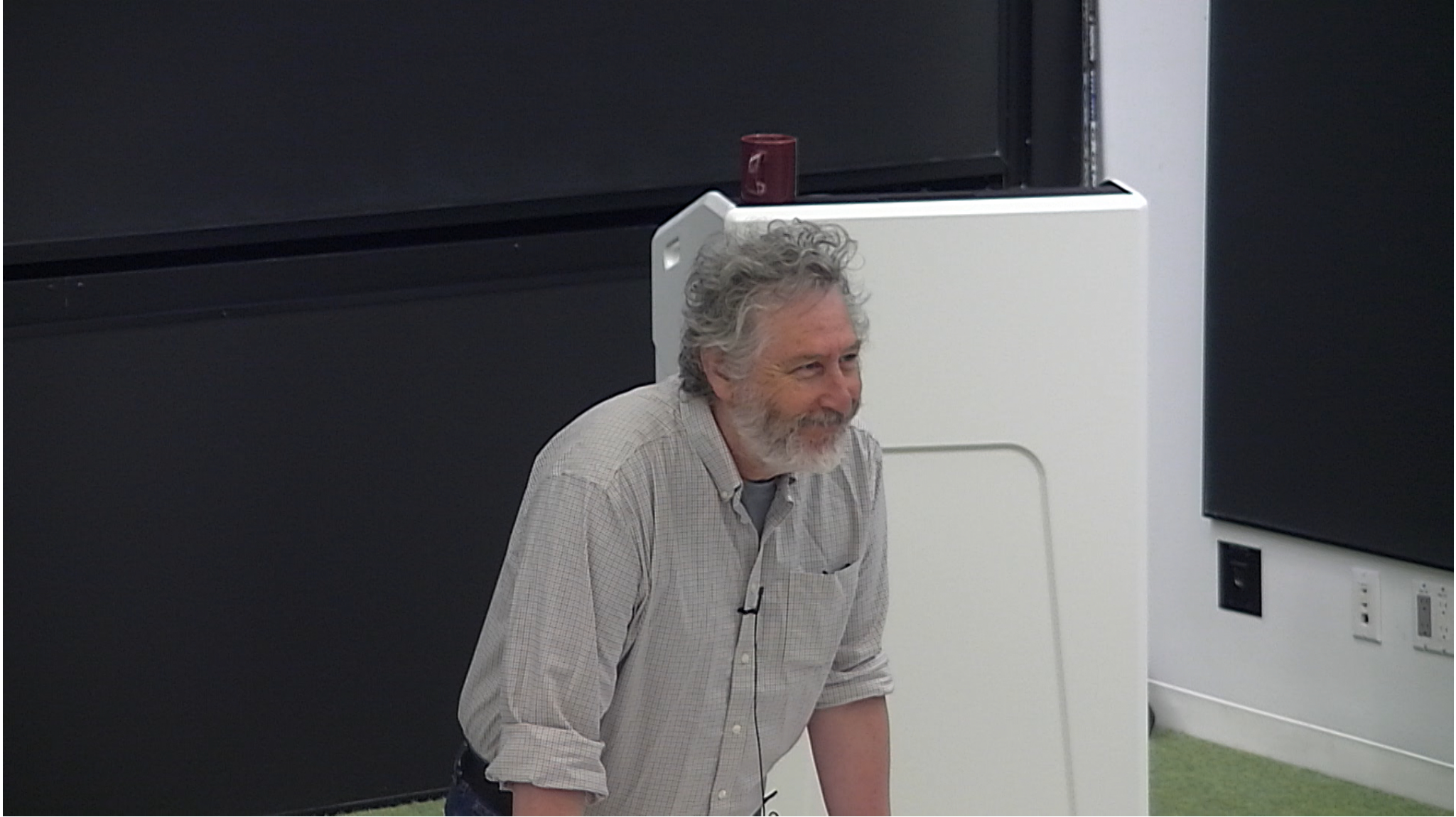


Title: PSI 2016/2017 Explorations in Quantum Information - Lecture 3

Date: Mar 22, 2017 09:00 AM

URL: <http://pirsa.org/17030060>

Abstract:

