Q11.e

April 26, 2023

[6]:
```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import os
from scipy import stats
from scipy import optimize
from scipy.optimize import curve_fit
from IPython.display import Image
from IPython.core.display import HTML
```

[24]:
```
#import measurements
df=pd.read_csv('Q11.e_data.csv')
```

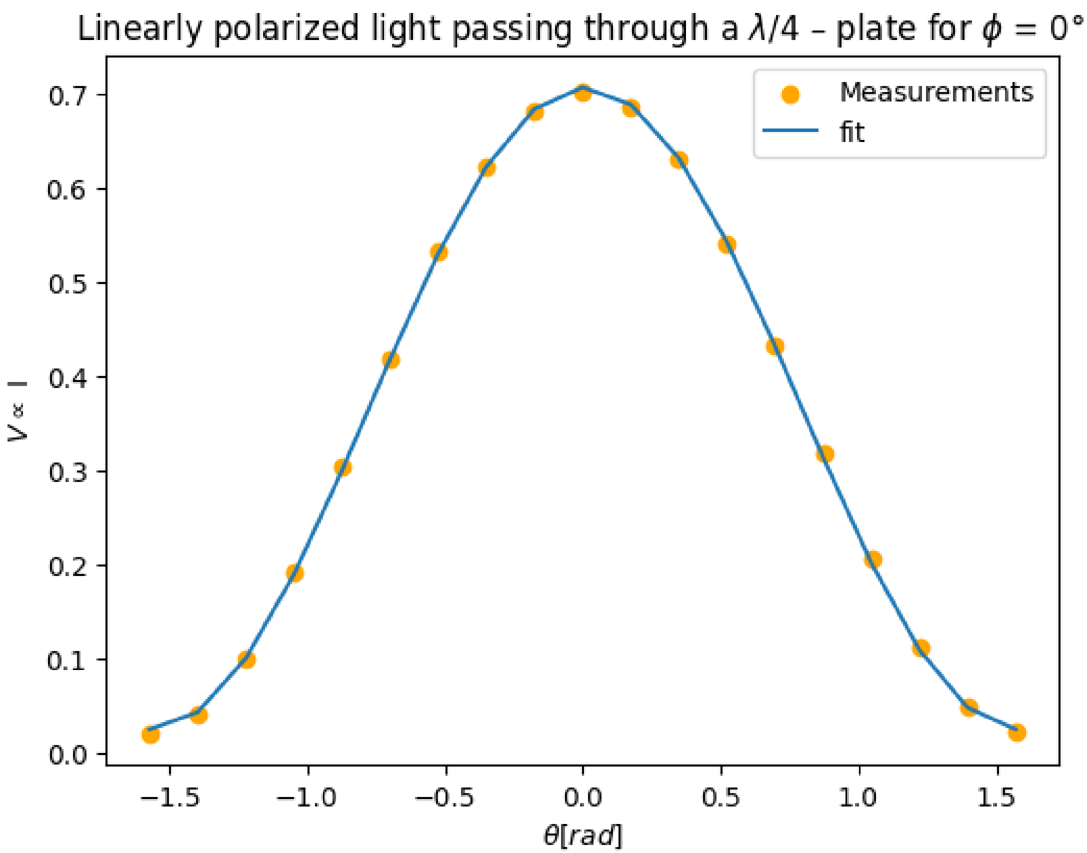
[25]:
```
#turn into arrays
a= np.array(df['LIN_POL_0°_plate'])
b= np.array(df['LIN_POL_30°_plate'])
c= np.array(df['LIN_POL_45°_plate'])
d= np.array(df['BBC1_No_plate'])
e= np.array(df['BBC1_0°_plate'])
f= np.array(df['BBC1_45°_plate'])
g= np.array(df['BBC2_No_plate'])
h= np.array(df['BBC2_0°_plate'])
i= np.array(df['BBC2_45°_plate'])
j= np.array(df['BBC3_No_plate'])
k= np.array(df['BBC3_0°_plate'])
l= np.array(df['BBC3_45°_plate'])
Angle_rad= np.array(df['Angle(rad)'])
Angle_deg= np.array(df['Angle(deg)'])
```

