Title: PSI 2016/2017 Explorations in Quantum Information - Lecture 11

Date: Apr 03, 2017 02:00 PM

URL: http://pirsa.org/17040010

Abstract:

NV

spin 1 electron ⊗ ^{15}N spin 1 ⊗ ^{13}C each is spin 1/2

$$\Delta S_z^2 + \omega_e S_z + \omega_Q S_z^N + \omega_N S_z^N + \omega_{Ne} S_z S_z^N + \frac{\omega_e}{2}\sigma_z + \omega_A S_z \sigma_z + \omega_B S_z \sigma_x$$

Δ: exchange

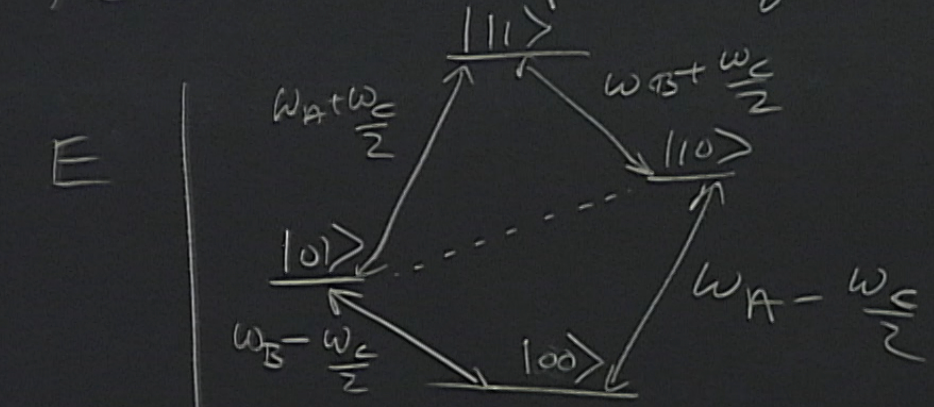
ω_e: Zeeman if magnetic field

$\frac{\omega_e}{2}\sigma_z$: Zeeman

$\omega_A S_z \sigma_z + \omega_B S_z \sigma_x$: hyperfine

3 GHz set E

How to Couple qubits

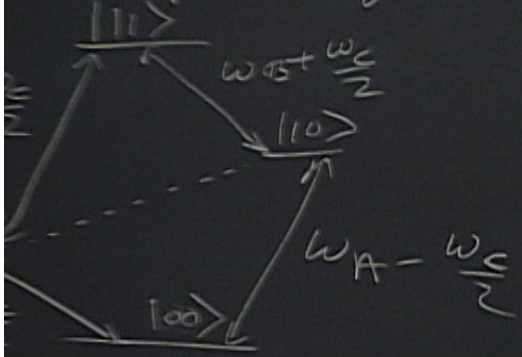


$$\mathcal{H} = \frac{\omega_A}{2}\sigma_z^A + \frac{\omega_B}{2}\sigma_z^B + \frac{\omega_c}{2}\sigma_z^A\sigma_z^B$$

distinguishable qubits

Energy of qubit A depends on state of B

Couple qubits



$\frac{\omega_A}{2}\sigma_z^A + \frac{\omega_B}{2}\sigma_z^B + \frac{\omega_C}{2}\sigma_z^A\sigma_z^B$

