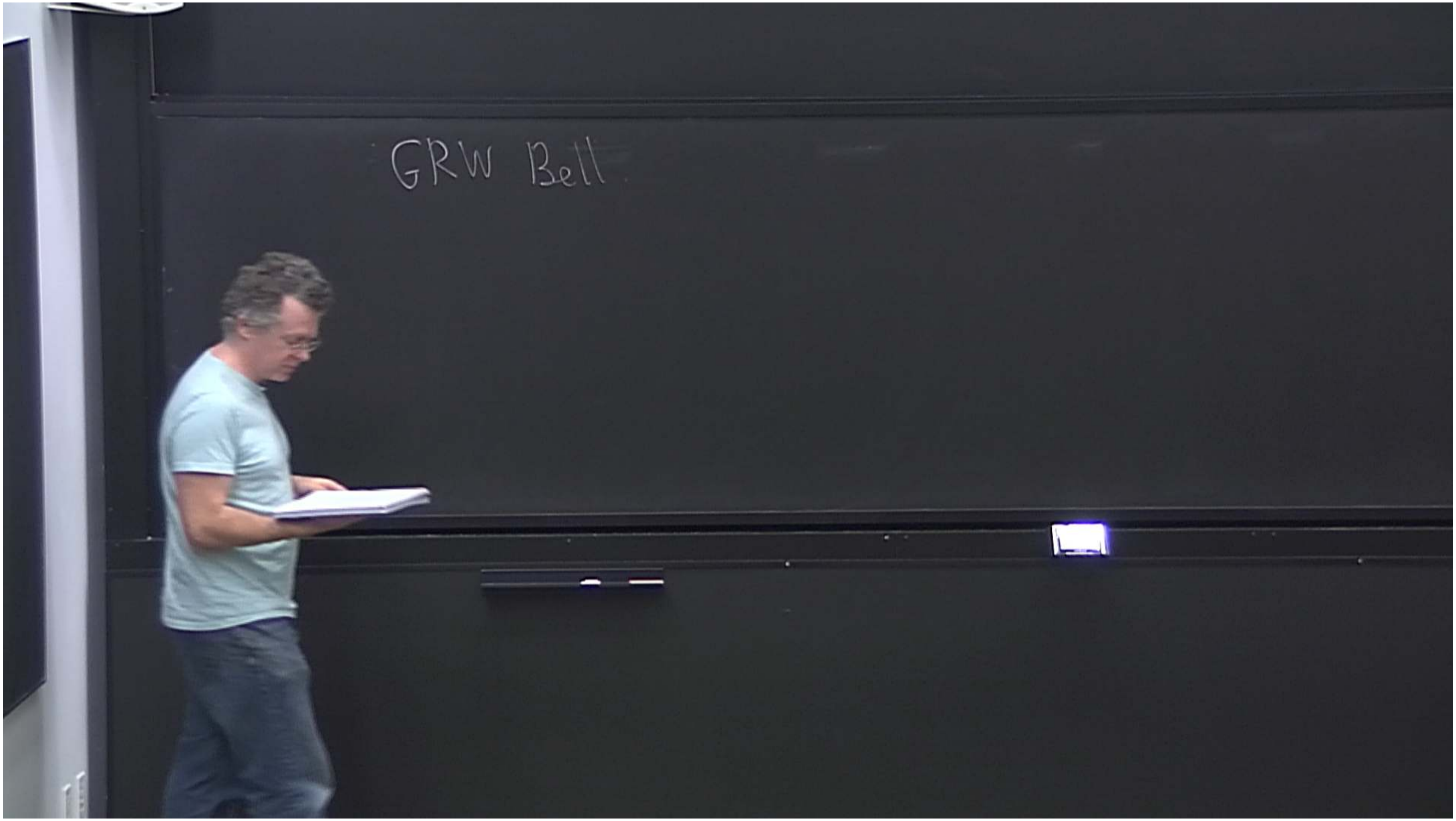
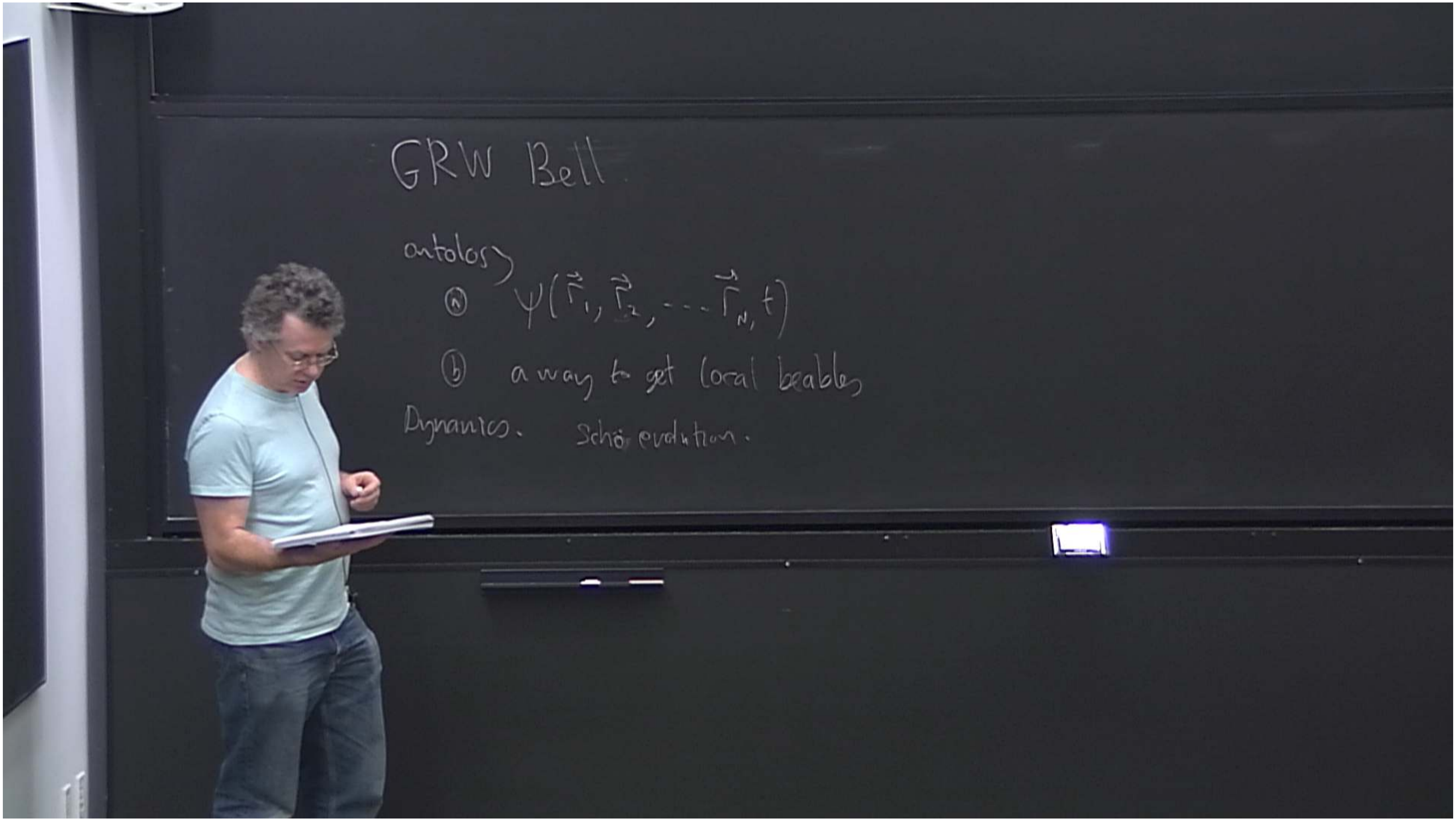
Title: Foundations of Quantum Mechanics-9

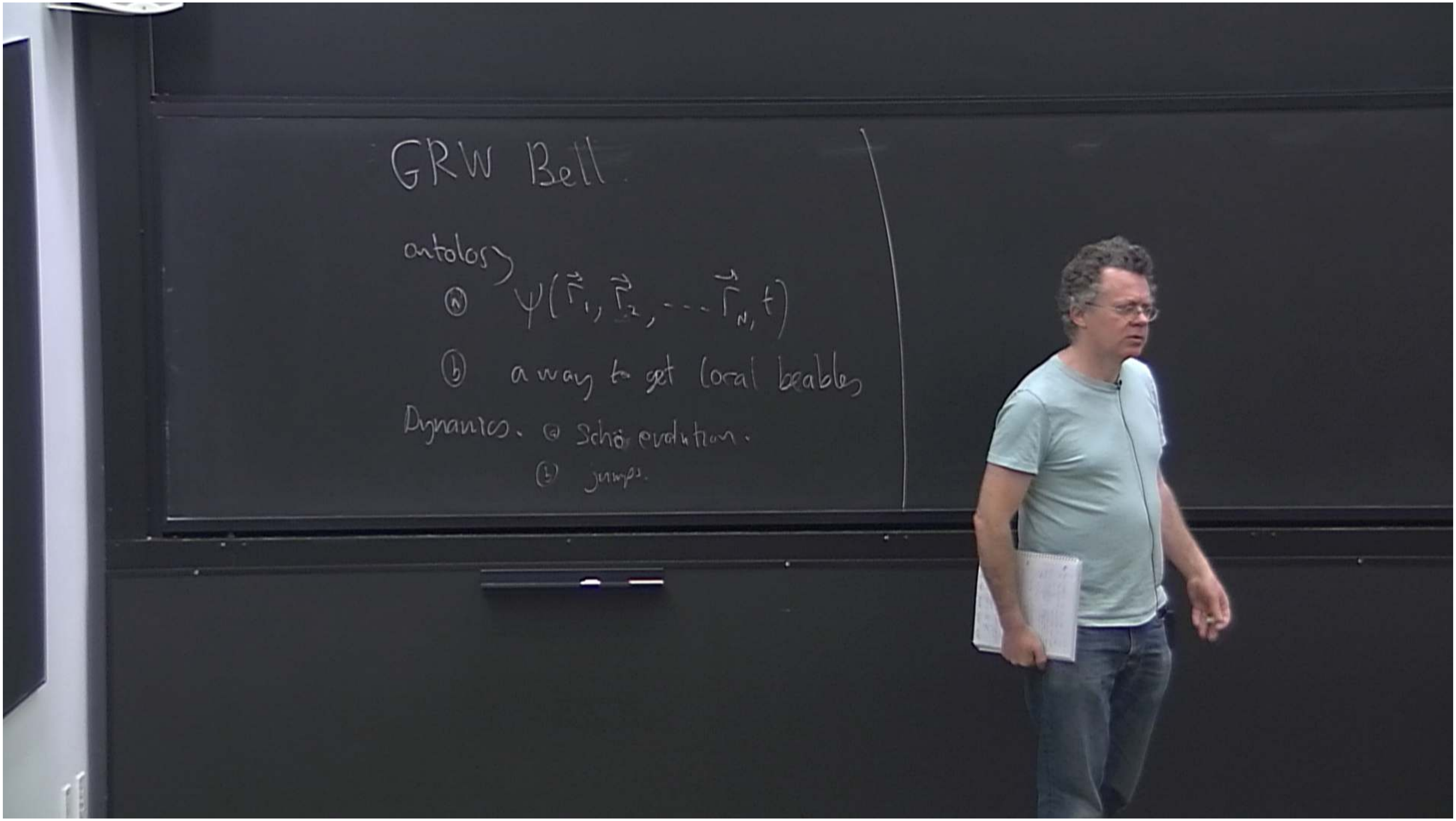
Date: Jan 15, 2015 11:30 AM

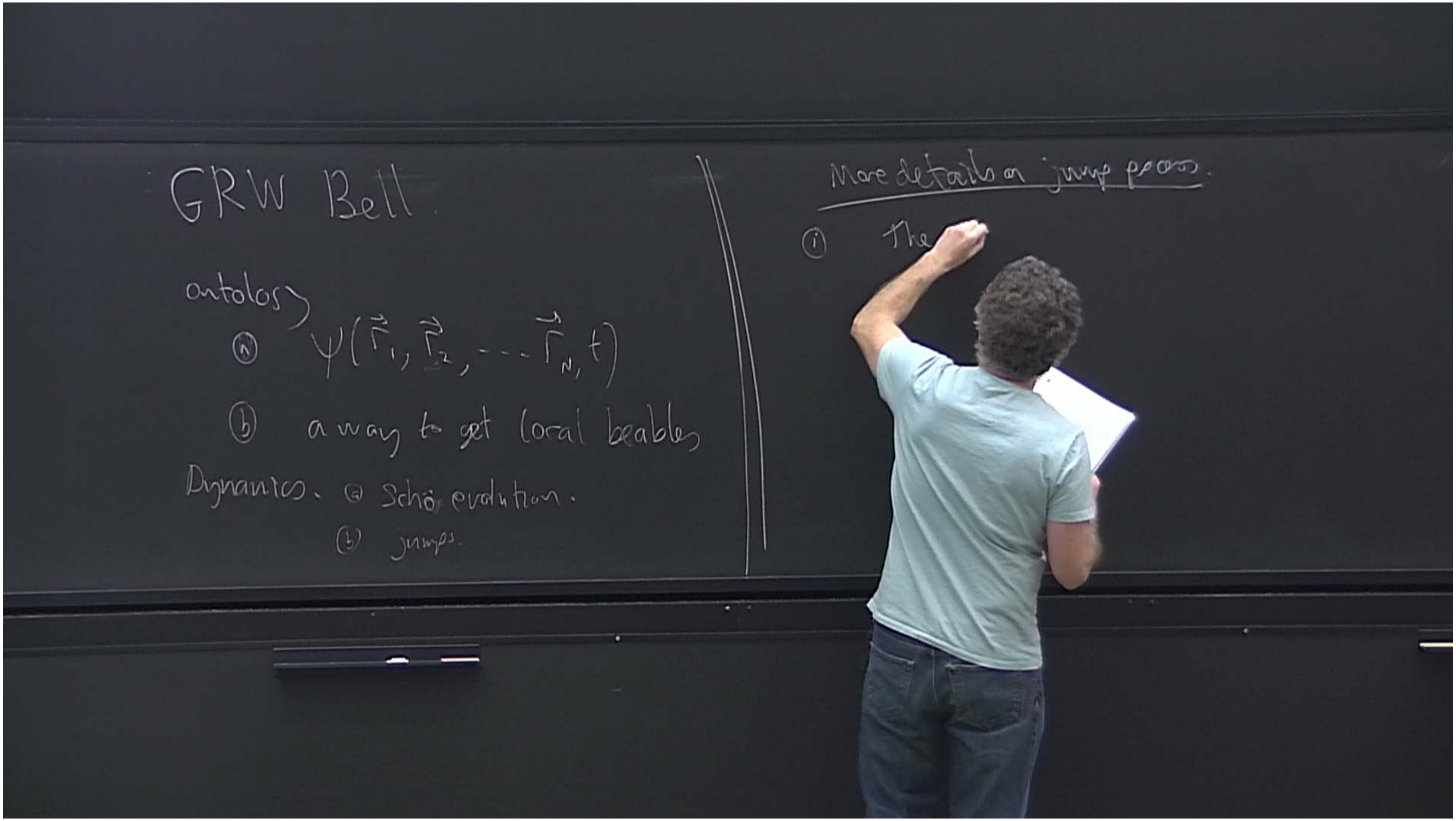
URL: http://pirsa.org/15010048

Abstract:

