Title: Problems with Computing Jet Quenching From AdS/CFT

Date: Nov 21, 2006 11:00 AM

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Abstract: I will discuss some ambiguities involved in using the AdS/CFT correspondence
to calculate the ultra-relativistic jet quenching parameter for quarks moving in
an N=4 super Yang-Mills thermal bath. Along the way, I will investigate the behavior of various string configurations on a five-dimensional AdS black hole
background.

Problems with Computing Jet Quenching from AdS/CFT

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Texas A&M University

with Philip Argyres and Mohammad Edalati

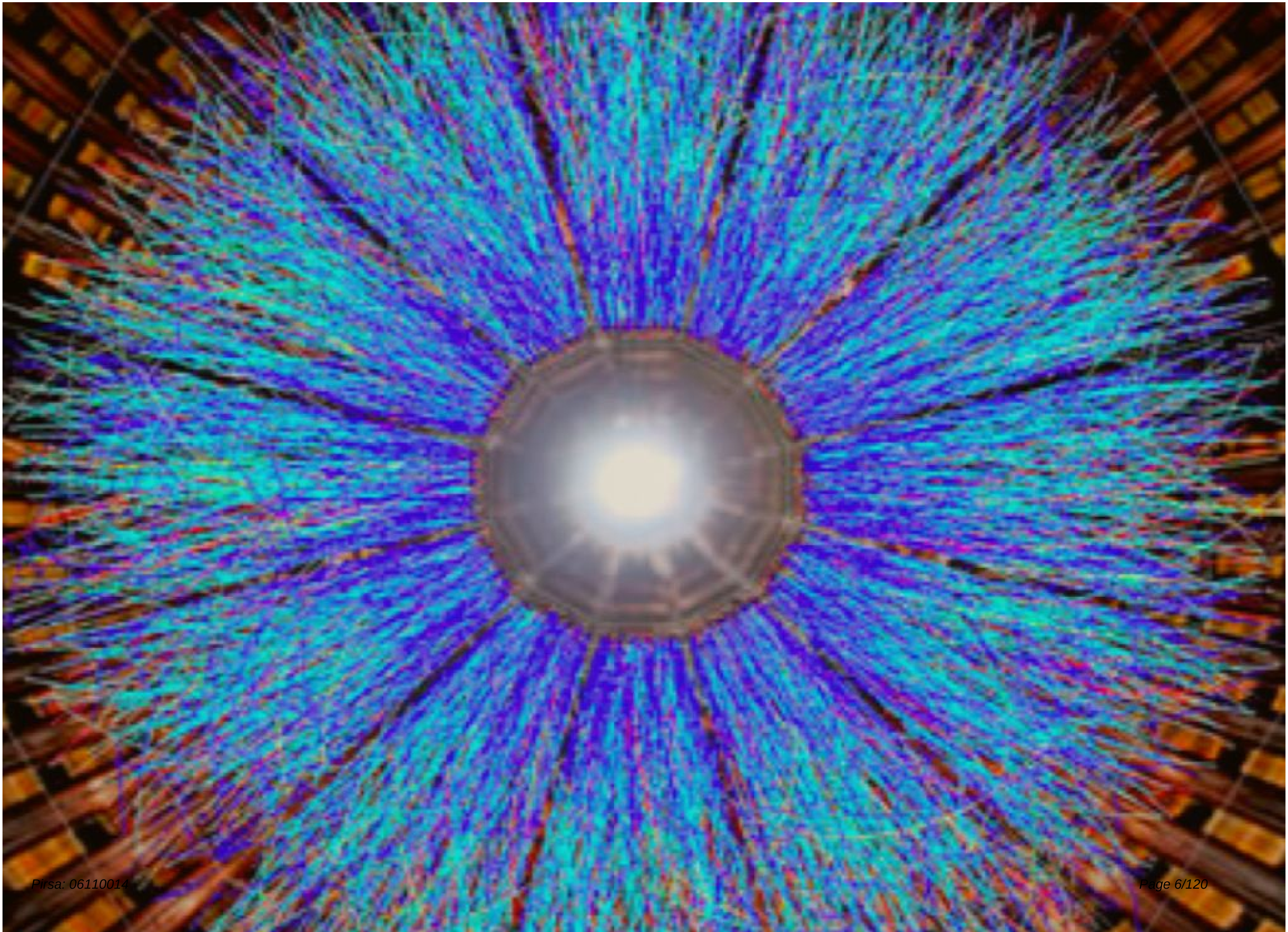
hep-th/0608118 and to appear


JANE
BOND

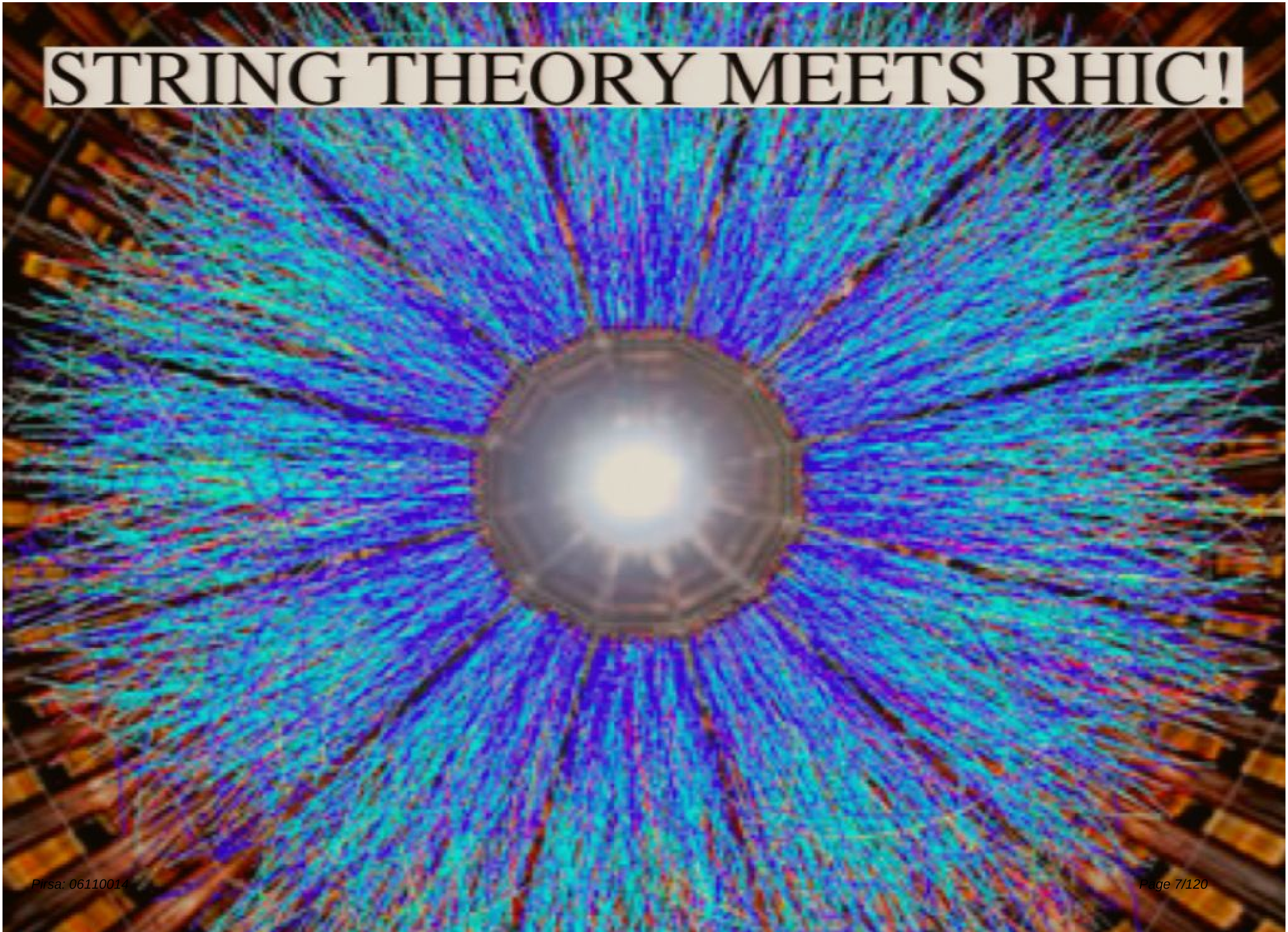
December 2006
issue of Esquire

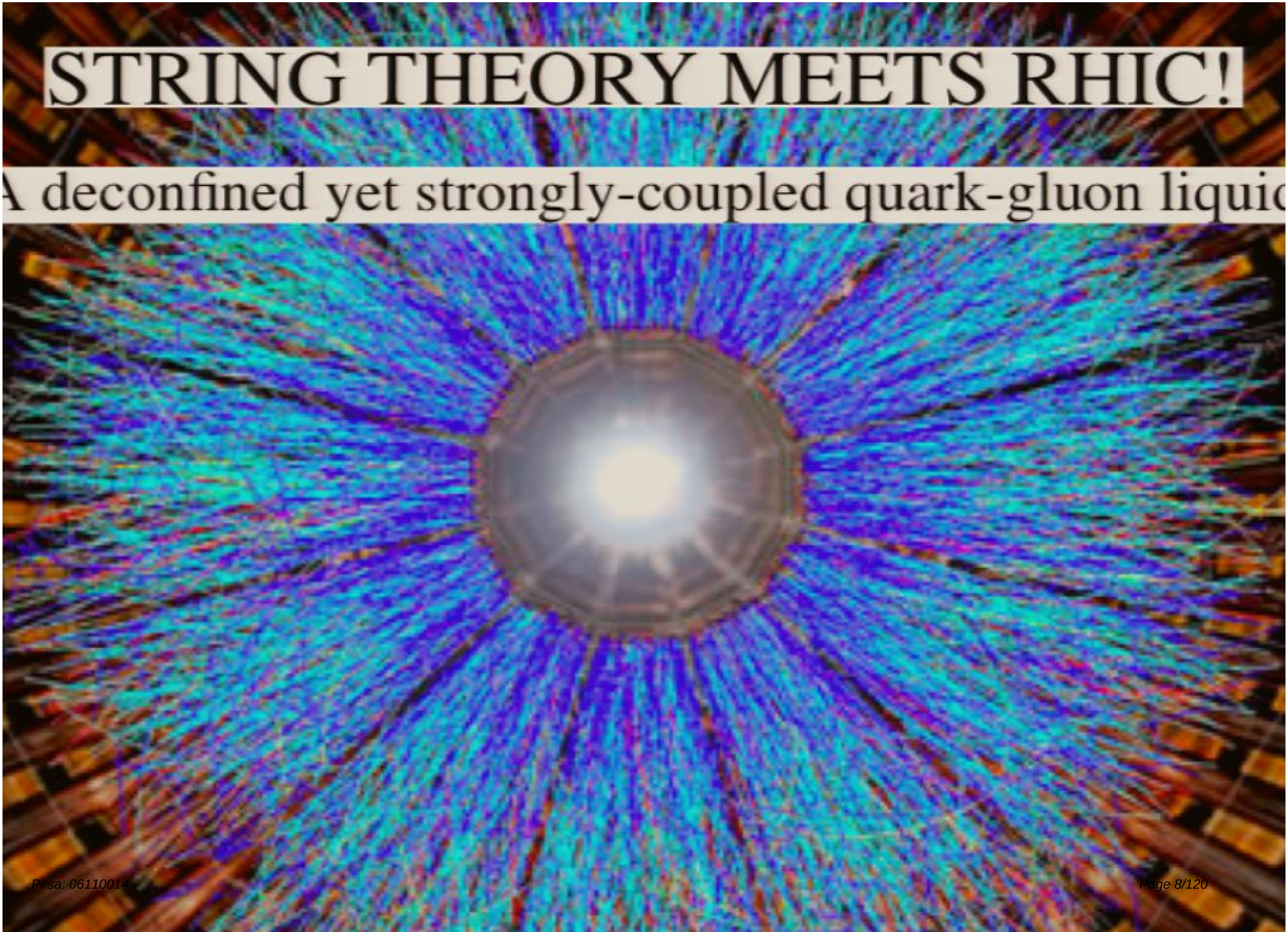
The string theorists just masturbate to their same ideas.

