Python/Healpy Tutorial

http://github.com/zonca/healpytut/

Preparation

Carver:

```
module load python
module load cmbdev
```

Your laptop
install Entough Python Distribution for Win/Mac http://www.enthought.com/products/epd_free.php

Components

- Ipython: Interactive shell
- Numpy: Array math
- Matplotlib: Plotting
- Scipy: Advanced scientific tools [FFT, spline, signal processing]
- Healpy: Healpix for python

Overview

- Basic types
- Arrays
- Plotting
- Code organization: modules,packages
- Healpy

Setup environment

.ipython/ipythonrc pdb 1, autocall 2
get help on function by calling: healpy.nside2npix?

Basic types

Lists

```
52
53 test_list = []
54 test_list.append(9)
55 print(test_list)
```

```
[9]
```

```
56
57 test_list.append("quite a long string")
58 test_list.append([1, 3, 4])
59 test_list.append(10)
60 print(test_list)
```

```
[9, 'quite a long string', [1, 3, 4], 10]
```

```
60
61 #Replace
62 test_list[2] = 1
63 print(test_list)
```

```
[9, 'quite a long string', 1, 10]
```

```
64
65 #Slicing
66 print(test_list[:2])
```

```
[9, 'quite a long string']
```

```
67 print(test_list[-1:])
```

```
[10]
```

first python **WARNING** Last element is excluded!!!

```
71 print(test_list[1:2])
```

```
['quite a long string']
```

this is C

```
76
77 for i in range(len(test_list)):
78     print(test_list[i])
```

```
9
quite a long string
1
10
```

this is Python

```
81
82 for element in test_list:
83     print(element)
```

```
9
quite a long string
1
10
```

Tuple

Like lists but not mutable, used for string interpolation, return of functions

```
87 test_tuple = (3, 4)
88 print(test_tuple[0])
```

```
3
```

```
89
90 #test_tuple[0] = 2
```

Dictionary

```
95
96 test_dict = {}
97
98 test_dict["LFI28M"] = 127.
99 test_dict["LFI28S"] = 12.
100
101 print(test_dict)
```

```
{'LFI28S': 12.0, 'LFI28M': 127.0}
```

```
102
103 print(test_dict["LFI28M"])
```

```
127.0
```

```
107
108 for k,v in test_dict.iteritems(): #Dictionary is **NOT ORDERED**
109
110     print("Channel %s has value %.2f" % (k,v)) #C-style string formatting
```

```
Channel LFI28S has value 12.00
Channel LFI28M has value 127.00
```

Strings

```
109
110 # type of quotes does not matter
111 test_string = "a quite long string"
112 test_string = 'a quite long string'
113
114 # multiline strings
115 test_string = """
116 This is a multiline
117 string,
118 keeps formatting"""
119
120 print(test_string)
```

```
This is a multiline
string,
keeps formatting
```

```
121
122 #strings interpolation
123
124 print("either using " + str(1.0) + " concatenation or interpolation for int %04d
    , float %.2f, exp %.1e" % (3, 1/3., 2.3))
```

```
either using 1.0 concatenation or interpolation for int 0003, float 0.33, exp
    2.3e+00
```

Functions

```
133
134 def sum_diff(a, b, take_abs=False):
135     if take_abs:
136         return abs(a+b), abs(a-b)
137     else:
138         return a+b, a-b
139
140
141 a=2; b=3
142 absum, abdiff = sum_diff(a, b)
143 ab_sumdiff = sum_diff(a, b)
144
145 print(absum)
```

```
5
```

```
141 print(ab_sumdiff)
```

```
(5, -1)
```

Integer division

second python **WARNING**

```
# 1/2 = 0 because they are integers
# 1./2 = .5 because 1. is float
# to avoid do at beginning of software
# from __future__ import division
```

Arrays

```

import numpy as np
a = np.array([1, 4, 5])
print(a.dtype)
```

```
int32
```

```
a[0] = .9
print(a)
```

```
[0 4 5]
```

