Title: Particle Physics Lecture

Speakers: Junwu Huang

Collection: Particle Physics

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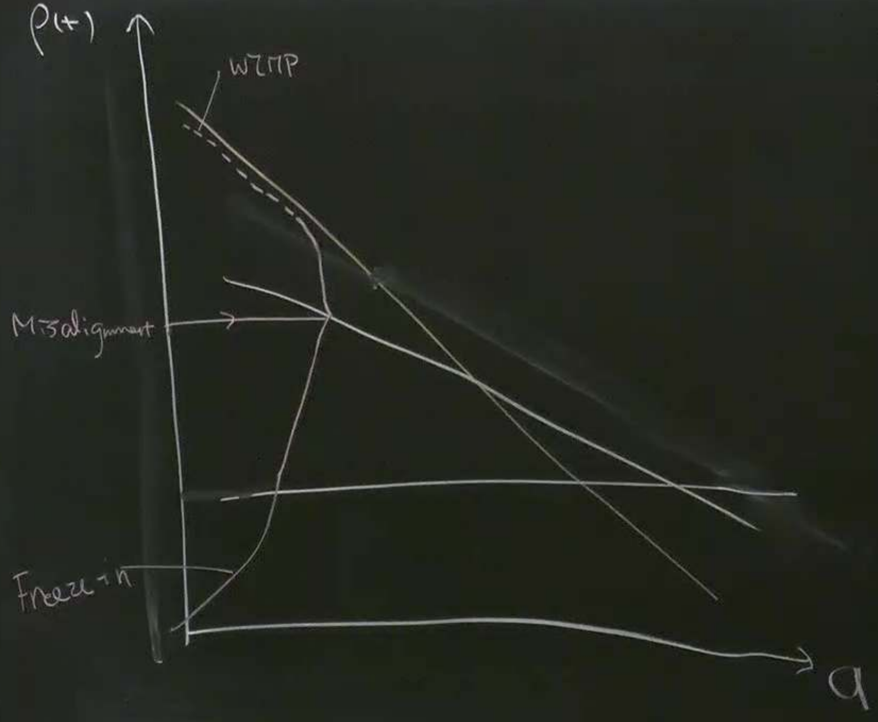
URL: https://pirsa.org/24030026



String + DW production.

$a \to a + 2\pi f_a$

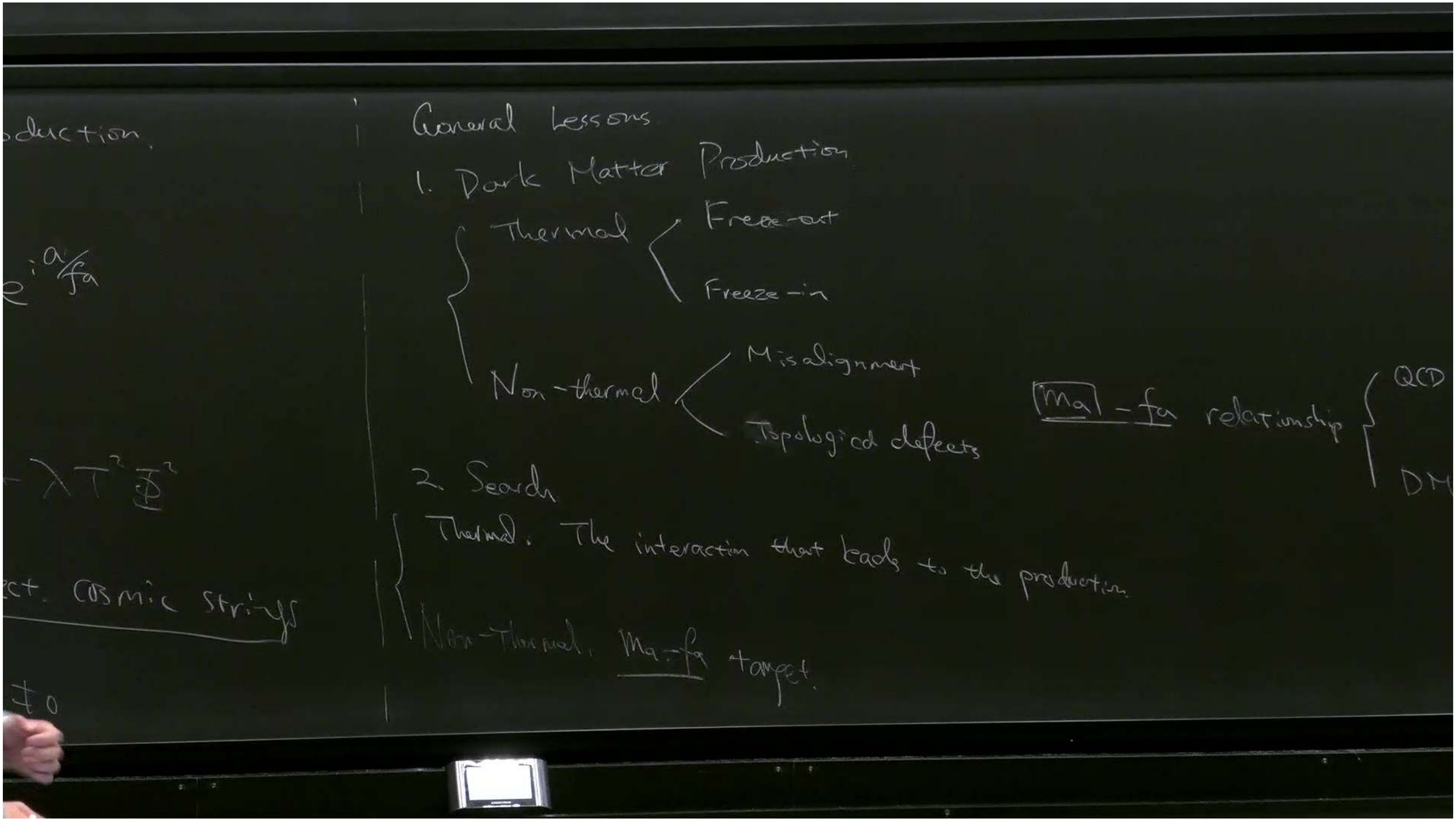
$$\Phi = (f_a + \rho)\, e^{i a / f_a}$$

U(1) breaking.

$$V \supset \lambda(|\Phi|^2 - f_a^2)^2 + \lambda T^2 \Phi^2$$

⇒ Topological defect. cosmic strings

⇒ DW when $m_a \neq 0$



duction.

$e^{i a/f_a}$

$\lambda T^2 \Phi^2$

ect. cosmic strings

$\neq 0$

General Lessons.

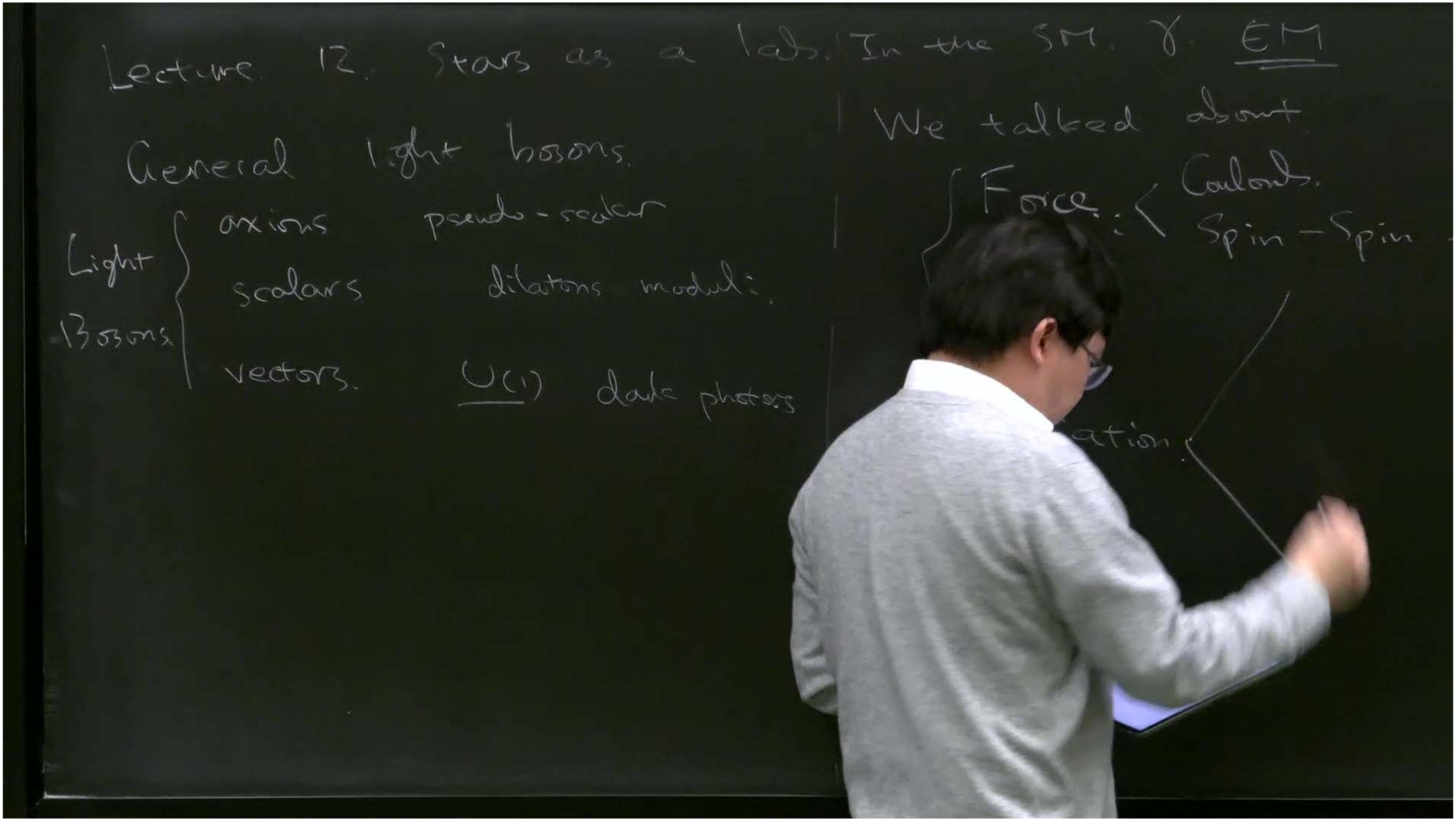
1. Dark Matter Production.

