

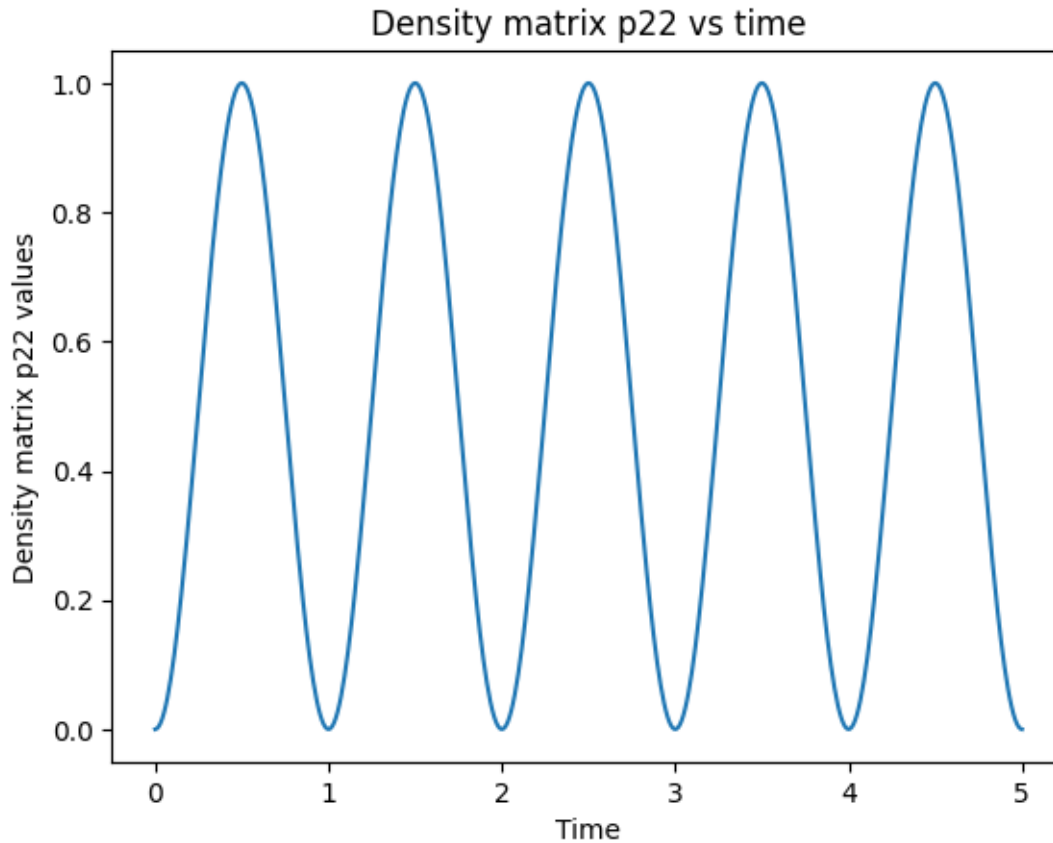
Hw1_Code

January 16, 2023

```
[ ]: from qutip import *  
import numpy as np  
import matplotlib.pyplot as plt
```

0.1 4A

```
[ ]: delta = 0  
Omega = 2*np.pi  
  
H = -delta/2 * sigmaz() + Omega / 2 * sigmax()  
psi0 = fock(2,0)  
rho0 = ket2dm(psi0)  
tlist = np.linspace(0,5,500)  
  
res = mesolve(H, rho0, tlist)  
p22_vals = [np.abs((state * state.dag())[1,1]) for state in res.states]  
  
plt.title("Density matrix p22 vs time")  
plt.xlabel("Time")  
plt.ylabel("Density matrix p22 values")  
plt.plot(tlist, p22_vals)  
plt.show()
```



