Examples_spectra

March 22, 2018

1 Examples of spectra

1.1 Toolboxes

```
In [1]: import numpy as np
        import rt_anatools
        import matplotlib.pyplot     as plt
        from scipy.signal import lfilter # For red noise generation
        %matplotlib inline
```

1.2 Parameters

```
In [131]: N = 5000
          t = np.arange(N)
          Fs = 1.
          units = 'days'
```

1.3 I/ White noise

1.3.1 Compute time serie

```
In [132]: y_white = np.random.randn(N)
```

1.3.2 Generate spectra

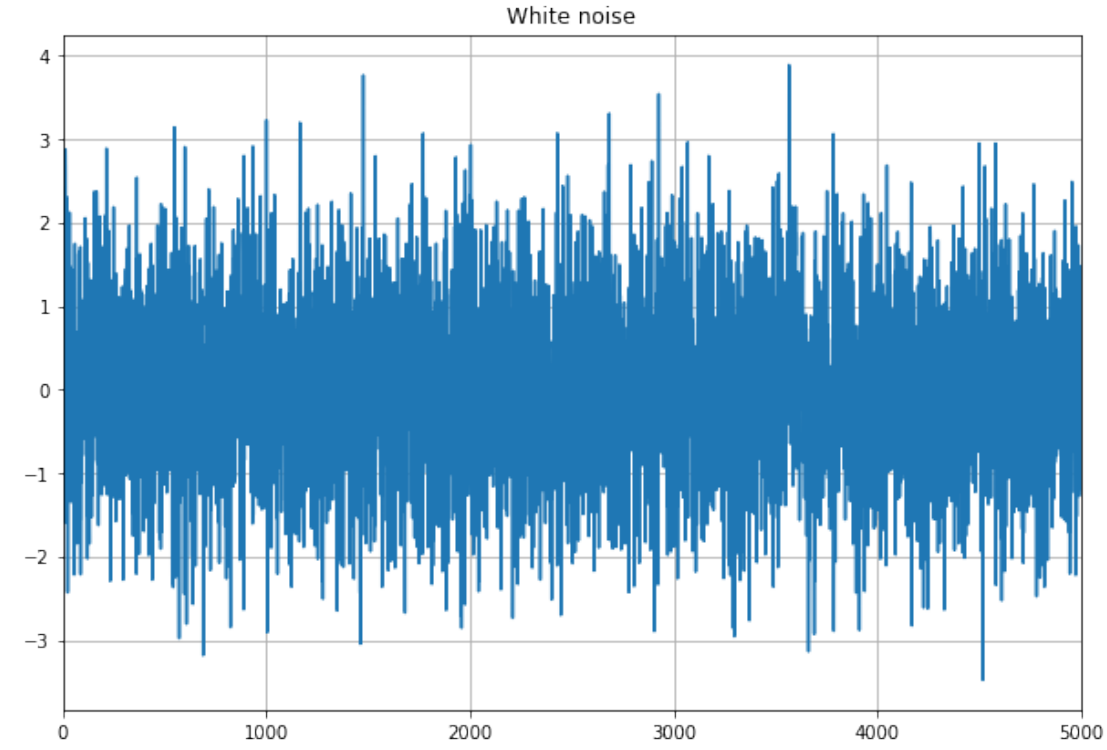
```
In [133]: PSD_white,freq = rt_anatools.compute_spectrum(y_white,Fs,taper=None,dof=2)
          PSD_white_20,freq_20 = rt_anatools.compute_spectrum(y_white,Fs,taper=None,dof=20)
```

