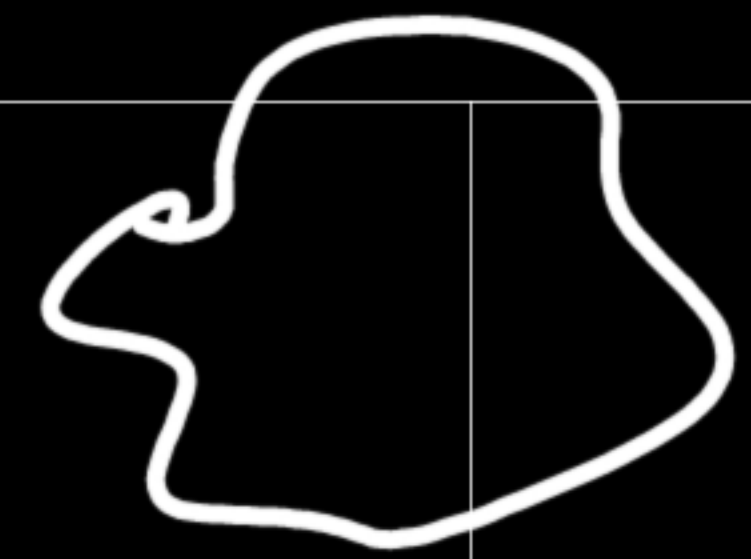




$$D=10$$

$$N=(1,1)$$

$$N=(7,0)$$

IIA

IIB

$$g_{\mu\nu} b_{\mu\nu} \oplus C_1, C_3$$

$$C_0, C_2, C_4$$



$$1) D=10$$

$$N=1$$

SYM
SU(4)

$$\frac{A^I_{\mu} \psi^A_{\mu}}{2!}$$

2) $\mu \nu \omega \epsilon \mu \nu$

3) $h \epsilon \mu \nu \omega \epsilon \mu \nu$

$$P=9 \text{ (1002, energy)}$$

$$|0\rangle^I$$

$$\alpha_n^M, b_r^M$$

$\downarrow h \epsilon \mu \nu \omega \epsilon \mu \nu$

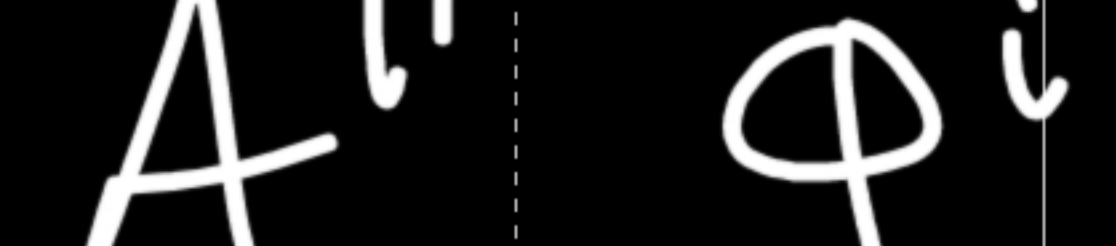
$$D=4, \text{SYM } N=4 \text{ f) } M_{Pl} = 10^{19} \text{ GeV}$$

$$\alpha' M_1^2 = \alpha_{-n}^M \alpha_n^M + \dots$$

11D3 : $\alpha_{-m}^M, \alpha_{-m}^i, b_{-r}^M, b_{-r}^i$

$$N$$

$$\mu = 0, 1, 2, 3, \dots, 9$$

$A^\mu, \Phi^i, \psi^i, \lambda$
 wavy ψ^i

 loop A^μ
 2 photon

N
SUG

[illegible]

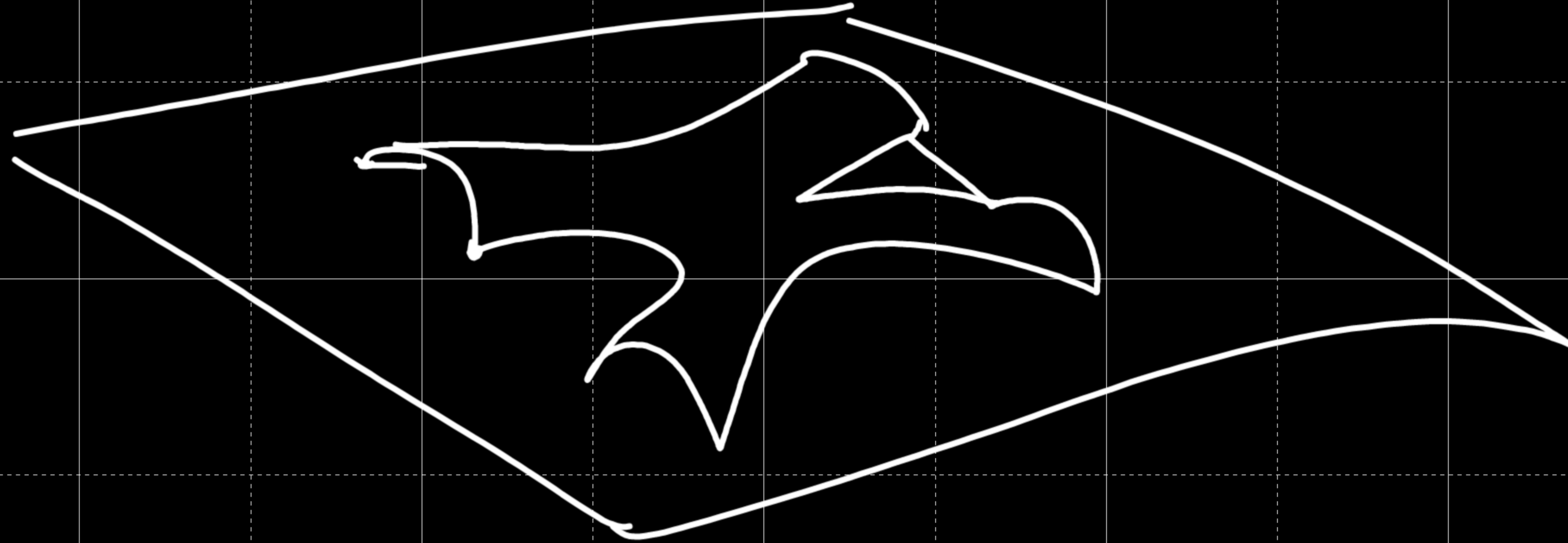
A hand-drawn graph on a grid. A horizontal dashed line is labeled 'M' below it. A wavy line starts at a point on the left vertical axis, oscillates around the dashed line, and ends at a point on the right vertical axis. The amplitude of the oscillations decreases from left to right.

$$T_{DP} \sim \frac{1}{g_{\text{eff}}^2}$$

$$(1 + \gamma_0 \gamma_{1/2}^2) e^{-1} \approx 0$$

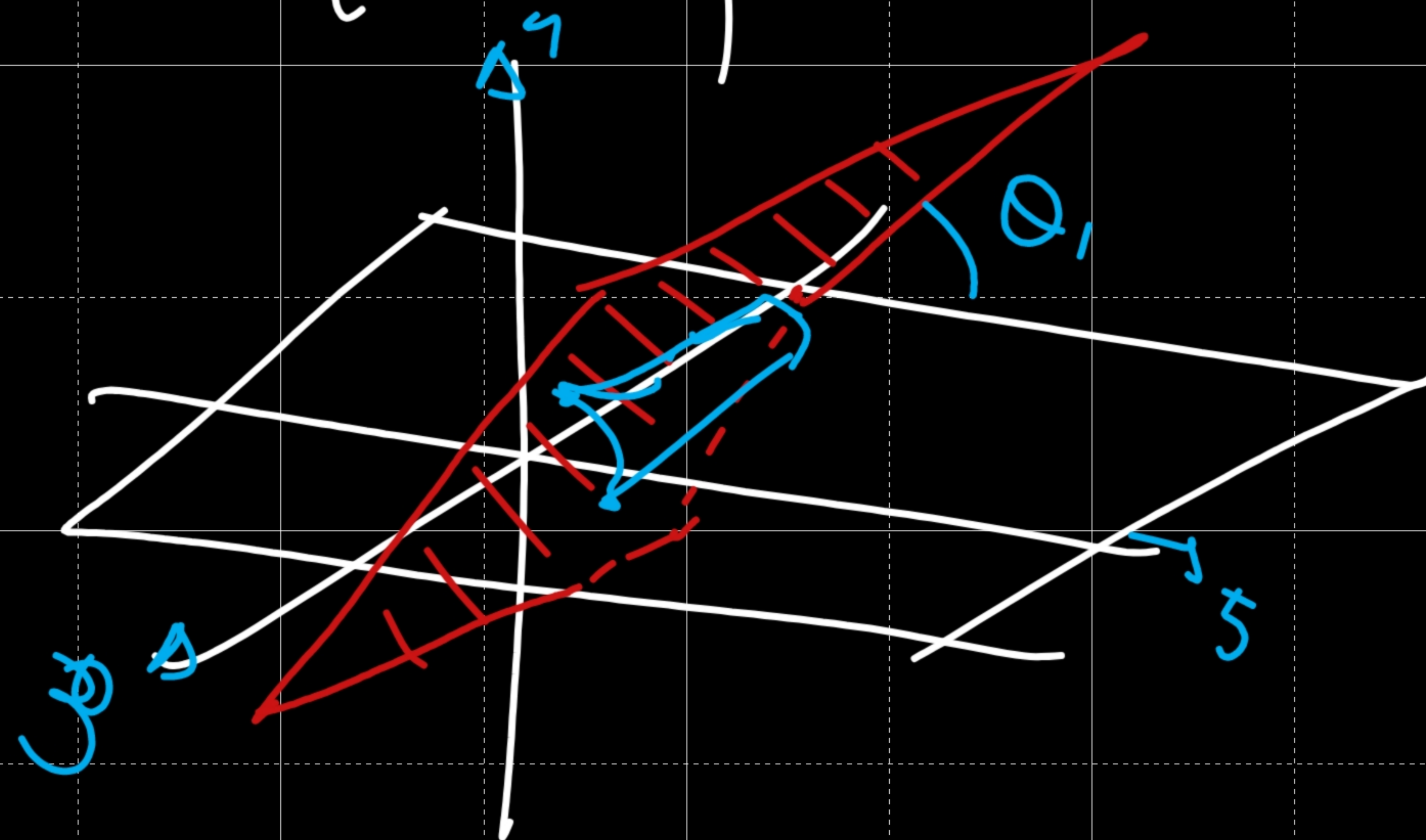
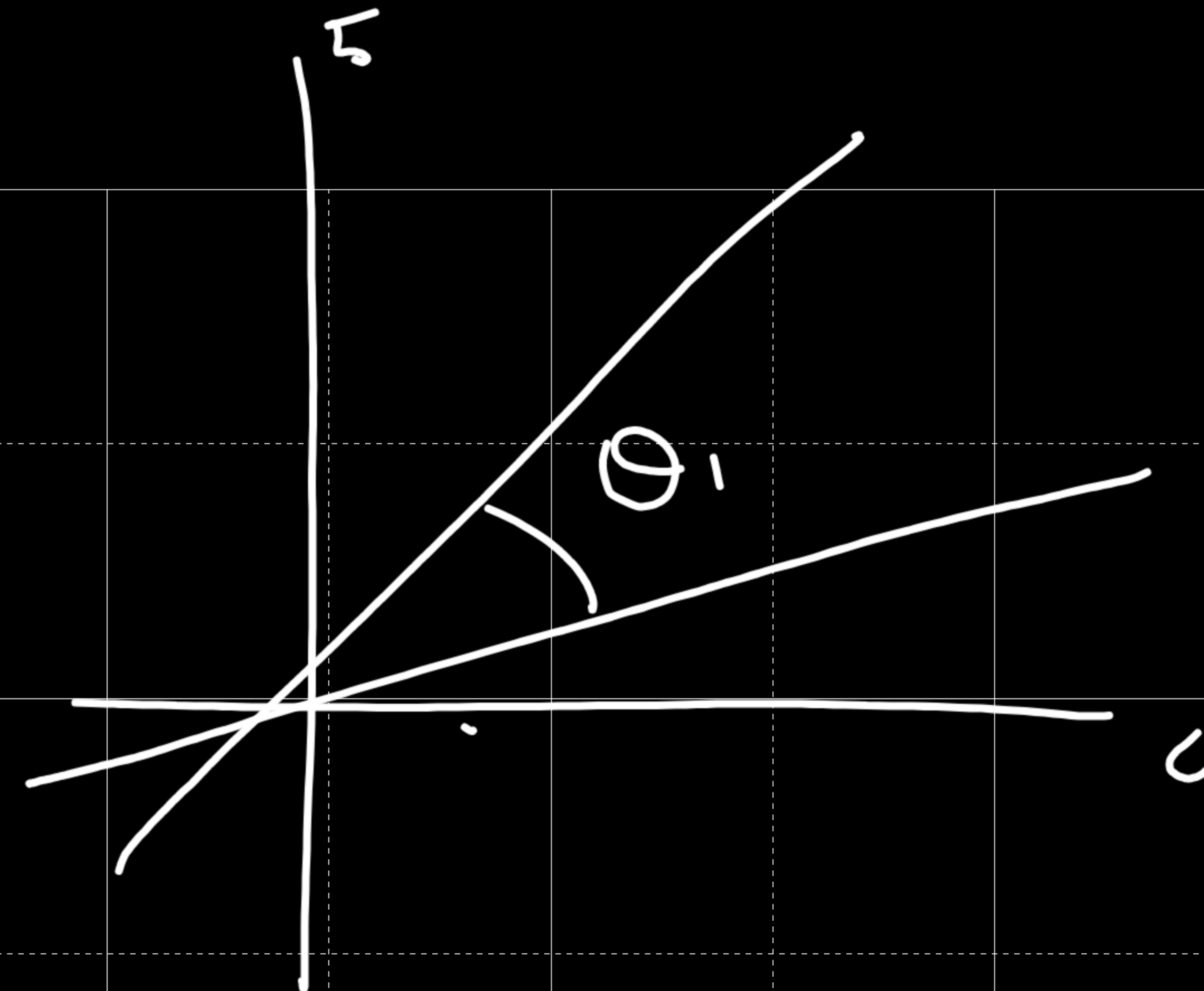
$$(1 + \gamma_0 \gamma_{1/2}^2) e^{-1} \approx 0$$

$$S = S_p + \int \left(\textcircled{A_\mu} \partial_\mu X^r \right) d\sigma \bigg|_{\sigma=0}^{\sigma=2}$$



