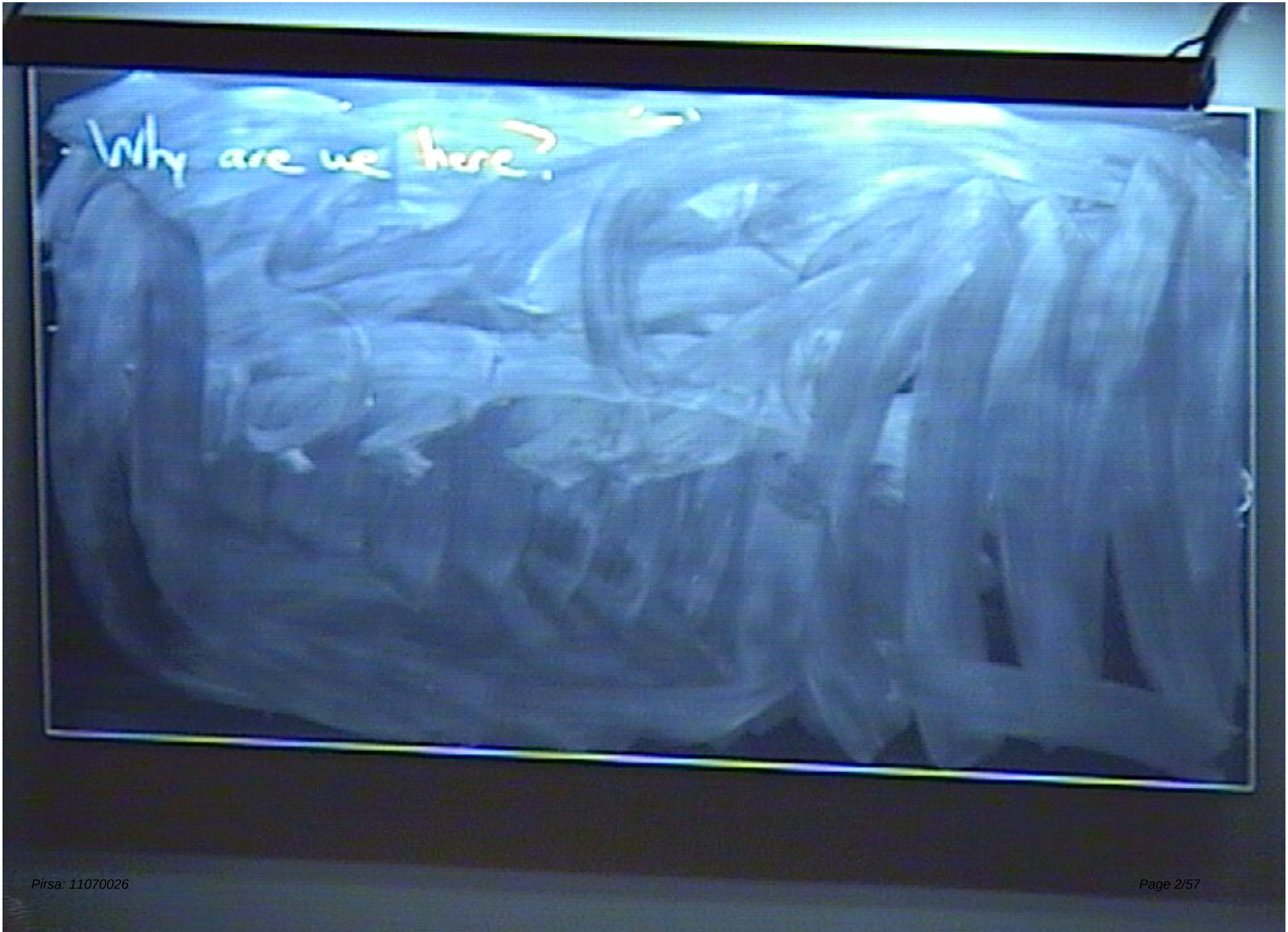
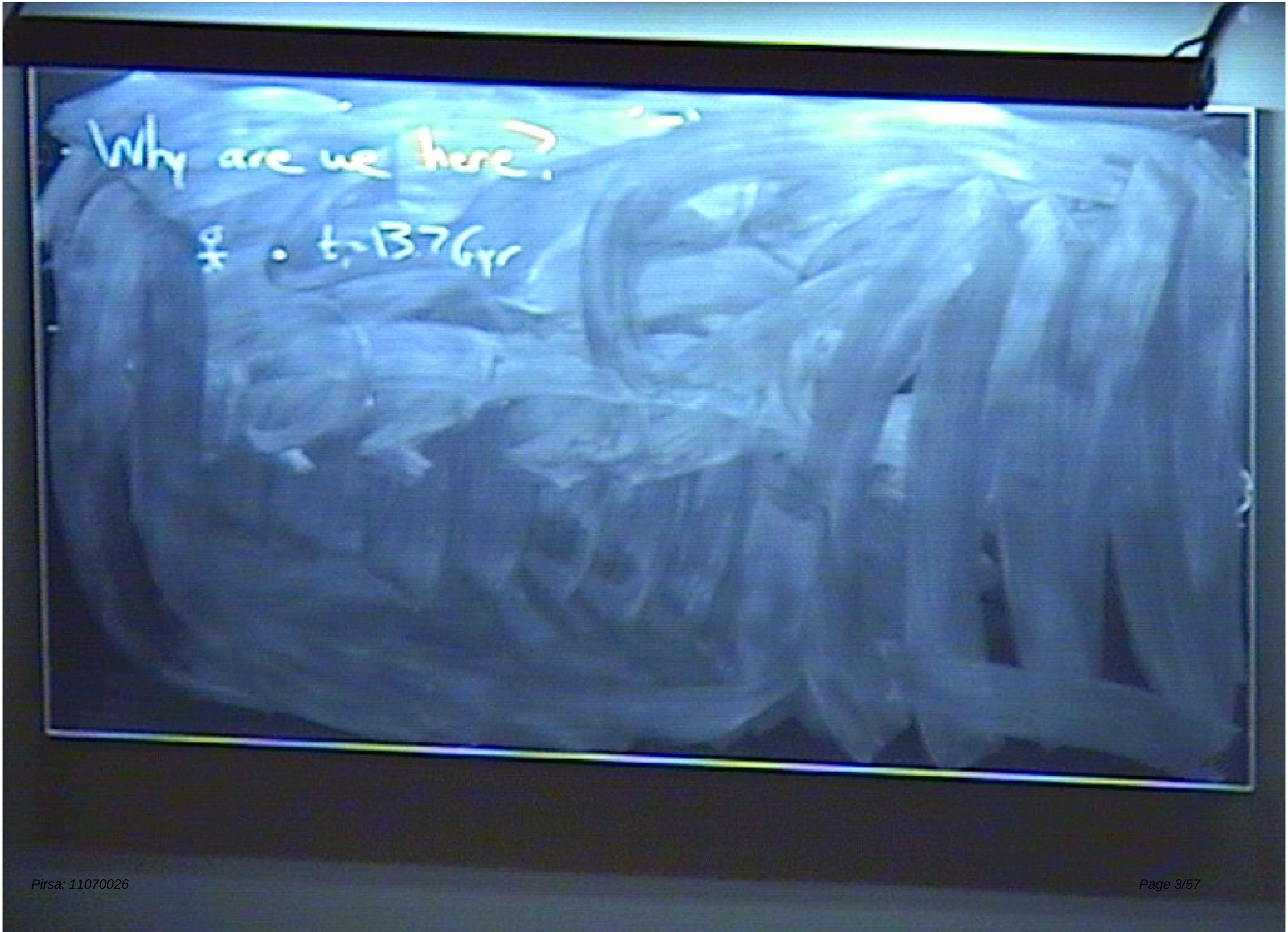
Title: The Arrow of Time in an Eternal Universe

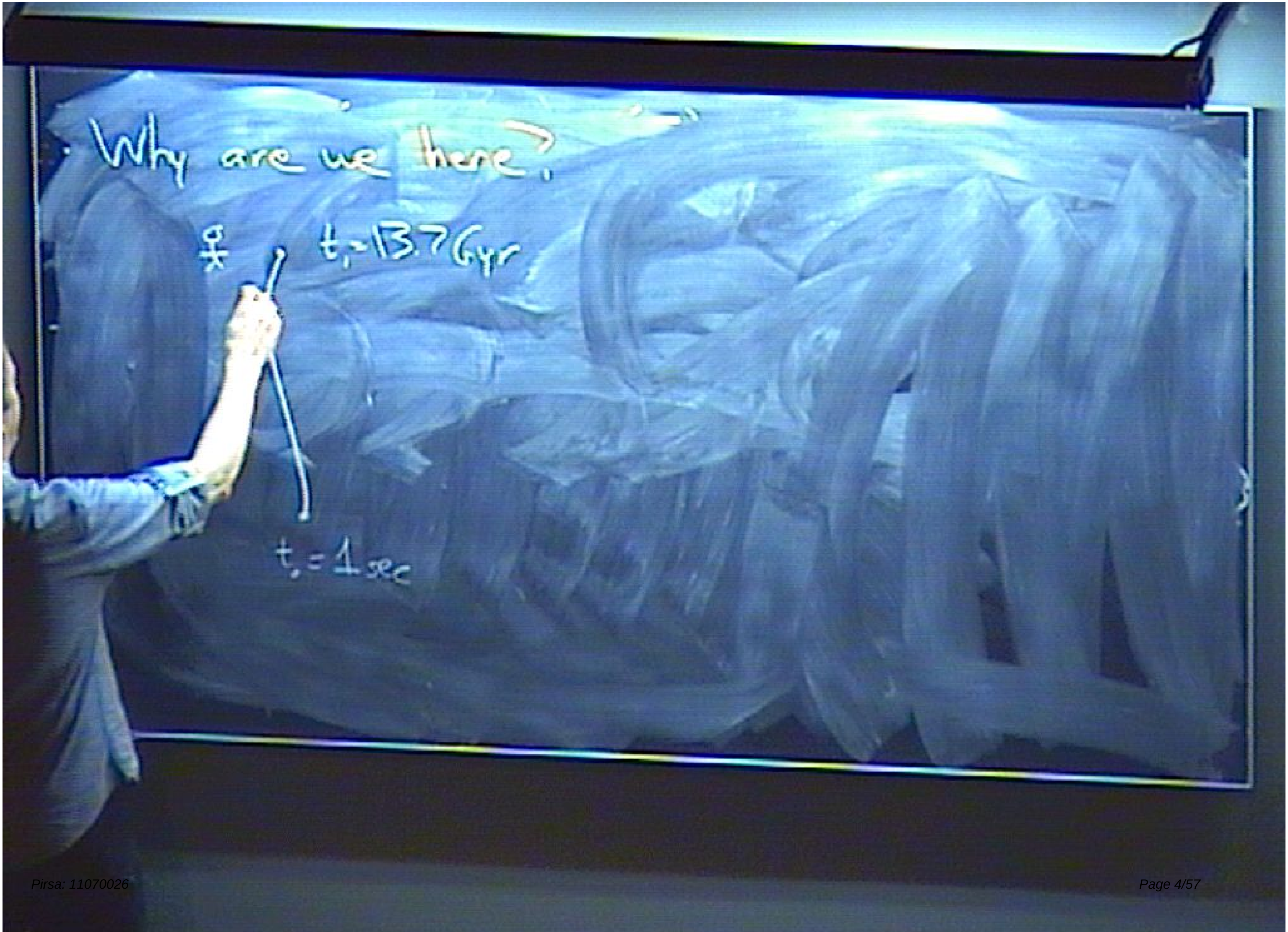
Date: Jul 16, 2011 10:40 AM

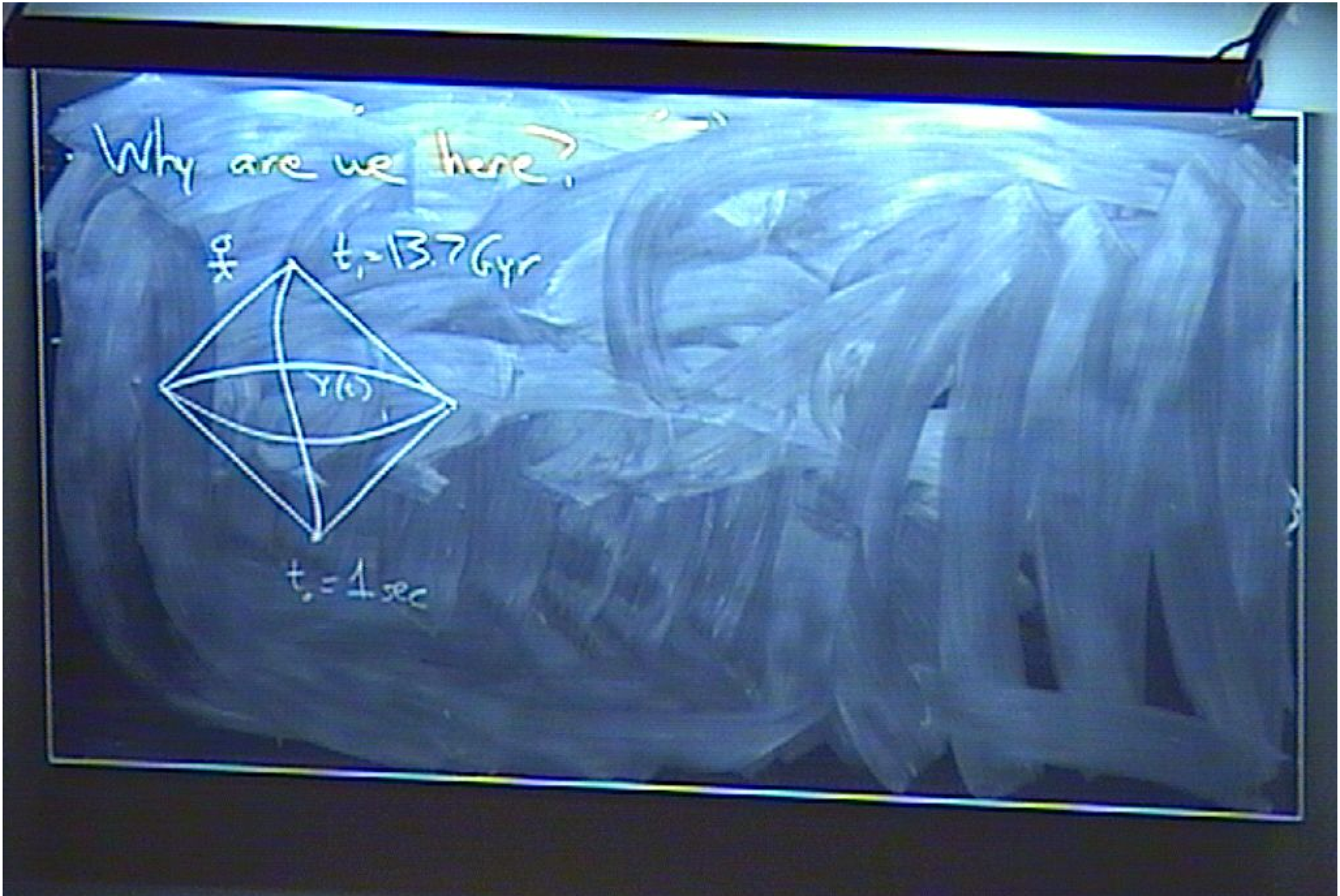
URL: http://pirsa.org/11070026

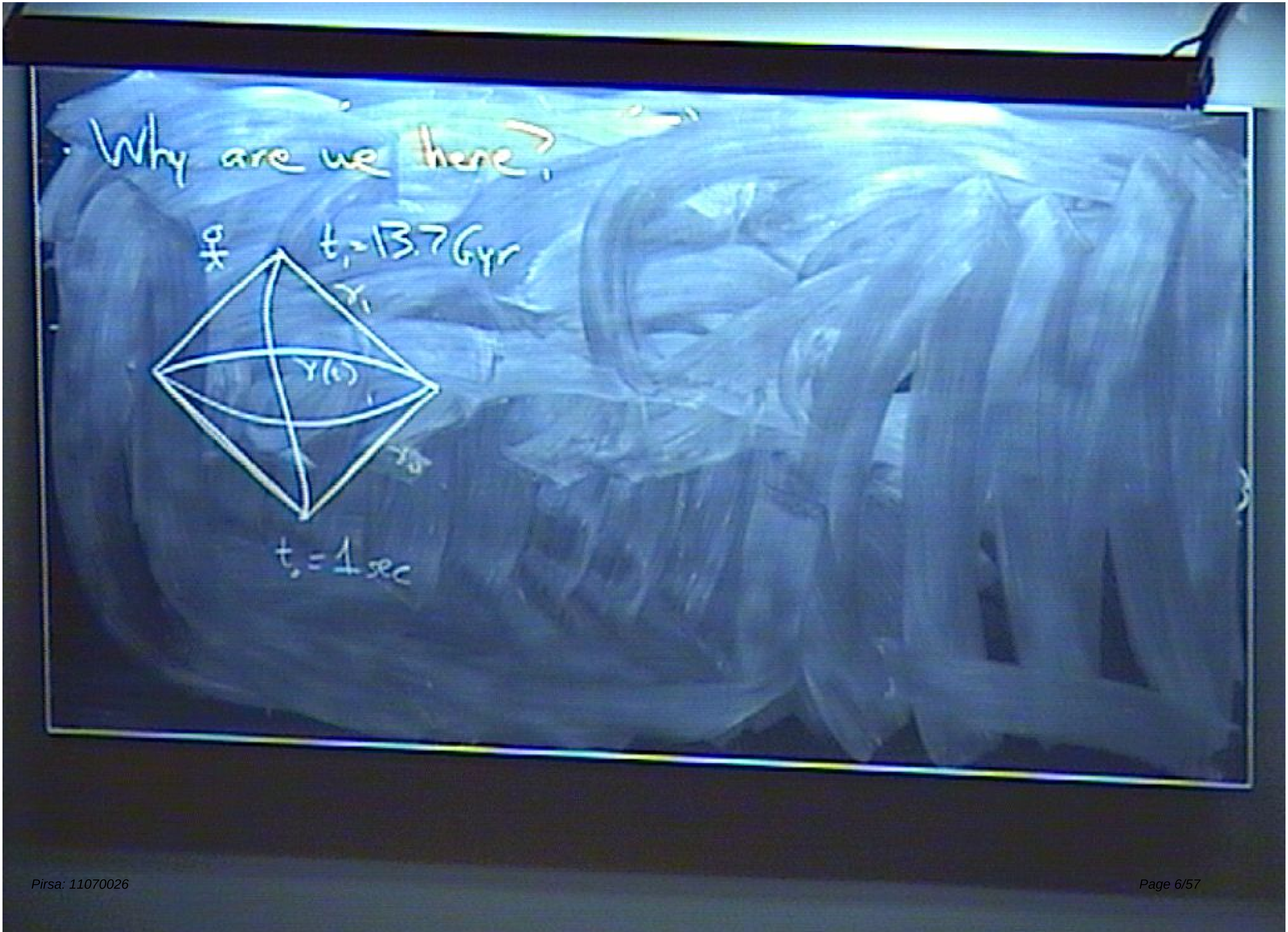
Abstract: If we imagine that the universe is truly eternal, special challenges arise for attempts to solve cosmological fine-tuning problems, especially the low entropy of the early universe. If the space of states is finite, the universe should spend most of its time near equilibrium. If the space of states is infinite, it becomes difficult to understand why our universe was in a particular low-entropy state.
I will discuss approaches to addressing this problem in a model-independent fashion.

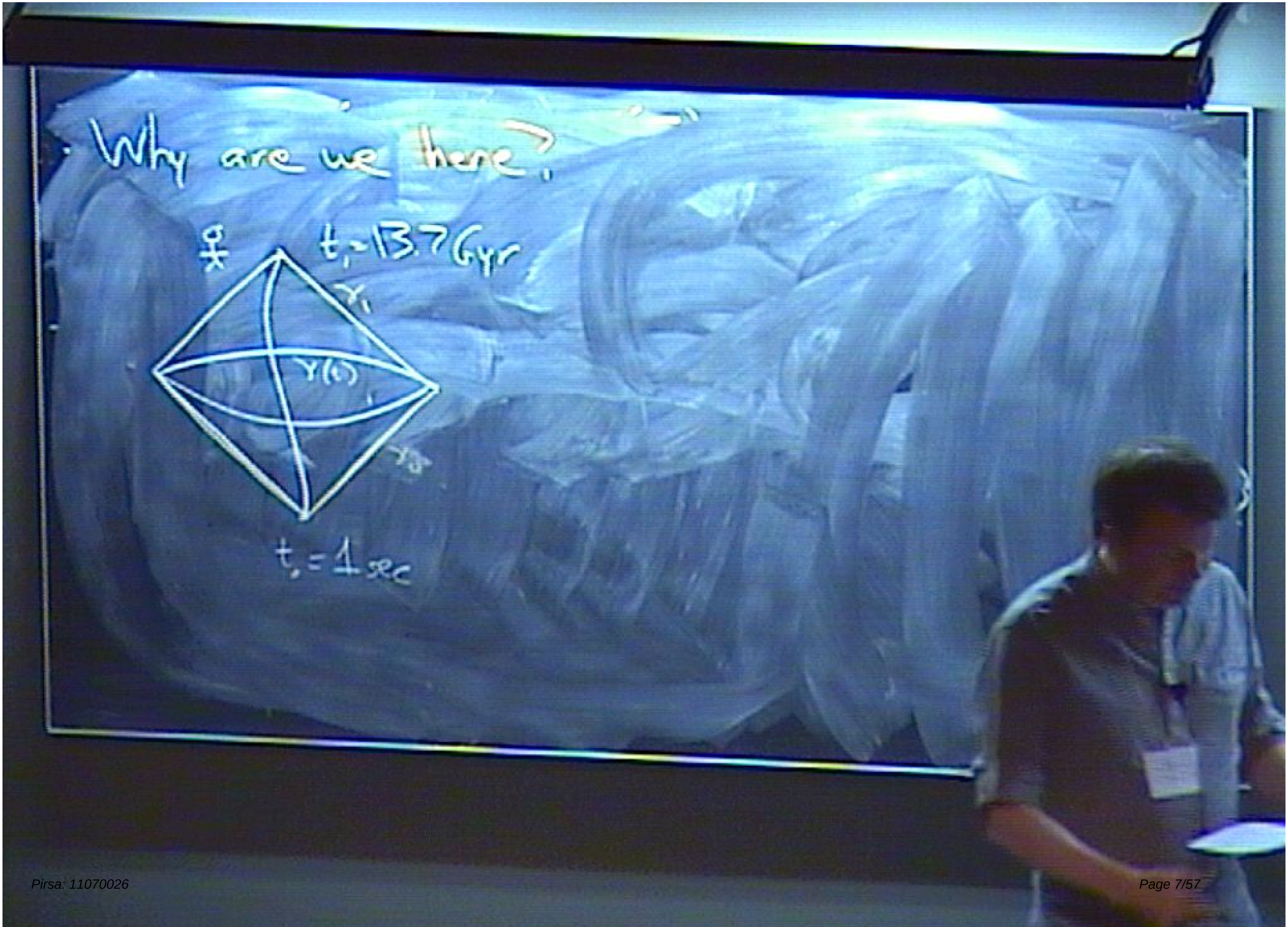

Why are we here?

