Tools for data analyses in Cosmology

- Aula 10 -

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Healpy

Previously on healpy class ...

Map $\Rightarrow$ C_ℓ [anafast]

C_ℓ $\Rightarrow$ fits file [write_cl]

fits file $\Rightarrow$ C_ℓ [read_cl]

$$\ell_{\rm max} = 3 \times {\rm N_{side}} - 1$$

e.g.: $\quad {\rm N_{side}} = 1024 \Rightarrow \ell_{\rm max} = 3071$

Spherical harmonic transforms

healpy.sphtfunc.synfast

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

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

$$C_\ell \quad \Rightarrow \quad \texttt{Map}$$

Spherical harmonic transforms

How to use:

```
In [134]: mapa1 = hp.synfast(Cls,1024, alm=False, pol=False, pixwin=False,
fwhm=np.deg2rad(0.))
/home/camila/anaconda3_4p3p1/lib/python3.6/site-packages/healpy/sphtfunc.py:296:
FutureChangeWarning: The order of the input cl's will change in a future release.
Use new=True keyword to start using the new order.
See documentation of healpy.synalm.
  category=FutureChangeWarning)
Sigma is 0.000000 arcmin (0.000000 rad)
-> fwhm is 0.000000 arcmin

In [135]: len(mapa1)
Out[135]: 12582912
```

Spherical harmonic transforms

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Use new=True keyword to start using the new order.
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  category=FutureChangeWarning)
Sigma is 0.000000 arcmin (0.000000 rad)
-> fwhm is 0.000000 arcmin

