astrolyze Documentation

Release 0.2.1

Christof Buchbender

October 23, 2015

Contents

Astrolyze is a python-package with several functions for reduction and analysis of (mainly) radioastronomical data. It is developed over the course of my Diploma and PhD thesis and beyond. I share this package here because I think that it may be useful to other astronomers. The package is open for collaboration.

Please read the *Motivation - What is astrolyze all about* section first if you are new to the package.

Warning: AstroLyze is functional but not stable. It is provided on a best-effort base momentarily.

CHAPTER 1

Installation of astrolyze

astrolyze is only tested on Linux/Ubuntu so far.

1.1 Installation

Astrolyze is available via pypi, use:

```
sudo pip install astrolyze --user
```

to install the package.

When installed with the –user flag the package will be installed in:

```
/home/USERNAME/.local/lib/python2.7/site-packages/astrolyze
```

The configuration files for *astrolyze* are installed in:

```
/home/USERNAME/.astrolyze/
```

Further a script to configure the database for additional information is installed in:

```
/home/USERNAME/.local/bin/
```

1.2 Dependencies

1.2.1 Python

astrolyze depends on the following python packages:

```
     astropy
     numpy
     scipy
     matplotlib
     pysqlite
     docutils
     generaltools
```

After installation of astrolyze via pip a list of these packages "requirements.txt" is copied to

/home/USER/.astrolyze/

The dependencies can be installed via pip:

```
pip install -r ~/.astrolyze/requirements.txt
```

Warning: Astrolyze does not work in python3 yet. Since the Gildas Python extension is not yet available for python 3!!

1.2.2 Gildas

To be able to use GILDAS from within astrolyze it is enough to have a working GILDAS installation compiled with the python support. The actual GILDAS version and installation instructions can be found here:

http://www.iram.fr/IRAMFR/GILDAS/

1.2.3 Miriad

Also Miriad just has to be installed and working. At the moment only the smooth function of miriad is used in astrolyze but it is worth installing it since it it a common task.

A package for Ubuntu 14.04 (works for 15.04 as well) can be found here:

ftp://ftp.astro.umd.edu/progs/carma/miriad_2014.7/miriad_linux64_u14_gfortran.tar.gz

and instructions for the installation of the package here:

http://vilhelmp.blogspot.de/2011/10/installing-sma-miriad-in-latest-ubuntu.html

1.3 Configuration of the (optional) Database

Astrolyze can store META Information for Sources, Lines and Calibration Uncertainties in a database. Based on the information deduced from the naming convention the additional information is loaded automatically when a map is opened.

astrolyze can read:

- Additional informations of the source
- Frequencies and wavelengths
- Calibration error for specific telescopes

The database has to be populated after installation This is done via the three text files in the `/home/USER/.astrolyze/cfg` folder that contains:

galaxy_parameter.txt:

```
#   Name     MorphType    Distance[pc]     VLSR[km/s]   RA            DEC             PA[degrees] Inclinat
    M33      SA(s)cd      840e3            -179         01:33:51.02   +30:39:36.7     -22.5       56
    NGC3627  SAB(s)b      9.1e6            727          11:20:15.027  +12:59:29.58    173         64
```

line_parameter.txt:

```
# line_name frequency[GHz]
HCOP10      89.188523
HCN10       88.6304156
12CO10      115.271204
13CO10      110.2013543
```

```
12CO21      230.542408
HI          1.427583133
HALPHA      457121.40
```

calibration_error.txt:

```
# telescope     species     cal_error   Reference
WISE            2.4MUM      0.15        guess
IRAC            3.6MUM      0.1         guess
IRAC            4.5MUM      0.1         guess
WISE            4.6MUM      0.15        guess
IRAC            5.8MUM      0.1         guess
IRAC            8MUM        0.1         guess
WISE            12MUM       0.15        guess
WISE            22MUM       0.15        guess
MIPS            24MUM       0.07        Spitzers Observers Manual v.8.0
MIPS            70MUM       0.07        Spitzers Observers Manual v.8.0
PACS            100MUM      0.2         Kramer et al. 2010
PACS            160MUM      0.2         Kramer et al. 2010
SPIRE           250MUM      0.15        Kramer et al. 2010
SPIRE           350MUM      0.15        Kramer et al. 2010
SPIRE           500MUM      0.15        Kramer et al. 2010
GISMO           2MM         0.15        guess
```

The Names of the source telescope and lines have to be exactly how they are used in the map names. However the writing can be an arbitrary mix of upper an lower case characters. Internally Astrolyze converts them to upper case before comparing.

To generate the database from these files you have to run the script:

```
> ~/.local/bin/astrolyze_opt_db_setup.py
```

installed in *.local/bin*.

CHAPTER 2

Motivation - What is astrolyze all about

First, before delving into the details of the astrolyze package, here a few examples are given of what astrolyze is all about. The following is a short teaser of some of the features of astrolyze; a thorough introduction with more features and possibilities are given in the label-naming-convention.

2.1 Inter-operating Fits, Gildas and Miriad

A central concept of *astrolyze* is to enable to use different astronomically map formats and different programs from within python seamlessly. Say, for example, that you have a Fits image called `M33_30m_12CO10_Tmb_12.fits` and that you want to smooth it in miriad to 40 arcsec resolution, re-project it with Gildas to a new central coordinate and finally convert it back to fits-format:

This is how you would do it with astrolyze:

```
from astrolyze import *
map_ = FitsMap('M33_30m_12CO10_Tmb_12.fits')
map_ = map_.toMiriad()
map_ = map_.smooth(40)
map_ = map_.toGildas()
map_ = map_.reproject(coordinate=['01:34:50.890', '+31:08:28.03'])
map_ = map_.toFits()
```

Please note the special format of the map name. The format follows a certain `naming convention` that **has** to be used with astrolyze. The reason for the naming conventions and it's internal logic is explained below.

Note: As a side note I use an underscore for the `map_` variable, because otherwise the python function `map` is overwritten which may lead to problems.

2.2 Changing map units

With astrolyze the units of a map can be quickly transformed between common units used in (Radio-) Astronomy (as far as the conversion was implemented already). Take for example again the `M33_30m_12CO10_Tmb_12.fits` map. Following the naming convention this map is in main beam temperature (Tmb). Changing its units to `JyB` is as easy as:

```
from astrolyze import *
map_ = FitsMap('M33_30m_12CO10_Tmb_12.fits')
map_ = map_.change_unit('JyB')
```

Another side note: It's only that easy when astrolyze is set-up with the database so that astrolyze knows about the frequency/wavelenght of the line in the map.

Warning: Please double check the results of the unit conversion.

2.3 Working with stacks of images

The previous examples demonstrated how single maps can be used in astrolyze. It is further possible to work on a stack of images and perform tasks on all of them.

To create a stack, all files that are going to be in the stack have to be located in one folder (with possible sub-folders NOTE: The functionality with sub-folders is not thoroughly tested, yet.) A stack is initialized as follows:

```
from astrolyze import *
example_stack = Stack('path_to_folder')
```

The maps can be a mix of GILDAS, Fits and MIRIAD maps. The Instance of the Stack object (here: `example_stack`) contains a variable called stack which is a list with Instances of the corresponding maps Objects (GildasMap, FitsMap and MiriadMap).

The stack module provides several tools to `unify` the stack for further analysis. The maps can be all re-gridded and re-projected to the same central coordinates, pixel-sizes and dimensions as a given template image via:

```
example_stack.unify_dimensions(template='path_to_template_file',
                               folder='path_to_output_folder') .
```

Also the maps can be all smoothed to the same resolution, by default this is the largest resolution found in the stack but can also be given manually:

```
example_stack.unify_resolutions(folder='path_to_output_folder') .
```

Astrolyze includes unit conversions that can be used to change all maps to the same resolutions as long as the input and output units are programmed. For the stack:

```
example_stack.unify_units(folder='path_to_output_folder') ,
```

can be used.

2.4 Producing SEDs

Build on-top of the stack module astrolyze, contains the `sed` module which allows to analyze and plot **dust-seds**. SEDs can be read out for an arbitrary number of positions or for the entire maps. In the latter case temperature, mass, beta and chi^2 maps will be created.

When all maps have the same resolution and dimension (i.e. pixel size and number) producing temperature maps can be done as follows:

```
from astrolyze import *
sed = SedStack(folder='path_to_input_folder', full_map=True,
       output_folder='path_to_output_folder') .
```

To generate SEDs at given coordinates it is easiest to provide a separate file (e.g. `coordinates.txt`) with the names and coordinates of the positions to be extracted as follows:

```
source_1    1:34:7.00     +30:47:52.00
source_2    1:33:55.80    +30:43:2.00
source_3    1:33:52.40    +30:39:18.00
  .              .             .
  .              .             .
  .              .             .
```

Then a stack of seds can be created:

```python
from astrolyze import *
seds = SedStack(folder='path_to_input_folder', flux_acquisition='pixel')
```

By default the SED is also directly fitted. One can produce a quick preview plot of the SEDs via:

```python
for i in seds.sed_stack:
    i.create_figure()
```

2.5 Not only images ...

Last but not least astrolyze is also able to work with 30m class spectra from within python based on the same principles used to work with images/maps. The implementation makes extensive use of pyGildas. For example if you have a file with the spectra of a cube, e.g. `M33_30m_12CO10_Tmb_21_cube.30m` you can extract the spectra that corresponds closest to a given coordinate as follows:

```python
from astrolyze import *
spectra = ClassSpectra('M33_30m_12CO10_Tmb_21_cube.30m')
coordinate = ['1:34:7.00', '+30:47:52.00']
spectrum = spectra.get_spectra_from_cube(coordinate)
# To show the spectrum in the Class window
spectrum.quick_view()
```

CHAPTER 3

Manual

This manual explains how astrolyze can be used to ease reduction, analysis and modification of (radio-)astronomical data and images.

3.1 astrolyze

I started to develop astrolyze to be able to inter-operate the Programs PyFits, MIRIAD and GILDAS. One reason was that the Gildas task are very cumbersome to script and once scripted, the scripts are not very flexible. Also there are some tasks in GILDAS that are (in my opinion) easier to use than in miriad and vice-versa, due to different sets of features.

However, the real power of astrolyze comes from it's internal tracking of changes to the most important parameters of the maps (or spectral-files), which are stored directly in the file-names. This principle is based on a *naming-convention*. An additional databases can be setup so that more informations can be loaded depending on the file-name-keywords.

3.1.1 Naming Convention

A Name that follows the 'Naming Convention' is for example: `M33_30m-HERA_CO21_Ta*_12_cube_regrid.fits`

All items **MUST** be separated by an underscore (_) and **HAVE** to include at the following properties in this very order:

1. source
2. telescope
3. species (wavelength OR frequency OR line-name)
4. flux unit
5. resolution

When opening a map with astrolyze these items are transferred to python variables of the *Map class* (see below). All additional items separated by underscores are treated as comments. Comments are not transferred to individual internal variables of the map objects but are passed on as a list to the single variable *comments*.

The last item is followed by the files extension:

- .fits -> FITS
- .gdf, .mean, .velo, .width, .lmv -> GILDAS
- nothing -> MIRIAD (Miriads file format uses directories to store the data.)

Maps that are not following this name convention are **not** supported. This is to assure that all parts of the program work, since they strongly depend on the parameters passed on by the file-name.

