Title: 13/14 PSI - Explorations in Particle Theory - Lecture 1

Date: Apr 07, 2014 09:00 AM

URL: http://pirsa.org/14030044

Abstract:

PSI: Explorations in Particle Theory

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office hr 2:30 pm (?)

(I) Introduction to Dark Matter

PSI: Explorations in Particle Theory

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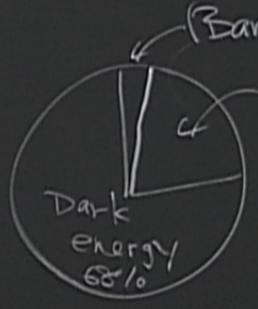
(I) Introduction to Dark Matter



1) What is DM? Can we incorporate it into SM?

2) Why is there more baryonic matter than antibaryons?

We focus on cosmology b/c:

1) Known new physics
2) Many current + upcoming experiments
3) Particle physics + cosmology = successful!
4) Good chance to learn a lot about particle physics

Outline of Course

Week I: Early universe & thermal (WIMP) dark matter

Week II: Detection of WIMP DM, non-thermal DM

Week III: Baryogenesis & asymmetric DM

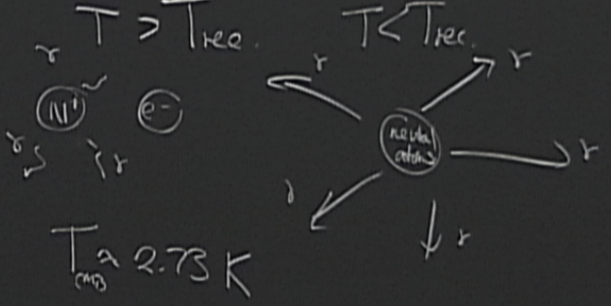
Today

1. Evidence for DM
   - cosmology
   - galaxies & galaxy cluster
2. DM hypothesis
3. Challenges for DM

1. Evidence for DM

- cosmology

cosmic microwave bkd

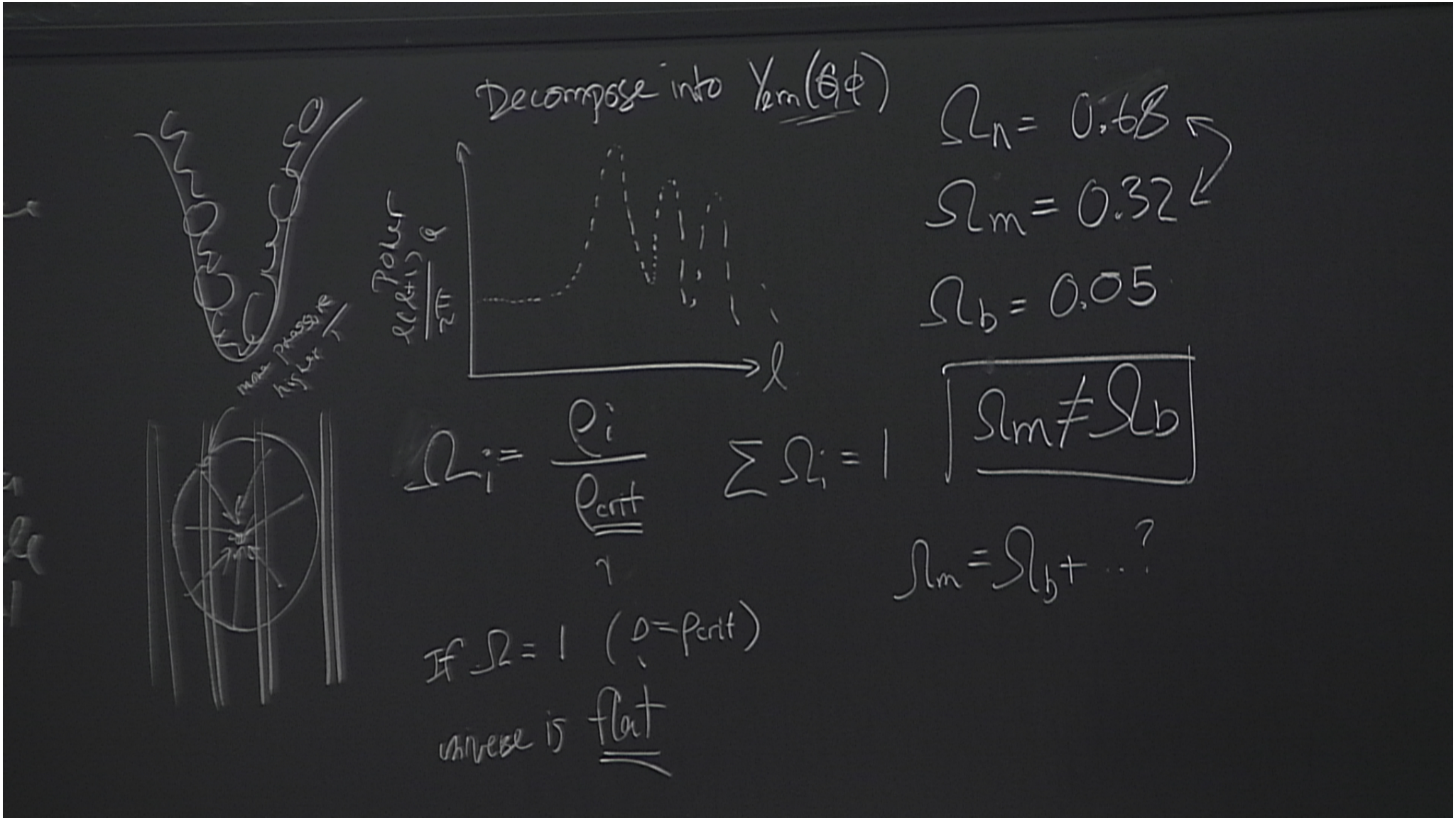


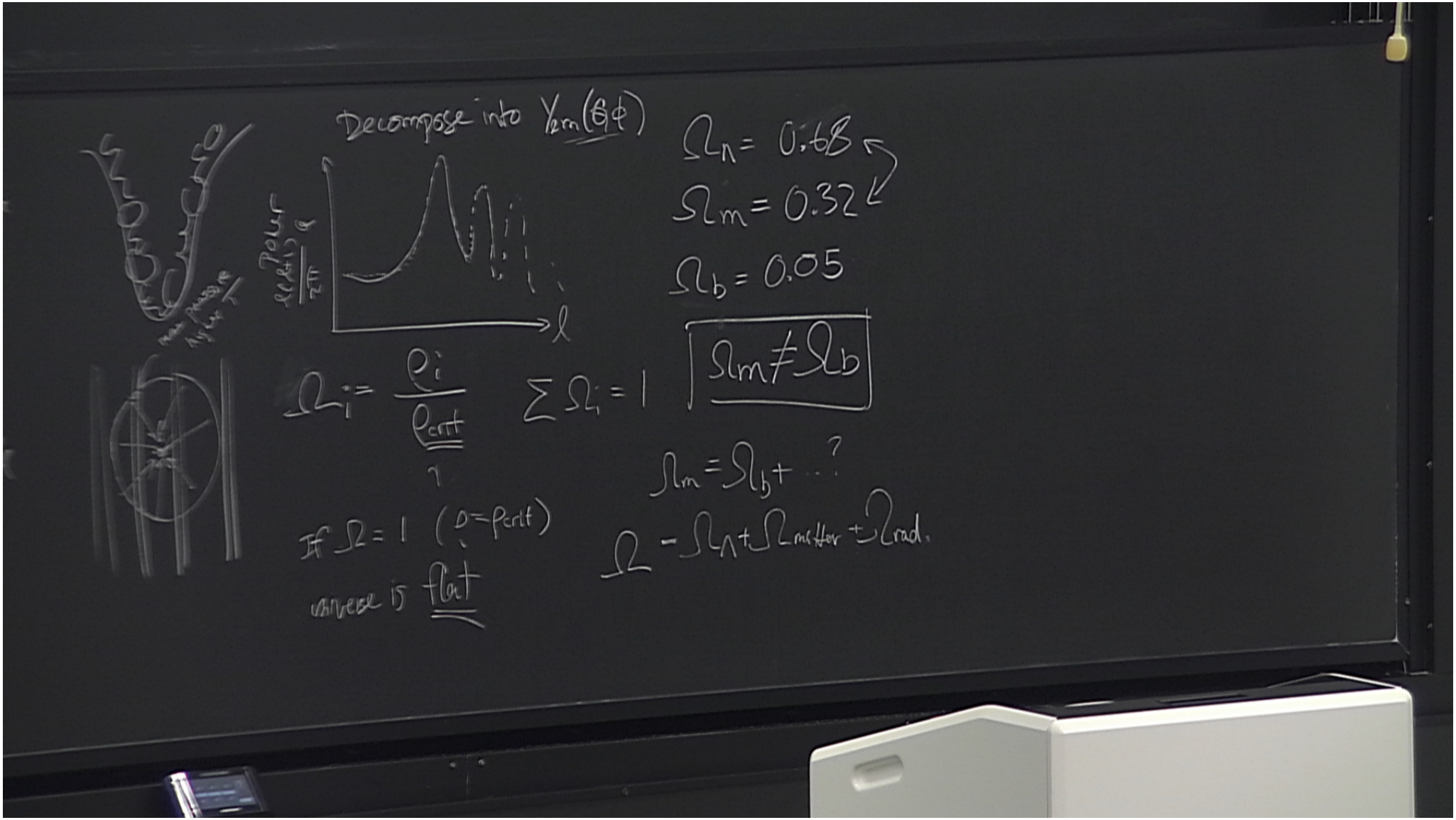
we (B) (B)

