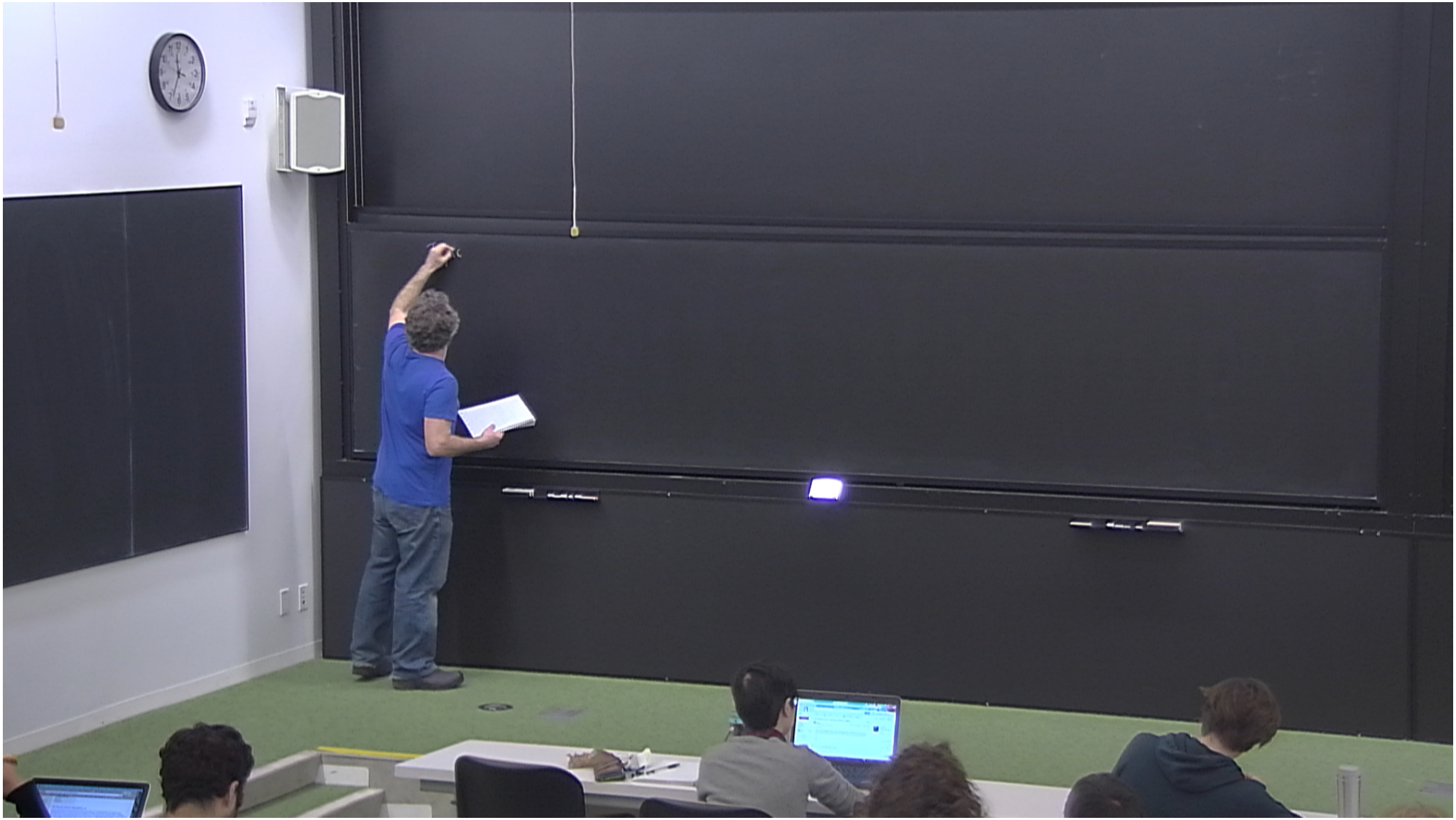
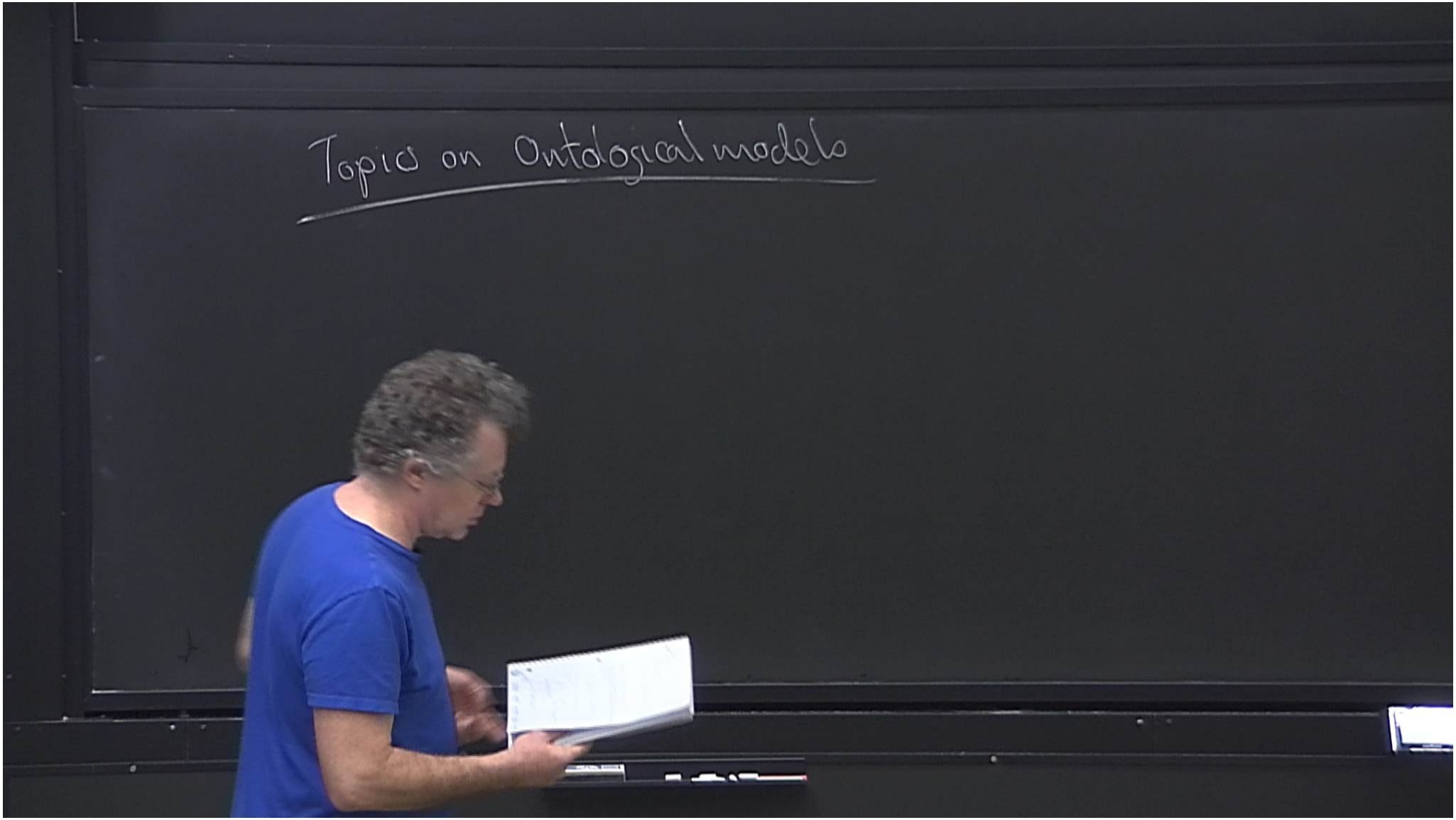
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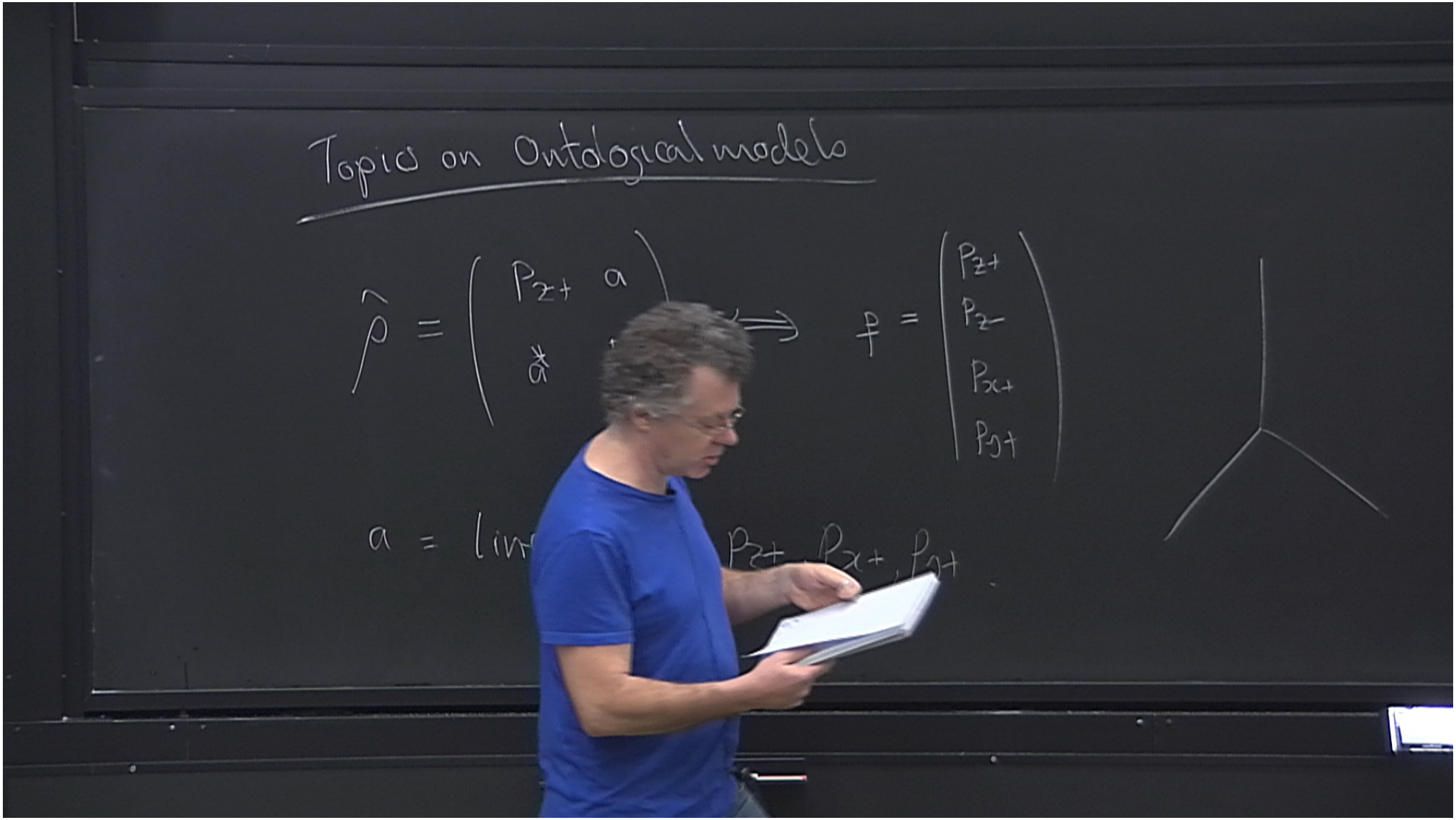
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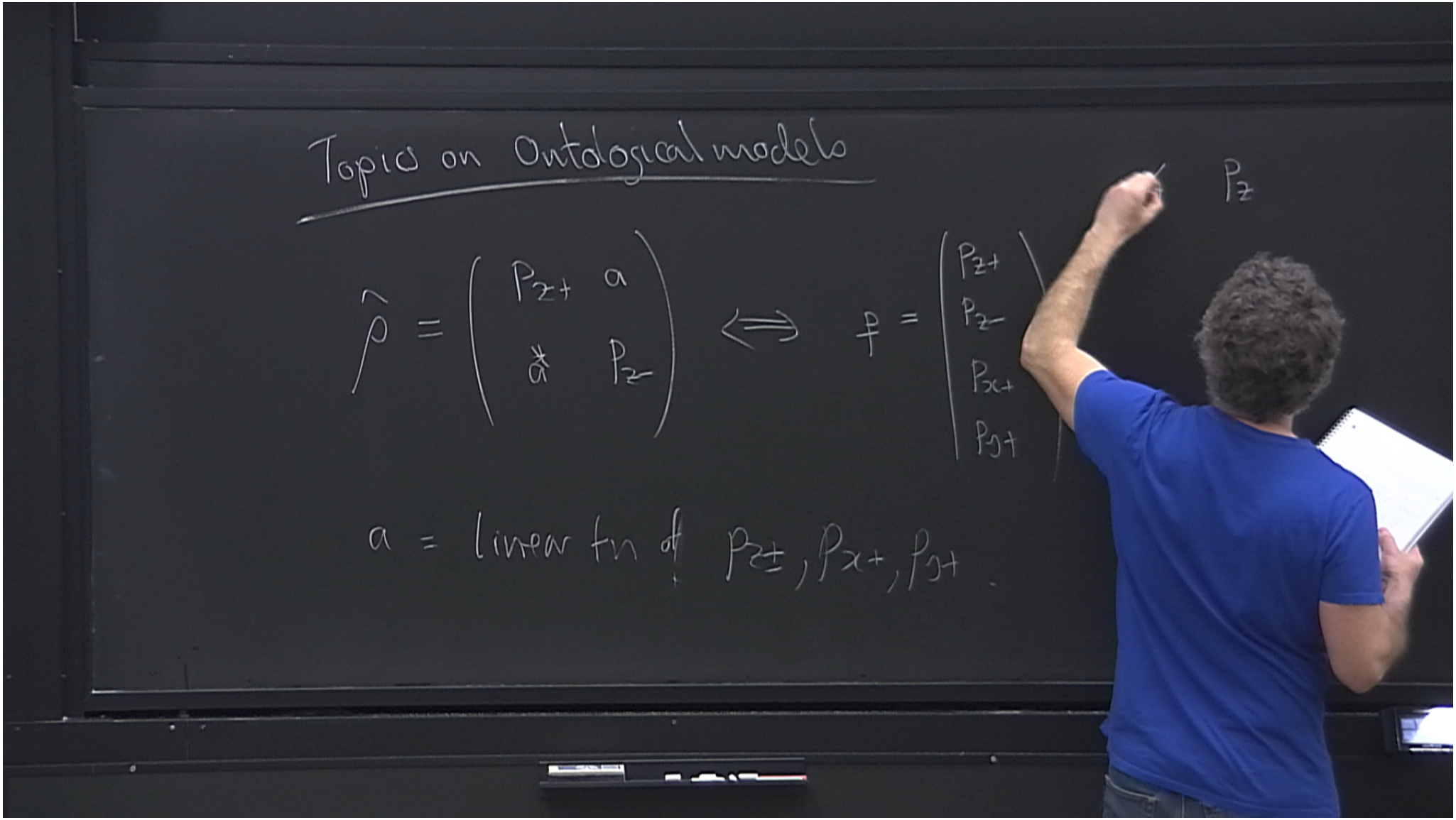
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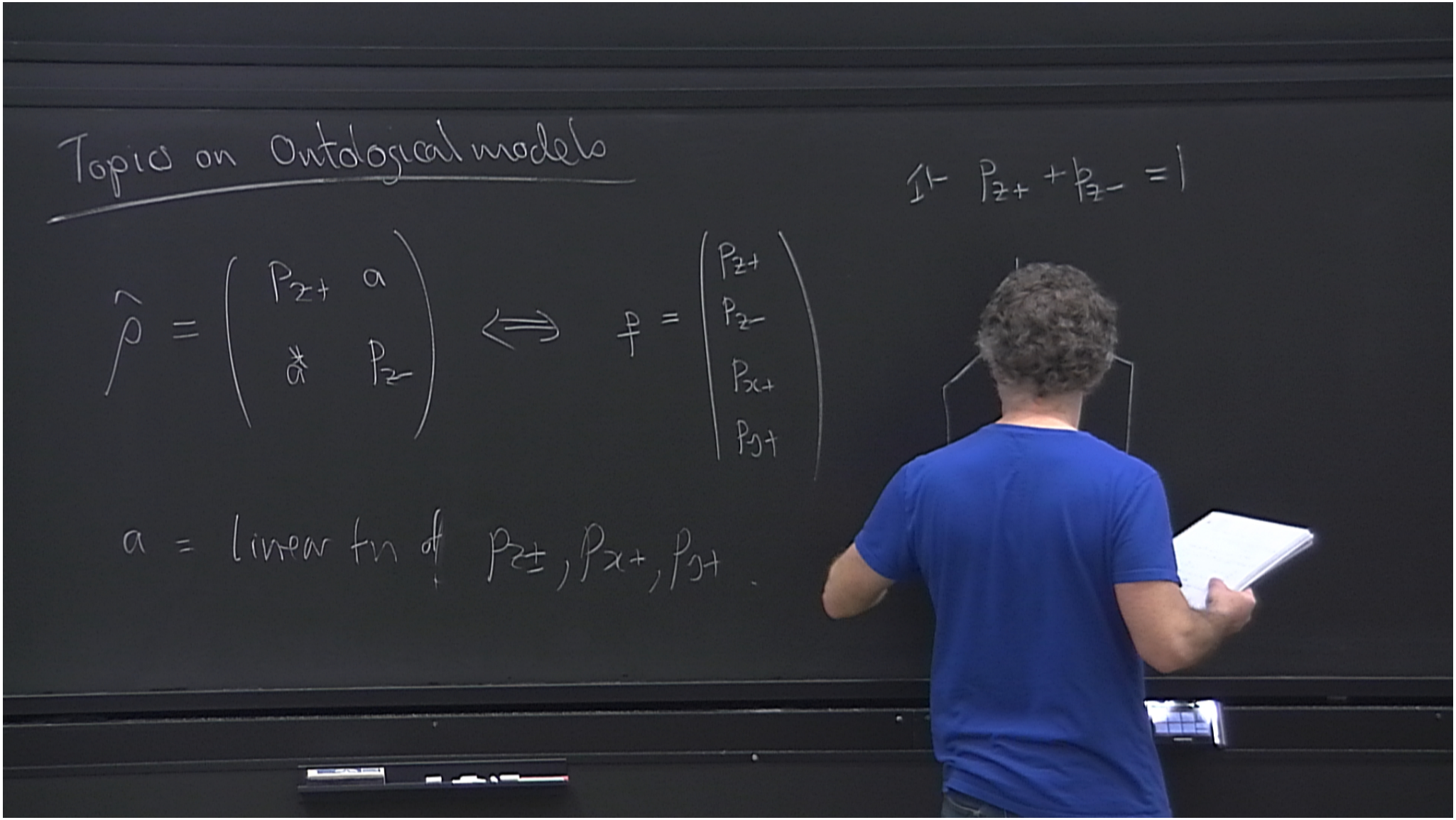
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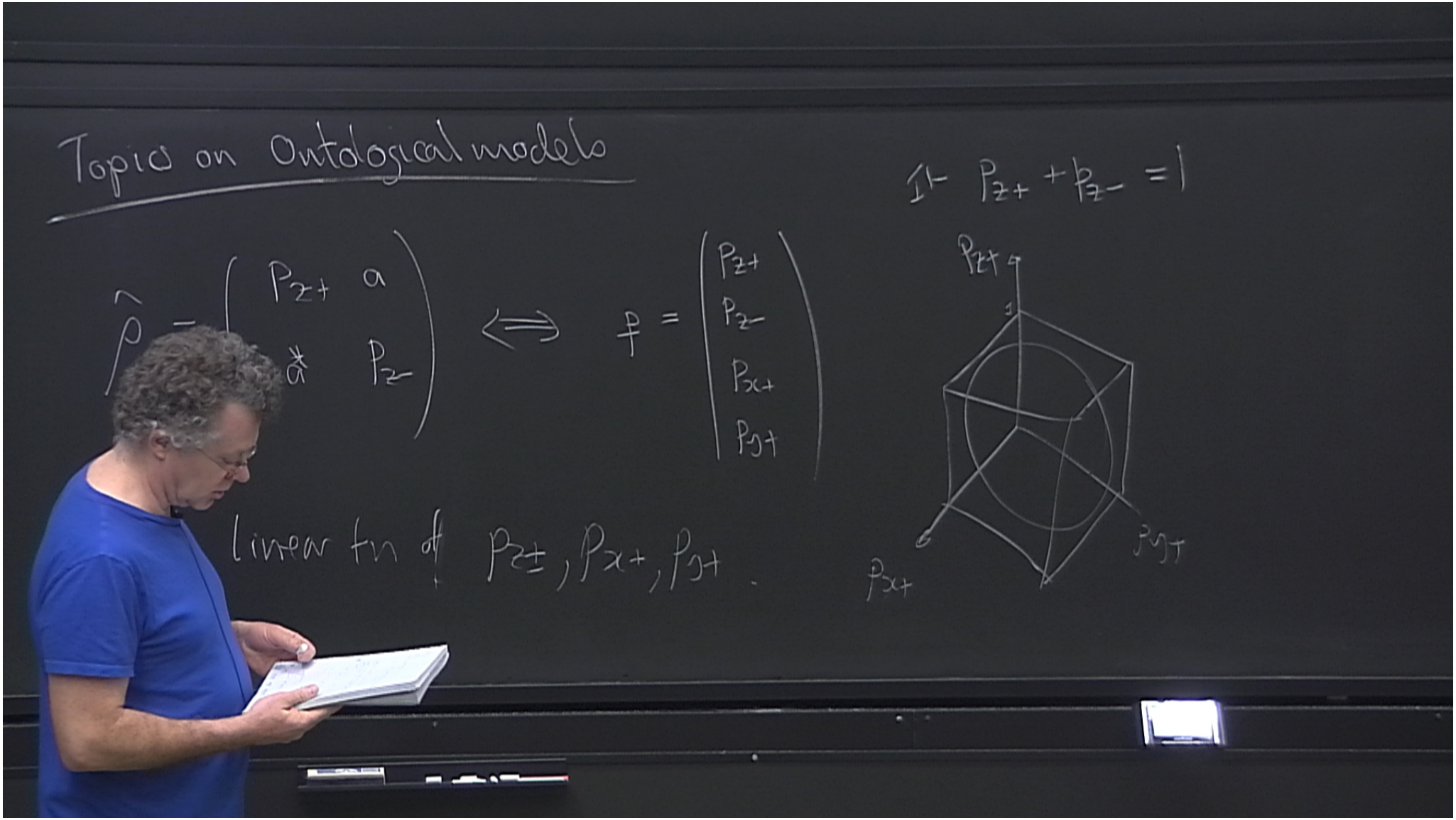