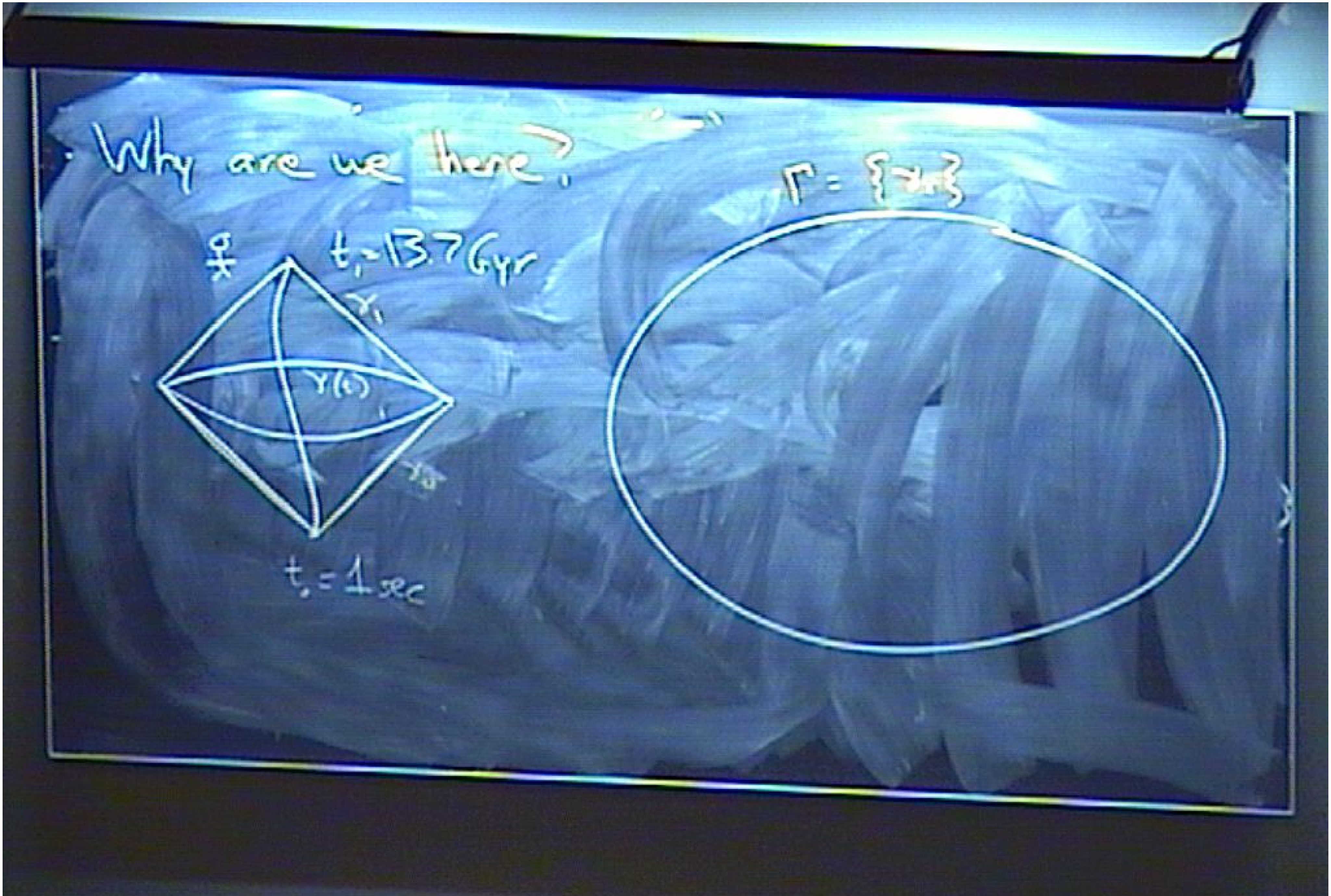

Why are we here?
$t_0 \sim 13.7$ Gyr

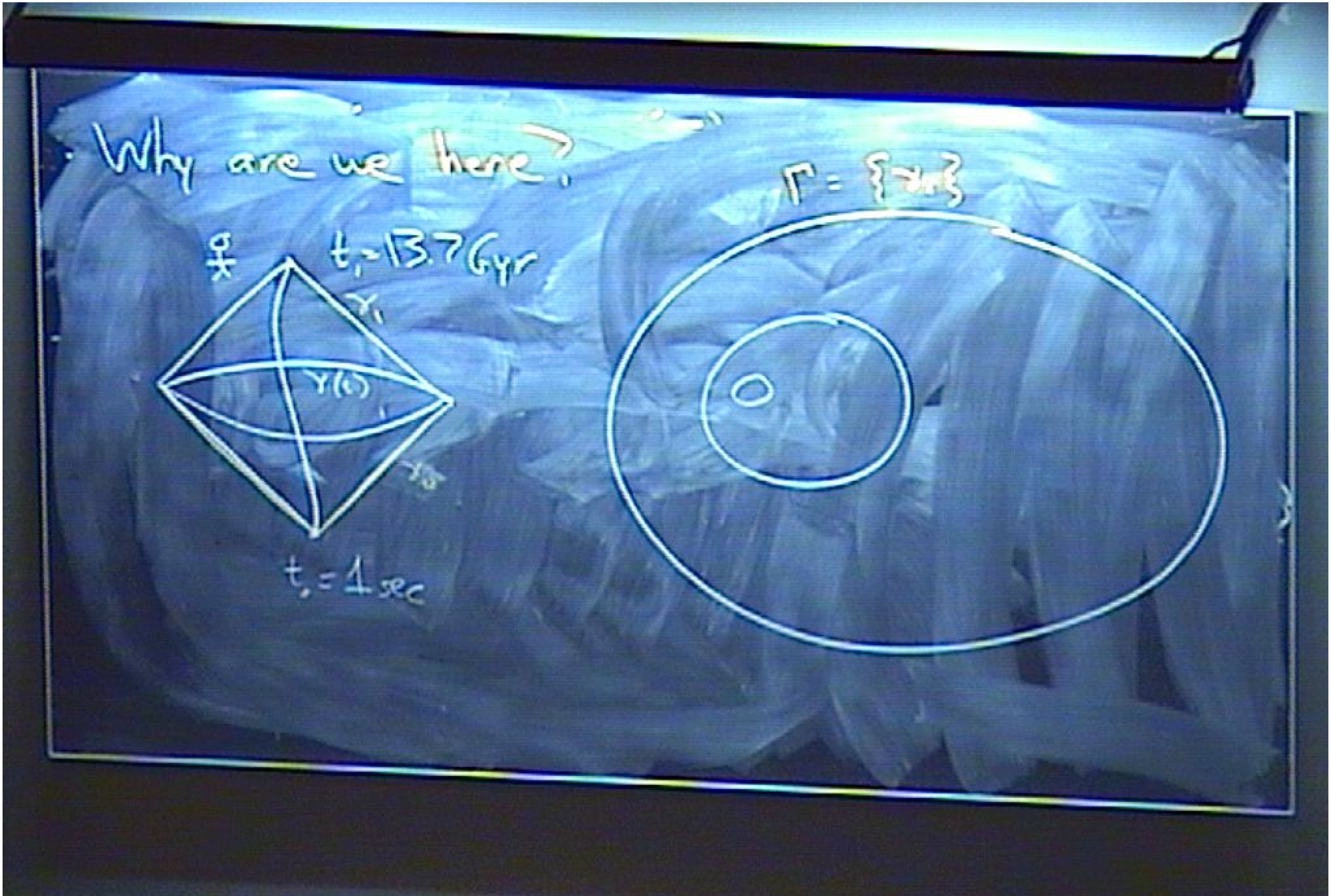

Why are we here?
t1 = 13.7 Gyr
t0 = 1 sec

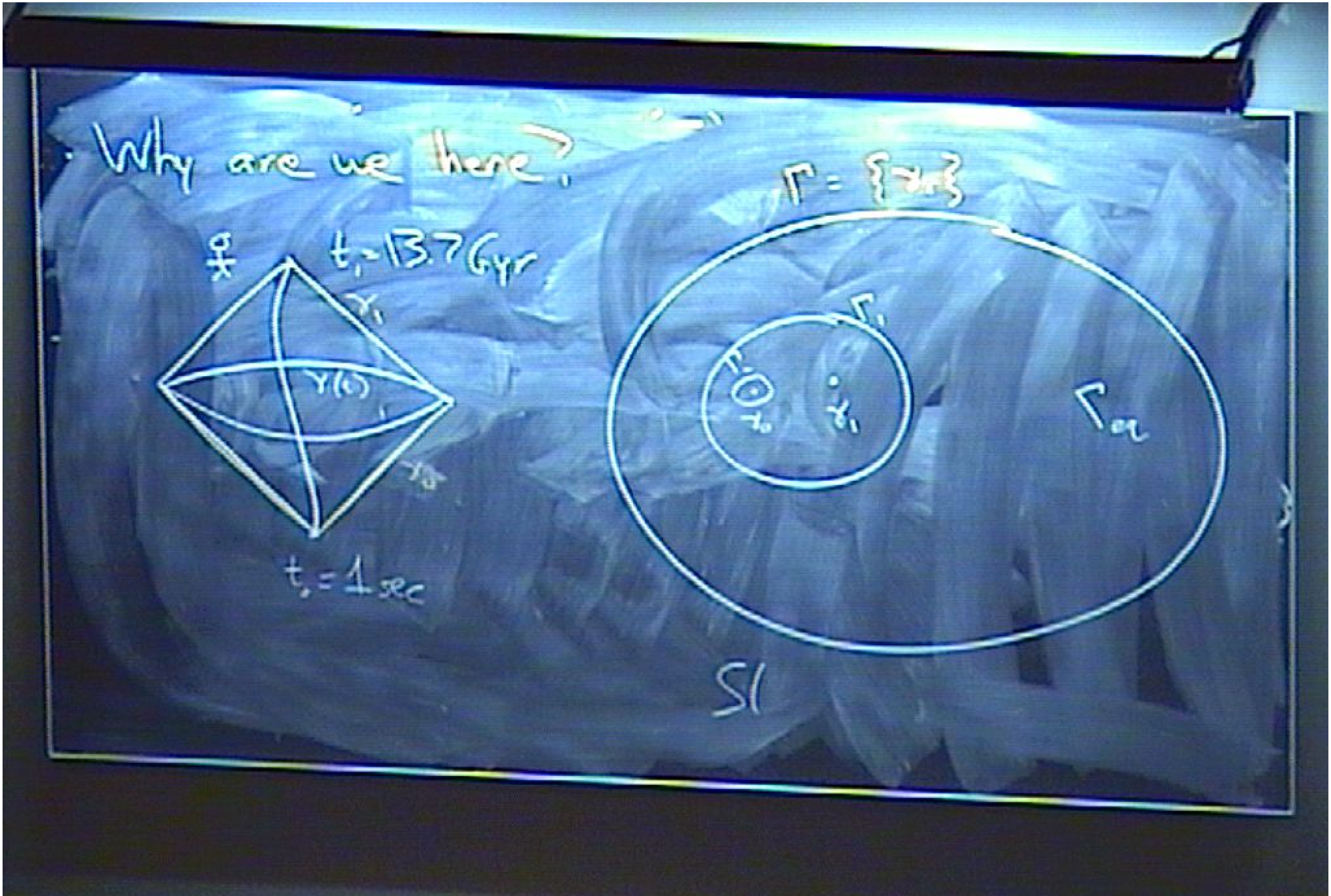

Why are we here?
$t_1 = 13.7$ Gyr
$Y(t)$
$t_0 = 1$ sec

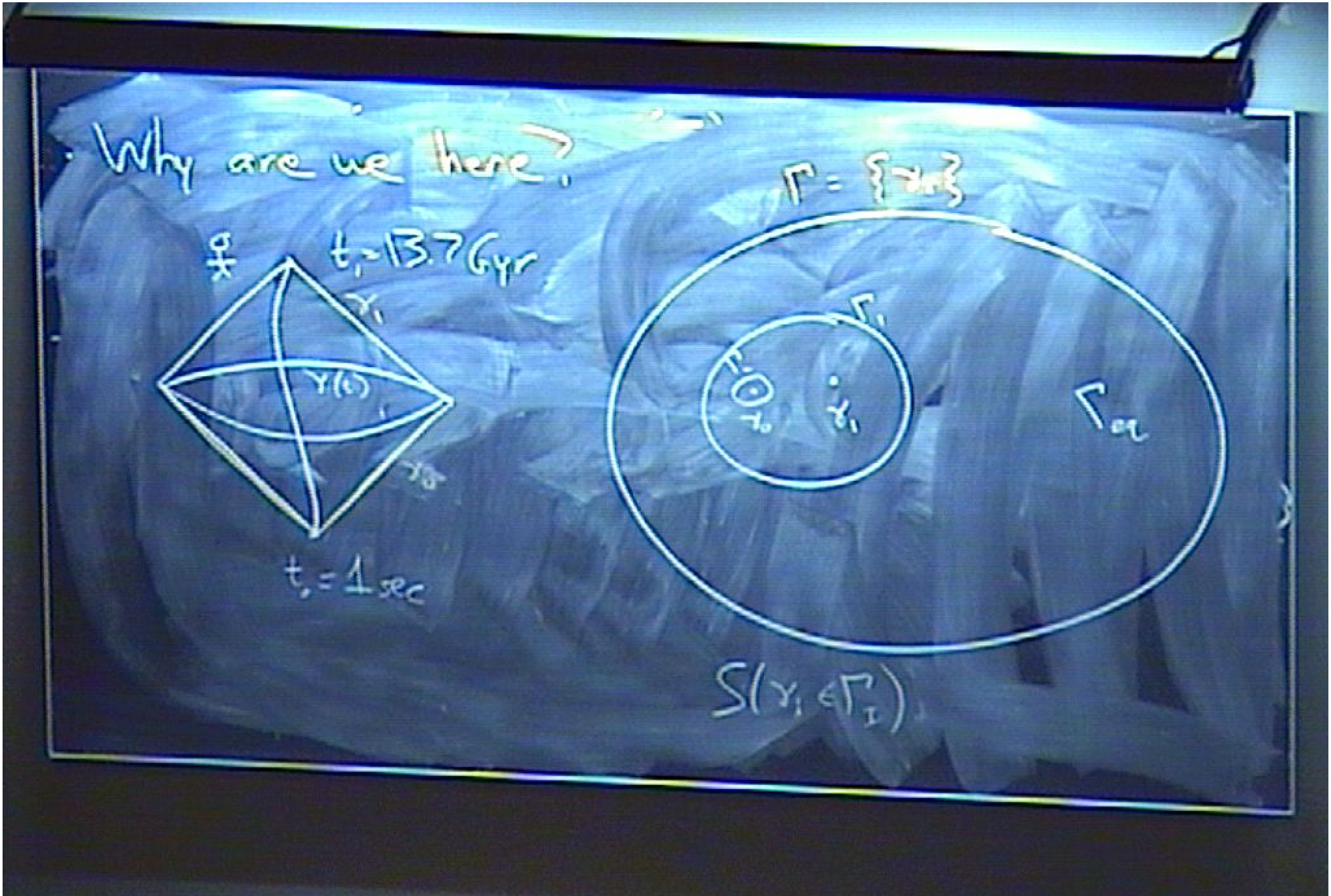

Why are we here?
t₁ = 13.7 Gyr
γ₁
γ(t)
γ₀
t₀ = 1 sec

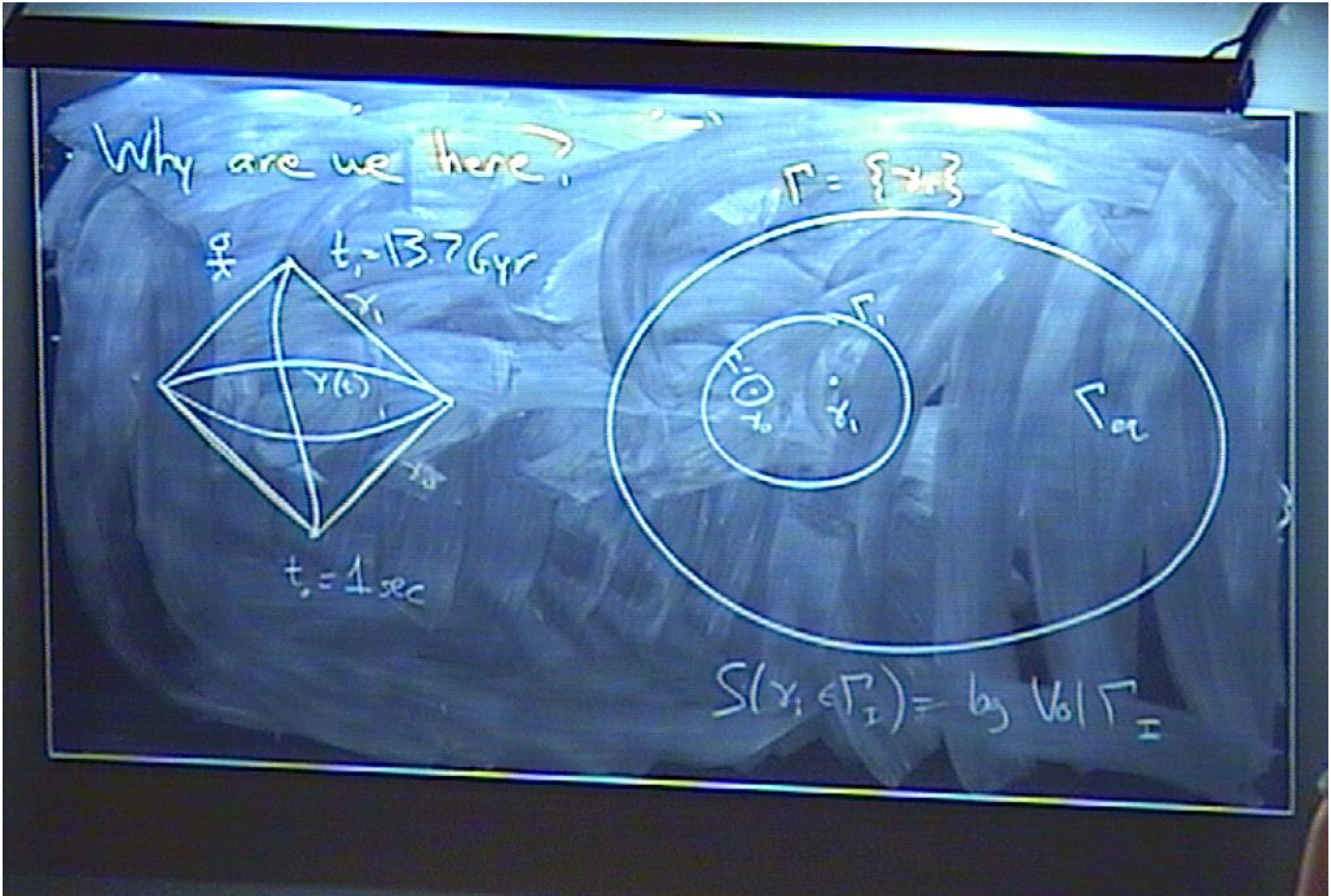

Why are we here?
$t_1 = 13.7$ Gyr
γ_1
$\gamma(t)$
γ_0
$t_0 = 1$ sec

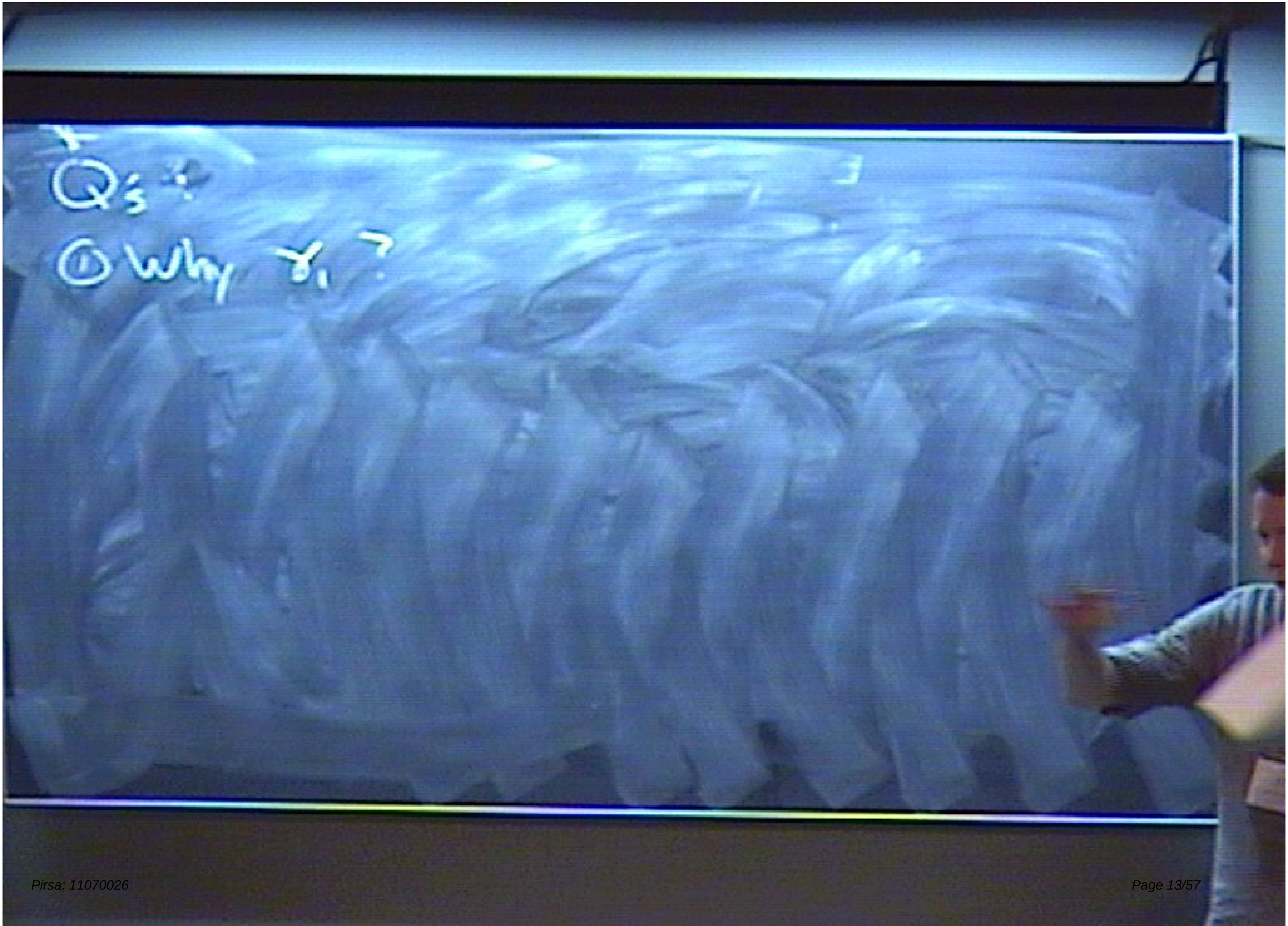

Why are we there?
t₁ = 13.7 Gyr
γ₁
γ(t)
γ₀
t₀ = 1 sec
Γ =

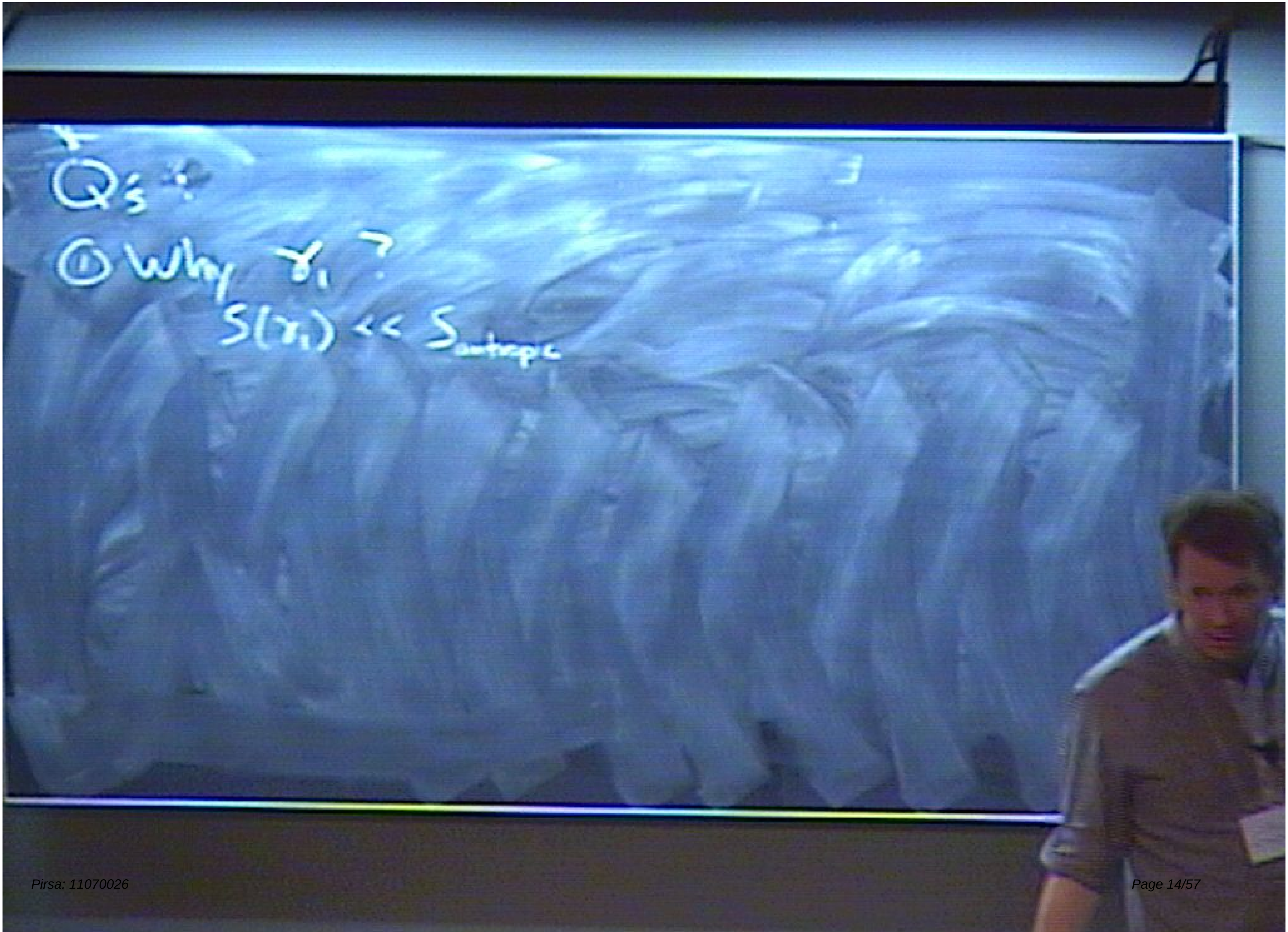

Why are we here?
t1 = 13.7 Gyr
γ1
γ(t)
γ0
t0 = 1 sec
Γ = {γn}

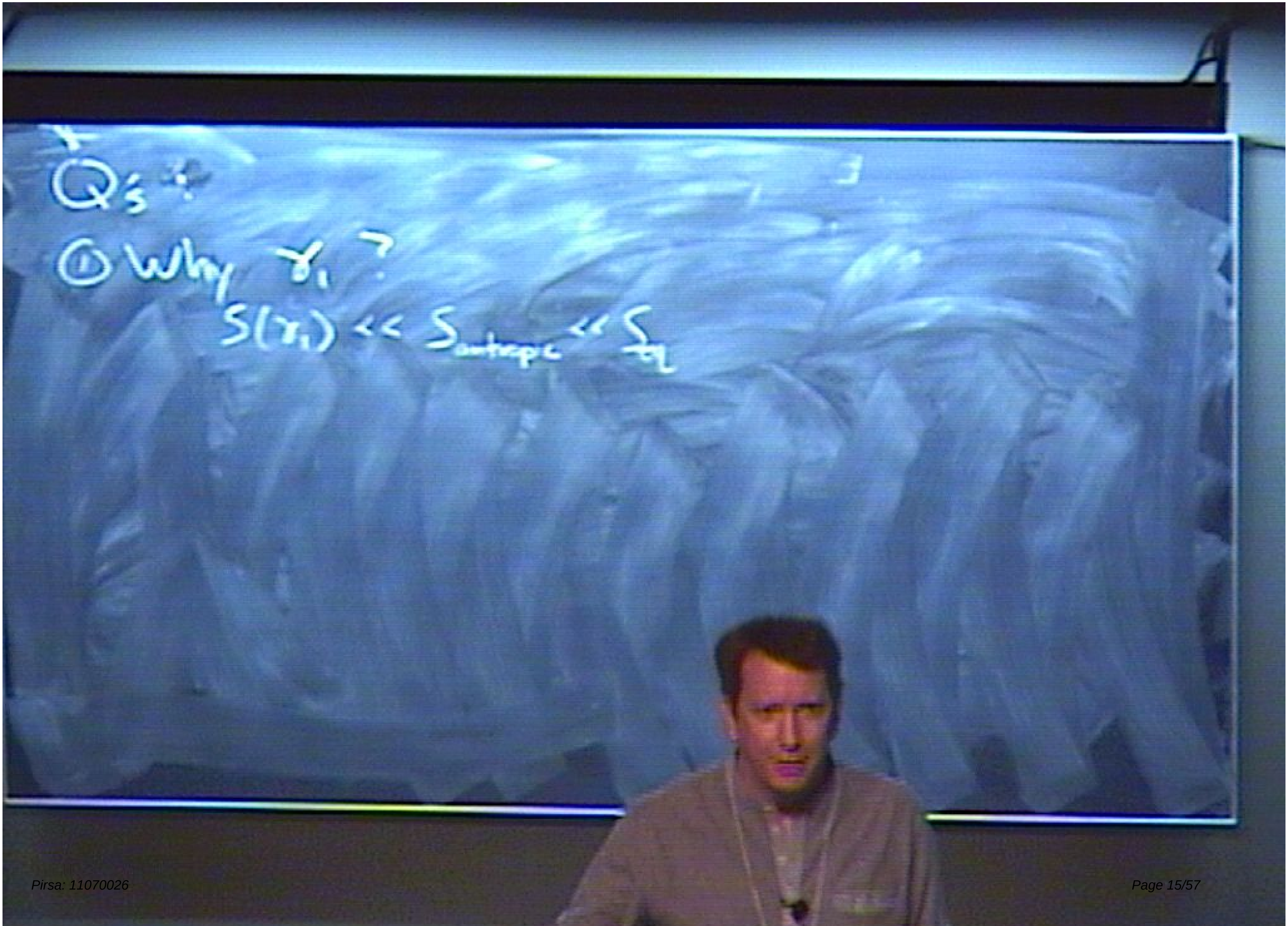

Why are we here?
t1 = 13.7 Gyr
γ1
γ(t)
γ0
t0 = 1 sec
Γ = {γn}
Γ1
Γ0
γ0
γ1
Γeq
Ω

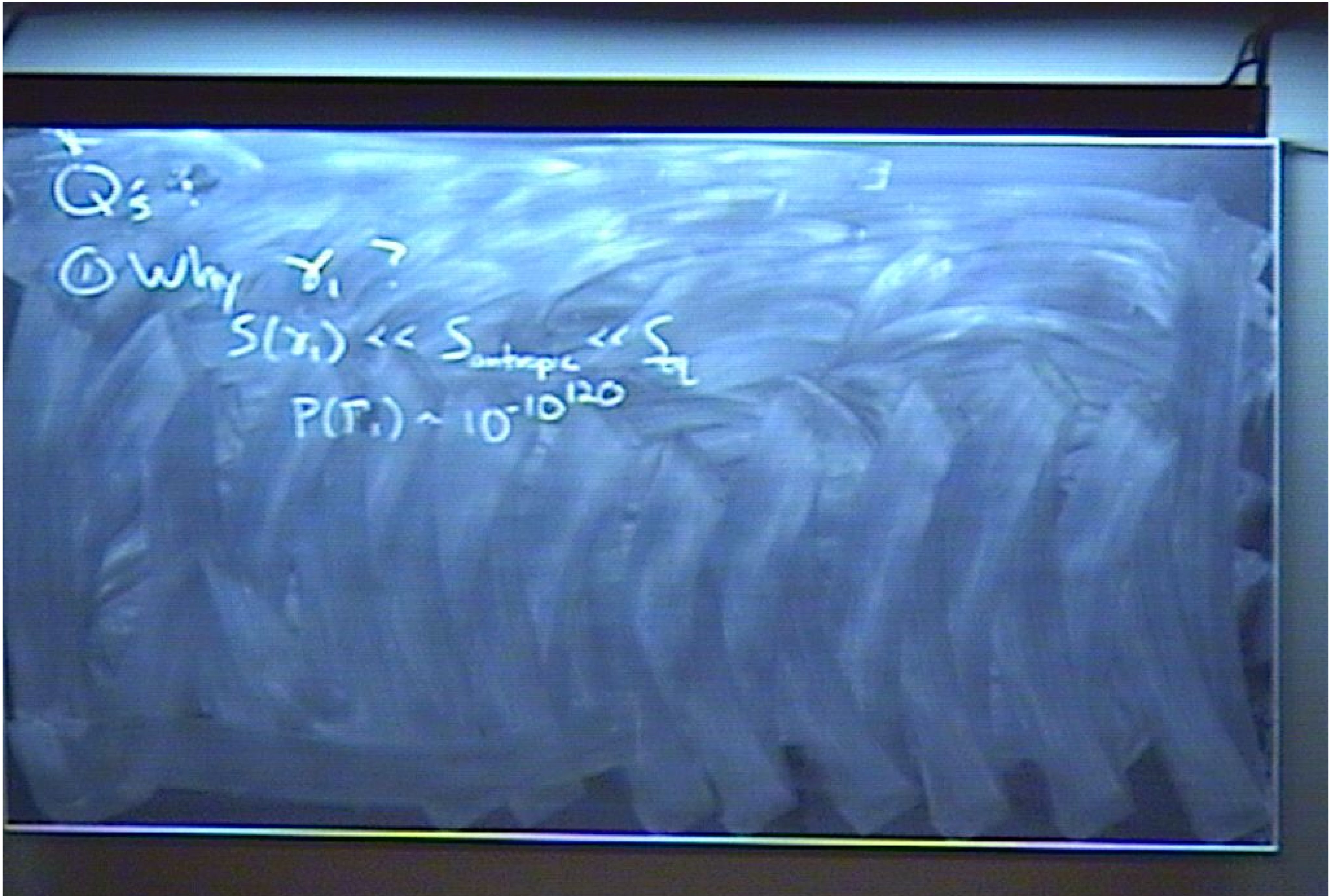

Why are we here?
$t_1 = 13.7$ Gyr
$\gamma(t)$
$t_0 = 1$ sec
Γ_1
γ_0
γ_1
Γ_{eq}
$S(\gamma_1 \in \Gamma_I)$


Why are we here?
t₁ = 13.7 Gyr
γ₁
γ(t)
γ₀
t₀ = 1 sec
Γ₁
γ₀
γ₁
Γeq
S(γ₁ ∈ Γ_I) = log Vol Γ_I


Q's:
① Why γ_1 ?


Q's
① Why γ1 ?
S(γ1) << S


Q's
① Why γ1 ?
S(γ1) << S_antropic << S_eq


Q's:
① Why γ_1?
$S(\gamma_1) \ll S_{\text{entropic}} \ll S_{eq}$
$P(\gamma_1) \sim 10^{-10^{120}}$

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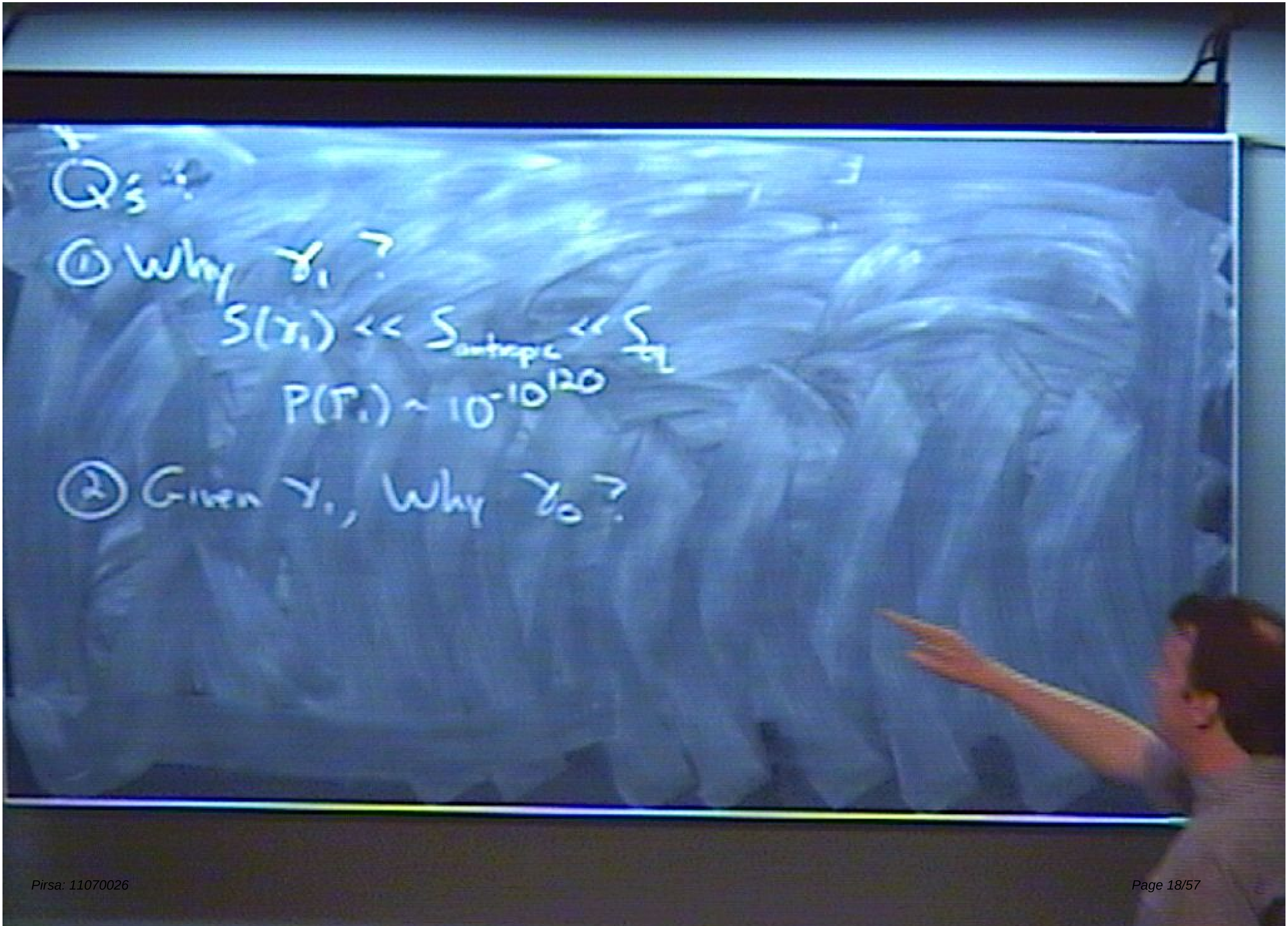
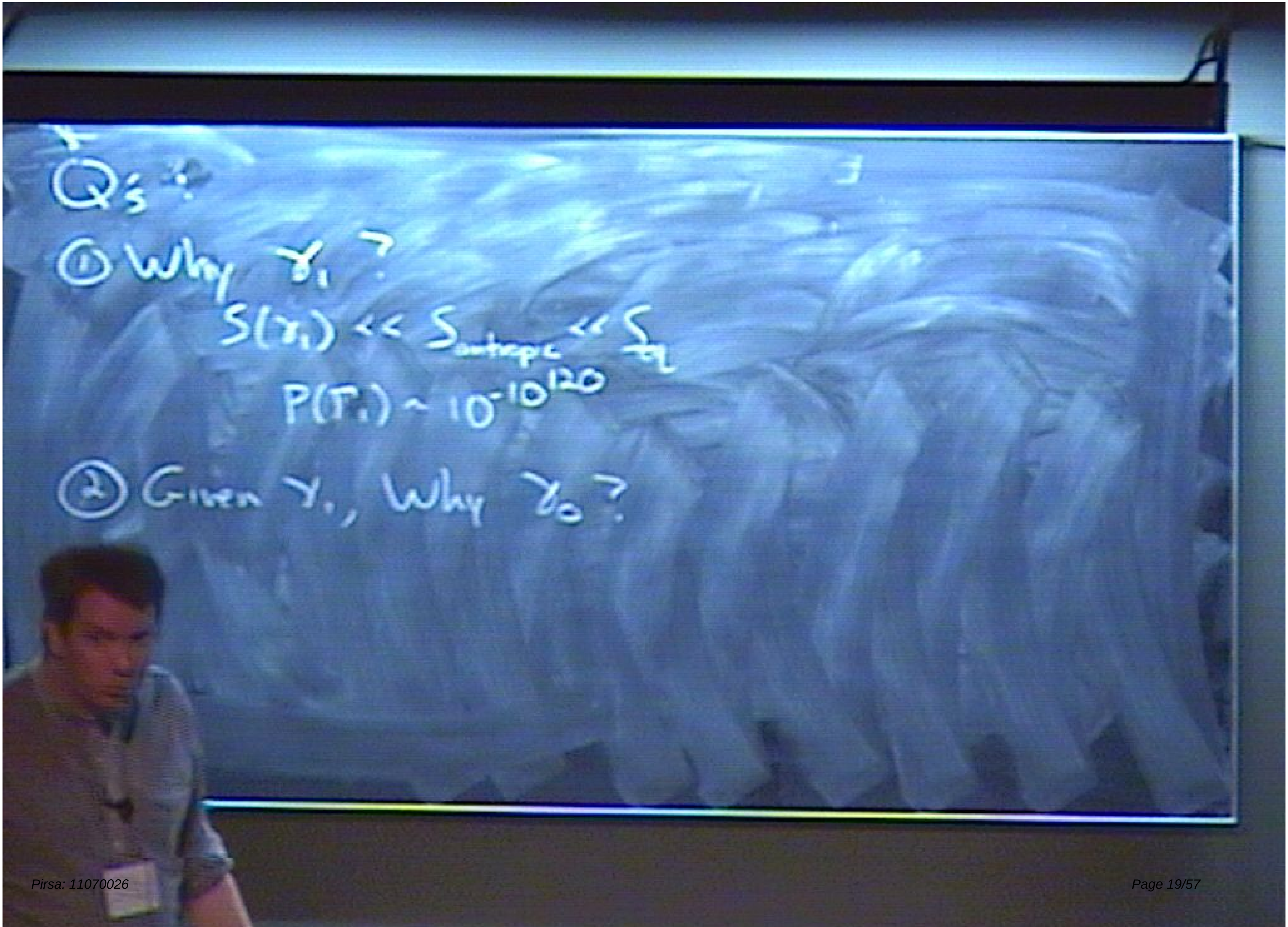
② Given γ_1, Why γ_0?


