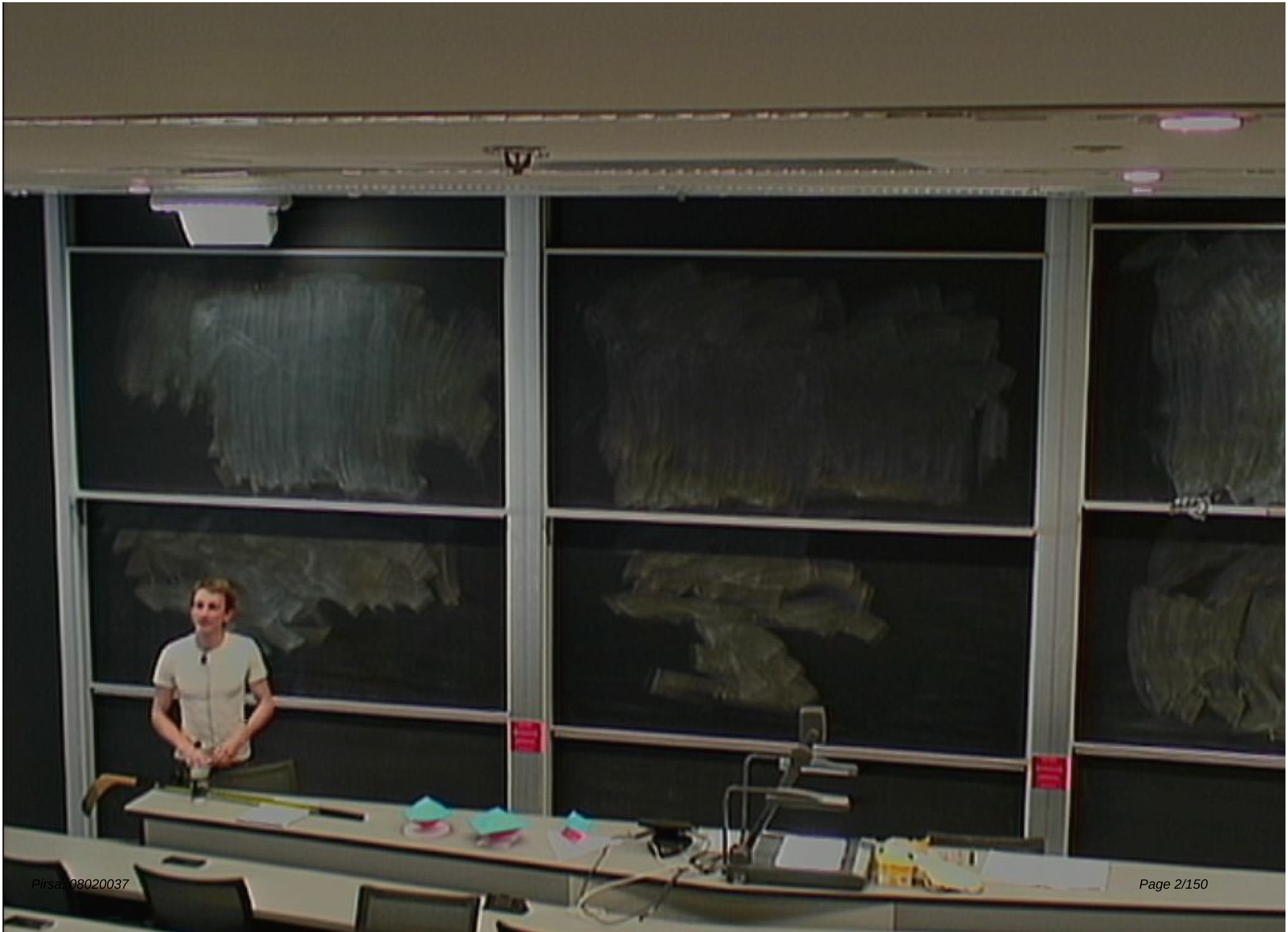
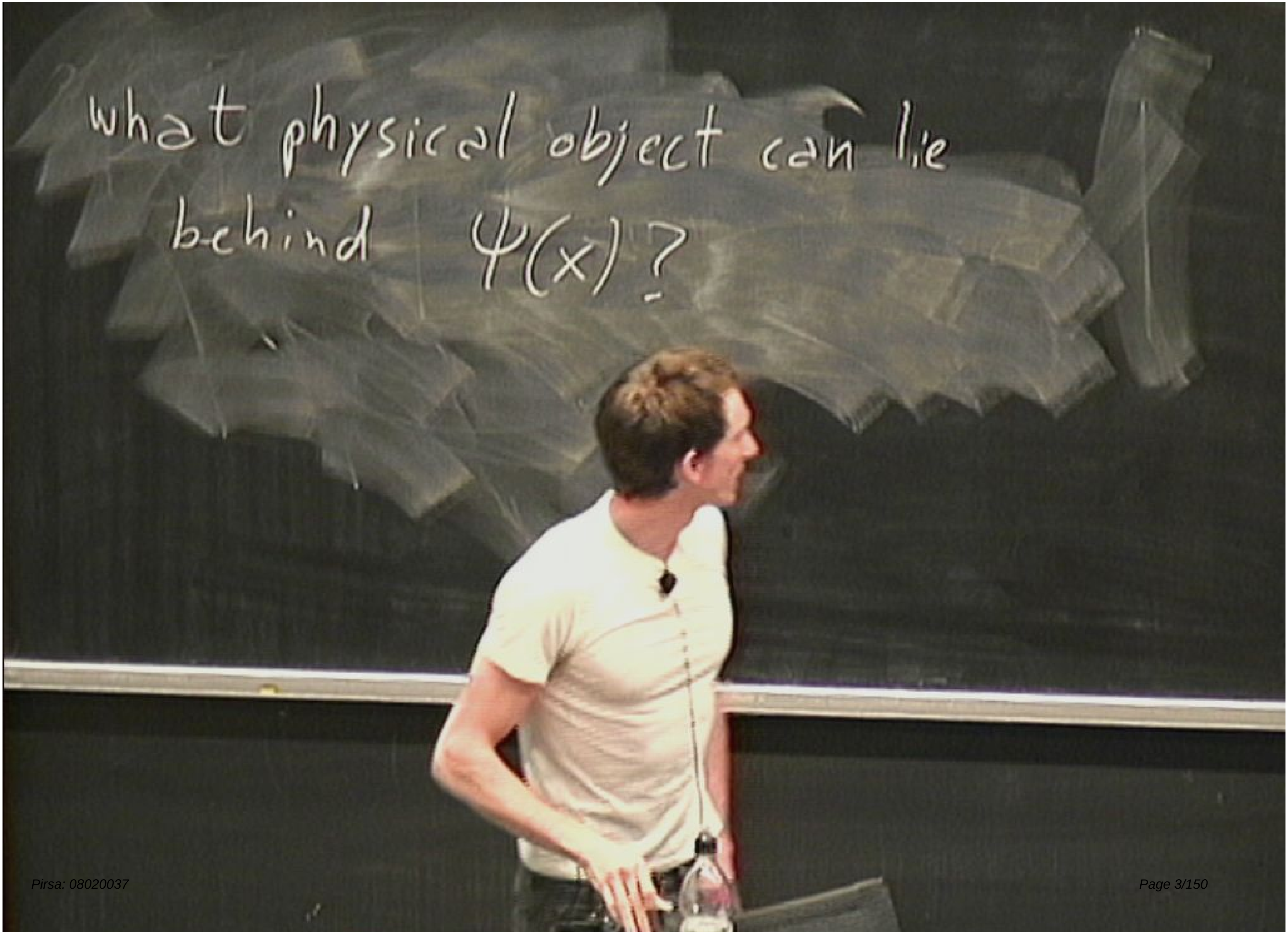
Title: Metaphysical deductions and assumptions in quantum and classical physics

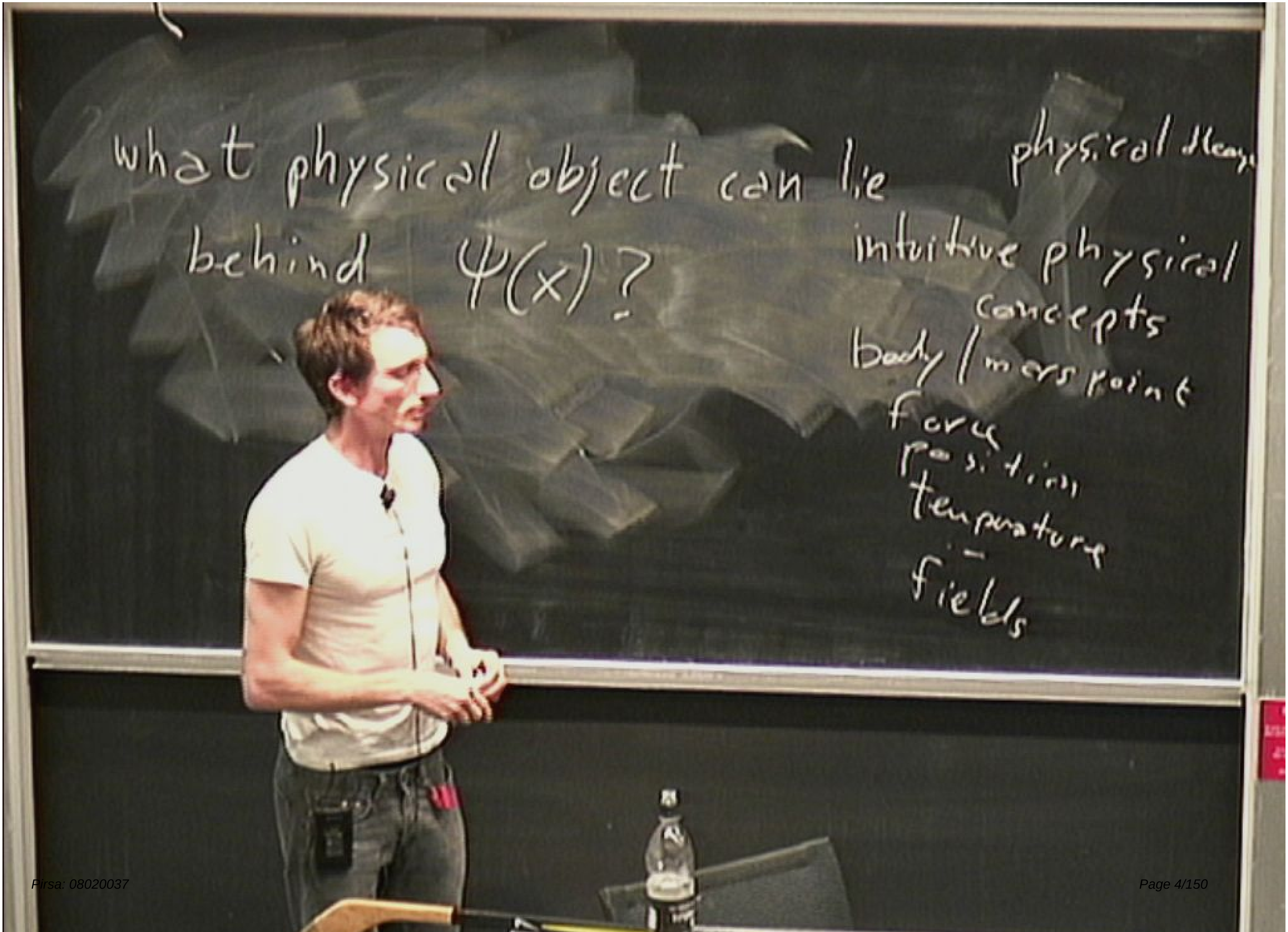
Date: Feb 13, 2008 04:00 PM

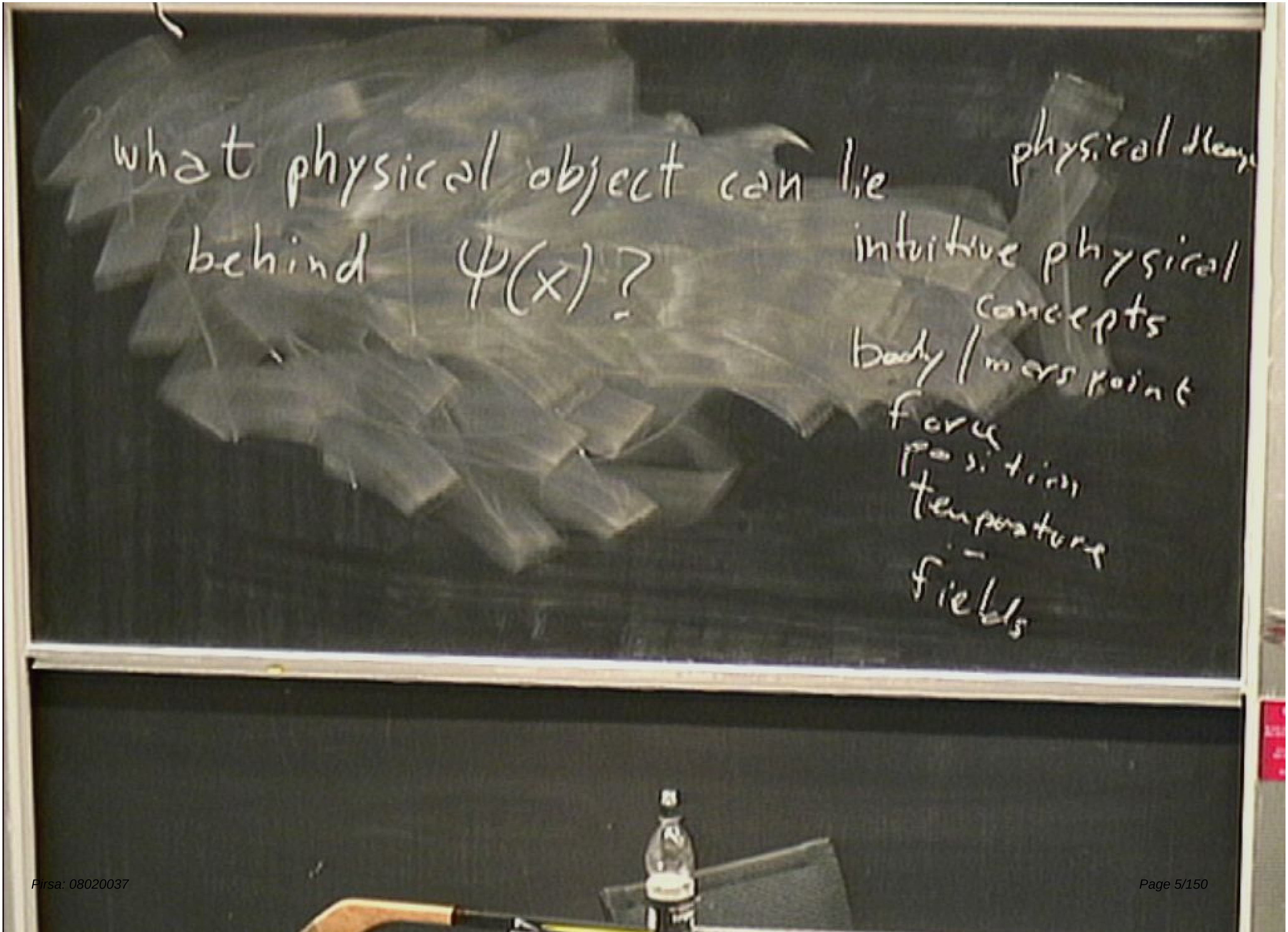
URL: http://pirsa.org/08020037

Abstract: I should like to show how particular mathematical properties can limit our metaphysical choices, by discussing old and new theorems within the statistical-model framework of Mielnik, Foulis & Randall, and Holevo, and what these theorems have to say about possible metaphysical models of quantum mechanics. Time permitting, I should also like to show how metaphysical assumptions lead to particular mathematical choices, by discussing how the assumption of space as a relational concept leads to a not widely known frame-invariant formulation of classical point-particle mechanics by FÃ¶ppl and Zanstra, and related research topics in continuum mechanics and general relativity.




what physical object can lie
behind $\psi(x)$?


what physical object can lie
behind ψ(x)?
physical
intuitive physical
concepts
body / mass point
force
position
temperature
fields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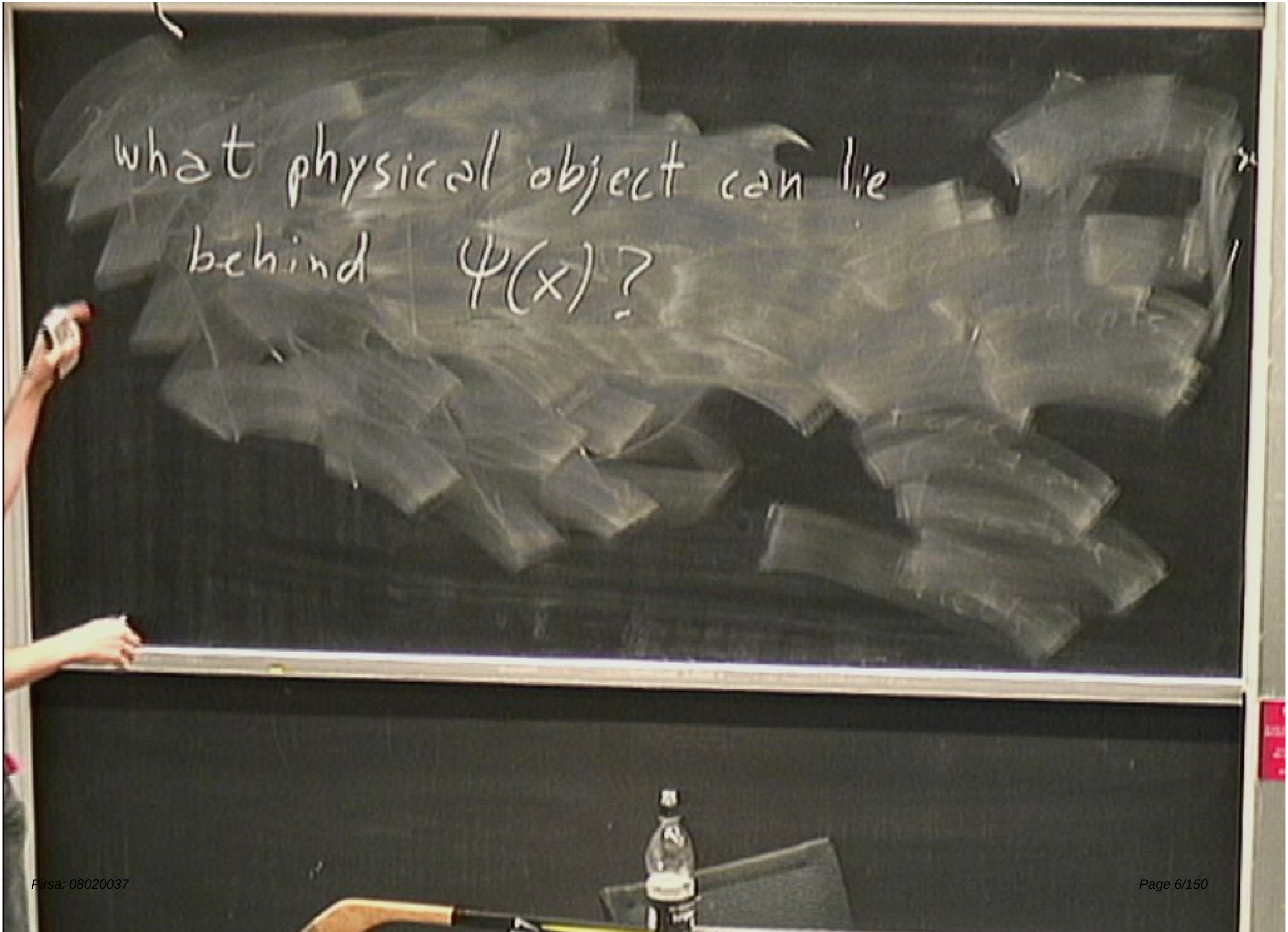
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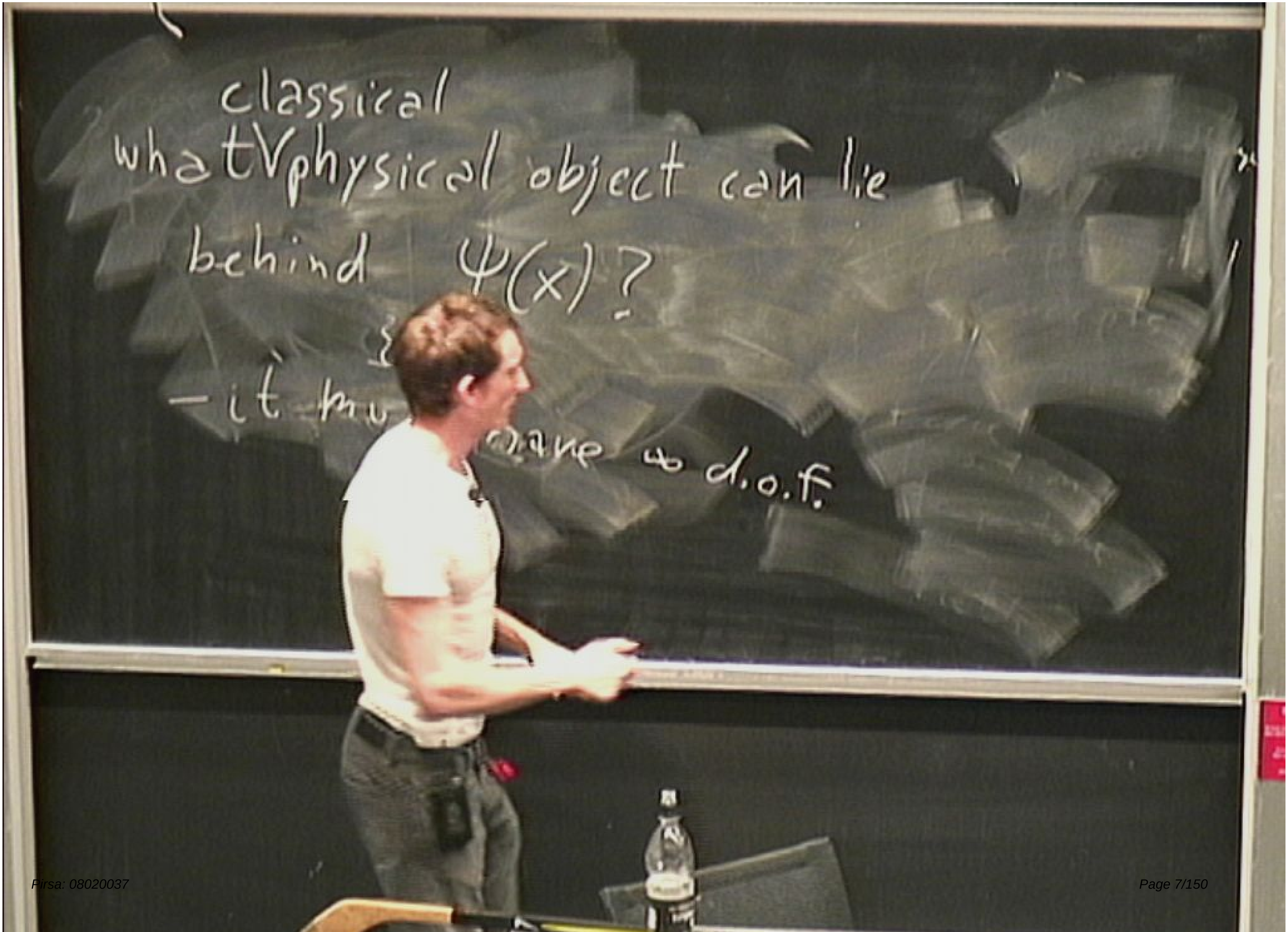
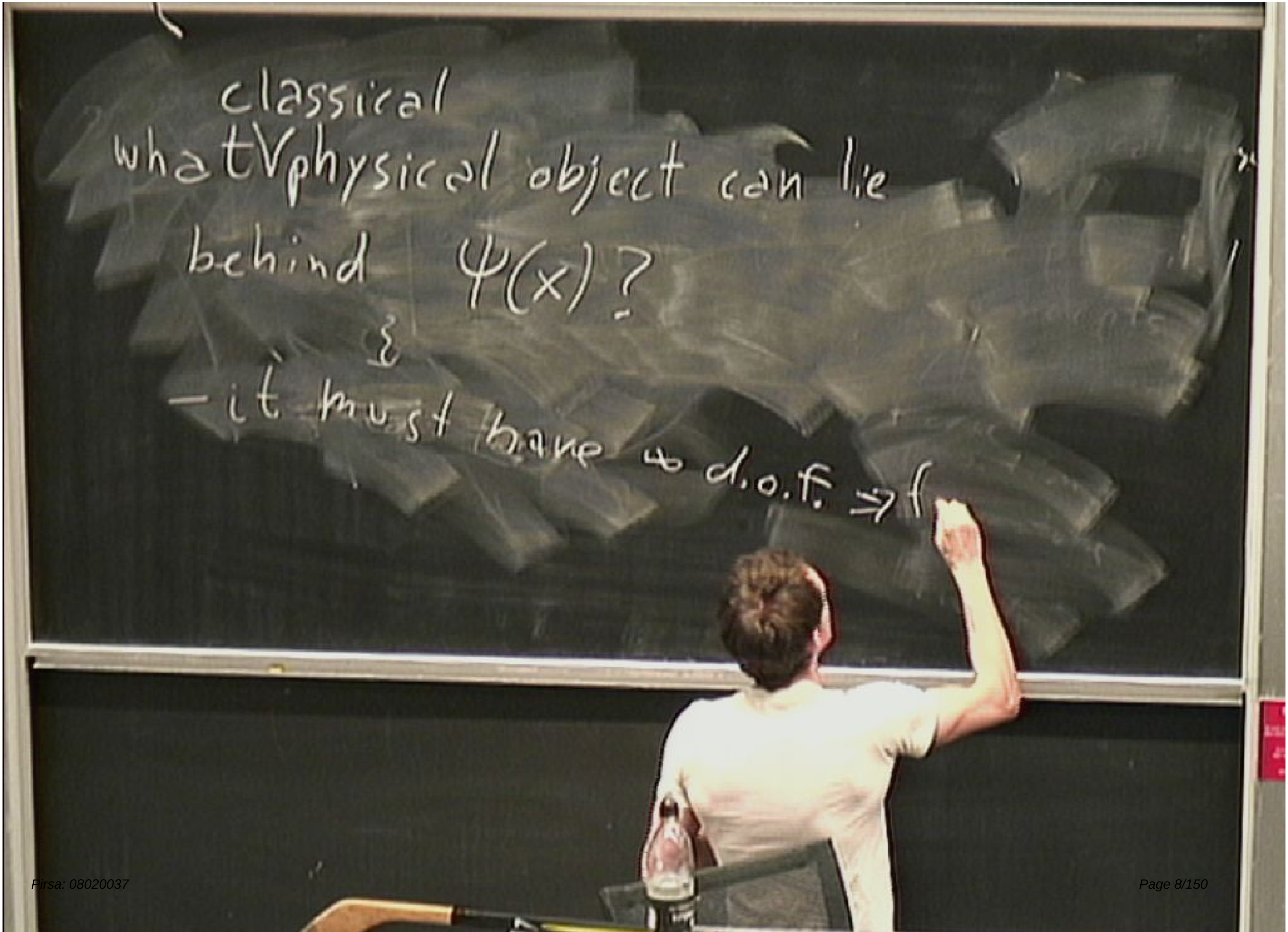
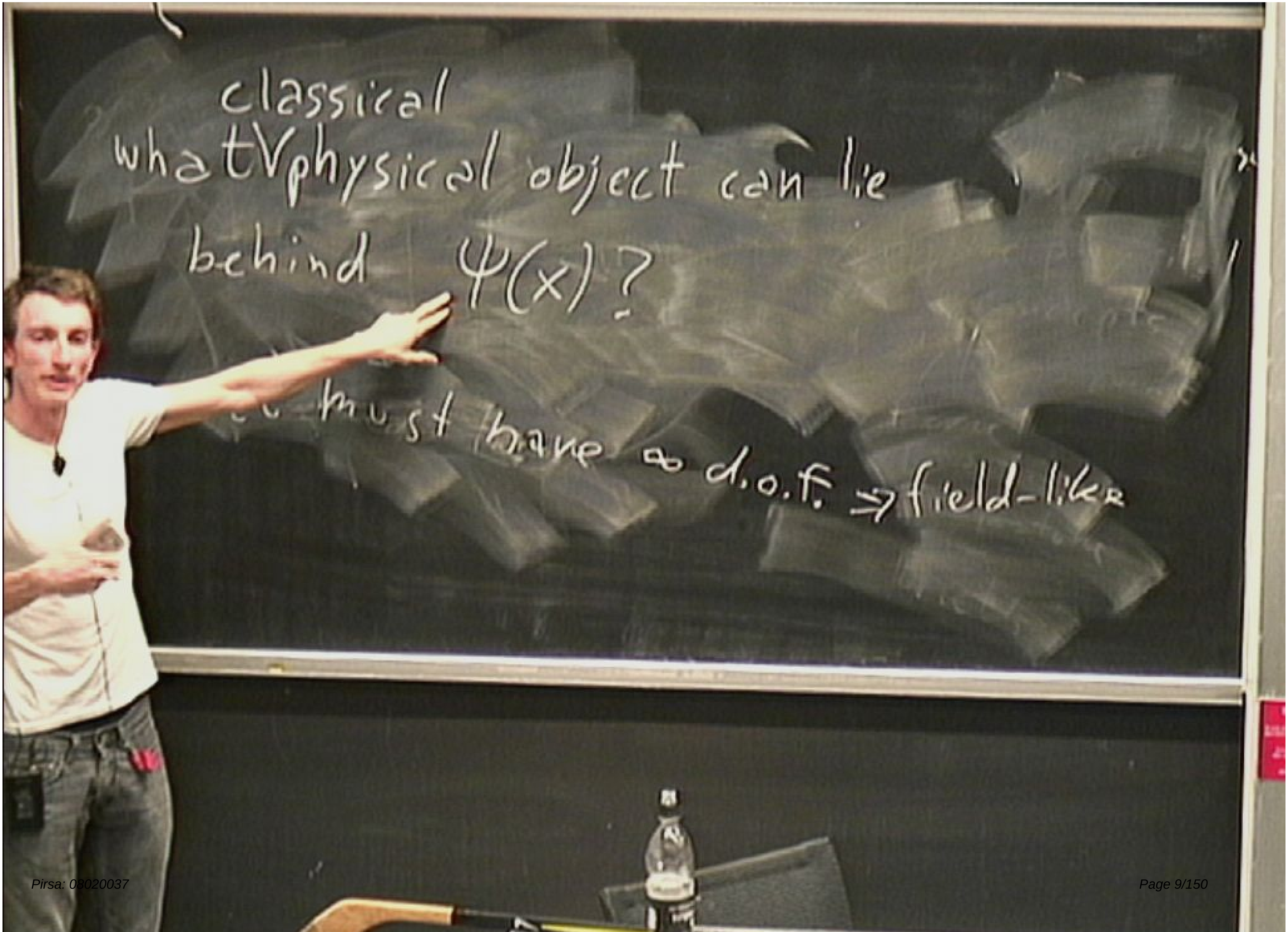
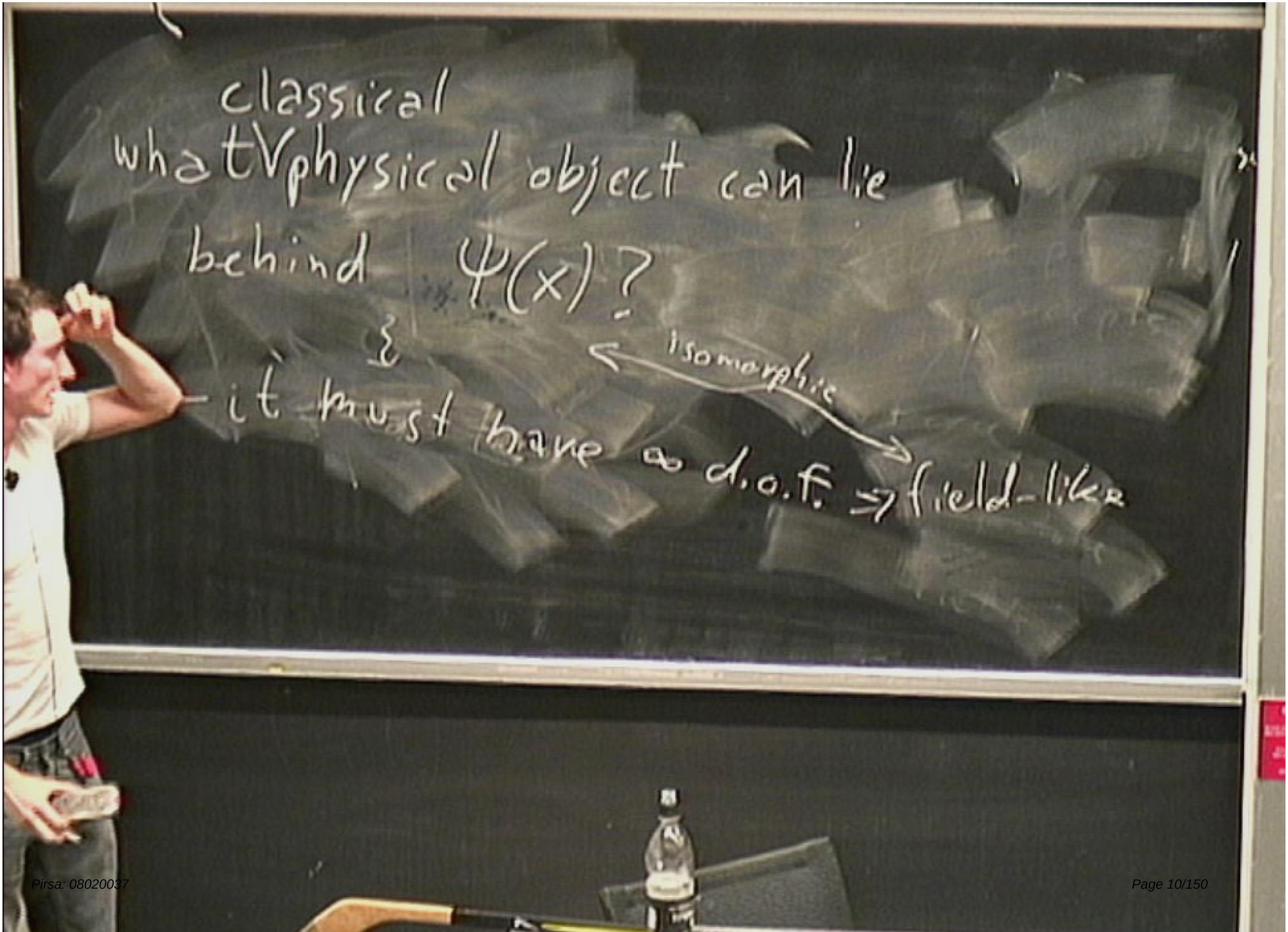

classical
what physical object can lie
behind ψ(x)?
d.o.f.


classical
what physical object can lie
behind ψ(x)?
- it must have ∞ d.o.f. ⇒ f


classical
what physical object can lie
behind ψ(x)?
must have ∞ d.o.f. ⇒ field-like


classical
what physical object can lie
behind ψ(x)?
isomorphic
it must have ∞ d.o.f. ⇒ field-like

classical

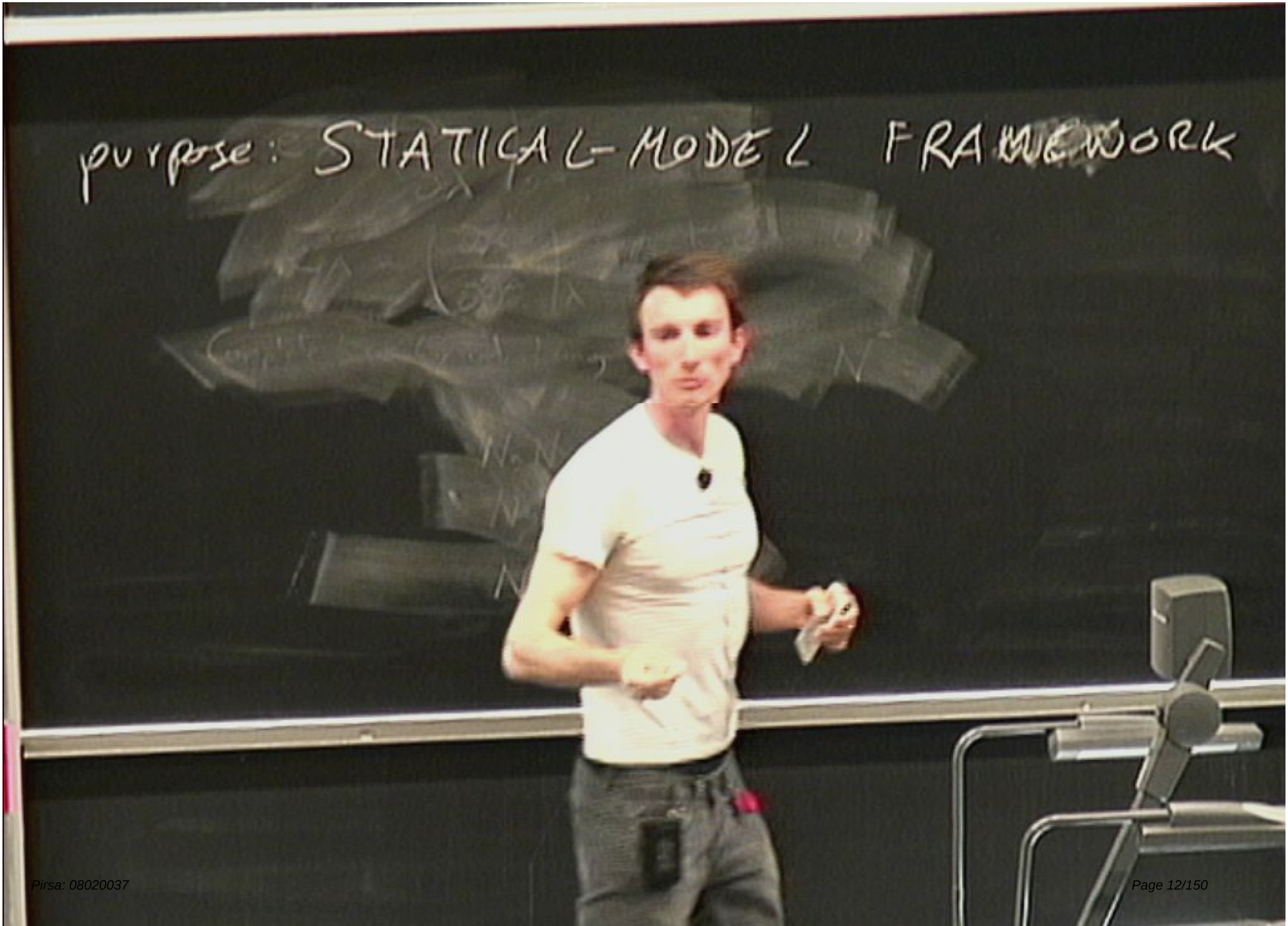
what physical object can lie behind $\psi(x)$?

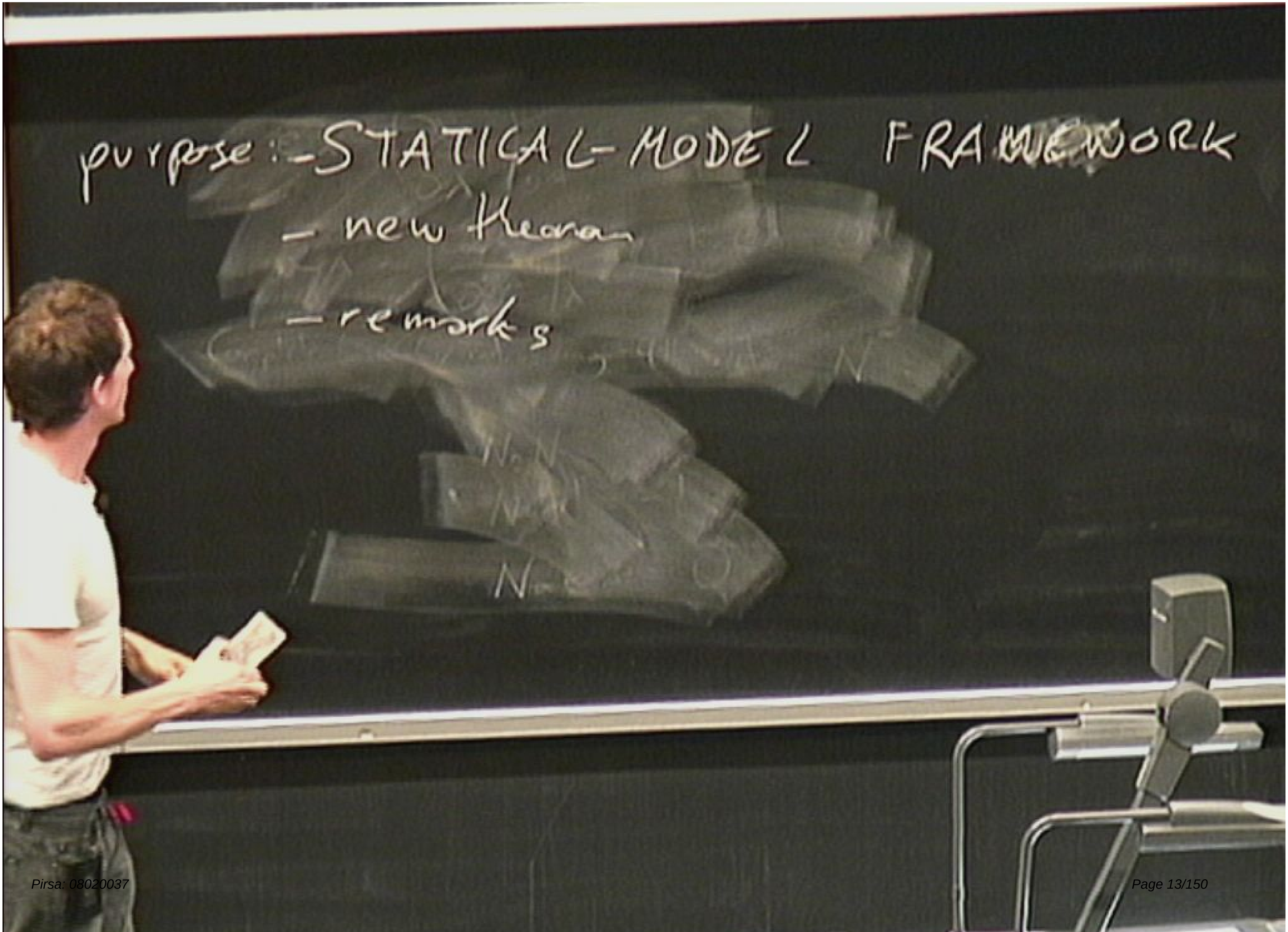
pilot-wave

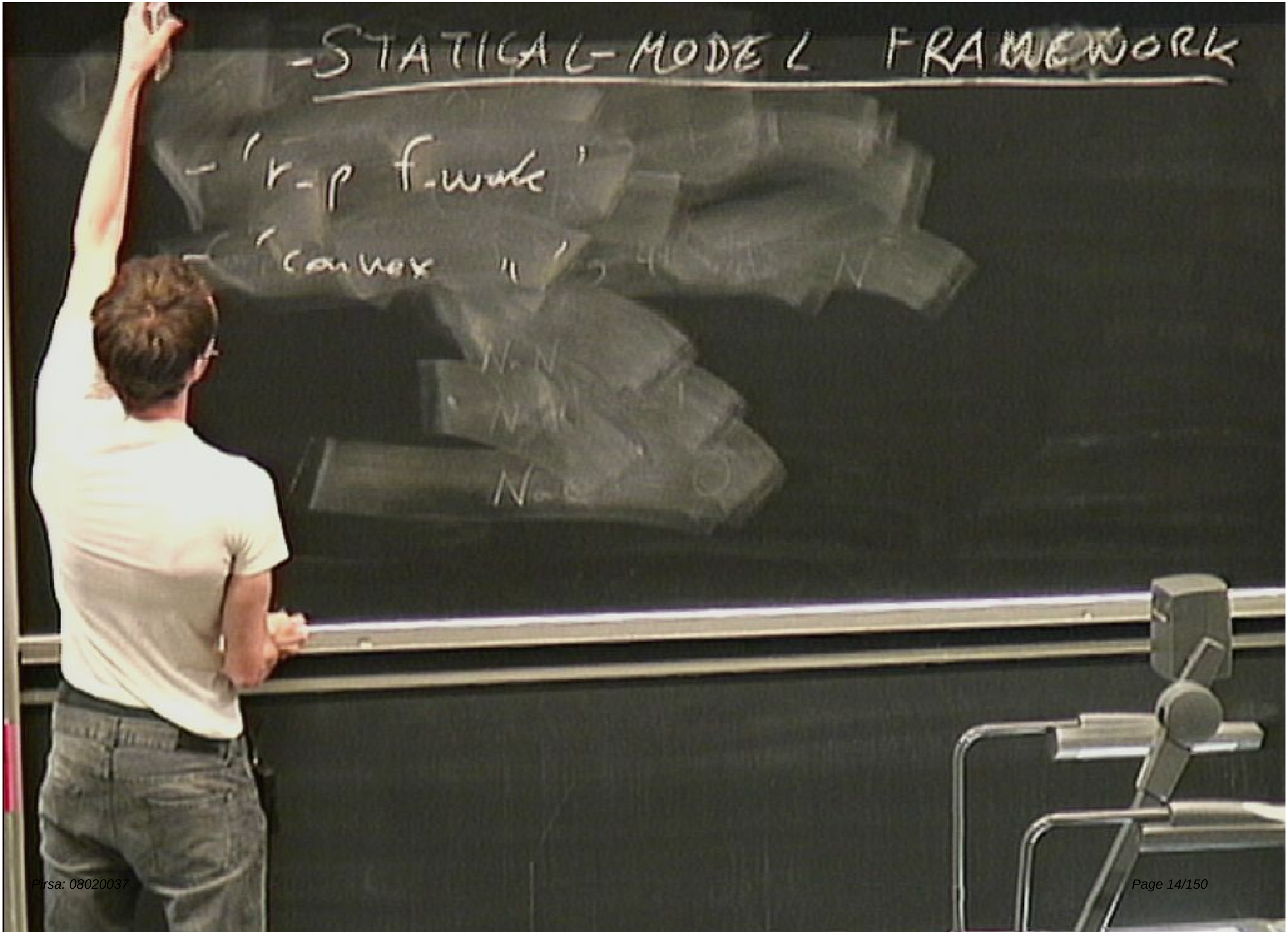
plausib. distr.

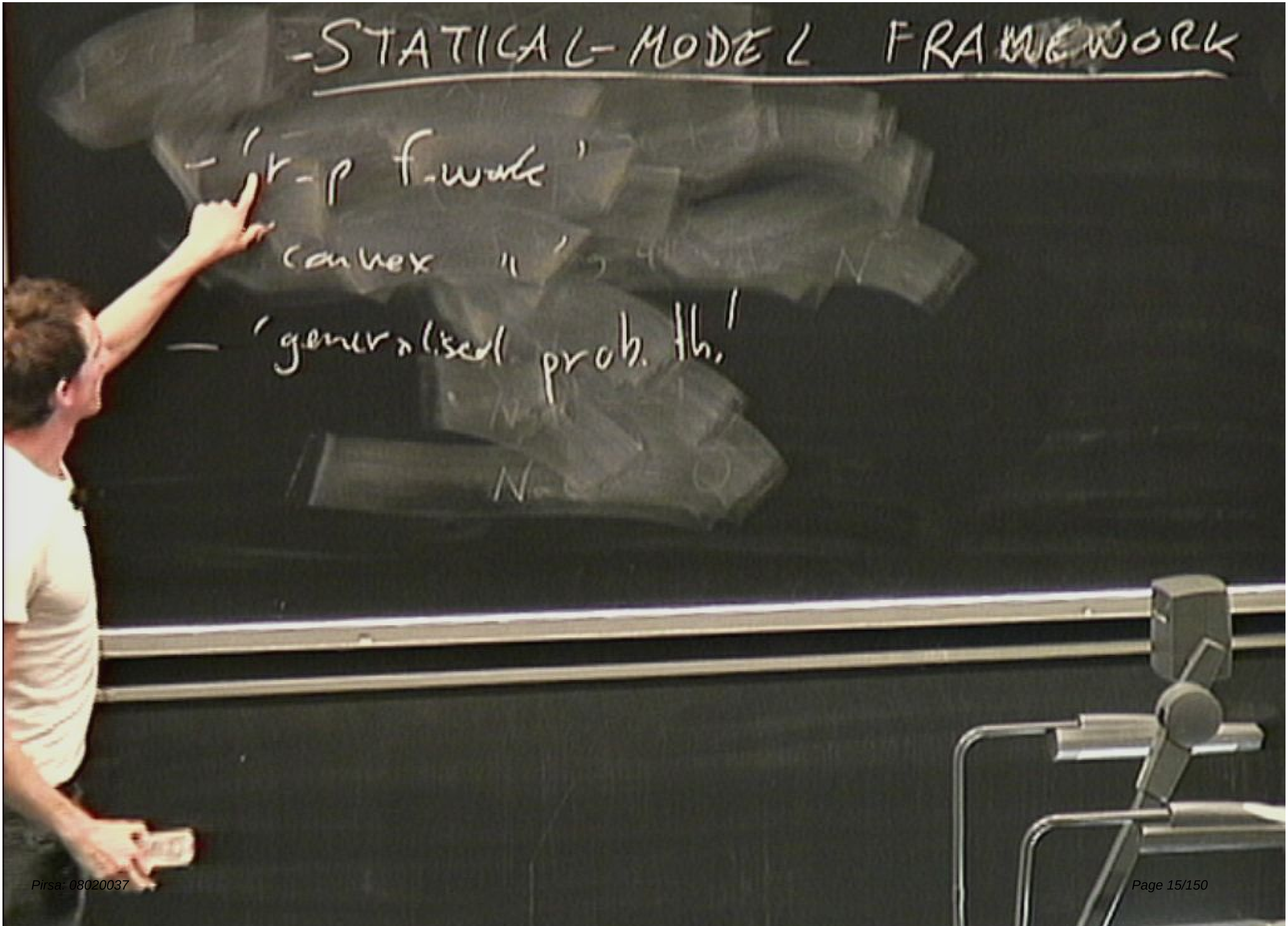
isomorphic

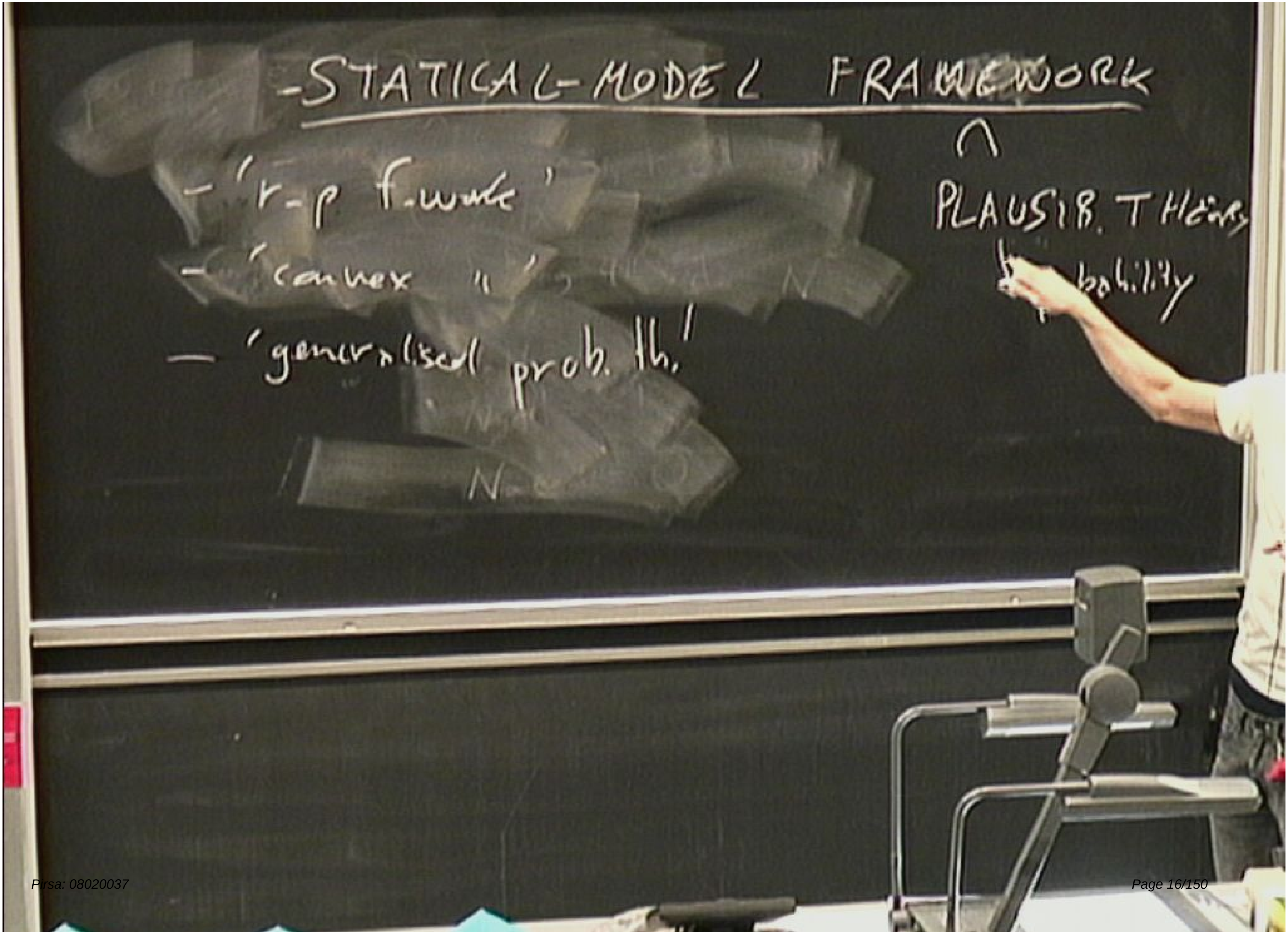
– it must have ∞ d.o.f. $\Rightarrow$ field-like

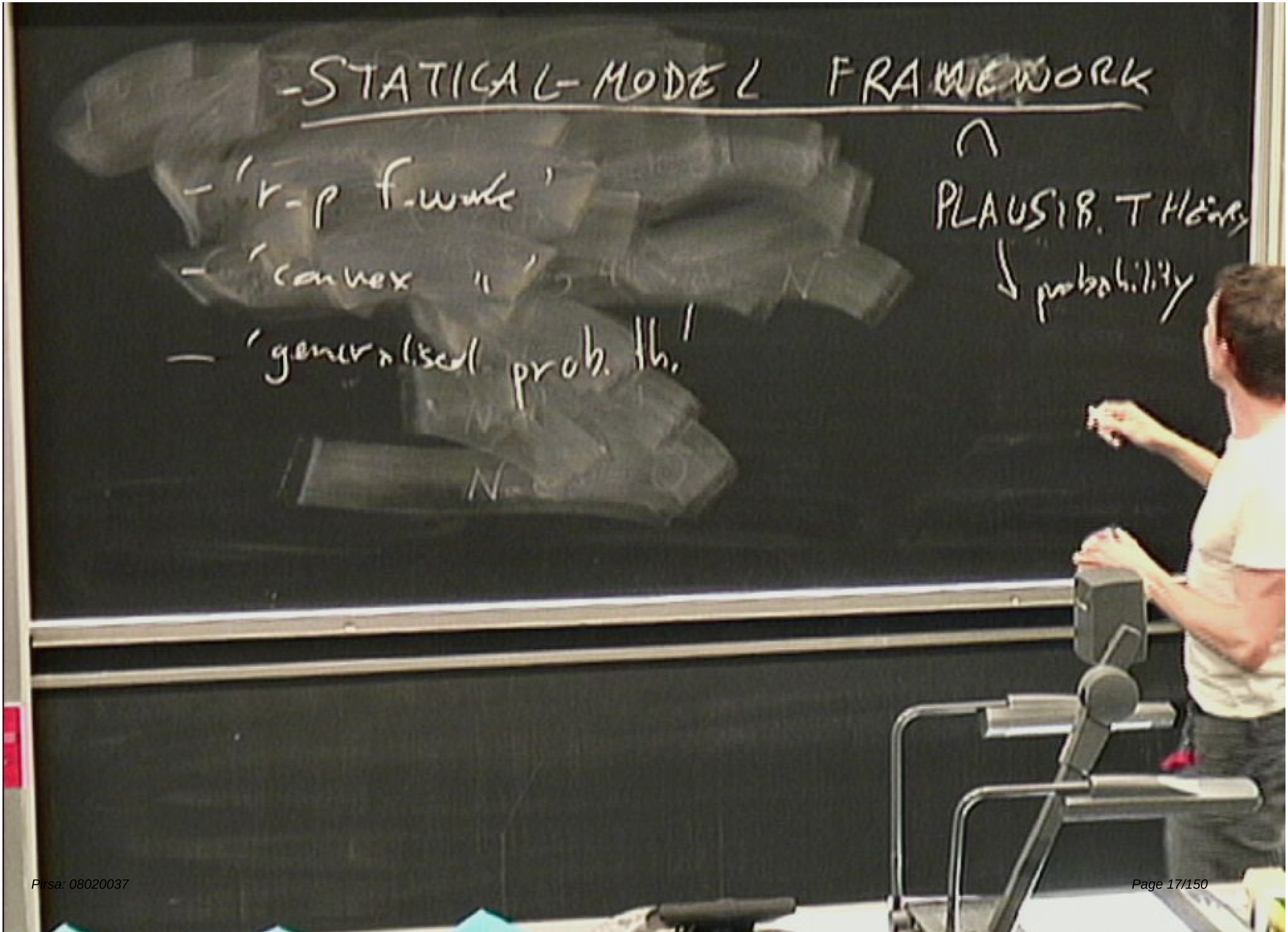

purpose: STATICAL-MODEL FRAMEWORK

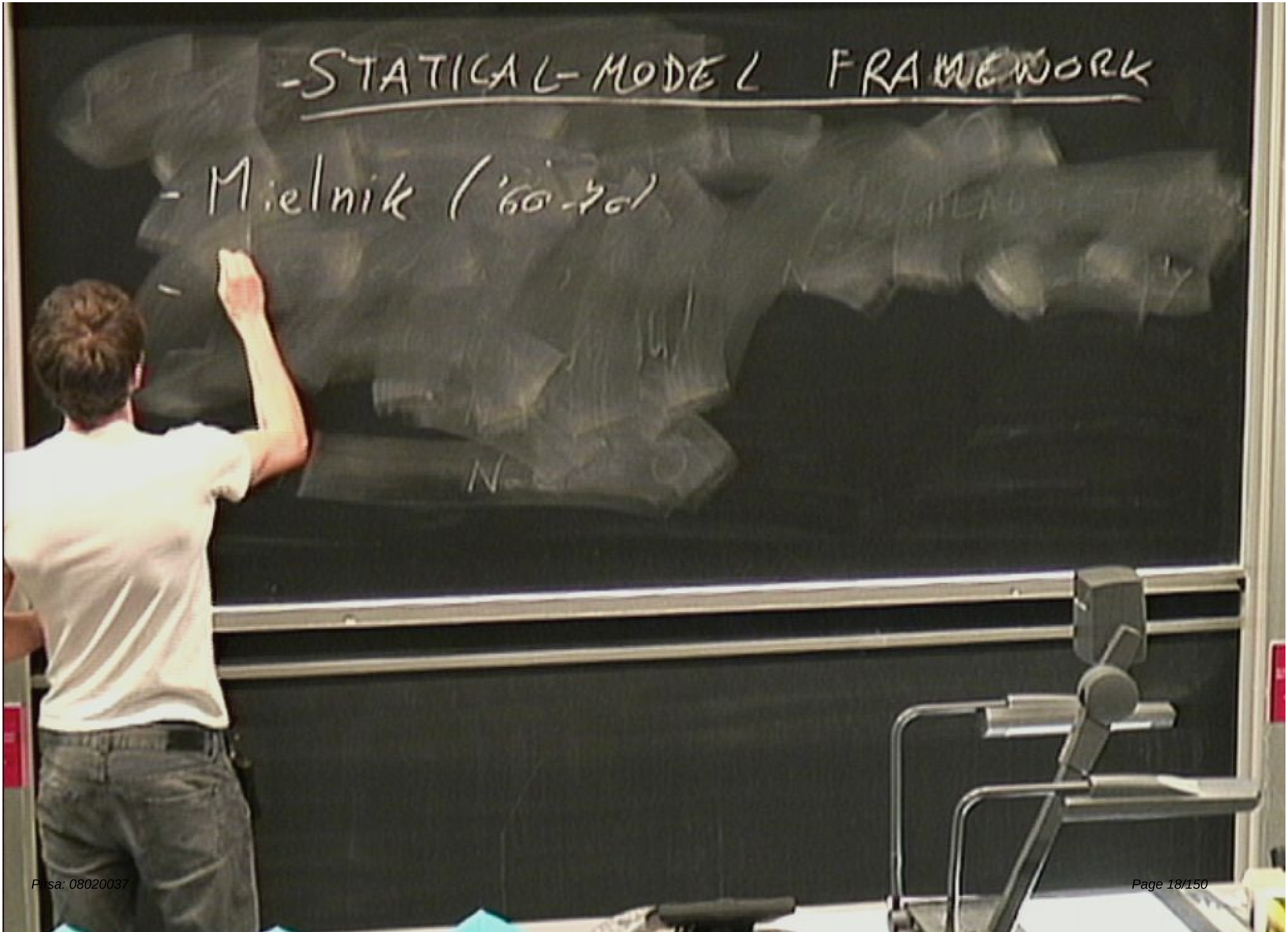

purpose: STATICAL-MODEL FRAMEWORK
– new theorem
– remarks


-STATICAL-MODEL FRAMEWORK
- 'r-p f-work'
'convex "'


-STATICAL-MODEL FRAMEWORK
– 'r-p f-work'
convex "
– 'generalised prob. th.'

