hpproj Documentation

Release 0.9.3

Alexandre Beelen, Marian Douspis

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Contents

HealPixProjection is a project to allow easy and efficient projection of healpix maps onto planar grids. It can be used as a standalone program *hpproj.cutsky()*

```
$ cutsky 0.0 0.0 --mapfilenames HFI_SkyMap_857_2048_R2.00_full.fits
```

or as a python function

```
from hpproj import cutsky
result = cutsky([0.0, 0.0], maps={'HFI 857': {'filename': 'HFI_SkyMap_857_2048_R2.00_
↪full.fits'}})
```

or as a python class, for optimization when producting several cuts

```
from hpproj import CutSky, to_coord
cutsky = CutSky({'Planck 857': {'filename': 'HFI_SkyMap_857_2048_R2.00_full.fits'}})
result = cutsky.cut_fits(to_coord([0., 0.])
```

Note: For science applications requiring high photometric accuracy, we recommend the drizzlib software developed by CADE, which uses a flux-conserving drizzling method to reproject data between HEALPix and local WCS. Drizzlib is available as standalone software (IDL python) here: http://cade.irap.omp.eu/dokuwiki/doku.php?id=software . An online interface, drizzweb, is available here: http://drizzweb.irap.omp.eu/ .

You can also have a look into the `reproject.reproject_from_healpix()` function from the reproject package.

CHAPTER 1

Features

- Galactic and equatorial system supported
- All projection system from `wcs`
- Project several healpix maps at once, efficiently !
- Output in `fits`, `png` or `votable`
- Perform *n-dim projections* !

See *Basic Usage* for more information on how to use `cutsky`

CHAPTER 2

Installation

Install `hpproj` using pip :

```
$ pip install hpproj
```

or by running setuptools on source. For more information see the installation page.

CHAPTER 3

Contribute

- Issues Tracker
- Source Code

CHAPTER 4

Support

If you are having issues, please let us know.

CHAPTER 5

License

This project is licensed under the LGPL+3.0 license.

CHAPTER 6

Contents:

6.1 Installation

hpproj is tested against python 2.7 and 3.5 and can be installed using *pip* or from *source*

6.1.1 pip

```
$ pip install hpproj
```

This will install the latest release of hpproj

6.1.2 source

```
$ git clone https://git.ias.u-psud.fr/abeelen/hpproj.git
$ cd hpproj
$ python setup.py install
```

This will install the master tree of hpproj. It is probably wiser to checkout a specific version before installation

```
$ git clone https://git.ias.u-psud.fr/abeelen/hpproj.git
$ cd hpproj
$ git checkout 0.4
$ python setup.py install
```

6.1.3 Dependencies

hpproj require the following librairies

- numpy>=1.13

- matplotlib>=2.0
- astropy>=2.0
- healpy>=1.9
- photutils>=0.4

The specific versionning are those you are being used in the test suit. Both *pip* and *source* install should install those library if they are missing.

6.2 Basic Usage

Caution: All the healpix maps *must* have a proper header defining their :

- frame using the `COORDSYS` keyword,
- order using the `ORDERING` keyword.

However you can correct the headers in the construction of the list of maps

```
maps = [ {'HFI 100': {'filename': 'data/HFI_SkyMap_100_2048_R2.00_full.fits',
↪'COORDSYS': 'C'}}]
```

There is two main way to use `hpproj`, the first way is to use the standalone program on the command line, this will efficiently produce cuts for similar maps, or use it programmatically from within a python script or program which will offer an additional speed-up on high memory system.

6.2.1 From the command line - `cutsky`

The command line program is called *cutsky* and takes 3 arguments at minimum, the longitude and latitude of the desired projection (by default in `galactic` coordinate, but see below) and a list of healpix map to cut from :

```
$ cutsky 0.0 0.0 --mapfilenames data/HFI_SkyMap_100_2048_R2.00_full.fits  data/HFI_
↪SkyMap_857_2048_R2.00_full.fits
```

by default this will produce two `png` files centered on galactic longitude and latitude (0,0). Fits images of central photometries can be obtain using the `--fits` or `--phot` options. Help on `cutsky` can be obtain by

```
$ cutsky -h

usage: cutsky [-h] [--npix NPIX | --radius RADIUS] [--pixsize PIXSIZE]
              [--coordframe {galactic,fk5}]
              [--ctype {AZP,SZP,TAN,STG,SIN,ARC,ZPN,ZEA,AIR,CYP,CEA,CAR,MER,COP,COE,
↪COD,COO,SFL,PAR,MOL,AIT,BON,PCO,TSC,CSC,QSC,HPX,XPH}]
              [--mapfilenames MAPFILENAMES [MAPFILENAMES ...]] [--fits]
              [--png] [--votable aperture [aperture ...]] [--outdir OUTDIR] [-v | -q]␣
↪[--conf CONF]
              lon lat

Reproject the spherical sky onto a plane.

positional arguments:
  lon                   longitude of the projection [deg]
```

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```
  lat                   latitude of the projection [deg]

optional arguments:
  -h, --help            show this help message and exit
  --npix NPIX           number of pixels (default 256)
  --radius RADIUS       radius of the requested region [deg]
  --pixsize PIXSIZE     pixel size [arcmin] (default 1)
  --coordframe {galactic,fk5}
                        coordinate frame of the lon. and lat. of the
                        projection and the projected map (default: galactic)
  --ctype {AZP,SZP,TAN,STG,SIN,ARC,ZPN,ZEA,AIR,CYP,CEA,CAR,MER,COP,COE,COD,COO,SFL,
↪PAR,MOL,AIT,BON,PCO,TSC,CSC,QSC,HPX,XPH}
                        any projection code supported by wcslib (default:TAN)

input maps:
  one of the two options must be present
  --mapfilenames MAPFILENAMES [MAPFILENAMES ...]
                        absolute path to the healpix maps
  --conf CONF           absolute path to a config file

output:
  --fits                output fits file
  --png                 output png file (Default: True if nothing else)
  --votable aperture [aperture ...]
                        list of aperture [arcmin] to make circular aperture photometry
  --outdir OUTDIR       output directory (default:.)

general:
  -v, --verbose         verbose mode
  -q, --quiet           quiet mode
```

It takes two float arguments, the latitude and longitude center of the requested projection, either in galactic or equatorial coordinate frame (controled by the `--coordframe` option) and a list of healpix maps, either on the command line with the `--mapfilenames` argument or describe in a config file (with the `--conf` option). Several other optional arguments can also be set like `--npix` the number of pixels, their size (`--pixsize`) or the projection type `--ctype`.

The cutted maps can be saved as fits (`--fits`) or png (`--png`) and central circular aperture photometry can be performed and saved as a votable (`--votable aperture`). The output products directory can be tune using the `--outdir` option. All theses options can also be provided by the config file.

The config file follows a simple ini syntax with a global section `[cutsky]` to gather all previous options. The rest of the sections is used to describe the healpix maps used by `cutsky`. The section name `[test]` will be used as a legend and index by `cutsky`.