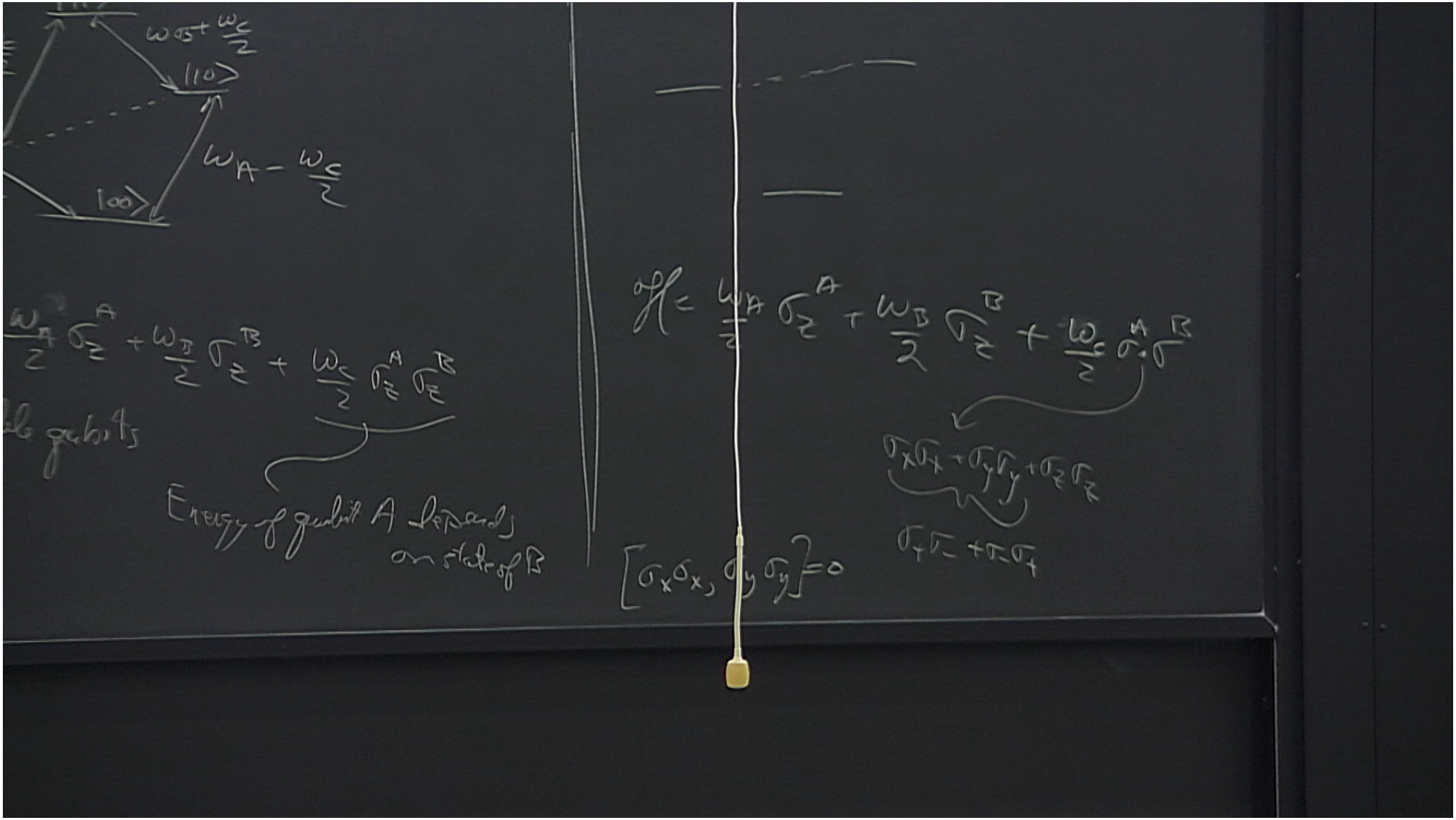
ble qubits

Energy of qubit A depends on state of B

$\mathcal{H} = \frac{\omega_A}{2}\sigma_z^A + \frac{\omega_B}{2}\sigma_z^B + \frac{\omega_C}{2}\sigma^A\sigma^B$

$\sigma_x\sigma_x + \sigma_y\sigma_y + \sigma_z\sigma_z$

$\sigma_+\sigma_- + \sigma_-\sigma_+$


$\omega_B + \frac{\omega_c}{2}$
$|10\rangle$
$\omega_A - \frac{\omega_c}{2}$
$|00\rangle$
$\frac{\omega_A}{2}\sigma_z^A + \frac{\omega_B}{2}\sigma_z^B + \frac{\omega_c}{2}\sigma_z^A\sigma_z^B$
Energy of qubit A depends on state of B
$\mathcal{H} = \frac{\omega_A}{2}\sigma_z^A + \frac{\omega_B}{2}\sigma_z^B + \frac{\omega_c}{2}\vec{\sigma}^A\cdot\vec{\sigma}^B$
$\sigma_x\sigma_x + \sigma_y\sigma_y + \sigma_z\sigma_z$
$\sigma_+\sigma_- + \sigma_-\sigma_+$
$[\sigma_x\sigma_x, \sigma_y\sigma_y] = 0$

Control

$\mathcal{H}$ includes $\sigma_z^A \sigma_z^B$

ideally

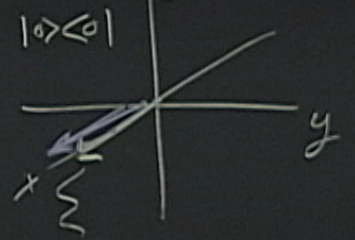
$\sigma_x^A \to \sigma_x^B$

$\sigma_y^A \to \sigma_y^B$

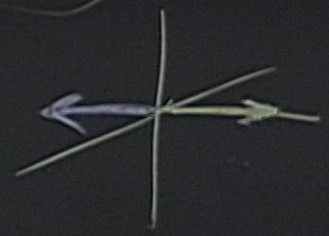
$\sigma_z^A \to \sigma_z^B$

$\mathbb{1} \to \mathbb{1}$

$= |1\rangle\langle 1|^B \otimes \sigma_x^A$ $\xrightarrow{\sigma_z \sigma_z}$ $\sigma_y^A \sigma_z^B = \sigma_y^A E_+^B - \sigma_y E_-^B$



