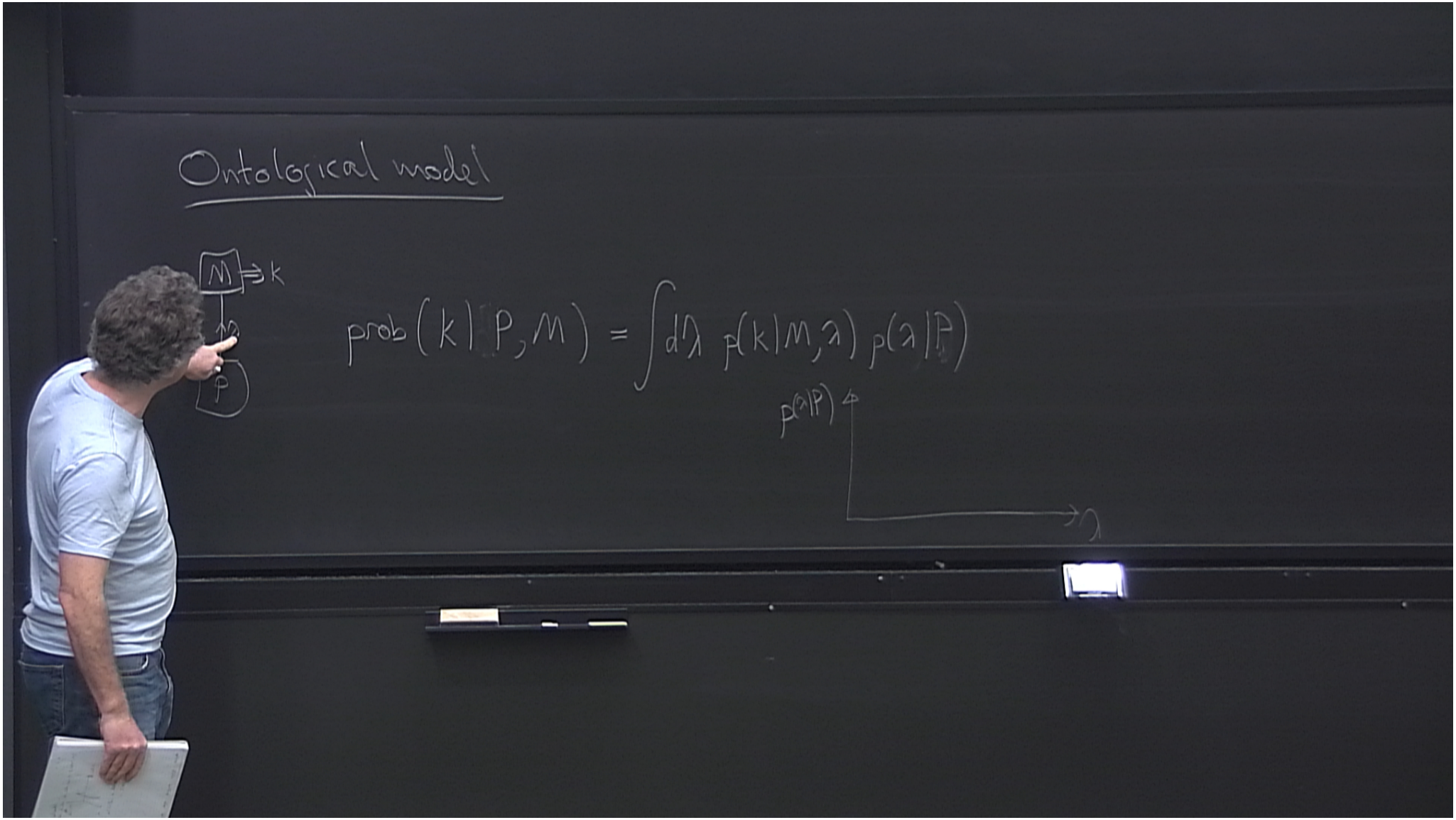
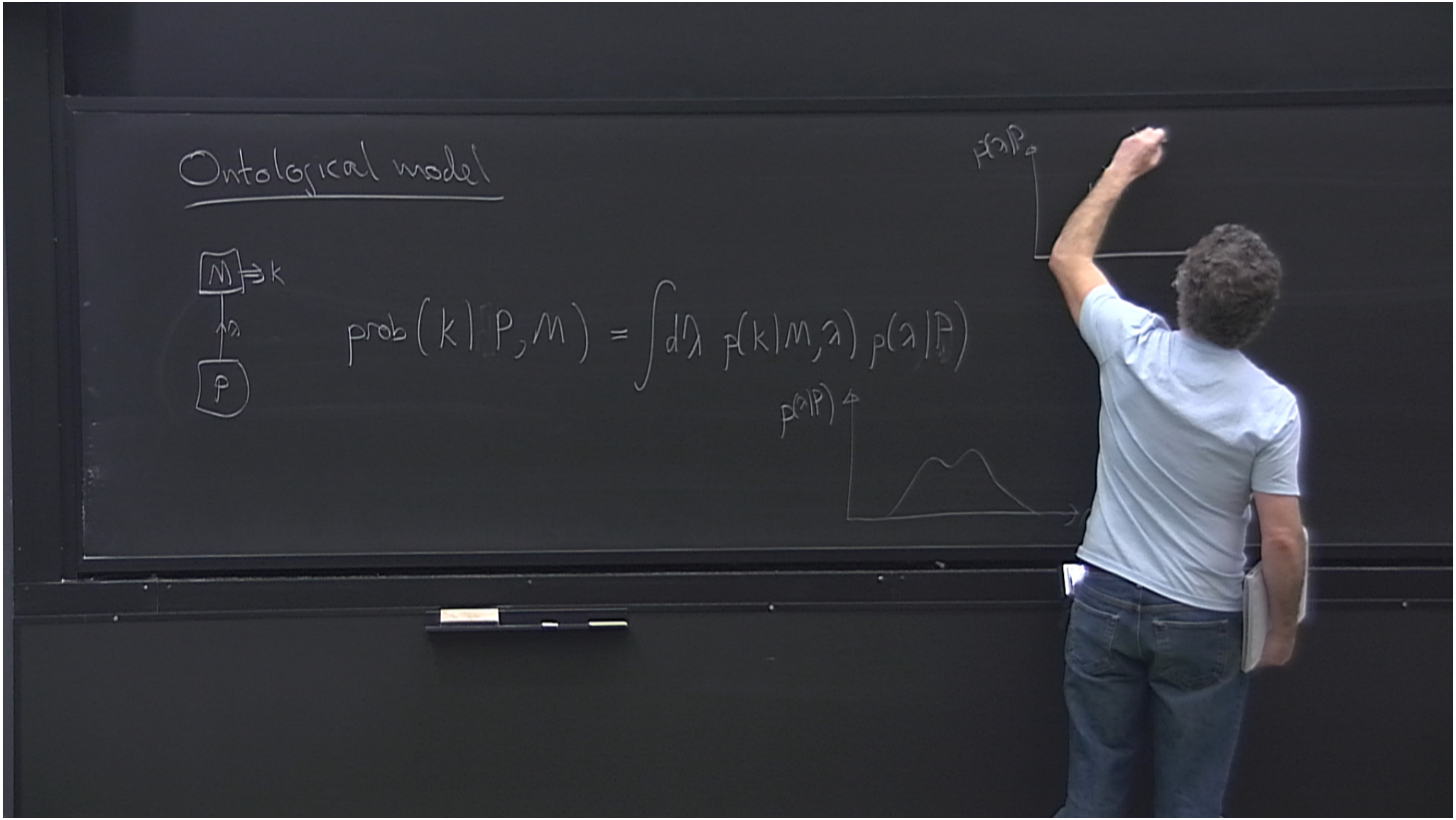
Title: Foundations of Quantum Mechanics-5

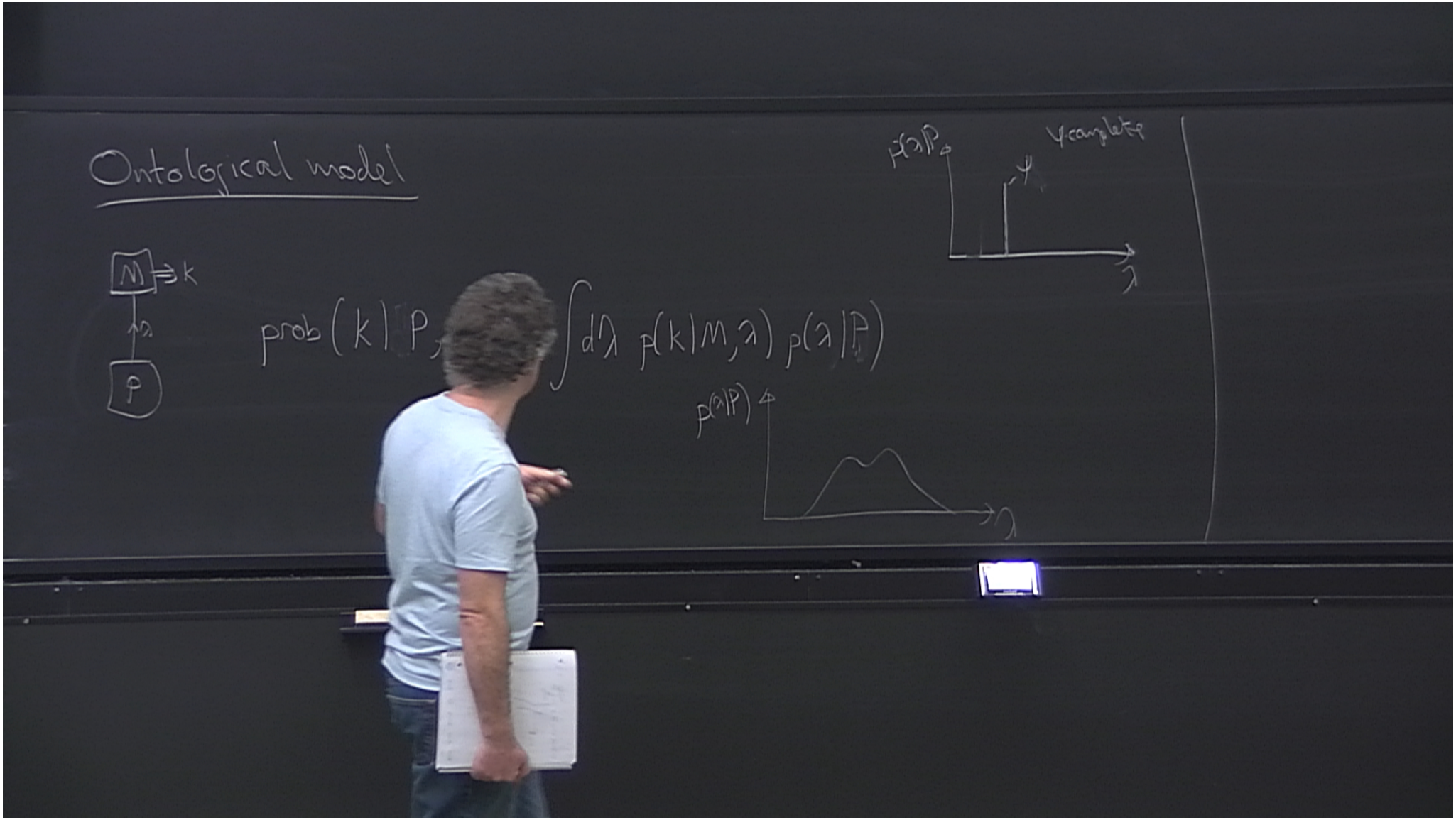
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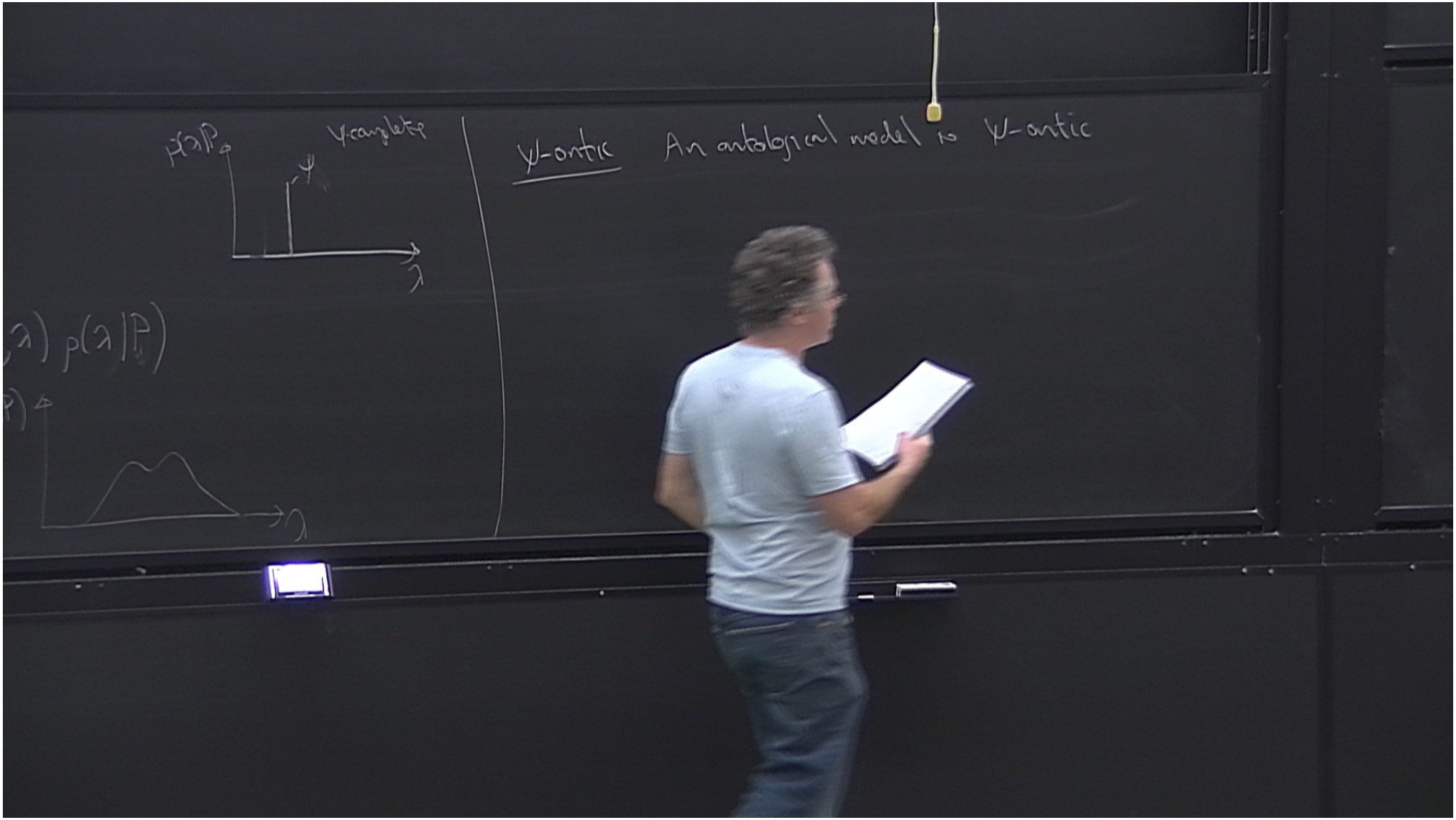
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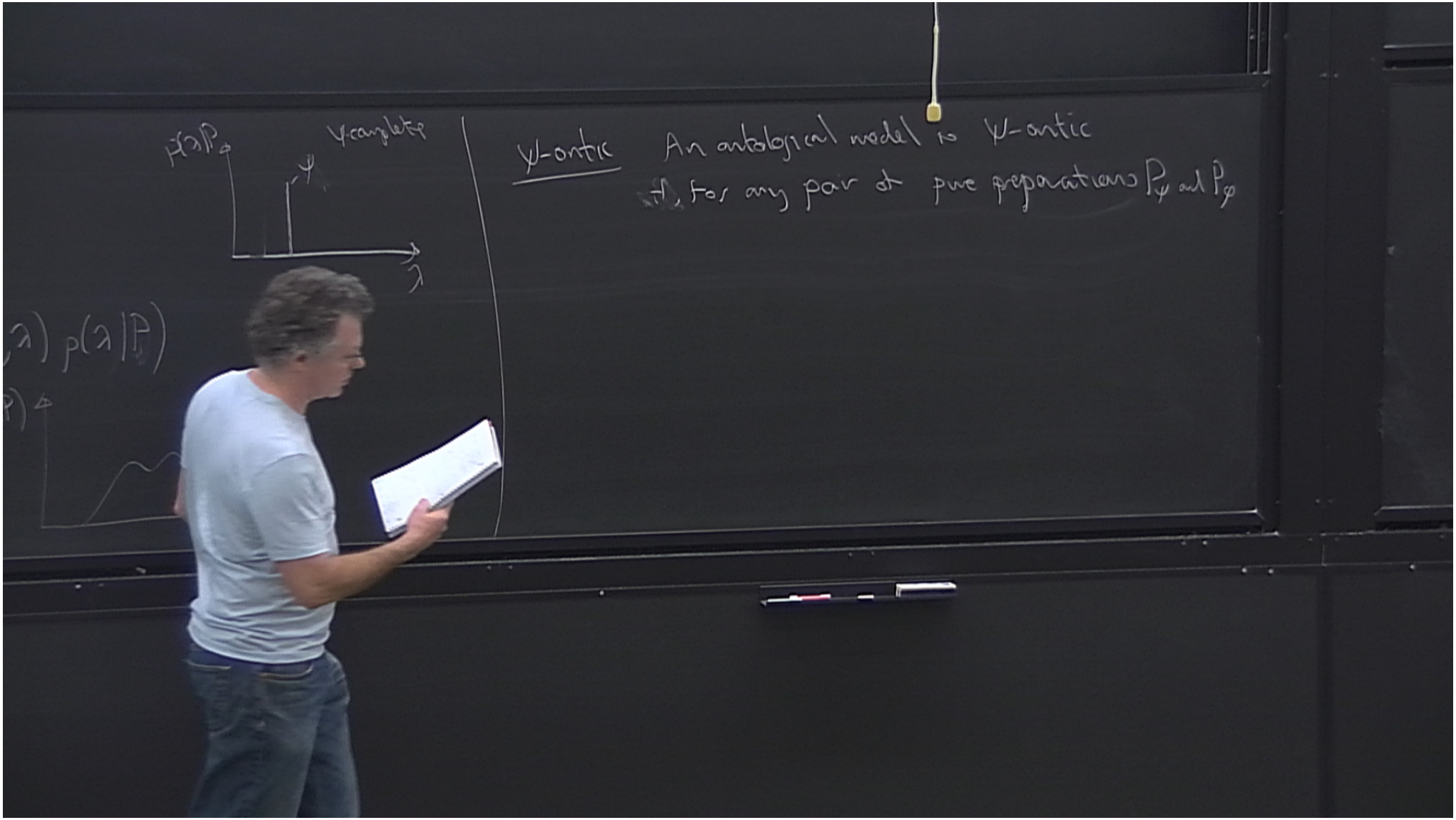
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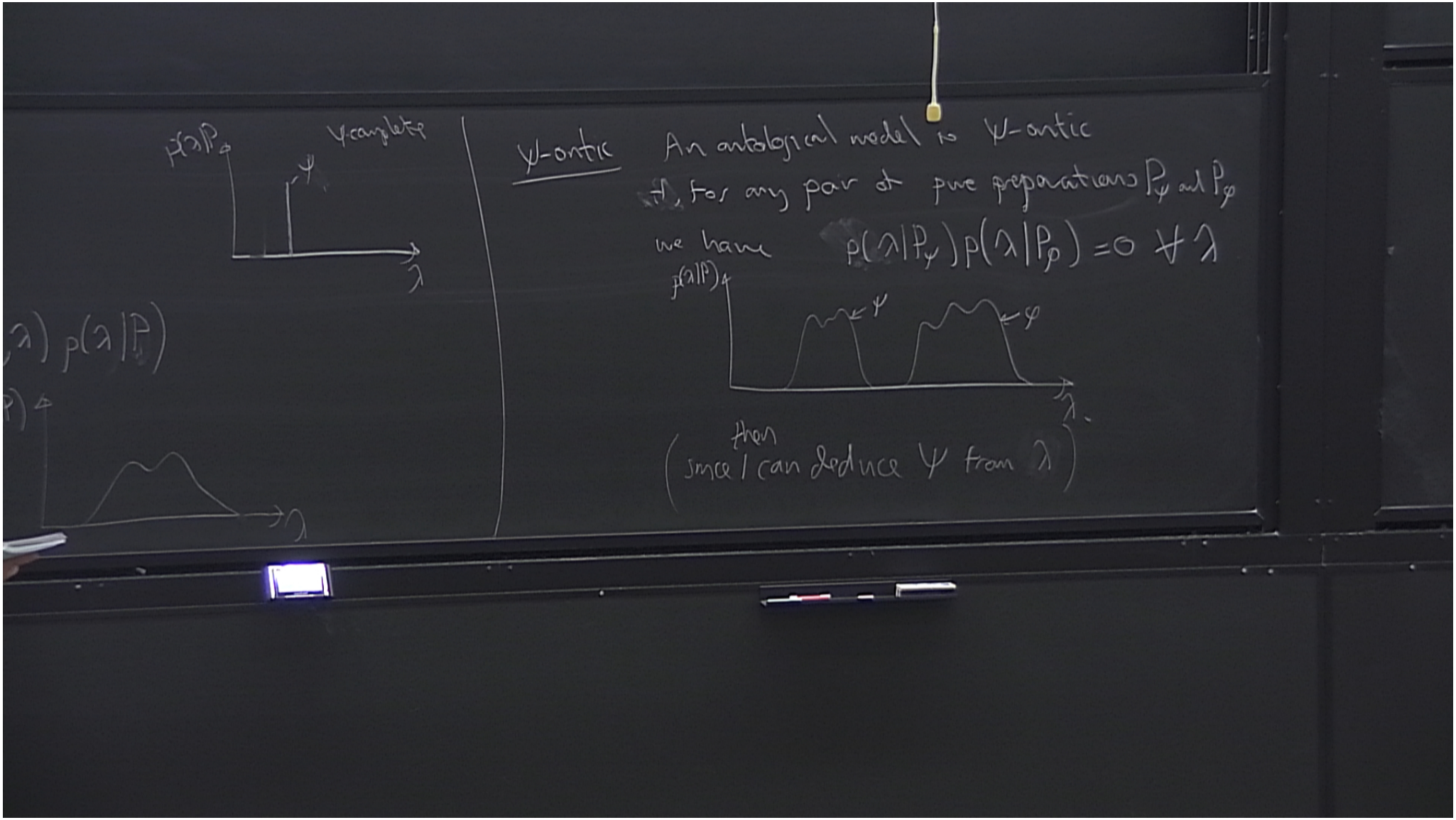

