Title: Asymptotic safety â€“ a quantum theory of gravity and matter

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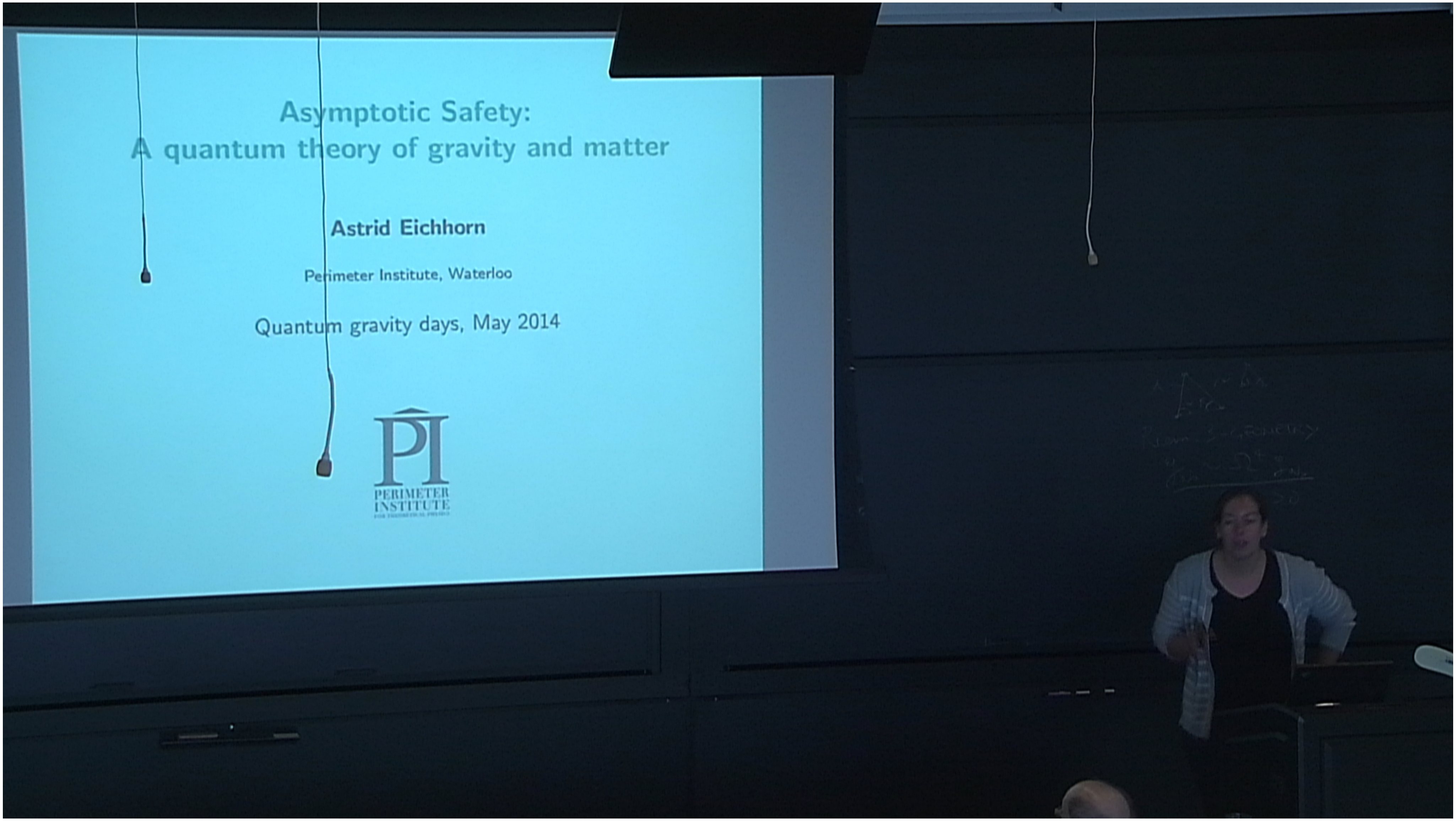
Abstract:


Asymptotic Safety:
A quantum theory of gravity and matter
Astrid Eichhorn
Perimeter Institute, Waterloo
Quantum gravity days, May 2014
PERIMETER INSTITUTE

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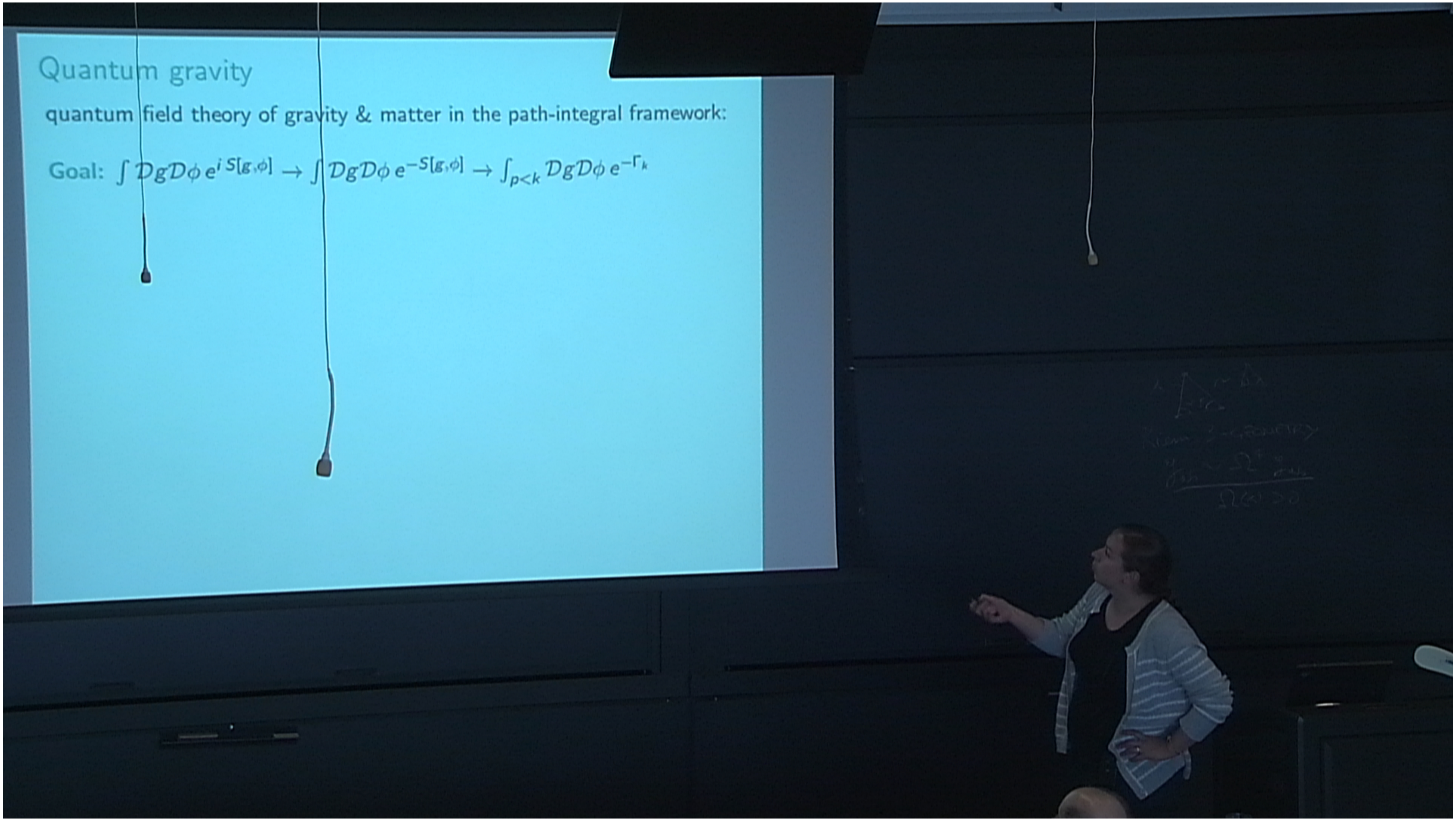