$\xrightarrow{\sigma_z \sigma_z}$



$\sigma_x = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$

$\sigma_x \otimes \mathbb{1} = \sigma_x \otimes E_+ + \sigma_x \otimes E_-$

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

Control

$\mathcal{H}$ includes $\sigma_z \otimes \sigma_z$

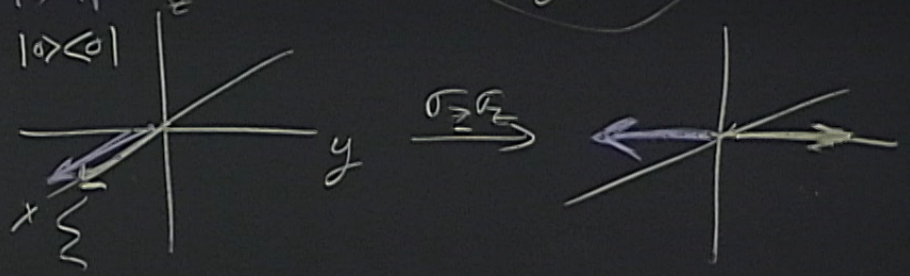
ideally $\sigma_x^A \to \sigma_x^B$

$\sigma_y^A \to \sigma_y^B$

$\sigma_z^A \to \sigma_z^B$

$\mathbb{1} \to \mathbb{1}$

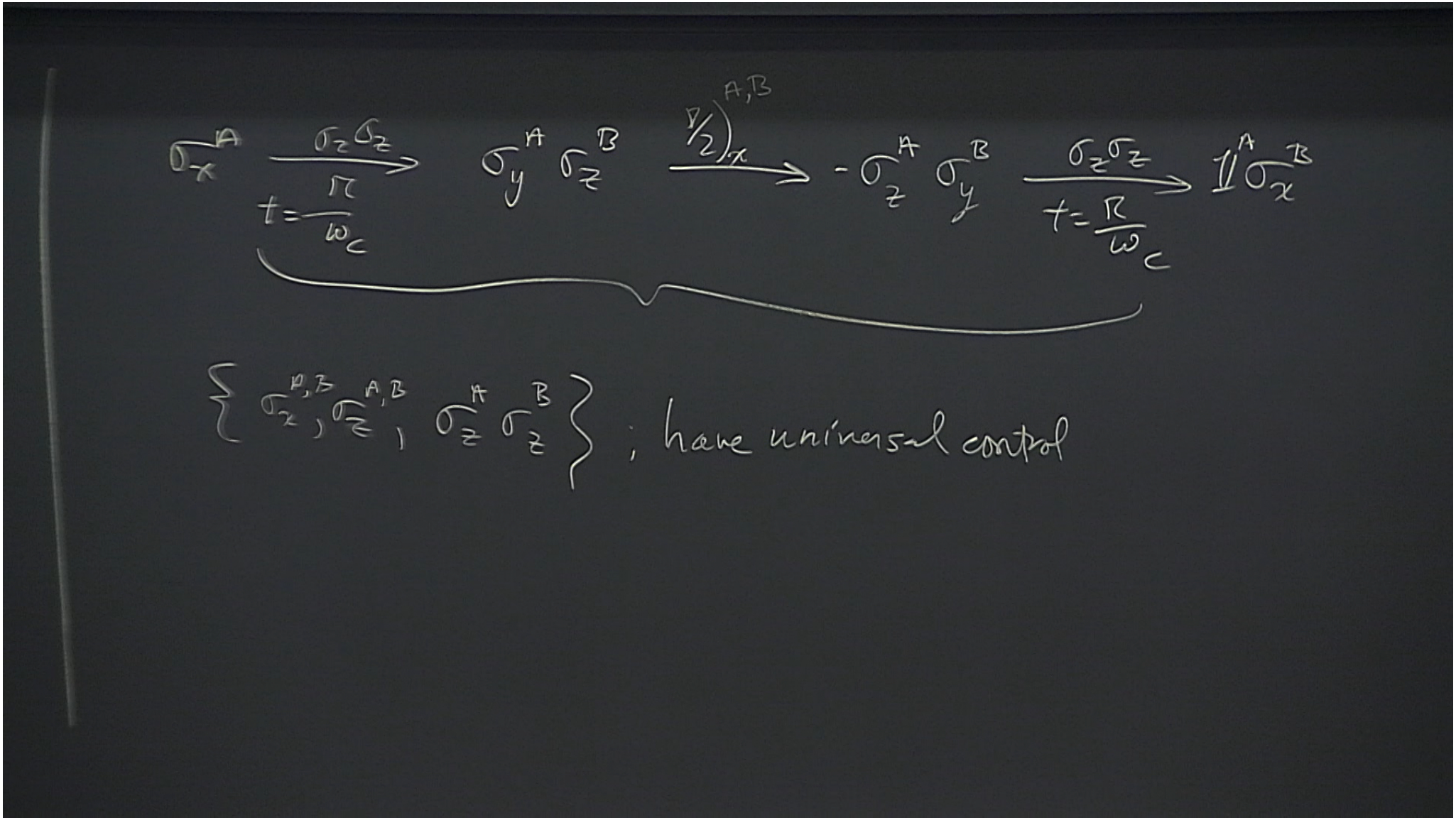
$= |1\rangle\langle 1|^B \otimes \sigma_x^A \xrightarrow{\sigma_z \otimes \sigma_z} \sigma_y^A \otimes \sigma_z^B = \sigma_y^A \otimes E_+^B - E_-^B$



$\sigma_x = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$

$\sigma_x \otimes \mathbb{1} = \sigma_x \otimes E_+ + \sigma_x \otimes E_-$

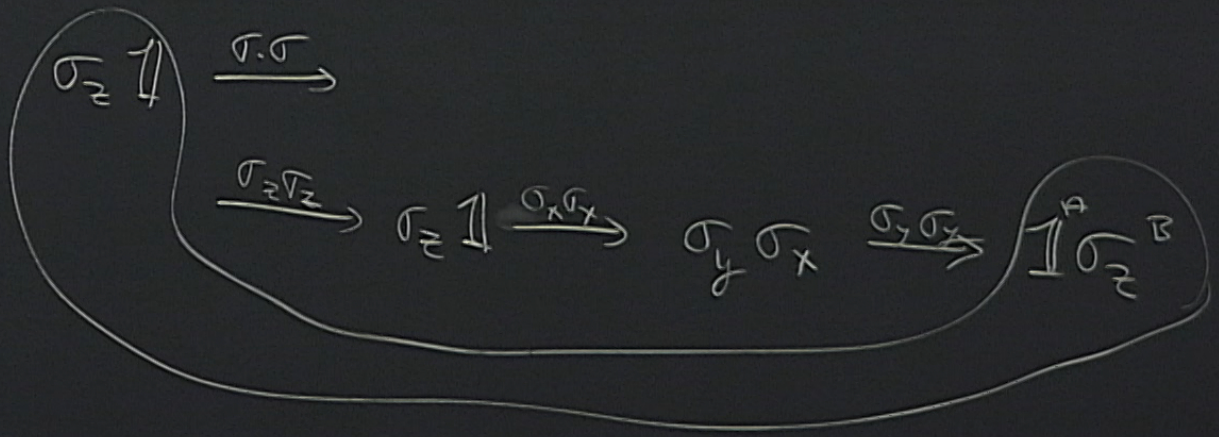
$E_\pm = \frac{(\mathbb{1} \pm \sigma_z)}{2}$


