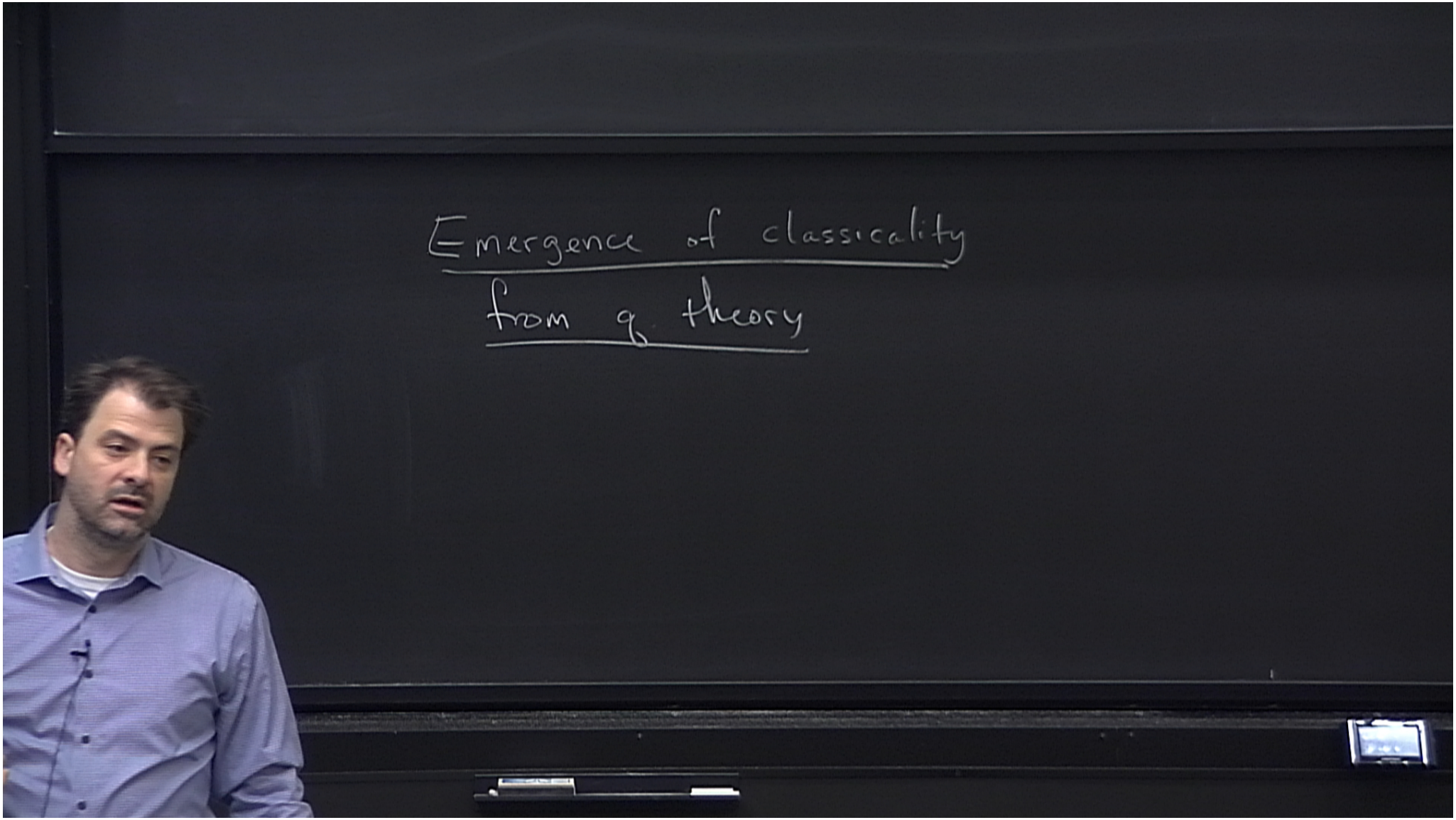
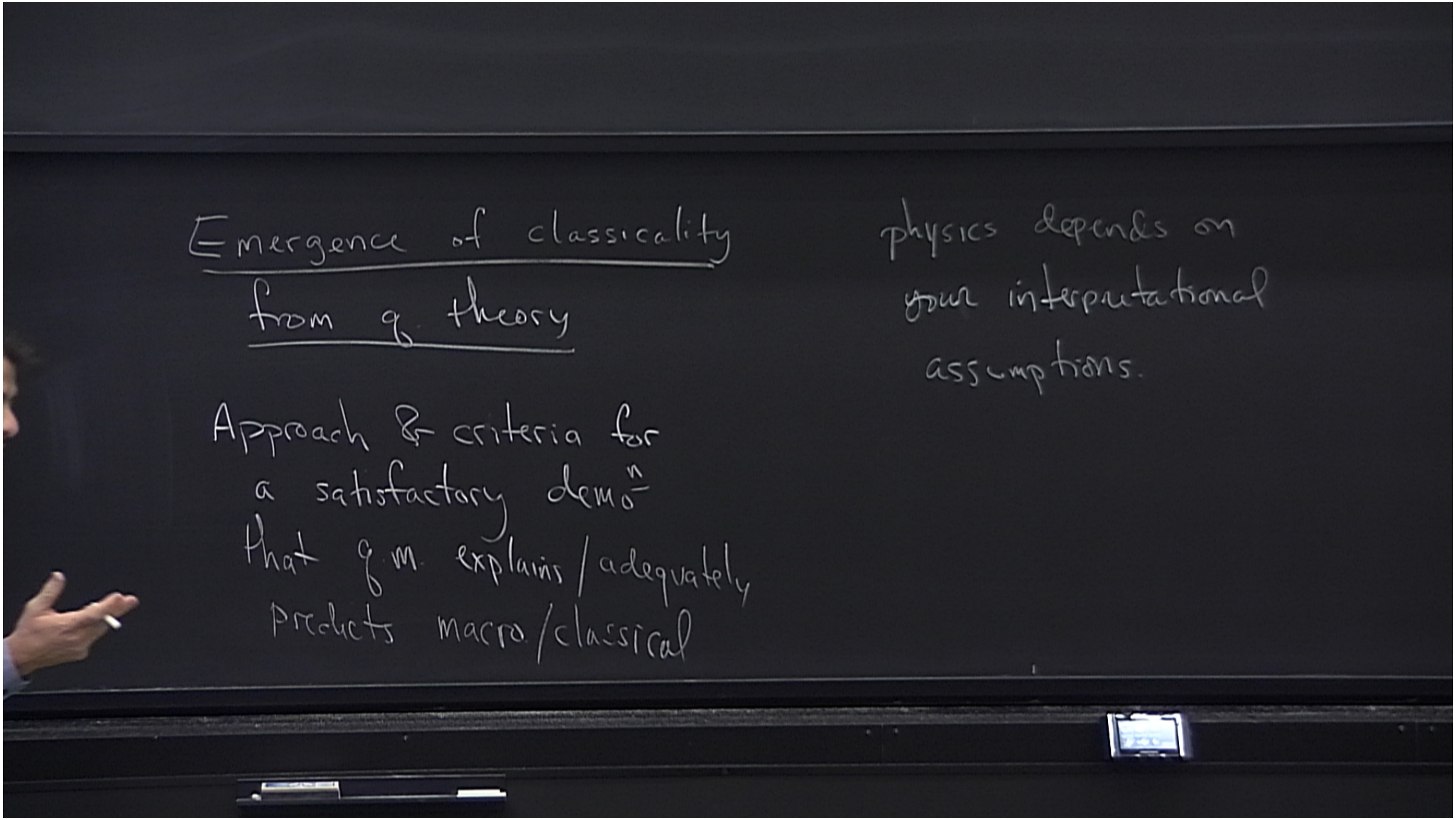
Title: PSI 2016/2017 Foundations of Quantum Mechanics (Review) - Lecture 11

Date: Jan 17, 2017 11:30 AM

URL: http://pirsa.org/17010043

Abstract:


Emergence of classicality
from q. theory

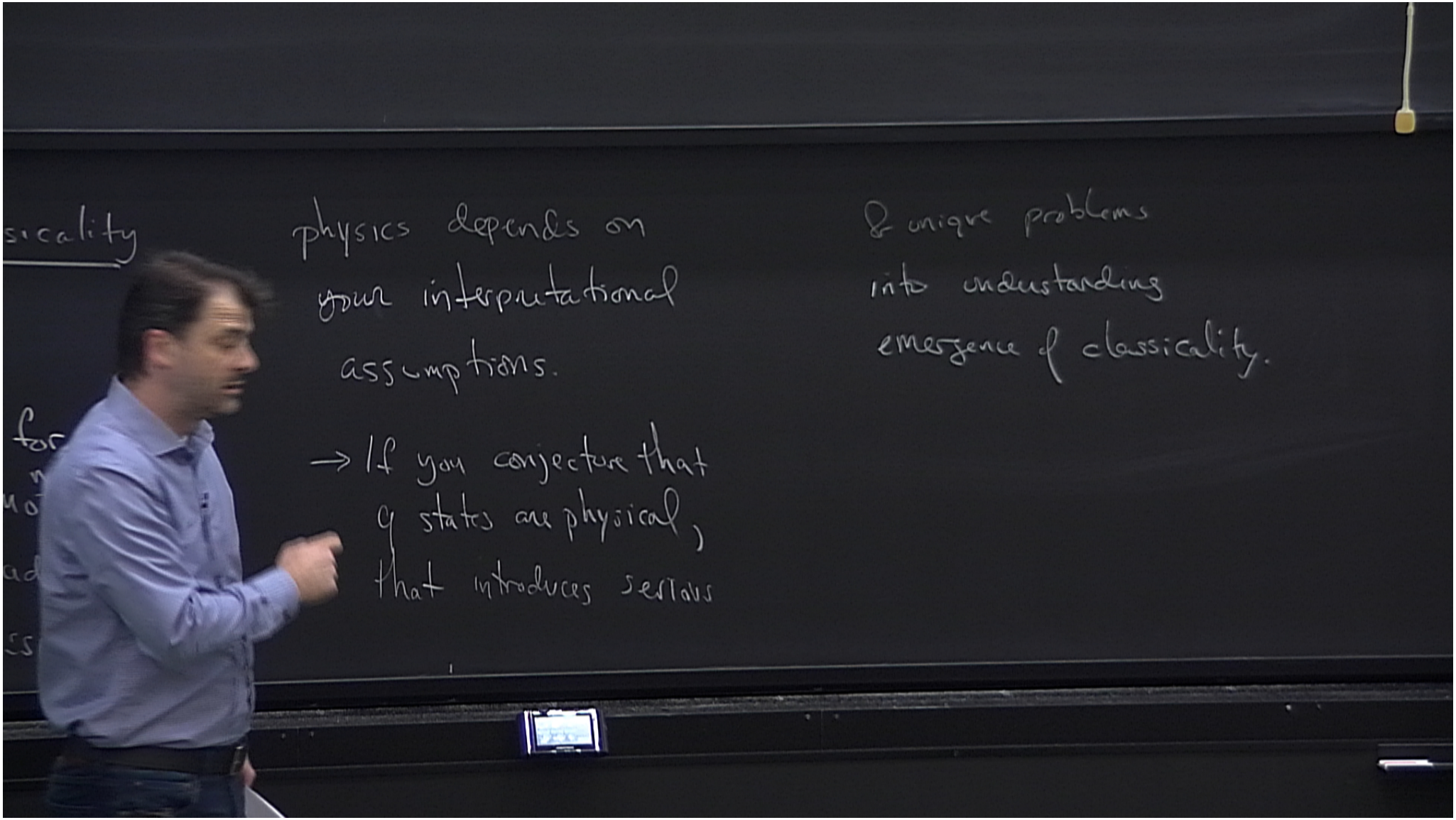

Emergence of classicality
from q. theory
physics depends on
your interpretational
assumptions.
Approach & criteria for
a satisfactory demo^n
that q.m. explains / adequately
predicts macro / classical

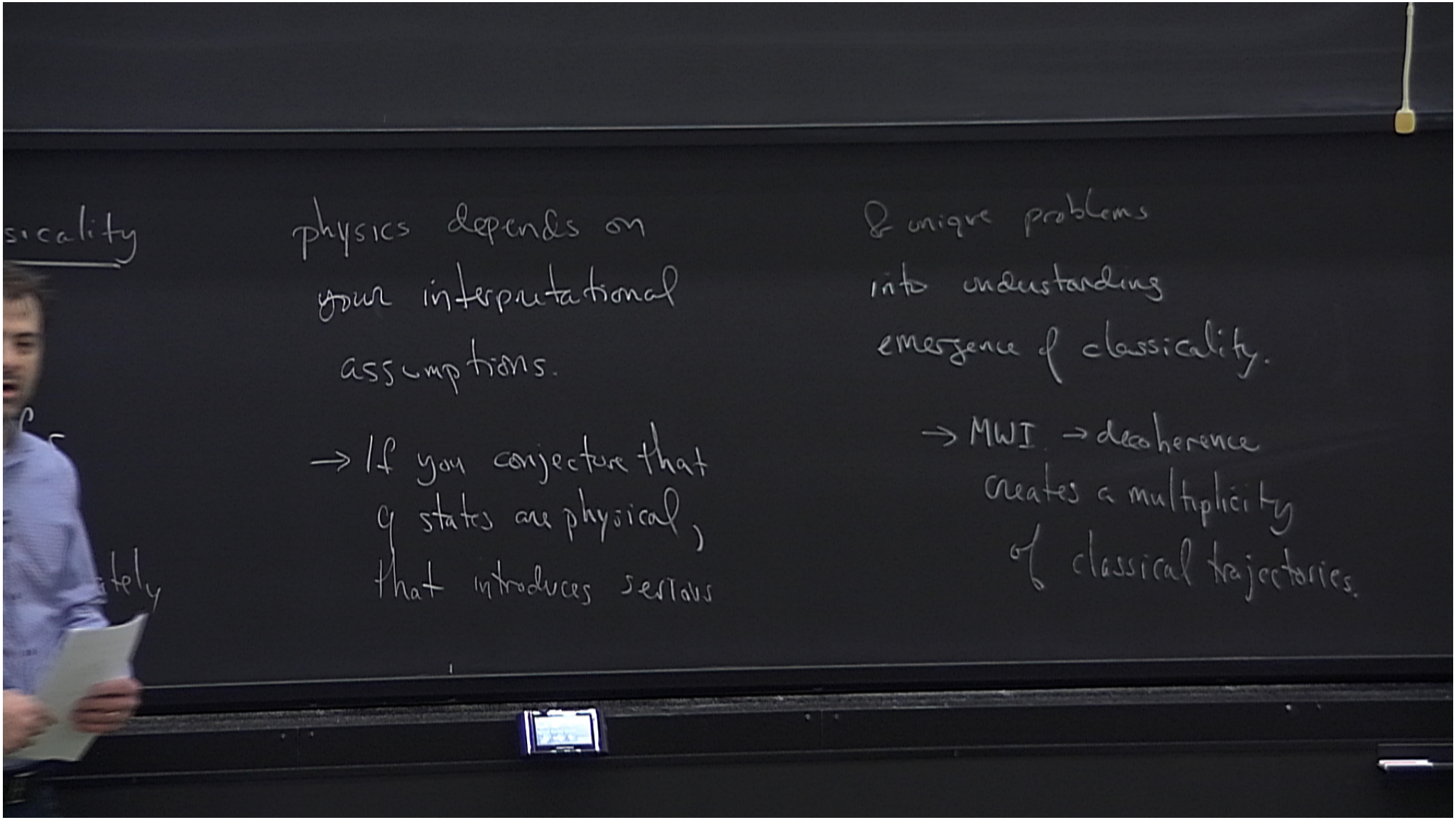
Emergence of classicality from q. theory

