Title: Foundations of Quantum Mechanics #2

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Abstract: Interferometry, measurement and interpretation. Beyond the quanta.

Measurement and Interpretation

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"It would seem that the theory is exclusively concerned with the 'results of measurement' and has nothing to say about anything else. When the 'system' in question is the whole world where is the 'measurer' to be found? Inside, rather than outside, presumably. What exactly qualifies some subsystems to play this role? Was the world wave function waiting to jump for thousands of millions of years until a single-celled living creature appeared? Or did it have to wait a little longer for some more highly qualified measurer - with a PhD?"

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- Some solutions to the measurement problem

$$L\frac{d^2 q}{dt^2} + R\frac{dq}{dt} + Cq = 0$$

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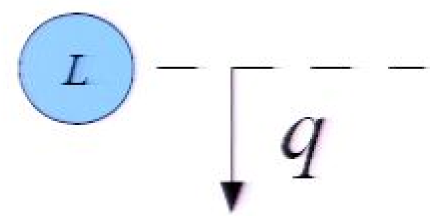

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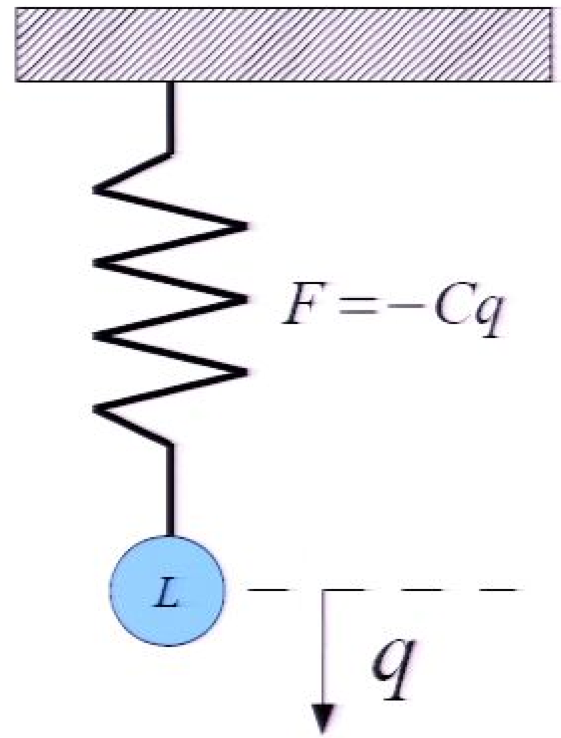

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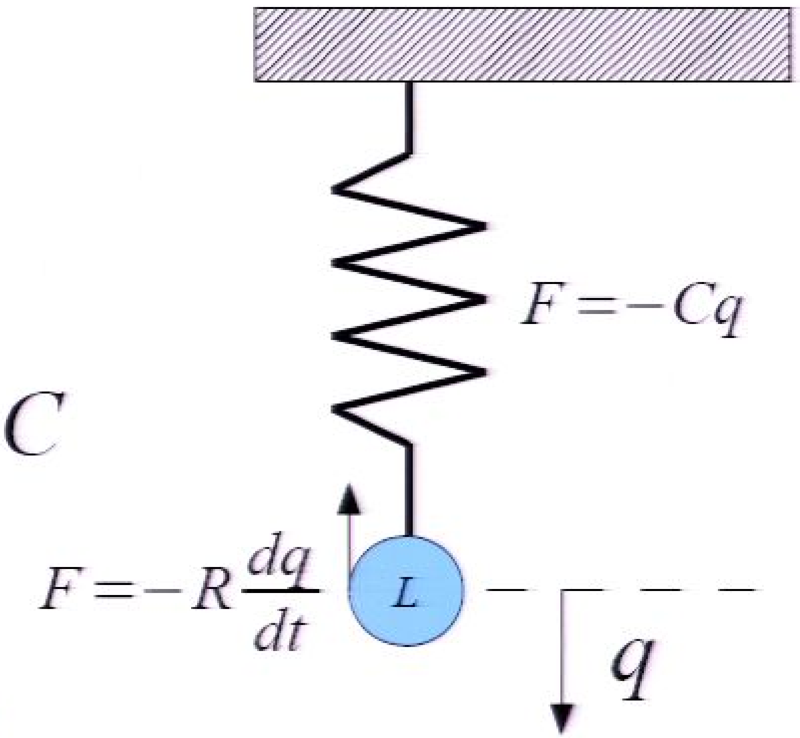
and in a viscous medium with resistance R



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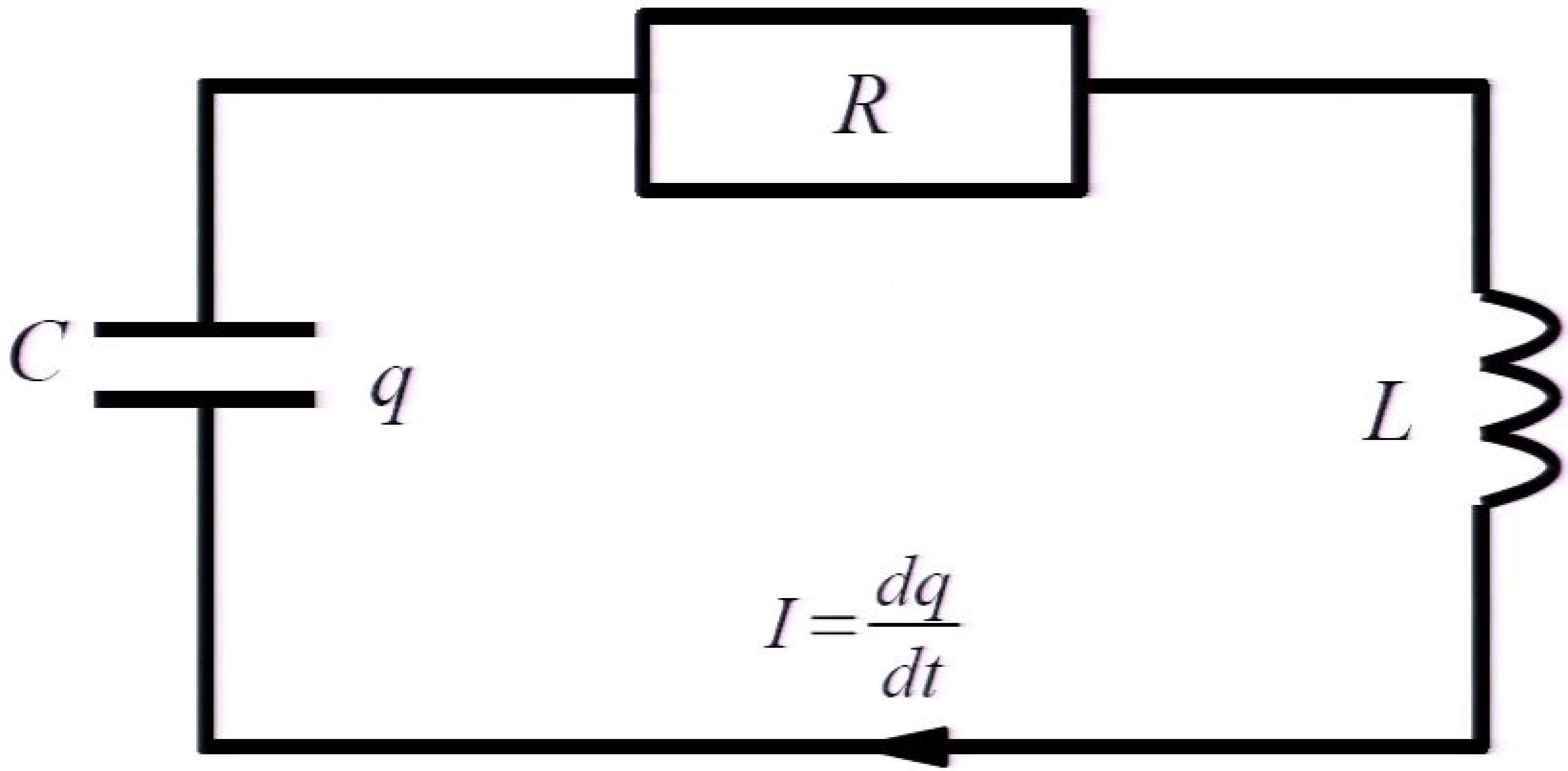

Interpretation and physics

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  - Experiments make lights flash, things go click, pointers to point at numbers on a dial, printers to squirt ink on papers.
  - Something in the the mathematics of the theory has got to be identified as telling you which lights will or will not flash, when or how often things go click, what numbers get pointed to, what pretty patterns get ejected from the printer.

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  - Before and after coin flipped?
  - Before and after result seen?

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  - At the minimum a theory must tell us

