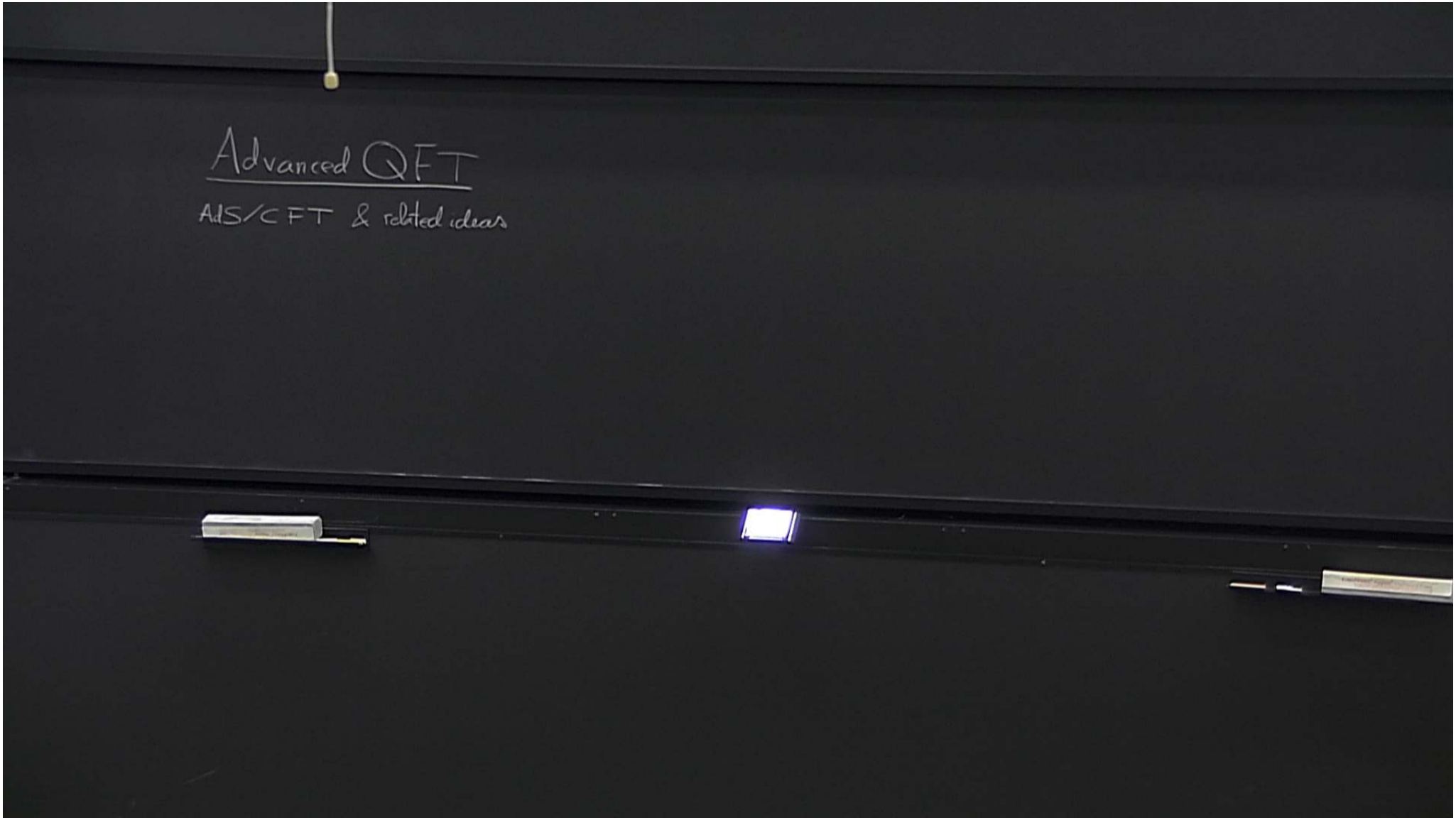
Title: 12/13 PSI - Explorations in String Theory Lecture 1

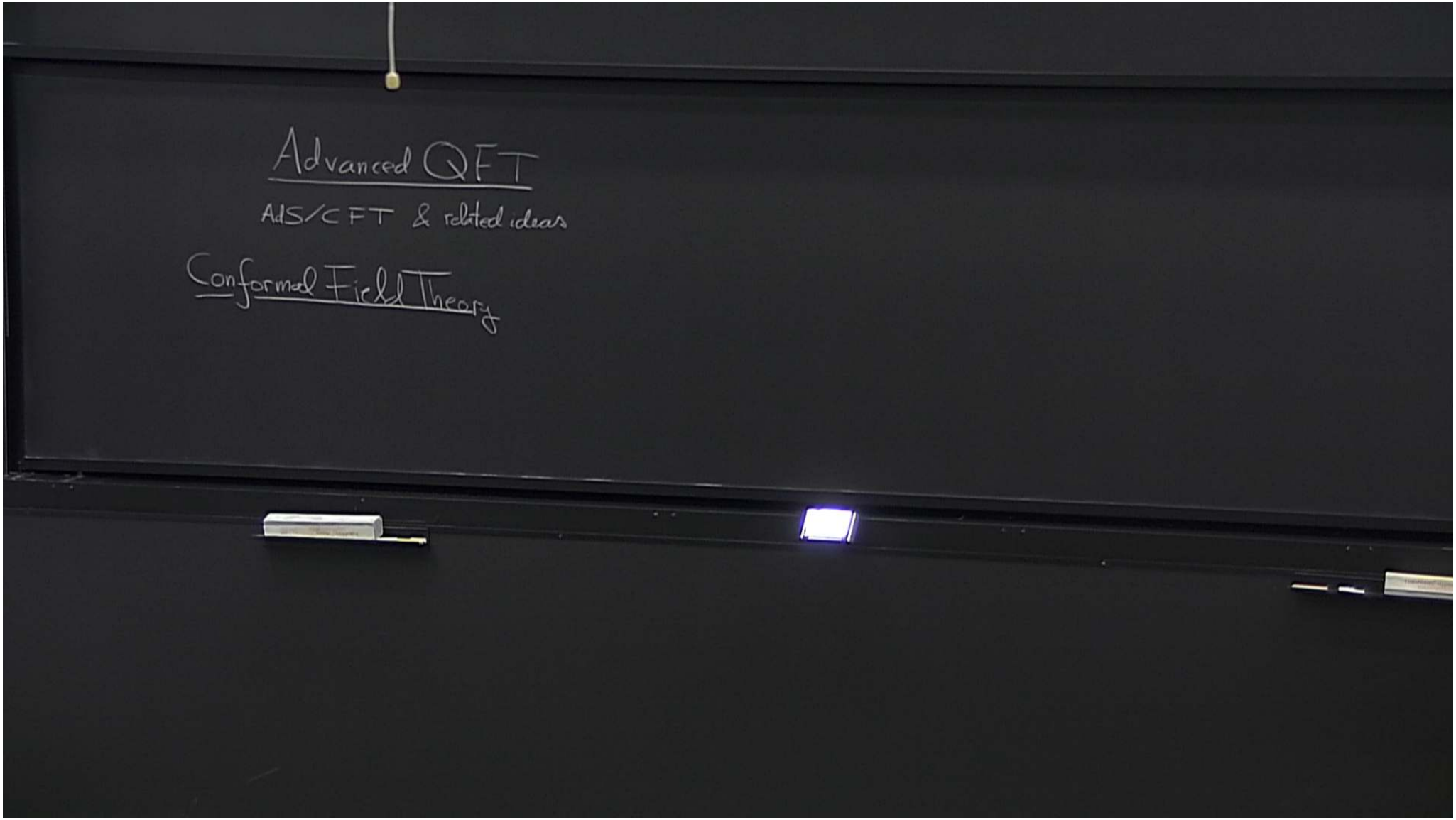
Date: Apr 08, 2013 11:30 AM

URL: http://pirsa.org/13040084

Abstract:


Advanced QFT


Advanced QFT
AdS/CFT & related ideas


Advanced QFT
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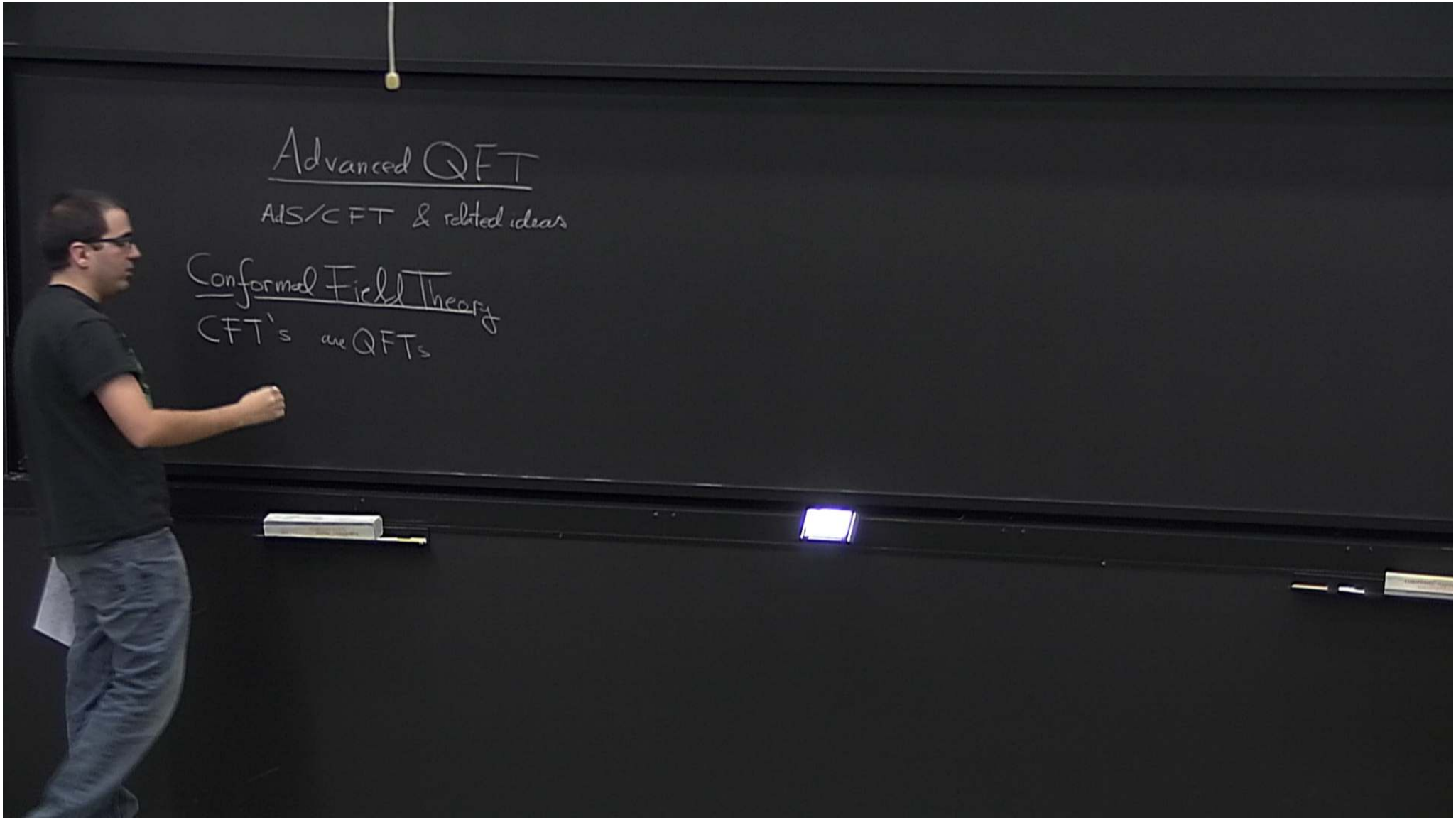
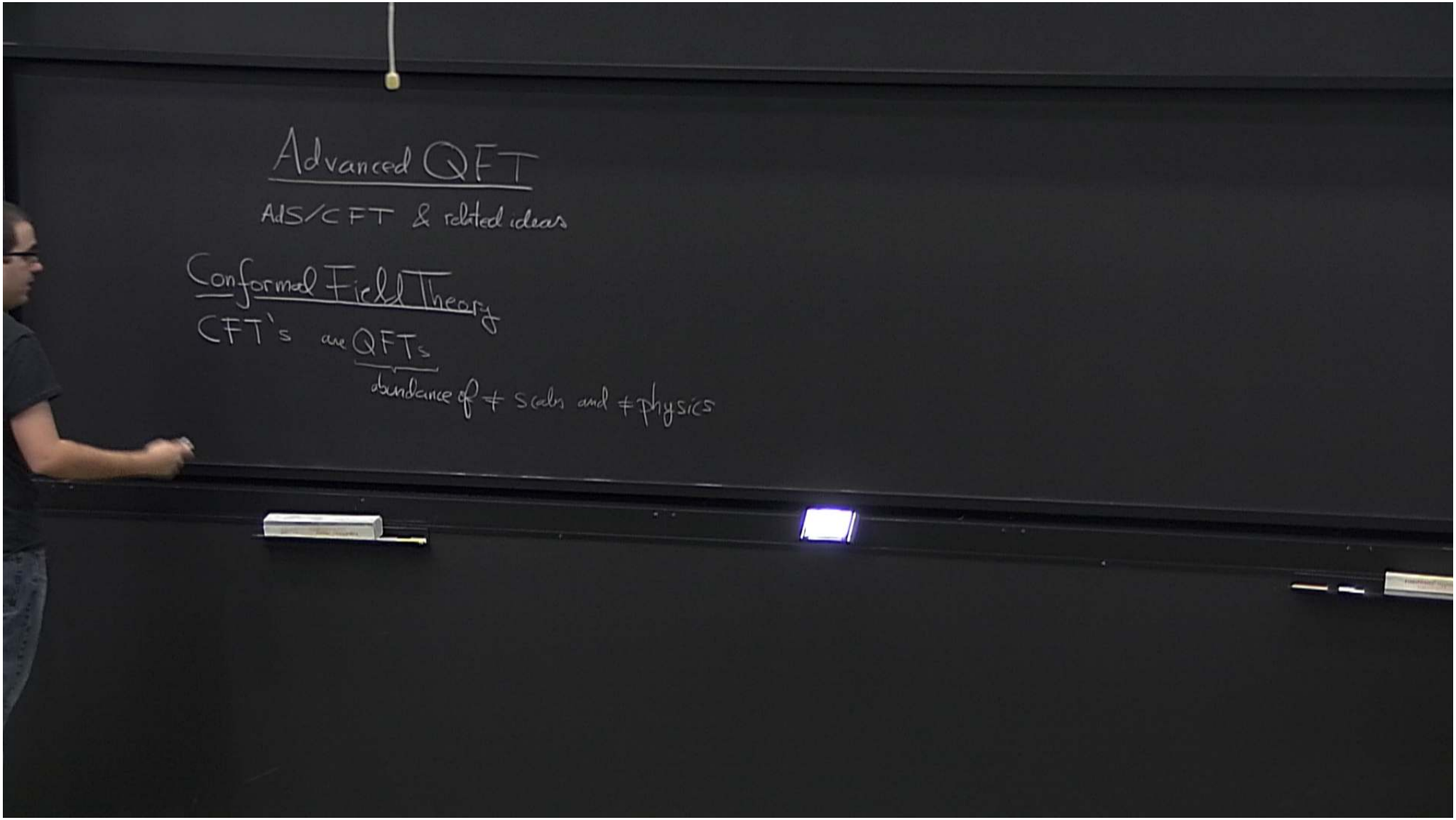
Conformal Field Theory


