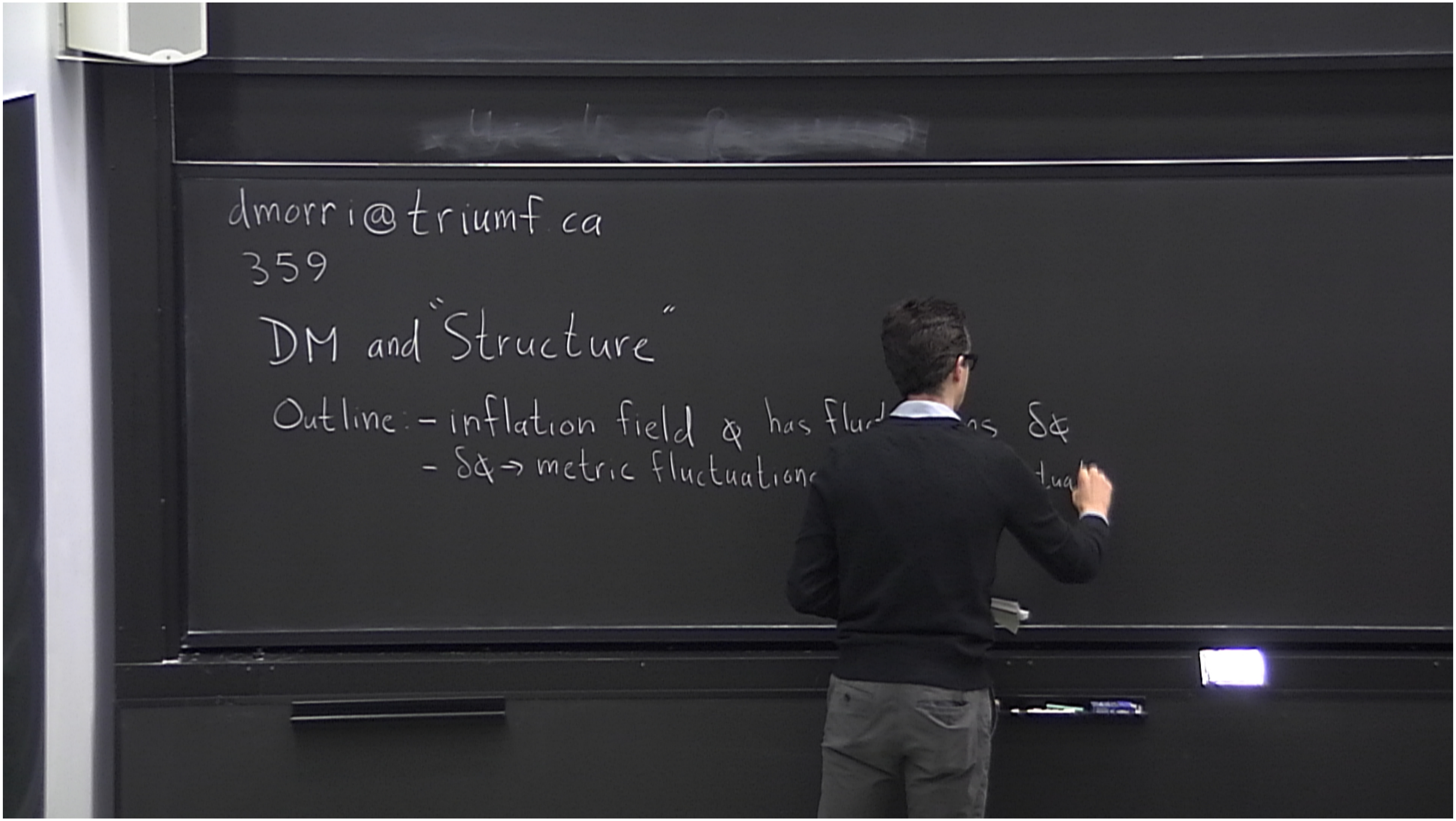
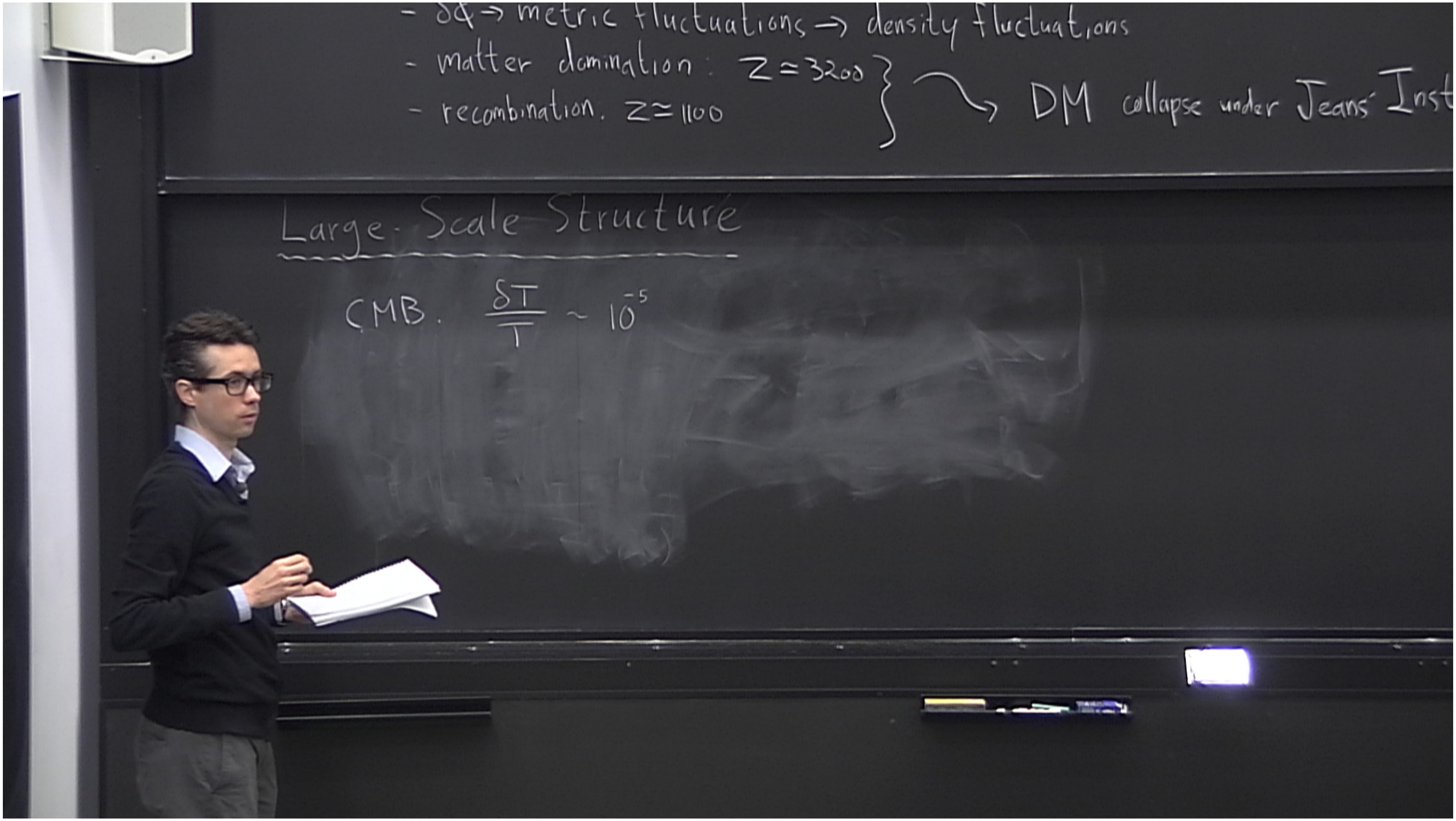
Title: Explorations in Particle Theory - Lecture 2

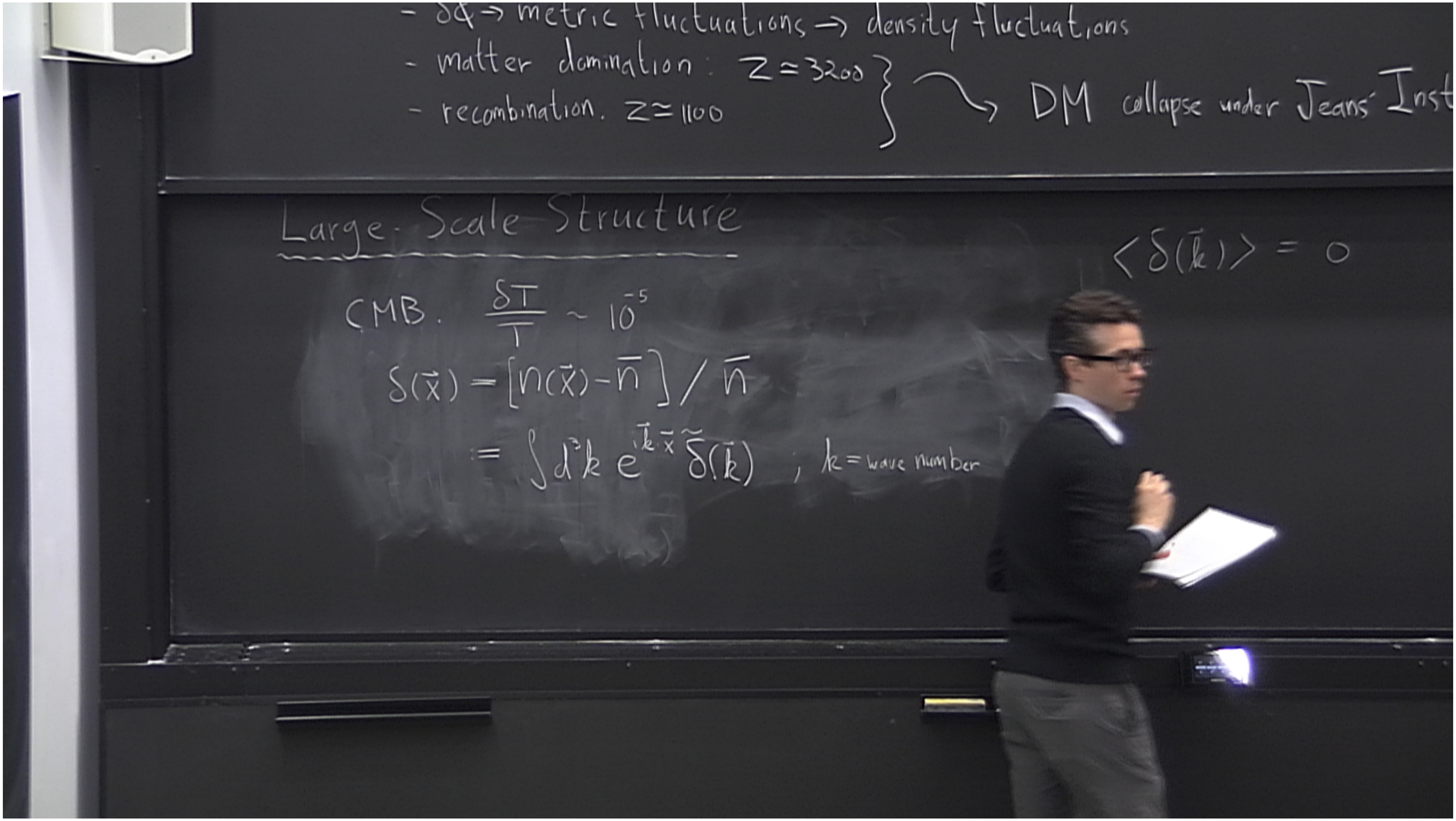
Date: Apr 03, 2012 09:00 AM

URL: http://pirsa.org/12040001

Abstract:


dmorri@triumf.ca
359
DM and "Structure"
Outline: - inflation field φ has
δφ
- δφ → metric