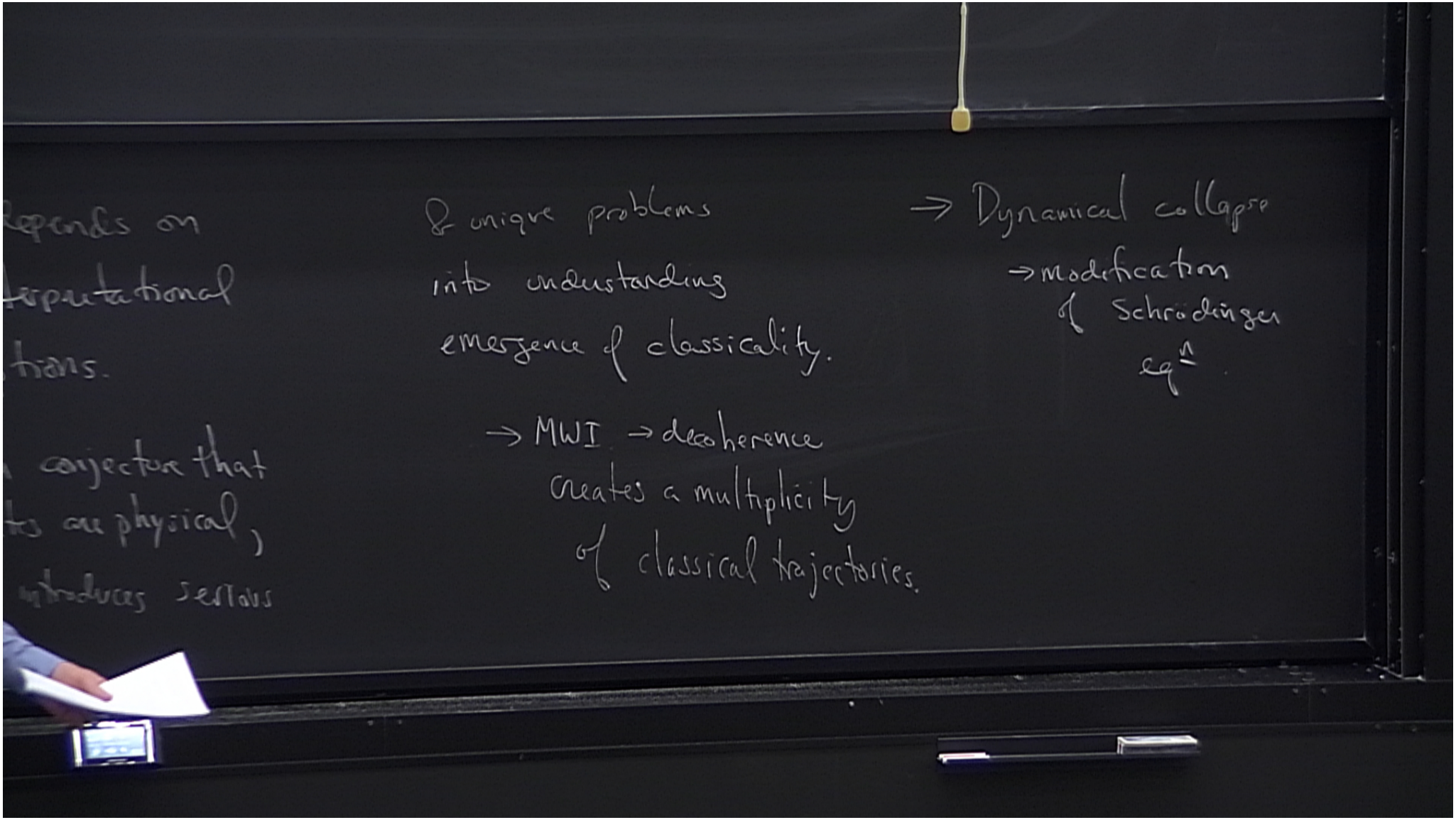
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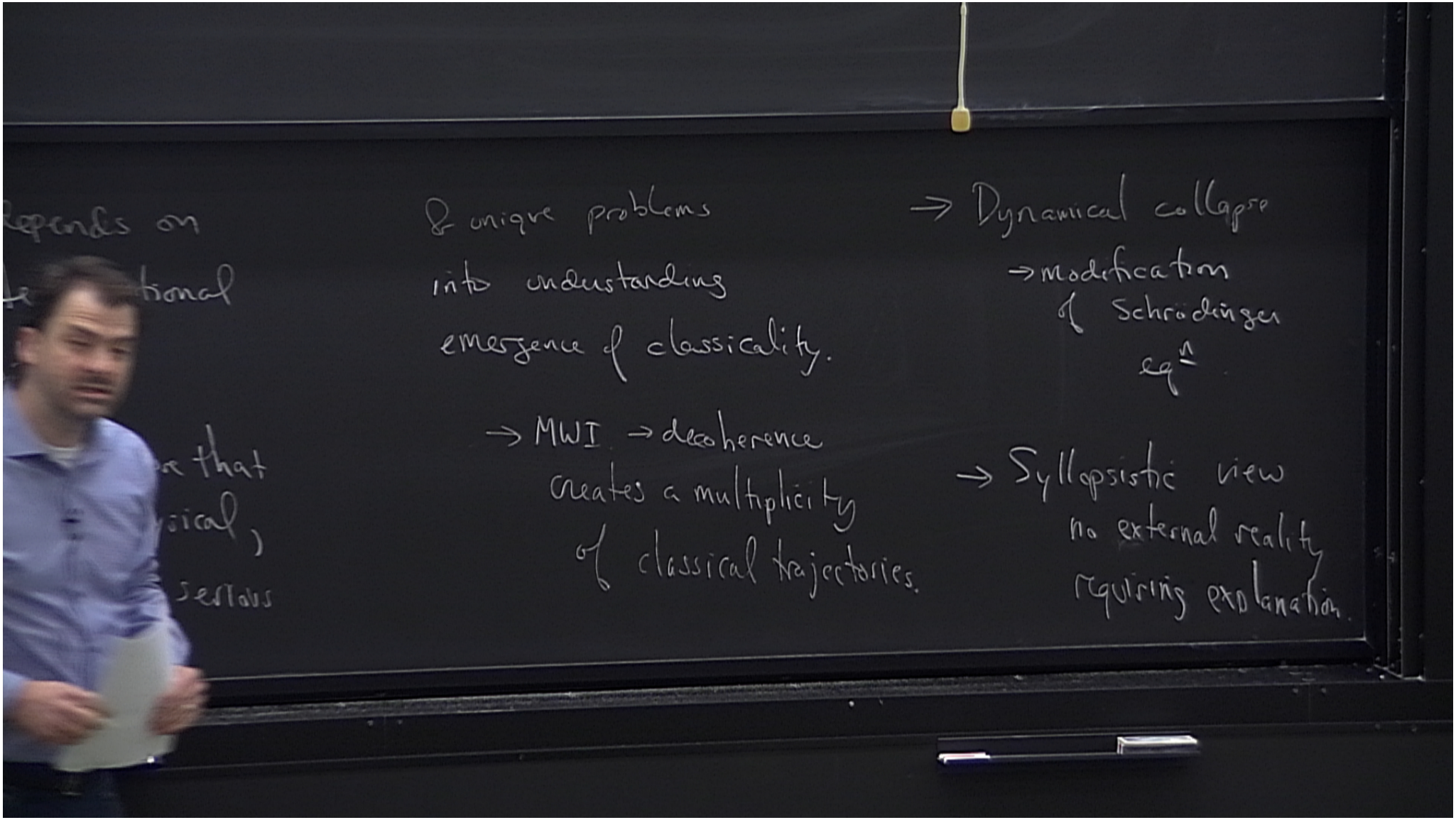
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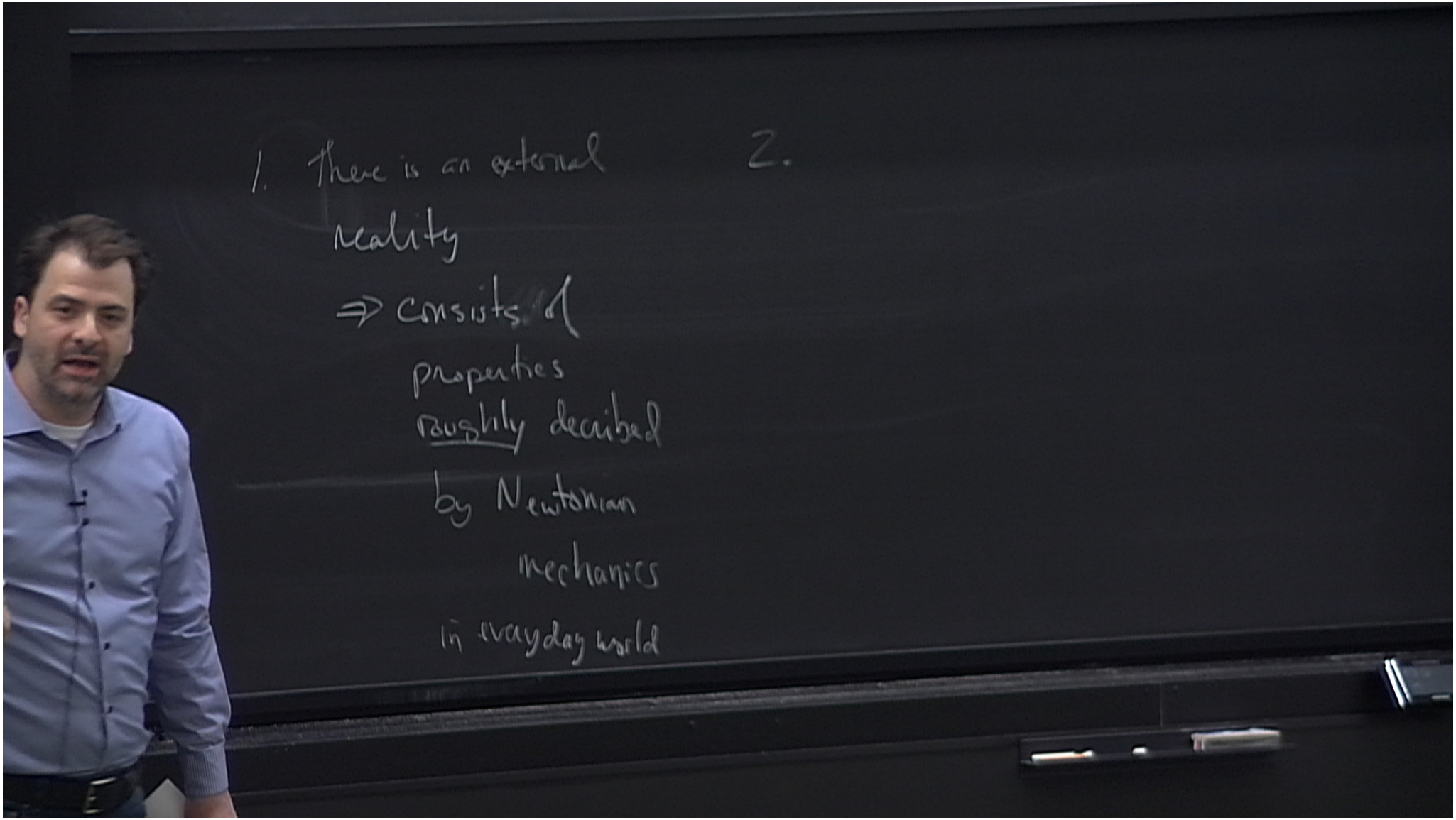
→ If you conjecture that q states are physical


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physics depends on your interpretational assumptions.
→ If you conjecture that q states are physical, that introduces serious
& unique problems into understanding emergence of classicality.


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→ If you conjecture that ψ states are physical, that introduces serious
& unique problems into understanding emergence of classicality.
→ MWI → decoherence creates a multiplicity of classical trajectories.

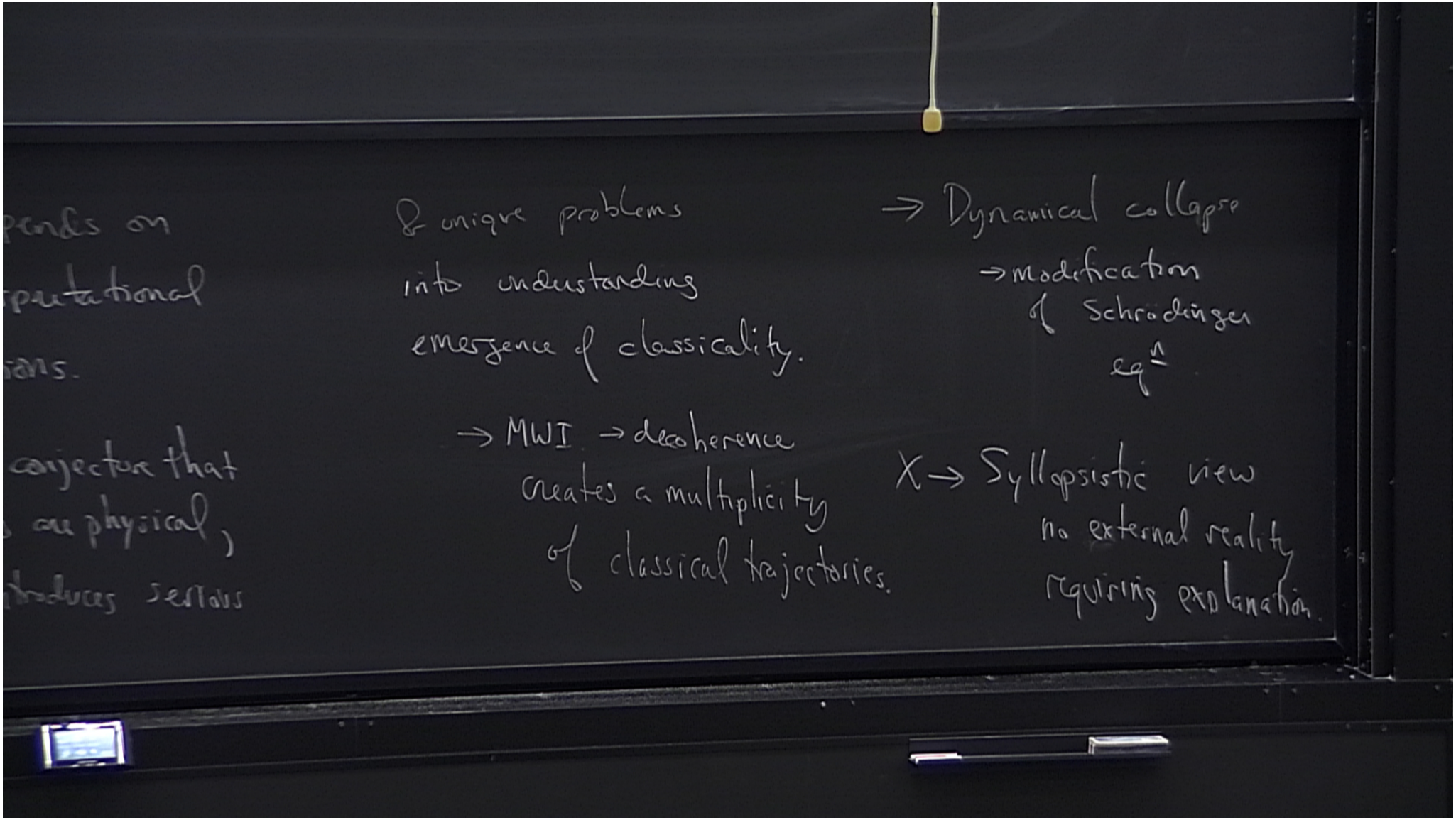

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→ Syllapsistic view
no external reality
requiring explanation.

