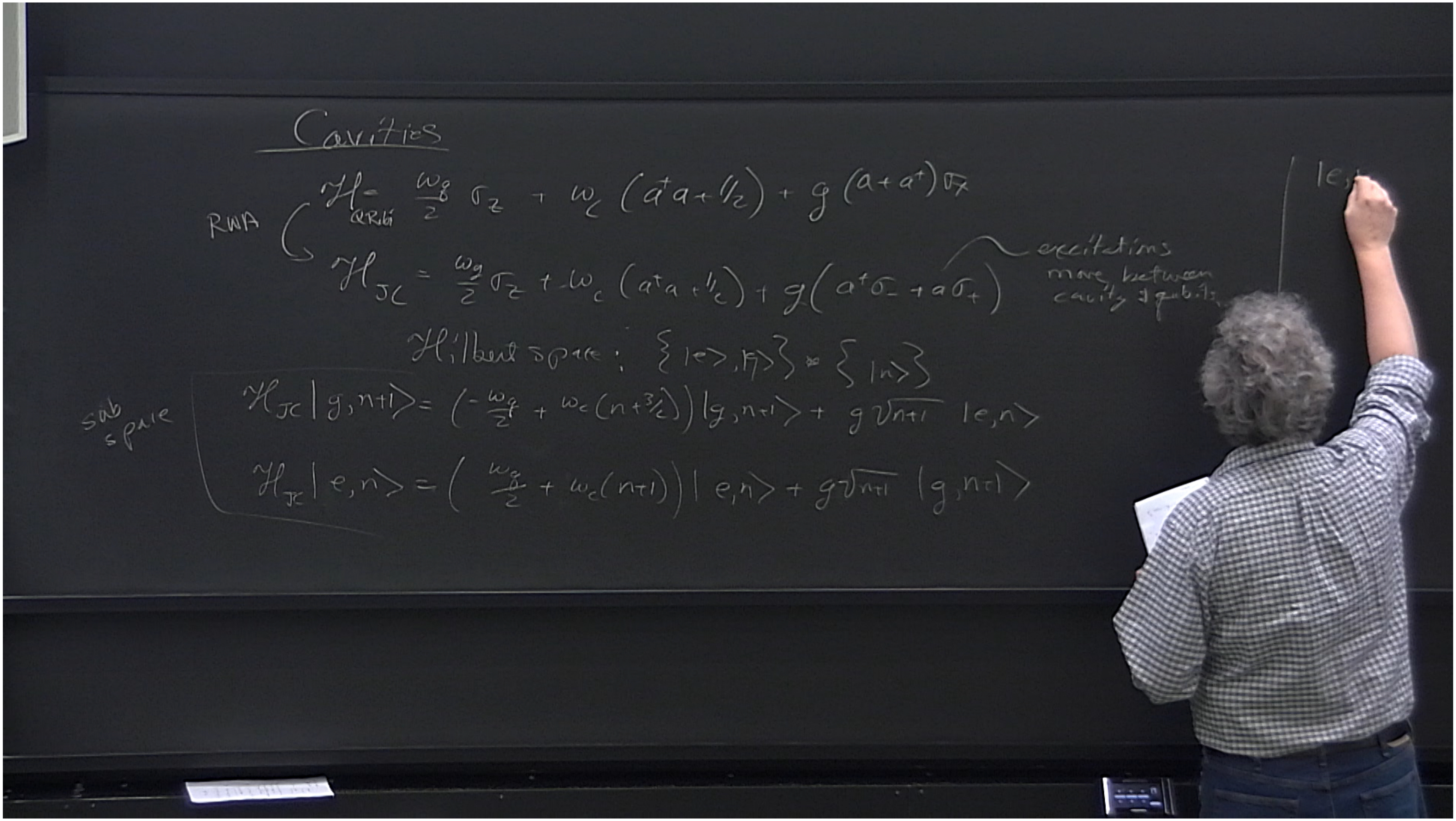
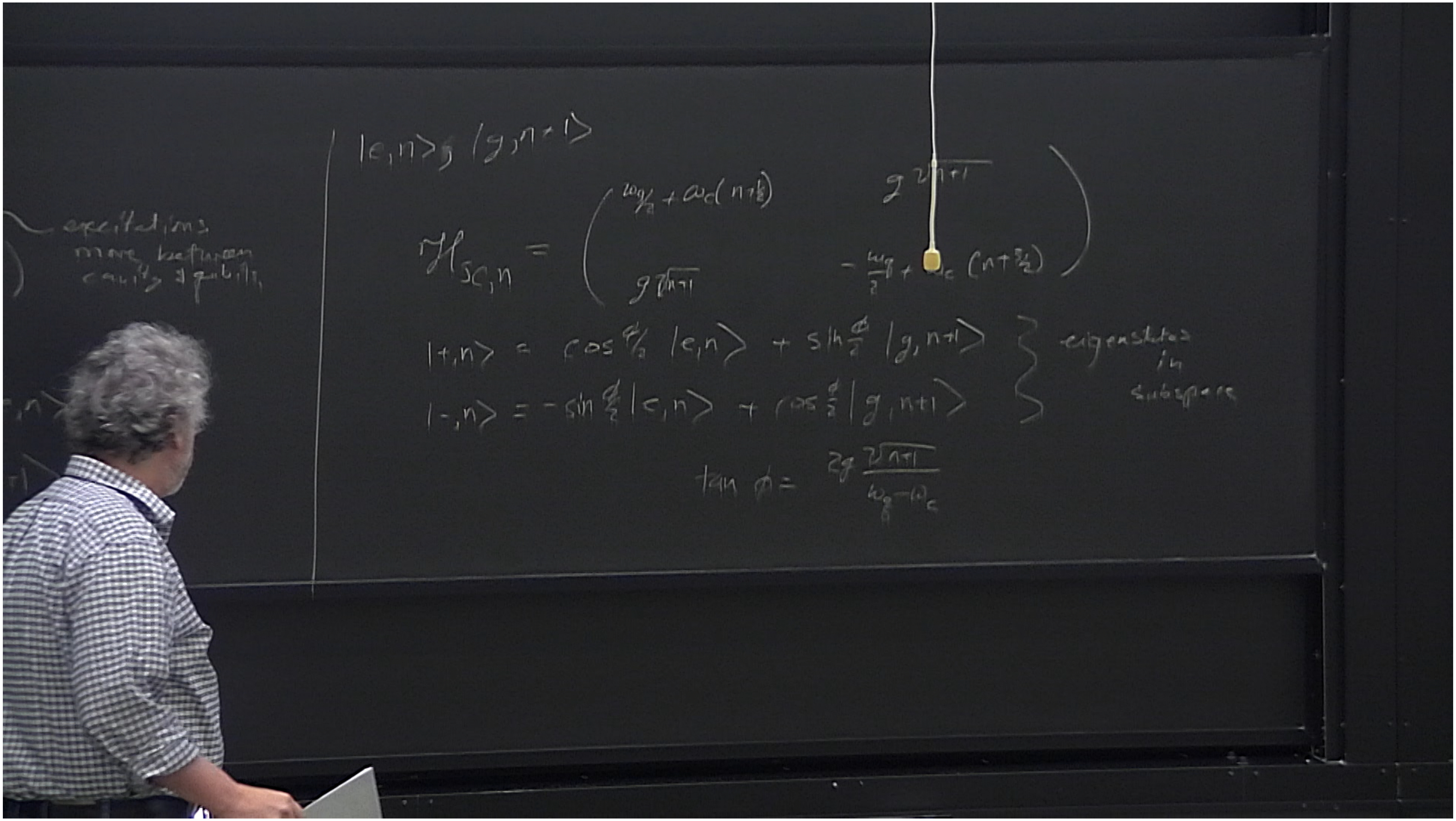
Title: PSI 2016/2017 Explorations in Quantum Information - Lecture 13

