Title: Lecture - QFT II, PHYS 603

Speakers: Francois David

Collection/Series: Quantum Field Theory II (Core), PHYS 603, November 12 - December 11, 2024

Subject: Condensed Matter, Particle Physics, Quantum Fields and Strings

Date: November 26, 2024 - 9:00 AM

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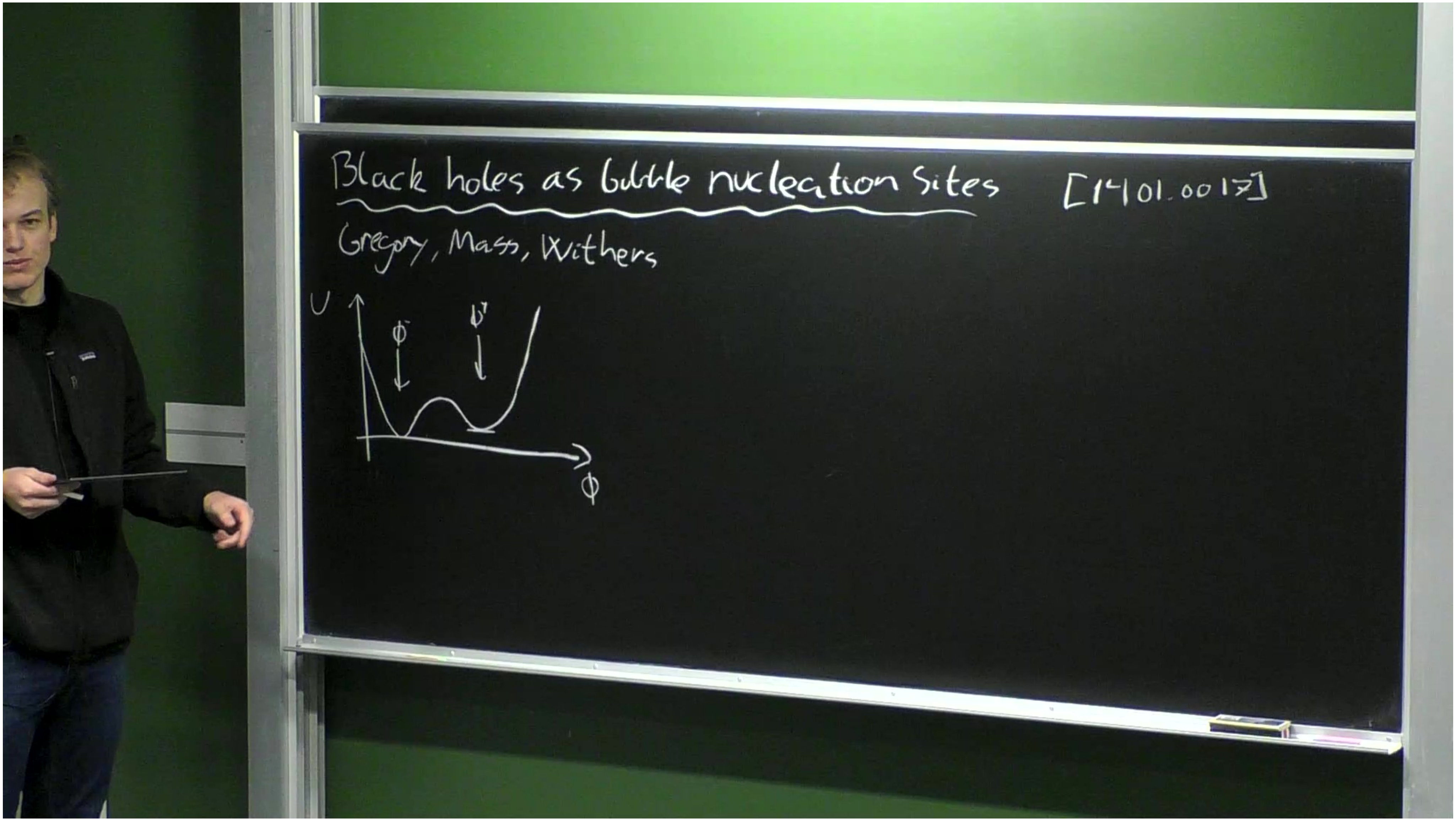
Black holes as bubble nucleation sites
[1401.0017]
Gregory, Mass, Withers
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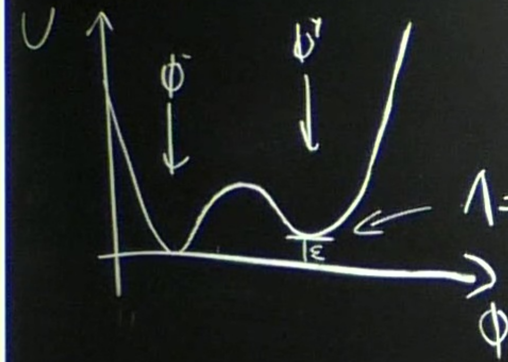
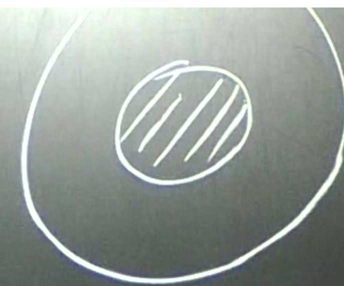


