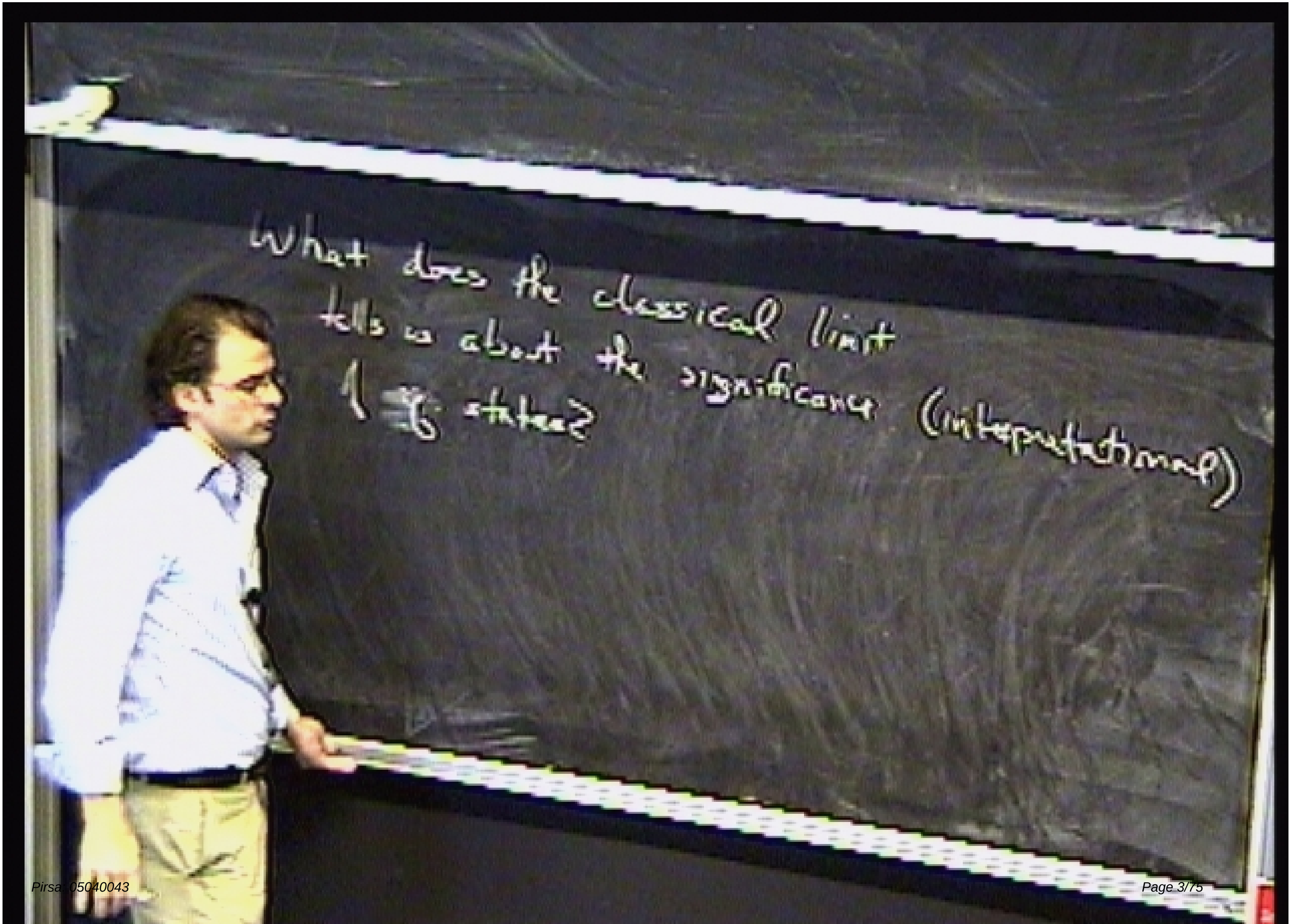
Title: Interpretation of Quantum Theory: Lecture 25

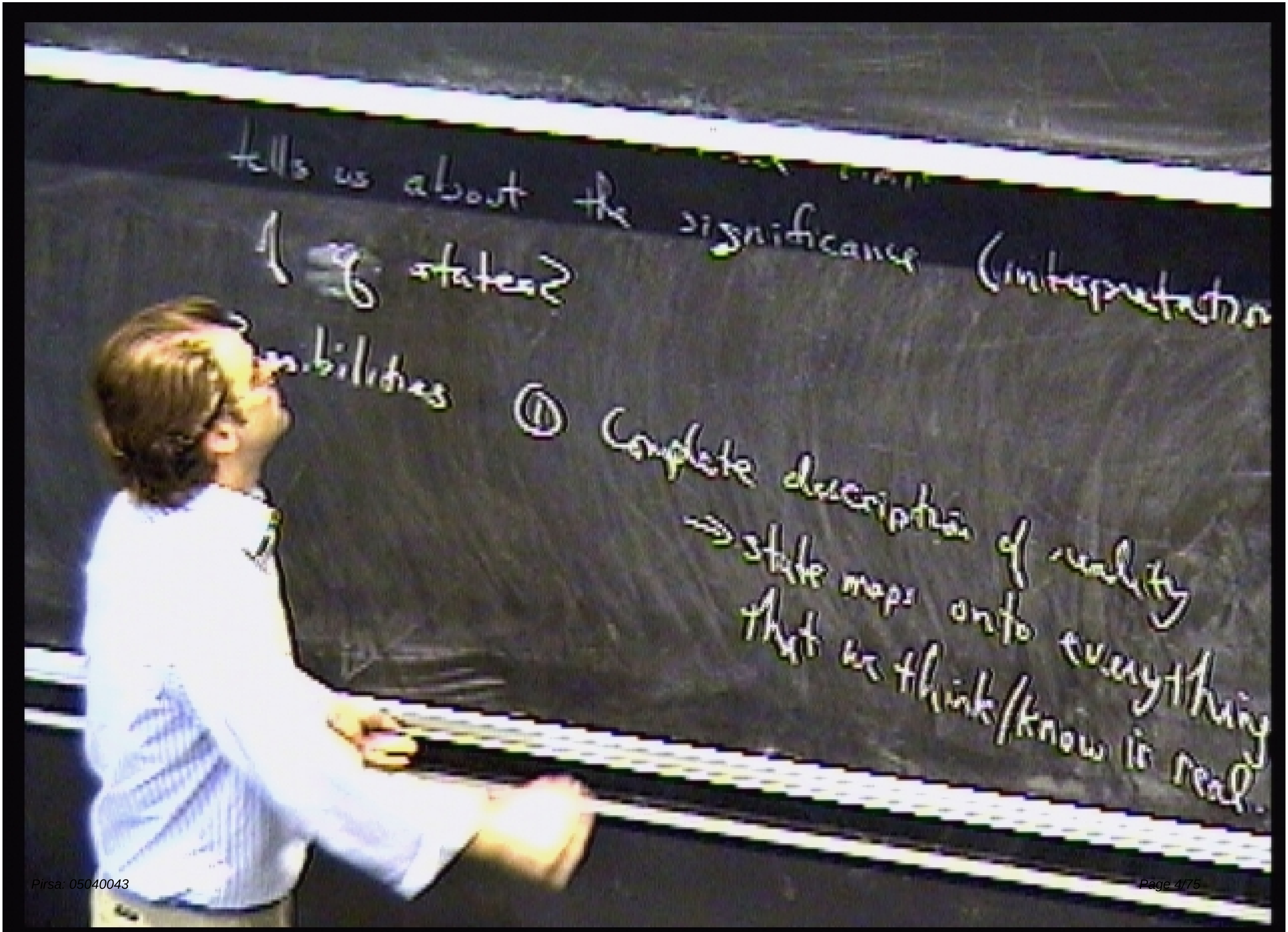
Date: Apr 05, 2005 02:15 PM

URL: http://pirsa.org/05040043

Abstract:

Spring Seminars on
Complexity and Networks
May 19, — June 16, 2005
PI, Thursdays. 2.15. p.m


What does the classical limit
tells us about the significance (interpretational)
of states?


tells us about the significance (interpretation
of states?
bilities ① Complete description of reality
⇒ state maps onto everything
that we think/know is real...

② Partial description of what is real

(2) Partial description of what is 'real'

e.g. de Broglie Bohm

... is real.

(2) Q. States give a Partial description of what is real
e.g. deBroglie Bohm

(3) Q states have nothing real about them.
Statistical Information only.

... knows is real.

(2) Q. States give a
Partial description of what is real
e.g. deBroglie Bohm

(3) Q states have nothing real about them.
Statistical Information only.
Ehrenfest (1927)

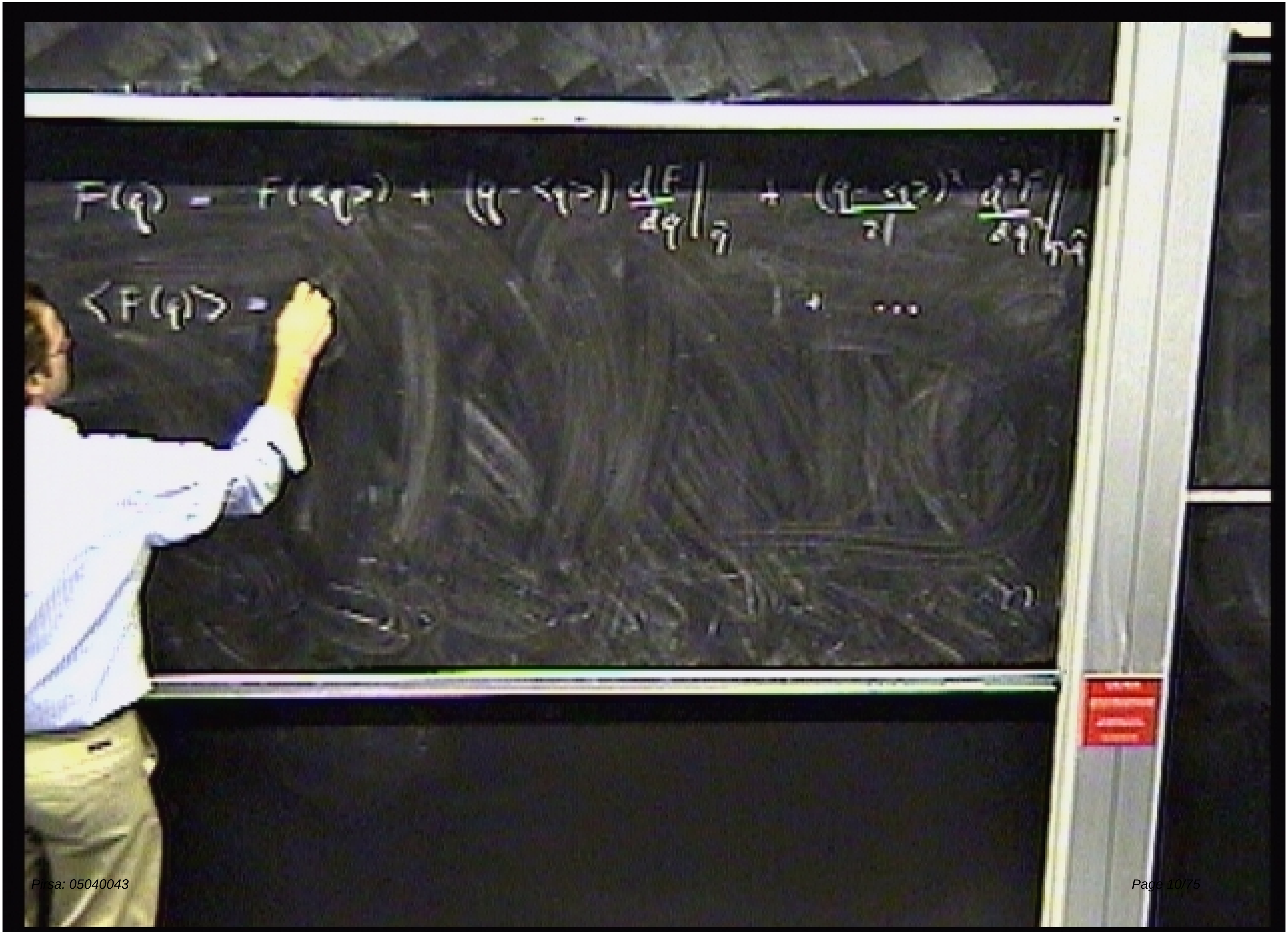
... Brahm

(3) ① states have nothing real about them.
Statistical Information only.

Ehrenfest (1927)

$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m} \qquad \langle \hat{q}\rangle \equiv \langle \psi_t | \hat{q} | \psi_t\rangle$$

$$\frac{d\langle p\rangle}{dt} = \langle F(\hat{q})\rangle \equiv \left\langle \frac{dV}{dq}\bigg|_{\hat{q}} \right\rangle$$


$F(q) = F(\langle q \rangle) + (q - \langle q \rangle) \frac{dF}{dq}\Big|_{\bar{q}} + \frac{(q - \langle q \rangle)^2}{2!} \frac{d^2F}{dq^2}\Big|_{q=\bar{q}}$
$\langle F(q) \rangle = \quad + \; \ldots$

$$F(q) = F(\langle q\rangle) + (q-\langle q\rangle)\left.\frac{dF}{dq}\right|_{\langle q\rangle} + \frac{(q-\langle q\rangle)^2}{2!}\left.\frac{d^2F}{dq^2}\right|_{\langle q\rangle}$$

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

Expand about q expectation value,

$$F(q) = F(\langle q\rangle) + (q - \langle q\rangle)\left.\frac{dF}{dq}\right|_{\langle q\rangle} + \frac{(q-\langle q\rangle)^2}{2!}\left.\frac{d^2F}{dq^2}\right|_{\langle q\rangle}$$

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

Expand about q expectation value,

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

~~Δp~~ Δq can be very narrow compared to the scale

set by $\frac{d^2V}{dq^2}$

Expand about q expectation value,

$$F(q) = F(\langle q \rangle) + (q - \langle q \rangle) \frac{dF}{dq}\Big|_{\langle q \rangle} + \frac{(q-\langle q \rangle)^2}{2!} \frac{d^2F}{dq^2}\Big|_{\langle q \rangle}$$

