>>> flag = PropertyFilterFlag.from_flag("no_filter")
>>> flag.displayed_flag
"Not used in filters"
>>> flag2 = PropertyFilterFlag.from_flag("MY_UNKNOWN_FLAG")
ValuerError: No PropertyFilterFlag defined with the flag 'MY_UNKNOWN_FLAG'.
```

Object catalogs and catalog fields

New in version 0.5.0

class astrophysix.simdm.catalogs.catalog.**Catalog**(**args*, ***kwargs*)
Result object catalog class (Simulation data model)

Parameters

- **target_object** (*TargetObject*) – catalog object type (mandatory)
- **name** (string) – catalog name (mandatory)
- **description** (string) – catalog description

__eq__(*other*)
Catalog comparison method

other: ***Catalog*** Other catalog instance to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property catalog_fields
Catalog *CatalogField* list (*ObjectList*)

property datafiles
Catalog *Datafile* list (*ObjectList*)

property description
Catalog description

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property name
Catalog name

property nobjects
Returns the total number of objects in this catalog

property target_object
Catalog associated *TargetObject*.

to_pandas()
Convert a Catalog into a Pandas Dataframe object

Returns **df** – pandas DataFrame containing the catalog data

Return type pandas.DataFrame

property uid

class astrophysix.simdm.catalogs.catalog.**CatalogField**(**args*, ***kwargs*)

__eq__(*other*)
CatalogField comparison method

other: ***CatalogField*** catalog field object to compare to

__ne__(*other*)
Not an implied relationship between "rich comparison" equality methods in Python 2.X but only in Python 3.X see https://docs.python.org/2.7/reference/datamodel.html#object.__ne__

other: other instance to compare to

__unicode__()
String representation of the instance

property field_value_stats
Returns (min., max., mean, std) tuple for this field value array

property field_values
Catalog field values. Can be edited.

Returns **vals**

Return type 1D numpy.ndarray

property field_values_md5sum

galactica_valid_alias(*alias_value*)

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property nobjects
Returns the number of objects in this catalog field => size of the field value 1D array

property object_property
Associated target object property (*ObjectProperty*)

property property_name
Associated target object property name

to_pandas()
Convert a CatalogField into a `pandas.Series` object

property uid

2.1.15 Miscellaneous

Datatype enum

class astrophysix.simdm.utils.**DataType**(*value*)
Value data type enum

Example

```
>>> dt = DataType.INTEGER
>>> dt.name
"Integer number"
```

BOOLEAN = ('bool', 'Boolean')

COMPLEX = ('comp', 'Complex number')

DATETIME = ('time', 'Datetime')

INTEGER = ('int', 'Integer number')

RATIONAL = ('rat', 'Rational number')

REAL = ('real', 'Real number')

STRING = ('str', 'String')

classmethod from_key(*k*)

Parameters **key** (`string`) – data type key

Returns **t** – Physics matching the requested key.

Return type *DataType*

Raises **ValueError** – if requested key does not match any physics.

Example

```
>>> dt = DataType.from_key("rat")
>>> dt.name
"Rational number"
>>> dt2 = DataType.from_key("MY_UNKNOWN_DTYPE")
ValuerError: No DataType defined with the key 'MY_UNKNOWN_DTYPE'.
```

property key
Data type index key

Object lists

class astrophysix.simdm.utils.**ObjectList**(*obj_class*, *index_prop_name*)
Generic object list container class

Parameters

- **obj_class** (type) – base class of the objects that can be added to the list
- **index_prop_name** (string) – object property name used as a list index
- **validity_check** (callable) – method called upon object addition into the list. Default None.

Examples

