

Title: Many-Body Localization in translation invariant systems?

Date: Sep 09, 2014 03:30 PM

URL: <http://pirsa.org/14090027>

Abstract: Roughly speaking, Many-Body Localization (MBL) refers to the state of a material that fails to thermalize. Though MBL has mostly been studied in quenched disordered systems, several authors have recently proposed that this phase could be realized in clean (translation invariant) systems too. In this talk, I will discuss this idea and ask to which extent an MBL phase can indeed be expected in systems without quenched disorder. Hopefully, the discussion shed also some light on the localization-delocalization transition for more generic many-body systems. From joint work with W. De Roeck (Leuven), M. Mueller (Trieste), M. Schiulaz (Trieste).



W. De Roeck | π Milbr-Schwarz

W. De Roeck | π Miller-Schulz

$$H = \sum_{X \in V} H_x \quad i \rightarrow \dots \rightarrow j$$

1) 'Empirical' $K(T) = \hbar_T \left(\int_0^{\infty} dt \sum_x J_x(t) J_0(0) \right)$

W. De Roeck | π Müller-Schulz

$$H = \sum_{X \in V} H_x \quad \overset{i}{\circ} \quad \overset{\rightarrow}{\dots} \quad \overset{\circ}{v}$$

1) 'Empirical' $K(T) = \bar{h}_T \left(\int_0^T dt \sum_x J_x(t) \right)$

2) 'Eigenstate' $H = \sum_x \sigma_x^{(3)} w_x$
 w_x i.i.d

W. De Roeck | π Müller-Schulz

$$H = \sum_{X \in V} H_x \quad i \rightarrow \dots \rightarrow v$$

1) 'Empirical' $K(T) = \frac{1}{T} \left(\int_0^T dt \sum_x J_x(t) J_0(0) \right)$

2) 'Eigenstate' $H = \sum_x \sigma_x^{(3)} w_x + J \left(\sigma_x^{(1)} \sigma_{x+1}^{(1)} + \sigma_{x+2}^{(1)} \right)$
 w_x i.i.d

W. De Roeck | π Miller-Schulz

$$H = \sum_{X \in V} H_X$$

1) 'Empirical'

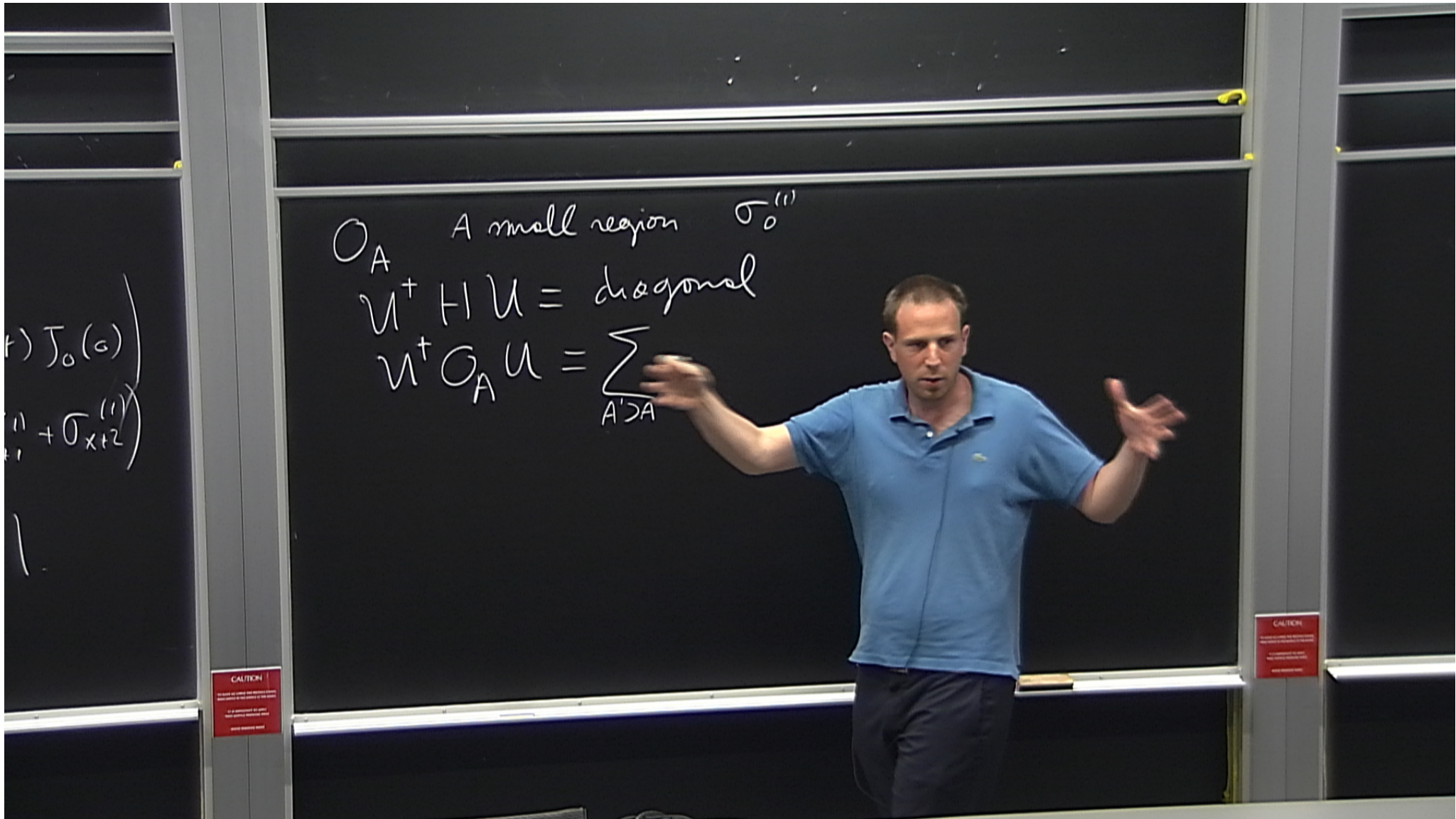
$$K(T) = \overline{h}_T \left(\int_0^{\infty} dt \sum_X J_X(t) J_0(0) \right)$$

2) 'Eigenstate'

$$H = \sum_X \sigma_X^{(3)} w_X + J \left(\sigma_X^{(1)} \sigma_{X+1}^{(1)} + \sigma_{X+2}^{(1)} \right)$$

w_X i.i.d

$$J \ll 1$$

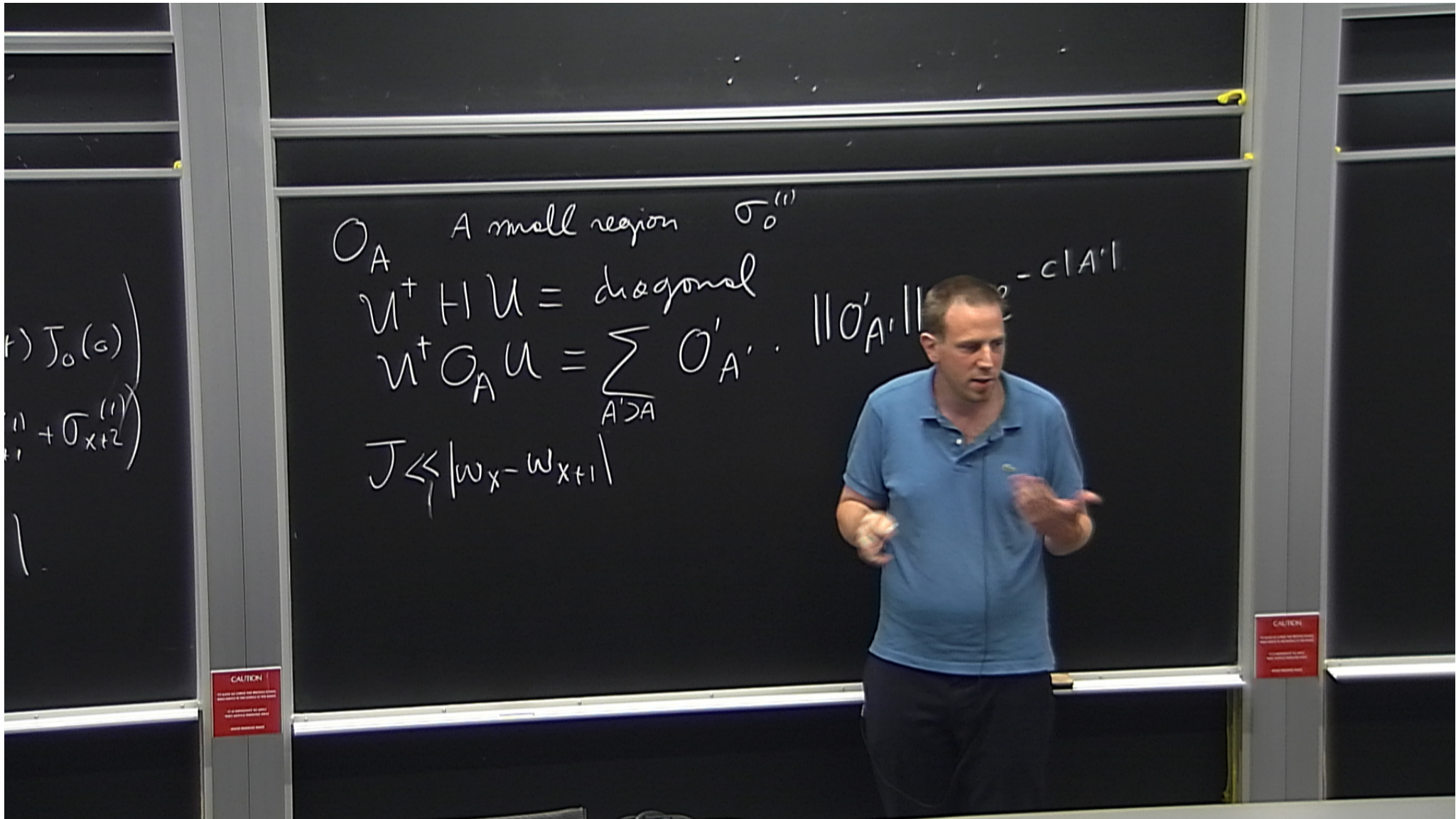


O_A A small region $\sigma_0^{(1)}$

$$U^T H U = \text{diagonal}$$

$$U^T O_A U = \sum_{A' \supset A} O_{A'}$$

$$\|O_{A'}\| \leq e^{-c|A'|}$$



O_A A small region $\sigma_0^{(1)}$

$$U^T H U = \text{diagonal}$$

$$U^T O_A U = \sum_{A' \neq A} O_{A'} \cdot \|O_{A'}\|^{-2} - c|A'|$$

$$J \ll |\omega_x - \omega_{x+1}|$$

$$J_0(\sigma) \\ + \sigma_{x+2}^{(1)}$$

CAUTION

CAUTION

O_A A small region

$$U^\dagger H U = \text{diagonal}$$

$$U^\dagger O_A U = \sum_{A' \supset A} O_{A'}$$

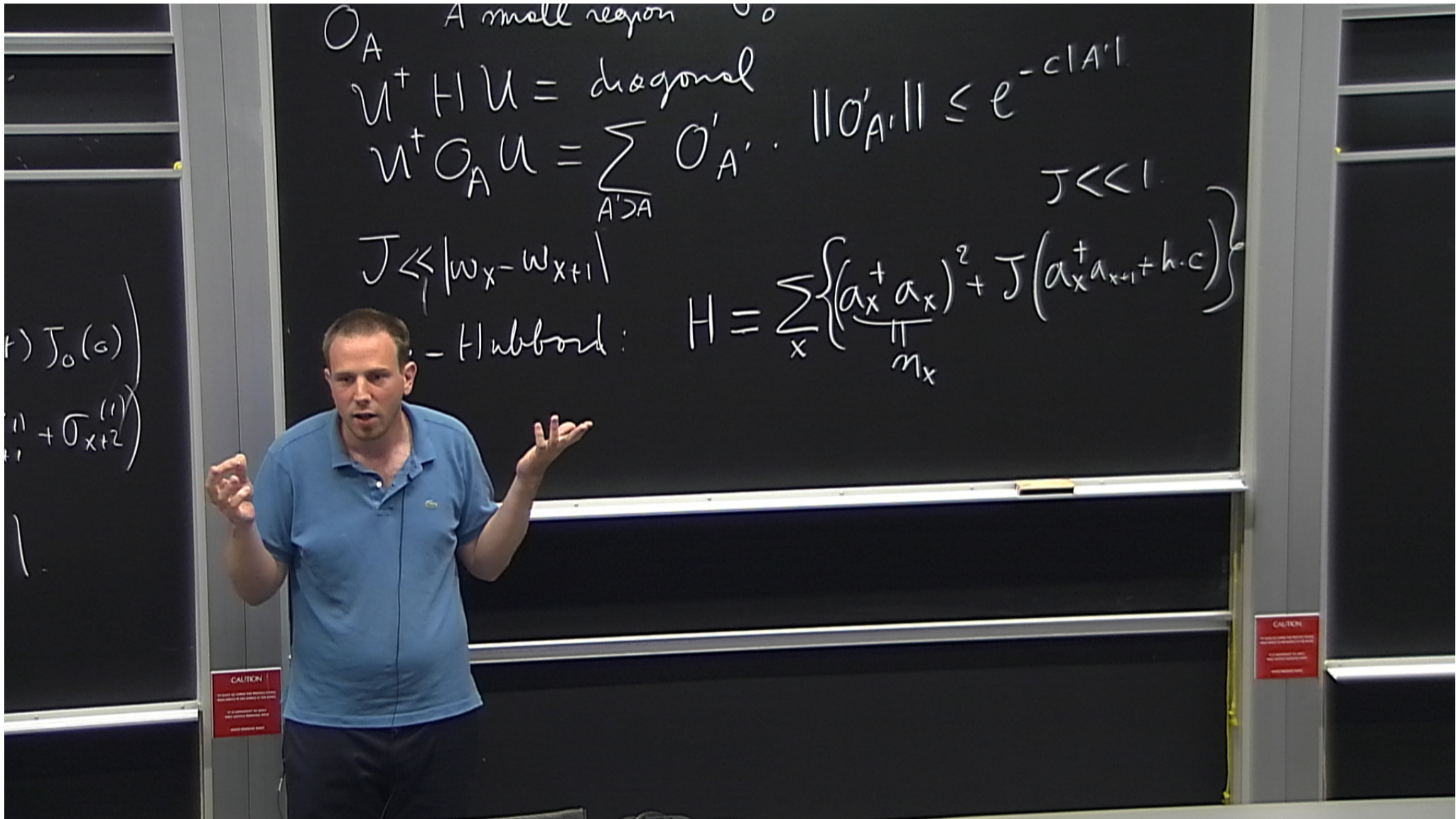
$$\|O_{A'}\| \leq e^{-c|A'|}$$

$$J \ll |w_x - w_{x+1}|$$

Bose-Hubbard: $H = \sum_x \left\{ a_x^\dagger a_x \right\} + J \left(a_x^\dagger a_{x+1} + h.c. \right)$

$$J_0(c)$$
$$+ \sigma_{x+2}$$

CAUTION



O_A A small region

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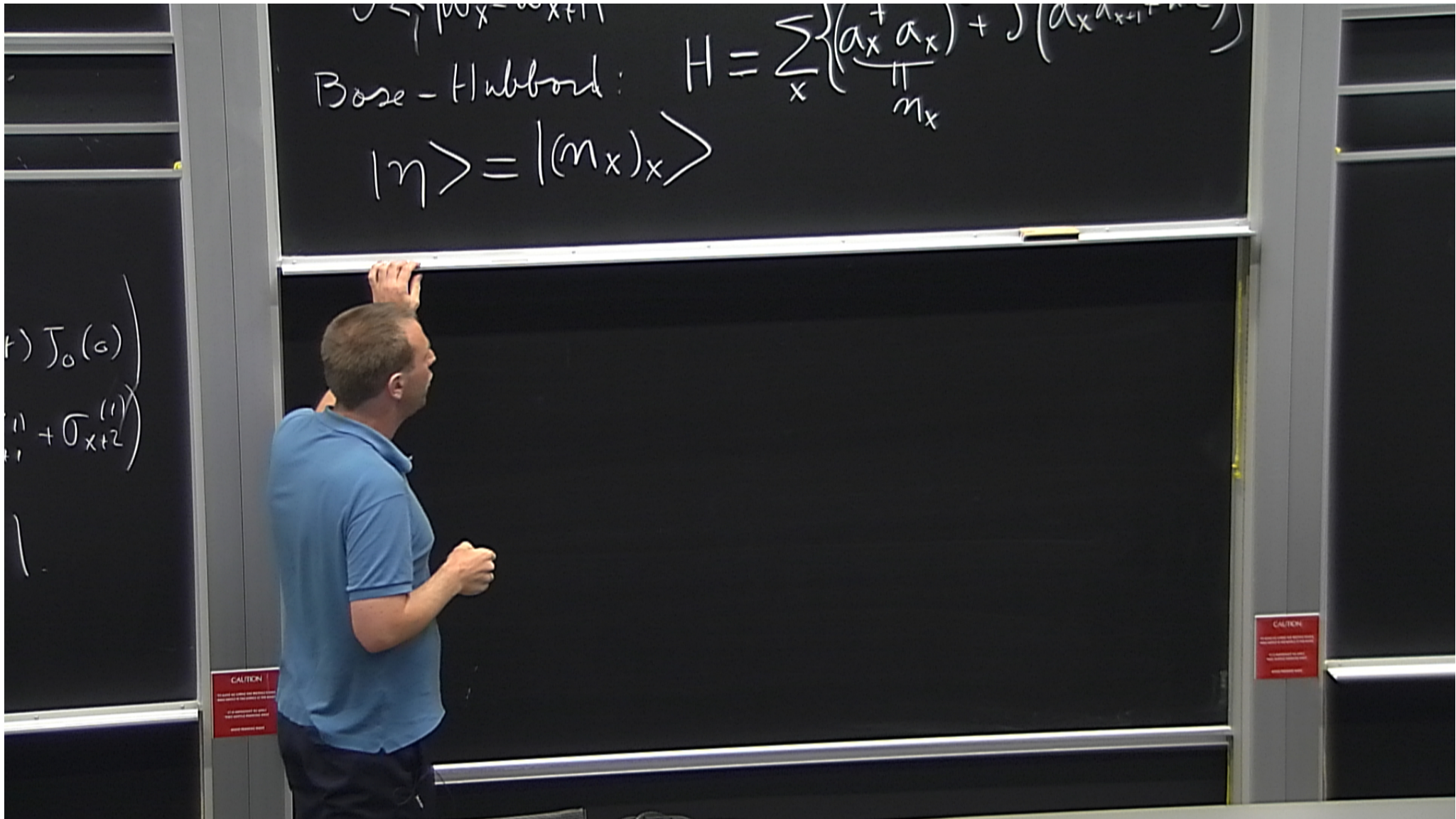
$J \ll 1$

$$J \ll |w_x - w_{x+1}|$$

- Hubbard:

$$H = \sum_x \left\{ \frac{\hbar^2}{m_x} (a_x^\dagger a_x)^2 + J (a_x^\dagger a_{x+1} + h.c.) \right\}$$