$$P(K|I,J)$$

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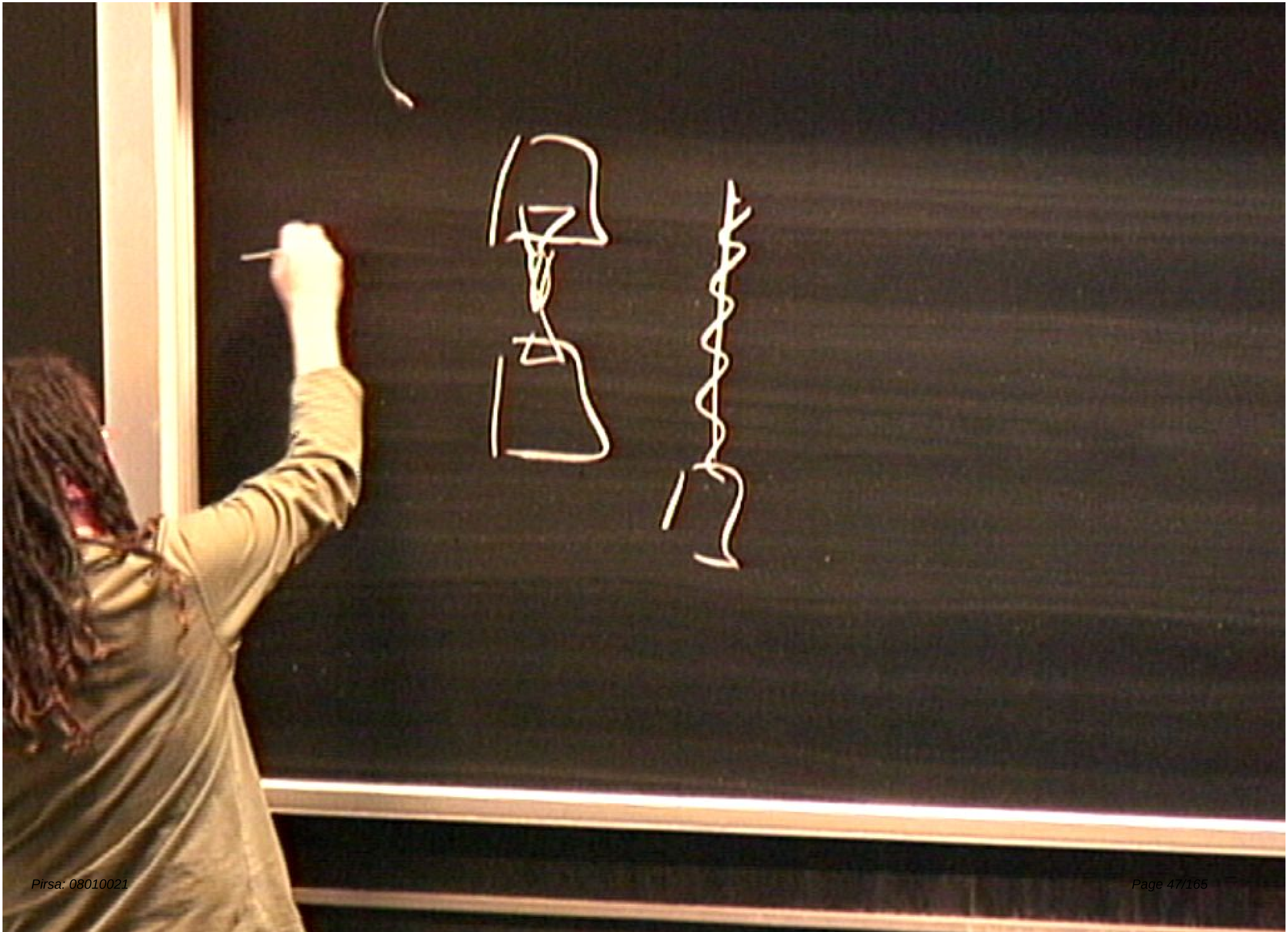
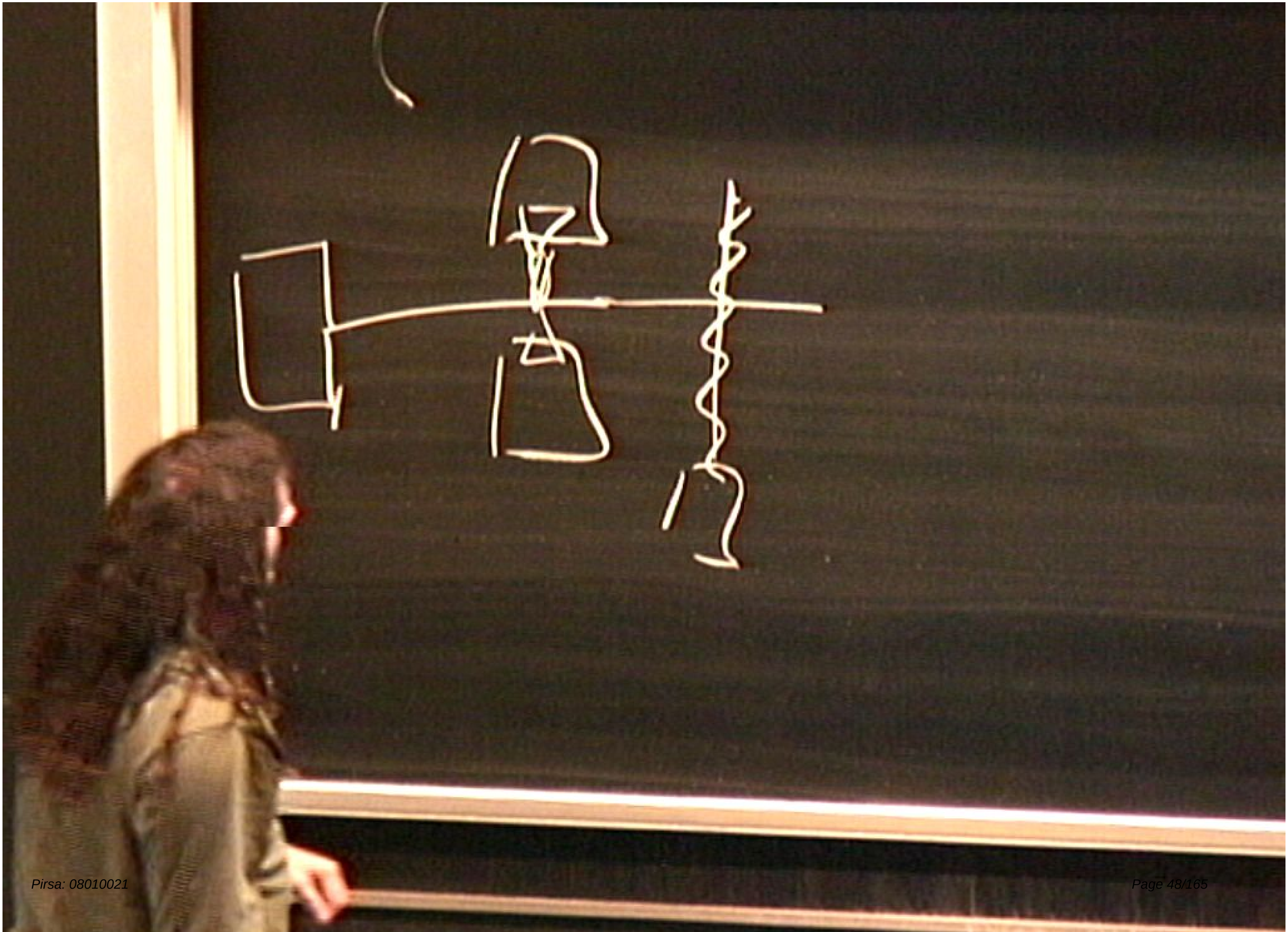
Evolution of prepared system is linear:

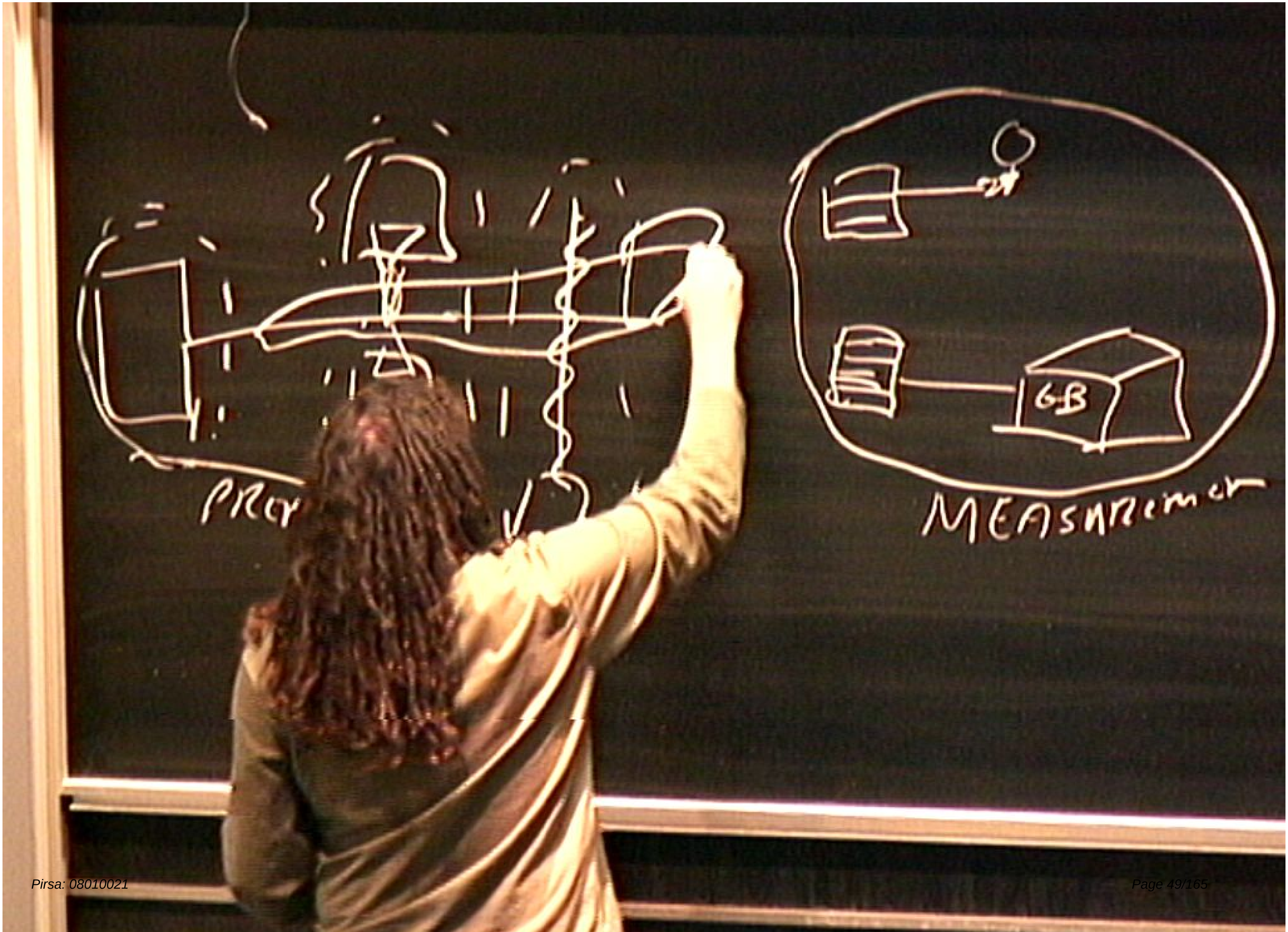
If $\psi_1 \rightarrow \psi'_1$, $\psi_2 \rightarrow \psi'_2$ then $\alpha\psi_1+\beta\psi_2 \rightarrow \alpha\psi'_1+\beta\psi'_2$

