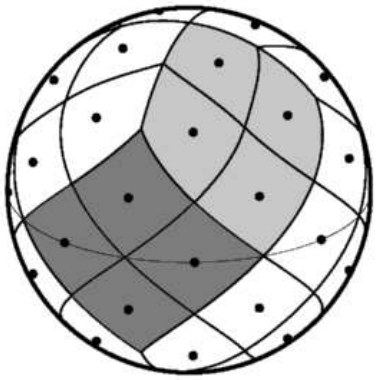
HEALPix IDL Facilities Overview



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Abstract: This document is an overview of the **HEALPix** IDL facilities.

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Using the HEALPix IDL facilities

The current version of the **HEALPix** package provides an IDL startup file which defines various environment variables for your convenience, and adds the **HEALPix** IDL directory tree to your `IDL_PATH`. In order to utilise this feature, the user should invoke IDL using the commands `hidl` or `hidlde` which are aliases defined in the **HEALPix** profile created during the installation process for the package.

Changes between release 2.0 and 2.1

Several routines have been added or improved since version 2.0, as listed below. Note that thanks to the newer `IDL-astron` library, FITS read/write routines in IDL-Healpix routines can now deal with **FITS files larger than 2GB** (on architectures supporting 64bit addressing).
Using 64 bit integers available since version 5.2 of IDL the maximum resolution parameter Nside supported has increased from $2^{13} = 8192$ to $2^{29} = 536870912$, corresponding to 3.46 10^{18} pixels on the sphere.

- New routines in version 2.1 include
  - `ximview`: visualisation routine developed by J. P. Leahy intended for quick-look inspection of HEALPix images (as well as ordinary 2-D images) at the level of individual pixels. Features include panning, zooming, blinking, image statistics and peak finding.
  - `hpx2gs`: turns a healpix data set into a Google Earth/Google Sky-compatible image
  - `ianafast`: interface to (F90) `anafast` and (C++) `anafast_cxx` facilities
  - `isynfast`: interface to F90 `synfast` facility
  - `ismoothing`: interface to F90 `smoothing` facility
  - `bin_llcl`: $C(l)$ binning
  - `bl2fits`: writes $B(l)$ or $W(l)$ window into FITS file
  - `neighbours_nest`, `neighbours_ring`: find immediate neighbours of a given pixel
  - `query_strip`: find pixels lying within a colatitude strip
- Routines with extended/improved user interface or new functionalities include
  - `mollview, gnomview, cartview, orthview`:
    - `ONLINE` keyword is now redundant,

    - introduction of `GLSIZE` and `IGLSIZE` to control automatic labeling of graticules, see Fig. 2 on page 78
    - addition of `SILENT` and `EXECUTE` keywords, see Fig. 2 on page 78
    - addition of `ASINH` keyword to allow better visualisation of highly contrasted maps; see Figure 3 on page 79,
    - under certain circumstances, can process high resolution cut sky data sets without creating full sky dummy maps,
    - accept gzip compressed FITS files,
    - accept polarized cut sky maps,
    - accept multi-dimensional online arrays,
    - more robust `OUTLINE` option.
  - `median_filter`: bugs correction
  - `ud_grade`: more robust user interface
  - `change_polcconv`: new `/FORCE` keyword
  - `remove_dipole`: more accurate
  - `query_disc`: when the disc center is located at one of the poles, *only* the pixels overlapping with the disc are now returned.
- Miscellaneous
  - `mollcursor, gnomcursor...`: an X11 patch is given so that these routines work under Mac OS X 10.4 and 10.5.

Changes between release 1.2 and 2.0

Some new routines have been introduced since version 1.2, as listed below. Most of the routines that already existed now have extended capabilities. Those of them with improved or extended user interface are listed below. They all remain backward compatible (ie, they can be used with codes written around version 1.1 and 1.2 without any edition).

- New routines in version 2.0 include
  - `median_filter`
  - `nside2templates`, `same_shape_pixels_ring`, `same_shape_pixels_nest`, `template_pixel_ring`, `template_pixel_nest`
  - `loaddata_healpix`: replaces loaddata to avoid conflict with other libraries
  - ...
- Routines with extended/improved user interface or new functionalities include

- `fits2cl`: addition of /RSHOW, /SHOW keywords to plot power spectra while they are read; possibility to read power spectra from a file containing a_{lm} coefficients.
- `gnomview`, `mollview`, `orthview`, `cartview` faster FITS file reading (by up to a factor 6); can deal with WMAP polarized maps FITS format; extension of the OUTLINE keyword to plot set of points; addition of the HBOUND keyword to overplot pixel boundaries; ...
- `read_tqu`, `read_fits_cut4`, `read_fits_map`: addition of output keywords NSIDE, ORDERING, COORDSYS
- `reorder`: simpler interface to ordering conversion with addition of /N2R and /R2N keywords
- write_tqu, write_fits_cut4, write_fits_sb: faster FITS file writing (by a factor 10 or more);
- ...

alm2fits

Location in HEALPix directory tree: src/idl/fits/alm2fits.pro

This IDL routine provides a means to write spherical harmonic coefficients (and optional errors) and their index label to a FITS file. Each signal is written to a separate binary table extension. The routine also writes header information if required. The facility is primarily designed to allow the user to write a FITS files containing constraints for a constrained realisation performed by the **HEALPix** facility **synfast**.

FORMAT

IDL> ALM2FITS, index, alm_array, fitsfile, [HDR = , XHDR =]

QUALIFIERS

index — Long array containing the index for the corresponding array of alm coefficients (and erralm if required). The index i is related to l, m by the relation
$i = \ell^2 + \ell + m + 1$

alm_array — Real array of alm coefficients written to the file. This has dimension (nl,nalm,nsig) – corresponding to
nl = number of l,m indices
nalm = 2 for real and imaginary parts of alm coefficients or 4 for above plus corresponding error values
nsig = number of signals to be written (1 for any of T E B or 3 if ALL to be written). Each signal is stored in a separate extension.

fitsfile — String containing the name of the file to be written.

KEYWORDS

HDR = — String array containing the primary header for the FITS file.

XHDR = String array containing the extension header. If ALL signals are required, then each extension table is given this header.

NOTE: optional header strings should NOT include the header keywords explicitly written by this routine.

DESCRIPTION

alm2fits writes the input alm coefficients (and associated errors if required) into a FITS file. Each signal type is written as a separate binary table extension. Optional headers conforming to the FITS convention can also be written to the output file. All required FITS header keywords are automatically generated by the routine and should NOT be duplicated in the optional header inputs. The keywords EXTNAME and TTYPE* are now also automatically generated.

RELATED ROUTINES

This section lists the routines related to **alm2fits**.

idl	version 6.0 or more is necessary to run alm2fits.
fits2alm	provides the complimentary routine to read in alm coefficients from a FITS file.
lm2index	converts the alm order and degree (ℓ, m) into the index $i = \ell^2 + \ell + m + 1$ required by alm2fits.
cl2fits	routine to write a power spectrum into a FITS file.
fits2cl	routine to read/compute $C(l)$ power spectra from a file containing $C(l)$ or a_{lm} coefficients
alteralm	utilises the output file generated by alm2fits.
synfast	utilises the output file generated by alm2fits.

EXAMPLE:

```
alm2fits, index, alm, 'alm.fits', HDR = hdr, XHDR = xhdr
```

alm2fits writes the coefficients stored in the variable `alm` to the output FITS file `alm.fits` with optional headers passed by the string variables `hdr` and `xhdr`.

ang2vec

Location in HEALPix directory tree: src/idl/toolkit/ang2vec.pro

This IDL facility convert the position angles of points on the sphere into their 3D position vectors.

FORMAT

IDL> ANG2VEC , Theta, Phi, Vector [, ASTRO=]

QUALIFIERS

Theta — input: scalar or vector,
colatitude in radians measured southward from north pole (in [0,π]).
If ASTRO is set, Theta is the latitude in degrees measured northward from the equator (in [-90, 90]).

Phi — input: scalar or vector of same size as Theta,
longitude in radians measured eastward (in [0, 2π]).
If ASTRO is set, it is the longitude in degree measured eastward (in [0,360]).

Vector — output : array,
three dimensional cartesian position vector (x, y, z) normalised to unity. The north pole is $(0, 0, 1)$. The coordinates are ordered as follows $x(0), \ldots, x(n-1)$, $y(0), \ldots, y(n-1)$, $z(0), \ldots, z(n-1)$

KEYWORDS

ASTRO = — if set Theta and Phi are the latitude and longitude in degrees instead of the colatitude and longitude in radians.

DESCRIPTION ang2vec performs the geometrical transform from the position angles of points (θ, ϕ) into their position vectors (x, y, z): $x = \sin\theta\cos\phi$, $y = \sin\theta\sin\phi$, $z = \cos\theta$

RELATED ROUTINES

This section lists the routines related to **ang2vec** .

idl	version 6.0 or more is necessary to run ang2vec .
pix2xxx, ...	conversion between vector or angles and pixel index
vec2ang	conversion from position vectors to angles

EXAMPLE:

```
lat = -45 ; latitude in degrees
long = 120 ; longitude in degrees
ang2vec, lat, lon, /astro, vec
```

will return in `vec` the 3D cartesian position vector of the point of latitude -45 deg and longitude 120 deg

bin_llcl

Location in HEALPix directory tree: src/idl/misc/bin_llcl.pro

This IDL facility provides a means to bin an angular power spectrum into arbitrary bins.

FORMAT

IDL> BIN_LLCL, Llcl_in, Bin, L_out, Llcl_out, [Dllcl, DELTAL=, /FLATTEN, /HELP, /UNIFORM]

QUALIFIERS

Llcl_in — 1D vector: **input** power spectrum (given for each l starting at 0).

Bin — **input**: binning in l to be applied,
–either a scalar interpreted as the step size of a regular binning, the first bins are then {0, `bin` - 1},{`bin`, 2`bin`-1}, ...
–or a 1D vector, interpreted as the lower bound of each bin, ie the first bins are {bin[0],bin[1]-1}, {bin[1], bin[2]-1}, ...

L_out — contains on **output** the center of each bin l_b.

Llcl_out — contains on **output** the binned power spectrum $C(b)$, ie the (weighted) average of the input $C(l)$ over each bin.

Dllcl — **optional**, contains on **output** a rough estimate of the rms of the binned C(l) for a full sky observation $C(b)\sqrt{2/((2l_b+1)\Delta l_b)}$

DELTAL= — **optional**, contains on **output** the size of each bin $\Delta l(b)$

KEYWORDS

/FLATTEN — if set, the $C(l)$ is internally multiplied by $l(l+1)/2\pi$ before being binned.
By default, the input `Llcl_in` is binned as is.

/HELP	if set, an extended help is printed and the code exits.
/UNIFORM	if set, the $C(l)$ in each bin is given the same weight. By default a weight $\propto 2l+1$ is used (inverse cosmic variance weighting). Note that this weighting affects `Llcl_out` but not `L_out`.

DESCRIPTION

bin_llcl bins the input power spectrum (as is, or after flattening by a $l(l+1)/2\pi$ factor) according to an arbitrary binning scheme defined by the user. Different weighting scheme (uniform or inverse variance) can be applied inside the bins.

RELATED ROUTINES

This section lists the routines related to **bin_llcl**.

idl	version 6.0 or more is necessary to run bin_llcl.
fits2cl	facility to read a power spectrum from a FITS file.

EXAMPLE:

```
init_healpix
fits2cl, cl, !healpix.directory+'/test/cl.fits', multipoles=l
fl = l*(l+1) / (2.  * !pi)
bin_llcl, fl*cl[*,0], 10, lb, bbcb, /uniform
plot, l, fl*cl[*,0]
oplot, lb, bbcb, psym = 4
```

Read a power spectrum, bin it with a binsize of 10 and a uniform weighting, and overplot the input spectrum and its binned version.

bl2fits

Location in HEALPix directory tree: src/idl/fits/bl2fits.pro

This IDL facility provides a means to write into a FITS file as an ascii table extension a (beam) window function $W(\ell)$ or $W(\ell)$. Adds additional headers if required. The facility is primarily intended to allow the user to write an arbitrary window function into a FITS file in the correct format to be ingested by the **HEALPix** simulation facility **synfast**.

FORMAT

IDL> BL2FITS, bl_array, fitsfile, [HDR = , /HELP, XHDR =]

QUALIFIERS

bl_array	real or double array of Bl coefficients to be written to file. This has dimension (lmax+1,n) with $1 \leq n \leq 3$, given in the sequence T E B.
fitsfile	String containing the name of the file to be written.

KEYWORDS

HDR =	String array containing the (non-trivial) primary header for the FITS file.
/HELP	If set, a help message is printed out, no file is written
XHDR =	String array containing the (non-trivial) extension header for the FITS file.

DESCRIPTION

bl2fits writes the input $B(\ell)$ or $W(\ell)$ coefficients into a FITS file containing an ascii table extension. Optional headers conforming to the FITS convention can also be written to the output file. All required FITS header keywords (like SIMPLE, BITPIX, ...) are automatically generated by the routine and should NOT be duplicated in the optional header inputs (they would be ignored anyway). The one/two/three column(s) are automatically named `TEMPERATURE`, `GRAD`, `CURL` respectively. If the window function is provided in a double precision array, the output format will automatically feature more decimal places.

RELATED ROUTINES

This section lists the routines related to **bl2fits**.

idl	version 6.0 or more is necessary to run bl2fits.
fits2cl	provides the complimentary routine to read in a window function or power spectrum from a FITS file.
synfast	utilises the output file generated by bl2fits(option `beam_file`).

EXAMPLE:

```
beam1 = gaussbeam(10., 2000, 1)
beam2 = gaussbeam(15., 2000, 1)
beam = (beam1 + beam2) / 2.
bl2fits, beam, 'beam.fits'
```

bl2fits writes the beam window function stored in the variable `beam` (=Legendre transform of a circular beam) into the output FITS file `beam.fits`.

cartcursor

Location in HEALPix directory tree: src/idl/visu/cartcursor.pro

This IDL facility provides a point-and-click interface for finding the astronomical location, value and pixel index of the pixels nearest to the pointed position on a cartesian projection of a **HEALPix** map.

FORMAT

IDL> CARTCURSOR, [cursor_type=, file_out=]

QUALIFIERS

see mollcursor

DESCRIPTION

cartcursor should be called immediately after cartview. It gives the longitude, latitude, map value and pixel number corresponding to the cursor position in the window containing the map generated by orthview. For more details, or in case of problems under **Mac OS X**, see mollcursor.

RELATED ROUTINES

This section lists the routines related to **cartcursor**.

see mollcursor

EXAMPLE:

```
cartcursor
```

After cartview has read in a map and generated its cartesian projection, cartcursor is run to determine the position and flux of bright synchrotron sources, for example.

cartview

Location in HEALPix directory tree: src/idl/visu/cartview.pro

This IDL facility provides a means to visualise a cartesian projection (where the longitude and latitude are treated as the cartesian abscissa and ordinate) of **HEALPix** and COBE Quad-Cube maps in an IDL environment. It also offers the possibility to generate gif and postscript images of the projected map.

FORMAT

IDL> CARTVIEW, File, [Select,] [CHARSIZE=, ... WINDOW=, XPOS=, YPOS=]

QUALIFIERS

For a full list of qualifiers see mollview

KEYWORDS

For a full list of keywords see mollview

DESCRIPTION

cartview reads in a **HEALPix** sky map in FITS format and generates a cartesian projection of it, that can be visualized on the screen or exported in a GIF, PNG or Postscript file. cartview allows the selection of the coordinate system, point of projection, map size, color table, color bar inclusion, linear or log scaling, histogram equalised color scaling, maximum and minimum range for the plot, plot-title *etc.* It also allows the representation of the polarization field.

RELATED ROUTINES

This section lists the routines related to **cartview**.

see mollview

EXAMPLE:

```
map = findgen(48)
triangle= create_struct('coord','G','ra',[0,80,0],'dec',[40,45,65])
cartview,map,/online,res=45,graticule=[45,30],rot=[10,20,30],pysize=250,$
   title='Cartesian cylindrical (full sky)',subtitle='cartview', $
   outline=triangle
```

makes a cartesian cylindrical projection of map (see Figure 1a on page 77) after an arbitrary rotation, with a graticule grid (with a 45^o step in longitude and 30^o in latitude) and an arbitrary triangular outline

change_polcconv

Location in HEALPix directory tree: src/idl/fits/change_polcconv.pro

This IDL facility changes the coordinate convention in FITS file containing a polarised sky map. The main effect is to change the sign of the U Stokes parameter, and add/update the POLCCONV FITS header with either COSMO or IAU value.

FORMAT

IDL> CHANGE_POLCCONV , File_In, File_Out [, /I2C, /C2I, /C2C, /I2I, /FORCE]

QUALIFIERS

File_In	name of a FITS file to be read
File_Out	name of a FITS file to be written, after modification of the polarisation coordinate convention, if applicable

KEYWORDS

/I2C	changes from IAU to COSMO coordinate convention -if POLCCONV is not found or found with value 'IAU', it is added/replaced with value 'COSMO', and the sign of the U stokes parameter map is changed -if POLCCONV already has value 'COSMO', File_In is copied unchanged into File_Out
/C2I	changes from COSMO to IAU coordinate convention -if POLCCONV is not found or found with value 'COSMO', it is added/replaced with value 'IAU', and the sign of the U stokes parameter map is changed -if POLCCONV already has value 'IAU', File_In is copied unchanged into File_Out
/C2C	does NOT change coordinate system -if POLCCONV is found with value 'IAU', pro-

gram will issue error message and no file is written
-in all other case POLCCONV is set/added with value 'COSMO', but data is NOT changed

/I2I — does NOT change coordinate system
-if POLCCONV is found with value 'COSMO', program will issue error message and no file is written
-in all other case POLCCONV is set/added with value 'IAU', but data is NOT changed

/FORCE — if set, the value of POLCCONV read from the FITS header is ignored. The sign of U is swapped (if used with /C2I or /I2C), and the FITS keyword is updated accordingly.

DESCRIPTION

This routine will change the sign of the U Stokes parameters (and related quantities, such as the TU and QU cross-correlations) and update the 'POLCCONV' FITS keyword where applicable. The recognised format are:
- standard Healpix full sky polarised format
- cut sky Healpix polarised format
- WMAP 2nd year polarised format

RELATED ROUTINES

This section lists the routines related to **change_polcconv** .

idl — version 6.0 or more is necessary to run change_polcconv

write_fits_cut4 — This **HEALPix** IDL facility can be used to write a (polarised or unpolarised) cut sky map into a FITS file.

read_fits_cut4 — This **HEALPix** IDL facility can be used to read a (polarised or unpolarised) cut sky map from a FITS file.

write_tqu — This **HEALPix** IDL facility can be used to write a polarised full sky map (with either the standard Healpix format or the WMAP 2nd year format) into a FITS file

read_tqu — This **HEALPix** IDL facility can be used to read

a polarised cut sky map from a FITS file

EXAMPLE:

```
change_polcconv, 'map_cosmo.fits','map_iau.fits',/c2i
```

Modify the file 'map_cosmo.fits', which was using the 'COSMO' convention for polarisation coordinate convention into 'map_iau.fits' which uses the 'IAU' convention

cl2fits

Location in HEALPix directory tree: src/idl/fits/cl2fits.pro

This IDL facility provides a means to write into a FITS file as an ascii table extension the power spectrum coefficients passed to the routine. Adds additional headers if required. The facility is primarily intended to allow the user to write a theoretical power spectrum into a FITS file in the correct format to be ingested by the **HEALPix** simulation facility **synfast**.