- Thermal
  - Freeze-out
  - Freeze-in
- Non-thermal
  - Misalignment
  - Topological defects

$\boxed{m_a} - f_a$ relationship
- QCD
- DM

2. Search

- Thermal. The interaction that leads to the production.
- Non-Thermal. $m_a - f_a$ target.



Lecture 12. Stars as a lab.

General light bosons.

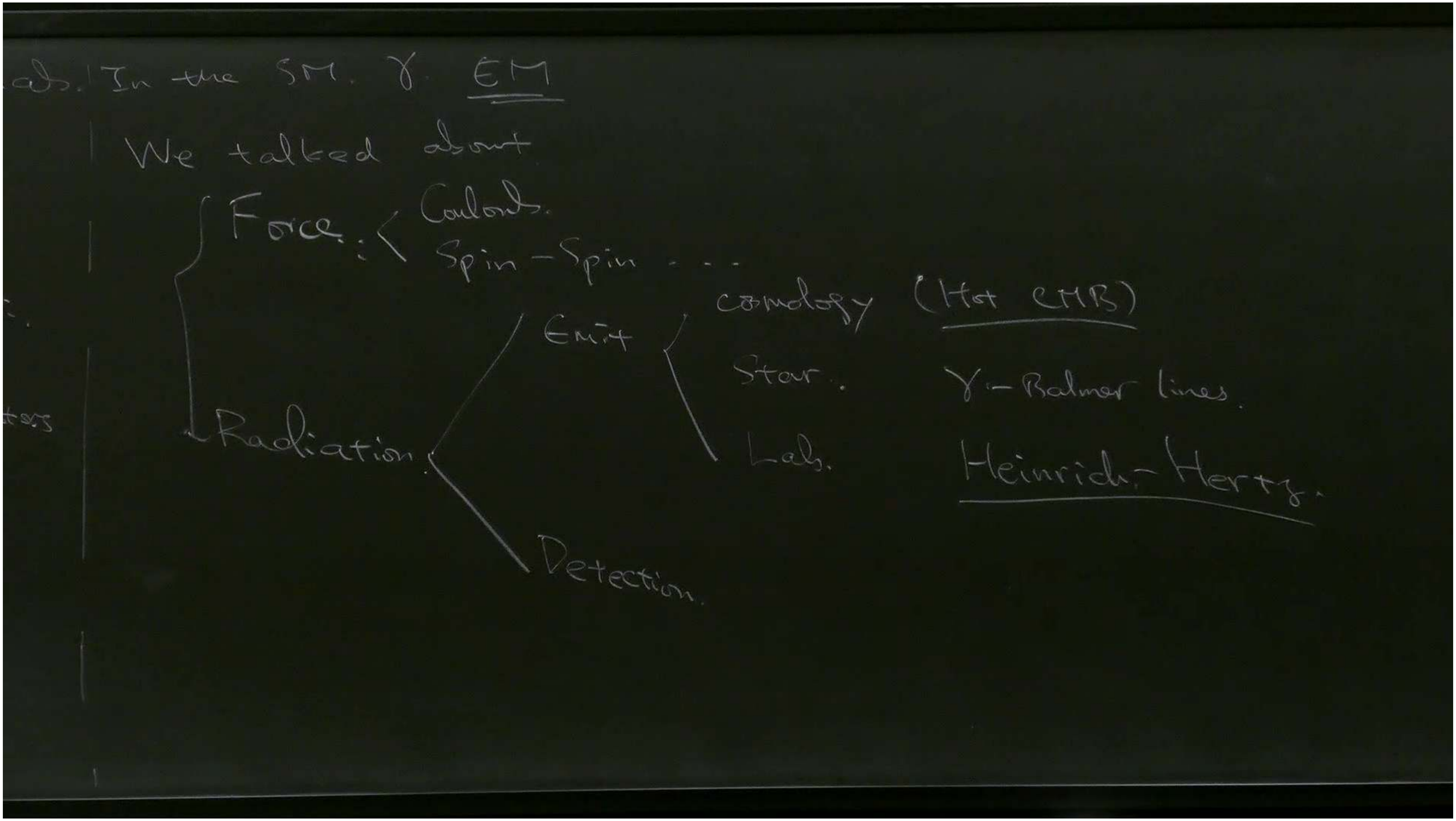
Light Bosons
- axions pseudo-scalar
- scalars dilatons moduli.
- vectors. U(1) dark photons

In the SM. γ. EM

We talked about

Force: Coulomb. / Spin-Spin

ation.



ds. In the SM. γ. EM

We talked about

- Force:
  - Coulomb.
  - Spin-Spin ...
- Radiation.
  - Emit
    - cosmology (Hot CMB)
    - Star. γ-Balmer lines.
    - Lab. Heinrich-Hertz.
  - Detection.

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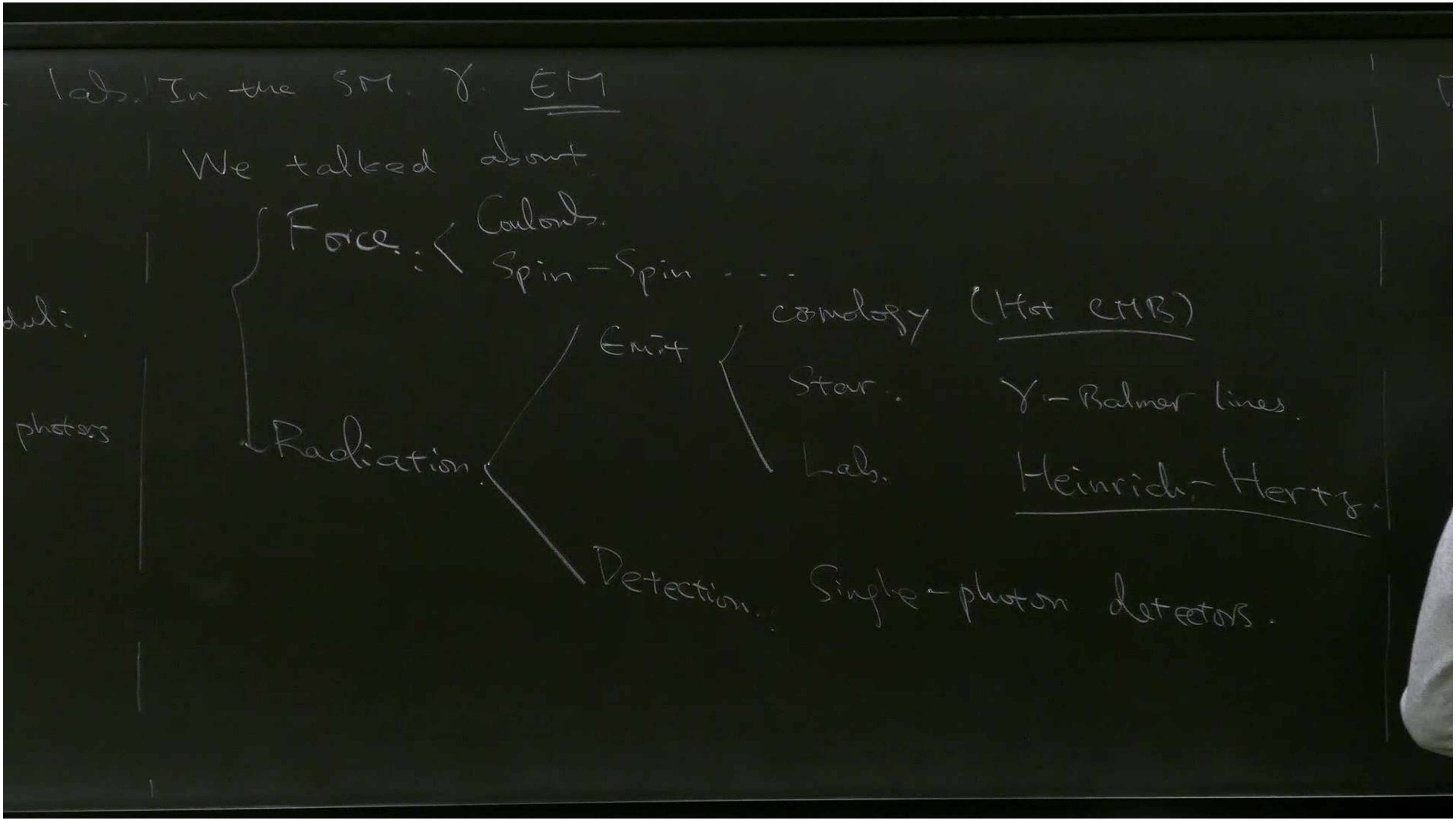