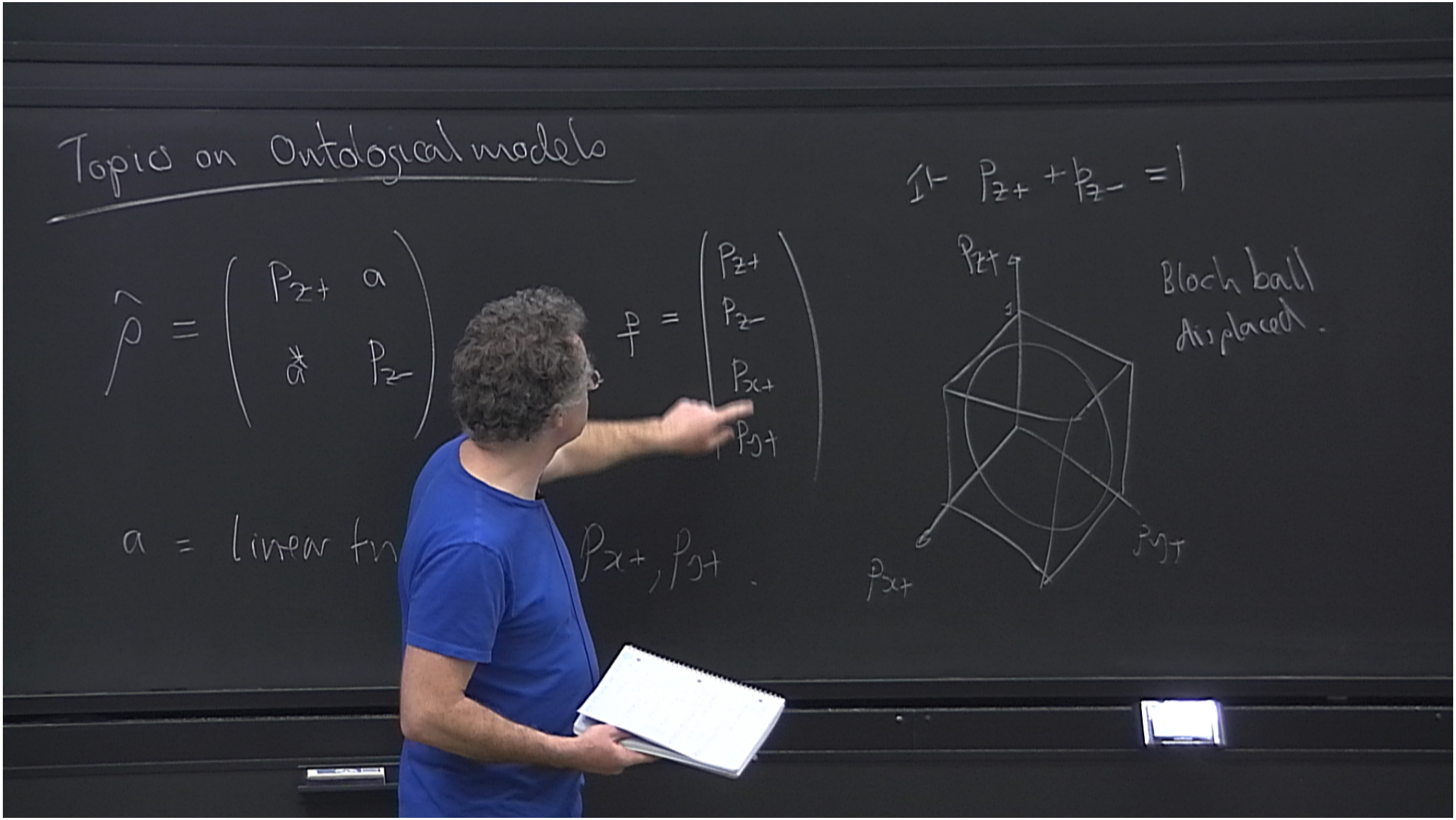

Topics on Ontological models

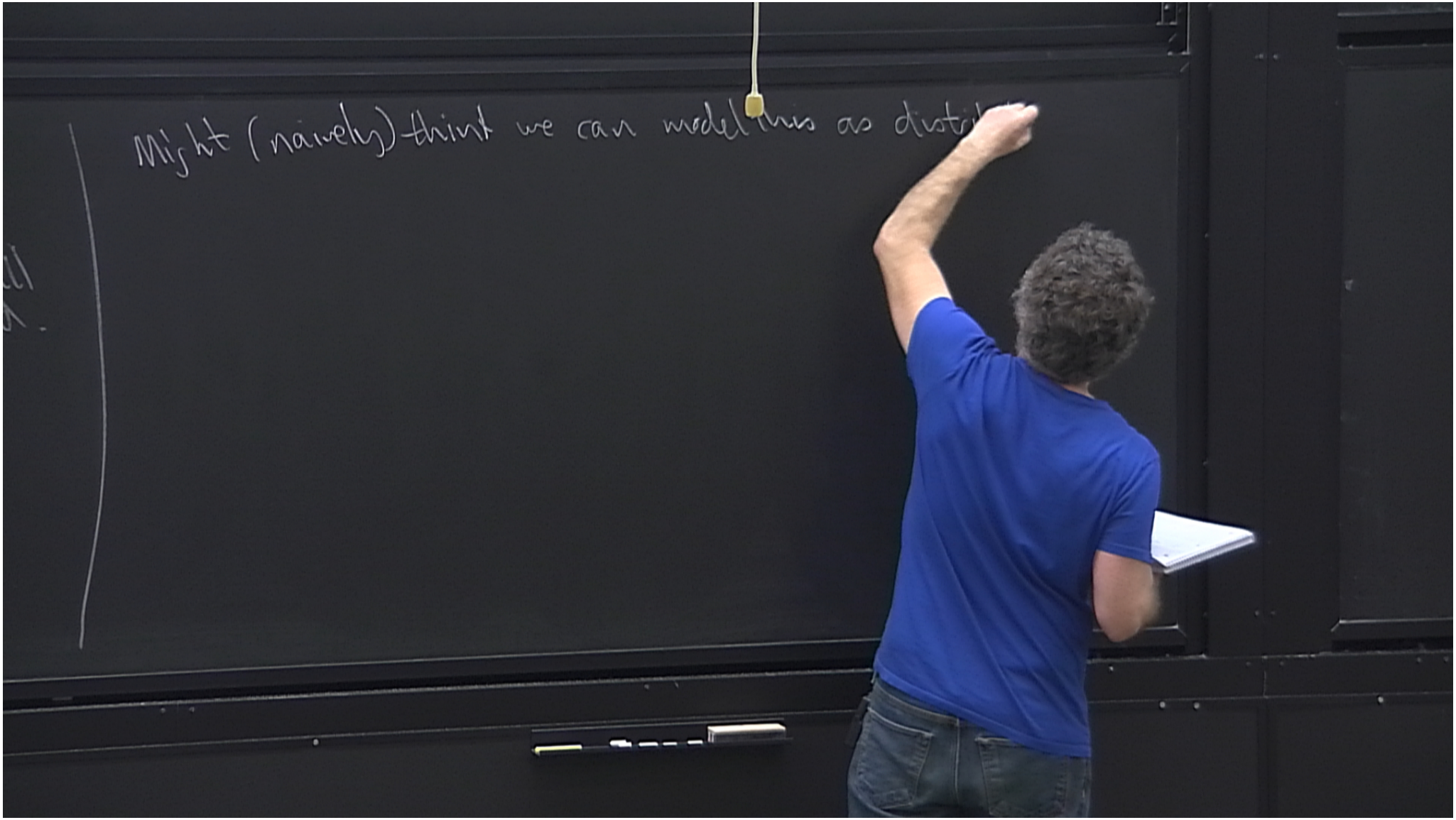

Topics on Ontological models
$\hat{\rho} = \begin{pmatrix} P_{z+} & a \\ a^* & \end{pmatrix}$
$\vec{p} = \begin{pmatrix} P_{z+} \\ P_{z-} \\ P_{x+} \\ P_{y+} \end{pmatrix}$
$a = \lim$
P_{z+}, P_{x+}, P_{y+}

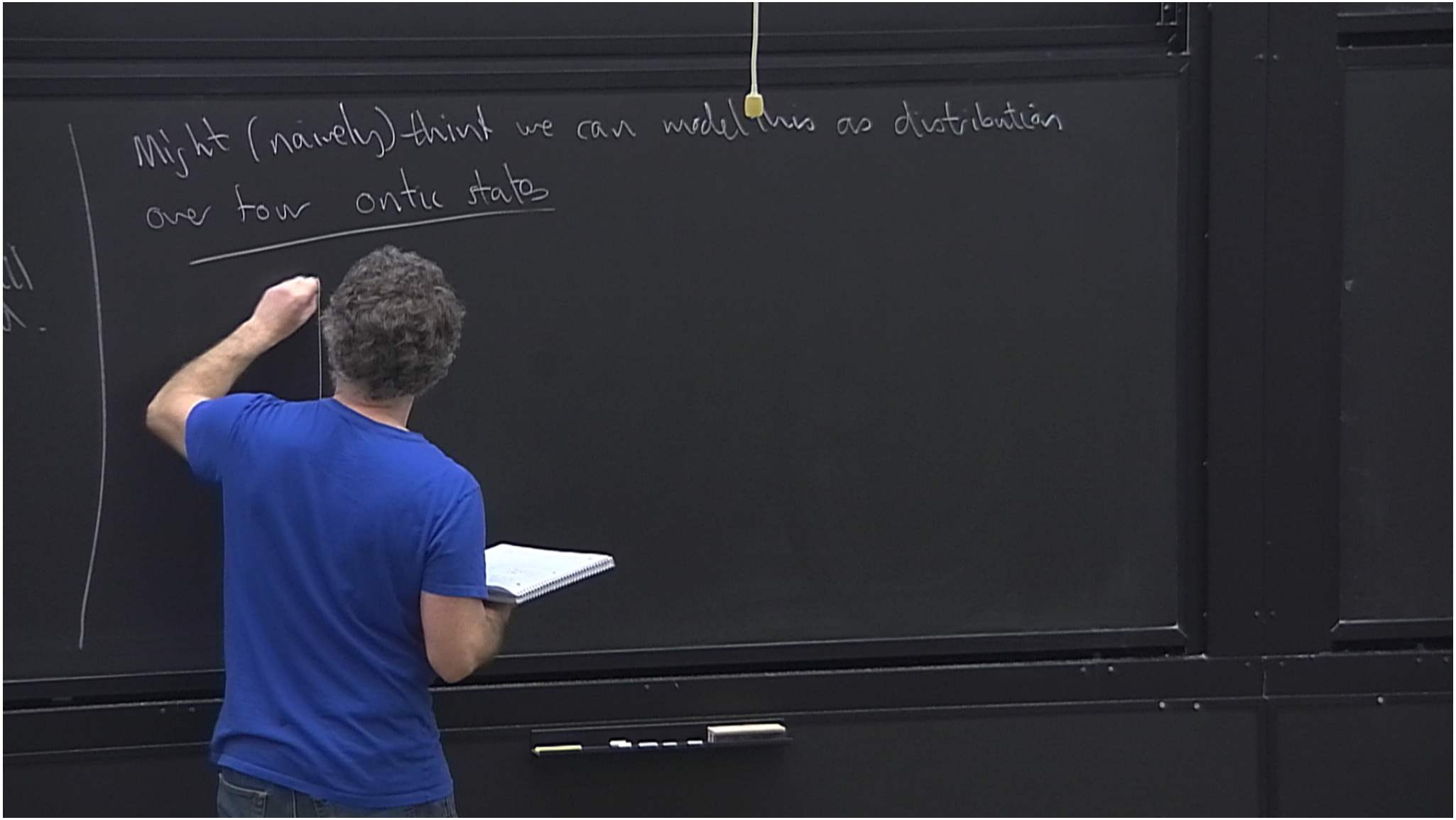

Topics on Ontological models
$\hat{\rho} = \begin{pmatrix} P_{z+} & a \\ a^* & P_{z-} \end{pmatrix} \Longleftrightarrow \vec{p} = \begin{pmatrix} P_{z+} \\ P_{z-} \\ P_{x+} \\ P_{y+} \end{pmatrix}$
a = linear fn of $P_{z\pm}, P_{x+}, P_{y+}$.
P_z


Topics on Ontological models
If $p_{z+} + p_{z-} = 1$
$\hat{\rho} = \begin{pmatrix} p_{z+} & a \\ a^* & p_{z-} \end{pmatrix} \Longleftrightarrow \vec{p} = \begin{pmatrix} p_{z+} \\ p_{z-} \\ p_{x+} \\ p_{y+} \end{pmatrix}$
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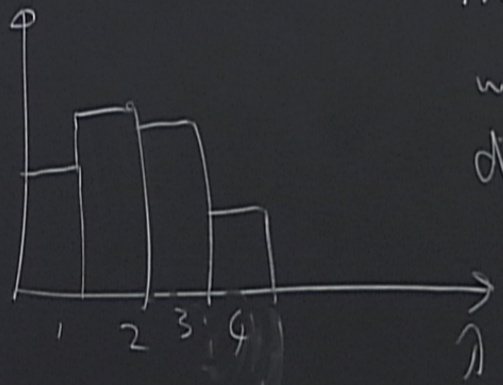

Topics on Ontological models
If $p_{z+} + p_{z-} = 1$
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linear fn of $p_{z\pm}, p_{x+}, p_{y+}$.
p_{z+}
1
p_{y+}
p_{x+}


Topics on Ontological models
If $P_{z+} + P_{z-} = 1$
$\hat{\rho} = \begin{pmatrix} P_{z+} & a \\ a^* & P_{z-} \end{pmatrix}$
$\vec{p} = \begin{pmatrix} P_{z+} \\ P_{z-} \\ P_{x+} \\ P_{y+} \end{pmatrix}$
a = linear fn P_{x+}, P_{y+}
P_{z+}
P_{x+}
P_{y+}
Bloch ball displaced.