Warning type is integer

```

a = np.array([1, 4, 5], dtype=np.double)
a[0] = .9
print(a)
```

```
[ 0.9  4.   5. ]
```

```

#same slicing as lists
a = np.arange(20)
print(a[10:18:2]) #2 is the step
```

```
[10 12 14 16]
```

```

#2D same as IDL, shape is always a **tuple**
a = np.zeros((3, 4))
a[1, 3] = 2
print(a)
```

```
[[ 0.  0.  0.  0.]
 [ 0.  0.  0.  2.]
 [ 0.  0.  0.  0.]]
```

```

#array itself is an object, so it has methods associated
print(a.mean())
```

```
0.166666666667
```

```
print(a.std())
```

```
0.552770798393
```

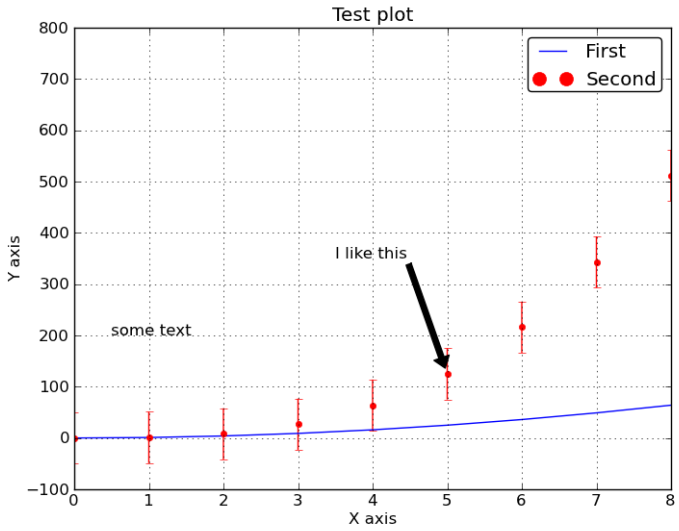
```
print(a.flatten())
```

```
[ 0.  0.  0.  0.  0.  0.  0.  2.  0.  0.  0.  0.]
```

Plotting

Interactively with ipython -pylab

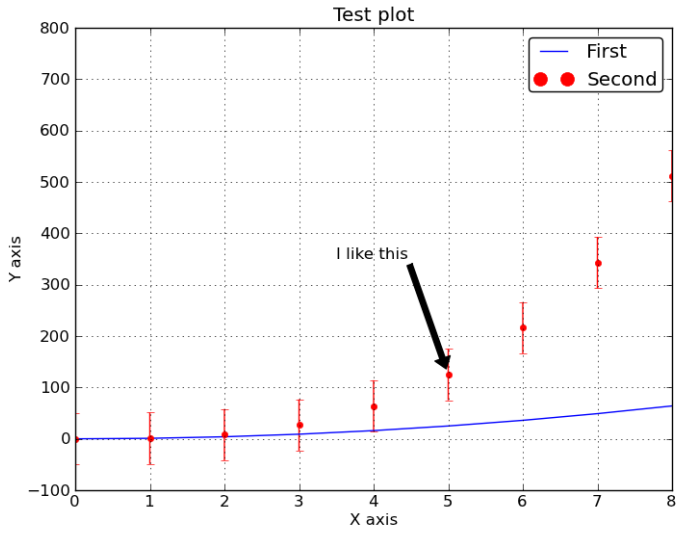
```
188
189 from pylab import *
190 plot(arange(10), arange(10)**2, label='First')
191 errorbar(arange(10), arange(10)**3, 50., None, 'r.', markersize=10, label='
    Second')
192 annotate('I like this', xy=(5, 125), xytext=(3.5, 350),
193             arrowprops=dict(facecolor='black', shrink=0.05),
194             )
195 text(0.5, 200,'some text')
196 grid()
197 legend(loc=0)
198 xlabel('X axis'); ylabel('Y axis')
199 xlim([0, 8])
200 title('Test plot')
201 savefig('plot.png')
202 show()
```



