healpy Documentation

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CONTENTS

healpy is a Python package to handle pixelated data on the sphere. It is based on the Hierarchical Equal Area isoLatitude Pixelization (HEALPix) scheme and bundles the *HEALPix* C++ library.

HEALPix was developed to efficiently process Cosmic Microwave Background data from Cosmology experiments like BOOMERANG and WMAP but it is now used in other branches of Astrophysics to store data from all-sky surveys. The target audience used to be primarily the Cosmology scientific community but currently anyone interested in handling pixelated data on the sphere is very welcome to propose new features.

healpy provides utilities to:

- convert between sky coordinates and pixel indices in HEALPix nested and ring schemes
- find pixels within a disk, a polygon or a strip in the sky
- apply coordinate transformations between Galactic, Ecliptic and Equatorial reference frames
- apply custom rotations either to vectors or full maps
- read and write HEALPix maps to disk in FITS format
- upgrade and downgrade the resolution of existing HEALPix maps
- visualize maps in Mollweide, Gnomonic and Cartographic projections
- transform maps to Spherical Harmonics space and back using multi-threaded C++ routines
- compute Auto and Cross Power Spectra from maps and create map realizations from spectra

CHAPTER

ONE

TUTORIAL

1.1 healpy tutorial

See the Jupyter Notebook version of this tutorial at https://github.com/healpy/healpy/blob/master/doc/healpy_tutorial.ipynb

See a executed version of the notebook with embedded plots at https://gist.github.com/zonca/9c114608e0903a3b8ea0bfe41c96f255

Choose the `inline` backend of `maptlotlib` to display the plots inside the Jupyter Notebook

```
import matplotlib.pyplot as plt

%matplotlib inline
```

```
import numpy as np
import healpy as hp
```

1.1.1 NSIDE and ordering

Maps are simply numpy arrays, where each array element refers to a location in the sky as defined by the Healpix pixelization schemes (see the healpix website).

Note: Running the code below in a regular Python session will not display the maps; it's recommended to use an IPython shell or a Jupyter notebook.

The resolution of the map is defined by the *NSIDE* parameter, which is generally a power of 2.

```
NSIDE = 32
print(
    "Approximate resolution at NSIDE {} is {:.2} deg".format(
        NSIDE, hp.nside2resol(NSIDE, arcmin=True) / 60
    )
)
```

The function `healpy.pixelfunc.nside2npix` gives the number of pixels *NPIX* of the map:

```
NPIX = hp.nside2npix(NSIDE)
print(NPIX)
```

The same pixels in the map can be ordered in 2 ways, either RING, where they are numbered in the array in horizontal rings starting from the North pole:

```
m = np.arange(NPIX)
hp.mollview(m, title="Mollview image RING")
hp.graticule()
```

The standard coordinates are the **colatitude** θ, 0 at the North Pole, $\pi/2$ at the equator and π at the South Pole and the **longitude** ϕ between 0 and 2π eastward, in a Mollview projection, $\phi = 0$ is at the center and increases eastward toward the left of the map.

We can also use vectors to represent coordinates, for example `vec` is the normalized vector that points to $\theta = \pi/2, \phi = 3/4\pi$:

```
vec = hp.ang2vec(np.pi / 2, np.pi * 3 / 4)
print(vec)
```

We can find the indices of all the pixels within 10 degrees of that point and then change the value of the map at those indices:

```
ipix_disc = hp.query_disc(nside=32, vec=vec, radius=np.radians(10))
```

```
m = np.arange(NPIX)
m[ipix_disc] = m.max()
hp.mollview(m, title="Mollview image RING")
```

We can retrieve colatitude and longitude of each pixel using `pix2ang`, in this case we notice that the first 4 pixels cover the North Pole with pixel centers just ~1.5 degrees South of the Pole all at the same latitude. The fifth pixel is already part of another ring of pixels.

```
theta, phi = np.degrees(hp.pix2ang(nside=32, ipix=[0, 1, 2, 3, 4]))
```

```
theta
```

```
phi
```

The RING ordering is necessary for the Spherical Harmonics transforms, the other option is NESTED ordering which is very efficient for map domain operations because scaling up and down maps is achieved just multiplying and rounding pixel indices. See below how pixel are ordered in the NESTED scheme, notice the structure of the 12 HEALPix base pixels (NSIDE 1):

```
m = np.arange(NPIX)
hp.mollview(m, nest=True, title="Mollview image NESTED")
```

All `healpy` routines assume RING ordering, in fact as soon as you read a map with `read_map`, even if it was stored as NESTED, it is transformed to RING. However, you can work in NESTED ordering passing the `nest=True` argument to most `healpy` routines.

1.1.2 Reading and writing maps to file

For the following section, it is required to download larger maps by executing from the terminal the bash script `healpy_get_wmap_maps.sh` which should be available in your path.

This will download the higher resolution WMAP data into the current directory.

```
!healpy_get_wmap_maps.sh
```

```
wmap_map_I = hp.read_map("wmap_band_iqumap_r9_7yr_W_v4.fits")
```

By default, input maps are converted to *RING* ordering, if they are in *NESTED* ordering. You can otherwise specify `nest=True` to retrieve a map is NESTED ordering, or `nest=None` to keep the ordering unchanged.

By default, `read_map` loads the first column, for reading other columns you can specify the `field` keyword.

`write_map` writes a map to disk in FITS format, if the input map is a list of 3 maps, they are written to a single file as I,Q,U polarization components:

```
hp.write_map("my_map.fits", wmap_map_I, overwrite=True)
```

1.1.3 Visualization

As shown above, mollweide projection with `mollview` is the most common visualization tool for HEALPIX maps. It also supports coordinate transformation, `coord` does Galactic to ecliptic coordinate transformation, `norm='hist'` sets a histogram equalized color scale and `xsize` increases the size of the image. `graticule` adds meridians and parallels.

```
hp.mollview(
    wmap_map_I,
    coord=["G", "E"],
    title="Histogram equalized Ecliptic",
    unit="mK",
    norm="hist",
    min=-1,
    max=1,
)
hp.graticule()
```

`gnomview` instead provides gnomonic projection around a position specified by `rot`, for example you can plot a projection of the galactic center, `xsize` and `ysize` change the dimension of the sky patch.

```
hp.gnomview(wmap_map_I, rot=[0, 0.3], title="GnomView", unit="mK", format="%.2g")
```

`mollzoom` is a powerful tool for interactive inspection of a map, it provides a mollweide projection where you can click to set the center of the adjacent gnomview panel. ## Masked map, partial maps

By convention, HEALPIX uses $-1.6375 * 10^{30}$ to mark invalid or unseen pixels. This is stored in healpy as the constant `UNSEEN`.

All `healpy` functions automatically deal with maps with `UNSEEN` pixels, for example `mollview` marks in grey those sections of a map.

There is an alternative way of dealing with UNSEEN pixel based on the numpy`MaskedArray` class, `hp.ma` loads a map as a masked array, by convention the mask is 0 where the data are masked, while numpy defines data masked when the mask is True, so it is necessary to flip the mask.

```
mask = hp.read_map("wmap_temperature_analysis_mask_r9_7yr_v4.fits").astype(np.bool)
wmap_map_I_masked = hp.ma(wmap_map_I)
wmap_map_I_masked.mask = np.logical_not(mask)
```

Filling a masked array fills in the `UNSEEN` value and return a standard array that can be used by `mollview`. `compressed()` instead removes all the masked pixels and returns a standard array that can be used for examples by the matplotlib `hist()` function:

```
hp.mollview(wmap_map_I_masked.filled())
```

```
plt.hist(wmap_map_I_masked.compressed(), bins=1000);
```

1.1.4 Spherical Harmonics transforms

`healpy` provides bindings to the C++ HEALPIX library for performing spherical harmonic transforms. `hp.anafast` computes the angular power spectrum of a map:

```
LMAX = 1024
cl = hp.anafast(wmap_map_I_masked.filled(), lmax=LMAX)
ell = np.arange(len(cl))
```

therefore we can plot a normalized CMB spectrum and write it to disk:

```
plt.figure(figsize=(10, 5))
plt.plot(ell, ell * (ell + 1) * cl)
plt.xlabel("$\ell$")
plt.ylabel("$\ell(\ell+1)C_{\ell}$")
plt.grid()
hp.write_cl("cl.fits", cl, overwrite=True)
```

Gaussian beam map smoothing is provided by `hp.smoothing`:

```
wmap_map_I_smoothed = hp.smoothing(wmap_map_I, fwhm=np.radians(1.))
hp.mollview(wmap_map_I_smoothed, min=-1, max=1, title="Map smoothed 1 deg")
```

For more information see the HEALPix primer

CHAPTER

TWO

INSTALLATION

2.1 Installation procedure for Healpy

2.1.1 Requirements

Healpy depends on the HEALPix C++ and cfitsio C libraries. Source code for both is included with Healpy and is built automatically, so you do not need to install them yourself. Only Linux and MAC OS X are supported, not Windows.

2.1.2 Binary installation with conda (RECOMMENDED)

Conda forge provides a conda channel with a pre-compiled version of `healpy` for linux 64bit and MAC OS X platforms, you can install it in Anaconda with:

```
conda config --add channels conda-forge
conda install healpy
```

2.1.3 Source installation with Pip

It is possible to build the latest `healpy` with pip

```
pip install --user healpy
```

If you have installed with `pip`, you can keep your installation up to date by upgrading from time to time:

```
pip install --user --upgrade healpy
```

On Linux with newer compilers many users reported compilation errors like `configure: error: cannot run C compiled programs`, the solution is to specifiy the flags for the C and CXX compiler:

CC=gcc CXX=g++ CFLAGS='-fPIC' CXXFLAGS='-fPIC' pip install –user healpy

2.1.4 Compilation issues with Mac OS

Currently most people report they cannot install *healpy* on Mac OS either via *pip* or building from source, due to the impossibility of compiling the *HEALPix* based extension. The only options right now are using *conda-forge* or *Macports*.

2.1.5 Installation on Mac OS with MacPorts

If you are using a Mac and have the MacPorts package manager, it's even easer to install Healpy with:

```
sudo port install py27-healpy
```

Binary *apt-get* style packages are also available in the development versions of Debian (sid) and Ubuntu (utopic).

2.1.6 Almost-as-quick installation from official source release

Healpy is also available in the Python Package Index (PyPI). You can download it with:

```
curl -O https://pypi.python.org/packages/source/h/healpy/healpy-1.7.4.tar.gz
```

and build it with:

```
tar -xzf healpy-1.7.4.tar.gz
pushd healpy-1.7.4
python setup.py install --user
popd
```

If everything goes fine, you can test it:

```
python
```

```
>>> import matplotlib.pyplot as plt
>>> import numpy as np
>>> import healpy as hp
>>> hp.mollview(np.arange(12))
>>> plt.show()
```

or run the test suite with nose:

```
cd healpy-1.7.4 && python setup.py test
```

2.1.7 Building against external Healpix and cfitsio

Healpy uses pkg-config to detect the presence of the Healpix and cfitsio libraries. pkg-config is available on most systems. If you do not have pkg-config installed, then Healpy will download and use (but not install) a Python clone called pykg-config.

If you want to provide your own external builds of Healpix and cfitsio, then download the following packages:

- pkg-config
- HEALPix autotools-style C++ package
- cfitsio

If you are going to install the packages in a nonstandard location (say, `--prefix=/path/to/local`), then you should set the environment variable `PKG_CONFIG_PATH=/path/to/local/lib/pkgconfig` when building. No other environment variable settings are necessary, and you do not need to set `PKG_CONFIG_PATH` to use Healpy after you have built it.

Then, unpack each of the above packages and build them with the usual `configure; make; make install` recipe.

2.1.8 Development install

Developers building from a snapshot of the github repository need:

- `autoconf` and `libtool` (in Debian or Ubuntu: `sudo apt-get install autoconf automake libtool pkg-config`)
- *cython* > 0.16
- run `git submodule init` and `git submodule update` to get the bundled HEALPix sources

the best way to install healpy if you plan to develop is to build the C++ extensions in place with:

```
python setup.py build_ext --inplace
```

then add the `healpy/healpy` folder to your `PYTHONPATH`.

In case of compilation errors, see the note above in the `pip` section.

2.1.9 Clean

When you run "python setup.py", temporary build products are placed in the "build" directory. If you want to clean out and remove the `build` directory, then run:

```
python setup.py clean --all
```

CHAPTER

THREE

REFERENCE

3.1 `pixelfunc` – Pixelisation related functions

3.1.1 conversion from/to sky coordinates

pix2ang(nside, ipix[, nest, lonlat])	pix2ang : nside,ipix,nest=False,lonlat=False -> theta[rad],phi[rad] (default RING)
pix2vec(nside, ipix[, nest])	pix2vec : nside,ipix,nest=False -> x,y,z (default RING)
ang2pix(nside, theta, phi[, nest, lonlat])	ang2pix : nside,theta[rad],phi[rad],nest=False,lonlat=False -> ipix (default:RING)
vec2pix(nside, x, y, z[, nest])	vec2pix : nside,x,y,z,nest=False -> ipix (default:RING)
vec2ang(vectors[, lonlat])	vec2ang: vectors [x, y, z] -> theta[rad], phi[rad]
ang2vec(theta, phi[, lonlat])	ang2vec : convert angles to 3D position vector
get_all_neighbours(nside, theta[, phi, ...])	Return the 8 nearest pixels.
get_interp_weights(nside, theta[, phi, ...])	Return the 4 closest pixels on the two rings above and below the location and corresponding weights.
get_interp_val(m, theta, phi[, nest, lonlat])	Return the bi-linear interpolation value of a map using 4 nearest neighbours.

healpy.pixelfunc.pix2ang

healpy.pixelfunc.**pix2ang**(*nside*, *ipix*, *nest=False*, *lonlat=False*)

pix2ang : nside,ipix,nest=False,lonlat=False -> theta[rad],phi[rad] (default RING)

Parameters

nside [int or array-like] The healpix nside parameter, must be a power of 2, less than 2**30

ipix [int or array-like] Pixel indices

nest [bool, optional] if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

lonlat [bool, optional] If True, return angles will be longitude and latitude in degree, otherwise, angles will be co-latitude and longitude in radians (default)

Returns

theta, phi [float, scalar or array-like] The angular coordinates corresponding to ipix. Scalar if all input are scalar, array otherwise. Usual numpy broadcasting rules apply.

See also:

ang2pix, ***vec2pix***, ***pix2vec***

Examples

```
>>> import healpy as hp
>>> hp.pix2ang(16, 1440)
(1.5291175943723188, 0.0)
```

```
>>> hp.pix2ang(16, [1440,  427, 1520,    0, 3068])
(array([ 1.52911759,  0.78550497,  1.57079633,  0.05103658,  3.09055608]),␣
↪array([ 0.        ,  0.78539816,  1.61988371,  0.78539816,  0.78539816]))
```

```
>>> hp.pix2ang([1, 2, 4, 8], 11)
(array([ 2.30052398,  0.84106867,  0.41113786,  0.2044802 ]), array([ 5.49778714,␣
↪ 5.89048623,  5.89048623,  5.89048623]))
```

```
>>> hp.pix2ang([1, 2, 4, 8], 11, lonlat=True)
(array([ 315. ,  337.5,  337.5,  337.5]), array([-41.8103149 ,  41.8103149 ,  66.
↪44353569,  78.28414761]))
```

healpy.pixelfunc.pix2vec

healpy.pixelfunc.**pix2vec**(*nside*, *ipix*, *nest=False*)

pix2vec : nside,ipix,nest=False -> x,y,z (default RING)

Parameters

nside [int, scalar or array-like] The healpix nside parameter, must be a power of 2, less than 2**30

ipix [int, scalar or array-like] Healpix pixel number

nest [bool, optional] if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

Returns

x, y, z [floats, scalar or array-like] The coordinates of vector corresponding to input pixels. Scalar if all input are scalar, array otherwise. Usual numpy broadcasting rules apply.

