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# healpy Documentation

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## 1.1 Healpy tutorial

### 1.1.1 Creating and manipulating maps

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 IPython:

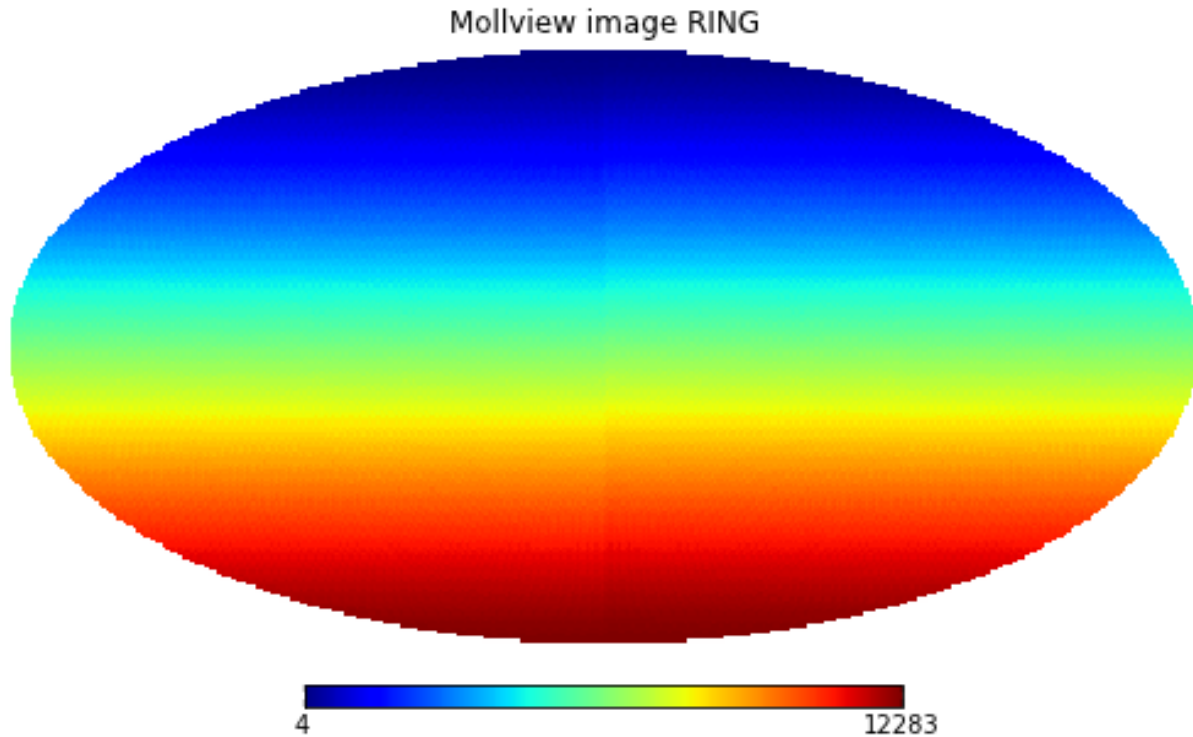
```
% ipython
```

...then select the appropriate backend display:

```
>>> %matplotlib inline # for IPython notebook
>>> %matplotlib qt     # using Qt (e.g. Windows)
>>> %matplotlib osx    # on Macs
>>> %matplotlib gtk    # GTK
```

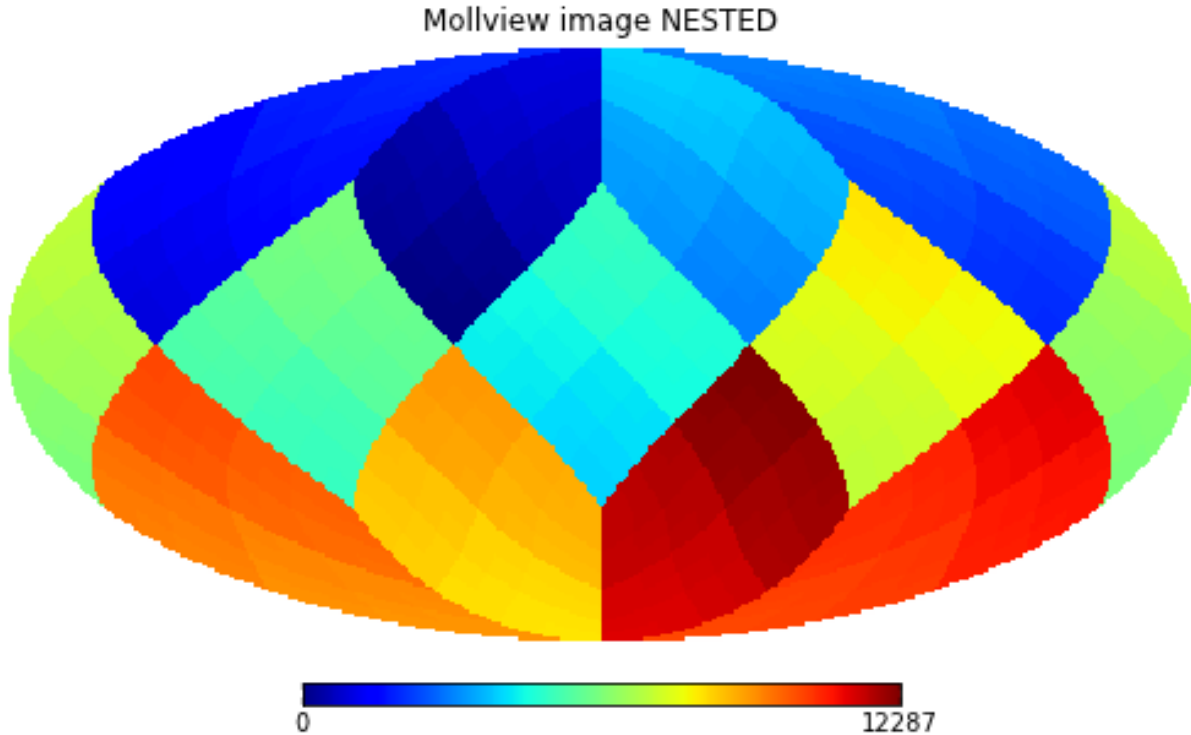
The resolution of the map is defined by the *NSIDE* parameter. The *nside2npix()* function gives the number of pixel *NPIX* of the map:

```
>>> import numpy as np
>>> import healpy as hp
>>> NSIDE = 32
>>> m = np.arange(hp.nside2npix(NSIDE))
>>> hp.mollview(m, title="Mollview image RING")
```