Might (naively) think we can model this as

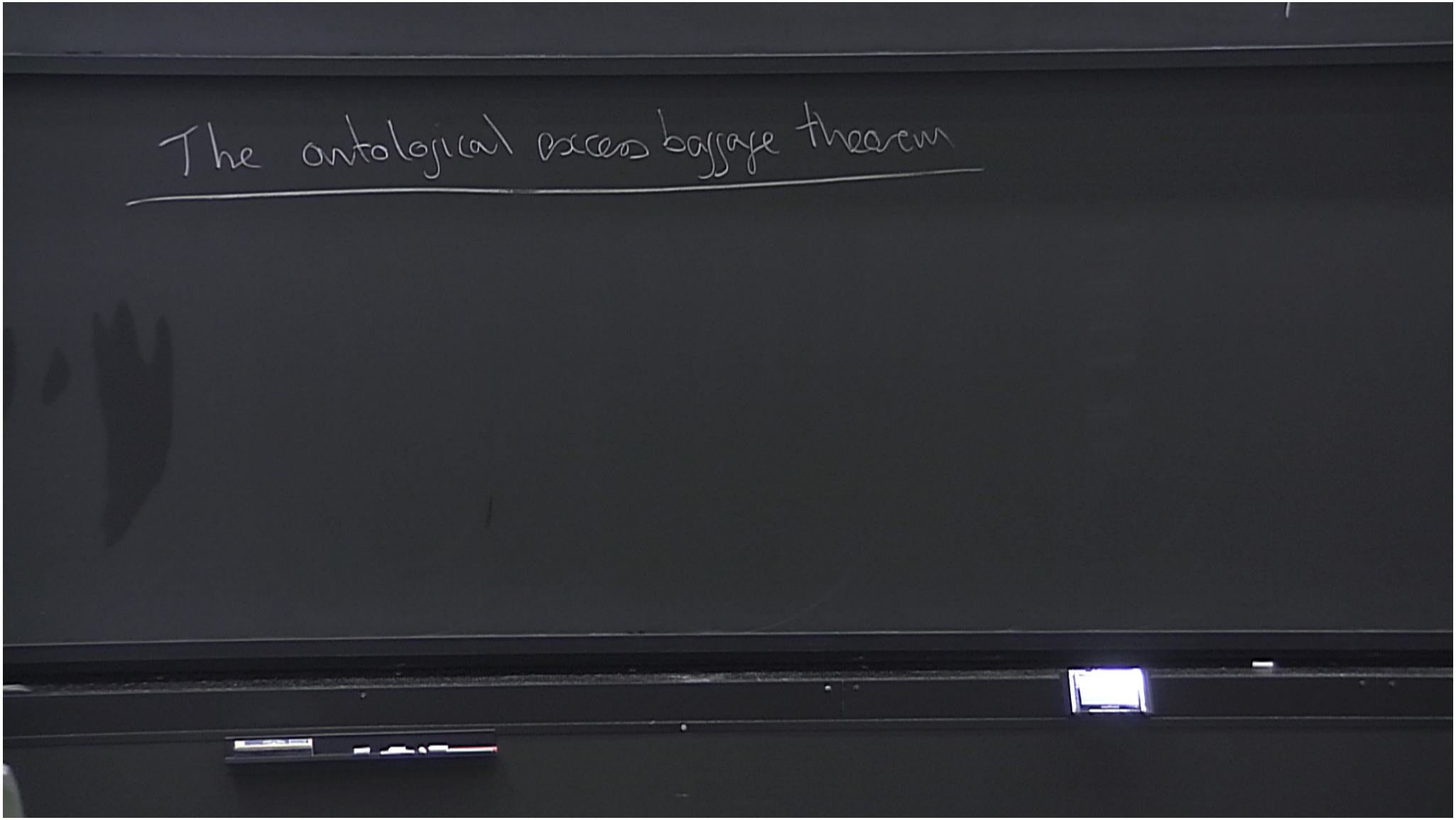

Might (naively) think we can model this as distribution
over four ontic states

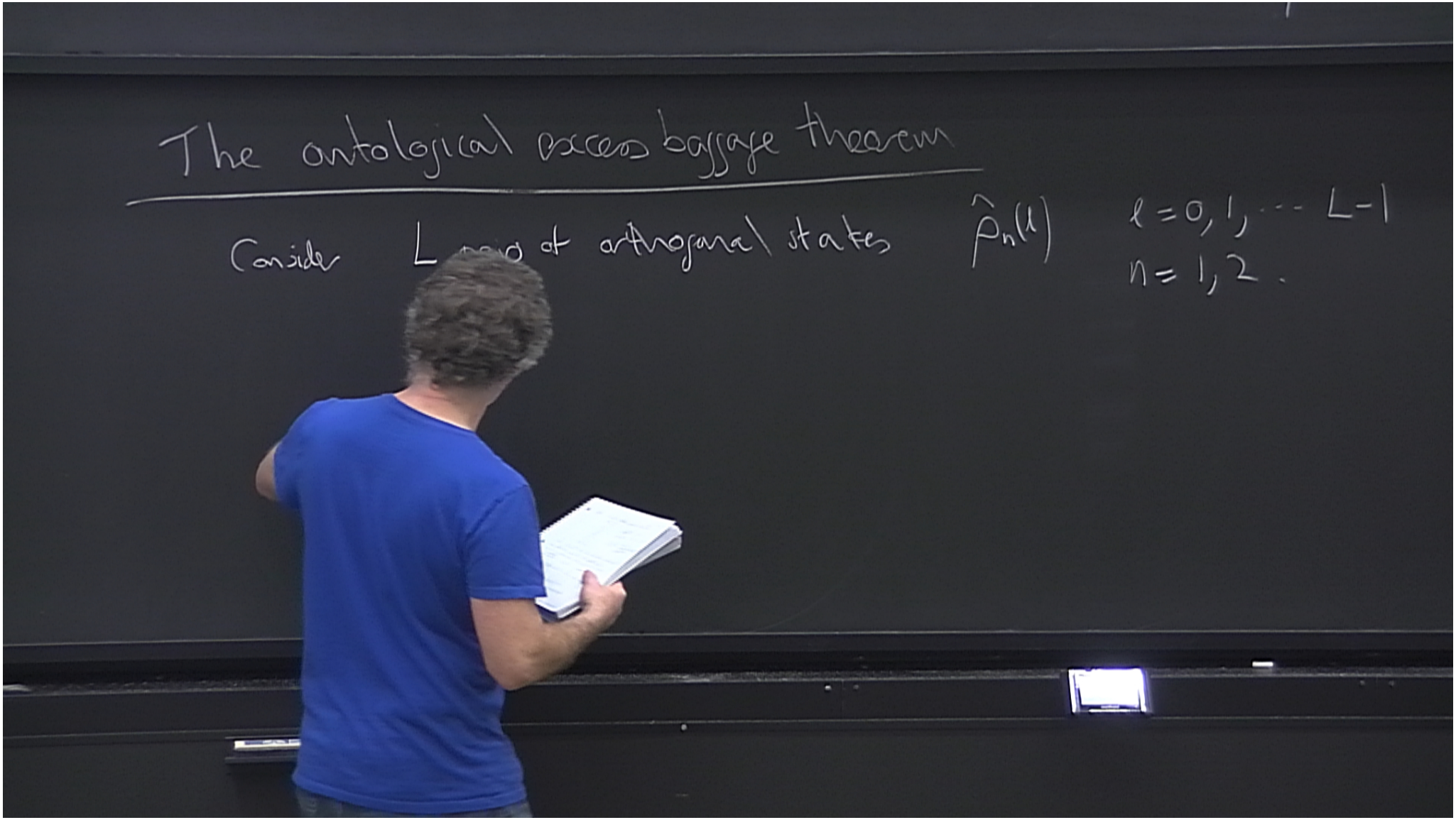
Might (naively) think we can model this as distribution over four ontic states



Then diffeat $\hat{p}$ would correspond to diff ent distributions.

Can we do this? Answer - No!


The ontological excess baggage theorem


The ontological excess baggage theorem
Consider L pairs of orthogonal states $\hat{\rho}_n(l)$ $l = 0, 1, \cdots L-1$
$n = 1, 2$.

The ontological excess baggage theorem

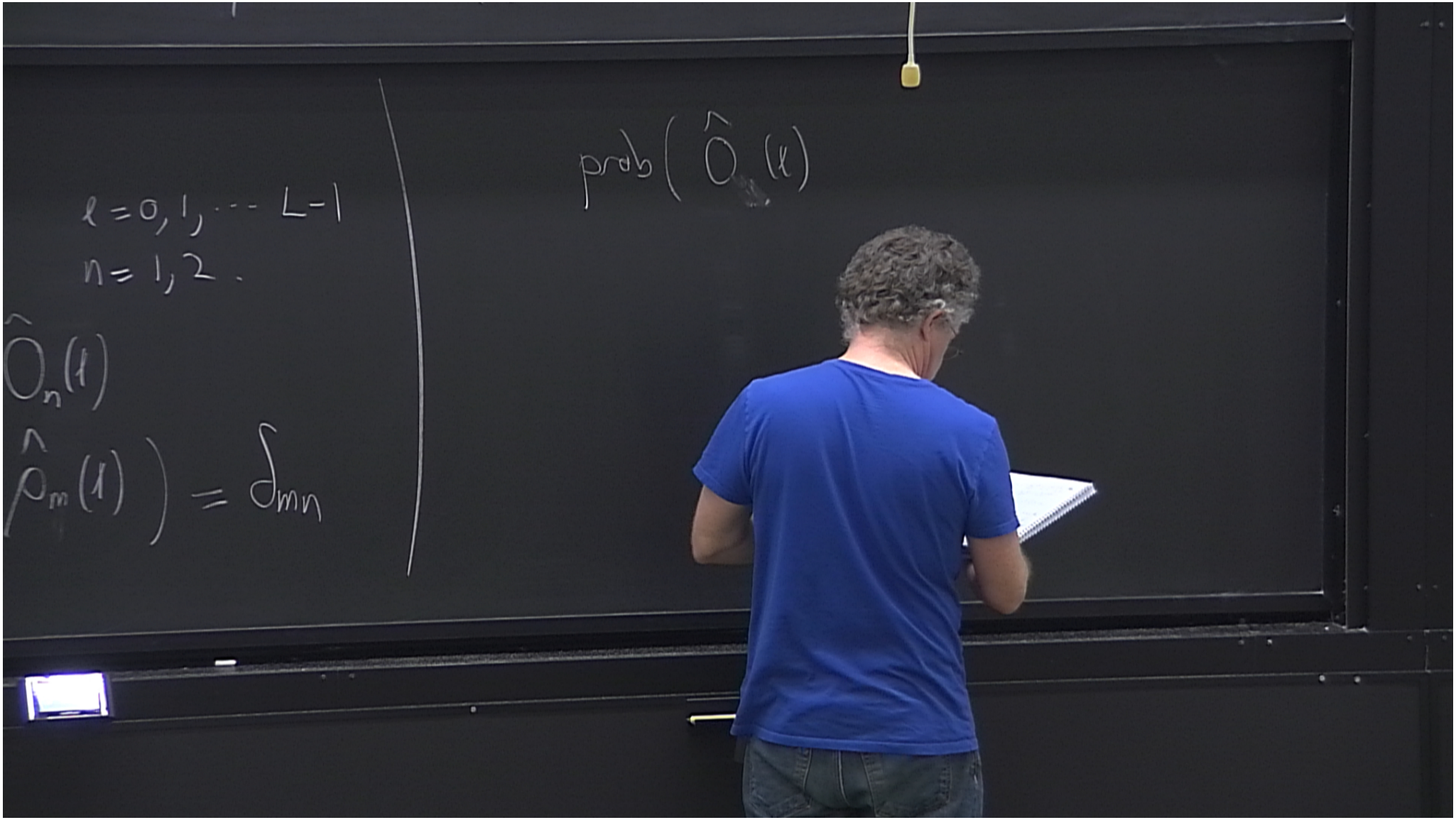
Consider L pairs of orthogonal states $\hat{\rho}_n(\ell)$ $\ell = 0, 1, \cdots L-1$
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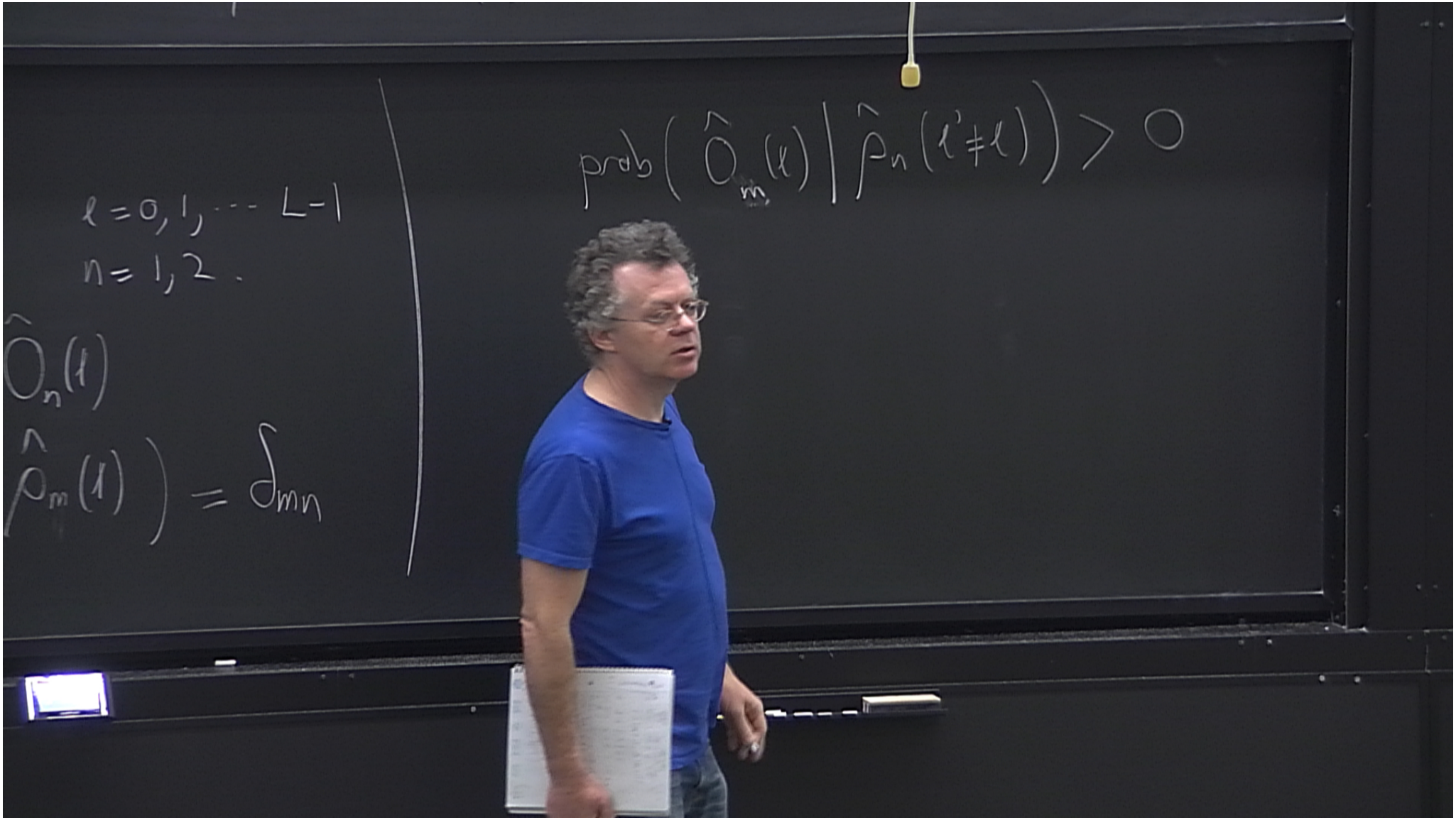


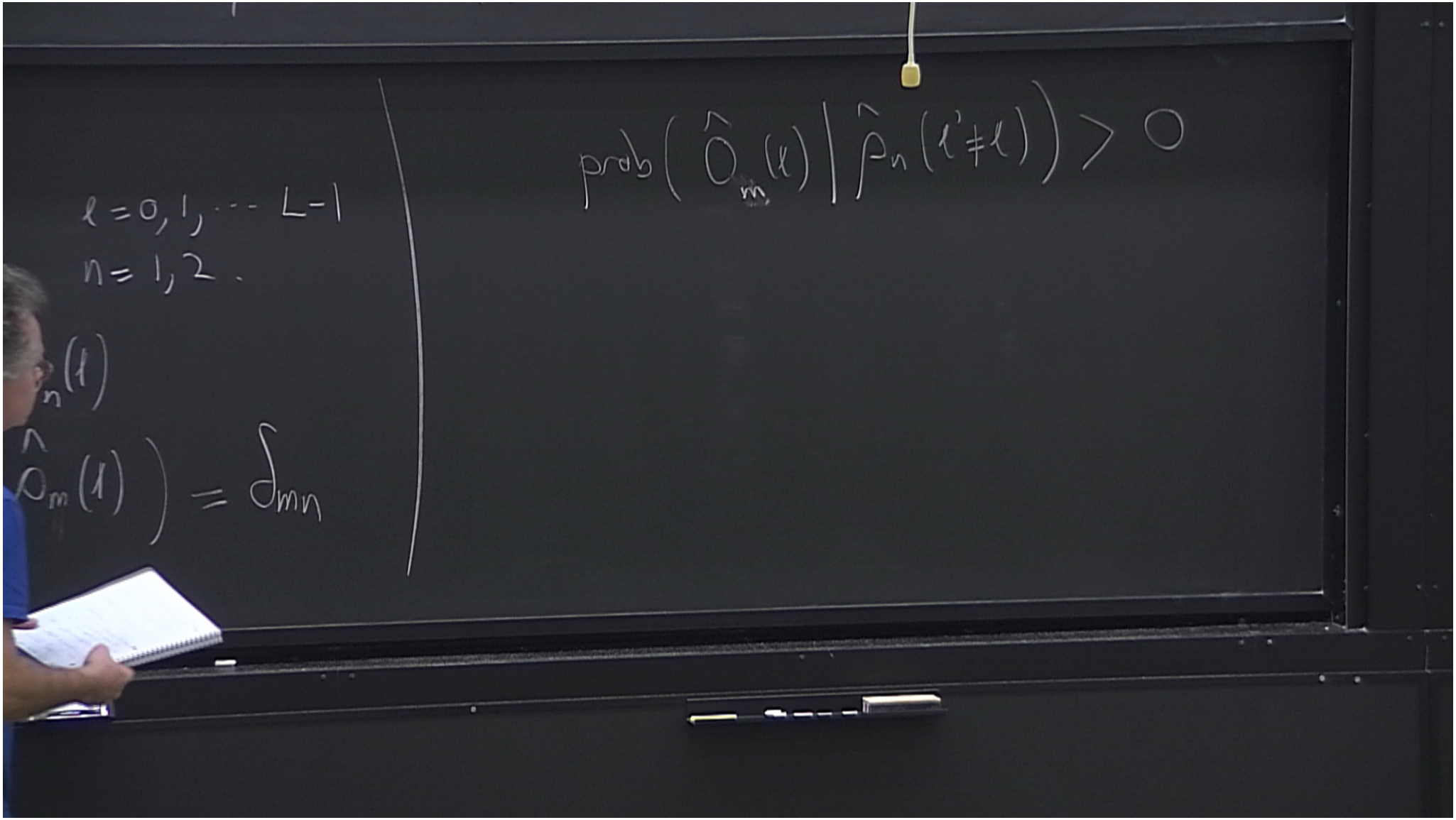
The ontological excess baggage theorem

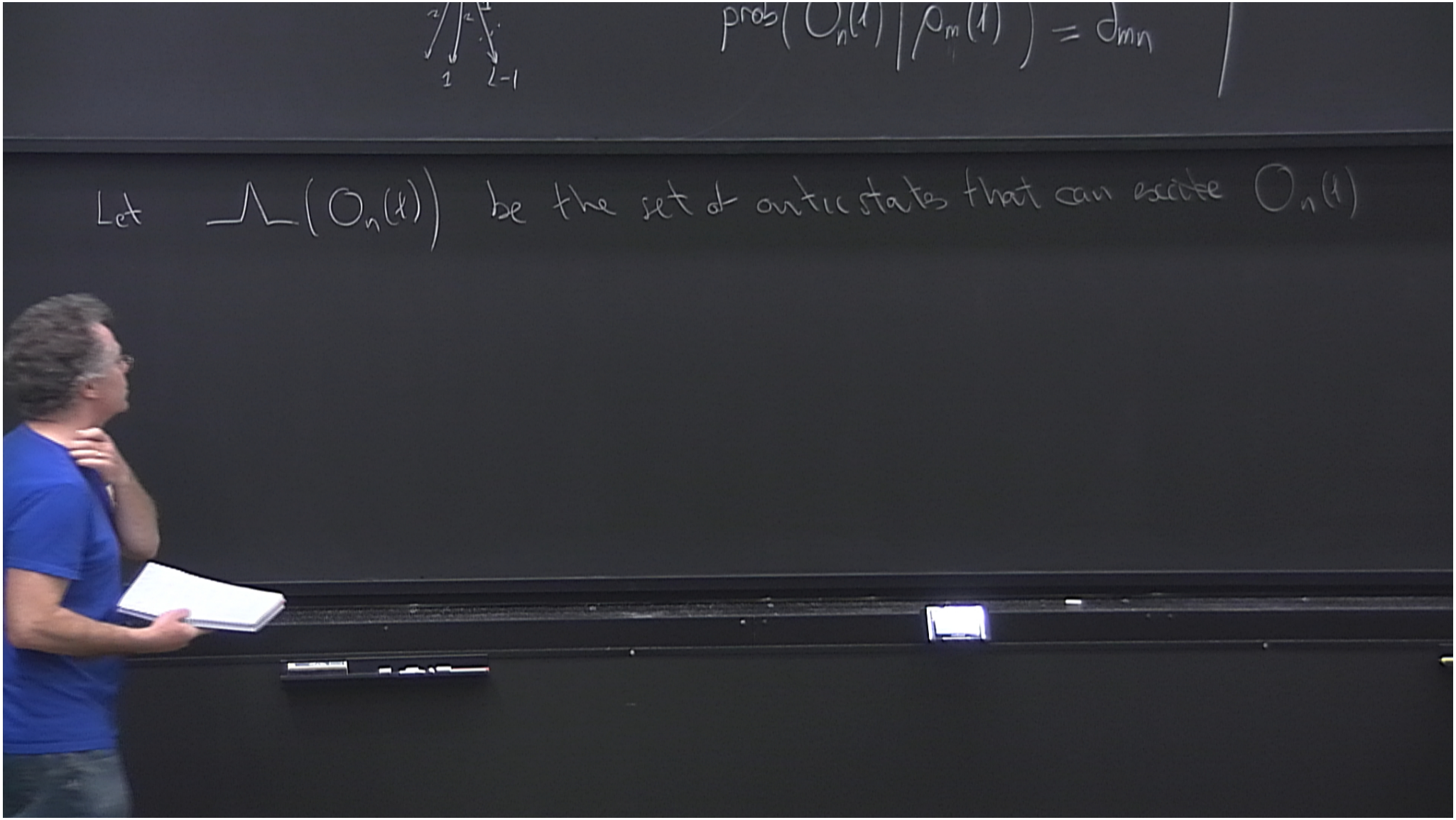
Consider L pairs of orthogonal states $\hat{\rho}_n(l)$ $l = 0, 1, \cdots L-1$, $n = 1, 2$.