```
[cutsky]
npix = 256
pixsize = 2
coordframe = galactic
png = True

[SMICA]
filename = hpproj/data/CMB_I_SMICA_128_R2.00.fits
docut = False

[HFI 100]
filename = hpproj/data/HFI_SkyMap_100_128_R2.00_RING.fits
```

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```
[HFI 857]
filename = hpproj/data/HFI_SkyMap_857_128_R2.00_NESTED.fits
docut = True
docontour = True
```

6.2.2 As a function call - `cutsky()`

It is also possible to call `cutsky` from a python program or script, as a function. You first need to define a list of maps on which to perform the cuts, as list of tuple with at minimum `(filename.fits, {'legend': "legend"))` given the full path to the healpix map, and a dictionnary with a least the key `legend`

```
from hpproj import cutsky

maps = [('data/HFI_SkyMap_100_2048_R2.00_full.fits', {'legend': 'HFI 100', 'aperture
↪': [1, 2, 3]}),
        ('data/HFI_SkyMap_857_2048_R2.00_full.fits', {'legend': 'HFI 857', 'docontour
↪': True})]

result = cutsky([0.0, 0.0], maps=maps)
```

The first argument is the latitude and longitude of the requested maps, by default in `galactic` frame (see the `coordframe` keyword), and the `maps` list define the healpix maps.

This will produce a list of dictionnaries containing 4 keys:

- `legend`,
- `fits` an ~astropy.io.fits.ImageHDU,
- `png`, a b61encoded png image of the fits
- `phot`, the corresponding photometry

Additionnal parameters can by passed to the function :

- `patch=[256,1]` : the size of the patch in pixel, and the size of the pixels in arcmin
- `ctype='TAN'` : the desired type of projection

6.2.3 As an object - `CutSky`

It is however more efficient to use cutsky as an object :

```
from hpproj import CutSky, to_coord

maps = [('data/HFI_SkyMap_100_2048_R2.00_full.fits', {'legend': 'HFI 100', 'aperture
↪': [1, 2, 3]}),
        ('data/HFI_SkyMap_857_2048_R2.00_full.fits', {'legend': 'HFI 857', 'docontour
↪': True})]

cutsky = CutSky(maps, low_mem=False)

coord = to_coord([0.0,0.0])
result = cutsky.cut_fits(coord) # Will only produce the 'fits' key
```

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```
result = cutsky.cut_png(coord)  # Will only produce the 'png' key (and 'fits' if␣
↪absent)
result = cutsky.cut_phot(coord) # Will only produce the 'phot' key (and fits' if␣
↪absent)
```

The result product should be similar to the `cutsky()` function. However with the `low_mem` keyword the healpix maps will be read only once in memory, for all `cut_*` calls. Similar to `cutsky()` several keyword parameters can be passed to `CutSky()` :

- `npix=256` : the size of the patch in pixels
- `pixsize=1` : the size of the pixels in arcmin
- `ctype='TAN'`: the desired type of projection

6.2.4 As internal calls - `hp_helper`

Alternatively if you simply want to get a projected array, you can use the *`hp_project()`* function

```
from astropy.io import fits
from astropy.coordinates import SkyCoord
import healpy as hp
from hpproj import hp_project

hp_data, hp_header = hp.read_map('data/HFI_SkyMap_100_2048_R2.00_full.fits', h=True)
hp_header = fits.Header(hp_header)

hdu = hp_project(hp_data, hp_header, SkyCoord(0, 0, unit='deg'))
```

Or, if you prefer to get full control, you can also use the internal functions like *`build_wcs()`* and *`hp_to_wcs()`*

```
from astropy.io import fits
import healpy as hp
import hpproj as hpp

hp_data, hp_header = hp.read_map('data/HFI_SkyMap_100_2048_R2.00_full.fits', h=True)
hp_header = fits.Header(hp_header)
hp_hdu = fits.ImageHDU(hp_data, hp_header)

w = hpp.build_wcs(0, 0)

proj_map = hpp.hp_to_wcs(hp_data, hp_header, w)
```

Note that both *hp_project* and *hp_to_wcs* accept either an *~astropy.io.fits.ImageHDU*, or both *hp_data, hp_header*

6.3 *n-d* Projections !

hpproj allow for *n-d* projections, for *d=3* to *d=0*

Caution: `healpy` by default change any healpix map into the RING pixelization scheme without changing its header. Be sure to read the maps with the *nest=None*

First let's setup the dataset :

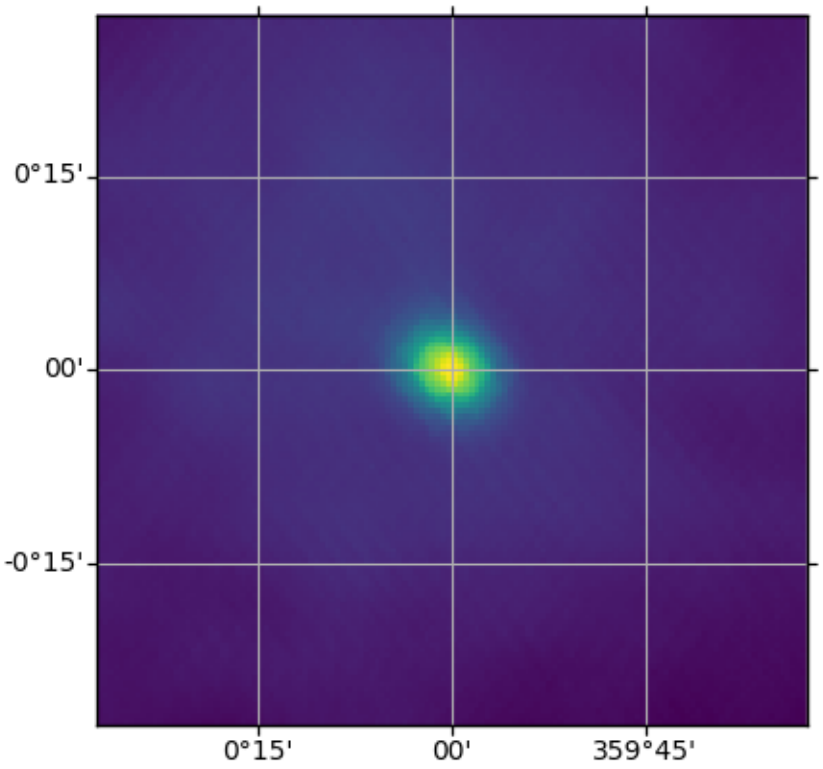
```
import numpy as np
import matplotlib.pyplot as plt
import healpy as hp

from astropy.io import fits
from astropy.coordinates import SkyCoord
from astropy.utils.data import download_file
from astropy.wcs import WCS
from astropy.table import Table

from hpproj import hp_stack

# Retrieve the Planck 857 GHz all sky map
irsa_url = 'http://irsa.ipac.caltech.edu/data/Planck/release_2/all-sky-maps/maps/'
url = irsa_url + 'HFI_SkyMap_857_2048_R2.02_full.fits'
filename = download_file(url, cache=True)

hp_data, hp_header = hp.read_map(filename, h=True, nest=None)
hp_hdu = fits.ImageHDU(hp_data, fits.Header(hp_header))
hp_hdu.header['UNIT'] = 'MJy/sr'

