example-ultrastrong-coupling-groundstate

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1 QuTiP example: Groundstate of an ultra-strong coupled atom-cavity system

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For more information about QuTiP see http://qutip.org

```
In [1]: %pylab inline
```

```
Populating the interactive namespace from numpy and matplotlib
```

```
In [2]: from qutip import *
        import time
        from mpl_toolkits.mplot3d import Axes3D
```

```
In [3]: def compute(N, wc, wa, glist, use_rwa):

            # Pre-compute operators for the hamiltonian
            a  = tensor(destroy(N), qeye(2))
            sm = tensor(qeye(N), destroy(2))
            nc = a.dag() * a
            na = sm.dag() * sm

            idx = 0
            na_expt = zeros(shape(glist))
            nc_expt = zeros(shape(glist))
            for g in glist:

                # recalculate the hamiltonian for each value of g
                if use_rwa:
                    H = wc * nc + wa * na + g * (a.dag() * sm + a * sm.dag())
                else:
                    H = wc * nc + wa * na + g * (a.dag() + a) * (sm + sm.dag())

                # find the groundstate of the composite system
                evals, ekets = H.eigenstates()
                psi_gnd = ekets[0]
                na_expt[idx] = expect(na, psi_gnd)
                nc_expt[idx] = expect(nc, psi_gnd)

                idx += 1

            return nc_expt, na_expt, ket2dm(psi_gnd)
```

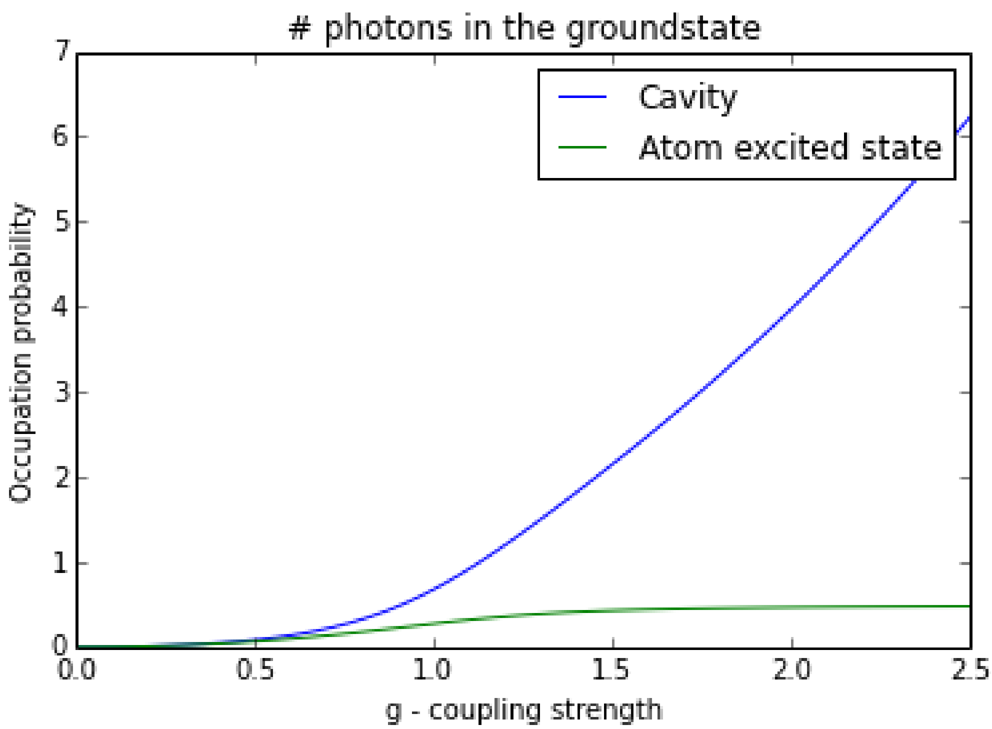
```
#
# set up the calculation
#
wc = 1.0 * 2 * pi   # cavity frequency
wa = 1.0 * 2 * pi   # atom frequency
N = 20              # number of cavity fock states
use_rwa = False     # Set to True to see that non-RWA is necessary in this regime

glist = linspace(0, 2.5, 50) * 2 * pi # coupling strength vector

start_time = time.time()
nc, na, rhoss_final = compute(N, wc, wa, glist, use_rwa)
print('time elapsed = ' + str(time.time() - start_time))
```