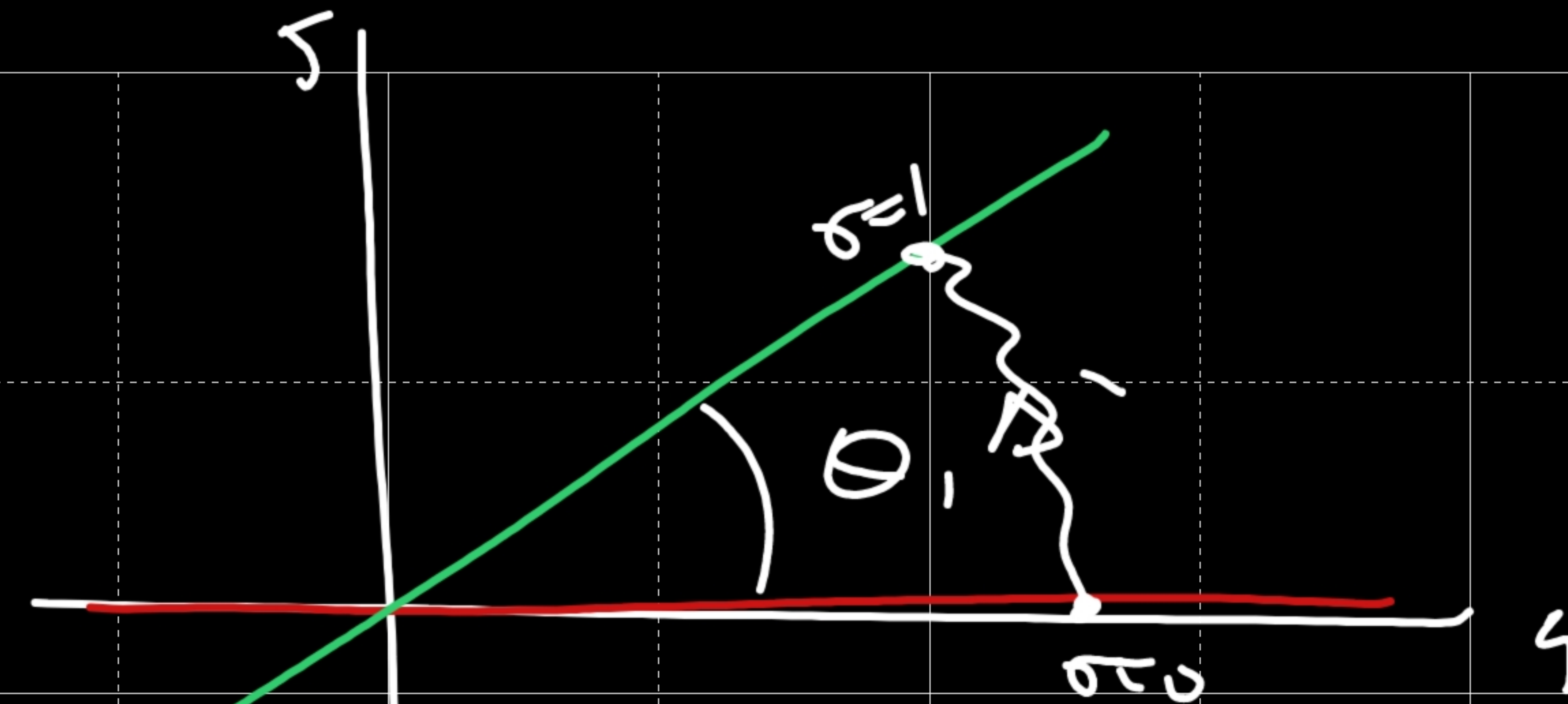
1. $D6_{a,b}$ Ha $\mathbb{R}^{1,4} \times T^2 \times T^2 \times T^2$

	0 1 2 3	4 5	6 7	8 9
$D6_a$	-----			
$D6_b$	-----	$\bigcirc_1$	$\bigcirc_2$	$\bigcirc_3$



$$\sigma=0 \left\{ \begin{array}{l} \partial_\sigma X^\mu = 0 \quad N \\ \partial_\tau X^\mu = 0, \quad D \end{array} \right.$$

$$\sigma=1 \left\{ \begin{array}{l} \partial_\sigma (X^4(\tau,1) \cos \theta_1 + X^5(\tau,1) \sin \theta_1) = 0 \quad N \\ \partial_\sigma (-X^4(\tau,1) \sin \theta_1 + X^5 \cos \theta_1) = 0 \quad D \end{array} \right.$$



$$\sigma=0 \quad X^\mu(\sigma, \tau) = \pm \sqrt{2\alpha'} \sum_n \alpha_n \cos(n\sigma\tau) e^{in\tau\tau} \quad (\partial_\sigma^2 - \partial_\tau^2) X^\mu|_{\sigma=0} = 0$$

$$X^5(\sigma, \tau) = \pm \sqrt{2\alpha'} \sum_n \beta_n \sin(n\sigma\tau) e^{in\tau\tau} \quad \partial_\sigma X^\mu|_{\sigma=0} = 0$$

$$\sigma=1: \quad -\alpha_n \sin(\pi n) \cdot \cos \theta_1 + \beta_n \cos(\pi n) \sin \theta_1 = 0$$

$$-\alpha_n \cos(\pi n) \sin \theta_1 + \beta_n \sin(\pi n) \cos \theta_1 = 0$$

$$\alpha_n = \pm \beta_n; \quad \alpha_n \sin(\pi n \pm \theta_1) = 0$$

$$n_{\pm} = m \pm \frac{\theta_1}{\pi}$$

$$m \in \mathbb{Z}$$

$$\alpha_{n_+}, \alpha_{n_-}$$

$$1. \underbrace{X^0, X^1, X^2, X^3}_N :$$

$$\alpha_{-n}^a, \alpha_n^a \quad n \in \mathbb{Z}$$

$$b_{-r}^a, b_r^a \quad r \in \mathbb{Z} + \frac{1}{2}$$

$$a=0,1,2,3$$

$$2. \begin{cases} X^4, X^5, \Theta_1 \\ X^6, X^7, \Theta_2 \\ X^8, X^9, \Theta_3 \end{cases}$$

$$\alpha_{n_{\pm}}^1, b_{r_{\pm}}^1$$

$$\alpha_{n_{\pm}}^2$$

$$n_{\pm} = m \pm \frac{\Theta_1}{\pi}, \quad r_{\pm} = r \pm \frac{1}{2}$$

$$r_{\pm} = r \pm \frac{1}{2}$$

$$[\alpha_n, \alpha_m] = n \delta_{n+m,0}$$

$$\{b_r, b_s\} = \delta_{r+s,0}$$

$$[\alpha_{n_{\pm}}^I, \alpha_{n'_{\pm}}^J] = n_{\pm} \delta_{n+n',0} \delta^{IJ}$$

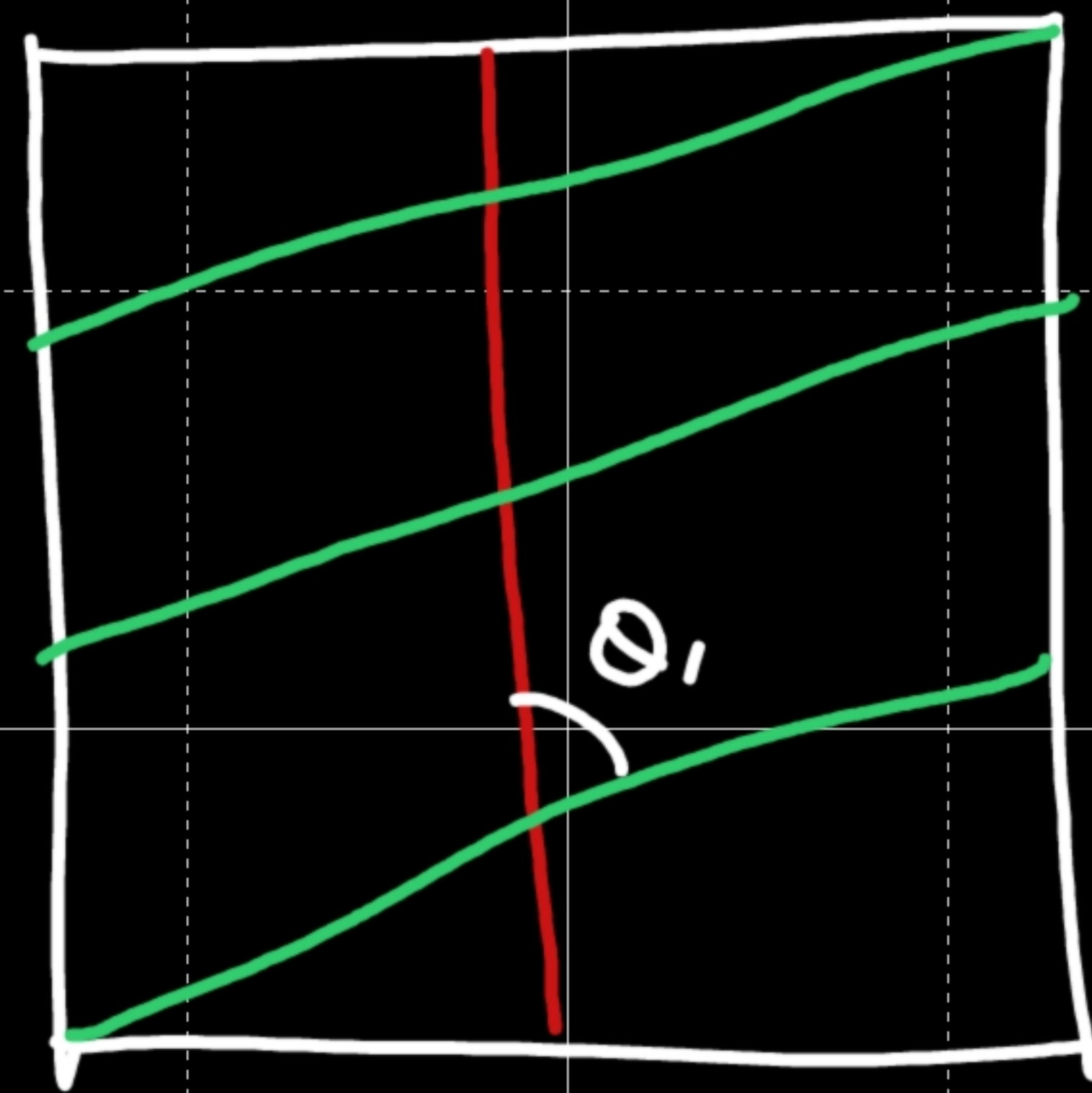
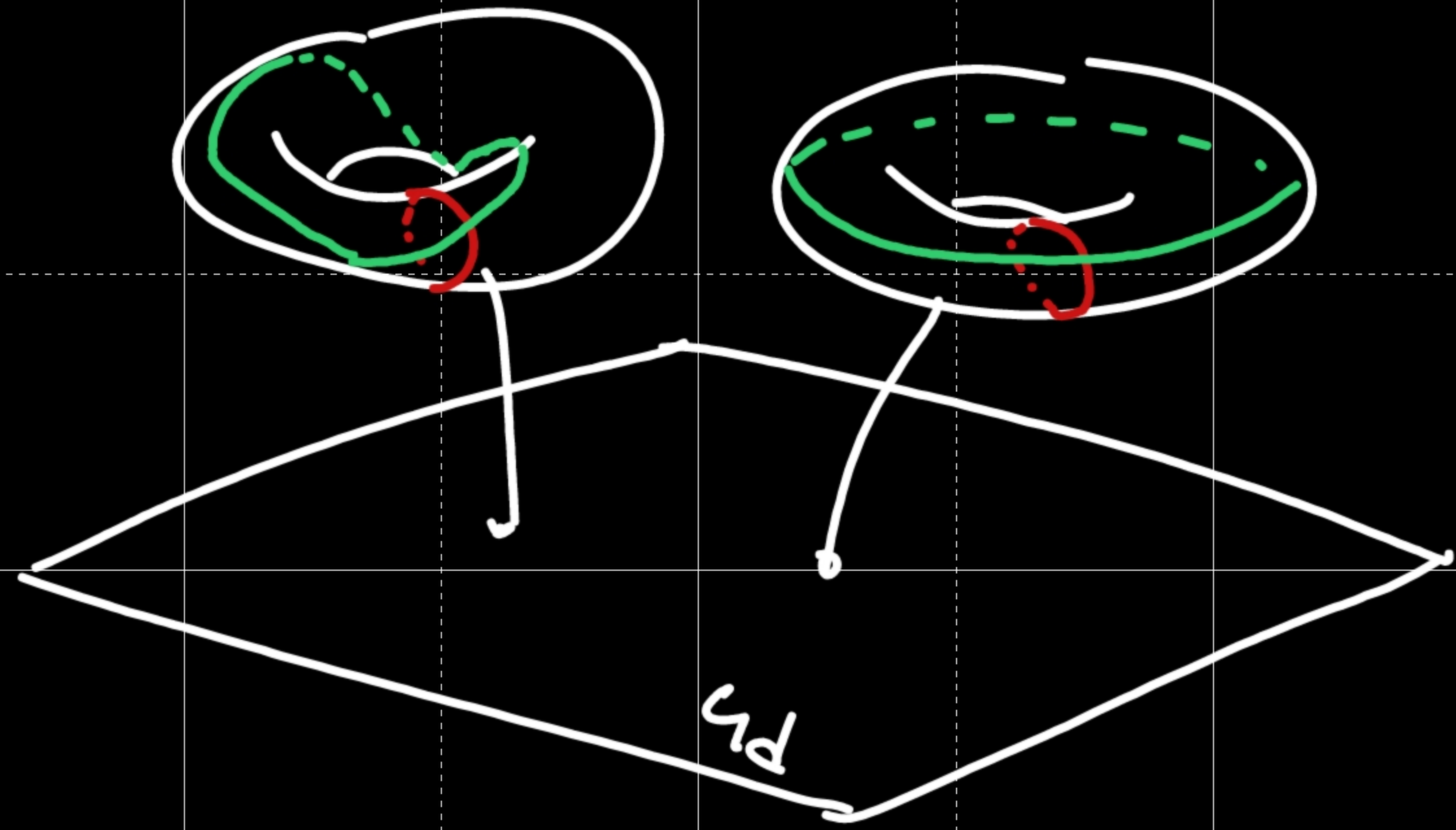
$$\{b_{r_{\pm}}^I, b_{s_{\pm}}^J\} = \delta_{r+s,0} \delta^{IJ}$$

$$\begin{matrix} ab \\ ba \end{matrix} \left(\begin{matrix} aa \\ bb \end{matrix} \right) \uparrow Y_M$$