# Fetch the PCCS catalog
cds_url = 'http://cdsarc.u-strasbg.fr/ftp/cats/J/A+A/594/A26/fits/'
url = cds_url + 'PCCS_857_R2.01.fits'

PCCS = Table.read(download_file(url, cache=True))
# Select a few sources
PCCS = PCCS[np.abs(PCCS['GLAT']) > 30]
PCCS = PCCS[:500]
```

6.3.1 3-d projections

hpproj allow for stacking in the healpix map

```
coords = SkyCoord(PCCS['RA'].data, PCCS['DEC'].data, unit="deg")
pixsize = hp.nside2resol(hp_hdu.header['NSIDE'], arcmin=True) /60 /4
hdu = hp_stack(hp_hdu, coords, pixsize=pixsize, shape_out=(128, 128))
```

hdu is an `astropy.io.fits.ImageHDU` containing the stack of all the requested positions. One can also use the *keep* option to retrieve all the individual maps



6.3.2 2.5-d projections

Using some more in-depth routine of *hpproj*, it is possible to place 2 sources at a relative given position on a map

```
from astropy.visualization import ImageNormalize, HistEqStretch

from hpproj import build_wcs_2pts
from hpproj import hp_to_wcs

coord_LMC = SkyCoord("05:23:34.60", "-69:45:22.0", unit=(u.hourangle, u.deg))
coord_SMC = SkyCoord("00h52m38s", "-72:48:01", unit=(u.hourangle, u.deg))

pair_coord = (coord_LMC, coord_SMC)

relative_pos = [0.3, 0.7]
shape_out = (512, 1024)

wcs = build_wcs_2pts(pair_coord, shape_out=shape_out, relative_pos=relative_pos)
img = hp_to_wcs(hp_hdu, wcs, shape_out)

norm = ImageNormalize(stretch=HistEqStretch(img))

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1, projection=wcs)
```

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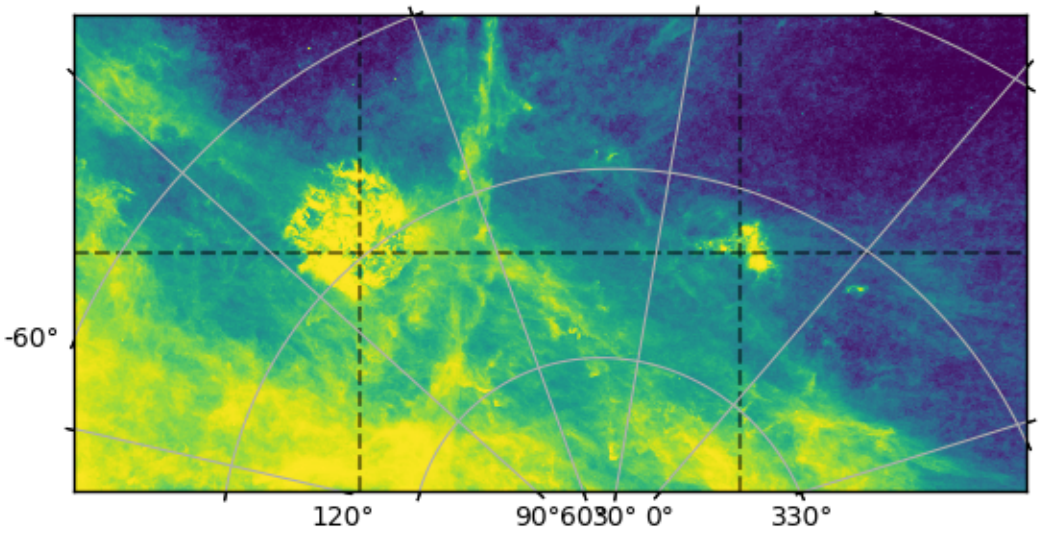
```
ax.imshow(img, origin='lower', interpolation='none', norm=norm)
ax.grid()

ax.axhline(0.5 * img.shape[0], linestyle='--', c='k', alpha=0.5)
for pos in relative_pos:
    ax.axvline(pos * img.shape[1], linestyle='--', c='k', alpha=0.5)
```

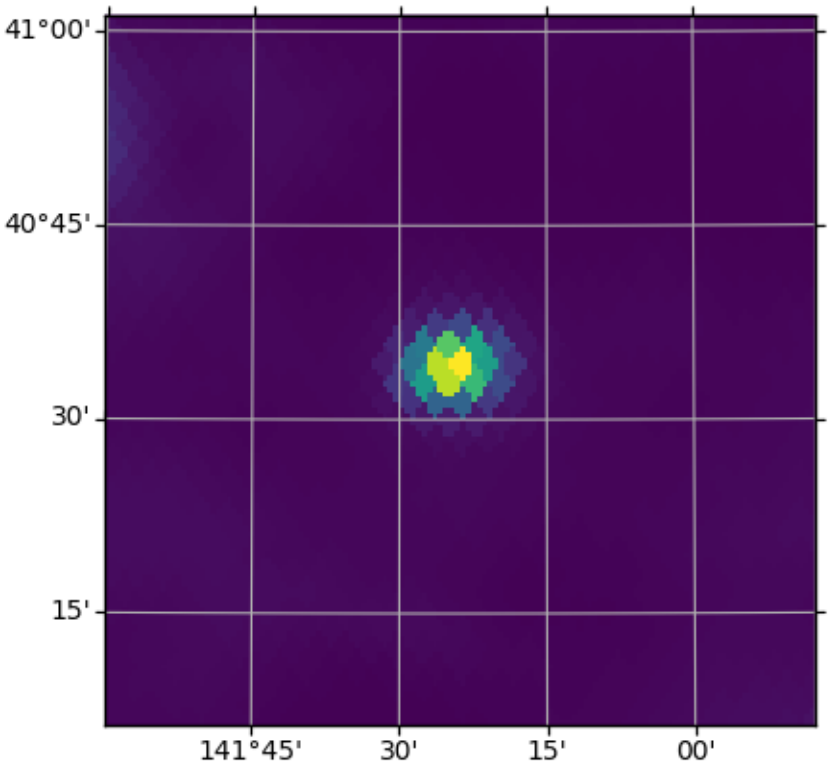


6.3.3 2-d Projections

This is the most common projection, from an healpix map to a 2D map