→ acoustic wave propagation

Suppose we have a decoupled particle

potential well


Decompose into $Y_{lm}(\theta\phi)$
$\Omega_\Lambda = 0.68$
$\Omega_m = 0.32$
$\Omega_b = 0.05$
Power
l
$\Omega_i = \frac{\rho_i}{\rho_{crit}}$
$\sum \Omega_i = 1$
$\Omega_m \neq \Omega_b$
$\Omega_m = \Omega_b + \ldots ?$
If $\Omega = 1$ ($\rho = \rho_{crit}$)
universe is flat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$\Omega_m = \Omega_b + \ldots$?
If $\Omega = 1$ ($\rho = \rho_{crit}$)
universe is flat
$\Omega = \Omega_\Lambda + \Omega_{matter} + \Omega_{rad.}$

- galaxies & galaxy clusters
  - ↳ first discovered DM
  - "see" DM!
  - spiral galaxies → rotating

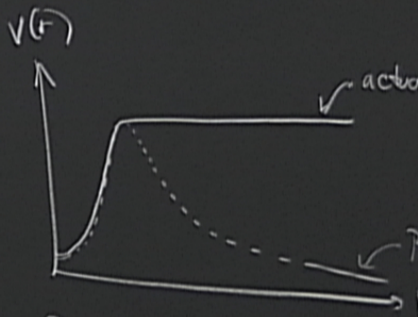
straight on

Light from galaxy is Doppler shifted
↳ V(r)

Doppler shift → $\frac{v^2}{r} = \frac{GM(r)}{r^2}$ ← mass enclosed at radius r → also

↓

estimate by looking at stars, gas, etc



Possible concl:
- gravity is wrong
- new, invisible matter → extend far beyond VS matter

$v^2 = \frac{GM(r)}{r}$

flat → $M(r) \sim r$

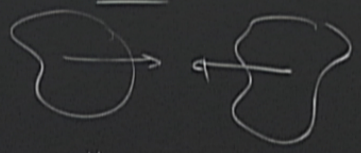
$M(r) = \int \rho(r) d^3r \Rightarrow \rho \sim r^{-2}$

→ also see DM on local scales

- zoom out & look at galaxy clusters

Bullet cluster : see separation b/w dark & vis. matter

Initial



After

How can we study matter?