Advanced QFT
AdS/CFT & related ideas
Conformal Field Theory
CFT's are QFTs


Advanced QFT
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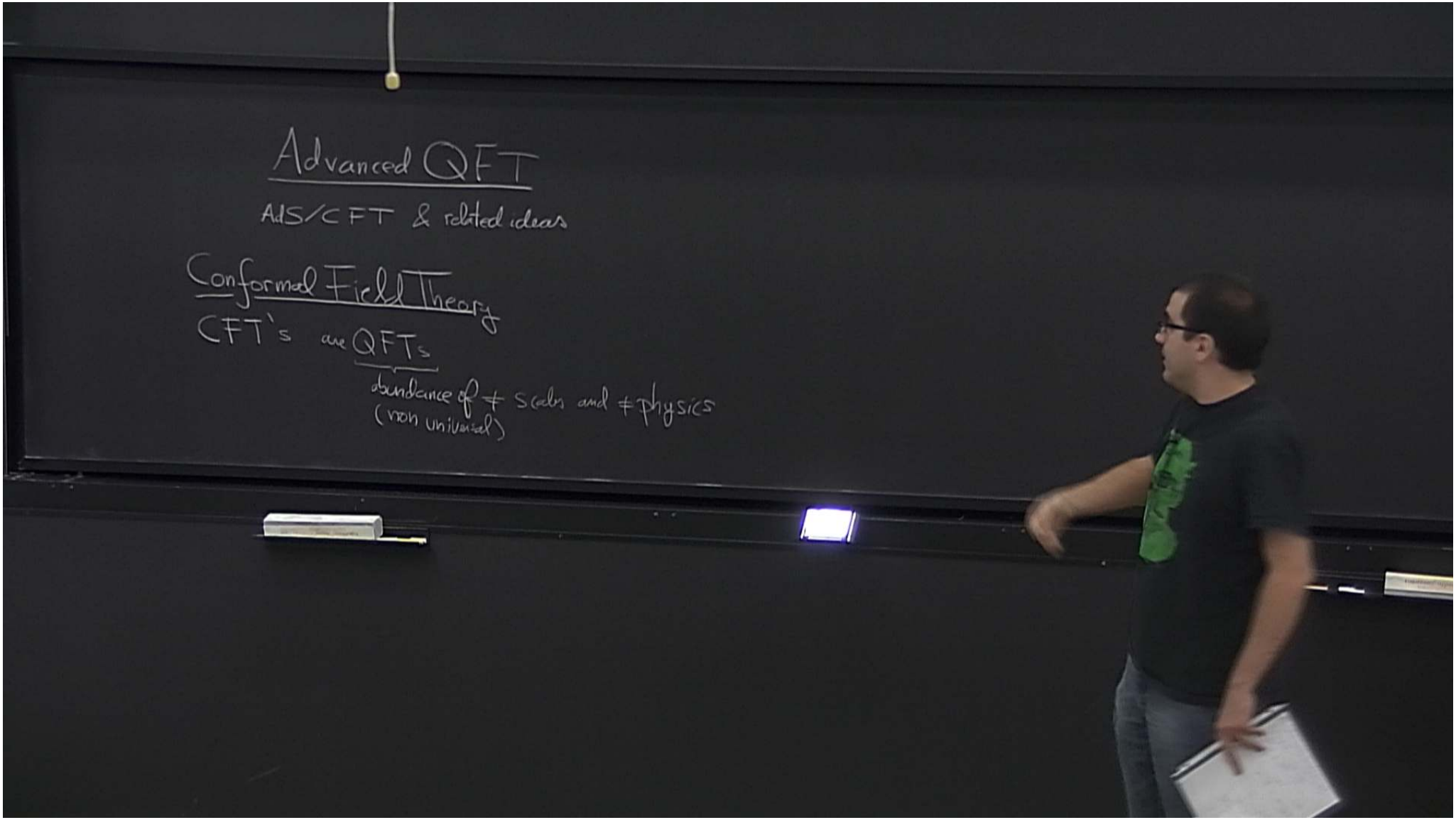
Conformal Field Theory
CFT's are QFTs
abundance of ≠ scales and ≠ physics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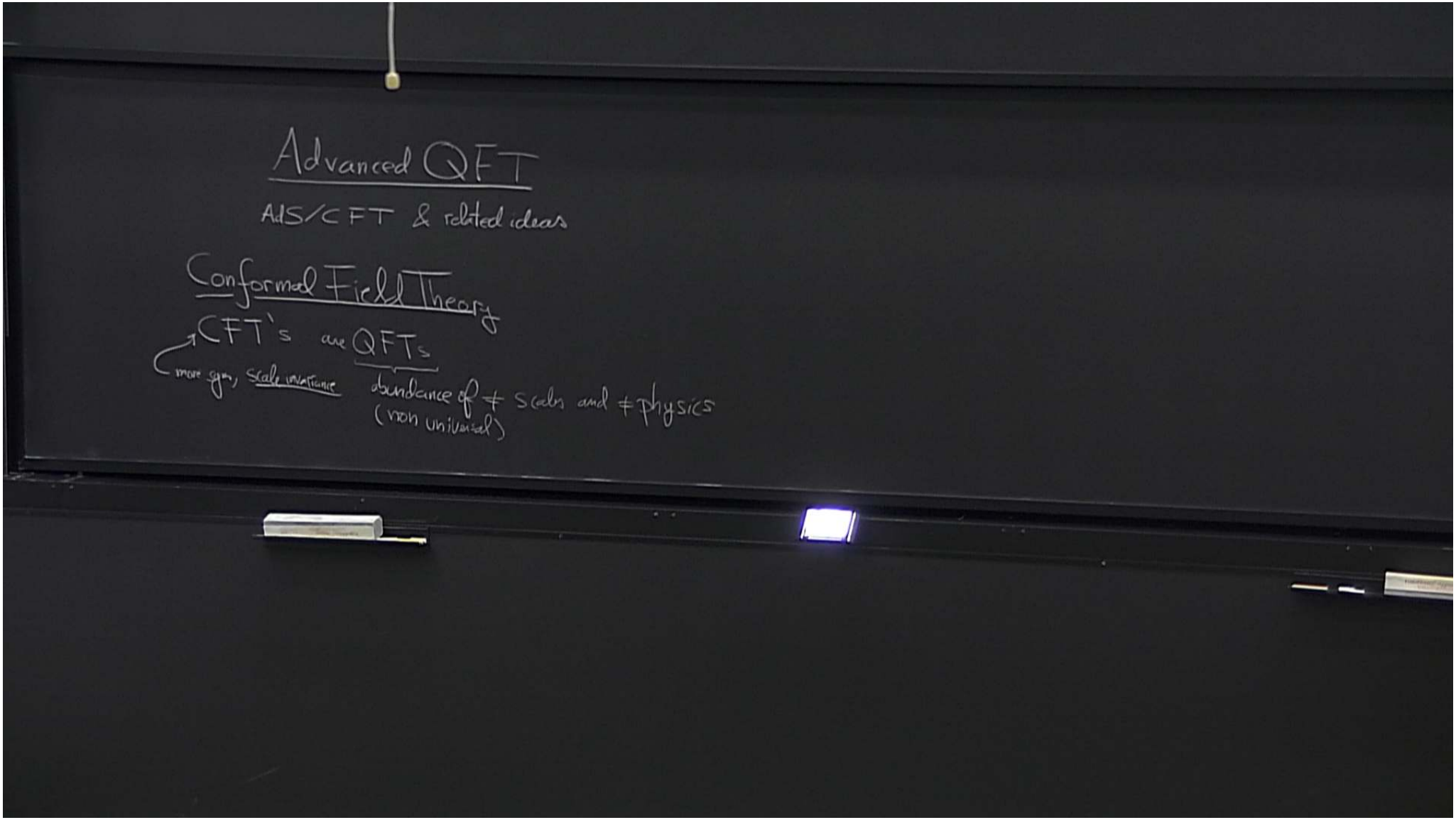
CFT's are QFTs
abundance of ≠ scales and ≠ physics
(non universal)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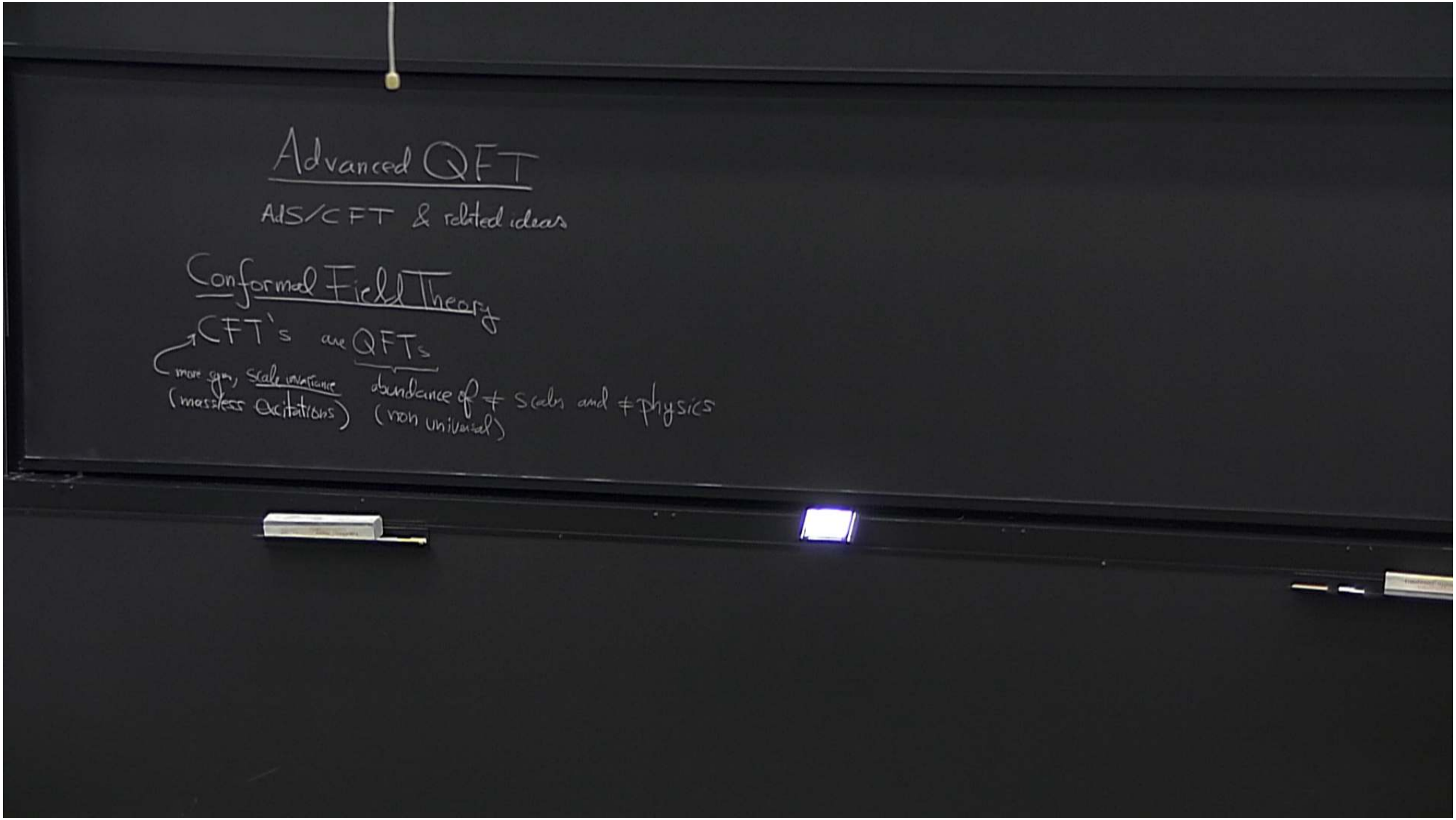
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CFT's are QFTs
more gen, scale invariance
(massless excitations)
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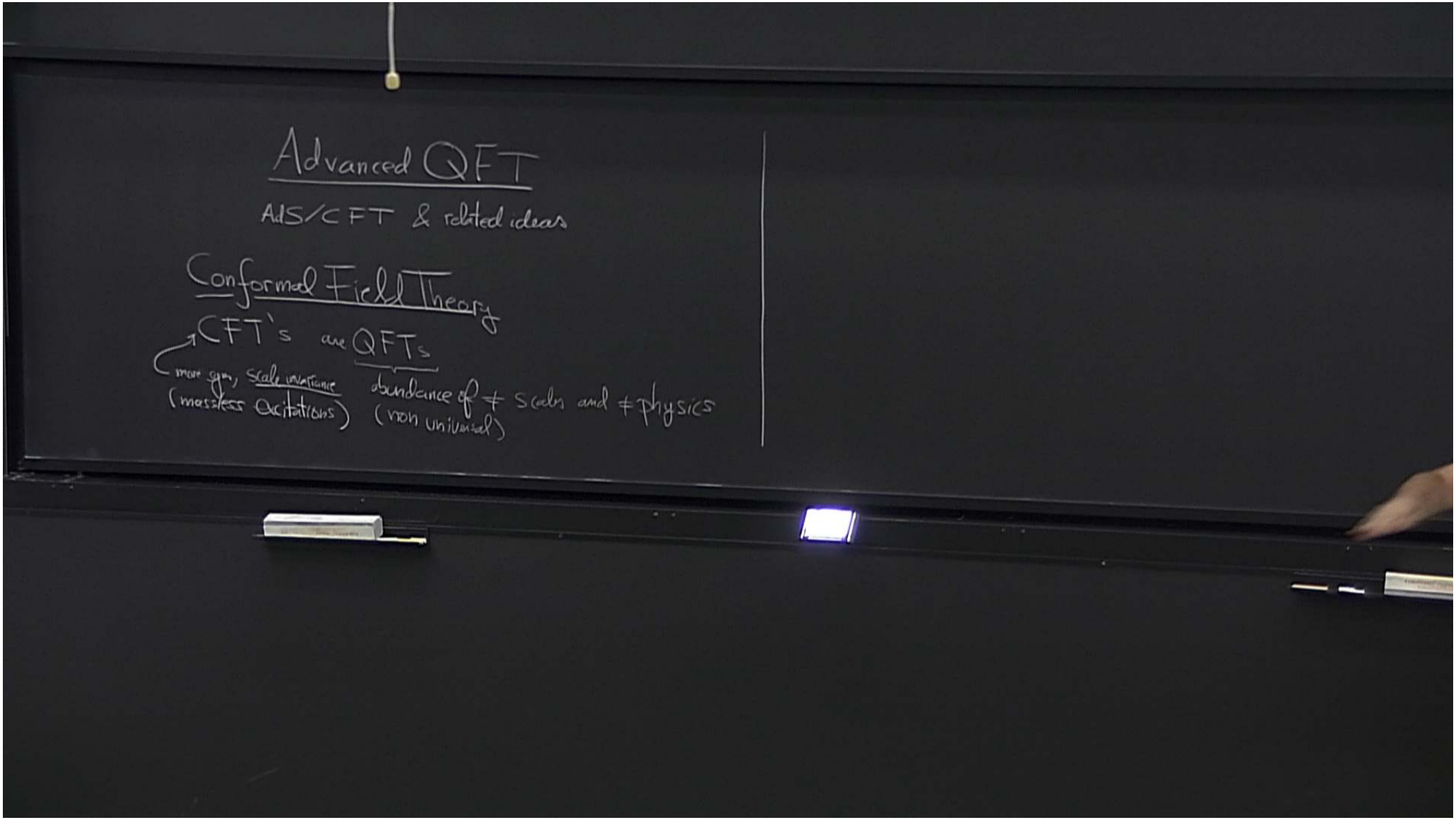
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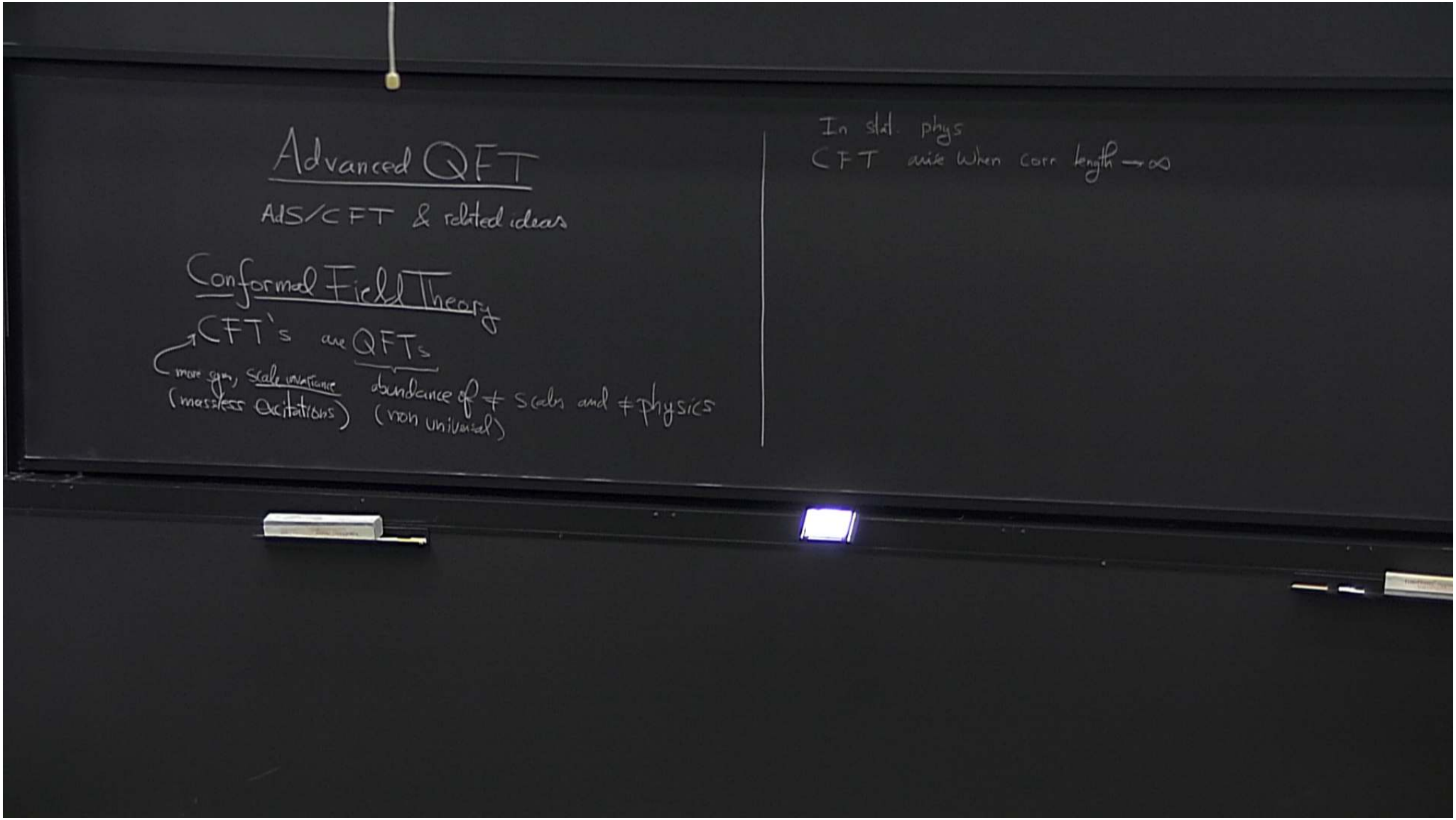
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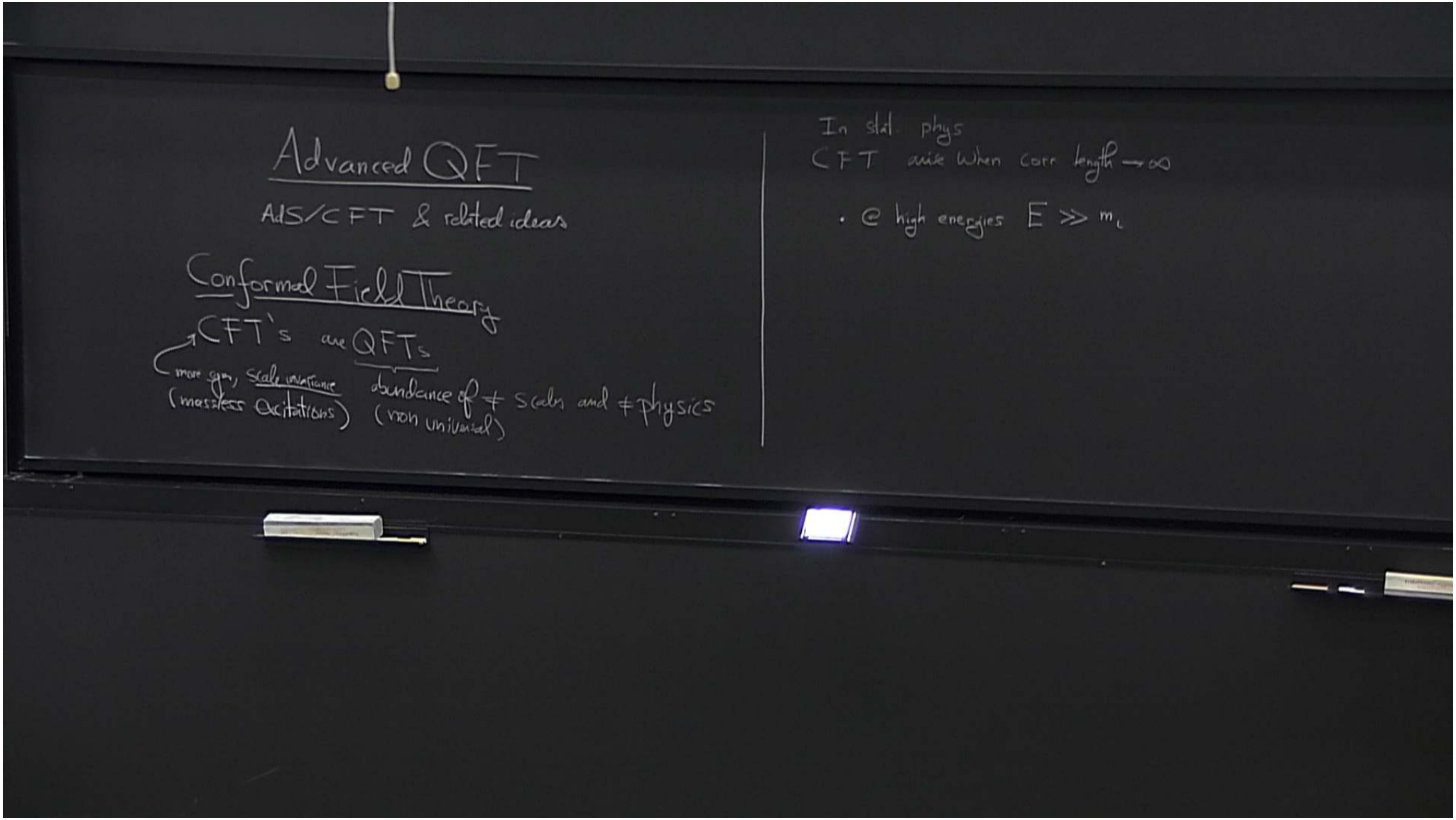
In std. phys
CFT arise when corr length → ∞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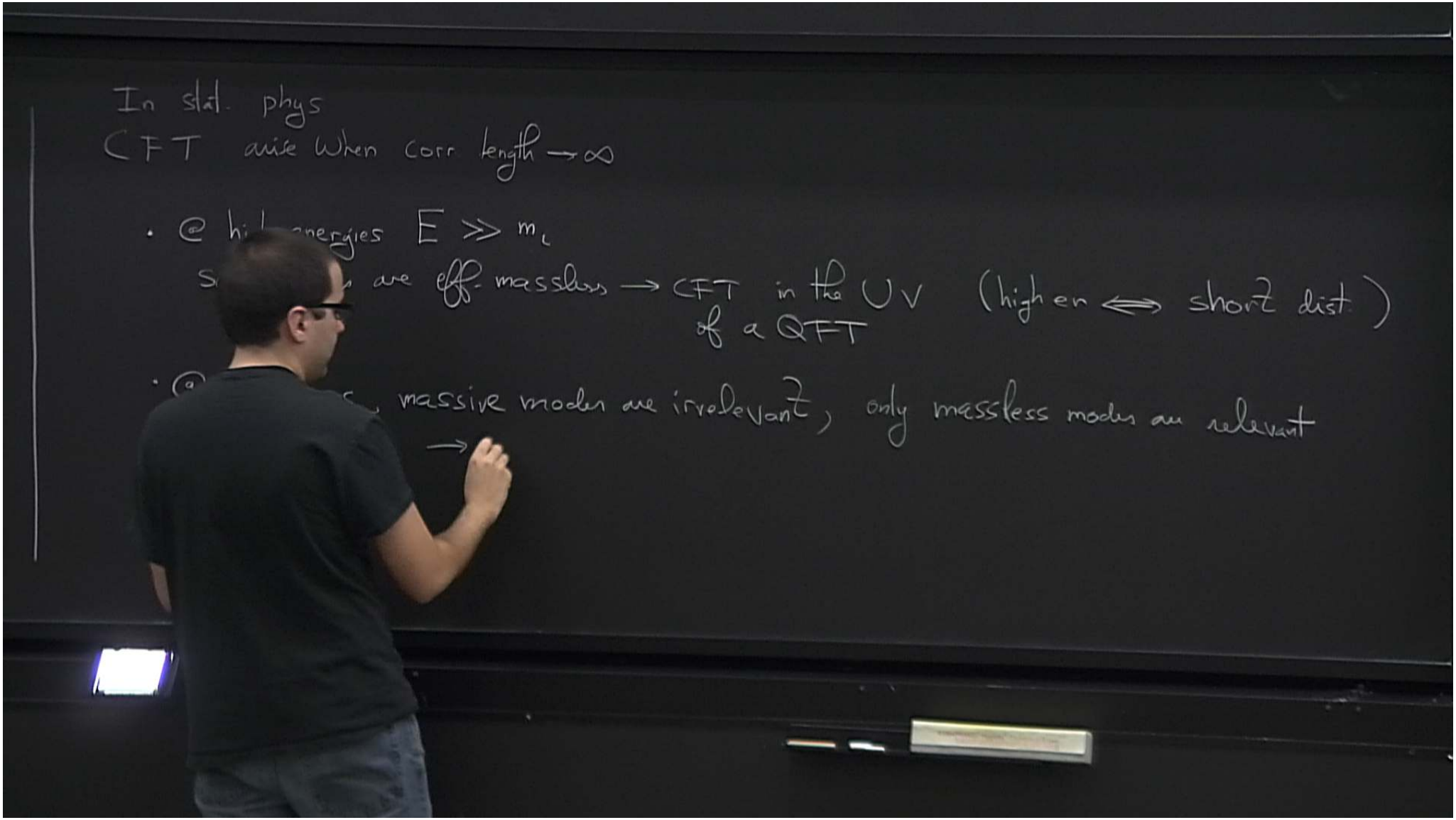
In std. phys
CFT arise when corr length → ∞
• @ high energies E ≫ m

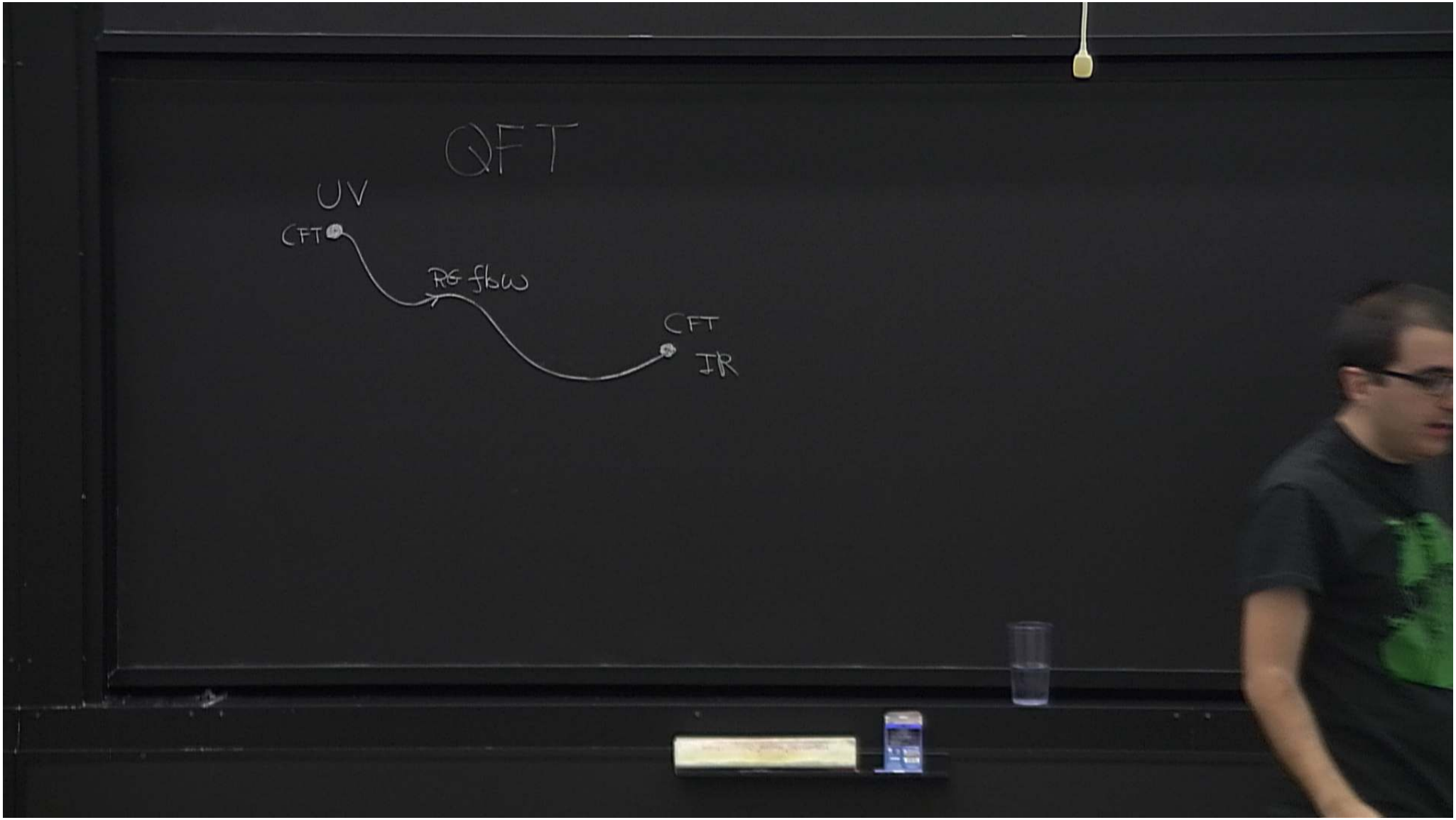
In stat. phys
CFT arise when corr length $\to \infty$

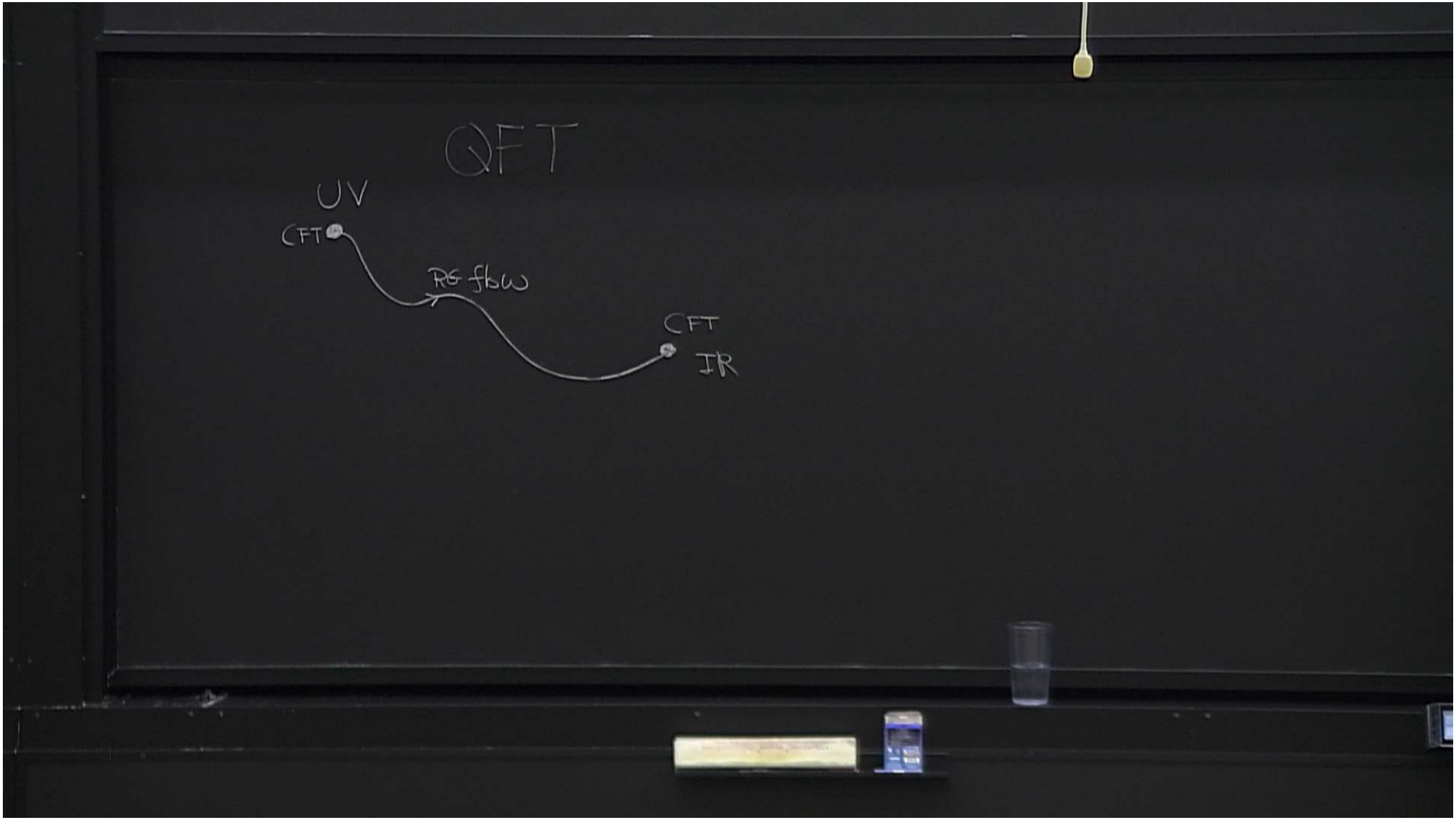
- @ high energies $E \gg m_i$
  so particles are eff. massless $\to$ CFT in the UV of a QFT (high en $\Leftrightarrow$ short dist.)


