In [ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
%matplotlib inline
```

In [ ]:
```
from google.colab import files
uploaded=files.upload()
```

Choose Files | No file chosen — Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.

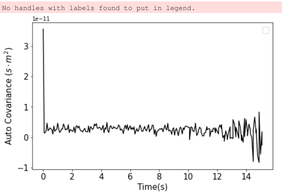
```
Saving 1.06.csv to 1.06 (1).csv
```

In [ ]:
```
# csv 파일을 읽어서 DataFrame 객체로 만듦. 인덱스 컬럼은 point로 설정
dg = pd.read_csv('1.06.csv')
dg=dg[:228]
t=np.array(dg['t'])
#v
```

In [ ]:
```
v=np.array(dg['v1'])
v=np.vstack((v,np.array(dg['v2'])))
v=np.vstack((v,np.array(dg['v3'])))
v=np.vstack((v,np.array(dg['v4'])))
v=np.vstack((v,np.array(dg['v5'])))
v=np.vstack((v,np.array(dg['v6'])))
v=np.vstack((v,np.array(dg['v7'])))
v=np.vstack((v,np.array(dg['v8'])))
v=np.vstack((v,np.array(dg['v9'])))
v=np.vstack((v,np.array(dg['v10'])))
```

In [ ]:
```
# autocorrelation, (averaged over all trajectory)
autocorr = np.zeros(228)

autocorr[0] = np.average(v*v)

for i in range (227):
    autocorr[i+1] = np.average(v[:,i+1:]*v[:,:-i-1])



fig = plt.figure(1,figsize=(8,5))
plt.plot(t, autocorr,color='black')
#plt.ylim(-1e-10, 2e-10)    # y축의 범위: [ymin, ymax]
# plt.axis([0, 5, 0, 20])  # X, Y축의 범위: [xmin, xmax, ymin, ymax]
#plt.xlim(0.5, 25)
plt.legend(fontsize=15)
plt.xticks(fontsize=15)
plt.yticks(fontsize=15)
plt.xlabel('Time(s)',fontsize=15)
plt.ylabel('Auto Covariance ($s \cdot m^2$)',fontsize=15)
plt.savefig('auto_covar_1.06.png')
plt.show()
# this shows delta_correlation
```

```
No handles with labels found to put in legend.
```



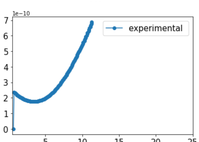
In [ ]:
```
# csv 파일을 읽어서 DataFrame 객체로 만듦. 인덱스 컬럼은 point로 설정
df = pd.read_csv('1.06.csv')
df=df[:228]
df
x=np.array(df['x1'])
x=np.vstack((x,np.array(df['x2'])))
x=np.vstack((x,np.array(df['x3'])))
x=np.vstack((x,np.array(df['x4'])))
x=np.vstack((x,np.array(df['x5'])))
y=np.array(df['y1'])
y=np.vstack((y,np.array(df['y2'])))
y=np.vstack((y,np.array(df['y3'])))
y=np.vstack((y,np.array(df['y4'])))
y=np.vstack((y,np.array(df['y5'])))
# x
# y
```

In [ ]:
```
p = 10
q = 171
num = q - p
for i,arr in enumerate(x) :
  if i == 0 :
    arr = arr[p:q]
    xt = np.array(arr)
  else :
    arr = arr[p:q]
    xt = np.vstack((xt,arr))

for i,arr in enumerate(y) :

  if i == 0 :
    arr = arr[p:q]
    yt = np.array(arr)
  else :
    arr = arr[p:q]
    yt = np.vstack((yt,arr))


