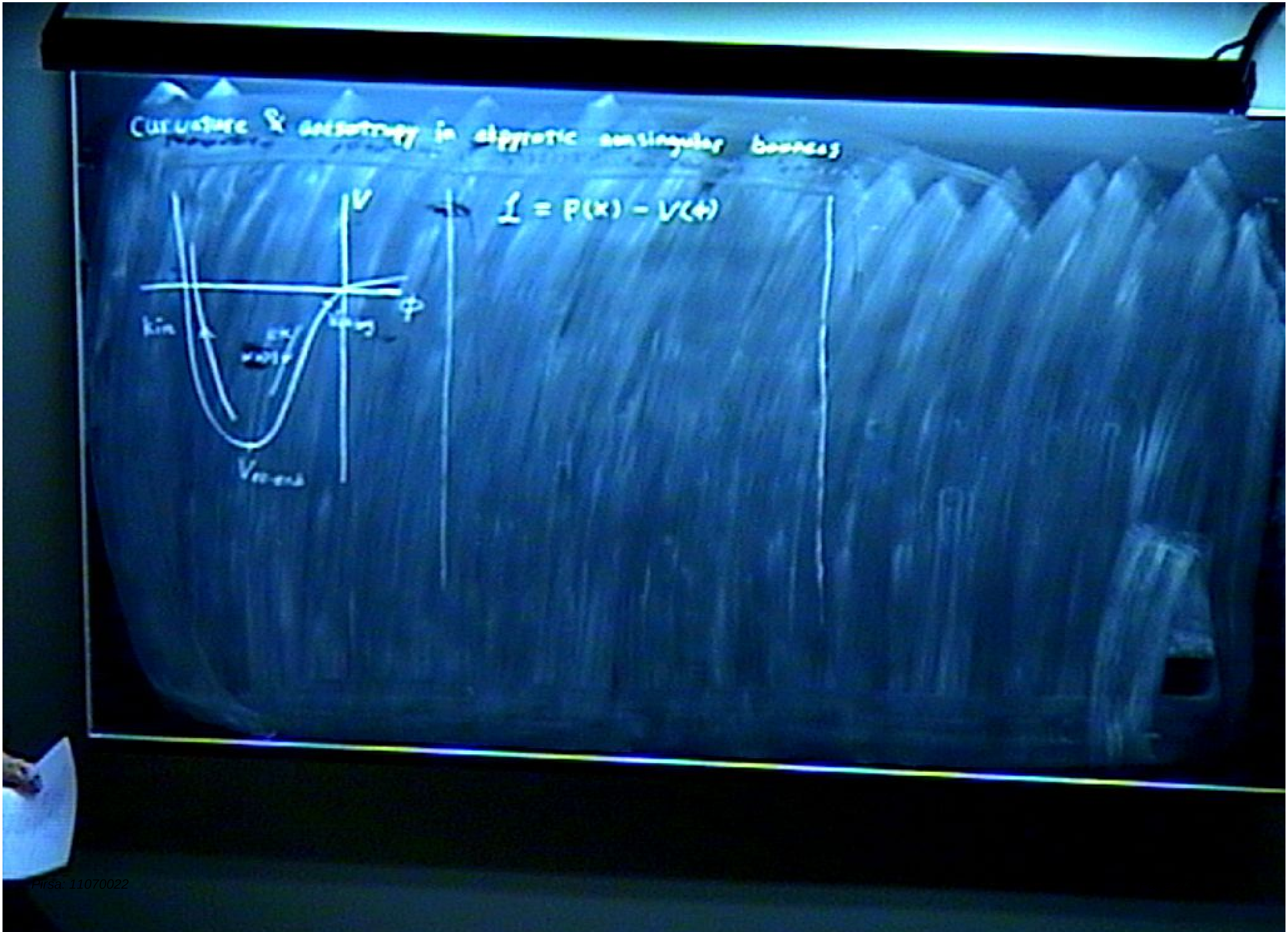
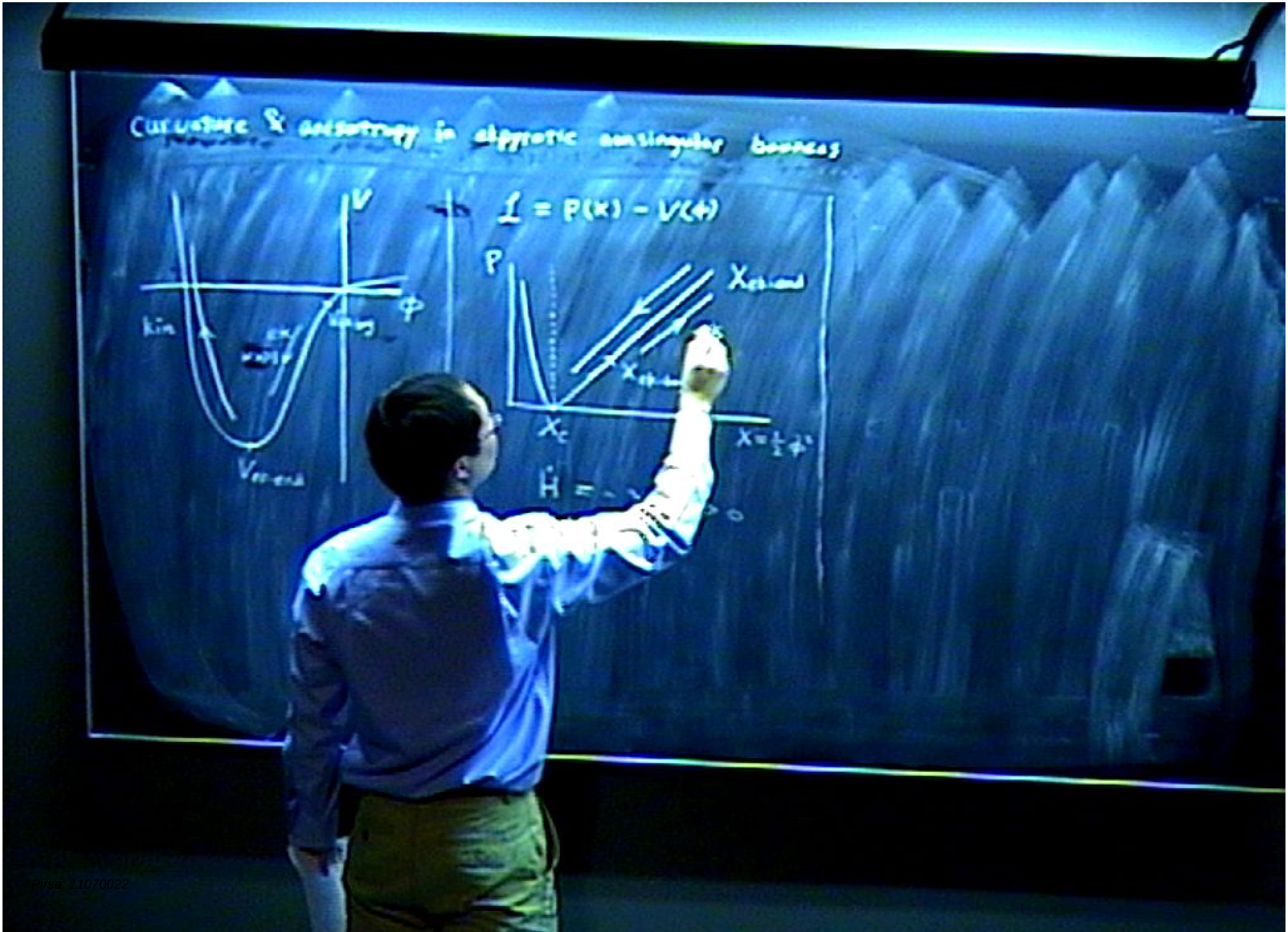
Title: Curvature and Anisotropy Near a Nonsingular Bounce

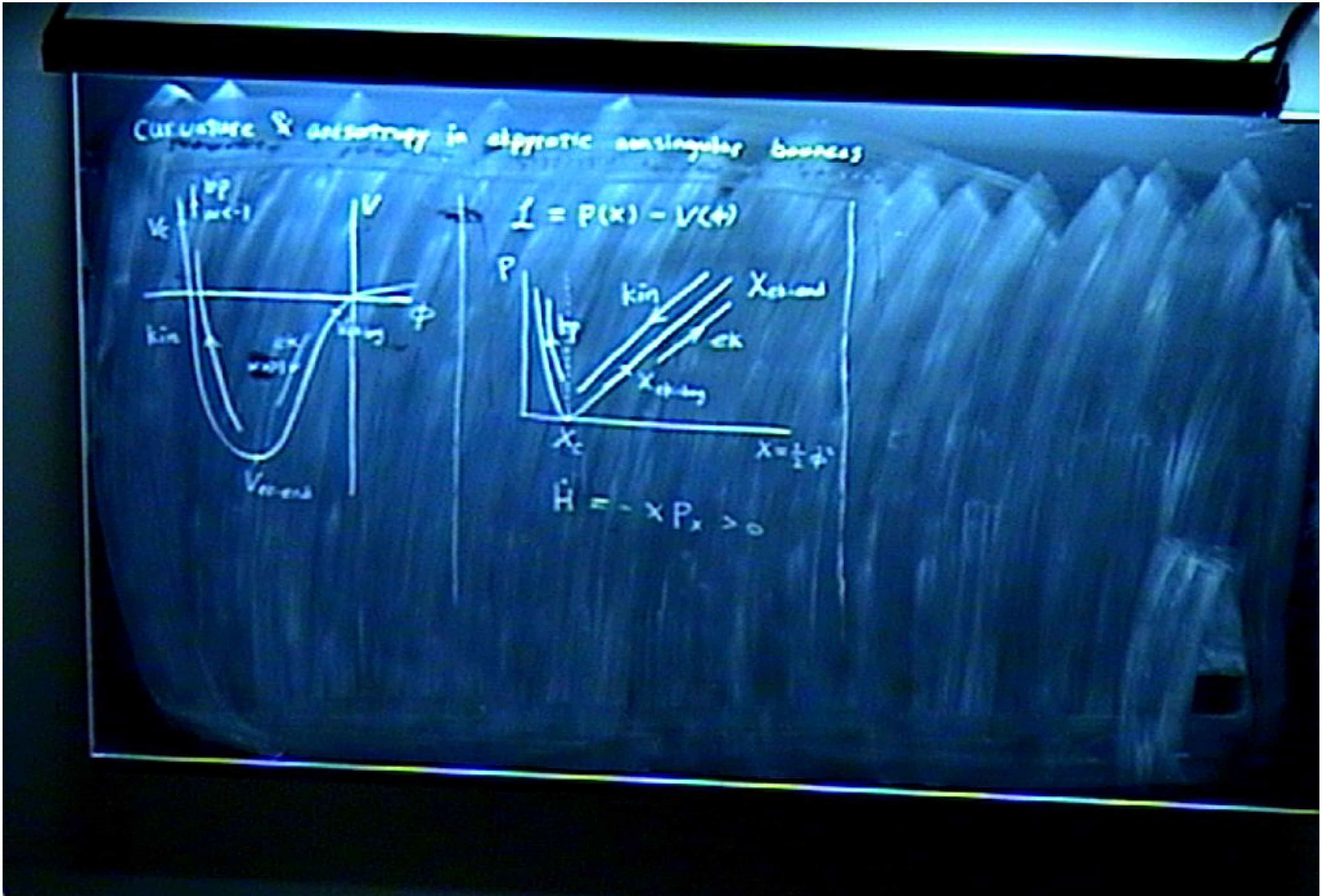
Date: Jul 14, 2011 05:00 PM

URL: http://pirsa.org/11070022

Abstract: Problematic growths of curvature and anisotropy are found in nonsingular bouncing cosmologies that include both an ekpyrotic phase and a bouncing phase. Classically, initial curvature and anisotropy that are suppressed during the ekpyrotic phase will grow back exponentially during the nonsingular bouncing phase. Besides, curvature perturbations and anisotropy are generated by quantum fluctuations during the ekpyrotic phase. In the bouncing phase, an adiabatic curvature perturbation grows to dominate and gives rise to a blue spectrum that spoils the scale-invariance. Meanwhile, a scalar shear perturbation grows nonlinear and creates an overwhelming anisotropy that disrupts the nonsingular bounce altogether.