See also:

ang2pix, ***pix2ang***, ***vec2pix***

Examples

```
>>> import healpy as hp
>>> hp.pix2vec(16, 1504)
(0.99879545620517241, 0.049067674327418015, 0.0)
```

```
>>> hp.pix2vec(16, [1440,  427])
(array([ 0.99913157,  0.5000534 ]), array([ 0.        ,  0.5000534]), array([ 0.
↪04166667,  0.70703125]))
```

```
>>> hp.pix2vec([1, 2], 11)
(array([ 0.52704628,  0.68861915]), array([-0.52704628, -0.28523539]), array([-0.
↪66666667,  0.66666667]))
```

healpy.pixelfunc.ang2pix

healpy.pixelfunc.**ang2pix**(*nside*, *theta*, *phi*, *nest=False*, *lonlat=False*)
ang2pix : nside,theta[rad],phi[rad],nest=False,lonlat=False -> ipix (default:RING)

Parameters

nside [int, scalar or array-like] The healpix nside parameter, must be a power of 2, less than 2**30

theta, phi [float, scalars or array-like] Angular coordinates of a point on the sphere

nest [bool, optional] if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

pix [int or array of int] The healpix pixel numbers. Scalar if all input are scalar, array otherwise. Usual numpy broadcasting rules apply.

See also:

pix2ang, ***pix2vec***, ***vec2pix***

Examples

Note that some of the test inputs below that are on pixel boundaries such as theta=pi/2, phi=pi/2, have a tiny value of 1e-15 added to them to make them reproducible on i386 machines using x87 floating point instruction set (see https://github.com/healpy/healpy/issues/528).

```
>>> import healpy as hp
>>> hp.ang2pix(16, np.pi/2, 0)
1440
```

```
>>> print(hp.ang2pix(16, [np.pi/2, np.pi/4, np.pi/2, 0, np.pi], [0., np.pi/4, np.
↪pi/2 + 1e-15, 0, 0]))
[1440  427 1520    0 3068]
```

```
>>> print(hp.ang2pix(16, np.pi/2, [0, np.pi/2 + 1e-15]))
[1440 1520]
```

```
>>> print(hp.ang2pix([1, 2, 4, 8, 16], np.pi/2, 0))
[   4   12   72  336 1440]
```

```
>>> print(hp.ang2pix([1, 2, 4, 8, 16], 0, 0, lonlat=True))
[   4   12   72  336 1440]
```

healpy.pixelfunc.vec2pix

healpy.pixelfunc.**vec2pix**(*nside*, *x*, *y*, *z*, *nest=False*)
vec2pix : nside,x,y,z,nest=False -> ipix (default:RING)

Parameters

nside [int or array-like] The healpix nside parameter, must be a power of 2, less than 2**30

x,y,z [floats or array-like] vector coordinates defining point on the sphere

nest [bool, optional] if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

Returns

ipix [int, scalar or array-like] The healpix pixel number corresponding to input vector. Scalar if all input are scalar, array otherwise. Usual numpy broadcasting rules apply.

See also:

ang2pix, ***pix2ang***, ***pix2vec***

Examples

```
>>> import healpy as hp
>>> hp.vec2pix(16, 1, 0, 0)
1504
```

```
>>> print(hp.vec2pix(16, [1, 0], [0, 1], [0, 0]))
[1504 1520]
```

```
>>> print(hp.vec2pix([1, 2, 4, 8], 1, 0, 0))
[  4  20  88 368]
```

healpy.pixelfunc.vec2ang

healpy.pixelfunc.**vec2ang**(*vectors*, *lonlat=False*)

vec2ang: vectors [x, y, z] -> theta[rad], phi[rad]

Parameters

vectors [float, array-like] the vector(s) to convert, shape is (3,) or (N, 3)

lonlat [bool, optional] If True, return angles will be longitude and latitude in degree, otherwise, angles will be co-latitude and longitude in radians (default)

Returns

theta, phi [float, tuple of two arrays] the colatitude and longitude in radians

See also:

ang2vec, **rotator.vec2dir**, **rotator.dir2vec**

healpy.pixelfunc.ang2vec

healpy.pixelfunc.**ang2vec**(*theta*, *phi*, *lonlat=False*)

ang2vec : convert angles to 3D position vector

Parameters

theta [float, scalar or arry-like] colatitude in radians measured southward from north pole (in [0,pi]).

phi [float, scalar or array-like] longitude in radians measured eastward (in [0, 2*pi]).

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

vec [float, array] if theta and phi are vectors, the result is a 2D array with a vector per row otherwise, it is a 1D array of shape (3,)

See also:

vec2ang, **rotator.dir2vec**, **rotator.vec2dir**

healpy.pixelfunc.get_all_neighbours

healpy.pixelfunc.**get_all_neighbours**(*nside*, *theta*, *phi=None*, *nest=False*, *lonlat=False*)

Return the 8 nearest pixels.

Parameters

nside [int] the nside to work with

theta, phi [scalar or array-like] if phi is not given or None, theta is interpreted as pixel number, otherwise, theta[rad],phi[rad] are angular coordinates

nest [bool] if `True`, pixel number will be NESTED ordering, otherwise RING ordering.

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

ipix [int, array] pixel number of the SW, W, NW, N, NE, E, SE and S neighbours, shape is (8,) if input is scalar, otherwise shape is (8, N) if input is of length N. If a neighbor does not exist (it can be the case for W, N, E and S) the corresponding pixel number will be -1.

See also:

get_interp_weights, *get_interp_val*

Examples

```
>>> import healpy as hp
>>> print(hp.get_all_neighbours(1, 4))
[11  7  3 -1  0  5  8 -1]
```

```
>>> print(hp.get_all_neighbours(1, np.pi/2, np.pi/2))
[ 8  4  0 -1  1  6  9 -1]
```

```
>>> print(hp.get_all_neighbours(1, 90, 0, lonlat=True))
[ 8  4  0 -1  1  6  9 -1]
```

healpy.pixelfunc.get_interp_weights

healpy.pixelfunc.**get_interp_weights**(*nside*, *theta*, *phi=None*, *nest=False*, *lonlat=False*)

Return the 4 closest pixels on the two rings above and below the location and corresponding weights. Weights are provided for bilinear interpolation along latitude and longitude

Parameters

nside [int] the healpix nside

theta, phi [float, scalar or array-like] if phi is not given, theta is interpreted as pixel number, otherwise theta[rad],phi[rad] are angular coordinates

nest [bool] if `True`, NESTED ordering, otherwise RING ordering.

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

res [tuple of length 2] contains pixel numbers in res[0] and weights in res[1]. Usual numpy broadcasting rules apply.

See also:

get_interp_val, ***get_all_neighbours***

Examples

Note that some of the test inputs below that are on pixel boundaries such as theta=pi/2, phi=pi/2, have a tiny value of 1e-15 added to them to make them reproducible on i386 machines using x87 floating point instruction set (see https://github.com/healpy/healpy/issues/528).

```
>>> import healpy as hp
>>> pix, weights = hp.get_interp_weights(1, 0)
>>> print(pix)
[0 1 4 5]
>>> weights
array([ 1.,  0.,  0.,  0.])
```

```
>>> pix, weights = hp.get_interp_weights(1, 0, 0)
>>> print(pix)
[1 2 3 0]
>>> weights
array([ 0.25,  0.25,  0.25,  0.25])
```

```
>>> pix, weights = hp.get_interp_weights(1, 0, 90, lonlat=True)
>>> print(pix)
[1 2 3 0]
>>> weights
array([ 0.25,  0.25,  0.25,  0.25])
```

```
>>> pix, weights = hp.get_interp_weights(1, [0, np.pi/2 + 1e-15], 0)
>>> print(pix)
[[ 1  4]
 [ 2  5]
 [ 3 11]
 [ 0  8]]
>>> np.testing.assert_allclose(
...     weights,
...     np.array([[ 0.25,  1.  ],
...               [ 0.25,  0.  ],
...               [ 0.25,  0.  ],
...               [ 0.25,  0.  ]]), rtol=0, atol=1e-14)
```

healpy.pixelfunc.get_interp_val

healpy.pixelfunc.**get_interp_val**(*m*, *theta*, *phi*, *nest=False*, *lonlat=False*)

Return the bi-linear interpolation value of a map using 4 nearest neighbours.

Parameters

m [array-like] a healpix map, accepts masked arrays

theta, phi [float, scalar or array-like] angular coordinates of point at which to interpolate the map

nest [bool] if True, the is assumed to be in NESTED ordering.

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

val [float, scalar or arry-like] the interpolated value(s), usual numpy broadcasting rules apply.

See also:

get_interp_weights, *get_all_neighbours*

Examples

```
>>> import healpy as hp
>>> hp.get_interp_val(np.arange(12.), np.pi/2, 0)
4.0
>>> hp.get_interp_val(np.arange(12.), np.pi/2, np.pi/2)
5.0
>>> hp.get_interp_val(np.arange(12.), np.pi/2, np.pi/2 + 2*np.pi)
5.0
>>> hp.get_interp_val(np.arange(12.), np.linspace(0, np.pi, 10), 0)
array([ 1.5       ,  1.5       ,  1.5       ,  2.20618428,  3.40206143,
        5.31546486,  7.94639458,  9.5       ,  9.5       ,  9.5       ])
>>> hp.get_interp_val(np.arange(12.), 0, np.linspace(90, -90, 10), lonlat=True)
array([ 1.5       ,  1.5       ,  1.5       ,  2.20618428,  3.40206143,
        5.31546486,  7.94639458,  9.5       ,  9.5       ,  9.5       ])
```

3.1.2 conversion between NESTED and RING schemes

nest2ring(nside, ipix)	Convert pixel number from NESTED ordering to RING ordering.
ring2nest(nside, ipix)	Convert pixel number from RING ordering to NESTED ordering.
reorder(map_in[, inp, out, r2n, n2r])	Reorder a healpix map from RING/NESTED ordering to NESTED/RING

healpy.pixelfunc.nest2ring

healpy.pixelfunc.**nest2ring**(*nside*, *ipix*)

Convert pixel number from NESTED ordering to RING ordering.

Parameters

nside [int, scalar or array-like] the healpix nside parameter

ipix [int, scalar or array-like] the pixel number in NESTED scheme

Returns

ipix [int, scalar or array-like] the pixel number in RING scheme

See also:

ring2nest, *reorder*

Examples

```
>>> import healpy as hp
>>> hp.nest2ring(16, 1130)
1504
```

```
>>> print(hp.nest2ring(2, np.arange(10)))
[13  5  4  0 15  7  6  1 17  9]
```

```
>>> print(hp.nest2ring([1, 2, 4, 8], 11))
[ 11   2  12 211]
```

healpy.pixelfunc.ring2nest

healpy.pixelfunc.**ring2nest**(*nside*, *ipix*)

Convert pixel number from RING ordering to NESTED ordering.

Parameters

nside [int, scalar or array-like] the healpix nside parameter

ipix [int, scalar or array-like] the pixel number in RING scheme

Returns

ipix [int, scalar or array-like] the pixel number in NESTED scheme

See also:

nest2ring, *reorder*

Examples

```
>>> import healpy as hp
>>> hp.ring2nest(16, 1504)
1130
```

```
>>> print(hp.ring2nest(2, np.arange(10)))
[ 3  7 11 15  2  1  6  5 10  9]
```

```
>>> print(hp.ring2nest([1, 2, 4, 8], 11))
[ 11  13  61 253]
```

healpy.pixelfunc.reorder

healpy.pixelfunc.**reorder**(*map_in*, *inp=None*, *out=None*, *r2n=None*, *n2r=None*)

Reorder a healpix map from RING/NESTED ordering to NESTED/RING

Parameters

map_in [array-like] the input map to reorder, accepts masked arrays

inp, out ['RING' or 'NESTED'] define the input and output ordering

r2n [bool] if True, reorder from RING to NESTED

n2r [bool] if True, reorder from NESTED to RING

Returns

map_out [array-like] the reordered map, as masked array if the input was a masked array

See also:

nest2ring, ***ring2nest***

Notes

if r2n or n2r is defined, override inp and out.

Examples

```
>>> import healpy as hp
>>> hp.reorder(np.arange(48), r2n = True)
array([13,  5,  4,  0, 15,  7,  6,  1, 17,  9,  8,  2, 19, 11, 10,  3, 28,
       20, 27, 12, 30, 22, 21, 14, 32, 24, 23, 16, 34, 26, 25, 18, 44, 37,
       36, 29, 45, 39, 38, 31, 46, 41, 40, 33, 47, 43, 42, 35])
>>> hp.reorder(np.arange(12), n2r = True)
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
>>> hp.reorder(hp.ma(np.arange(12.)), n2r = True)
masked_array(data = [  0.   1.   2.   3.   4.   5.   6.   7.   8.   9.  10.  11.],
             mask = False,
       fill_value = -1.6375e+30)
<BLANKLINE>
>>> m = [np.arange(12.), np.arange(12.), np.arange(12.)]
>>> m[0][2] = hp.UNSEEN
>>> m[1][2] = hp.UNSEEN
>>> m[2][2] = hp.UNSEEN
>>> m = hp.ma(m)
>>> hp.reorder(m, n2r = True)
masked_array(data =
 [[0.0 1.0 -- 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0]
 [0.0 1.0 -- 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0]
 [0.0 1.0 -- 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0]],
             mask =
 [[False False  True False False False False False False False False False]
 [False False  True False False False False False False False False False]
 [False False  True False False False False False False False False False]],
       fill_value = -1.6375e+30)
<BLANKLINE>
```

3.1.3 nside/npix/resolution

nside2npix(nside)	Give the number of pixels for the given nside.
npix2nside(npix)	Give the nside parameter for the given number of pixels.
nside2order(nside)	Give the resolution order for a given nside.
order2nside(order)	Give the nside parameter for the given resolution order.
nside2resol(nside[, arcmin])	Give approximate resolution (pixel size in radian or arcmin) for nside.
nside2pixarea(nside[, degrees])	Give pixel area given nside in square radians or square degrees.
max_pixrad(nside[, degrees])	Maximum angular distance between any pixel center and its corners
isnsideok(nside[, nest])	Returns `True` if nside is a valid nside parameter, `False` otherwise.
isnpixok(npix)	Return `True` if npix is a valid value for healpix map size, `False` otherwise.
get_map_size(m)	Returns the npix of a given map (implicit or explicit pixelization).
get_min_valid_nside(npix)	Returns the minimum acceptable nside so that npix <= nside2npix(nside).
get_nside(m)	Return the nside of the given map.
maptype(m)	Describe the type of the map (valid, single, sequence of maps).
ud_grade(map_in, nside_out[, pess, ...])	Upgrade or degrade resolution of a map (or list of maps).

healpy.pixelfunc.nside2npix

healpy.pixelfunc.**nside2npix**(*nside*)

Give the number of pixels for the given nside.

Parameters

nside [int] healpix nside parameter; an exception is raised if nside is not valid (nside must be a power of 2, less than 2**30)

Returns

npix [int] corresponding number of pixels

Notes

Raise a ValueError exception if nside is not valid.

Examples

```
>>> import healpy as hp
>>> import numpy as np
>>> hp.nside2npix(8)
768
```

```
>>> np.all([hp.nside2npix(nside) == 12 * nside**2 for nside in [2**n for n in␣
↪range(12)]])
True
```

```
>>> hp.nside2npix(7)
588
```

healpy.pixelfunc.npix2nside

healpy.pixelfunc.**npix2nside**(*npix*)

Give the nside parameter for the given number of pixels.

Parameters

npix [int] the number of pixels

Returns

nside [int] the nside parameter corresponding to npix

Notes

Raise a ValueError exception if number of pixel does not correspond to the number of pixel of a healpix map.

Examples

```
>>> import healpy as hp
>>> hp.npix2nside(768)
8
```

```
>>> np.all([hp.npix2nside(12 * nside**2) == nside for nside in [2**n for n in␣
↪range(12)]])
True
```

```
>>> hp.npix2nside(1000)
Traceback (most recent call last):
    ...
ValueError: Wrong pixel number (it is not 12*nside**2)
```

healpy.pixelfunc.nside2order

healpy.pixelfunc.**nside2order**(*nside*)

Give the resolution order for a given nside.

Parameters

nside [int] healpix nside parameter; an exception is raised if nside is not valid (nside must be a power of 2, less than 2**30)

Returns

order [int] corresponding order where nside = 2**(order)

Notes

Raise a ValueError exception if nside is not valid.

Examples

```
>>> import healpy as hp
>>> import numpy as np
>>> hp.nside2order(128)
7
```

```
>>> np.all([hp.nside2order(2**o) == o for o in range(30)])
True
```

```
>>> hp.nside2order(7)
Traceback (most recent call last):
    ...
ValueError: 7 is not a valid nside parameter (must be a power of 2, less than␣
↪2**30)
```

healpy.pixelfunc.order2nside

healpy.pixelfunc.**order2nside**(*order*)

Give the nside parameter for the given resolution order.