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

$\Delta p \, \Delta q$ can be very narrow compared to the scale

set by $\frac{d^2V}{dq^2} \sim L^{-2}$

fluctuation

can be negligible for macroscopic systems

$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m}$$

$$\frac{d\langle p\rangle}{dt} = F(\langle q\rangle)$$

$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m}$$

$$\frac{d\langle p\rangle}{dt} \approx F(\langle q\rangle)$$

Ex: particle $1g$. $t \sim 10^{10}$ years, $\Delta q(t) \sim 1\,cm$

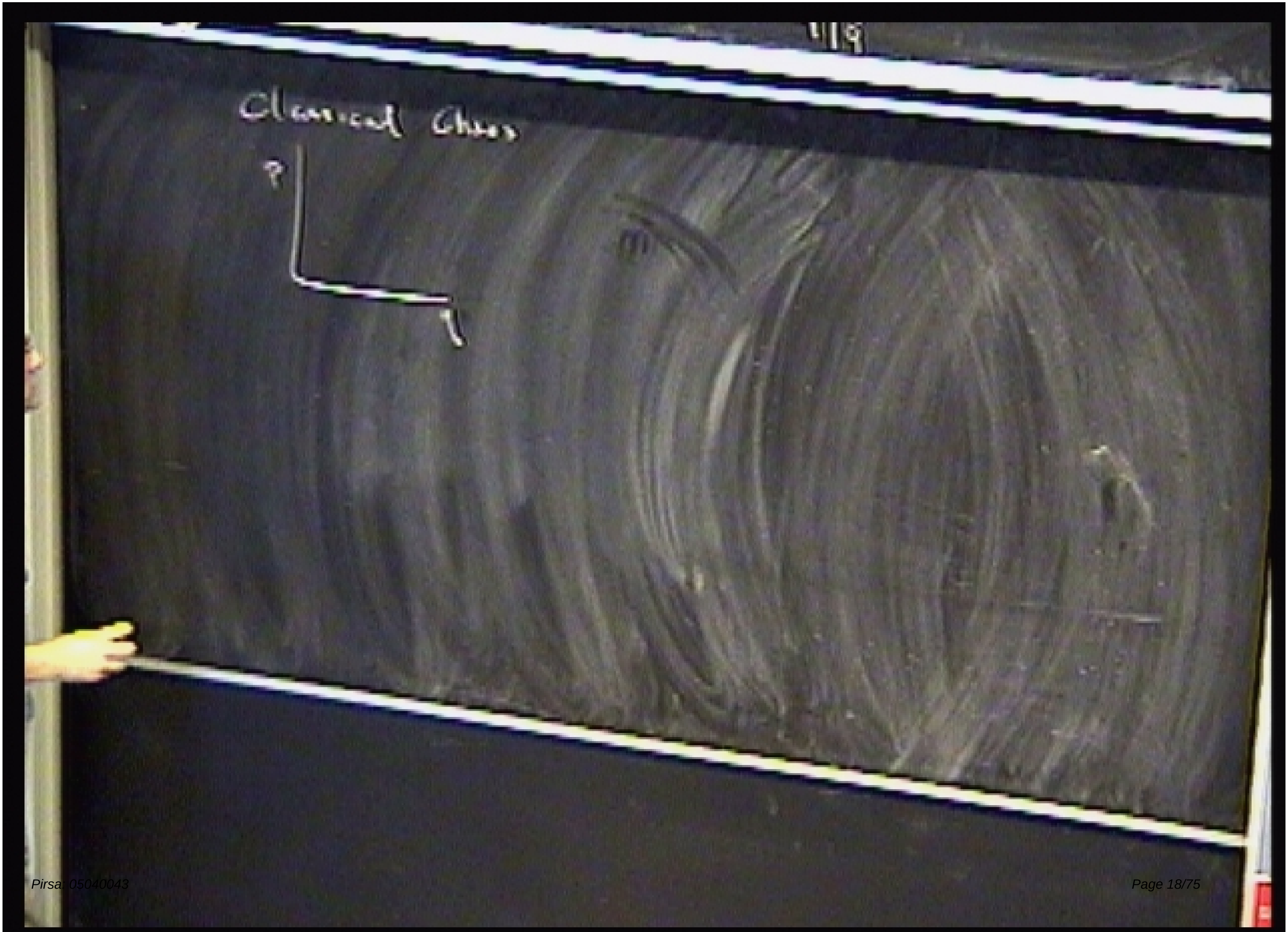
Start from narrow wave packet before $\Delta q(0) \sim 1\,Å$

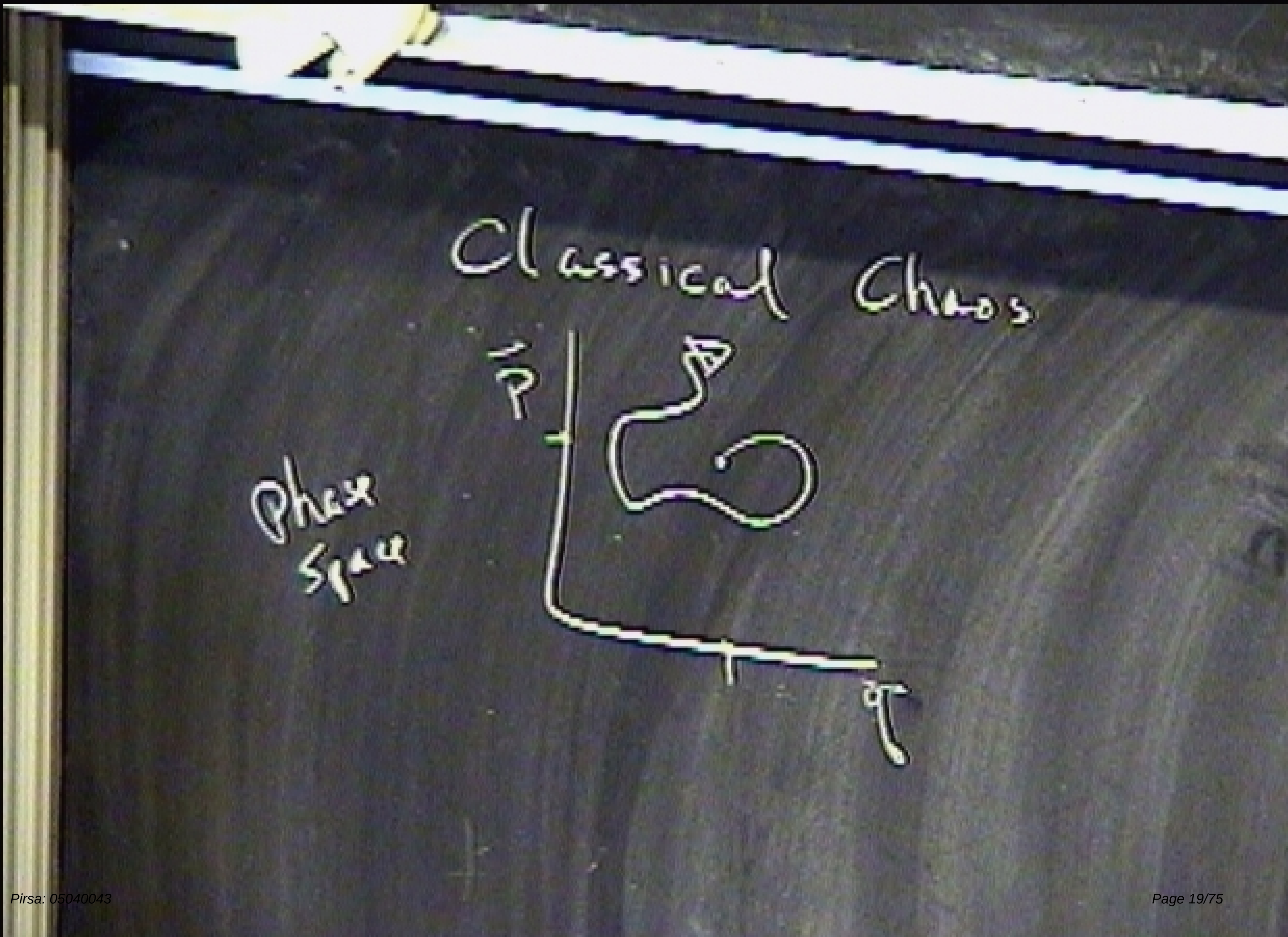
$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m}$$

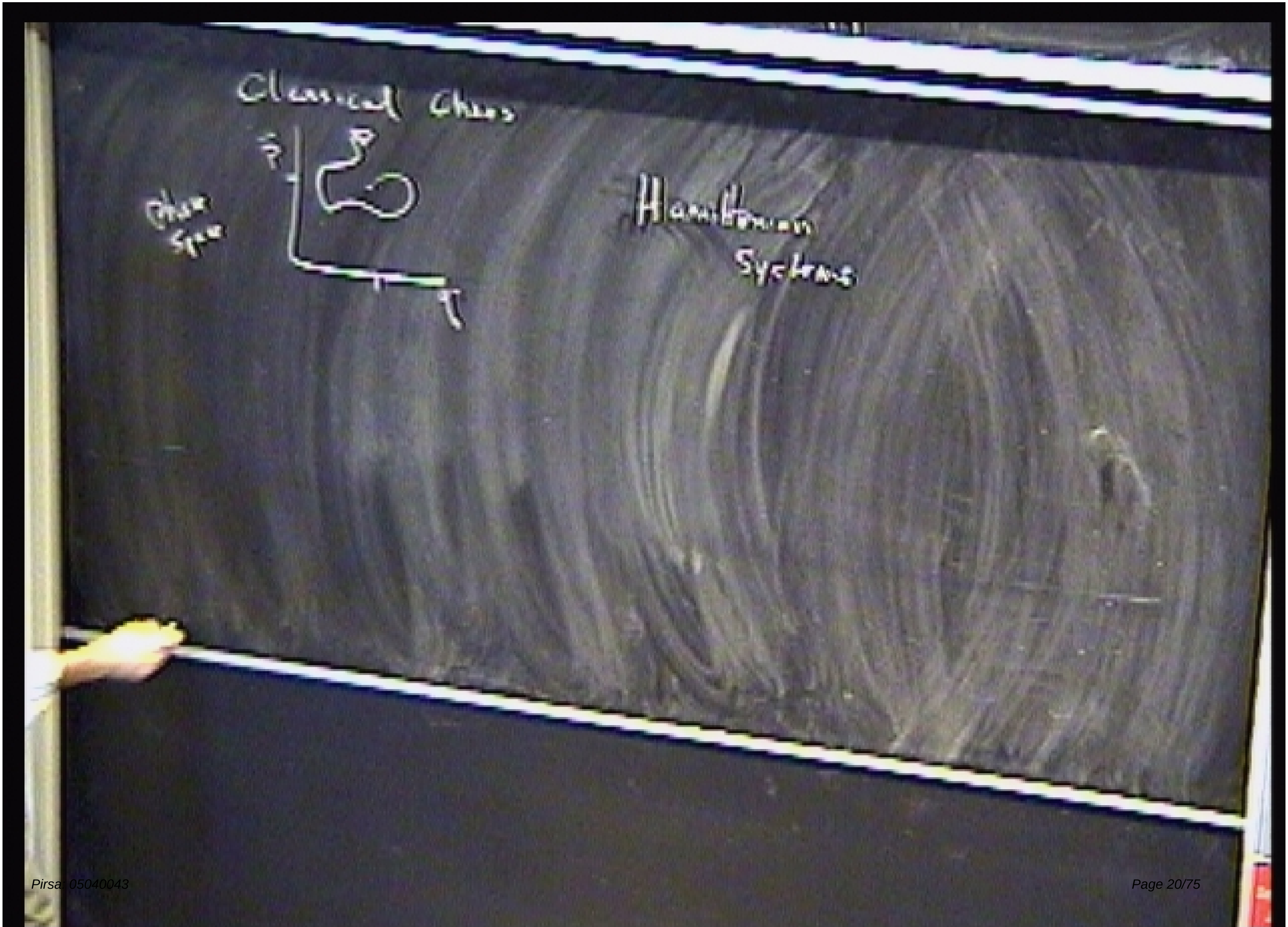
$$\frac{d\langle p\rangle}{dt} = F(\langle q\rangle)$$

Exa particle $1g$. $t = 10^{19}$ years, $\Delta q(t) \approx 1\,cm$

Start from narrow wave packet before $\Delta q(0) \sim 1Å$

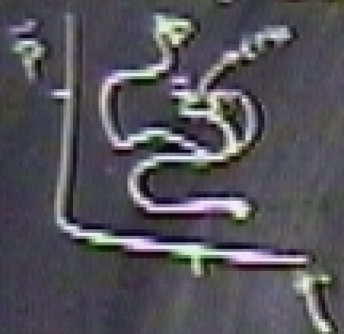

Classical Chaos
p
q


Classical Chaos
Phase Space
$\vec{p}$
$\vec{q}$


Classical Chaos
Phase Space
Hamiltonian Systems

Classical Chaos

Phase space

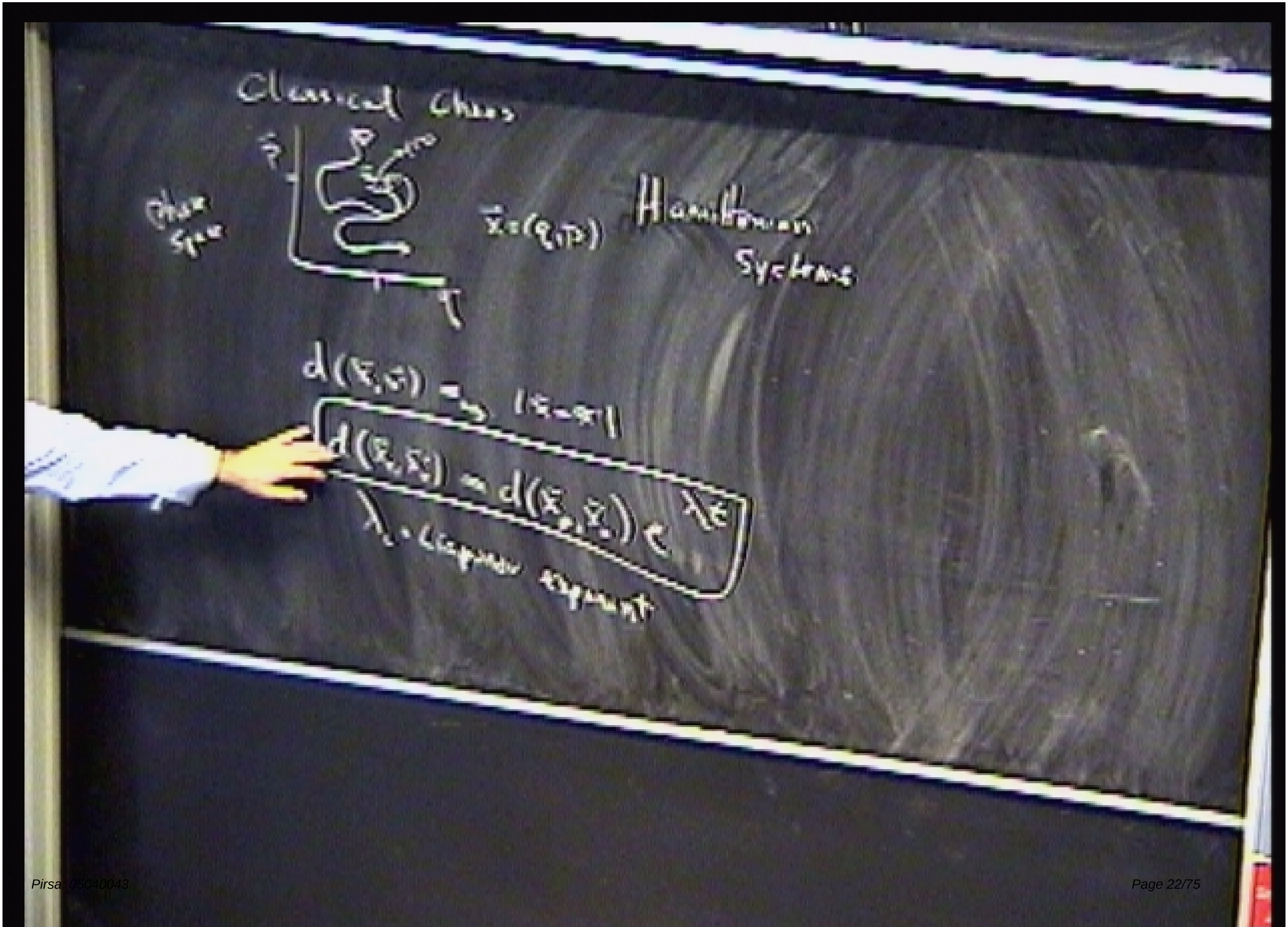


$\vec{x} = (\vec{q}, \vec{p})$ Hamiltonian Systems

$d(\vec{x},\vec{y}) = \text{Eucl.}\ |\vec{x}-\vec{y}|$

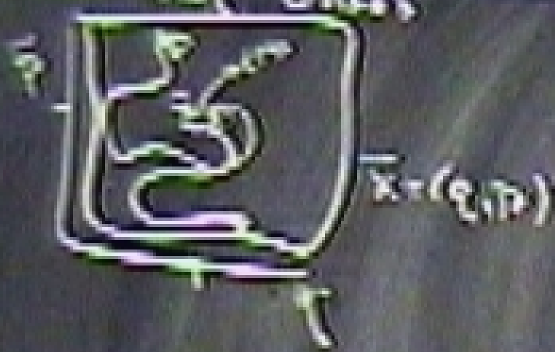
$d(\vec{x}_t,\vec{x}'_t) \approx d(\vec{x}_0,\vec{x}'_0)\, e^{\lambda t}$

