Title: Q7-branes in type IIB string theory

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Abstract: We review basic properties of effective worldvolume theory describing the dynamics of Dirichlet branes in type II supergravity backgrounds and then show that the SL(2,R) symmetry of IIB supergravity allows for the existence of new supersymmetric 7-brane configurations called Q7-branes. The Q7-branes differ from the D7-branes, in particular, by their coupling to the dilaton, axion and to `magnetic\' gauge field duals thereof. The appearance of Q7-branes and their instanton duals may indicate the existence of a new, yet unexplored, perturbative vacuum of type IIB string theory.

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$\tau = C_0 + i\, e^{-\phi}$ - axion-dilaton

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$$R_{mn} - \frac{1}{2} g_{mn} R = T_{mn}(\tau)$$

$$D_m(e^{2\phi} D^m C_0) = 0$$

$$D_m D^m \phi - e^{2\phi} (\partial_m C_0)^2 = 0$$

7-brane solutions of IIB supergravity

10D me

$ds^{\prime}$

7-brane solutions of IIB supergravity

10D metric:

$$ds^2 = -dt^2 + d\,\vec{x}_7^{\,2} + a(z,\bar{z})\,dz\,d\bar{z}, \qquad z = x^8 + i\,x^9$$

$(i = 8, 9)$ - coordinates normal to the 7-brane

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$$a(z,\bar{z}) = (\mathrm{Im}\,\tau)\,|f|^2$$

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$$\boxed{e^{2\pi i \tau} = z - z_0} \;\longrightarrow\; \tau = \frac{1}{2\pi i}\ln\left(z - z_0\right)$$ - D7-brane solution

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$Q = \det (q_\alpha{}^\beta), \quad e^q \tau_0 = \tau_0$ - SL(2,R) fixed point

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BI field — NS-NS gauge field

$$\mathcal{F}_2 = d\mathcal{A}(\xi) + B_2(x(\xi))$$

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$$C_0 \to C_0 + b, \; C_2 \to C_2 - b\, B_2$$ axion shift symmetry

constant (b)

SL(2,R)~SU(1,1) invariance (S-duality) of IIB supergravity *(J. Schwarz 83)*

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Bosonic sector: G_{MN}; C_4; B_2, C_2; B_6, C_6; C_0, ϕ; $C_{\vdots}$

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$$\mathcal{M}^{\alpha\beta} = \mathcal{M}^{\beta\alpha} = e^{\phi}\begin{pmatrix} C_0^2 + e^{-2\phi} & C_0 \\ C_0 & 1 \end{pmatrix}, \qquad \mathcal{M}^{\alpha\beta}\mathcal{M}_{\beta}{}^{\gamma} = \qquad \mathcal{M} \to U\mathcal{M}U'$$

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Bosonic sector: $\underbrace{G_{MN};\, C_4;}_{\text{SL(2,R) singlets}}\ \underbrace{B_2, C_2;}_{A_2{}^{\alpha}}\ \underbrace{B_6, C_6;}_{A_6{}^{\alpha}}\ C_0, \phi;\ C_8$

SL(2,R) singlets $\quad A_2{}^{\alpha}$ doublets $A_6{}^{\alpha}$

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$$F_9^{\alpha\beta} = *F_1^{\alpha\beta}, \quad dF_9^{\alpha\beta} = \frac{1}{4} F_3^{(\alpha} \wedge F_7^{\beta)}$$

$$F_9^{\alpha\beta} = dA_8^{\alpha\beta} + \cdots$$

Relation between C_8 and $A_8{}^{\alpha\beta}$ and the SL(2,R) charge of the 7-brane

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Q7-branes: $\det q =: Q \neq 0 \quad \Rightarrow \quad q \neq U^T q^D U$

(Meessen & Ortín 99; Bergshoeff, Gran, Roest 02)

Q7-brane coupling to IIB SUGRA
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$$q_{\alpha\beta} * F_9^{\alpha\beta} = q_{\alpha\beta}\, F_1^{\alpha\beta} = q_{\alpha\beta}\, \mathcal{M}^{\alpha\gamma}\, d\mathcal{M}_{\gamma}{}^{\beta} = (T^2 - 4Q)\, d\chi'(\phi, C_0) \qquad Q = \det q_{\alpha\beta}$$

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Q7-brane charge $q_{\alpha\beta}$ acts as the generator of the shift symmetry