Parameters

order [int] the resolution order

Returns

nside [int] the nside parameter corresponding to order

Notes

Raise a ValueError exception if order produces an nside out of range.

Examples

```
>>> import healpy as hp
>>> hp.order2nside(7)
128
```

```
>>> print(hp.order2nside(np.arange(8)))
[  1   2   4   8  16  32  64 128]
```

```
>>> hp.order2nside(31)
Traceback (most recent call last):
    ...
ValueError: 2147483648 is not a valid nside parameter (must be a power of 2, less␣
↪than 2**30)
```

healpy.pixelfunc.nside2resol

healpy.pixelfunc.**nside2resol**(*nside*, *arcmin=False*)

Give approximate resolution (pixel size in radian or arcmin) for nside.

Resolution is just the square root of the pixel area, which is a gross approximation given the different pixel shapes

Parameters

nside [int] healpix nside parameter, must be a power of 2, less than 2**30

arcmin [bool] if True, return resolution in arcmin, otherwise in radian

Returns

resol [float] approximate pixel size in radians or arcmin

Notes

Raise a ValueError exception if nside is not valid.

Examples

```
>>> import healpy as hp
>>> hp.nside2resol(128, arcmin = True)
27.483891294539248
```

```
>>> hp.nside2resol(256)
0.0039973699529159707
```

```
>>> hp.nside2resol(7)
0.1461895297066412
```

healpy.pixelfunc.nside2pixarea

healpy.pixelfunc.**nside2pixarea**(*nside*, *degrees=False*)

Give pixel area given nside in square radians or square degrees.

Parameters

nside [int] healpix nside parameter, must be a power of 2, less than 2**30

degrees [bool] if True, returns pixel area in square degrees, in square radians otherwise

Returns

pixarea [float] pixel area in square radian or square degree

Notes

Raise a ValueError exception if nside is not valid.

Examples

```
>>> import healpy as hp
>>> hp.nside2pixarea(128, degrees = True)
0.2098234113027917
```

```
>>> hp.nside2pixarea(256)
1.5978966540475428e-05
```

```
>>> hp.nside2pixarea(7)
0.021371378595848933
```

healpy.pixelfunc.max_pixrad

healpy.pixelfunc.**max_pixrad**(*nside*, *degrees=False*)

Maximum angular distance between any pixel center and its corners

Parameters

nside [int] the nside to work with

degrees [bool] if True, returns pixel radius in degrees, in radians otherwise

Returns

rads: double angular distance (in radians or degrees)

Examples

```
>>> '%.14f' % max_pixrad(1)
'0.84106867056793'
>>> '%.14f' % max_pixrad(16)
'0.06601476143251'
```

healpy.pixelfunc.isnsideok

healpy.pixelfunc.**isnsideok**(*nside*, *nest=False*)

Returns `True` if nside is a valid nside parameter, `False` otherwise.

NSIDE needs to be a power of 2 only for nested ordering

Parameters

nside [int, scalar or array-like] integer value to be tested

Returns

ok [bool, scalar or array-like] `True` if given value is a valid nside, `False` otherwise.

Examples

```
>>> import healpy as hp
>>> hp.isnsideok(13, nest=True)
False
```

```
>>> hp.isnsideok(13, nest=False)
True
```

```
>>> hp.isnsideok(32)
True
```

```
>>> hp.isnsideok([1, 2, 3, 4, 8, 16], nest=True)
array([ True,  True, False,  True,  True,  True], dtype=bool)
```

healpy.pixelfunc.isnpixok

healpy.pixelfunc.**isnpixok**(*npix*)

Return `True` if npix is a valid value for healpix map size, `False` otherwise.

Parameters

npix [int, scalar or array-like] integer value to be tested

Returns

ok [bool, scalar or array-like] `True` if given value is a valid number of pixel, `False` otherwise

Examples

```
>>> import healpy as hp
>>> hp.isnpixok(12)
True
```

```
>>> hp.isnpixok(768)
True
```

```
>>> hp.isnpixok([12, 768, 1002])
array([ True,  True, False], dtype=bool)
```

healpy.pixelfunc.get_map_size

healpy.pixelfunc.**get_map_size**(*m*)

Returns the npix of a given map (implicit or explicit pixelization).

If map is a dict type, assumes explicit pixelization: use nside key if present, or use nside attribute if present, otherwise use the smallest valid npix given the maximum key value. otherwise assumes implicit pixelization and returns len(m).

Parameters

m [array-like or dict-like] a map with implicit (array-like) or explicit (dict-like) pixellization

Returns

npix [int] a valid number of pixel

Notes

In implicit pixellization, raise a ValueError exception if the size of the input is not a valid pixel number.

Examples

```
>>> import healpy as hp
 >>> m = {0: 1, 1: 1, 2: 1, 'nside': 1}
 >>> print(hp.get_map_size(m))
 12
```

```
>>> m = {0: 1, 767: 1}
>>> print(hp.get_map_size(m))
768
```

```
>>> print(hp.get_map_size(np.zeros(12 * 8 ** 2)))
768
```

healpy.pixelfunc.get_min_valid_nside

healpy.pixelfunc.**get_min_valid_nside**(*npix*)

Returns the minimum acceptable nside so that npix <= nside2npix(nside).

Parameters

npix [int] a minimal number of pixel

Returns

nside [int] a valid healpix nside so that 12 * nside ** 2 >= npix

Examples

```
>>> import healpy as hp
>>> hp.pixelfunc.get_min_valid_nside(355)
8
>>> hp.pixelfunc.get_min_valid_nside(768)
8
```

healpy.pixelfunc.get_nside

healpy.pixelfunc.**get_nside**(*m*)

Return the nside of the given map.

Parameters

m [sequence] the map to get the nside from.

Returns

nside [int] the healpix nside parameter of the map (or sequence of maps)

Notes

If the input is a sequence of maps, all of them must have same size. If the input is not a valid map (not a sequence, unvalid number of pixels), a TypeError exception is raised.

healpy.pixelfunc.maptype

healpy.pixelfunc.**maptype**(*m*)

Describe the type of the map (valid, single, sequence of maps). Checks : the number of maps, that all maps have same length and that this length is a valid map size (using *isnpixok()*).

Parameters

m [sequence] the map to get info from

Returns

info [int] -1 if the given object is not a valid map, 0 if it is a single map, *info* > 0 if it is a sequence of maps (*info* is then the number of maps)

Examples

```
>>> import healpy as hp
>>> hp.pixelfunc.maptype(np.arange(12))
0
>>> hp.pixelfunc.maptype([np.arange(12), np.arange(12)])
2
```

healpy.pixelfunc.ud_grade

healpy.pixelfunc.**ud_grade**(*map_in*, *nside_out*, *pess=False*, *order_in='RING'*, *order_out=None*, *power=None*, *dtype=None*)

Upgrade or degrade resolution of a map (or list of maps).

in degrading the resolution, ud_grade sets the value of the superpixel as the mean of the children pixels.

Parameters

map_in [array-like or sequence of array-like] the input map(s) (if a sequence of maps, all must have same size)

nside_out [int] the desired nside of the output map(s)

pess [bool] if `True`, in degrading, reject pixels which contains a bad sub_pixel. Otherwise, estimate average with good pixels

order_in, order_out [str] pixel ordering of input and output ('RING' or 'NESTED')

power [float] if non-zero, divide the result by (nside_in/nside_out)**power Examples: power=-2 keeps the sum of the map invariant (useful for hitmaps), power=2 divides the mean by another factor of (nside_in/nside_out)**2 (useful for variance maps)

dtype [type] the type of the output map

Returns

map_out [array-like or sequence of array-like] the upgraded or degraded map(s)

Examples

```
>>> import healpy as hp
>>> hp.ud_grade(np.arange(48.), 1)
array([  5.5 ,   7.25,   9.  ,  10.75,  21.75,  21.75,  23.75,  25.75,
        36.5 ,  38.25,  40.  ,  41.75])
```

3.1.4 Masking pixels

UNSEEN	Special value used for masked pixels
mask_bad(m[, badval, rtol, atol])	Returns a bool array with `True` where m is close to badval.
mask_good(m[, badval, rtol, atol])	Returns a bool array with `False` where m is close to badval.
ma(m[, badval, rtol, atol, copy])	Return map as a masked array, with `badval` pixels masked.

healpy.pixelfunc.UNSEEN

`healpy.pixelfunc.`**`UNSEEN = -1.6375e+30`**

Special value used for masked pixels

healpy.pixelfunc.mask_bad

`healpy.pixelfunc.`**`mask_bad`**(*m*, *badval=-1.6375e+30*, *rtol=1e-05*, *atol=1e-08*)

Returns a bool array with `True` where m is close to badval.

Parameters

m [a map (may be a sequence of maps)]

badval [float, optional] The value of the pixel considered as bad (*UNSEEN* by default)

rtol [float, optional] The relative tolerance

atol [float, optional] The absolute tolerance

Returns

mask a bool array with the same shape as the input map, `True` where input map is close to badval, and `False` elsewhere.

See also:

mask_good, ***ma***

Examples

```
>>> import healpy as hp
>>> import numpy as np
>>> m = np.arange(12.)
>>> m[3] = hp.UNSEEN
>>> hp.mask_bad(m)
array([False, False, False,  True, False, False, False, False, False,
       False, False, False], dtype=bool)
```

healpy.pixelfunc.mask_good

healpy.pixelfunc.**mask_good**(*m*, *badval=-1.6375e+30*, *rtol=1e-05*, *atol=1e-08*)

Returns a bool array with `False` where m is close to badval.

Parameters

m [a map (may be a sequence of maps)]

badval [float, optional] The value of the pixel considered as bad (*UNSEEN* by default)

rtol [float, optional] The relative tolerance

atol [float, optional] The absolute tolerance

Returns

a bool array with the same shape as the input map, `False` where input map is close to badval, and `True` elsewhere.

See also:

mask_bad, ***ma***

Examples

```
>>> import healpy as hp
>>> m = np.arange(12.)
>>> m[3] = hp.UNSEEN
>>> hp.mask_good(m)
array([ True,  True,  True, False,  True,  True,  True,  True,  True,
        True,  True,  True], dtype=bool)
```

healpy.pixelfunc.ma

healpy.pixelfunc.**ma**(*m*, *badval=-1.6375e+30*, *rtol=1e-05*, *atol=1e-08*, *copy=True*)

Return map as a masked array, with `badval` pixels masked.

Parameters

m [a map (may be a sequence of maps)]

badval [float, optional] The value of the pixel considered as bad (*UNSEEN* by default)

rtol [float, optional] The relative tolerance

atol [float, optional] The absolute tolerance

copy [bool, optional] If `True`, a copy of the input map is made.

Returns

a masked array with the same shape as the input map, masked where input map is close to badval.

See also:

mask_good, ***mask_bad***, **numpy.ma.masked_values**

Examples

```
>>> import healpy as hp
>>> m = np.arange(12.)
>>> m[3] = hp.UNSEEN
>>> hp.ma(m)
masked_array(data = [0.0 1.0 2.0 -- 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0],
             mask = [False False False  True False False False False False False␣
↪False False],
       fill_value = -1.6375e+30)
<BLANKLINE>
```

3.1.5 Map data manipulation

fit_dipole(m[, nest, bad, gal_cut])	Fit a dipole and a monopole to the map, excluding bad pixels.
fit_monopole(m[, nest, bad, gal_cut])	Fit a monopole to the map, excluding unseen pixels.
remove_dipole(m[, nest, bad, gal_cut, ...])	Fit and subtract the dipole and the monopole from the given map m.
remove_monopole(m[, nest, bad, gal_cut, ...])	Fit and subtract the monopole from the given map m.
get_interp_val(m, theta, phi[, nest, lonlat])	Return the bi-linear interpolation value of a map using 4 nearest neighbours.

healpy.pixelfunc.fit_dipole

healpy.pixelfunc.**fit_dipole**(*m*, *nest=False*, *bad=-1.6375e+30*, *gal_cut=0*)

Fit a dipole and a monopole to the map, excluding bad pixels.

Parameters

m [float, array-like] the map to which a dipole is fitted and subtracted, accepts masked maps

nest [bool] if `False` m is assumed in RING scheme, otherwise map is NESTED

bad [float] bad values of pixel, default to *UNSEEN*.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] degrees are not taken into account

Returns

res [tuple of length 2] the monopole value in res[0] and the dipole vector (as array) in res[1]

See also:

remove_dipole, ***fit_monopole***, ***remove_monopole***

healpy.pixelfunc.fit_monopole

healpy.pixelfunc.**fit_monopole**(*m*, *nest=False*, *bad=-1.6375e+30*, *gal_cut=0*)

Fit a monopole to the map, excluding unseen pixels.

Parameters

m [float, array-like] the map to which a dipole is fitted and subtracted, accepts masked arrays

nest [bool] if `False` m is assumed in RING scheme, otherwise map is NESTED

bad [float] bad values of pixel, default to *UNSEEN*.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] degrees are not taken into account

Returns

res: float fitted monopole value

See also:

fit_dipole, ***remove_monopole***, ***remove_monopole***

healpy.pixelfunc.remove_dipole

healpy.pixelfunc.**remove_dipole**(*m*, *nest=False*, *bad=-1.6375e+30*, *gal_cut=0*, *fitval=False*, *copy=True*, *verbose=True*)

Fit and subtract the dipole and the monopole from the given map m.

Parameters

m [float, array-like] the map to which a dipole is fitted and subtracted, accepts masked arrays

nest [bool] if `False` m is assumed in RING scheme, otherwise map is NESTED

bad [float] bad values of pixel, default to *UNSEEN*.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] are not taken into account

fitval [bool] whether to return or not the fitted values of monopole and dipole

copy [bool] whether to modify input map or not (by default, make a copy)

verbose [bool] print values of monopole and dipole

Returns

res [array or tuple of length 3] if fitval is False, returns map with monopole and dipole subtracted, otherwise, returns map (array, in res[0]), monopole (float, in res[1]), dipole_vector (array, in res[2])

See also:

fit_dipole, ***fit_monopole***, ***remove_monopole***

healpy.pixelfunc.remove_monopole

healpy.pixelfunc.**remove_monopole**(*m*, *nest=False*, *bad=-1.6375e+30*, *gal_cut=0*, *fitval=False*, *copy=True*, *verbose=True*)

Fit and subtract the monopole from the given map m.

Parameters

m [float, array-like] the map to which a monopole is fitted and subtracted

nest [bool] if `False` m is assumed in RING scheme, otherwise map is NESTED

bad [float] bad values of pixel, default to *UNSEEN*.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] are not taken into account

fitval [bool] whether to return or not the fitted value of monopole

copy [bool] whether to modify input map or not (by default, make a copy)

verbose: bool whether to print values of monopole

Returns

res [array or tuple of length 3] if fitval is False, returns map with monopole subtracted, otherwise, returns map (array, in res[0]) and monopole (float, in res[1])

See also:

fit_dipole, ***fit_monopole***, ***remove_dipole***

3.2 sphtfunc – Spherical harmonic transforms

3.2.1 From map to spherical harmonics

anafast(map1[, map2, nspec, lmax, mmax, ...])	Computes the power spectrum of a Healpix map, or the cross-spectrum between two maps if *map2* is given.
map2alm(maps[, lmax, mmax, iter, pol, ...])	Computes the alm of a Healpix map.

healpy.sphtfunc.anafast

healpy.sphtfunc.**anafast**(*map1*, *map2=None*, *nspec=None*, *lmax=None*, *mmax=None*, *iter=3*, *alm=False*, *pol=True*, *use_weights=False*, *datapath=None*, *gal_cut=0*, *use_pixel_weights=False*)

Computes the power spectrum of a Healpix map, or the cross-spectrum between two maps if *map2* is given. No removal of monopole or dipole is performed. The input maps must be in ring-ordering.