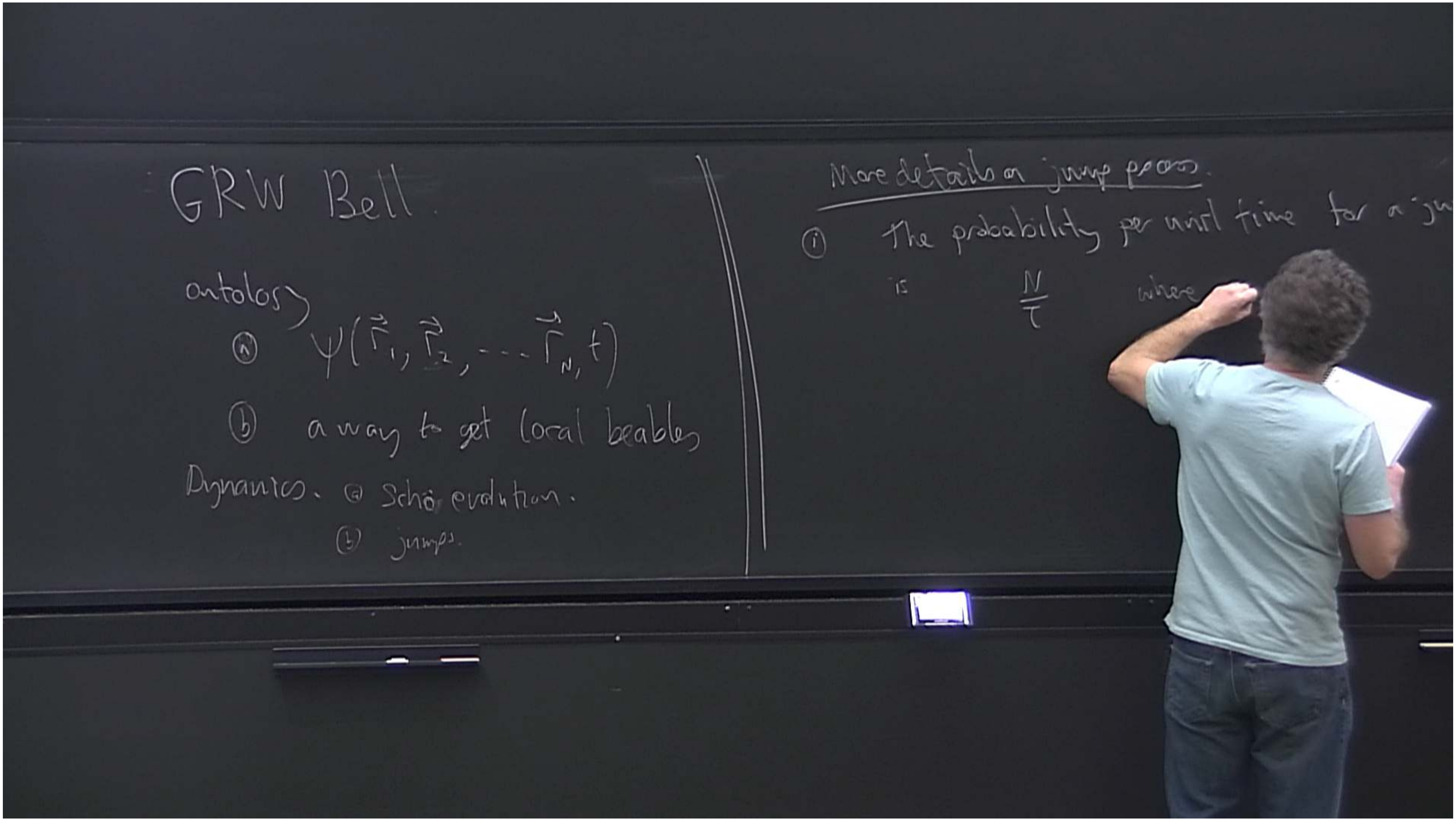

GRW Bell

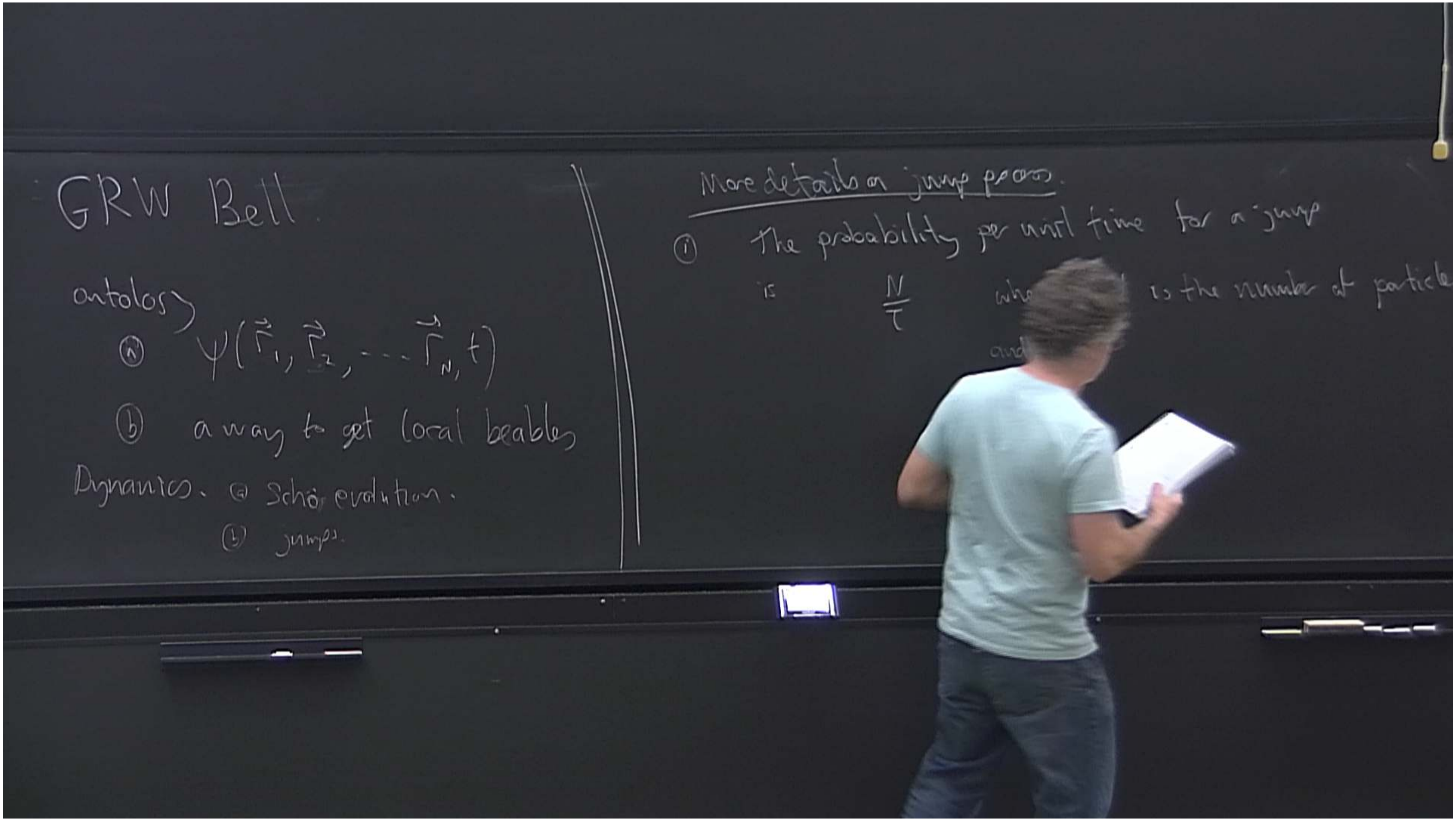

GRW Bell
ontology
(a) $\psi(\vec{r}_1, \vec{r}_2, \ldots \vec{r}_N, t)$
(b) a way to get local beables
Dynamics. Schö evolution.


GRW Bell
ontology
ⓐ $\psi(\vec{r}_1, \vec{r}_2, \dots \vec{r}_N, t)$
ⓑ a way to get local beables
Dynamics. ⓐ Schö evolution.
ⓑ jumps.



GRW Bell
ontology
(a) $\psi(\vec{r}_1, \vec{r}_2, \ldots \vec{r}_N, t)$
(b) a way to get local beables
Dynamics. (a) Schrö. evolution.
(b) jumps.
More details on jump process.
(i) The

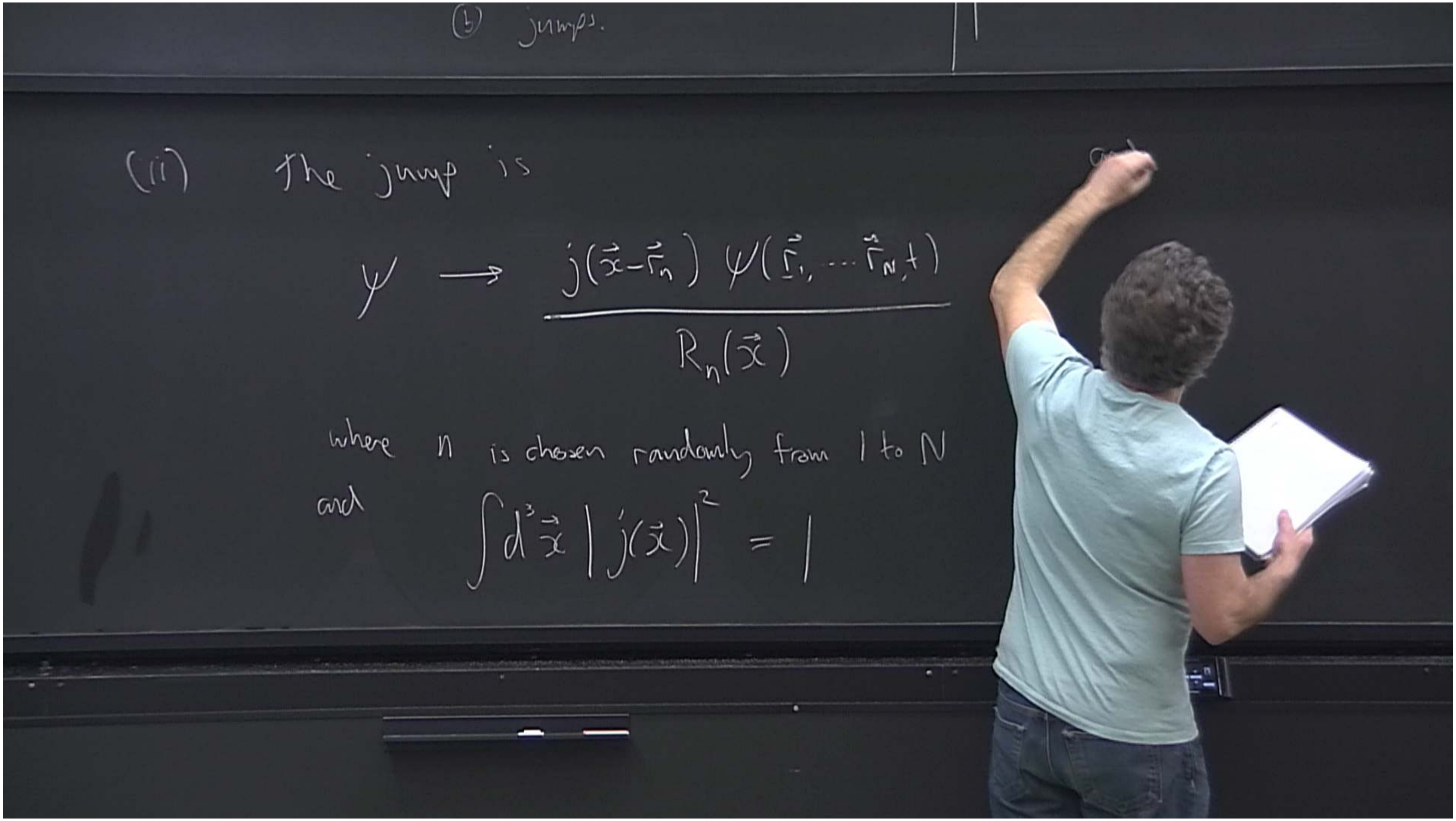

GRW Bell
ontology
(a) ψ(r₁, r₂, ... r_N, t)
(b) a way to get local beables
Dynamics. (a) Schrö. evolution.
(b) jumps.
More details on jump process.
(i) The probability per unit time for a ju
is N/τ where


GRW Bell
ontology
(a) ψ(r1, r2, ... rN, t)
(b) a way to get local beables
Dynamics. (a) Schrö evolution.
(b) jumps.
More details on jump process.
(i) The probability per unit time for a jump
is N/τ
is the number of particle

More details on jump process.

(i) The probability per unit time for a jump is $\frac{N}{\tau}$ where N is the number of particles and τ is a new constant of nature.

$$\text{prob}\begin{pmatrix} m \text{ events} \\ \text{in time } T \end{pmatrix} = \frac{e^{-\left(\frac{NT}{\tau}\right)}\left(\frac{N}{\tau}T\right)^m}{m!}$$


(b) jumps.
(ii) The jump is
$\psi \longrightarrow \dfrac{j(\vec{x}-\vec{r}_n)\,\psi(\vec{r}_1,\dots\vec{r}_N,t)}{R_n(\vec{x})}$
where n is chosen randomly from 1 to N
and $\int d^3\vec{x}\,|j(\vec{x})|^2 = 1$

and $$|R_n(x)|^2 = \int d^3\vec{r}_1\, d^3\vec{r}_2 \cdots d^3\vec{r}_N \, \left| j(x - r_n)\, \psi \right|^2$$

and $$|R_n(x)|^2 = \int d^3\vec{r}_1\, d^3\vec{r}_2 \ldots d^3\vec{r}_N\, |j(\vec{x}-\vec{r}_n)\,\psi|^2$$

(iii) The collapse centre, $\vec{x}$, is chosen with probability

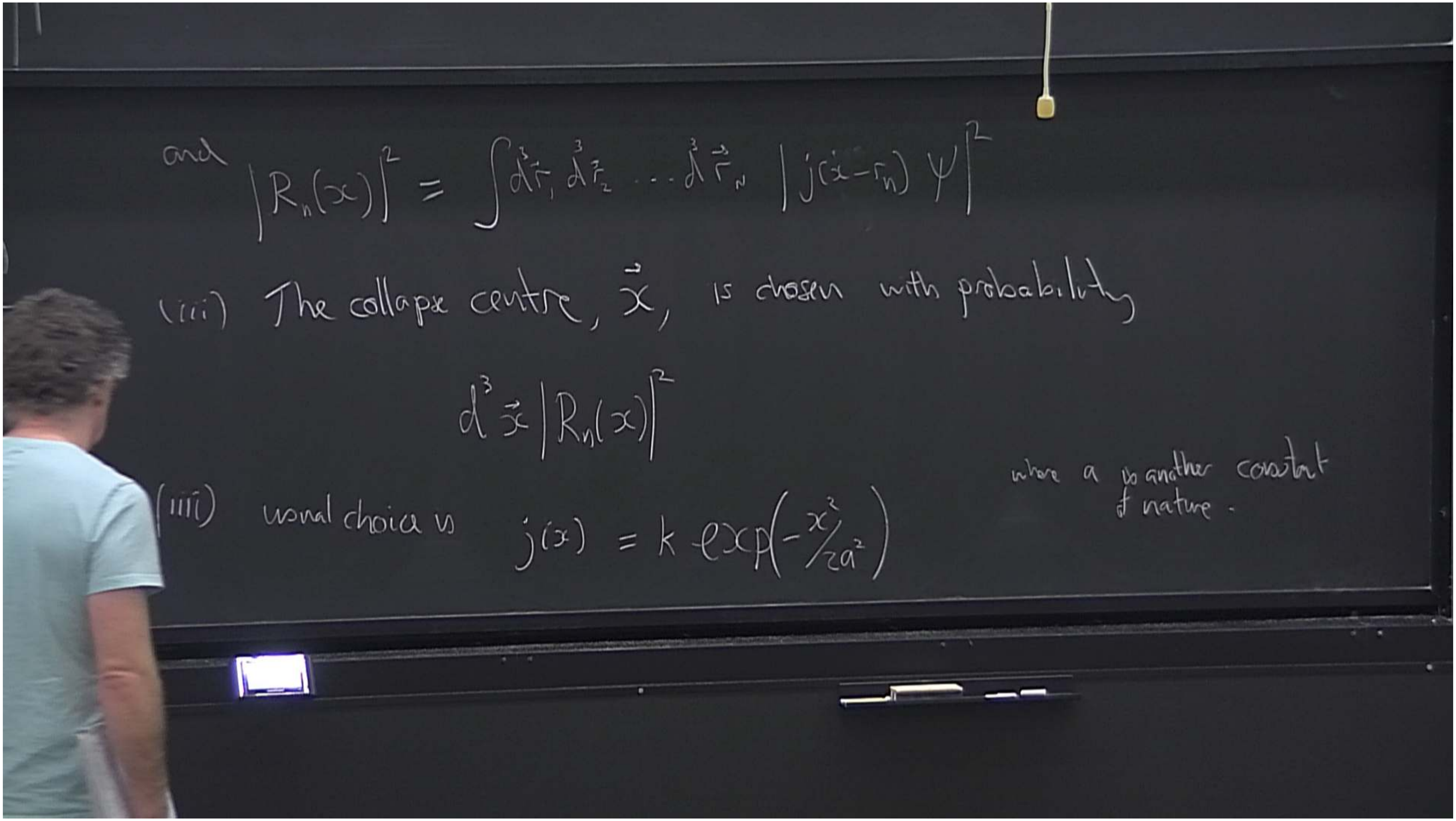
$$d^3\vec{x}\, |R_n(x)|^2$$

and $$\left|R_n(x)\right|^2 = \int d^3\vec{r}_1\, d^3\vec{r}_2 \ldots d^3\vec{r}_N \left| j(\vec{x}-\vec{r}_n)\, \psi \right|^2$$

(iii) The collapse centre, $\vec{x}$, is chosen with probability

$$d^3\vec{x} \left|R_n(x)\right|^2$$

(iiii) usual choice is $$j(x) = k \exp\left(-x^2/2a^2\right)$$ where a is another constant of nature.