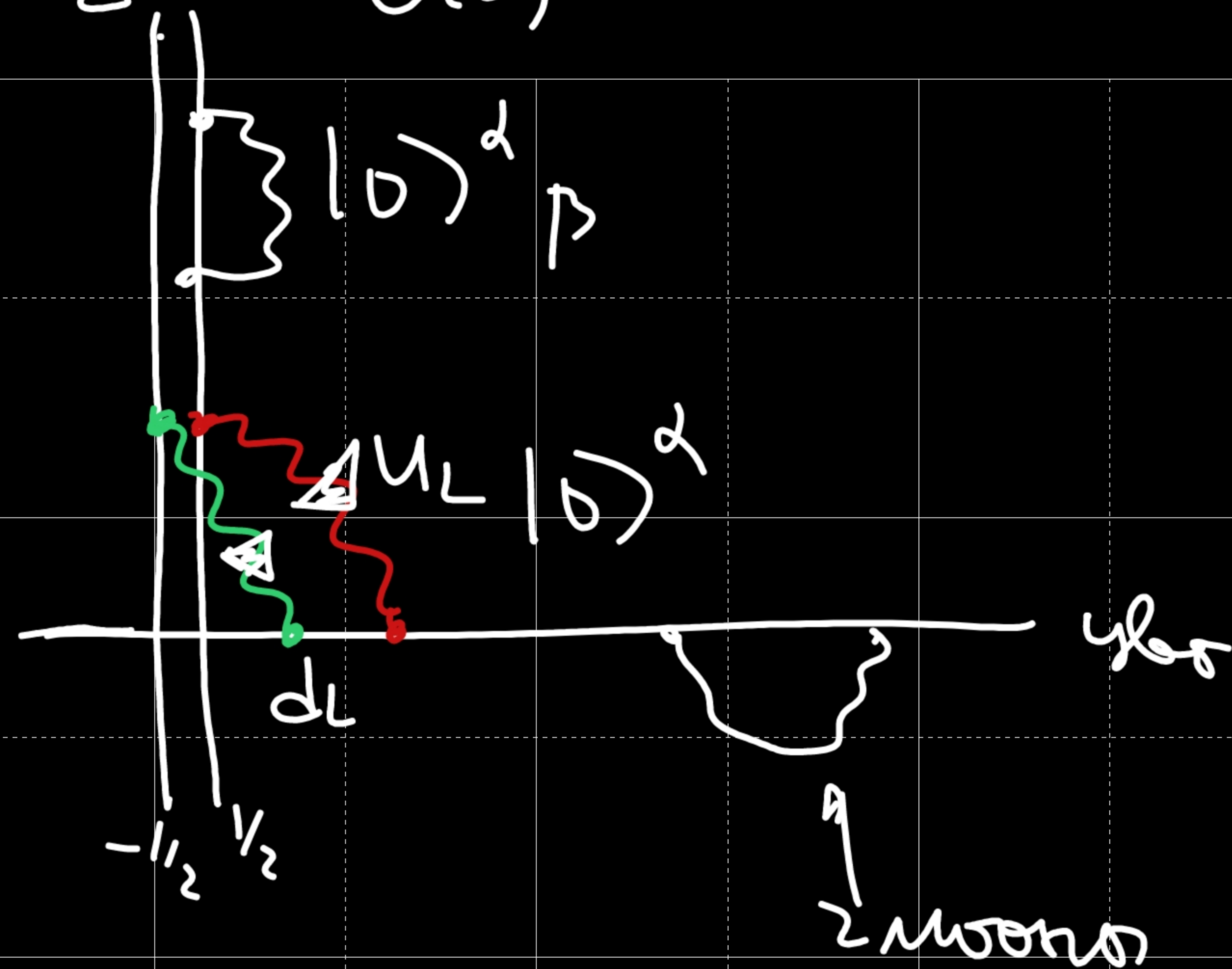
$$2' M^2 = N_B + N_F + a \sum_I V_I - a ; \quad \begin{array}{l} a = -\frac{1}{2} \text{ NS} \\ a = 0 \text{ R} \end{array}$$

$$\sum_n \alpha_{-n} \alpha_n$$

$$V_I = \frac{\Theta_I}{\pi}$$



$$L \rightarrow U(2)$$



$$|0>^d \quad |0>^1, |0>^2$$

$$d=1,2$$

$$U(2) = SU(2) \times U(1)$$

$$\bar{q}_1, \bar{q}_2$$

$$U(1) \quad Q = \bar{q}_1 + \bar{q}_2$$

$$I_3 = (\bar{q}_1 - \bar{q}_2) \frac{1}{2}$$

$$S_P = T \int d^2 \Sigma \sqrt{-h} \left(\textcircled{G_{\mu\nu}} h^{\alpha\beta} + \textcircled{B_{\mu\nu}} e^{\alpha\beta} \right) \partial_\alpha X^\mu \partial_\beta X^\nu$$

$$\alpha = \overline{0,1}, \quad \Sigma^\alpha = (\xi^0, \xi^1)$$

$$\mu = \overline{0, D-1}$$

- SM (e, u, ...)

- Modern interpretation

- Bewegung dS

- Notizen $V = V(\phi)$

↑
interpretation



$$\mathcal{L} = \sqrt{-g} \left(\frac{1}{2} (\partial \phi)^2 - V(\phi) \right)$$

- $N=60$, $\frac{a}{a_0} = e^{60}$

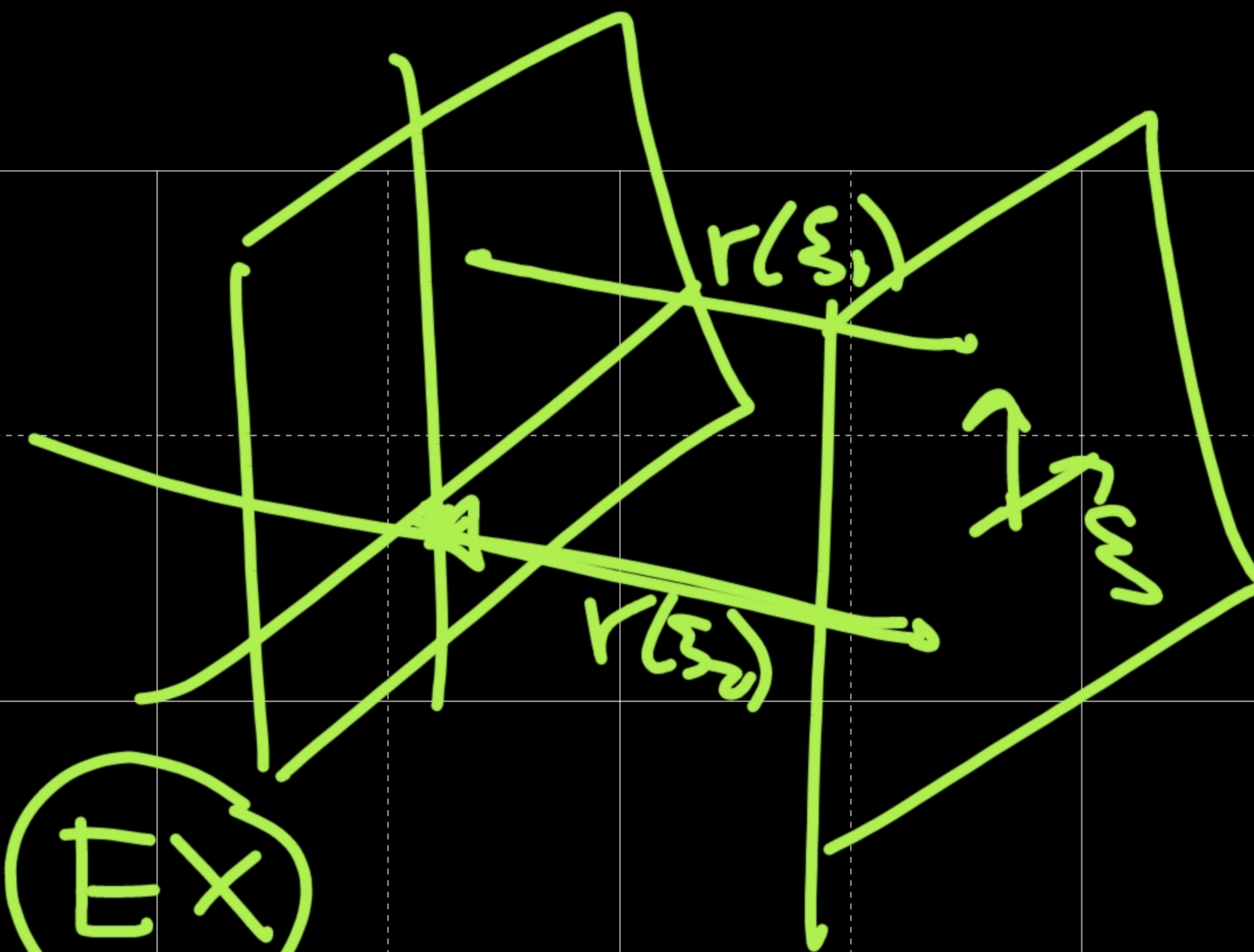
- slow-roll $\left\{ \begin{array}{l} \frac{1}{2} \dot{\phi}^2 \ll V \\ \ddot{\phi} \ll H |\dot{\phi}| \end{array} \right\} \Rightarrow$

$$\epsilon = \frac{1}{2} \left(\frac{V' M_{\text{Pl}}}{V} \right)^2 \ll 1$$

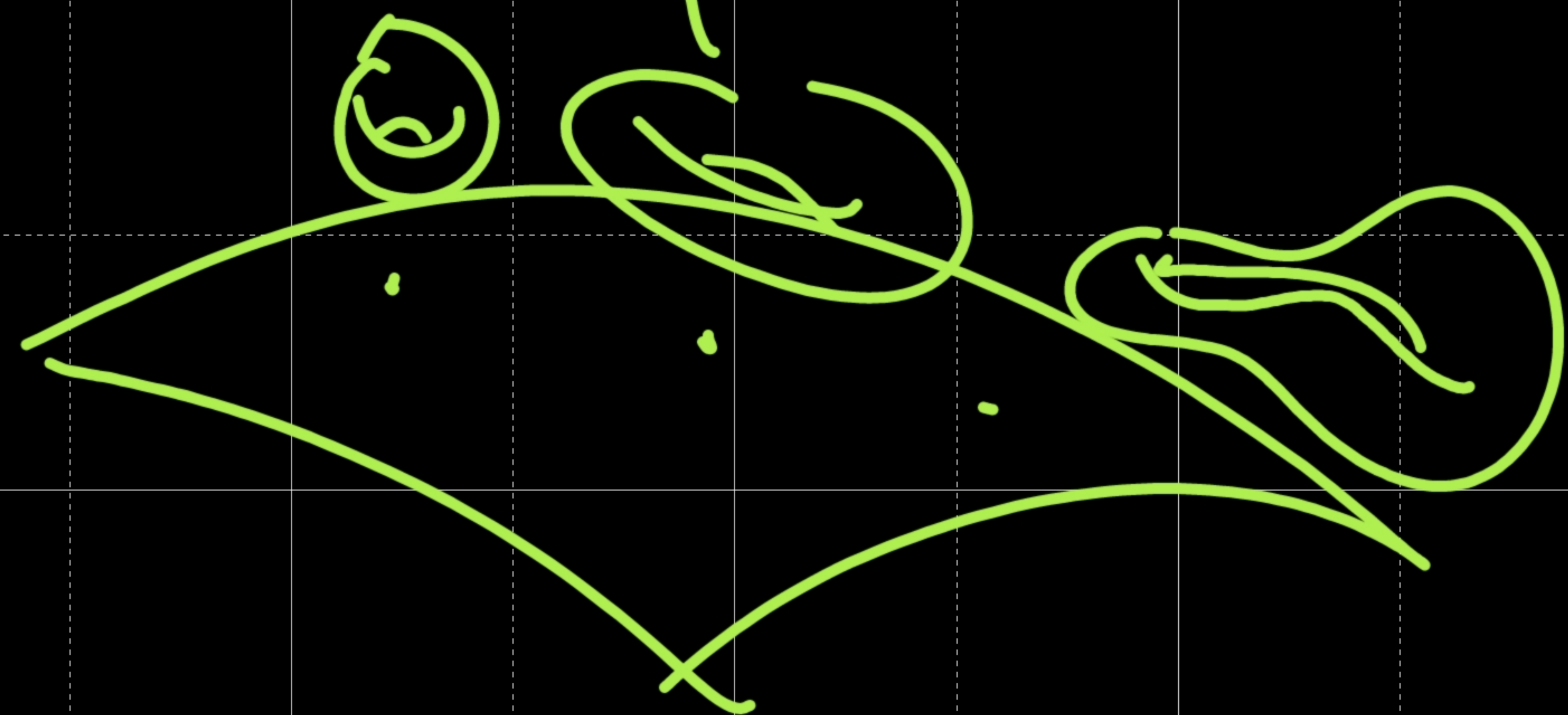
$$\eta = \frac{V'' M_{\text{Pl}}^2}{V} \quad |\eta| \ll 1$$

откр.: { - расст. $m/2$, ∂ раствн $\odot$
 - урн $m/2$, ∂ раствн

замкн.: { - none аксионс $B_{\mu\nu}$
 - none модулс (KCLT)



$B_{\mu\nu}$ $\odot EX$
 $\frac{d}{dt} \phi$



- SM из $D6-D6$ мод урн
 - $D3-\bar{D3}$ инеренси

10D $\rightarrow$ 4d

(EX):

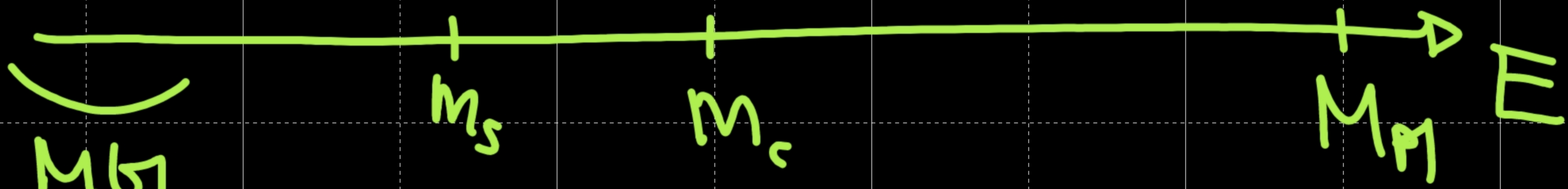
$$\square_5 \Phi(x^\mu, z) = 0$$

$$\mathbb{R}^{1,3} \times S^1_R$$

$$z \sim z + R$$

$$\Phi(x^\mu, z) = \sum_n \phi_n(x) e^{\frac{in z}{R}}, \quad n \in \mathbb{Z}$$

$$m_n^2 = \frac{n^2}{R^2}$$



$\phi_n(x)$ n.p.m. $n \neq 0$
He unTef.

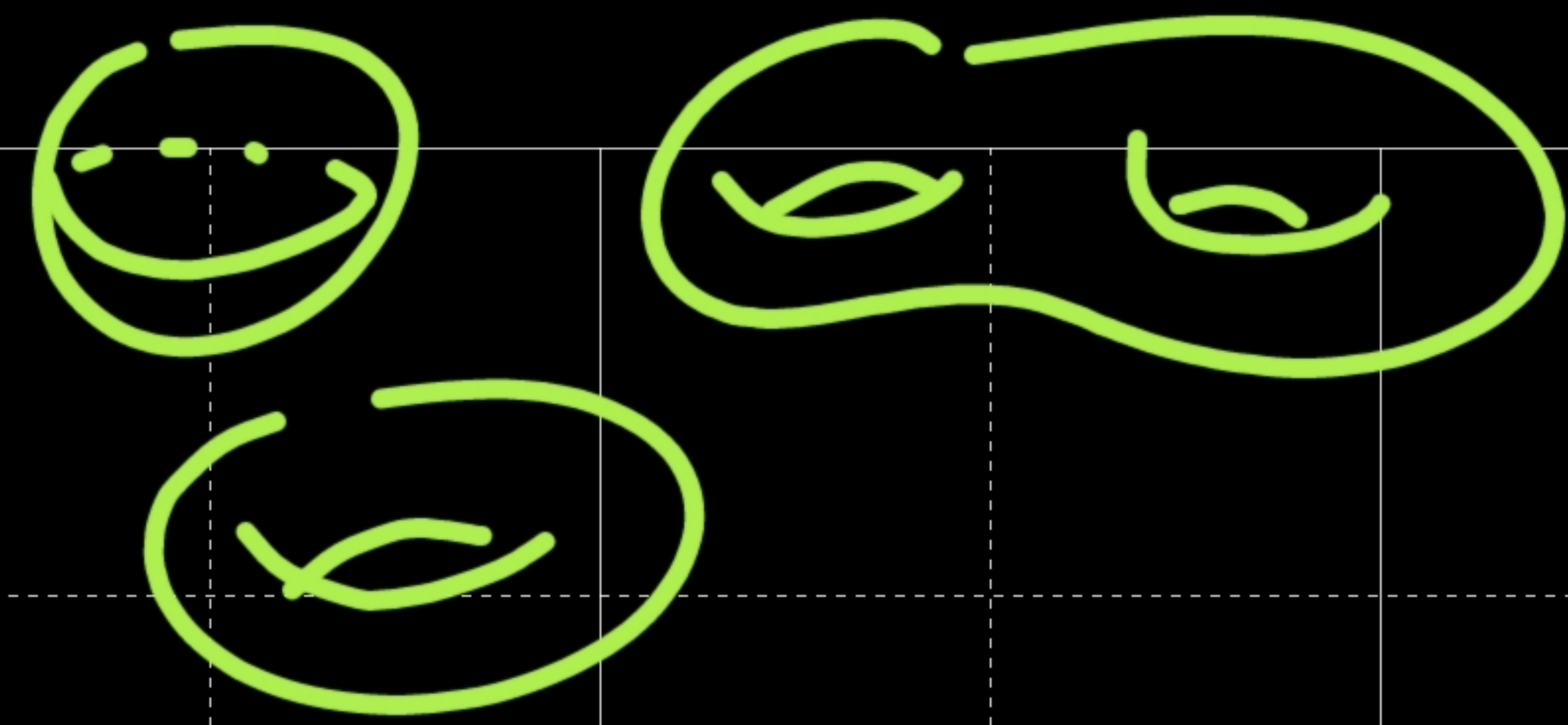
$\phi_0(x)$

moduli stabilization
problem

6D $\rightarrow$ 4D

$$X^M = (x^\mu, y^m)$$

$$M = \overline{0,5}, \quad \mu = \overline{0,3}, \quad m = \overline{1,2}$$



J. Louis
T. Grimm

$$S = \int d^6x \sqrt{-G} \left[M_6^4 R[G] - M_6^2 F_{MN} F^{MN} \right]$$

$$F_{MN} = 2\partial_{[M} A_{N]}$$

$$ds^2 = g_{\mu\nu}(x) dx^\mu dx^\nu + \Phi(x)^2 \tilde{g}_{mn}(y) dy^m dy^n$$



$$G_{MN} = \begin{bmatrix} g_{\mu\nu}(x) & 0 \\ 0 & \tilde{g}_{mn}(y) \Phi(x)^2 \end{bmatrix}$$

$$1 \quad S_R = M_6^4 \int d^4 x \sqrt{-G} R[G] = \det G_{\mu\nu} = \det g_{\mu\nu} \cdot \Phi^4(x)$$

$$= \int d^4 x \int d^2 y \sqrt{g} \Phi^2(x) \left(R_1(g) + R_2(g) + \# g^{\mu\nu} \partial_\mu \Phi \partial_\nu \Phi \cdot \Phi^{\#} \right. \\ \left. g_{\mu\nu} \rightarrow h_{\mu\nu}(x) = \Phi^2(x) \cdot g_{\mu\nu}(x) + \dots \right)$$