$J_0(c)$
 σ_{x+2}



$$J \ll |w_x - w_{x+1}|$$

$$\text{Bose-Hubbard: } H = \sum_x \left\{ \frac{(a_x^\dagger a_x)^2}{m_x} + J (a_x^\dagger a_{x+1} + \text{h.c.}) \right\}$$

$$|\eta\rangle = |(m_x)_x\rangle \quad m_x \sim T^{1/2} \gg 1$$

$$t) \mathcal{J}_0(c)$$

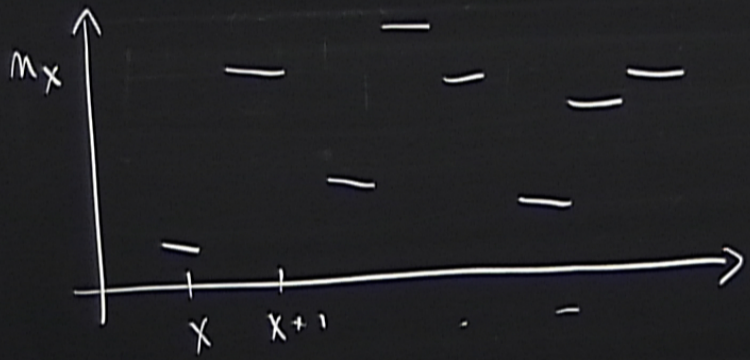
$$+ \sigma_{x+2}^{(1)}$$

CAUTION

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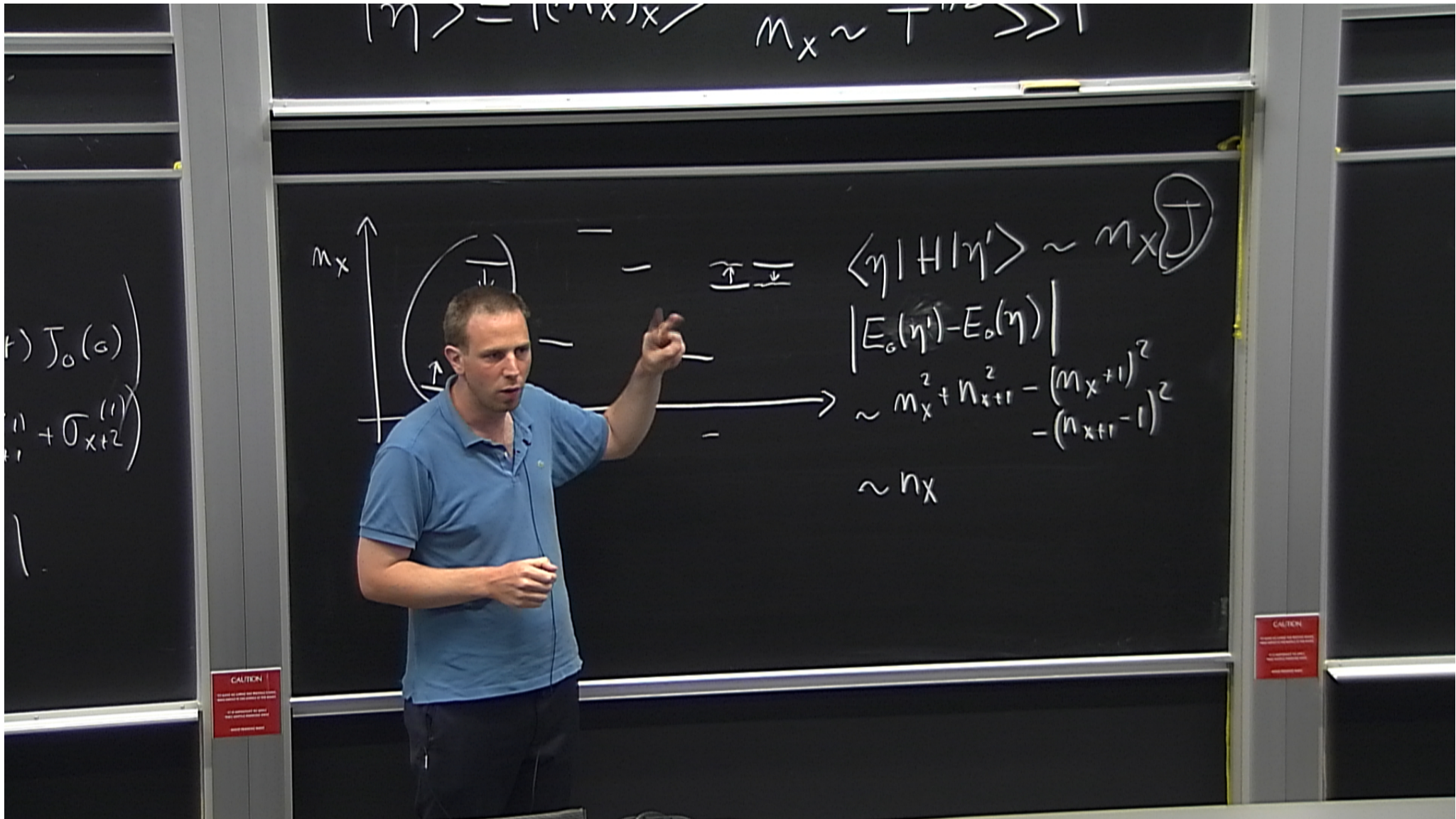
$$|\eta\rangle = |(m_x)_x\rangle \quad m_x \sim T^{1/2} \gg 1$$

$$t) \int_0(\sigma)$$
$$+ \sigma_{x+2}^{(1)}$$



CAUTION
Do not touch the chalkboard
or the chalkboard eraser
as they are hot.

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or the chalkboard eraser
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$$\langle \eta | H | \eta' \rangle \sim n_x J$$

$$m_x \sim T^{-1} \gg 1$$



$$\langle \eta | H | \eta' \rangle \sim n_x J$$

$$|E_0(\eta') - E_0(\eta)|$$

$$\sim m_x^2 + n_{x+1}^2 - (m_x + 1)^2 - (n_{x+1} - 1)^2$$

$$\sim n_x$$

$$f) J_0(\sigma)$$

$$+ \sigma_{x+2}^{(1)}$$

CAUTION
 Do not lean on the blackboard
 as it is supported by glass
 and may shatter under stress

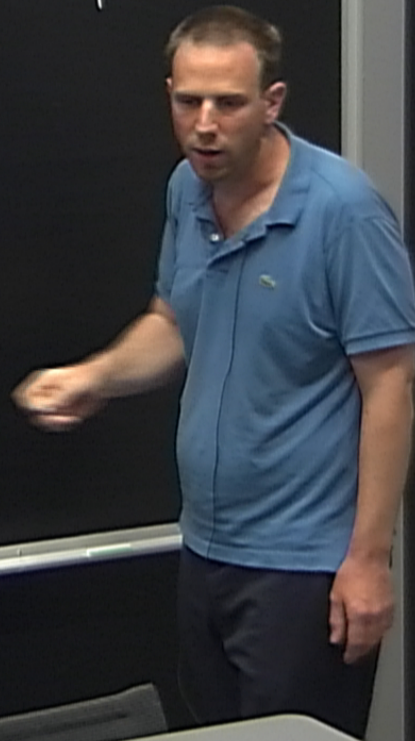
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Carlo, Becca, Schiro, Fabrizio (2012)

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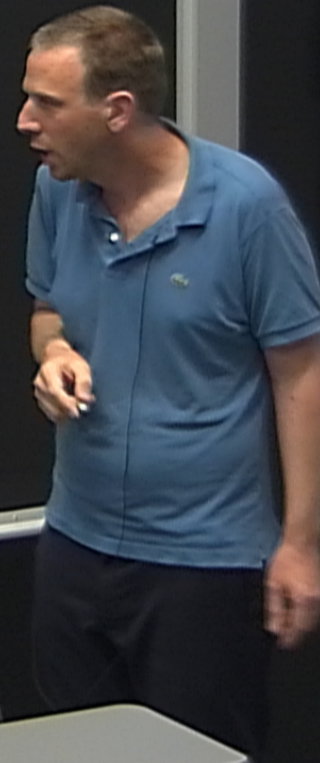
$$H = \sum (a_x^\dagger a_x)^q + (a_{x+1}^\dagger a_x + h.c.) \quad q > 2$$



CAUTION
DO NOT TOUCH THE BOARD WHEN IT IS HOT
OR WHEN IT IS BEING USED BY OTHERS
PLEASE REPORT ANY DAMAGE TO THE STAFF

Carleo, Becca, Schiro, Fabrizio (2012)

$$H = \sum_{m_x} (a_x^+ a_x)^{q-1} + \underbrace{(a_{x+1}^+ a_x + h c)}_{m_x} \quad q > 2.$$



Carleso, Becca, Schiro, Fabrizio (2012)

$$H = \sum_{m_x^{q-1}} (a_x^+ a_x)^q + \underbrace{(a_{x+1}^+ a_x + h c)}_{m_x} \quad q > 2.$$

$K(T)$ non perturbative in $T \rightarrow \infty$.

$$K(T) \leq O\left(\frac{1}{T^n}\right) \quad \forall n.$$

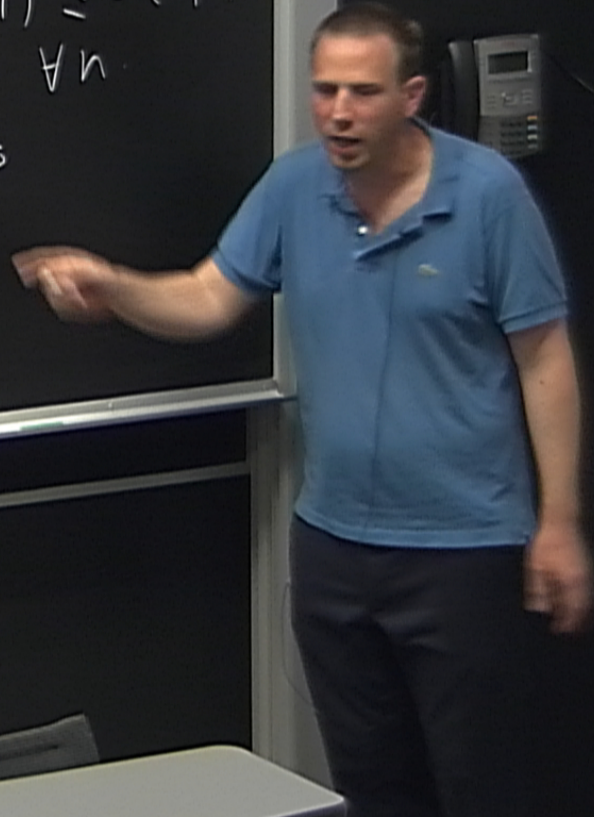
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$$\lim_{T \rightarrow \infty} T^n \left(\frac{1}{h T} \int_0^{T^n} dt \sum_x \gamma_x(t) \rho_0(0) \right) = 0$$



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Carlo, Becca, Schiro, Fabrizio (2012)

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CAUTION
 ALL INFORMATION CONTAINED
 HEREIN IS UNCLASSIFIED EXCEPT
 WHERE SHOWN OTHERWISE





W. De Roeck | π Miller-Schulz

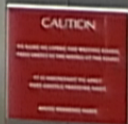
$$H = \sum_{x \in V} H_x \quad i \rightarrow \dots \rightarrow v$$

'Empirical'
'Eigenstate'

$$\kappa(T) = \frac{1}{h_T} \int_0^{\infty} dt \sum_x J_x(t) J_0(0)$$

$$H = \sum_x \sigma_x^{(z)} w_x + J \left(\sigma_x^{(1)} \sigma_{x+1}^{(1)} + \sigma_{x+2}^{(1)} \right)$$

w_x i.i.d. $J \ll 1$

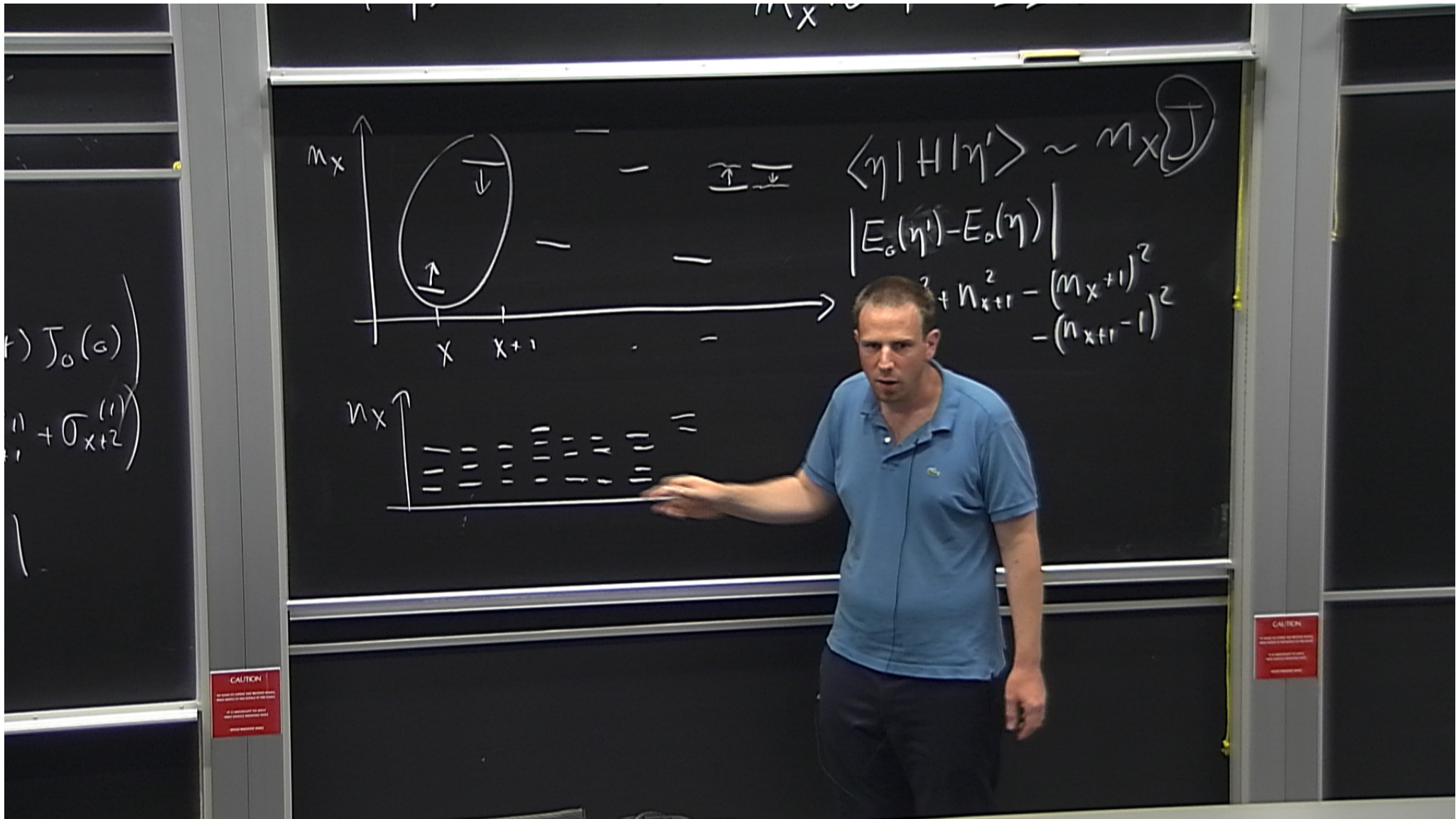


W. De Roeck | π Miller-Schulz

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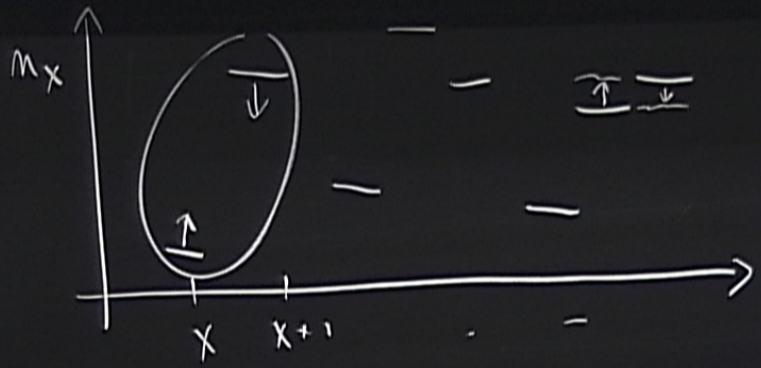
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 w_x i.i.d. $J \ll 1$