and $|R_n(x)|^2 = \int d^3\vec{r}_1\, d^3\vec{r}_2 \ldots d^3\vec{r}_N\, |j(\vec{x}-\vec{r}_n)\,\psi|^2$
(iii) The collapse centre, $\vec{x}$, is chosen with probability
$d^3\vec{x}\,|R_n(x)|^2$
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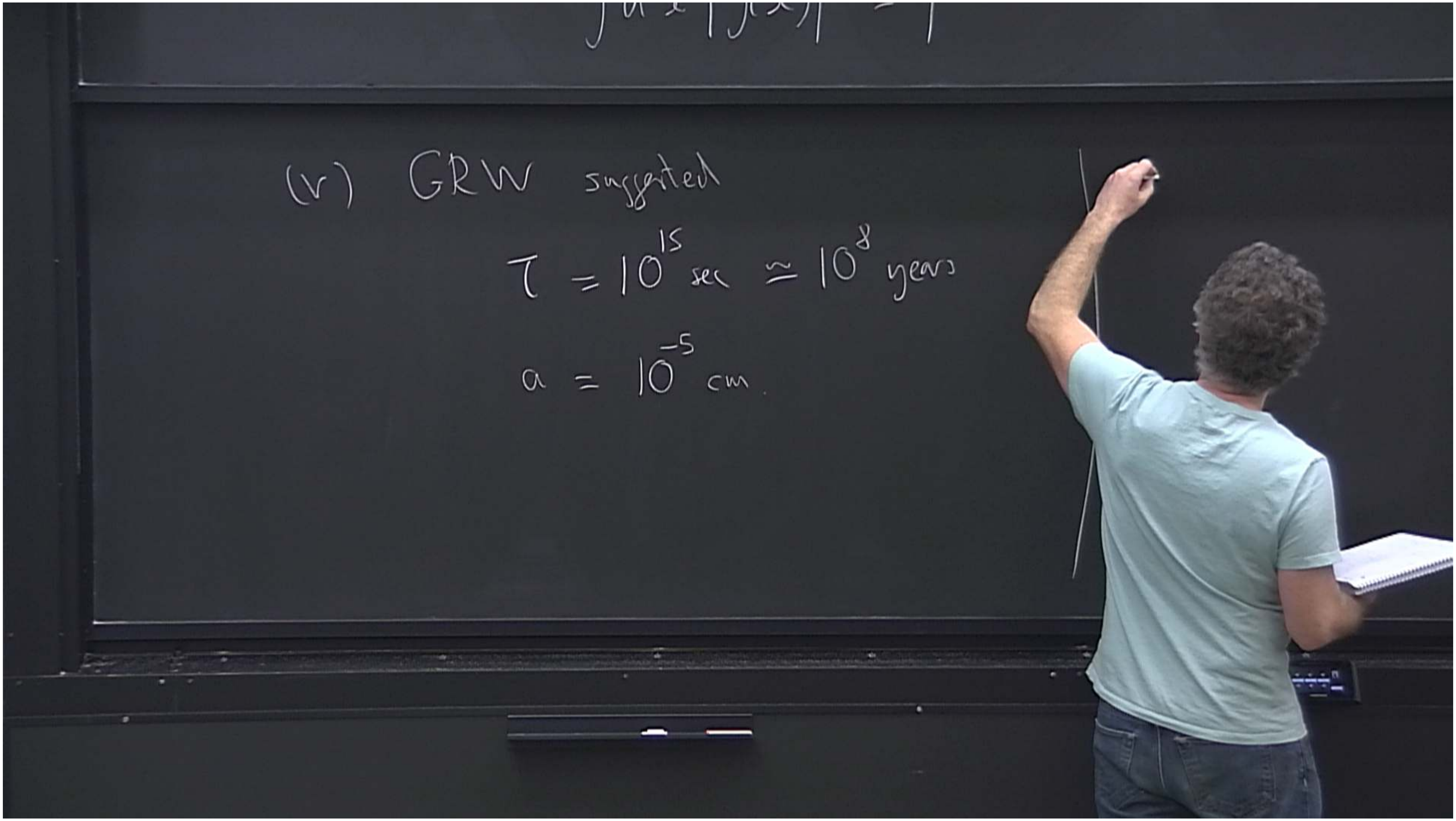
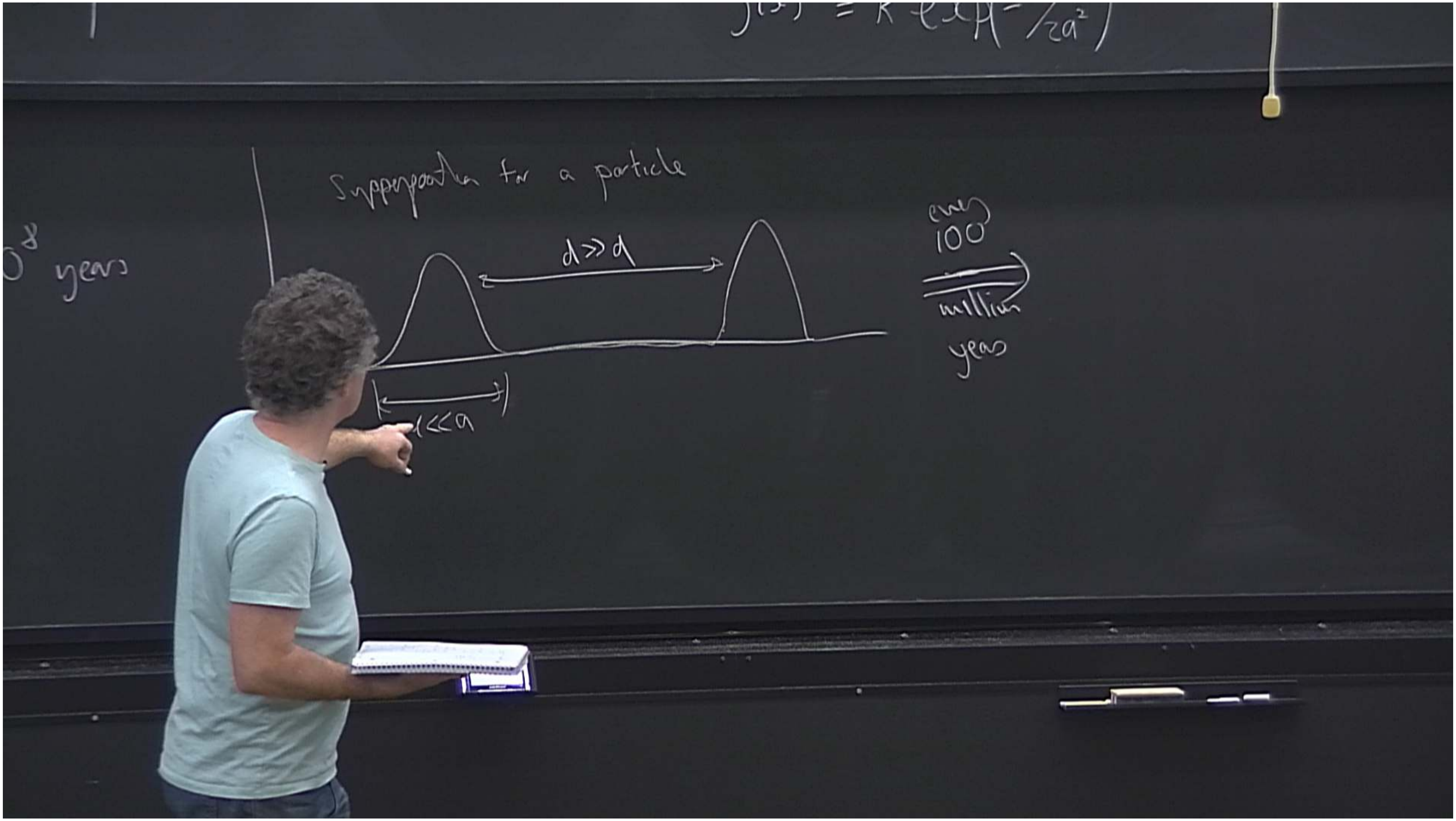
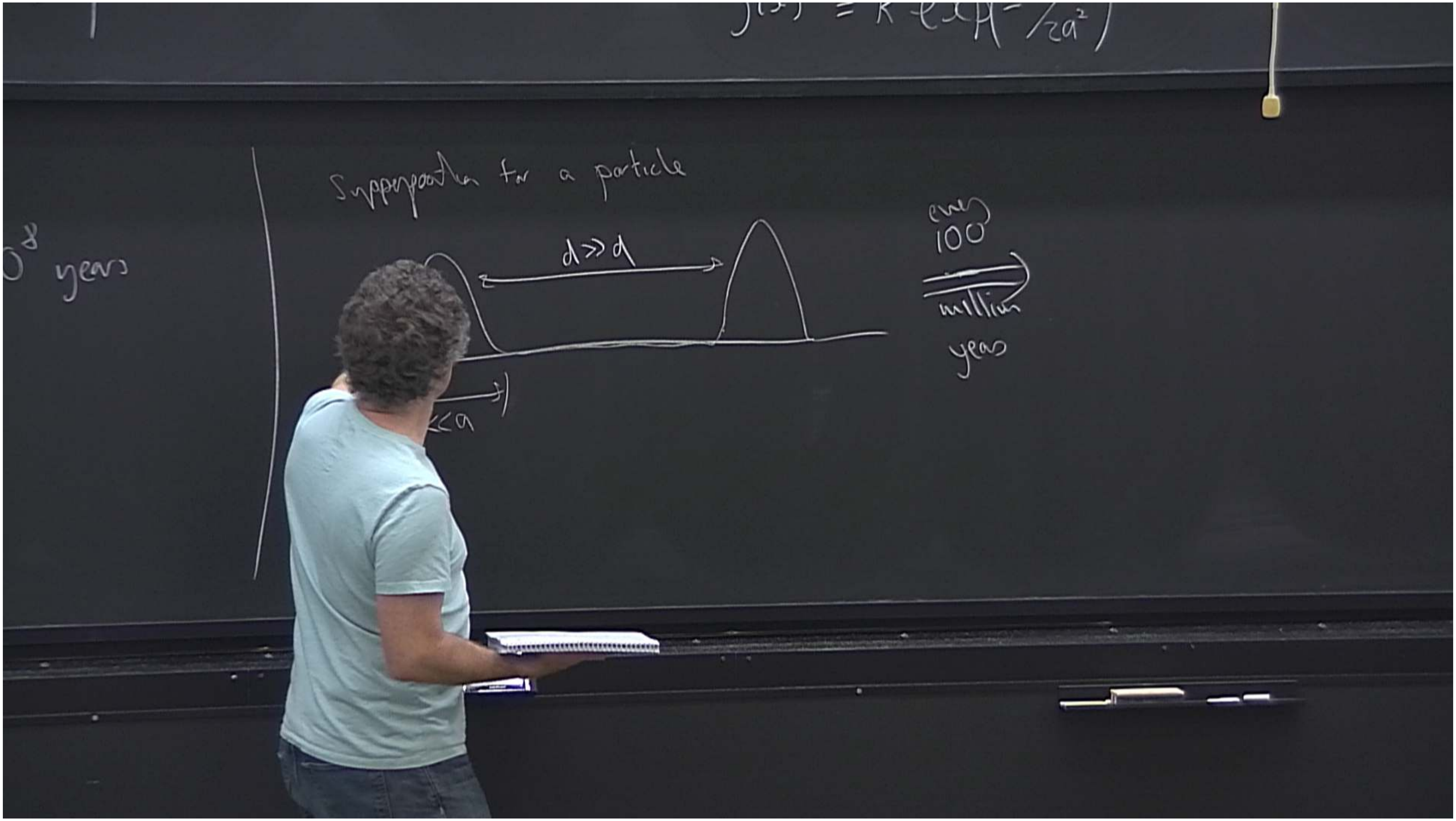
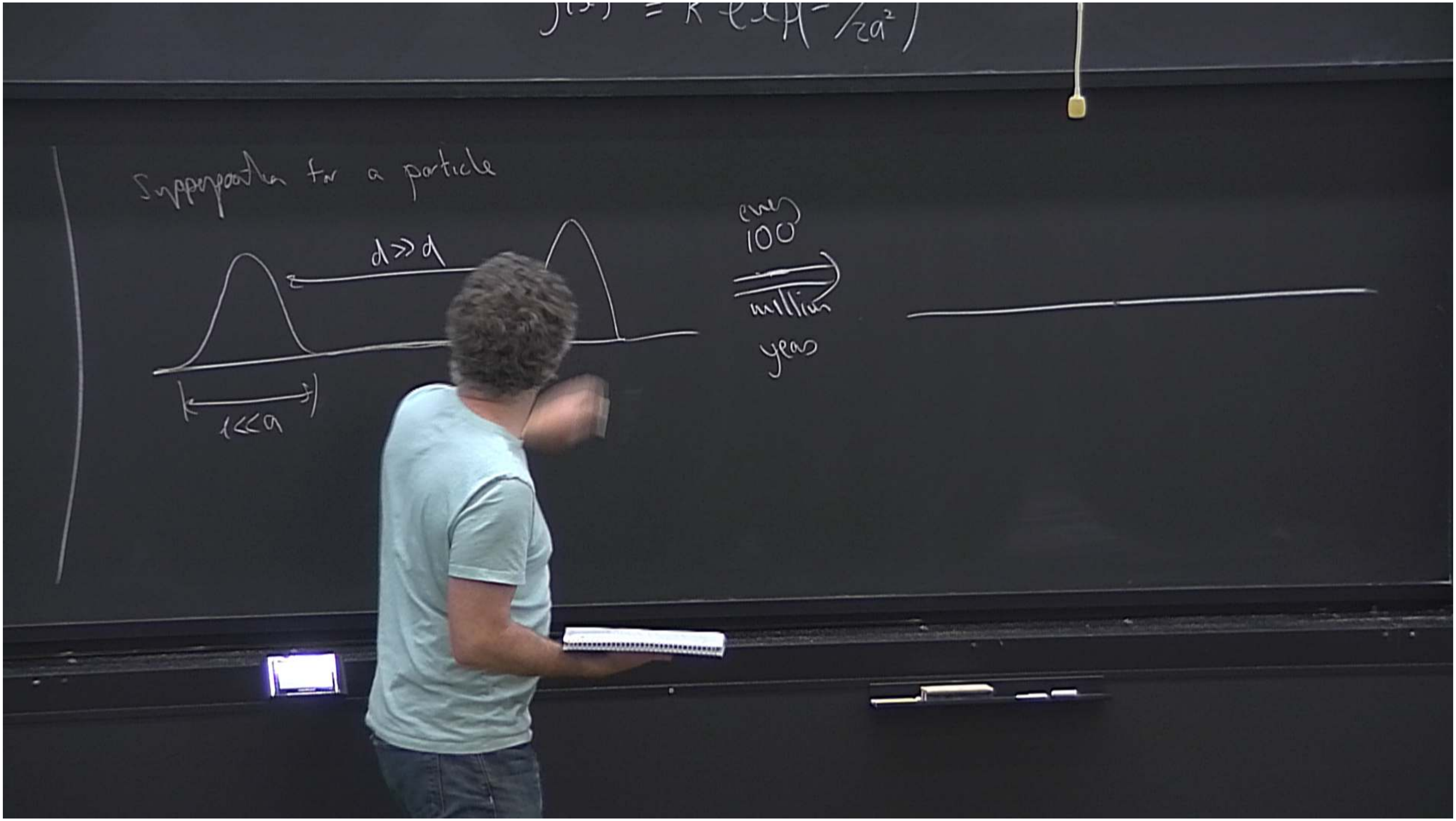
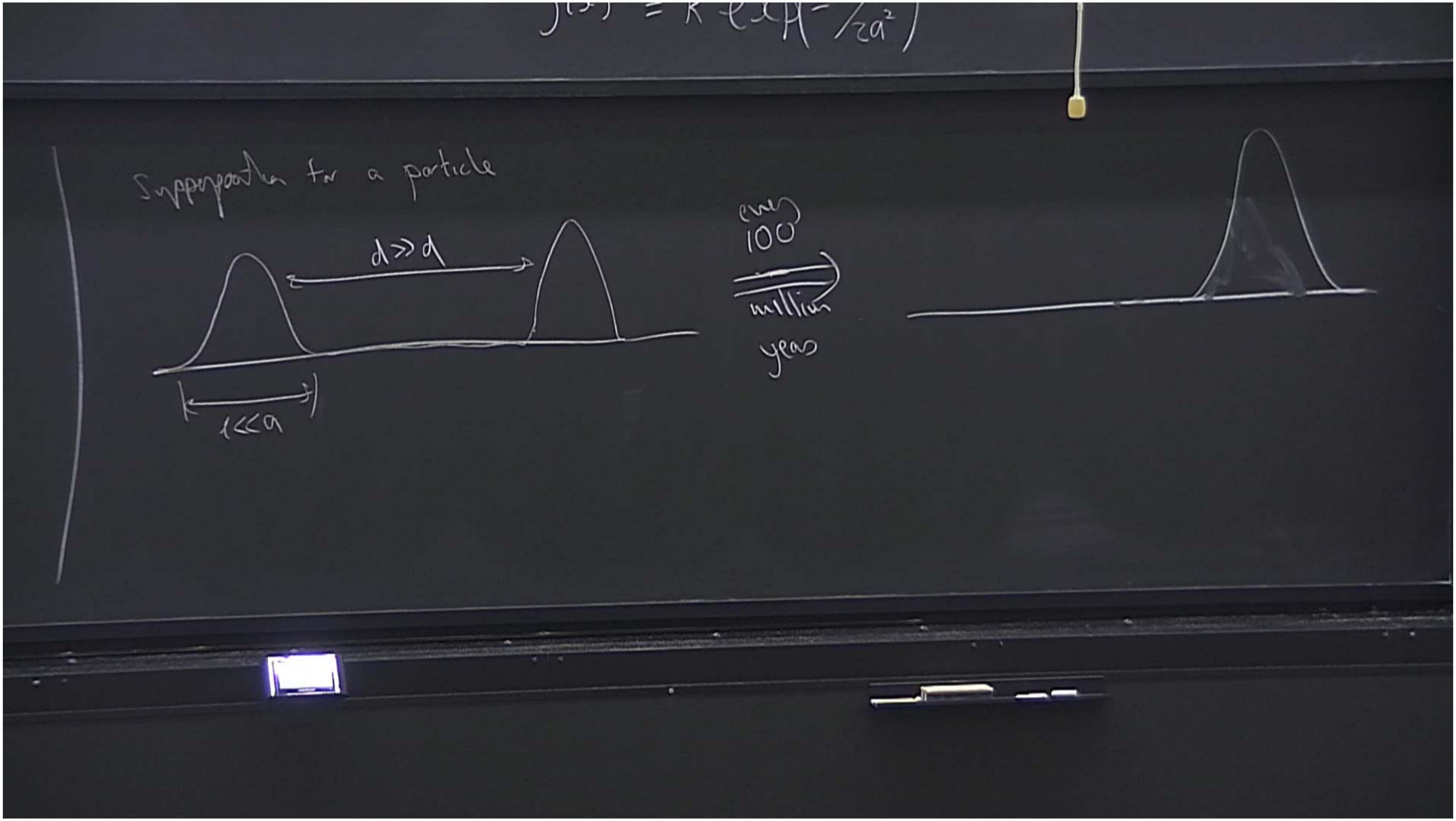
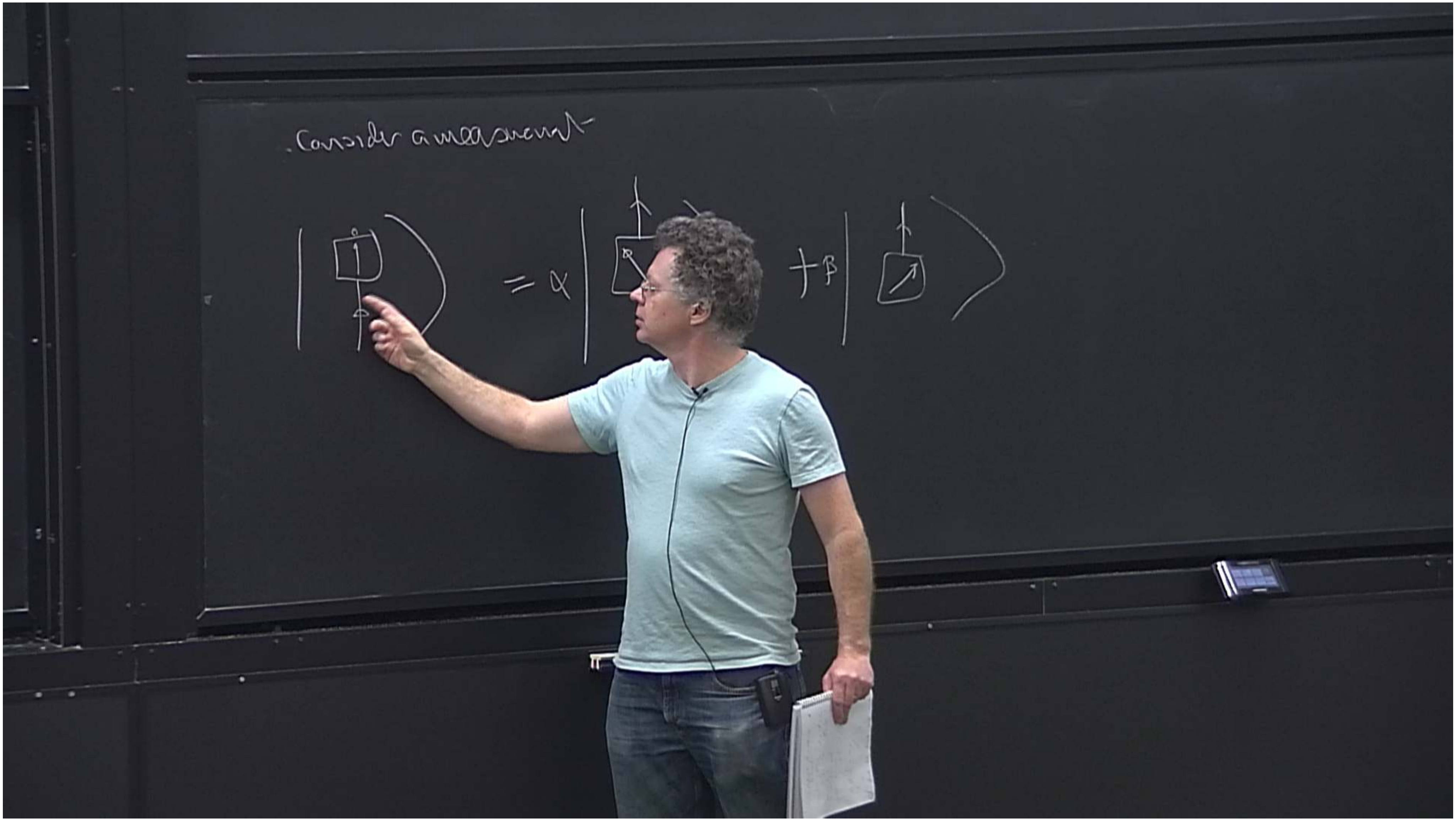