In software

USE NAMESPACES

```
208
209 import matplotlib.pyplot as plt
210 import numpy as np
211 plt.figure()
212 plt.plot(np.arange(10), np.arange(10)**2, label='First')
213 plt.errorbar(np.arange(10), np.arange(10)**3, 50., None, 'r.', markersize=10,
    label='Second')
214 plt.annotate('I like this', xy=(5, 125), xytext=(3.5, 350),
215             arrowprops=dict(facecolor='black', shrink=0.05),
216             )
217 plt.grid()
218 plt.legend(loc=0)
219 plt.xlabel('X axis'); plt.ylabel('Y axis')
220 plt.xlim([0, 8])
221 plt.title('Test plot')
222 plt.savefig('plot.png')
223 show()
```



no namespaces?

```
title = "My title"
title("Other title")
```

Error:

```
Traceback (most recent call last):
  File "/home/zonca/p/software/pyreport/pyreport/main.py", line 180, in executeblock
    exec block_text in self.namespace
  File "<string>", line 3, in <module>
TypeError: 'str' object is not callable
```

Code organization

Modules

```

# Modules are just .py files containing functions, simplest library
# usually they can be imported in other scripts or executed

if __name__ == '__main__':
    print('Executing this just if directly called as python this_script.py')

#example
import healpy
print(healpy.pixelfunc)
```

```
<module 'healpy.pixelfunc' from '/usr/local/lib/python2.7/dist-packages/healpy
    /pixelfunc.pyc'>
```

```
print(healpy.pixelfunc.nside2npix)
```

```
<function nside2npix at 0xae9e4fc>
```

Packages

collection of modules in a folder with an __init__.py file which defines what is imported on the main level

```

# for example:

import healpy
```

```
254 print(healpy)
```

```
<module 'healpy' from '/usr/local/lib/python2.7/dist-packages/healpy/__init__.pyc'>
```

```
255 print(healpy.nside2npix)
```

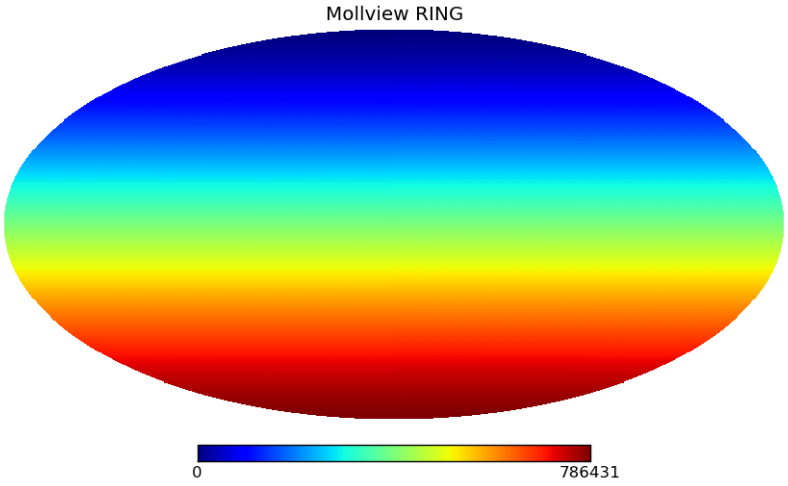
```
<function nside2npix at 0xae9e4fc>
```

Best practice Start with a single module and then split into several modules importing in __init__.py the most important functions and classes, *NOT* internal functions.