FORMAT

IDL> CL2FITS, cl_array, fitsfile, [HDR = , /HELP, XHDR = , CMBFAST =, UNITS=]

QUALIFIERS

cl_array	real or double array of Cl coefficients to be written to file. This has dimension either (lmax+1,6) given in the sequence T E B TxE TxB ExB **or** (lmax+1,4) given in the sequence T E B TxE **or** (lmax+1) for T alone. The convention for the power spectrum is that it is not normalised by the Harrison-Zeldovich (flat) spectrum.
fitsfile	String containing the name of the file to be written.

KEYWORDS

HDR =	String array containing the (non-trivial) primary header for the FITS file.
/HELP	If set, a help message is printed out, no file is written
XHDR =	String array containing the (non-trivial) extension header for the FITS file.
CMBFAST =	if set, the routine will add the keyword 'POLNORM = CMBFAST' in the FITS header, meaning that the polarization power spectra have the

same convention as CMBFAST (and Healpix 1.2). If this keyword is not present in the input FITS file, `synfast` will issue a warning when simulating a polarization map from that power spectrum, but no attempt to renormalize the power spectra will be made. To actually perform the renormalization, see convert_oldhpx2cmbfast

UNITS = String scalar containing units of power spectrum (eg, uK^2, Kelvin**2, ...), to be put in keywords 'TUNIT*' of the extension header. If provided, will override the values present in XHDR (if any).

NOTE: optional header strings should NOT include the header keywords explicitly written by this routine.

DESCRIPTION

cl2fits writes the input power spectrum coefficients into a FITS file containing an ascii table extension. Optional headers conforming to the FITS convention can also be written to the output file. All required FITS header keywords (like SIMPLE, BITPIX, ...) are automatically generated by the routine and should NOT be duplicated in the optional header inputs (they would be ignored anyway). The one/four/six column(s) are automatically named `TEMPERATURE`, `GRAD`, `CURL`, `G-T`, `C-T` and `C-G` respectively. If the power spectrum is provided in a double precision array, the output format will automatically feature more decimal places. The current implementation is much faster than the one available in Healpix 1.10 thanks to replacing an internal loop by vector operations.

RELATED ROUTINES

This section lists the routines related to **cl2fits**.

idl — version 6.0 or more is necessary to run cl2fits.

fits2cl — provides the complimentary routine to read in a power spectrum from a FITS file.

convert_oldhpx2cmbfast — convert an existing power spectrum FITS file from the polarization convention used in Healpix 1.1 to the one used in Healpix 1.2 (and CMBFAST).

bl2fits	facility to write a window function into a FITS file.
fits2alm, alm2fits	routines to read and write a_{lm} coefficients
synfast	utilises the output file generated by cl2fits.

EXAMPLE:

```
cl2fits, pwrsp, 'spectrum.fits', HDR = hdr, XHDR = xhdr
```

cl2fitswrites the power spectrum stored in the variable `pwrsp` to the output FITS file `spectrum.fits` with optional headers passed by the string variables `hdr` and `xhdr`.

convert_oldhpx2cmbfast

Location in HEALPix directory tree: src/idl/fits/convert_oldhpx2cmbfast.pro

This IDL facility provides a means to change the normalization of polarization power spectra in a FITS file from Healpix 1.1 convention to Healpix 1.2 (which is the same as CMBFAST).

FORMAT

IDL> CONVERT_OLDHPX2CMBFAST, file_in, [file_out, NO_RENORM=]

QUALIFIERS

file_in	String containing the name of the FITS file with the power spectra to be read.
file_out	(OPTIONAL) String containing the name of the file to be written after renormalization. If absent, `file_in` will be used for output

KEYWORDS

NO_RENORM =	if set, the renormalization is not done. but the keyword POLNORM = CMBFAST is added to the FITS header (useful if the FITS file is already in CMBFAST format).

DESCRIPTION

convert_oldhpx2cmbfast does the conversion from the polarization normalisation used in **HEALPix** 1.1 to the one used in **HEALPix** 1.2 (see the Healpix primer document). A keyword POLNORM = CMBFAST is added to the header to keep track of which files have been renormalized. If this keyword is not present in the input FITS file, **synfast** will issue a warning when simulating a polarization map from that power spectrum, but no attempt to renormalize the power spectra will be made.

RELATED ROUTINES

This section lists the routines related to **convert_oldhpx2cmbfast**.

idl	version 6.0 or more is necessary to run convert_oldhpx2cmbfast.
cl2fits	provides the a routine to write a power spectrum to a FITS file.
fits2cl	provides the complimentary routine to read in a power spectrum from a FITS file.
synfast	utilises the output file generated by convert_oldhpx2cmbfast.

EXAMPLE:

```
convert_oldhpx2cmbfast, 'cl_flat.fits'
```

convert_oldhpx2cmbfast will renormalize the polarization power spectra read from 'cl_flat.fits', and write them in the same file.

euler_matrix_new

Location in HEALPix directory tree: src/idl/misc/euler_matrix_new.pro

This IDL facility provides a means to generate a 3D rotation Euler matrix parametrized by three angles and three axes of rotation.

FORMAT

IDL> matrix = EULER_MATRIX_NEW(a1, a2, a3 [, X=, Y=, ZYX=, DEG=])

QUALIFIERS

matrix	a 3x3 array containing the Euler matrix
a1	input, float scalar, angle of the first rotation, expressed in radians, unless DEG (see below) is set
a2	angle of the second rotation, same units as a1
a3	angle of the third rotation, same units as a1

KEYWORDS

DEG=	if set, the angles are in degrees instead of radians
X=	if set, uses the classical mechanics convention (ZXZ): rotation a1 around original Z axis, rotation a2 around intermediate X axis, rotation a3 around final Z axis (see Goldstein for more details). (**default:** this convention is used)
Y=	if set, uses the quantum mechanics convention (ZYZ): rotation a1 around original Z axis, rotation a2 around intermediate Y axis, rotation a3 around final Z axis.
ZYX=	if set, uses the aeronautics convention (ZYX): rotation a1 around original Z axis, rotation a2 around intermediate Y axis, rotation a3 around final X axis.

DESCRIPTION

euler_matrix_new allows the generation of a rotation Euler matrix. The user can choose the three Euler angles, and the three axes of rotation.
If vec is an N×3 array containing N 3D vectors,
vecr = vec # euler_matrix_new(a1,a2,a3,/Y)
will be the rotated vectors

This routine supersedes euler_matrix, which had inconsistent angle definitions. The relation between the two routines is as follows :

euler_matrix_new(a,b,c,/X) = euler_matrix(−a,−b,−c,/X)
= Transpose(euler_matrix(c, b, a,/X))

euler_matrix_new(a,b,c,/Y) = euler_matrix(−a, b,−c,/Y)
= Transpose(euler_matrix(c,−b, a,/Y))

euler_matrix_new(a,b,c,/Z) = euler_matrix(−a, b,−c,/Z)

RELATED ROUTINES

This section lists the routines related to **euler_matrix_new**.

idl	version 6.0 or more is necessary to run euler_matrix_new.
rotate_coord	apply a rotation to a set of position vectors and polarization Stokes parameters.

fits2alm

Location in HEALPix directory tree: src/idl/fits/fits2alm.pro

This IDL routine provides a means to read from a FITS file binary table extension(s) containing spherical harmonic coefficients $a_{\ell m}$ (and optional errors) and their index. Reads header information if required. The facility is intended to enable the user to read the output from the **HEALPix** facilities **anafast** and **synfast**.

FORMAT

IDL> FITS2ALM, index, alm_array, fitsfile, [signal, HDR = , XHDR =]

QUALIFIERS

index	Long array containing the index for the corresponding array of $a_{\ell m}$ coefficients (and errors if required). The index i is related to (l, m) by the relation $i = \ell^2 + \ell + m + 1$. This has dimension nl (see below).
alm_array	Real or double array of alm coefficients read from the file. This has dimension (nl,nalm,nsig) – corresponding to nl = number of (l, m) indices nalm = 2 for real and imaginary parts of alm coefficients or 4 for above plus corresponding error values nsig = number of signals to be written (1 for any of T E B or 3 if ALL to be written). Each signal is stored in a separate extension.
fitsfile	String containing the name of the file to be read.
signal	String defining the signal coefficients to read Valid options: 'T', 'E', 'B' or 'ALL' (**default:** 'T').

KEYWORDS

HDR =	String array containing the primary header for the FITS file.
XHDR =	String array containing the extension header(s). If ALL signals are required, then the three extension headers are returned appended into one string array.

DESCRIPTION

fits2alm reads binary table extension(s) which contain the $a_{\ell m}$ coefficients (and associated errors if present) from a FITS file. FITS headers can also optionally be read from the input file.

RELATED ROUTINES

This section lists the routines related to **fits2alm**.

idl	version 6.0 or more is necessary to run fits2alm.
alm2fits	provides the complimentary routine to write alm coefficients into a FITS file.
index2lm	converts the index $i = \ell^2 + \ell + m + 1$ returned by fits2alminto ℓ and m
fits2cl	routine to read/compute $C(l)$ power spectra from a file containing $C(l)$ or a_{lm} coefficients
alteralm	provides $a_{\ell m}$ coefficients file to be read by fits2alm.
anafast	provides $a_{\ell m}$ coefficients file to be read by fits2alm.
synfast	provides $a_{\ell m}$ coefficients file to be read by fits2alm.

EXAMPLE:

```
fits2alm, index, alm, 'alm.fits', HDR = hdr, XHDR = xhdr
```

fits2alm reads from the input FITS file `alm.fits` the $a_{\ell m}$ coefficients into the variable `alm` with optional headers passed by the string variables `hdr` and `xhdr`. Upon return `index` will contain the value of $\ell^2 + \ell + m + 1$ for each $a_{\ell m}$ found in the file.

fits2cl

Location in HEALPix directory tree: src/idl/fits/fits2cl.pro

This IDL facility provides a means to read from a FITS file an ascii or binary table extension containing power spectrum ($C(l)$) or spherical harmonics (a_{lm}) coefficients, and returns the corresponding power spectrum ($C(l) = \sum_m a_{lm} a^*_{lm}/(2l+1)$). Reads primary and extension headers if required. The facility is intended to enable the user to read the output from the **HEALPix** facility **anafast**.

FORMAT

IDL> FITS2CL, cl_array, fitsfile, [HDR =,/HELP, /INTERACTIVE, MULTIPOLES=, /RSHOW, /SHOW, /SILENT=, XHDR =]

QUALIFIERS

cl_array — real array of C_ℓ coefficients read or computed from the file. The output dimension depends on the contents of the file. This has dimension either (lmax+1,6) given in the sequence T E B TxE TxB ExB **or** (lmax+1,4) for T E B TxE **or** (lmax+1) for T alone. The convention for the power spectrum is that it is not normalised by the Harrison-Zeldovich (flat) spectrum.

fitsfile — String containing the name of the FITS file to be read. The file contains either $C(l)$ power spectra or a_{lm} coefficients. In either cases, $C(l)$ is returned.

KEYWORDS

HDR = — String array containing on output the primary header read from the FITS file.

/HELP — If set, produces an extended help message (using the doc_library IDL command).

/INTERACTIVE — If set, the plots generated by `/SHOW` and `/RSHOW`

	options are produced using iPlot routine, allowing for interactive cropping, zooming and annotation of the plots. This ; requires IDL 6.4 or newer to work properly.
MULTIPOLES =	vector containing on output the multipoles ℓ for which the power spectra are provided. They are either - read from the file (1st column in the Planck format), - or generated by the routine (assuming that all multipoles from 0 to lmax included are provided).
/RSHOW	If set, the raw power spectra $C(l)$ read from the file are plotted
/SHOW	If set, the rescaled power spectra $l(l+1)C(l)/2\pi$ are plotted
/SILENT	If set, no message is issued during normal execution
XHDR =	String array containing on output the extension header read from the FITS file.

DESCRIPTION

fits2cl reads the power spectrum coefficients from a FITS file containing an ascii table extension. Descriptive headers conforming to the FITS convention can also be read from the input file.

RELATED ROUTINES

This section lists the routines related to **fits2cl**.

idl	version 6.0 or more is necessary to run fits2cl.
bin_llcl	facility to bin a spectrum read with fits2cl.
bl2fits	facility to write a window function into a FITS file.
cl2fits	provides the complimentary routine to write a power spectrum to a FITS file.
fits2alm, alm2fits	routines to read and write a_{lm} coefficients
anafast	provides the output file to be read by fits2cl.

EXAMPLE:

```
fits2cl, pwrsp, '$HEALPIX/test/cl.fits', HDR = hdr, XHDR = xhdr
```

fits2cl reads a power spectrum from the input FITS file `$HEALPIX/test/cl.fits` into the variable `pwrsp`, with optional headers passed by the string variables `hdr` and `xhdr`.

gaussbeam

Location in HEALPix directory tree: src/idl/misc/gaussbeam.pro

This IDL facility provides the window function in ℓ space for a gaussian axisymmetric beam of given FWHM.

FORMAT

IDL> beam=GAUSSBEAM (Fwhm, Lmax [, Dim])

QUALIFIERS

Fwhm	Full Width Half Maximum of the gaussian beam, in arcmin (scalar real)
Lmax	the window function is computed for the multipoles ℓ in {0,...,Lmax}
Dim	scalar integer, optional. If absent or set to 0 or 1, the output has size (Lmax+1) and is the temperature beam; if set to $2 \leq$ Dim ≤ 4 , the output has size (Lmax+1,Dim) and contains in that order : the TEMPERATURE beam, the GRAD/ELECTRIC polarization beam the CURL/MAGNETIC polarization beam the TEMPERATURE*GRAD beam

DESCRIPTION

gaussbeam computes the ℓ space window function of a gaussian beam of FWHM Fwhm. For a sky of underlying power spectrum $C(\ell)$ observed with beam of given FWHM, the measured power spectrum will be $C(\ell)_{\rm meas} = C(\ell)B(\ell)^2$ where $B(\ell)$ is given by gaussbeam(Fwhm,Lmax). The polarization beam is also provided (when Dim > 1) assuming a perfectly co-polarized beam (eg, Challinor et al 2000, astro-ph/0008228)

RELATED ROUTINES

This section lists the routines related to **gaussbeam** .

idl	version 6.0 or more is necessary to run gaussbeam
healpixwindow	computes the ℓ space window function associated with a **HEALPix** pixel size
synfast	f90 code to generate CMB maps of given power spectrum convolved with a gaussian beam
smoothing	f90 code to smooth existing **HEALPix** maps with a gaussian beam
anafast	f90 code to compute the power spectrum of a **HEALPix** sky map

EXAMPLE:

```
beam = gaussbeam(5.,1200)
```

beam contains the window function in {0,...,1200} of a gaussian beam of fwhm 5 arcmin

getdisc_ring

Location in HEALPix directory tree: src/idl/toolkit/getdisc_ring.pro

This routine is obsolete. Use query_disc instead.

getsize_fits

Location in HEALPix directory tree: src/idl/fits/getsize_fits.pro

This IDL function reads the number of maps and/or the pixel ordering of a FITS file containing a **HEALPix** map.

FORMAT

IDL> var = GETSIZE_FITS (File, [Nmaps =, Nside =, Mlpol =, Ordering =, Obs_Npix =, Type =, Header =])

QUALIFIERS

File — name of a FITS file containing the **HEALPix** map(s).

var — contains on output the number of pixels stored in a map FITS file. Each pixel is counted only once (even if several information is stored on each of them, see nmaps). Depending on the data storage format, result may be :
– equal or smaller to the number Npix of Healpix pixels available over the sky for the given resolution (Npix = 12*nside*nside)
– equal or larger to the number of non blank pixels (obs_npix)

Nmaps= — contains on output the number of maps in the file

Nside= — contains on output the **HEALPix** resolution parameter $N_{\rm side}$

Mlpol= — contains on output the maximum multipole used to generate the map

Ordering= — contains on output the pixel ordering scheme: either 'RING' or 'NESTED'

Obs_Npix= — contains on output the number of non blanck pixels. It is set to -1 if it can not be determined from header

Type= — Healpix/FITS file type
<0 : file not found, or not valid
0 : image only fits file, deprecated Healpix format (var = $12{N_{\rm side}}^2$)
1 : ascii table, generally used for C(l) storage
2 : binary table : with implicit pixel indexing (full sky) (var = $12{N_{\rm side}}^2$)
3 : binary table : with explicit pixel indexing (generally cut sky) (var $\leq 12{N_{\rm side}}^2$)
999 : unable to determine the type

Header= contains on output the FITS extension header

DESCRIPTION

getsize_fits gets the number of pixels in a FITS file. If the file follows the **HEALPix** standard, the routine can also get the resolution parameter Nside, the ordering scheme, ..., and can determine the type of data set contained in the file.

RELATED ROUTINES

This section lists the routines related to **getsize_fits** .

idl	version 6.0 or more is necessary to run getsize_fits
read_fits_map	This **HEALPix** IDL facility can be used to read in maps written by getsize_fits .
sxaddpar	This IDL routine (included in **HEALPix** package) can be used to update or add FITS keywords to `Header`
reorder	This **HEALPix** IDL routine can be used to reorder a map from NESTED scheme to RING scheme and vice-versa.
write_fits_sb	routine to write multi-column binary FITS table

EXAMPLE:

```
npix = getsize_fits(!healpix.directory+'/test/map.fits', nside=nside, $
   mlpol=lmax, type=filetype)
print, npix, nside, lmax, filetype
```

should produce something like
196608 128 256 2
meaning that the map contained in that file has 196608 pixels, the resolution parameter is nside=128, the maximum multipole was 256, and this a full sky map (type 2).

gnomcursor

Location in HEALPix directory tree: src/idl/visu/gnomcursor.pro

This IDL facility provides a point-and-click interface for finding the astronomical location, value and pixel index of the pixels nearest to the pointed position on a gnomonic projection of a **HEALPix** map.

FORMAT

IDL> GNOMCURSOR, [cursor_type=, file_out=]

QUALIFIERS

see mollcursor

DESCRIPTION

gnomcursor should be called immediately after gnomview. It gives the longitude, latitude, map value and pixel number corresponding to the cursor position in the window containing the map generated by gnomview. For more details, or in case of problems under **Mac OS X**, see mollcursor.

RELATED ROUTINES

This section lists the routines related to **gnomcursor**.

see mollcursor

EXAMPLE:

```
gnomcursor
```

After gnomview has read in a map and generated its gnomonic projection, gnomcursor is run to determine the position and flux of bright synchrotron sources, for example.

gnomview

Location in HEALPix directory tree: src/idl/visu/gnomview.pro

This IDL facility provides a means to visualise a Gnomonic projection (radial projection onto a tangent plane) of **HEALPix** and COBE Quad-Cube maps in an IDL environment. It also offers the possibility to generate gif and postscript images of the projected map.

FORMAT

IDL> GNOMVIEW, File, [Select,] [CHARSIZE=, ... WINDOW=, XPOS=, YPOS=]

QUALIFIERS

For a full list of qualifiers see mollview

KEYWORDS

For a full list of keywords see mollview

DESCRIPTION

gnomview reads in a **HEALPix** sky map in FITS format and generates a Gnomonic projection of it, that can be visualized on the screen or exported in a GIF, PNG, Postscript or FITS file. gnomview allows the selection of the coordinate system, point of projection, map size, color table, color bar inclusion, linear or log scaling, histogram equalised color scaling, maximum and minimum range for the plot, plot-title *etc.* It also allows the representation of the polarization field.