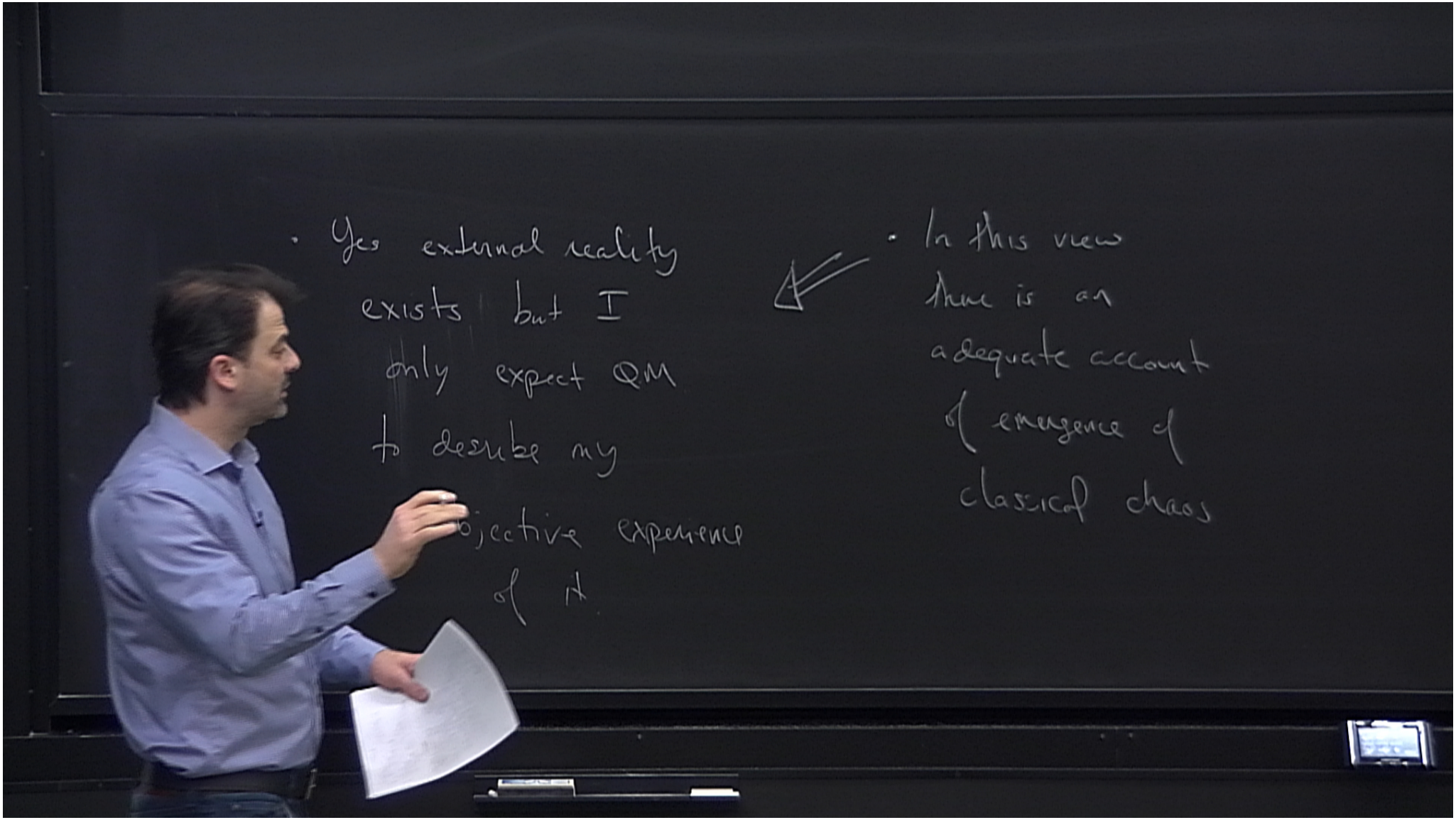

1. There is an external reality
⇒ consists of properties roughly described by Newtonian mechanics in everyday world
2.

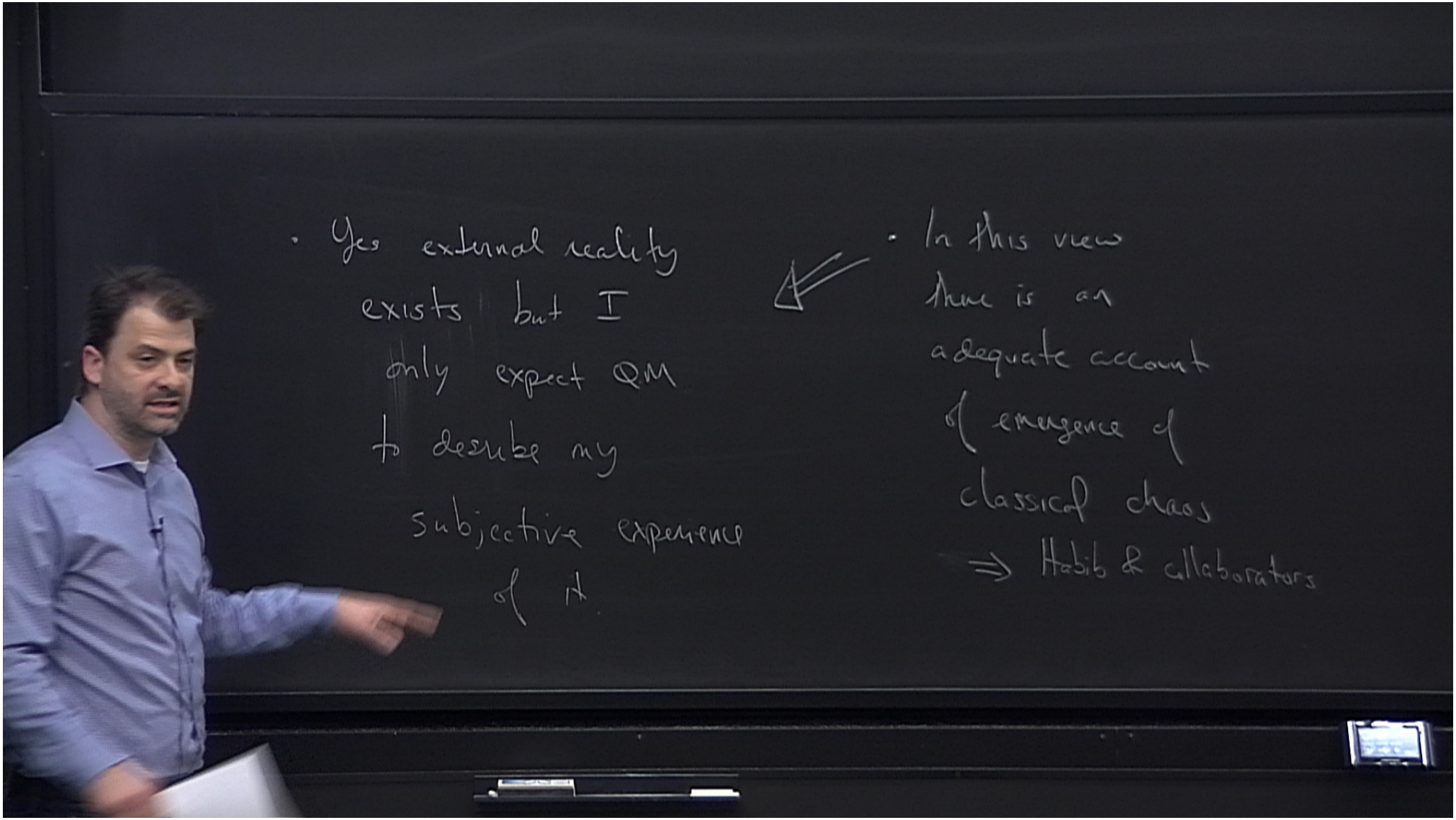
1. There is an external reality
⇒ consists of properties roughly described by Newtonian mechanics in everyday world

2. There should be mathematical elements in our fundamental theory that correspond to those elements.


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- Yes external reality exists but I only expect QM to desribe my subjective experience of it


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· In this view there is an adequate account of emergence of classical chaos


· Yes external reality exists but I only expect QM to decribe my subjective experience of it
· In this view there is an adequate account of emergence of classical chaos ⇒ Habib & collaborators

Ehrenfest theorem

- Wavepacket is narrow enough then $\langle q \rangle, \langle p \rangle$ follow a classical trajectory

$$\langle q \rangle_t \sim q(t)$$

$$\langle p \rangle_t \sim p(t)$$

Ehrenfest theorem

- Wavepacket is narrow

  enough then $\langle q \rangle$, $\langle p \rangle$

  follow a classical trajectory

$$\langle q \rangle_t \sim q(t)$$

$$\langle p \rangle_t \sim p(t)$$

narrow

$\langle q \rangle, \langle p \rangle$

classical trajectory

$\rangle_t \sim q(t)$

$p\rangle_t \sim p(t)$

Classical chaos.

Sensitivity to init. cond^{n}s

$$d(t) = |X_a(t) - X_b(t)|$$

$$d(t) \sim d(0) e^{\lambda t}$$

$\lambda \sim$ Lyapunov exponent.

Classical $H(q,p,t)$

that is classified chaotic.

$\rightarrow$ Quantum $\hat{H}(\hat{q},\hat{p},t)$

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$\Delta q = \sqrt{\langle q^2\rangle - \langle q\rangle^2} = \Delta q(0)\, e^{\lambda t}$

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$$\Delta q = \sqrt{\langle q^2\rangle - \langle q\rangle^2} = \Delta q(0)\, e^{\lambda t}$$

On a time-scale $t_b \sim \frac{1}{\lambda^{-1}} \log\left(\frac{L_m}{\Delta q(0)}\right)$

where L_m ~ is a macro length scale.

$\langle q\rangle_t \neq q_c(t)$

$\langle p\rangle_t \neq p_c(t)$

Ehrenfest theorem

- Wavepacket is narrow enough then $\langle q \rangle, \langle p \rangle$ follow a classical trajectory

$$\langle q \rangle_t \simeq q(t)$$
$$\langle p \rangle_t \simeq p(t)$$

Classical chaos

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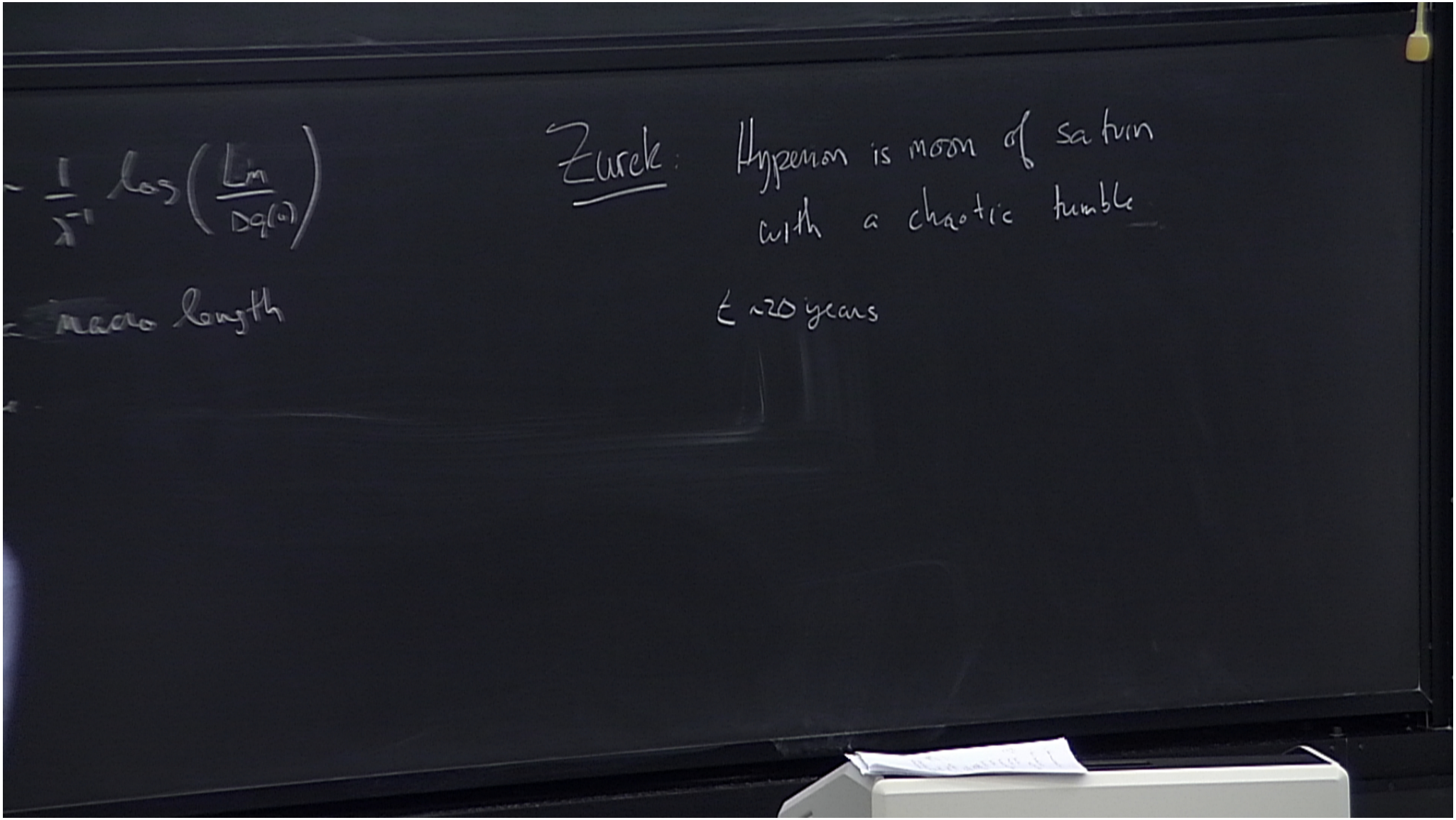
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$\frac{1}{\lambda^{-1}} \log\left(\frac{L_m}{D_{q(0)}}\right)$
macro length
Zurek: Hyperion is moon of saturn with a chaotic tumble
$t \sim 20$ years