Curvature & anisotropy in ekpyrotic nonsingular bounces
ℒ = P(X) − V(φ)
V
φ
kin


Curvature & anisotropy in ekpyrotic nonsingular bounces
V
Φ
kin
$\mathcal{L} = P(X) - V(\phi)$
P
$X_{ek\text{-}end}$
X_c
$X = \frac{1}{2}\dot\phi^2$
$V_{ek\text{-}end}$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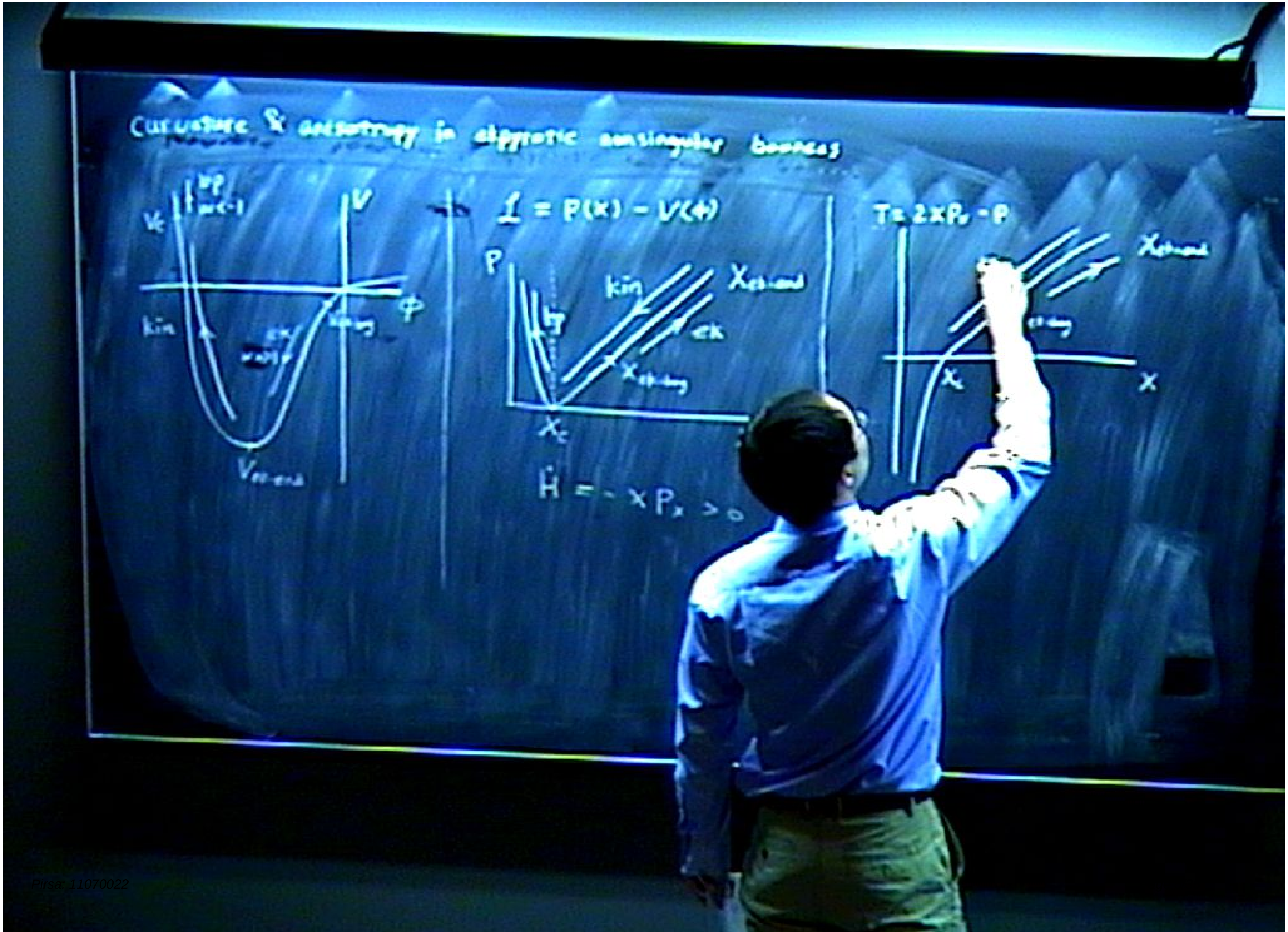
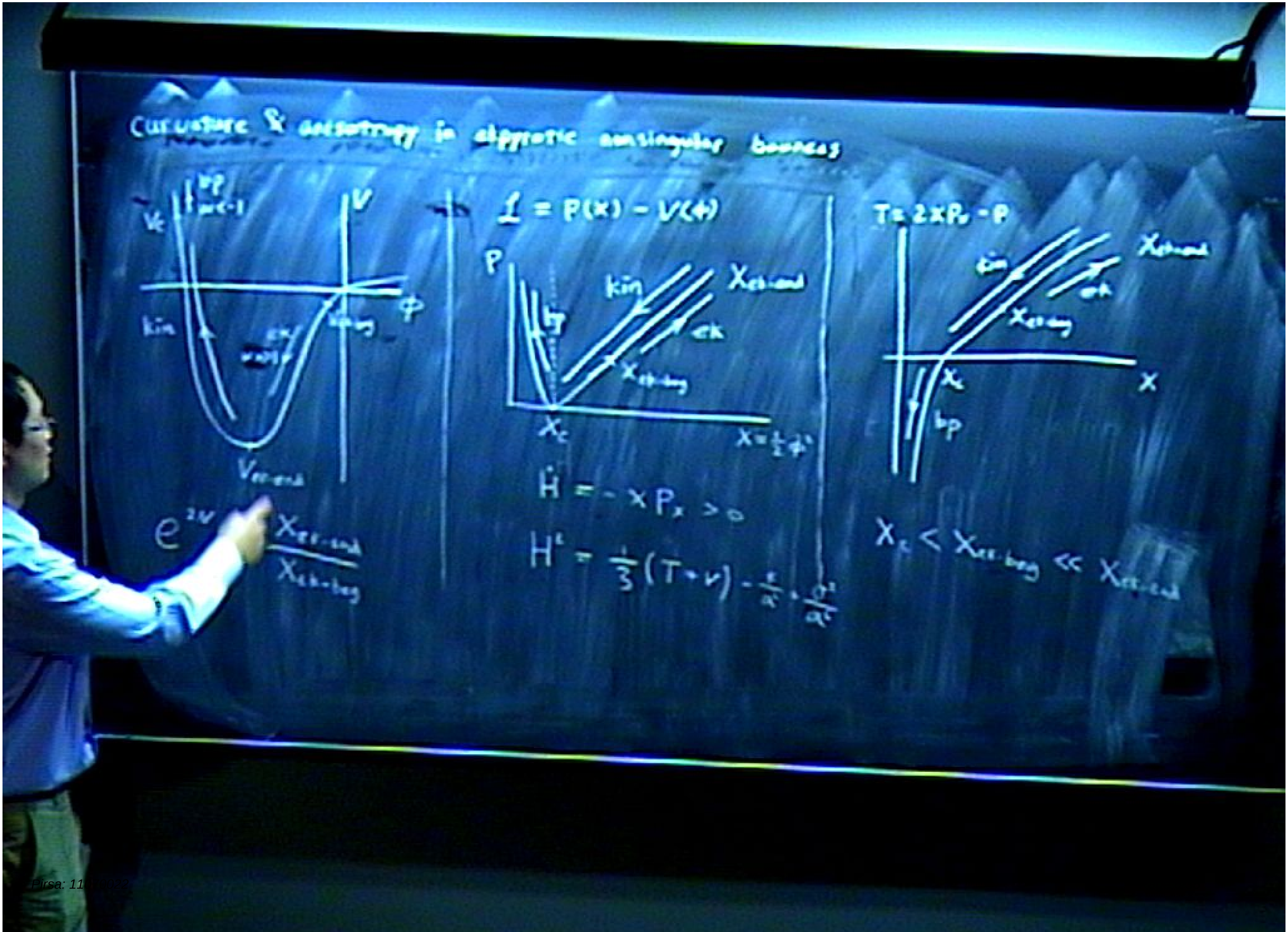
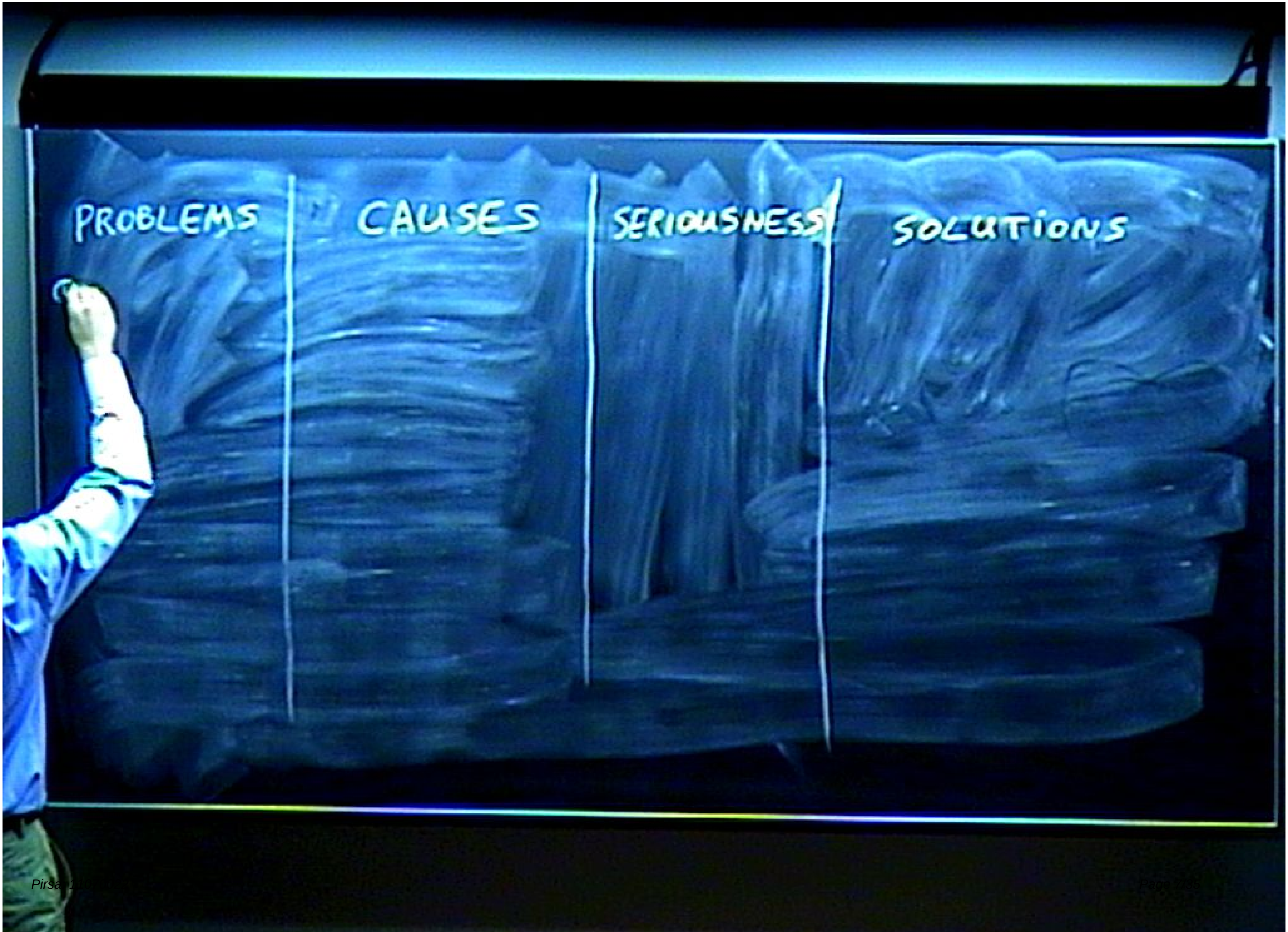
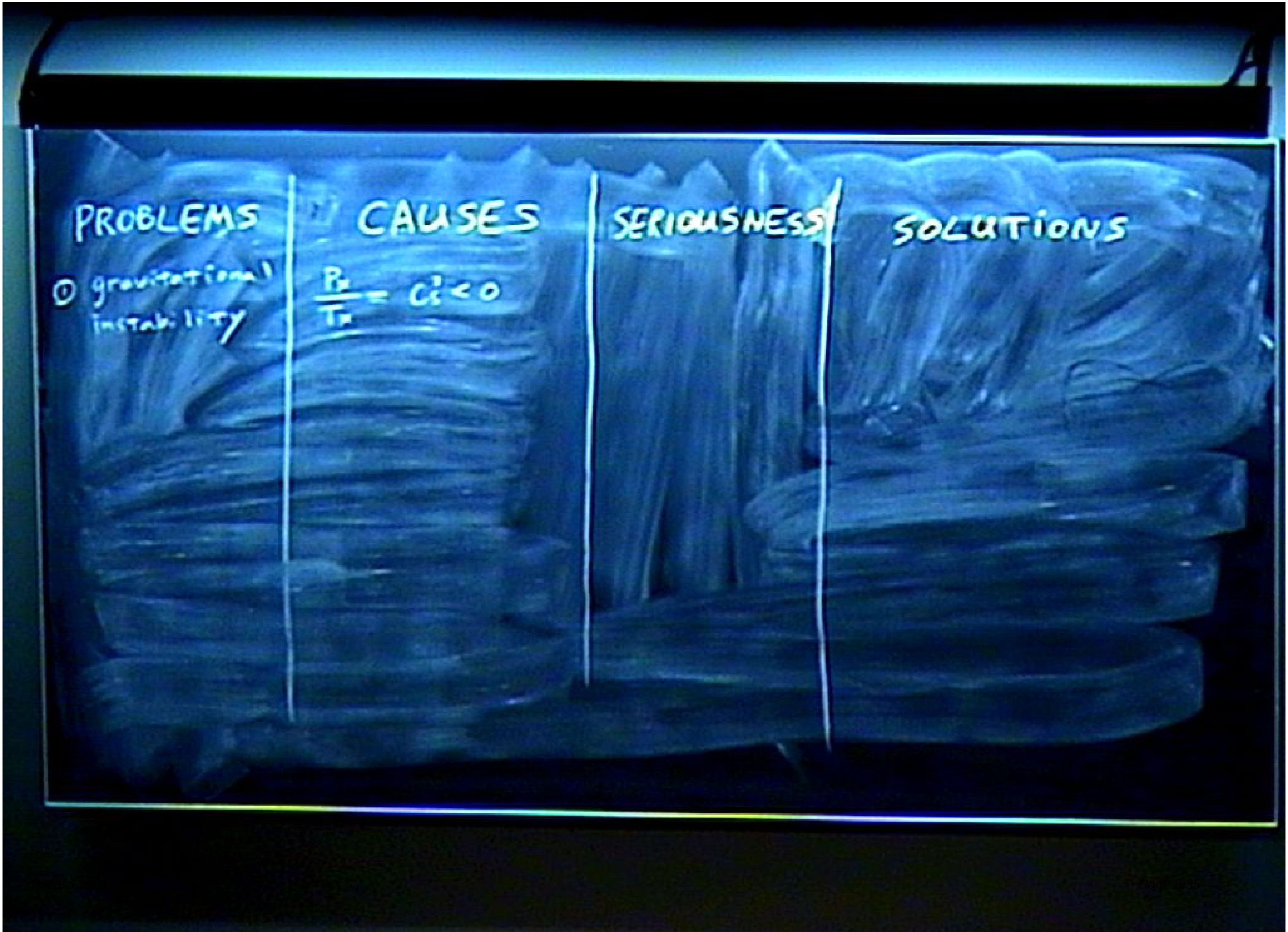
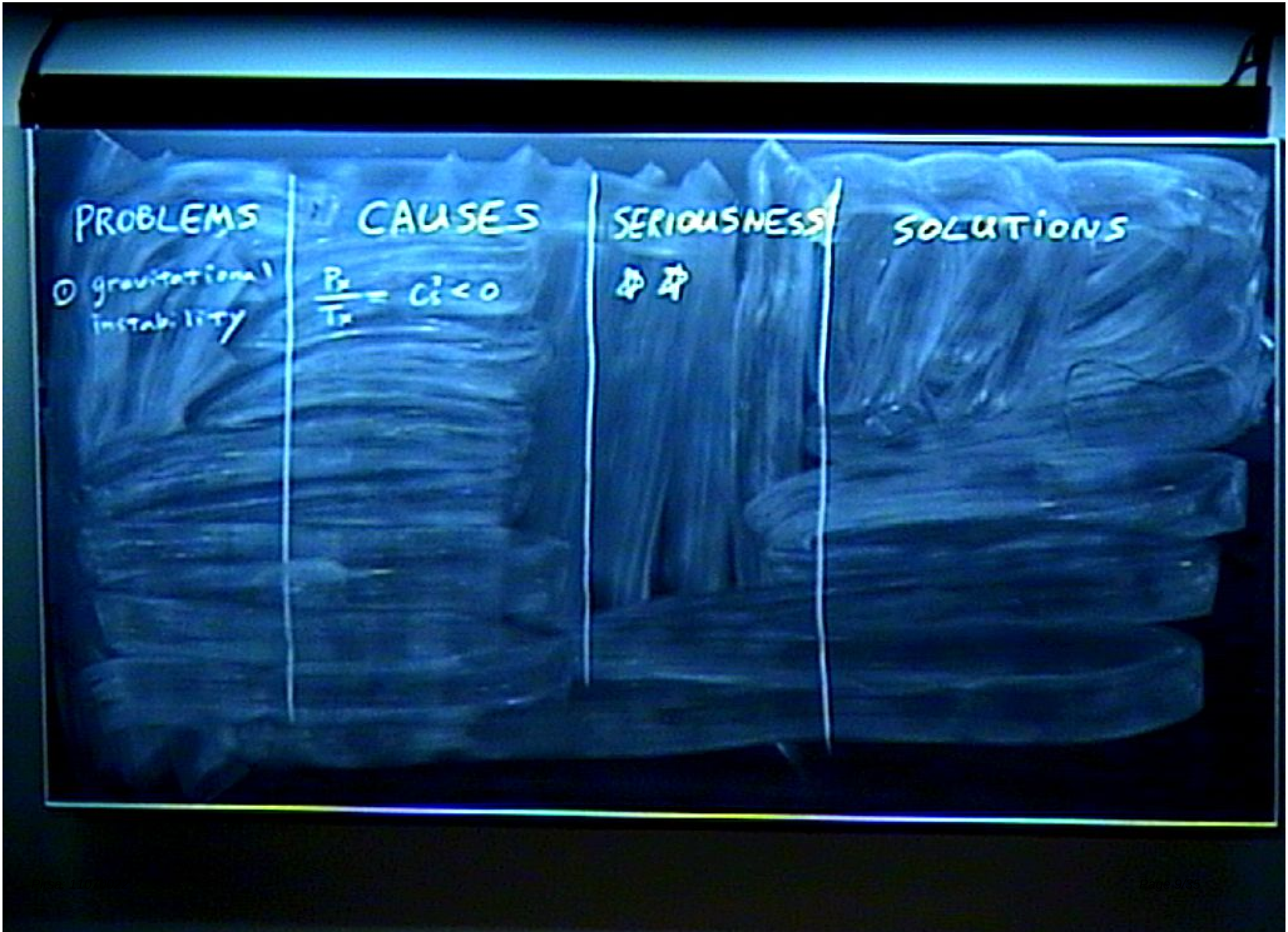
φ
kin
$\mathcal{L} = P(X) - V(\phi)$
P
kin
$X_{ek\text{-}end}$
ek
X_c
$X = \frac{1}{2}\dot\phi^2$
$\dot H = -X P_X > 0$

