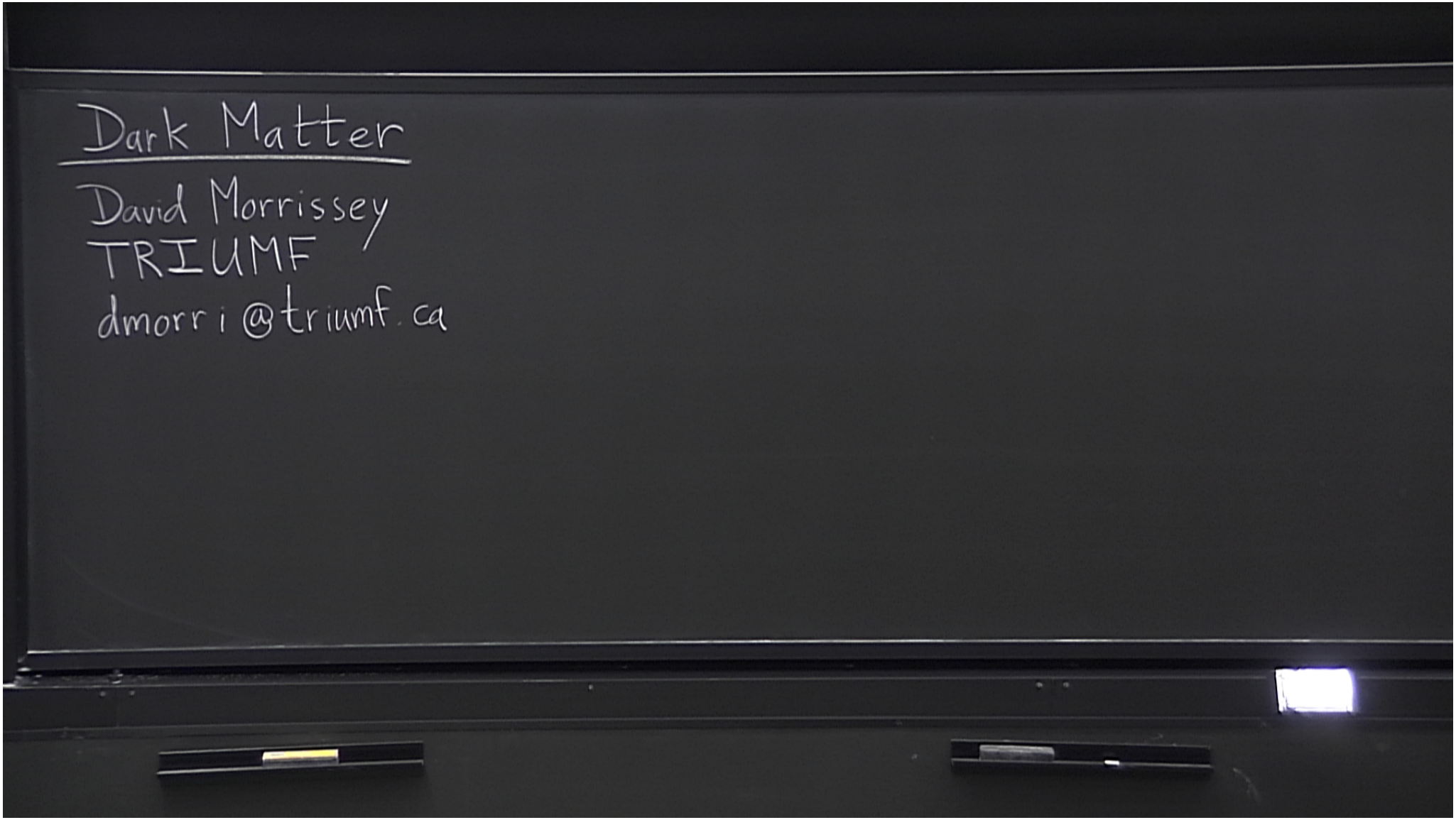
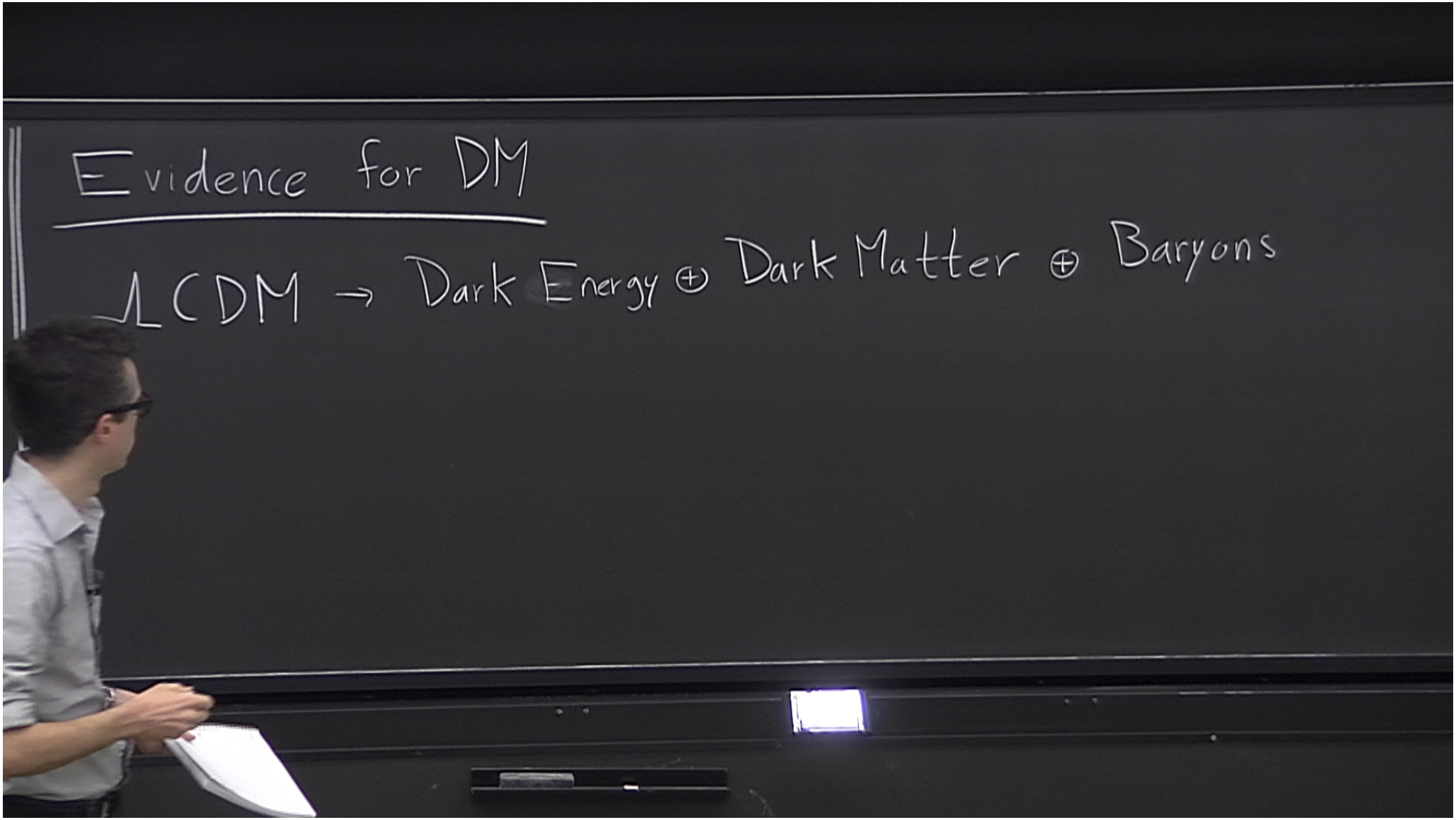
Title: Explorations in Particle Theory - Lecture 1

Date: Apr 02, 2012 09:00 AM

URL: http://pirsa.org/12040000

Abstract:

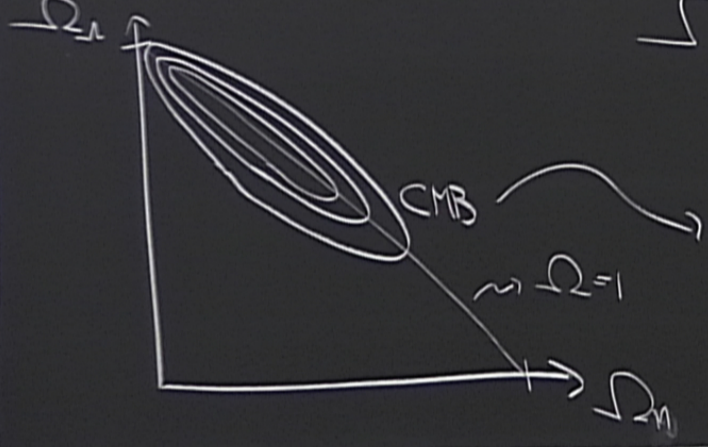

Dark Matter
David Morrissey
TRIUMF
dmorri@triumf.ca

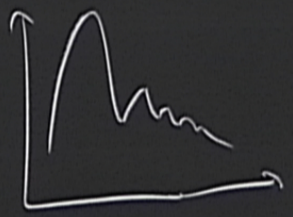

Evidence for DM
ΛCDM → Dark Energy ⊕ Dark Matter ⊕ Baryons

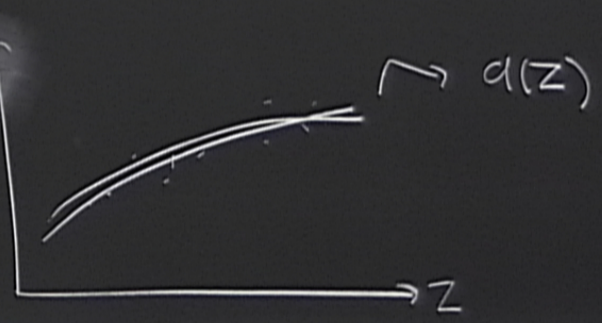
Evidence for DM

ΛCDM → Dark Energy ⊕ Dark Matter ⊕ Baryons

$\Omega_i = \rho_i / \rho_c$







Dark Matter ⊕ Baryons

$\Omega_\Lambda = 0.72$

$\Omega_M = 0.22$

$\Omega_b = 0.05$

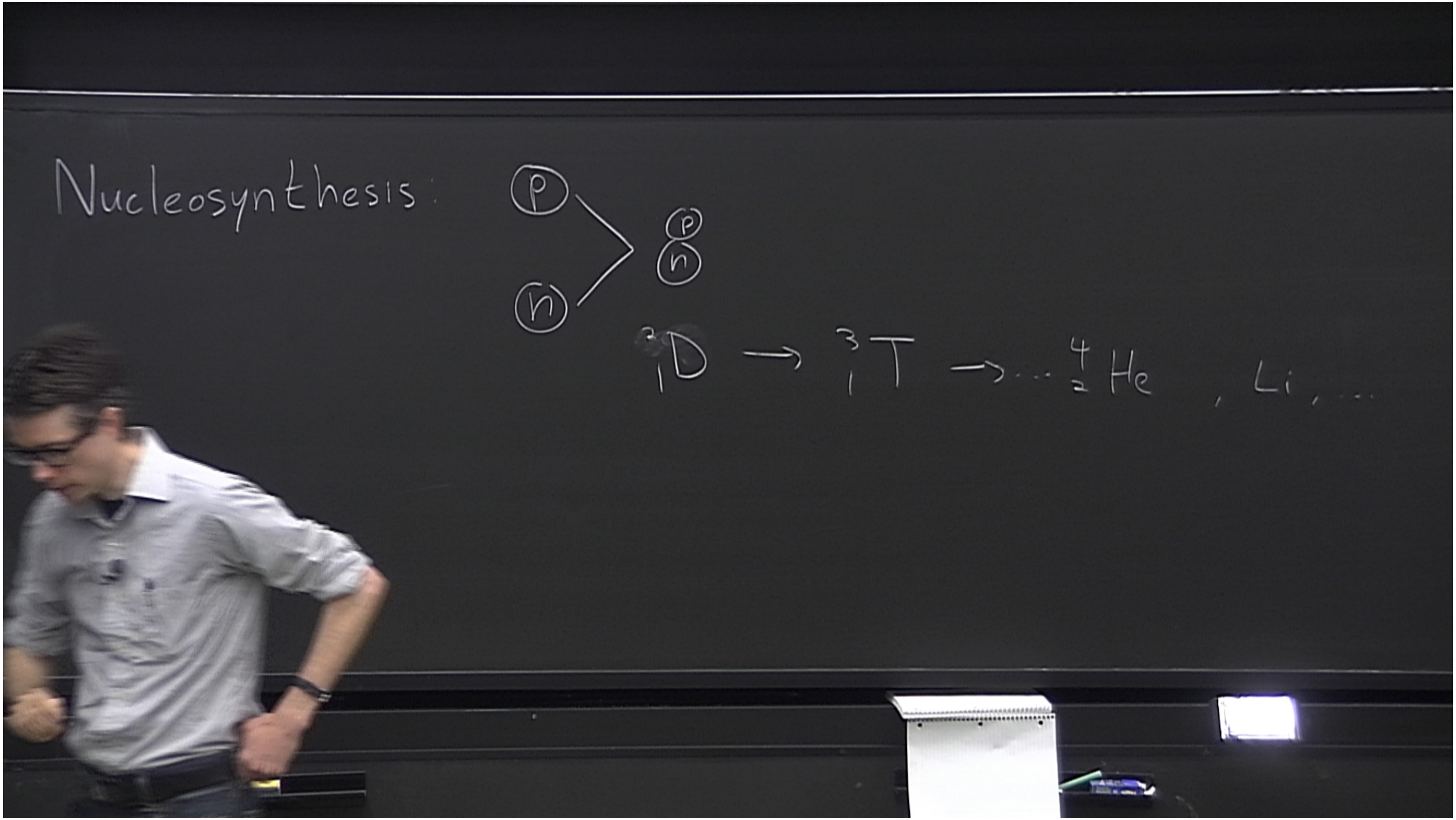
ρ_c

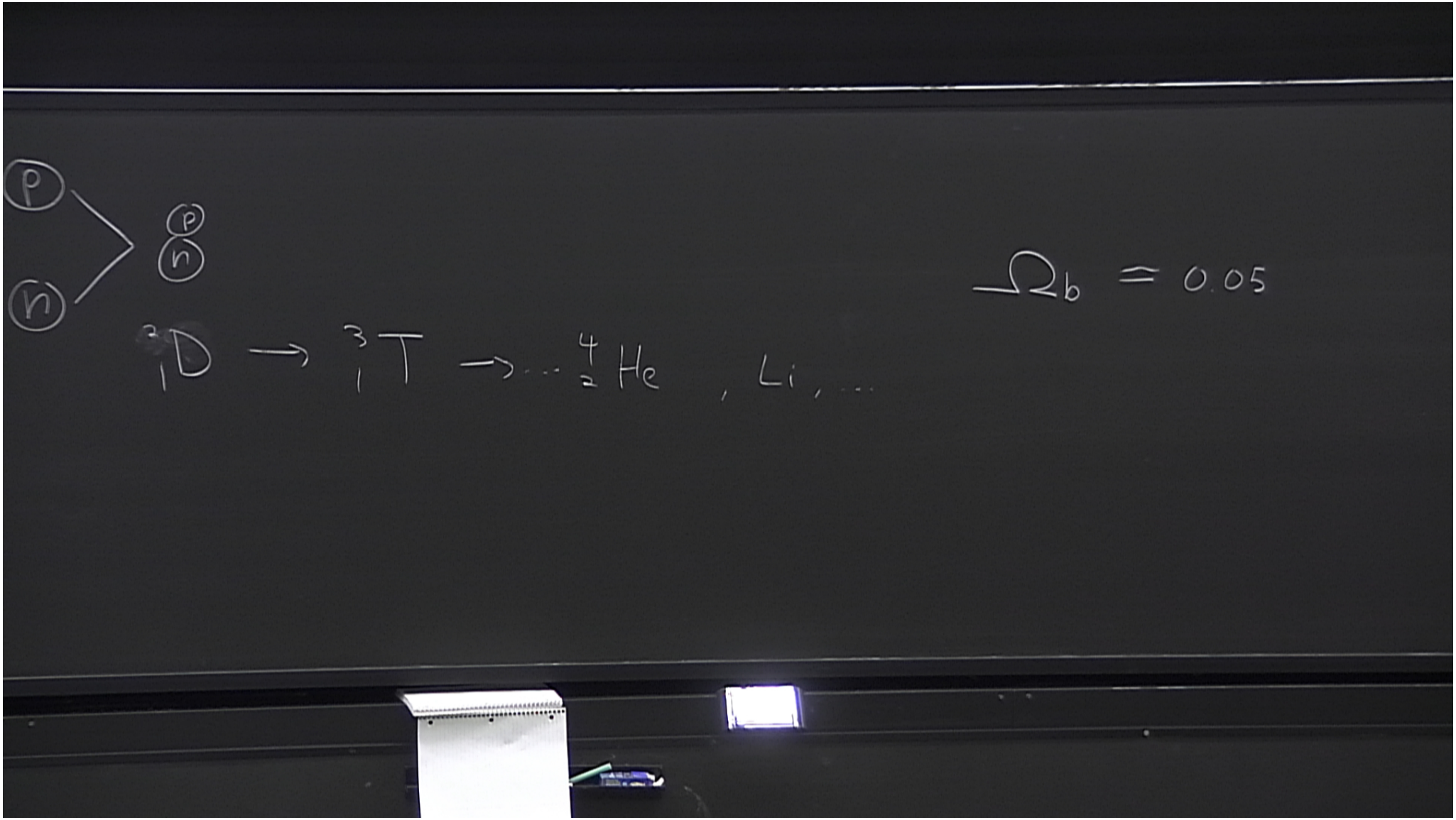
SNIA

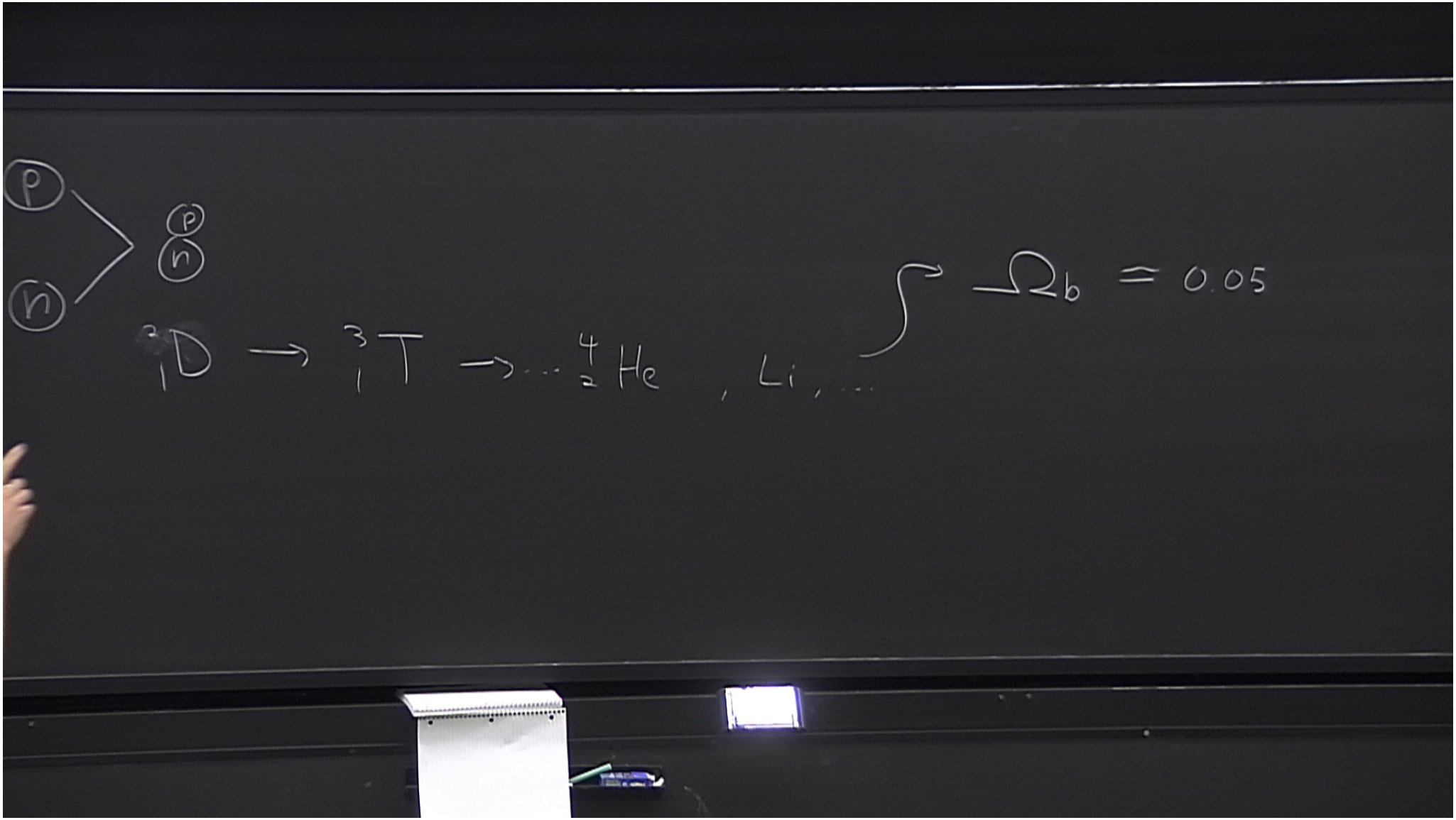
d

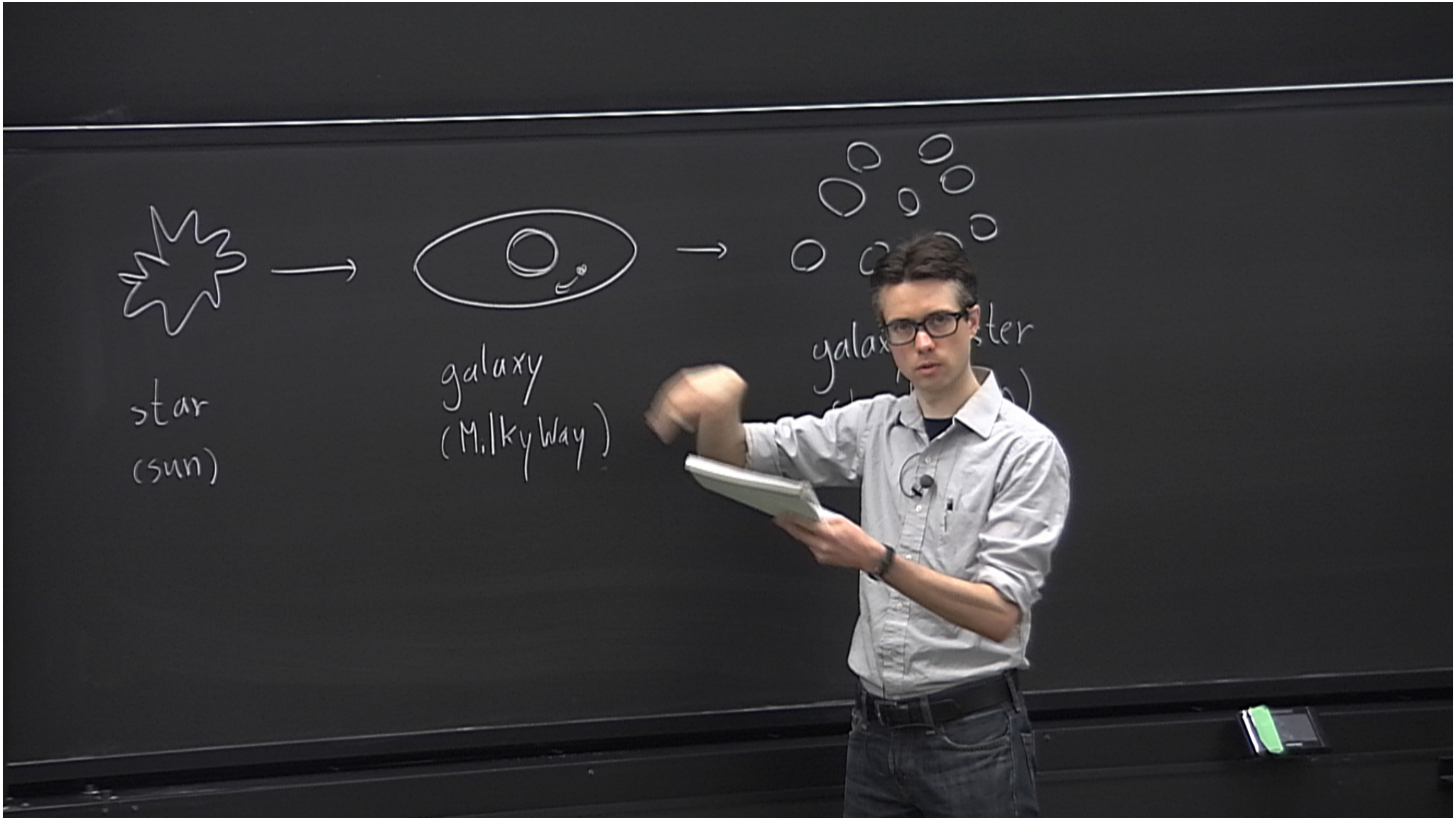