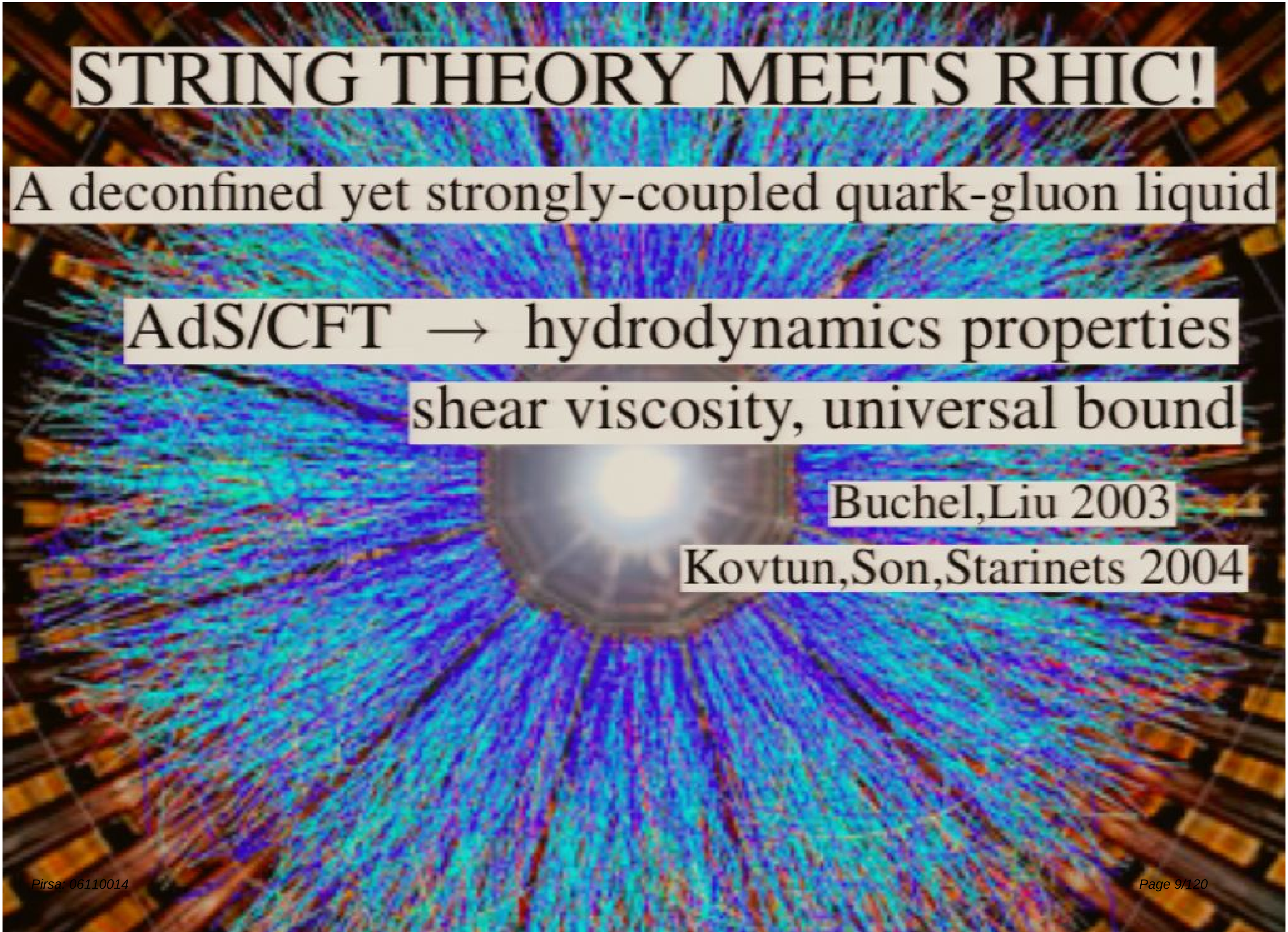
December 2006
issue of Esquire



STRING THEORY MEETS RHIC!




STRING THEORY MEETS RHIC!
deconfined yet strongly-coupled quark-gluon liqui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A deconfined yet strongly-coupled quark-gluon liquid
AdS/CFT → hydrodynamics properties
shear viscosity, universal bound
Buchel,Liu 2003
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STRING THEORY MEETS RHIC!

A deconfined yet strongly-coupled quark-gluon liquid

AdS/CFT $\rightarrow$ hydrodynamics properties

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Buchel,Liu 2003

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$\rightarrow$ Transport properties– energy loss of quarks

Casalderrey-Solana,Teaney

Herzog,Karch,Kovtun,Kozcaz,Yaffe

Liu,Rajagopal,Wiedemann

Gubser

Outline

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- Ambiguities in applying AdS/CFT at finite temperature

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- Extracting the friction coefficient

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- Extracting the friction coefficient
- Extracting the jet quenching parameter

Ambiguities in applying the AdS/CFT correspondence at finite temperature

(Maldacena 1997)

Ambiguities in applying the AdS/CFT correspondence at finite temperature

First, a brief review of the zero temperature case:

$$4\text{D } N = 4\ SU(N_c)\ \text{SYM} \quad = \quad \text{IIB strings on } AdS_5 \times S^5$$

for large N_c and 't Hooft coupling $\lambda \equiv g_{YM}^2 N_c$

(Maldacena 1997)