$\ell = 0, 1, \cdots L-1$
$n = 1, 2.$
$\hat{O}_n(\ell)$
$\hat{\rho}_m(\ell)) = \delta_{mn}$
$\text{prob}(\hat{O}(\ell)$


$\ell = 0, 1, \cdots L-1$
$n = 1, 2.$
$\hat{O}_n(\ell)$
$\hat{\rho}_m(\ell')) = \delta_{mn}$
$\text{prob}(\hat{O}_m(\ell) | \hat{\rho}_n(\ell' \neq \ell)) > 0$


$\ell = 0, 1, \cdots L-1$
$n = 1, 2.$
$\hat{\rho}_n(\ell)$
$\hat{\rho}_m(\ell) \Big) = \delta_{mn}$
$\text{prob}\left(\hat{O}_m(\ell) \,\middle|\, \hat{\rho}_n(\ell' \neq \ell) \right) > 0$

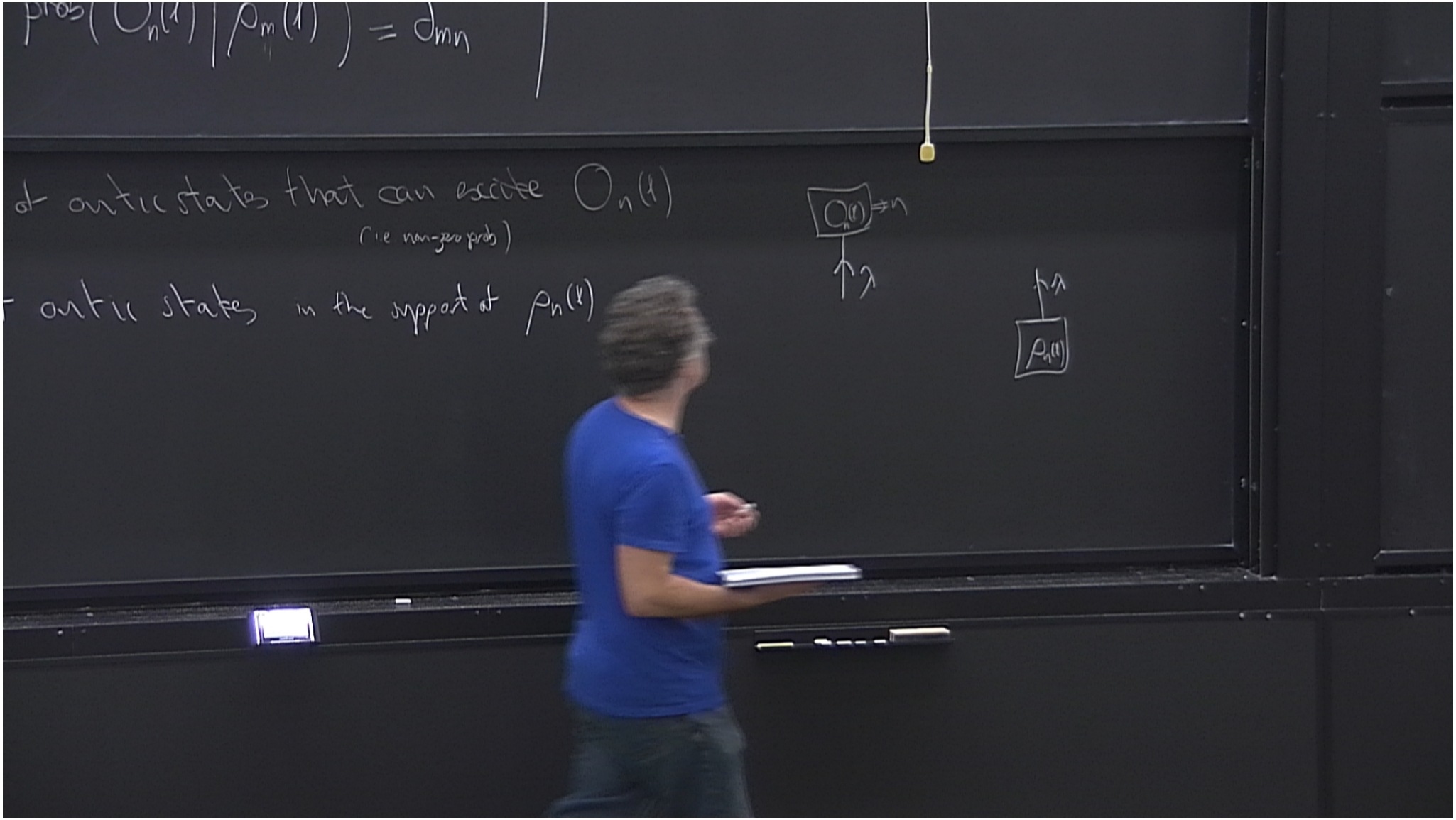

$\text{prob}(O_n(t) | \rho_m(t)) = \delta_{mn}$
Let $\Lambda(O_n(t))$ be the set of outlier states that can excite $O_n(t)$

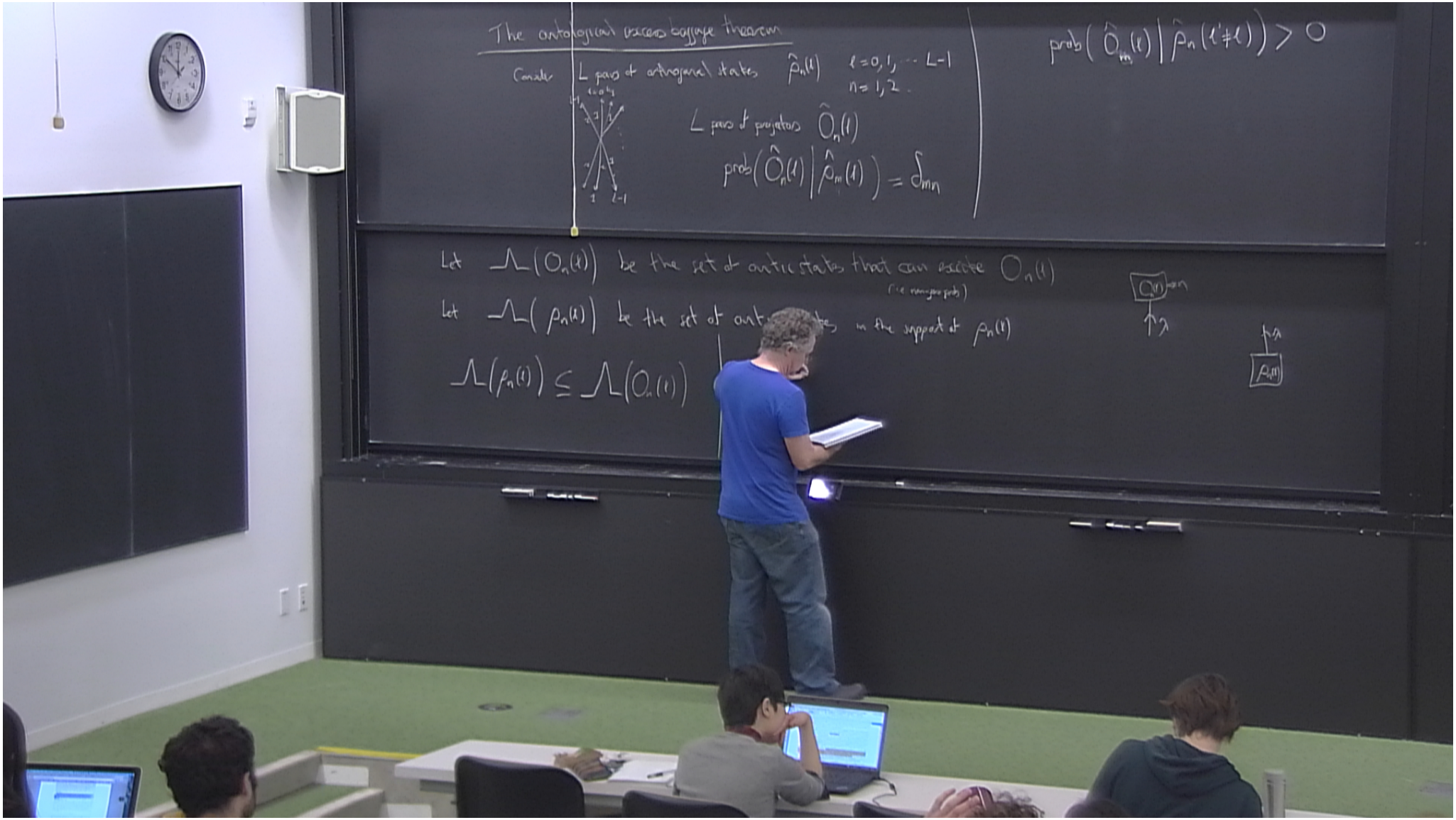


$\text{prob}\left(O_n(l) \,\middle|\, \rho_m(l)\right) = \delta_{mn}$

Let $\Lambda\left(O_n(l)\right)$ be the set of outer states that can excite $O_n(l)$ (i.e. non-zero prob)

Let $\Lambda\left(\rho_n(l)\right)$ be the set of outer states in the support of $\rho_n(l)$


prob($O_n(t)$ | $\rho_m(t)$) = δ_{mn}
of outic states that can excite $O_n(t)$
(i.e non-zero prob)
outic states in the support of $\rho_n(t)$
$O_n(t)$
$\rho_n(t)$

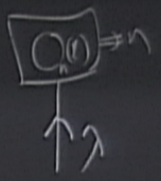

The ontological excess baggage theorem
Consider L pairs of orthogonal states $\hat{\rho}_n(\ell)$ $\ell = 0, 1, \cdots L-1$ $n = 1, 2$.
L pairs of projectors $\hat{O}_n(\ell)$
$\text{prob}(\hat{O}_n(\ell) | \hat{\rho}_m(\ell)) = \delta_{mn}$
$\text{prob}(\hat{O}_m(\ell) | \hat{\rho}_n(\ell' \neq \ell)) > 0$
Let $\Lambda(O_n(\ell))$ be the set of ontic states that can excite $O_n(\ell)$
(i.e. non-zero prob)
Let $\Lambda(\rho_n(\ell))$ be the set of ontic states in the support of $\rho_n(\ell)$
$\Lambda(\rho_n(\ell)) \leq \Lambda(O_n(\ell))$

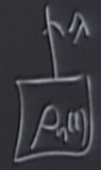
$\text{prob}\left(O_n(t) \,\middle|\, \rho_m(t)\right) = \delta_{mn}$

be the set of outic states that can excite $O_n(t)$
(i.e non-zero prob)

be the set of outic states [illegible] support of $\rho_n(t)$

$\Lambda(O_n(t))$





$\text{prob}\left(O_n(t) \,\middle|\, \rho_m(t)\right) = \delta_{mn}$

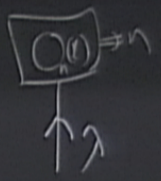
be the set of outic states that can excite $O_n(t)$
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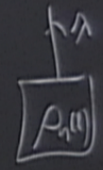
be the set of outic states in the support of $\rho_n(t)$

$\left\langle O_m(t) \,\middle|\, \rho_{n\neq m}(t) \right\rangle = 0$

$\Lambda(O_n(t))$

$\Lambda(O_m(t)) \cap \Lambda(\rho_{n\neq m}(t)) = \emptyset$



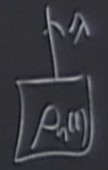


$\text{prob}\left(O_n(t) \,\middle|\, \rho_m(t)\right) = \delta_{mn}$

be the set of outic states that can excite $O_n(t)$
(i.e non-zero prob)



be the set of outic states in the support of $\rho_n(t)$



$\text{prob}\left(O_m(t) \,\middle|\, \rho_{n\neq m}(t)\right) = 0$

$\Lambda\left(O_n(t)\right)$

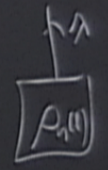
$\Lambda\left(O_m(t)\right) \cap \Lambda\left(\rho_{n\neq m}(t)\right) = \emptyset$

$\text{prob}\left(O_n(t) \,\middle|\, \rho_m(t)\right) = \delta_{mn}$

be the set of outic states that can excite $O_n(t)$
(i.e non-zero prob)



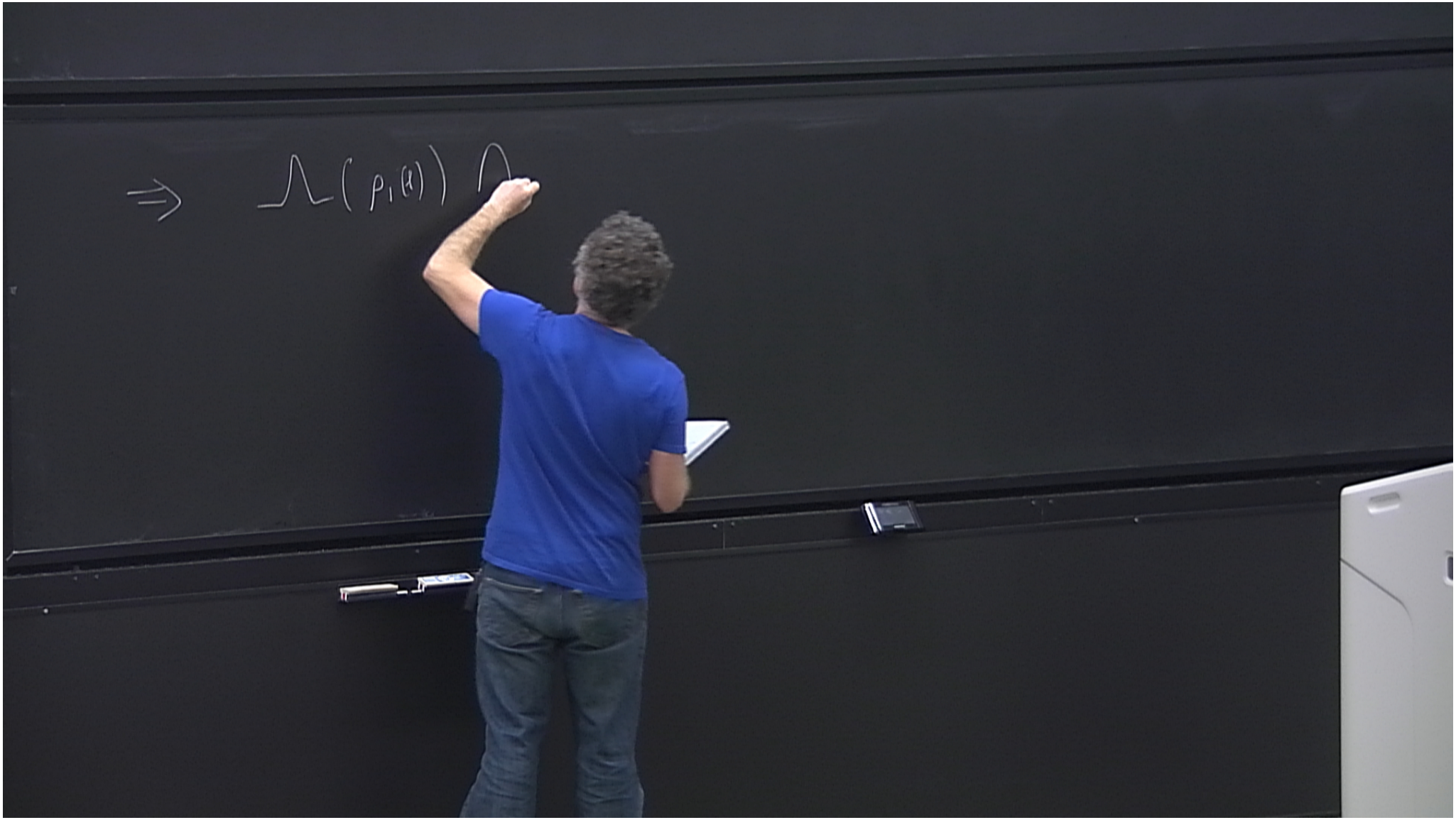
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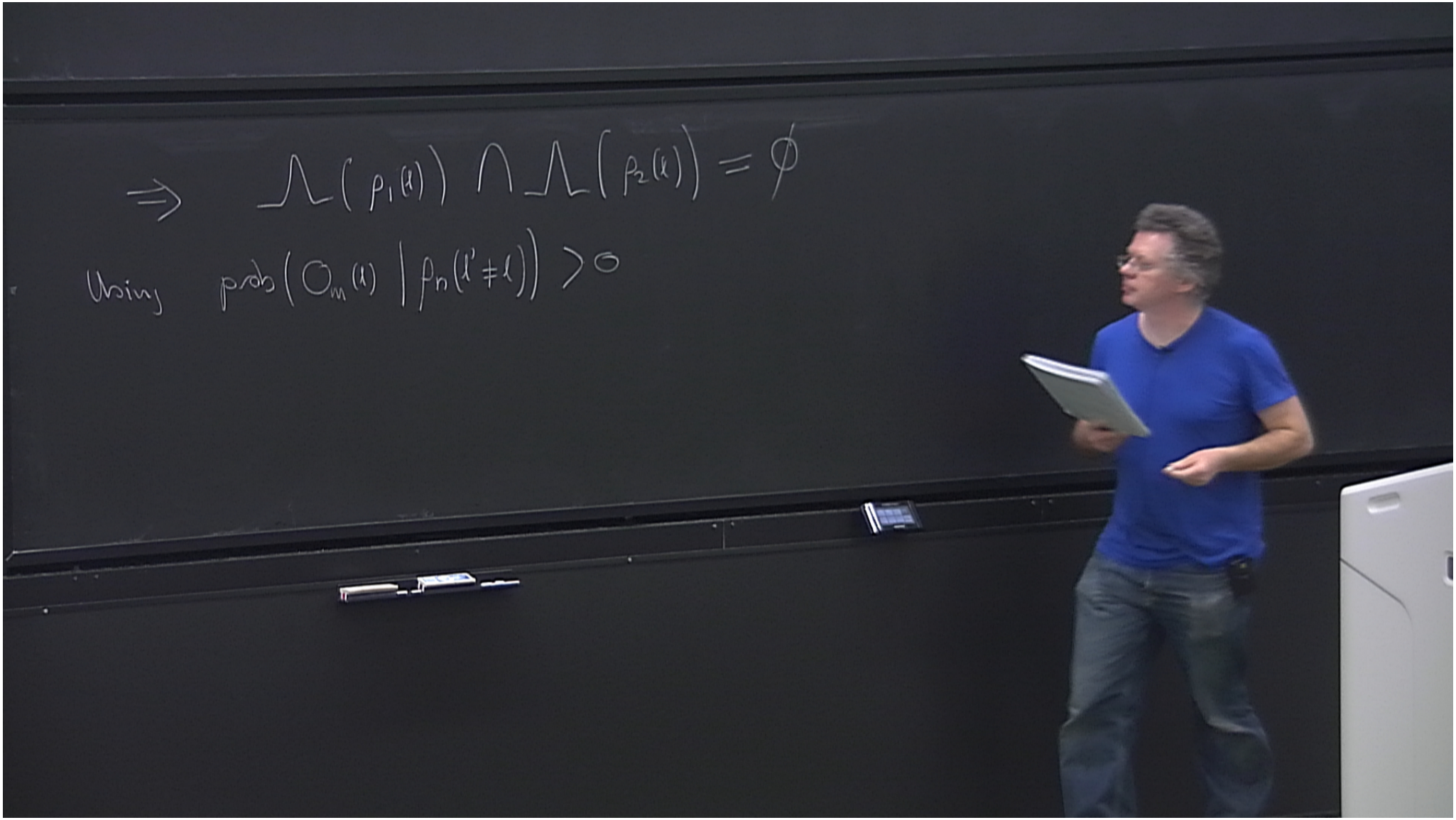