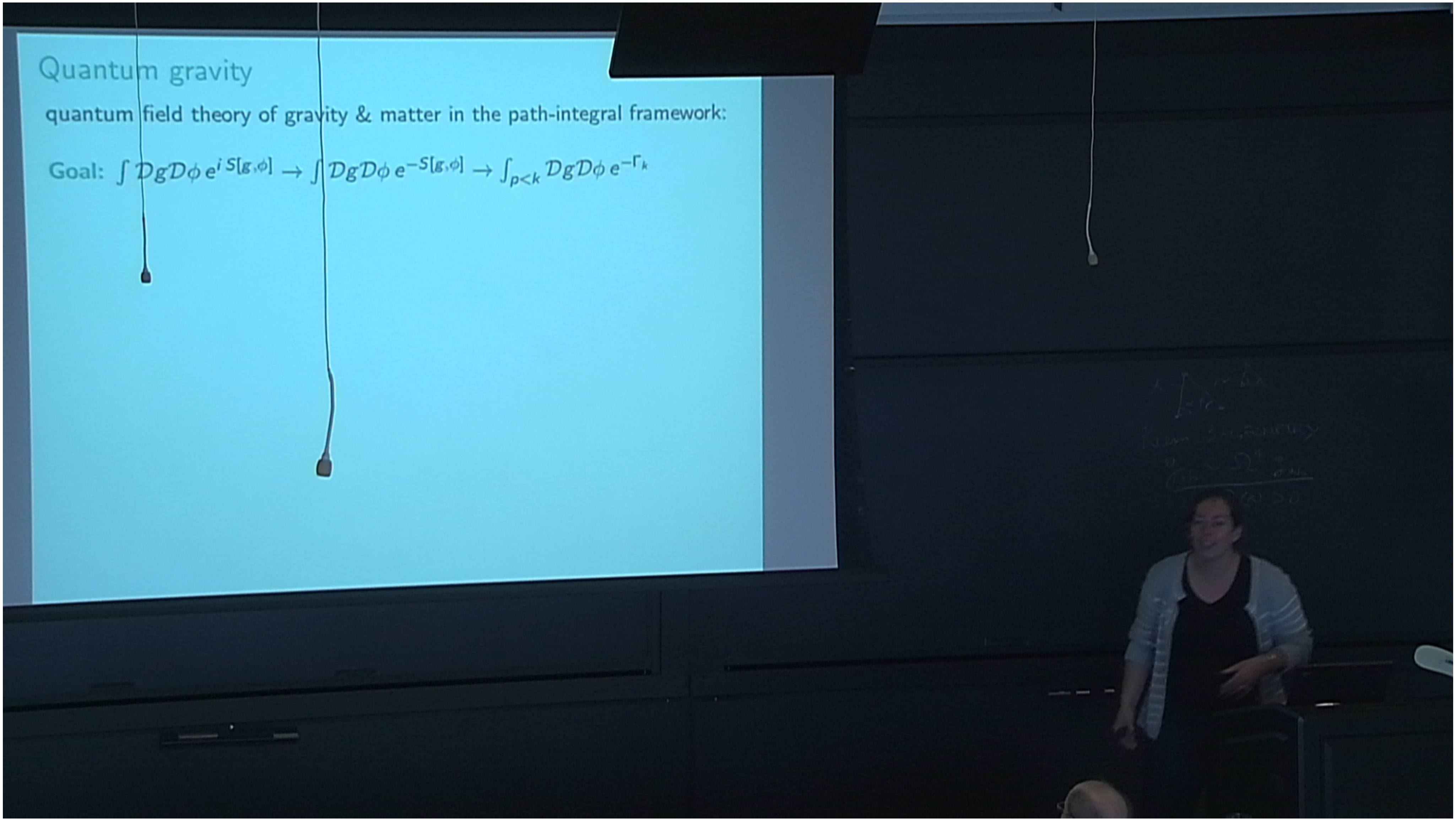


Quantum gravity
quantum field theory of gravity & matter in the path-integral framework:
Goal: $\int \mathcal{D}g\mathcal{D}\phi\, e^{i\,S[g,\phi]} \rightarrow \int \mathcal{D}g\mathcal{D}\phi\, e^{-S[g,\phi]} \rightarrow \int_{p<k} \mathcal{D}g\mathcal{D}\phi\, e^{-\Gamma_k}$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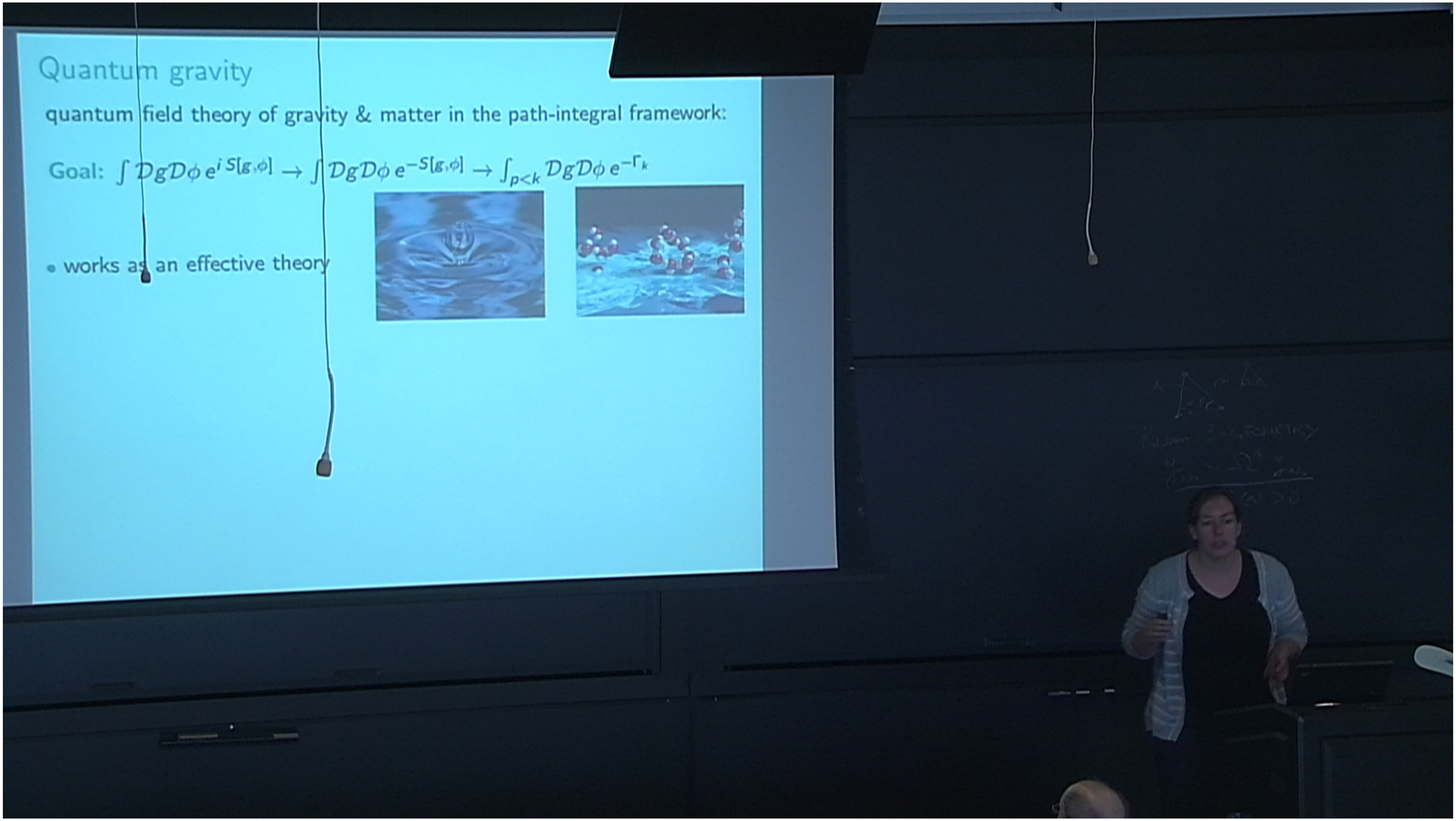