Q's:
① Why γ1 ?
S(γ1) << S << S
P(γ1) ~ 10^-10^120
② Given γ1, Why γ0 ?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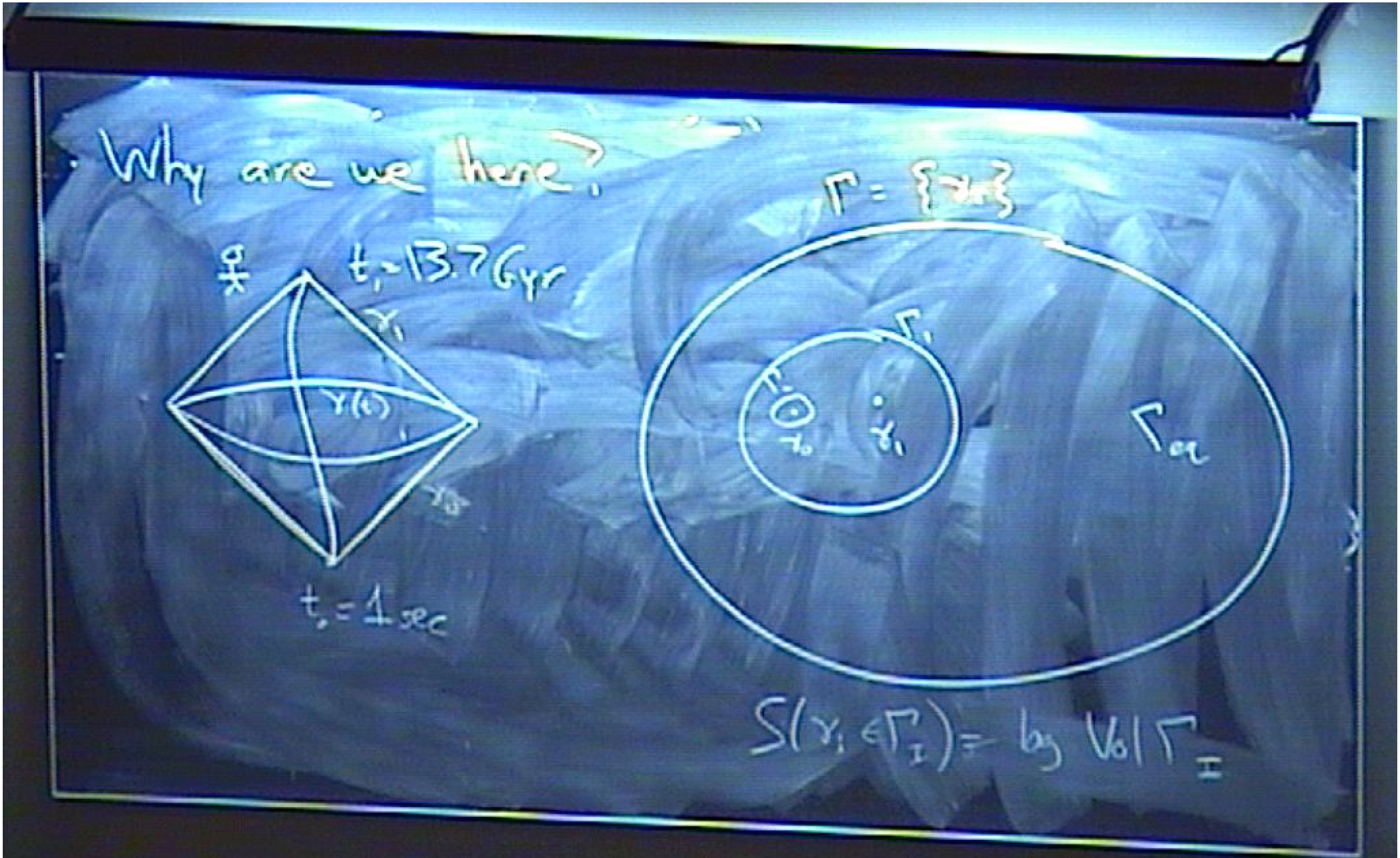
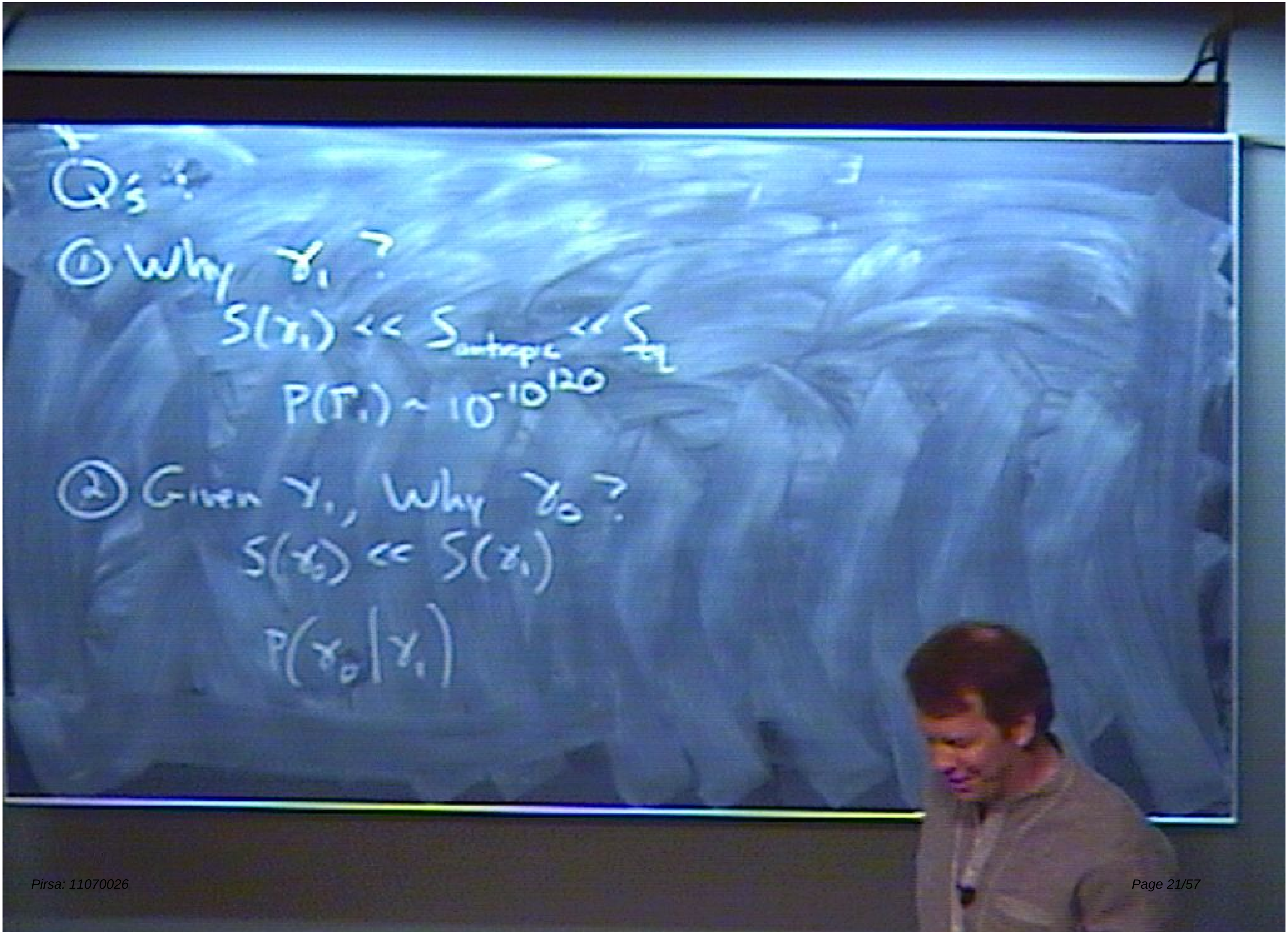


Why are we here?
$t_1 = 13.7\,Gyr$
γ_1
$\gamma(t)$
γ_0
$t_0 = 1\,sec$
$\Gamma = \{\gamma_n\}$
Γ_1
Γ_0
γ_0
γ_1
Γ_{eq}
$S(\gamma_i \in \Gamma_I) = \log Vol\, \Gamma_I$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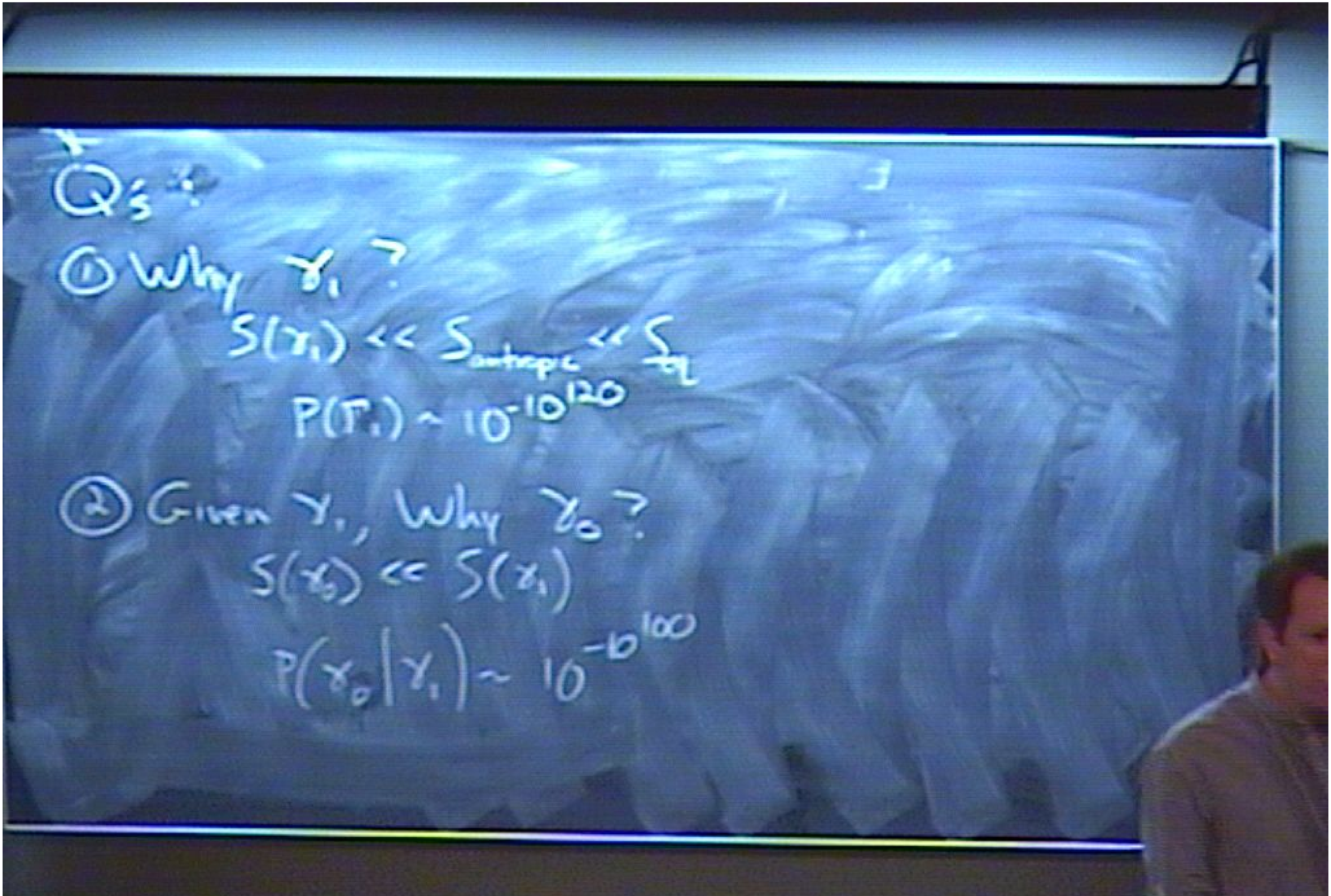
② Given γ1, Why γ0 ?
S(γ0) << S(γ1)
P(γ0 | γ1)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S(γ1) << S anthropic << S eq
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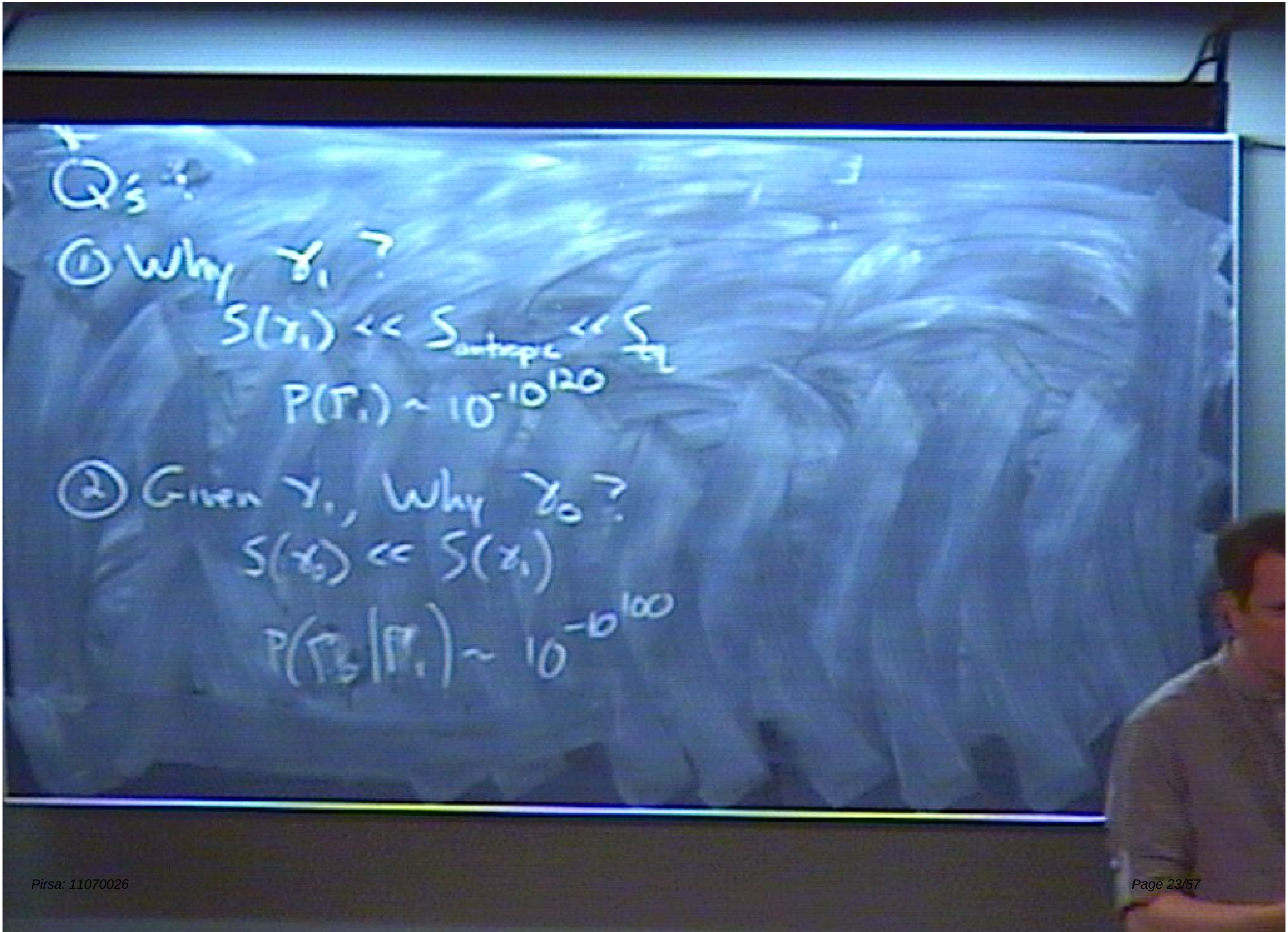
② Given γ1, Why γ0 ?
S(γ0) << S(γ1)
P(γ0 | γ1) ~ 10^-10^100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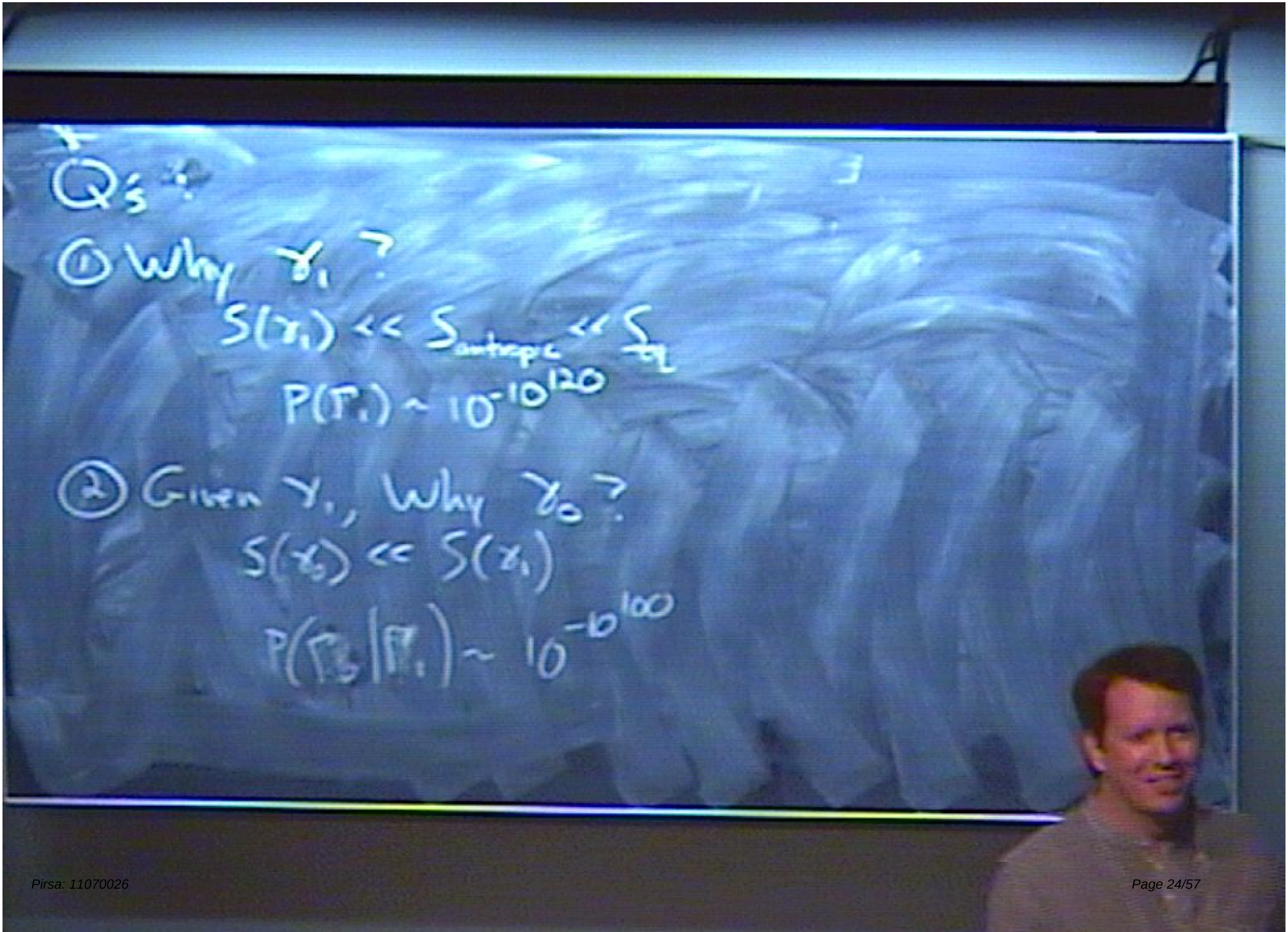
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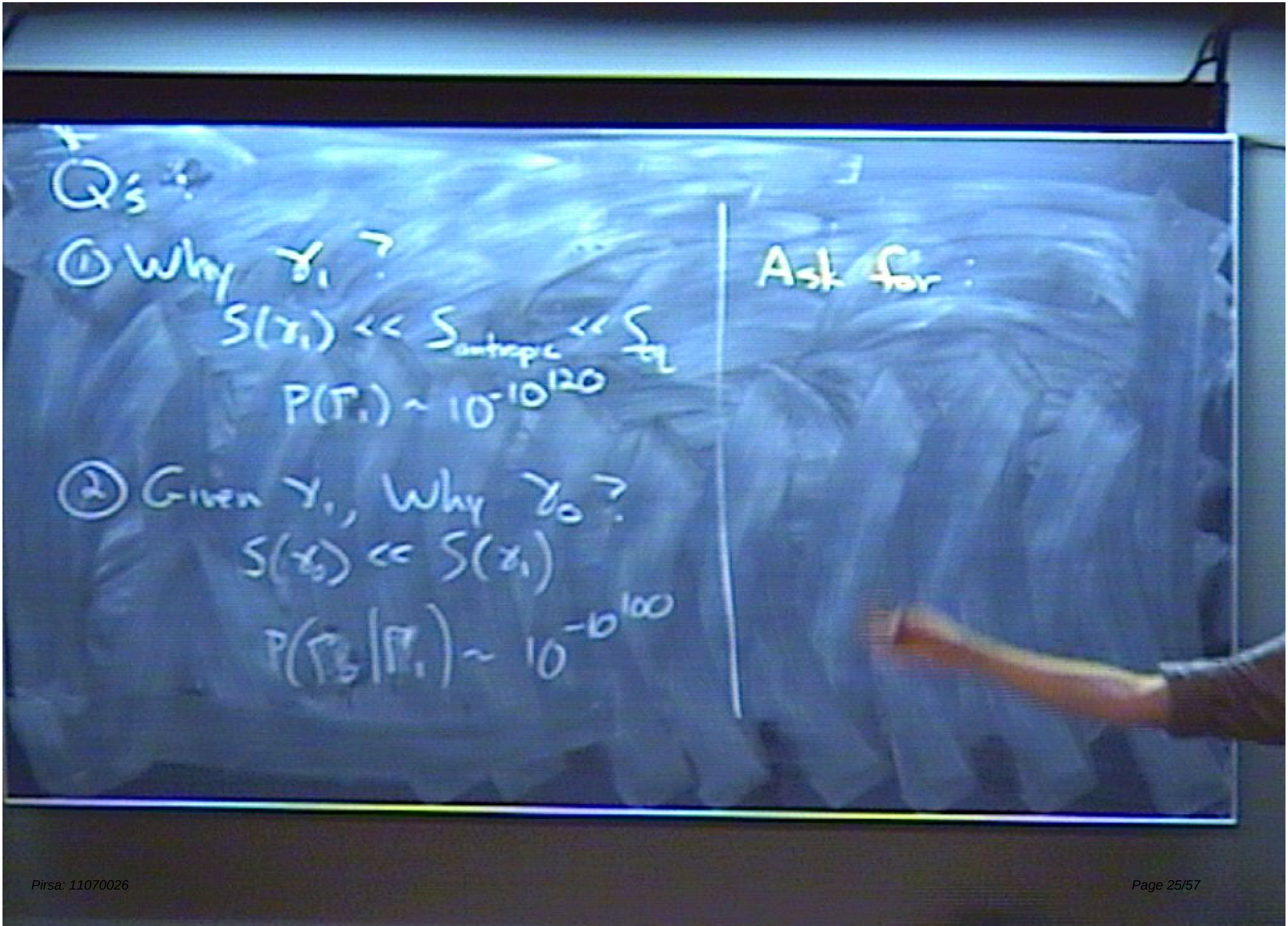
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Ask for:

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Ask for:

$$f(\Gamma_0|\Gamma_1)$$

fraction of trajectories <u>realized</u> in the U passing through Γ_1 that started in Γ_0