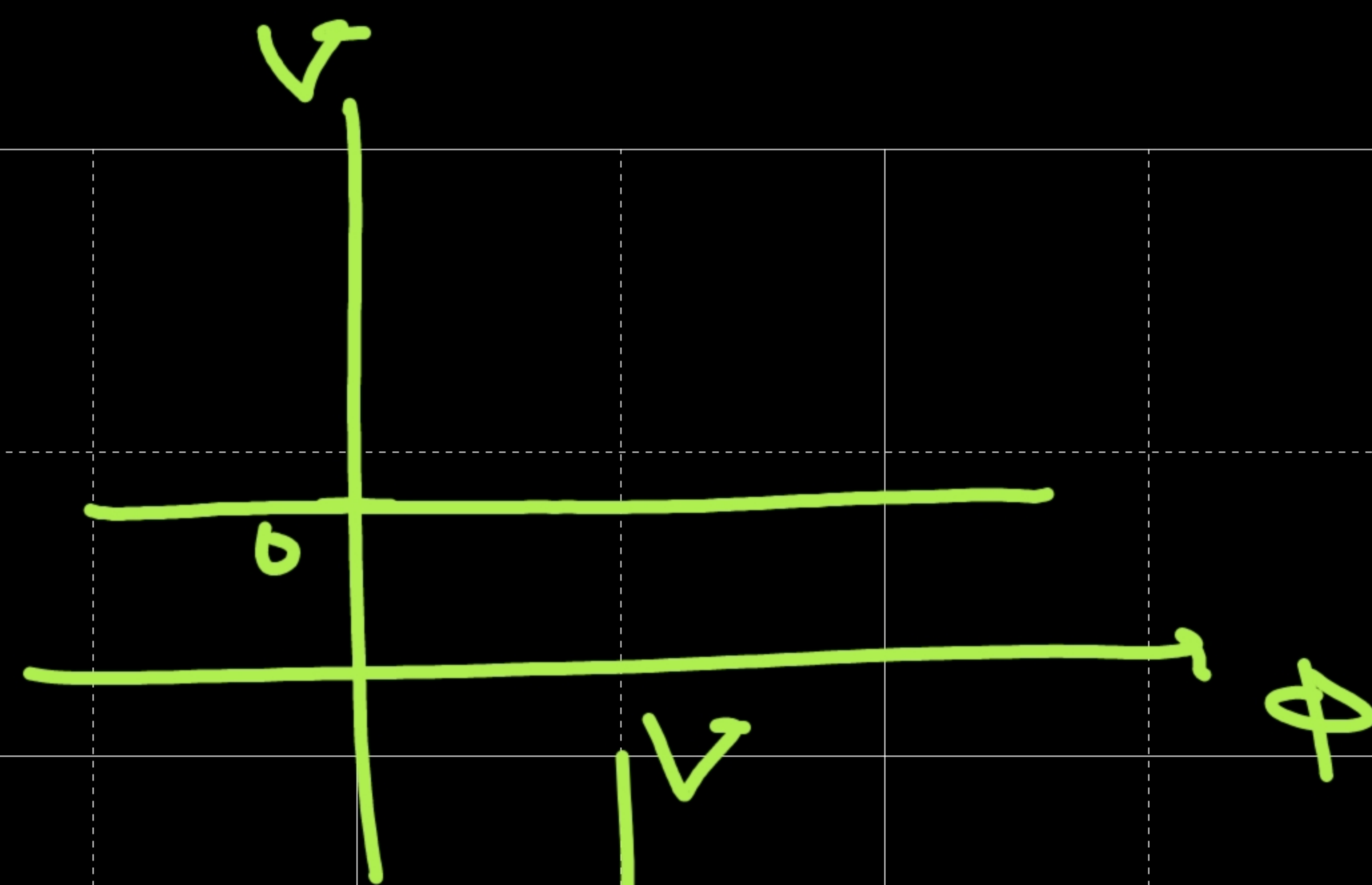
$$S_R = M_6^4 \int d^4 x \sqrt{-h} \left[R_1[h] - V(\Phi) + \dots \right] R_2 = \frac{1}{4} G^{\mu\nu} \partial_\mu G_{\kappa\lambda} \partial_\nu G^{\kappa\lambda} + \dots$$

$$\boxed{V(\Phi) \sim (2g-2) \frac{1}{\Phi^4}}$$

$$; \quad \int d^2 y R_2[g] = 2g-2$$

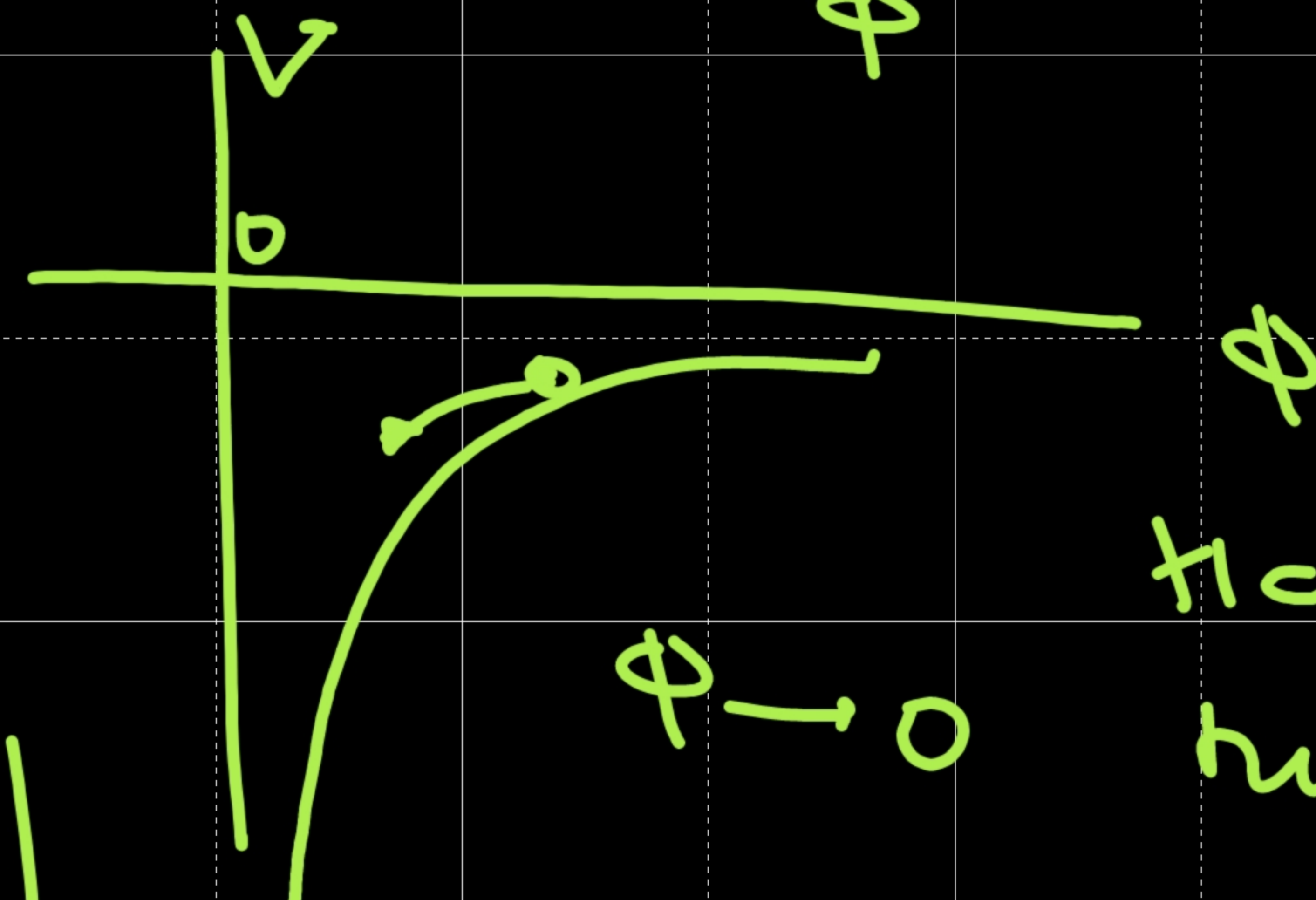
$$V(\phi) \sim (2g-2) \frac{1}{\phi^4}$$

1) $\mathbb{H}^2$ $g=1$, $V(\phi)=0$

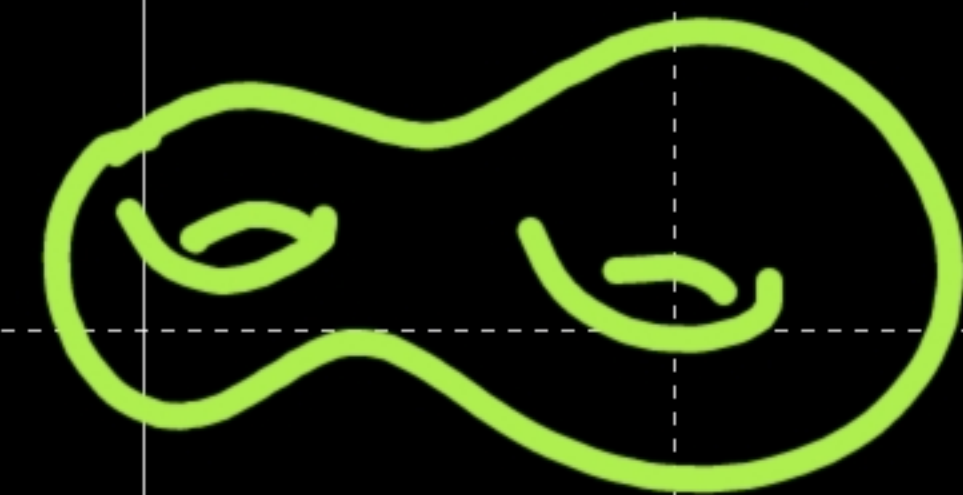


нет масс

2) $\mathbb{D}^2$, $g=0$, $V(\phi) \sim -\frac{1}{\phi^4}$:



пер. усл.
низк. энергии

3) $g>1$  $V(\phi) \sim \frac{1}{\phi^4}$



нет комп.

$$2) S_{EM} = M_6^2 \int d^6 x \sqrt{G} F_{MN} F^{MN} \quad ; \quad F_{\mu\nu}, F_{\mu m}, F_{mn}$$

$$\int_{M_3} F_{mn} dy^m \wedge dy^n = \left(\int_{M_3} d^2 y \, \epsilon^{mn} F_{mn} \right) = n \in \mathbb{Z}$$

↑
normalized



$$F_{mn} = \sum_I F^I \omega_I{}_{mn}$$

$$\int d^6 x \sqrt{G} F_{MN} F^{MN} \rightarrow \int d^4 x \sqrt{-h} \left(-\frac{h^2}{\phi_6} \right)$$