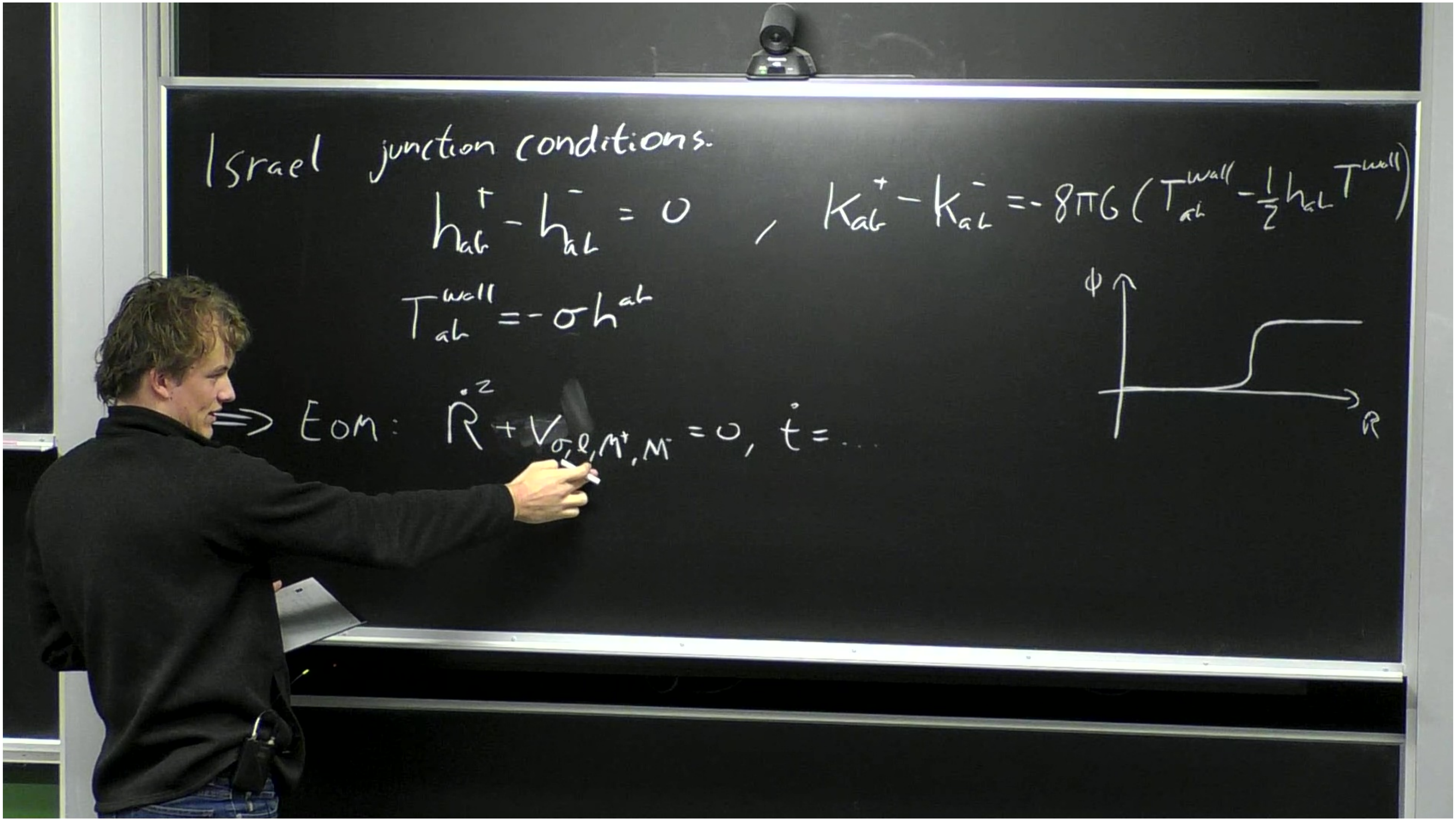
$$\Lambda = \frac{3}{\ell^2} = 8\pi G \varepsilon > 0$$



Assumptions: $\Gamma \sim e^{-\frac{B}{\hbar}}$, $B = S_E(\phi) - S_E(\phi^+)$

$$ds^2 = -f(r)\,dt^2 + \frac{1}{f(r)}\,dr^2 + r^2\,d\Omega^2$$

$$f_- = 1 - \frac{2M_-}{r}, \quad f_+(r) = 1 - \frac{2M^+}{r} + \frac{r^2}{\ell^2}$$


Israel junction conditions.
$h^+_{ab} - h^-_{ab} = 0$, $K^+_{ab} - K^-_{ab} = -8\pi G\left(T^{wall}_{ab} - \frac{1}{2}h_{ab}T^{wall}\right)$
$T^{wall}_{ab} = -\sigma h^{ab}$
$\Rightarrow$ EOM: $\dot{R}^2 + V_{\sigma,\ell,M^+,M^-} = 0$, $\dot{t} = \ldots$
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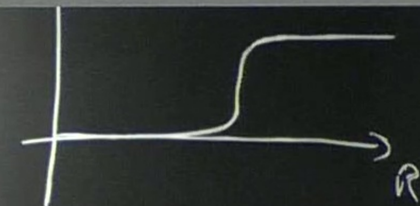
R