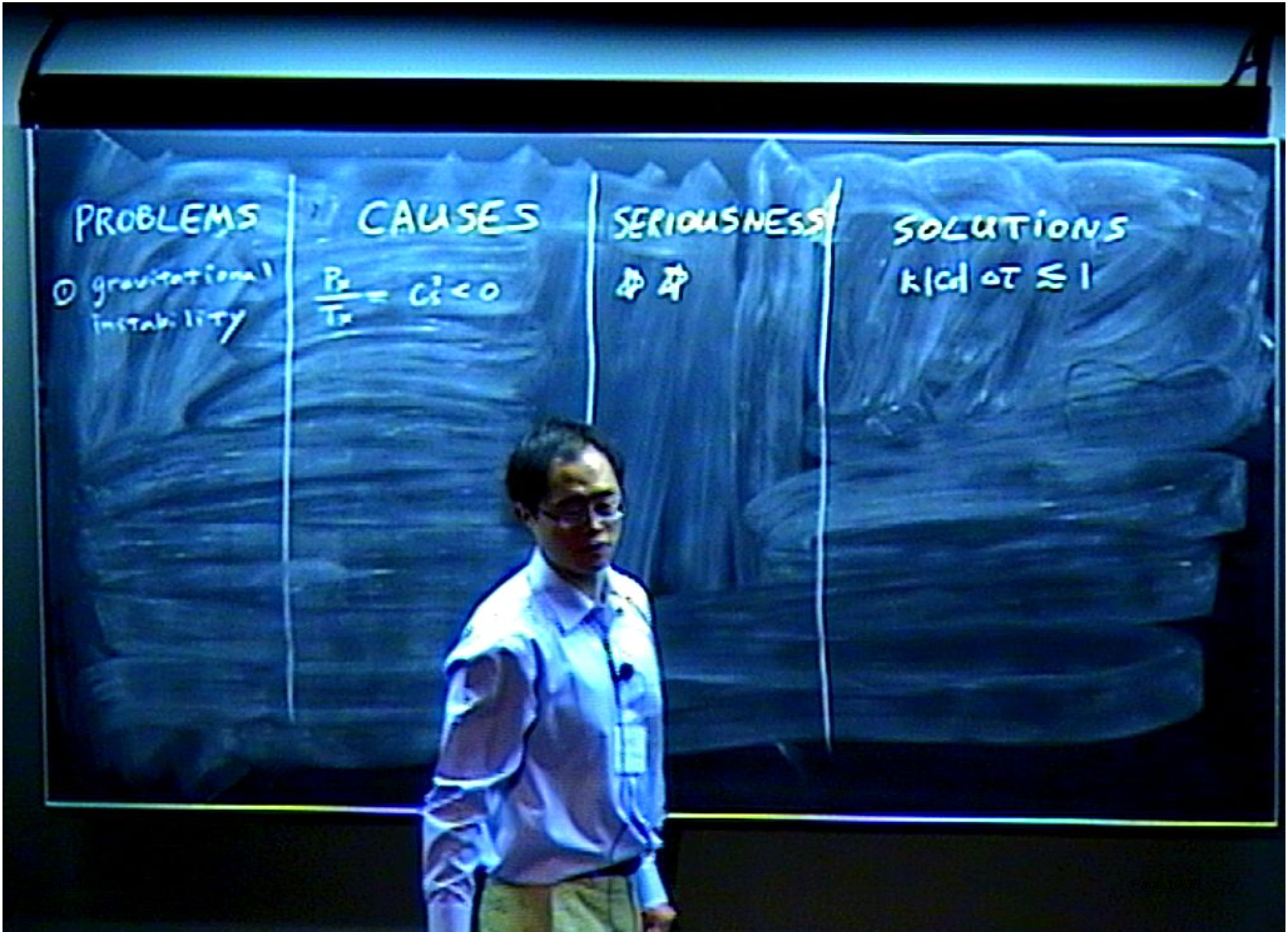

Curvature & anisotropy in ekpyrotic nonsingular bounces
V
φ
kin
V_ek-end
L = P(X) − V(φ)
P
kin
X_ek-end
X_ek-beg
X_c
Ḣ = − X P_X > 0
T = 2XP_X − P
X_ek-end
X_c
X


Curvature & anisotropy in ekpyrotic nonsingular bounces
L = P(X) − V(φ)
X = ½ φ̇²
Ḣ = − X P_X > 0
H² = ⅓ (T + V) − k/a² + σ²/a⁶
T = 2XP_X − P
X_c < X_ek-beg << X_ek-end
V_ek-end
kin
bp
X_ek-end
X_ek-beg
X_c


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
$\frac{P_x}{T_x} = c_i^2 < 0$


PROBLEMS
CAUSES
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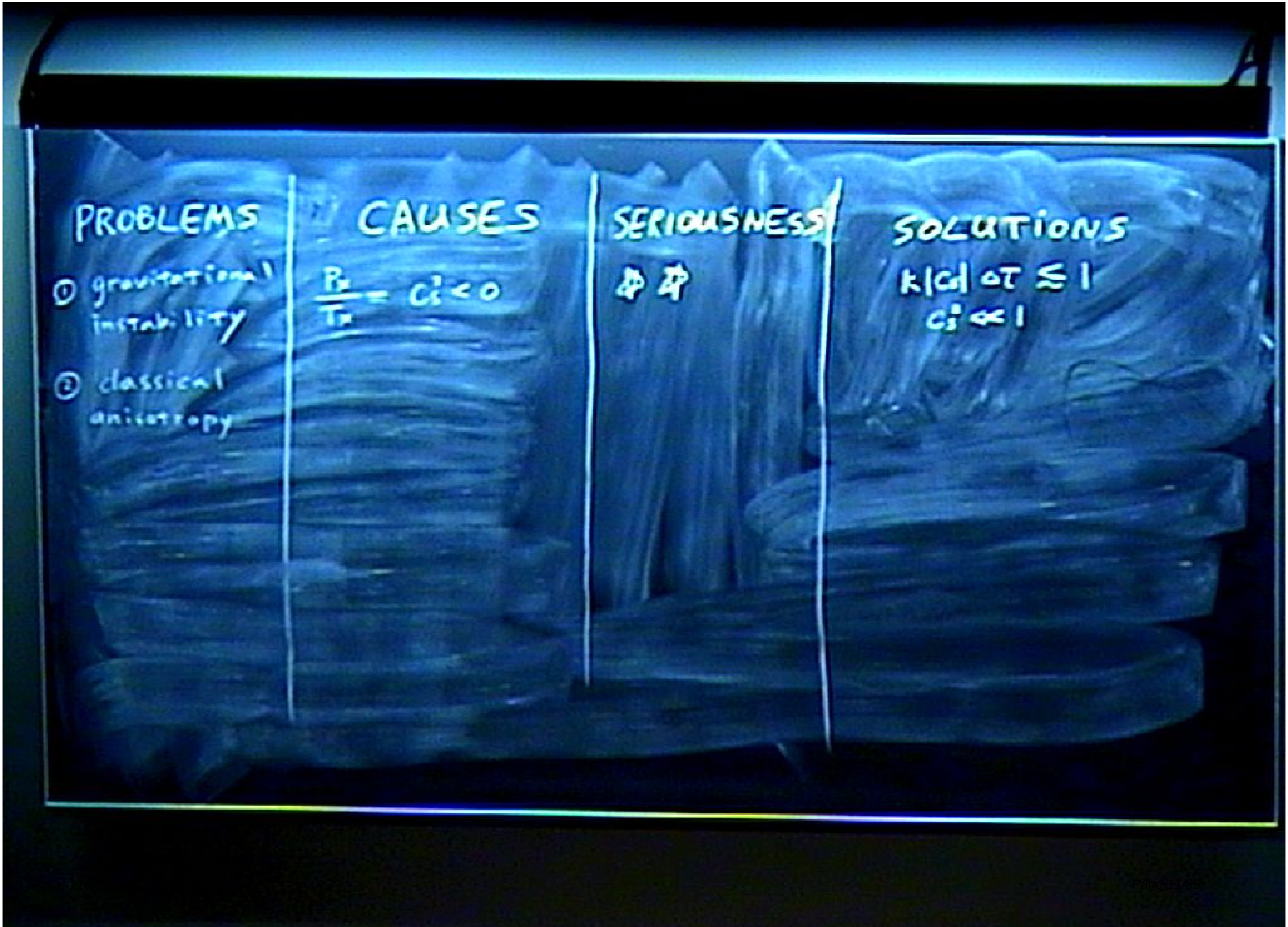
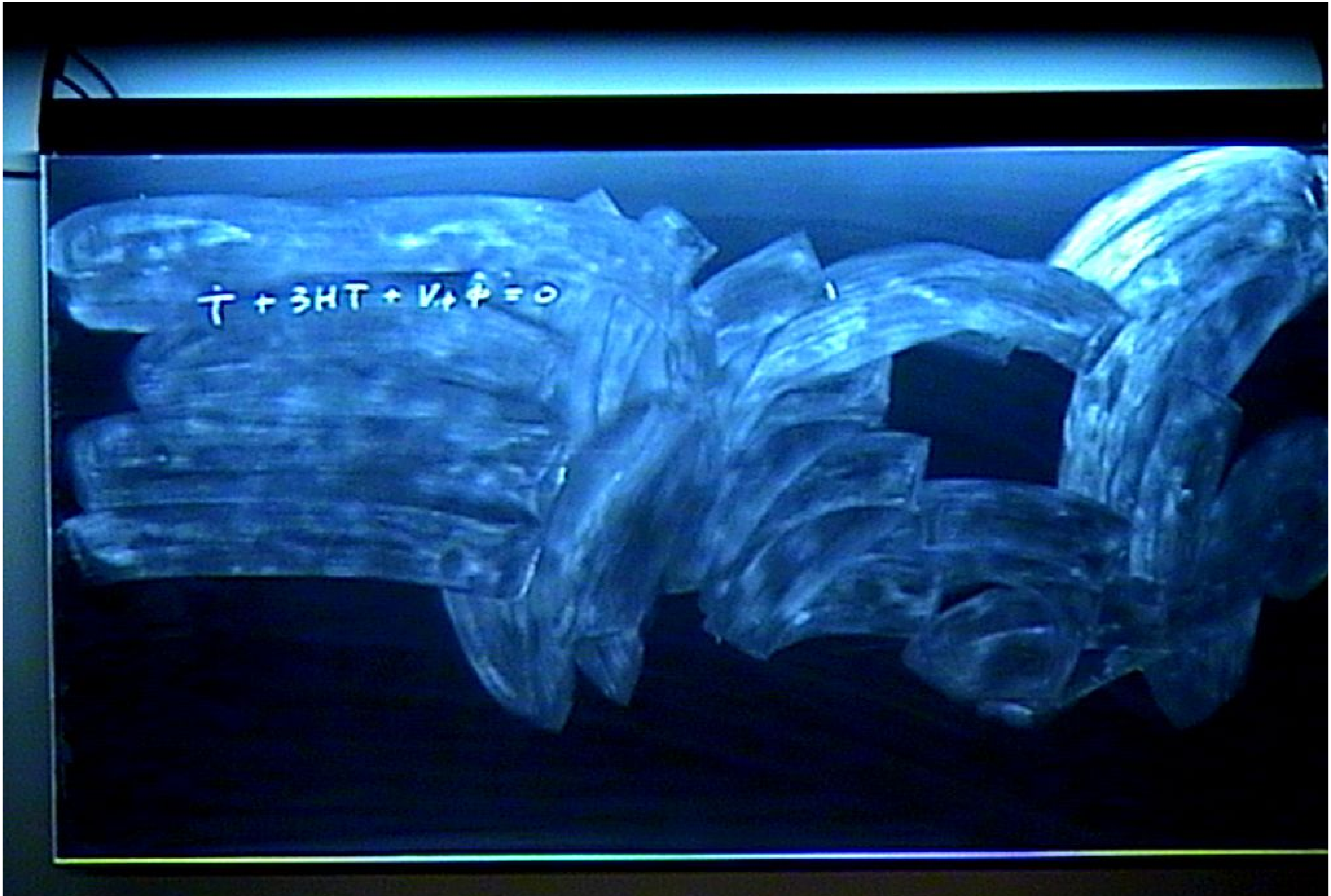
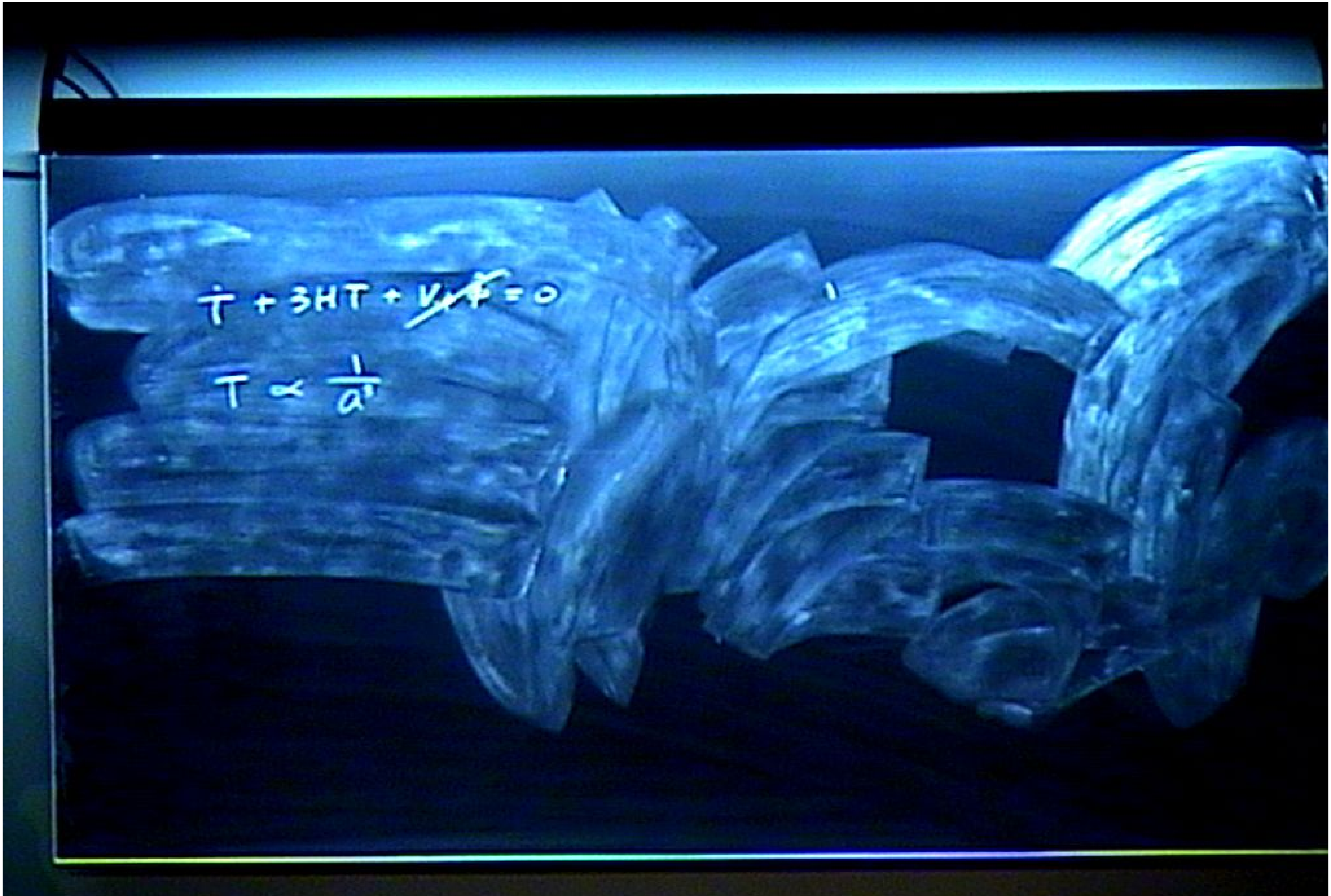
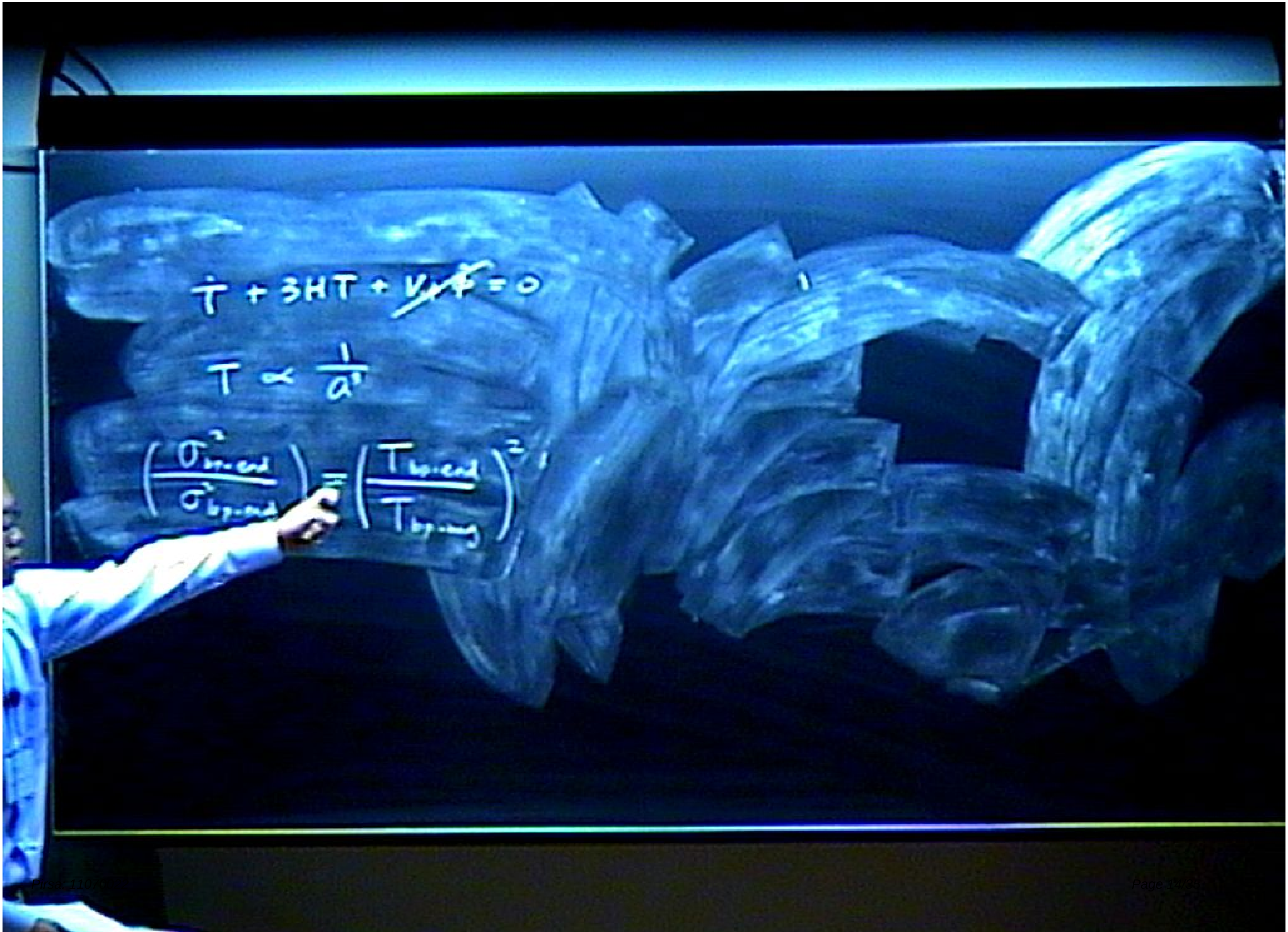
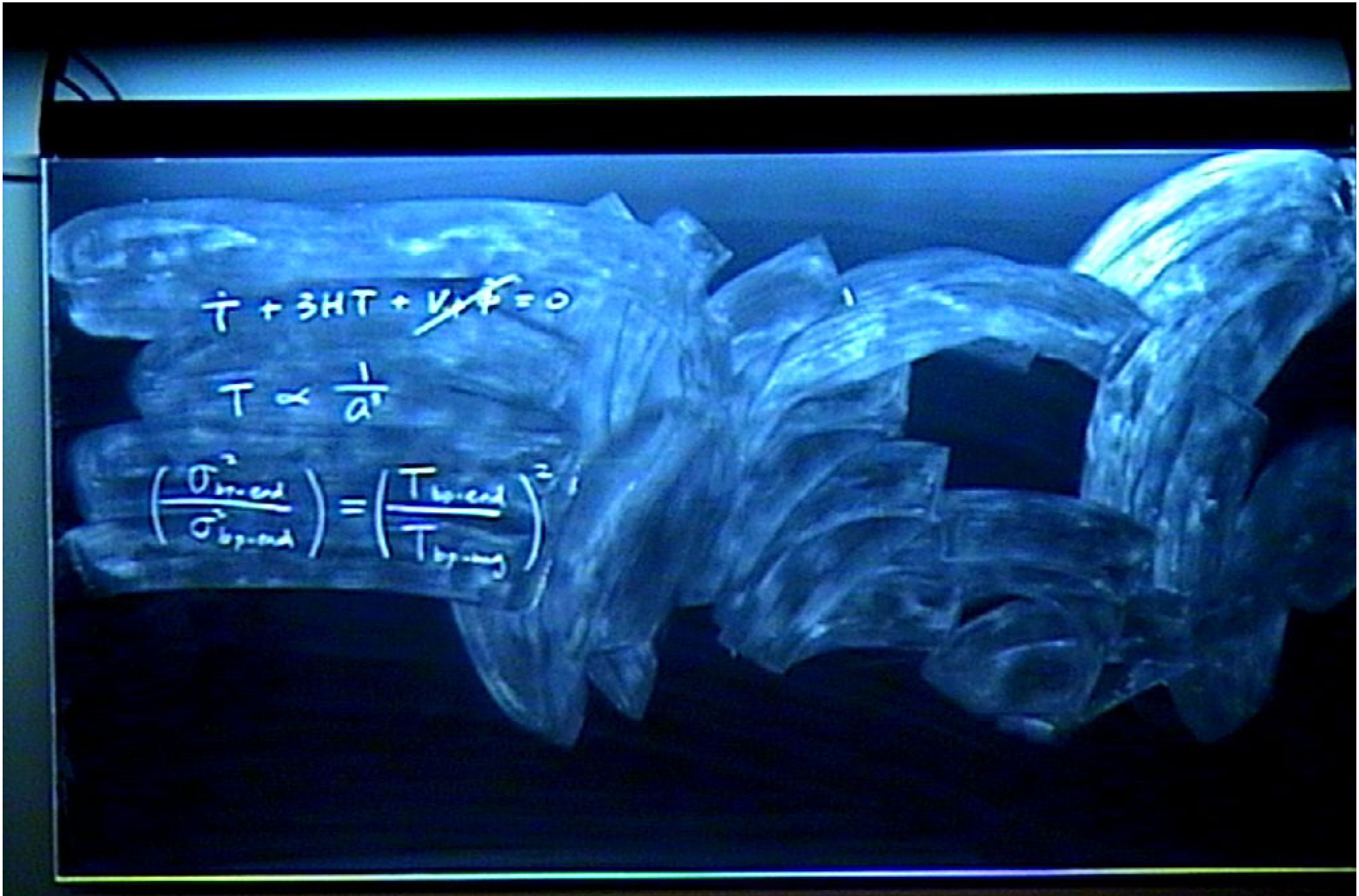
SOLUTIONS
① gravitational instability