$\sigma_x^A \xrightarrow[t=\frac{\pi}{\omega_c}]{\sigma_z\sigma_z} \sigma_y^A\sigma_z^B \xrightarrow{(\pi/2)_x^{A,B}} -\sigma_z^A\sigma_y^B \xrightarrow[t=\frac{\pi}{\omega_c}]{\sigma_z\sigma_z} \mathbb{1}^A\sigma_x^B$
$\{\sigma_z^{A,B}, \sigma_z^{A,B}, \sigma_z^A\sigma_z^B\}$; have universal control

isotropic mixing Hamiltonian

$\sigma \cdot \sigma = \sigma_x\sigma_x + \sigma_y\sigma_y + \sigma_z\sigma_z$

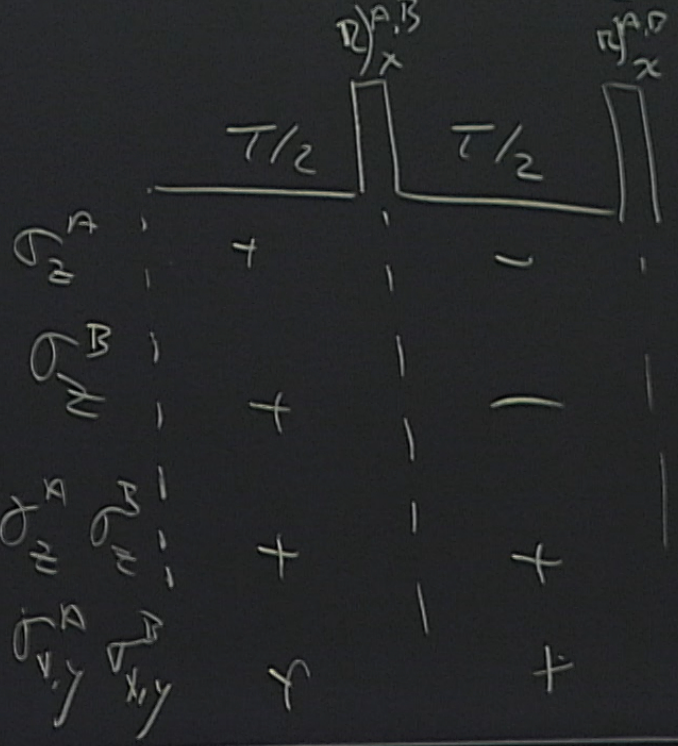
$\mathcal{H} = e^{-i\vec{r}\cdot\vec{\sigma}\theta} = e^{-i\sigma_x\sigma_x\theta}\, e^{-i\sigma_y\sigma_y\theta}\, e^{-i\sigma_z\sigma_z\theta}$