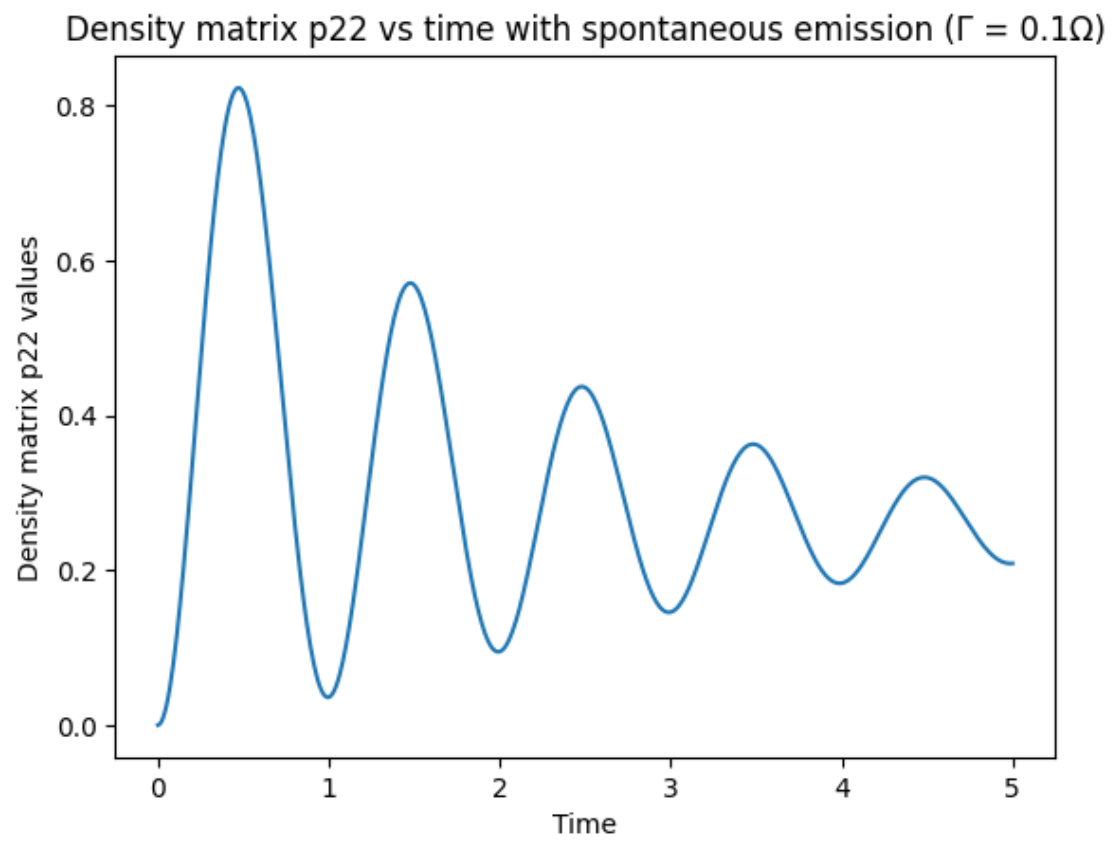
0.2 4B

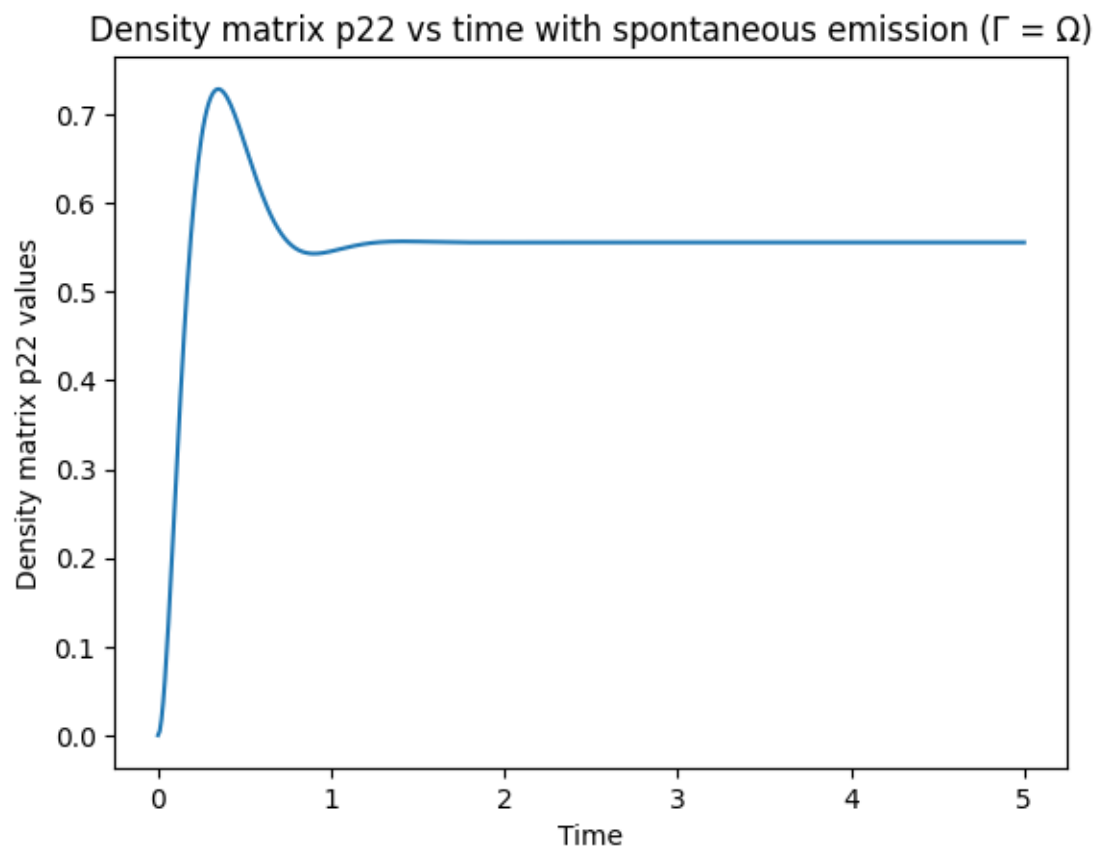
```
[ ]: # Collapse operator for spontaneous emission

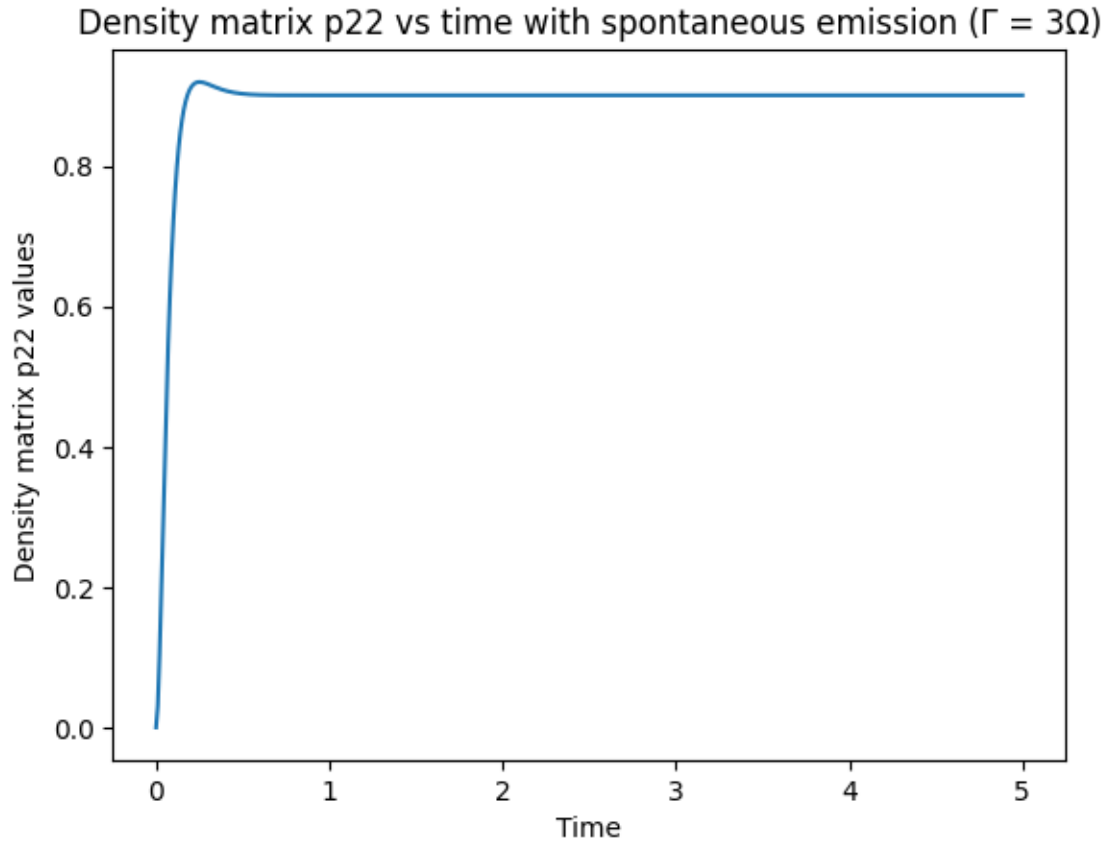
def plot_spontaneous_emssion(gamma, gamma_str):
    c_se = np.sqrt(gamma) * sigmam()
    res = mesolve(H, rho0, tlist, c_ops=c_se)
    p22_vals = [np.abs((state * state.dag())[1,1]) for state in res.states]

    plt.title("Density matrix p22 vs time with spontaneous emission ( $\Gamma = \{ \}$ )".
    ↪format(gamma_str))
    plt.xlabel("Time")
    plt.ylabel("Density matrix p22 values")
    plt.plot(tlist, p22_vals)
    plt.show()

plot_spontaneous_emssion(0.1*Omega, "0.1Ω")
plot_spontaneous_emssion(Omega, "Ω")
plot_spontaneous_emssion(3*Omega, "3Ω")
```