Using the example file-name above, opening this file with astrolyze as follows:

```
from astrolyze import *
map_ = FitsMap('M33_30m_12CO10_Tmb_12_cube_regrid.fits')
```

would generate the following variables:

```
map_.source = 'M33'
map_.telescope = '30m'
map_.species = '12CO10'
map_.fluxUnit = 'Tmb'
map_.resolution = '12'
map_.comments = ['cube', 'regrid']
map_.dataFormat = 'fits'
```

Using the parameter database with line-names, objects and telescope parameters, that can be edited by the user (see Installation of astrolyze), astrolyze pulls more information about the object, telescope and line emission of the map. When the information is present it generates automatically the following variables:

```
map_.frequency [Hz]
map_.wavelength [m]
map_.calibrationError
map_.type [Hubble Type]
map_.distance [pc]
map_.vlsr [km/s]
map_.centralPosition [RA, DEC] J2000
map_.pa [degrees]
map_.inclination [degrees]
map_.R25 [kpc]
```

If not present in the database these variables are set to ‘NaN’ (Not a Number).

Although, all of this information is somewhat redundant to the header information in the files, it has been decided to go that way since unfortunately not all headers are kept up to date and manipulating the file name is easier to do.

Nevertheless, the maps module tries to keep track if a variable that should go into the header of a fits file is changed and up-dates the header subsequently (This is however hard to maintain and not true in all cases, though.).

Last but not least using this name convention has another benefit since it makes the life of your fellow astronomers easier when they have to work with your data since they readily know their most important basic properties.

3.2 Modules

astrolyze is divided in different modules and classes which can inter-operate with each other and which are:

- maps
- spectra
- sed
- functions
- lte

In the following I will introduce the individual modules of astrolyze and their functionality.

Not all functions of the individual astrolyze modules will be covered in this manual-page. All functions are documented and can be found HERE TODO. The next sections attempts to show the basis principles, structure and work-flow of astrolyze.

3.2.1 maps

The `maps` module is the heart of the astrolyze package. It provides the framework to work with astronomical images (and spectra). It is able to modify and to track the most important properties of the maps such that they are always fast at hand if needed. Further it contains genuine functions written in python (and pyGildas), alongside wrapper functions to functions and tasks of *GILDAS* and *MIRIAD*.

The `maps` module contains the following modules/Classes itself:

- main.Main
- fits.FitsMap
- gildas.GilsdasMap
- miriad.MiriadMap
- stack.Stack
- tools

3.2.2 main

This module contains the class: `Main`, which is the parent class for all actions not depending on the actual data-type. In principle it is the implementation of the *Naming Convention* and is not directly used to open a map. All other classes in maps inherit from the `Main` class, such that it is used any time the other modules of maps are used. Also the *Using the sed module* uses Main.

Variables created by Main

When opening a map with `Main` variables are created that contain information about the maps and can be used to work with the data. The variables are class attributes. They can be accessed by attaching them to the object with a dot between object and attribute:

```
object.attribute
```

In astrolyze the maps that are opened are objects. The information for the variables come from different places:

From naming convention

```
map_name
prefix
source
telescope
species
fluxUnit
resolution
comments
dataFormat
```

Calculated Values

Assuming a Gaussian beam size the following variables are calculates from the `resolution` keyword.

```
beamSizeM2        Beam-Size in m^2
beamSizeSterad    Beam-Size in sterad
```

Known Format endings of the different file types

These variables contain a list that contain all strings that are recognized by the system as a valid file name ending (TODO: find the correct name for file ending).

```
fits_formats
miriad_formats
gildas_formats
class_formats
```

Warning: These are hard-coded, should be initialized via the cfg/ folder of the package when installing.

Variables loaded from Database

As explained in TODO. Astrolyze uses a database to store additional informations about maps. The database is set-up during installation as explained in Installation of astrolyze.

From Line Database

Using the `species` keyword:

```
frequency  : [GHz]
wavelength : [TODO]
```

From Galaxy Database

Using the `source` keyword.:

```
centralPosition : [RA, DEC]
distance : [kpc]
R25 : [kpc TODO]
inclination : [degrees]
vlsr : [km/s]
pa : [degrees]
type :  The Hubble type of the galaxy.
```

From Calibration Database

Using the `species` and `telescope` keywords.:

```
calibrationError
```

The in-depth documentation of the internal functions can be found here *Main*.

3.3 fits

The fits module contains the class `FitsMap`. This class inherits all functions from `Main` but adds functionality and methods needed to work with fits data. This class makes use of the *python-pyfits* package. Please check the pyfits web-page (follow the previous link) for the pyfits documentation.

To open a fits-map do, e.g.

```
from astrolyze import *
map = FitsMap('M33_30m_12CO10_Tmb_12.fits')
```

3.3.1 Variables created by FitsMap

Opening a Fits map creates, besides the variables discussed in *Main* the following additional variables specific to the `FitsMap`:

Variables loaded with pyfits

```
header : a dictionary with the fits-header cards
data : numpy.ndarray containing the data
hdulist : Some fits-files have more than one plane. HDUlist contains all
      planes.
```

Calculated values

Because the fits-header is read via *python-pyfits* the pixel dimensions are known and thus the pixel-sizes can be calulated:

```
pixelSizeM2 : [m^2]
pixelSizeSterad [sterad] .
```

Known header keywords

```
headerKeywords : A dictionary containing different fits-header keywords that
         are used for the same quantity.
```

3.3.2 Known names of units

The `FitsMap` class contains the method `change_unit` which is able to check the conversion that is needed to change to the desired unit. However for this another `Unit Naming Convention` is needed. The following variables contain lists of valid names for certain variables:

```
tmb_names
jansky_beam_names
MJy_per_sterad_names
erg_sec_pixel_names
erg_sec_beam_names
jansky_pixel_names
erg_sec_sterad_names
known_units .
```

Warning: This should also be setup during installation of astrolyze to be able to customize unit-names easily.

3.3.3 Working with Fits Maps

Changing Formats

Note: Changing formats works the same way in all `maps` modules.

The loaded fits map can be transformed to the Gildas and Miriad Formats via the methods:

```
toGildas()
toMiriad()
```

and from either of the other two Formats to Fits via:

```
toFits()
```

This creates a copy of the image in the Gildas, Miriad (or Fits) Format on the disk in the same folder as the actual map. To keep working with the map in the new format one can use:

```
map = map.toGildas()
```

to change the out-put folder there are two ways:

```
1. Set the ``map.prefix`` variable to the new path prior to
   changing the map format as shown above.
2. Give the new path to the function, e.g. map.toGildas(folder='new_path')
```

Thus e.g.:

```
map.prefix = 'new_path'
map = map.toGildas()
```

or:

```
map = map.toGildas(folder='new_path')
```

Making use of Pyfits

As listed in *Variables created by FitsMap* a `data` and a `header` variable is created. These are a numpy.ndarray of the image data and a dictionary containing the header keywords with their arguments. Thus changing the properties of the fits map and the header variables is straight-forward.

For example you may want to change the units of a map `M33_30m_12CO10_Tmb_12.fits` that is in main beam temperature to Jansky/beam by multiplying all pixels with the corresponding conversion factor. This can be done via:

```
from astrolyze import *
map = FitsMap('M33_30m_12CO10_Tmb_12.fits')
conversion_factor = map.flux_conversion()
map.data = map.data * conversion_factor
```

The conversion factor between the two units is calculated here via `flux_conversion` please refer to the function fro more details.

Having changed the unit it may be a good idea to change the header variables that stores the actual unit as well as the unit-keyword from the naming convention., this can be done as follows:

```
from astrolyze import *
map = FitsMap('M33_30m_12CO10_Tmb_12.fits')
print map.header['BUNIT']
map.unit = 'JyB'
map.header['BUNIT'] = 'Jy/beam'
```

Note: The individual functions in of the `FitsMap`-class change the header of the Fits file automatically if map properties are changed. At the same time they have access to all fits-header variables if needed.

Finally you may want to save the modified image as a new fits file which can be done with:

```
map.updateFile()
```

This creates a file called M33_30m_12CO10_JyB_12.fits

Change Map Units

Since it is easy to modify all pixel via *python-pyfits* the function `change_unit` that converts units into another is implemented in the `FitsMap`-class. See the documentation of `change_unit` for the conversions that are implemented.

Using the information from the "Naming Convention" and the additional information from the database, the code has all information to calculate the conversion factors. And also to decide which conversion is to be applied. Changes are possible between any of the units that are implemented.

Warning: This is not thoroughly tested yet!!

For example the same change of units as in the previous section can be done as follows:

```
from astrolyze import *
map = FitsMap('M33_30m_12CO10_Tmb_12.fits')
map = map.change_unit('JyB')
```

3.4 Using gildas

When Opening a Gildas map with:

```
from astrolyze import *
map = GildasMap('M33_30m_12CO10_Tmb_12.gdf')   ,
```

astrolyze uses pyGildas to read some of the header variables and stores them as python variables. The following values are read.

3.4.1 Variables

Gildas Specific

```
dimensions
naxis_1 : number of pixels in x-axis.
naxis_2 : number of pixels in y-axis.

crpix_1 : The reference pixel (x-axis).
crval_1 : The coordinate value at crpix_1 [radians].
cdelt_1 : The pixel increment.

crpix_2 : Same as crpix_1 for y-axis.
crval_2 : Same as crval_1 for y-axis.
cdelt_2 : Same as crdelt_1 for y-axis.

ra_coordinate : RA coordinate.
dec_coordinate : DEC coordinate

ra_coordinate : TODO
dec_coordinate : TODO

central_coordinate_degrees : TODO
central_coordinate_equatorial : TODO
```

Note: If needed more variables can be loaded when opening a Gildas map without problems , so far only those that were needed are implemented.

3.5 How is Gildas used by astrolyze

Gildas is used in two different ways in Atrolyze:

```
1. A Gildas script, with a final exit at the end is created and executed via
   the os python package, sending commands to the bash.
2. The pyGildas package is used directly by astrolyze to tun command in SIC.
```

The first method is mainly used to wrap GREG (and maybe later CLASS) tasks since these are cumbersome to script so far in Gildas. To do so the GildasMap method create an `init` file and a temporary Greg script that is (normally) deleted after execution. The standard script looks as follows:

```
exit
```

3.5.1 Wrapping Gildas Tasks

3.5.2 Direc use of pyGildas

3.6 Using miriad

A miriad map is opened with:

```
from astrolyze import *
map = GildasMap('M33_30m_12CO10_Tmb_12.gdf')   ,
```

In this mode only the variables created by `main` are created.

Only the `"smooth"` function from miriad is implemented in astrolyze see `smooth()`. When all header variables are set correctly this function is aware of the map units and beam sizes and can calculate the correct scaling that has to be applied after convolution. The way astrolyze is set up the smooth function expects the map to be in units of `Jy/beam`.

Warning: Miriad could be excluded from astrolyze in the future if the GILDAS smooth wrapper is programmed such that it is aware of different input variables.

3.7 Using the stack module

The `Stack` class builds on top of the classes:

```
Main
FitsMap
GildasMap
MiriadMap
```

It provides the possibility to load a "stack" of maps inside a folder at once and perform changes on all maps. It's intention is mainly to provide means to unify maps for further processing. Tasks such as for example pixel-to-pixel comparisons or the creation of temperature-maps from SED-fits needs individual maps to be on the same resolution and/or the same pixel grid.

•

3.8 Using the sed module

The module SED makes extensive use of the stack functionality of the maps module...

3.9 Using Functions

The module `functions` contains all functions that are not directly related to manipulation of maps or spectra and counter intuitive also all constants used in astrolyze as long as they are not available by the standard python installation (this may not be true however.).

3.10 Using LTE

3.11 References

CHAPTER 4

Cookbook

Producing dust-temperature, dust-mass and β maps from a list of images at different temperature by fitting multi-greybody components to the spectral energy distribution at every pixel.