labs. In the SM. γ. EM

dul:

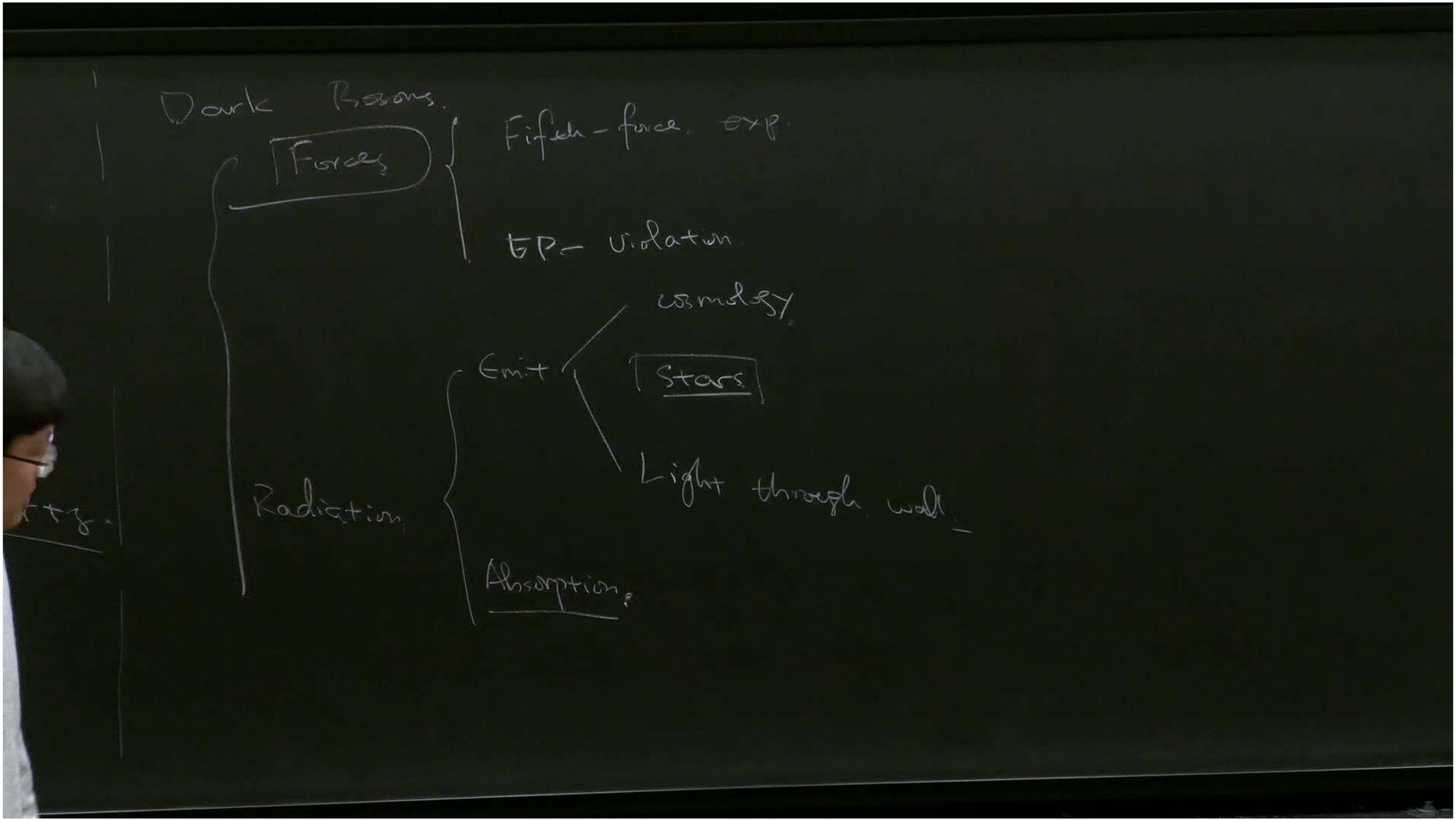
photons

We talked about

Force: < Coulomb. / Spin-Spin . . .

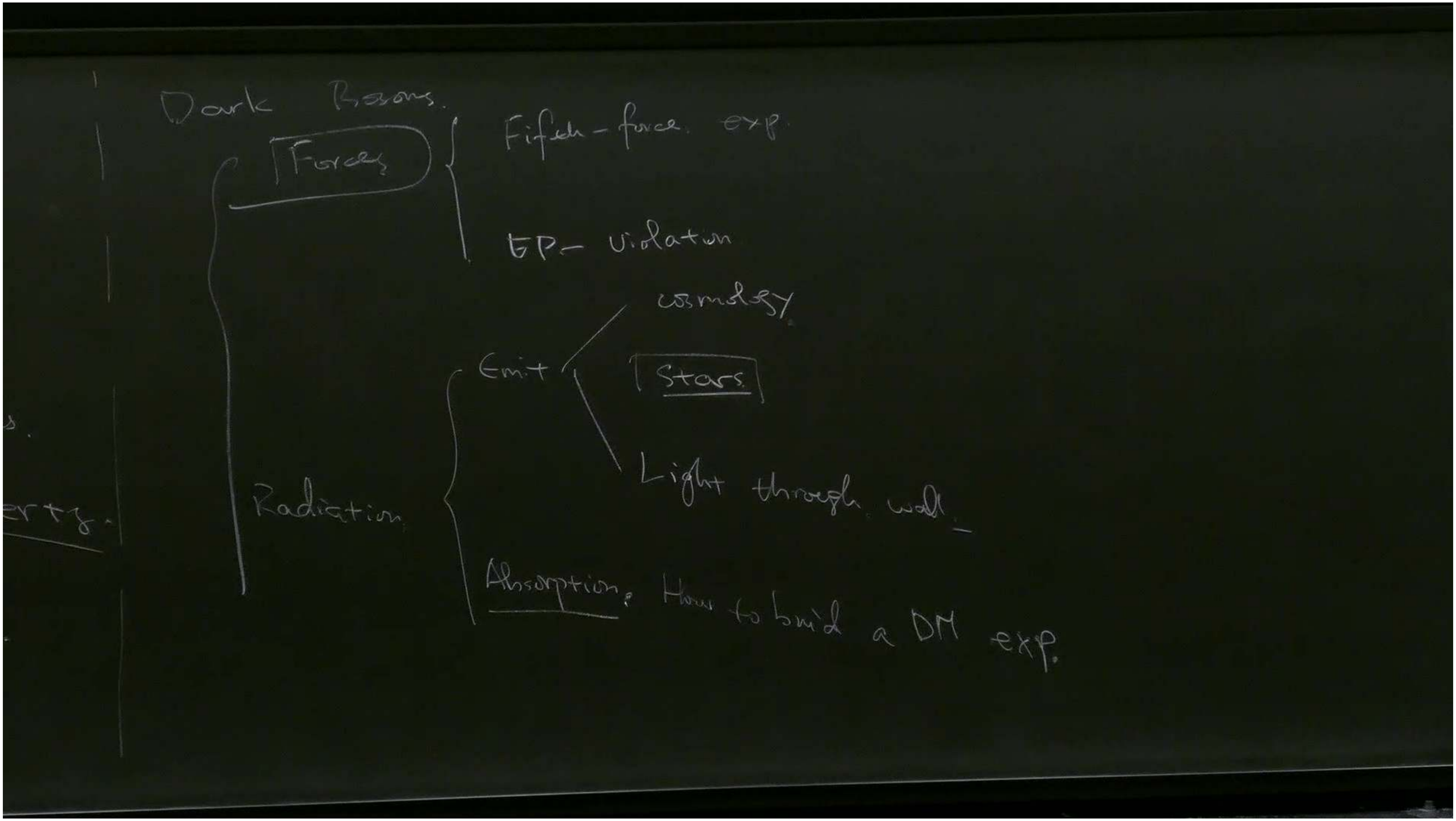
Radiation < Emit < cosmology (Hot CMB) / Star. γ - Balmer lines. / Lab. Heinrich Hertz.