```
from hpproj import hp_project

coord = SkyCoord(141.397513059, 40.5638050454, unit="deg", frame="galactic")
pixsize = hp.nside2resol(hp_hdu.header['NSIDE'], arcmin=True) / 60 / 4
hdu = hp_project(hp_hdu, coord, pixsize=pixsize, shape_out=(128, 128))
```

hdu is then an `astropy.io.fits.ImageHDU` containing the requested region on the sky and it's corresponding header, which can be easily plotted with, for e.g., *matplotlib*

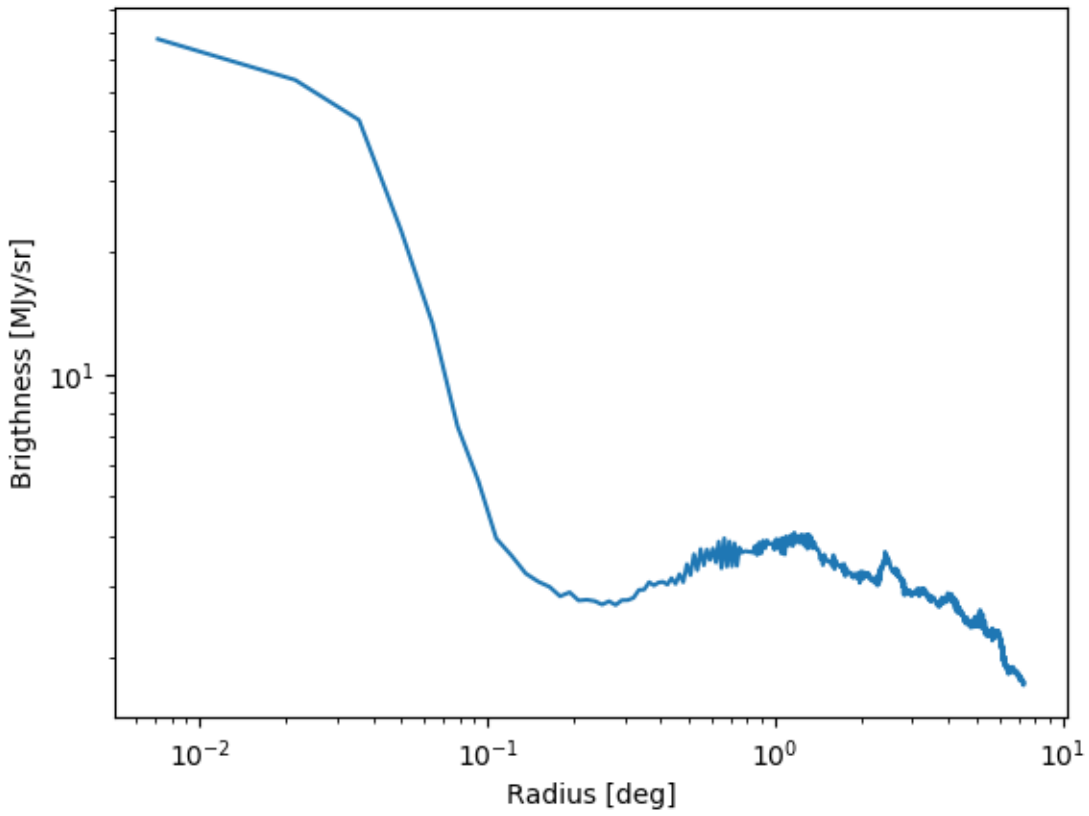


6.3.4 1-d Projections

The 1-d projection goes from an healpix map to a intensity profile

```
from hpproj import hp_profile

coord = SkyCoord(202.4865871680179, 47.181795866475426, unit="deg")
hdu = hp_profile(hp_hdu, coord)
```

hdu is then an `astropy.io.fits.ImageHDU` with the profile centered on the requested coordinates



6.3.5 0-d Projections

The 0-d projection goes from an healpix map to an aperture photometry, of a given position

```
from hpproj import hp_photometry
from astropy.coordinates import SkyCoord, Angle

coord = SkyCoord(202.4865871680179, 47.181795866475426, unit="deg")
apertures = Angle(hp.nside2resol(hp_hdu.header['NSIDE'], arcmin=True) / 60, "deg") *␣
↪[7, 10, 15]
result = hp_photometry(hp_hdu, coord, apertures=apertures)
```

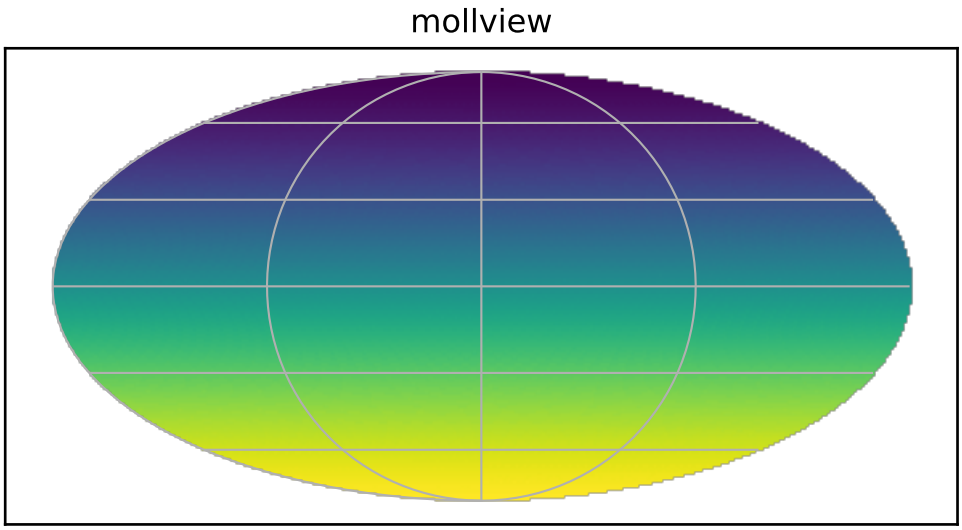
result is then an `astropy.table.Table` with the aperture photometry

```
Out[1]:
<Table length=1>
brigthness    background   n_pix
MJy / sr      MJy / sr
float64       float64      int64
------------- ------------ -----
2.51999285723 1.2330693081   151
```

6.4 Visualization

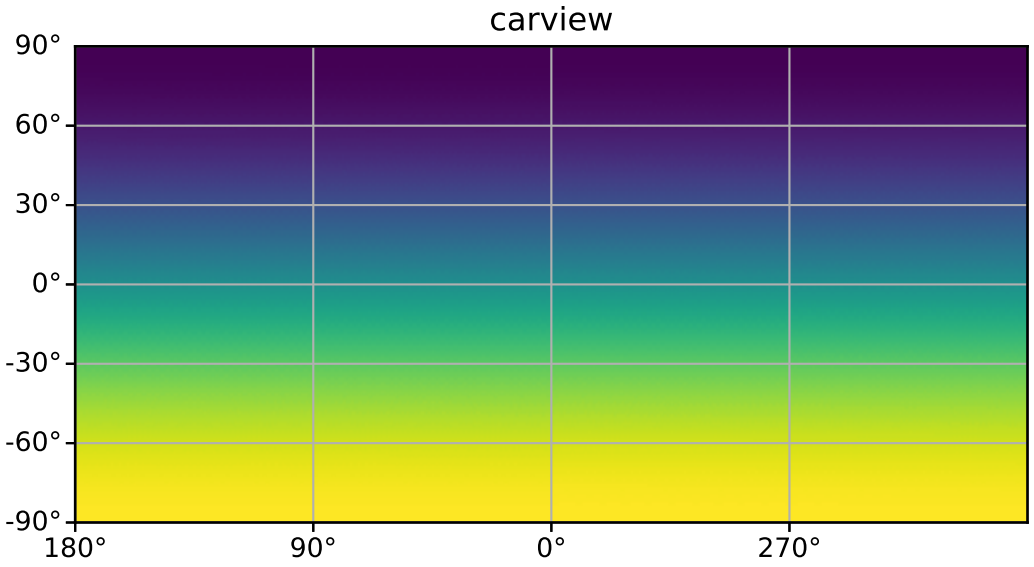
The HealPixProjection routines can easily be used to display a full sky map with different projections. In the *hpproj.visu* module, several projection have been implemented