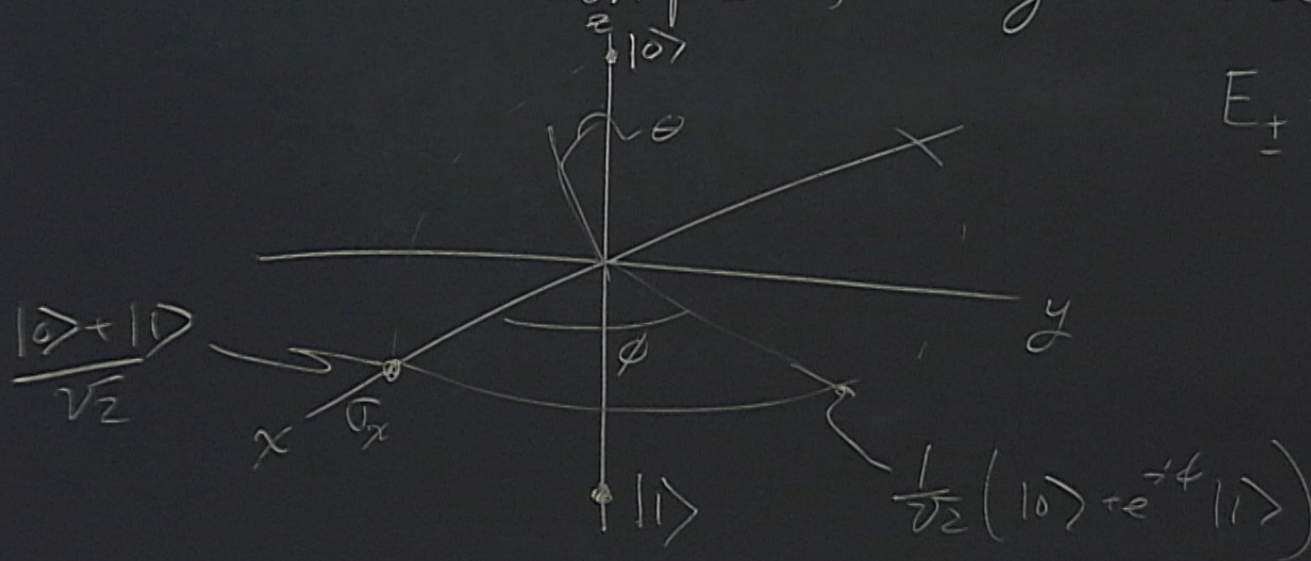


Qubit Dynamics

Bloch Sphere

Complete, for any 2-level system.

$$E_{\pm} = \frac{(1 \pm \sigma_z)}{2}$$



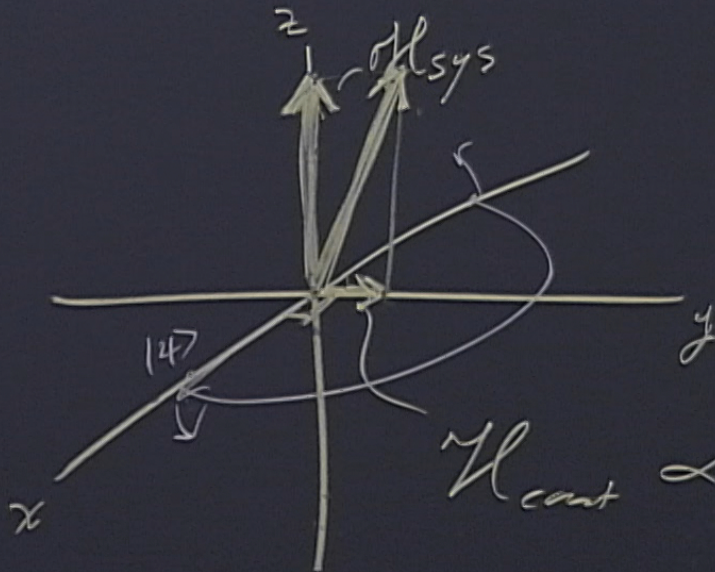
surface BS = pure states
interior = mixed states.