$$\int_0^{\infty} \sigma_0(\omega)$$

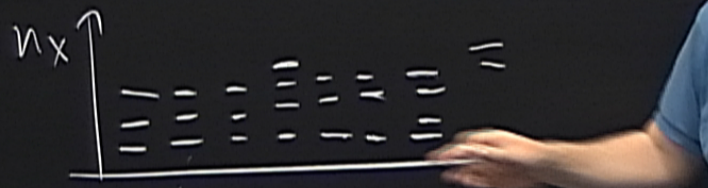
$$+ \sigma_{x+2}^{(1)}$$



$$\langle \eta | H | \eta' \rangle \sim n_x J$$

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CAUTION

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$$W^\dagger O_A U = \sum_{A' \supset A} O_{A'}$$

$$J \ll 1$$

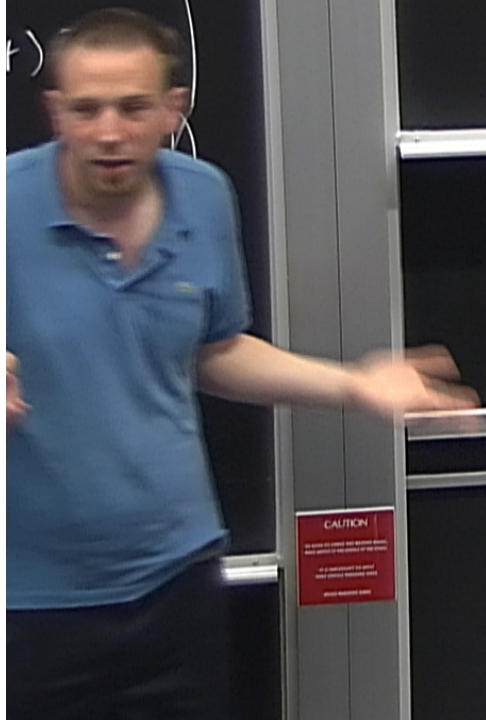
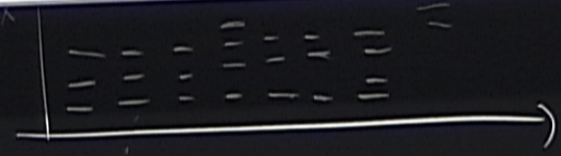
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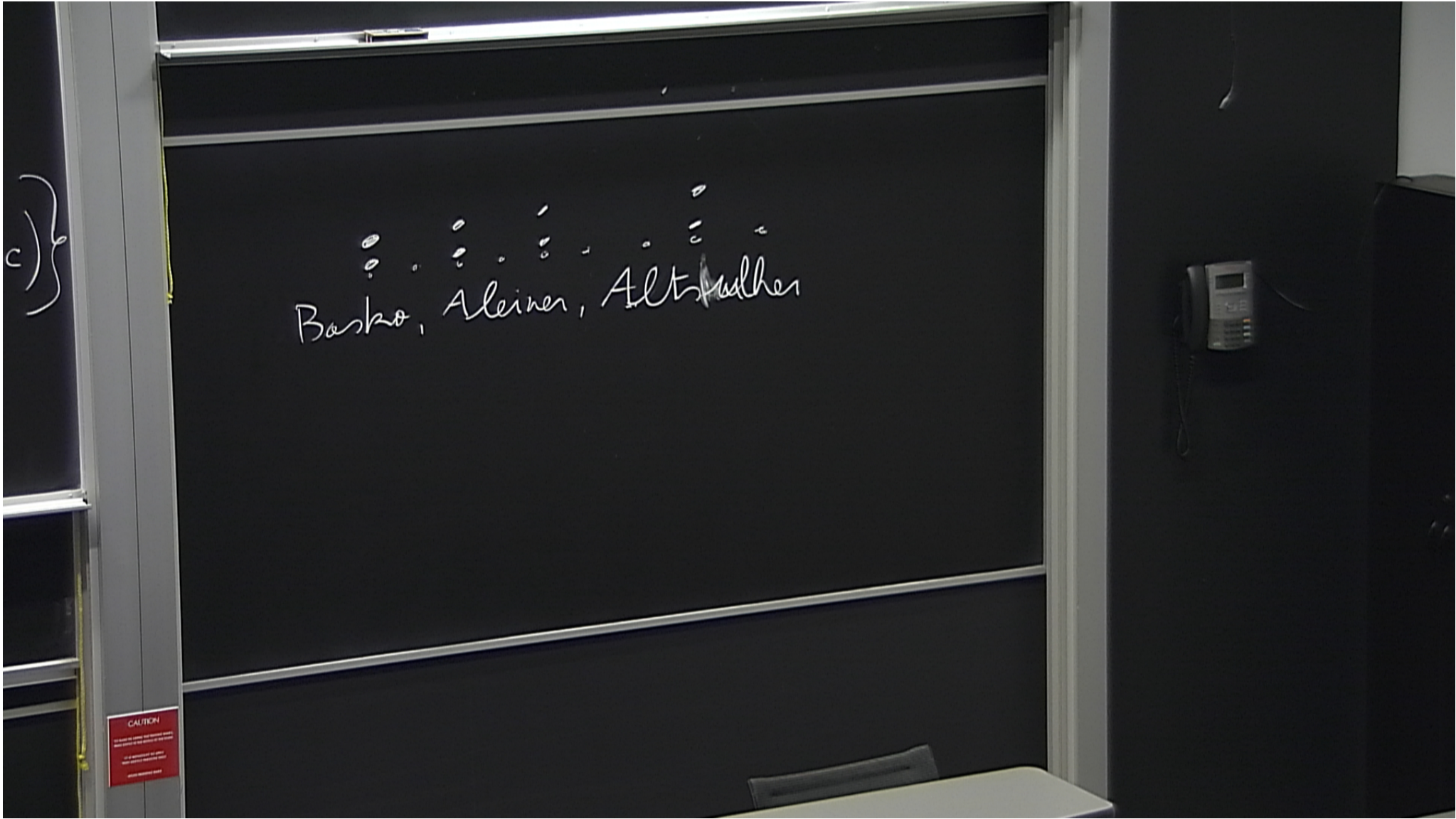
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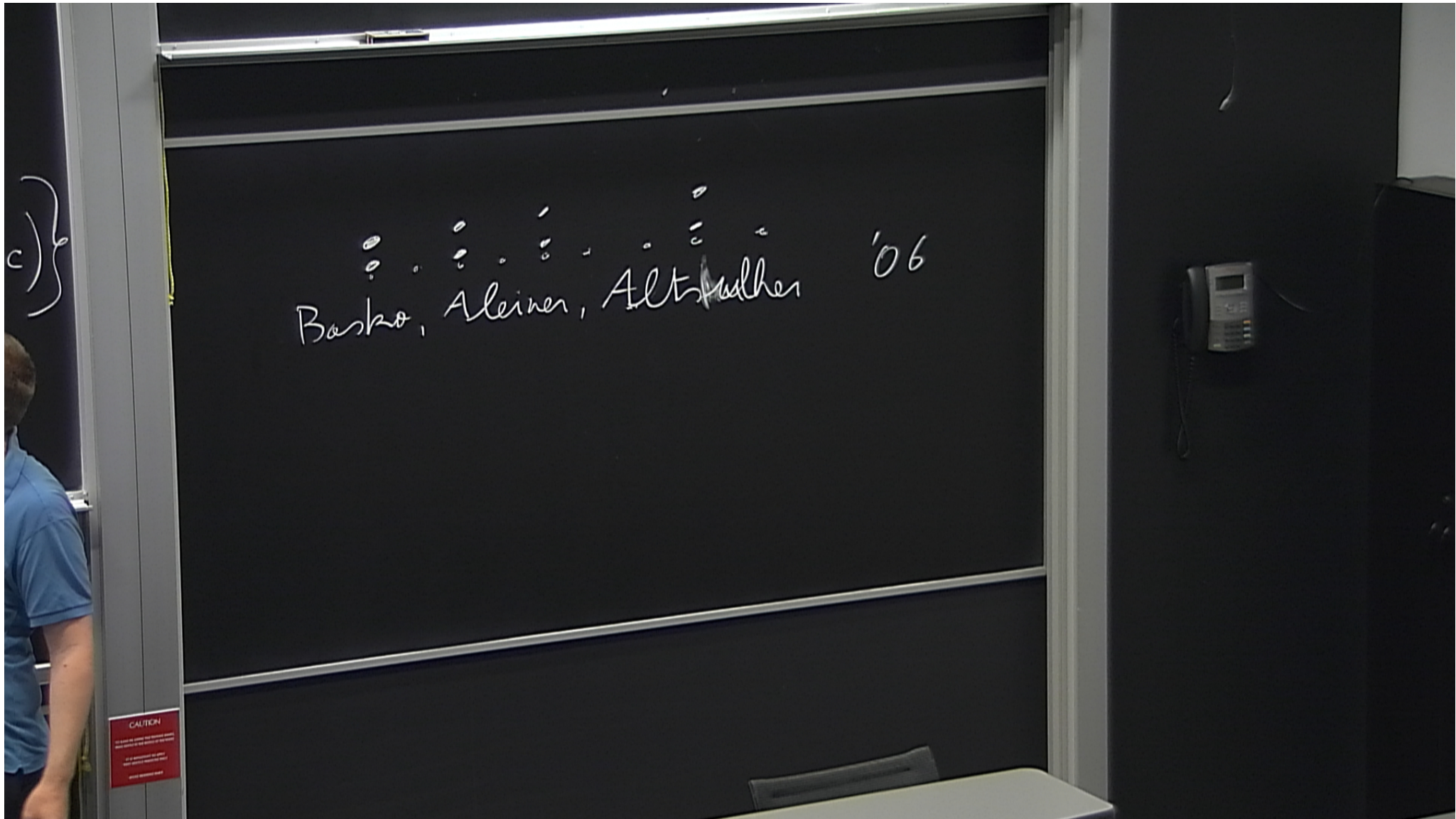
$$m_x \sim T^{1/2} \gg 1$$



CAUTION
Do not touch the glass or the board.
If a panel of the glass is broken, do not touch the board.

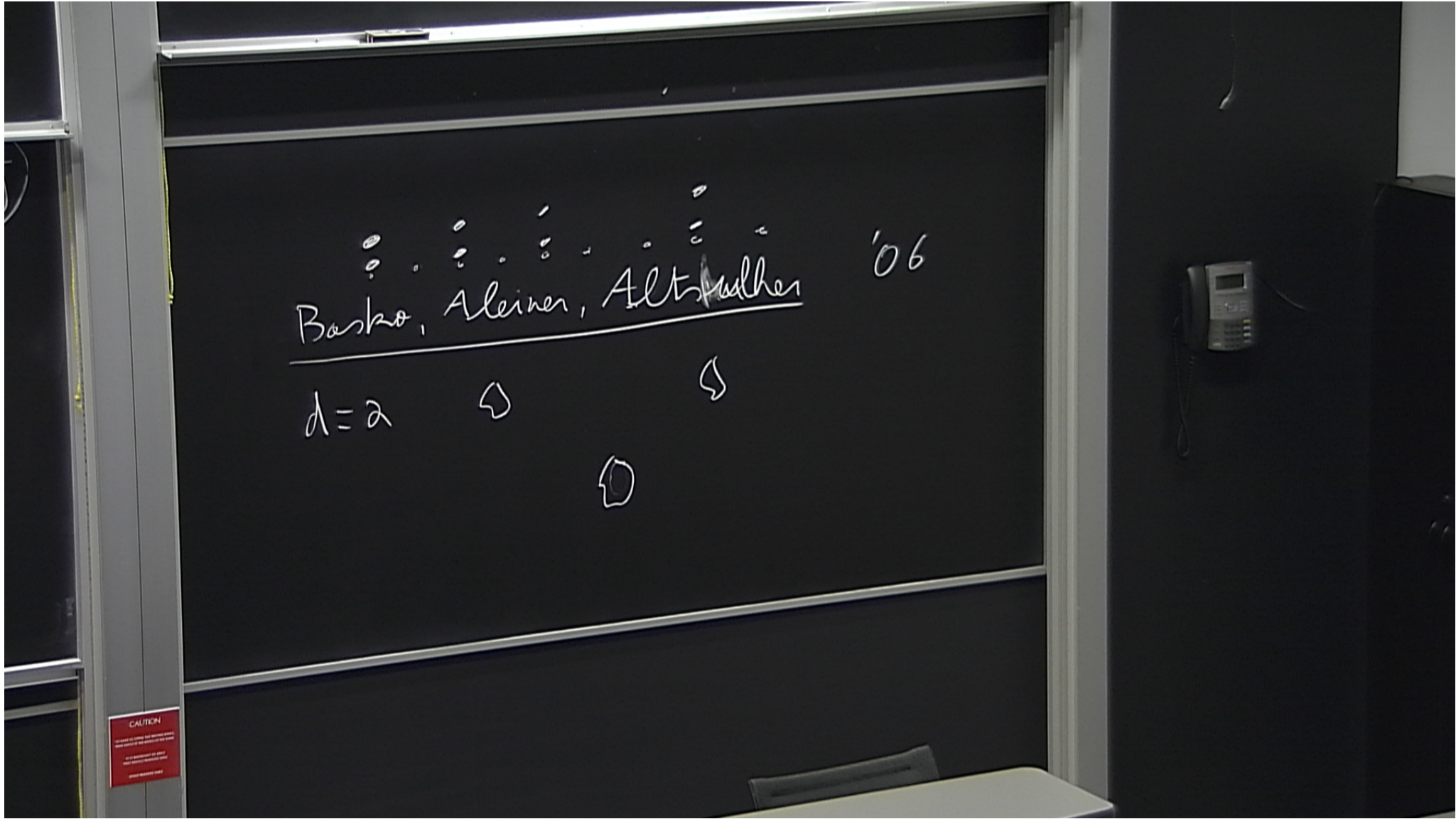
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$J \ll |w_x - w_{x+1}|$ $J \ll 1$
 Bose-Hubbard: $H = \sum_x \left\{ \frac{(a_x^\dagger a_x)^2}{m_x} + J \dots \right\}$
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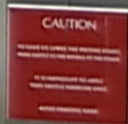