→ 1) X-ray, other signals of vis.

→ 2) Gravitational lensing "total matter"

↳ DM

→ DM can't interact too much

$\frac{GM(r)}{r}$

$\rightarrow M(r) \sim r$

$= \int \rho(r) d^3r \Rightarrow \rho \sim r^{-2}$

tars. gas.

te

Today

① Evidence for DM
- cosmology
- galaxies & galaxy clusters

② DM hypothesis

③ Challenges for DM

② Dark Matter Hypothesis

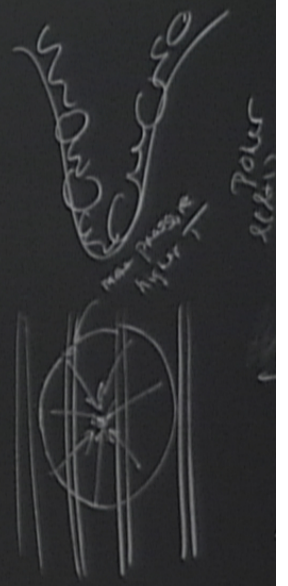
At least one NEW kind of particle:

→ we're only seen DM via gravity

a) non-luminous → can't interact w/ $U(1)_{EM}$ or $SU(3)_c$

$\pi^0 \not\to \gamma\gamma$

b) ≤ feebly interacting w/ itself & visible particles



(2) Dark Matter Hypothesis

At least one NEW kind of particle:

→ we're only seen DM via gravity

a) non-luminous → can't interact $\bar{\chi}$ $U(1)_{EM}$ or $SU(3)_c$

$\pi^0 \to \gamma\gamma$

b) ≤ feebly interacting $\bar{\chi}$ itself & visible particles

c) long-lived $t \gtrsim 14 \times 10^9$ yr

d) non-relativistic at structure formation

SM particles → do any satisfy?

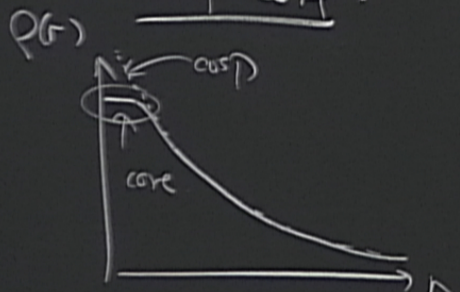
(a) (c) (d)