- δφ → metric fluctuations → density fluctuations
- matter domination: z ≃ 3200
- recombination. z ≃ 1100
DM collapse under Jeans Inst
Large Scale Structure
CMB. δT/T ~ 10^-5



- $\delta\phi \to$ metric fluctuations $\to$ density fluctuations
- matter domination: $z \simeq 3200$
- recombination. $z \simeq 1100$
DM collapse under Jeans' Inst
Large Scale Structure
$\langle \delta(\vec{k}) \rangle = 0$
CMB. $\frac{\delta T}{T} \sim 10^{-5}$
$\delta(\vec{x}) = [n(\vec{x}) - \bar{n}] / \bar{n}$
$:= \int d^3k \, e^{i\vec{k}\cdot\vec{x}} \tilde{\delta}(\vec{k})$; k = wave number

$\Big\} \rightarrow$ DM collapse under Jeans' Instability

$$\langle \delta(\vec{k}) \rangle = 0$$

$$\langle \delta(\vec{k})\,\delta(\vec{k}') \rangle = P(k)\,(2\pi)^3\,\delta^{(3)}(\vec{k}-\vec{k}')$$

$\hookrightarrow$ early on, different $\vec{k}$ evolve

; k = wave number

→ DM collapse under Jeans' Instability

$$\langle \delta(\vec{k}) \rangle = 0$$

$$\langle \delta(\vec{k}) \delta(\vec{k}') \rangle = P(k)\,(2\pi)^3\,\delta^{(3)}(\vec{k}-\vec{k}')$$

↳ early on, different $\vec{k}$ evolve independently

ber

ons → density fluctuations

= 3200 } → DM collapse under Jeans' Instability

$$\langle \delta(\vec{k}) \rangle = 0$$

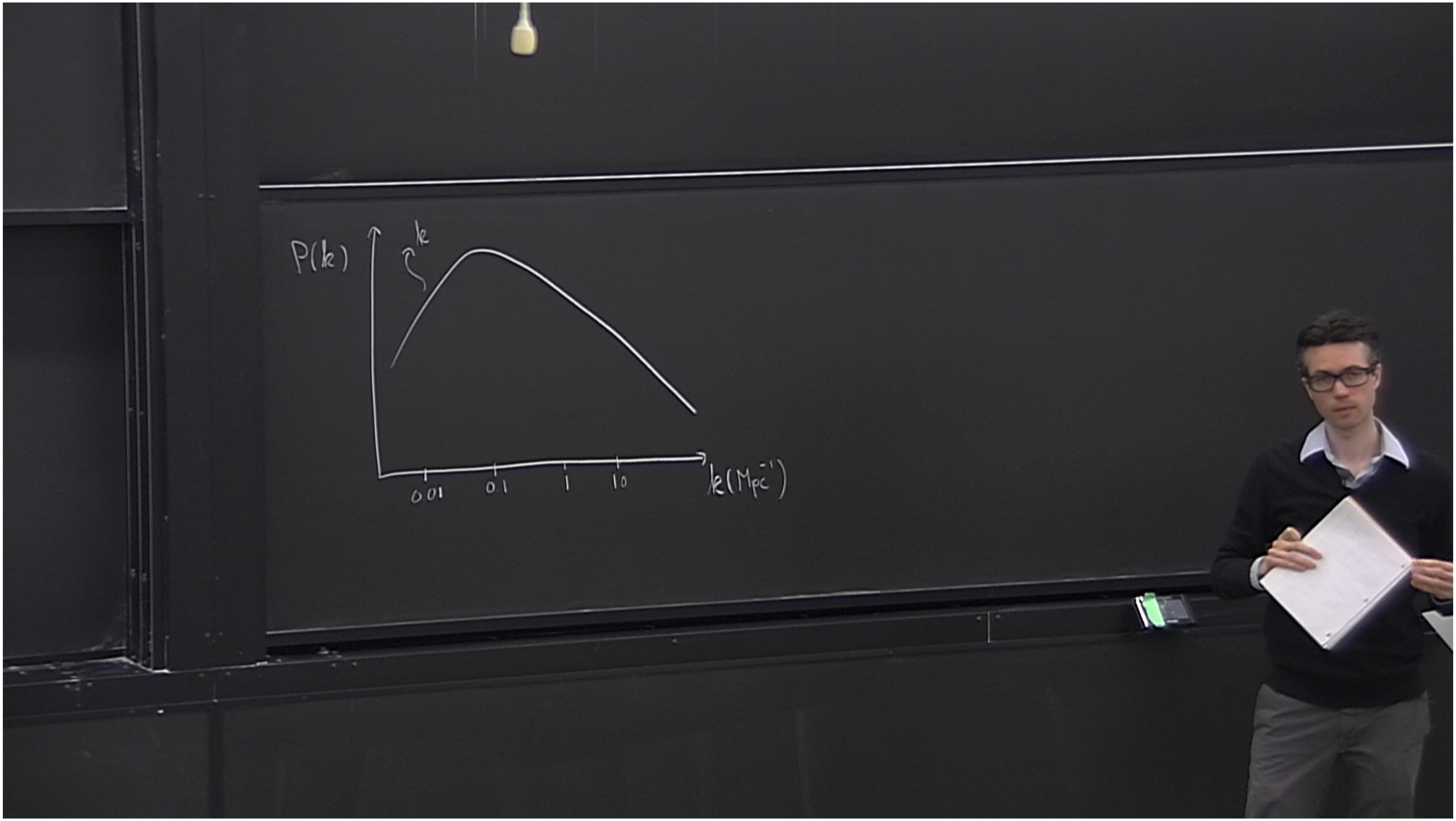
$$\langle \delta(\vec{k})\delta(\vec{k}') \rangle = P(k)\,(2\pi)^3\,\delta^{(3)}(\vec{k}-\vec{k}')$$

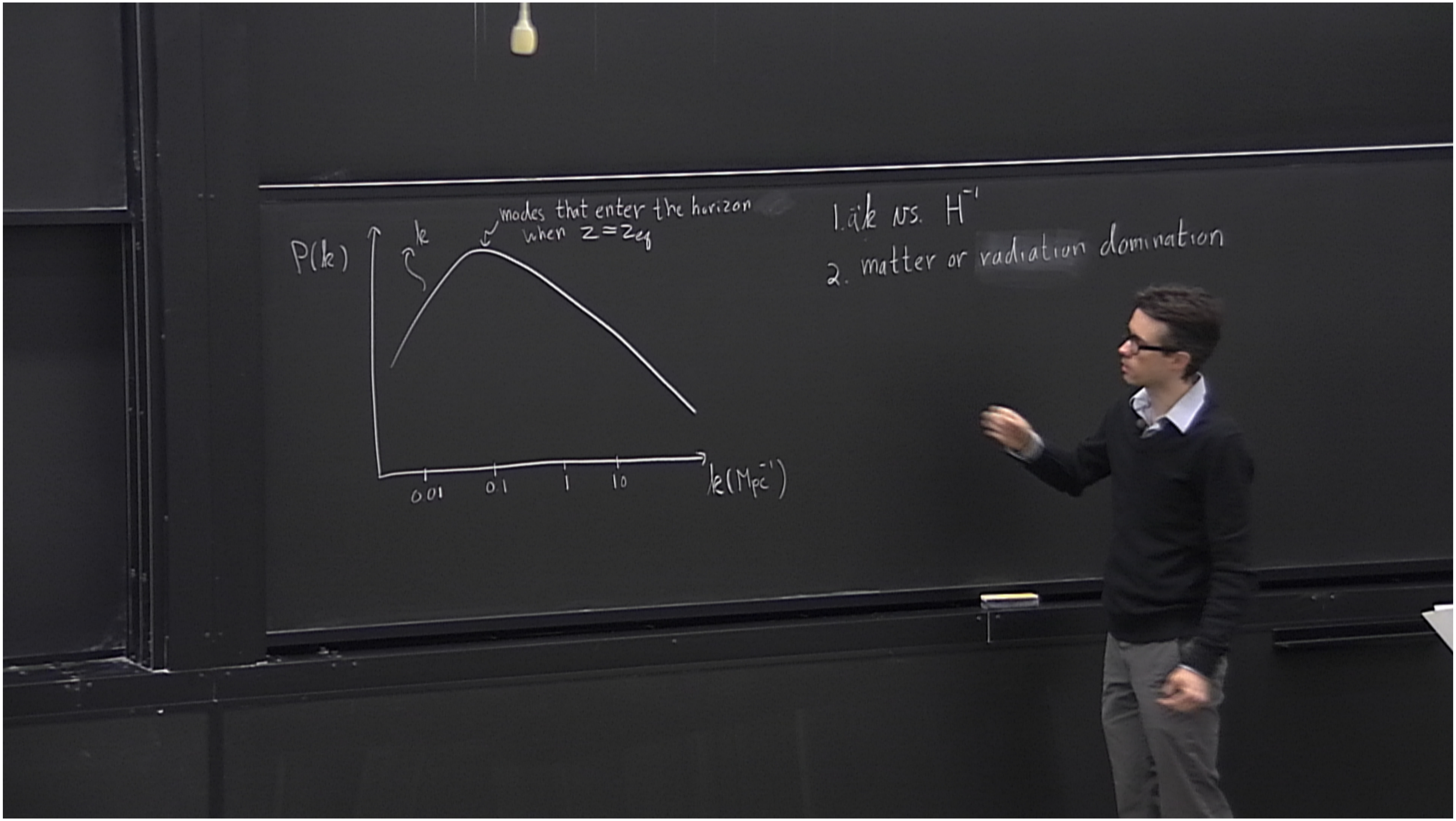
↳ early on, different $\vec{k}$ evolve independently