In stat. phys
CFT arise when corr length → ∞
• @ hi energies E ≫ m
are eff. massless → CFT in the UV of a QFT (high en ⟺ short dist)
massive modes are irrelevant, only massless modes are relevant
→

In stat. phys
CFT arise when corr length $\to \infty$

- @ high energies $E \gg m_i$
  so particles are eff. massless $\to$ CFT in the UV of a QFT (high en $\Leftrightarrow$ short dist.)
- @ low energies, massive modes are irrelevant, only massless modes are relevant
  $\to$ CTF in the IR (low en. or large distances) of a QFT


QFT
UV
CFT
RG flow
CFT
IR


QFT
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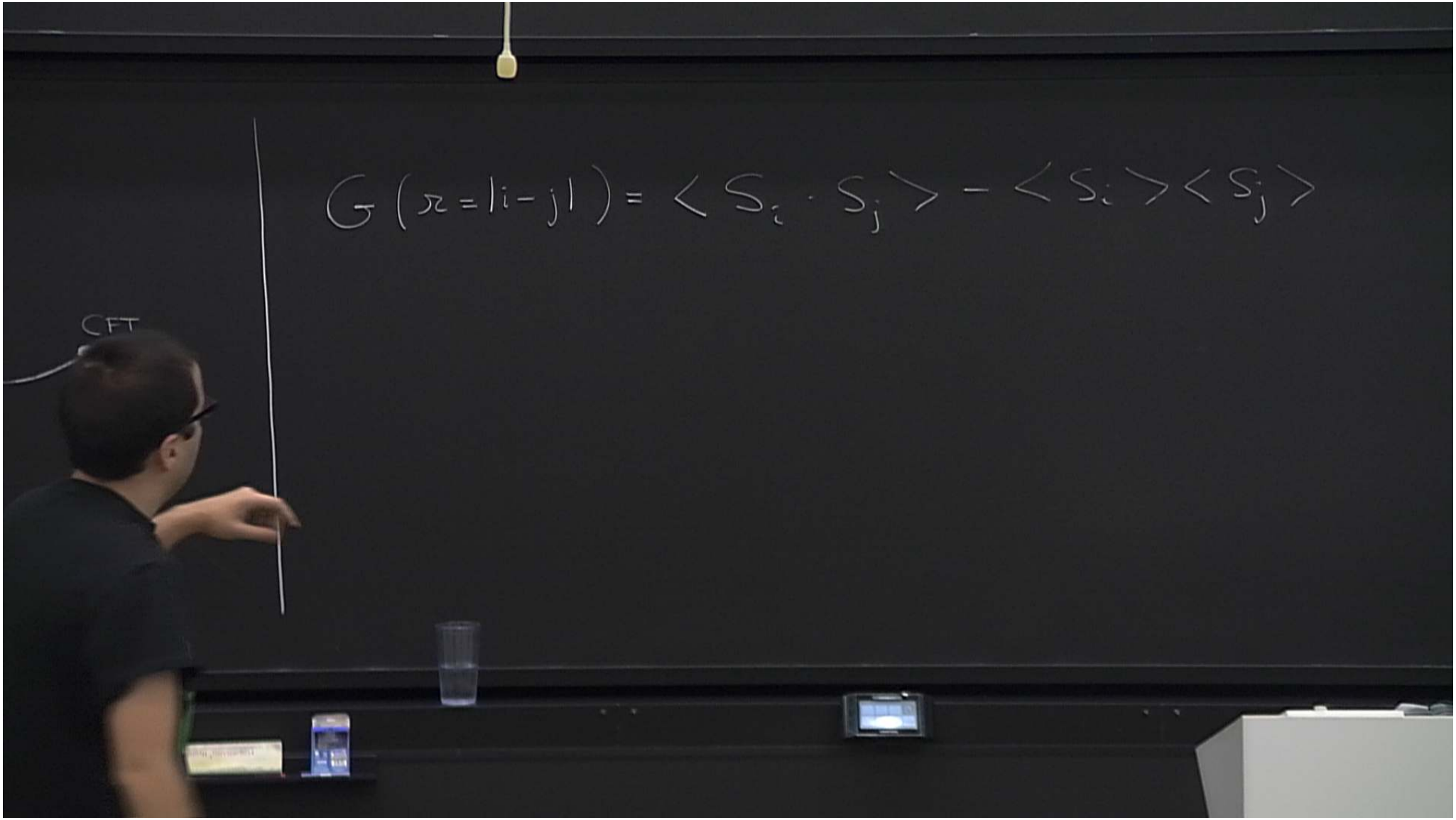
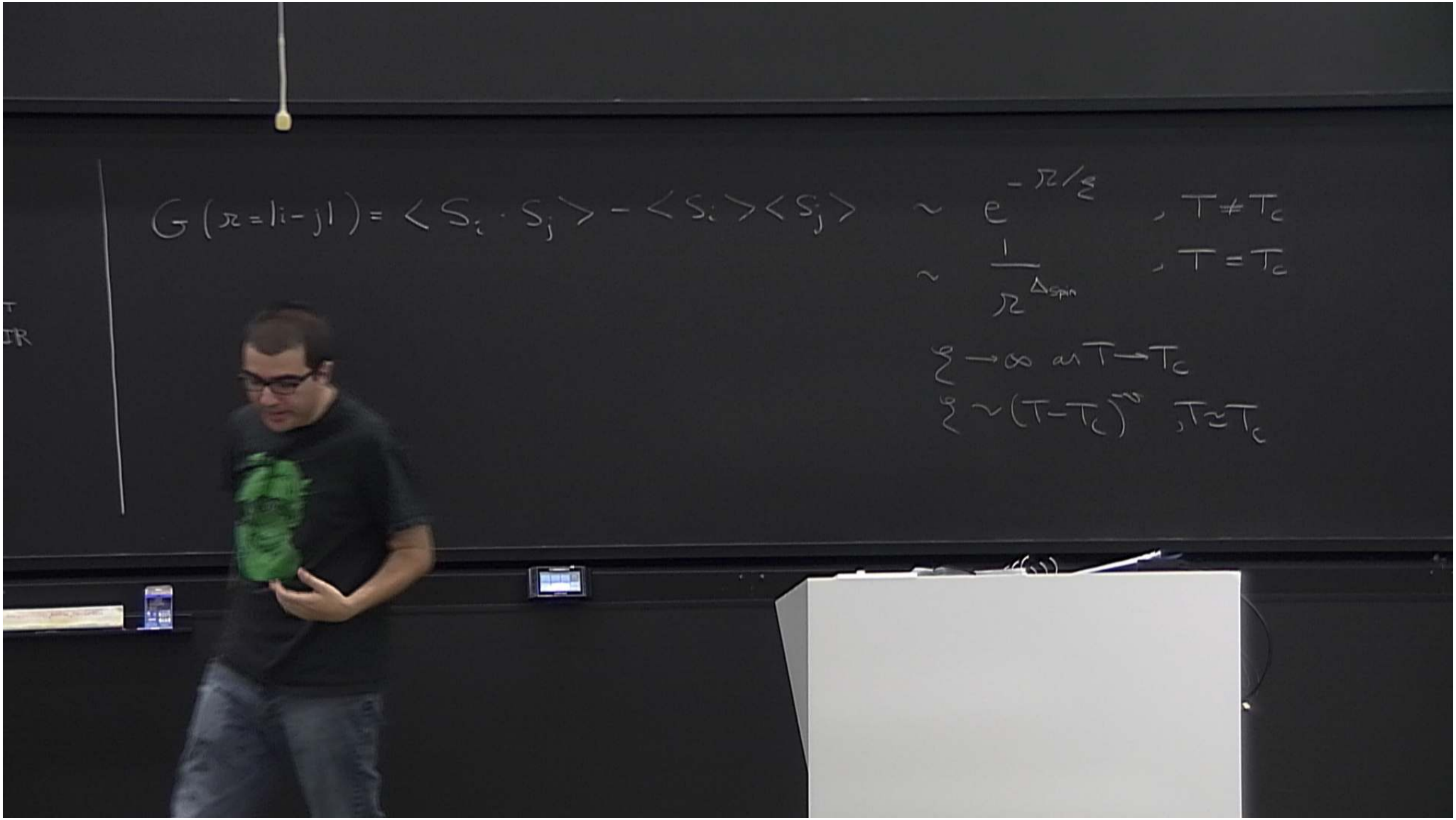
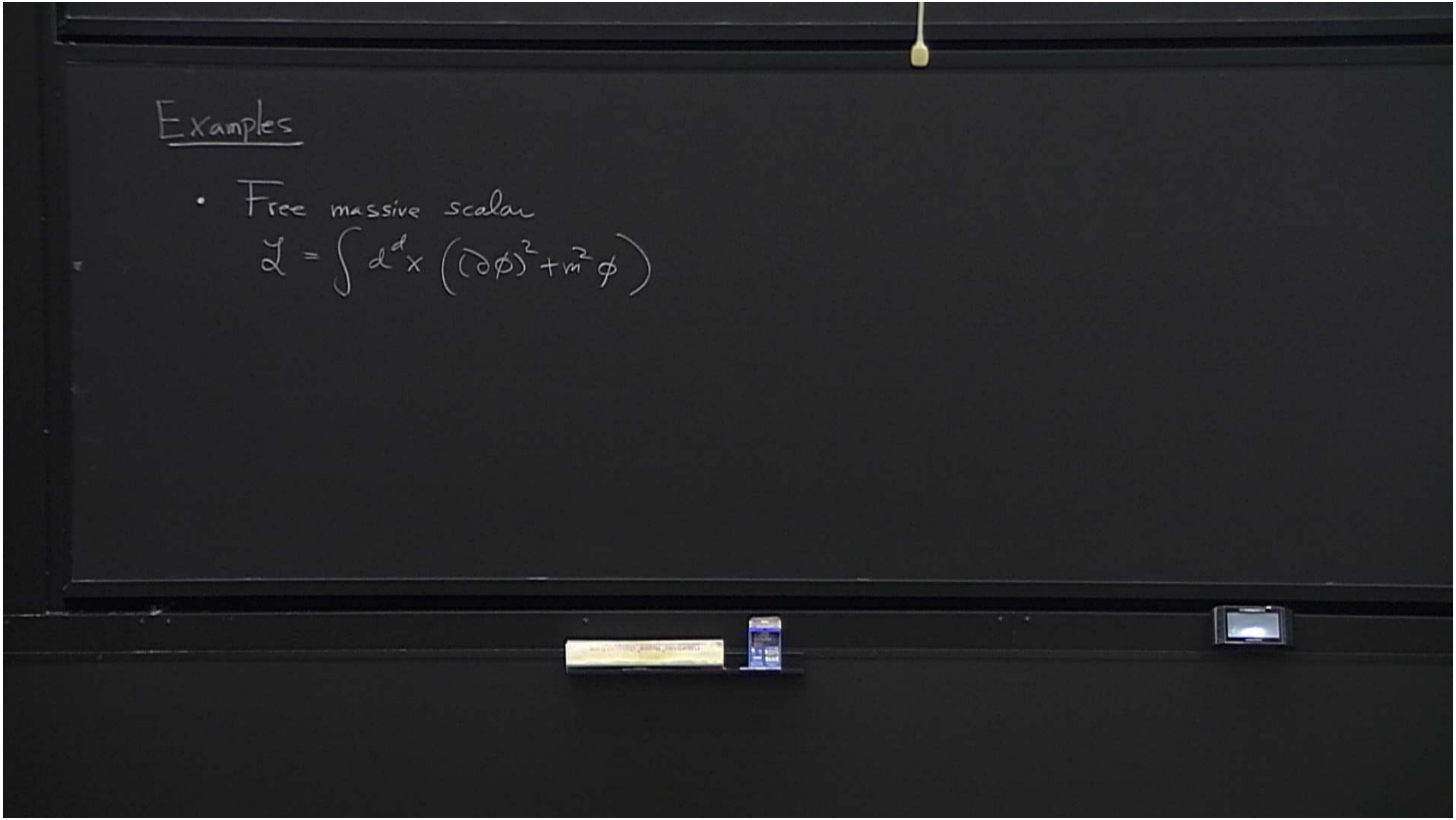

$G(r = |i-j|) = \langle S_i \cdot S_j \rangle - \langle S_i \rangle \langle S_j \rangle$
CFT

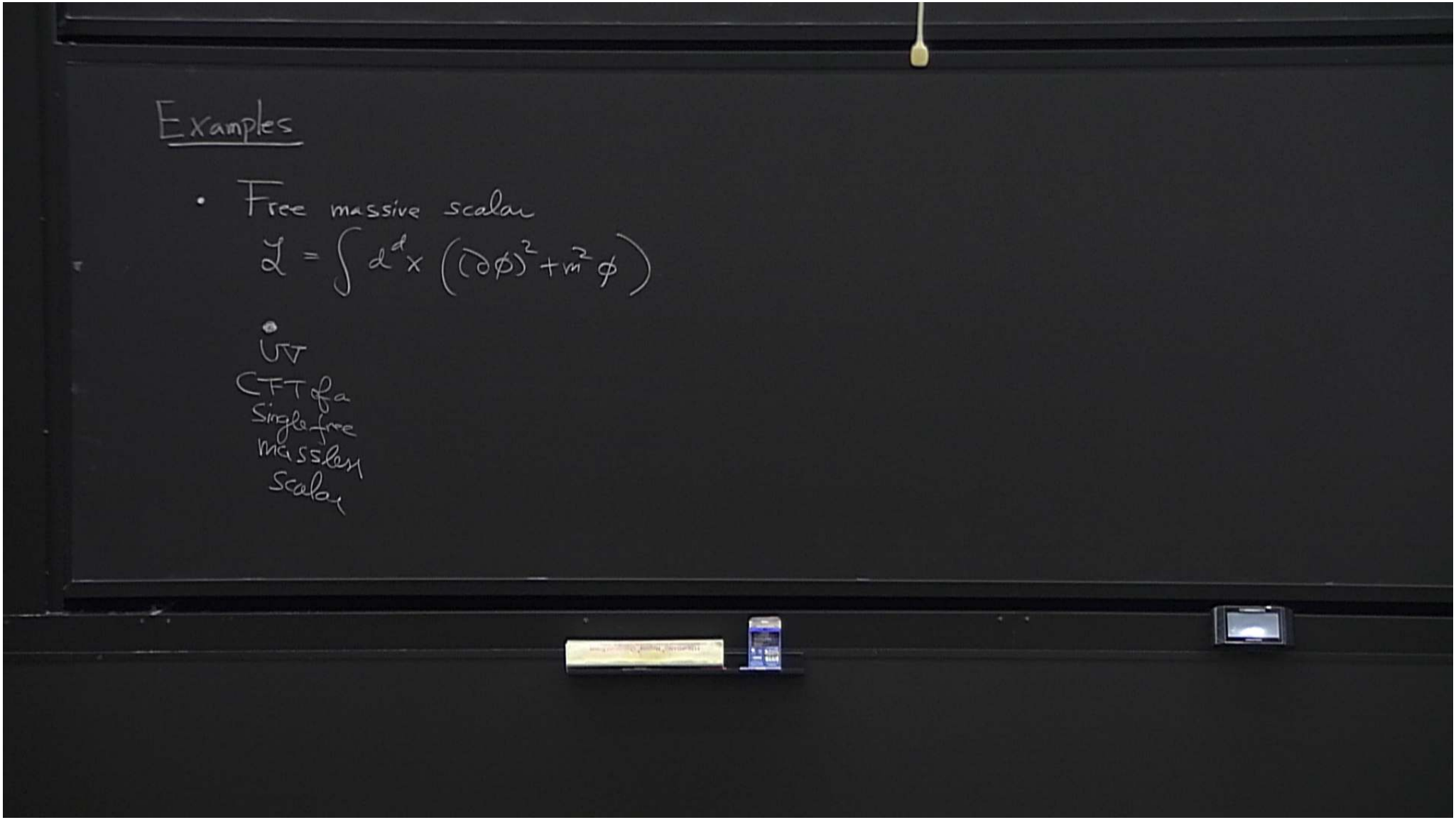

$G(r=|i-j|) = \langle S_i \cdot S_j \rangle - \langle S_i \rangle \langle S_j \rangle \sim e^{-r/\xi}$, $T \neq T_c$
$\sim \frac{1}{r^{\Delta_{spin}}}$, $T = T_c$
$\xi \to \infty$ as $T \to T_c$
$\xi \sim (T - T_c)^{\nu}$, $T \simeq T_c$

Examples

- Free massive scalar

$$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi \right)$$

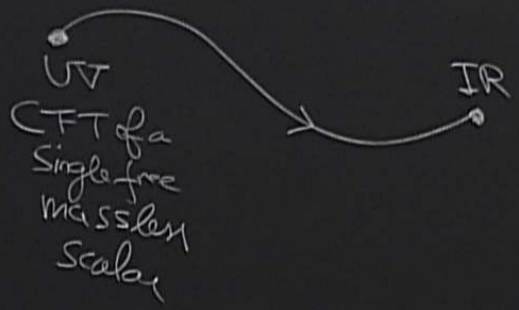



Examples
• Free massive scalar
$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi \right)$
• UV CFT of a single free massless scalar

Examples

- Free massive scalar

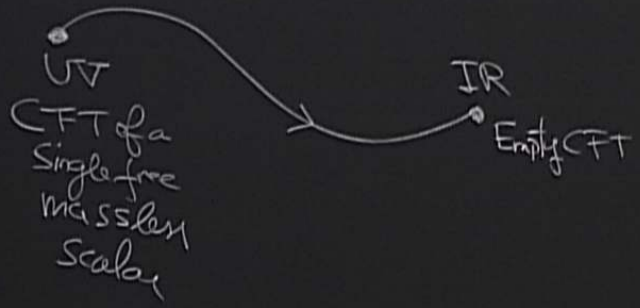
$$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi \right)$$



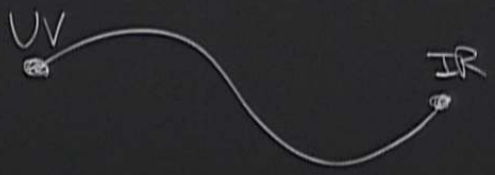
Examples

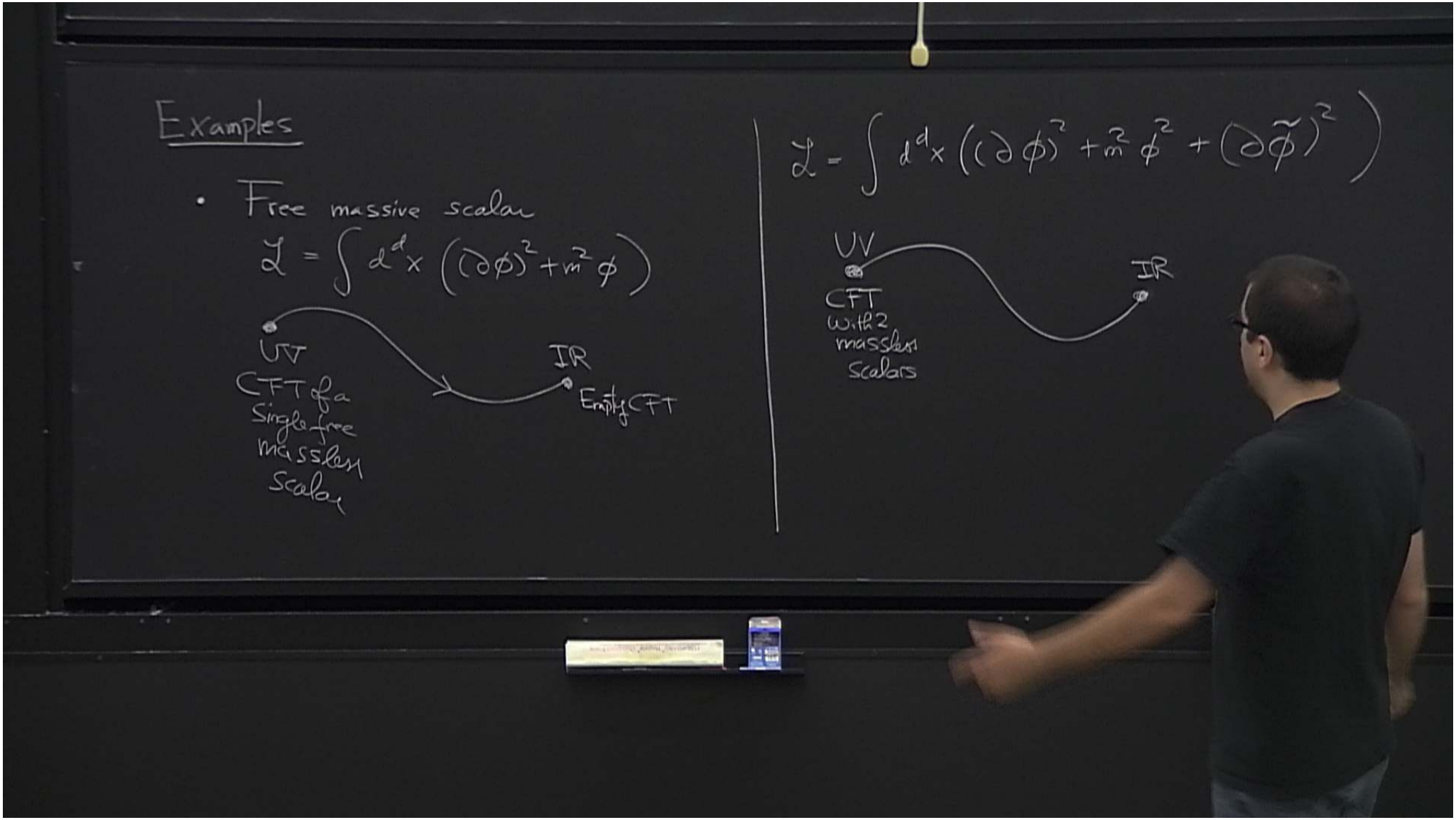
- Free massive scalar

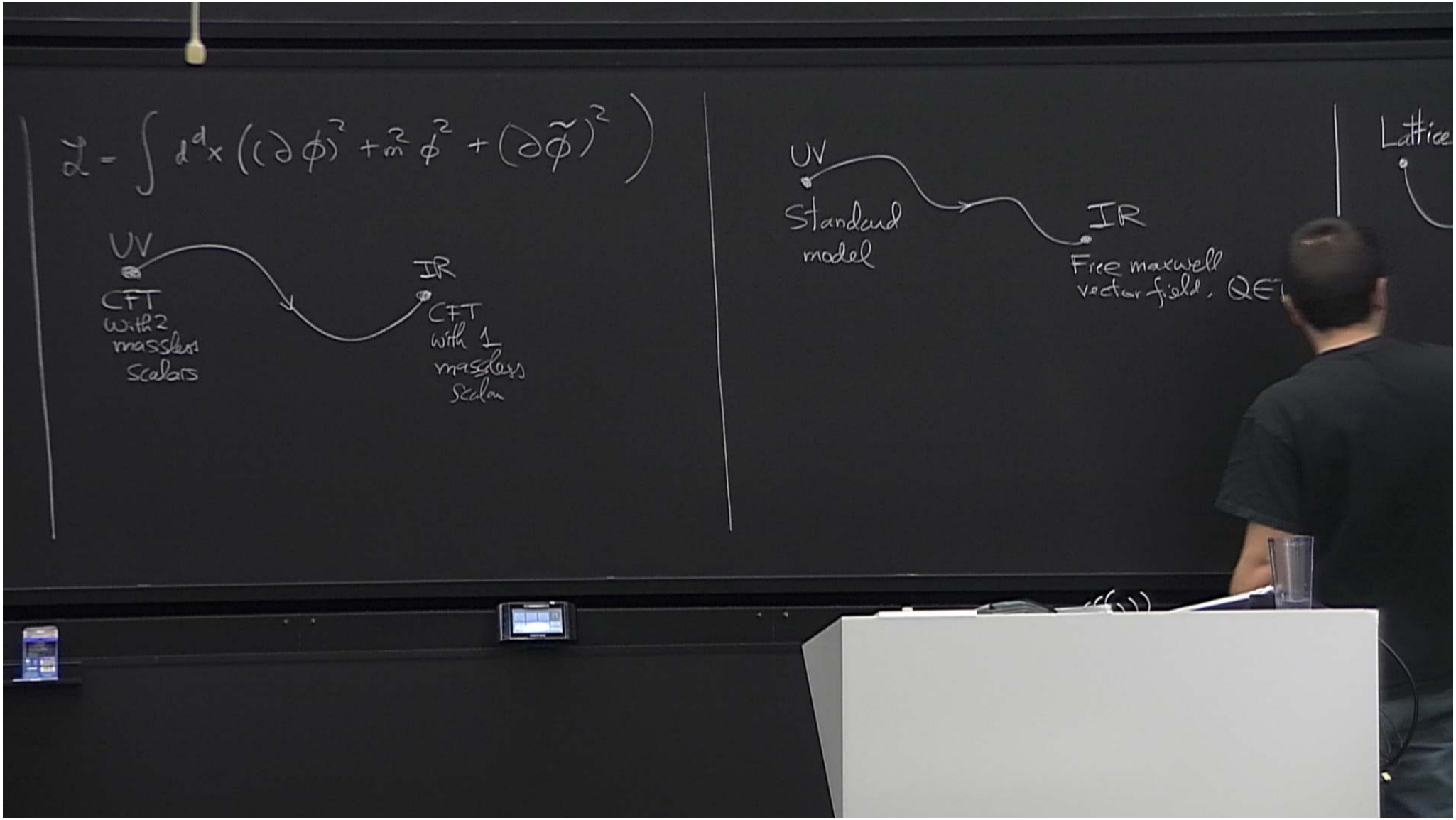
$$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi \right)$$