0.0.1 Task 1:

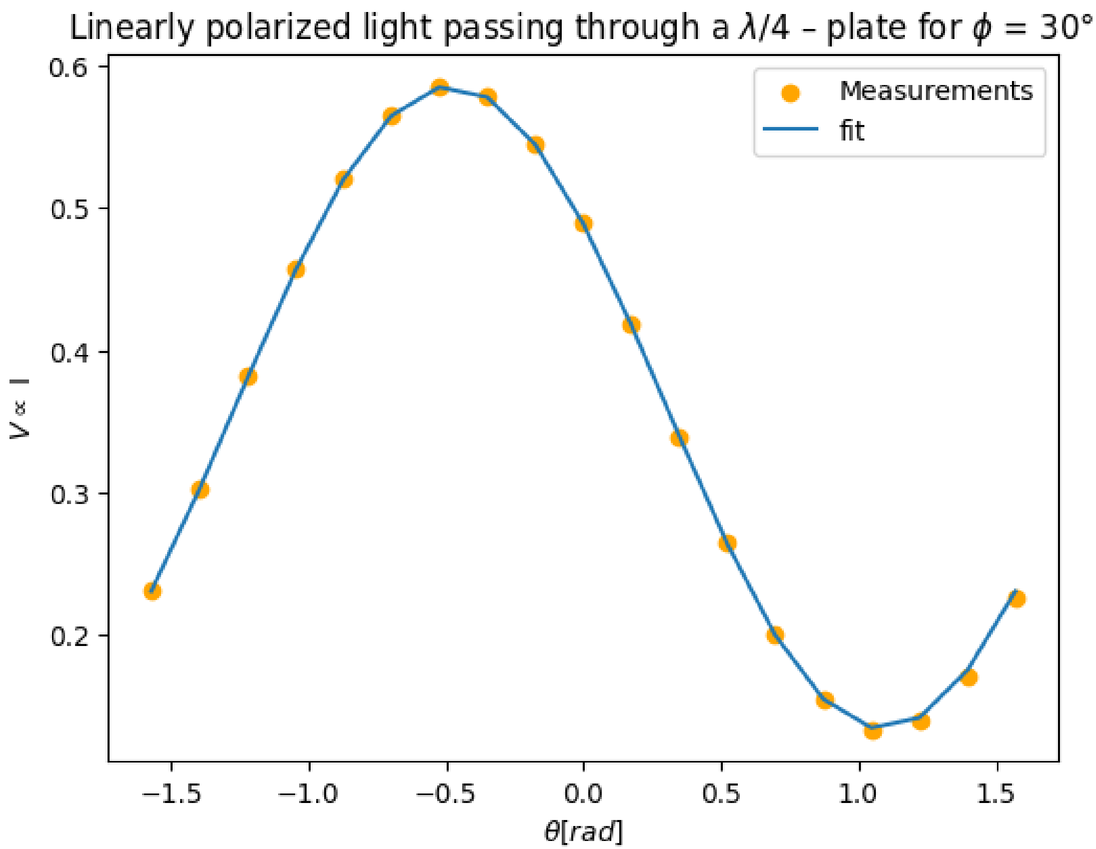
[113]:
```
def f1(x,I,m,n):
    return (I)/2*(1+np.cos(2*(x-m))*np.cos(2*(n-m)))
```

[114]:
```
plt.scatter(Angle_rad,a,label= "Measurements", color='orange')
popt, pcov = curve_fit(f1,Angle_rad,a, p0 = [1,1,1])
plt.plot(Angle_rad,f1(Angle_rad, popt[0],popt[1], popt[2]),label = "fit")
```

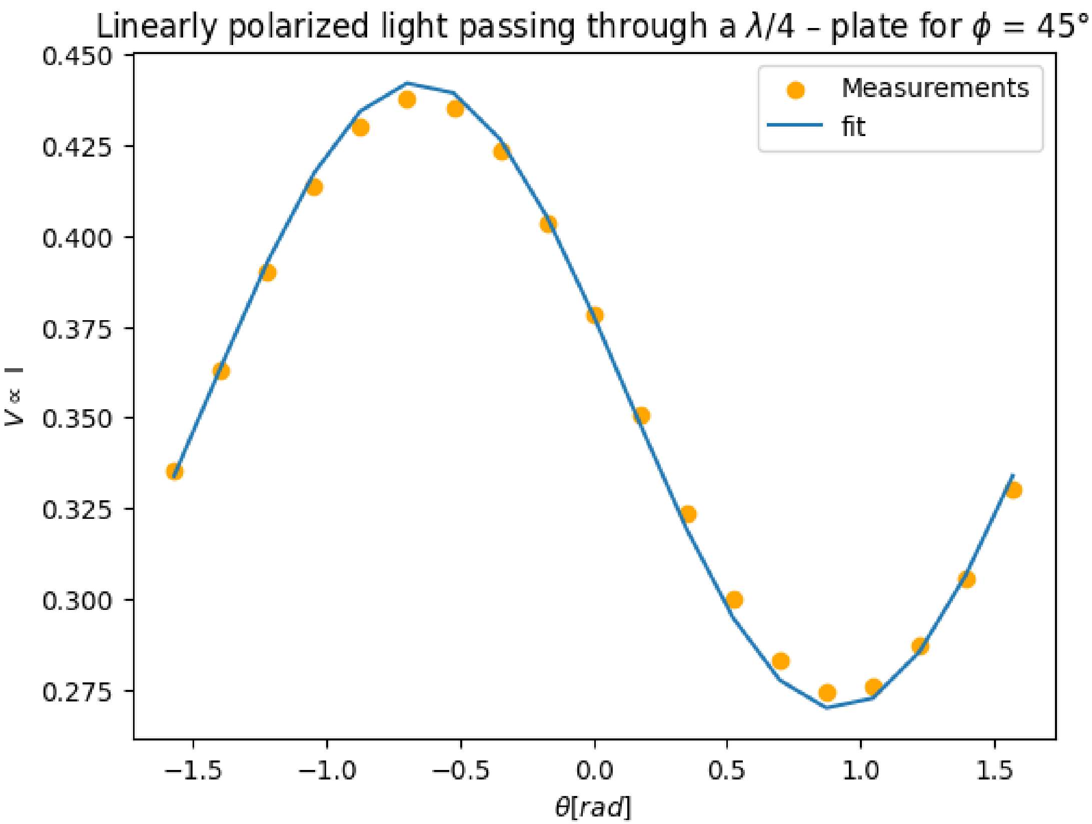
```
plt.title(r'Linearly polarized light passing through a $\lambda/4$ - plate for␣
  ↪$\phi$ = 0° ')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```



[115]:
```
plt.scatter(Angle_rad,b,label= "Measurements", color='orange')
popt2, pcov2 = curve_fit(f1,Angle_rad,b, p0 = [1,1,1])
plt.plot(Angle_rad,f1(Angle_rad, popt2[0],popt2[1], popt2[2]),label = "fit")
plt.title(r'Linearly polarized light passing through a $\lambda/4$ - plate for␣
  ↪$\phi$ = 30° ')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```