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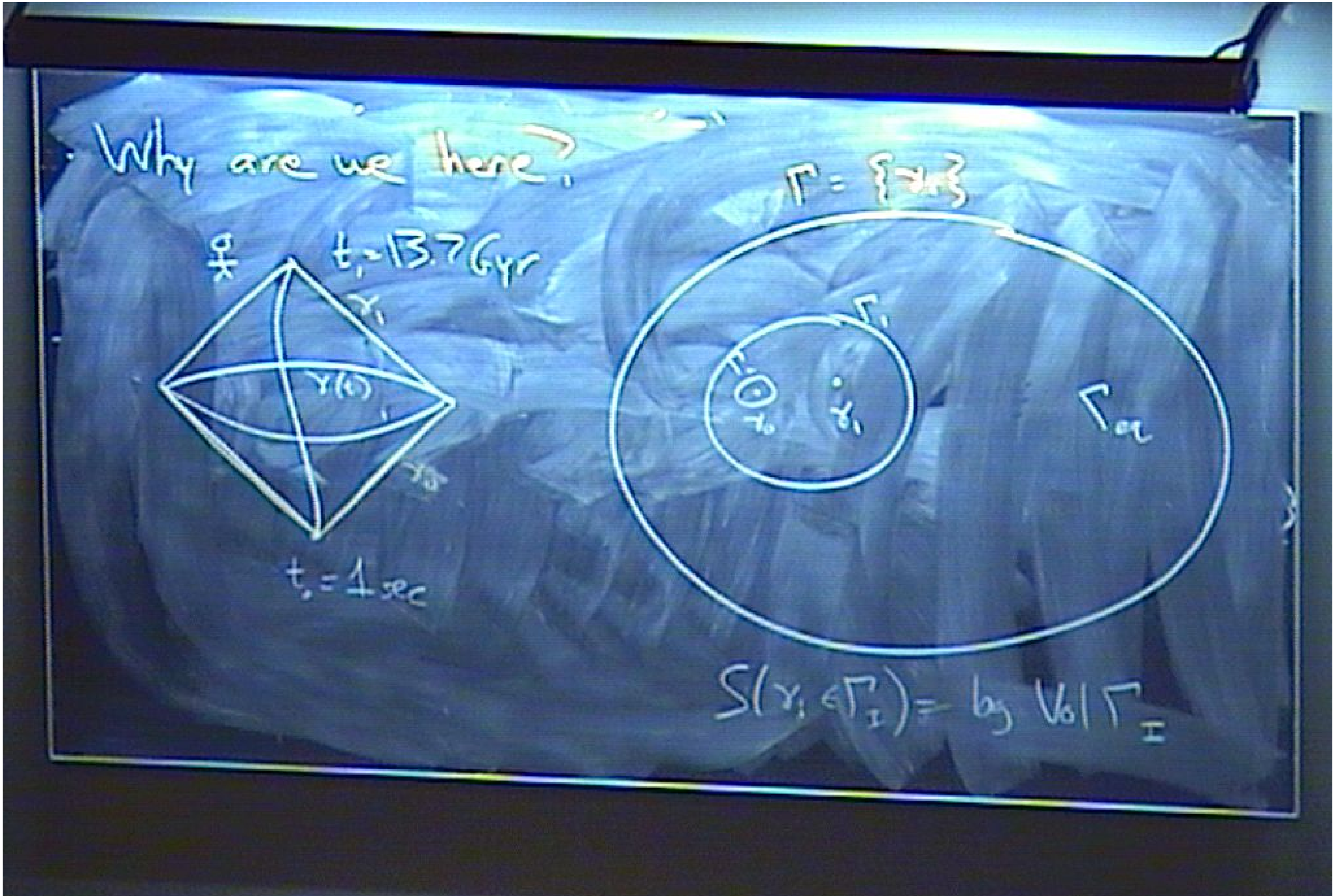

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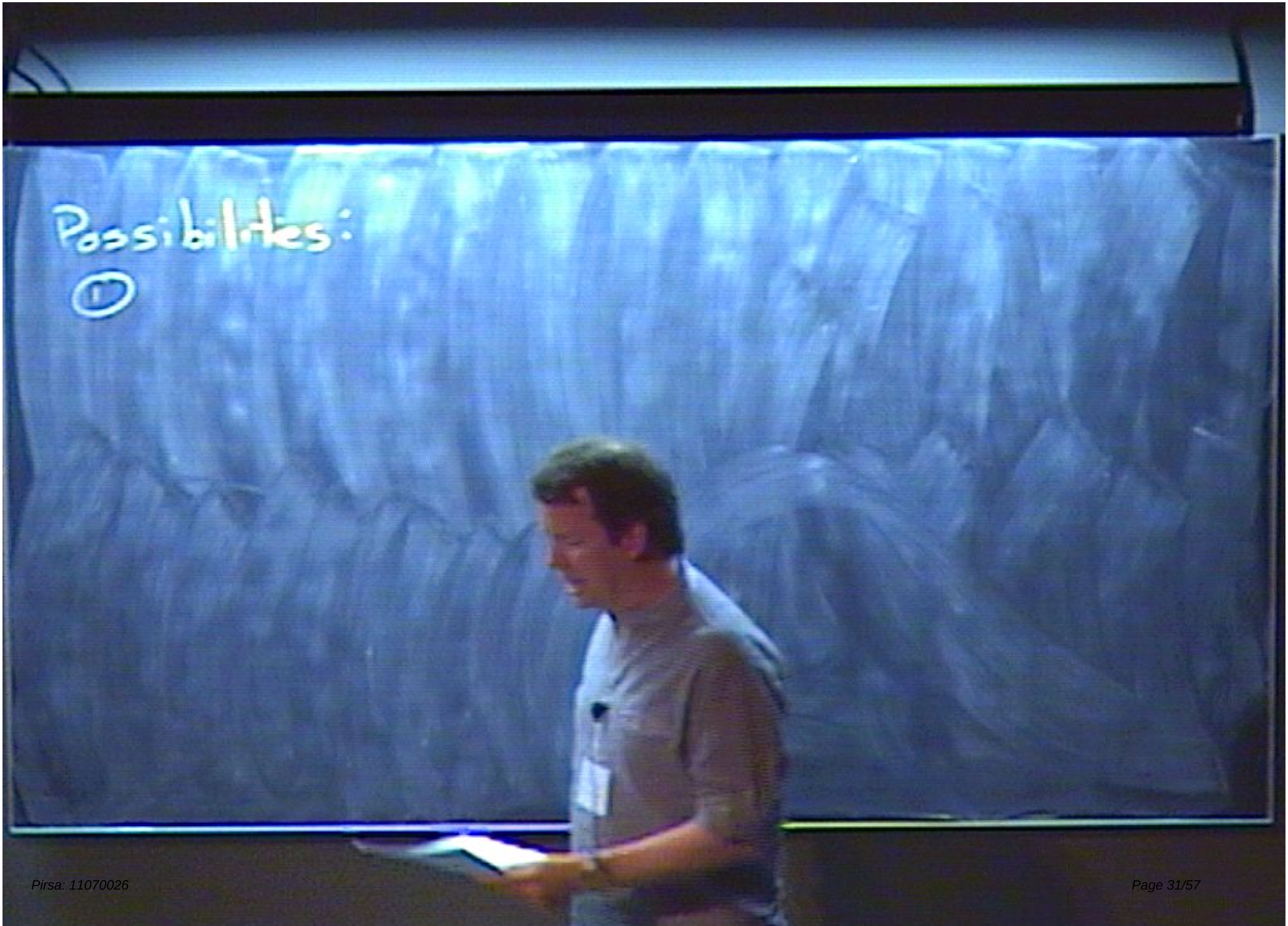
Possibilities:
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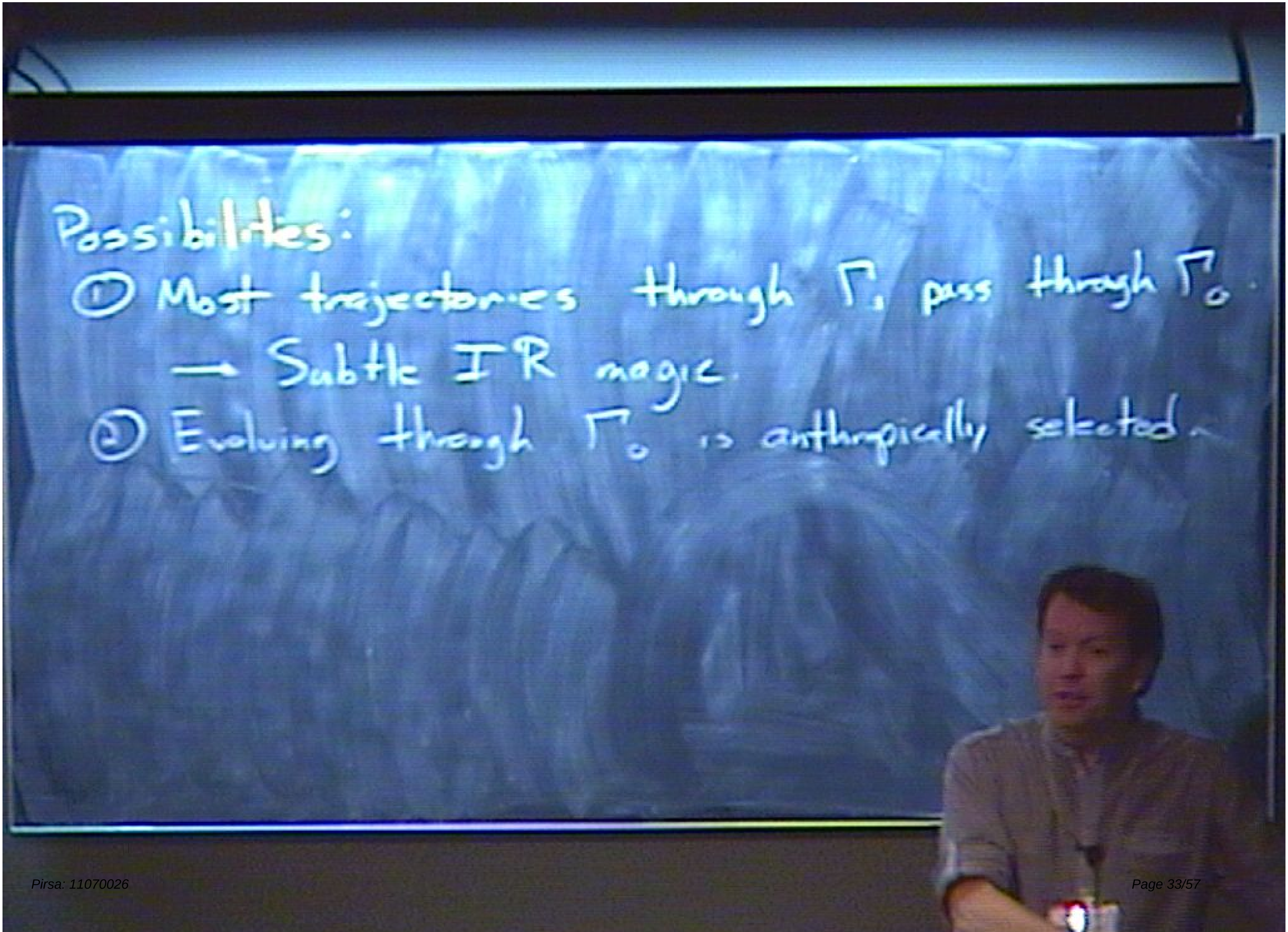
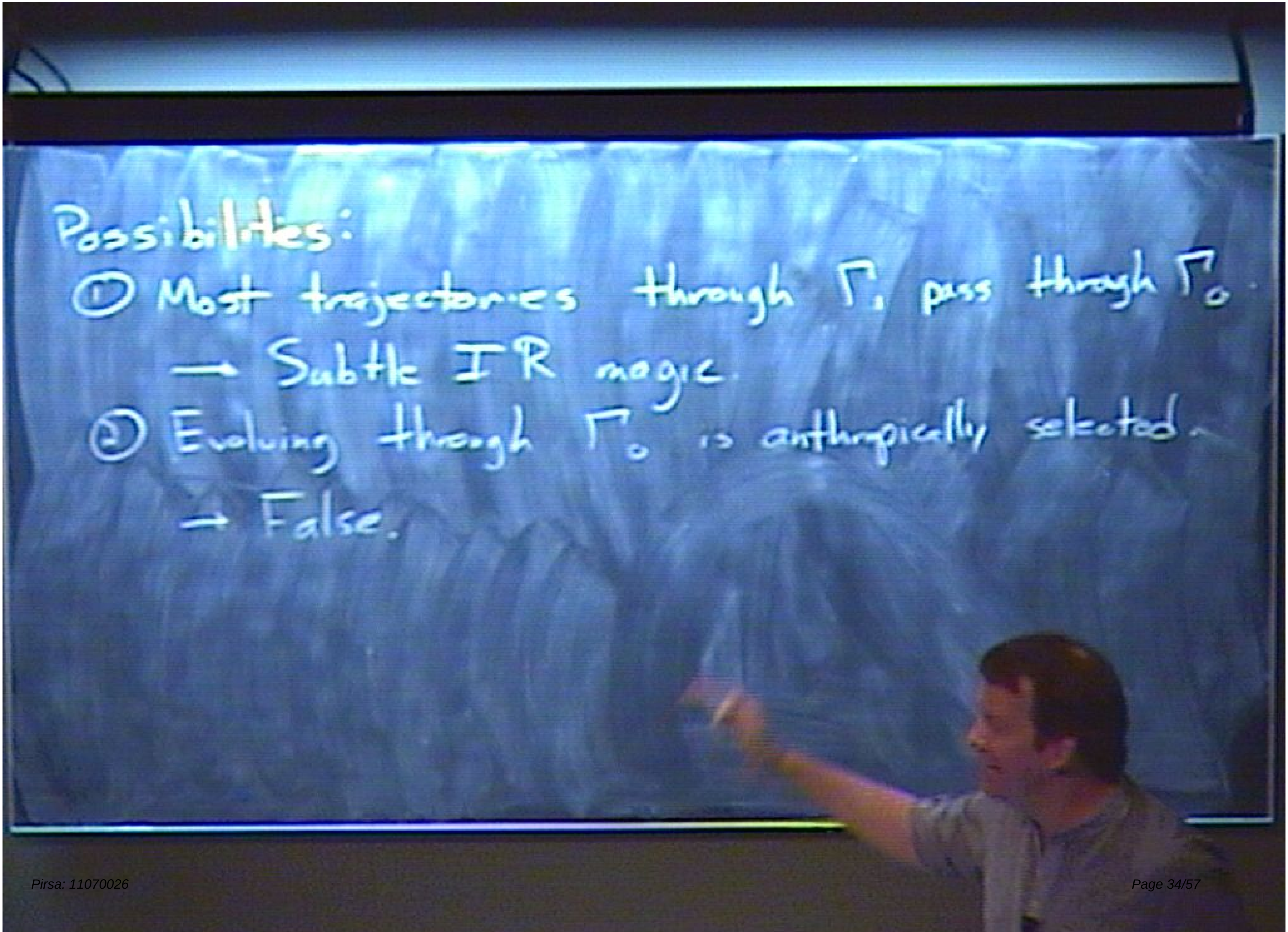
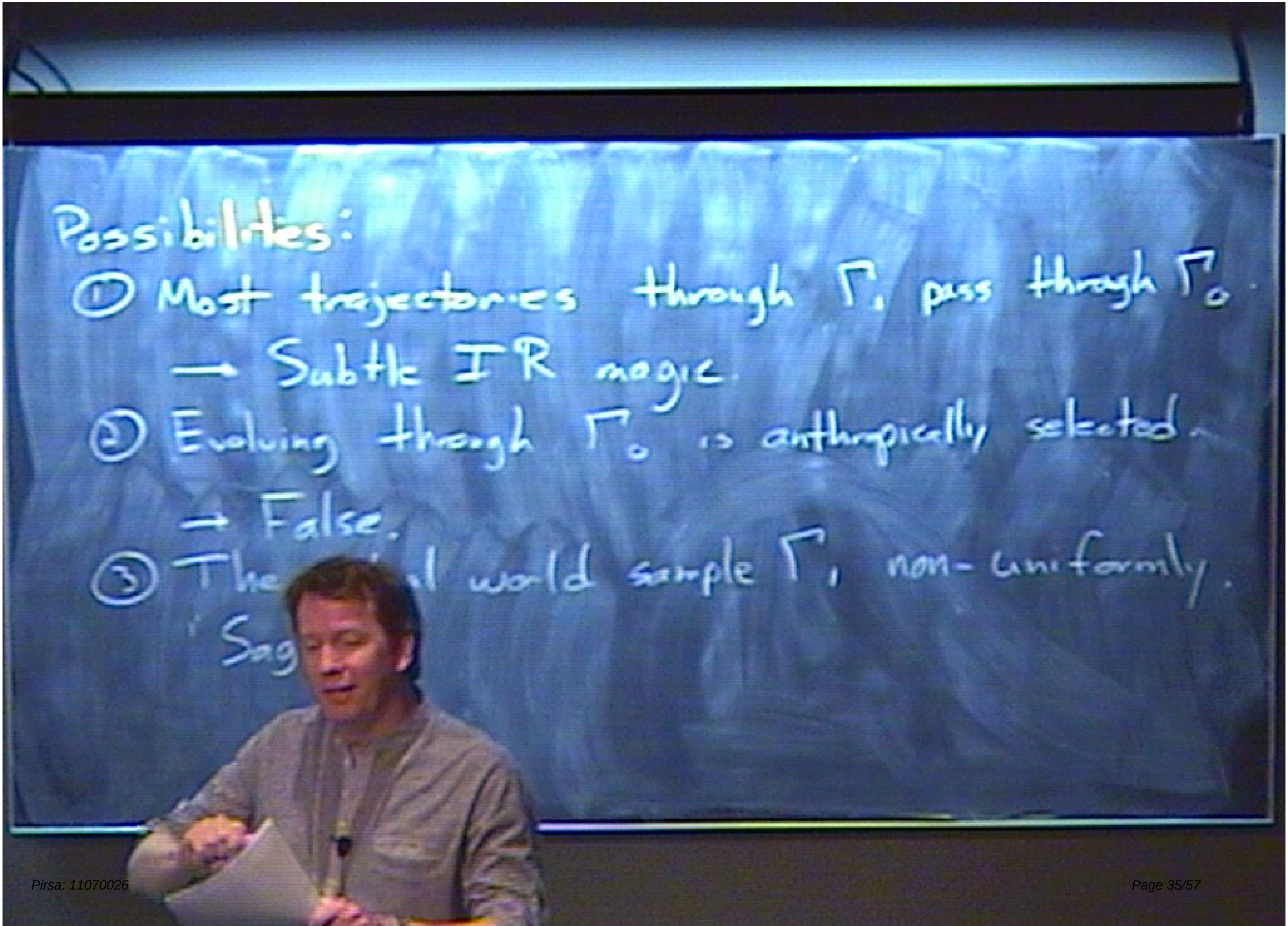
Possibilities:

① Most trajectories through Γ_1 pass through Γ_0.


Possibilities:
① Most trajectories through Γ_1 pass through Γ_0.
→ Subtle IR magic.
② Evolving through Γ_0 is anthropically selected.


Possibilities:
① Most trajectories through Γ_1 pass through Γ_0.
→ Subtle IR magic.
② Evolving through Γ_0 is anthropically selected.
→ False.


Possibilities:
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③ The
world sample Γ_1 non-uniformly.

Possibilities:

1. Most trajectories through Γ_1 pass through Γ_0.
   → Subtle IR magic.
2. Evolving through Γ_0 is anthropically selected.
   → False.
3. The actual world sample Γ_1 non-uniformly.
   "Sagan": If $S(t+\Delta t) \gg S(t)$,
   then $S(t-\Delta t) \ll S(t)$ probably.