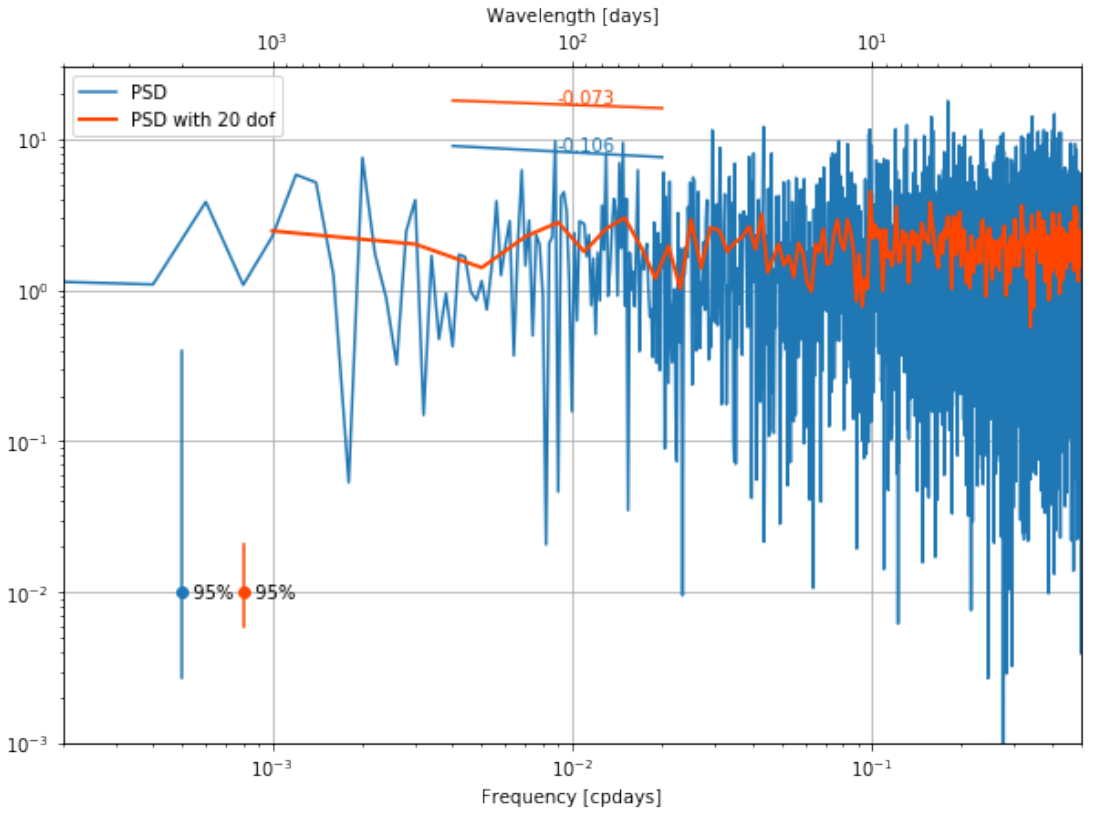
1.3.3 Plot figure

```
In [134]: fig = plt.figure(figsize=(10,15));
          ### Time serie
          plt.subplot(2,1,1)
          plt.plot(t,y_white)
          plt.xlim([t.min(),t.max()])
          plt.title('White noise')
          plt.grid()
          ### Plot spectra
```

```
plt.subplot(2,1,2)
## Original spectrum
plt_psd = plt.loglog(freq,PSD_white,label='PSD')
color_PSD = plt_psd[0].get_color()
# Plot slope
slope_PSD = rt_anatools.compute_spectrum_slope(PSD_white,freq,[1e-3,.1])
rt_anatools.plot_spectrum_slope(4e-3,2e-2,9,slope_PSD,color=color_PSD)
# Plot confidence interval
conf_coeff = rt_anatools.confidence_fft(2, alpha=0.95)
conf_point = [5e-4,1e-2]
plt.loglog(conf_point[0],conf_point[1],'o',color=color_PSD)
plt.loglog([conf_point[0],conf_point[0]],\
           [conf_point[1]*conf_coeff[0],conf_point[1]*conf_coeff[1]],\
           color=color_PSD)
txt = plt.text(conf_point[0],conf_point[1],'  95%',verticalalignment='center')
## Filtered spectrum
plt_psd = plt.loglog(freq_20,PSD_white_20,label='PSD with 20 dof',color='orangered',li
color_PSD_20 = plt_psd[0].get_color()
# Plot slope
slope_PSD_20 = rt_anatools.compute_spectrum_slope(PSD_white_20,freq_20,[1e-3,.1])
rt_anatools.plot_spectrum_slope(4e-3,2e-2,18,slope_PSD_20,color=color_PSD_20)
# Plot confidence interval
conf_coeff_20 = rt_anatools.confidence_fft(20, alpha=0.95)
conf_point_20 = [8e-4,1e-2]
plt.loglog(conf_point_20[0],conf_point_20[1],'o',color=color_PSD_20)
plt.loglog([conf_point_20[0],conf_point_20[0]],\
           [conf_point_20[1]*conf_coeff_20[0],conf_point_20[1]*conf_coeff_20[1]],\
           color=color_PSD_20)
txt = plt.text(conf_point_20[0],conf_point_20[1],'  95%',verticalalignment='center')
### Customize plot
plt.grid()
plt.legend()
plt.ylim([1e-3,30])
plt.xlim([freq[1],freq[-1]])
ax = plt.gca()
ax.set_xlabel('Frequency [cp' + units + ']')
rt_anatools.add_wavelength_axis_to_spectrum(ax,units)
```

Out[134]: <matplotlib.axes._subplots.AxesSubplot at 0x11074cb90>


White noise
4
3
2
1
0
−1
−2
−3
0
1000
2000
3000
4000
5000


Wavelength [days]
10^3
10^2
10^1
PSD
PSD with 20 dof
-0.073
-0.106
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
95%
95%
10^{-3}
10^{-2}
10^{-1}
Frequency [cpdays]

1.4 II/ Red noise

1.4.1 Compute time serie

```
In [135]: y_red = lfilter(np.array([1]),np.array([1,-0.99]), np.random.randn(N))
          y_red = y_red/np.std(y_red)
```

1.4.2 Generate spectra

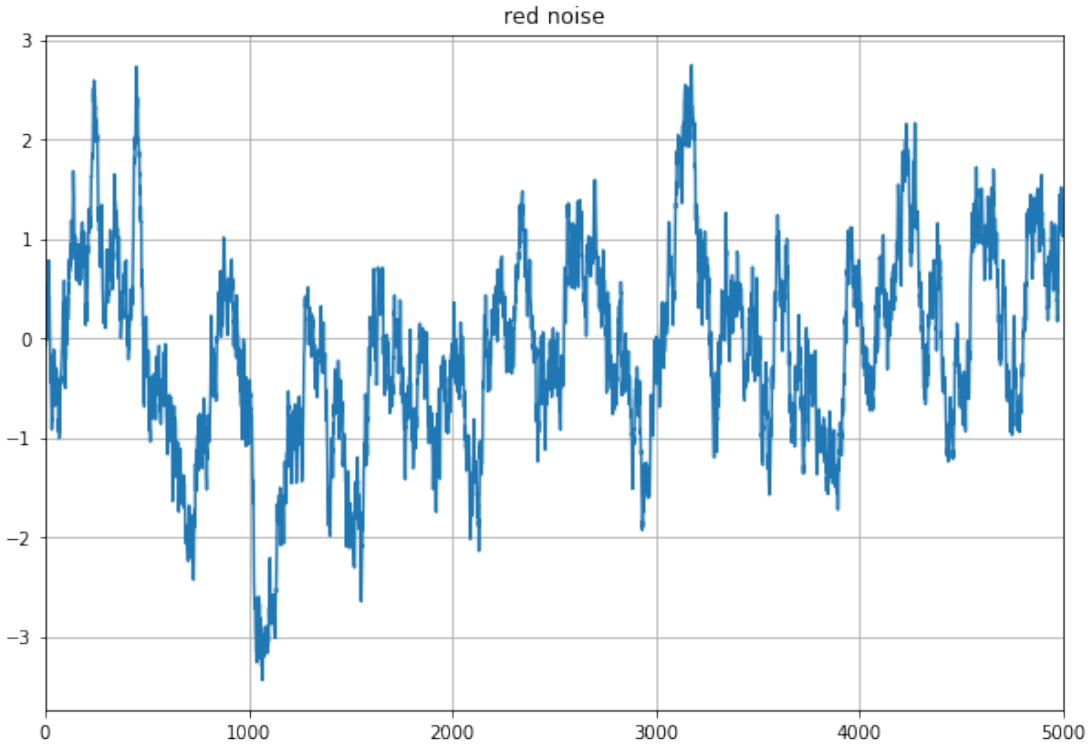
```
In [136]: PSD_red,freq        = rt_anatools.compute_spectrum(y_red,Fs,taper=None,dof=2)
          PSD_red_H,freq      = rt_anatools.compute_spectrum(y_red,Fs,taper='Hann',dof=2)
          PSD_red_H20,freq_20 = rt_anatools.compute_spectrum(y_red,Fs,taper='Hann',dof=20)
```