0.3 4C

```
[ ]: def plot_spontaneous_emssion_mcsolve(gamma, gamma_str):
    c_se = np.sqrt(gamma) * sigmam()
    e_11 = ket2dm(fock(2,1))

    ntraj = [1, 10, 100, 1000]

    res = mcsolve(H, psi0, tlist, c_ops=c_se, e_ops=e_11, ntraj=ntraj)

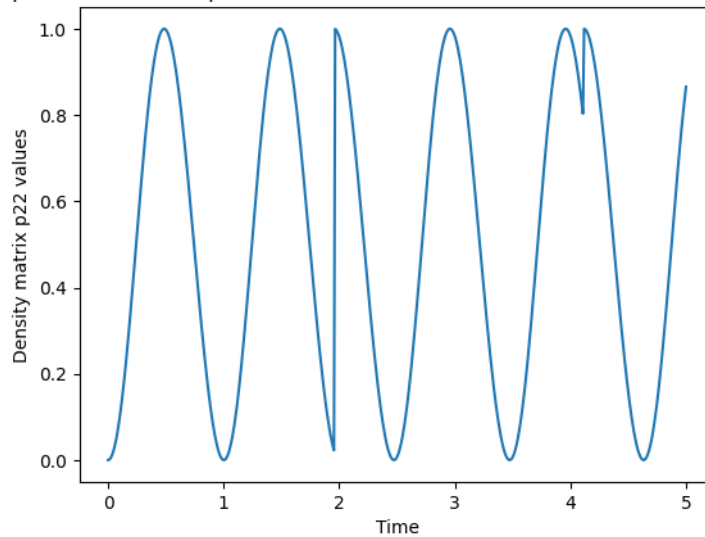
    count = 0
    for traj in ntraj:
        plt.title("Density matrix p22 vs time with spontaneous emission ( $\Gamma = \square$ 
↪{ }) solved with mcsolve (trajectory = { })".format(gamma_str, traj))
        plt.xlabel("Time")
        plt.ylabel("Density matrix p22 values")
        plt.plot(tlist, res.expect[count][0])
        plt.show()
```

```
count+=1
```