Healpix supports two different ordering schemes, *RING* or *NESTED*. By default, healpy maps are in *RING* ordering. In order to work with *NESTED* ordering, all map related functions support the *nest* keyword, for example:

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



### 1.1.2 Reading and writing maps to file

Maps are read with the `read_map()` function:

```
>>> wmap_map_I = hp.read_map('../healpy/test/data/wmap_band_imap_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:

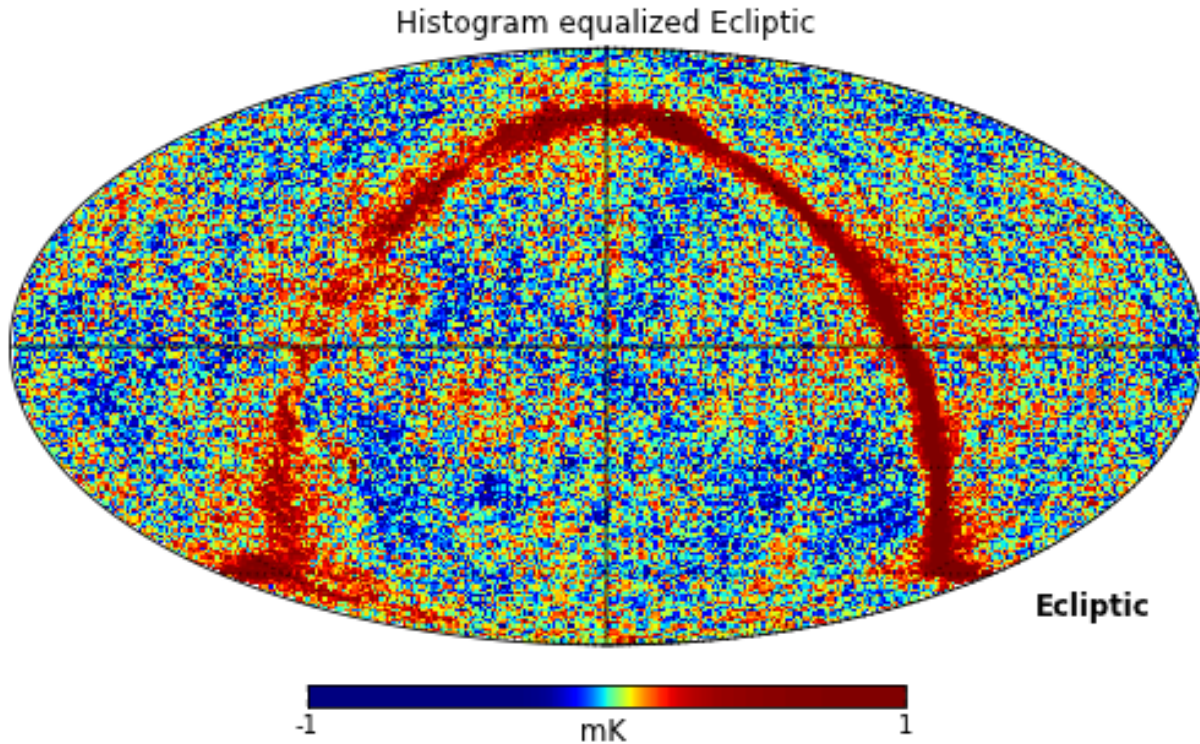
```
>>> hp.write_map("my_map.fits", wmap_map_I)
```

### 1.1.3 Visualization

Mollweide projection with `mollview()` is the most common visualization tool for HEALPIX maps. It also supports coordinate transformation:

```
>>> hp.mollview(wmap_map_I, coord=['G','E'], title='Histogram equalized Ecliptic',
↳ unit='mK', norm='hist', min=-1,max=1, xsize=2000)
>>> hp.graticule()
```

`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.



`gnomview()` instead provides gnomonic projection around a position specified by `rot`:

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

shows a projection of the galactic center, `xsize` and `ysize` change the dimension of the sky patch.

`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.

### 1.1.4 Masked map, partial maps

By convention, HEALPIX uses  $-1.6375e+30$  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 that sections of a map.

There is an alternative way of dealing with UNSEEN pixel based on the numpy MaskedArray class, `ma()` loads a map as a masked array:

```
>>> mask = hp.read_map('../healpy/test/data/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)
```

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.

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



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:

```
>>> import matplotlib.pyplot as plt
>>> plt.hist(wmap_map_I_masked.compressed(), bins = 1000)
```

## 1.1.5 Spherical harmonic transforms

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

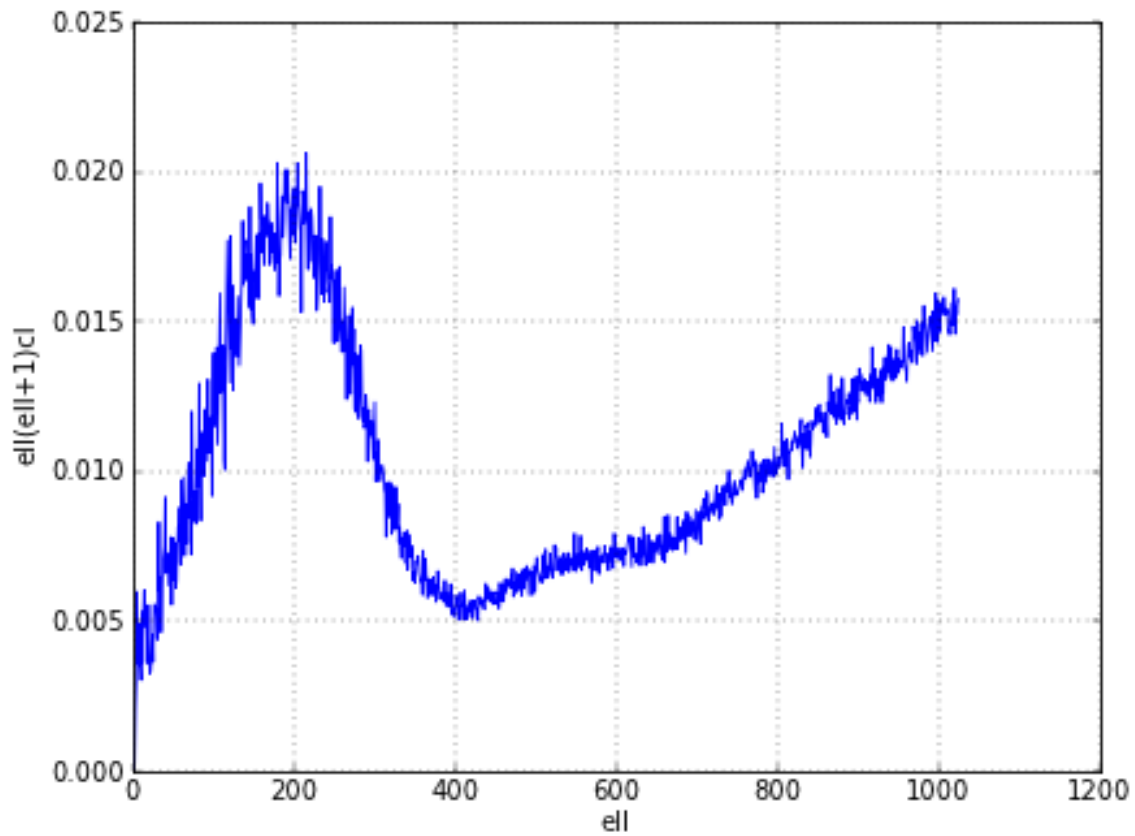
```
>>> LMAX = 1024
>>> cl = hp.anafast(wmap_map_I_masked.filled(), lmax=LMAX)
```

the relative *ell* array is just:

```
>>> ell = np.arange(len(cl))
```

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

```
>>> plt.figure()
>>> plt.plot(ell, ell * (ell+1) * cl)
>>> plt.xlabel('ell'); plt.ylabel('ell(ell+1)cl'); plt.grid()
>>> hp.write_cl('cl.fits', cl)
```



Gaussian beam map smoothing is provided by `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')
```

## 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
```

### 2.1.4 Installation on Mac OS with MacPorts

If you are using a Mac and have the [MacPorts](#) package manager, it's even easier 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 \(utopic\)](#).

## 2.1.5 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
```