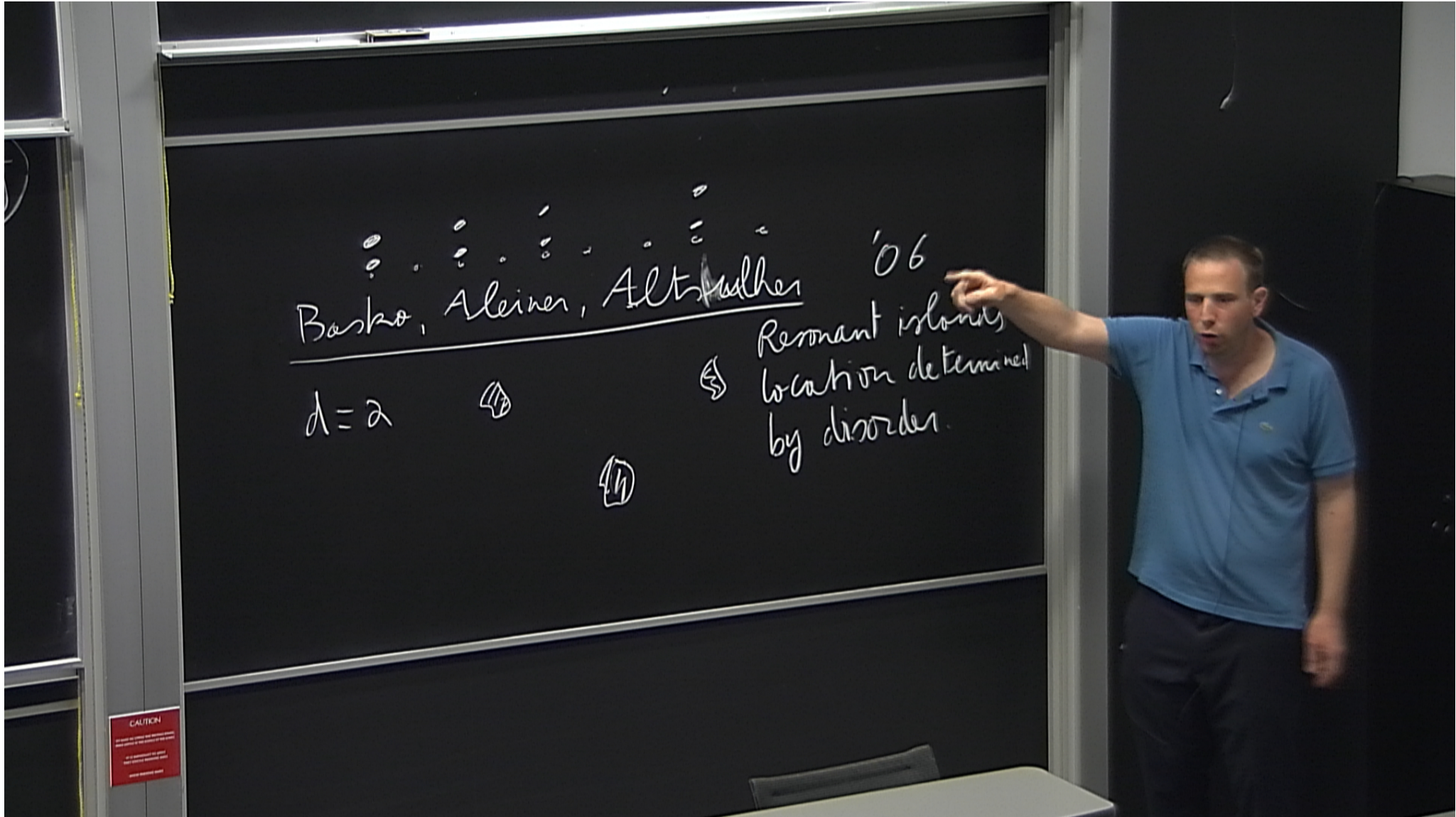
W. De Roeck | π Miller-Schulz

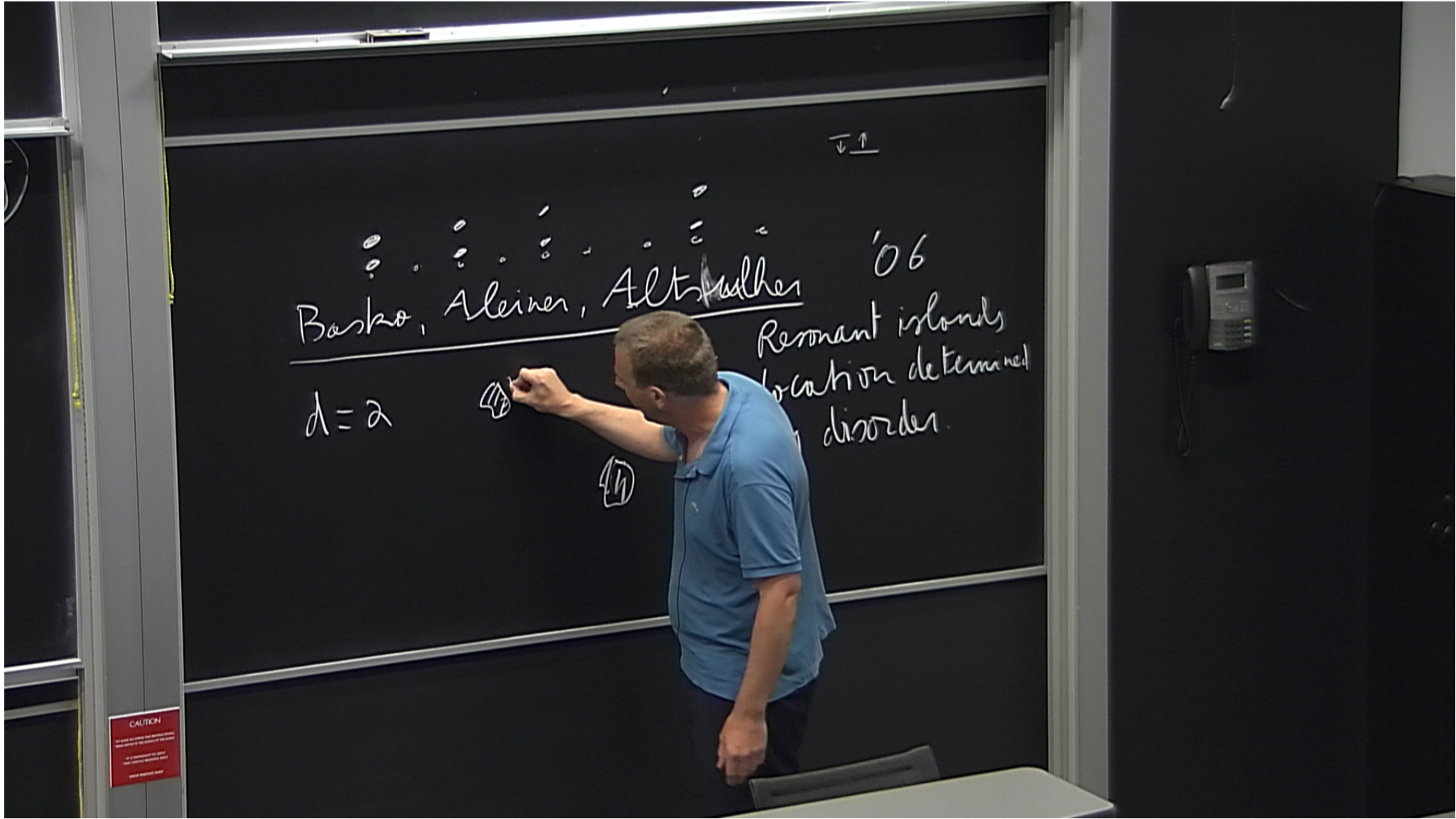
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1) 'Empirical' $K(T) = \frac{1}{h_T} \int_0^T dt \sum_x J_x(t) J_0(0)$

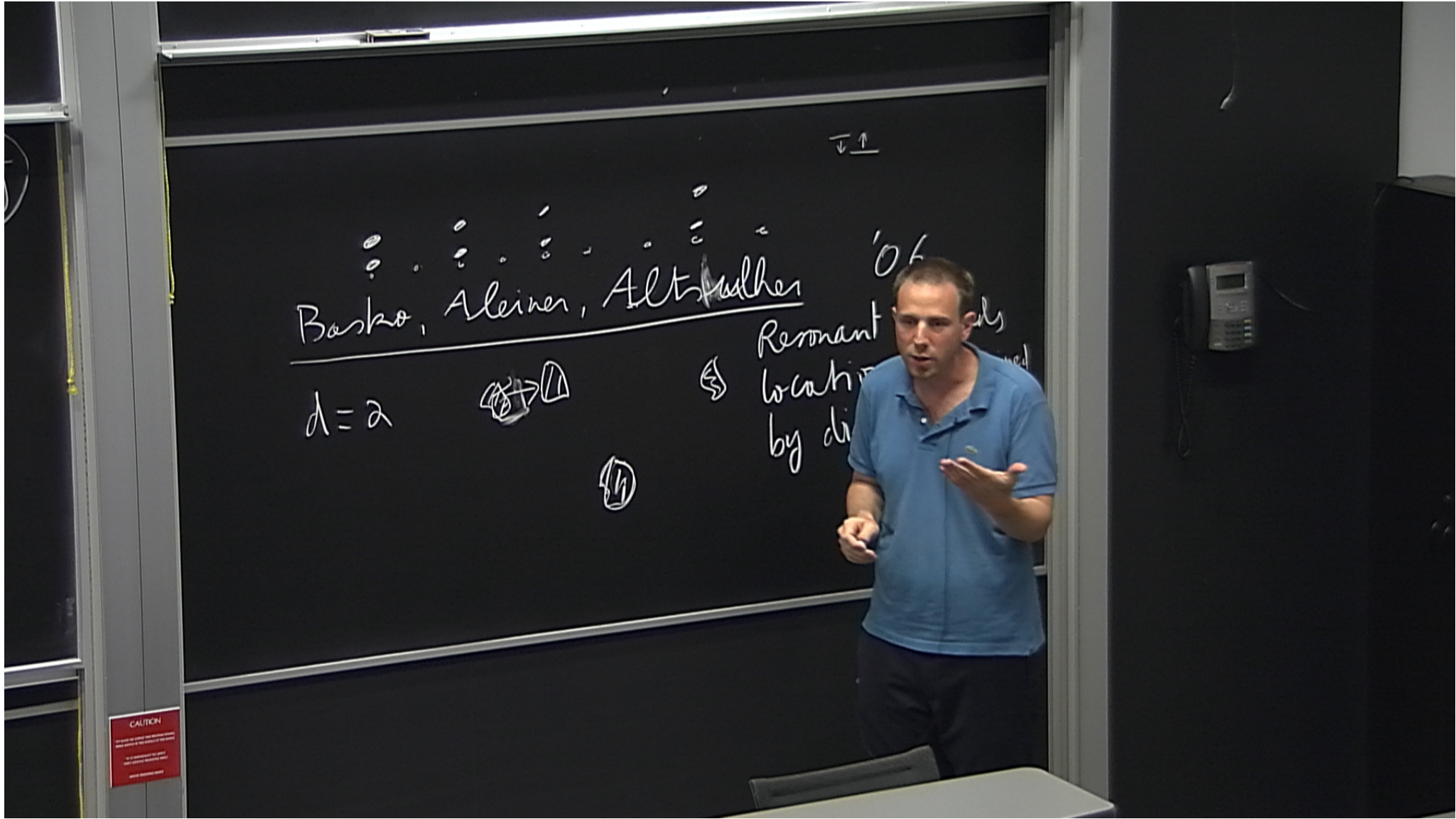
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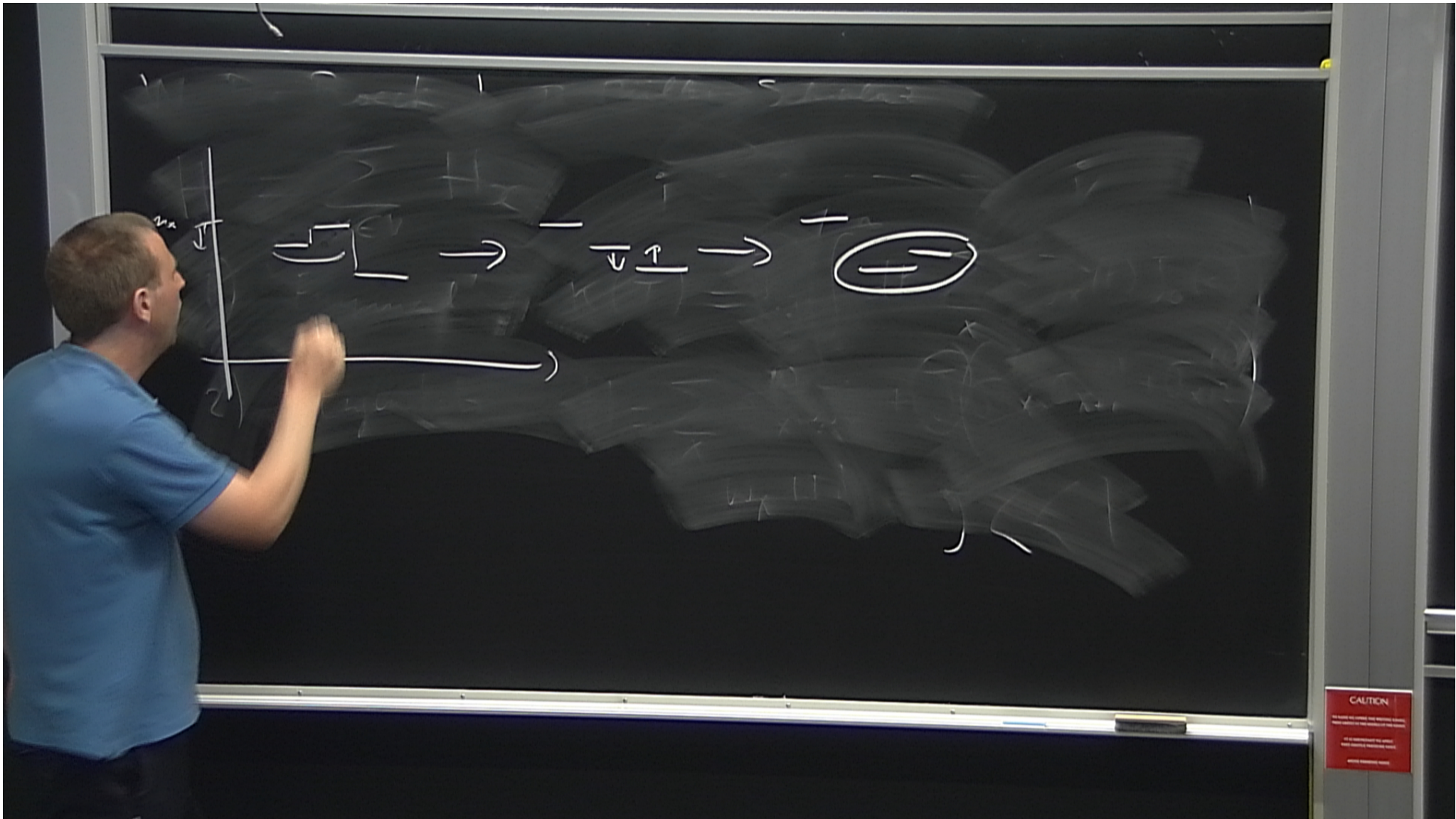