Quarks in AdS/CFT

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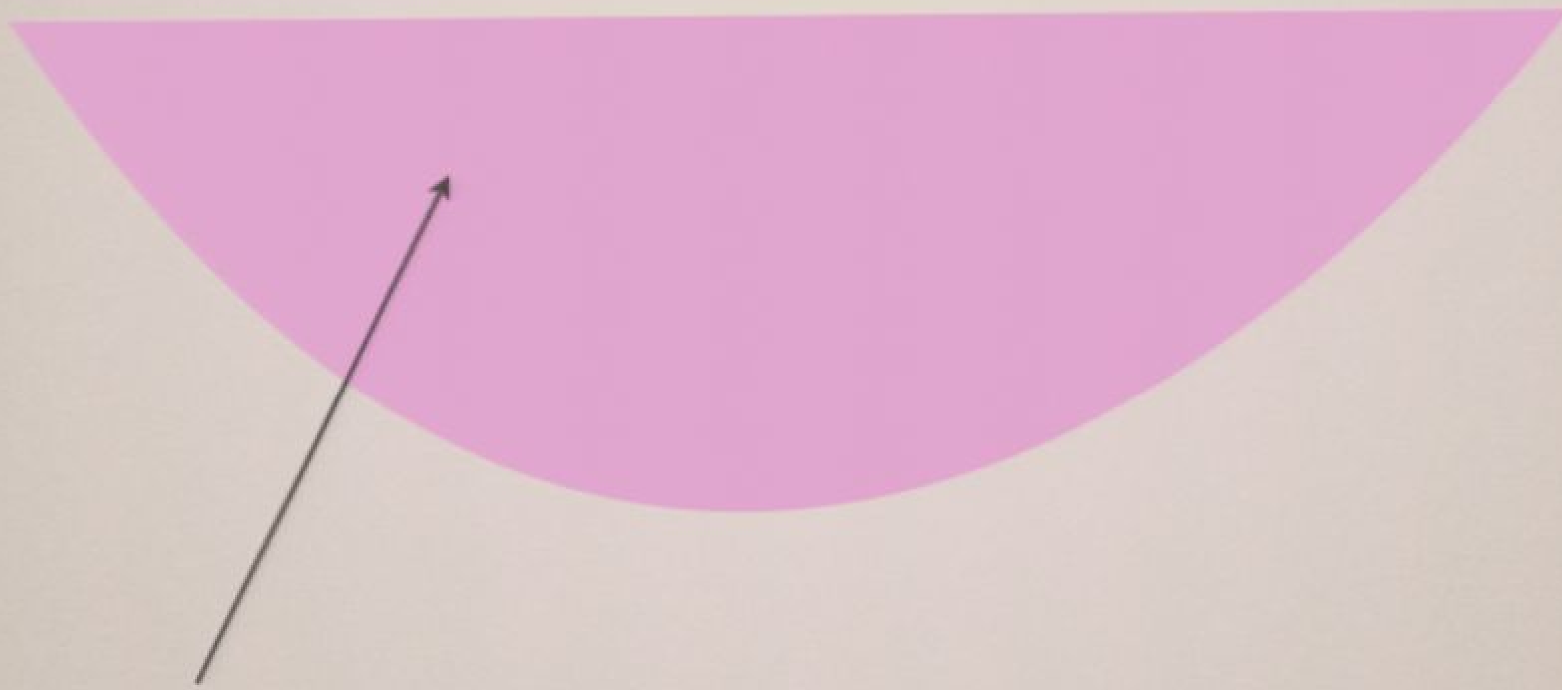
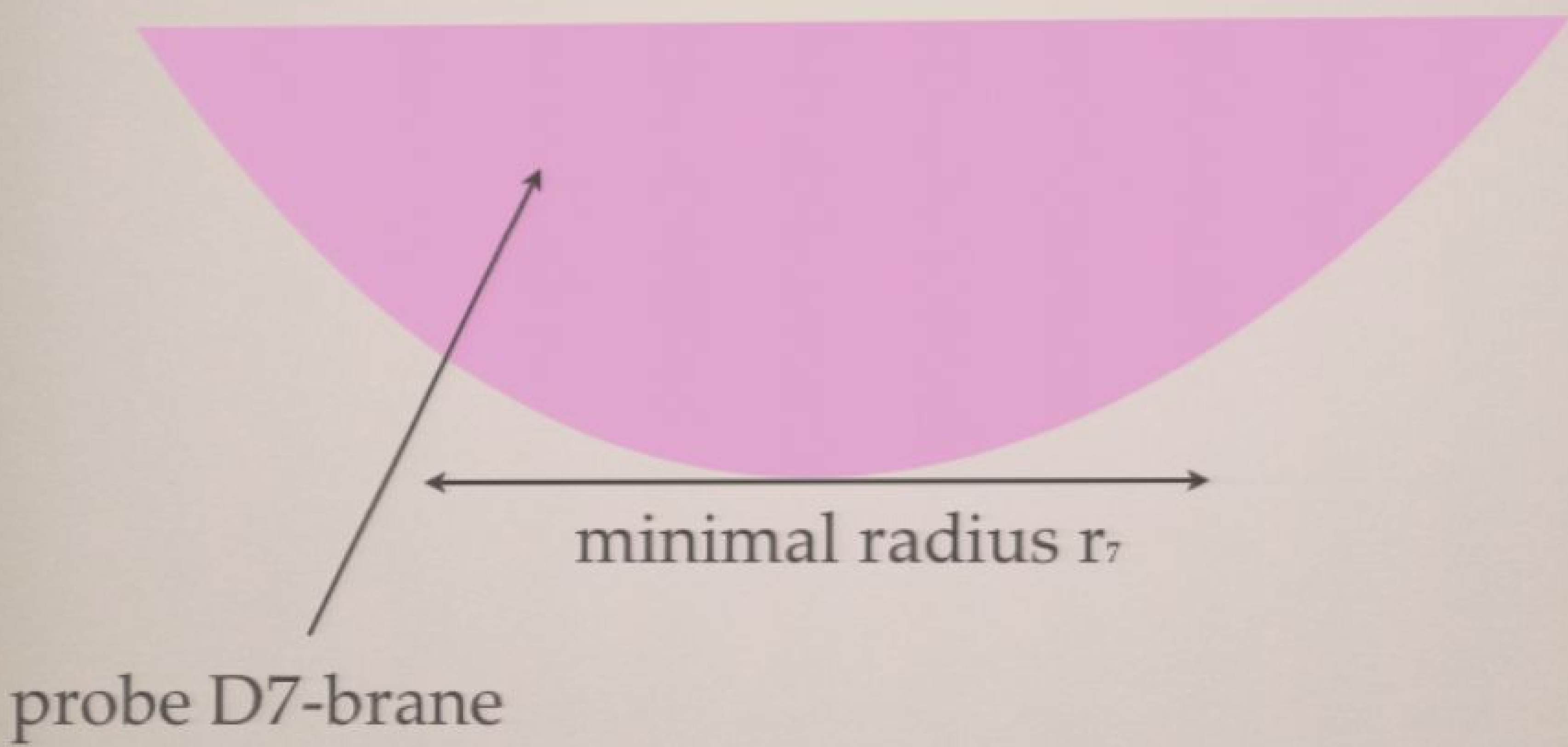


