Title: Interpretation of Quantum Theory: Lecture 9

Date: Feb 01, 2005 02:30 PM

URL: http://pirsa.org/05020002

Abstract:

Stanford Encyclopedia of Phil. Bohmian Mech.
Online

Encycl. of Phil. BM
Dürr Zanghì, Tumulka
de Broglie Bohm, Bohmian mechanics
dB 1927 Bohm 1952 (1951)
What is BM?. Formulation of nonrel. QM

Stanford Encyclopedia of Phil.
Online

Bohmian Mech.

Encycl. of Phil. BM

Dürr, Zanghì, Tumulka

de Broglie Bohm

dB 1927 Bohmian mechanics

Bohm 1952 (1951)

What is BM? Formulation of named QM

Why is it neglected? What's wrong with it?

Stanford Encyclopedia of Phil.
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Bohmian Mech.

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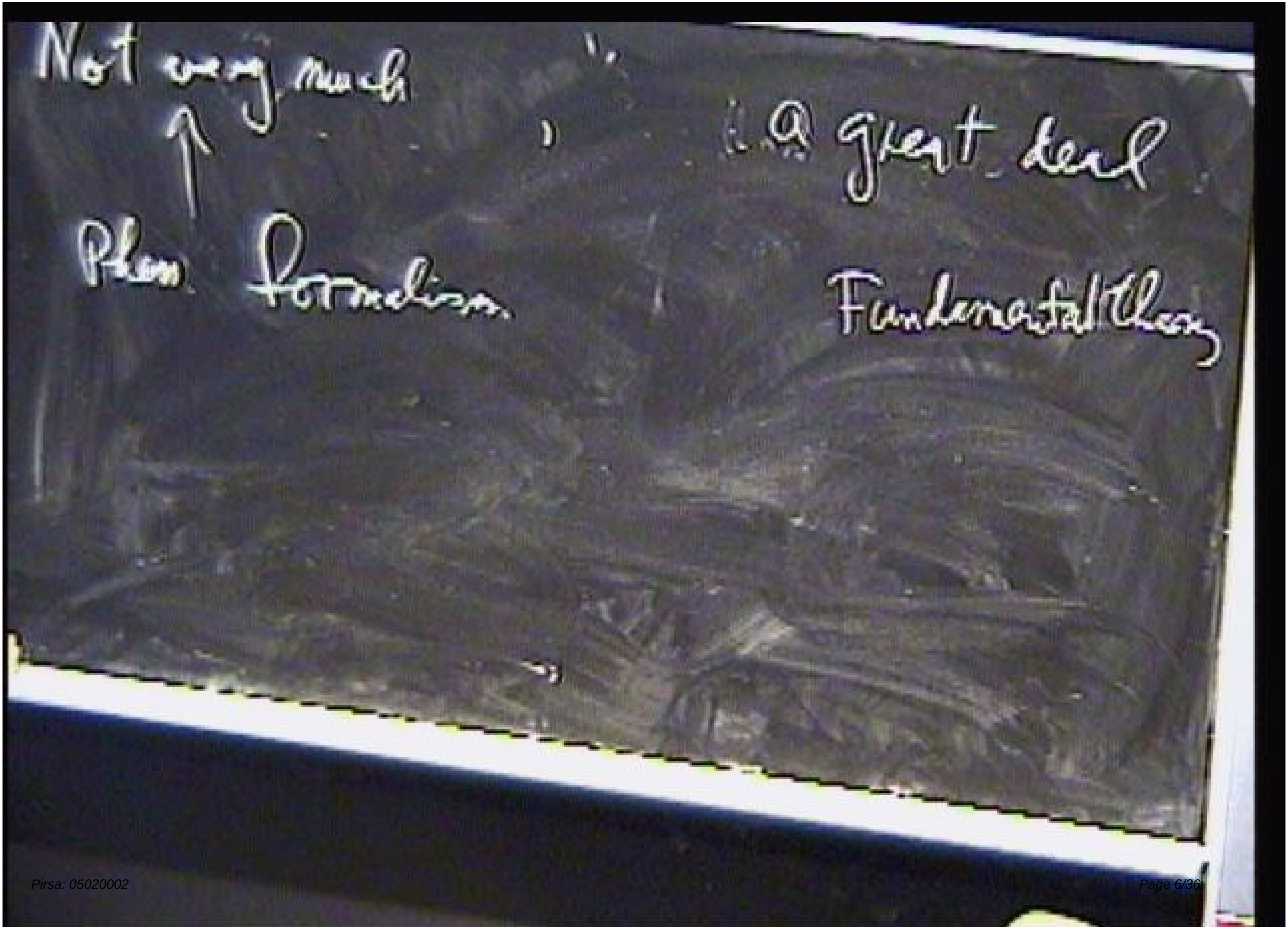
Bohm 1952 (1951)

What is BM? Formulation of [illegible] QM

Why is it neglected? What's wrong with QT?


Not very much
i.e. a great deal
Phen formalism
Fundamental theory

Not very much

↑

Phen. formalism

a great deal

Fundamental theory

Not clear what QT is about?