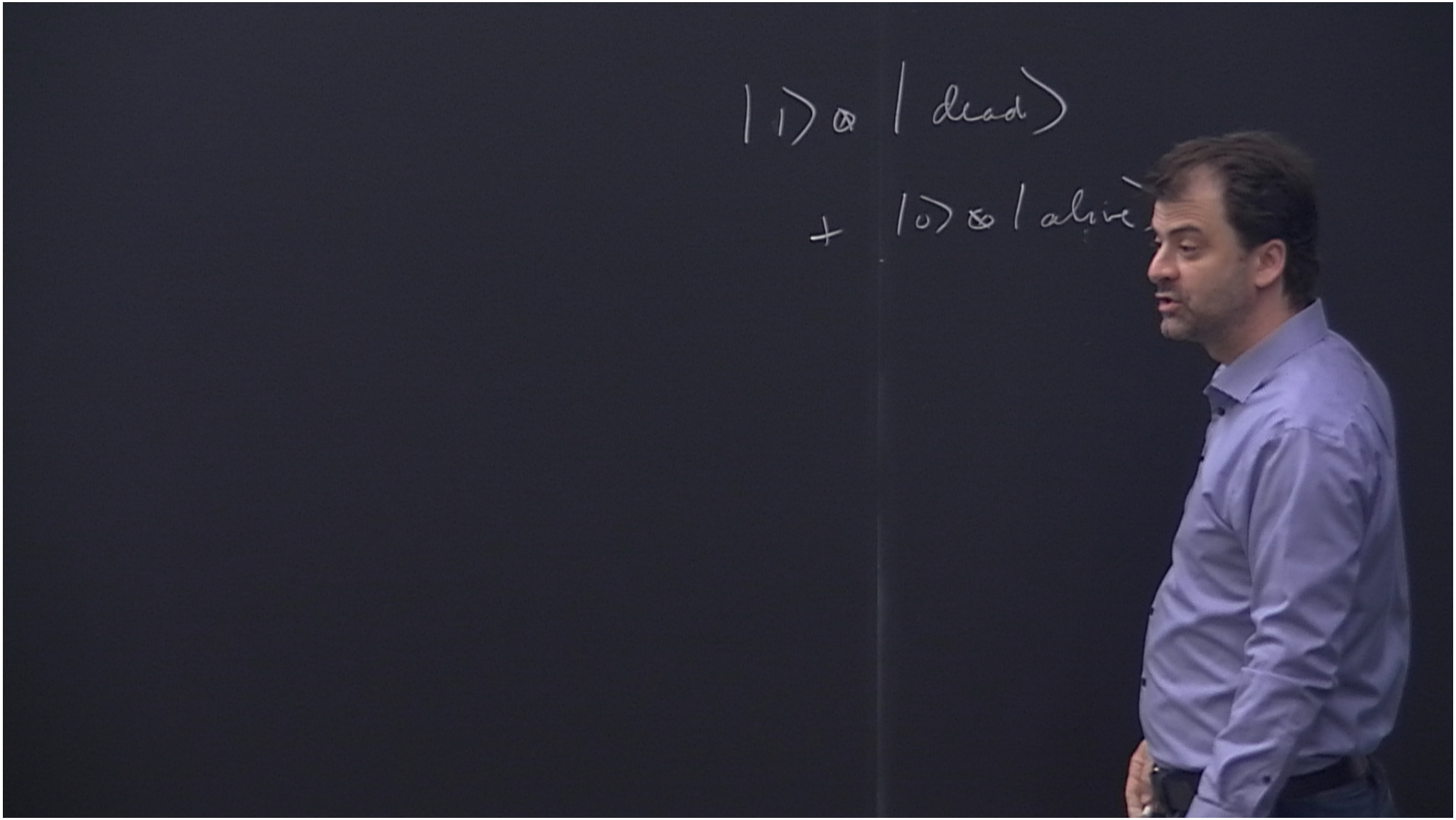
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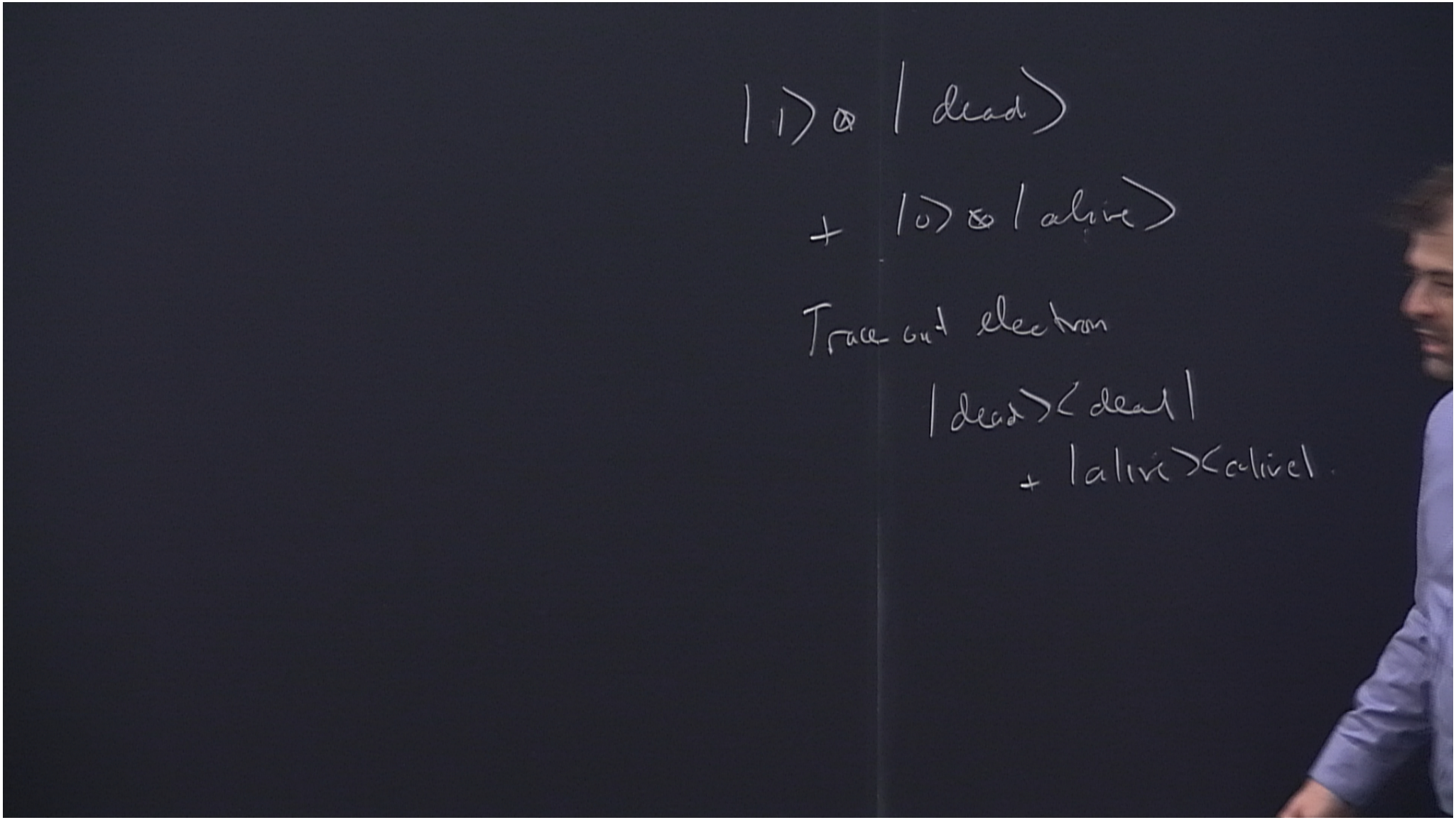
macro length

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$t \sim 20$ years.

Assumption: if q. states are physical then we need a decoherence story.


|1⟩⊗|dead⟩
+ |0⟩⊗|alive⟩


|1⟩⊗|dead⟩
+ |0⟩⊗|alive⟩
Trace out electron
|dead⟩⟨dead|
+ |alive⟩⟨alive|.

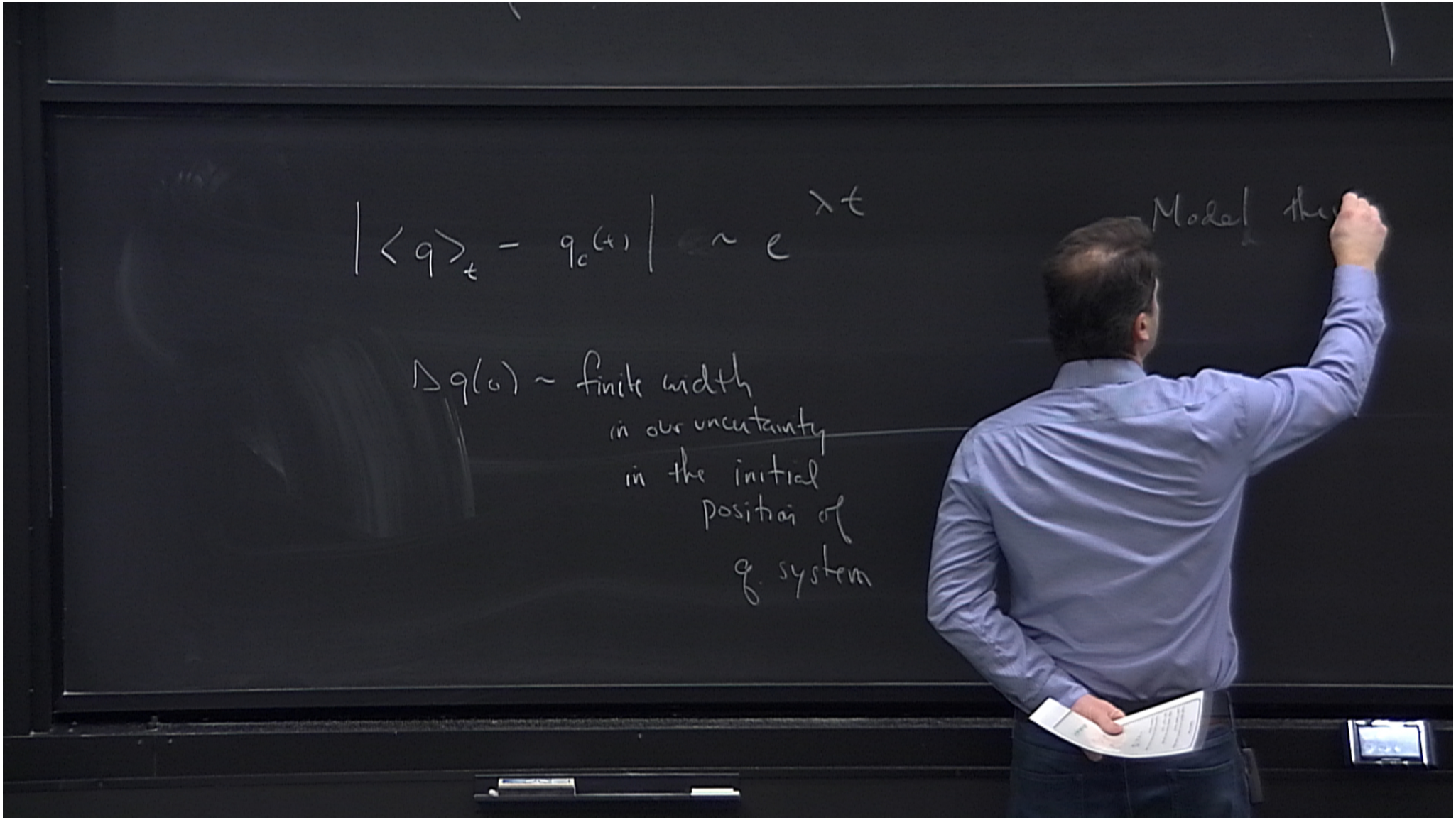
$|1\rangle \otimes |dead\rangle$

$+ |0\rangle \otimes |alive\rangle$

Trace out electron

$|dead\rangle\langle dead|$

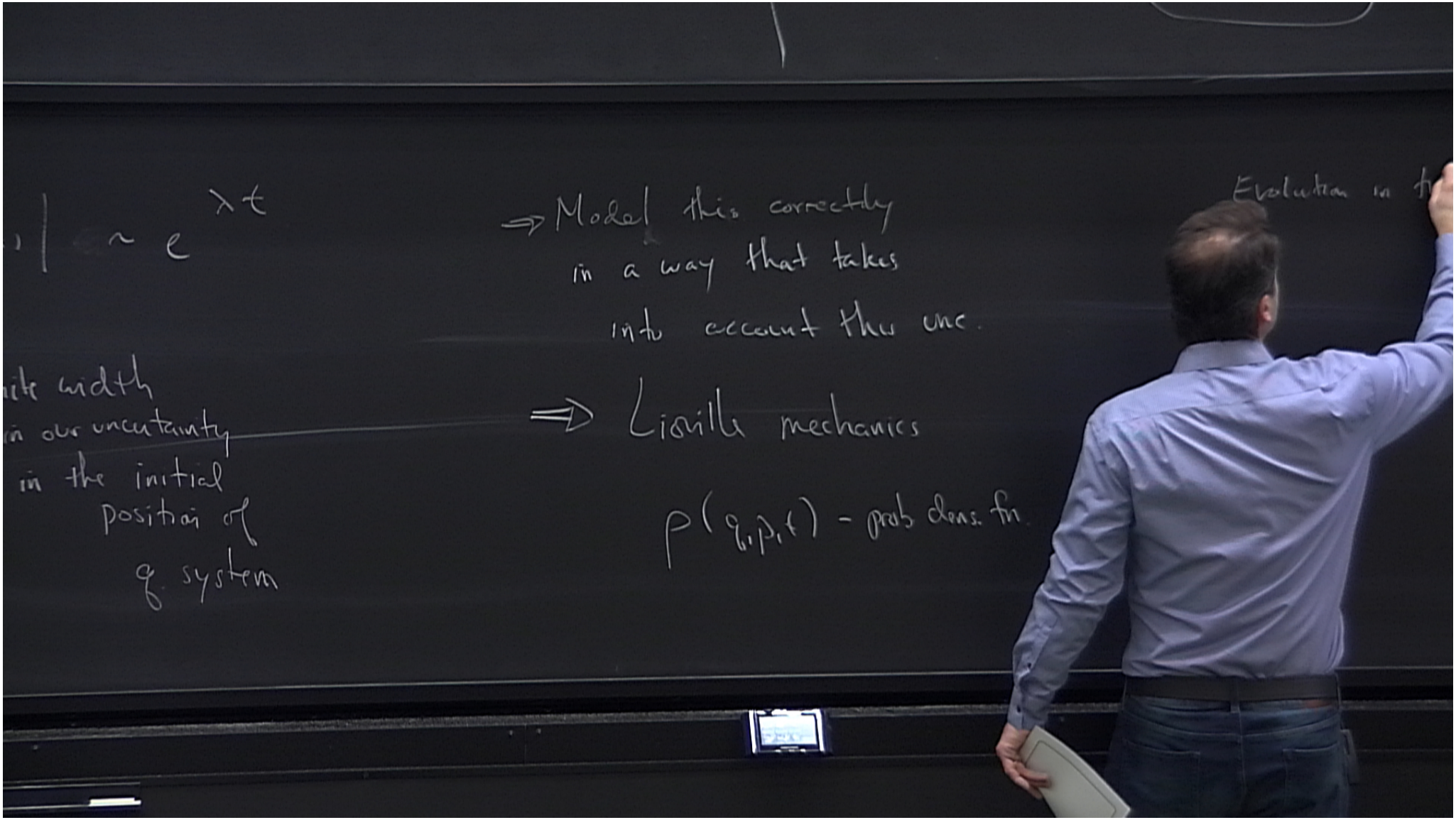
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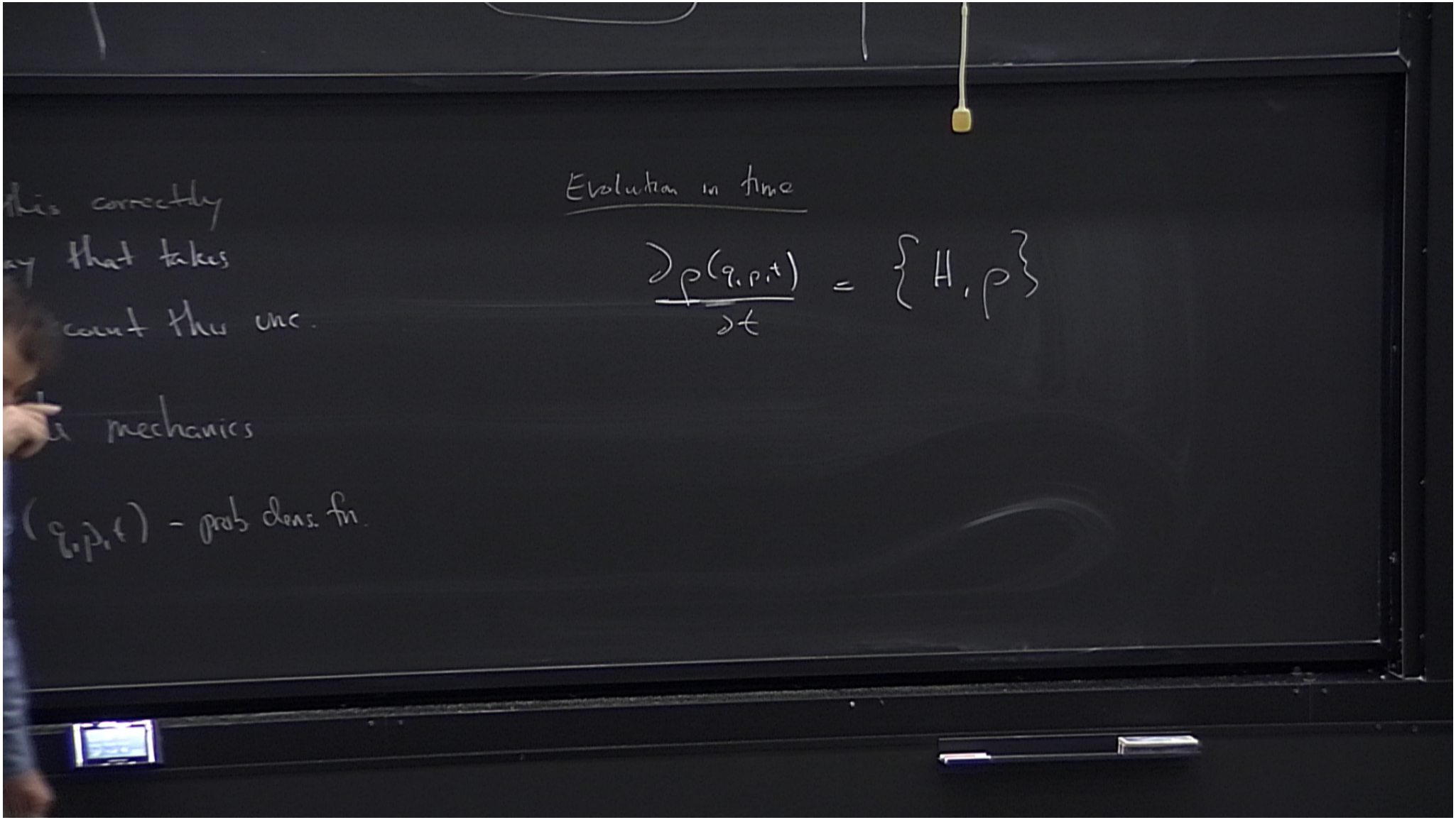