RELATED ROUTINES

This section lists the routines related to **gnomview**.

see mollview

EXAMPLES: #1

```
gnomview, 'planck100GHZ-LFI.fits', rot=[160,-30], reso_arcmin=2., $
   pxsize = 500., $
   title='Simulated Planck LFI Sky Map at 100GHz', $
   min=-100,max=100
```

gnomview reads in the map 'planck100GHZ-LFI.fits' and generates an output image of the size of 500×500 screen pixels, with a resolution of 2 arcmin/screen pixel at the center. The temperature scale has been set to lie between ± 100, and the units will show as μK. The title 'Simulated Planck LFI Sky Map at 100GHz' has been appended to the image. The map is centered at (l =160, b =-30)

EXAMPLES: #2

```
map = findgen(48)
triangle= create_struct('coord','G','ra',[0,80,0],'dec',[40,45,65])
gnomview,map,/online,res=25,graticule=[45,30],rot=[10,20,30],$
   title='Gnomic projection',subtitle='gnomview', $
   outline=triangle
```

makes a gnomic projection of map (see Figure 1b on page 77) after an arbitrary rotation, with a graticule grid (with a 45^o step in longitude and 30^o in latitude) and an arbitrary triangular outline

healpixwindow

Location in HEALPix directory tree: src/idl/misc/healpixwindow.pro

This IDL facility provides the window function in ℓ associated with the Healpix pixel of resolution Nside.

FORMAT

IDL> wpix=HEALPIXWINDOW (Nside [, Dim, Directory])

QUALIFIERS

Nside	resolution parameter
Wpix	the pixel window function, computed for the multipoles ℓ in {0,...,4Nside}
Dim	scalar integer, optional. If absent or set to 0 or 1, the output has size (4 Nside+1) and is the temperature window function; if set to $2 \leq$ Dim ≤ 4 , the output has size (4 Nside+1,Dim) and contains in that order : the TEMPERATURE window function, the GRAD/ELECTRIC polarization one the CURL/MAGNETIC polarization one the TEMPERATURE*GRAD one.
Directory	directory in which the precomputed pixel window file is looked for. (**default:** $)HEALPIX/data/

DESCRIPTION

healpixwindow computes the ℓ space window function due to the finite size of the **HEALPix** pixels. The typical size of a pixel (square root of its uniform surface area) is $\sqrt{3/\pi}\ 3600/N_{\rm side}$ arcmin. If a unpixelised sky has a power spectrum $C(\ell)$, the same sky pixelised with a resolution parameter Nside will have the power spectrum $C(\ell)_{\rm pix} = C(\ell)W(\ell)^2$ where $W(\ell)$ is given by healpixwindow (Nside). The polarized pixel window function is also provided (when Dim > 1). This routine reads some FITS files located in the subdirectory `data/` of the **HEALPix** distribution, unless the keyword `Directory` is set otherwise.

RELATED ROUTINES

This section lists the routines related to **healpixwindow** .

idl	version 6.0 or more is necessary to run healpixwindow
gaussbeam	computes the ℓ space window function associated with a gaussian beam
synfast	f90 code to generate CMB maps of given power spectrum at a given resolution (=pixel size)
anafast	f90 code to compute the power spectrum of a **HEALPix** sky map

EXAMPLE:

```
wpix = healpixwindow (256)
```

wpix contains the window function in {0,...,1024} of the **HEALPix** pixel with resolution parameter 256 (pixel size of 13.7 arcmin)

hpx2gs

Location in HEALPix directory tree: src/idl/visu/hpx2gs.pro

This IDL facility provides a means to turn a **HEALPix** map into a image that can be visualized with Google Earth or Google Sky.

FORMAT IDL> hpx2gs, File, [Select,] [COLT=, ... TITLEPLOT=]

QUALIFIERS

File — Required
name of a FITS file containing the **HEALPix** map in an extension or in the image field,
or name of an *online* variable (either array or structure) containing the **HEALPix** map (See note below);
if Save is set : name of an IDL saveset file containing the **HEALPix** map stored under the variable `data`
(**default:** none)

Select — Optional
column of the BIN FITS table to be plotted, can be either
– a name : value given in TTYPEi of the FITS file
NOT case sensitive and can be truncated,
(only letters, digits and underscore are valid)
– an integer : number i of the column containing the data, starting with 1 (also valid if `File` is an online array)
(**default:** 1 for full sky maps, 'SIGNAL' column for FITS files containing cut sky maps)

KEYWORDS

COORD_IN = — 1-character scalar, describing the input data coordinate system:
either 'C' or 'Q' : Celestial2000 = eQuatorial,
'E' : Ecliptic,
'G' : Galactic.
If set, it will over-ride the coordinates read from the FITS file header (when applicable). In absence of information, the input coordinates is assumed to be celestial.
The data will be rotated so that the output coordinates are Celestial, as expected by Google Sky

/HELP — Prints out the documentation header

KML = — Name of the KML file to be created (if the `.kml` suffix is missing, it will be added automatically) (**default:** `'hpx2googlesky.kml'`)

PNG = — Name of the PNG overlay file to be created. Only to be used if you want the filename to be different from the default ((**default:** same as KML file, with a `.png` suffix instead of `.kml`))

RESO_ARCMIN = — Pixel angular size in arcmin (at the equator) of

the cartesian map generated (**default:** 30)

SUBTITLE = information on the data, will appear in KML file `GroundOverlay description` field

TITLEPLOT = information on the data, will appear in KML file `GroundOverlay name` field

COLT=, FACTOR=, FLIP=, GLSIZE=, GRATICULE=, HBOUND=,
HIST_EQUAL=, IGLSIZE=, IGRATICULE=, LOG=, MAX=, MIN=, NESTED=,

NO_DIPOLE =, NO_MONOPLE=, OFFSET=
OUTLINE=, POLARIZATION=, PREVIEW=,
QUADCUBE=, SAVE=, SILENT= those keywords have the same meaning as in cartview and mollview

DESCRIPTION

hpx2gs reads in a **HEALPix** sky map in FITS format or from a memory array and generates a cartesian projection of it in a PNG file, as well as a Google Sky compatible KML file. Missing or unobserved pixels in the input data will be totally 'transparent' in the output file.

RELATED ROUTINES

This section lists the routines related to **hpx2gs**.

see cartview

EXAMPLE:

```
map = findgen(48)
hpx2gs, map, kml='my_map.kml',title='my map in Google'
```

produces in `my_map.kml` and in `my_map.png` an image of the input map that can be seen with Google Sky. To do so, start GoogleEarth or GoogleSky and open `my_map.kml`.

ianafast

Location in HEALPix directory tree: src/idl/interfaces/ianafast.pro

This IDL facility provides an interface to 'anafast' F90 and 'anafast_cxx' C++ facilities

FORMAT

IDL> IANAFAST, map1_in [, cl_out, alm1_out=, alm2_out=, binpath=, cxx=, double=, help=, healpix_data=, iter_order=, keep_tmp_files=, map2_in=, maskfile=, nested=, nlmax=, nmmax=, ordering=, plmfile=, polarisation=, regression=, ring=, show_cl=, simul_type=, silent=, theta_cut_deg=, tmpdir=, weighted=, won=, w8file=, w8dir=]

QUALIFIERS

map1_in	required input: 1st input map, can be a FITS file, or a memory array containing the map to analyze
cl_out	optional output: auto or cross power spectrum $C(l)$, can be a FITS file or a memory array

KEYWORDS

alm1_out=	output alm of 1st map, must be a FITS file (**default:** alm not kept)
alm2_out=	output alm of 2nd map (if any, must be a FITS file) (**default:** alm not kept)
binpath=	full path to back-end routine (**default:** $HEXE/anafast, then $HEALPIX/bin/anafast or $HEALPIX/src/cxx/$HEALPIX_TARGET-/bin/anafast_cxx, then $HEALPIX/src/cxx/generic_gcc/bin/anafast_cxx

	if cxx is set) – a binpath starting with / (or \), or $ is interpreted as absolute – a binpath starting with ./ is interpreted as relative to current directory – all other binpathes are relative to $HEALPIX
/cxx	if set, the C++ back-end anafast_cxx is invoked instead of F90 anafast, AND the parameter file is written accordingly
/double	if set, I/O is done in double precision (**default:** single precision I/O)
/help	if set, prints extended help
healpix_data=	directory with Healpix precomputed files (only for C++ back_end when weighted=1) (**default:** $HEALPIX/data)
iter_order=	order of iteration in the analysis (**default:** 0)
/keep_tmp_files	if set, temporary files are not discarded at the end of the run
map2_in=	2nd input map (FITS file or array), if provided, Cl_out will contain the cross power spectra of the 2 maps (**default:** no 2nd map)
maskfile=	pixel mask (FITS file or array) (**default:** no mask)
/nested=	if set, signals that *all* maps and mask read online are in NESTED scheme (does not apply to FITS file), see also /ring and Ordering
nlmax=	maximum multipole of analysis, *required* for C++ anafast_cxx, optional for F90 anafast
nmmax=	maximum degree m, only valid for C++ anafast_cxx (**default:** nlmax)
ordering=	either 'RING' or 'NESTED', ordering of online maps and masks, see /ring and /ordering
plmfile=	FITS file containing precomputed Spherical Harmonics (**default:** no file)
/polarisation	if set analyze temperature + polarization (same as simul_type = 2)
regression=	0, 1 or 2, regress out best fit monopole and/or dipole before alm analysis (**default:** 0, analyze raw map)
/ring	see /nested and ordering above

/show_cl	if set, and `cl_out` is defined, the produced $l(l+1)C(l)/2\pi$ will be plotted
simul_type=	1 or 2, analyze temperature only or temperature + polarization
/silent	if set, works silently
theta_cut_deg=	cut around the equatorial plane
tmpdir=	directory in which are written temporary files (**default:** /tmp)
/weighted	same as won (**default:** apply weighting)
/won	if set, a weighting scheme is used to improve the quadrature (**default:** apply weighting)
w8file=	FITS file containing weights (**default:** determined automatically by back-end routine). Do not set this keyword unless you really know what you are doing
w8dir=	directory where the weights are to be found (**default:** determined automatically by back-end routine)

DESCRIPTION

ianafast is an interface to 'anafast' F90 and 'anafast_cxx' C++ facilities. It requires some disk space on which to write the parameter file and the other temporary files. Most data can be provided/generated as an external FITS file, or as a memory array.

RELATED ROUTINES

This section lists the routines related to **ianafast**.

idl	version 6.0 or more is necessary to run ianafast.
anafast	F90 facility called by ianafast.
anafast_cxx	C++ called by ianafast.
isynfast	IDL Interface to F90 synfast
ismoothing	IDL Interface to F90 smoothing

EXAMPLE:

```
whitenoise = randomn(seed, nside2npix(256))
ianafast, whitenoise, cl, /ring, /silent
plot, cl[*,0]
```

will plot the power spectrum of a white noise map

ismoothing

Location in HEALPix directory tree: src/idl/interfaces/ismoothing.pro

This IDL facility provides an interface to F90 'smoothing' facility

FORMAT

IDL> ISMOOTHING, map1_in, map_out [, beam_file=, binpath=, double=, fwhm_arcmin=, help=, iter_order=, keep_tmp_files=, lmax=, nlmax=, nested=, ordering=, plmfile=, regression=, ring=, simul_type=, silent=, theta_cut_deg=, tmpdir=, won=, w8file=, w8dir=]

QUALIFIERS

map1_in	required input: input map, can be a FITS file, or a memory array containing the map to smooth
map2_out	required output: output smoothed map, can be a FITS file, or a memory array

KEYWORDS

beam_file=	beam window function, either a FITS file or an array
binpath=	full path to back-end routine (**default:** $HEXE/smoothing, then $HEALPIX/bin/smoothing) – a binpath starting with / (or \), or $ is interpreted as absolute – a binpath starting with ./ is interpreted as relative to current directory – all other binpathes are relative to $HEALPIX
/double	if set, I/O is done in double precision (**default:** single precision I/O)

fwhm_arcmin=	gaussian beam FWHM in arcmin (**default:** 0)
/help	if set, prints extended help
iter_order=	order of iteration in the analysis (**default:** 0)
/keep_tmp_files	if set, temporary files are not discarded at the end of the run
lmax=, nlmax=	maximum multipole of smoothing (**default:** determined by back-end routine (ie, smoothing))
/nested	if set, signals that *all* maps and mask read online are in NESTED scheme (does not apply to FITS file), see also /ring and Ordering
ordering=	either 'RING' or 'NESTED', ordering of online maps and masks, see /ring and Ordering
plmfile=	FITS file containing precomputed Spherical Harmonics (**default:** no file)
regression=	0, 1 or 2, regress out best fit monopole and/or dipole before alm analysis (**default:** 0, analyze raw map)
/ring	see /nested and Ordering above
simul_type=	1 or 2, analyze temperature only or temperature + polarization
/silent	if set, works silently
theta_cut_deg=	cut around the equatorial plane
tmpdir=	directory in which are written temporary files (**default:** /tmp)
/won	if set, a weighting scheme is used to improve the quadrature (**default:** apply weighting)
w8file=	FITS file containing weights (**default:** determined automatically by back-end routine). Do not set this keyword unless you really know what you are doing
w8dir=	directory where the weights are to be found (**default:** determined automatically by back-end routine)

DESCRIPTION

ismoothing is an interface to 'smoothing' F90 facility. It requires some disk space on which to write the parameter file and the other temporary files. Most data can be provided/generated as an external FITS file, or as a memory array.

RELATED ROUTINES

This section lists the routines related to **ismoothing**.

idl	version 6.0 or more is necessary to run ismoothing.
smoothing	F90 facility called by ismoothing.
ianafast	IDL Interface to F90 anafast and C++ anafast_cxx
isynfast	IDL Interface to F90 synfast

EXAMPLE:

```
whitenoise = randomn(seed, nside2npix(256))
ismoothing, whitenoise, rednoise, fwhm=120, /ring, simul=1,/silent
mollview, whitenoise,title='White noise'
mollview, rednoise, title='Smoothed white Noise'
```

will generate and plot a white noise map and its smoothed version

isynfast

Location in HEALPix directory tree: src/idl/interfaces/isynfast.pro

This IDL facility provides an interface to F90 'synfast' facility. It can be used to generate sky maps and/or a_{lm} from power spectra ($C(l)$), synthesize maps from a_{lm} or simulate maps from $C(l)$ and constraining a_{lm}.

FORMAT

IDL> ISYNFAST, cl_in [, map_out, alm_in=, alm_out=, apply_windows=, beam_file=, binpath=, double=, fwhm_arcmin=, help=, iseed=, keep_tmp_files=, lmax=, nlmax=, nside=, nsmax=, plmfile=, simul_type=, silent=, tmpdir=, windowfile=, winfiledir=]

QUALIFIERS

cl_in
: input power spectrum, can be a FITS file, or a memory array containing the $C(l)$, used to generate a map or a set of gaussian alm
If empty quotes (") or a zero (0) are provided, it will be interpreted as "No input C(l)", in which case some input alm's (alm_in) are required.

map_out
: optional output: map synthetised from the power spectrum or from constraining alm

KEYWORDS

alm_in=
: optional input (constraining) alm (**default:** no alm)

alm_out=
: contains on output the effective alm

/apply_windows
: if set, beam and pixel windows are applied to input alm_in (if any)

beam_file=
: beam window function, either a FITS file or an array

binpath=	full path to back-end routine (**default:** $HEXE/synfast, then $HEALPIX/bin/synfast) – a binpath starting with / (or \), or $ is interpreted as absolute – a binpath starting with ./ is interpreted as relative to current directory – all other binpathes are relative to $HEALPIX
/double	if set, I/O is done in double precision (**default:** single precision I/O)
fwhm_arcmin=	gaussian beam FWHM in arcmin (**default:** 0)
/help	if set, prints extended help
iseed=	integer seed of radom sequence (**default:** 0)
/keep_tmp_files	if set, temporary files are not discarded at the end of the run
lmax=, nlmax=	maximum multipole simulation (**default:** 2*$N_{\rm side}$)
nside=, nsmax=	Healpix resolution parameter $N_{\rm side}$
plmfile=	FITS file containing precomputed Spherical Harmonics (**default:** no file)
simul_type=	1) Temperature only 2) Temperature + polarisation 3) Temperature + 1st derivatives 4) Temperature + 1st & 2nd derivatives 5) T+P + 1st derivatives 6) T+P + 1st & 2nd derivates (**default:** 2: T+P)
/silent	if set, works silently
tmpdir=	directory in which are written temporary files (**default:** /tmp)
windowfile=	FITS file containing pixel window (**default:** determined automatically by back-end routine). Do not set this keyword unless you really know what you are doing
winfiledir=	directory where the pixel windows are to be found (**default:** determined automatically by back-end routine). Do not set this keyword unless you really know what you are doing

DESCRIPTION

isynfast is an interface to F90 'synfast' F90 facility. It requires some disk space on which to write the parameter file and the other temporary files. Most data can be provided/generated as an external FITS file, or as a memory array.

RELATED ROUTINES

This section lists the routines related to **isynfast**.

idl	version 6.0 or more is necessary to run isynfast.
synfast	F90 facility called by isynfast.
ismoothing	IDL Interface to F90 smoothing
ianafast	IDL Interface to F90 anafast and C++ anafast_cxx

EXAMPLE:

```
isynfast, '$HEALPIX/test/cl.fits', map, fwhm=30, nside=256, /silent
mollview, map, 1, title='I'
mollview, map, 2, title='Q'
```

will synthetize and plot I and Q maps constistent with WMAP-1yr best fit power spectrum and observed with a circular gaussian 30 arcmin beam.

index2lm

Location in HEALPix directory tree: src/idl/misc/index2lm.pro

This IDL routine provides a means to convert the $a_{\ell m}$ index $i = \ell^2 + \ell + m + 1$ (as returned by eg the fits2alm routine) into ℓ and m.

FORMAT

IDL> INDEX2LM, index, l, m

QUALIFIERS

index	Long array containing on INPUT the index $i = \ell^2 + \ell + m + 1$.
l	Long array containing on OUTPUT the order ℓ. It has the same size as `index`.
m	Long array containing on OUTPUT the degree m. It has the same size as `index`.

DESCRIPTION

index2lm converts $i = \ell^2 + \ell + m + 1$ into (ℓ, m). Note that the index i is only defined for $0 \leq |m| \leq \ell$.

RELATED ROUTINES

This section lists the routines related to **index2lm**.

idl	version 6.0 or more is necessary to run index2lm.
fits2alm	reads a FITS file containing $a_{\ell m}$ values.
alm2fits	writes $a_{\ell m}$ values into a FITS file.
lm2index	routine complementary to index2lm: converts (ℓ, m) into $i = \ell^2 + \ell + m + 1$.

EXAMPLE:

```
index2lm, index, l, m
```

will return in `l` and `m` the order ℓ and degree m such that `index` $= \ell^2 + ell + m + 1$

init_healpix

Location in HEALPix directory tree: src/idl/misc/init_healpix.pro

This IDL facility creates an IDL system variable (!HEALPIX) containing various **HEALPix** related quantities

FORMAT

IDL> INIT_HEALPIX [,VERBOSE=]

KEYWORDS

VERBOSE = if set, turn on the verbose mode, giving a short description of the variables just created.

DESCRIPTION

init_healpix defines the IDL system variable and structure !HEALPIX containing several quantities and character string necessary to **HEALPix** , eg : allowed resolution parameters Nside, full path to package directory, package version...

RELATED ROUTINES

This section lists the routines related to **init_healpix**.

idl version 6.0 or more is necessary to run init_healpix.

!HEALPIX IDL system variable defined by init_healpix.