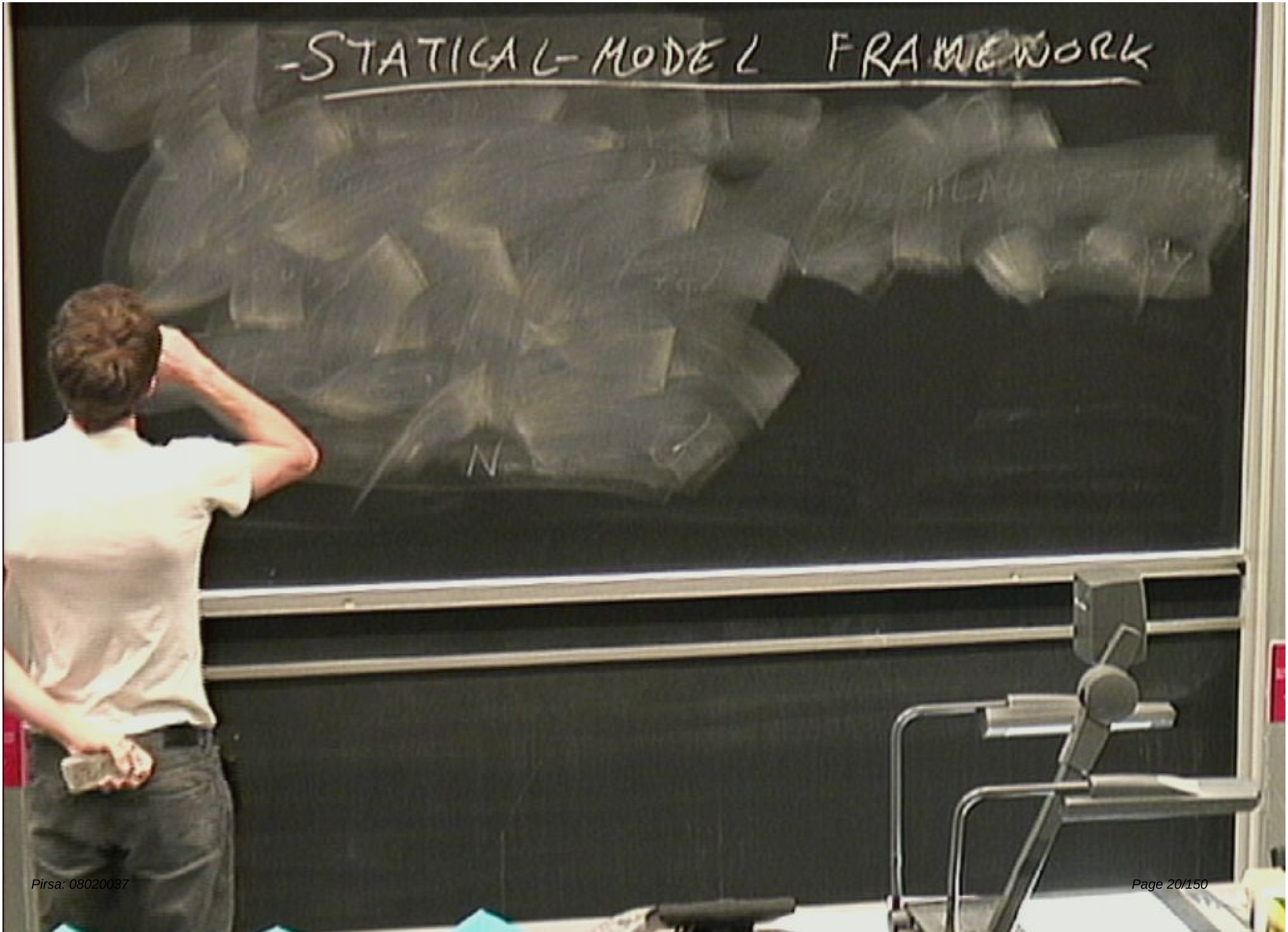

-STATICAL-MODEL FRAMEWORK
– 'r-p f-work'
– 'convex " '
– 'generalised prob. th.'
PLAUSIB. THEORY


-STATICAL-MODEL FRAMEWORK
- 'r-p f-work'
- 'convex " '
- 'generalised prob. th.'
PLAUSIB. THEORY
probability


-STATICAL-MODEL FRAMEWORK
- Mielnik ('60-70)

STATICAL-MODEL FRAMEWORK

- Mielnik ('60-'70)
- Foulis & Randall ('70)
- HOLEVO ('70-'80)


-STATICAL-MODEL FRAMEWORK
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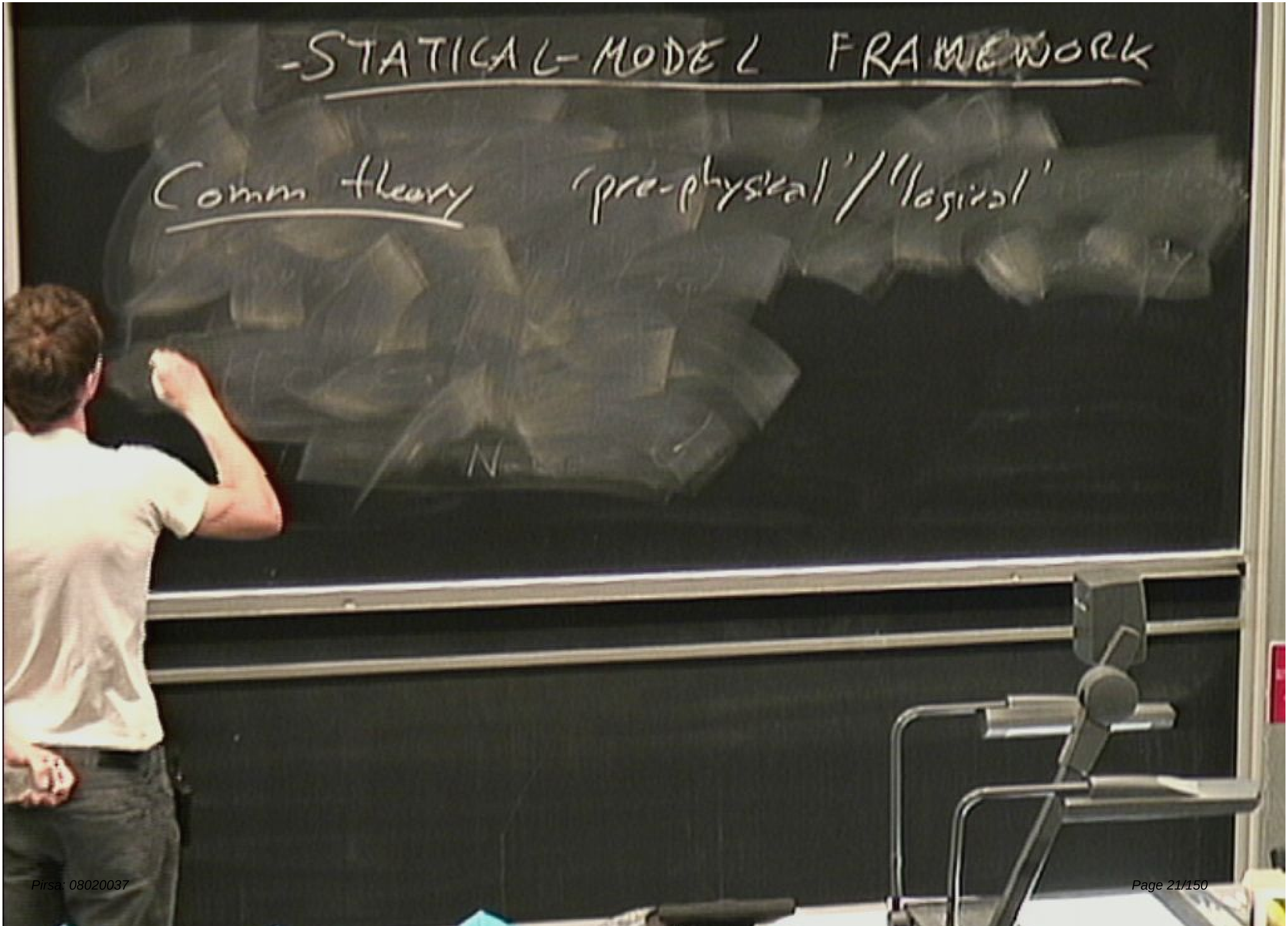
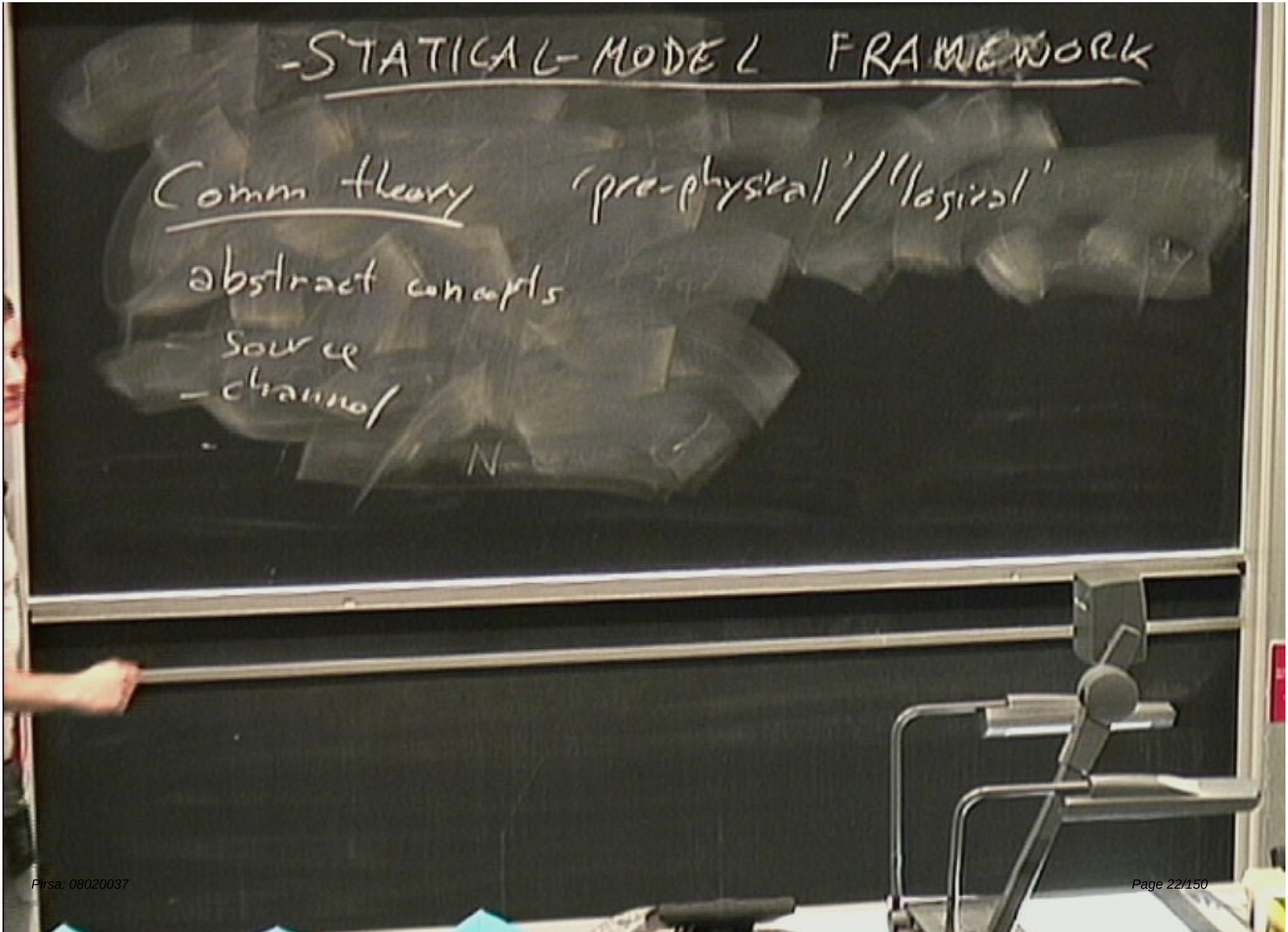
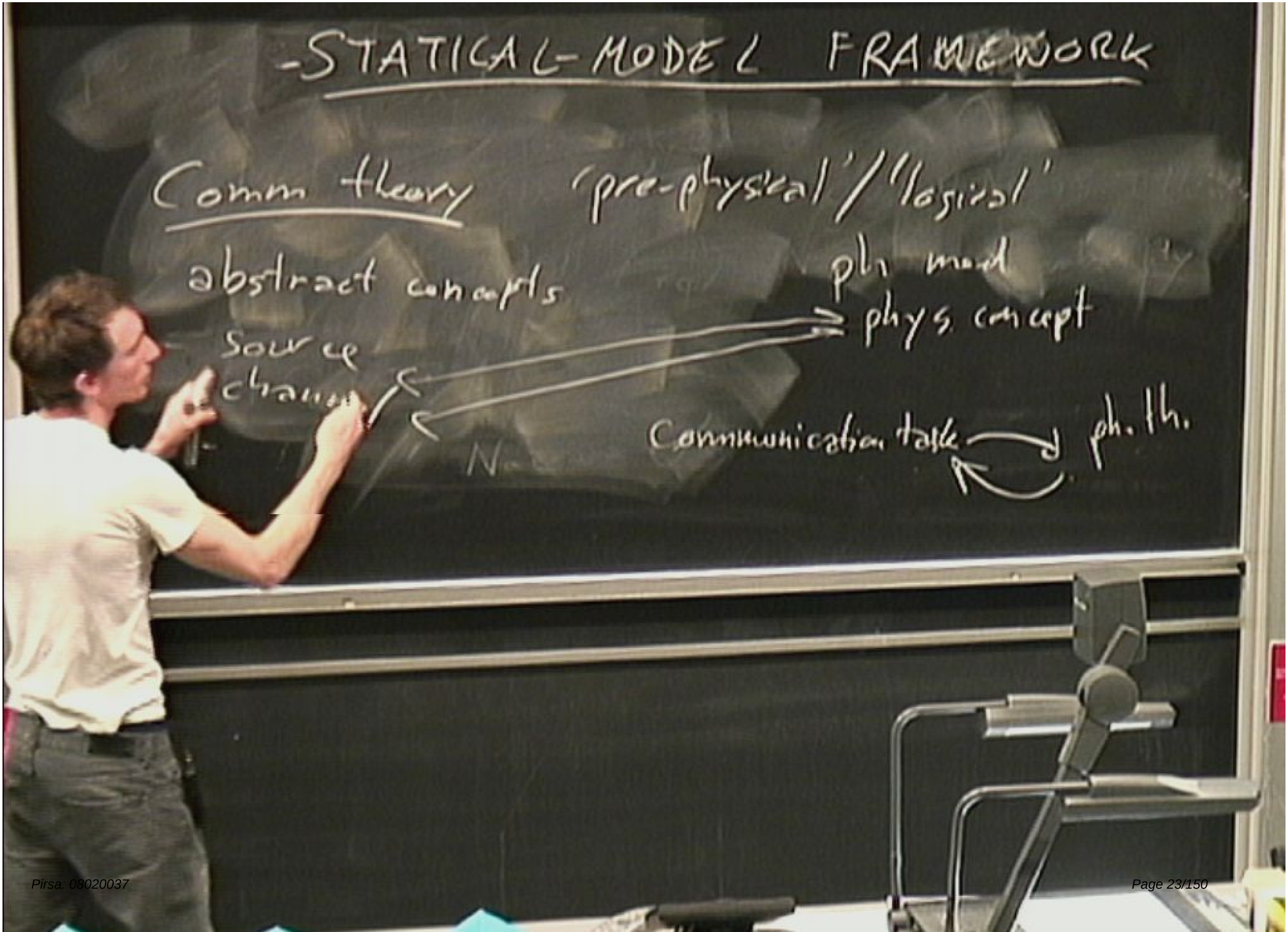

-STATICAL-MODEL FRAMEWORK
Comm theory
'pre-physical'/'logical'
N


-STATICAL-MODEL FRAMEWORK
Comm theory 'pre-physical'/'logical'
abstract concepts
source
- channel


-STATICAL-MODEL FRAMEWORK
Comm theory
'pre-physical'/'logical'
abstract concepts
ph. mod
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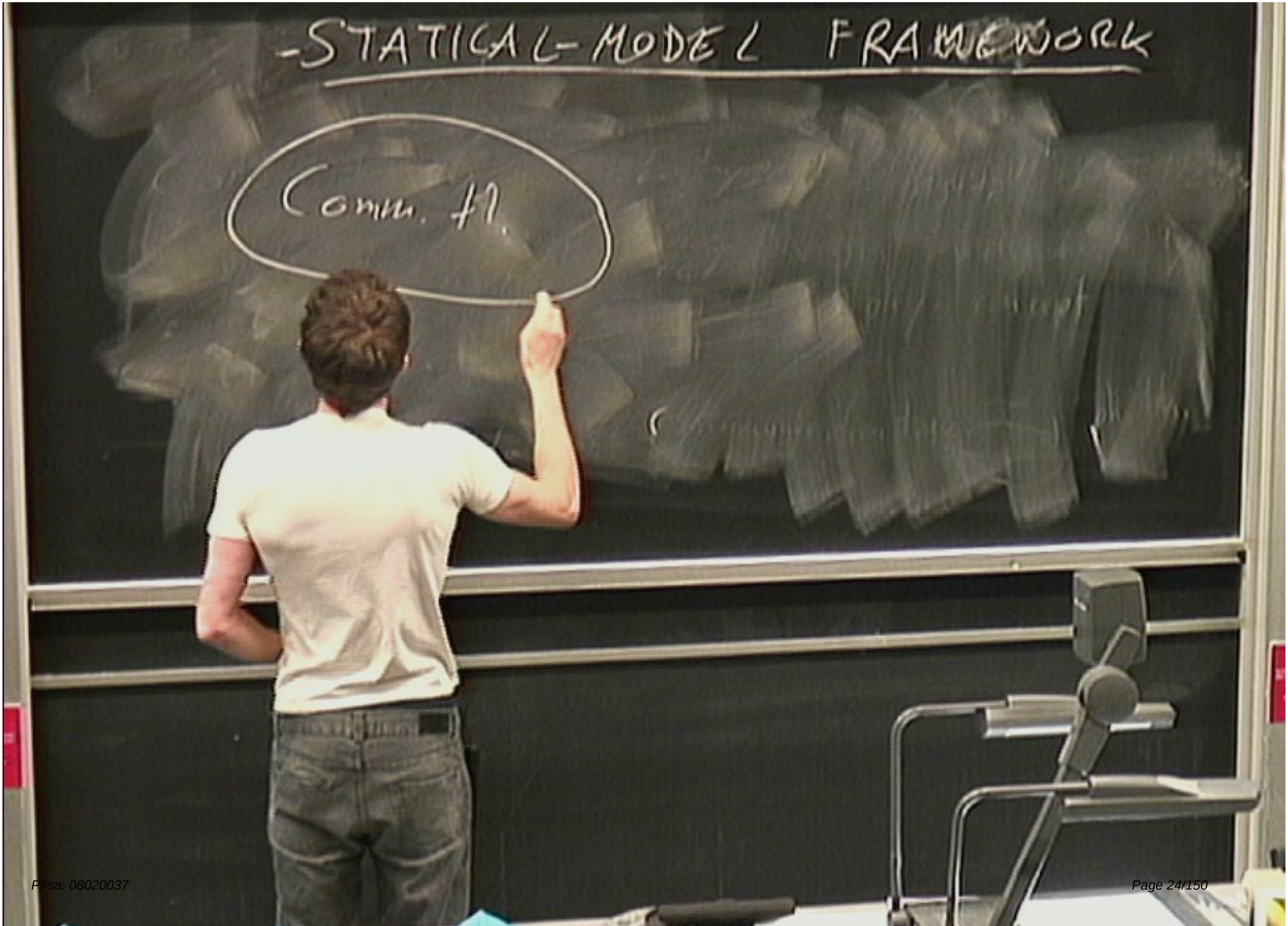
Communication task
ph. th.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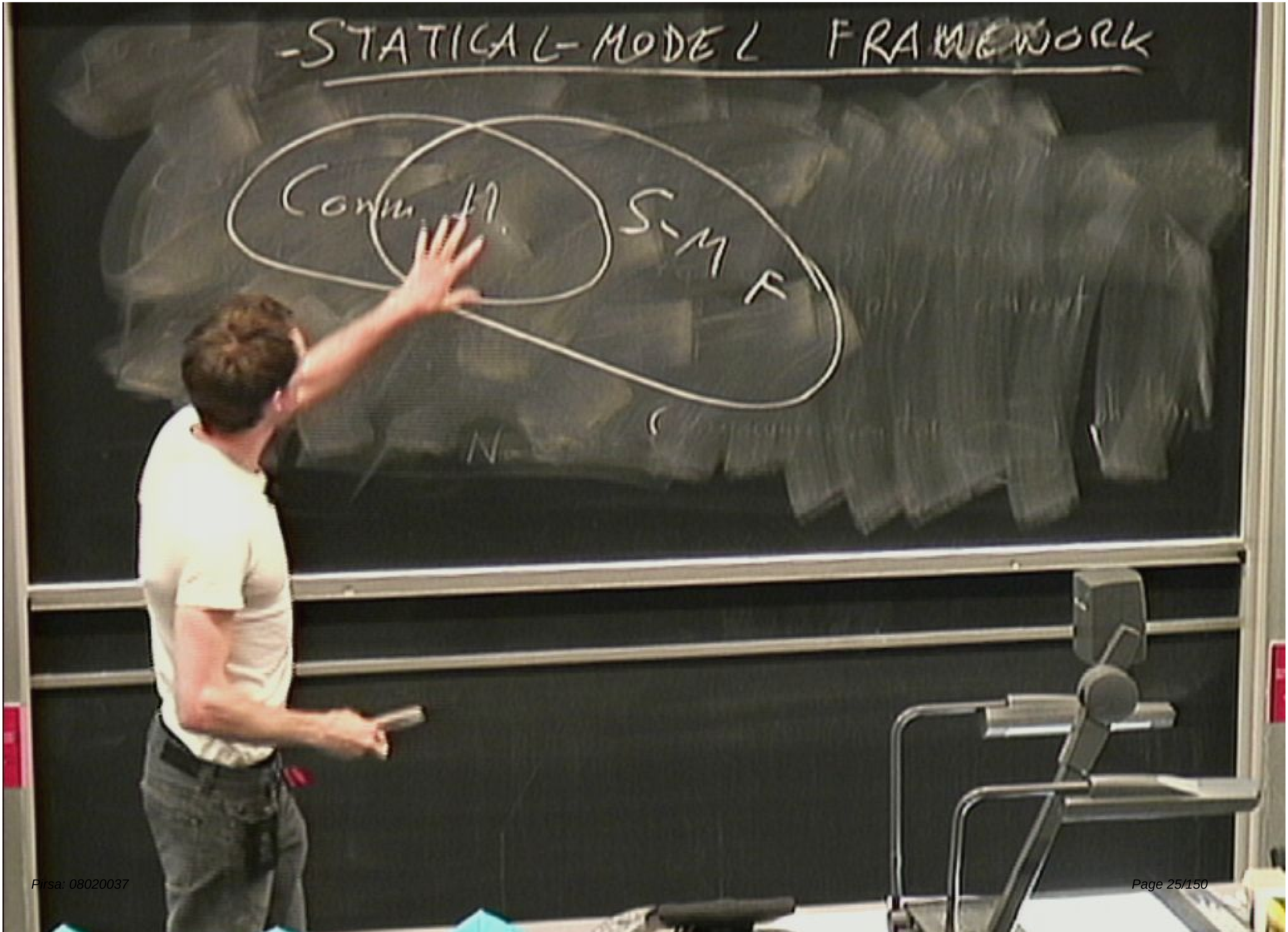
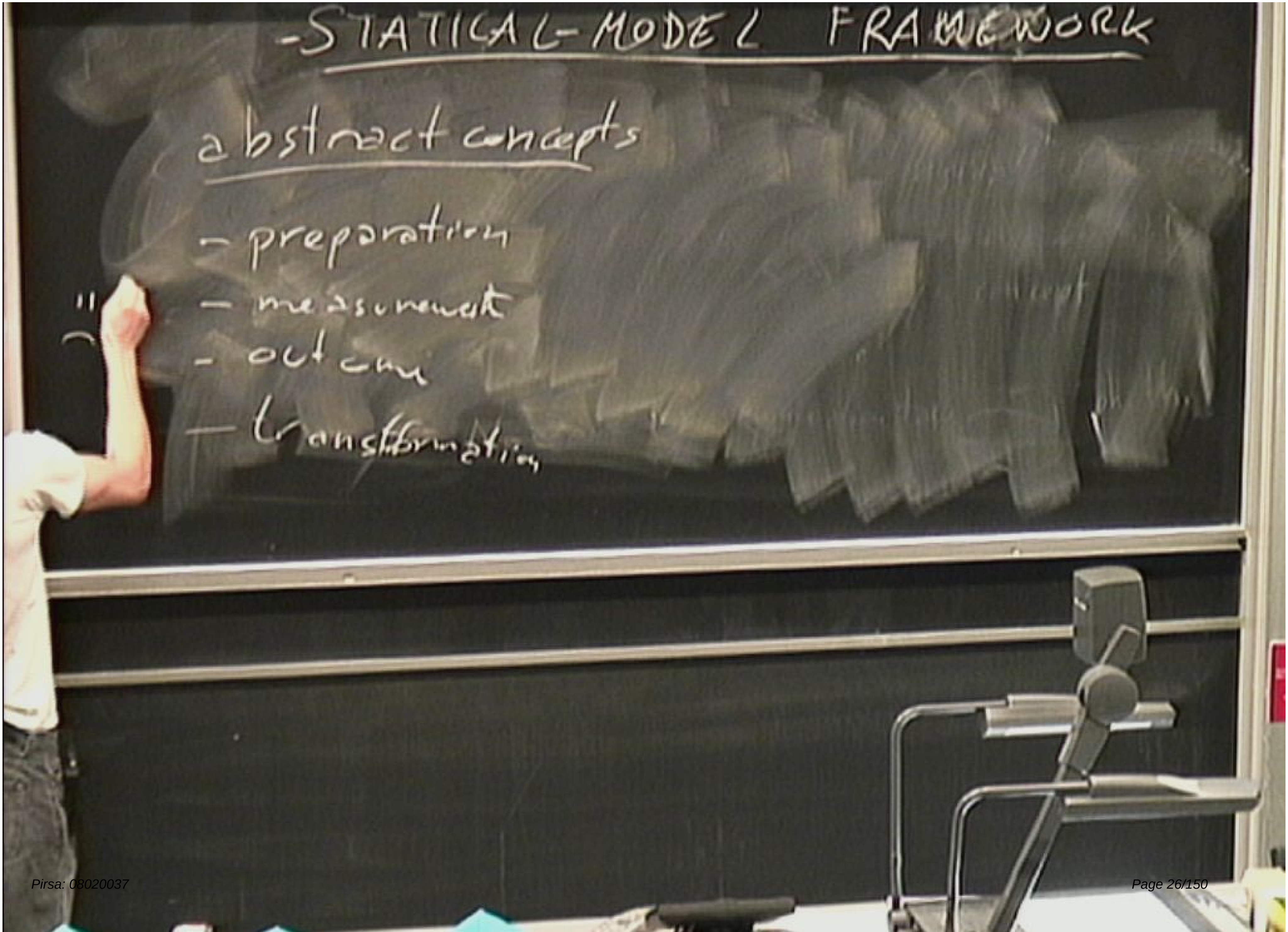
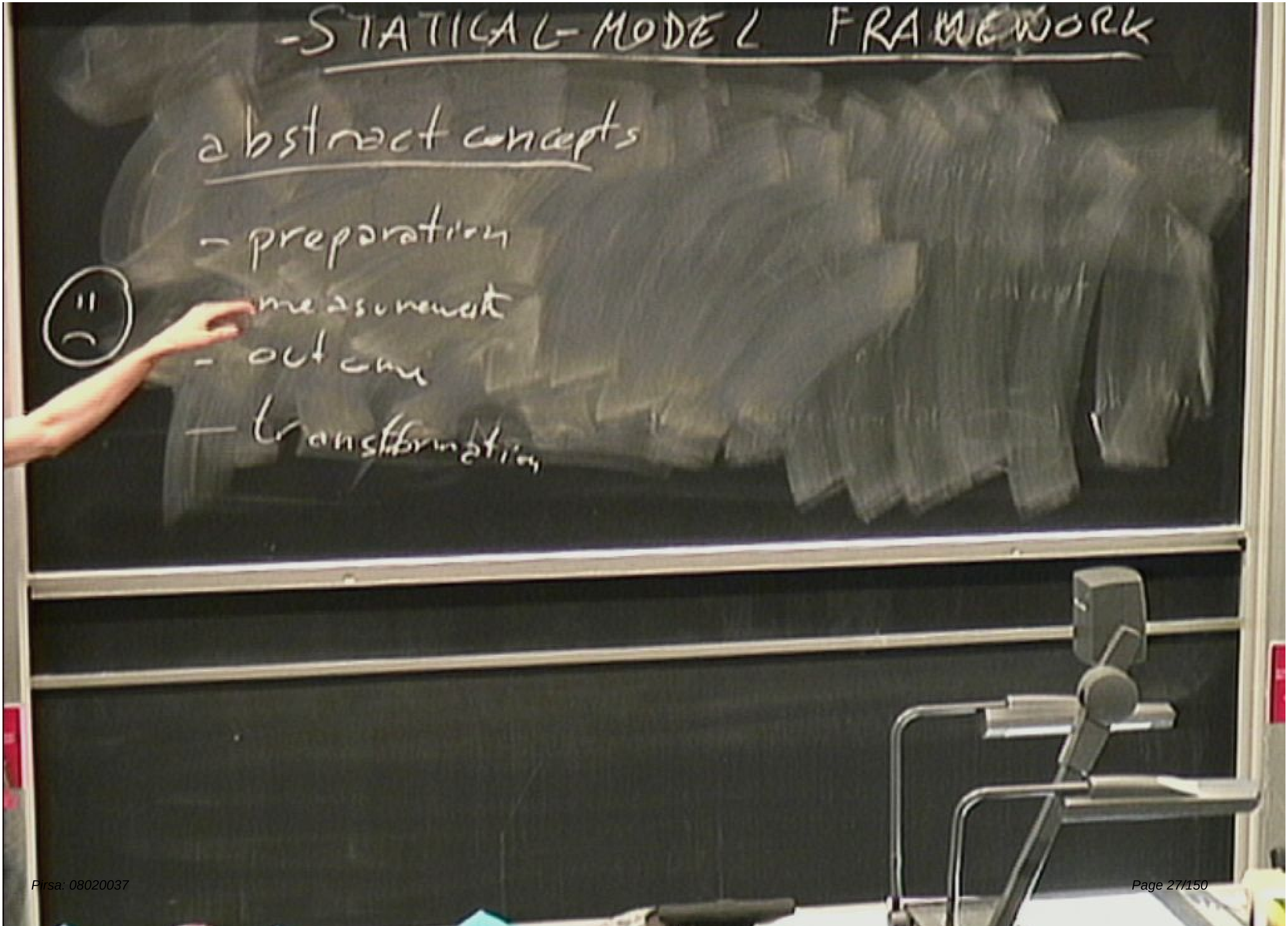
Comm. fl.


-STATICAL-MODEL FRAMEWORK
Comm. H.
S-M F


-STATICAL-MODEL FRAMEWORK
abstract concepts
- preparation
- measurement
- outcome
- transformation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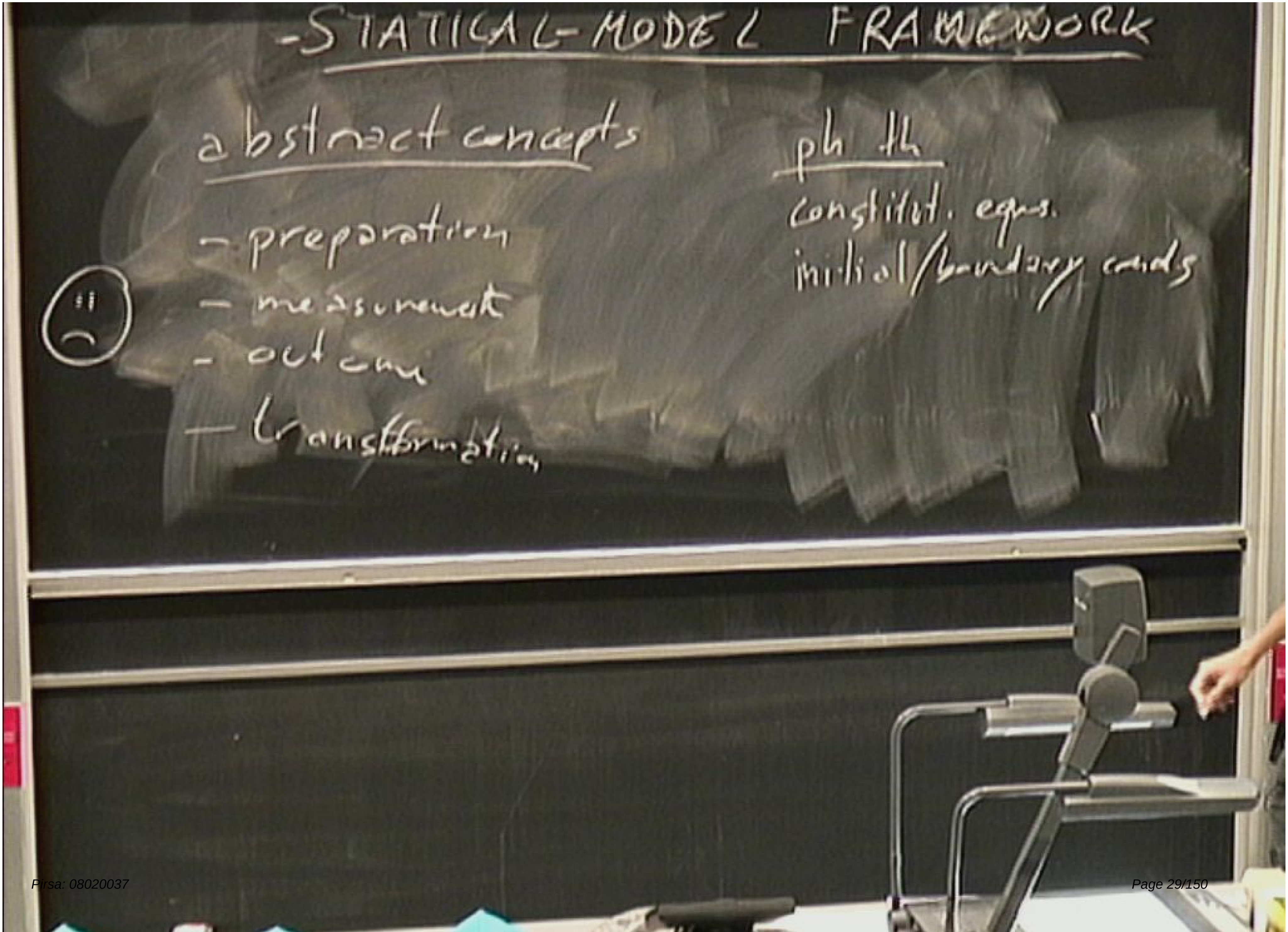
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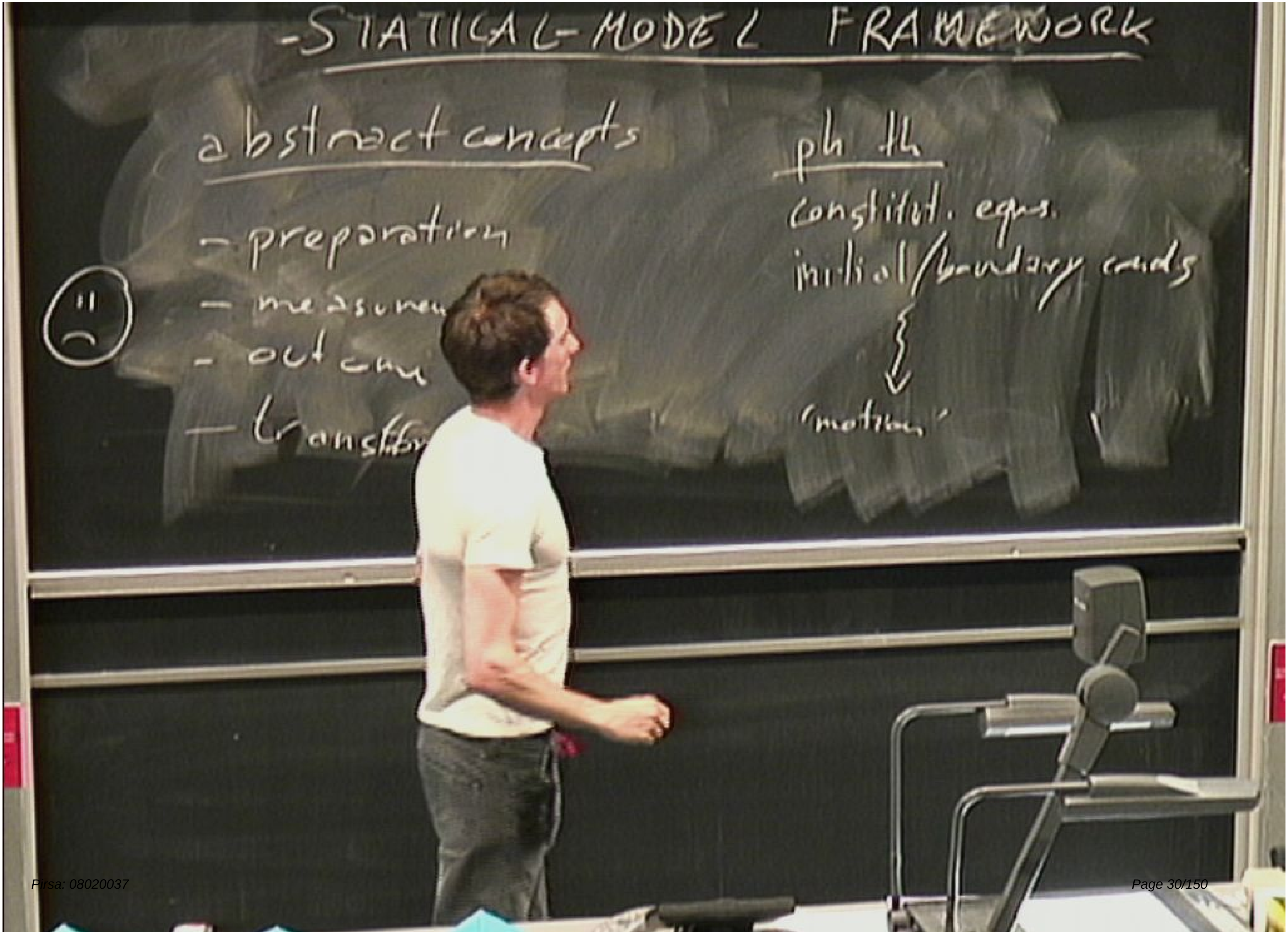
- preparation
- measurement
- outcome
- transformation
ph th
constitut. eqns.
initial/boundary conds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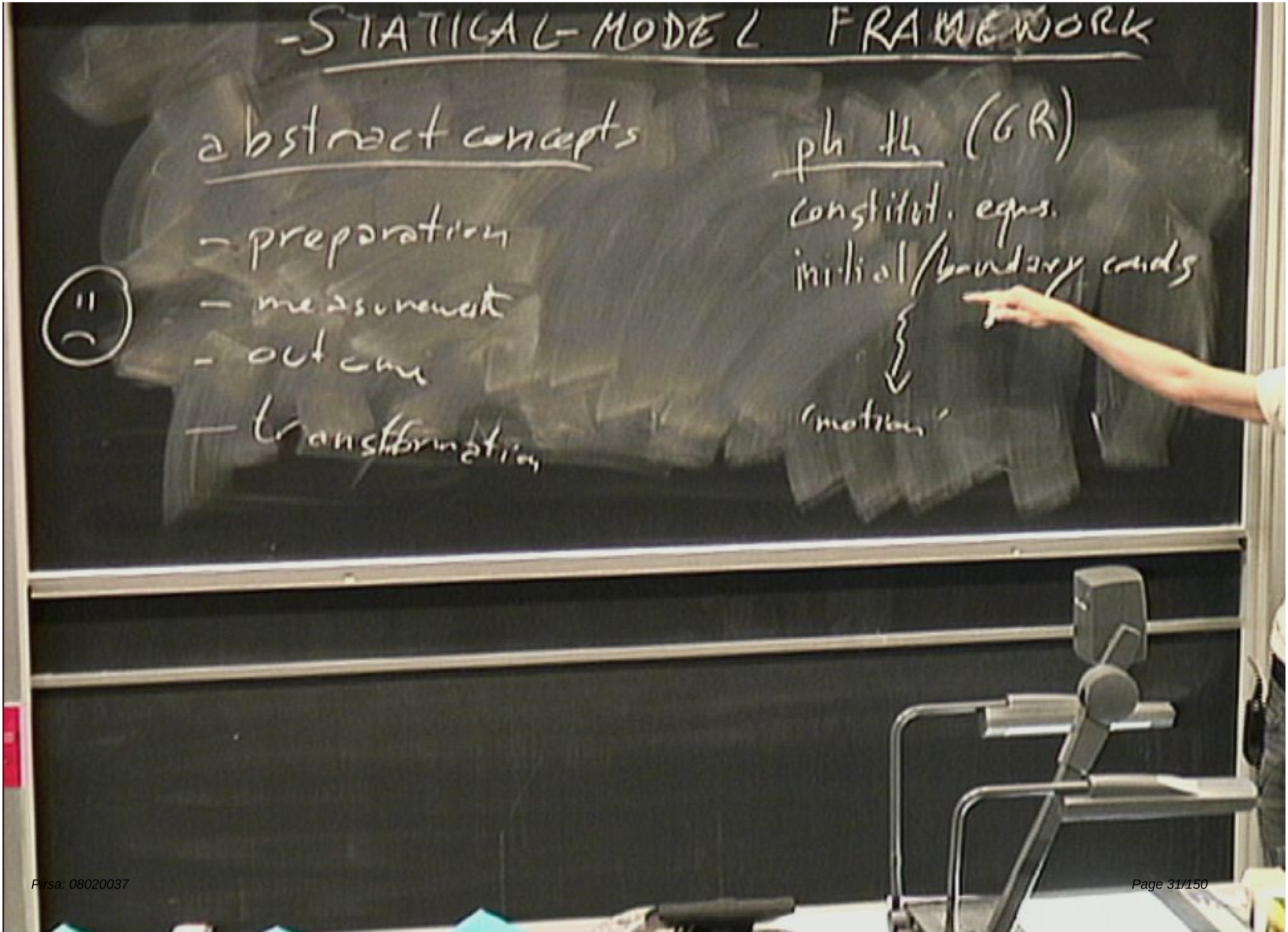
-STATICAL-MODEL FRAMEWORK
abstract concepts
- preparation
- measurement
- outcome
- transformation
ph th (GR)
constitut. eqns.
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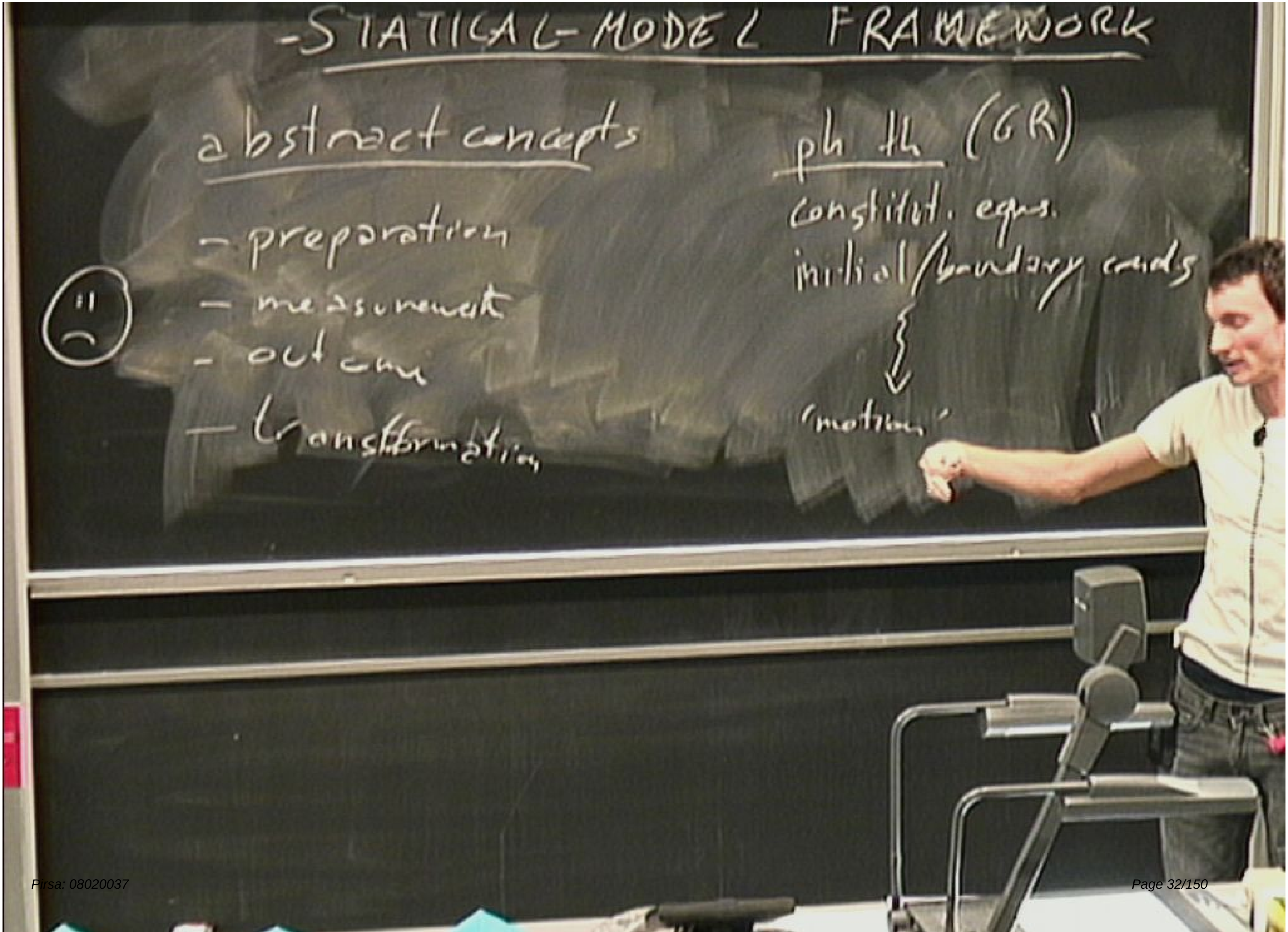
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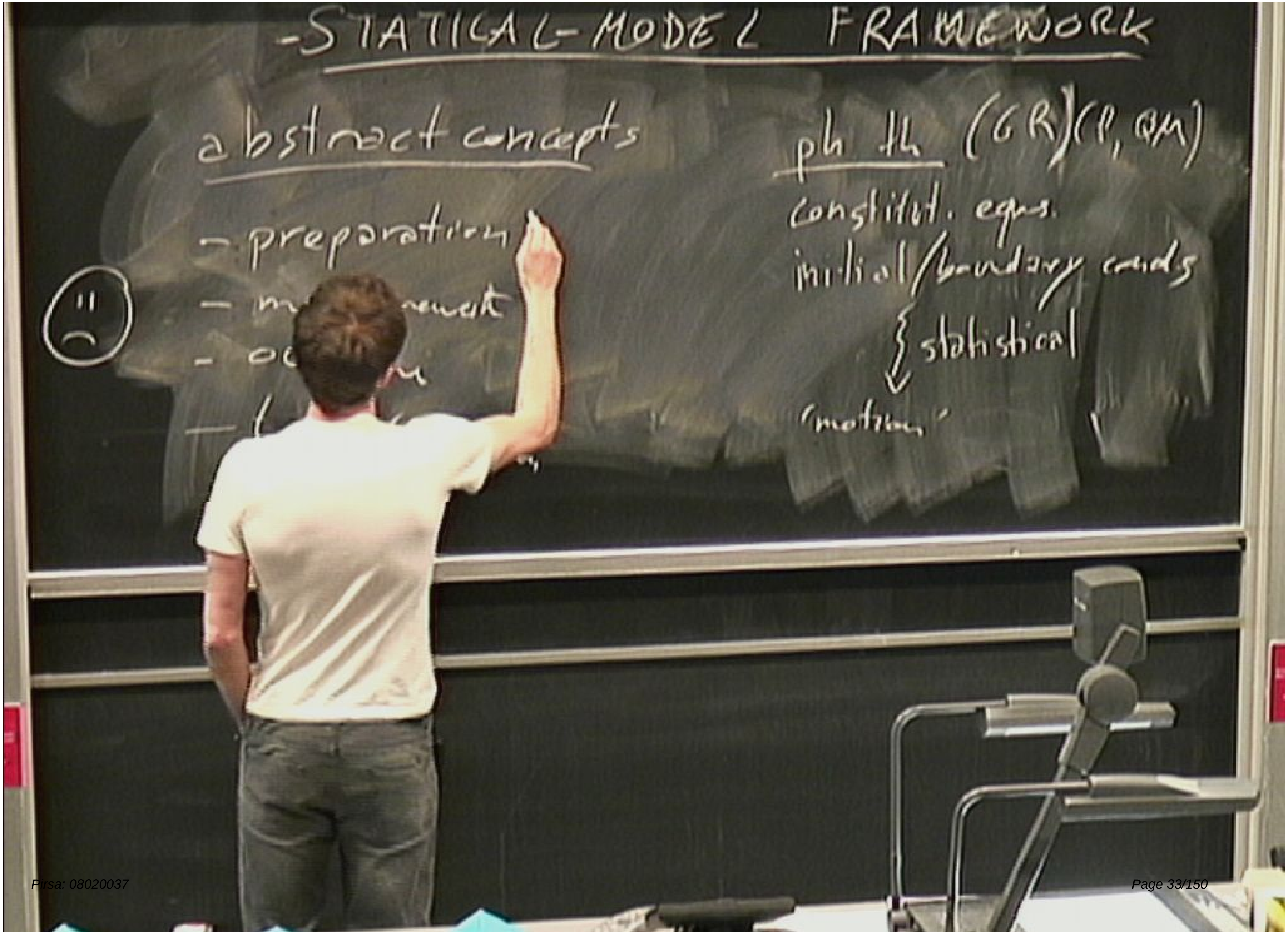
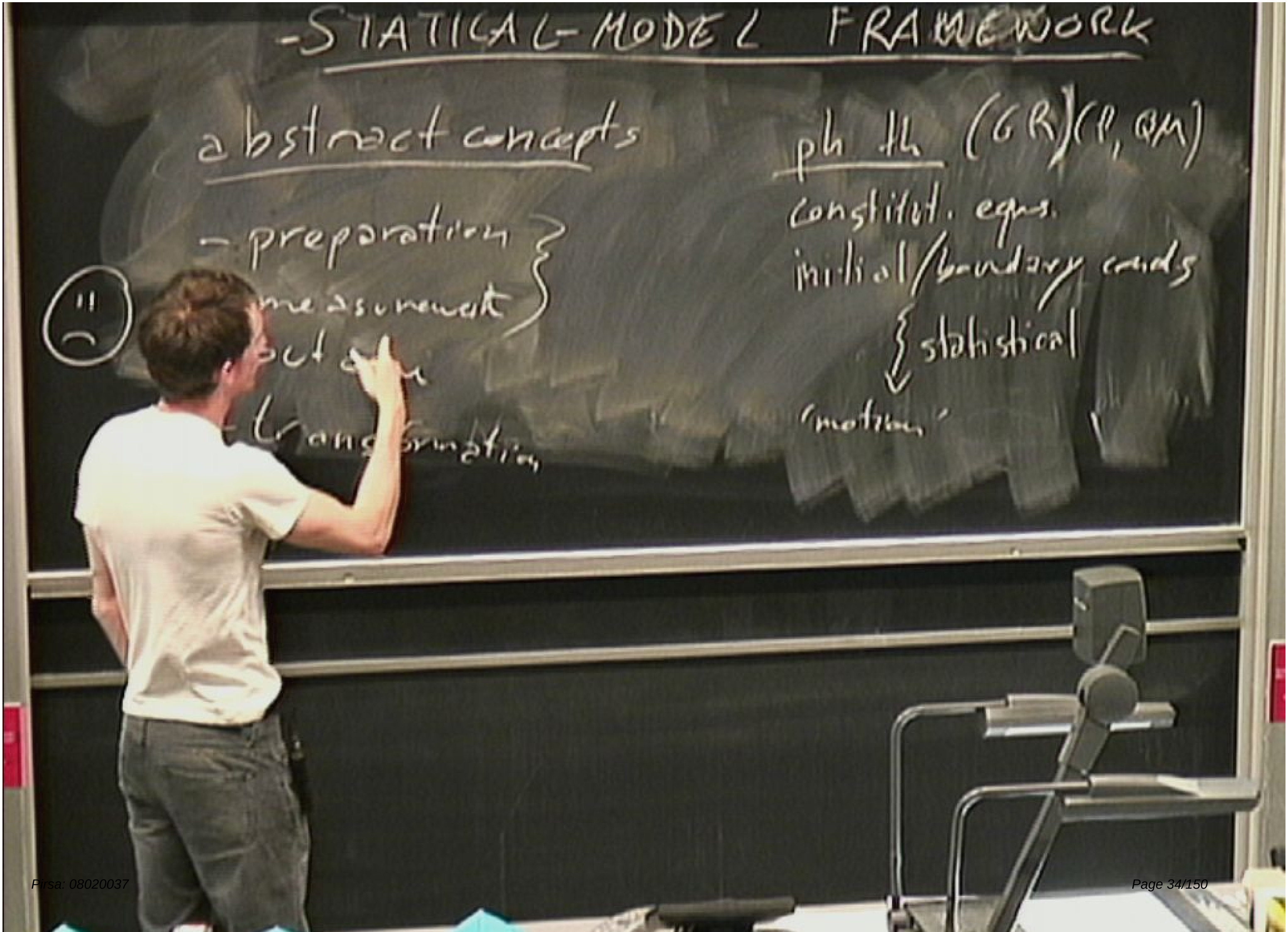

FRAMEWORK
abstract concepts
- preparation
constitut. eqns.
initial/boundary conds
statistical
'motion'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measurement
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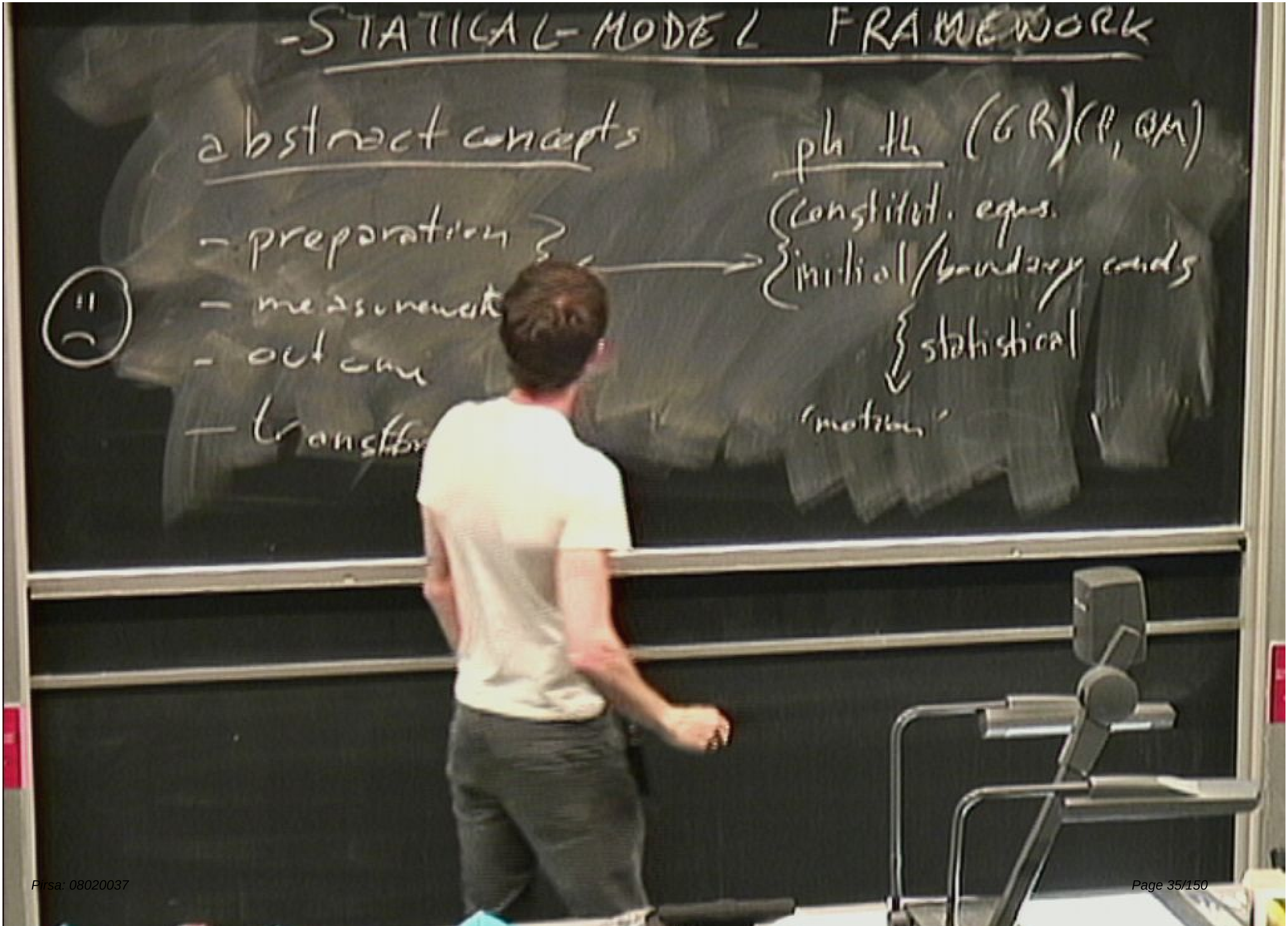
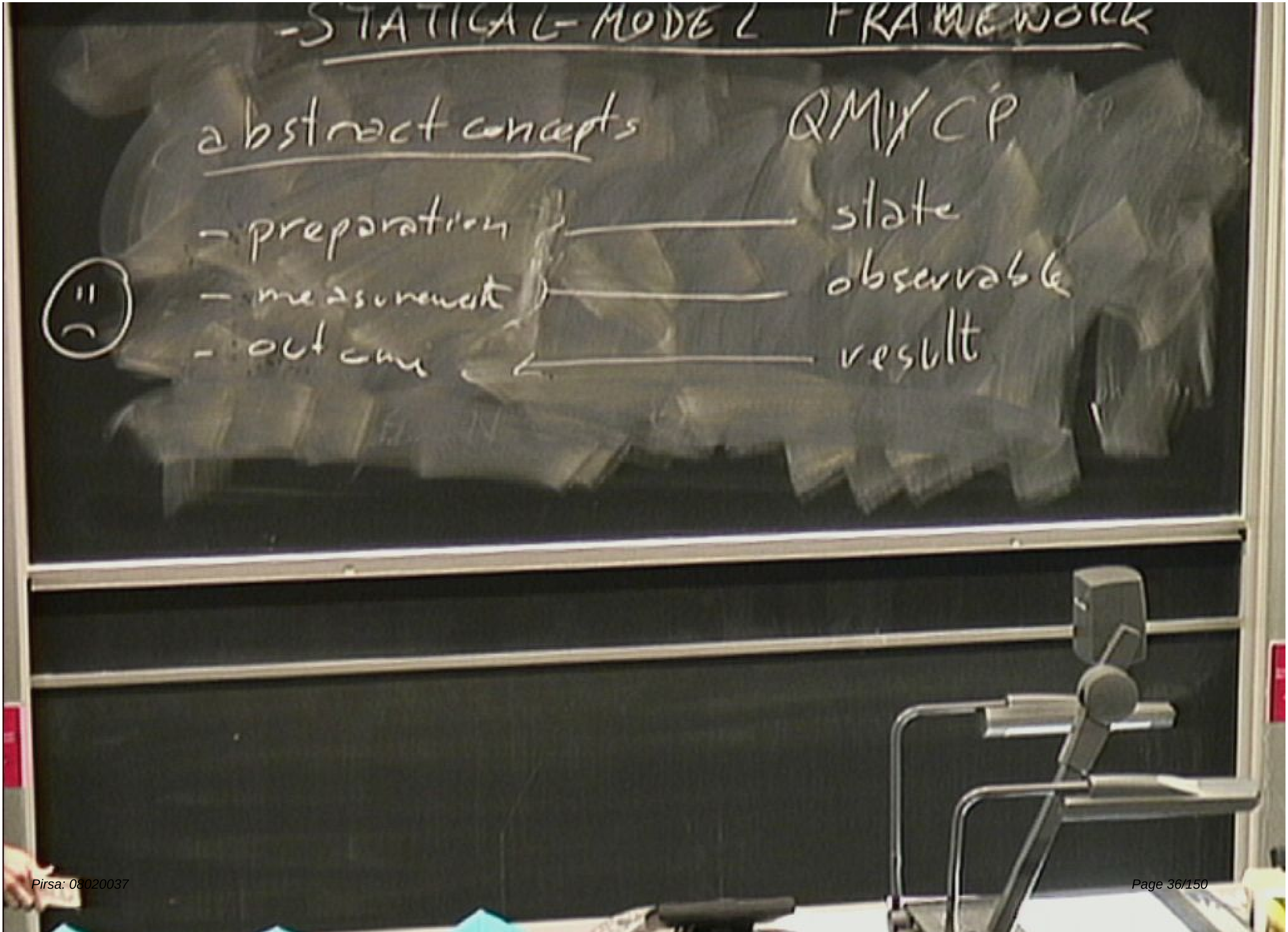
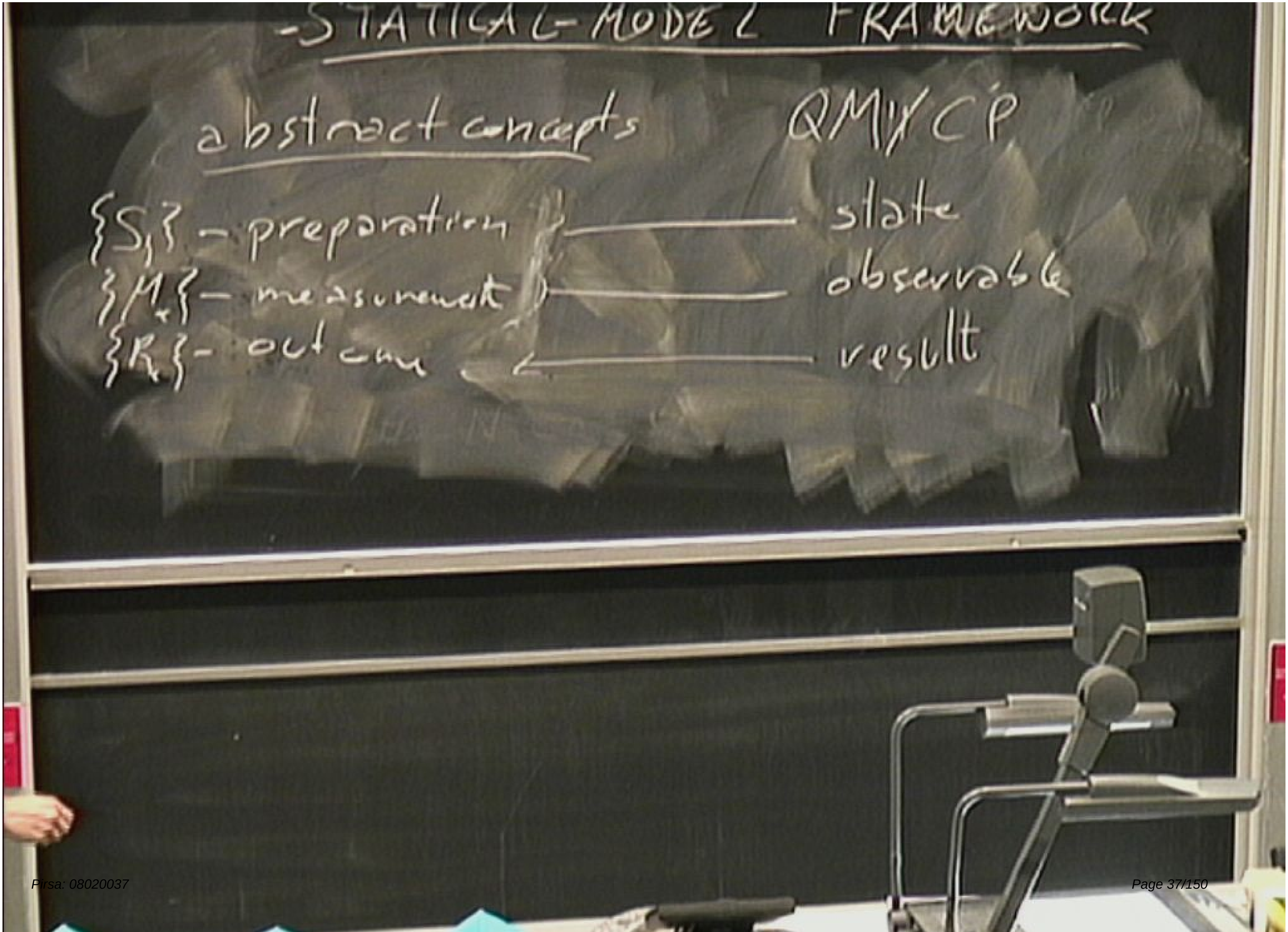