$|\langle q \rangle_t - q_c(t)| \sim e^{\lambda t}$
Model the
$\Delta q(0) \sim$ finite width
in our uncertainty
in the initial
position of
q. system

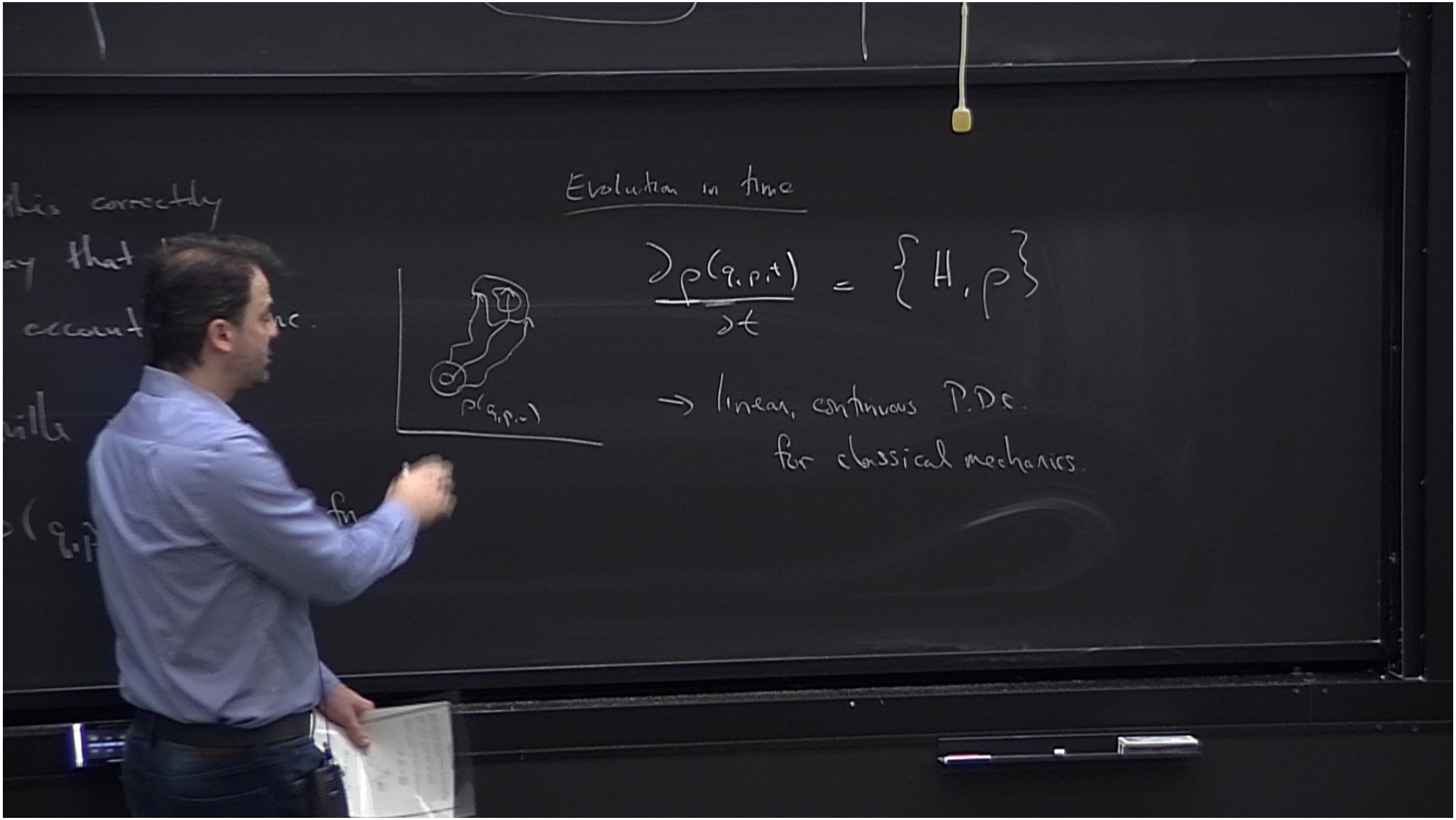
$\sim e^{\lambda t}$

⇒ Model this correctly in a way that takes into account the unc.

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$\sim e^{\lambda t}$
⇒ Model this correctly
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⇒ Liouville mechanics
$\rho(q, p, t)$ - prob dens. fn
in the initial
position of
q system


this correctly
ay that takes
count thru unc.
mechanics
(q,p,t) - prob dens. fn.
Evolution in time
$\frac{\partial \rho(q,p,t)}{\partial t} = \{H, \rho\}$


Evolution in time
$\frac{\partial \rho(q,p,t)}{\partial t} = \{H, \rho\}$
$\rho(q,p,\cdot)$
→ linear, continuous P.D.E.
for classical mechanics.

Evolution in time

$$\frac{\partial \rho(q,p,t)}{\partial t} = \{H, \rho\}$$



$\Rightarrow$ linear, continuous P.D.E. for classical mechanics.

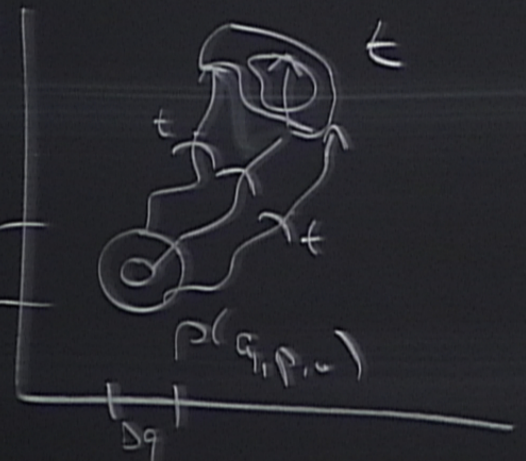
symplectic

$\Rightarrow$ areas are conserved.

fn

Evolution in time

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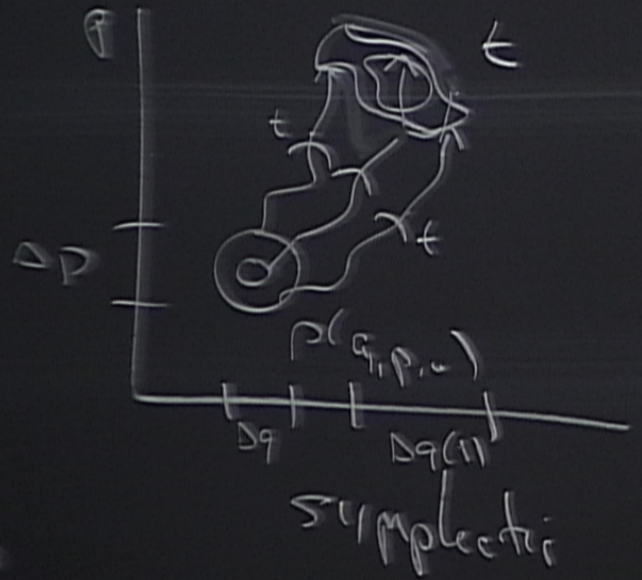
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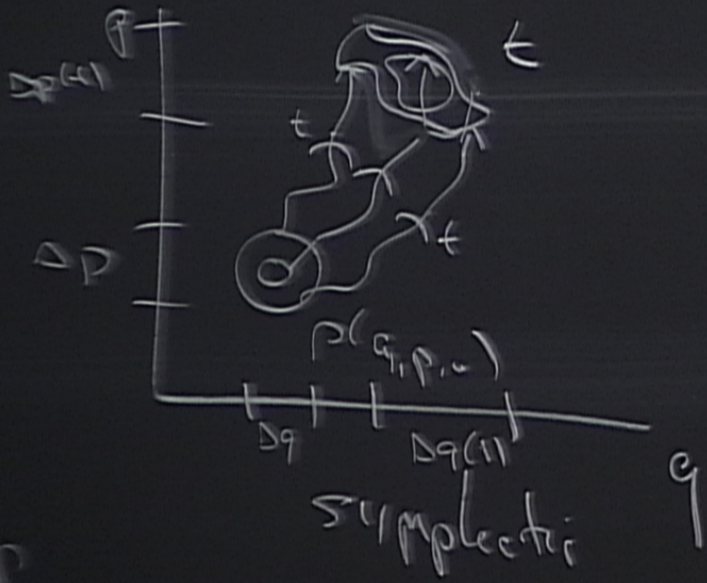
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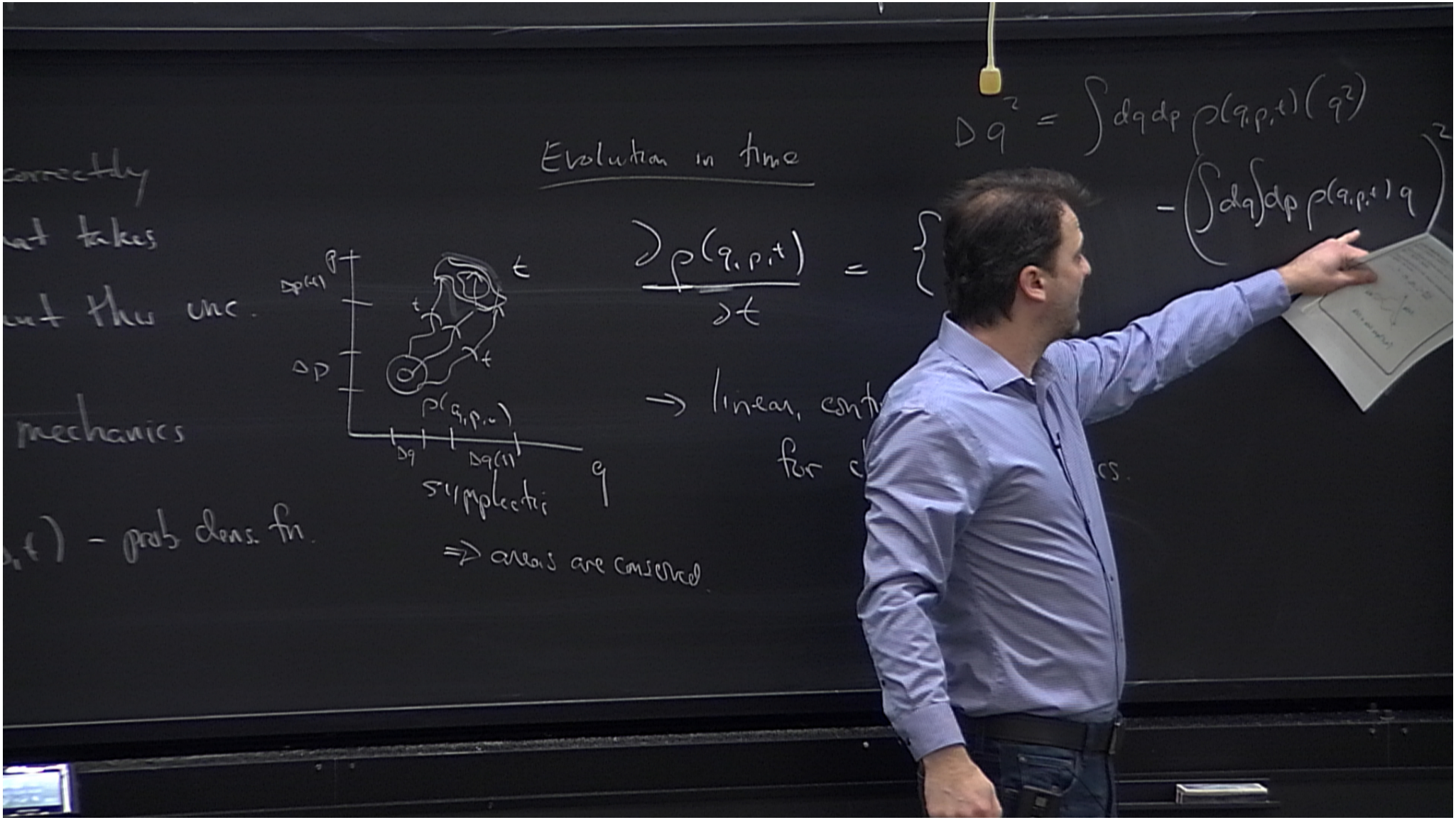


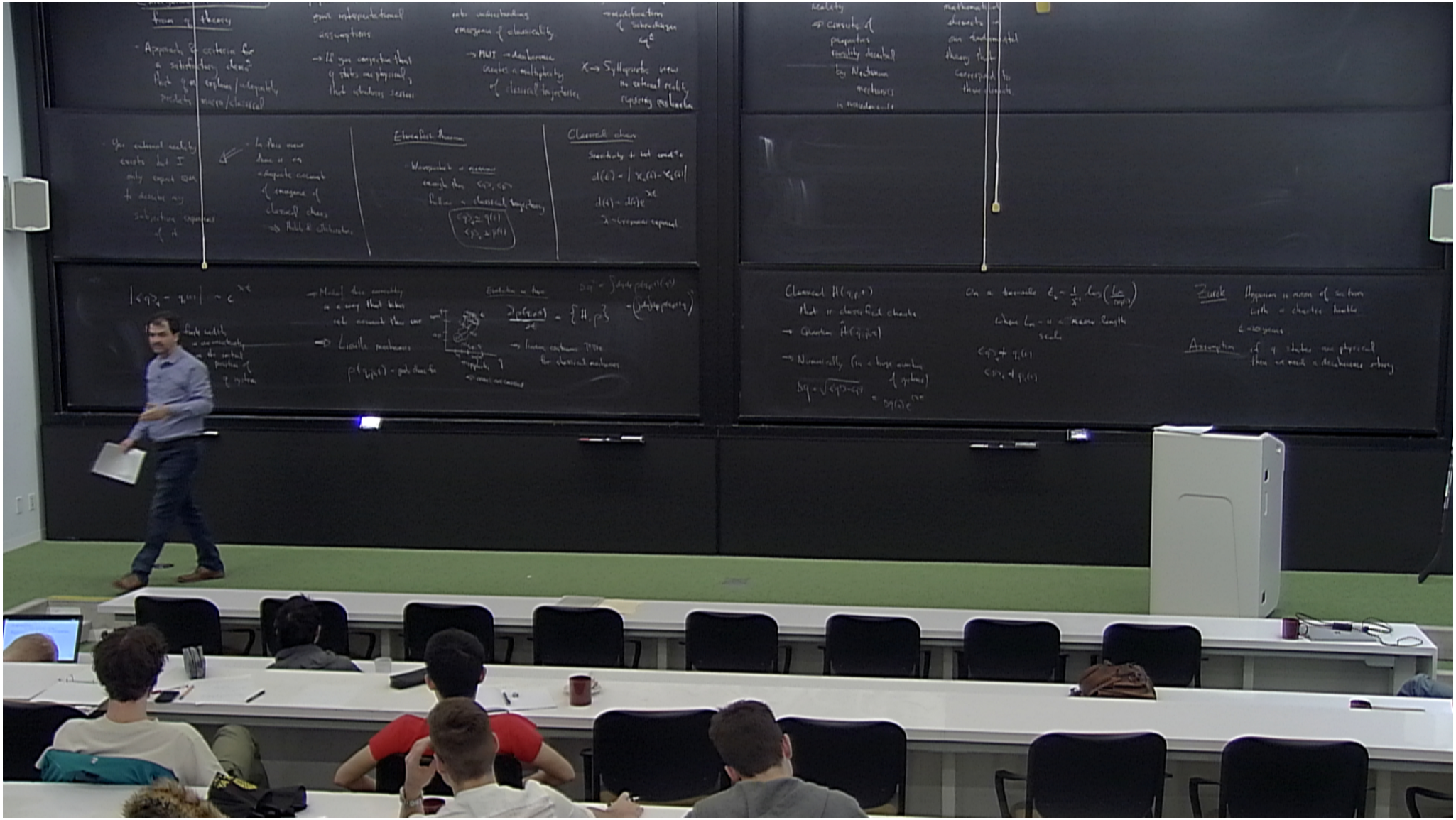
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$\Rightarrow$ areas are conserved.