```
>>> run1 = Simulation(simu_code=arepo, name="Pure-hydro run (isolated galaxy)")
>>> run2 = Simulation(simu_code=arepo, name="MHD run")
>>> run3 = project.simulation.add(Simulation(simu_code=arepo, name="Hydro run␣
↪with BH feedback")
>>> run4 = Simulation(simu_code=arepo, name="MHD run with BH feedback")
>>> project.simulation.add(run1)
>>> project.simulation.add(run2)
>>> project.simulation.add(run3)
>>> project.simulation.add(run4, insert_pos=2)  # Insert at position 2, not␣
↪appendend at the end of the list
>>> len(project.simulations)
4
>>> print(str(project.simulations))
Simulation list :
+---+-----------------------------------+-----------------------------------------
↪------+
| # |               Index               |                            Item          ␣
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
| 0 | Pure-hydro run (isolated galaxy)  | 'Pure-hydro run (isolated galaxy)'␣
↪simulation |
+---+-----------------------------------+-----------------------------------------
↪------+
| 1 | MHD run                           | 'MHD run' simulation                    ␣
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
| 2 | MHD run with BH feedback          | 'MHD run with BH feedback' simulation   ␣
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
| 3 | Hydro run with BH feedback        | 'Hydro run with BH feedback' simulation␣
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
>>> run3 is project.simulations[3]  # Search by item position
True
>>> project.simulations["MHD run"]  # Search by item index value
'MHD run' simulation
>>> del project.simulations[0]
>>> del project.simulations["MHD run"]
```

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```
>>> del project.simulations[run4]
>>> print(str(project.simulations))
Simulation list :
+---+-----------------------------------+-----------------------------------------
↪------+
| # |               Index               |                            Item
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
| 0 | Hydro run with BH feedback        | 'Hydro run with BH feedback' simulation
↪      |
+---+-----------------------------------+-----------------------------------------
↪------+
```

__delitem__(*item*)
Delete an object from the list.

Parameters **item** (`object` or `int` or `string`) – instance to delete, object position in the list (`int`) or index property value (`string`) of the object to remove from the list.

__eq__(*other*)
Object list comparison method

Parameters **other** (*ObjectList*) – other object list to compare to

__getitem__(*index*)
Get an object from the list.

Parameters **item** (`int` or `string`) – object position in the list (`int`) or index property value (`string`) of the object to fetch from the list.

Returns **o** – Found object in the list. None if none were found.

Return type `object` of type self.object_class

Raises

- **AttributeError** – if the search index type is neither an `int` nor a `string`.
- **IndexError** – if the `int` search index value is lower than 0 or larger than the length of the list - 1.

__iter__()
Basic object list iterator

__len__()
Size of the object list

__unicode__()
String representation of the instance

add(*obj*, *insert_pos=- 1*)
Adds a instance to the list at a given position

Parameters

- **obj** (`object`) – instance to insert in the list
- **insert_pos** (`int`) – insertion position in the simulation list. Default -1 (last).

add_validity_check_method(*can_add_meth*)
Add an object addition validity check method to the list of addition validity check methods

Parameters **can_add_meth** (Callable) – object addition validity check method

find_by_uid(*uid*)
Find an object in the list with a matching UUID

Parameters **uid** (UUID or string) – UUID or UUID string representation of the object to search for.

Returns **o**

Return type Matching object with corresponding UUID,if any. Otherwise returns None

galactica_validity_check(***kwargs*)
Perform validity checks on this instance and eventually log warning messages.

Parameters **kwargs** (dict) – keyword arguments (optional)

property index_attribute_name
Name of the object property used as an index in this object list

property object_class
Type of object that can be added into the list

2.1.16 Physical quantities/constants/units

class astrophysix.units.unit.**Unit**(*name=''*, *base_unit=None*, *coeff=1.0*, *dims=None*, *descr=None*, *latex=None*)
Dimensional physical unit class

Parameters

- **name** (string) – Unit name
- **base_unit** (Unit instance) – Composite unit from which this instance should be initialised
- **coeff** (float) – dimensionless value of the unit instance.
- **dims** (8-tuple of int) – dimension of the unit object expressed in the international unit system (kg, m, s, K, A, mol, rad, cd)
- **descr** (string or **None**) – Unit description
- **latex** (string or **None**) – Unit displayed name (latex format)