Healpy

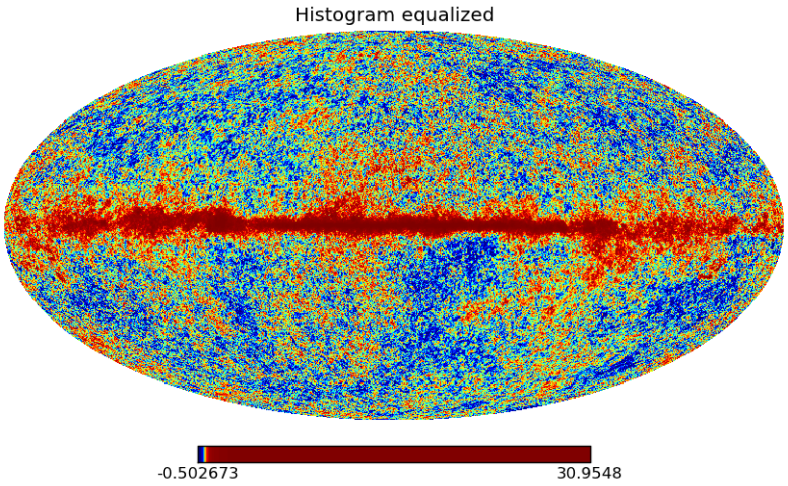
in background calling C++ Healpix for most transforms
healpy by default works in RING

```
266
267 import healpy
268
269 m = np.arange(healpy.nside2npix(256))
270 healpy.mollview(m, min=0, max=m.max(), title='Mollview RING', nest=False)
271 show()
```



http://lambda.gsfc.nasa.gov/data/map/dr4/skymaps/7yr/raw/wmap_band_imap_r9_7yr_W_v4.fits

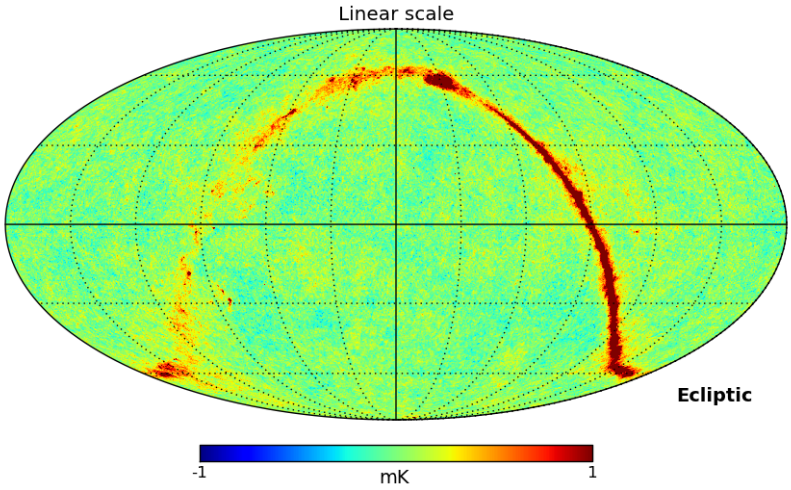
```
274
275 filename = 'wmap_band_imap_r9_7yr_W_v4.fits'
276 m = healpy.read_map(filename) #by default converts to RING!!
277
278 healpy.mollview(m, title='Histogram equalized', nest=False, norm='hist')
279 show()
```



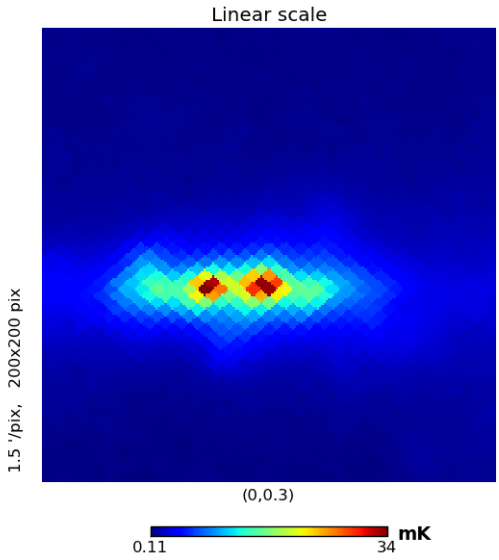

```
279 m = healpy.read_map(filename, nest=True) #keeps nested
280
281 healpy.mollview(m, coord=['G','E'], title='Linear scale', unit='mK', nest=True,
        min=-1,max=1, xsize=2000) #xsize increases resolution
282
283 healpy.graticule()
```

```
0.0 180.0 -180.0 180.0
The interval between parallels is 30 deg -0.00'.
The interval between meridians is 30 deg -0.00'.
```

```
281 show()
```




```
283
284 healpy.gnomview(m, rot=[0,0.3], title='Linear scale', unit='mK', format='%.2g',
        nest=True)
285 show()
```




```
287
288 print(healpy.fit_dipole(m, gal_cut=20)) # degrees
```

```
(0.01858625016436204, array([-0.00071935,  0.00231184,  0.00520954]))
```