Q7-brane

Q7-brane Wess-Zumino term

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- and under gauge transformations of tensor fields A_r (r=2,4,6,8)

$$\delta A_8^{\alpha\beta} = d\Lambda_7^{\alpha\beta} + \frac{1}{4} A_2^{(\alpha}\, \delta A_6^{\beta)} + \frac{1}{6} A_2^{\alpha} A_2^{\beta}\, \delta A_4 + \frac{2}{3} A_4 A_2^{(\alpha}\, \delta A_2^{\beta)} + \frac{1}{3\cdot 2^6} A_2^{\alpha} A_2^{\beta}\, \epsilon_{\gamma\delta} A_2^{\gamma}\, \delta A_2^{\delta}$$

$$\delta A_6^{\alpha} = d\Lambda_5^{\alpha} - \frac{1}{3} A_2^{\alpha}\, \delta A_4 + \frac{2}{3} A_4\, \delta A_2^{\alpha} + \frac{1}{48} A_2^{\alpha} \epsilon_{\gamma\delta}\, A_2^{\gamma}\, \delta A_2^{\delta}$$

$$\delta A_4 = d\Lambda_3 + \frac{i}{16} \epsilon_{\gamma\delta}\, A_2^{\gamma}\, \delta A_2^{\delta}, \qquad \delta A_2^{\alpha} = d\Lambda_1^{\alpha}$$

Q7-brane Wess-Zumino term

$$L_{WZ} = q_{\alpha\beta}\left[A_8^{\alpha\beta} + A_6^{(\alpha}\mathcal{F}_2^{\beta)} + \frac{1}{2}A_4\mathcal{F}_2^{\alpha}\mathcal{F}_2^{\beta} + \frac{1}{64}\left(\frac{1}{3}A_2^{\alpha}A_2^{\beta} - A_2^{(\alpha}\mathcal{F}_2^{\beta)} + \mathcal{F}_2^{\alpha}\mathcal{F}_2^{\beta}\right)\epsilon_{\gamma\delta}A_2^{\gamma}\mathcal{F}_2^{\delta}\right]$$

$$-\frac{1}{6\cdot 8^3}Q^{1/2}\left[e^{-4i\sqrt{Q}\chi'}\frac{i}{(\mathrm{Im}\tau_0)^2}\left((\mathcal{F}_2^1 - \mathcal{F}_2^2) + i\tau_0(\mathcal{F}_2^1 + \mathcal{F}_2^2)\right)^4 + \text{c.c.}\right]$$

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At det q=Q=0 the Q7-brane WZ term reduces to the SL(2,R)-covariant D7-brane WZ term with a single BI field

Q7-brane Wess-Zumino term

$$L_{WZ} = q_{\alpha\beta}\left[A_8^{\alpha\beta} + A_6^{(\alpha}\mathcal{F}_2^{\beta)} + \frac{1}{2}A_4\mathcal{F}_2^{\alpha}\mathcal{F}_2^{\beta} + \frac{1}{64}\left(\frac{1}{3}A_2^{\alpha}A_2^{\beta} - A_2^{(\alpha}\mathcal{F}_2^{\beta)} + \mathcal{F}_2^{\alpha}\mathcal{F}_2^{\beta}\right)\epsilon_{\gamma\delta}A_2^{\gamma}\mathcal{F}_2^{\delta}\right]$$

$$-\frac{1}{6\cdot 8^3}Q^{1/2}\left[e^{-4i\sqrt{Q}\chi'}\frac{i}{(\mathrm{Im}\tau_0)^2}\left((\mathcal{F}_2^1 - \mathcal{F}_2^2) + i\tau_0(\mathcal{F}_2^1 + \mathcal{F}_2^2)\right)^4 + \text{c.c.}\right]$$

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Missi

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- kinetic term for 2 BI fields

$$L_{DBI}^{D7} = e^{\phi}\sqrt{-\det\left(g_{mn} + e^{-\frac{\phi}{2}}\mathcal{F}_{mn}\right)}$$

"Kinetic" term for the BI fields on the Q7-brane

Q7-branes are ½ BPS solutions of IIB supergravity

(Bergshoeff, Gran, Roest 02; Bergshoeff, Hartong, Ortín, Roest 06)