$\sigma \cdot \sigma \Rightarrow$ swap

trouble

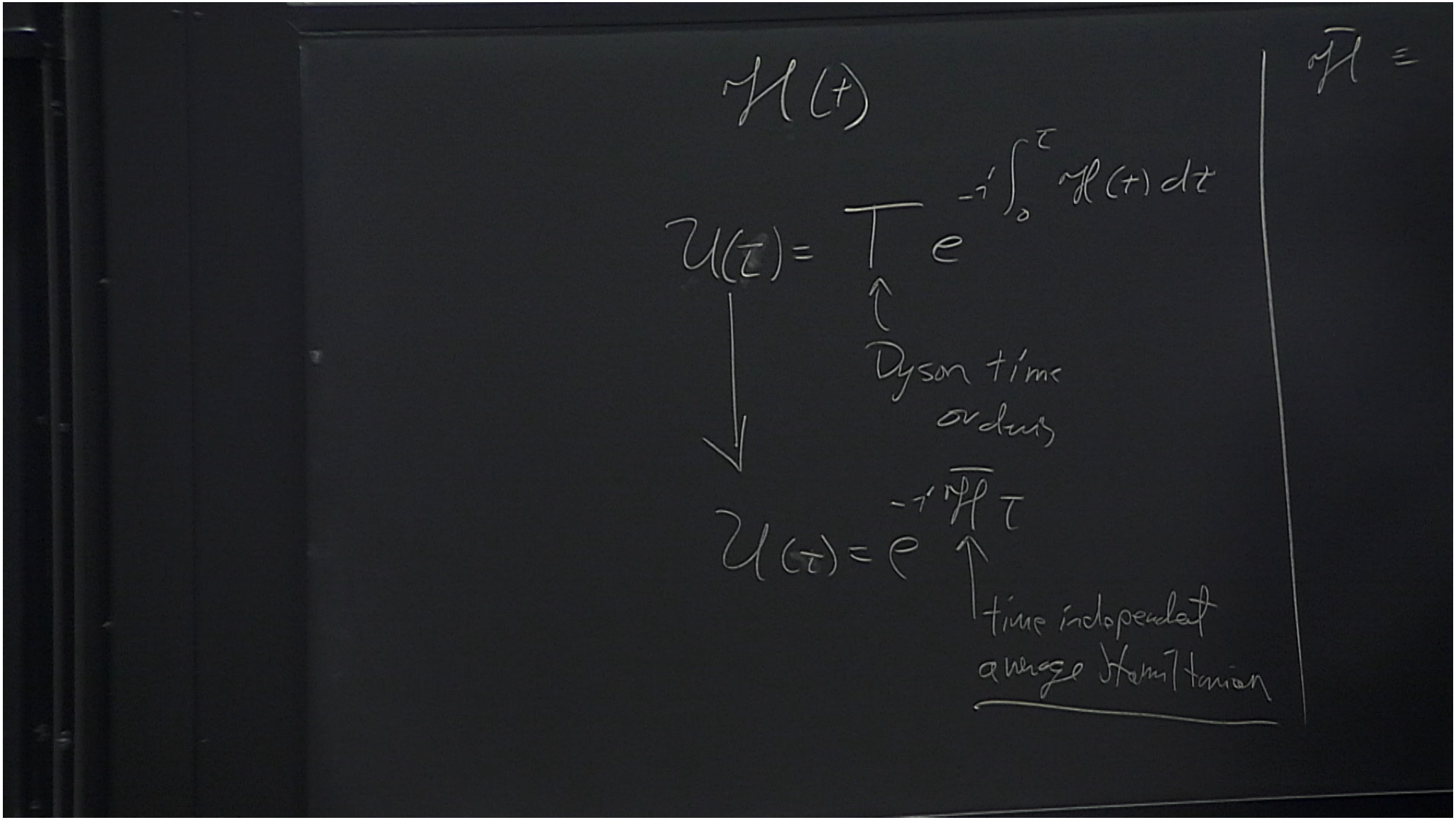
$$\mathcal{H}_{Full} = \frac{\omega}{2}\left(\sigma_z^A + \sigma_z^B\right) + \frac{\Delta\omega}{2}\left(\sigma_z^A - \sigma_z^B\right) + \frac{\omega_x}{2}\,\sigma^A \cdot \sigma^B$$



on average over this process

$\langle \sigma_z^A \rangle \to 0$

$\langle \sigma_z^B \rangle \to 0$


$\mathcal{H}(t)$
$U(\tau) = T\, e^{-i\int_0^\tau \mathcal{H}(t)\,dt}$
Dyson time ordering
$U(\tau) = e^{-i\bar{\mathcal{H}}\tau}$
time independent average Hamiltonian
$\bar{\mathcal{H}} =$

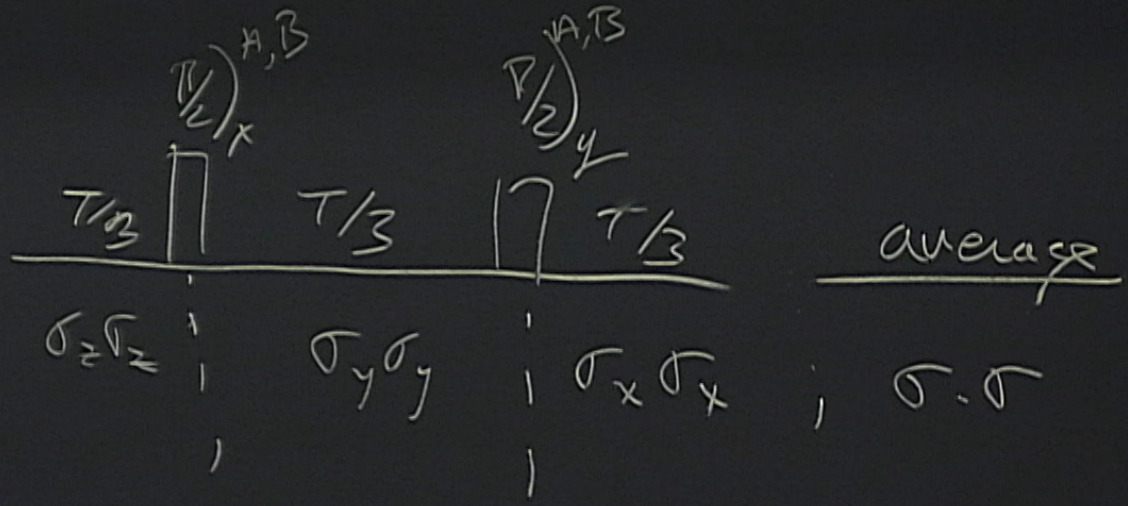
$\bar{\mathcal{H}}$ = Hamiltonian of effective process over an interval,