λ = Lyapunov exponent


Classical Chaos
Phase Space
$\vec{x} = (\vec{q}, \vec{p})$
Hamiltonian Systems
λ_L = Lyapunov exponent

Classical Chaos

Phase Space Ω



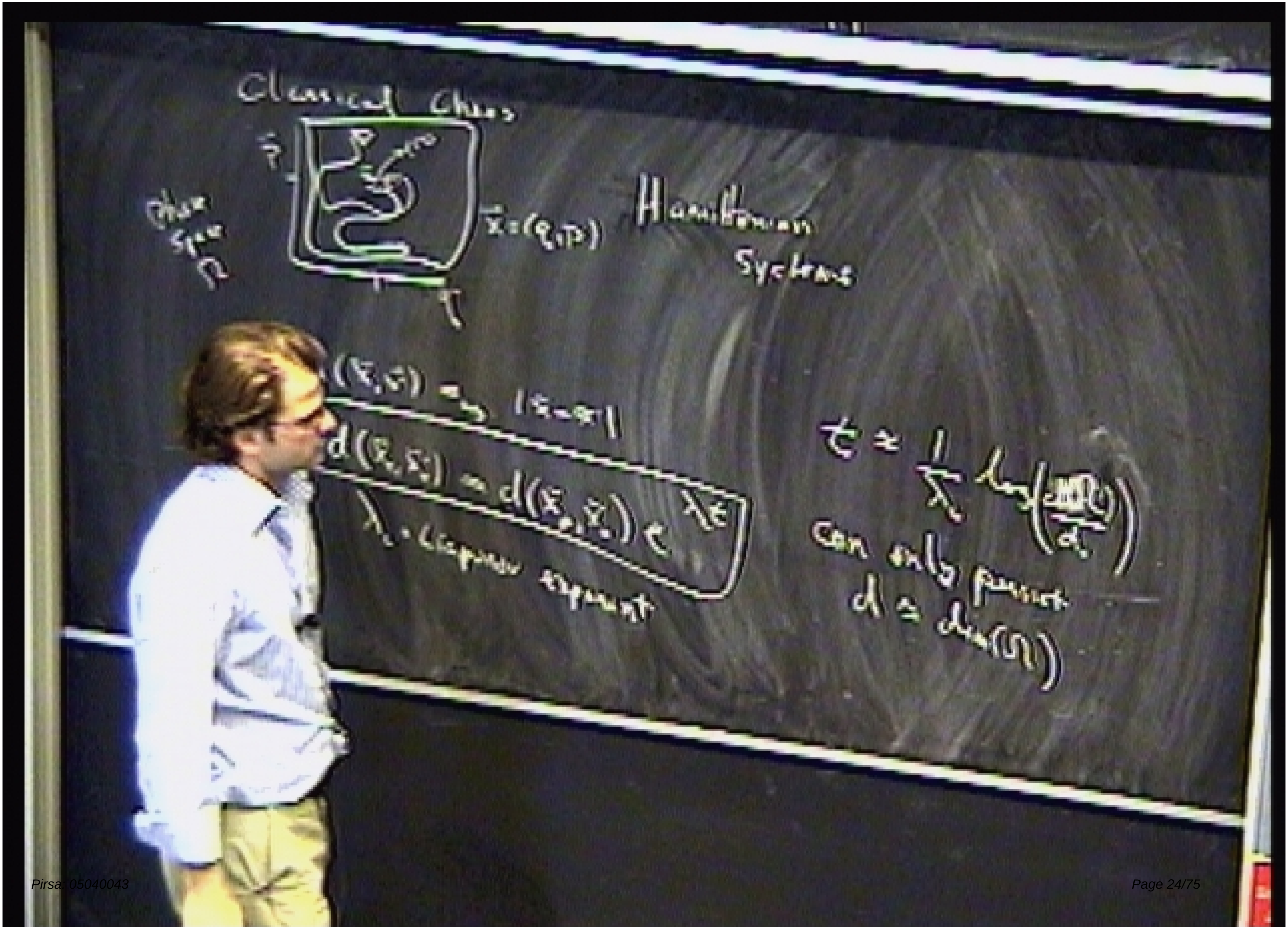
Hamiltonian Systems

$d(\vec{x},\vec{x}') =_{eg} |\vec{x}-\vec{x}'|$

$$\boxed{d(\vec{x}_t,\vec{x}'_t) \approx d(\vec{x}_0,\vec{x}'_0)\, e^{\lambda t}}$$

λ = Liapunov exponent

can only persist $d \lesssim \dim(\Omega)$


Classical Chaos
Hamiltonian Systems
$\vec{x} = (\vec{q}, \vec{p})$
$d(\vec{x}_t, \vec{x}'_t) \approx d(\vec{x}_0, \vec{x}'_0)\, e^{\lambda t}$
λ_L = Lyapunov exponent
can only predict
$d \simeq \dim(\Omega)$

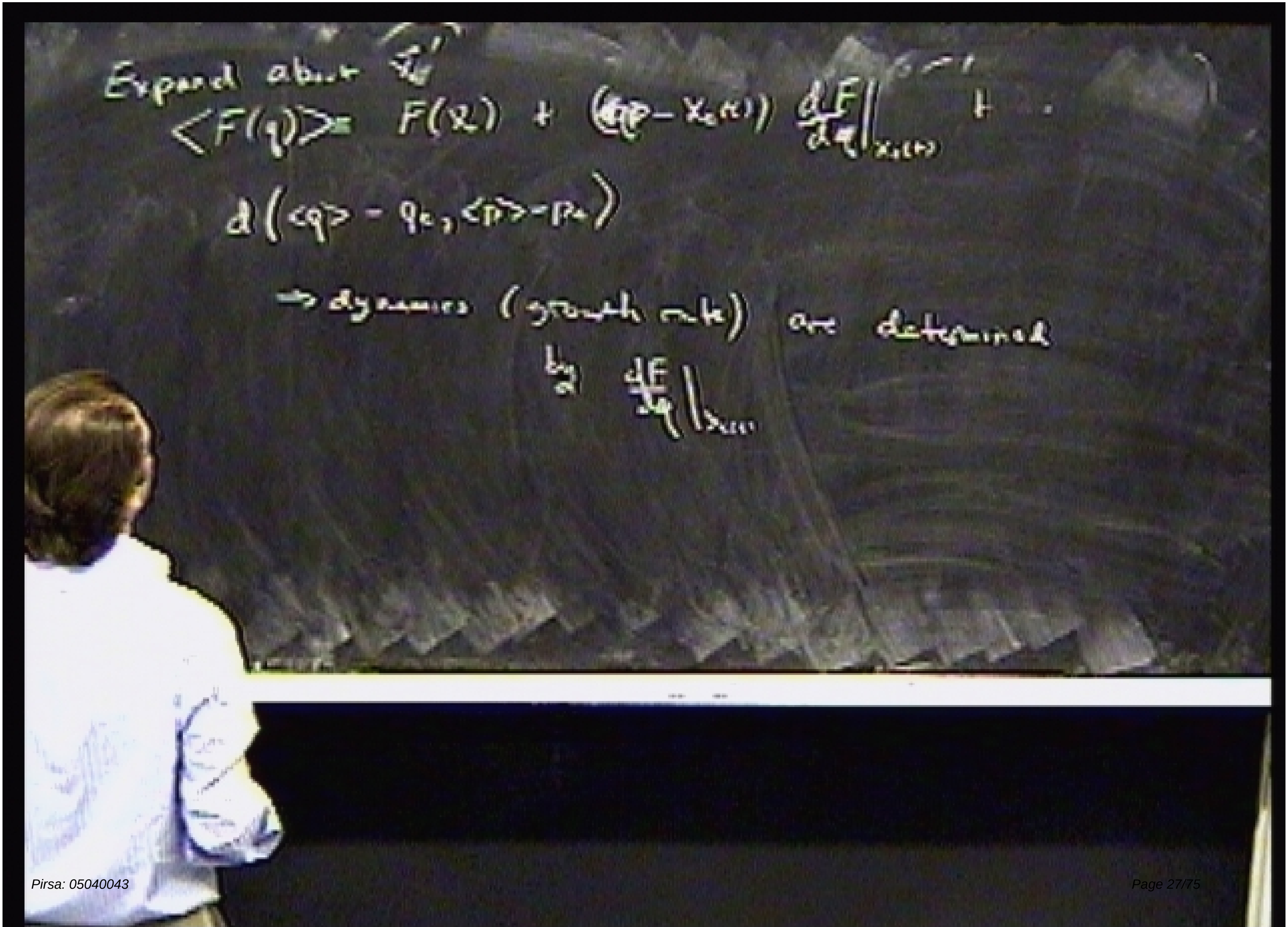
Expand about x_{cl}

$$F(q) = F(x) + (q - x_{cl}(t)) \left.\frac{dF}{dq}\right|_{x_{cl}(t)} + \dots$$

Expand about $\bar{x}_c$

$$\langle F(q)\rangle = F(x_c) + (\langle q\rangle - x_c(t))\,\frac{dF}{dq}\Big|_{x_c(t)} + \ldots$$

$$d(\langle q\rangle - q_c, \langle p\rangle - p_c)$$


Expand about x_c
$\langle F(q)\rangle = F(x_c) + (\langle q\rangle - x_c(t)) \frac{dF}{dq}\Big|_{x_c(t)} + \ldots$
$d(\langle q\rangle - q_c, \langle p\rangle - p_c)$
$\Rightarrow$ dynamics (growth rate) are determined
by $\frac{dF}{dq}\Big|_{x_c(t)}$

Expand about q_c

$H(q,p)$

$$\langle F(q)\rangle = F(\bar{q}) + (\langle q\rangle - x_c(t)) \left.\frac{dF}{dq}\right|_{x_c(t)} + \dots$$

$$d(\langle q\rangle - q_c, \langle p\rangle - p_c)$$

$\Rightarrow$ dynamics (growth rate) are determined by $\left.\frac{dF}{dq}\right|_{x_c(t)}$

nian

ystems

$$\frac{dq_i}{dt} = \frac{\partial H}{\partial p_i}$$

$$\frac{dp_i}{dt} = -\frac{\partial H}{\partial q_i}$$

$$\vec{X} = (q_1, p_1, \ldots\ldots q_n, p_n)$$

Expand about x_c

$$\langle F(q) \rangle = F(x_c) + (\langle q \rangle - x_c(t)) \left. \frac{dF}{dq} \right|_{x_c(t)} + \ldots$$

$H(q,p)$

$$d(\langle q \rangle - q_c, \langle p \rangle - p_c)$$

$\Rightarrow$ dynamics (growth rate) are determined

by $\left(\left. \frac{\partial H}{\partial q} \right|_{x_c}, \frac{\partial H}{\partial p} \right)$

Expand about $\vec{x}_c$

$$\langle F(q)\rangle = F(\vec{x}) + (\langle q\rangle - X_c(t))\,\frac{dH(q,p)}{dq}\Big|_{x_c(t)} + \dots$$

$$\boxed{d\left(\langle q\rangle - q_c, \langle p\rangle - p_c\right)}$$ = diff quantum expectation values & classical phase space point

→ dynamics (growth rate) are determined by $\left(\frac{\partial H}{\partial q}\Big|_{x_c(t)}, \frac{\partial H}{\partial p}\right)$

Chaotic → exponential growth of difference

Expand about $\vec{x}_c$

$$\langle F(q)\rangle = F(x_c) + (\langle q\rangle - x_c(t))\,\frac{dH}{dq}\bigg|_{x_c(t)} + \cdots$$

$\boxed{d_{qc}(\langle q\rangle - q_c, \langle p\rangle - p_c)}$ = diff quantum expectation values & classical phase space point

→ dynamics (growth rate) are determined by $\left(\frac{\partial H}{\partial q}\Big|_{x_c}, \frac{\partial H}{\partial p}\right)$

Chaotic → exponential growth of difference $\qquad d_{qc} \approx e^{\lambda t}$

→ $\langle \Delta q(t)\rangle$ grows exponentially $\qquad \langle \Delta q\rangle \approx e^{\lambda t}$

$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m}$$

$$\frac{d\langle p\rangle}{dt} = F(\langle q\rangle) + \Delta q$$

Ex: particle 1g, $t = 10^{19}$ years, $\Delta q(t) \simeq 1\,\mathrm{cm}$

Start from narrow wave packet before $\Delta q(0) \sim 1\,\text{Å}$

$$\frac{d\langle q\rangle}{dt} = \frac{\langle p\rangle}{m}$$

$$\frac{d\langle p\rangle}{dt} = F(\langle q\rangle) + \underset{\sim}{\Delta q}$$