Assumption: complete action for the Q7-brane should be invariant under ½ SUSY of IIB SUGRA background

$$\delta_\varepsilon L^{Q7}_{WZ} + \delta_\varepsilon L^{Q7}_{DBI} = 0$$

Up to the second order in $\mathcal{F}_2^\alpha$

$$L^{Q7}_{DBI} = \sqrt{-g_{(8)}}\left(T + \tfrac{1}{4}\, q_{\alpha\beta}\, \mathcal{F}^\alpha_{mn}\, \mathcal{F}^{\beta\, mn} + \ldots\right)$$

$T(\phi, C_0) = q_{\alpha\beta}\, \mathcal{M}^{\alpha\beta}$ - 'tension' scalar

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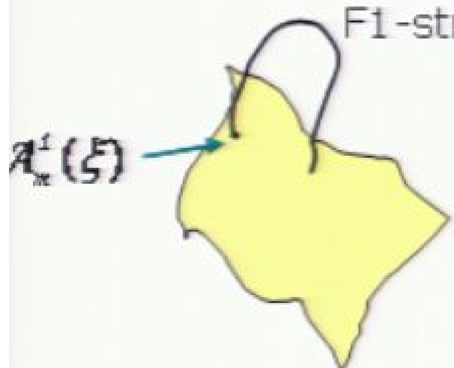

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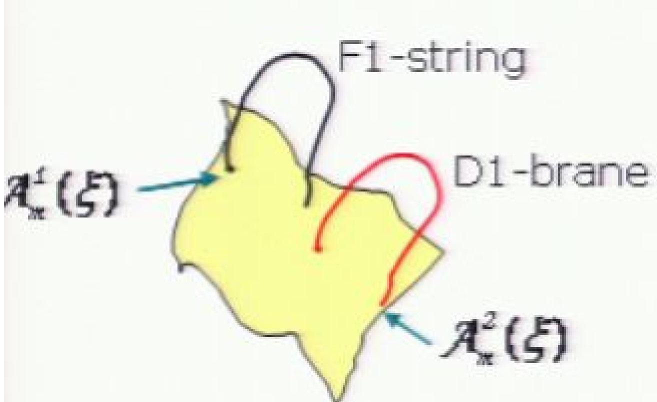

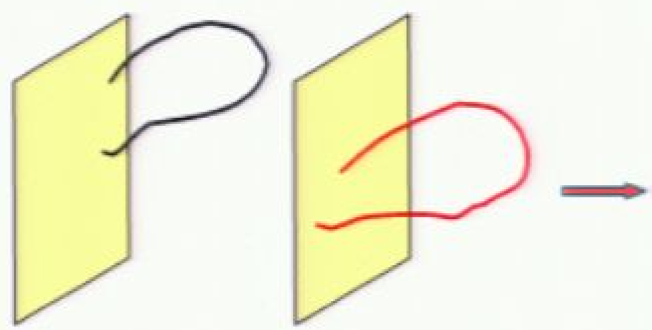

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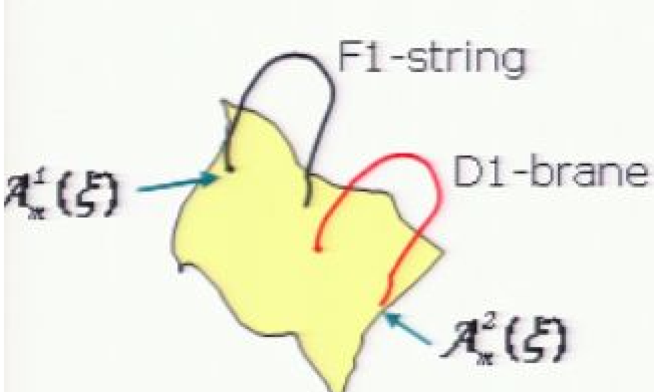