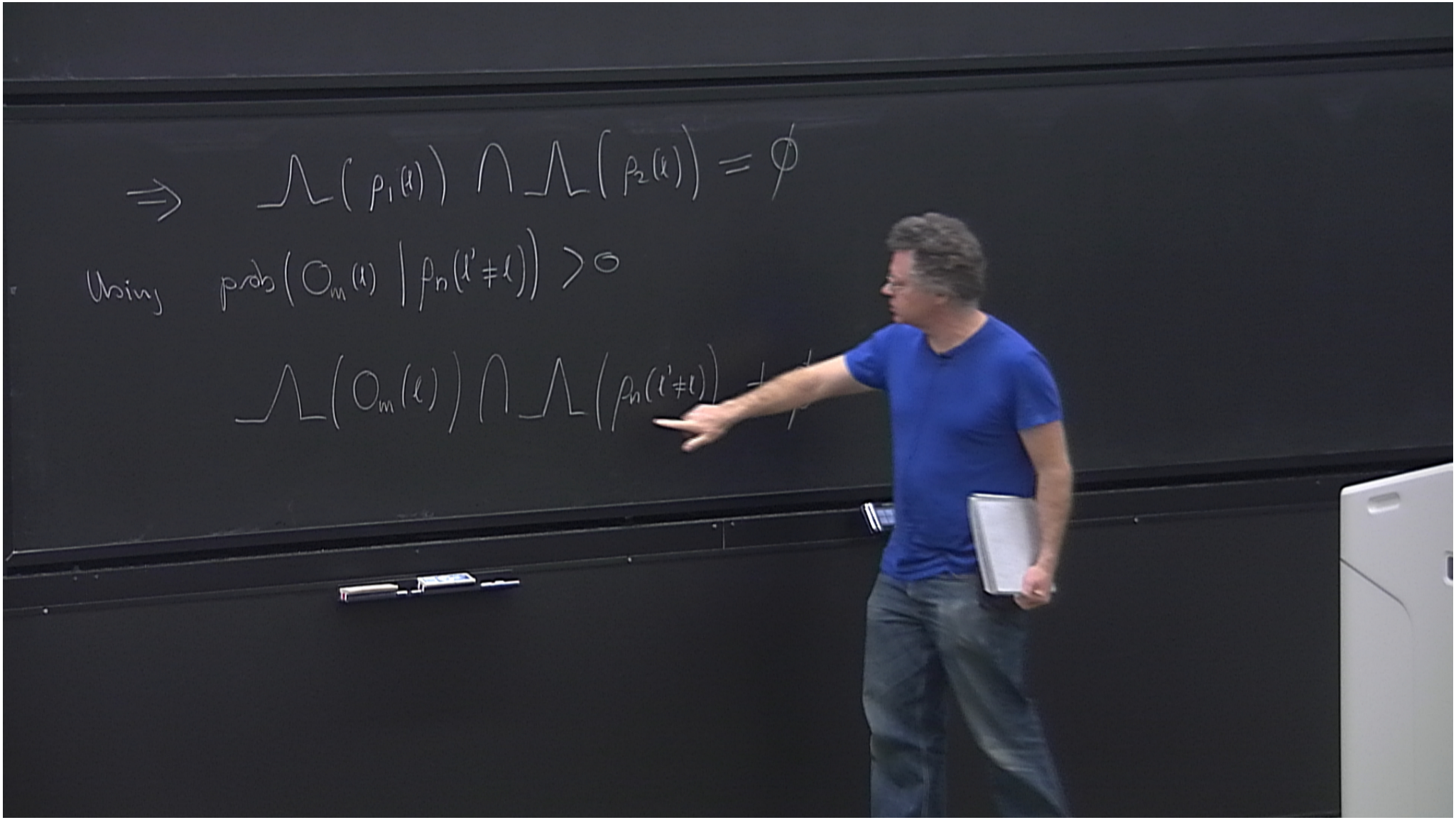
$\text{prob}\left(O_m(t) \,\middle|\, \rho_{n\neq m}(t)\right) = 0$

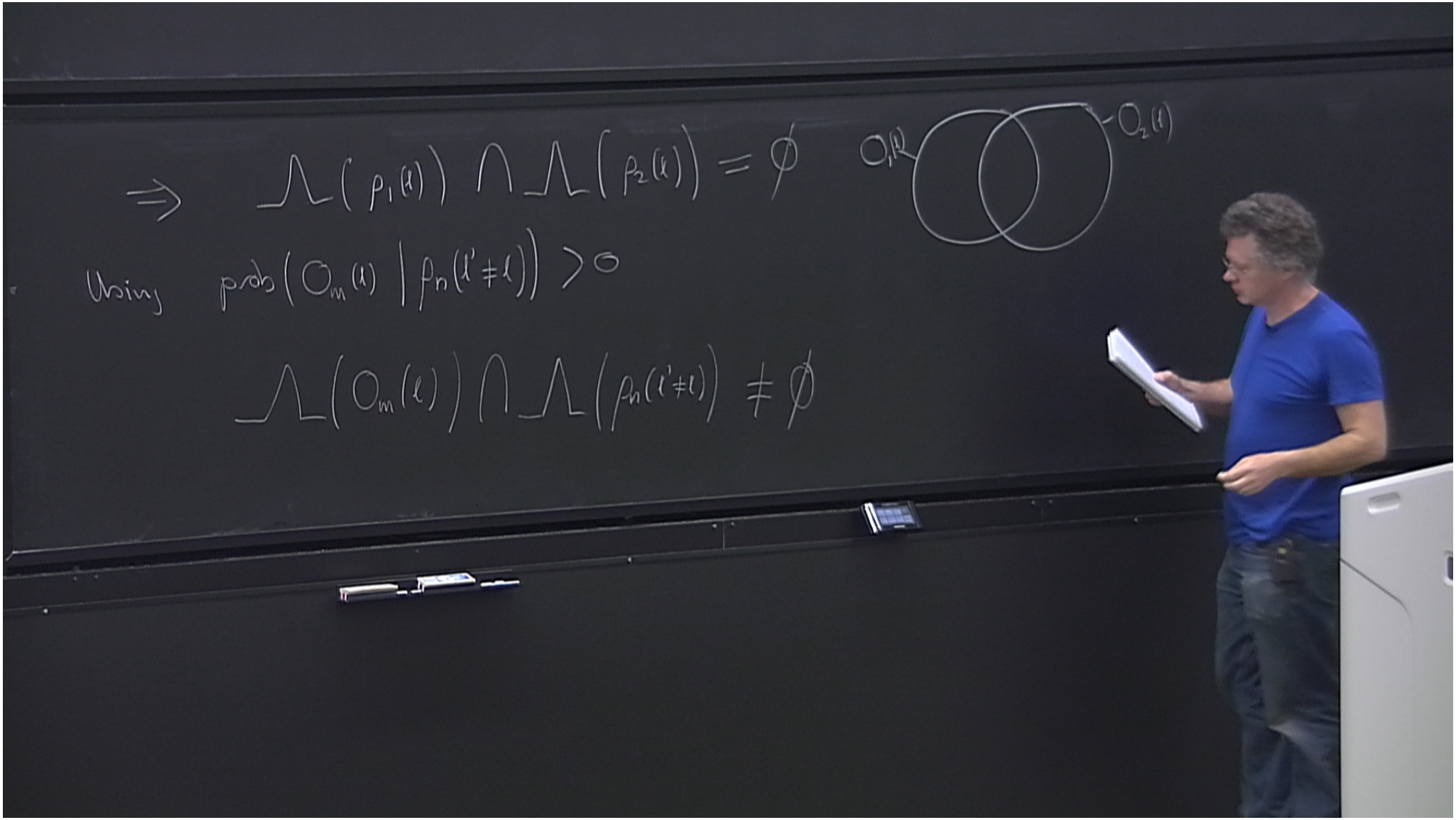
$\Lambda(O_n(t))$

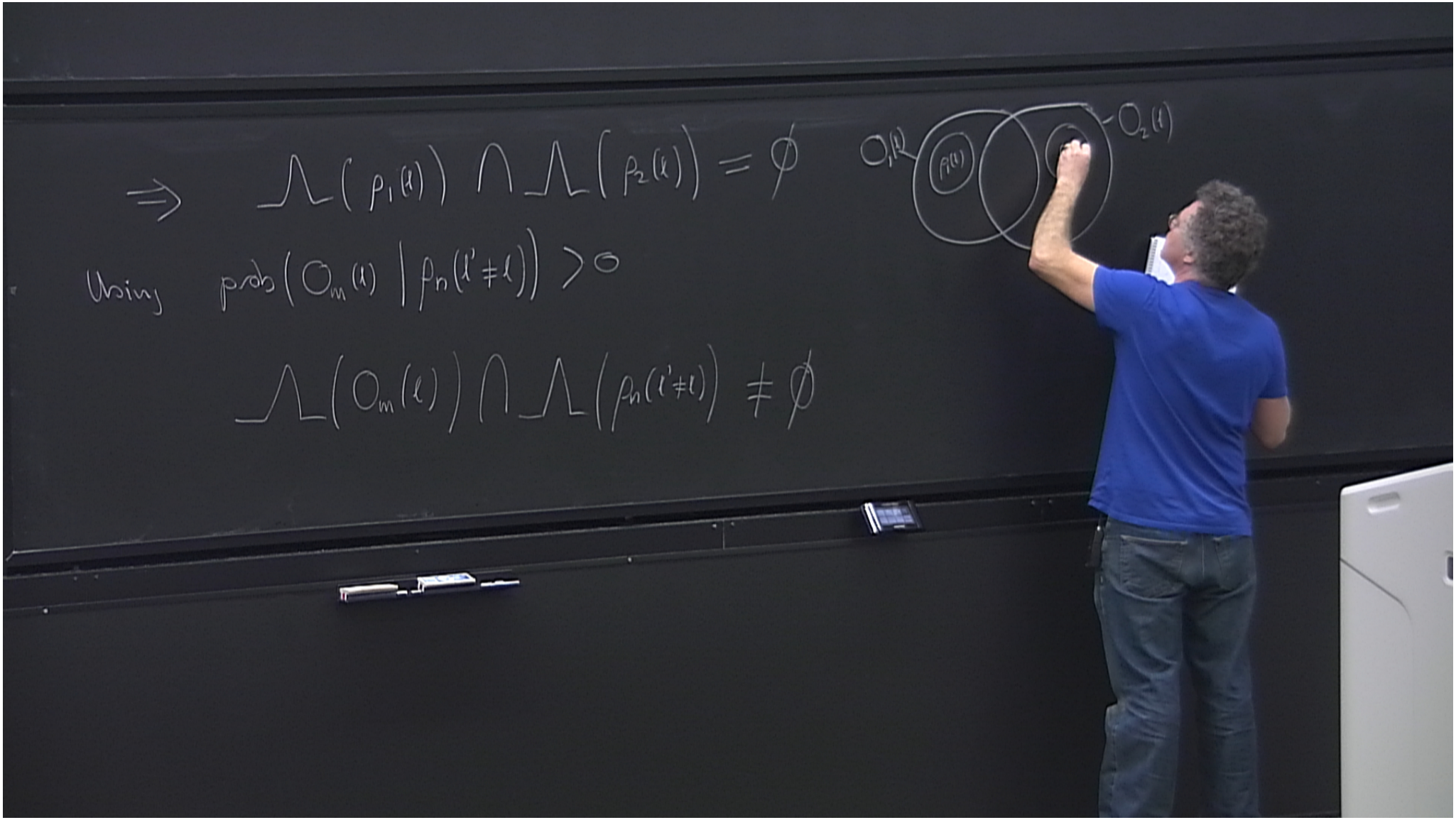
$\Lambda(O_m(t)) \cap \Lambda(\rho_{n\neq m}(t)) = \emptyset$

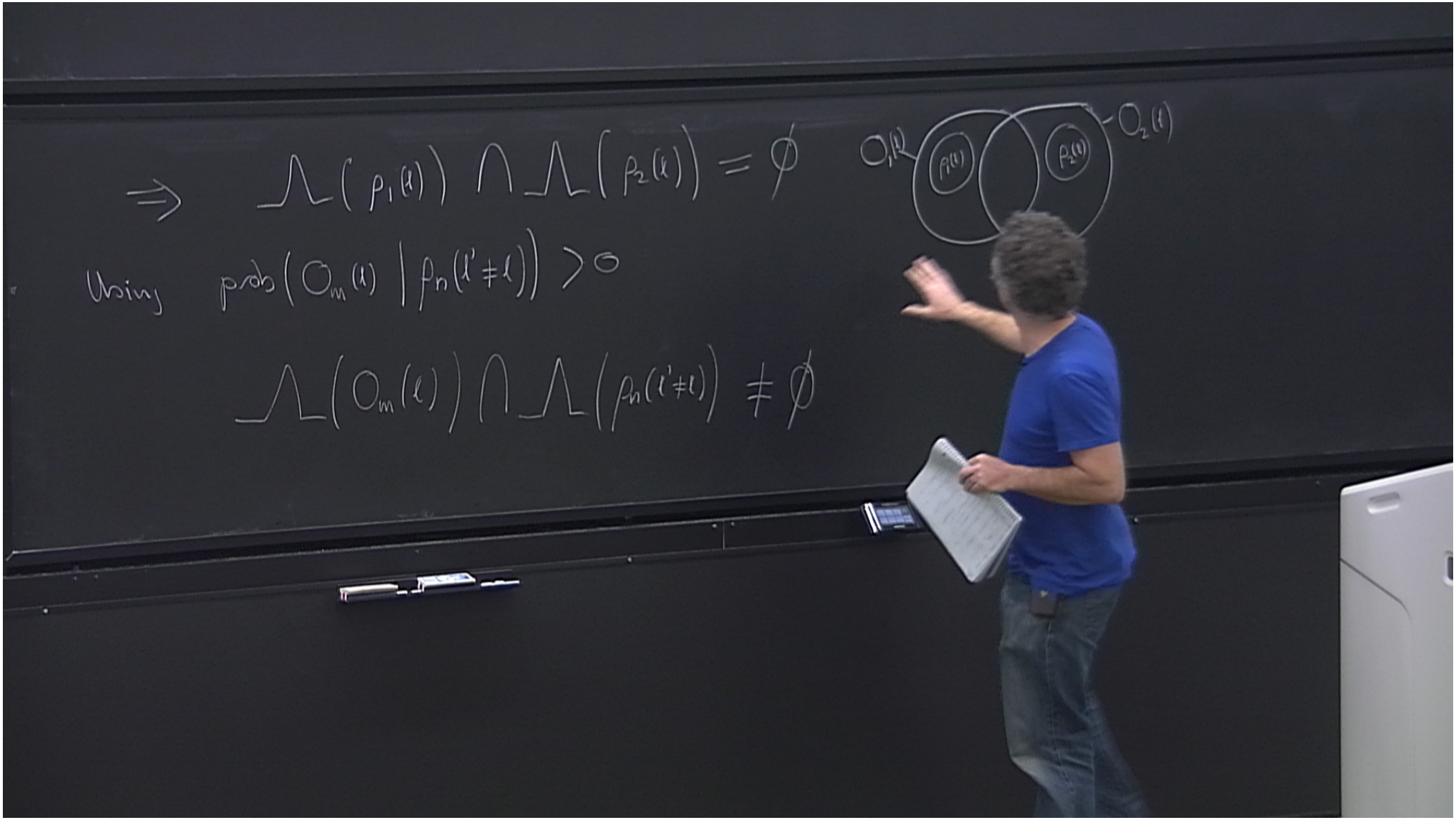

⇒
(p₁(t))

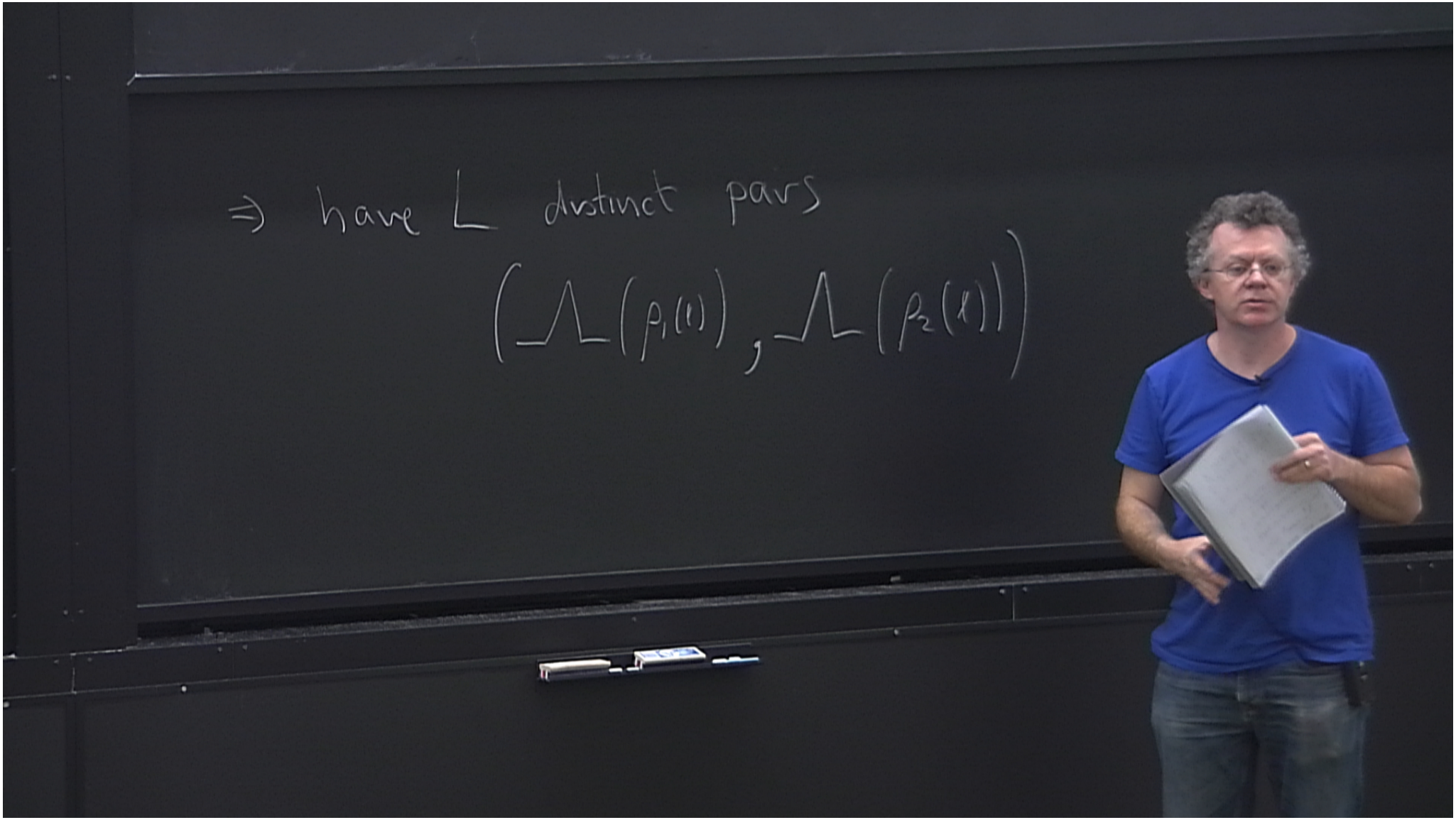

$\Rightarrow \quad \Lambda(\rho_1(t)) \cap \Lambda(\rho_2(t)) = \emptyset$
Using $\quad prob\left(O_m(t) \mid \rho_n(t' \neq t)\right) > 0$