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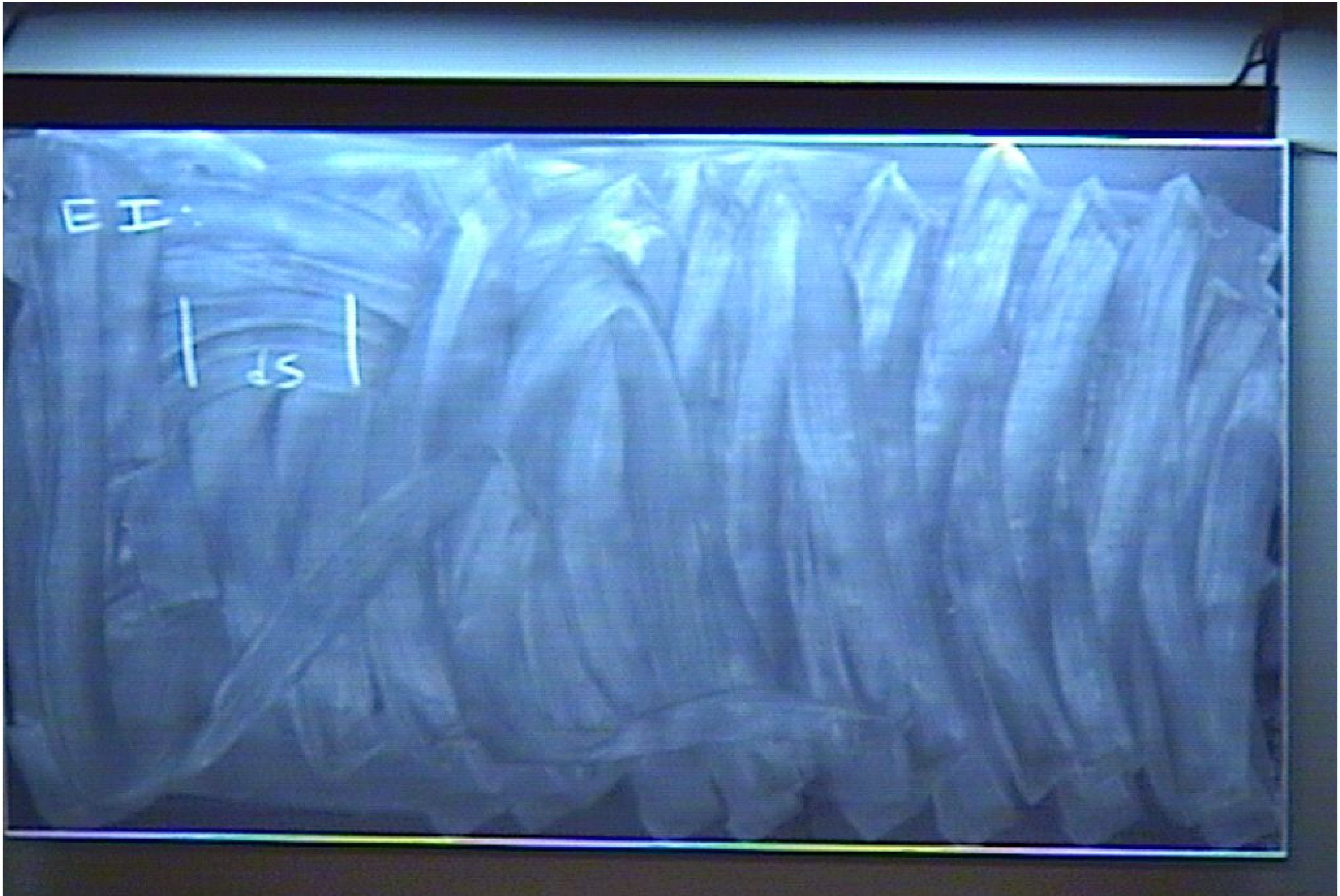
EI:
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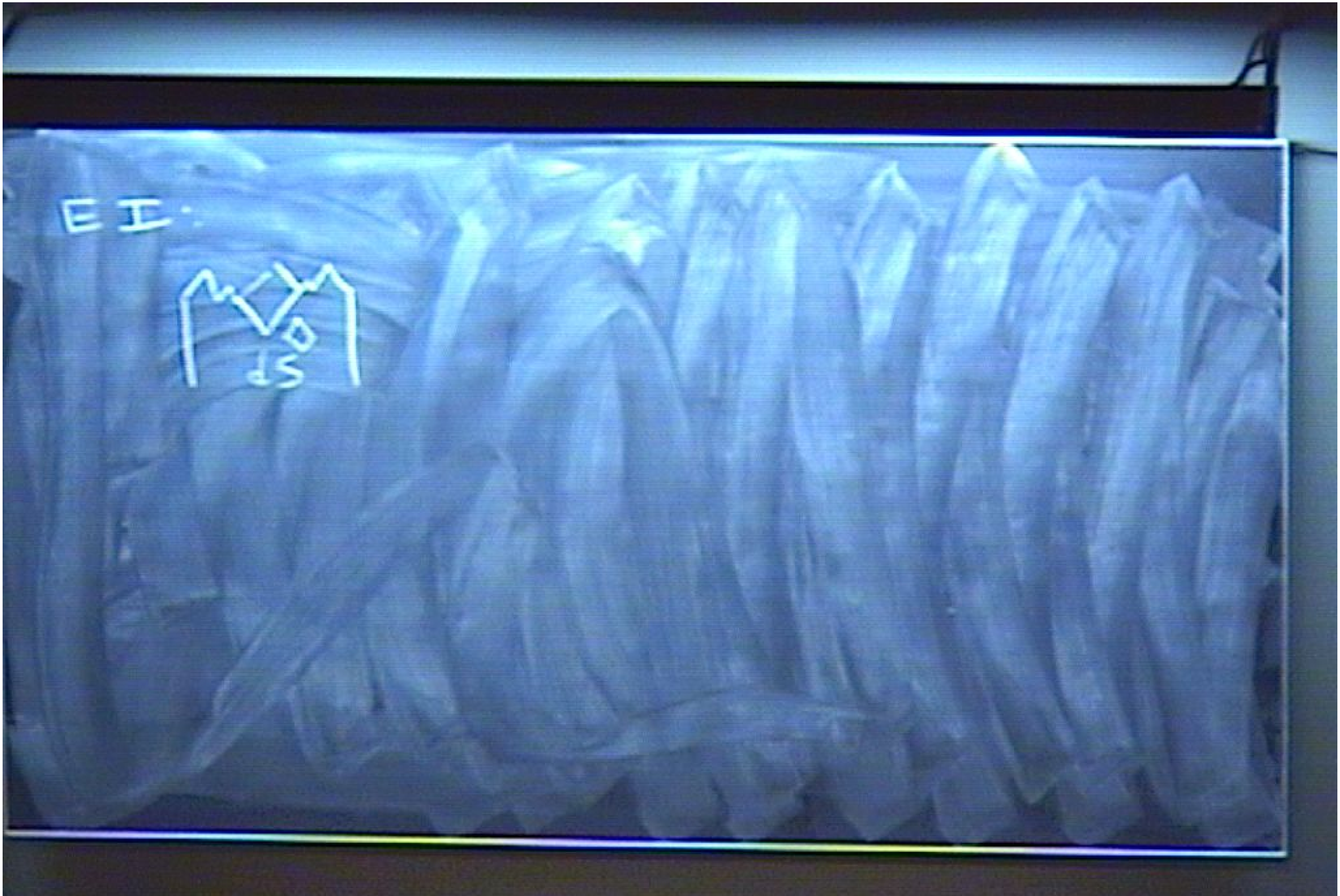
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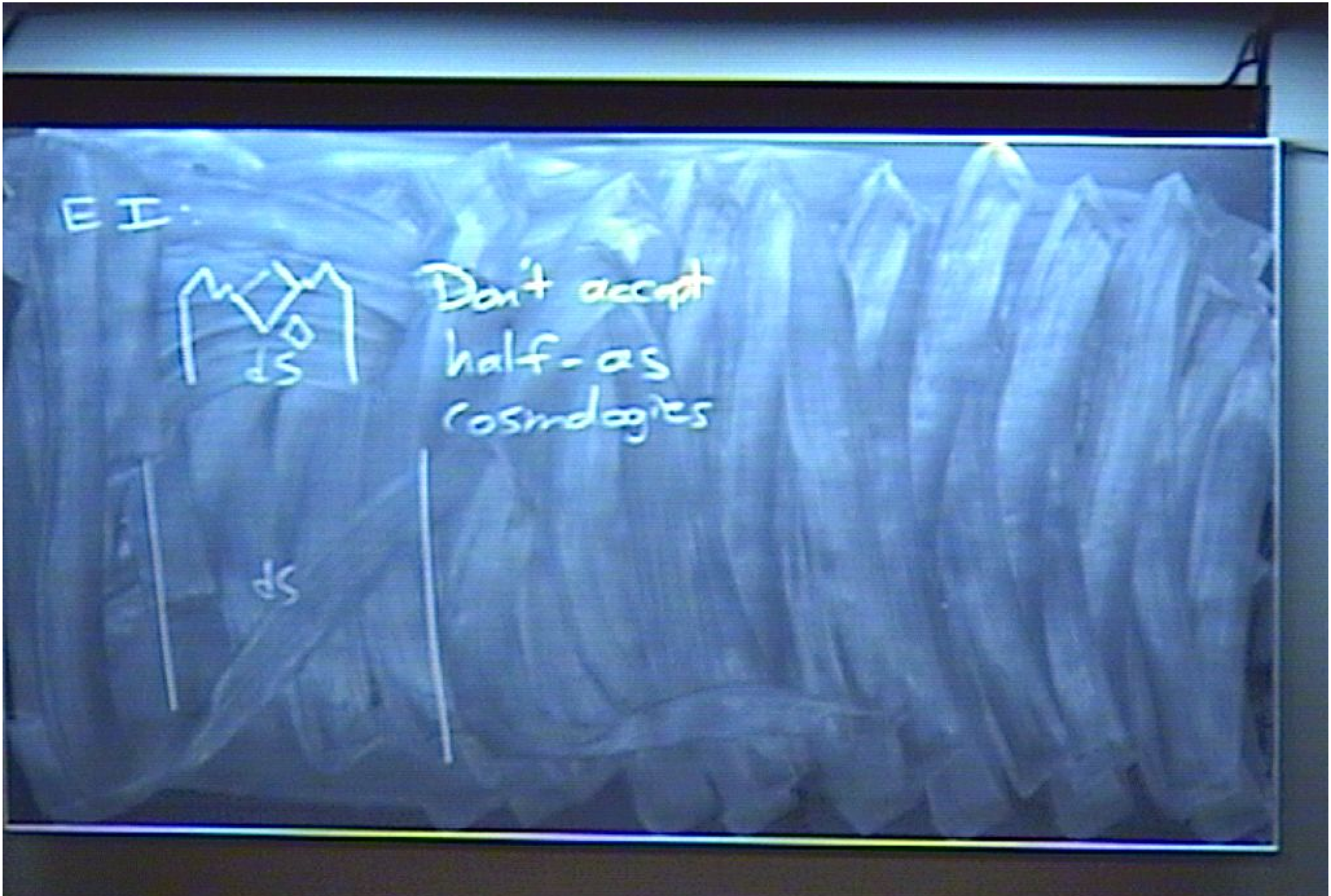
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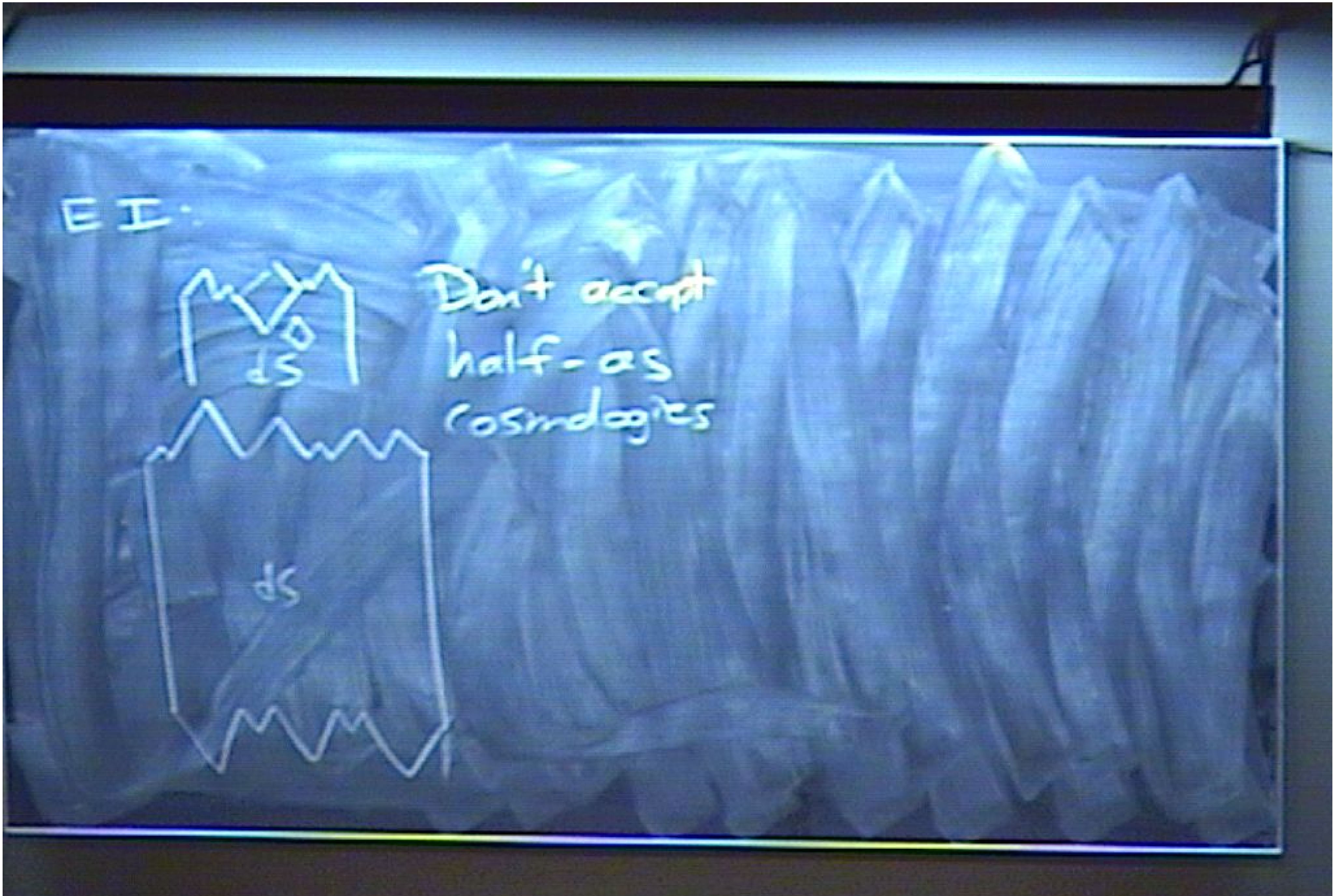
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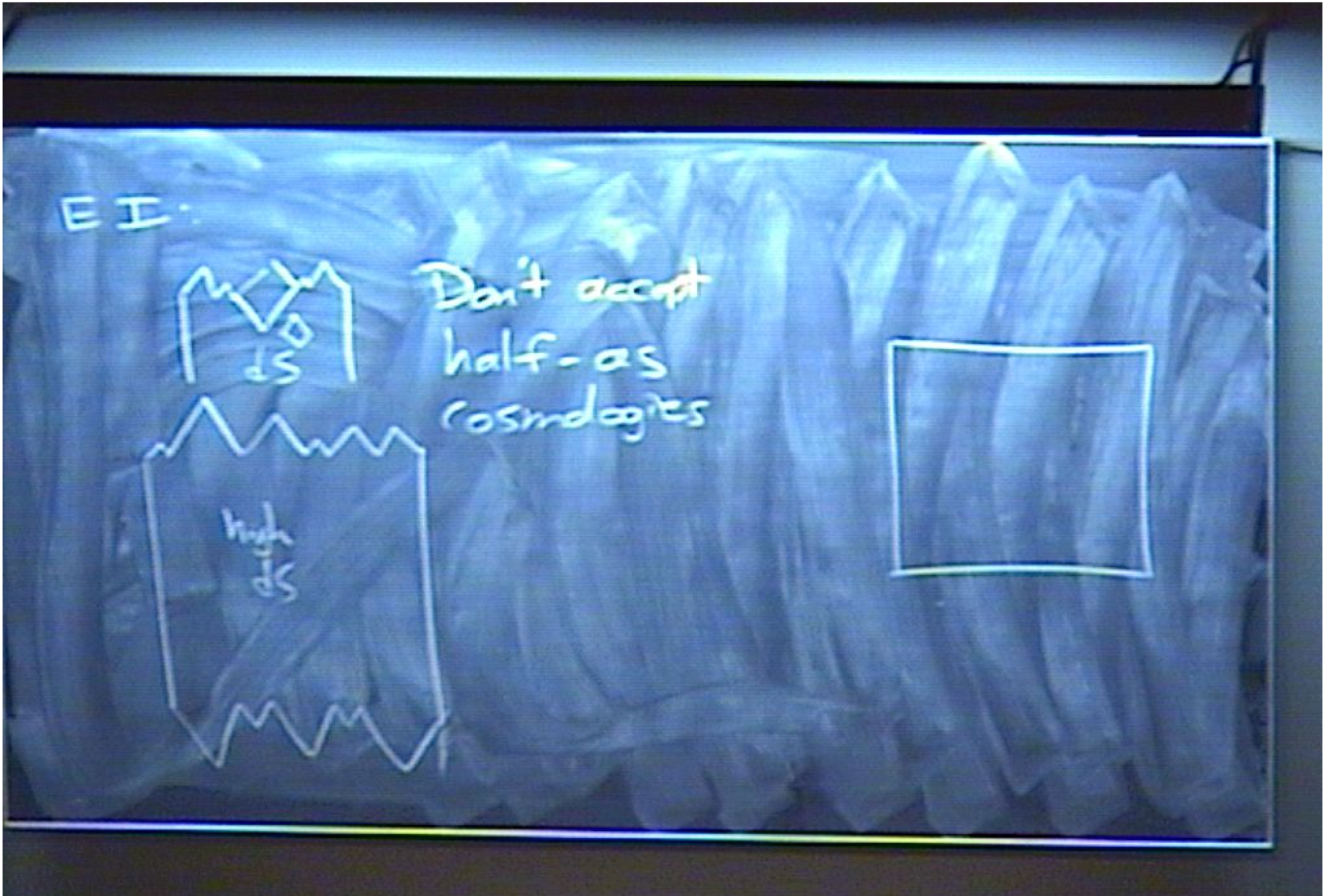
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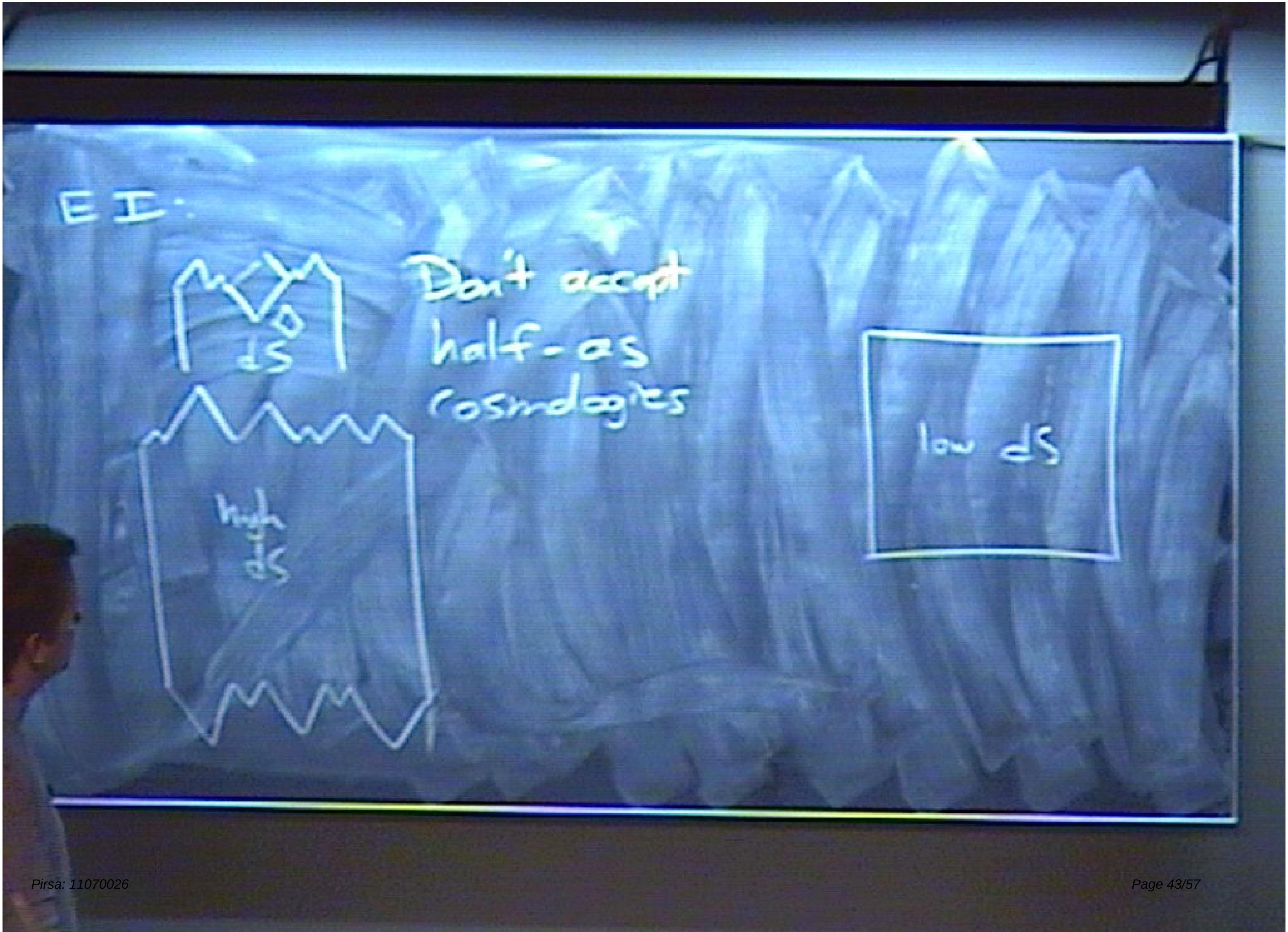