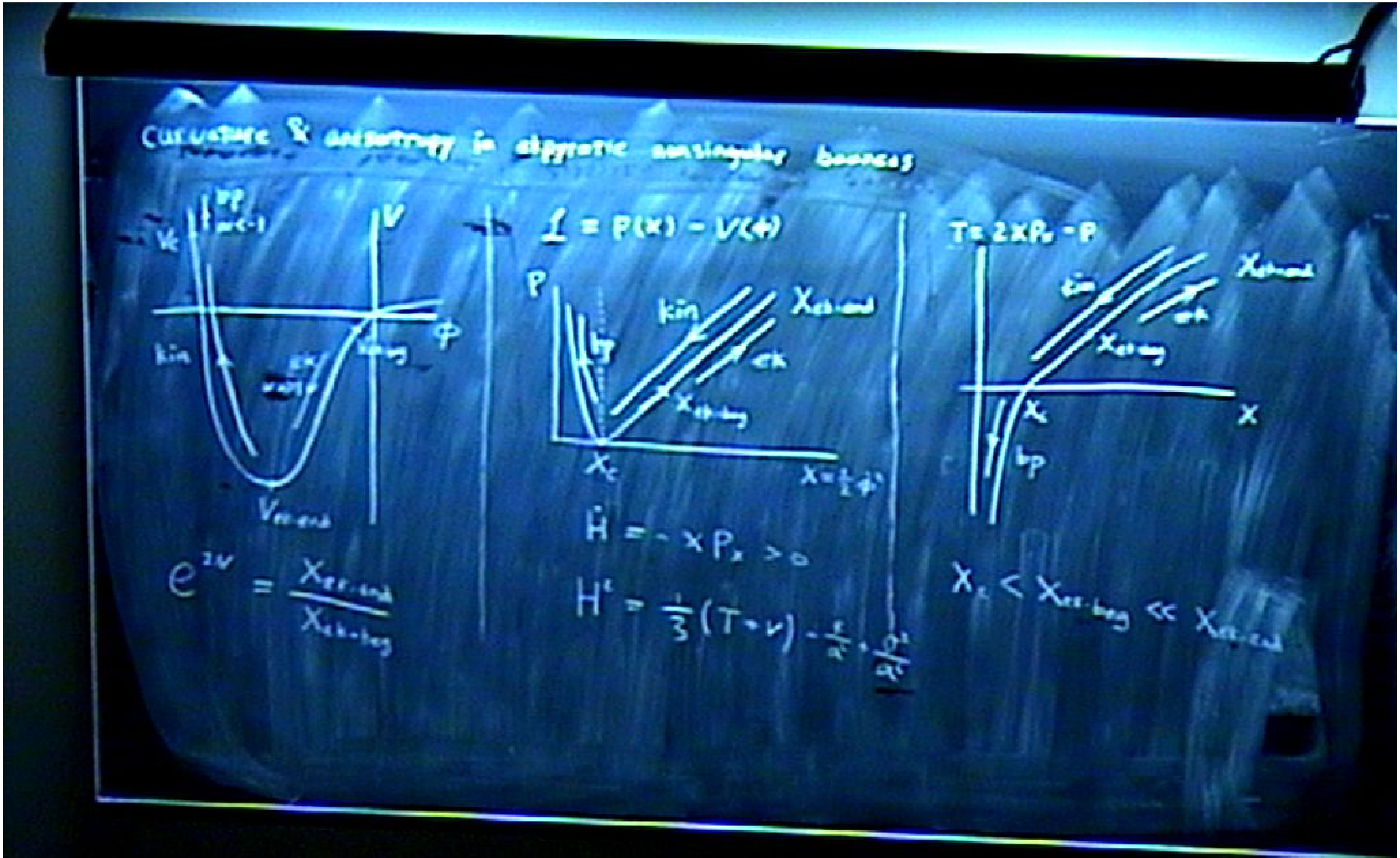

PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
② classical anisotropy
$\frac{P_x}{T_x} = c_s^2 < 0$
$k|c_s|\,\delta\tau \lesssim 1$
$c_s^2 \ll 1$