Ontological model
M
k
P
prob (k | P, M) = ∫ dλ p(k|M,λ) p(λ|P)
p(λ|P)
λ

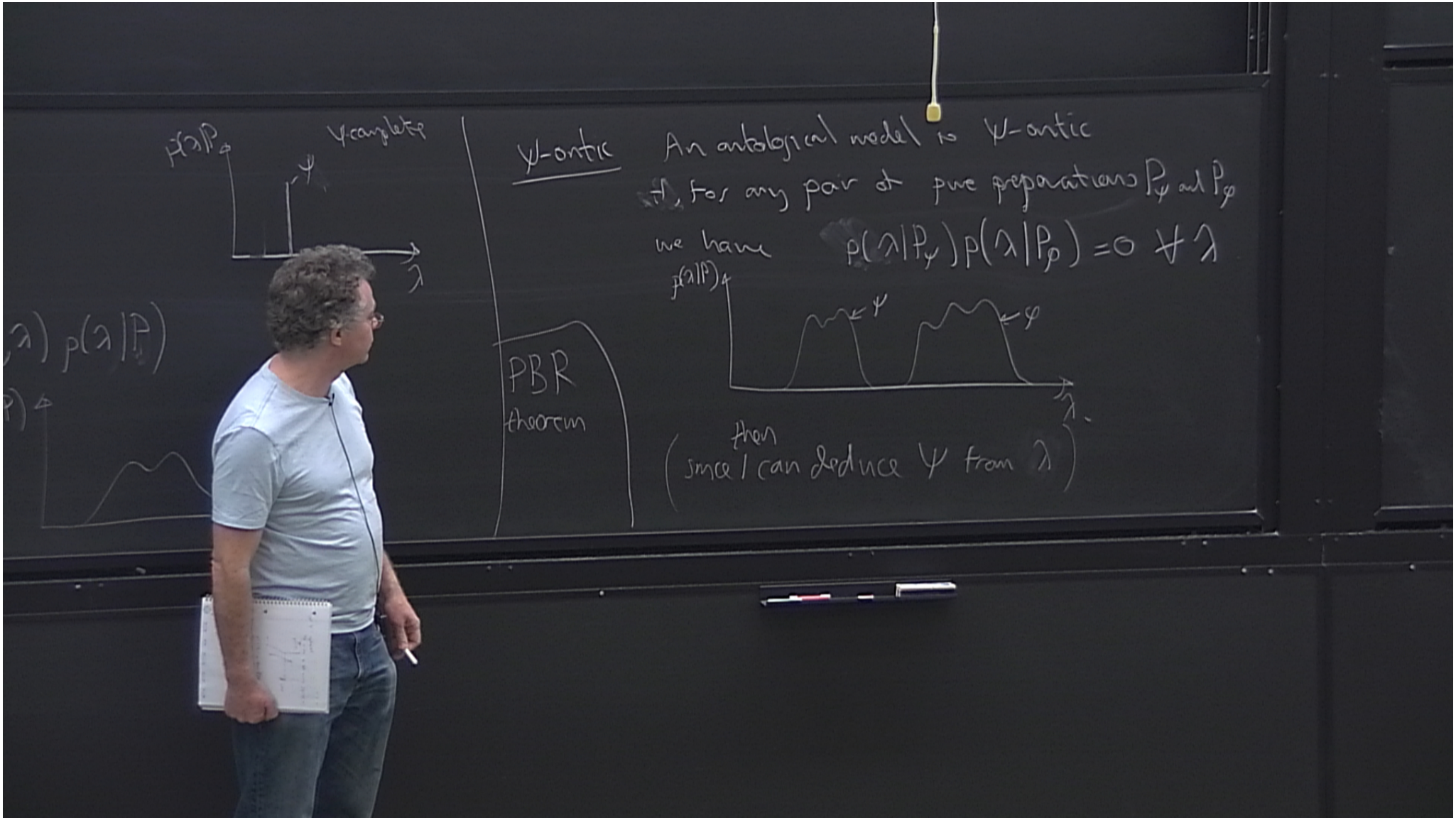

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p(λ|P)
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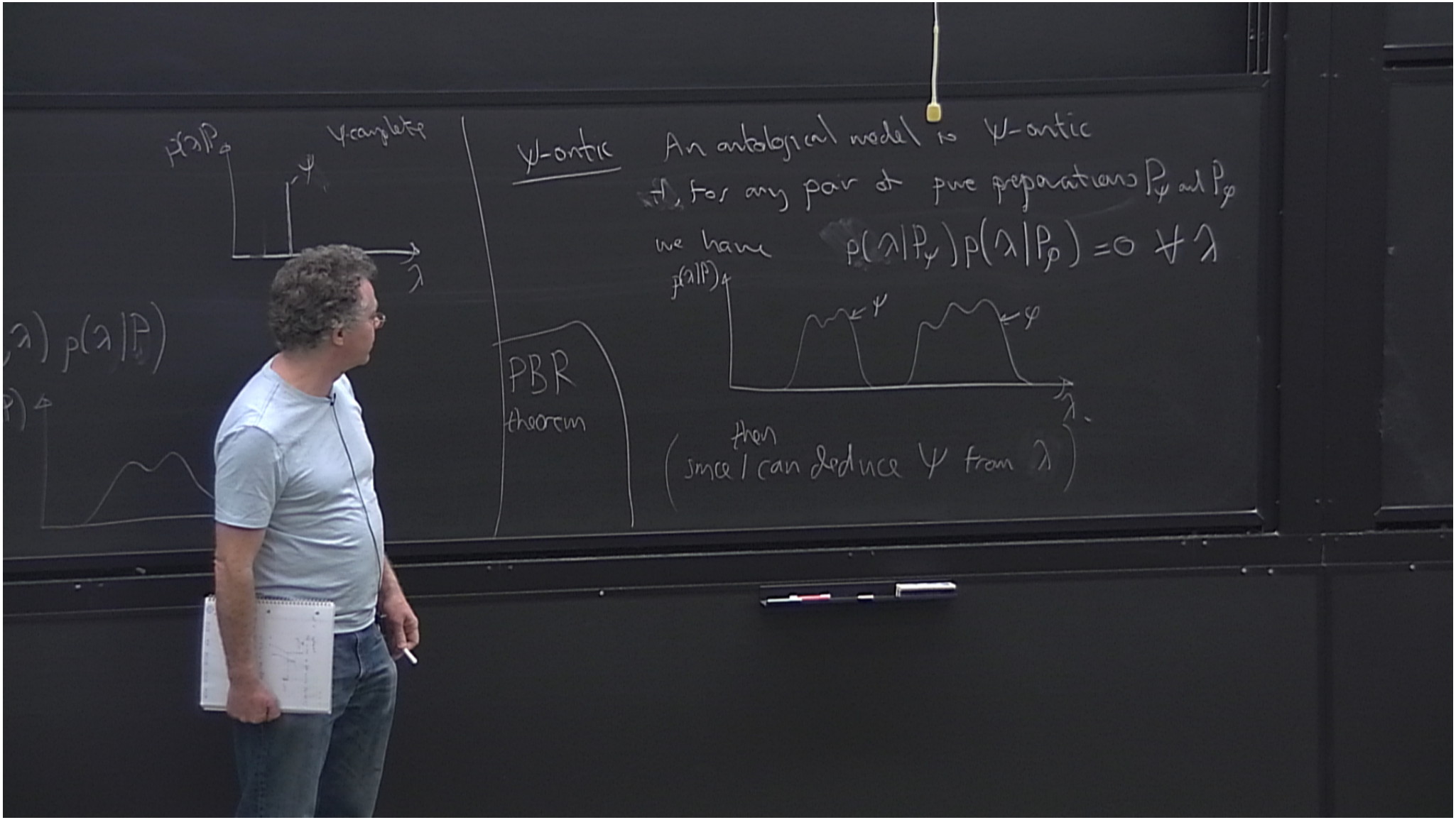

Ontological model
M
k
λ
ρ
prob (k | P, ∫ dλ p(k|M,λ) p(λ|P)
p(λ|P)
λ
H(λ|P
Y complete
Y
λ

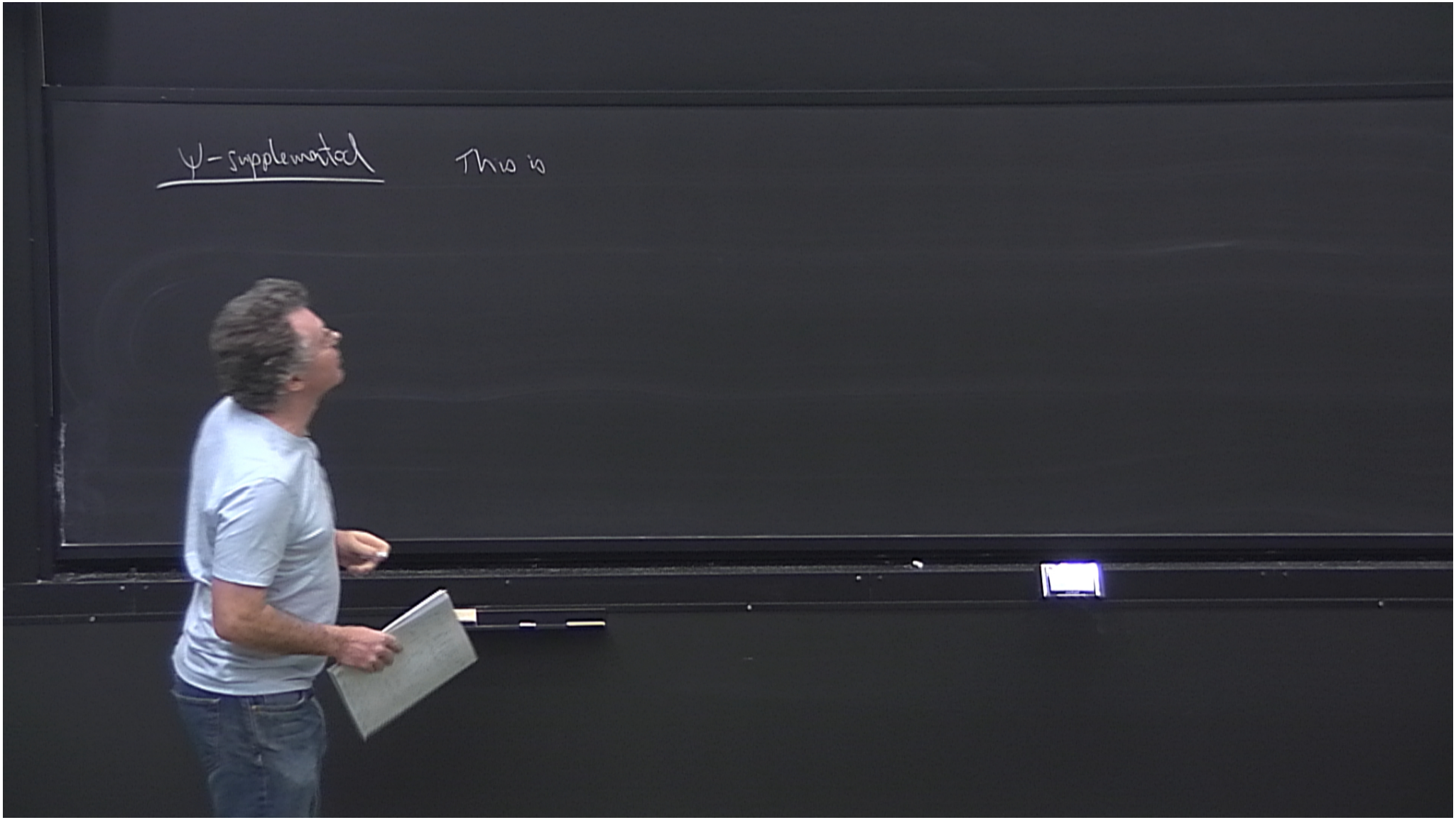

ψ-complete
ψ-ontic
An ontological model is ψ-ontic

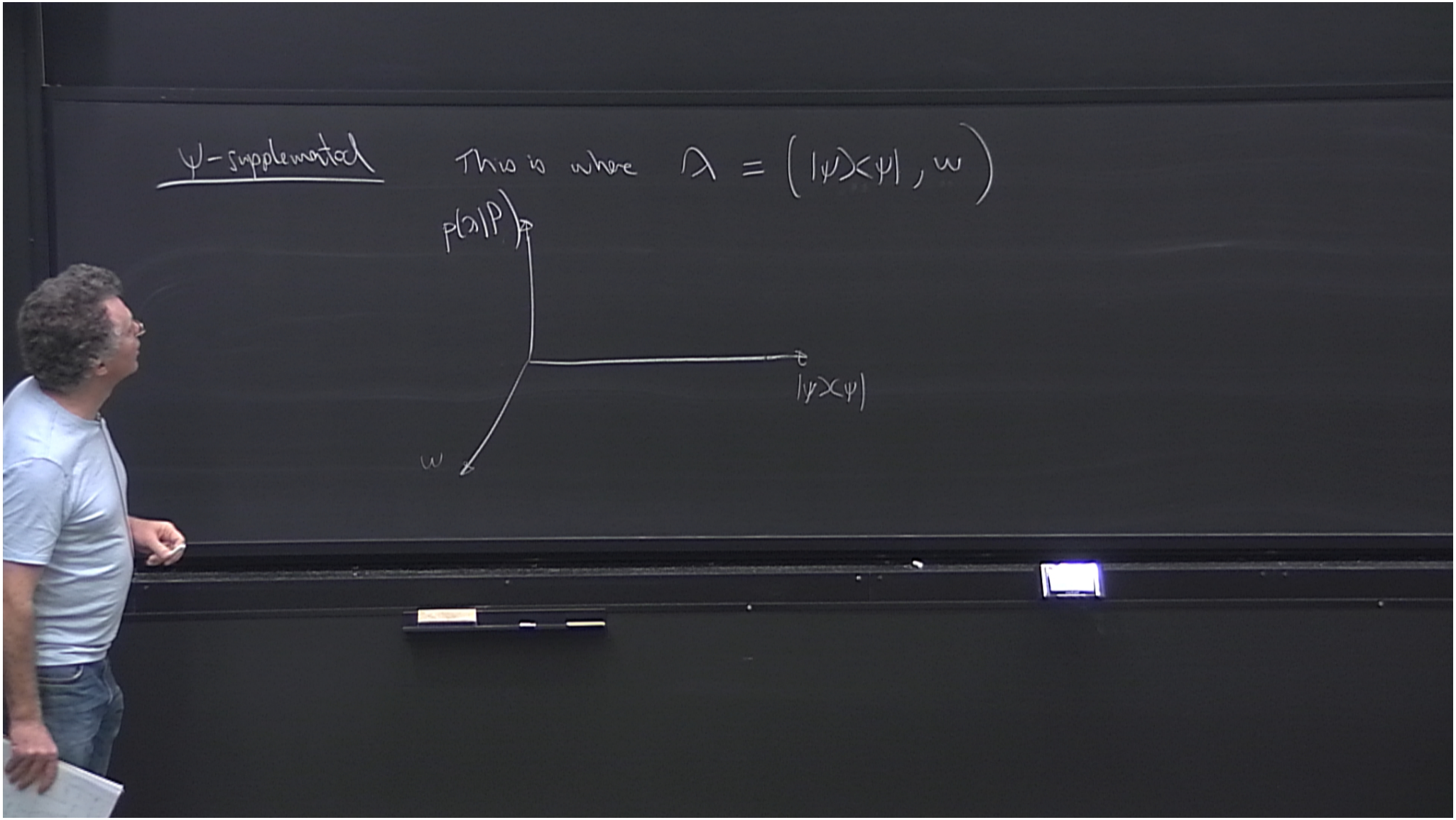

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An ontological model is ψ-ontic
if, for any pair of pure preparations P_ψ and P_φ
we have $p(\lambda|P_\psi)\,p(\lambda|P_\varphi) = 0 \;\forall\,\lambda$
ψ
φ
then
(since I can deduce ψ from λ)