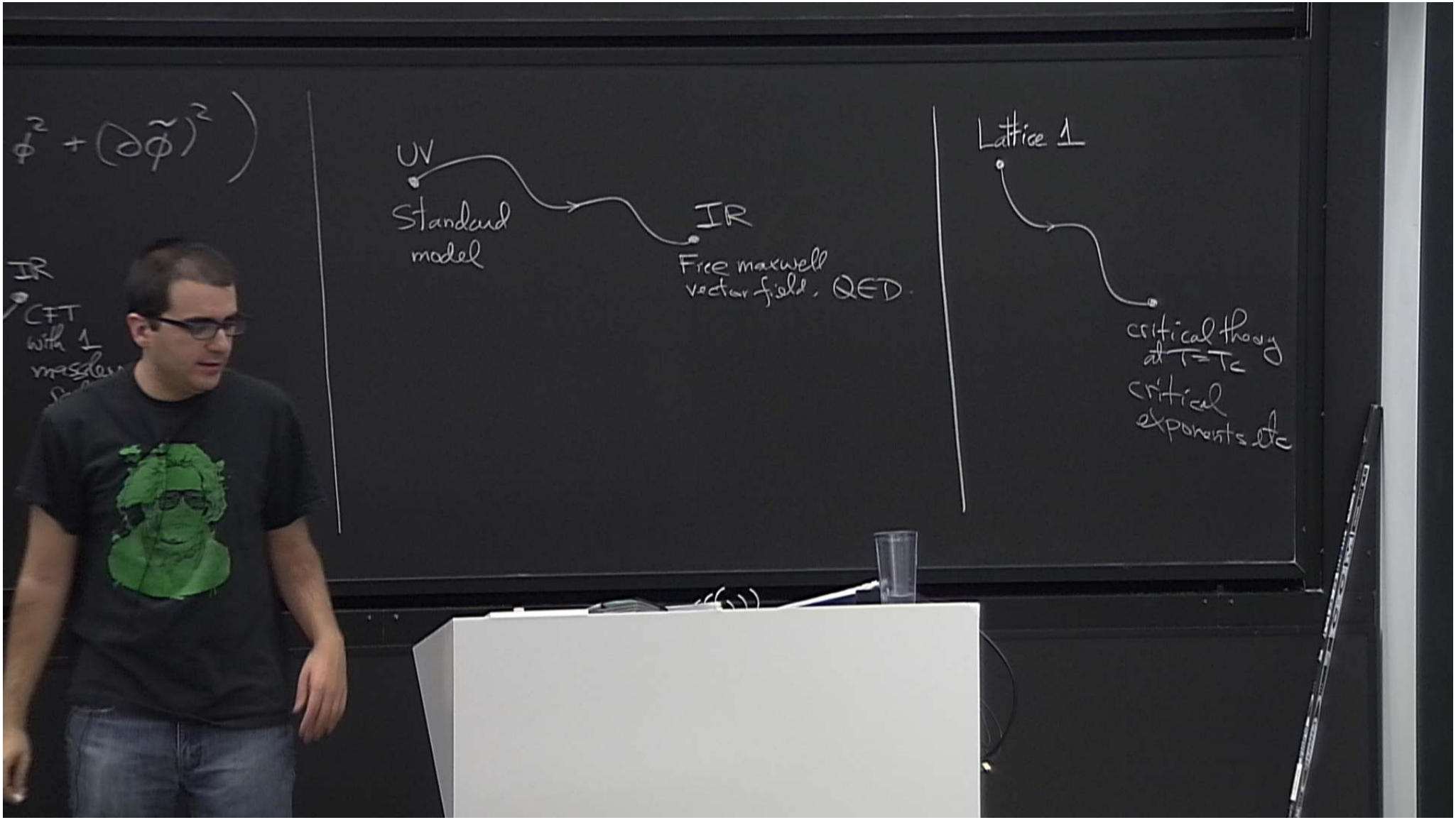


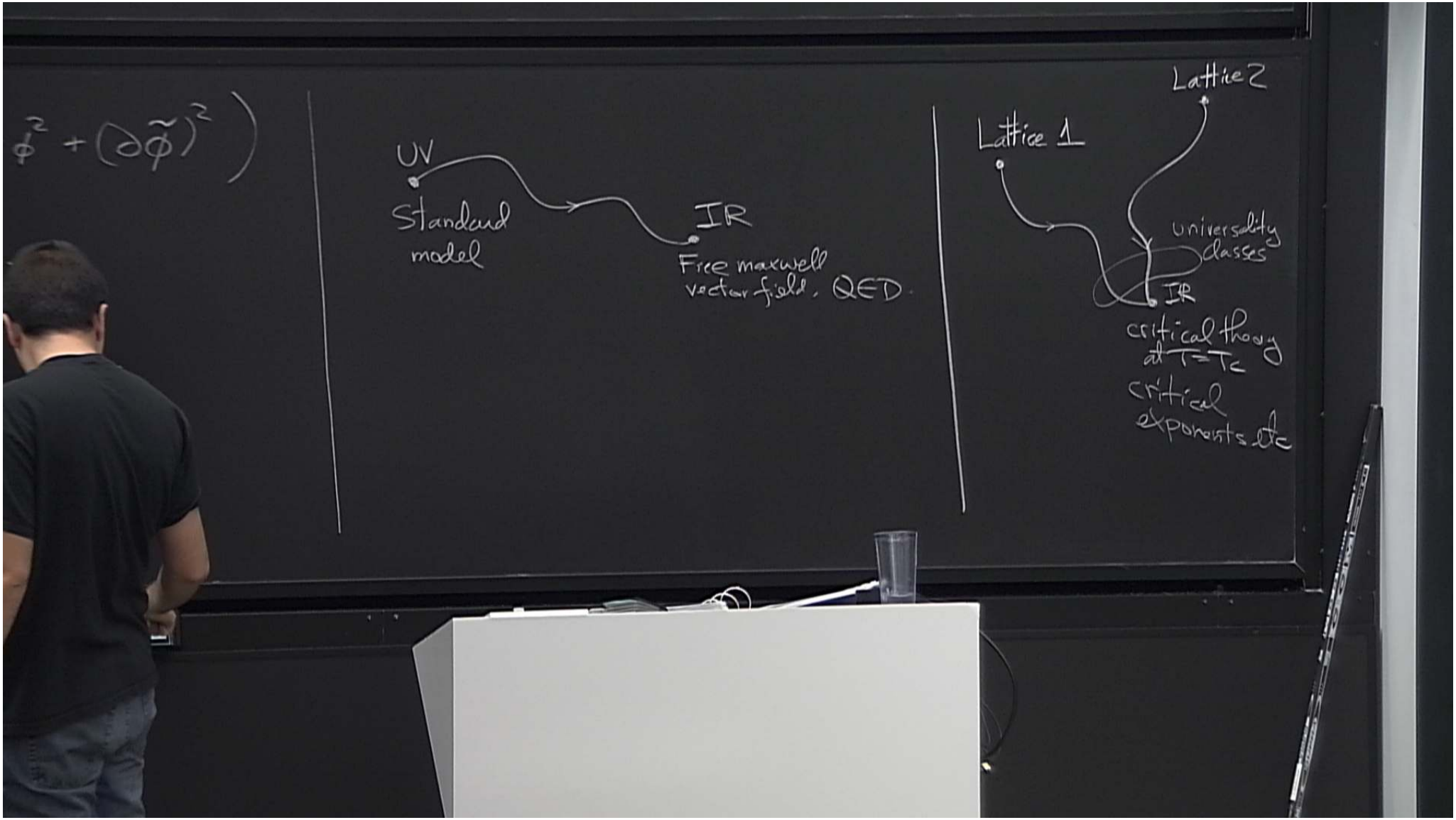
$$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi^2 + (\partial\tilde{\phi})^2 \right)$$

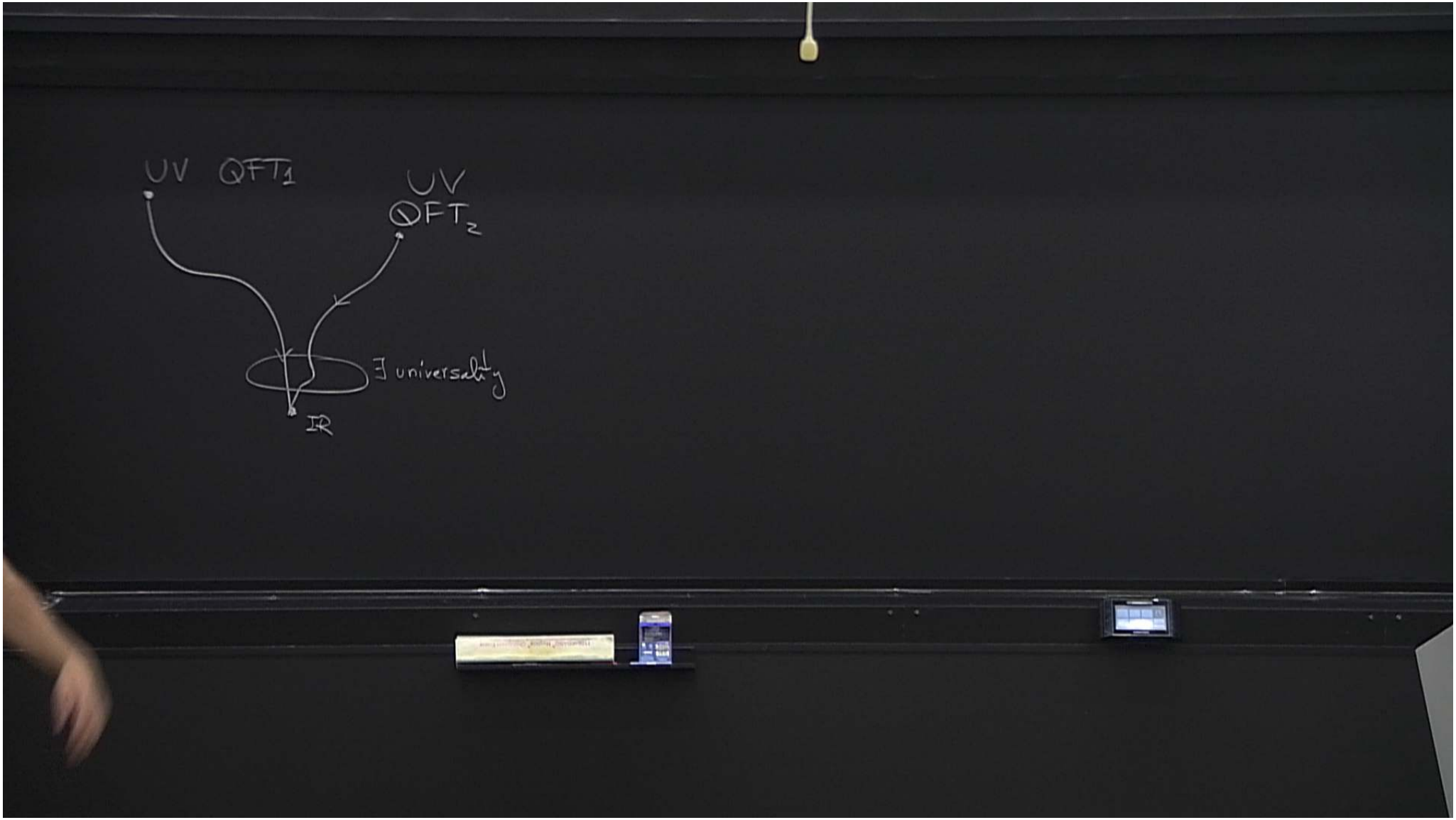


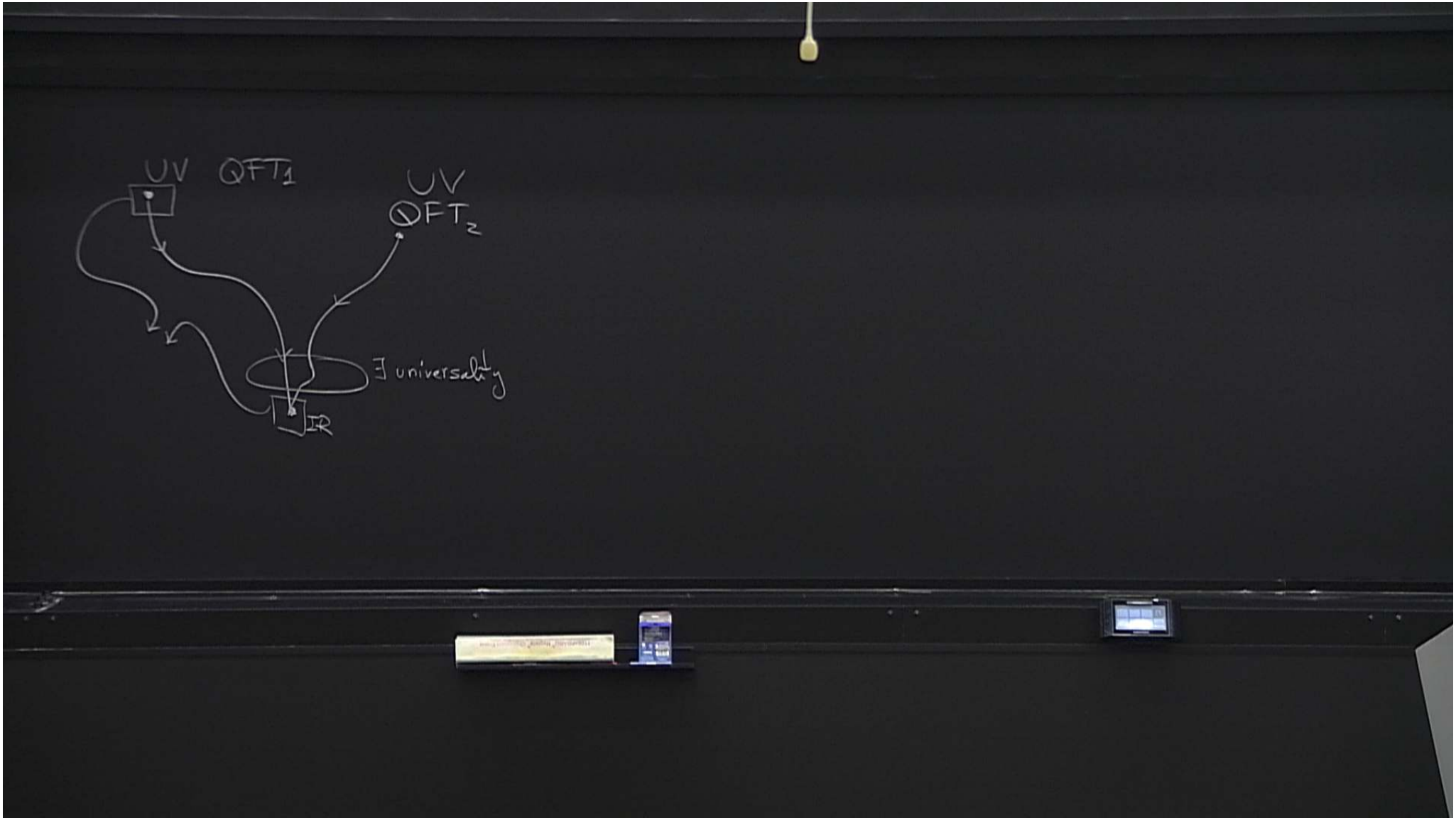

Examples
Free massive scalar
$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi \right)$
UV
CFT of a single free massless scalar
IR
Empty CFT
$\mathcal{L} = \int d^d x \left((\partial\phi)^2 + m^2 \phi^2 + (\partial\tilde{\phi})^2 \right)$
UV
CFT with 2 massless scalars
IR

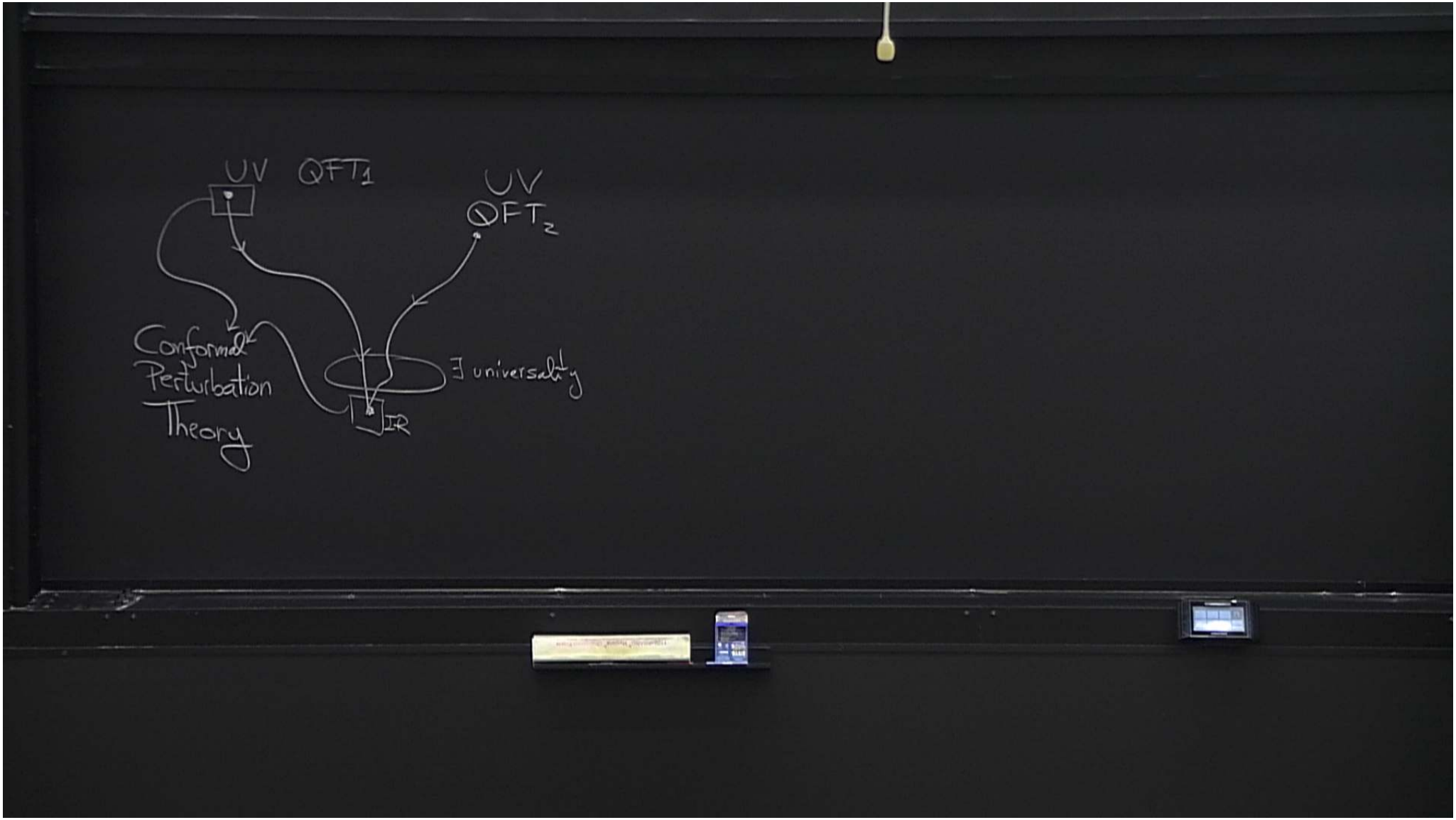

$\mathcal{L} = \int d^d x \left((\partial \phi)^2 + m^2 \phi^2 + (\partial \tilde{\phi})^2 \right)$
UV
CFT with 2 massless scalars
IR
CFT with 1 massless scalar
UV
Standard model
IR
Free maxwell vector field, QE
Lattice

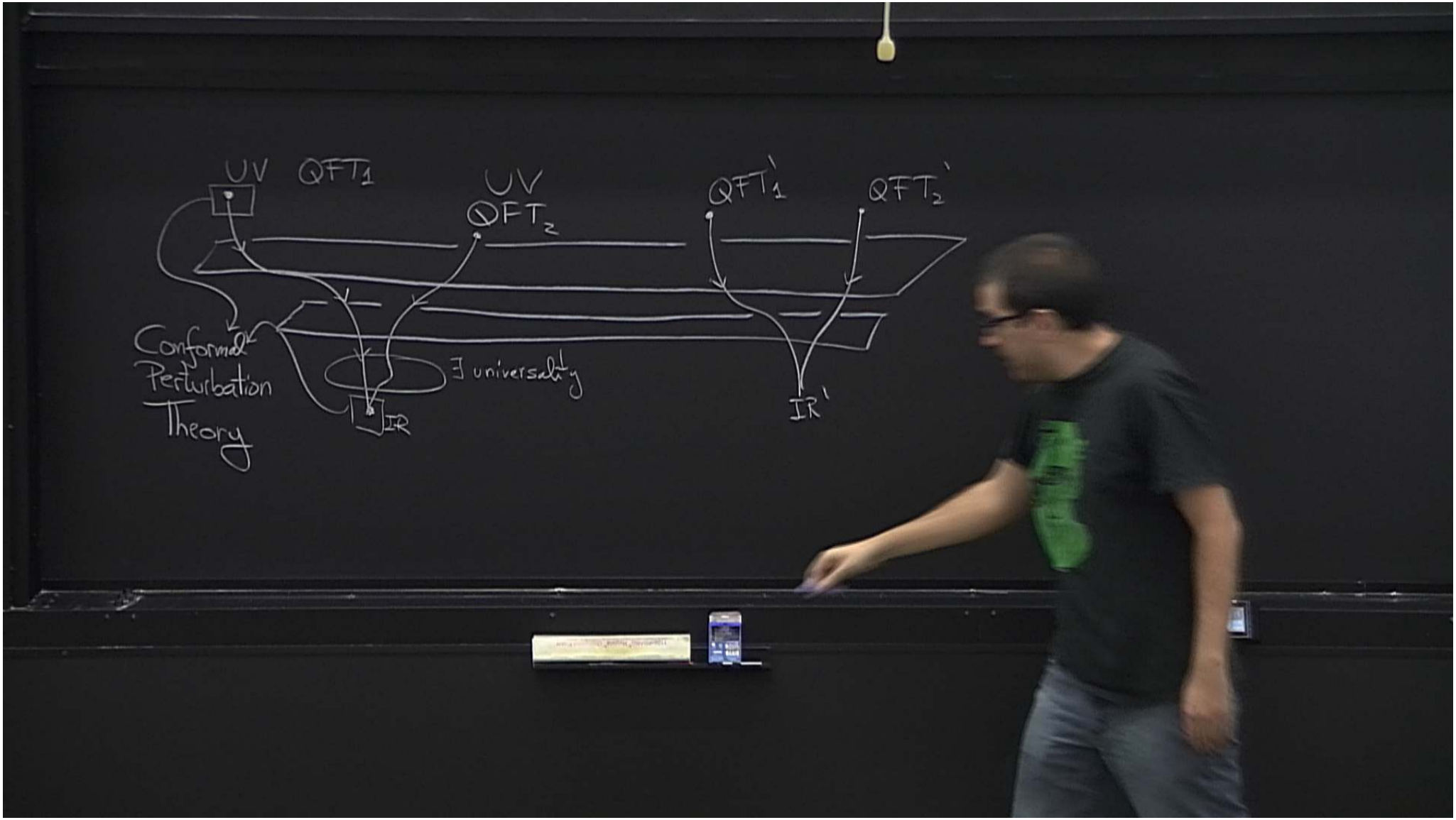

$\phi^2 + (\partial\tilde{\phi})^2$)
IR
CFT
with 1
UV
Standard
model
IR
Free maxwell
vector field. QED.
Lattice 1
critical theory
at T=Tc
critical
exponents etc