• wf's

measurement problem

Sch's cat

$\Psi = \Psi_{left} + \Psi_{right}$

$$\Psi = \frac{\Psi_{alive} + \Psi_{dead}}{\sqrt{2}}$$

- measurements $\leftrightarrows$ observations
  - implausible
  - vague

$$\Psi = \frac{\Psi_{alive} + \Psi_{dead}}{\sqrt{2}}$$

- measurements $\neq$ observations
    - implausible
    - vague

But "no HV's theorems" $\Longrightarrow$ "Measurement creates reality"

~~beyond~~

A B

C D

$$\Psi = \frac{\Psi_{alive} + \Psi_{dead}}{\sqrt{2}}$$

- measurements, observations
  - implausible
  - vague

But "no HV's theorems" $\Longrightarrow$ "Measurement creates reality" ~~revealed~~

$\psi \Updownarrow$ impossible relationship

$A=1$ and $B=1$ 9% $\Downarrow$ $C=1$ and $D=1$ never happens

According to BM, QT is about particles with positions

According to BM, QT is about particles with positions

State $\underbrace{Q_1,\ldots,Q_N}_{Q}$, $\psi(\underbrace{q_1,\ldots,q_N}_{q})$

$\uparrow$ actual

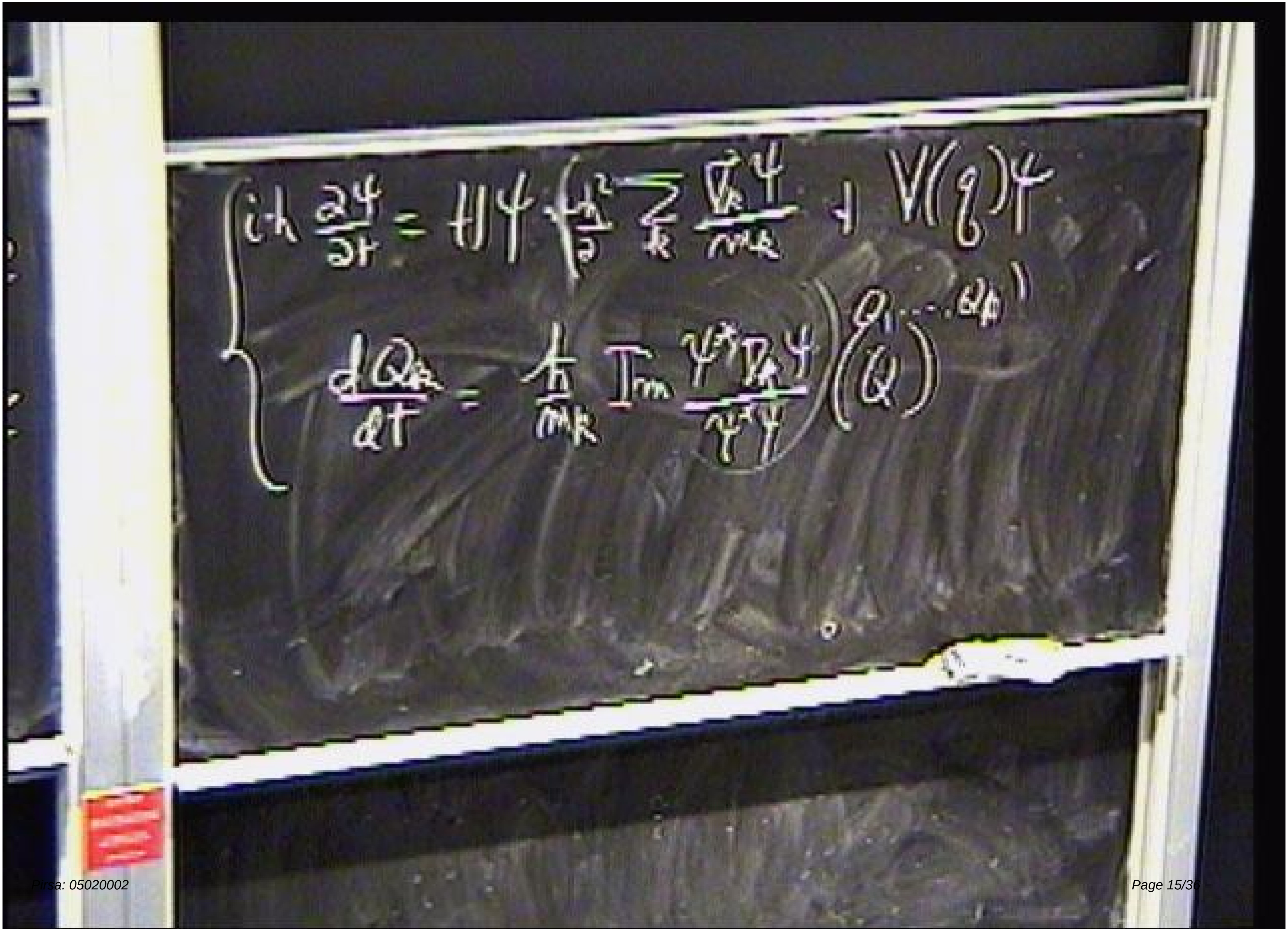
...s about particles
with positions

$(\ldots, \ldots, r_n)$

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi = -\frac{\hbar^2}{2} \sum_k \frac{\nabla_k^2 \psi}{m_k}$$

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi = -\frac{\hbar^2}{2}\sum_k \frac{\nabla_k^2 \psi}{m_k} + V(q)\psi$$

$$\frac{dQ_k}{dt} = \frac{\hbar}{m_k}\,\mathrm{Im}\,\frac{\psi^* \nabla_k \psi}{\psi^* \psi}\Bigg|_{Q = (Q_1 \ldots Q_N)}$$