$$\int_{\mathbb{Z}_2} \mathbb{Z}_2$$

$$V \sim (2g-2) \frac{M_6^4}{\phi^4} + \frac{m^2}{\phi^6} M_6^2$$

1) $g \geq 1$ $V \sim \frac{1}{\phi^6} + \dots$

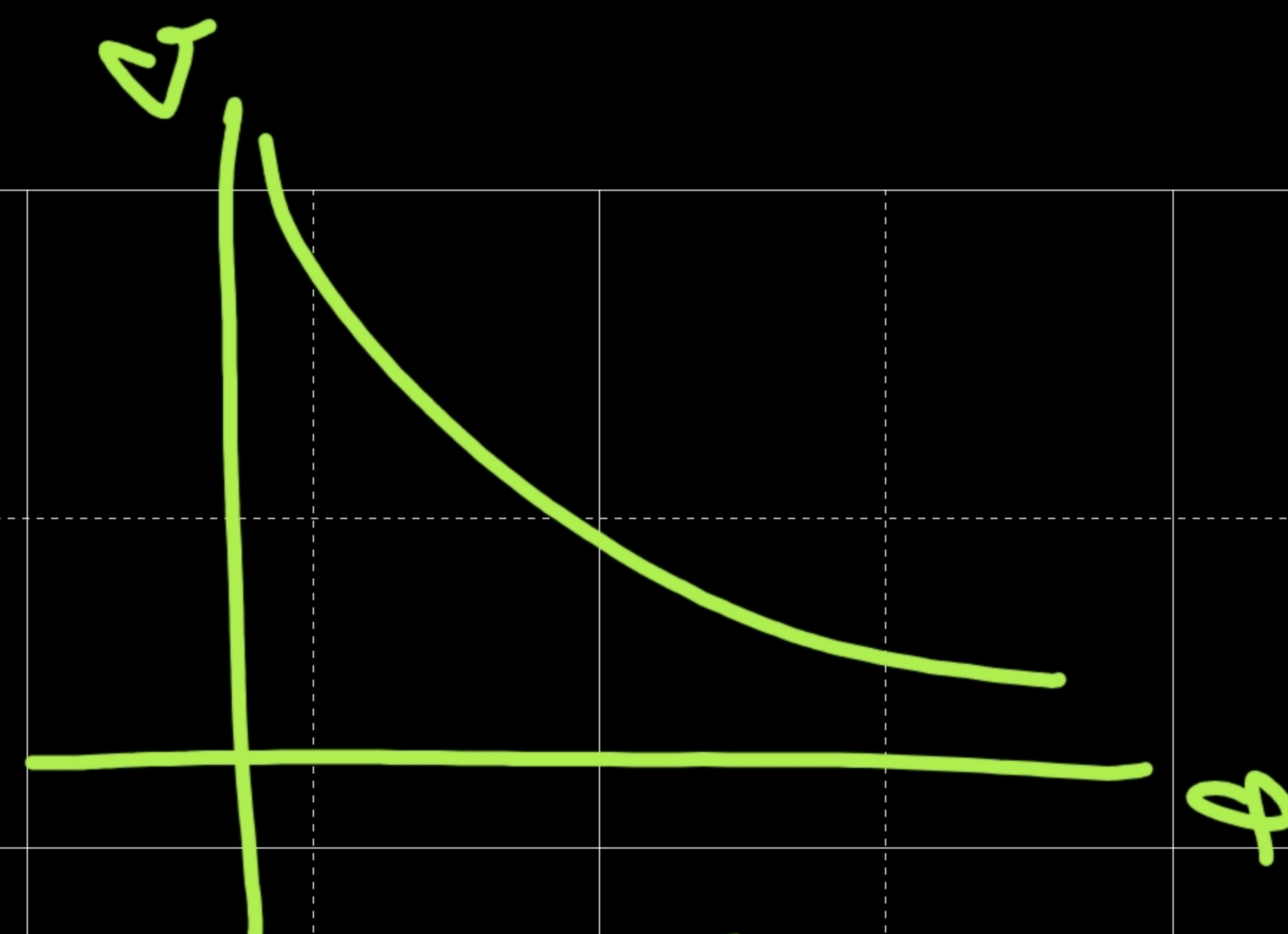
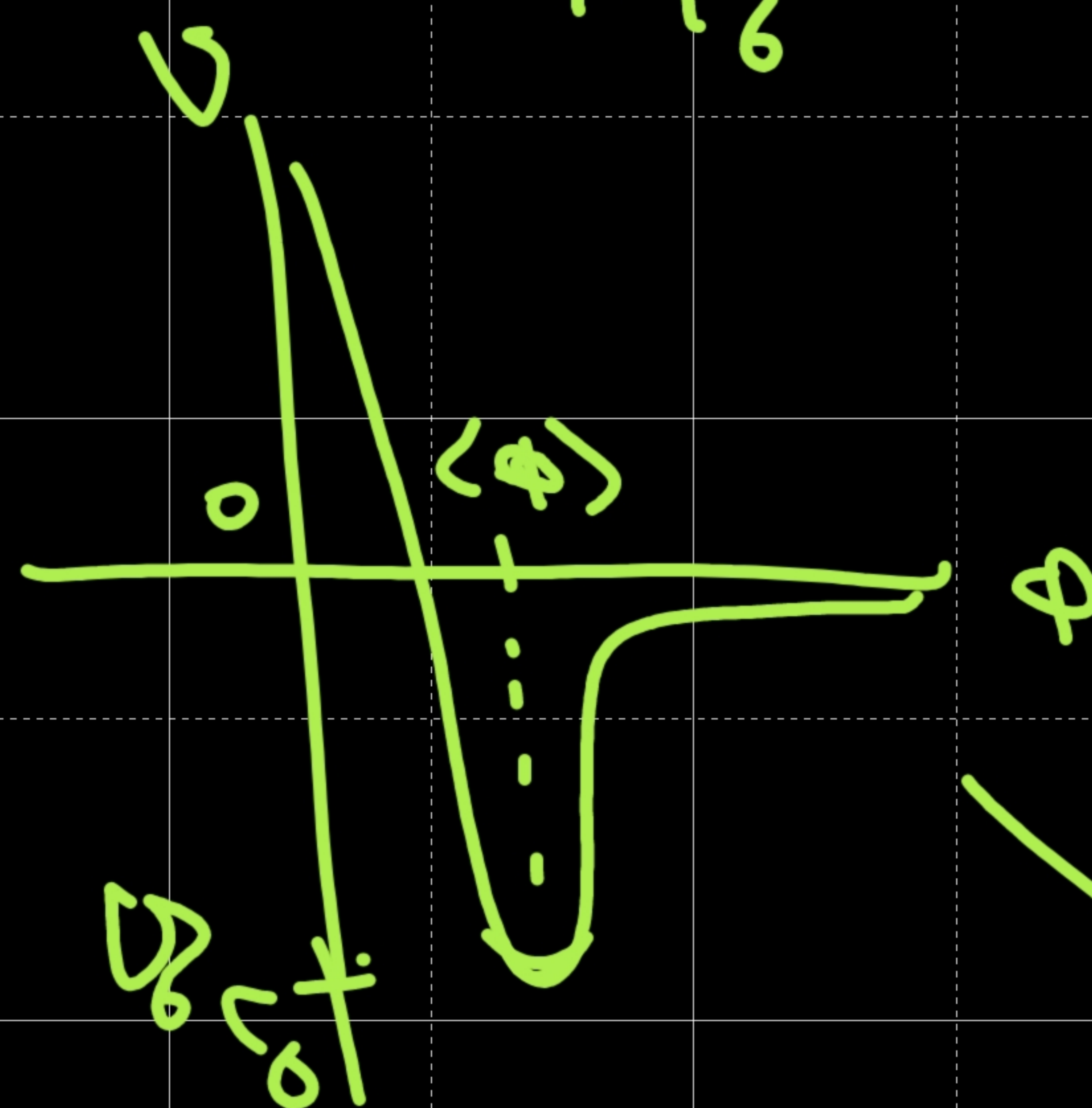
M_6

2) $g=0$, $\mathcal{F}^2$

$$\langle \phi \rangle = \frac{\sqrt{3}}{2} n$$

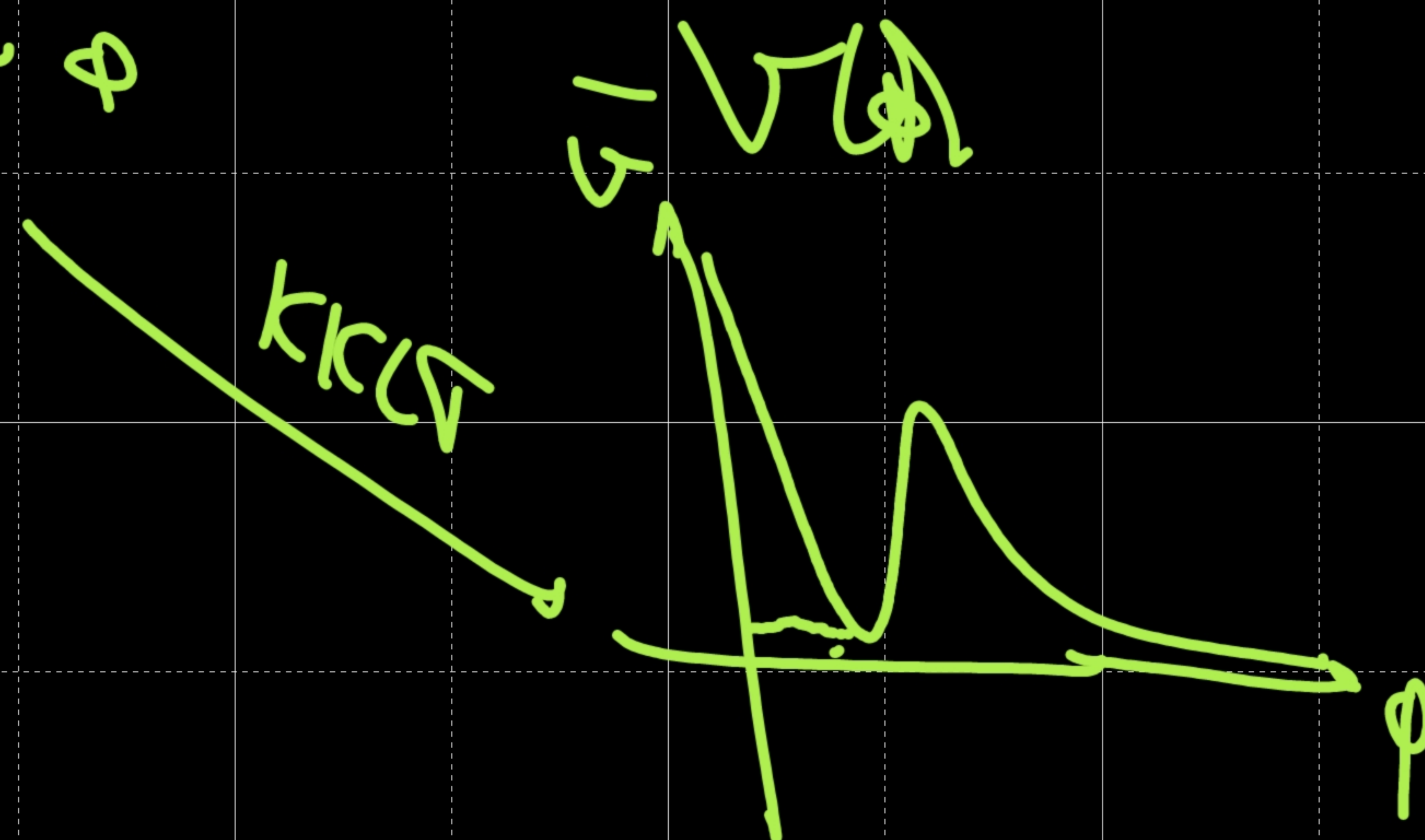
||

$AdS_4 \times S^2$



с ном. декон.

$$\mathcal{L} = \sqrt{-h} R[h] + \frac{1}{2} \partial_\mu \phi \partial^\mu \phi$$



Бракки

1. Траекторное возмущение (Dp-вариант)

$$\int_{\Sigma} d\sigma \partial_\sigma X^r A_r$$

IIA: $g_{\mu\nu}, b_{\mu\nu}, \Phi, C_{\mu}^{D0}, C_{\mu\nu\rho}^{D2}$

$$S_{D3} = \begin{cases} S_{WZ} = T \int_{\Sigma} C_{\mu\nu\rho} dx^\mu \wedge dx^\nu \wedge dx^\rho \\ S_{DBI} = T \int_{\Sigma} d^3\xi e^{\sqrt{-\det(g_{\alpha\beta} + b_{\alpha\beta} + F_{\alpha\beta})}} \end{cases}$$

$\{\xi^\alpha\}, \alpha=0,1,2$

$F_{\alpha\beta} = \partial_\alpha A_\beta - \partial_\beta A_\alpha$

EM: $g_{\mu\nu}, A_\mu \mid X^r = X^r(t)$

1) $S_P = -mc \int ds + \frac{e}{c} \int A_\mu dx^\mu = S_{WZ}$

2) $S_{Full} = S_P + \int d^4x \sqrt{-g} (R(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu})$

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

$$A_0 = \frac{e}{r} ; \text{ other } e = m$$

3. $S_{Full} = S_{D3} + S_{IIA}$

$ds^2 = \dots$

$i C_{012} = 1 - H(r)^{-1}$

D3: $G_{\mu\nu} dX^\mu dX^\nu$ $4 = 7 - 3$

$$ds^2 = H(r)^{-1/2} (-dt^2 + dx^1^2 + dx^2^2) + H(r)^{1/2} (dr^2 + r^2 d\Omega^2)$$

$\Delta H = \delta(r)$ $\vec{p}$
 $\frac{M}{r^3} = \vec{p}$

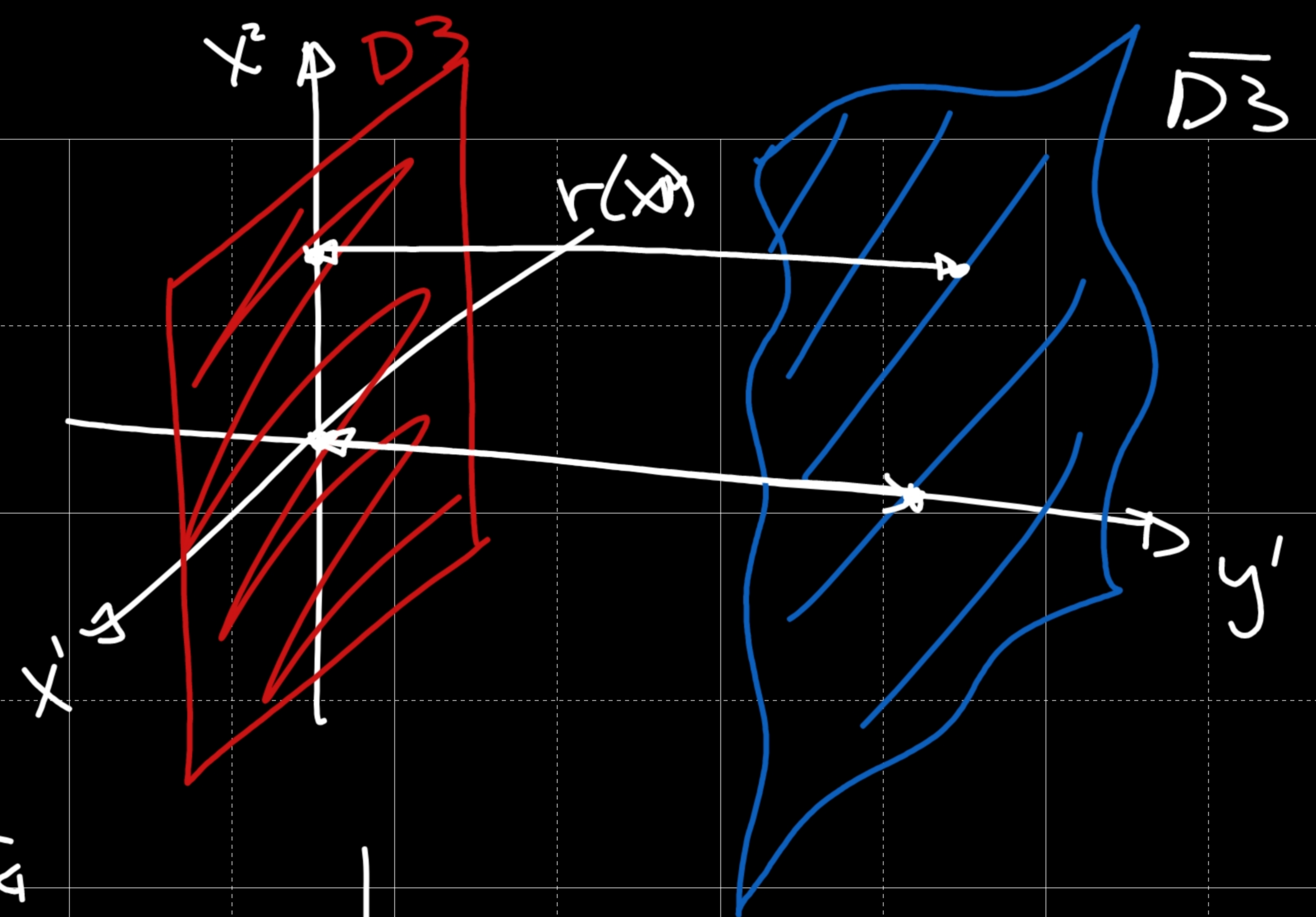
$C_{012} = 1 - H(r)^{-1}$; $H(r) = 1 + \frac{M}{r^4}$

- 2 p.c.b. hor.

$G_{00} = 1 + 2V_g$; $V_g = -\frac{M}{4r^4}$

- RR nonrenorm.