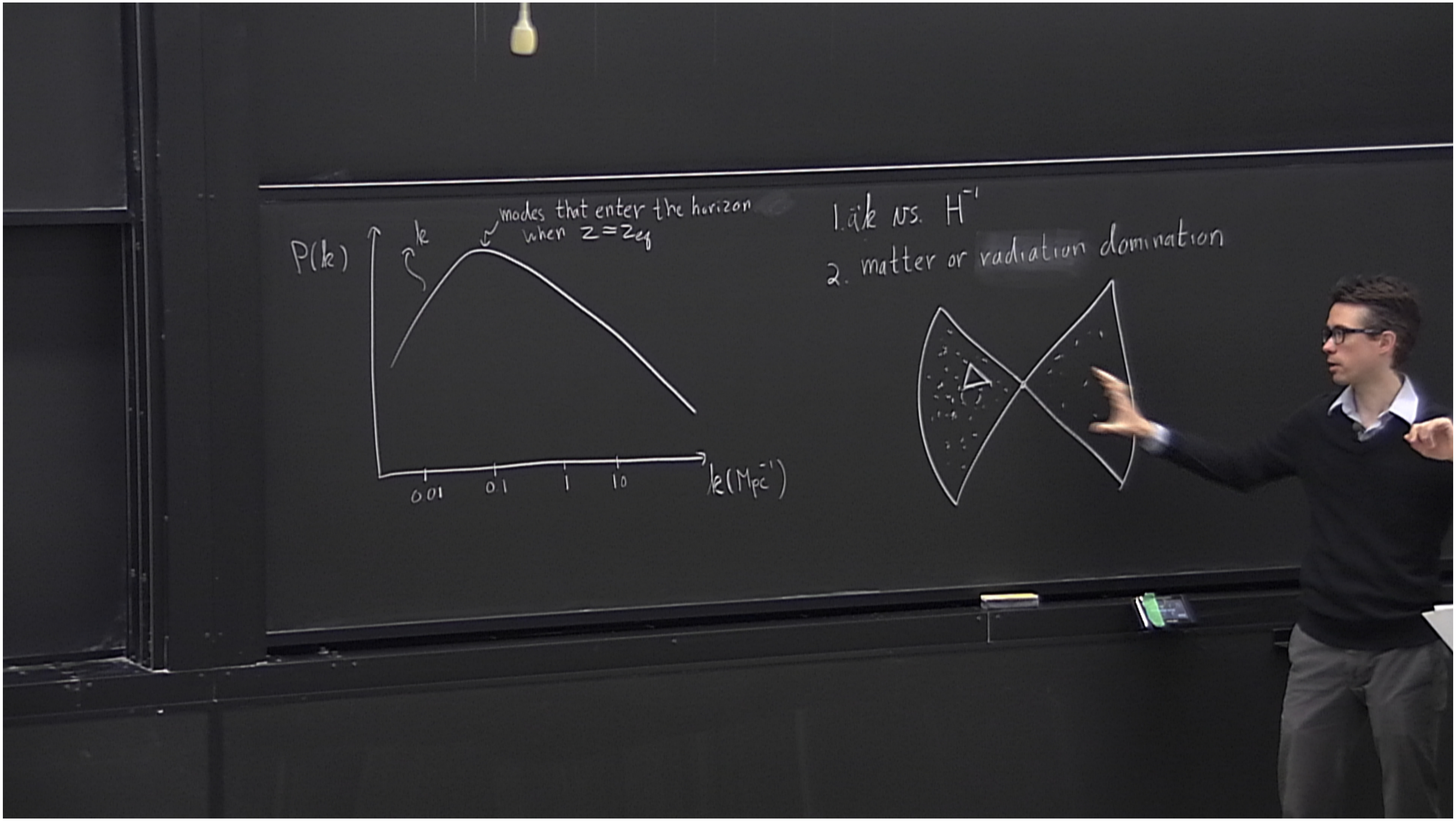
↳ matter power spectrum

$$\Delta^2 = \frac{k^3}{2\pi^2} P(k)$$

; k = wave number


P(k)
k
0.01
0.1
1
10
k(Mpc⁻¹)


P(k)
k
modes that enter the horizon
when z = z_eq
0.01
0.1
1
10
k(Mpc⁻¹)
1. ä k vs. H⁻¹
2. matter or radiation domination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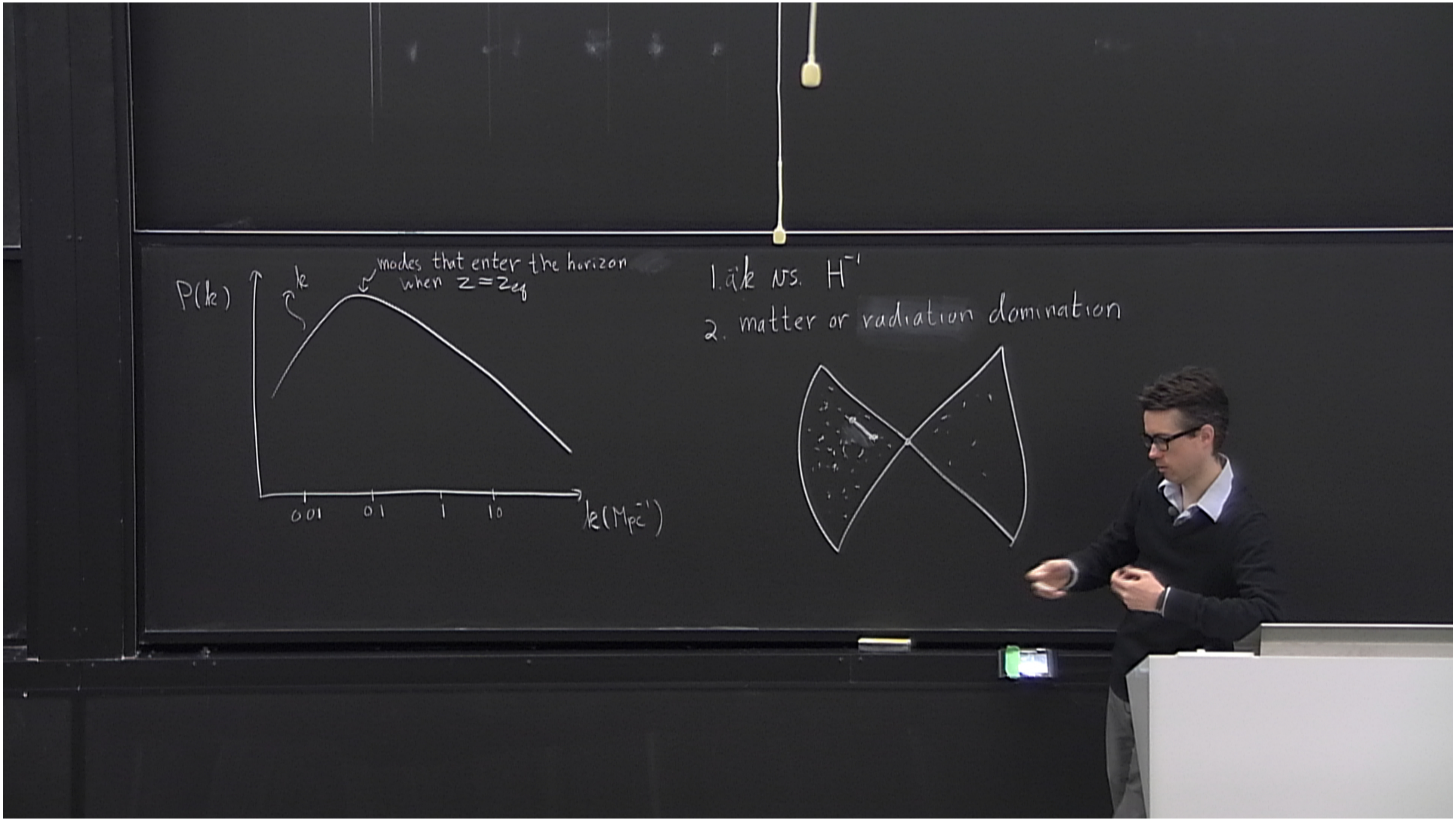
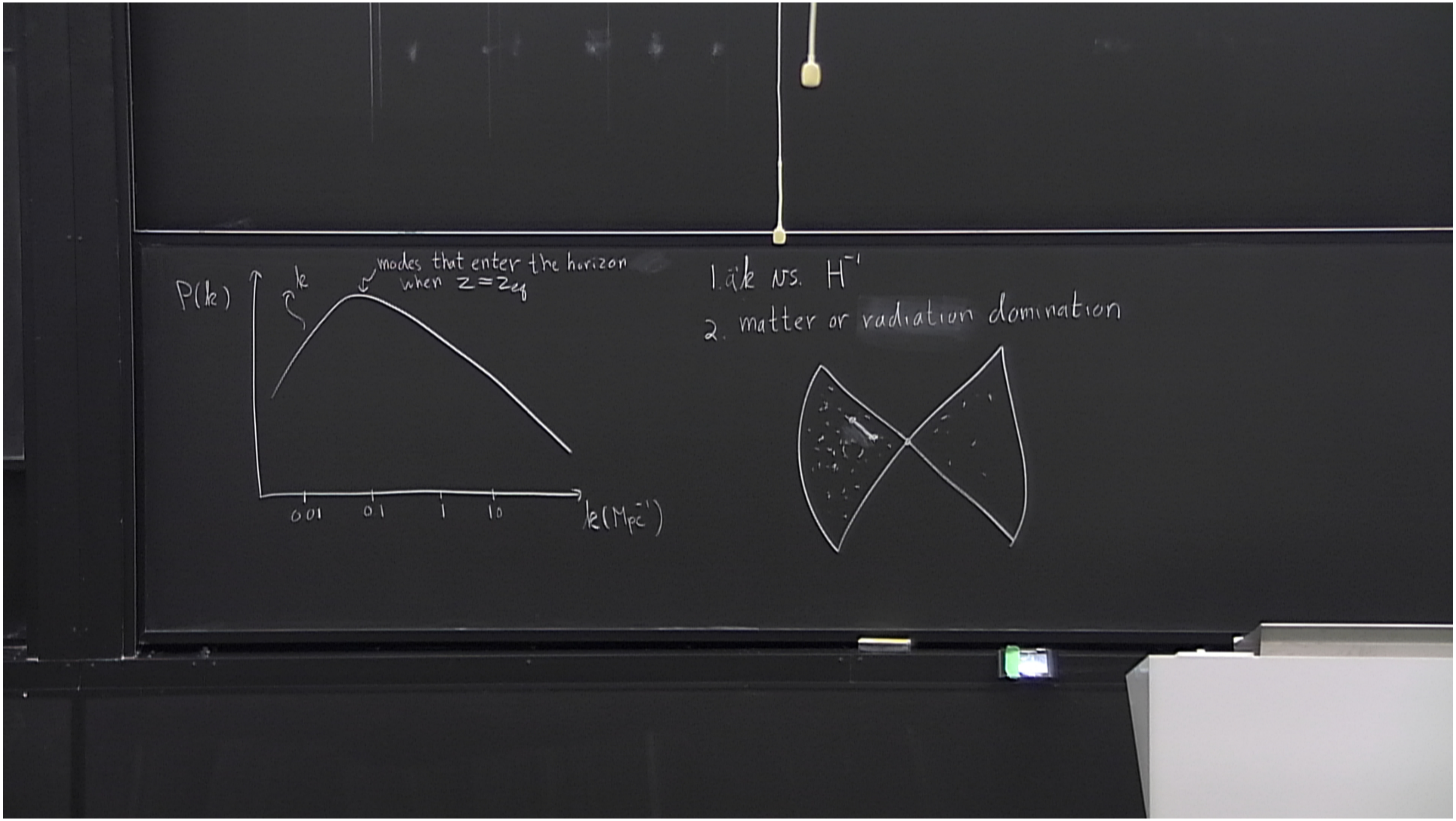