4.1 Setup initial guesses

The Sed and SedStack classes take initial guesses for temperatures, masses and beta values as input. These variables have to be given as lists with as many entries as there are components to be fitted.

```
>>> from astrolyze import *
>>> number_of_components = 2
>>> temperature_guesses = [20, 40]
>>> mass_guesses = [1e5, 1e3]
>>> beta_guess = [2]
```

Note: At the moment only a single beta value for both components can be used.

4.2 Prepare the maps with the different wavelength of the SED

To create an SedStack you have to have a folder that contains only the maps you want to use. At the beginning these can still have different formats, resolution and other parameters. You can use the Stack class to unify the maps. Especially to construct temperature and mass maps from these maps, the Stack of maps has to have the same resolution, flux unit, and dimensions (map/pixel size). In the following the process of unifying a set of images is shown.

```
>>> stack_ = Stack("InputFolder")
>>> stack_ = stack_.unify_units(unit="JyB", folder="output_folder1")
>>> stack_ = stack_.unify_resolutions(folder="output_folder2")  #  Default uses larges resolution fou
>>> stack_ = stack_.unify_dimensions(template="template_map", folder="output_folder3")
```

Here *template_map* is a map that has the dimension and pixel size one ones to obtain for the final SED-maps. output_folder1-3 should be physically distinct.

4.3 Loadind the SedStack and fitting

Now one can load the final stack of images and produce the SED maps

```
>>> sed_stack = SedStack('output_folder3', full_map=true, flux_acquisition='pixel', number_components
>>> sed_stack.get_sed_maps(folder="final_output_folder")
```

CHAPTER 5

Source Documenation

5.1 Maps

5.1.1 Main

class `astrolyze.maps.main.`**`Map`**(*map_name*, ***kwargs*)

`Map` is the parent Class for the `maps`-package. It contains all functions that are common to all supported map-formats, i.e. Fits, GILDAS and Miriad. This class is only supposed to be called through the FitsMap, GildasMap, and MiriadMap classes.

Parameters **`map_name`** (*string*) – The name and path of the file that is to be initialized to the maps package.

`change_map_name`(*source=None*, *telescope=None*, *species=None*, *fluxUnit=None*, *resolution=None*, *comments=None*, *dataFormat=False*, *prefix=None*)

This function can be used to change the names of the maps and make a copy of the file to the new name and/or location.

`flux_conversion`(*x=None*, *major=None*, *minor=None*, *nu_or_lambda='nu'*, *direction=None*)

Calulates conversion between K.km/s and Jy/beam and vise versa.

Parameters

- **`x`** (*float [GHz]*) – Wavelength/frequency. Defaults to the frequency of the loaded map, i.e. self.frequency
- **`major`** (*float*) – Major Axis Beam (arcsec). Default None, i.e. using self.resolution.
- **`minor`** (*float*) – Minor Axis Beam(arcsec). Default None, i.e. using self.resolution.
- **`nu_or_lambda`** (*string*) – Choose type of x: frequency = `'nu'` or wavelength = `'lambda'`.
- **`direction`** (*string*) – choose conversion direction `'kelvin_to_jansky'` means Kelvin to Jansky; `'jansky_to_kelvin'` Jansky to Kelvin.

Notes

If self.frequency and self.resolution are correctly set, this functions does not need any input. Otherwise this has to be given explicitly.

`get_beam_size`()

Calculates the beam-size in steradians and in m^2. Fot the latter the distance to the source has to be given.

Returns

- *Initialization if the variables*
- *self.beamSizeSterad and self.beamSizeM2*

Notes

The formula used is:

`resolutionToString`(*resolution=None*)

Converts the resolution list to a string to be printed and included in the file names.

`returnName`(*source=None*, *telescope=None*, *species=None*, *fluxUnit=None*, *resolution=None*, *comments=None*, *dataFormat=False*, *prefix=None*)

Returns the Name corresponding to the Name convention. Single keywords can be changed.

This function is useful to generate a writeout name for a changed file without overwriting the current `self.map_name`.

Parameters

- **`possible parameters from the "Naming Convention" plus the new`** (*All*) –
- **`prefix.`** –

5.1.2 FitsMap

class `astrolyze.maps.fits.`**`FitsMap`**(*map_name*)

Fits Map manipulation making extensive use of the pyfits package.

`change_unit`(*final_unit*, *frequency=None*, *debug=False*)

Changes the unit of a map

Parameters

- **`final_unit`** (*string*) – The unit to change the map to. Possible are:
  1. Jy/beam: `"JyB"` `"JyBeam"`
  2. Jy/pixel: `"JyP"`, `"JyPix"`, `"JyPixel"`
  3. MJy/sterad: `"MJyPsr"`, `"MJPSR"`, `"MJy/sr"`
  4. Main Beam Temperature: `"Tmb"`, `"T"`, `"Kkms"`
  5. erg/s/pixel: `"ergs"` `"ERGPSECPPIX"`, `"ERGPSECPPIXEL"`, `"ERG-S-1-Pixel"`, `"ERG-S-1"`
  6. erg/s/beam: `"ERGPSECPBEAM"`
  7. erg/s/sterad `"ERGPERSTER"`
- **`frequency`** (*float*) – Can be used if self.frequency is NaN. The frequency (in GHz) is needed for conversions between temperature and Jansky/Erg scale. Other conversions don't need it.

Notes

Warning: This function is still in development and not all conversions may work properly.

gauss_factor (*beamConv*, *beamOrig=None*, *dx1=None*, *dy1=None*)

Calculates the scaling factor to be applied after convolving a map in Jy/beam with a gaussian to get fluxes in Jy/beam again.

This function is a copy of the FORTRAN gaufac function from the Miriad package, which determine the Gaussian parameters resulting from convolving two gaussians. This function yields the same result as the MIRIAD gaufac function.

Parameters

- **beamConv** (*list*) – A list of the [major axis, minor axis, position_angle] of the gaussion used for convolution.
- **beamOrig** – Same format as beamConv but giving the parameters of the original beam of the map. As Default the self.resolution list is used.
- **dy1** (*dx1,*) – Being the pixel size in both dimensions of the map. By default the `CDELT1` and `CDELT2` keywords from the fits header are used.

Returns

- *fac* – Factor for the output Units.
- *amp* – Amplitude of resultant gaussian.
- *bmaj, bmin* – Major and minor axes of resultant gaussian.
- *bpa* – Position angle of the resulting gaussian.

get_pixel_size ()

Calculates the Area of a pixel in m^2 and steradians if distance is given. If not only steradians are calculated.

pix2sky (*pixel*, *degrees_or_equatorial='degrees'*)

Calculates the Coordinates of a given Pixel.

Parameters

- **pixel** (*list*) – Pixel of the map; [x, y].
- **degrees_or_equatorial** (*string*) – Either `"degrees"` or `"equatorial"`. Choosing the Format of the coordintates to be returnes. Defaults to `"degrees"`.

Returns **coordinate** – The coordinates corresponding to pixel. Either in Degrees or in Equatorial coordinates, depending on the parameter *degrees_or_equatorial*.

Return type list

read_aperture (*position*, *apertureSize=0*, *backgroundSize=0*, *output=False*, *annotation=False*, *newAnnotation=False*)

Extract the sum and mean flux inside an aperture of a given size and at a given position..

This function can be used to read the flux in the area of a circular aperture, as well as to correct for the background flux.

Parameters

- **position** (*list*) – The position in RA,DEC where the aperture is to be applied. The Format has to be either:

  - ['RA','DEC'] with strings representing equatorial coordinates, e.g. ['01:34:32.8', '+30:47:00.6'].

  or:

  - [RA, DEC] where RA and DEC being the coordinates in Grad.

- **apertureSize** (*float [arcsec]*) – The diameter of the aperture to be applied.
- **backgroundSize** (*float [arcsec]*) – The Size of the Anulli in which the background is to be estimated. The number to be given here correspond to the diameter of the circle in [arcsec] descibing the outer border of the annuli, measured from the position given in position. Thus, the background is measurd in the ring described by apertureSize and backgroundSize. Default is 0 and thus **no background substaction** is applied.
- **output** (*True or False*) – If True the function reports the calculated values during execution.
- **annotion** (*logical*) – If True a kvis annotation file `"apertures.ann"` containing the aperture used to integrate the flux is created. Default is False, i.e. not to create the aperture.
- **newAnnotation** (*logical*) – If True `"apertures.ann"` is overwritten. If False an old `"apertures.ann"` is used to append the new apertures. If it not exists a new one is created. The latter is the default.

Returns List

Return type [Sum, Mean, Number of pixels]

Notes

The pixel sizes have to be quadratic for the algorithm to work. It measures a circle by counting the pixels from the central pixel corresponding to the given coordinate.

read_flux (*position*)

Returns the value of the pixel that corresponds to the given positions of RA, DEC (J2000) in units of equatorial coordinates or degrees.

Parameters position (*list*) – The position in RA,DEC where the aperture is to be applied. The Format has to be either:

- ['RA','DEC'] with strings representing equatorial coordinates, e.g. ['01:34:32.8', '+30:47:00.6'].

or:

- [RA, DEC] where RA and DEC being the coordinates in Grad.

Returns flux – The flux at the given position.

Return type float

See also:

`sky2pix()`, `astFunc.equatorial_to_degrees()`, `wcs.wcs_sky2pix()`

sky2pix (*coordinate*, *origin=0*)

Calculates the Pixel corresponding to a given coordinate.

Parameters

- **coordinate** (*list*) – Either ['RA','DEC'], e.g. ['1:34:7.00', '+30:47:52.00'] in equatorial coordinates or [RA, DEC] in GRAD.

- **origin** (*int*) – 0 or 1; this steers how the first pixel is counted 0 is for usage with python as it starts to count from zero. 1 is the fits standart.

Returns **pixel** – [x, y]; the pixel coordinates of the map.

Return type List

toGildas(*prefix=None*)

Changes the current map to the Gildas Format.

The function takes changes to the map_name variables made outside of functions into account via `astrolyze.maps.main.Map.returnName()` into account.

Parameters **prefix** (*string or None*) – Path to location where the new gildas file will be stored. The default is None which defaults to the current self.prefix.

Examples

To continue working with the gildas map use:

```
>>> map = map.toGildas()
```

To only store the current map in the gildas format and go on working with the fits file use:

```
>>> map.toGildas()
```

Here map is an Instance of the FitsMap class.

toMiriad(*prefix=None*)

Changes the current map to the Miriad Format.

The function takes changes to the map_name variables made outside of functions into account via `maps.main.Map.returnName()` into account.

Parameters **prefix** (*string or None*) – Path to location where the new gildas file will be stored. The default is None which defaults to the current self.prefix.

Examples

This function works like `maps.mapClassFits.FitsMap.toGildas()` and the same Examples apply.

update_file(*backup=False*)

Writing changes to the self.data and/or self.header to the current file.

Parameters

- **backup** (*True or False*) – If True a copy of the original file is created having the extension "_old" after the file endind, i.e. some_name.fits -> some_name. fits_old.
- **Returns** –
- **---------** –
- **FitsMap** (*Instance*) –

Notes

If all variables that define the map name () are unchanged the current file is overwritten else

5.1.3 GildasMap

class `astrolyze.maps.gildas.`**`GildasMap`**(*map_name*)

Wrapping GILDAS functions to use them inline with Python.

`custom_go_spectrum`(*coordinate=False*, *size=False*, *angle=0*)

This function uses the `go spectrum` command from GREG to plot the spectra in a region given by `size` around the cooridinate given by `coordinate`.