$\sim a(z)$

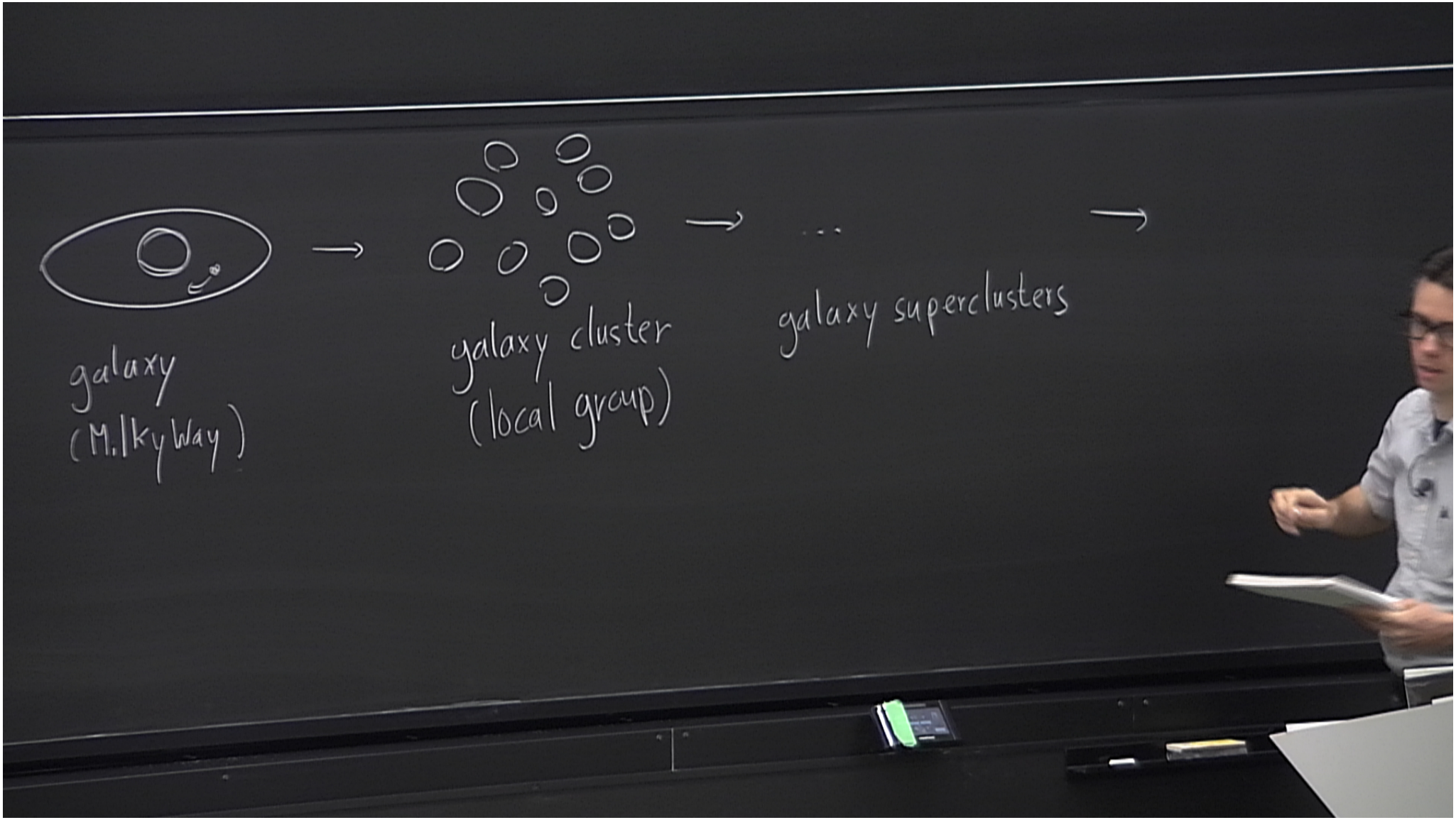
z

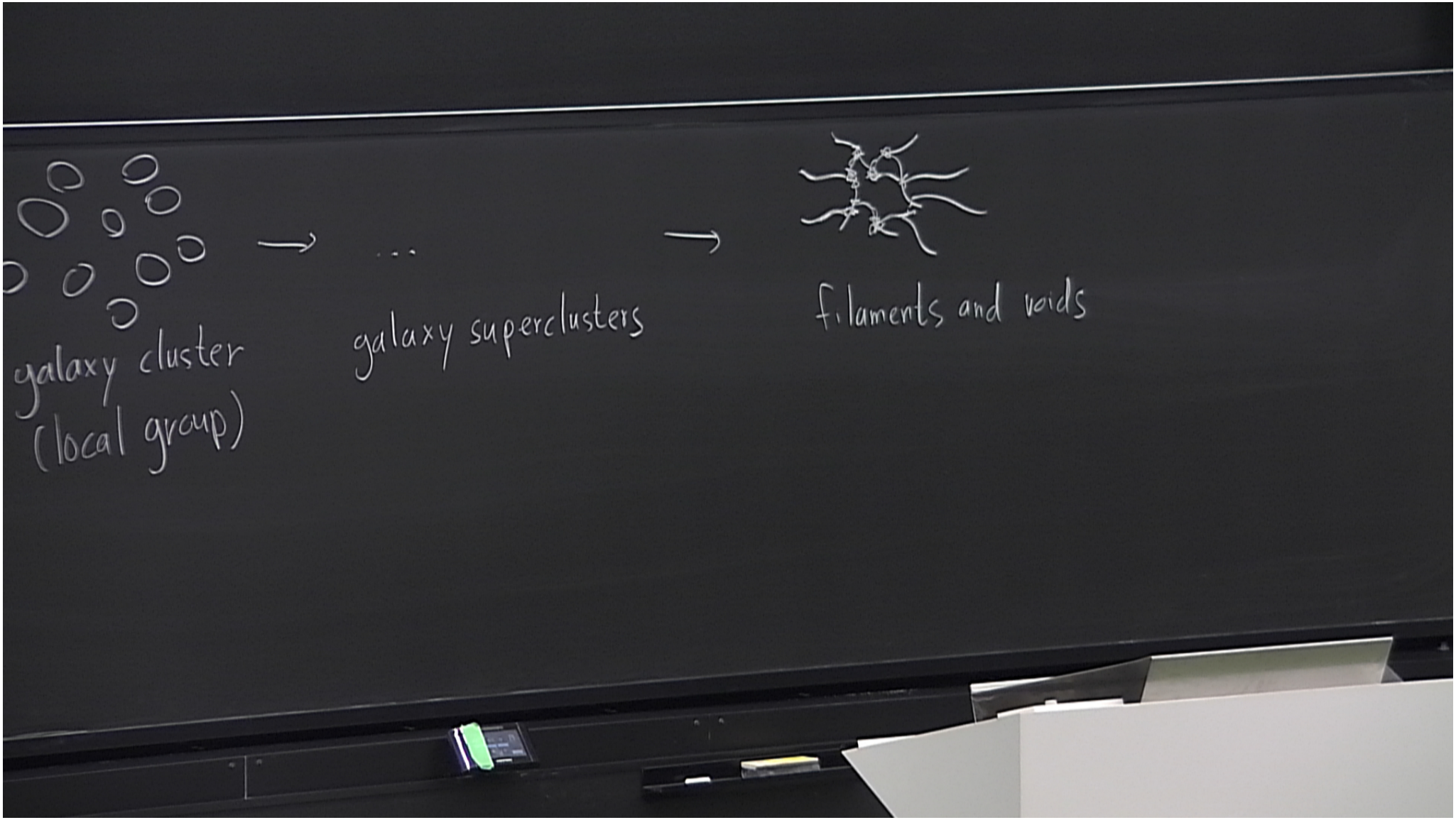

Nucleosynthesis:
p
n
p
n
$^{2}_{1}D \rightarrow {}^{3}_{1}T \rightarrow \cdots {}^{4}_{2}He$, Li, ...

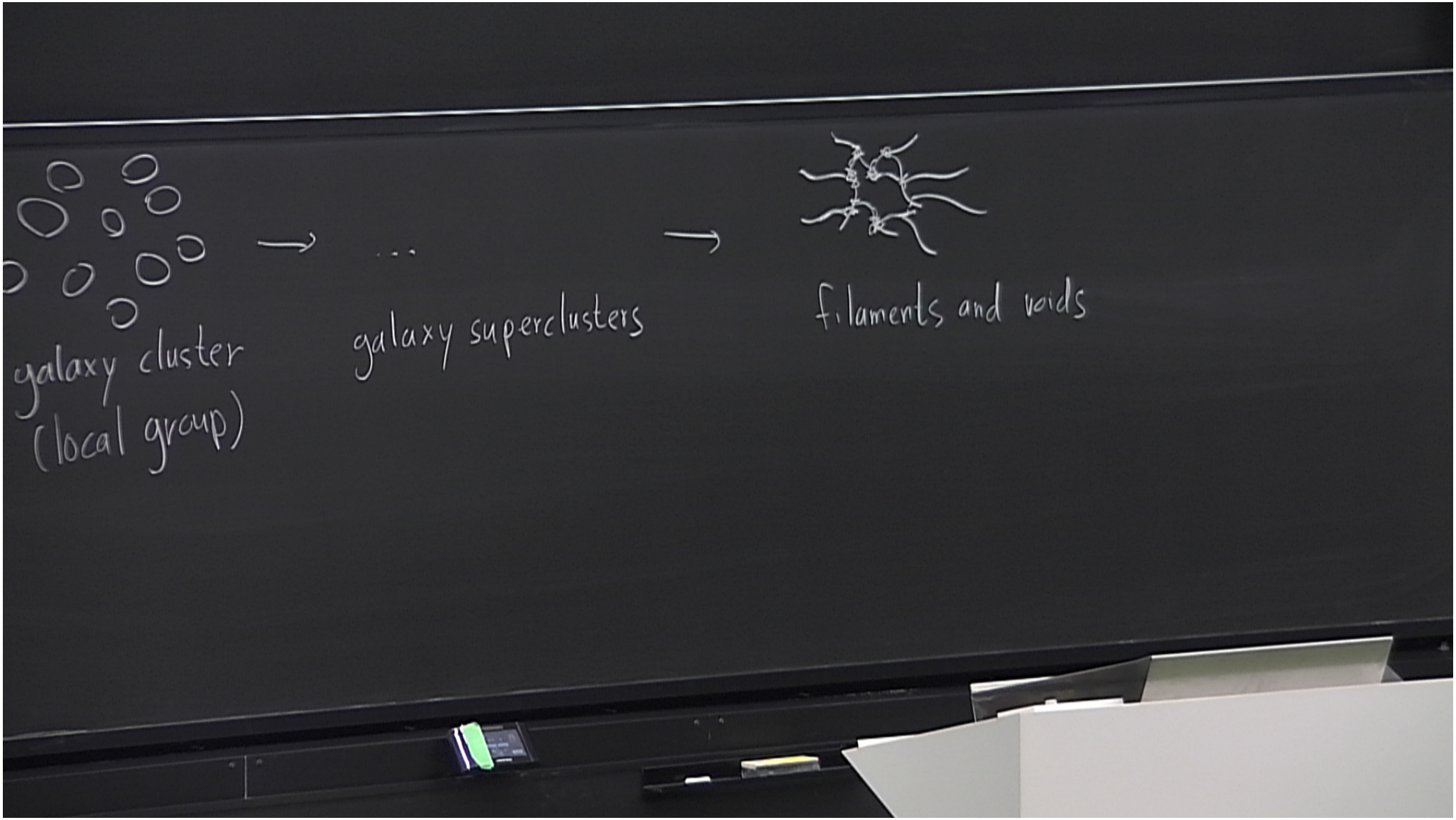

p
n
p
n
$\Omega_b \approx 0.05$
$^{2}_{1}D \rightarrow {}^{3}_{1}T \rightarrow \cdots {}^{4}_{2}He$, Li, ...

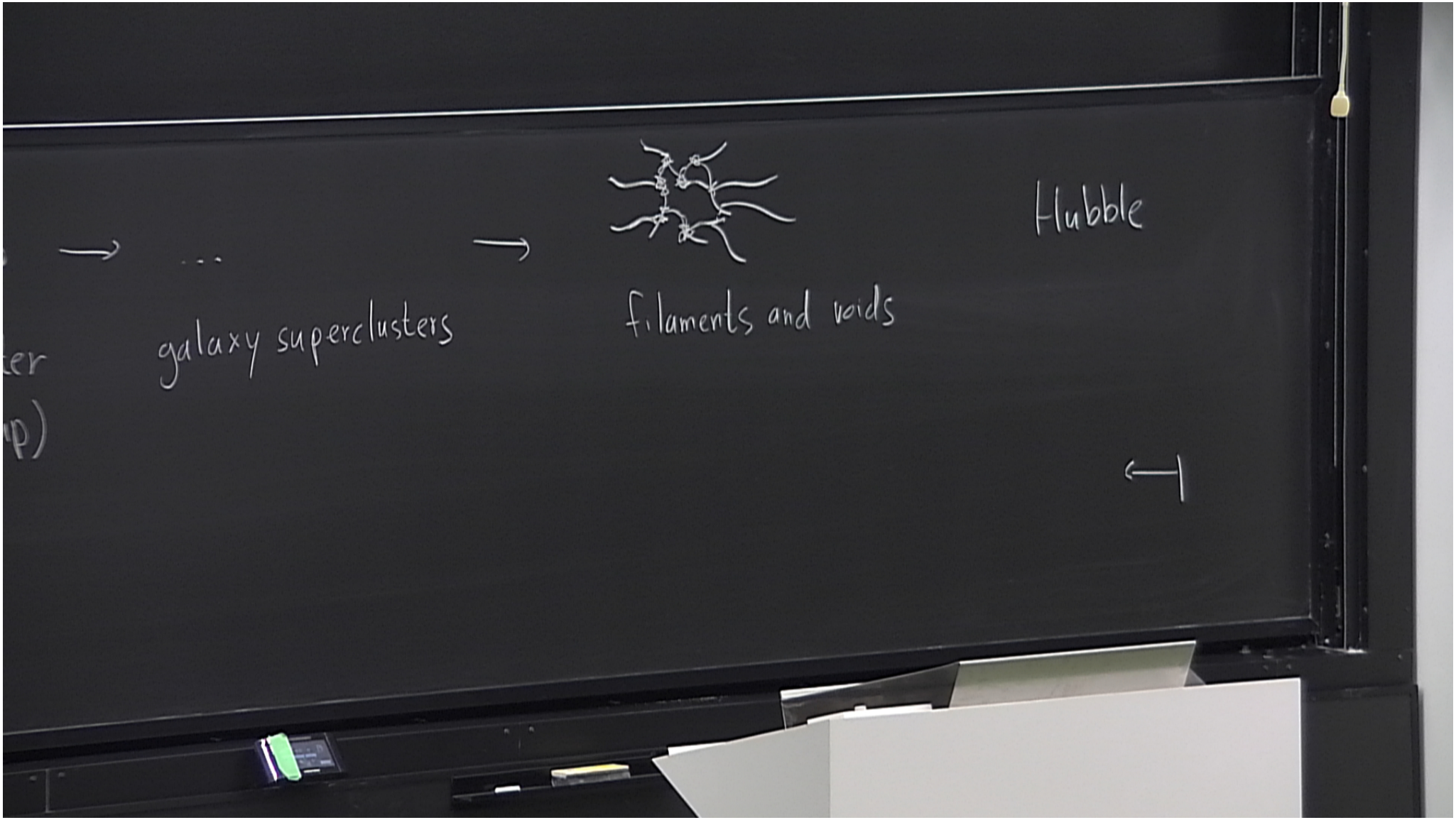

p
n
p
n
$^{2}_{1}D \rightarrow {}^{3}_{1}T \rightarrow \cdots {}^{4}_{2}He$, Li, ...
$\Omega_b \simeq 0.05$

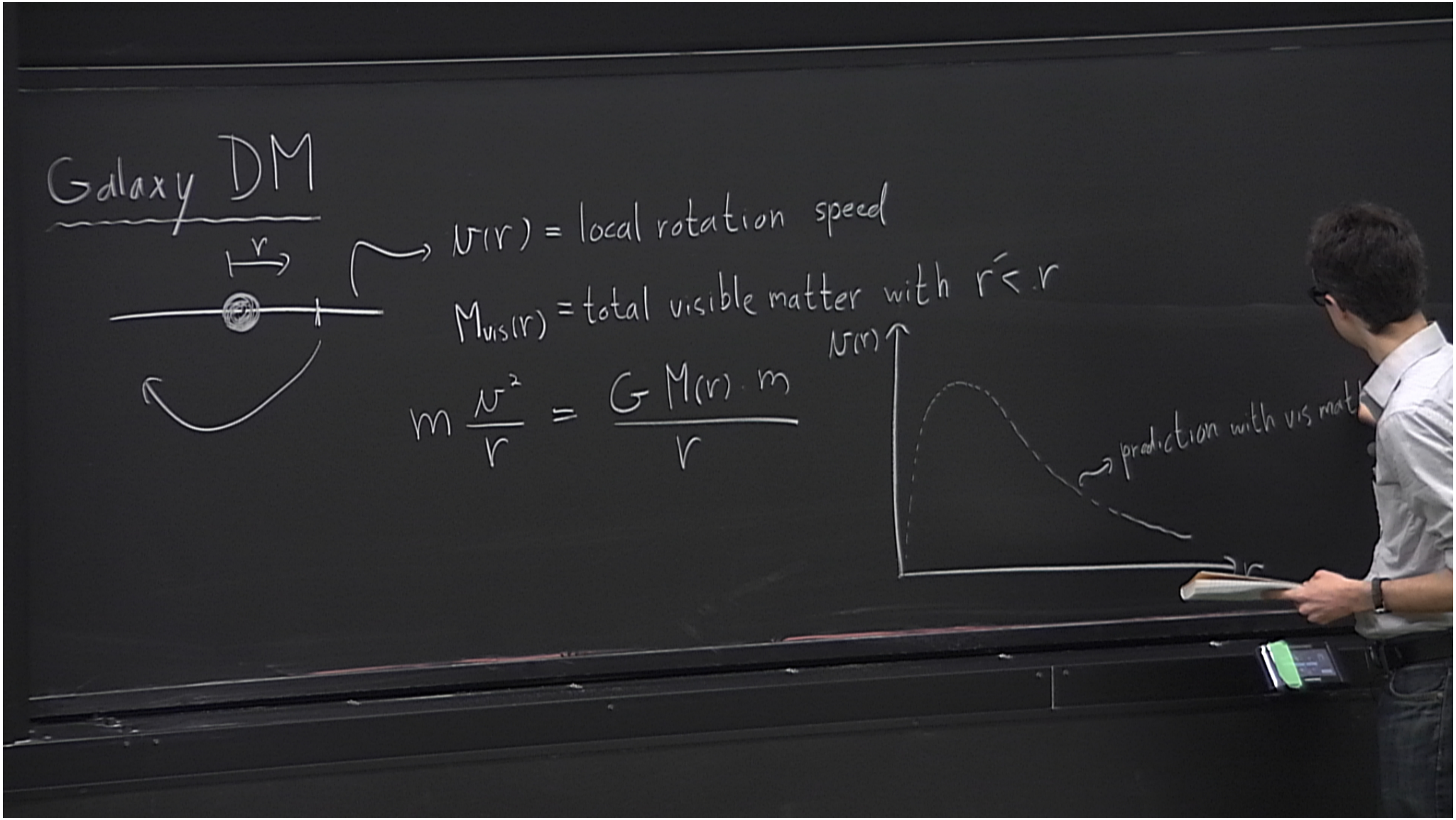

star
(sun)
galaxy
(Milky Way)