## 2.1.6 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.

## 2.1.7 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`.

## 2.1.8 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
```



## 3.1 pixelfunc – Pixelisation related functions

### 3.1.1 conversion from/to sky coordinates

<code>pix2ang(nside, ipix[, nest, lonlat])</code>	<code>pix2ang</code> : <code>nside, ipix, nest=False, lonlat=False</code> -> <code>theta[rad], phi[rad]</code> (default RING)
<code>pix2vec(nside, ipix[, nest])</code>	<code>pix2vec</code> : <code>nside, ipix, nest=False</code> -> <code>x, y, z</code> (default RING)
<code>ang2pix(nside, theta, phi[, nest, lonlat])</code>	<code>ang2pix</code> : <code>nside, theta[rad], phi[rad], nest=False, lonlat=False</code> -> <code>ipix</code> (default:RING)
<code>vec2pix(nside, x, y, z[, nest])</code>	<code>vec2pix</code> : <code>nside, x, y, z, nest=False</code> -> <code>ipix</code> (default:RING)
<code>vec2ang(vectors[, lonlat])</code>	<code>vec2ang</code> : <code>vectors [x, y, z]</code> -> <code>theta[rad], phi[rad]</code>
<code>ang2vec(theta, phi[, lonlat])</code>	<code>ang2vec</code> : convert angles to 3D position vector
<code>get_all_neighbours(nside, theta[, phi, ...])</code>	Return the 8 nearest pixels.
<code>get_interp_weights(nside, theta[, phi, ...])</code>	Return the 4 closest pixels on the two rings above and below the location and corresponding weights.
<code>get_interp_val(m, theta, phi[, nest, lonlat])</code>	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 longitude and co-latitude 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

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

```
>>> hp.ang2pix(16, [np.pi/2, np.pi/4, np.pi/2, 0, np.pi], [0., np.pi/4, np.pi/2,
↪0, 0])
array([1440,  427, 1520,    0, 3068])
```

```
>>> hp.ang2pix(16, np.pi/2, [0, np.pi/2])
array([1440, 1520])
```

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

```
>>> hp.ang2pix([1, 2, 4, 8, 16], 0, 0, lonlat=True)
array([ 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
```

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

```
>>> hp.vec2pix([1, 2, 4, 8], 1, 0, 0)
array([ 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 longitude and co-latitude 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 array-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
>>> hp.get_all_neighbours(1, 4)
array([11,  7,  3, -1,  0,  5,  8, -1])
```

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

```
>>> hp.get_all_neighbours(1, 90, 0, lonlat=True)
array([ 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**

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

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

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

```
>>> hp.get_interp_weights(1, [0, np.pi/2], 0)
(array([[ 1,  4],
       [ 2,  5],
       [ 3, 11],
       [ 0,  8]]), array([[ 0.25,  1.  ],
       [ 0.25,  0.  ],
       [ 0.25,  0.  ],
       [ 0.25,  0.  ]]))
```

### 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 array-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

<code>nest2ring(nside, ipix)</code>	Convert pixel number from NESTED ordering to RING ordering.
<code>ring2nest(nside, ipix)</code>	Convert pixel number from RING ordering to NESTED ordering.
<code>reorder(map_in, *args, **kwds)</code>	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
```

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

```
>>> hp.nest2ring([1, 2, 4, 8], 11)
array([ 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
```

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

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

## healpy.pixelfunc.reorder

healpy.pixelfunc.**reorder** (*map\_in*, \*args, \*\*kwds)

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)

>>> 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  True False False False False False False False]
 [False False  True False False False False False False False]],
            fill_value = -1.6375e+30)
```

### 3.1.3 nside/npix/resolution

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

Continued on next page



Table 3.3 – continued from previous page

<code>mctype(m)</code>	Describe the type of the map (valid, single, sequence of maps).
<code>ud_grade(map_in, *args, **kws)</code>	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` : inthealpix 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
```

```
>>> hp.order2nside(np.arange(8))
array([ 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*)

Maximum angular distance between any pixel center and its corners

**Parameters** *nside* : int

the nside to work with

**Returns** rads: double  
angular distance (in radians)

### Examples

```
>>> '%.15f' % max_pixrad(1)
'0.841068670567930'
>>> '%.15f' % max_pixrad(16)
'0.066014761432513'
```

### healpy.pixelfunc.isinsideok

healpy.pixelfunc.**isinsideok** (*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.isinsideok(13, nest=True)
False
```

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

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

```
>>> hp.isinsideok([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) pixelization

**Returns** npix : int

a valid number of pixel

## Notes

In implicit pixelization, 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  $12 * nside ** 2 \geq npix$

**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.maptypes(np.arange(12))
0
>>> hp.pixelfunc.maptypes([np.arange(12), np.arange(12)])
2
```

### healpy.pixelfunc.ud\_grade

healpy.pixelfunc.ud\_grade(*map\_in*, \**args*, \*\**kwds*)

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)

**peers** : 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

<i>UNSEEN</i>	Special value used for masked pixels
<i>mask_bad</i> ( <i>m</i> [, <i>badval</i> , <i>rtol</i> , <i>atol</i> ])	Returns a bool array with True where <i>m</i> is close to <i>badval</i> .
Continued on next page	



Table 3.4 – continued from previous page

<code>mask_good(m[, badval, rtol, atol])</code>	Returns a bool array with <code>False</code> where <code>m</code> is close to <code>badval</code> .
<code>ma(m[, badval, rtol, atol, copy])</code>	Return <code>map</code> as a masked array, with <code>badval</code> 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],
             fill_value = -1.6375e+30)
```