In [137]: len(mapa1)
Out[137]: 2

In [138]: len(mapa1[0]), len(mapa1[1])
Out[138]: (12582912, 3148795)
```

Spherical harmonic transforms

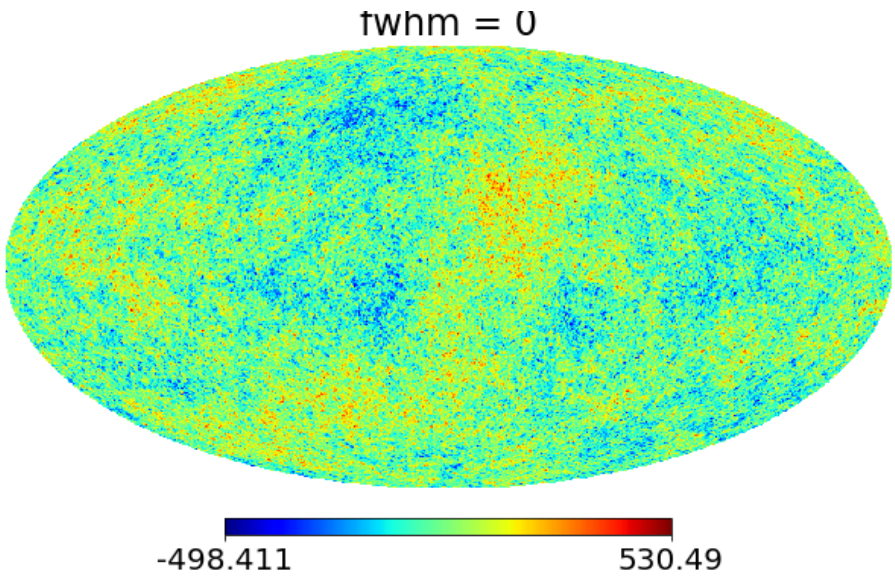
Exercise:

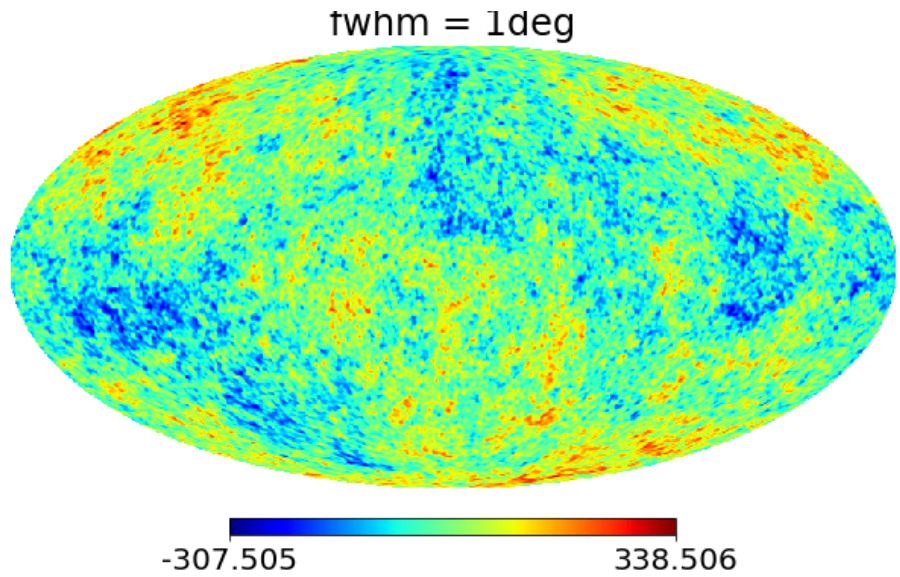
1. Generate two CMB maps ($\texttt{N}_{\texttt{side}} = 512$), with and without smoothing it ($\texttt{fwhm} = 0.25$ deg). Visualize them and observe their difference.
2. Calculate the angular power spectrum from each one.
   Are they different? Why???
3. Generate 3 CMB maps ($\texttt{N}_{\texttt{side}} = 512$) and calculate their angular power spectra. Plot them.
   Are they different? Are they different from the seed C_ℓ's?
   Why???

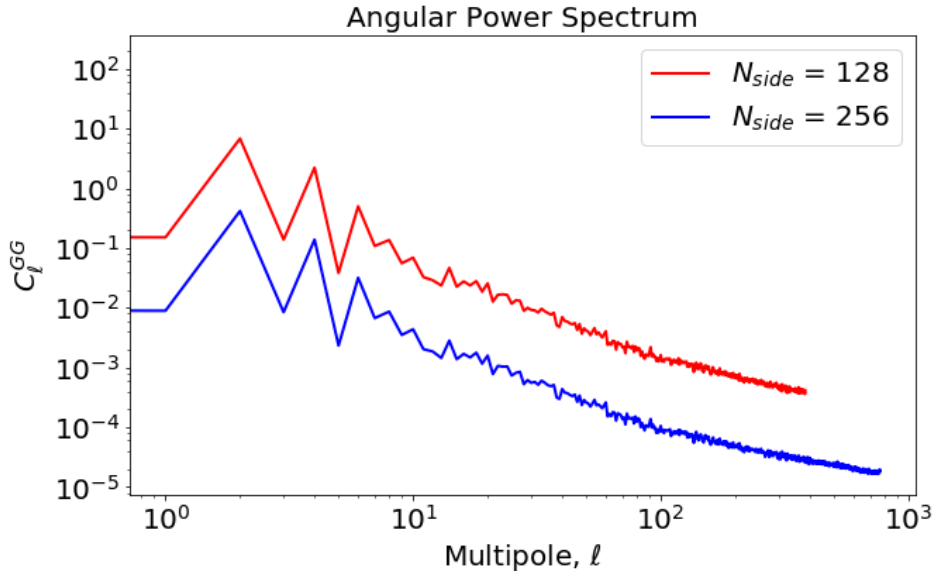