$V_{RR} = \pm \frac{M}{4r^4}$ $\begin{matrix} D3 \\ D3 \end{matrix}$



$g_{\alpha\beta} = \partial_\alpha X^\mu \partial_\beta X^\nu G_{\mu\nu}$
 $X^\mu = (t, x^1, x^2, r, \theta^1, \dots, \theta^5)$
 $r(\xi)$

$$V_{\text{tot}} = T_3 \left(1 - \frac{1}{8\pi^2 r^4 T_3} \right), \quad T_3 = \frac{1}{(2\pi)^3 \alpha'^2 g_s} \quad \alpha' \sim M_{\text{Pl}}^{-2}$$

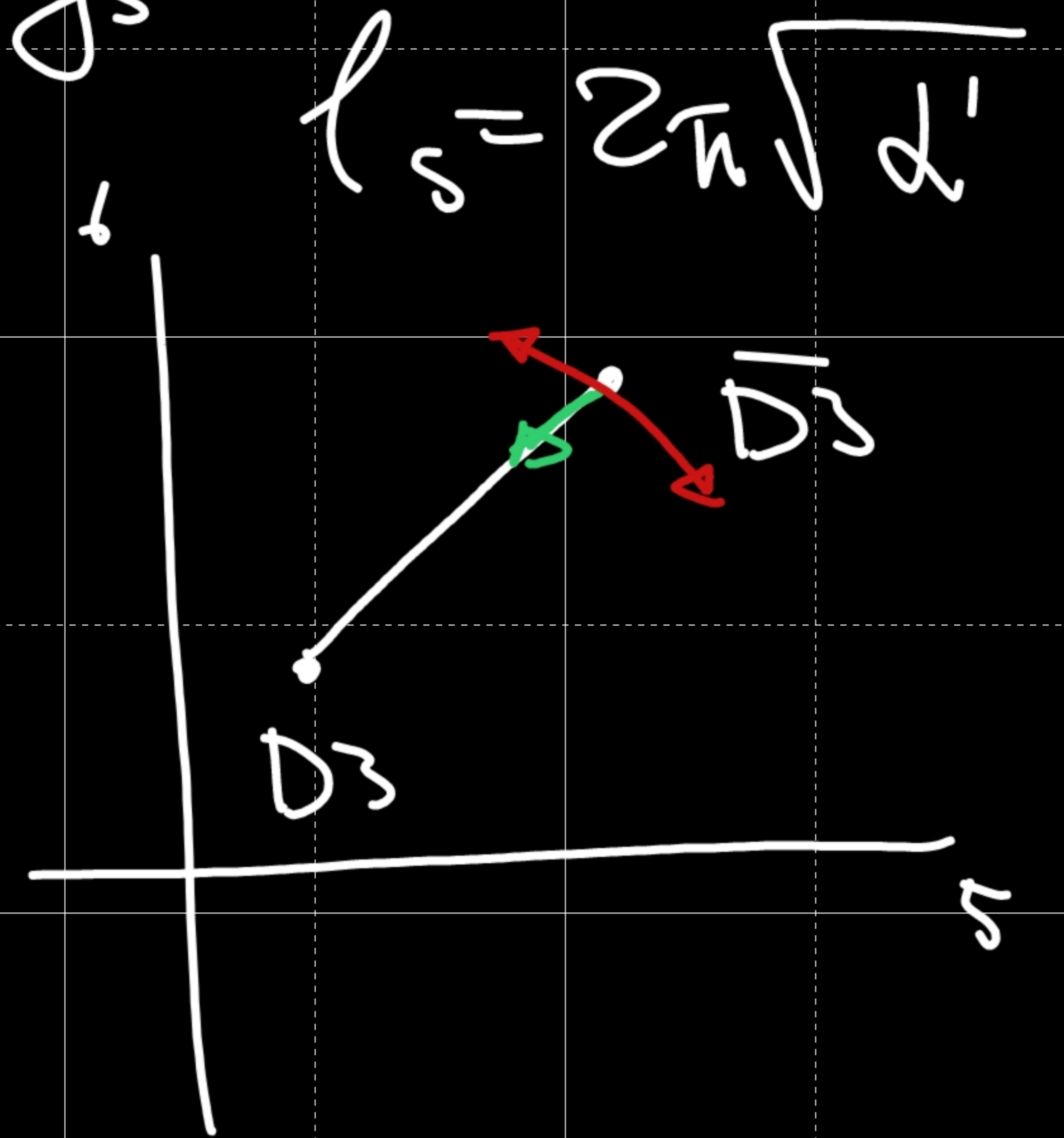
$$\ell_s \ll r < d,$$

$$d = (V_{\text{vol}})^{1/6}$$

$$X^M = (X^\alpha, \bar{y}^a)$$

Σ^α - on sup. sphere

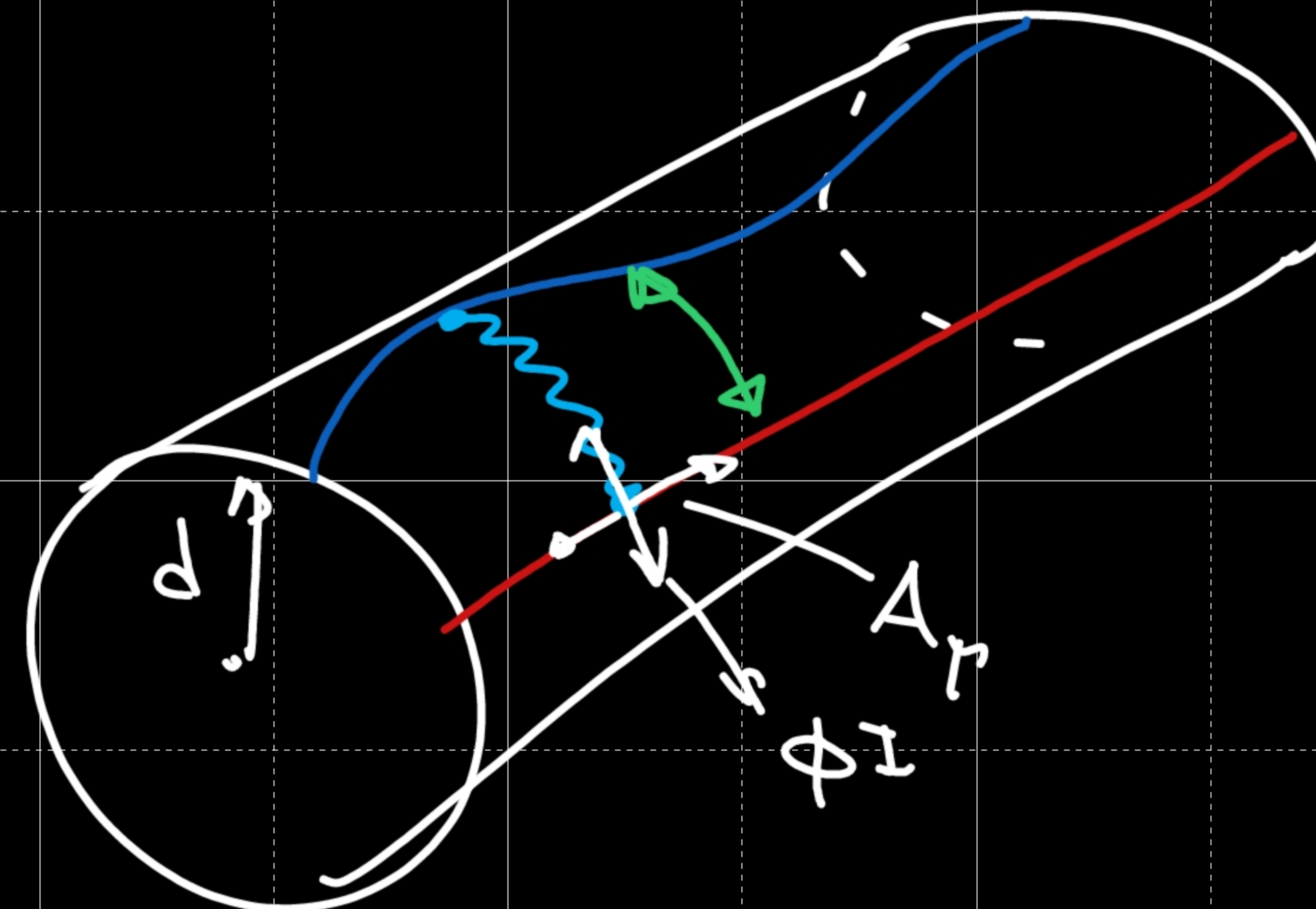
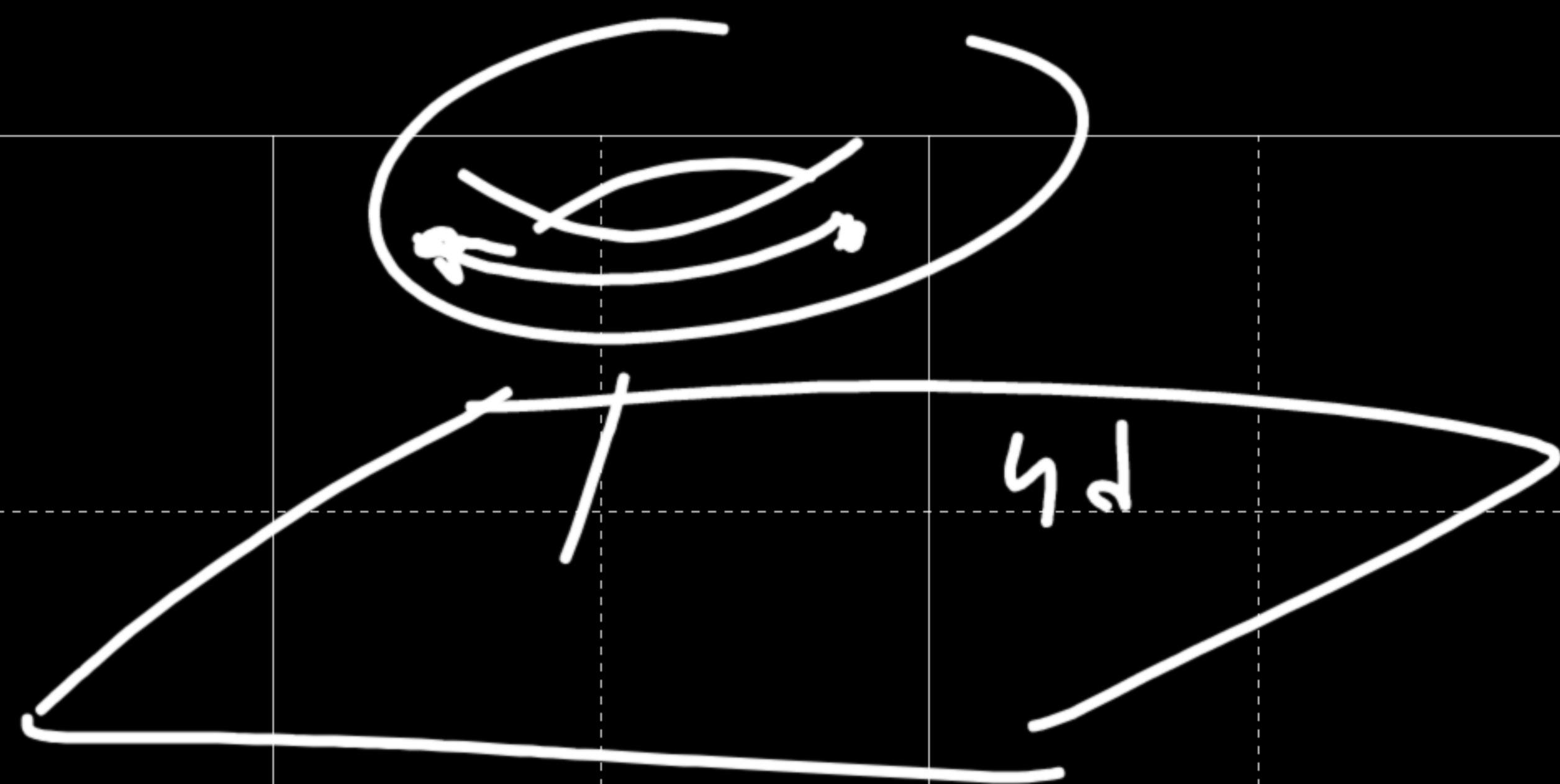
fix gauge: $X^\alpha = \Sigma^\alpha$; $r(\xi)^2 = (\underbrace{\bar{y}^a(\xi) - y^a}_{r(\xi) \cdot n^a})^2$

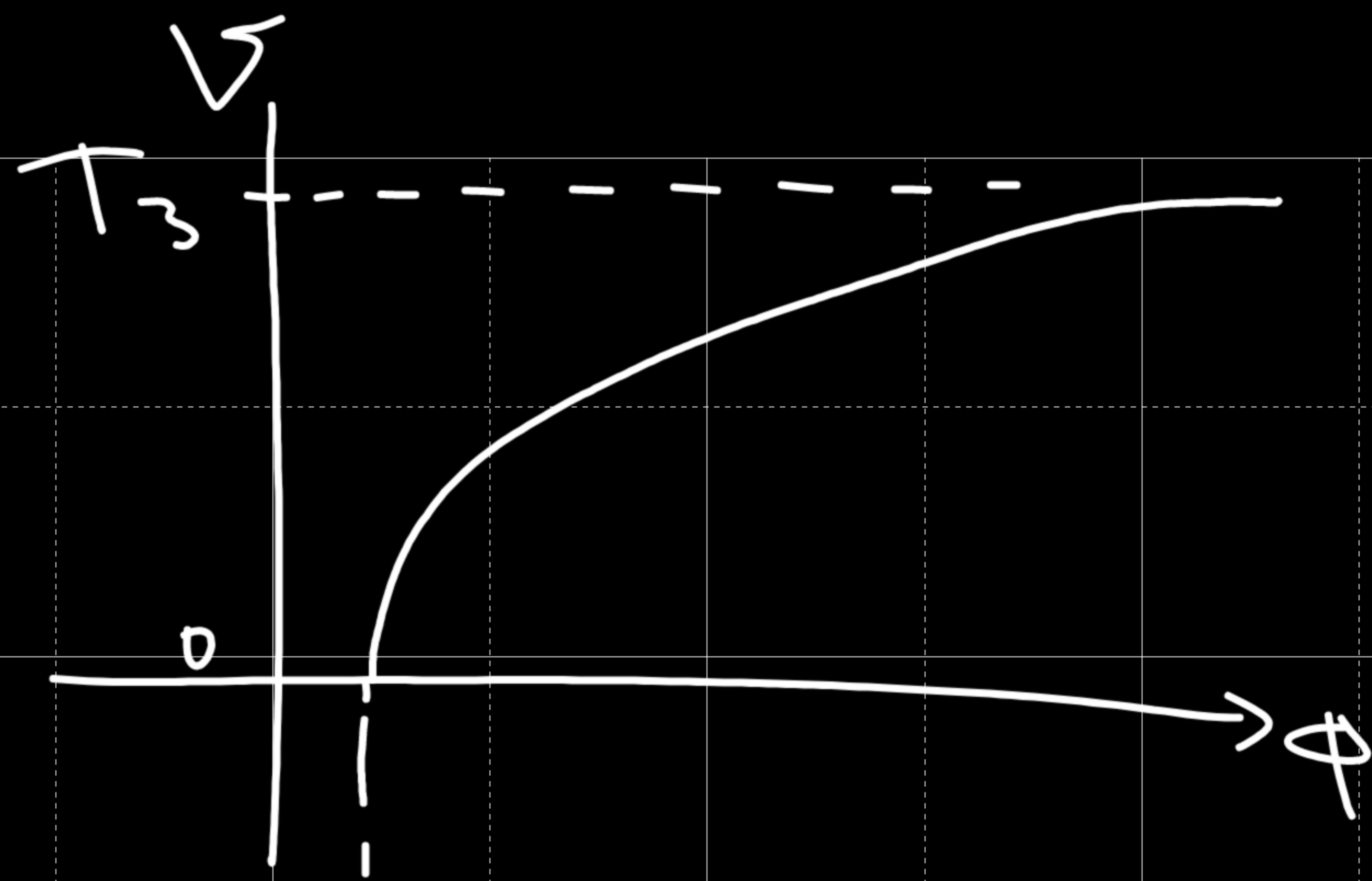


$$\det g_{\alpha\beta} = 1 + \eta^{\alpha\beta} \partial_\alpha r(\xi) \partial_\beta r(\xi); \quad r(\xi) \cdot n^a$$

$$\phi(\xi) = \sqrt{T_3} \cdot r(\xi)$$

$$\mathcal{L} = -\frac{1}{2} \sum_{\mu, \nu} (\partial_\mu \phi)^2 - \left(T_3 - \frac{c}{\phi^4} \right), \quad c = \frac{T_3}{\partial_\mu \xi \partial^\mu \xi}$$