probe D7-brane

(Karch, Katz 2002)

Quarks in AdS/CFT



(Karch, Katz 2002)

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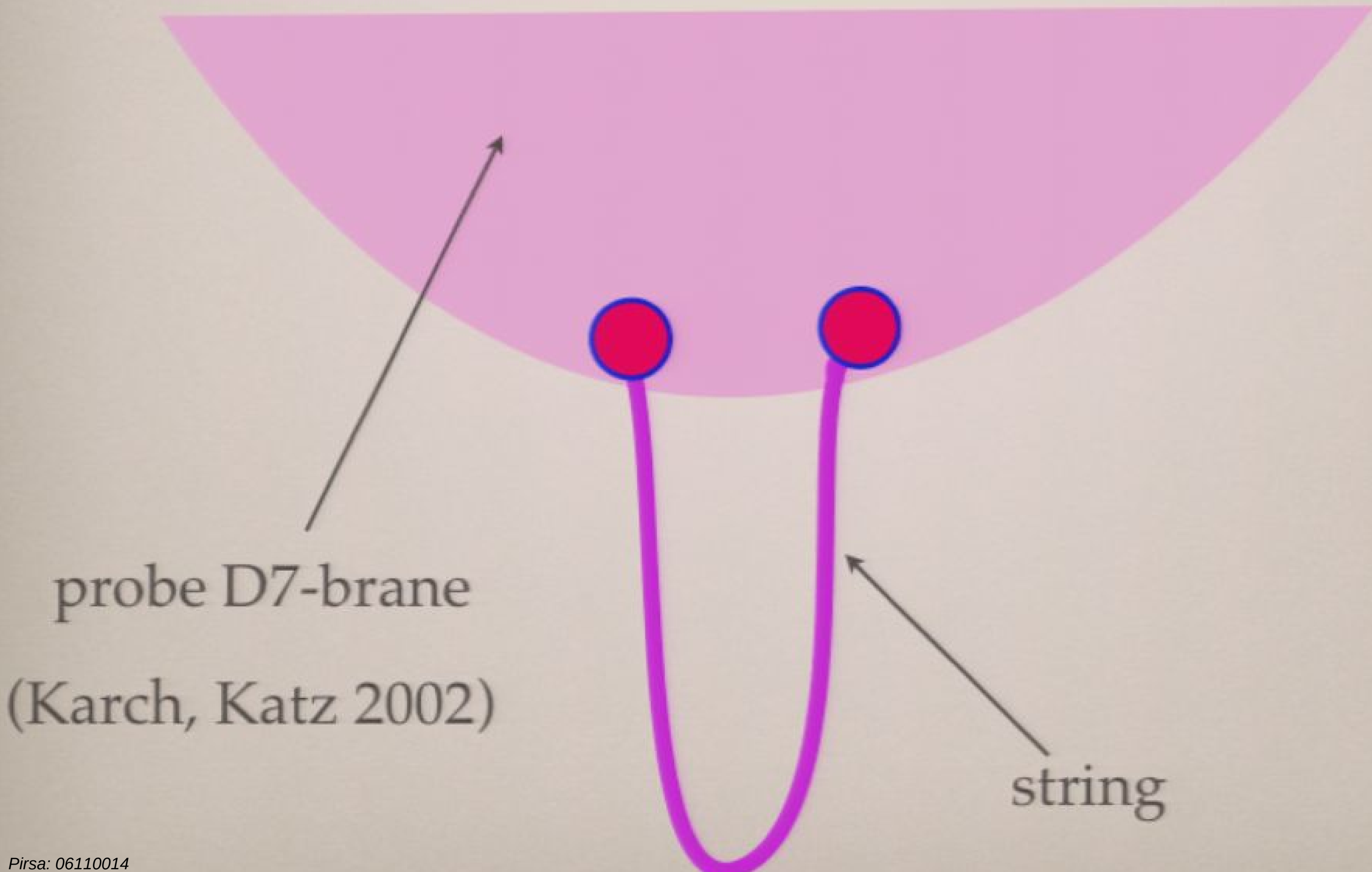