$\Delta q \sim$ diameter of satellite

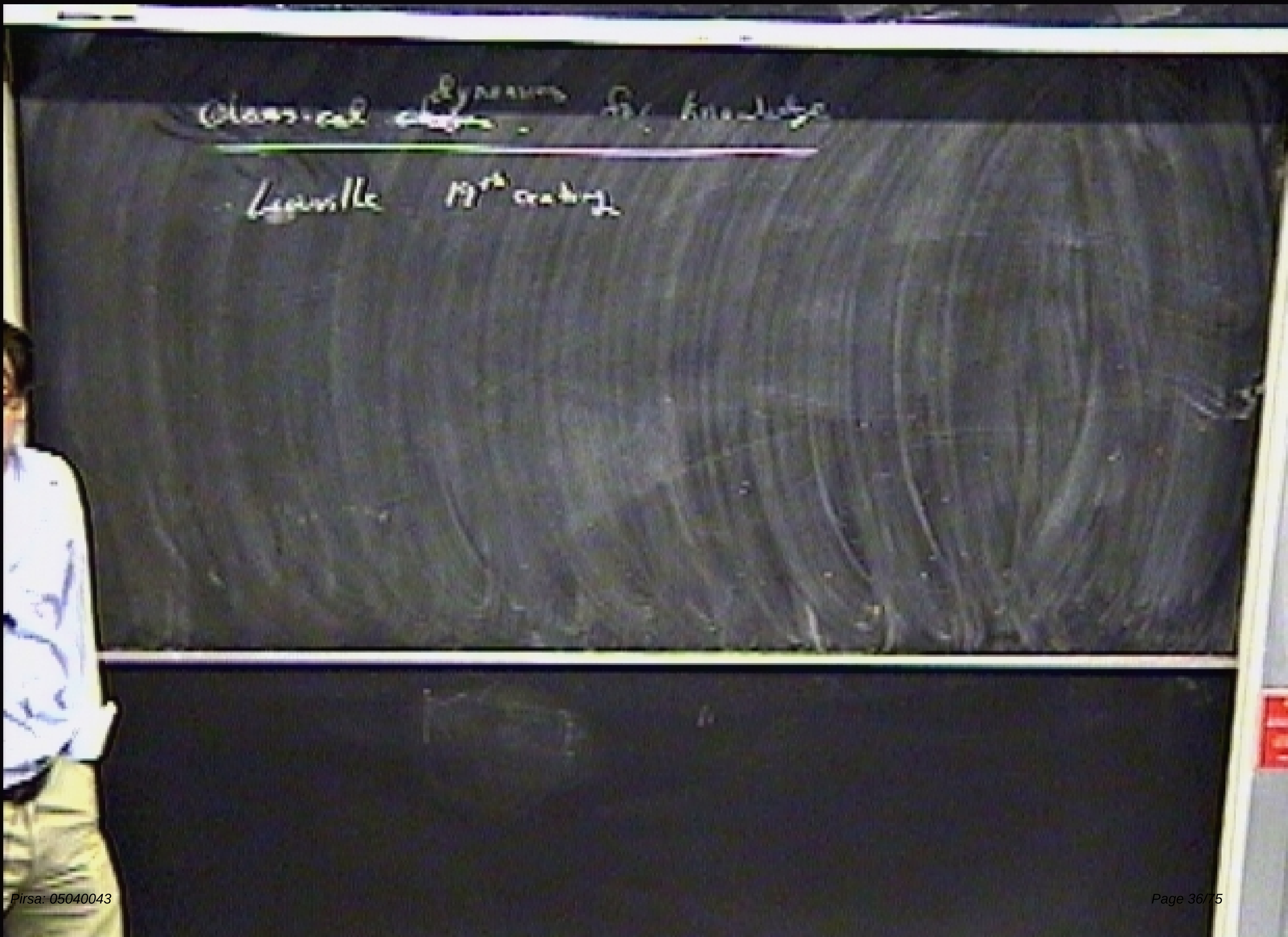
$t \sim 20$ years

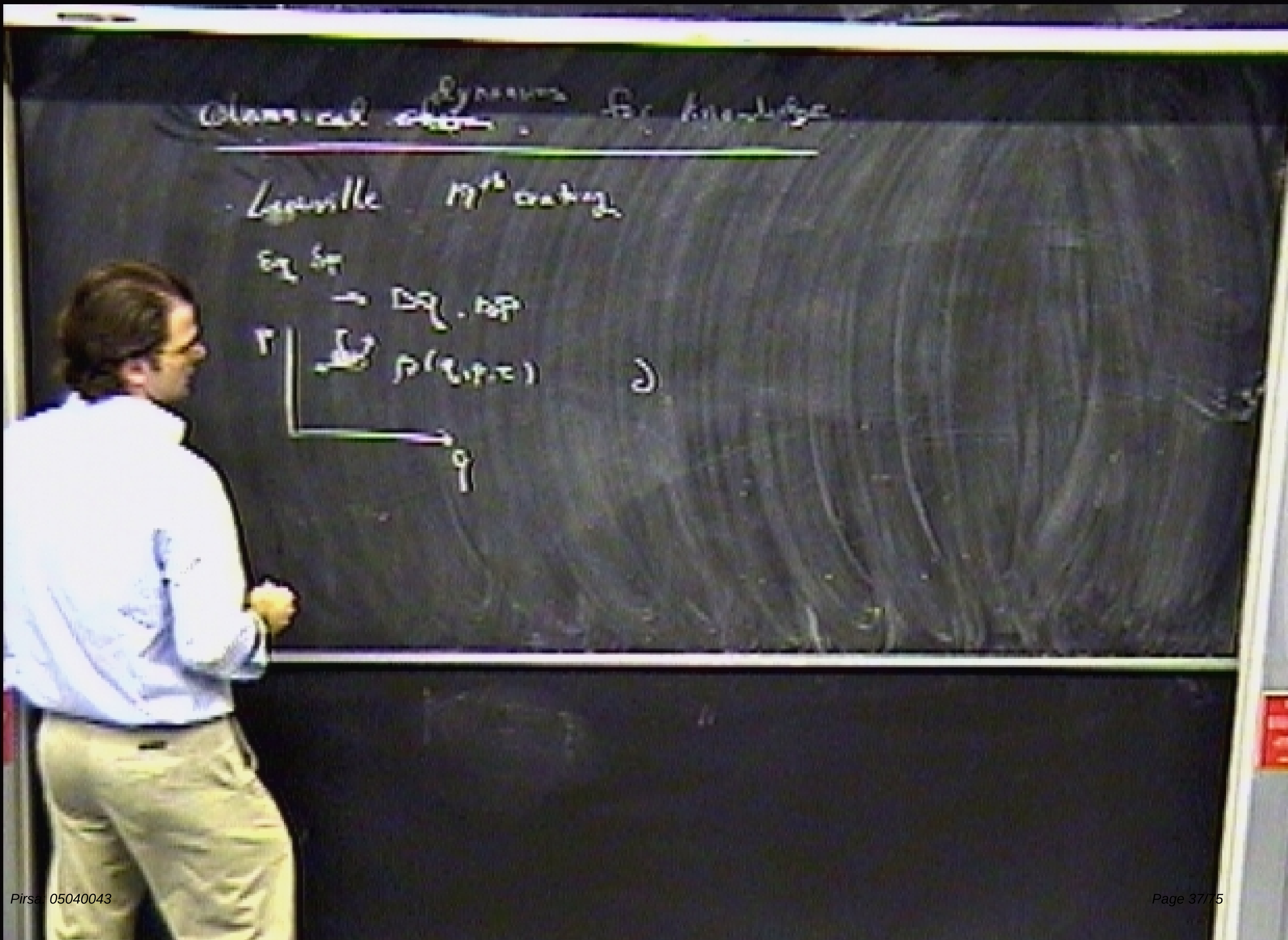
Exp. particle $1\,g$, $t \sim 10^{11}$ years, $\Delta q(t) \sim 1\,cm$

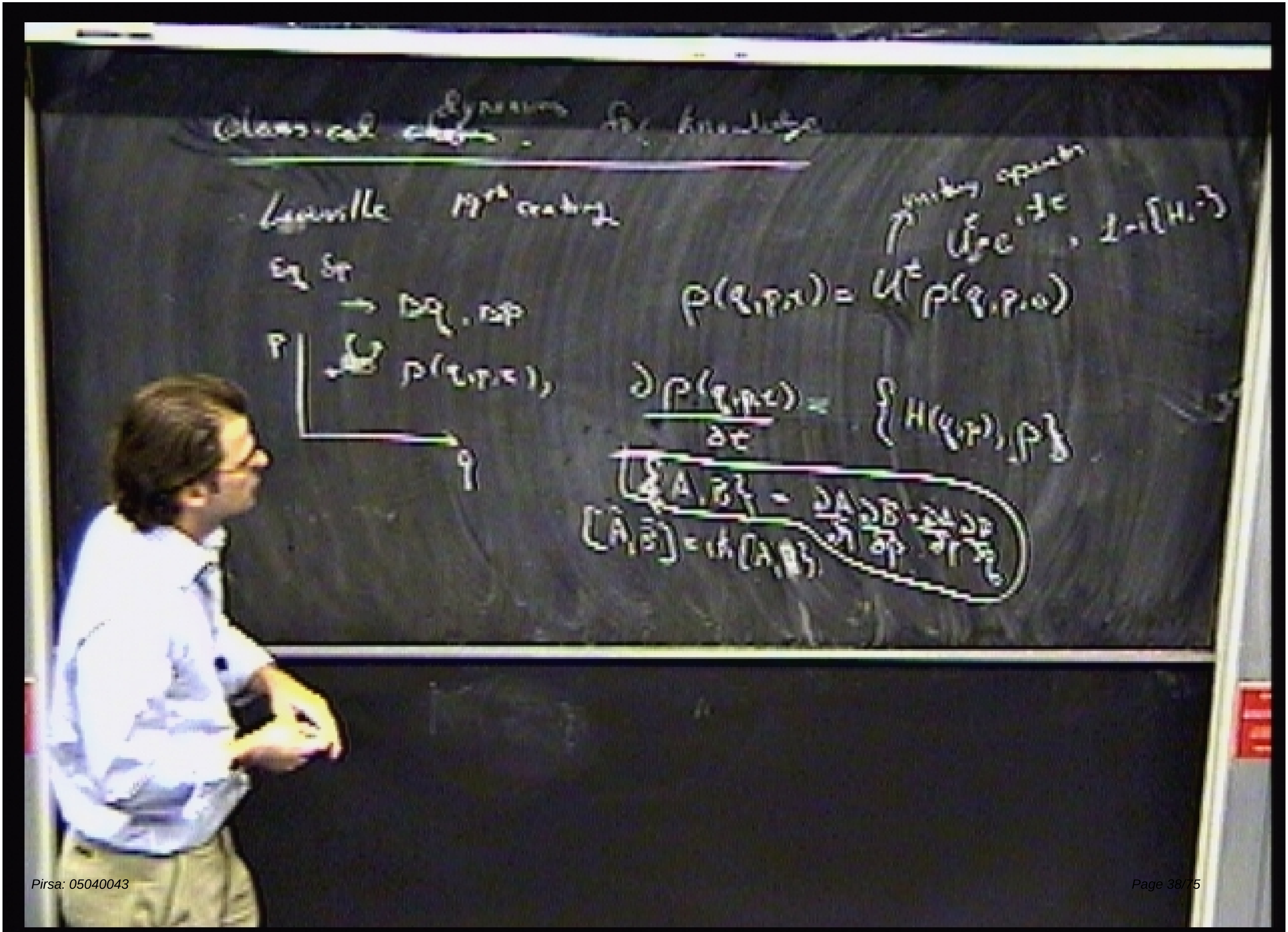
Start from narrow wave packet before $\Delta q(t) \sim 1\,Å$

$\Delta q \sim$ diameter of satellite

$t \sim 20$ years.

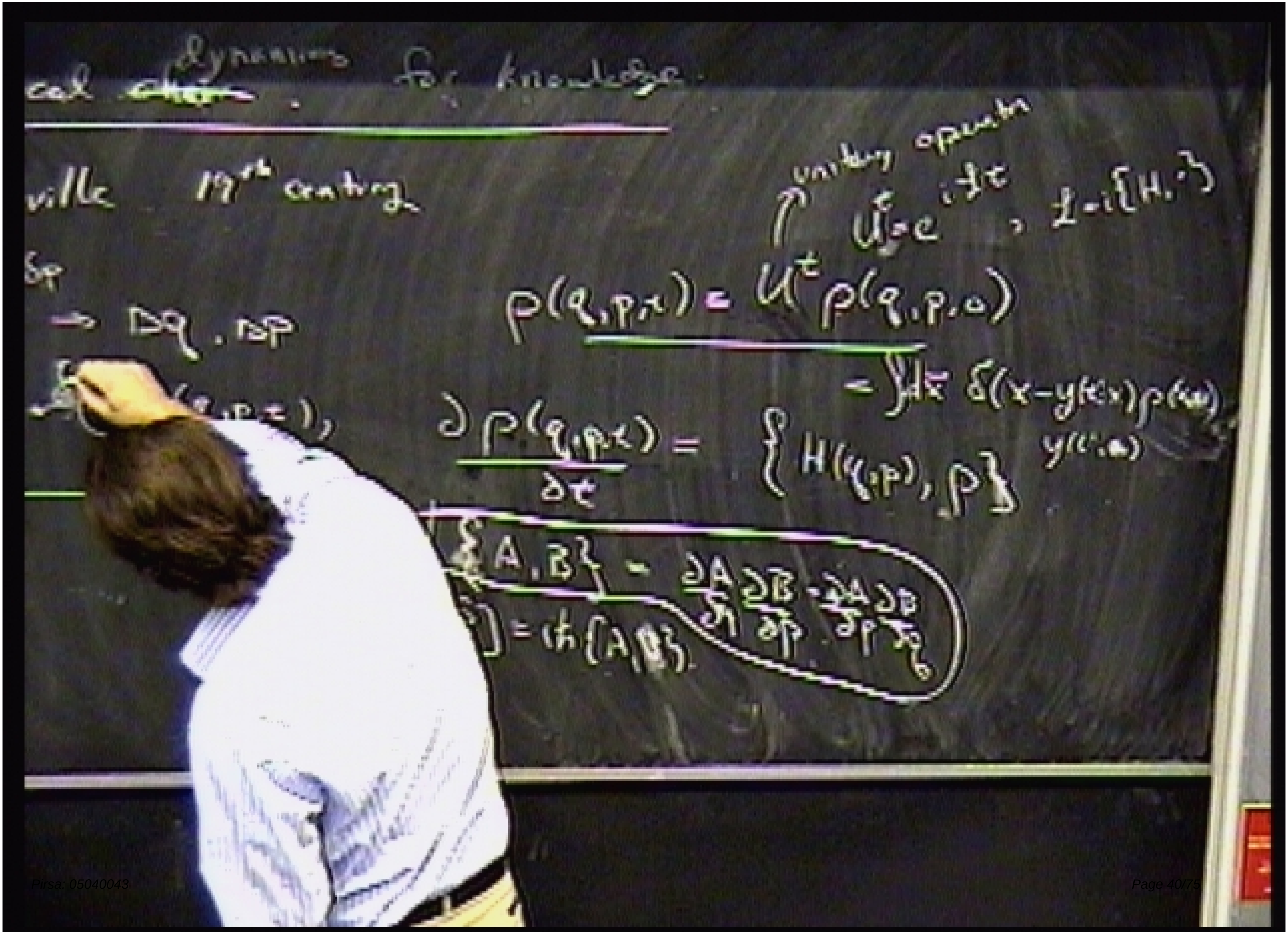

Classical
Liouville 19th century


Classical dynamics for knowledge.
Liouville mechanics
p(q,p,t)


Liouville
p(q,p,t) = U^t p(q,p,0)
{H(q,p), p}
q

$O(q,p) \quad \rightarrow \quad O = q$
$\qquad\qquad\qquad\quad O = p$

$$\langle O \rangle_t = \int dq\, dp \; O(q,p)\, \rho(q,p,t)$$



dynamics for knowledge
19th century
unitary operator
ρ(q,p,t) = U^t ρ(q,p,0)
∂ρ(q,p,t)/∂t = {H(q,p), ρ}
{A,B} = ∂A/∂q ∂B/∂p − ∂A/∂p ∂B/∂q

...cal dynamics for knowledge.