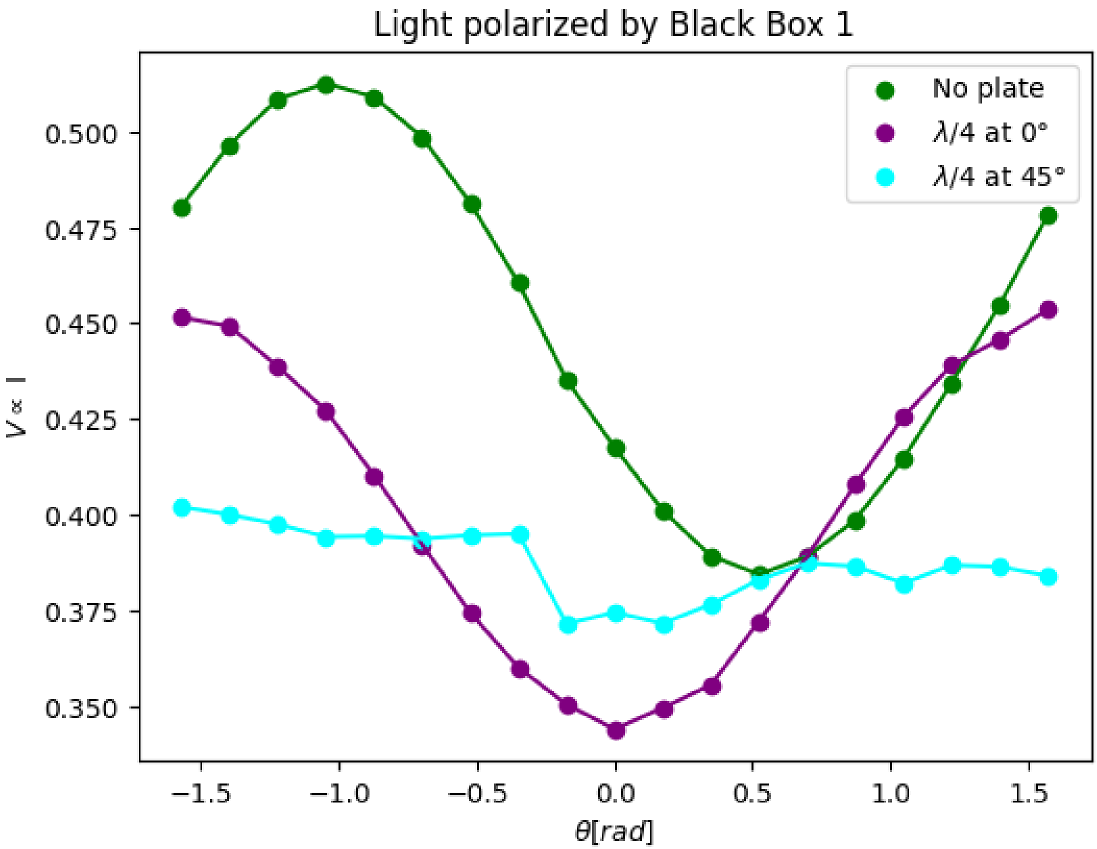
[116]:
```python
plt.scatter(Angle_rad,c,label= "Measurements", color='orange')
popt3, pcov3 = curve_fit(f1,Angle_rad,c, p0 = [1,1,1])
plt.plot(Angle_rad,f1(Angle_rad, popt3[0],popt3[1], popt3[2]),label = "fit")
plt.title(r'Linearly polarized light passing through a $\lambda/4$ - plate for␣
 ↪$\phi$ = 45° ')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```



0.0.2 Task 2:

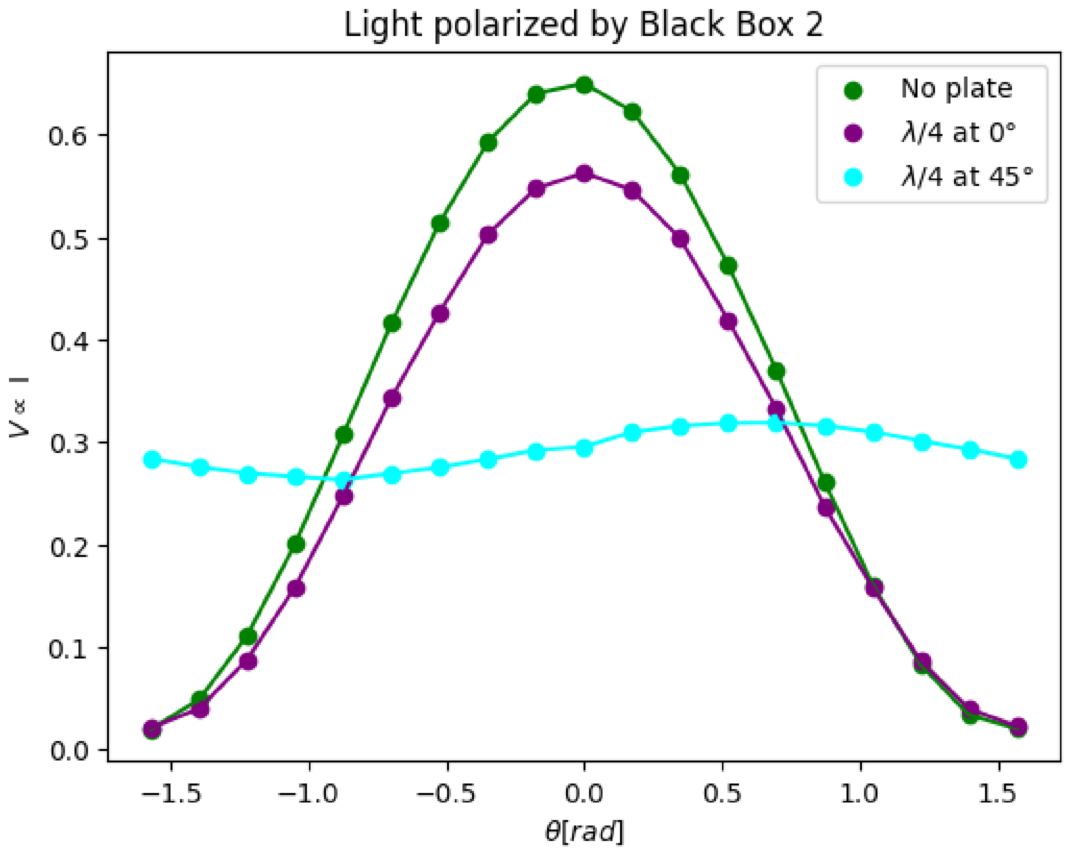
Black Box 1:

[137]:
```
plt.scatter(Angle_rad,d, color='green', label="No plate")
plt.plot(Angle_rad,d, color='green')
plt.scatter(Angle_rad,e, color='purple', label=r"$\lambda/4$ at 0°")
plt.plot(Angle_rad,e, color='purple')
plt.scatter(Angle_rad,f, color='cyan',  label=r"$\lambda/4$ at 45°")
plt.plot(Angle_rad,f, color='cyan')
plt.title(r'Light polarized by Black Box 1')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```