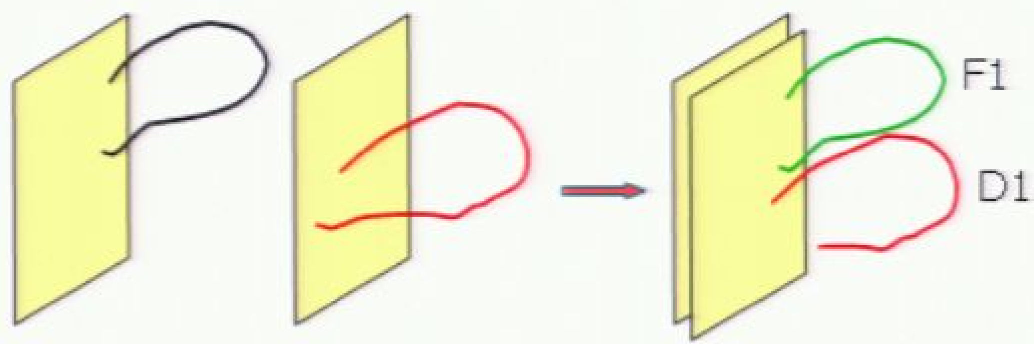

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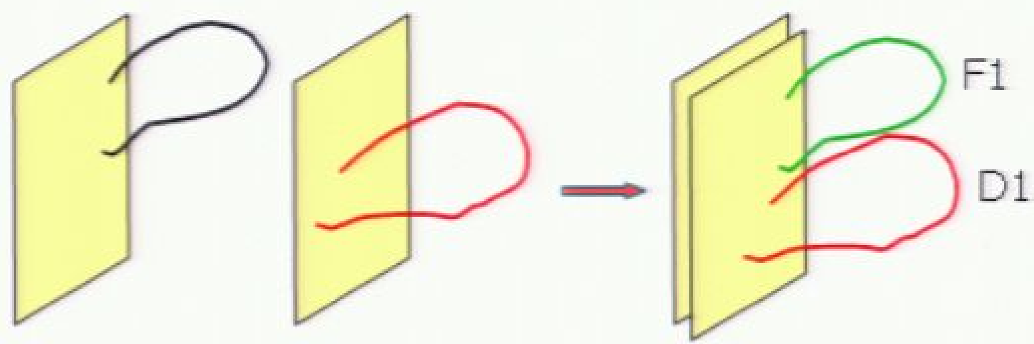

Reminds a picture of 2 coincident D-branes
though with only 2 **Abelian** gauge fields

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- Gauge invariance of the Q7-brane coupling (WZ term) requires 2 abelian BI fields on Q7 worldvolume

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  E. Bergshoeff, J. Hartong, A. Ploegh and D.S. arXiv:0801.4956 [hep-th]

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½ BPS solutions of Euclidean IIB supergravity

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$\tau = \chi + ie^{-\phi}$

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$\frac{SL(2,R)}{SO(2) \times SL(2,Z)}$ – orbifold

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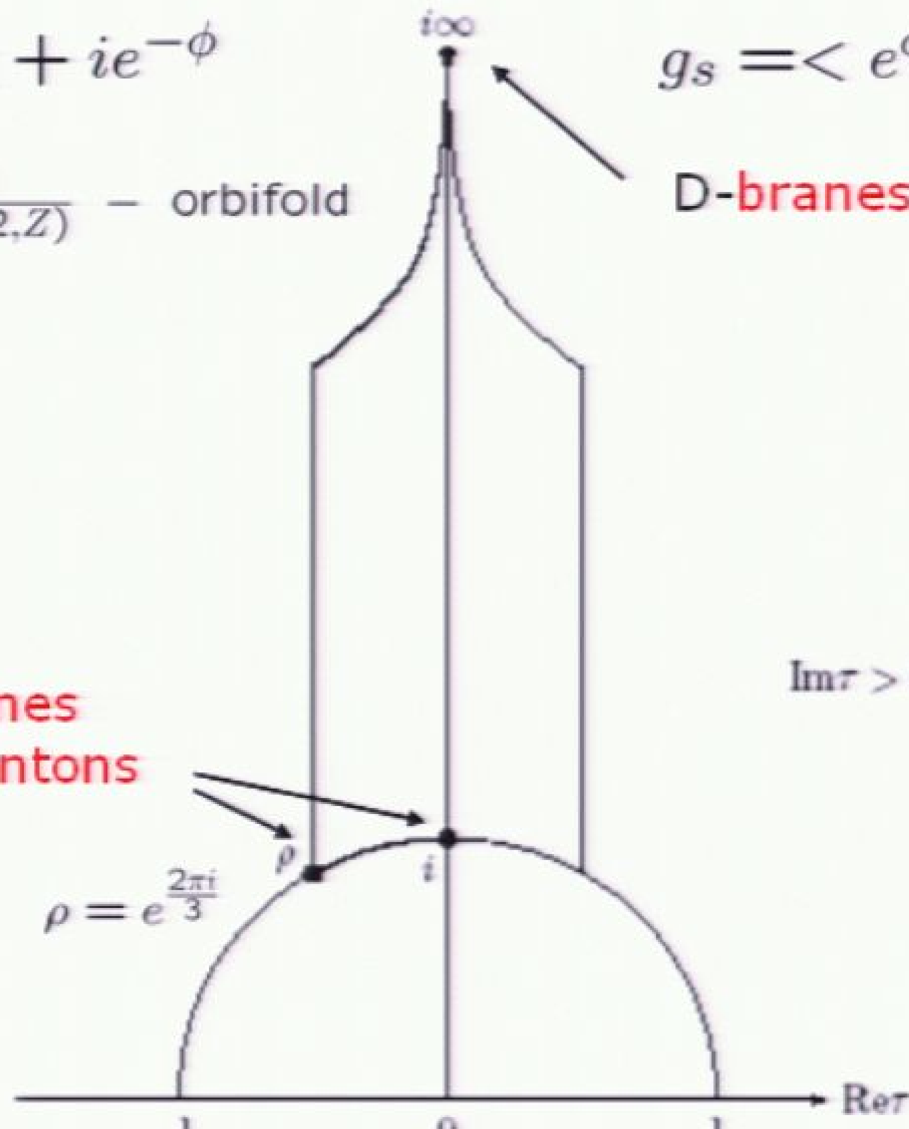

