Title: Self-testing of quantum systems

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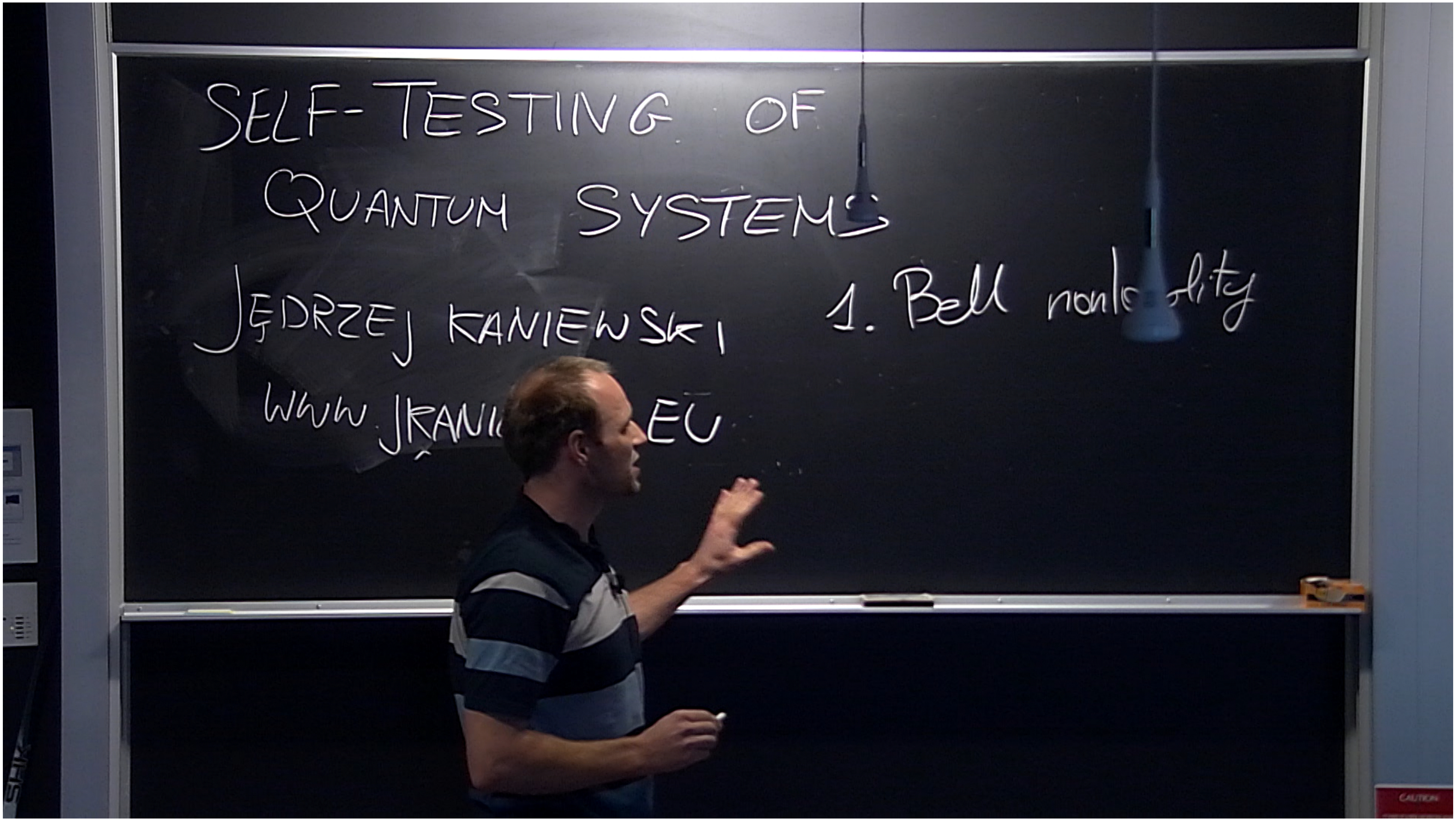
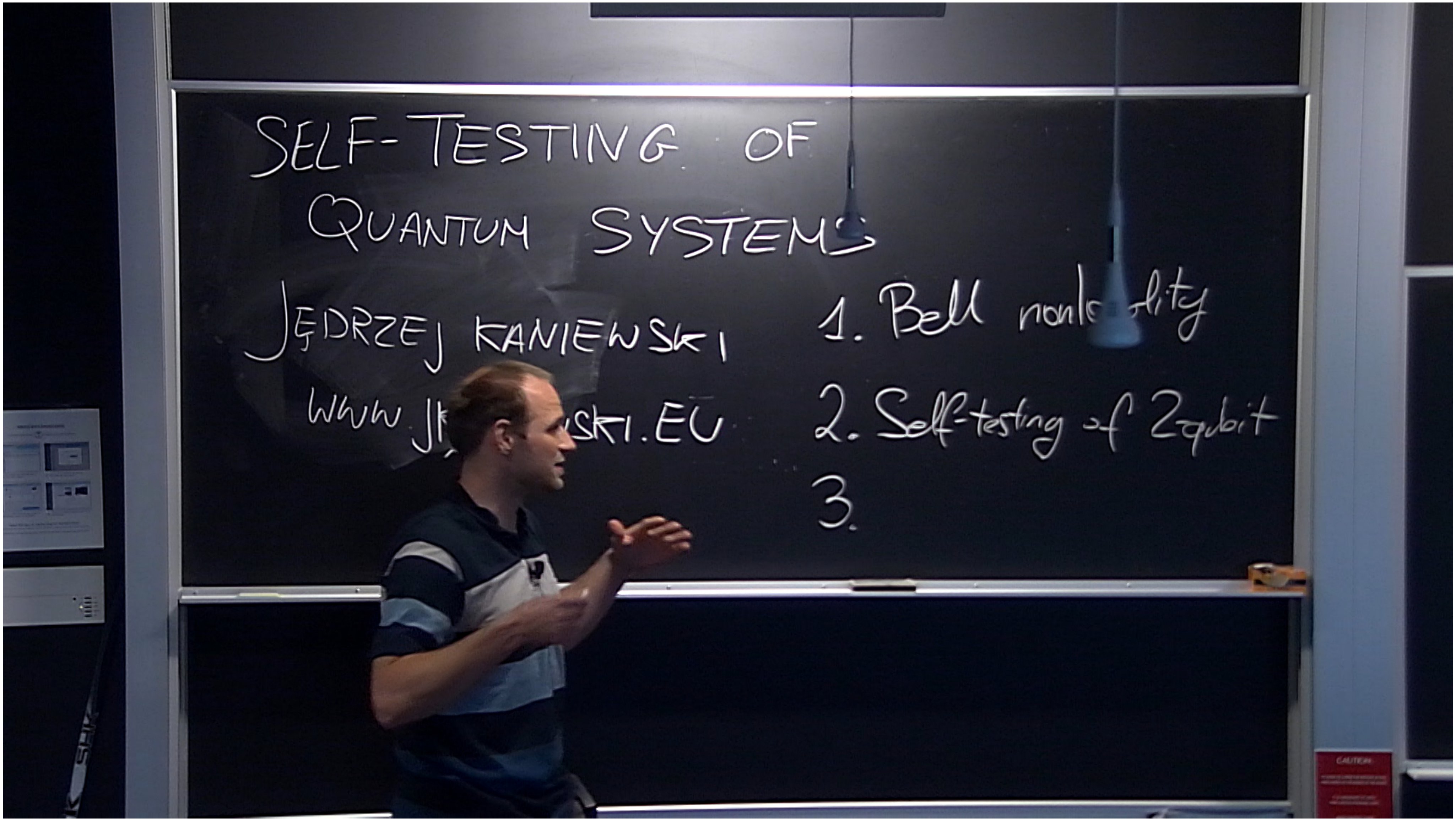
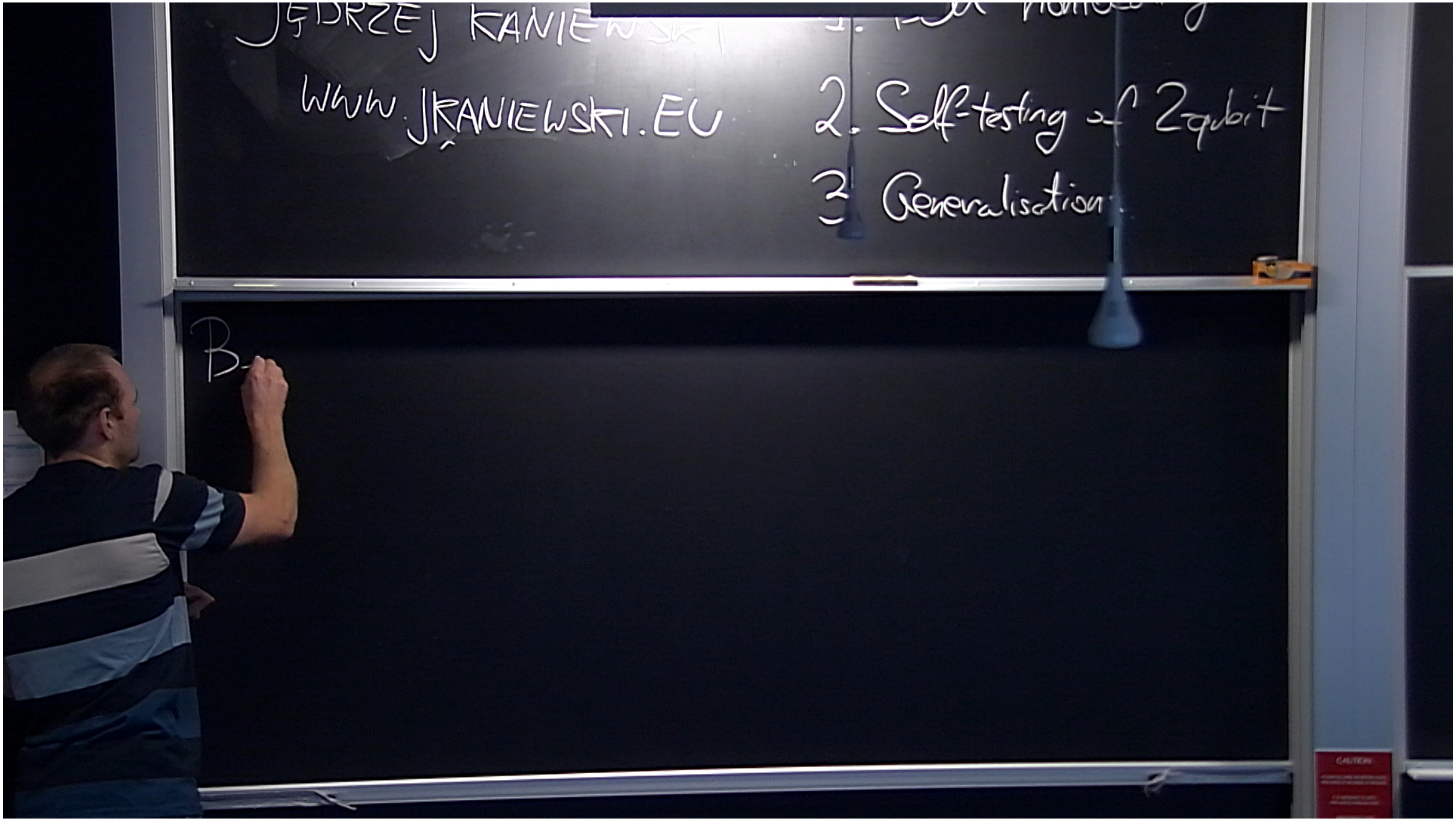
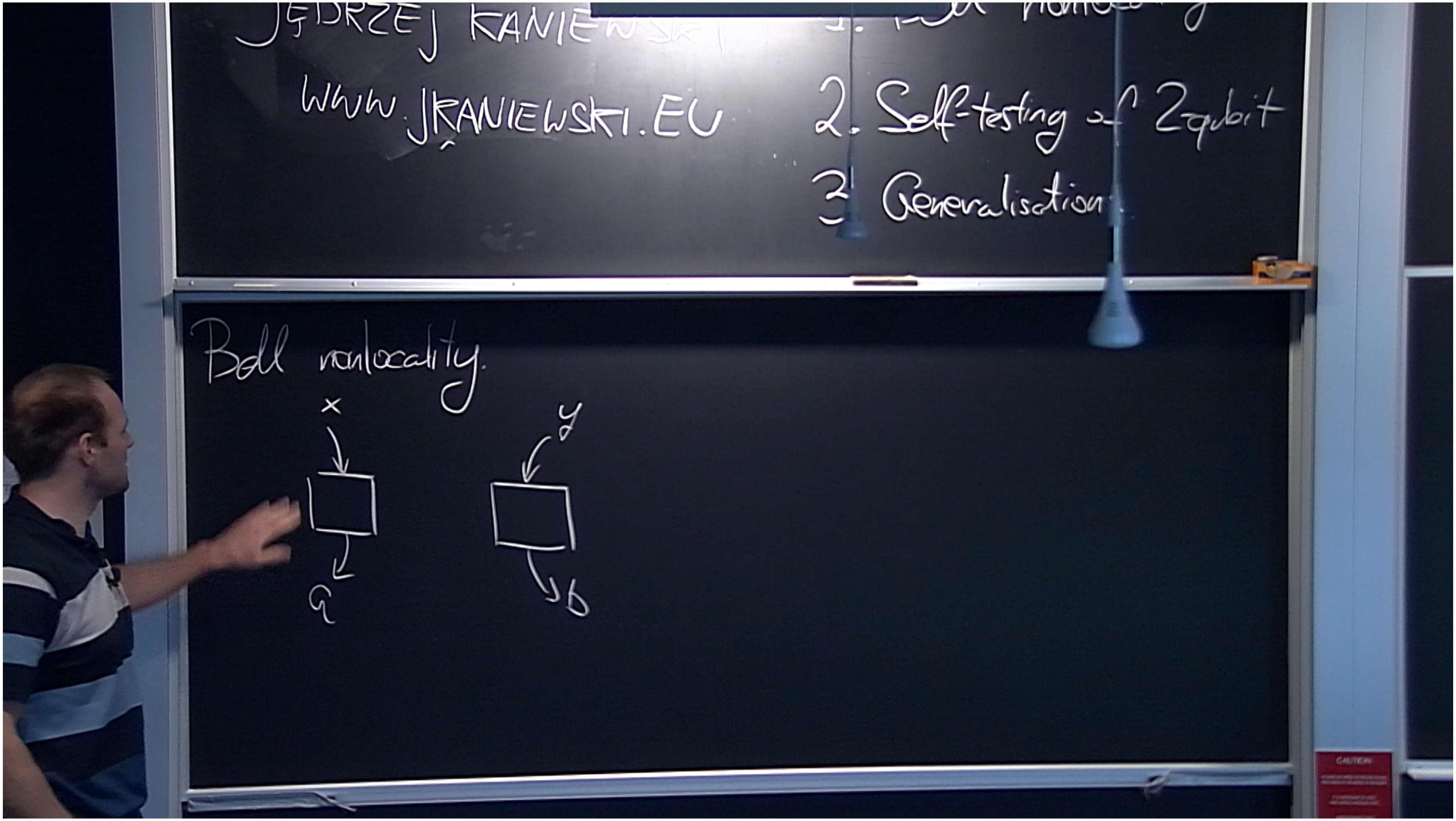
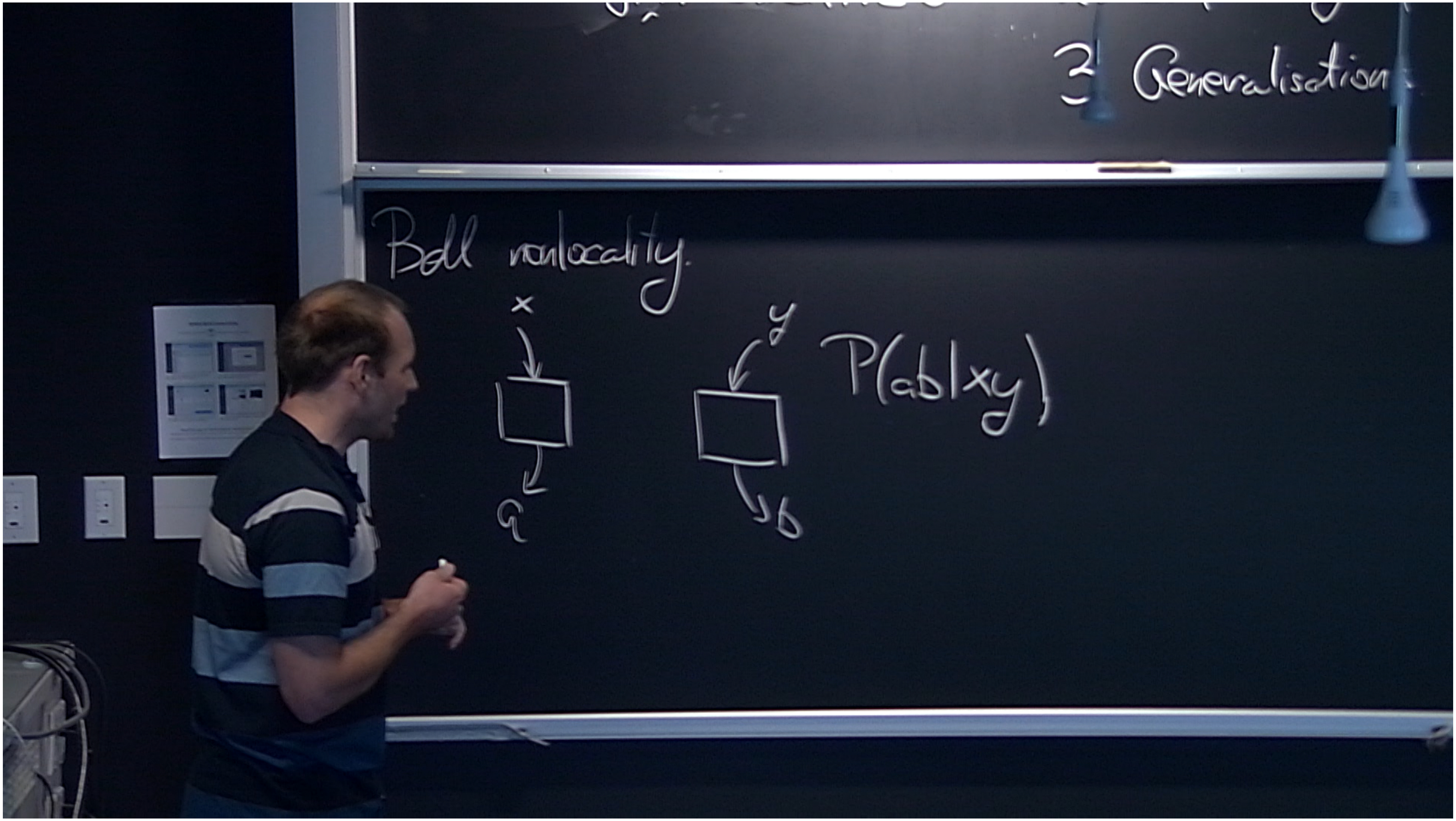
Abstract: <p>Violations of Bell inequalities have traditionally been used to refute a local-realistic description of the world. Not surprisingly, under the assumption that the world is quantum, they can be used to certify quantum devices. What is surprising is that in some cases this characterisation turns out to be (almost) complete, i.e.~we can determine (almost) everything about the devices and this phenomenon is known as self-testing of quantum systems. Although the first self- testing results can be traced back to the works of Tsirelson published in the 80's, the topic has remained largely unknown until the seminal work of Mayers and Yao in 1998. It has received further exposure with the advent of device-independent quantum cryptography to which it is closely connected. In this talk I will give a brief introduction to the topic of self-testing and discuss some recent developments, e.g.~robust self-testing, weak self-testing, self-testing of entangled measurements, self-testing of high-dimensional systems or self-testing in prepare-and-measure scenarios.</p>