Unitary dynamics

$$U = e^{i \frac{\theta}{2} \hat{n} \cdot \vec{\sigma}}$$

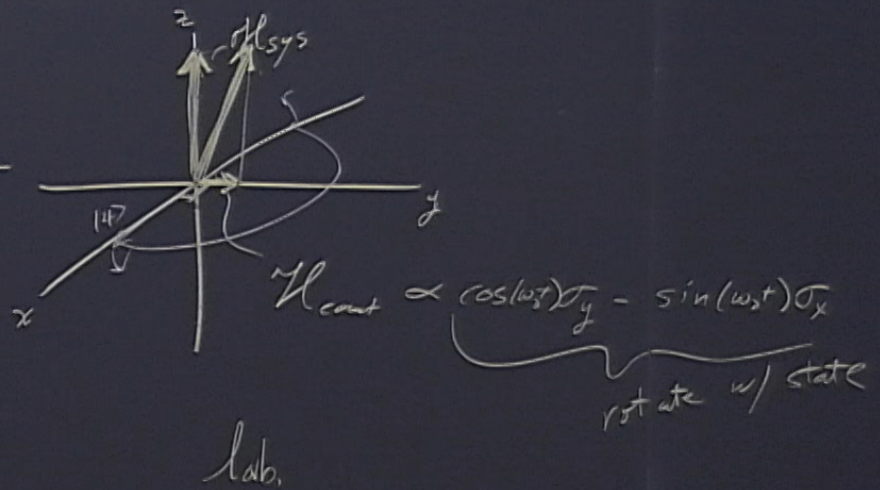
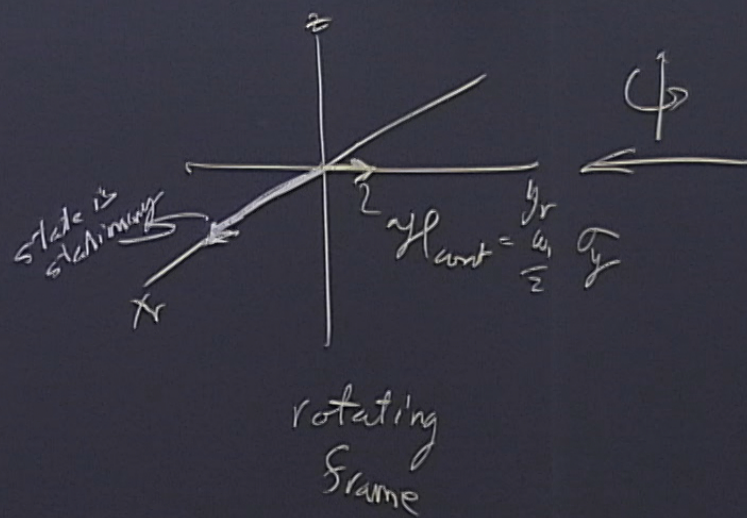
unit vector, about which rotating.

angle of rotation



$$H_{cont} \propto \underbrace{(\cos(\omega t)\sigma_y - \sin(\omega t)\sigma_x)}_{\text{rotate w/ state}}$$

lab,



Control on Bloch Sphere.