(v) GRW suggested
$\tau = 10^{15}$ sec $\simeq 10^{8}$ years
$a = 10^{-5}$ cm.

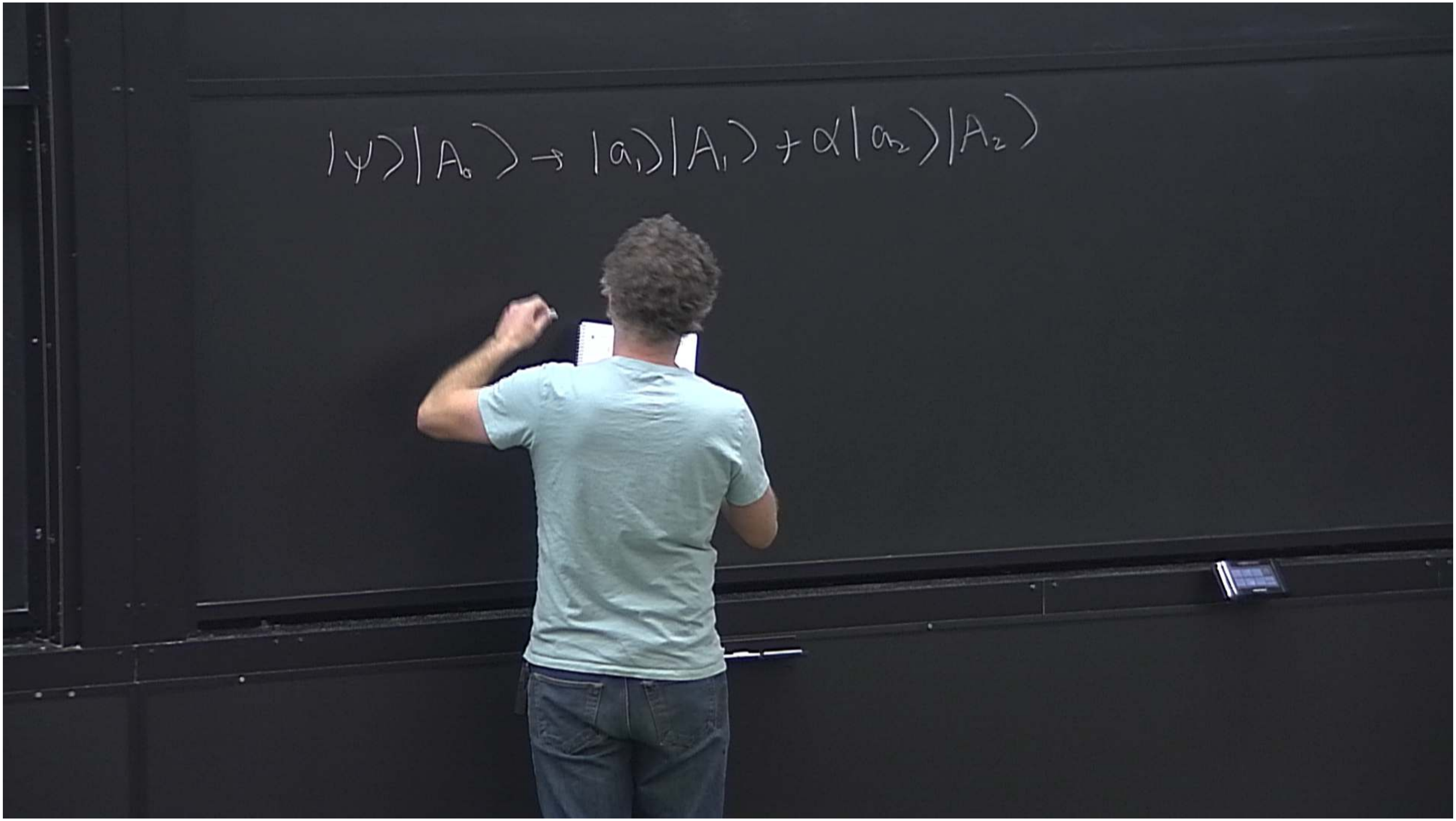

for a particle
every
100
million
years
years

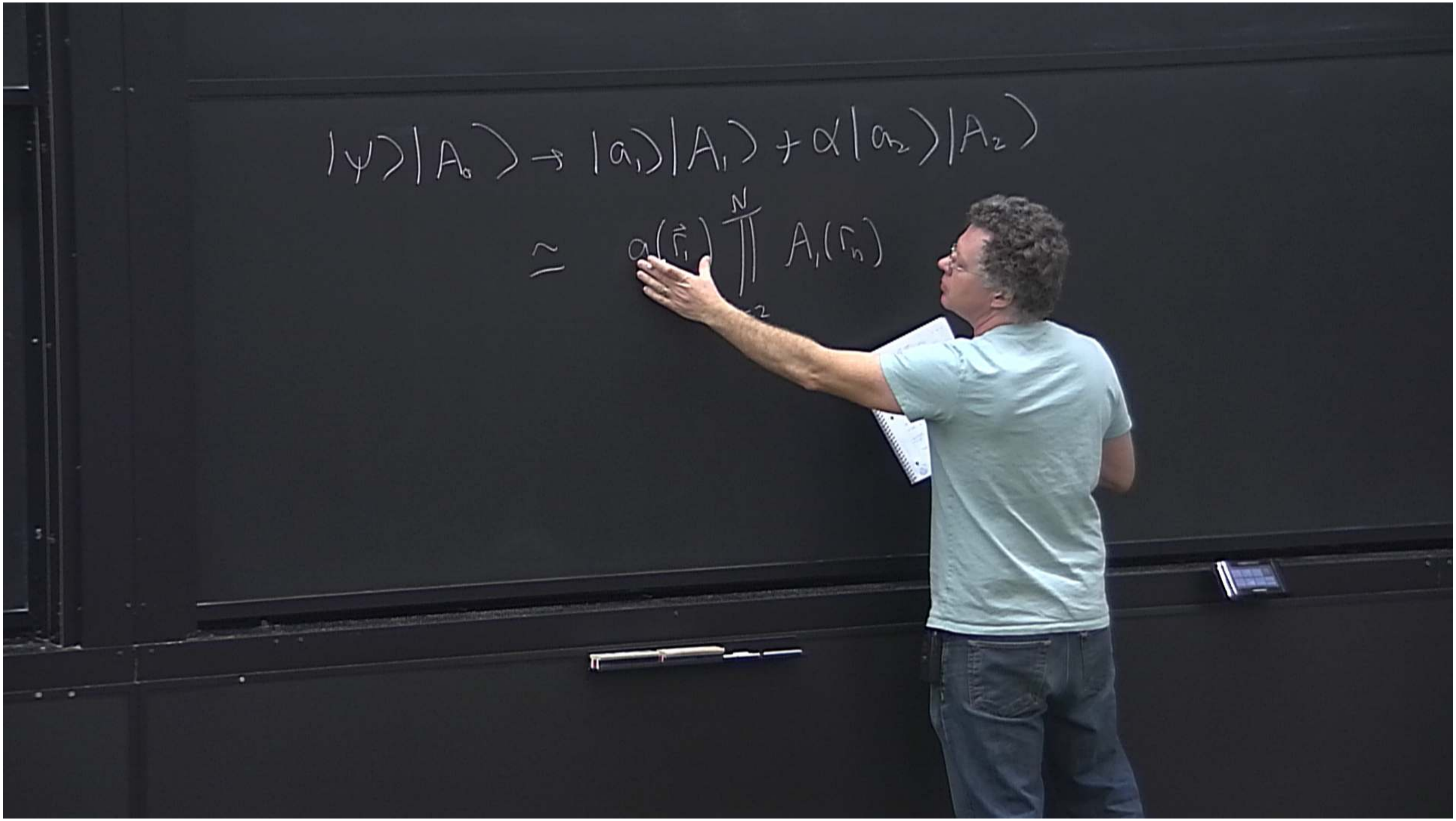

Superposition for a particle
$d \gg d$
every 100 million years
years

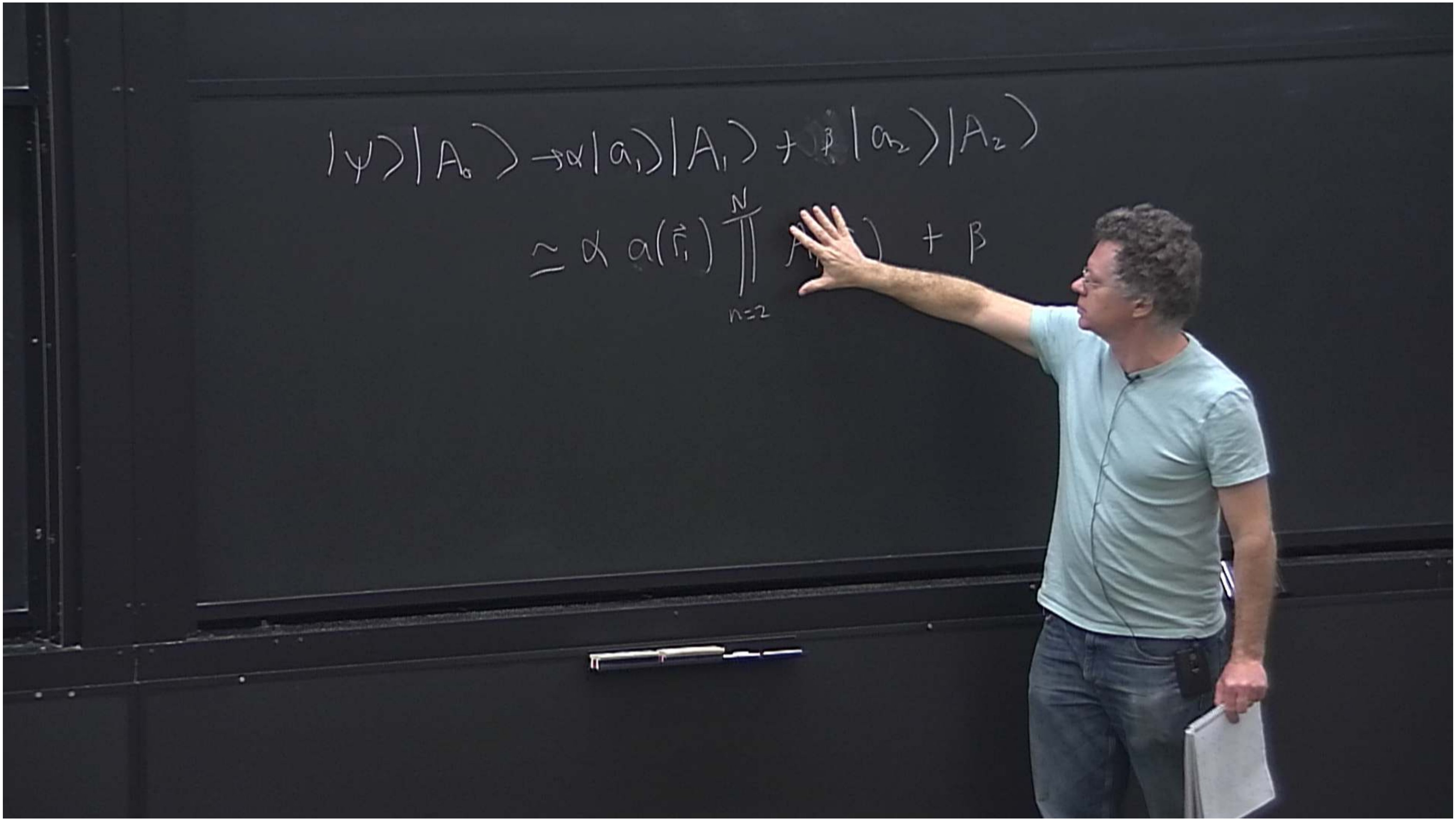

Superposition for a particle
d >> a
l << a
every
100
million
years

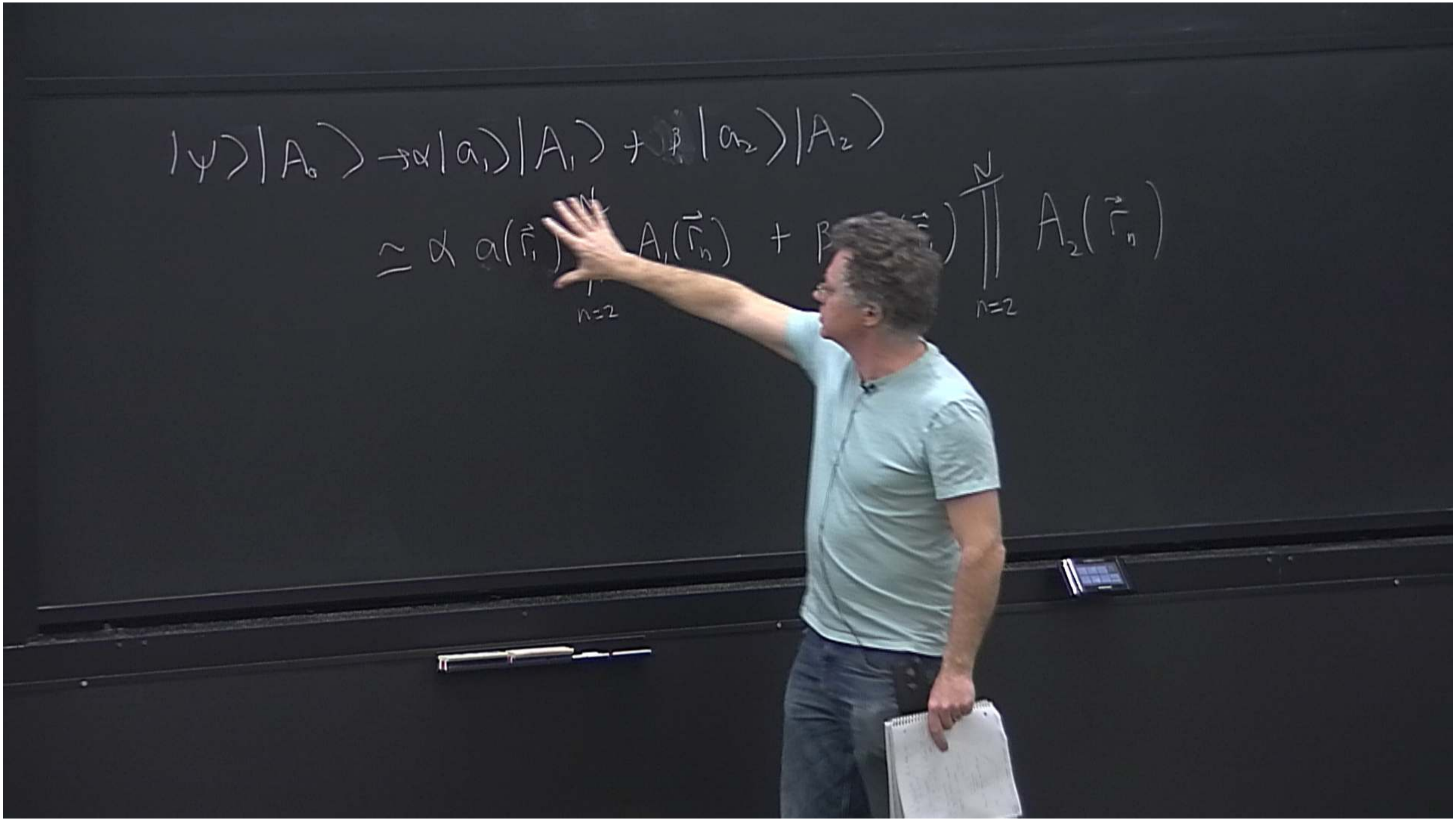

Superposition for a particle
d>>a
1<<a
every
100
million
years


Consider a measurement
= α
+ β


$|\psi\rangle|A_0\rangle \to |a_1\rangle|A_1\rangle + \alpha|a_2\rangle|A_2\rangle$

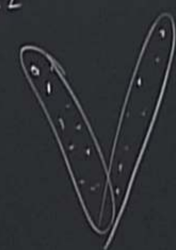