③ Challenges to DM → N-body sim:
↳ "prediction" of universe

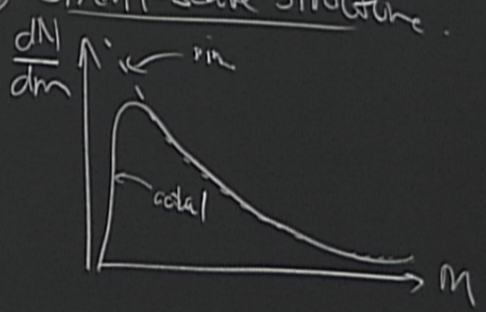
a) Structure formation

2 features not reproduced

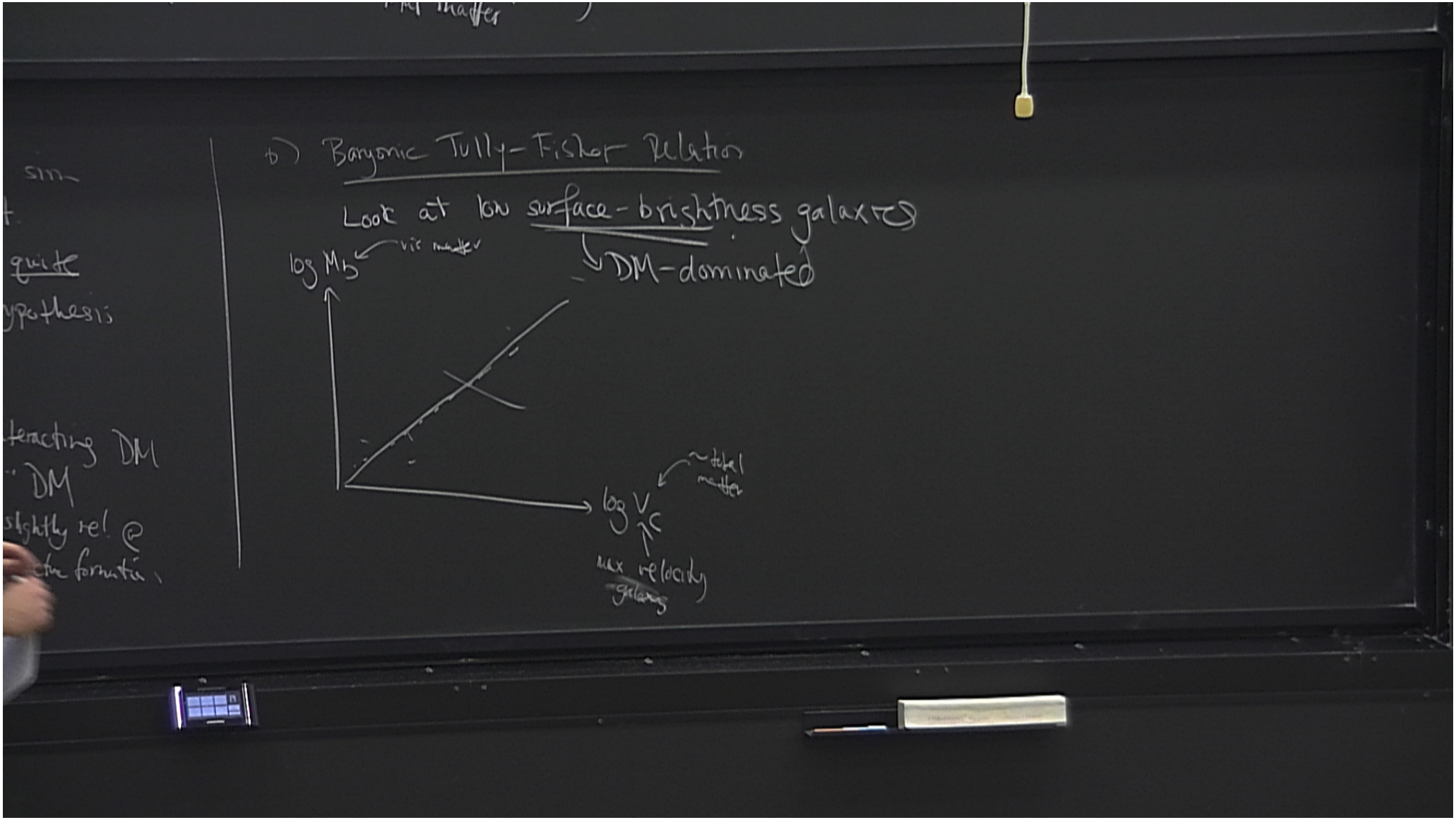
① Cusp-core



② Small-scale structure



Problem ≠ sim
- obs. limit
- DM isn't quite like the hypothesis
↓
motivates
- self-interacting DM
- "warm" DM
  ⇝ slightly rel. @ structure formation