Detection: Single-photon detectors.



Dark Bosons.

- Forces
  - Fifth-force exp.
  - EP- violation
- Radiation
  - Emit
    - cosmology
    - Stars
    - Light through wall
  - Absorption.



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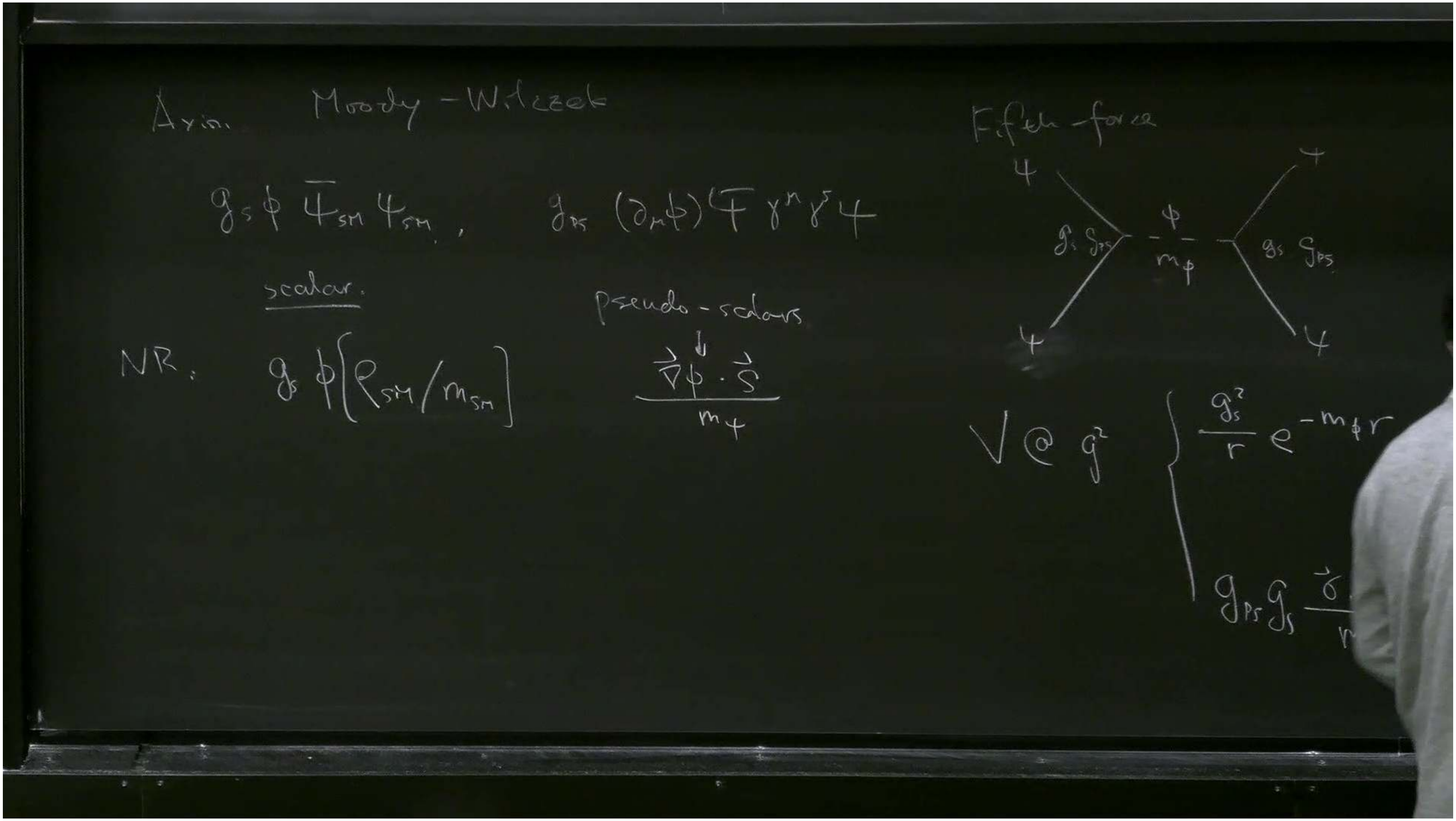
Dark Bosons.

Forces
- Fifth-force exp.
- EP- Violation

Radiation
- Emit
  - cosmology
  - Stars
  - Light through wall
- Absorption: How to build a DM exp.



Axion Moody-Wilczek

$g_s \phi \bar{\Psi}_{SM} \Psi_{SM}$, $g_{PS} (\partial_\mu \phi) \bar{\Psi} \gamma^\mu \gamma^5 \Psi$

scalar. pseudo-scalars

NR: $g_s \phi \left[\rho_{SM} / m_{SM} \right]$ $\quad \dfrac{\vec{\nabla}\phi \cdot \vec{S}}{m_\Psi}$

Fifth-force

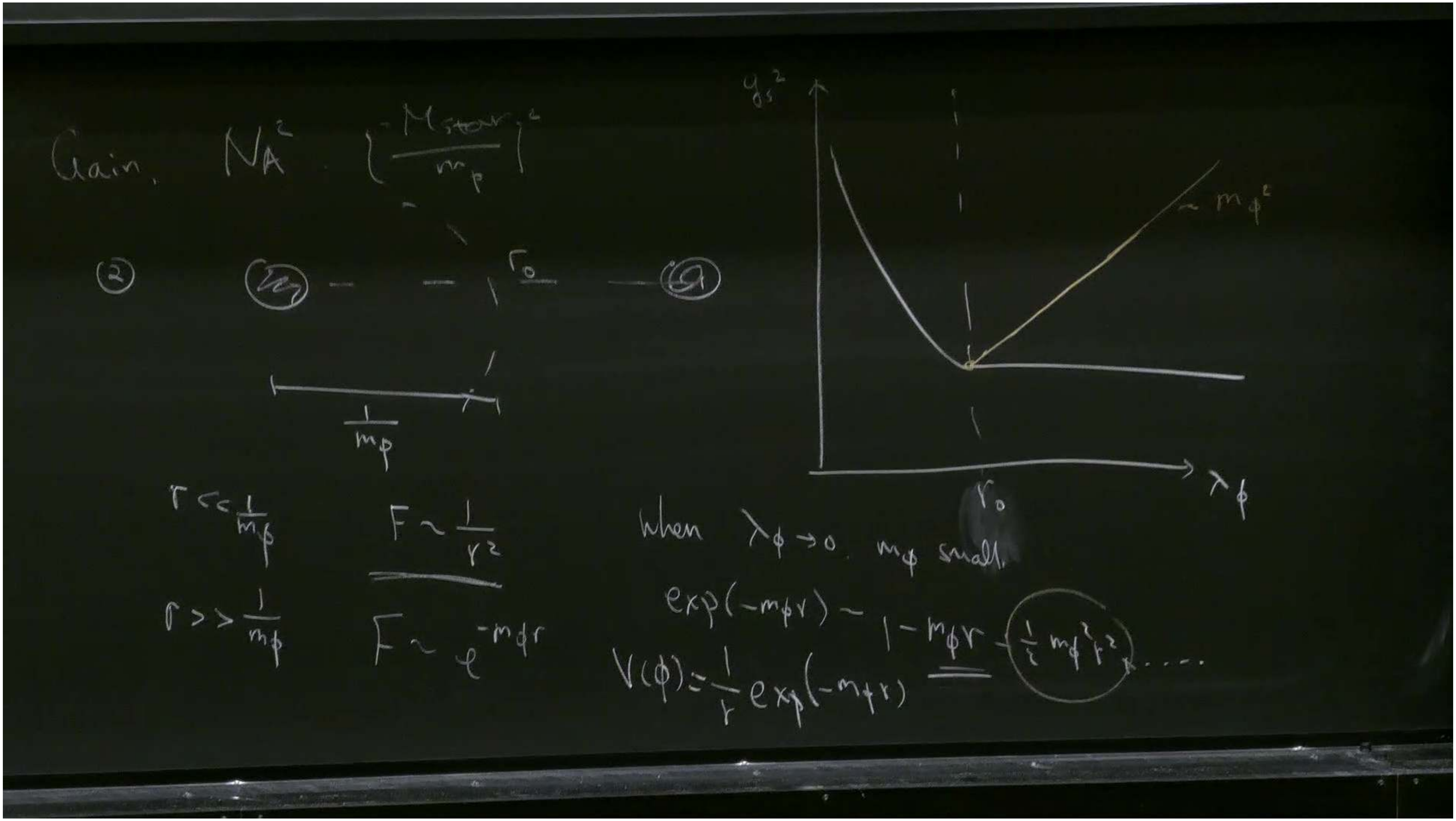
$V @ g^2 \left\{ \begin{array}{l} \dfrac{g_s^2}{r} e^{-m_\phi r} \\ \\ g_{PS} g_s \dfrac{\vec{\sigma}}{m} \end{array} \right.$