```
import matplotlib.pyplot as plt
import numpy as np
import healpy as hp
from astropy.wcs import WCS
from hpproj import mollview

# Ring like healpix map
nside = 2**6
hp_map = np.arange(hp.nside2npix(nside))
hp_header = {'NSIDE': nside,
             'ORDERING': 'RING',
             'COORDSYS': 'G'}

# Projection of the map and plotting
_ = mollview(hp_map, hp_header)
fig = plt.figure()
ax = fig.add_subplot(1,1,1, projection=WCS(_.header))
ax.imshow(_.data, origin='lower', interpolation='none')
ax.grid()
ax.set_title('mollview')
```



Note that these maps have a proper `WCS` header and thus can be easily used to overplot markers and artists.

Other classical projections have been implemented



6.5 API

6.5.1 cutsky

cutsky module, mainly use *`hpproj.hp_helper`* functions

class hpproj.cutsky.**CutSky**(*maps=None*, *npix=256*, *pixsize=1*, *ctype='TAN'*, *low_mem=True*)

Container for Healpix maps and cut_* methods

...

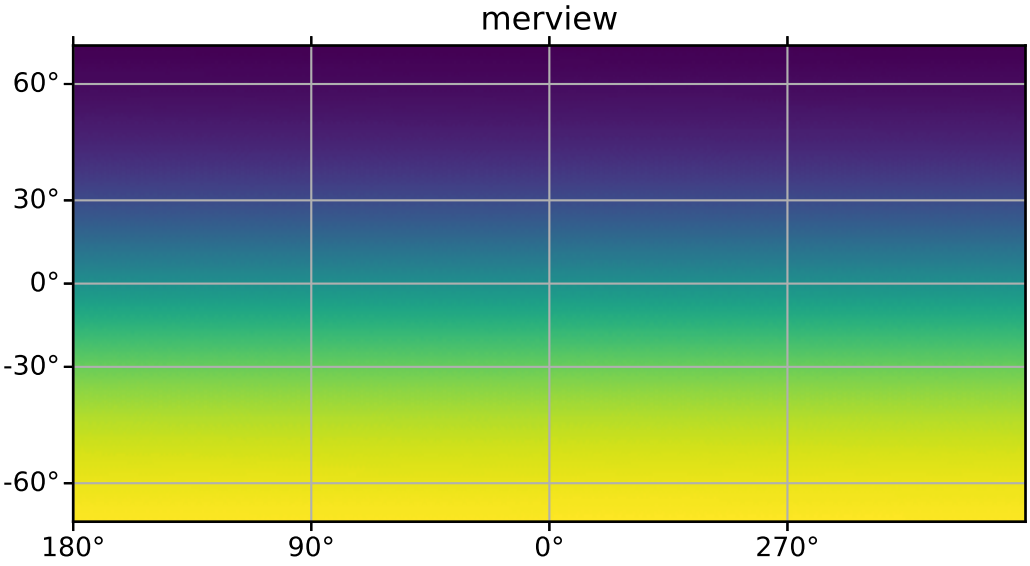
Attributes

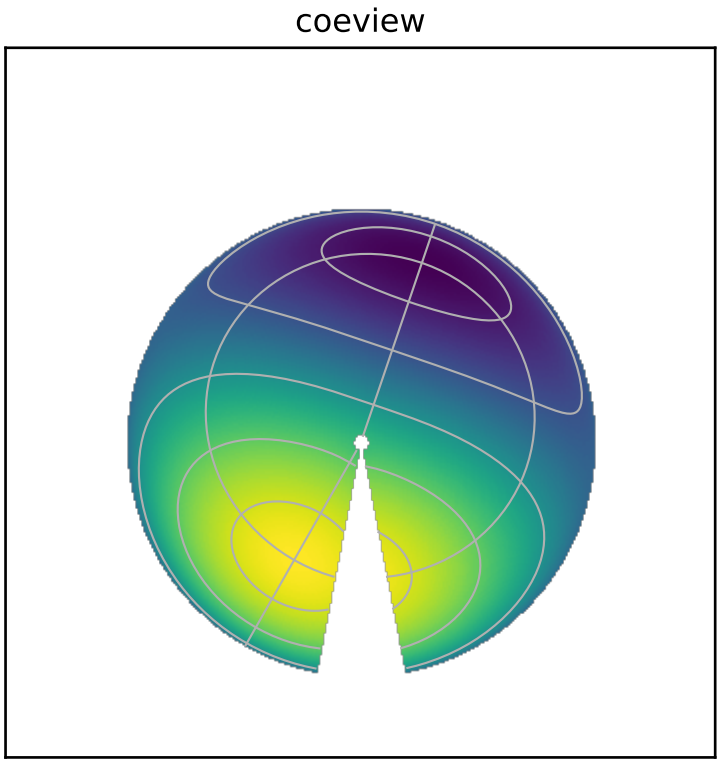
npix [int] the number of pixels for the square maps

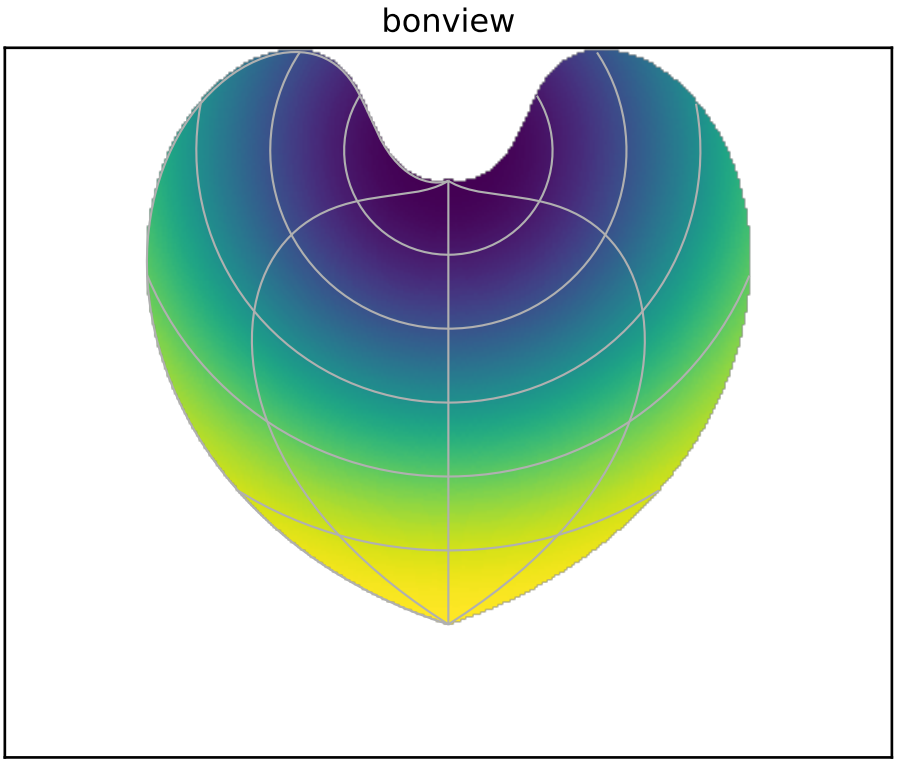
pixsize [float] the size of the pixels [arcmin]

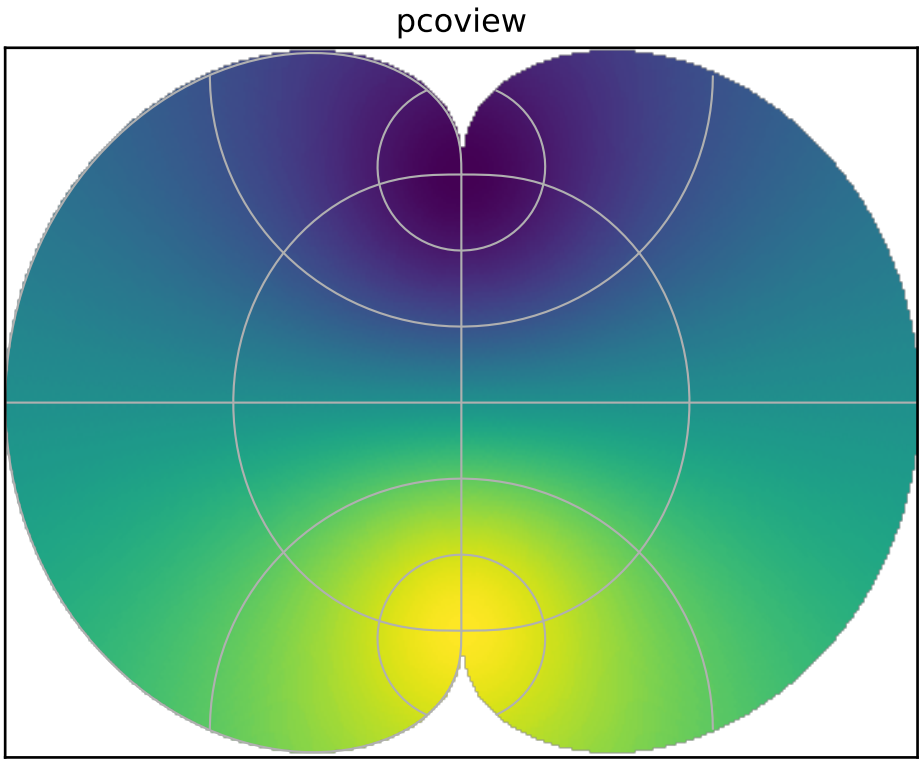
ctype [str] a valid projection type (default : TAN)

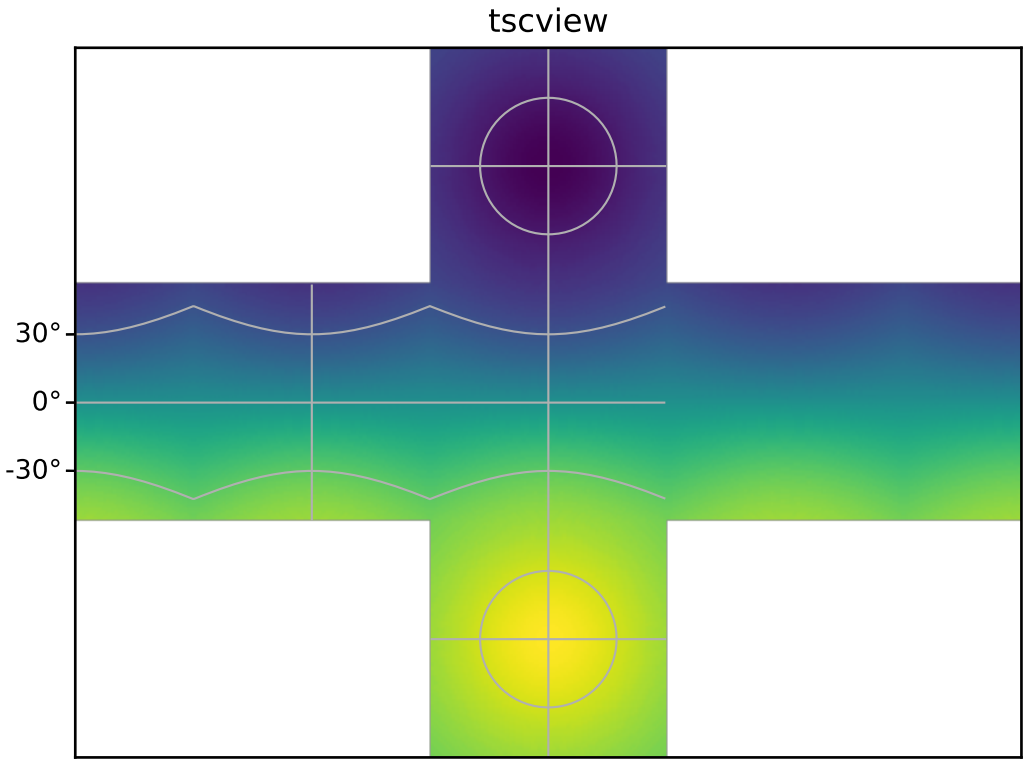
maps [dictonnary] a grouped dictionnary of gen_hpmap tuples (filename, map, header) (see :func:~init)


merview
60°
30°
0°
-30°
-60°
180°
90°
0°
270°


coeview


bonview


pcoview


tscview
30°
0°
-30°

Methods

cut(cut_type, **kwargs)	helper function to cut into the maps
cut_fits(coord[, maps_selection])	Efficiently cut the healpix maps and return cutted fits file with proper header
cut_phot([coord, maps_selection, apertures])	Efficiently cut the healpix maps and return cutted fits file with proper header and corresponding photometry
cut_png([coord, maps_selection])	Efficiently cut the healpix maps and return cutted fits file with proper header and corresponding png

cut (*cut_type*, ***kwargs*)
helper function to cut into the maps

Parameters

cut_type [str (fits|png|phot|votable)] define what to cut_type

coord [SkyCoord] the sky coordinate for the projection. Its frame will be used for the projection

maps_selection [list] optionnal list of the 'legend' or filename of the map to select a subsample of them.

Returns

list of dictionnaries the dictionnary output depends on cut_type

cut_fits (*coord*, *maps_selection=None*)
Efficiently cut the healpix maps and return cutted fits file with proper header

Parameters

coord [SkyCoord] the sky coordinate for the projection. Its frame will be used for the projection

maps_selection [list] optionnal list of the 'legend' or filename of the map to select a subsample of them.

Returns

list of dictionnaries the dictionnary has 2 keys : * 'legend' (the opts{'legend'} see __init__()) * 'fits' an ImageHDU

cut_phot (*coord=None*, *maps_selection=None*, *apertures=None*)
Efficiently cut the healpix maps and return cutted fits file with proper header and corresponding photometry

Parameters

coord [SkyCoord] the sky coordinate for the projection. Its frame will be used for the projection

maps_selection [list] optionnal list of the 'legend' or filename of the map to select a subsample of them.

apertures: float or list of float aperture size in arcmin, if None, the aperture are guessed from the input map

Returns

list of dictionnaries the dictionnary has 3 keys : * 'legend' (the opts{'legend'} see __init()), * 'fits' an ImageHDU, * 'phot', the corresponding photometry

cut_png(*coord=None*, *maps_selection=None*)
Efficiently cut the healpix maps and return cutted fits file with proper header and corresponding png

Parameters

coord [SkyCoord] the sky coordinate for the projection. Its frame will be used for the projection

maps_selection [list] optionnal list of the 'legend' or filename of the map to select a subsample of them.

Returns

list of dictionnaries the dictionnary has 3 keys : * 'legend' (the opts{'legend'} see __init()), * 'fits' an ImageHDU, * 'png', a b61encoded png image of the fits

hpproj.cutsky.**cutsky**(*lonlat=None*, *maps=None*, *patch=None*, *coordframe='galactic'*, *ctype='TAN'*, *apertures=None*)
Old interface to cutsky – Here mostly for compability

Parameters

lonlat [array of 2 floats] the longitude and latitude of the center of projection [deg]

maps: a dict or a list either a dictionnary (old interface) or a list of tuple (new interface) : ‘‘‘ {legend: {'filename': full_filename_to_healpix_map.fits,

'docontour': True }, # optionnal

... } ` or ` [(full_filename_to_healpix_map.fits, {'legend': legend,