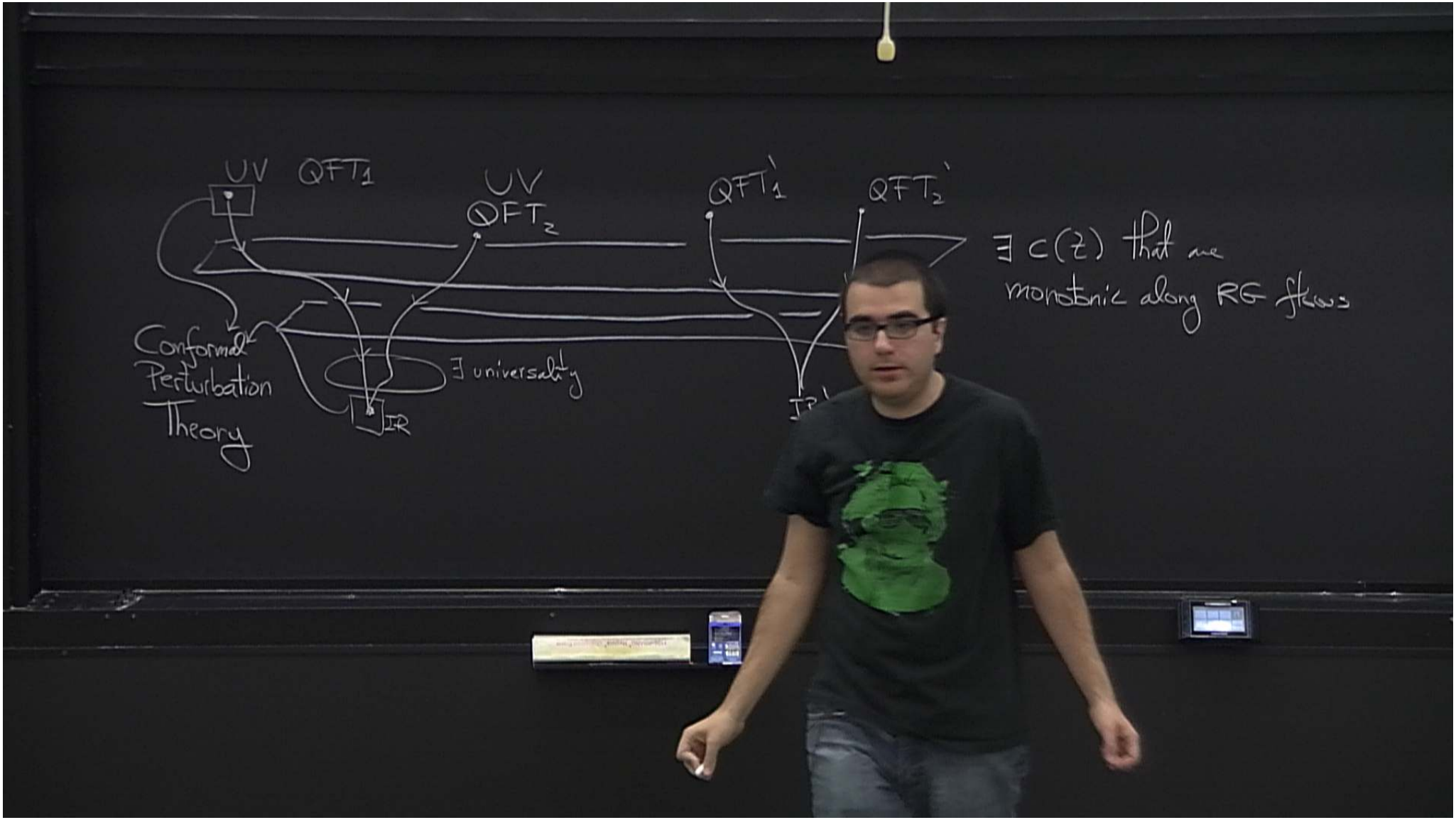

$\phi^2 + (\partial\tilde{\phi})^2$)
UV
Standard model
IR
Free maxwell vector field. QED
Lattice 2
Lattice 1
universality classes
IR
critical theory at T=Tc
critical exponents etc

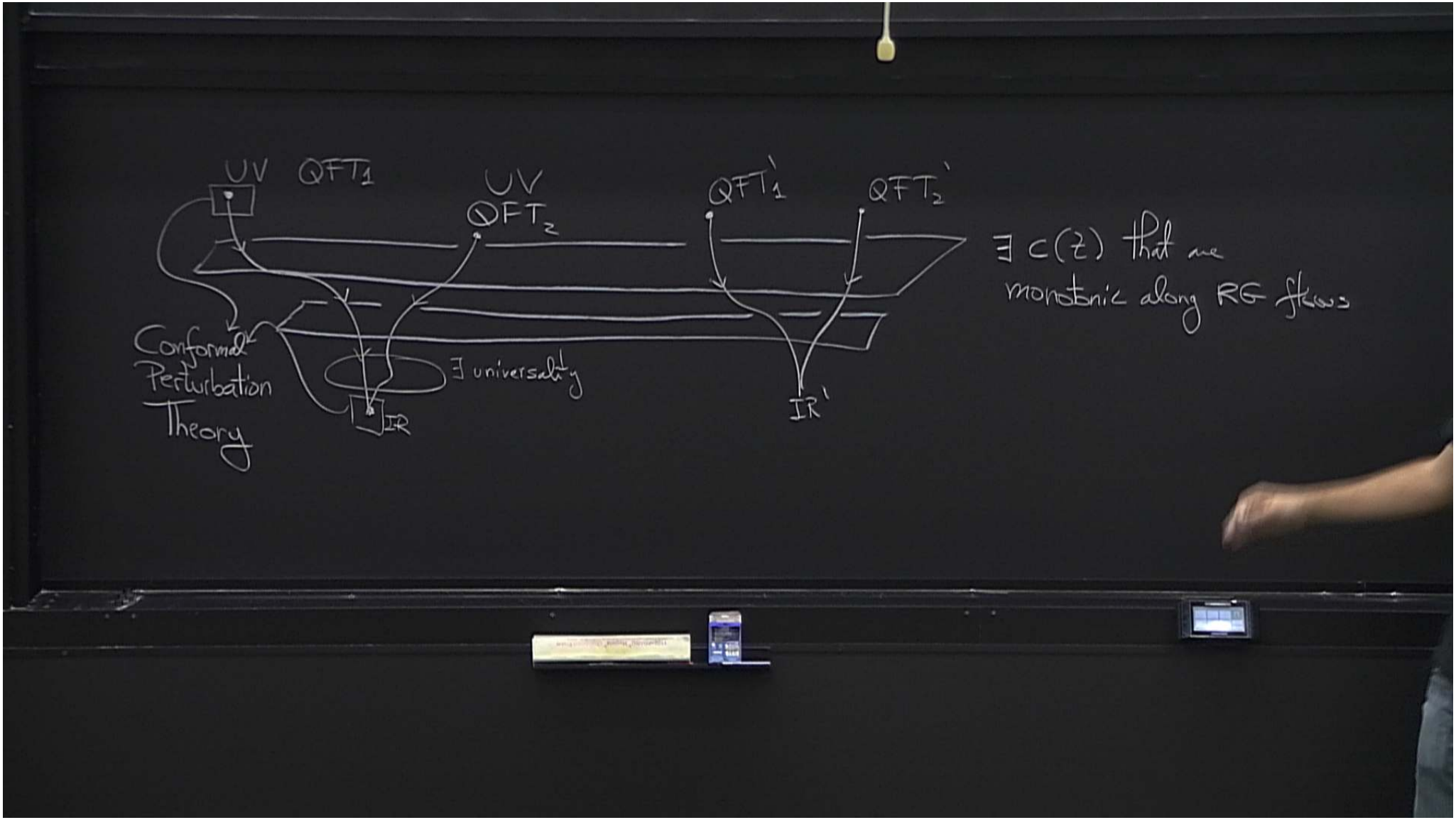

UV QFT1
UV
QFT2
∃ universality
IR


UV QFT1
UV QFT2
∃ universality
IR


UV QFT1
UV QFT2
Conformal Perturbation Theory
∃ universality
IR


UV QFT1
UV QFT2
QFT1'
QFT2'
Conformal Perturbation Theory
∃ universality
IR
IR'


UV QFT1
UV QFT2
QFT1'
QFT2'
∃ c(z) that are monotonic along RG flows
Conformal Perturbation Theory
∃ universality
IR


UV QFT1
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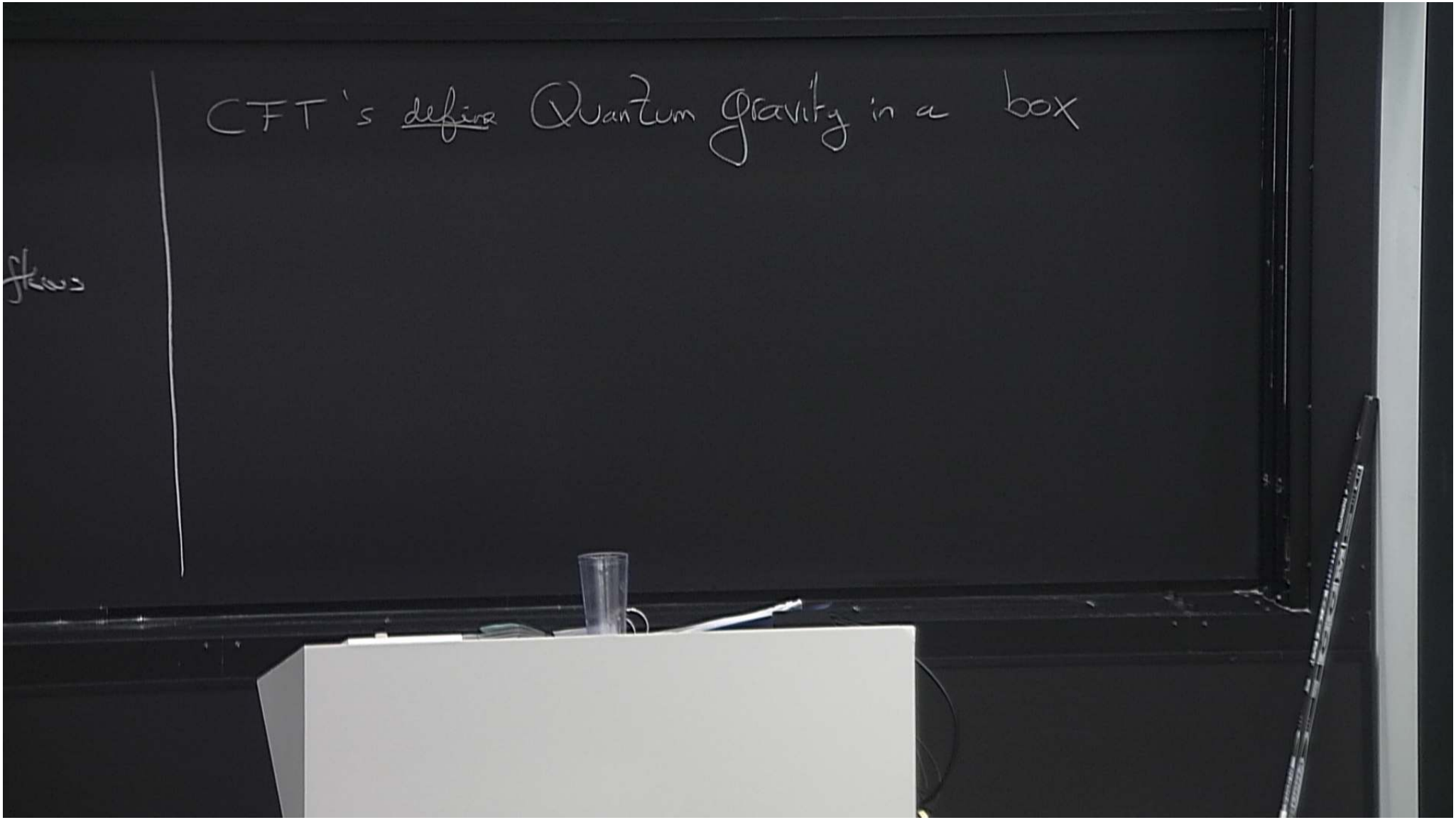
CFT's define Quantum gravity in a box

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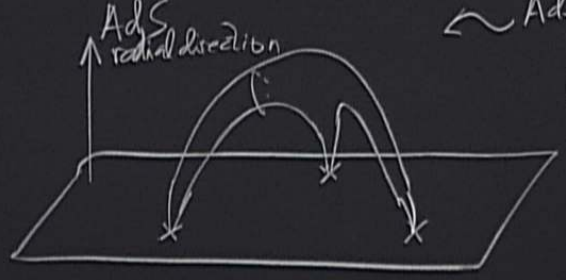
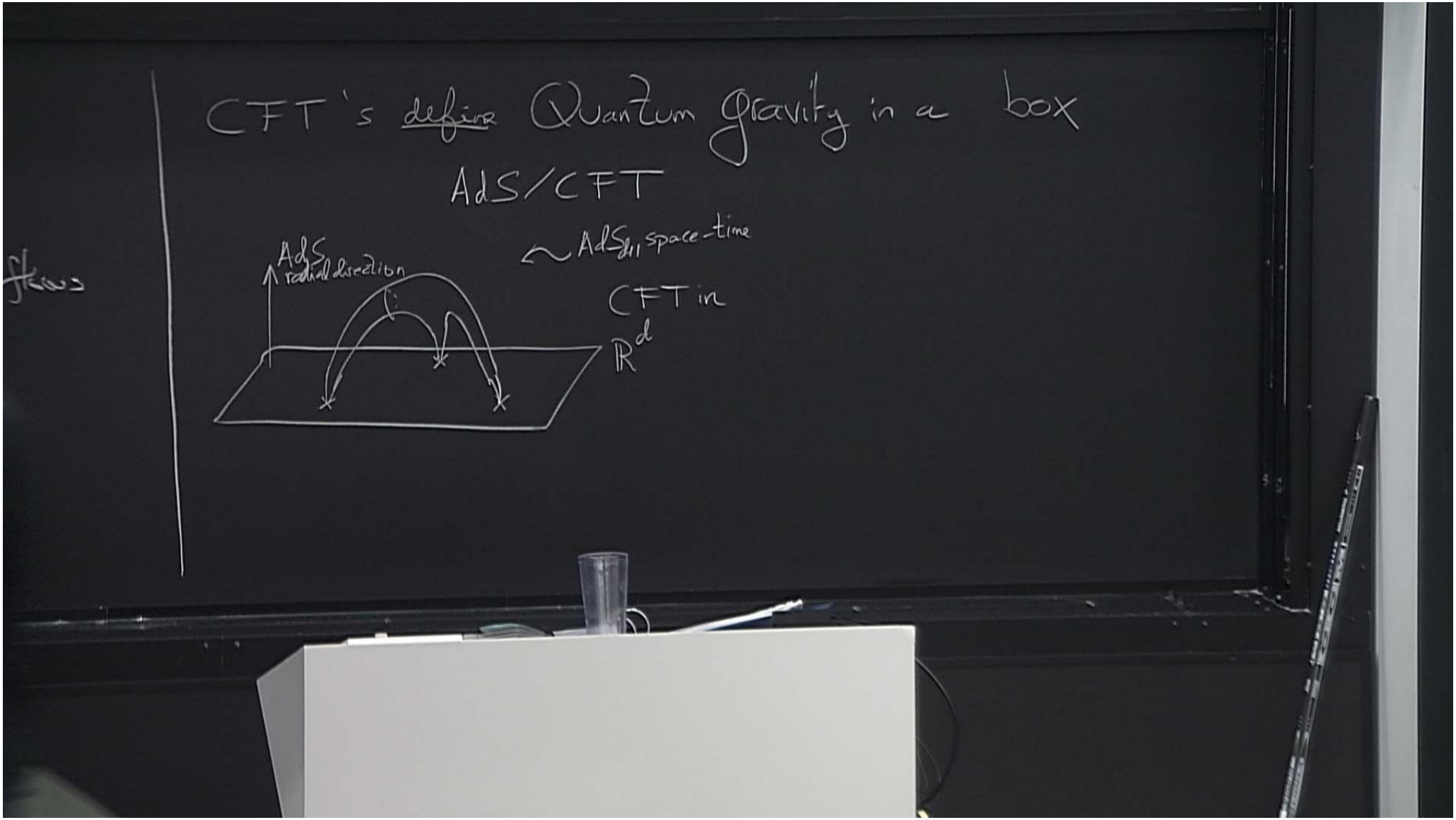
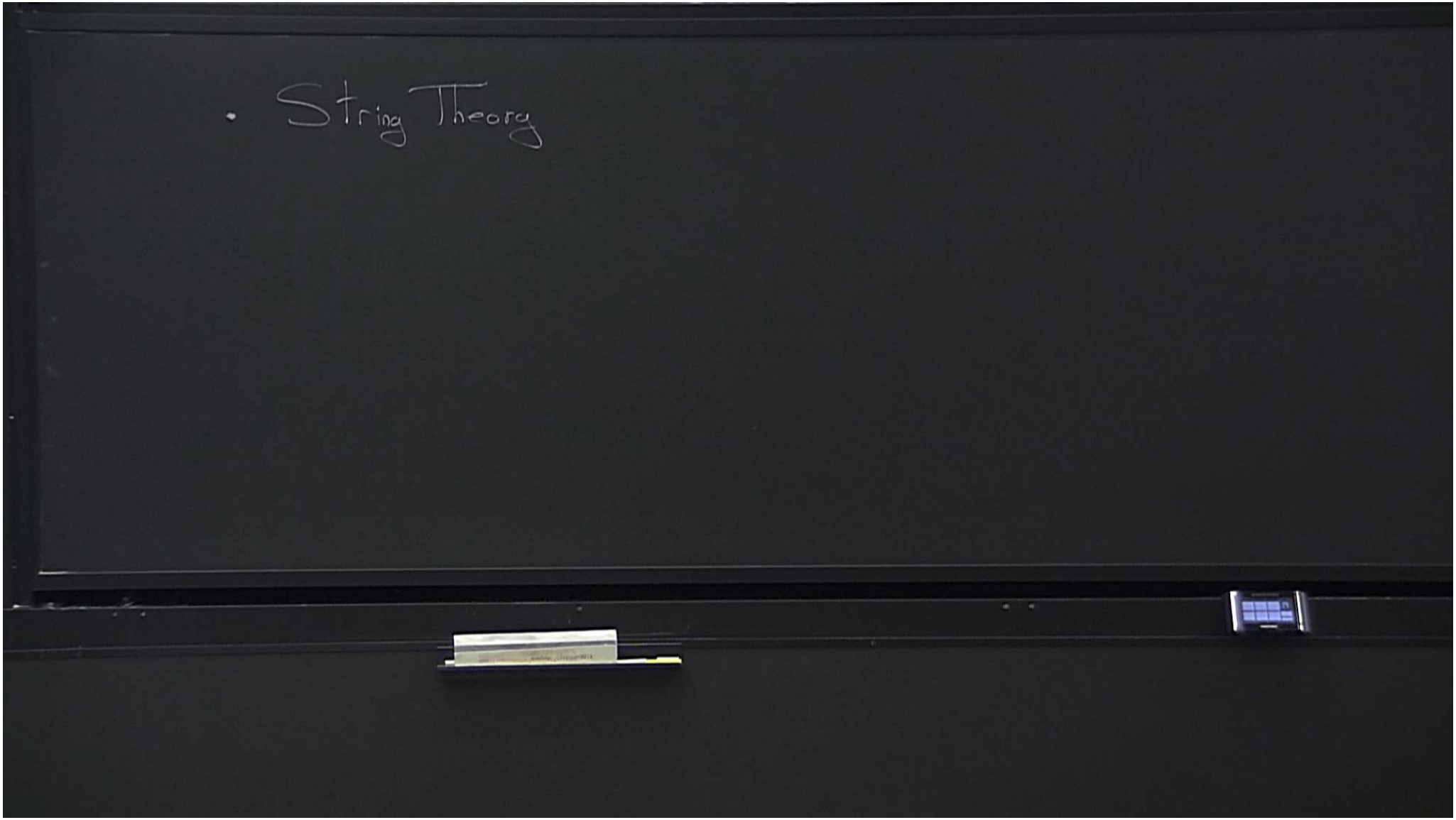
AdS/CFT

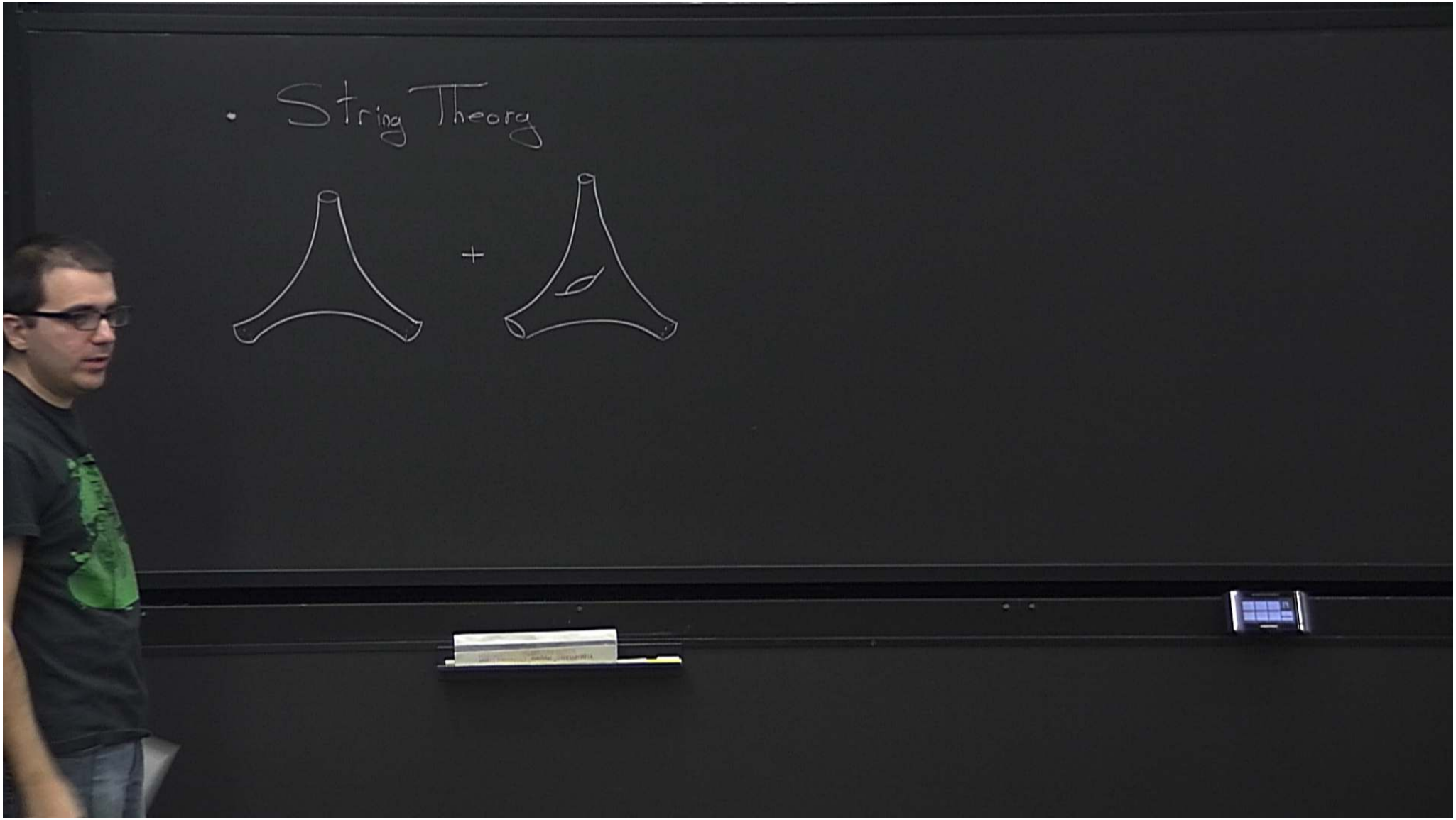


$\sim$ AdS_{d+1} space-time

CFT in $\mathbb{R}^d$


CFT's define Quantum gravity in a box
AdS/CFT
AdS radial direction
~ AdS$_{d+1}$ space-time
CFT in
$\mathbb{R}^d$