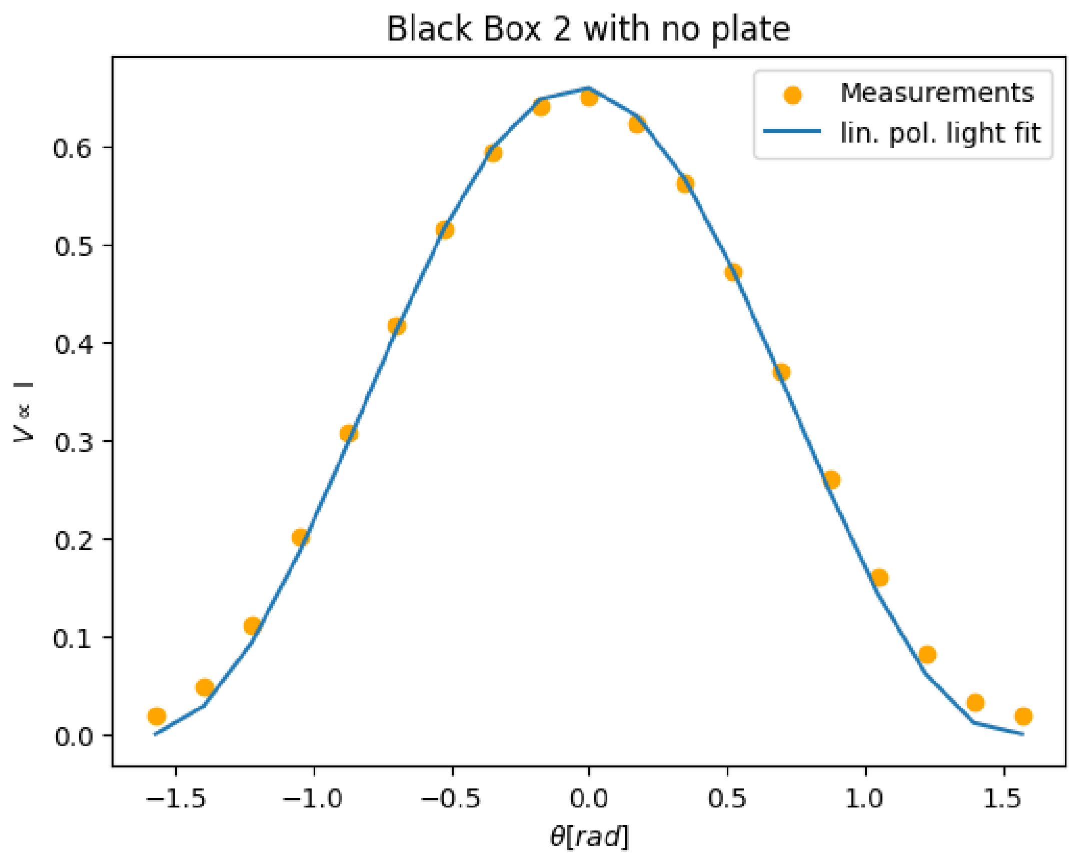
Black Box 2:

[135]:
```
plt.scatter(Angle_rad,g, color='green', label="No plate")
plt.plot(Angle_rad,g, color='green')
plt.scatter(Angle_rad,h, color='purple', label=r"$\lambda/4$ at 0°")
plt.plot(Angle_rad,h, color='purple')
plt.scatter(Angle_rad,i, color='cyan',  label=r"$\lambda/4$ at 45°")
plt.plot(Angle_rad,i, color='cyan')
plt.title(r'Light polarized by Black Box 2')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```

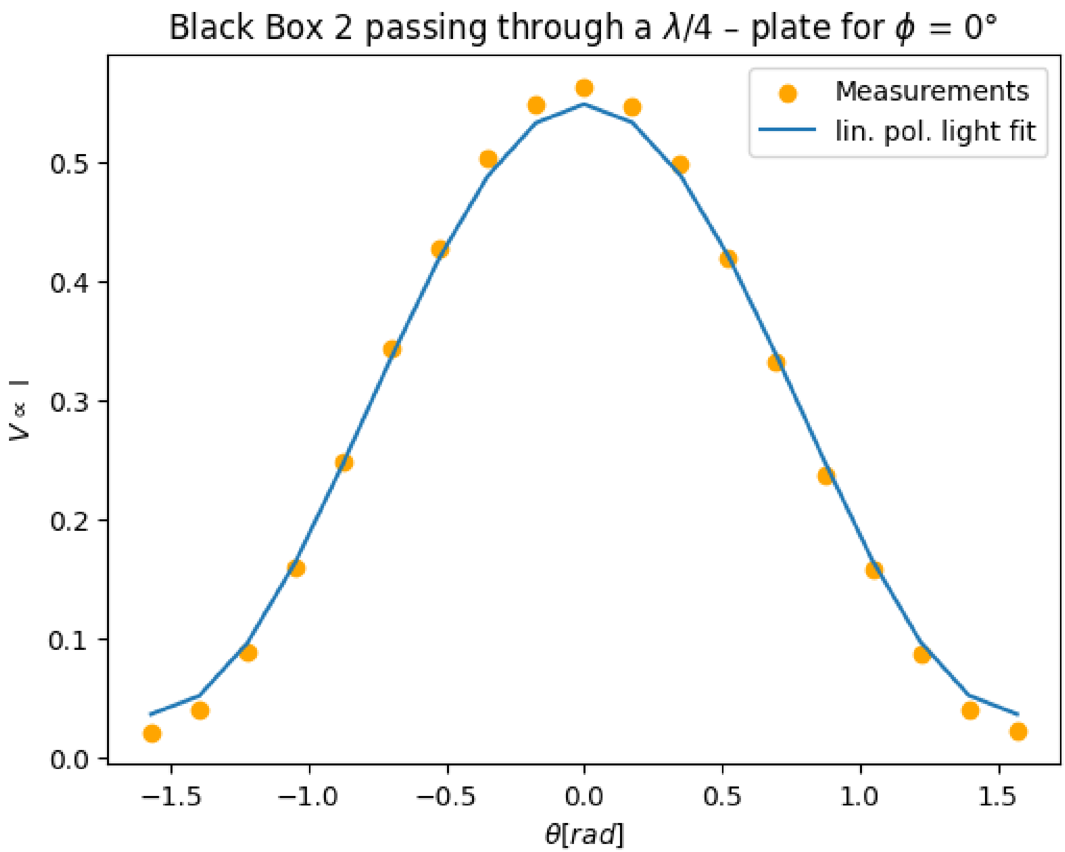



```
[18]: def f2(x2,I2,n2):
          return I2*np.cos(x2-n2)**2
```

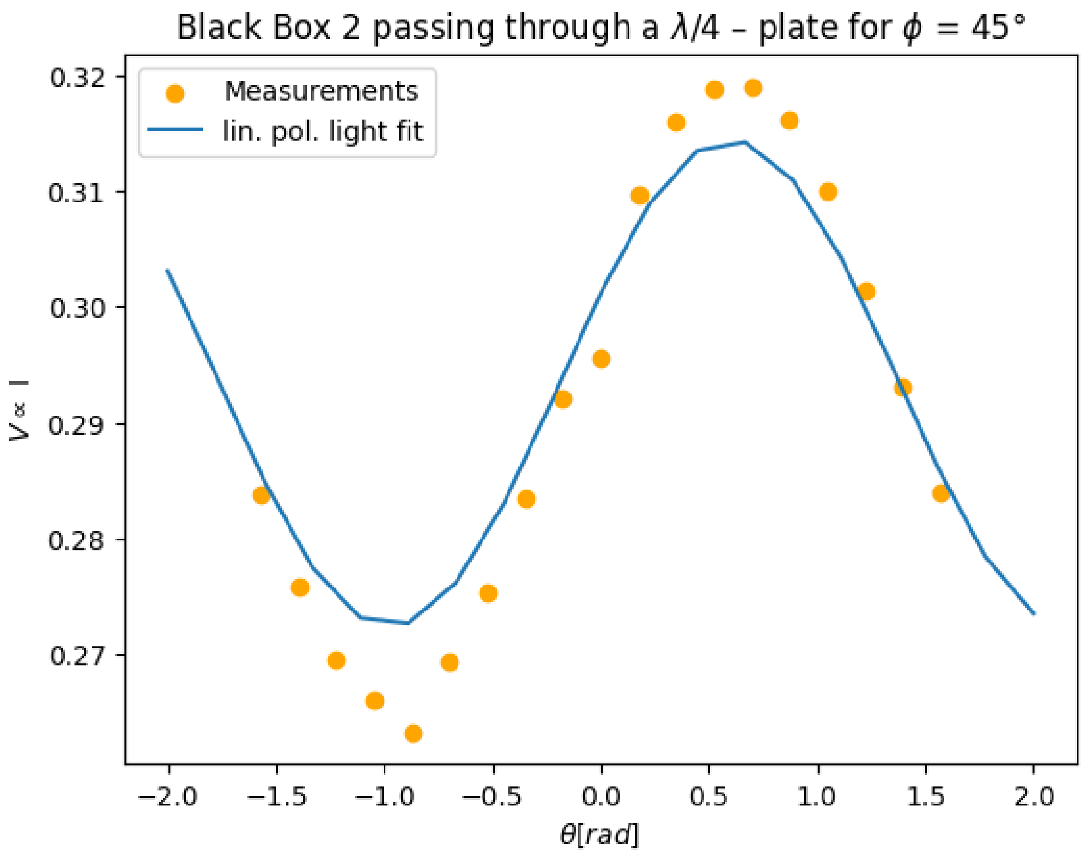
```
[149]: plt.scatter(Angle_rad,g,label= "Measurements", color='orange')
       popt4, pcov4 = curve_fit(f2,Angle_rad,g, p0 = [1,1])
       plt.plot(Angle_rad,f2(Angle_rad, popt4[0],popt4[1]),label = "lin. pol. light␣
        ↪fit")
       plt.title(r'Black Box 2 with no plate')
       plt.xlabel(r"$\theta  [rad]$")
       plt.ylabel(r"$V \propto$ I")
       plt.legend()
       plt.show()
```



[168]:
```
plt.scatter(Angle_rad,h,label= "Measurements", color='orange')
popt5, pcov5 = curve_fit(f1,Angle_rad,h, p0 = [1,1,1])
plt.plot(Angle_rad,f1(Angle_rad, popt5[0],popt5[1], popt5[2]),label = "lin. pol.
 ↪ light fit")
plt.title(r'Black Box 2 passing through a $\lambda/4$ - plate for $\phi$ = 0°')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```