### 3.1.5 Map data manipulation

<code>fit_dipole(m[, nest, bad, gal_cut])</code>	Fit a dipole and a monopole to the map, excluding bad pixels.
<code>fit_monopole(m[, nest, bad, gal_cut])</code>	Fit a monopole to the map, excluding unseen pixels.
<code>remove_dipole(m[, nest, bad, gal_cut, ...])</code>	Fit and subtract the dipole and the monopole from the given map m.
<code>remove_monopole(m[, nest, bad, gal_cut, ...])</code>	Fit and subtract the monopole from the given map m.
<code>get_interp_val(m, theta, phi[, nest, lonlat])</code>	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

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

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:  $3 * \text{nside} - 1$ )

**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

**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*)

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:  $3 * \text{nside} - 1$

**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

**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

<code>synfast</code> (cls, nside[, lmax, mmax, alm, pol, ...])	Create a map(s) from cl(s).
<code>alm2map</code> (alms, nside[, lmax, mmax, pixwin, ...])	Computes a Healpix map given the alm.
<code>alm2map_der1</code> (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(alm, 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** **alm** : 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 corresponding 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

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

#### healpy.sphtfunc.smoothing

`healpy.sphtfunc.smoothing` (*map\_in*, \*args, \*\*kws)

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.

**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\*inside-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.

**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, *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]

**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  $\langle alm \times alm2 \rangle$  if *alm* (and *alm2*) is one alm, or the auto- and cross-spectra  $\langle alm*[i] \times *alm2*[j] \rangle$  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(inside, pol=False)

Return the pixel window function for the given inside.

**Parameters** inside : int

The inside for which to return the pixel window function

pol : bool, optional

If True, return also the polar pixel window. Default: False

**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

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

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<i>gauss_beam</i> (fwhm[, lmax, pol])	Gaussian beam window function
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#### healpy.sphtfunc.gauss\_beam

healpy.sphtfunc.**gauss\_beam** (*fwhm*, *lmax*=512, *pol*=False)

Gaussian beam window function

Computes the spherical transform of an axisymmetric gaussian beam

For a sky of underlying power spectrum  $C(l)$  observed with beam of given FWHM, the measured power spectrum will be  $C(l)_{\text{meas}} = C(l) B(l)^2$  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

## 3.3 visufunc – Visualisation

### 3.3.1 Map projections

---

<i>mollview</i> ([map, fig, rot, coord, unit, ...])	Plot a healpix map (given as an array) in Mollweide projection.
<i>gnomview</i> ([map, fig, rot, coord, unit, ...])	Plot a healpix map (given as an array) in Gnomonic projection.
<i>cartview</i> ([map, fig, rot, zat, coord, unit, ...])	Plot a healpix map (given as an array) in Cartesian projection.
<i>orthview</i> ([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, notext=False,
                        norm=None, hold=False, margins=None, sub=None, nlocs=2, re-
                        turn_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)

**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='%0.3g', cbar=True, cmap=None, norm=None, hold=False, sub=None, margins=None, notext=False, return\_projected\_map=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 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'

**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

if True returns the projected map in a 2d numpy array

**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, 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 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'

**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)

**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*, *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)

**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

---

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

---

## healpy.visufunc.graticule

`healpy.visufunc.graticule` (*dpar=None, dmer=None, coord=None, local=None, \*\*kws*)

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

<code>projplot(*args, **kws)</code>	<code>projplot</code> is a wrapper around <code>matplotlib.Axes.plot()</code> to take into account the
<code>projscatter(*args, **kws)</code>	<code>Projscatter</code> is a wrapper around <code>matplotlib.Axes.scatter()</code> to take into account the spherical projection.
<code>projtext(*args, **kws)</code>	<code>Projtext</code> is a wrapper around <code>matplotlib.Axes.text()</code> to take into account the spherical projection.

## healpy.visufunc.projplot

`healpy.visufunc.projplot` (*\*args, \*\*kws*)

`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(theta, phi) # plot a line going through points at coord_
→ (theta[0], theta[1])
projplot(theta, phi, '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 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, **kws)`

`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(theta, phi) # plot points at coord (theta[0], theta[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, **kws)`

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

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

#### healpy.fitsfunc.read\_map

`healpy.fitsfunc.read_map(filename, field=0, dtype=<type '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

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`

**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=<type '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 we use: I\_STOKES for 1 component, I/Q/U\_STOKES for 3 components, II, IQ, IU, QQ, QU, UU for 6 components, COLUMN\_0, COLUMN\_1... otherwise

**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

<code>read_alm(filename[, hdu, return_mmax])</code>	Read alm from a fits file.
<code>write_alm(filename, alms[, out_dtype, lmax, ...])</code>	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  $index = m*(2*lmax + 1 - m)/2 + 1$ . The conversion is done in this function.