-STATICAL-MODEL FRAMEWORK
abstract concepts
- preparation
- outcome
ph th (GR)(P, QM)
constitut. eqns.
initial/boundary conds
statistical
'motion'

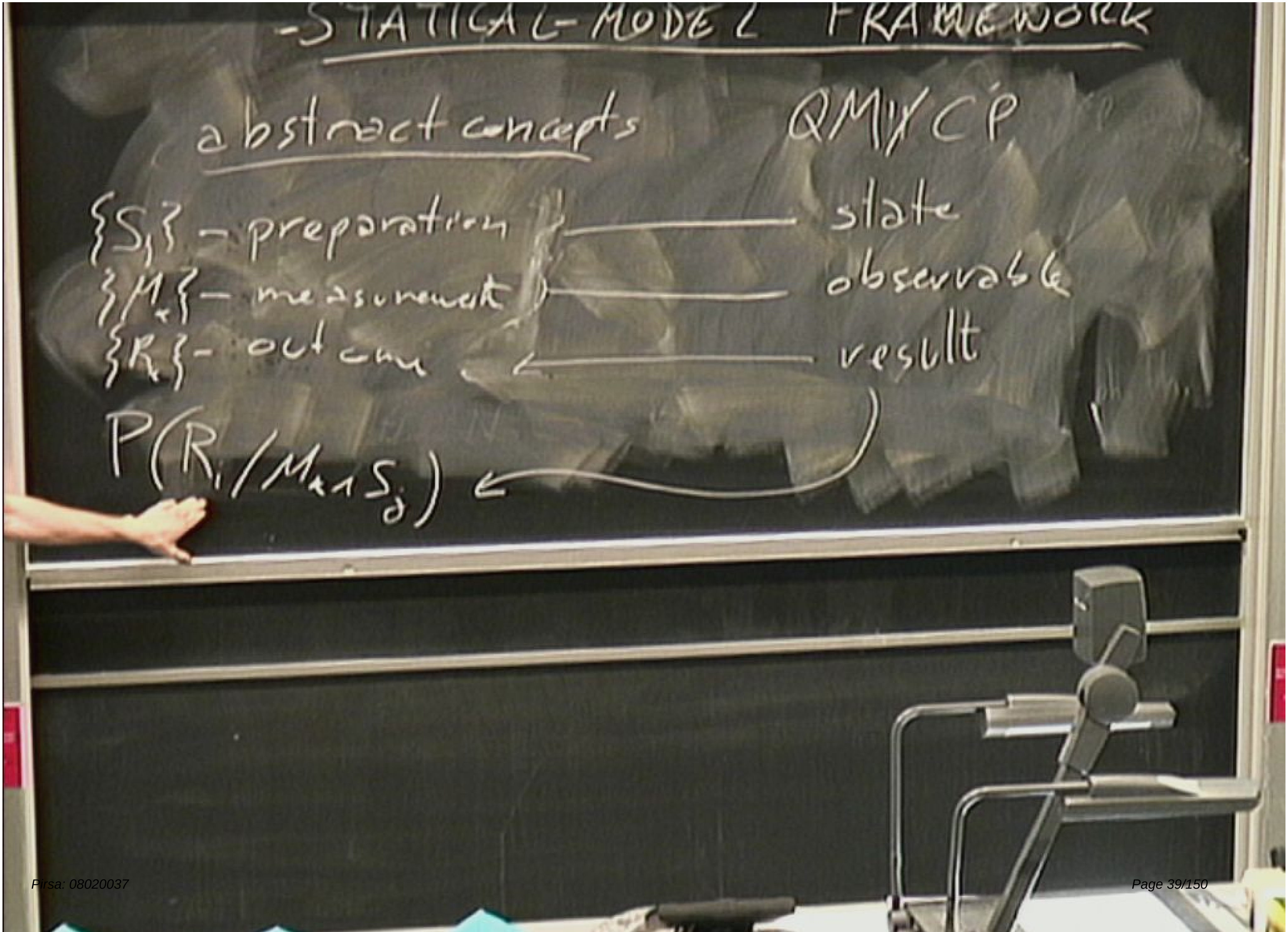

-STATICAL-MODEL FRAMEWORK
abstract concepts
QM/CP
- preparation
state
- measurement
observable
- outcome
result

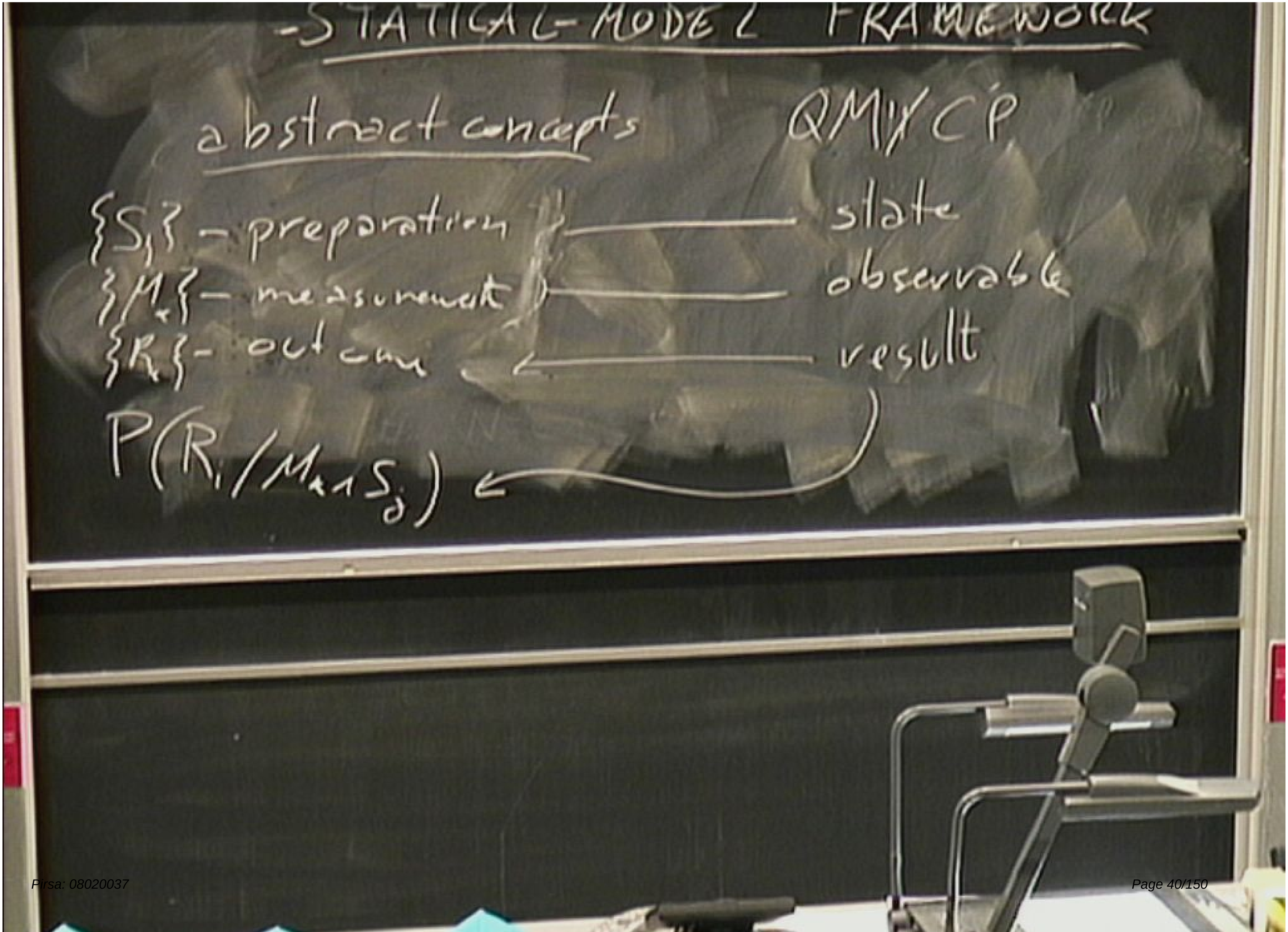

STATICAL-MODEL FRAMEWORK
abstract concepts
QM/CP
{S_i} - preparation
state
{M_k} - measurement
observable
{R_r} - outcome
result

-STATICAL-MODEL FRAMEWORK

abstract concepts	QM/CP
$\{S_j\}$ – preparation	state
$\{M_k\}$ – measurement	observable
$\{R_i\}$ – outcome	result

$$P(R_i / M_k \wedge S_j)$$


-STATICAL-MODEL FRAMEWORK
abstract concepts
QM / CP
{S_j} - preparation
state
{M_k} - measurement
observable
{R_i} - outcome
result
$P(R_i / M_k \wedge S_j)$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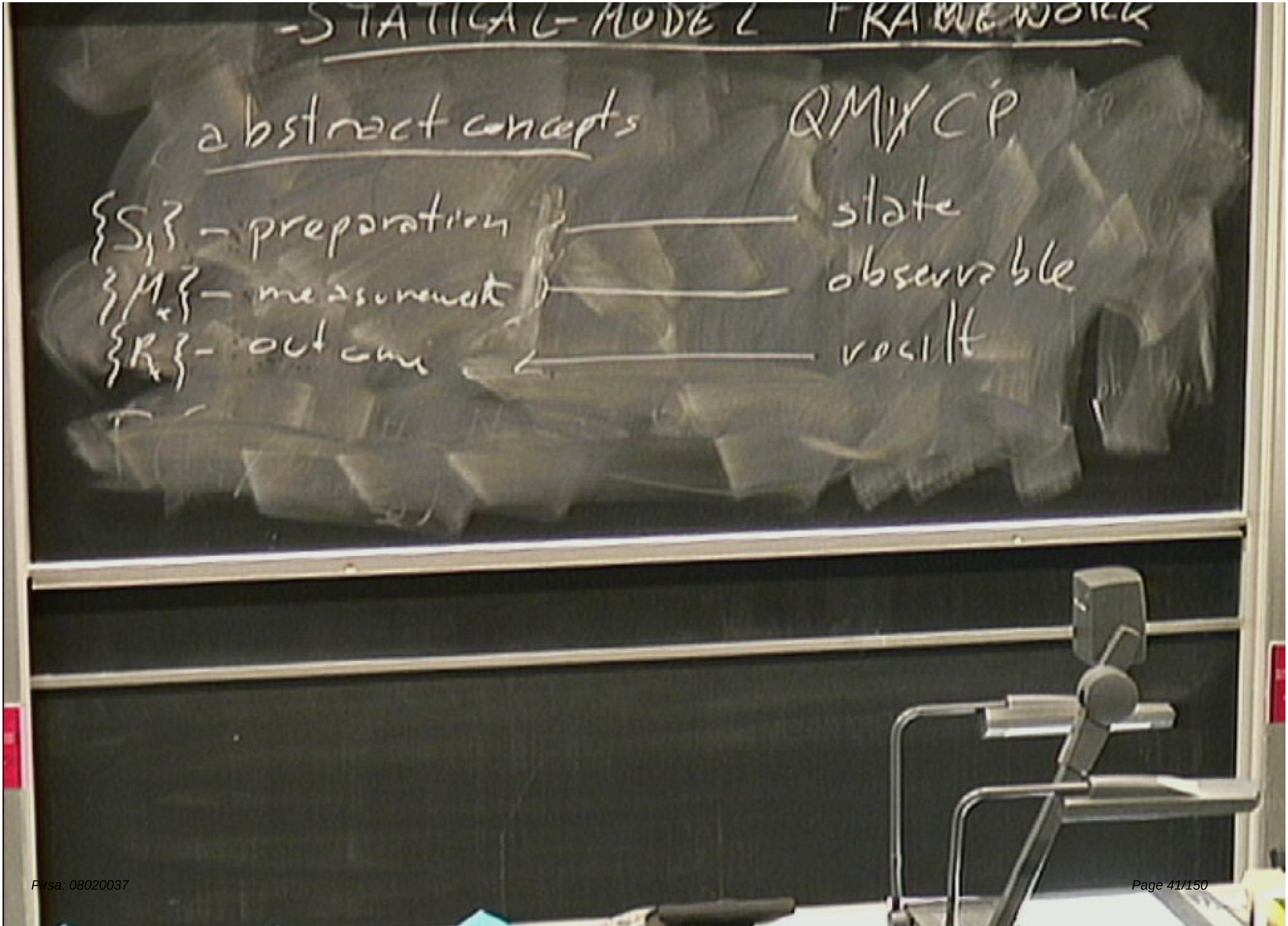
abstract concepts
QM/CP
{S_j} – preparation
state
{M_k} – measurement
observable
{R_i} – outcome
result
P(R_i / M_k ∧ S_j)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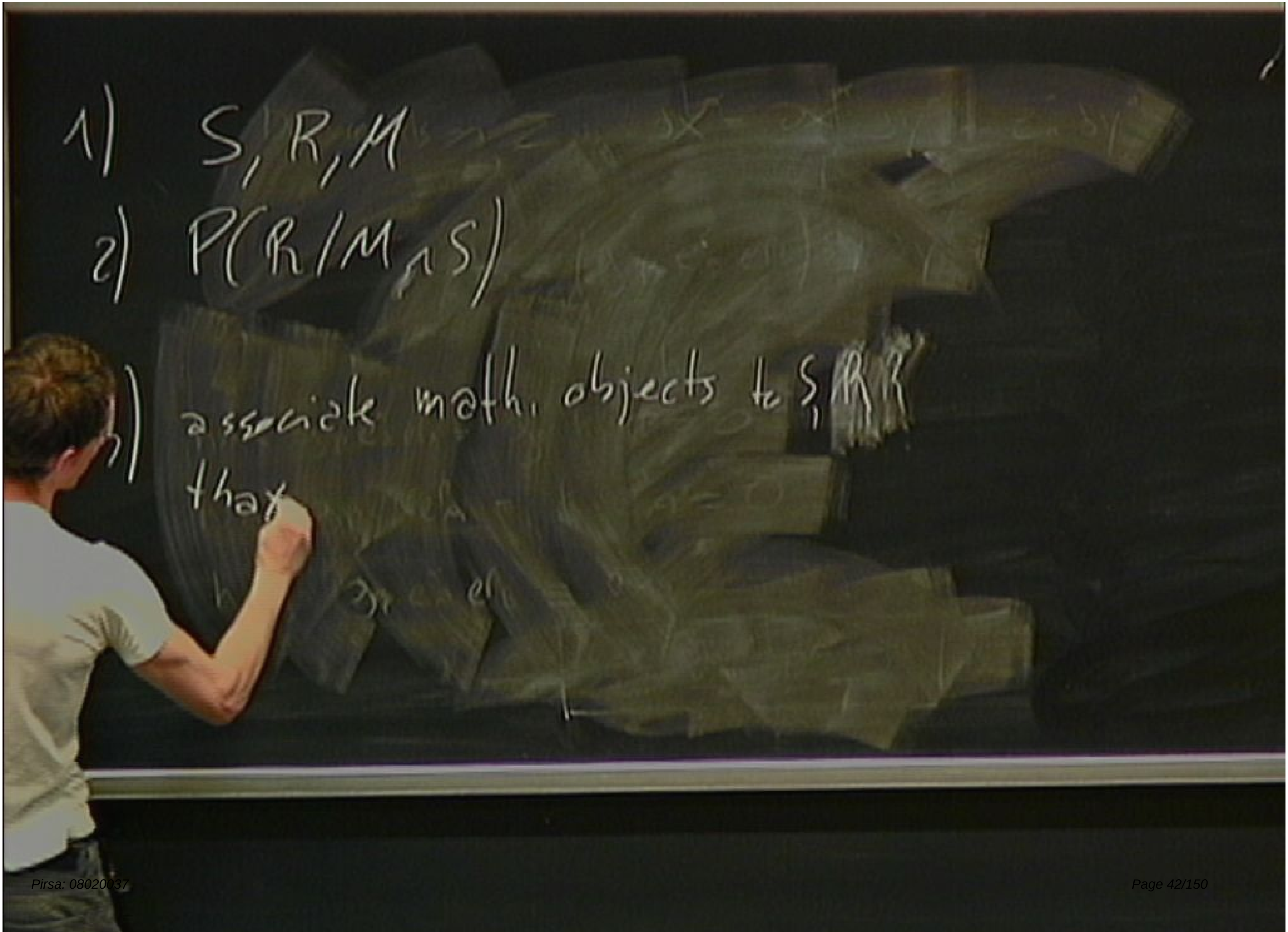

1) S, R, M
2) P(R/M ∧ S)
3) associate math. objects to S, R, ?
that

1) S, R, M

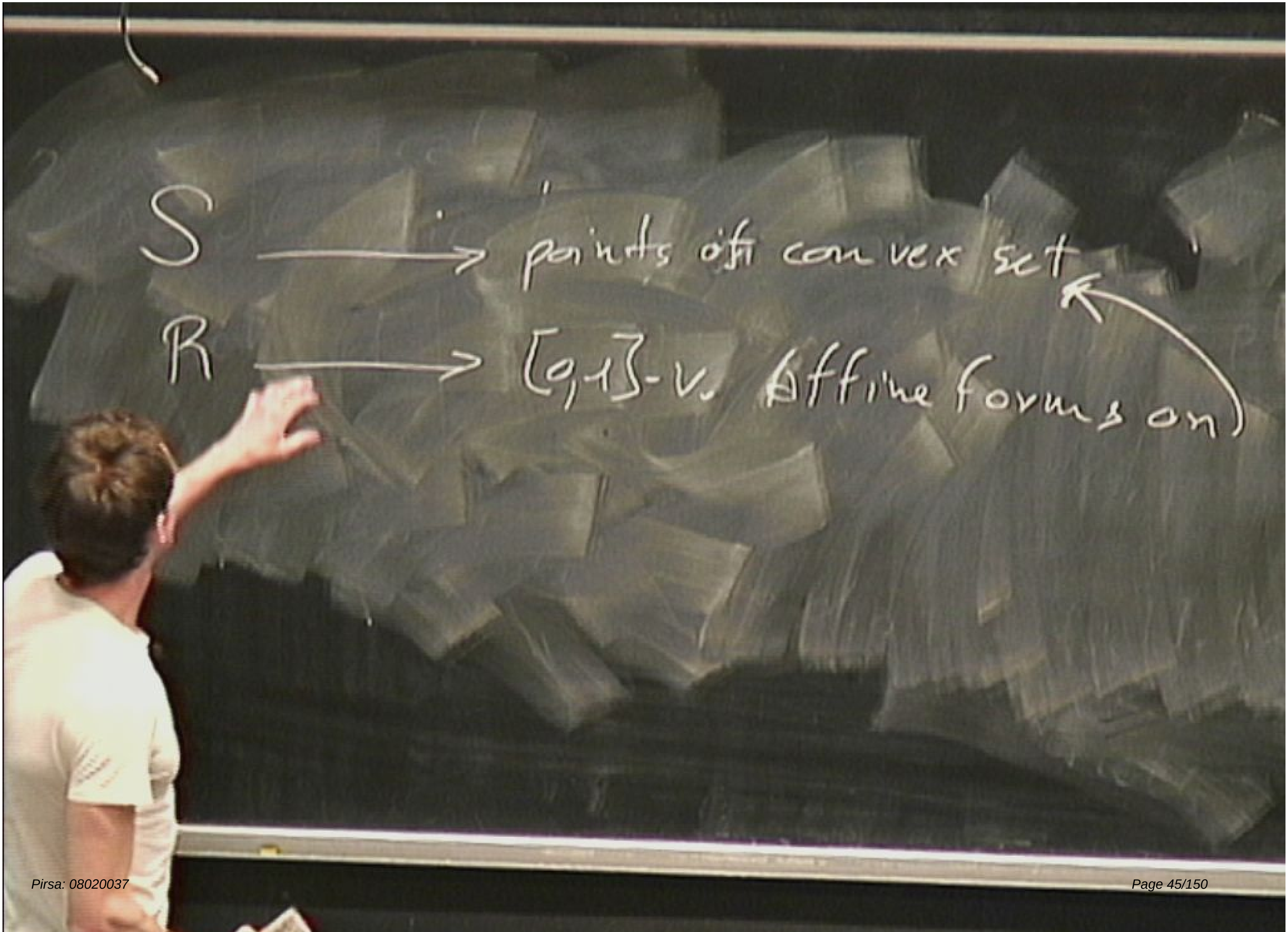
2) $P(R/M \wedge S)$

3) associate math. objects to S, R that 'encode' the statistical properties of the ph. model

1) identify S, R, M

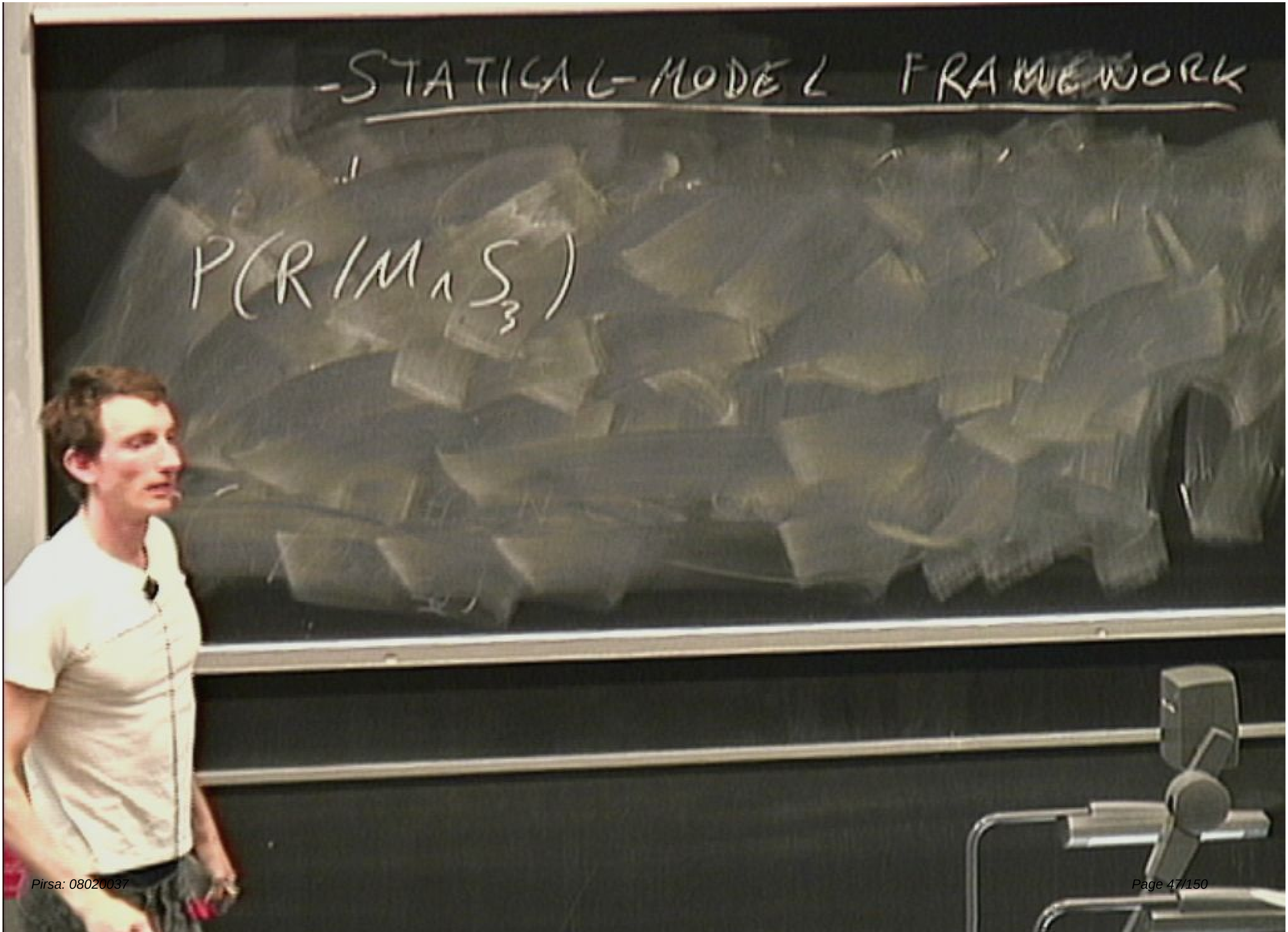
2) $P(R/M, S)$

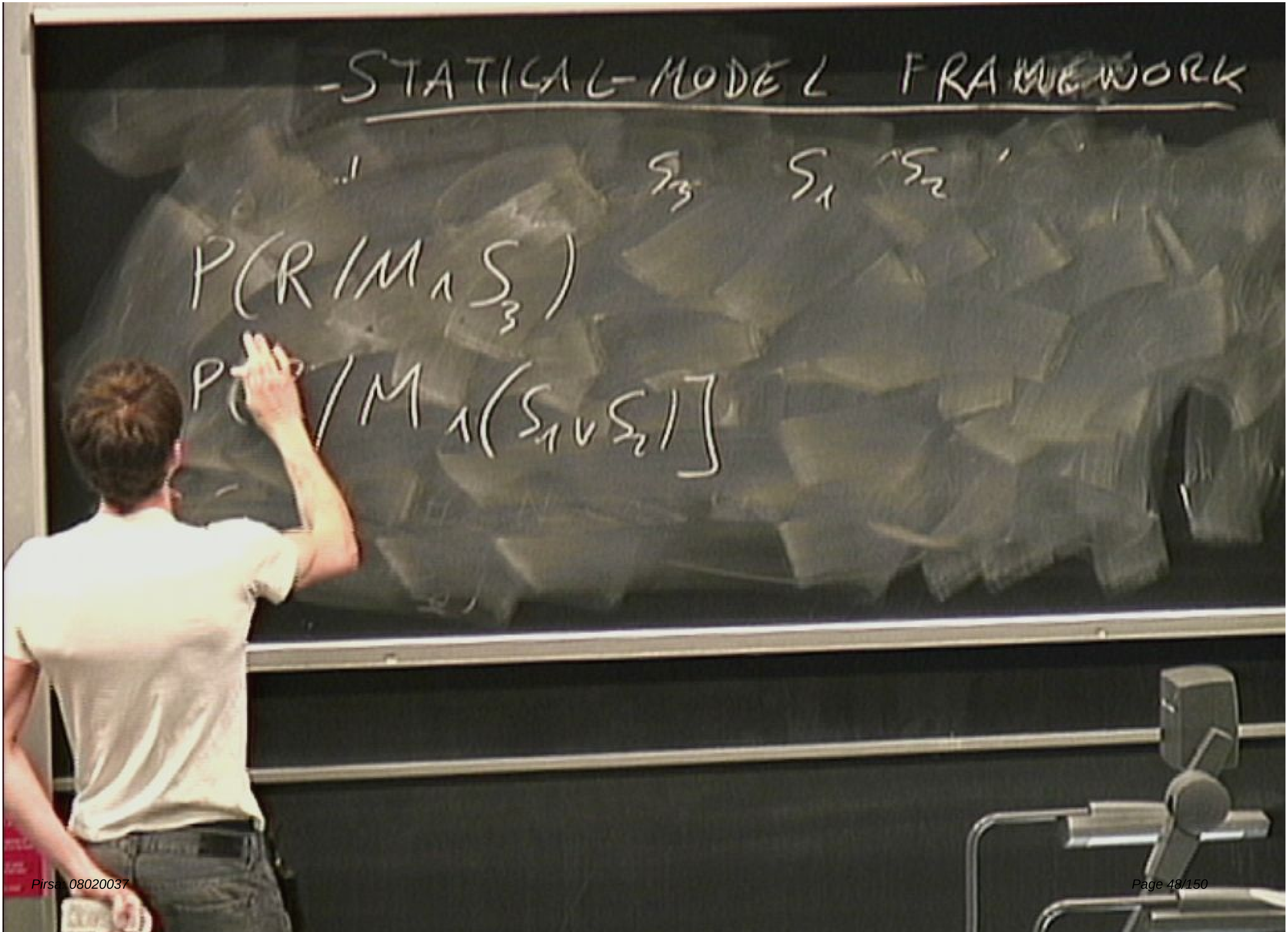
3) associate math. objects to S, R
that 'encode' the statistical properties
of the ph. model

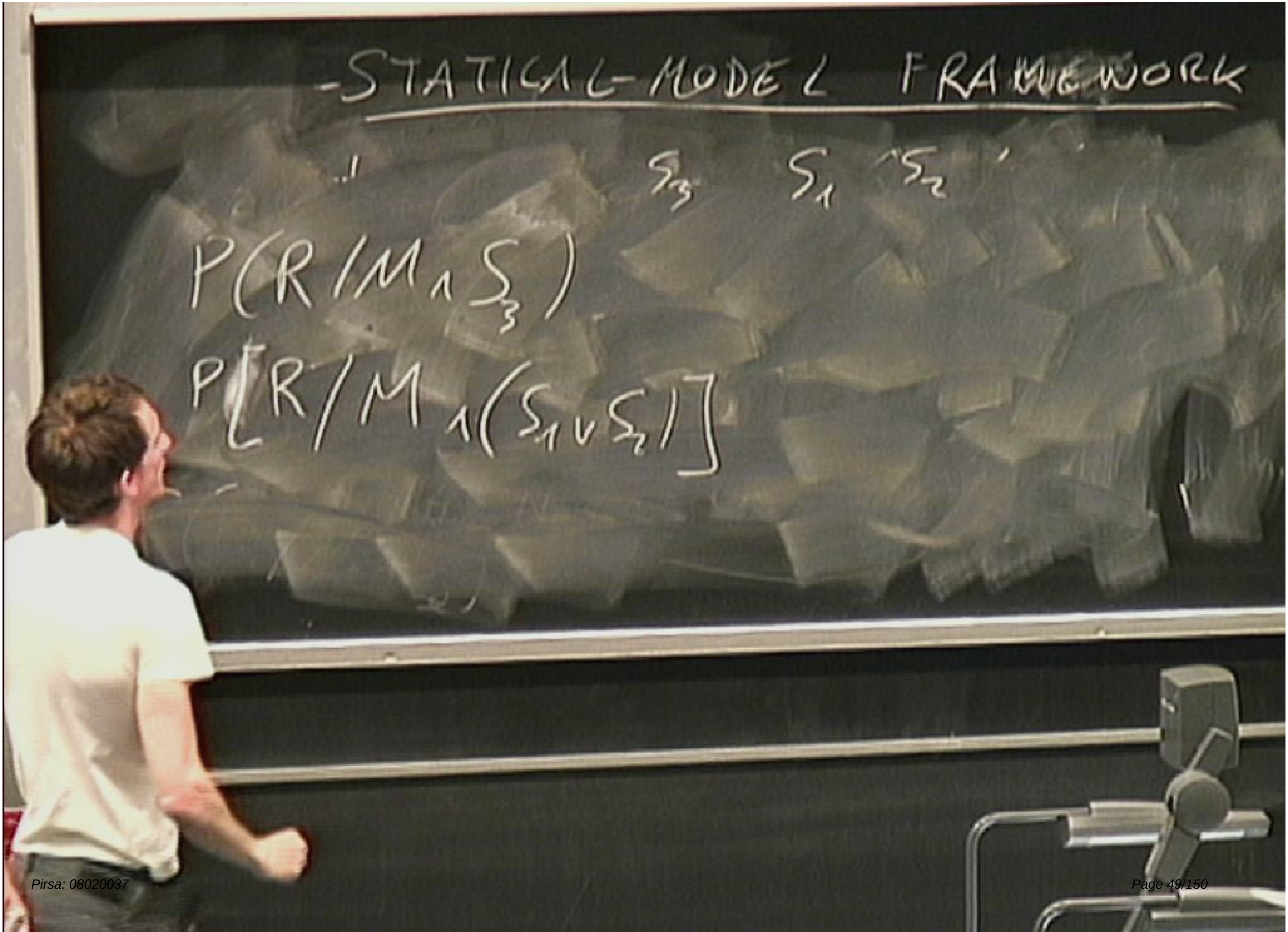

S → points of a convex set
R → [0,1]-v. affine forms on

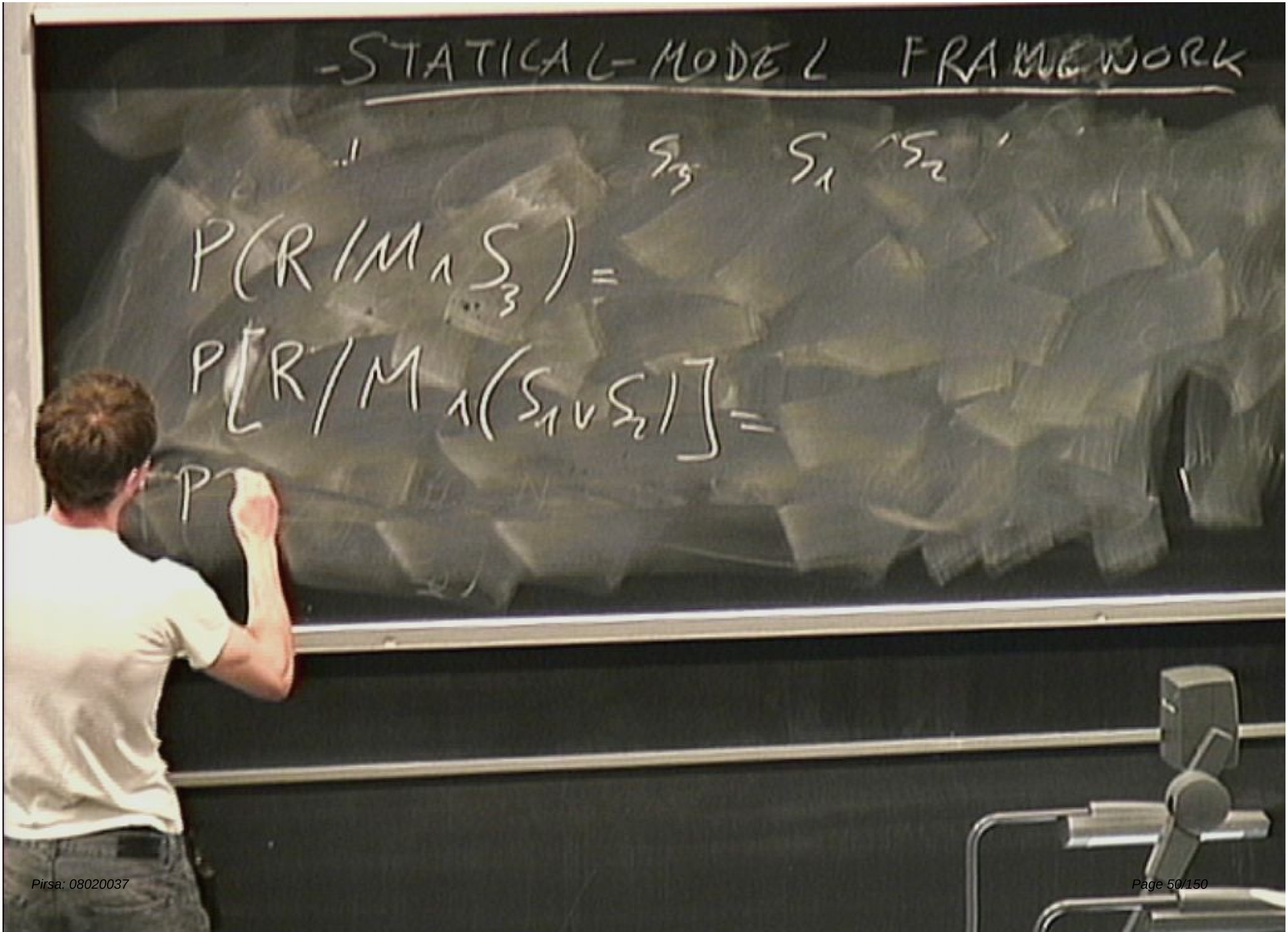
S $\longrightarrow$ points of a convex set

R $\longrightarrow$ [0,1]-v. affine forms on


-STATICAL-MODEL FRAMEWORK
$P(R|M \wedge S_3)$


STATICAL-MODEL FRAMEWORK
S3 S1 S2
P(R/M∧S3)
P(/M∧(S1∨S2)]


-STATICAL-MODEL FRAMEWORK
S_3 S_1 S_2
$P(R/M \wedge S_3)$
$P[R/M \wedge (S_1 \vee S_2)]$


-STATICAL-MODEL FRAMEWORK
S3 S1 S2
P(R/M ∧ S3) =
P[R/M ∧ (S1 ∨ S2)] =
P

-STATICAL-MODEL FRAMEWORK

$S_3 \quad S_1 \quad S_2$

$$P(R/M \wedge S_3) =$$

$$P[R/M \wedge (S_1 \vee S_2)] =$$

$$P(R/M \wedge S_1) \times P(S_1) + P(R/M \wedge S_2) \times P(S_2)$$

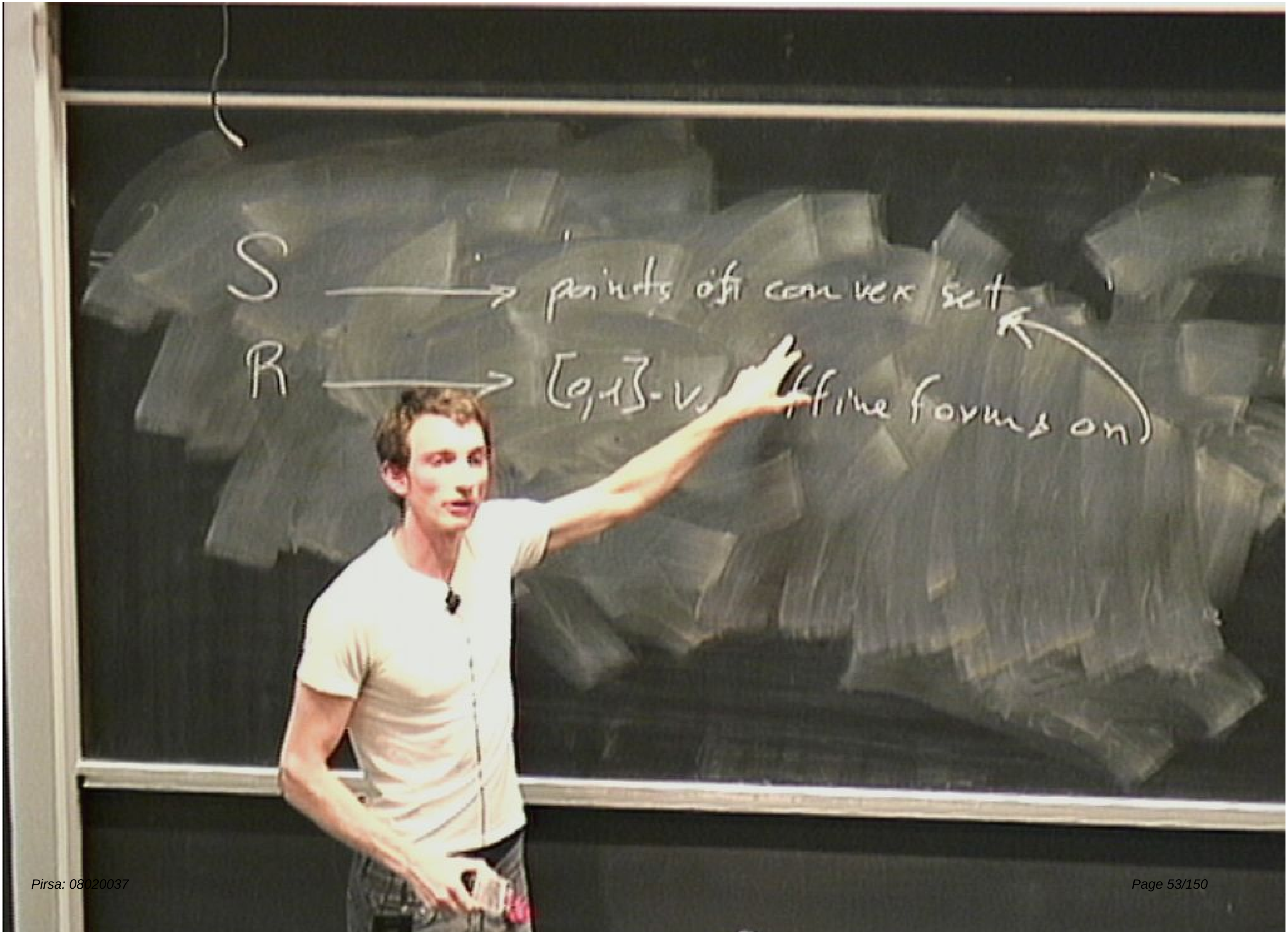
-STATICAL-MODEL FRAMEWORK

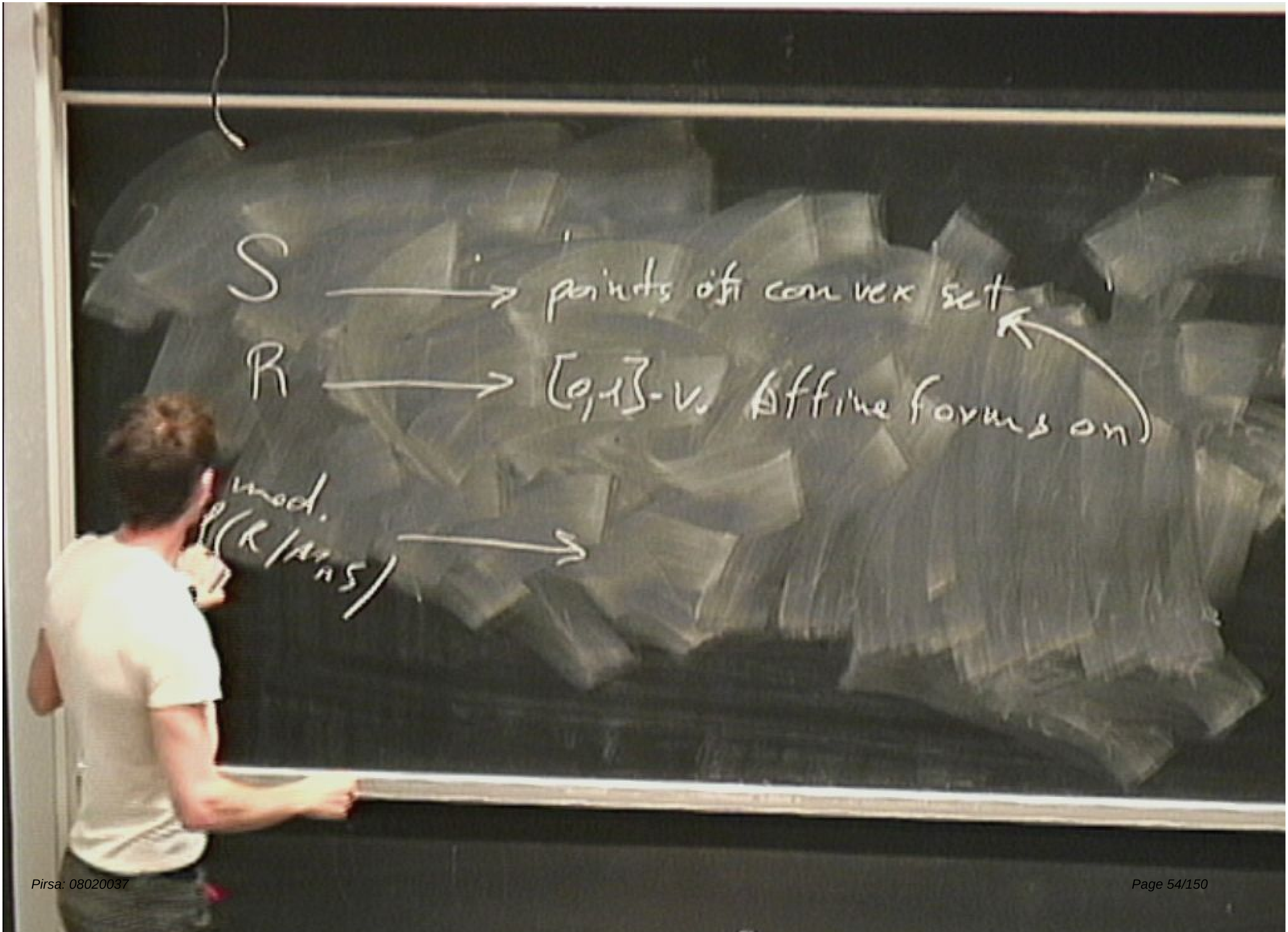
$S_3 \quad S_1 \quad S_2$

$$P(R / M \wedge S_3) =$$

$$P[R / M \wedge (S_1 \vee S_2)] =$$

$$P(R / M \wedge S_1) \times P(S_1) + P(R / M \wedge S_2) \times P(S_2)$$


S → points of convex set
R → [0,1]-v
ffine forms on


S → points of convex set
R → [0,1]-v. affine forms on
mod.

$S \longrightarrow$ points of a convex set

$R \longrightarrow$ $[0,1]$-v. affine forms on

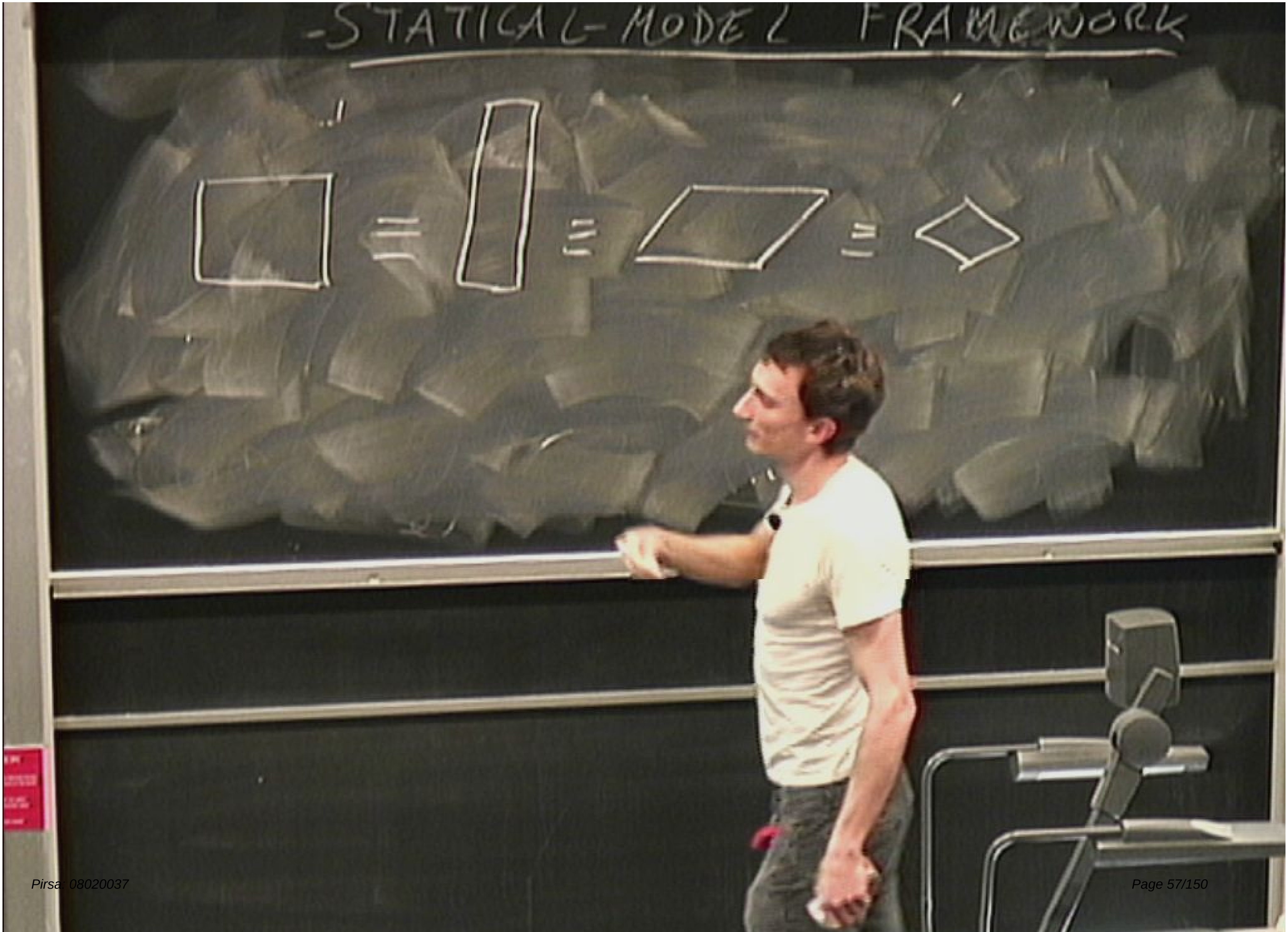
ph. mod.