T_{ab}^{wall}

$\Rightarrow$ EOM: $\dot{R}^2 + V_{\sigma,\ell,M^+,M^-} = 0, \quad t = \ldots$

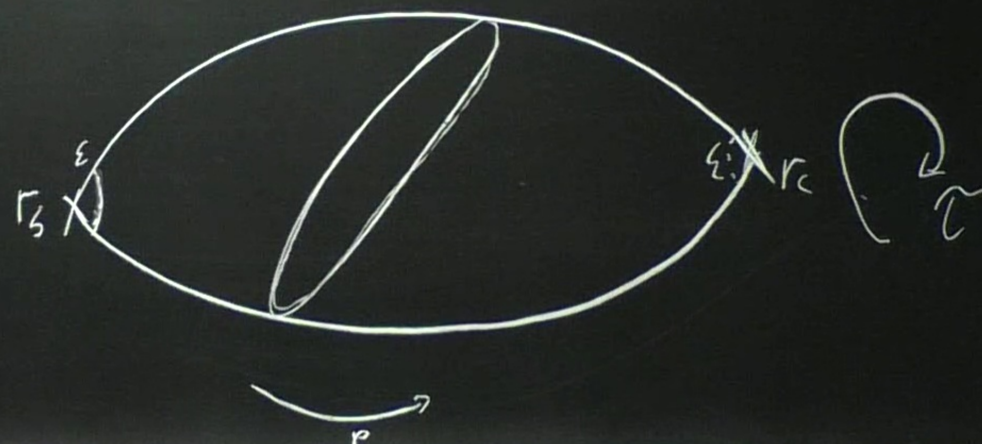


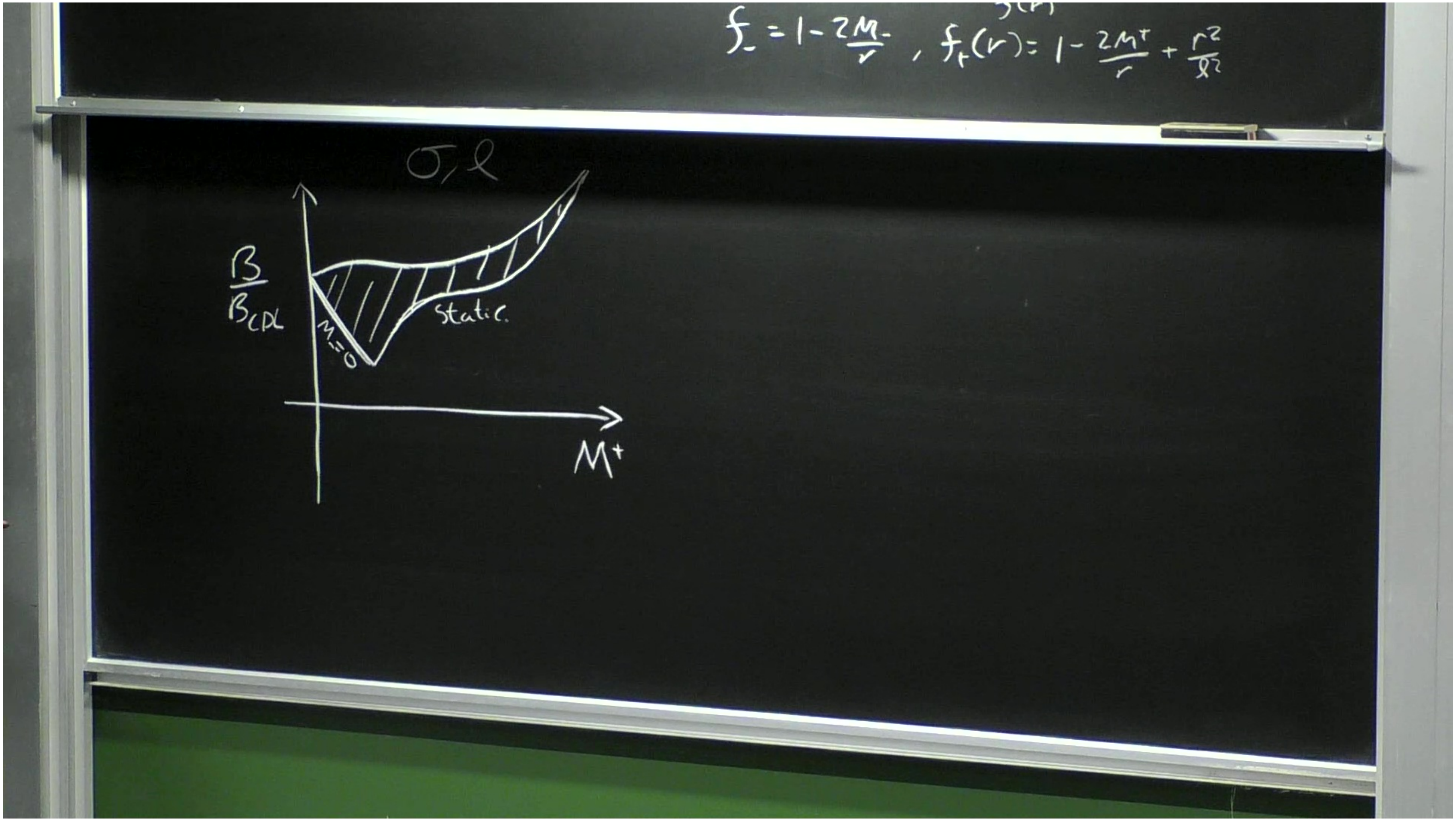
$t \to -i\tau$