$i\hbar \frac{\partial \psi}{\partial t} = H\psi = -\frac{\hbar^2}{2} \sum_k \frac{\partial_k^2 \psi}{m_k} + V(q)\psi$
$q = (q_1, \dots, q_N)$
$\frac{dQ_k}{dt} = \frac{\hbar}{m_k} \mathrm{Im} \frac{\psi^* \partial_k \psi}{\psi^* \psi}(Q)$

$$\begin{cases} i\hbar \dfrac{\partial\psi}{\partial t} = H\psi = -\dfrac{\hbar^2}{2}\sum_k \dfrac{\partial_k^2\psi}{m_k} + V(q)\psi \\[2ex] \dfrac{dQ_k}{dt} = \left(\dfrac{\hbar}{m_k}\,\mathrm{Im}\,\dfrac{\psi^*\partial_k\psi}{\psi^*\psi}\right)\overset{(q_1,\dots,q_N)}{(Q)} = \dfrac{J_k}{\rho} \end{cases}$$

$$i\hbar \frac{\partial \psi}{\partial t} = H\psi = -\frac{\hbar^2}{2}\sum_k \frac{\nabla_k^2 \psi}{m_k} + V(q)\psi$$

$$(Q_1 \ldots Q_N)$$

$$\frac{dQ_k}{dt} = \frac{\hbar}{m_k}\,\mathrm{Im}\,\frac{\psi^* \nabla_k \psi}{\psi^* \psi}(Q) = \frac{J_k}{\rho}$$

Spin 0 $\quad \psi(q) \in \mathbb{C}$

Spin $\frac{1}{2}$ $\quad \psi(q) \in \mathbb{C}^2 \quad \psi(q) = \begin{pmatrix} \psi_1(q) \\ \psi_2(q) \end{pmatrix}$

$$= \frac{\hbar}{m} \,\mathrm{Im}\, \frac{\nabla_k \psi}{\psi} = \frac{\nabla_k S}{m}$$

spin 0

$$\psi = R e^{iS/\hbar}$$

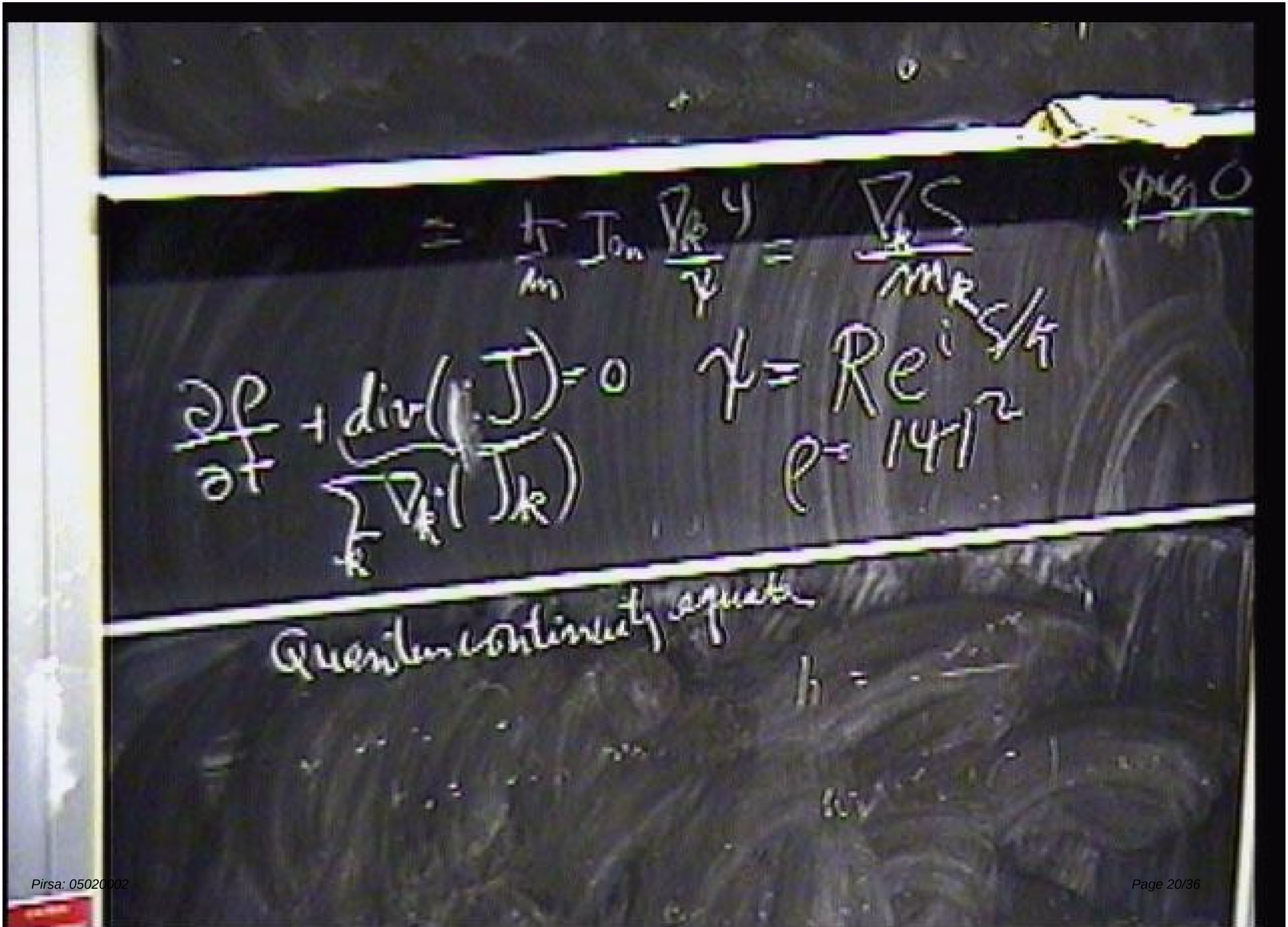
$h =$

$$= \frac{\hbar}{m}\,\mathrm{Im}\,\frac{\nabla_k \psi}{\psi} = \frac{\nabla_k S}{m} \qquad \rho$$