Parameters

map1 [float, array-like shape (Npix,) or (3, Npix)] Either an array representing a map, or a sequence of 3 arrays representing I, Q, U maps. Must be in ring ordering.

map2 [float, array-like shape (Npix,) or (3, Npix)] Either an array representing a map, or a sequence of 3 arrays representing I, Q, U maps. Must be in ring ordering.

nspec [None or int, optional] The number of spectra to return. If None, returns all, otherwise returns cls[:nspec]

lmax [int, scalar, optional] Maximum l of the power spectrum (default: 3*nside-1)

mmax [int, scalar, optional] Maximum m of the alm (default: lmax)

iter [int, scalar, optional] Number of iteration (default: 3)

alm [bool, scalar, optional] If True, returns both cl and alm, otherwise only cl is returned

pol [bool, optional] If True, assumes input maps are TQU. Output will be TEB cl's and correlations (input must be 1 or 3 maps). If False, maps are assumed to be described by spin 0 spherical harmonics. (input can be any number of maps) If there is only one input map, it has no effect. Default: True.

datapath [None or str, optional] If given, the directory where to find the weights data.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] are not taken into account

use_pixel_weights: bool, optional If True, use pixel by pixel weighting, healpy will automatically download the weights, if needed

Returns

res [array or sequence of arrays] If *alm* is False, returns cl or a list of cl's (TT, EE, BB, TE, EB, TB for polarized input map) Otherwise, returns a tuple (cl, alm), where cl is as above and alm is the spherical harmonic transform or a list of almT, almE, almB for polarized input

healpy.sphtfunc.map2alm

healpy.sphtfunc.**map2alm**(*maps*, *lmax=None*, *mmax=None*, *iter=3*, *pol=True*, *use_weights=False*, *datapath=None*, *gal_cut=0*, *use_pixel_weights=False*)

Computes the alm of a Healpix map. The input maps must all be in ring ordering.

Parameters

maps [array-like, shape (Npix,) or (n, Npix)] The input map or a list of n input maps. Must be in ring ordering.

lmax [int, scalar, optional] Maximum l of the power spectrum. Default: 3*nside-1

mmax [int, scalar, optional] Maximum m of the alm. Default: lmax

iter [int, scalar, optional] Number of iteration (default: 3)

pol [bool, optional] If True, assumes input maps are TQU. Output will be TEB alm's. (input must be 1 or 3 maps) If False, apply spin 0 harmonic transform to each map. (input can be any number of maps) If there is only one input map, it has no effect. Default: True.

use_weights: bool, scalar, optional If True, use the ring weighting. Default: False.

datapath [None or str, optional] If given, the directory where to find the weights data.

gal_cut [float [degrees]] pixels at latitude in [-gal_cut;+gal_cut] are not taken into account

use_pixel_weights: bool, optional If True, use pixel by pixel weighting, healpy will automatically download the weights, if needed

Returns

alms [array or tuple of array] alm or a tuple of 3 alm (almT, almE, almB) if polarized input.

Notes

The pixels which have the special *UNSEEN* value are replaced by zeros before spherical harmonic transform. They are converted back to *UNSEEN* value, so that the input maps are not modified. Each map have its own, independent mask.

3.2.2 From spherical harmonics to map

synfast(cls, nside[, lmax, mmax, alm, pol, ...])	Create a map(s) from cl(s).
alm2map(alms, nside[, lmax, mmax, pixwin, ...])	Computes a Healpix map given the alm.
alm2map_der1(alm, nside[, lmax, mmax])	Computes a Healpix map and its first derivatives given the alm.

healpy.sphtfunc.synfast

healpy.sphtfunc.**synfast**(*cls*, *nside*, *lmax=None*, *mmax=None*, *alm=False*, *pol=True*, *pixwin=False*, *fwhm=0.0*, *sigma=None*, *new=False*, *verbose=True*)

Create a map(s) from cl(s).

Parameters

cls [array or tuple of array] A cl or a list of cl (either 4 or 6, see *synalm()*)

nside [int, scalar] The nside of the output map(s)

lmax [int, scalar, optional] Maximum l for alm. Default: min of 3*nside-1 or length of the cls - 1

mmax [int, scalar, optional] Maximum m for alm.

alm [bool, scalar, optional] If True, return also alm(s). Default: False.

pol [bool, optional] If True, assumes input cls are TEB and correlation. Output will be TQU maps. (input must be 1, 4 or 6 cl's) If False, fields are assumed to be described by spin 0 spherical harmonics. (input can be any number of cl's) If there is only one input cl, it has no effect. Default: True.

pixwin [bool, scalar, optional] If True, convolve the alm by the pixel window function. Default: False.

fwhm [float, scalar, optional] The fwhm of the Gaussian used to smooth the map (applied on alm) [in radians]

sigma [float, scalar, optional] The sigma of the Gaussian used to smooth the map (applied on alm) [in radians]

Returns

maps [array or tuple of arrays] The output map (possibly list of maps if polarized input). or, if alm is True, a tuple of (map,alm) (alm possibly a list of alm if polarized input)

Notes

The order of the spectra will change in a future release. The new= parameter help to make the transition smoother. You can start using the new order by setting new=True. In the next version of healpy, the default will be new=True. This change is done for consistency between the different tools (alm2cl, synfast, anafast). In the new order, the spectra are ordered by diagonal of the correlation matrix. Eg, if fields are T, E, B, the spectra are TT, EE, BB, TE, EB, TB with new=True, and TT, TE, TB, EE, EB, BB if new=False.

healpy.sphtfunc.alm2map

healpy.sphtfunc.**alm2map**(*alms*, *nside*, *lmax=None*, *mmax=None*, *pixwin=False*, *fwhm=0.0*, *sigma=None*, *pol=True*, *inplace=False*, *verbose=True*)

Computes a Healpix map given the alm.

The alm are given as a complex array. You can specify lmax and mmax, or they will be computed from array size (assuming lmax==mmax).

Parameters

alms [complex, array or sequence of arrays] A complex array or a sequence of complex arrays. Each array must have a size of the form: mmax * (2 * lmax + 1 - mmax) / 2 + lmax + 1

nside [int, scalar] The nside of the output map.

lmax [None or int, scalar, optional] Explicitly define lmax (needed if mmax!=lmax)

mmax [None or int, scalar, optional] Explicitly define mmax (needed if mmax!=lmax)

pixwin [bool, optional] Smooth the alm using the pixel window functions. Default: False.

fwhm [float, scalar, optional] The fwhm of the Gaussian used to smooth the map (applied on alm) [in radians]

sigma [float, scalar, optional] The sigma of the Gaussian used to smooth the map (applied on alm) [in radians]

pol [bool, optional] If True, assumes input alms are TEB. Output will be TQU maps. (input must be 1 or 3 alms) If False, apply spin 0 harmonic transform to each alm. (input can be any number of alms) If there is only one input alm, it has no effect. Default: True.

inplace [bool, optional] If True, input alms may be modified by pixel window function and beam smoothing (if alm(s) are complex128 contiguous arrays). Otherwise, input alms are not modified. A copy is made if needed to apply beam smoothing or pixel window.

Returns

maps [array or list of arrays] A Healpix map in RING scheme at nside or a list of T,Q,U maps (if polarized input)

Notes

Running map2alm then alm2map will not return exactly the same map if the discretized field you construct on the sphere is not band-limited (for example, if you have a map containing pixel-based noise rather than beam-smoothed noise). If you need a band-limited map, you have to start with random numbers in lm space and transform these via alm2map. With such an input, the accuracy of map2alm->alm2map should be quite good, depending on your choices of lmax, mmax and nside (for some typical values, see e.g., section 5.1 of https://arxiv.org/pdf/1010.2084).

healpy.sphtfunc.alm2map_der1

healpy.sphtfunc.**alm2map_der1**(*alm*, *nside*, *lmax=None*, *mmax=None*)

Computes a Healpix map and its first derivatives given the alm.

The alm are given as a complex array. You can specify lmax and mmax, or they will be computed from array size (assuming lmax==mmax).

Parameters

alm [array, complex] A complex array of alm. Size must be of the form mmax(lmax-mmax+1)/2+lmax

nside [int] The nside of the output map.

lmax [None or int, optional] Explicitly define lmax (needed if mmax!=lmax)

mmax [None or int, optional] Explicitly define mmax (needed if mmax!=lmax)

Returns

m, d_theta, d_phi [tuple of arrays] The maps correponding to alm, and its derivatives with respect to theta and phi. d_phi is already divided by sin(theta)

3.2.3 Spherical harmonic transform tools

smoothing(map_in[, fwhm, sigma, ...])	Smooth a map with a Gaussian symmetric beam.
smoothalm(alms[, fwhm, sigma, beam_window, ...])	Smooth alm with a Gaussian symmetric beam function.
alm2cl(alms1[, alms2, lmax, mmax, lmax_out, ...])	Computes (cross-)spectra from alm(s).
synalm(cls[, lmax, mmax, new, verbose])	Generate a set of alm given cl.
almxfl(alm, fl[, mmax, inplace])	Multiply alm by a function of l.
pixwin(nside[, pol, lmax])	Return the pixel window function for the given nside.
Alm()	This class provides some static methods for alm index computation.

healpy.sphtfunc.smoothing

healpy.sphtfunc.**smoothing**(*map_in*, *fwhm=0.0*, *sigma=None*, *beam_window=None*, *pol=True*, *iter=3*, *lmax=None*, *mmax=None*, *use_weights=False*, *use_pixel_weights=False*, *datapath=None*, *verbose=True*)

Smooth a map with a Gaussian symmetric beam.

No removal of monopole or dipole is performed.

Parameters

map_in [array or sequence of 3 arrays] Either an array representing one map, or a sequence of 3 arrays representing 3 maps, accepts masked arrays

fwhm [float, optional] The full width half max parameter of the Gaussian [in radians]. Default:0.0

sigma [float, optional] The sigma of the Gaussian [in radians]. Override fwhm.

beam_window: array, optional Custom beam window function. Override fwhm and sigma.

pol [bool, optional] If True, assumes input maps are TQU. Output will be TQU maps. (input must be 1 or 3 alms) If False, each map is assumed to be a spin 0 map and is treated independently (input can be any number of alms). If there is only one input map, it has no effect. Default: True.

iter [int, scalar, optional] Number of iteration (default: 3)

lmax [int, scalar, optional] Maximum l of the power spectrum. Default: 3*nside-1

mmax [int, scalar, optional] Maximum m of the alm. Default: lmax

use_weights: bool, scalar, optional If True, use the ring weighting. Default: False.

use_pixel_weights: bool, optional If True, use pixel by pixel weighting, healpy will automatically download the weights, if needed

datapath [None or str, optional] If given, the directory where to find the weights data.

verbose [bool, optional] If True prints diagnostic information. Default: True

Returns

maps [array or list of 3 arrays] The smoothed map(s)

healpy.sphtfunc.smoothalm

healpy.sphtfunc.**smoothalm**(*alms*, *fwhm=0.0*, *sigma=None*, *beam_window=None*, *pol=True*, *mmax=None*, *verbose=True*, *inplace=True*)

Smooth alm with a Gaussian symmetric beam function.

Parameters

alms [array or sequence of 3 arrays] Either an array representing one alm, or a sequence of arrays. See *pol* parameter.

fwhm [float, optional] The full width half max parameter of the Gaussian. Default:0.0 [in radians]

sigma [float, optional] The sigma of the Gaussian. Override fwhm. [in radians]

beam_window: array, optional Custom beam window function. Override fwhm and sigma.

pol [bool, optional] If True, assumes input alms are TEB. Output will be TQU maps. (input must be 1 or 3 alms) If False, apply spin 0 harmonic transform to each alm. (input can be any number of alms) If there is only one input alm, it has no effect. Default: True.

mmax [None or int, optional] The maximum m for alm. Default: mmax=lmax

inplace [bool, optional] If True, the alm's are modified inplace if they are contiguous arrays of type complex128. Otherwise, a copy of alm is made. Default: True.

verbose [bool, optional] If True prints diagnostic information. Default: True

Returns

alms [array or sequence of 3 arrays] The smoothed alm. If alm[i] is a contiguous array of type complex128, and *inplace* is True the smoothing is applied inplace. Otherwise, a copy is made.

healpy.sphtfunc.alm2cl

healpy.sphtfunc.**alm2cl**(*alms1*, *alms2=None*, *lmax=None*, *mmax=None*, *lmax_out=None*, *nspec=None*)

Computes (cross-)spectra from alm(s). If alm2 is given, cross-spectra between alm and alm2 are computed. If alm (and alm2 if provided) contains n alm, then n(n+1)/2 auto and cross-spectra are returned.

Parameters

alm [complex, array or sequence of arrays] The alm from which to compute the power spectrum. If n>=2 arrays are given, computes both auto- and cross-spectra.

alms2 [complex, array or sequence of 3 arrays, optional] If provided, computes cross-spectra between alm and alm2. Default: alm2=alm, so auto-spectra are computed.

lmax [None or int, optional] The maximum l of the input alm. Default: computed from size of alm and mmax_in

mmax [None or int, optional] The maximum m of the input alm. Default: assume mmax_in = lmax_in

lmax_out [None or int, optional] The maximum l of the returned spectra. By default: the lmax of the given alm(s).

nspec [None or int, optional] The number of spectra to return. None means all, otherwise returns cl[:nspec]

Returns

cl [array or tuple of n(n+1)/2 arrays] the spectrum <*alm* x *alm2*> if *alm* (and *alm2*) is one alm, or the auto- and cross-spectra *<alm*[i] x *alm2*[j]> if alm (and alm2) contains more than one spectra. If more than one spectrum is returned, they are ordered by diagonal. For example, if *alm* is almT, almE, almB, then the returned spectra are: TT, EE, BB, TE, EB, TB.*

healpy.sphtfunc.synalm

`healpy.sphtfunc.`**`synalm`**(*cls*, *lmax=None*, *mmax=None*, *new=False*, *verbose=True*)

Generate a set of alm given cl. The cl are given as a float array. Corresponding alm are generated. If lmax is None, it is assumed lmax=cl.size-1 If mmax is None, it is assumed mmax=lmax.

Parameters

cls [float, array or tuple of arrays] Either one cl (1D array) or a tuple of either 4 cl or of n*(n+1)/2 cl. Some of the cl may be None, implying no cross-correlation. See *new* parameter.

lmax [int, scalar, optional] The lmax (if None or <0, the largest size-1 of cls)

mmax [int, scalar, optional] The mmax (if None or <0, =lmax)

new [bool, optional] If True, use the new ordering of cl's, ie by diagonal (e.g. TT, EE, BB, TE, EB, TB or TT, EE, BB, TE if 4 cl as input). If False, use the old ordering, ie by row (e.g. TT, TE, TB, EE, EB, BB or TT, TE, EE, BB if 4 cl as input).

Returns

alms [array or list of arrays] the generated alm if one spectrum is given, or a list of n alms (with n(n+1)/2 the number of input cl, or n=3 if there are 4 input cl).

Notes

The order of the spectra will change in a future release. The new= parameter help to make the transition smoother. You can start using the new order by setting new=True. In the next version of healpy, the default will be new=True. This change is done for consistency between the different tools (alm2cl, synfast, anafast). In the new order, the spectra are ordered by diagonal of the correlation matrix. Eg, if fields are T, E, B, the spectra are TT, EE, BB, TE, EB, TB with new=True, and TT, TE, TB, EE, EB, BB if new=False.

healpy.sphtfunc.almxfl

`healpy.sphtfunc.`**`almxfl`**(*alm*, *fl*, *mmax=None*, *inplace=False*)

Multiply alm by a function of l. The function is assumed to be zero where not defined.

Parameters

alm [array] The alm to multiply

fl [array] The function (at l=0..fl.size-1) by which alm must be multiplied.

mmax [None or int, optional] The maximum m defining the alm layout. Default: lmax.

inplace [bool, optional] If True, modify the given alm, otherwise make a copy before multiplying.

Returns

alm [array] The modified alm, either a new array or a reference to input alm, if inplace is True.

healpy.sphtfunc.pixwin

healpy.sphtfunc.**pixwin**(*nside*, *pol=False*, *lmax=None*)
Return the pixel window function for the given nside.

Parameters

nside [int] The nside for which to return the pixel window function

pol [bool, optional] If True, return also the polar pixel window. Default: False

lmax [int, optional] Maximum l of the power spectrum (default: 3*nside-1)

Returns

pw or pwT,pwP [array or tuple of 2 arrays] The temperature pixel window function, or a tuple with both temperature and polarisation pixel window functions.

healpy.sphtfunc.Alm

class healpy.sphtfunc.**Alm**
This class provides some static methods for alm index computation.

