example-spin-chain

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1 QuTiP example: Dynamics of a Spin Chain

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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
```

Hamiltonian:

$$H = -\frac{1}{2}\sum_n^N h_n \sigma_z(n) - \frac{1}{2}\sum_n^{N-1}[J_x^{(n)}\sigma_x(n)\sigma_x(n+1) + J_y^{(n)}\sigma_y(n)\sigma_y(n+1) + J_z^{(n)}\sigma_z(n)\sigma_z(n+1)]$$

```
In [3]: def integrate(N, h, Jx, Jy, Jz, psi0, tlist, gamma, solver):

            si = qeye(2)
            sx = sigmax()
            sy = sigmay()
            sz = sigmaz()

            sx_list = []
            sy_list = []
            sz_list = []

            for n in range(N):
                op_list = []
                for m in range(N):
                    op_list.append(si)

                op_list[n] = sx
                sx_list.append(tensor(op_list))

                op_list[n] = sy
                sy_list.append(tensor(op_list))

                op_list[n] = sz
                sz_list.append(tensor(op_list))

            # construct the hamiltonian
            H = 0
```

```
    # energy splitting terms
    for n in range(N):
        H += - 0.5 * h[n] * sz_list[n]

    # interaction terms
    for n in range(N-1):
        H += - 0.5 * Jx[n] * sx_list[n] * sx_list[n+1]
        H += - 0.5 * Jy[n] * sy_list[n] * sy_list[n+1]
        H += - 0.5 * Jz[n] * sz_list[n] * sz_list[n+1]

    # collapse operators
    c_op_list = []

    # spin dephasing
    for n in range(N):
        if gamma[n] > 0.0:
            c_op_list.append(sqrt(gamma[n]) * sz_list[n])

    # evolve and calculate expectation values
    if solver == "me":
        result = mesolve(H, psi0, tlist, c_op_list, sz_list)
    elif solver == "mc":
        ntraj = 250
        result = mcsolve(H, psi0, tlist, c_op_list, sz_list, ntraj)

    return result.expect
```

```
In [4]: #
        # set up the calculation
        #
        solver = "me"   # use the ode solver
        #solver = "mc"   # use the monte-carlo solver

        N = 6            # number of spins

        # array of spin energy splittings and coupling strengths. here we use
        # uniform parameters, but in general we don't have too
        h  = 1.0 * 2 * pi * ones(N)
        Jz = 0.1 * 2 * pi * ones(N)
        Jx = 0.1 * 2 * pi * ones(N)
        Jy = 0.1 * 2 * pi * ones(N)
        # dephasing rate
        gamma = 0.01 * ones(N)

        # intial state, first spin in state |1>, the rest in state |0>
        psi_list = []
        psi_list.append(basis(2,1))
        for n in range(N-1):
            psi_list.append(basis(2,0))
        psi0 = tensor(psi_list)

        tlist = linspace(0, 50, 200)

        start_time = time.time()
```

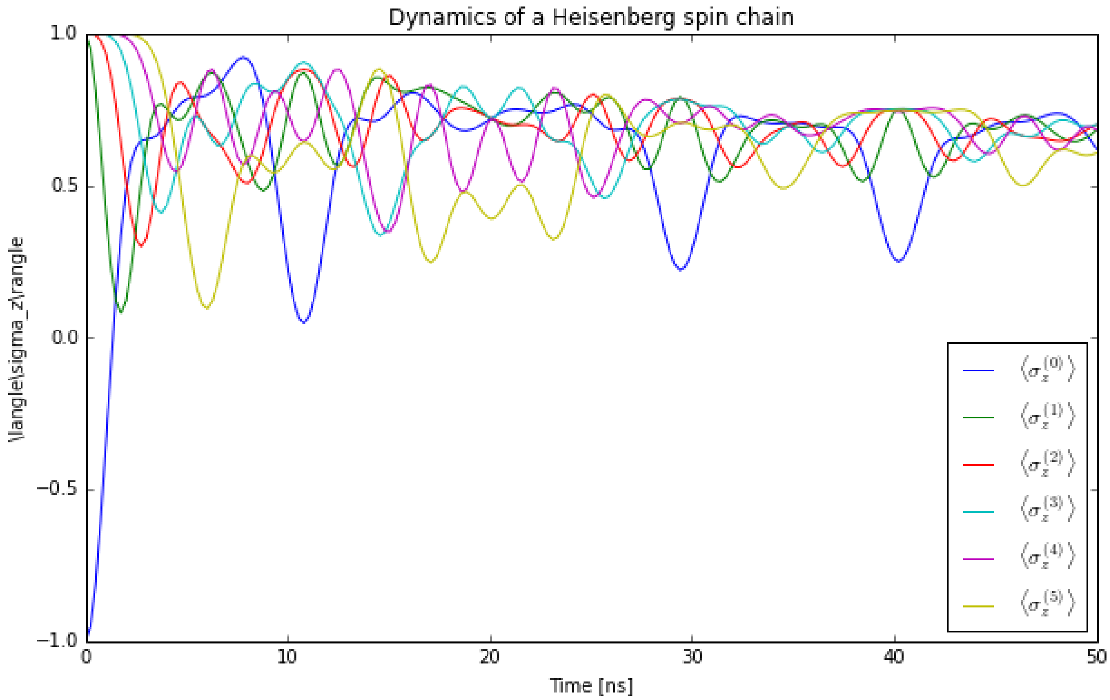
```
    sz_expt = integrate(N, h, Jx, Jy, Jz, psi0, tlist, gamma, solver)
    print('time elapsed = ' +str(time.time() - start_time))
```

```
time elapsed = 0.44784116744995117
```

In [5]:
```
# plot
figure(figsize=(10,6))

for n in range(N):
    plot(tlist, real(sz_expt[n]), label=r'$\langle\sigma_z^{(%d)}\rangle$'%n)

legend(loc=0)
xlabel(r'Time [ns]')
ylabel(r'\langle\sigma_z\rangle')
title(r'Dynamics of a Heisenberg spin chain');
```



1.0.1 Software version:

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

version_table()
```

Out[6]:
```
<IPython.core.display.HTML at 0x7f08f6651c88>
```