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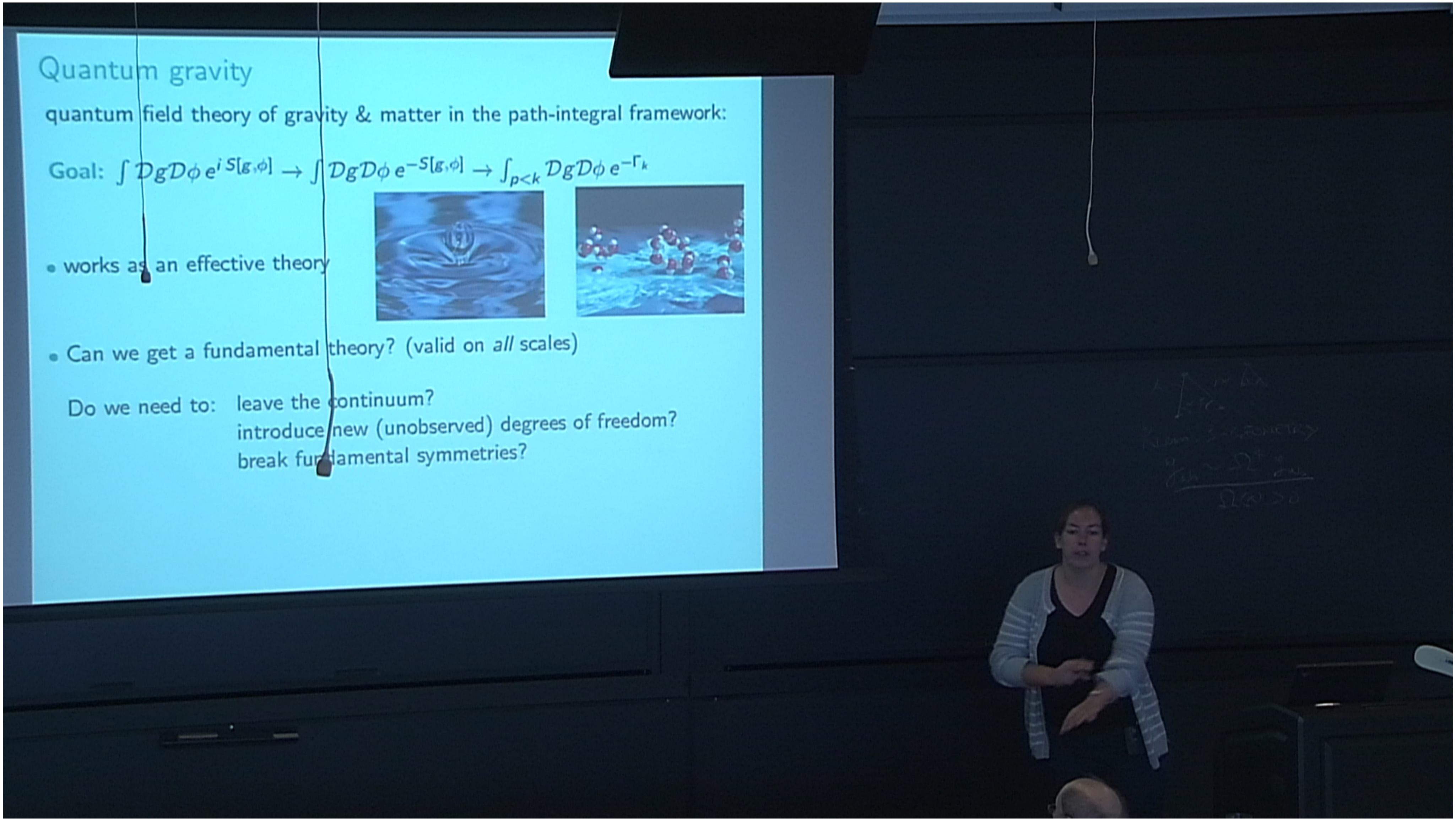
• works as an effective theory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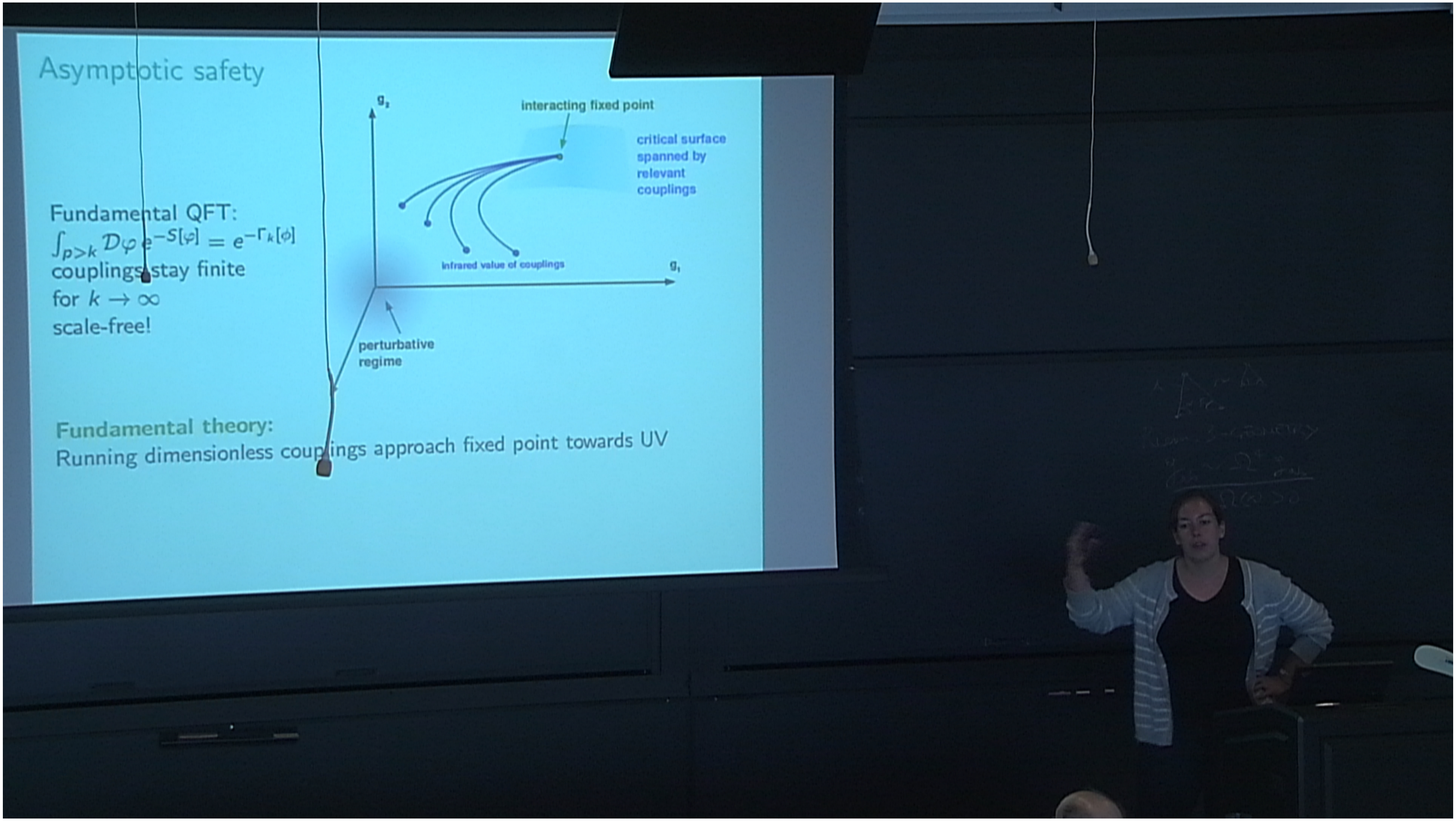
• works as an effective theory
• Can we get a fundamental theory? (valid on *all* scales)
Do we need to: leave the continuum?
introduce new (unobserved) degrees of freedom?
break fundamental symmetries?