EXAMPLES: #1

```
init_healpix,/verbose
```

init_healpix will create the system variable !Healpix, and give a short description of the tags available.

EXAMPLES: #2

```
help, !healpix, /structure
```

will print the content of the !Healpix system structure.

lm2index

Location in HEALPix directory tree: src/idl/misc/lm2index.pro

This IDL routine provides a means to convert the $a_{\ell m}$ degree and order (ℓ, m) into the index $i = \ell^2 + \ell + m + 1$ (in order to be fed to alm2fits routine for instance)

FORMAT

IDL> LM2INDEX, l, m, index

QUALIFIERS

l	Long array containing on INPUT the order ℓ.
m	Long array containing on INPUT the degree m.
index	Long array containing on OUTPUT the index $i = \ell^2 + \ell + m + 1$.

DESCRIPTION

lm2index converts (ℓ, m) into $i = \ell^2 + \ell + m + 1$. Note that by definition $0 \leq |m| \leq \ell$ (the routine does not check for this).

RELATED ROUTINES

This section lists the routines related to **lm2index**.

idl	version 6.0 or more is necessary to run lm2index.
fits2alm	reads a FITS file containing $a_{\ell m}$ values.
alm2fits	writes $a_{\ell m}$ values into a FITS file.
index2lm	routine complementary to lm2index: converts $i = \ell^2 + \ell + m + 1$ into (ℓ, m).

EXAMPLE:

```
lm2index, l, m, index
```

will return in `index` in value $\ell^2 + \ell + m + 1$

median_filter

Location in HEALPix directory tree: src/idl/toolkit/median_filter.pro

This IDL facility allows the median filtering of a Healpix map.

FORMAT

IDL> MEDIAN_FILTER (InputMap, Radius, MedianMap [,ORDERING=, /RING, /NESTED, /FILL_HOLES, /DEGREES, /ARCMIN])

QUALIFIERS

InputMap	(IN) either an IDL array containing a full sky Healpix map to filter ('online' usage), or the name of an external FITS file containing a full sky or cut sky map
Radius	(IN) radius of the disk on which the median is computed. It is in Radians, unless `/DEGREES` or `/ARCMIN` are set
MedianMap	(OUT) either an IDL variable containing on output the filtered map, or the name of an external FITS file to contain the map. Should be of same type of `InputMap`. Flagged pixels (ie, having the value `!healpix.bad_value`) are left unchanged, unless `/FILL_HOLES` is set.

KEYWORDS

/ARCMIN	If set, `Radius` is in arcmin rather than radians
/DEG	If set, `Radius` is in degrees rather than radians
/FILL_HOLES	If set, flagged pixels are replaced with the median of the valid pixels found within a distance `Radius`. If there are any.
/NESTED	Same as ORDERING='NESTED'
ORDERING=	Healpix map ordering, should be either 'RING' or 'NESTED'. Only applies to 'online' usage.

/RING Same as ORDERING='RING'

DESCRIPTION

median_filter allows the median filtering of a Healpix map. Each pixel of the output map is the median value of the input map pixels found within a disc of given radius centered on that pixel. Flagged pixels can be either left unchanged or 'filled in' with that same scheme.
If the map is polarized, each of the three Stokes components is filtered separately.
The input and output can either be arrays or FITS files, but they to be both arrays or both FITS files.

RELATED ROUTINES

This section lists the routines related to **median_filter** .

idl version 6.0 or more is necessary to run median_filter

EXAMPLE:

```
median_filter ('map.fits', 10., /arcmin, 'med.fits')
```

Writes in 'med.fits' the median filtered map of 'map.fits' using a disc radius of 10 arcmin

EXAMPLE:

```
map = randomn(seed, nside2npix(256))
median_filter (map, 0.5, /deg, med)
```

Returns in `med` the median filtered map of `map` using a disc radius of 0.5 degrees

mollcursor

Location in HEALPix directory tree: src/idl/visu/mollcursor.pro

This IDL facility provides a point-and-click interface for finding the astronomical location, value and pixel index of the pixels nearest to the pointed position on a Mollweide projection of a **HEALPix** map.

FORMAT

IDL> MOLLCURSOR, [cursor_type=, file_out=]

QUALIFIERS

cursor_type= cursor type to be used
(**default:** 34)

file_out= file containing on output the list of point selected with the cursor.
If set to 1, the file will take its default name: 'cursor_catalog.txt'.
If set to a non-empty character string, the file name will be that string

DESCRIPTION

mollcursor should be run immediately following mollview. It gives the longitude, latitude, map value and pixel number corresponding to the cursor position in the window containing the map generated by mollview. Mouse buttons are used to select the function :

left button = display the information relative to the current cursor position,

middle button = print out this information in the IDL command window

right button = quit mollcursor

Note on Mac OS X, X11 and IDL cursor: on some versions of Mac OS X, in particular Tiger (ie, 10.4.*) and Leopard (ie, 10.5.*), the IDL function `cursor`, and therefore **HEALPix** mollcursor, gnomcursor, ... will not work properly under X11. To solve this problem, type
under Tiger (10.4):

```
defaults write com.apple.x11 wm_click_through -bool true
```

or, under Leopard (10.5):

```
defaults write org.x.x11 wm_click_through -bool true
```

at your X11 prompt and restart X11 (tips found respectively at http://marc.sauvage.free.fr/SApMUG/Xnotes.html and https://sympa.obspm.fr/wws/arc/micros-mac/2008-06/msg00001.html). To make the patch permanent, add the line above into your .bashrc (or .cshrc, depending on your shell) file, and restart X11.
And finally, mollcursor obviously requires the '3 button mouse' to be enabled, which can be done in the X11 Preferences menu.

RELATED ROUTINES

This section lists the routines related to **mollcursor**.

idl	version 6.0 or more is necessary to run mollcursor
ghostview	ghostview or a similar facility is required to view the Postscript image generated by mollcursor.
xv	xv or a similar facility is required to view the GIF/PNG image generated by mollcursor(a browser can also be used).
synfast	This **HEALPix** facility will generate the FITS format sky map to be input to mollcursor.

cartview	IDL facility to generate a Cartesian projection of a **HEALPix** map.
cartcursor	interactive cursor to be used with cartview
gnomview	IDL facility to generate a gnomonic projection of a **HEALPix** map.
gnomcursor	interactive cursor to be used with gnomview
mollview	IDL facility to generate a Mollweide projection of a **HEALPix** map.
mollcursor	interactive cursor to be used with mollview
orthview	IDL facility to generate an orthographic projection of a **HEALPix** map.
orthcursor	interactive cursor to be used with orthview

EXAMPLE:

```
mollcursor
```

After mollview reads in a map and generates its mollweide projection, mollcursor is run to know the position and flux of bright synchrotron sources, for example.

mollview

Location in HEALPix directory tree: src/idl/visu/mollview.pro

This IDL facility provides a means to visualise a full sky Mollweide projection of **HEALPix** and COBE Quad-Cube maps in an IDL environment. It also offers the possibility to generate gif and postscript images of the projected map.

FORMAT

IDL> MOLLVIEW, File, [Select,] [/ASINH, CHARSIZE=, COLT=, ... WINDOW=, XPOS=, YPOS=]

Several visualization routines have a similar interface. Their qualifiers and keywords are all listed here, and the routines to which they apply are coded in the 'routine' column as: C: cartview, G: gnomview, M: mollview, O: orthview and all: all of them

Qualifiers should appear in the order indicated. They can take a range of values, and some of them are optional.
Keywords are optional, and can appear in any order. They take the form `keyword=value` and can be abbreviated to a non ambiguous form (ie, `factor=10.0` can be replaced by `fac = 10.0`). They generally can take a range of values, but some of them (noted as `/keyword` below) are boolean switches: they are either present (or set to 1) or absent (or set to 0).

QUALIFIERS

name	routines	description
File	all	Required name of a (possibly gzip compressed) FITS file containing the **HEALPix** map in an extension or in the image field, *or* name of an *online* variable (either array or structure) containing the **HEALPix** map (See note below); if Save is set : name of an IDL saveset file containing the **HEALPix** map stored under the variable `data` (**default:** none) Note on online data: in order to preserve the integrity of the input data, the content of the array or structure `File` is replicated before being possibly altered by the map making process. Therefore plotting online data will require more memory than reading the data from disc directly, and is not recommended to visualize data sets of size comparable to that of the computer memory. Note on high resolution cut sky data: cut sky data (in which less than 50% of the sky is observed), can be processed with a minimal memory foot-print, by not allocating fake full map. In the current release, two restrictions apply: the input data set must be read from a FITS file in 'cut4' format, and the `POLARIZATION` IDL keyword (described below) must be 0 (default value). See the Examples #4 below (on page 78).
Select	all	Optional column of the BIN FITS table to be plotted, can be either – a name : value given in TTYPEi of the FITS file NOT case sensitive and can be truncated, (only letters, digits and underscore are valid) – an integer : number i of the column containing the data, starting with 1 (also valid if `File` is an online array) (**default:** 1 for full sky maps, 'SIGNAL' column for FITS files containing cut sky maps) (see the Examples below)

KEYWORDS

name	routines	description
/ASINH	all	if set, the color table is altered to emulate the effect of replacing the data by $\sinh^{-1}$(data) in order to enhance the low contrast regions. Can be used in conjonction with Factor and Offset, but can *not* be used with /LOG nor /HIST_EQUAL. see also: Factor, Hist_Equal, Log, Offset
CHARSIZE=	all	overall multiplicative factor applied to the size of all; characters appearing on the plot (**default:** 1.0)
COLT=	all	color table number, in [-40,40]. If colt< 0, the IDL color table abs(colt) is used, but the scale is reversed (ie a red to blue scale becomes a blue to red scale). Note: -0.1 can be used as negative 0. (**default:** 33 (Blue-Red))
COORD=	all	vector with 1 or 2 elements describing the coordinate system of the map; either – 'C' or 'Q' : Celestial2000 = eQuatorial, – 'E' : Ecliptic, – 'G' : Galactic if coord = ['x','y'] the map is rotated from system 'x' to system 'y' if coord = ['y'] the map is rotated to coordinate system 'y' (with the original system assumed to be Galactic unless indicated otherwise in the input file) see also: Rot
/CROP	all	if set the GIF/PNG file only contains the map and no title, color bar, ... see also: Gif, Png

name	routines	description
EXECUTE=	all	character string containing IDL command(s) to be executed in the plotting window. See Figure 2 on page 78
FACTOR=	all	multiplicative factor to be applied to the valid data the data plotted is of the form Factor*(data + Offset) This does not affect the flagged pixels Can be used together with ASINH or LOG see also: : ASINH, Offset, LOG (**default:** 1.0)
FITS=	-G–	string containing the name of an output fits file with the rectangular map in the primary image if set to 1 : output the plot in plot_gnomonic.fits if set to a file name : output the plot in that file (**default:** 0: no .FITS done) The resulting FITS file can be read with eg. map=`readfits`(*filename*). When used in conjonction with `FITS`, the `ROT` keyword should take the form (lon0, [lat0]), ie, no extra rotation around the center of the plot.
/FLIP	all	if set the longitude increases to the right, whereas by default (astronomical convention) it increases towards the left

name	**routines**	**description**
GAL_CUT=	–M-	(positive float) specifies the symmetric galactic cut in degrees outside of which the monopole and/or dipole fitting is done (**default:** 0: monopole and dipole fit done on the whole sky) (see also: : No_dipole, No_monopole)
GIF=	all	string containing the name of a .GIF output if set to 1 : output the plot in plot_[projection].gif if set to a file name : output the plot in that file Please note that the resulting GIF image might not always look as expected. The reason for this is a problem with 'backing store' in the IDL-routine TVRD. Please read the IDL documentation for more information. (**default:** no .GIF done) see also: Crop, Png, Ps and Preview
GLSIZE=	all	character size of the graticule labels in units of `Charsize`. (**default:** 0: no labeling of graticules). see also: Charsize, Graticule
GRATICULE=	all	if set, puts a graticule (ie, longitude and latitude grid) in the *output* astrophysical coordinates with delta_long = delta_lat = gdef degrees if set to a scalar $x >$ gmin then delta_long = delta_lat = x if set to [x,y] with $x, y >$ gmin then delta_long = x and delta_lat = y cartview : gdef = 45, gmin = 0 gnomview : gdef = 5, gmin = 0 mollview : gdef = 45, gmin = 10 orthview : gdef = 45, gmin = 10 Note that the graticule will rotate with the sphere is Rot is set. To outline only the equator set graticule=[360,90]. The automatic labeling of the graticule is controlled by `Glsize` (**default:** 0 [no graticule]) see also: Igraticule, Rot, Coord, Glsize

name	routines	description
/HALF_SKY	—O	if set, only shows only one half of the sky (centered on (0,0) or on the location parametrized by Rot) instead of the full sky
HBOUND=	all	if set to a valid $N_{\rm side}$, will overplot the **HEALPix** pixel boundaries corresponding to that $N_{\rm side}$ on top of the map.
/HELP	all	if set, the routine header is printed (by doc_library) and nothing else is done
/HIST_EQUAL	all	if set, uses a histogram equalized color mapping (useful for non gaussian data field) (**default:** uses linear color mapping and puts the level 0 in the middle of the color scale (ie, green for Blue-Red) unless Min and Max are not symmetric) see also: Asinh, Log
HXSIZE=	all	horizontal dimension (in cm) of the Postscript printout (**default:** 26 cm $\simeq$ 10 in) see also: Pxsize
IGLSIZE=	all	character size of the input coordinates graticule labels in units of `Charsize`. (**default:** 0: no labeling of graticules). see also: Charsize, Igraticule
IGRATICULE=	all	if set, puts a graticule (ie, longitude and latitude grid) in the *input* astrophysical coordinates. See Graticule for conventions and details. If both Graticule and Igraticule are set, the latter will be represented with dashes. The automatic labeling of the graticule is controlled by `Iglsize` (**default:** 0 [no graticule]) see also: Graticule, Rot, Coord, Iglsize
/LOG	all	display the log of map. This is intended for application to positive definite maps only, eg. Galactic foreground emission templates; for arbitrary maps, use /ASINH instead. see also: Asinh, Factor, Hist_Equal, Offset
MAX=	all	Set the maximum value for the plotted signal (**default:** is to use the actual signal maximum).
MIN=	all	Set the minimum value for the plotted signal (**default:** is to use the actual signal minimum).

name	**routines**	**description**
/NESTED	all	specify that the online data is ordered in the nested scheme
/NO_DIPOLE	–MO	if set (and Gal_cut is not set) the best fit monopole *and* dipole over all valid pixels are removed; if Gal_cut is set to $b > 0$, the best monopole and dipole fit is performed on all valid pixels with |galactic latitude| $> b$ (in deg) and is removed from all valid pixels (**default:** 0 (no monopole or dipole removal)) can NOT be used together with No_monopole see also: Gal_cut, No_monopole
/NO_MONOPOLE	–MO	if set (and Gal_cut is not set) the best fit monopole over all valid pixels is removed; if Gal_cut is set to $b > 0$, the best monopole fit is performed on all valid pixels with |galactic latitude| $> b$ (in deg) and is removed from all valid pixels (**default:** 0 (no monopole removal)) can NOT be used together with No_dipole see also: Gal_cut, No_dipole
/NOBAR	all	if set, color bar is not present
/NOLABELS	all	if set, color bar labels (min and max) are not present, (**default:** labels are present)
/NOPOSITION	-G–	if set, the astronomical location of the map central point is not indicated
OFFSET=	all	additive factor to be applied to the valid data the data plotted is of the form Factor*(data + Offset) This does not affect the flagged pixels can be used together with ASINH or LOG see also : ASINH, Offset, LOG (**default:** 0.0)

name	routines	description
OUTLINE=	all	IDL (meta-)structure containing the description of one (or several) outline(s) to be overplotted on the final map. For each contour or point list, the corresponding (sub)structure should contain the following fields : – 'COORD' coordinate system (either, 'C', 'G', or 'E') of the contour – 'RA' RA/longitude coordinates of the contour vertices (array or scalar) – 'DEC' Dec/latitude coordinates of the contour vertices (array or scalar) – 'LINE[STYLE]' (optional, scalar) **+2**: black dashes, **+1**: black dots, **0**: black solid (default), **-1**: black dots on white background, **-2**: black dashes on white background – 'PSY[M]' (optional, scalar) symbol used to represent vertices (same meaning as standard PSYM in IDL). If ≤ 0, the vertices are represented with the chosen symbols, and connected, by arcs of geodesics; if > 0, only the vertices are shown (**default:** 0) – 'SYM[SIZE]' (optional, scalar) vertice symbol size (same meaning as SYMSIZE in IDL) Notes: when applicable, the vertices are connected by segments of geodesics. To obtain a better looking outline, increase the number of vertices provided. The outline does not have to be closed. The procedure will NOT attempt to close the outline. Several outlines can be overplotted at once by gathering the respective structures into one meta-structure. see also: Coord, Graticule
PNG=	all	string containing the name of a .PNG output if set to 1 : output the plot in plot_[projection].png if set to a file name : output the plot in that file Please note that the resulting PNG image might not always look as expected. The reason for this is problems with 'backing store' in the IDL-routine TVRD. Please read the IDL documentation for more information. (**default:** no .PNG done) see also: Crop, Gif, Ps and Preview

name	routines	description
POLARIZATION=	all	if set to 0 no polarization information is plotted. 1 the AMPLITUDE $P = \sqrt{(U^2 + Q^2)}$ of the polarisation is plotted (as long as the input data contains polarisation information (ie, Stokes parameter Q and U for each pixel)) 2 the ANGLE $\phi = \tan^{-1}(U/Q)/2$ of the polarisation is plotted Note: the angles are color coded with a fixed color table (independent of Colt) 3 –the temperature is color coded (with a color table defined by Colt) –and the polarisation is overplot as headless VECTORS (**default:** 0) **Note:** The representation of the polarization direction (options 2 and 3 above), include the effects of the rotations and/or changes or astronomical coordinates (controlled by ROT and COORD respectively) but do not include the effects of the distortions induced by the projection from the sphere to the plan. Because the polarization usually has more power at small scales, it must generally be represented on maps of small patches of the sky to remain legible, in which case the projection-induced distortions are small.
/PREVIEW	all	if set, there is a 'ghostview' preview of the postscript file or a 'xv' preview of the gif file see also: Gif, Png and Ps
PS=	all	if set to 0 : no postscript output if set to 1 : output the plot in plot_cartesian, plot_gnomic.ps, plot_mollweide.ps or plot_orthographic respectively if set to a file name : output the plot in that file (**default:** 0) see also: Preview, Gif, Png
PXSIZE=	all	set the number of horizontal screen_pixels or postscript_color_dots of the plot (useful for high definition color printer) (**default:** 800 (Mollview and full sky Orthview), 600 (half sky Orthview), 500 (Cartview and Gnomonic))
PYSIZE=	CG–	set the number of vertical screen_pixels or postscript_color_dots of the plot (**default:** Pxsize)

name	routines	description
RESO_ARCMIN=	CG–	size of screen_pixels or postscript_color_dots in arcmin (**default:** 1.5)
ROT=	all	vector with 1, 2 or 3 elements specifing the rotation angles in DEGREES to apply to the map in the 'output' coordinate system (see Coord) = (lon0, [lat0, rat0]) lon0 : longitude of the point to be put at the center of the plot the longitude increases Eastward, ie to the left of the plot (**default:** 0) lat0 : latitude of the point to be put at the center of the plot (**default:** 0) rot0 : anti clockwise rotation to apply to the sky around the center (lon0, lat0) before projecting (**default:** 0) see also: : FITS
/SAVE	all	if set, assumes that File is in IDL saveset format, the variable saved should be DATA
/SILENT	all	if set, the program runs silently
SUBTITLE=	all	String containing the subtitle to the plot see also: Titleplot
TITLEPLOT=	all	String containing the title of the plot, if not set the title will be File see also: Subtitle
/TRANSPARENT	C—	If set, the input data pixels with value `!healpix.bad_value`($=-1.6375e30$) will appear totally transparent on the output PNG file (instead of the usual grey). Active only in conjunction with /CROP and PNG
UNITS=	all	String containing the units, to be put on the right hand side of the color bar, overrides the value read from the input file, if any see also: Nobar, Nolabels
WINDOW=	all	IDL window index (integer) – if WINDOW < 0: virtual window: no visible window opened. Can be used with PNG or GIF, in particular is those files are larger than the screen. – if WINDOW in $[0, 31]$: the specified IDL window with index WINDOW is used (or reused). Can be used to have a sequence of images appear in the same window – if WINDOW > 31: a free (=unused) window with a random index > 31 will be created and used. (**default:** 32)

name	**routines**	**description**
XPOS=	all	The X position on the screen of the lower left corner of the window, in device coordinate
YPOS=	all	The Y position on the screen of the lower left corner of the window, in device coordinate

DESCRIPTION

mollview reads in a **HEALPix** sky map in FITS format and generates a Mollweide projection of it, that can be visualized on the screen or exported in a PNG or Postscript file.mollview allows the selection of the coordinate system, map size, color table, color bar inclusion, linear or log scaling, histogram equalised color scaling, maximum and minimum range for the plot, plot-title *etc.* It also allows the representation of the polarization field.