modes that enter the horizon
when z = z_eq
P(k)
k
0.01
0.1
1
10
k(Mpc^-1)
1. ak vs. H^-1
2. matter or radiation domination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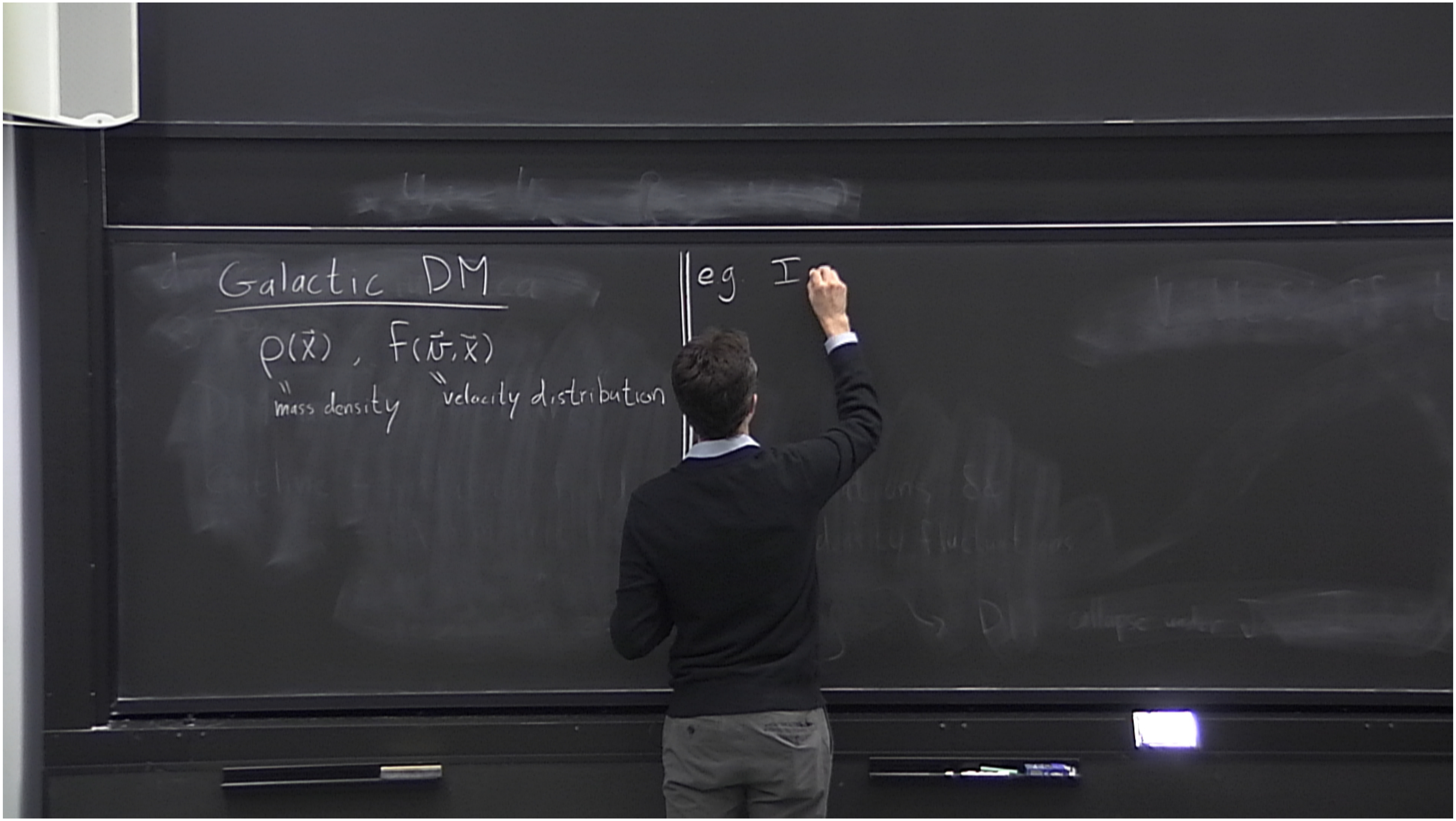
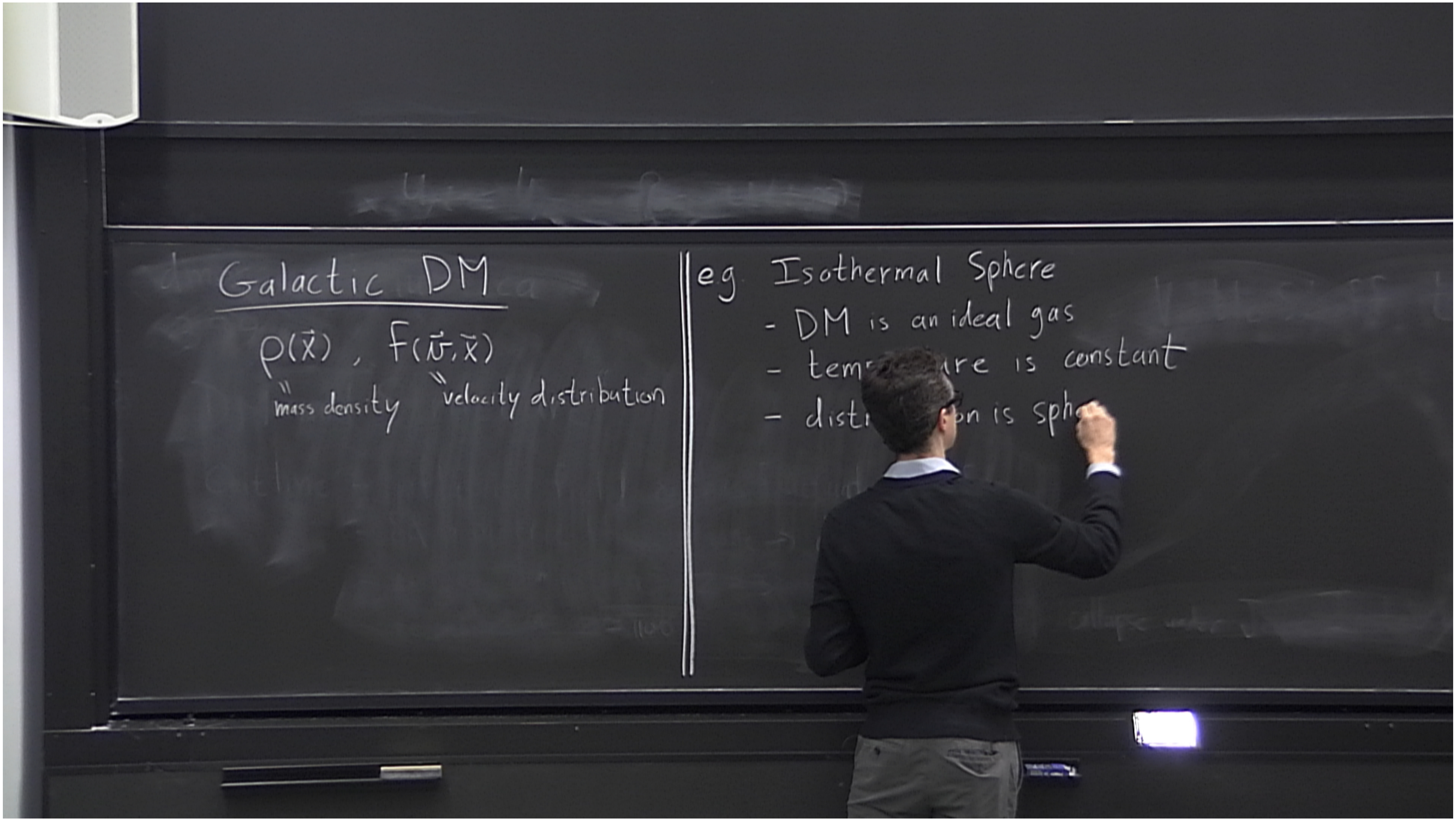
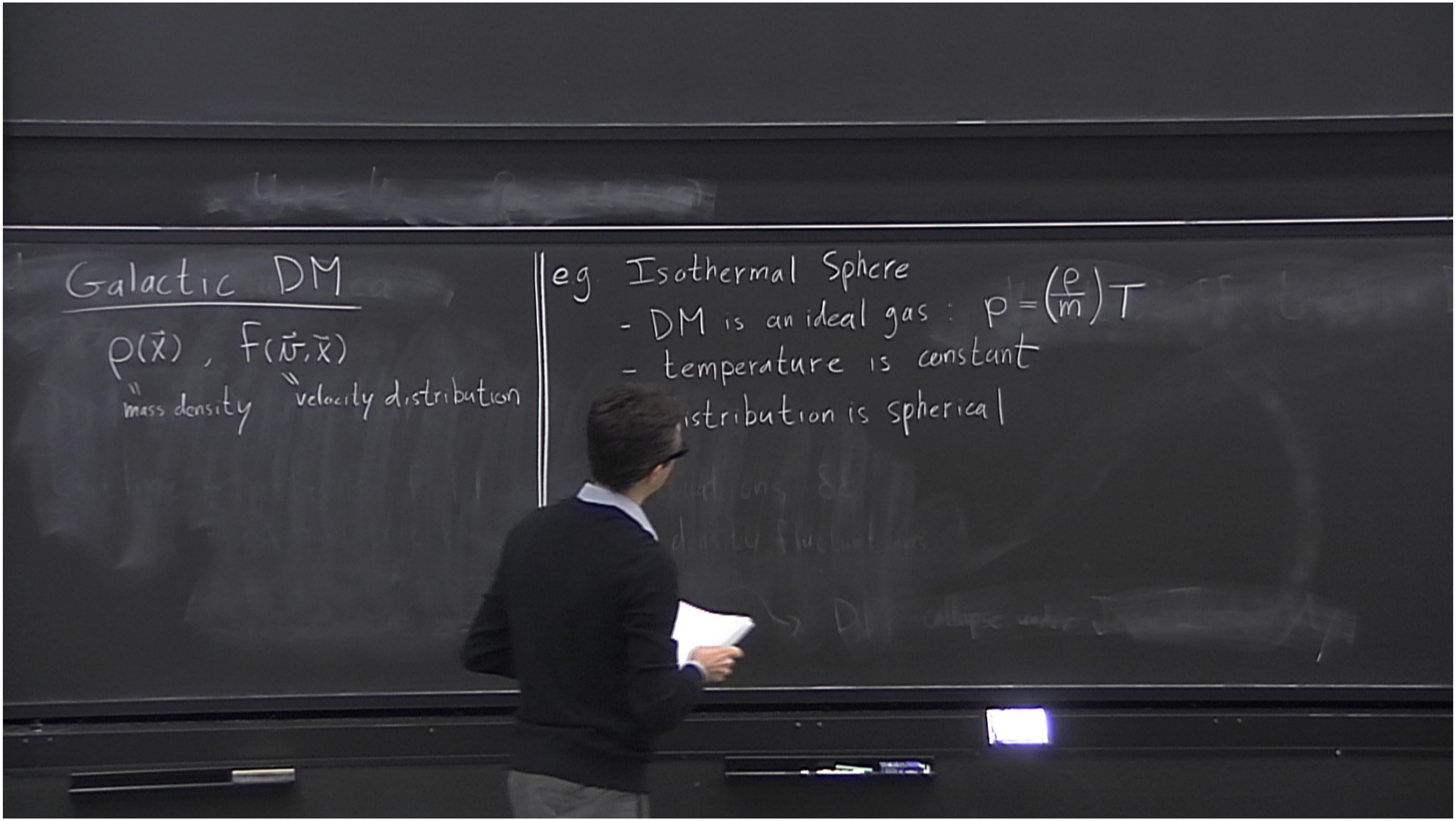
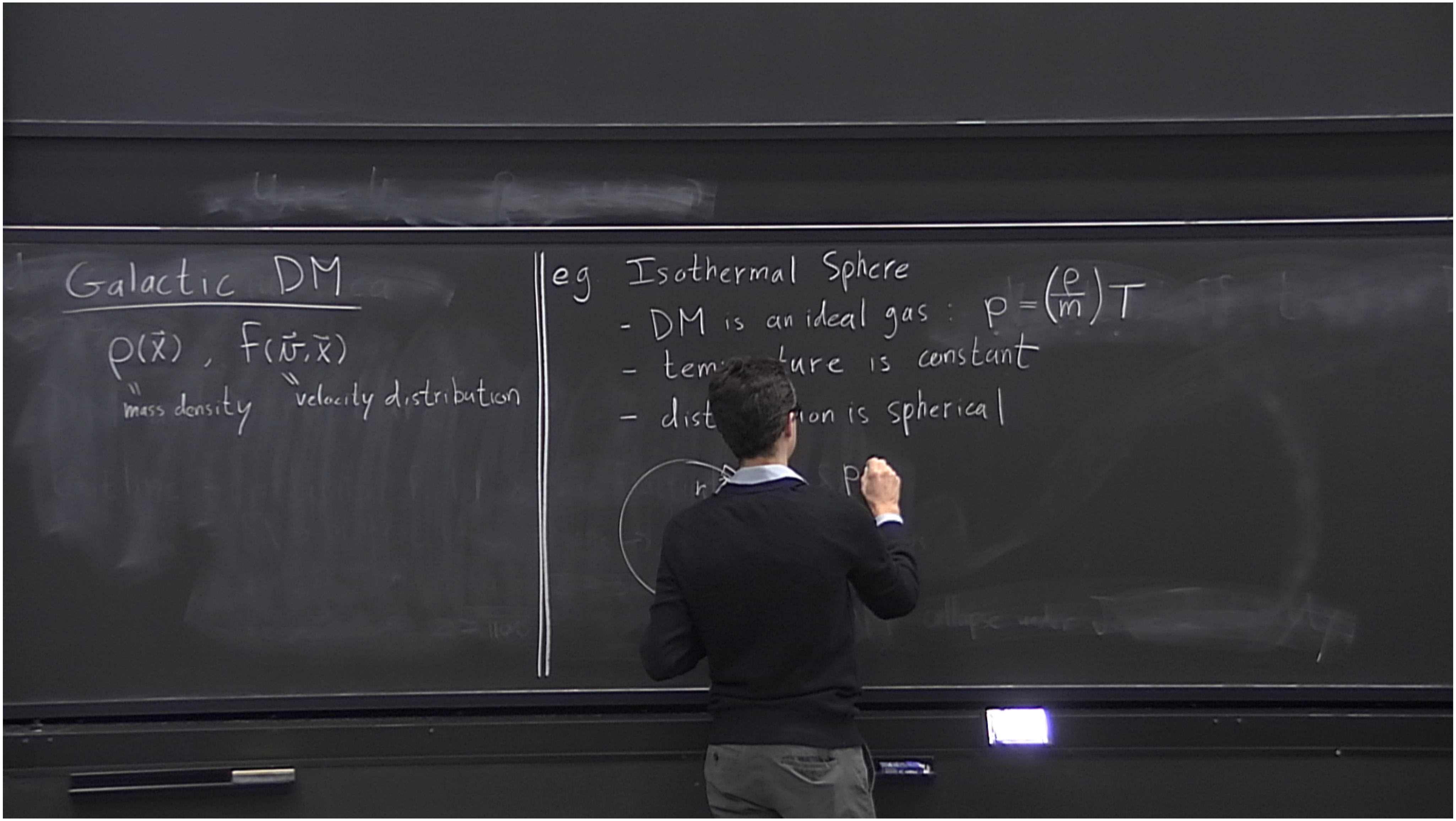