1. $\mathcal{H}_{\text{sys}} = -\omega_0 \sigma_z$

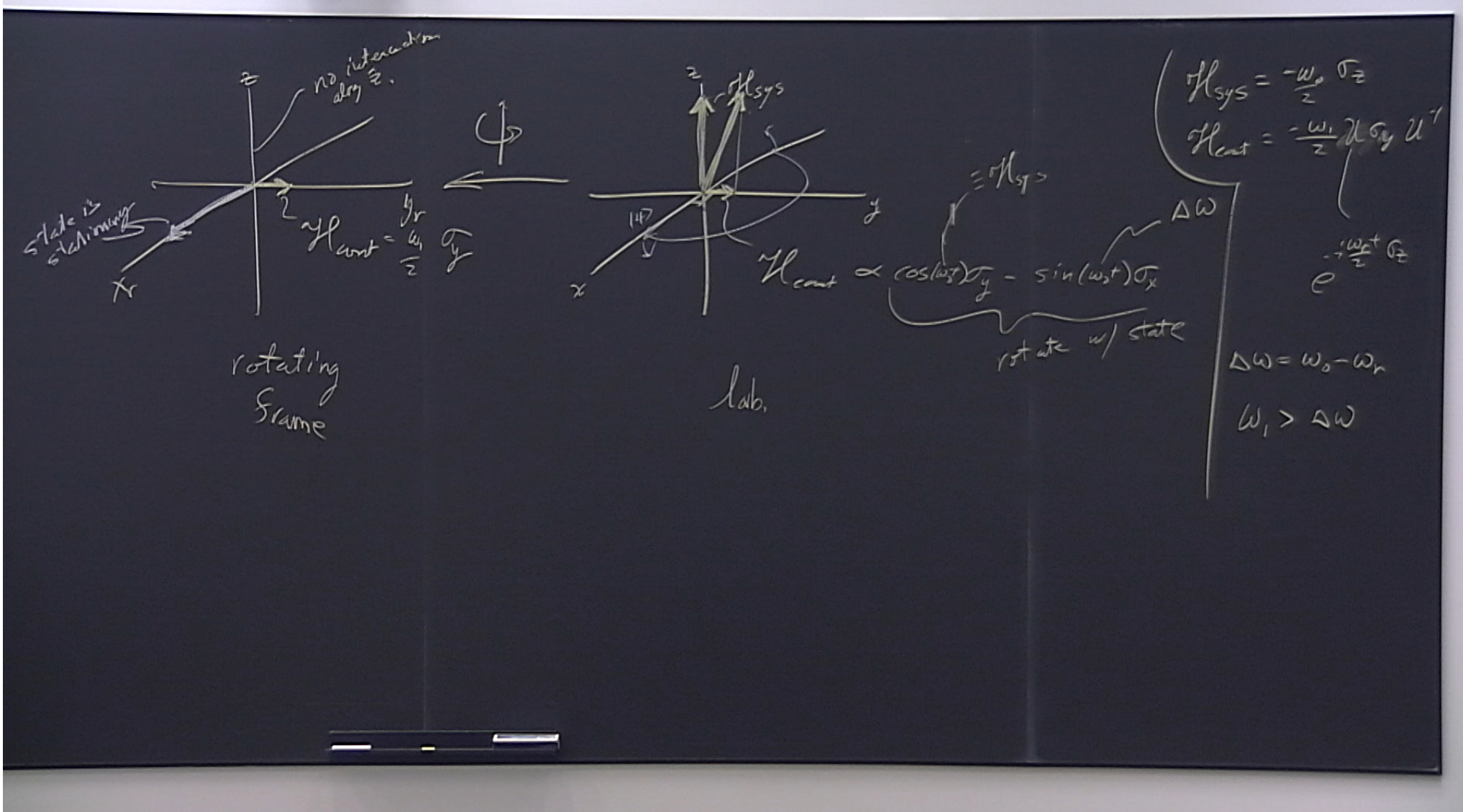
↓
take $\mathcal{H}_{\text{sys}} = 0$; add $\mathcal{H}_{\text{int}} = -\omega_1 \sigma_y$
for some short time.

very difficult

2. $\mathcal{H}_{\text{sys}} = -\omega_0 \sigma_z$

make $\mathcal{H}_{\text{control}}$ time dependent
& on resonance.