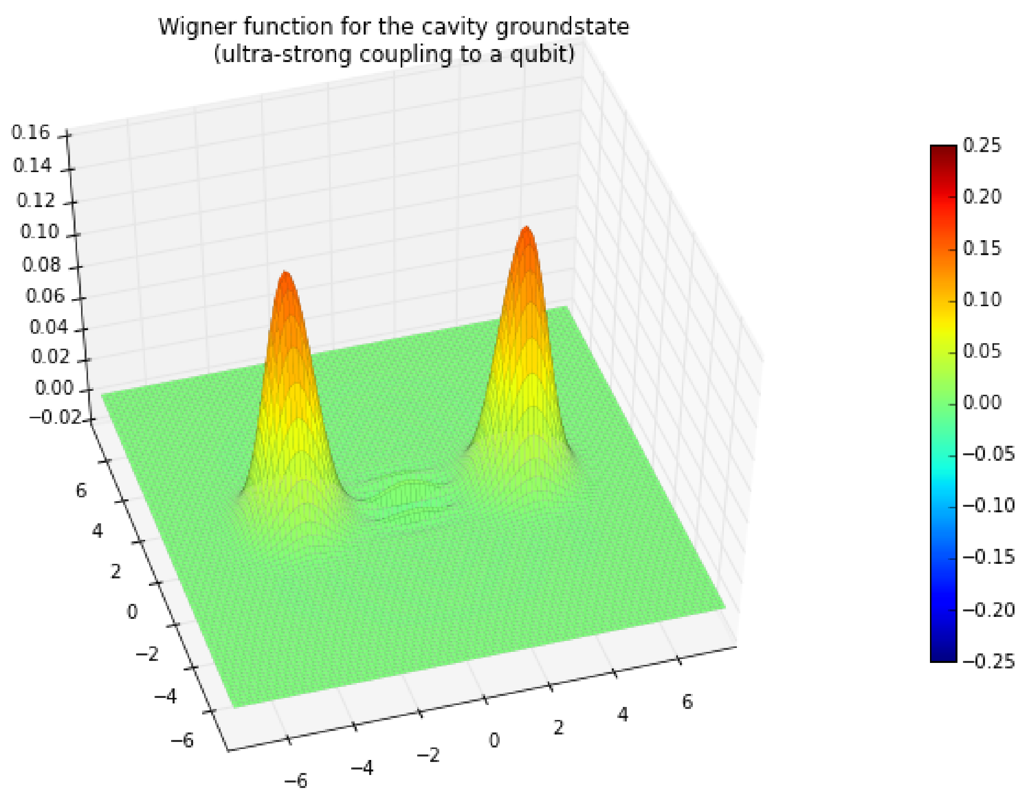
```
time elapsed = 1.5806598663330078
```

In [4]:
```
#
# plot the cavity and atom occupation numbers as a function of
#
figure(1)
plot(glist/(2*pi), nc)
plot(glist/(2*pi), na)
legend(("Cavity", "Atom excited state"))
xlabel('g - coupling strength')
ylabel('Occupation probability')
title('# photons in the groundstate');
```



In [5]:
```
#
# plot the cavity wigner function for the cavity state (final coupling strenght)
```

```
#
fig = plt.figure(2, figsize=(9, 6))
rho_cavity = ptrace(rhoss_final, 0)
xvec = linspace(-7.5,7.5,100)
X,Y = meshgrid(xvec, xvec)
W = wigner(rho_cavity, xvec, xvec)
ax = Axes3D(fig, azim=-107, elev=49)
surf=ax.plot_surface(X, Y, W, rstride=1, cstride=1, cmap=cm.jet, alpha=1.0, linewidth=0.05,
                     vmax=0.25, vmin=-0.25)
ax.set_xlim3d(-7.5, 7.5)
ax.set_ylim3d(-7.5, 7.5)
fig.colorbar(surf, shrink=0.65, aspect=20)
title("Wigner function for the cavity groundstate\n(ultra-strong coupling to a qubit)");
```



1.1 Software version:

```
In [6]: from qutip.ipynbtools import version_table

        version_table()

Out[6]: <IPython.core.display.HTML at 0x7f9305419278>
```