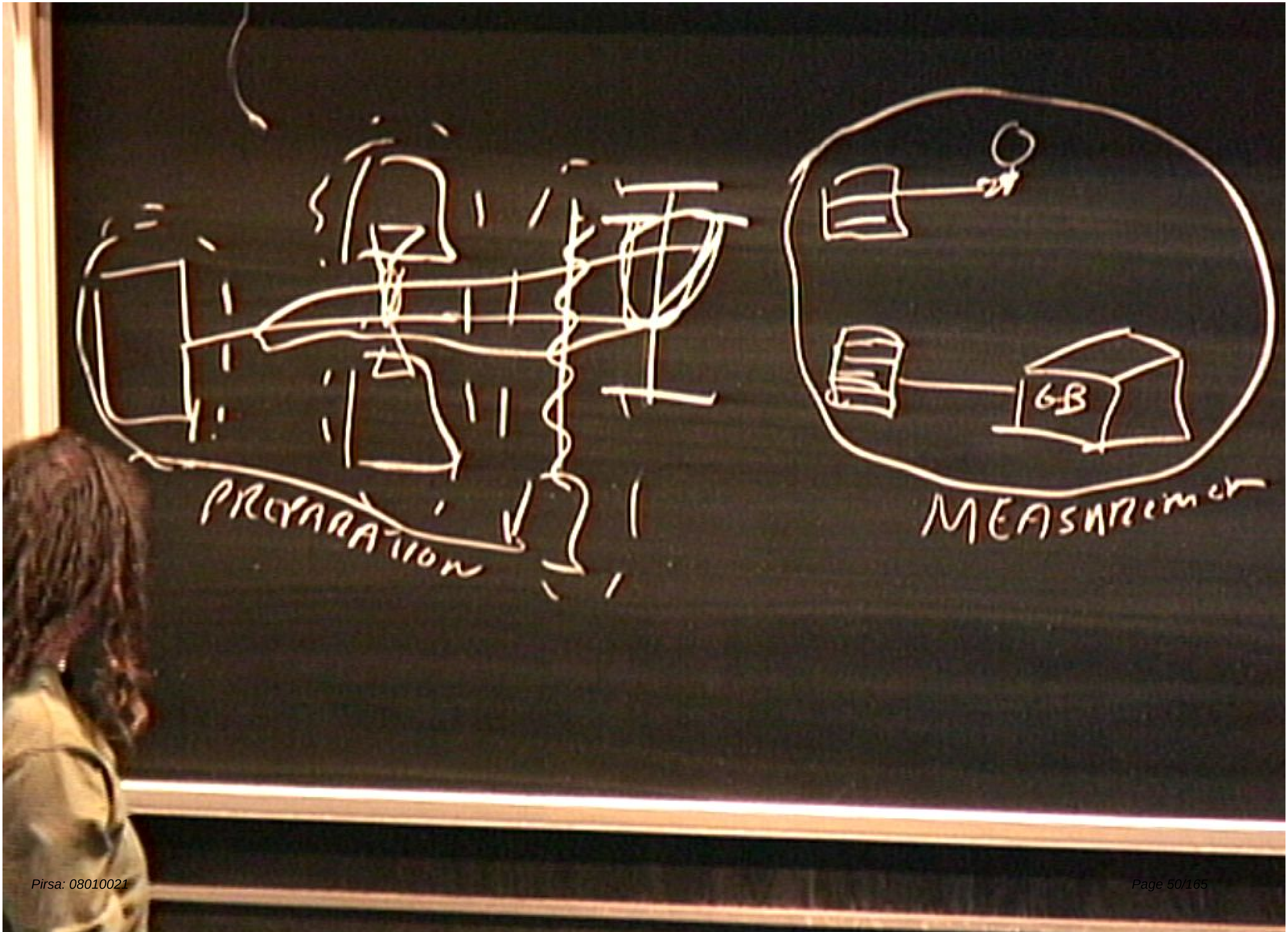
Is Quantum theory a fundamental theory?

- In classical physics, when we look a the apparatus used to prepare and measure a system (eg. voltmeters, batteries, rulers) they are composed of components that can be described by the same laws as the system they perform experiments upon.






GB
MEASUREMENT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GB
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  - Does quantum mechanics enable us to describe apparatus, equipment, chairs etc?
  - Is the process of measurement itself described by quantum theory?
  - In short, is quantum theory a universal theory or not?

The Measurement Problem!

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so that the measuring device state corresponds to something like a big pointer pointing at the letter "U" Φ_u

We also want it to interact with a different state:
so that the measuring device output state corresponds to something like a big pointer pointing at the letter "D" Φ_d

This requires $\psi_d \Phi_0 E_0 \rightarrow \psi_d \Phi_d E_d$

But Schrodinger evolution is linear, so that means: $\frac{1}{\sqrt{2}}(\psi_u + \psi_d)\Phi_0 E_0 \rightarrow \frac{1}{\sqrt{2}}(\psi_u \Phi_u E_u + \psi_d \Phi_d E_d$

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  - The universe branches in a particular way. There is, in effect, extra structure to the universe than just the wavefunction and Schrodinger evolution. This extra structure determines the basis in which quantum events occur.

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  - The universe branches in a particular way. There is, in effect, extra structure to the universe than just the wavefunction and Schrodinger evolution. This extra structure determines the basis in which quantum events occur.
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    - *It is our perception which divides, not the universe.*

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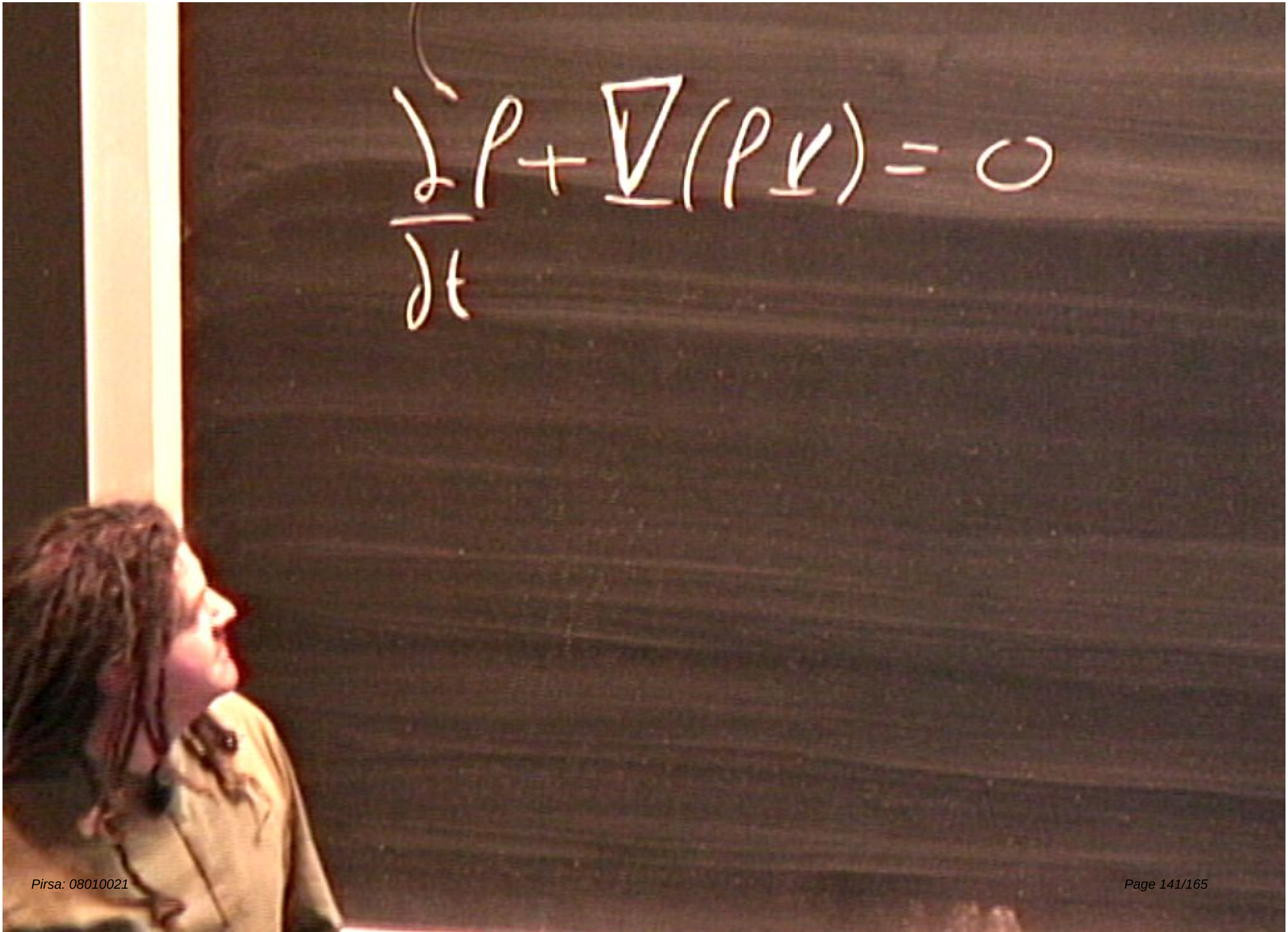
$$J(x,t)=\frac{\psi^*(x,t)\hbar\nabla\psi(x,t)-\psi(x,t)\hbar\nabla\psi^*(x,t)}{2im}=\frac{P(x,t)\hbar\nabla S(x,t)}{m}=P(x,t)\dot{x}$$

[redacted]