$\mathrm{Im}\tau > 0$ upper half–plane

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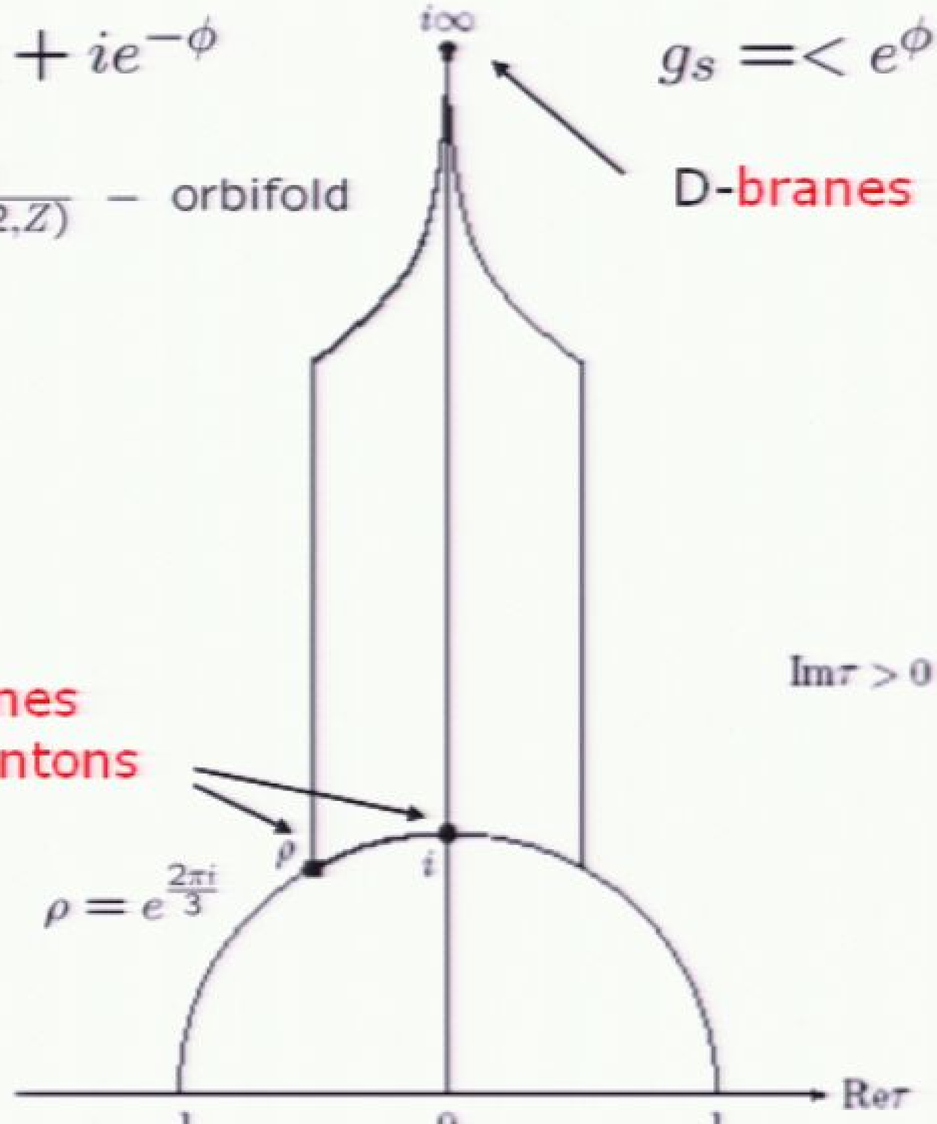