SELF-TESTING OF
QUANTUM SYSTEMS
JĘDRZEJ KANIEWSKI
1. Bell


SELF-TESTING OF
QUANTUM SYSTEMS
JĘDRZEJ KANIEWSKI
WWW.JK
SKI.EU
1. Bell nonl
lity
2. Self-testing of 2 qubit
3.


WWW.JKANIEWSKI.EU
2. Self-testing of 2qubit
3. Generalisation


WWW.JKANIEWSKI.EU
2. Self-testing of 2qubit
3. Generalisation
Bell nonlocality.
x
y
a
b


3 Generalisations
Bell nonlocality.
x
y
a
b
P(ab|xy)

a b

(i) $P(ab|xy) = \sum_{\lambda} p(\lambda)\, q_A(a|x,\lambda) \cdot q_B(b|y,\lambda)$

SELF-TESTING OF QUANTUM SYSTEMS

JĘDRZEJ KANIEWSKI

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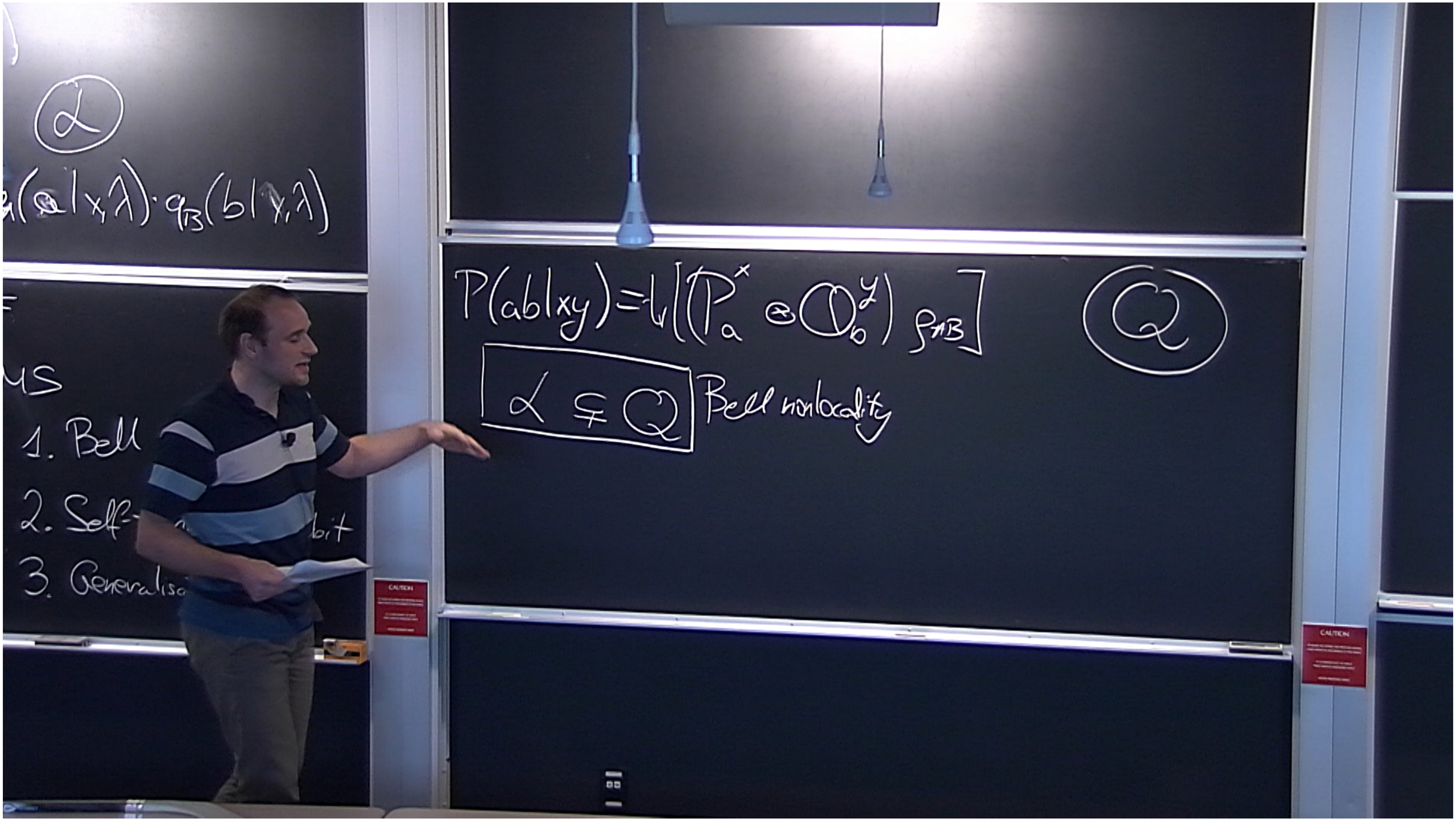
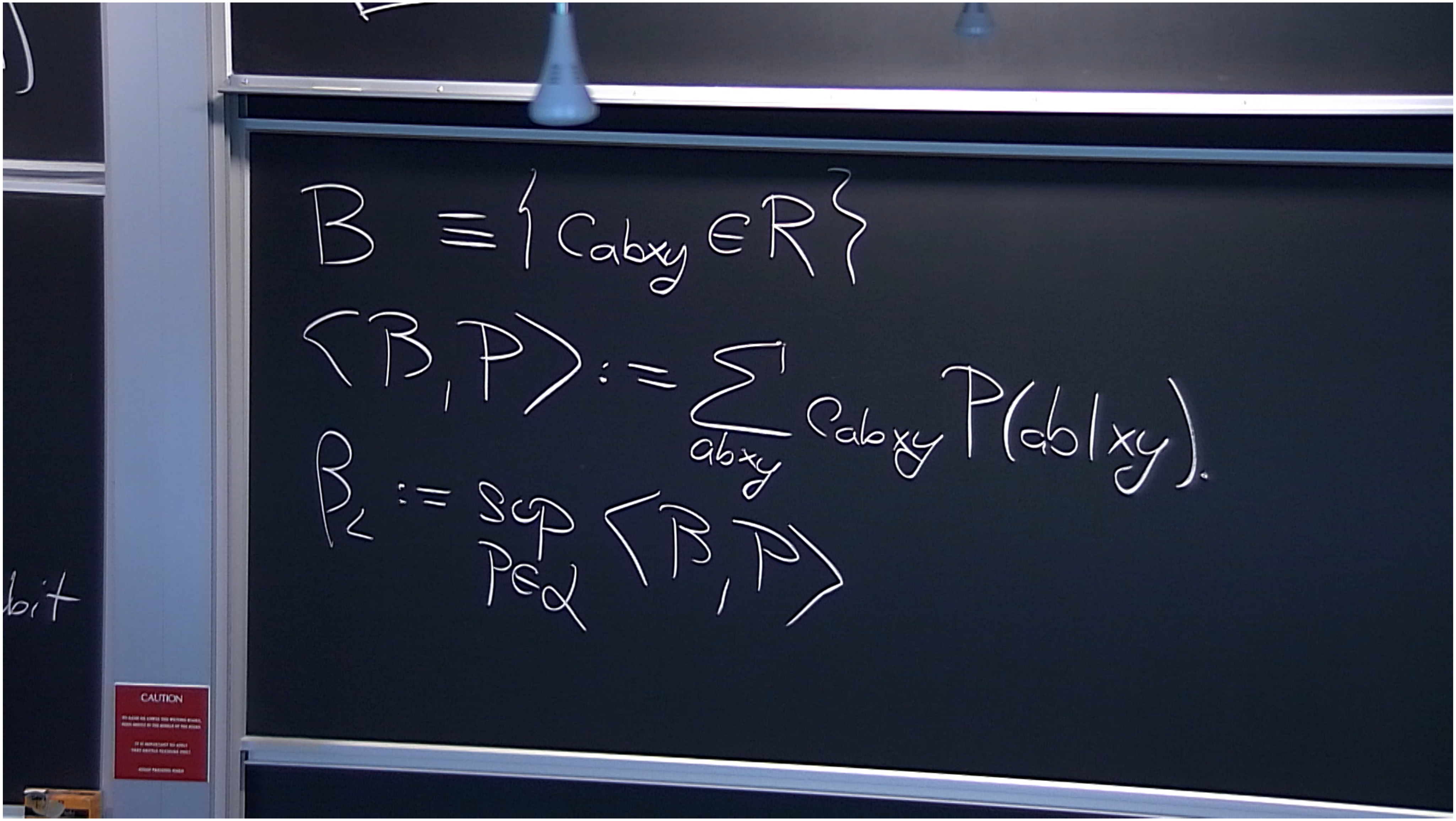
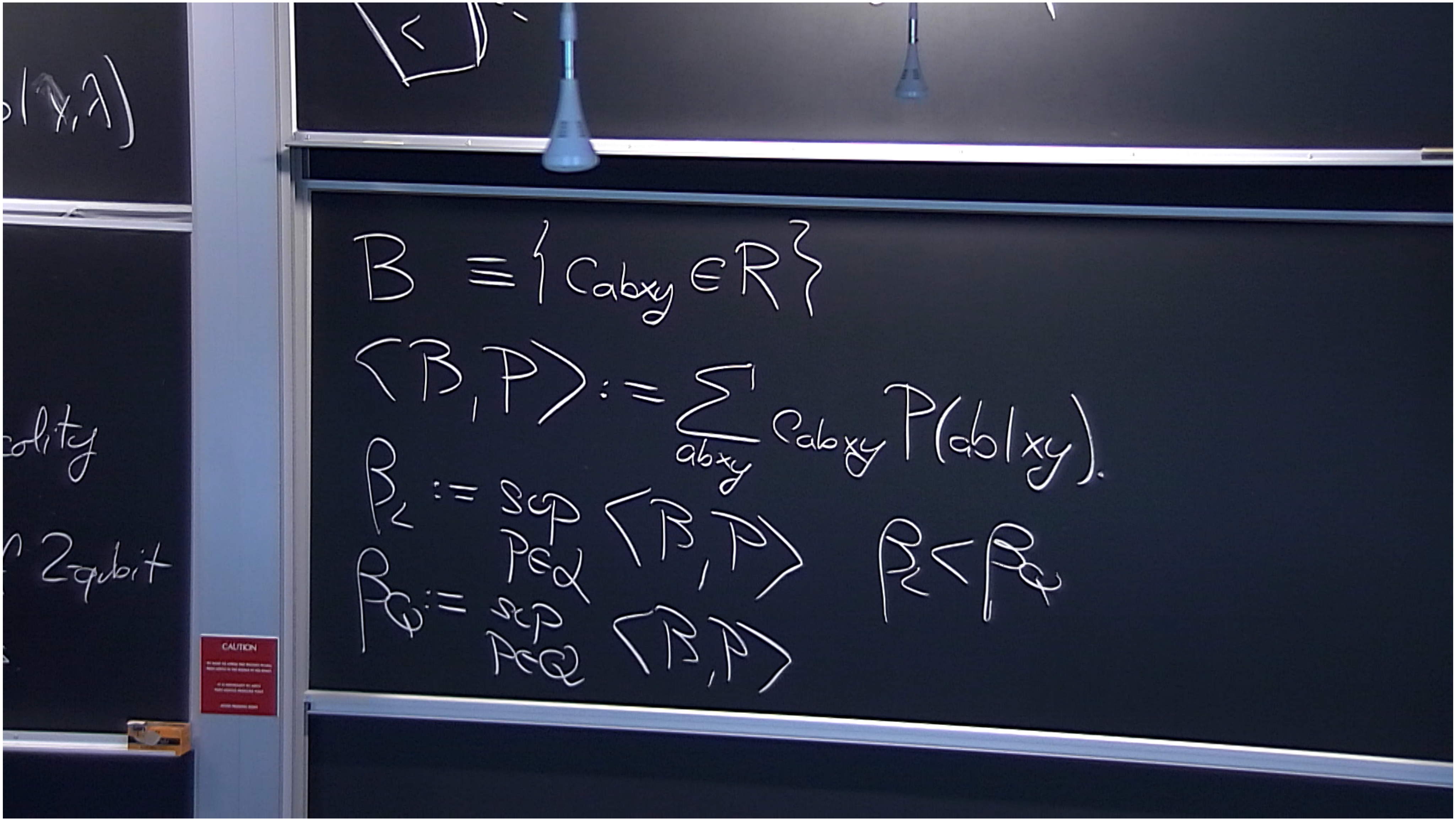
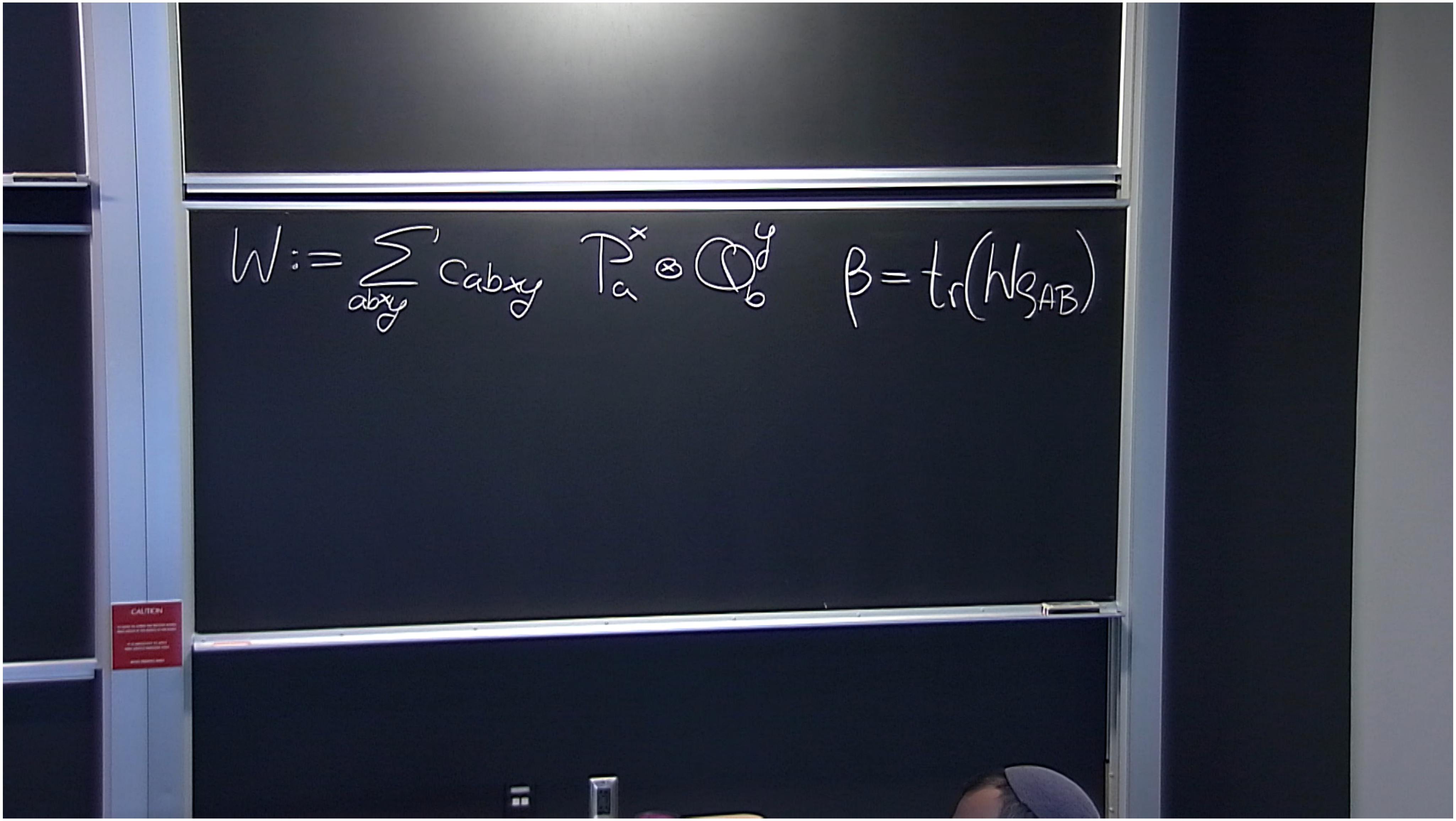
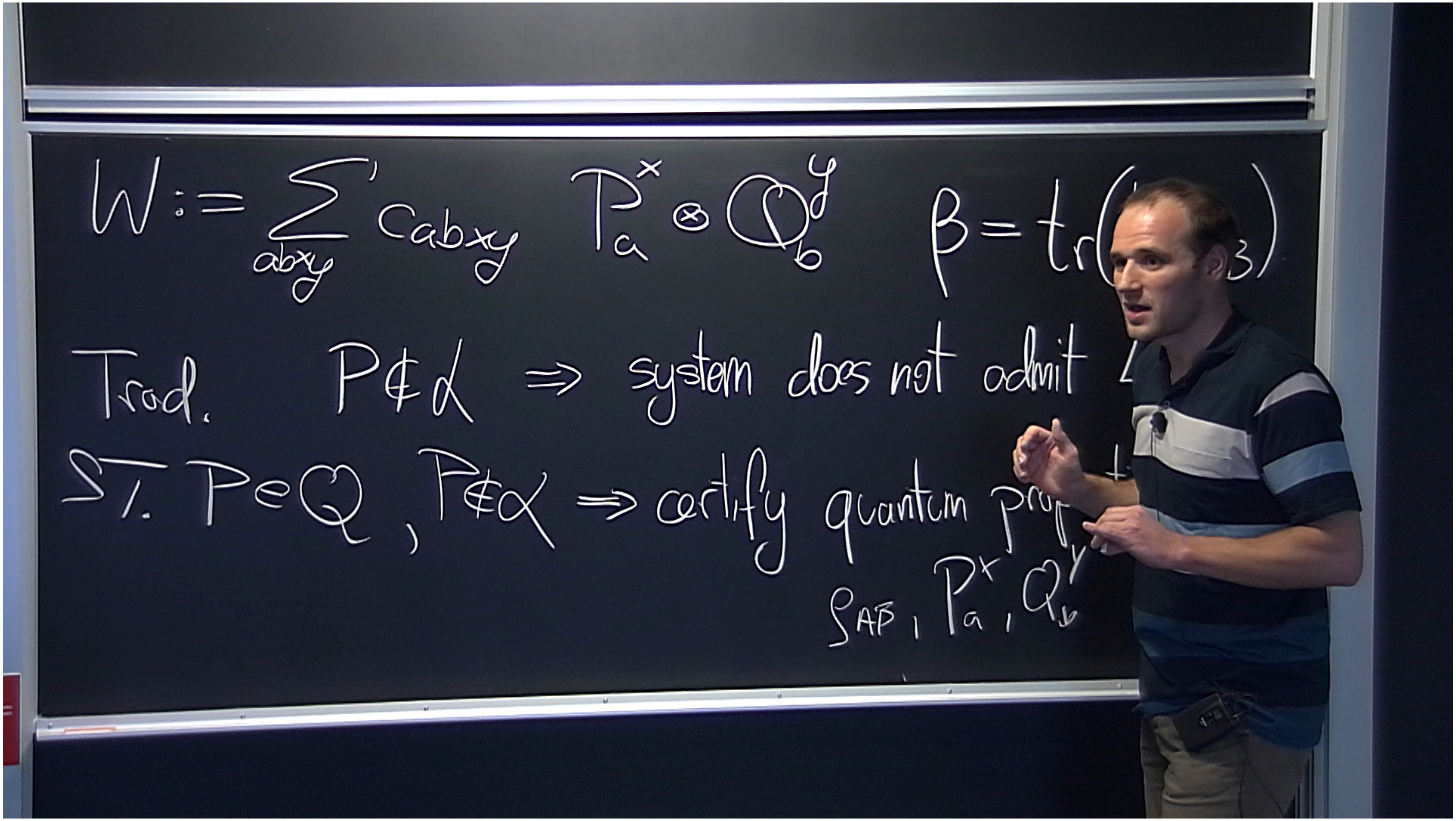
1. Bell nonlocality
2. Self-testing of 2-qubit