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,t) - prob dens. fn.
Evolution in time
$\frac{\partial \rho(q,p,t)}{\partial t} = \{$
$\Delta q^2 = \int dq\,dp\,\rho(q,p,t)(q^2)$
$-\left(\int dq \int dp\,\rho(q,p,t)\,q\right)^2$
$\Delta p(t)$
Δp
$\rho(q,p,0)$
Δq
$\Delta q(t)$
q
p
t
symplectic
$\Rightarrow$ areas are conserved
$\Rightarrow$ linear, cons
for c
cs.


Ehrenfest theorem
Classical chaos
Classical H(q,p,t)
Zurek
Assertion

$$Dq^2 = \int dq\,dp\,\rho(q,p,t)\,(q^2) - \left(\int dq \int dp\,\rho(q,p,t)\,q\right)^2$$

$$= \{H, \rho\}$$

$\frac{1}{\lambda^{-1}} \log\left(\frac{L_m}{D_q(\alpha)}\right)$

= macro length

Zurek: Hyperion is moon of saturn with a chaotic tumble

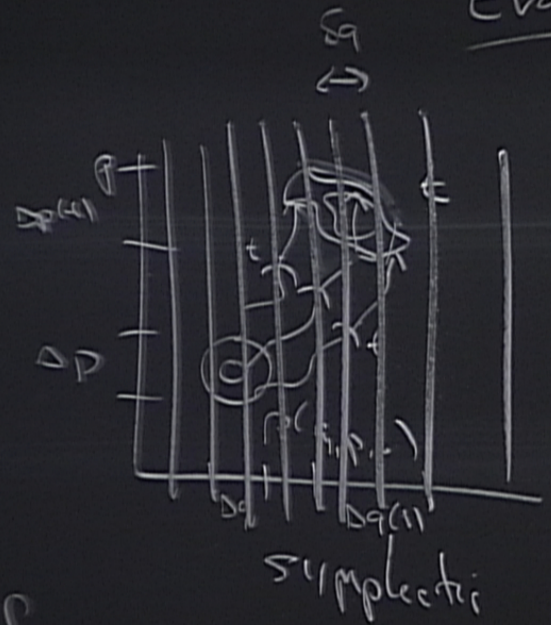
$t \sim 20$ years.

Assumption: if q states are physical then we need a decoherence story.

Evolution in time

$$\Delta q^2 = \int dq\,dp\,\rho(q,p,t)\,(q^2$$

$$-\left(\int dq \int dp\,\rho(q\right.$$



unc.

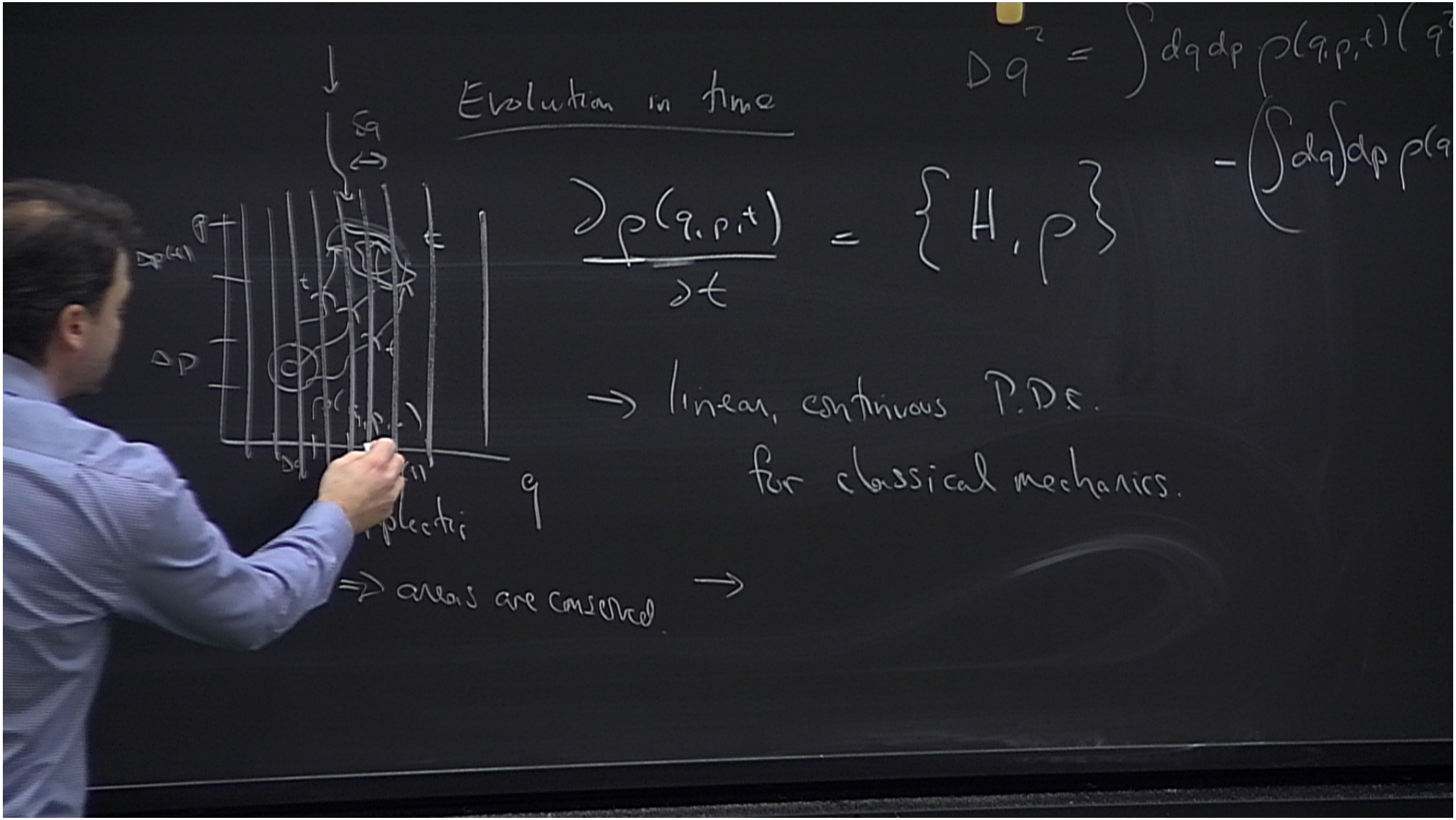
$$\frac{\partial \rho(q,p,t)}{\partial t} = \{H,\rho\}$$

$\rightarrow$ linear, continuous P.D.E.
for classical mechanics.

symplectic

dens. fn.

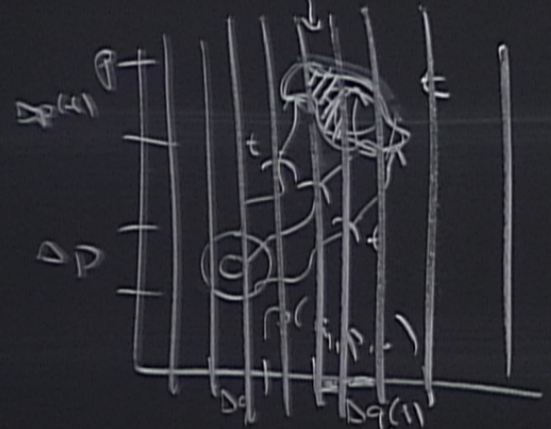
$\Rightarrow$ areas are conserved $\rightarrow$


Evolution in time
$\Delta q^2 = \int dq\,dp\,\rho(q,p,t)\,(q$
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Δq
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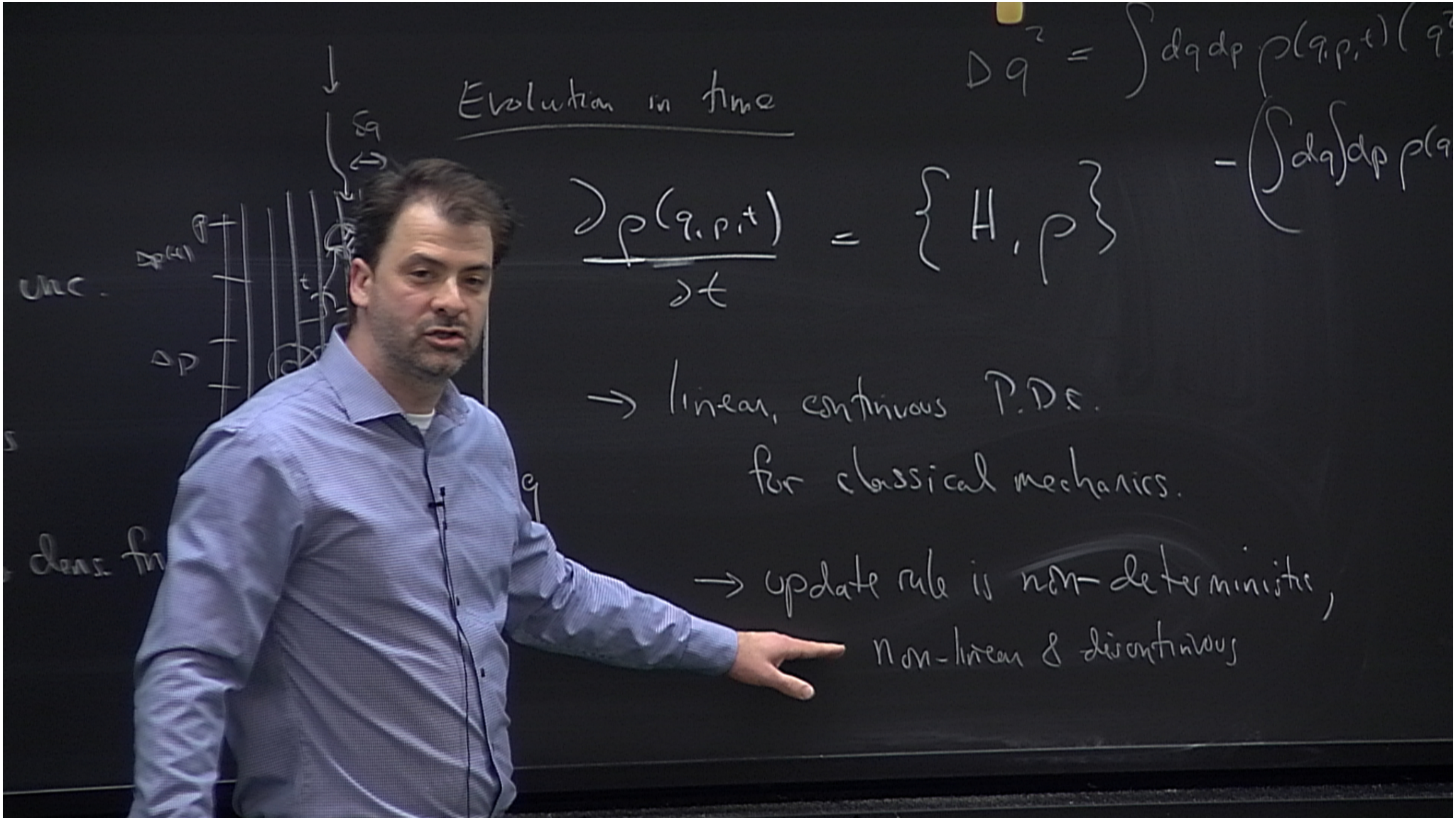
→ linear, continuous P.D.E.
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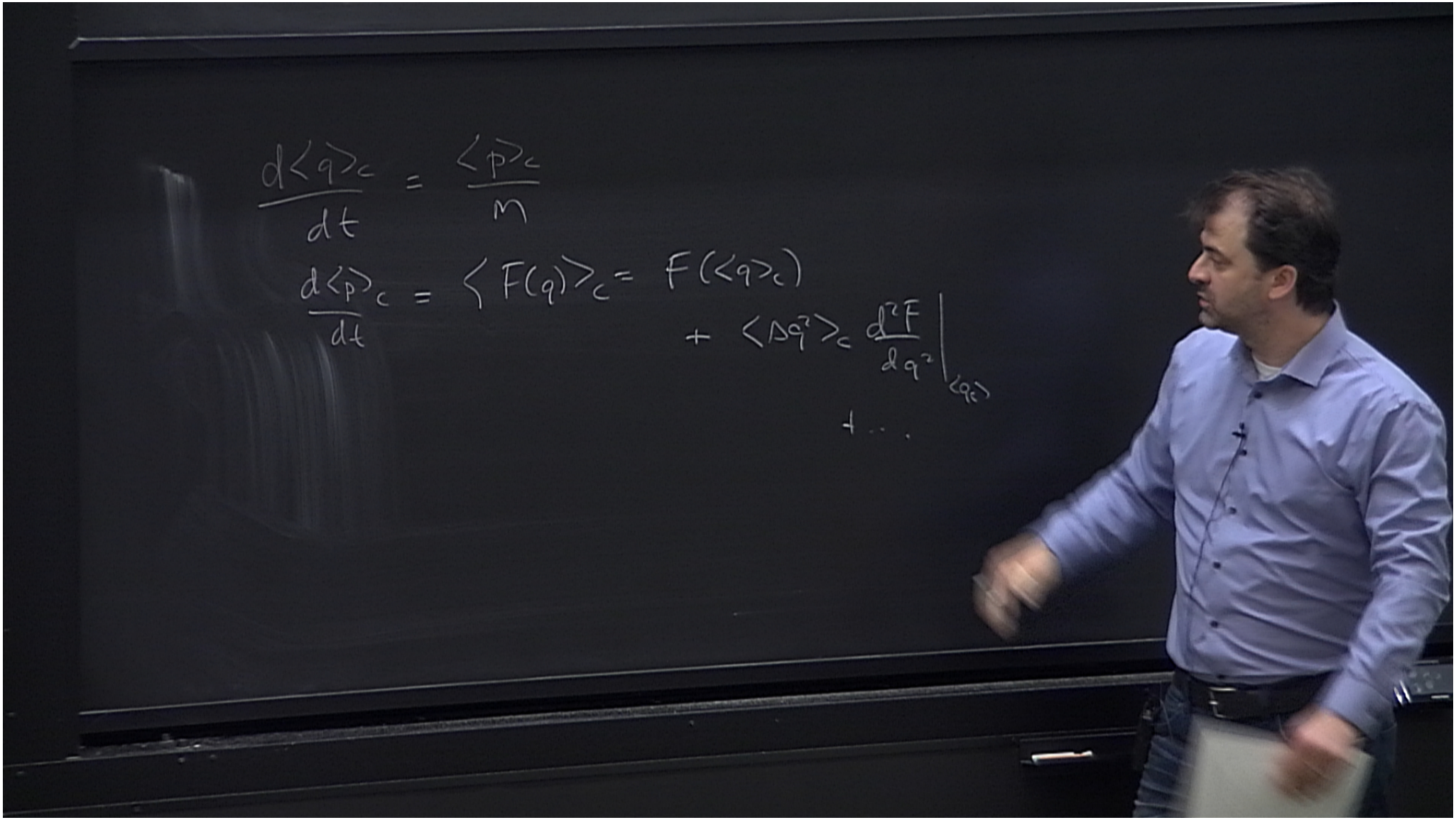
symplectic

⇒ areas are conserved →

unc.