$|\psi\rangle|A_0\rangle \to |a_1\rangle|A_1\rangle + \alpha|a_2\rangle|A_2\rangle$
$\simeq a(\vec{r}_1)\prod^{N} A_1(r_n)$

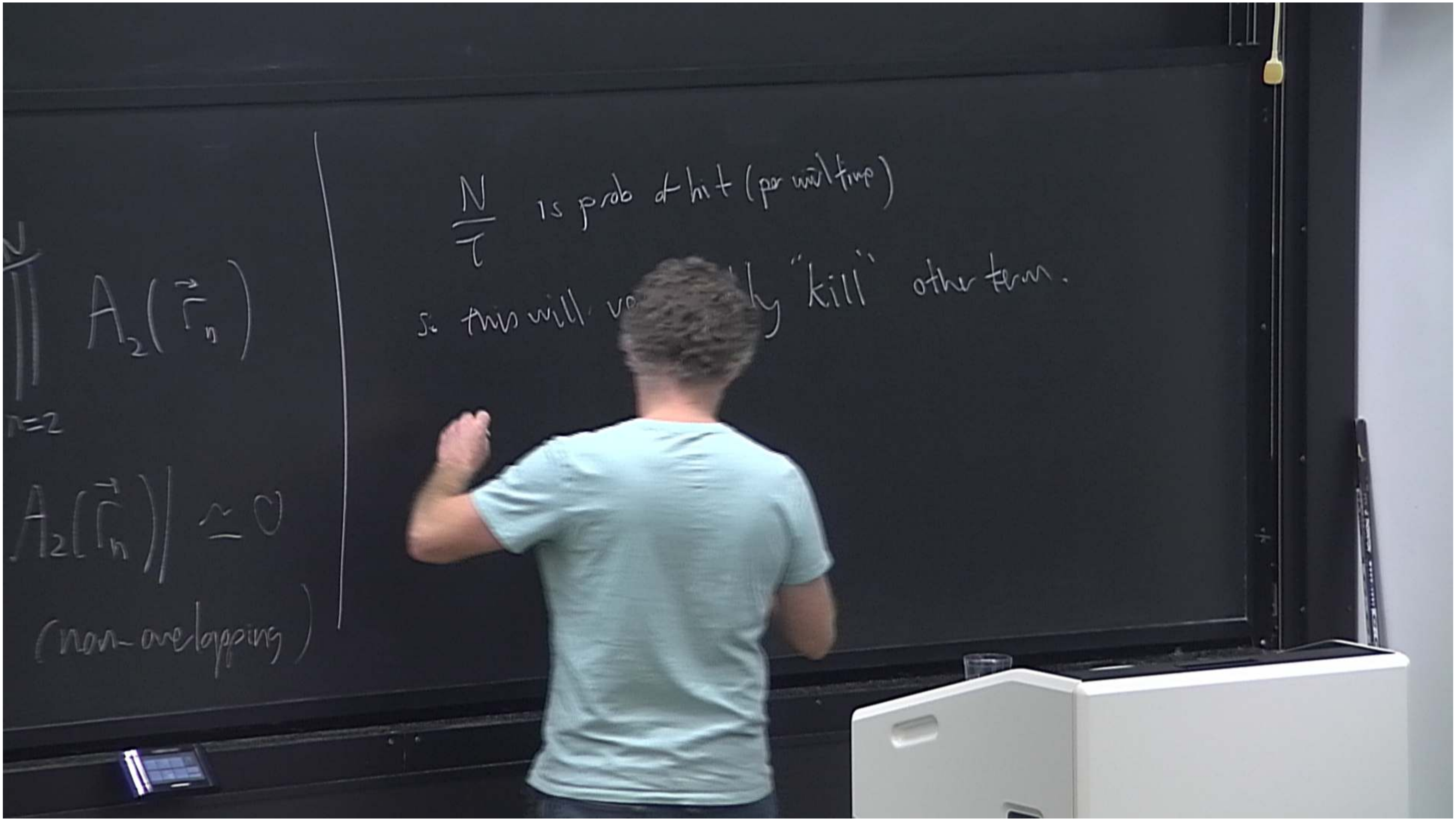

$|\psi\rangle|A_0\rangle \to \alpha|a_1\rangle|A_1\rangle + \beta|a_2\rangle|A_2\rangle$


$|\psi\rangle|A_0\rangle \to \alpha|a_1\rangle|A_1\rangle + \beta|a_2\rangle|A_2\rangle$

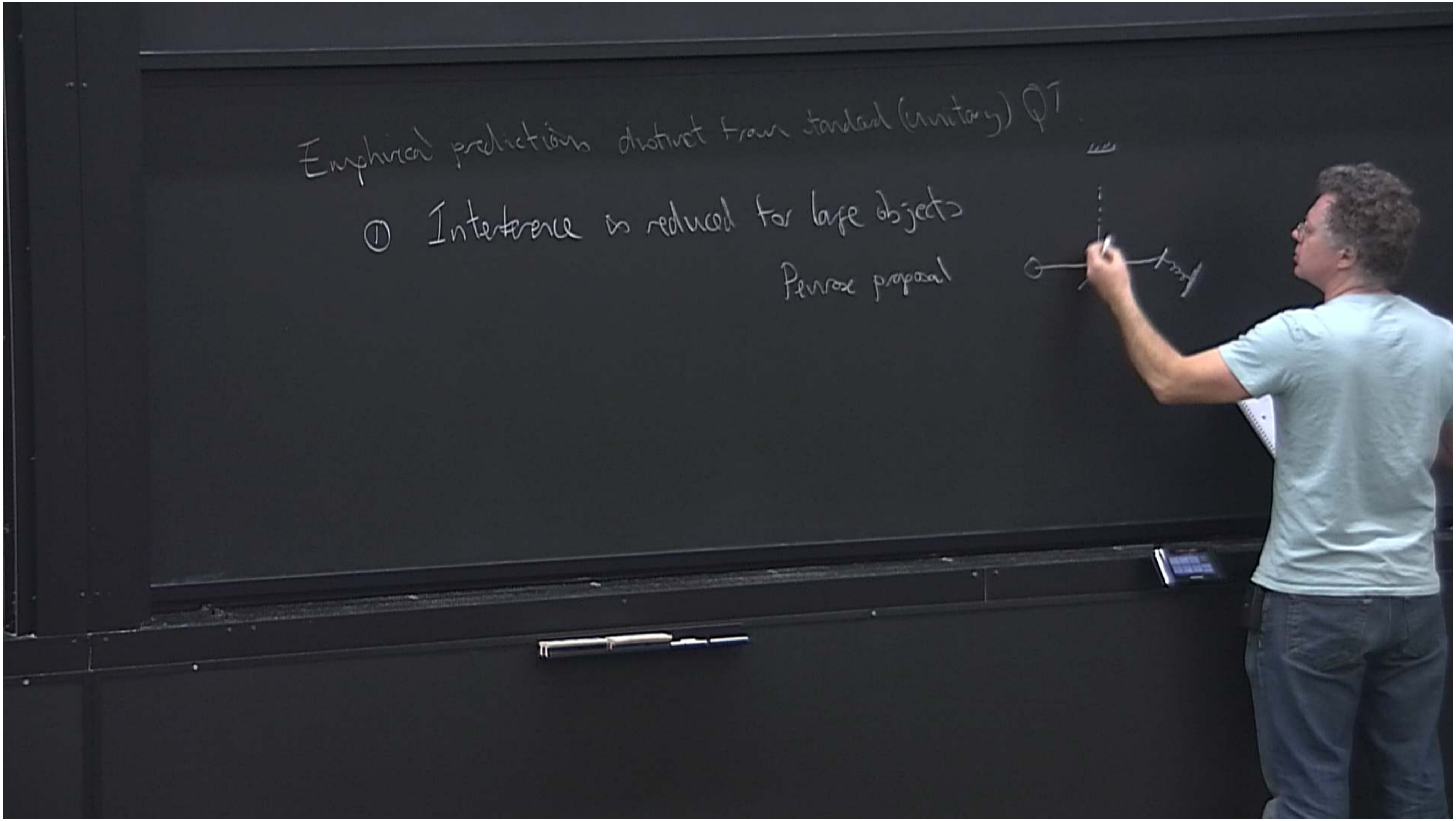
$$|\psi\rangle|A_0\rangle \to \alpha|a_1\rangle|A_1\rangle + \beta|a_2\rangle|A_2\rangle$$

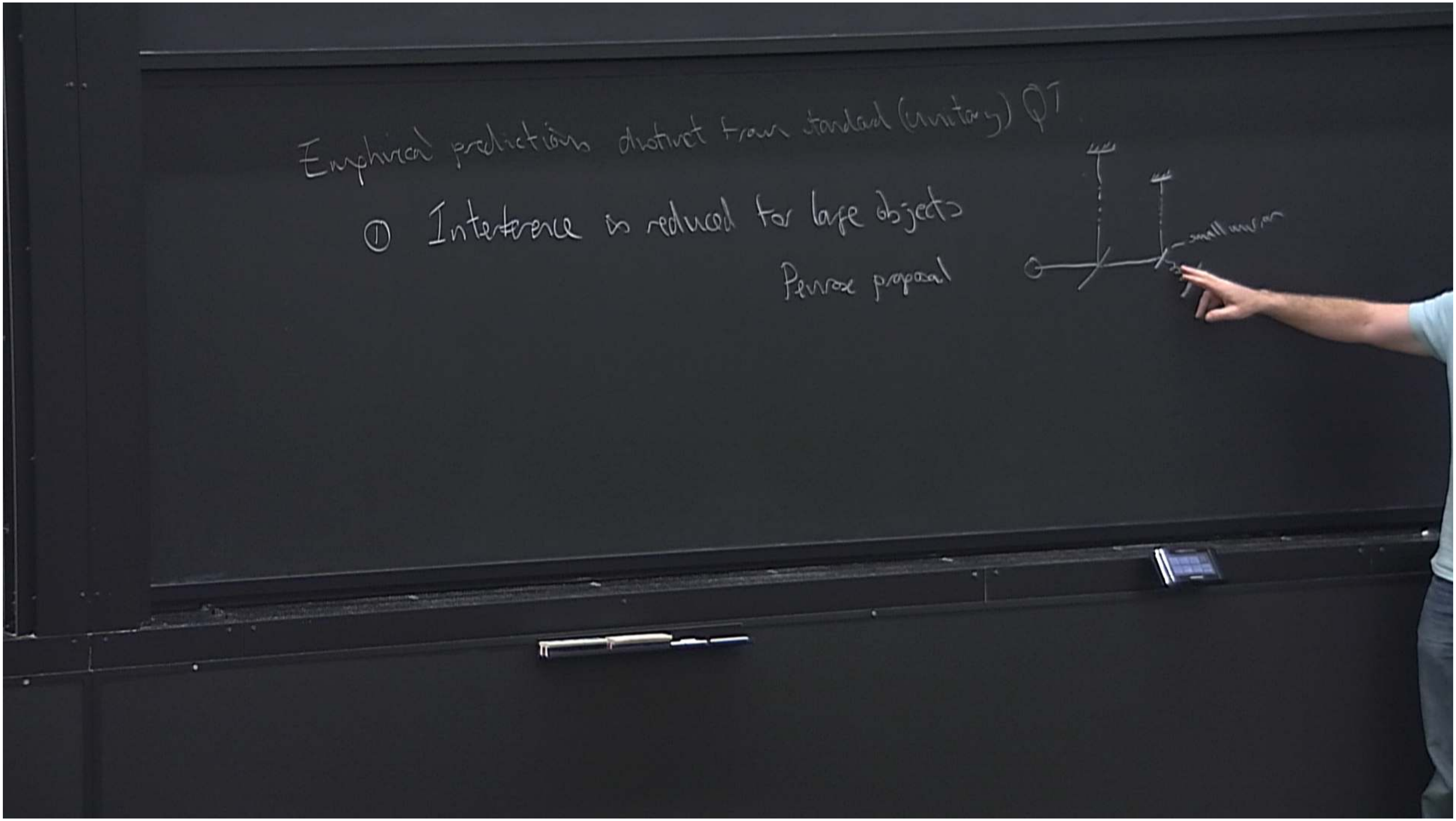
$$\simeq \alpha\, a(\vec{r}_1)\prod_{n=2}^{N} A_1(\vec{r}_n) + \beta\, a_2(\vec{r}_1)\prod_{n=2}^{N} A_2(\vec{r}_n)$$