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PBR
theorem
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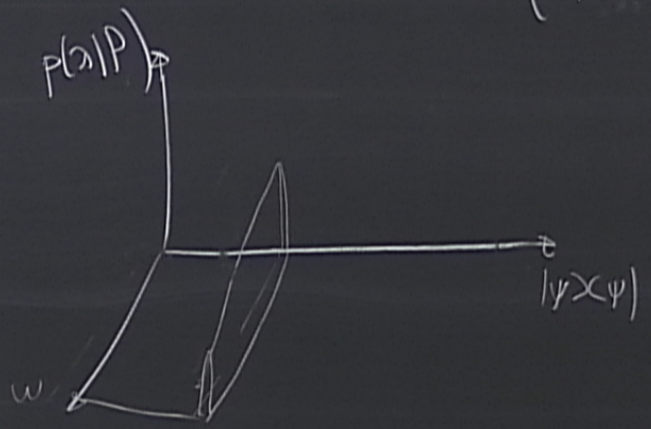

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then
since I can deduce ψ from λ


ψ-supplemental
This is


ψ-supplemented
This is where $\Lambda = (|\psi\rangle\langle\psi|, w)$
$p(\lambda|P)$
$|\psi\rangle\langle\psi|$
w

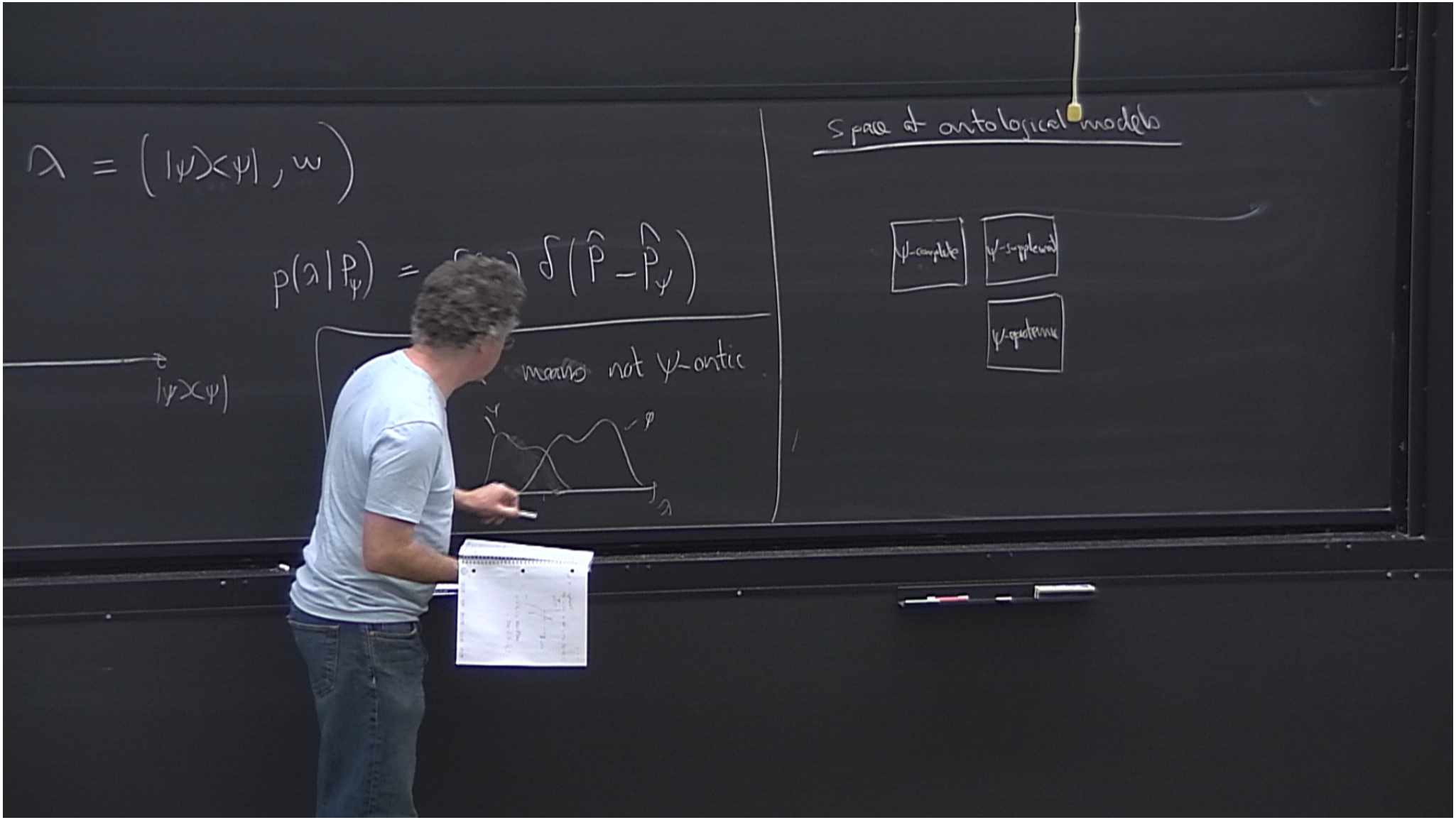
ψ-supplemented

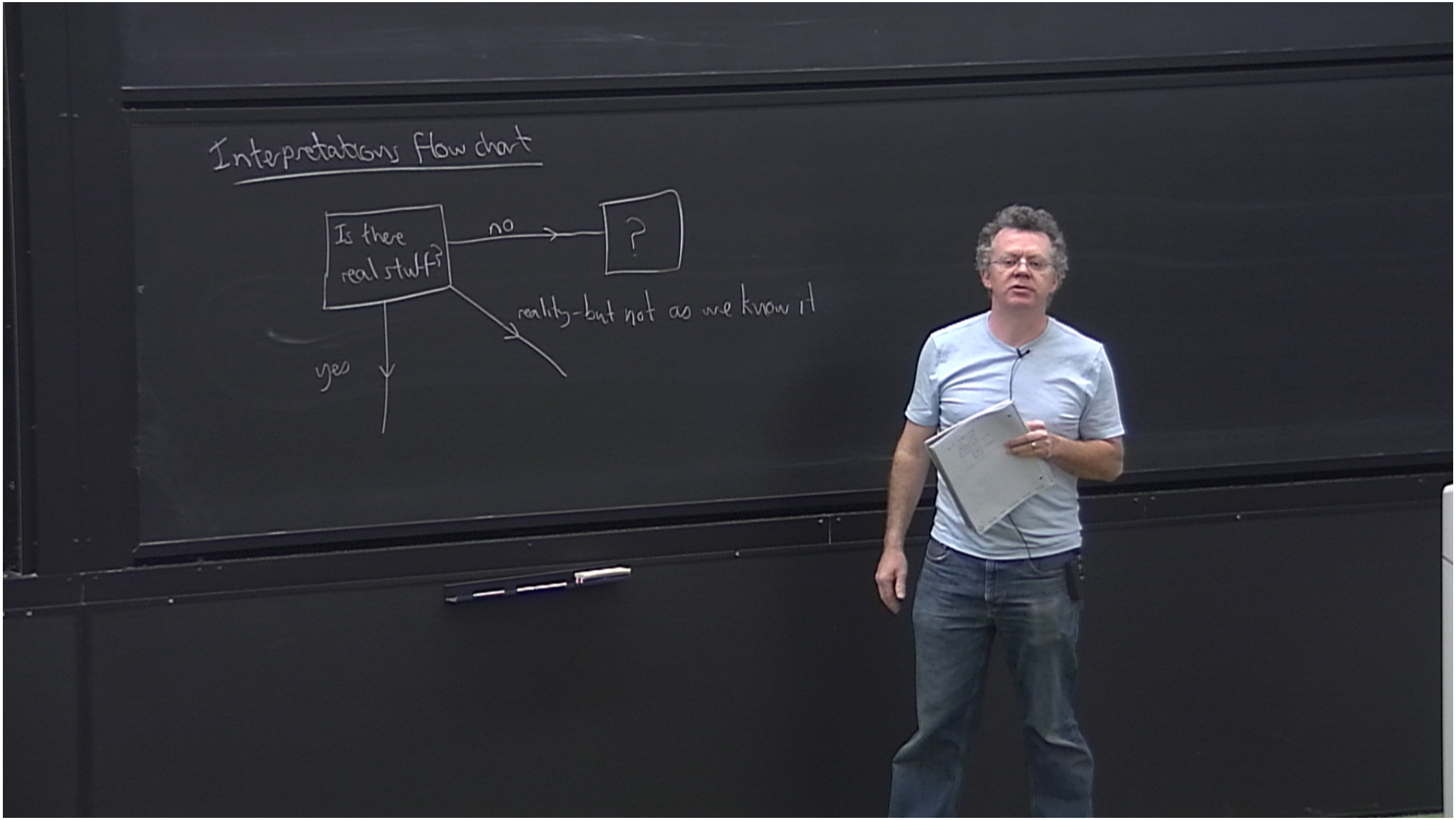
This is where $\lambda = (|\psi\rangle\langle\psi|, w)$

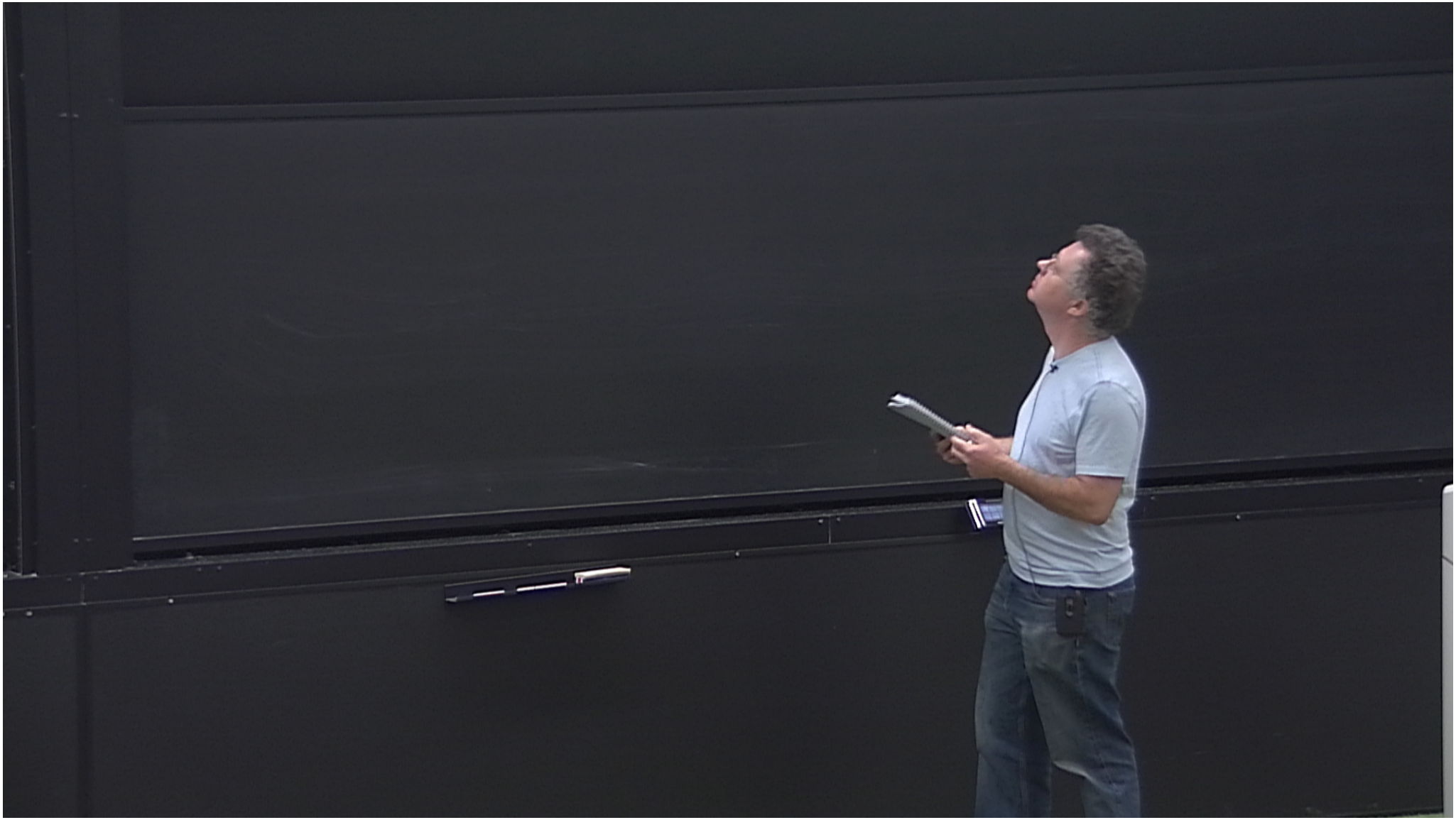


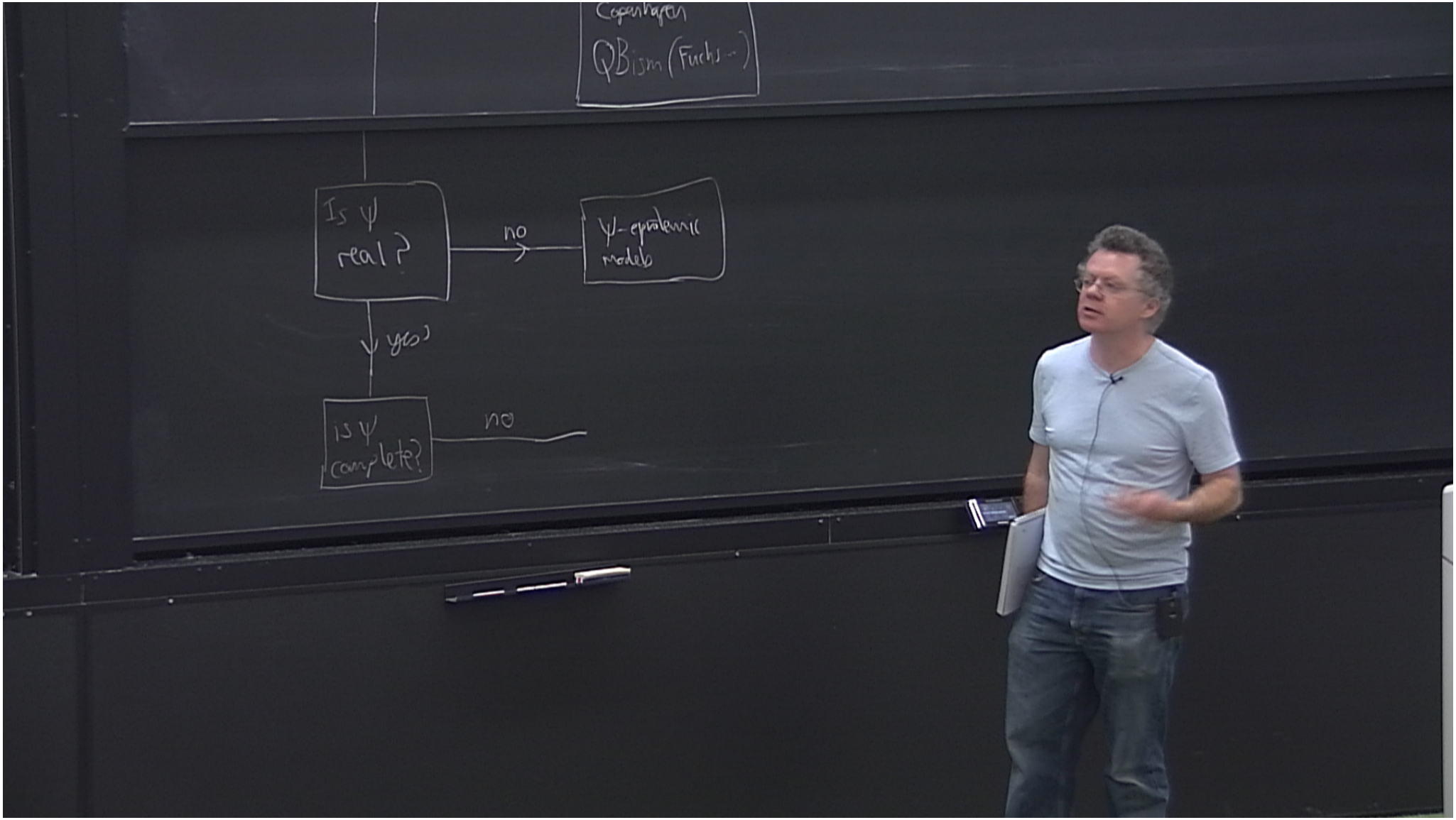
$$p(\lambda|\hat{P}_\psi) = f(w)\,\delta(\hat{P} - \hat{P}_\psi)$$