Methods

getlm(lmax[, i])	Get the l and m from index and lmax.
getidx(lmax, l, m)	Returns index corresponding to (l,m) in an array describing alm up to lmax.
getsize(lmax[, mmax])	Returns the size of the array needed to store alm up to *lmax* and *mmax*
getlmax(s[, mmax])	Returns the lmax corresponding to a given array size.

healpy.sphtfunc.Alm.getlm

static Alm.**getlm**(*lmax*, *i=None*)
Get the l and m from index and lmax.

Parameters

lmax [int] The maximum l defining the alm layout

i [int or None] The index for which to compute the l and m. If None, the function return l and m for i=0..Alm.getsize(lmax)

healpy.sphtfunc.Alm.getidx

static Alm.**getidx**(*lmax*, *l*, *m*)
Returns index corresponding to (l,m) in an array describing alm up to lmax.

Parameters

lmax [int] The maximum l, defines the alm layout

l [int] The l for which to get the index

m [int] The m for which to get the index

Returns

idx [int] The index corresponding to (l,m)

healpy.sphtfunc.Alm.getsize

static Alm.**getsize**(*lmax*, *mmax=None*)

Returns the size of the array needed to store alm up to *lmax* and *mmax*

Parameters

lmax [int] The maximum l, defines the alm layout

mmax [int, optional] The maximum m, defines the alm layout. Default: lmax.

Returns

size [int] The size of the array needed to store alm up to lmax, mmax.

healpy.sphtfunc.Alm.getlmax

static Alm.**getlmax**(*s*, *mmax=None*)

Returns the lmax corresponding to a given array size.

Parameters

s [int] Size of the array

mmax [None or int, optional] The maximum m, defines the alm layout. Default: lmax.

Returns

lmax [int] The maximum l of the array, or -1 if it is not a valid size.

3.2.4 Other tools

gauss_beam(fwhm[, lmax, pol])	Gaussian beam window function
beam2bl(beam, theta, lmax)	Computes a transfer (or window) function b(l) in spherical harmonic space from its circular beam profile b(theta) in real space.
bl2beam(bl, theta)	Computes a circular beam profile b(theta) in real space from its transfer (or window) function b(l) in spherical harmonic space.

healpy.sphtfunc.gauss_beam

healpy.sphtfunc.**gauss_beam**(*fwhm*, *lmax=512*, *pol=False*)

Gaussian beam window function

Computes the spherical transform of an axisimmetric gaussian beam

For a sky of underlying power spectrum C(l) observed with beam of given FWHM, the measured power spectrum will be C(l)_meas = C(l) B(l)^2 where B(l) is given by gaussbeam(Fwhm,Lmax). The polarization beam is also provided (when pol = True) assuming a perfectly co-polarized beam (e.g., Challinor et al 2000, astro-ph/0008228)

Parameters

fwhm [float] full width half max in radians

lmax [integer] ell max

pol [bool] if False, output has size (lmax+1) and is temperature beam if True output has size (lmax+1, 4) with components: * temperature beam * grad/electric polarization beam * curl/magnetic polarization beam * temperature * grad beam

Returns

beam [array] beam window function [0, lmax] if dim not specified otherwise (lmax+1, 4) contains polarized beam

healpy.sphtfunc.beam2bl

healpy.sphtfunc.**beam2bl**(*beam*, *theta*, *lmax*)

Computes a transfer (or window) function b(l) in spherical harmonic space from its circular beam profile b(theta) in real space.

Parameters

beam [array] Circular beam profile b(theta).

theta [array] Radius at which the beam profile is given. Has to be given in radians with same size as beam.

lmax [integer] Maximum multipole moment at which to compute b(l).

Returns

bl [array] Beam window function b(l).

healpy.sphtfunc.bl2beam

healpy.sphtfunc.**bl2beam**(*bl*, *theta*)

Computes a circular beam profile b(theta) in real space from its transfer (or window) function b(l) in spherical harmonic space.

Parameters

bl [array] Window function b(l) of the beam.

theta [array] Radius at which the beam profile will be computed. Has to be given in radians.

Returns

beam [array] (Circular) beam profile b(theta).

3.3 visufunc – Visualisation

3.3.1 Map projections

mollview([map, fig, rot, coord, unit, ...])	Plot a healpix map (given as an array) in Mollweide projection.
gnomview([map, fig, rot, coord, unit, ...])	Plot a healpix map (given as an array) in Gnomonic projection.

Continued on next page

Table 11 – continued from previous page

cartview([map, fig, rot, zat, coord, unit, ...])	Plot a healpix map (given as an array) in Cartesian projection.
orthview([map, fig, rot, coord, unit, ...])	Plot a healpix map (given as an array) in Orthographic projection.

healpy.visufunc.mollview

healpy.visufunc.**mollview**(*map=None*, *fig=None*, *rot=None*, *coord=None*, *unit=''*, *xsize=800*, *title='Mollweide view'*, *nest=False*, *min=None*, *max=None*, *flip='astro'*, *remove_dip=False*, *remove_mono=False*, *gal_cut=0*, *format='%g'*, *format2='%g'*, *cbar=True*, *cmap=None*, *badcolor='gray'*, *bgcolor='white'*, *notext=False*, *norm=None*, *hold=False*, *margins=None*, *sub=None*, *nlocs=2*, *return_projected_map=False*)

Plot a healpix map (given as an array) in Mollweide projection.

Parameters

map [float, array-like or None] An array containing the map, supports masked maps, see the *ma* function. If None, will display a blank map, useful for overplotting.

fig [int or None, optional] The figure number to use. Default: create a new figure

rot [scalar or sequence, optional] Describe the rotation to apply. In the form (lon, lat, psi) (unit: degrees) : the point at longitude *lon* and latitude *lat* will be at the center. An additional rotation of angle *psi* around this direction is applied.

coord [sequence of character, optional] Either one of 'G', 'E' or 'C' to describe the coordinate system of the map, or a sequence of 2 of these to rotate the map from the first to the second coordinate system.

unit [str, optional] A text describing the unit of the data. Default: ''

xsize [int, optional] The size of the image. Default: 800

title [str, optional] The title of the plot. Default: 'Mollweide view'

nest [bool, optional] If True, ordering scheme is NESTED. Default: False (RING)

min [float, optional] The minimum range value

max [float, optional] The maximum range value

flip [{'astro', 'geo'}, optional] Defines the convention of projection : 'astro' (default, east towards left, west towards right) or 'geo' (east towards right, west towards left)

remove_dip [bool, optional] If `True`, remove the dipole+monopole

remove_mono [bool, optional] If `True`, remove the monopole

gal_cut [float, scalar, optional] Symmetric galactic cut for the dipole/monopole fit. Removes points in latitude range [-gal_cut, +gal_cut]

format [str, optional] The format of the scale label. Default: '%g'

format2 [str, optional] Format of the pixel value under mouse. Default: '%g'

cbar [bool, optional] Display the colorbar. Default: True

notext [bool, optional] If True, no text is printed around the map

norm [{'hist', 'log', None}] Color normalization, hist= histogram equalized color mapping, log= logarithmic color mapping, default: None (linear color mapping)

cmap [a color map] The colormap to use (see matplotlib.cm)

badcolor [str] Color to use to plot bad values

bgcolor [str] Color to use for background

hold [bool, optional] If True, replace the current Axes by a MollweideAxes. use this if you want to have multiple maps on the same figure. Default: False

sub [int, scalar or sequence, optional] Use only a zone of the current figure (same syntax as subplot). Default: None

margins [None or sequence, optional] Either None, or a sequence (left,bottom,right,top) giving the margins on left,bottom,right and top of the axes. Values are relative to figure (0-1). Default: None

return_projected_map [bool] if True returns the projected map in a 2d numpy array

See also:

gnomview, ***cartview***, ***orthview***, **azeqview**

healpy.visufunc.gnomview

healpy.visufunc.**gnomview**(*map=None*, *fig=None*, *rot=None*, *coord=None*, *unit=''*, *xsize=200*, *ysize=None*, *reso=1.5*, *title='Gnomonic view'*, *nest=False*, *remove_dip=False*, *remove_mono=False*, *gal_cut=0*, *min=None*, *max=None*, *flip='astro'*, *format='%.3g'*, *cbar=True*, *cmap=None*, *badcolor='gray'*, *bgcolor='white'*, *norm=None*, *hold=False*, *sub=None*, *margins=None*, *notext=False*, *return_projected_map=False*, *no_plot=False*)

Plot a healpix map (given as an array) in Gnomonic projection.

Parameters

map [array-like] The map to project, supports masked maps, see the *ma* function. If None, use a blank map, useful for overplotting.

fig [None or int, optional] A figure number. Default: None= create a new figure

rot [scalar or sequence, optional] Describe the rotation to apply. In the form (lon, lat, psi) (unit: degrees) : the point at longitude *lon* and latitude *lat* will be at the center. An additional rotation of angle *psi* around this direction is applied.

coord [sequence of character, optional] Either one of 'G', 'E' or 'C' to describe the coordinate system of the map, or a sequence of 2 of these to rotate the map from the first to the second coordinate system.

unit [str, optional] A text describing the unit of the data. Default: ''

xsize [int, optional] The size of the image. Default: 200

ysize [None or int, optional] The size of the image. Default: None= xsize

reso [float, optional] Resolution (in arcmin). Default: 1.5 arcmin

title [str, optional] The title of the plot. Default: 'Gnomonic view'

nest [bool, optional] If True, ordering scheme is NESTED. Default: False (RING)

min [float, scalar, optional] The minimum range value

max [float, scalar, optional] The maximum range value

flip [{'astro', 'geo'}, optional] Defines the convention of projection : 'astro' (default, east towards left, west towards right) or 'geo' (east towards roght, west towards left)

remove_dip [bool, optional] If `True`, remove the dipole+monopole

remove_mono [bool, optional] If `True`, remove the monopole

gal_cut [float, scalar, optional] Symmetric galactic cut for the dipole/monopole fit. Removes points in latitude range [-gal_cut, +gal_cut]

format [str, optional] The format of the scale label. Default: '%g'

cmap [a color map] The colormap to use (see matplotlib.cm)

badcolor [str] Color to use to plot bad values

bgcolor [str] Color to use for background

hold [bool, optional] If True, replace the current Axes by a MollweideAxes. use this if you want to have multiple maps on the same figure. Default: False

sub [int or sequence, optional] Use only a zone of the current figure (same syntax as subplot). Default: None

margins [None or sequence, optional] Either None, or a sequence (left,bottom,right,top) giving the margins on left,bottom,right and top of the axes. Values are relative to figure (0-1). Default: None

notext: bool, optional If True: do not add resolution info text. Default=False

return_projected_map [bool, optional] if True returns the projected map in a 2d numpy array

no_plot [bool, optional] if True no figure will be created

See also:

mollview, ***cartview***, ***orthview***, **azeqview**

healpy.visufunc.cartview

healpy.visufunc.**cartview**(*map=None*, *fig=None*, *rot=None*, *zat=None*, *coord=None*, *unit=''*, *xsize=800*, *ysize=None*, *lonra=None*, *latra=None*, *title='Cartesian view'*, *nest=False*, *remove_dip=False*, *remove_mono=False*, *gal_cut=0*, *min=None*, *max=None*, *flip='astro'*, *format='%.3g'*, *cbar=True*, *cmap=None*, *badcolor='gray'*, *bgcolor='white'*, *norm=None*, *aspect=None*, *hold=False*, *sub=None*, *margins=None*, *notext=False*, *return_projected_map=False*)

Plot a healpix map (given as an array) in Cartesian projection.

Parameters

map [float, array-like or None] An array containing the map, supports masked maps, see the *ma* function. If None, will display a blank map, useful for overplotting.

fig [int or None, optional] The figure number to use. Default: create a new figure

rot [scalar or sequence, optional] Describe the rotation to apply. In the form (lon, lat, psi) (unit: degrees) : the point at longitude *lon* and latitude *lat* will be at the center. An additional rotation of angle *psi* around this direction is applied.

coord [sequence of character, optional] Either one of 'G', 'E' or 'C' to describe the coordinate system of the map, or a sequence of 2 of these to rotate the map from the first to the second coordinate system.

unit [str, optional] A text describing the unit of the data. Default: ‘’

xsize [int, optional] The size of the image. Default: 800

lonra [sequence, optional] Range in longitude. Default: [-180,180]

latra [sequence, optional] Range in latitude. Default: [-90,90]

title [str, optional] The title of the plot. Default: ‘Mollweide view’

nest [bool, optional] If True, ordering scheme is NESTED. Default: False (RING)

min [float, optional] The minimum range value

max [float, optional] The maximum range value

flip [{‘astro’, ‘geo’}, optional] Defines the convention of projection : ‘astro’ (default, east towards left, west towards right) or ‘geo’ (east towards roght, west towards left)

remove_dip [bool, optional] If `True`, remove the dipole+monopole

remove_mono [bool, optional] If `True`, remove the monopole

gal_cut [float, scalar, optional] Symmetric galactic cut for the dipole/monopole fit. Removes points in latitude range [-gal_cut, +gal_cut]

format [str, optional] The format of the scale label. Default: ‘%g’

cbar [bool, optional] Display the colorbar. Default: True

notext [bool, optional] If True, no text is printed around the map

norm [{‘hist’, ‘log’, None}, optional] Color normalization, hist= histogram equalized color mapping, log= logarithmic color mapping, default: None (linear color mapping)

cmap [a color map] The colormap to use (see matplotlib.cm)

badcolor [str] Color to use to plot bad values

bgcolor [str] Color to use for background

hold [bool, optional] If True, replace the current Axes by a CartesianAxes. use this if you want to have multiple maps on the same figure. Default: False

sub [int, scalar or sequence, optional] Use only a zone of the current figure (same syntax as subplot). Default: None

margins [None or sequence, optional] Either None, or a sequence (left,bottom,right,top) giving the margins on left,bottom,right and top of the axes. Values are relative to figure (0-1). Default: None

return_projected_map [bool] if True returns the projected map in a 2d numpy array

See also:

mollview, ***gnomview***, ***orthview***, **azeqview**

healpy.visufunc.orthview

healpy.visufunc.**orthview**(*map=None*, *fig=None*, *rot=None*, *coord=None*, *unit=''*, *xsize=800*, *half_sky=False*, *title='Orthographic view'*, *nest=False*, *min=None*, *max=None*, *flip='astro'*, *remove_dip=False*, *remove_mono=False*, *gal_cut=0*, *format='%g'*, *format2='%g'*, *cbar=True*, *cmap=None*, *badcolor='gray'*, *bgcolor='white'*, *notext=False*, *norm=None*, *hold=False*, *margins=None*, *sub=None*, *return_projected_map=False*)

Plot a healpix map (given as an array) in Orthographic projection.

Parameters

map [float, array-like or None] An array containing the map. If None, will display a blank map, useful for overplotting.

fig [int or None, optional] The figure number to use. Default: create a new figure

rot [scalar or sequence, optional] Describe the rotation to apply. In the form (lon, lat, psi) (unit: degrees) : the point at longitude *lon* and latitude *lat* will be at the center. An additional rotation of angle *psi* around this direction is applied.

coord [sequence of character, optional] Either one of 'G', 'E' or 'C' to describe the coordinate system of the map, or a sequence of 2 of these to rotate the map from the first to the second coordinate system.

half_sky [bool, optional] Plot only one side of the sphere. Default: False

unit [str, optional] A text describing the unit of the data. Default: ''

xsize [int, optional] The size of the image. Default: 800

title [str, optional] The title of the plot. Default: 'Orthographic view'

nest [bool, optional] If True, ordering scheme is NESTED. Default: False (RING)

min [float, optional] The minimum range value

max [float, optional] The maximum range value

flip [{'astro', 'geo'}, optional] Defines the convention of projection : 'astro' (default, east towards left, west towards right) or 'geo' (east towards roght, west towards left)

remove_dip [bool, optional] If `True`, remove the dipole+monopole

remove_mono [bool, optional] If `True`, remove the monopole

gal_cut [float, scalar, optional] Symmetric galactic cut for the dipole/monopole fit. Removes points in latitude range [-gal_cut, +gal_cut]

format [str, optional] The format of the scale label. Default: '%g'

format2 [str, optional] Format of the pixel value under mouse. Default: '%g'

cbar [bool, optional] Display the colorbar. Default: True

notext [bool, optional] If True, no text is printed around the map

norm [{'hist', 'log', None}] Color normalization, hist= histogram equalized color mapping, log= logarithmic color mapping, default: None (linear color mapping)

cmap [a color map] The colormap to use (see matplotlib.cm)

badcolor [str] Color to use to plot bad values

bgcolor [str] Color to use for background

hold [bool, optional] If True, replace the current Axes by an OrthographicAxes. use this if you want to have multiple maps on the same figure. Default: False

sub [int, scalar or sequence, optional] Use only a zone of the current figure (same syntax as subplot). Default: None

margins [None or sequence, optional] Either None, or a sequence (left,bottom,right,top) giving the margins on left,bottom,right and top of the axes. Values are relative to figure (0-1). Default: None

return_projected_map [bool] if True returns the projected map in a 2d numpy array

See also:

mollview, ***gnomview***, ***cartview***, **azeqview**

3.3.2 Graticules

graticule([dpar, dmer, coord, local])	Draw a graticule on the current Axes.
delgraticules()	Delete all graticules previously created on the Axes.

healpy.visufunc.graticule

healpy.visufunc.**graticule**(*dpar=None*, *dmer=None*, *coord=None*, *local=None*, ***kwds*)

Draw a graticule on the current Axes.