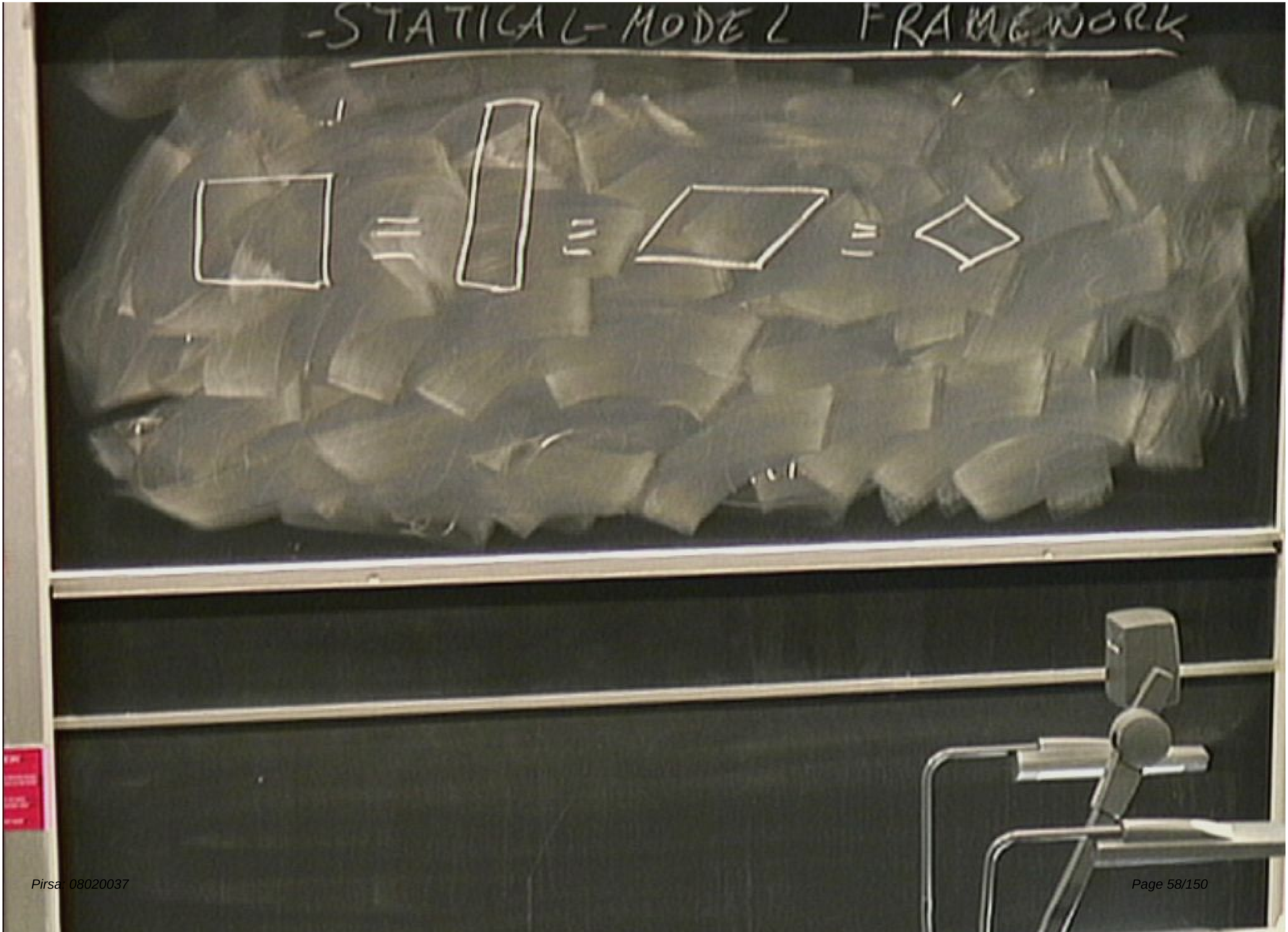
$P(R \mid A \wedge S) \longrightarrow$

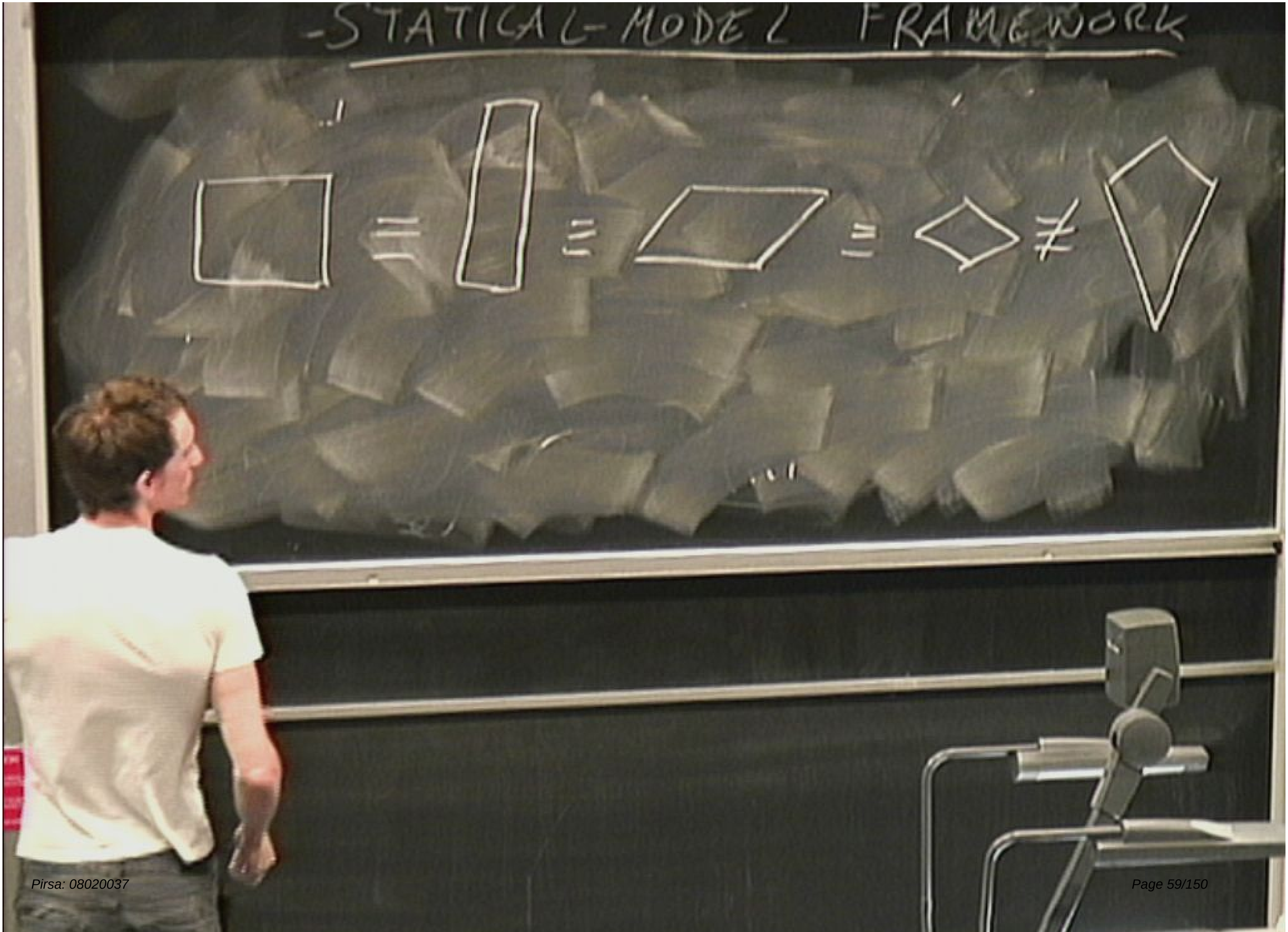
$S \longrightarrow$ points of convex set

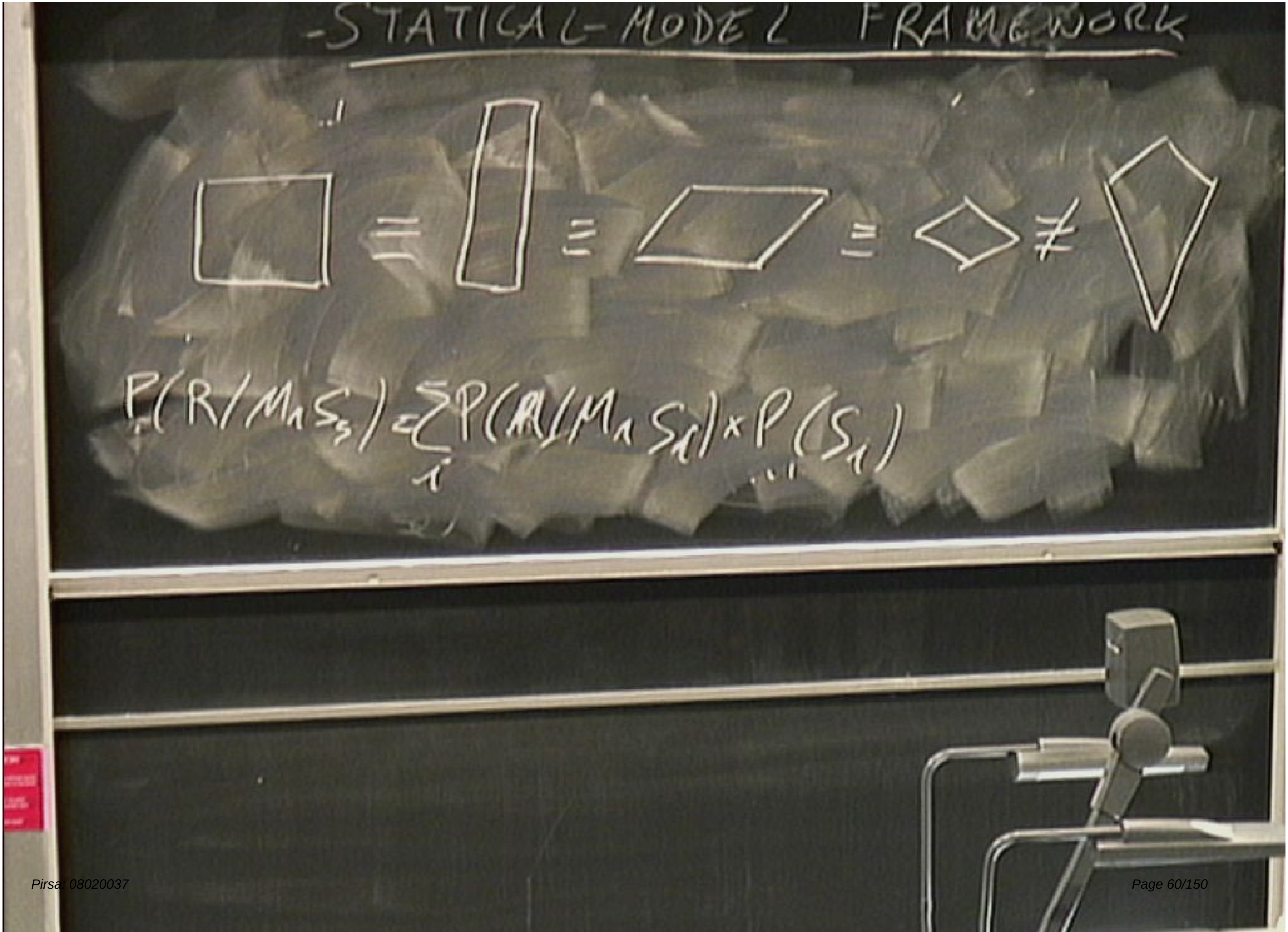
$R \longrightarrow$ $[0,1]$-v. affine forms on

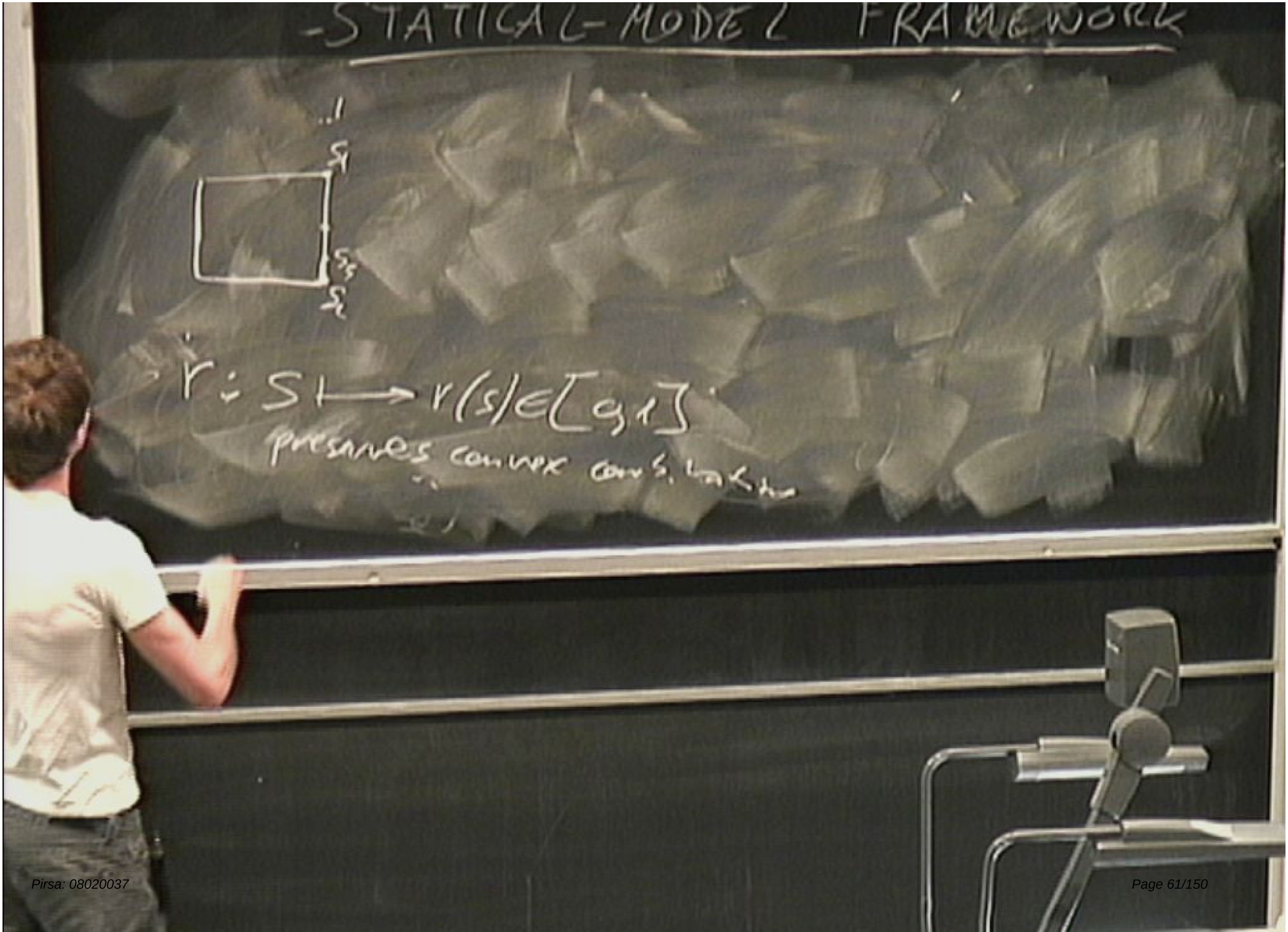
ph. mod.
$P(R/A \cap S) \longrightarrow \square$

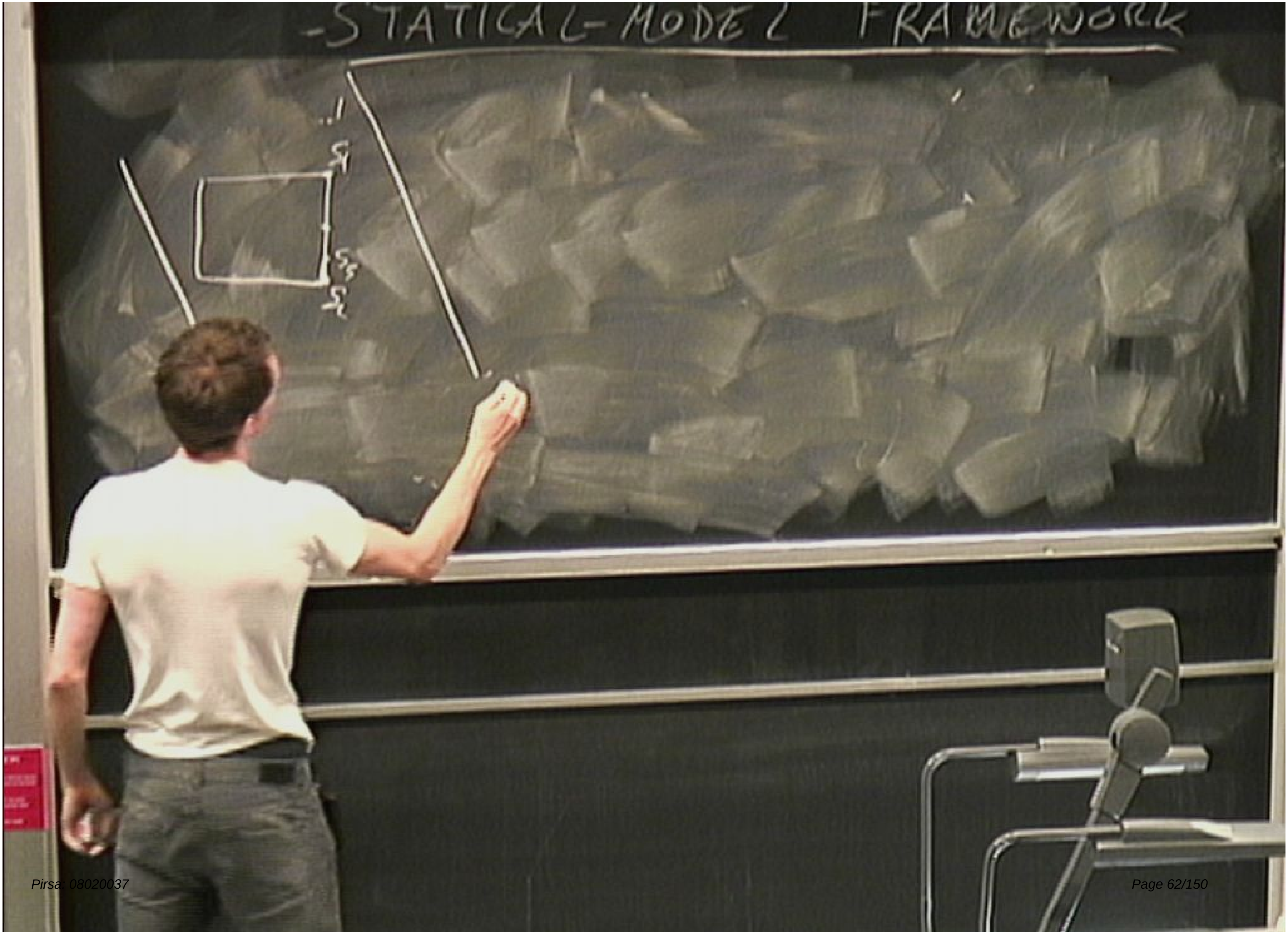

-STATICAL-MODEL FRAMEWORK

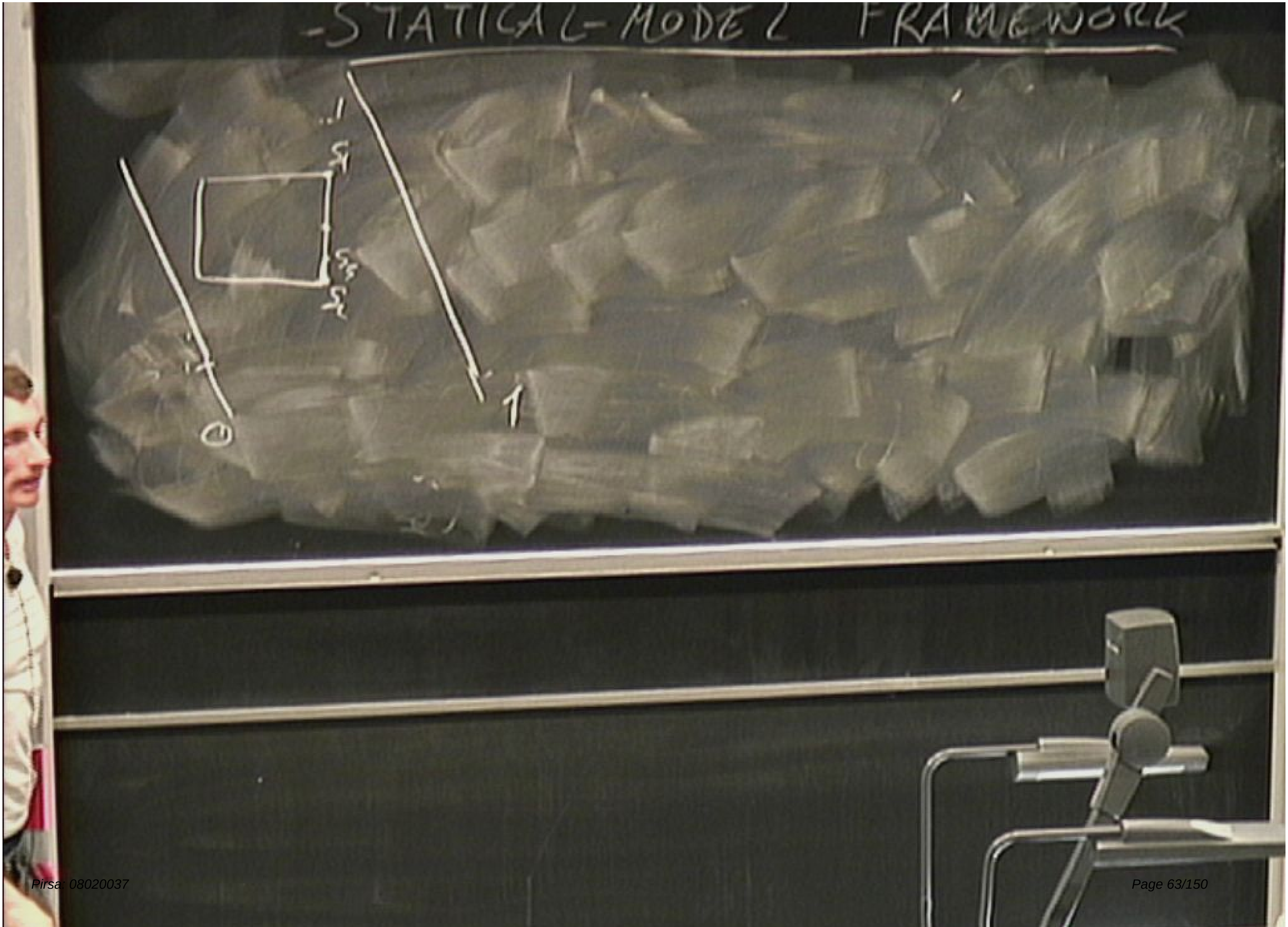

-STATICAL-MODEL FRAMEWORK

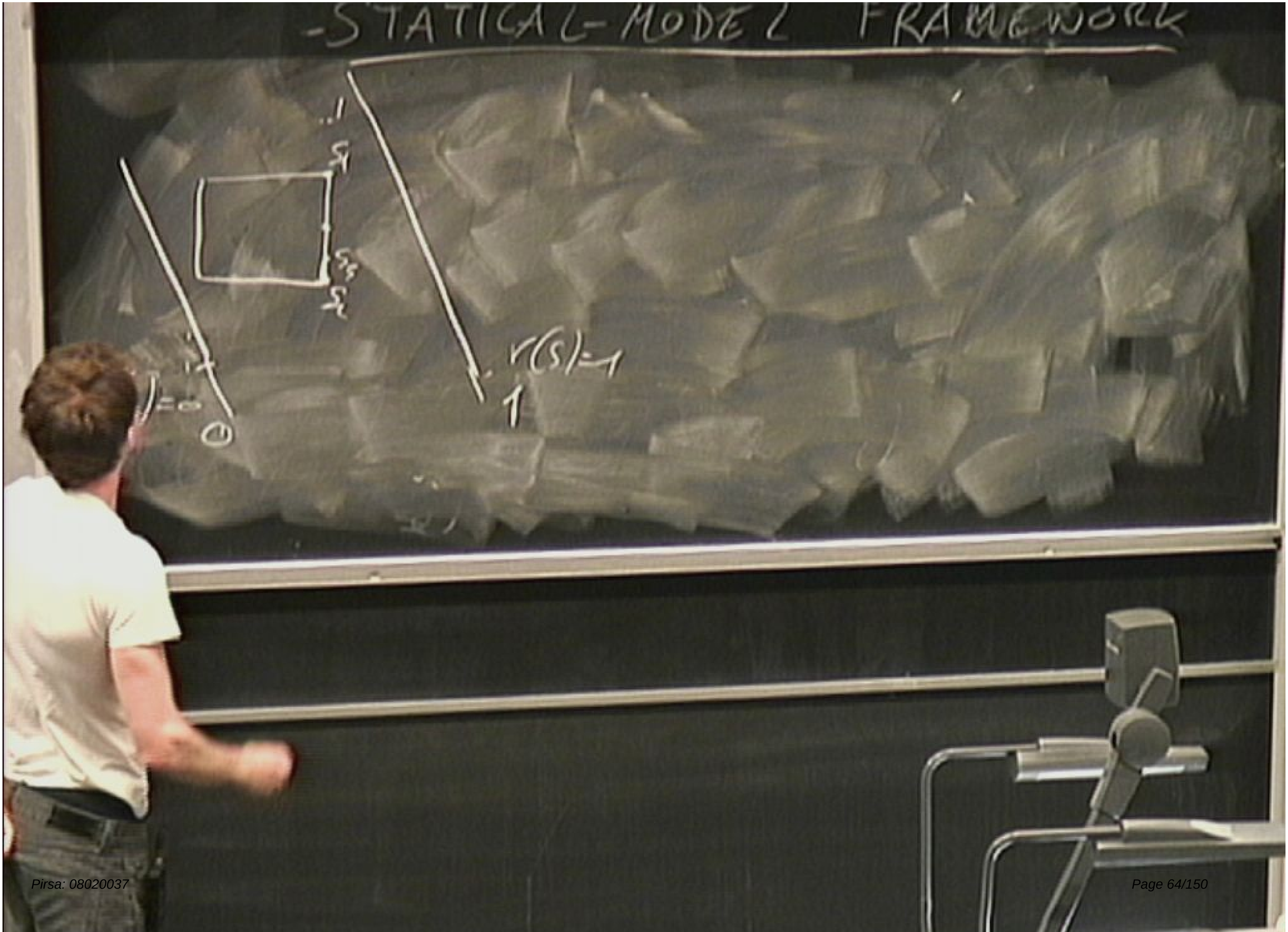

-STATICAL-MODEL FRAMEWORK

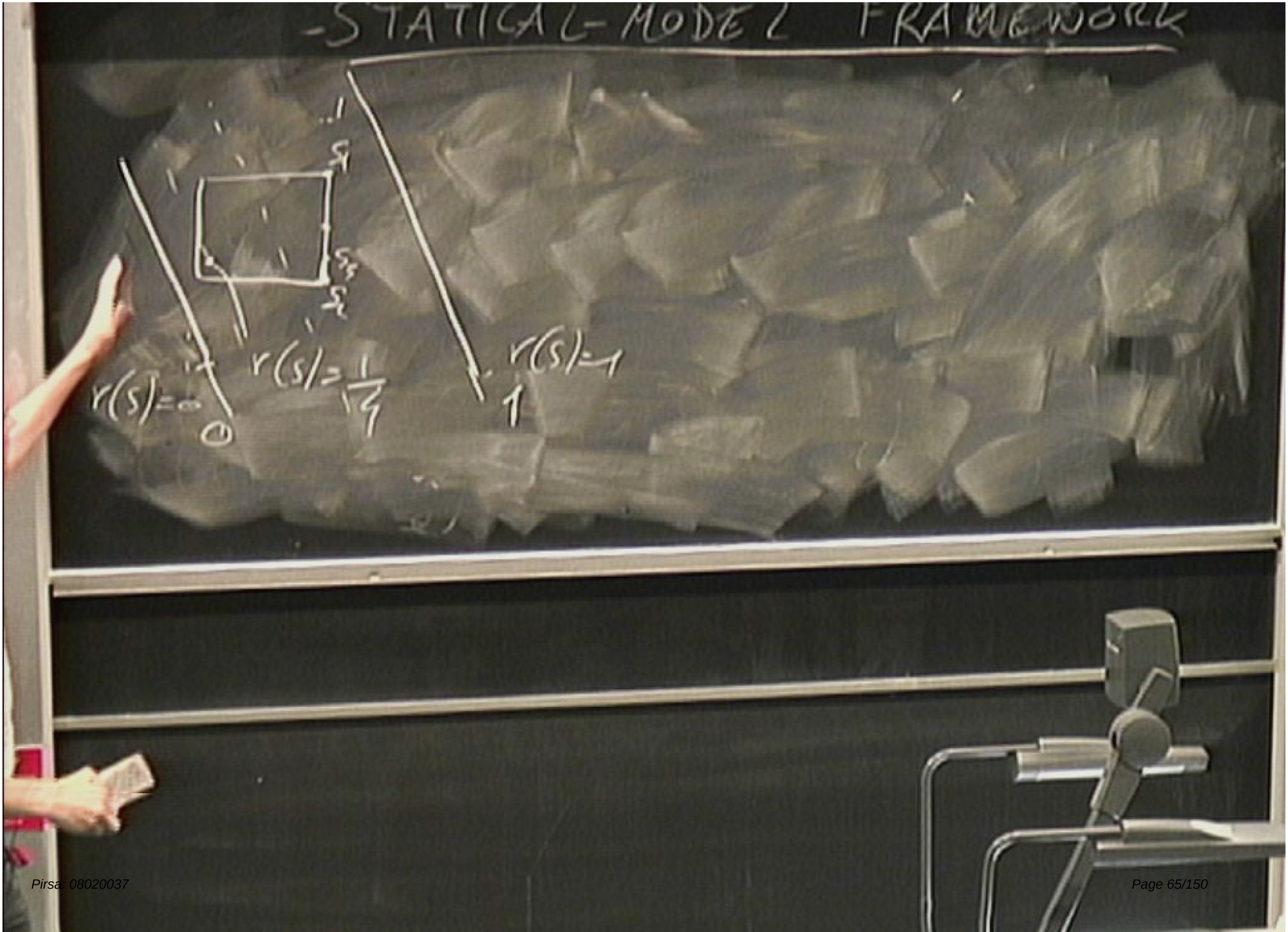

-STATICAL-MODEL FRAMEWORK
$P(R/M_n S_j) = \sum_i P(R/M_n S_i) \times P(S_i)$

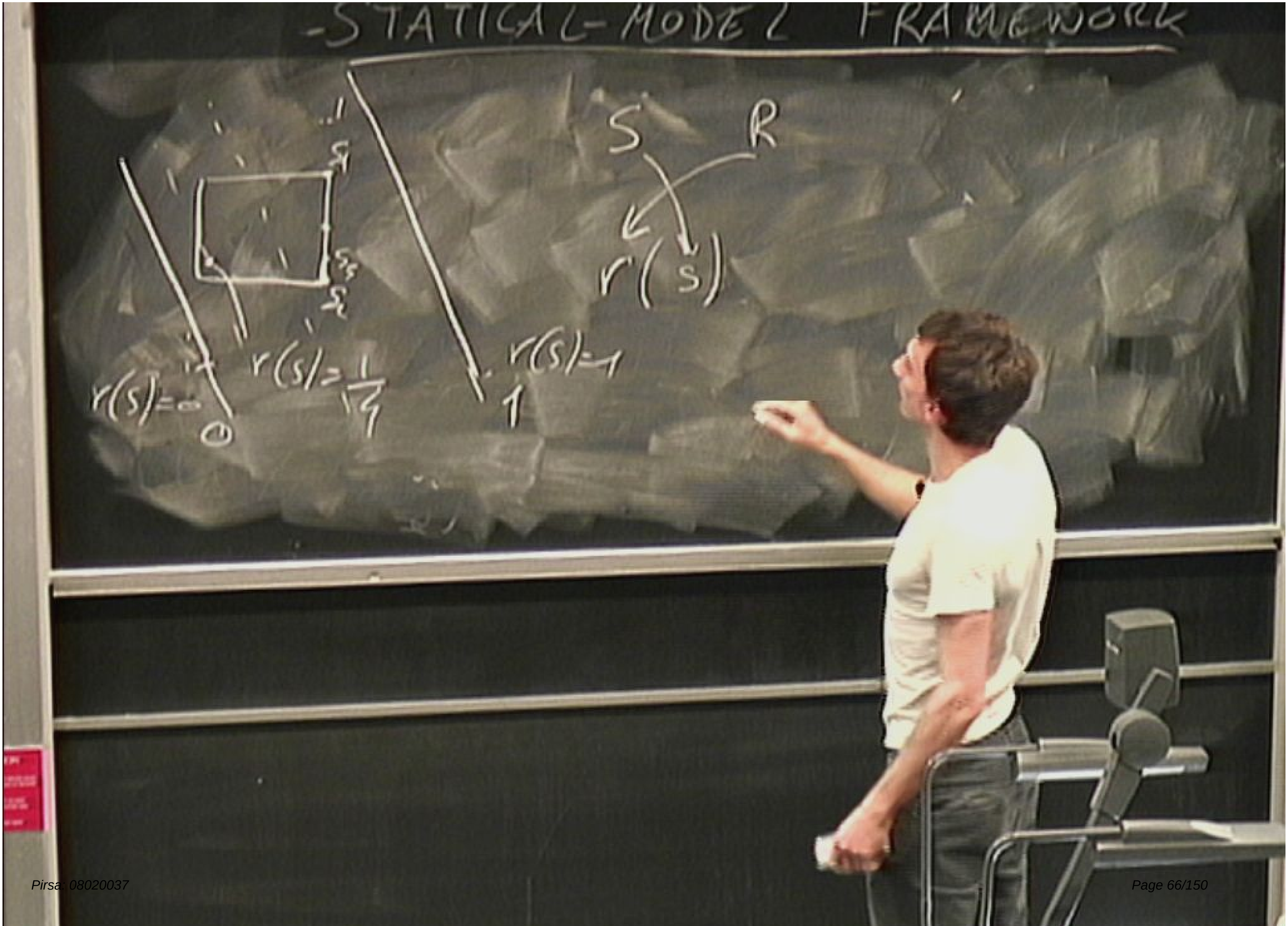

-STATICAL-MODEL FRAMEWORK
s_1
s_3
s_2
r : S ⟼ r(s) ∈ [0,1]
preserves convex combinations

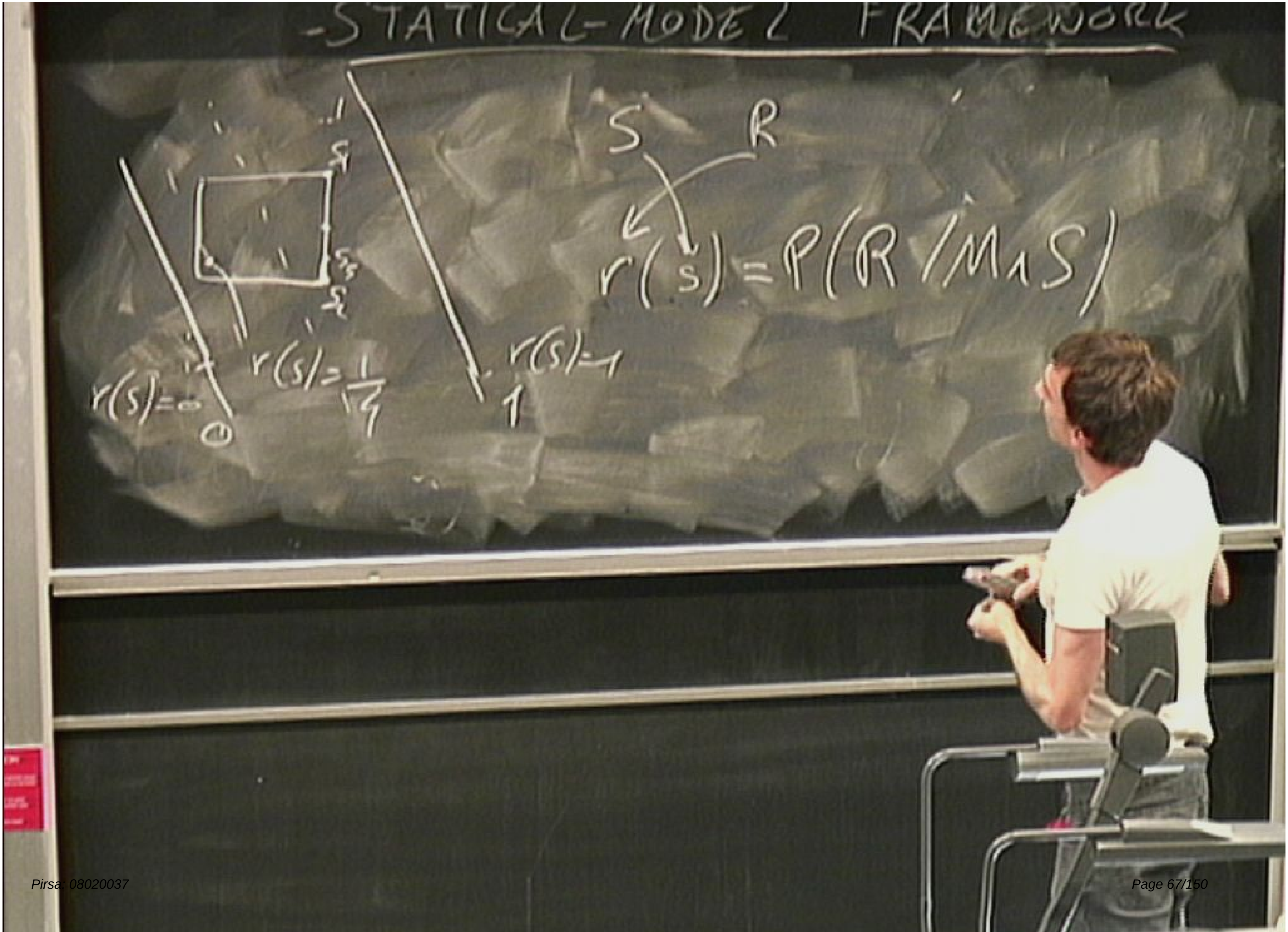

-STATICAL-MODEL FRAMEWORK


-STATICAL-MODEL FRAMEWORK


-STATICAL-MODEL FRAMEWORK
r(s)-1


-STATICAL-MODEL FRAMEWORK
r(s)=∞
0
r(s)=1/√q
r(s)=1
1

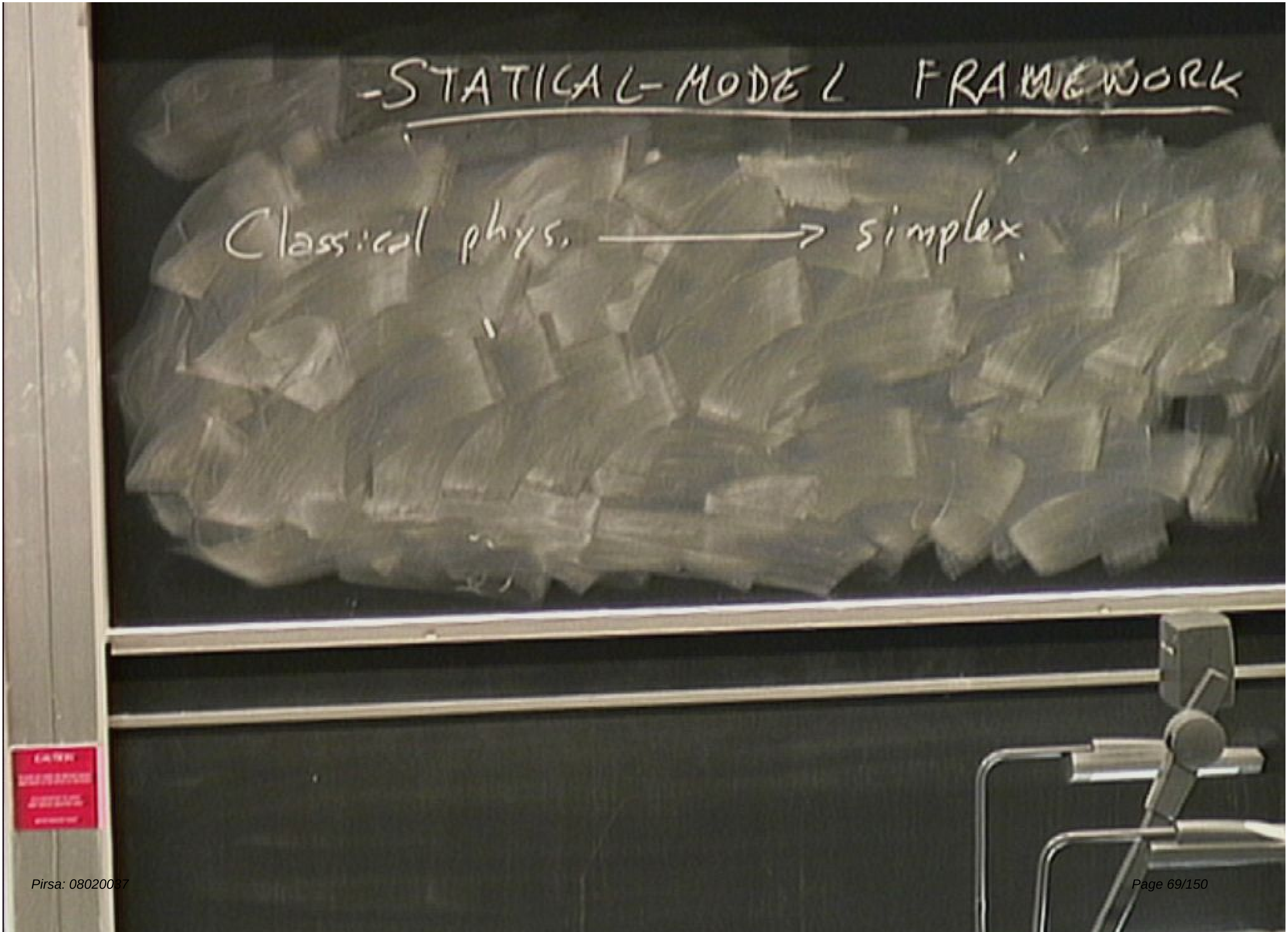

-STATICAL-MODEL FRAMEWORK
S
R
r(s)
r(s)=∞
r(s)=1/√2
r(s)=1
1
0

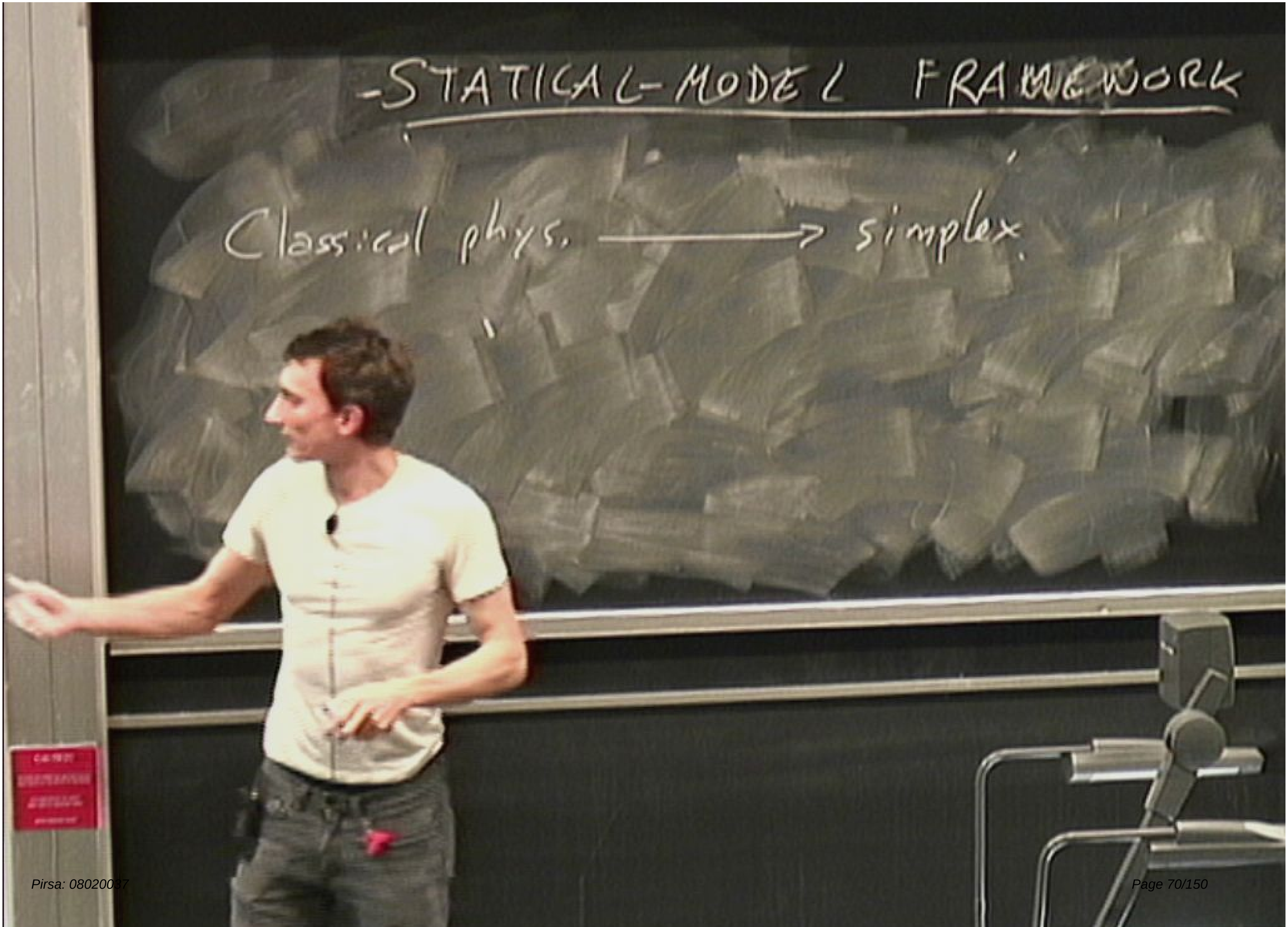

-STATICAL-MODEL FRAMEWORK
S
R
r(s) = P(R/M,S)
r(s)=∞
r(s)→1

$S \longrightarrow$ points of convex set

$R \longrightarrow$ $[0,1]$-v. affine forms on

ph. mod.
$P(R|A \cap S) \longrightarrow$ + forms


STATICAL-MODEL FRAMEWORK
Classical phys. → simplex.

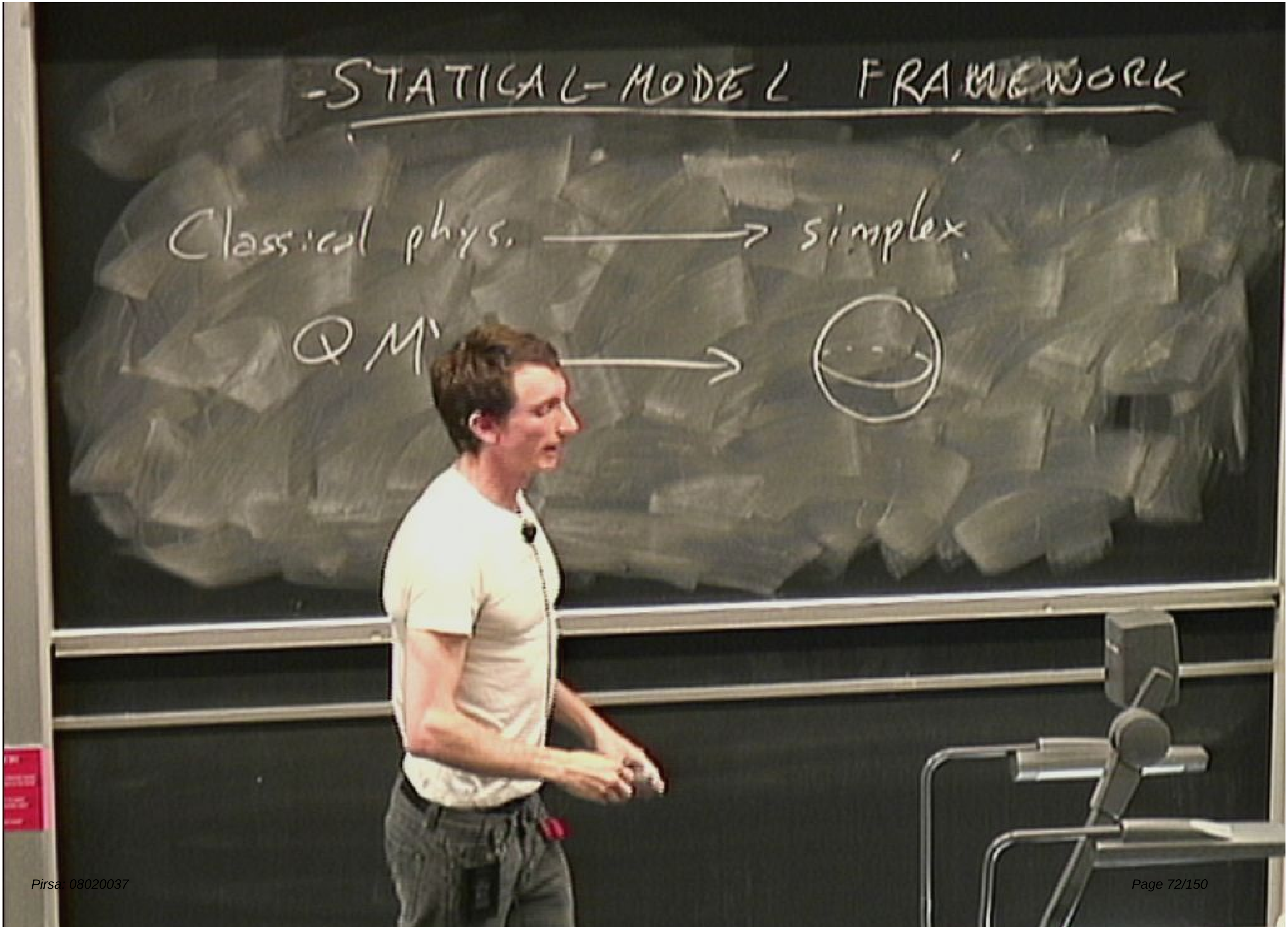

-STATICAL-MODEL FRAMEWORK
Classical phys. → simplex

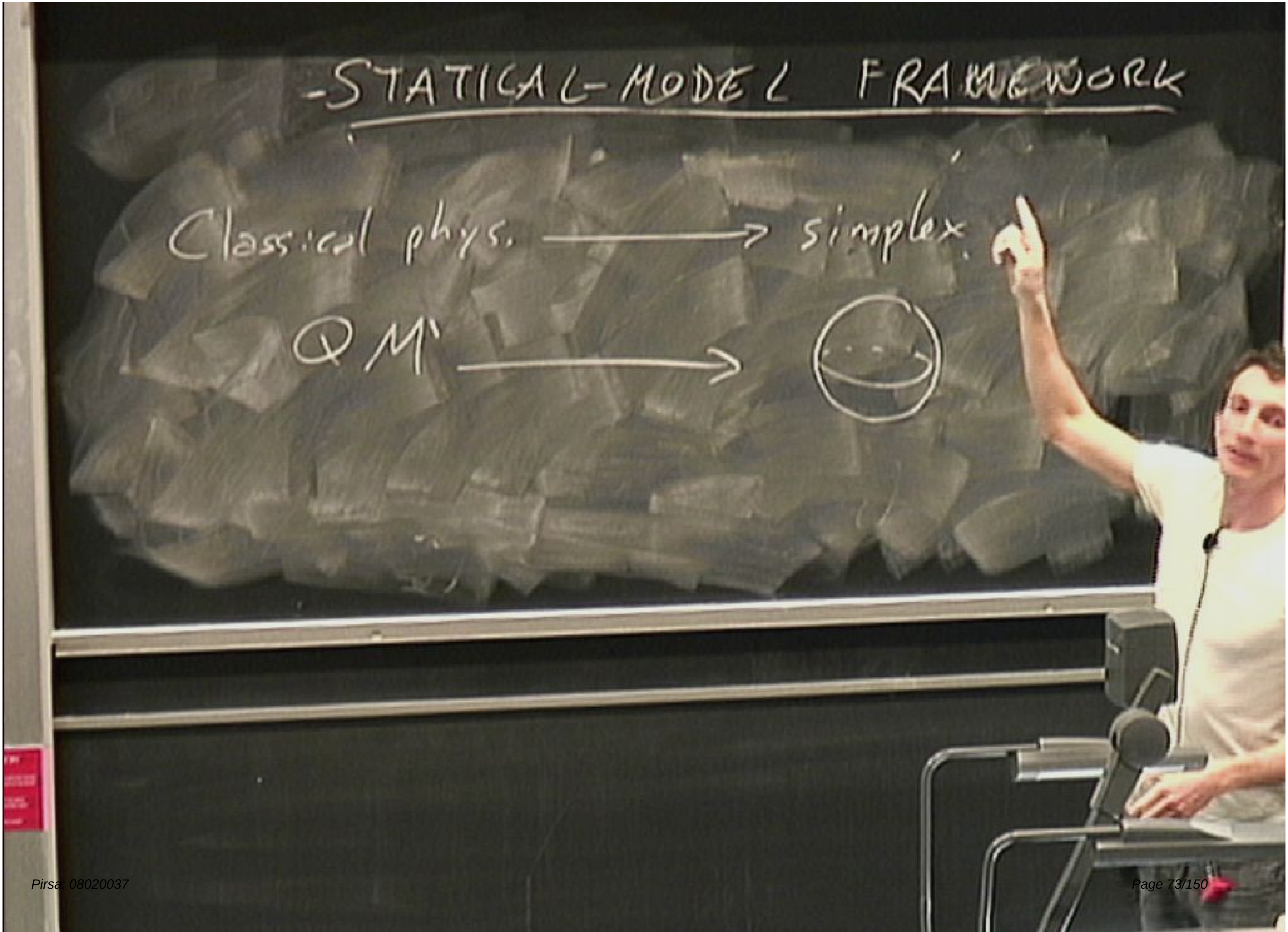
$S \longrightarrow$ points of convex set

$R \longrightarrow$ $[0,1]$-v. affine forms on

ph. mod.
$P(R/\sim \cap S)$ $\longrightarrow$

'pure' preparations
+ forms


-STATICAL-MODEL FRAMEWORK
Classical phys. → simplex.
QM →


-STATICAL-MODEL FRAMEWORK
Classical phys. → simplex
QM →

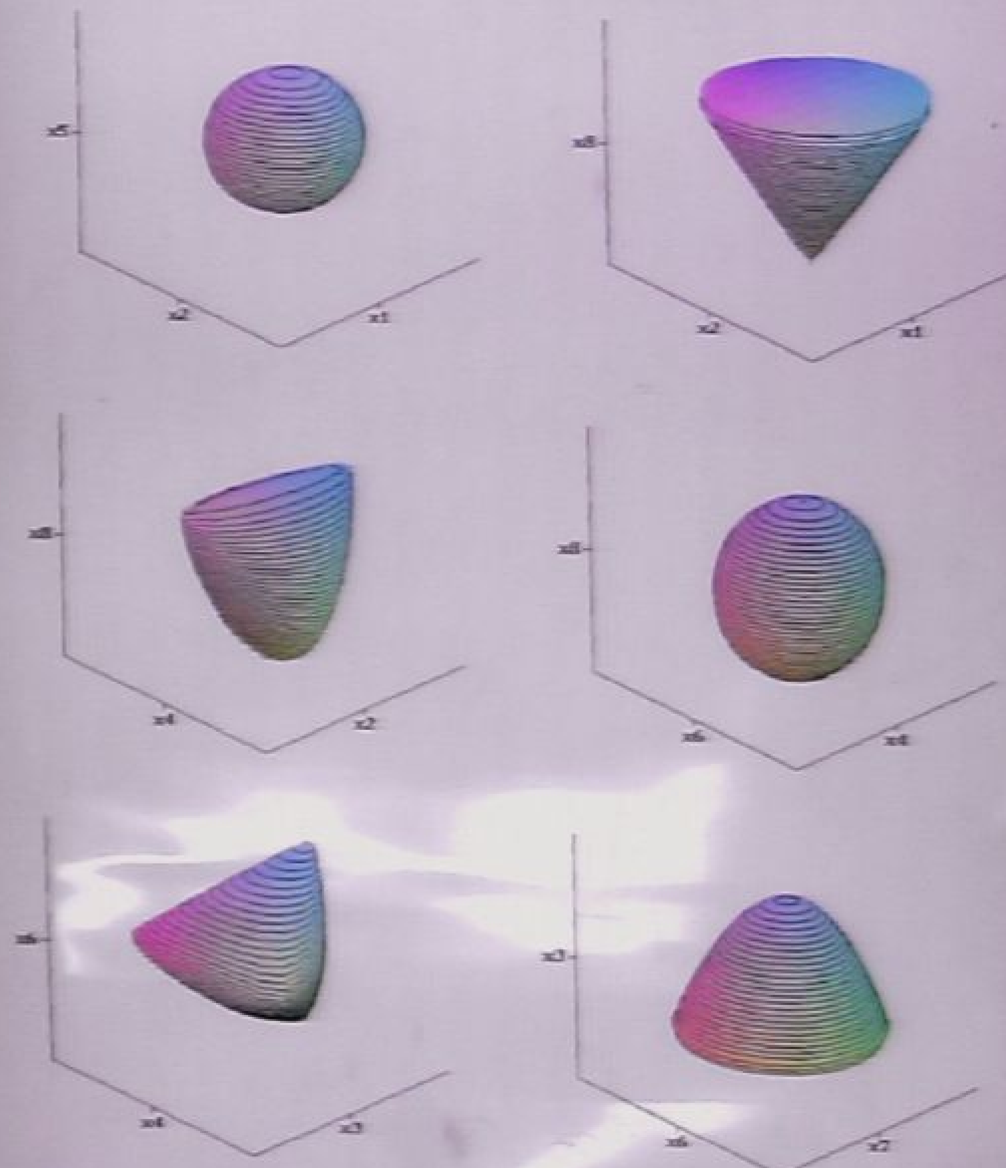


Figure 1: Some three-dimensional sections of the eight-dimensional set $\mathcal{D}_3$ of the statistical operators for a three-level quantum system.

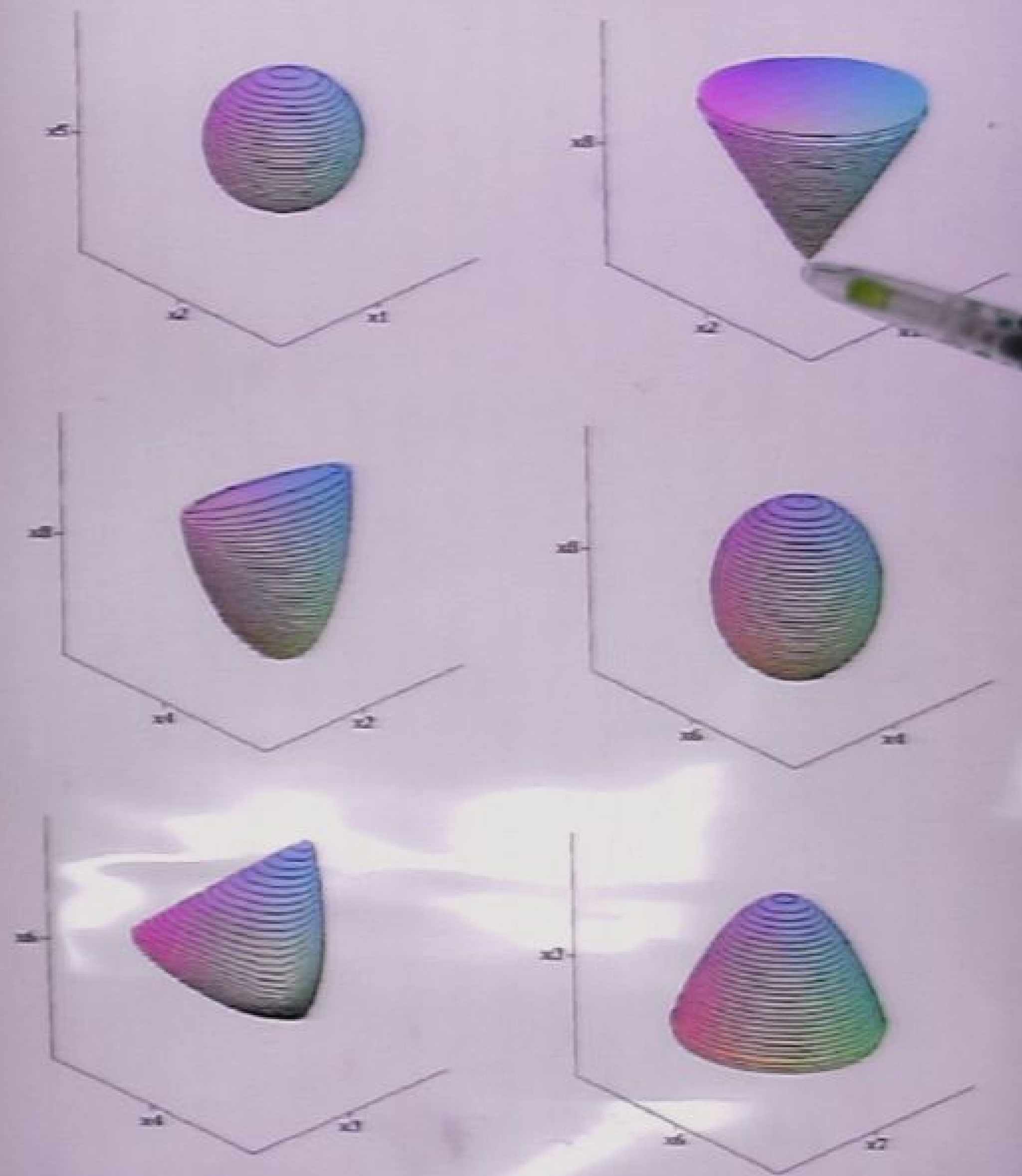
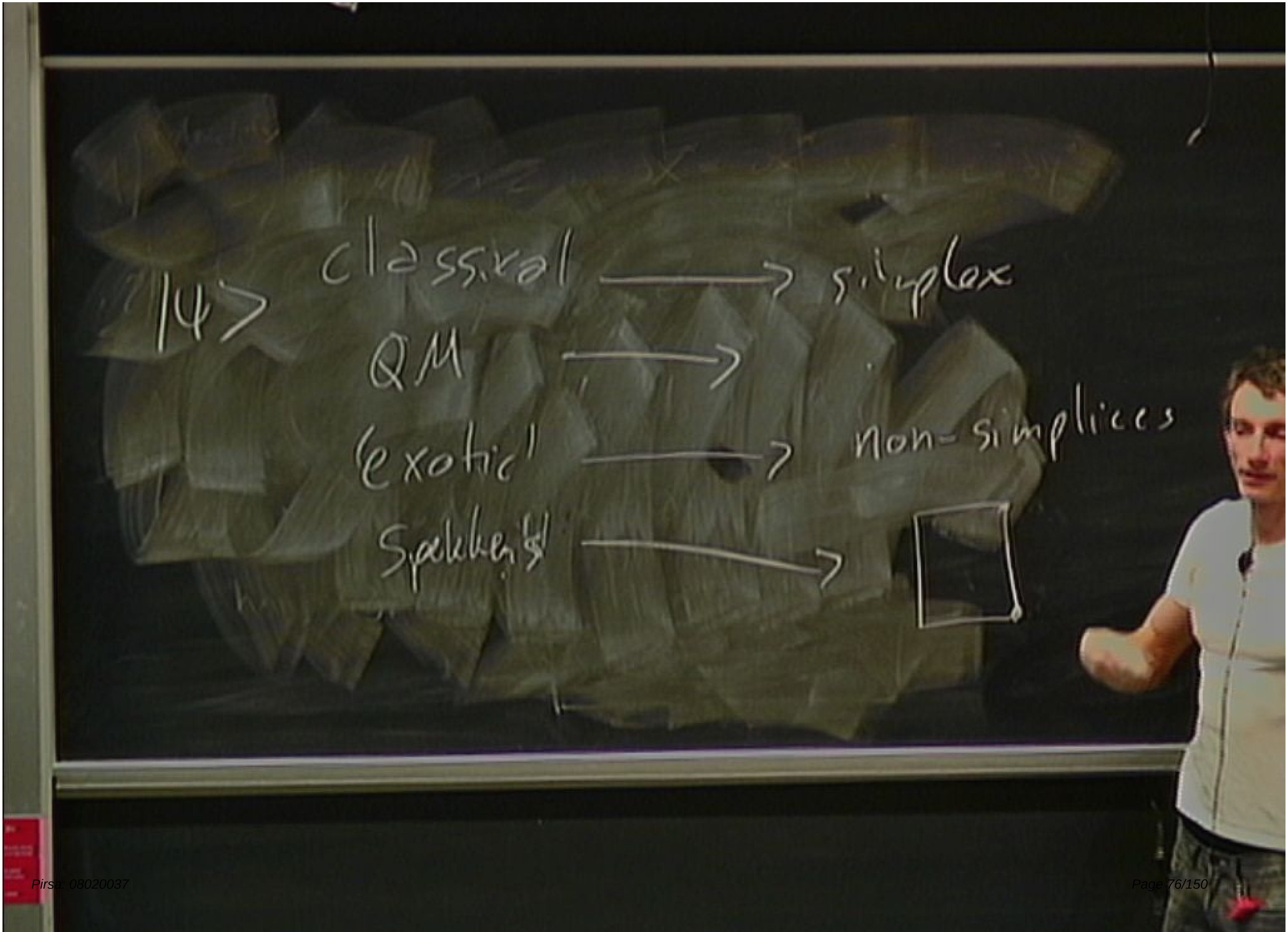
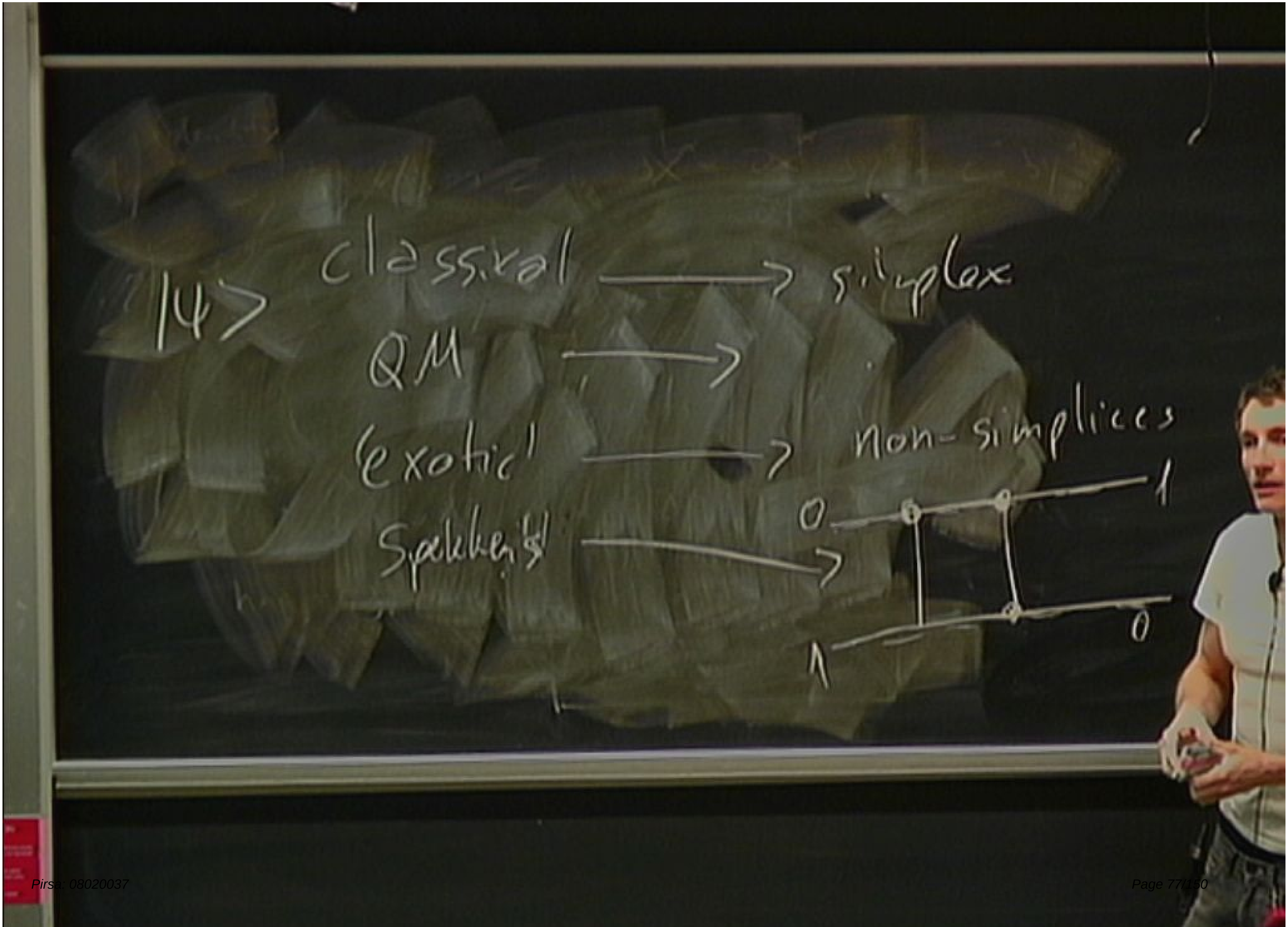
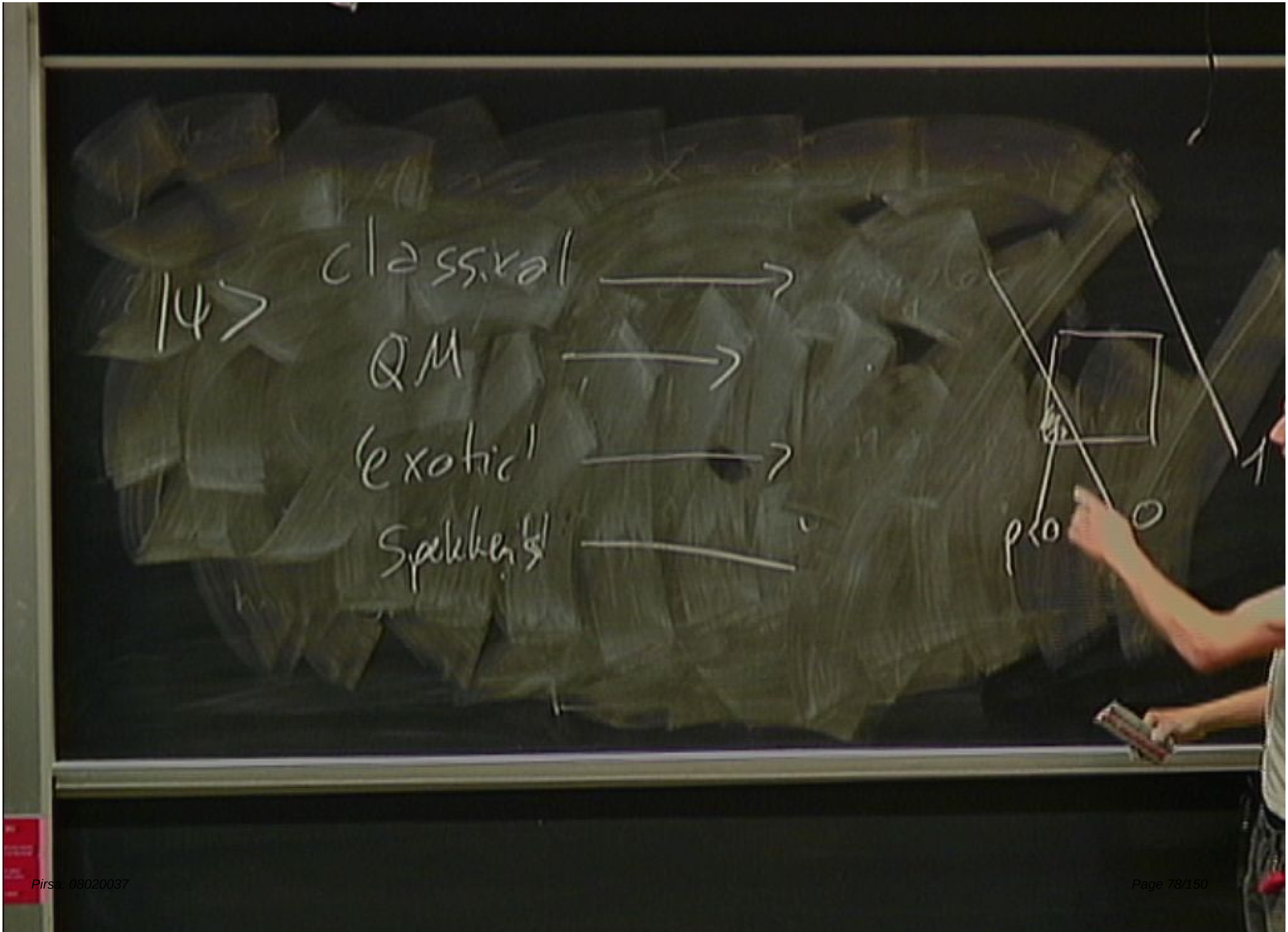
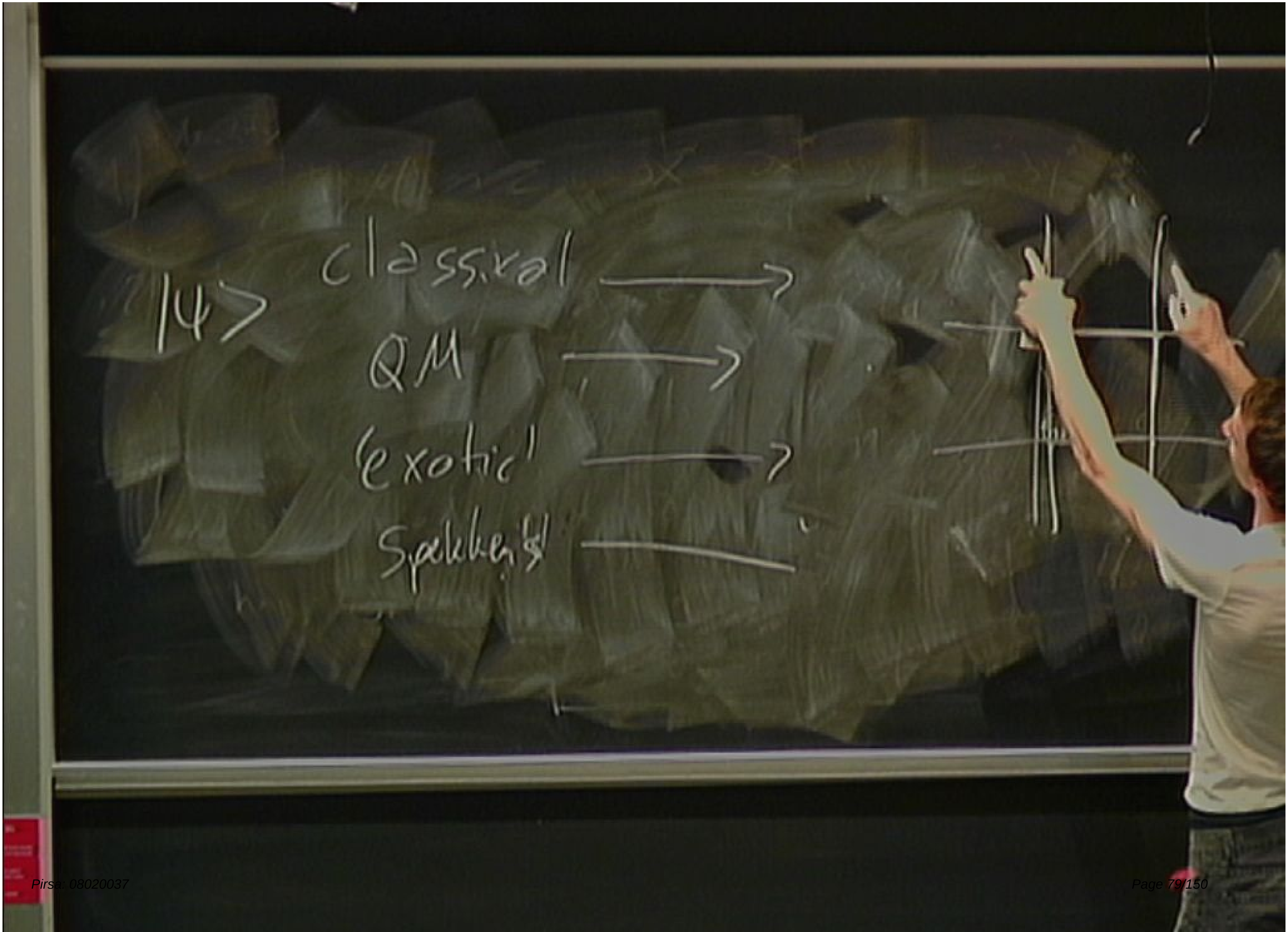