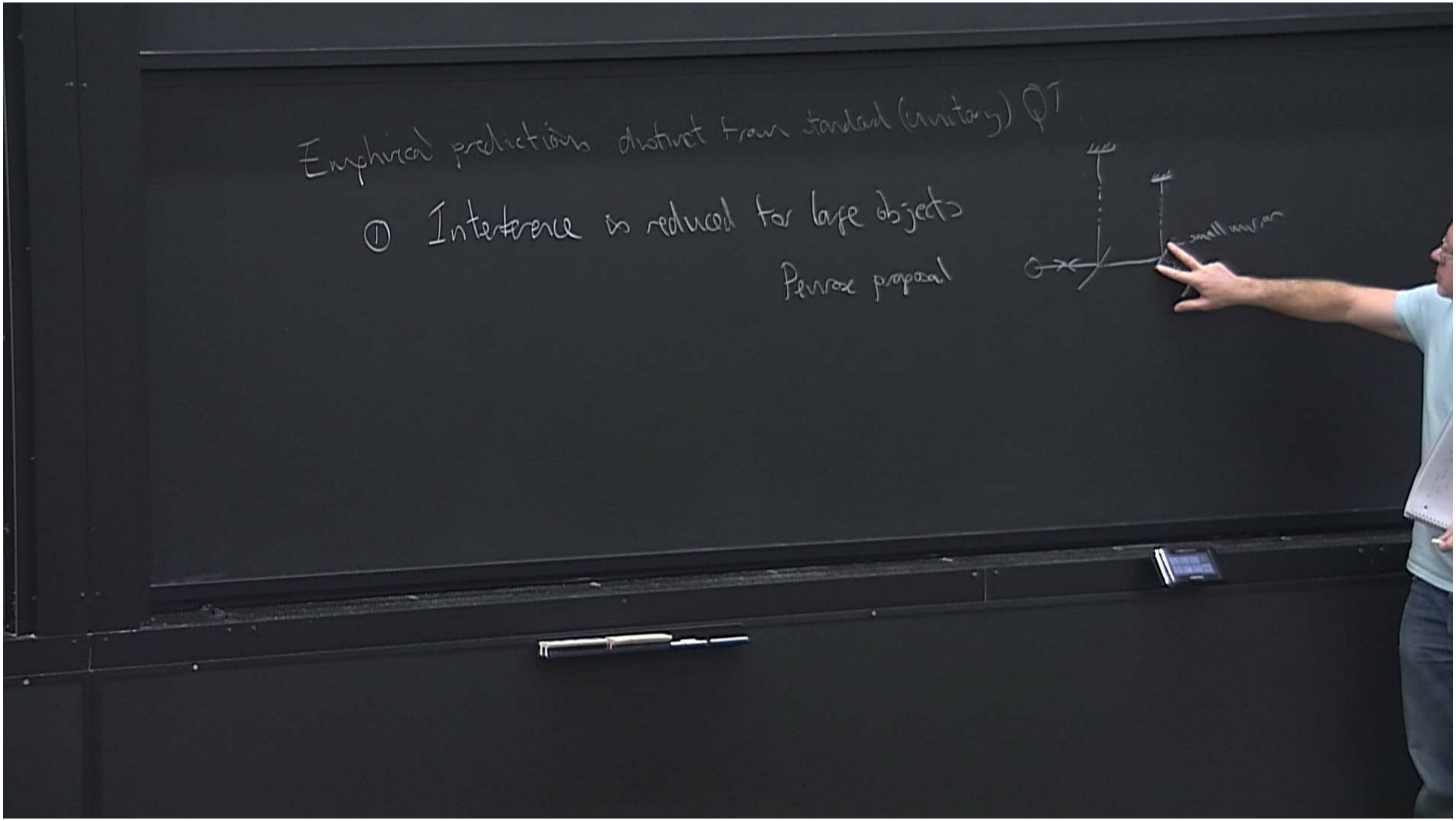




N/τ is prob of hit (per unit time)
"kill" other term.
(non-overlapping)


Empirical predictions distinct from standard (unitary) QT
① Interference is reduced for large objects
Penrose proposal


Emphirical predictions distinct from standard (unitary) QT
① Interference is reduced for large objects
Penrose proposal
small mirror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Empirical predictions distinct from standard (unitary) QT

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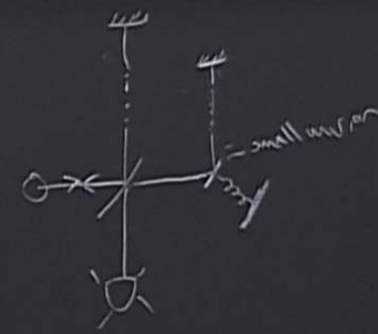

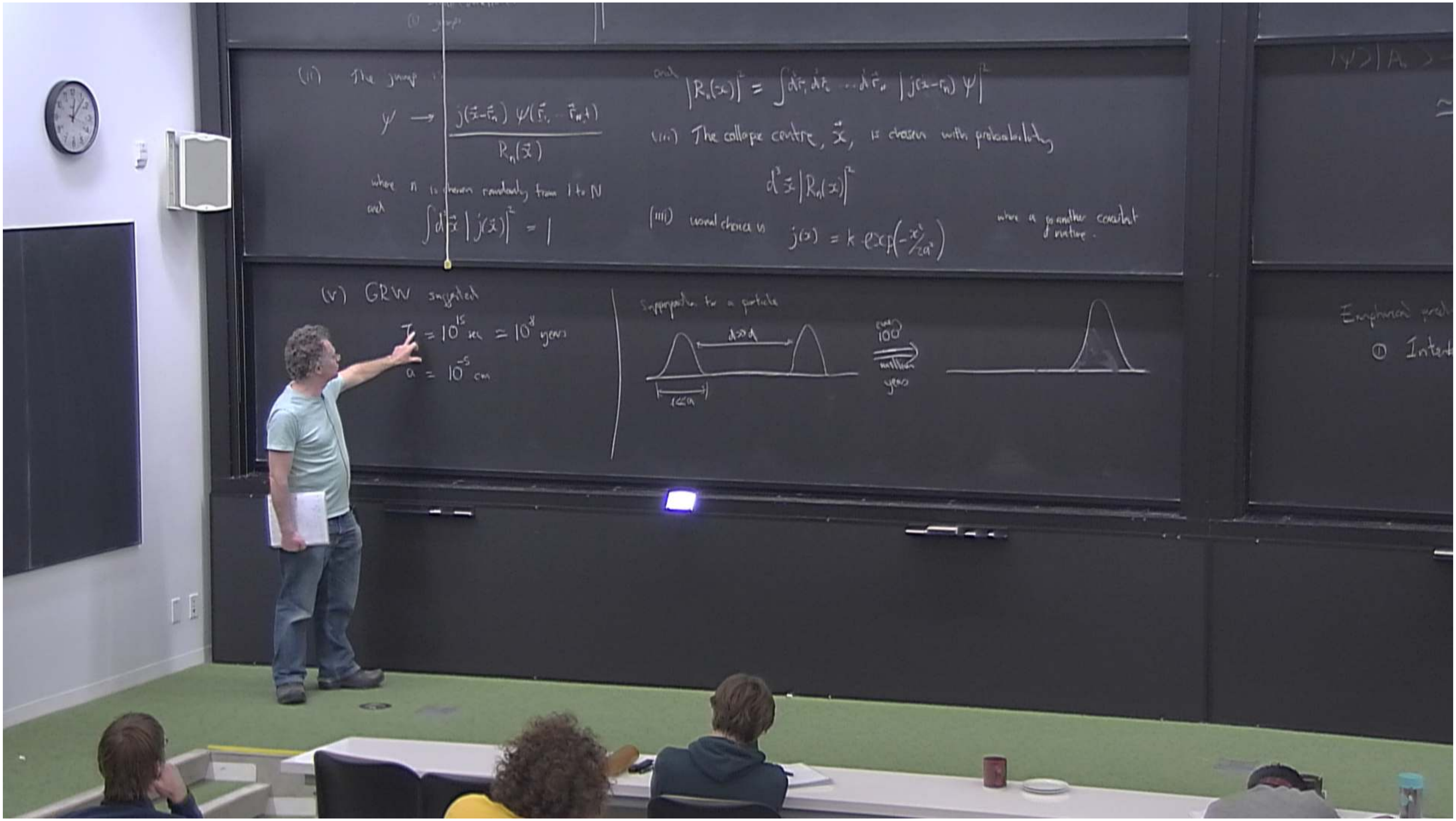
(ii) The jump is
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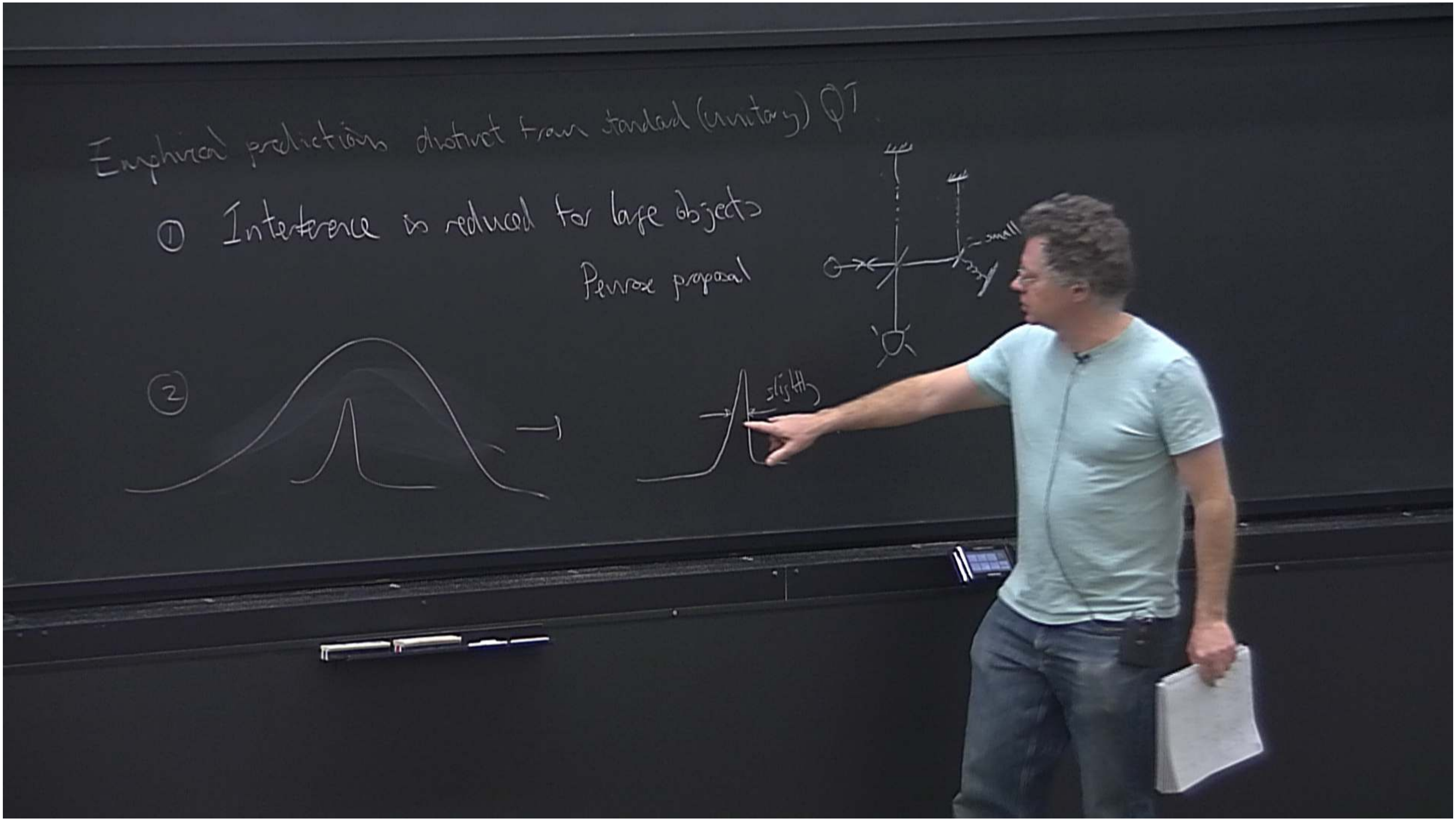
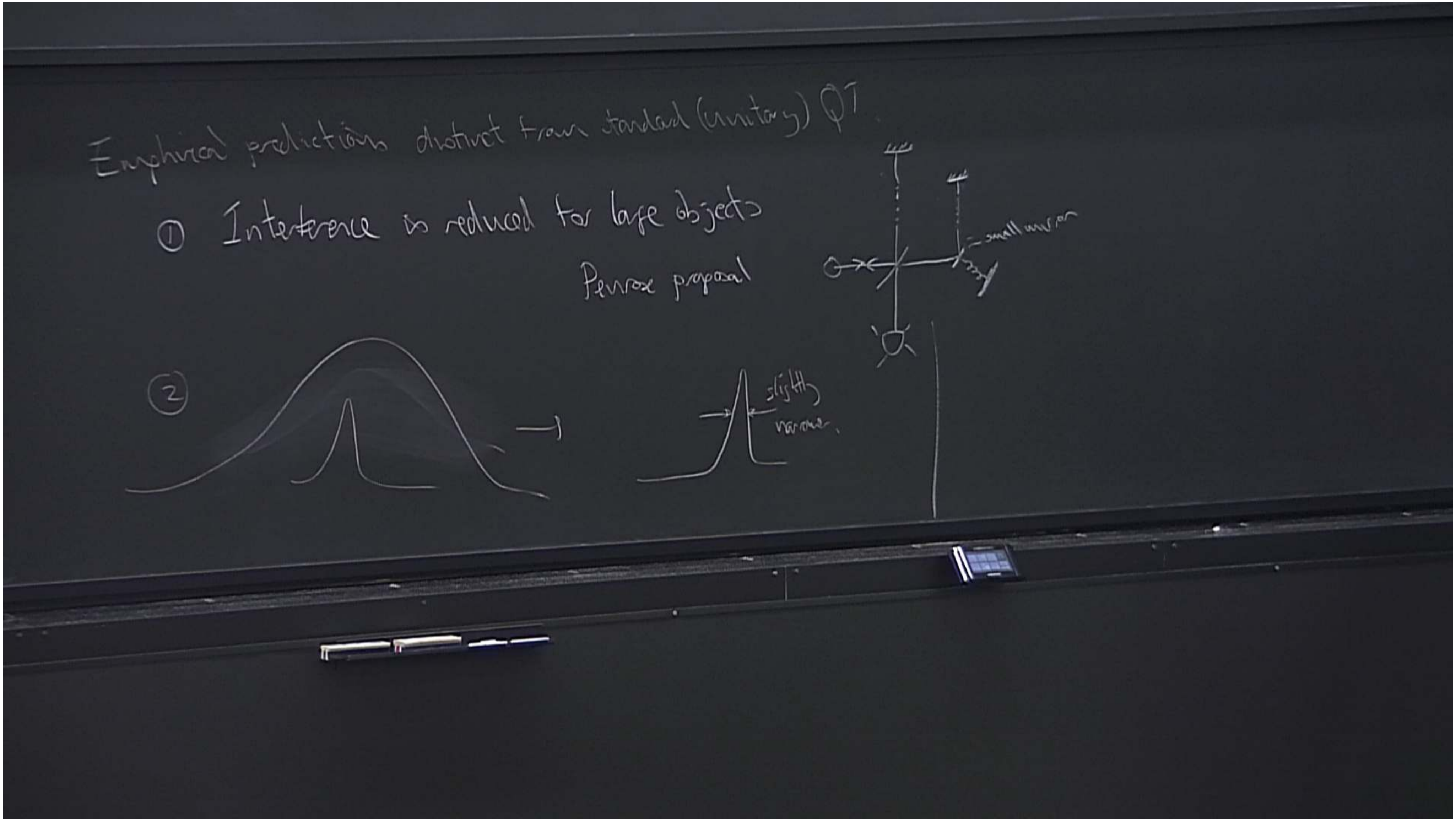
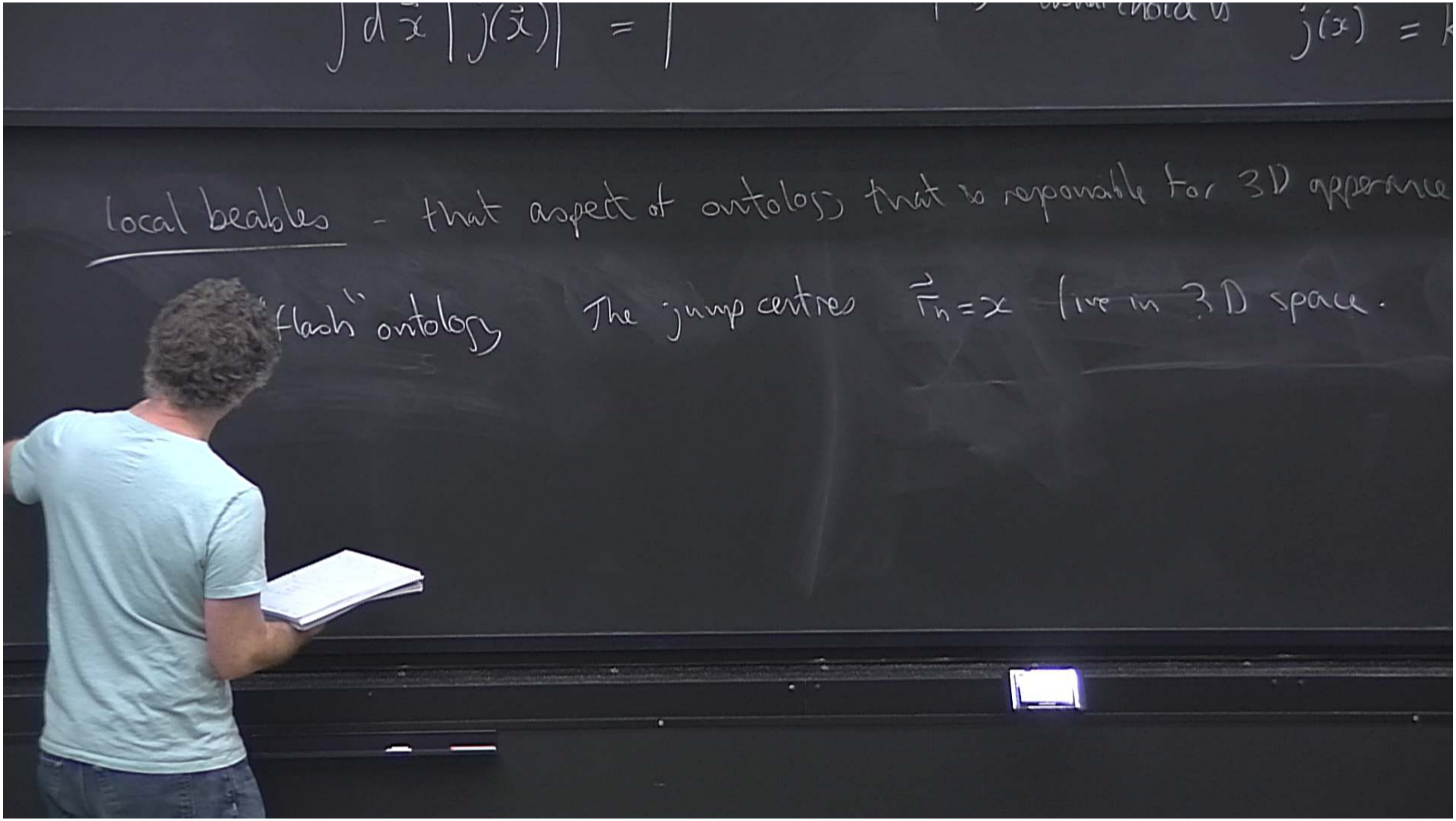
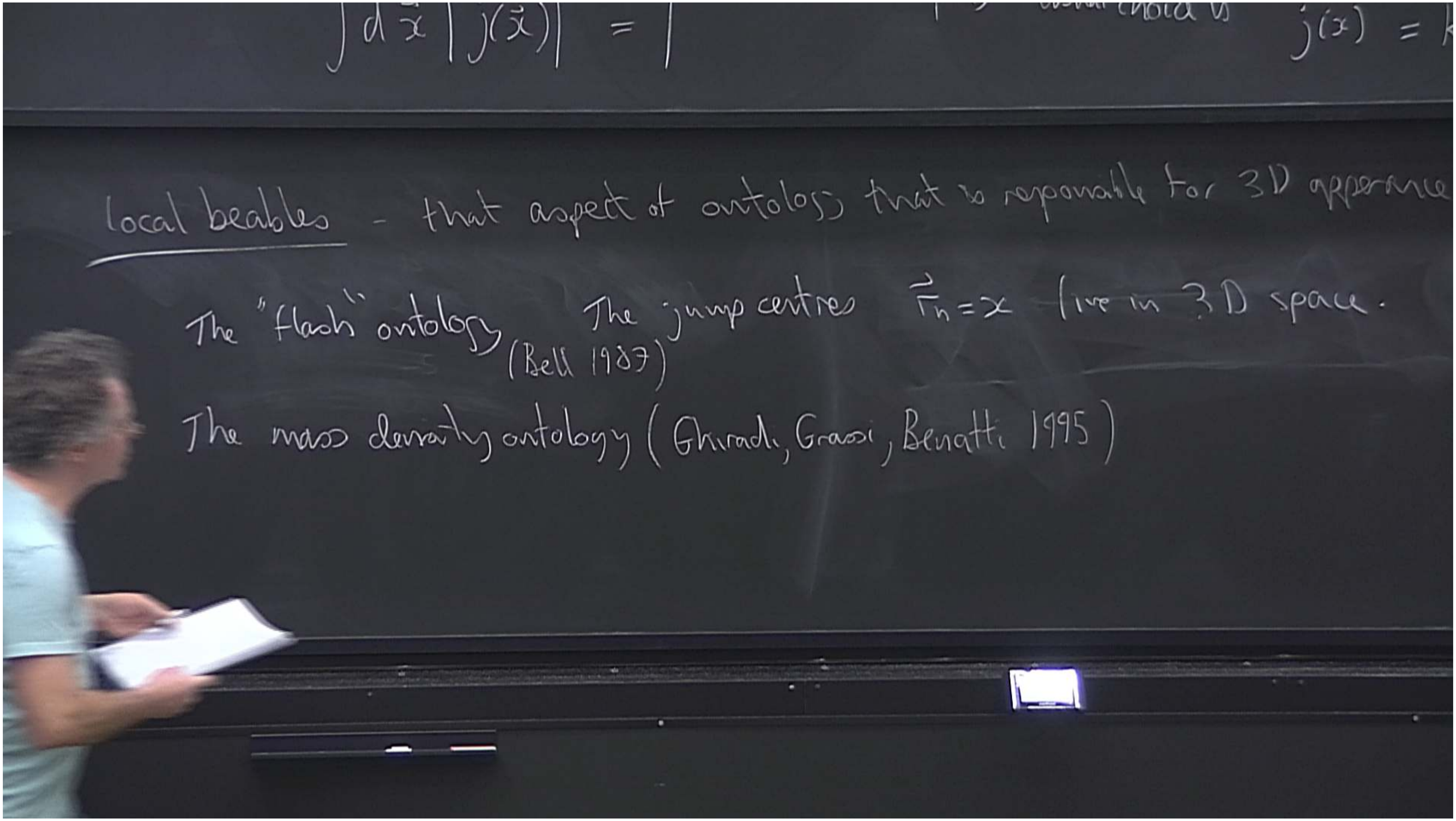
where a is another constant of nature.
(v) GRW suggested
a = 10⁻⁵ cm
Superposition for a particle
d>>a
years