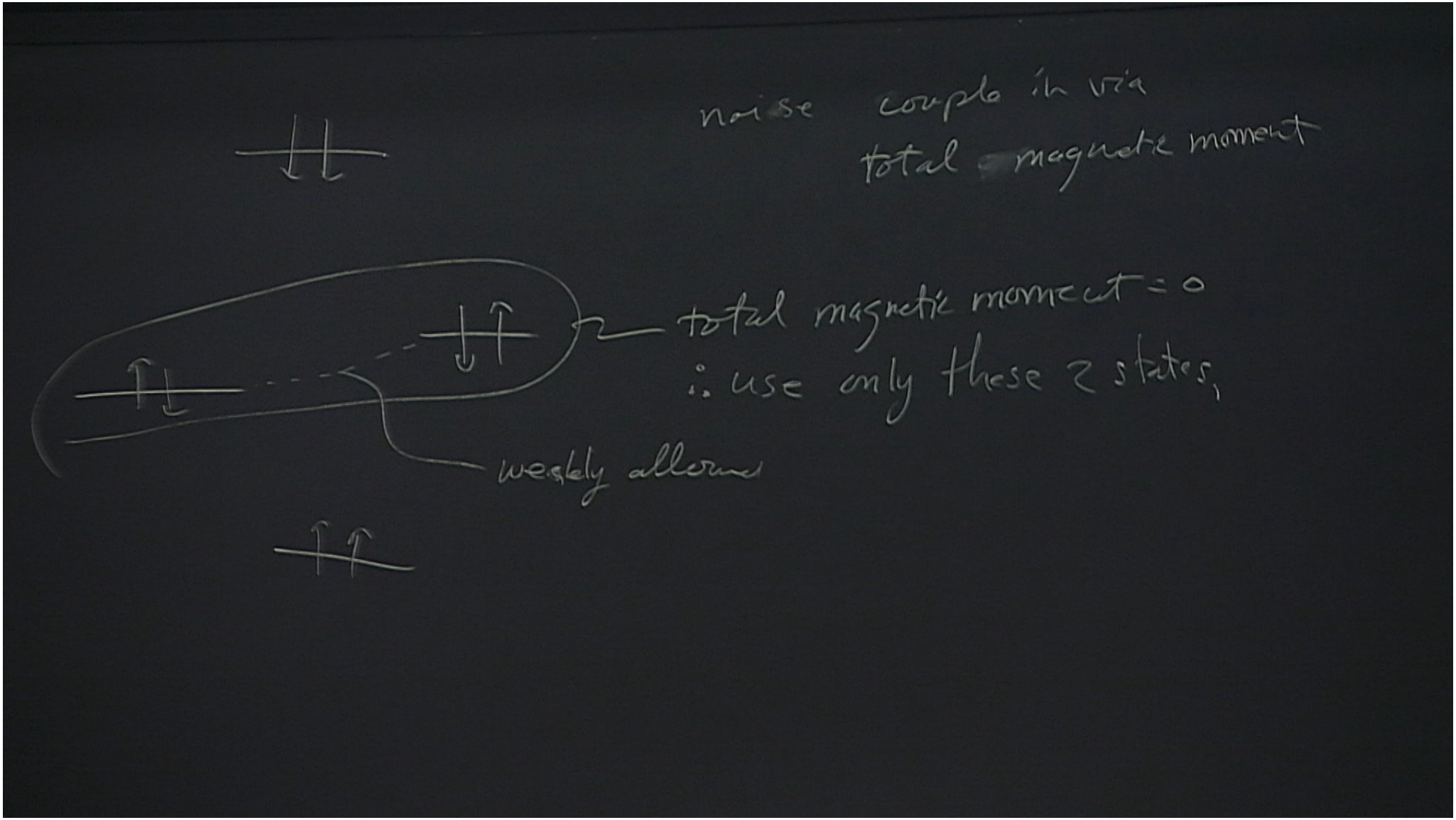
$$\bar{\mathcal{H}} = \mathcal{H}^{(0)} + \mathcal{H}^{(1)} + \mathcal{H}^{(2)} \cdots$$