easy



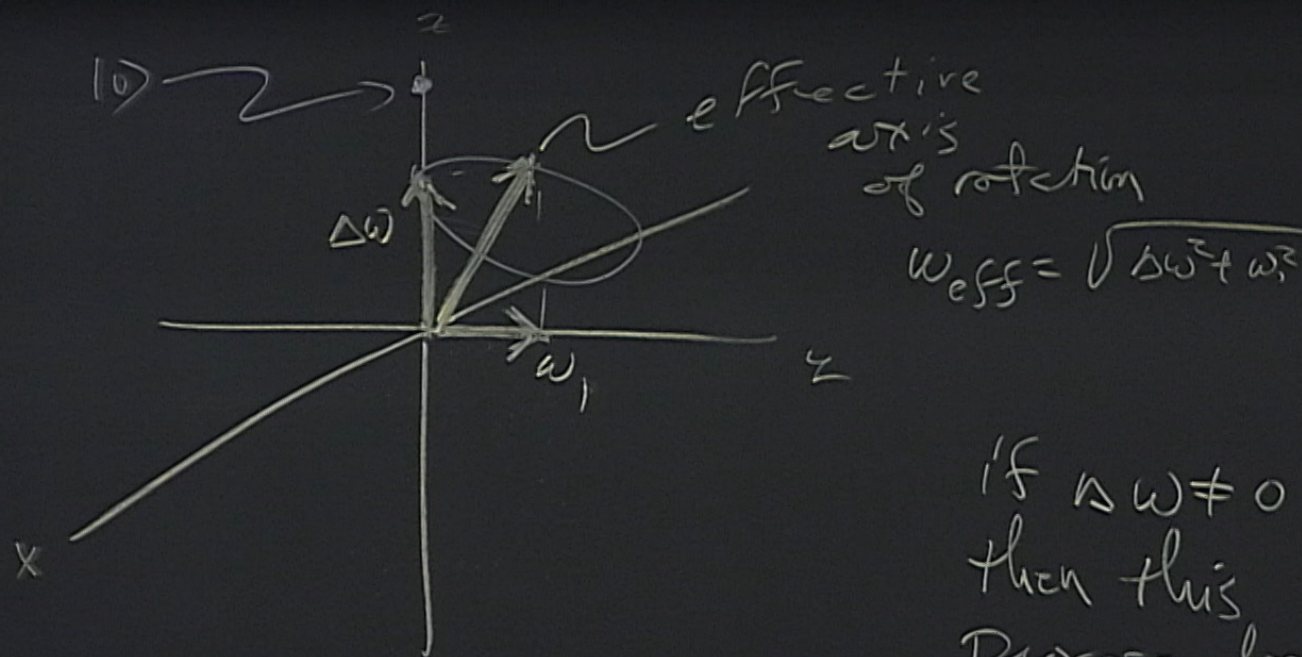
Bloch Eqs (rotating frame)

very difficult

$$\frac{d\langle\sigma_x\rangle}{dt} = -\Delta\omega\langle\sigma_y\rangle + \omega_1\langle\sigma_z\rangle$$