$$\psi = R e^{iS/\hbar}$$

$$\frac{\partial \rho}{\partial t} + \underbrace{\mathrm{div}(J)}_{\sum \nabla_{k_i}(J_k)} = 0$$

$$h =$$


= ħ/m Im ∇k ψ / ψ = ∇k S / mk
∂ρ/∂t + div(J) = 0
Σk ∇k(Jk)
ψ = R e^(iS/ħ)
ρ = |ψ|²
Quantum continuity equation
h =

$$\begin{cases} i\hbar \dfrac{\partial \psi}{\partial t} = H\psi = -\dfrac{\hbar^2}{2} \displaystyle\sum_k \dfrac{\nabla_k^2 \psi}{m_k} + V(q)\psi \\[2ex] \dfrac{dQ_k}{dt} = \dfrac{\hbar}{m_k} \operatorname{Im} \dfrac{\psi^* \nabla_k \psi}{\psi^* \psi}(Q) = \dfrac{J_k}{\rho} \end{cases}$$

$$Q = (Q_1, \ldots, Q_N)$$

spin 0 $\quad \psi(q) \in \mathbb{C}$

spin $\frac{1}{2}$ $\quad \psi(q) \in \mathbb{C}^2 \quad \psi(q) = \begin{pmatrix} \psi_1(q) \\ \psi_2(q) \end{pmatrix}$

deterministic

initial data $\psi_0(q)$, $Q_1(0)$, … $Q_n(0)$

No other axioms!

"Derivation"

$J = \rho v$

$v = \frac{J}{\rho}$

eterministic

initial data $\psi_0(q)$, $Q_1(q)$, ... $Q_N(q)$

other axioms!

ivation "

$J = \rho v$

Gal. cov.

$v = \frac{J}{\rho}$

deterministic

initial data $\psi_0(q)$, $Q_1(0)$, ... $Q_n(0)$

No other axioms!

Derivation "

$J = \rho v$ $\qquad v = \frac{J}{\rho}$

Gal. cov.

$E = h\nu \Rightarrow p = \hbar k \rightarrow$ SE

deterministic

initial data $\psi_0(q)$, $Q_1(0)$, ... $Q_N(0)$

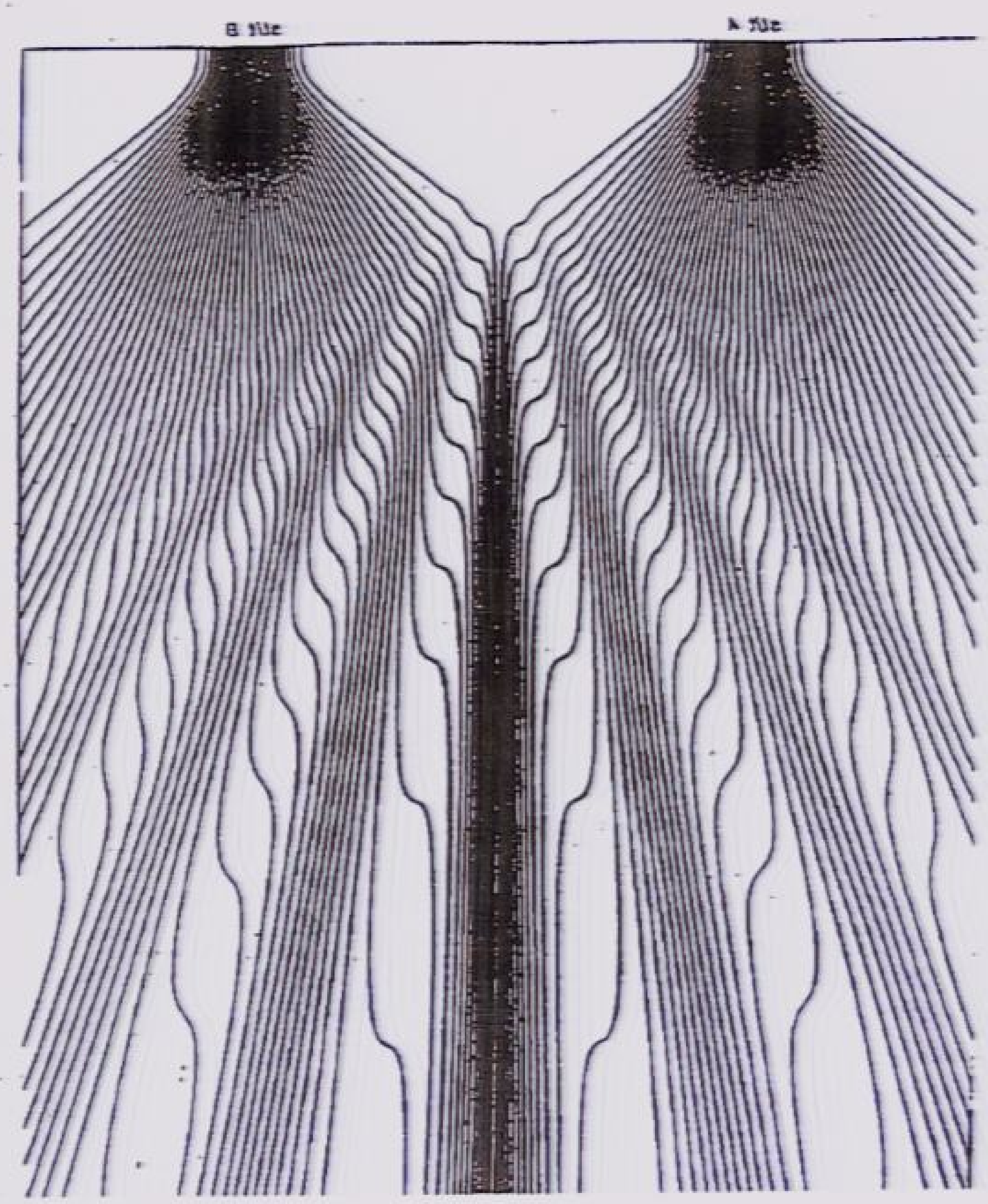
No other axioms!