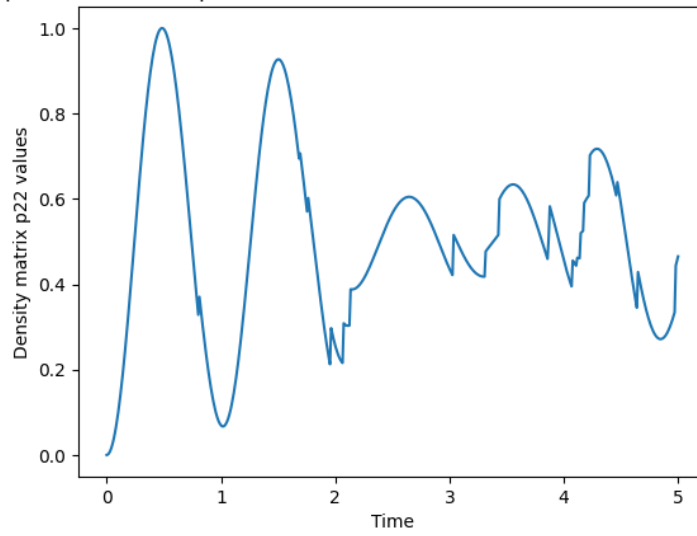
```
plot_spontaneous_emssion_mcsolve(0.1*Omega, "0.1 $\Omega$ ")  
plot_spontaneous_emssion_mcsolve(Omega, " $\Omega$ ")  
plot_spontaneous_emssion_mcsolve(3*Omega, "3 $\Omega$ ")
```

```
10.0%. Run time: 1.18s. Est. time left: 00:00:00:10  
20.0%. Run time: 1.74s. Est. time left: 00:00:00:06  
30.0%. Run time: 2.19s. Est. time left: 00:00:00:05  
40.0%. Run time: 2.66s. Est. time left: 00:00:00:03  
50.0%. Run time: 3.09s. Est. time left: 00:00:00:03  
60.0%. Run time: 3.55s. Est. time left: 00:00:00:02  
70.0%. Run time: 4.02s. Est. time left: 00:00:00:01  
80.0%. Run time: 4.47s. Est. time left: 00:00:00:01  
90.0%. Run time: 4.92s. Est. time left: 00:00:00:00  
100.0%. Run time: 5.39s. Est. time left: 00:00:00:00  
Total run time: 5.43s
```

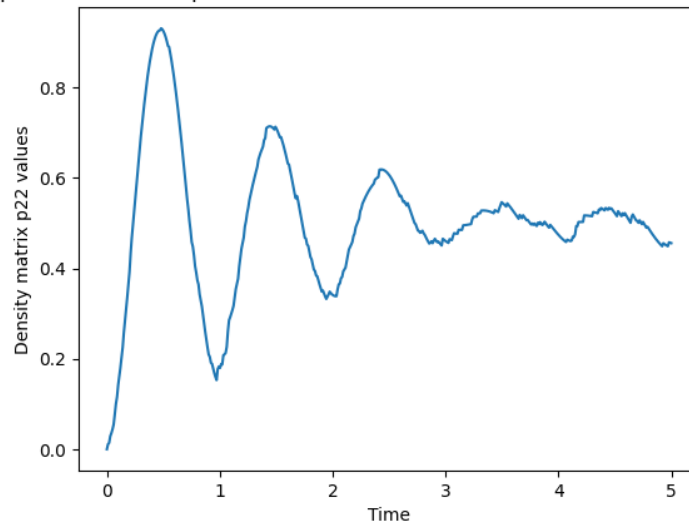
Density matrix p22 vs time with spontaneous emission ($\Gamma = 0.1\Omega$) solved with mcsolve (trajectory = 1)



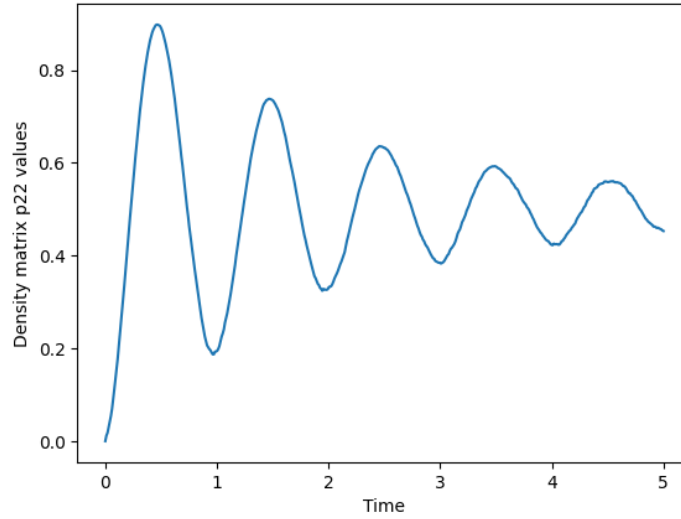
Density matrix p_{22} vs time with spontaneous emission ($\Gamma = 0.1\Omega$) solved with mcsolve (trajectory = 10)



Density matrix p_{22} vs time with spontaneous emission ($\Gamma = 0.1\Omega$) solved with mcsolve (trajectory = 100)



Density matrix p22 vs time with spontaneous emission ($\Gamma = 0.1\Omega$) solved with mcsolve (trajectory = 1000)