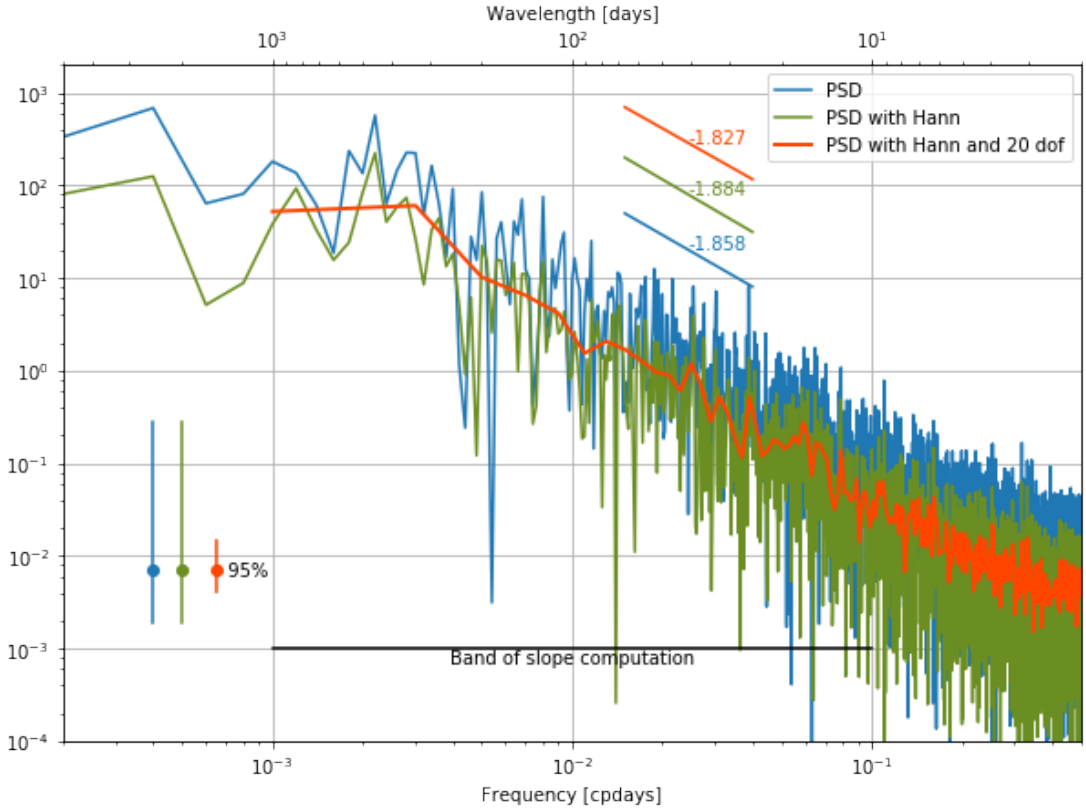
1.4.3 Plot figure

```
In [151]: fig = plt.figure(figsize=(10,15));plt.clf()
          ### Time serie
          plt.subplot(2,1,1)
          plt.plot(t,y_red)
          plt.xlim([t.min(),t.max()])
          plt.title('red noise')
          plt.grid()
          ### Plot spectra
          plt.subplot(2,1,2)
          freq_lim_slope = [1e-3,.1]
          ## Original spectrum
          plt_psd = plt.loglog(freq,PSD_red,label='PSD')
          color_PSD = plt_psd[0].get_color()
          # Plot slope
          slope_PSD = rt_anatools.compute_spectrum_slope(PSD_red,freq,freq_lim_slope)
          rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,50,slope_PSD,color=color_PSD)
          # Plot confidence interval
          conf_coeff = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point = [4e-4,7e-3]
          plt.loglog(conf_point[0],conf_point[1],'o',color=color_PSD)
          plt.loglog([conf_point[0],conf_point[0]],\
                     [conf_point[1]*conf_coeff[0],conf_point[1]*conf_coeff[1]],\
                     color=color_PSD)
          ## Hann window spectrum
          plt_psd = plt.loglog(freq,PSD_red_H,label='PSD with Hann',color='olivedrab')
          color_PSD_H = plt_psd[0].get_color()
          # Plot slope
          slope_PSD_H = rt_anatools.compute_spectrum_slope(PSD_red_H,freq,freq_lim_slope)
          rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,2e2,slope_PSD_H,color=color_PSD_H)
          # Plot confidence interval
          conf_coeff_H = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point_H = [5e-4,7e-3]
          plt.loglog(conf_point_H[0],conf_point_H[1],'o',color=color_PSD_H)
          plt.loglog([conf_point_H[0],conf_point_H[0]],\
```

```
            [conf_point_H[1]*conf_coeff_H[0],conf_point_H[1]*conf_coeff_H[1]],\
            color=color_PSD_H)
        ## Hann window and filtered spectrum
        plt_psd = plt.loglog(freq_20,PSD_red_H20,label='PSD with Hann and 20 dof',color='orang
        color_PSD_H20 = plt_psd[0].get_color()
        # Plot slope
        slope_PSD_H20 = rt_anatools.compute_spectrum_slope(PSD_red_H20,freq_20,freq_lim_slope)
        rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,7e2,slope_PSD_H20,color=color_PSD_H20)
        # Plot confidence interval
        conf_coeff_H20 = rt_anatools.confidence_fft(20, alpha=0.95)
        conf_point_H20 = [6.5e-4,7e-3]
        plt.loglog(conf_point_H20[0],conf_point_H20[1],'o',color=color_PSD_H20)
        plt.loglog([conf_point_H20[0],conf_point_H20[0]],\
            [conf_point_H20[1]*conf_coeff_H20[0],conf_point_H20[1]*conf_coeff_H20[1]],\
            color=color_PSD_H20)
        txt = plt.text(conf_point_H20[0],conf_point_H20[1],'  95%',verticalalignment='center')
        ### Customize plot
        plt.grid()
        plt.legend()
        plt.ylim([1e-4,2e3])
        plt.xlim([freq[1],freq[-1]])
        plt.plot(freq_lim_slope,[1e-3,1e-3],'k')
        plt.text(.01,7e-4,'Band of slope computation',horizontalalignment='center')
        ax = plt.gca()
        ax.set_xlabel('Frequency [cp' + units + ']')
        rt_anatools.add_wavelength_axis_to_spectrum(ax,units)
```

```
Out[151]: <matplotlib.axes._subplots.AxesSubplot at 0x12dcda190>
```