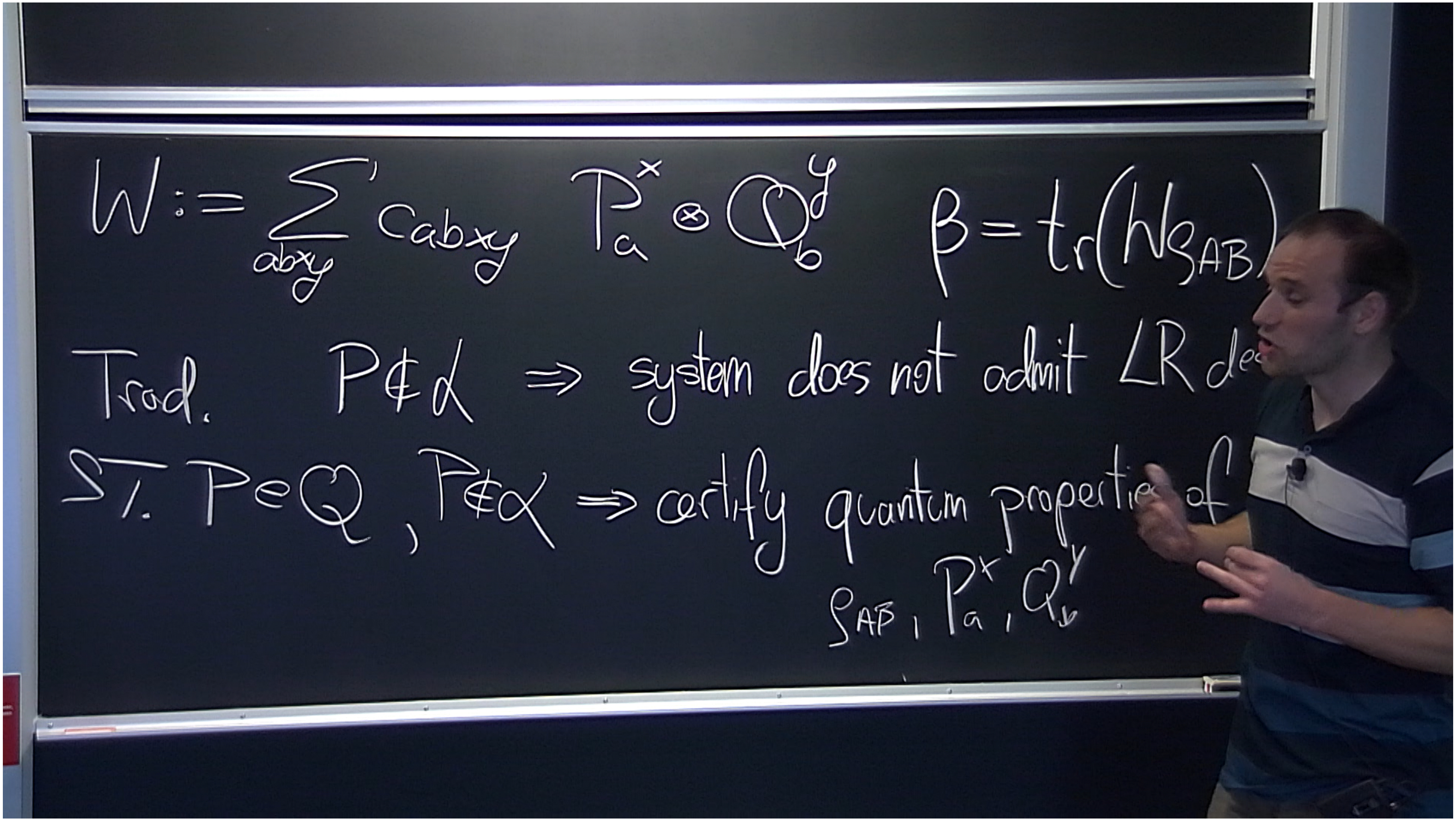

P(ab|xy) = tr[(P_a^x ⊗ Q_b^y) ρ_AB]
Q
L ⊊ Q
Bell nonlocality
1. Bell
2. Self-
bit
3. Generalis
CAUTION

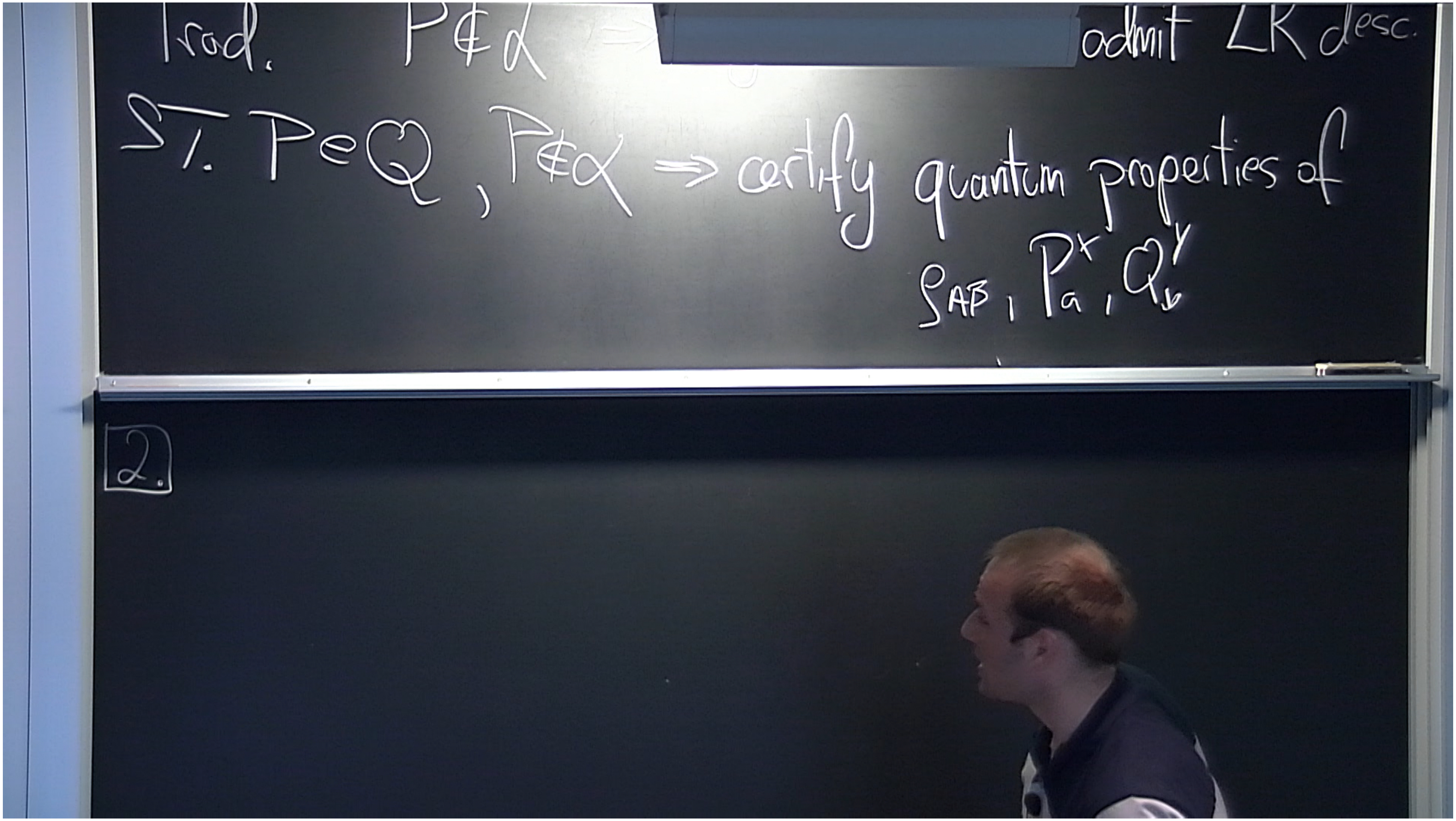

$B \equiv \{c_{abxy} \in \mathbb{R}\}$
$\langle B, P \rangle := \sum_{abxy} c_{abxy} P(ab|xy).$
$\beta_{\mathcal{L}} := \sup_{P \in \mathcal{L}} \langle B, P \rangle$
bit
CAUTION


$B \equiv \{c_{abxy} \in R\}$
$\langle B, P \rangle := \sum_{abxy} c_{abxy} P(ab|xy).$
$\beta_L := \sup_{P \in L} \langle B, P \rangle$
$\beta_L < \beta_Q$
$\beta_Q := \sup_{P \in Q} \langle B, P \rangle$
cality
2-qubit
CAUTION


$W := \sum_{abxy}' c_{abxy} \, P_a^x \otimes Q_b^y$
$\beta = tr(W \rho_{AB})$
CAUTION


$W := \sum'_{abxy} c_{abxy} P_a^x \otimes Q_b^y$
$\beta = tr($
Trad. $P \notin \mathcal{L} \Rightarrow$ system does not admit
ST. $P \in Q$, $P \notin \mathcal{L} \Rightarrow$ certify quantum prop
ρ_{AB}, P_a^x, Q_b^y


$W := \sum_{abxy}' c_{abxy} P_a^x \otimes Q_b^y$
$\beta = tr(W \rho_{AB})$
Trad. $P \notin \mathcal{L} \Rightarrow$ system does not admit LR de
ST. $P \in Q, P \notin \mathcal{L} \Rightarrow$ certify quantum properties of
ρ_{AB}, P_a^x, Q_b^y


Trad. $P \notin \mathcal{L}$ ⇒ admit LR desc.
ST. $P \in Q$, $P \notin \mathcal{L}$ ⇒ certify quantum properties of
ρ_{AB}, P_a^x, Q_b^y
2.