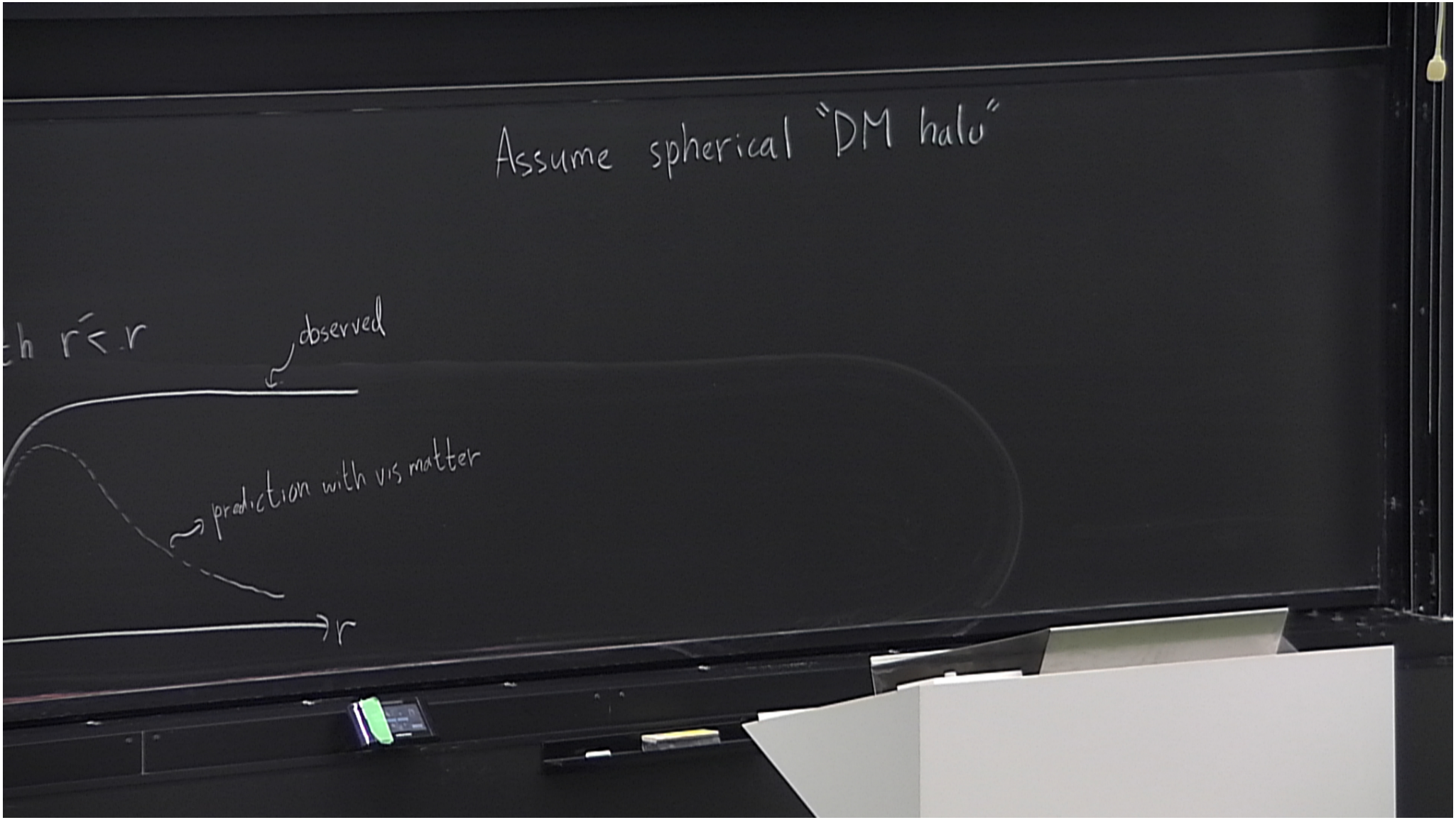

galaxy
(Milky Way)
galaxy cluster
(local group)
galaxy superclusters

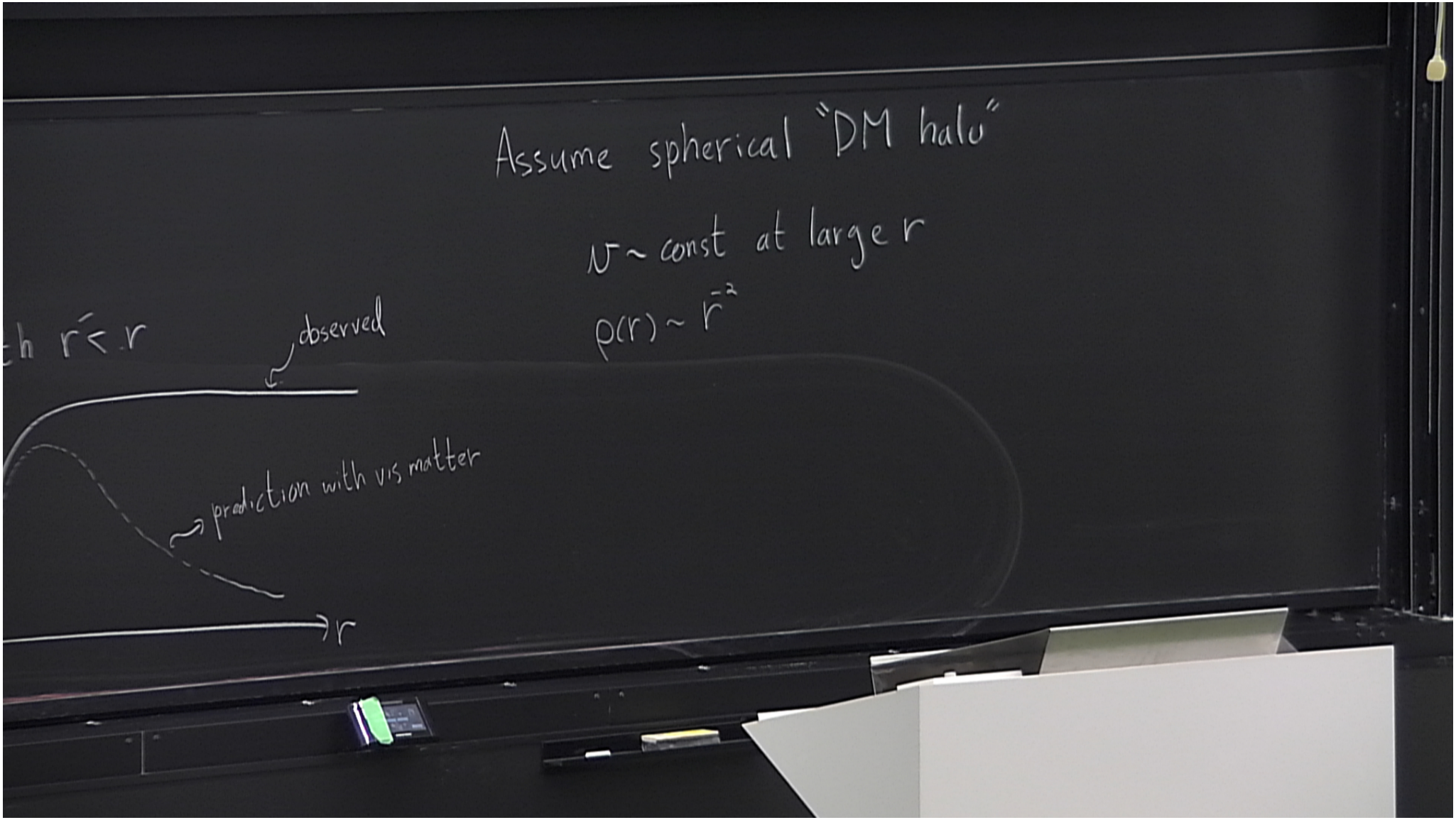

galaxy cluster
(local group)
galaxy superclusters
filaments and voids

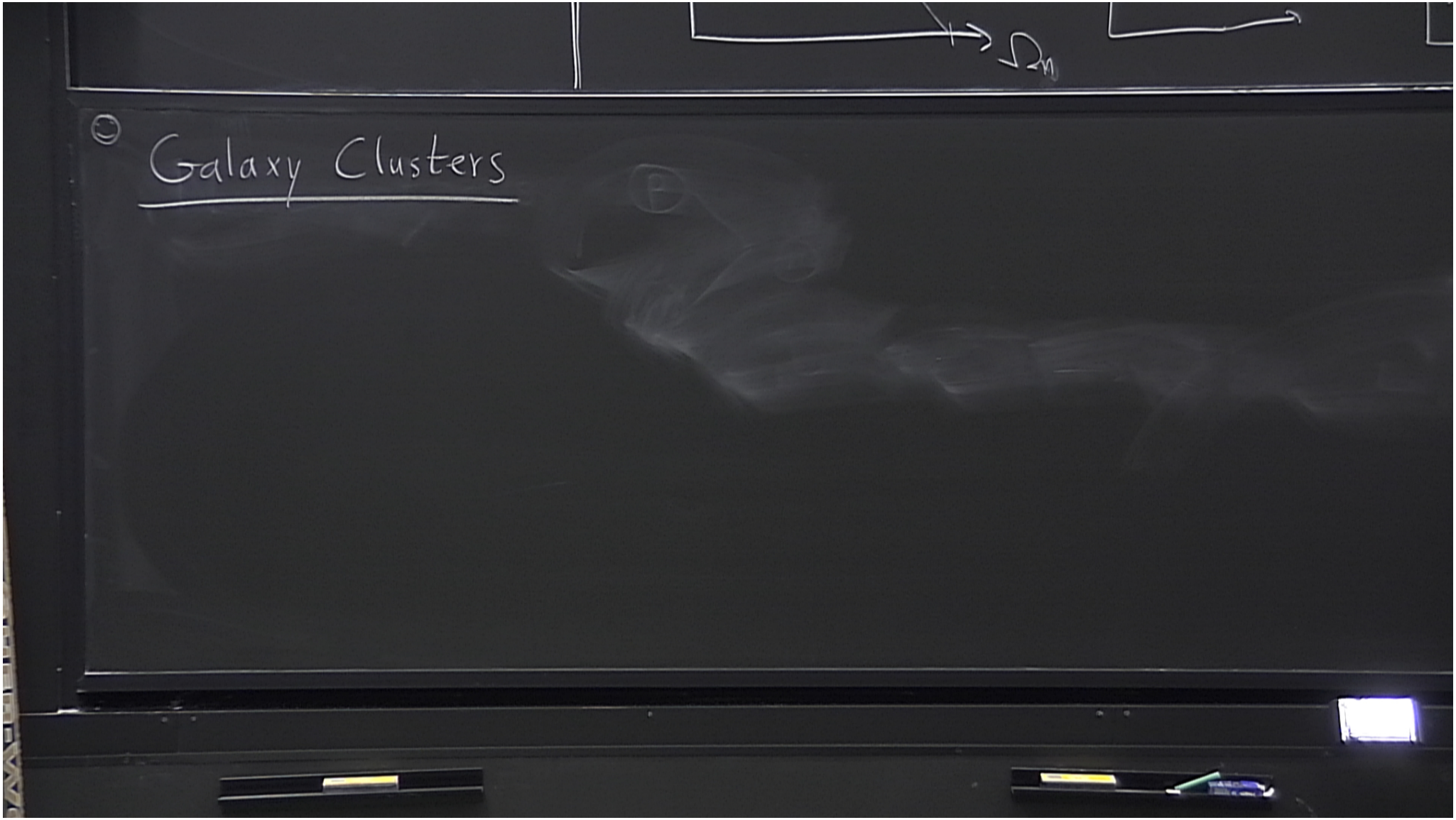

galaxy cluster
(local group)
galaxy superclusters
filaments and voids

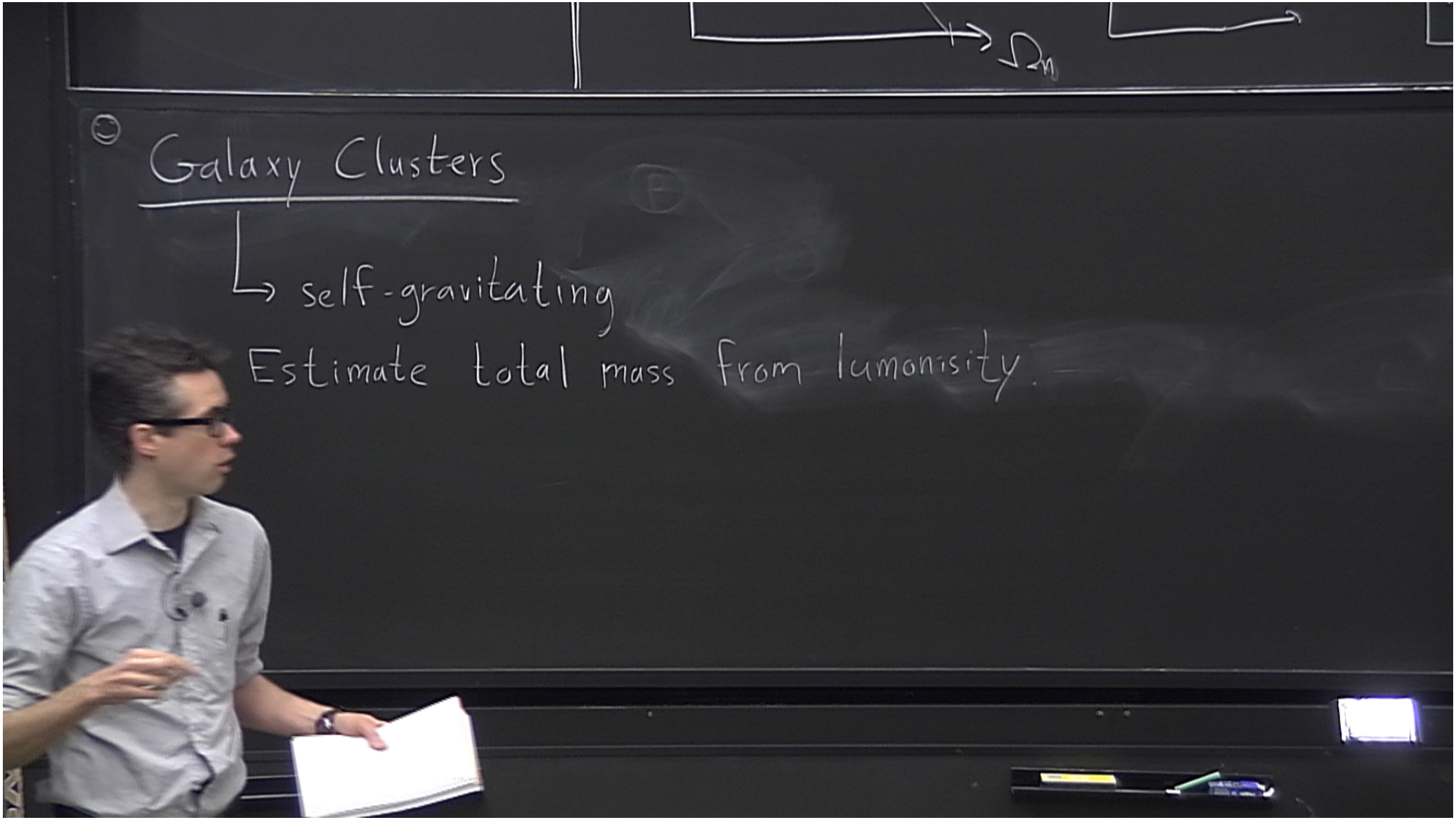

galaxy superclusters
filaments and voids
Hubble

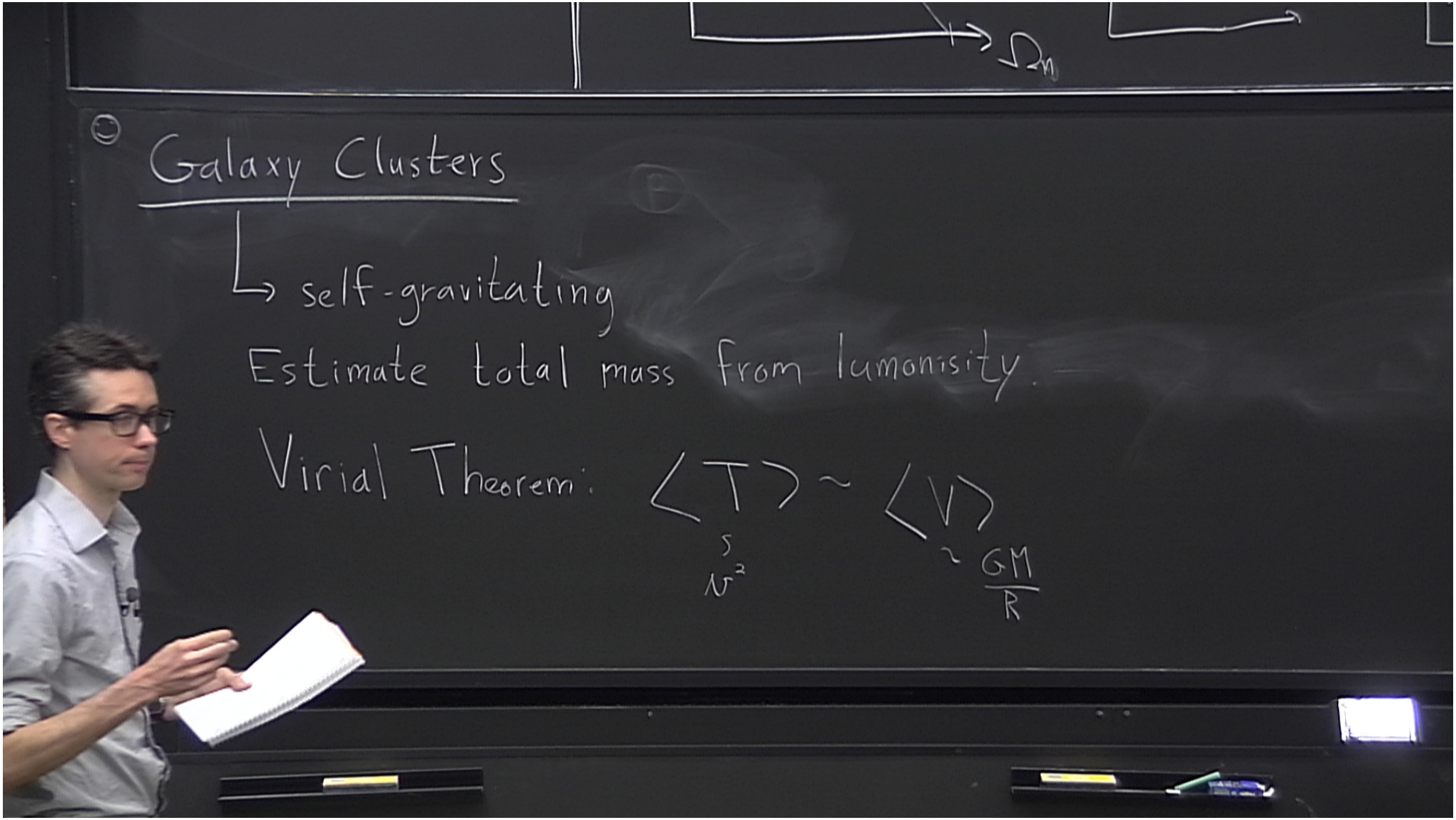

Galaxy DM
r
v(r) = local rotation speed