RELATED ROUTINES

This section lists the routines related to **mollview**.

idl	version 6.0 or more is necessary to run mollview
ghostview	ghostview or a similar facility is required to view the Postscript image generated by mollview.
xv	xv or a similar facility is required to view the GIF/PNG image generated by mollview (a browser can also be used).
synfast	This **HEALPix** facility will generate the FITS format sky map to be input to mollview.
cartview	IDL facility to generate a Cartesian projection of a **HEALPix** map.
cartcursor	interactive cursor to be used with cartview
gnomview	IDL facility to generate a gnomonic projection of a **HEALPix** map.
gnomcursor	interactive cursor to be used with gnomview
mollview	IDL facility to generate a Mollweide projection of a **HEALPix** map.
mollcursor	interactive cursor to be used with mollview
orthview	IDL facility to generate an orthographic projection of a **HEALPix** map.

orthcursor interactive cursor to be used with orthview

EXAMPLES: #2

```
map = findgen(48)
triangle= create_struct('coord','G','ra',[0,80,0],'dec',[40,45,65])
mollview,map, graticule=[45,30],rot=[10,20,30],$
     title='Mollweide projection',subtitle='mollview', $
     outline=triangle
```

makes a Mollweide projection of a pixel index map (see Figure 1c on page 77) after an arbitrary rotation, with a graticule grid (with a 45^o step in longitude and 30^o in latitude) and an arbitrary triangular outline

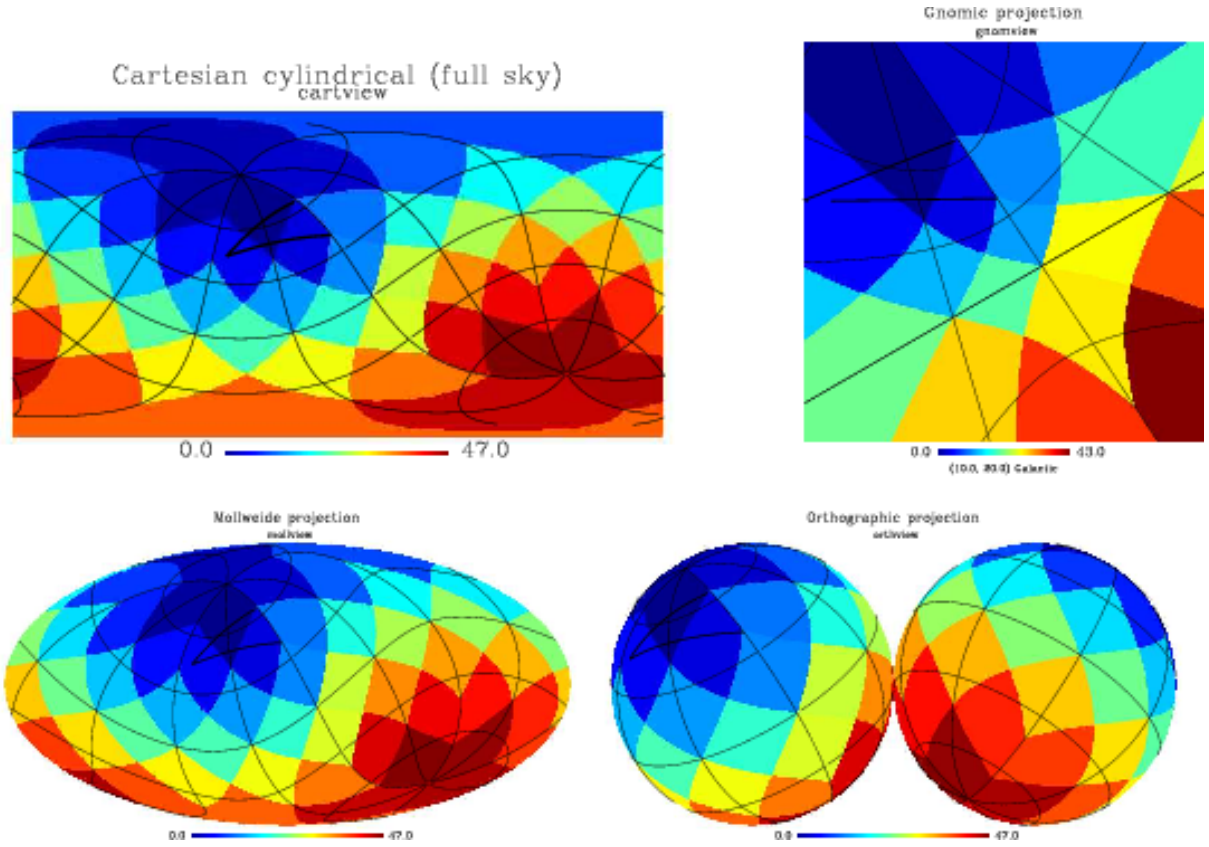

Figure 1: Figures produced by cartview, gnomview, mollview and orthview, see respective routine documentation for details.

EXAMPLES: #3

```
map = findgen(48)
mycommand = 'x=findgen(64)/10.  & ' + $
     'plot,x,sin(x),pos=[0.8,0.8,0.99,0.99],/noerase &' +$
     'xyouts,0.5,0.5,''Hello World !'',/normal,charsize=2,align=0.5'
mollview,map, execute=mycommand, png='plot_example_execute.png',/preview,$
     /graticule,/glsize
```

produces a PNG file containing a Mollweide projection of a pixel index map with labeled graticules, a simple sine wave in the upper right corner, and some greetings, as shown on Figure 2 on page 78

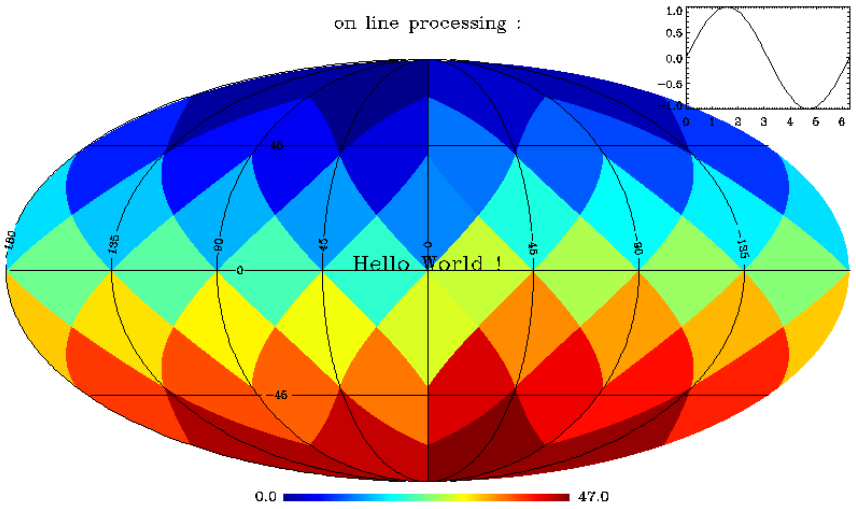

Figure 2: Figure produced by example #3.

EXAMPLES: #4

```
pixel = l64indgen(400000)
signal = pixel * 10.0
file = 'cutsky.fits'
write_fits_cut4, file, pixel+100000, signal, nside=32768, /ring
gnomview, file, rot=[0,90], grat=30, title='high res.  cut-sky map'
```

produces and plots a high resolution map (6.4 arcsec/pixel), in which only a very small subset of pixels is observed

EXAMPLES: #5

```
file = 'wmap_band_iqumap_r9_5yr_K_v3.fits'
mollview, file, title='Linear Color Scale', /silent
mollview, file,/asinh,title='Sinh!u-1!n Color Scale' , /silent
mollview, file,/hist, title='Histogram Equalized Color Scale', /silent
mollview, file,/log, title='Log Scale', /silent
```

produces Mollweide projections of the same map (here the WMAP-5yr K band) with various color scales: linear, Inverse Hyperbolic Sine, Histogram Equalized, and Log. See Figure 3 on page 79

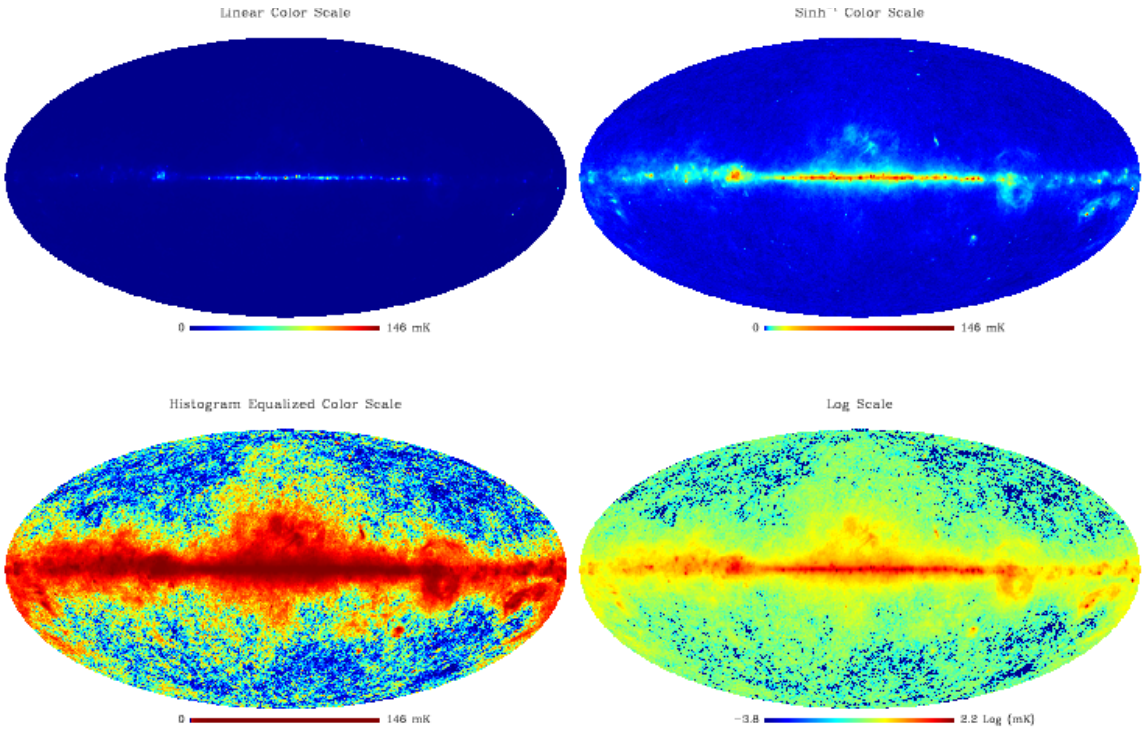

Figure 3: Illustration (generated by example #5) of the various color scales available.

EXAMPLES: #1

```
mollview, 'planck100GHZ-LFI.fits', min=-100, max=100, /graticule, $
   title='Simulated Planck LFI Sky Map at 100GHz'
```

mollview reads in the map 'planck100GHZ-LFI.fits' and generates an output image in which the temperature scale has been set to lie between $\pm$ 100 (μK), a graticule with a 45 degree step in longitude and latitude is drawn, and the title 'Simulated Planck LFI Sky Map at 100GHz' appended to the image.

neighbours_nest

Location in HEALPix directory tree: src/idl/toolkit/neighbours_nest.pro

This IDL facility returns the number and indices of the topological immediate neighbours of a central pixel. The pixels are ordered in a clockwise sense (when watching the sphere from the outside) about the central pixel with the southernmost pixel in first element. For the four pixels in the southern corners of the equatorial faces which have two equally southern neighbours the routine returns the southwestern pixel first and proceeds clockwise.

FORMAT

IDL> neighbours_nest (Nside, Ipix0, Listpix [,Nneigh])

QUALIFIERS

Nside	**HEALPix** resolution parameter (scalar integer), should be a valid Nside (power of 2)
Ipix0	NESTED-scheme index of central pixel in [0,12*Nside^2-1]
Listpix	output: list of neighbouring pixel (NESTED scheme index) of size `Nneigh`
Nneigh	optional output: number of neighbours of pixel `#Ipix0`. Usually 8, sometimes 7 (for 8 particular pixels) or 6 (if Nside=1)

DESCRIPTION

neighbours_nest calls `pix2xy_nest` to find location of central pixel within the pixelisation base-face, and then `xy2pix_nest` to find neighbouring pixels within the same face, or one of the bit manipulation routines if the neighbouring pixel is on a different base-face.

RELATED ROUTINES

This section lists the routines related to **neighbours_nest**.

idl	version 6.0 or more is necessary to run neighbours_nest .
neighbours_ring	returns topological immediate neighbouring pixels of a given central pixel, using RING indexing.
query_disc, query_polygon, query_strip, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon, latitude strip and triangle
nest2ring, ring2nest	conversion between NESTED and RING indices

EXAMPLE:

```
neighbours_nest , 4, 1, list, nneigh
print,nneigh,list
```

will return:8 90 0 2 3 6 4 94 91, listing the NESTED-indexed 8 neighbors of pixel #1 for Nside=4

neighbours_ring

Location in HEALPix directory tree: src/idl/toolkit/neighbours_ring.pro

This IDL facility returns the number and indices of the topological immediate neighbours of a central pixel. The pixels are ordered in a clockwise sense (when watching the sphere from the outside) about the central pixel with the southernmost pixel in first element. For the four pixels in the southern corners of the equatorial faces which have two equally southern neighbours the routine returns the southwestern pixel first and proceeds clockwise.

FORMAT

IDL> neighbours_ring (Nside, Ipix0, Listpix [,Nneigh])

QUALIFIERS

Nside	**HEALPix** resolution parameter (scalar integer), should be a valid Nside (power of 2)
Ipix0	RING-scheme index of central pixel in [0,12*Nside^2-1]
Listpix	output: list of neighbouring pixel (RING scheme index) of size `Nneigh`
Nneigh	optional output: number of neighbours of pixel `#Ipix0`. Usually 8, sometimes 7 (for 8 particular pixels) or 6 (if Nside=1)

DESCRIPTION

neighbours_ring calls ring2nest, neighbours_nest and nest2ring

RELATED ROUTINES

This section lists the routines related to **neighbours_ring**.

idl	version 6.0 or more is necessary to run neighbours_ring .

neighbours_nest	returns topological immediate neighbouring pixels of a given central pixel, using NESTED indexing.
query_disc, query_polygon, query_strip, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon, latitude strip and triangle
nest2ring, ring2nest	conversion between NESTED and RING indices

EXAMPLE:

```
neighbours_ring , 4, 1, list, nneigh
print,nneigh,list
```

will return:8 16 6 5 0 3 2 8 7 listing the RING-indexed 8 neighbors of pixel #1 for Nside=4

npix2nside

Location in HEALPix directory tree: src/idl/toolkit/npix2nside.pro

This IDL facility provides the **HEALPix** resolution parameter Nside corresponding to Npix pixels over the full sky.

FORMAT

IDL> Nside=NPIX2NSIDE (Npix [,ERROR=])

QUALIFIERS

Npix	number of pixels over the full sky (scalar integer), should be a valid Npix ($N_{\rm pix} = 12N_{\rm side}^2$ with $N_{\rm side}$ power of 2 in $\{1, \ldots, 2^{29}\}$)
Nside	on output: resolution parameter if Npix is valid, -1 otherwise

KEYWORDS

ERROR =	error flag, set to 1 on output if Npix is NOT valid, or stays to 0 otherwise.

DESCRIPTION

npix2nside checks that the given Npix is valid ($N_{\rm pix} = 12N_{\rm side}^2$ with $N_{\rm side}$ a power of 2 in $\{1, \ldots, 2^{29}\}$) and then computes the corresponding resolution parameter $N_{\rm side}$.

RELATED ROUTINES

This section lists the routines related to **npix2nside** .

idl	version 6.0 or more is necessary to run npix2nside .
nside2npix	computes Npix corresponding to Nside
pix2xxx, ang2xxx, vec2xxx, ...	conversion between vector or angles and pixel index and vice-versa

vec2pix, pix2vec	conversion between vector and pixel index
nest2ring, ring2nest	conversion between NESTED and RING indices

EXAMPLE:

```
Nside = npix2nside(49152, ERROR=error)
```

Nside will be 64 because 49152 is a valid pixel number (=12*64^2 and 64 is a power of 2), and error will be 0

EXAMPLE:

```
Nside = npix2nside(49151, ERROR=error)
```

Nside will be -1 and error: 1, because 49151 is not a valid number of **HEALPix** pixels over the full sky.

nside2npix

Location in HEALPix directory tree: src/idl/toolkit/nside2npix.pro

This IDL facility provides the number of pixels Npix over the full sky corresponding to resolution parameter Nside.

FORMAT

IDL> Npix=NSIDE2NPIX (Nside [,ERROR=])

QUALIFIERS

Nside	**HEALPix** resolution parameter (scalar integer), should be a valid Nside (power of $2 \leq 2^{29}$)
Npix	number of pixels, Npix = 12*Nside^2 if Nside is a valid resolution parameter or -1 otherwise

KEYWORDS

ERROR =	error flag, set to 1 on output if Nside is NOT valid, or stays to 0 otherwise.

DESCRIPTION

nside2npix checks that the given Nside is valid (power of 2 in $\{1, \ldots, 2^{29}\}$) and then computes the corresponding number of pixels $N_{\rm pix} = 12 N_{\rm side}^2$.

RELATED ROUTINES

This section lists the routines related to **nside2npix**.

idl	version 6.0 or more is necessary to run nside2npix .
npix2nside	computes Nside corresponding to Npix
pix2xxx, ang2xxx, vec2xxx, ...	conversion between vector or angles and pixel index and vice-versa
vec2pix, pix2vec	conversion between vector and pixel index

nest2ring, ring2nest	conversion between NESTED and RING indices

EXAMPLE:

```
Npix = nside2npix(256, ERROR=error)
```

Npix will be 786432 the number of pixels over the full sky for the **HEALPix** resolution parameter 256 and error will be 0

EXAMPLE:

```
Npix = nside2npix(248, ERROR=error)
```

Npix will be -1 and error: 1, because 248 is not a valid value for a **HEALPix** resolution parameter

nside2ntemplates

Location in HEALPix directory tree: src/idl/toolkit/nside2ntemplates.pro

This IDL facility provides the number of template pixels Ntemplates corresponding to resolution parameter Nside. Each template pixel has a different shape that *can not* be matched (by rotation or reflexion) to that of any of the other templates.