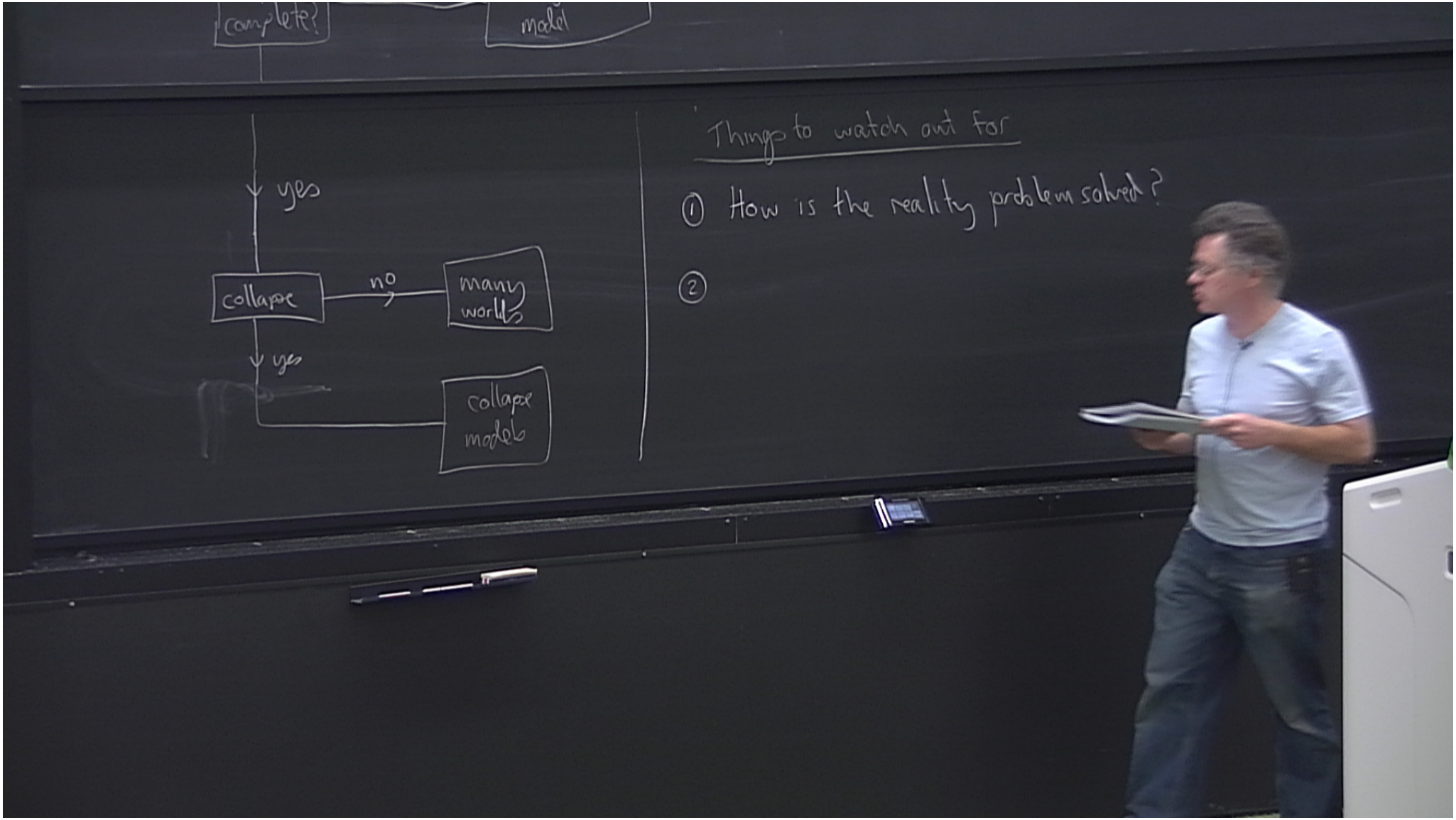

Space of ontological models
ψ-complete
ψ-supplement
ψ-epistemic

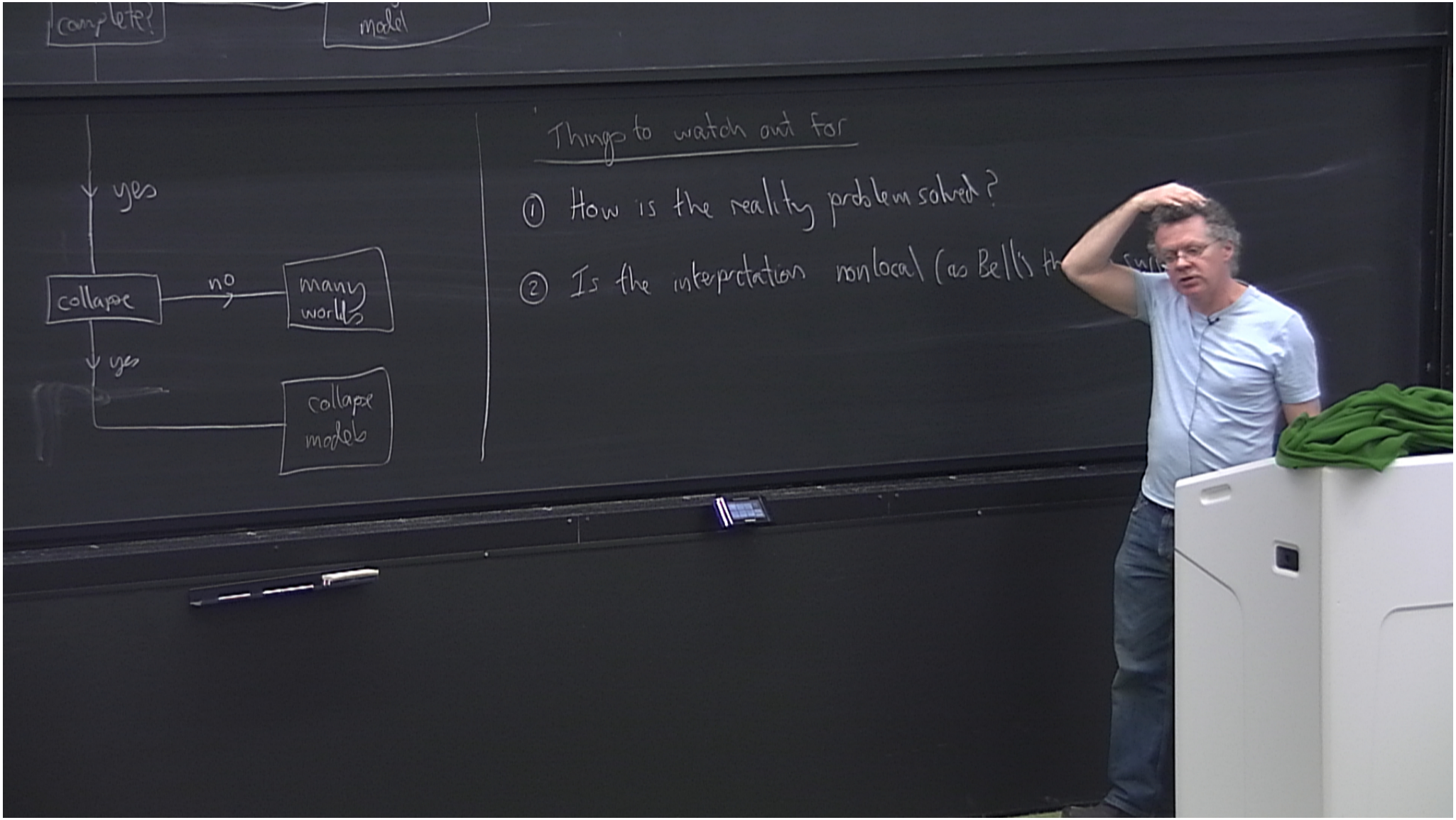

$\lambda = (|\psi\rangle\langle\psi|, w)$
$p(\lambda|P_\psi) = \delta(\hat{P} - \hat{P}_\psi)$
$|\psi\rangle\langle\psi|$
Space of ontological models
ψ-complete
ψ-supplement
ψ-epistemic
mains not ψ-ontic

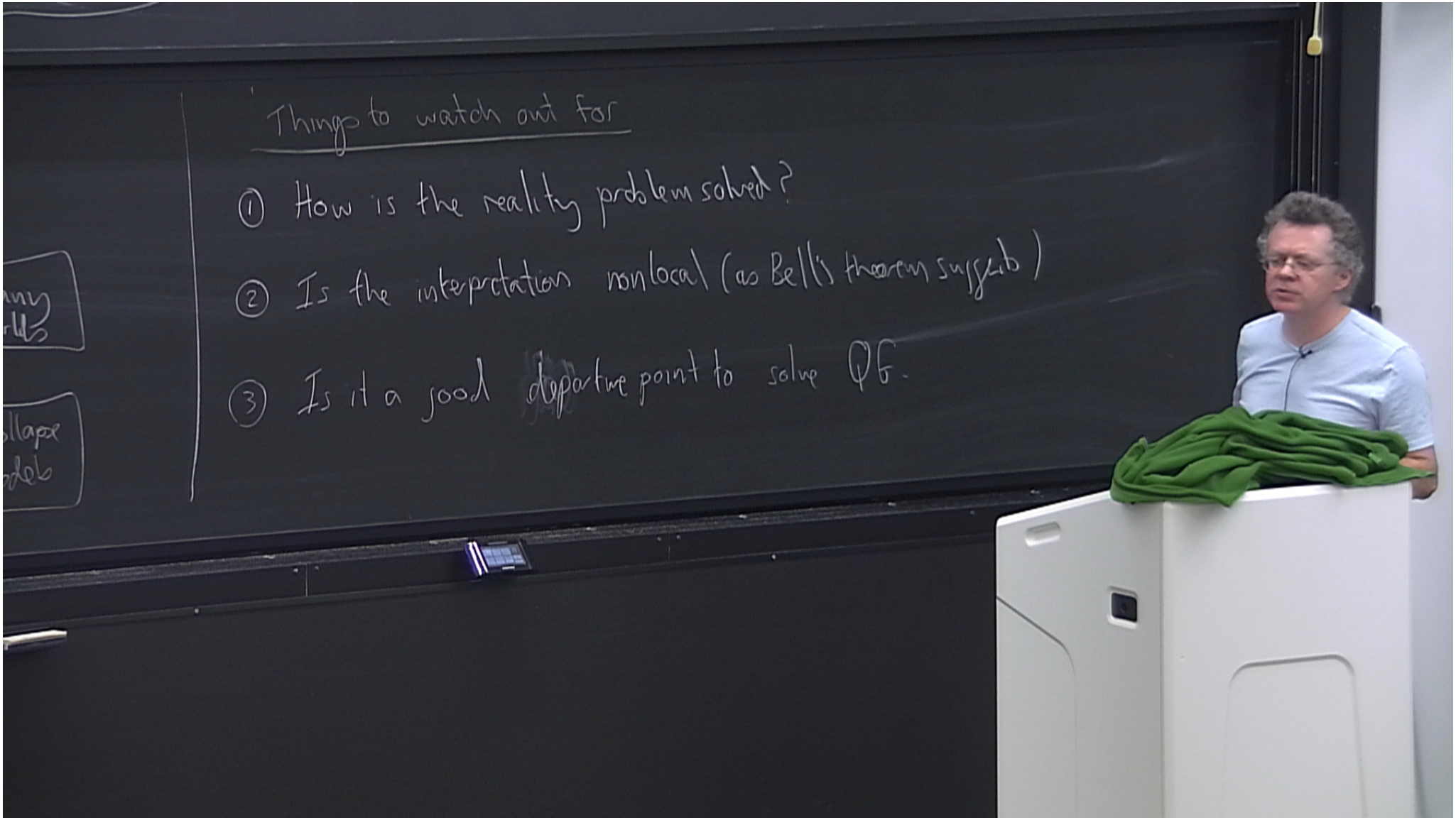

Interpretations flow chart
Is there real stuff?
no
?
reality-but not as we know it
yes

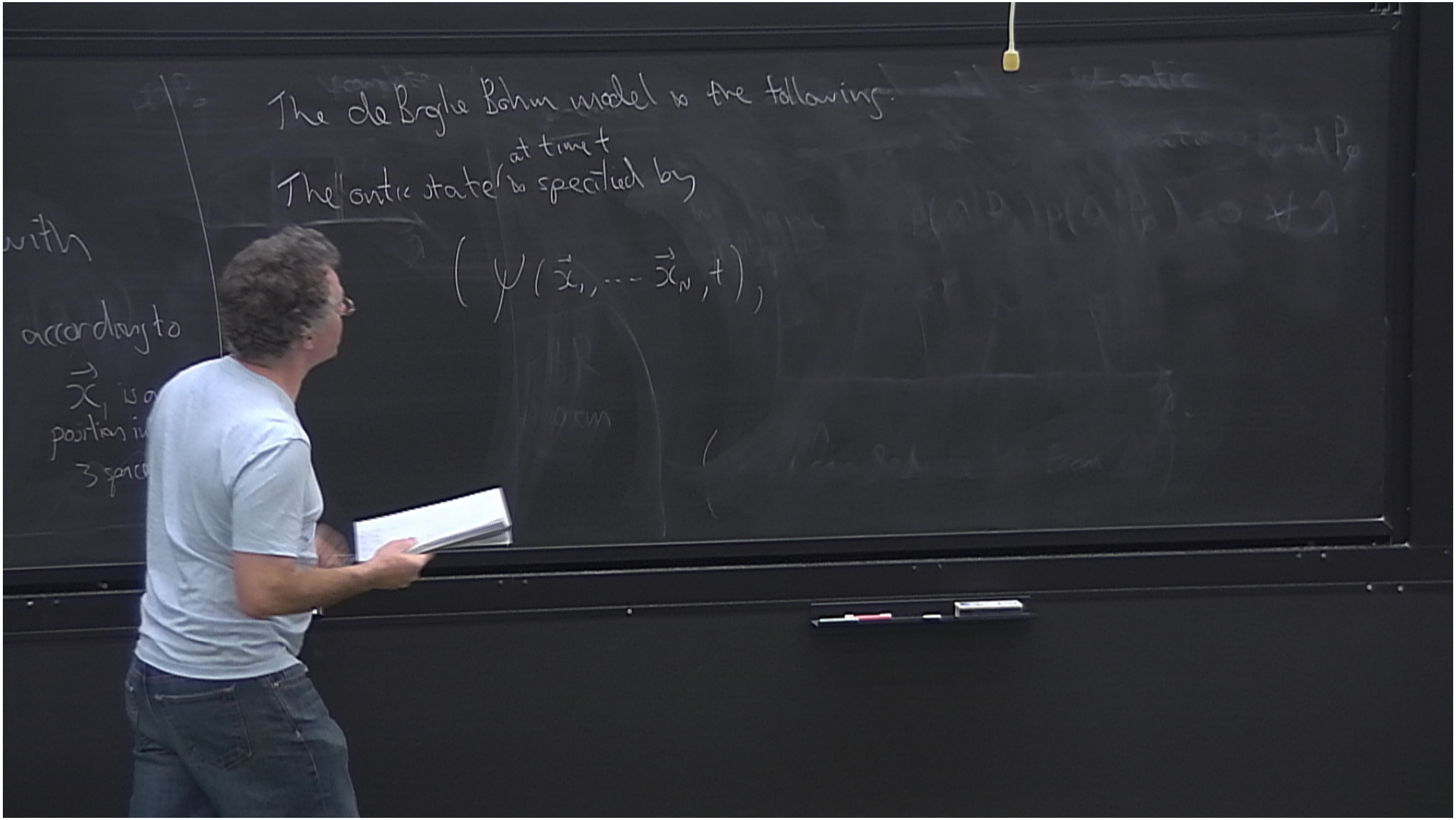


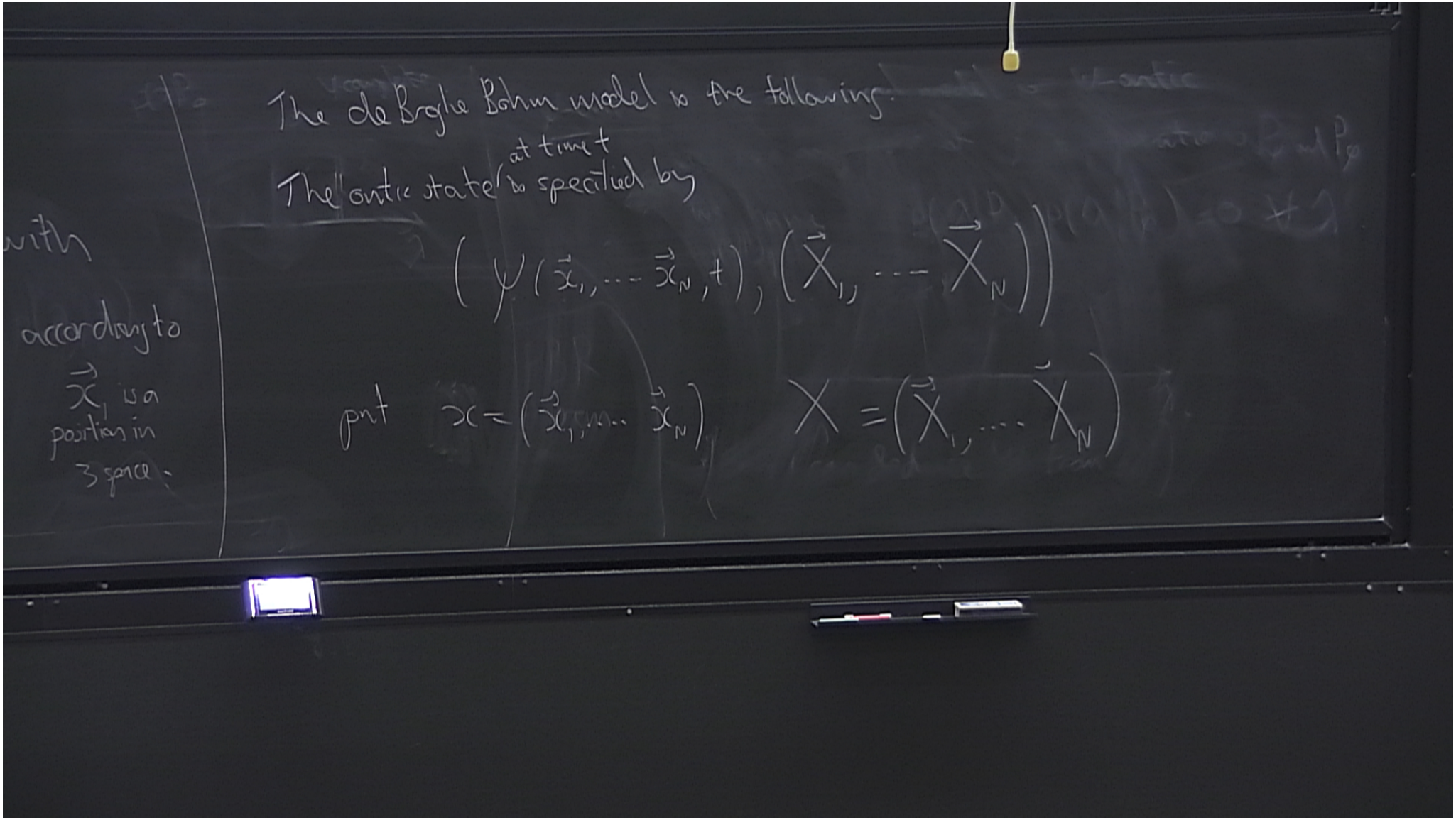

Copenhagen
QBism (Fuchs...)
Is ψ real?
no
ψ-epistemic models
yes
Is ψ complete?
no