M_vis(r) = total visible matter with r' < r
m v²/r = G M(r) m / r
v(r)
prediction with vis mat

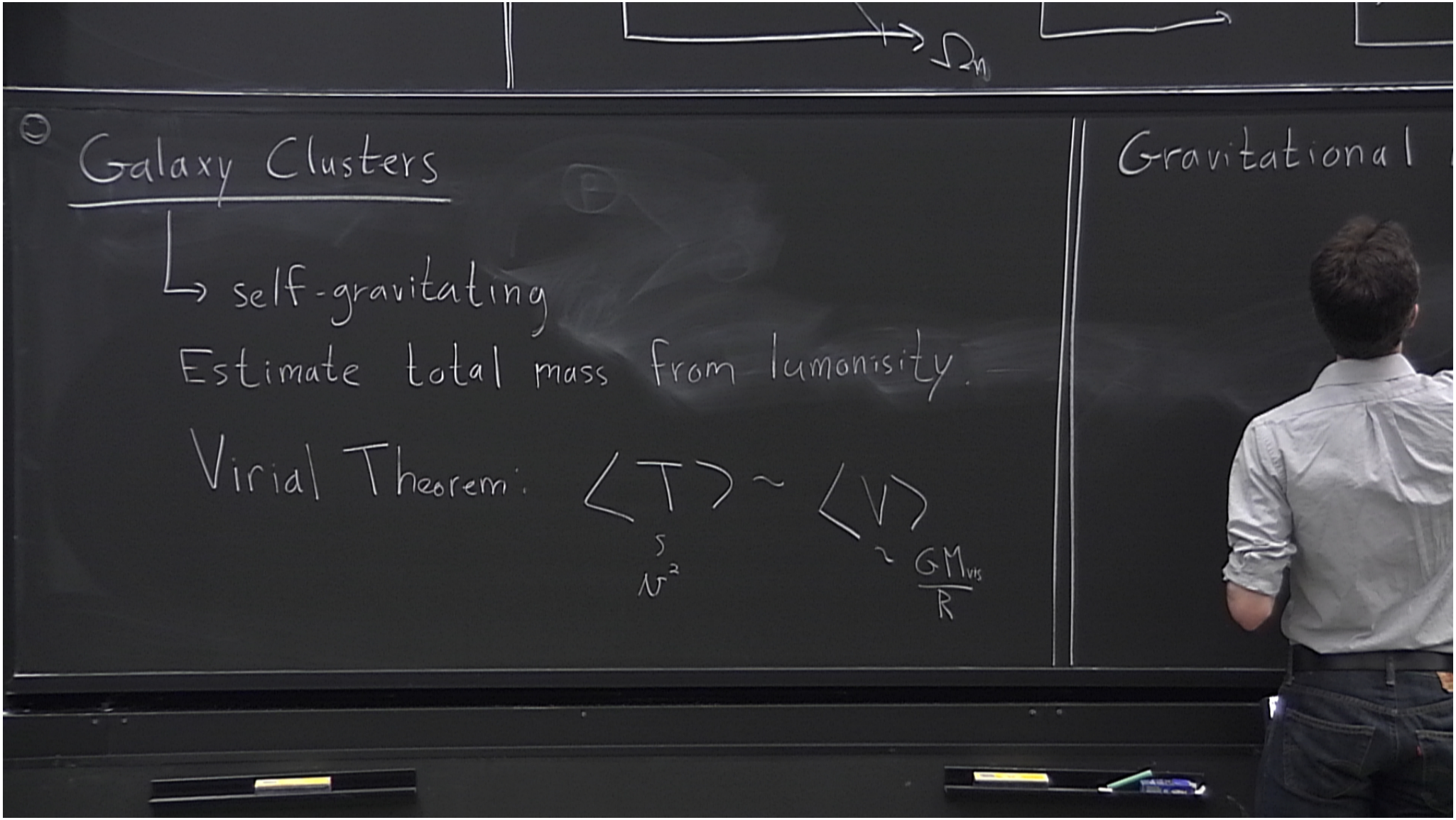

Assume spherical "DM halo"
observed
prediction with vis matter
r

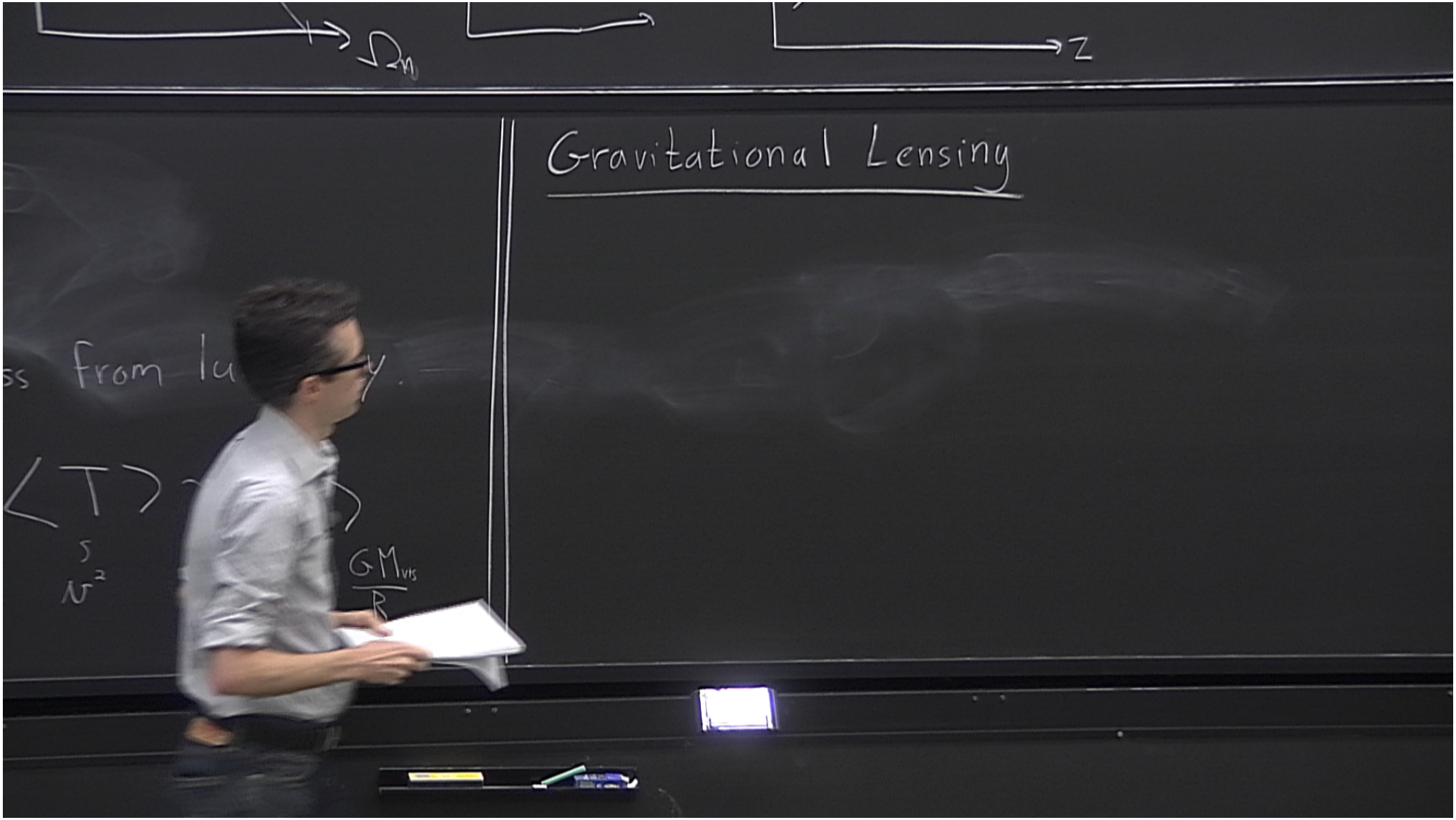

Assume spherical "DM halo"
$v \sim$ const at larger r
$\rho(r) \sim r^{-2}$
th $r' < r$
observed
prediction with vis matter
r

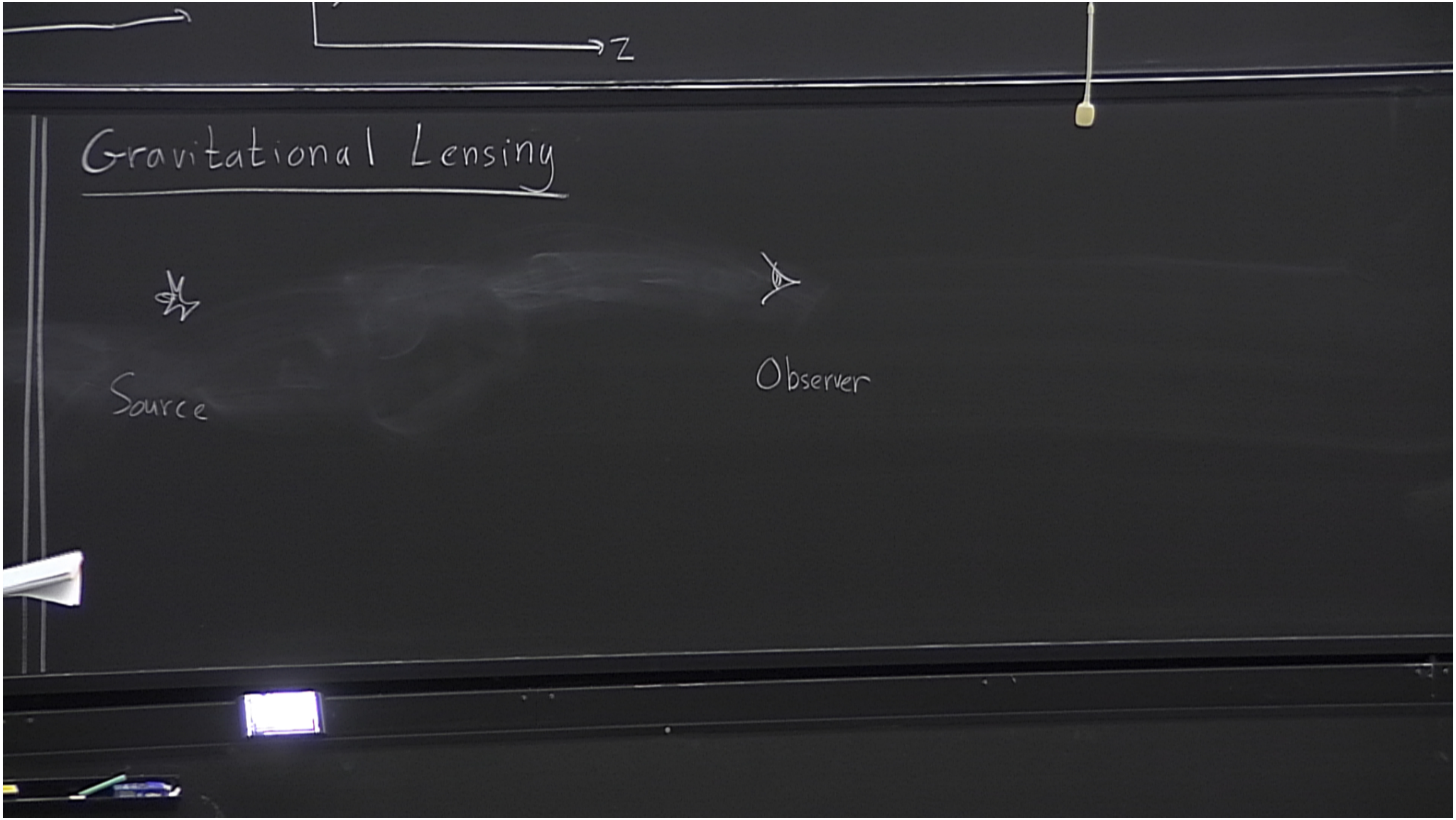

Ω_m
Galaxy Clusters


Ω_m
Galaxy Clusters
self-gravitating
Estimate total mass from luminosity.