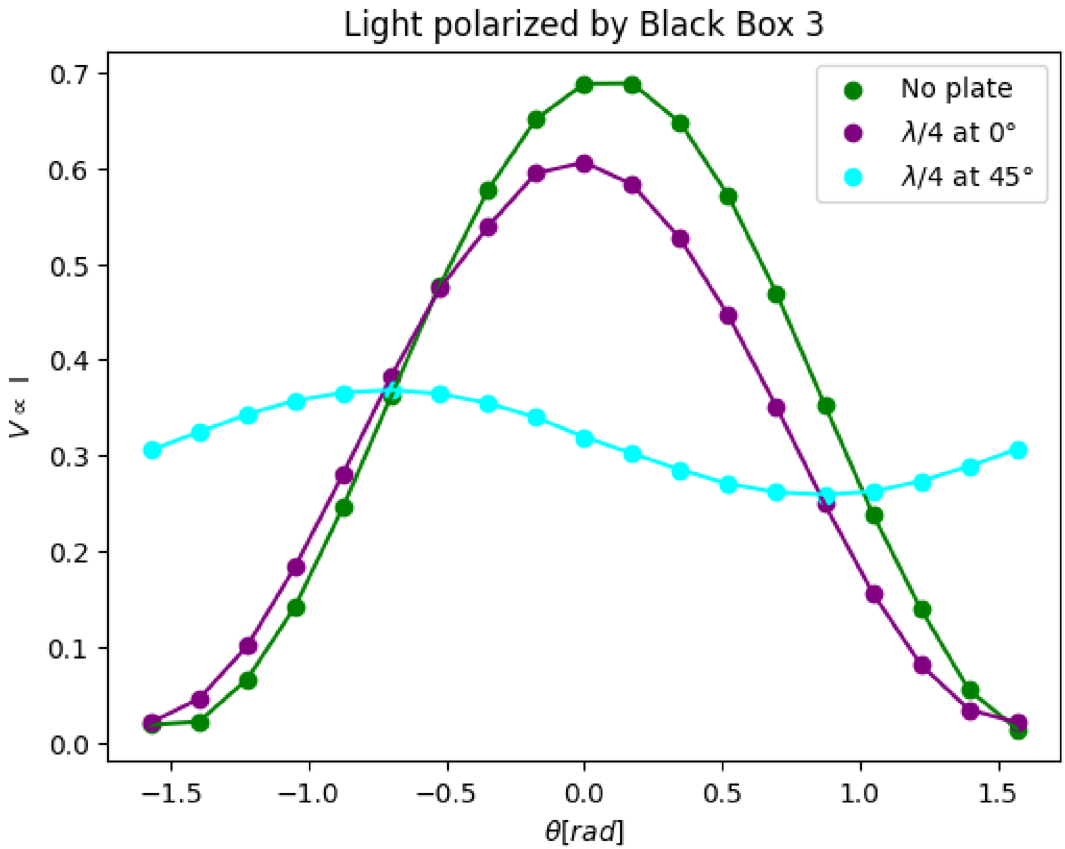


[169]:
```
rando = np.linspace(-2,2,19)
plt.scatter(Angle_rad,i,label= "Measurements", color='orange')
popt6, pcov6 = curve_fit(f1,rando,i, p0 = [1,1,1])
plt.plot(rando,f1(rando, popt6[0],popt6[1], popt6[2]),label = "lin. pol. light␣
↪fit")
plt.title(r'Black Box 2 passing through a $\lambda/4$ - plate for $\phi$ = 45°')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```

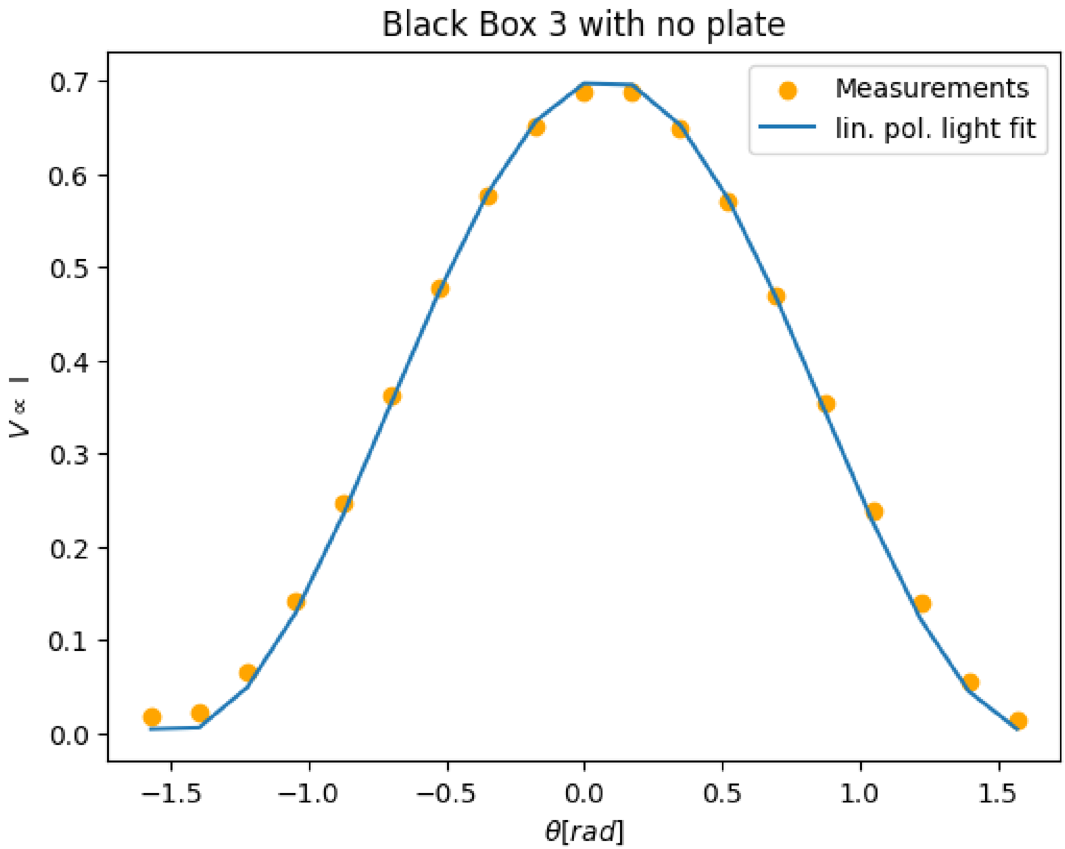


Black Box 3:

[139]:
```
plt.scatter(Angle_rad,j, color='green', label="No plate")
plt.plot(Angle_rad,j, color='green')
plt.scatter(Angle_rad,k, color='purple', label=r"$\lambda/4$ at 0°")
plt.plot(Angle_rad,k, color='purple')
plt.scatter(Angle_rad,l, color='cyan',  label=r"$\lambda/4$ at 45°")
plt.plot(Angle_rad,l, color='cyan')
plt.title(r'Light polarized by Black Box 3')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```