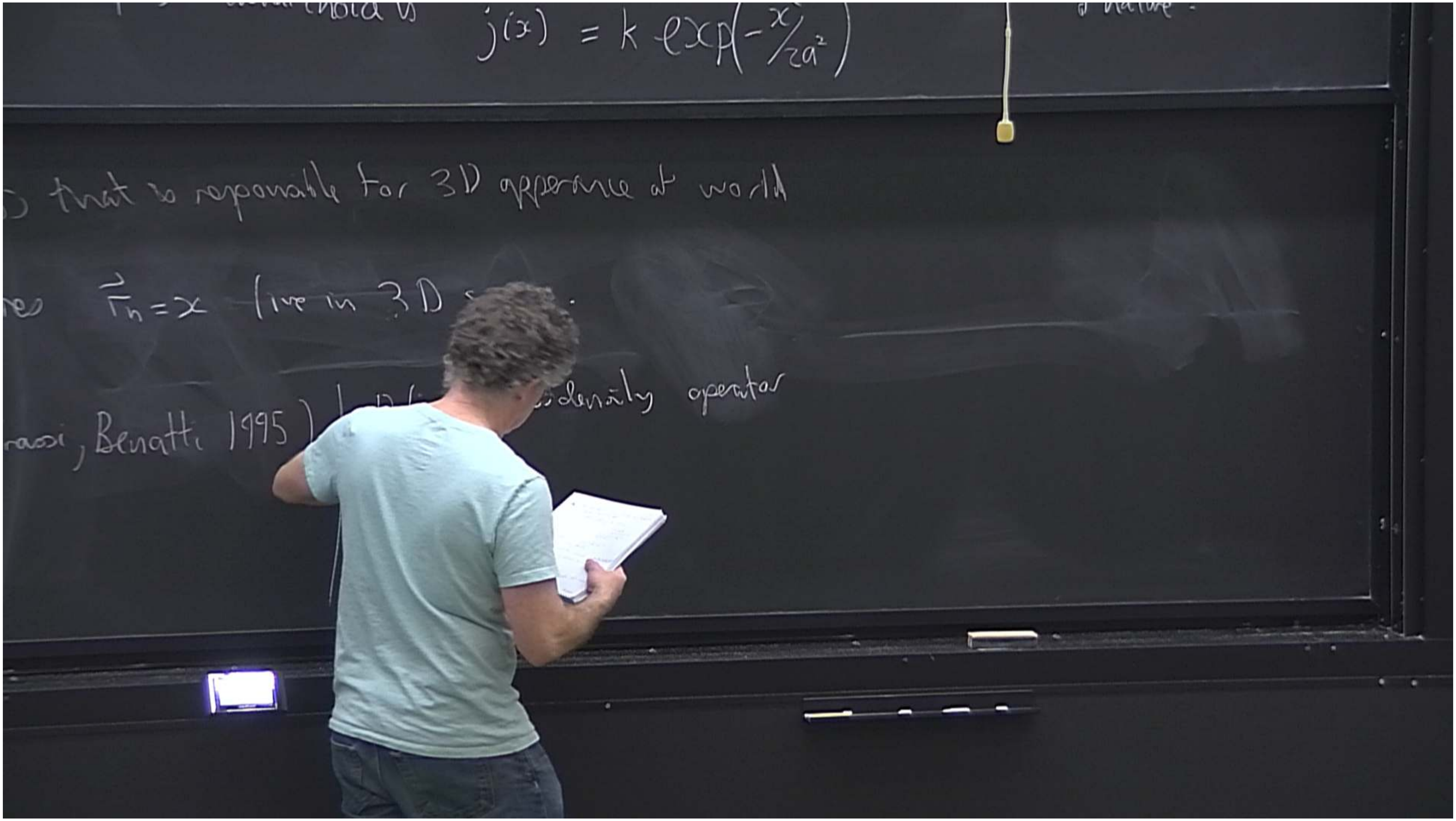
Empirical predictions distinct from standard (unitary) QT
① Interference is reduced for large objects
Penrose proposal
small
②
slightly

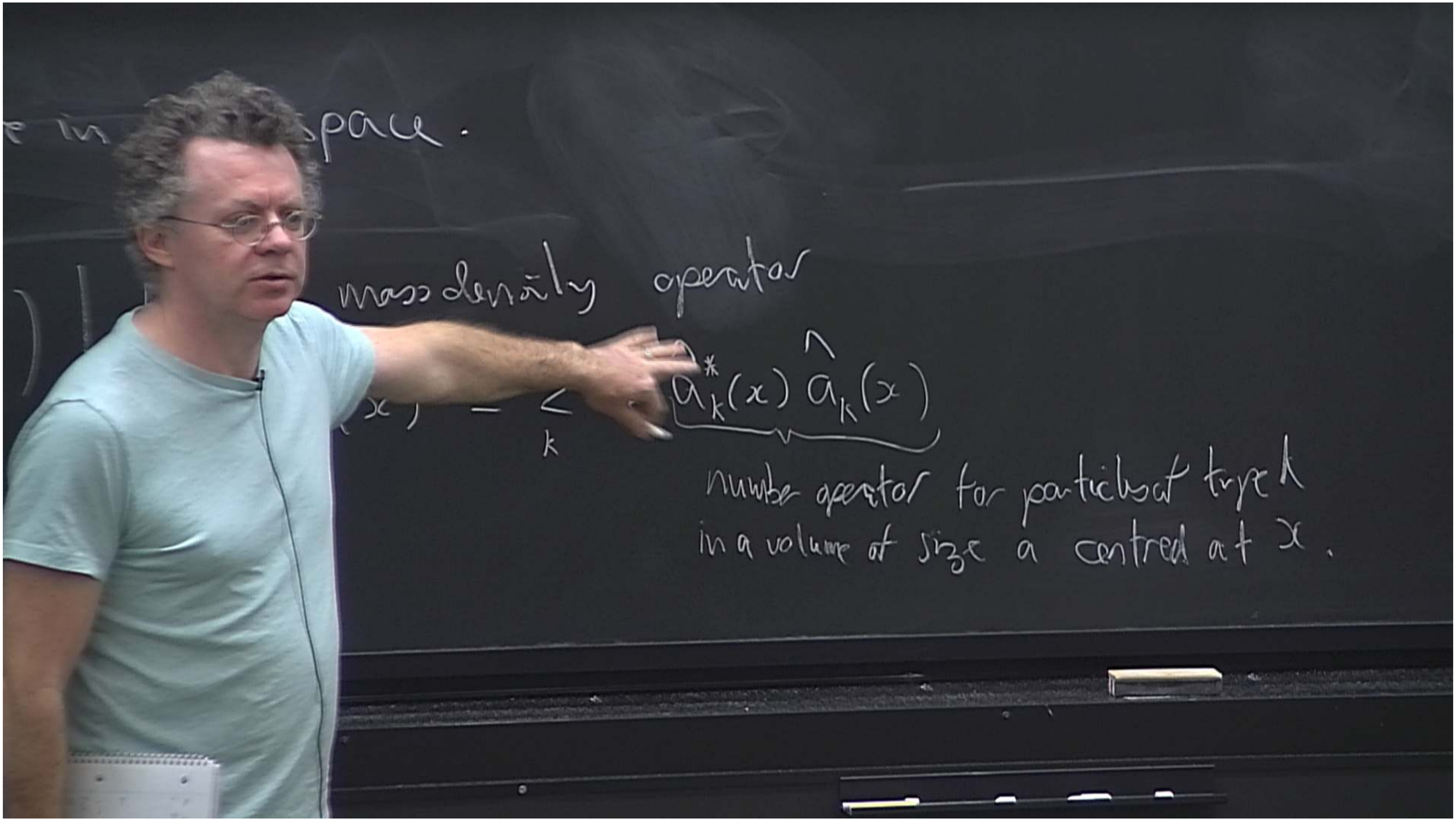

Empirical predictions distinct from standard (unitary) QT
1 Interference is reduced for large objects
Penrose proposal
small mirror
2
slightly
narrower.


local beables - that aspect of ontology that is responsible for 3D appearance
"flash" ontology
The jump centres $\vec{r}_n = x$ live in 3D space.



$\int d\vec{x}\, |j(\vec{x})| = 1$
choice is $j(x) = k$
local beables - that aspect of ontology that is responsible for 3D appearance
The "flash" ontology (Bell 1987)
The jump centres $\vec{r}_n = x$ live in 3D space.
The mass density ontology (Ghirardi, Grassi, Benatti 1995)


j(x) = k exp(-x²/2a²)
that is responsible for 3D apperance of world
live in 3D
Benatti 1995
density operator

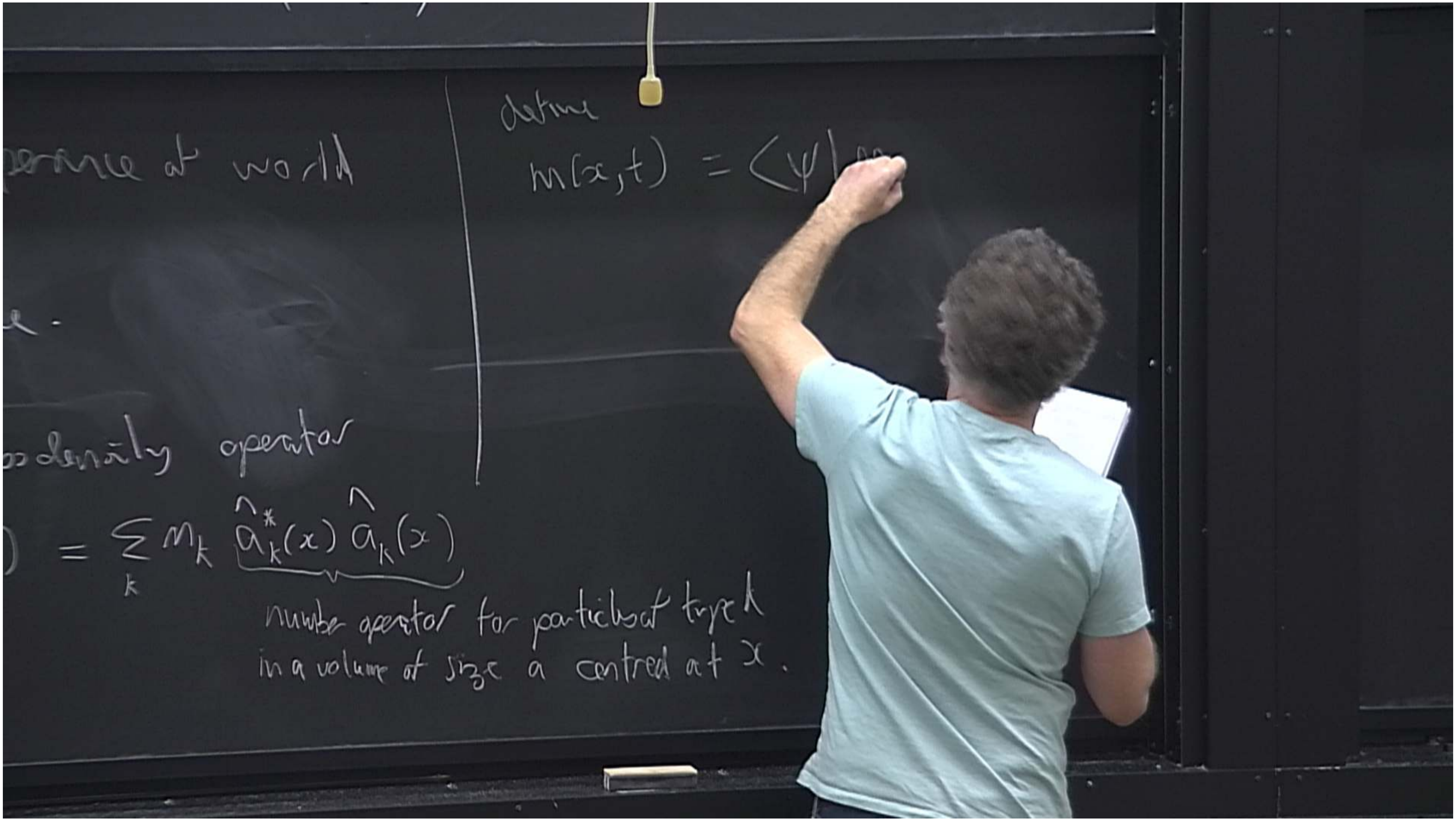

mass density operator
number operator for particles of type k
in a volume of size a centred at x.