'docontour': True}), # optionnal

...] ‘‘‘

patch [array of [int, float]] [int] the number of pixels and [float] the size of the pixel [arcmin]

coordframe [str] the coordinate frame used for the position AND the projection

ctype: str a valid projection type (default: TAN)

apertures: float of list of floats aperture in arcmin for the circular aperture photometry

Returns

list of dictionnaries the dictionnary has 4 keys : * 'legend' (see maps above), * 'fits' an ImageHDU, * 'png', a b61encoded png image of the fits * 'phot', the corresponding photometry

hpproj.cutsky.**main**(*argv=None*)
The main routine.

hpproj.cutsky.**save_result**(*output*, *result*)
Save the results of the main function

hpproj.cutsky.**to_coord**(*lonlat=None*, *coordframe='galactic'*)
helper function to get a SkyCoord object using the old interface

Parameters

lonlat [array of 2 floats] the longitude and latitude of the center of projection [deg]

coordframe [str] the coordinate frame used for the position AND the projection

Returns

:class:'~astropy.coordinates.SkyCoord' the corresponding SkyCoord

hpproj.cutsky.**to_new_maps**(*maps*)
Transform old dictionnary type healpix map list used by cutsky to list of tuple used by Cutsky

Parameters

maps [dict] a dictionnary with key being the legend of the image : ‘‘‘ {legend: {‘filename’: full_filename_to_healpix_map.fits,

‘docontour’: True },

... }

‘‘‘

Returns

a list of tuple following the new convention:

‘‘‘

[(full_filename_to_healpix_map.fits, {‘legend’: legend,

‘docontour’: True}),

...]

‘‘‘

6.5.2 helpers

Series of helper function to deal with healpix maps

hpproj.hp_helper.**hp_is_nest**(*hp_header*)
Return True if the healpix header is in nested

Parameters

hp_header [Header] the header

Returns

boolean : True if the header is nested

hpproj.hp_helper.**hp_celestial**(*hp_header*)
Retrieve the celestial system used in healpix maps. From Healpix documentation this can have 3 forms :

- ‘EQ’, ‘C’ or ‘Q’ : Celestial2000 = eQuatorial,
- ‘G’ : Galactic
- ‘E’ : Ecliptic,

only Celestial and Galactic are supported right now as the Ecliptic coordinate system was just recently pulled to astropy

Similar to wcs_to_celestial_frame but for header from healpix maps

Parameters

hp_header [Header] the header of the healpix map

Returns

frame [BaseCoordinateFrame subclass instance] An instance of a BaseCoordinateFrame subclass instance that best matches the specified WCS.

hpproj.hp_helper.**hp_to_wcs**(**args*, ***kargs*)
Project an Healpix map on a wcs header, using nearest neighbors.

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

wcs [astropy.wcs.WCS] wcs object to project with

shape_out [tuple] shape of the output map (n_y, n_x)

order [int (0|1)] order of the interpolation 0: nearest-neighbor, 1: bi-linear interpolation

Returns

array_like the projected map in a 2D array of shape shape_out

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**hp_to_wcs_ipx**(*hp_header*, *wcs*, *shape_out=(512*, *512)*)
Return the indexes of pixels of a given wcs and shape_out, within a nside healpix map.

Parameters

hp_header [astropy.fits.header.Header] header of the healpix map, should contain nside and coordsys and ordering

wcs [astropy.wcs.WCS] wcs object to project with

shape_out [tuple] shape of the output map (n_y, n_x)

Returns

2D array_like mask for the given map

array_like corresponding pixel indexes

Notes

The map could then easily be constructed using

proj_map = np.ma.array(np.zeros(shape_out), mask=~mask, fill_value=np.nan) proj_map[mask] = healpix_map[ipix]

hpproj.hp_helper.**hp_project**(**args*, ***kargs*)
Project an healpix map at a single given position

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

pixsize [float] size of the pixel (in degree)

shape_out [tuple] shape of the output map (n_y, n_x)

order [int (0|1)] order of the interpolation 0: nearest-neighbor, 1: bi-linear interpolation

projection [tuple of str] the coordinate ('GALACTIC', 'EQUATORIAL') and projection ('TAN', 'SIN', 'GSL', ...) system

Returns

:class:'astropy.io.fits.PrimaryHDU' containing the array and the corresponding header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**gen_hpmap**(*maps*)
Generator function for large maps and low memory system

Parameters

maps [list]

A list of Nmap tuples with either:

- (filename, path_to_localfilename, healpix header)
- (filename, healpix vector, healpix header)

Returns

tuple Return a tuple (filename, healpix map, healpix header) corresponding to the inputed list

hpproj.hp_helper.**build_hpmap**(*filenames*, *low_mem=True*)
From a filename list, build a tuple usable with gen_hmap()