Q , Q $\Rightarrow$ certify quantum properties of ρ_{AB}, P_a^x, Q_b^y

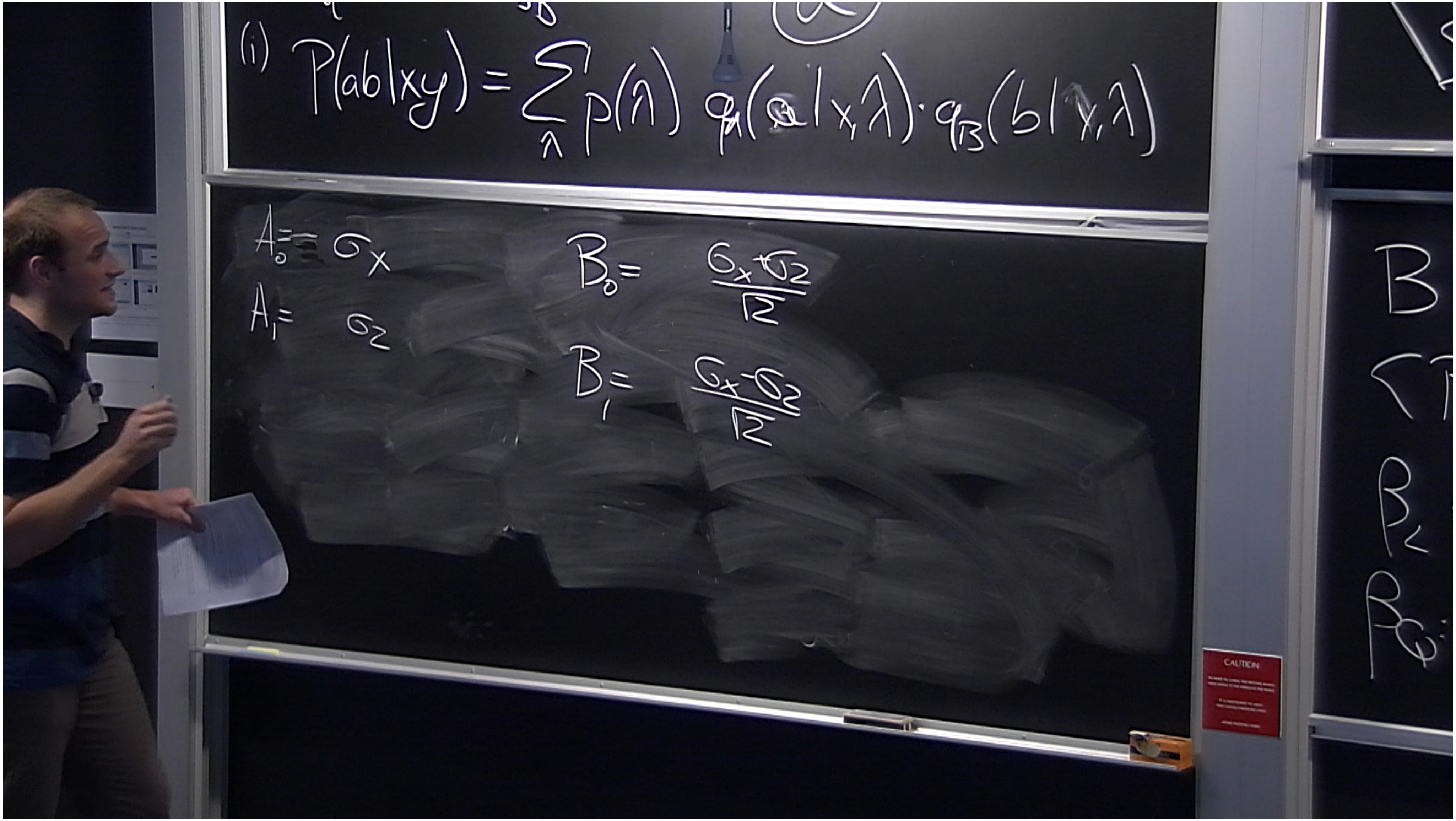
$\boxed{2.}$ $F_0, F_1 \geq 0$ $\quad F_0 + F_1 = \mathbb{1}$ $\quad A = F_0 - F_1$ $\quad A = A^\dagger$