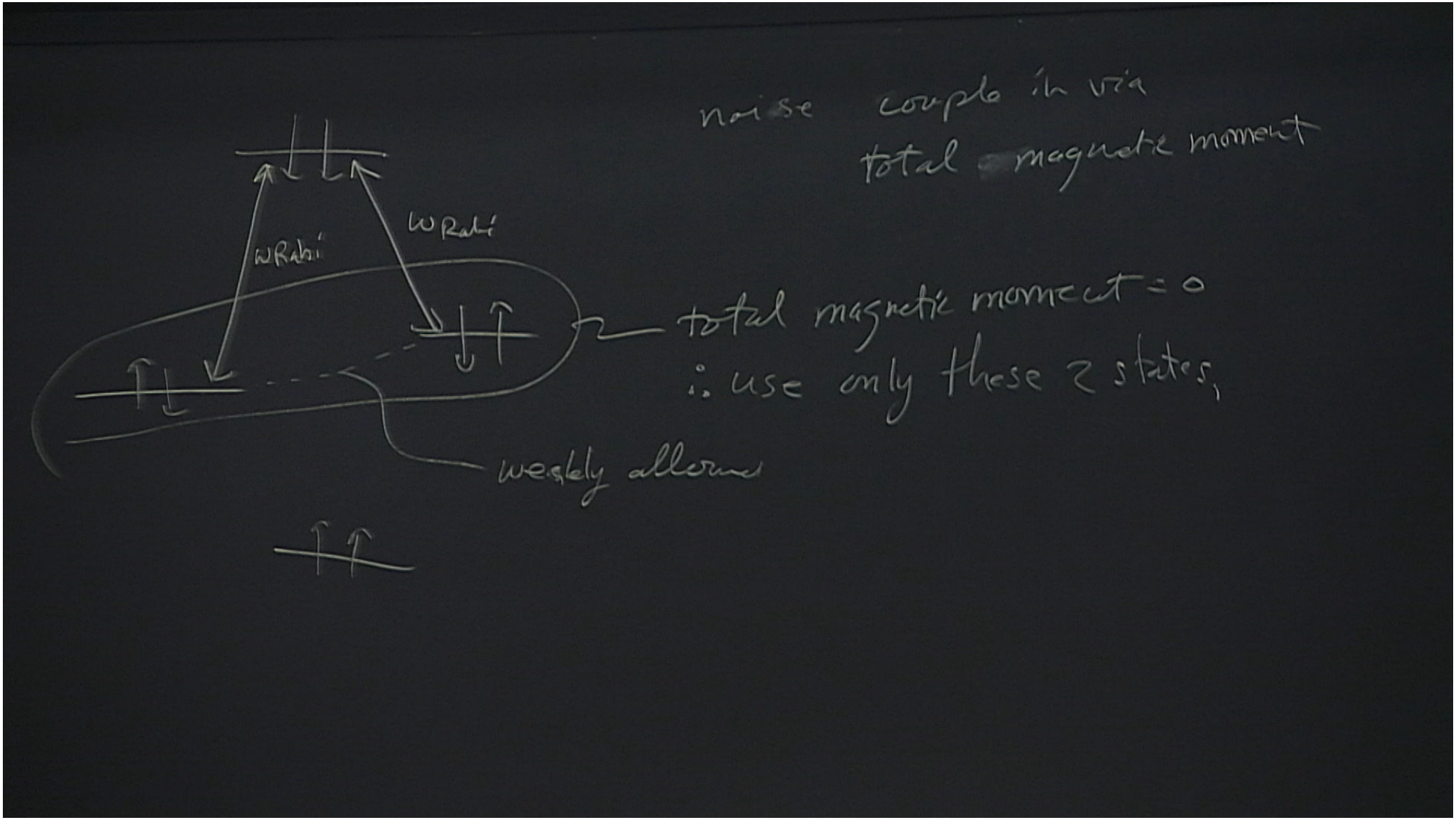
$$\mathcal{H}^{(0)} = \frac{1}{\tau}\int \mathcal{H}(t)\,dt$$

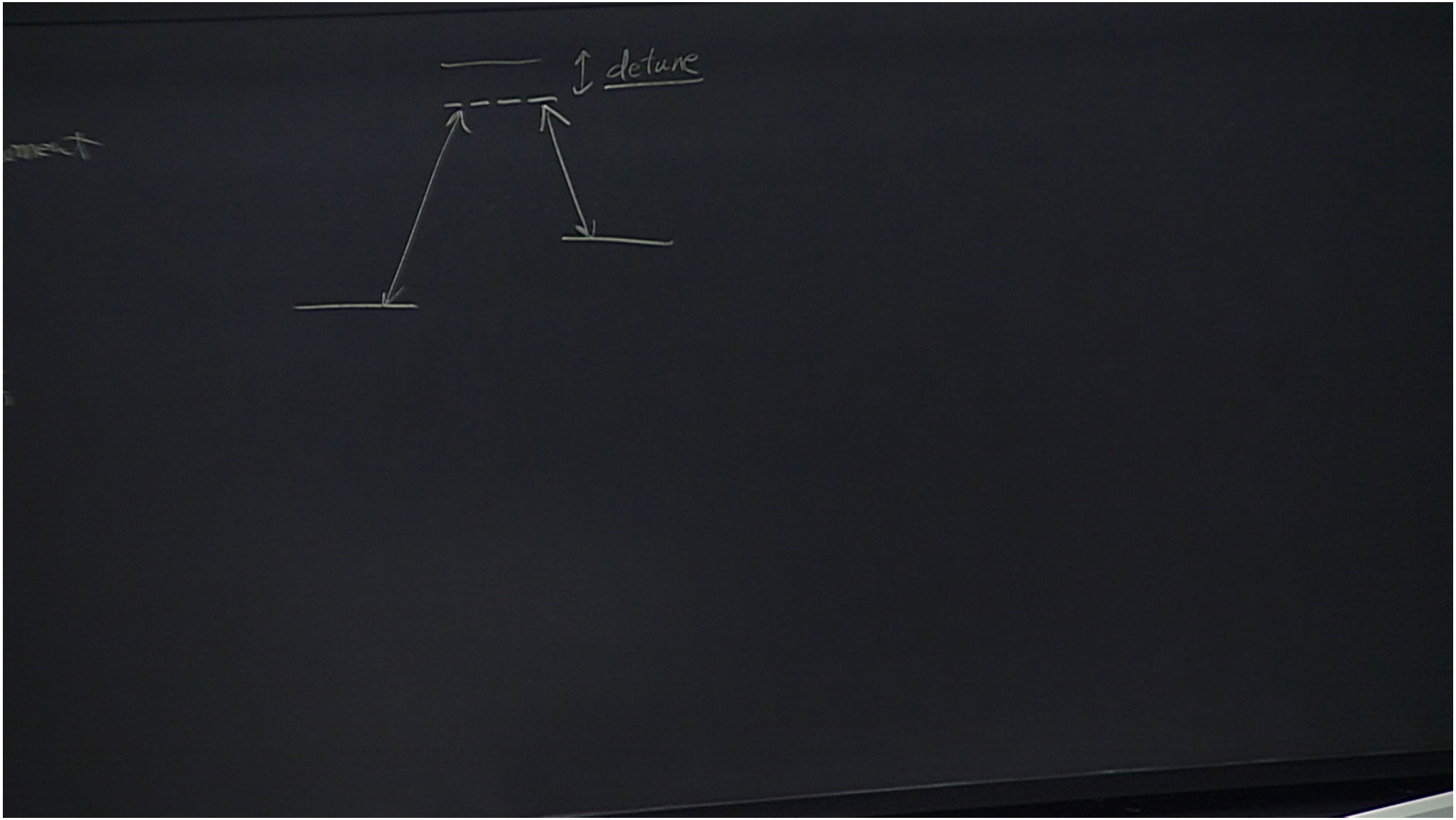
$$\mathcal{H}^{(1)} = \frac{-i}{2\tau}\int_0^\tau dt_2 \int_0^{t_2} dt_1 \left[\mathcal{H}(t_2), \mathcal{H}(t_1)\right]$$