Galactic DM
ρ(x⃗) , f(v⃗, x⃗)
mass density
velocity distribution
eg. I


Galactic DM
$\rho(\vec{x})$, $f(\vec{v}, \vec{x})$
mass density
velocity distribution
eg. Isothermal Sphere
- DM is an ideal gas
- tem re is constant
- dist on is sph


Galactic DM
ρ(x⃗) , f(v⃗, x⃗)
mass density
velocity distribution
eg Isothermal Sphere
- DM is an ideal gas : p = (ρ/m) T
- temperature is constant
istribution is spherical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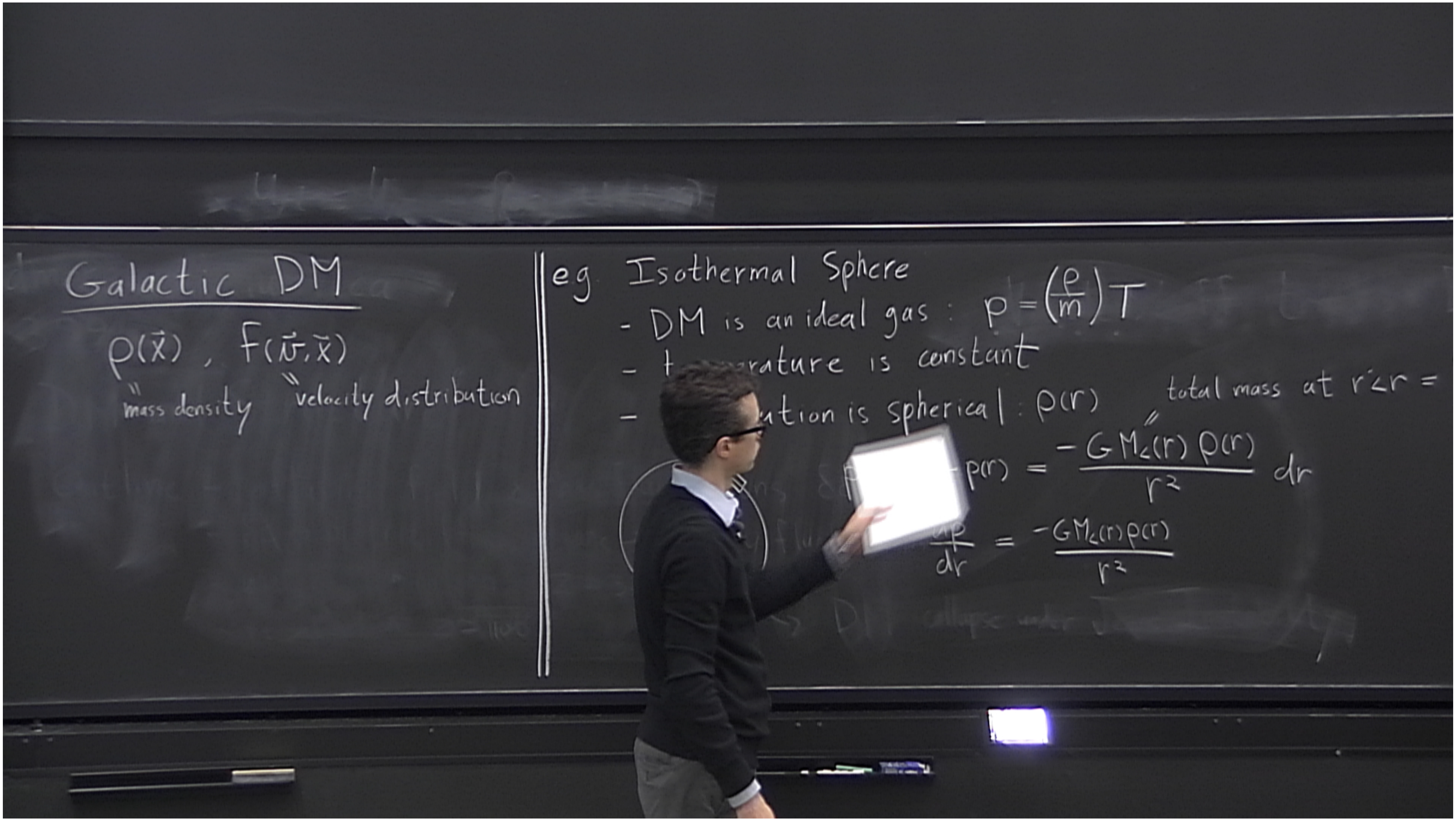
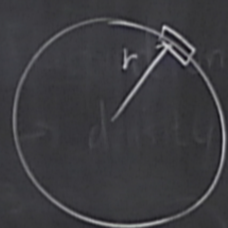