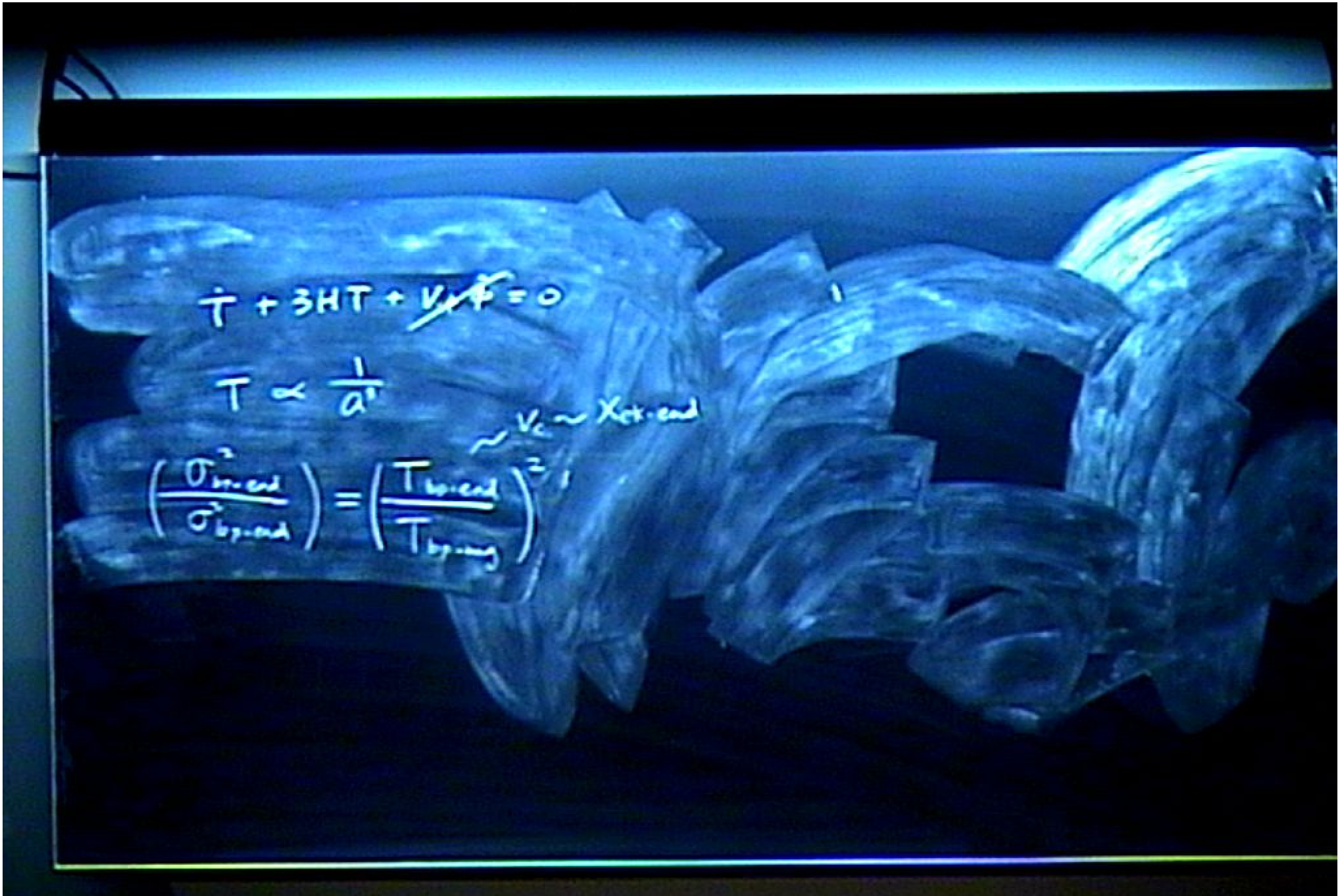

$\dot{T} + 3HT + V_{,\phi}\dot{\phi} = 0$

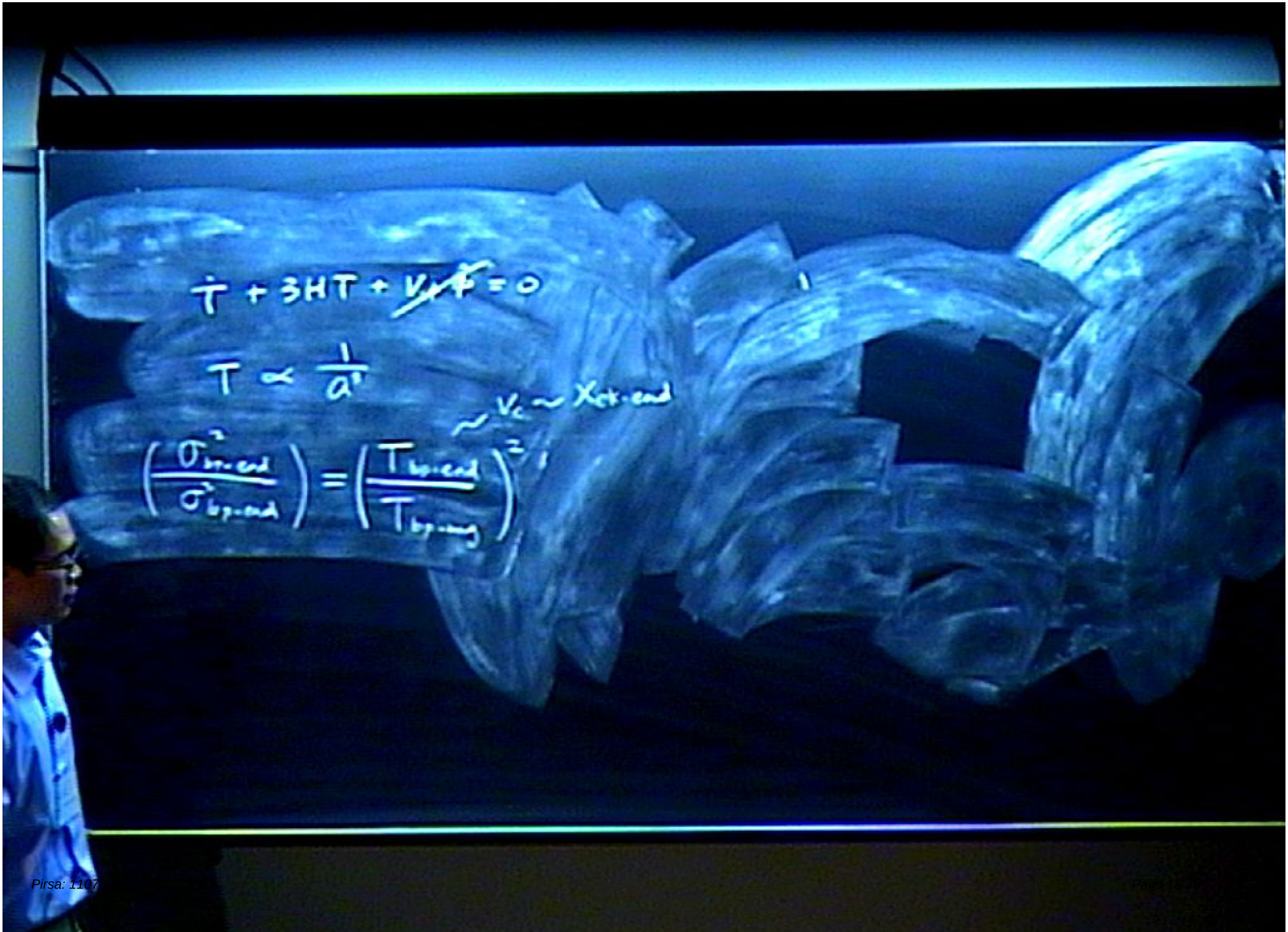

$\dot{T} + 3HT + \nabla\cdot\vec{p} = 0$
$T \propto \frac{1}{a^3}$



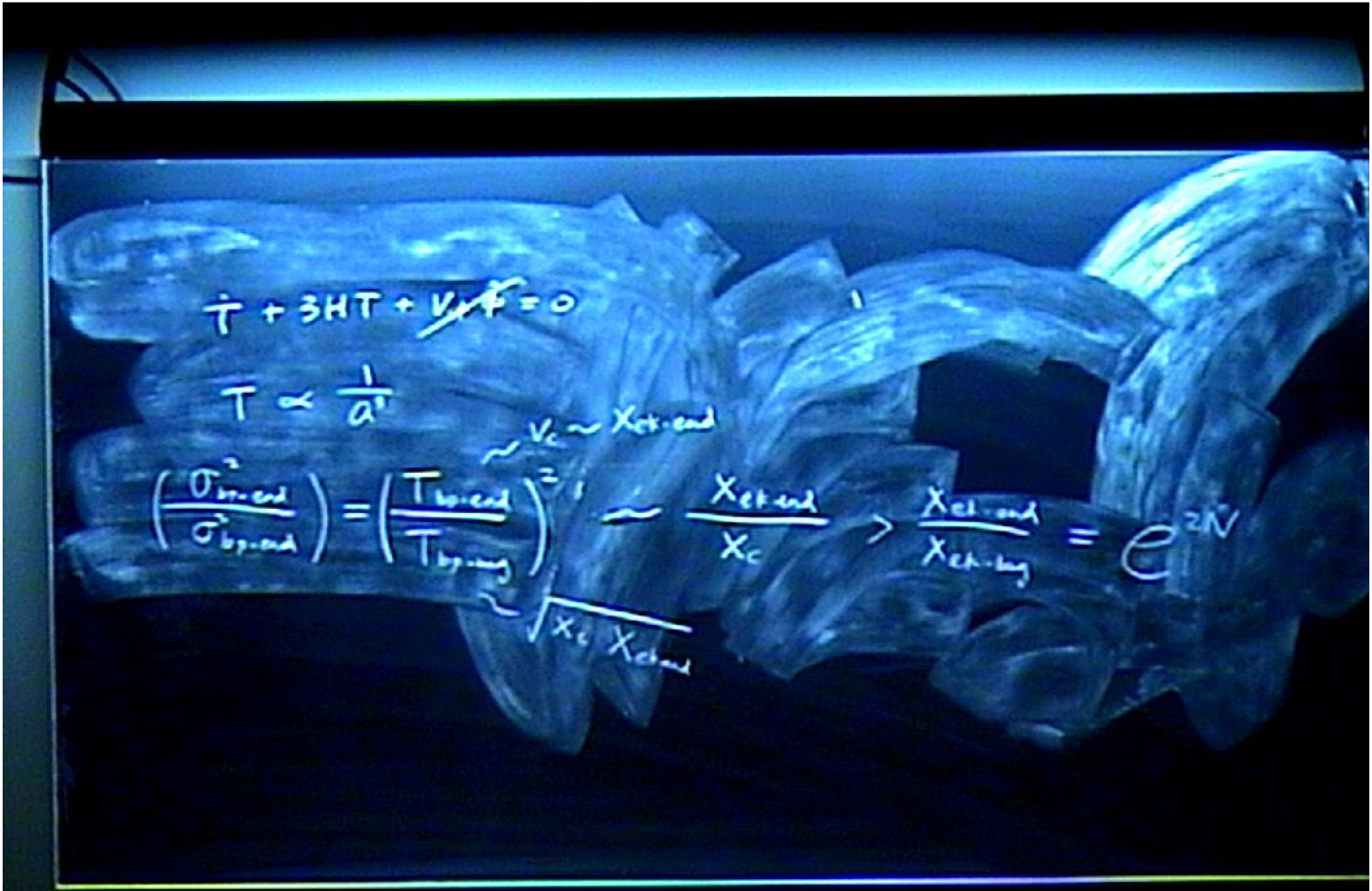

$\dot{T} + 3HT + V_{,\phi} = 0$
$T \propto \frac{1}{a^3}$
$\left(\frac{\sigma^2_{\text{by-end}}}{\sigma^2_{\text{beg-end}}}\right) = \left(\frac{T_{\text{by-end}}}{T_{\text{beg-ing}}}\right)^2$


Curvature & anisotropy in ekpyrotic nonsingular bounces
V
φ
kin
$\mathcal{L} = P(X) - V(\phi)$
P
kin
ek
X_c
$T = 2XP_x - P$
X
bp
$\dot{H} = -XP_x > 0$
$e^{2V} = \frac{X_{ek\text{-}end}}{X_{ek\text{-}beg}}$
$X_c < X_{ek\text{-}beg} \ll X_{ek\text{-}end}$

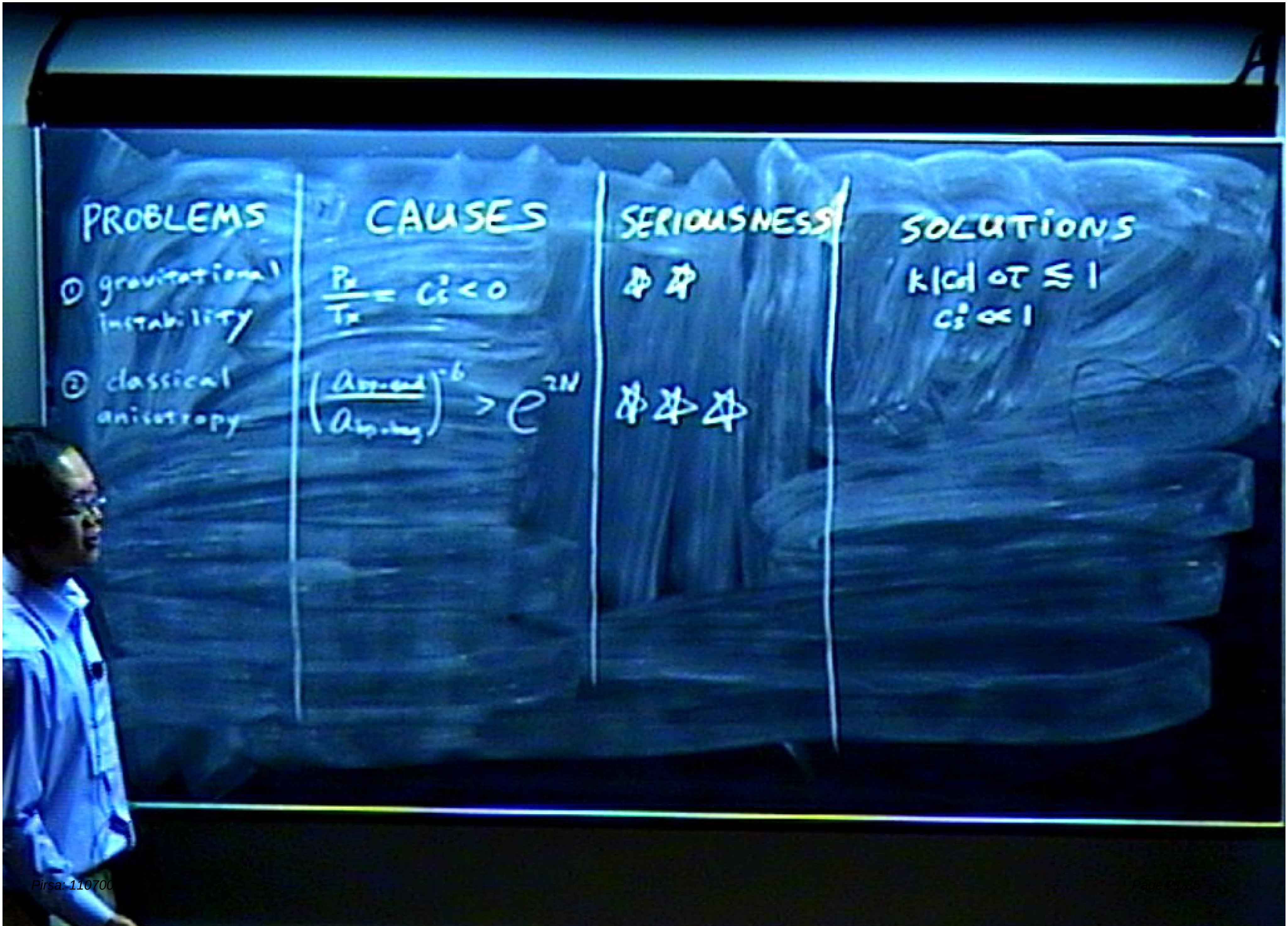

Ṫ + 3HT + V∇Φ = 0
T ∝ 1/a³
~ V_c ~ X_ek-end
(σ²_bp-end / σ²_bp-end) = (T_bp-end / T_bp-eng)²

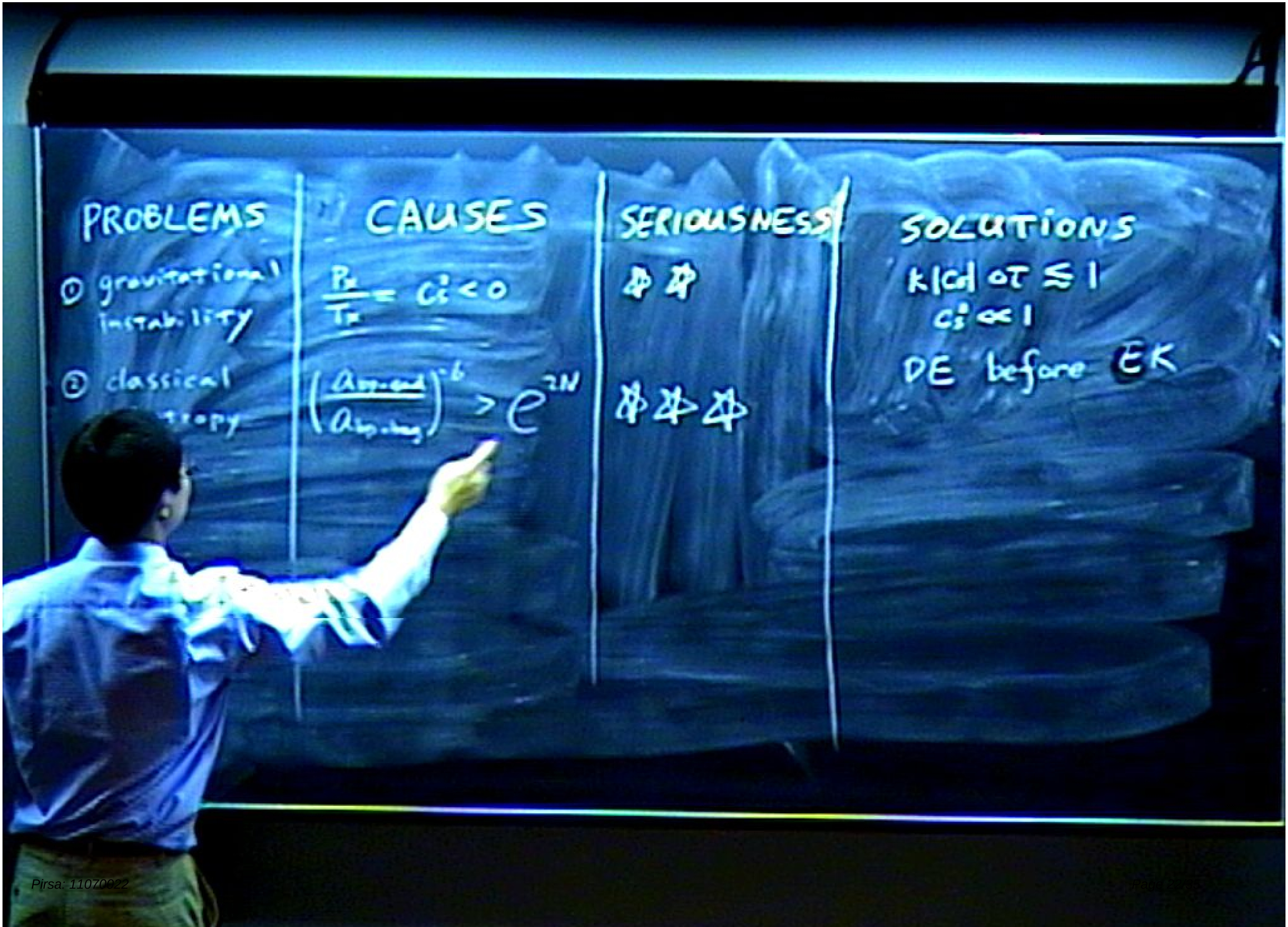

$\dot{T} + 3HT + V_{,\phi} = 0$
$T \propto \frac{1}{a^3}$
$\sim V_c \sim X_{ct\text{-}end}$
$\left(\frac{\sigma^2_{bp\text{-}end}}{\sigma^2_{bp\text{-}end}}\right) = \left(\frac{T_{bp\text{-}end}}{T_{bp\text{-}beg}}\right)^2$