Asymptotic safety
g2
interacting fixed point
critical surface
spanned by
relevant
couplings
infrared value of couplings
g1
perturbative
regime
Fundamental QFT:
$\int_{p>k} \mathcal{D}\varphi\, e^{-S[\varphi]} = e^{-\Gamma_k[\phi]}$
couplings stay finite
for $k \to \infty$
scale-free!
Fundamental theory:
Running dimensionless couplings approach fixed point towards UV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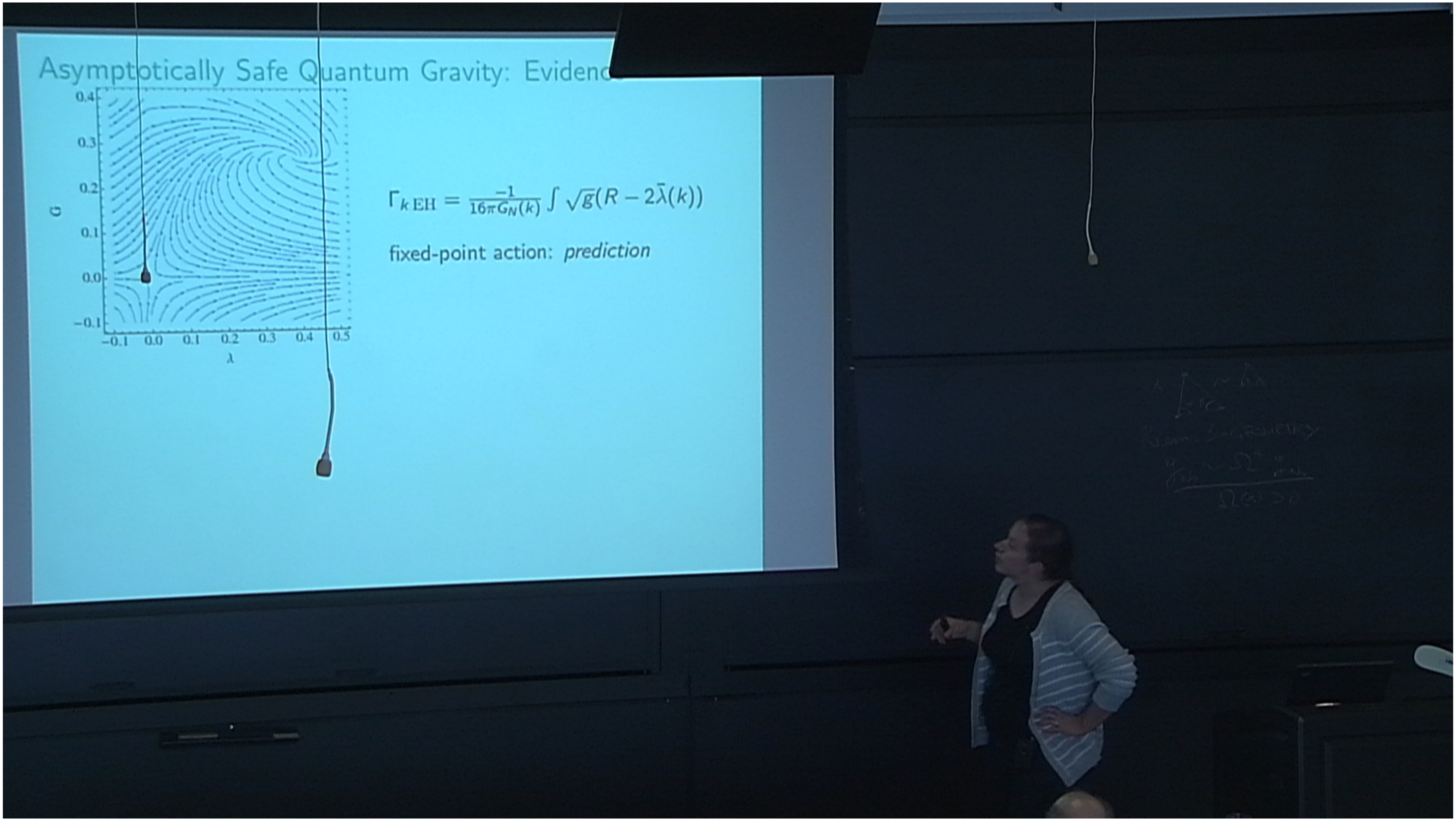
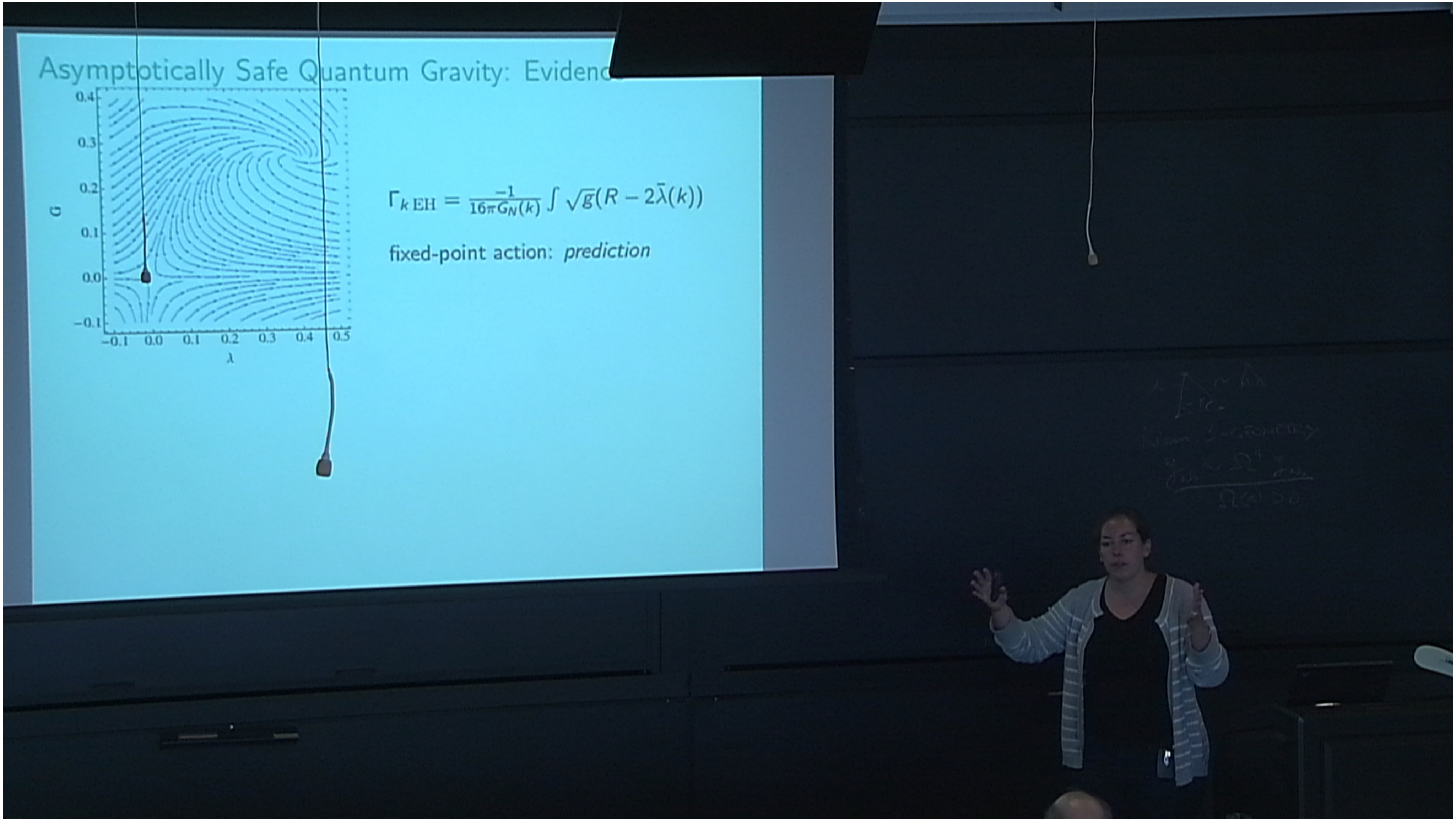

Asymptotically Safe Quantum Gravity: Evidenc
$\Gamma_{k\,\mathrm{EH}} = \frac{-1}{16\pi G_N(k)} \int \sqrt{g}(R - 2\bar{\lambda}(k))$
fixed-point action: *prediction*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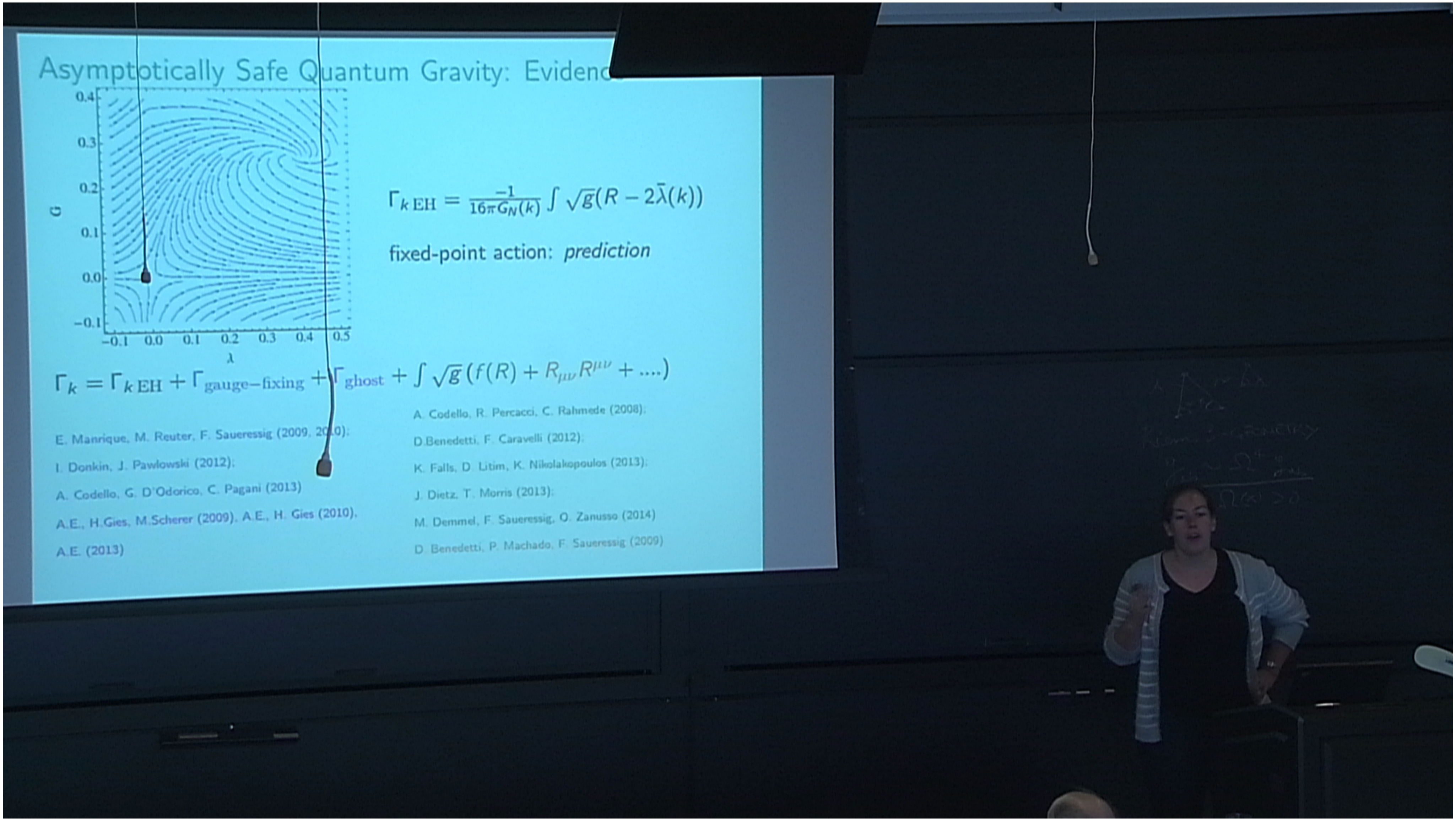
fixed-point action: *prediction*
G
λ
0.4
0.3
0.2
0.1
0.0
−0.1