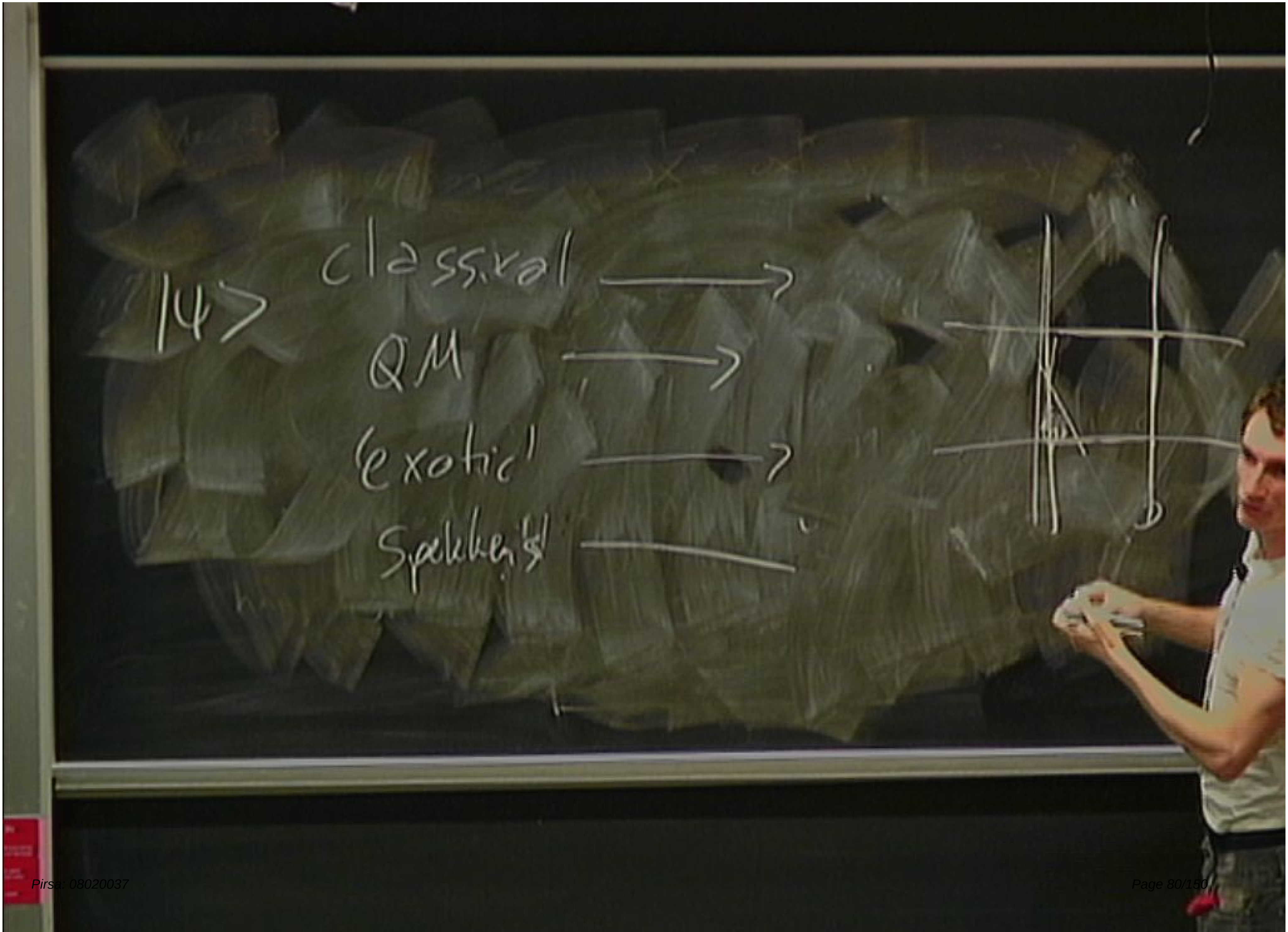
Figure 1: Some three-dimensional sections of the eight-dimensional set $\mathcal{D}_3$ of the statistical operators for a three-level quantum system.

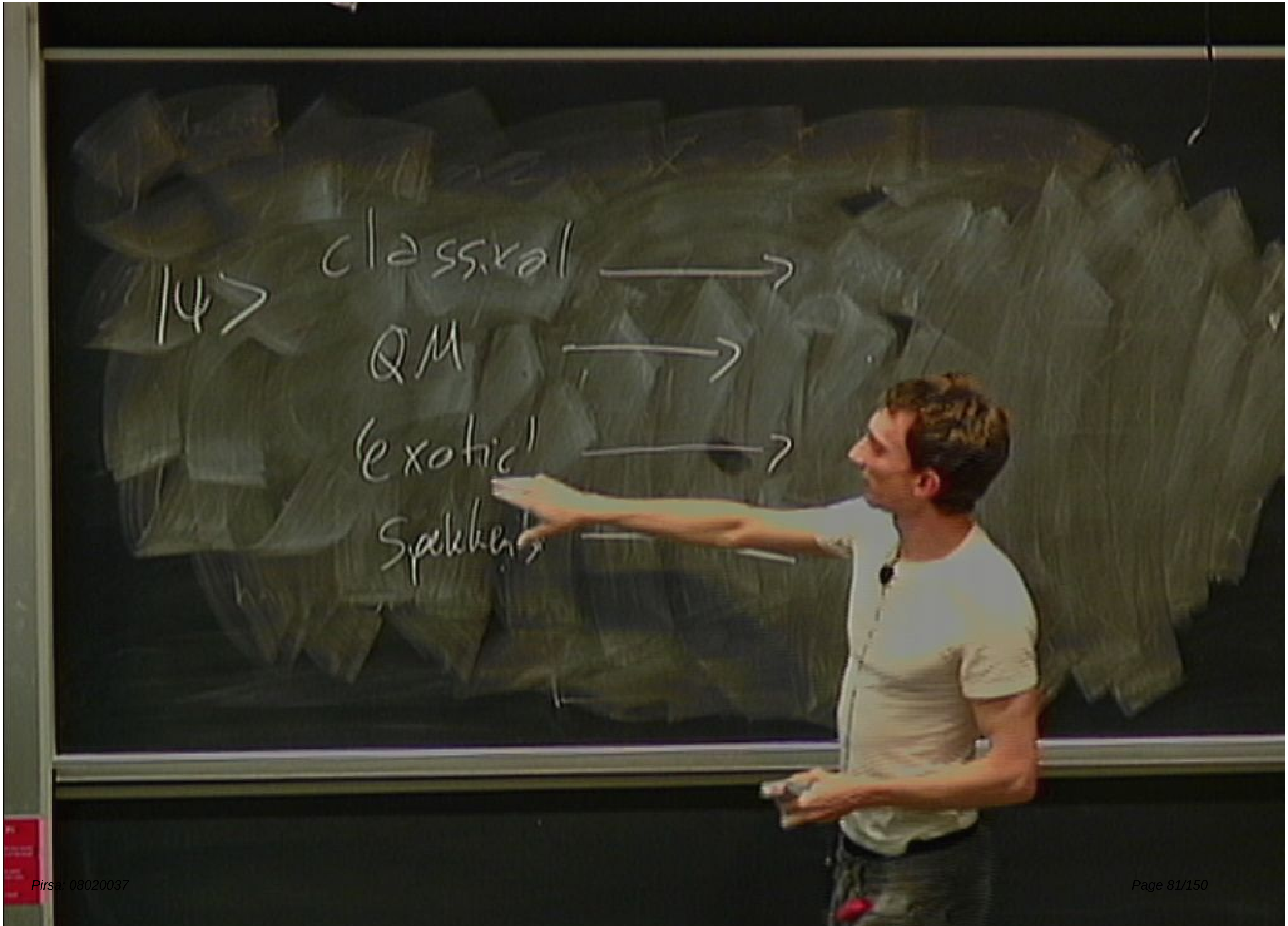

|ψ>
classical
simplex
QM
'exotic'
non-simplices
Spekkens'


|ψ>
classical
simplex
QM
exotic
non-simplices
Spekkens'
0
1
1
0


|ψ>
classical
QM
'exotic'
Spekkens'
prob
0
1


|ψ>
classical
QM
'exotic'
Spekkens'


|ψ>
classical
QM
'exotic'
Spekkens'


|ψ>
classical
QM
'exotic'
Spekkens

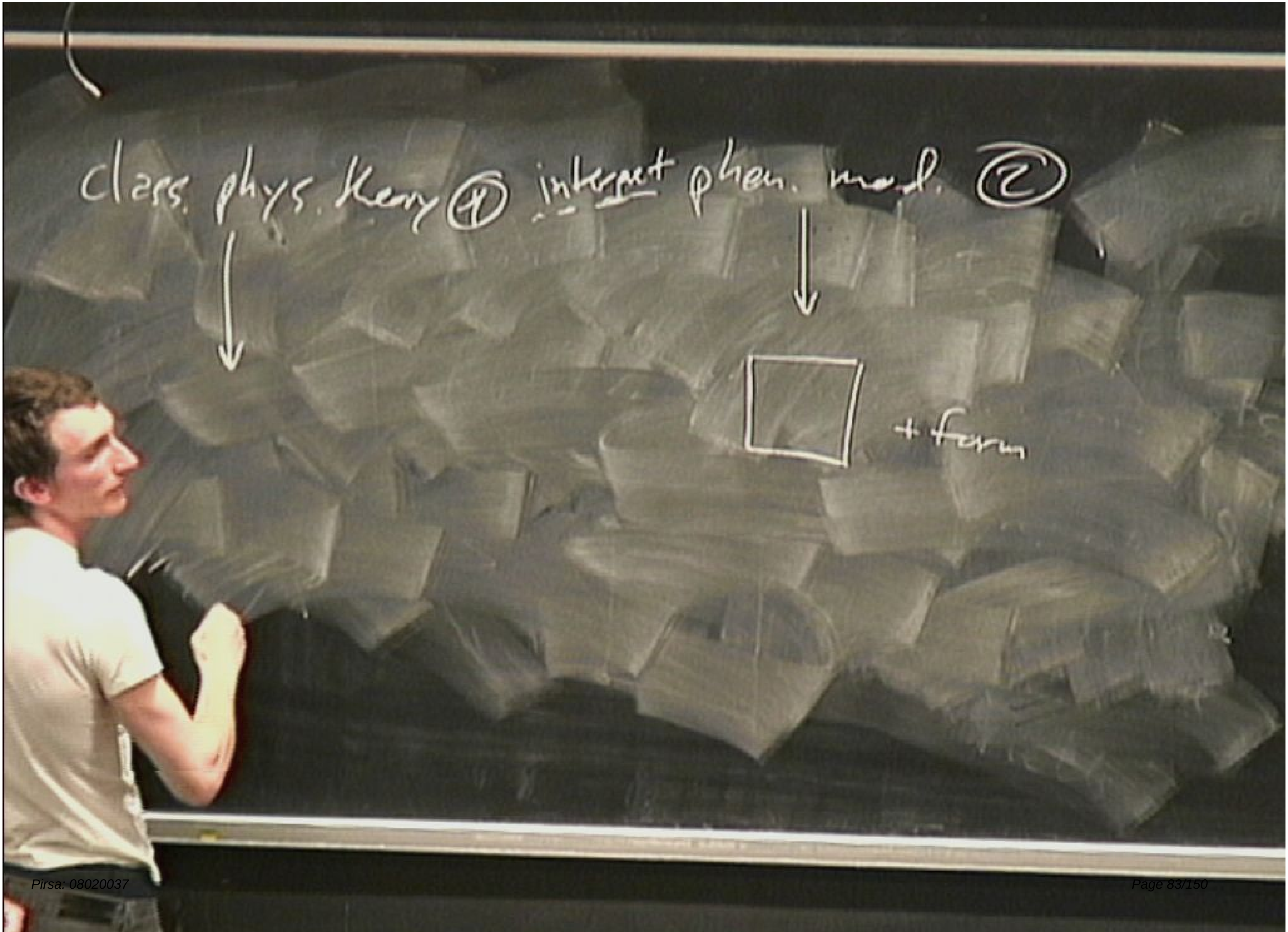
$|\psi\rangle$

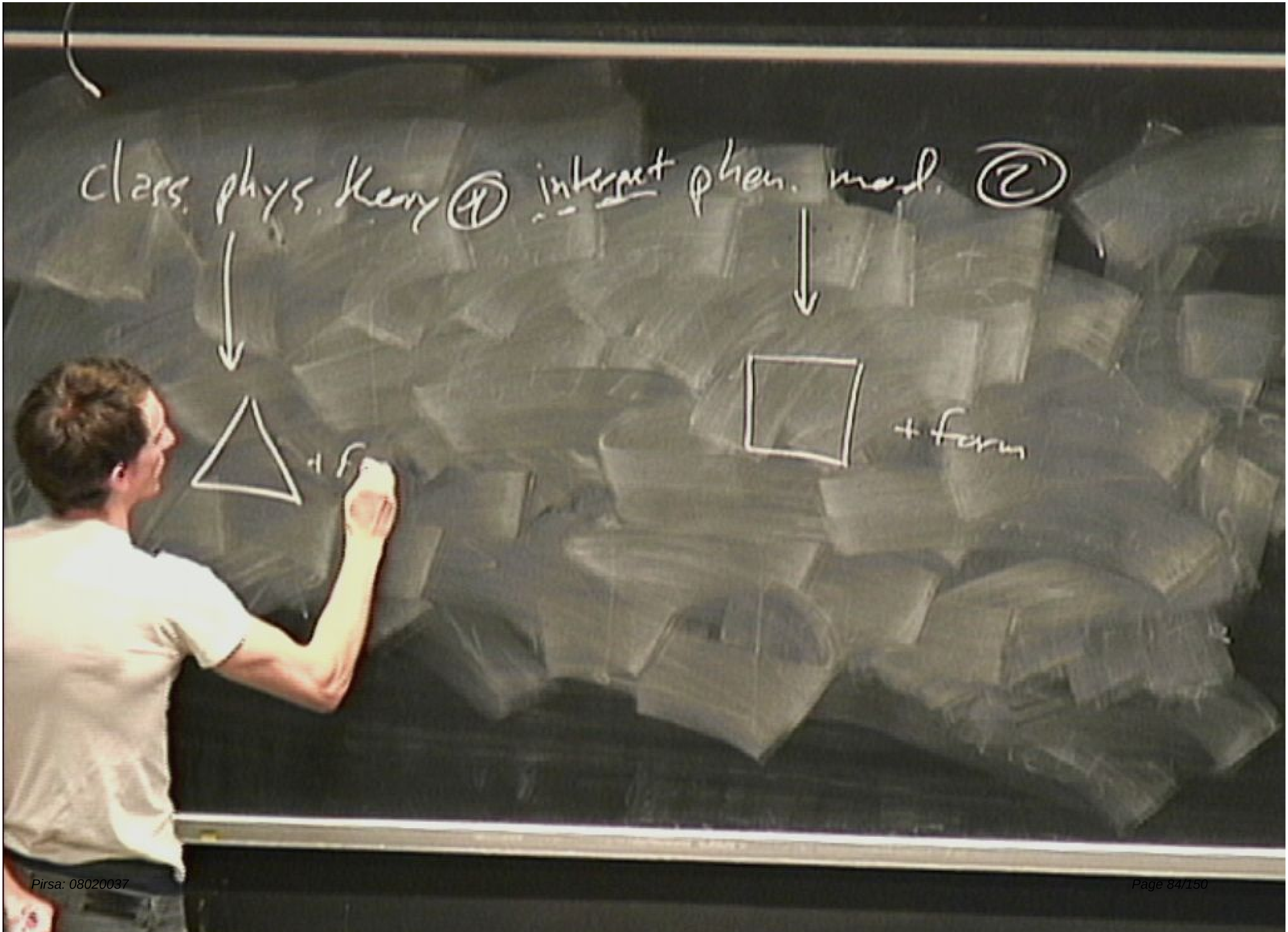
classical $\longrightarrow$

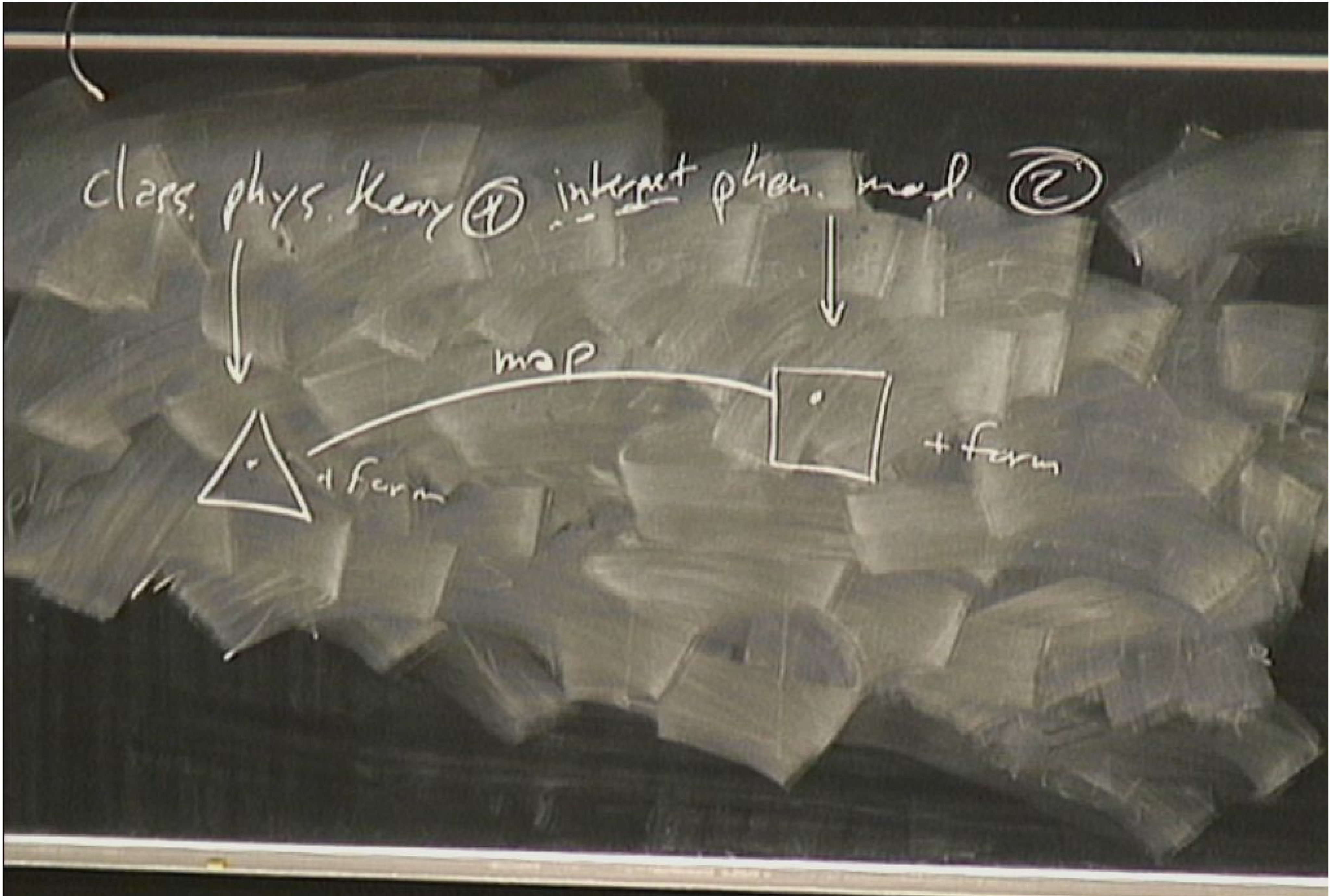
QM $\longrightarrow$

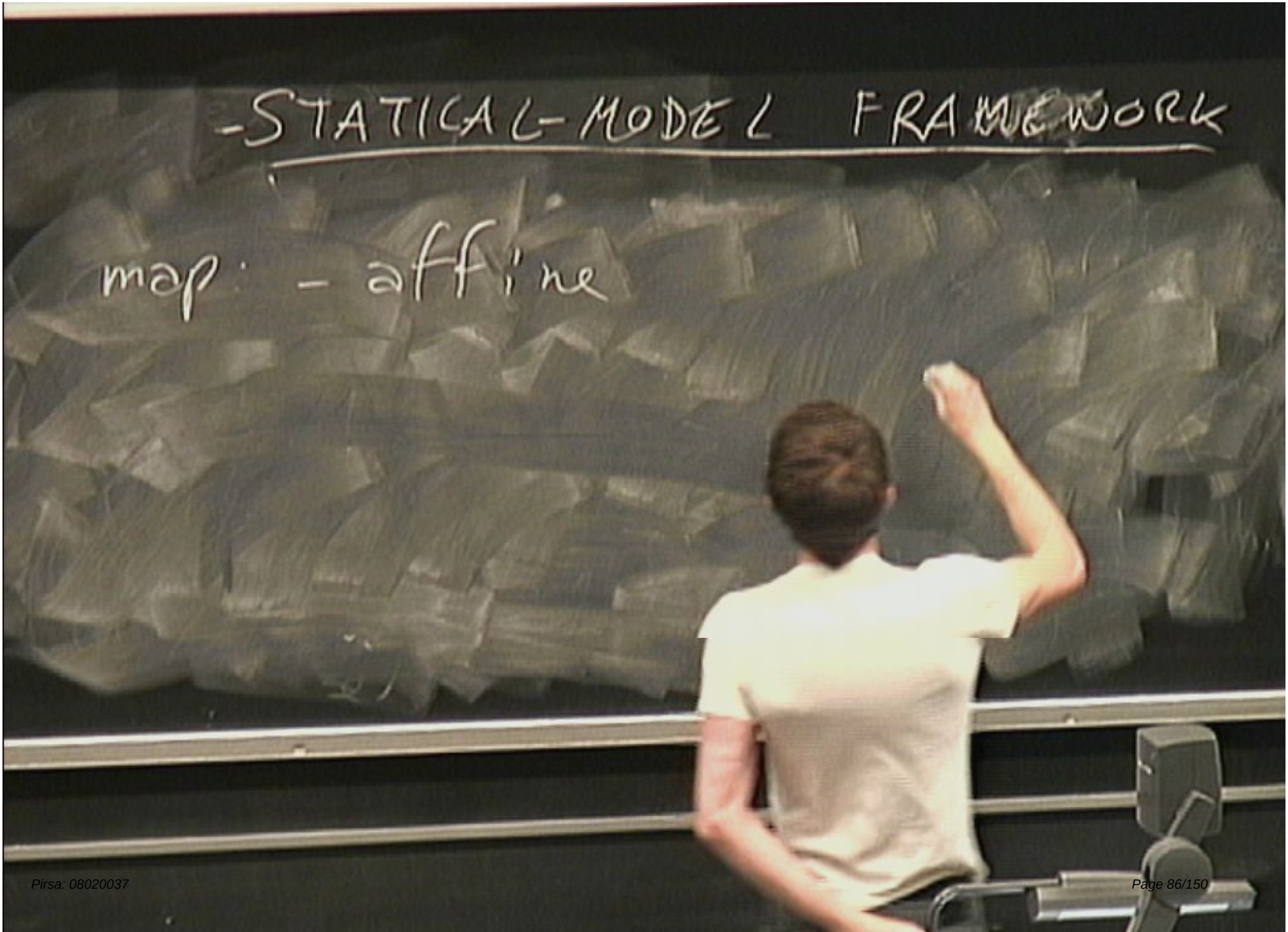
'exotic' $\longrightarrow$?

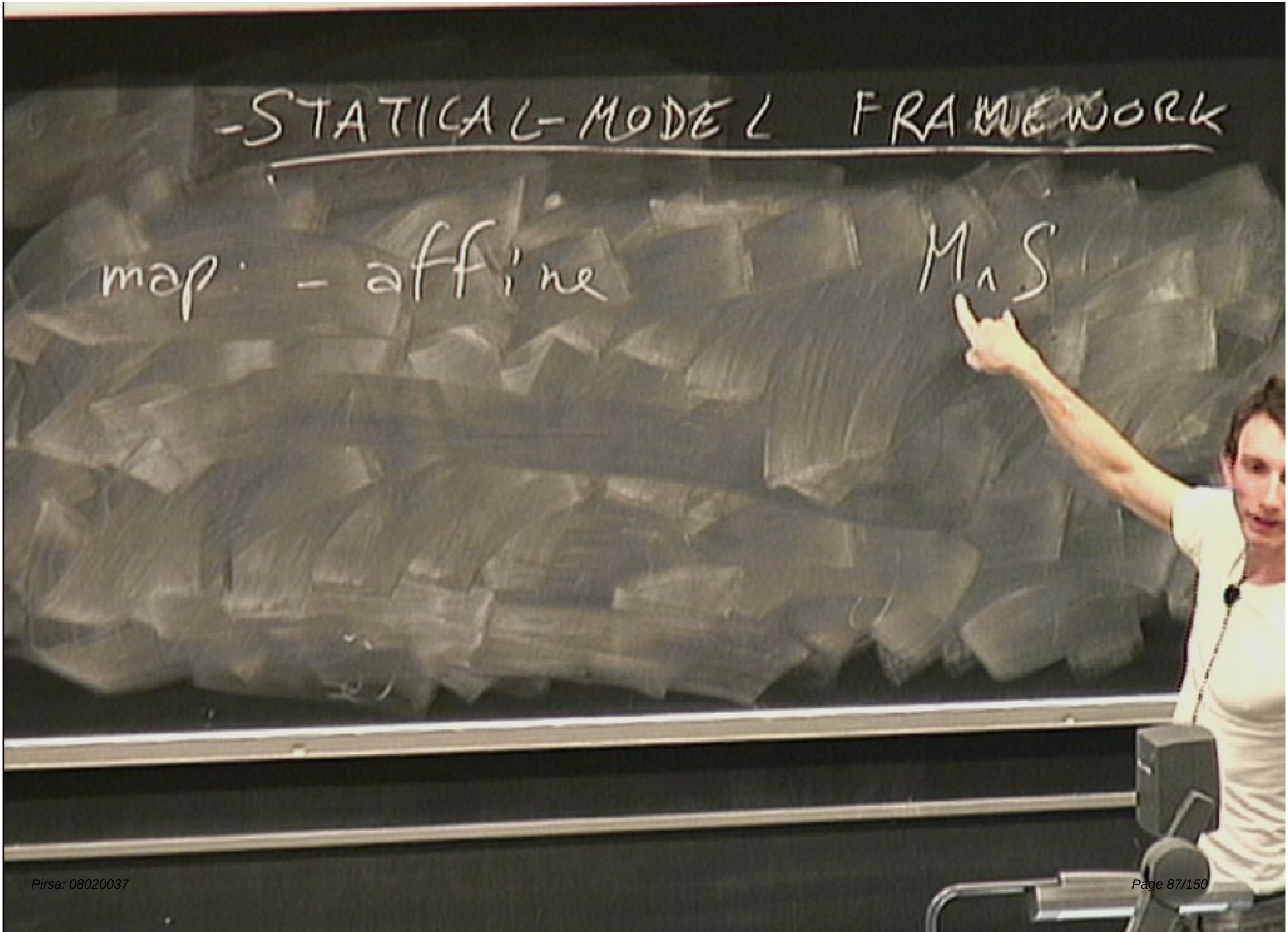
Spekkens'! $\longrightarrow$


class. phys. theory 1
interpret phen. mod. 2
+ form


class. phys. theory 1 interpret phen. mod. 2
+ form

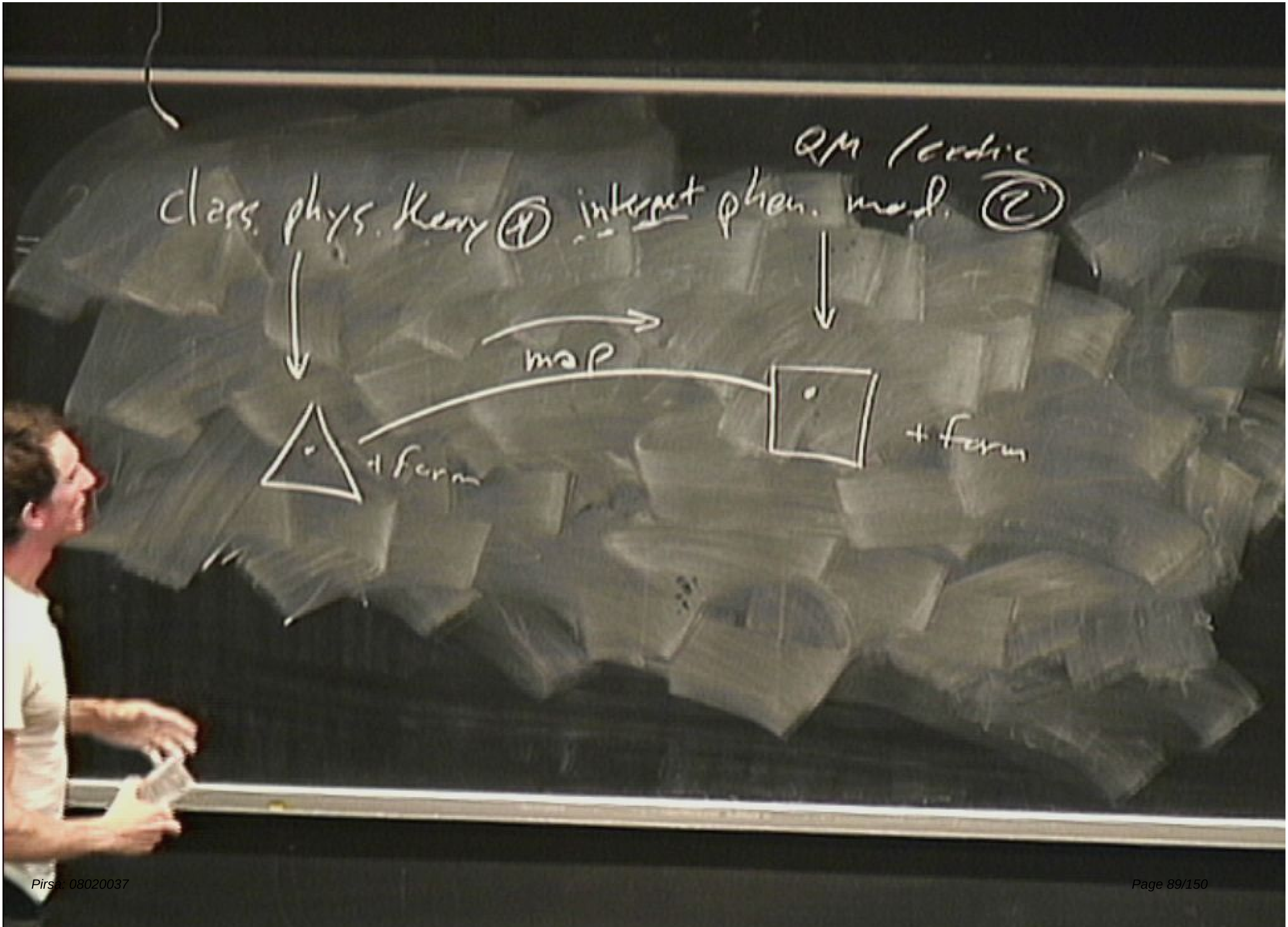

class. phys. theory 1
interpret phen. mod. 2
map
+ form
+ form

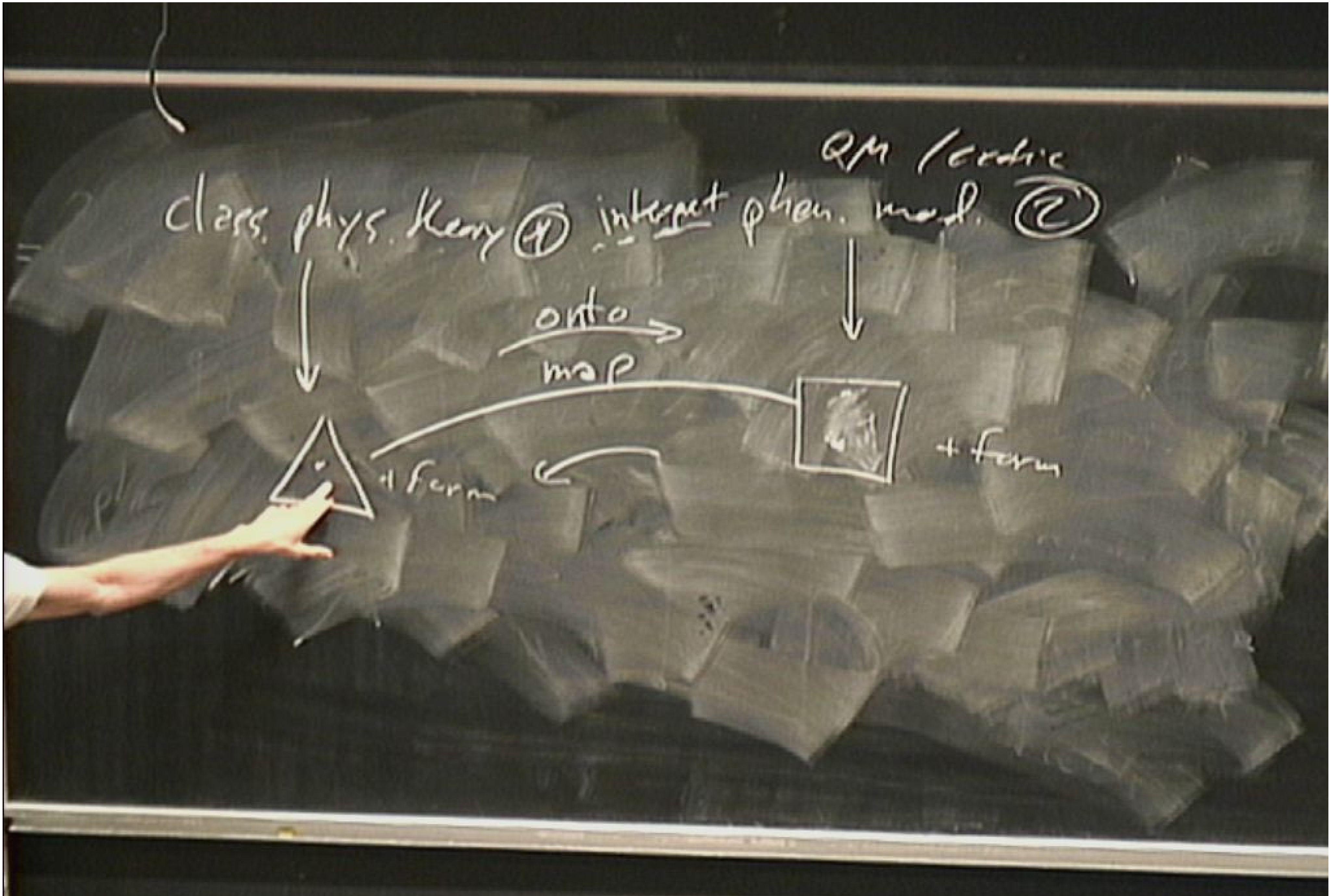

-STATICAL-MODEL FRAMEWORK
map: - affine

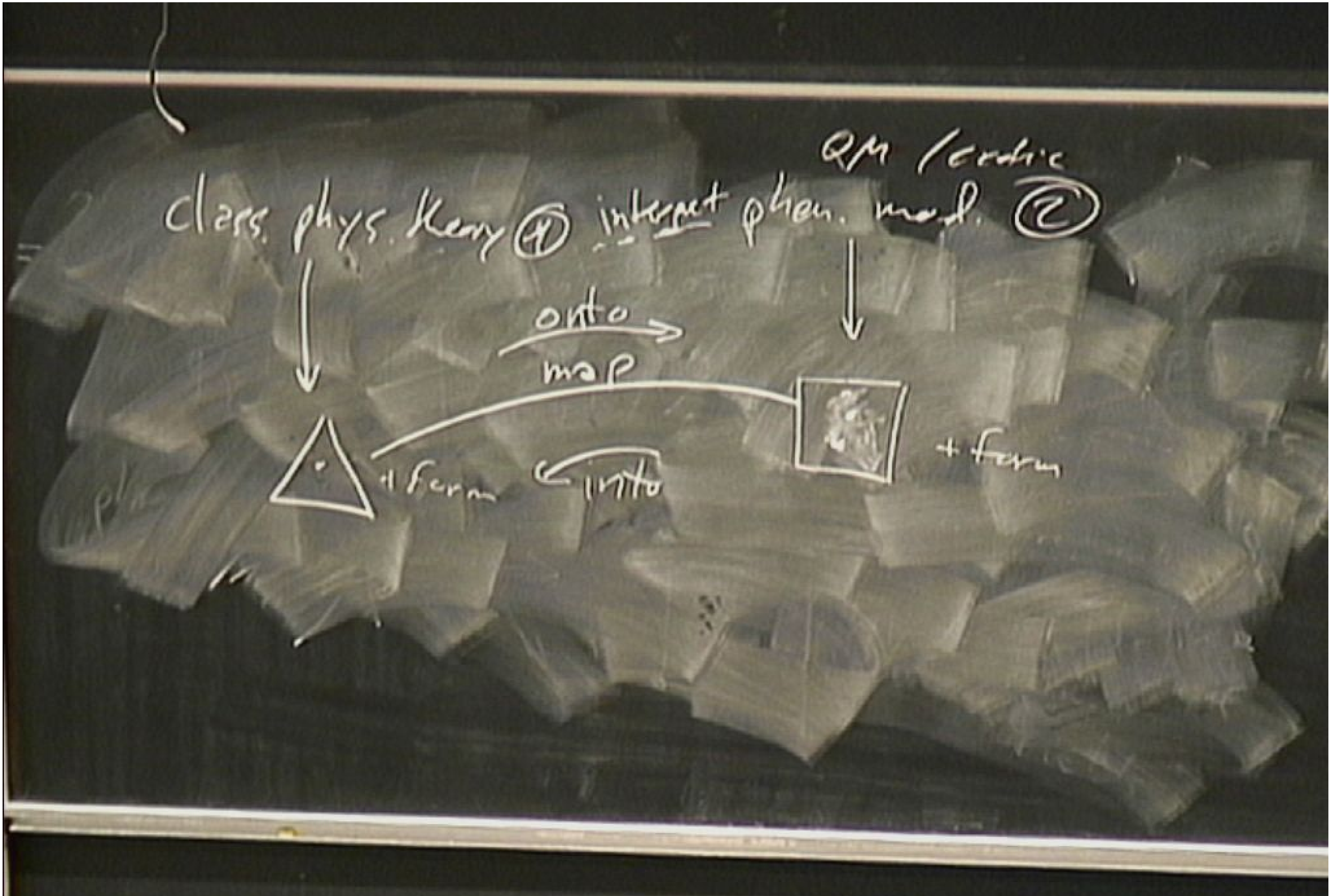

-STATICAL-MODEL FRAMEWORK
map: - affine
M∧S

-STATICAL-MODEL FRAMEWORK

map: - affine $\quad M_{\wedge} S_{\wedge}$

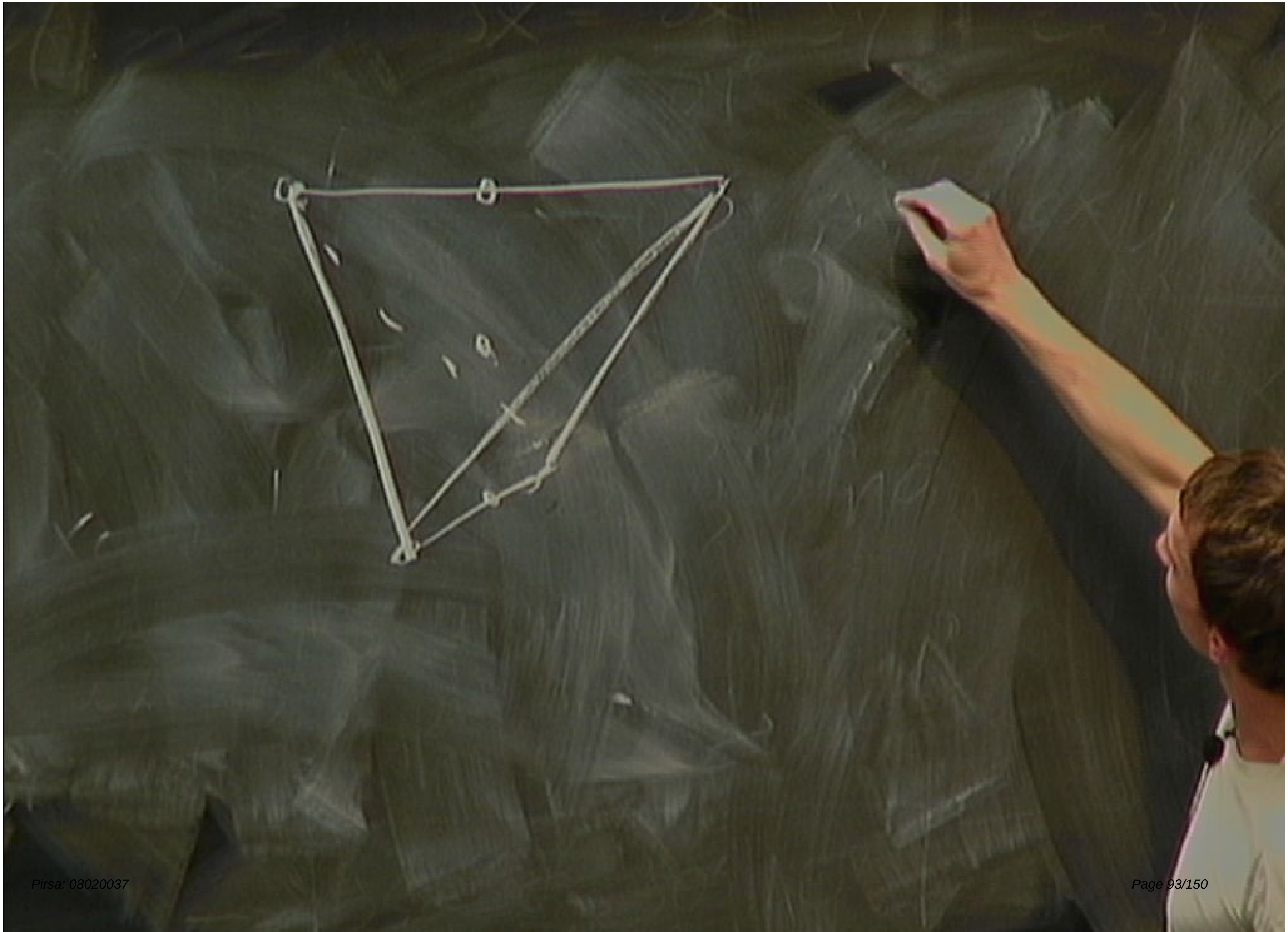

QM
class. phys. theory ① interpret phen. mod. ②
map
+ form
+ form

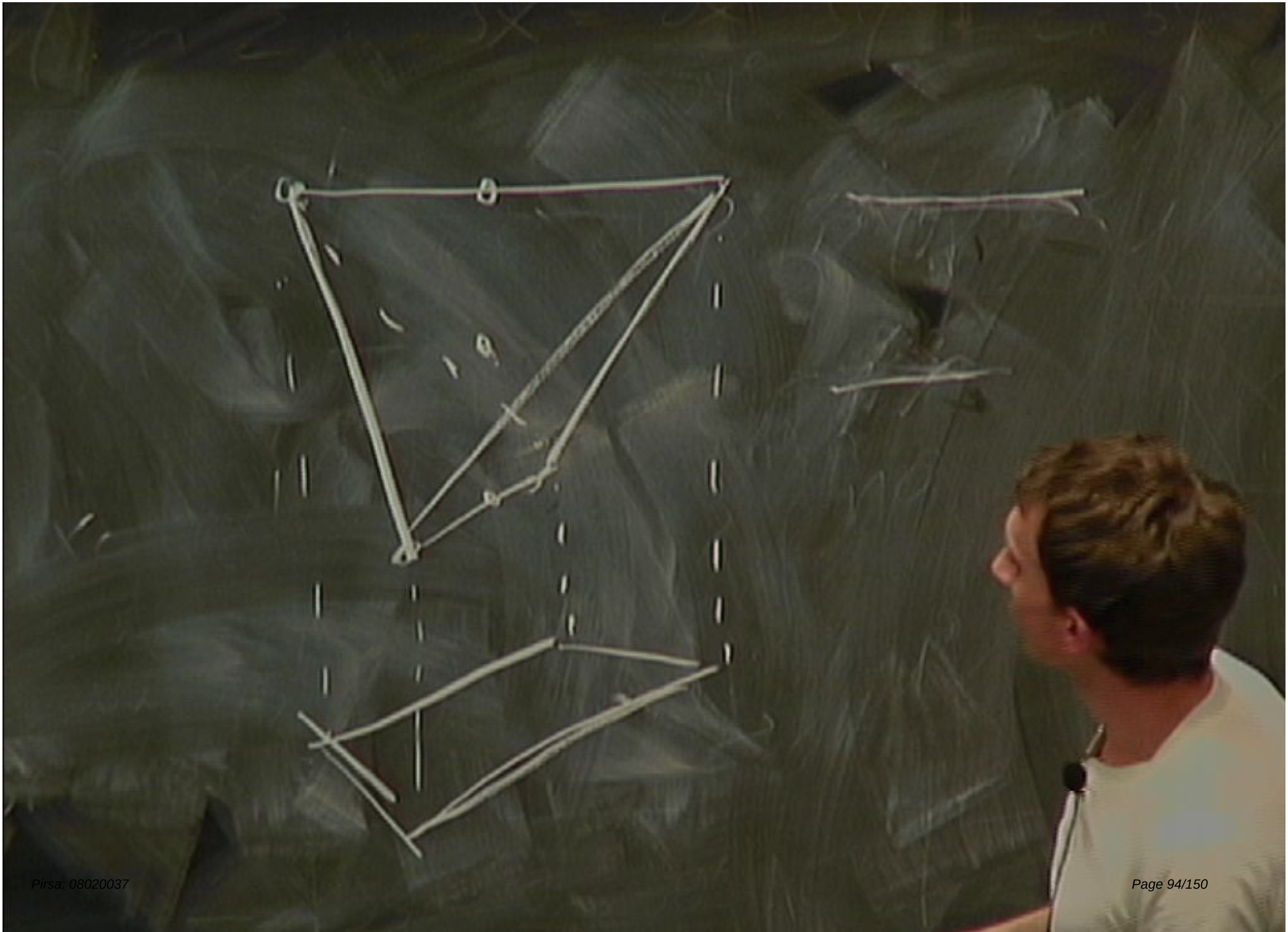

class. phys. theory
phen. mod.
onto
map
+ form
+ form

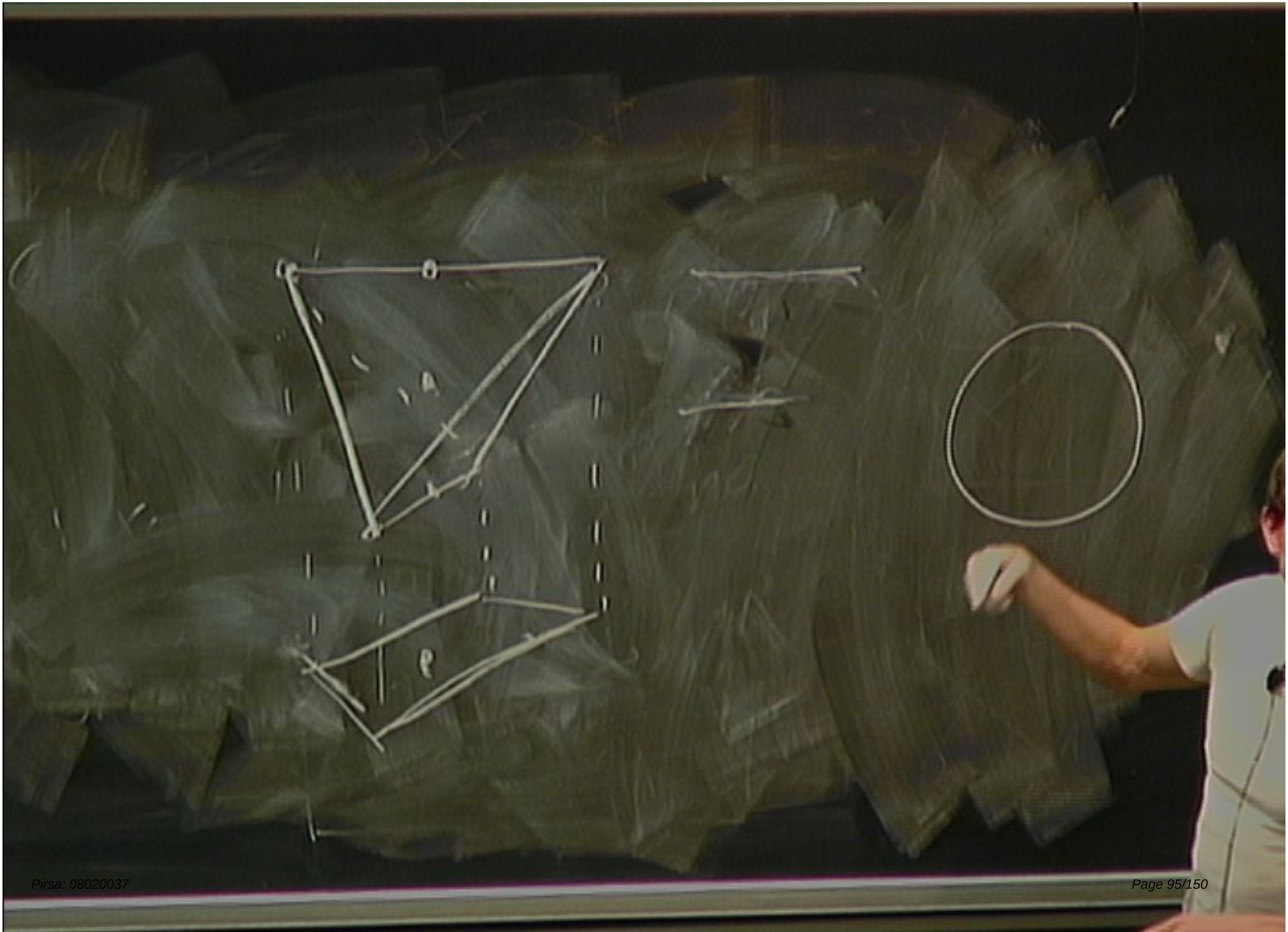

class. phys. theory (1)
interpret phen. mod. (2)
onto
map
+ form
into
+ form

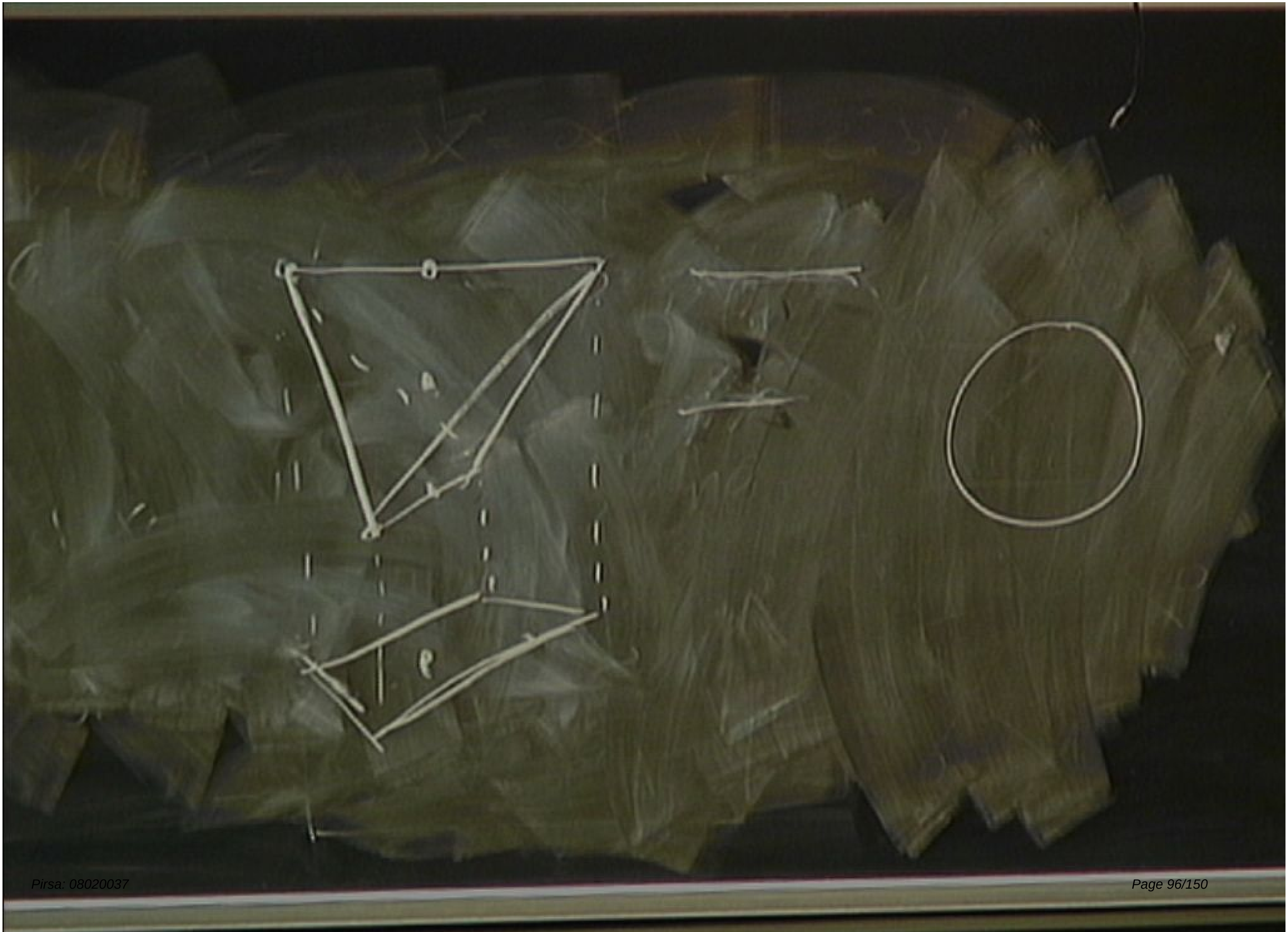
-STATICAL-MODEL FRAMEWORK

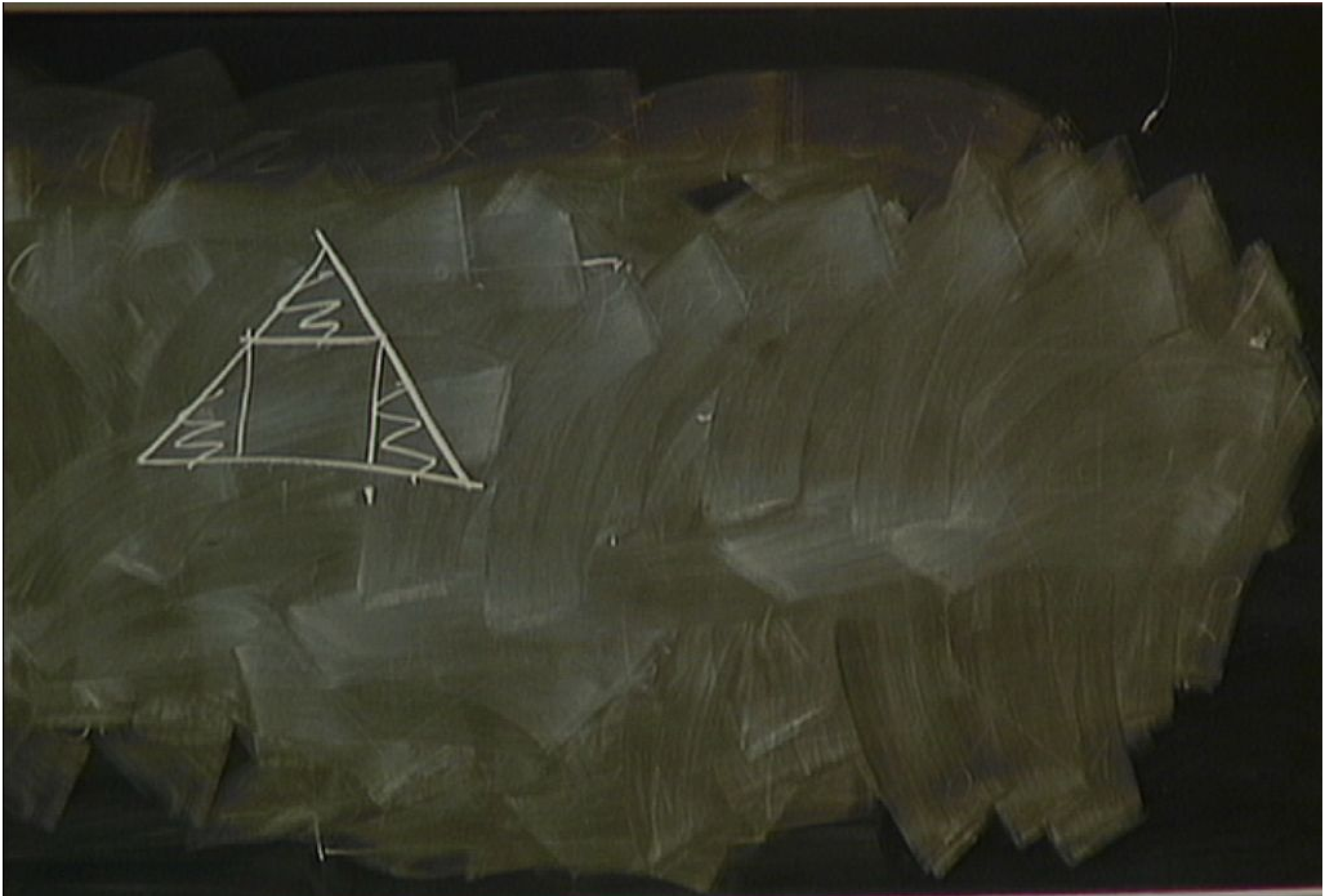
Th. Holevo: Any ph. model can be interpreted as a classical th. with constraints on the measurements