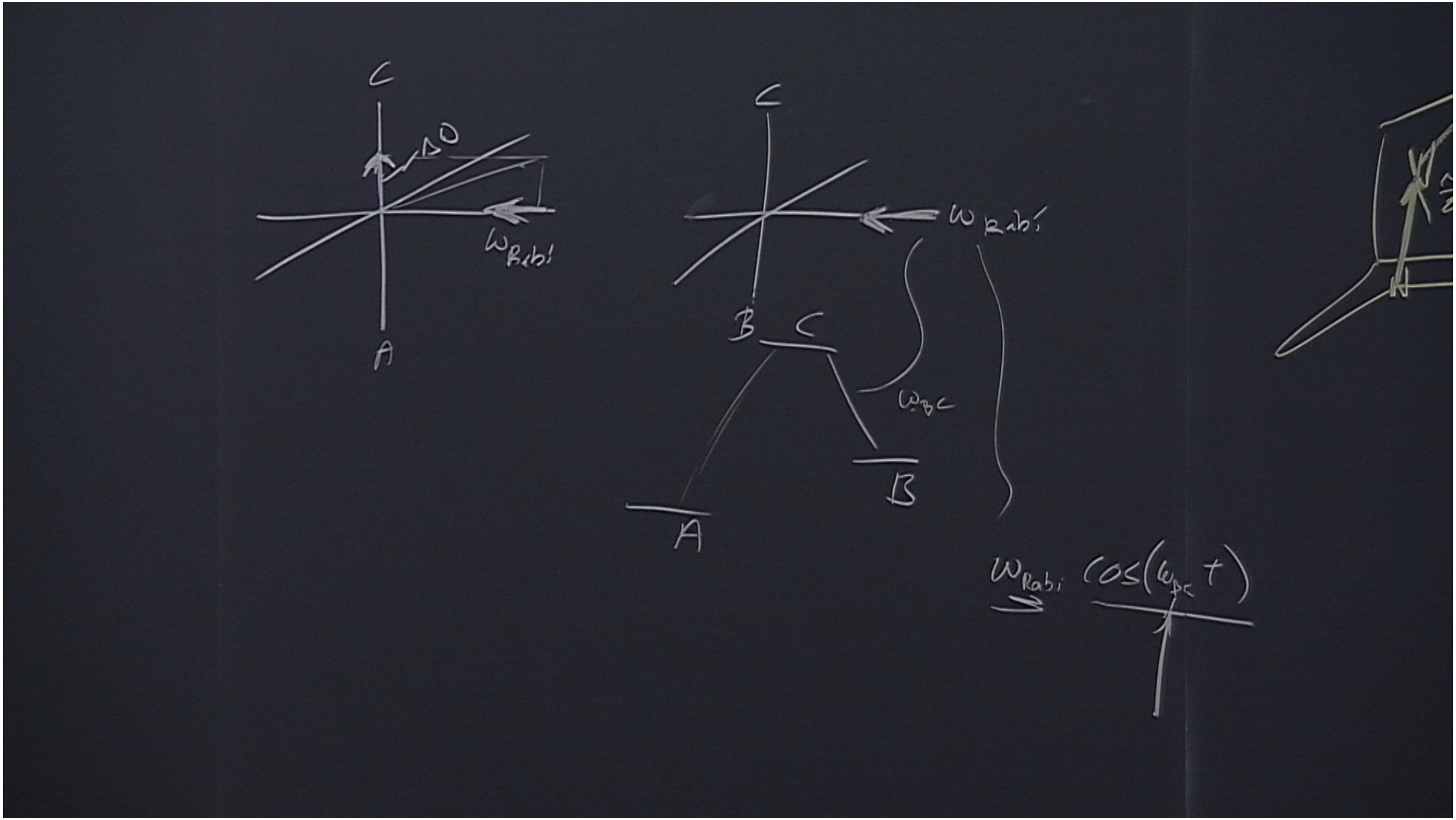
$\sigma_z \sigma_z$ ⟶ average Hamiltonia $\sigma \cdot \sigma$




noise couple in via
total magnetic moment
total magnetic moment = 0
∴ use only these 2 states;
weakly allowed


noise couple in via
total magnetic moment
ωRabi
ωRabi
total magnetic moment = 0
∴ use only these 2 states;
weakly allowed


detune


C
Δ0
ω_{Rabi}
A
C
ω_{Rabi}
B
C
ω_{BC}
B
A
$\omega_{Rabi}\cos(\omega_{BC}t)$