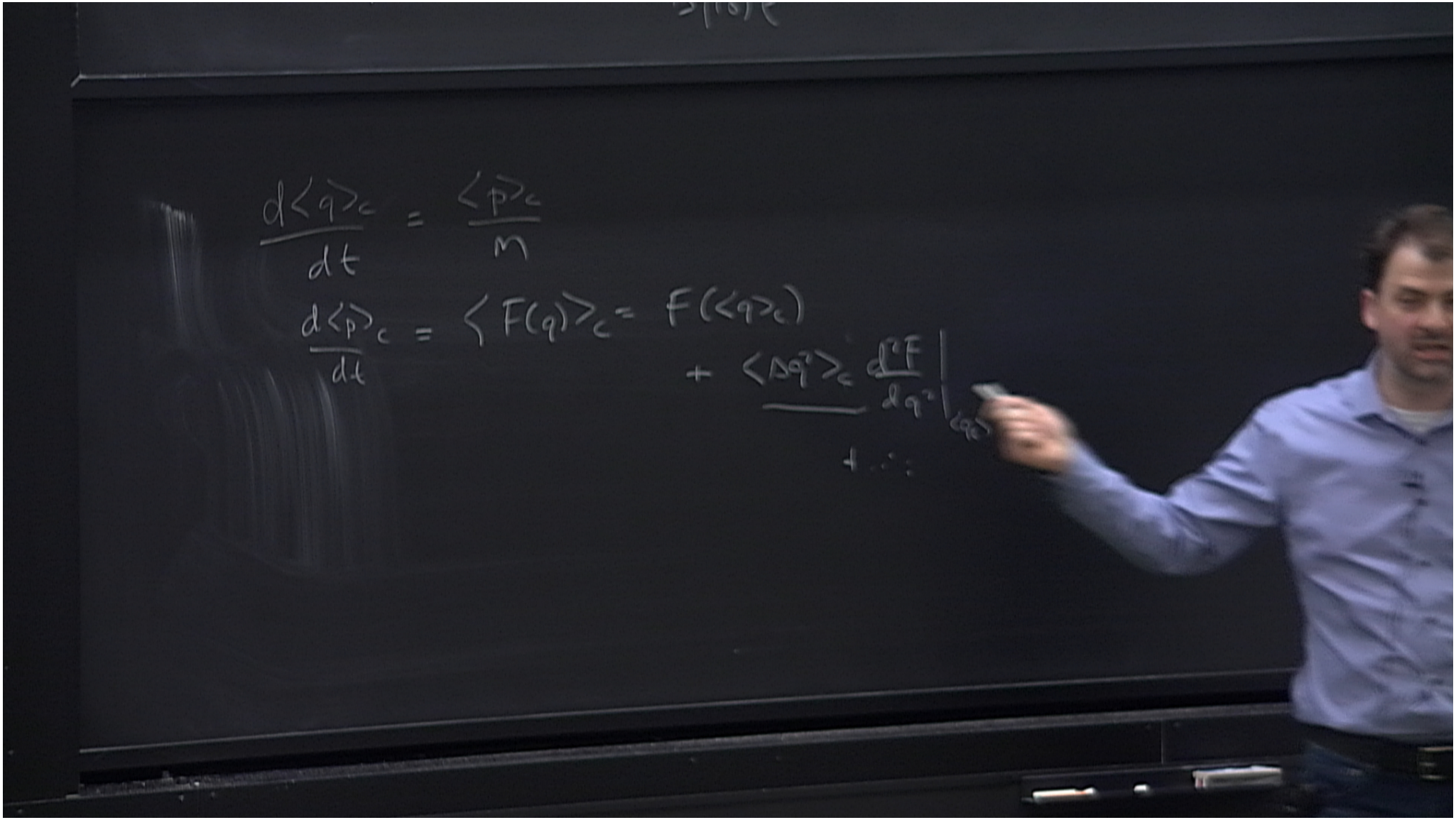
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$-\left(\int dq \int dp\,\rho(q$
unc.
$\Delta p(t)$
Δp
Δq
→ linear, continuous P.D.E.
for classical mechanics.
→ update rule is non-deterministic,
non-linear & discontinuous

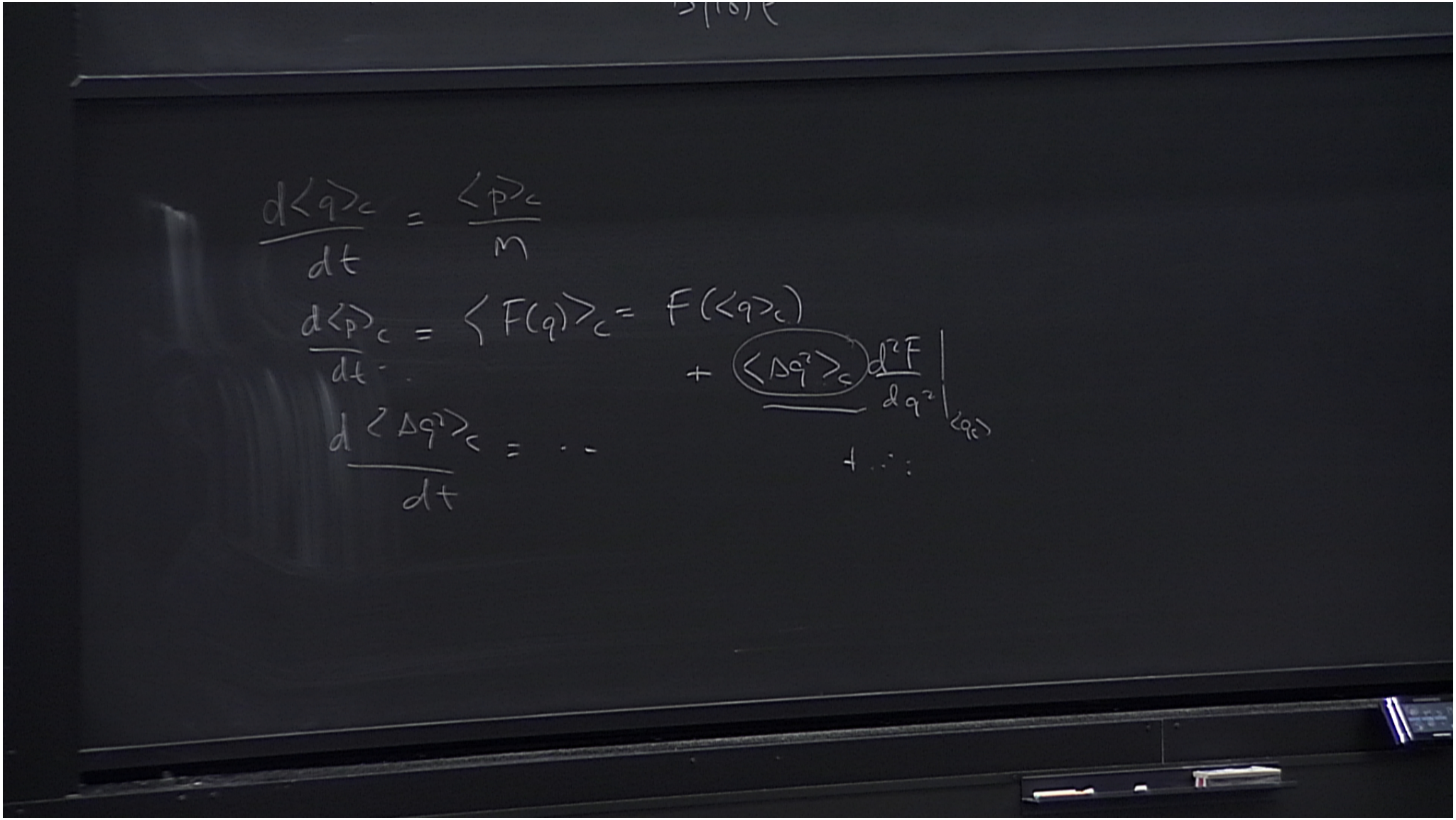

$\frac{d\langle q\rangle_c}{dt} = \frac{\langle p\rangle_c}{m}$
$\frac{d\langle p\rangle_c}{dt} = \langle F(q)\rangle_c = F(\langle q\rangle_c)$
$+ \langle \Delta q^2\rangle_c \left.\frac{d^2F}{dq^2}\right|_{\langle q\rangle}$
$+ \ldots$

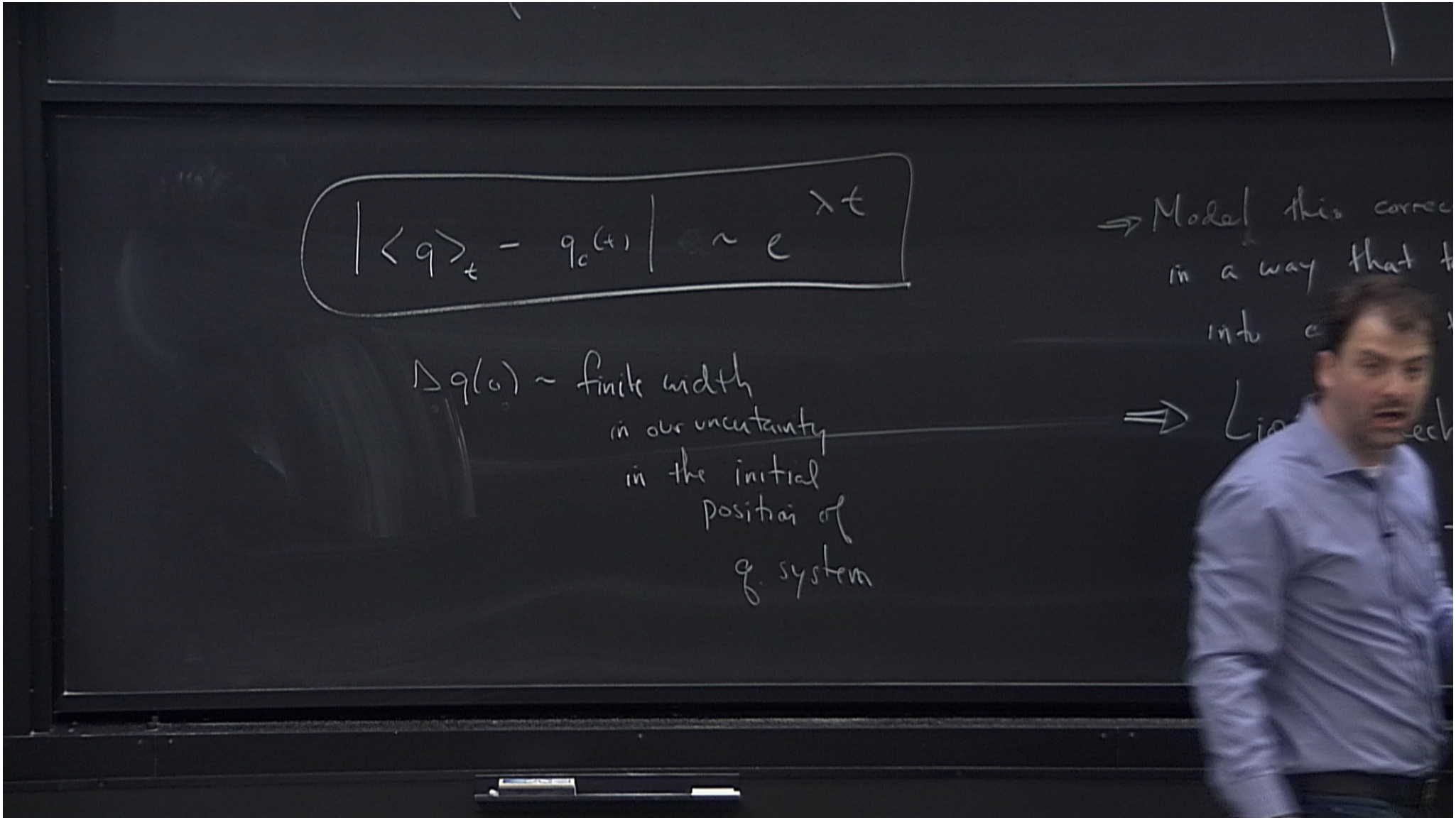
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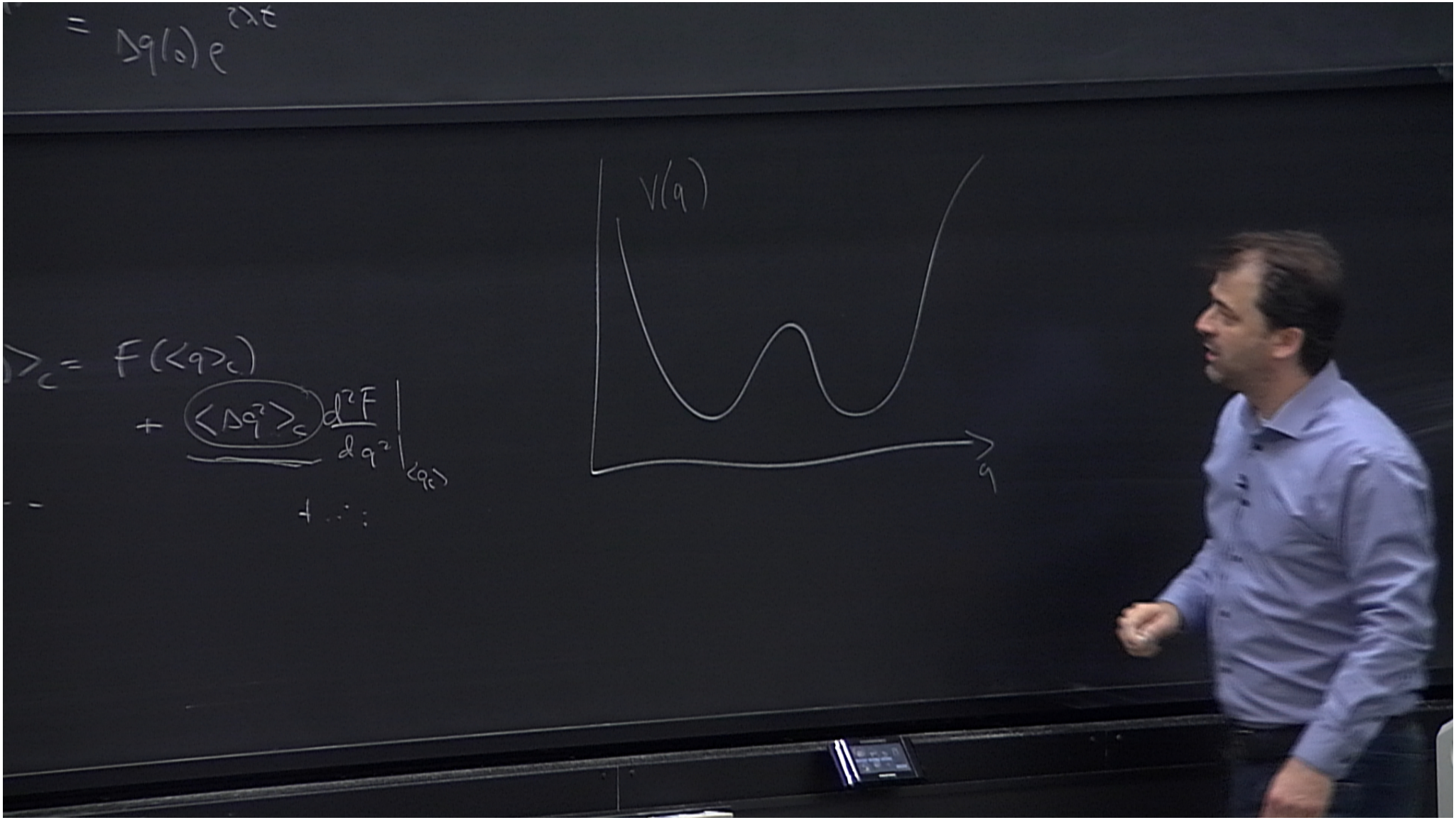
$$\frac{d\langle p\rangle_c}{dt} = \langle F(q)\rangle_c = F(\langle q\rangle_c) + \langle \Delta q^2\rangle_c \left.\frac{d^2F}{dq^2}\right|_{\langle q\rangle} + \dots$$