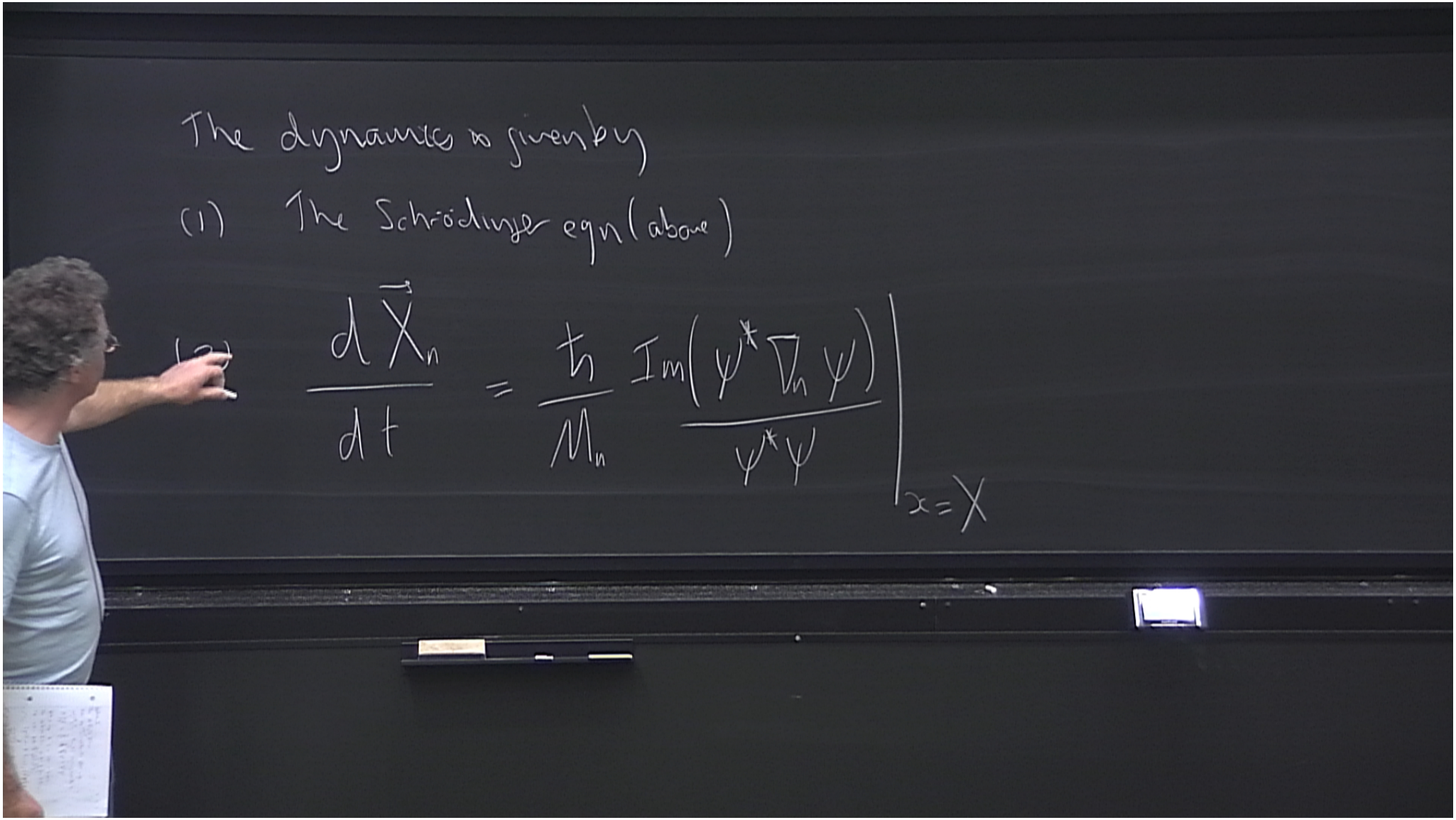

complete?
model
yes
collapse
no
many worlds
yes
collapse models
Things to watch out for
① How is the reality problem solved?
②

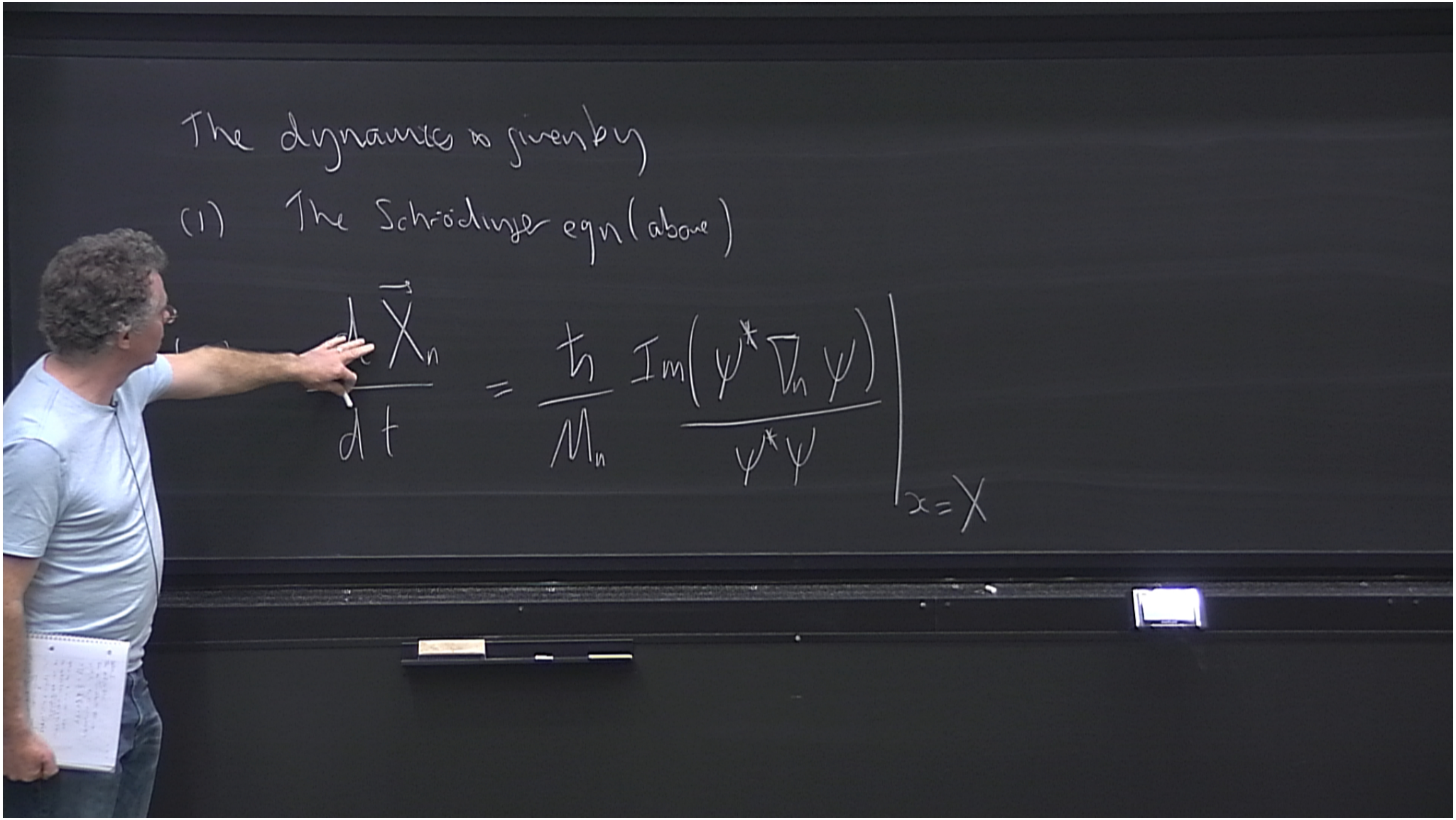

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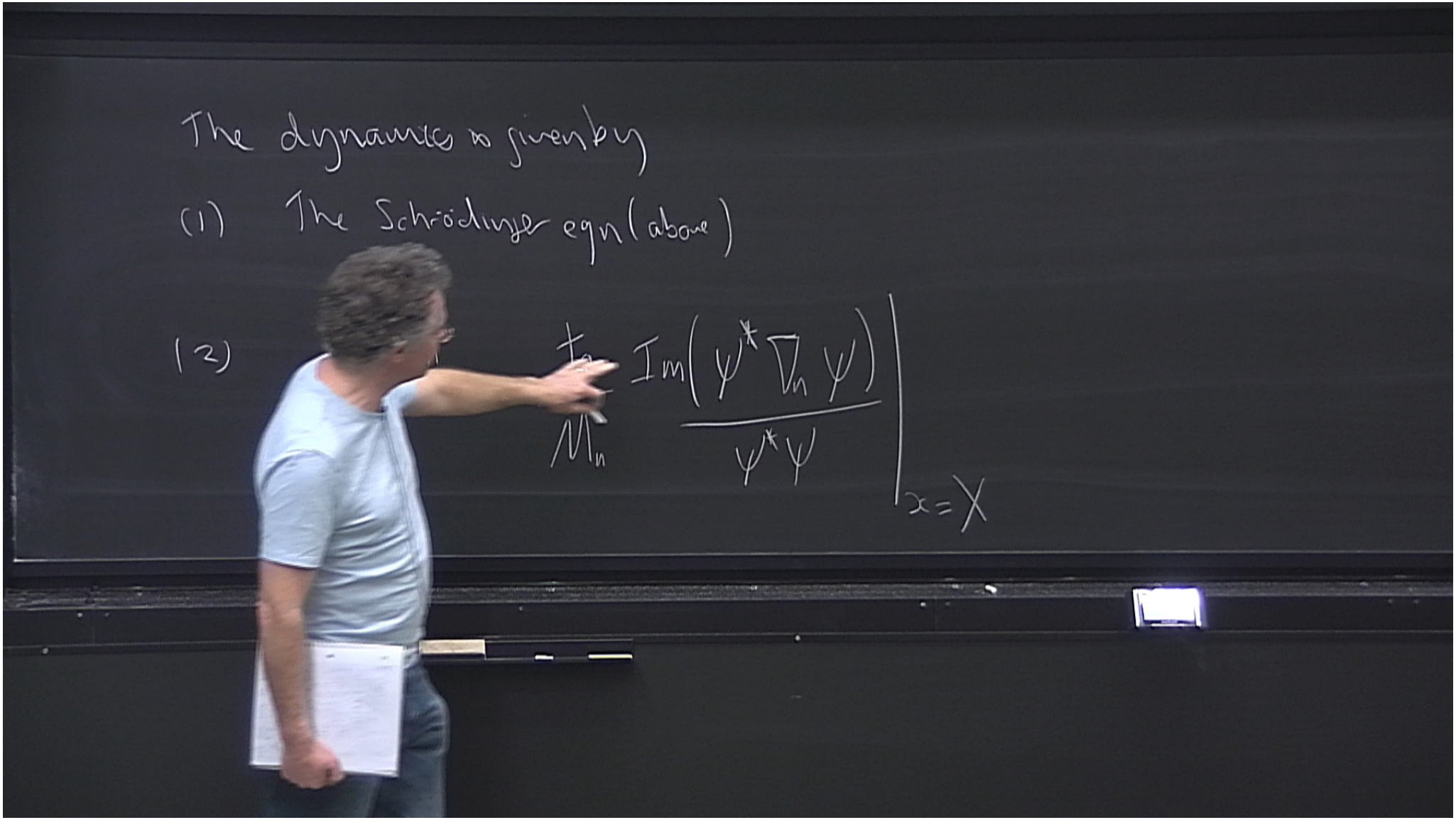

Things to watch out for
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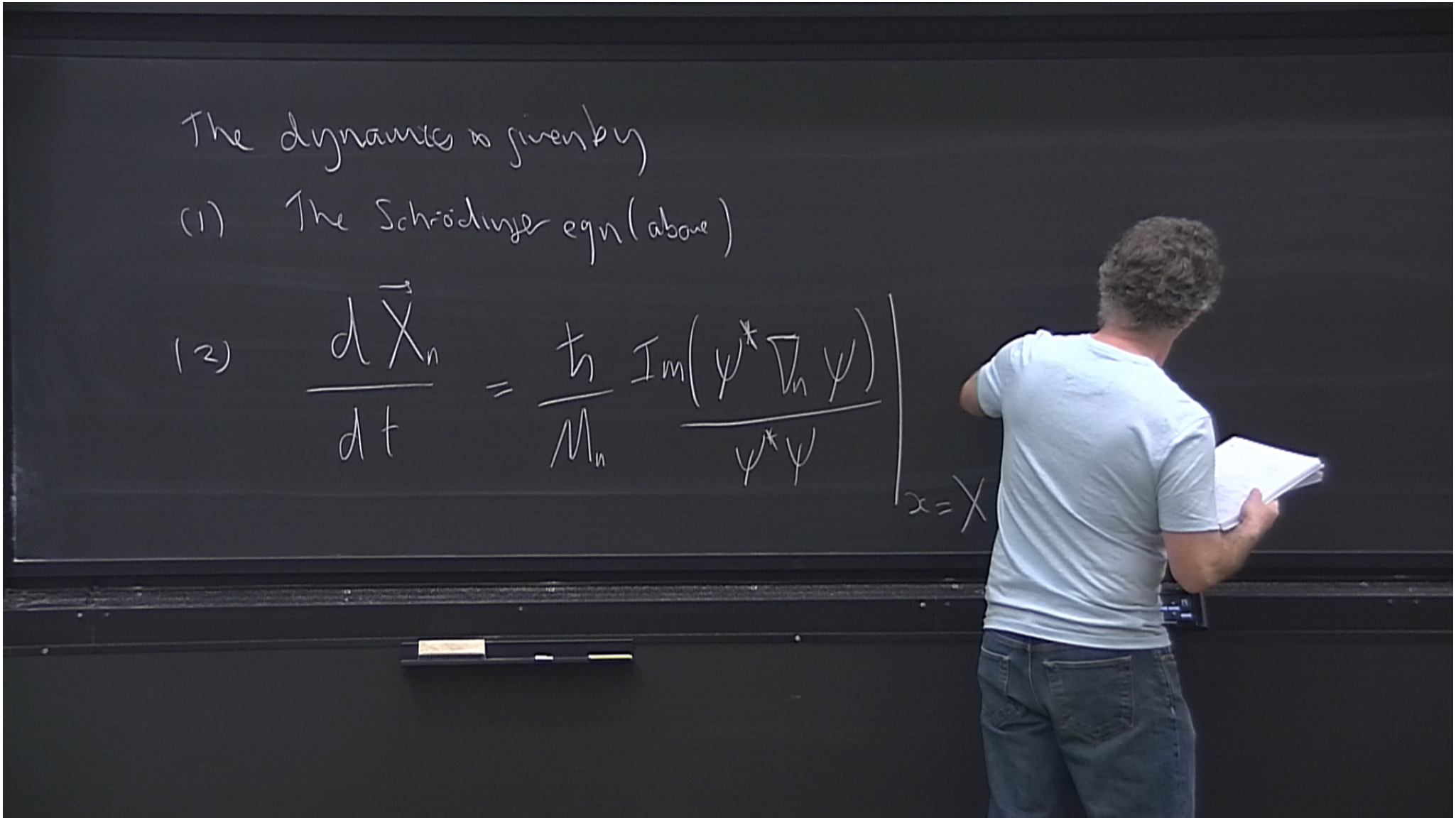

The de Broglie Bohm model is the following:
The ontic state at time t is specified by
$(\psi(\vec{x}_1, \cdots \vec{x}_N, t),$
with
according to
$\vec{x}_1$ is a
position in
3 spac

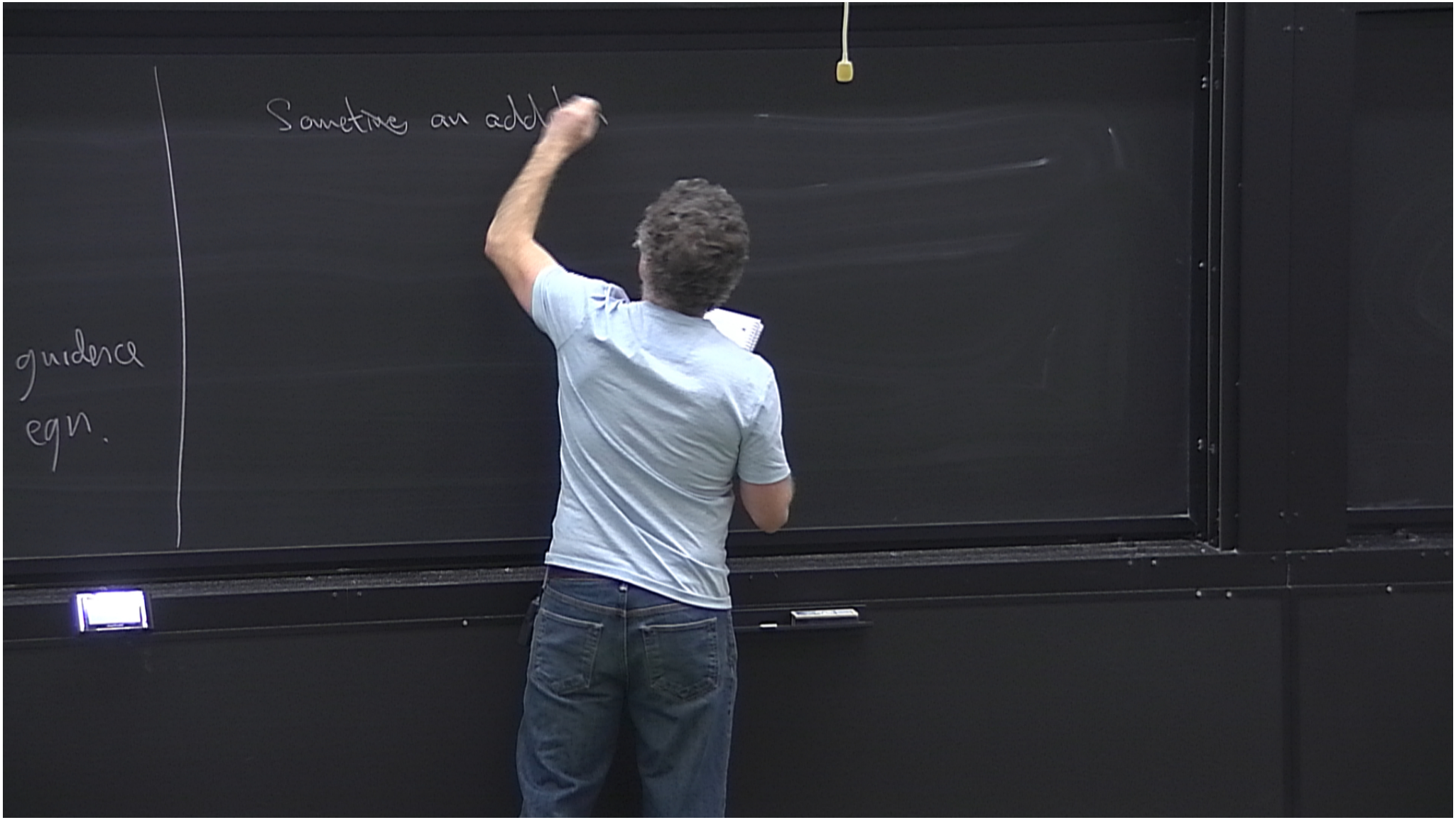

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The ontic state at time t is specified by
$\left(\psi(\vec{x}_1, \cdots \vec{x}_N, t), (\vec{X}_1, \cdots \vec{X}_N)\right)$
with
according to
$\vec{x}_1$ is a position in 3 space.
pnt $x = (\vec{x}_1, \cdots \vec{x}_N)$
$X = (\vec{X}_1, \cdots \vec{X}_N)$