Galactic DM
ρ(x⃗) , f(v⃗, x⃗)
" mass density " velocity distribution
eg. Isothermal Sphere
- DM is an ideal gas : p = (ρ/m) T
- temperature is constant
- ation is spherical : ρ(r)
total mass at r'<r =
ρ(r) = −G M<(r) ρ(r) / r² dr
dp/dr = −G M<(r) ρ(r) / r²

ly distribution

eg. Isothermal Sphere

- DM is an ideal gas: $p = \left(\frac{\rho}{m}\right) T$
- temperature is constant
- distribution is spherical: $\rho(r)$

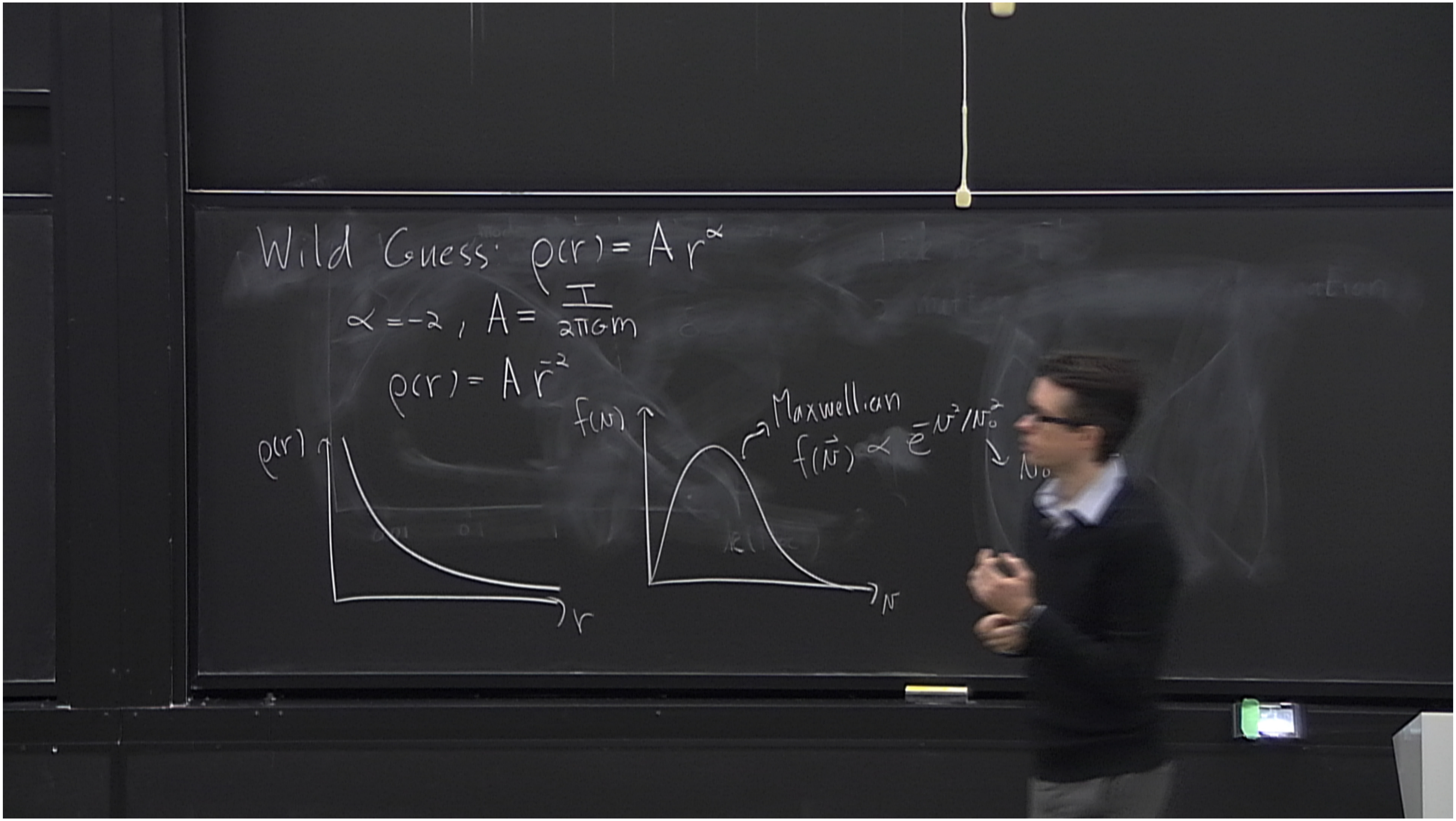
total mass at $r' < r = \int_0^r dr' \, 4\pi r'^2 \rho(r')$