...ville 19th century

δp

$\to \Delta q, \Delta p$

$\rho(q,p,t)$,

unitary operator

$U^t = e^{\mathcal{L} t}$, $\mathcal{L} = i\{H, \cdot\}$

$$\rho(q,p,t) = U^t \rho(q,p,0)$$

$$= \int dx\, \delta(x - y(t;x))\, \rho(x,0)$$

$y(t;x)$

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

$$\{A,B\} = \frac{\partial A}{\partial q}\frac{\partial B}{\partial p} - \frac{\partial A}{\partial p}\frac{\partial B}{\partial q}$$

$$[\hat{A}, \hat{B}] = i\hbar\{A,B\}$$

q

$O(q,p) \leftrightarrow \begin{matrix} O = q \\ O = p \end{matrix}$

$$\langle O \rangle_t = \int_\Omega dq\, dp\; O(q,p)\, \rho(q,p,t)$$

$$\frac{d\langle q \rangle_t}{dt} = \frac{\langle p \rangle_t}{m}$$

$$\Delta q^2 = \langle q^2 \rangle_t - \langle q \rangle_t^2$$

$$\frac{d\langle p \rangle_t}{dt} = \langle F(q) \rangle_t = F(\langle q \rangle_t) + \frac{\Delta q^2}{2} \frac{\partial^2 F}{\partial q^2}\bigg|_{q=\langle q \rangle_t} + \dots$$

$O(q,p) \quad \leftrightarrow \quad \begin{matrix} O = q \\ O = p \end{matrix}$

$$\langle O \rangle_c = \int_{\mathbb{R}} dq \int dp \; O(q,p) \, \rho(q,p,t)$$

$$\frac{d\langle q \rangle_c}{dt} = \frac{\langle p \rangle_c}{m}$$

$$\Delta q^2 = \langle q^2 \rangle_c - \langle q \rangle_c^2$$

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

$$O(q,p) \quad \rightarrow \quad O = q, \quad O = p$$

$$\langle O \rangle_t = \int_\Omega dq\,dp\; O(q,p)\,\rho(q,p,t)$$

$$\Delta q^2 = \langle q^2 \rangle_t - \langle q \rangle_t^2$$

$$\frac{d\langle q \rangle_t}{dt} = \frac{\langle p \rangle_t}{m}$$

$$\frac{d\boxed{\langle p \rangle_t}}{dt} = \langle F(q) \rangle_t = F(\langle q \rangle_t) + \frac{\Delta q^2}{2}\,\frac{\partial^2 F}{\partial q^2}\bigg|_{q=\langle q \rangle_t} + \ldots$$

Classical ~~statistical~~ dynamics for knowledge

Liouville 19th century

Ep. St. $\rightarrow \delta q, \delta p$

$\rho(q,p,t)$,

Liouville operator

$U_t = e^{iLt}$, $L = -i\{H,\cdot\}$

$$\rho(q,p,t) = U^t \rho(q,p,0)$$

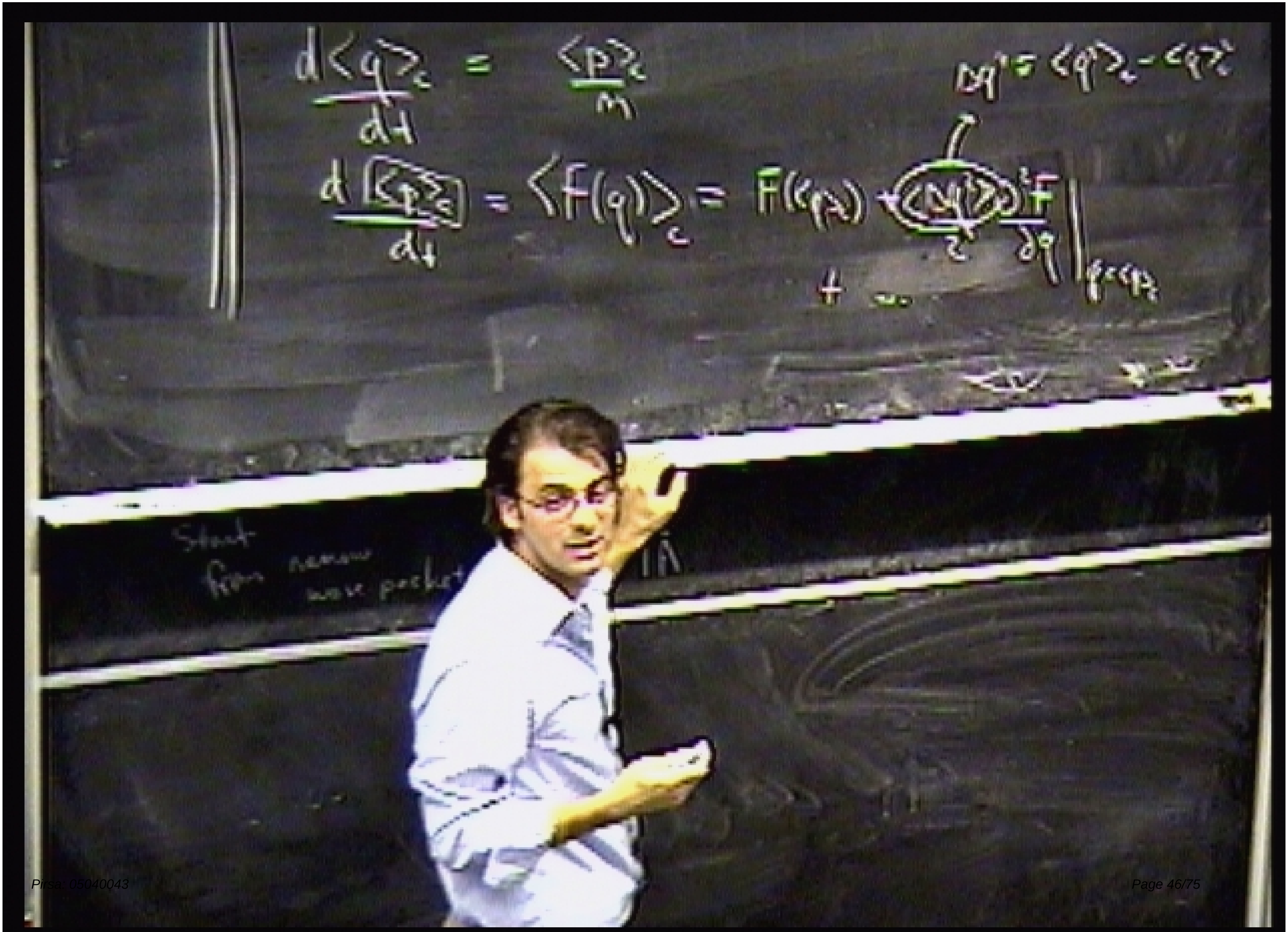
$$= \int dx\, \delta(x - y(t,x))\,\rho(x)$$

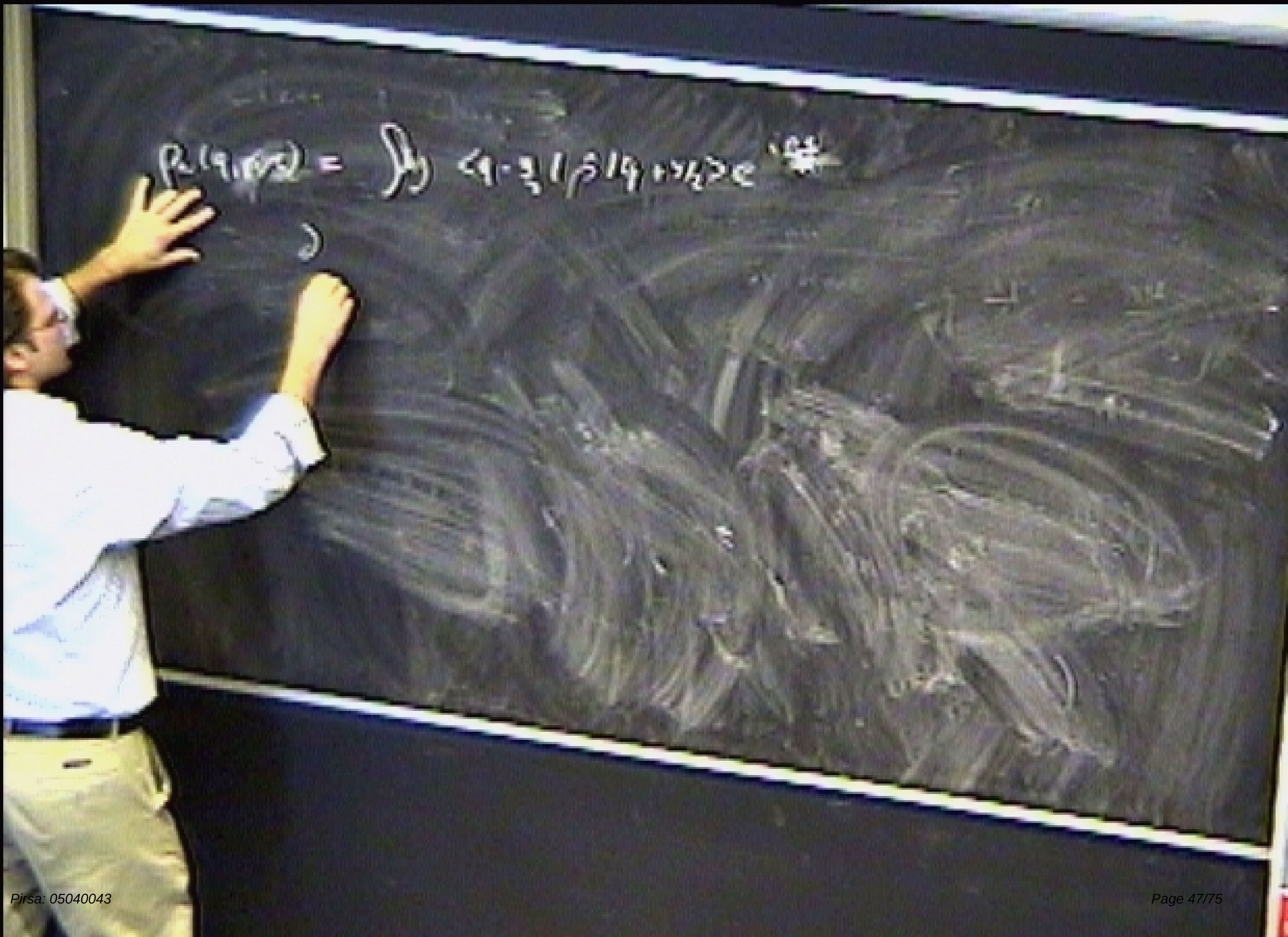
$y(t,x)$

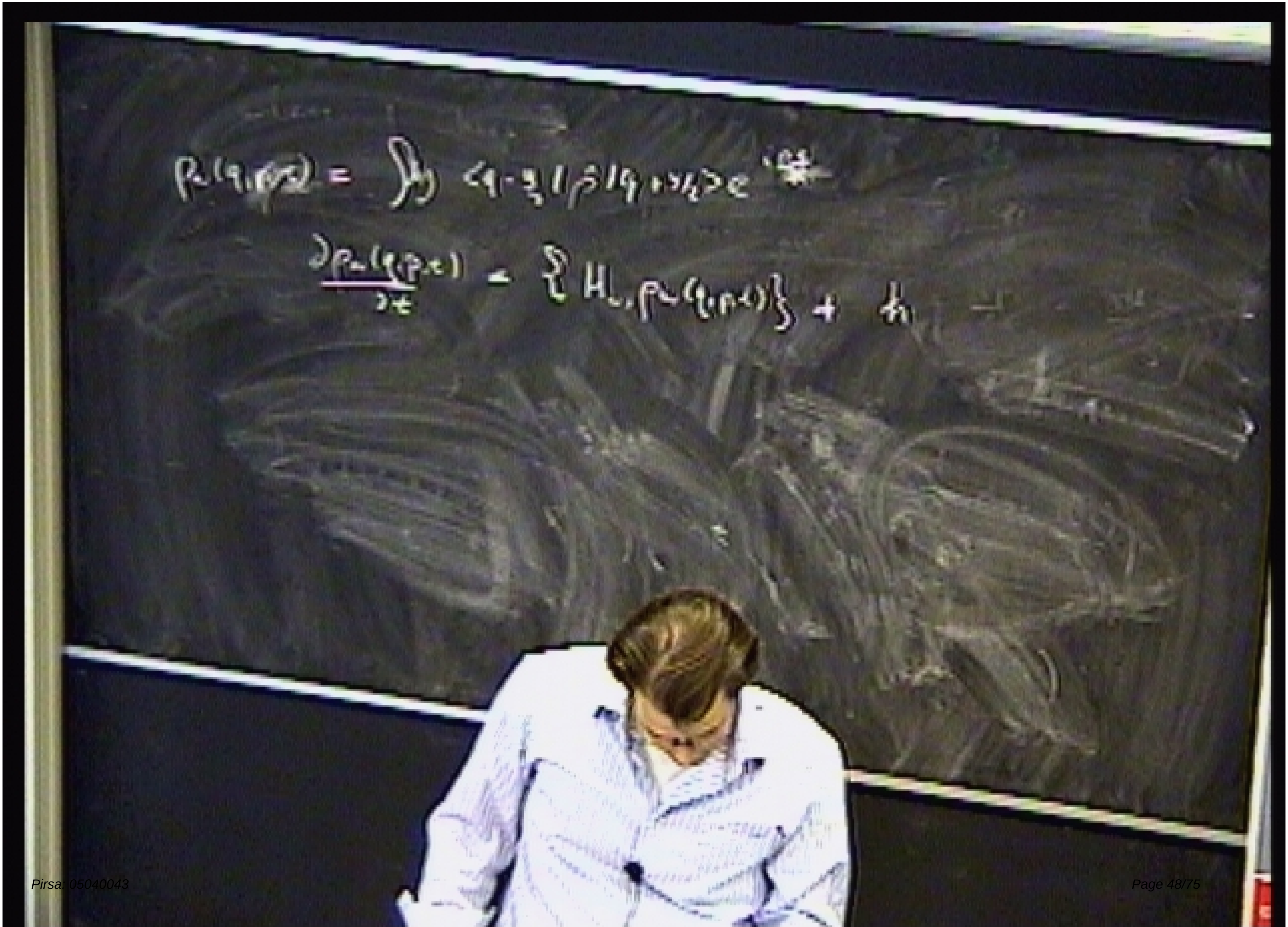
$$\frac{\partial \rho(q,p,t)}{\partial t} = \{H(q,p), \rho\}$$

$$\{A,B\} = \frac{\partial A}{\partial q}\frac{\partial B}{\partial p} - \frac{\partial A}{\partial p}\frac{\partial B}{\partial q}$$