$$\frac{d\langle\sigma_y\rangle}{dt} = \Delta\omega\langle\sigma_x\rangle$$

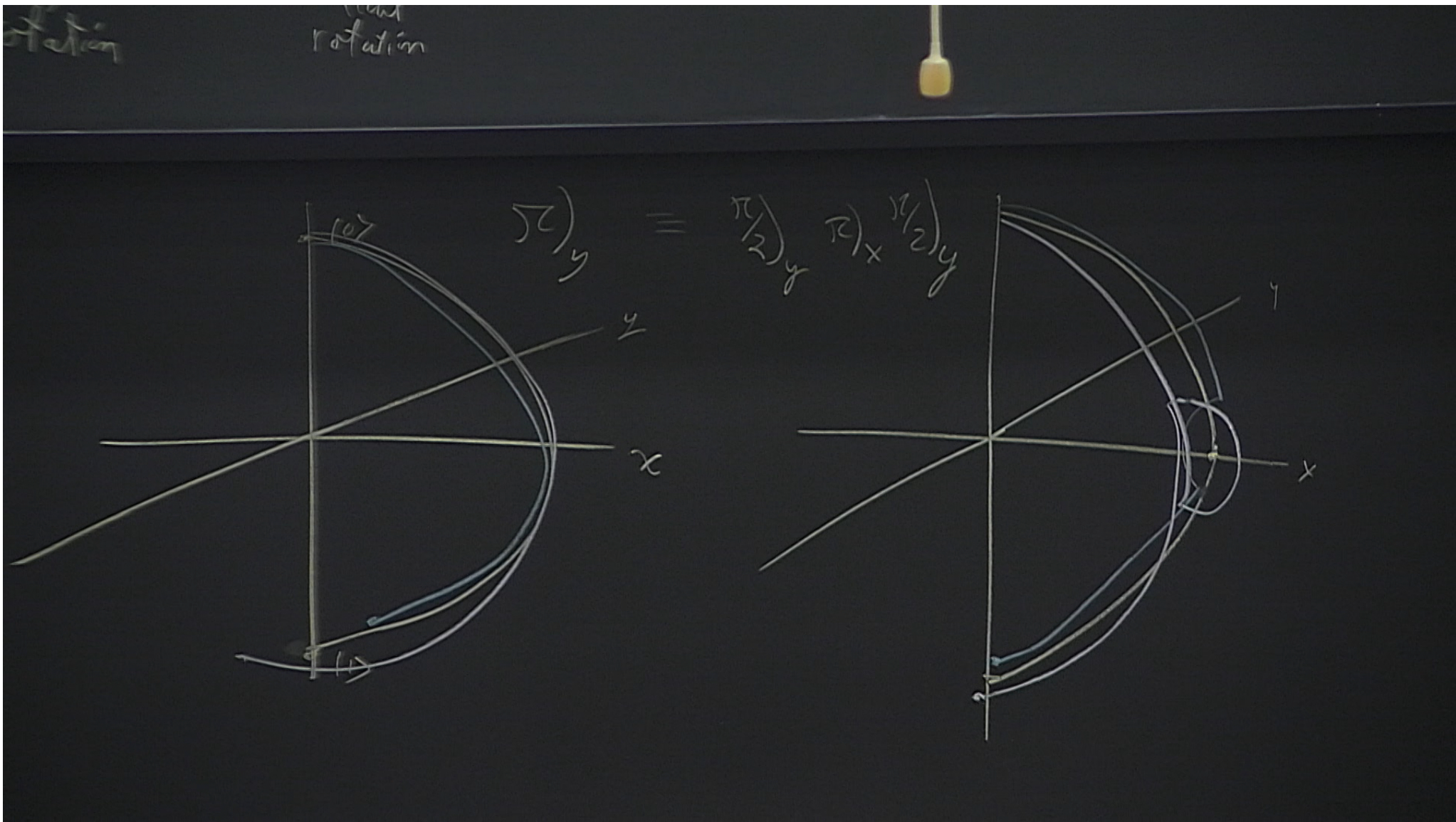
$$\frac{d\langle\sigma_z\rangle}{dt} = \underbrace{\quad}_{\substack{\mathcal{H}_{\text{sys}} \\ \text{rotation}}} \quad \underbrace{-\omega_1\langle\sigma_x\rangle}_{\substack{\mathcal{H}_{\text{rot}} \\ \text{rotation}}}$$



if $\Delta\omega \neq 0$
 then this
 process does
 not take $|0\rangle \rightarrow |1\rangle$

Find a sequence of rotations
that give the desired
gate.