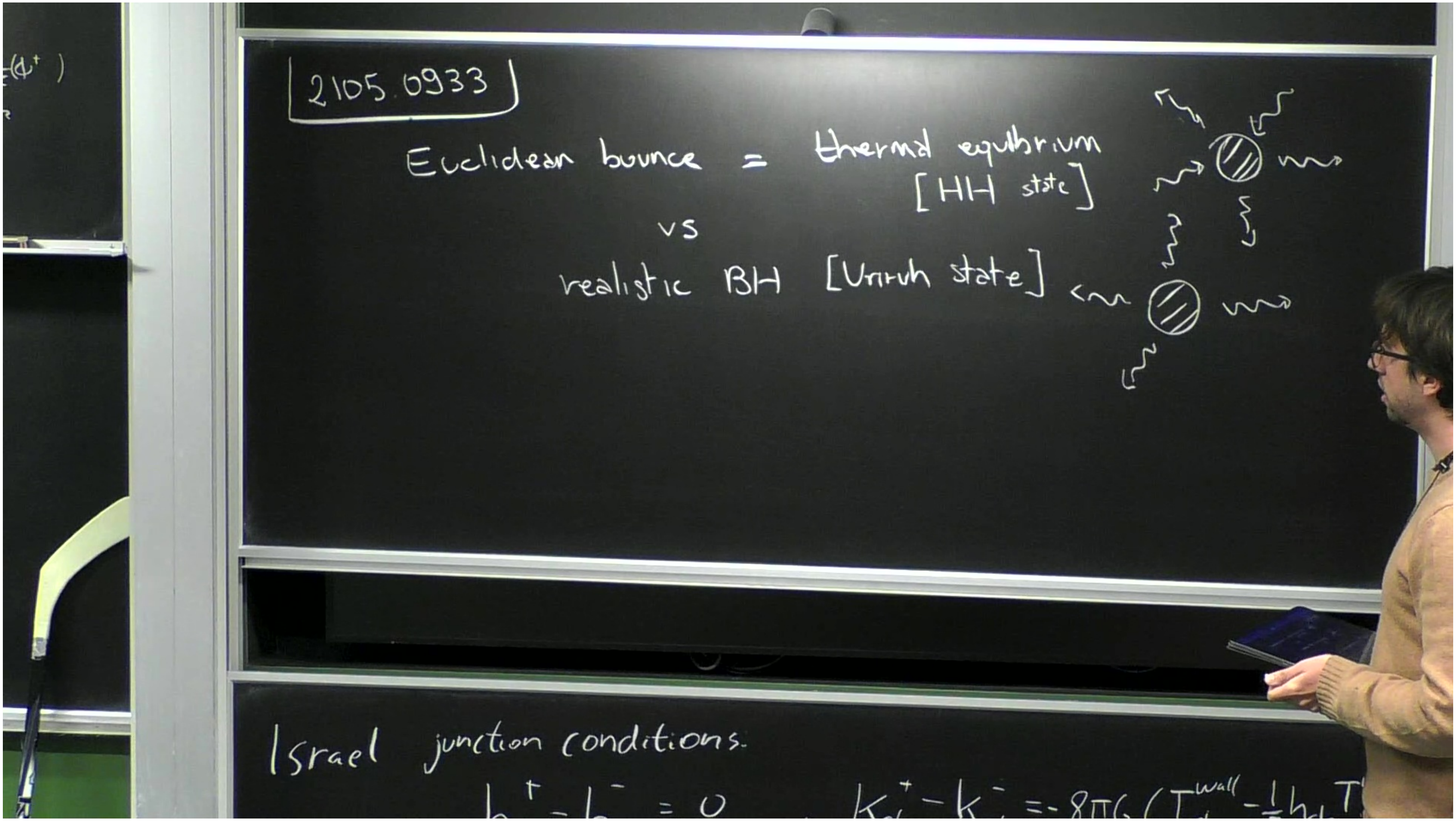
Near horizon BH:

$$ds^2 = f'(r_3)(r-r_3)\,d\tau^2 + \frac{1}{f'(r_3)(r-r_3)}\,dr^2 + r^2 d\Omega^2 \to d\rho^2 + \rho^2\left(\frac{f'(r_3)}{2}\,d\tau\right)^2 + r^2 d\Omega^2$$