Ω_n
Galaxy Clusters
self-gravitating
Estimate total mass from luminosity.
Virial Theorem: $\langle T \rangle \sim \langle V \rangle$
$\sim v^2$
$\sim \frac{GM}{R}$

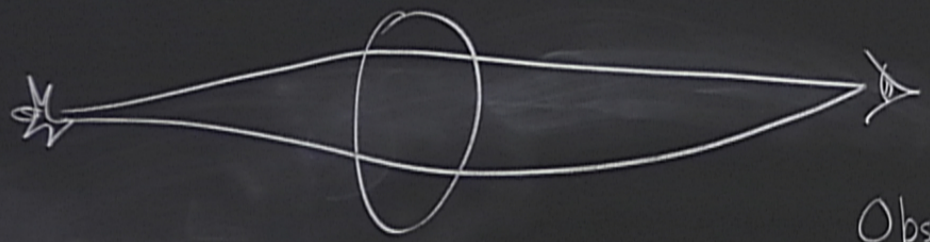

Galaxy Clusters
self-gravitating
Estimate total mass from lumonisity.
Virial Theorem: $\langle T \rangle \sim \langle V \rangle$
$\sim \frac{5}{v^2}$
$\sim \frac{GM_{vis}}{R}$
Gravitational


Gravitational Lensing
from lu
y.
$\langle T \rangle$
$\frac{5}{v^2}$
$\frac{GM_{vis}}{R}$
Ω_m
z


z
Gravitational Lensing
Source
Observer

z

Gravitational Lensing



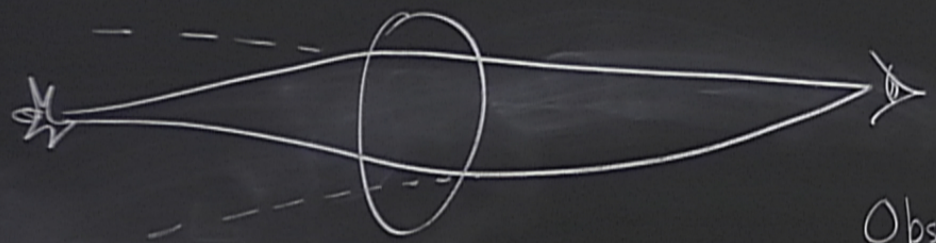
Source

Galaxy Cluster

Observer

→ z

Gravitational Lensing



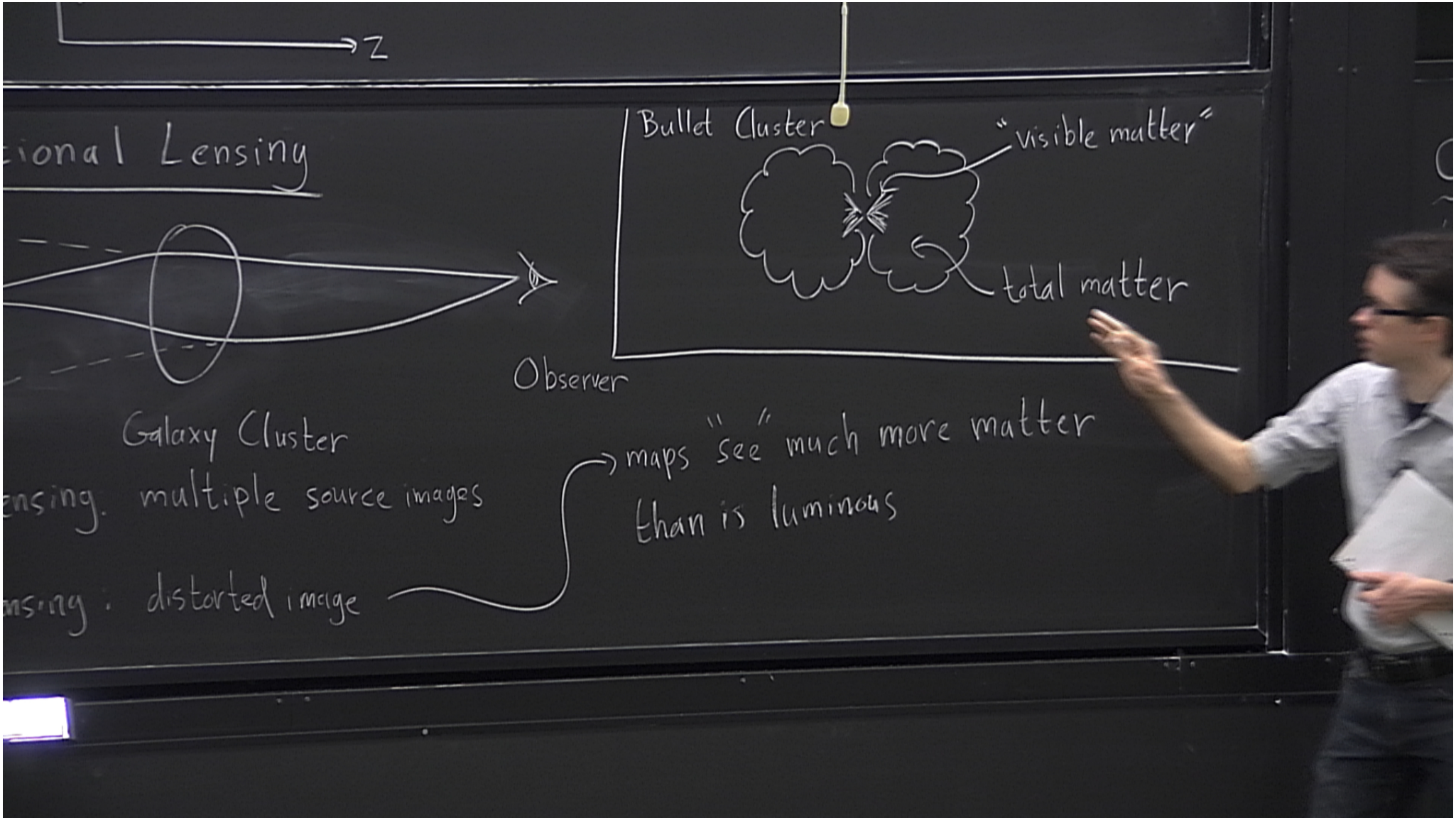
Source

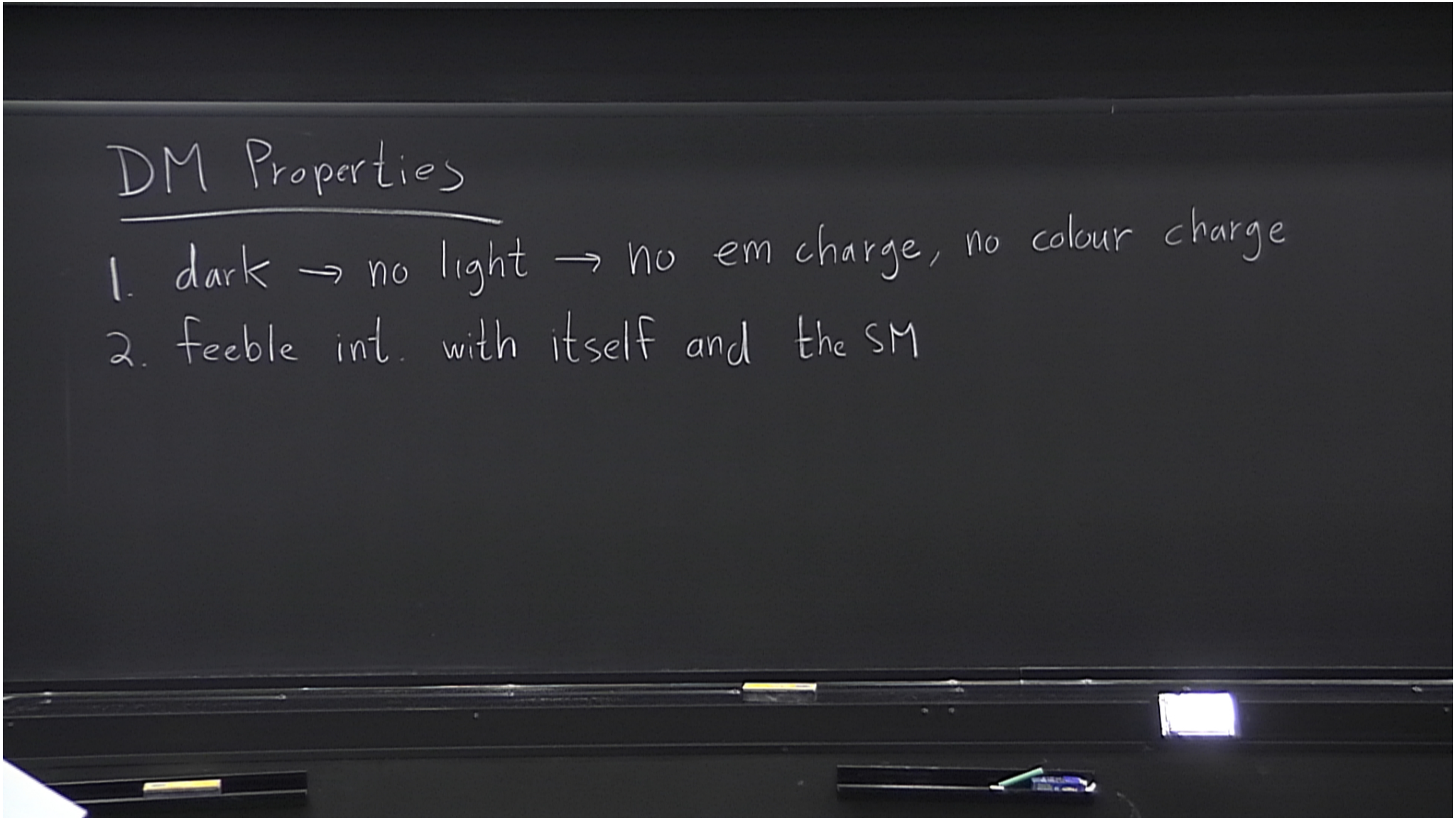
Galaxy Cluster

Observer

Strong Lensing: multiple source images

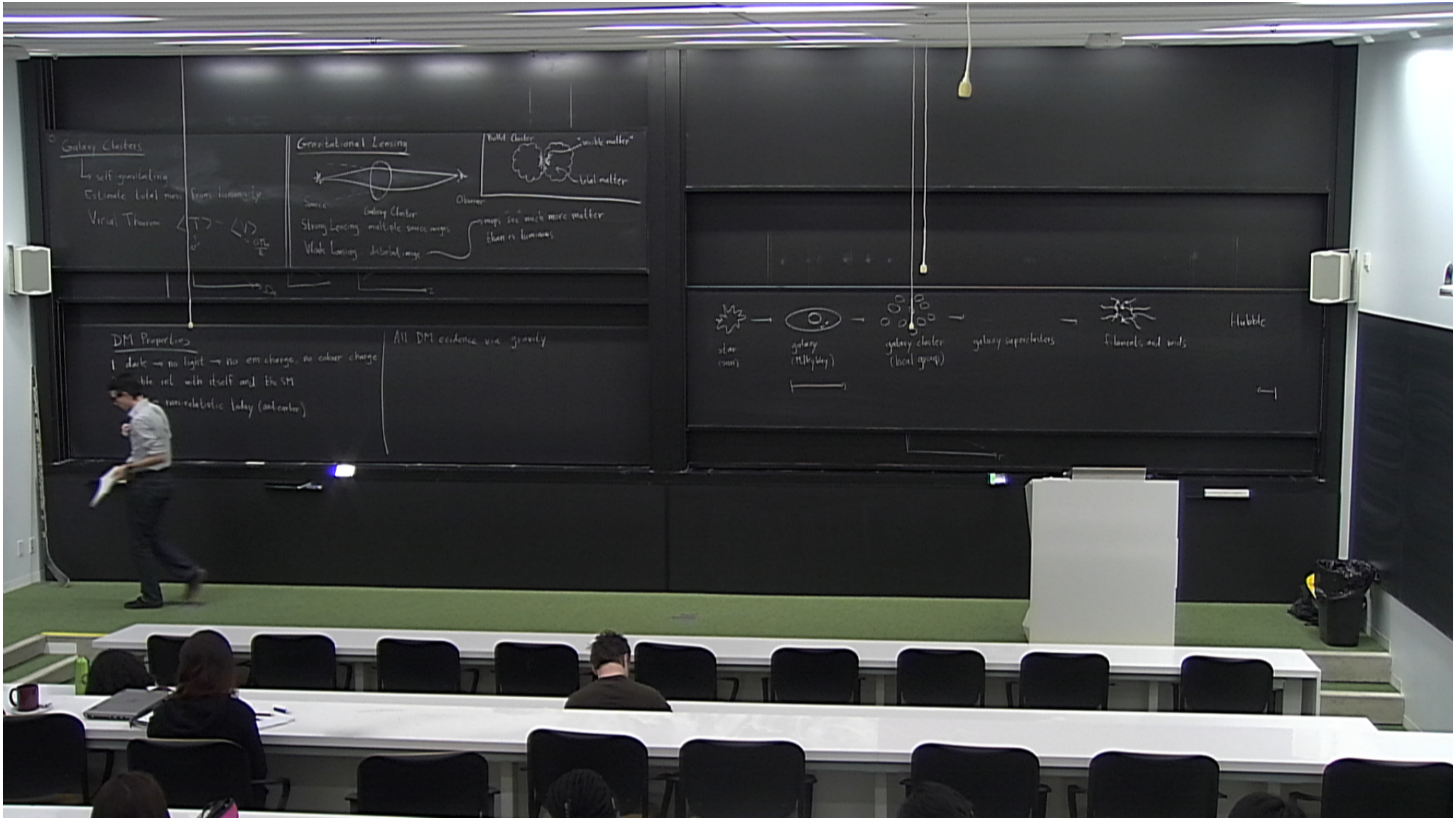
Weak Lensing: distorted image → maps "see" much more matter than is luminous

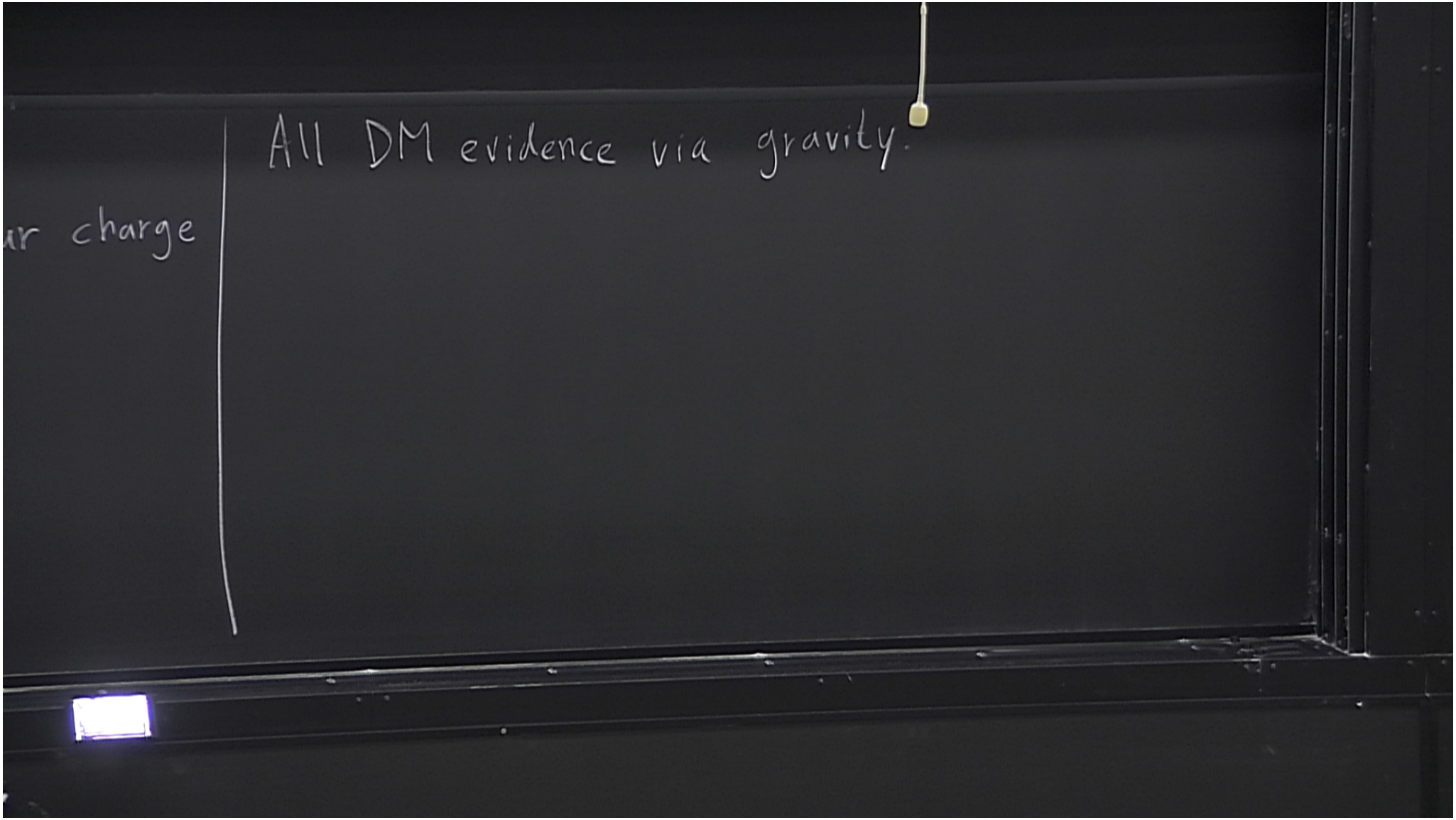

z
ional Lensing
Galaxy Cluster
ensing. multiple source images
nsing. distorted image
Observer
Bullet Cluster
"visible matter"
total matter
maps "see" much more matter
than is luminous