Parameters

dpar, dmer [float, scalars] Interval in degrees between meridians and between parallels

coord [{'E', 'G', 'C'}] The coordinate system of the graticule (make rotation if needed, using coordinate system of the map if it is defined).

local [bool] If True, draw a local graticule (no rotation is performed, useful for a gnomonic view, for example)

See also:

delgraticules

Notes

Other keyword parameters will be transmitted to the projplot function.

healpy.visufunc.delgraticules

healpy.visufunc.**delgraticules**()

Delete all graticules previously created on the Axes.

See also:

graticule

3.3.3 Tracing lines or points

projplot(*args, **kwds)	projplot is a wrapper around `matplotlib.Axes.plot()` to take into account the spherical projection.
projscatter(*args, **kwds)	Projscatter is a wrapper around `matplotlib.Axes.scatter()` to take into account the spherical projection.
projtext(*args, **kwds)	Projtext is a wrapper around `matplotlib.Axes.text()` to take into account the spherical projection.

healpy.visufunc.projplot

`healpy.visufunc.`**`projplot`**(**args*, ***kwds*)

projplot is a wrapper around `matplotlib.Axes.plot()` to take into account the spherical projection.

You can call this function as:

```
projplot(theta, phi)        # plot a line going through points at coord (theta,␣
↪phi)
projplot(theta, phi, 'bo')  # plot 'o' in blue at coord (theta, phi)
projplot(thetaphi)          # plot a line going through points at coord␣
↪(thetaphi[0], thetaphi[1])
projplot(thetaphi, 'bx')    # idem but with blue 'x'
```

Parameters

theta, phi [float, array-like] Coordinates of point to plot. Can be put into one 2-d array, first line is then *theta* and second line is *phi*. See *lonlat* parameter for unit.

fmt [str] A format string (see `matplotlib.Axes.plot()` for details)

lonlat [bool, optional] If True, theta and phi are interpreted as longitude and latitude in degree, otherwise, as colatitude and longitude in radian

coord [{'E', 'G', 'C', None}] The coordinate system of the points, only used if the coordinate coordinate system of the Axes has been defined and in this case, a rotation is performed

rot [None or sequence] rotation to be applied =(lon, lat, psi) : lon, lat will be position of the new Z axis, and psi is rotation around this axis, all in degree. if None, no rotation is performed

direct [bool] if True, the rotation to center the projection is not taken into account

See also:

projscatter, ***projtext***

Notes

Other keywords are passed to `matplotlib.Axes.plot()`.

healpy.visufunc.projscatter

`healpy.visufunc.`**`projscatter`**(**args*, ***kwds*)

Projscatter is a wrapper around `matplotlib.Axes.scatter()` to take into account the spherical projection.

You can call this function as:

```
projscatter(theta, phi)      # plot points at coord (theta, phi)
projplot(thetaphi)           # plot points at coord (thetaphi[0], thetaphi[1])
```

Parameters

theta, phi [float, array-like] Coordinates of point to plot. Can be put into one 2-d array, first line is then *theta* and second line is *phi*. See *lonlat* parameter for unit.

lonlat [bool, optional] If True, theta and phi are interpreted as longitude and latitude in degree, otherwise, as colatitude and longitude in radian

coord [{'E', 'G', 'C', None}, optional] The coordinate system of the points, only used if the coordinate coordinate system of the axes has been defined and in this case, a rotation is performed

rot [None or sequence, optional] rotation to be applied =(lon, lat, psi) : lon, lat will be position of the new Z axis, and psi is rotation around this axis, all in degree. if None, no rotation is performed

direct [bool, optional] if True, the rotation to center the projection is not taken into account

See also:

projplot*, *projtext

Notes

Other keywords are passed to `matplotlib.Axes.plot()`.

healpy.visufunc.projtext

`healpy.visufunc.`**`projtext`**`(`*args*, ***kwds*`)`

Projtext is a wrapper around `matplotlib.Axes.text()` to take into account the spherical projection.

Parameters

theta, phi [float, array-like] Coordinates of point to plot. Can be put into one 2-d array, first line is then *theta* and second line is *phi*. See *lonlat* parameter for unit.

text [str] The text to be displayed.

lonlat [bool, optional] If True, theta and phi are interpreted as longitude and latitude in degree, otherwise, as colatitude and longitude in radian

coord [{'E', 'G', 'C', None}, optional] The coordinate system of the points, only used if the coordinate coordinate system of the axes has been defined and in this case, a rotation is performed

rot [None or sequence, optional] rotation to be applied =(lon, lat, psi) : lon, lat will be position of the new Z axis, and psi is rotation around this axis, all in degree. if None, no rotation is performed

direct [bool, optional] if True, the rotation to center the projection is not taken into account

See also:

projplot*, *projscatter

Notes

Other keywords are passed to `matplotlib.Axes.text()`.

3.4 `fitsfunc` – FITS file related functions

3.4.1 Reading/writing maps

read_map(filename[, field, dtype, nest, ...])	Read a healpix map from a fits file.
write_map(filename, m[, nest, dtype, ...])	Writes a healpix map into a healpix file.

healpy.fitsfunc.read_map

healpy.fitsfunc.**read_map**(*filename*, *field=0*, *dtype=<class 'numpy.float64'>*, *nest=False*, *partial=False*, *hdu=1*, *h=False*, *verbose=True*, *memmap=False*)

Read a healpix map from a fits file. Partial-sky files, if properly identified, are expanded to full size and filled with UNSEEN.

Parameters

filename [str or HDU or HDUList or pathlib.Path instance] the fits file name

field [int or tuple of int, or None, optional] The column to read. Default: 0. By convention 0 is temperature, 1 is Q, 2 is U. Field can be a tuple to read multiple columns (0,1,2) If the fits file is a partial-sky file, field=0 corresponds to the first column after the pixel index column. If None, all columns are read in.

dtype [data type or list of data types, optional] Force the conversion to some type. Passing a list allows different types for each field. In that case, the length of the list must correspond to the length of the field parameter. Default: np.float64 if None, keep the dtype of the input FITS file

nest [bool, optional] If True return the map in NEST ordering, otherwise in RING ordering; use fits keyword ORDERING to decide whether conversion is needed or not If None, no conversion is performed.

partial [bool, optional] If True, fits file is assumed to be a partial-sky file with explicit indexing, if the indexing scheme cannot be determined from the header. If False, implicit indexing is assumed. Default: False. A partial sky file is one in which OBJECT=PARTIAL and INDXSCHM=EXPLICIT, and the first column is then assumed to contain pixel indices. A full sky file is one in which OBJECT=FULLSKY and INDXSCHM=IMPLICIT. At least one of these keywords must be set for the indexing scheme to be properly identified.

hdu [int, optional] the header number to look at (start at 0)

h [bool, optional] If True, return also the header. Default: False.

verbose [bool, optional] If True, print a number of diagnostic messages

memmap [bool, optional] Argument passed to astropy.io.fits.open, if True, the map is not read into memory, but only the required pixels are read when needed. Default: False.

Returns

m | (m0, m1, ...) [, header] [array or a tuple of arrays, optionally with header appended] The map(s) read from the file, and the header if *h* is True.

healpy.fitsfunc.write_map

healpy.fitsfunc.**write_map**(*filename*, *m*, *nest=False*, *dtype=<class 'numpy.float32'>*, *fits_IDL=True*, *coord=None*, *partial=False*, *column_names=None*, *column_units=None*, *extra_header=()*, *overwrite=False*)

Writes a healpix map into a healpix file.

Parameters

filename [str] the fits file name

m [array or sequence of 3 arrays] the map to write. Possibly a sequence of 3 maps of same size. They will be considered as I, Q, U maps. Supports masked maps, see the *ma* function.

nest [bool, optional] If True, ordering scheme is assumed to be NESTED, otherwise, RING. Default: RING. The map ordering is not modified by this function, the input map array should already be in the desired ordering (run *ud_grade* beforehand).

fits_IDL [bool, optional] If True, reshapes columns in rows of 1024, otherwise all the data will go in one column. Default: True

coord [str] The coordinate system, typically 'E' for Ecliptic, 'G' for Galactic or 'C' for Celestial (equatorial)

partial [bool, optional] If True, fits file is written as a partial-sky file with explicit indexing. Otherwise, implicit indexing is used. Default: False.

column_names [str or list] Column name or list of column names, if None here the default column names based on the number of columns: 1 : "TEMPERATURE", 2 : ["Q_POLARISATION", "U_POLARISATION"], 3 : ["TEMPERATURE", "Q_POLARISATION", "U_POLARISATION"], 6 : ["II", "IQ", "IU", "QQ", "QU", "UU"] COLUMN_1, COLUMN_2... otherwise (FITS is 1-based)

column_units [str or list] Units for each column, or same units for all columns.

extra_header [list] Extra records to add to FITS header.

dtype: np.dtype or list of np.dtypes, optional The datatype in which the columns will be stored. Will be converted internally from the numpy datatype to the fits convention. If a list, the length must correspond to the number of map arrays. Default: np.float32.

overwrite [bool, optional] If True, existing file is silently overwritten. Otherwise trying to write an existing file raises an OSError (IOError for Python 2).

3.4.2 Reading/writing alm

read_alm(filename[, hdu, return_mmax])	Read alm from a fits file.
write_alm(filename, alms[, out_dtype, lmax, ...])	Write alms to a fits file.

healpy.fitsfunc.read_alm

healpy.fitsfunc.**read_alm**(*filename*, *hdu=1*, *return_mmax=False*)

Read alm from a fits file.

In the fits file, the alm are written with explicit index scheme, index = l**2+l+m+1, while healpix cxx uses index = m*(2*lmax+1-m)/2+l. The conversion is done in this function.

Parameters

filename [str or HDUList or HDU or pathlib.Path instance] The name of the fits file to read

hdu [int, or tuple of int, optional] The header to read. Start at 0. Default: hdu=1

return_mmax [bool, optional] If true, both the alms and mmax is returned in a tuple. Default: return_mmax=False

Returns

alms[, mmax] [complex array or tuple of a complex array and an int] The alms read from the file and optionally mmax read from the file

healpy.fitsfunc.write_alm

healpy.fitsfunc.**write_alm**(*filename*, *alms*, *out_dtype=None*, *lmax=-1*, *mmax=-1*, *mmax_in=-1*, *overwrite=False*)

Write alms to a fits file.

In the fits file the alms are written with explicit index scheme, index = l*l + l + m +1, possibly out of order. By default write_alm makes a table with the same precision as the alms. If specified, the lmax and mmax parameters truncate the input data to include only alms for which l <= lmax and m <= mmax.

Parameters

filename [str] The filename of the output fits file

alms [array, complex or list of arrays] A complex ndarray holding the alms, index = m*(2*lmax+1-m)/2+l, see Alm.getidx

lmax [int, optional] The maximum l in the output file

mmax [int, optional] The maximum m in the output file

out_dtype [data type, optional] data type in the output file (must be a numpy dtype). Default: *alms*.real.dtype

mmax_in [int, optional] maximum m in the input array

3.4.3 Reading/writing cl

read_cl(filename[, dtype, h])	Reads Cl from a healpix file, as IDL fits2cl.
write_cl(filename, cl[, dtype, overwrite])	Writes Cl into a healpix file, as IDL cl2fits.

healpy.fitsfunc.read_cl

healpy.fitsfunc.**read_cl**(*filename*, *dtype=<class 'numpy.float64'>*, *h=False*)

Reads Cl from a healpix file, as IDL fits2cl.

Parameters

filename [str or HDUList or HDU or pathlib.Path instance] the fits file name

dtype [data type, optional] the data type of the returned array

Returns

cl [array] the cl array

healpy.fitsfunc.write_cl

healpy.fitsfunc.**write_cl**(*filename*, *cl*, *dtype=<class 'numpy.float64'>*, *overwrite=False*)
Writes Cl into a healpix file, as IDL cl2fits.

Parameters

filename [str] the fits file name

cl [array] the cl array to write to file

overwrite [bool, optional] If True, existing file is silently overwritten. Otherwise trying to write an existing file raises an OSError (IOError for Python 2).

3.4.4 Reading/writing column in fits file

mrdfits	
mwrfits	

3.4.5 Helper

getformat(t)	Get the FITS convention format string of data type t.

healpy.fitsfunc.getformat

healpy.fitsfunc.**getformat**(*t*)
Get the FITS convention format string of data type t.

Parameters

t [data type] The data type for which the FITS type is requested

Returns

fits_type [str or None] The FITS string code describing the data type, or None if unknown type.

3.5 Pixel querying routines

query_disc()	Returns pixels whose centers lie within the disk defined by *vec* and *radius* (in radians) (if *inclusive* is False), or which overlap with this disk (if *inclusive* is True).
query_polygon()	Returns the pixels whose centers lie within the convex polygon defined by the *vertices* array (if *inclusive* is False), or which overlap with this polygon (if *inclusive* is True).
query_strip()	Returns pixels whose centers lie within the colatitude range defined by *theta1* and *theta2* (if inclusive is False), or which overlap with this region (if *inclusive* is True).
boundaries()	Returns an array containing vectors to the boundary of the nominated pixel.

3.5.1 healpy.query_disc

healpy.**query_disc**()

Returns pixels whose centers lie within the disk defined by *vec* and *radius* (in radians) (if *inclusive* is False), or which overlap with this disk (if *inclusive* is True).

Parameters

nside [int] The nside of the Healpix map.

vec [float, sequence of 3 elements] The coordinates of unit vector defining the disk center.

radius [float] The radius (in radians) of the disk

inclusive [bool, optional] If False, return the exact set of pixels whose pixel centers lie within the disk; if True, return all pixels that overlap with the disk, and maybe a few more. Default: False

fact [int, optional] Only used when inclusive=True. The overlapping test will be done at the resolution fact*nside. For NESTED ordering, fact must be a power of 2, less than 2**30, else it can be any positive integer. Default: 4.

nest: bool, optional if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

buff: int array, optional if provided, this numpy array is used to contain the return values and must be at least long enough to do so

Returns

ipix [int, array] The pixels which lie within the given disk.

3.5.2 healpy.query_polygon

healpy.**query_polygon**()

Returns the pixels whose centers lie within the convex polygon defined by the *vertices* array (if *inclusive* is False), or which overlap with this polygon (if *inclusive* is True).

Parameters

nside [int] The nside of the Healpix map.

vertices [float, array-like] Vertex array containing the vertices of the polygon, shape (N, 3).

inclusive [bool, optional] If False, return the exact set of pixels whose pixel centers lie within the polygon; if True, return all pixels that overlap with the polygon, and maybe a few more. Default: False.

fact [int, optional] Only used when inclusive=True. The overlapping test will be done at the resolution fact*nside. For NESTED ordering, fact must be a power of 2, less than 2**30, else it can be any positive integer. Default: 4.

nest: bool, optional if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

buff: int array, optional if provided, this numpy array is used to contain the return values and must be at least long enough to do so

Returns

ipix [int, array] The pixels which lie within the given polygon.

3.5.3 healpy.query_strip

healpy.**query_strip**()

Returns pixels whose centers lie within the colatitude range defined by *theta1* and *theta2* (if inclusive is False), or which overlap with this region (if *inclusive* is True). If theta1<theta2, the region between both angles is considered, otherwise the regions 0<theta<theta2 and theta1<theta<pi.