"Derivation"

$J = \rho v$ $\quad v = \frac{J}{\rho}$

Gal. cov.

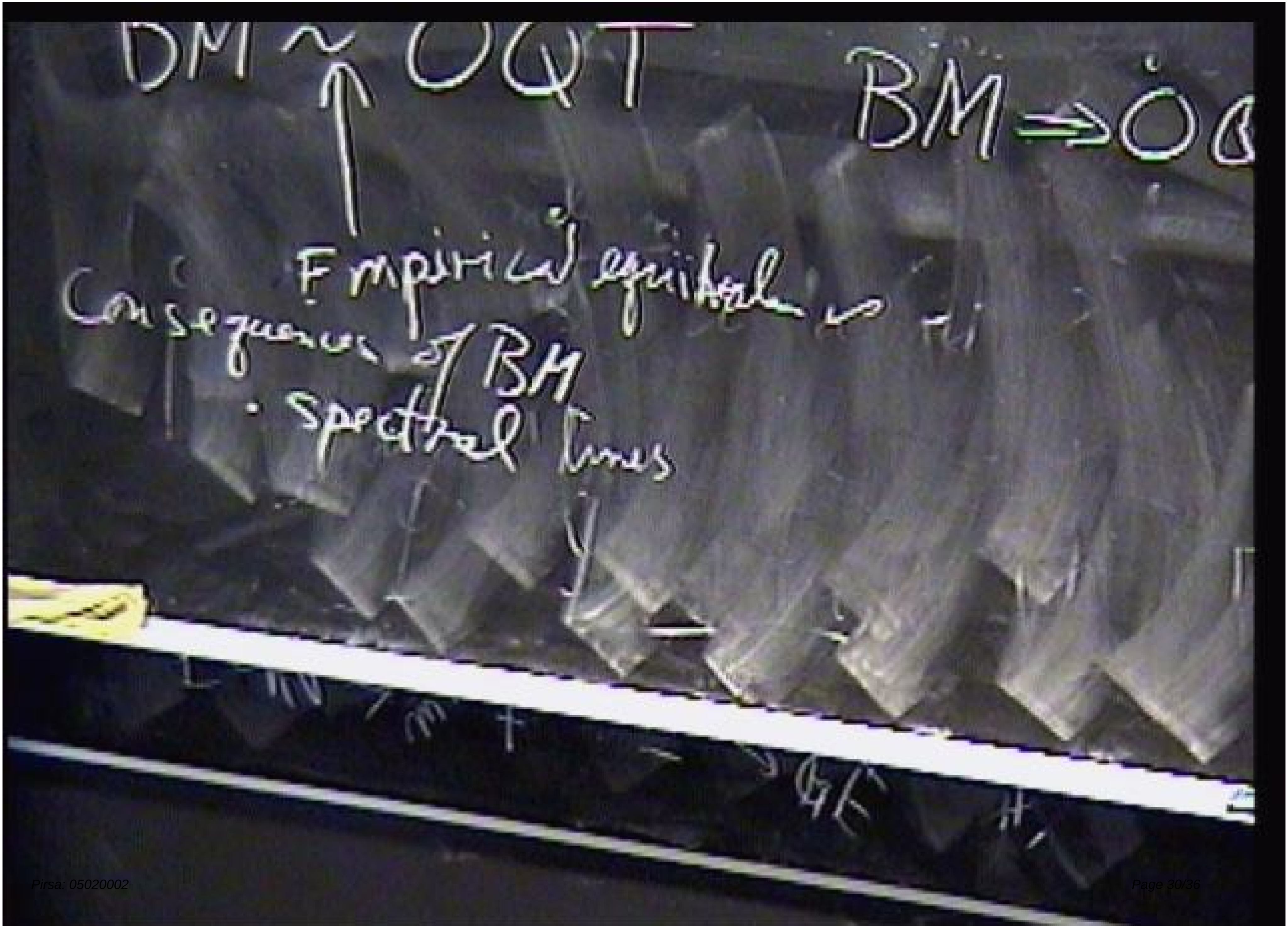
$E = h\nu \Rightarrow p = \hbar k$ → SE, → GE