$$S_E^{M} = S_E^{M-B} + S_E^{B}$$




$f_- = 1 - \frac{2M_-}{r}$, $f_+(r) = 1 - \frac{2M^+}{r} + \frac{r^2}{\ell^2}$
σ, ℓ
$\frac{B}{B_{CDL}}$
static
$M_- = 0$
M^+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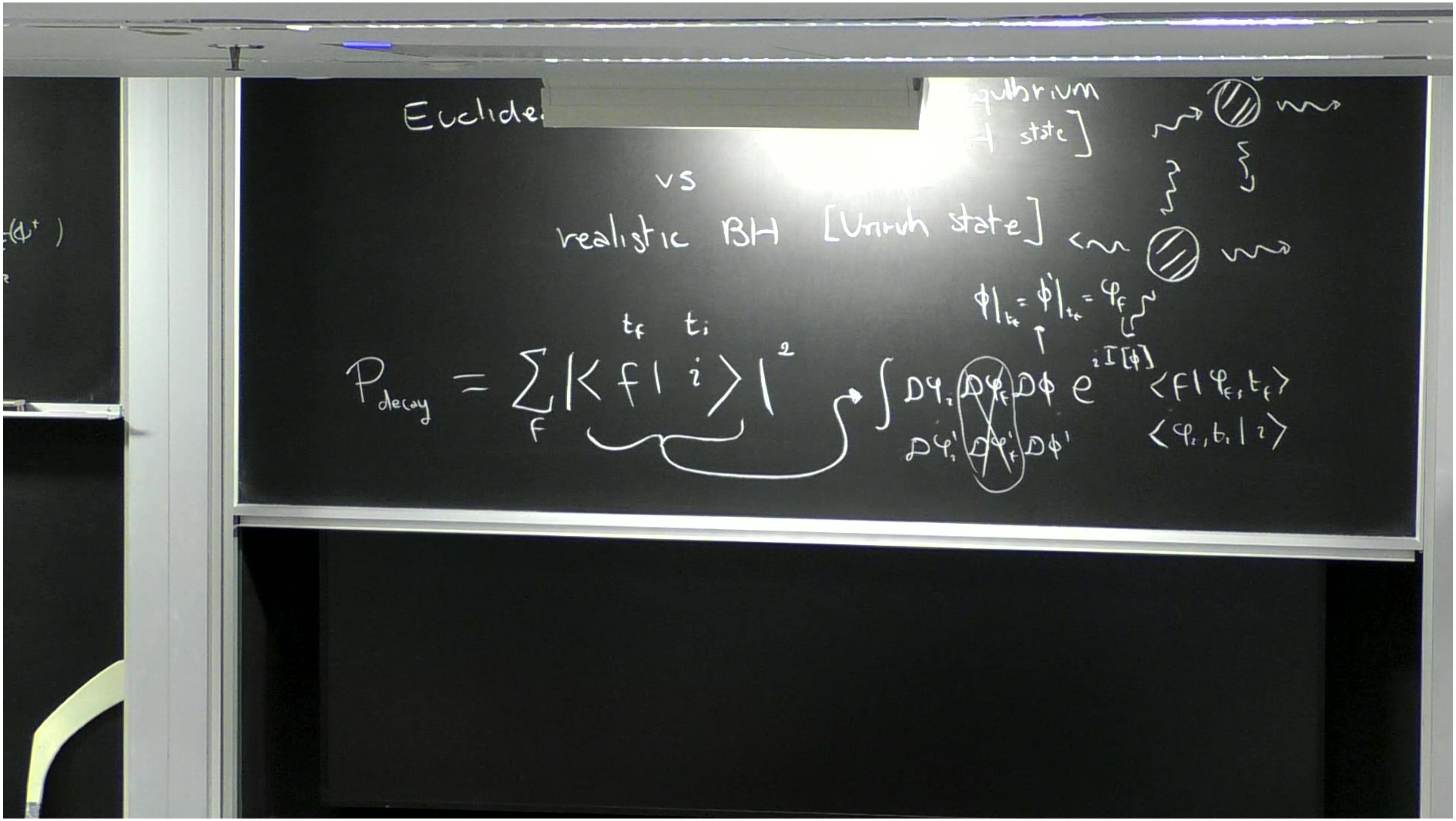
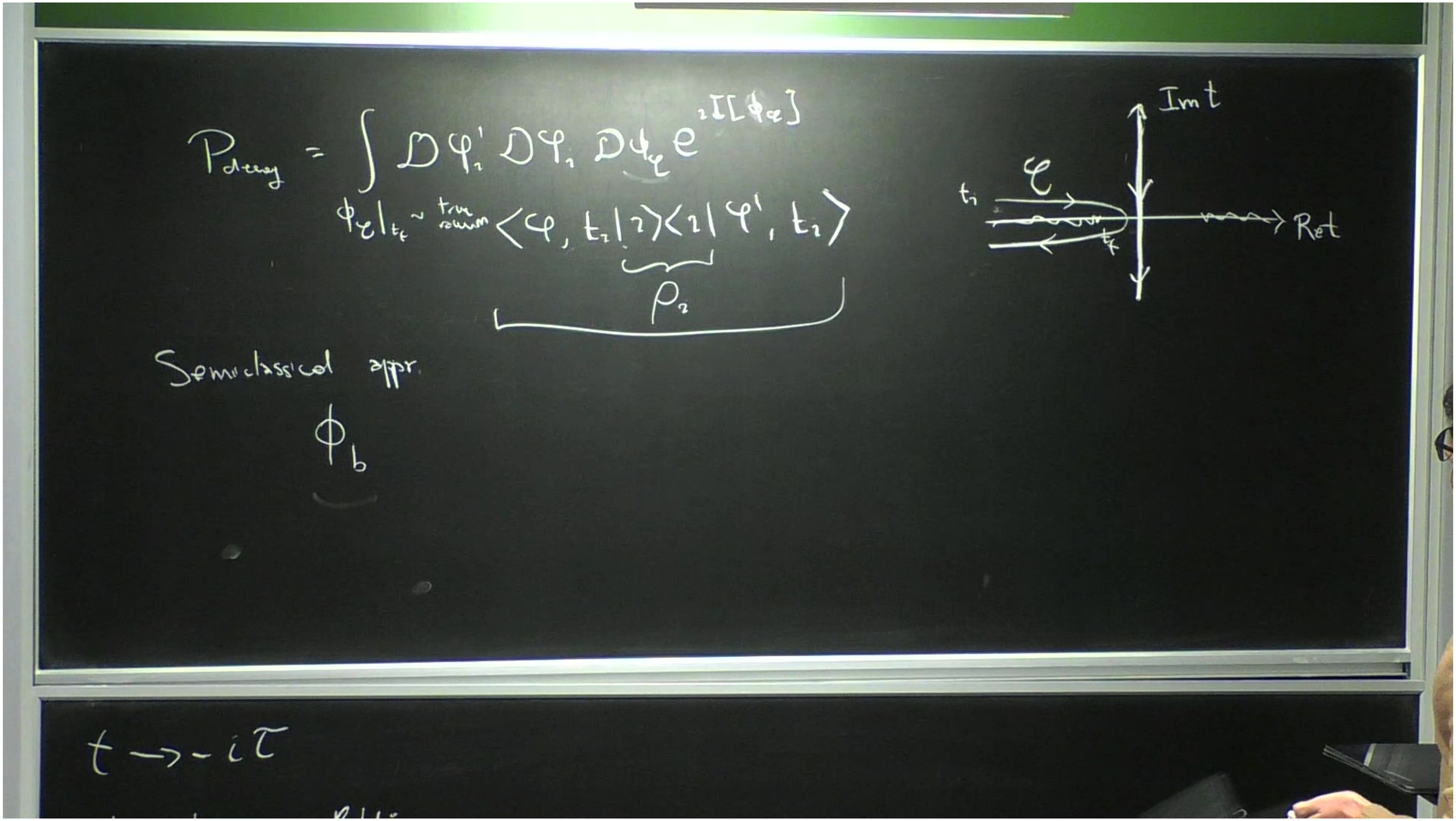
Euclidean bounce = thermal equilibrium
[HH state]
vs
realistic BH [Unruh state]
Israel junction conditions.