Parameters

- **`coordinate`** (*list*) – A list with the coordinates in floats in units of Degrees, or in string for equatorial coordinates. Default to `False` which means that the center of the map, determined from the map header, is used.
- **`size`** (*list*) – The region around the `coordinate` from which spectra are plotted in arcsec, e.g. size = [50, 50] means a region of 50x50 arcsec around the given cooridnate. Defaults to None, which translates to size = [0, 0] which in turn is interpreted as the full map size by GREG.
- **`angle`** (*float [degrees]*) – Needed if the map is rotated to get the correct offsets. Defaults to 0.

`goRot`(*angle*, *prefix=None*)

Wrapper for the GREG go rot command, which rotates maps around their central coordinate stored in the header.

Parameters

- **`angle`** (*float [deg]*) – Rotation angle.
- **`prefix`** (*string*) – The path where the output is to be stored if different from the current prefix of the map.

Returns **GildasMap Object**

Return type Instance for the reprojected map.

Examples

```
>>> map.goRot(45)
```

To change the central coordinate first use `maps.gildas.GildasMap.reproject()` e.g.:

```
>>> map = map.reproject(coord=['new_RA_string','new_DEC_string'])
>>> map.goRot(45)
```

`lmv`(*fileout=None*, *prefix=None*)

Wrapper for the lmv command of GILDAS/CLASS. Extracts spectra from a spectral cube.

Parameters

- **`fileout`** (*string*) – The name of the class file to write the spectra to. Defaults to the map_name with .30m ending.
- **`prefix`** (*string*) – The path were the class file will be stores. Defaults to the current path.

`mask`(*polygon*, *prefix=None*)

Wrapper for the GREG task mask:

Parameters

- **polygon** (*string*) – path to a GILDAS polygon file with ending `".pol"`
- **prefix** (*string*) – The path where the output is to be stored if different from the current prefix of the map.

Returns **mapObject**

Return type The masked map object.

Examples

```
>>> map.mask('poly/sourceA.pol')
```

moments (*velo_range=[0, 0], threshold=0, smooth='YES', prefix=None, comment=None*)
Wraps the GILDAS/GREG task moments.

Creates the first three moments of the map.

Parameters

- **velo_range** (*list*) – Velocity range for the integration.
- **threshold** (*float*) – Value under which pixels are blanked.
- **smooth** (*string*) – One of Either `"NO"` or `"YES"`. Controls if the map is smoothed in velocity before applying the cut threshold. Getting rid of noise peaks over the threshold. Defaults to `'YES'`
- **prefix** (*string*) – The path where the output is to be stored if different from the current prefix of the map.
- **comment** (*string*) – Optional comments to be added to the new map name.

Returns **mean** – The zeroth moment, i.e. the integrated intensity, is returned as a GildasMap object.

Return type MapObject

quick_preview (*save=False, filename=None, window=True*)
Plotting the map and optionally save the figure.

Parameters

- **save** (*True or False*) – Choose wether or nor to save the figure.
- **filename** (*string*) – The filename to for the saved plot. If None defaults to `'quick_preview.eps'`.
- **window** (*True or False*) – Choose whether the image display is opened or not. Default True.

reproject (*template=None, coord=None, prefix=None, keep_pixsize=False*)
Wraps the GREG task reproject. Either use template *or* coord.

Parameters

- **template** (*string*) – Full path to a map in GDF Format whose central coordinate and pixel size will serve as a template.
- **coord** (*list*) – List of coordinate strings in RA DEC (J2000) that will become the new centre of the map.
- **prefix** (*string*) – The path where the output is to be stored if different from the current prefix of the map. If None the current self.prefix of the GildasMap instance is used.

- **keep_pixsize** (*bool*) – If False reproject guesses the new pixel sizes after reprojection these are normally smaller than the original ones. If True the old pixel sizes are enforced.

Returns **GildasMap Object**

Return type Instance for the reprojected map.

Raises

- `SystemExit` – If both **template** and **coord** are not `None`.
- `ValueError` – If keep_pixsize is not a boolean.

Examples

```
>>> map.reproject(coord = ['1:34:32.8', '30:47:00.6'])
>>> map.reproject(template = 'M33_SPIRE_250_JyB_18.1.gdf')
```

References

For more information on the Gildas task see: .. [1] www.iram.fr/GILDAS/

save_figure(*name=None*)
Helper function that saves the current plot.

set_defaults()
Reset all selection criteria.

slice(*coordinate1*, *coordinate2*, *prefix=None*, *comment=None*)
Wrapper for the GREG task slice. Producing Position velocity cuts trough a map between coordinate1 and coordinate2.

Parameters

- **coordinate1** (*string*) – The coordinate where the cut trough the map starts.
- **coordinate2** (*string*) – The coordinate where the cut trough the map ends.

Returns

Return type A GildasMap object containing the slice.

Notes

This only works with cubes.

smooth(*new_resolution*, *old_resolution=None*, *prefix=None*)
Wrapper for the GILDAS/GREG task gauss_smooth.

Parameters

- **new_resolution** (*float or list*) – The resulting resolution after the smoothing. It can be:

1. a float: i.e. the final major and minor beamsize. The position angle will default to 0.
2. a list with two floats: [major_axis, minor_axis]. The position angle defaults to 0.
3. a list with three floats: [major_axis, minor_axis, position_angle].

- **old_resolution** (*float or list*) – Same format as new_resolution. Defaults to self.resolution of the map instance.
- **prefix** (*string*) – The path where the output is to be stored if different from the current prefix of the map.

Notes

Warning: The gauss_smooth Task from GILDAS only gives correct output units when the map is on a temperature or "per pixel" scale. **Maps in Jy/Beam won't be in Jy/Beam after smoothing.**

spectrum(*coordinate*, *fileout=None*, *prefix=None*, *create_spectrum=True*)

Wrapper to the GILDAS/GREG spectrum command.

Extracting a spectrum from a cube at a given positions. By default it also creates a 30m file readable by class from the table.

Parameters

- **coordinate** (*list*) – A list with the coordinates in floats in units of Degrees, or in string for equatorial coordinate.
- **fileout** (*string*) – The name of the table where the spectrum will be stored. Default is the same name as the map with `".tab"` as ending.
- **prefix** – The path to the folder where the newly created file will be stored. Defaults to the prefix currently stored in self.prefix.
- **create_spectrum** (*True or False*) – Turn the creation of a 30m with the spectrum of `False` or on `True`.

Examples

```
>>> from astrolyze.maps import *
>>> map =  GildasMap('M33_PdBI_12co10_Tmb_22.0_2kms.gdf')
>>> coordinate = ['1:34:7.00', '+30:47:52.00']
>>> map.spectrum(coordinate)
```

Creates M33_PdBI_12co10_Tmb_22.0_2kms.tab in the present folder.

toFits()

Converts the actual map to a Fits map.

Returns

Return type FitsMap Object.

Examples

With:

```
>>> map = gildasMap('M33_MIPS_24mum_JyB_5.gdf')
>>> map = map.toFits()
```

it is possible to continue working with the fits map, using the `maps.fits.FitsMap` class.

toMiriad()

Converts the actual map to a Miriad map.

Returns

Return type MiriadMap Object.

Examples

With:

```
>>> map = gildasMap('M33_MIPS_24mum_JyB_5.gdf')
>>> map = map.toMiriad()
```

it is possible to continue working with the Miriad map, using `maps.miriad.MiriadMap` class.

5.1.4 MiriadMap

class `astrolyze.maps.miriad.`**MiriadMap**(*map_name*)

smooth(*new_resolution*, *old_resolution=None*, *scale='‘*)

Smoothes a miriad map to the new resolution.

Parameters

- **new_resolution** (*float or list*) – The resolution in of the smoothed image. Can be a:
  - float: Output beam has same major and minor axis [arcsec] and the position angle (PA) [degrees] is 0.
  - A list with two entries: The major and minor axis. PA is 0. E.g. [major_axis, minor_axis]
  - A list with three entries: [major_axis, minor_axis, PA]
- **old_resolution** (*float*) – If None the self.resolution information is taken into account. Otherwise, it is assumed that old_resolution is the actual resolution of the map.
- **scale** (*string*) – If unset (scale='‘), the miriad function will attempt to make the units of the smoothed image be Jy/beam for Gaussian convolution. If `0.0`, then the convolution integral is scaled (multipled) by the inverse of the volume of the convolving function. Otherwise, the integral is scaled by “scale”

Returns **MiriadMap** – The smoothed image.

Return type object

Notes

The function used to calculate the fwhm (Omega) of the convolving Gaussian for both major and minor axis is:

$$\Omega_{\rm convolve} = \sqrt{\Omega_{\rm new}^2 - \Omega_{\rm old}^2}$$

toFits()

Converts the actual map to a Fits map.

Returns

Return type FitsMap Object.

Examples

With:

```
>>> map = miriadMap('M33_MIPS_24mum_JyB_5')
>>> map = map.toFits()
```

it is possible to continue working with the Fits map, using `maps.fits.FitsMap` class.

toGildas()

Converts the actual map to a Gildas map.

Returns

Return type GildasMap Object.

Examples

With:

```
>>> map = miriadMap('M33_MIPS_24mum_JyB_5')
>>> map = map.toGildas()
```

it is possible to continue working with the Fits map, using `maps.gildas.GildasMap` class.

toMiriad()

Copies the actual map changing the name such that it takes changes in keywords into account.

Returns

Return type MiriadMap Object.

Examples

With:

```
>>> map = miriadMap('M33_MIPS_24mum_JyB_5')
>>> map = map.toMiriad()
```

it is possible to continue working with the Miriad map, using `maps.gildas.MiriadMap` class.

5.1.5 Stack

class `astrolyze.maps.stack.`**Stack**(*folder*, *data_format=None*)

Class to work with several maps at once.

Allows to treat all images inside a folder simultaneously. This allows to to perform the same transformations on all maps.

The images in the input folder can have arbitrary formats, units, resolutions and other properties. The Stack class can help to unify the different parameters of the maps to help comparing them.

Parameters

- **folder** (*str*) – The folder containing the images that are to be treated as a stack

- **data_format** (*str*) – If not None filter images by format.

Examples

The stack class can be used like builtin objects that are iterable e.g.:

```
>>> st = Stack("folder_name")
>>> list_map_names = [i.map_name for i in st]
```

Note: *Stack* is also the basis for the `astrolyze.sed.Sed` package.

copy_structure (*old_prefix*, *new_prefix*)

Copies a folder structure from old_prefix to new_prefix. To assure all folders exists before working with or copying data.

Parameters

- **list** (*list*) – A list containing the relative or absolute paths to files.
- **old_prefix** (*string*) – The old path to the folder structure that has to be copied. Has to actually appear in all the strings in list.
- **new_prefix** (*string*) – The path to where the folder structure is to be copied.

Notes

This is useful if one is working on many files stored in several sub-folders retrieved using `get_list()`.

Examples

Say the folder structure is like this

```
>>> ls ../modified/
co10/
co21/
>>> ls ../modfied/co10/
map1/
map2/
>>> ls ../modified/co21/
map1/
map2/
```

This can be copied to say ../even_more_modified by doing as follows:

```
>>> from astrolyze.maptools import *
>>> list = maptools.get_list(../modified)
>>> maptools.copy_structure(list, old_prefix='../modified',
>>>                         new_prefix='../even_more_modified')
```

get_list (*data_format=None*, *depth=False*)

Loading a list of files in all sub-folders.

Parameters

- **folder** (*string*) – The path to the folder that has to be parsed.
- **data_format** (*string*) – Search for specific files containing the string, e.g. '.fits'

- **depth** (*integer*) – The steps into the sub-folder system. Defaults to maximum depth.