−0.1 0.0 0.1 0.2 0.3 0.4 0.5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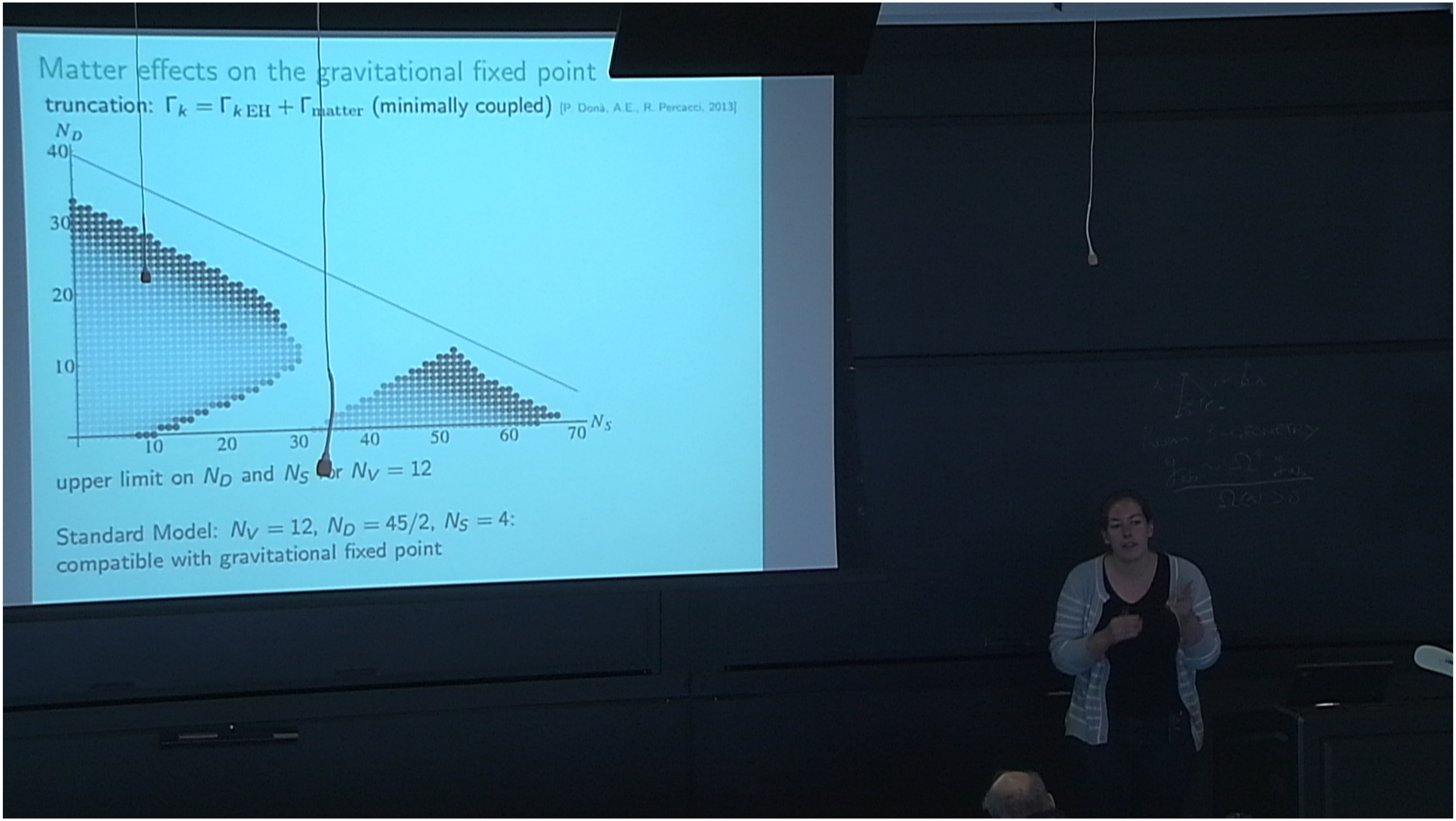
λ
$\Gamma_{k\,\mathrm{EH}} = \frac{-1}{16\pi G_N(k)} \int \sqrt{g}(R - 2\bar{\lambda}(k))$
fixed-point action: *prediction*
$\Gamma_k = \Gamma_{k\,\mathrm{EH}} + \Gamma_{\mathrm{gauge-fixing}} + \Gamma_{\mathrm{ghost}} + \int \sqrt{g}\,(f(R) + R_{\mu\nu}R^{\mu\nu} + ...)$
E. Manrique, M. Reuter, F. Saueressig (2009, 2010);
I. Donkin, J. Pawlowski (2012);
A. Codello, G. D'Odorico, C. Pagani (2013)
A.E., H.Gies, M.Scherer (2009), A.E., H. Gies (2010),
A.E. (2013)
A. Codello, R. Percacci, C. Rahmede (2008);
D.Benedetti, F. Caravelli (2012);
K. Falls, D. Litim, K. Nikolakopoulos (2013);
J. Dietz, T. Morris (2013);
M. Demmel, F. Saueressig, O. Zanusso (2014)
D. Benedetti, P. Machado, F. Saueressig (2009)


Does matter matter?