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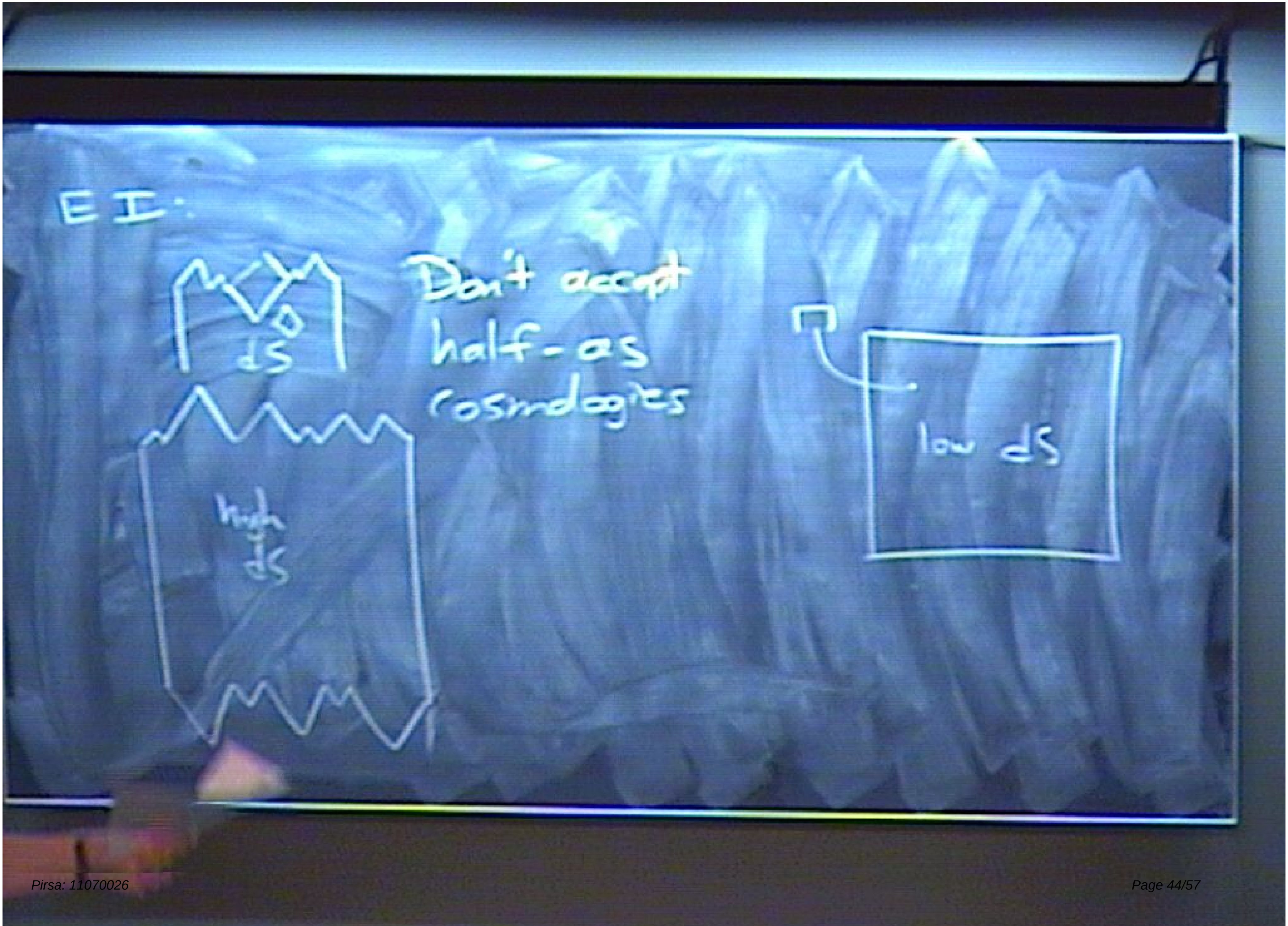
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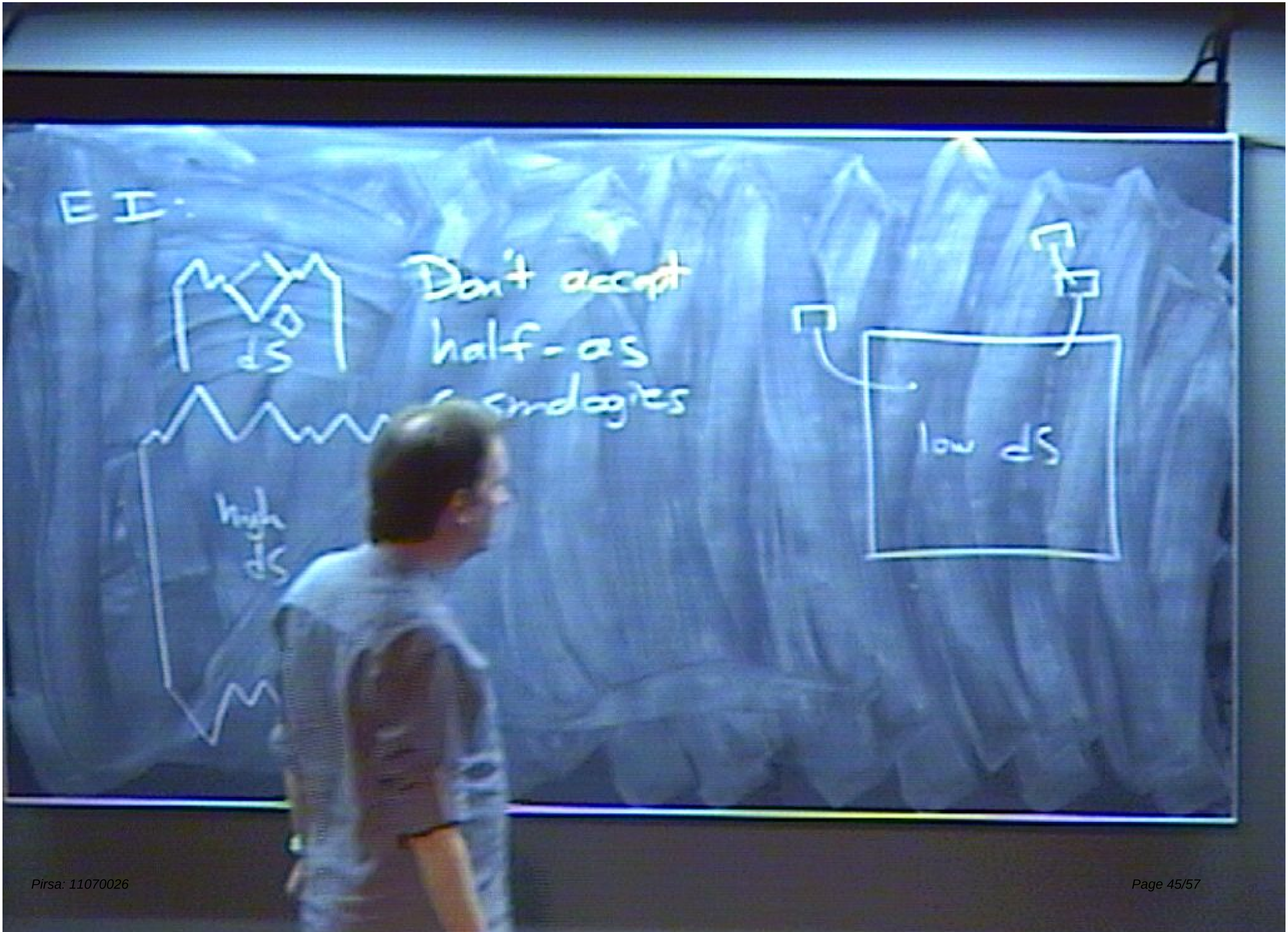
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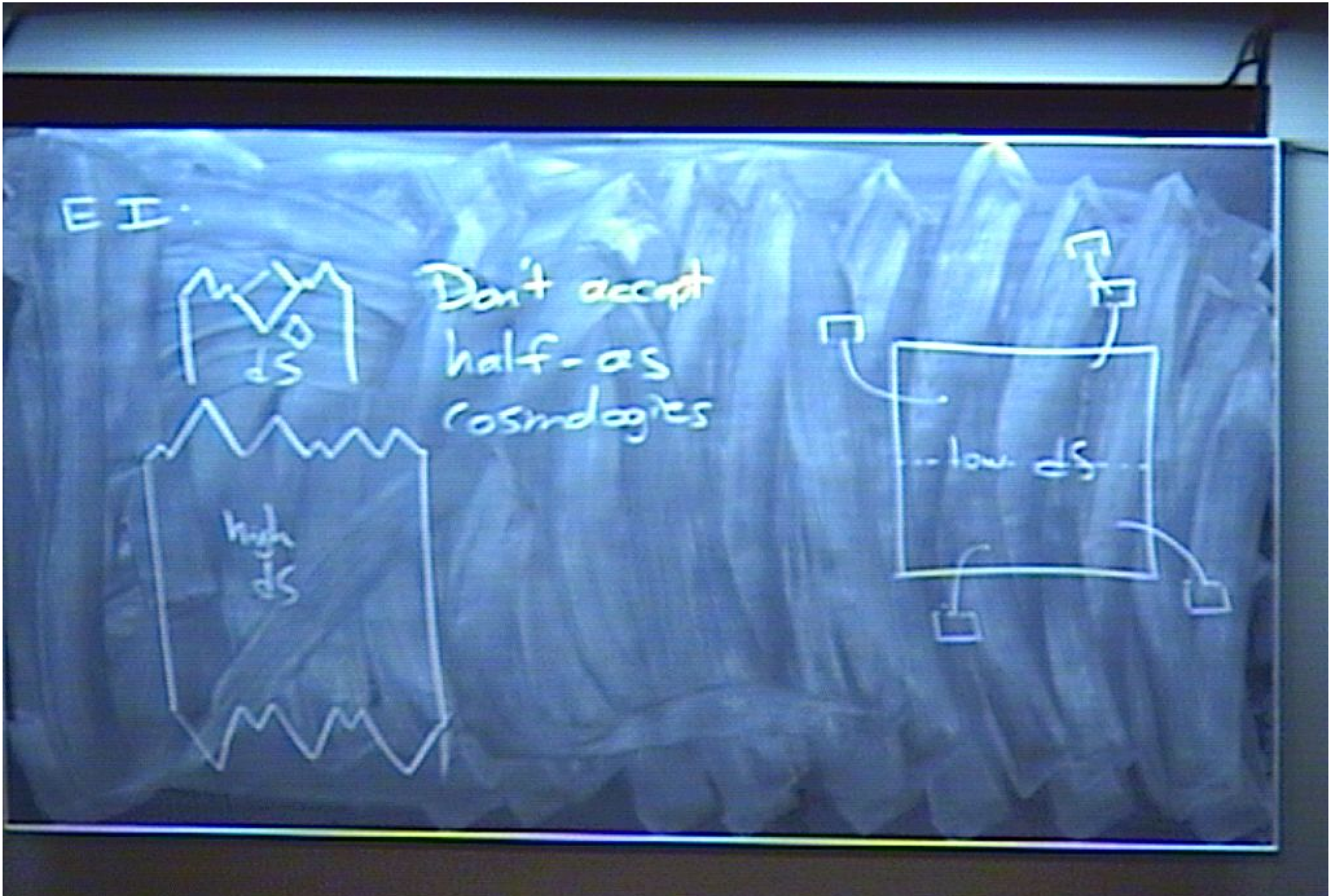
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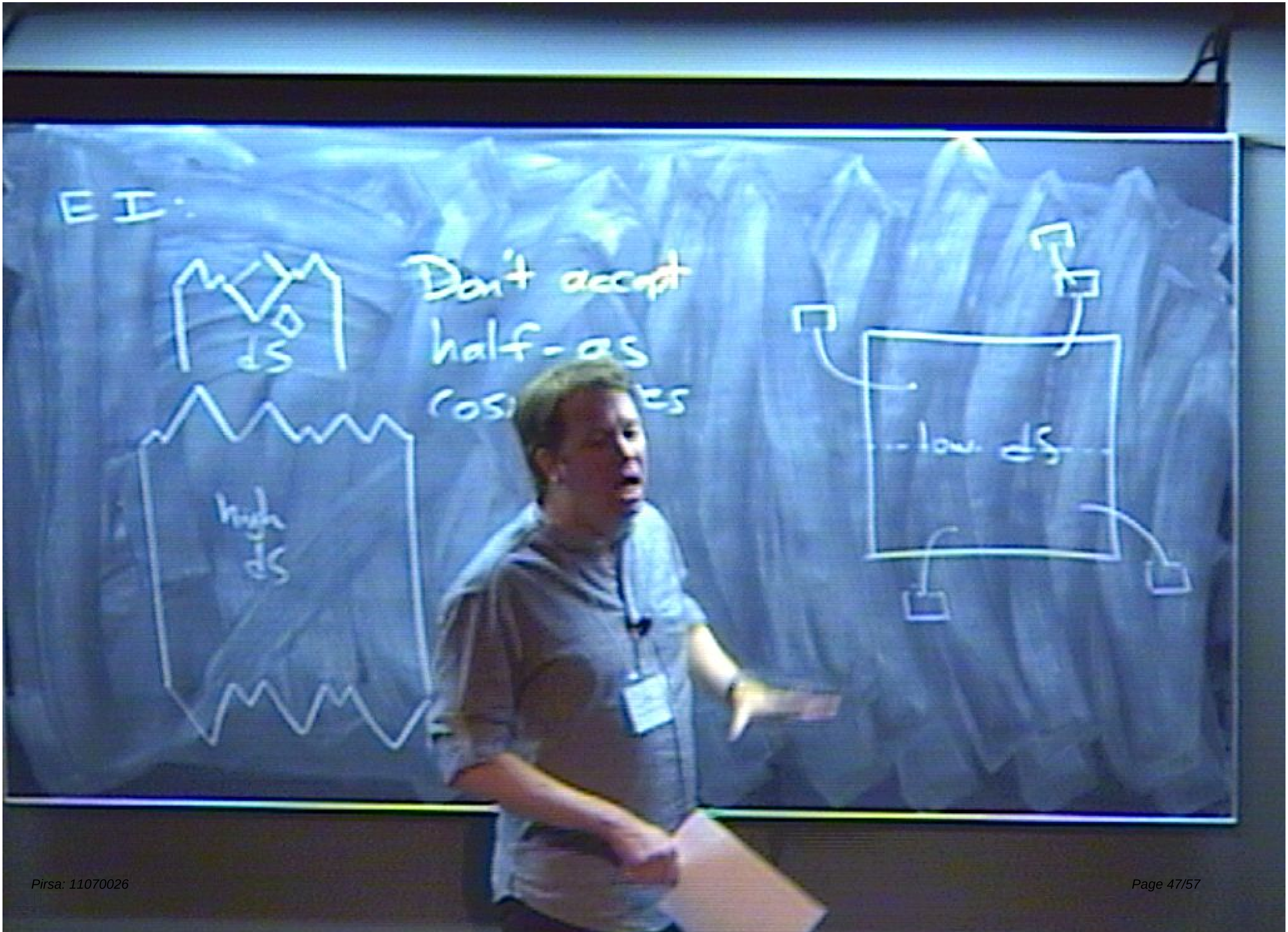
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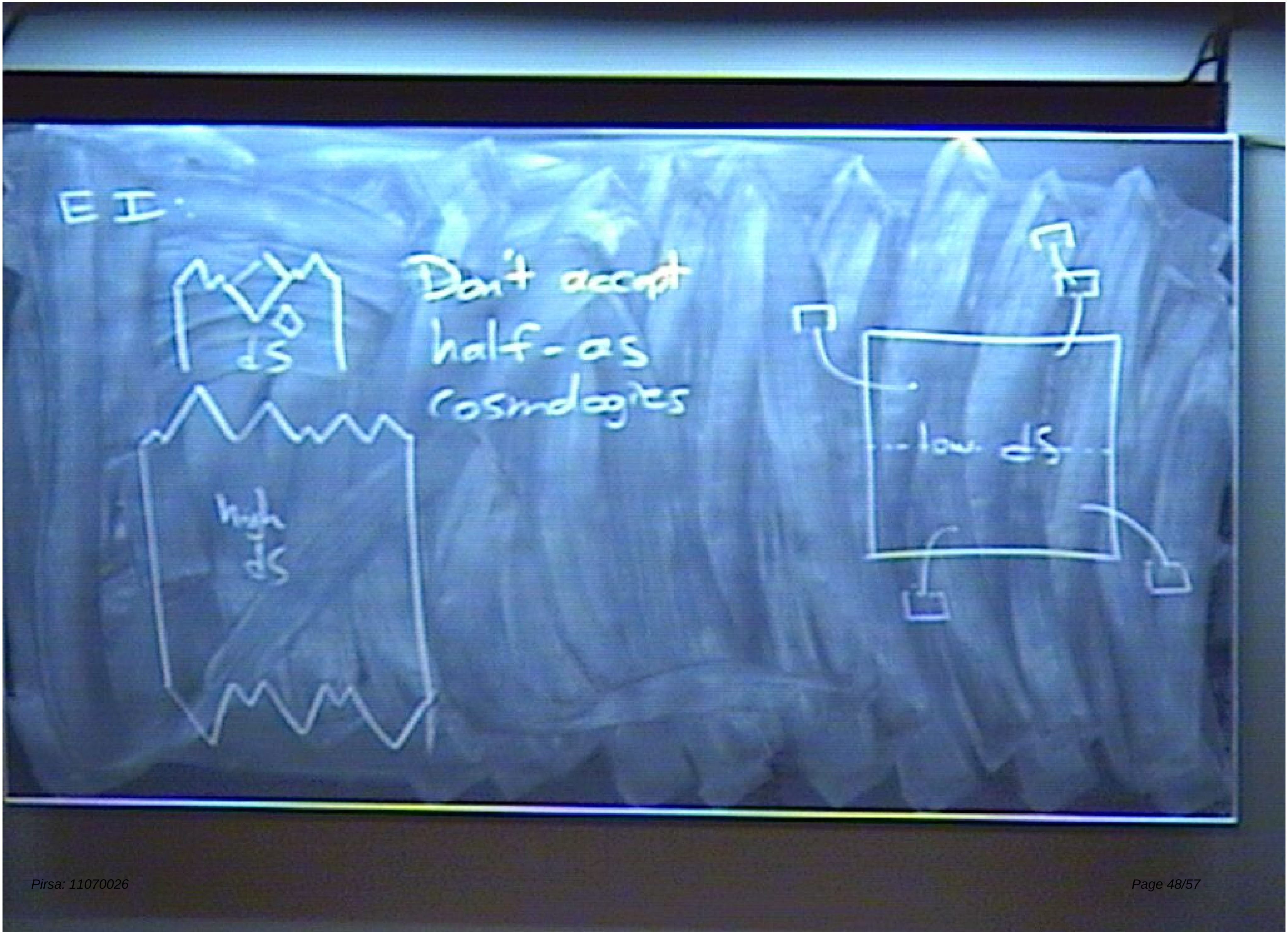
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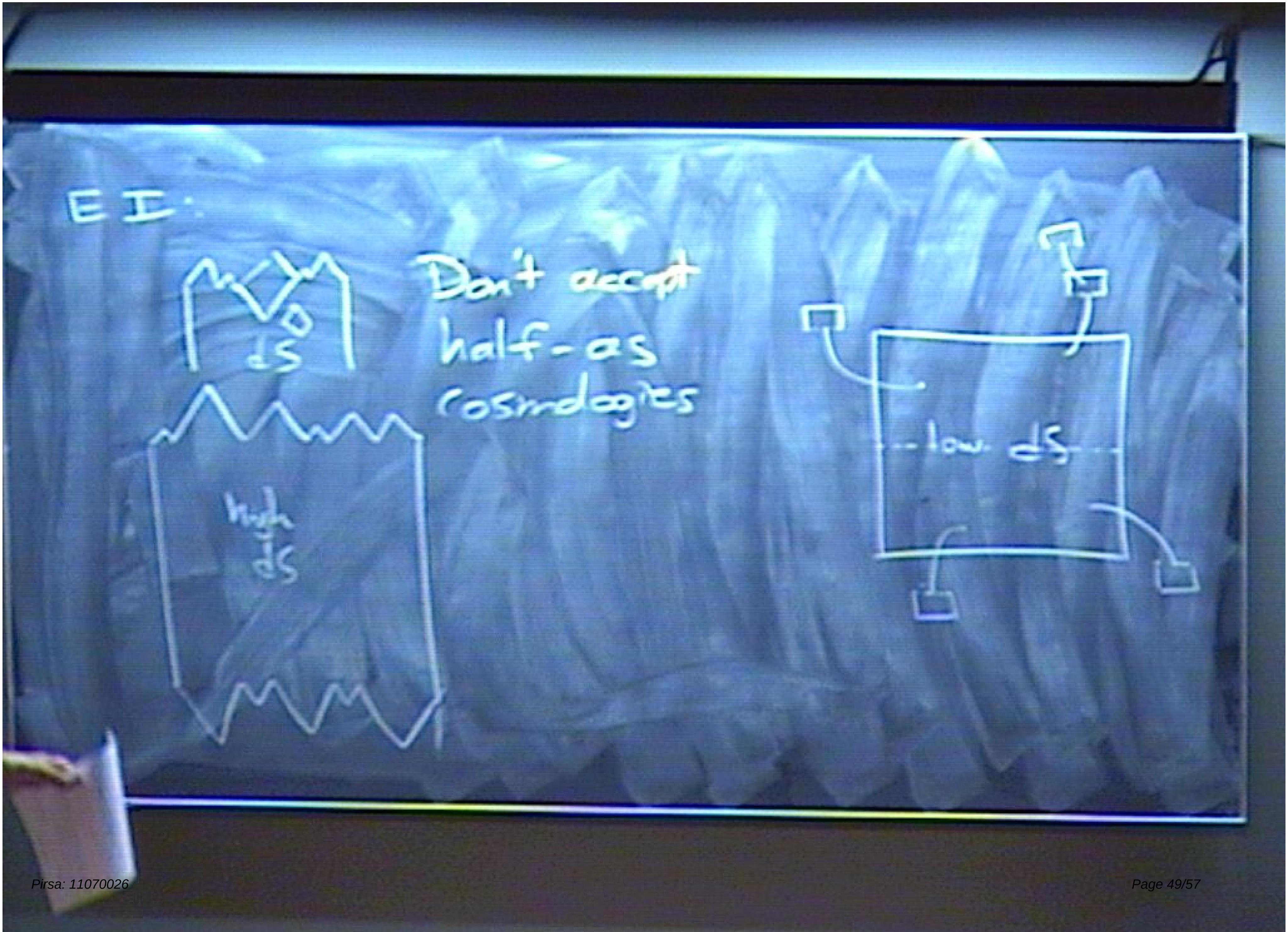
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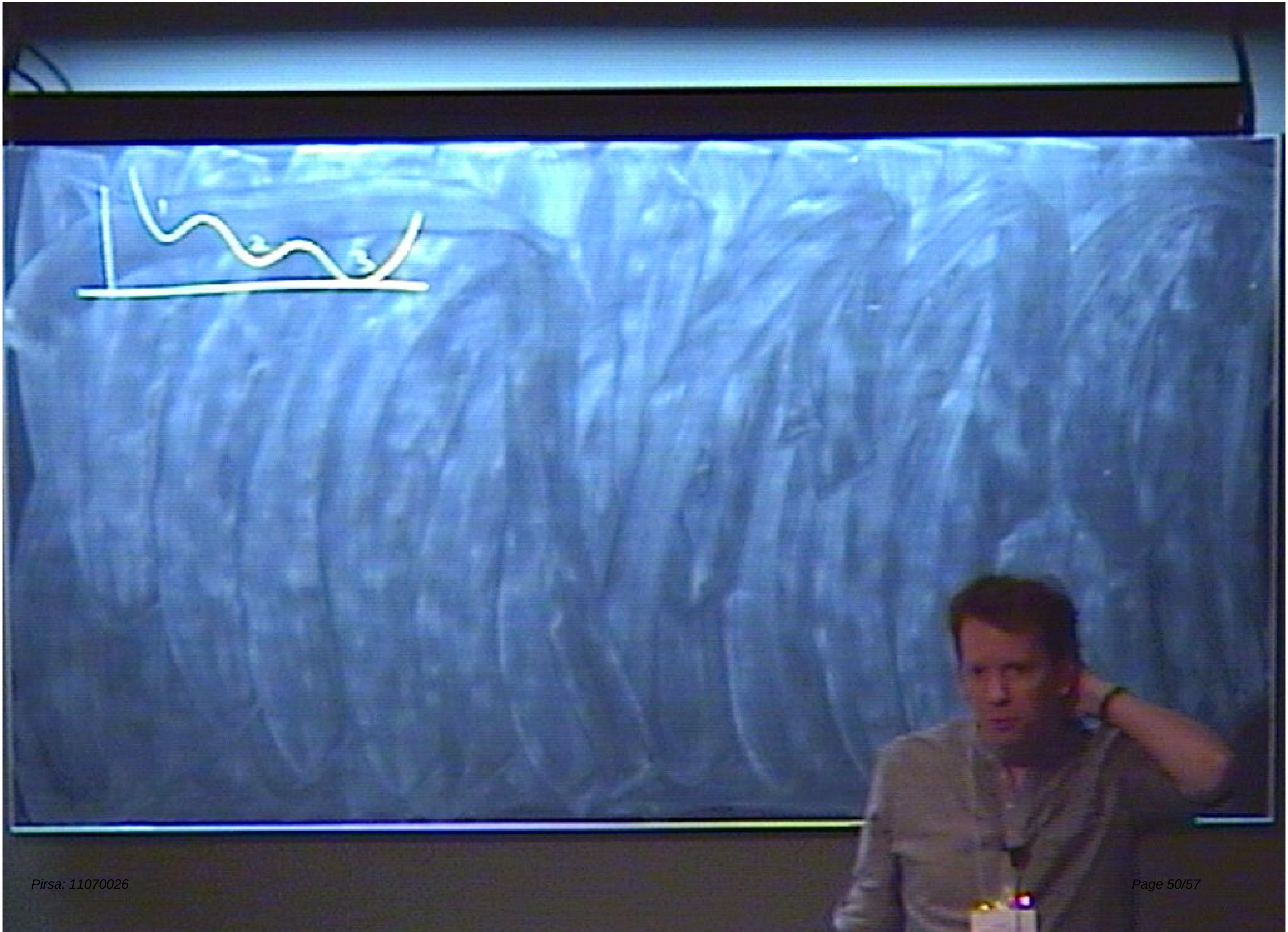