red noise
3
2
1
0
−1
−2
−3
0
1000
2000
3000
4000
5000


Wavelength [days]
10^3
10^2
10^1
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
PSD
PSD with Hann
PSD with Hann and 20 dof
-1.827
-1.884
-1.858
95%
Band of slope computation
10^{-3}
10^{-2}
10^{-1}
Frequency [cpdays]

1.5 III/ One harmonic

1.5.1 Compute time serie

```
In [138]: f1 = 1/100.
          y_harmo = np.cos(2*np.pi*f1*t)+0.001*np.random.randn(N)
```

1.5.2 Generate spectra

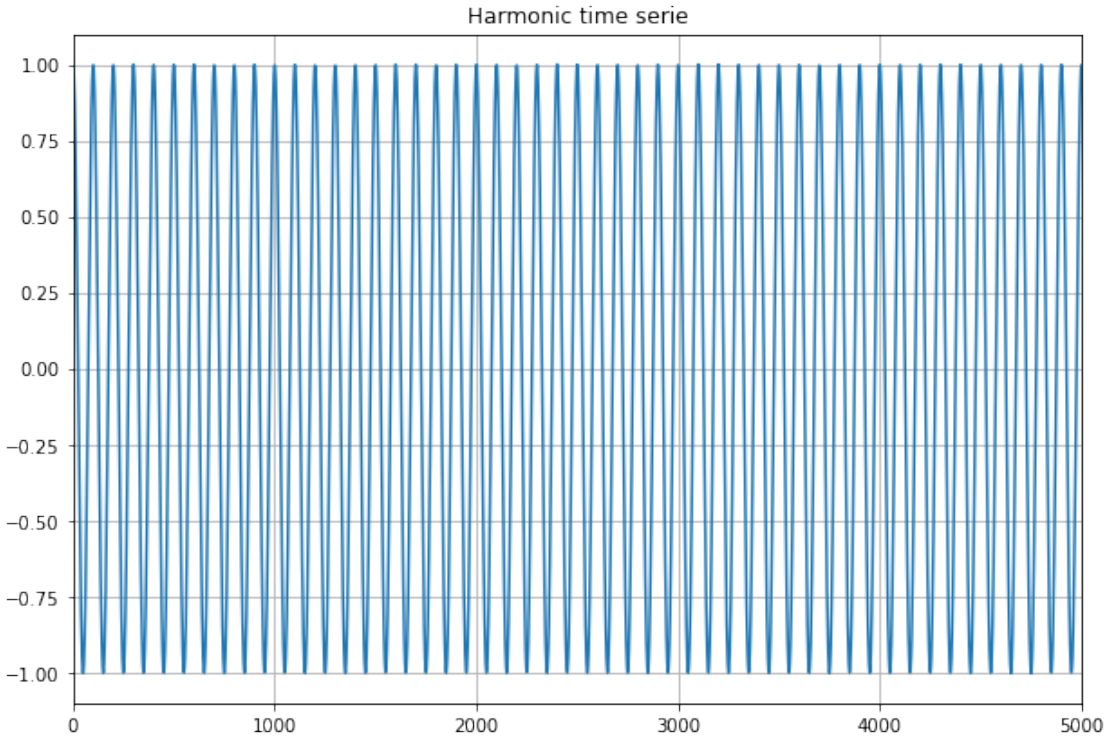
```
In [139]: PSD_harmo,freq       = rt_anatools.compute_spectrum(y_harmo,Fs,taper=None,dof=2)
          PSD_harmo_20,freq_20 = rt_anatools.compute_spectrum(y_harmo,Fs,taper=None,dof=20)
```