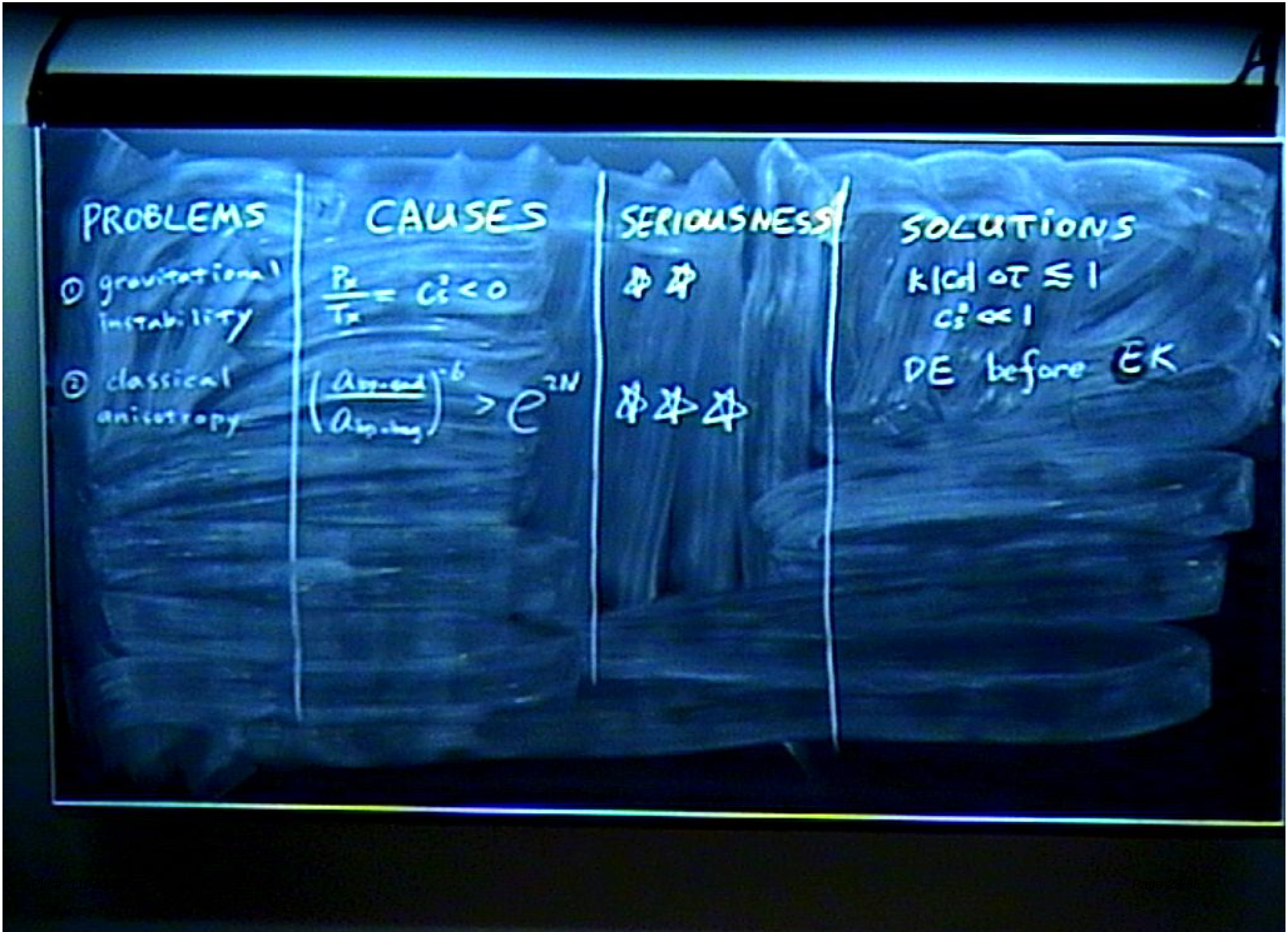

Ṫ + 3HT + V,T = 0
T ∝ 1/a³
~ Vc ~ Xek-end
(σ²bp-end / σ²bp-end) = (Tbp-end / Tbp-beg)² ~ Xek-end / Xc > Xek-end / Xek-beg = e^2N
~ √(Xc Xek-end)



$\dot{T} + 3HT + \nabla \cdot \vec{v} = 0$
$T \propto \frac{1}{a^3}$
$\left(\frac{\sigma^2_{bp\text{-}end}}{\sigma^2_{bp\text{-}end}}\right) = \left(\frac{T_{bp\text{-}end}}{T_{bp\text{-}beg}}\right)^2 \sim \frac{X_{ek\text{-}end}}{X_c} > \frac{X_{ek\text{-}end}}{X_{ek\text{-}beg}} = e^{2N}$
$V_c \sim X_{ek\text{-}end}$
$\sim \sqrt{X_c X_{ek\text{-}end}}$


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
② classical anisotropy


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
② classical
DE before EK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① gravitational instability
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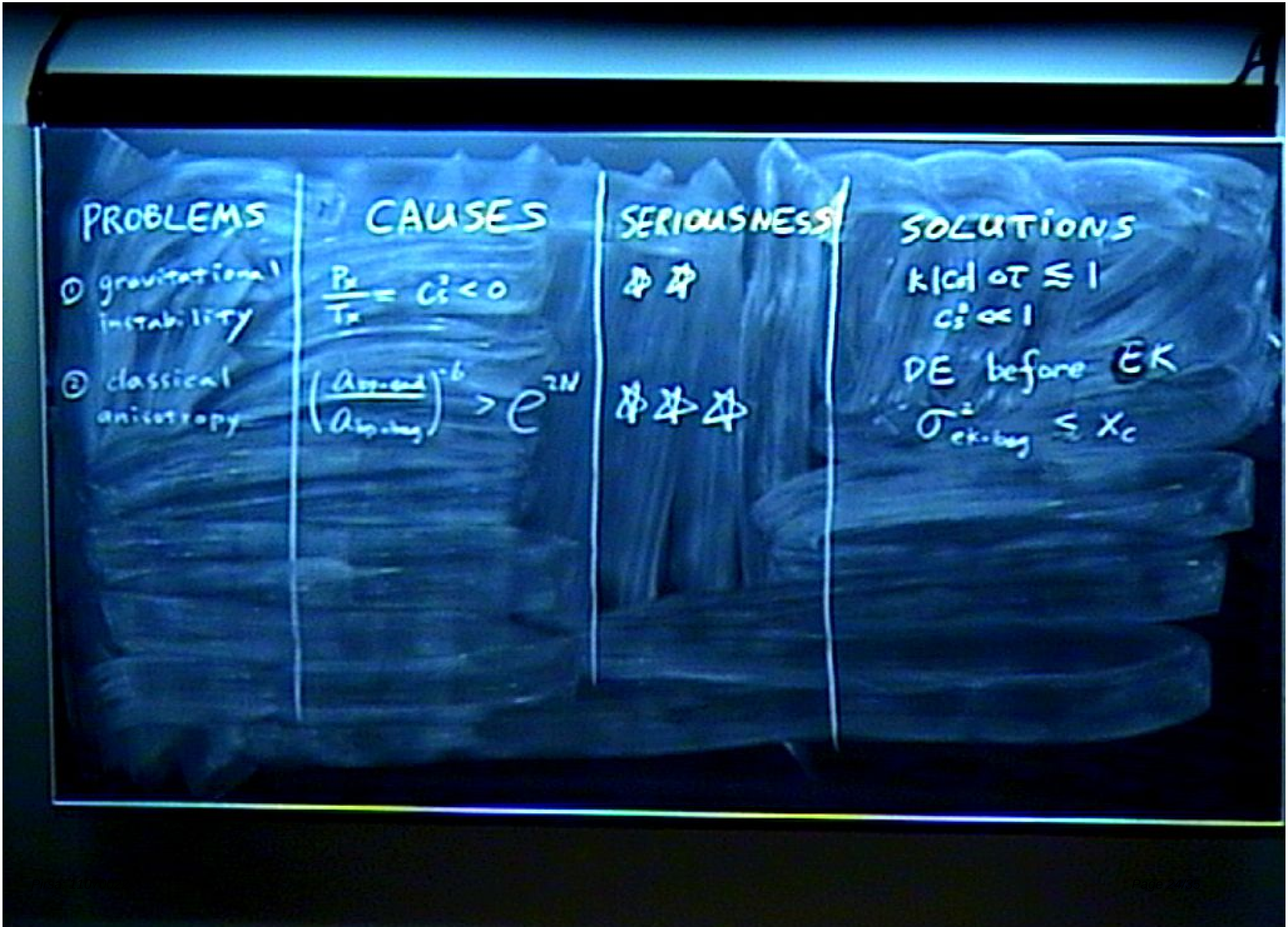
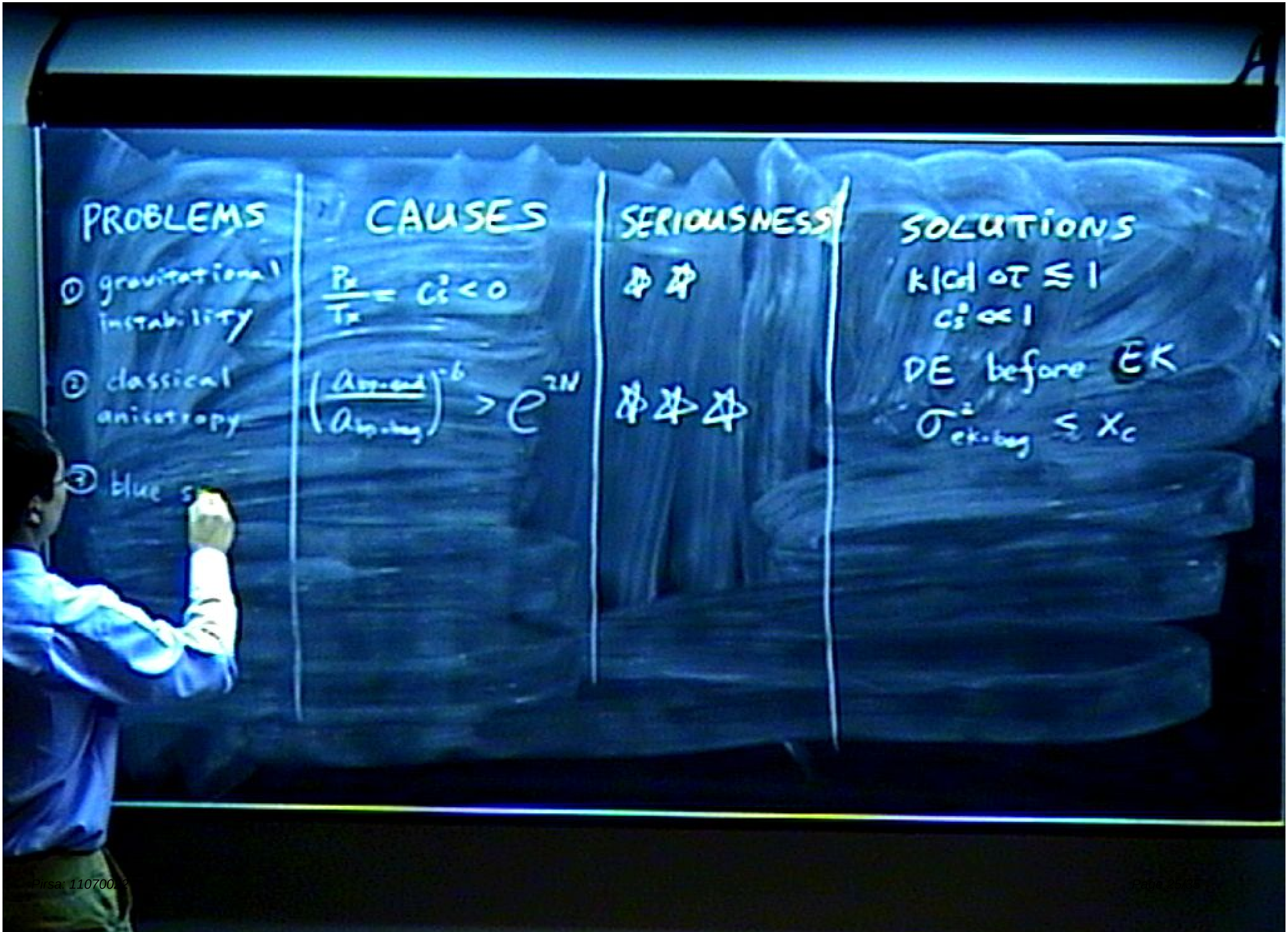
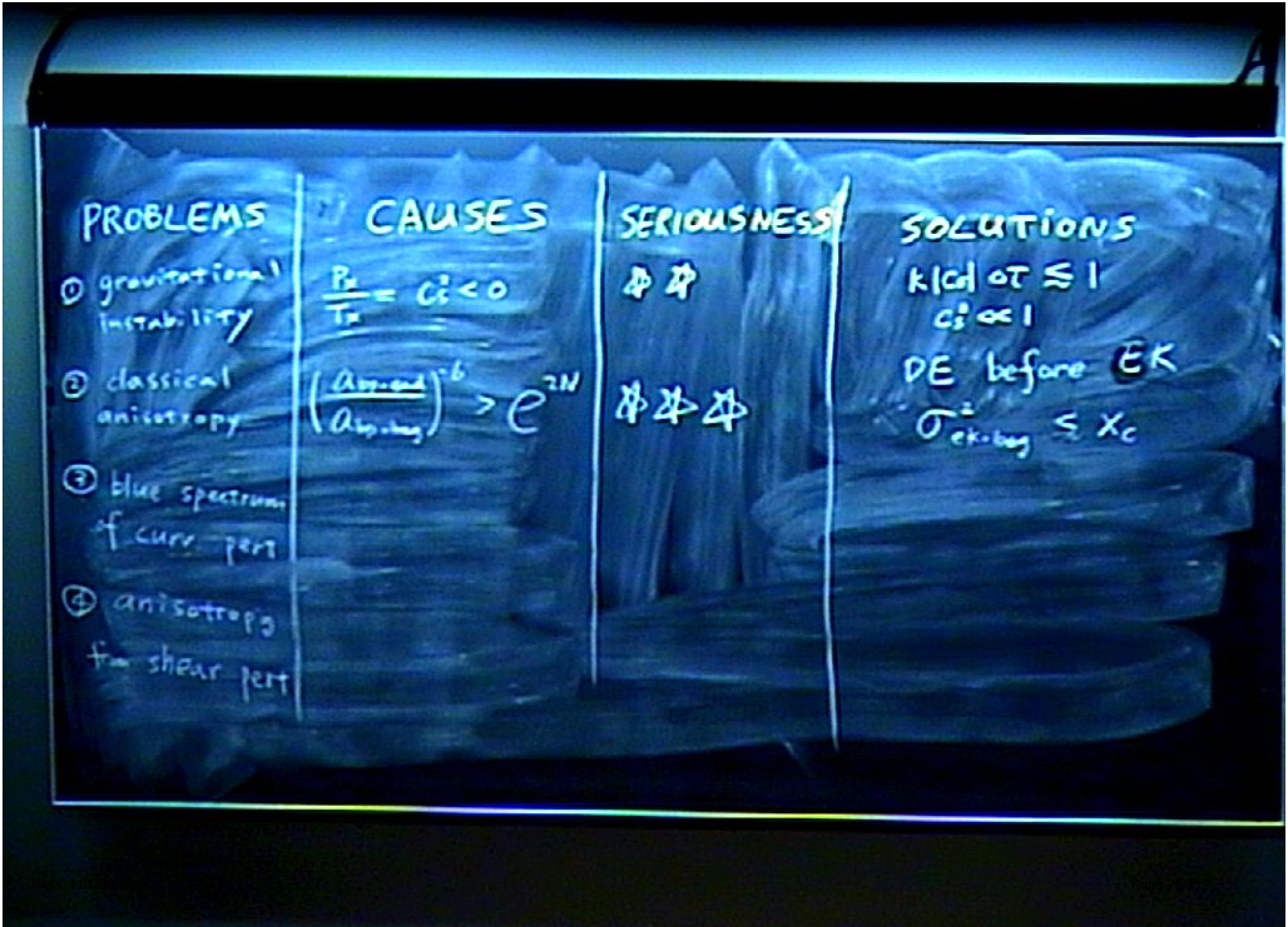

PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
② classical anisotropy
DE before EK