(always possible



Bloch Eqs (rotating frame)

$$\frac{d\langle\sigma_x\rangle}{dt} = \underbrace{-\Delta\omega\langle\sigma_y\rangle}_{\text{always on}} + \underbrace{\omega_1\langle\sigma_z\rangle}_{\text{under our control}}$$

$$\frac{d\langle\sigma_y\rangle}{dt} = \Delta\omega\langle\sigma_x\rangle$$

$$\frac{d\langle\sigma_z\rangle}{dt} =$$

$\underbrace{\hspace{1cm}}_{\substack{\text{H}_{\text{sys}} \\ \text{rotation}}}$

$\underbrace{-\omega_1\langle\sigma_x\rangle}_{\substack{\text{H}_{\text{rot}} \\ \text{rotation}}}$

$\underbrace{-\frac{\langle\sigma_z\rangle}{T_1}}_{\text{energy relaxation}}$

decoherence from energy relaxation

$-\frac{\langle\sigma_x\rangle}{T_2'}$

$-\frac{\langle\sigma_y\rangle}{T_2'}$

difficult

y difficult

Bloch Eqs (rotating frame)

$$\frac{d\langle \sigma_x \rangle}{dt} = \underbrace{-\Delta\omega \langle \sigma_y \rangle}_{\text{always on}} + \underbrace{\omega_1 \langle \sigma_z \rangle}_{\text{under our control}}$$

$$\frac{d\langle \sigma_y \rangle}{dt} = \Delta\omega \langle \sigma_x \rangle$$

$$\frac{d\langle \sigma_z \rangle}{dt} =$$

$\underbrace{\hspace{1cm}}_{\substack{\omega_{\text{sys}} \\ \text{rotation}}}$

$\underbrace{-\omega_1 \langle \sigma_x \rangle}_{\substack{\omega_{\text{RF}} \\ \text{rotation}}}$

$\underbrace{-\frac{\langle \sigma_z \rangle}{T_1}}_{\text{energy relaxation}}$

$+\frac{\langle \sigma_z \rangle_0}{T_1}$

decoherence from energy relaxation

$-\frac{\langle \sigma_x \rangle}{T_2^*}$

$-\frac{\langle \sigma_x \rangle}{T_2^{\text{other}}}$

$-\frac{\langle \sigma_y \rangle}{T_2^*}$

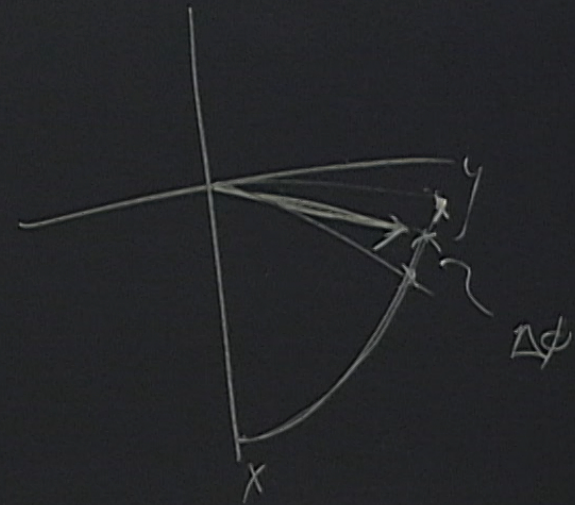
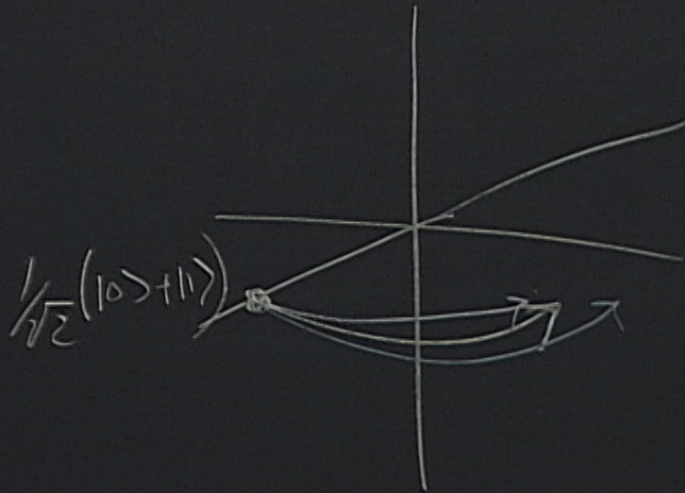
$-\frac{\langle \sigma_y \rangle}{T_2^{\text{other}}}$