FORMAT

IDL> Ntemplates=NSIDE2NTEMPLATES (Nside [,ERROR=])

QUALIFIERS

Nside	**HEALPix** resolution parameter (scalar integer), should be a valid Nside (power of 2 in $\{1, \ldots, 8192\}$)
Ntemplates	number of templates

KEYWORDS

ERROR =	error flag, set to 1 on output if Nside is NOT valid, or stays to 0 otherwise.

DESCRIPTION

nside2ntemplates outputs the number of template pixels

$$N_{\mathrm{template}} = \frac{1 + N_{\mathrm{side}}(N_{\mathrm{side}} + 6)}{4}.$$

If the argument N_{side} is not valid, a warning is issued and the error flag is raised.

RELATED ROUTINES

This section lists the routines related to **nside2ntemplates**.

idl	version 6.0 or more is necessary to run nside2ntemplates .

template_pixel_ring	
template_pixel_nest	return the template pixel associated with any **HEALPix** pixel
same_shape_pixels_ring	
same_shape_pixels_nest	return the ordered list of pixels having the same shape as a given pixel template

EXAMPLE:

```
Ntemplates = nside2ntemplates(256, ERROR=error)
```

Ntemplates will be 16768 the number of template pixels for the **HEALPix** resolution parameter 256 and error will be 0

orthcursor

Location in HEALPix directory tree: src/idl/visu/orthcursor.pro

This IDL facility provides a point-and-click interface for finding the astronomical location, value and pixel index of the pixels nearest to the pointed position on a orthographic projection of a **HEALPix** map.

FORMAT

IDL> ORTHCURSOR, [cursor_type=, file_out=]

QUALIFIERS

see mollcursor

DESCRIPTION

orthcursor should be called immediately after orthview. It gives the longitude, latitude, map value and pixel number corresponding to the cursor position in the window containing the map generated by orthview. For more details, or in case of problems under **Mac OS X**, see mollcursor.

RELATED ROUTINES

This section lists the routines related to **orthcursor**.

see mollcursor

EXAMPLE:

```
orthcursor
```

After orthview has read in a map and generated its orthographic projection, orthcursor is run to determine the position and flux of bright synchrotron sources, for example.

orthview

Location in HEALPix directory tree: src/idl/visu/orthview.pro

This IDL facility provides a means to visualise a full sky or half sky orthographic projection (projection onto a tangent plane from a point located at infinity) of **HEALPix** and COBE Quad-Cube maps in an IDL environment. It also offers the possibility to generate gif and postscript images of the projected map.

FORMAT

IDL> ORTHVIEW, File, [Select,] [CHARSIZE=, ... WINDOW=, XPOS=, YPOS=]

QUALIFIERS

For a full list of qualifiers see mollview

KEYWORDS

For a full list of keywords see mollview

DESCRIPTION

orthview reads in a **HEALPix** sky map in FITS format and generates an orthographic projection of it, that can be visualized on the screen or exported in a GIF, PNG, Postscript or FITS file. orthview allows the selection of the coordinate system, point of projection, map size, color table, color bar inclusion, linear or log scaling, histogram equalised color scaling, maximum and minimum range for the plot, plot-title *etc.* It also allows the representation of the polarization field.

RELATED ROUTINES

This section lists the routines related to **orthview**.

see mollview

EXAMPLE:

```
map = findgen(48)
triangle= create_struct('coord','G','ra',[0,80,0],'dec',[40,45,65])
orthview,map,/online,graticule=[45,30],rot=[10,20,30],$
   title='Orthographic projection',subtitle='orthview' $
   outline=triangle
```

makes an orthographic projection of map (see Figure 1d on page 77) after an arbitrary rotation, with a graticule grid (with a 45^o step in longitude and 30^o in latitude) and an arbitrary triangular outline

pix2xxx, ang2xxx, vec2xxx, nest2ring, ring2nest

Location in HEALPix directory tree: src/idl/toolkit/

These routines provide conversion between pixel number in the **HEALPix** map and (θ, ϕ) or (x, y, z) coordinates on the sphere. Some of these routines are listed here.

QUALIFIERS

name (dim.)	type	in/out	description
nside	scalar integer	IN	N_{side} parameter for the **HEALPix** map.
ipnest(n)	vector integer	—	pixel identification number in NESTED scheme over the range $\{0,N_{pix}-1\}$.
ipring(n)	vector integer	—	pixel identification number in RING scheme over the range $\{0,N_{pix}-1\}$.
theta(n)	vector double	—	colatitude in radians measured southward from north pole in $\{0,\pi\}$
phi(n)	vector double	—	longitude in radians, measured eastward in $\{0,2\pi\}$.
vector(n,3)	array double	—	three dimensional cartesian position vector (x, y, z). The north pole is $(0, 0, 1)$. An output vector is normalised to unity. The coordinates are ordered as follows $x(0), \ldots, x(n-1),\ y(0), \ldots, y(n-1),\ z(0), \ldots, z(n-1)$
vertex(n,3,4)	array double	optional OUT	three dimensional cartesian position vector (x, y, z). Contains the location of the four vertices (=corners) of a pixel in the order North, West, South, East. The coordinates are ordered as follows $x_N(0), \ldots, x_N(n-1),\ y_N(0), \ldots, y_N(n-1),\ z_N(0), \ldots, z_N(n-1), x_W(0), \ldots, x_W(n-1),\ y_W(0), \ldots, y_W(n-1),\ z_W(0), \ldots, z_W(n-1)$, and so on with South and East vertices

ROUTINES:

`pix2ang_ring, nside, ipring, theta, phi`

renders *theta* and *phi* coordinates of the nominal pixel center given the pixel number *ipring* and a map resolution parameter *nside*.

`pix2vec_ring, nside, ipring, vector [,vertex]`

renders cartesian vector coordinates of the nominal pixel center given the pixel number *ipring* and a map resolution parameter *nside*. Optionally returns the location of the 4 vertices for the pixel(s) under consideration

`ang2pix_ring, nside, theta, phi, ipring`

renders the pixel number *ipring* for a pixel which, given the map resolution parameter *nside*, contains the point on the sphere at angular coordinates *theta* and *phi*.

`vec2pix_ring, nside, vector, ipring`

renders the pixel number *ipring* for a pixel which, given the map resolution parameter *nside*, contains the point on the sphere at cartesian coordinates *vector*.

`pix2ang_nest, nside, ipnest, theta, phi`

renders *theta* and *phi* coordinates of the nominal pixel center given the pixel number *ipnest* and a map resolution parameter *nside*.

`pix2vec_nest, nside, ipnest, vector [,vertex]`

renders cartesian vector coordinates of the nominal pixel center given the pixel number *ipnest* and a map resolution parameter *nside*. Optionally returns the location of the 4 vertices for the pixel(s) under consideration

`ang2pix_nest, nside, theta, phi, ipnest`

renders the pixel number *ipnest* for a pixel which, given the map resolution parameter *nside*, contains the point on the sphere at angular coordinates *theta* and *phi*.

`vec2pix_nest, nside, vector, ipnest`

renders the pixel number *ipnest* for a pixel which, given the map resolution parameter *nside*, contains the point on the sphere at cartesian coordinates *vector*.

`nest2ring, nside, ipnest, ipring`

performs conversion from NESTED to RING pixel number.

`ring2nest, nside, ipring, ipnest`

performs conversion from RING to NESTED pixel number.

RELATED ROUTINES

This section lists the routines related to **pix2xxx, ang2xxx, vec2xxx, nest2ring, ring2nest**.

idl	version 6.0 or more is necessary to run pix2xxx, ang2xxx,... .
npix2nside	computes Nside (resolution) corresponding to Npix (total pixel number)
nside2npix	computes Npix corresponding to Nside
ang2vec, vec2ang	geometrical conversion between position angles and position vector

EXAMPLE:

```
pix2ang_ring, 256, [17,1000], theta, phi
print,theta,phi
```

returns
0.0095683558 0.070182078
2.8797933 5.4620872
position of 2 pixels 17 and 1000 in the RING scheme with parameter 256.

query_disc

Location in HEALPix directory tree: src/idl/toolkit/query_disc.pro

This IDL facility provides a means to find the index of all pixels within an angular distance `Radius` from a defined center.

FORMAT

IDL> query_disc , Nside, Vector0, Radius, Listpix, [Nlist, DEG=, NESTED=, INCLUSIVE=]

QUALIFIERS

Nside	**HEALPix** resolution parameter used to index the pixel list (scalar integer)
Vector0	position vector of the disc center (3 elements vector) NB : the norm of Vector0 does not have to be one, what is consider is the intersection of the sphere with the line of direction Vector0.
Radius	radius of the disc (in radians, unless DEG is set), (scalar real)
Listpix	on output: list of ordered index for the pixels found within a radius Radius of the position defined by vector0. The RING numbering scheme is used unless the keyword `NESTED` is set. (=-1 if the radius is too small and no pixel is found)
Nlist	on output: number of pixels in Listpix (=0 if no pixel is found).

KEYWORDS

DEG =	if set `Radius` is in degrees instead of radians
NESTED =	if set, the output list uses the NESTED numbering scheme instead of the default RING
INCLUSIVE =	if set, all the pixels overlapping (even partially) with the disc are listed, otherwise only those whose center lies within the disc are listed

DESCRIPTION

query_disc finds the pixels within the given disc in a selective way WITHOUT scanning all the sky pixels. The numbering scheme of the output list and the inclusiveness of the disc can be changed

RELATED ROUTINES

This section lists the routines related to **query_disc** .

idl	version 6.0 or more is necessary to run query_disc .
ang2pix, pix2ang	conversion between angles and pixel index
vec2pix, pix2vec	conversion between vector and pixel index
query_disc, query_polygon, query_strip, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon, latitude strip and triangle

EXAMPLE:

```
query_disc , 256L, [.5,.5,0.], 10., listpix, nlist, /Deg, /Nest
```

On return listpix contains the index of the (5982) pixels within 10 degrees from the point on the sphere having the direction [.5,.5,0.]. The pixel indices correspond to the Nested scheme with resolution 256.

query_polygon

Location in HEALPix directory tree: src/idl/toolkit/query_polygon.pro

This IDL facility provides a means to find the index of all pixels belonging to a sperical polygon defined by its vertices

FORMAT

IDL> query_polygon , Nside, Vlist, Listpix, [Nlist, NESTED=, INCLUSIVE=]

QUALIFIERS

Nside	**HEALPix** resolution parameter used to index the pixel list (scalar integer)
Vlist	3D cartesian position vector of the polygon vertices. Array of dimension (n,3) where n is the number of vertices
Listpix	on output: list of ordered index for the pixels found in the polygon. The RING numbering scheme is used unless the keyword `NESTED` is set. (=-1 if the polygon is too small and no pixel is found)
Nlist	on output: number of pixels in Listpix (=0 if no pixel is found).

KEYWORDS

NESTED =	if set, the output list uses the NESTED numbering scheme instead of the default RING
INCLUSIVE =	if set, all the pixels overlapping (even partially) with the polygon are listed, otherwise only those whose center lies within the polygon are listed

DESCRIPTION

query_polygon finds the pixels within the given polygon in a selective way WITHOUT scanning all the sky pixels. The polygon should be convex, or have only one concave vertex. The edges should not intersect each other. The numbering scheme of the output list and the inclusiveness of the polygon can be changed

RELATED ROUTINES

This section lists the routines related to **query_polygon** .

idl	version 6.0 or more is necessary to run query_polygon .
ang2pix, pix2ang	conversion between angles and pixel index
vec2pix, pix2vec	conversion between vector and pixel index
query_disc, query_polygon, query_strip, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon, latitude strip and triangle

EXAMPLE:

```
query_polygon , 256L, [[0,1,1,0],[0,0,1,1],[1,0,-1,0]], listpix, nlist
```

On return listpix contains the index of the (131191) pixels contained in the polygon with vertices of cartesian coordinates (0,0,1), (1,0,0), (1,1,-1) and (0,1,0). The pixel indices correspond to the RING scheme with resolution 256.

query_strip

Location in HEALPix directory tree: src/idl/toolkit/query_strip.pro

This IDL facility provides a means to find the index of all pixels belonging to a latitude strip defined by its bounds

FORMAT

IDL> query_strip , Nside, Theta1, Theta2, Listpix, [Nlist, NESTED=, INCLUSIVE=, HELP=]

QUALIFIERS

Nside	**HEALPix** resolution parameter used to index the pixel list (scalar integer)
Theta1	colatitude lower bound in radians measured from North Pole (between 0 and π).
Theta2	colatitude upper bound in radians measured from North Pole (between 0 and π). If theta1< theta2, the pixels lying in [theta1,theta2] are output, otherwise, the pixel lying in [0, theta2] and those lying in [theta1, π] are output.
Listpix	on output: list of ordered index for the pixels found in the strip. The RING numbering scheme is used unless the keyword `NESTED` is set. (=-1 if the strip is too small and no pixel is found)
Nlist	on output: number of pixels in Listpix (=0 if no pixel is found).

KEYWORDS

NESTED =	if set, the output list uses the NESTED numbering scheme instead of the default RING
INCLUSIVE =	if set, all the pixels overlapping (even partially) with the strip are listed, otherwise only those whose center lies within the strip are listed

/HELP	if set, the routine prints its documentation header and exits.

DESCRIPTION

query_strip finds the pixels within the given strip in a selective way WITHOUT scanning all the sky pixels. The numbering scheme of the output list and the inclusiveness of the strip can be changed

RELATED ROUTINES

This section lists the routines related to **query_strip** .

idl	version 6.0 or more is necessary to run query_strip .
ang2pix, pix2ang	conversion between angles and pixel index
vec2pix, pix2vec	conversion between vector and pixel index
query_disc, query_polygon, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon and triangle

EXAMPLE:

```
query_strip , 256, 0.75*!PI, !PI/5, listpix, nlist, /nest
```

Returns the NESTED pixel index of all pixels with colatitude in [0,π/5] and those with colatitude in [3π/4,π]

query_triangle

Location in HEALPix directory tree: src/idl/toolkit/query_triangle.pro

This IDL facility provides a means to find the index of all pixels belonging to a sperical triangle defined by its vertices

FORMAT

IDL> query_triangle , Nside, Vector1, Vector2, Vector3, Listpix, [Nlist, NESTED=, INCLUSIVE=]

QUALIFIERS

Nside	**HEALPix** resolution parameter used to index the pixel list (scalar integer)
Vector1	3D cartesian position vector of the triangle first vertex
Vector2	3D cartesian position vector of the triangle second vertex
Vector3	3D cartesian position vector of the triangle third vertex NB : the norm of Vector* does not have to be one, what is considered is the intersection of the sphere with the line of direction Vector*.
Listpix	on output: list of ordered index for the pixels found in the triangle. The RING numbering scheme is used unless the keyword `NESTED` is set. (=-1 if the triangle is too small and no pixel is found)
Nlist	on output: number of pixels in Listpix (=0 if no pixel is found).

KEYWORDS

NESTED =	if set, the output list uses the NESTED numbering scheme instead of the default RING
INCLUSIVE =	if set, all the pixels overlapping (even partially) with the triangle are listed, otherwise only those whose center lies within the triangle are listed

DESCRIPTION

query_triangle finds the pixels within the given triangle in a selective way WITHOUT scanning all the sky pixels. The numbering scheme of the output list and the inclusiveness of the triangle can be changed

RELATED ROUTINES

This section lists the routines related to **query_triangle** .

idl	version 6.0 or more is necessary to run query_triangle .
ang2pix, pix2ang	conversion between angles and pixel index
vec2pix, pix2vec	conversion between vector and pixel index
query_disc, query_polygon, query_strip, query_triangle	render the list of pixels enclosed respectively in a given disc, polygon, latitude strip and triangle

EXAMPLE:

```
query_triangle , 256L, [1,0,0],[0,1,0],[0,0,1], listpix, nlist
```

On return listpix contains the index of the (98560) pixels lying in the octant $(x > 0, y > 0, y > 0)$. The pixel indices correspond to the RING scheme with resolution 256.

read_fits_cut4

Location in HEALPix directory tree: src/idl/fits/read_fits_cut4.pro

This IDL facility reads a cut sky **HEALPix** map from a FITS file according to the **HEALPix** convention. The format used for the FITS file follows the one used for Boomerang98 and is adapted from COBE/DMR. This routine can also be used to read polarized cut sky map, where each Stokes parameter is stored in a different extension of the same FITS file.

FORMAT

IDL> READ_FITS_CUT4 , File, Pixel, Signal [, N_Obs, Serror, EXTENSION=, HDR=, XHDR=, NSIDE=, ORDERING=, COORDSYS=]

QUALIFIERS

File	name of a FITS file in which the map is to be written
Pixel	(OUT, LONG vector), index of observed (or valid) pixels
Signal	(OUT, FLOAT vector), value of signal in each observed pixel
N_Obs	(OUT, LONG or INT vector, Optional), number of observation per pixel
Serror	(OUT, FLOAT vector, Optional), *rms* of signal in pixel. For white noise, this is $\propto 1/\sqrt{\text{n\_obs}}$

KEYWORDS

EXTENSION =	(IN, optional), 0 based number of extension to read. Extension 0 contains the temperature information, while extensions 1 and 2 contain respectively the Q and U Stokes parameters related information. (**default:** 0)

HDR =	(OUT, optional), String array containing the primary header.
XHDR =	(OUT, optional), String array containing the extension header.
NSIDE=	(OUT, optional), returns on output the **HEALPix** resolution parameter, as read from the FITS header. Set to -1 if not found
ORDERING=	(OUT, optional), returns on output the pixel ordering, as read from the FITS header. Either 'RING' or 'NESTED' or ' ' (if not found).
COORDSYS=	(OUT, optional), returns on output the astrophysical coordinate system used, as read from FITS header (value of keywords COORDSYS or SKYCOORD)

DESCRIPTION

RELATED ROUTINES

This section lists the routines related to **read_fits_cut4** .

idl	version 6.0 or more is necessary to run read_fits_cut4
write_fits_cut4	This **HEALPix** IDL facility can be used to generate the FITS format *cut-sky* maps complient with **HEALPix** convention and readable by read_fits_cut4 .
read_fits_cut4, read_fits_map	
read_tqu, read_fits_s	**HEALPix** IDL routines to read cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets from FITS files
sxpar	This IDL routine (included in **HEALPix** package) can be used to extract FITS keywords from the header(s) HDR or XHDR read with read_fits_cut4 .

read_fits_map

Location in HEALPix directory tree: src/idl/fits/read_fits_map.pro

This IDL facility reads in a **HEALPix** map from a FITS file.