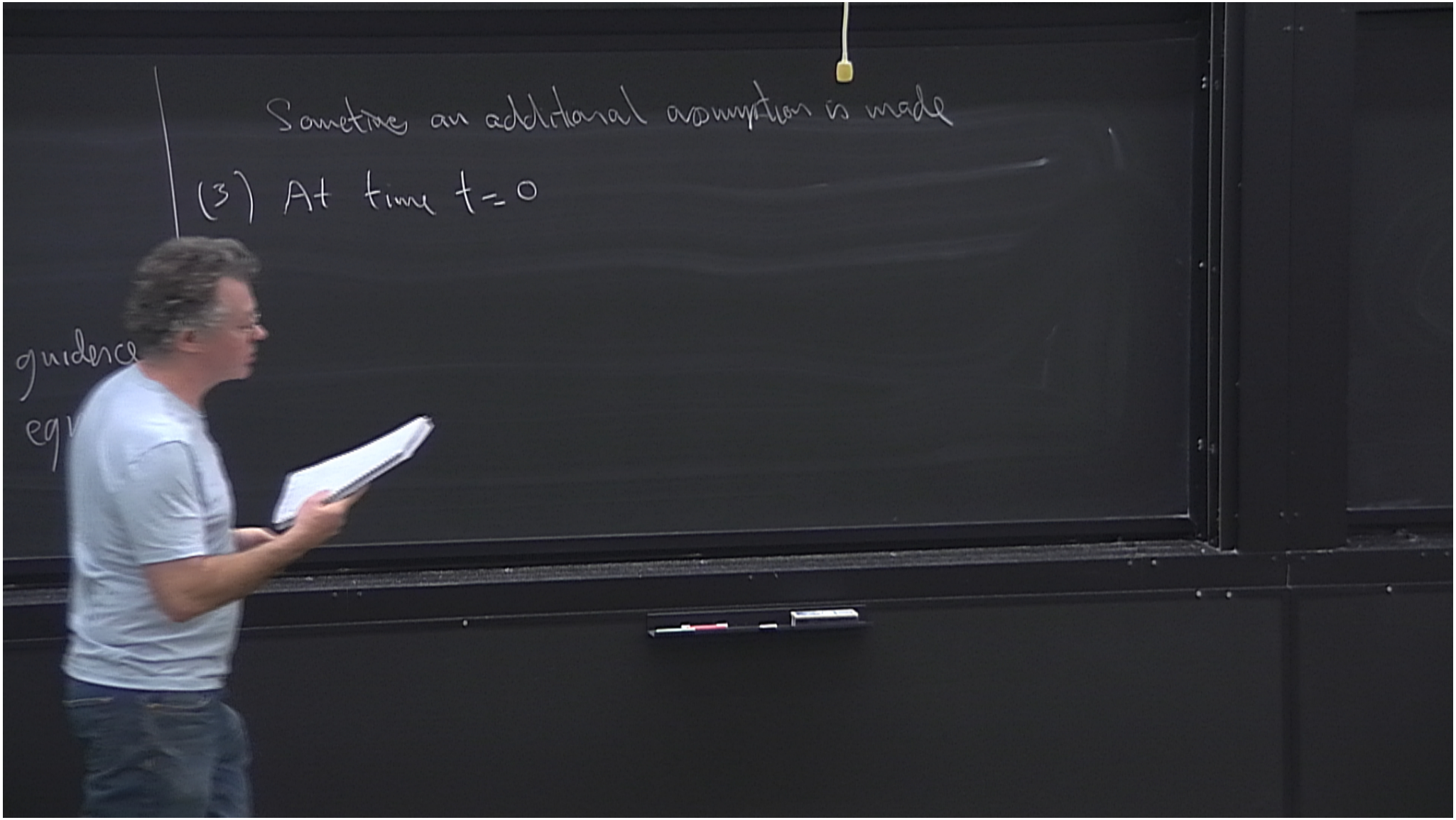

The dynamics is given by
(1) The Schrödinger eqn (above)
(2) $\frac{d\vec{X}_n}{dt} = \frac{\hbar}{M_n} \mathrm{Im}\left(\frac{\psi^* \nabla_n \psi}{\psi^* \psi}\right)\Big|_{x=X}$

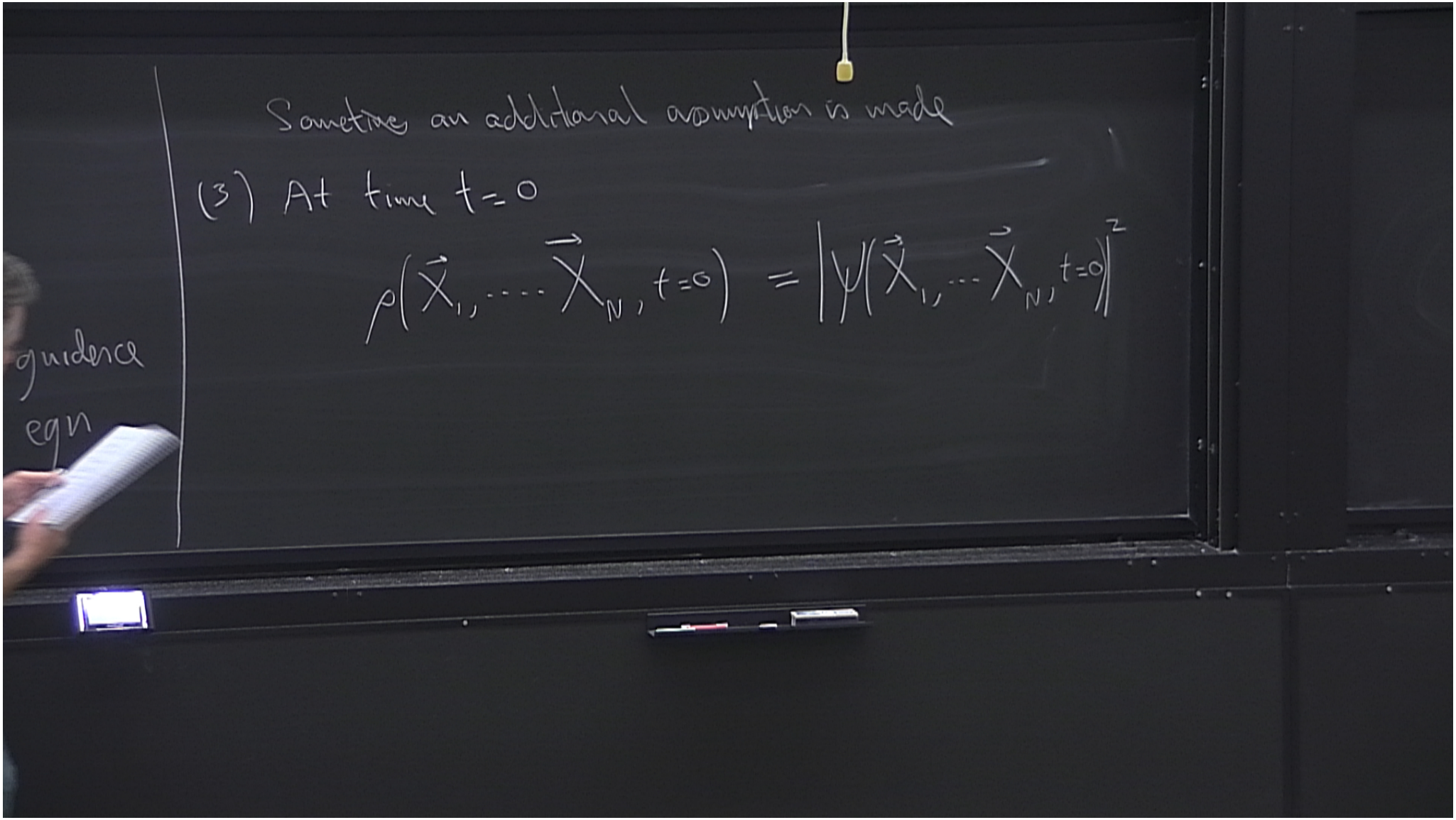

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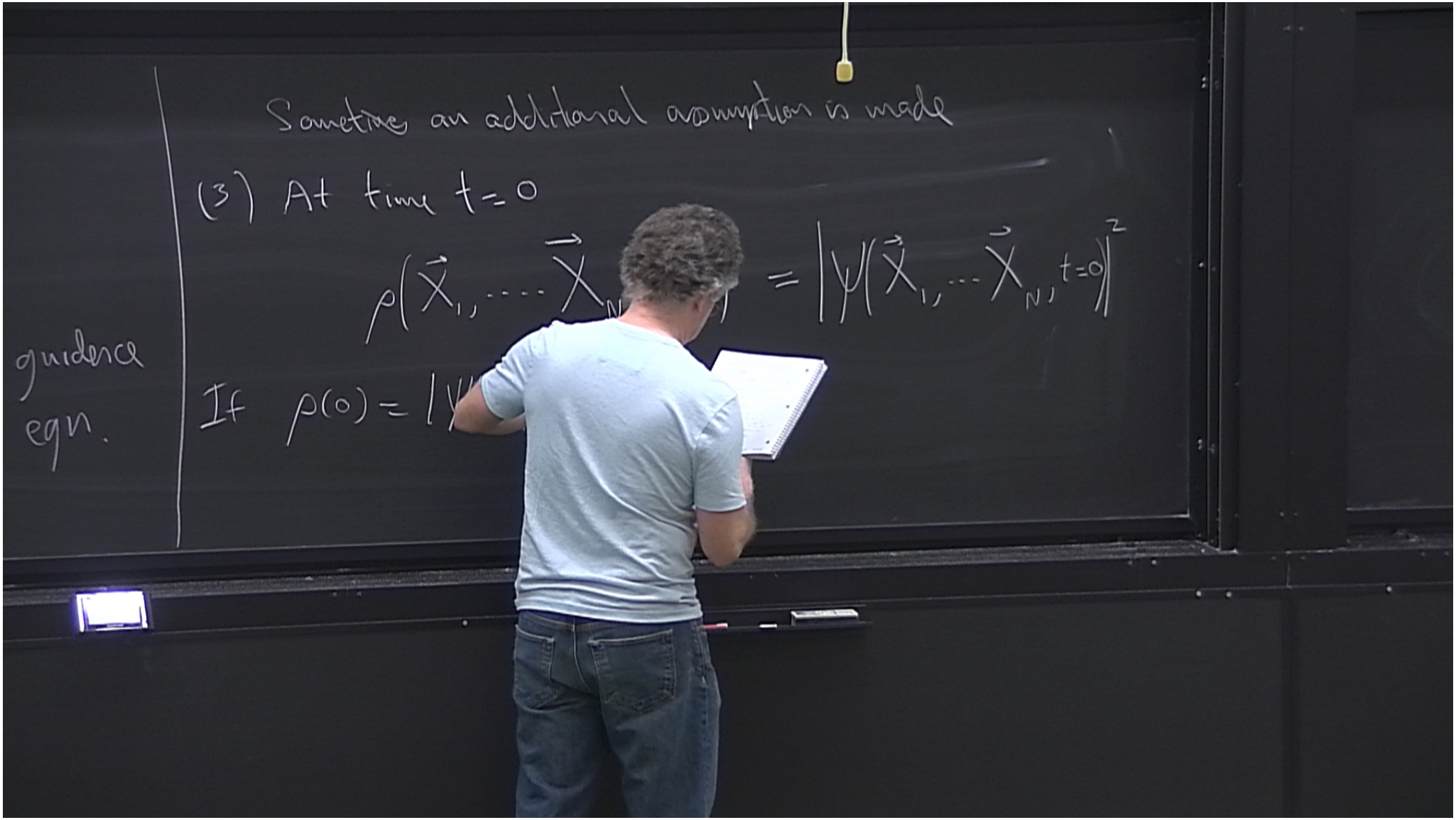

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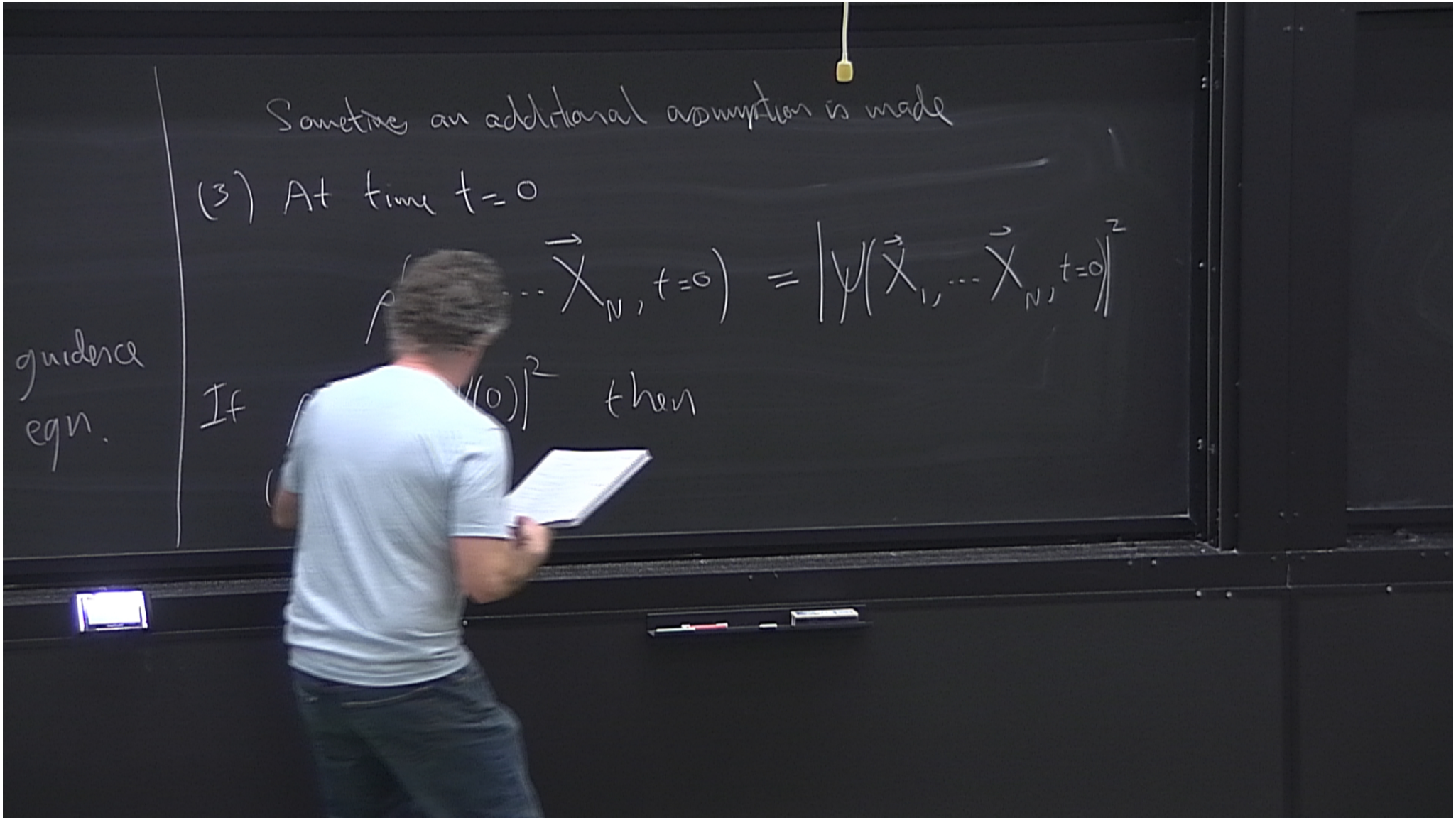

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guidera
eqn.


Sometime an additional assumption is made
(3) At time t=0
guidance
eq


Sometime an additional assumption is made
(3) At time $t=0$
$\rho(\vec{X}_1, \cdots \vec{X}_N, t=0) = |\psi(\vec{X}_1, \cdots \vec{X}_N, t=0)|^2$
guidance
eqn


Sometime an additional assumption is made
(3) At time t=0
guidance eqn.