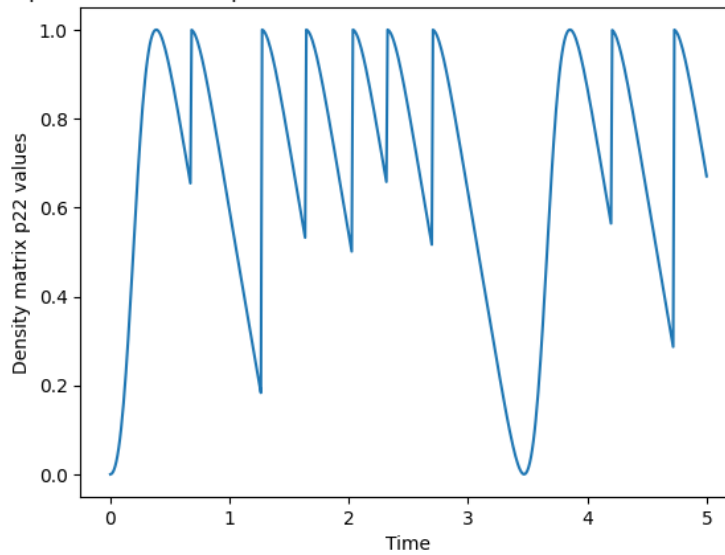


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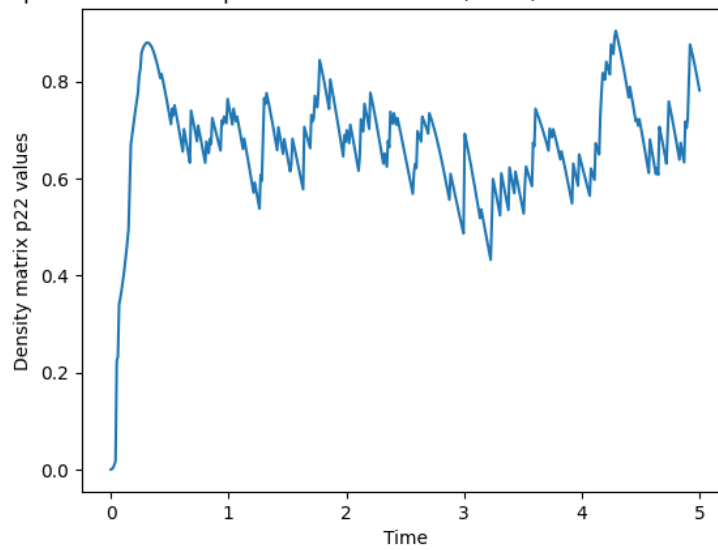
10.0%. Run time: 1.30s. Est. time left: 00:00:00:11
20.0%. Run time: 1.94s. Est. time left: 00:00:00:07
30.0%. Run time: 2.45s. Est. time left: 00:00:00:05
40.0%. Run time: 2.96s. Est. time left: 00:00:00:04
50.0%. Run time: 3.50s. Est. time left: 00:00:00:03
60.0%. Run time: 4.02s. Est. time left: 00:00:00:02
70.0%. Run time: 4.51s. Est. time left: 00:00:00:01
80.0%. Run time: 5.05s. Est. time left: 00:00:00:01
90.0%. Run time: 5.55s. Est. time left: 00:00:00:00
100.0%. Run time: 6.05s. Est. time left: 00:00:00:00
Total run time: 6.08s

```

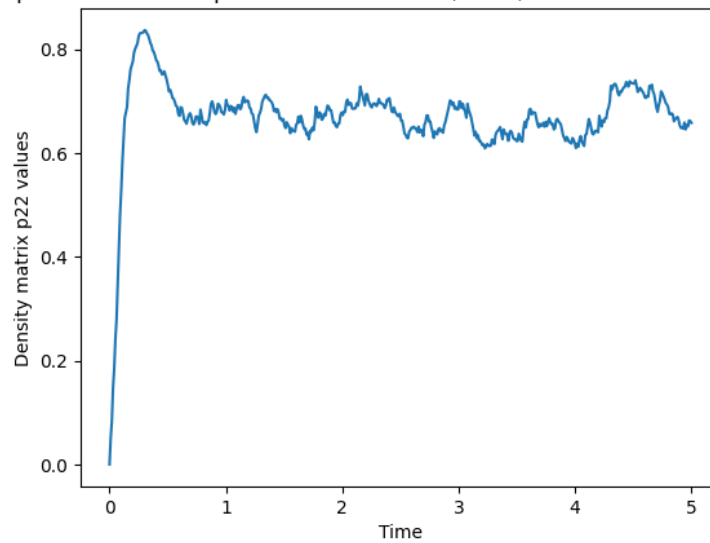
Density matrix p22 vs time with spontaneous emission ($\Gamma = \Omega$) solved with mcsolve (trajectory = 1)



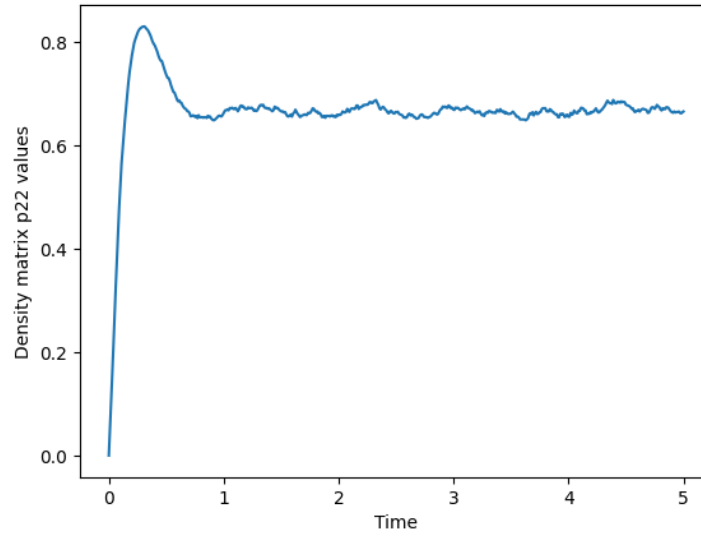
Density matrix p22 vs time with spontaneous emission ($\Gamma = \Omega$) solved with mcsolve (trajectory = 10)