Returns

- **final_list** (*array*) – Array with the string to the files in the folder and sub folders.
- *folder_list* – Array with the strings to the folders. Only if depth is set.

get_map_format (*map_name*)

This function creates returns the correct `GildasMap`, `FitsMap` or `MiriadMap` object without that the data format of the map has to be given.

Parameters **map_name** (*string*) – Path and name of the input map.

Returns

- Either a `GildasMap`, `FitsMap` or ``MiriadMap‘ Either a
- `Map` class object depending on the data format of the input map.

pixel_pixel_compare (*folder=None*, *plot=False*, *tol=1000000.0*)

Producing a pixel-to-pixel comparison for all combinations possible between the maps of the stack.

Parameters

- **folder** (*string*) – Path to the folder where the text files with the pixel to pixel comparisons are stored
- **plot** (*[True | False]*) – Decides whether to produce pixel-to-pixel plots directly.
- **tol** (*float*) – The tolerance for the maximum difference between the values of the pixel of two compared maps. Default to 1e6.

  returns

  - *Created text files in the specified folders that contain two columns*
  - *with the pixel-to-pixel comparisons. These can be used*

unify_dimensions (*template=None*, *folder=None*)

Reproject all maps to the same central coordinates and map dimensions. All properties of one template map are copied to all the other maps using the `"reproject"` task of GILDAS.

Parameters

- **template** (*string*) – Path to the map that will serve as a template, it may be one of the input maps of the stack.
- **folder** (*string*) – Path to the folder where the output maps are stored.

unify_formats (*target_format='fits'*, *folder=None*)

Converts all maps to the `target_format` which has to be one that is known to astrolyze. Please see TODO for a list of kwon formats. Default is fits.

Parameters

- **target_format** (*string*) – The format to which all maps are converted.
- **folder** (*string*) – Path to the folder where the new maps are stored. If `None` the current folder will be used.

unify_projections (*coordinate=None*, *angle=None*, *folder=None*)

Changing the central coordinate and the rotation angle.

unify_resolutions (*folder=None*, *resolution=False*)

Smoothing all maps to the same resolution; either the maximum resolution found in the stack or a given resolution.

Parameters

- **`resolution`** (*float or list*) – This may be either:
  1. A list with three entries, i.e. [[minor_fwhm], [major_fwhm], [position_angle]]
  2. A list with two entries, position_angle defaults to 0, i.e. [[minor_fwhm], [major_fwhm]]
  3. A float. Same minor, major fwhm pa=0
- **`folder`** (*string*) – The path tot the folder in which the files are to be stored.

Notes

The position angle of the output images is fixed to `Zero` and can currently not be modified.

Depending on the map units different scaling normalizations have to be used after smoothing such that the output units are correct. This function tries to deduce the scaling by itself based on the unit that is given in the map name. Be sure that this is correct otherwise the flux values may be wrong in the output images.

`unify_units`(*unit='JyB'*, *folder=None*, *debug=True*)
Change all maps in the stack to the same unit.

Parameters

- **`unit`** (*string*) – See `astrolyze.maps.fits.FitsMap.change_units()` for details.
- **`folder`** (*string*) – The target folder. By default the maps are put into their current folder.

5.1.6 Tools

`astrolyze.maps.tools.`**`copy_structure`**(*list*, *old_prefix*, *new_prefix*)
Copies a folder structure from old_prefix to new_prefix. To assure all folders exists before working with or copying data.

Parameters

- **`list`** (*list*) – A list containing the relative or absolute paths to files.
- **`old_prefix`** (*string*) – The old path to the folder structure that has to be copied. Has to actually appear in all the strings in list.
- **`new_prefix`** (*string*) – The path to where the folder structure is to be copied.

Notes

This is usefull if one is working on many files stored in several sub-folders retrieved using `get_list()`.

Examples

Say the folder structure is like this

```
>>> ls ../modified/
co10/
co21/
>>> ls ../modfied/co10/
map1/
map2/
>>> ls ../modified/co21/
map1/
map2/
```

This can be copied to say ../even_more_modified by doing as follows:

```
>>> from astrolyze.maptools import *
>>> list = maptools.get_list(../modified)
>>> maptools.copy_structure(list, old_prefix='../modified',
>>>                         new_prefix='../even_more_modified')
```

`astrolyze.maps.tools.`**`get_list`**(*folder*, *data_format=None*, *depth=False*)

Loading a list of files in all subfolders.

Parameters

- **`folder`** (*string*) – The path to the folder that has to be parsed.
- **`data_format`** (*string*) – Search for specific files containing the string, e.g. '.fits'
- **`depth`** (*integer*) – The steps into the subfolder system. Defaults to maximum depth.

Returns

- **final_list** (*array*) – Array with the string to the files in the folder and sub folders.
- *folder_list* – Array with the strings to the folders. Only if depth is set.

`astrolyze.maps.tools.`**`unifyMaps`**(*list*, *tinMap*, *folder='reg'*)

changes the dimensions and pixel sizes off all maps to that of a template map.

`astrolyze.maps.tools.`**`unifyResolution`**(*liste*, *resolution=False*, *folder='smooth'*, *scaling=''*)

Approved.

`astrolyze.maps.tools.`**`unifyUnits`**(*list*, *folder='units'*)

NOT READY YET!

5.2 Spectra

class `astrolyze.spectra.class_.`**`ClassSpectra`**(*map_name*, *nameConvention=True*)

Provides some usefull automated functions to work on Class Spectra in an convenient way.

Examples

Extracting a spectra at a given position from a spectral cube can be done as follows

```
>>> from astrolyze.spectra import *
>>>
>>> cube = ClassSpectra(filename)
>>> coordinate = ['1:34:7.00', '+30:47:52.00']
>>> cube.get_spectra_from_cube(coordinate)
Generates a 30m file with comment extract in the actual cube.prefix path.
```

get_average_spectrum(*prefix=None*)
Averages all spectra in a cube.

Parameters **prefix** (*string*) – The new path where the averaged spectrum will be stored.

Notes

So far no selection is made so the files of the input file have to be consistent.

get_region_from_cube(*coordinate*, *angle=0*, *prefix=None*, *accuracy=10*)
The same as :py:func:`get_spectra_from_cube` but returns all spectra found inside a circular region arounf coordinate and in a radius of accuracy arcsec. ("set match "'accuracy')

get_spectra_from_cube(*coordinate*, *angle=0*, *prefix=None*, *accuracy=2*, *region=False*)
Extracts one spectra at the position of coordinates from a spectral cube.

Parameters

- **coordinate** (*list*) – Equatorial coordinates, e.g. ['1:34:7.00', '+30:47:52.00']
- **angle** (*float*) – If the cube was rotated before the angle has to be specified to calculate the correct offset.
- **prefix** (*string*) – The new path where the averaged spectrum will be stored.
- **accuracy** (*float*) – The tolerance in arcsec to find a spectra corresponding to the given coordinate.
- **region** (*True or False*) – Returns either all spectra found `True` or only the first `False`.

Returns With the first spectrum in the list of spectra within the accuracy range with the given coordinate.

Return type 30m file

quick_view(*number=1*)
Helper Functions that displays the first spectrum of the loaded file.

save_figure(*name=None*)
Helper function that saves the current plot.

set_defaults()
Reset all selection criteria.

5.3 SEDs

class `astrolyze.sed.sed.`**Sed**(*source_name*, *coordinate*, *flux_array*, *number_components=2*, *init_fit=True*, *temperature_guess=None*, *mass_guess=None*, *beta_guess=None*)
This class handles a single SED. Basically it is able to fit, and plot the sed.

Parameters

- **source_name** (*string*) – The name of the source to which the SED corresponds to.
- **coordinate** (*list*) – The coordinate of the source. [RA, DEC]

- **flux_array** (*list*) – The array that is created by SedStack with the entries of wavelength, flux, and error.
- **init_fit** (*logic*) – Controls whether the SED is fitted already during creation.
- **number_components** (*int*) – The number of greybody components to be fitted. Default: 2.
- **temperature_guess** (*list*) – List with the intial guesses for the temperature
- **mass_guess** (*list*) – List with the intial guesses for the masses
- **beta_guess** (*list*) – List with the intial guesses of the beta value

create_figure(*save=True, plotLegend=False, color=['black'], marker=['x'], title=None, x_label=None, y_label=None, nu_or_lambda='nu', fontdict=None, textStringLoc=[1, 1], lineWidth=0.5, kappa='easy', x_range='normal', prefix='./', **kwargs*)

Creates a quick preview of the loaded SED. TODO: extend documentation.

grey_body_fit()

" Fitting a multi componenet grey body to the input data in flux_array.

See also:

() py:func:*astrolyze.functions.astro_functions.grey_body_fit*

plot_sed(*axes=<matplotlib.axes.AxesSubplot object>, nu_or_lambda='nu', color='black', linewidth=0.5, x_range='normal'*)

Plot a multi component greybody model.

Parameters

- **nu_or_lambda** – plot against frequency `'nu'` or wavelenght `'lambda'`
- **kappa** – The kappa to use. `'easy'` or `'Kruegel'`. Please refer to `functions.astroFunctions.greyBody()` for more information.
- **xRange** (*PLEASE ADD DESCRIPTION*) –
- **linewidth** (*float*) – The linewidth of the plotted lines. Default to 0.5.
- **color** (*matplotlib conform color*) – the color of the plotted lines. Default to `'black'`.

class `astrolyze.sed.sed.`**SedStack**(*folder, data_format='.fits', coordinates=False, flux_acquisition='pixel', aperture=None, annotation=False, full_map=False, output_folder=None, number_components=2, mass_guess=None, temperature_guess=None, beta_guess=None*)

Reads in the SEDs from the maps stored under the input folder at given coordinates and creates a stack of Sed objects.

Parameters

- **folder** (*str*) – Input Folder
- **data_format** (*str*) – Filter on data format. Default *.fits*
- **coordinates** (*list*) – Coordinates where the SEDs should be extracted.
- **full_map** (*bool*) – If True temperature, mass and beta maps will be created by fitting the SEDs at every pixel.
- **flux_acquisition** (*str*) – *aperture* or *pixel* see explanation in `astrolyze.fits.FitsMap.flux_read`

- **aperture** (*int*) – Aperture to use for flux extraction if flux_acquisition == *aperture*
- **annotation** (*bool*) – If true a kvis annotation file is created with the positions where the SEDs, have been extracted.
- **output_folder** (*str*) – Where the data is stored.
- **number_components** (*int*) – Number of SED components to fit.
- **mass_guess** (*list*) – List with guesses for the initial dust mass. Has to have at least the same lenght as there are *number_components*
- **temperature_guess** (*list*) – List with guesses for the initial dust temperature. Has to have at least the same lenght as there are *number_components*
- **beta_guess** (*list*) – List with a guess for the beta value to be used has to be list with singel entry beta_guess=[2.].

get_map_seds (*output_folder*)

This functions fits the SED at every pixel of the input maps.

Parameters output_folder (*string*) – The path to the folder where the temperature, mass, beta and chisq maps are created. If the folder does not exist is will be created.

Notes

Depending on the number of pixels in the input image this function may take a good while to finish.

Examples

Note that the maps have to be exactly the same size for this function to work. This can be achieved with e.g.:

```
from astrolyze import *
stack = Stack('some_input_folder')
output_folder = 'some_output_folder'
template = 'Path_to_a _template_map'
stack = stack.unify_dimension(template, folder)
```

get_seds ()

Creates a stack of SEDs from the stack of maps loaded from the input folder if particular coordinates are given.

load_coordinates (*input_file*)

Loads the coordinated where the SEDs should be evaluated from either a file or a list. Both are not possible.

Parameters filein (*string*) – Path to file that cotains the coordinates format has to be:

source_name RA DEC

RA, DEC has to be for epoch J2000 in Equatorial coordinates, see below for examples of the syntax.