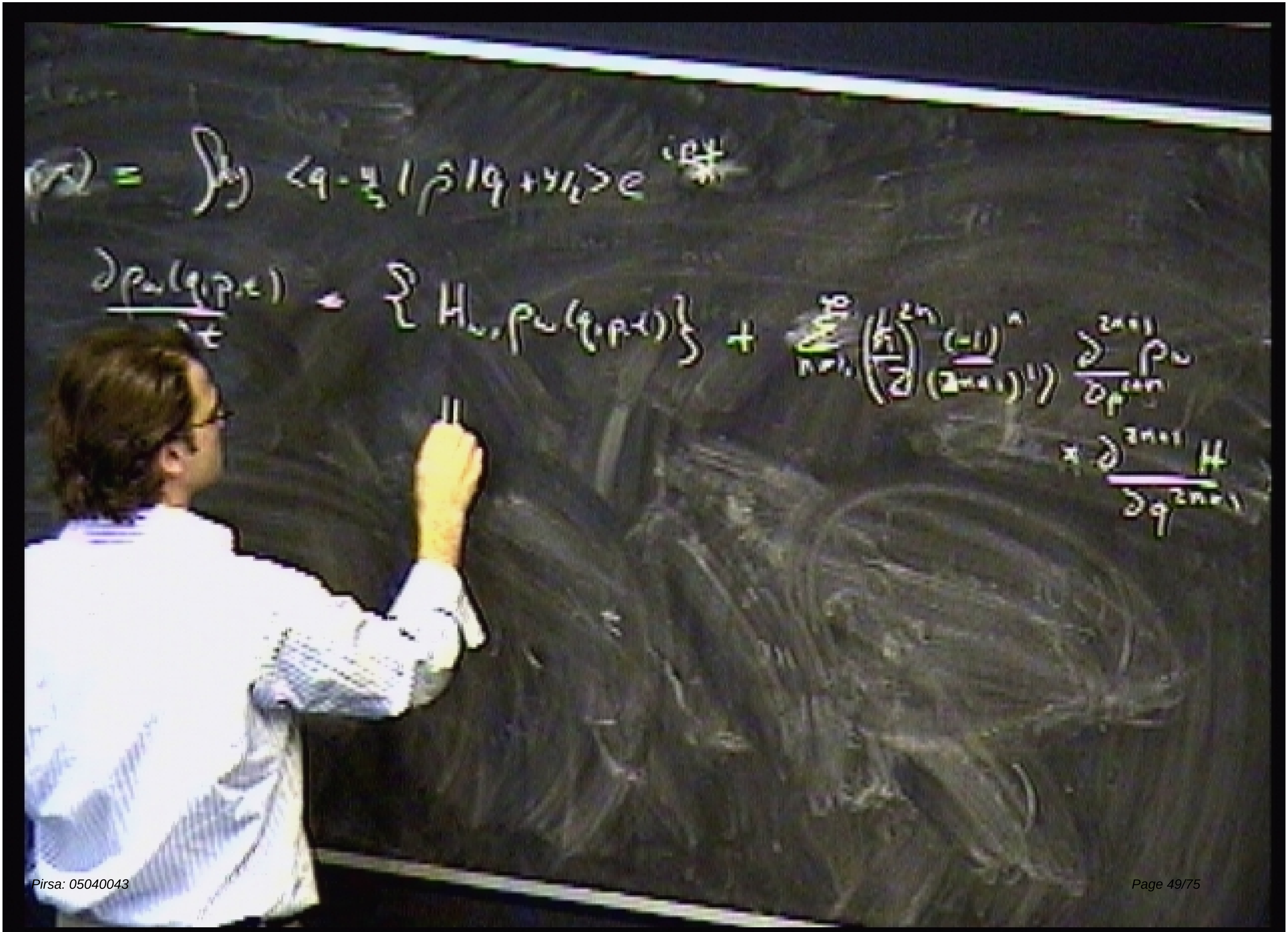
$$[\hat{A},\hat{B}] = i\hbar\{A,B\}$$


d⟨q⟩_c/dt = ⟨p⟩_c/m
Δq² = ⟨q²⟩_c − ⟨q⟩_c²
d⟨p⟩_c/dt = ⟨F(q)⟩_c = F(⟨q⟩_c) + (Δq)²/2 ∂²F/∂q² |_{q=⟨q⟩_c} + ...
Start from narrow wave packet

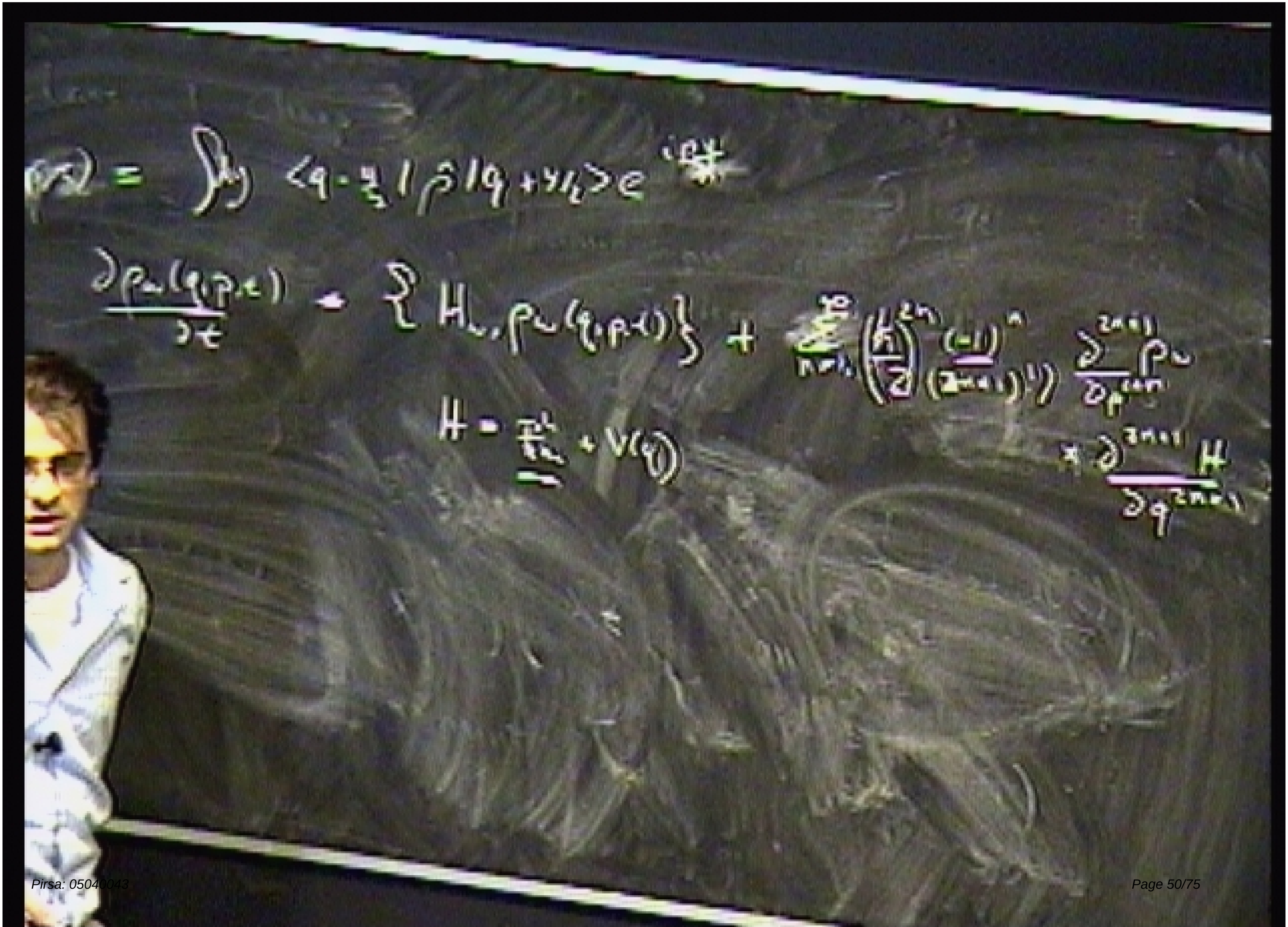




$\rho_W(q,p,t) = \int dy \, \langle q - \frac{y}{2} | \hat{\rho} | q + \frac{y}{2} \rangle e^{ipy/\hbar}$
$\frac{\partial \rho_W(q,p,t)}{\partial t} = \{ H_W, \rho_W(q,p,t) \} + \hbar$



$\rho_W(q,p) = \int dy \, \langle q - y/2 | \hat{\rho} | q + y/2 \rangle e^{ipy/\hbar}$
$\frac{\partial \rho_W(q,p,t)}{\partial t} = \{ H_W, \rho_W(q,p,t) \} + \sum_{n\geq 1}^{\infty} \left(\frac{\hbar}{2}\right)^{2n} \frac{(-1)^n}{(2n+1)!} \frac{\partial^{2n+1} \rho_W}{\partial p^{2n+1}} \times \frac{\partial^{2n+1} H}{\partial q^{2n+1}}$
$=$

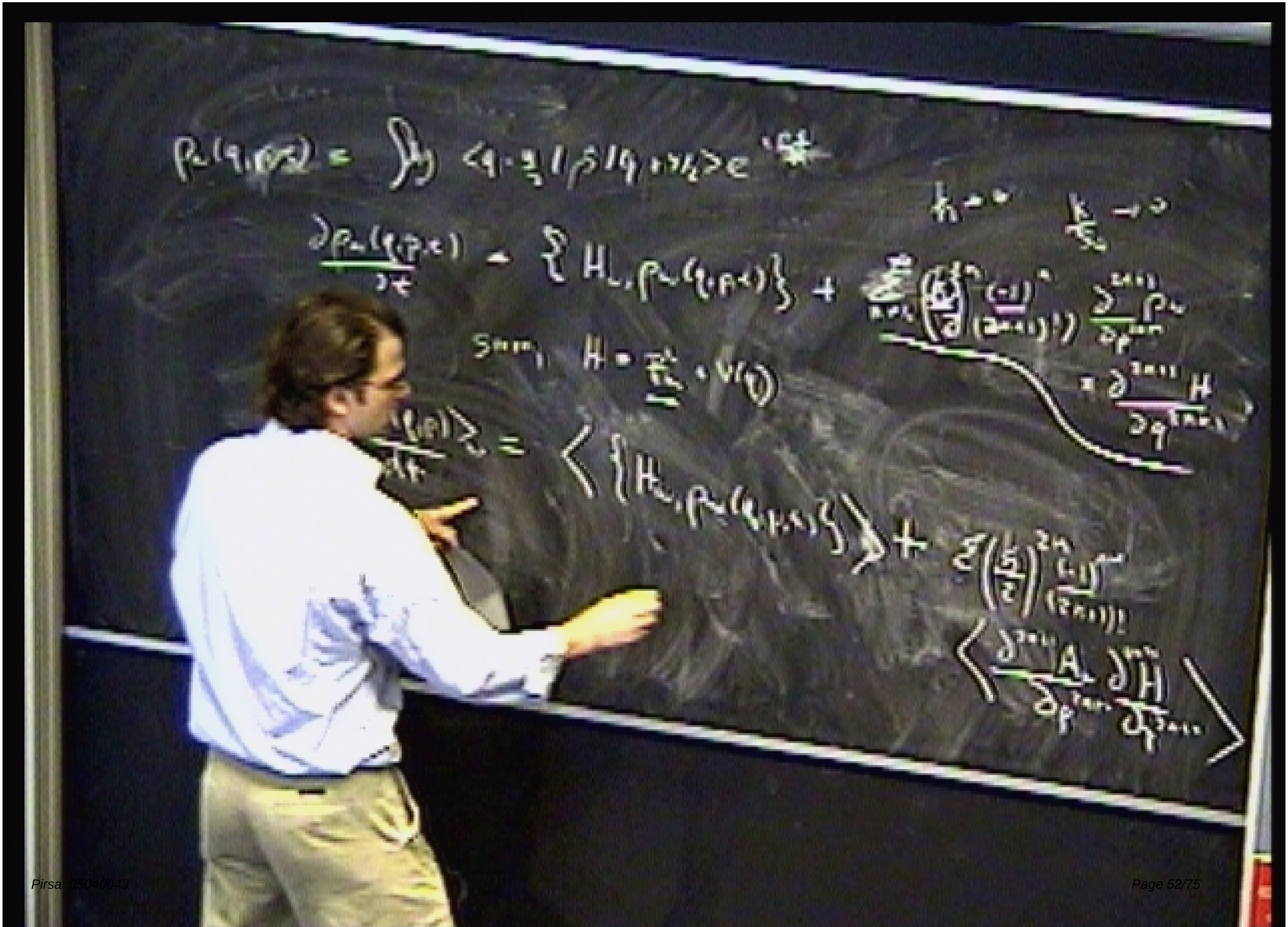

$\rho_W(q,p) = \int dy \, \langle q - \frac{y}{2} | \hat{\rho} | q + \frac{y}{2} \rangle e^{ipy/\hbar}$
$\frac{\partial \rho_W(q,p,t)}{\partial t} = \{ H_W, \rho_W(q,p,t) \} + \sum_{n=1}^{\infty} \left(\frac{\hbar}{2}\right)^{2n} \frac{(-1)^n}{(2n+1)!} \frac{\partial^{2n+1} \rho_W}{\partial p^{2n+1}} \times \frac{\partial^{2n+1} H}{\partial q^{2n+1}}$
$H = \frac{p^2}{2m} + V(q)$

$$\rho_W(q,p,t) = \int dy \, \langle q - \tfrac{y}{2} | \hat{\rho} | q + \tfrac{y}{2} \rangle e^{ipy/\hbar}$$

$$\frac{\partial \rho_W(q,p,t)}{\partial t} = \{ H_W, \rho_W(q,p,t) \} + \sum_{n=1} \left(\frac{\hbar}{2}\right)^{2n} \frac{(-1)^n}{(2n+1)!} \frac{\partial^{2n+1} \rho_W}{\partial p^{2n+1}} \frac{\partial^{2n+1} H}{\partial q^{2n+1}}$$

Simm, $H = \frac{p^2}{2m} + V(q)$

$$\frac{d\langle A_W(q,p) \rangle}{dt}$$



$$\rho_w(q,p,t) = \int dy \, \langle q - \tfrac{y}{2} | \hat{\rho} | q + \tfrac{y}{2} \rangle e^{ipy/\hbar}$$

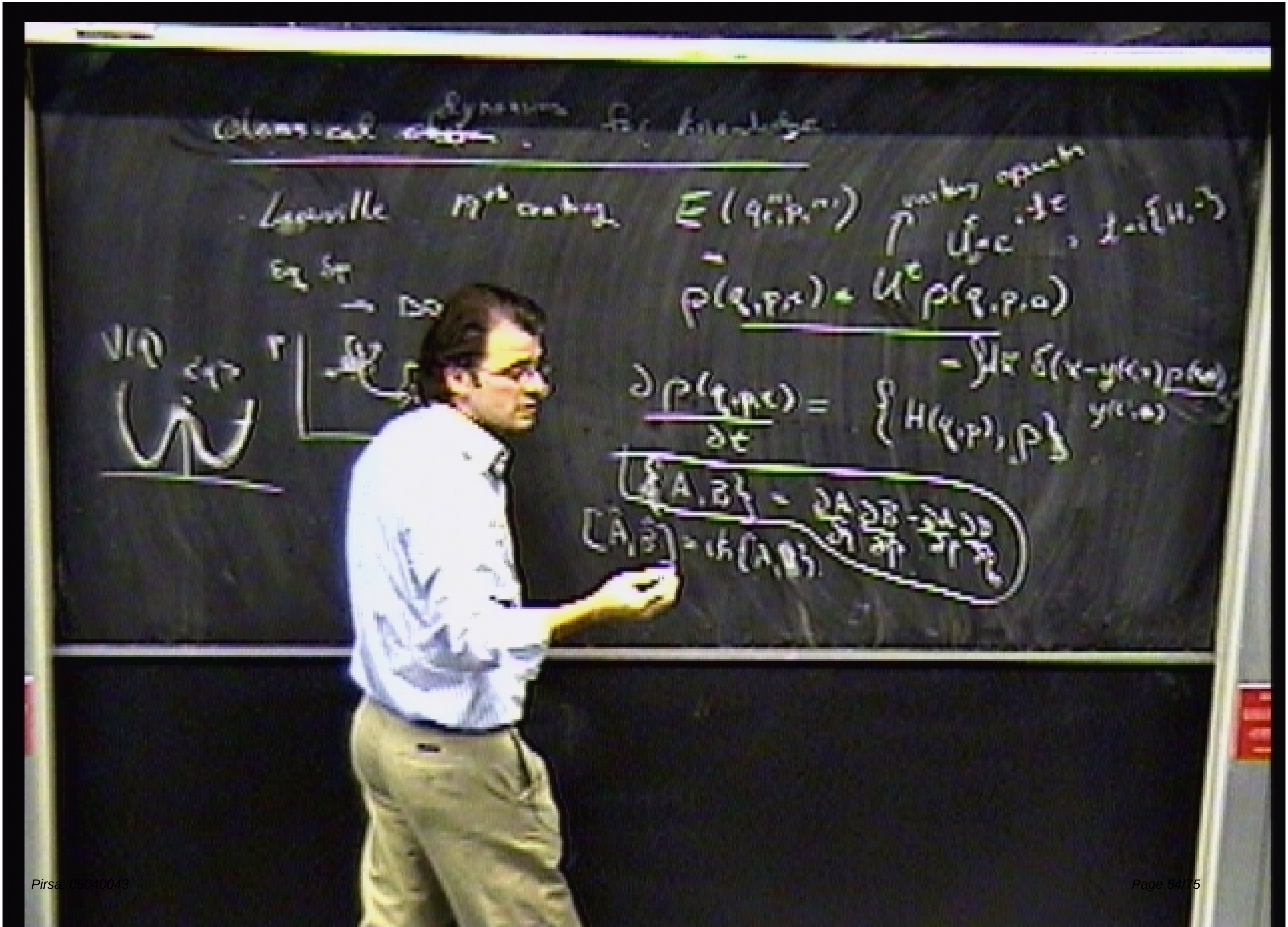
$\hbar \to 0$ $\quad \frac{\hbar}{S_0} \to 0$