Parameters

nside [int] The nside of the Healpix map.

theta1 [float] First colatitude (radians)

theta2 [float] Second colatitude (radians)

inclusive ; bool If False, return the exact set of pixels whose pixels centers lie within the region; if True, return all pixels that overlap with the region.

nest: bool, optional if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

buff: int array, optional if provided, this numpy array is used to contain the return values and must be at least long enough to do so

Returns

ipix [int, array] The pixels which lie within the given strip.

3.5.4 healpy.boundaries

healpy.**boundaries**()

Returns an array containing vectors to the boundary of the nominated pixel.

The returned array has shape (3, 4*step), the elements of which are the x,y,z positions on the unit sphere of the pixel boundary. In order to get vector positions for just the corners, specify step=1.

Parameters

nside [int] The nside of the Healpix map.

pix [int] Pixel identifier

step [int, optional] Number of elements for each side of the pixel.

nest [bool, optional] if True, assume NESTED pixel ordering, otherwise, RING pixel ordering

Returns

boundary [float, array] x,y,z for positions on the boundary of the pixel

3.6 rotator – Rotation and geometry functions

3.6.1 Rotation

Rotator([rot, coord, inv, deg, eulertype])	Rotation operator, including astronomical coordinate systems.
rotateVector(rotmat, vec[, vy, vz, do_rot])	Rotate a vector (or a list of vectors) using the rotation matrix given as first argument.

Continued on next page

Table 20 – continued from previous page

rotateDirection(rotmat, theta[, phi, ...])	Rotate the vector described by angles theta,phi using the rotation matrix given as first argument.

healpy.rotator.Rotator

class healpy.rotator.**Rotator**(*rot=None*, *coord=None*, *inv=None*, *deg=True*, *eulertype='ZYX'*)

Rotation operator, including astronomical coordinate systems.

This class provides tools for spherical rotations. It is meant to be used in the healpy library for plotting, and for this reason reflects the convention used in the Healpix IDL library.

Parameters

rot [None or sequence] Describe the rotation by its euler angle. See `euler_matrix_new()`.

coord [None or sequence of str] Describe the coordinate system transform. If *rot* is also given, the coordinate transform is applied first, and then the rotation.

inv [bool] If True, the inverse rotation is defined. (Default: False)

deg [bool] If True, angles are assumed to be in degree. (Default: True)

eulertype [str] The Euler angle convention used. See `euler_matrix_new()`.

Examples

```
>>> r = Rotator(coord=['G','E'])  # Transforms galactic to ecliptic coordinates
>>> theta_gal, phi_gal = np.pi/2., 0.
>>> theta_ecl, phi_ecl = r(theta_gal, phi_gal)  # Apply the conversion
>>> print(theta_ecl)
1.66742286715
>>> print(phi_ecl)
-1.62596400306
>>> theta_ecl, phi_ecl = Rotator(coord='ge')(theta_gal, phi_gal) # In one line
>>> print(theta_ecl)
1.66742286715
>>> print(phi_ecl)
-1.62596400306
>>> vec_gal = np.array([1, 0, 0]) #Using vectors
>>> vec_ecl = r(vec_gal)
>>> print(vec_ecl)
[-0.05488249 -0.99382103 -0.09647625]
```

Attributes

mat The matrix representing the rotation.

coordin The input coordinate system.

coordout The output coordinate system.

coordinstr The input coordinate system in str.

coordoutstr The output coordinate system in str.

rots The sequence of rots defining the rotation.

coords The sequence of coords defining the rotation.

Methods

I(self, *args, **kwds)	Rotate the given vector or direction using the inverse matrix.
__call__(self, *args, **kwds)	Use the rotator to rotate either spherical coordinates (theta, phi) or a vector (x,y,z).
angle_ref(self, *args, **kwds)	Compute the angle between transverse reference direction of initial and final frames
do_rot(self, i)	Returns True if rotation is not (close to) identity.
rotate_alm(self, alm[, lmax, mmax, inplace])	Rotate Alms with the transform defined in the Rotator object
rotate_map_alms(self, m[, ...])	Rotate a HEALPix map to a new reference frame in spherical harmonics space
rotate_map_pixel(self, m)	Rotate a HEALPix map to a new reference frame in pixel space

healpy.rotator.Rotator.I

Rotator.**I**(*self*, **args*, ***kwds*)

Rotate the given vector or direction using the inverse matrix. rot.I(vec) <==> rot(vec,inv=True)

healpy.rotator.Rotator.__call__

Rotator.**__call__**(*self*, **args*, ***kwds*)

Use the rotator to rotate either spherical coordinates (theta, phi) or a vector (x,y,z). You can use lonla keyword to use longitude, latitude (in degree) instead of theta, phi (in radian). In this case, returns longitude, latitude in degree.

Accepted forms:

r(x,y,z) # x,y,z either scalars or arrays r(theta,phi) # theta, phi scalars or arrays r(lon,lat,lonlat=True) # lon, lat scalars or arrays r(vec) # vec 1-D array with 3 elements, or 2-D array 3xN r(direction) # direction 1-D array with 2 elements, or 2xN array

Parameters

vec_or_dir [array or multiple arrays] The direction to rotate. See above for accepted formats.

lonlat [bool, optional] If True, assumes the input direction is longitude/latitude in degrees. Otherwise, assumes co-latitude/longitude in radians. Default: False

inv [bool, optional] If True, applies the inverse rotation. Default: False.

healpy.rotator.Rotator.angle_ref

Rotator.**angle_ref**(*self*, **args*, ***kwds*)

Compute the angle between transverse reference direction of initial and final frames

For example, if angle of polarisation is psi in initial frame, it will be psi+angle_ref in final frame.

Parameters

dir_or_vec [array] Direction or vector (see Rotator.__call__)

lonlat: bool, optional If True, assume input is longitude,latitude in degrees. Otherwise, theta,phi in radian. Default: False

inv [bool, optional] If True, use the inverse transforms. Default: False

Returns

angle [float, scalar or array] Angle in radian (a scalar or an array if input is a sequence of direction/vector)

healpy.rotator.Rotator.do_rot

Rotator.**do_rot**(*self*, *i*)

Returns True if rotation is not (close to) identity.

healpy.rotator.Rotator.rotate_alm

Rotator.**rotate_alm**(*self*, *alm*, *lmax=None*, *mmax=None*, *inplace=False*)

Rotate Alms with the transform defined in the Rotator object

see the docstring of the rotate_alm function defined in the healpy package, this function **returns** the rotated alms, does not rotate in place

healpy.rotator.Rotator.rotate_map_alms

Rotator.**rotate_map_alms**(*self*, *m*, *use_pixel_weights=True*, *lmax=None*, *mmax=None*)

Rotate a HEALPix map to a new reference frame in spherical harmonics space

This is generally the best strategy to rotate/change reference frame of maps. If the input map is band-limited, i.e. it can be represented exactly by a spherical harmonics transform under a specific lmax, the map rotation will be invertible.

Parameters

m [np.ndarray] Input map, 1 map is considered I, 2 maps:[Q,U], 3 maps:[I,Q,U]

use_pixel_weights [bool, optional] Use pixel weights in map2alm

Returns

m_rotated [np.ndarray] Map in the new reference frame

healpy.rotator.Rotator.rotate_map_pixel

Rotator.**rotate_map_pixel**(*self*, *m*)

Rotate a HEALPix map to a new reference frame in pixel space

It is generally better to rotate in spherical harmonics space, see the rotate_map_alms method. A case where pixel space rotation is better is for heavily masked maps where the spherical harmonics transform is not well defined. This function first rotates the pixels centers of the new reference frame to the original reference frame, then uses hp.get_interp_val to interpolate bilinearly the pixel values, finally fixes Q and U polarization by the modification to the psi angle caused by the Rotator using Rotator.angle_ref. Due to interpolation, this function generally suppresses the signal at high angular scales.

Parameters

m [np.ndarray] Input map, 1 map is considered I, 2 maps:[Q,U], 3 maps:[I,Q,U]

Returns

m_rotated [np.ndarray] Map in the new reference frame

get_inverse	

healpy.rotator.rotateVector

`healpy.rotator.`**`rotateVector`**(*rotmat*, *vec*, *vy=None*, *vz=None*, *do_rot=True*)

Rotate a vector (or a list of vectors) using the rotation matrix given as first argument.

Parameters

rotmat [float, array-like shape (3,3)] The rotation matrix

vec [float, scalar or array-like] The vector to transform (shape (3,) or (3,N)), or x component (scalar or shape (N,)) if vy and vz are given

vy [float, scalar or array-like, optional] The y component of the vector (scalar or shape (N,))

vz [float, scalar or array-like, optional] The z component of the vector (scalar or shape (N,))

do_rot [bool, optional] if True, really perform the operation, if False do nothing.

Returns

vec [float, array] The component of the rotated vector(s).

See also:

Rotator

healpy.rotator.rotateDirection

`healpy.rotator.`**`rotateDirection`**(*rotmat*, *theta*, *phi=None*, *do_rot=True*, *lonlat=False*)

Rotate the vector described by angles theta,phi using the rotation matrix given as first argument.

Parameters

rotmat [float, array-like shape (3,3)] The rotation matrix

theta [float, scalar or array-like] The angle theta (scalar or shape (N,)) or both angles (scalar or shape (2, N)) if phi is not given.

phi [float, scalar or array-like, optionnal] The angle phi (scalar or shape (N,)).

do_rot [bool, optional] if True, really perform the operation, if False do nothing.

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

angles [float, array] The angles of describing the rotated vector(s).

See also:

Rotator

3.6.2 Geometrical helpers

vec2dir(vec[, vy, vz, lonlat])	Transform a vector to angle given by theta,phi.
dir2vec(theta[, phi, lonlat])	Transform a direction theta,phi to a unit vector.
angdist(dir1, dir2[, lonlat])	Returns the angular distance between dir1 and dir2.

healpy.rotator.vec2dir

healpy.rotator.**vec2dir**(*vec*, *vy=None*, *vz=None*, *lonlat=False*)

Transform a vector to angle given by theta,phi.

Parameters

vec [float, scalar or array-like] The vector to transform (shape (3,) or (3,N)), or x component (scalar or shape (N,)) if vy and vz are given

vy [float, scalar or array-like, optional] The y component of the vector (scalar or shape (N,))

vz [float, scalar or array-like, optional] The z component of the vector (scalar or shape (N,))

lonlat [bool, optional] If True, return angles will be longitude and latitude in degree, otherwise, angles will be longitude and co-latitude in radians (default)

Returns

angles [float, array] The angles (unit depending on *lonlat*) in an array of shape (2,) (if scalar input) or (2, N)

See also:

***dir2vec()*,pixelfunc.ang2vec(),pixelfunc.vec2ang()**

healpy.rotator.dir2vec

healpy.rotator.**dir2vec**(*theta*, *phi=None*, *lonlat=False*)

Transform a direction theta,phi to a unit vector.

Parameters

theta [float, scalar or array-like] The angle theta (scalar or shape (N,)) or both angles (scalar or shape (2, N)) if phi is not given.

phi [float, scalar or array-like, optionnal] The angle phi (scalar or shape (N,)).

lonlat [bool] If True, input angles are assumed to be longitude and latitude in degree, otherwise, they are co-latitude and longitude in radians.

Returns

vec [array] The vector(s) corresponding to given angles, shape is (3,) or (3, N).

See also:

***vec2dir()*,pixelfunc.ang2vec(),pixelfunc.vec2ang()**

healpy.rotator.angdist

healpy.rotator.**angdist**(*dir1*, *dir2*, *lonlat=False*)
Returns the angular distance between dir1 and dir2.

Parameters

dir1, dir2 [float, array-like] The directions between which computing the angular distance. Angular if len(dir) == 2 or vector if len(dir) == 3. See *lonlat* for unit

lonlat [bool, scalar or sequence] If True, angles are assumed to be longitude and latitude in degree, otherwise they are interpreted as colatitude and longitude in radian. If a sequence, lonlat[0] applies to dir1 and lonlat[1] applies to dir2.

Returns

angles [float, scalar or array-like] The angle(s) between dir1 and dir2 in radian.

Examples

```
>>> import healpy as hp
>>> hp.rotator.angdist([.2,0], [.2, 1e-6])
array([  1.98669331e-07])
```

3.7 projector – Spherical projections

3.7.1 Basic classes

SphericalProj([rot, coord, flipconv])	This class defines functions for spherical projection.
GnomonicProj([rot, coord, xsize, ysize, reso])	This class provides class methods for Gnomonic projection.
MollweideProj([rot, coord, xsize])	This class provides class methods for Mollweide projection.
CartesianProj([rot, coord, xsize, ysize, ...])	This class provides class methods for Cartesian projection.

healpy.projector.SphericalProj

class healpy.projector.**SphericalProj**(*rot=None*, *coord=None*, *flipconv=None*, ***kwds*)
This class defines functions for spherical projection.

This class contains class method for spherical projection computation. It should not be instantiated. It should be inherited from and methods should be overloaded for desired projection.

Attributes

arrayinfo Dictionary with information on the projection array

Methods

ang2xy(self, theta[, phi, lonlat, direct])	From angular direction to position in the projection plane (%s).
get_center(self[, lonlat])	Get the center of the projection.
get_extent(self)	Get the extension of the projection plane.
get_fov(self)	Get the field of view in degree of the plane of projection
ij2xy(self[, i, j])	From image array indices to position in projection plane (%s).
projmap(self, map, vec2pix_func[, rot, coord])	Create an array containing the projection of the map.
set_flip(self, flipconv)	flipconv is either 'astro' or 'geo'.
vec2xy(self, vx[, vy, vz, direct])	From unit vector direction to position in the projection plane (%s).
xy2ang(self, x[, y, lonlat, direct])	From position in the projection plane to angular direction (%s).
xy2ij(self, x[, y])	From position in the projection plane to image array index (%s).
xy2vec(self, x[, y, direct])	From position in the projection plane to unit vector direction (%s).

healpy.projector.SphericalProj.ang2xy

SphericalProj.**ang2xy**(*self*, *theta*, *phi=None*, *lonlat=False*, *direct=False*)

From angular direction to position in the projection plane (%s).

Input:

- theta: if phi is None, theta[0] contains theta, theta[1] contains phi
- phi : if phi is not None, theta,phi are direction
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in %s plane.

healpy.projector.SphericalProj.get_center

SphericalProj.**get_center**(*self*, *lonlat=False*)

Get the center of the projection.

Input:

- **lonlat** [if True, will return longitude and latitude in degree,] otherwise, theta and phi in radian

Return:

- theta,phi or lonlat depending on lonlat keyword

healpy.projector.SphericalProj.get_extent

SphericalProj.**get_extent**(*self*)

Get the extension of the projection plane.

Return: extent = (left,right,bottom,top)

healpy.projector.SphericalProj.get_fov

SphericalProj.**get_fov**(*self*)
Get the field of view in degree of the plane of projection

Return: fov: the diameter in radian of the field of view

healpy.projector.SphericalProj.ij2xy

SphericalProj.**ij2xy**(*self*, *i=None*, *j=None*)
From image array indices to position in projection plane (%s).

Input:

- if i and j are None, generate arrays of i and j as input
- i : if j is None, i[0], j[1] define array indices in %s image.
- j : if defined, i,j define array indices in image.
- projinfo : additional projection information.

Return:

- x,y : position in projection plane.

healpy.projector.SphericalProj.projmap

SphericalProj.**projmap**(*self*, *map*, *vec2pix_func*, *rot=None*, *coord=None*)
Create an array containing the projection of the map.

Input:

- vec2pix_func: a function taking theta,phi and returning pixel number
- **map: an array containing the spherical map to project,** the pixelisation is described by vec2pix_func

Return:

- a 2D array with the projection of the map.

Note: the Projector must contain information on the array.

healpy.projector.SphericalProj.set_flip

SphericalProj.**set_flip**(*self*, *flipconv*)
flipconv is either 'astro' or 'geo'. None will be default.

With 'astro', east is toward left and west toward right. It is the opposite for 'geo'

healpy.projector.SphericalProj.vec2xy

SphericalProj.**vec2xy**(*self*, *vx*, *vy=None*, *vz=None*, *direct=False*)
From unit vector direction to position in the projection plane (%s).

Input:

- vx: if vy and vz are None, vx[0],vx[1],vx[2] defines the unit vector.
- vy,vz: if defined, vx,vy,vz define the unit vector
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in %s plane.

healpy.projector.SphericalProj.xy2ang

SphericalProj.**xy2ang**(*self*, *x*, *y=None*, *lonlat=False*, *direct=False*)
From position in the projection plane to angular direction (%s).