Gain: $N_A^2 \cdot \left[\frac{-M_{star}}{m_p}\right]^2$

$\Longleftarrow$

$\swarrow$

$\left(\frac{1}{r^2}+\frac{m_\phi}{r}\right)e^{-m_\phi r}$



Gain. $N_A^2 \cdot \left(\frac{M_{star}}{m_\phi}\right)^2$

$r \ll \frac{1}{m_\phi}$ $F \sim \frac{1}{r^2}$

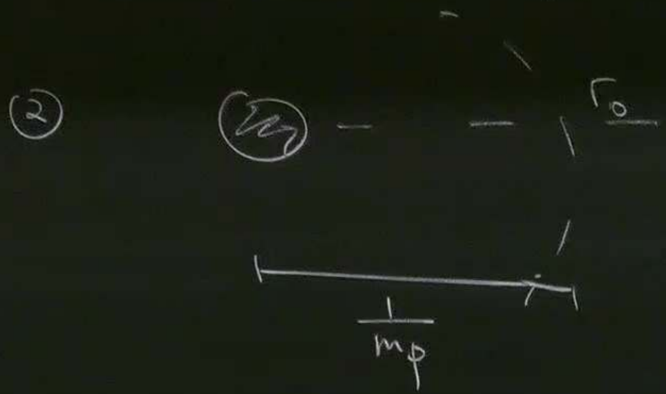
$r \gg \frac{1}{m_\phi}$ $F \sim e^{-m_\phi r}$

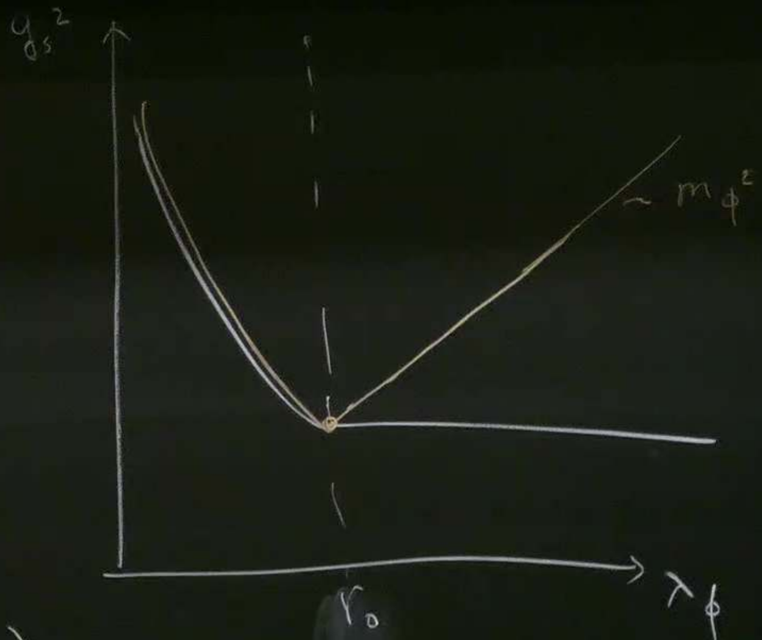
when $\lambda_\phi \to 0$. m_ϕ small.

$\exp(-m_\phi r) \sim 1 - m_\phi r + \frac{1}{2} m_\phi^2 r^2 + \dots$

$V(\phi) = \frac{1}{r} \exp(-m_\phi r)$

Gain. $N_A^2 \left(\frac{M_{star}}{m_p}\right)^2$





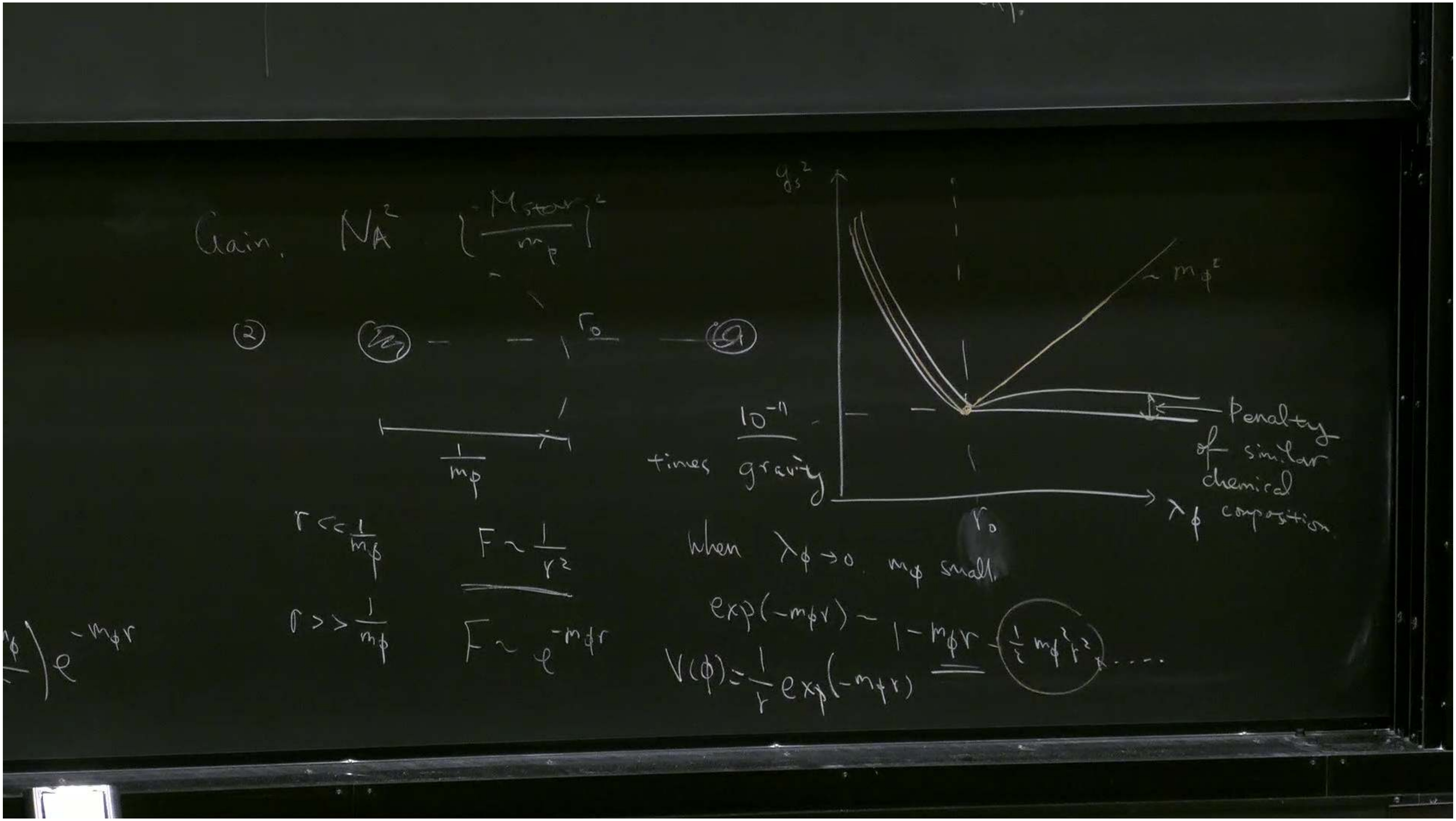
$r << \frac{1}{m_\phi}$ $F \sim \frac{1}{r^2}$

$r >> \frac{1}{m_\phi}$ $F \sim e^{-m_\phi r}$

When $\lambda_\phi \to 0$. m_ϕ small.

$\exp(-m_\phi r) \sim 1 - \underline{\underline{m_\phi r}} + \frac{1}{2} m_\phi^2 r^2 + \cdots$

$V(\phi) = \frac{1}{r} \exp(-m_\phi r)$



Gain. $N_A^2 \left(\frac{M_{star}}{m_p}\right)^2$

② r_0

$\frac{1}{m_\phi}$

$r << \frac{1}{m_\phi}$ $F \sim \frac{1}{r^2}$

$\phi) e^{-m_\phi r}$ $r >> \frac{1}{m_\phi}$ $F \sim e^{-m_\phi r}$

when $\lambda_\phi \to 0$. m_ϕ small.