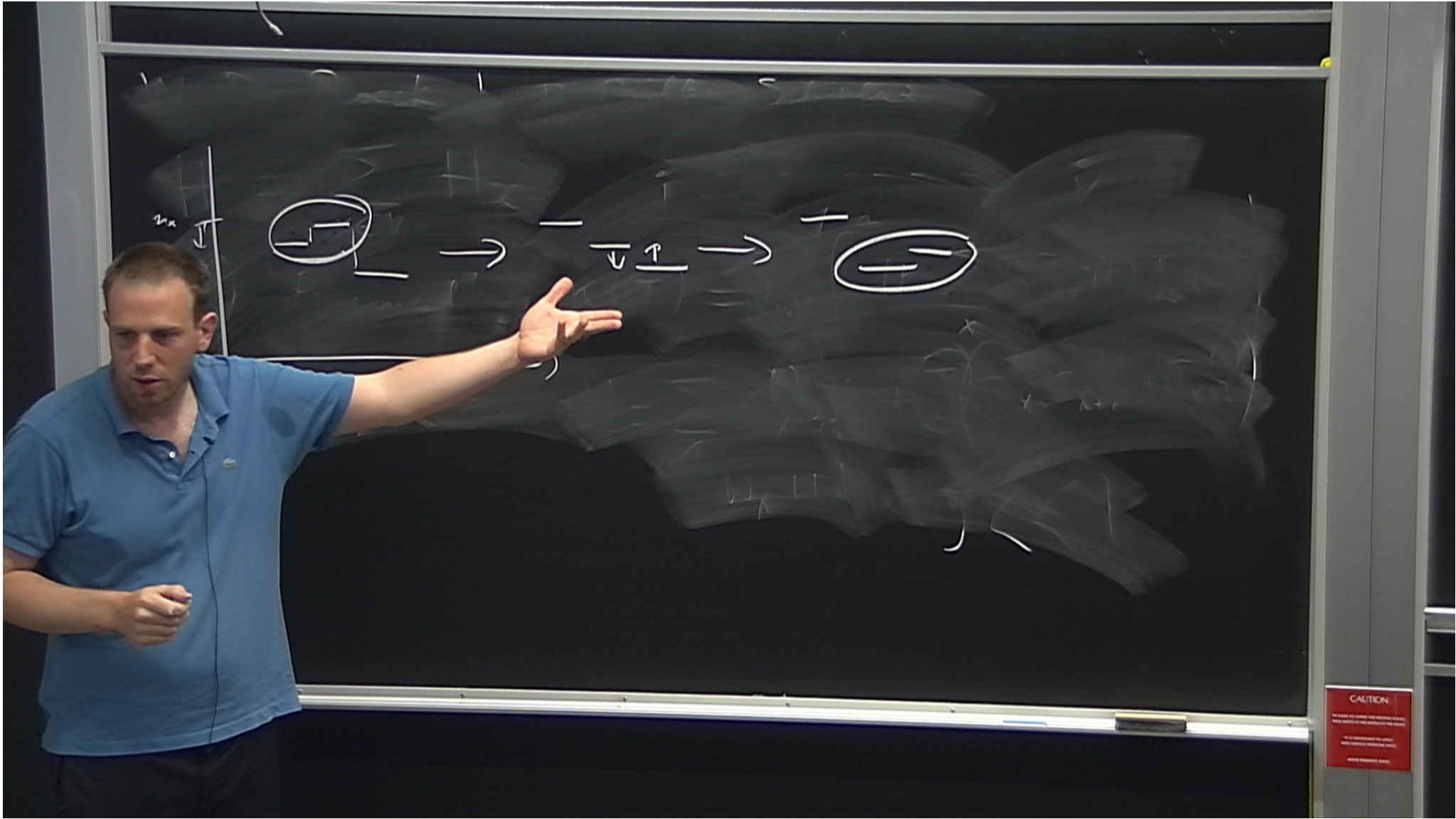


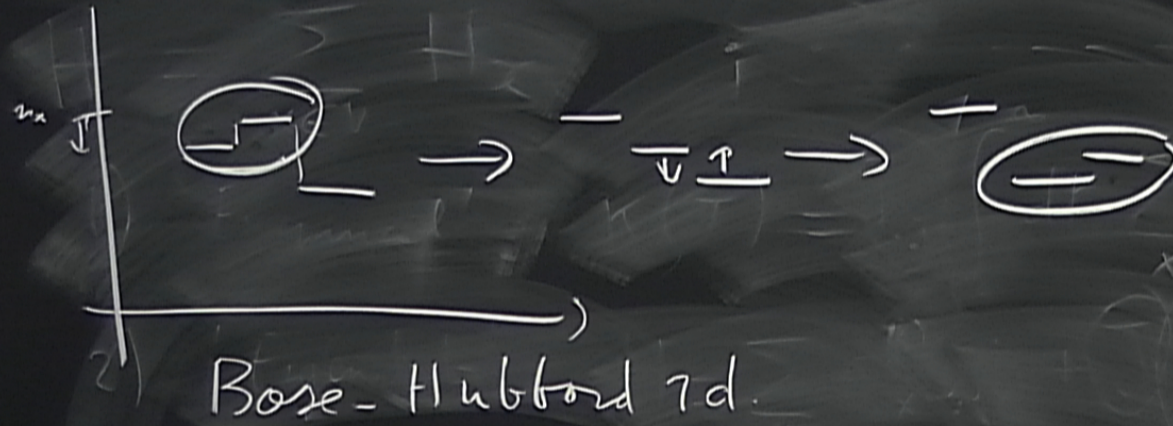




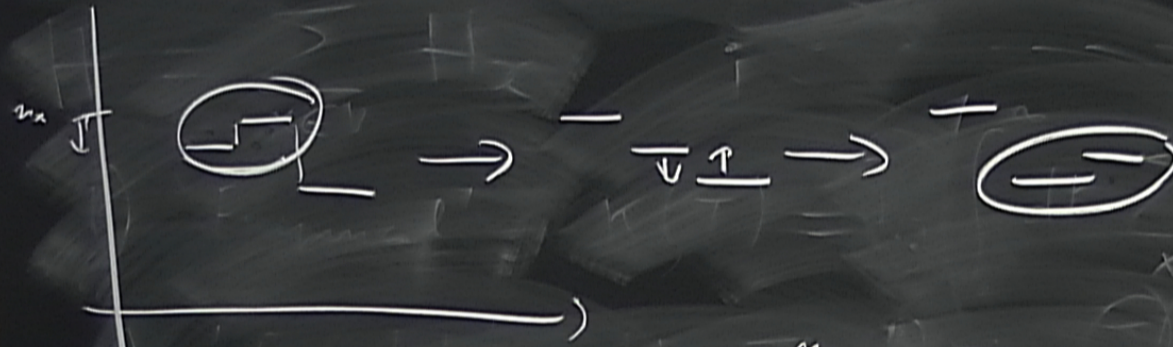




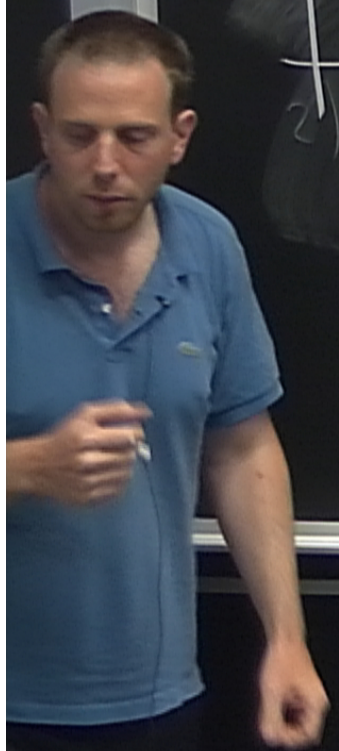
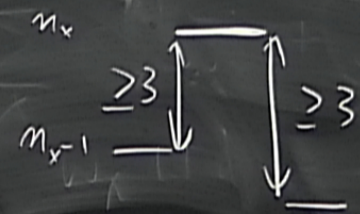




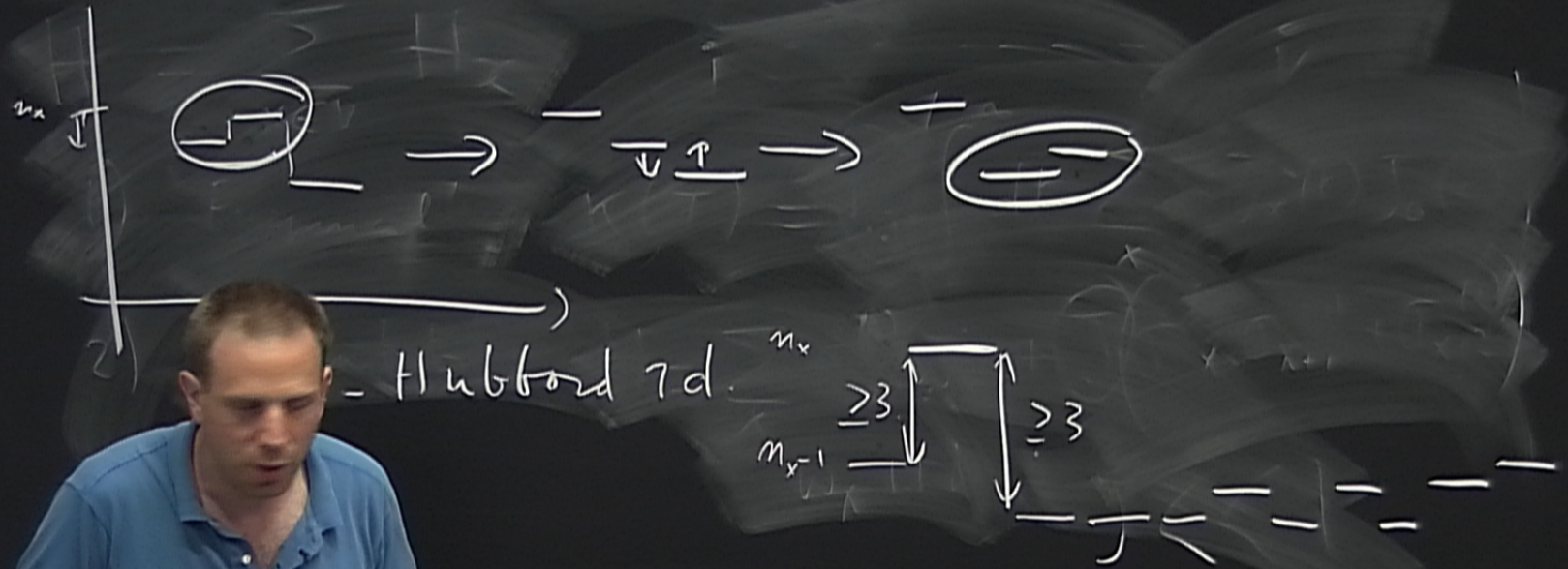
CAUTION
 THE BOARD IS HOTTER THAN MEXICAN CHILI.
 PLEASE BE CAREFUL AND DON'T TOUCH IT.
 ALL INFORMATION IS GREAT
 AND SHOULD BE KEPT
 AT ALL TIMES.
 WWW.MEXICAN.COM



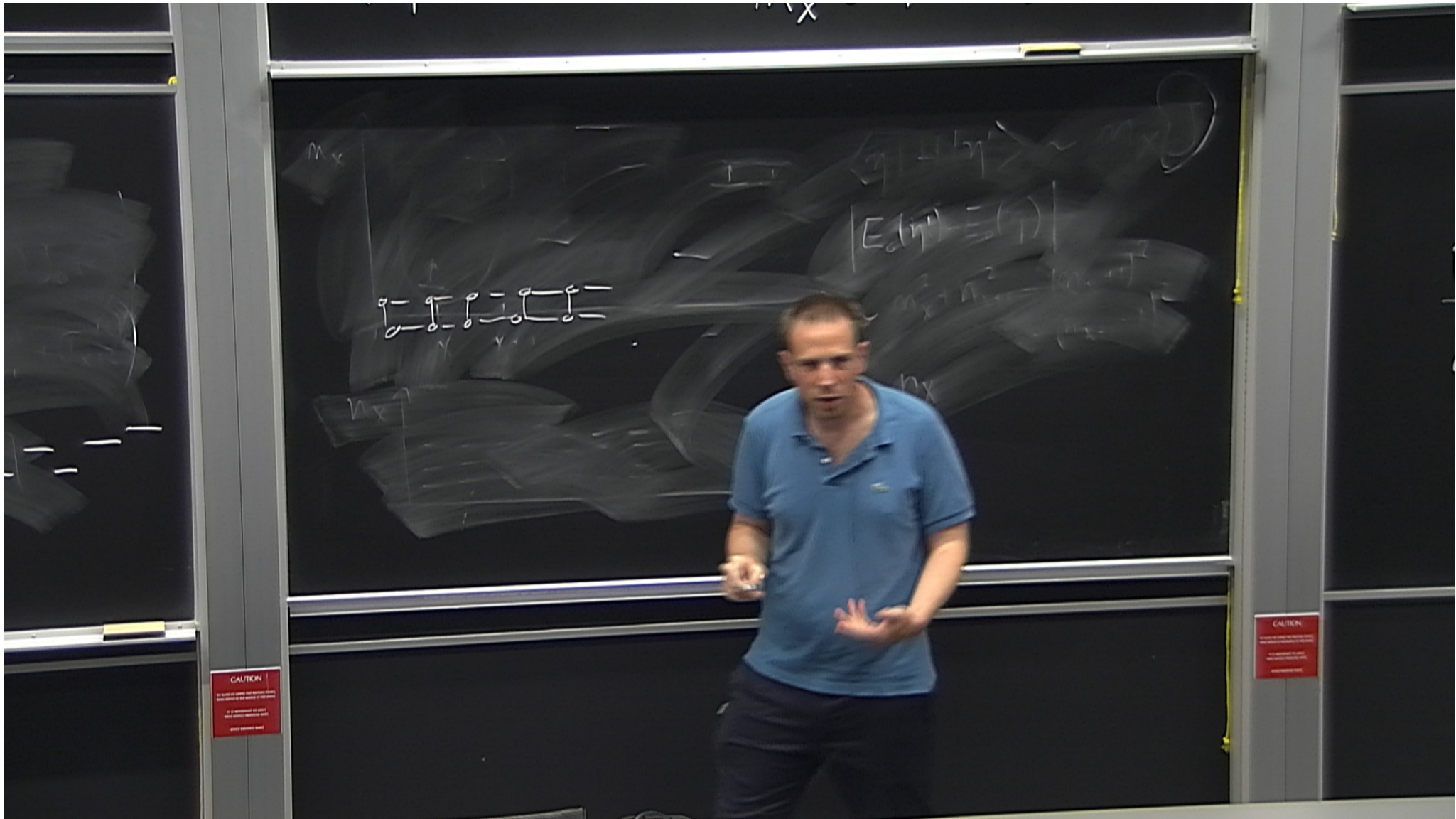
Bose-Hubbard 7d.

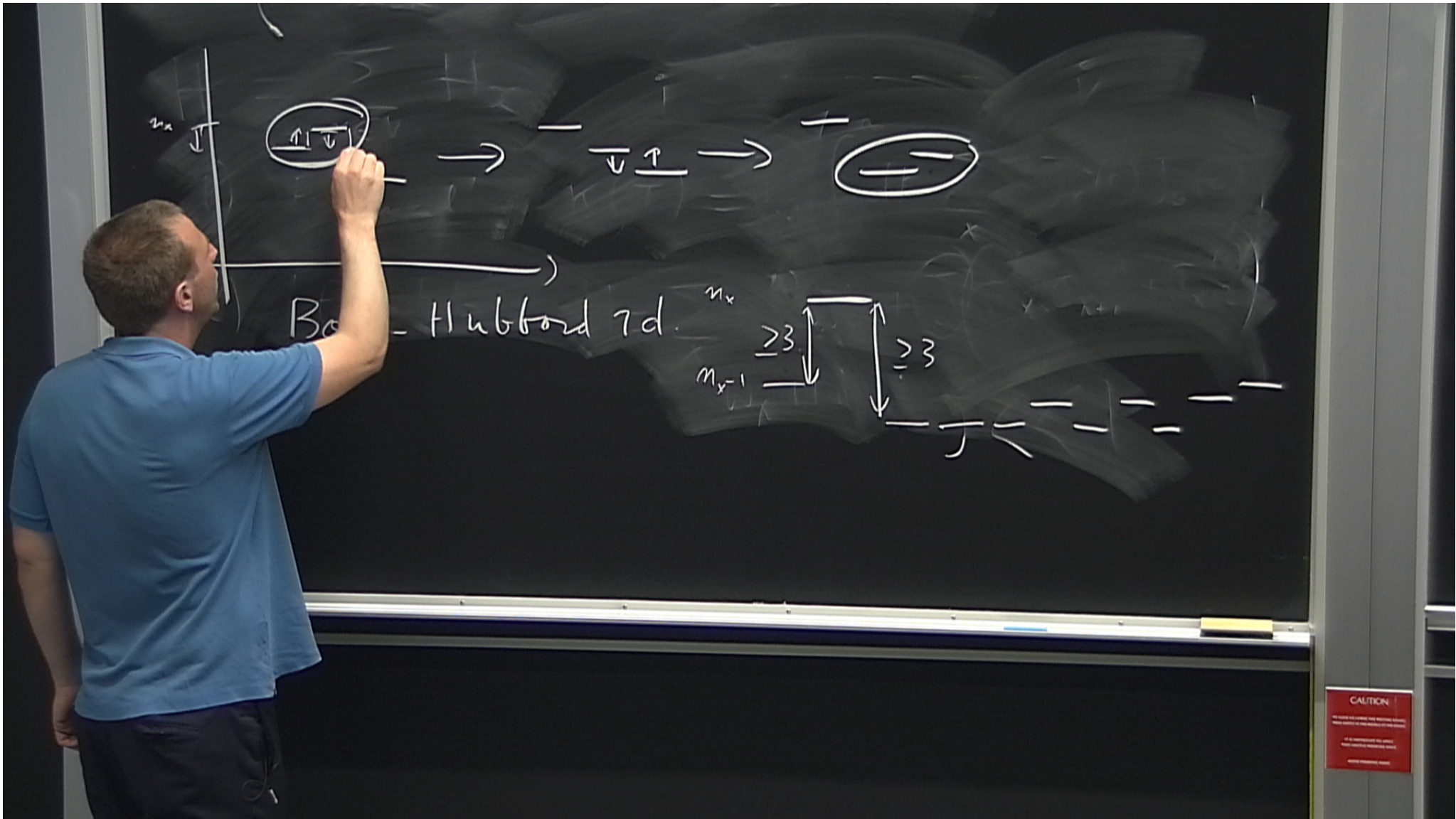


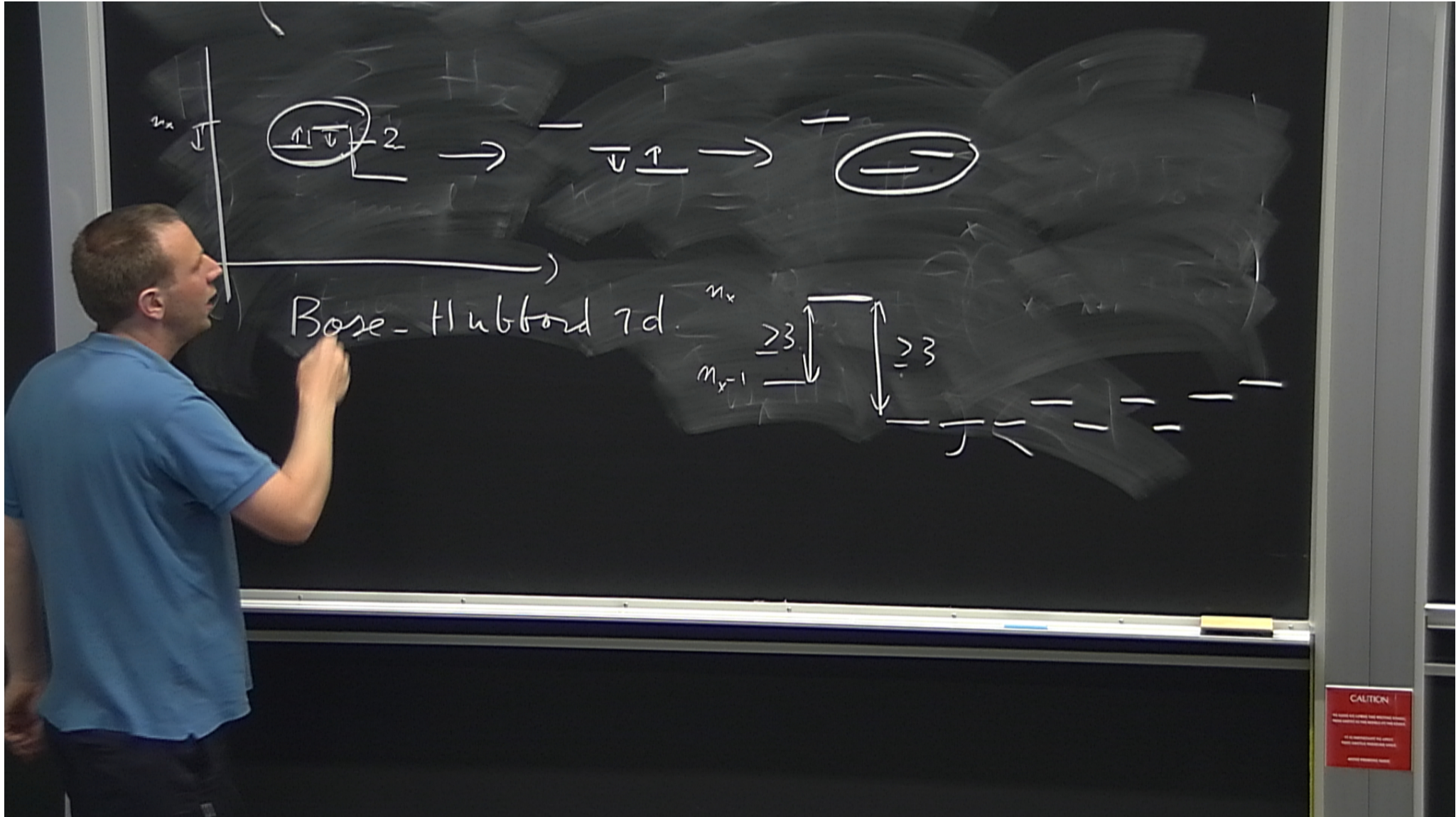
CAUTION
 Do not touch the surface of the board.
 Do not touch the board when it is hot.
 Do not touch the board when it is wet.