Sometime an additional assumption is made
(3) At time t=0
guidance eqn.
If
then

Sometime an additional assumption is made

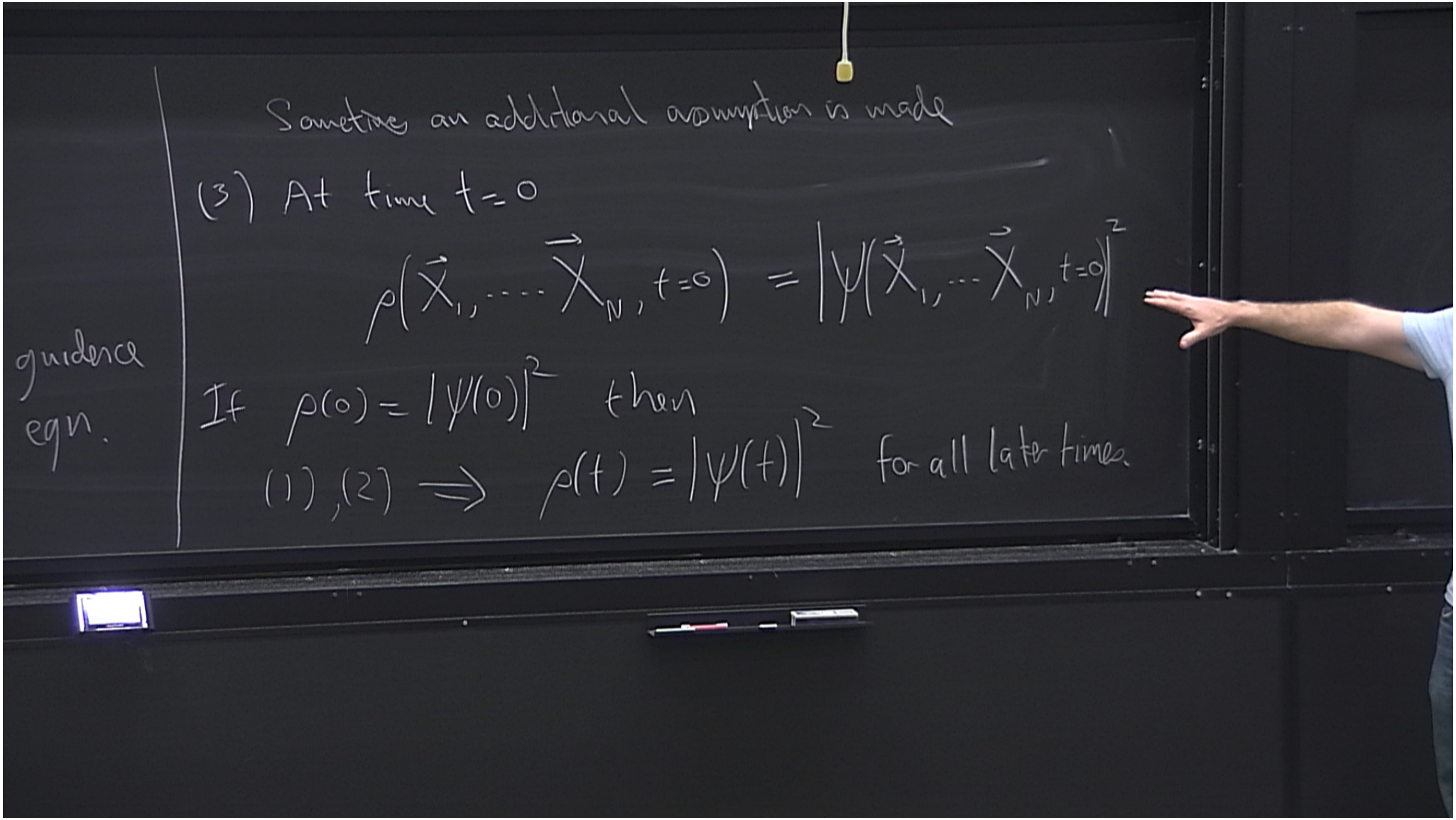
(3) At time $t=0$

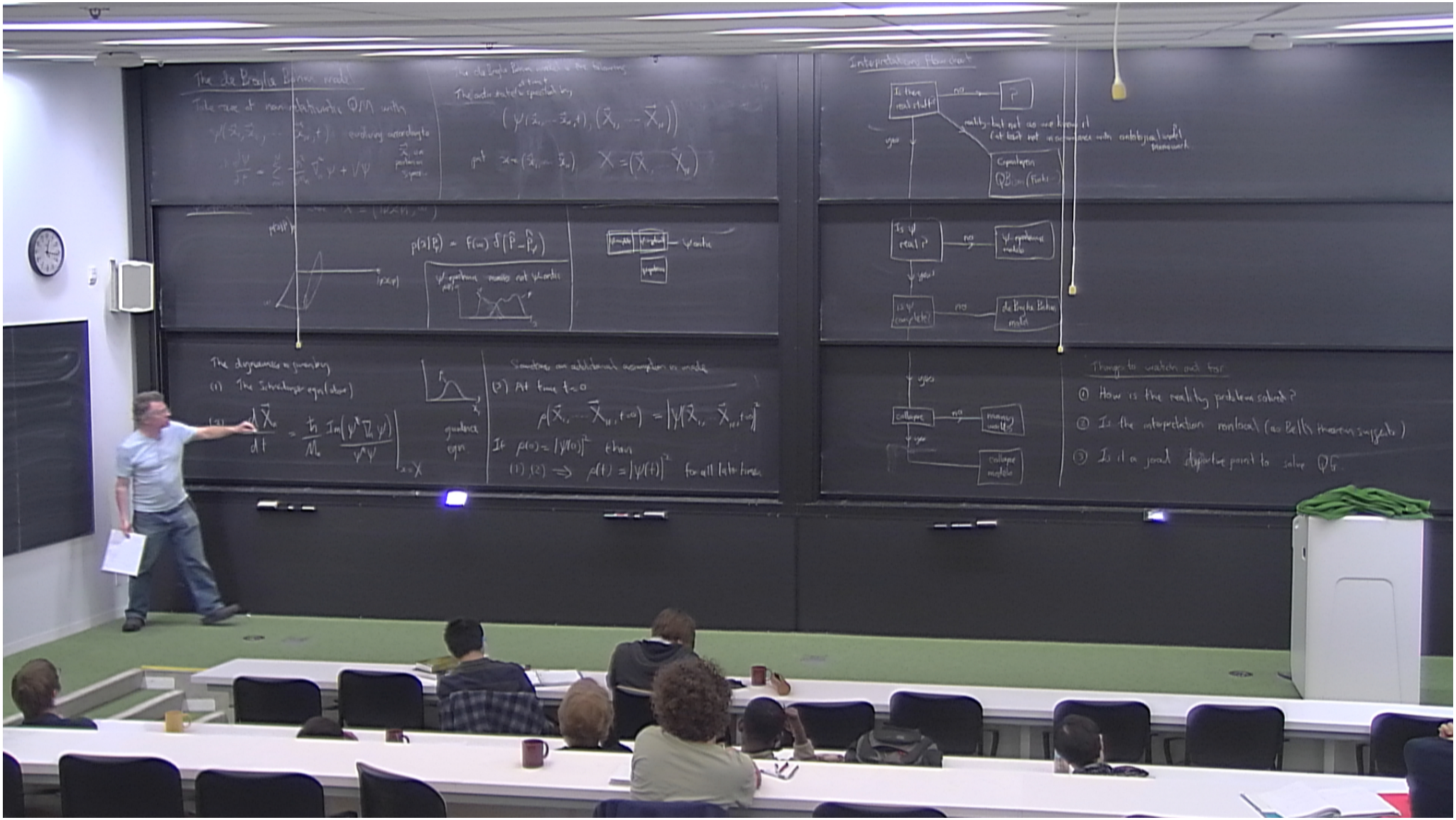
$$\rho(\vec{X}_1, \cdots \vec{X}_N, t=0) = |\psi(\vec{X}_1, \cdots \vec{X}_N, t=0)|^2$$

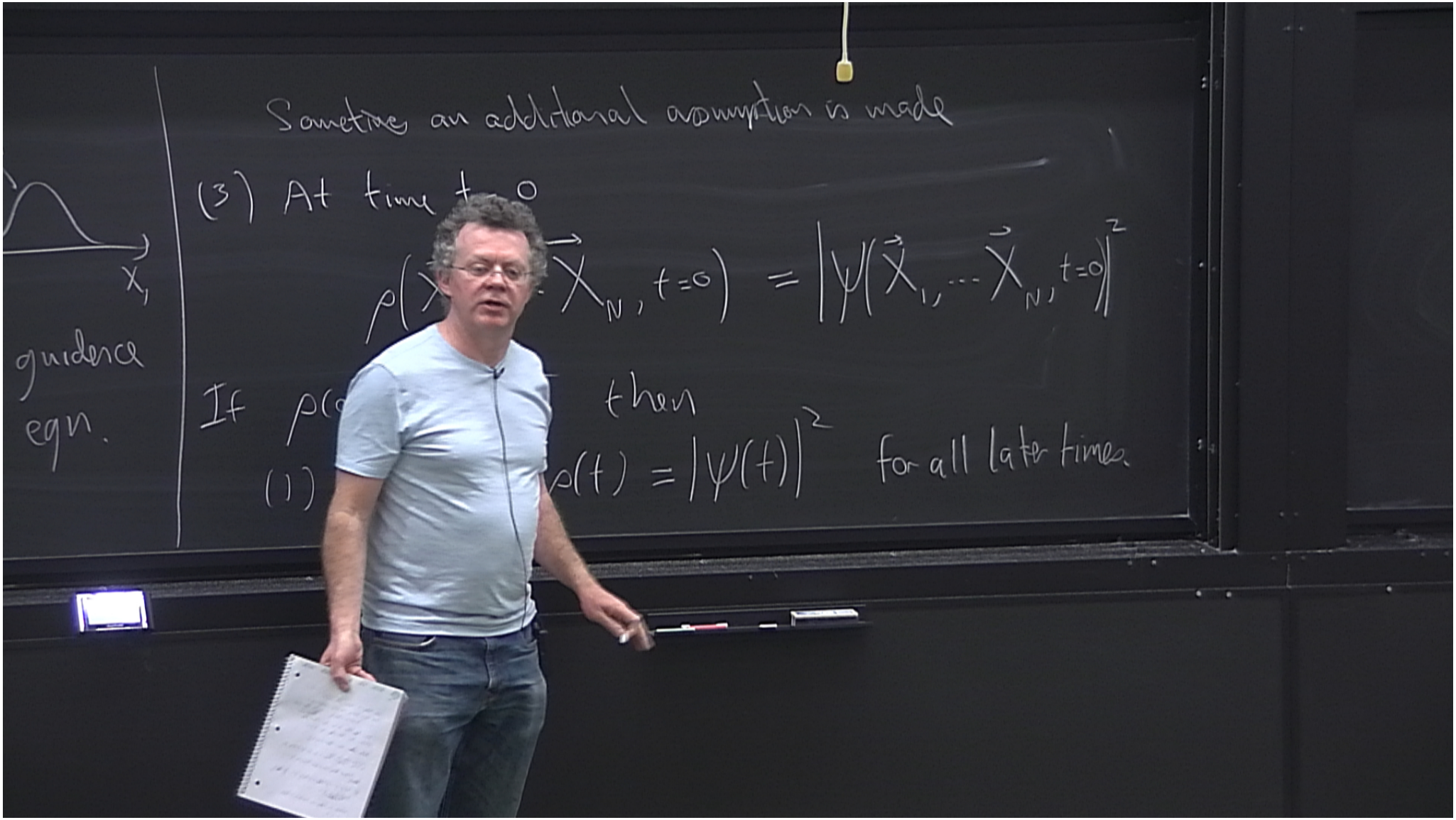
guidance eqn.

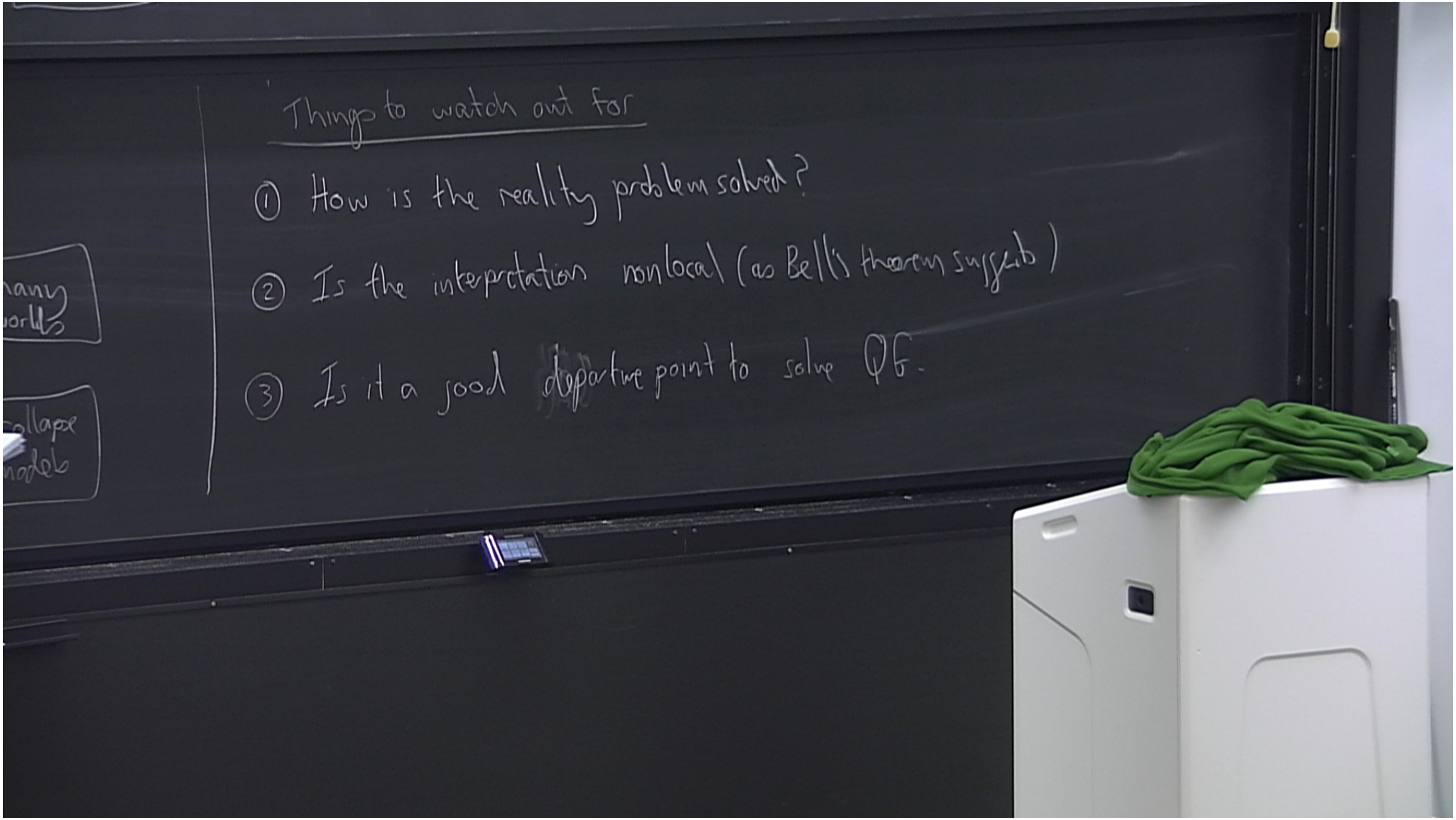
If $\rho(0) = |\psi(0)|^2$ then

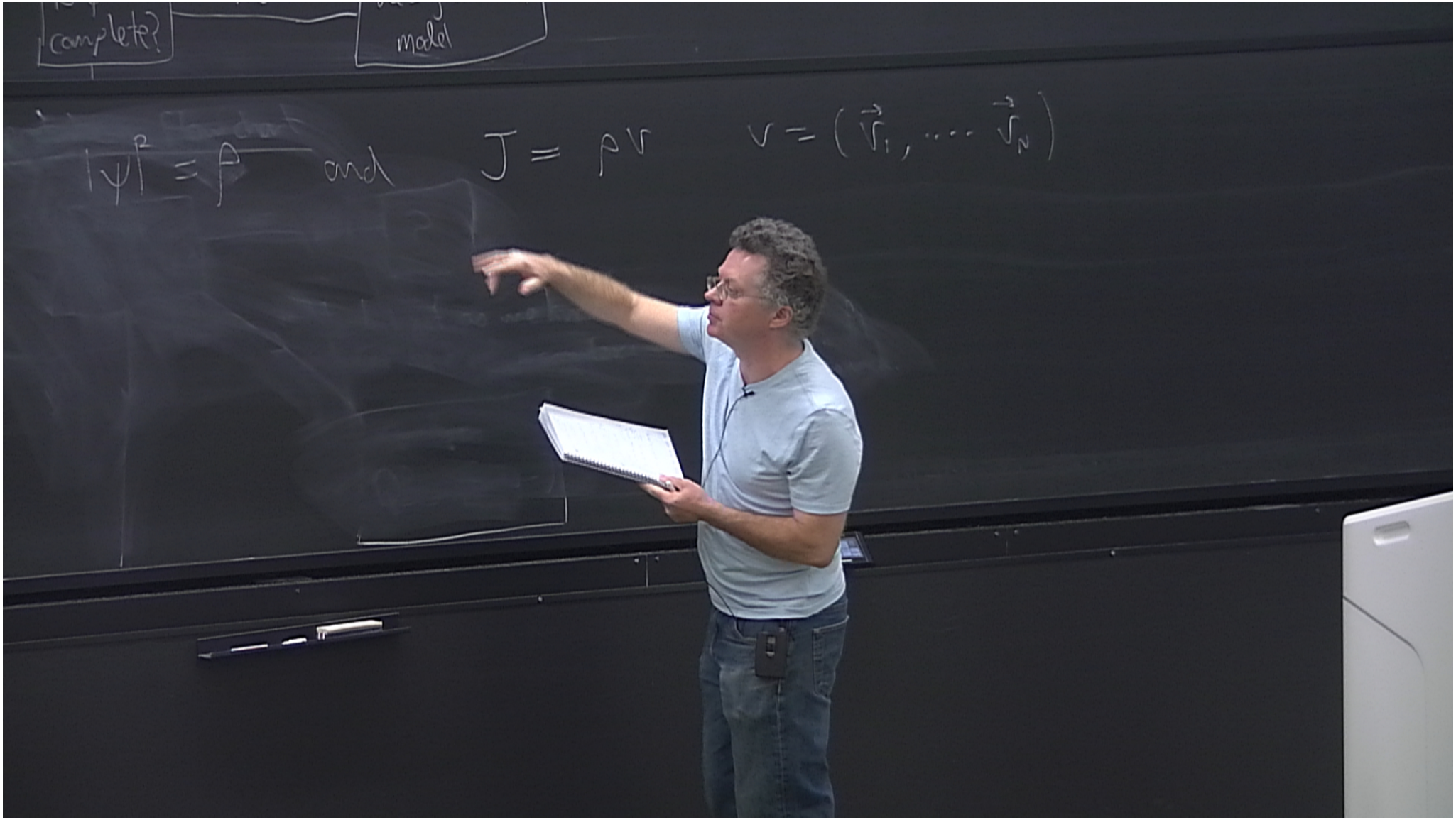
(1), (2) $\Rightarrow$ $\rho(t) = |\psi(t)|^2$ for all later times.