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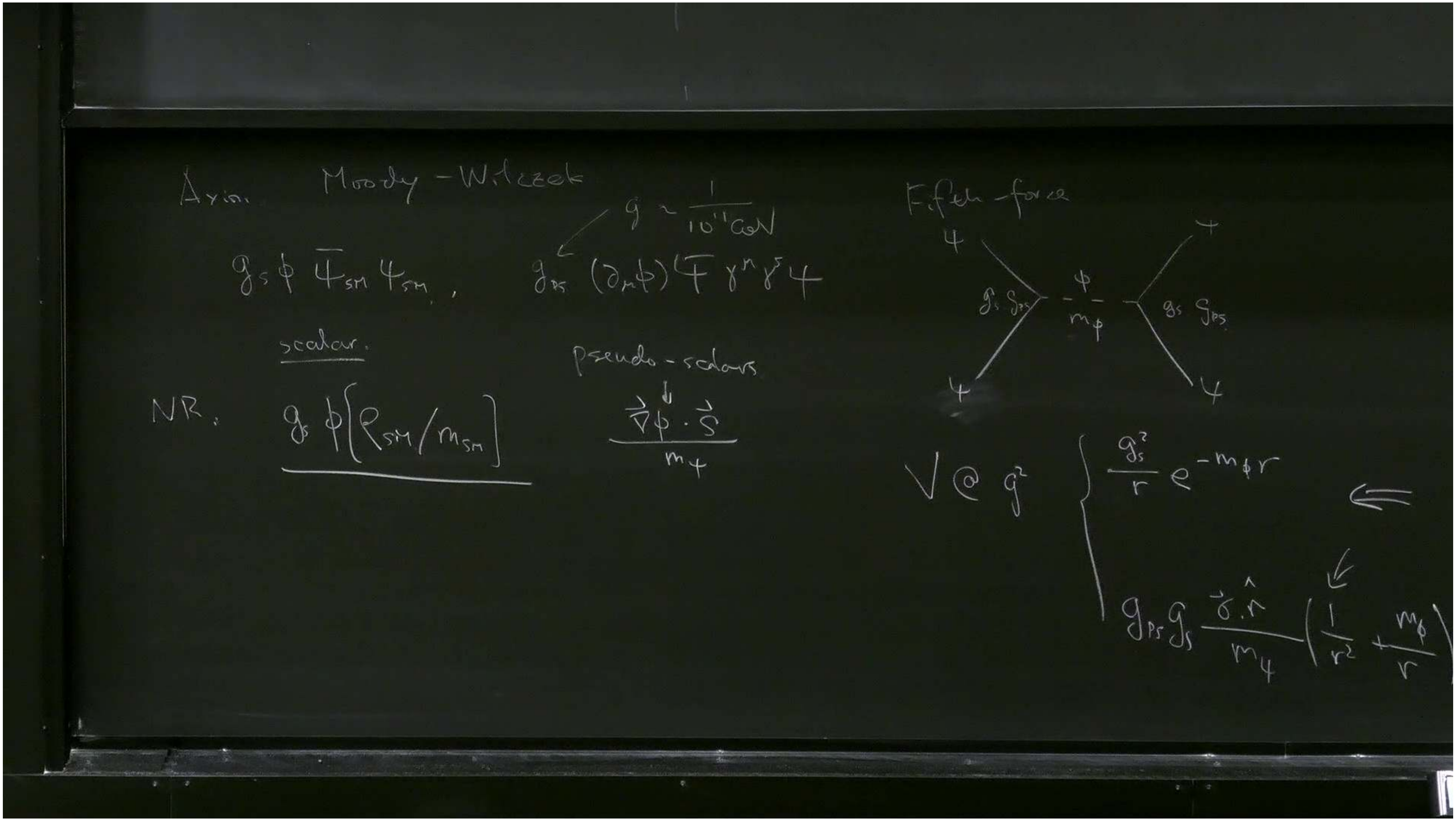


Axion   Moody-Wilczek

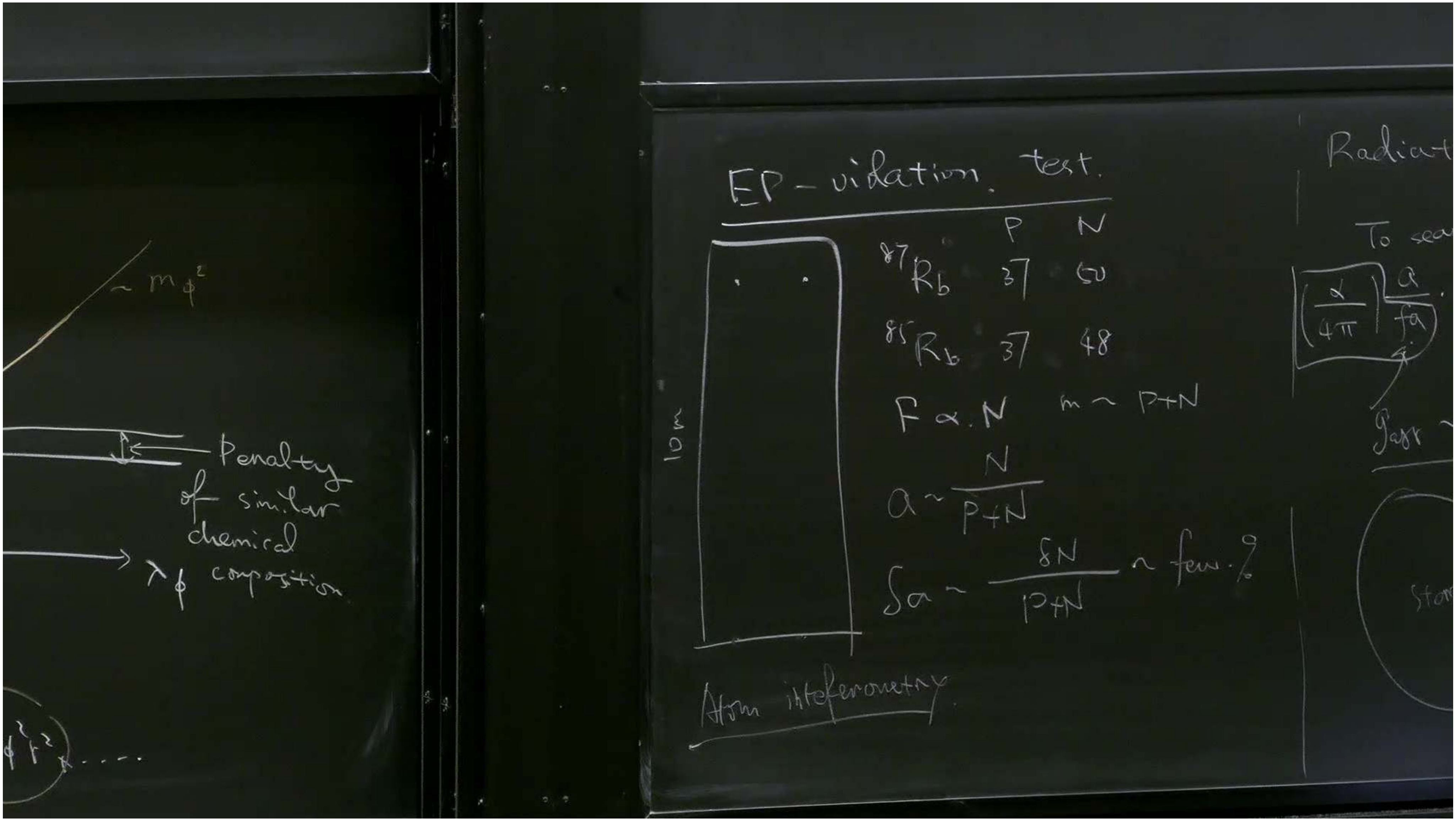
$$g \sim \frac{1}{10^{11}\,\text{GeV}}$$

$$g_s \phi \bar{\Psi}_{SM} \Psi_{SM}\,, \qquad g_{PS}\, (\partial_\mu \phi)\, \bar{\Psi} \gamma^\mu \gamma^5 \Psi$$

scalar   pseudo-scalars

NR: $g_s \phi \left[\rho_{SM}/m_{SM}\right]$ $\dfrac{\vec{\nabla}\phi \cdot \vec{S}}{m_\Psi}$

$$V @ g^2 \begin{cases} \dfrac{g_s^2}{r} e^{-m_\phi r} & \Leftarrow \\ g_{PS} g_s \dfrac{\vec{\sigma}\cdot\hat{r}}{m_\Psi}\left(\dfrac{1}{r^2} + \dfrac{m_\phi}{r}\right) & \swarrow \end{cases}$$



$\sim m_\phi^2$

Penalty of similar chemical composition

λ_ϕ

$\phi^2 r^2 x \ldots$

EP-violation test.