Input:

- x : if y is None, x[0], x[1] define the position in %s plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

healpy.projector.SphericalProj.xy2ij

SphericalProj.**xy2ij**(*self*, *x*, *y=None*)
From position in the projection plane to image array index (%s).

Input:

- x : if y is None, x[0], x[1] define the position in %s plane.
- y : if defined, x,y define the position in projection plane.
- projinfo : additional projection information.

Return:

- i,j : image array indices.

healpy.projector.SphericalProj.xy2vec

SphericalProj.**xy2vec**(*self*, *x*, *y=None*, *direct=False*)
From position in the projection plane to unit vector direction (%s).

Input:

- x : if y is None, x[0], x[1] define the position in %s plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

get_proj_plane_info	
mkcoord	
set_proj_plane_info	

healpy.projector.GnomonicProj

class healpy.projector.**GnomonicProj**(*rot=None*, *coord=None*, *xsize=None*, *ysize=None*, *reso=None*, ***kwds*)

This class provides class methods for Gnomonic projection.

Attributes

arrayinfo Dictionary with information on the projection array

Methods

ang2xy(self, theta[, phi, lonlat, direct])	From angular direction to position in the projection plane (Gnomonic).
get_center(self[, lonlat])	Get the center of the projection.
get_extent(self)	Get the extension of the projection plane.
get_fov(self)	Get the field of view in degree of the plane of projection
ij2xy(self[, i, j])	From image array indices to position in projection plane (Gnomonic).
projmap(self, map, vec2pix_func[, rot, coord])	Create an array containing the projection of the map.
set_flip(self, flipconv)	flipconv is either 'astro' or 'geo'.
vec2xy(self, vx[, vy, vz, direct])	From angular direction to position in the projection plane (Gnomonic).
xy2ang(self, x[, y, lonlat, direct])	From position in the projection plane to angular direction (Gnomonic).
xy2ij(self, x[, y])	From position in the projection plane to image array index (Gnomonic).
xy2vec(self, x[, y, direct])	From position in the projection plane to unit vector direction (Gnomonic).

healpy.projector.GnomonicProj.ang2xy

GnomonicProj.**ang2xy**(*self*, *theta*, *phi=None*, *lonlat=False*, *direct=False*)

From angular direction to position in the projection plane (Gnomonic).

Input:

- theta: if phi is None, theta[0] contains theta, theta[1] contains phi

- phi : if phi is not None, theta,phi are direction
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Gnomonic plane.

healpy.projector.GnomonicProj.get_center

GnomonicProj.**get_center**(*self*, *lonlat=False*)

Get the center of the projection.

Input:

- **lonlat** [if True, will return longitude and latitude in degree,] otherwise, theta and phi in radian

Return:

- theta,phi or lonlat depending on lonlat keyword

healpy.projector.GnomonicProj.get_extent

GnomonicProj.**get_extent**(*self*)

Get the extension of the projection plane.

Return: extent = (left,right,bottom,top)

healpy.projector.GnomonicProj.get_fov

GnomonicProj.**get_fov**(*self*)

Get the field of view in degree of the plane of projection

Return: fov: the diameter in radian of the field of view

healpy.projector.GnomonicProj.ij2xy

GnomonicProj.**ij2xy**(*self*, *i=None*, *j=None*)

From image array indices to position in projection plane (Gnomonic).

Input:

- if i and j are None, generate arrays of i and j as input
- i : if j is None, i[0], j[1] define array indices in Gnomonic image.
- j : if defined, i,j define array indices in image.
- projinfo : additional projection information.

Return:

- x,y : position in projection plane.

healpy.projector.GnomonicProj.projmap

GnomonicProj.**projmap**(*self*, *map*, *vec2pix_func*, *rot=None*, *coord=None*)
Create an array containing the projection of the map.

Input:

- vec2pix_func: a function taking theta,phi and returning pixel number
- **map: an array containing the spherical map to project,** the pixelisation is described by vec2pix_func

Return:

- a 2D array with the projection of the map.

Note: the Projector must contain information on the array.

healpy.projector.GnomonicProj.set_flip

GnomonicProj.**set_flip**(*self*, *flipconv*)
flipconv is either 'astro' or 'geo'. None will be default.

With 'astro', east is toward left and west toward right. It is the opposite for 'geo'

healpy.projector.GnomonicProj.vec2xy

GnomonicProj.**vec2xy**(*self*, *vx*, *vy=None*, *vz=None*, *direct=False*)
From angular direction to position in the projection plane (Gnomonic).

Input:

- theta: if phi is None, theta[0] contains theta, theta[1] contains phi
- phi : if phi is not None, theta,phi are direction
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Gnomonic plane.

healpy.projector.GnomonicProj.xy2ang

GnomonicProj.**xy2ang**(*self*, *x*, *y=None*, *lonlat=False*, *direct=False*)
From position in the projection plane to angular direction (Gnomonic).

Input:

- x : if y is None, x[0], x[1] define the position in Gnomonic plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

healpy.projector.GnomonicProj.xy2ij

GnomonicProj.**xy2ij**(*self*, *x*, *y=None*)

From position in the projection plane to image array index (Gnomonic).

Input:

- x : if y is None, x[0], x[1] define the position in Gnomonic plane.
- y : if defined, x,y define the position in projection plane.
- projinfo : additional projection information.

Return:

- i,j : image array indices.

healpy.projector.GnomonicProj.xy2vec

GnomonicProj.**xy2vec**(*self*, *x*, *y=None*, *direct=False*)

From position in the projection plane to unit vector direction (Gnomonic).

Input:

- x : if y is None, x[0], x[1] define the position in Gnomonic plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

get_proj_plane_info	
mkcoord	
set_proj_plane_info	

healpy.projector.MollweideProj

class healpy.projector.**MollweideProj**(*rot=None*, *coord=None*, *xsize=800*, ***kwds*)

This class provides class methods for Mollweide projection.

Attributes

arrayinfo Dictionary with information on the projection array

Methods

ang2xy(self, theta[, phi, lonlat, direct])	From angular direction to position in the projection plane (Mollweide).
get_center(self[, lonlat])	Get the center of the projection.

Continued on next page

Table 26 – continued from previous page

get_extent(self)	Get the extension of the projection plane.
get_fov(self)	Get the field of view in degree of the plane of projection
ij2xy(self[, i, j])	From image array indices to position in projection plane (Mollweide).
projmap(self, map, vec2pix_func[, rot, coord])	Create an array containing the projection of the map.
set_flip(self, flipconv)	flipconv is either 'astro' or 'geo'.
vec2xy(self, vx[, vy, vz, direct])	From unit vector direction to position in the projection plane (Mollweide).
xy2ang(self, x[, y, lonlat, direct])	From position in the projection plane to angular direction (Mollweide).
xy2ij(self, x[, y])	From position in the projection plane to image array index (Mollweide).
xy2vec(self, x[, y, direct])	From position in the projection plane to unit vector direction (Mollweide).

healpy.projector.MollweideProj.ang2xy

MollweideProj.**ang2xy**(*self*, *theta*, *phi=None*, *lonlat=False*, *direct=False*)

From angular direction to position in the projection plane (Mollweide).

Input:

- theta: if phi is None, theta[0] contains theta, theta[1] contains phi
- phi : if phi is not None, theta,phi are direction
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Mollweide plane.

healpy.projector.MollweideProj.get_center

MollweideProj.**get_center**(*self*, *lonlat=False*)

Get the center of the projection.

Input:

- **lonlat** [if True, will return longitude and latitude in degree,] otherwise, theta and phi in radian

Return:

- theta,phi or lonlat depending on lonlat keyword

healpy.projector.MollweideProj.get_extent

MollweideProj.**get_extent**(*self*)

Get the extension of the projection plane.

Return: extent = (left,right,bottom,top)

healpy.projector.MollweideProj.get_fov

MollweideProj.**get_fov**(*self*)
Get the field of view in degree of the plane of projection

Return: fov: the diameter in radian of the field of view

healpy.projector.MollweideProj.ij2xy

MollweideProj.**ij2xy**(*self*, *i=None*, *j=None*)
From image array indices to position in projection plane (Mollweide).

Input:

- if i and j are None, generate arrays of i and j as input
- i : if j is None, i[0], j[1] define array indices in Mollweide image.
- j : if defined, i,j define array indices in image.
- projinfo : additional projection information.

Return:

- x,y : position in projection plane.

healpy.projector.MollweideProj.projmap

MollweideProj.**projmap**(*self*, *map*, *vec2pix_func*, *rot=None*, *coord=None*)
Create an array containing the projection of the map.

Input:

- vec2pix_func: a function taking theta,phi and returning pixel number
- **map: an array containing the spherical map to project,** the pixelisation is described by vec2pix_func

Return:

- a 2D array with the projection of the map.

Note: the Projector must contain information on the array.

healpy.projector.MollweideProj.set_flip

MollweideProj.**set_flip**(*self*, *flipconv*)
flipconv is either 'astro' or 'geo'. None will be default.

With 'astro', east is toward left and west toward right. It is the opposite for 'geo'

healpy.projector.MollweideProj.vec2xy

MollweideProj.**vec2xy**(*self*, *vx*, *vy=None*, *vz=None*, *direct=False*)
From unit vector direction to position in the projection plane (Mollweide).

Input:

- vx: if vy and vz are None, vx[0],vx[1],vx[2] defines the unit vector.
- vy,vz: if defined, vx,vy,vz define the unit vector
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Mollweide plane.

healpy.projector.MollweideProj.xy2ang

MollweideProj.**xy2ang**(*self*, *x*, *y=None*, *lonlat=False*, *direct=False*)
From position in the projection plane to angular direction (Mollweide).

Input:

- x : if y is None, x[0], x[1] define the position in Mollweide plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

healpy.projector.MollweideProj.xy2ij

MollweideProj.**xy2ij**(*self*, *x*, *y=None*)
From position in the projection plane to image array index (Mollweide).

Input:

- x : if y is None, x[0], x[1] define the position in Mollweide plane.
- y : if defined, x,y define the position in projection plane.
- projinfo : additional projection information.

Return:

- i,j : image array indices.

healpy.projector.MollweideProj.xy2vec

MollweideProj.**xy2vec**(*self*, *x*, *y=None*, *direct=False*)
From position in the projection plane to unit vector direction (Mollweide).

Input:

- x : if y is None, x[0], x[1] define the position in Mollweide plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

get_proj_plane_info	
mkcoord	
set_proj_plane_info	

healpy.projector.CartesianProj

class healpy.projector.**CartesianProj**(*rot=None*, *coord=None*, *xsize=800*, *ysize=None*, *lonra=None*, *latra=None*, ***kwds*)

This class provides class methods for Cartesian projection.

Attributes

arrayinfo Dictionary with information on the projection array

Methods

ang2xy(self, theta[, phi, lonlat, direct])	From angular direction to position in the projection plane (Cartesian).
get_center(self[, lonlat])	Get the center of the projection.
get_extent(self)	Get the extension of the projection plane.
get_fov(self)	Get the field of view in degree of the plane of projection
ij2xy(self[, i, j])	From image array indices to position in projection plane (Cartesian).
projmap(self, map, vec2pix_func[, rot, coord])	Create an array containing the projection of the map.
set_flip(self, flipconv)	flipconv is either 'astro' or 'geo'.
vec2xy(self, vx[, vy, vz, direct])	From unit vector direction to position in the projection plane (Cartesian).
xy2ang(self, x[, y, lonlat, direct])	From position in the projection plane to angular direction (Cartesian).
xy2ij(self, x[, y])	From position in the projection plane to image array index (Cartesian).
xy2vec(self, x[, y, direct])	From position in the projection plane to unit vector direction (Cartesian).

healpy.projector.CartesianProj.ang2xy

CartesianProj.**ang2xy**(*self*, *theta*, *phi=None*, *lonlat=False*, *direct=False*)

From angular direction to position in the projection plane (Cartesian).

Input:

- theta: if phi is None, theta[0] contains theta, theta[1] contains phi
- phi : if phi is not None, theta,phi are direction
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Cartesian plane.

healpy.projector.CartesianProj.get_center

CartesianProj.**get_center**(*self*, *lonlat=False*)
Get the center of the projection.

Input:

- **lonlat** [if True, will return longitude and latitude in degree,] otherwise, theta and phi in radian

Return:

- theta,phi or lonlat depending on lonlat keyword

healpy.projector.CartesianProj.get_extent

CartesianProj.**get_extent**(*self*)
Get the extension of the projection plane.

Return: extent = (left,right,bottom,top)

healpy.projector.CartesianProj.get_fov

CartesianProj.**get_fov**(*self*)
Get the field of view in degree of the plane of projection

Return: fov: the diameter in radian of the field of view

healpy.projector.CartesianProj.ij2xy

CartesianProj.**ij2xy**(*self*, *i=None*, *j=None*)
From image array indices to position in projection plane (Cartesian).

Input:

- if i and j are None, generate arrays of i and j as input
- i : if j is None, i[0], j[1] define array indices in Cartesian image.
- j : if defined, i,j define array indices in image.
- projinfo : additional projection information.

Return:

- x,y : position in projection plane.

healpy.projector.CartesianProj.projmap

CartesianProj.**projmap**(*self*, *map*, *vec2pix_func*, *rot=None*, *coord=None*)
Create an array containing the projection of the map.

Input:

- vec2pix_func: a function taking theta,phi and returning pixel number

- **map: an array containing the spherical map to project,** the pixelisation is described by vec2pix_func

Return:

- a 2D array with the projection of the map.

Note: the Projector must contain information on the array.

healpy.projector.CartesianProj.set_flip

CartesianProj.**set_flip**(*self*, *flipconv*)
flipconv is either 'astro' or 'geo'. None will be default.

With 'astro', east is toward left and west toward right. It is the opposite for 'geo'

healpy.projector.CartesianProj.vec2xy

CartesianProj.**vec2xy**(*self*, *vx*, *vy=None*, *vz=None*, *direct=False*)
From unit vector direction to position in the projection plane (Cartesian).

Input:

- vx: if vy and vz are None, vx[0],vx[1],vx[2] defines the unit vector.
- vy,vz: if defined, vx,vy,vz define the unit vector
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- x, y: position in Cartesian plane.

healpy.projector.CartesianProj.xy2ang

CartesianProj.**xy2ang**(*self*, *x*, *y=None*, *lonlat=False*, *direct=False*)
From position in the projection plane to angular direction (Cartesian).

Input:

- x : if y is None, x[0], x[1] define the position in Cartesian plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

healpy.projector.CartesianProj.xy2ij

CartesianProj.**xy2ij**(*self*, *x*, *y=None*)
From position in the projection plane to image array index (Cartesian).

Input:

- x : if y is None, x[0], x[1] define the position in Cartesian plane.
- y : if defined, x,y define the position in projection plane.
- projinfo : additional projection information.

Return:

- i,j : image array indices.

healpy.projector.CartesianProj.xy2vec

CartesianProj.**xy2vec**(*self*, *x*, *y=None*, *direct=False*)

From position in the projection plane to unit vector direction (Cartesian).

Input:

- x : if y is None, x[0], x[1] define the position in Cartesian plane.
- y : if defined, x,y define the position in projection plane.
- lonlat: if True, angle are assumed in degree, and longitude, latitude
- flipconv is either 'astro' or 'geo'. None will be default.

Return:

- theta, phi : angular direction.

get_proj_plane_info	
mkcoord	
set_proj_plane_info	

3.8 zoomtool – Interactive visualisation

3.8.1 Interactive map visualization

mollzoom([map, fig, rot, coord, unit, ...])	Interactive mollweide plot with zoomed gnomview.

healpy.zoomtool.mollzoom

healpy.zoomtool.**mollzoom**(*map=None*, *fig=None*, *rot=None*, *coord=None*, *unit=''*, *xsize=800*, *title='Mollweide view'*, *nest=False*, *min=None*, *max=None*, *flip='astro'*, *remove_dip=False*, *remove_mono=False*, *gal_cut=0*, *format='%g'*, *cmap=None*, *norm=None*, *hold=False*, *margins=None*, *sub=None*)

Interactive mollweide plot with zoomed gnomview.

CHAPTER

FOUR

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- search

4.1 License

4.1.1 Licenses

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