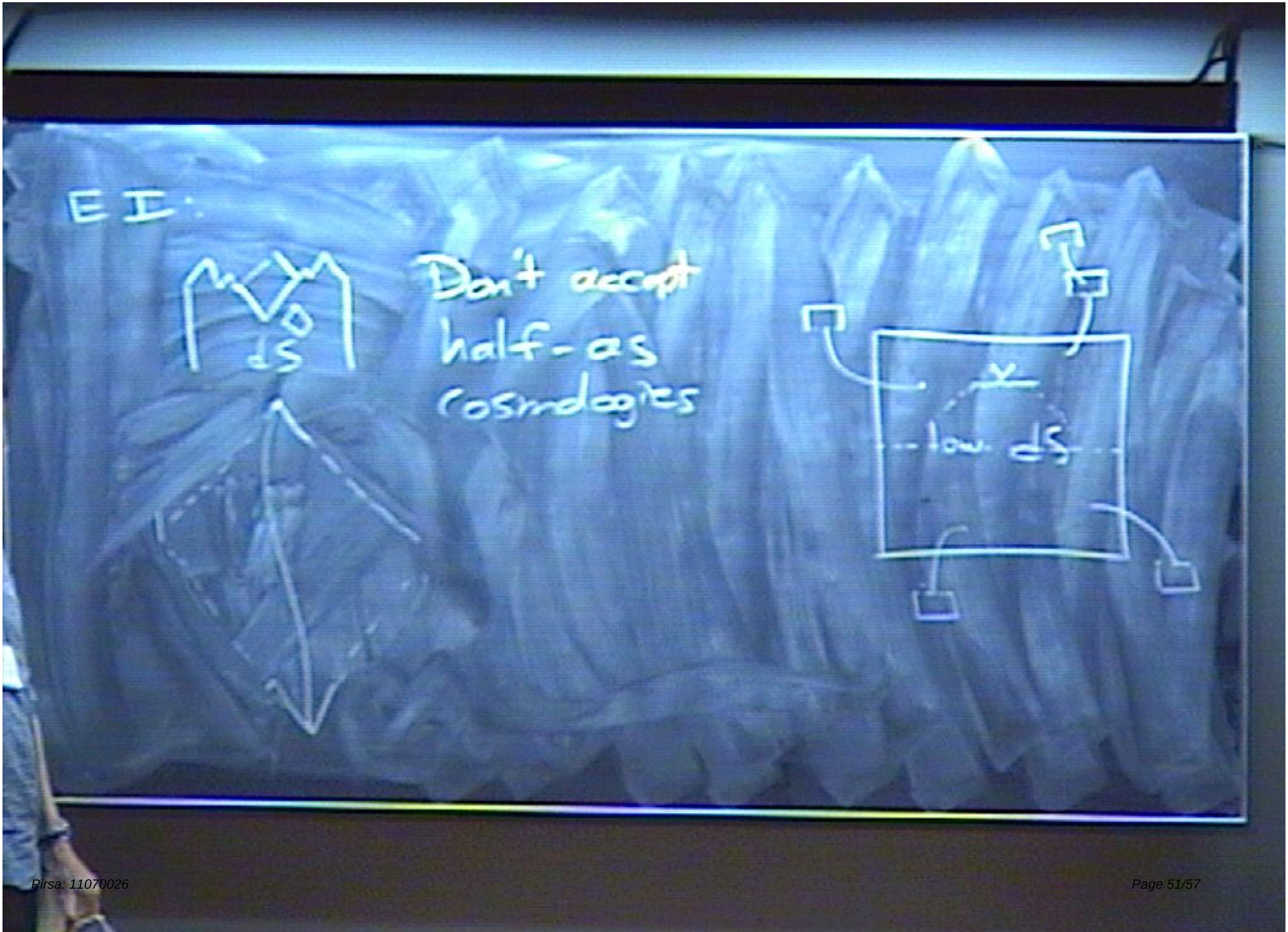
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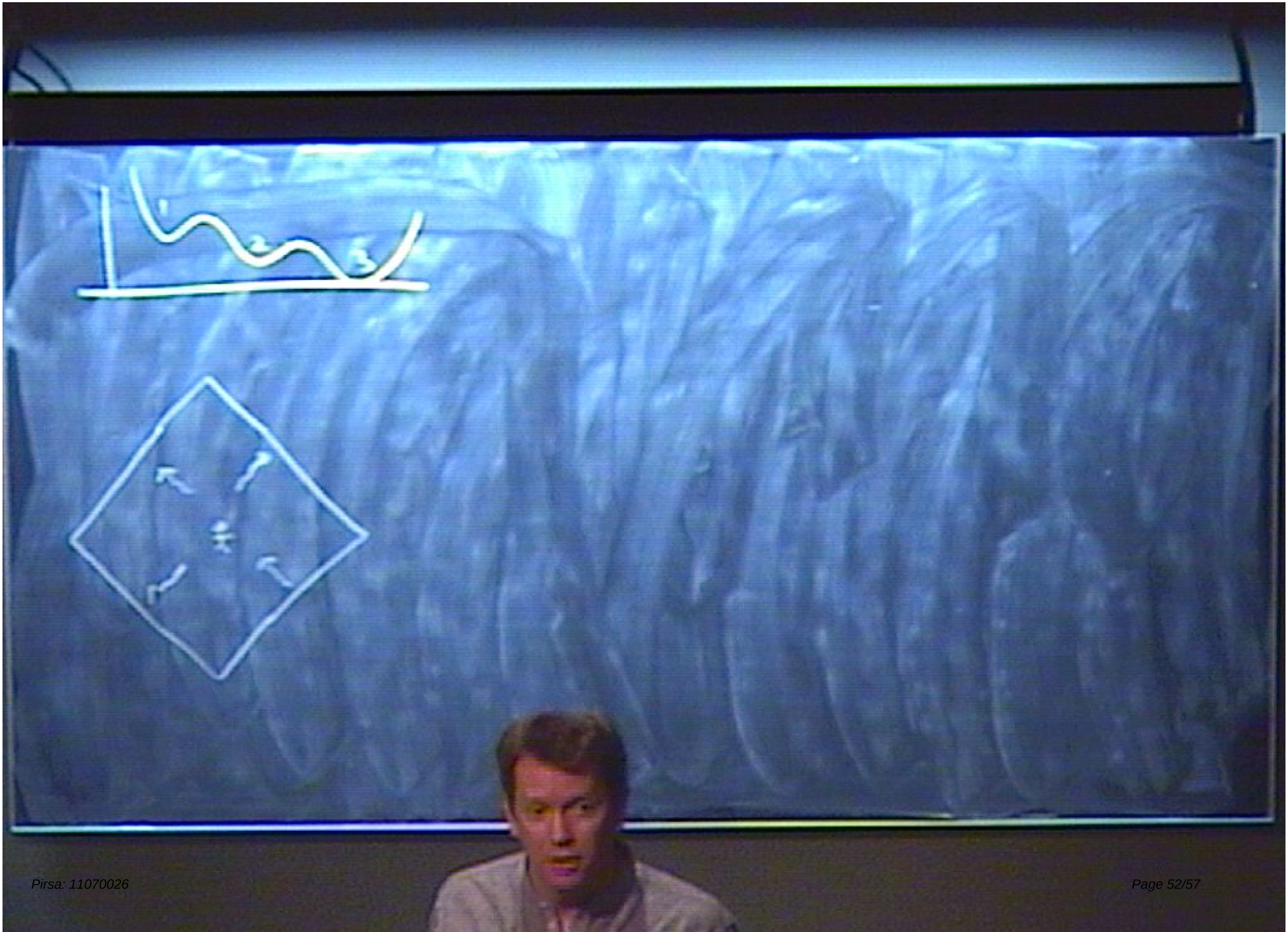
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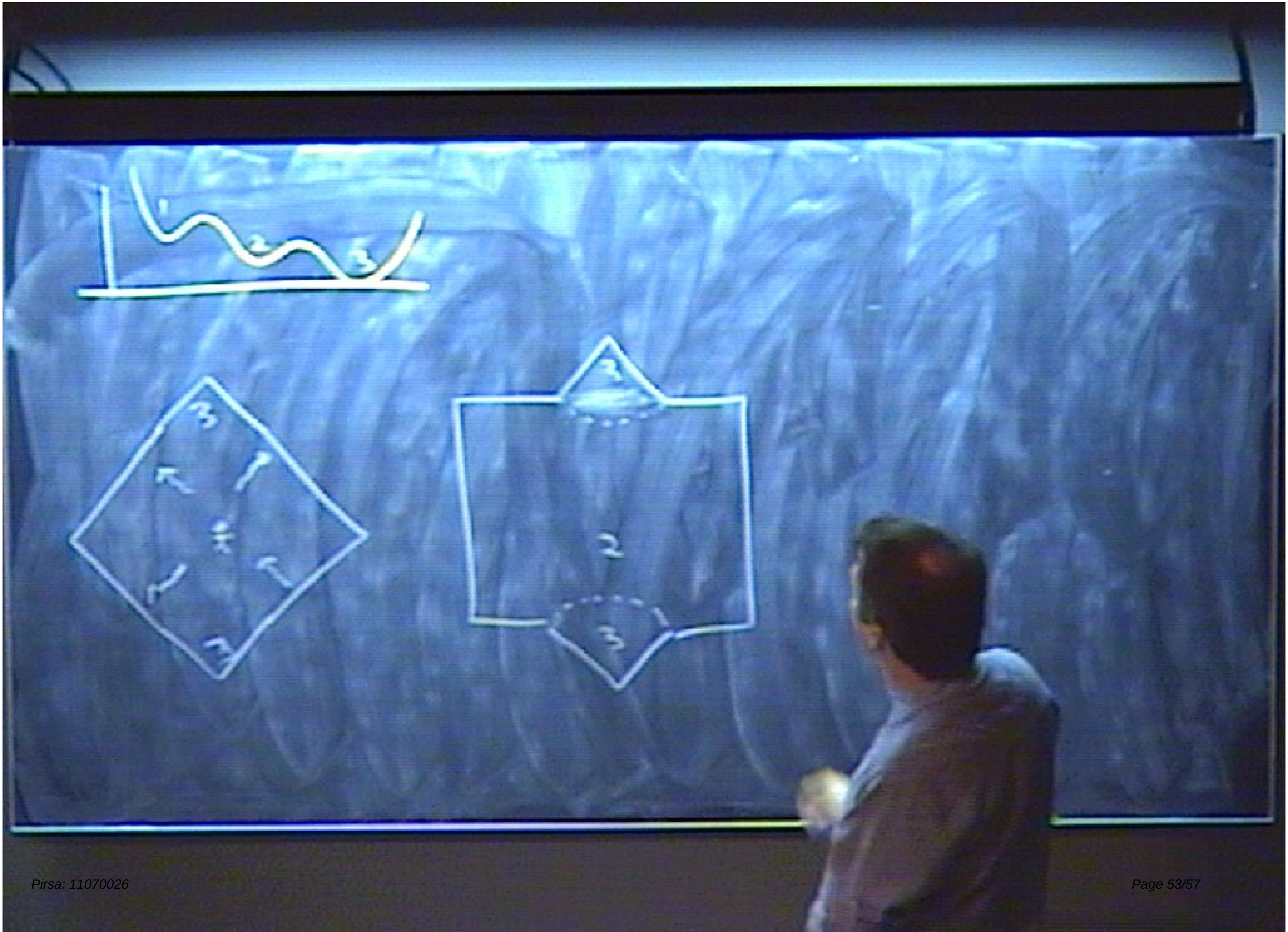