Euclide
quilbrium
state]
vs
realistic BH [Unruh state]
$\phi|_{t_f} = \phi'|_{t_f} = \varphi_f$
$t_f \quad t_i$
$P_{decay} = \sum_f |\langle f | i \rangle|^2$
$\int D\varphi_i D\varphi_f D\phi \, e^{iI[\phi]} \langle f | \varphi_f, t_f \rangle$
$D\varphi_i' D\varphi_f' D\phi' \quad \langle \varphi_i, t_i | i \rangle$


$P_{decay} = \int \mathcal{D}\varphi_1' \, \mathcal{D}\varphi_1 \, \mathcal{D}\phi_{\mathcal{C}} \, e^{iI[\phi_{\mathcal{C}}]}$
$\phi_{\mathcal{C}}|_{t_f} \sim$ true vacuum $\langle \varphi, t_1 | ? \rangle \langle ? | \varphi', t_1 \rangle$
$\rho_?$
Im t
Re t
$\mathcal{C}$
t_1
t_f
Semiclassical appr.
ϕ_b
$t \to -i\tau$

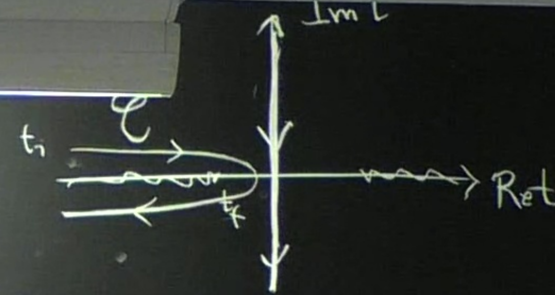
$$P_{decay} = \int \mathcal{D}\varphi_2' \, \mathcal{D}\varphi_1 \, \mathcal{D}$$

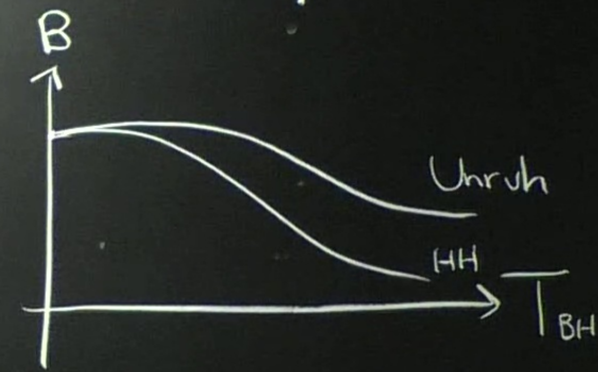
$$\phi_{\varepsilon}\big|_{t_f} \sim \text{true vacuum} \quad \underbrace{\langle \varphi, t_2 | \underbrace{2\rangle\langle 2}_{\rho_2} | \varphi', t_2 \rangle}$$

Semiclassical appr.

ϕ_b

$$\Gamma \sim e^{-B}$$





$\boxed{2105.0933}$

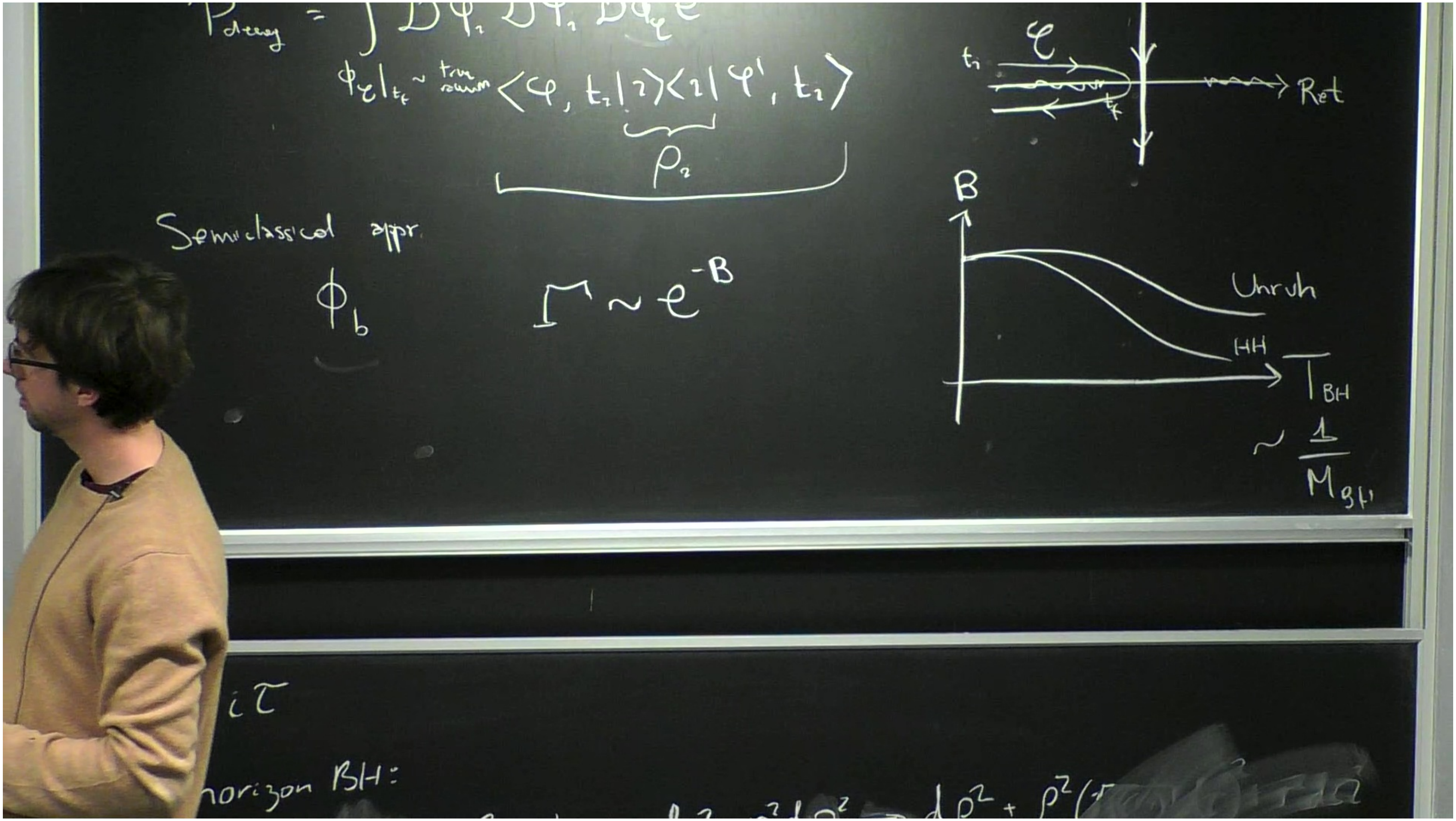
Euclidean bounce = thermal equilibrium
[HH state]

vs

realistic BH [Unruh state]