Smoothing

```
291
292 m_smoothed = healpy.smoothing(m, fwhm=60, arcmin=True)
293 healpy.mollview(m_smoothed, min=-1, max=1, title='Map smoothed 1 deg')
```

Rotator

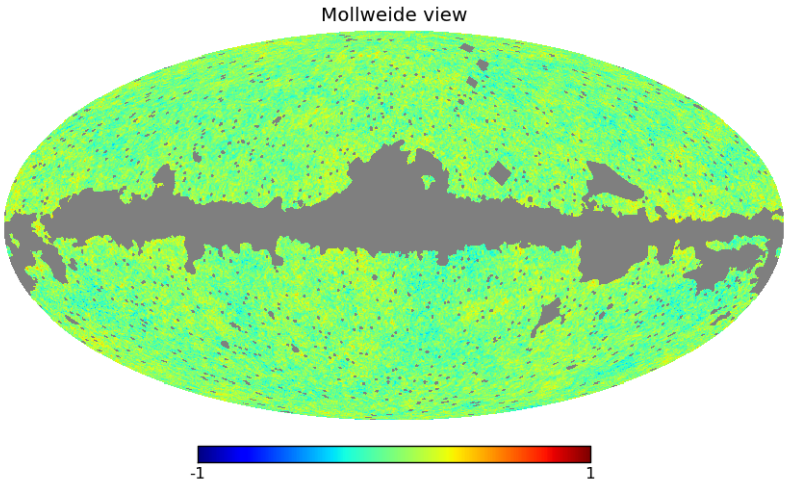
```
297
298 rot = healpy.Rotator(coord=['G','E'])
299 theta_gal, phi_gal = np.pi/2., 0.
300 theta_ecl, phi_ecl = rot(theta_gal, phi_gal)
301 print(theta_ecl, phi_ecl)
```

```
(1.6674228671489519, -1.625964003063237)
```

Masking

http://lambda.gsfc.nasa.gov/data/map/dr4/ancillary/masks/wmap_temperature_analysis_mask_r9_7yr_v4.fits

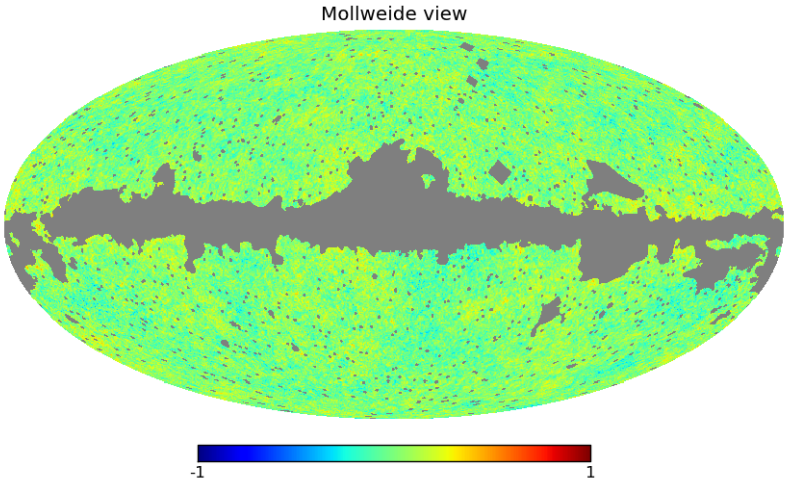
```
306
307 mask = healpy.read_map('wmap_temperature_analysis_mask_r9_7yr_v4.fits').astype(
        np.bool)
308
309 m = healpy.read_map(filename)
310
311 #method 1: multiply arrays
312 m_masked = m.copy()
313 m_masked[np.logical_not(mask)] = healpy.UNSEEN
314 healpy.mollview(m_masked, min=-1, max=1)
315 show()
```