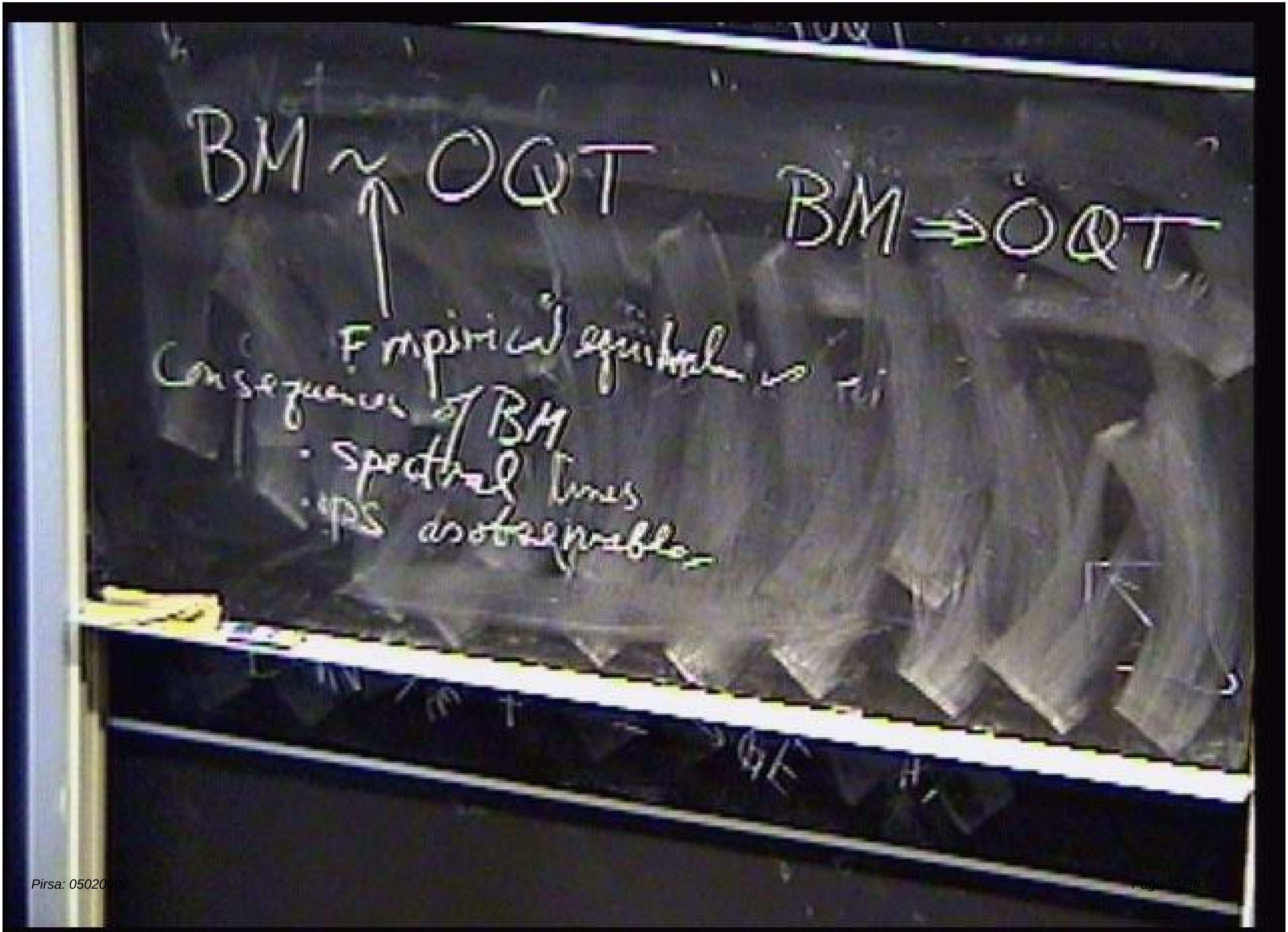


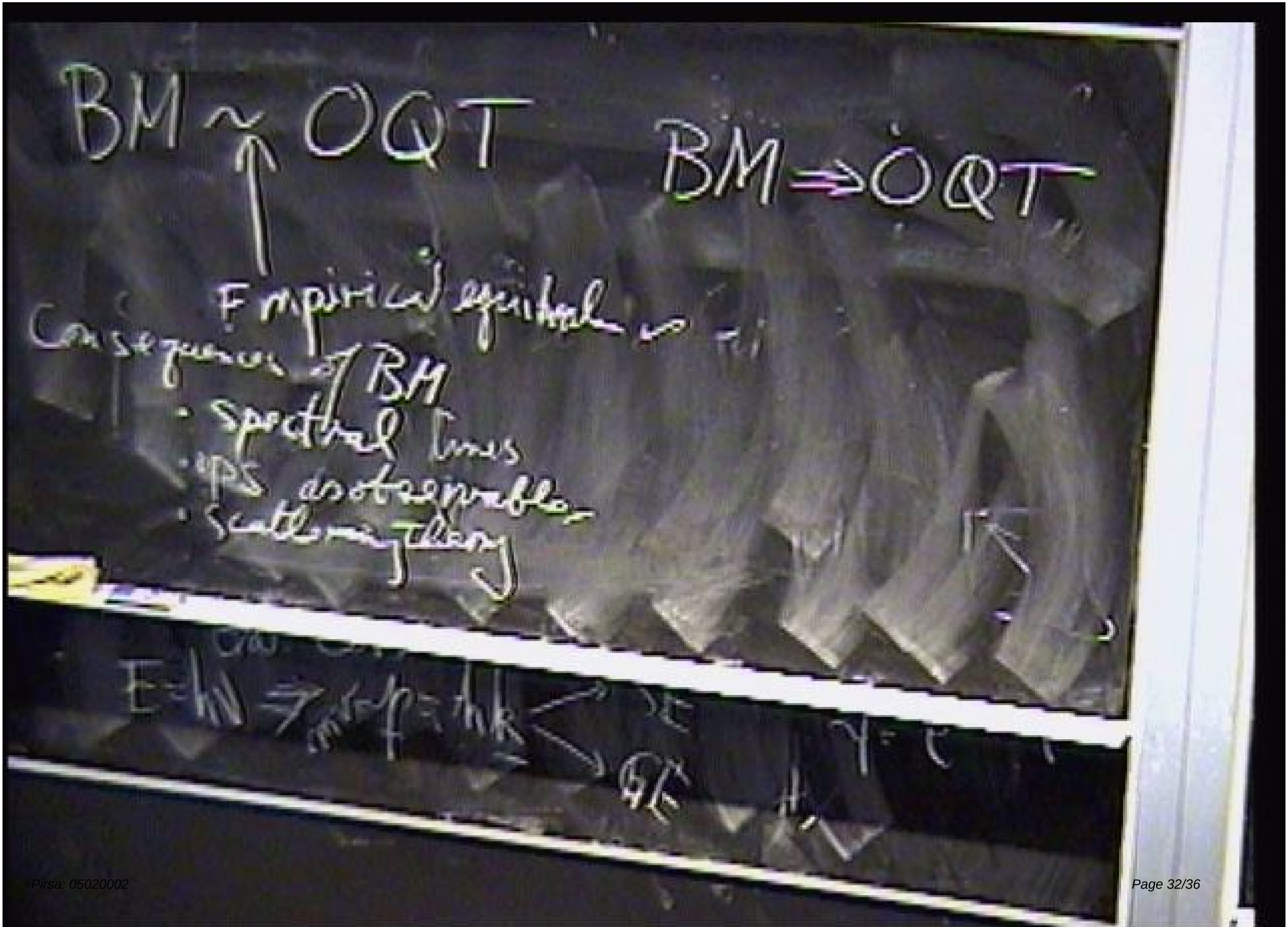

BM ~ OQT
Empirical

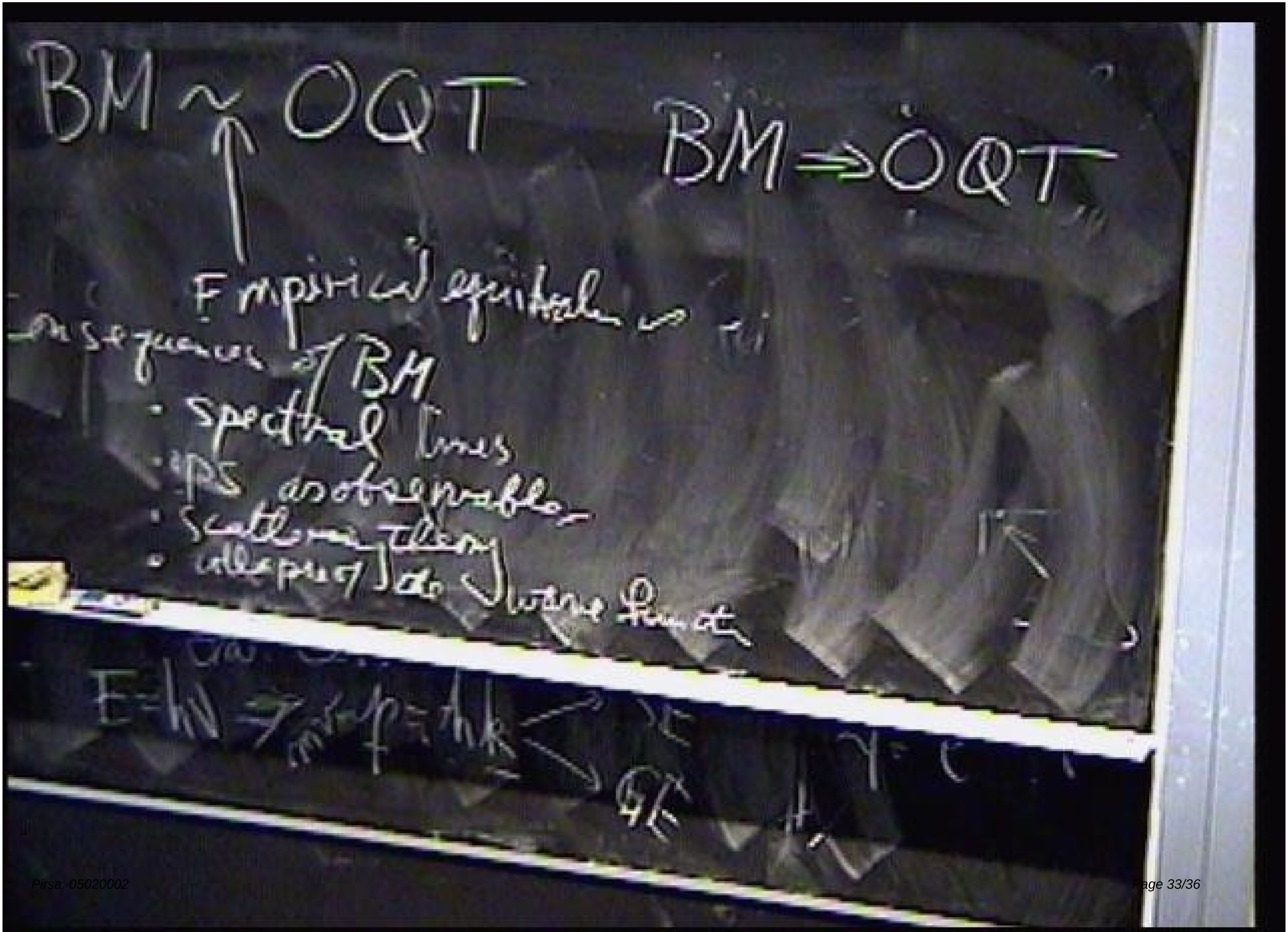

BM ~ OQT
Empirical equivalent
BM ⇒ OQT

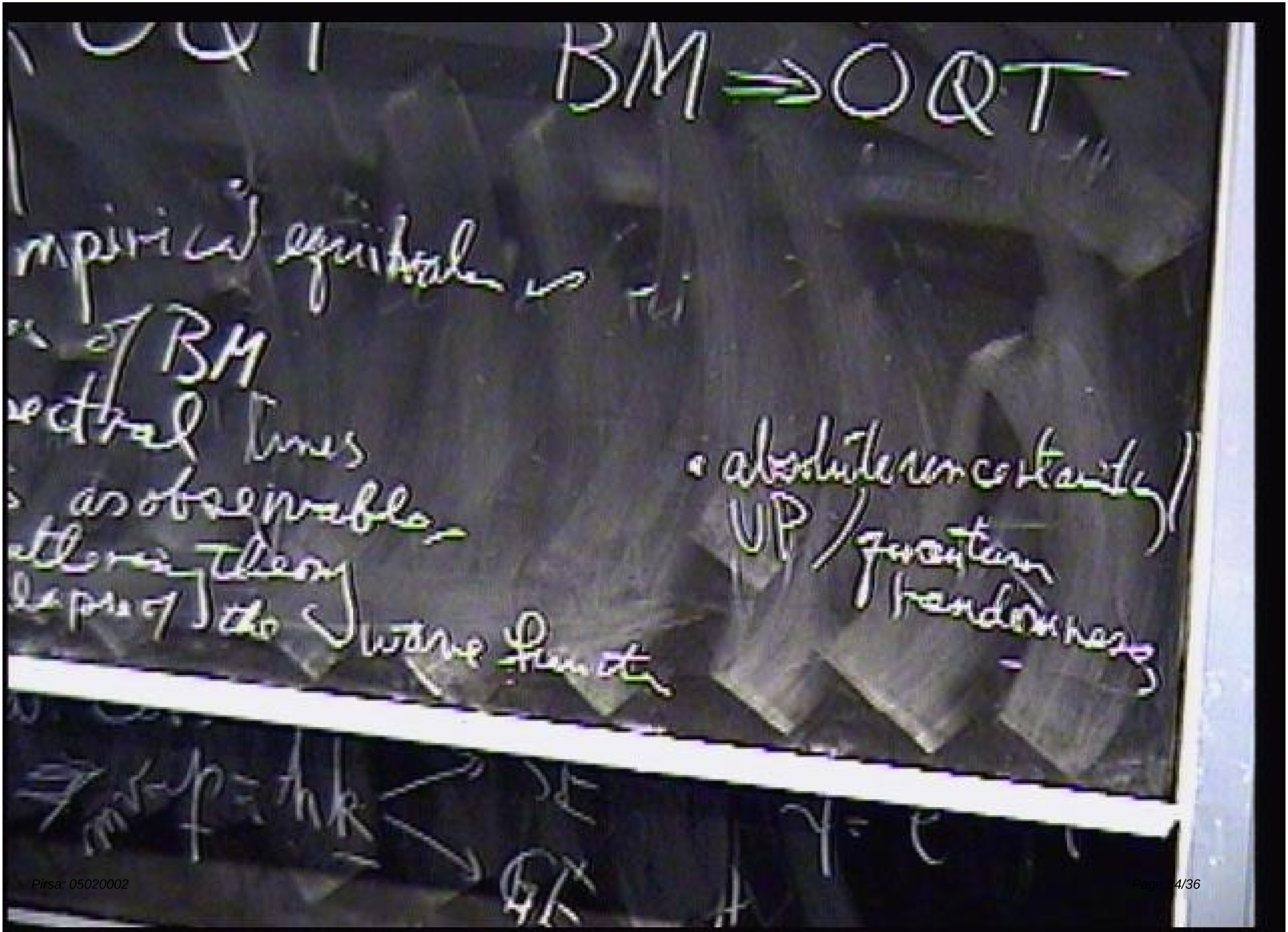

BM ~ OQT
BM → ȮQT
Empirical equivalence
consequence of BM


BM ~ OQT
BM ⇒ ȮQ
Empirical equivalence
Consequences of BM
· spectral lines


BM ~ OQT
Empirical equivalence
BM ⇒ OQT
Consequences of BM
· spectral times


BM ~ OQT
BM ⇒ OQT
Empirical equivalence
Consequences of BM
· spectral lines
· Scattering theory


BM ~ OQT
BM ⇒ OQT
Empirical equivalence
consequences of BM
• spectral lines
• QS as observables
• scattering theory
• collapse of the wave function
E=hν


BM ⇒ OQT
of BM
absolute uncertainty
UP / quantum randomness
the wave function

AU: A typical Bohmian universe is in a QE

A typical Bohmian universe is in q. QE.

A Bohmian universe in QE is one with AU, in which it is impossible to know more about a system than its wf allows: $|\psi(q)|^2$ distrib'l