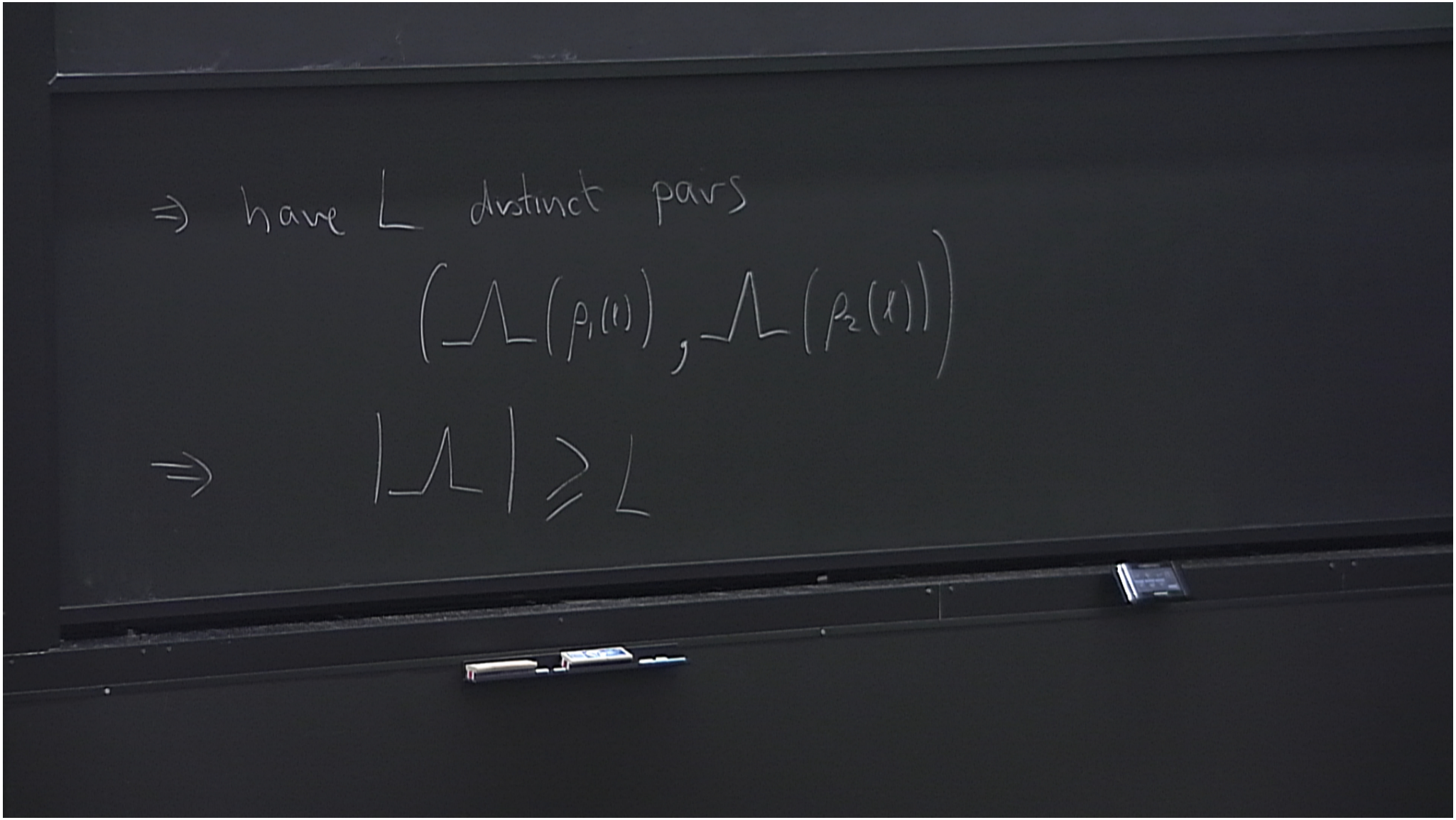

$\Rightarrow \Lambda(\rho_1(l)) \cap \Lambda(\rho_2(l)) = \emptyset$
Using $\text{prob}(O_m(l) \mid \rho_n(l' \neq l)) > 0$
$\Lambda(O_m(l)) \cap \Lambda(\rho_n(l' \neq l))$

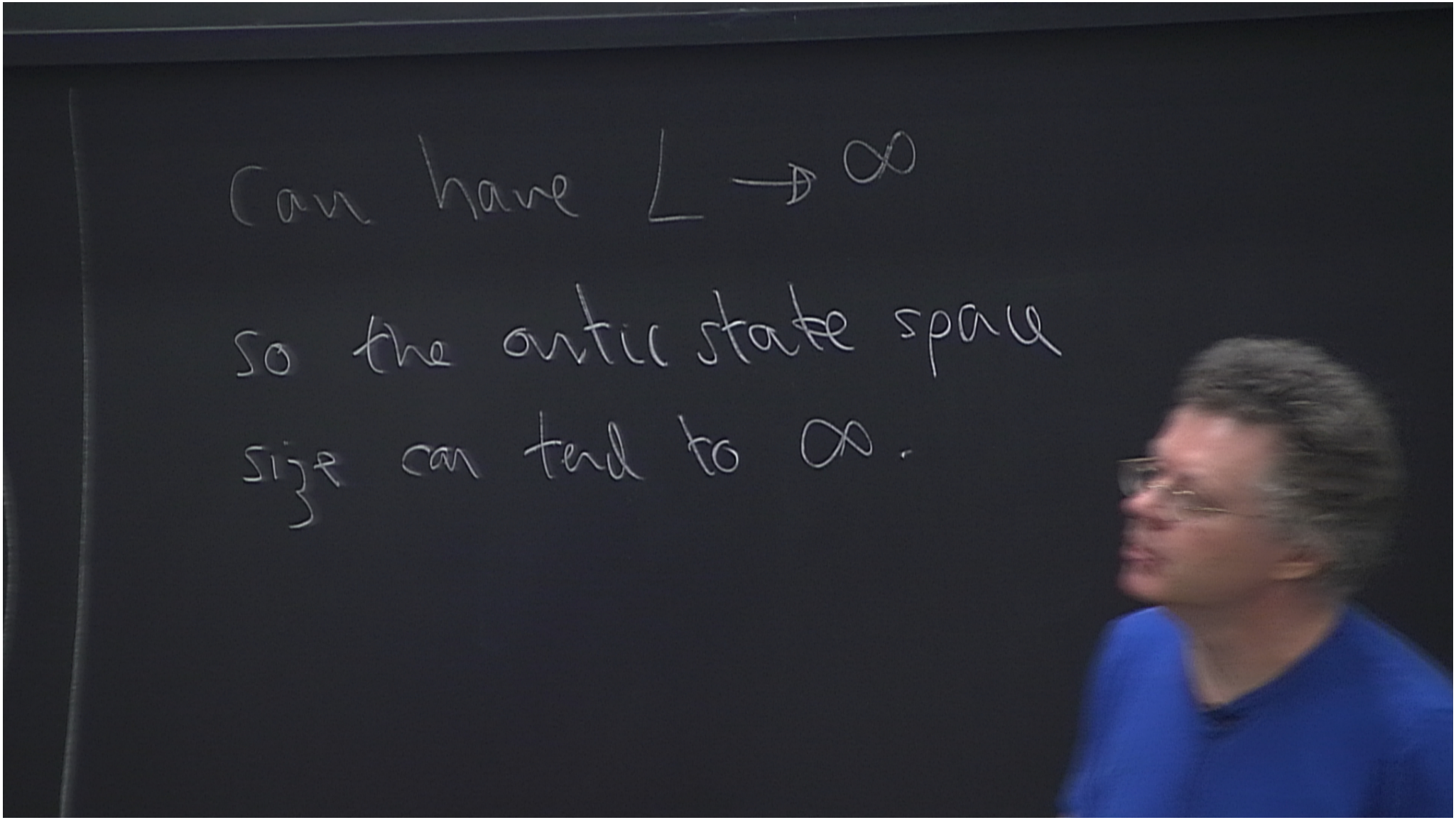

$\Rightarrow \Lambda(\rho_1(\ell)) \cap \Lambda(\rho_2(\ell)) = \emptyset$
$O_1(\ell)$
$O_2(\ell)$
Using $\text{prob}(O_m(\ell) \mid \rho_n(\ell' \neq \ell)) > 0$
$\Lambda(O_m(\ell)) \cap \Lambda(\rho_n(\ell' \neq \ell)) \neq \emptyset$

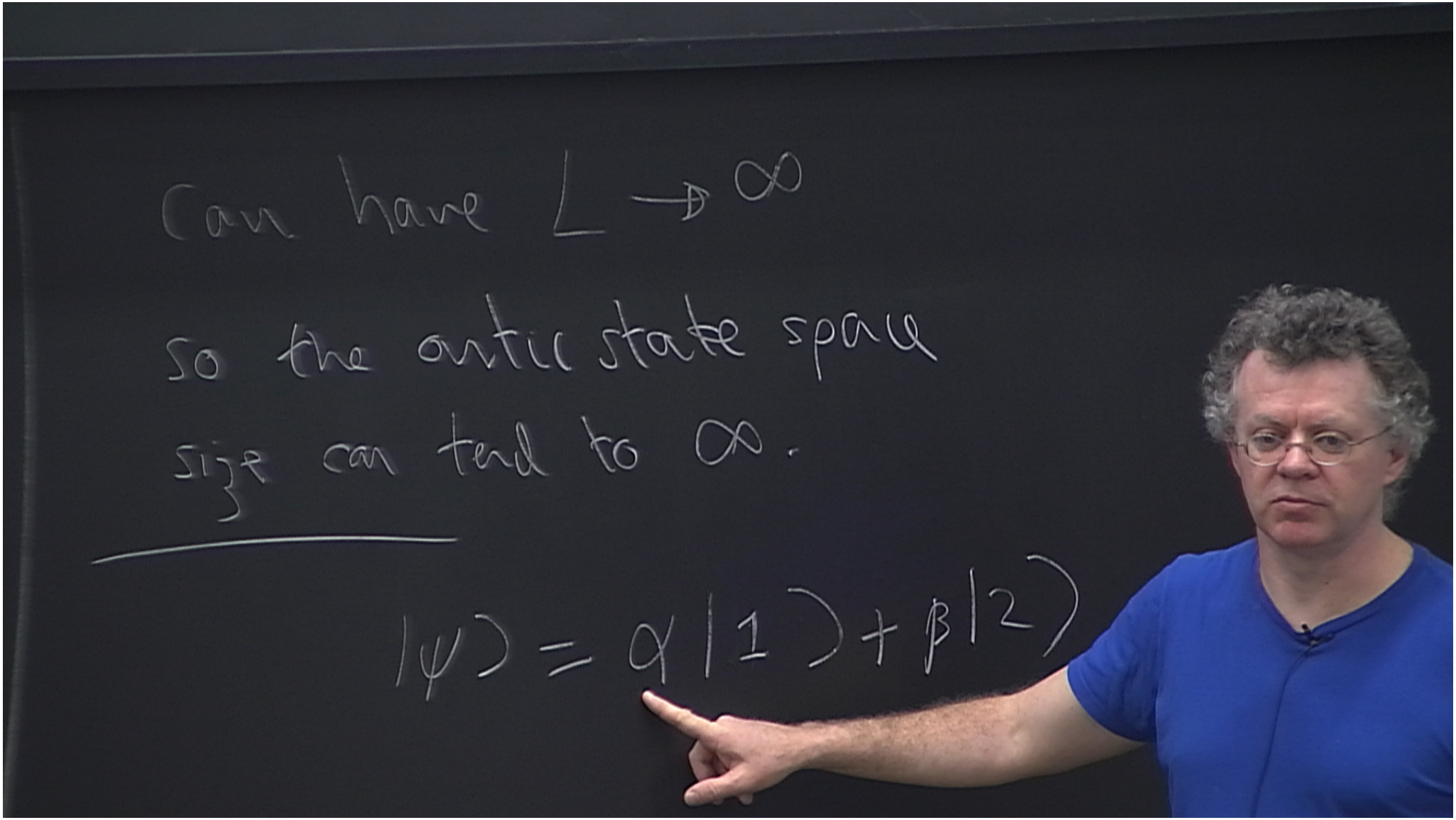

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$O_1(\ell)$
$p_1(\ell)$
$O_2(\ell)$
Using $\text{prob}(O_m(\ell) \mid p_n(\ell' \neq \ell)) > 0$
$\Lambda(O_m(\ell)) \cap \Lambda(p_n(\ell' \neq \ell)) \neq \emptyset$

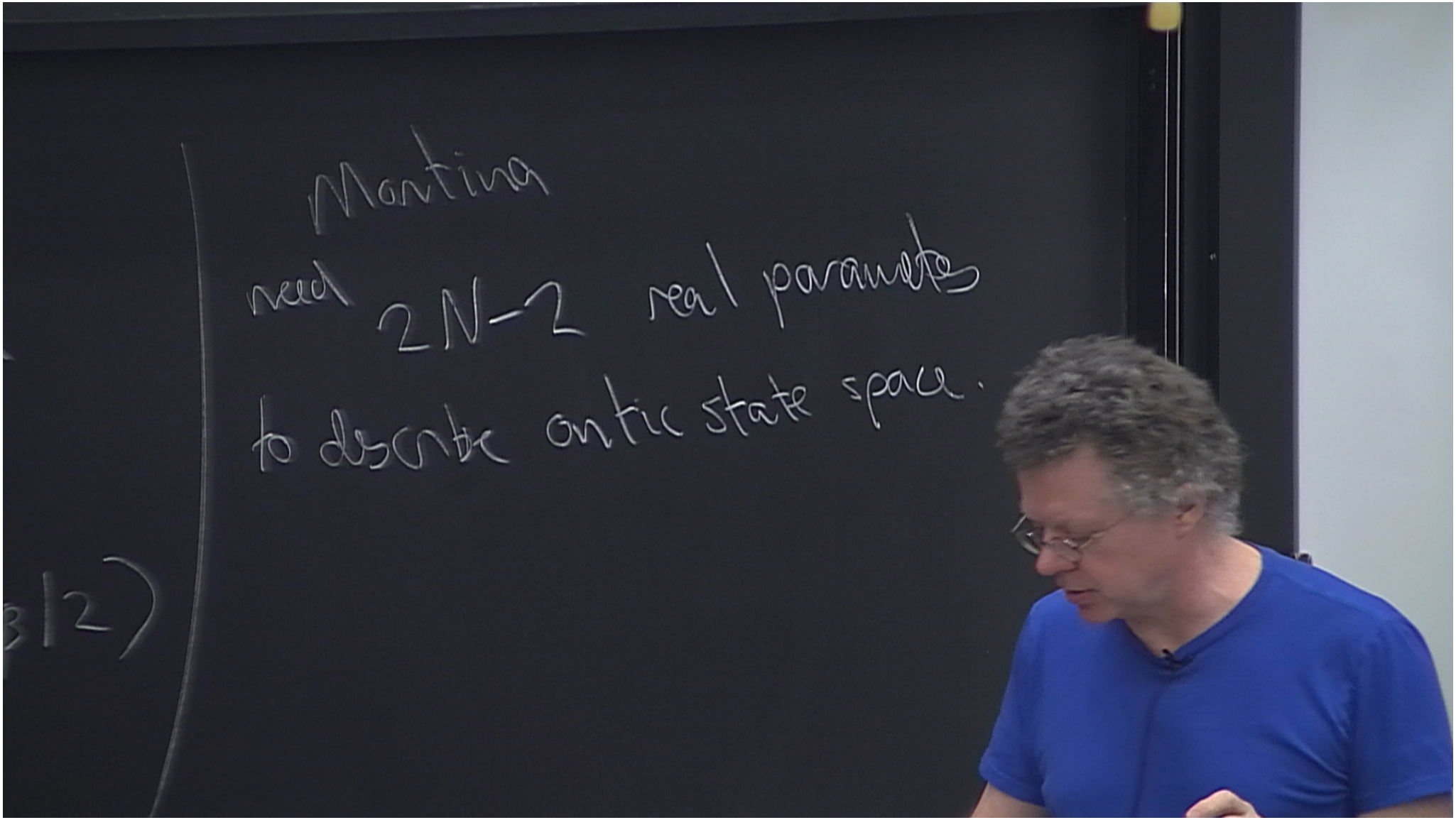

$\Rightarrow \Lambda(\rho_1(\ell)) \cap \Lambda(\rho_2(\ell)) = \emptyset$
$O_1(\ell)$
$\rho_1(\ell)$
$\rho_2(\ell)$
$O_2(\ell)$
Using $\text{prob}(O_m(\ell) \mid \rho_n(\ell' \neq \ell)) > 0$
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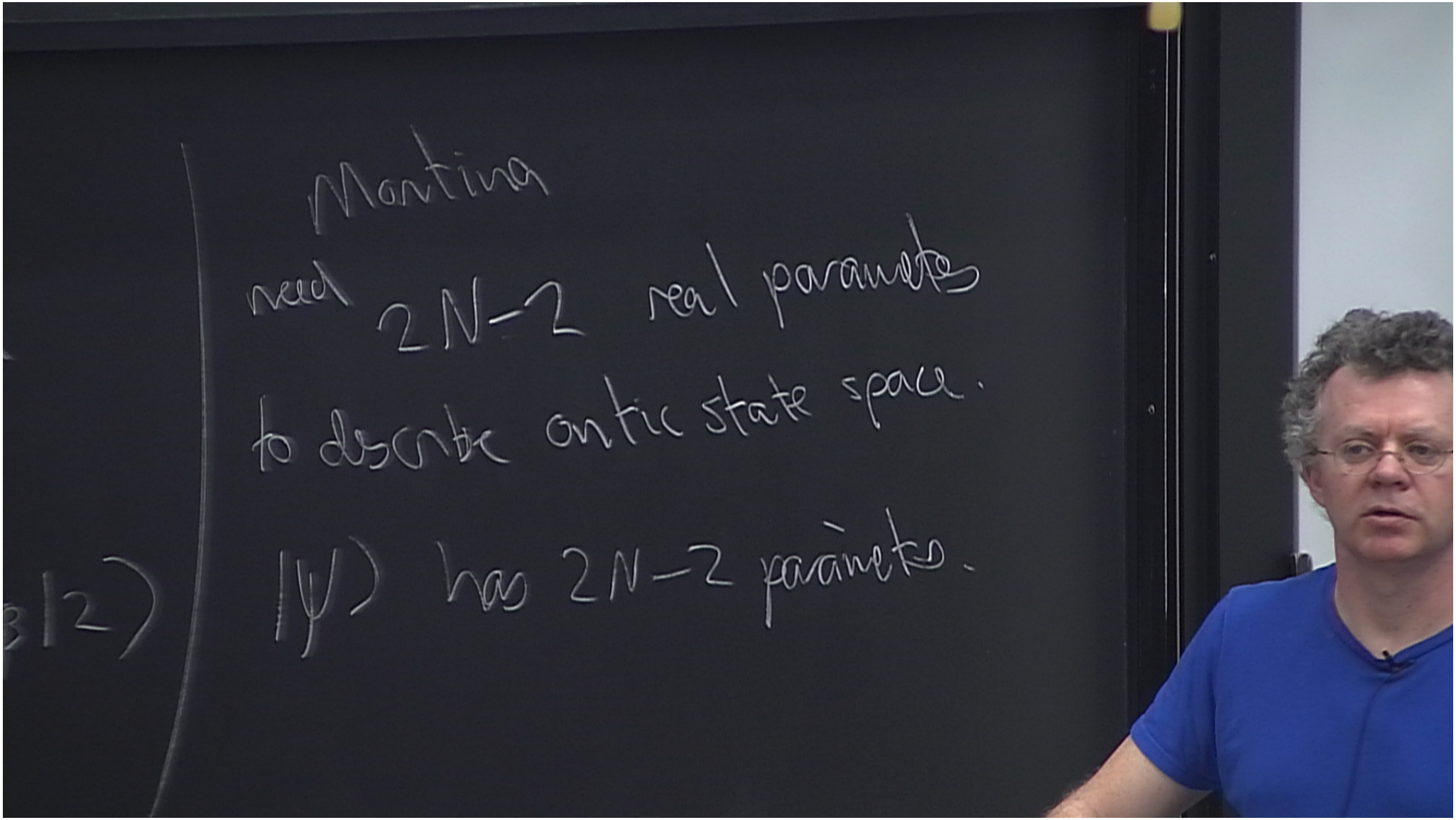