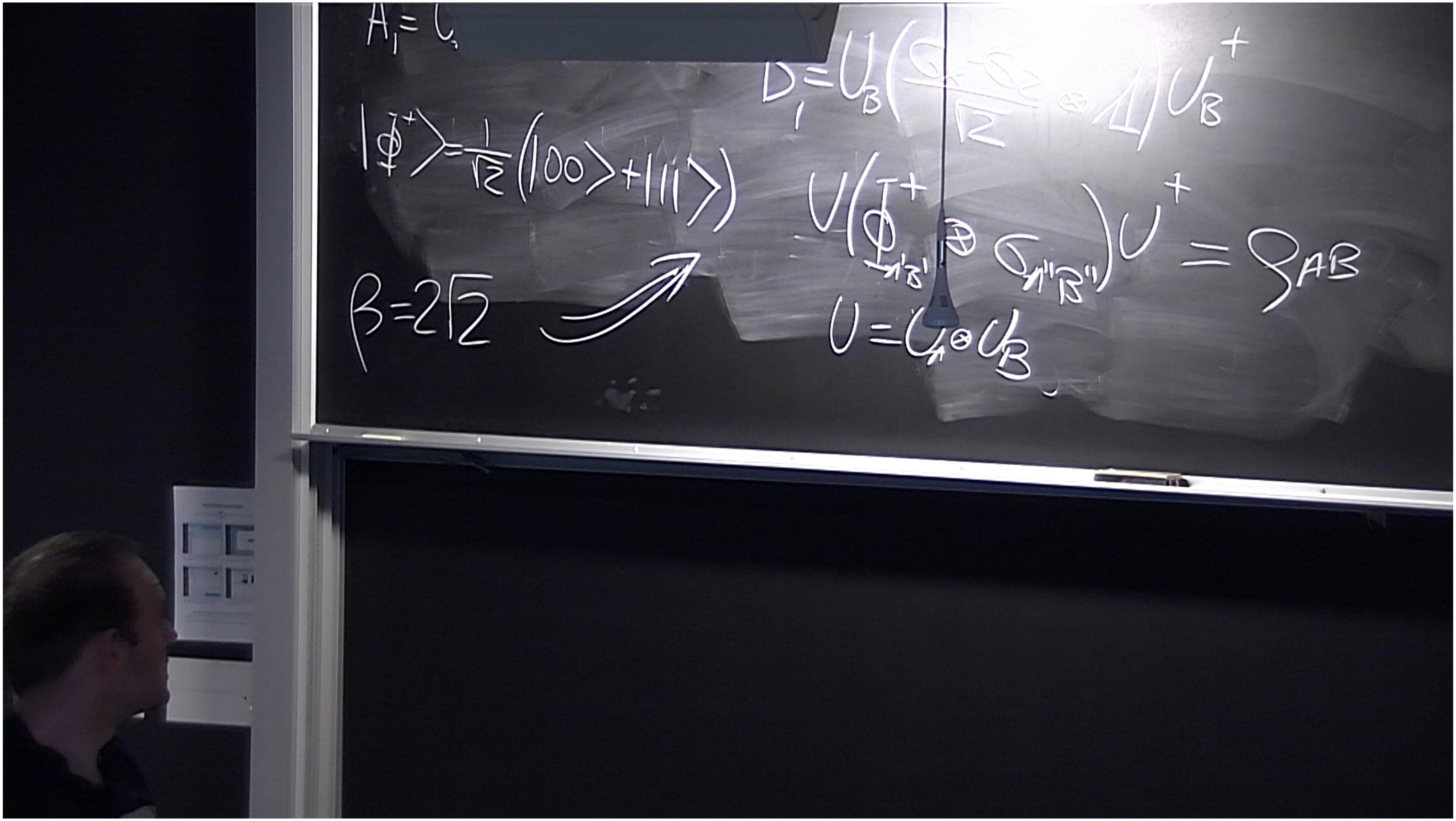
$-\mathbb{1} \leq A \leq \mathbb{1}$

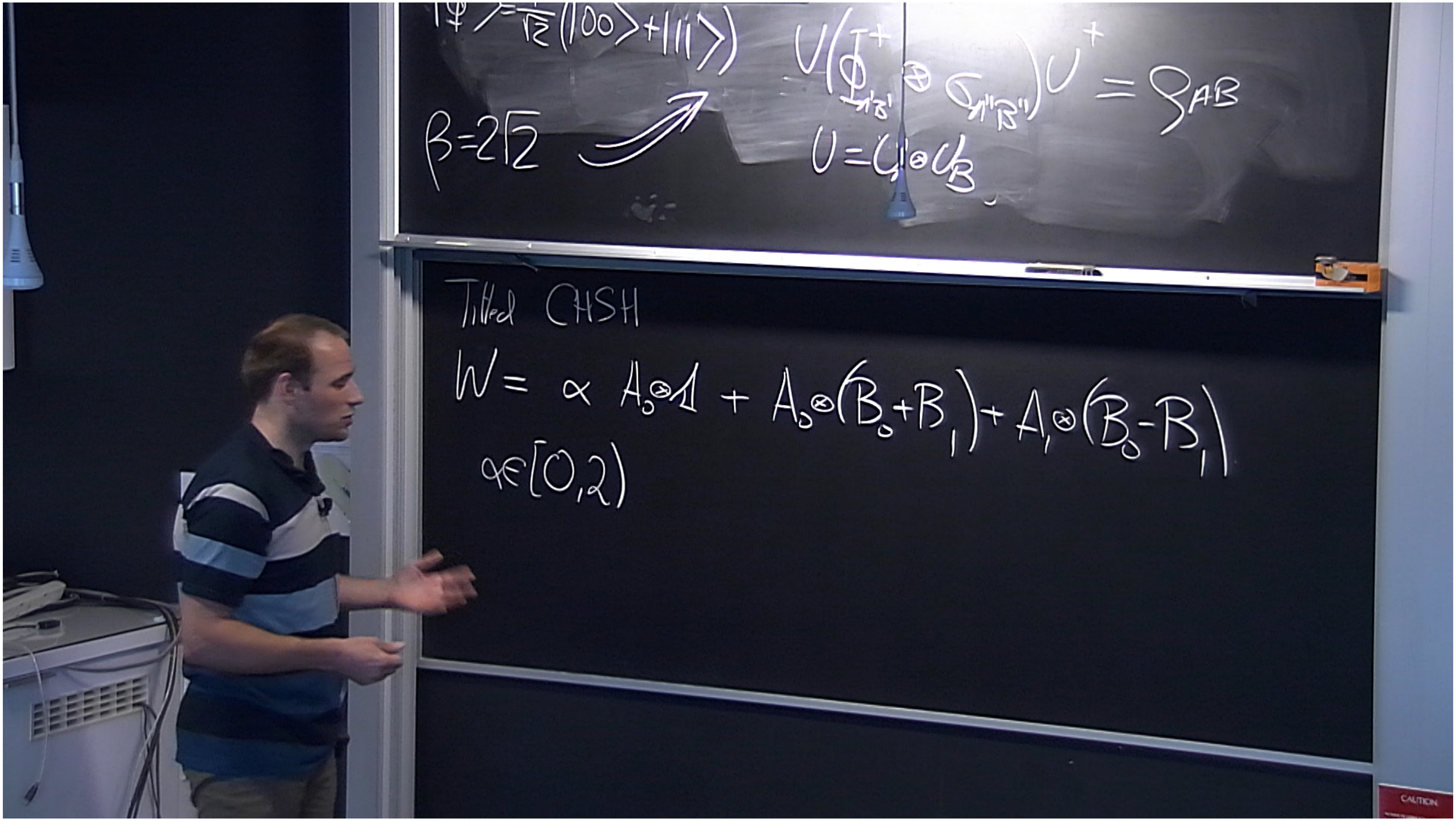
CHSH ineq.

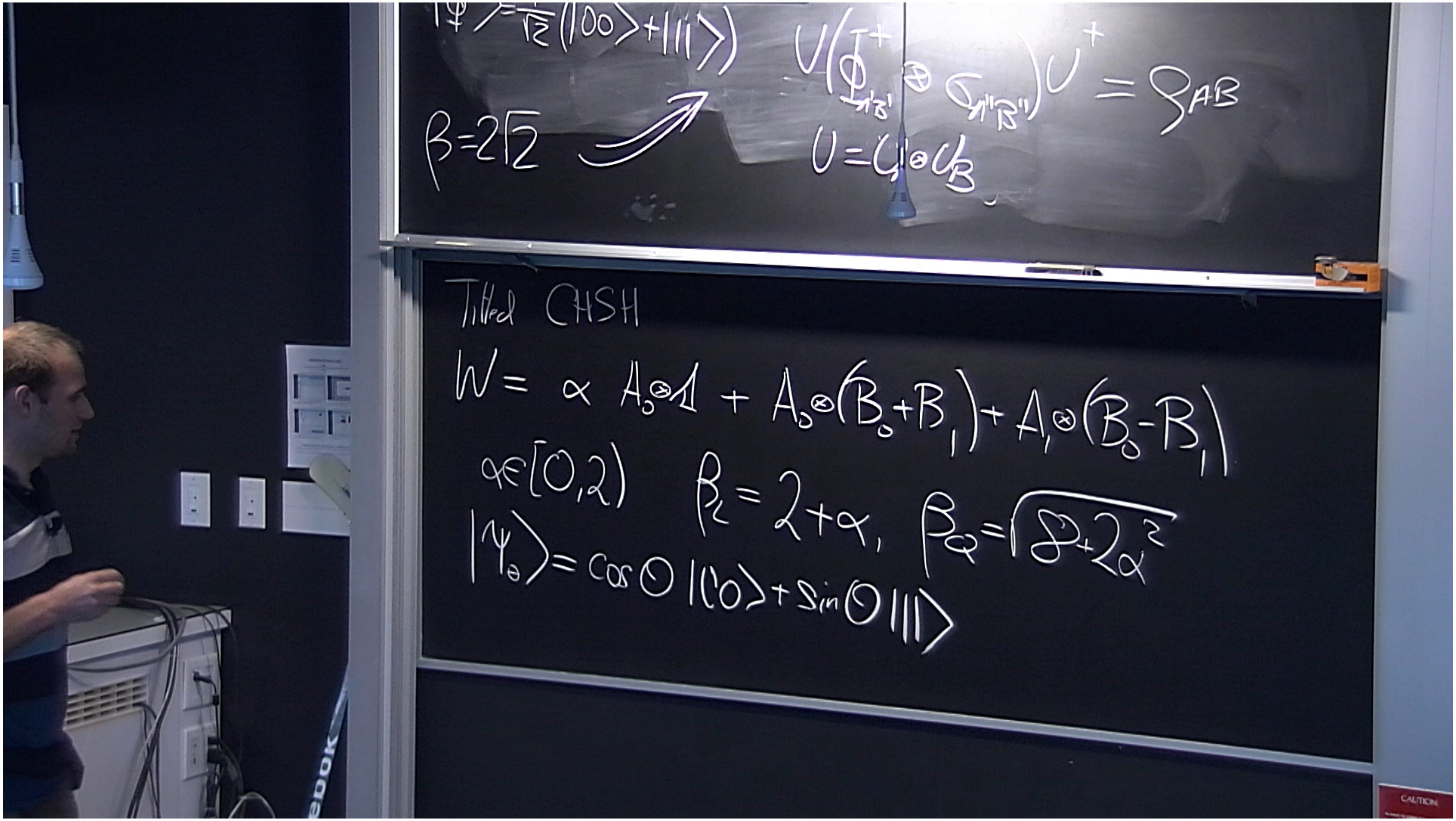
$$W = A_0 \otimes (B_0 + B_1) + A_1 \otimes (B_0 - B_1)$$

$$\beta_L = 2 \qquad \beta_Q = 2\sqrt{2}$$


(i) $P(ab|xy) = \sum_\lambda p(\lambda)\, q_A(a|x,\lambda)\cdot q_B(b|y,\lambda)$
$A_0 = \sigma_x$
$A_1 = \sigma_z$
$B_0 = \frac{\sigma_x+\sigma_z}{\sqrt{2}}$
$B_1 = \frac{\sigma_x-\sigma_z}{\sqrt{2}}$
CAUTION


$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$
$\beta = 2\sqrt{2}$
$U(\Phi^+_{A'B'} \otimes \sigma_{A''B''})U^\dagger = \rho_{AB}$
$U = U_A \otimes U_B$


$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$
$U(\Phi^+_{A'B'} \otimes \sigma_{A''B''})U^+ = \rho_{AB}$
$\beta = 2\sqrt{2}$
$U = U_A \otimes U_B$
Tilted CHSH
$W = \alpha A_0 \otimes 1 + A_0 \otimes (B_0 + B_1) + A_1 \otimes (B_0 - B_1)$