quantum fluctuations of all fields drive Renormalization Group flow:

Matter effects on the gravitational fixed point

truncation: $\Gamma_k = \Gamma_{k\,\mathrm{EH}} + \Gamma_{\mathrm{matter}}$ (minimally coupled) [P. Donà, A.E., R. Percacci, 2013]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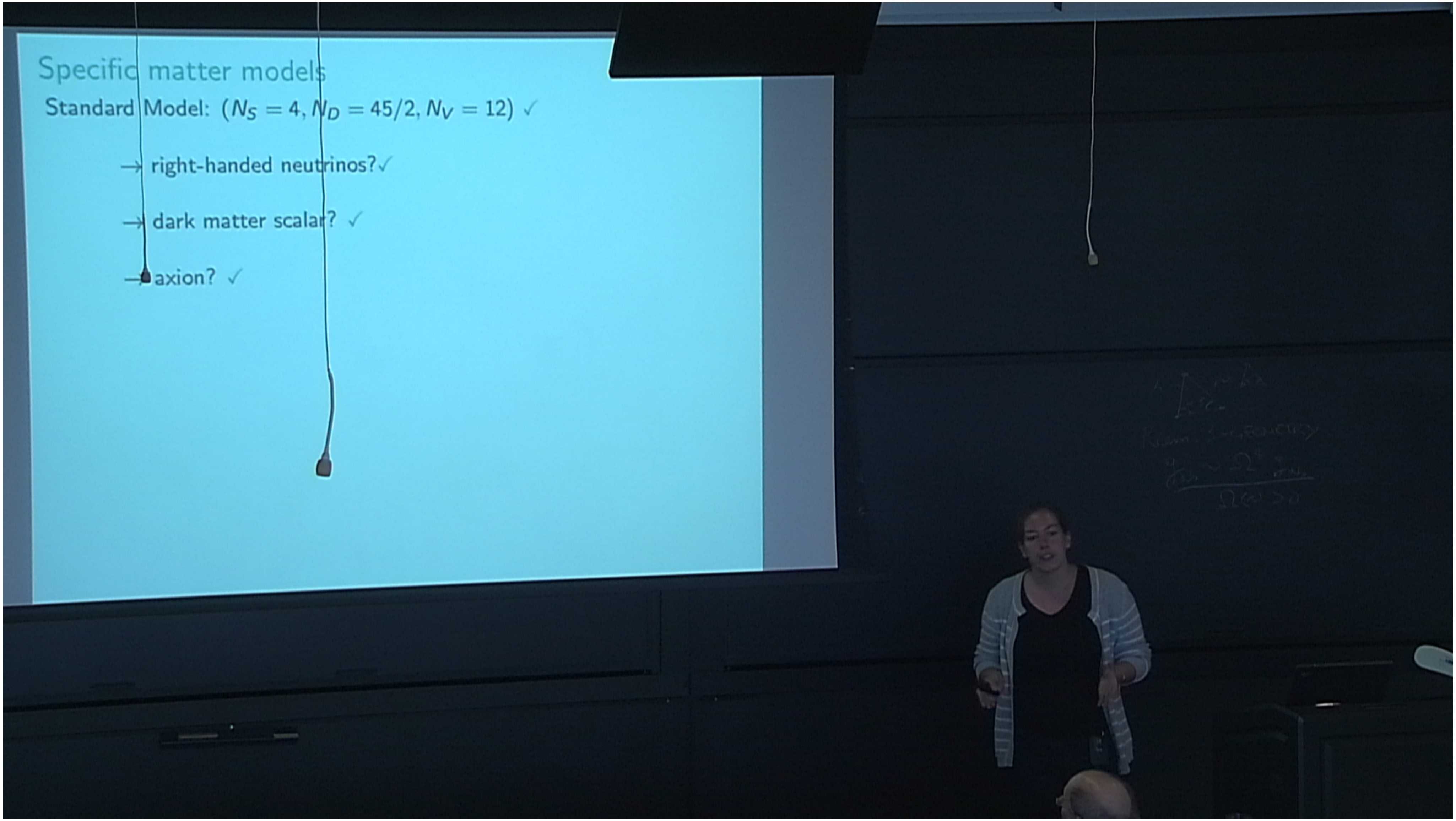
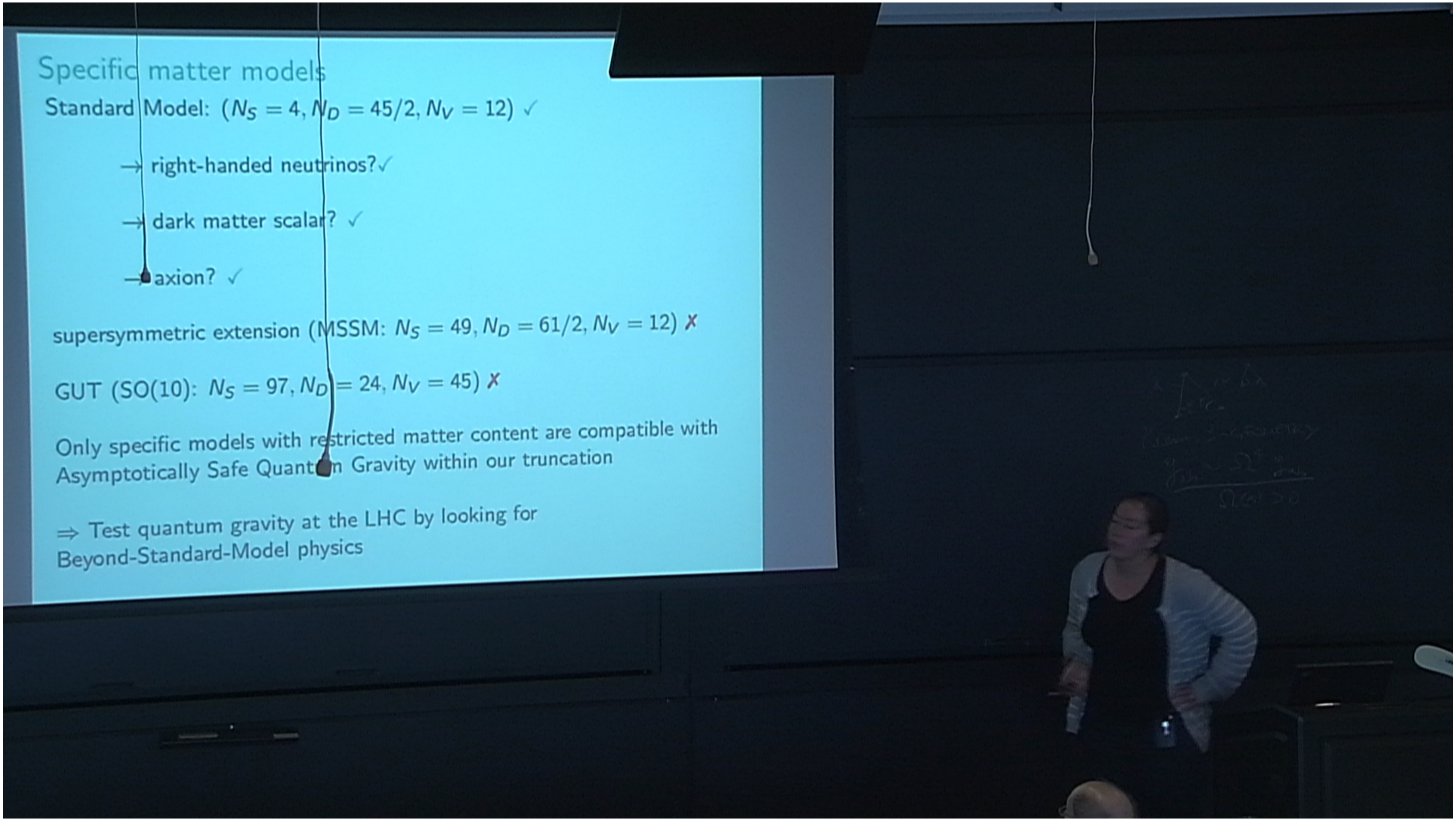
N_D
40
30
20
10
10
20
30
40
50
60
70
N_S
upper limit on N_D and N_S for $N_V = 12$
Standard Model: $N_V = 12$, $N_D = 45/2$, $N_S = 4$:
compatible with gravitational fixed point


Specific matter models
Standard Model: $(N_S = 4, N_D = 45/2, N_V = 12)$ ✓