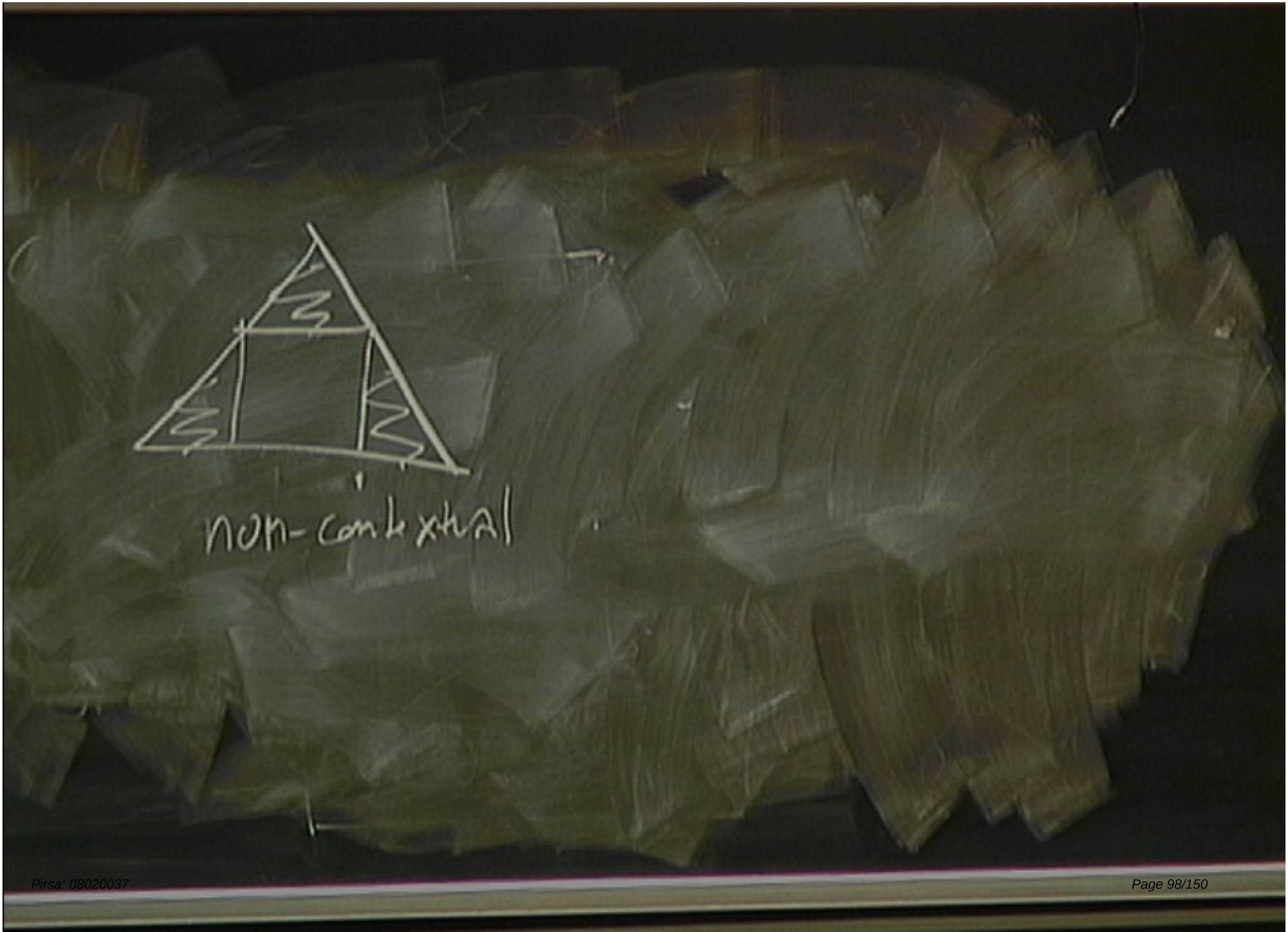


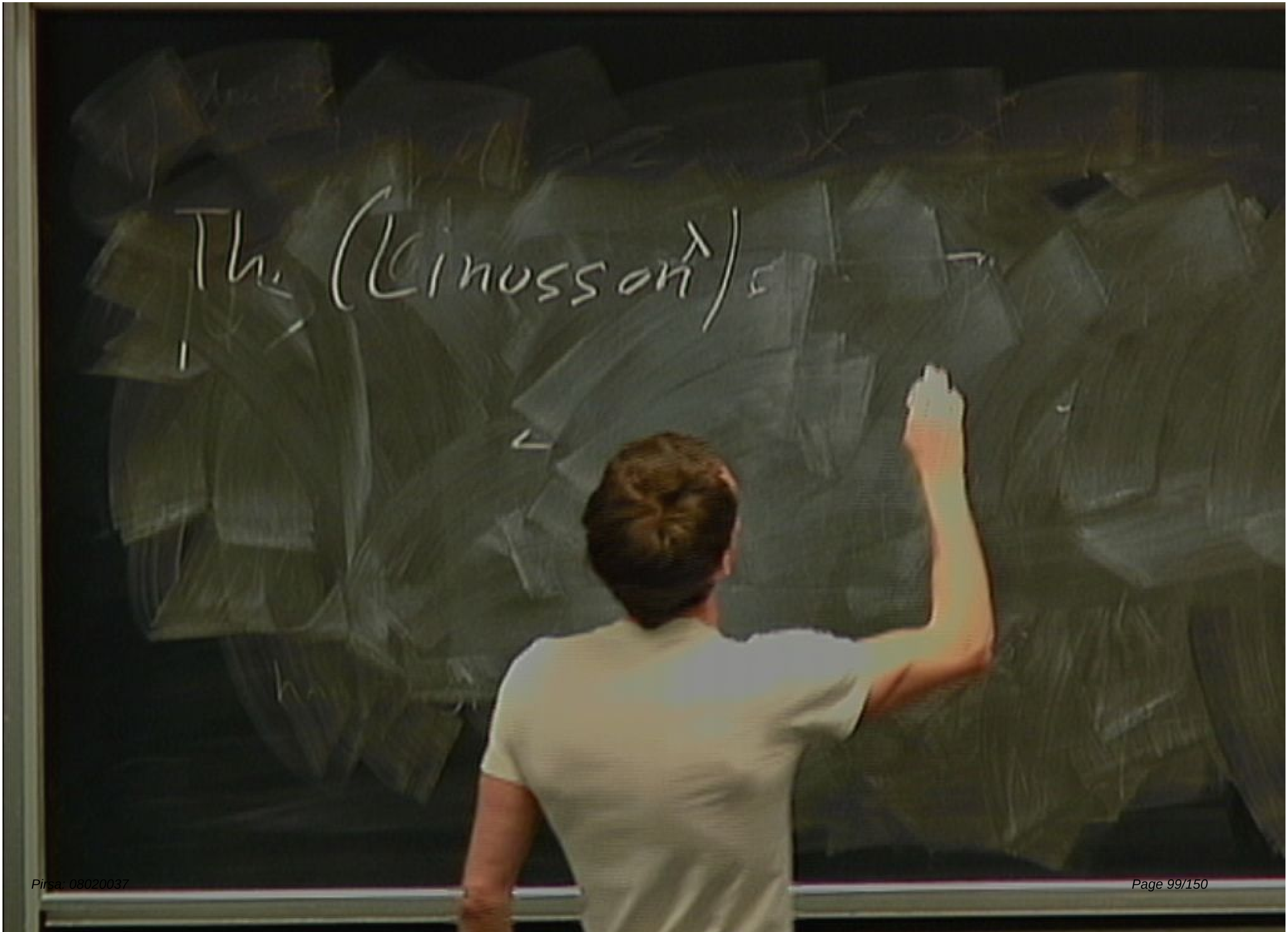


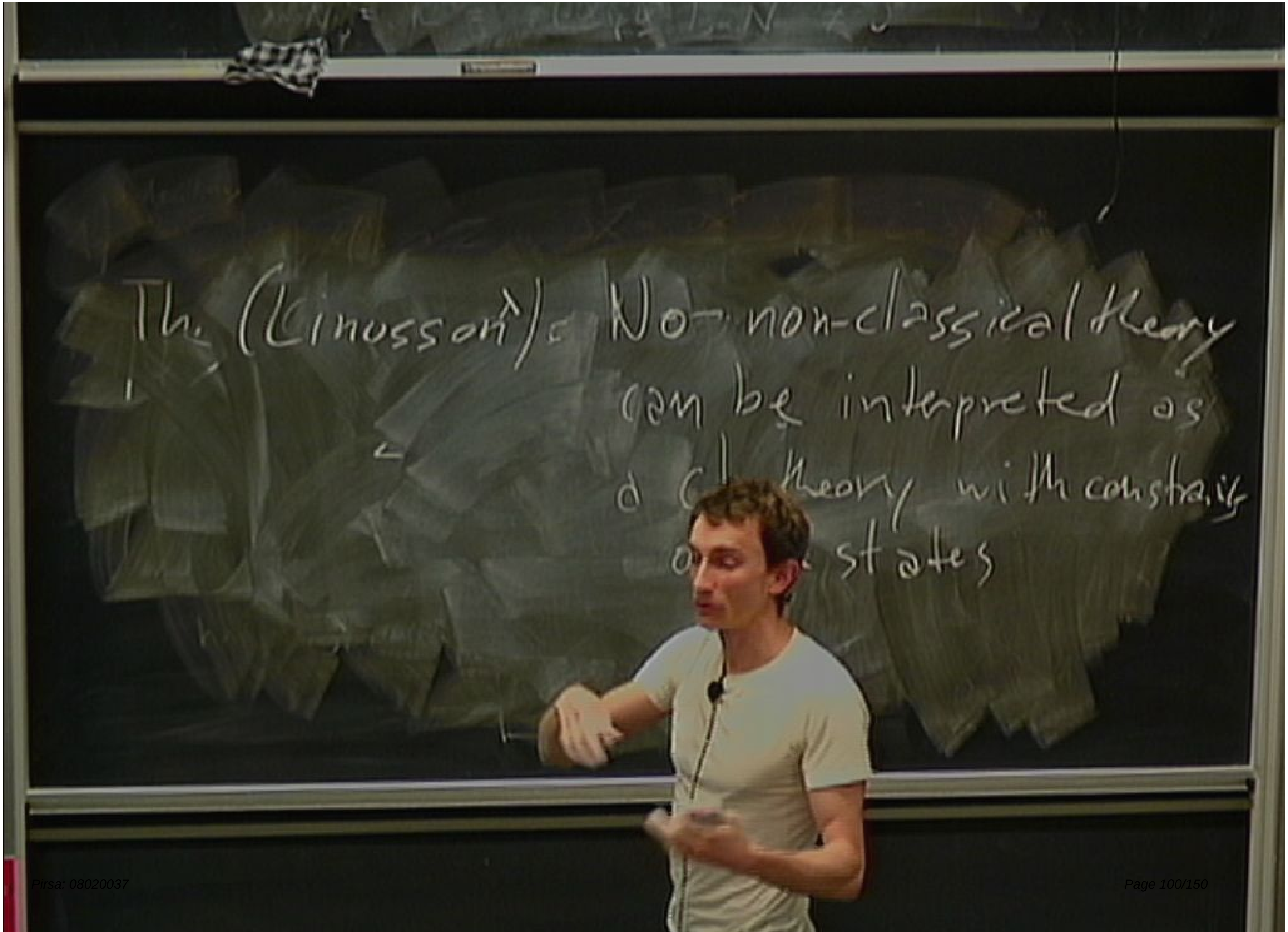




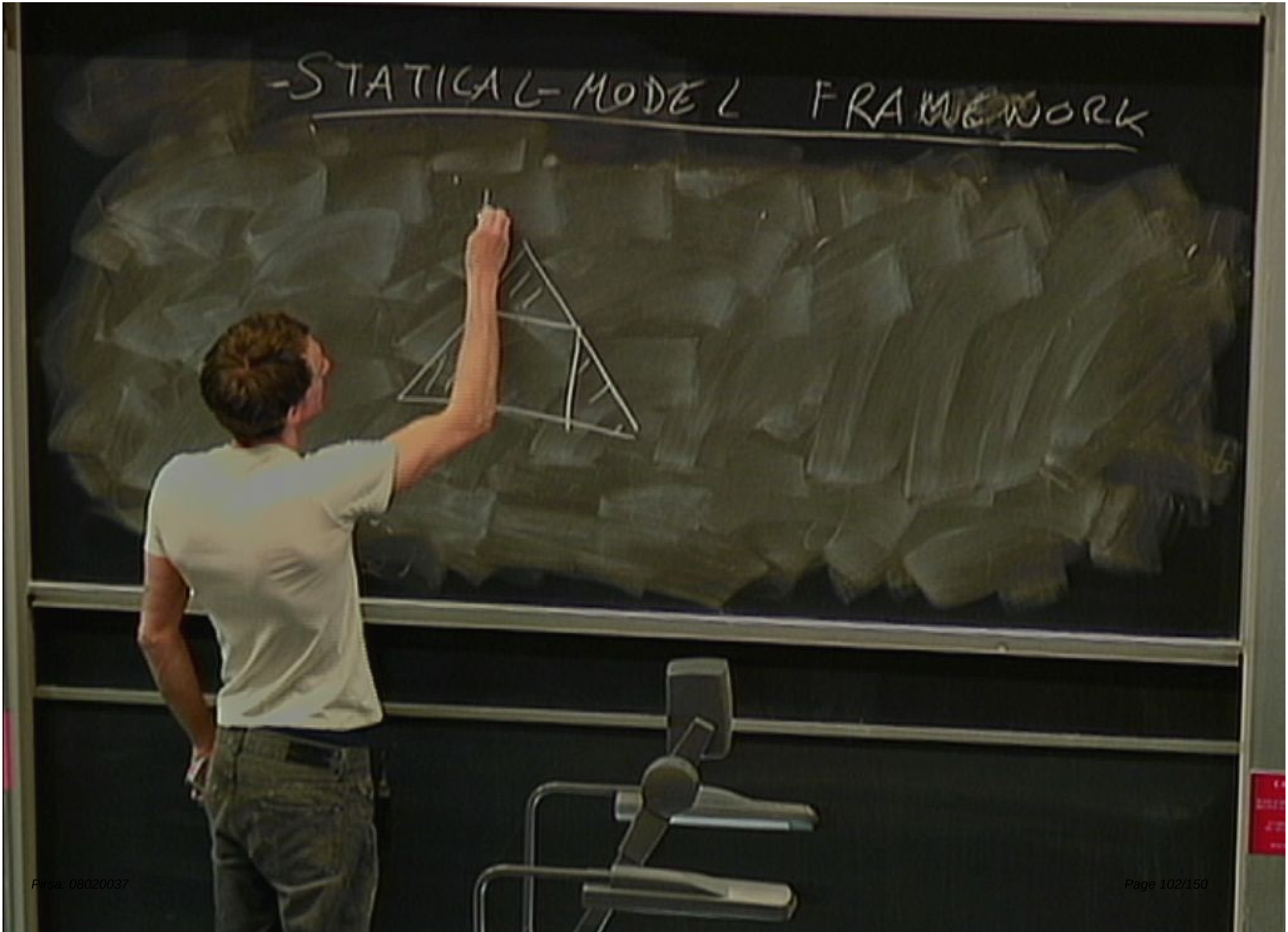


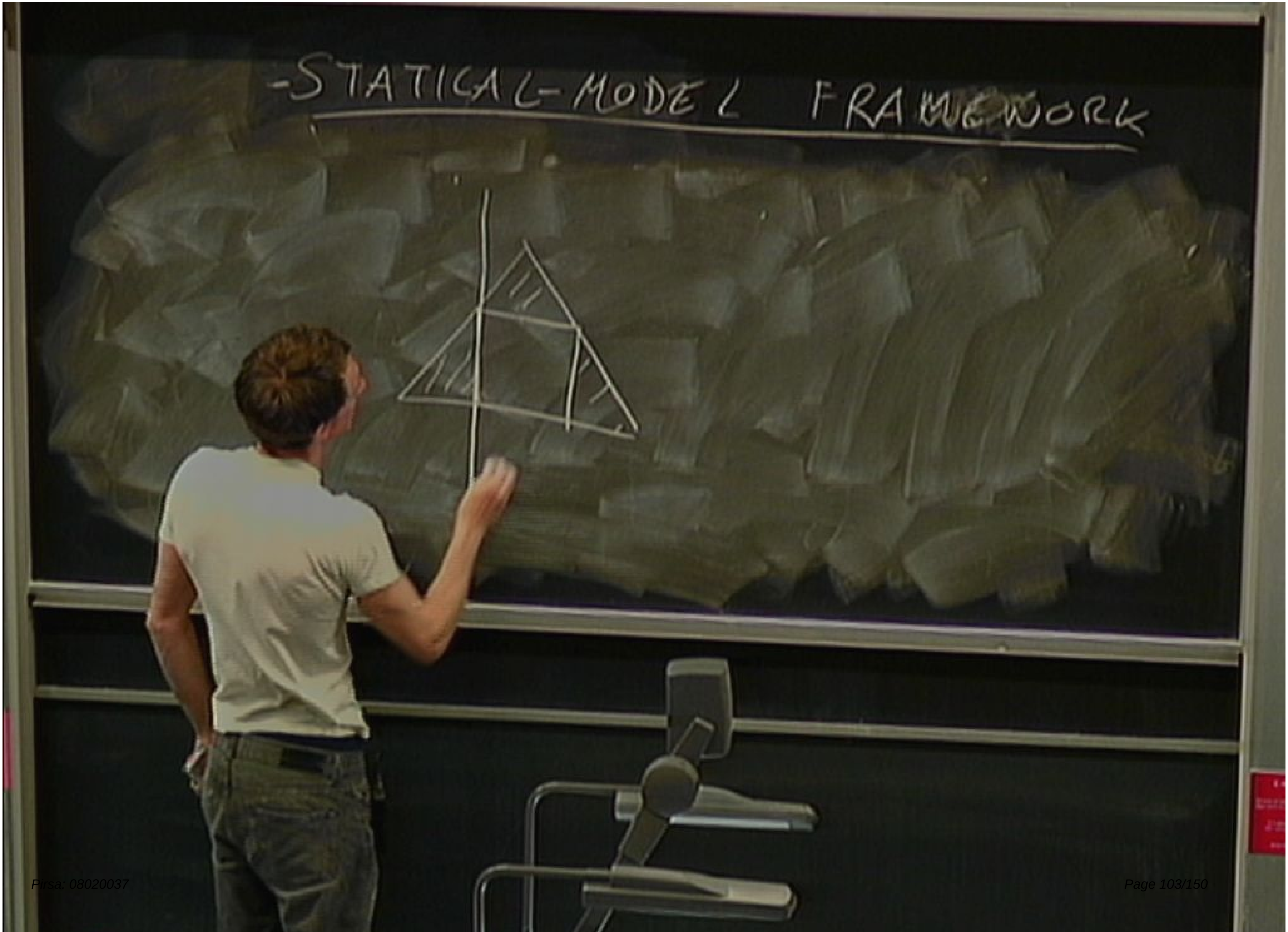

non-contextual

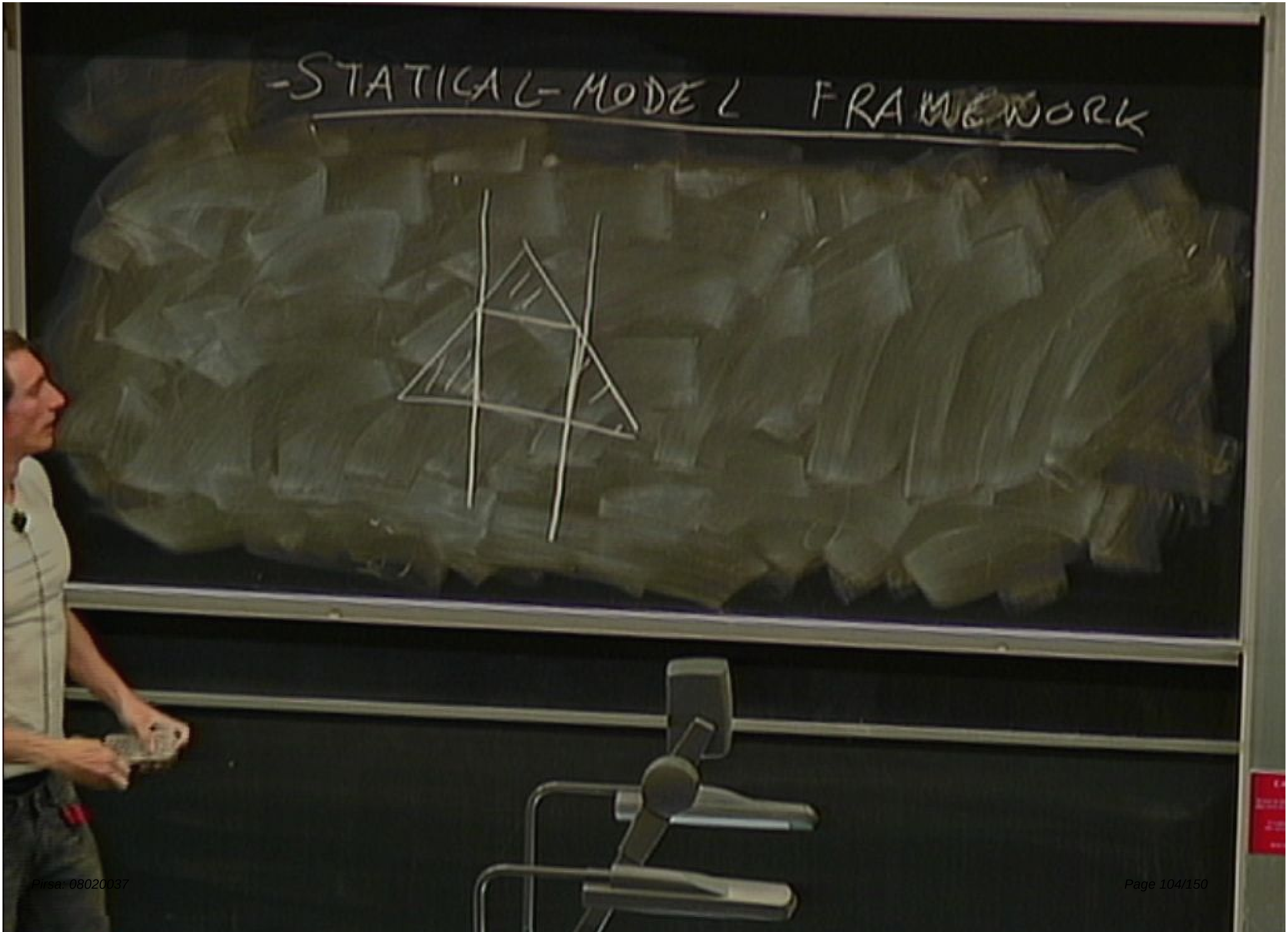

Th. (Linossan)

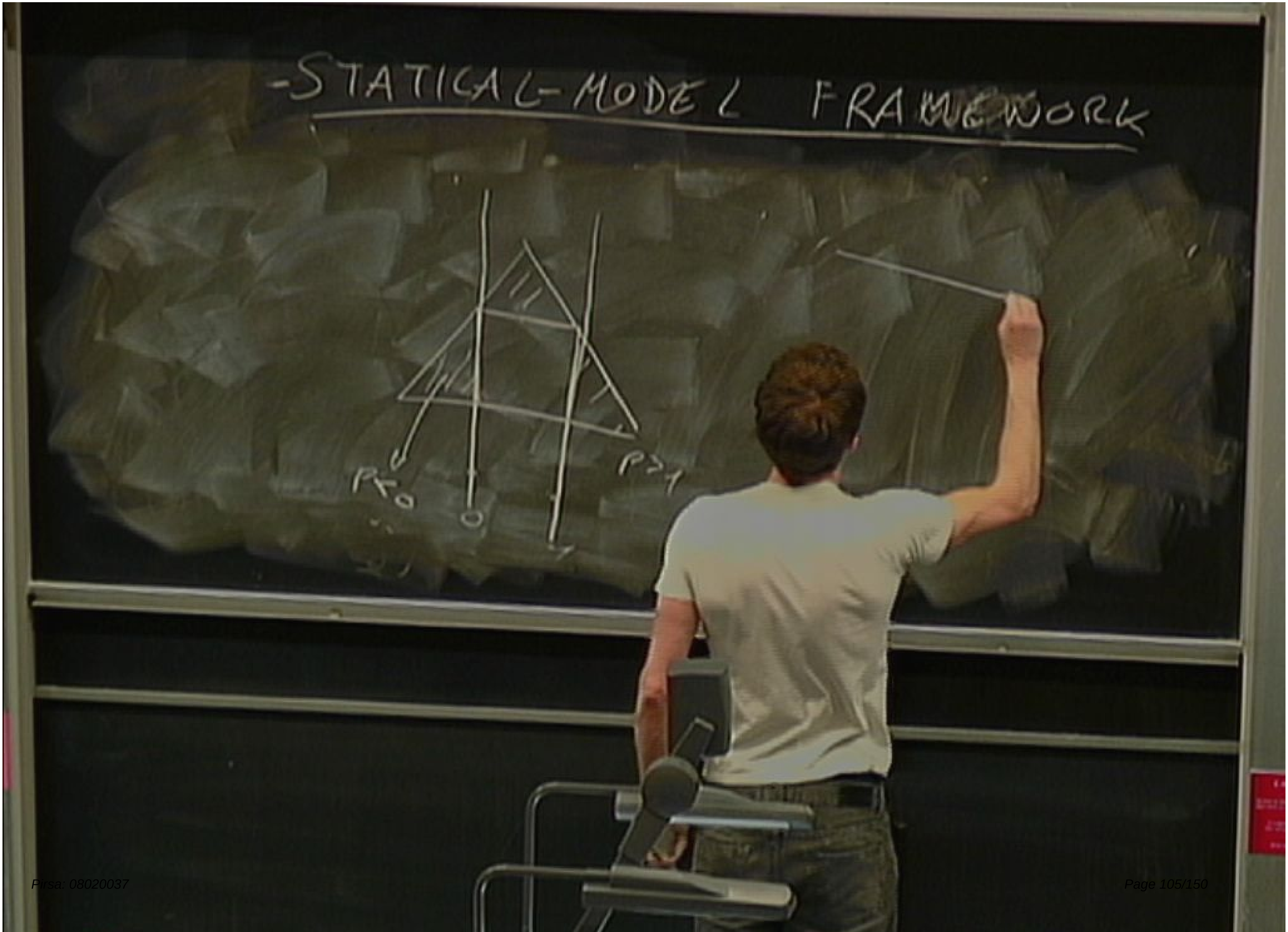

Th. (Linusson): No non-classical theory
can be interpreted as
a cl. theory with constraints
states

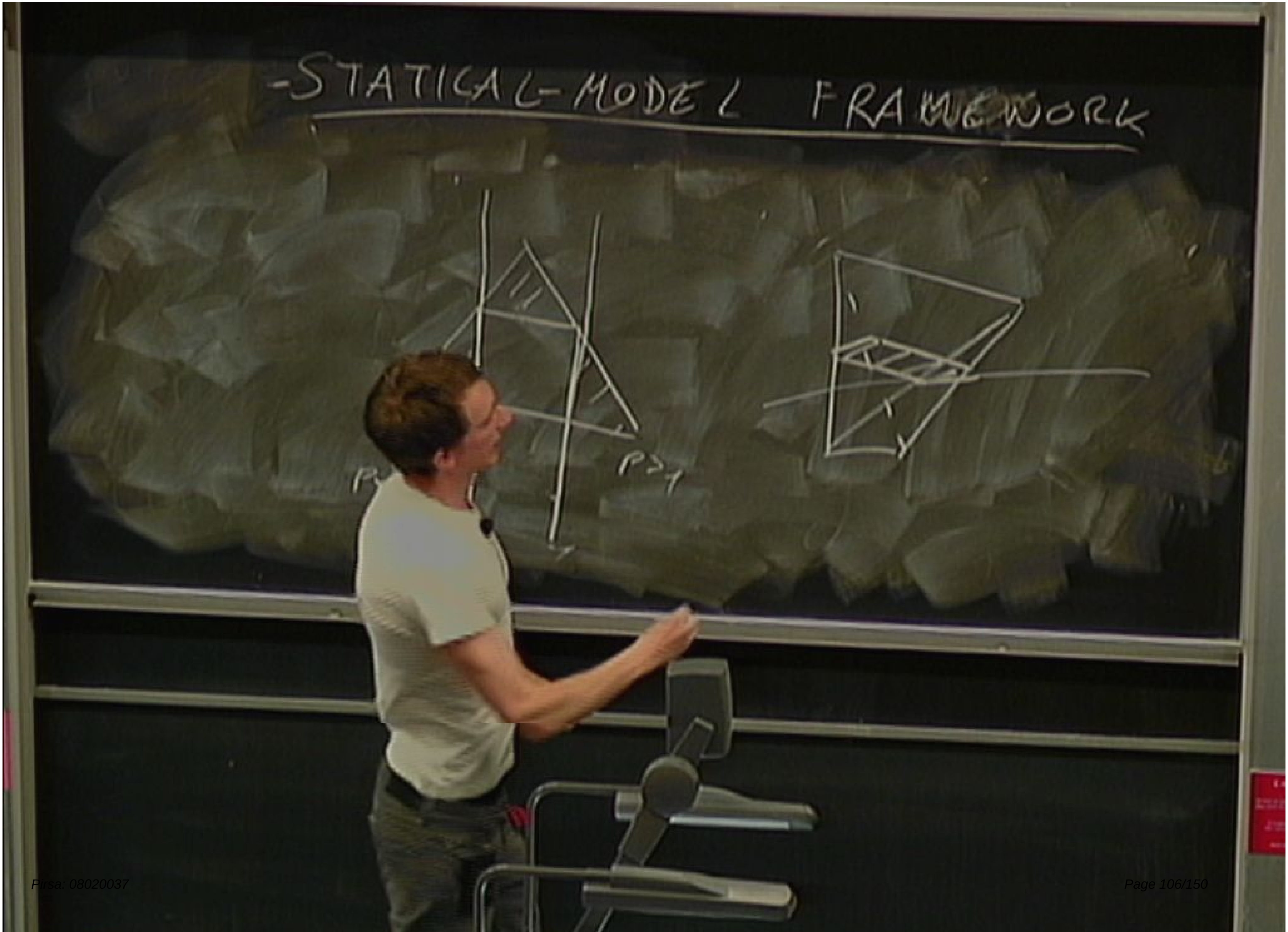
Th. (Linusson): No non-classical theory can be interpreted as a cl. theory with constraints on the states

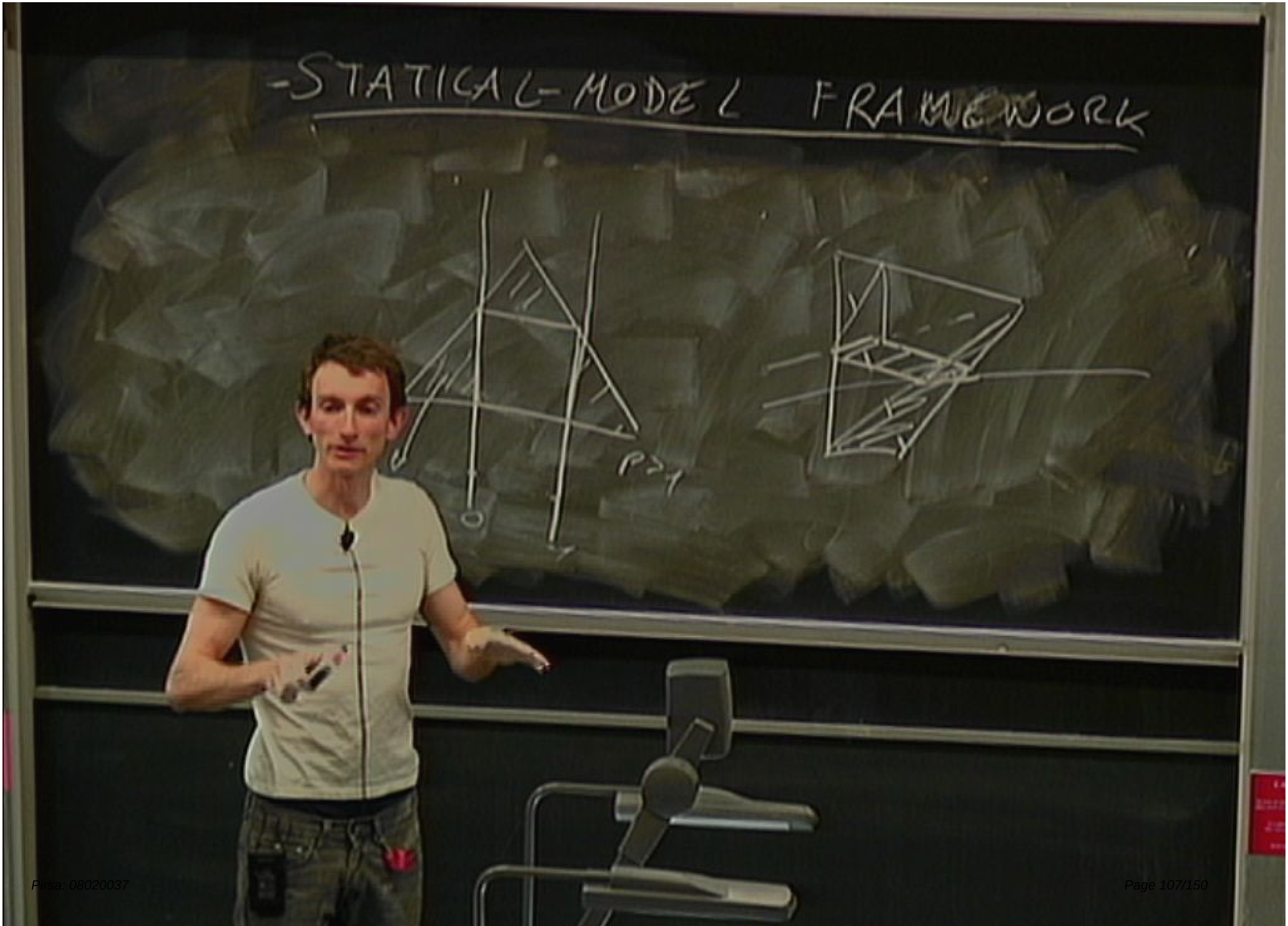

-STATICAL-MODEL FRAMEWORK

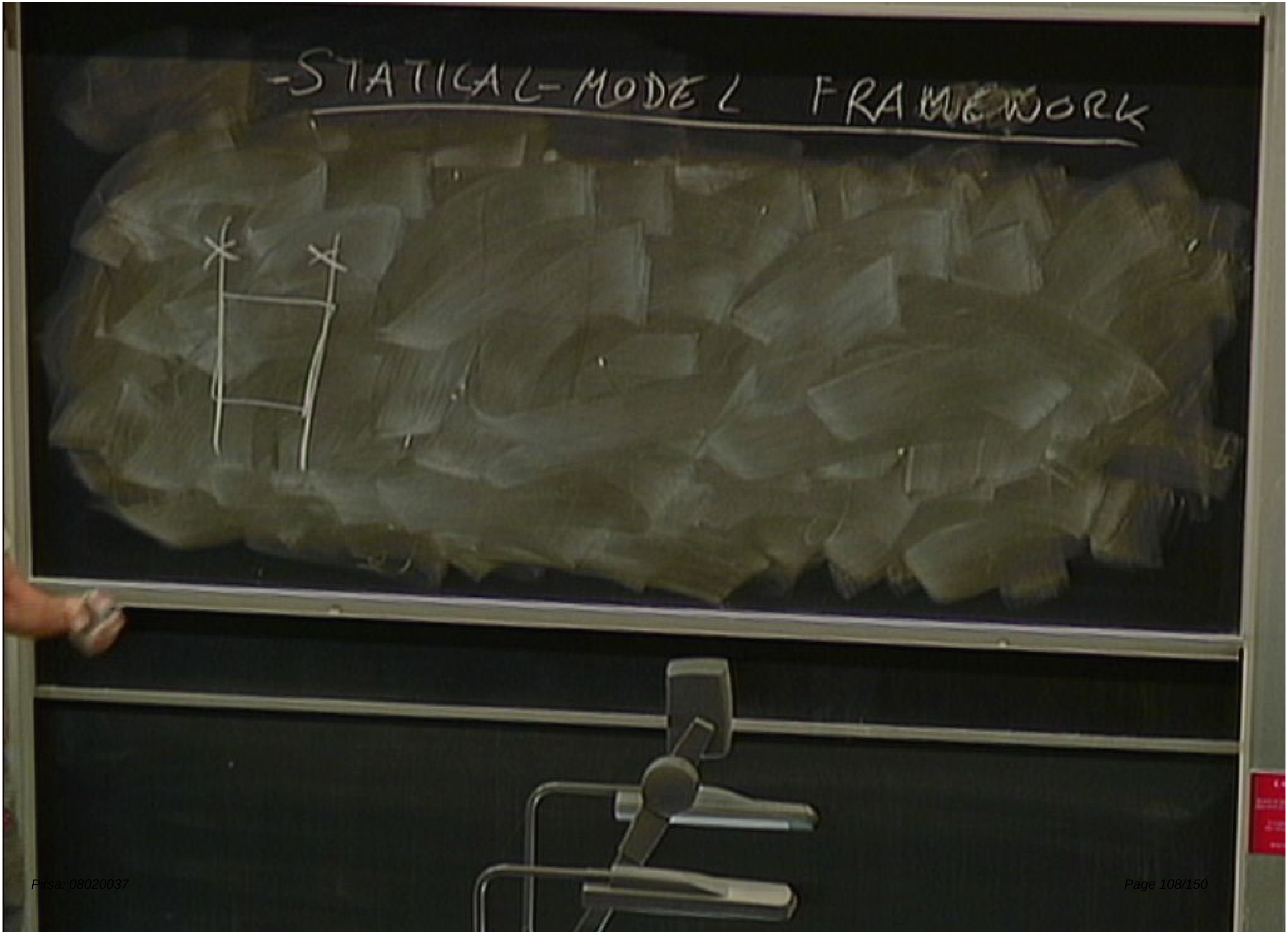

-STATICAL-MODEL FRAMEWORK

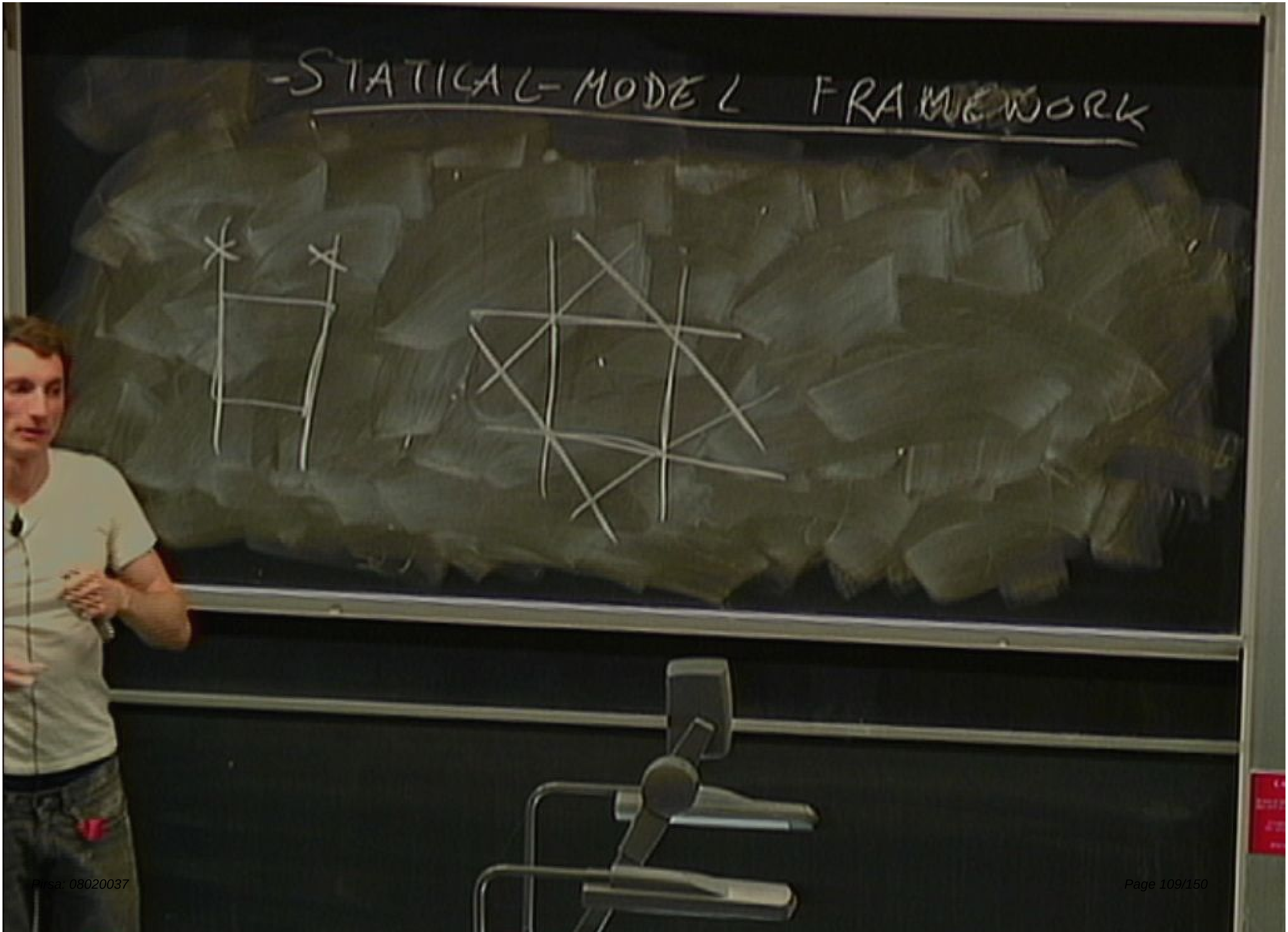

-STATICAL-MODEL FRAMEWORK

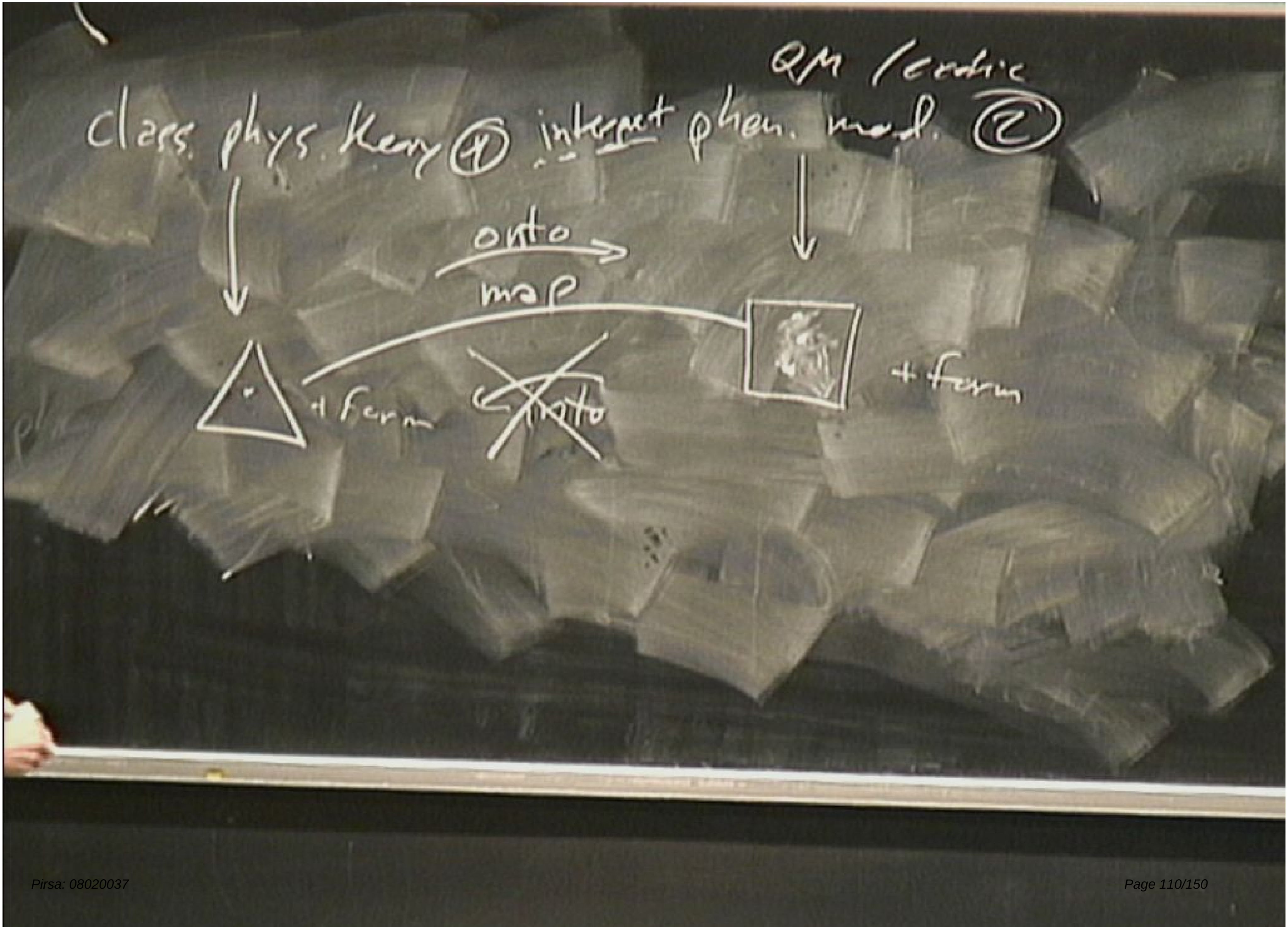

-STATICAL-MODEL FRAMEWORK
P<0
0
P>1

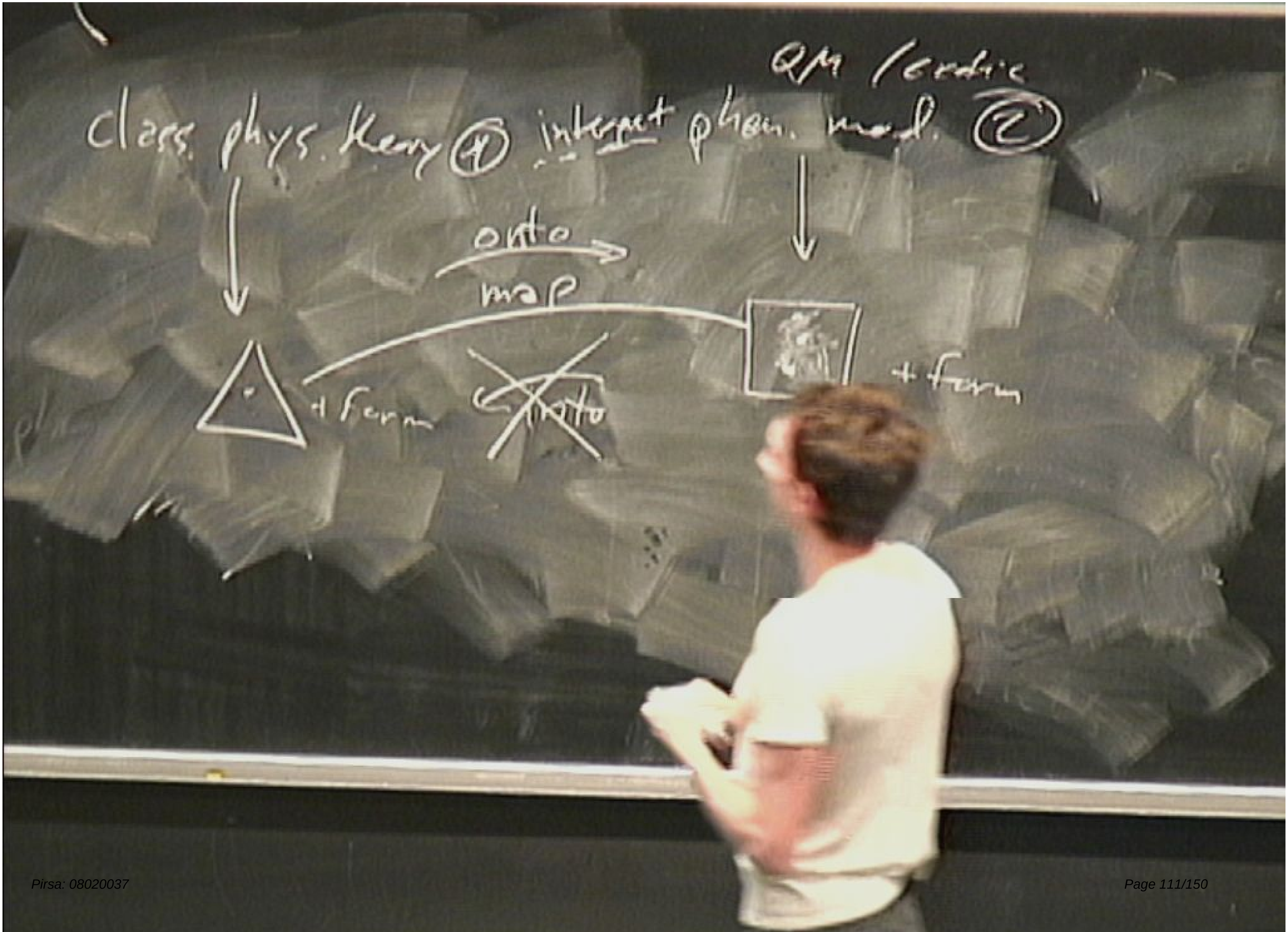

-STATICAL-MODEL FRAMEWORK

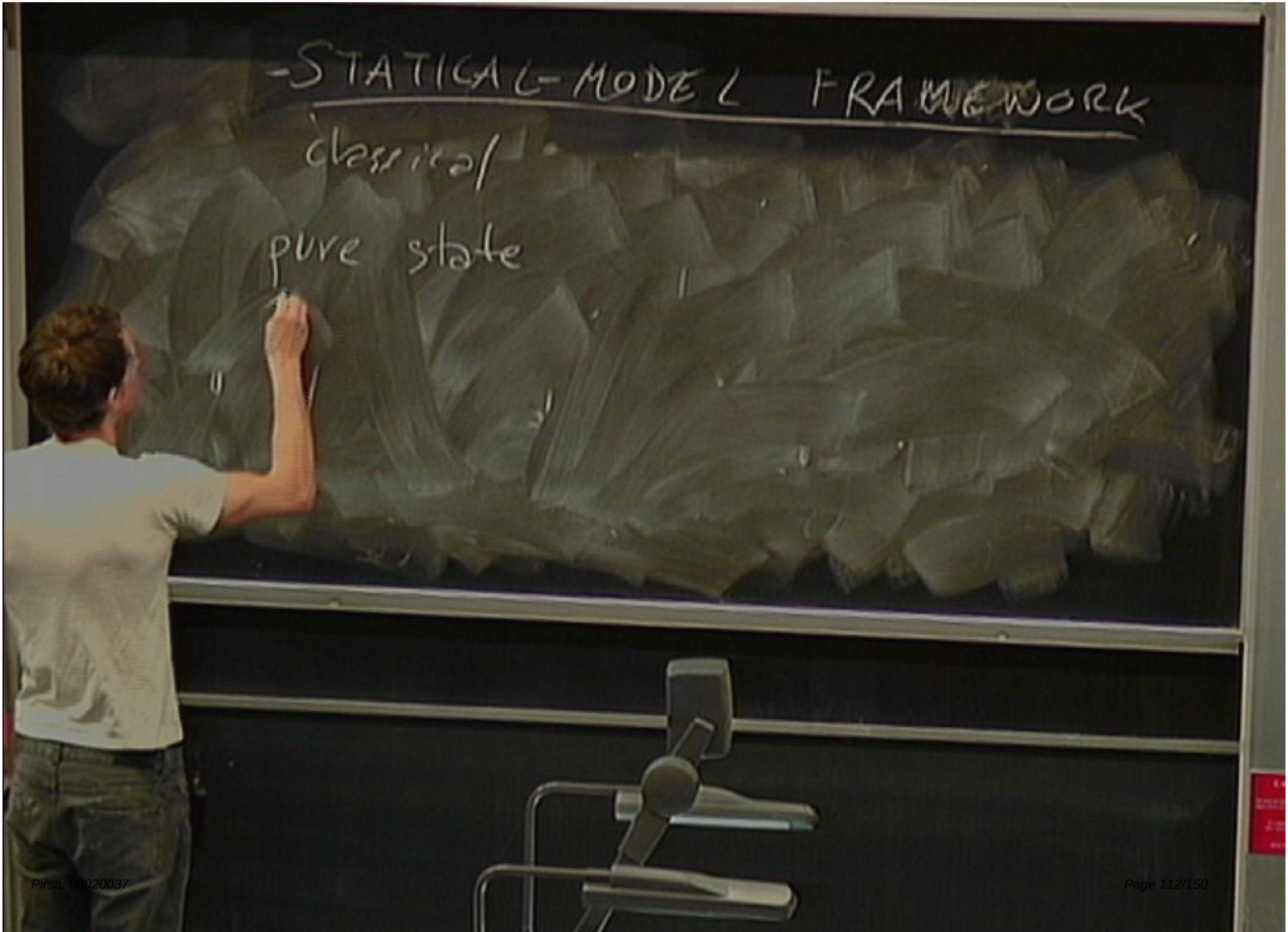

-STATICAL-MODEL FRAMEWORK

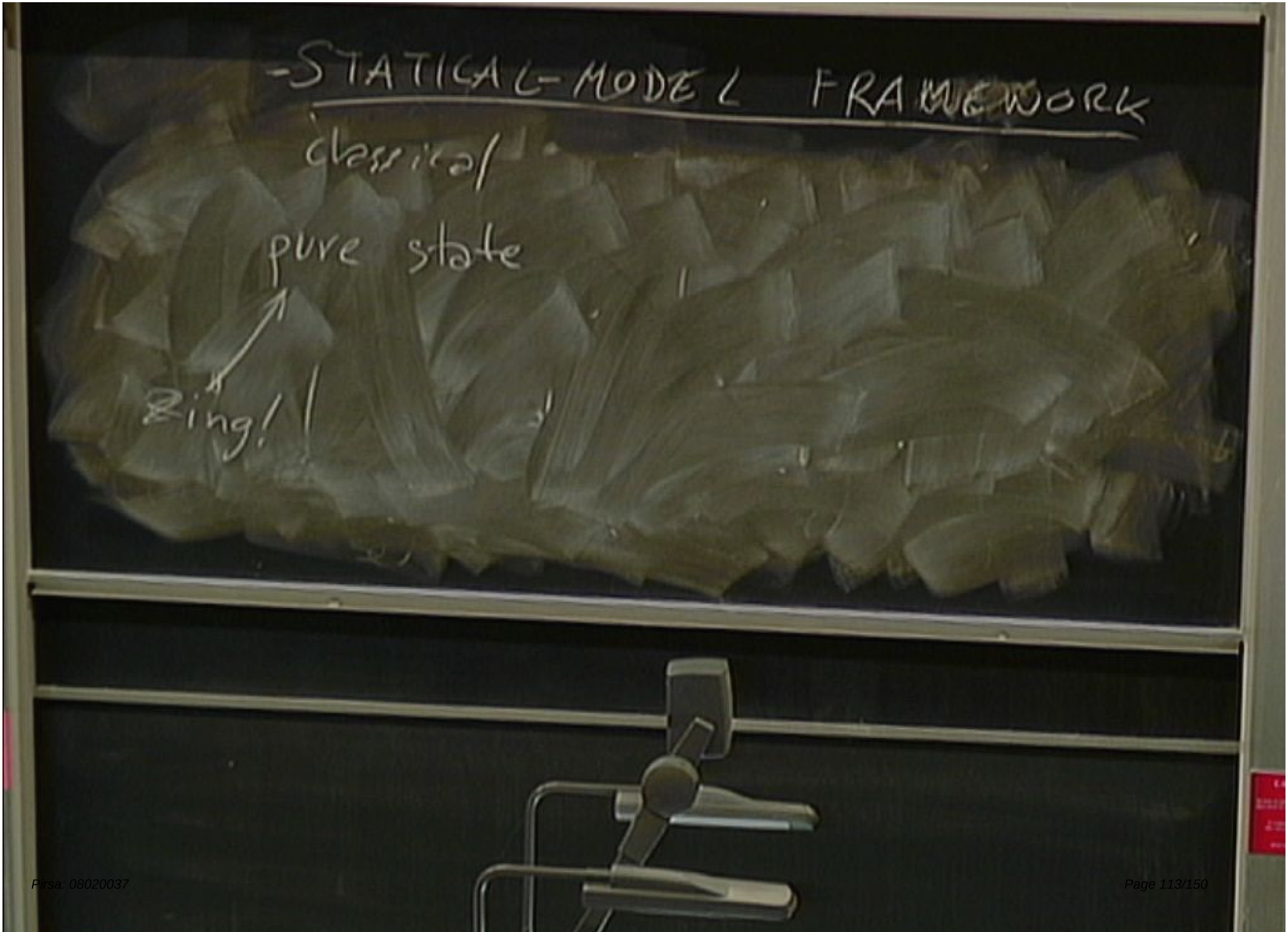

-STATICAL-MODEL FRAMEWORK

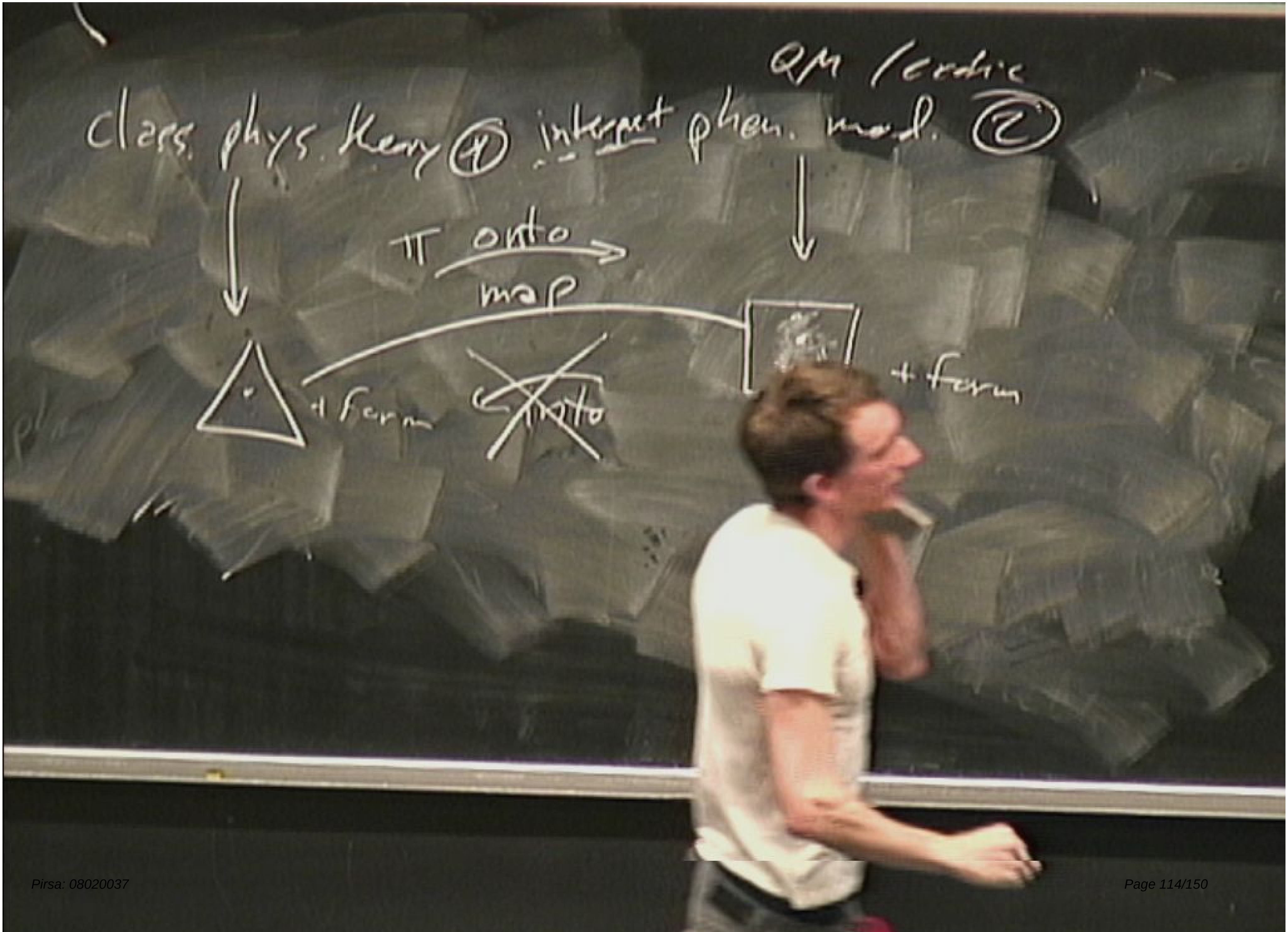

-STATICAL-MODEL FRAMEWORK

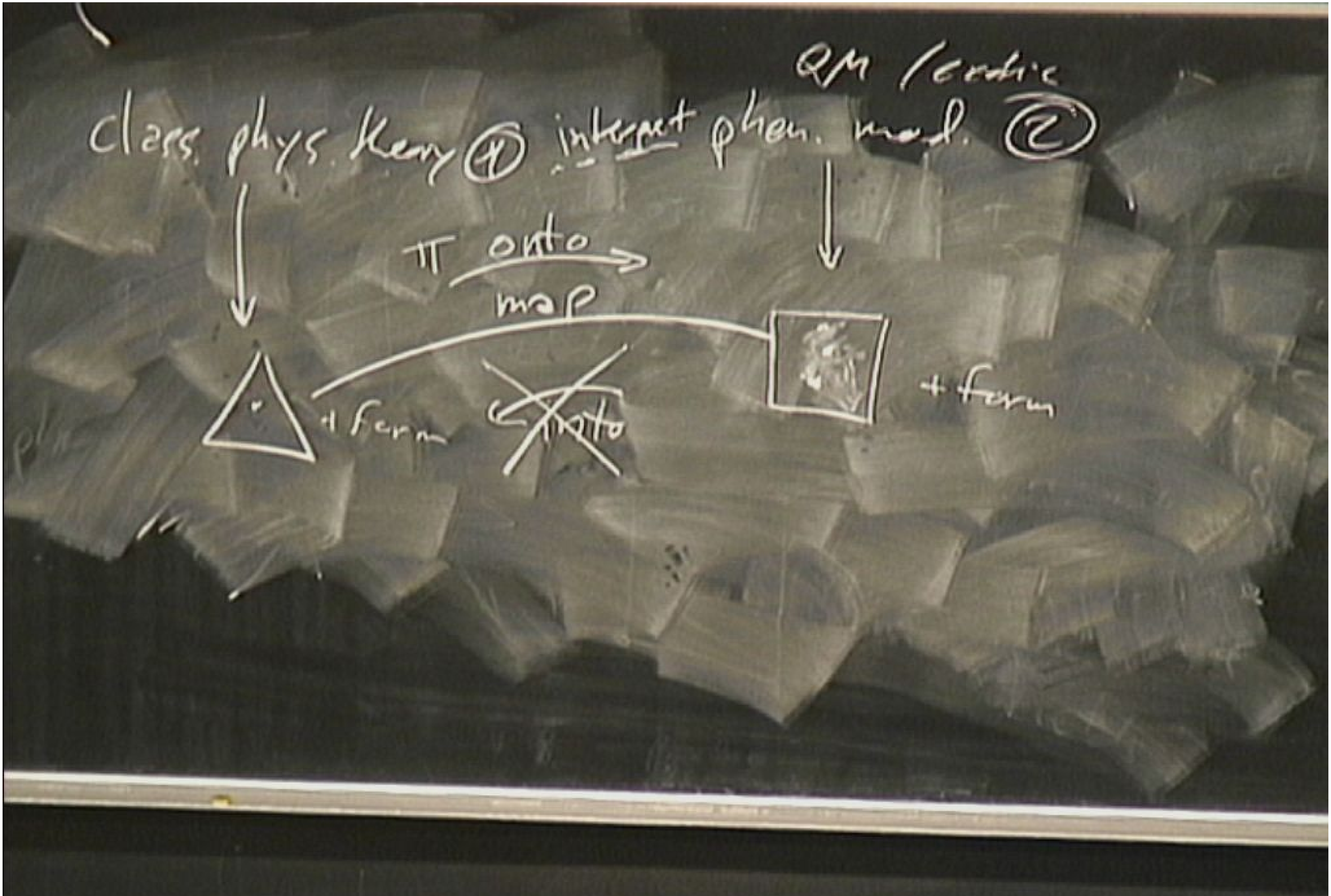

QM / ergodic
class. phys. theory (1) interpret phen. mod. (2)
onto map
+ ferm
~~onto~~
+ ferm