10 m

	P	N
^{87}Rb	37	50
^{85}Rb	37	48

$F \propto N \quad m \sim P+N$

$$a \sim \frac{N}{P+N}$$

$$\delta a \sim \frac{\delta N}{P+N} \sim \text{few } \%$$

Atom interferometry

Radiat

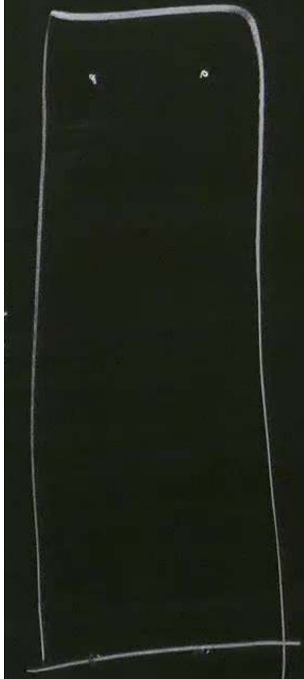
To sea

$$\left(\frac{\alpha}{4\pi}\right)\frac{a}{f_a}$$

$g_{a\gamma\gamma} \sim$

Stor

EP - violation test.



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$F \propto N \quad m \sim P+N$

$$a \sim \frac{N}{P+N}$$

$$\delta a \sim \frac{\delta N}{P+N} \sim \text{few} \, \%$$

Atom interferometry.

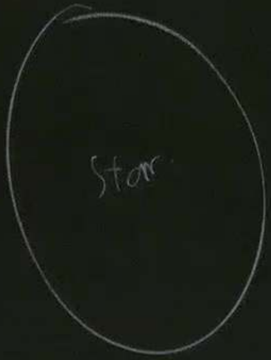
Radiation. Stars.

To search for. PS. interactions.

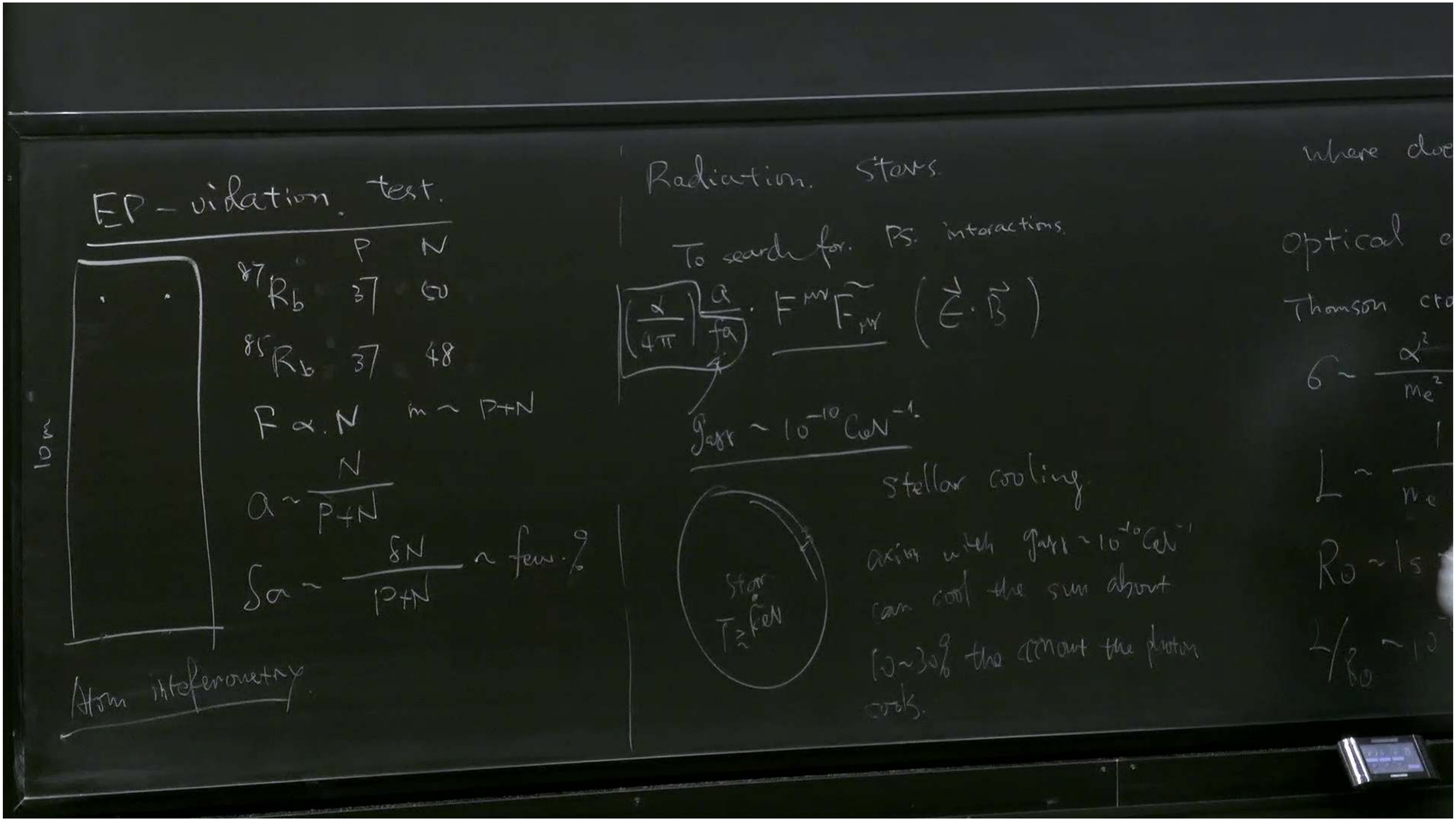
$$\boxed{\left(\frac{\alpha}{4\pi}\right)\frac{a}{f_a}} \cdot \underline{F^{\mu\nu}\tilde{F}_{\mu\nu}} \quad \left(\vec{E}\cdot\vec{B}\right)$$

$$\underline{g_{a\gamma\gamma} \sim 10^{-10}\,\text{GeV}^{-1}}$$

stellar cooling.



axion with $g_{a\gamma\gamma} \sim 10^{-10}\,\text{GeV}^{-1}$ can cool the sun about 10~30% the amount the photon cools.



EP - violation test.

	P	N
^{87}Rb	37	50
^{85}Rb	37	48

$F \propto N$ $m \sim P+N$

$a \sim \frac{N}{P+N}$

$\delta a \sim \frac{\delta N}{P+N} \sim$ few. %

10 m

Atom interferometry.

Radiation. Stars.

To search for. PS. interactions.

$\boxed{\left(\frac{\alpha}{4\pi}\right)} \frac{a}{f_a} \cdot \underline{F^{\mu\nu}\tilde{F}_{\mu\nu}} \left(\vec{E} \cdot \vec{B}\right)$

$\underline{g_{a\gamma\gamma} \sim 10^{-10} GeV^{-1}}$

stellar cooling.

star

$T \gtrsim keV$

axion with $g_{a\gamma\gamma} \sim 10^{-10} GeV^{-1}$ can cool the sun about 10~30% the amount the photon cools.