→ right-handed neutrinos?✓
→ dark matter scalar? ✓
→ axion? ✓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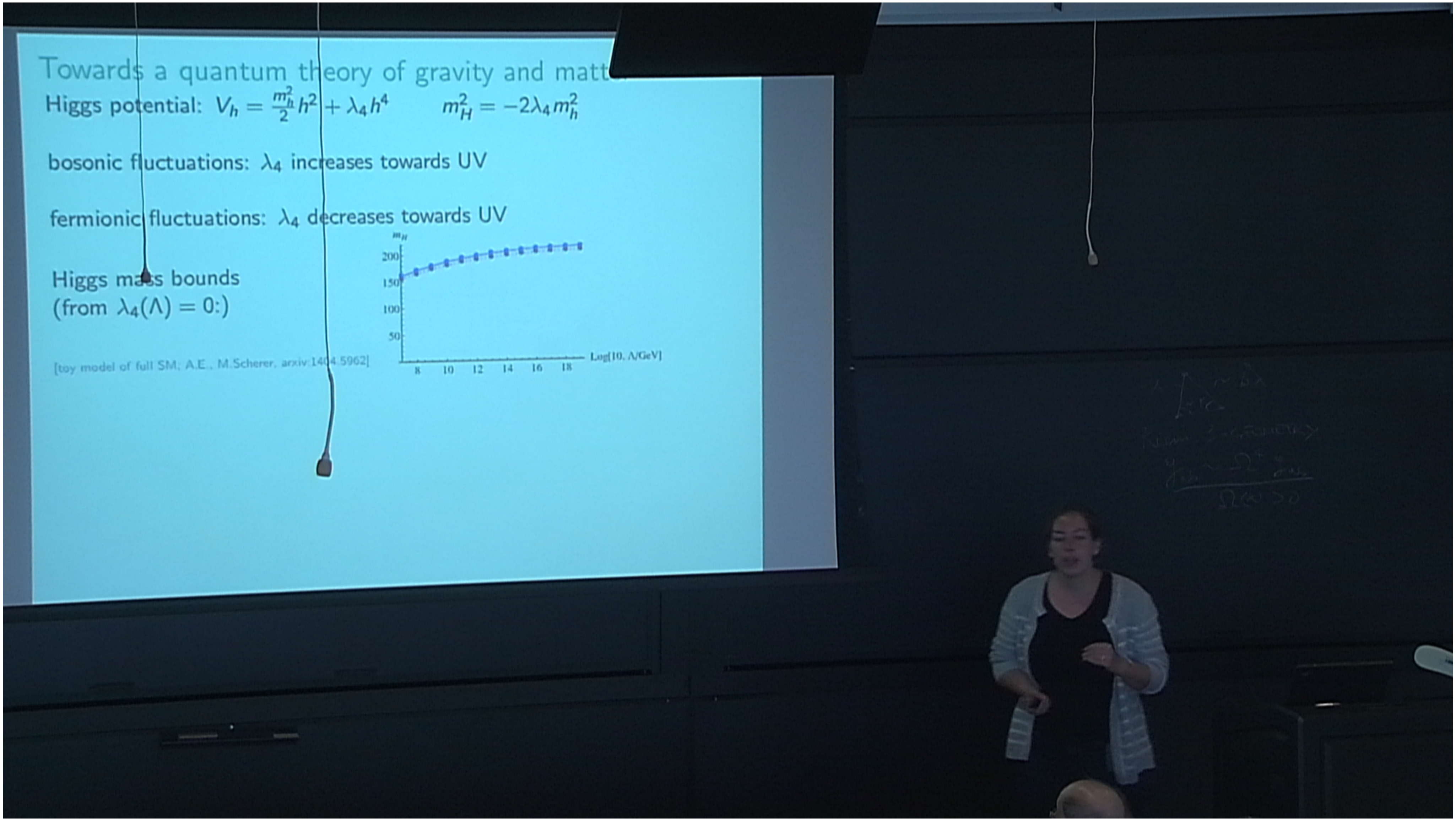
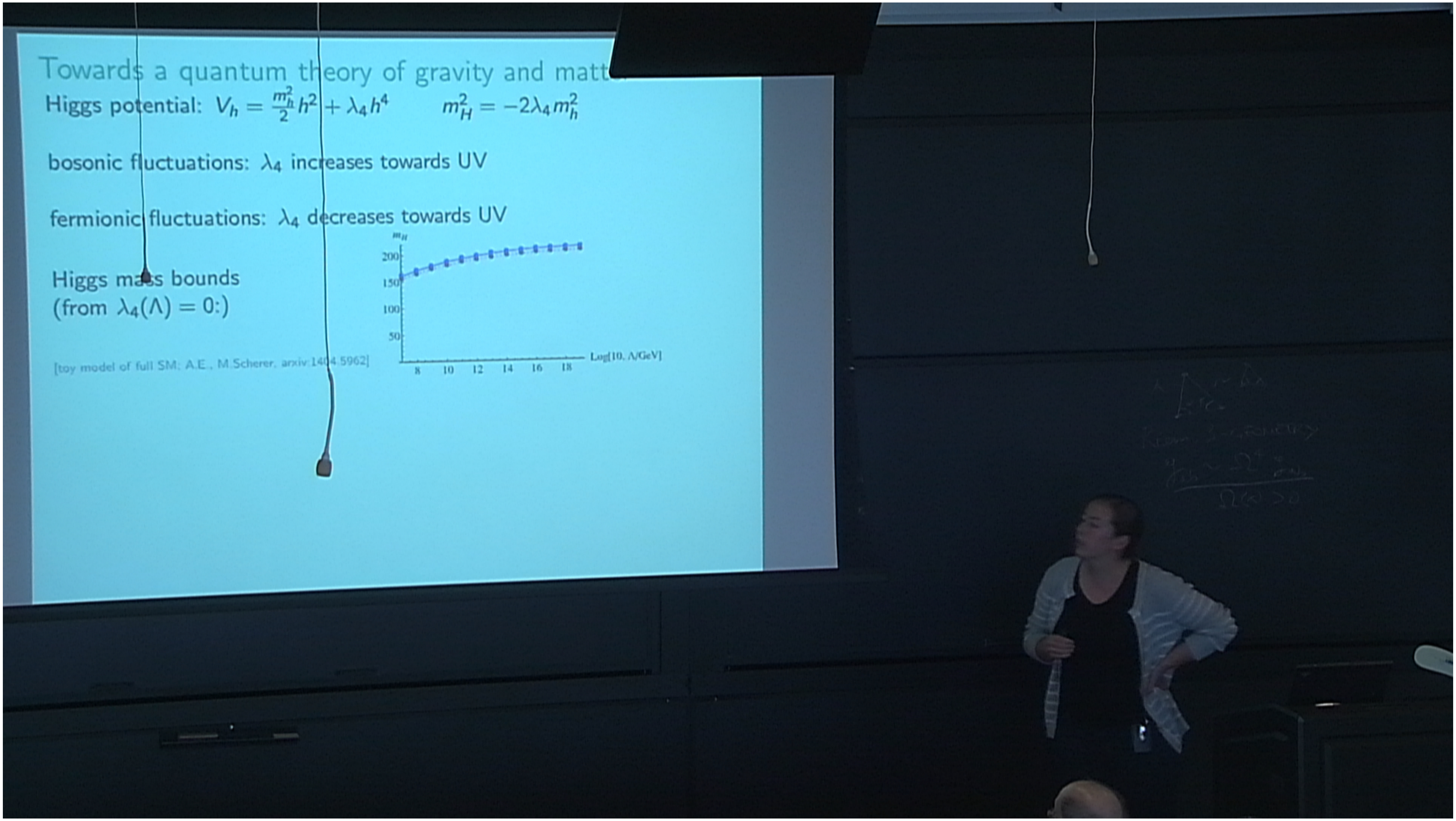
supersymmetric extension (MSSM: $N_S = 49, N_D = 61/2, N_V = 12$) ✗
GUT (SO(10): $N_S = 97, N_D = 24, N_V = 45$) ✗
Only specific models with restricted matter content are compatible with Asymptotically Safe Quantum Gravity within our truncation
⇒ Test quantum gravity at the LHC by looking for Beyond-Standard-Model physics


Towards a quantum theory of gravity and matt
Higgs potential: $V_h = \frac{m_h^2}{2} h^2 + \lambda_4 h^4$ $m_H^2 = -2\lambda_4 m_h^2$