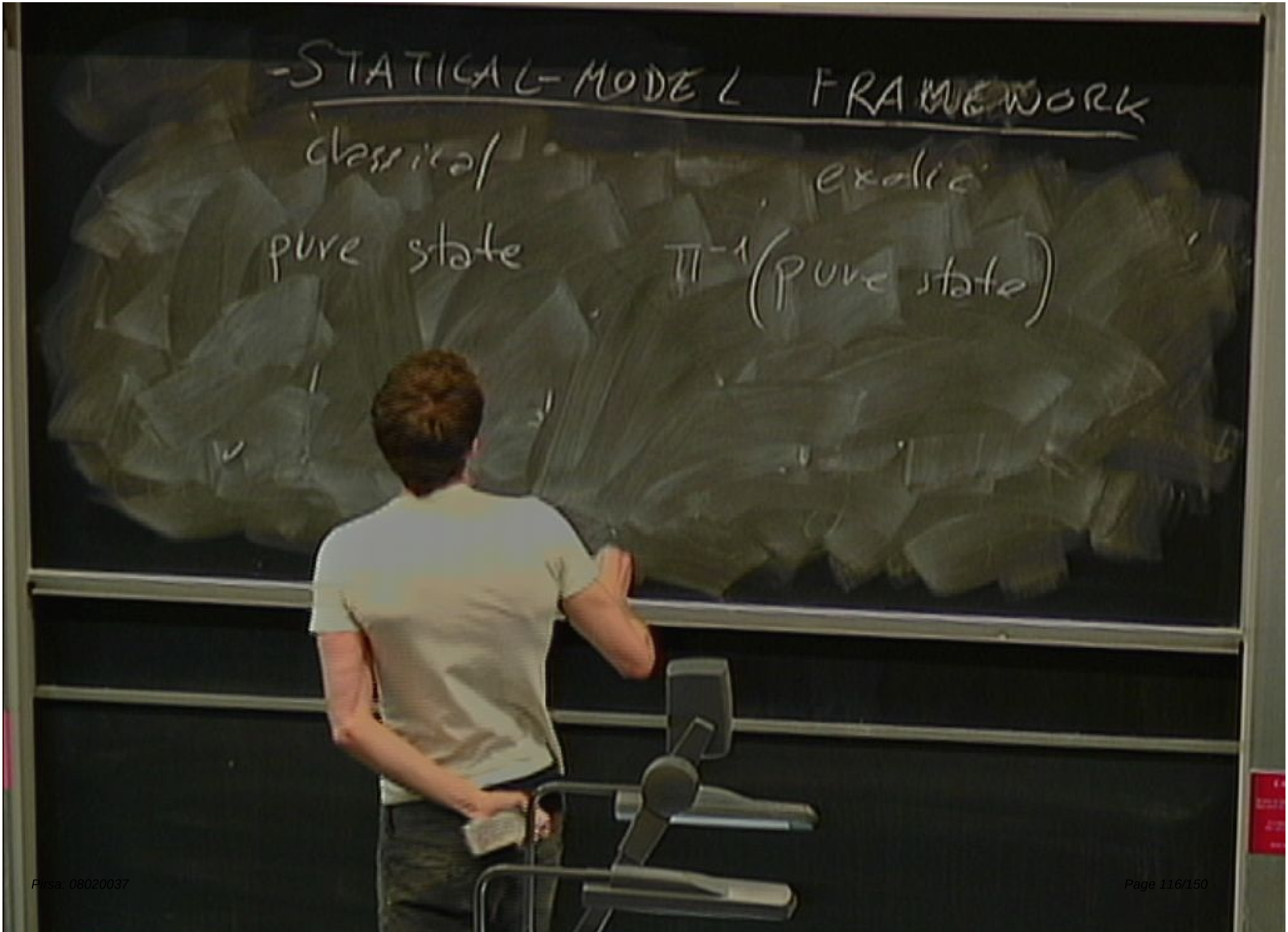

QM / ergodic
class. phys. theory (1)
integrat phen. mod. (2)
onto map
+ ferm
+ ferm


-STATICAL-MODEL FRAMEWORK
classical
pure state


-STATICAL-MODEL FRAMEWORK
classical
pure state
Ring!


QM / ergodic
class. phys. theory (1)
phen. mod. (2)
π onto map
+ ferm
+ ferm


QM
class. phys. theory ①
interpret
phen. mod. ②
π onto
map
+ ferm
onto
+ ferm


-STATICAL-MODEL FRAMEWORK
classical
exotic
pure state
Π⁻¹(pure state)

QM / ergodic

class. phys. theory (1) interpret phen. mod. (2)

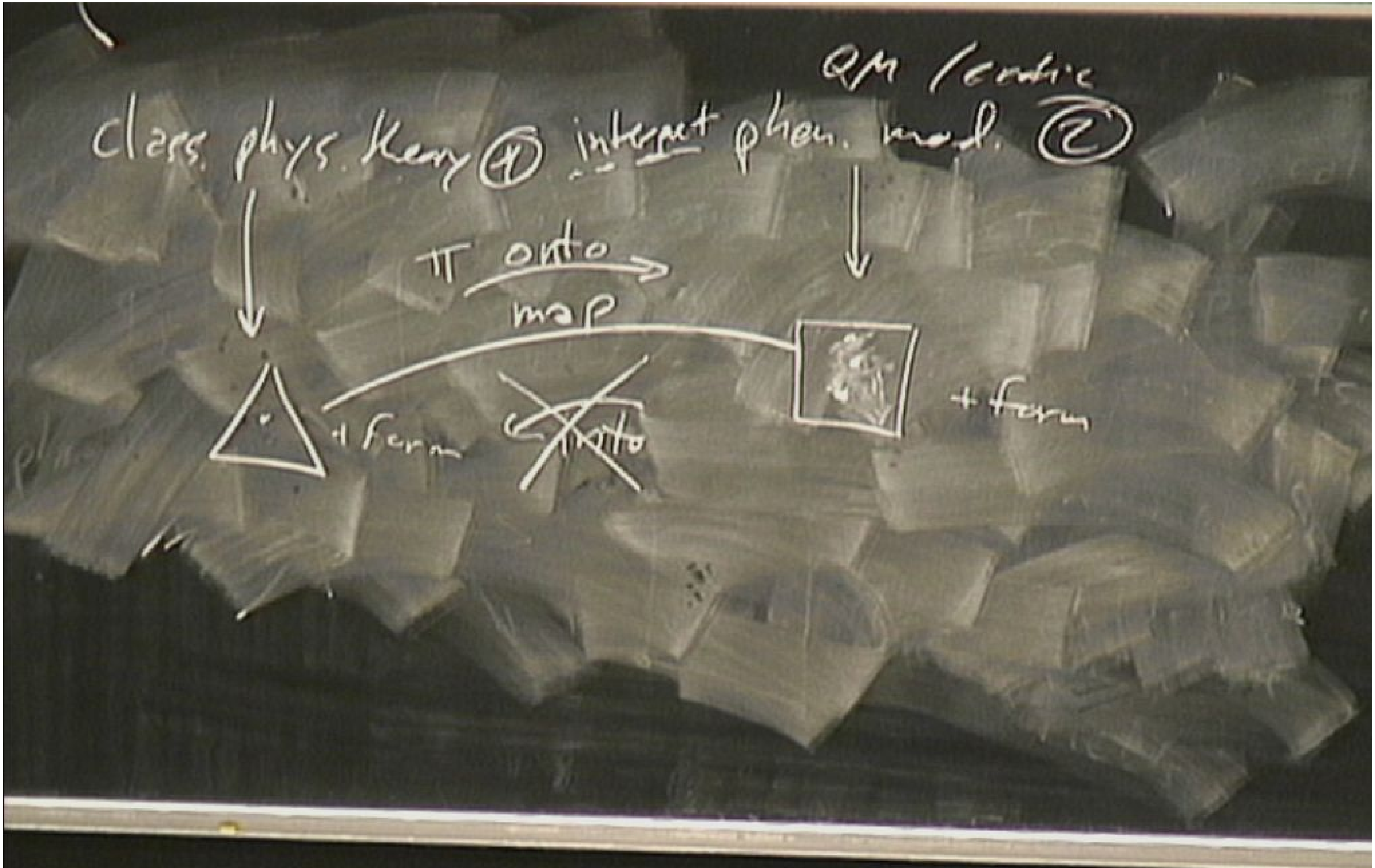
π onto map

+ ferm ~~onto~~ + ferm

-STATICAL-MODEL FRAMEWORK

classical exotic

pure state $\Rightarrow \pi^{-1}$(pure state)

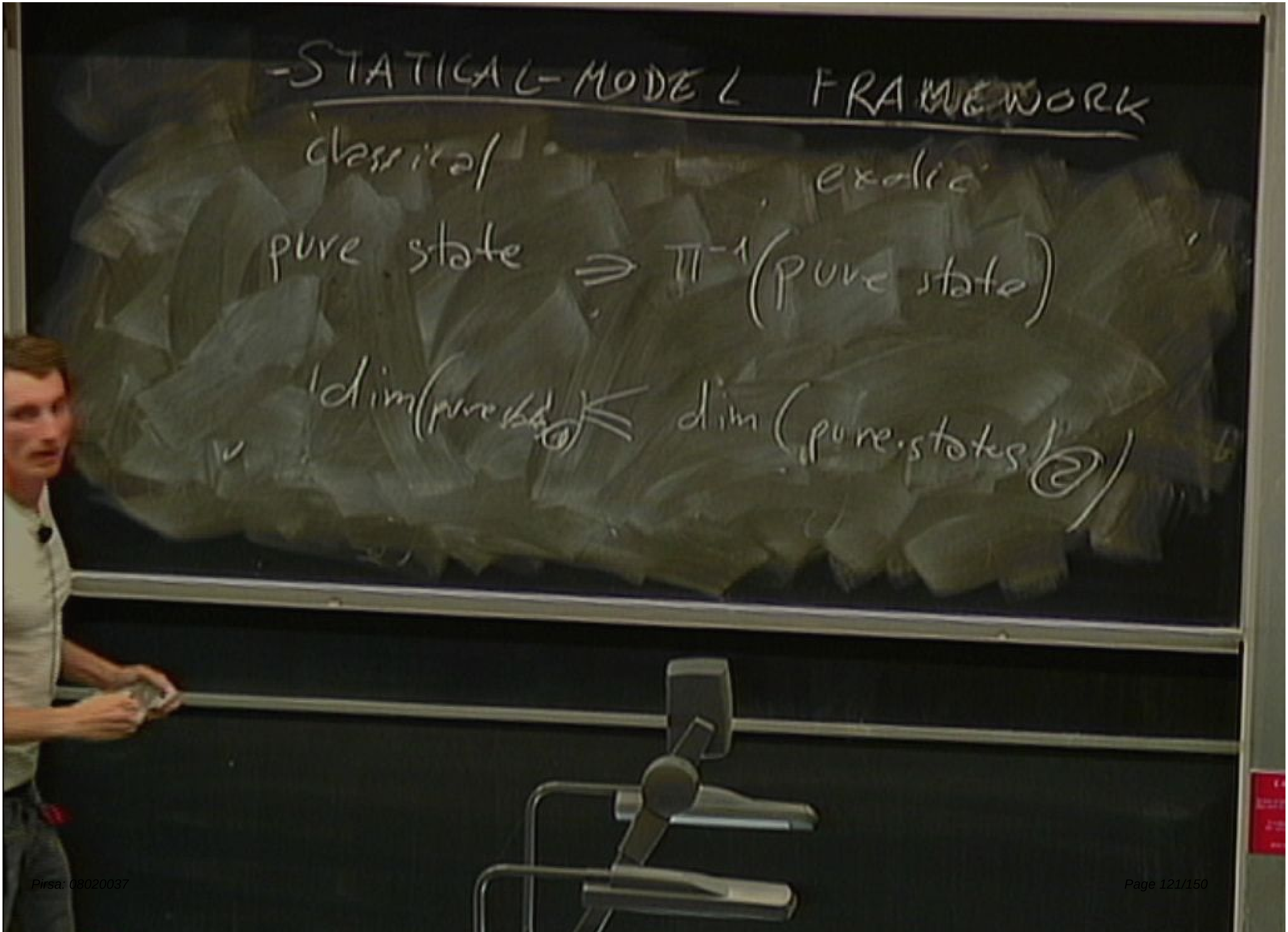

class. phys. theory ① interpret phen. mod. ②
π onto map
+ ferm
+ ferm

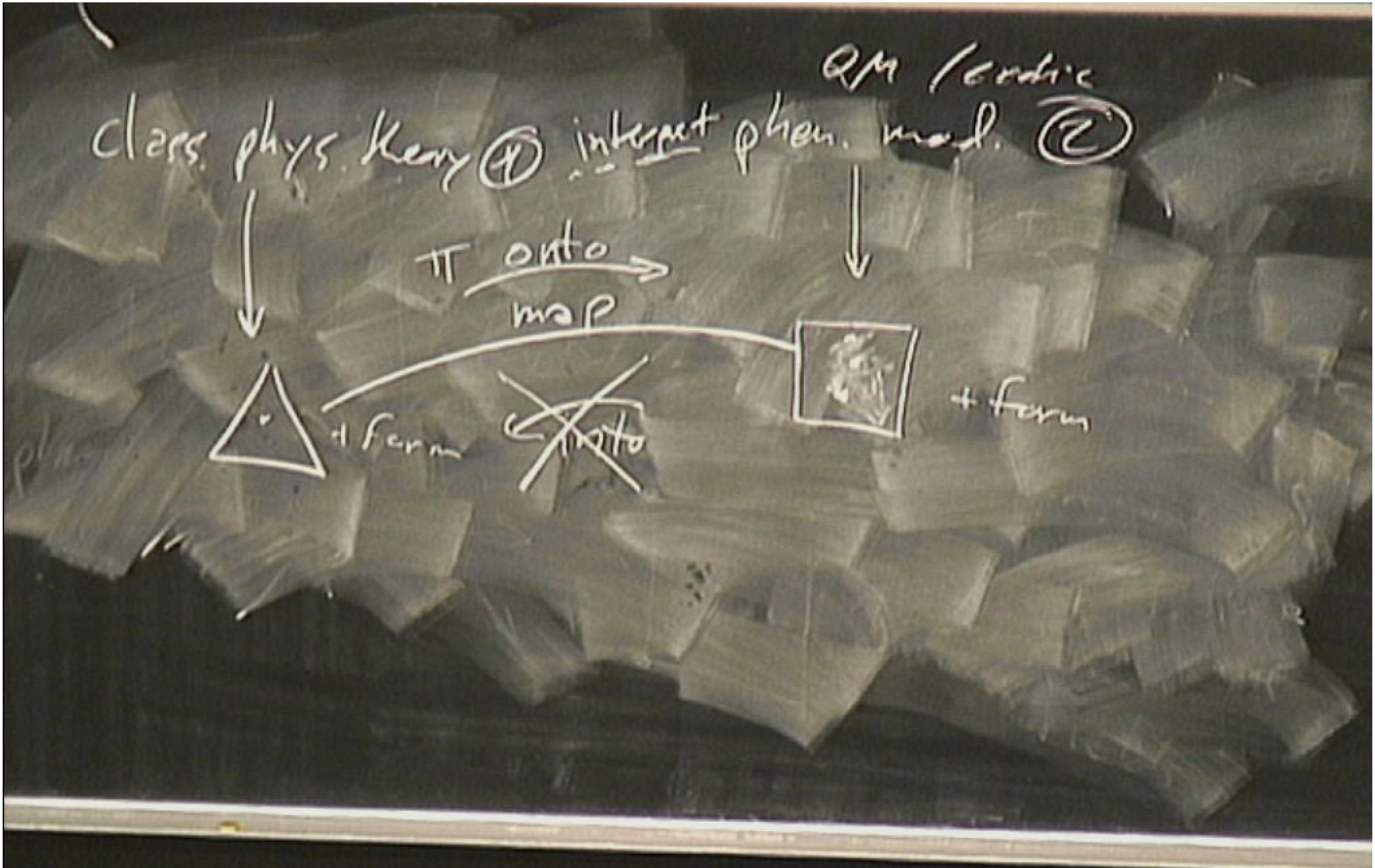
-STATICAL-MODEL FRAMEWORK

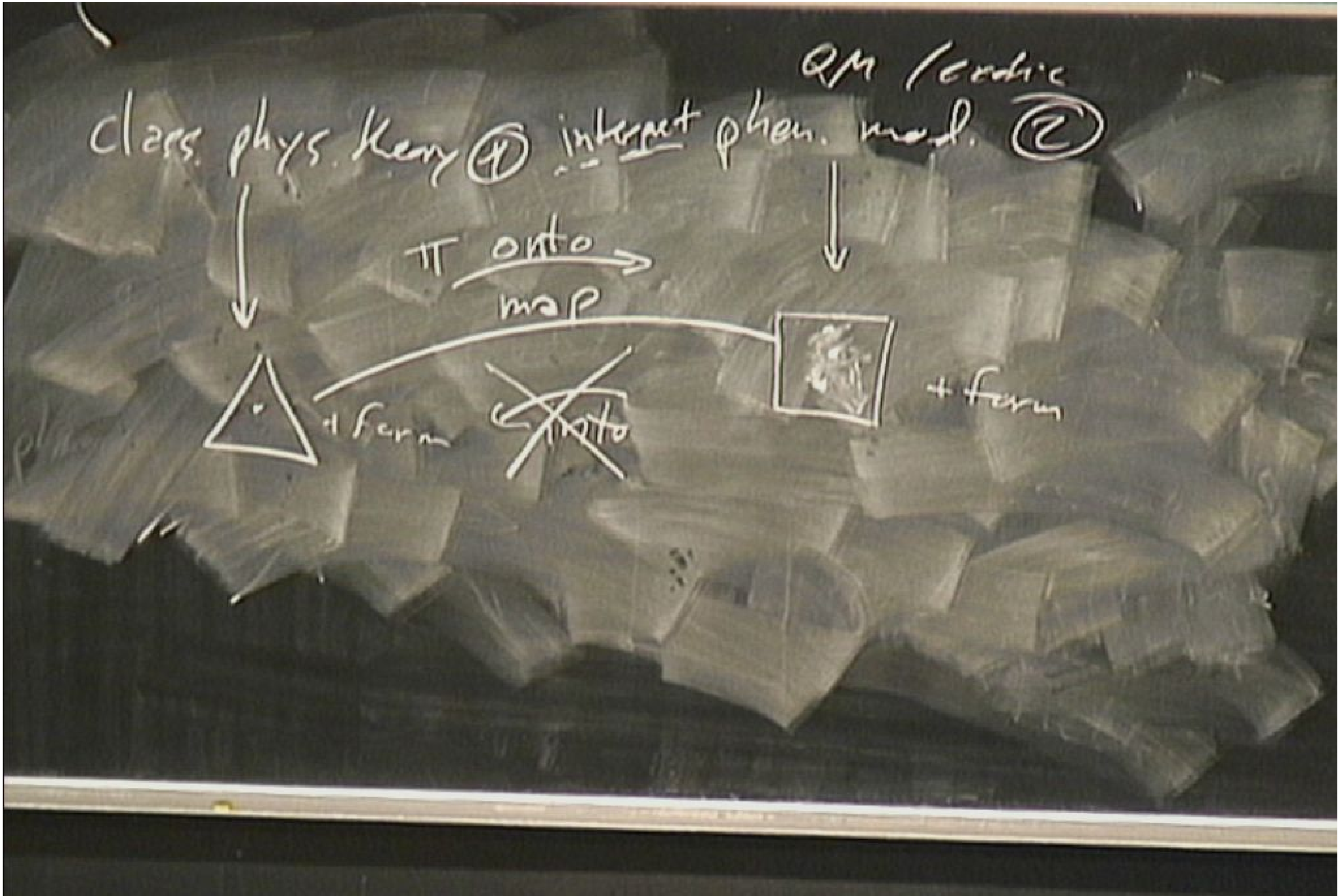
classical exotic

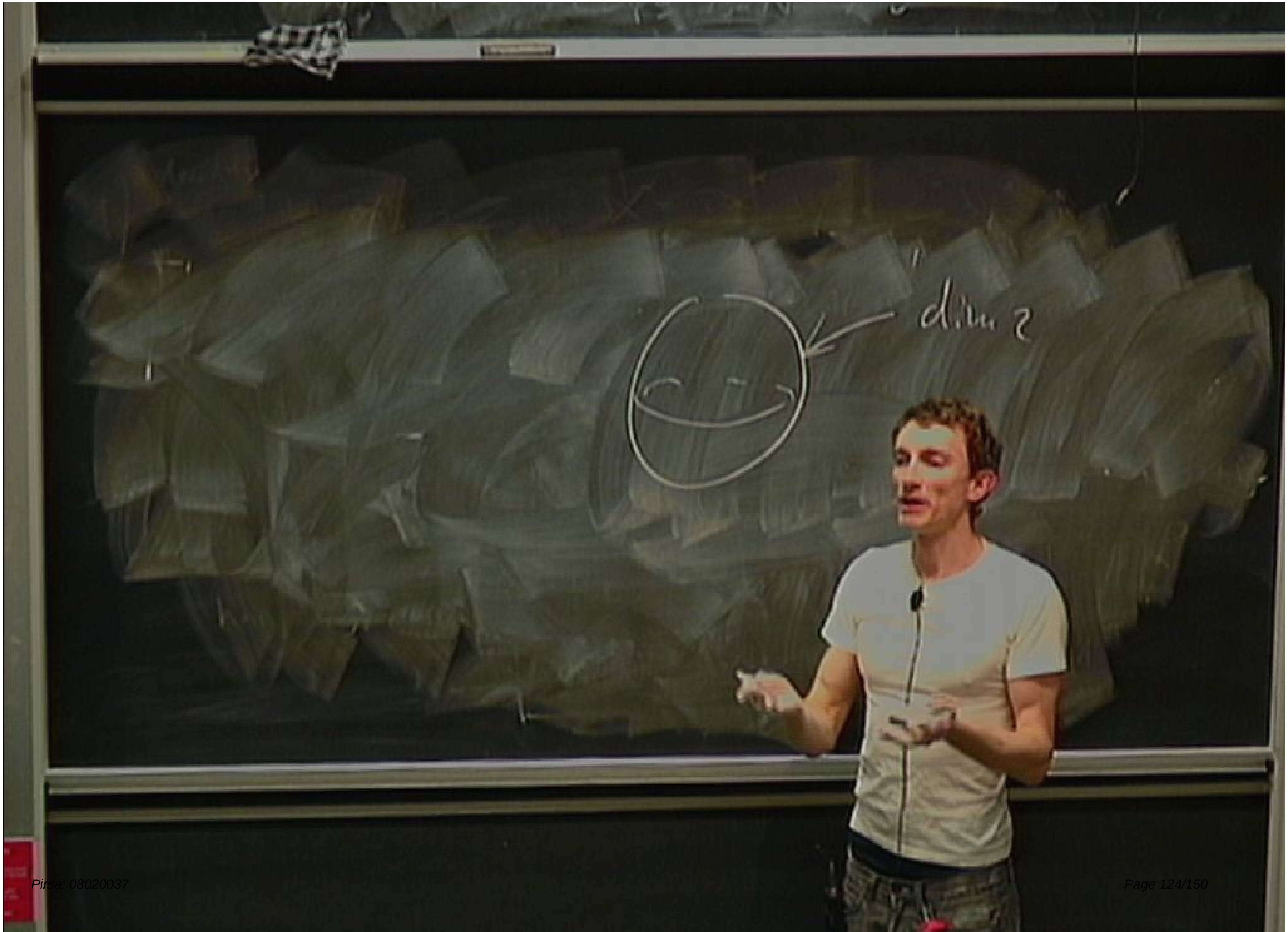
pure state $\Rightarrow \pi^{-1}$(pure state)

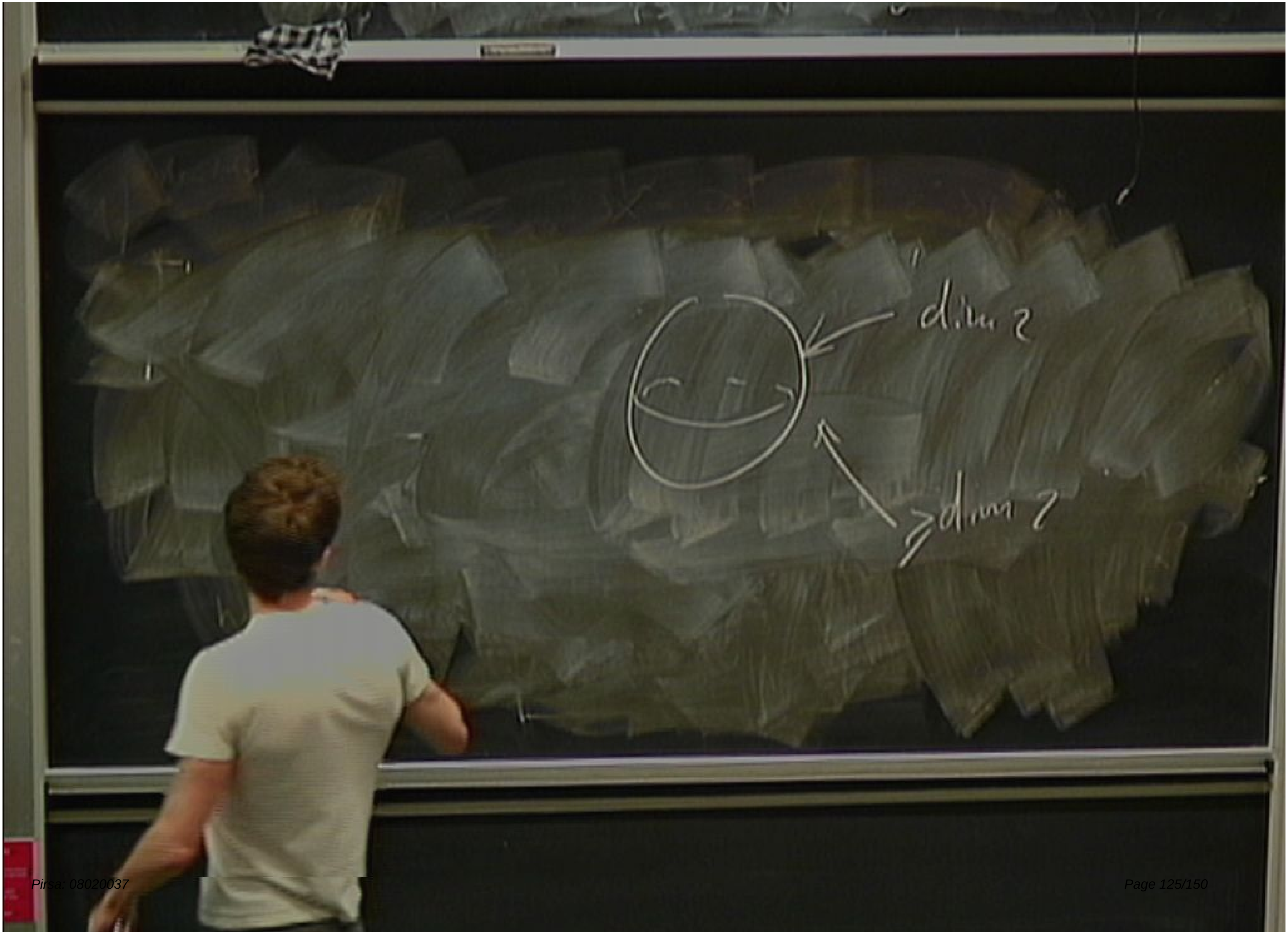
dim(pure states)


-STATICAL-MODEL FRAMEWORK
classical
exotic
pure state ⇒ π⁻¹(pure state)
dim(pure state@) < dim(pure states@)

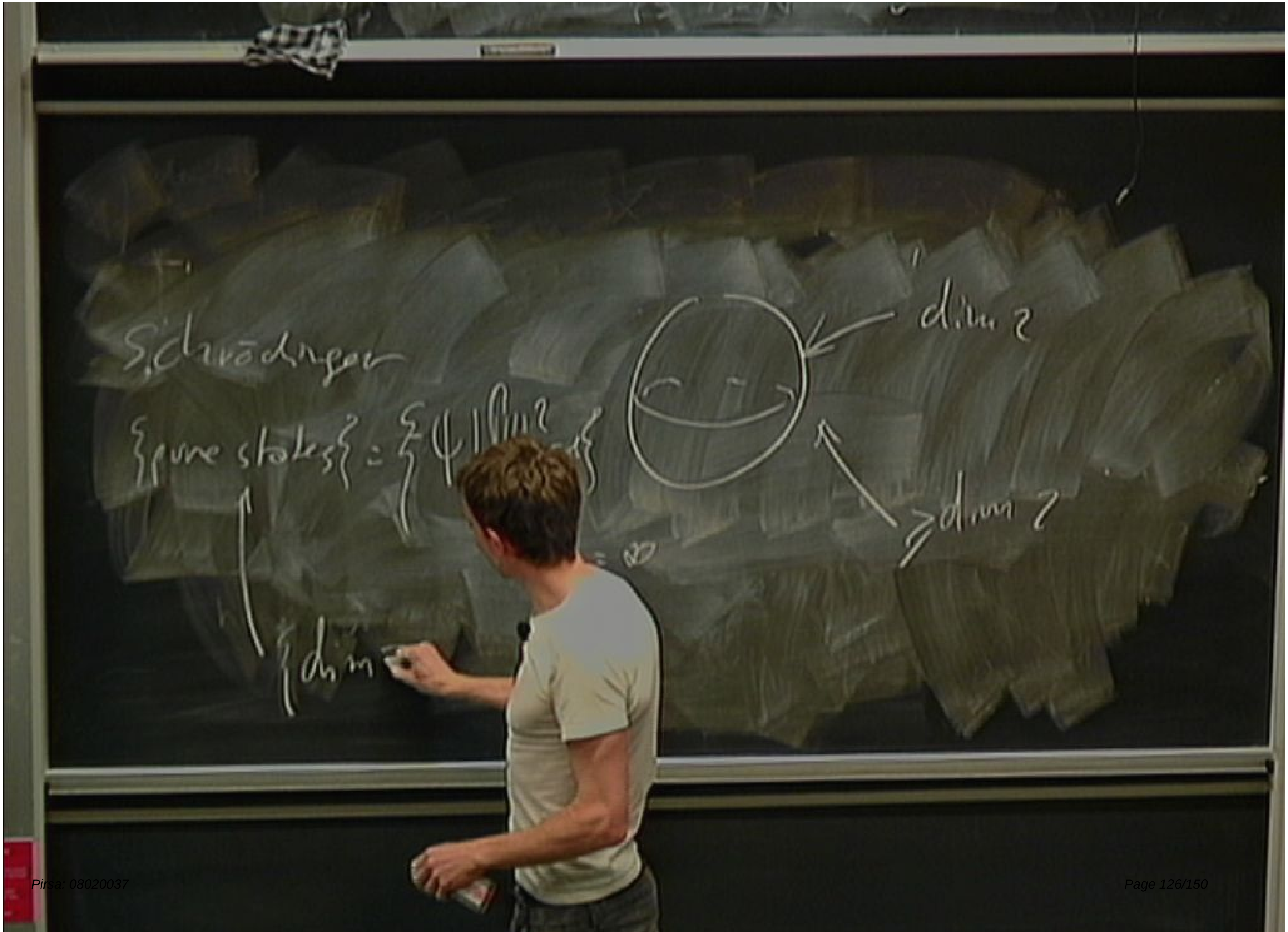

QM / ergodic
class. phys. theory (1) interpret phen. mod. (2)
π onto map
+ ferm
onto
+ ferm

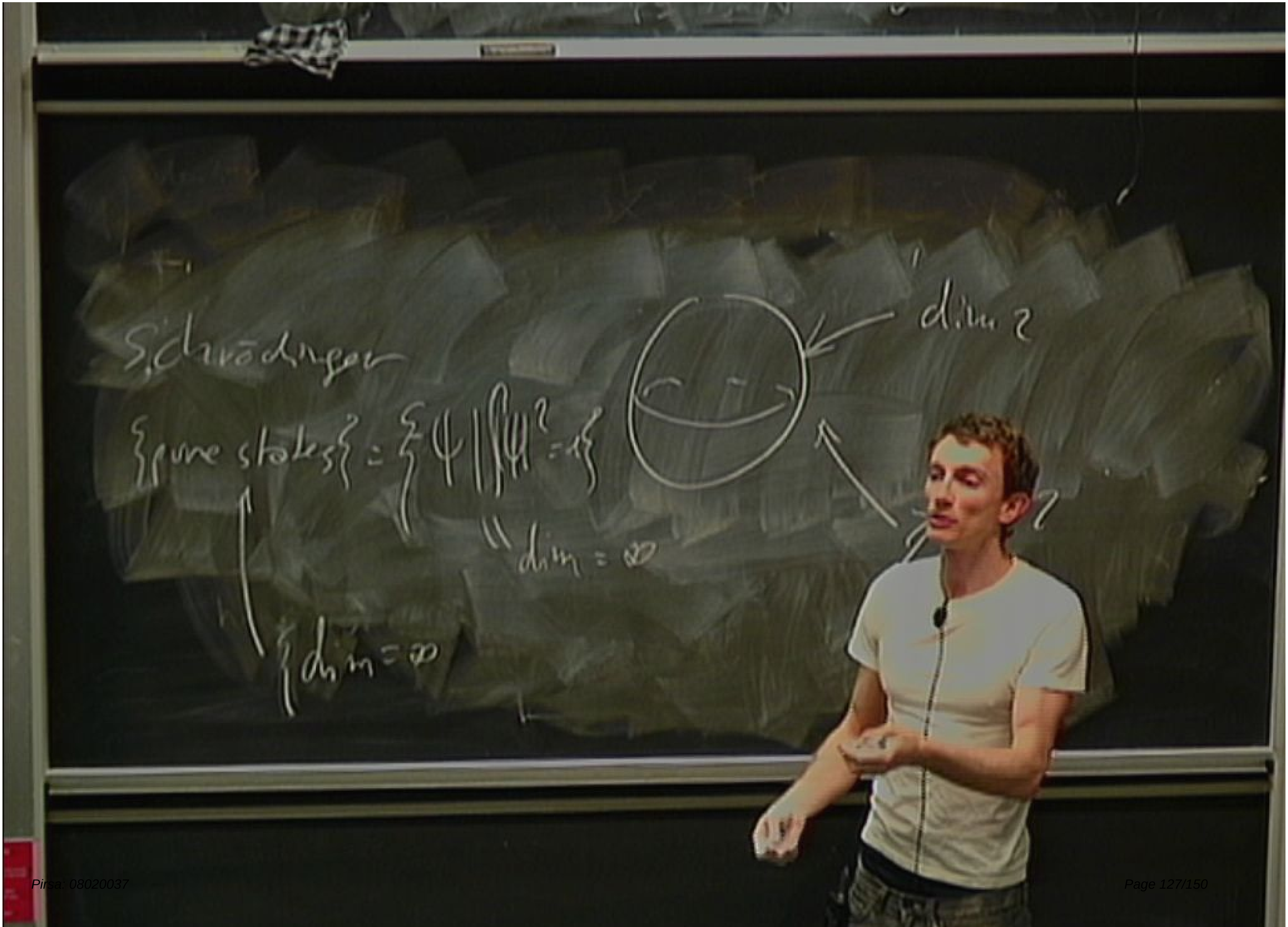

QM / ergodic
class. phys. theory ① interpret phen. mod. ②
π onto map
+ ferm
onto
+ ferm

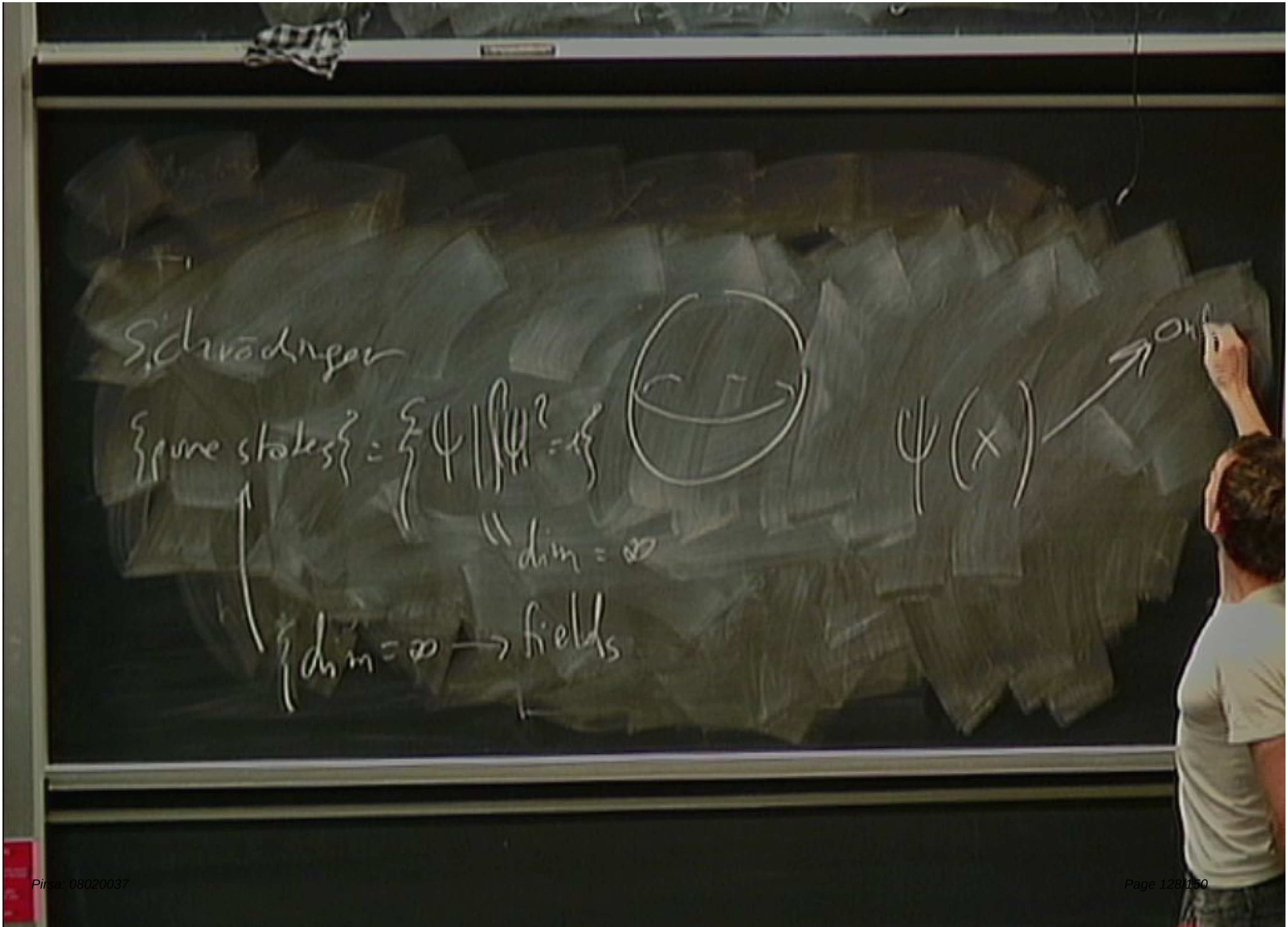

dim 2

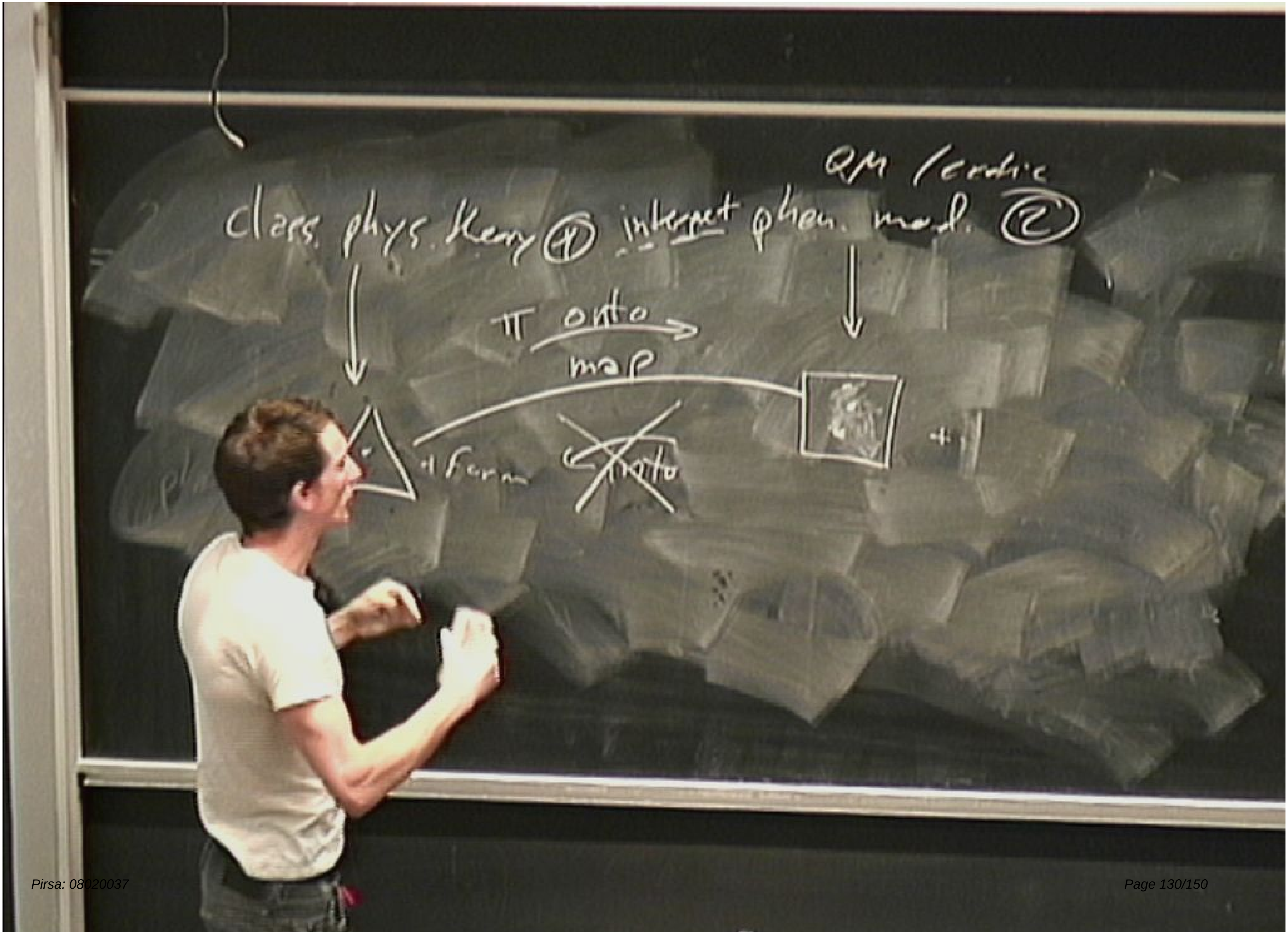


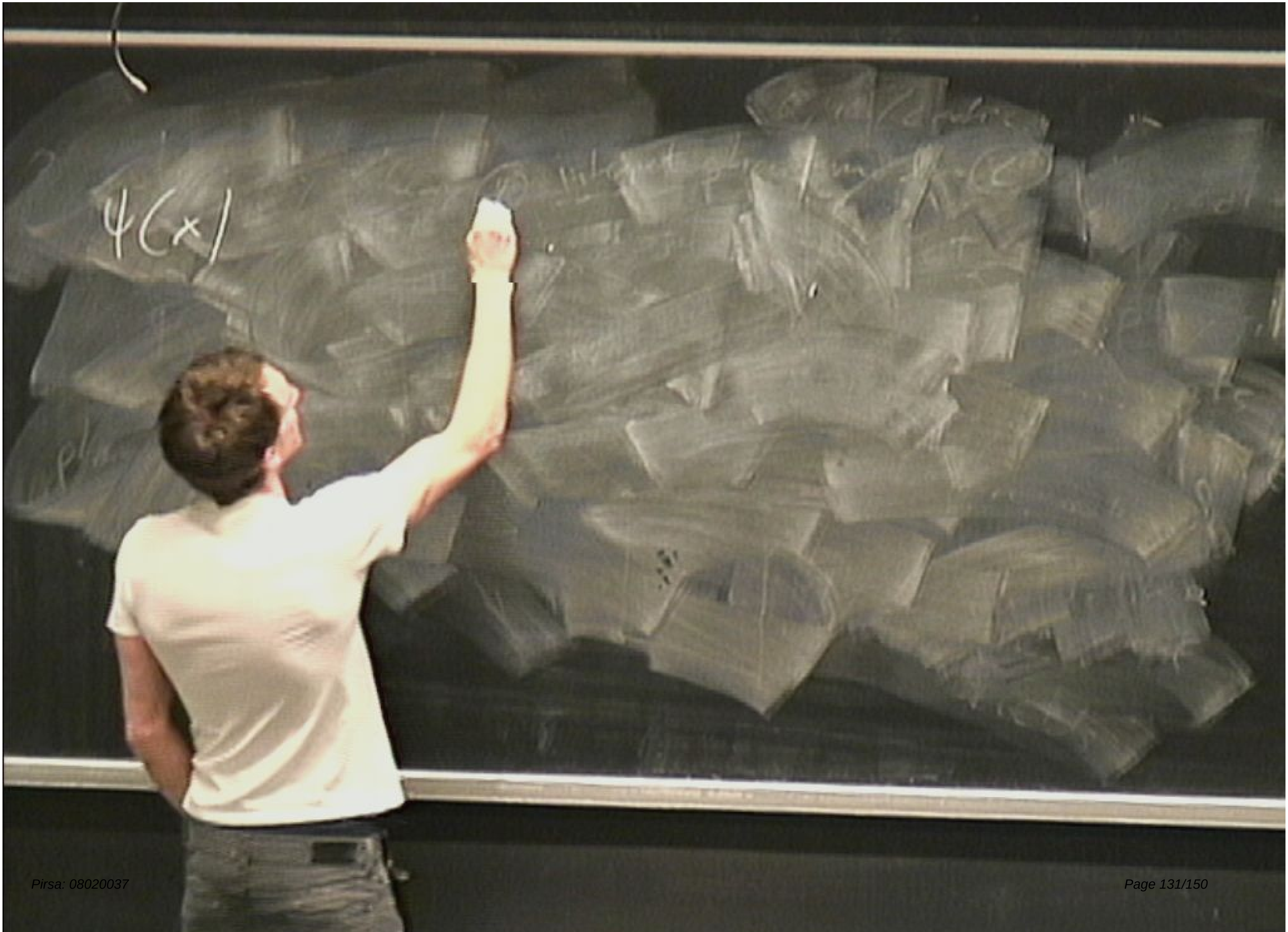
dim ?
≥ dim ?