1. в квант. t одна фаза ~~А~~

2. slow-roll

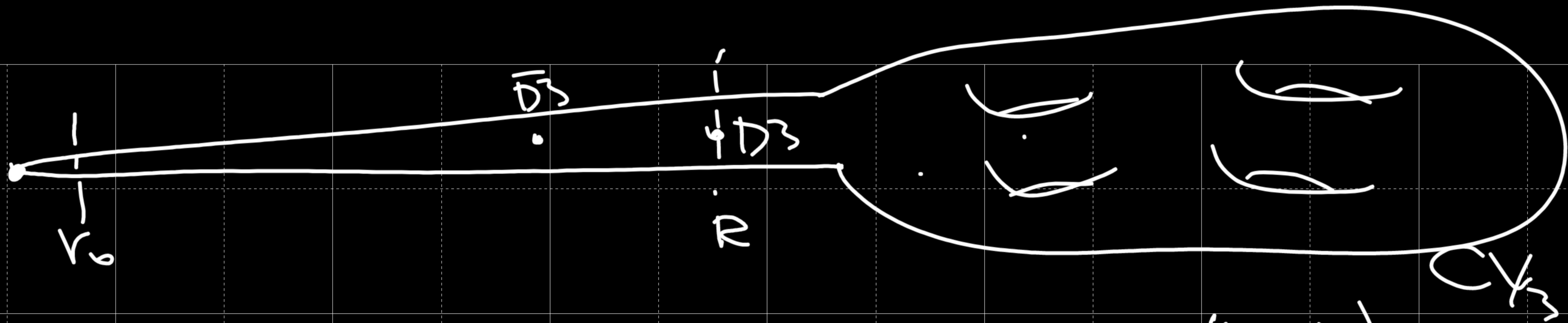
$$\eta = \frac{V'' \bar{M}_{Pl}^2}{V} \simeq \frac{20 \cdot c \bar{M}_{Pl}^2}{T_3 \phi^6}$$

(EX): $M_{Pl}^2 = (g_H g_N)^{-1}$ - прод. масса Планка

$$G_{10}^{-1} = G_N^{-1} Vol_6$$

$$\eta \simeq -2 \frac{Vol_6}{r} \simeq -\left(\frac{d}{r}\right)^6$$

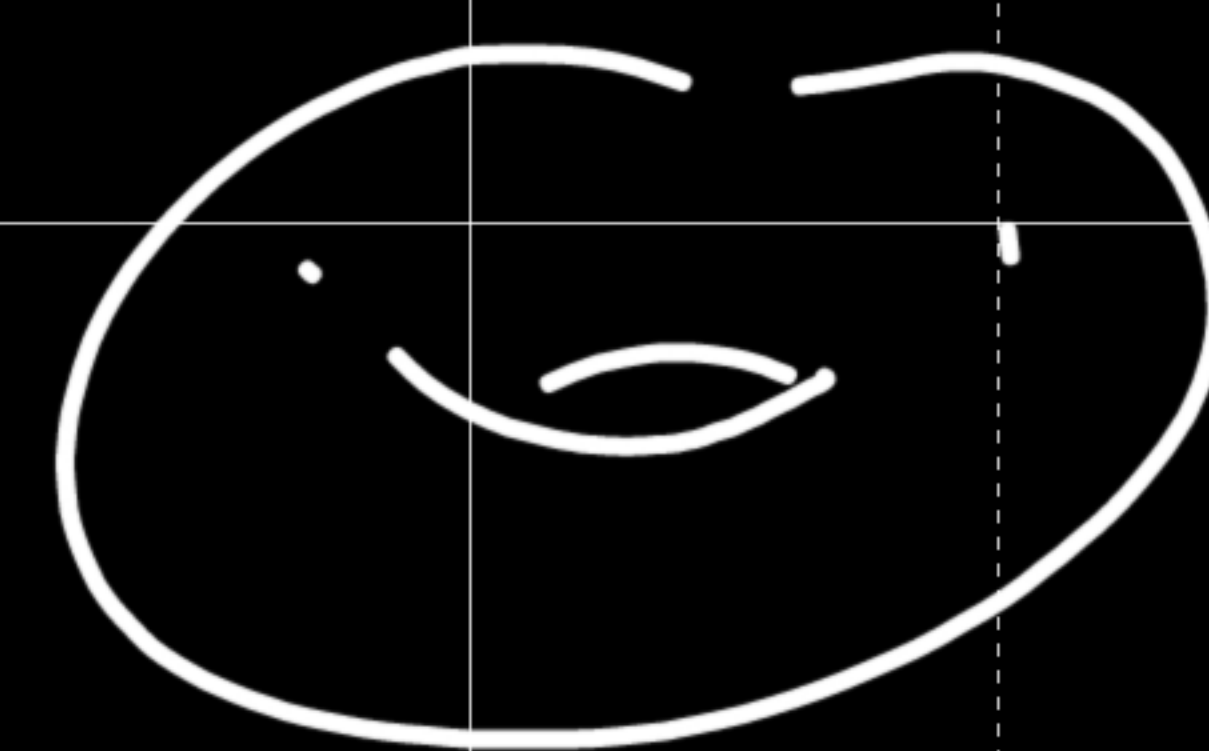
$$|\eta| \ll 1, \quad r \gg d$$



$$\mathcal{L} = -\frac{1}{2}(\partial\Phi)^2 - 2T_3 a_0^4 \left(1 - a_0^4 \frac{R^4 T_3^2}{\phi^4} \right) ;$$

$$\eta' = a_0^4 \eta$$

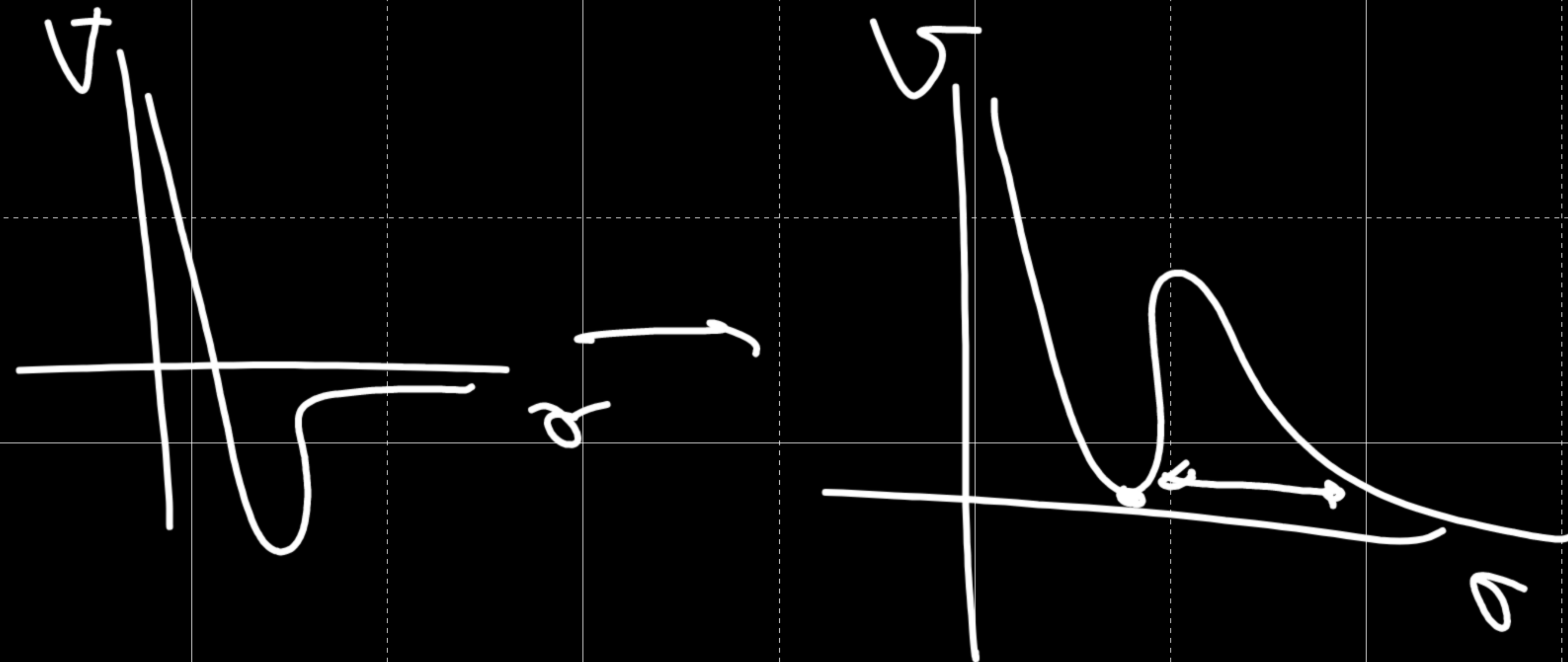
tune



VKLT

- Type IIB 10D $\longrightarrow$ 4D $SU(2)_A + AdS$ vacuum

- T-duality $AdS \longrightarrow dS$



10D IIB на $(Y_3, (z', z'', z''') = (z^I)$

- $R_{mn} = 0$

- $\omega_2 \neq d\lambda$
 $\omega_{I\bar{J}} dz^I \wedge d\bar{z}^{\bar{J}}$

- $\Omega_4 = \frac{1}{3!} \Omega_{IJK}(z) dz^I \wedge d\bar{z}^{\bar{J}} \wedge d\bar{z}^{\bar{K}}, \Omega_4 \neq d\alpha$
 $d\Omega_4 = 0$

- На пространстве метрика кэлерова

$ds^2 = g_{I\bar{J}} dz^I d\bar{z}^{\bar{J}}, g_{I\bar{J}} = \frac{\partial^2}{\partial z^I \partial \bar{z}^{\bar{J}}} K(z, \bar{z})$

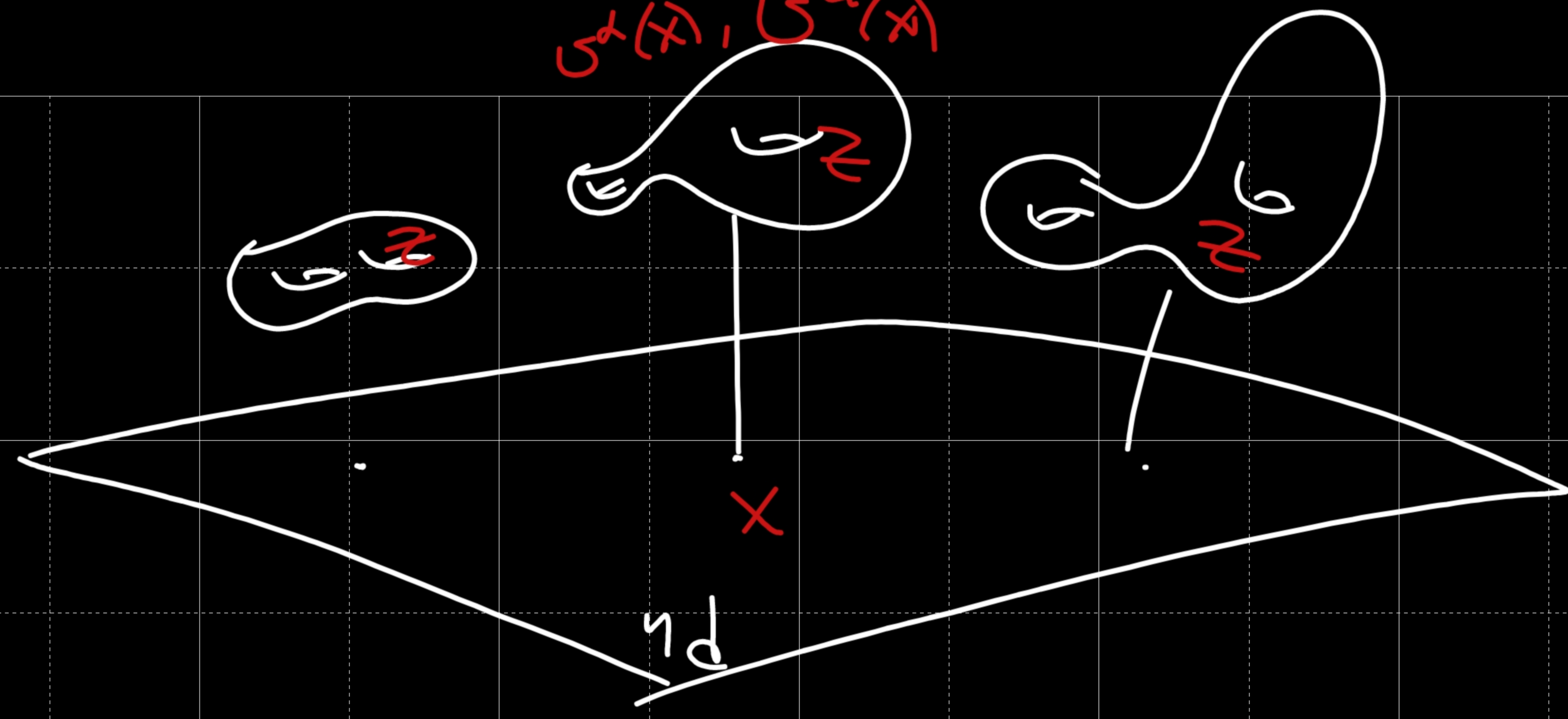
$\partial_{\bar{I}} \omega_{J\bar{K}} = 0$

$\partial_{\bar{I}} \omega_{J\bar{K}} = 0$

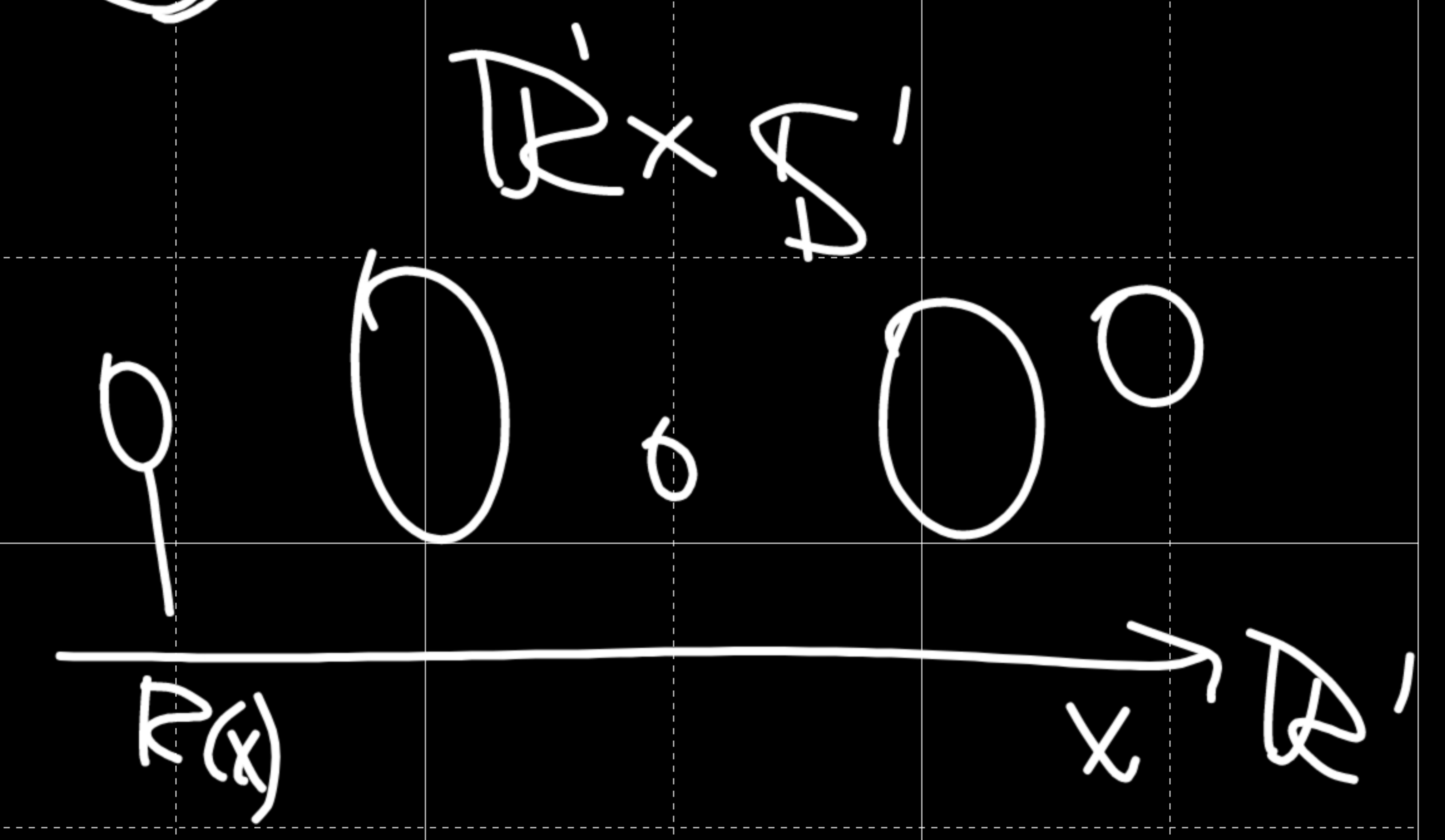
$\uparrow$
 $K \rightarrow \text{кэлерово}$

$K \rightarrow \text{кэлерово потенциал}$

$U^a(x), U^a(x)$



$g_{mn} \rightarrow g_{mn} + \delta g_{mn}$
 ω_{mn}
 Ω_{mnk}



Модули

$$m, n = \overline{1, 6}$$

$$I, \bar{I} = \overline{1, 3}$$

Hodge
diamond

- деформ. $g_{mn} \rightarrow g_{mn} + \delta g_{mn}$

- предпосл.: - не коорд.