• String Theory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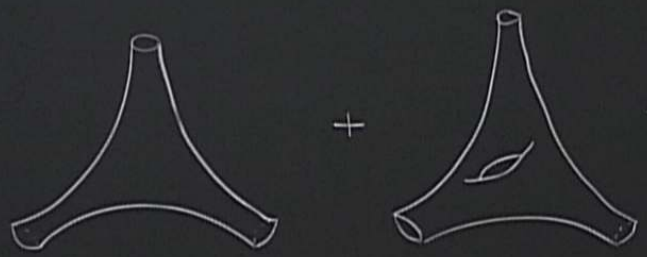
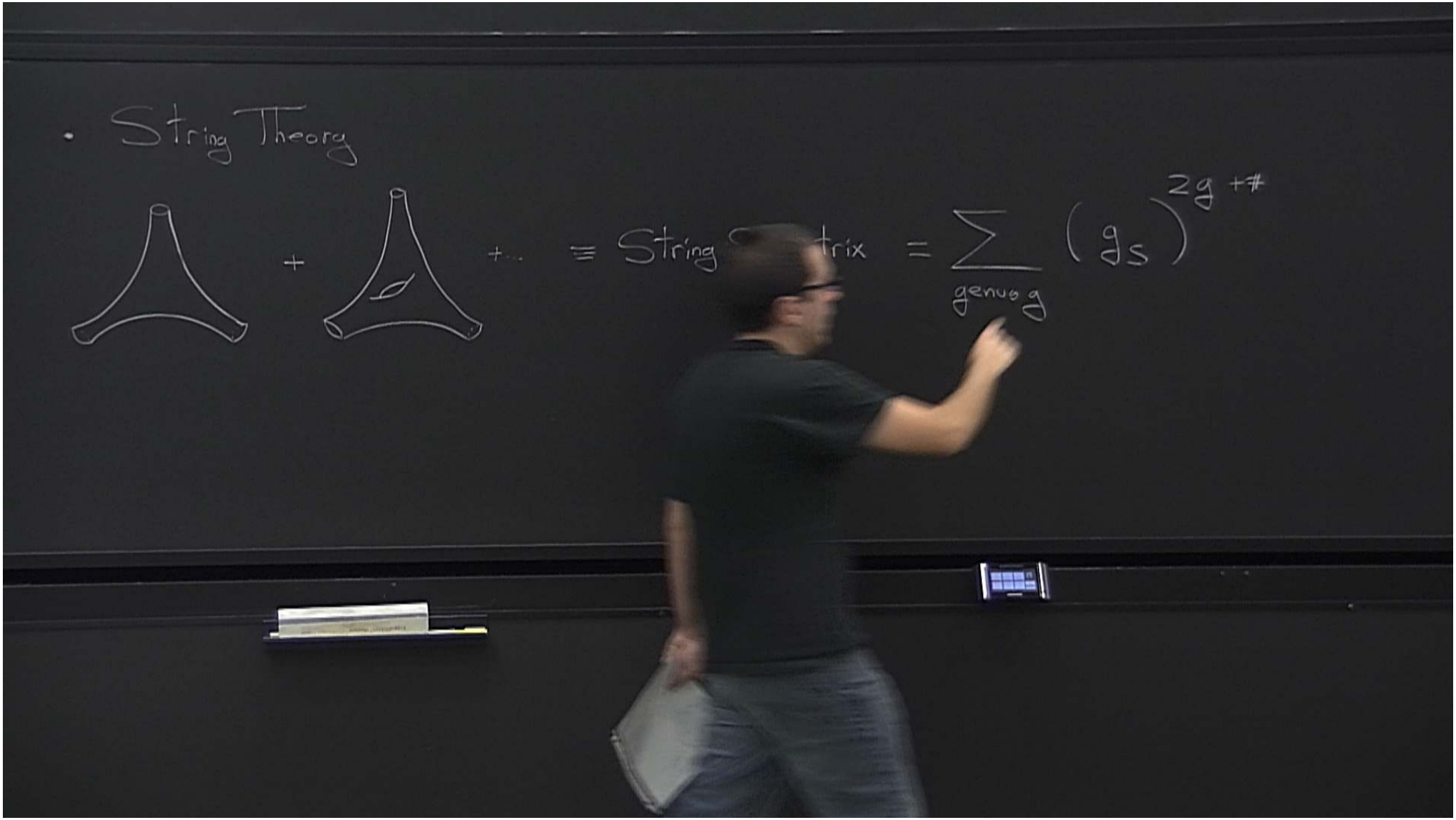
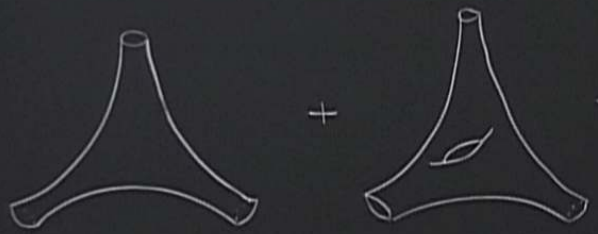


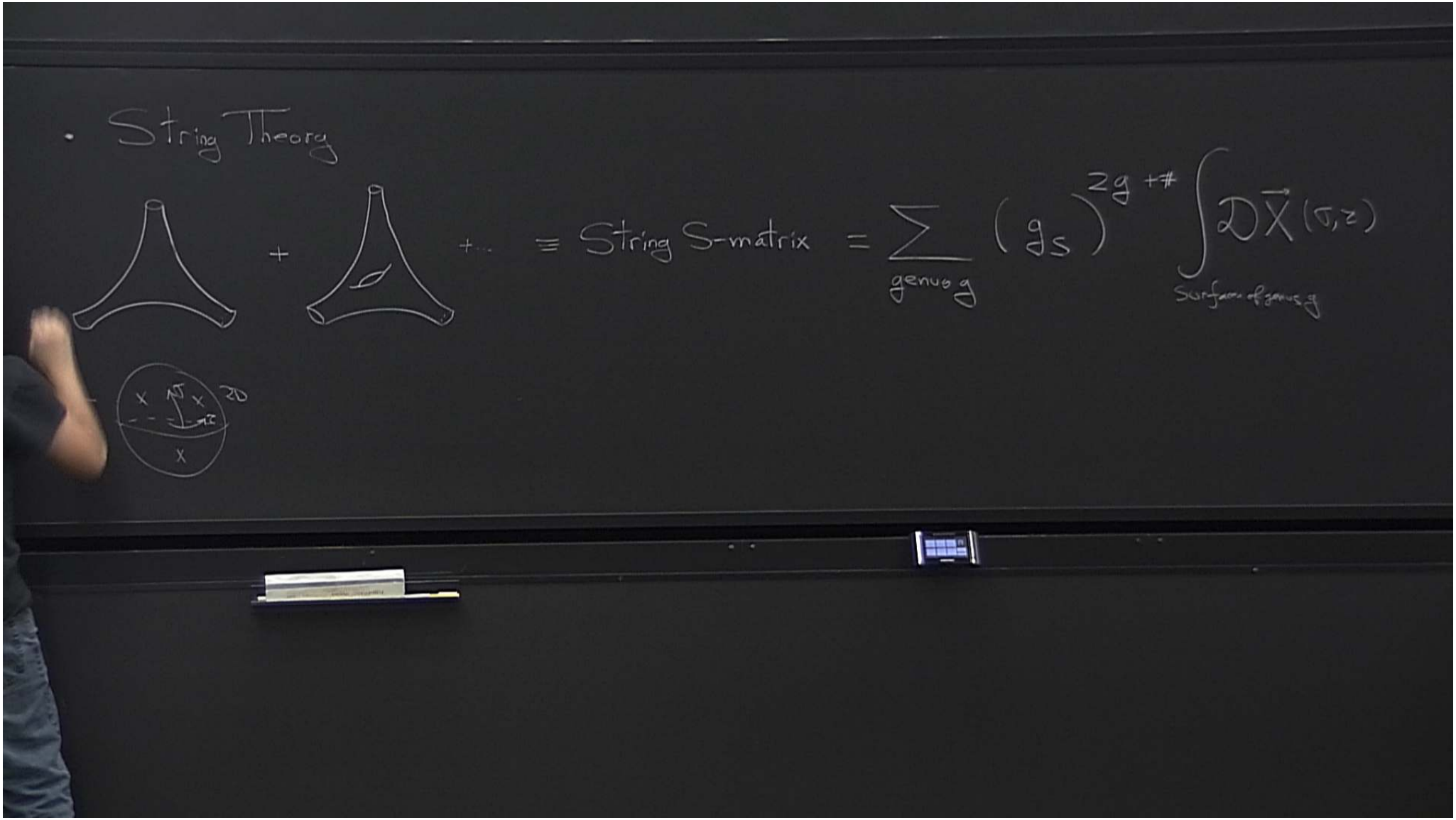
+ ... ≡ String S-matrix =


• String Theory
+
+ ...
≡ String
trix
=
genus g
$(g_s)^{2g+\#}$

• String Theory

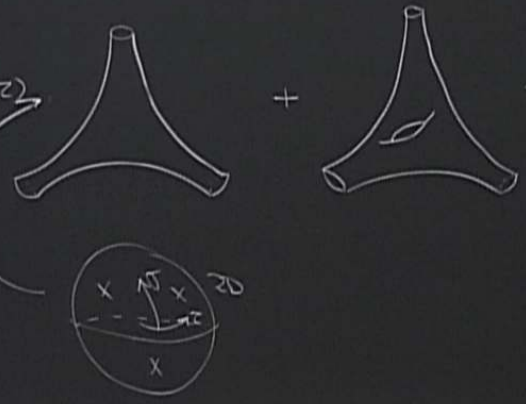


$\equiv$ String S-matrix $= \sum_{\text{genus } g} (g_s)^{2g+\#}$

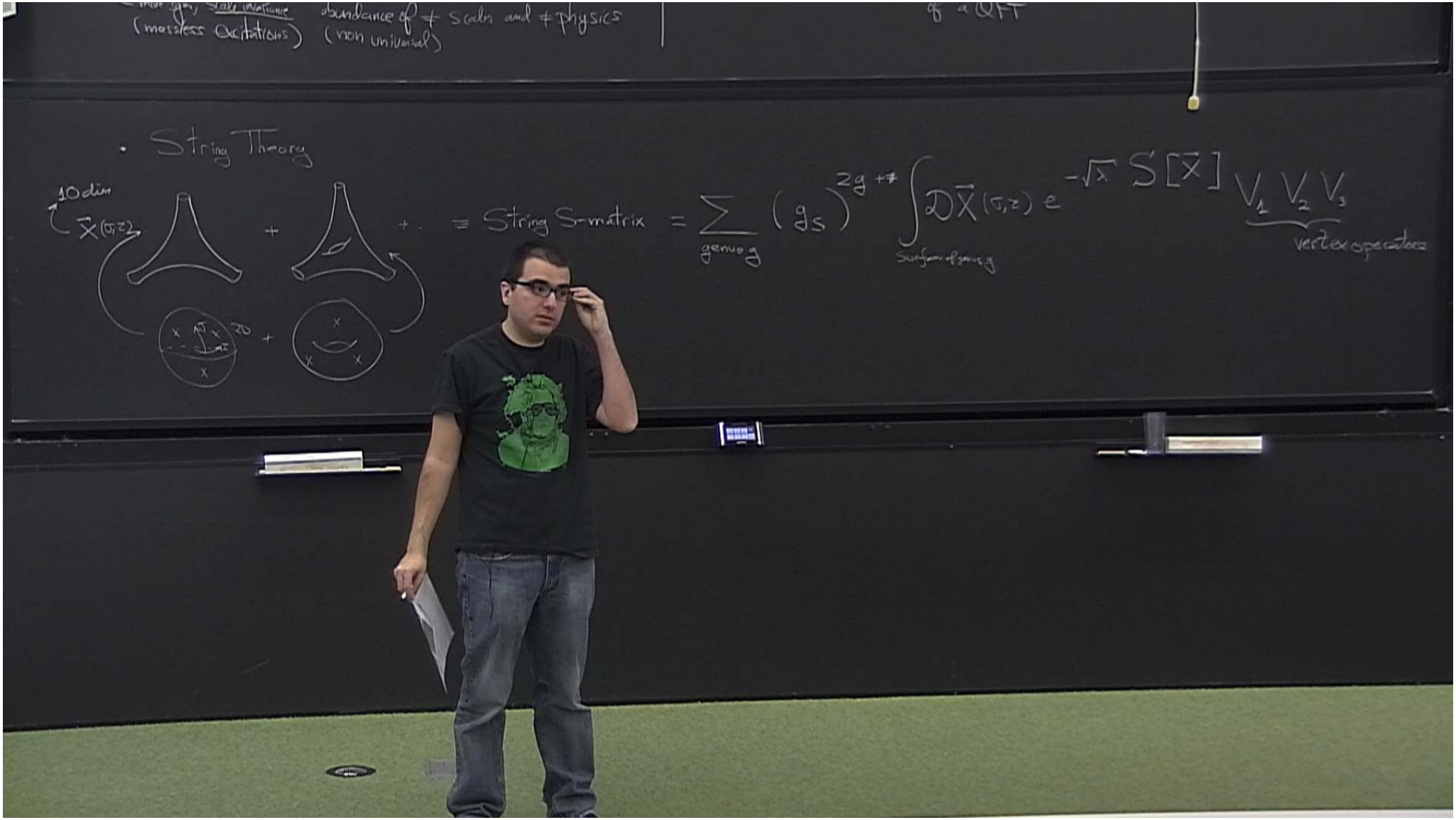

• String Theory
+
+ ... ≡ String S-matrix = $\sum_{\text{genus } g} (g_s)^{2g+\#} \int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)$
X
X
X
2D