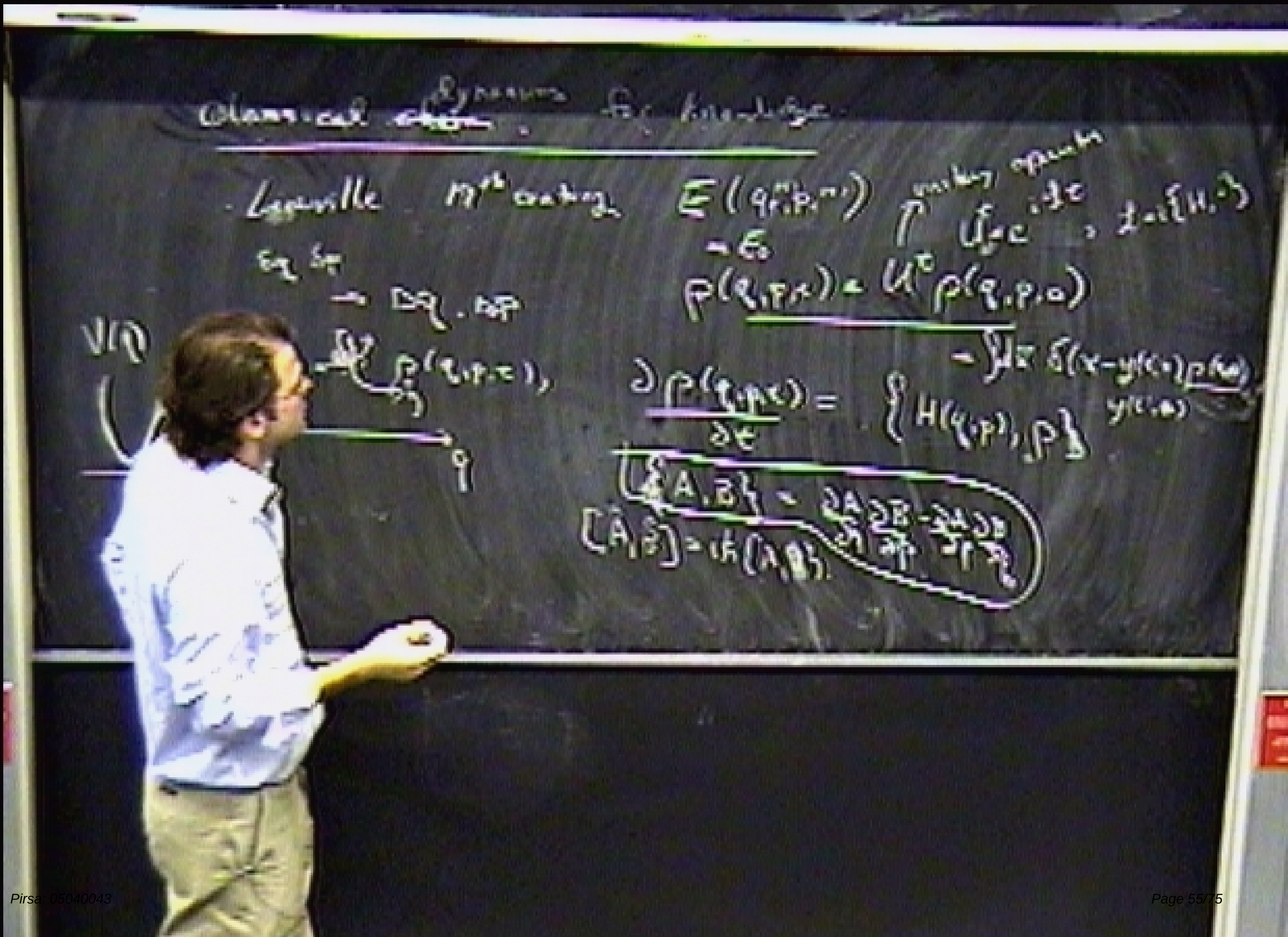
$$\frac{\partial \rho_w(q,p,t)}{\partial t} = \{ H_c, \rho_w(q,p,t) \} + \sum_{n=1}^{\infty} \left(\frac{\hbar}{2}\right)^{2n} \frac{(-1)^n}{(2n+1)!} \frac{\partial^{2n+1} \rho_w}{\partial p^{2n+1}} \frac{\partial^{2n+1} H}{\partial q^{2n+1}}$$

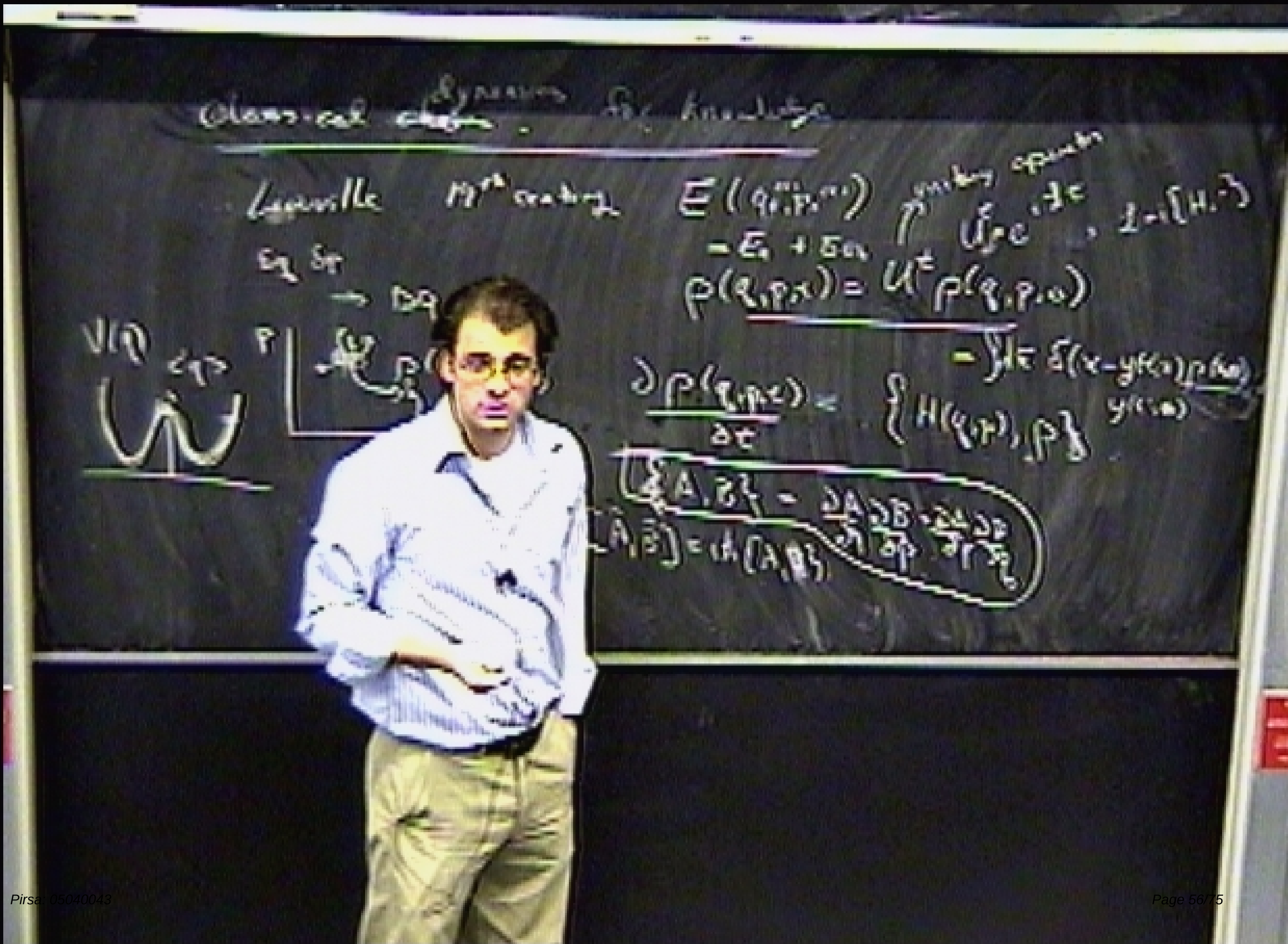
Simm, $H = \frac{p^2}{2m} + V(q)$

$$\frac{d \langle A(q,p) \rangle_t}{dt} = \left\langle \{ H_c, \rho_w(q,p,t) \} \right\rangle_t + \sum_{n} \left(\frac{\hbar}{2}\right)^{2n} \frac{(-1)^n}{(2n+1)!} \left\langle \frac{\partial^{2n+1} A}{\partial p^{2n+1}} \frac{\partial^{2n+1} H}{\partial q^{2n+1}} \right\rangle$$

$$\langle Q \rangle_t = \int dq \, dp \, \rho_w(q,p,t) \, Q(q,p)$$




Liouville
$\rho(q,p,t) = U^t \rho(q,p,0)$
$\frac{\partial \rho(q,p,t)}{\partial t} = \{H(q,p), \rho\}$
$\{A,B\} = \frac{\partial A}{\partial q}\frac{\partial B}{\partial p} - \frac{\partial A}{\partial p}\frac{\partial B}{\partial q}$
$[\hat{A},\hat{B}] = i\hbar\{A,B\}$