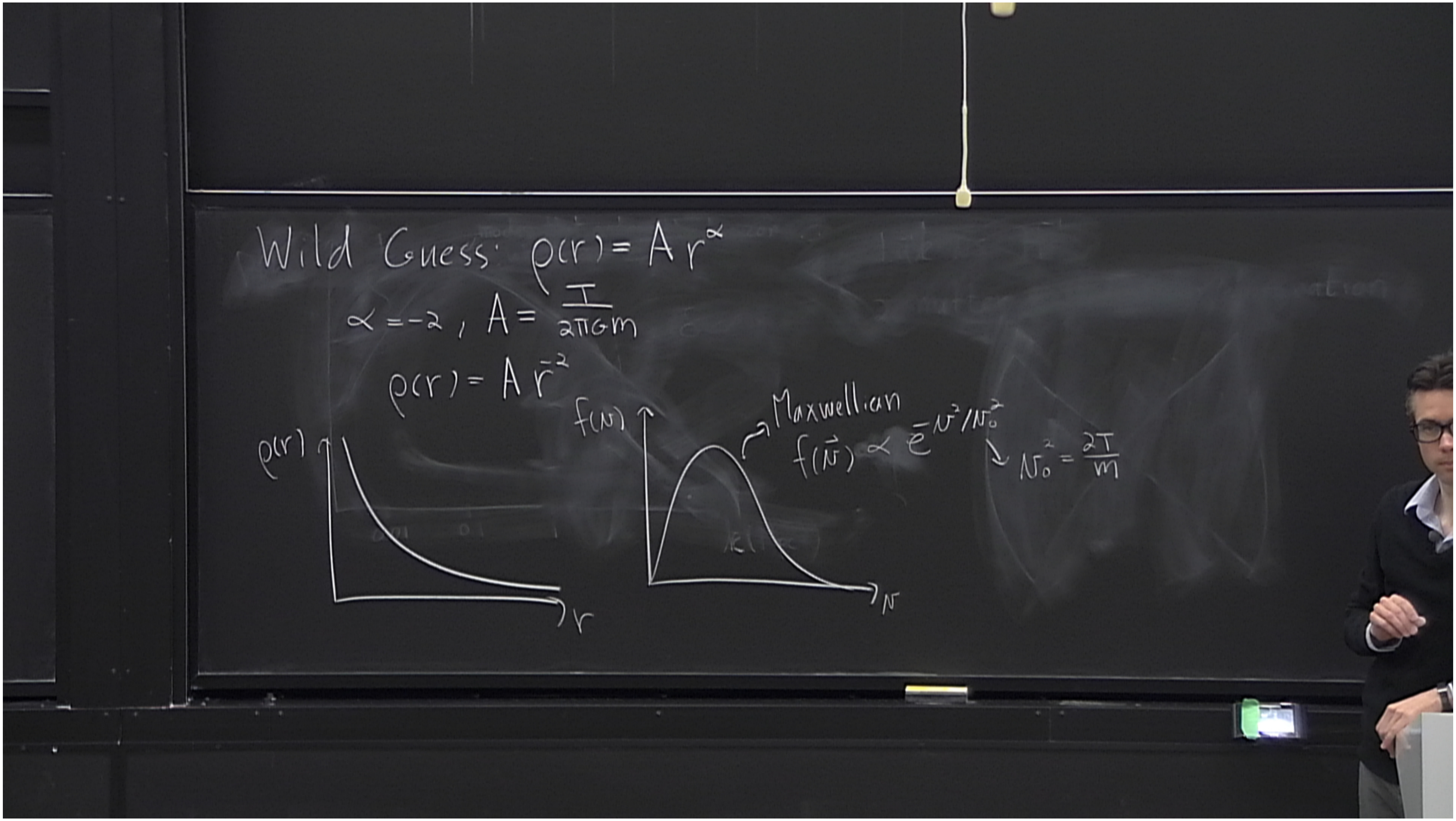


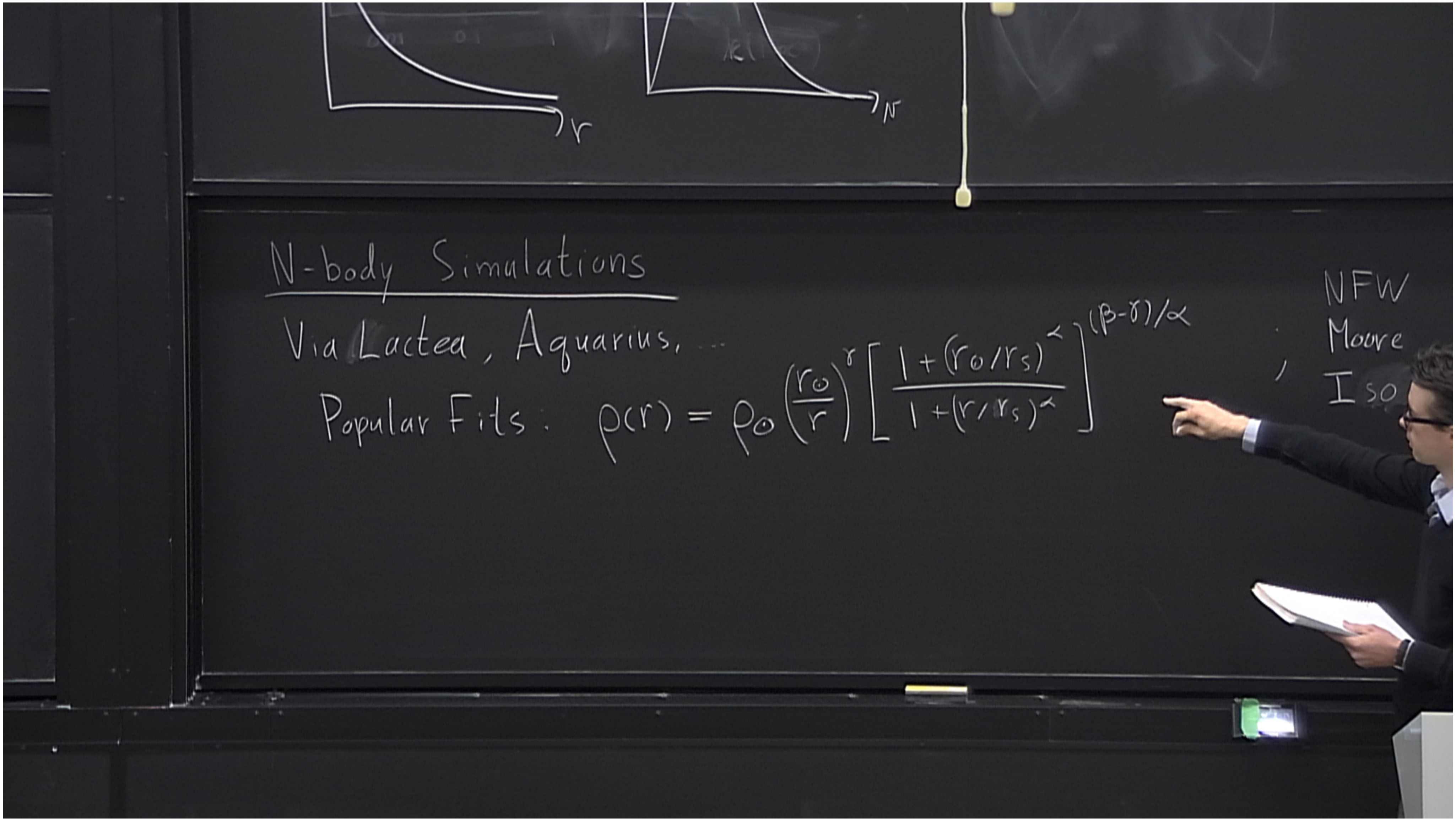
$$p(r+dr) - p(r) = \frac{-G M_<(r)\, \rho(r)}{r^2}\, dr$$

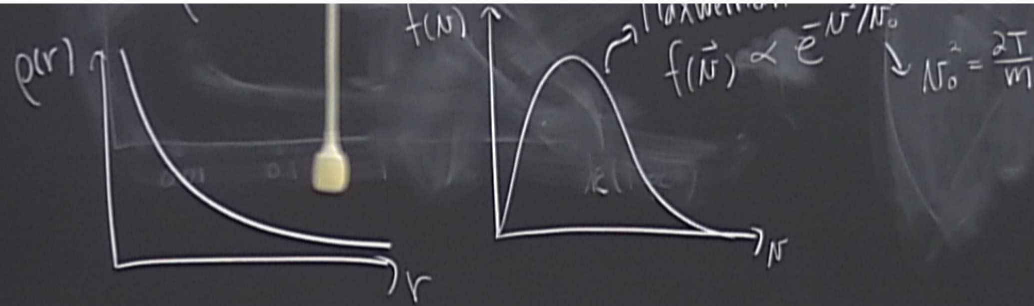
$$\frac{dp}{dr} = \frac{-G M_<(r)\, \rho(r)}{r^2}$$

$$\frac{d}{dr}\left(\frac{r^2}{\rho}\frac{d\rho}{dr}\right) = \frac{-Gm}{T} 4\pi\, r^2 \rho$$


Wild Guess: ρ(r) = A r^α
Maxwellian


Wild Guess: $\rho(r) = A r^{\alpha}$
$\alpha = -2$, $A = \frac{T}{2\pi G m}$
$\rho(r) = A r^{-2}$
$\rho(r)$
r
$f(v)$
Maxwellian
$f(\vec{v}) \propto e^{-v^2/v_0^2}$
$v_0^2 = \frac{2T}{m}$
v


r
N
N-body Simulations
Via Lactea, Aquarius, ...
Popular Fits: $\rho(r) = \rho_\odot \left(\frac{r_\odot}{r}\right)^\gamma \left[\frac{1+(r_\odot/r_s)^\alpha}{1+(r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$,
NFW
Moore
Iso



N-body Simulations

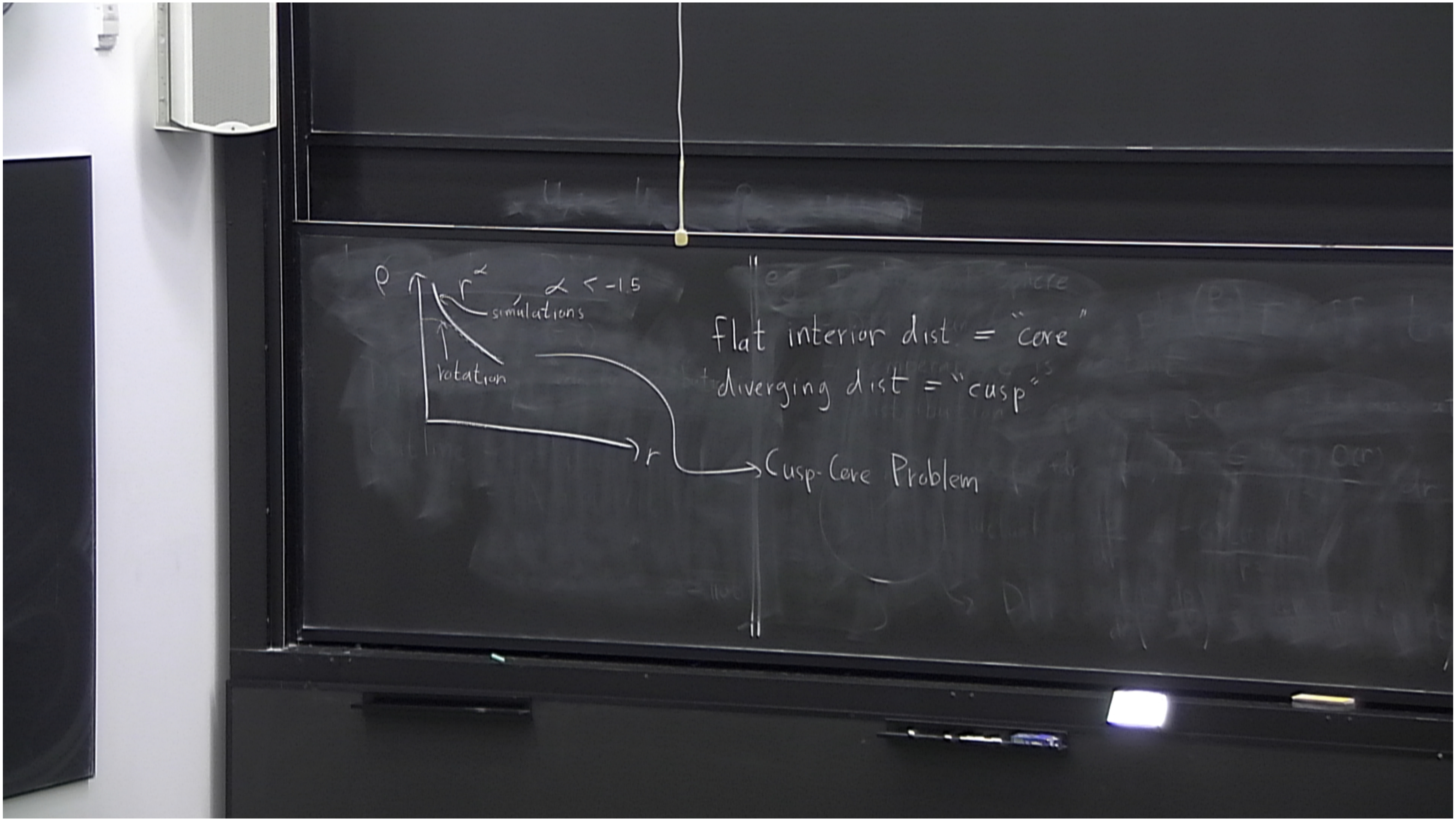
Via Lactea, Aquarius, ...