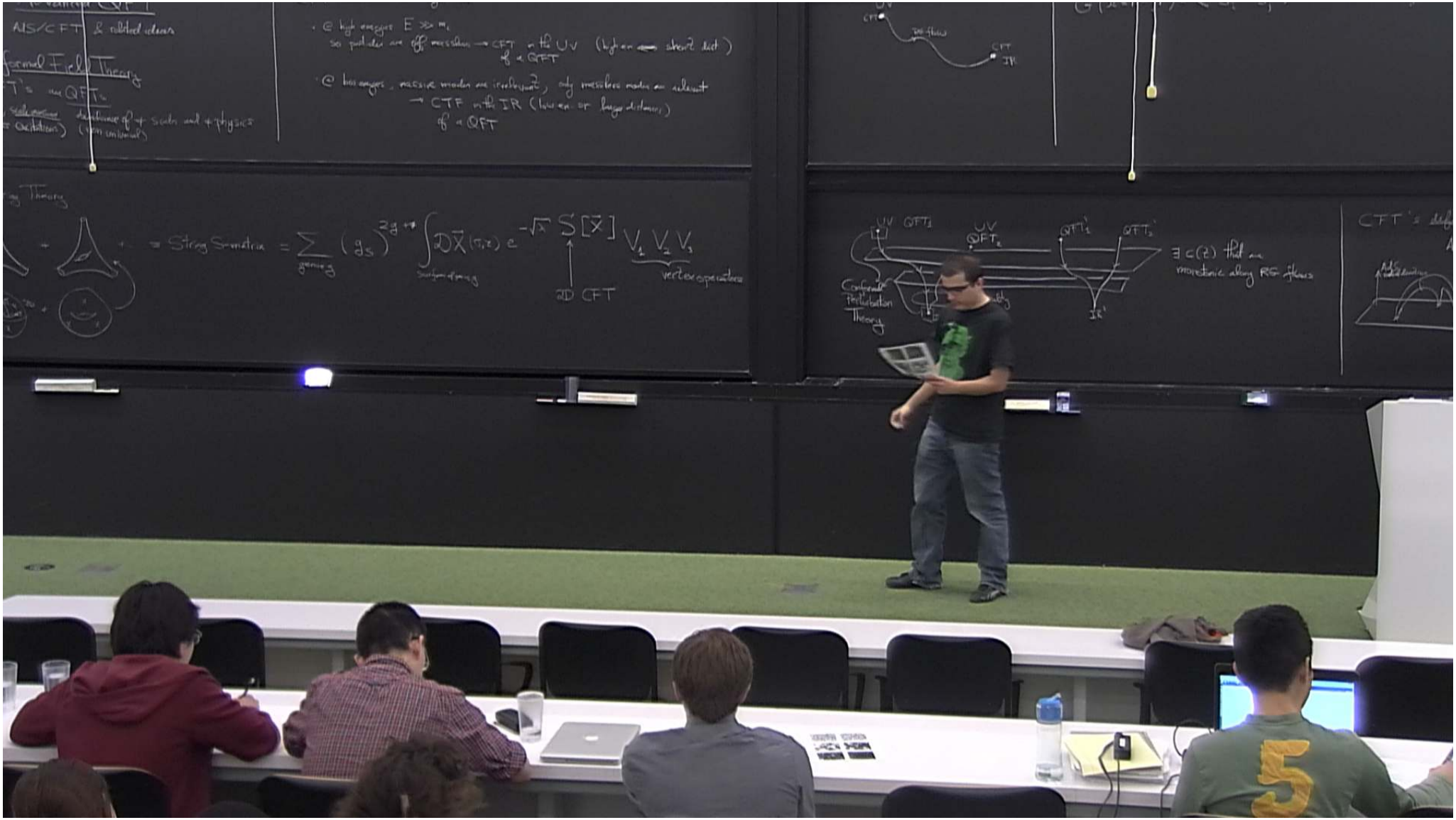
• String Theory

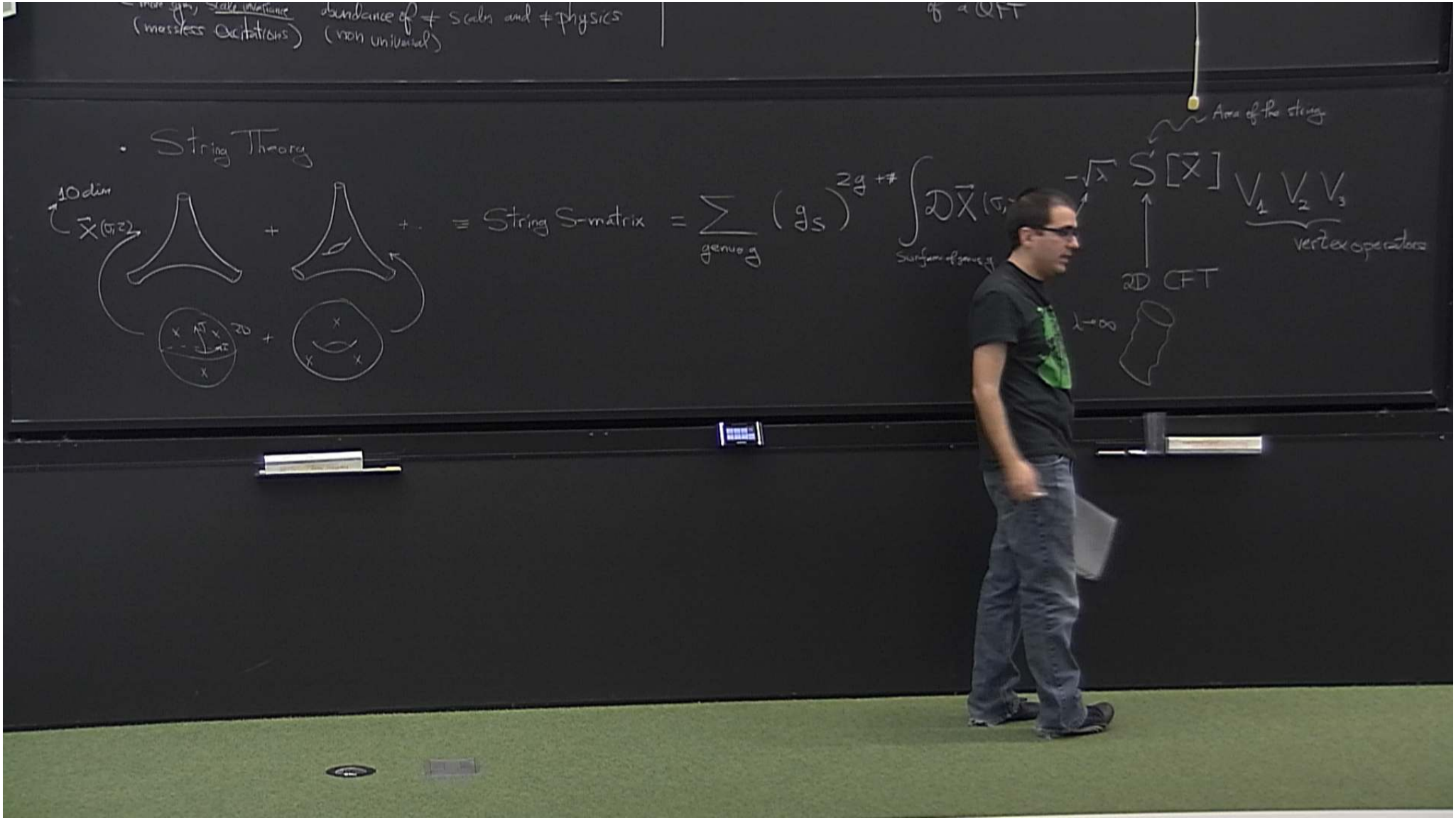
10 dim $\vec{X}(\sigma,\tau)$

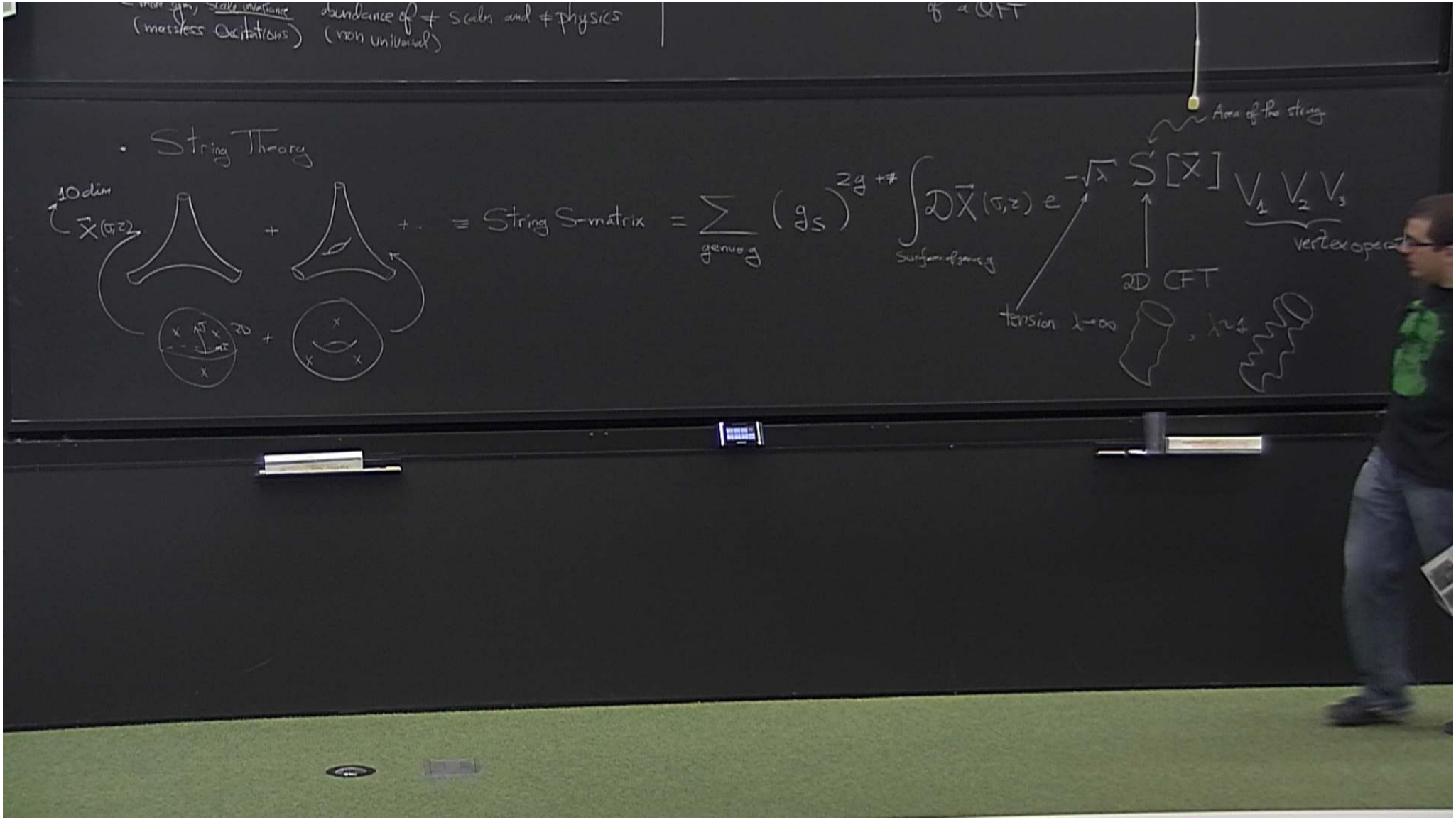


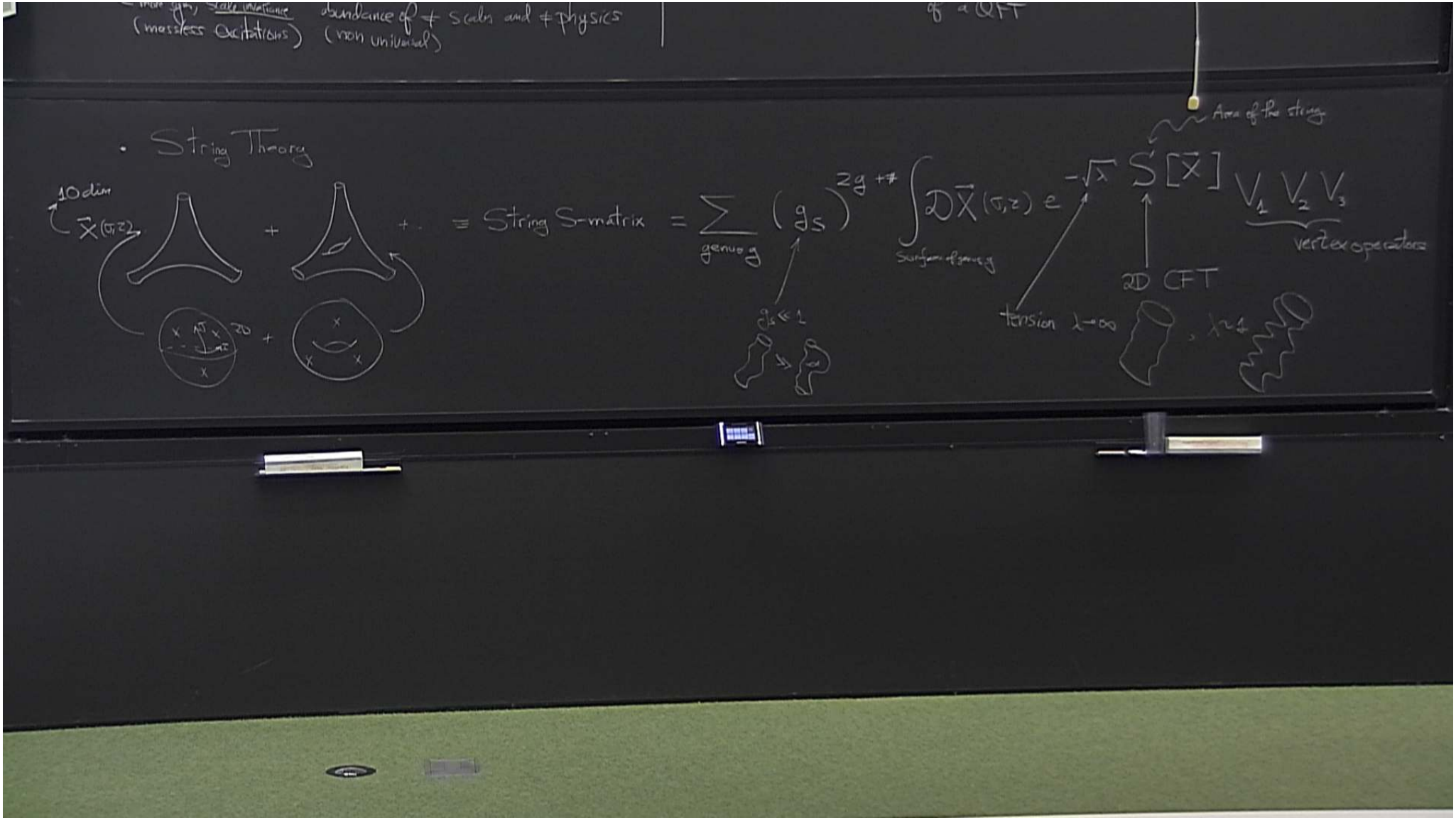
$+$ $+\cdots \equiv$ String S-matrix $= \sum_{\text{genus } g} (g_s)^{2g+\#} \int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,\tau)$

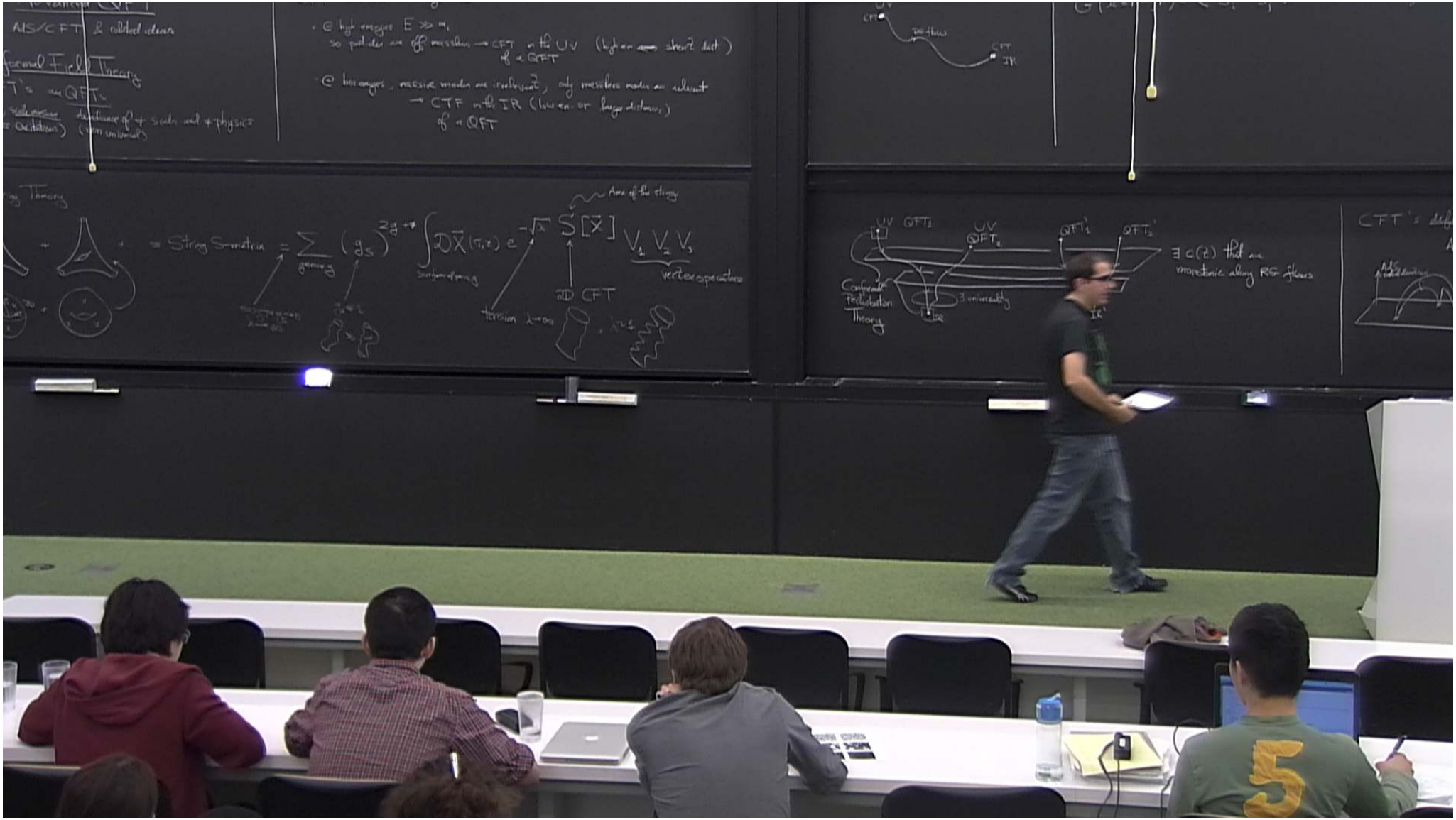

(massless excitations)
abundance of ∞ scales and ∞ physics
(non universal)
String Theory
10 dim
$\vec{X}(\sigma,z)$
= String S-matrix = $\sum_{\text{genus } g} (g_s)^{2g+\#} \int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)\, e^{-\sqrt{\alpha'} S[\vec{X}]} V_1 V_2 V_3$
vertex operators

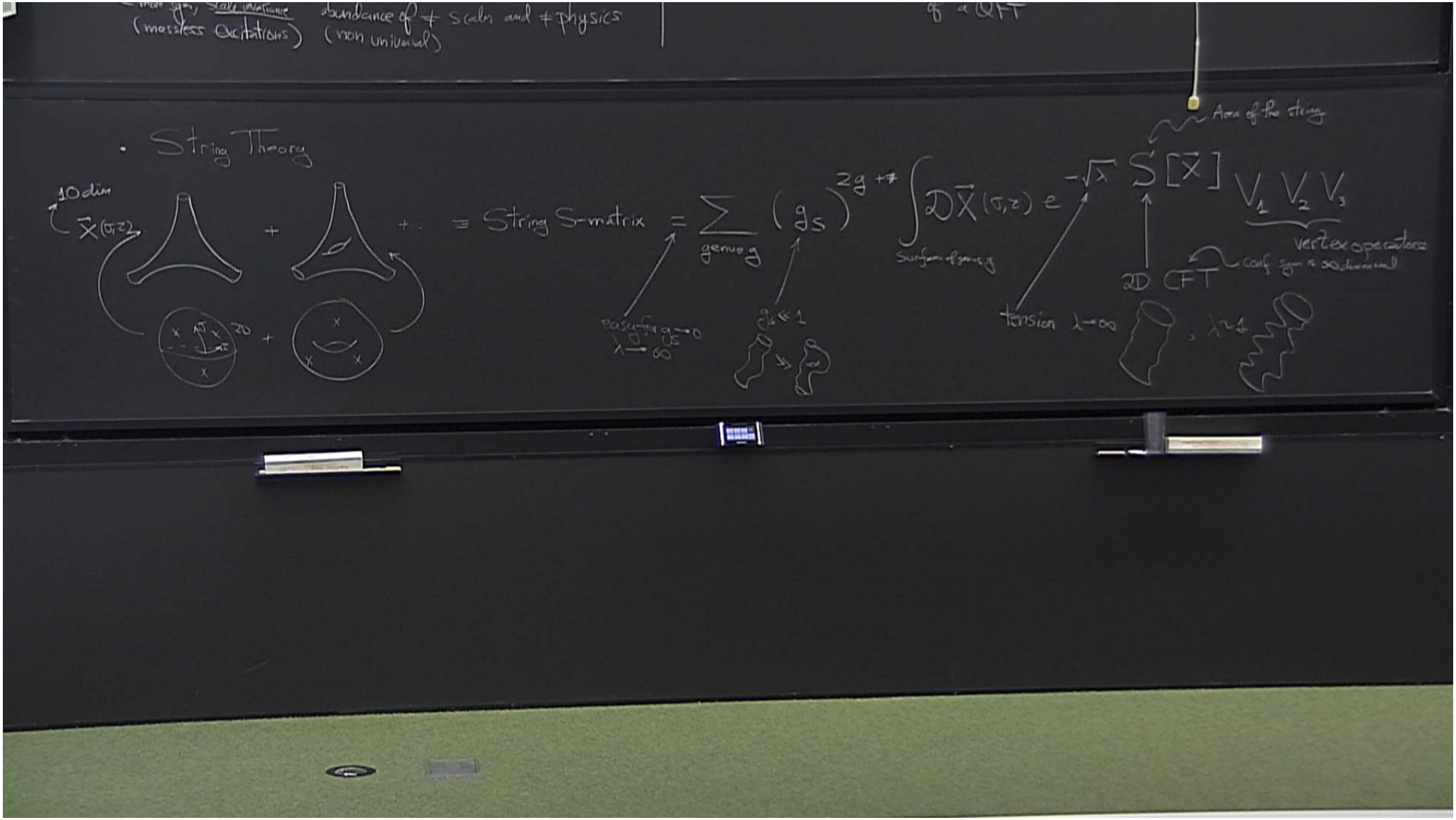

AdS/CFT & related ideas
Conformal Field Theory
QFT's
String Theory
= String Semantics
2D CFT
vertex operators
UV
IR
CFT
Conformal Perturbation Theory

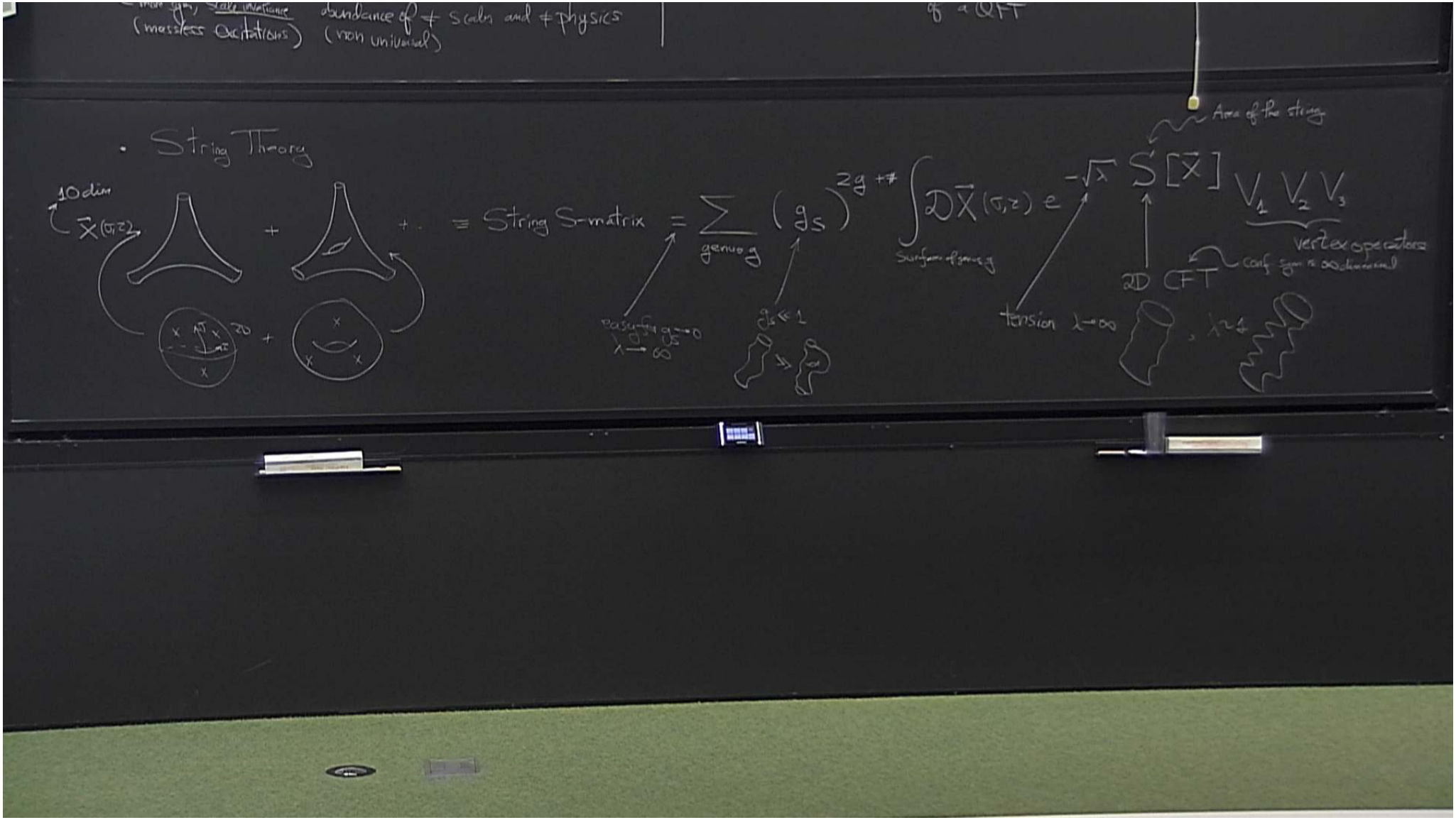

(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
String Theory
10 dim
Area of the string
String S-matrix
2D CFT
vertex operators

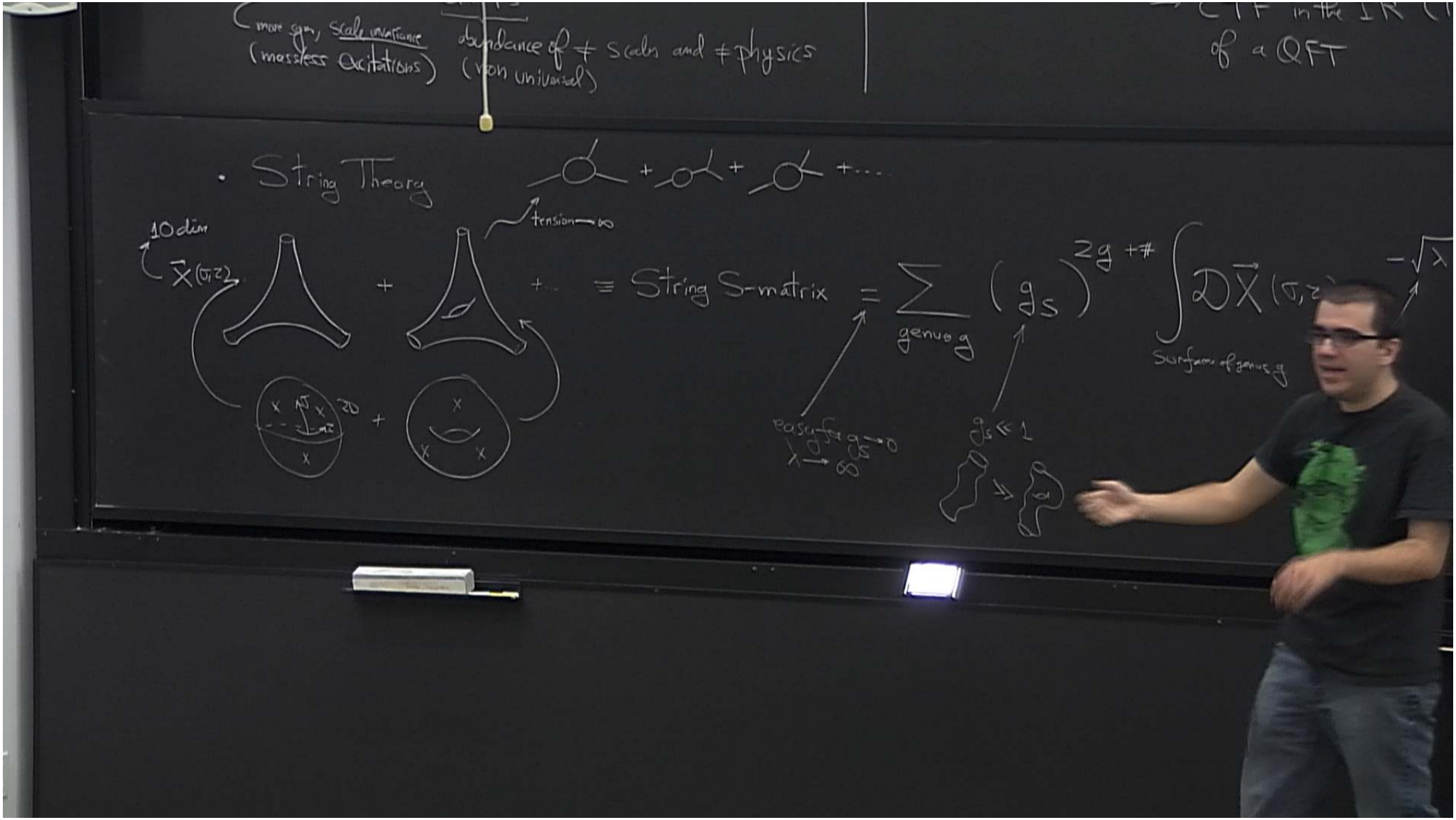

(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
of a QFT
Area of the string
String Theory
10 dim
$\vec{X}(\sigma,z)$
$\equiv$ String S-matrix $= \sum_{\text{genus } g} (g_s)^{2g+\#} \int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)\, e^{-\sqrt{\lambda}\, S[\vec{X}]}\, V_1 V_2 V_3$
vertex operators
2D CFT
tension $\lambda \to \infty$