$$\frac{\partial \rho}{\partial t} + \underline{\nabla}(\rho \underline{v}) = 0$$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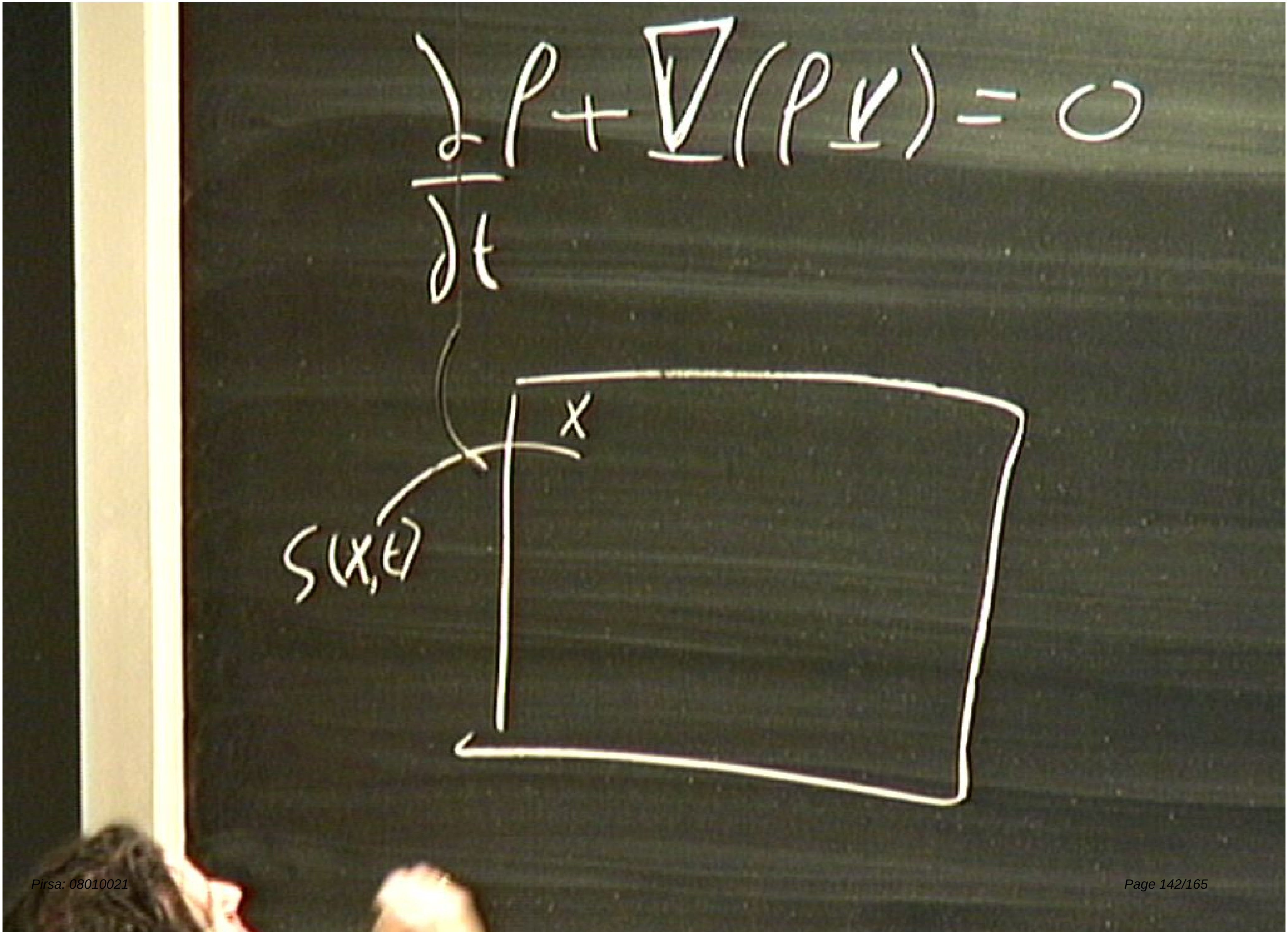
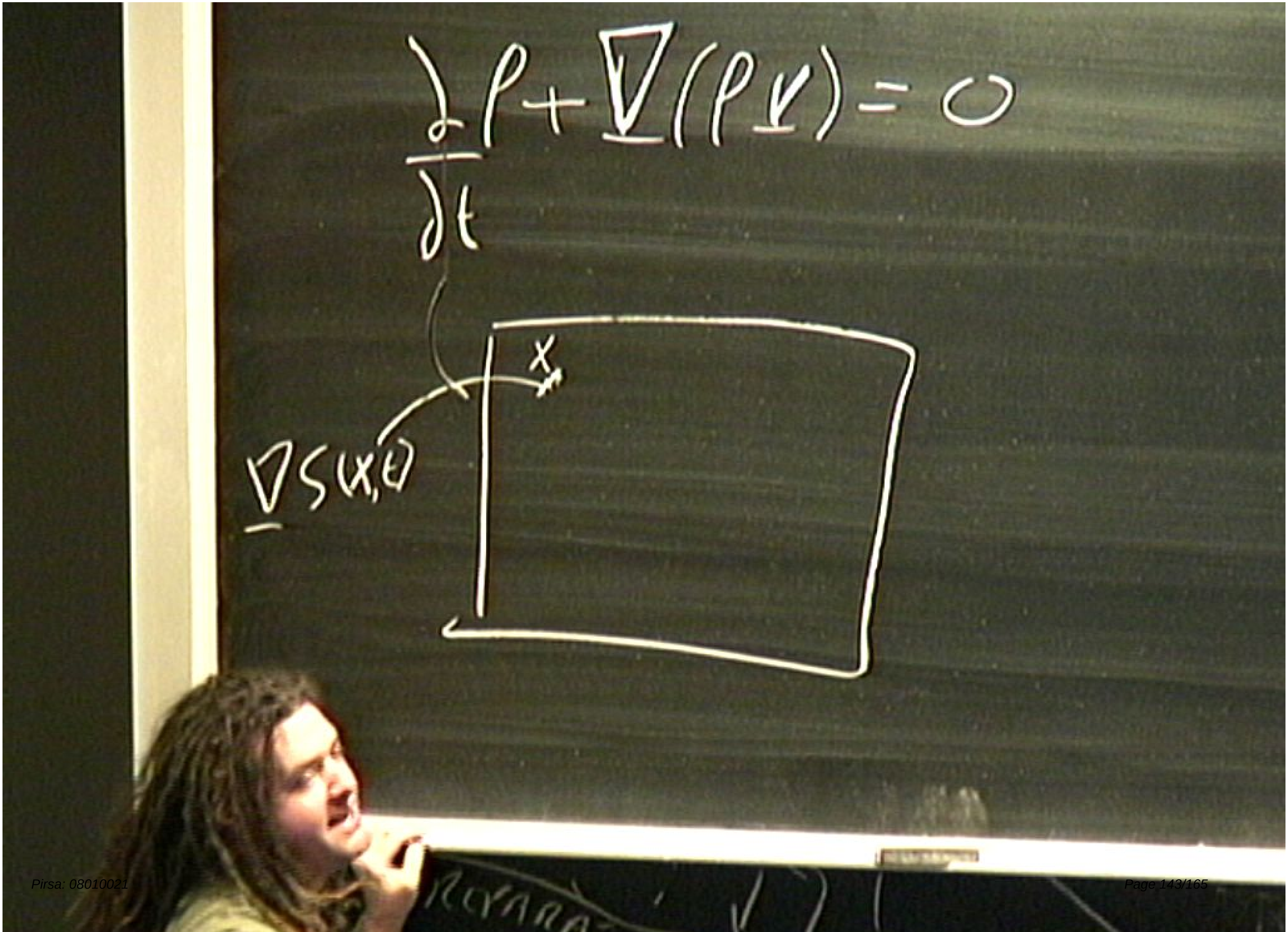
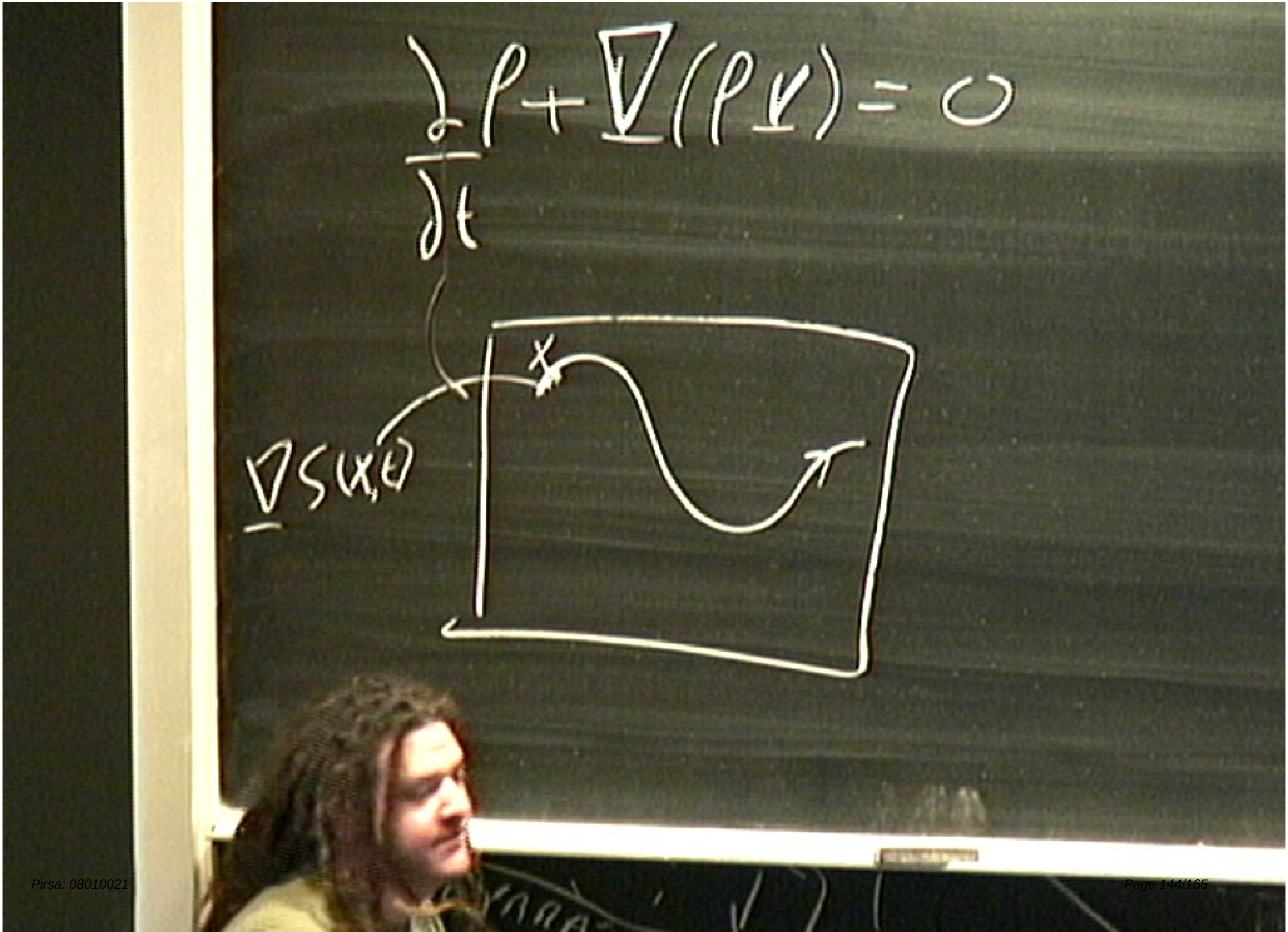

$\frac{\partial}{\partial t}\rho + \nabla(\rho v) = 0$
x
S(x,t)


$\frac{\partial}{\partial t}\rho + \underline{\nabla}(\rho \underline{v}) = 0$
$\underline{\nabla} S(x,t)$
x