Date: Apr 05, 2017 09:00 AM

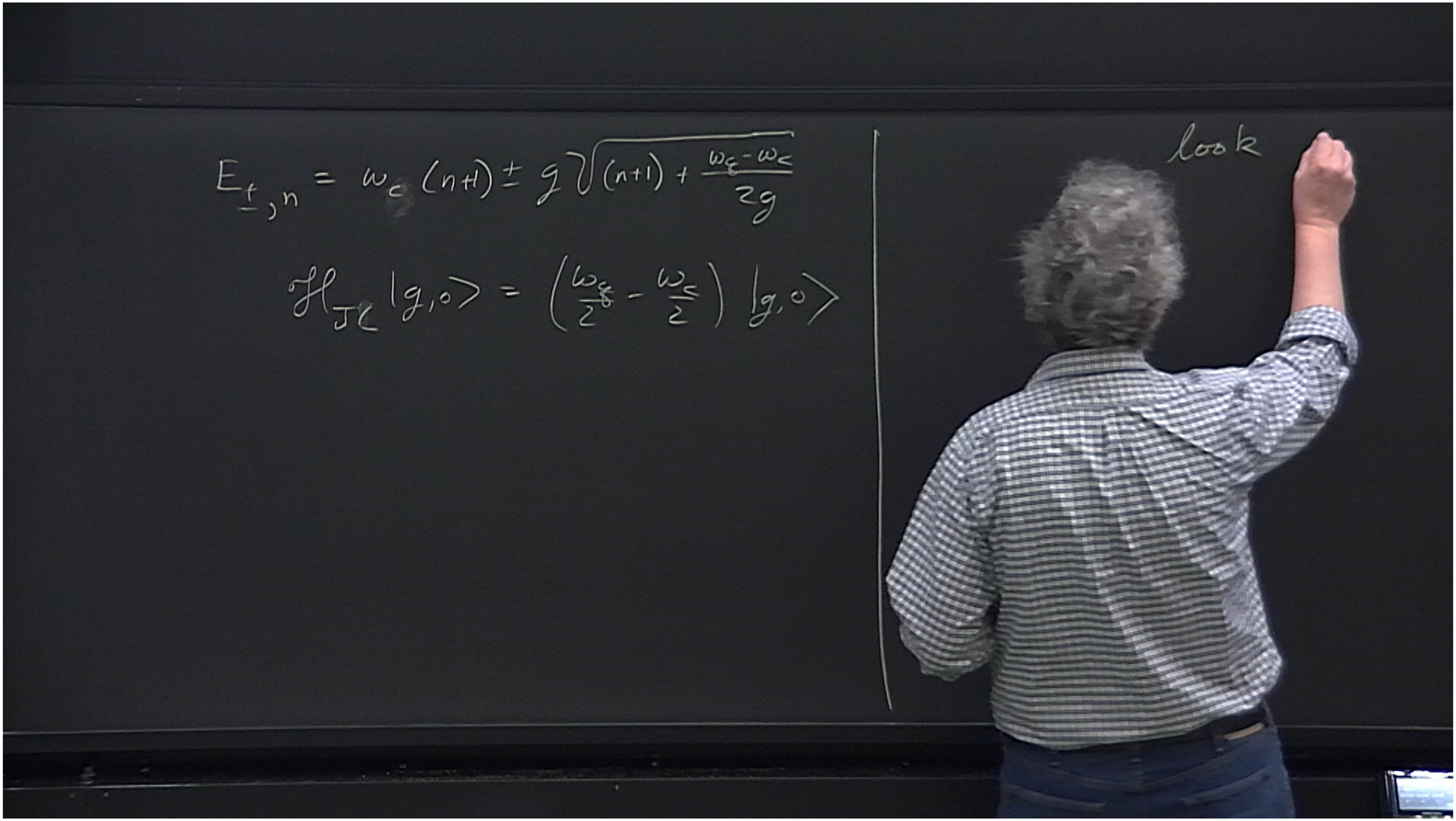
URL: http://pirsa.org/17040012

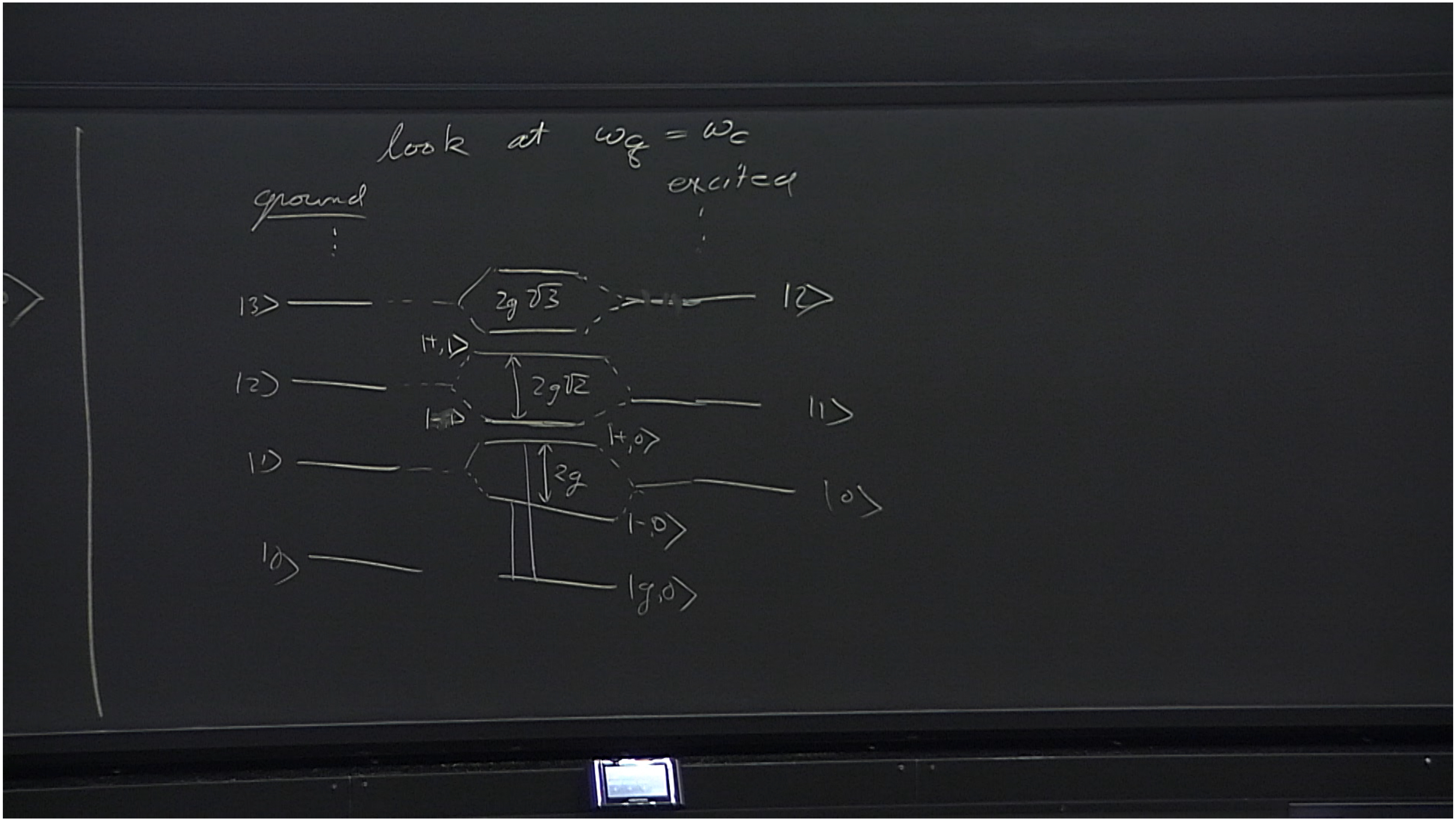
Abstract:


Cavities
$\mathcal{H}_{QRabi} = \frac{\omega_q}{2}\sigma_z + \omega_c(a^\dagger a + 1/2) + g(a + a^\dagger)\sigma_x$
RWA
$\mathcal{H}_{JC} = \frac{\omega_q}{2}\sigma_z + \omega_c(a^\dagger a + 1/2) + g(a^\dagger \sigma_- + a\sigma_+)$
excitations move between cavity & qubits
Hilbert space: $\{|e\rangle, |g\rangle\} \otimes \{|n\rangle\}$
sub space
$\mathcal{H}_{JC}|g, n+1\rangle = \left(-\frac{\omega_q}{2} + \omega_c(n + 3/2)\right)|g, n+1\rangle + g\sqrt{n+1}\,|e, n\rangle$
$\mathcal{H}_{JC}|e, n\rangle = \left(\frac{\omega_q}{2} + \omega_c(n+1)\right)|e, n\rangle + g\sqrt{n+1}\,|g, n+1\rangle$



excitations move between cavity & qubit
$|e,n\rangle, |g,n+1\rangle$
$\mathcal{H}_{SC,n} = \begin{pmatrix} \omega_q/2 + \omega_c(n+\frac{1}{2}) & g\sqrt{n+1} \\ g\sqrt{n+1} & -\frac{\omega_q}{2} + \omega_c(n+\frac{3}{2}) \end{pmatrix}$
$|+,n\rangle = \cos\frac{\phi}{2}|e,n\rangle + \sin\frac{\phi}{2}|g,n+1\rangle$
$|-,n\rangle = -\sin\frac{\phi}{2}|e,n\rangle + \cos\frac{\phi}{2}|g,n+1\rangle$
eigenstates in subspace
$\tan\phi = \frac{2g\sqrt{n+1}}{\omega_q - \omega_c}$