```
In [24]: lmax = len(Cls1)
    ...: ell = np.arange(lmax)
    ....:
    ...: Dls1 = ell*(ell+1)*Cls1/(2.*np.pi)
    ...: Dls2 = ell*(ell+1)*Cls2/(2.*np.pi)
    ....:
    ...: pyplot.plot(ell, Dls1,linewidth=2.0, color="red")
    ...: pyplot.plot(ell, Dls2,linewidth=2.0, color="blue")
    ...:
```

Spherical harmonic transforms

Result: [1.] and [2.]

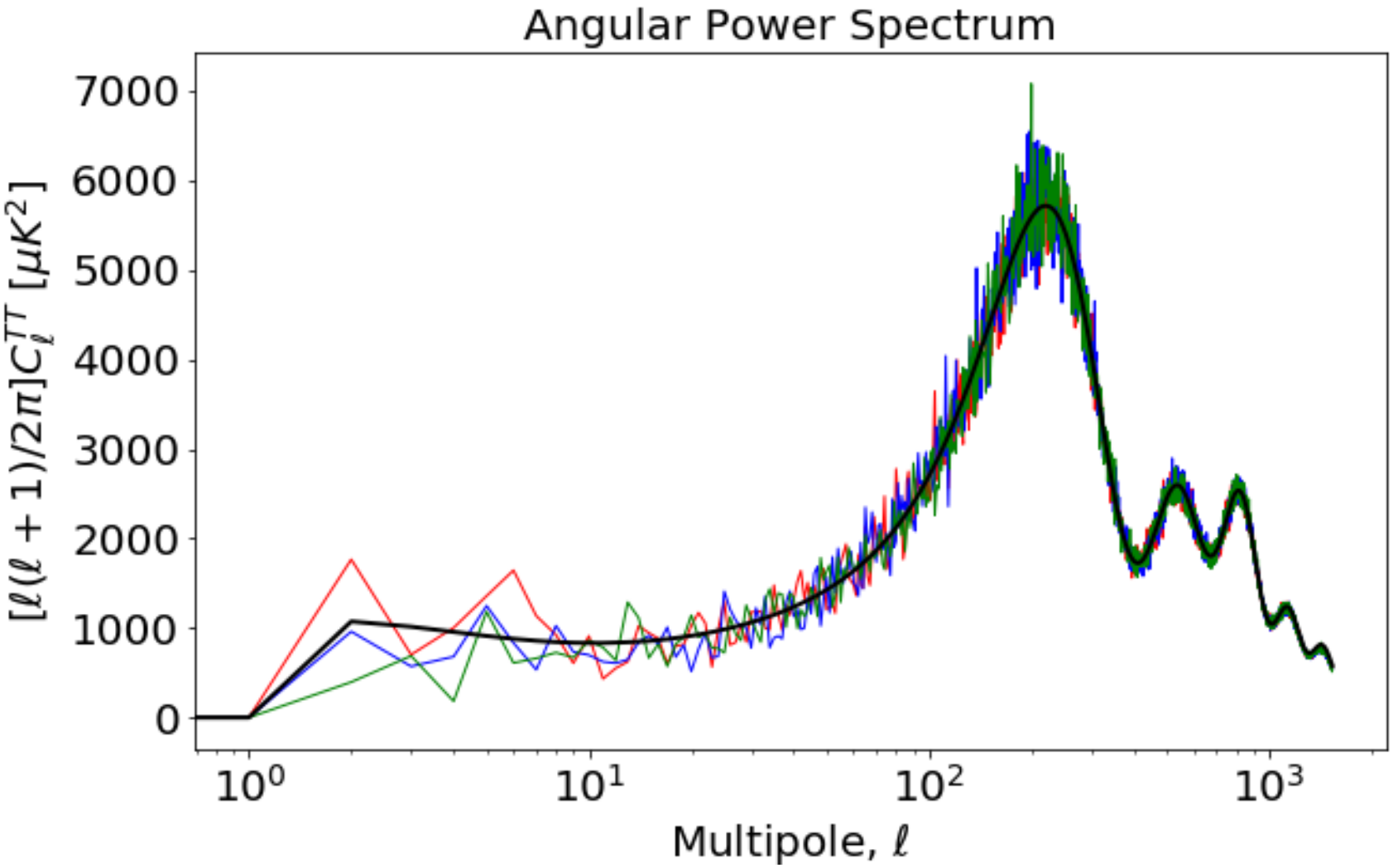






Spherical harmonic transforms

Result: [3.]



Spherical harmonic transforms

healpy.sphtfunc.map2alm

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

Computes the alm of an Healpix map.

Map $\Rightarrow$ $a_{\ell m}$

Spherical harmonic transforms

How to use:

```
In [37]: mapa = hp.synfast(Cls,512, alm=True)
    ...: mapa1 = mapa[0]
    ...: alm1 = mapa[1]
    ...:
    ...: alm2 = hp.map2alm(mapa1)
    ...:
/home/camila/anaconda3_4p3p1/lib/python3.6/site-packages/healpy/sphtfunc.py:296:
FutureChangeWarning: The order of the input cl's will change in a future release.
Use new=True keyword to start using the new order.
See documentation of healpy.synalm.
  category=FutureChangeWarning)
Sigma is 0.000000 arcmin (0.000000 rad)
-> fwhm is 0.000000 arcmin

In [38]: alm1
Out[38]:
array([  0.00000000e+00+0.j        ,   0.00000000e+00+0.j        ,
        -2.14133876e+01+0.j        , ...,  -3.50413313e-02+0.00337266j,
        -6.32502151e-03+0.00877434j,  -3.41529796e-03+0.01982115j])

In [39]: alm2
Out[39]:
array([ -6.13163569e-06+0.j        ,   1.24310824e-05+0.j        ,
        -2.14134013e+01+0.j        , ...,  -3.50413313e-02+0.00337266j,
        -6.32502151e-03+0.00877434j,  -3.41529796e-03+0.01982115j])
```

Spherical harmonic transforms

healpy.sphtfunc.alm2map

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

Computes an Healpix map given the alm.

$a_{\ell m} \Rightarrow$ Map
$\hookrightarrow$ complex array

Spherical harmonic transforms

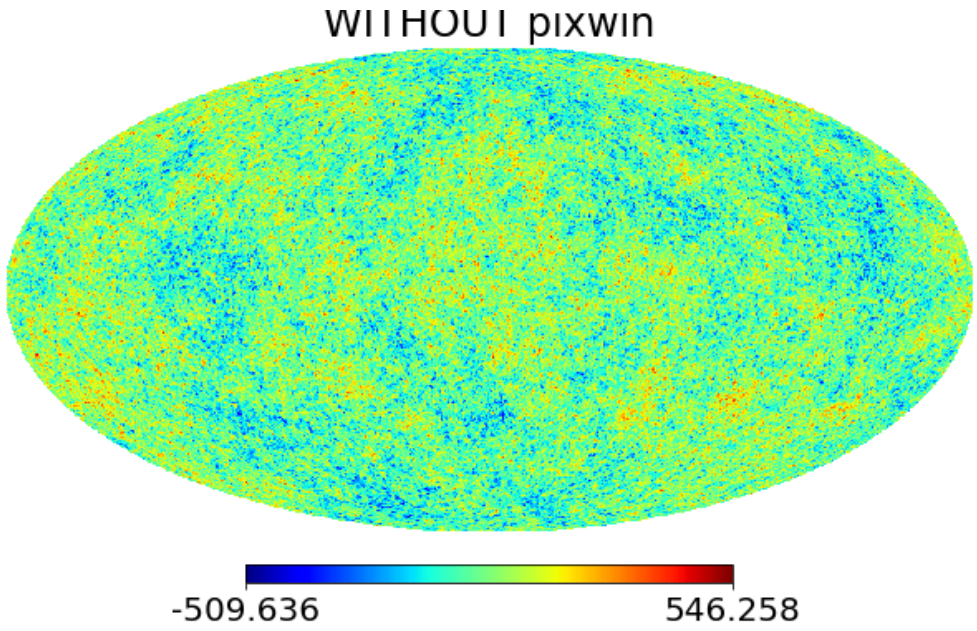
How to use:

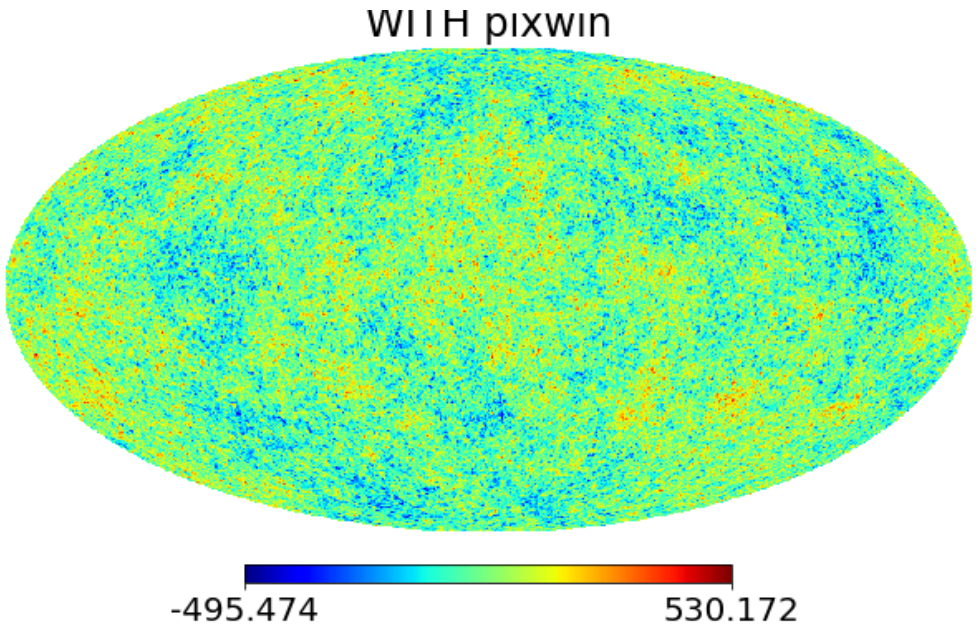
```
In [30]: mapa1 = hp.synfast(Cls,512, alm=True, pol=False, pixwin=False,
fwhm=np.deg2rad(0.))
    ...: alms = mapa1[1]
    ...:
    ...: mapa2 = hp.alm2map(alms, 512, pixwin=True)
    ...:
    ...: hp.mollview(mapa1[0], title="WITHOUT pixwin")
    ...: pyplot.savefig("mapa1.png")
    ...: hp.mollview(mapa2, title="WITH pixwin")
    ...: pyplot.savefig("mapa1_pixwin.png")
    ...:
    ...: hp.mollview(mapa2-mapa1[0], title="WITH pixwin")
    ...: pyplot.savefig("dif_pixwin.png")
    ...:
```