∂ρ/∂t + ∇(ρv) = 0
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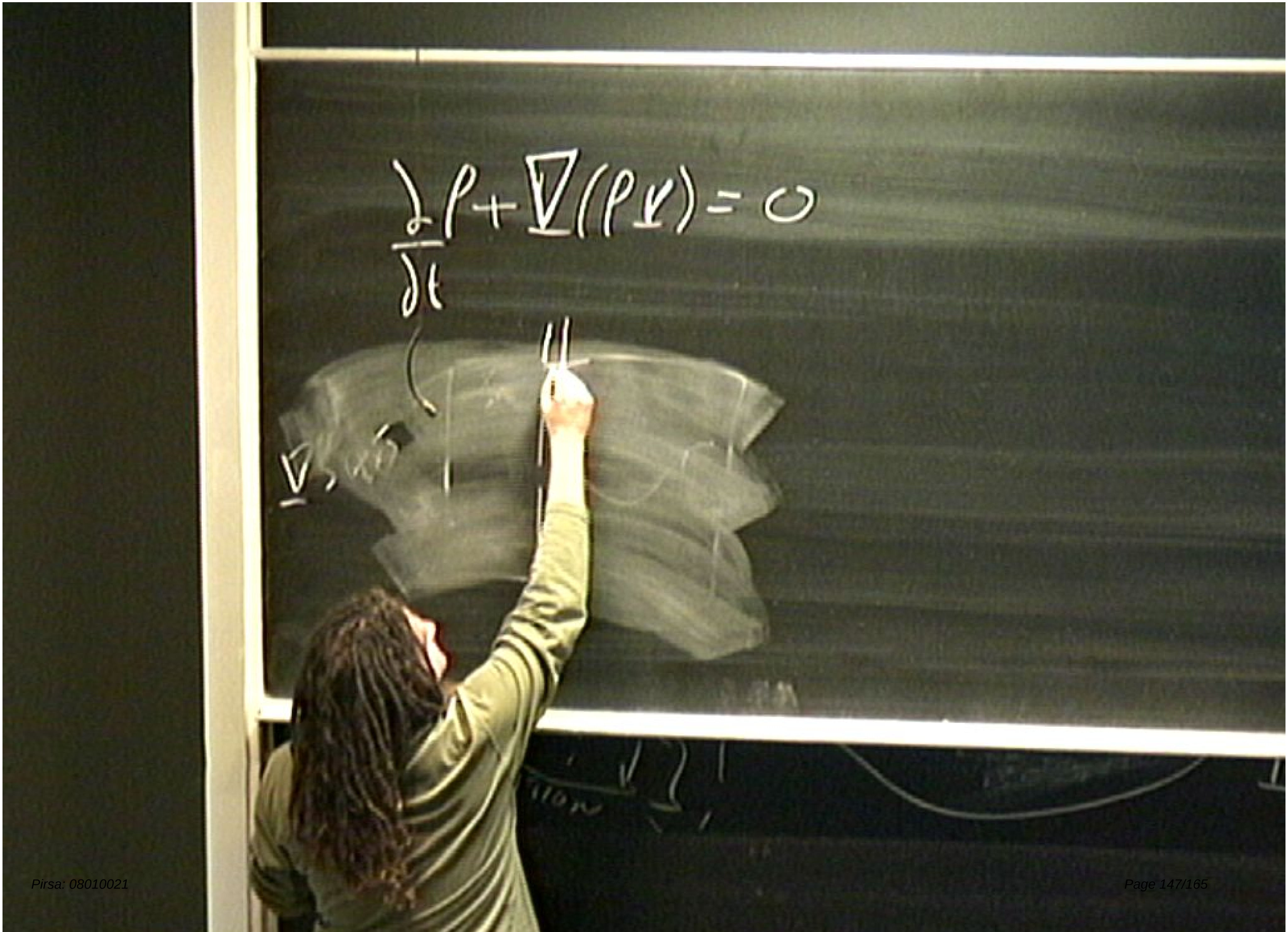
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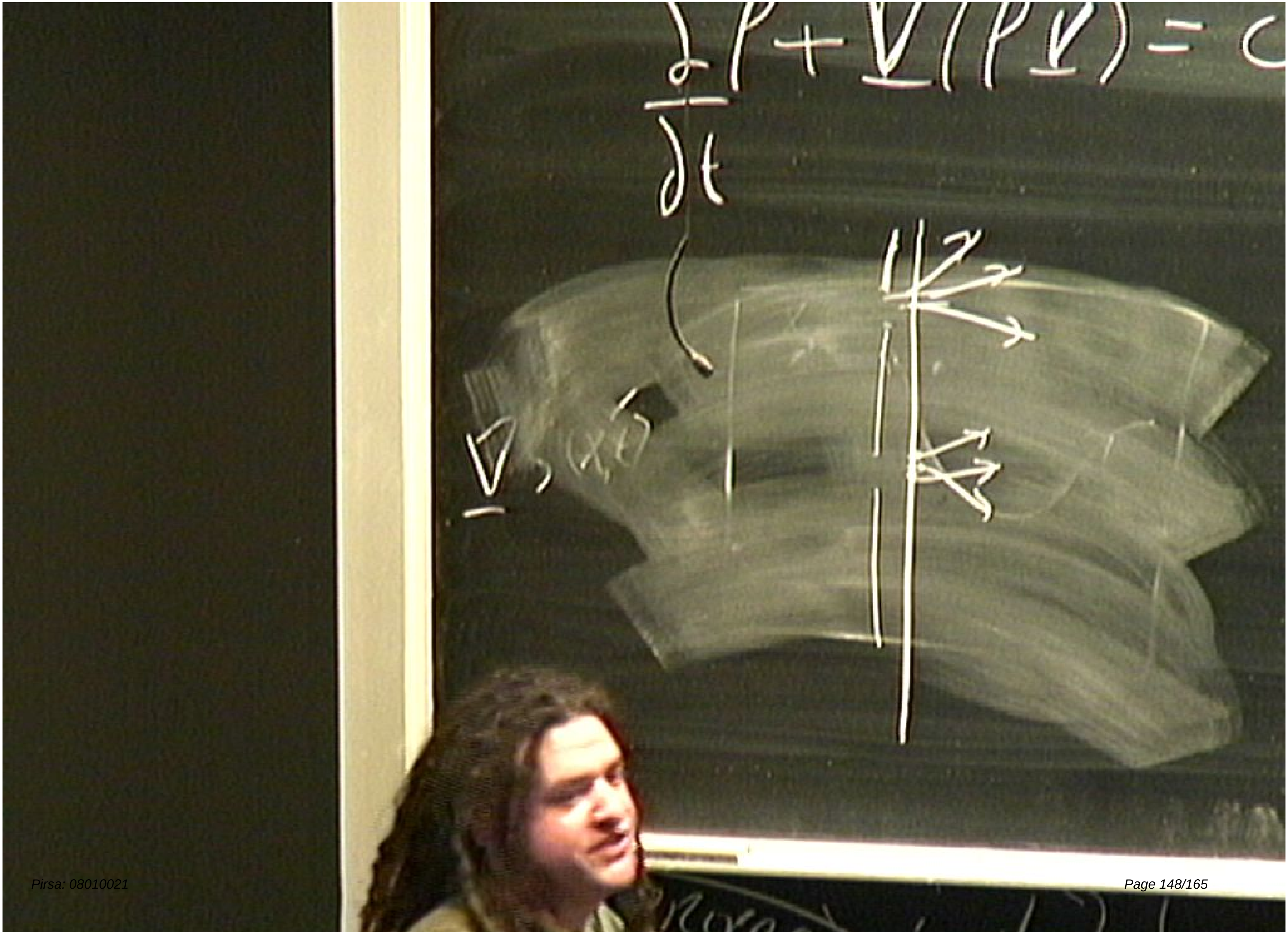