FORMAT

IDL> READ_FITS_MAP , File, T_sky, [Hdr, Exthdr, PIXEL=, SILENT=, NSIDE=, ORDERING=, COORDSYS=]

QUALIFIERS

File	name of a FITS file containing the **HEALPix** map in an extension or in the image field
T_sky	variable containing on output the **HEALPix** map
Hdr	(optional), string variable containing on output the FITS primary header
Exthdr	(optional), string variable containing on output the FITS extension header
PIXEL=	(optional), pixel number to read from or pixel range to read (in the order of appearance in the file), starting from 0. if ≥ 0 scalar : read from pixel to the end of the file if two elements array : reads from pixel[0] to pixel[1] (included) if absent : read the whole file
NSIDE=	(optional), returns on output the **HEALPix** resolution parameter, as read from the FITS header. Set to -1 if not found
ORDERING=	(optional), returns on output the pixel ordering, as read from the FITS header. Either 'RING' or 'NESTED' or

	' ' (if not found).
COORDSYS=	(optional), returns on output the astrophysical coordinate system used, as read from FITS header (value of keywords COORDSYS or SKYCOORD)

KEYWORDS

SILENT=	if set, no message is issued during normal execution

DESCRIPTION

read_fits_map reads in a **HEALPix** sky map from a FITS file, and outputs the variable `T_sky`, where the optional variables `Hdr` and `Exthdr` contain respectively the primary and extension headers. According to **HEALPix** convention, the map should be is stored as a FITS file binary table extension. Note:the routine read_tqu which requires less memory is recommended when reading *large polarized* maps.

RELATED ROUTINES

This section lists the routines related to **read_fits_map**.

idl	version 6.0 or more is necessary to run read_fits_map
read_fits_cut4, read_fits_map	
read_tqu, read_fits_s	**HEALPix** IDL routines to read cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets from FITS files
sxpar	This IDL routine (included in **HEALPix** package) can be used to extract FITS keywords from the header(s) Hdr or Xhdr read with read_fits_map.
synfast	This **HEALPix** facility will generate the FITS format sky map that can be read by read_fits_map.
write_fits_map	This **HEALPix** IDL facility can be used to generate the FITS format sky maps complient with **HEALPix** convention and readable by read_fits_map.

EXAMPLE:

```
read_fits_map, 'planck100GHZ-LFI.fits', map, hdr, xhdr, /silent
```

read_fits_map reads in the file 'planck100GHZ-LFI.fits' and outputs the **HEALPix** map in `map`, the primary header in `hdr` and the extension header in `xhdr`.

read_fits_s

Location in HEALPix directory tree: src/idl/fits/read_fits_s.pro

This IDL facility reads a FITS file into an IDL structure.

FORMAT

IDL> READ_FITS_S , File, Prim_stc, [Xten_stc, MERGE=, EXTENSION=]

QUALIFIERS

File	name of a FITS file containing the healpix map(s) in an extension or in the image field
Prim_stc	variable containing on output an IDL structure with the following fields: - primary header (tag : 0, tag name : HDR) - primary image (if any, tag : 1, tag name : IMG)
Xten_stc	(optional), variable containing on output an IDL structure with the following fields: - extension header (tag : 0, tag name : HDR) - data column 1 (if any, tag : 1, tag name given by TTYPE1 (with all spaces removed and only letters, digits and underscore) - data column 2 (if any, tag : 2, tag name given by TTYPE2) ...
EXTENSION=	(optional), scalar integer containing on input the extension to be read (0 based) (**default:** 0)

KEYWORDS

MERGE=	if set `Prim_stc` contains : - the concatenated primary and extension header (tag name : HDR) - primary image (if any, tag name : IMG)

- data column 1 ...
and `Exten_stc` is set to 0
(**default:** :) not set (or set to 0)

DESCRIPTION

read_fits_s reads in any type of FITS file (Image, Binary table or Ascii table) and outputs the data in IDL structures

RELATED ROUTINES

This section lists the routines related to **read_fits_s** .

idl	version 6.0 or more is necessary to run read_fits_s
synfast	This **HEALPix** facility will generate the FITS format sky map that can be read by read_fits_s .
read_fits_cut4, read_fits_map	
read_tqu, read_fits_s	**HEALPix** IDL routines to read cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets from FITS files
write_fits_sb	This **HEALPix** IDL facility can be used to generate FITS format sky maps readable by read_fits_s .

EXAMPLE:

```
read_fits_s , 'dmr_skymap_90a_4yr.fits', pdata, xdata
```

read_fits_s reads in the file 'dmr_skymap_90a_4yr.fits'. On output, pdata contains the primary header and xdata is a structure whose first field is the extension header, and the other fields are vectors with respective tag names PIXEL, SIGNAL, N_OBS, SERROR, ... (see `help,/struc,xdata`)

read_tqu

Location in HEALPix directory tree: src/idl/fits/read_tqu.pro

This IDL facility reads a temperature+polarization Healpix map (T,Q,U) from a binary table FITS file, with optionally the error (dT,dQ,dU) and correlation (dQU, dTU, dTQ) from separate extensions

FORMAT

IDL> READ_TQU , File, TQU, [Extension=, Hdr=, Xhdr=, Help=, Nside=, Ordering=, Coordsys=]

QUALIFIERS

File — name of a FITS file from which the maps are to be read

TQU — : array of Healpix maps of size ($N_{\rm pix}$,3,`n_ext`) where $N_{\rm pix}$ is the total number of Healpix pixels on the sky, and `n_ext` ≤ 3 is the number of extensions read
Three maps are available in each extension of the FITS file :
-the temperature+polarization Stokes parameters maps (T,Q,U) in extension 0
-the error maps (dT,dQ,dU) in extension 1 (if applicable)
-the correlation maps (dQU, dTU, dTQ) in extension 2 (if applicable)

Extension= — (optional),
extension unit from which to read the data (0 based). If absent, all available extensions are read

Hdr= — (optional),
string variable containing on output the contents of the primary header. (If already present, FITS reserved keywords will be automatically updated).

Xhdr= — (optional),
string variable containing on output the contents

of the extension header. If several extensions are read, then the extension headers are returned appended into one string array.

Nside= (optional),
returns on output the **HEALPix** resolution parameter, as read from the FITS header. Set to -1 if not found

Ordering= (optional),
returns on output the pixel ordering, as read from the FITS header. Either 'RING' or 'NESTED' or ' ' (if not found).

Coordsys= (optional),
returns on output the astrophysical coordinate system used, as read from FITS header (value of keywords COORDSYS or SKYCOORD)

KEYWORDS

Help if set, an extensive help is displayed and no file is read

DESCRIPTION

read_tqu reads out Stokes parameters (T,Q,U) maps for the whole sky into a FITS file. It is also possible to read the error per pixel for each map and the correlation between fields, as subsequent extensions of the same FITS file (see qualifiers above). Therefore the file may have up to three extensions with three maps in each. Extensions can be written together or one by one (in their physical order) using the Extension option

RELATED ROUTINES

This section lists the routines related to **read_tqu**.

idl version 6.0 or more is necessary to run read_tqu

synfast This **HEALPix** f90 facility can be used to generate temperature+polarization maps that can be read with read_tqu

write_tqu This **HEALPix** IDL facility can be used to write out temperature+polarization that can be read by

	read_tqu.
read_fits_cut4, read_fits_map	
read_tqu, read_fits_s	**HEALPix** IDL routines to read cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets from FITS files
read_fits_s	This general purpose **HEALPix** IDL facility can be used to read into an IDL structure maps contained in binary table FITS files.
sxpar	This IDL routine (included in **HEALPix** package) can be used to extract FITS keywords from the header(s) HDR or XHDR read with read_tqu.

EXAMPLE:

```
read_tqu, 'map_polarization.fits', TQU, xhdr=xhdr
```

Reads into `TQU` the polarization maps contained in the FITS file 'map_polarization.fits'. The variable `xhdr` will contain the extension(s) header.

remove_dipole

Location in HEALPix directory tree: src/idl/misc/remove_dipole.pro

This IDL facility provides a means to fit and remove the dipole and monopole from a **HEALPix** map.

FORMAT

IDL> REMOVE_DIPOLE, Map [,Weight, BAD_DATA=, GAL_CUT=, COORD_IN=, COORD_OUT=, Dipole=, Monopole=, /NOREMOVE, NSIDE=, /ONLY-MONOPOLE, ORDERING=, PIXEL=, UNITS=, /HELP]

QUALIFIERS

Map
: input and output, vector
map from which monopole and dipole are to be removed (also used for output). Assumed to be a full sky data set, unless PIXEL is set and has the same size as map

Weight
: input, vector, optional
same size as map, describe weighting scheme to apply to each pixel for the fit
(**default:** uniform weight)

BAD_DATA =
: scalar float, value given on input to bad pixels
(**default:** `!healpix.bad_value` $\equiv -1.6375\ 10^{30}$).

GAL_CUT=
: if set to a value larger than 0, the pixels with galactic latitude $|b|$ <gal_cut degrees are not considered in the fit.
NB: the cut is *really* done in Galactic coordinates. If the input coordinates are different (see Coord_In), the map is rotated into galactic before applying the cut.

COORD_IN =
: string, coordinate system (either 'Q' or 'C': equatorial, 'G': galactic or 'E': ecliptic)
(**default:** 'G' (galactic))

COORD_OUT =	string, coordinate system (see above) in which to output dipole vector in variable Dipole (**default:** same as coord_in)
Dipole=	OUTPUT, 3d vector, coordinates of best fit dipole (done simultaneously with monopole), same units as input map
Monopole=	OUTPUT, scalar float, value found for the best fit monopole (done simultaneously with dipole), same units as input map
NSIDE=	scalar integer, healpix resolution parameter
ORDERING=	string, ordering scheme (either 'RING' or 'NESTED')
PIXEL=	input, vector, gives the Healpix index of the pixels whose temperature is actually given in map (for cut sky maps). If present, must match Map in size. If absent, it is assumed that the map covers the whole sky.
UNITS=	string, units of the input map

KEYWORDS

/NOREMOVE	if set, the best fit dipole and monopole are computed but not removed (ie, Map is unchanged)
/ONLYMONOPOLE	if set, fit (and remove) only the monopole
/HELP	if set, only display documentation header

DESCRIPTION

remove_dipolemakes a simultaneous least square fit of the monopole and dipole on all the valid pixels of Map (those with a value different from BAD_DATA) with a galactic latitude larger in magnitude than GAL_CUT (in degrees). The position of the pixels on the sky is reconstructed from NSIDE and ORDERING. If Map does not cover the full sky, the actual indices of the concerned pixels should be given in PIXEL

RELATED ROUTINES

This section lists the routines related to **remove_dipole**.

idl	version 6.0 or more is necessary to run remove_dipole.

reorder

Location in HEALPix directory tree: src/idl/toolkit/reorder.pro

This IDL facility allows the reordering of a full sky map from NESTED to RING scheme and vice-versa.

FORMAT

IDL> Result = REORDER (Input_map [, In=, Out=, N2R=, R2N=])

QUALIFIERS

Result	variable containing on output the reordered map
Input_map	variable containing the input map
In=	specifies the input ordering, can be either 'RING' or 'NESTED'
Out=	specifies the output ordering, can be either 'RING' or 'NESTED'

KEYWORDS

N2R=	If set, does the NESTED to RING conversion, equivalent to In='NESTED' and Out='RING'
R2N=	If set, does the RING to NESTED conversion, equivalent to In='RING' and Out='NESTED'

DESCRIPTION

reorder allows the reordering of a full sky map from NESTED to RING scheme and vice-versa

RELATED ROUTINES

This section lists the routines related to **reorder** .

idl	version 6.0 or more is necessary to run reorder

EXAMPLE:

```
map_nest = reorder(map_ring, in='ring', out='nest')
```

The RING ordered map `map_ring` is converted to the NESTED map `map_nest`.

rotate_coord

Location in HEALPix directory tree: src/idl/misc/rotate_coord.pro

This IDL facility provides a means to rotate a set of 3D position vectors (and their Stokes parameters Q and U) between to astrophysical coordinate systems or by an arbitrary rotation.

FORMAT

IDL> Outvec = ROTATE_COORD(Invec [, Inco=, Outco=, Euler_Matrix=, Stokes_Parameters=])

QUALIFIERS

Invec	input, array of size (n,3) : set of 3D position vectors
Outvec	output, array of size (n,3) : rotated 3D vectors
Inco=	input, character string (either 'Q' or 'C': equatorial, 'G': galactic or 'E': ecliptic) describing the input coordinate system
Outco=	input, character string (see above) describing the output coordinate system. Can not be used together with Euler_Matrix
Euler_Matrix=	input, array of size (3,3). Euler Matrix describing the rotation to apply to vectors. (**default:** unity : no rotation). Can not be used together with a change in coordinates.
Stokes_Parameters=	input and output, array of size (n, 2) : values of the Q and U Stokes parameters on the sphere for each of the input position vector. Q and U are defined wrt the local parallel and meridian and are therefore transformed in a non trivial way in case of rotation

DESCRIPTION

rotate_coord is a generalisation of the Astro library routine `skyconv`. It allows a rotation of 3D position vectors between two standard astronomic coordinates system but also an arbitrary rotation described by its Euler Matrix. It can also be applied to compute the effect of a rotation on the linear polarization Stokes parameters (Q and U) expressed in local coordinates system at the location of each of the input 3D vectors.

RELATED ROUTINES

This section lists the routines related to **rotate_coord**.

idl	version 6.0 or more is necessary to run rotate_coord.
euler_matrix_new	constructs the Euler Matrix for a set of three angles and three axes of rotation

same_shape_pixels_XXXX

Location in HEALPix directory tree: src/idl/toolkit/same_shape_pixels_nest.pro, src/idl/toolkit/same_shape_pixels_ring.pro

These IDL facilities provide the ordered list of all **HEALPix** pixels having the same shape as a given template, for a resolution parameter $N_{\rm side}$.

FORMAT

IDL> same_shape_pixels_nest, Nside, Template, List_Pixels_Nest [, Reflexion, NREPLICATIONS=]

FORMAT

IDL> same_shape_pixels_ring, Nside, Template, List_Pixels_Ring [, Reflexion, NREPLICATIONS=]

QUALIFIERS

Nside	(IN, scalar) the **HEALPix** $N_{\rm side}$ parameter.
Template	(IN, scalar) identification number of the template (this number is independent of the numbering scheme considered).
List_Pixel_Nest	(OUT, vector) ordered list of NESTED scheme identification numbers for all pixels having the same shape as the template provided
List_Pixel_Ring	(OUT, vector) ordered list of RING scheme identification numbers for all pixels having the same shape as the template provided
Reflexion	(OUT, OPTIONAL, vector) in {0, 3} encodes the transformation(s) to apply to each of the returned pixels to match exactly in shape and position the template provided. 0: rotation around the polar axis only, 1: rotation + East-West swap (ie, reflexion around meridian), 2: rotation + North-South swap (ie, reflexion around Equator), 3: rotation + East-West and North-South swaps

KEYWORDS

NREPLICATIONS (OUT, OPTIONAL, scalar) number of pixels having the same shape as the template. It is also the length of the vectors `List_Pixel_Nest`, `List_Pixel_Ring` and `Reflexion`. It is either 8, 16, $4N_{\rm side}$ or $8N_{\rm side}$.

DESCRIPTION

same_shape_pixels_XXXX provide the ordered list of all **HEALPix** pixels having the same shape as a given template, for a resolution parameter $N_{\rm side}$. Depending on the template considered the number of such pixels is either 8, 16, $4N_{\rm side}$ or $8N_{\rm side}$. The template pixels are all located in the Northern Hemisphere, or on the Equator. They are chosen to have their center located at

$$z = \cos(\theta) \geq 2/3, \qquad 0 < \phi \leq \pi/2,$$
$$2/3 > z \geq 0, \qquad \phi = 0, \quad \text{or} \quad \phi = \frac{\pi}{4N_{\rm side}}.$$

They are numbered continuously from 0, starting at the North Pole, with the index increasing in ϕ, and then increasing for decreasing z.

EXAMPLE:

```
same_shape_pixels_ring, 256, 1234, list_pixels, reflexion, nrep=np
```

Returns in `list_pixels` the RING-scheme index of the all the pixels having the same shape as the template #1234 for $N_{\rm side} = 256$. Upon return `reflexion` will contain the reflexions to apply to each pixel returned to match the template, and `np` will contain the number of pixels having that same shape (16 in that case).

RELATED ROUTINES

This section lists the routines related to **same_shape_pixels_XXXX**.

nside2templates returns the number of template pixel shapes avail-

	able for a given $N_{\rm side}$.
template_pixel_ring	
template_pixel_nest	return the template shape matching the pixel provided

template_pixel_xxxx

Location in HEALPix directory tree: src/idl/toolkit/template_pixel_nest.pro, src/idl/toolkit/template_pixel_ring.pro

These IDL facilities provide the index of the template pixel associated with a given **HEALPix** pixel, for a resolution parameter $N_{\rm side}$.

FORMAT

IDL> template_pixel_nest, Nside, Pixel_Nest, Template, Reflexion

FORMAT

IDL> template_pixel_ring, Nside, Pixel_Ring, Template, Reflexion

QUALIFIERS

Nside	(IN, scalar) the **HEALPix** $N_{\rm side}$ parameter.
Pixel_Nest	(IN, scalar or vector) NESTED scheme pixel identification number(s) over the range $\{0,12{N_{\rm side}}^2 - 1\}$.
Pixel_Ring	(IN, scalar or vector) RING scheme pixel identification number(s) over the range $\{0,12{N_{\rm side}}^2 - 1\}$.
Template	(OUT, scalar or vector) identification number(s) of the template matching in shape the pixel(s) provided (the numbering scheme of the pixel templates is the same for both routines).
Reflexion	(OUT, scalar or vector) in {0, 3} encodes the transformation(s) to apply to each pixel provided to match exactly in shape and position its respective template. 0: rotation around the polar axis only, 1: rotation + East-West swap (ie, reflexion around meridian), 2: rotation + North-South swap (ie, reflexion around Equator), 3: rotation + East-West and North-South swaps

DESCRIPTION

template_pixel_xxxx provide the index of the template pixel associated with a given **HEALPix** pixel, for a resolution parameter $N_{\rm side}$.

Any pixel can be *matched in shape* to a single of these templates by a combination of a rotation around the polar axis with reflexion(s) around a meridian and/or the equator.

The template pixels are all located in the Northern Hemisphere, or on the Equator. They are chosen to have their center located at

$$\begin{aligned} z = \cos(\theta) \geq 2/3, \qquad & 0 < \phi \leq \pi/2, \\ 2/3 > z \geq 0, \qquad & \phi = 0, \quad \text{or} \quad \phi = \frac{\pi}{4N_{\rm side}}. \end{aligned}$$

They are numbered continuously from 0, starting at the North Pole, with the index increasing in ϕ, and then increasing for decreasing z.

EXAMPLE:

```
template_pixel_ring, 256, 500000, template, reflexion
```

Returns in `template` the index of the template pixel (16663) whose shape matches that of the pixel #500000 for $N_{\rm side} = 256$. Upon return `reflexion` will contain 2, meaning that the template must be reflected around a meridian and around the equator (and then rotated around the polar axis) in order to match the pixel.

RELATED ROUTINES

This section lists the routines related to **template_pixel_xxxx**.

nside2templates	returns the number of template pixel shapes available for a given $N_{\rm side}$.
same_shape_pixels_ring	
same_shape_pixels_nest	return the ordered list of pixels having the same shape as a given pixel template

ud_grade

Location in HEALPix directory tree: src/idl/toolkit/ud_grade.pro

This IDL facility provides a means to upgrade/degrade or reorder a Healpix full sky map contained in a FITS file or loaded in memory.