- отсюда CV_3 (с.г. $R_{mn} = 0$)

- раскредоблем на δ аргументи формам

1) $\omega_\alpha = \omega_{\alpha I \bar{J}} d\bar{z}^I \wedge d\bar{z}^{\bar{J}}$, $\alpha = 1, h^{1,1}$

$d\omega_\alpha = 0$, $\omega_\alpha \neq d\lambda_\alpha$; $\{\omega_\alpha\} = \text{bas } H^{1,1}$

2) $\{\chi_\alpha\} = \text{bas } H^{2,1}$

$d\chi_\alpha = 0$, $\chi_\alpha \neq d\alpha_\alpha$

$\chi_\alpha = \frac{1}{2} \chi_{\alpha I \bar{J} \bar{K}} d\bar{z}^I \wedge d\bar{z}^{\bar{J}} \wedge d\bar{z}^{\bar{K}}$

CV_3 :

$$h^{1,1} = h^{2,2}$$

$$h^{2,1} = h^{1,2}$$

$$h^{3,0} = 1 = h^{0,3}$$

- $\delta g_{I\bar{J}}(z)$, uz $R_{mn}(g+\delta g) = R_{mn}(g) = 0$

ne loop.

de φ . k71-p0b02
cnykyp0

$$\delta g_{I\bar{J}}(z) = \sum_{\alpha=1}^{h^{1,1}} \psi_{\alpha}^I(x) \omega_{\alpha I\bar{J}}(z)$$

$$dz^I \wedge d\bar{z}^{\bar{J}} = \frac{1}{2} (dz^I \otimes d\bar{z}^{\bar{J}} - d\bar{z}^{\bar{J}} \otimes dz^I)$$

- $g_{mn} + \delta g_{mn}$

$$\delta g_{I\bar{J}} = \sum_{a=1}^{h^{1,2}} \psi_a^I(x) \Omega_{IKL} g^{K\bar{L}} g^{\bar{L}I} \bar{\chi}_{aJ\bar{K}\bar{L}}(z)$$

$$\delta g_{I\bar{J}} = \dots \bar{\psi}_a$$

$$X' + iX'' = z,$$

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$$S_{EH} = \int \sqrt{-G} R_{10}(G) d^{10}x =$$

$$= \int d^4x \sqrt{-g_4} R(g_4) + \int d^4x \sqrt{-g_4} g^{\mu\nu} \partial_\mu \psi \partial_\nu \psi G_{\alpha\beta}(\psi)$$

$$G_{\alpha\beta}(\psi) = \frac{1}{4!} \int_{C\chi_3} \omega_\alpha \wedge \star \omega_\beta$$

$$G_{\alpha\beta}(\chi) = \frac{1}{4!} \int_{C\chi_3} \chi_\alpha \wedge \star \chi_\beta$$

$$+ \int d^4x \sqrt{-g_4} g^{\mu\nu} \partial_\mu \psi^a \partial_\nu \psi^b G_{ab}$$

$$IIA \xrightarrow{C\chi} N=2 D=4 \quad \text{Louis Grinm}$$

$$\xrightarrow{C\chi \times \text{orient}} N=1 D=4$$

Ansatz KKL T

$$T = b + i\sigma$$

$$0. \text{IBD} = 10 \rightarrow D=4 \quad \text{has } \chi (h'' = 1)$$

$$z = 1, h^{2,1} + 2$$

$$1. \text{Moduli: } (U^a(x), \tau = C_0 + e^{i\phi}, \sigma(x)) = \mathbb{Z}^I$$

$x^M - 4d$

$$V = e^K \left[K^{\bar{I}\bar{J}} \left(D_{\bar{I}} W D_{\bar{J}} \bar{W} - 3 |W|^2 \right) \right], \quad K_{\bar{I}\bar{J}} = \frac{\partial^2 K}{\partial \bar{Z}^{\bar{I}} \partial \bar{Z}^{\bar{J}}}$$

$$W_0 = \int (F_3 + i H_3) \wedge \Omega$$

$$\partial_{\bar{I}} W + \partial_{\bar{I}} K \cdot W$$

$$K = -3 \ln[+2\sigma] - \ln\left[-\frac{1}{8}(\tau - \bar{\tau})\right] - \ln\left[-i \int \Omega \wedge \bar{\Omega}\right]$$

$$K + \bar{T} \partial_{\bar{T}} K \partial_T K = 3 \quad (\text{no scale})$$

$$T = i\sigma$$

$$\textcircled{\text{EX}} \quad V = e^K \quad K^{i\bar{j}} \partial_i W \bar{\partial}_{\bar{j}} W \quad Z^i = (\psi^a, \tau)$$

$$\min V \text{ о.т. н.р.} \quad \partial_i W = 0 \quad ; \quad \text{стабильн. } Z^i$$

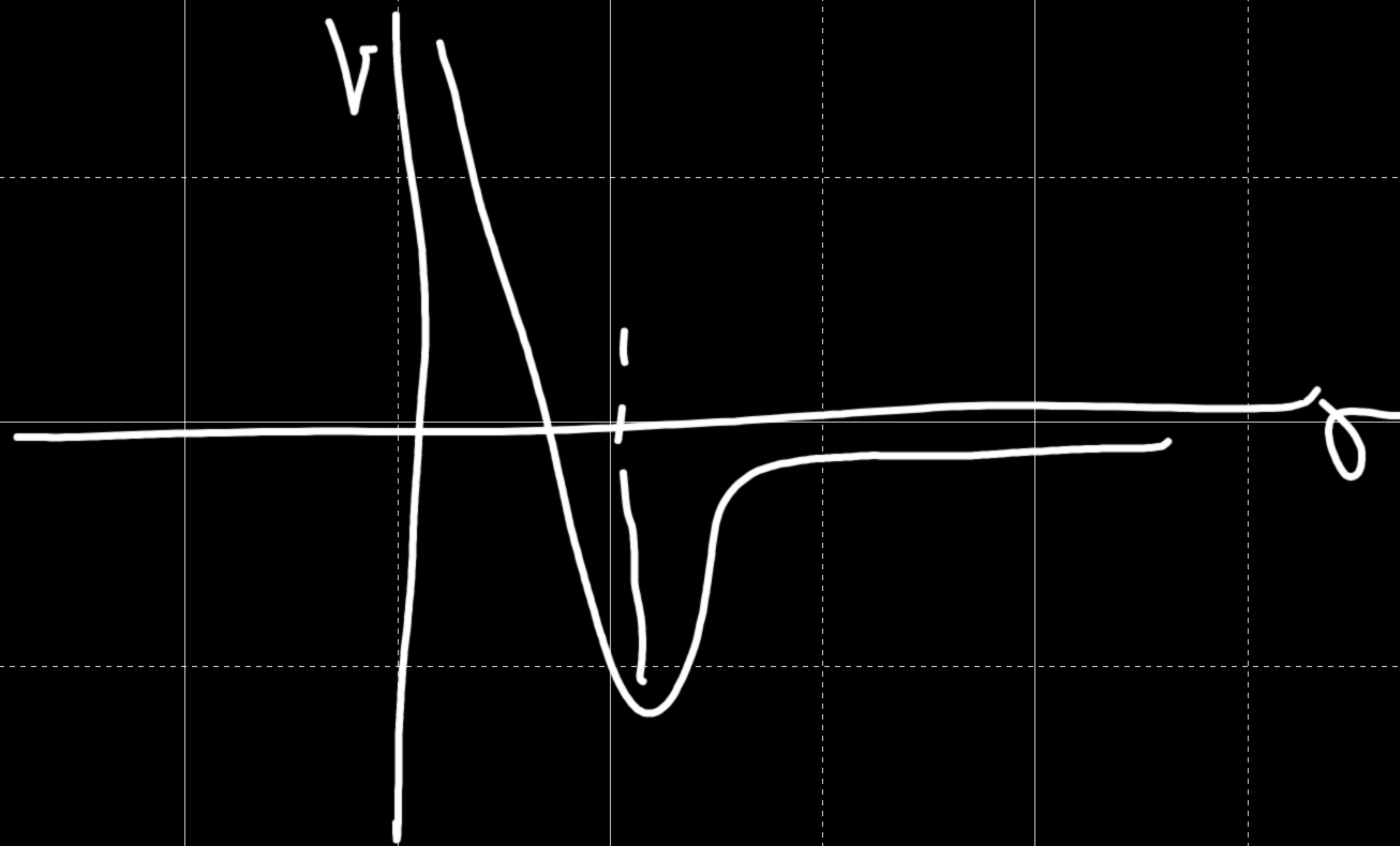
$$\textcircled{\text{о.т. н.р.}} \quad T \neq i\sigma$$

2. Трех

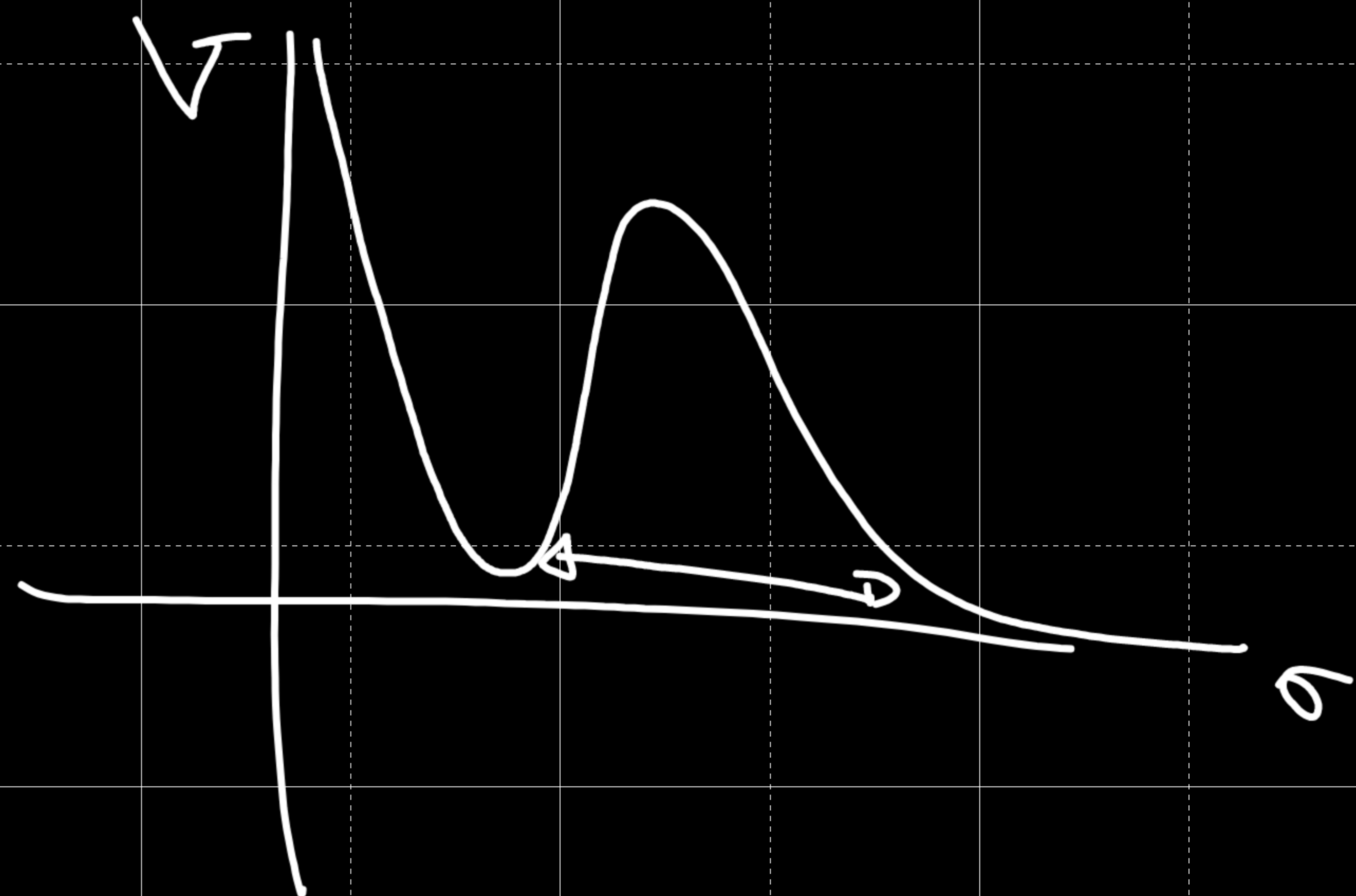
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$$W = W_0 + A e^{i a T} \quad A, a = \text{const}$$

$$V = \frac{a A e^{-a \sigma}}{2 \sigma^2} \left[\frac{1}{3} a A e^{-a \sigma} + W_0 + A e^{-a \sigma} \right]$$



$$3 + \overline{D}3 \Leftrightarrow 8V = \frac{2}{9}$$



$$S = \int d^2x \sqrt{-h} \left(G_{\mu\nu} \frac{\partial x^\mu}{\partial \sigma} \frac{\partial x^\nu}{\partial \tau} B_{\mu\nu} \right) \phi$$

$$Z = \int \mathcal{D}X \mathcal{D}h e^{-S}$$

$$- \alpha_-^{\mu} \bar{\alpha}_-^{\nu} |0\rangle - g_{\mu\nu} b_{\mu} \phi$$

$$0 = \beta_G^{1-loop} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R_{\mu\nu} - T_{\mu\nu}$$

$$- G_{\mu\nu} B_{\mu\nu} \phi \rightarrow \text{SUGRA}$$

$$0 = \beta_B = \nabla_\mu H^{\mu\nu\rho} + \dots$$

$$0 = \beta_A$$