⇒ have L distinct pairs
$(\Lambda_L(\rho_1(x)), \Lambda_L(\rho_2(x)))$

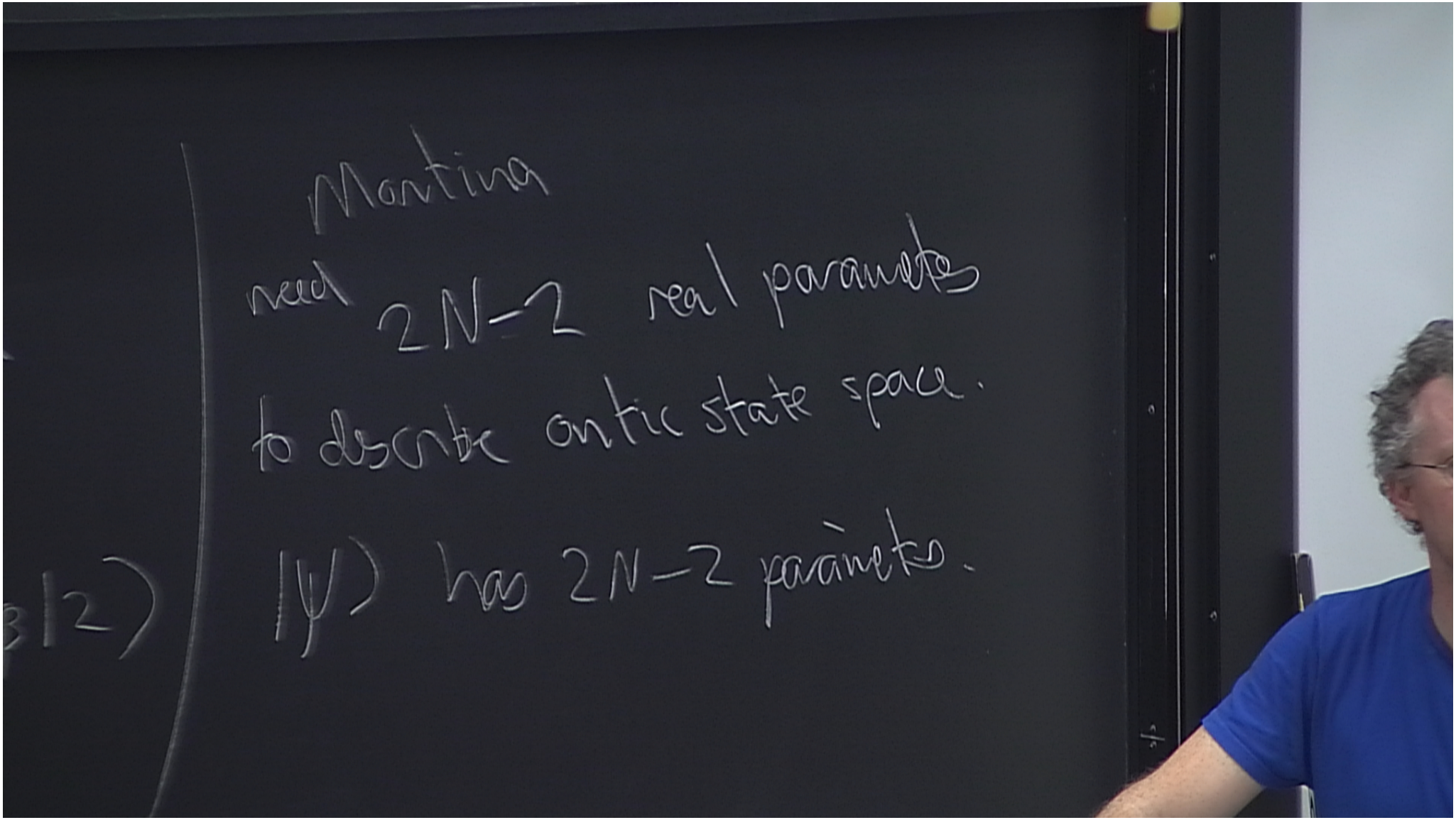

⇒ have L distinct pairs
$(\Lambda(p_1(1)), \Lambda(p_2(1)))$
⇒ $|\Lambda| \geq L$

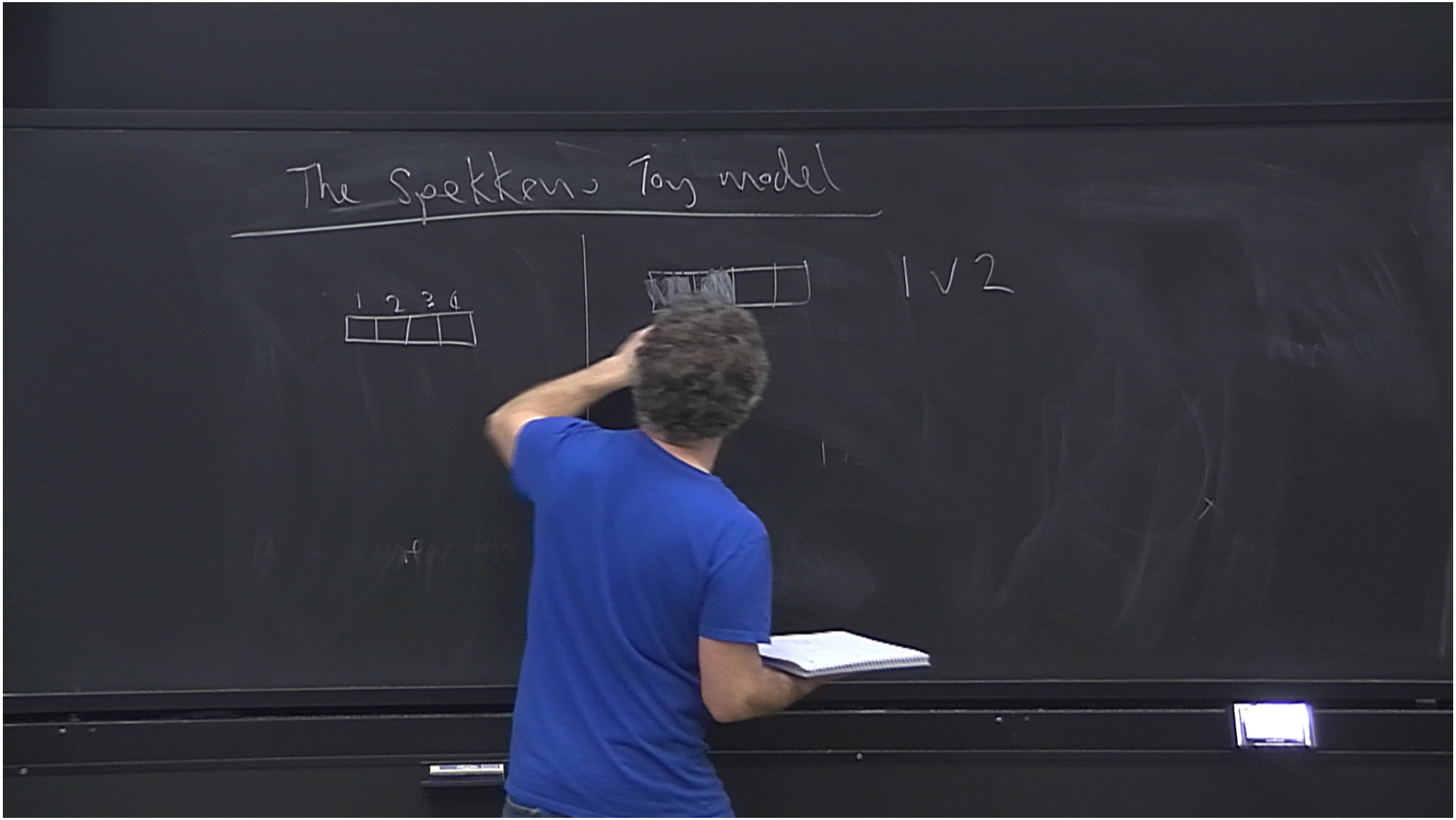

Can have $L \to \infty$
so the antic state space
size can tend to ∞.

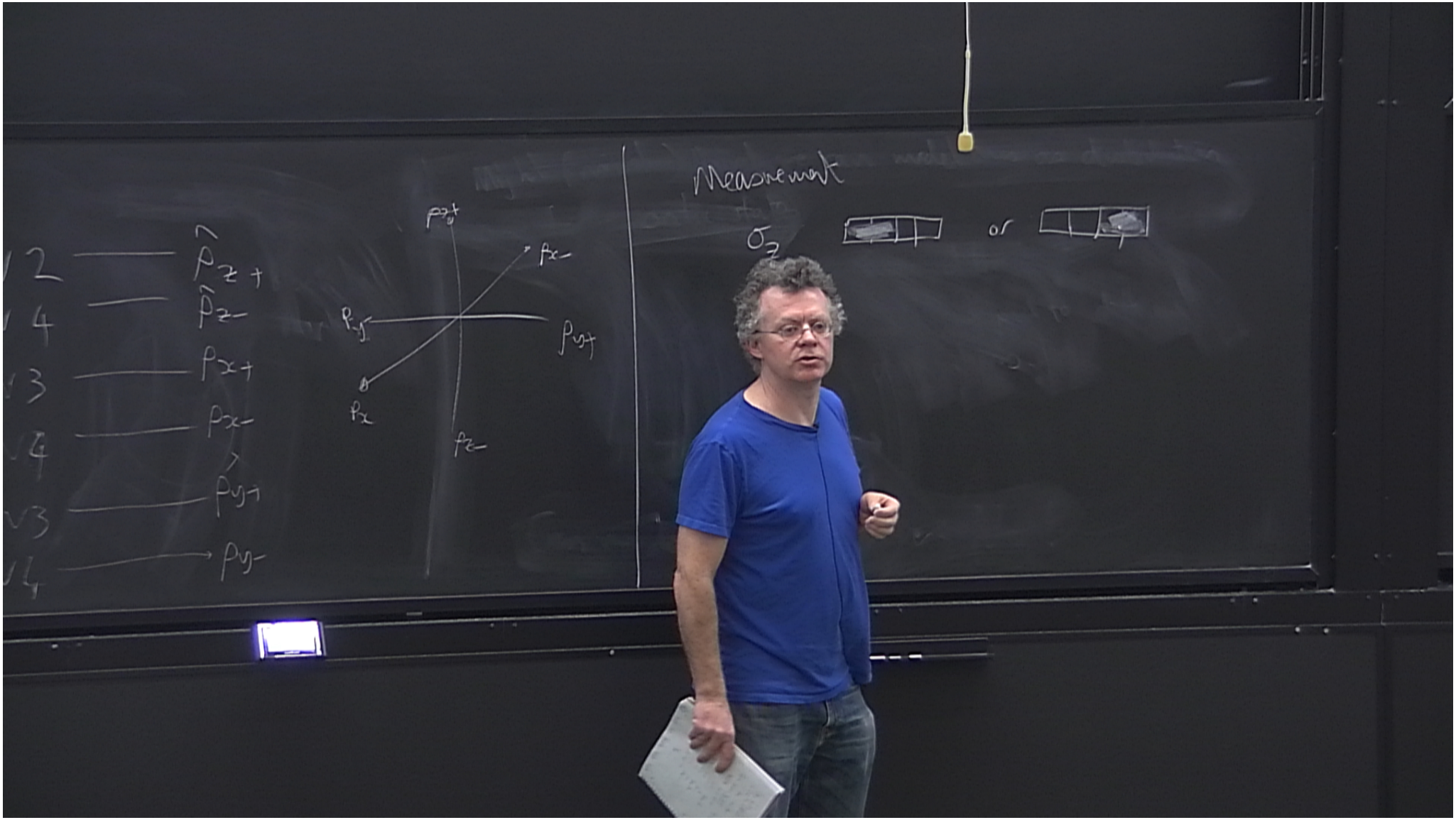

Can have $L \to \infty$
so the ontic state space
size can tend to ∞.
$|\psi\rangle = \alpha|1\rangle + \beta|2\rangle$

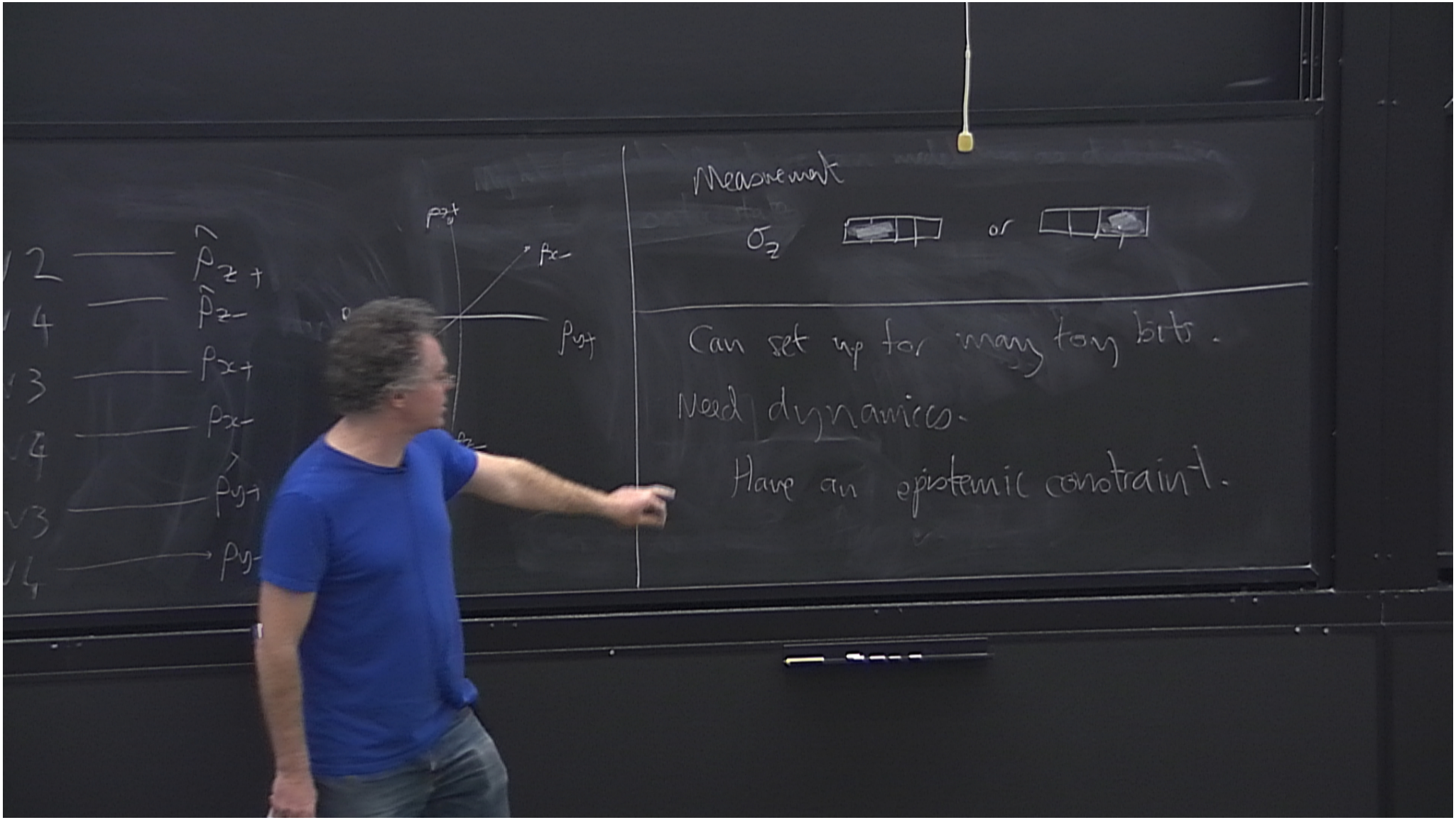

Montina
need 2N-2 real parameters
to describe ontic state space.
3|2)

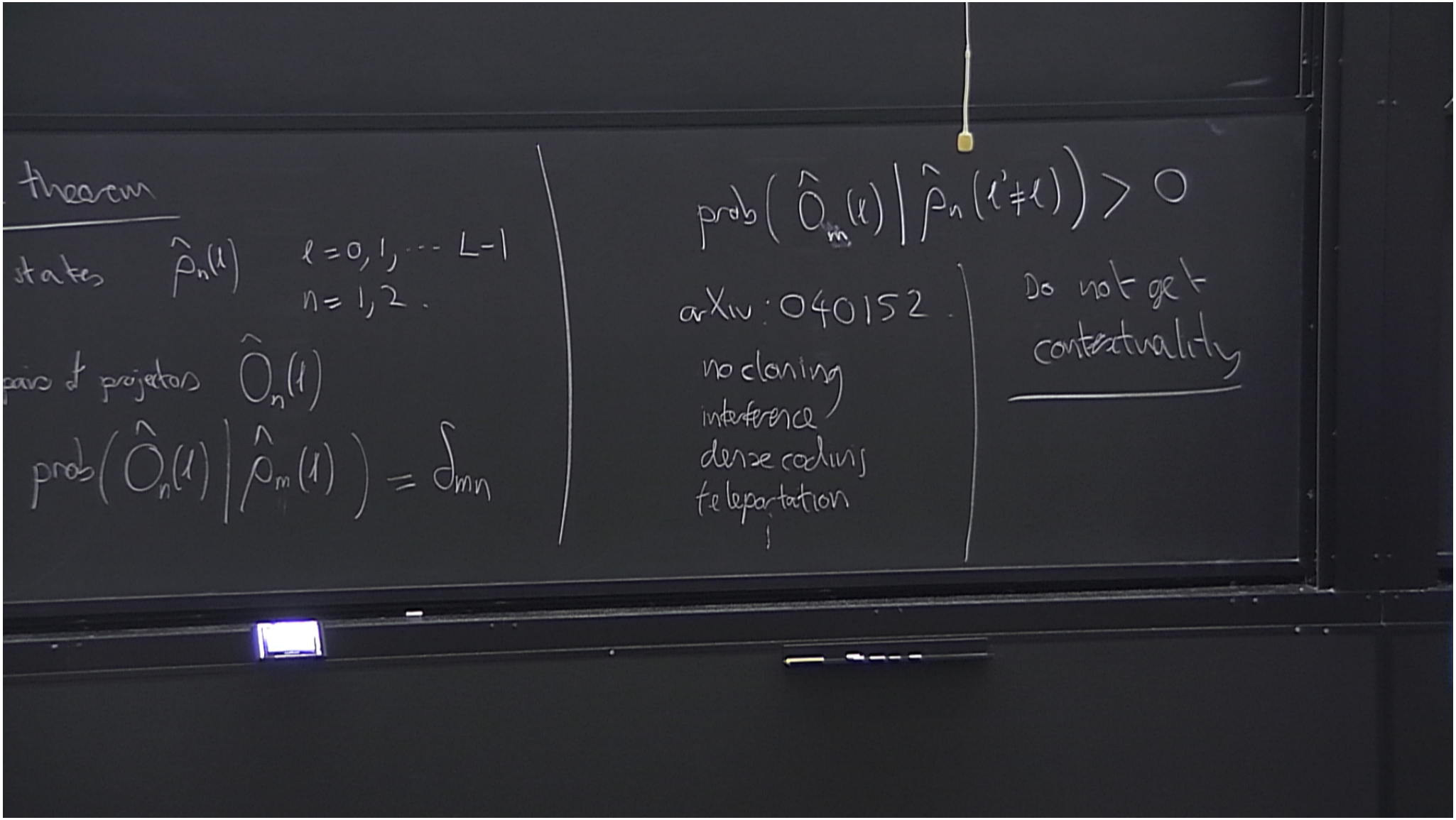

Martina
need 2N−2 real parameters
to describe ontic state space.
|ψ⟩ has 2N−2 parameters.