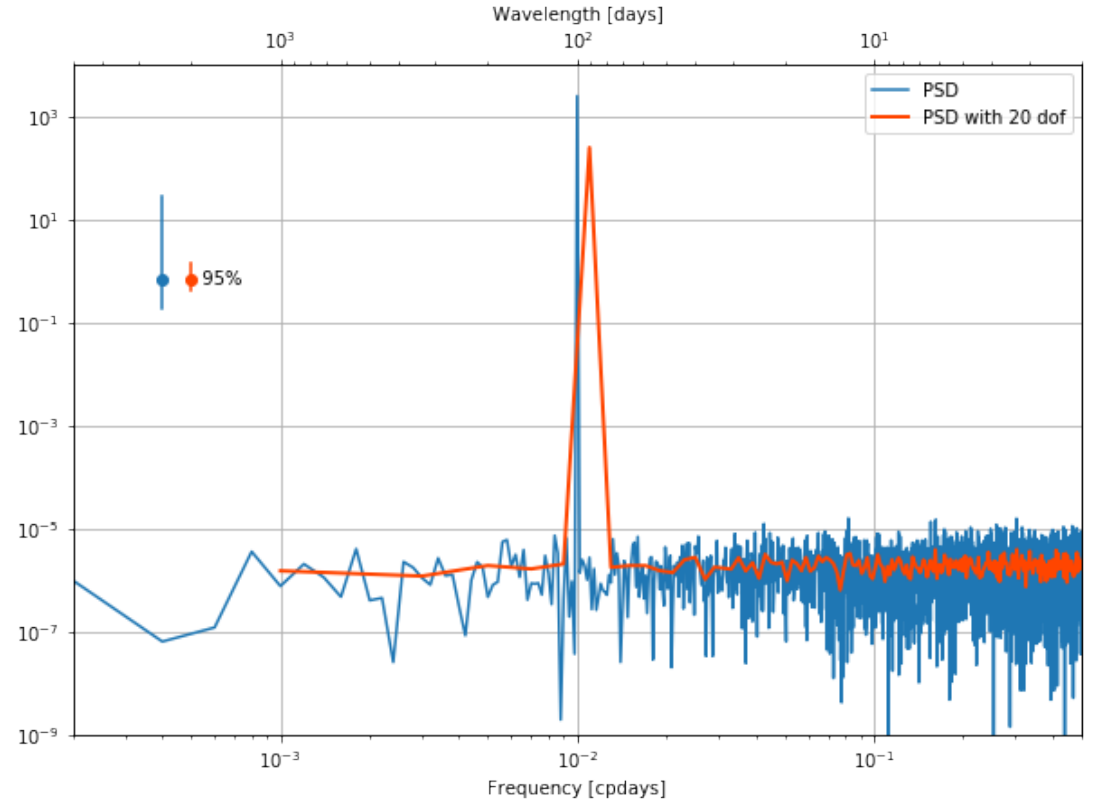
1.5.3 Plot figure

```
In [140]: fig = plt.figure(figsize=(10,15));plt.clf()
          plt.subplot(2,1,1)
          plt.plot(t,y_harmo)
          plt.xlim([t.min(),t.max()])
          plt.title('Harmonic time serie')
          plt.grid()
          plt.subplot(2,1,2)
          ### Original spectrum
          plt_psd = plt.loglog(freq,PSD_harmo,label='PSD')
          color_PSD = plt_psd[0].get_color()
          # Plot confidence interval
          conf_coeff = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point = [4e-4,7e-1]
          plt.loglog(conf_point[0],conf_point[1],'o',color=color_PSD)
          plt.loglog([conf_point[0],conf_point[0]],\
                     [conf_point[1]*conf_coeff[0],conf_point[1]*conf_coeff[1]],\
                     color=color_PSD)
          ### Filtered spectrum
          plt_psd = plt.loglog(freq_20,PSD_harmo_20,label='PSD with 20 dof',color='orangered',li
          color_PSD_20 = plt_psd[0].get_color()
          # Plot confidence interval
          conf_coeff_20 = rt_anatools.confidence_fft(20, alpha=0.95)
          conf_point_20 = [5e-4,7e-1]
          plt.loglog(conf_point_20[0],conf_point_20[1],'o',color=color_PSD_20)
          plt.loglog([conf_point_20[0],conf_point_20[0]],\
                     [conf_point_20[1]*conf_coeff_20[0],conf_point_20[1]*conf_coeff_20[1]],\
                     color=color_PSD_20)
          txt = plt.text(conf_point_20[0],conf_point_20[1],'  95%',verticalalignment='center')
          ### Customize plot
          plt.grid()
          plt.legend()
          plt.ylim([1e-9,1e4])
          plt.xlim([freq[1],freq[-1]])
          ax = plt.gca()
```

```
        ax.set_xlabel('Frequency [cp' + units + ']')
        rt_anatools.add_wavelength_axis_to_spectrum(ax,units)
```

Out[140]: <matplotlib.axes._subplots.AxesSubplot at 0x12b63af50>


Harmonic time serie
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
1000
2000
3000
4000
5000


Wavelength [days]
10^3
10^2
10^1
PSD
PSD with 20 dof
95%
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
10^{-3}
10^{-2}
10^{-1}
Frequency [cpdays]

1.6 IV/ Leaking harmonic

1.6.1 Compute time serie

```
In [141]: f1 = 1/99.
          y_harmo2 = np.cos(2*np.pi*f1*t)+0.001*np.random.randn(N)
```