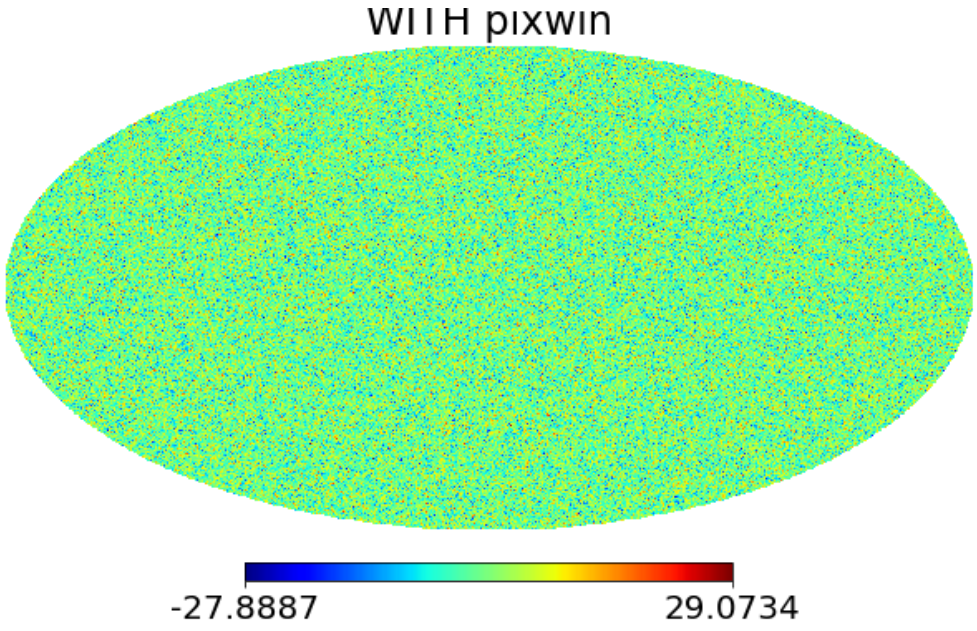
Python x IDL: the "seed"!

Spherical harmonic transforms

How to use:







Spherical harmonic transforms

healpy.sphtfunc.alm2map_der1

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

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

↘ Less parameters.

$a_{\ell m} \Rightarrow$ Map + its 1st derivatives

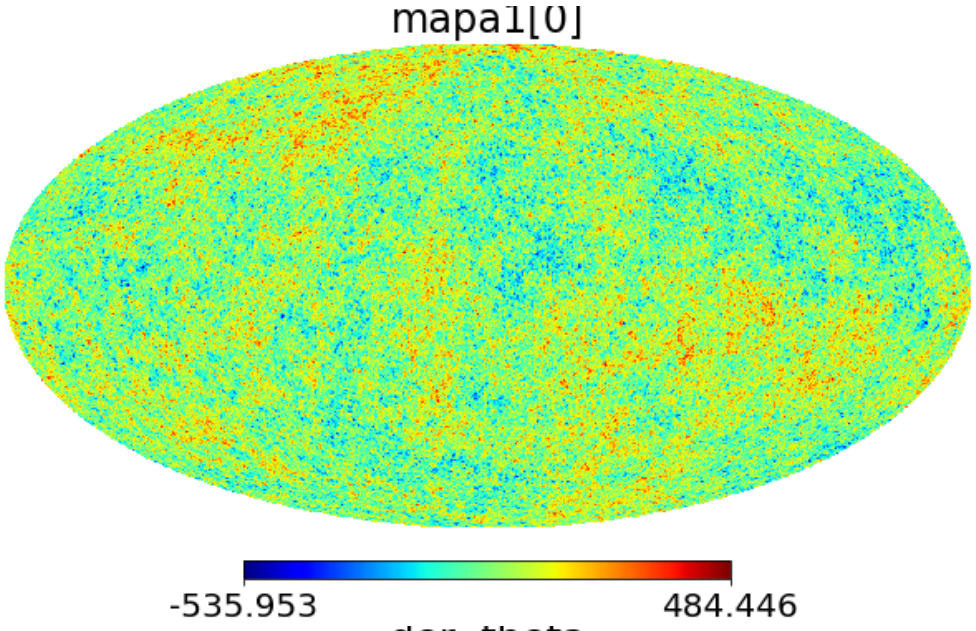
Spherical harmonic transforms

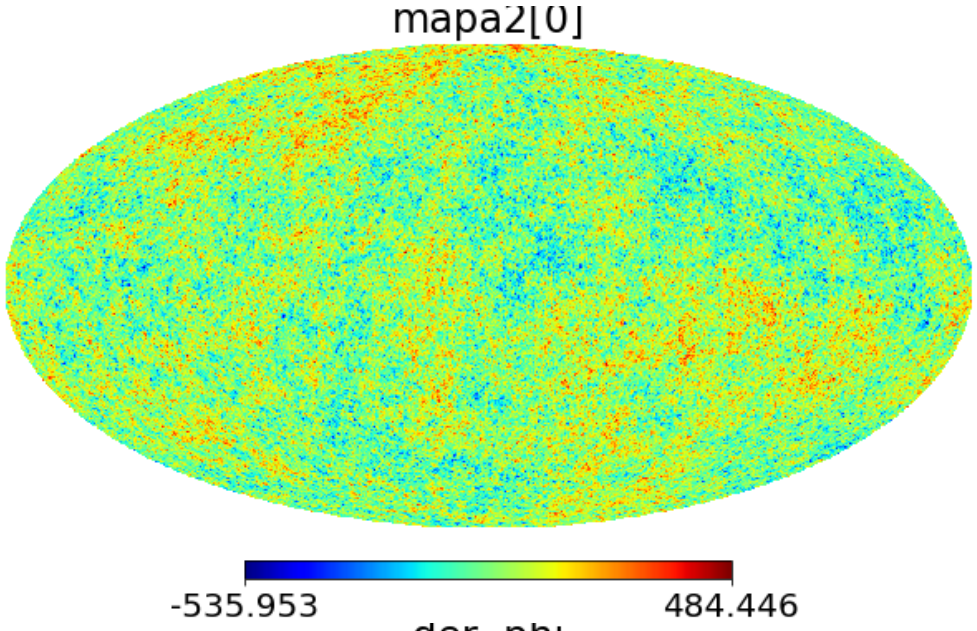
Exercise:

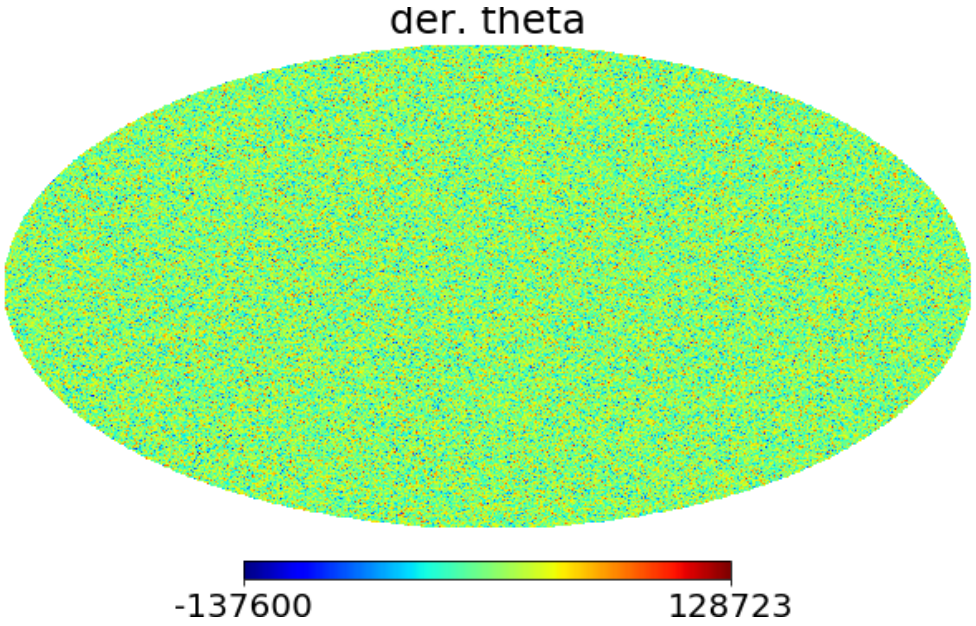
1. From the Planck best-fit C_ℓ's, generate a map and the corresponding $a_{\ell m}$.
2. Use this $a_{\ell m}$ set to generate back the CMB map, besides its first derivatives.
3. Compare the CMB maps from [1.] and [2.] and visualize the derivatives.

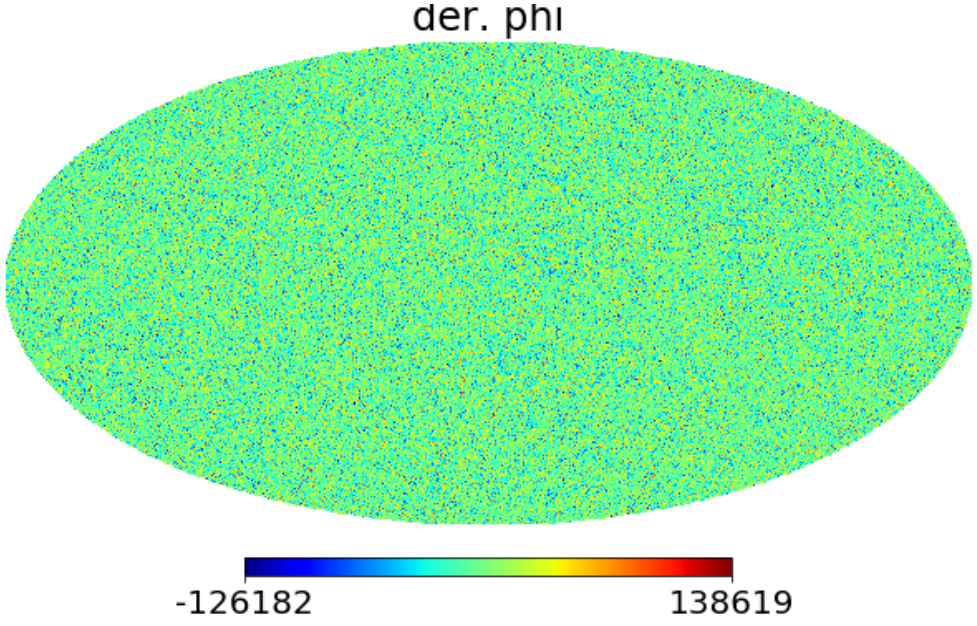
Spherical harmonic transforms

Results:









Spherical harmonic transforms

healpy.fitsfunc.write_alm

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

Write alms to a fits file.

healpy.fitsfunc.read_alm

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

Read alm from a fits file.

Spherical harmonic transforms

Exercise:

1. Generate the $a_{\ell m}$ from a map (you already have it) and write it to a fits file.
2. Read the fits file you just save to verify if it was correctly written.

Spherical harmonic transforms

Obs.:

```
In [59]: alms1
Out[59]:
array([  0.00000000+0.j        ,   0.00000000+0.j        ,
       -24.37779492+0.j        , ...,   0.05781267+0.00217739j,
        -0.04033944-0.03193015j,  -0.03127322-0.00663547j])

In [59]:

In [60]: alms2
Out[60]:
(array([  0.00000000+0.j        ,   0.00000000+0.j        ,
       -24.37779492+0.j        , ...,   0.05781267+0.00217739j,
        -0.04033944-0.03193015j,  -0.03127322-0.00663547j]),
1535)  <---
```