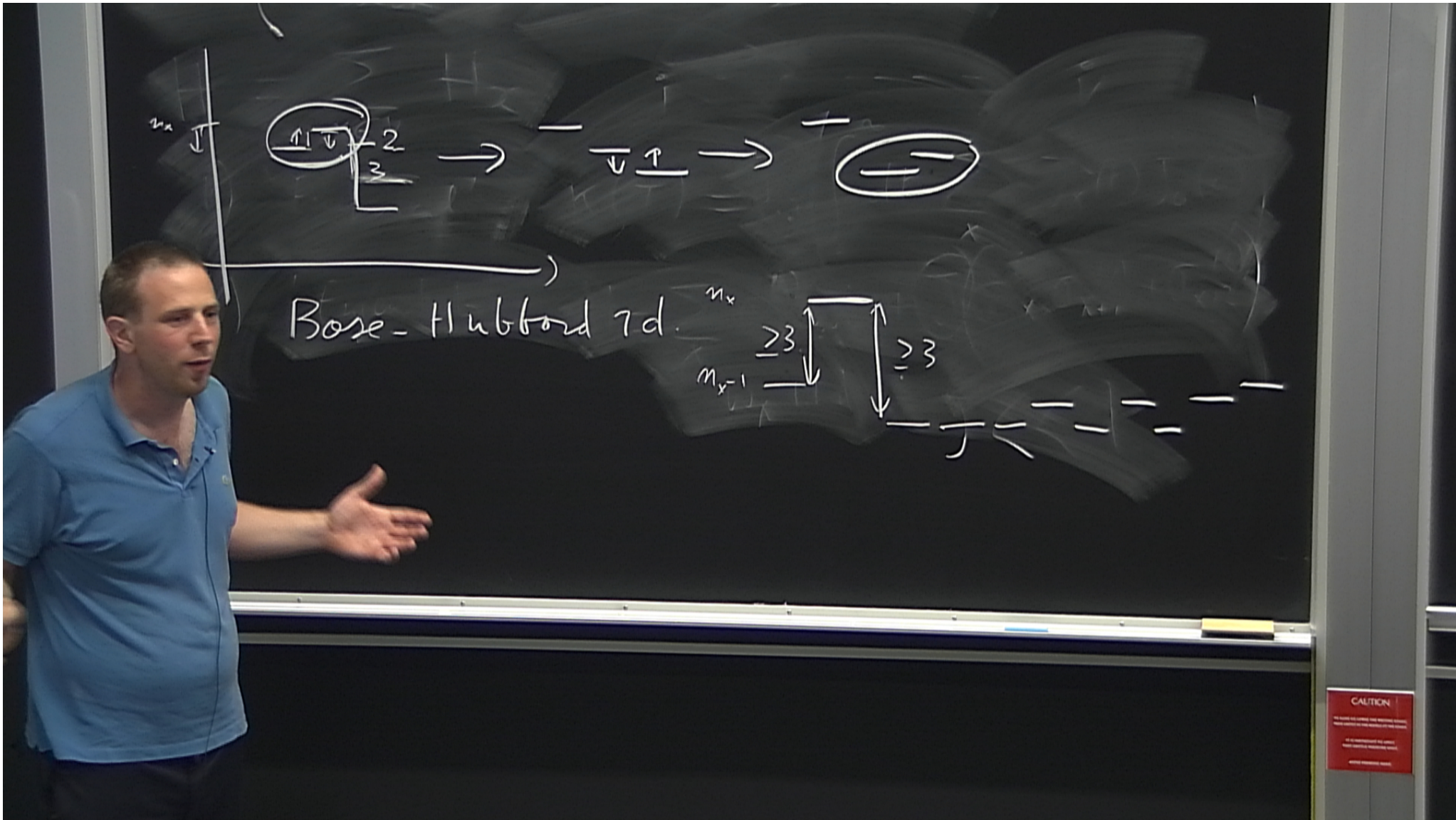


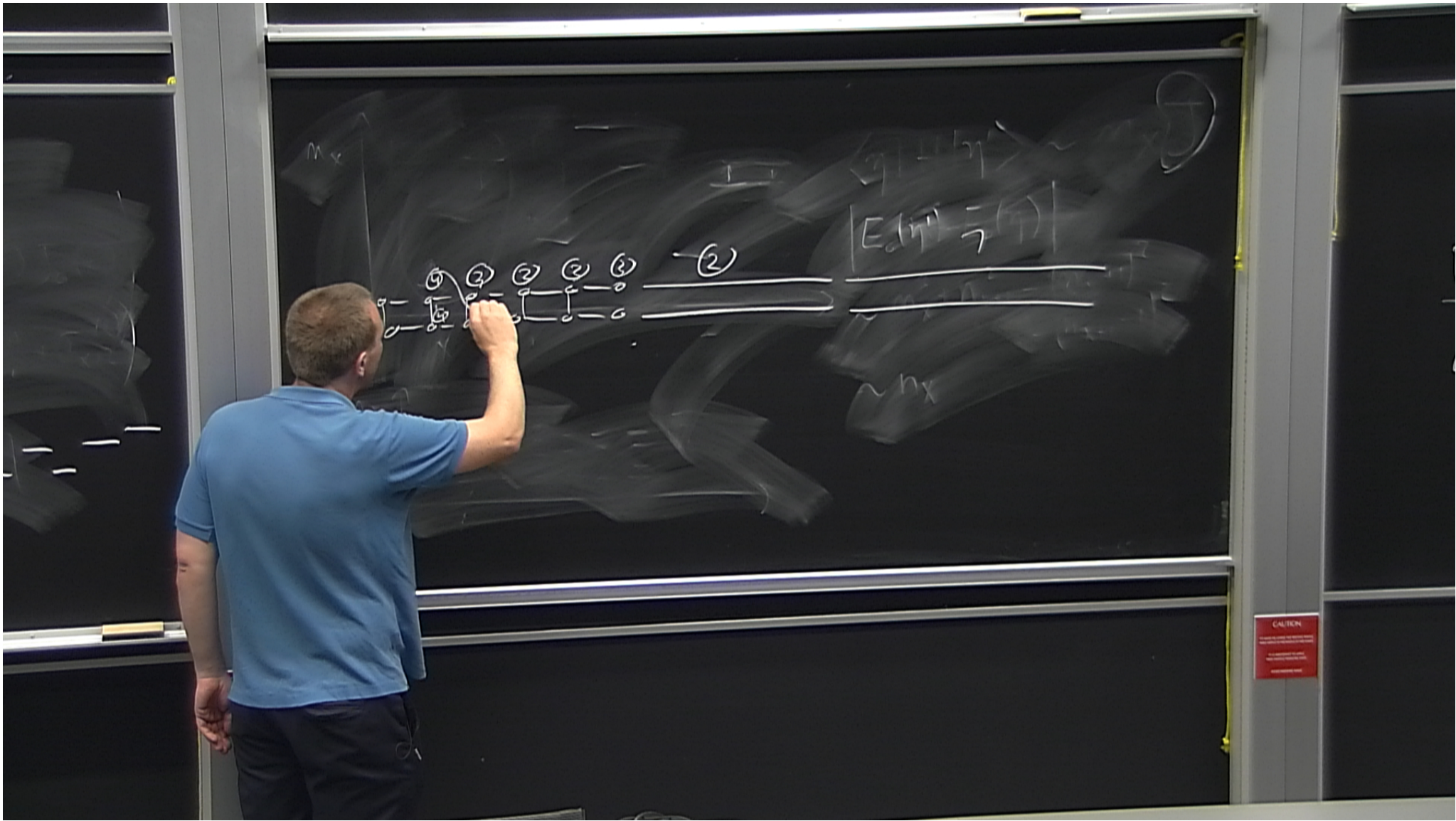
CAUTION
 This board is covered with electrical wiring.
 Please do not touch the wiring or the board.
 If you have any questions, please contact the staff.
 Thank you for your attention.