PROBLEMS
CAUSES
SERIOUSNESS
SOLUTIONS
① gravitational instability
② classical anisotropy
③ blue
DE before EK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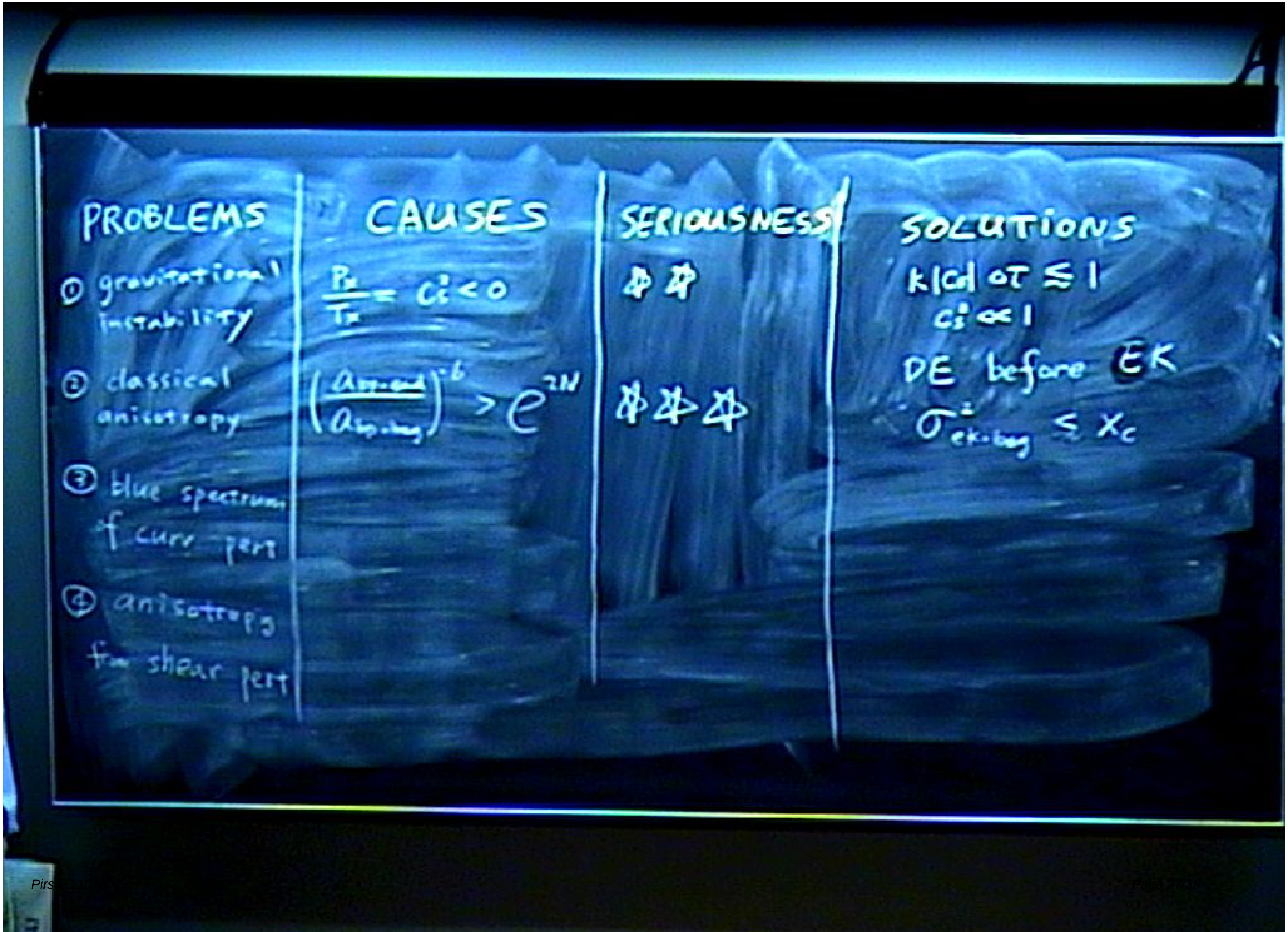
SOLUTIONS
① gravitational instability
$\frac{P_x}{T_x} = c_s^2 < 0$
$k|c_s| \sigma\tau \lesssim 1$
$c_s^2 \ll 1$
② classical anisotropy
$\left(\frac{a_{bg\text{-}end}}{a_{bg\text{-}beg}}\right)^{-6} > e^{2N}$
DE before EK
$\sigma^2_{ek\text{-}beg} \lesssim x_c$
③ blue spectrum of curv pert
④ anisotropy for shear pert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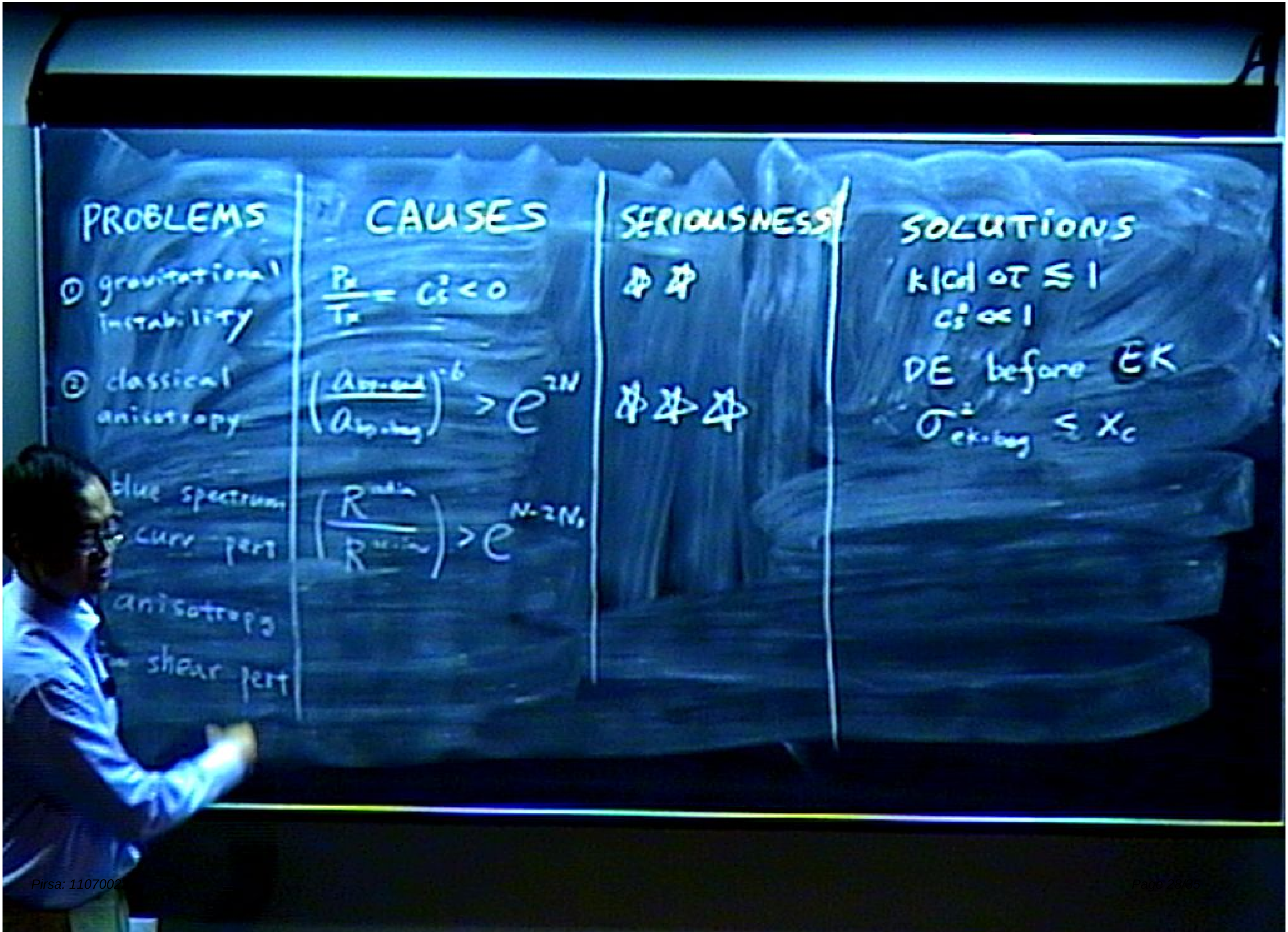
① gravitational instability
$\frac{P}{T} = c_i^2 < 0$
$k|c_i|\,\sigma\tau \lesssim 1$
$c_s^2 \ll 1$
② classical anisotropy
$\left(\frac{a}{a}\right)^{6} > e^{2N}$
DE before EK
$\sigma^2_{ek\text{-}beg} \lesssim X_c$
③ blue spectrum of curv pert
④ anisotropy from shear pert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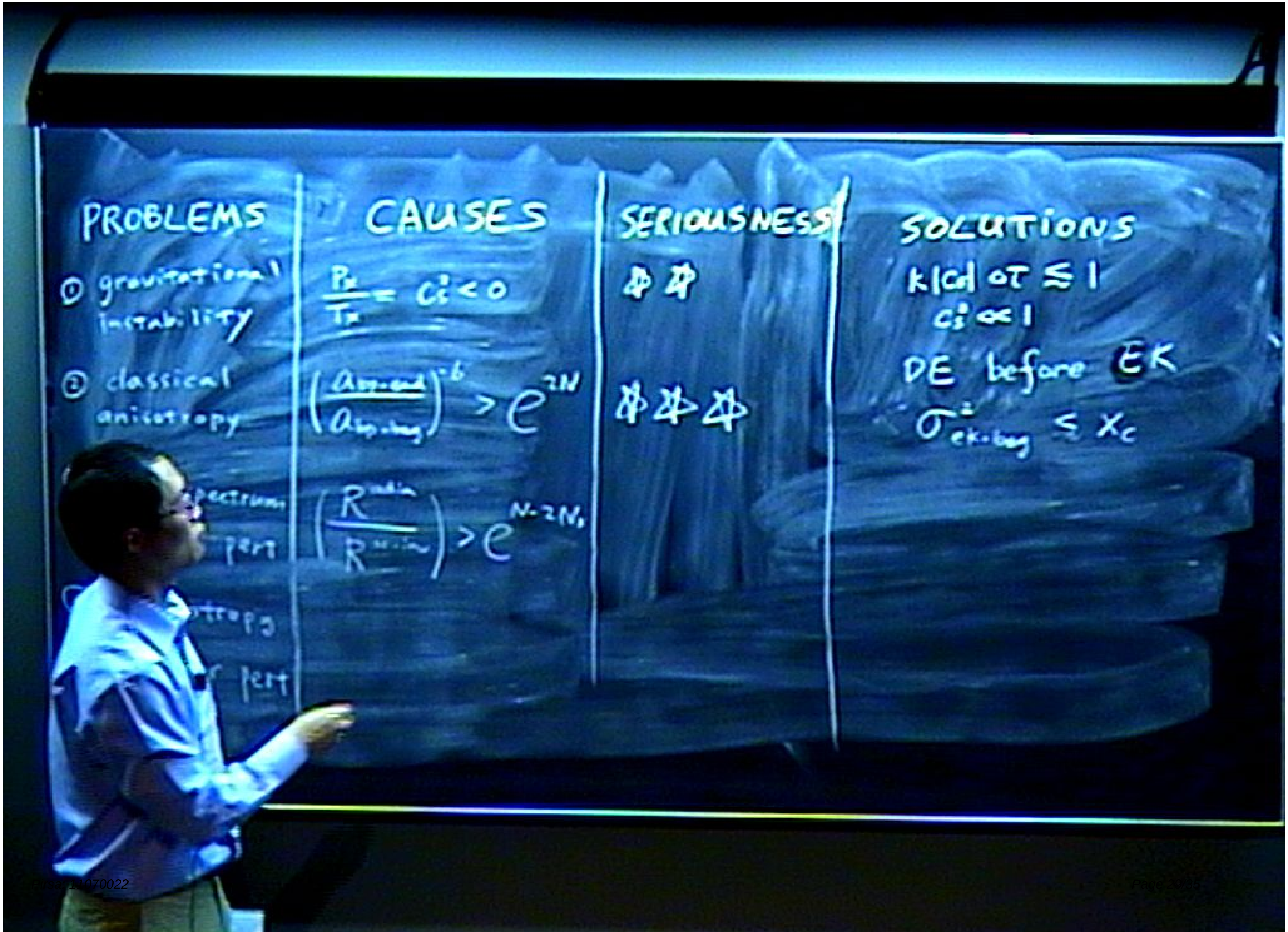
① gravitational instability
② classical anisotropy
blue spectrum
curv pert
anisotropy
shear pert
DE before EK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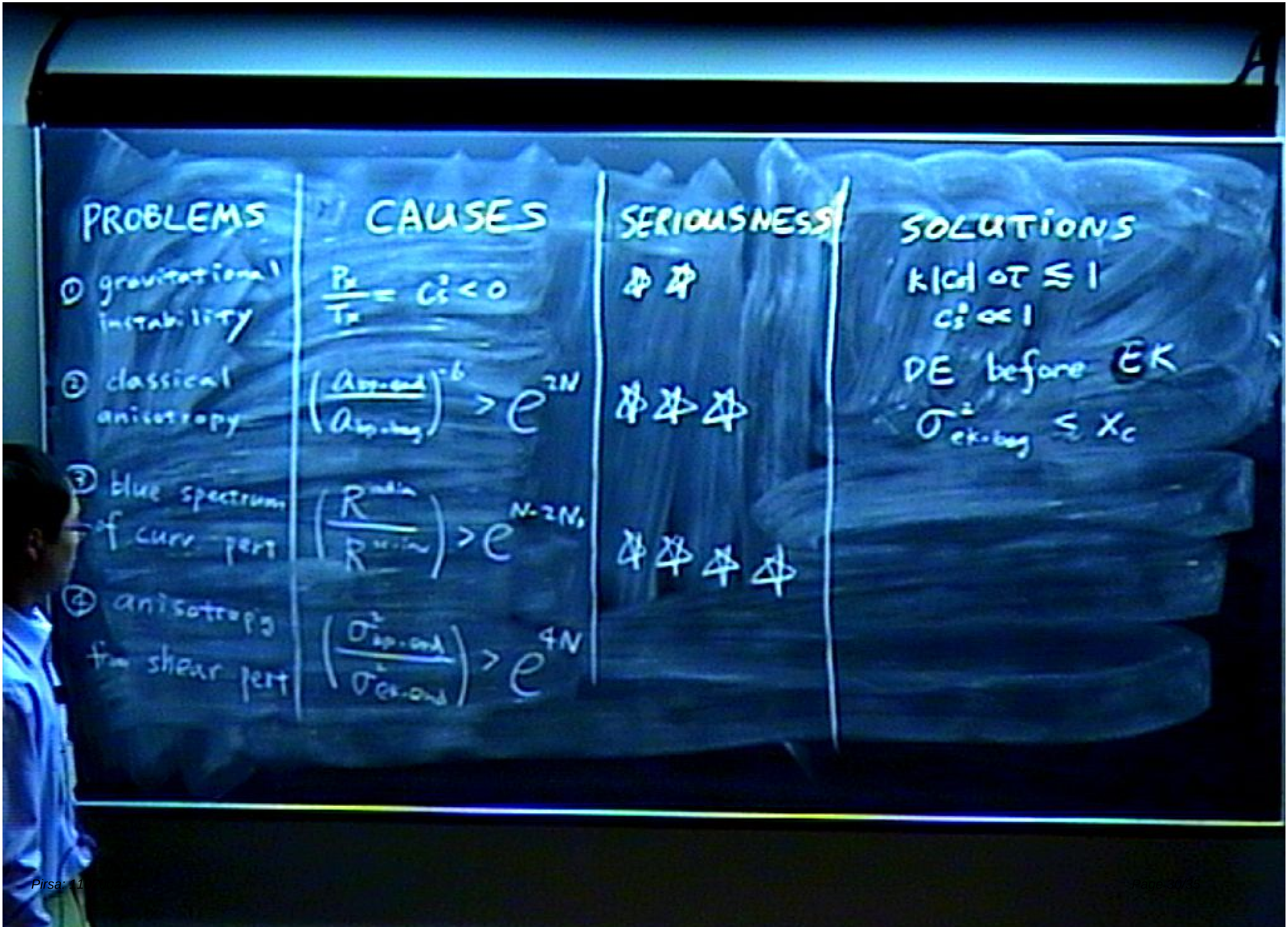
① gravitational instability
② classical anisotropy
pert
pert
DE before EK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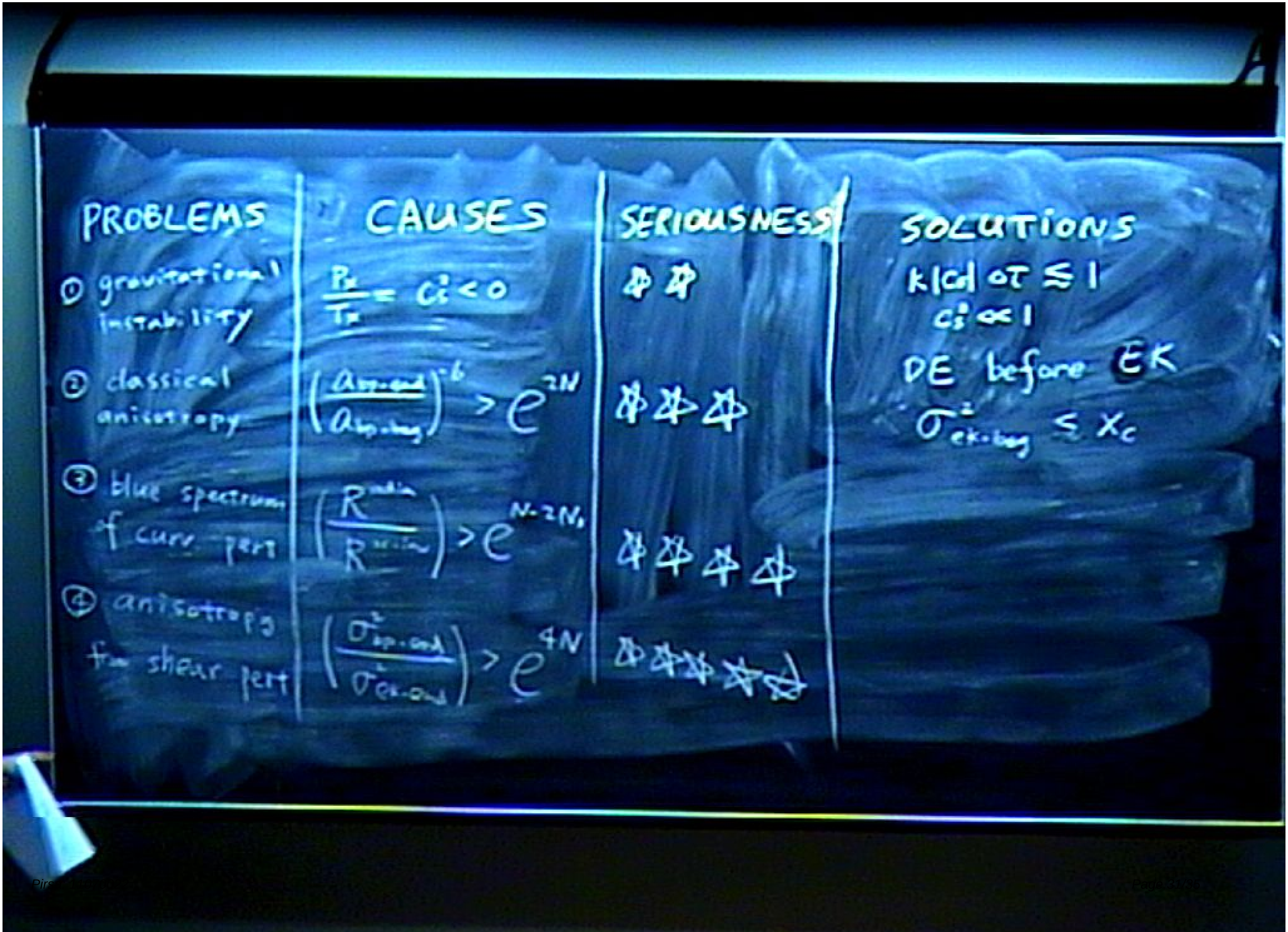
SOLUTIONS
① gravitational instability
$\frac{P_k}{T_k} = c_s^2 < 0$
k|c| δτ ≲ 1
$c_s^2 \ll 1$
② classical anisotropy
$\left(\frac{a_{bp\text{-}end}}{a_{bp\text{-}beg}}\right)^{-6} > e^{2N}$
DE before EK
$\sigma^2_{ek\text{-}beg} \lesssim X_c$
③ blue spectrum of curv pert
$\left(\frac{R^{\min}}{R^{\min}}\right) > e^{N-2N_0}$
④ anisotropy from shear pert
$\left(\frac{\sigma^2_{bp\text{-}end}}{\sigma^2_{ek\text{-}end}}\right) > e^{4N}$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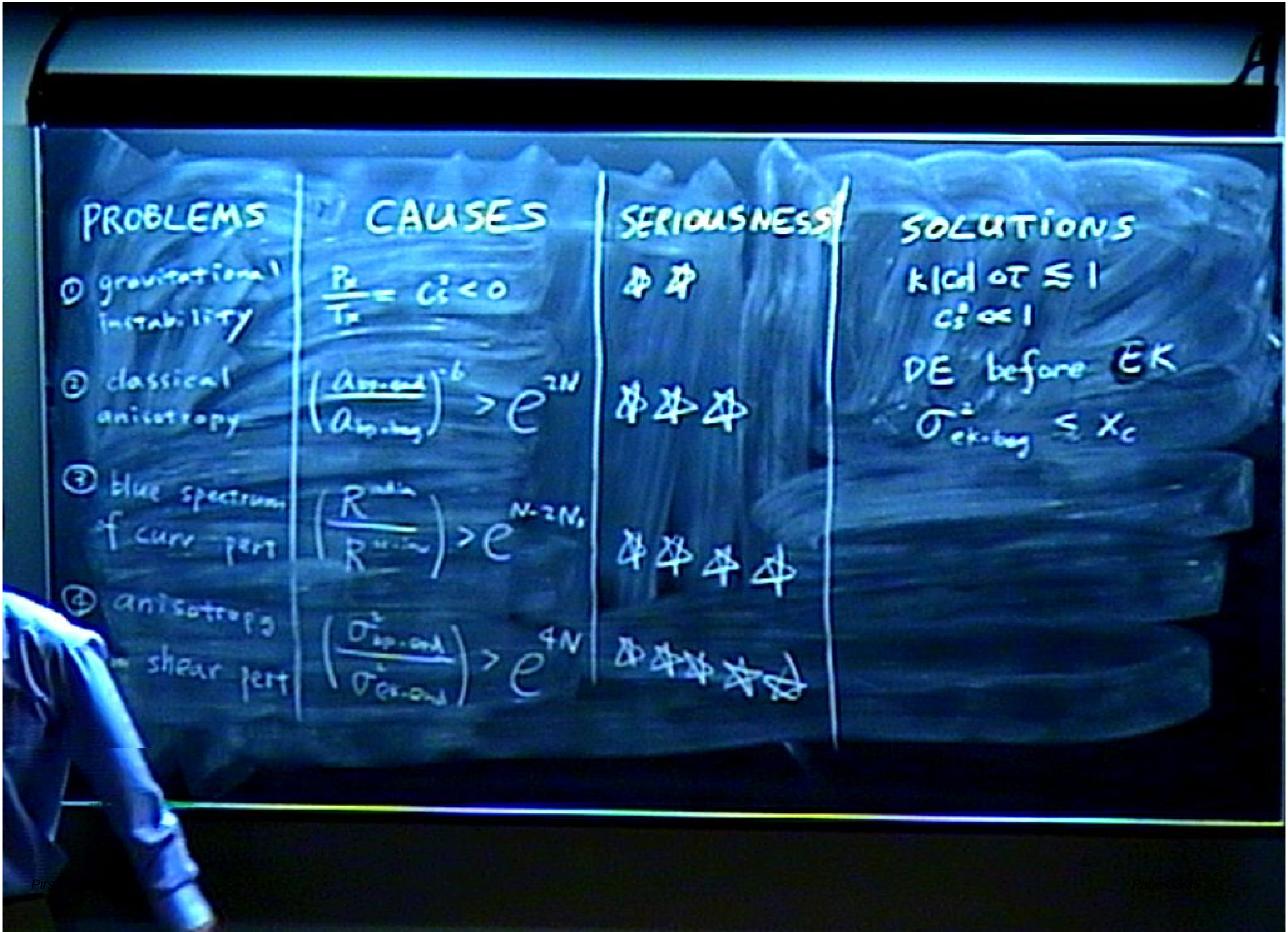
① gravitational instability
② classical anisotropy
③ blue spectrum of curv. pert
④ anisotropy from shear pert
DE before EK