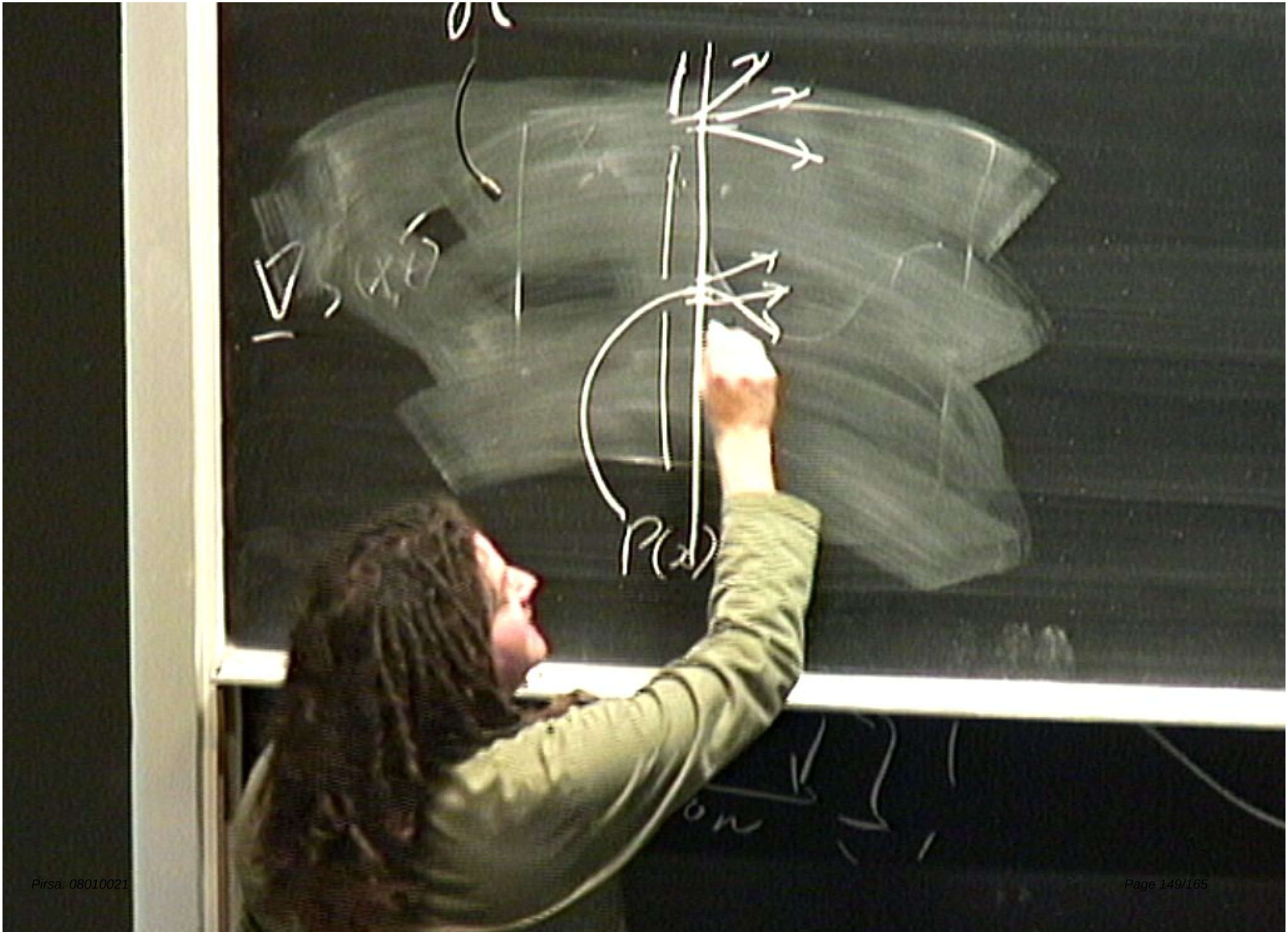
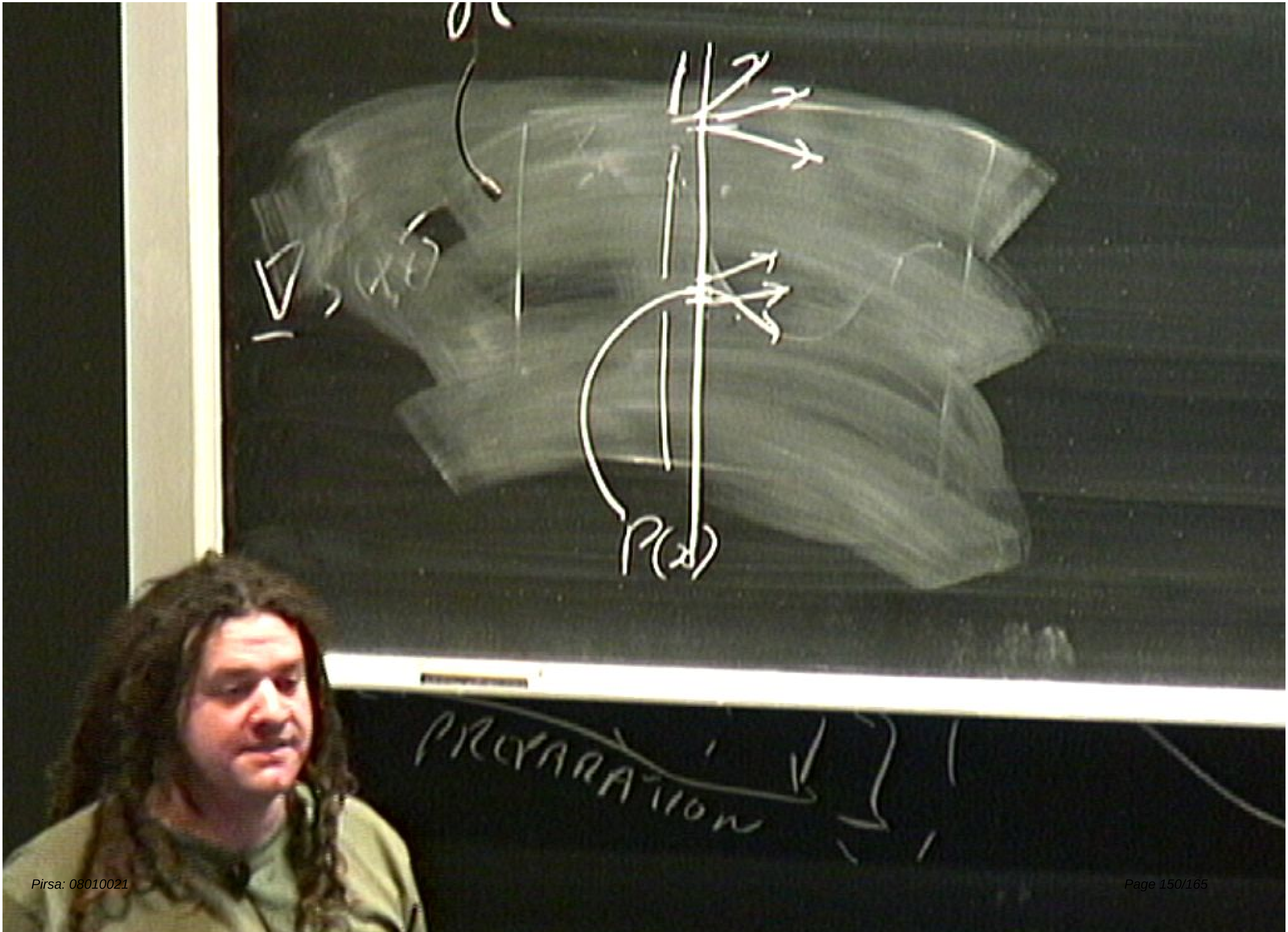
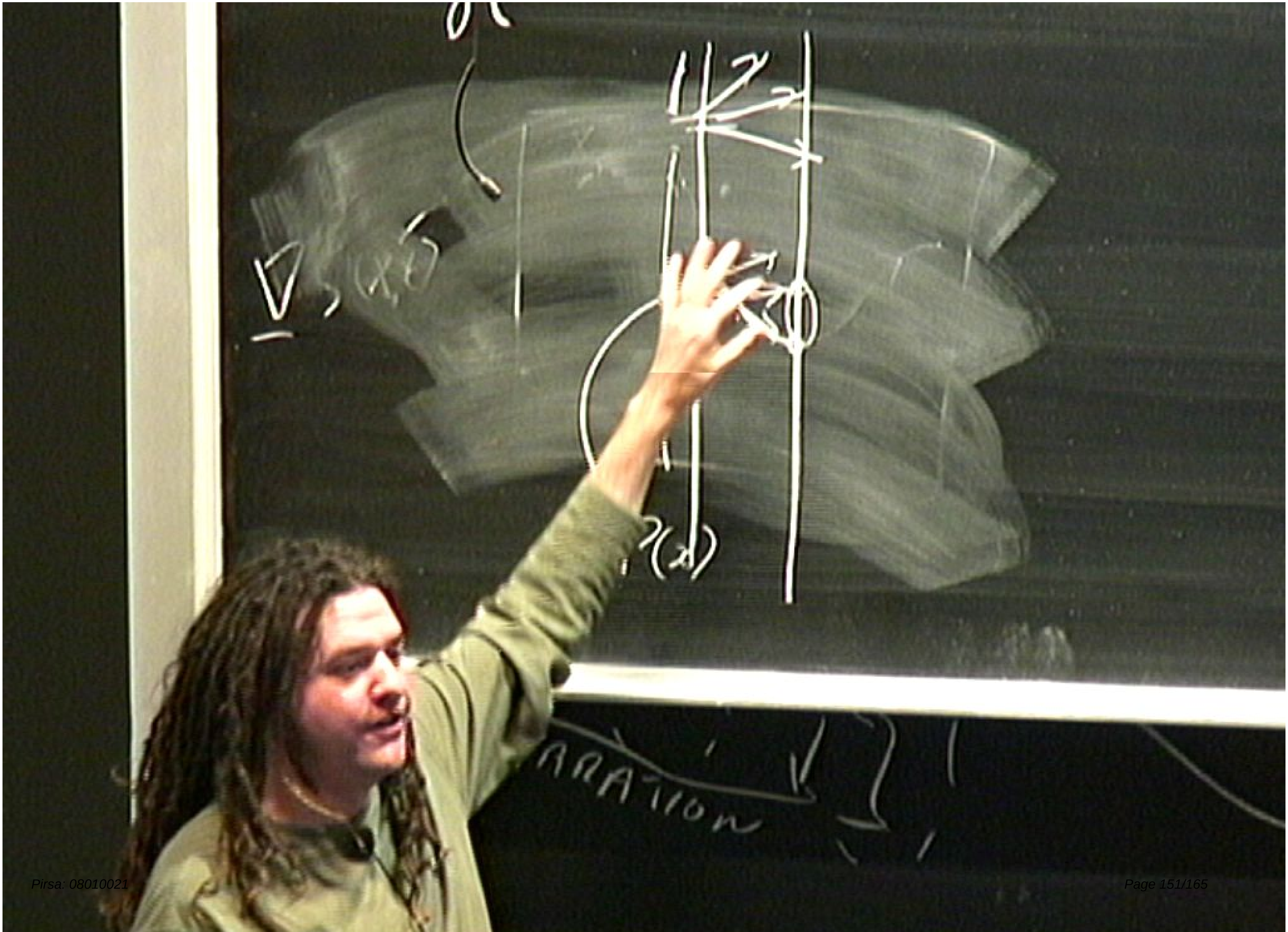
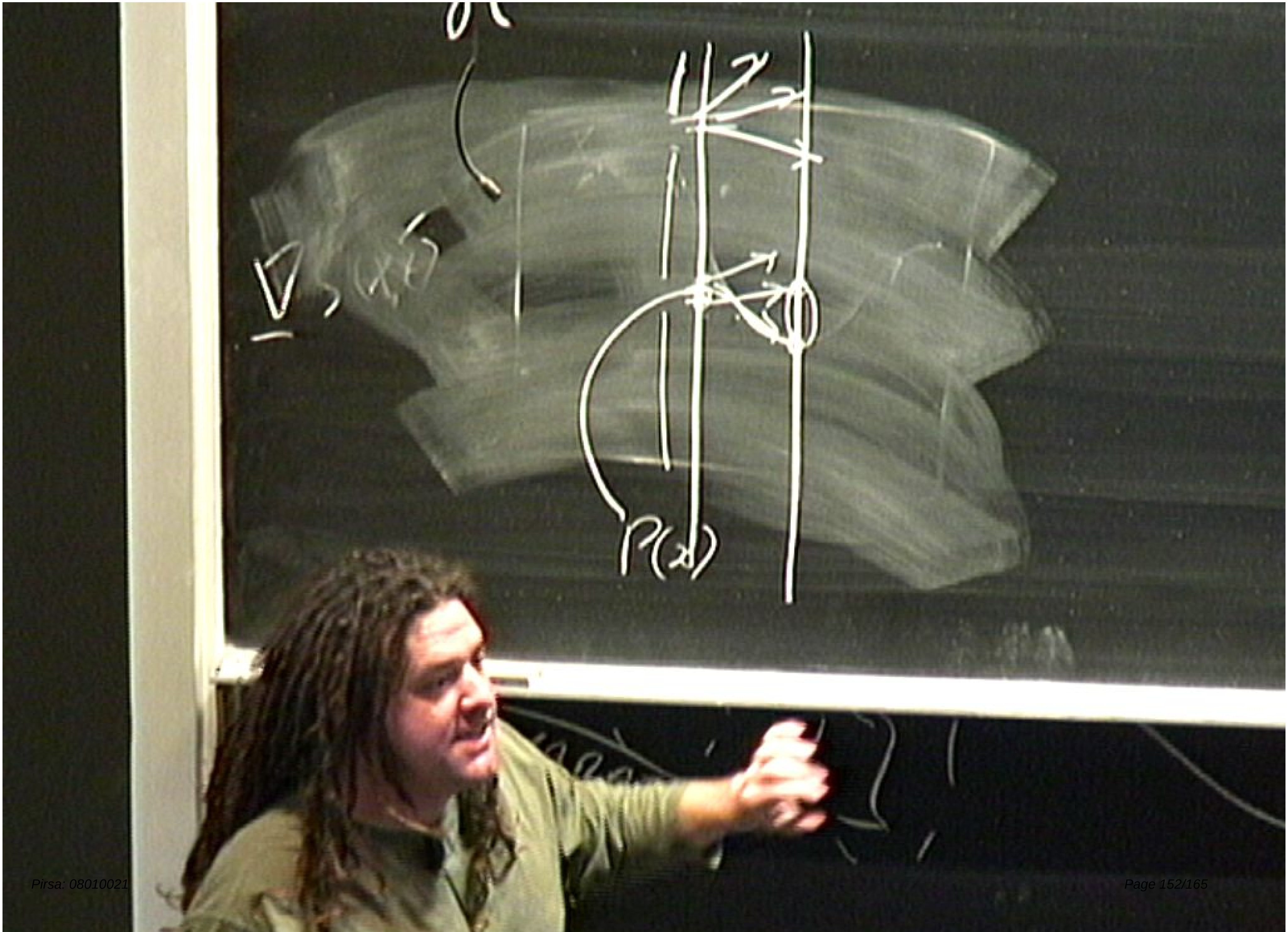
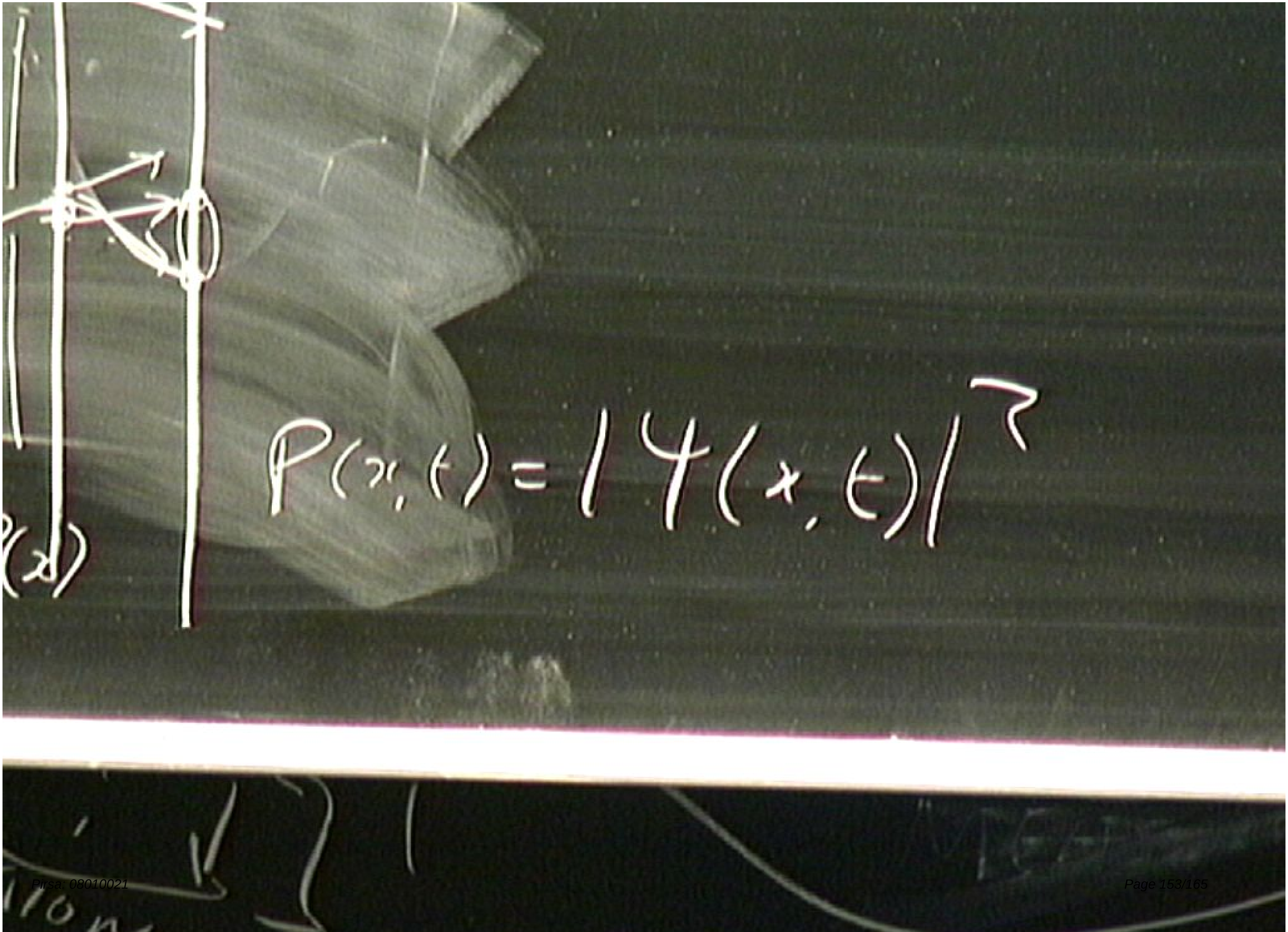