Parameters

filenames: list A list of Nmap filenames of healpix maps or a tuple with (hp_map, hp_header)

low_mem [bool] On low memory system, do not read the maps themselves (default: only header)

Returns

tuple list A list of tuple which can be used by gen_hpmap

hpproj.hp_helper.**hpmap_key**(*hp_map*)
Generate an key from the hp_map tuple to sort the hp_maps by map properties

Parameters

hp_map: tuple A tuple from (build|gen)_hpmap : (filename, healpix map, healpix header)

Returns

str A string with the map properties

hpproj.hp_helper.**wcs_to_profile**(*hdu*, *wcs*, *shape_out=512*)
Centered profile from 2D map

Parameters

hdu [astropy.fits.ImageHDU] hdu containing the 2D array and corresponding header, the profile will be made from the CRVAL position

wcs [astropy.wcs.WCS] wcs object to describe the radius of the profile

shape_out [int] shape of the output profile

Returns

:class:'astropy.fits.ImageHDU' 1D hdu image containing the profile and the corresponding header

hpproj.hp_helper.**hp_to_profile**(**args*, ***kargs*)
Extract radial profile from healpix map

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

wcs [astropy.wcs.WCS] wcs object to describe the radius of the profile

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the profile

shape_out [int] shape of the output profile

std [bool] return the standard deviation

Returns

:class:'astropy.fits.ImageHDU' 1D hdu image containing the profile and the corresponding header, optionnaly a second ImageHDU containing the standard deviation

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**hp_profile**(**args*, ***kargs*)
Project an healpix map at a single given position

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

pixsize [float] size of the pixel (in degree)

npix [int] number of pixels in the final map, the reference pixel will be at the center

Returns

:class:‘astropy.io.fits.PrimaryHDU‘ containing the array and the corresponding header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**hp_stack**(**args*, ***kargs*)
Perform stacking on an healpix map

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coords [list of astropy.coordinate.SkyCoord] list of sky coordinates for the center of the cropped maps

pixsize [float] size of the pixel (in degree)

shape_out [tuple] shape of the output map (n_y, n_x)

order [int (0|1)] order of the interpolation 0: nearest-neighbor, 1: bi-linear interpolation

projection [tuple of str] the coordinate ('GALACTIC', 'EQUATORIAL') and projection ('TAN', 'SIN', 'GSL', ...) system

keep [boolean (default False)] return all the cropped maps as a 3D cube instead of one stack map

Returns

':class:~fits.ImageHDU‘ hdu containing the stack image or cube and corresponding header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**hp_to_aperture**(**args*, ***kargs*)
Raw aperture summation on an healpix map

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coords [list of astropy.coordinate.SkyCoord] the sky coordinates for the center of the apertures

apertures [list of *:class:astropy.coordinates.Angles*] aperture angle in which we perfom summation

Returns

npix, apertures [array_like] 2 arrays containing the number of pixels, and sum of the pixels within the aperture respectively

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.hp_helper.**hp_photometry**(**args*, ***kargs*)

Aperture photometry on an healpix map at a single given position

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ...header

coords [astropy.coordinate.SkyCoord] the sky coordinates for the center of the apertures

apertures [3 *:class:astropy.coordinates.Angles*] 3 floats defining the aperture radius and inner/outer annulus radii

Returns

:class:'astropy.io.fits.BinaryHDU' table containing the photometry

Notes

You can access a function using only catalogs with the ._coord() method

Series of helper function to deal with building wcs objects

hpproj.wcs_helper.**build_wcs**(**args*, ***kwargs*)

Construct a WCS object for a 2D image Parameters ———- coord : astropy.coordinate.SkyCoord

the sky coordinate of the center of the projection

or

lon,lat [floats] the sky coordinates of the center of projection and

src_frame [keyword, str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the longitude and latitude (default EQUATORIAL)

pixsize [float] size of the pixel (in degree)

shape_out [tuple] shape of the output map (n_y,n_x)

proj_sys [str ('GALACTIC', 'EQUATORIAL')] the coordinate system of the plate (from HEALPIX maps....)

proj_type [str ('TAN', 'SIN', 'GSL', ...)] the projection system to use

Returns