Examples

```
>>> cs_m_s = Unit(name="cs", coeff=340.0, dims=(0, 1, -1, 0, 0, 0, 0, 0), descr=
↪"sound speed unit")
>>> print("sound speed = {v:g} m/h".format(v=cs_m_s.express(km/hour)))
sound speed = 1224 km/h
>>>
>>> dens = Unit(name="Msun/kpc^3", base_unit=Msun/kpc**3, descr="Solar mass per␣
↪cubic kiloparsec",
                latex="{u1:s}.{u2:s}^{{-3}}".format(u1=Msun.latex, u2=kpc.latex))
>>> print(dens)
(6.76957356533e-29 m^-3.kg)
```

UNKNOWN_PHYSICAL_TYPE = 'unknown'

__eq__(*other*)
Checks Unit instance equality

Parameters **other** (*Unit*) – other unit instance to compare to

Returns **e** – True if *Unit.coeff* and *Unit.dimensions* are identical, otherwise False.

Return type bool

appropriate_unit(*nearest_log10=1.0*)
Try to find the better suited unit (among available equivalent units to represent this unit).

Parameters **nearest_log10** (float) – log of the nearest value to round to. Default 1.0.

Example

```
>>> u = 2426.2 * U.ly
>>> bv, bu = u.appropriate_unit()
>>> print("Appropriate unit : 2426.2 ly = {v:g} {bu:s}".format(v=bv, bu=bu.
↪name))
Appropriate unit : 2426.2 ly = 0.743876 kpc
```

property coeff
Constant value of this unit

classmethod create_unit(*name=''*, *base_unit=None*, *coeff=1.0*, *dims=None*, *descr=None*, *latex=None*)
Add a new Unit instance to the registry

Parameters

- **name** (string) – Unit name
- **base_unit** (Unit instance) – Composite unit from which this instance should be initialised
- **coeff** (float) – dimensionless value of the unit instance.
- **dims** (8-tuple of int) – dimension of the unit object expressed in the international unit system (kg, m, s, K, A, mol, rad, cd)
- **descr** (string or **None**) – Unit description
- **latex** (string or **None**) – Unit displayed name (latex format)

Raises **ValueError** – If the provided *name* already corresponds to a unit in the registry.

property description
Unit description

property dimensions
Unit dimension array

equivalent_unit_list()
Get the equivalent unit list (with same physical type)

Example

```
>>> print(U.kg.equivalent_unit_list())
[g : (0.001 kg), t : (1000 kg), mH : (1.66e-27 kg), Msun : (1.9889e+30 kg),␣
↪Mearth : (5.9722e+24 kg)]
```

express (*unit*)

Unit conversion method. Gives the conversion factor of this *Unit* 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*) – unit in which the conversion is made

Returns **fact** – conversion factor of this unit expressed in **unit**

Return type float

Examples

- Conversion of a kpc expressed in light-years :

```
>>> factor = kpc.express(ly)
>>> print("1 kpc = {fact:f} ly".format(fact=factor))
1 kpc = 3261.563777 ly
```

- Conversion of $1 M_{\odot}$ into kpc/Myr :

```
>>> print(Msun.express(kpc/Myr))
UnitError: Incompatible dimensions between :
- Msun : (1.9889e+30 kg) (type: mass) and
- (977792 m.s^-1) (type: velocity)
```

classmethod from_name (*unit_name*)

Get a *Unit* from its name in the astrophysix unit registry.

Parameters **unit_name** (string) – name of the unit to search.

Raises **AttributeError** – if *unit_name* attribute does not correspond to any unit in the astrophysix unit registry.

identical (*other_unit*)

Strict unit instance comparison method

Parameters **other_unit** (*Unit*) – other unit to compare to.

Returns **e** – True only if *other_unit* is equals to *self* AND has identical name/description/LaTex formula. Otherwise returns False.