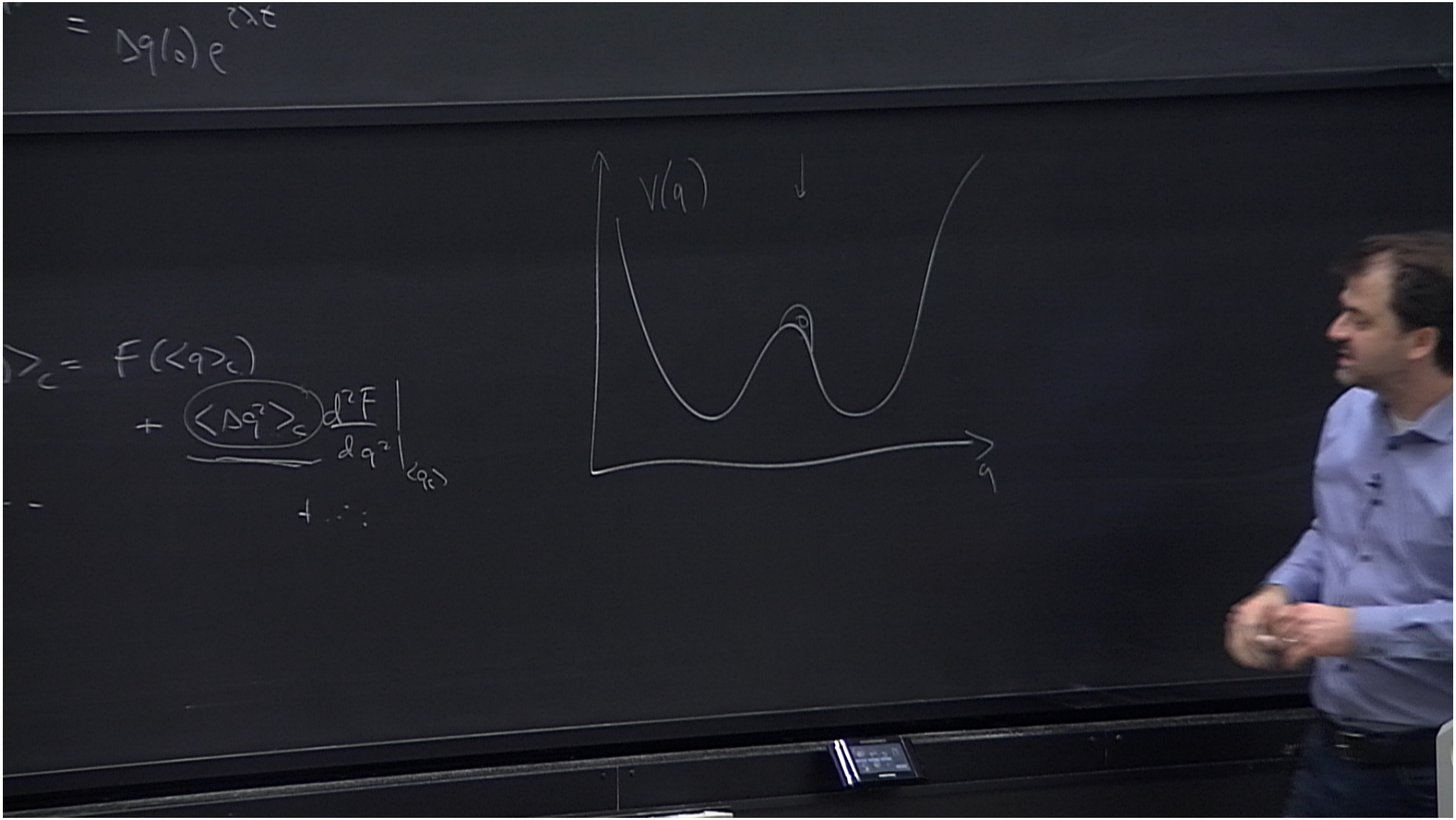

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$+ \langle \Delta q^2\rangle_c \frac{d^2F}{dq^2}\Big|_{\langle q\rangle}$
$+ \cdots$

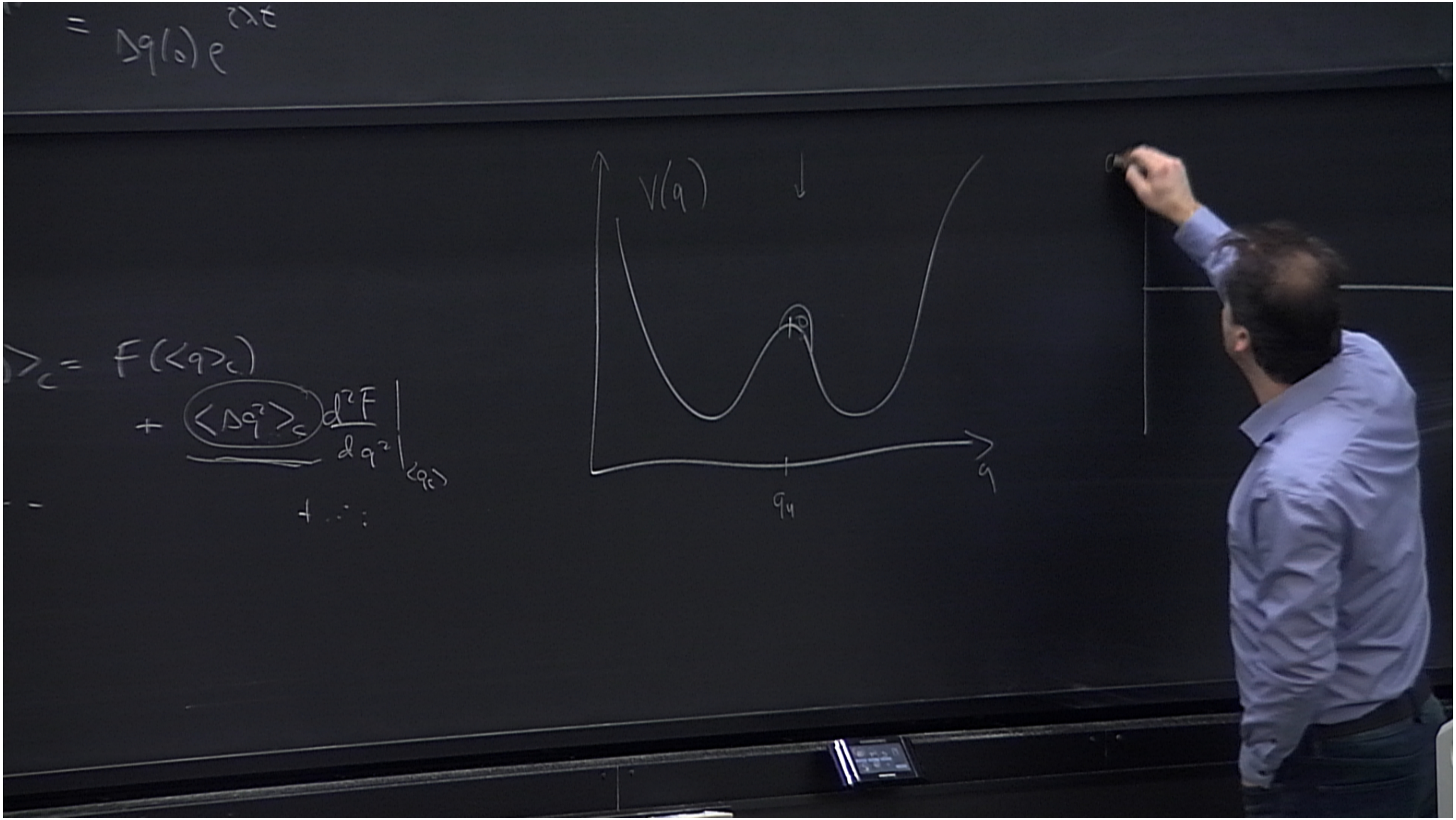

$\frac{d\langle q\rangle_c}{dt} = \frac{\langle p\rangle_c}{m}$
$\frac{d\langle p\rangle_c}{dt} = \langle F(q)\rangle_c = F(\langle q\rangle_c)$
$+ \langle \Delta q^2\rangle_c \frac{d^2F}{dq^2}\Big|_{\langle q\rangle}$

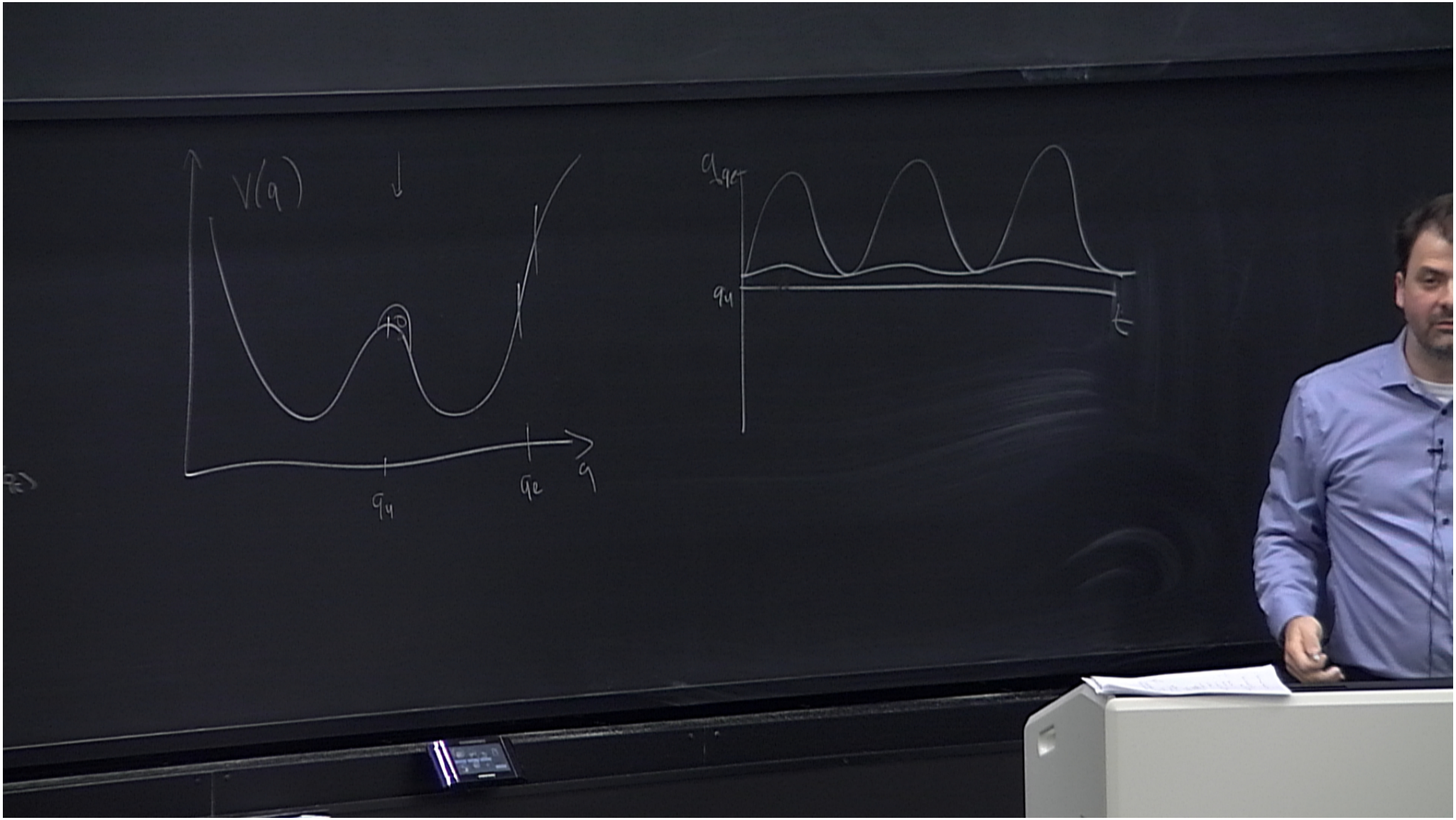

$\frac{d\langle q\rangle_c}{dt} = \frac{\langle p\rangle_c}{m}$
$\frac{d\langle p\rangle_c}{dt} = \langle F(q)\rangle_c = F(\langle q\rangle_c)$
$+ \langle \Delta q^2\rangle_c \frac{d^2F}{dq^2}\Big|_{\langle q\rangle}$
$\frac{d\langle \Delta q^2\rangle_c}{dt} = \cdots$
$+ \cdots$


$|\langle q \rangle_t - q_c(t)| \sim e^{\lambda t}$
$\Rightarrow$ Model this
in a way that
into
$\Delta q(0) \sim$ finite width
in our uncertainty
in the initial
position of
q. system
$\Rightarrow$

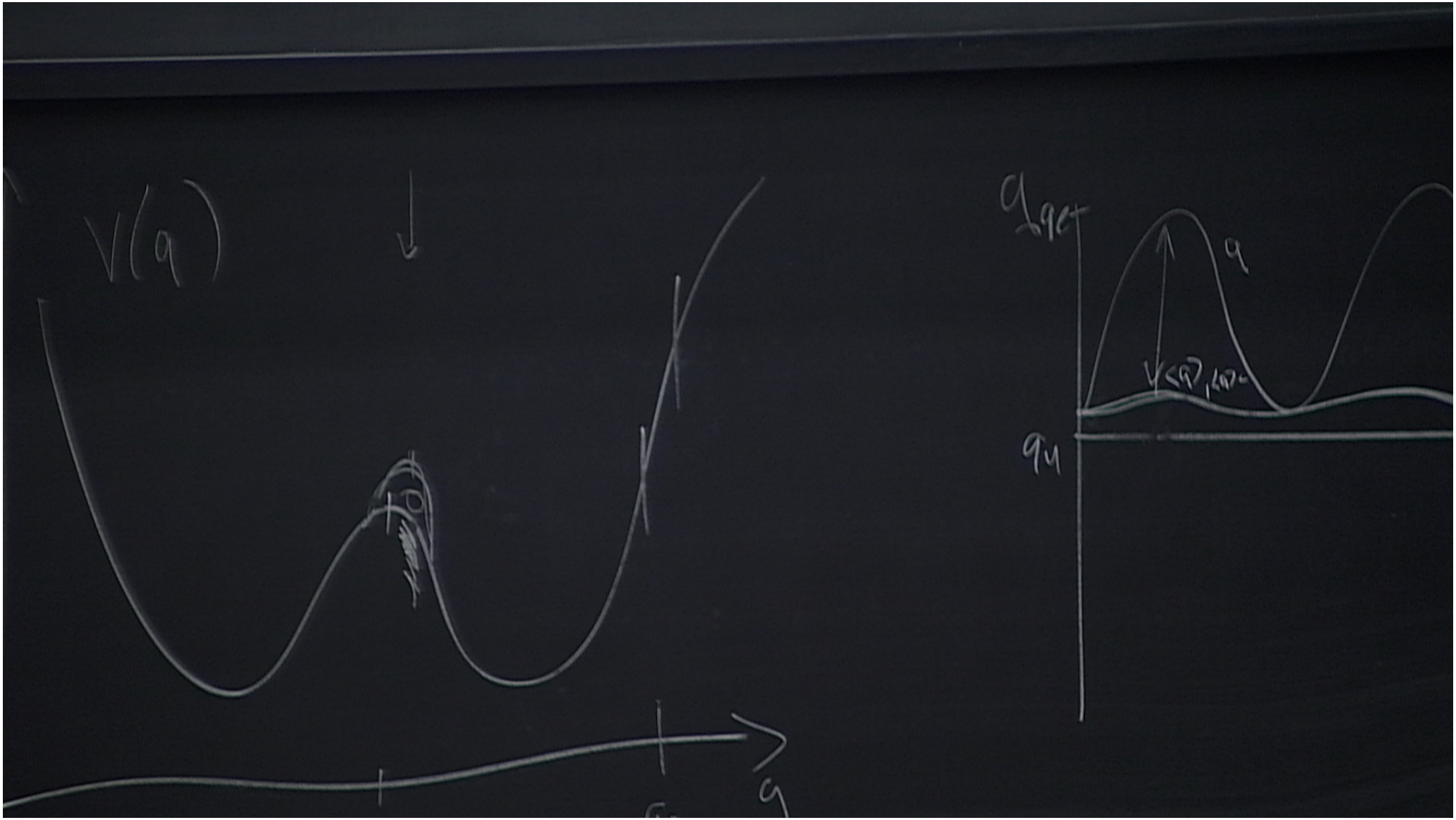

= Δq(0) e^{zλt}
V(q)
q
>c = F(<q>c)
+ <Δq²>c d²F/dq² |<q>c
+ ...


= Δq(0) e^{zλt}
V(q)
q
>_c = F(<q>_c)
+ <Δq²>_c d²F/dq² |_{<q>_c}
+ ...


= Δq(0) e^{zλt}
V(q)
q
q_4
F(⟨q⟩_c)
⟨Δq²⟩_c d²F/dq² |_⟨q⟩


V(q)
q_A
q_e
q
q_{act}
q_A
t


V(q)
q_4
q_{qc}
q
<q>
q_4
t


V(q)
q
q