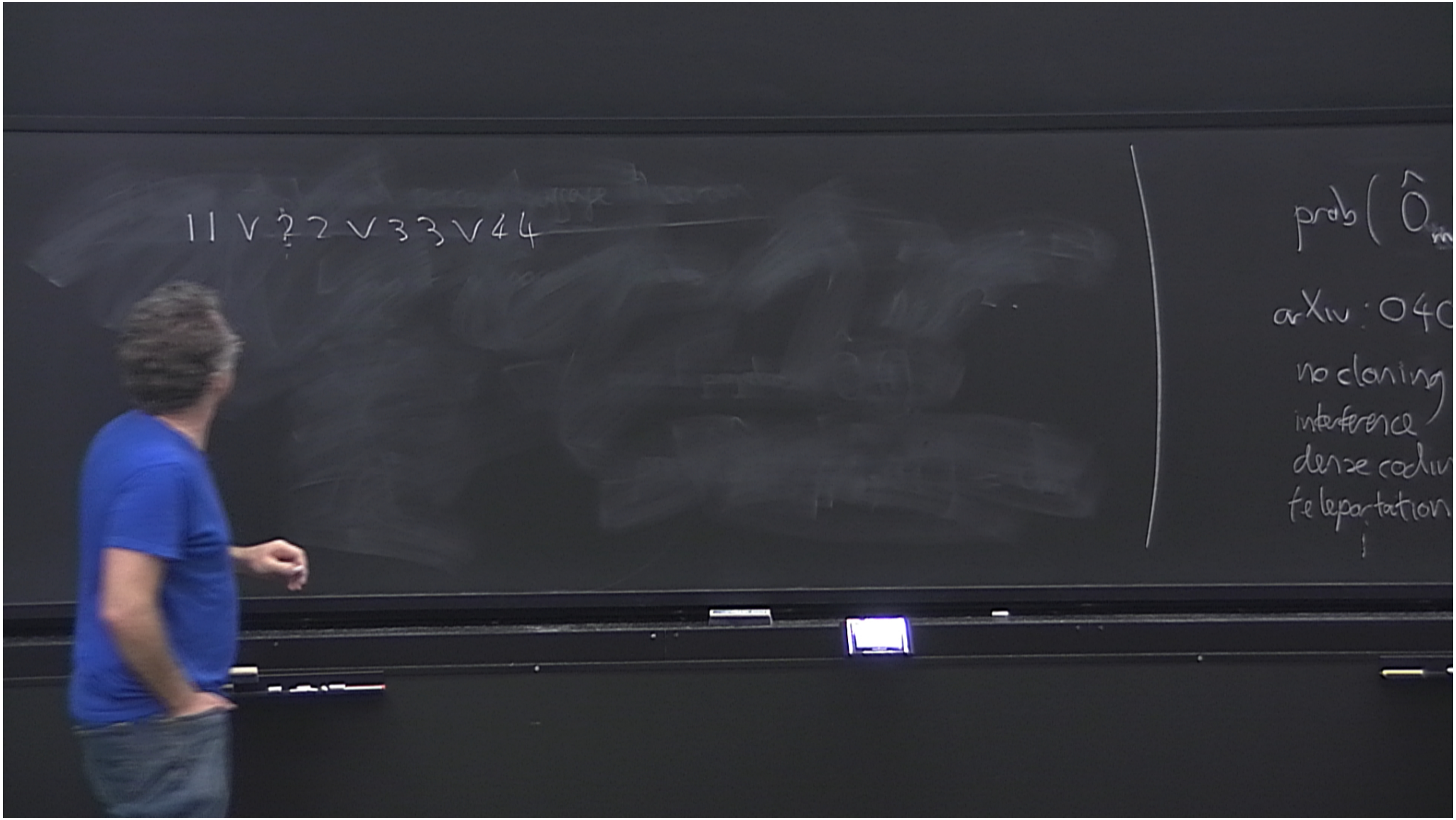

Montina
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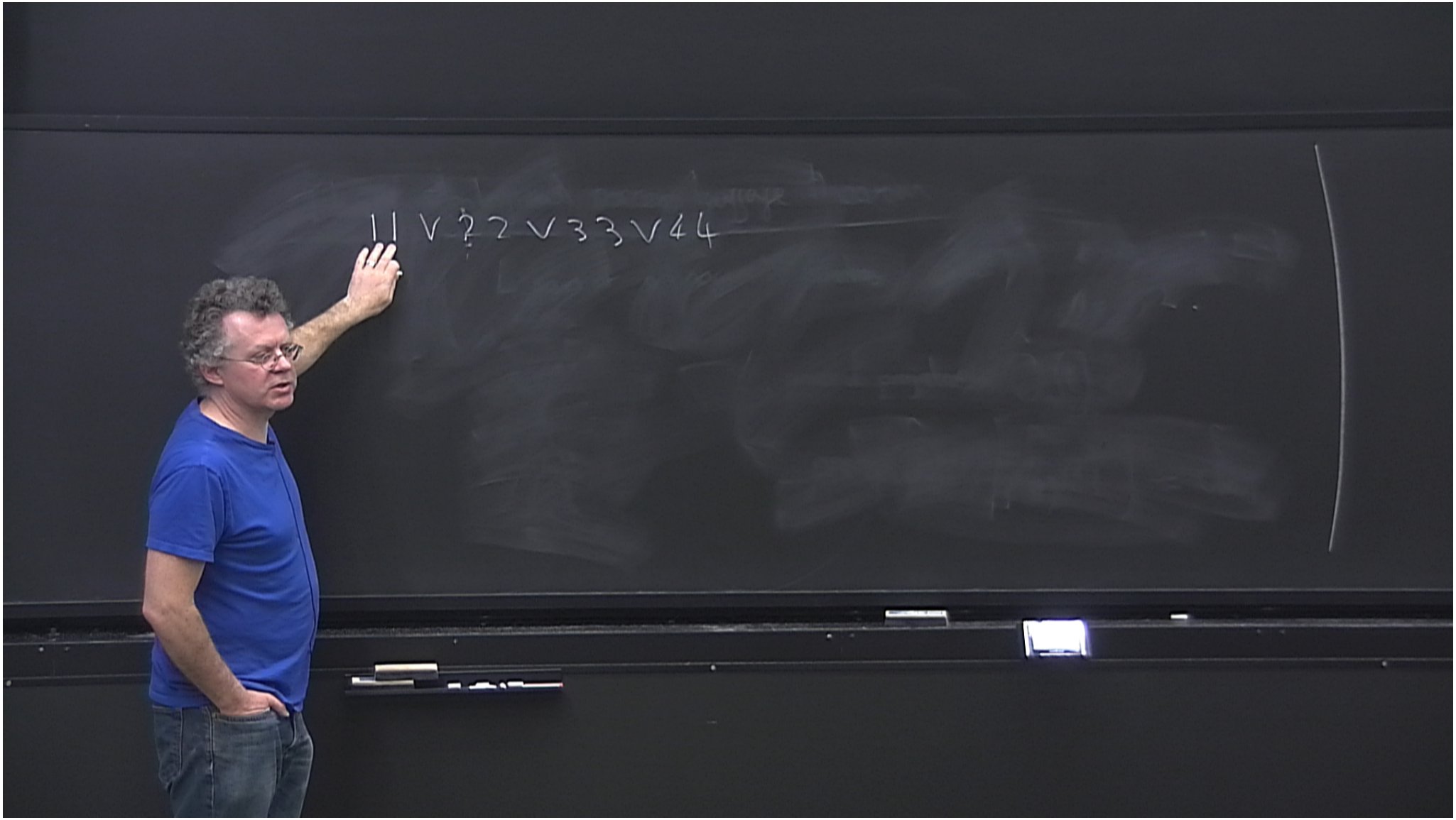

The Spekkens Toy model
1 2 3 4
1 v 2

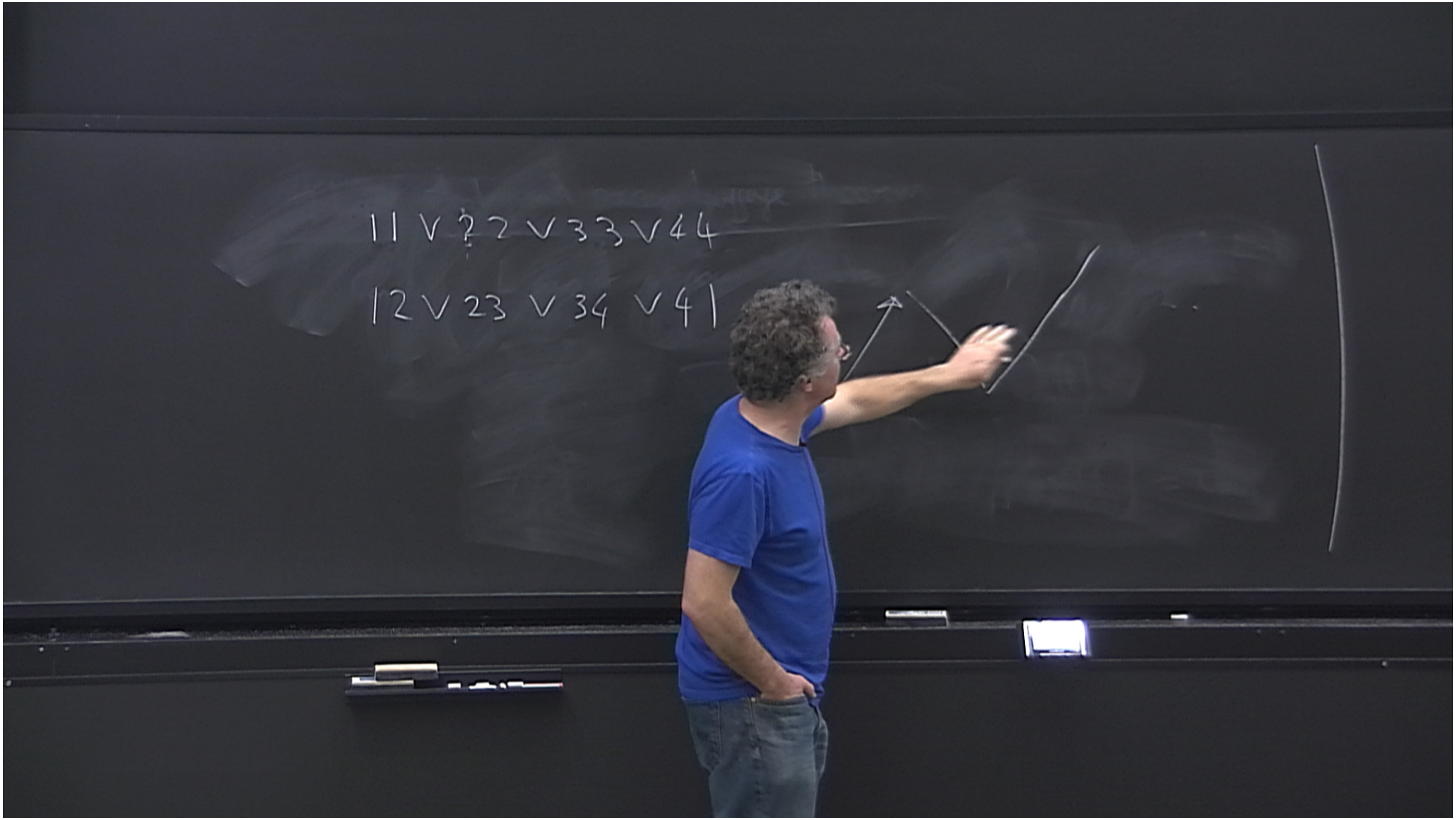

Measurement
or

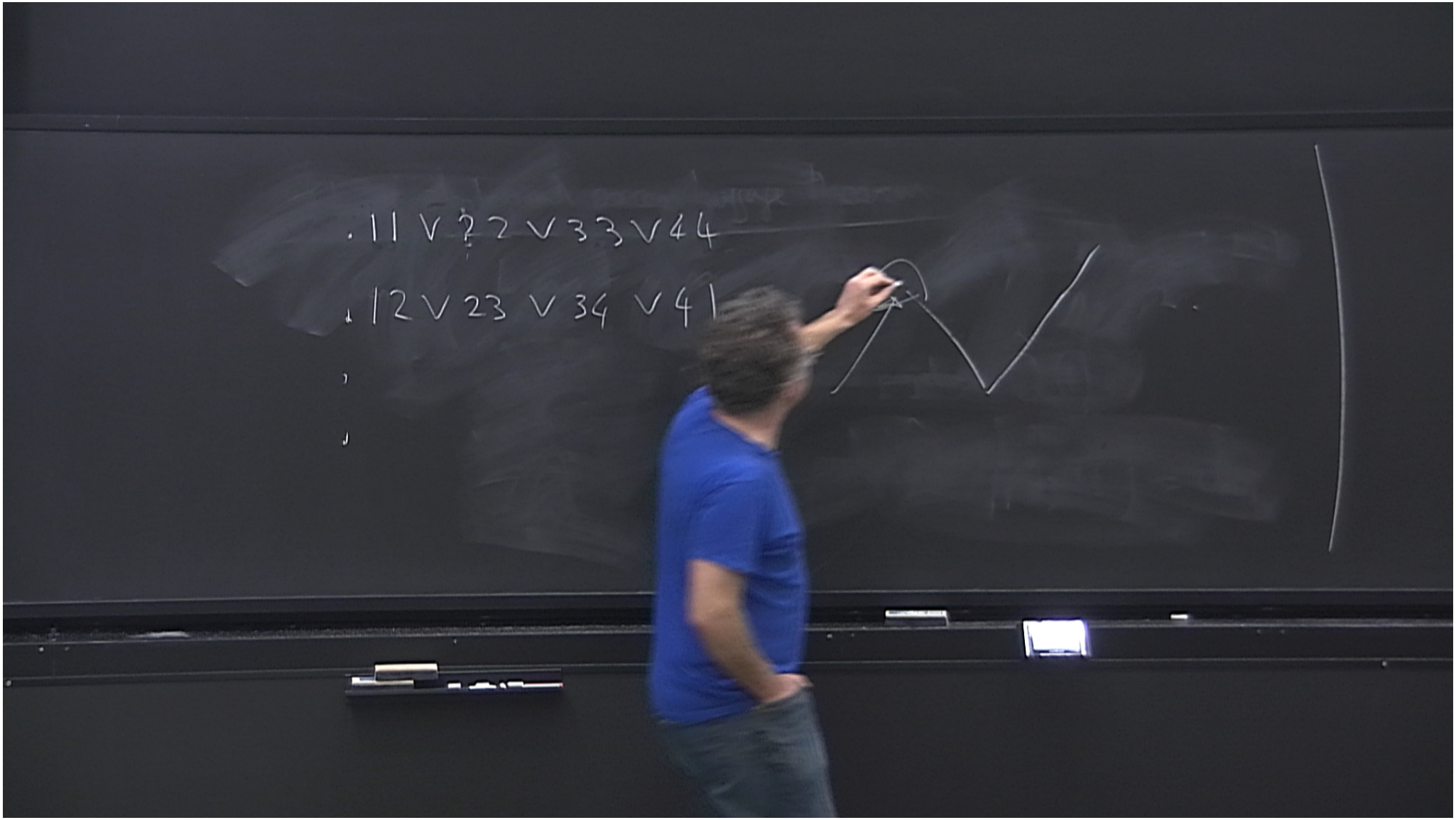

Measurement
or
Can set up for many toy bits.
Need dynamics.
Have an epistemic constraint.

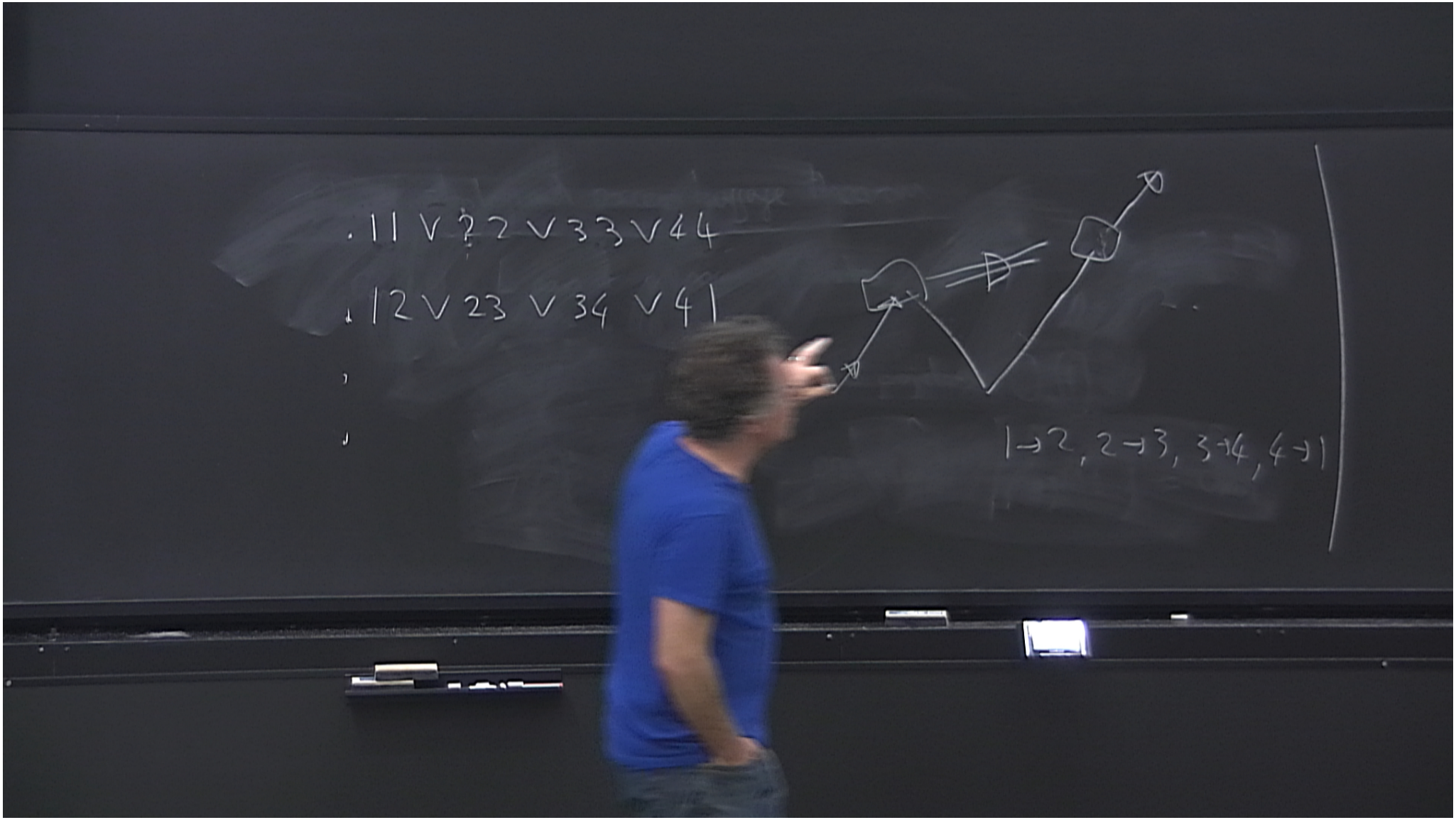

theorem
states $\hat{\rho}_n(\ell)$ $\ell = 0, 1, \cdots L-1$
$n = 1, 2$.
pairs of projectors $\hat{O}_n(\ell)$
$\text{prob}\left(\hat{O}_n(\ell) \middle| \hat{\rho}_m(\ell)\right) = \delta_{mn}$
$\text{prob}\left(\hat{O}_m(\ell) \middle| \hat{\rho}_n(\ell' \neq \ell)\right) > 0$
arXiv: 040152
no cloning
interference
dense coding
teleportation
Do not get
contextuality


11 V ?2 V 33 V 44
prob(Ô
arXiv : 04
no cloning
interference
dense codi
teleportation


|| V ? 2 V 3 3 V 4 4


11 V ?2 V 33 V 44
12 V 23 V 34 V 41


11 V 22 V 33 V 44
12 V 23 V 34 V 41


1 V 2 V 3 V 4
1 2 V 2 3 V 3 4 V 4 1
1→2, 2→3, 3→4, 4→1