Return type bool

info ()

Print information about this unit. If any, print the name and description of this unit, then print the value of this unit and the list of equivalent unit contained in the built-in unit registry associated with their conversion factor.

Example

```
>>> U.kpc.info()
Unit : kpc
----------
Kiloparsec
Value
-----
3.0856775814671917e+19 m
Equivalent units
----------------
* m             :    3.24078e-20 kpc
* um            :    3.24078e-26 kpc
* mm            :    3.24078e-23 kpc
* cm            :    3.24078e-22 kpc
* nm            :    3.24078e-29 kpc
* km            :    3.24078e-17 kpc
* Angstrom      :    3.24078e-30 kpc
* au            :    4.84814e-09 kpc
* pc            :           0.001 kpc
* Mpc           :            1000 kpc
* Gpc           :           1e+06 kpc
* Rsun          :    2.25399e-11 kpc
* ly            :    0.000306601 kpc
```

is_base_unit()
Checks whether the Unit is a base SI Unit (kg, m, s, K, A, mol, rad, cd).

Returns **b** – True only if unit is a base SI unit(kg, m, s, K, A, mol, rad, cd). Otherwise returns False.

Return type bool

classmethod iterate_units(*phys_type=None*)
Unit iterator method. Iterates over all units in the astrophysix unit registry.

Parameters **phys_type** (string) – Name of the physical quantity type of the units to iterate over. Default **None** (all physical quantities).

Yields **u** (*Unit*) – unit of the required physical quantity type, if any given.

property latex
Unit displayed name (LaTex format)

property name
Unit name

property physical_type
Get the unit physical type (dimensioned physical quantity).

Returns **t** – The name of the physical quantity, or *Unit.UNKNOWN_PHYSICAL_TYPE* if the physical quantity is unknown.

Return type string

2.1.17 Utils

class astrophysix.utils.file.**FileType**(*value*)
File type enum

Example

```
>>> ft = FileType.ASCII_FILE
>>> ft.alias
"ASCII"
>>> ft.extension_list
[".dat", ".DAT", ".txt", ".TXT", ".ini", ".INI"]
```

ASCII_FILE = ('ASCII', ['.dat', '.DAT', '.txt', '.TXT', '.ini', '.INI'])

CSV_FILE = ('CSV', ['.csv', '.CSV'])

FITS_FILE = ('FITS', ['.fits', '.FITS'])

HDF5_FILE = ('HDF5', ['.h5', '.H5', '.hdf5', '.HDF5'])

JPEG_FILE = ('JPEG', ['.jpg', '.jpeg', '.JPG', '.JPEG'])

JSON_FILE = ('JSON', ['.json', '.JSON'])

PICKLE_FILE = ('PICKLE', ['.pkl', '.PKL', '.pickle', '.sav', '.save'])

PNG_FILE = ('PNG', ['.png', '.PNG'])

TARGZ_FILE = ('TARGZ', ['.tar.gz', '.TAR.GZ', '.TAR.gz', '.tar.GZ', '.tgz', '.TGZ'])

XML_FILE = ('XML', ['.xml', '.XML'])

__unicode__()
String representation of the enum value. Returns alias.

property alias
Returns file type alias

property default_extension
Returns the first item in the file type extension list

property extension_list
Returns file type valid extension list

property file_regexp
Returns filename matching regular expression for the current file type

classmethod from_alias(*alias*)
Find a FileType according to its alias

Parameters **alias** (string) – required file type alias

Returns **ft** – File type matching the requested alias.

Return type *FileType*

Raises **ValueError** – if requested alias does not match any file type.

Example

```
>>> ft = FileType.from_alias("PNG")
>>> ft.extension_list
[".png", ".PNG"]
>>> ft2 = FileType.from_alias("MY_UNKNOWN_FILETYPE")
ValuerError: No FileType defined with the alias 'MY_UNKNOWN_FILETYPE'.
```

CHAPTER

THREE

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PYTHON MODULE INDEX

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