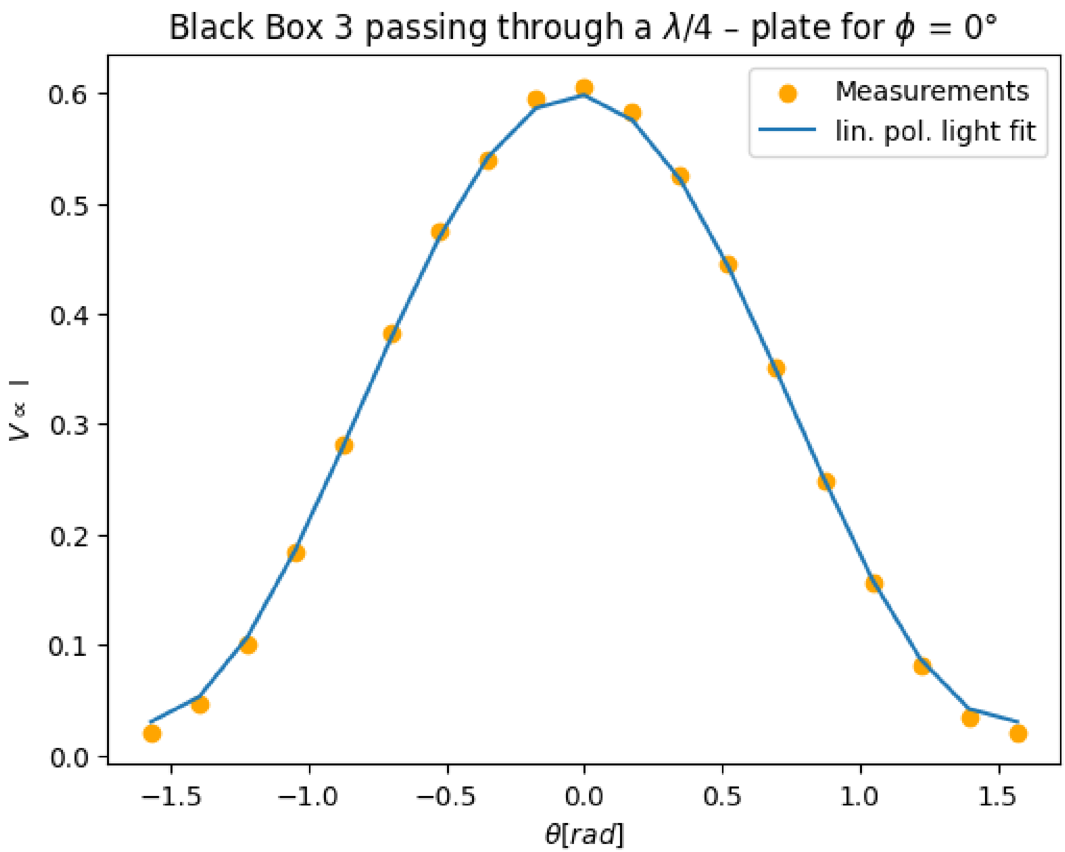


[174]:
```
plt.scatter(Angle_rad,j,label= "Measurements", color='orange')
popt7, pcov7 = curve_fit(f2,Angle_rad,j, p0 = [1,1])
plt.plot(Angle_rad,f2(Angle_rad, popt7[0],popt7[1]),label = "lin. pol. light␣
↪fit")
plt.title(r'Black Box 3 with no plate')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```

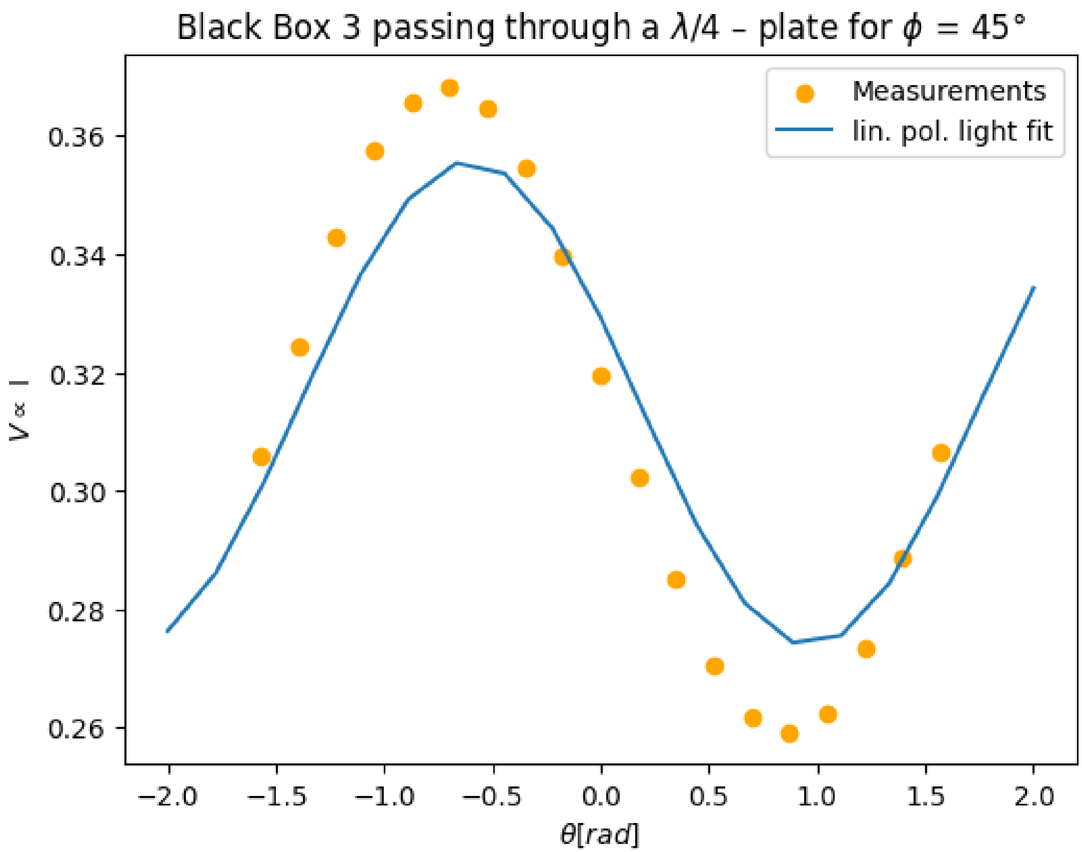


[175]:

```
plt.scatter(Angle_rad,k,label= "Measurements", color='orange')
popt8, pcov8 = curve_fit(f1,Angle_rad,k, p0 = [1,1,1])
plt.plot(Angle_rad,f1(Angle_rad, popt8[0],popt8[1], popt8[2]),label = "lin. pol.
  ↪ light fit")
plt.title(r'Black Box 3 passing through a $\lambda/4$ - plate for $\phi$ = 0°')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```



[176]:
```
plt.scatter(Angle_rad,l,label= "Measurements", color='orange')
popt6, pcov6 = curve_fit(f1,rando,l, p0 = [1,1,1])
plt.plot(rando,f1(rando, popt6[0],popt6[1], popt6[2]),label = "lin. pol. light␣
↪fit")
plt.title(r'Black Box 3 passing through a $\lambda/4$ - plate for $\phi$ = 45°')
plt.xlabel(r"$\theta  [rad]$")
plt.ylabel(r"$V \propto$ I")
plt.legend()
plt.show()
```


Black Box 3 passing through a $\lambda/4$ – plate for ϕ = 45°
Measurements
lin. pol. light fit
$V \propto I$
0.36
0.34
0.32
0.30
0.28
0.26
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
$\theta[rad]$