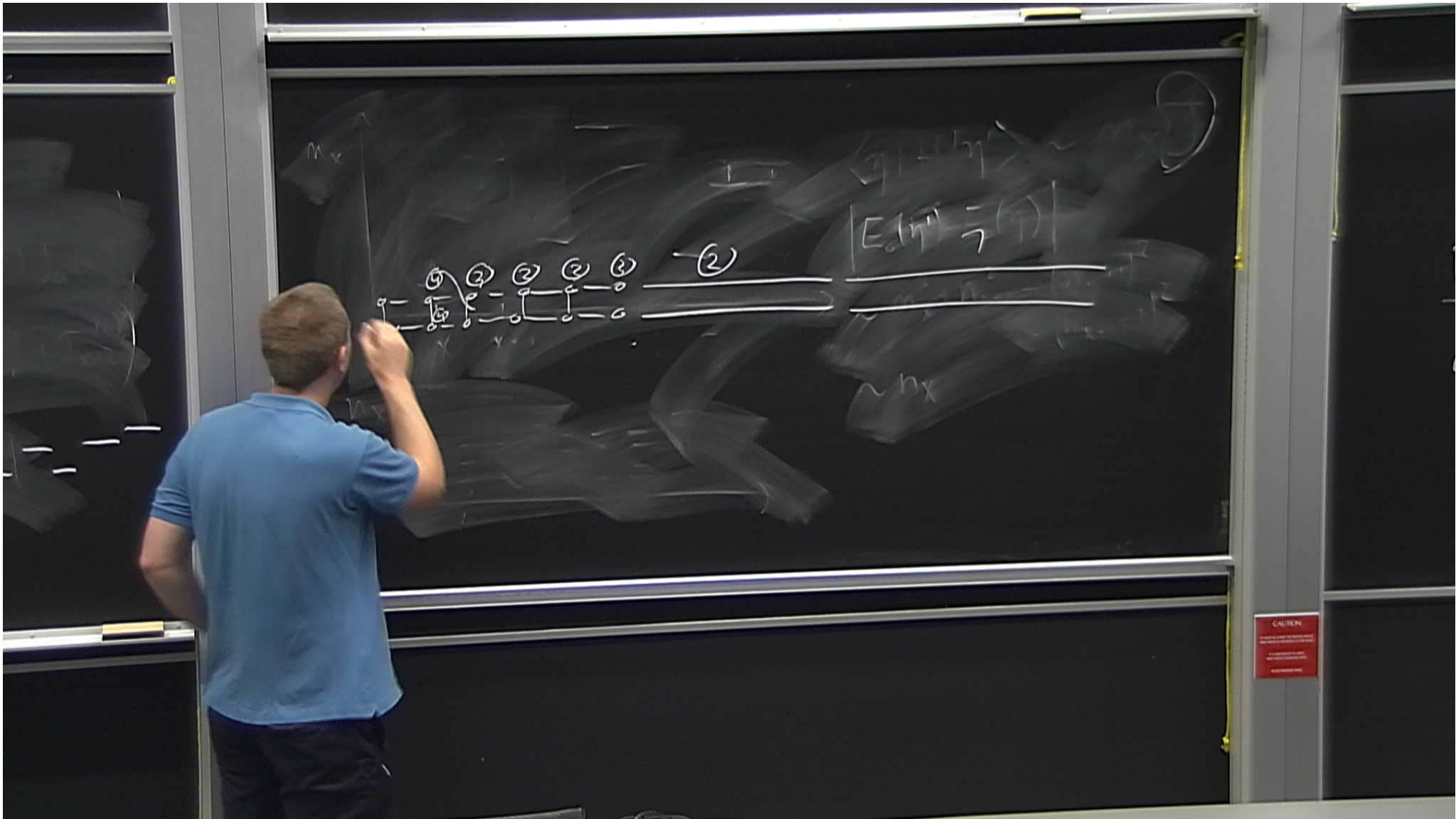


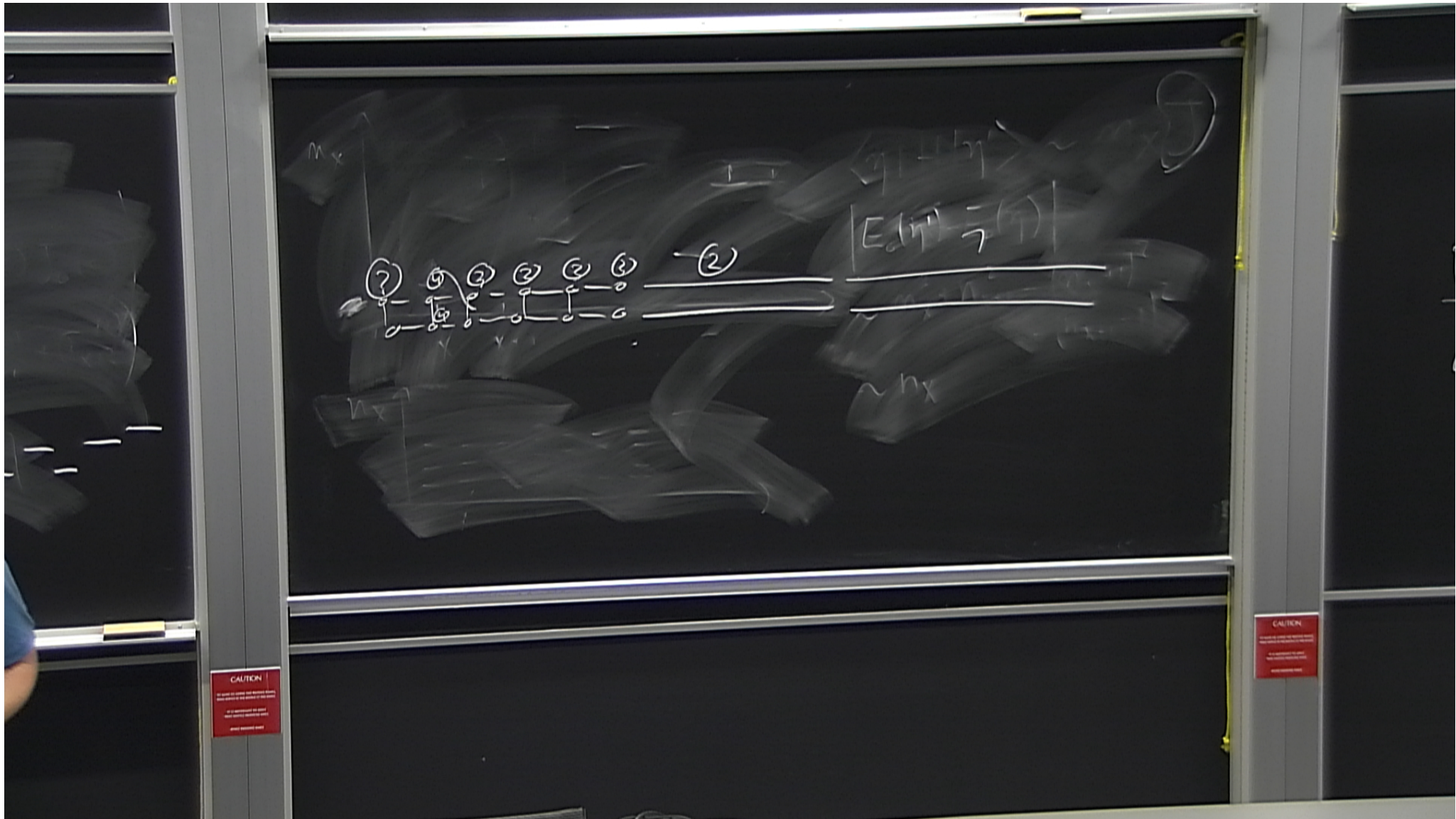






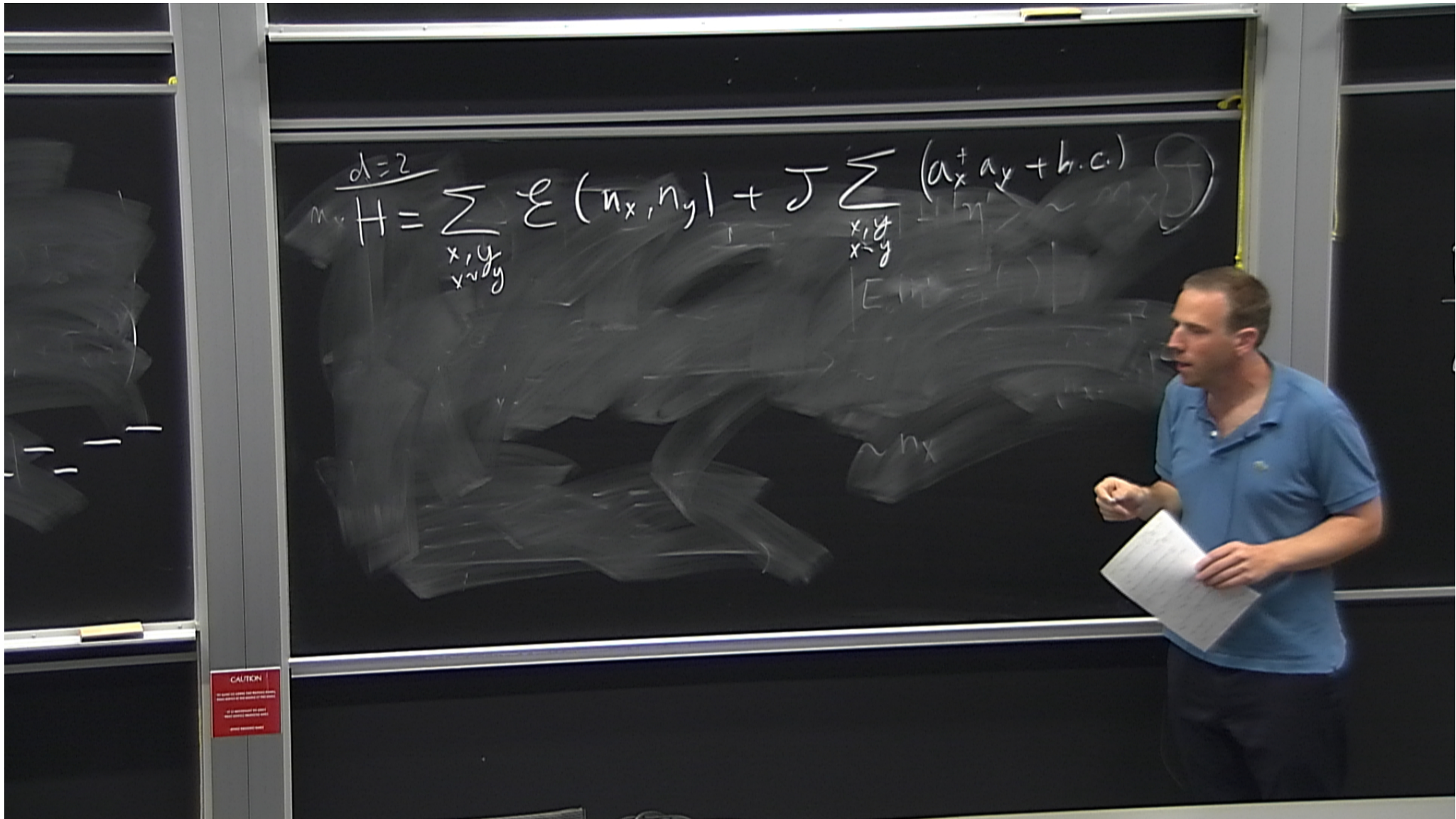






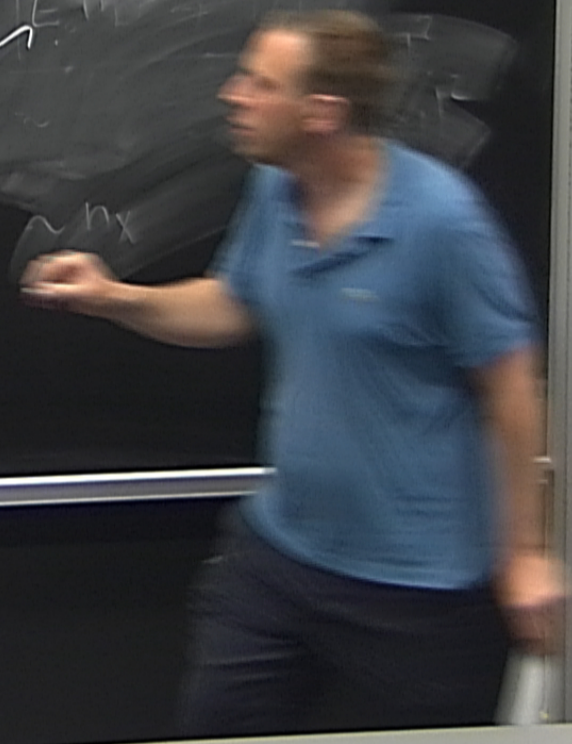
CAUTION
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$$m \frac{d=2}{H} = \sum_{\substack{x,y \\ x',y'}} \mathcal{E}(n_x, n_y) + J \sum_{\substack{x,y \\ x',y'}} (a_x^+ a_y + h.c.)$$

Resonant in first order

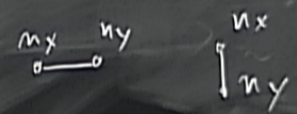


CAUTION

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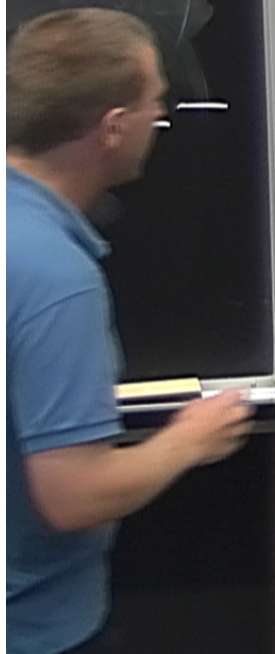
Resonant in first order.



CAUTION
Do not touch the board when the board is in use.
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$$m \frac{d=2}{H} = \sum_{\substack{x,y \\ x,y}} \mathcal{E}(n_x, n_y) + J \sum_{\substack{x,y \\ x,y}} (a_x^+ a_y + h.c.)$$

Resonant in first order

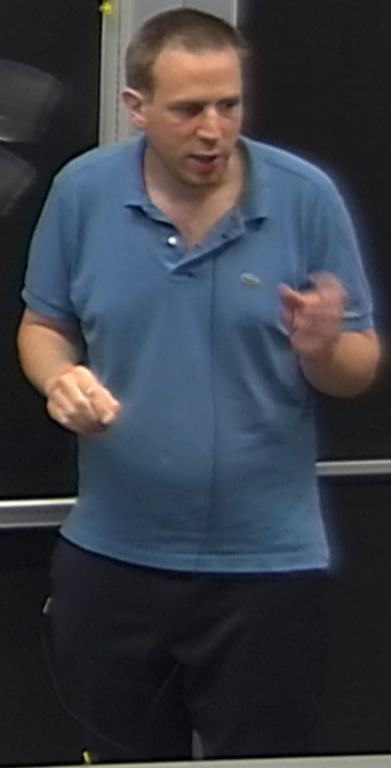
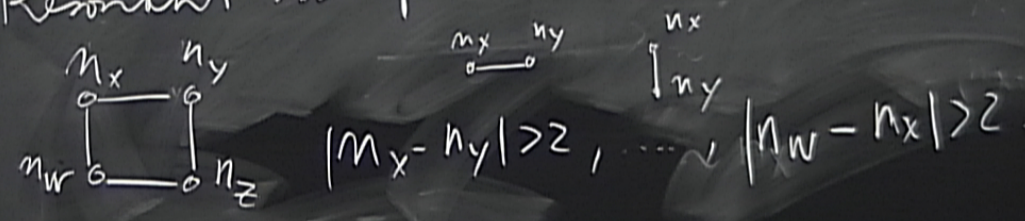


CAUTION
Do not touch the board when the projector is on.
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$$m \frac{d=2}{H} = \sum_{\substack{x,y \\ x \neq y}} \mathcal{E}(n_x, n_y) + J \sum_{\substack{x,y \\ x \neq y}} (a_x^\dagger a_y + \text{h.c.})$$

Resonant in first order

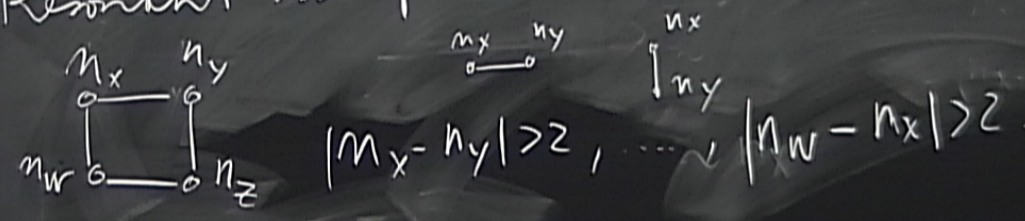


CAUTION

$$d=2$$

$$H = \sum_{\substack{x,y \\ x^2+y^2}} \epsilon(n_x, n_y) + J \sum_{\substack{x,y \\ x^2+y^2}} (a_x^\dagger a_y + \text{h.c.})$$

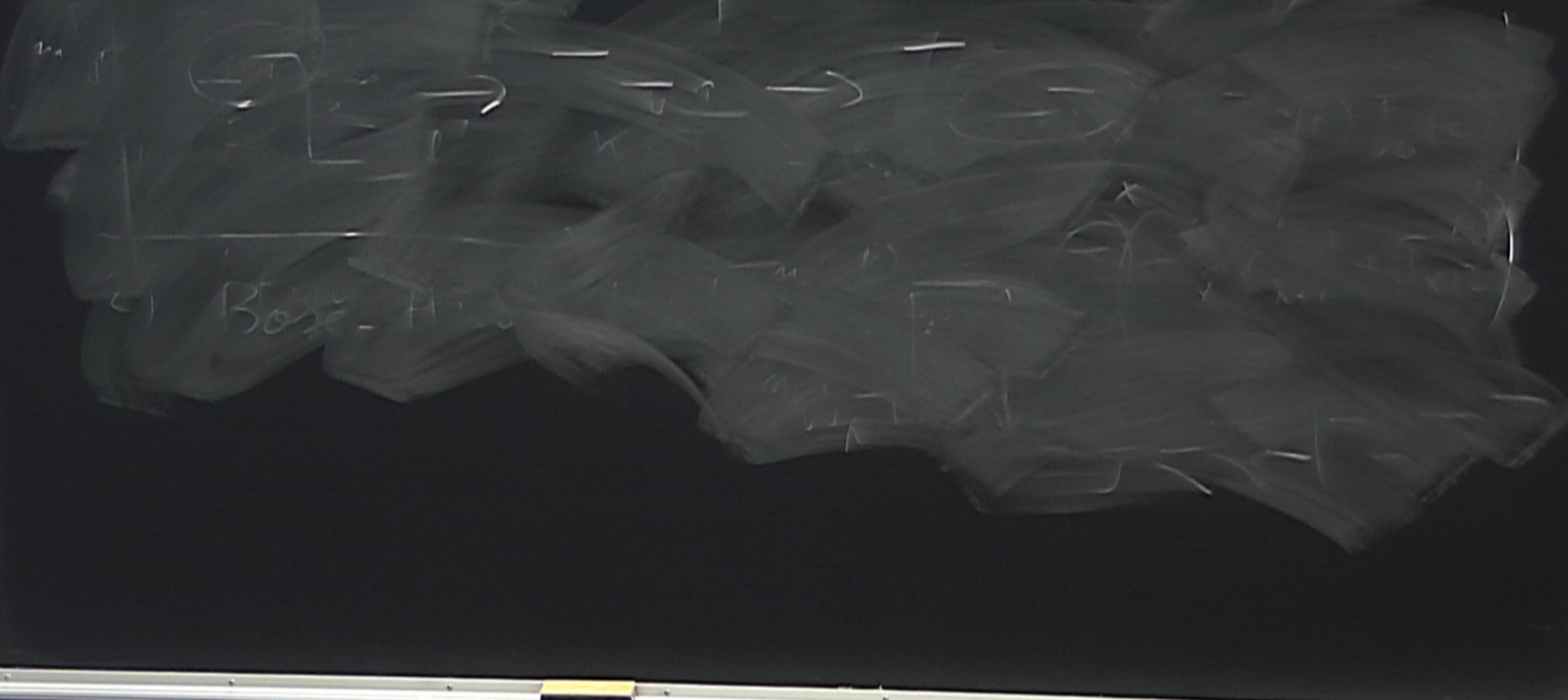
Resonant in first order



CAUTION

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H res $\langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \text{ if} \end{cases}$

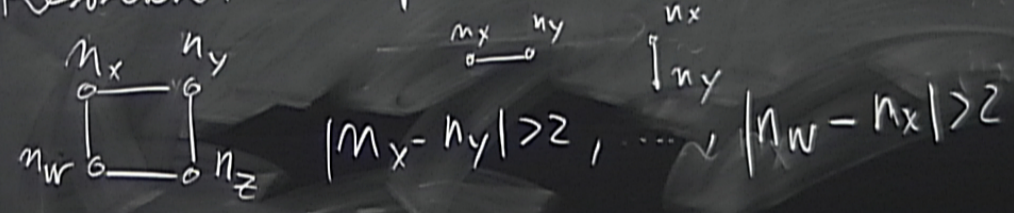


CAUTION
Please do not touch the screen when it is on.
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$\langle \gamma | = H_0 | \gamma \rangle$

$$H = \sum_{\substack{x,y \\ x',y'}} \underbrace{\mathcal{E}(n_x, n_y)}_{H_0} + J \sum_{\substack{x,y \\ x',y'}} (a_x^\dagger a_y + \text{h.c.})$$

Resonant in first order

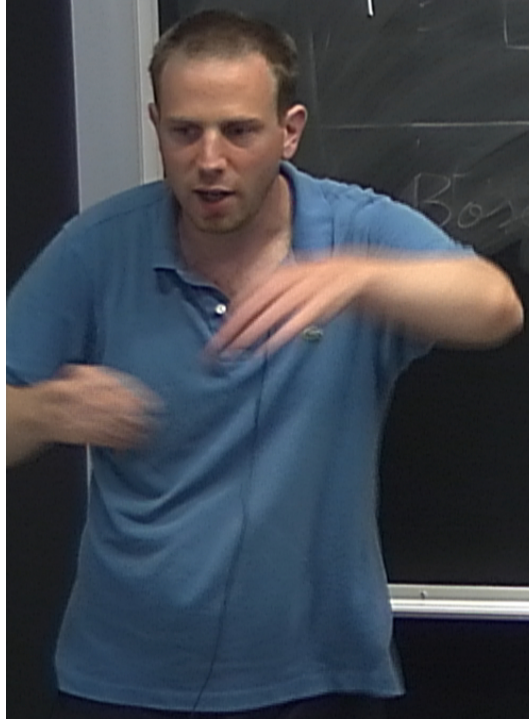


CAUTION

CAUTION

$H_{res} \quad \langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \end{cases} \text{ if } H_0(\eta) = H_0(\eta')$

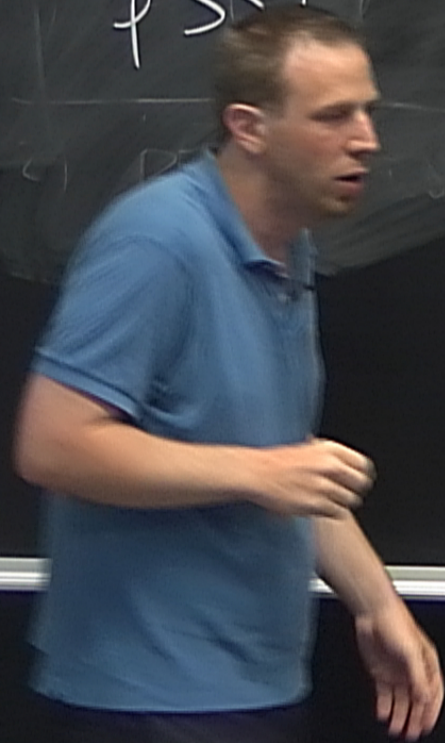
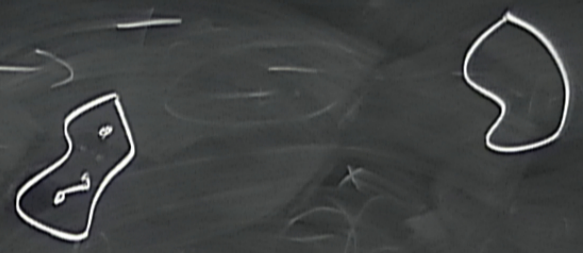
$p \ll 1$



CAUTION
Do not touch the board when it is hot.
Do not touch the board when it is hot.
Do not touch the board when it is hot.

$$H_{res} \quad \langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \end{cases} \text{ if } H_0(\eta) = H_0(\eta')$$

$p \ll 1$
 $p \gg 1$



CAUTION

$H_{res} \quad \langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \end{cases} \text{ if } H_0(\eta) = H_0(\eta')$