PROBLEMS	CAUSES	SERIOUSNESS	SOLUTIONS
① gravitational instability	$\frac{P_x}{T_x} = c_s^2 < 0$	★★	$k\lvert c_s\rvert\,\delta\tau \lesssim 1$ $c_s^2 \ll 1$
② classical anisotropy	$\left(\frac{a_{bp\text{-}end}}{a_{bp\text{-}beg}}\right)^{-6} > e^{2N}$	★★★	DE before EK $\sigma^2_{ek\text{-}beg} \leq x_c$
③ blue spectrum of curv pert	$\left(\frac{R^{min}}{R^{init}}\right) > e^{N-2N_0}$	★★★★	
④ anisotropy from shear pert	$\left(\frac{\sigma^2_{bp\text{-}end}}{\sigma^2_{ek\text{-}end}}\right) > e^{4N}$	★★★★★	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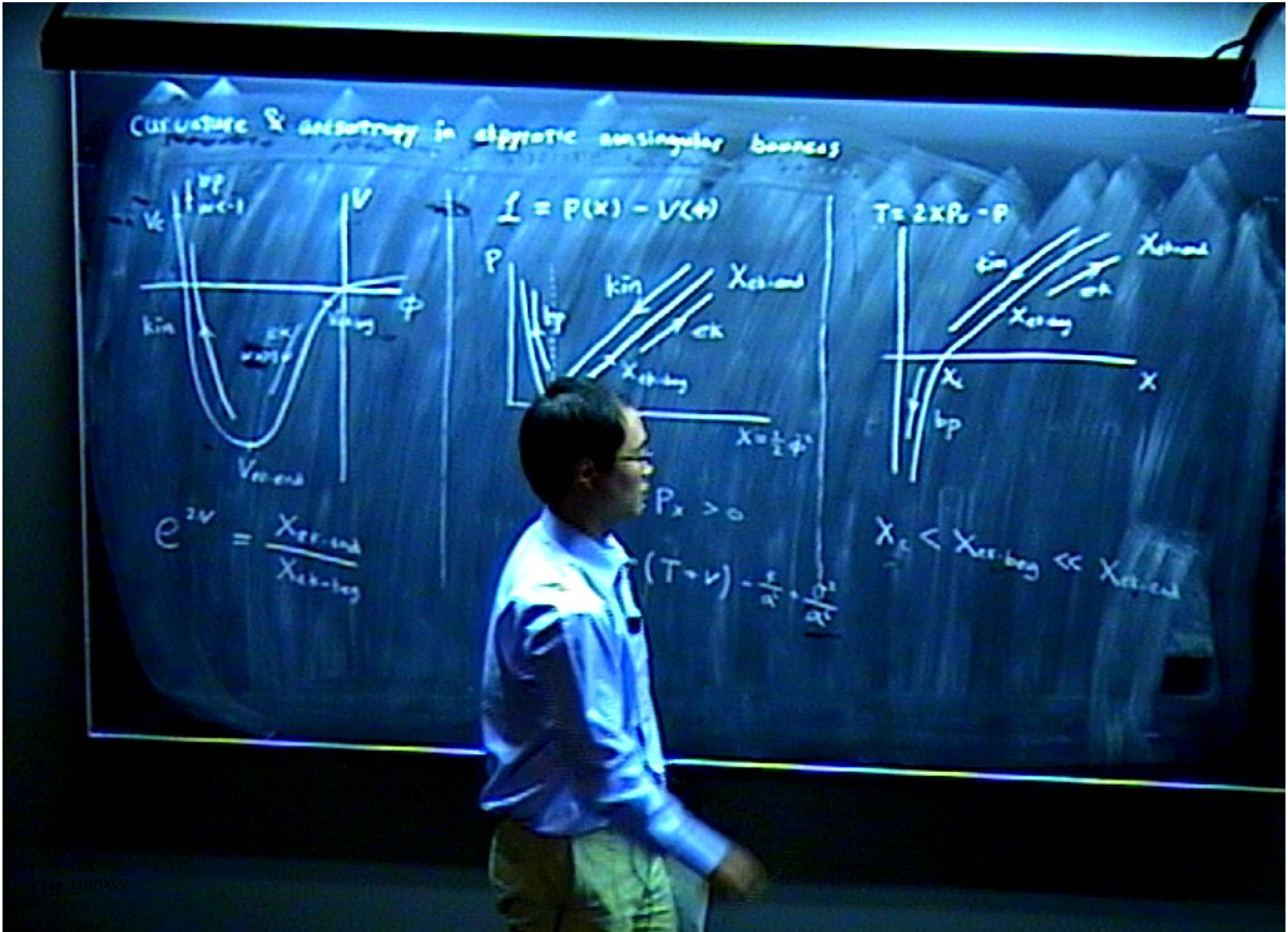
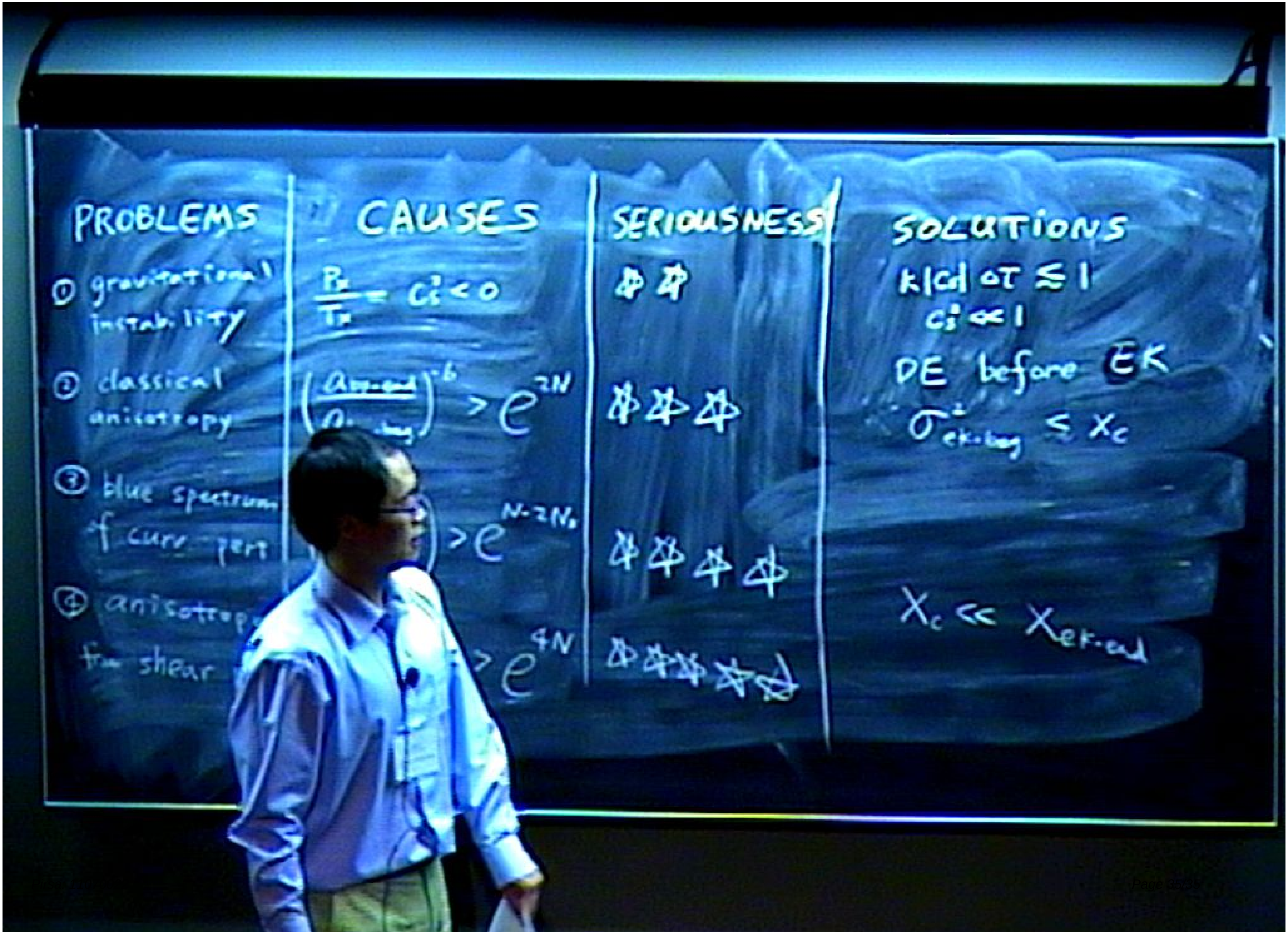


L = P(X) - V(φ)
T = 2XP_X - P
X_ek-end
X_ek-beg
kin
ek
bp
X
X_c
V_ek-end
e^2V = X_ek-end / X_ek-beg
P_X > 0
X_c < X_ek-beg << X_ek-end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