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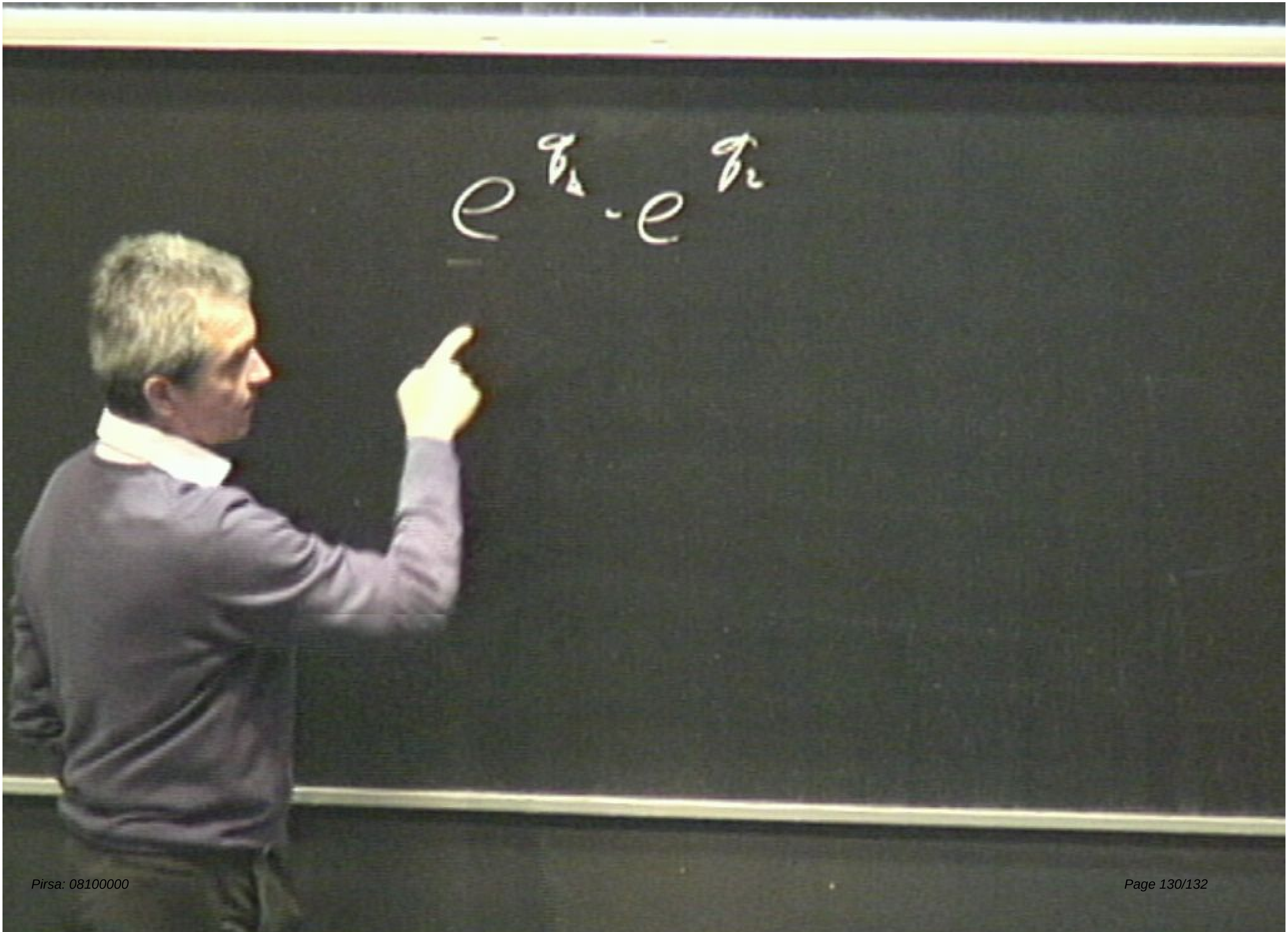
$e^{\phi_1} - e^{\phi_2}$

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q

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