T_2^{other}

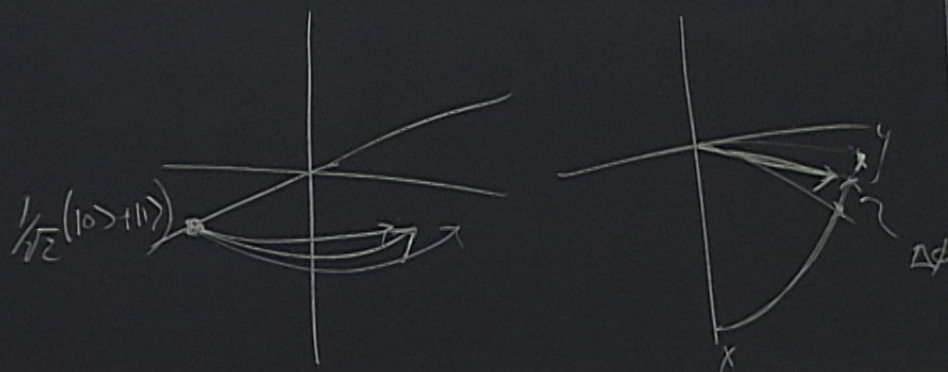
$\equiv$

ω_0 varies

variation in the rotation rate about $\hat{z}$



$T_2^{\text{other}} \equiv \frac{\omega_0 \text{ varies}}{\rightarrow \text{variation in the rotation rate about } \hat{z}}$



cylindrical sym.

noise $K_0 = (1-2P)^{1/2} \mathbb{I}$
 $T_2' = T_1$ $K_1 = \sqrt{P} \sigma_x$
 $K_2 = \sqrt{P} \sigma_y$

2D sym $K_0 = (1-P)^{1/2} \mathbb{I}$
 $T_2' = 2T_1$ $K_1 = \sqrt{P} \sigma_x$
 $K_2 = 0$

Black Eqs (rotating frame)

difficult

$$\frac{d\langle\sigma_x\rangle}{dt} = \underbrace{-\Omega\omega\langle\sigma_y\rangle}_{\text{always on}} + \underbrace{\omega_1\langle\sigma_z\rangle}_{\text{under our control}}$$

$$\frac{d\langle\sigma_y\rangle}{dt} = \Omega\omega\langle\sigma_x\rangle$$

$$\frac{d\langle\sigma_z\rangle}{dt} =$$

$\underbrace{\hspace{1cm}}_{\text{rf sys rotation}}$

$\underbrace{-\omega_1\langle\sigma_x\rangle}_{\text{rf field rotation}}$

decoherence from energy relaxation

$$-\frac{\langle\sigma_x\rangle}{T_2'}$$

$$-\frac{\langle\sigma_y\rangle}{T_2'}$$

$$-\frac{\langle\sigma_z\rangle}{T_1}$$

energy relaxation

$$-\frac{\langle\sigma_x\rangle}{T_2^{\text{other}}}$$

$$-\frac{\langle\sigma_y\rangle}{T_2^{\text{other}}}$$

variations in sys chl

$$\frac{1}{T_2^{\text{eff}}} = \frac{1}{T_2'} + \frac{1}{T_2^{\text{other}}}$$

$$+\frac{\langle\sigma_z\rangle_0}{T_1}$$