b) Baryonic Tully-Fisher Relation
Look at low surface-brightness galaxies
DM-dominated
log M_b
vis matter
log V_c
~total matter
max velocity galaxy
quite
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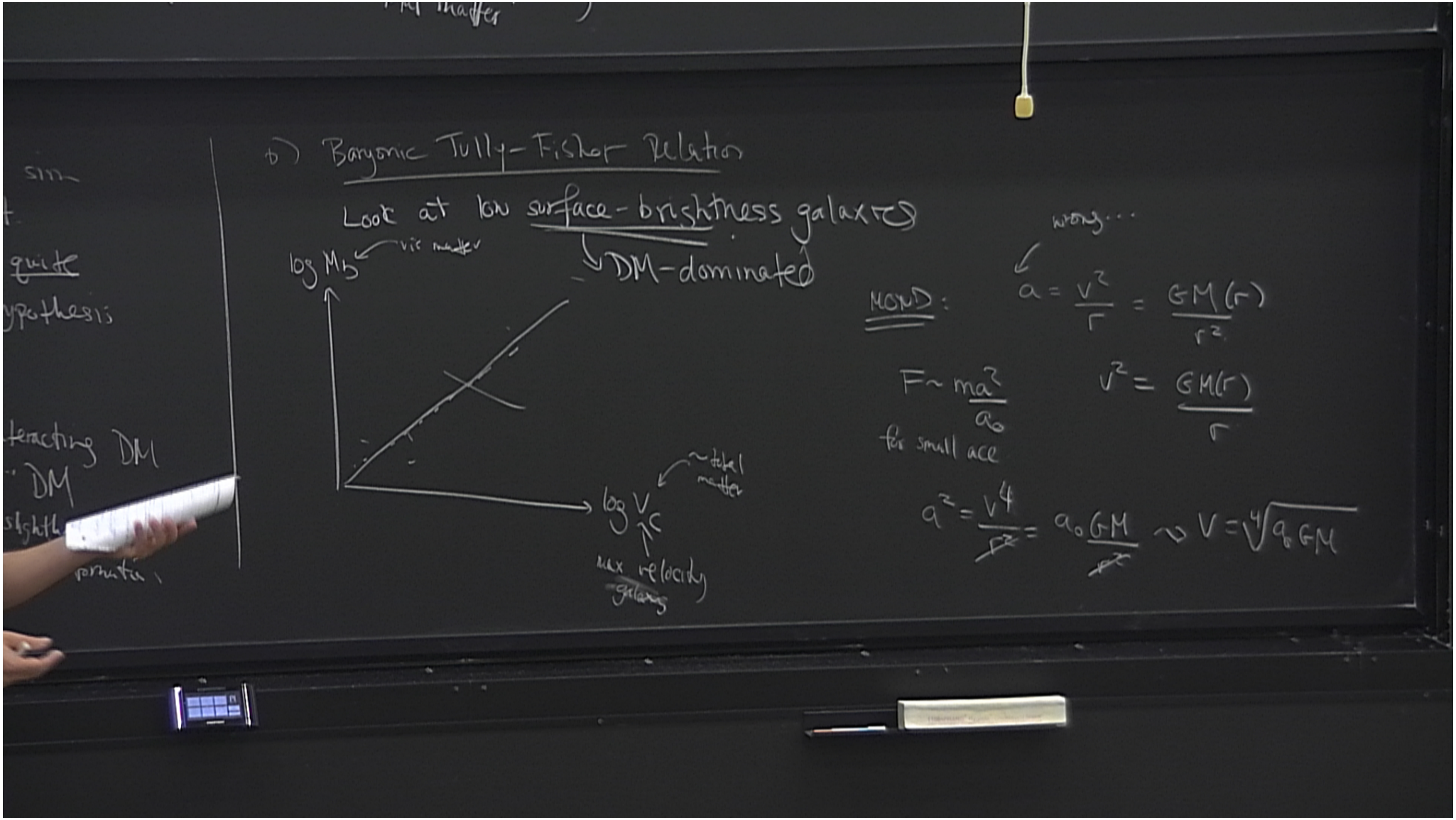
b) Baryonic Tully-Fisher Relation
Look at low surface-brightness galaxies
DM-dominated
log M_b
vis matter
log V_c
~total matter
max velocity galaxies
wrong...
MOND:
$a = \frac{v^2}{r} = \frac{GM(r)}{r^2}$
$F \sim \frac{ma^2}{a_0}$
for small acc
$v^2 = \frac{GM(r)}{r}$
$a^2 = \frac{v^4}{r^2} = a_0 \frac{GM}{r^2} \rightsquigarrow v = \sqrt[4]{a_0 GM}$