Density matrix p22 vs time with spontaneous emission ($\Gamma = \Omega$) solved with mcsolve (trajectory = 100)



Density matrix p22 vs time with spontaneous emission ($\Gamma = \Omega$) solved with mcsolve (trajectory = 1000)

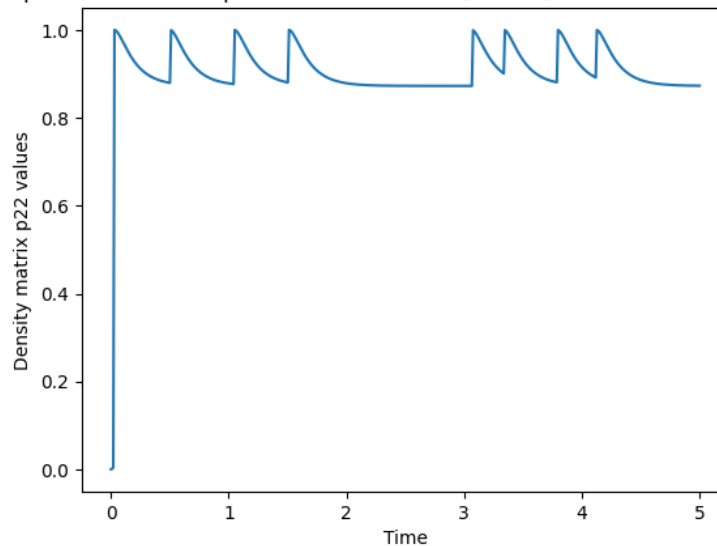


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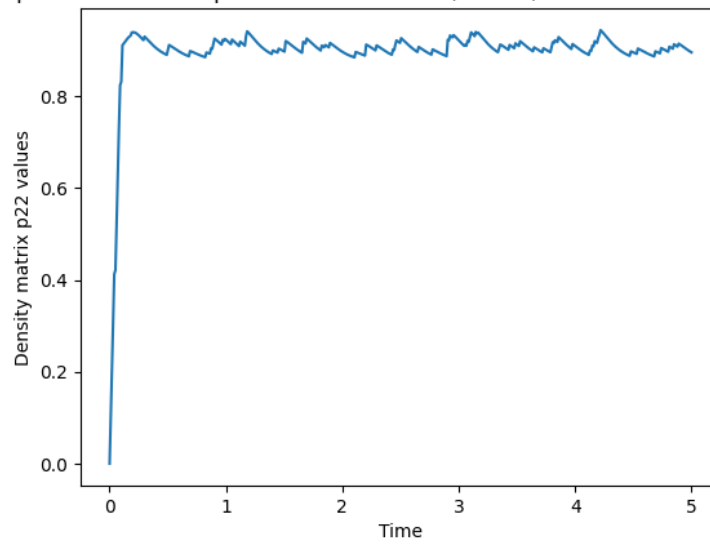
10.0%. Run time: 1.32s. Est. time left: 00:00:00:11
20.0%. Run time: 1.96s. Est. time left: 00:00:00:07
30.0%. Run time: 2.45s. Est. time left: 00:00:00:05
40.0%. Run time: 3.01s. Est. time left: 00:00:00:04
50.0%. Run time: 3.55s. Est. time left: 00:00:00:03
60.0%. Run time: 4.08s. Est. time left: 00:00:00:02
70.0%. Run time: 4.62s. Est. time left: 00:00:00:01
80.0%. Run time: 5.16s. Est. time left: 00:00:00:01
90.0%. Run time: 5.66s. Est. time left: 00:00:00:00
100.0%. Run time: 6.18s. Est. time left: 00:00:00:00
Total run time: 6.21s