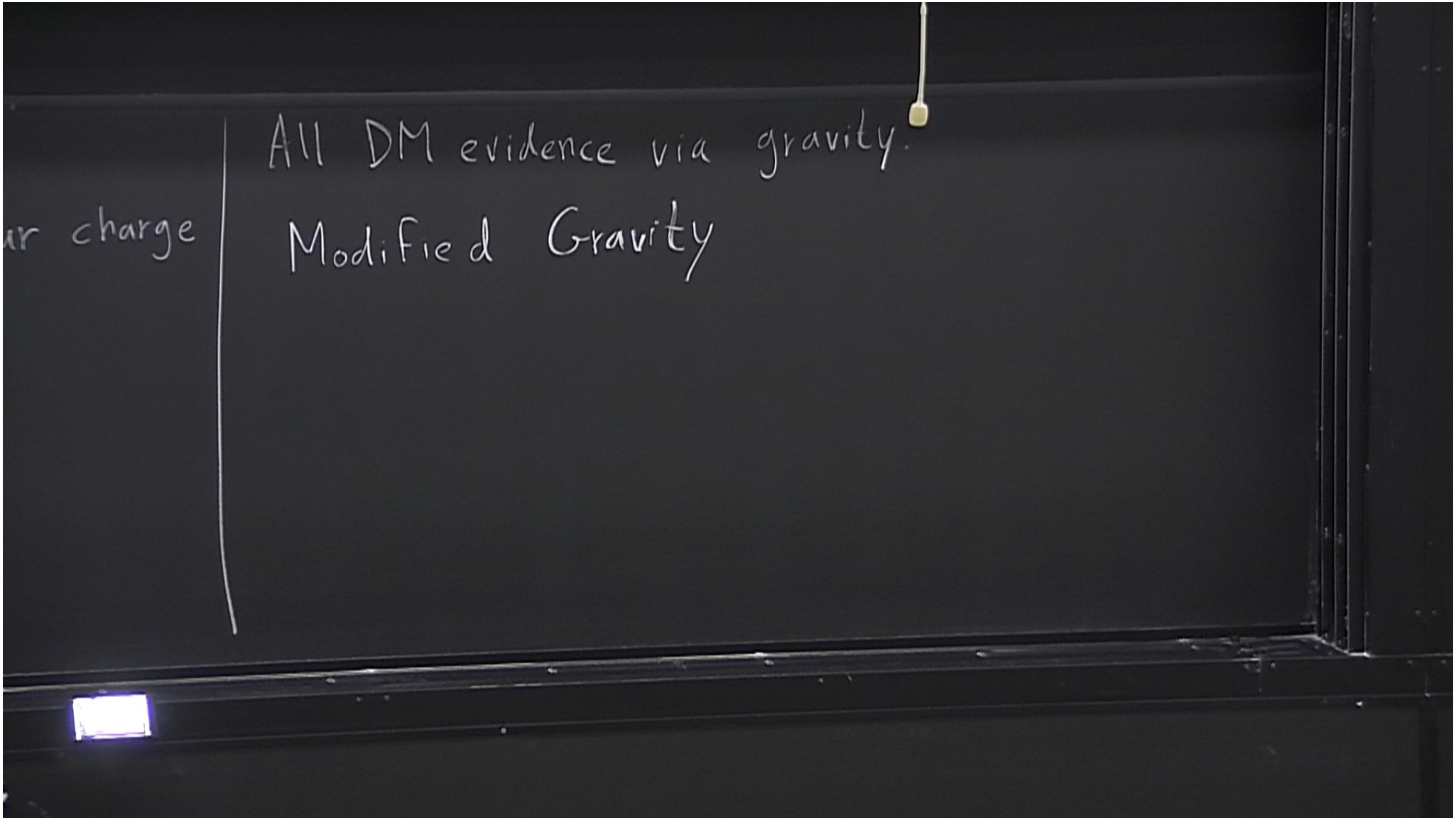

DM Properties
1. dark → no light → no em charge, no colour charge
2. feeble int. with itself and the SM

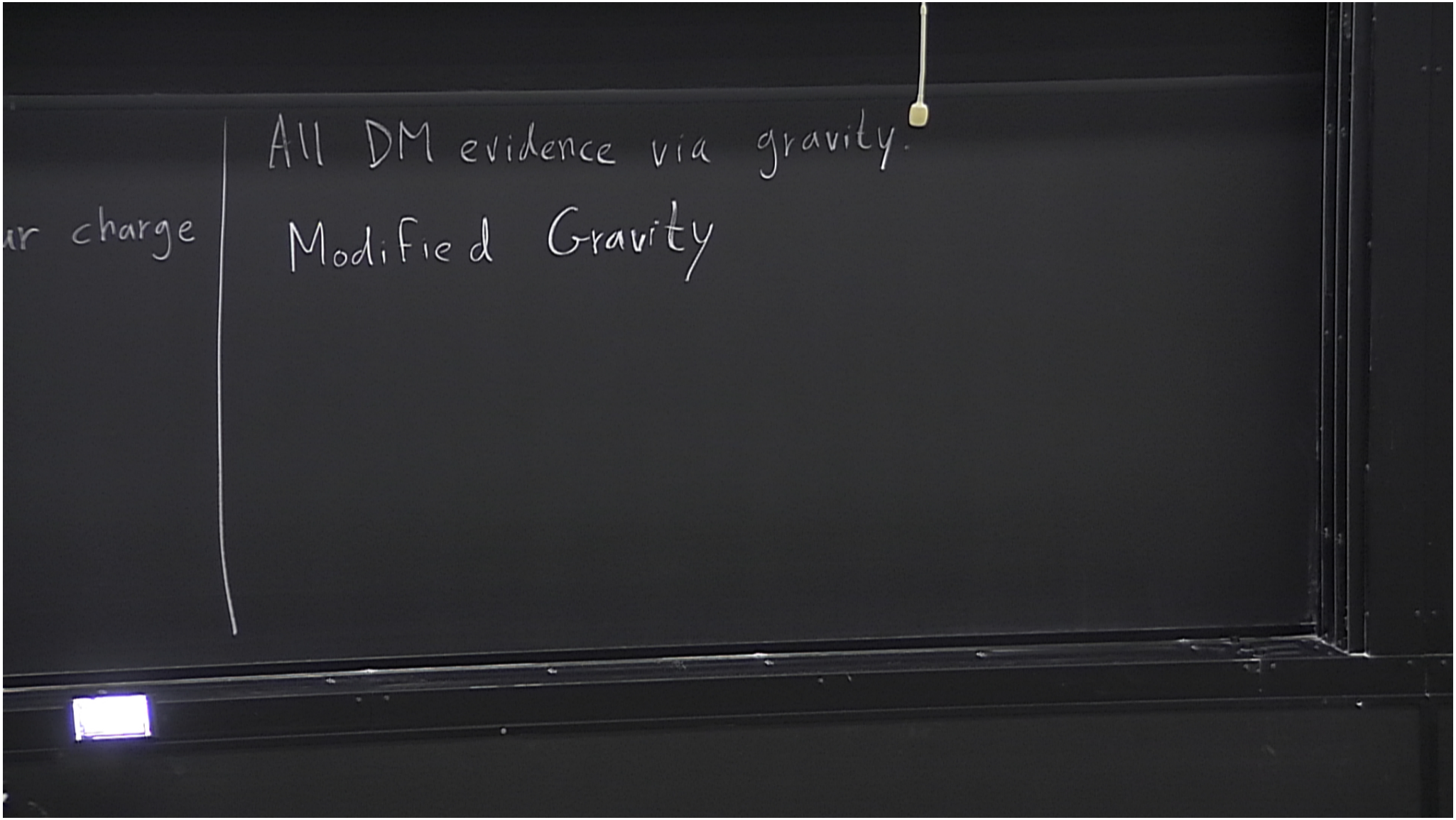
DM Properties

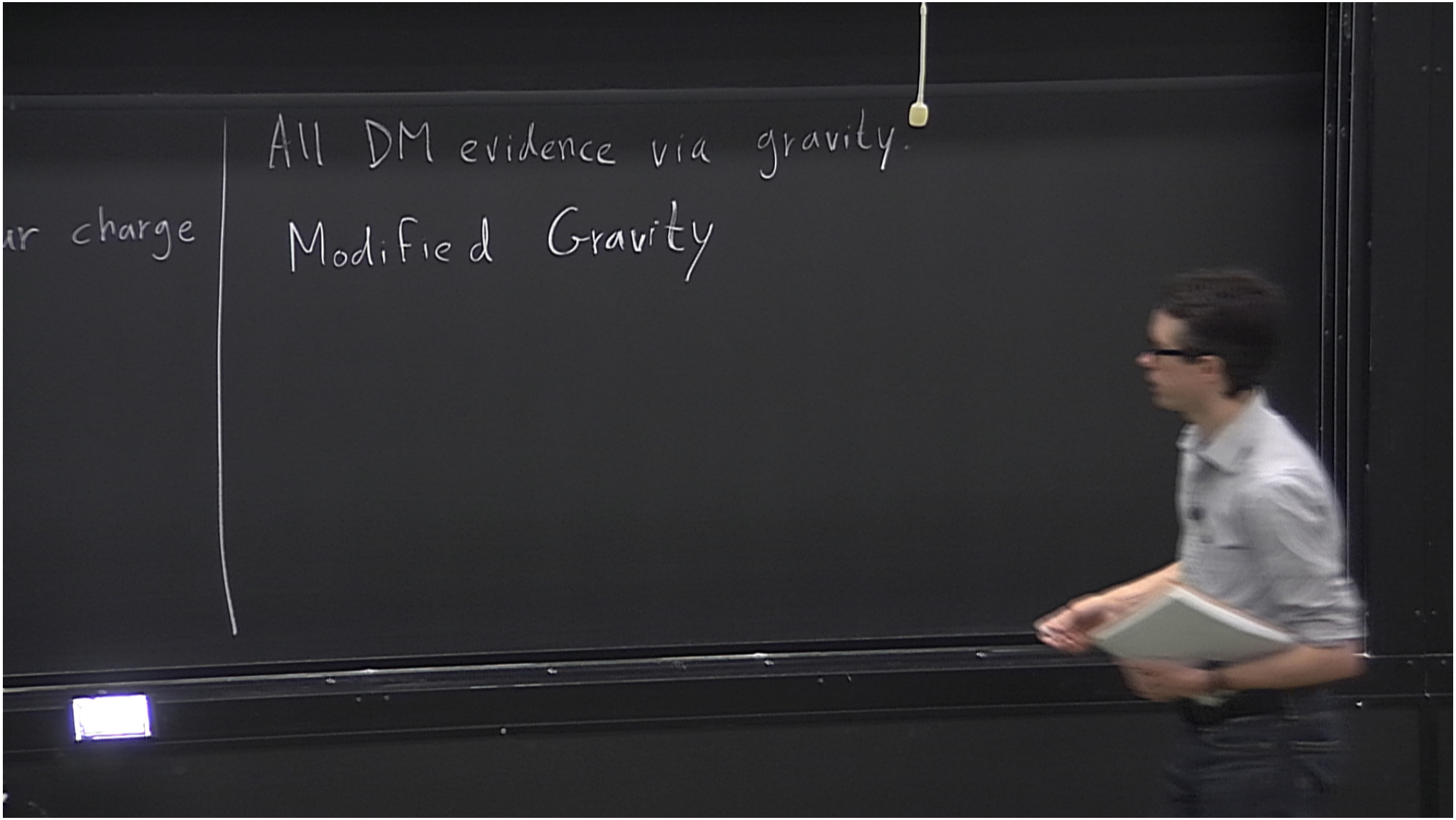
1. dark → no light → no em charge, no colour charge
2. feeble int. with itself and the SM
3. cold → non-relatistic today (and earlier)