bosonic fluctuations: λ_4 increases towards UV
fermionic fluctuations: λ_4 decreases towards UV
Higgs mass bounds
(from $\lambda_4(\Lambda) = 0$:)
[toy model of full SM; A.E., M.Scherer, arxiv:1404.5962]
m_H
200
150
100
50
Log[10, Λ/GeV]
8
10
12
14
16
18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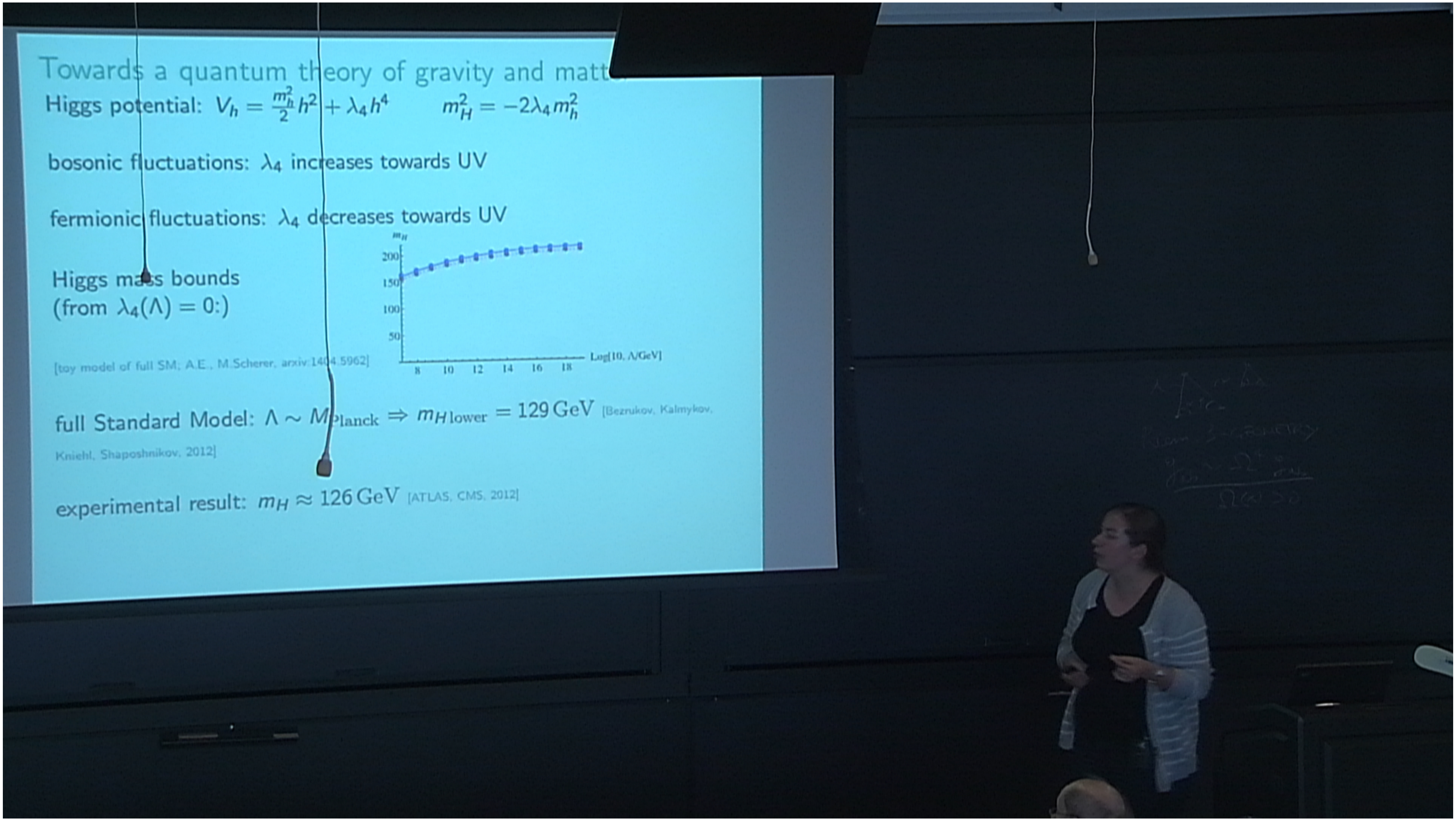
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50
8 10 12 14 16 18
Log[10, Λ/GeV]
full Standard Model: $\Lambda \sim M_{\rm Planck} \Rightarrow m_{H\,\rm lower} = 129\,\rm GeV$ [Bezrukov, Kalmykov, Kniehl, Shaposhnikov, 2012]
experimental result: $m_H \approx 126\,\rm GeV$ [ATLAS, CMS, 2012]