Returns

- **self.coordinates** (*list*)
- **self.source_names** (*list*) – Format:: [[source_name_1, RA_1, DEC_1] , ... , [source_name_N, RA_N, DEC_N]]

Examples

The format of the coordinates given in the file must be in Equatorial: >>> equatorial_coordinates = ['02:23:21', '-02:23:21']

5.4 LTE

Functions to calculate LTE column densities.

TODO: Add Documentation.

`astrolyze.lte.lte.`**`calc_N`**(*molecule*, *excitation_temperature*, *J*, *W*)

Calculates the column density for a molecule. !!! LOOK into the remaining Code and merge!!!

`astrolyze.lte.lte.`**`calc_excitation_temperature`**(*Tb*, *nu*)

Calculation of the excitation temperature of an optically thick 12CO line under the assumption of LTE.

Parameters **`Tb`** –

`astrolyze.lte.lte.`**`calc_jnu`**(*nu*, *T*)

Calculates J_ν needed for lte_column_density.

Parameters

- **`nu`** (*float*) – Frequency
- **`T`** (*float*) – Temperature

Notes

The formula (in cgs units) implemented here is:

$$\mathcal{J}_\nu(T) = \frac{h\nu}{k}\frac{1}{e^{h\nu/kT_{ex}} - 1}$$

where:

- k: the Boltzman constant in CGS
- h: the PLanck constant in CGS
- ν: the frequency
- T: exitation temperature

References

Mike Zielinsky

`astrolyze.lte.lte.`**`lte_column_density`**(*nu*, *Tmb*, *excitation_temperature*, *J*, *Z*, *mu*)

This function calculates the Column densities of linear molecules

Units are all to be given in cgs Z is the array of partition function values for the corresponding temperatures in T these are the log values of Z

Notes

The implemented formula, taken from Doktorarbeit is:

$$N = \frac{3h}{8\pi^3\mu^2}\frac{Z}{J}\frac{exp(\frac{h\nu}{kT_{ex}})}{[1 - exp(-\frac{h\nu}{kT_{ex}})]}(\mathcal{J}_\nu(T_{ex}) - \mathcal{J}_\nu(T_{BG}))^{-1}\int T_{mb}d\nu,$$

where:

- k: the Boltzman constant in CGS
- h: the PLanck constant in CGS
- W: integrated Intensity in Kelvin cm/s
- Aul: the Einstein coeffiecient of the transition
- gu: the statistical Weight of the upper level
- Eu: the Energy of the upper level
- exitation_temperature
- Z: the partition Function

References

add reference to Zielinsky

Warning: Extend documentation!!!!

This script generates a dictionary storing the information of molecular transitions.

class `astrolyze.lte.molecule_parameter.`**`Molecule`**(*nu*, *Q*, *T*, *Eu*, *Aul*, *gu*, *mu*, *name=''*)

A class holding attributes that define the characteristics of an individual tansition of a molecules.

The `astrolyze.functions.astro_functions.calc_N()` routine depends on this class.

Parameters

- **nu** (*float*) –
- **Q** (*list*) – The partition function of the molecule evaluated at discreet temperatures. Given in T.
- **T** (*list*) – The temperatures at which the partition functions was evaluated. The value of Q used finally is interpolated to the excitation_temperature give.
- **Eu** (*float*) – Energy of the upper state of the transition.
- **Aul** (*float*) – The Einstein coefficient. For the transition of upper-to-lower state.
- **gu** (*float*) – ADD DESCRIPTION.
- **mu** (*float*) – ADD DESCRIPTION.
- **name** (*string*) – The name of the molecule.

5.5 Functions

5.5.1 astro_functions

`astrolyze.functions.astro_functions.`**`LTIR`**(*p2*, *kappa='Kruegel'*, *xmin=3.0*, *xmax=1100.0*, *beamConv=True*, *distance=847000.0*, *unit='JyB'*)

Integration of a multi-component greybody model.

Parameters

- **p2** (*list*) – The parameters defining the multi-component greybody model. Same format as p in `astrolyze.functions.astroFunctions.multi_component_grey_body()`
- **kappa** (*string*) – The dust extinction coefficient used to describe the greybodies. See: py:func:*grey_body*
- **xmax** (*xmin,*) – The integration range in units of micron. Defaults to 3 – 110 micron. The definition of LTIR from [DA]
- **beamConv** (*True or False*) – For units in Lsun the code is not well written. Hardcoded conversion between an 28" and 40" beam. !! CHANGE !!
- **unit** (*string*) – If `'Lsun'` the returned integrated flux is in units of solar luminosities (erg s^-1). For this a distance is needed. If `'JyB'` the units are Jy/beam; distance is not used.

Notes

Needs some work to be generally usable. For units in Jy/beam the code seems to be safe.

References

`astrolyze.functions.astro_functions.`**`analytic_linear_fit`**(*x*, *y*, *x_error*, *y_error*)

This function resembles the analytical solution following chaper 8 from [TA].

Parameters

- **x** (*float or list*) – x measurements. Data.
- **y** (*float or list*) – y measurements. Data.
- **y_error** (*float or list*) – The y measurment errors.
- **x_error** (*float or list*) – The x measurment errors. If unset only errors in y are taken into account.

Notes

Without errors the following holds:

$$y = A + Bx$$

$$A = \frac{\Sigma(x^2) \cdot \Sigma(y) - \Sigma(x) \cdot \Sigma(x \cdot y)}{\Delta}$$

$$B = N \frac{\Sigma(x \cdot y) - \Sigma(x) \cdot \Sigma(y)}{\Delta}$$

$$\Delta = N \cdot \Sigma(x^2) - (\Sigma(x))^2$$

Warning: This has to be checked.

References

`astrolyze.functions.astro_functions.`**`anti_line`**(*p*, *y*)

Inverse of a line returning the x value corresponding to a y value, i.e. *x = y/m - b*.

Parameters **p** (*list*) – Contains the slope and the y-axis intersection of the line [m, b].

Returns **y**

Return type value of x corresponding to y.

`astrolyze.functions.astro_functions.`**`black_body`**(*x*, *T*, *nu_or_lambda='nu'*)

Calculation of the flux density of a black body at a temperature T and a wavelenght/frequency x.

Parameters

- **x** (*float or numpy array*) – wavelength [GHz] or frequency [micron]; specify type in nu_or_lambda
- **T** (*float [Kelvin]*) – Temperature of the black_body
- **nu_or_lambda** (*string*) – Specify whether x is a frequency ν `'nu'` or a wavelenght λ `'lambda'`; default is `'nu'`.

Returns **Flux density in Jansky**

Return type float [Jy]

Notes

This functions resembles the following formulas for input in frequency:

$$B_{\nu} = \frac{2h\nu^3}{c^2}(e^{\frac{h\nu}{kT}} - 1)^{-1}$$

and for input in wavelenght:

$$B_{\lambda} = \frac{2hc^2}{\lambda^5}(e^{\frac{h\lambda}{kT}} - 1)^{-1}$$

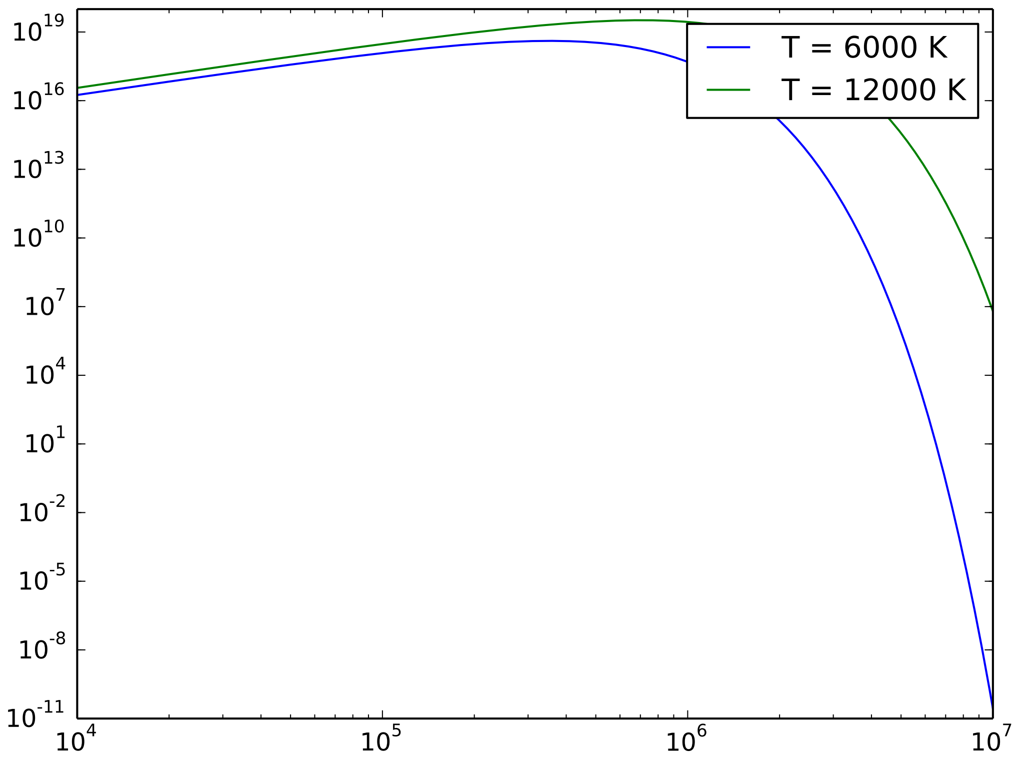
Both formulas are scaled by 1e26, thus returning the flux in Jansky.

Examples

The function works with linear numpy arrays. Thus the black_body can be evaluated at many points at the same time. Using matplotlib it can also be plotted:

```
import numpy as np
import matplotlib.pyplot as plt
import astrolyze.functions.astro_functions as astFunc

frequency_range = np.arange(1e4, 1e7, 1e4)
temperature_1 = 6000
temperature_2 = 12000  # Kelvin
blackbody_1 = astFunc.black_body(frequency_range, temperature_1)
blackbody_2 = astFunc.black_body(frequency_range, temperature_2)
figure = plt.figure()
axis = figure.add_subplot(111)
pl = axis.loglog(frequency_range, blackbody_1, label='T = 6000 K')
pl = axis.loglog(frequency_range, blackbody_2, label='T = 12000 K')
pl = axis.legend()
plt.savefig('black_body.eps')
```



`astrolyze.functions.astro_functions.`**`calc_offset`**(*central_coordinate*, *offset_coordinate*, *angle=0*, *output_unit='farcsec'*)

Calculates the offset between two coordinates.

Parameters

- **`central_coordinate`** (*list*) – The reference coordinate in degrees or equatorial.
- **`offset_coordinate`** (*list*) – The second coordinate, the offset will be with rescpect to central_coordinate.
- **`angle`** (*float*) – The angle in degrees, allowing rotated systems.

Returns **rotated_offset** – The offsets, rotated only if angle given.

Return type list

Notes

This functions includes a correction of the RA offset with declination:

`astrolyze.functions.astro_functions.`**`degrees_to_equatorial`**(*degrees*)

Converts RA, DEC coordinates in degrees to equatorial notation.

Parameters **`degrees`** (*list*) – The coordinates in degrees in the format of: [23.4825, 30.717222]

Returns **equatorial** – The coordinates in equatorial notation, e.g. corresponding ['1:33:55.80', '+30:43:2.00'].

Return type list

`astrolyze.functions.astro_functions.`**`equatorial_to_degrees`**`(`*equatorial*`)`

Converts RA, DEC coordinates in equatorial notation to degrees.