**Parameters filename :** str or HDUList or HDU

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  $l \leq lmax$  and  $m \leq mmax$ .

**Parameters filename :** str

The filename of the output fits file

**alms :** array, complex or list of arrays

A complex ndarray holding the alms,  $index = m*(2*lmax + 1 - m)/2 + 1$ , 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

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

#### healpy.fitsfunc.read\_cl

`healpy.fitsfunc.read_cl` (*filename*, *dtype*=<type 'numpy.float64'>, *h*=False)  
 Reads Cl from a healpix file, as IDL fits2cl.

**Parameters** **filename** : str or HDUList or HDU

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*=<type '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

<code>mrdfits(filename[, hdu])</code>	Read a table in a fits file.
<code>mwrfits(filename, data[, hdu, colnames, keys])</code>	Write columns to a fits file in a table extension.

### healpy.fitsfunc.mrdfits

`healpy.fitsfunc.mrdfits` (*filename*, *hdu=1*)

Read a table in a fits file.

**Parameters** **filename** : str or HDUList or HDU

The name of the fits file to read, or an HDUList or HDU instance.

**hdu** : int, optional

The header to read. Start at 0. Default: `hdu=1`

**Returns** **cols** : a list of arrays

A list of column data in the given header

### healpy.fitsfunc.mwrfits

`healpy.fitsfunc.mwrfits` (*filename*, *data*, *hdu=1*, *colnames=None*, *keys=None*)

Write columns to a fits file in a table extension.

**Parameters** **filename** : str

The fits file name

**data** : list of 1D arrays

A list of 1D arrays to write in the table

**hdu** : int, optional

The header where to write the data. Default: 1

**colnames** : list of str

The column names

**keys** : dict-like

A dictionary with keywords to write in the header

## 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

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

### 3.5.1 healpy.query\_disc

`healpy.query_disc` (*nside*, *vec*, *radius*, *inclusive=False*, *fact=4*, *nest=False*, *ndarray buff=None*)

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` (*nside*, *vertices*, *inclusive=False*, *fact=4*, *nest=False*, *ndarray buff=None*)

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` (*nside*, *theta1*, *theta2*, *inclusive=False*, *nest=False*, *ndarray buff=None*)

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` (*nside, pix, step=1, nest=False*)

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

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

<i>mat</i>	The matrix representing the rotation.
<i>coordin</i>	The input coordinate system.
<i>coordout</i>	The output coordinate system.
<i>coordinstr</i>	The input coordinate system in str.
<i>coordoutstr</i>	The output coordinate system in str.
<i>rots</i>	The sequence of rots defining the rotation.
<i>coords</i>	The sequence of coords defining the rotation.

## healpy.rotator.Rotator.mat

Rotator.**mat**

The matrix representing the rotation.

### healpy.rotator.Rotator.coordin

`Rotator.coordin`  
The input coordinate system.

### healpy.rotator.Rotator.coordout

`Rotator.coordout`  
The output coordinate system.

### healpy.rotator.Rotator.coordinstr

`Rotator.coordinstr`  
The input coordinate system in str.

### healpy.rotator.Rotator.coordoutstr

`Rotator.coordoutstr`  
The output coordinate system in str.

### healpy.rotator.Rotator.rots

`Rotator.rots`  
The sequence of rots defining the rotation.

### healpy.rotator.Rotator.coords

`Rotator.coords`  
The sequence of coords defining the rotation.

### Methods

<code>I(*args, **kws)</code>	Rotate the given vector or direction using the inverse matrix.
<code>__call__(*args, **kws)</code>	Use the rotator to rotate either spherical coordinates (theta, phi) or a vector (x,y,z).
<code>angle_ref(*args, **kws)</code>	Compute the angle between transverse reference direction of initial and final frames
<code>do_rot(i)</code>	Returns True if rotation is not (close to) identity.
<code>get_inverse()</code>	

### healpy.rotator.Rotator.I

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

### healpy.rotator.Rotator.\_\_call\_\_

`Rotator.__call__ (*args, **kwargs)`

Use the rotator to rotate either spherical coordinates (theta, phi) or a vector (x,y,z). You can use lonlat 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 (*args, **kwargs)`

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  $\psi + \text{angle\_ref}$  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 (i)`

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

### healpy.rotator.Rotator.get\_inverse

`Rotator.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, optional

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

<code>vec2dir(vec[, vy, vz, lonlat])</code>	Transform a vector to angle given by theta,phi.
<code>dir2vec(theta[, phi, lonlat])</code>	Transform a direction theta,phi to a unit vector.
<code>angdist(dir1, dir2[, lonlat])</code>	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, optional

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

<code>SphericalProj</code> ( <i>rot</i> , <i>coord</i> , <i>flipconv</i> )	This class defines functions for spherical projection.
<code>GnomonicProj</code> ( <i>rot</i> , <i>coord</i> , <i>xsize</i> , <i>ysize</i> , <i>reso</i> )	This class provides class methods for Gnomonic projection.
<code>MollweideProj</code> ( <i>rot</i> , <i>coord</i> , <i>xsize</i> )	This class provides class methods for Mollweide projection.
<code>CartesianProj</code> ( <i>rot</i> , <i>coord</i> , <i>xsize</i> , <i>ysize</i> , ...)	This class provides class methods for Cartesian projection.