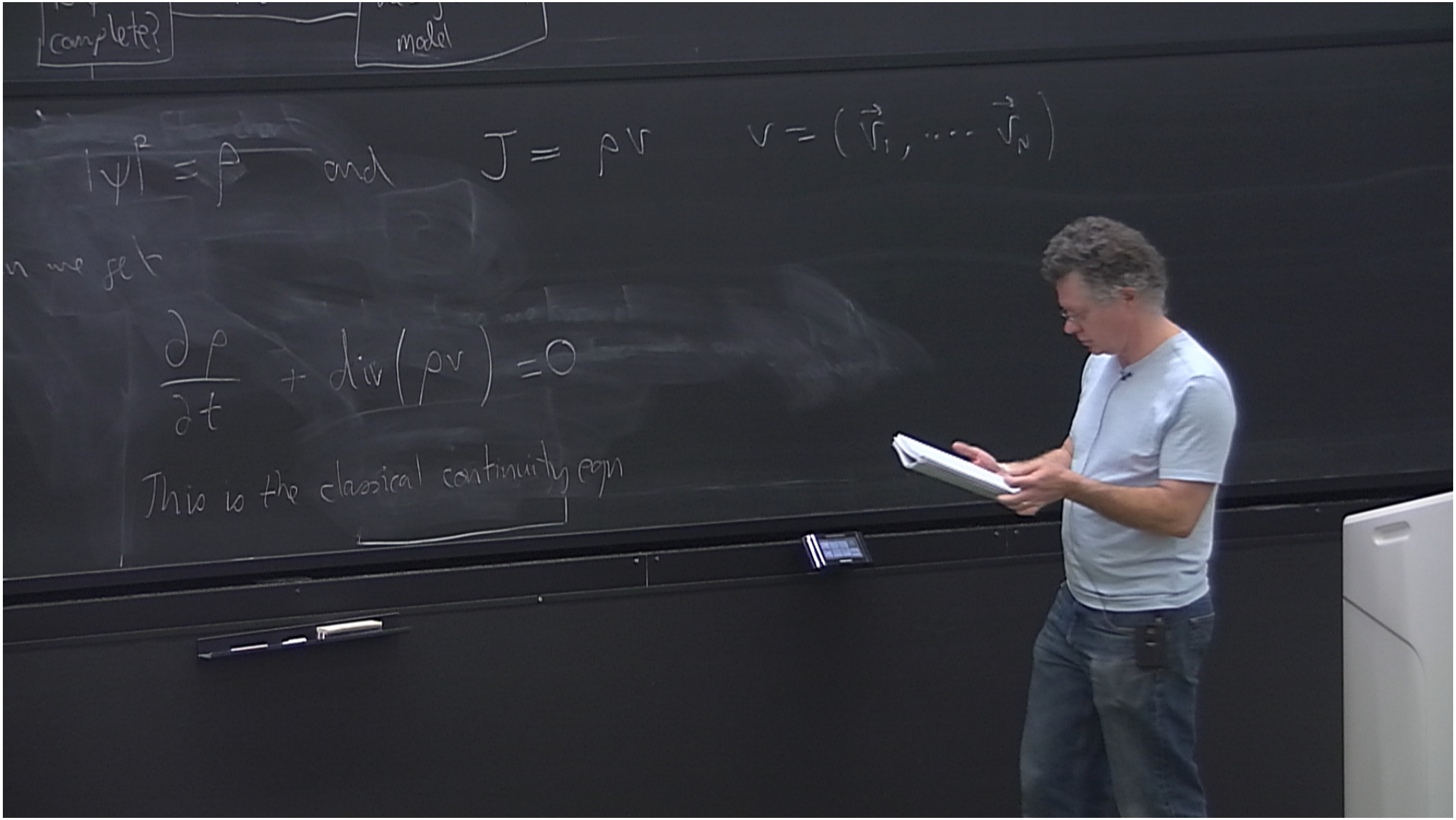


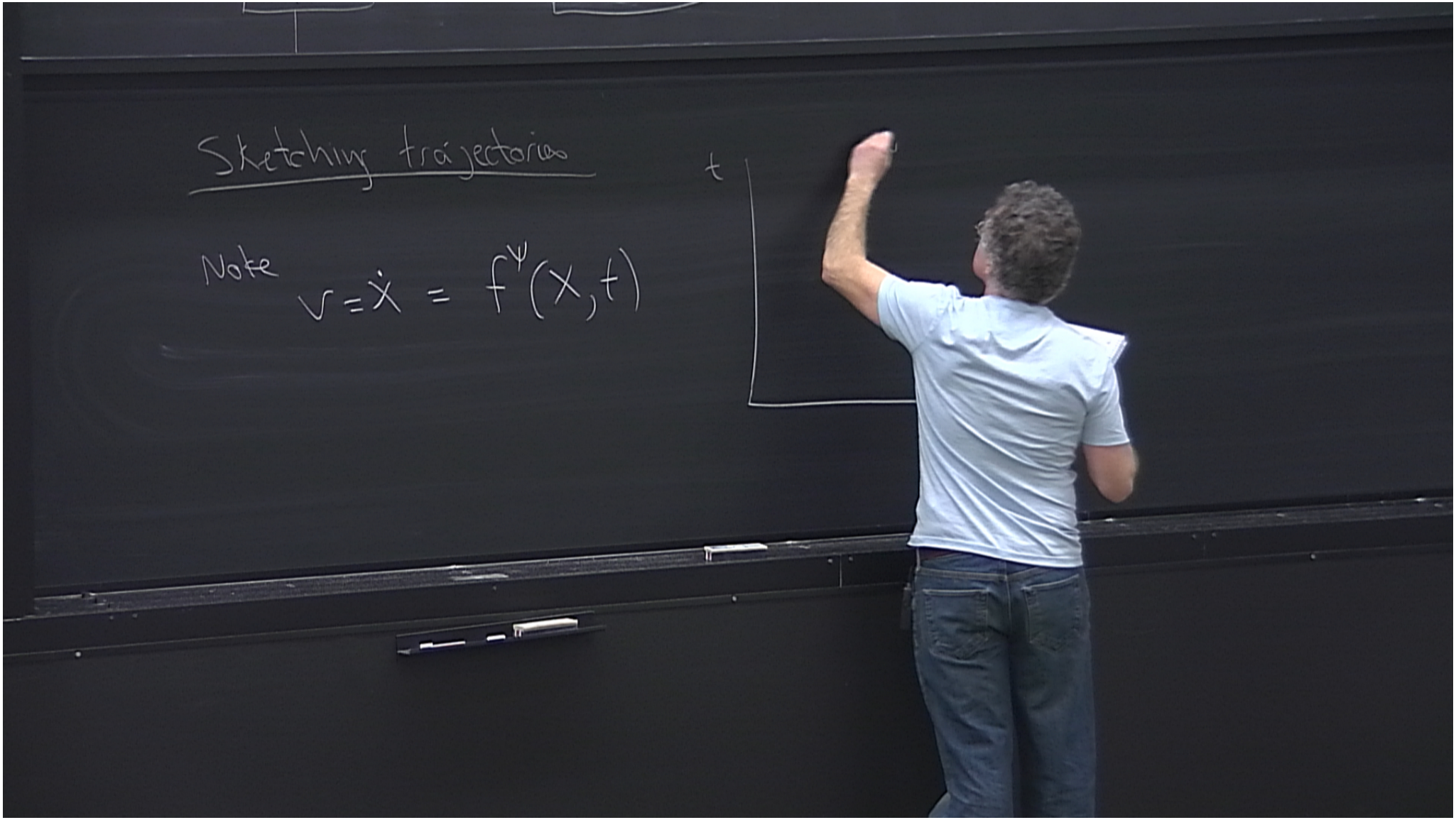

The de Broglie Bohm model
Interpretations flowchart
Is there real stuff?
no
yes
Is ψ real?
Is ψ complete?
collapse
many worlds
collapse models
Things to watch out for
① How is the reality problem solved?
② Is the interpretation nonlocal (as Bell's theorem suggests)
③ Is it a good starting point to solve QG.

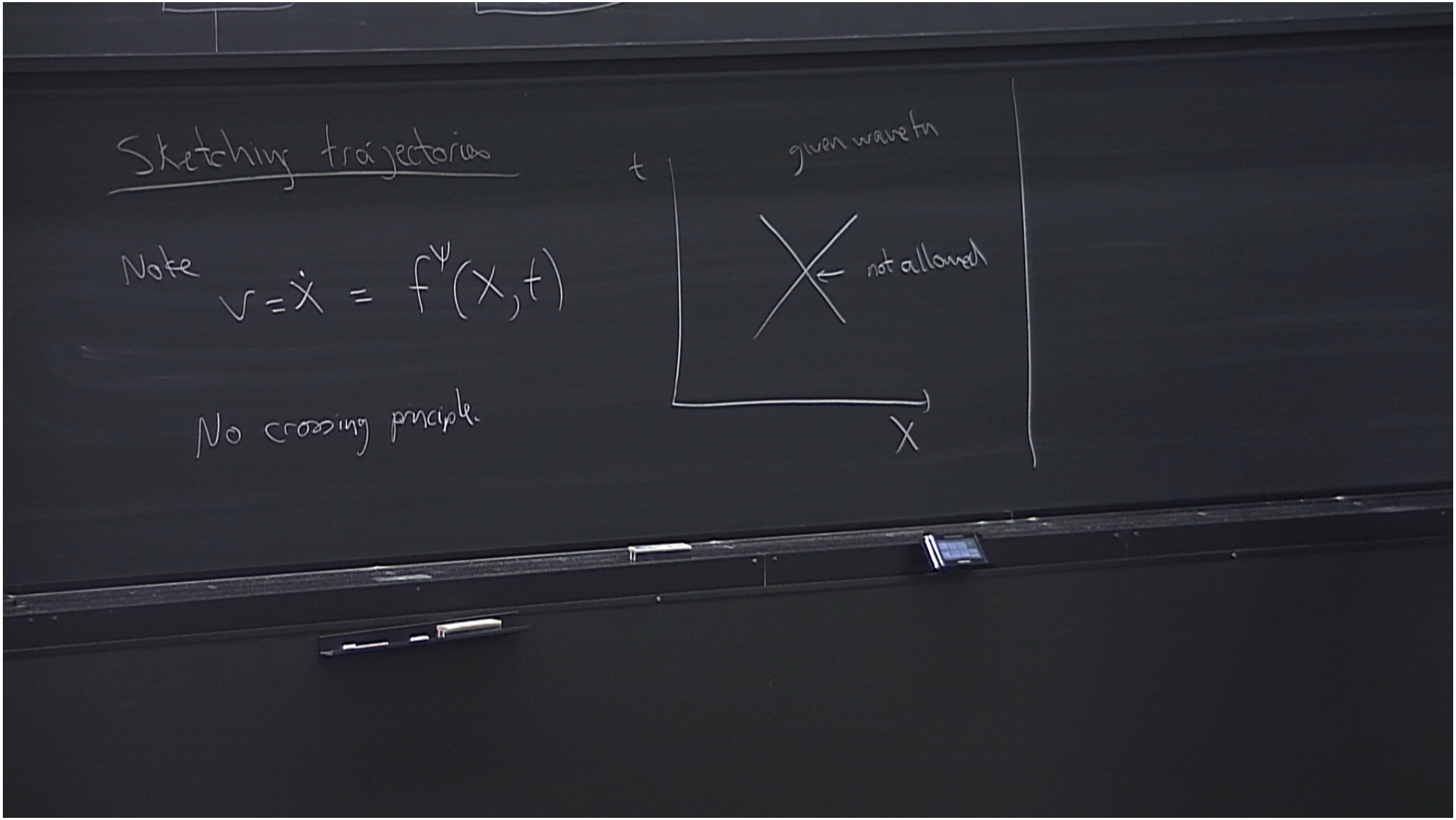

Sometime an additional assumption is made
(3) At time t = 0
$\rho(\vec{X}_1, \cdots \vec{X}_N, t=0) = |\psi(\vec{X}_1, \cdots \vec{X}_N, t=0)|^2$
guidance eqn.
then
$\rho(t) = |\psi(t)|^2$ for all later times.

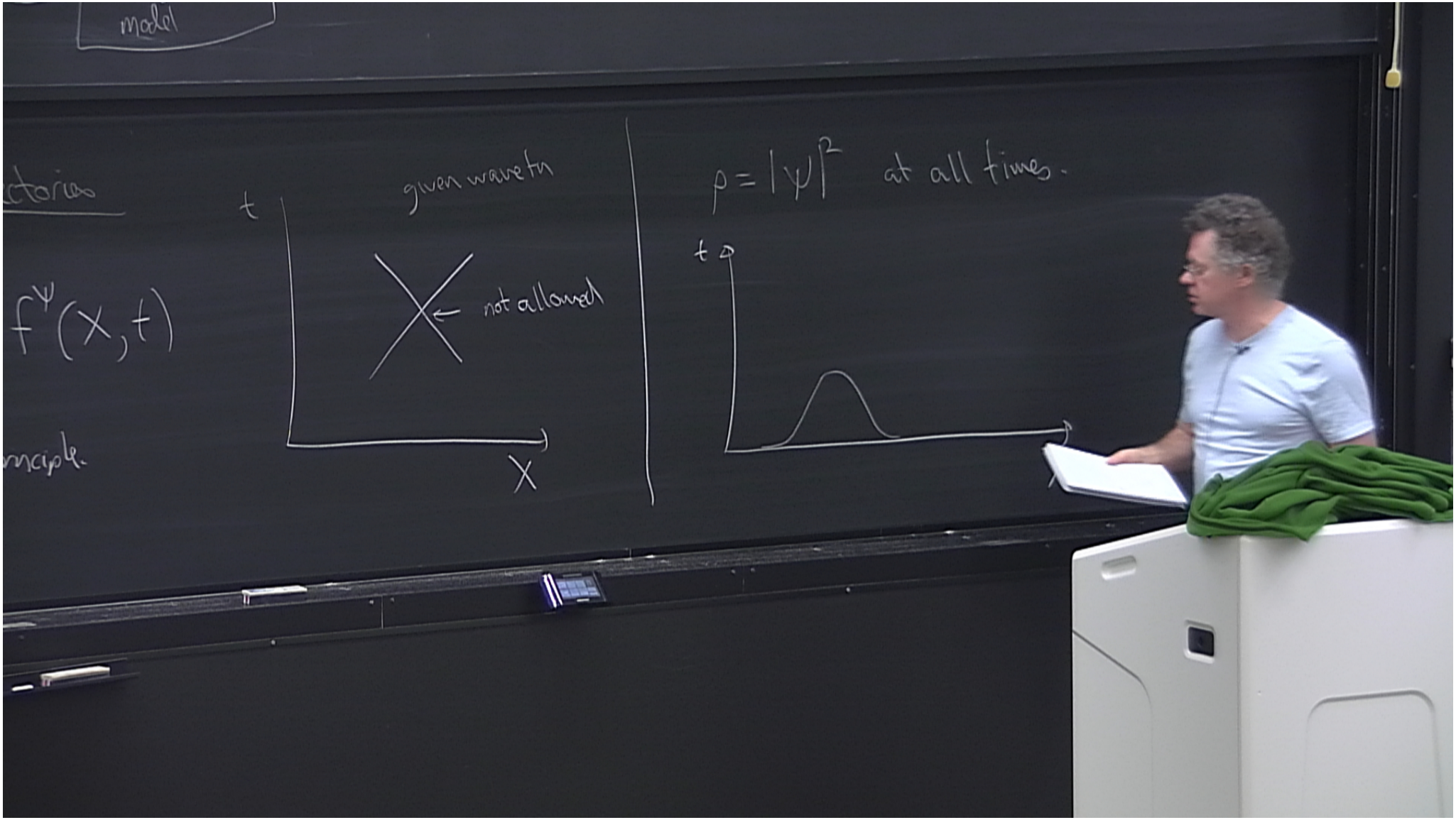

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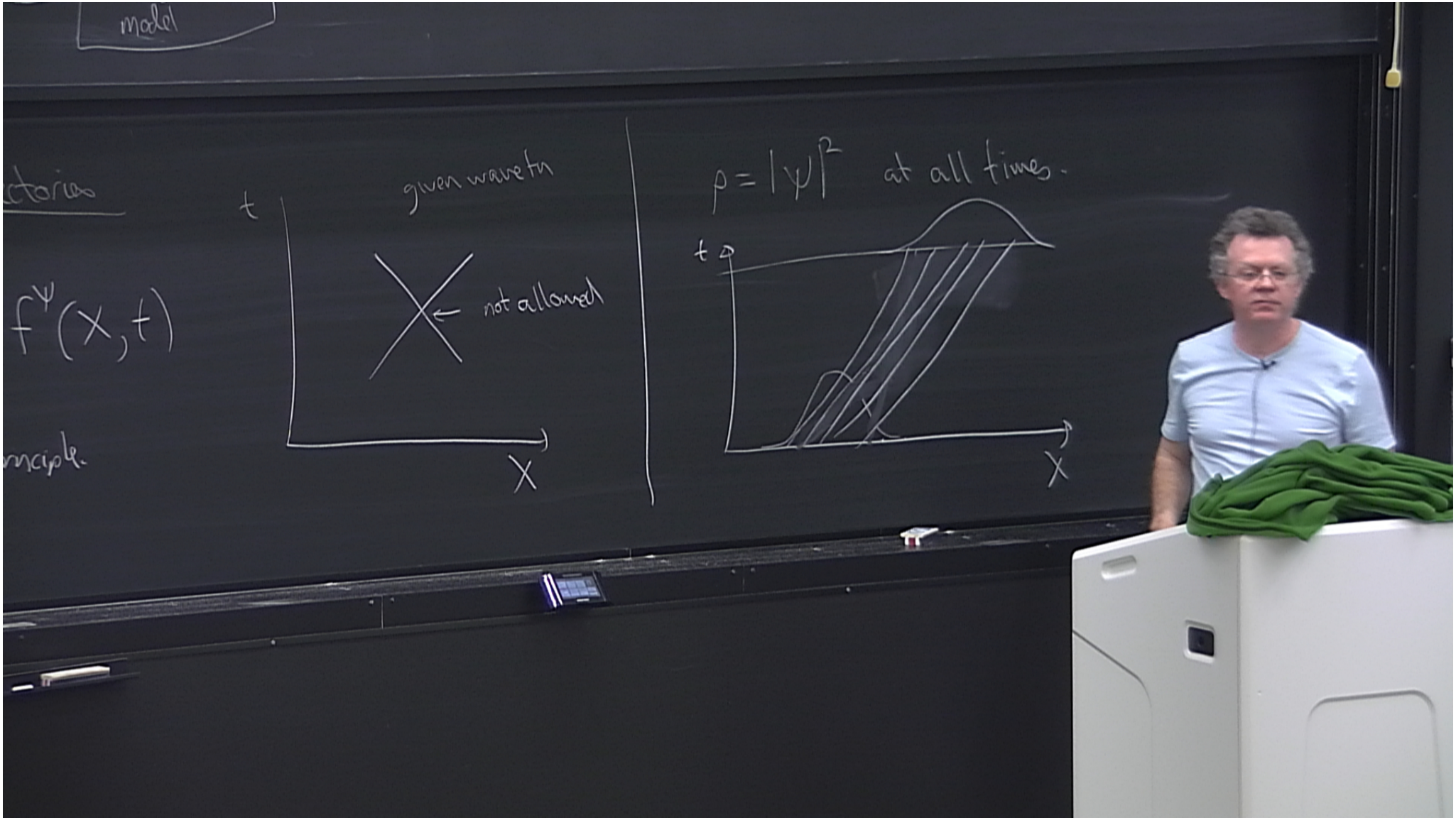

complete?
model
$|\psi|^2 = \rho$ and $J = \rho v$ $v = (\vec{v}_1, \cdots \vec{v}_N)$


complete?
model
$|\psi|^2 = \rho$ and $J = \rho v$ $v = (\vec{v}_1, \cdots \vec{v}_N)$
we get
$\frac{\partial \rho}{\partial t} + \mathrm{div}(\rho v) = 0$
This is the classical continuity eqn


Sketching trajectories
Note
$v = \dot{x} = f^{\psi}(x, t)$
t


Sketching trajectories
Note
$v = \dot{x} = f^{\Psi}(X, t)$
No crossing principle.
t
given wave fn
not allowed
X


model
given wavefn
t
not allowed
X
$\rho = |\psi|^2$ at all times.
t
X


model
given wavefn
t
X
not allowed
$\rho = |\psi|^2$ at all times.
t
X