P(x)
PREPARATION






$P(x,t) = |\psi(x,t)|^2$

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$$\psi(x,t)=|\psi(x,t)|e^{iS(x,t)}$$

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If, at some position x' $\quad |\psi_u(x',t)| \approx 0$ or $|\psi_d(x',t)| \approx 0$

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If, at some position x' $\quad |\psi_u(x',t)|\approx 0$ or $|\psi_d(x',t)|\approx 0$

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$\quad S(x',t)\approx S_u(x',t)$

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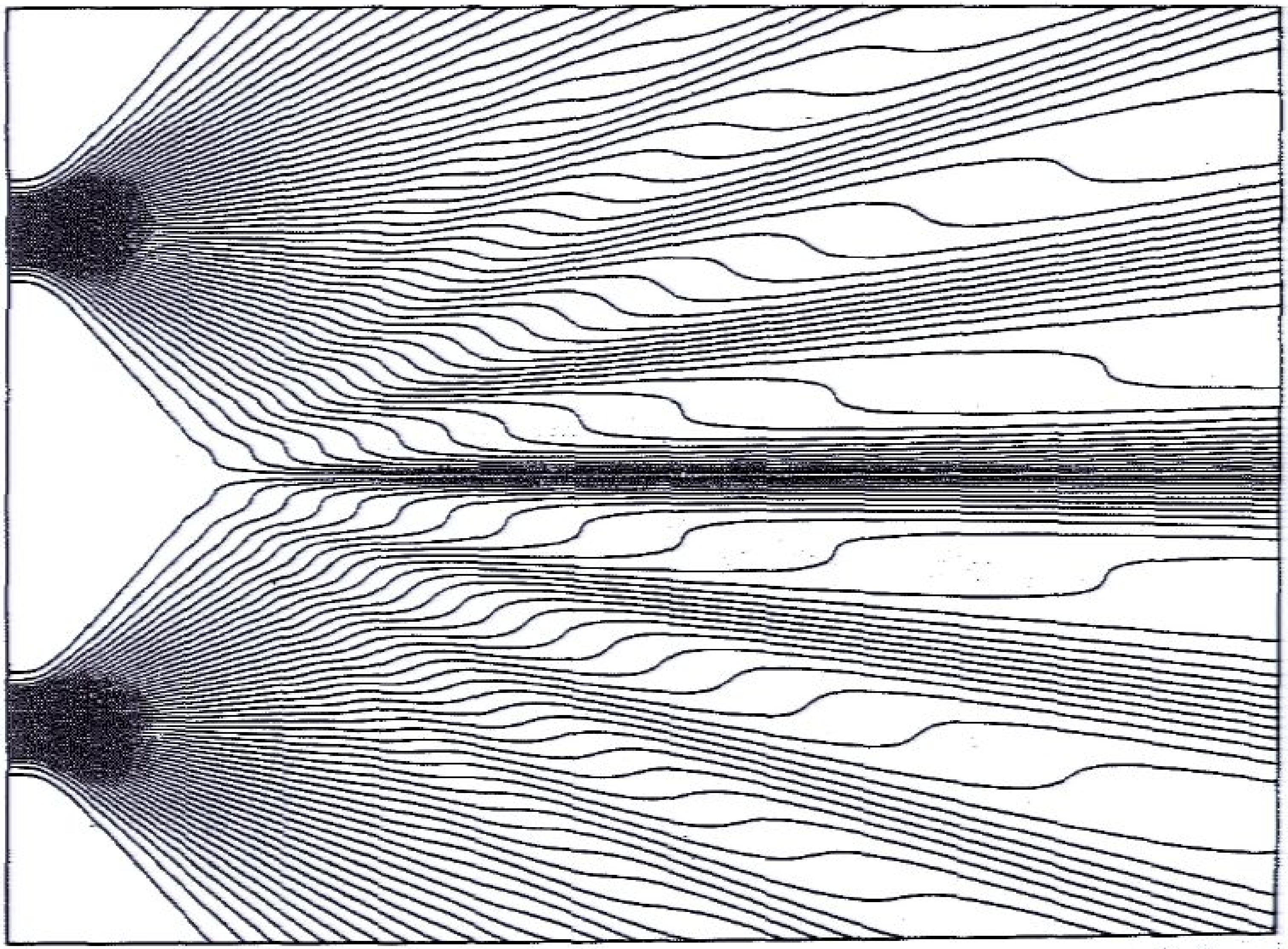
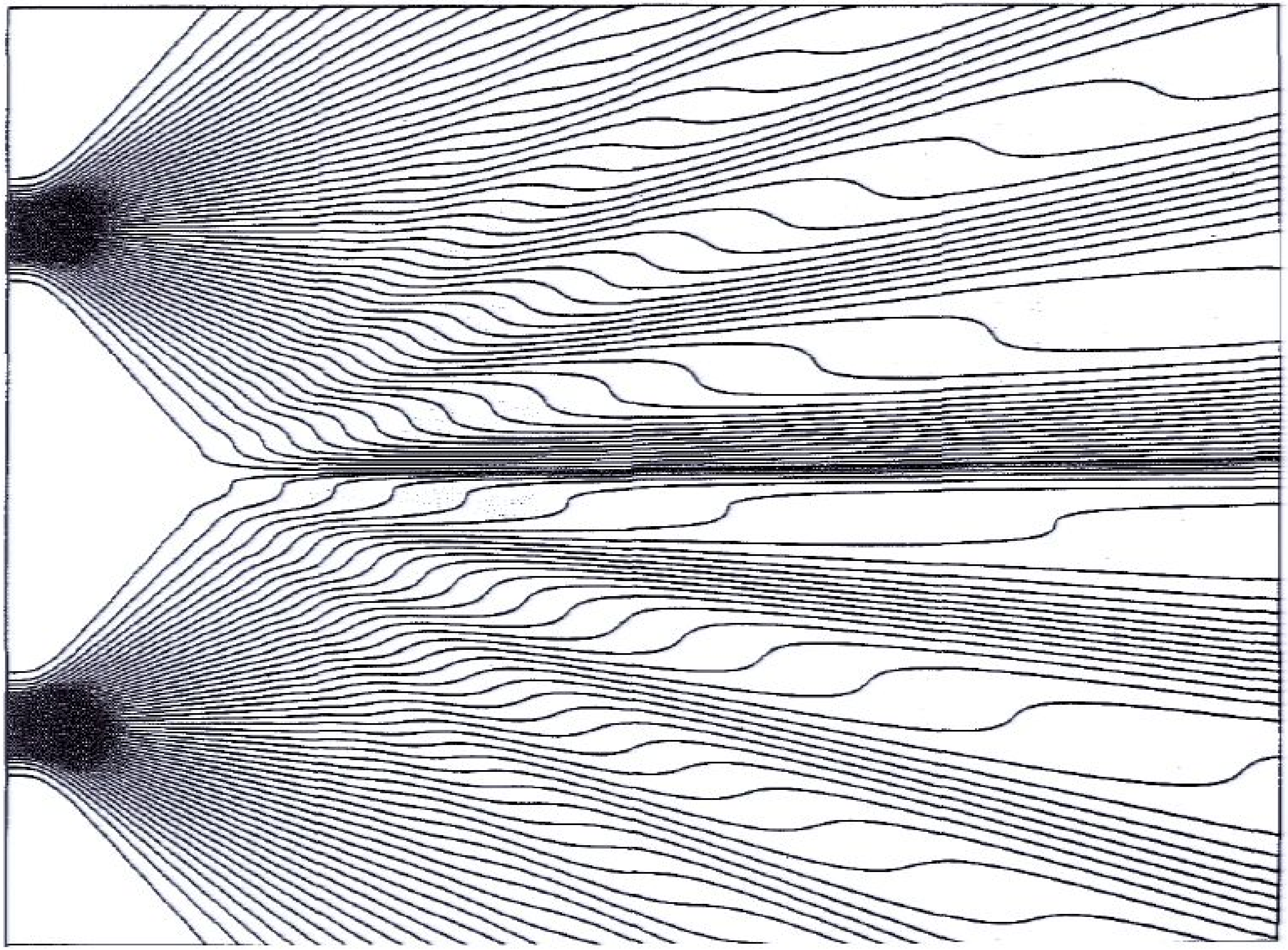