… in 3D space.

Define mass density operator

$$\hat{M}(x) = \sum_k m_k \underbrace{\hat{a}^*_k(x)\, \hat{a}_k(x)}$$

number operator for particles of type k in a volume of size a centred at x.


define
n(x,t) = ⟨ψ|
world
density operator
= Σ_k n_k a*_k(x) a_k(x)
number operator for particles of type k
in a volume of size a centred at x.

for 3D apperance of world

3D space.

Define mass density operator

$$\hat{M}(x) = \sum_k m_k \underbrace{\hat{a}^*_k(x)\,\hat{a}_k(x)}$$

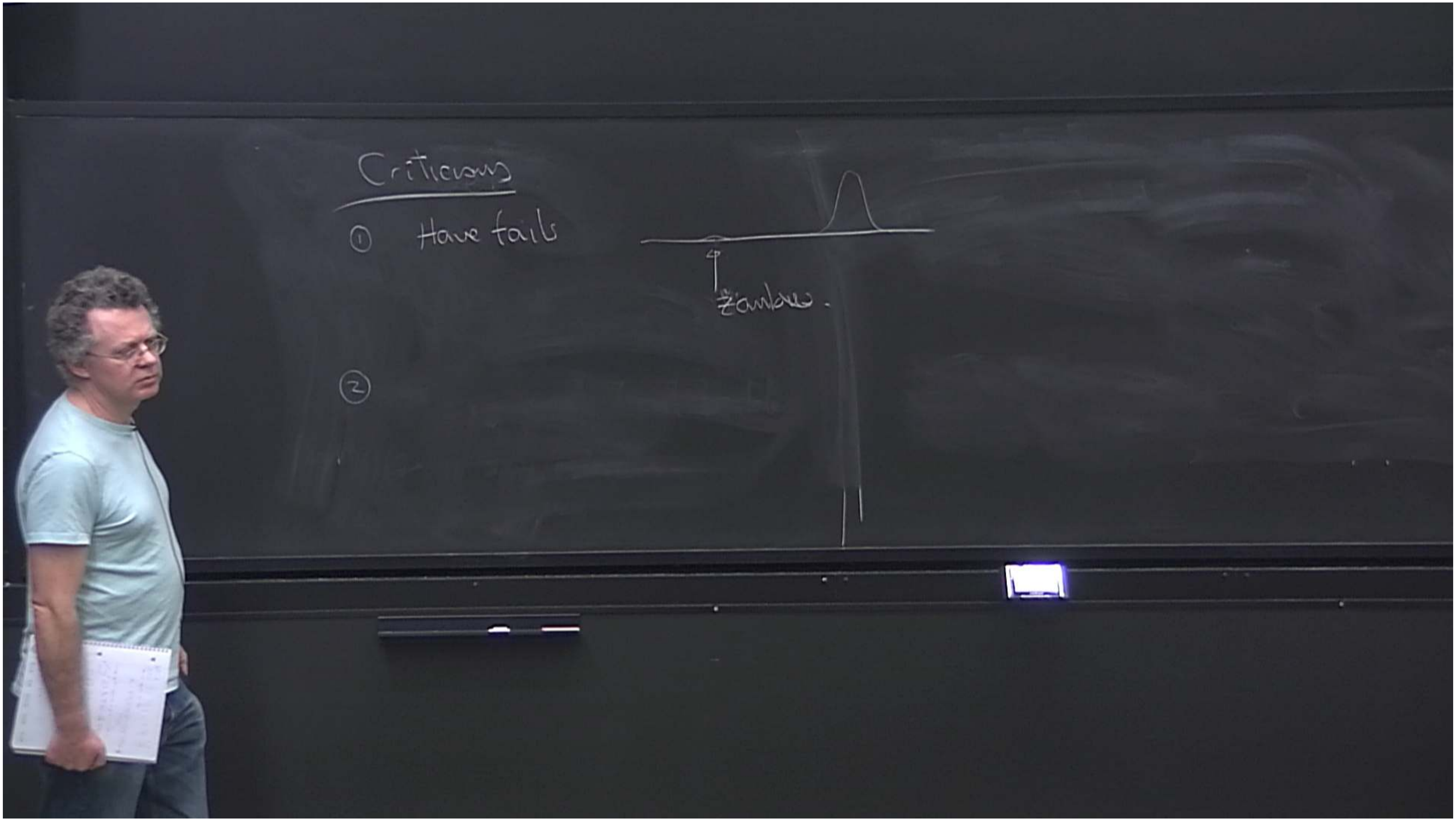
number operator for particle of type k
in a volume of size a centred at x.

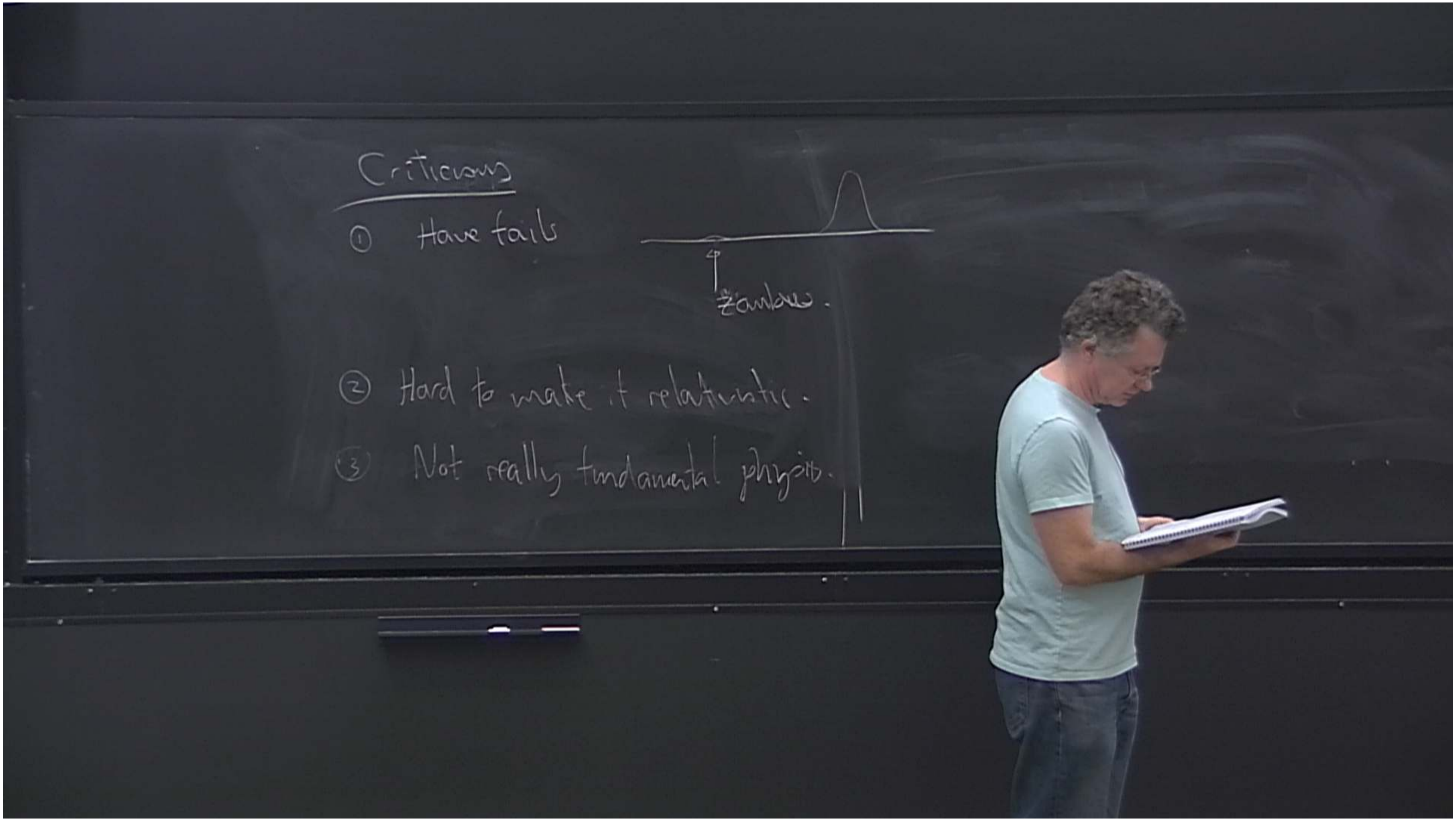
define

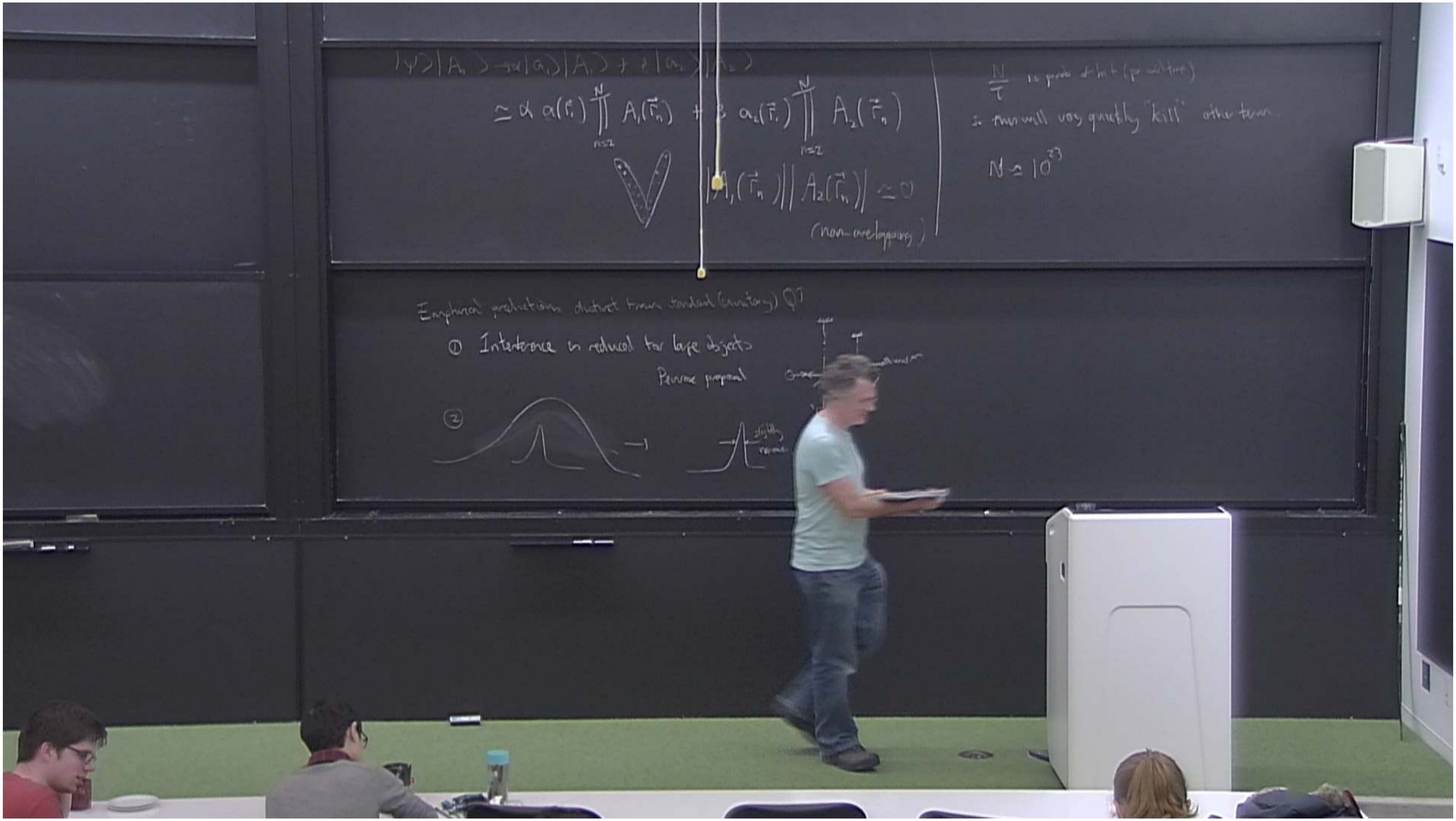
$m(x,t) = \langle\psi|\hat{m}|\psi\rangle$

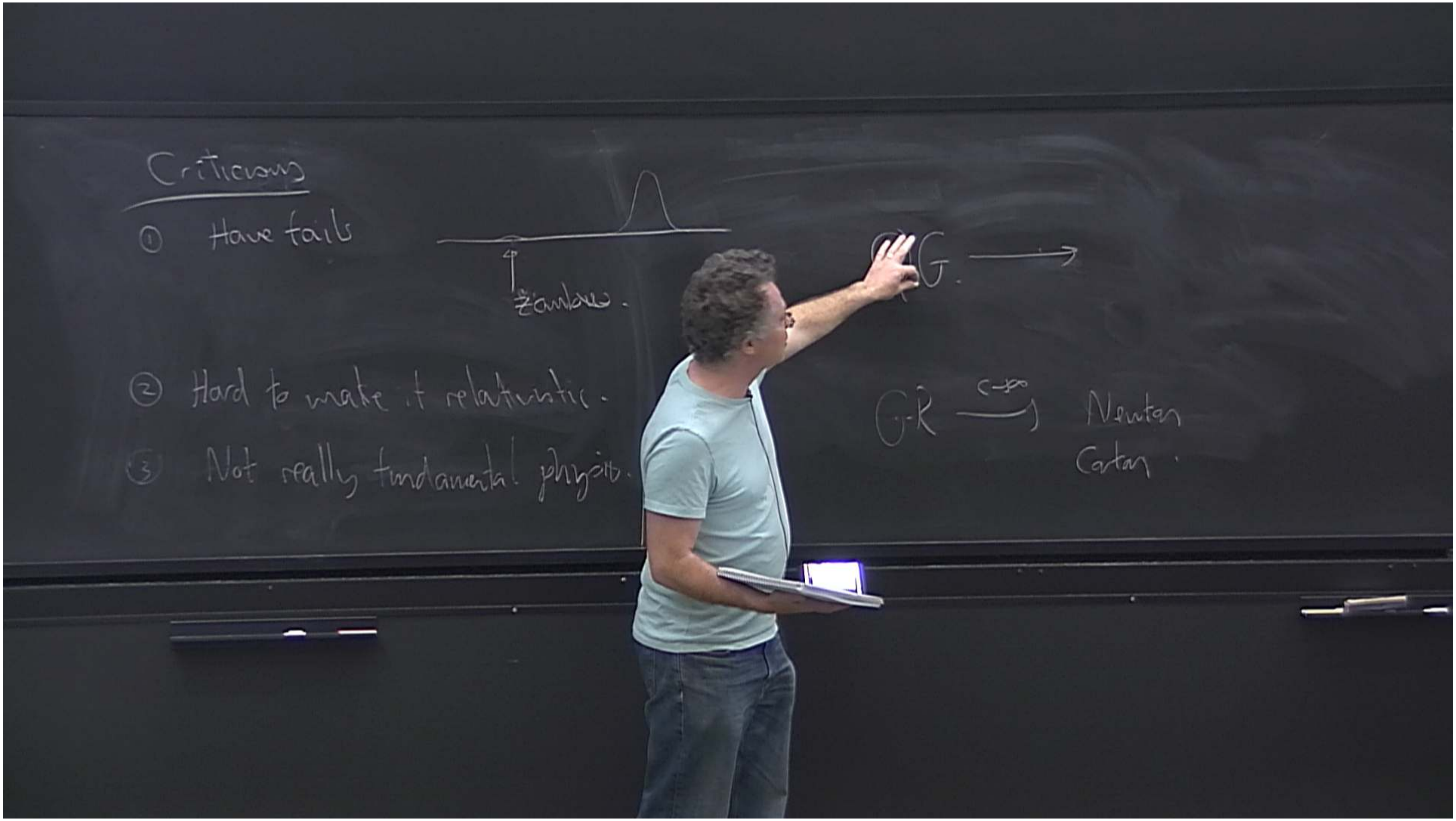
gives a mass density

→ the local beable.


Criticisms
1 Have tails
2


Criticisms
① Wave tails
Zombies.
② Hard to make it relativistic.
③ Not really fundamental physics.


Interference is reduced for large objects
Penrose proposal
(non-overlapping)
$N \simeq 10^{23}$


Criticisms
② Hard to make it relativistic.
③ Not really fundamental physics.
G.R
c→∞
Newton Cartan