### healpy.projector.SphericalProj

**class** `healpy.projector.SphericalProj` (*rot=None*, *coord=None*, *flipconv=None*, *\*\*kws*)

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

<code>arrayinfo</code>	Dictionary with information on the projection array
------------------------	---

### healpy.projector.SphericalProj.arrayinfo

SphericalProj.**arrayinfo**

Dictionary with information on the projection array

## Methods

<code>ang2xy(theta[, phi, lonlat, direct])</code>	From angular direction to position in the projection plane (%s).
<code>get_center([lonlat])</code>	Get the center of the projection.
<code>get_extent()</code>	Get the extension of the projection plane.
<code>get_fov()</code>	Get the field of view in degree of the plane of projection
<code>get_proj_plane_info()</code>	
<code>ij2xy([i, j])</code>	From image array indices to position in projection plane (%s).
<code>mkcoord(coord)</code>	
<code>projmap(map, vec2pix_func[, rot, coord])</code>	Create an array containing the projection of the map.
<code>set_flip(flipconv)</code>	flipconv is either 'astro' or 'geo'. None will be default.
<code>set_proj_plane_info(**kwds)</code>	
<code>vec2xy(vx[, vy, vz, direct])</code>	From unit vector direction to position in the projection plane (%s).
<code>xy2ang(x[, y, lonlat, direct])</code>	From position in the projection plane to angular direction (%s).
<code>xy2ij(x[, y])</code>	From position in the projection plane to image array index (%s).
<code>xy2vec(x[, y, direct])</code>	From position in the projection plane to unit vector direction (%s).

### healpy.projector.SphericalProj.ang2xy

SphericalProj.**ang2xy** (*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** (*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** ()

Get the extension of the projection plane.

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

**healpy.projector.SphericalProj.get\_fov**

SphericalProj.**get\_fov** ()

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.get\_proj\_plane\_info**

SphericalProj.**get\_proj\_plane\_info** ()

**healpy.projector.SphericalProj.ij2xy**

SphericalProj.**ij2xy** (*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.mkcoord**

SphericalProj.**mkcoord** (*coord*)

### healpy.projector.SphericalProj.projmap

SphericalProj.**projmap** (*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** (*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.set\_proj\_plane\_info

SphericalProj.**set\_proj\_plane\_info** (\*\**kws*)

### healpy.projector.SphericalProj.vec2xy

SphericalProj.**vec2xy** (*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** (*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** (*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** (*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.

### healpy.projector.GnomonicProj

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

This class provides class methods for Gnomonic projection.

#### Attributes

---

*arrayinfo*

Dictionary with information on the projection array

---

## healpy.projector.GnomonicProj.arrayinfo

GnomonicProj.**arrayinfo**

Dictionary with information on the projection array

### Methods

<code>ang2xy(theta[, phi, lonlat, direct])</code>	From angular direction to position in the projection plane (Gnomonic).
<code>get_center([lonlat])</code>	Get the center of the projection.
<code>get_extent()</code>	
<code>get_fov()</code>	
<code>get_proj_plane_info()</code>	
<code>ij2xy([i, j])</code>	From image array indices to position in projection plane (Gnomonic).
<code>mkcoord(coord)</code>	
<code>projmap(map, vec2pix_func[, rot, coord])</code>	Create an array containing the projection of the map.
<code>set_flip(flipconv)</code>	flipconv is either 'astro' or 'geo'. None will be default.
<code>set_proj_plane_info([xsize, ysize, reso])</code>	
<code>vec2xy(vx[, vy, vz, direct])</code>	From angular direction to position in the projection plane (Gnomonic).
<code>xy2ang(x[, y, lonlat, direct])</code>	From position in the projection plane to angular direction (Gnomonic).
<code>xy2ij(x[, y])</code>	From position in the projection plane to image array index (Gnomonic).
<code>xy2vec(x[, y, direct])</code>	From position in the projection plane to unit vector direction (Gnomonic).

## healpy.projector.GnomonicProj.ang2xy

GnomonicProj.**ang2xy** (*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** (*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** ()

### healpy.projector.GnomonicProj.get\_fov

GnomonicProj.**get\_fov** ()

### healpy.projector.GnomonicProj.get\_proj\_plane\_info

GnomonicProj.**get\_proj\_plane\_info** ()

### healpy.projector.GnomonicProj.ij2xy

GnomonicProj.**ij2xy** (*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.mkcoord

GnomonicProj.**mkcoord** (*coord*)

### healpy.projector.GnomonicProj.projmap

GnomonicProj.**projmap** (*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** (*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.set\_proj\_plane\_info

GnomonicProj.**set\_proj\_plane\_info** (*xsize=200, ysize=None, reso=1.5*)

### healpy.projector.GnomonicProj.vec2xy

GnomonicProj.**vec2xy** (*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** (*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** (*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:**

- *ij* : image array indices.