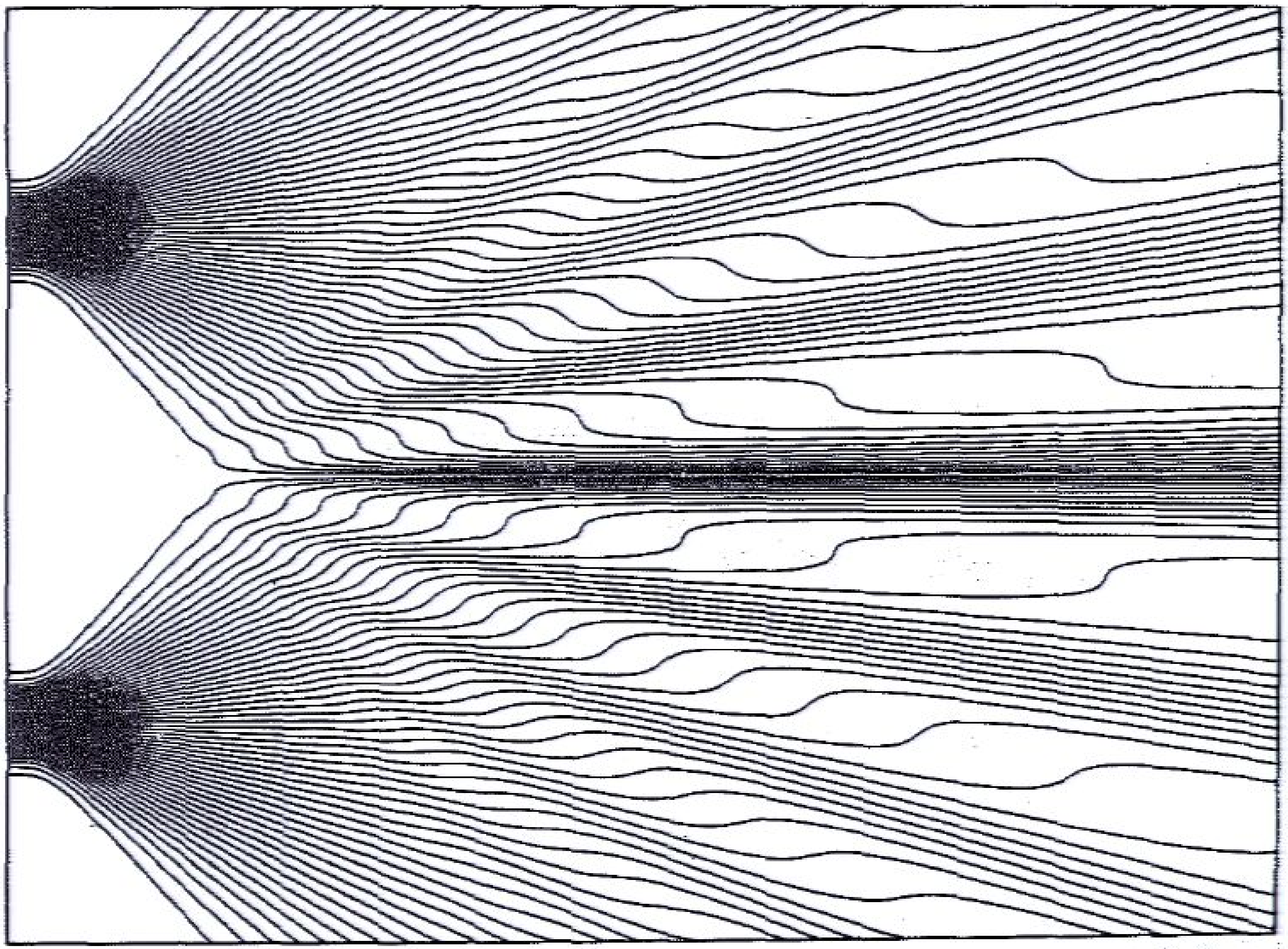
Source: Bohm, Hiley
The Undivided Universe pg. 33

Hidden Variables



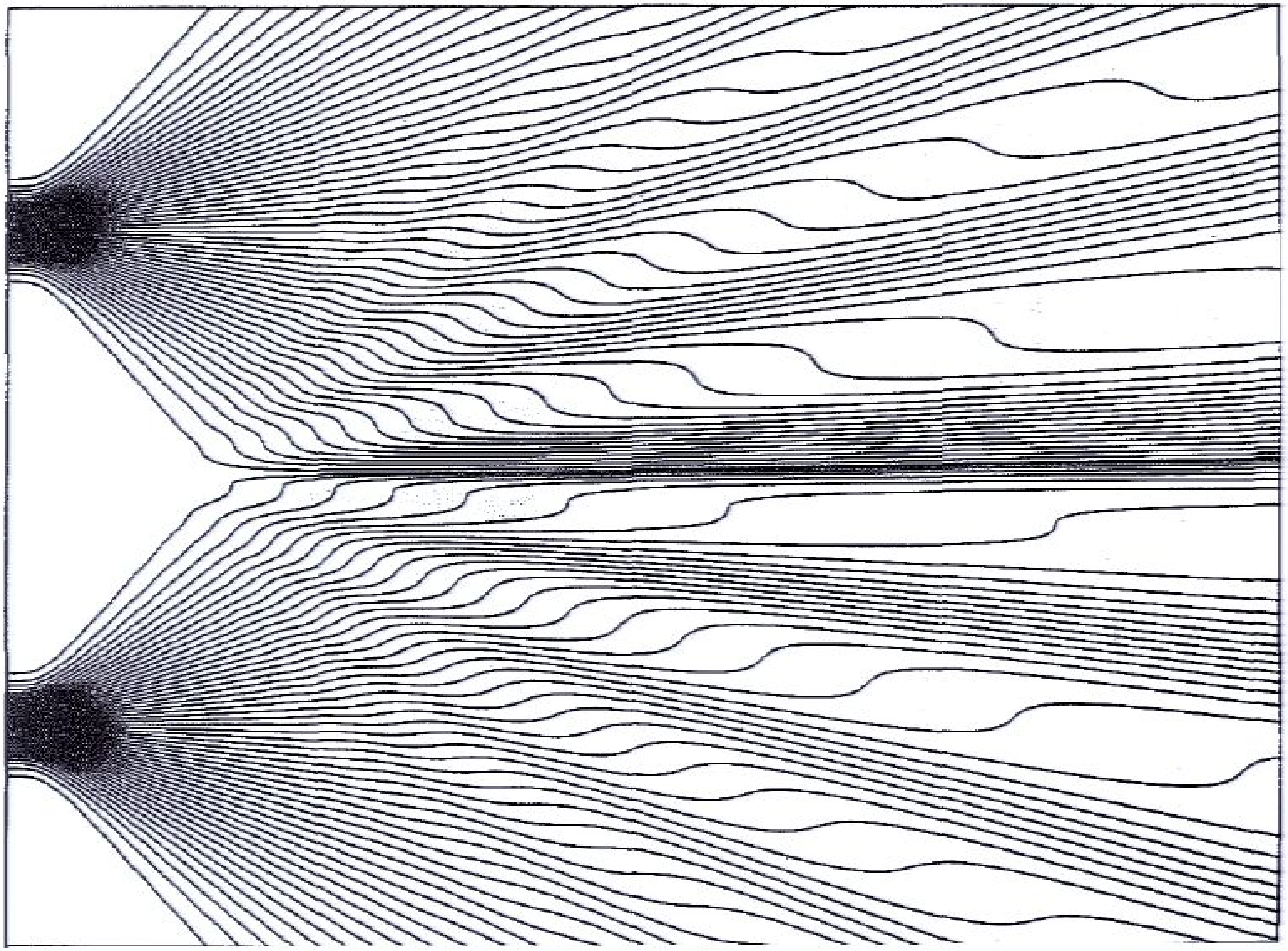
Source: Bohm, Hiley
The Undivided Universe pg. 53

Hidden Variables



Source: Bohm, Hiley
The Undivided Universe pg. 33

Hidden Variables



An Introduction to Quantum Foundations
Lecture 2: Measurement and Interpretation

Source: Bohm, Hiley
The Undivided Universe pg. 53

New Horizons in
Fundamental Physics

Hidden Variables

With two degrees of freedom:

$$\Psi(x,y,t)=|\Psi(x,y,t)|e^{iS(x,y,t)}$$

$$P(x,y|t=t_0)=|\Psi(x,y,t_0)|^2$$

Hidden Variables

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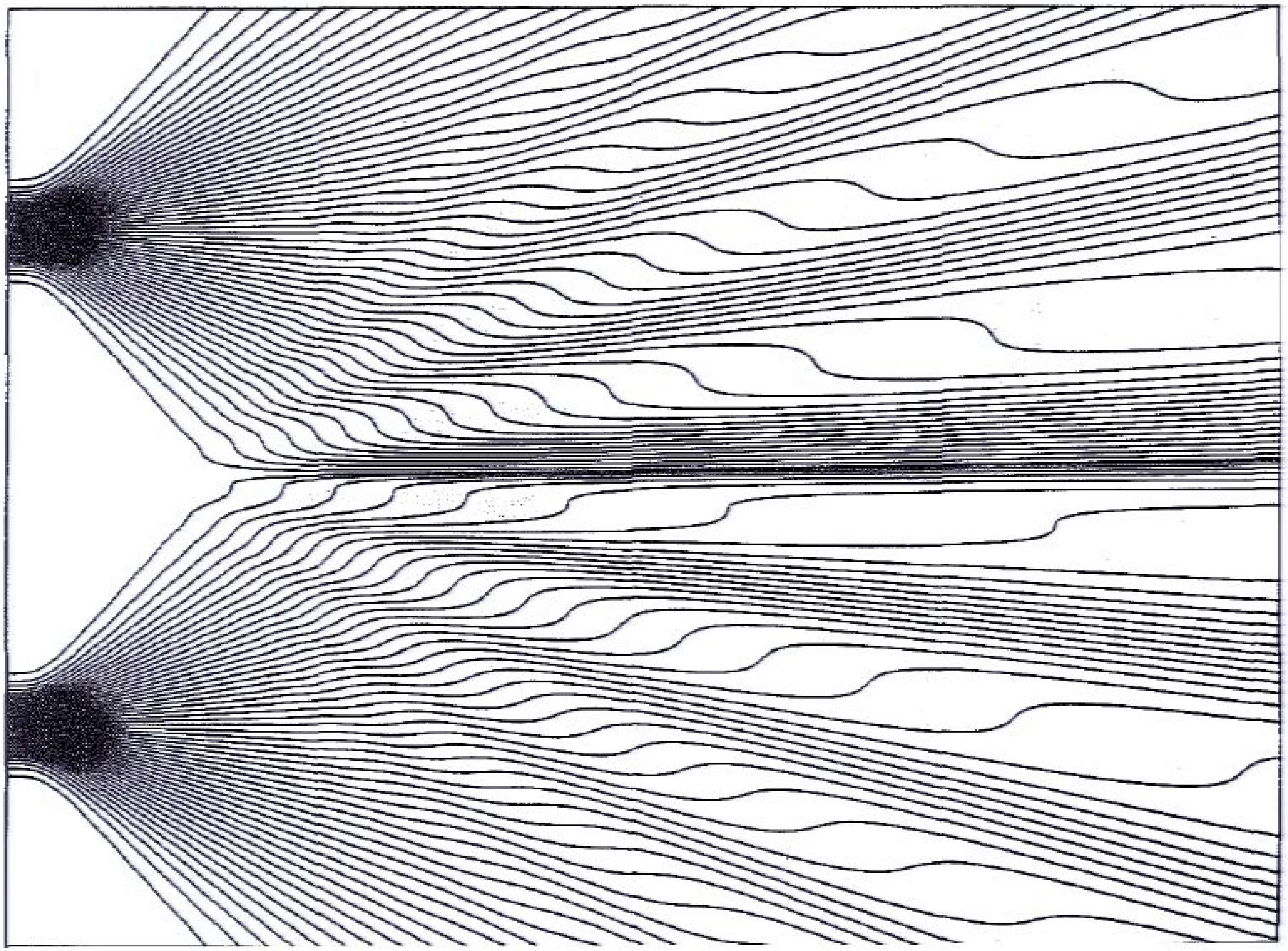

Source: Bohm, Hiley
The Undivided Universe pg. 53