```

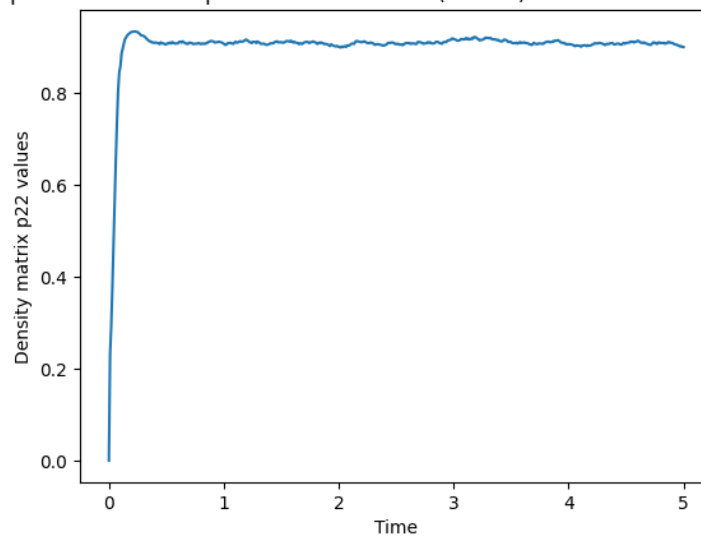
Density matrix p22 vs time with spontaneous emission ($\Gamma = 3\Omega$) solved with mcsolve (trajectory = 1)



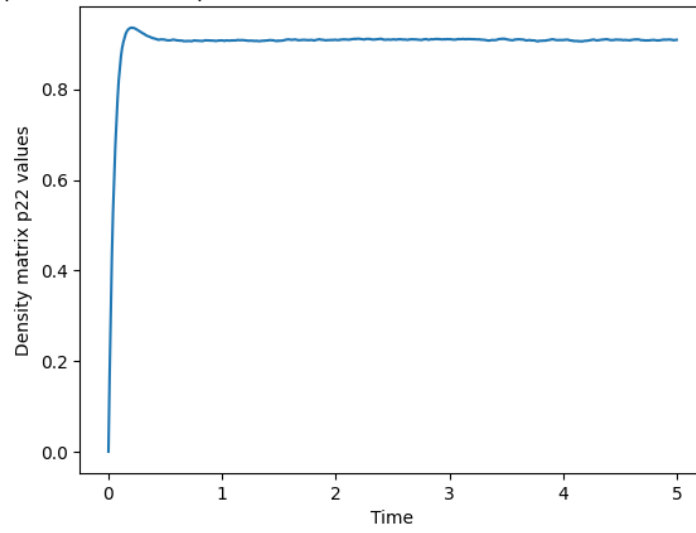
Density matrix p22 vs time with spontaneous emission ($\Gamma = 3\Omega$) solved with mcsolve (trajectory = 10)



Density matrix p22 vs time with spontaneous emission ($\Gamma = 3\Omega$) solved with mcsolve (trajectory = 100)



Density matrix p22 vs time with spontaneous emission ($\Gamma = 3\Omega$) solved with mcsolve (trajectory = 1000)



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