Parameters **`equatorial`** (*list*) – The coordinates in degress in equatorial notation, e.g. ['1:33:55.80', '+30:43:2.00']

Returns **degrees** – The coordinates in degreees, e.g. [23.4825, 30.717222].

Return type list

Raises `SystemExit` – If `equatorial` is not a list of strings in the above format.

`astrolyze.functions.astro_functions.`**`freq_to_vel_resolution`**`(`*center_frequency*, *frequency_resolution*`)`

Function to convert a frequency resolution to a velocity resolution for a given center frequency.

Parameters

- **`center_frequency`** (*float*) – Center frequency in GHz.
- **`frequency_resolution`** (*float*) – The frequency resolution in MHz.

Returns

Return type velocity_resolution in km/s.

Notes

Uses the formula TODO v_LSR = c((nu0-nuObs)/nu0)

Approved!

`astrolyze.functions.astro_functions.`**`frequency_to_wavelength`**`(`*frequency*`)`

Converting frequency to wavelength.

Parameters **`frequency`** (*float [GHZ]*) –

Returns **wavelength**

Return type float [micron]

`astrolyze.functions.astro_functions.`**`gauss1D`**`(`*x*, *fwhm*, *offset=0*, *amplitude=1*`)`

Calulcates 1D Gaussian.

Parameters

- **`x`** (*float or numpy.ndarray*) – the x-axis value/values where the Gaussian is to be calulated.
- **`fwhm`** (*float*) – The width of the Gaussian.
- **`offset`** – The offset in x direction from 0. Default is 0.
- **`amplitude`** – The height of the Gaussian. Default is 1.

Returns **gauss** – The y value for the specified Gaussian distribution evaluated at x.

Return type float or np.ndarray

Notes

The function used to describe the Gaussian is:

$$f = \frac{1}{fwhm * sqrt(2 * \pi)} * e^{-1/2(\frac{x-x0}{fwhm})^2}$$

astrolyze.functions.astro_functions.**gauss2D**(*x*, *y*, *major*, *minor*, *pa=0*, *xOffset=0*, *yOffset=0*, *amplitude=1*)

Calculates a 2D Gaussian at position x y.

Parameters

- **x** (*float or numpy.ndarray*) – the x-axis value/values where the Gaussian is to be calculated.
- **y** (*float or numpy.ndarray*) – the y-axis value/values where the Gaussian is to be calculated.
- **minor** (*major,*) – The fwhm of the Gaussian in x and y direction.
- **pa** (*float*) – The position angle of the Gaussian in degrees. Default is 0.
- **yOffset** (*xOffset,*) – The offset in x and y direction from 0. Default is 0.
- **amplitude** – The height of the Gaussian. Default is 1.

Returns **gauss** – The y value for the specified Gaussian distribution evaluated at x.

Return type float or np.ndarray

Notes

The function used to describe the Gaussian is :

$$f = (amplitude * exp(-1(a * (x - xOffset)^2 + 2 * b * (x - xOffset) * (y - yOffset) + c * (y - yOffset)^2)))$$

where:

$$\begin{aligned} a &= cos(pa) * *2/(2 * major * *2) + sin(pa) * *2/(2 * minor * *2) \\ b &= (-1 * sin(2 * pa)/(4 * major * *2)) + (sin(2 * pa)/(4 * minor * *2)) \\ c &= sin(pa) * *2/(2 * major * *2) + cos(pa) * *2/(2 * minor * *2) \end{aligned}$$

astrolyze.functions.astro_functions.**generate_monte_carlo_data_line**(*data*, *errors*)

This function makes a Monte Carlo Simulation of a data Set of measurements it uses the random.gauss() function to generate a data point from a gauss distribution, that has a mean equal to the measurement and its standard deviation corresonding to the error of the measurement.

Parameters

- **data** (*list*) – A list of original measurements.
- **errors** (*list*) – A list of the corresponding errors.

Returns **newData** – The monte carlo simulated measurement.

Return type array in same format as data.

See also:

`random.gauss()`

astrolyze.functions.astro_functions.**generate_monte_carlo_data_sed**(*data*)

MonteCarlo Simulation of a set of flux measurements, assuming that the measurement data follows a gauss distribution.

This function makes use of the `random.gauss()` function to generate a data point from a gauss distribution, that has a mean equal to the Flux measurement and a standard deviation correponding to the error of the measurement.

Parameters **data** (*array*) –

Same format as in grey_body_fit function: data= [[x1, x2, x3, ...][y1, y2, y3, ...][z1, z2, z3, ...]]

with x = wavelenght/frequency, y = flux, z = error on flux.

Returns **newData** – The Monte-Carlo simulated measurement.

Return type array in same format as data.

See also:

`random.gauss()`

`astrolyze.functions.astro_functions.`**`grey_body`**`(`*p*, *x*, *nu_or_lambda='nu'*, *kappa='Kruegel'*, *distance=840000.0*`)`

Calculation of the flux density in Jansky of a grey_body under assumption of optically thin emission. Please see Notes below for an detailed description assumptions and equations used.

Parameters

- **`p`** (*list*) – List of the parameters defining a grey_body, being Temperature [K], column density or mass (dependent on the kappa used) and the grey_body slope index beta, respectively (refer to notes for more information): p = [T, N, beta]
- **`x`** (*float or numpy array*) – Wavelength [GHz] or frequency [micron]; specify type in nu_or_lambda
- **`kappa`** (*string*) –

  Chooses the dust extinction coefficient to use:

  – `"easy"` -> kappa = nu^beta; tau = N * kappa

  – `"Kruegel"` -> kappa = 0.04*(nu/250Ghz)^beta; tau = M/D^2 * kappa

  Please refer to Notes below, for further explanation.
- **`distance`** (*float*) – The distance to the source that is to be modeled if kappa `"Kruegel"` is used.

Other Parameters **nu_or_lambda** (*string*) – Specify whether x is a frequency ν `'nu'` or a wavelength λ `'lambda'`; default is `'nu'`. if lambda the input converted to a frequency in [GHz].

Notes

The general equation for a grey_body is:

$$S(x,\tau) = (black_body(x,T)) * [1 - e^{\tau}]\Omega$$

describing the flux coming from an solid angle Ω while τ is:

$$\tau_\nu = \frac{\kappa_d(\nu) * M_{dust}}{D^2\Omega}.$$

Here we assume optically thin emission and a source filling factor of unity. This simplifies the equation of the grey_body to:

$$S(x,\tau) = \tau * (black_body(x,T))$$

This script supports two versions of the dust extinction coefficient.:: A simple version without a lot of physics put into, kappa = `'easy'` which defaults to the following grey_body equation:

$$S(x,\tau) = N * x^\beta * black_body(x,T),$$

with N being a column density scaling factor.

The second version, kappa = `'Kruegel'` uses the dust extinction coefficient reported in [KS] which renders the used equation to:

$$\kappa = 0.04 * (\frac{x\,[GHz]}{250\,GHz})^{\beta}$$
$$S_{\nu} = M[kg]/D^2[m^2] * \kappa * black_body(x,T).$$

Examples

The same examples as for `black_body()` apply.

References

`astrolyze.functions.astro_functions.`**`grey_body_fit`**(*data*, *start_parameter*, *nu_or_lambda='nu'*, *fit_beta=False*, *fix_temperature=False*, *rawChiSq=None*, *kappa='Kruegel'*, *residuals=False*, *iterations=1000000000.0*)

This function fits a multi component grey body model to an observed SED for the optical thin case.

Parameters

- **`data`** (*array*) – The obseved data. Array of shape(3, x) first row has to be the X values (Frequency in [GHz]) of the measurements, second row the Y values (Flux [Jy]), and the third row the Z values the errors on the fluxes i.e.: data = array([[X1, X2, X3, ...], [Y1, Y2, Y3,...], [Z1, Z2, Z3, ...]])
- **`start_parameter`** (*array*) – Array of a first guess of the parameters of the grey_body components. The number of components is arbitrary. start_parameter = [[T1, T2, T3,...], [N1, N2, N3, ...], beta]
- **`fit_beta`** (*True or False*) – If True Beta is allowed to vary. Default is False.
- **`fix_temperature`** (*True or False*) – If True the Temperature is fixed allowed to vary.
- **`rawChiSq`** – if None the function gives the reduced chisq Value. If True the function gives chisq without dividing it by the dof

Returns

- **p2** (*list*) – The final grey_body parameters that reduce the least squares for the given dataset.
- *chisq/rawChiSq* – chisq is reduced chisq with degrees of freedom: dof= #dataPoints-#freeFitParameters-1

Other Parameters nu_or_lambda (*string*) – Specify whether x is a frequency ν `'nu'` or a wavelenght λ `'lambda'`; default is `'nu'`.:: **Don't** use `'lambda'` as this part of the `grey_body()` is not up-to-date.

See also:

`scipy.optimize.leastsq()` This function is used to perform the least squares

`fit.()`, `multi_component_grey_body()`, `grey_body()`, `black_body()`, `be()`

Notes

A one component fit has four free parameters if beta is allowed to vary or three if beta is fixed (one more than parameters to fit). Each additional component adds two more free paramters to fit. Assure that: number of data points > number of free parameters.

`astrolyze.functions.astro_functions.`**`grey_body_monte_carlo`**(*p*, *data*, *iterations*)

Function to evaluate the errors in the parameters fitted with the grey_body_fit function.

It uses Monte Carlo Simulated data (from `generate_monte_carlo_data_sed()`) and performs a fit to this new data giving back the results of the fit parameters.

Parameters

- **`p`** (*list*) – The parameters defining the multi component grey_body model to be fitted. Same format as p in `multi_component_grey_body()`
- **`data`** (*array*) – The actual measured data of the SED, same format as for `grey_body_fitFunction()`
- **`iterations`** (*int*) – Number of times new data is generated and fitted.

Returns

- *string* – Containing the mean, standard deviation of the fit parameters, ready to print out.
- **betaTlist** (*List of all fit results. Name misleading since it may not*) – include the beta.

`astrolyze.functions.astro_functions.`**`line`**(*p*, *x*)

Line *y* = *m***x* + *b* equation. Returns y value at point x.

Parameters **`p`** (*list*) – Contains the slope and the y-axis intersection of the line [m, b].

Returns y

Return type value of y corresponding to x.

`astrolyze.functions.astro_functions.`**`line_fit`**(*p*, *x*, *y*, *y_error*, *x_error=False*, *iterations=10000*)

Linear Fit to data, taking either errors in y or both in x and y into account.

Parameters

- **`p`** (*list*) – Containg slope (m) and y-axis intersection (b) p=[m, b]. Same as in `line()` and `antiline()`.
- **`x`** (*float or list*) – x measurements. Data.
- **`y`** (*float or list*) – y measurements. Data.
- **`y_error`** (*float or list*) – The y measurment errors.
- **`x_error`** (*float or list*) – The x measurment errors. If unset only errors in y are taken into account.

`astrolyze.functions.astro_functions.`**`line_monte_carlo`**(*p*, *x*, *y*, *x_error*, *y_error*, *iterations*, *fitIterations=1000000000.0*)

Gererate an estimate of the errors of the fitted parameters determined by the `line_fit()` function.

Parameters

- **`p`** (*list*) – Containg slope (m) and y-axis intersection (b) p=[m, b]. Same as in `line()` and `antiline()`.
- **`x`** (*float or list*) – x measurements. Data.
- **`y`** (*float or list*) – y measurements. Data.

- **`y_error`** (*float or list*) – The y measurment errors.
- **`x_error`** (*float or list*) – The x measurment errors. If unset only errors in y are taken into account.