WCS: :class:'~astropy.wcs.WCS' An corresponding wcs object

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.wcs_helper.**build_wcs_cube**(**args*, ***kwargs*)

Construct a WCS object for a 3D cube, where the 3rd dimension is an index Parameters ———- coord : astropy.coordinate.SkyCoord

the sky coordinate of the center of the projection

or

lon,lat [floats] the sky coordinates of the center of projection and

src_frame [keyword, str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the longitude and latitude (default EQUATORIAL)

index [int] reference index

pixsize [float] size of the pixel (in degree)

shape_out [tuple] shape of the output map (n_y, n_x)

proj_sys [str ('GALACTIC', 'EQUATORIAL')] the coordinate system of the plate (from HEALPIX maps....)

proj_type [str ('TAN', 'SIN', 'GSL', ...)] the projection system to use

Returns

WCS: :class:'~astropy.wcs.WCS' An corresponding wcs object

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.wcs_helper.**build_wcs_2pts**(*coords*, *pixsize=None*, *shape_out=(512, 512)*, *proj_sys='EQUATORIAL'*, *proj_type='TAN'*, *relative_pos=(0.4, 0.6)*)

Construct a WCS object for a 2D image

Parameters

coords [class:*astropy.coordinate.SkyCoord*] the 2 sky coordinates of the projection, they will be horizontal in the resulting wcs

pixsize [float] size of the pixel (in degree) (default: None, use relative_pos and shape_out)

shape_out [tuple] shape of the output map (n_y,n_x)

coordsys [str ('GALACTIC', 'EQUATORIAL')] the coordinate system of the plate (from HEALPIX maps....) will be rotated anyway

proj_type [str ('TAN', 'SIN', 'GSL', ...)] the projection system to use, the first coordinate will be the projection center

relative_pos [tuple] the relative position of the 2 sources along the x direction [0-1] (will be computed if pixsize is given)

Returns

WCS: :class:'~astropy.wcs.WCS' An corresponding wcs object

Notes

By default relative_pos is used to place the sources, and the pixsize is derived, but if you define pixsize, then the relative_pos will be computed and the sources placed at the center of the image

hpproj.wcs_helper.**build_ctype**(*coordsys*, *proj_type*)
Build a valid spatial ctype for a wcs header

Parameters

coordsys [str ('GALATIC', 'EQUATORIAL')] the coordinate system of the plate

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

Returns

list: a list with the 2 corresponding spatial ctype

hpproj.wcs_helper.**equiv_celestial**(*frame*)
Return an equivalent ~astropy.coordfinates.builtin_frames

Notes

We do not care of the differences between ICRS/FK4/FK5

hpproj.wcs_helper.**rot_frame**(*coord*, *proj_sys*)
Retrieve the proper longitude and latitude

Parameters

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

proj_sys [str ('GALACTIC', 'EQUATORIAL')] the coordinate system of the plate (from HEALPIX maps....)

Returns

:class:'~astropy.coordinate.SkyCoord' rotated frame

6.5.3 visu

Series of full sky visualization function, with proper wcs header

hpproj.visu.**view**(**args*, ***kargs*)
projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**mollview**()
Mollweide projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**orthview**(**args*, ***kargs*)
Slant orthographic projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**carview**()

Plate carrée projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**merview**()

Mercator projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**coeview**()
Conic Equal Area projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**bonview**()
Bonne's Equal Area projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**pcoview**()
Hassler's polyconic projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:'astropy.io.fits.ImageHDU' 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

hpproj.visu.**tscview**()
Tangential spherical cube projection of the full sky

Parameters

hp_hdu [astropy.io.fits.ImageHDU] a pseudo ImageHDU with the healpix map and the associated header

or

hp_map [array_like] healpix map with corresponding...

hp_header [astropy.fits.header.Header] ... header

coord [astropy.coordinate.SkyCoord] the sky coordinate of the center of the projection

npix [int] number of pixels in the latitude direction

proj_sys [str, ('GALACTIC', 'EQUATORIAL')] the coordinate system of the projection

proj_type: str ('TAN', 'SIN', 'GSL', ...) any projection system supported by WCS

aspect [float] the resulting figure aspect ratio 1:aspect_ratio

Returns

:class:‘astropy.io.fits.ImageHDU‘ 2D images with header

Notes

You can access a function using only catalogs with the ._coord() method

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