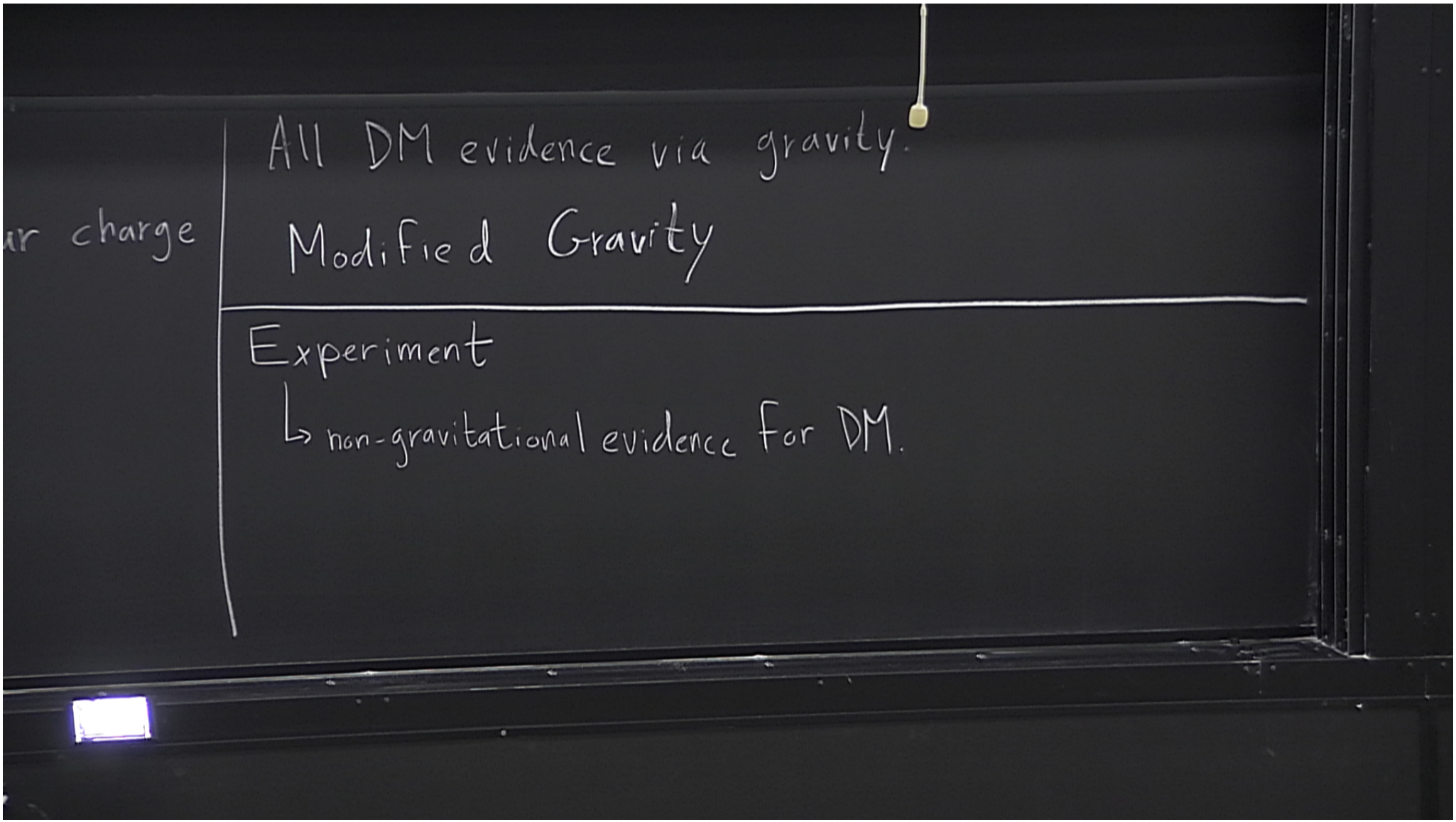

Galaxy Clusters
Gravitational Lensing
Bullet Cluster
"visible matter"
total matter
Source
Galaxy Cluster
Observer
Strong Lensing
Weak Lensing
DM Properties
All DM evidence via gravity
star
galaxy
galaxy cluster
galaxy superclusters
filaments and voids
Hubble

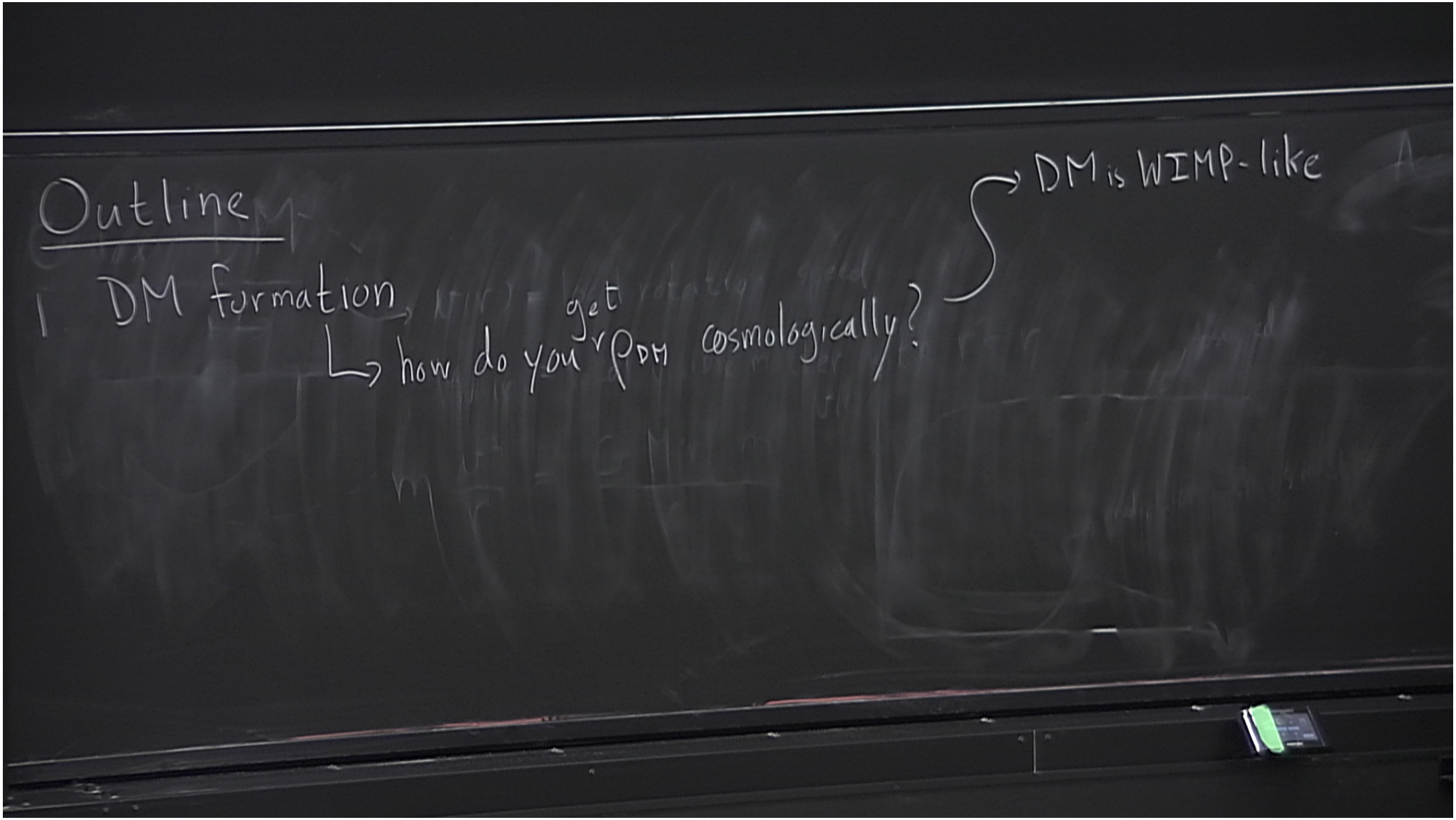

All DM evidence via gravity.
ur charge


ur charge
All DM evidence via gravity.
Modified Gravity


ur charge
All DM evidence via gravity.
Modified Gravity

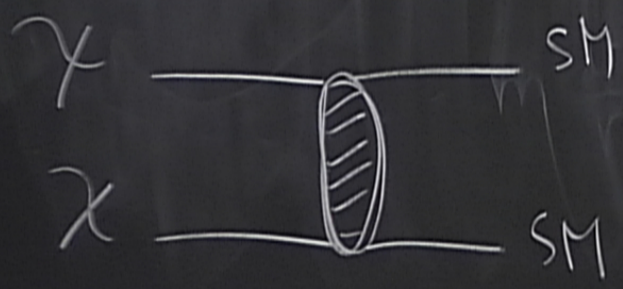

ur charge
All DM evidence via gravity.
Modified Gravity

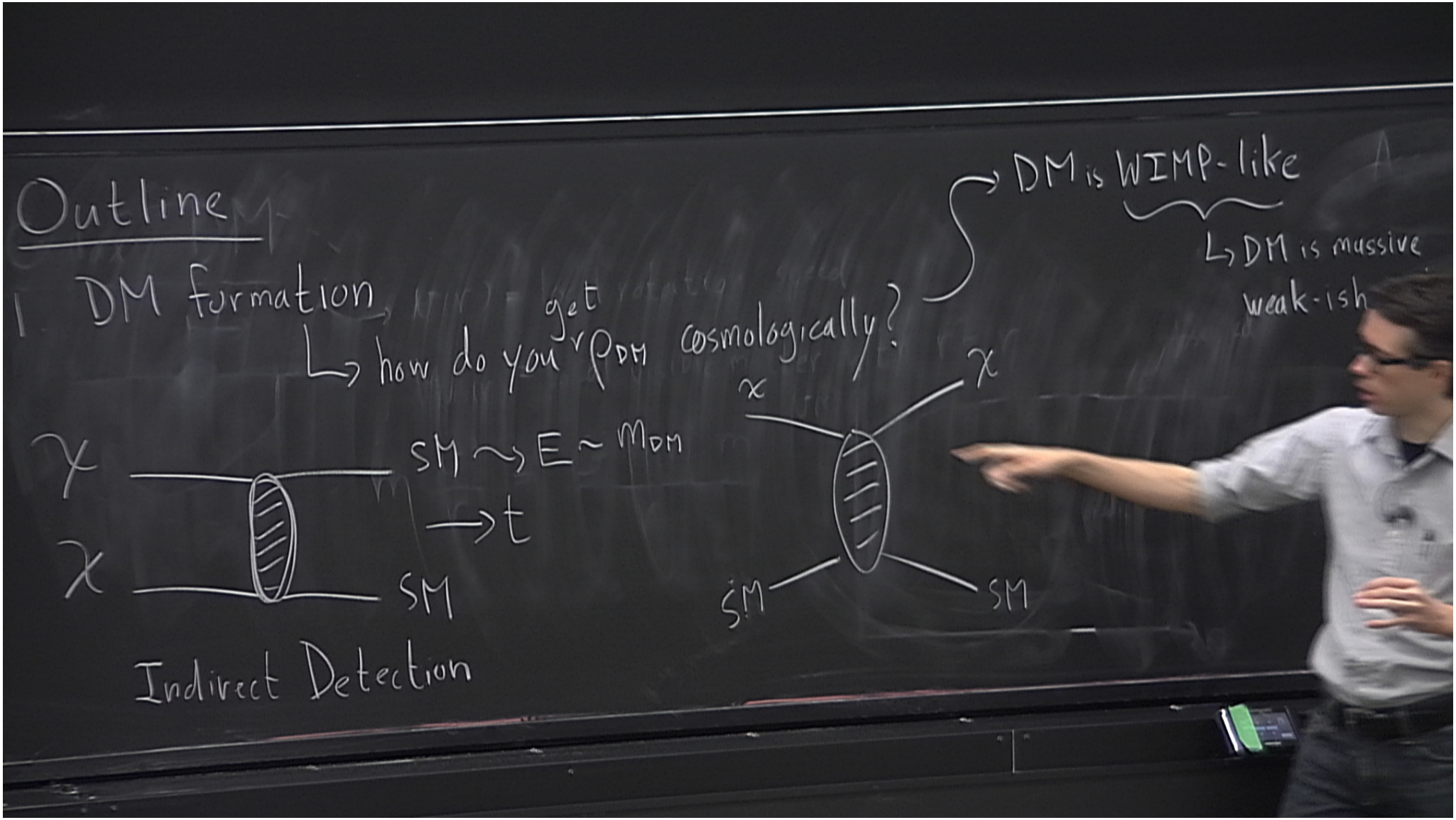

ur charge
All DM evidence via gravity.
Modified Gravity
Experiment
↳ non-gravitational evidence for DM.

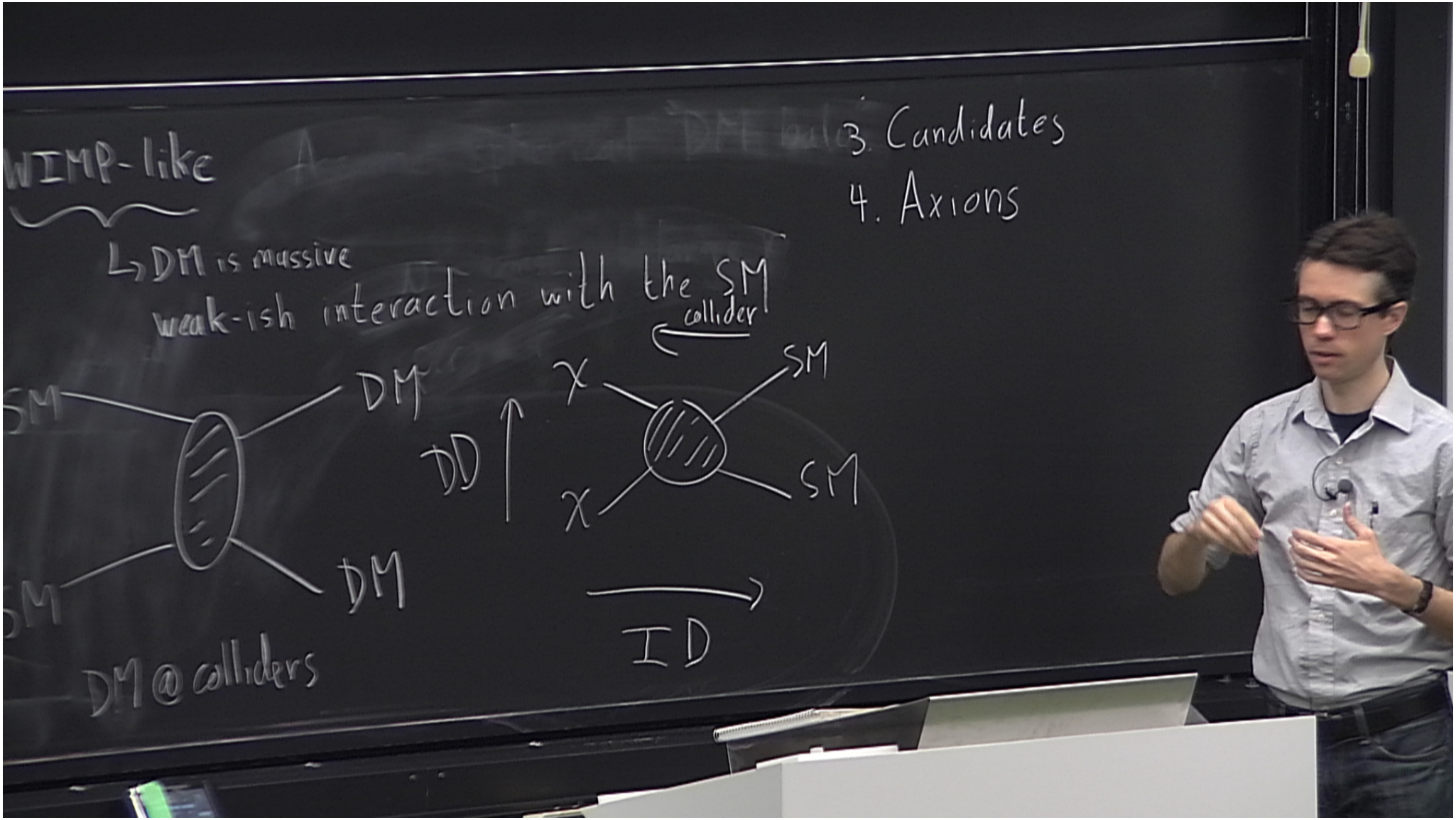

Outline
1. DM formation
how do you get ρ_{DM} cosmologically?
DM is WIMP-like

Outline

1. DM formation
   - ↳ how do you get ρ_{DM} cosmologically?
     - ↳ DM is WIMP-like
       - ↳ DM is massive weak-ish int




Outline
1. DM formation
↳ how do you get ρ_{DM} cosmologically?
↳ DM is WIMP-like
↳ DM is massive
weak-ish
χ
χ
SM ⇝ E ~ m_{DM}
→ t
SM
Indirect Detection
χ
χ
SM
SM


WIMP-like
↳ DM is massive
weak-ish interaction with the SM
3. Candidates
4. Axions
SM
DM
DM
SM
DM @ colliders
collider
DD
χ
χ
SM
SM
ID