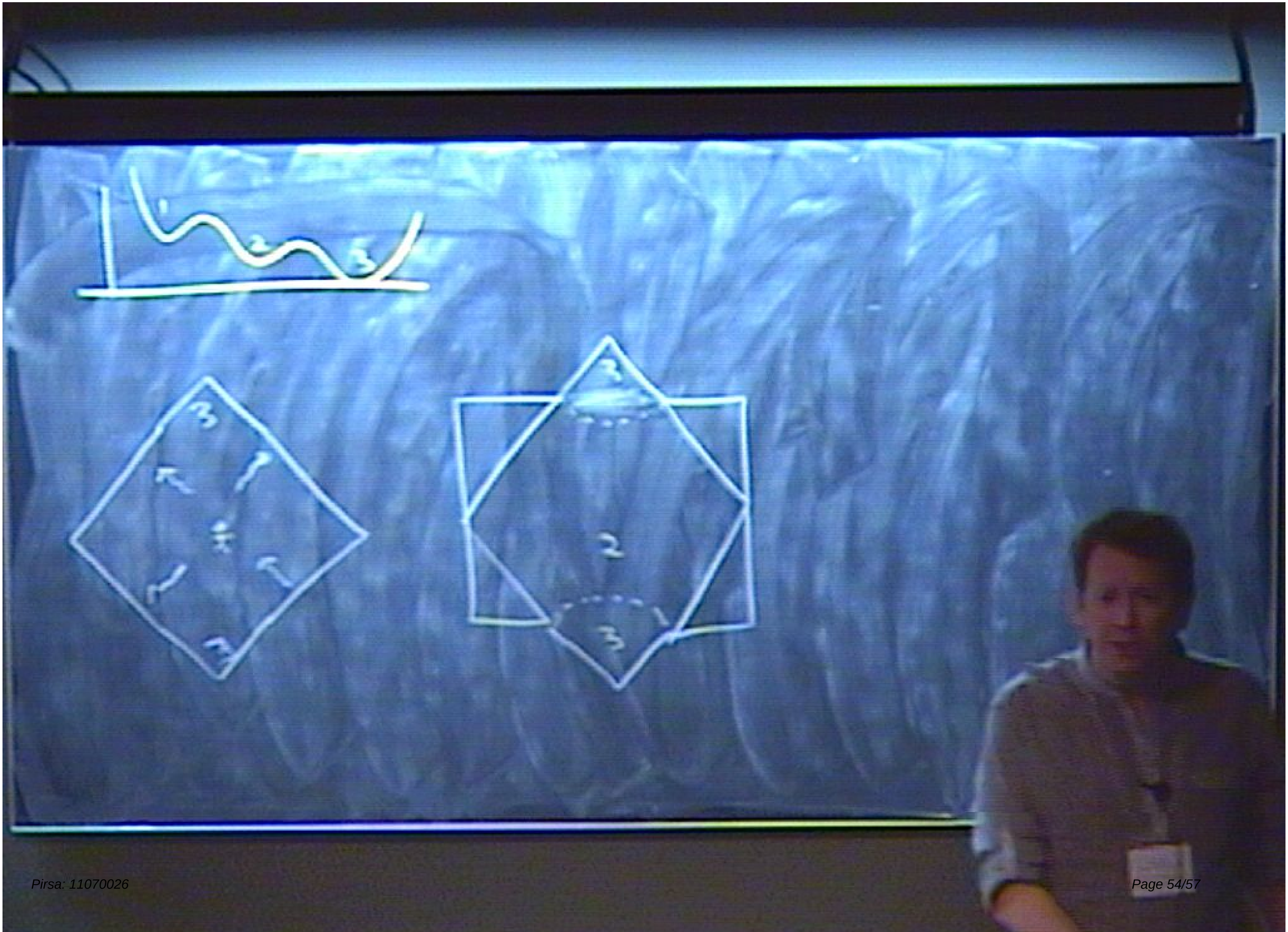
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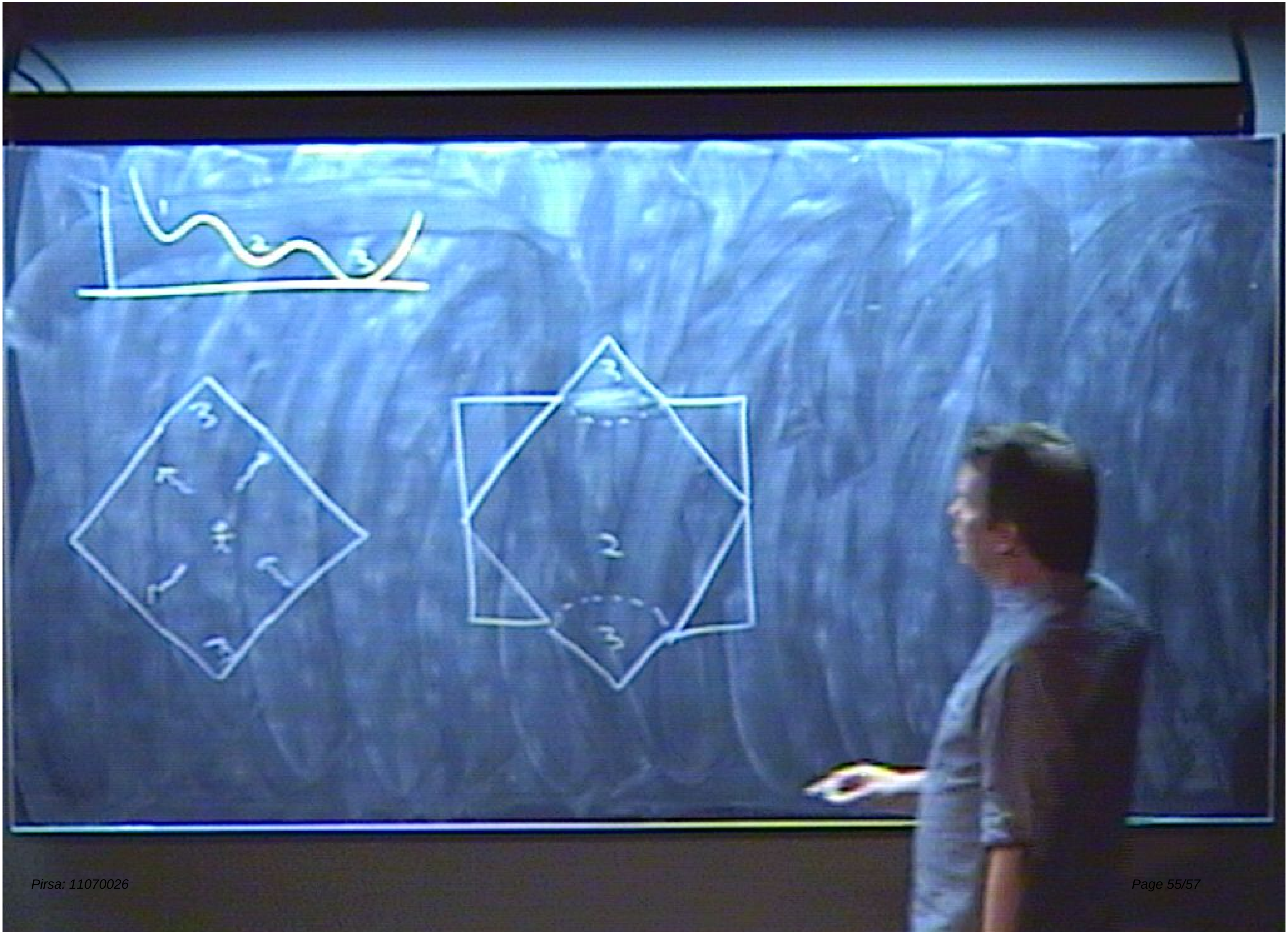

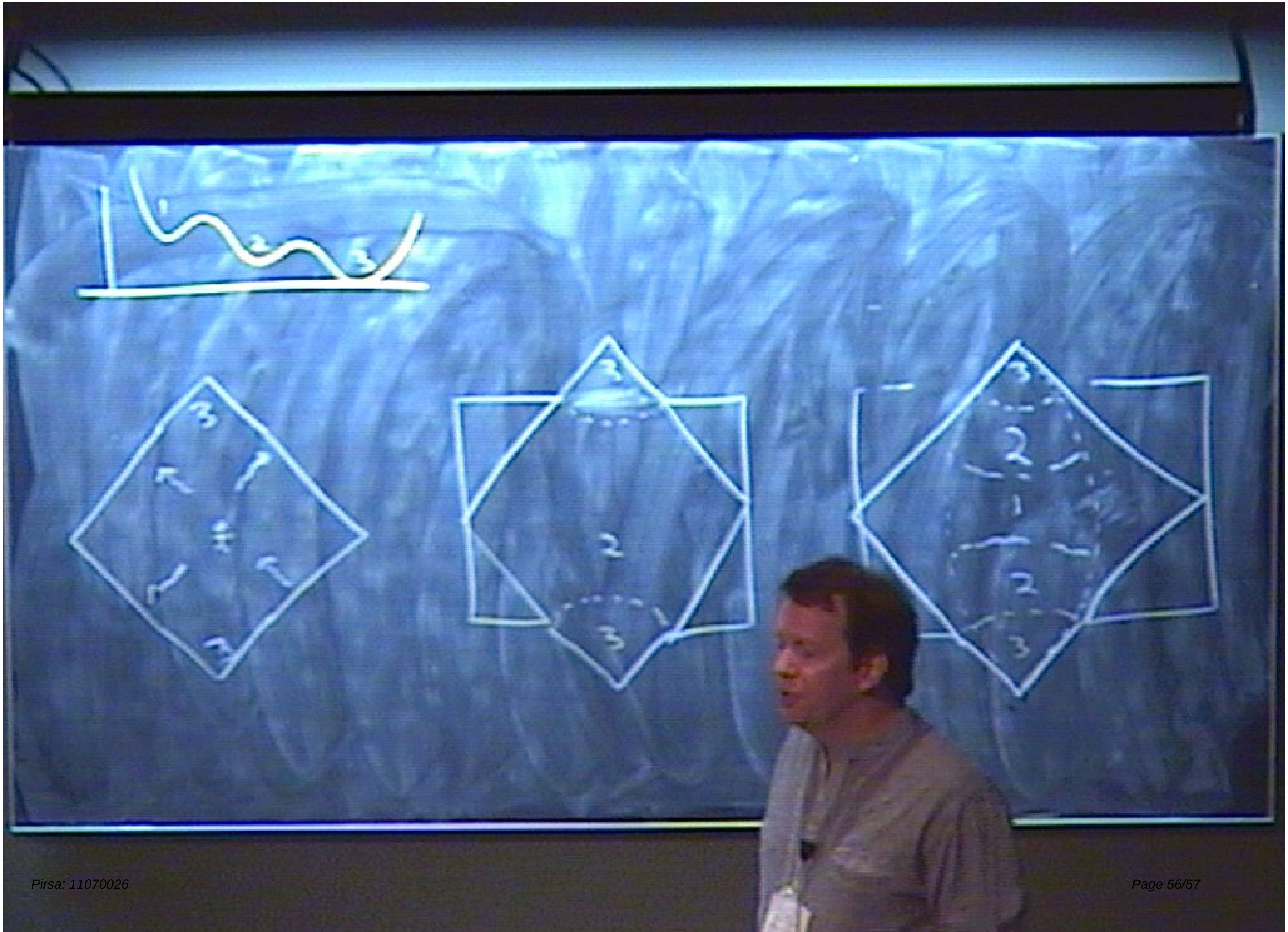
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