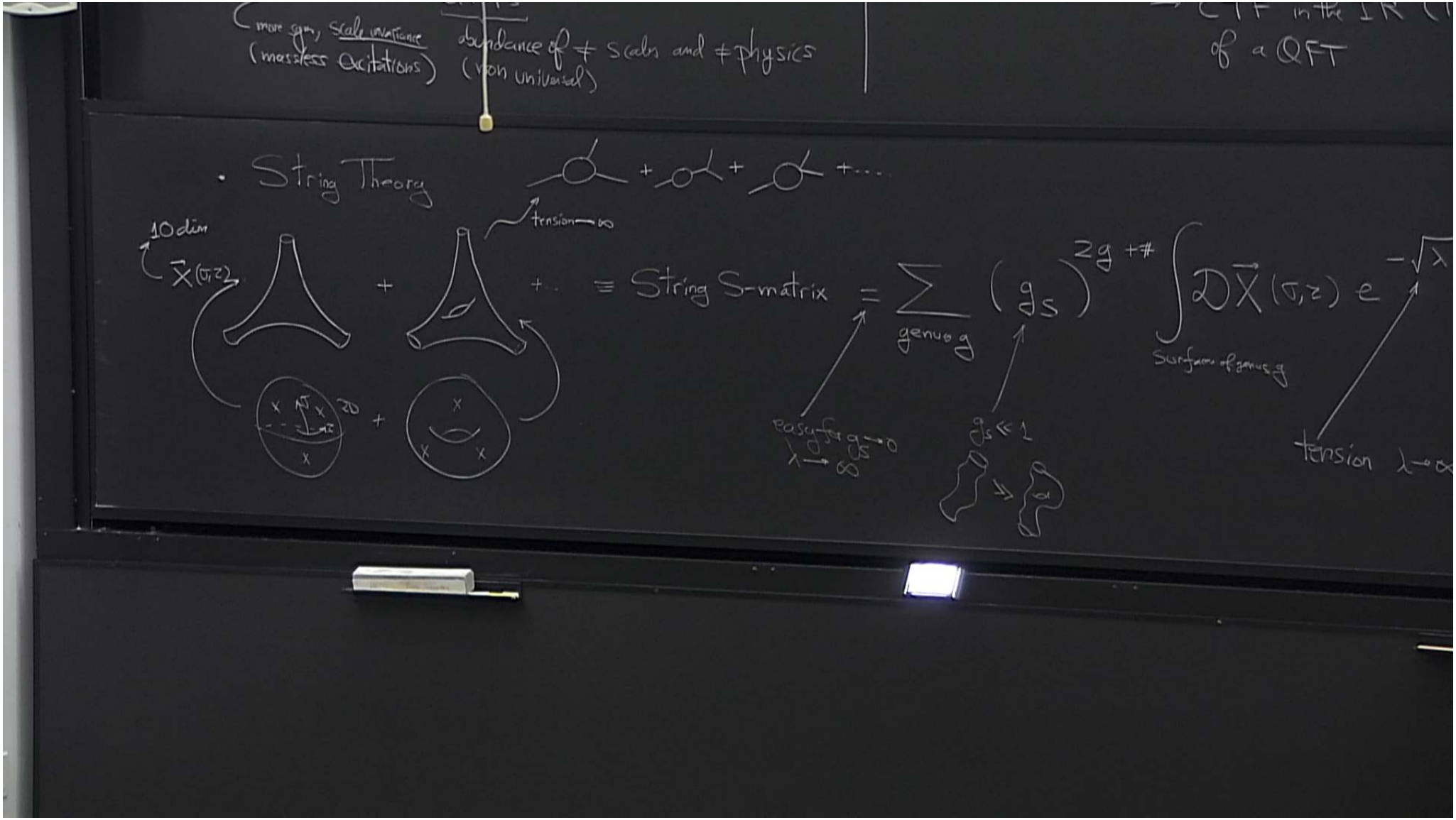

(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
of a QFT
String Theory
10 dim
$\vec{X}(\sigma,z)$
$\equiv$ String S-matrix $= \sum_{\text{genus } g} (g_s)^{2g+\#} \int_{\text{surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)\, e^{-\sqrt{\lambda}\, S[\vec{X}]}\, V_1 V_2 V_3$
Area of the string
vertex operators
2D CFT
tension $\lambda \to \infty$
$g_s \ll 1$

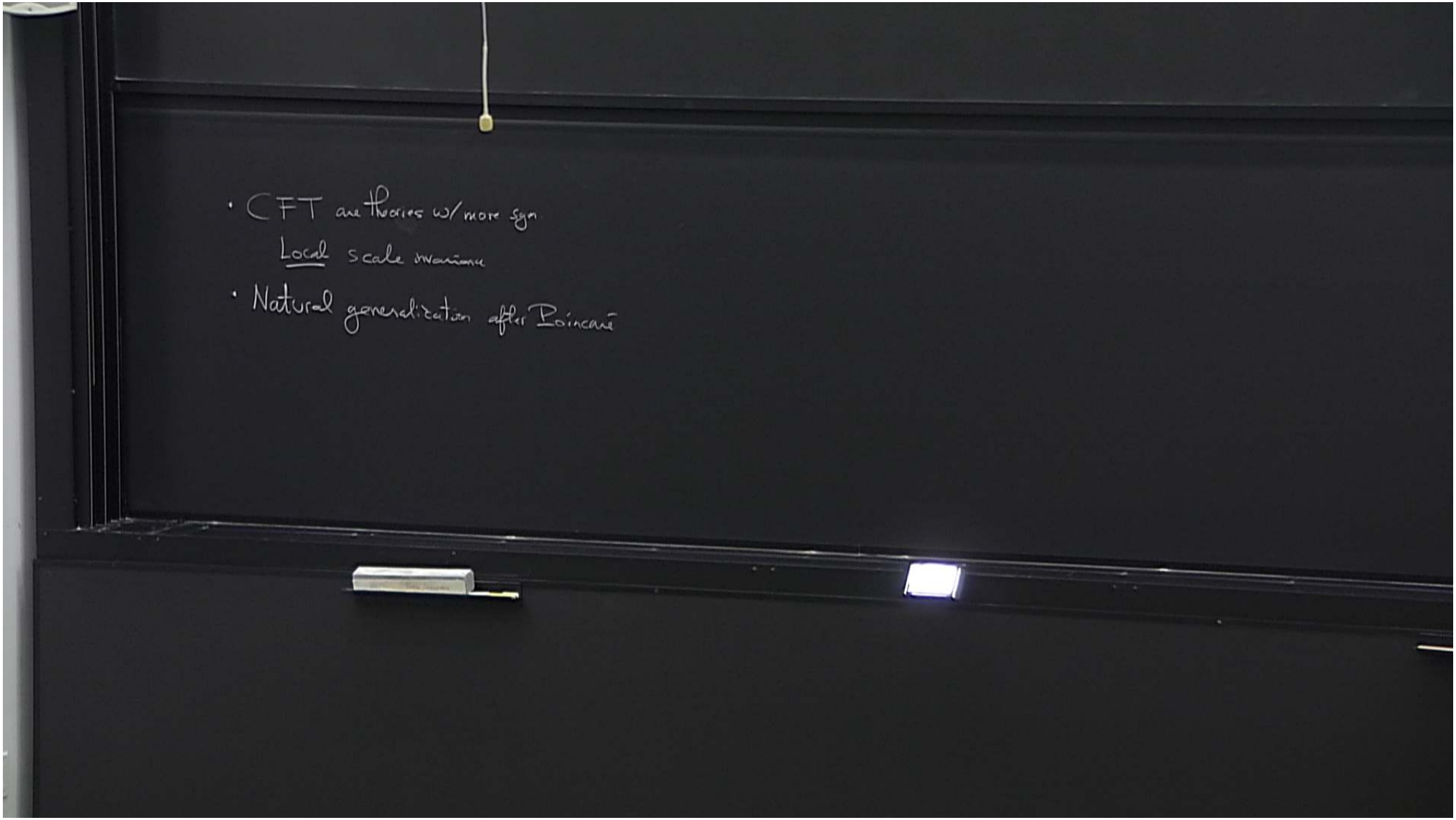

AdS/CFT & related ideas
Conformal Field Theory
@ high energies E ≫ m
→ CFT in the UV
of a QFT
@ low energies, massive modes are irrelevant, only massless modes are relevant
→ CTF in the IR (low-en or large distances)
of a QFT
String Theory
= String Sumatria
Area of the string
2D CFT
vertex operators
torsion
UV QFT1
QFT2
QFT1'
QFT2'
IR
∃ c(z) that are
marginal along RG flows
Conformal Perturbation Theory
CFT's

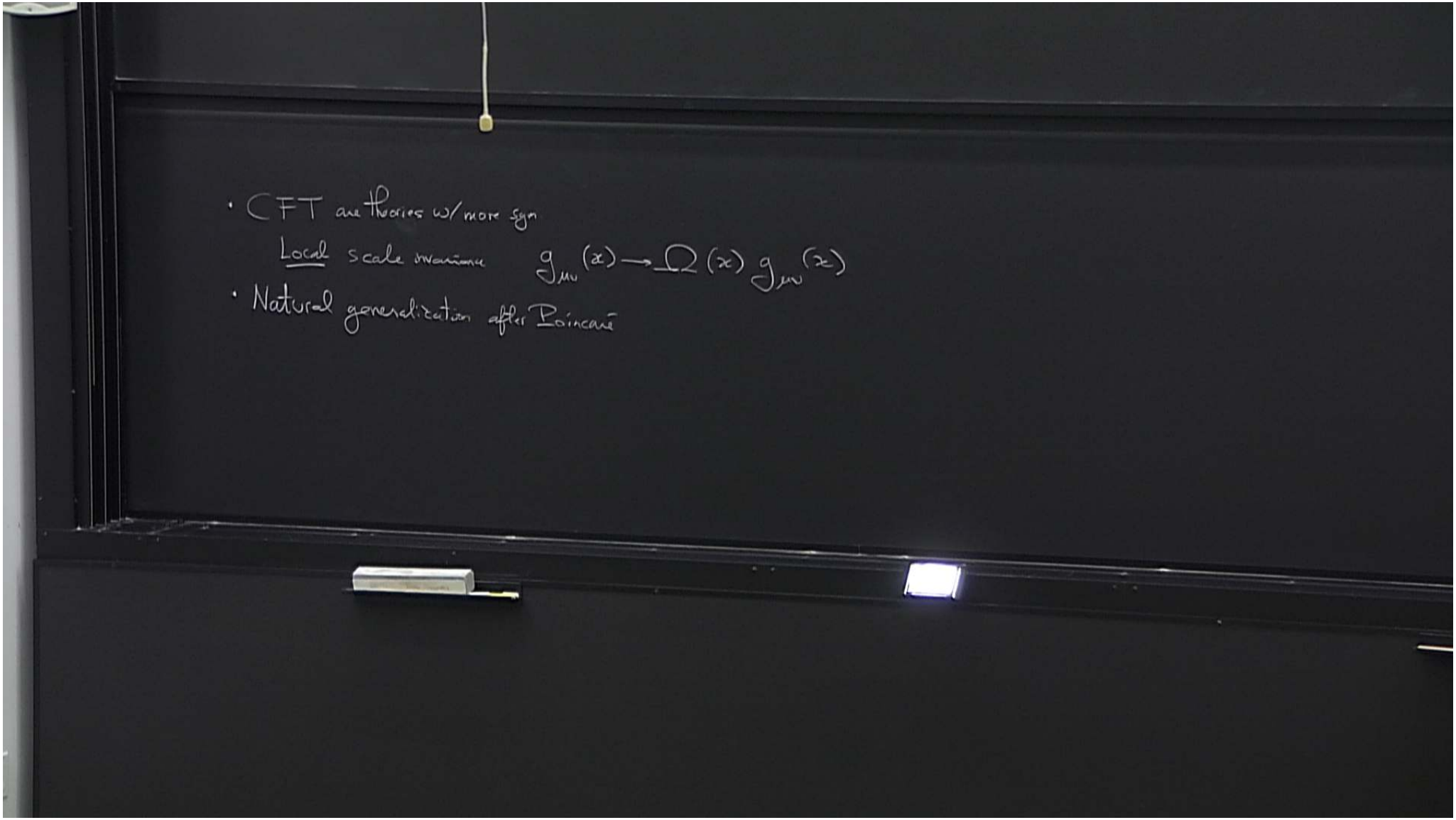

(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
String Theory
10 dim
$\vec{X}(\sigma,z)$
$\equiv$ String S-matrix $= \sum_{\text{genus } g} (g_s)^{2g+\#}$
$\int_{\text{surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)\, e^{-\sqrt{\lambda}\, S[\vec{X}]}$
Area of the string
$V_1\ V_2\ V_3$
vertex operators
2D CFT
conf. sym. in 2 dimensions
tension $\lambda \to \infty$
$g_s \ll 1$

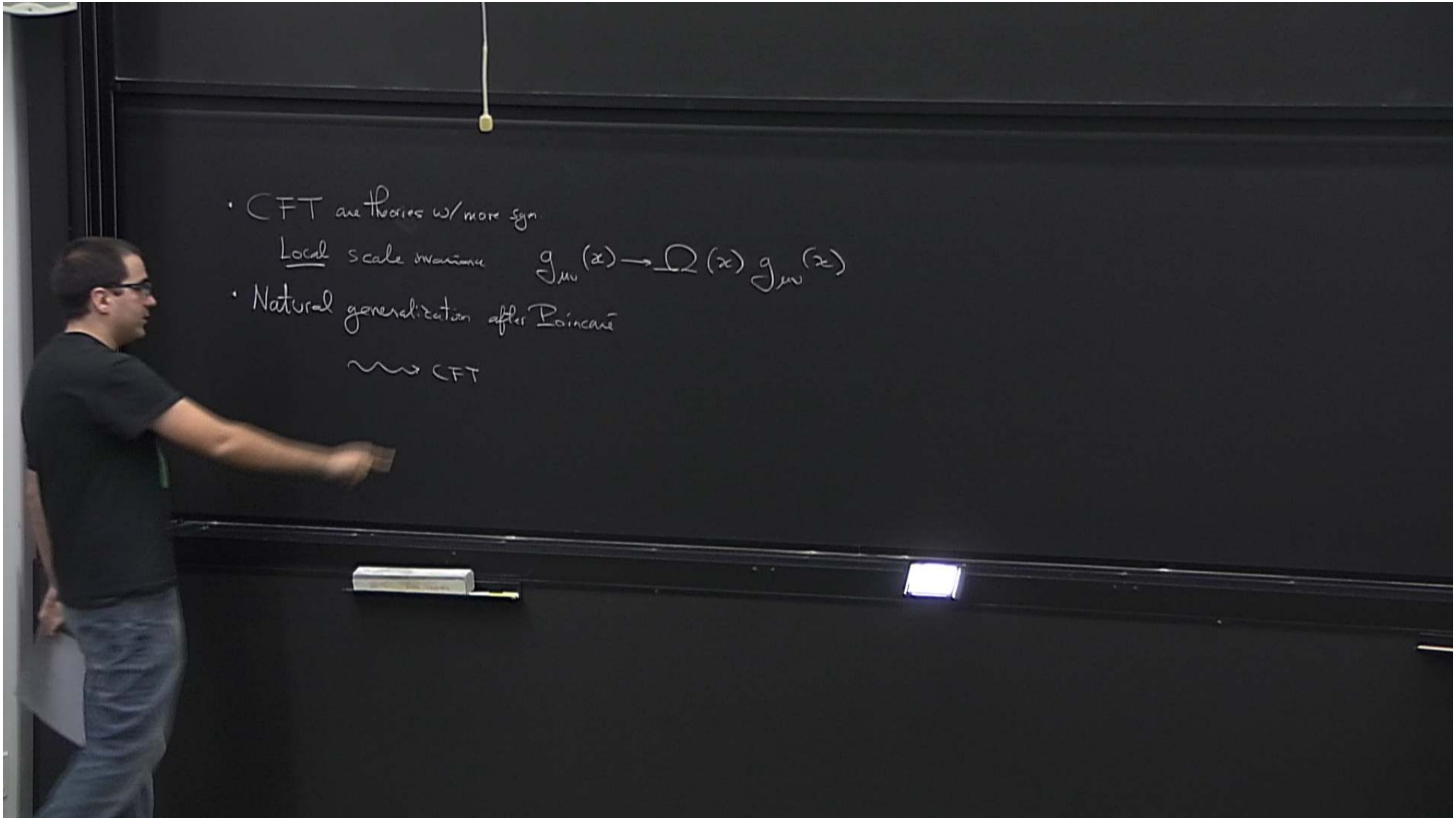

(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
of a QFT
Area of the string
String Theory
10 dim
$\vec{X}(\sigma,z)$
+
+ ... ≡ String S-matrix = $\sum_{\text{genus } g} (g_s)^{2g+\#}$
$\int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,z)\, e^{-\sqrt{\lambda}\, S[\vec{X}]}$
$V_1\ V_2\ V_3$
vertex operators
2D CFT
conf. sym. in ∞ dimensions
tension $\lambda \to \infty$
Surfaces of genus $g \to 0$
$\lambda \to \infty$
$g_s \ll 1$

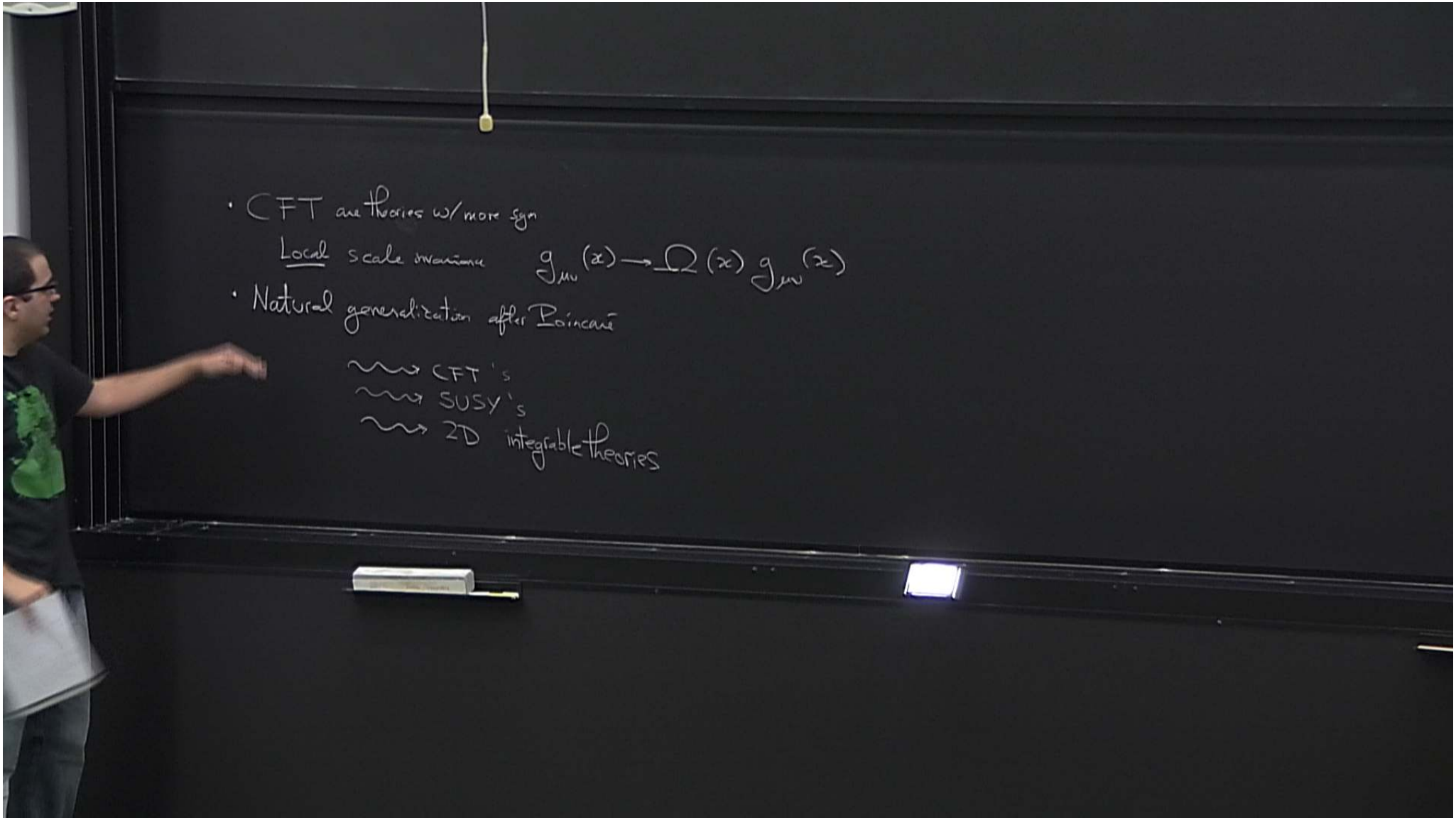

more gen, Scale invariance
(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
of a QFT
String Theory
10 dim
tension → ∞
= String S-matrix =
genus g
Surfaces of genus g

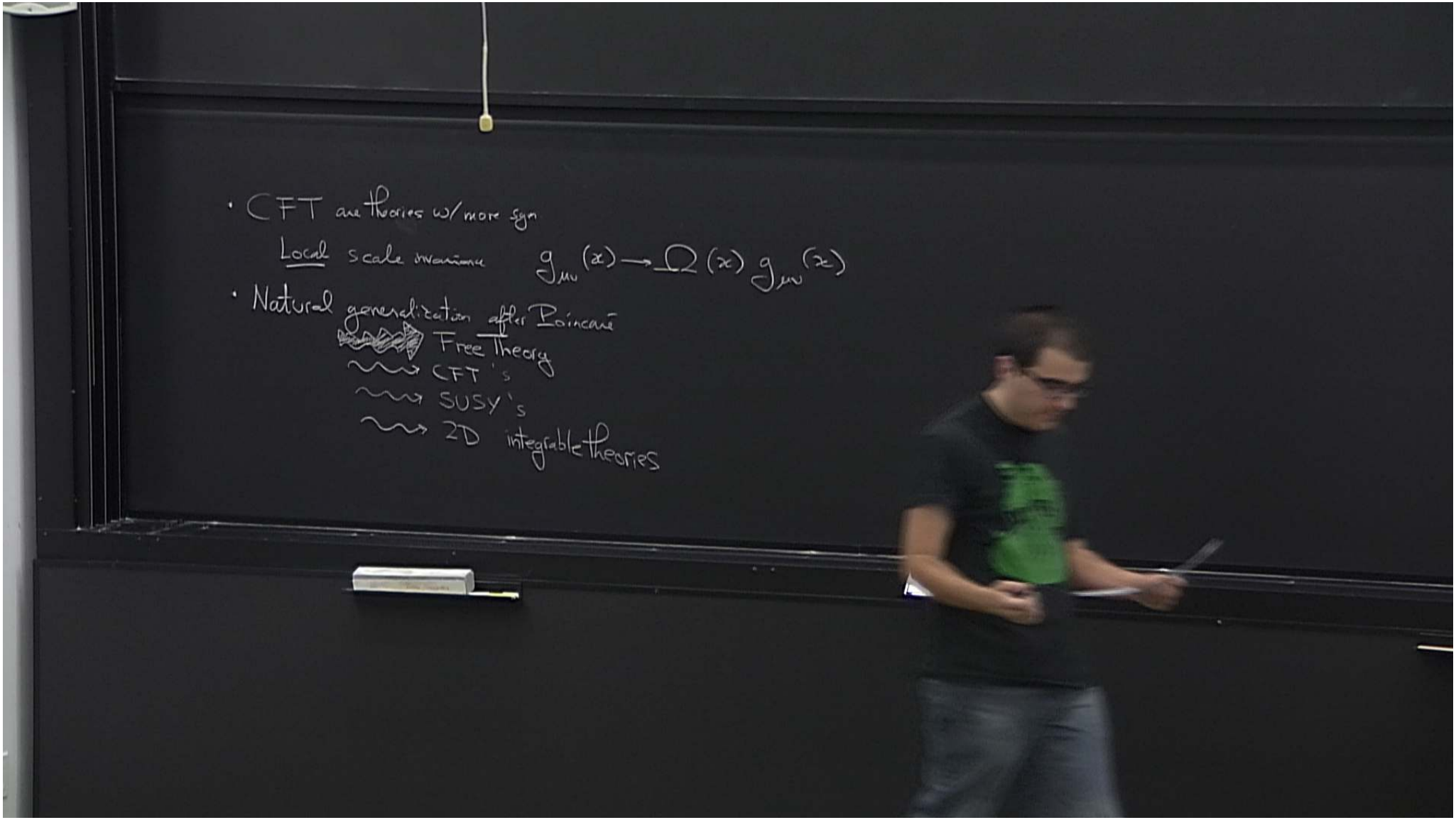

more gen, Scale invariance
(massless excitations)
abundance of ≠ scales and ≠ physics
(non universal)
of a QFT
String Theory
10 dim
$\vec{X}(\sigma,\tau)$
tension → ∞
+ ... ≡ String S-matrix = $\sum_{\text{genus } g} (g_s)^{2g-2+\#} \int_{\text{Surfaces of genus } g} \mathcal{D}\vec{X}(\sigma,\tau)\, e^{-\sqrt{\lambda}}$
$g_s \to 0$
$\lambda \to \infty$
$g_s \ll 1$
tension $\lambda \to \infty$


• CFT are theories w/ more sym
Local scale invariance
• Natural generalization after Poincaré


• CFT are theories w/ more sym
Local scale invariance $g_{\mu\nu}(x) \to \Omega(x)\, g_{\mu\nu}(x)$
• Natural generalization after Poincaré


• CFT are theories w/ more sym
Local scale invariance $g_{\mu\nu}(x) \to \Omega(x)\, g_{\mu\nu}(x)$
• Natural generalization after Poincaré
⇝ CFT


• CFT are theories w/ more sym
Local scale invariance $g_{\mu\nu}(x) \to \Omega(x)\, g_{\mu\nu}(x)$
• Natural generalization after Poincaré
CFT's
SUSY's
2D integrable theories


• CFT are theories w/ more sym
Local scale invariance $g_{\mu\nu}(x) \to \Omega(x)\, g_{\mu\nu}(x)$
• Natural generalization after Poincaré
Free Theory
CFT's
SUSY's
2D integrable theories