$p \ll 1$
 $p \gg 1$

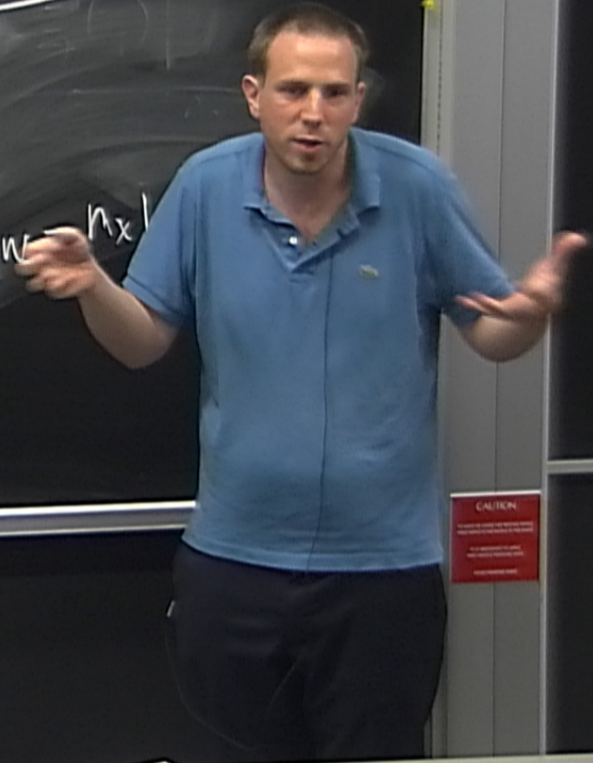
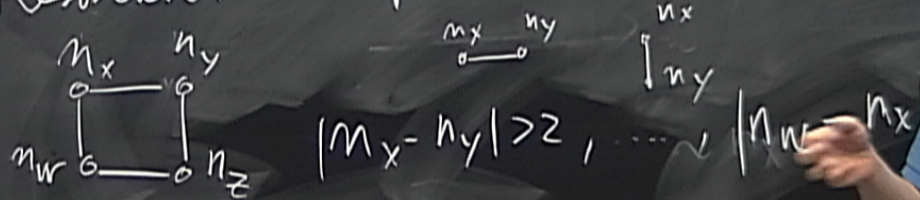


$$\langle \gamma | = H_0 \langle \gamma' |$$

$$H = \sum_{\substack{x,y \\ x',y'}} \mathcal{E}(n_x, n_y) + J \sum_{\substack{x,y \\ x',y'}} (a_x^\dagger a_y + h.c.)$$

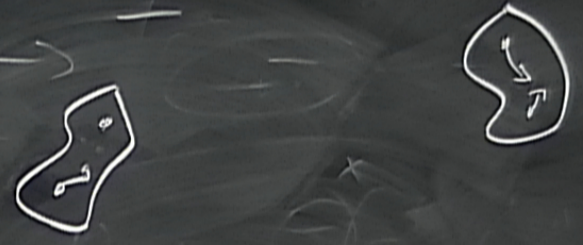
H_0

Resonant in first order

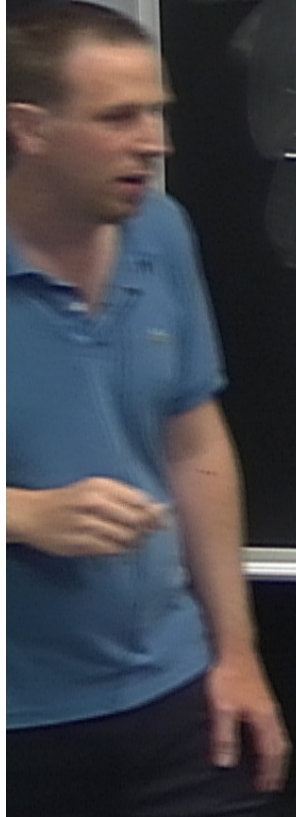


$H_{res} \quad \langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \end{cases} \text{ if } H_0(\eta) = H_0(\eta')$

$p \ll 1$
 $p \gg 1$



J^2 perturbation



CAUTION
 Do not touch the screen when it is hot.
 Do not touch the screen when it is wet.
 Do not touch the screen when it is dry.

H_{res} $\langle \eta | H | \eta' \rangle = \begin{cases} 0 \\ \langle \eta | H | \eta' \rangle \end{cases}$ if $H_0(\eta) = H_0(\eta')$

$p \ll 1$

$p \gg 1$

J^2 perturbation



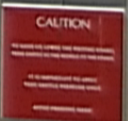
J^2 perturbation V $|\psi\rangle$ before absorption
 $|\psi'\rangle$ after "

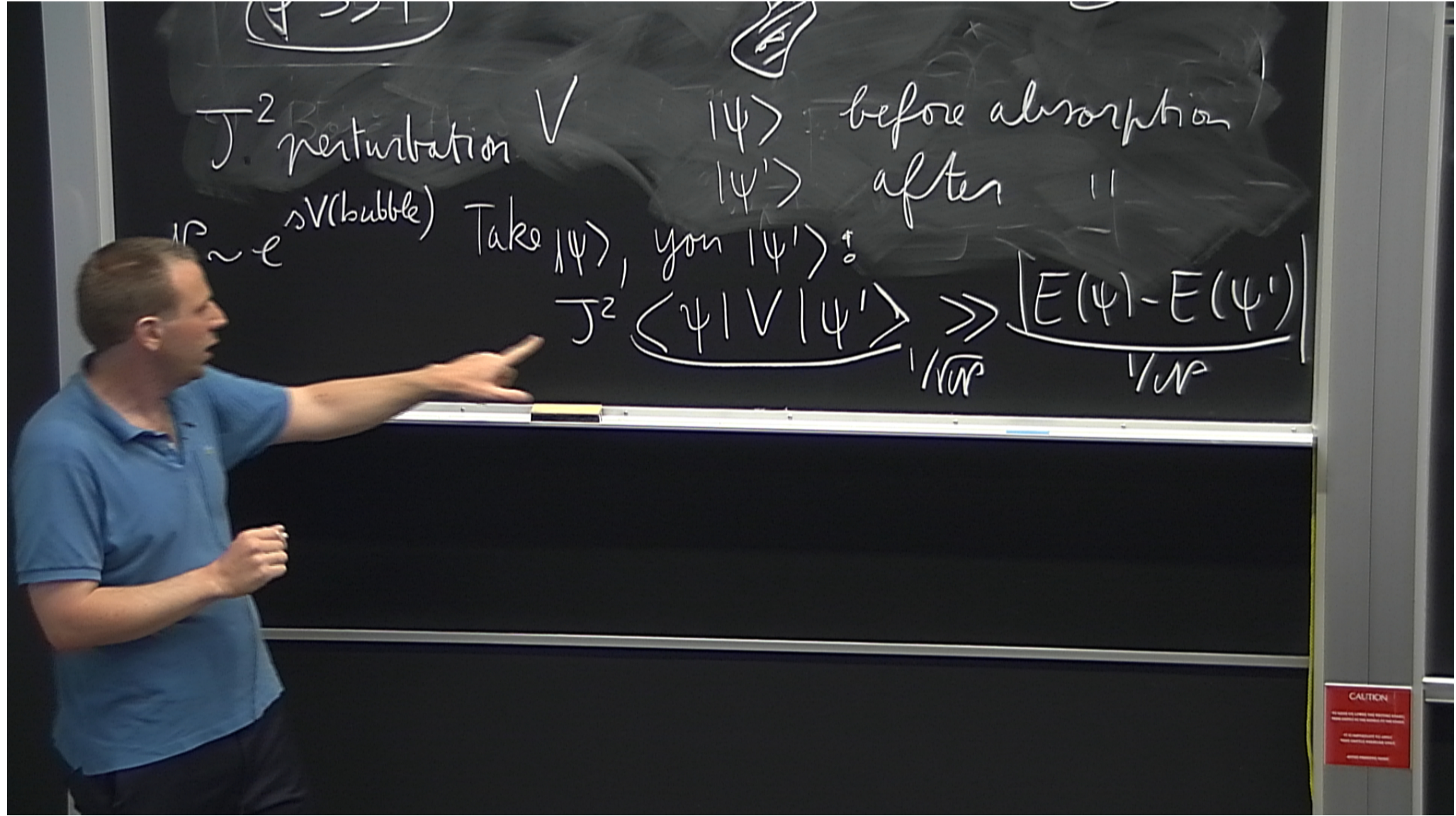
Take $|\psi\rangle$, you $|\psi'\rangle$!

$$J^2 \langle \psi | V | \psi' \rangle \gg |E(\psi) - E(\psi')|$$

J^2 perturbation V $|\psi\rangle$ before absorption
 $|\psi'\rangle$ after "

$\psi \sim e^{iS_V(\text{bubble})}$ Take $|\psi\rangle$, you $|\psi'\rangle$:

$$J^2 \langle \psi | V | \psi' \rangle \gg |E(\psi) - E(\psi')|$$




J^2 perturbation V $|\psi\rangle$ before absorption

$|\psi'\rangle$ after "

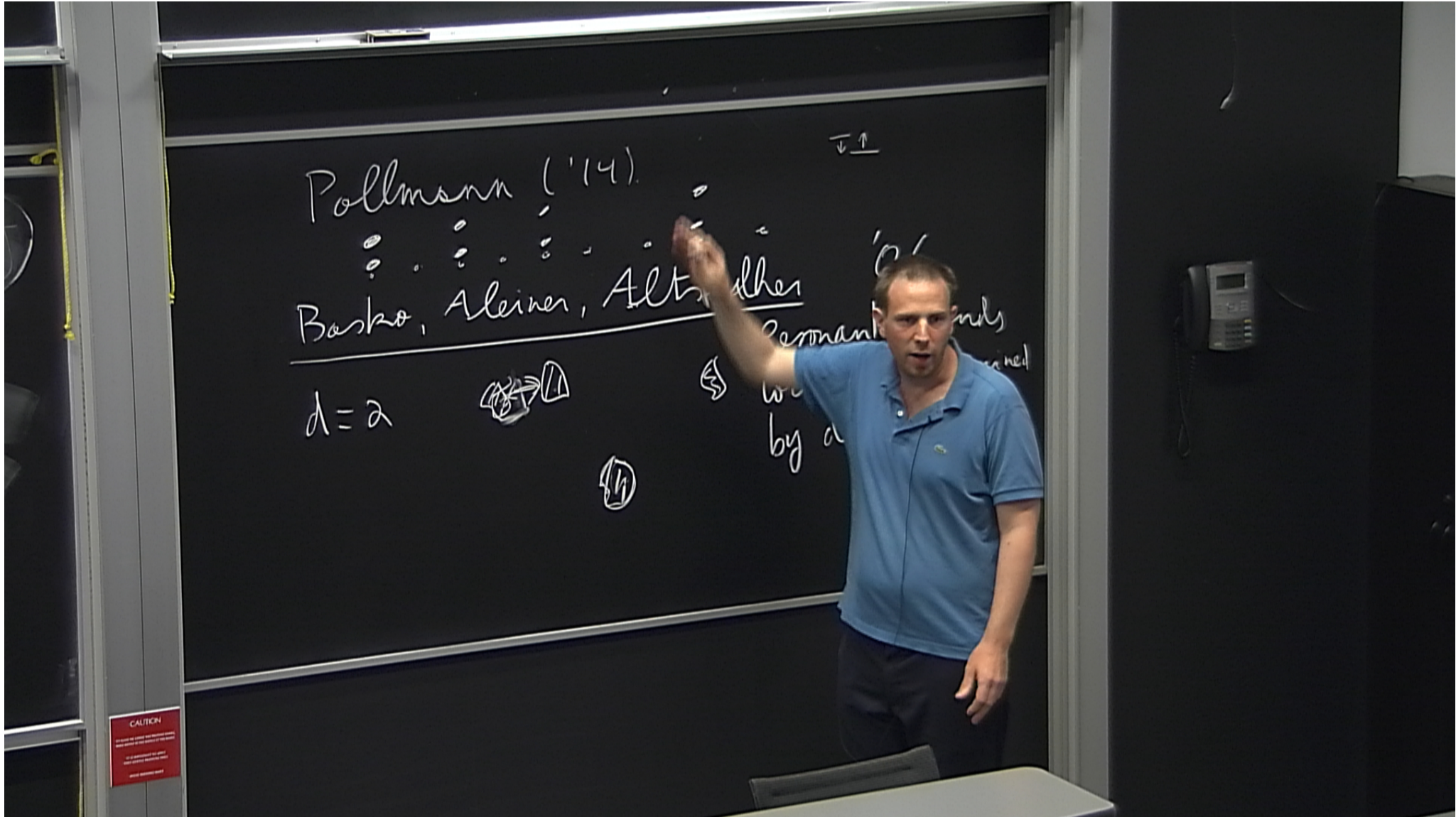
$\psi \sim e^{iV(\text{bubble})}$ Take $|\psi\rangle$, you $|\psi'\rangle$!

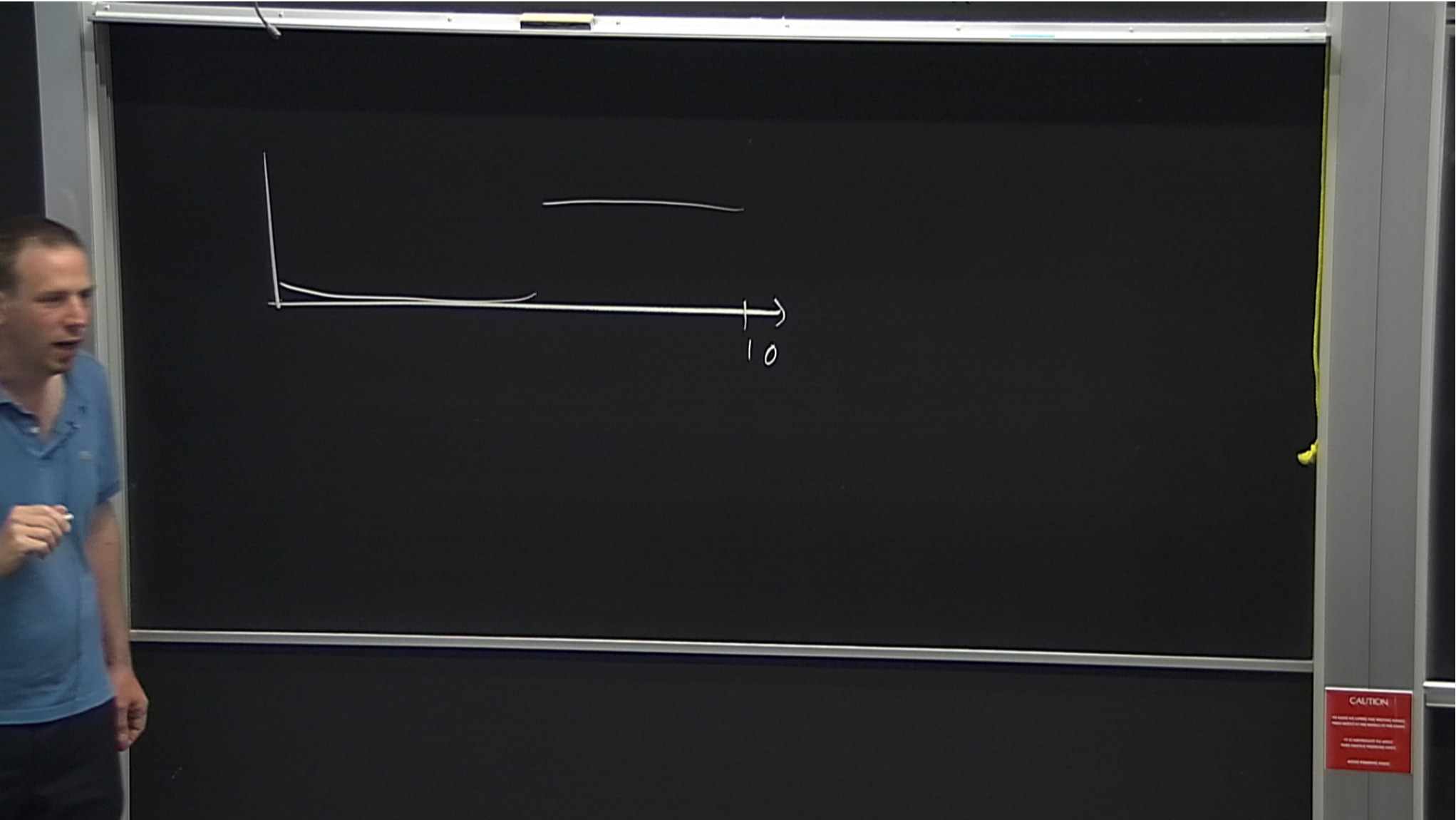
$$J^2 \langle \psi | V | \psi' \rangle \gg \frac{|E(\psi) - E(\psi')|}{\sqrt{\mu}}$$

J. Perturbation
 $\psi \sim e^{iS(\text{bubble})}$ Take $|\psi\rangle$, you $|\psi'\rangle$:
 $J^2 \langle \psi | V | \psi' \rangle \gg \frac{|E(\psi) - E(\psi')|}{\sqrt{\mu P}}$



CAUTION
 The floor is covered with electrical wires.
 Please do not touch the wires or the floor.
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CAUTION
Do not touch the control panel when the machine is running.
All components are hot when the machine is running.
Always use proper lifting technique.