$E_{\pm,n} = \omega_c (n+1) \pm g\sqrt{(n+1) + \frac{\omega_g - \omega_c}{2g}}$
$\mathcal{H}_{JC}|g,0\rangle = \left(\frac{\omega_g}{2} - \frac{\omega_c}{2}\right)|g,0\rangle$
look


look at $\omega_q = \omega_c$
ground
excited
|3>
|2>
|1>
|0>
2g√3
|+,1>
2g√2
|-,1>
|+,0>
2g
|-,0>
|g,0>
|2>
|1>
|0>

$= \omega_c$

excited

$$|+,0\rangle = \frac{1}{\sqrt{2}}\left(|g,1\rangle + |e,0\rangle\right)$$

$$|-,0\rangle = \frac{1}{\sqrt{2}}\left(|g,1\rangle - |e,0\rangle\right)$$

$|2\rangle$

$|1\rangle$

$0\rangle$

$|0\rangle$

$-,0\rangle$

$g,0\rangle$

$= \omega_c$

excited

$|2\rangle$

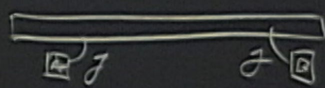
$|1\rangle$

$|0\rangle$

$$|+,0\rangle = \frac{1}{\sqrt{2}}\left(|g,1\rangle + |e,0\rangle\right)$$

$$|-,0\rangle = \frac{1}{\sqrt{2}}\left(|g,1\rangle - |e,0\rangle\right)$$

1. $|g,0,g\rangle$

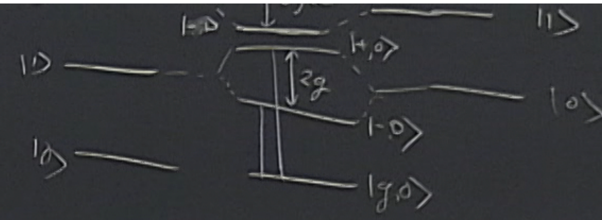



2. connect A to cavity, add 1 excitation,

$$\frac{1}{\sqrt{2}}\left(|g,1\rangle + |e,0\rangle\right) \otimes |g\rangle$$

3. disconnect A / connect B

$$\frac{1}{\sqrt{2}}\left(|g,1,e\rangle + |e,1,g\rangle\right) \Rightarrow \frac{1}{\sqrt{2}}\left(|g,e\rangle + |e,g\rangle\right) \otimes |1\rangle$$

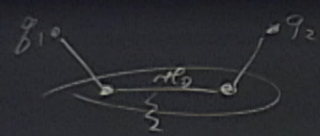



2. connect A to cavity, add

$\frac{1}{\sqrt{2}}\left(|g,1\rangle + |e,0\rangle\right)$

3. disconnect A / connect B

$\frac{1}{\sqrt{2}}\left(|g,1,e\rangle + |e,1,g\rangle\right)$

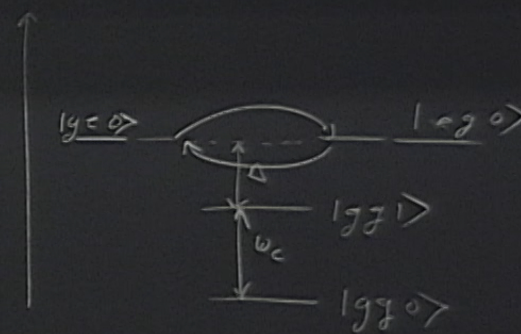



Couple 2 qubits via a virtual coupling to cavity.

2 qubits to have the same $\omega_q$.

detune cavity from them $\Delta$ ; $|\omega_c - \omega_q| < \Delta$

$$\mathcal{H} = \omega_c a^\dagger a + \frac{\omega_q}{2}\left(\sigma_z^A + \sigma_z^B\right) + \frac{g^2}{\Delta}\left(\sigma_+^A \sigma_-^B + \sigma_-^A \sigma_+^B\right)$$