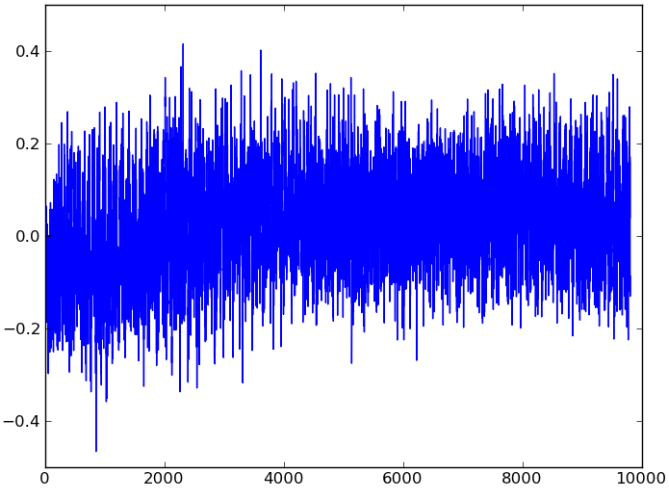

```
315
316 #method 2: numpy masked arrays
317 m_masked = healpy.ma(m)
318 print(m_masked)
```

```
[-0.12779275 -0.08507241  0.08297058 ...,  0.0255827   0.09494673
  0.03039758]
```

```
319 m_masked.mask = np.logical_not(mask)
320 healpy.mollview(m_masked.filled(), min=-1, max=1)
321 show()
```




```
322 figure()
323 plot(m_masked[:10000].compressed())
324 show()
```

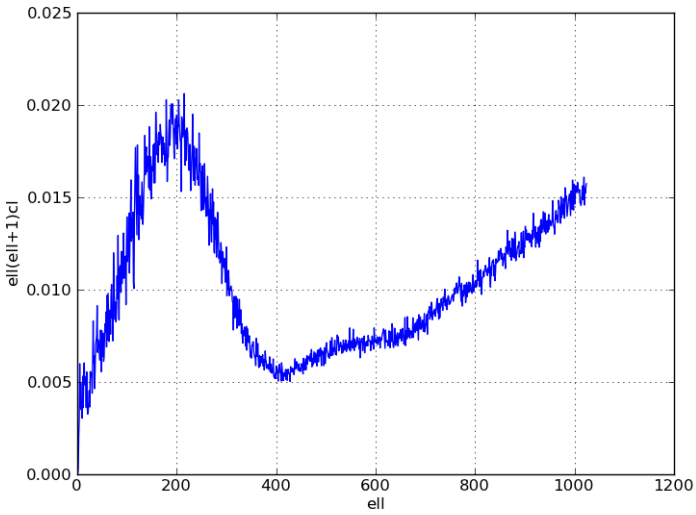



```
326
327 healpy.write_map('wmap_masked.fits', m_masked.filled(), coord='G')
```

```
Overwriting existing file 'wmap_masked.fits'.
```

Spectra

```
331
332 cl = healpy.anafast(m_masked.filled(), lmax=1024)
333 ell = np.arange(len(cl))
334 plt.figure()
335 plt.plot(ell, ell * (ell+1) * cl)
336 plt.xlabel('ell'); plt.ylabel('ell(ell+1)cl'); plt.grid()
337 show()
```




```
338
339 healpy.write_cl('cl.fits', cl)
```

```
Overwriting existing file 'cl.fits'.
```

```
341
342 from glob import glob #bash like file pattern matching
343
344 print(glob('*.fits'))
```

```
['wmap_masked.fits', 'wmap_band_imap_r9_7yr_W_v4.fits', 'cl.fits', '
    wmap_temperature_analysis_mask_r9_7yr_v4.fits']
```