FORMAT

IDL> UD_GRADE , Map_in, Map_out [, NSIDE_OUT=, ORDER_IN=, ORDER_OUT=, BAD_DATA=, PESSIMISTIC=]

QUALIFIERS

Map_in	input map: either a character string with the name of a fits file or a memory vector (real, integer, ...) containing a full sky Healpix data set.
Map_out	reordered map: if map_in was a filename, map_out should be a filename, otherwise map_out should point to a memory array

KEYWORDS

NSIDE_OUT =	output resolution parameter, can be larger or smaller than the input one (scalar integer). (**default:** same as input: map unchanged or simply reordered)
ORDER_IN =	input map ordering (either 'RING' or 'NESTED') (**default:** same as the input FITS keyword ORDERING if applicable).
ORDER_OUT =	output map ordering (either 'RING' or 'NESTED') (**default:** same as ORDER_IN).
BAD_DATA =	flag value of missing pixels. (**default:** `!healpix.bad_value` $\equiv -1.6375\ 10^{30}$).

PESSIMISTIC =	if set, during **degradation** each big pixel containing one bad or missing small pixel is also considered as bad, if not set, each big pixel containing at least one good pixel is considered as good (optimistic) default = 0 (:not set)

DESCRIPTION

ud_grade can upgrade/degrade a full sky **HEALPix** map using the hierarchical properties of **HEALPix** . It can also reorder a full sky map (from NEST to RING and vice-versa). It operates on FITS files as well as on memory variables. The degradation/upgradation is done assuming an intensive quantity (like temperature) that does not scale with surface area. In case of degradation a big pixel that contains at least one bad small pixel is considered as bad itself. When operating on FITS files, the header information from the input file that is not directly related the ordering/resolution is copied unchanged into the output file.

RELATED ROUTINES

This section lists the routines related to **ud_grade**.

idl	version 6.0 or more is necessary to run ud_grade .
reorder	reorder a full sky Healpix map.

EXAMPLES: #1

```
ud_grade , 'map_512.fits', 'map_256.fits', nside_out = 256
```

ud_grade reads the FITS file map_512.fits (that allegedly contains a map with NSIDE=512), and write in the FITS file map_256.fits a map degraded to resolution 256, with the same ordering.

EXAMPLES: #2

```
ud_grade , 'map_512.fits', 'map_Nest256.fits', nside_out = 256, $
  order_out = 'NESTED'
```

ud_grade reads the FITS file map_512.fits (that allegedly contains a map with NSIDE=512), and writes in the FITS file map_Nest256.fits a map degraded to resolution 256, with NESTED ordering.

EXAMPLES: #3

```
read_fits_map, 'map_Nest256.fits', mymap
ud_grade , mymap, mymap2, nside_out = 1024, order_in='NESTED', order_out='RING'
```

mymap is IDL variable containing a **HEALPix** NESTED-ordered map with resolution nside=256. ud_grade upgrades this map to a resolution of 1024, reorder it to RING and write it in the IDL vector mymap2.

vec2ang

Location in HEALPix directory tree: src/idl/toolkit/vec2ang.pro

This IDL facility convert the 3D position vectors of points into their angles on the sphere.

FORMAT

IDL> VEC2ANG , Vector, Theta, Phi [, ASTRO=]

QUALIFIERS

Vector — input, array,
three dimensional cartesian position vector (x, y, z) (not necessarily normalised). The north pole is $(0, 0, 1)$. The coordinates are ordered as follows $x(0), \ldots, x(n-1)$, $y(0), \ldots, y(n-1)$, $z(0), \ldots, z(n-1)$

Theta — output, vector,
vector, colatitude in radians measured southward from north pole in [0,π] (mathematical coordinates).
If ASTRO is set, Theta is the latitude in degrees measured northward from the equator, in [-90, 90] (astronomical coordinates).

Phi — output, vector,
longitude in radians measured eastward, in [0, 2π] (mathematical coordinates).
If ASTRO is set, Phi is the longitude in degree measured eastward, in [0,360] (astronomical coordinates).

KEYWORDS

ASTRO = — if set Theta and Phi are the latitude and longitude in degrees (astronomical coordinates) instead of the colatitude and longitude in radians (mathematical coordinates).

DESCRIPTION

vec2ang performs the geometrical transform from the 3D position vectors (x, y, z) of points into their angles (θ, ϕ) on the sphere: $x = \sin\theta\cos\phi$, $y = \sin\theta\sin\phi$, $z = \cos\theta$

RELATED ROUTINES

This section lists the routines related to **vec2ang** .

idl	version 6.0 or more is necessary to run vec2ang .
pix2xxx, ...	conversion between vector or angles and pixel index
ang2vec	conversion from angles to position vectors

EXAMPLE:

write_fits_cut4

Location in HEALPix directory tree: src/idl/fits/write_fits_cut4.pro

This IDL facility writes out a cut sky **HEALPix** map into a FITS file according to the **HEALPix** convention. The format used for the FITS file follows the one used for Boomerang98 and is adapted from COBE/DMR. This routine can be used to store polarized maps, where the information relative to the Stokes parameters I, Q and U are placed in extension 0, 1 and 2 respectively by successive invocation of the routine.

FORMAT

IDL> WRITE_FITS_CUT4 , File, Pixel, Signal [, N_Obs, Serror, COORDSYS=, EXTENSION=, HDR=, /NESTED, NSIDE=, ORDERING=, /POLARISATION, /RING, UNITS=, XHDR=]

QUALIFIERS

File	name of a FITS file in which the map is to be written
Pixel	(LONG or LONG64 vector), index of observed (or valid) pixels
Signal	(FLOAT or DOUBLE vector, same size as Pixel), value of signal in each observed pixel
N_Obs	(LONG or INT or LONG64 vector, Optional, same size as Pixel), number of observation per pixel. If absent, the field `N_OBS` will take a value of 1 in the output file. If set to a scalar constant, `N_OBS` will take this value in the output file
Serror	(FLOAT or DOUBLE vector, Optional, same size as Pixel) *rms* of signal in pixel, for white noise, this is $\propto 1/\sqrt{\text{n\_obs}}$ If absent, the field `SERROR` will take a value of

0.0 in the output file. If set to a scalar constant, SERROR will take this value in the output file

KEYWORDS

COORDSYS= (optional),
if set to either 'C', 'E' or 'G', specifies that the Healpix coordinate system is respectively Celestial=equatorial, Ecliptic or Galactic. (The relevant keyword is then added/updated in the extension header, but the map is NOT rotated)

EXTENSION= (optional),
(0 based) extension number in which to write data. (**default:** 0). If set to 0 (or not set) *a new file is written from scratch*. If set to a value larger than 1, the corresponding extension is added or updated, as long as all previous extensions already exist. All extensions of the same file should use the same ORDERING, NSIDE and COORDSYS.

HDR= (optional),
String array containing the information to be put in the primary header.

/NESTED if set, specifies that the map is in the NESTED ordering scheme
see also: Ordering and Ring

NSIDE= (optional),
scalar integer, **HEALPix** resolution parameter of the data set. The resolution parameter should be made available to the FITS file, either thru this qualifier, or via the header (see XHDR).

ORDERING= (optional),
if set to either 'ring' or 'nested' (case un-sensitive), specifies that the map is respectively in RING or NESTED ordering scheme
see also: Nested and Ring
The ordering information should be made available to the FITS file, either thru a combination of Ordering/Ring/Nested, or via the header (see XHDR).

/POLARISATION specifies that file will contain the I, Q and U polarisation Stokes parameter in extensions 0, 1 and

	2 respectively, and sets the FITS header keywords accordingly
/RING	if set, specifies that the map is in the RING ordering scheme see also: Ordering and Nested
UNITS=	(optional), string describing the physical units of the data set (only applies to Signal and Serror)
XHDR=	(optional), String array containing the information to be put in the extension header.

DESCRIPTION

RELATED ROUTINES

This section lists the routines related to **write_fits_cut4** .

idl	version 6.0 or more is necessary to run write_fits_cut4
read_fits_cut4	This **HEALPix** IDL facility can be used to read in maps written by write_fits_cut4 .
write_fits_cut4, write_fits_map	
write_tqu, write_fits_sb	**HEALPix** IDL routines to write cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets into FITS files
sxaddpar	This IDL routine (included in **HEALPix** package) can be used to update or add FITS keywords to the header in `HDR` and `XHDR`

EXAMPLES: #1

```
write_fits_cut4 , 'map_cut.fits', pixel, temperature, /ring, nside=32, /pol
```

writes in 'map_cut.fits' a FITS file containing the temperature measured in a set of **HEALPix** pixel.

EXAMPLES: #2

```
write_fits_cut4 , 'tqu_cut.fits', pixel, temperature, n_t, s_t, $
   /ring, nside=32, /pol
write_fits_cut4 , 'tqu_cut.fits', pixel, qstokes, n_q, s_q, $
   /ring, nside=32, /pol, ext=1
write_fits_cut4 , 'tqu_cut.fits', pixel, ustokes, n_u, s_u, $
   /ring, nside=32, /pol, ext=2
```

writes in 'tqu_cut.fits' a FITS file with three extensions, each of them containing information on the observed pixel, the measured signal, the number of observations and noise per pixel, for the three Stokes parameters I, Q and U respectively. The **HEALPix** ring ordered scheme and the resolution $N_{\rm side} = 32$ is assumed.

write_fits_map

Location in HEALPix directory tree: src/idl/fits/write_fits_map.pro

This IDL facility writes out a **HEALPix** map into a FITS file according to the **HEALPix** convention

FORMAT

IDL> WRITE_FITS_MAP , File, T_sky, [Header, Coordsys=, Nested=, Ring=, Ordering=, Units=]

QUALIFIERS

File	name of a FITS file in which the map is to be written
T_sky	variable containing the **HEALPix** map
Header	(optional), string variable containing on input the information to be added to the extension header. (If already present, FITS reserved keywords will be automatically updated).
Coordsys=	(optional), if set to either 'C', 'E' or 'G', specifies that the Healpix coordinate system is respectively Celestial=equatorial, Ecliptic or Galactic. (The relevant keyword is then added/updated in the extension header, but the map is NOT rotated)
Ordering=	(optional), if set to either 'ring' or 'nested' (case un-sensitive), specifies that the map is respectively in RING or NESTED ordering scheme see also: Nested and Ring
Units=	(optional), string describing the physical units of the data set

KEYWORDS

Nested	if set, specifies that the map is in the NESTED ordering scheme see also: Ordering and Ring
Ring	if set, specifies that the map is in the RING ordering scheme see also: Ordering and Nested

DESCRIPTION

write_fits_map writes out the full sky **HEALPix** map `T_sky` into the FITS file `File`. Extra information about the map can be given in `Header` according to the FITS header conventions. Coordinate systems can also be specified by `Coordsys`. Specifying the ordering scheme is compulsary and can be done either in `Header` or by setting `Ordering` or `Nested` or `Ring` to the correct value. If `Ordering` or `Nested` or `Ring` is set, its value overrides what is given in `Header`.

RELATED ROUTINES

This section lists the routines related to **write_fits_map** .

idl	version 6.0 or more is necessary to run write_fits_map
read_fits_map	This **HEALPix** IDL facility can be used to read in maps written by write_fits_map .
sxaddpar	This IDL routine (included in **HEALPix** package) can be used to update or add FITS keywords to `Header`
reorder	This **HEALPix** IDL routine can be used to reorder a map from NESTED scheme to RING scheme and vice-versa.
write_fits_cut4, write_fits_map write_tqu, write_fits_sb	**HEALPix** IDL routines to write cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets into FITS files
write_fits_sb	routine to write multi-column binary FITS table

EXAMPLE:

`write_fits_map, 'file.fits', map, coordsys='G', ordering='ring'`

write_fits_map writes out the RING ordered map `map` in Galactic coordinates into the file `file.fits`.

write_fits_sb

Location in HEALPix directory tree: src/idl/fits/write_fits_sb.pro

This IDL facility writes out a **HEALPix** map into a FITS file according to the **HEALPix** convention. It can also write an arbitray data set into a FITS binary table

FORMAT

IDL> WRITE_FITS_SB , File, Prim_Stc [, Xten_stc, Coordsys=, /Nested, /Ring, Ordering=, /Partial, Nside=, Extension=, /Nothealpix]

QUALIFIERS

File — name of a FITS file in which the map is to be written

Prim_stc — IDL structure containing the following fields:
- primary header
- primary image

Set it to 0 to get an empty primary unit

Xten_stc — (optional),
IDL structure containing the following fields:
- extension header
- data column 1
- data column 2

...

NB: because of some astron routines limitation, avoid using the single letters 'T' or 'F' as tagnames in the structures Prim_stc and Xten_stc.

KEYWORDS

Coordsys= — (optional),
if set to either 'C', 'E' or 'G', specifies that the Healpix coordinate system is respectively Celestial=equatorial, Ecliptic or Galactic. (The relevant keyword is then added/updated in the ex-

tension header, but the map is NOT rotated)

Ordering= (optional),
if set to either 'ring' or 'nested' (case un-sensitive), specifies that the map is respectively in RING or NESTED ordering scheme
see also: Nested and Ring

Nside= (optional),
scalar integer, **HEALPix** resolution parameter of the data set. Must be used when the data set does not cover the whole sky

Extension= (optional),
scalar integer, extension in which to write the data (0 based).
(**default:** 0)

/Nested (optional),
if set, specifies that the map is in the NESTED ordering scheme
see also: Ordering and Ring

/Ring (optional),
if set, specifies that the map is in the RING ordering scheme
see also: Ordering and Nested

/Partial (optional),
if set, the data set does not cover the whole sky. In that case the information on the actual map resolution should be given by the qualifier Nside (see above), or included in the FITS header enclosed in the Xten_stc.

/Nothealpix (optional),
if set, the data set can be arbitrary, and the restriction on the number of pixels do not apply. The keywords `Ordering`, `Nside`, `Nested`, `Ring` and `Partial` are ignored.

DESCRIPTION

write_fits_sb writes out the information contained in `Prim_stc` and `Exten_stc` in the primary unit and extension of the FITS file `File` respectively . Coordinate systems can also be specified by `Coordsys`. Specifying the ordering scheme is compulsary for **HEALPix** data sets and can be done either in `Header` or by setting `Ordering` or `Nested` or `Ring` to the correct value. If `Ordering` or `Nested` or `Ring` is set, its value overrides what is given in `Header`.

The data is assumed to represent a full sky data set with the number of data points npix = 12*Nside*Nside unless
Partial is set OR the input fits header contains OBJECT = 'PARTIAL'
AND
the Nside qualifier is given a valid value OR the FITS header contains a NSIDE
If `Nothealpix` is set, the restrictions on Nside a void.

RELATED ROUTINES

This section lists the routines related to **write_fits_sb**.

idl	version 6.0 or more is necessary to run write_fits_sb
read_fits_map	This **HEALPix** IDL facility can be used to read in maps written by write_fits_sb.
read_fits_s	This **HEALPix** IDL facility can be used to read into an IDL structure maps written by write_fits_sb.
sxaddpar	This IDL routine (included in **HEALPix** package) can be used to update or add FITS keywords to the header in `Prim_stc` and `Exten_stc`
write_fits_cut4, write_fits_map	
write_tqu, write_fits_sb	**HEALPix** IDL routines to write cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets into FITS files
write_tqu	This **HEALPix** IDL facility based on write_fits_sb is designed to write temperature+polarization (T,Q,U) maps

EXAMPLE:

```
npix = nside2npix(128)
f= randomn(seed,npix)
n= lindgen(npix)+3
map_FN = create_struct('HDR',[' '],'FLUX',f,'NUMBER',n)
write_fits_sb, 'map_fluxnumber.fits', 0, map_FN, coord='G', /ring
```

The structure map_FN is defined to contain a fictitious Flux+number map, where one field is a float and the other an integer. write_fits_sb writes out the contents of map_FN into the extension of the FITS file 'map_fluxnumber.fits'.

write_tqu

Location in HEALPix directory tree: src/idl/fits/write_tqu.pro

This IDL facility writes a temperature+polarization Healpix map (T,Q,U) into a binary table FITS file, with optionally the error (dT,dQ,dU) and correlation (dQU, dTU, dTQ) in separate extensions

FORMAT

IDL> WRITE_TQU , File, TQU, [Coordsys=, Nested=, Ring=, Ordering=, Extension=, Hdr=, Xhdr=, Units=, Help=]

QUALIFIERS

File — name of a FITS file in which the maps are to be written

TQU — : array of Healpix maps of size ($N_{\rm pix}$,3,`n_ext`) where $N_{\rm pix}$ is the total number of Healpix pixels on the sky, and `n_ext` ≤ 3.
Three maps are written in each extension of the FITS file :
-the temperature+polarization Stokes parameters maps (T,Q,U) in extension 0
-the error maps (dT,dQ,dU) (if `n_ext` ≥ 2) in extension 1
-the correlation maps (dQU, dTU, dTQ) (if `n_ext` = 3) in extension 2
it is also possible to write 3 maps directly in a given extension (provided the preceding extension, if any, is already filled in) by setting `Extension` to the extension number in which to write (0 based) and if `n_ext` + `Extension` ≤ 3

Coordsys= — (optional),
if set to either 'C', 'E' or 'G', specifies that the Healpix coordinate system is respectively Celestial=equatorial, Ecliptic or Galactic. (The relevant keyword is then added/updated in the extension header, but the map is NOT rotated)

Extension= (optional),
extension unit a which to put the data (0 based). The physical interpretation of the maps is determined by the extension in which they are written
see also: TQU

Hdr= (optional),
string variable containing on input the information to be added to the primary header. (If already present, FITS reserved keywords will be automatically updated).

Ordering= (optional),
if set to either 'ring' or 'nested' (case un-sensitive), specifies that the map is respectively in RING or NESTED ordering scheme
see also: Nested and Ring

Units= (optional),
string describing the physical units of the data set

Xhdr= (optional),
string variable containing on input the information to be added to the extension headerx. (If already present, FITS reserved keywords will be automatically updated). It will be repeated in each extension, except for TTYPE* and EXTNAME which are generated by the routine and depend on the extension

KEYWORDS

Help if set, an extensive help is displayed and no file is written

Nested if set, specifies that the map is in the NESTED ordering scheme
see also: Ordering and Ring

Ring if set, specifies that the map is in the RING ordering scheme
see also: Ordering and Nested

DESCRIPTION

write_tqu writes out Stokes parameters (T,Q,U) maps for the whole sky into a FITS file. It is also possible to write the error per pixel for each map and the correlation between fields, as subsequent extensions of the same FITS file (see qualifiers above). Therefore the file may have up to three extensions with three maps in each. Extensions can be written together or one by one (in their physical order) using the Extension option

RELATED ROUTINES

This section lists the routines related to **write_tqu**.

idl	version 6.0 or more is necessary to run write_tqu
read_tqu	This **HEALPix** IDL facility can be used to read in maps written by write_tqu.
read_fits_s	This **HEALPix** IDL facility can be used to read into an IDL structure maps written by write_tqu.
sxaddpar	This IDL routine (included in **HEALPix** package) can be used to update or add FITS keywords to the header(s) HDR or XHDR
write_fits_cut4, write_fits_map write_tqu, write_fits_sb	**HEALPix** IDL routines to write cut-sky maps, full-sky maps, polarized full-sky maps and arbitrary data sets into FITS files

EXAMPLE:

```
npix = nside2npix(64)
t = randomn(seed,npix)
q = randomn(seed,npix)
u = randomn(seed,npix)
TQU = [[t],[q],[u]]
write_tqu, 'map_polarization.fits', TQU, coord='G', /ring
```

The array TQU is defined to contain a fictitious polarisation map, with the 3 Stokes parameters T, Q and U. The map is assumed to be in Galactic coordinates, with a RING ordering of the pixels. write_tqu writes out the contents of TQU into the extension of the FITS file 'map_polarization.fits'.