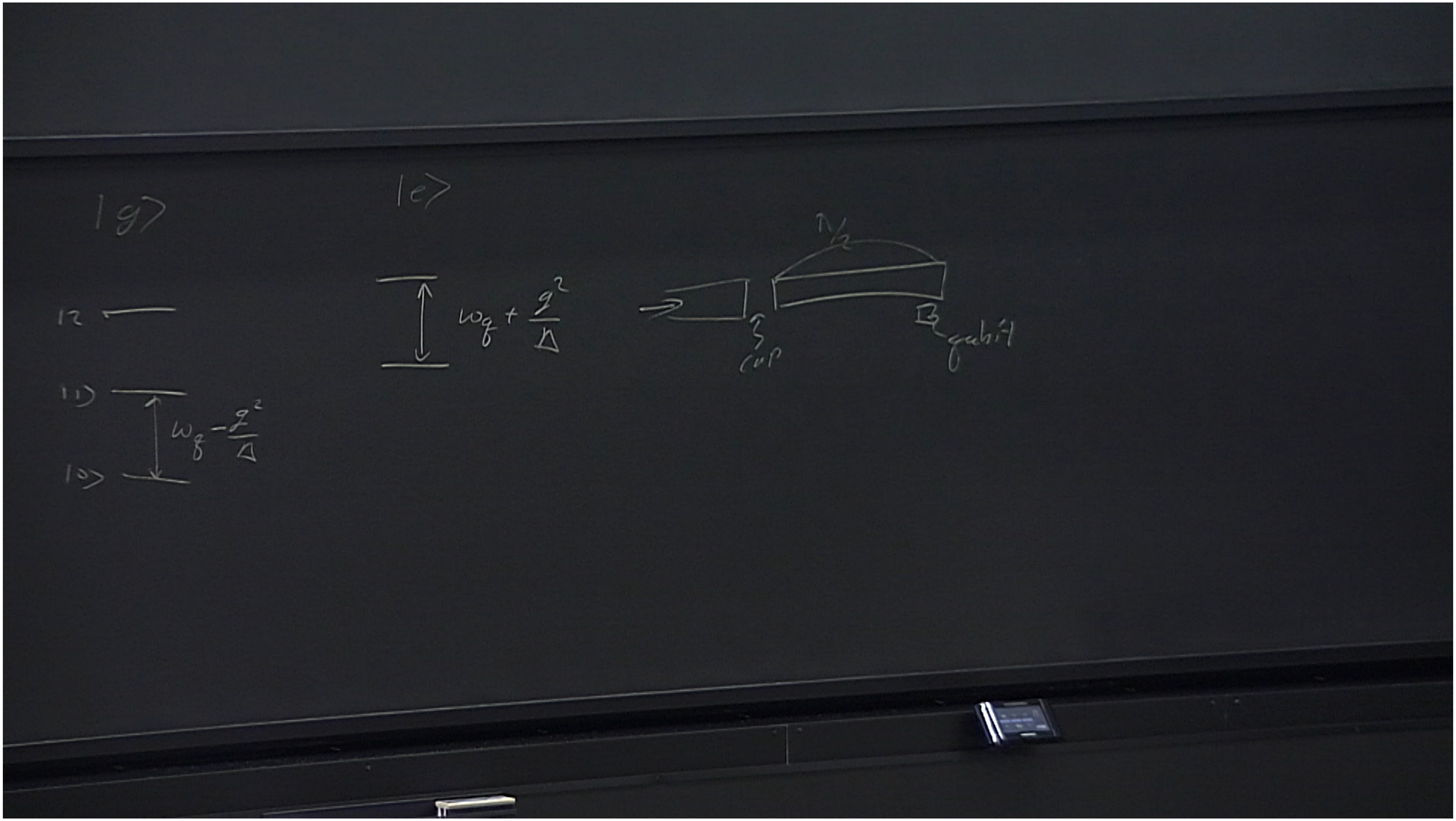
Detuned cavity $\omega_c - \omega_q = \Delta$

$$E_{\pm,n} = \omega_q(n+1) \pm \frac{\Delta}{2}\left(1+\left(2g\frac{\sqrt{n+1}}{\Delta}\right)^2\right)^{1/2}$$

if $2g\sqrt{n+1} \ll \Delta$

$$\simeq \omega_q(n+1) \pm \frac{\Delta}{2}\left(1+\frac{2g^2(n+1)}{\Delta^2}\right)$$

$$= \left(\omega_q \pm \frac{g^2}{\Delta}\right)(n+1) \pm \frac{\Delta}{2}$$


|g⟩
|e⟩
|1⟩
|0⟩
ω_q − g²/Δ
ω_q + g²/Δ
λ/2
qubit