### healpy.projector.GnomonicProj.xy2vec

GnomonicProj.**xy2vec** (*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.

### healpy.projector.MollweideProj

**class** healpy.projector.**MollweideProj** (*rot=None*, *coord=None*, *xsize=800*, *\*\*kws*)

This class provides class methods for Mollweide projection.

#### Attributes

---

*arrayinfo*

Dictionary with information on the projection array

---

### healpy.projector.MollweideProj.arrayinfo

MollweideProj.**arrayinfo**

Dictionary with information on the projection array

#### Methods

<code>ang2xy(theta[, phi, lonlat, direct])</code>	From angular direction to position in the projection plane (Mollweide).
<code>get_center([lonlat])</code>	Get the center of the projection.
<code>get_extent()</code>	
<code>get_fov()</code>	Get the field of view in degree of the plane of projection
<code>get_proj_plane_info()</code>	
<code>ij2xy([i, j])</code>	From image array indices to position in projection plane (Mollweide).
<code>mkcoord(coord)</code>	
<code>projmap(map, vec2pix_func[, rot, coord])</code>	Create an array containing the projection of the map.
<code>set_flip(flipconv)</code>	flipconv is either 'astro' or 'geo'. None will be default.
<code>set_proj_plane_info(xsize)</code>	
<code>vec2xy(vx[, vy, vz, direct])</code>	From unit vector direction to position in the projection plane (Mollweide).
<code>xy2ang(x[, y, lonlat, direct])</code>	From position in the projection plane to angular direction (Mollweide).
<code>xy2ij(x[, y])</code>	From position in the projection plane to image array index (Mollweide).
<code>xy2vec(x[, y, direct])</code>	From position in the projection plane to unit vector direction (Mollweide).

### healpy.projector.MollweideProj.ang2xy

MollweideProj.**ang2xy** (*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** (*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()

### healpy.projector.MollweideProj.get\_fov

MollweideProj.get\_fov()

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.get\_proj\_plane\_info

MollweideProj.get\_proj\_plane\_info()

### healpy.projector.MollweideProj.ij2xy

MollweideProj.ij2xy(*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.mkcoord

MollweideProj.mkcoord(*coord*)

### healpy.projector.MollweideProj.projmap

MollweideProj.projmap(*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** (*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.set\_proj\_plane\_info

MollweideProj.**set\_proj\_plane\_info** (*xsize*)

### healpy.projector.MollweideProj.vec2xy

MollweideProj.**vec2xy** (*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** (*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** (*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** (*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.

**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

---

**healpy.projector.CartesianProj.arrayinfo**

CartesianProj.**arrayinfo**

Dictionary with information on the projection array

**Methods**

<i>ang2xy</i> (theta[, phi, lonlat, direct])	From angular direction to position in the projection plane (Cartesian).
<i>get_center</i> ([lonlat])	Get the center of the projection.
<i>get_extent</i> ()	Get the extension of the projection plane.
<i>get_fov</i> ()	
<i>get_proj_plane_info</i> ()	
<i>ij2xy</i> ([i, j])	From image array indices to position in projection plane (Cartesian).
<i>mkcoord</i> (coord)	

Continued on next page

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<code>projmap</code> (map, vec2pix_func[, rot, coord])	Create an array containing the projection of the map.
<code>set_flip</code> (flipconv)	flipconv is either ‘astro’ or ‘geo’. None will be default.
<code>set_proj_plane_info</code> (xsize, ysize, lonra, latra)	
<code>vec2xy</code> (vx[, vy, vz, direct])	From unit vector direction to position in the projection plane (Cartesian).
<code>xy2ang</code> (x[, y, lonlat, direct])	From position in the projection plane to angular direction (Cartesian).
<code>xy2ij</code> (x[, y])	From position in the projection plane to image array index (Cartesian).
<code>xy2vec</code> (x[, y, direct])	From position in the projection plane to unit vector direction (Cartesian).

### healpy.projector.CartesianProj.ang2xy

`CartesianProj.ang2xy` (*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` (*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` ()

Get the extension of the projection plane.

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

### healpy.projector.CartesianProj.get\_fov

`CartesianProj.get_fov` ()

**healpy.projector.CartesianProj.get\_proj\_plane\_info**

`CartesianProj.get_proj_plane_info()`

**healpy.projector.CartesianProj.ij2xy**

`CartesianProj.ij2xy` (*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.mkcoord**

`CartesianProj.mkcoord` (*coord*)

**healpy.projector.CartesianProj.projmap**

`CartesianProj.projmap` (*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` (*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.set\_proj\_plane\_info**

`CartesianProj.set_proj_plane_info` (*xsize, ysize, lonra, latra*)

### healpy.projector.CartesianProj.vec2xy

CartesianProj.**vec2xy** (*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** (*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** (*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** (*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.

## 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.





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### 4.1.1 Licenses

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