1.6.2 Generate spectra

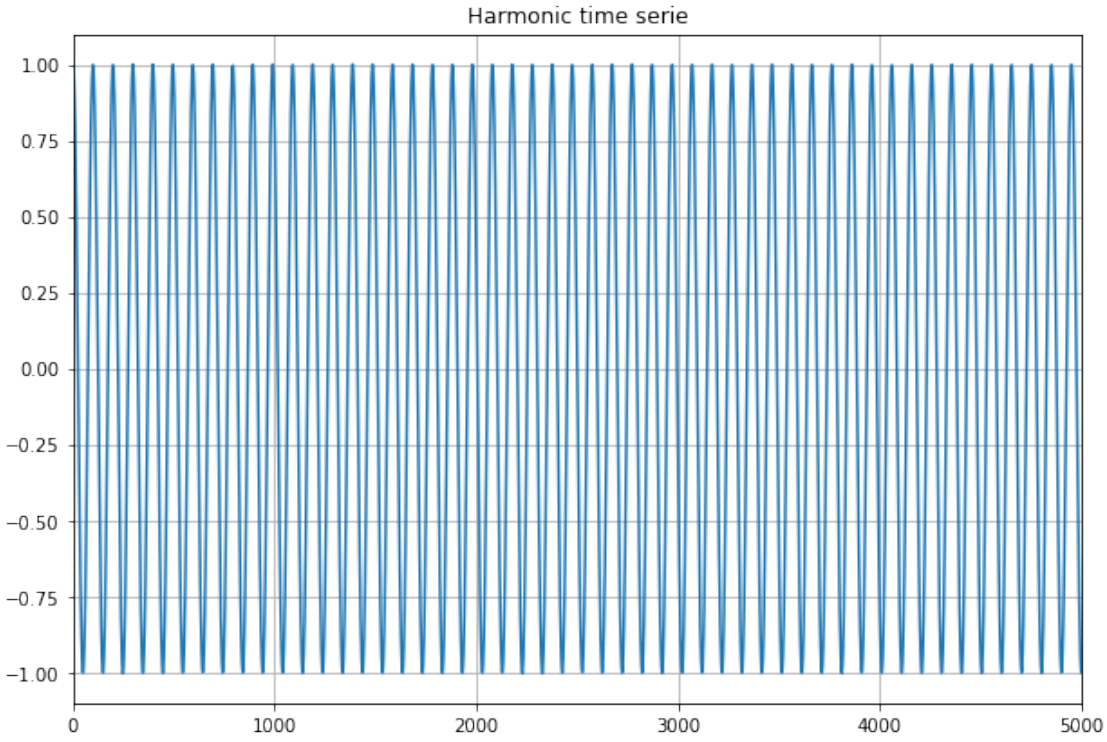
```
In [142]: PSD_harmo2,freq        = rt_anatools.compute_spectrum(y_harmo2,Fs,taper=None,dof=2)
          PSD_harmo2_H,freq      = rt_anatools.compute_spectrum(y_harmo2,Fs,taper='Hann',dof=2)
          PSD_harmo2_H20,freq_20 = rt_anatools.compute_spectrum(y_harmo2,Fs,taper='Hann',dof=20)
```

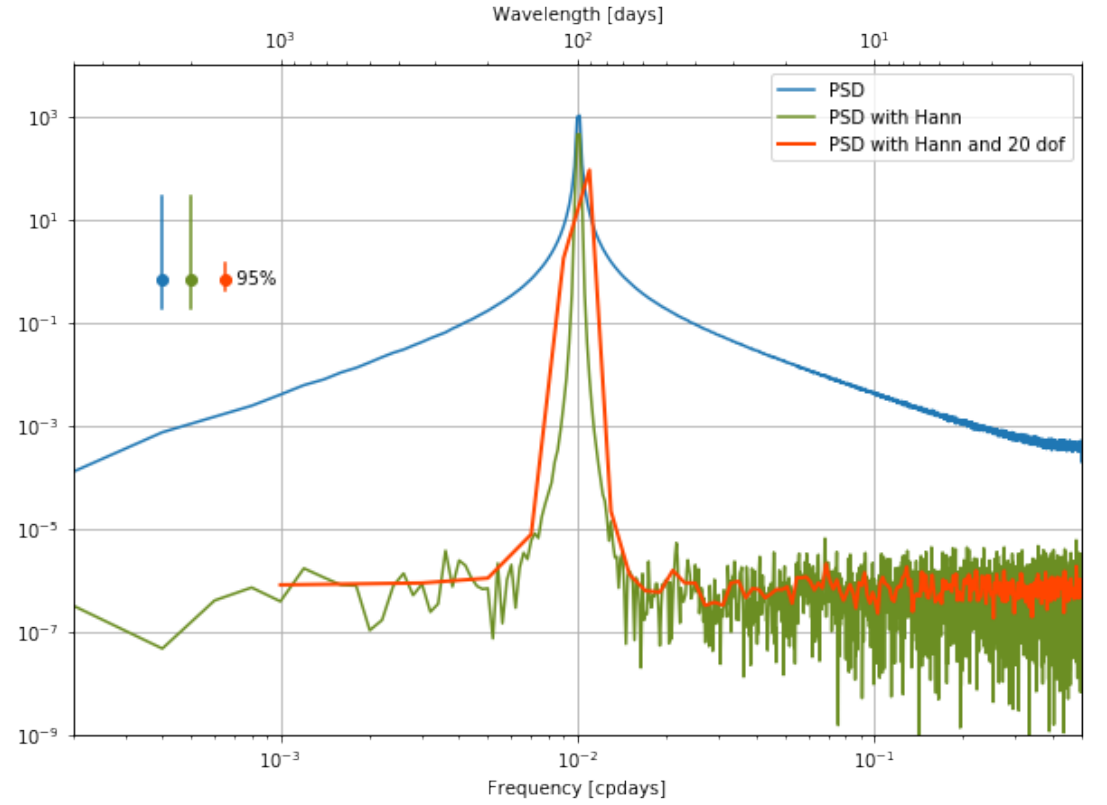
1.6.3 Plot figure

```
In [143]: fig = plt.figure(figsize=(10,15));plt.clf()
          plt.subplot(2,1,1)
          plt.plot(t,y_harmo2)
          plt.xlim([t.min(),t.max()])
          plt.title('Harmonic time serie')
          plt.grid()
          plt.subplot(2,1,2)
          ### Original spectrum
          plt_psd = plt.loglog(freq,PSD_harmo2,label='PSD')
          color_PSD = plt_psd[0].get_color()
          # Plot confidence interval
          conf_coeff = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point = [4e-4,7e-1]
          plt.loglog(conf_point[0],conf_point[1],'o',color=color_PSD)
          plt.loglog([conf_point[0],conf_point[0]],\
                     [conf_point[1]*conf_coeff[0],conf_point[1]*conf_coeff[1]],\
                     color=color_PSD)
          ### Hann window spectrum
          plt_psd = plt.loglog(freq,PSD_harmo2_H,label='PSD with Hann',color='olivedrab')
          color_PSD_H = plt_psd[0].get_color()
          # Plot confidence interval
          conf_coeff_H = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point_H = [5e-4,7e-1]
          plt.loglog(conf_point_H[0],conf_point_H[1],'o',color=color_PSD_H)
          plt.loglog([conf_point_H[0],conf_point_H[0]],\
                     [conf_point_H[1]*conf_coeff_H[0],conf_point_H[1]*conf_coeff_H[1]],\
                     color=color_PSD_H)
          ### Filtered spectrum
          plt_psd = plt.loglog(freq_20,PSD_harmo2_H20,label='PSD with Hann and 20 dof',color='or
          color_PSD_H20 = plt_psd[0].get_color()
          # Plot confidence interval
          conf_coeff_20 = rt_anatools.confidence_fft(20, alpha=0.95)
          conf_point_20 = [6.5e-4,7e-1]
          plt.loglog(conf_point_20[0],conf_point_20[1],'o',color=color_PSD_H20)
```

```
plt.loglog([conf_point_20[0],conf_point_20[0]],\
           [conf_point_20[1]*conf_coeff_20[0],conf_point_20[1]*conf_coeff_20[1]],\
           color=color_PSD_H20)
txt = plt.text(conf_point_20[0],conf_point_20[1],'  95%',verticalalignment='center')
### Customize plot
plt.grid()
plt.legend()
plt.ylim([1e-9,1e4])
plt.xlim([freq[1],freq[-1]])
ax = plt.gca()
ax.set_xlabel('Frequency [cp' + units + ']')
rt_anatools.add_wavelength_axis_to_spectrum(ax,units)
```

```
Out[143]: <matplotlib.axes._subplots.AxesSubplot at 0x129eade90>
```