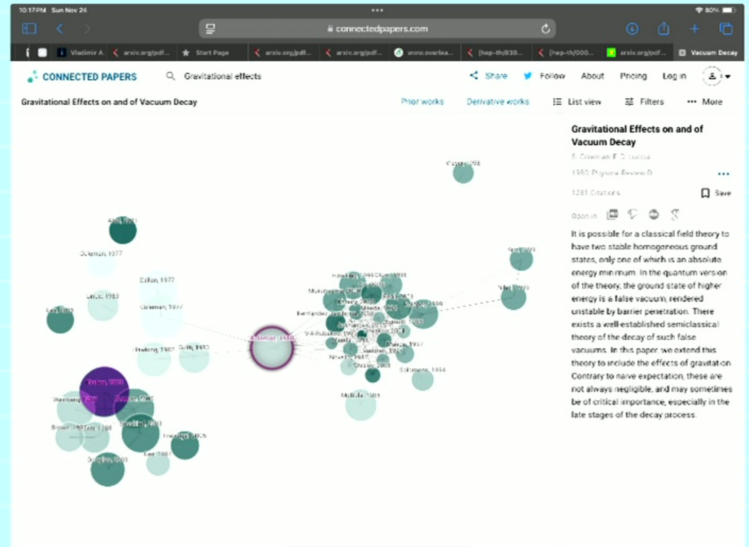
$$\phi|_{t_f} = \phi'|_{t_f} = \varphi_f$$

$$P_{decay} = \sum_f |\langle \overset{t_f}{f} | \overset{t_i}{i} \rangle|^2 \rightarrow \int \begin{array}{c} D\varphi_i\, \cancel{D\varphi_f}\, D\phi \\ D\varphi_i'\, \cancel{D\varphi_f'}\, D\phi' \end{array} e^{iI[\phi]} \begin{array}{c} \langle f | \varphi_f, t_f \rangle \\ \langle \varphi_i, t_i | i \rangle \end{array}$$


Semiclassical appr.
Γ ~ e^-B
B
Unruh
HH
T_BH
~ 1/M_BH
Ret
iτ
horizon BH:

de Sitter Vacua in String Theory

Shamit Kachru,[1,2] Renata Kallosh,[1] Andrei Linde[1] and Sandip P. Trivedi[3]



De Sitter vacua in string theory

Shamit Kachru (Stanford U., Phys. Dept. and SLAC), Renata Kallosh (Stanford U., Phys. Dept.), Andrei D. Linde (Stanford U., Phys. Dept.), Sandip P. Trivedi (Tata Inst.)

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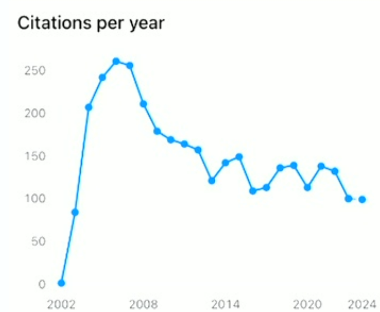

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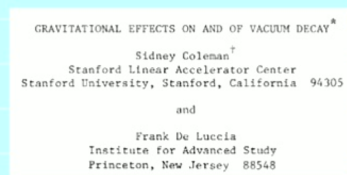
Plan for the talk:

I. Some reasons why it is hard :(to find de Sitter vacuum in string theory

II. Overview of the KKLT construction

III. Stability of the solution, relation to



GRAVITATIONAL EFFECTS ON AND OF VACUUM DECAY*

Sidney Coleman†
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

and

Frank De Luccia
Institute for Advanced Study
Princeton, New Jersey 08540

IV. People still talk about it! Controversies and relation to The Swampland Program

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I Some reasons why it is hard :c to find de Sitter vacuum in string theory

- No-go theorem by [Maldacena, Nuñez ; '00]

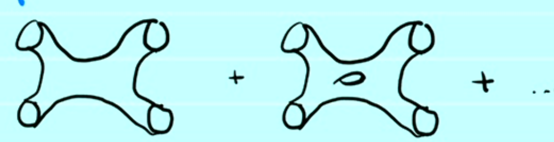
  In the second part of this paper, which can be read independently of the first, we show that there are no non-singular Randall-Sundrum or de-Sitter compactifications for large class of gravity theories.

  - without sources
  - without α' or g_s corrections

stringy corrections

quantum corrections

vs •



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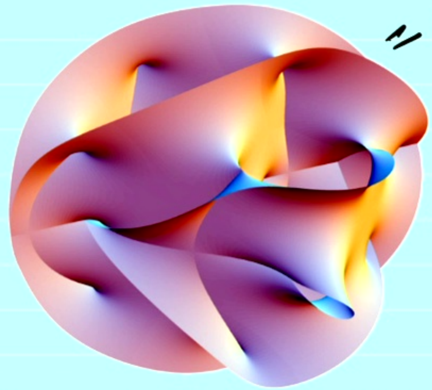
(I) Some reasons why it is hard :(to find de Sitter vacuum in string theory compactifications

- Moduli stabilization

10d spacetime =



$\sim CY_3$

$\times M_{4d}$

where we live

moduli $\equiv$ massless fields characterizing CY_3

- shape
- size

...