xt = np.array(xt)
yt = np.array(yt)
```

In [ ]:
```
tt = t[p:q]
```

In [ ]:
```
# Mean Square Displacement
MSD = np.zeros(num)
# # MSD[0]=0
for tau in range (num-1):
    MSD[tau+1] = np.average((x[:,tau+1:]-x[:,:-tau-1])**2+(y[:,tau+1:]-x[:,:-tau-1])**2)
plt.plot(tt,MSD,'o-',label='experimental ')
plt.xlim(0.5, 25)
plt.legend(fontsize=15)
plt.xticks(fontsize=15)
plt.yticks(fontsize=15)
plt.show
```

Out[ ]:
```
<function matplotlib.pyplot.show>
```



In [ ]:
```
t[50]
```

Out[ ]:
```
3.33
```

In [ ]:
```
from scipy.optimize import curve_fit

yy = np.zeros(num)
for tau in range (num-1):
    yy[tau+1] = np.average((xt[:,tau+1:]-xt[:,:-tau-1])**2+(yt[:,tau+1:]-yt[:,:-tau-1])**2)

def func(x,a,b,c) :
  return a*x**2+b*x+c


pp = 50
qq = 140
num = qq-pp
ttemp = t[pp]
ttt = tt[pp:qq]-ttemp
MSDt = MSD[pp:qq]
popt,pcov = curve_fit(func,ttt,MSDt)


popt
```

Out[ ]:
```
array([8.04654455e-12, 2.30174261e-12, 1.71931160e-10])
```

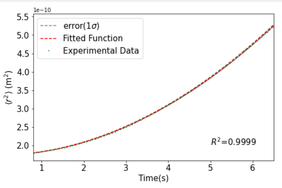
In [ ]:
```
from sklearn.metrics import r2_score
#MSDt - MSD
r2 = r2_score(MSDt,func(ttt,popt[0],popt[1],popt[2]))
r2
```

Out[ ]:
```
0.9998911376270724
```

In [ ]:
```
perr = np.sqrt(np.diag(pcov))
perr
```

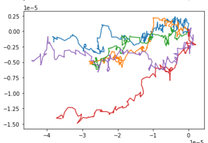
Out[ ]:
```
array([4.48506439e-14, 3.33526194e-13, 5.37236640e-13])
```

In [ ]:
```
xxx = np.linspace(ttt[0],ttt[-1],90)
xxxx = np.linspace(0,20,21)
x2 = np.linspace(0,15,171)

fig = plt.figure(1,figsize=(8,5))
plt.plot(xxx,func(xxx,popt[0],popt[1]+perr[1],popt[2]),'--',color='gray',ms=1,label='error(1$\sigma$)')
plt.plot(xxx,func(xxx,popt[0],popt[1]-perr[1],popt[2]),color='gray',ms=1)
plt.plot(xxx,func(xxx,popt[0],popt[1],popt[2]),'--',color='red',ms=1,label='Fitted Function')

plt.plot(ttt,MSDt,'o',color='green',ms=1,label='Experimental Data')

plt.xlim(0.8, 6.5)
plt.text(5.0,2e-10,f'$R^2$={r2:.4f}',fontsize=15)
plt.legend(fontsize=15)
plt.xticks(fontsize=15)
plt.yticks(fontsize=15)
plt.xlabel('Time(s)',fontsize=15)
plt.ylabel('$\quad \langle r^2 \rangle$ ($m^2$)',fontsize=15)
#plt.ylim(1.25e-10,1.8e-10)
plt.savefig('MSDfitted_1.06.png')
plt.show()
```



In [ ]:
```
plt.plot(df['x1'],df['y1'],df['x2'],df['y2'],df['x3'],df['y3'], df['x4'],df['y4'], df['x5'],df['y5'])
```

Out[ ]:
```
[<matplotlib.lines.Line2D at 0x7f25c05cecd0>,
 <matplotlib.lines.Line2D at 0x7f25c05ced90>,
 <matplotlib.lines.Line2D at 0x7f25c060cad0>,
 <matplotlib.lines.Line2D at 0x7f25c05c4710>,
 <matplotlib.lines.Line2D at 0x7f25c05c49d0>]
```



In [ ]:
```
m = popt[1]
m
```

Out[ ]:
```
2.301742612152749e-12
```

In [ ]:
```
err = perr[1]
err
```

Out[ ]:
```
3.3352619433308965e-13
```

In [ ]:
```

```