Harmonic time serie
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
1000
2000
3000
4000
5000


Wavelength [days]
10^3
10^2
10^1
PSD
PSD with Hann
PSD with Hann and 20 dof
95%
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
10^{-3}
10^{-2}
10^{-1}
Frequency [cpdays]

1.7 V/ 'Realistic' signal

1.7.1 Compute time serie

```
In [144]: f1 = 1/50.
          f2 = 1/110.
          y_reali = y_red + 0.7* np.cos(2*np.pi*f1*t) + 0.4*np.cos(2*np.pi*f2*t) + 0.1*y_white
```

1.7.2 Generate spectra

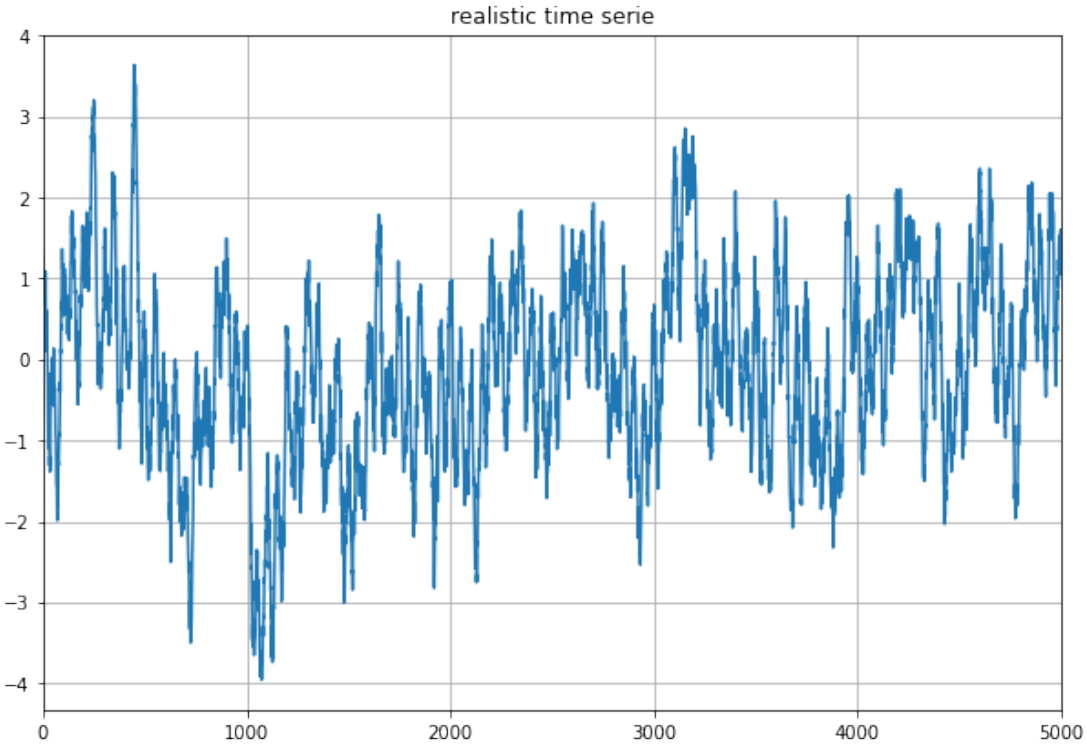
```
In [145]: PSD_reali,freq        = rt_anatools.compute_spectrum(y_reali,Fs,taper=None,dof=2)
          PSD_reali_H,freq      = rt_anatools.compute_spectrum(y_reali,Fs,taper='Hann',dof=2)
          PSD_reali_H20,freq_20 = rt_anatools.compute_spectrum(y_reali,Fs,taper='Hann',dof=20)
```