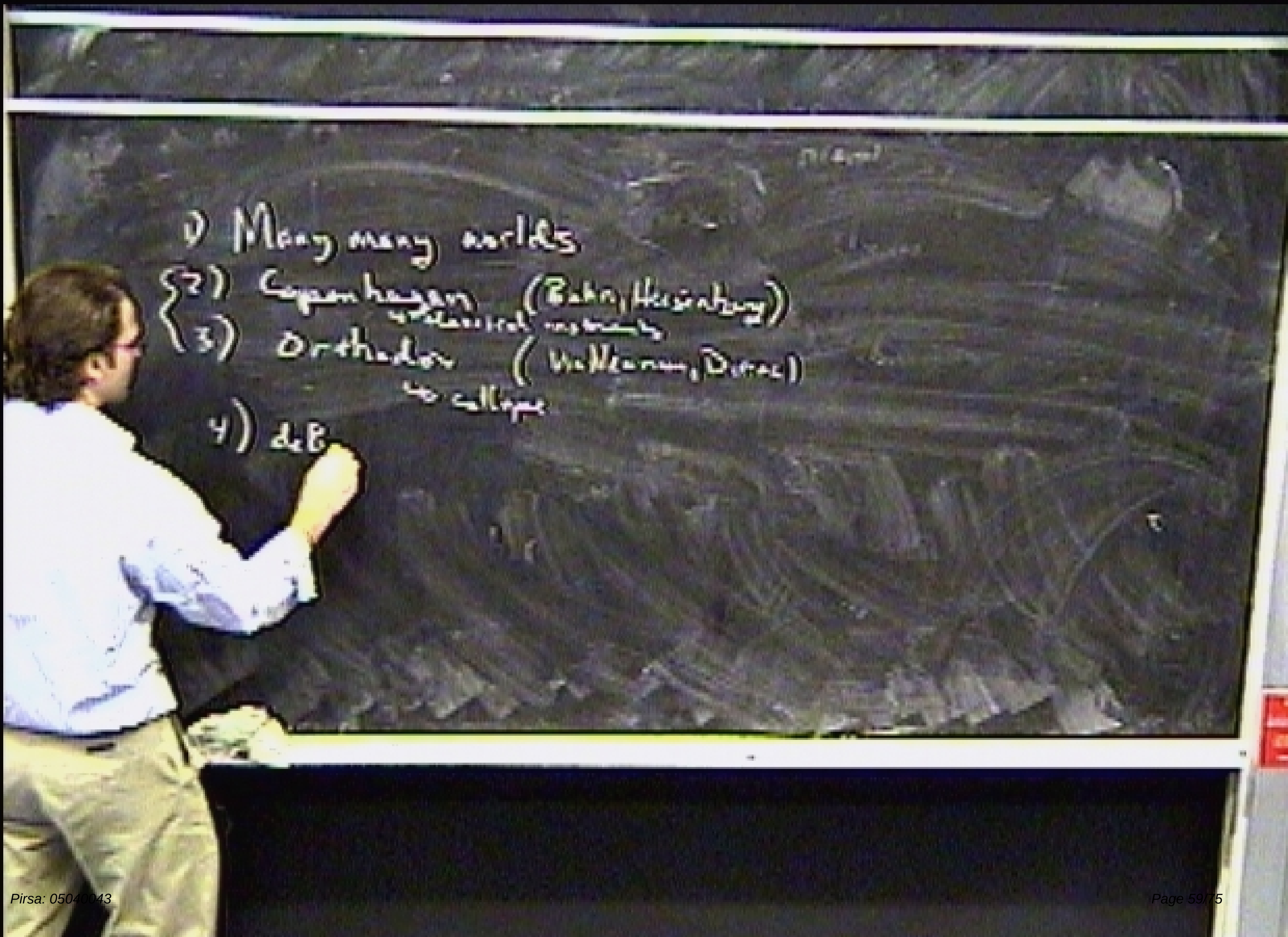
Sw

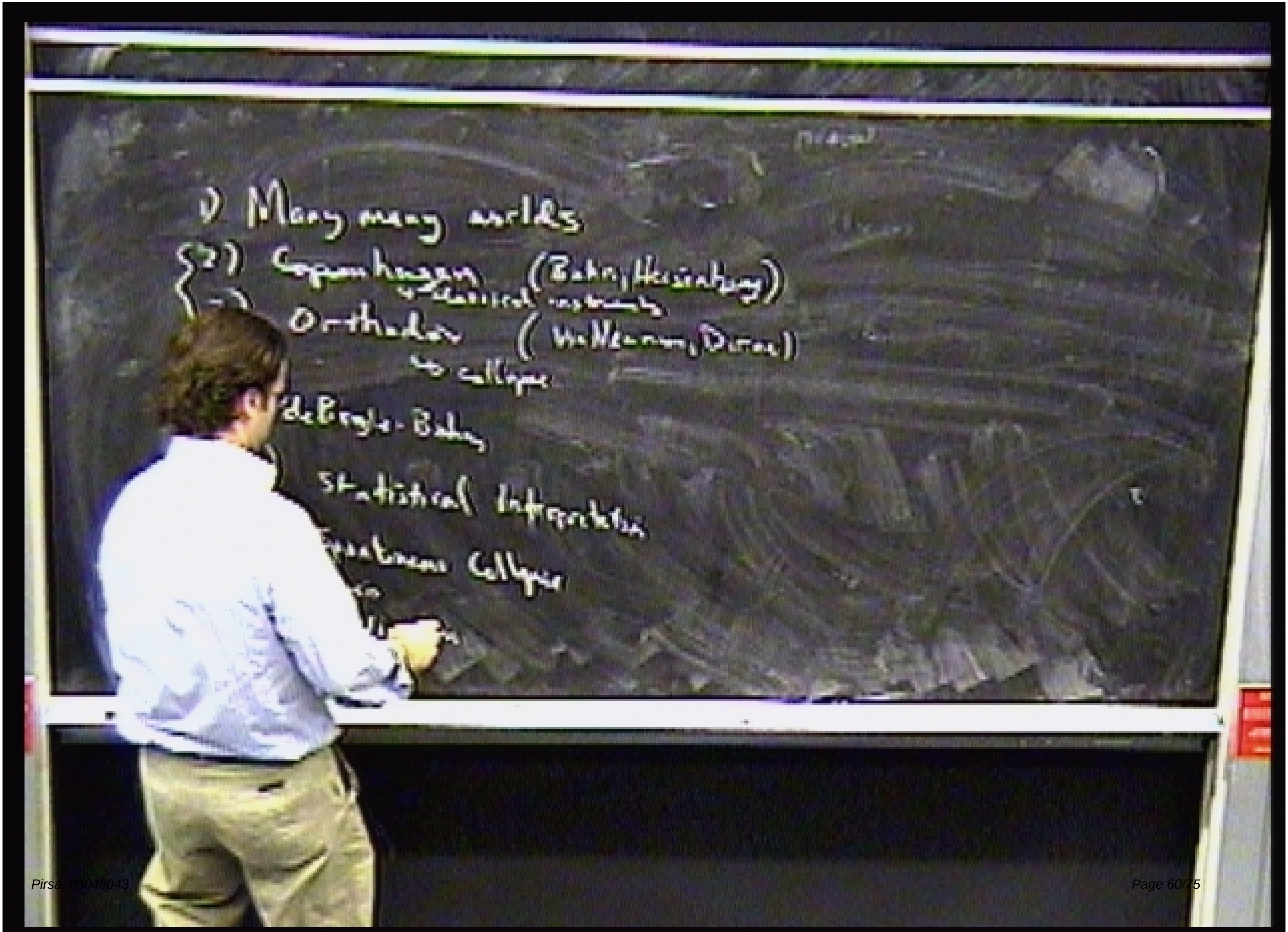
$$\frac{d\langle A_w(\rho|\rho)\rangle_\omega}{dt} =$$

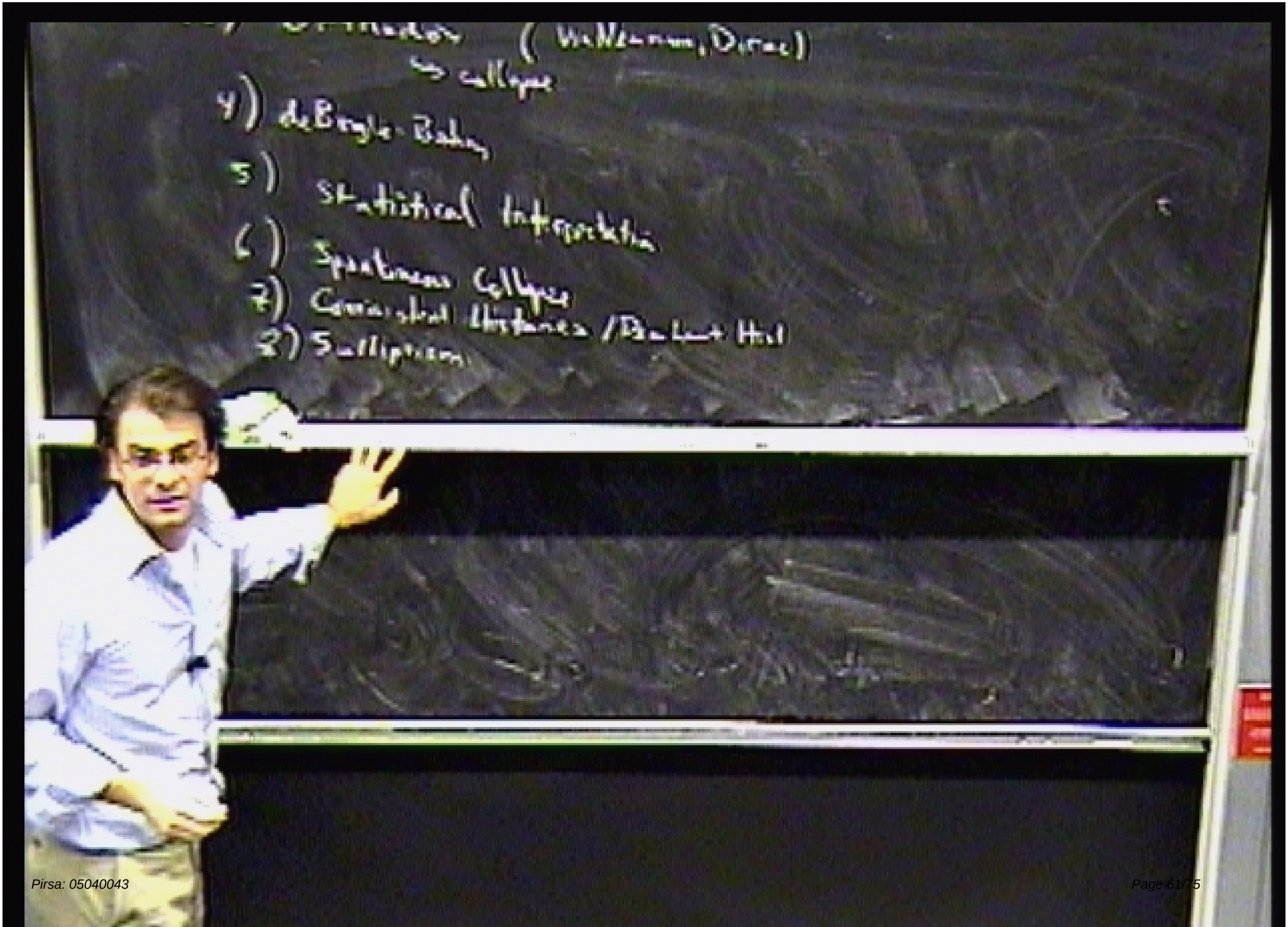
arxiv.org/abs/quant-ph/

ch

1) Many many worlds
2) Copenhagen
3) Or


1) Many many worlds
2) Copenhagen (Bohr, Heisenberg)
+ classical instruments
3) Orthodox (von Neumann, Dirac)
+ collapse
4) deB


1) Many many worlds
2) Copenhagen (Bohr, Heisenberg)
+ classical instruments
Orthodox (von Neumann, Dirac)
→ collapse
deBroglie-Bohm
Statistical Interpretation
Spontaneous Collapse


(von Neumann, Dirac)
↳ collapse
4) deBroglie-Bohm
5) Statistical Interpretation
6) Spontaneous Collapse
7) Consistent Histories
8) Solipsism

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
+ classical instruments

3) Orthodox (VonNeumann, Dirac)
→ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

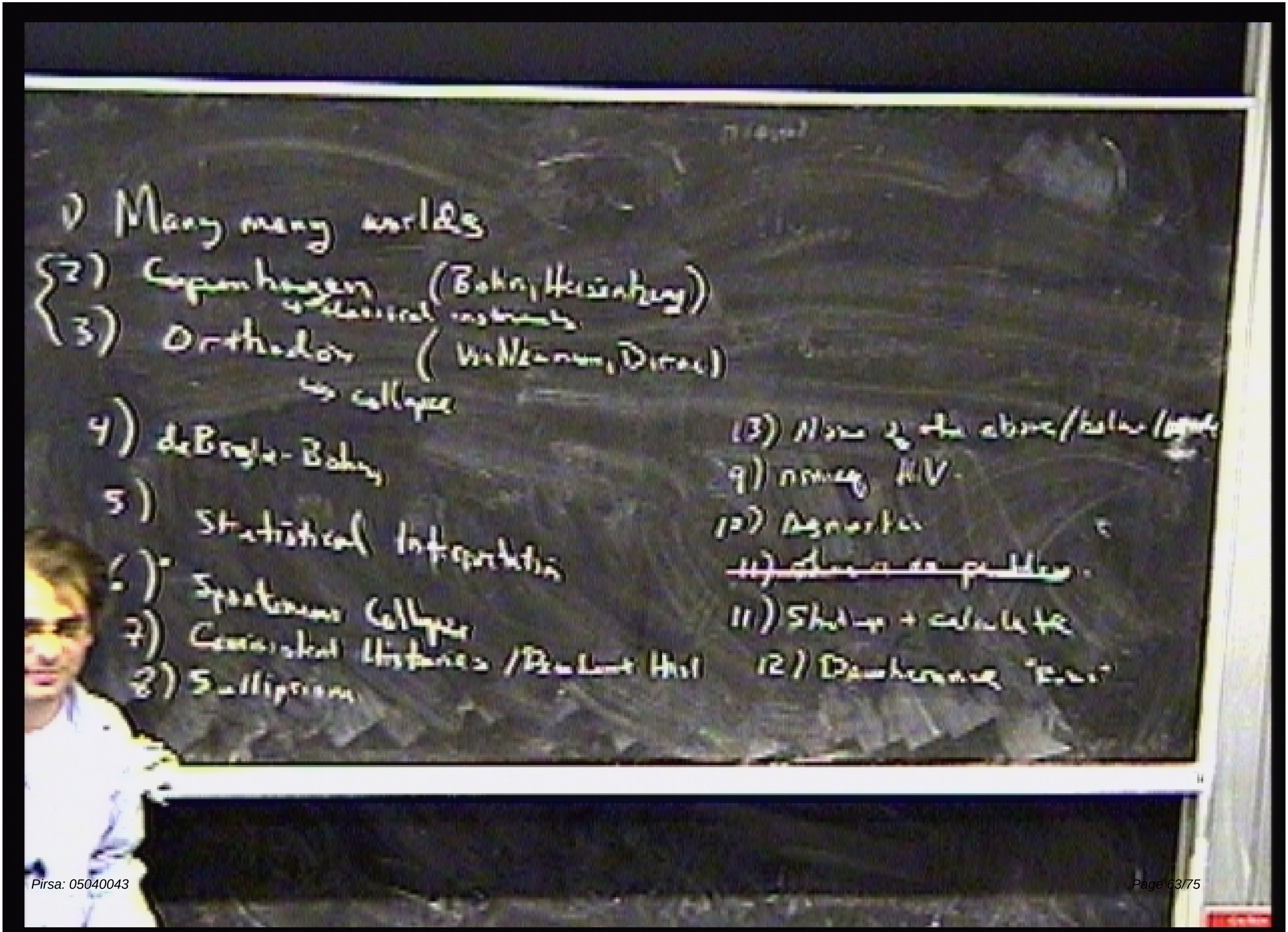
8) Sollipsism

9) nonloc. H.V.

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate


1) Many many worlds
2) Copenhagen (Bohr, Heisenberg)
+ classical instruments
3) Orthodox (von Neumann, Dirac)
collapse
4) deBroglie-Bohm
5) Statistical Interpretation
6) Spontaneous Collapse
7) Consistent Histories / Decoherent Hist
8) Solipsism
13) None of the above/below
10) Agnostic
11) Shut up + calculate
12) Decoherence

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
↳ classical instruments

3) Orthodox (von Neumann, Dirac)
↳ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism

(9) Q. Logic Approach

(8) None of the above / below / [illegible]

9) nonlocal HV

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "Rules"

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
→ classical instruments

3) Orthodox (von Neumann, Dirac)
→ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / [illegible]

8) Solipsism

15) Epistemic Interpretation

14) Q. Logic Approach

13) None of the above/other [illegible]

9) many MV

10) Agnostic

~~11) [illegible]~~

11) Shut up & calculate

12) Decoherence "[illegible]"

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
+ classical instruments

3) Orthodox (von Neumann, Dirac)
↳ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism

15) Epistemic Interpretation
(statistical, ind. systems)

14) Q. Logic Approach

13) None of the above/below

9) [illegible] HV

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "[illegible]"

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
↳ classical systems

3) Orthodox (von Neumann, Dirac)
↳ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism

16) Operational Approaches

15) Epistemic Interpretation
(beliefs(?), Inf. system)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) [illegible] HV

10) Agnostic

~~11) [illegible]~~

11) Shut up & calculate

12) Decoherence "[illegible]"

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
+ classical instruments

3) Orthodox (von Neumann, Dirac)
↳ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism / Anti-Realism

16) Operational Approaches

15) Epistemic Interpretation
(beliefs, info. system)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) non-eq. HV

10) Agnostics

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "E..."

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
↳ classical instruments

3) Orthodox (VonNeumann, Dirac)
↳ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism / Anti-Realism

18) QM as an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(hidden(?), loc. systems)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) Many HV

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "[illegible]"

19) [illegible] Approach (Sorkin)

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
+ classical instruments

3) Orthodox (Von Neumann, Dirac)
+ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism/Anti-Realism

18) QM is an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(beliefs(?), Inf. system)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) non-loc HV

10) Agnostics

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "[illegible]"

19) [illegible] Approach (Sorkin)

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
+ classical instruments

3) Orthodox (von Neumann, Dirac)
→ collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism / Anti-Realism

18) QM is an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(Spekkens(?), [illegible] systems)

14) Q Logic Approach

13) None of the above / below / [illegible]

9) non-eq. HV

10) Agnostic

~~11) [illegible] problem~~

11) Shut up + calculate

12) Decoherence "Kills"

19) Realism Approach (Sorkin)

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
classical instruments

3) Orthodox (von Neumann, Dirac)
↳ collapse

4) de Broglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist

8) Solipsism / Anti-Realism

18) QM is an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(Fuchs([illegible], [illegible] systems)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) non-eq HV

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "Ever"

19) Realism Approach (Sorkin)

1) Many, many worlds

2) Copenhagen (Bohr, Heisenberg)
classical instruments

3) Orthodox (von Neumann, Dirac)
collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist.

8) Solipsism / Anti-Realism

18) QM is an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(Spekkens(?), ... systems)

14) Q Logic Approach

13) None of the above/below/[illegible]

9) non-eq. HV

10) Agnostic

~~11) there is no problem~~

11) Shut up + calculate

12) Decoherence "Ever"

19) Preclusion Approach (Sorkin)

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg)
classical instruments

3) Orthodox (Von Neumann, Dirac)
collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / Decoherent Hist.

8) Solipsism / Anti-Realism

18) QM is an approximation

17) Modal Interpretations

16) Operational Approaches

15) Epistemic Interpretation
(... , ind. system)

14) Q Logic Approach

13) None of the above/below/...

9) many MV

10) Agnostic

~~11) [illegible]~~

11) Shut up + calculate

12) Decoherence "Ever"

(19) Realism Approach (Sorkin)

1) Many many worlds

2) Copenhagen (Bohr, Heisenberg) — classical instrument

3) Orthodox (von Neumann, Dirac) — has collapse

4) deBroglie-Bohm

5) Statistical Interpretation

6) Spontaneous Collapse

7) Consistent Histories / [illegible] Hal

8) Solipsism / Anti-Realism

(18) QM is an approximation

(17) Modal Interpretations

(16) Operational Approaches

15) Epistemic Interpretation (state(?), incl. system)

14) QL Logic Approach

(13) None of the above/below (agnost.)

9) many HV

10) Agnostic!

~~11) [illegible]~~

11) Shut up & calculate

12) Decoherence "[illegible]"