Returns

- **string** (*A string containing the results.*)
- **BList** (*A list containing the fittet y-Axis intersections.*)
- **MList** (*A list containing the fitted slopes.*)
- **chisqList** (*A list with the chisq values.*)
- **resultArray** (*Array with the mean and the standard deviations of*) – slopes and y-axis intersections, i.e. [mean(M), std(M), mean(B), std(B)]

See also:

`grey_body_fit()`, `generate_monte_carlo_data_line()`

`astrolyze.functions.astro_functions.`**`linear_error_function`**(*p*, *x*, *y*, *y_error*, *x_error*)

Error function, i.e. residual from the measured value, which has to be minimised in the least square fit taking X and Y Error into account.

Parameters

- **`p`** (*list*) – Same as in `line()` and `anti_line()`.
- **`x`** (*float or list*) – x measurements. Data.
- **`y`** (*float or list*) – y measurements. Data.
- **`x_error`** (*float or list*) – The x measurment errors.
- **`y_error`** (*float or list*) – The y measurment errors.

`astrolyze.functions.astro_functions.`**`multi_component_grey_body`**(*pMulti*, *x*, *nu_or_lambda='nu'*, *kappa='Kruegel'*)

Combines multiple grey_body functions and returns the flux density in Jansky for the input frequency/wavelenght.

Parameters

- **`pMulti`** (*nested lists*) – Similar to p from `grey_body()` but the three entries are lists, i.e.:: pMulti = [[T1, T2, T3, ...Tn], [N1, N2, N3,...Nn], [beta]]
- **`x`** (*float or numpy array*) – frequency [micron] (or wavelenght **Not maintained**, specify type in nu_or_lambda)

Returns

- **sum(snu)** (*float*) – All dust components summed.
- *snu* – A list with the fluxes of the individual components.

See also:

`black_body()`, `grey_body()`

Notes

Only one common beta for all components can be used. May be expanded to mutliple betas if needed.

Examples

Same as for black_body, but all returned grey_bodies may be plotted.

`astrolyze.functions.astro_functions.`**`redshifted_frequency`**`(`*rest_frequency*, *v_lsr*`)`

Calculates the sky frequency corresponding to a rest frequency for a source with a velocity v_lsr.

Parameters

- **`rest_frequency`** (*float*) – The frequency of the line at rest in Ghz (More often state the obvious :)).
- **`v_lsr`** (*float*) – The velocity of the source in km/s.

Returns **redshifted_frequency** – The sky frequency in GHz.

Return type float

Notes

The formula used is:

$$\nu_{sky} = \nu_{rest} * \frac{-1 v_{lsr}}{c + 1}$$

Approved!

`astrolyze.functions.astro_functions.`**`rotation_2d`**`(`*coordinate*, *angle*`)`

Implementation of the rotation matrix in two dimensions.

Parameters

- **`coordinates`** (*list of floats*) – Coordinates in the unrotated system [x, y].
- **`angle`** (*float*) – The rotation angle

Returns **[x_rotated, y_rotated]** – Coordinates in the rotated system.

Return type list of floats

`astrolyze.functions.astro_functions.`**`v_lsr`**`(`*center_frequency*, *observation_frequency*`)`

Calculates the velocity that corresponds to a certain frequency shift between two frequencies.

Parameters

- **`center_frequency`** (*float*) – center_frequency in GHz
- **`observation_frequency`** (*float*) – The observation frequency in GHz.

Returns **v_lsr** – The velocity corresponding to the frequency shift in km/s

Return type float

Notes

Approved!

`astrolyze.functions.astro_functions.`**`vel_to_freq_resolution`**`(`*center_frequency*, *velocity_resolution*`)`

Converts a velocity resolution to frequency resolution for a given center frequency.

Parameters

- **`center_frequency`** (*float*) – Center frequency in GHz.
- **`velocity_resolution`** – Velocity resolution in km/s.

Returns **frequency_resolution** – The corresponding frequency resolution in Mhz

Return type float

Notes

Approved!

5.5.2 units

Constant unit conversions available in this module are:

```
# Constant conversion factors.
#==============> Approved !!! <==========================
WattToErgs     = 1e7  # 1W = 1e7 erg/s
ErgsToWatt     = 1e-7  # 1W = 1e-7 erg/s
JanskyToWatt   = 1e-26  # 1Jy = 1e-26 W/m2/Hz
WattToJansky   = 1e26  # 1W  = 1 Jy * m2 * Hz
ErgsToJansky_cm  = 1e23  # 1 erg/s =  1e23 Jy * cm2 * Hz * s
JanskyToErgs_cm  = 1e-23  # 1 Jy = 1e-23 erg/s/cm2/Hz
ErgsToJansky_m  = 1e19  # 1 erg/s = 1e-19 Jy * m2 * Hz * s
```

`astrolyze.functions.units.`**`Int2Lum`**(*distance_in_pc*, *cm_or_m='cm'*)

Conversion factor to calculate luminosity from intensities by integrating over the sky 4 pi Distance^2.

Parameters

- **`distance_in_pc`** (*float*) – Distance to the source in parsecs.
- **`cm_or_m`** (*string*) – Choose wether the out put is in cm^2 = `'cm'` or in m^2 = `'m'`.

Notes

Approved.

`astrolyze.functions.units.`**`JyBToErgsB`**(*input_flux*, *distance*, *wavelength*, *invert=False*, *map_use=False*)

Conversion between Jy/beam and ergs/beam.

Parameters

- **`input_flux`** (*float*) – Flux to be converted in Jy/beam
- **`distance`** (*float*) – Distance to the source in parsec.
- **`wavelength`** (*float*) – Wavelength λ in μm.
- **`map_use`** –

Returns

- *The conversion factor (map_use = true) or the already converted flux*
- *(map_use = False).*
- *r*

`astrolyze.functions.units.`**`JyBToWKpc2`**(*input_flux*, *distance*, *major*, *minor*, *wavelength*, *invert=False*, *map_use=False*)

Conversion from JyB to W kpc^-2.

Parameters

- **`input_flux`** (*float*) – Flux to be converted.
- **`distance`** (*float*) – Distance to source in parsec.
- **`major`** (*float*) – Major Axis Beam (arcsec).
- **`minor`** (*float*) – Minor Axis Beam(arcsec).
- **`wavelength`** (*float*) – Wavelenght λ in μm.
- **`invert`** (*True or False*) – Changes the direction of conversion.

Returns **float**

Return type the converted Flux.

`astrolyze.functions.units.`**`JyBToWM2Kpc2`**(*input_flux*, *distance*, *major*, *minor*, *wavelength*, *invert=False*, *map_use=False*)

Conversion between Jy/beam and W m^-2 kpc^-2

Parameters

- **`input_flux`** (*float*) – Flux to be converted.
- **`distance`** (*float*) – Distance to source in parsec.
- **`major`** (*float*) – Major Axis Beam (arcsec).
- **`minor`** (*float*) – Minor Axis Beam(arcsec).
- **`wavelength`** (*float*) – Wavelenght λ in μm
- **`invert`** (*True or False*) – Changes the direction of conversion.

Returns **float**

Return type the converted Flux.

`astrolyze.functions.units.`**`WmToKkms`**(*x*, *resolution=0*, *sterad=False*, *ToKKms=False*, *m2_or_cm2='m'*, *nu_or_lambda='nu'*)

Conversion between W/m2 and K km/s.

Parameters

- **`x`** (*float*) – wavelenght/frequency [GHZ].
- **`resolution`** (*float*) –
- **`ToKKms`** (*True or False*) – Direction of the conversion.
- **`sterad`** (*True or False*) – If False convert from per beam to per sterad.
- **`m2_or_cm2`** (*string*) – Choose if conversion to/from W m-2 oder W cm-2. `'m2'` or `'cm2'`.

Returns **factor** – The conversion factor.

Return type float

`astrolyze.functions.units.`**`ergToKkms`**(*x*, *toErg=False*, *nu_or_lambda='nu'*)

Conversion between ergs/cm2/s/sr and K km/s.

Parameters

- **`x`** (*float*) – wavelenght/frequency [GHZ],

- **toErg** (*True or False*) – True converts the other direction, i.e. from K km/s to ergs/cm2/s/sr.
- **nu_or_lambda** (*string*) – Choose type of x: frequency = `'nu'` or wavelenght = `'lambda'`.

Returns **factor** – The conversion factor.

Return type float

Notes

Approved.

`astrolyze.functions.units.`**`jansky_to_kelvin`**(*x*, *major*, *minor*, *nu_or_lambda='nu'*)

Conversion from Jy/beam to K.km/s (Tmb).

Parameters

- **x** (*float*) – wavelength/frequency [GHZ],
- **major** (*float*) – Major Axis Beam (arcsec).
- **minor** (*float*) – Minor Axis Beam(arcsec).
- **nu_or_lambda** (*string*) – Choose type of x: frequency = `'nu'` or wavelength = `'lambda'`.

Notes

Same as `kelvin_to_jansky()`

`astrolyze.functions.units.`**`kelvin_to_jansky`**(*x*, *major*, *minor*, *nu_or_lambda='nu'*)

Conversion from K.km/s (Tmb) and Jy/beam.

Parameters

- **x** (*float*) – wavelength/frequency [GHZ],
- **major** (*float*) – Major Axis Beam (arcsec),
- **minor** (*float*) – Minor Axis Beam(arcsec),
- **nu_or_lambda** (*string*) – Choose type of x: frequency = `'nu'` or wavelength = `'lambda'`.

Notes

This function has been compared with the Time estimator from the [GILDAS] package ASTRO and yields the same conversion factors.

References

5.5.3 constants

```
# Natural Constants
c = 299792458.  # Speed of light [m]
c_in_cm = c * 1e2  # Speed of light [cm]
h = 6.62606896e-34  # Plancks constant [Js]
k = 1.3806503e-23  # Boltzman constant [m^2 kg s^-1 K^-1]
tBG = 2.7  # Cosmic Microwave Background Temperature in [K]
e = 2.7182818284  # Eulers number

# Natural Constants in cgs units.
k_CGS = 1.3806503e-16  # Boltzman constant [cm^2 g s^-1 K^-1]
h_CGS = 6.62606896e-27  # Plancks constant [Js]
c_CGS = 2.99792458e10  # Speed of light [cm]

# Conversion of distances
parsec_in_m_1 = 3.08568025e16
parsec_in_m = 3.085e16  # parsec in m
parsec_in_cm = 3.08568025e18  # parsec in cm
km_in_cm = 1e5

# Masses
m_sun = 1.9891e30  # [kg]
m_proton = 1.672621637e-27  # [kg]

# Gauss constants
# GaussArea/(height*FWHM)
gauss_constant = 1.064467

# Luminosities
LsunW = 3.846e26  # Watts
Lsunergs = 3.846e26*1e7  # erg/s
debye_to_EsuCm = 1.e-18  # Change from debye to esu/cm

# Angle Conversions
a2r = 4.848e-6  # arcsec to radian
a2d = 1./60/60  # arcsec to degree
r2d = 180./math.pi  # radian to degree
```

CHAPTER 6

Indices and tables

- genindex
- modindex
- search

Bibliography

[GILDAS] http://www.iram.fr/IRAMFR/GILDAS

[MIRIAD] http://www.atnf.csiro.au/computing/software/miriad/taskindex.html

[python-pyfits] http://www.stsci.edu/institute/software_hardware/pyfits

[DA] Dale et al. 2001; ApJ; 549:215-227

[TA] "An introduction to the study of uncertainties in physical measurement" by John R. Taylor.

[KS] Kruegel, E. & Siebenmorgen, R. 1994, A&A, 288, 929

[GILDAS] www.iram.fr/IRAMFR/GILDAS