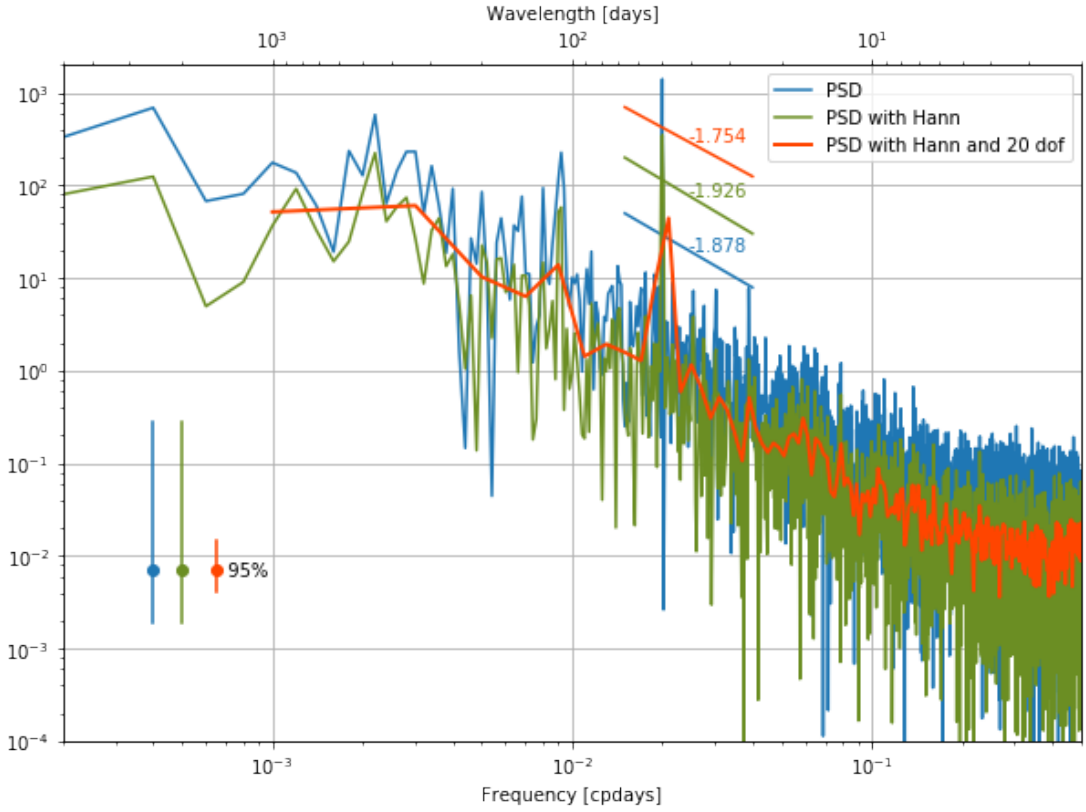
1.7.3 Plot figure

```
In [146]: fig = plt.figure(figsize=(10,15));plt.clf()
          plt.subplot(2,1,1)
          plt.plot(t,y_reali)
          plt.xlim([t.min(),t.max()])
          plt.title('realistic time serie')
          plt.grid()
          plt.subplot(2,1,2)
          freq_lim_slope = [1e-3,5e-2]
          ### Original spectrum
          plt_psd = plt.loglog(freq,PSD_reali,label='PSD')
          color_PSD = plt_psd[0].get_color()
          # Plot slope
          slope_PSD = rt_anatools.compute_spectrum_slope(PSD_reali,freq,freq_lim_slope)
          rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,50,slope_PSD,color=color_PSD)
          # Plot confidence interval
          conf_coeff = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point = [4e-4,7e-3]
          plt.loglog(conf_point[0],conf_point[1],'o',color=color_PSD)
          plt.loglog([conf_point[0],conf_point[0]],\
                     [conf_point[1]*conf_coeff[0],conf_point[1]*conf_coeff[1]],\
                     color=color_PSD)
          ### Hann window spectrum
          plt_psd = plt.loglog(freq,PSD_reali_H,label='PSD with Hann',color='olivedrab')
          color_PSD_H = plt_psd[0].get_color()
          # Plot slope
          slope_PSD_H = rt_anatools.compute_spectrum_slope(PSD_reali_H,freq,freq_lim_slope)
          rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,2e2,slope_PSD_H,color=color_PSD_H)
          # Plot confidence interval
          conf_coeff_H = rt_anatools.confidence_fft(2, alpha=0.95)
          conf_point_H = [5e-4,7e-3]
          plt.loglog(conf_point_H[0],conf_point_H[1],'o',color=color_PSD_H)
          plt.loglog([conf_point_H[0],conf_point_H[0]],\
                     [conf_point_H[1]*conf_coeff_H[0],conf_point_H[1]*conf_coeff_H[1]],\
```

```
            color=color_PSD_H)
        ### Filtered spectrum
        plt_psd = plt.loglog(freq_20,PSD_reali_H20,label='PSD with Hann and 20 dof',color='ora
        color_PSD_H20 = plt_psd[0].get_color()
        # Plot slope
        slope_PSD_H20 = rt_anatools.compute_spectrum_slope(PSD_reali_H20,freq_20,freq_lim_slop
        rt_anatools.plot_spectrum_slope(1.5e-2,4e-2,7e2,slope_PSD_H20,color=color_PSD_H20)
        # Plot confidence interval
        conf_coeff_H20 = rt_anatools.confidence_fft(20, alpha=0.95)
        conf_point_H20 = [6.5e-4,7e-3]
        plt.loglog(conf_point_H20[0],conf_point_H20[1],'o',color=color_PSD_H20)
        plt.loglog([conf_point_H20[0],conf_point_H20[0]],\
                   [conf_point_H20[1]*conf_coeff_H20[0],conf_point_H20[1]*conf_coeff_H20[1]],\
                   color=color_PSD_H20)
        txt = plt.text(conf_point_H20[0],conf_point_H20[1],'  95%',verticalalignment='center')
        ### Customize plot
        plt.grid()
        plt.legend()
        plt.ylim([1e-4,2e3])
        plt.xlim([freq[1],freq[-1]])
        ax = plt.gca()
        ax.set_xlabel('Frequency [cp' + units + ']')
        rt_anatools.add_wavelength_axis_to_spectrum(ax,units)
```

Out[146]: <matplotlib.axes._subplots.AxesSubplot at 0x129179990>


realistic time serie
4
3
2
1
0
−1
−2
−3
−4
0
1000
2000
3000
4000
5000


Wavelength [days]
10^3
10^2
10^1
PSD
PSD with Hann
PSD with Hann and 20 dof
-1.754
-1.926
-1.878
95%
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Frequency [cpdays]