$\alpha \in [0,2)$
CAUTION


$\beta = 2\sqrt{2}$
$U(\Phi^+_{A'B'} \otimes \sigma_{A''B''})U^\dagger = \rho_{AB}$
$U = U_A \otimes U_B$
Tilted CHSH
$W = \alpha A_0 \otimes \mathbb{1} + A_0 \otimes (B_0 + B_1) + A_1 \otimes (B_0 - B_1)$
$\alpha \in [0,2)$ $\beta_L = 2+\alpha,$ $\beta_Q = \sqrt{8 + 2\alpha^2}$
$|\Psi_\theta\rangle = \cos\theta\, |00\rangle + \sin\theta\, |11\rangle$
CAUTION

$$\frac{1}{\sqrt{3}}\left(|00\rangle + |11\rangle + |22\rangle\right)$$

$|0\rangle, |1\rangle$ $\quad$ $|1\rangle, |2\rangle$

$$c_0|00\rangle + c_1|11\rangle + c_2|22\rangle + c_3|33\rangle + \ldots$$

$$\rho_{AB}\,,\ P_a^x\,,\ Q_b^y \longrightarrow P$$

$$T$$

$$\rho_{AB}\,,\ [P_a^x]^T,\ [Q_b^y]^T \longrightarrow P$$

$$(\sigma_x, \sigma_y, \sigma_z) \xrightarrow{\text{transpose}} (\sigma_x, -\sigma_y, \sigma_z)$$


Tilted CHSH
= α A0⊗1 + A0⊗(B0
α∈[0,2)
βL = 2+α,
= cos θ |00⟩ + sin θ