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- Scale separation

II Overview of the KKLT construction

Two steps:

(1) Stabilize all moduli in a supersymmetric way

1.1 Fix all moduli except for volume with fluxes

1.2 Fix the volume with quantum corrections

AdS vacua with exponentially large warping

(2) Break supersymmetry and get a de Sitter vacuum → introducing $\overline{D3}$

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III Stability of the solution

The de Sitter vacua is metastable so following Coleman, De Luccia they argue

1) Do our dS vacua survive for a large number of Planck times? For instance, if we fine tune to get a small cosmological constant, is the dS vacuum sufficiently stable to survive during the 10^{10} years of the cosmological evolution? If the answer is positive, one can use the dS minimum for the phenomenological description of the current stage of acceleration (late-time inflation) of the universe.

2) Is the typical decay time of the dS vacuum longer or shorter than the recurrence time $t_r \sim e^{\mathbf{S_0}}$, where $\mathbf{S_0} = \frac{24\pi^2}{V_0}$ is the dS entropy [43]? If the decay time is longer than $t_r \sim e^{\mathbf{S_0}}$, one may need to address the issues about the consistency of the stringy description of dS space raised in [2, 5, 8].

to these questions

① Thin wall approximation

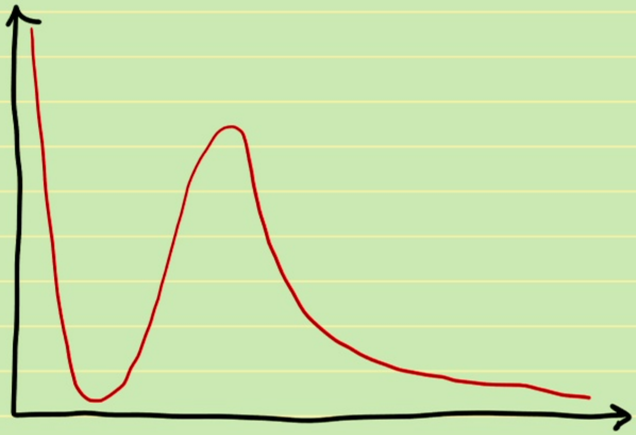
$$P \approx \exp\left(-\mathbf{S}(\varphi_0)\right) = \exp\left(-\frac{24\pi^2}{V_0}\right) \sim \exp\left(-10^{122}\right) \ .$$

$$t_{\text{decay}}^{\text{CDL}} \sim t_r \exp\left(-\frac{64\pi^2}{T^2}\right)$$

② No wall approximation

$$t_{\text{decay}}^{\text{HM}} = e^{-\mathbf{S_1}+\mathbf{S_0}} = t_r \ \exp\left(-\frac{24\pi^2}{V_1}\right) \ll t_r \ .$$

DIFFERENT PHYSICAL PROCESSES



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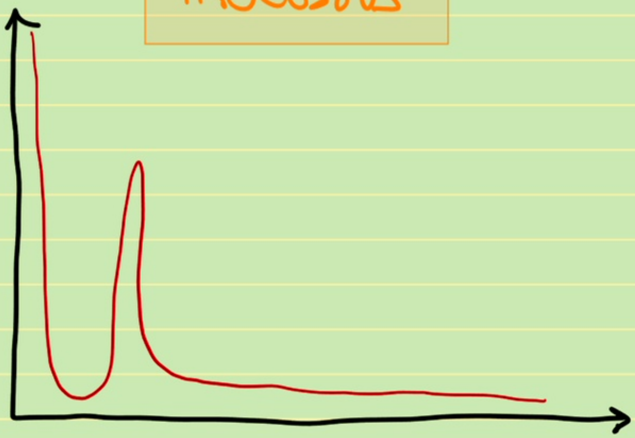

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IV Criticisms to KKLT

- Does the $\overline{D3}$ mechanism really work?
  singularities, backreaction, stability ...
- Moduli stabilization
  separation of scales $\begin{matrix} m_\tau \\ m_\rho \end{matrix}$ ~ can you justify the hierarchy?
- are the α' and g_s corrections really controlled?
  Dine-Seiberg problem
  ⊕ non susy ~ instability concerns
- Explicit construction with consistent uplift to 10d string theory?

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IV The de Sitter conjecture and the Swampland program

Conjecture 9: de Sitter Conjecture

A scalar potential of an EFT weakly coupled to Einstein gravity must satisfy

$$M_P \frac{|\nabla V|}{V} \geq c\,, \tag{9.1}$$

with c some $\mathcal{O}(1)$ constant. This was further refined by stating that the previous bound only needs to be imposed if the following condition on the second derivative of the potential is violated,

$$\min\left(\nabla_i \nabla_j V\right) \leq \frac{-c' V}{M_P^2}\,, \tag{9.2}$$

with c' another $\mathcal{O}(1)$ constant. This way, only dS minima (and not critical points in general) are ruled out.

No proof for this conjecture but people believe no de Sitter solution has been well formulated yet.

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ongoing research program

II Overview of the KKLT construction

① Stabilize all moduli in a supersymmetric way

1.1 Fix all moduli except for volume with fluxes

- Axio-dilaton $\tau = C_0 + i e^{-\phi}$
- complex structure

$$\begin{array}{ccc} \underset{\tau}{S^1 \times S^1} & \longrightarrow & X_{CY_4} \\ & & \downarrow \\ & & \underset{\Omega}{M_{CY_3}} \end{array}$$

But the volume ρ (Kahler modulus) does not appear in the potential $\longrightarrow$ FLAT DIRECTION

Find exponentially large warping in the compactification

$$ds^2_{10} = e^{2A(y)} \eta_{\mu\nu} dx^\mu dx^\nu + e^{-2A(y)} \tilde{g}_{mn} dy^m dy^n$$

$$e^{A_{min}} \sim e^{-\frac{2\pi K}{3 g_s M}}$$