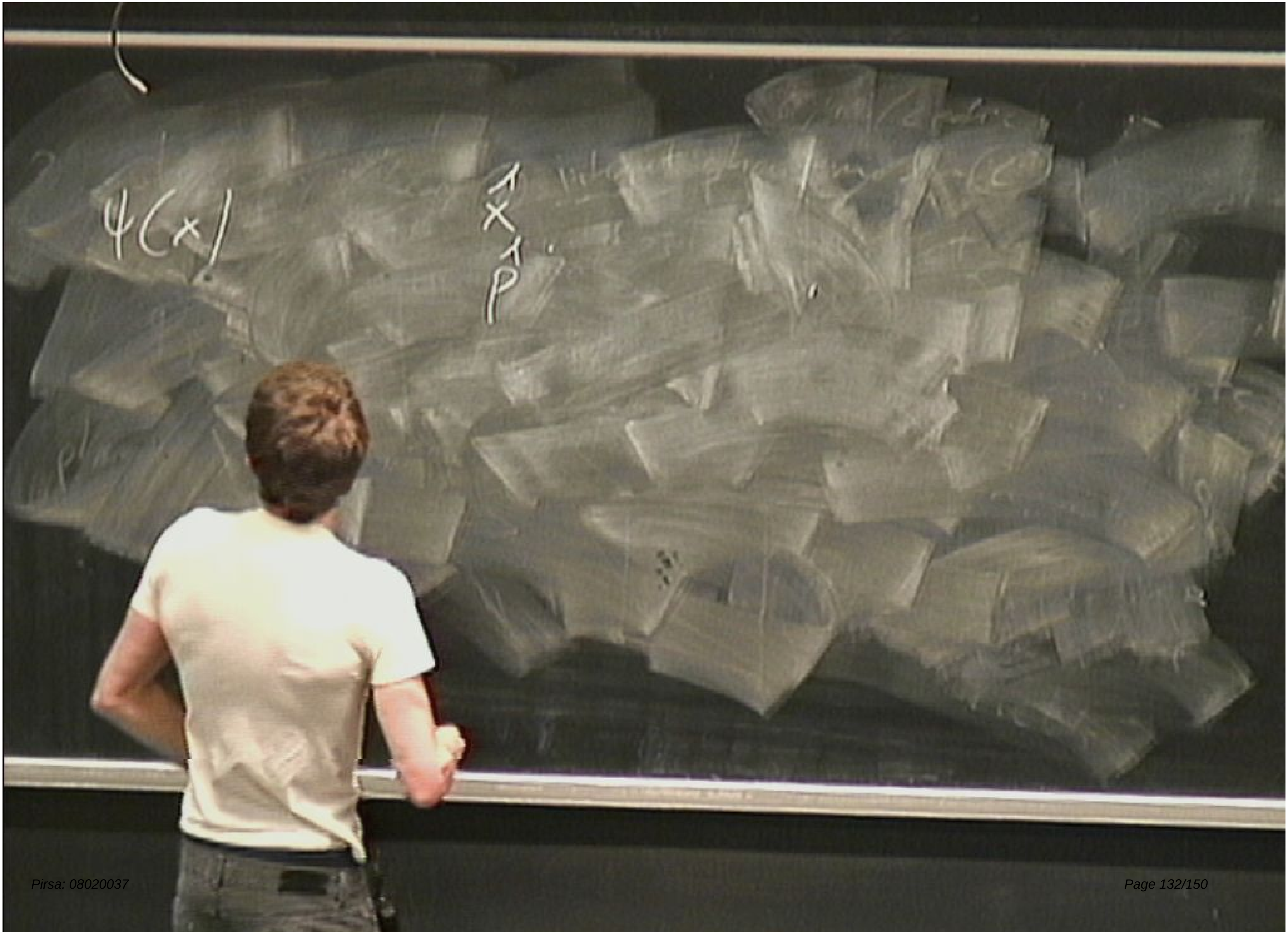

Schrödinger
{pure states} = {ψ |
dim 2
≥ dim 2
{dim

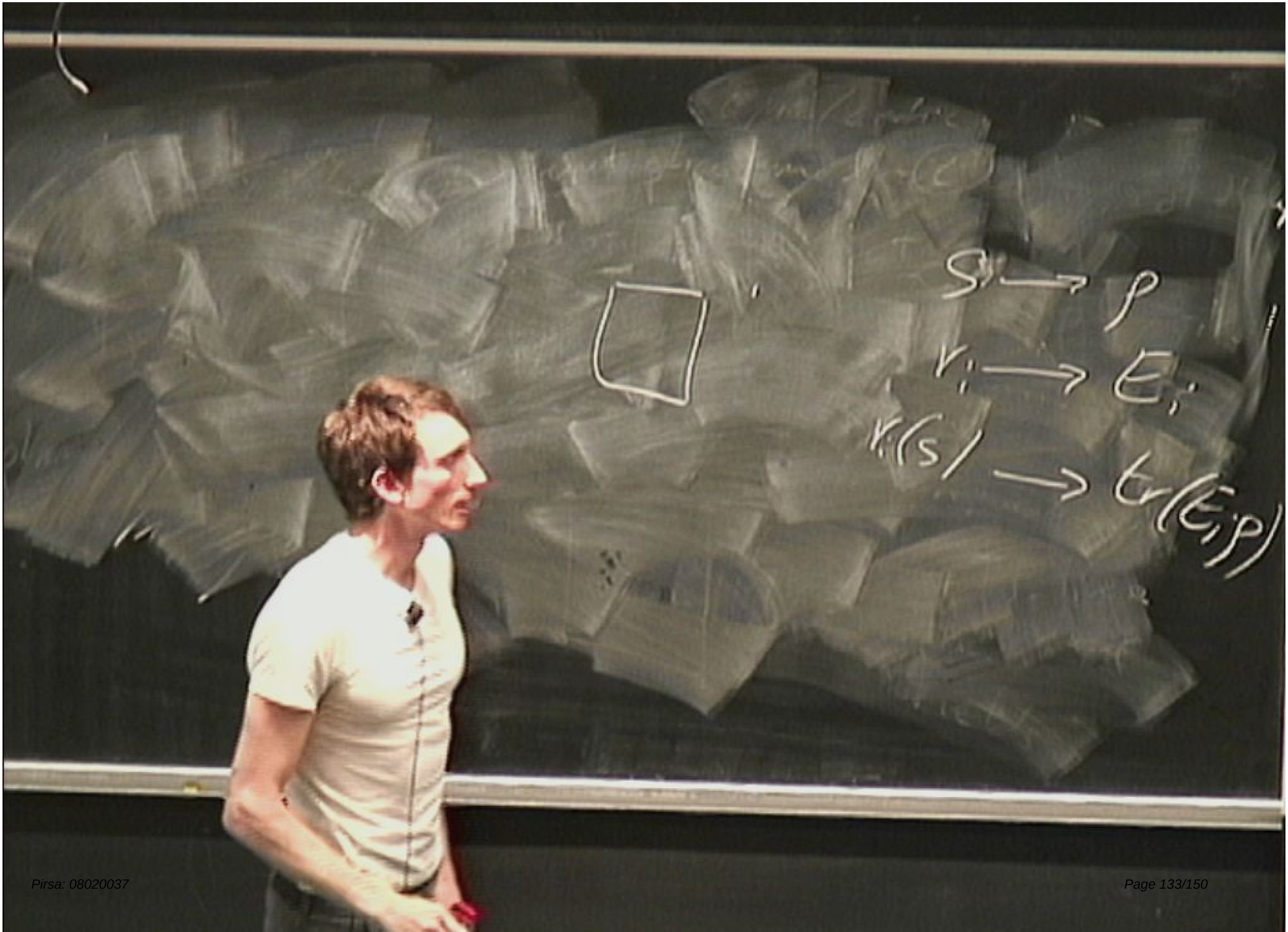

Schrödinger
{pure states} = {ψ | ∫|ψ|² = 1}
dim = ∞
dim = ∞
dim 2

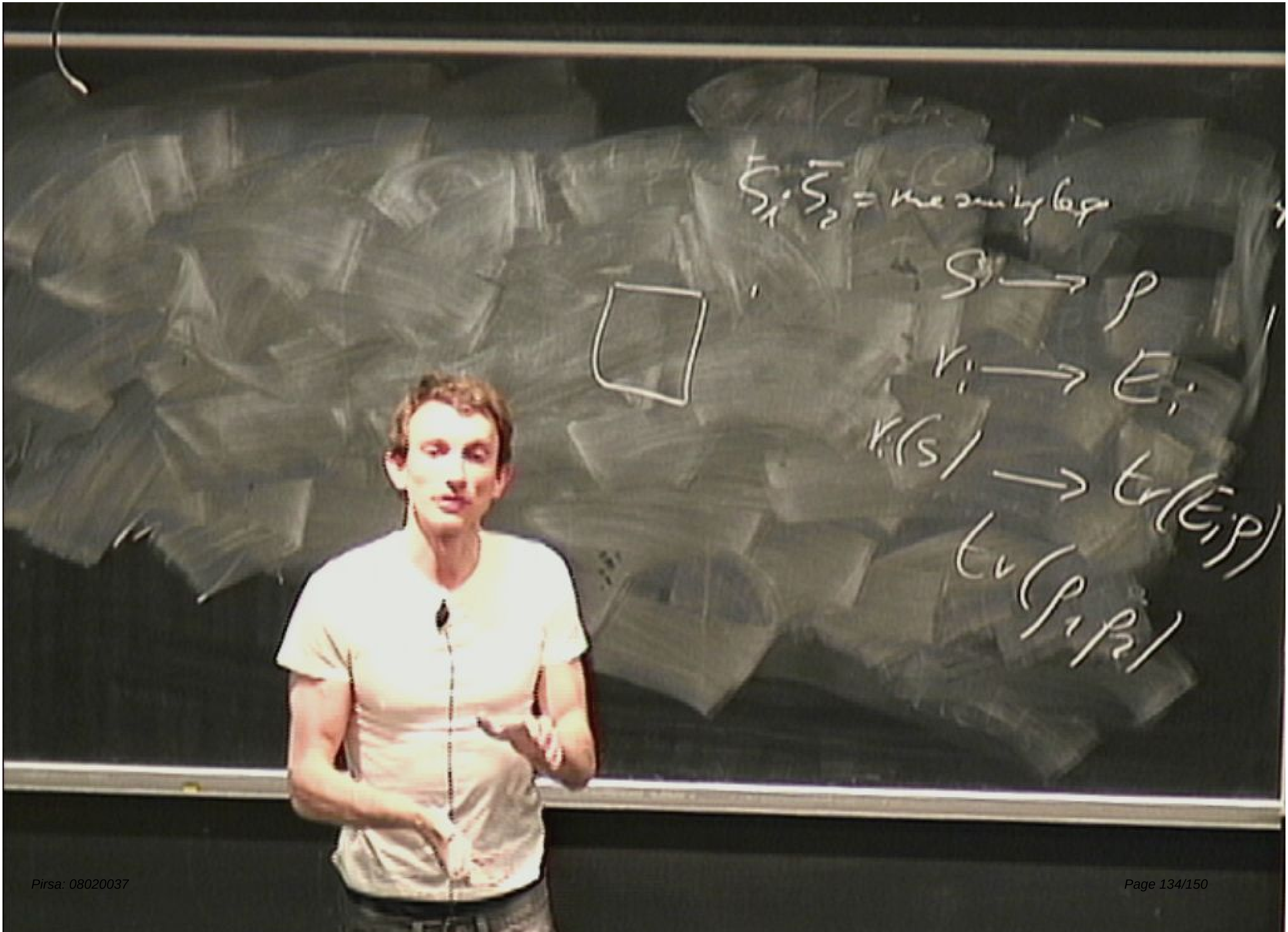

Schrödinger
{pure states} = {ψ | ∫|ψ|² = 1}
dim = ∞
dim = ∞ → fields
ψ(x)


QM / ergodic
class. phys. theory ① interpret phen. mod. ②
π onto map
+ form
onto
+


ψ(x)


ψ(x)
X̂
P̂


S → ρ
r_i → E_i
r_i(s) → tr(E_i ρ)


S ⟶ ρ
r_i ⟶ E_i
r_i(s) ⟶ tr(E_i ρ)
tr(ρ_1 ρ_2)

definitions of

MUB, SIC

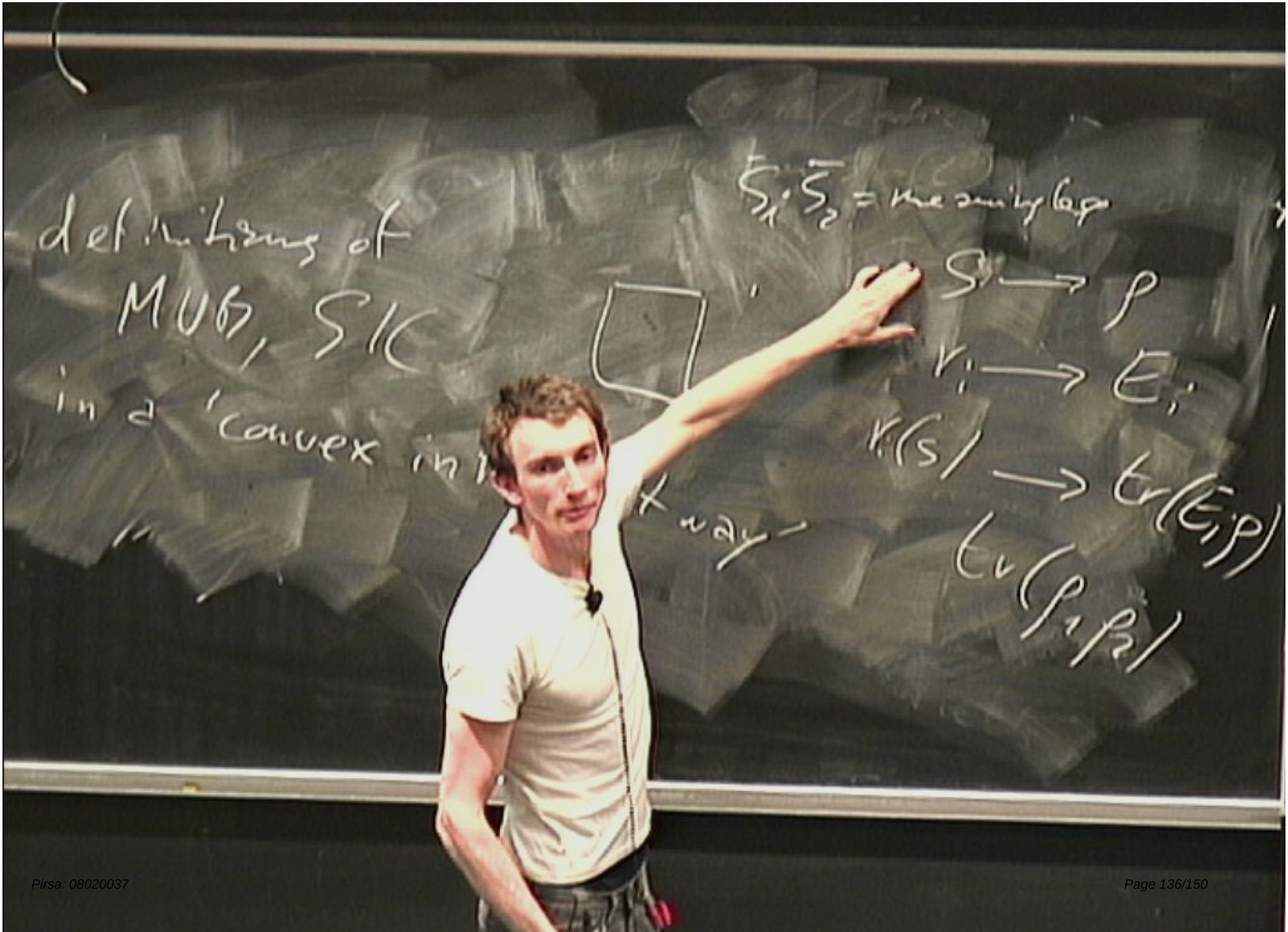
ξ_1, ξ_2 = the ... lengths

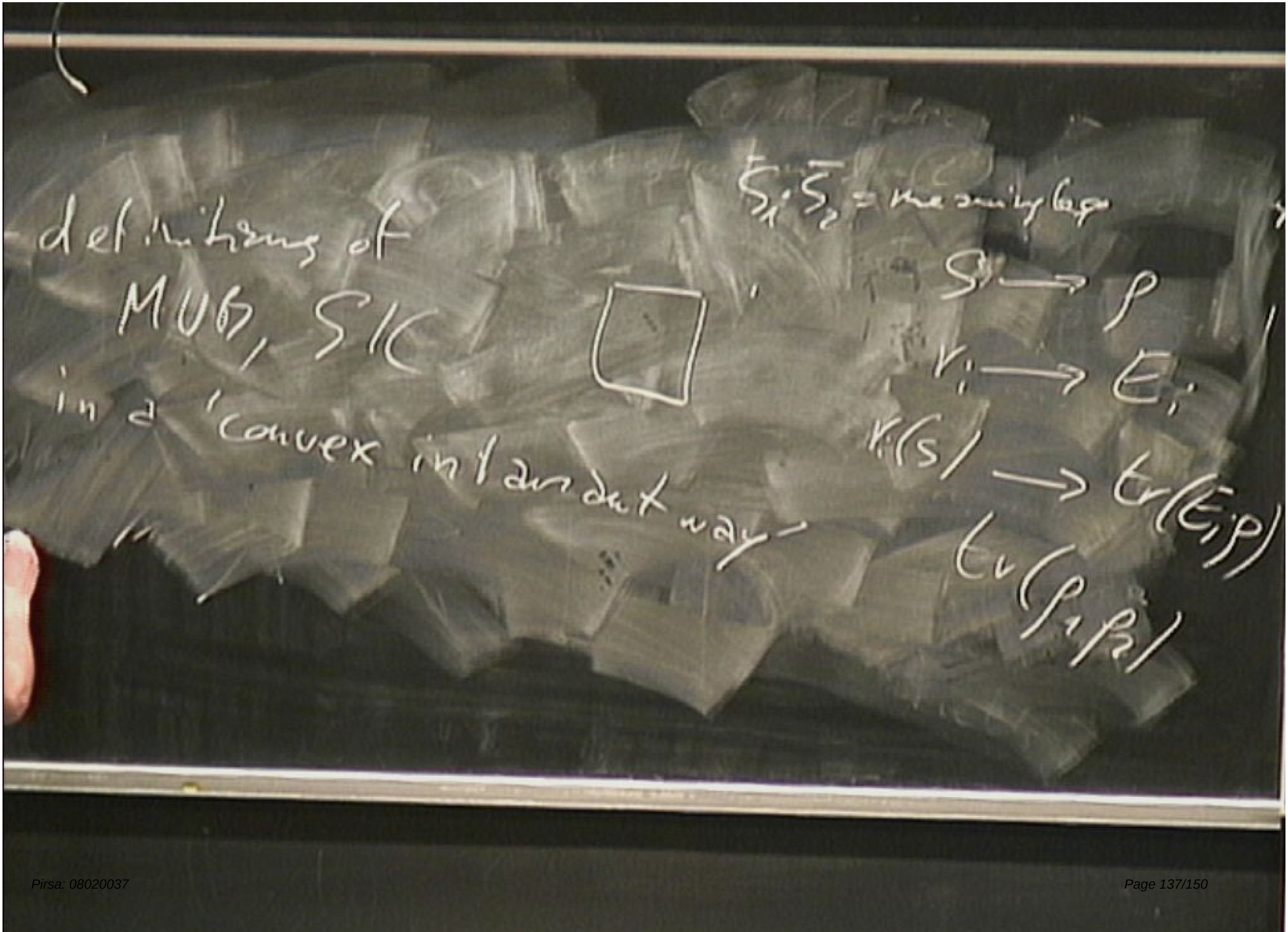
$S \longrightarrow \rho$

$r_i \longrightarrow E_i$

$r_i(s) \longrightarrow tr(E_i \rho)$

$tr(\rho_1 \rho_2)$


definitions of
MUB, SIC
in a 'convex
way
ρ
E_i
$tr(E_i\rho)$


definitions of
MUB, SIC
in a 'convex independent way'
$s \longrightarrow \rho$
$r_i \longrightarrow E_i$
$r_i(s) \longrightarrow tr(E_i\rho)$
$tr(\rho_1\rho_2)$

- definitions of MUB, SIC in a 'convex independent way'
- generalization
- entropy

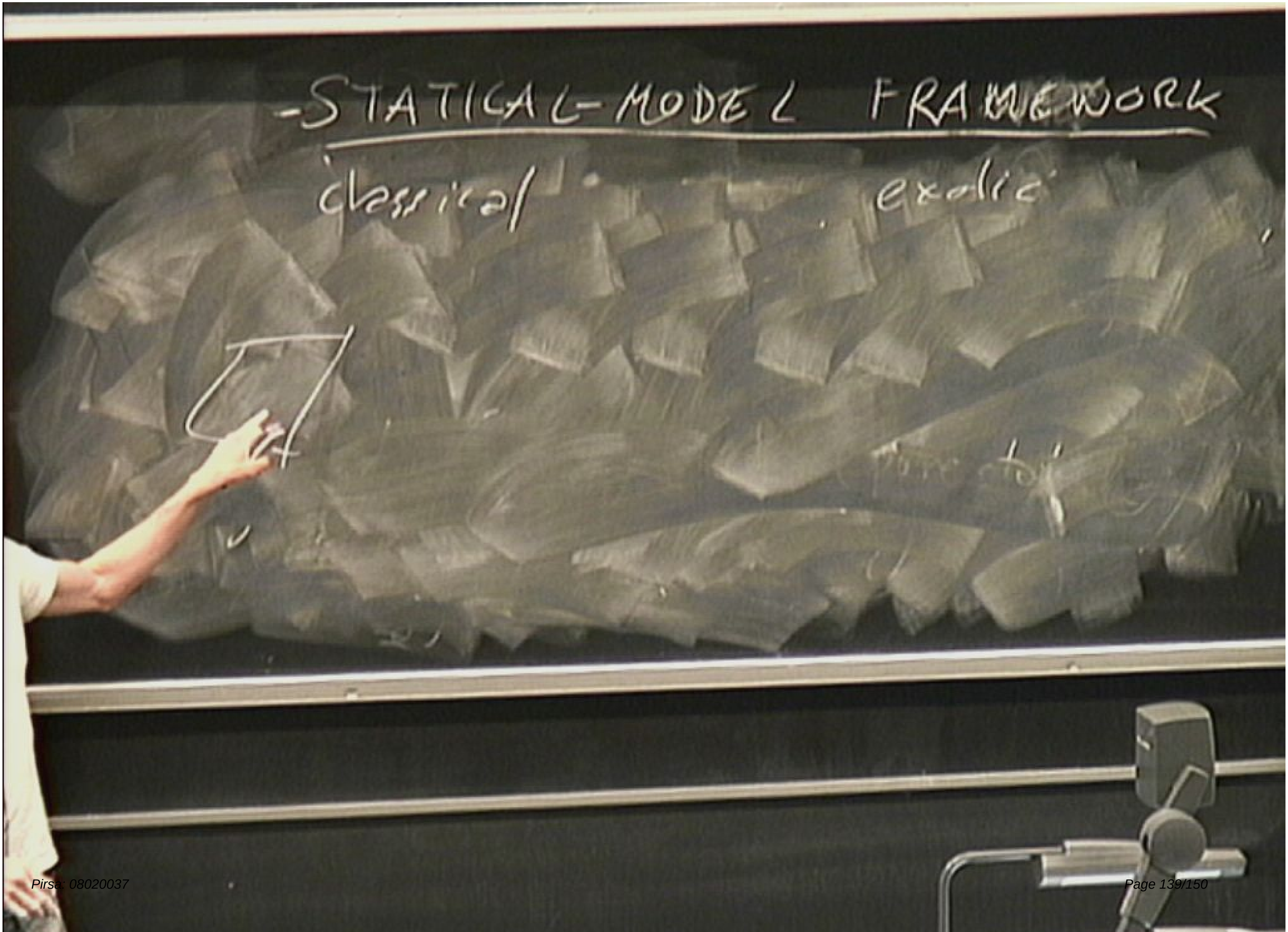
ξ_1, ξ_2 = measuring [illegible]

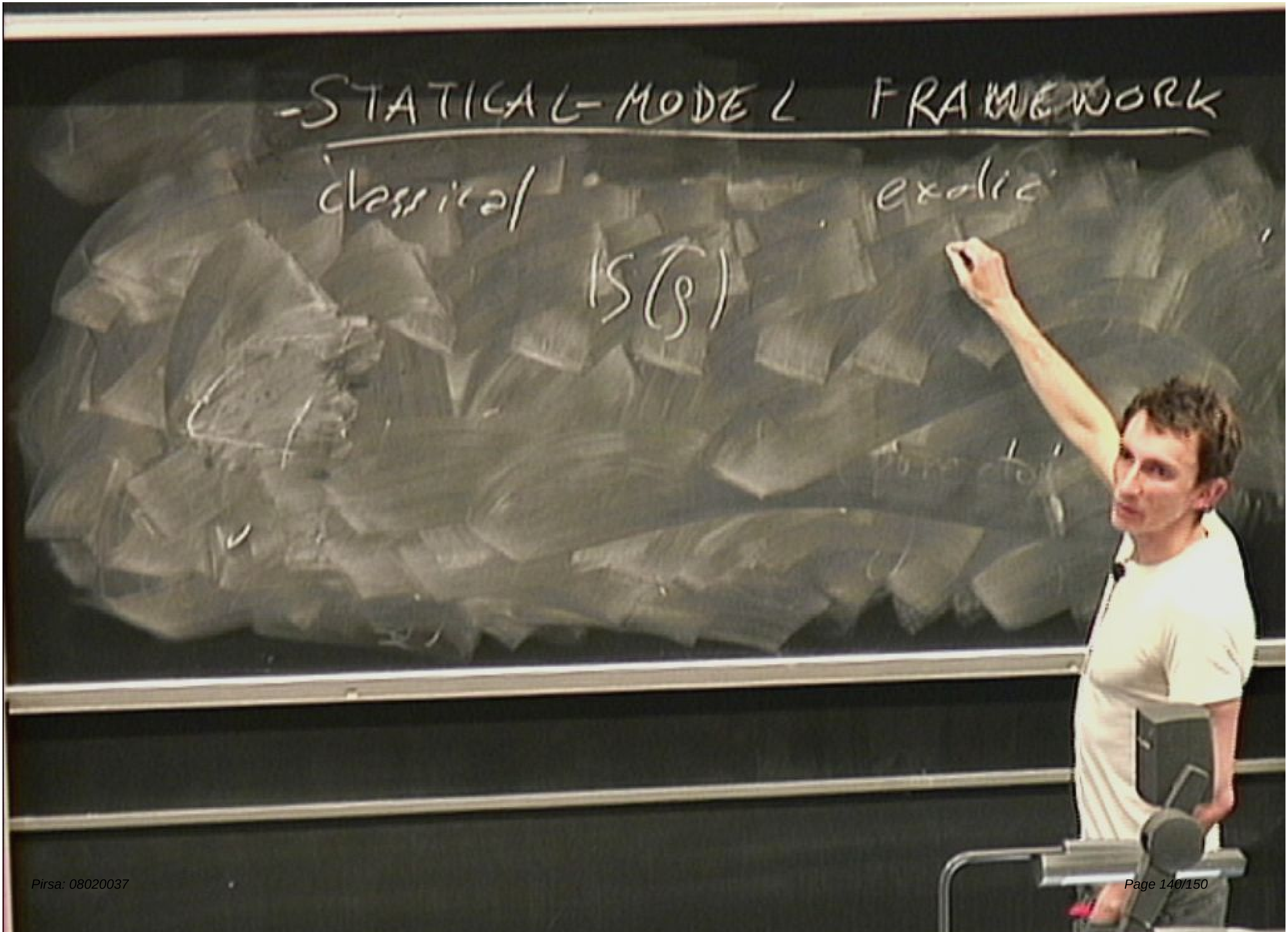
$S \longrightarrow \rho$

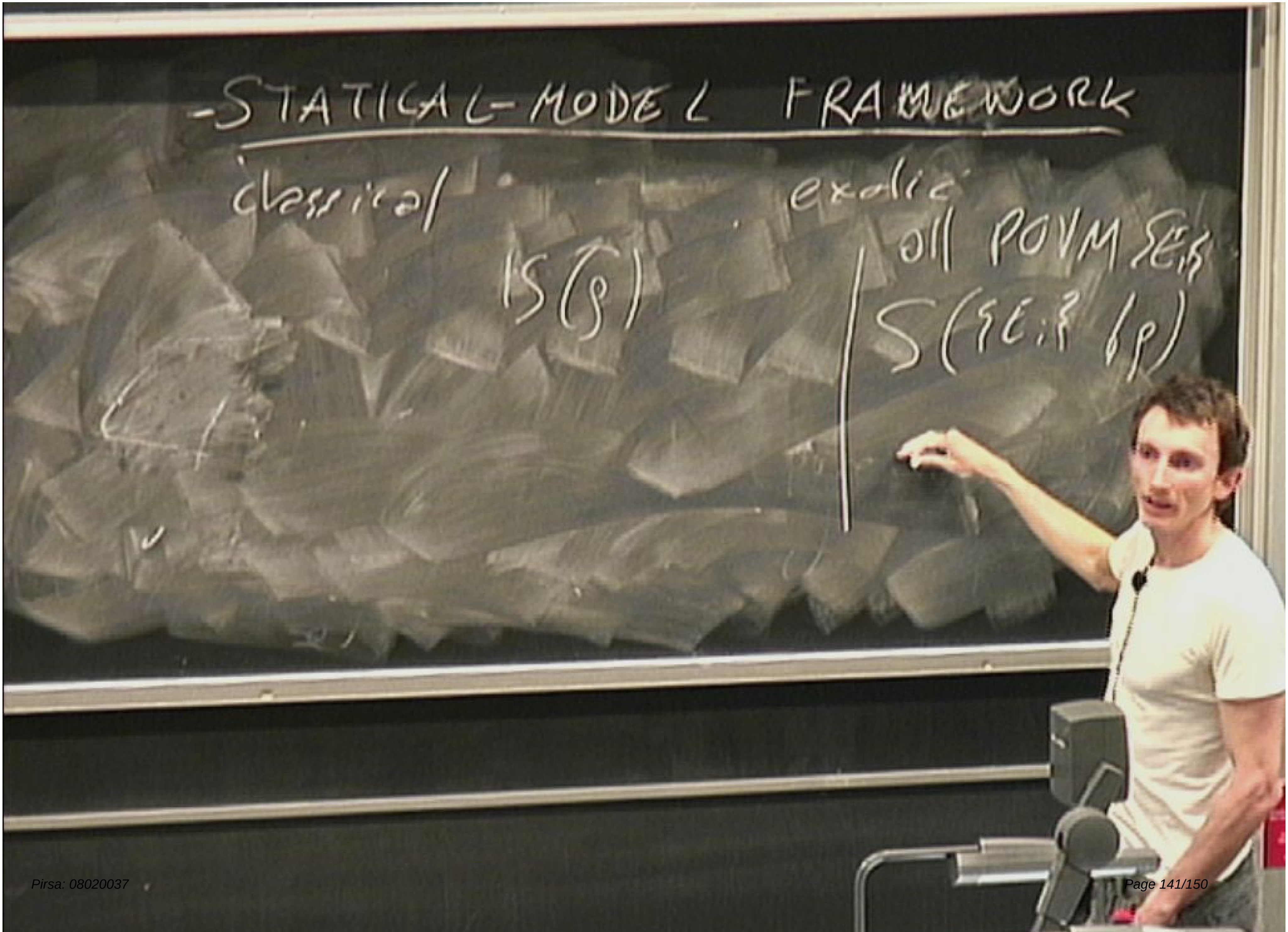
$r_i \longrightarrow E_i$

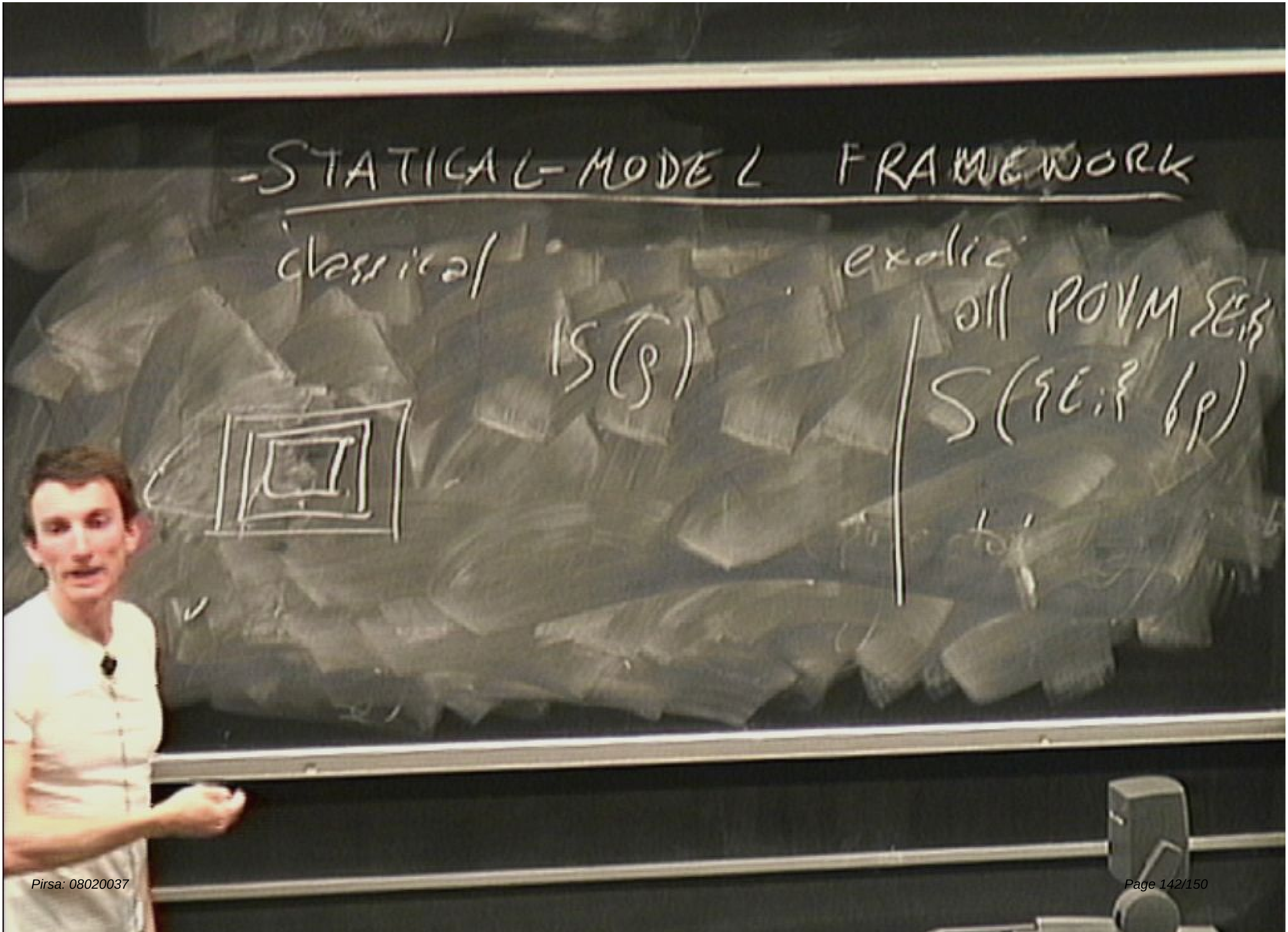
$r_i(s) \longrightarrow tr(E_i \rho)$

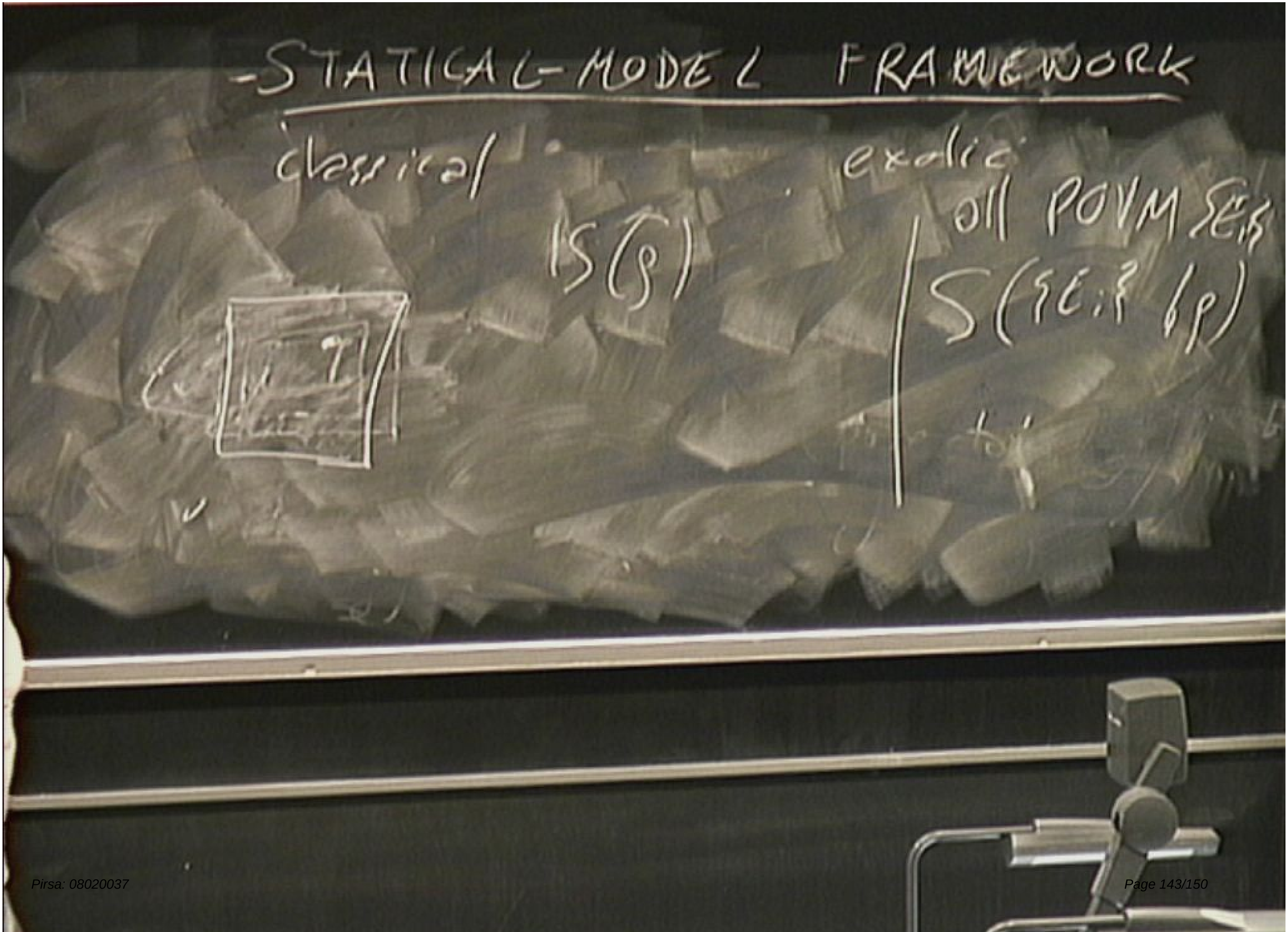
$tr(\rho_1 \rho_2)$


-STATICAL-MODEL FRAMEWORK
classical
exotic

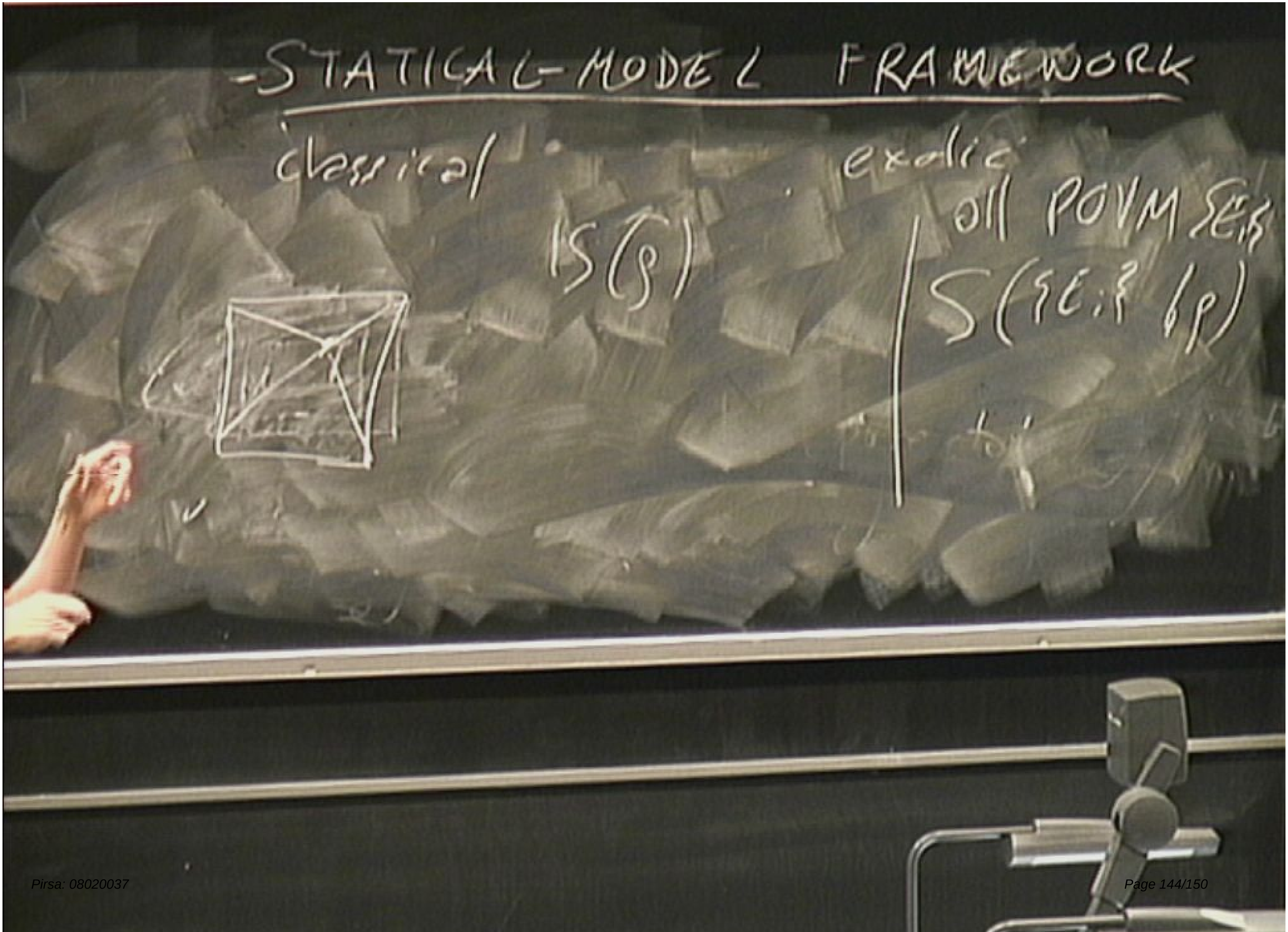

-STATICAL-MODEL FRAMEWORK
classical
exotic
S(ρ)

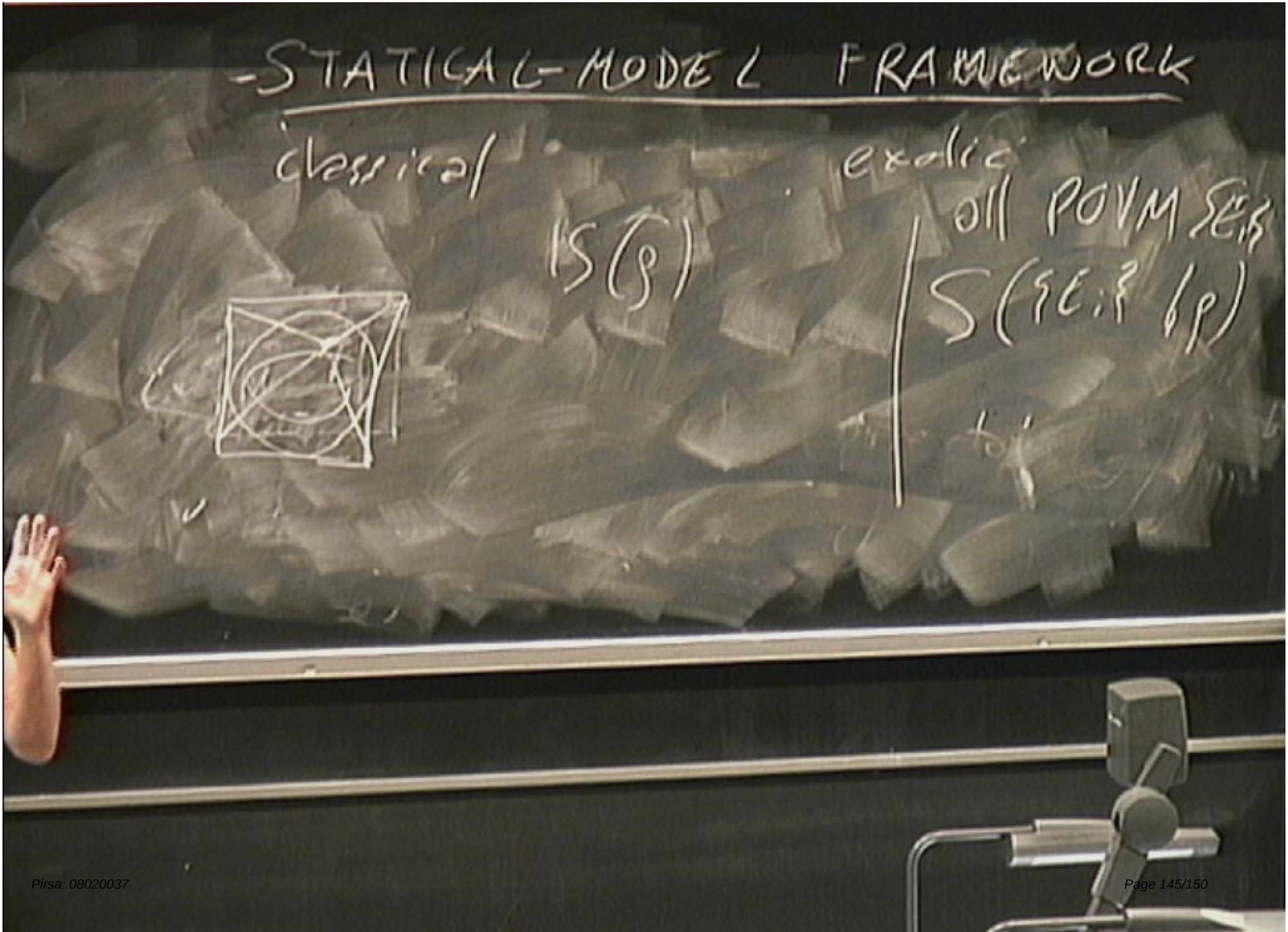

STATICAL-MODEL FRAMEWORK
classical/
exotic
all POVM $\{E_k\}$
$S(\rho)$
$S(\{E_k\}, \rho)$

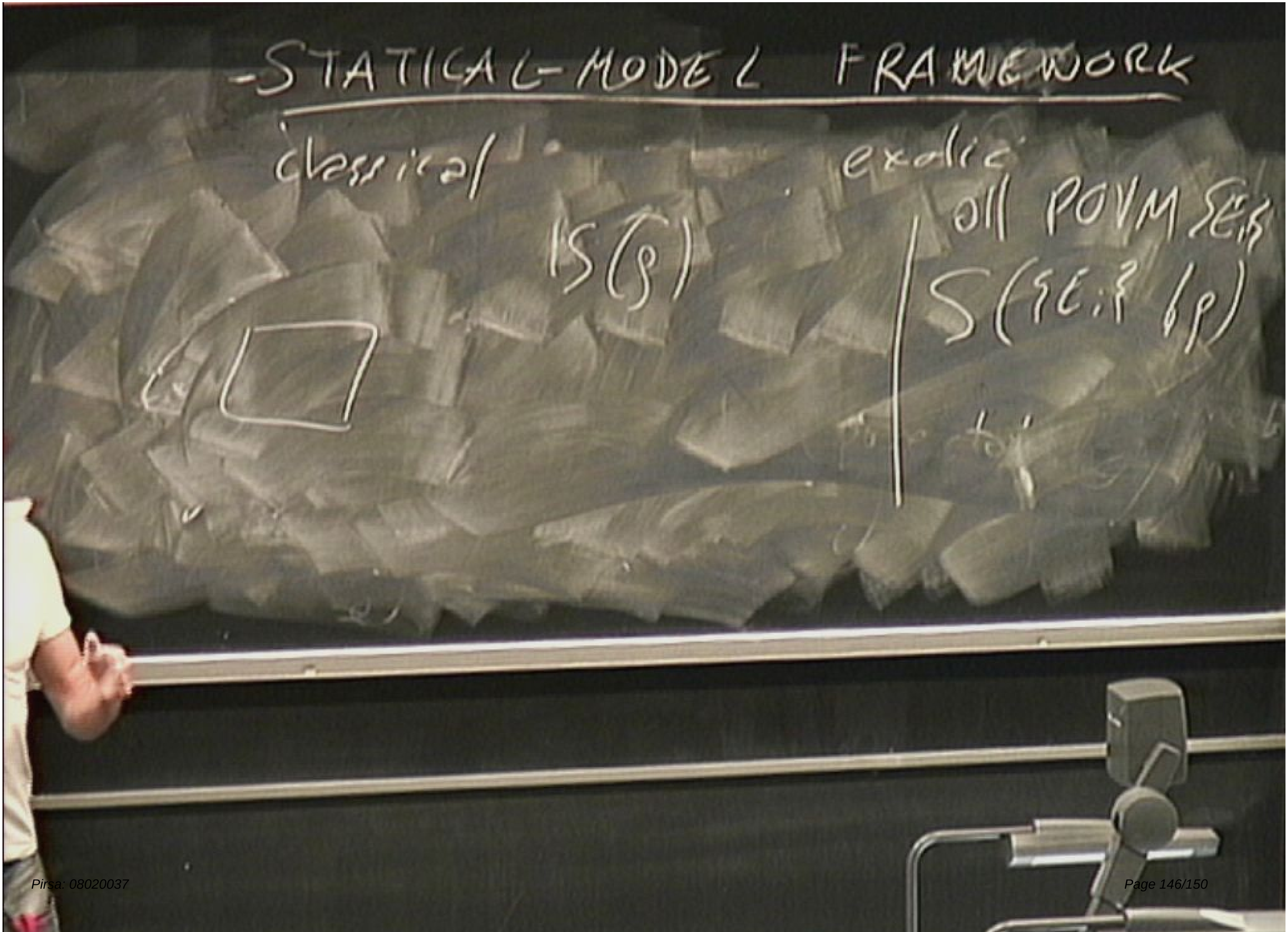

STATICAL-MODEL FRAMEWORK
classical
exotic
all POVM

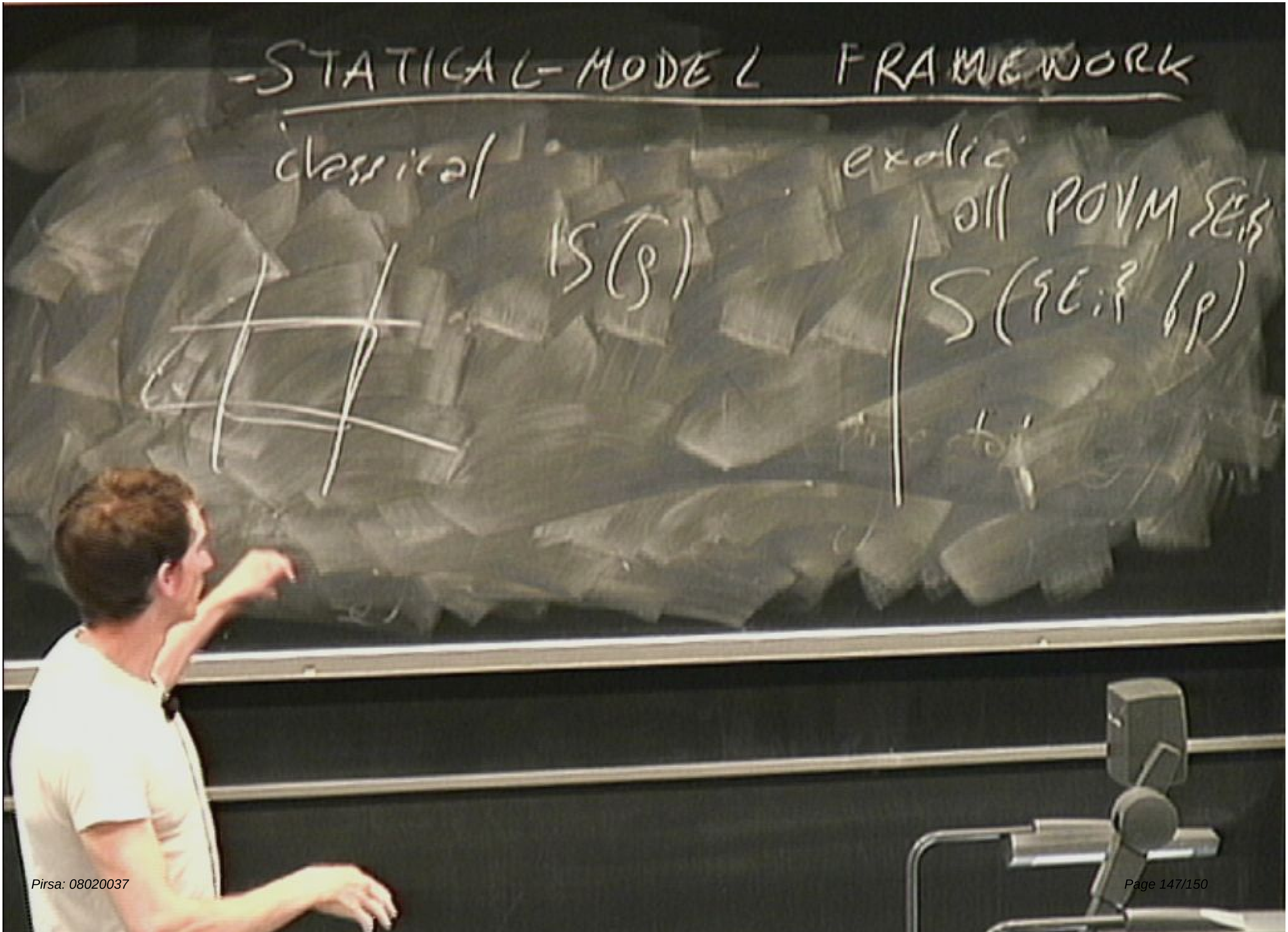


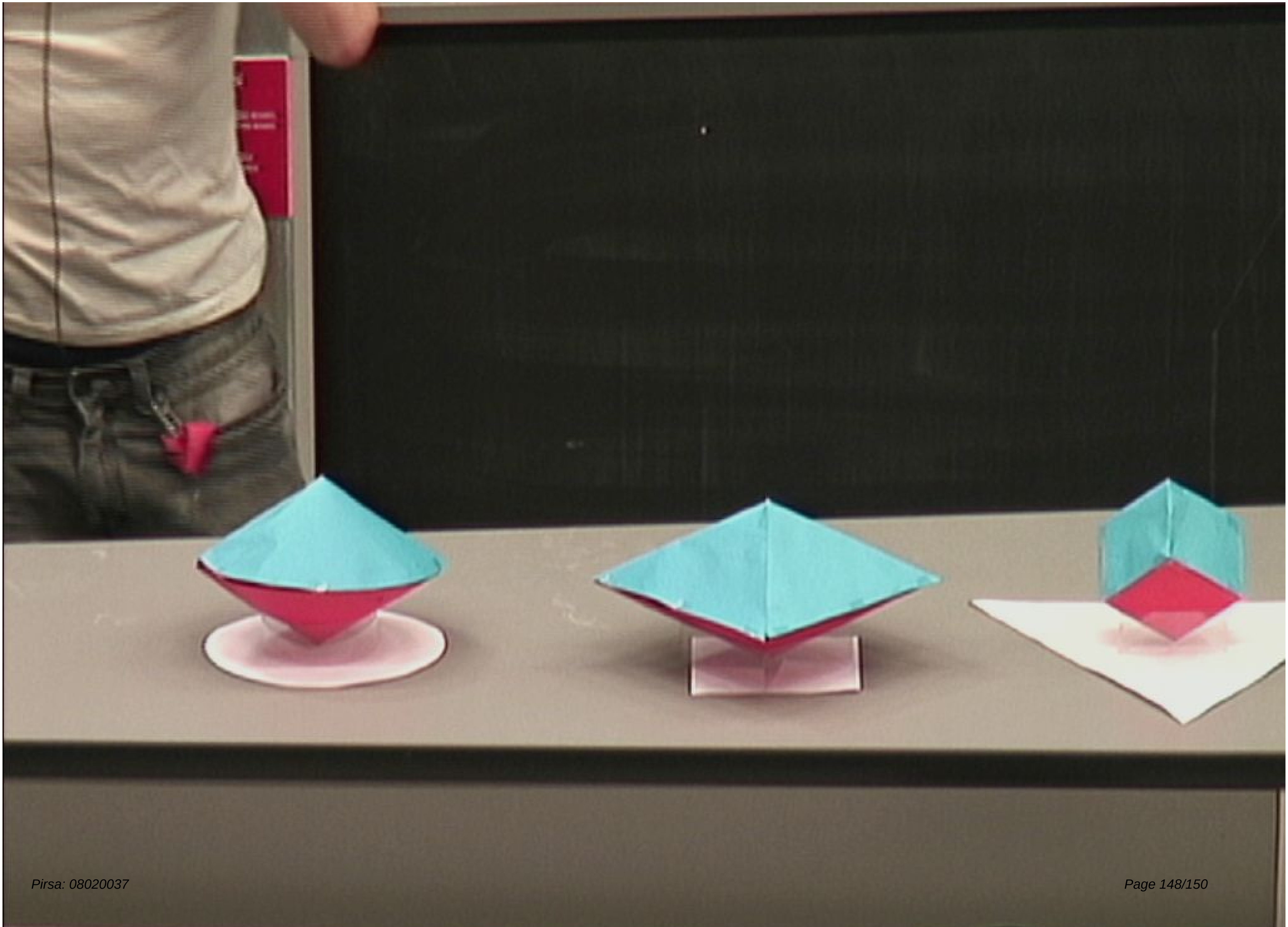
-STATICAL-MODEL FRAMEWORK
classical
exotic
all POVM {E_i}
S(ρ)
S({E_i} | ρ)

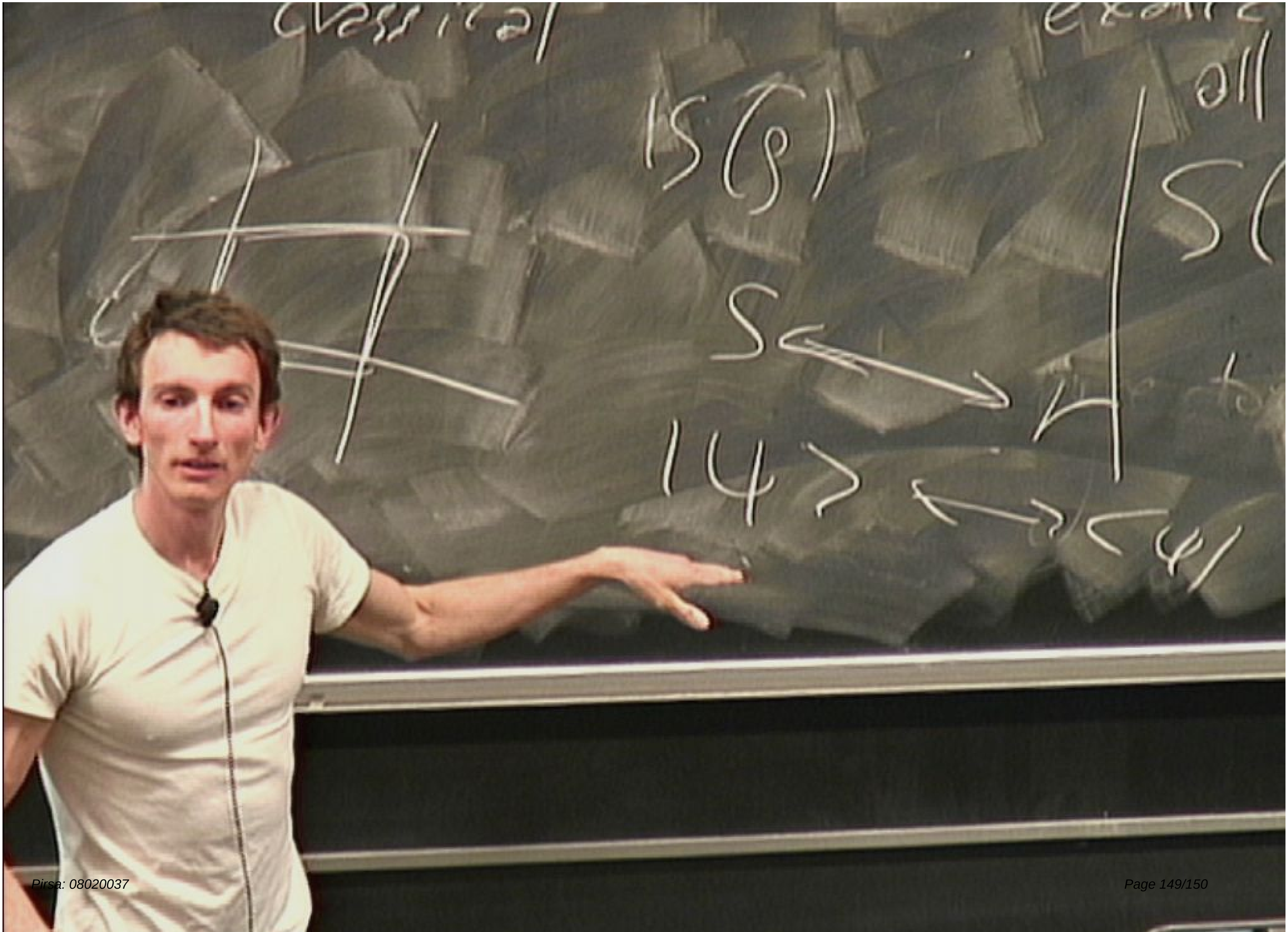

STATICAL-MODEL FRAMEWORK
classical
exotic
all POVM
S(ρ)

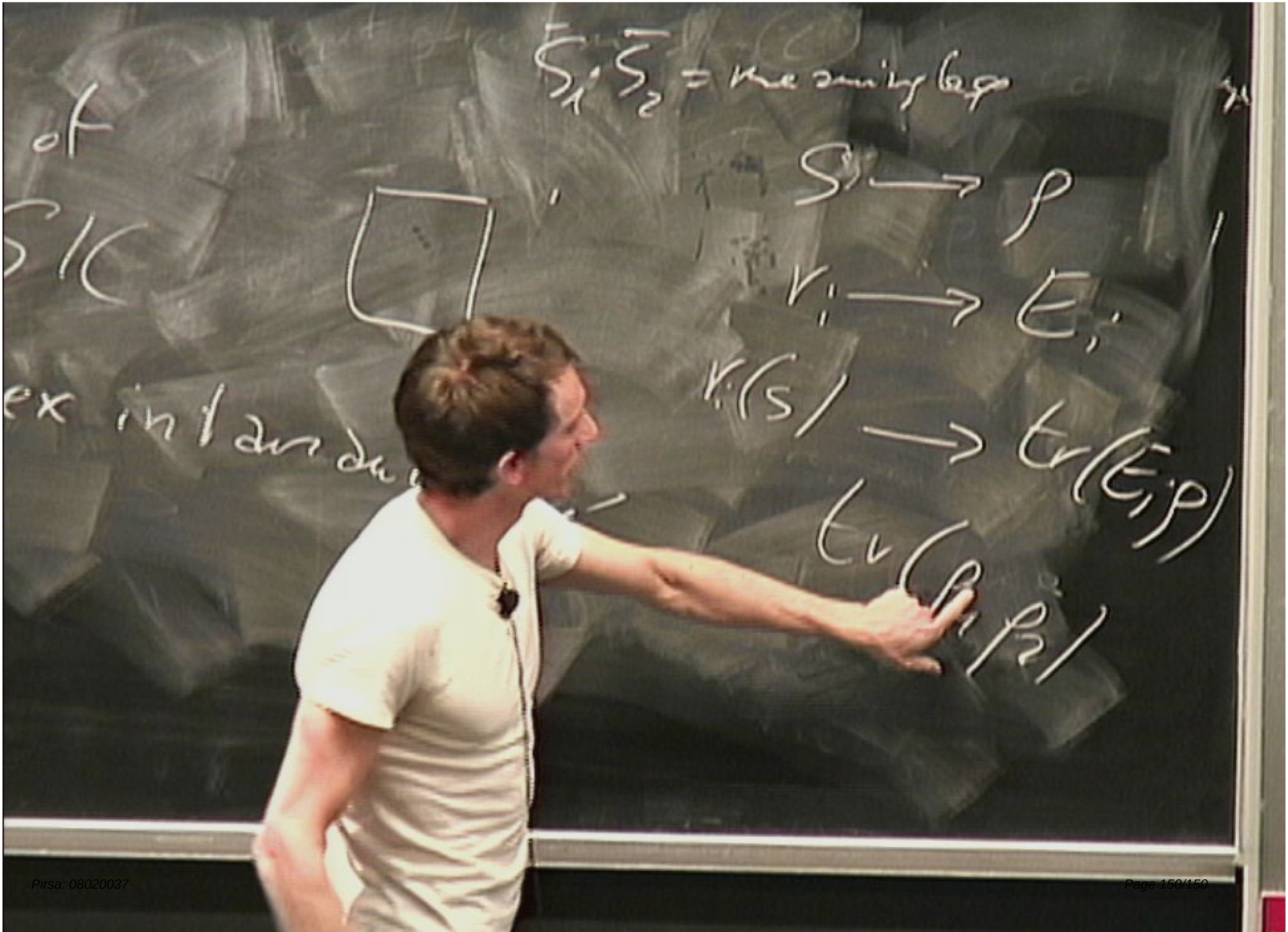

FRAMEWORK
classical
exotic
all POVM


-STATICAL-MODEL FRAMEWORK
classical
exotic
all POVM sets
S(ρ)


STATICAL-MODEL FRAMEWORK
classical
exotic
all POVM
S(ρ)




classical
S(ρ)
S
|ψ>
<ψ|


of
SIC
ex in standard
$S_i \longrightarrow \rho$
$r_i \longrightarrow E_i$
$r_i(s) \longrightarrow tr(E_i \rho)$
$tr(\rho_i \rho)$