where doe

optical e

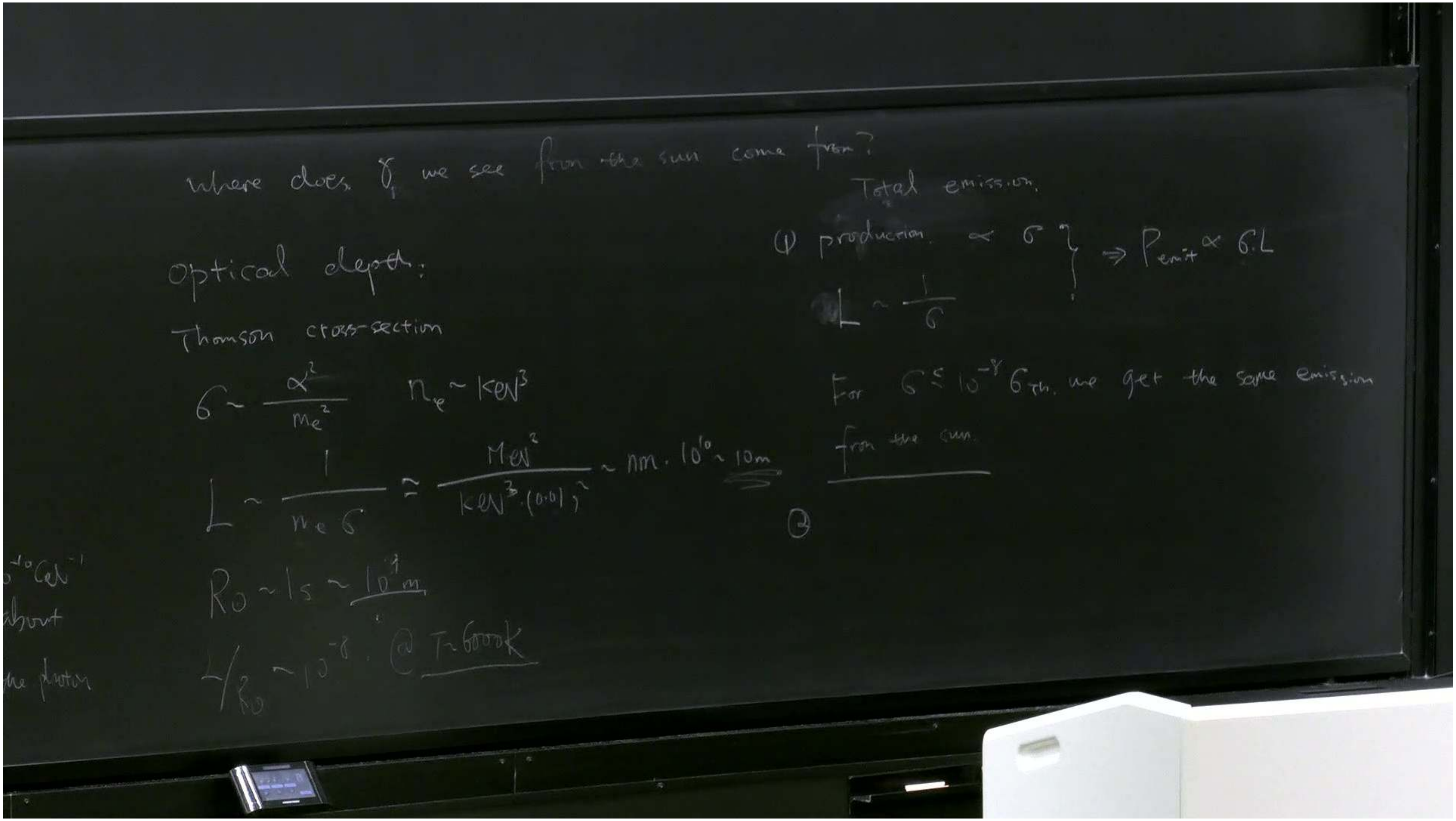
Thomson cro

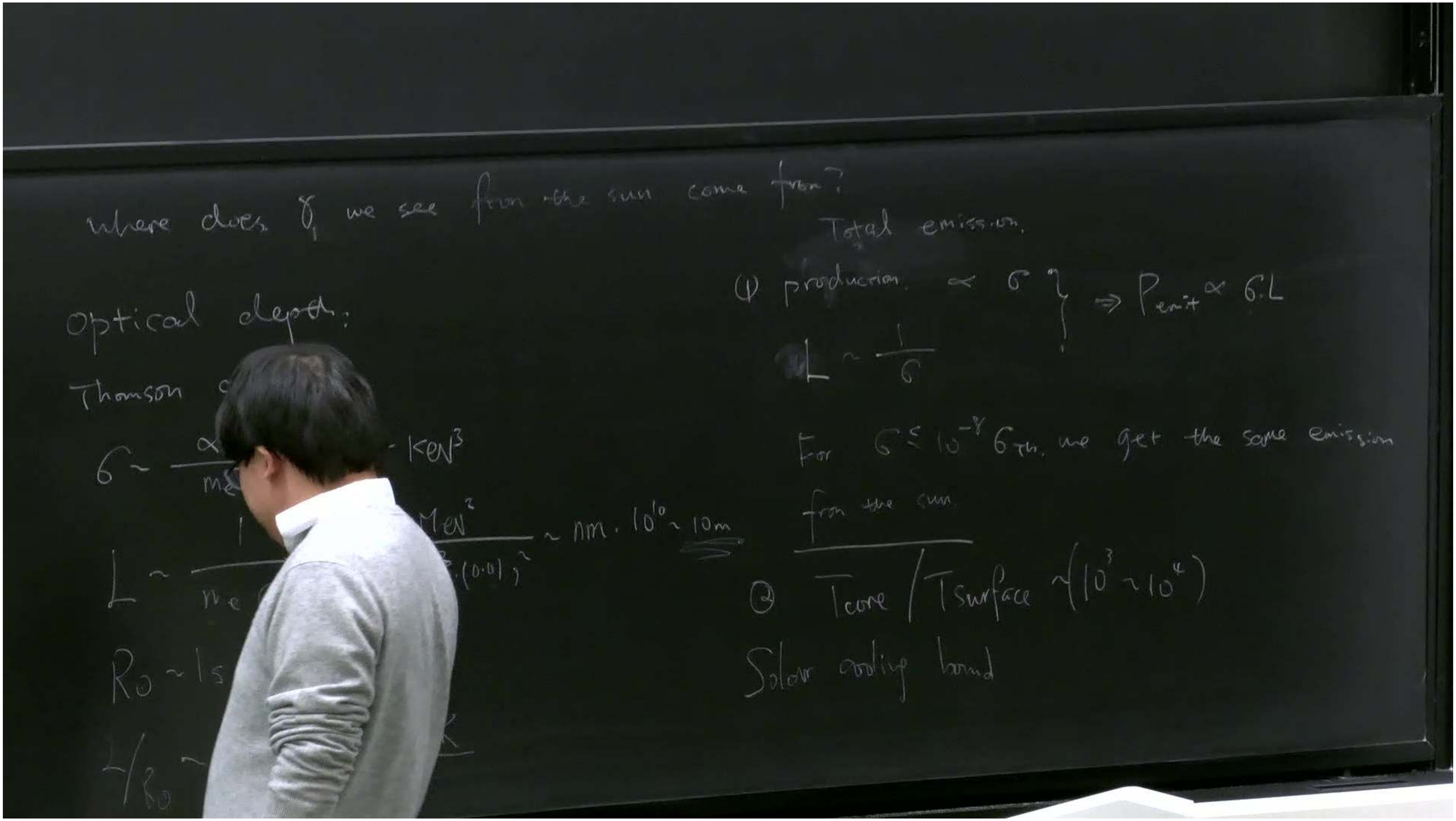
$\sigma \sim \frac{\alpha^2}{m_e^2}$

$L \sim \frac{1}{m_e}$

$R_\odot \sim 1s$

$L/R_\odot \sim 10$





where does γ we see from the sun come from?

Total emission.

optical depth:

Thomson s

$\sigma \sim \frac{\alpha}{m_e}$ ~ keV^3

① production $\propto \sigma$ } $\Rightarrow P_{emit} \propto \sigma \cdot L$

$L \sim \frac{1}{\sigma}$

For $\sigma \lesssim 10^{-8} \sigma_{Th}$, we get the same emission from the sun

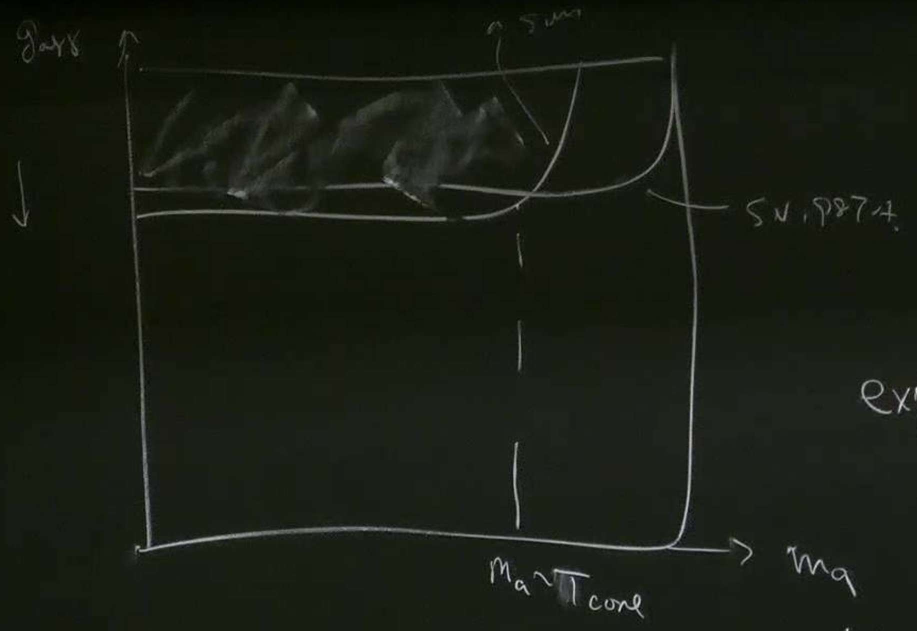
$L \sim \frac{1}{n_e}$ $\frac{\text{MeV}^2}{(0.01)^2}$ ~ nm · 10^{10} ~ 10m

② $T_{core} / T_{surface} \sim (10^3 \sim 10^4)$

$R_\odot \sim 1s$

Solar cooling bound

$L/R_\odot \sim$ K



$$\exp(-m_a/T)$$