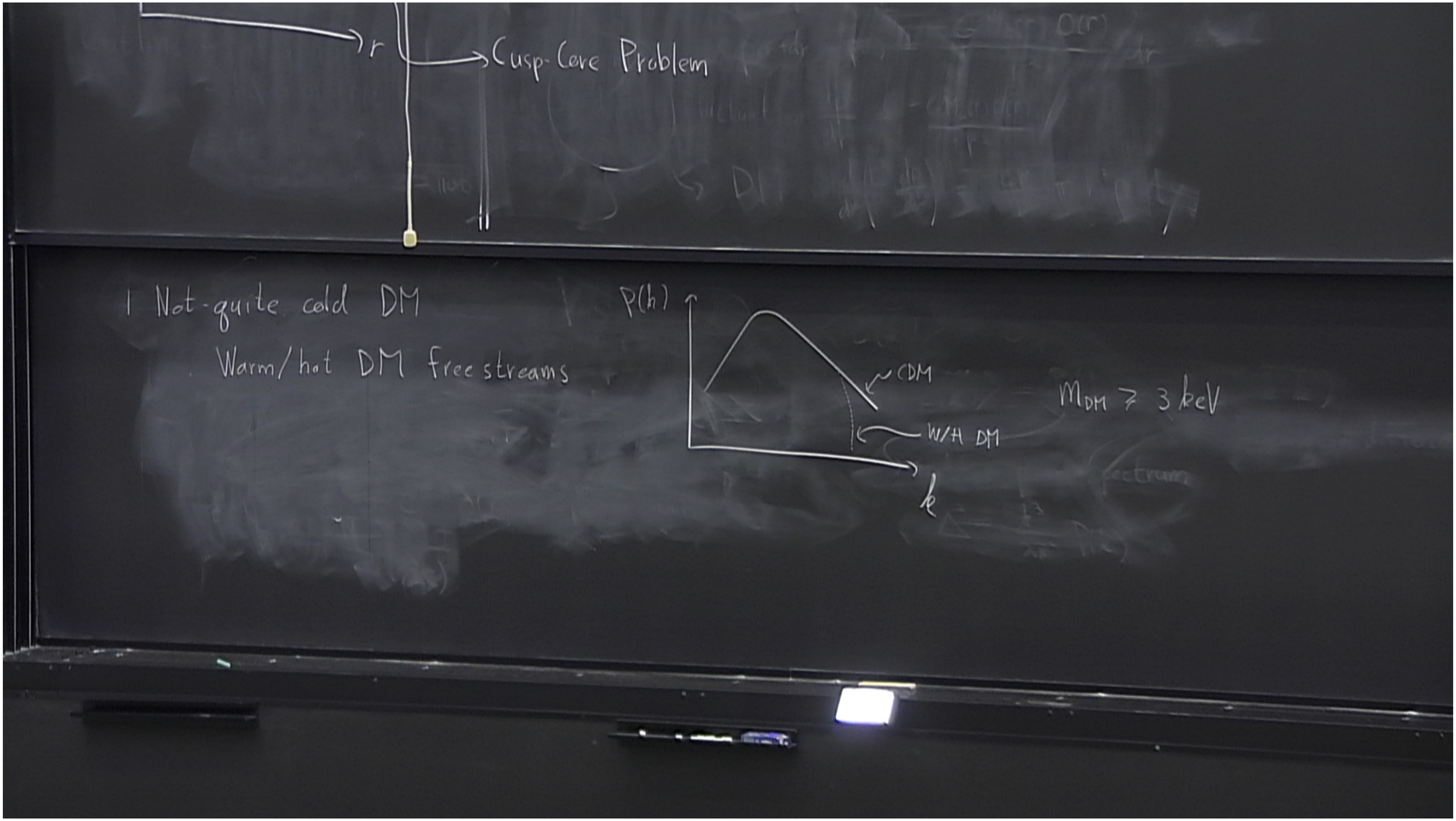
$r_\odot \simeq 8.5$ kpc

Popular Fits: $\rho(r) = \rho_0 \left(\frac{r_0}{r}\right)^{\gamma} \left[\frac{1+(r_0/r_s)^{\alpha}}{1+(r/r_s)^{\alpha}}\right]^{(\beta-\gamma)/\alpha}$,

	α	β	γ
NFW	1	3	1
Moore	1	3	1.16
Iso	2	2	0

Einasto: $\rho(r) = \rho_0 \exp\left(-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha} - 1\right]\right)$, $\alpha \simeq 1.7$


ρ
r^α
α < -1.5
simulations
rotation
r
flat interior dist = "core"
diverging dist = "cusp"
Cusp-Core Problem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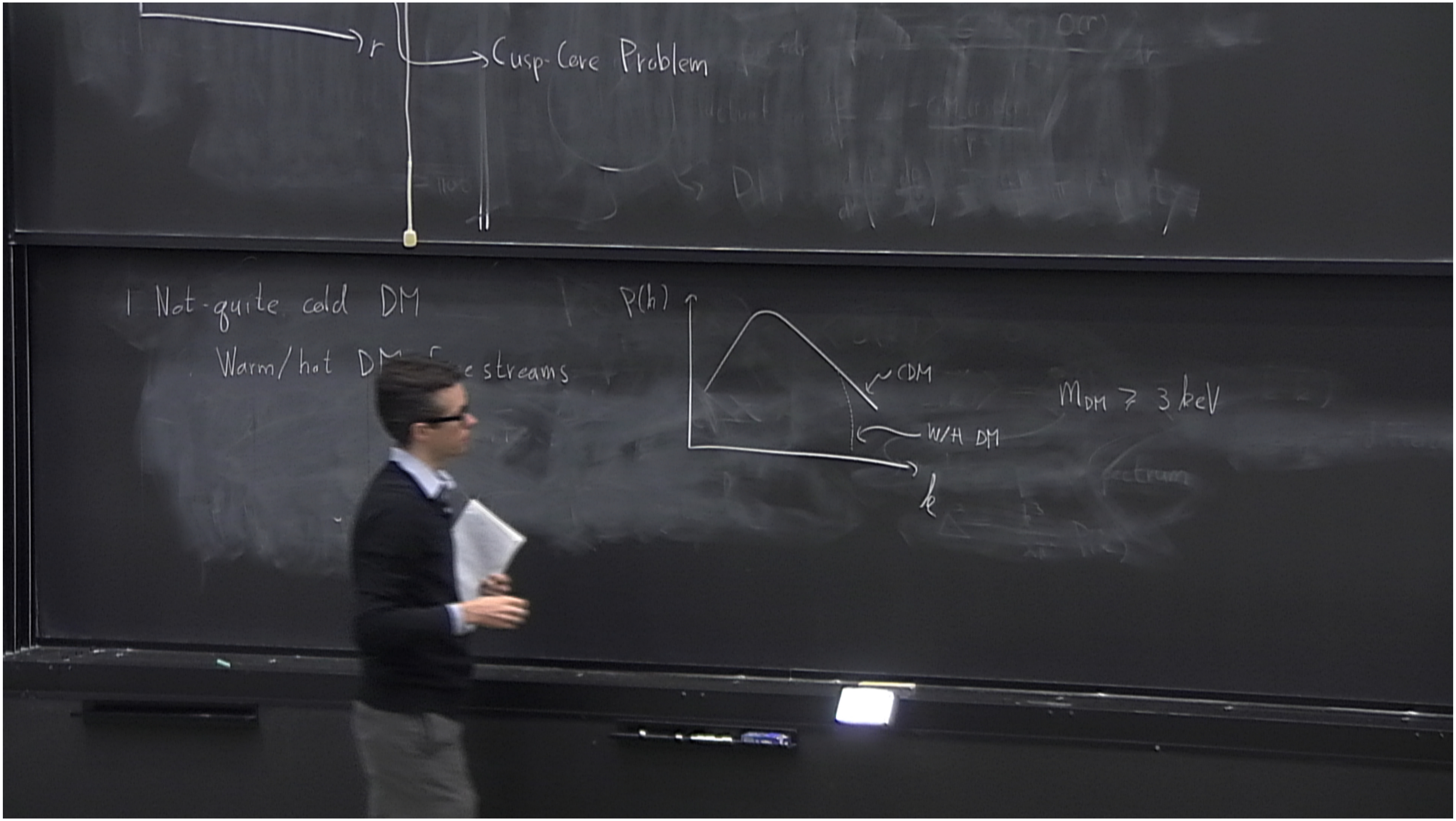
Cusp-Core Problem
1 Not-quite cold DM
Warm/hot DM free streams
P(k)
CDM
W/H DM
k
$m_{DM} \gtrsim 3$ keV



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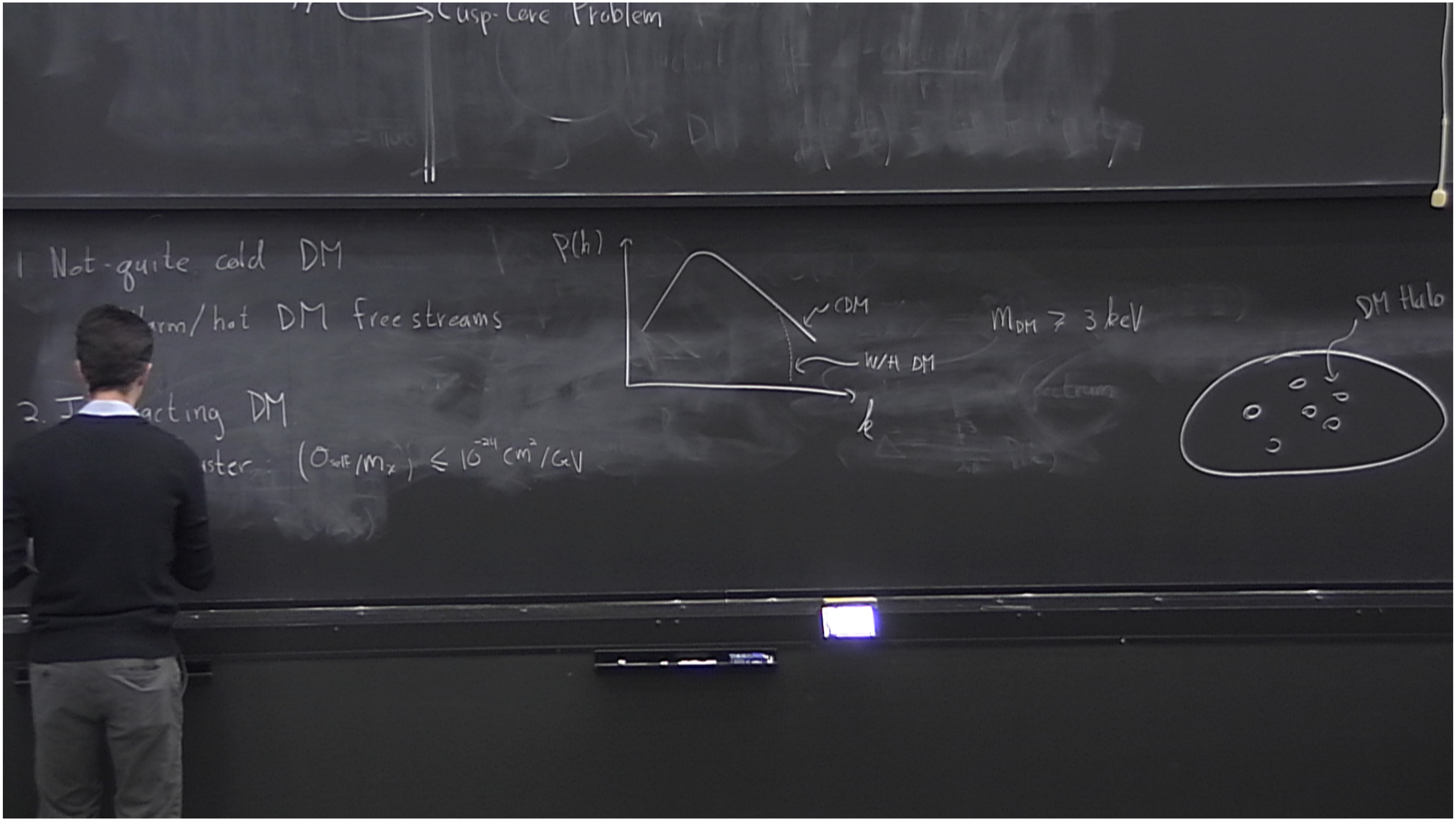

Cusp-Core Problem
1 Not-quite cold DM
arm/hot DM free streams
P(k)
CDM
W/H DM
k
$m_{DM} \gtrsim 3$ keV
DM Halo
2. acting DM
ster: $(\sigma_{self}/m_\chi) \leq 10^{-24}\ cm^2/GeV$