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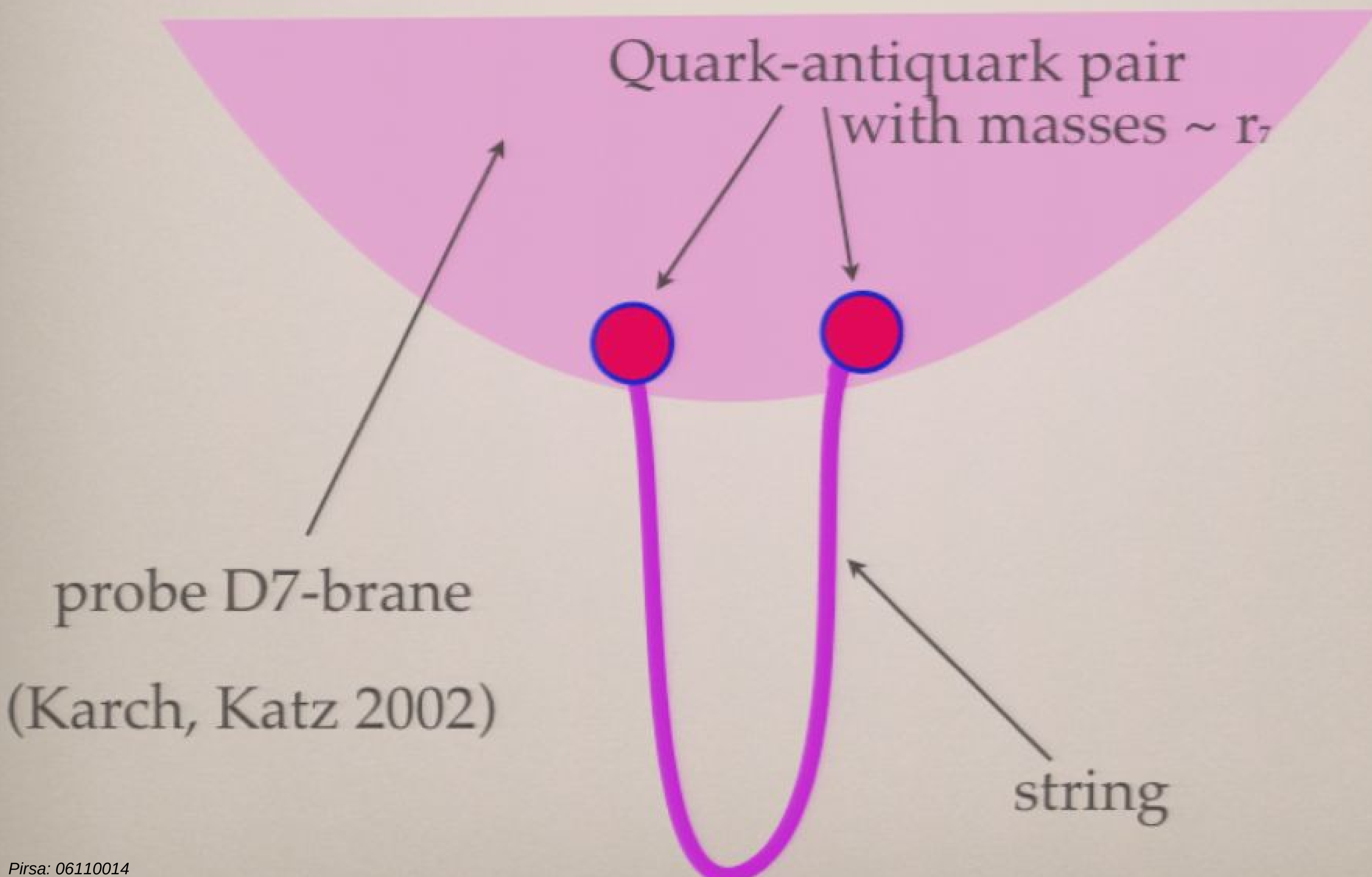
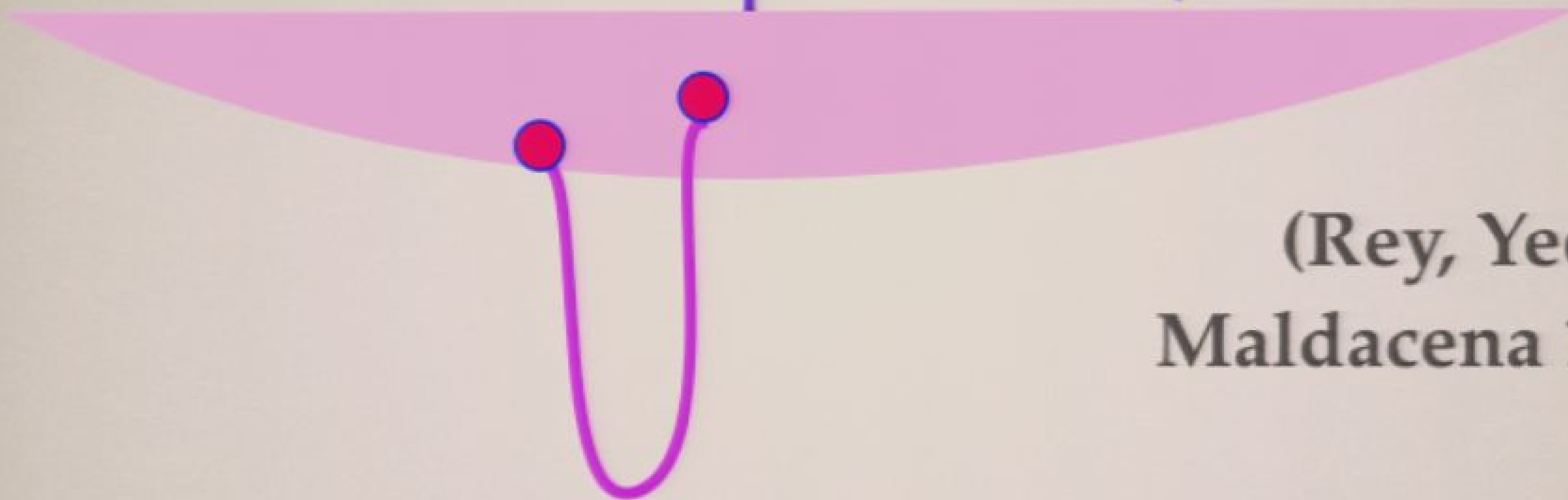


Wilson loops in AdS/CFT



(Rey, Yee;
Maldacena 1998)

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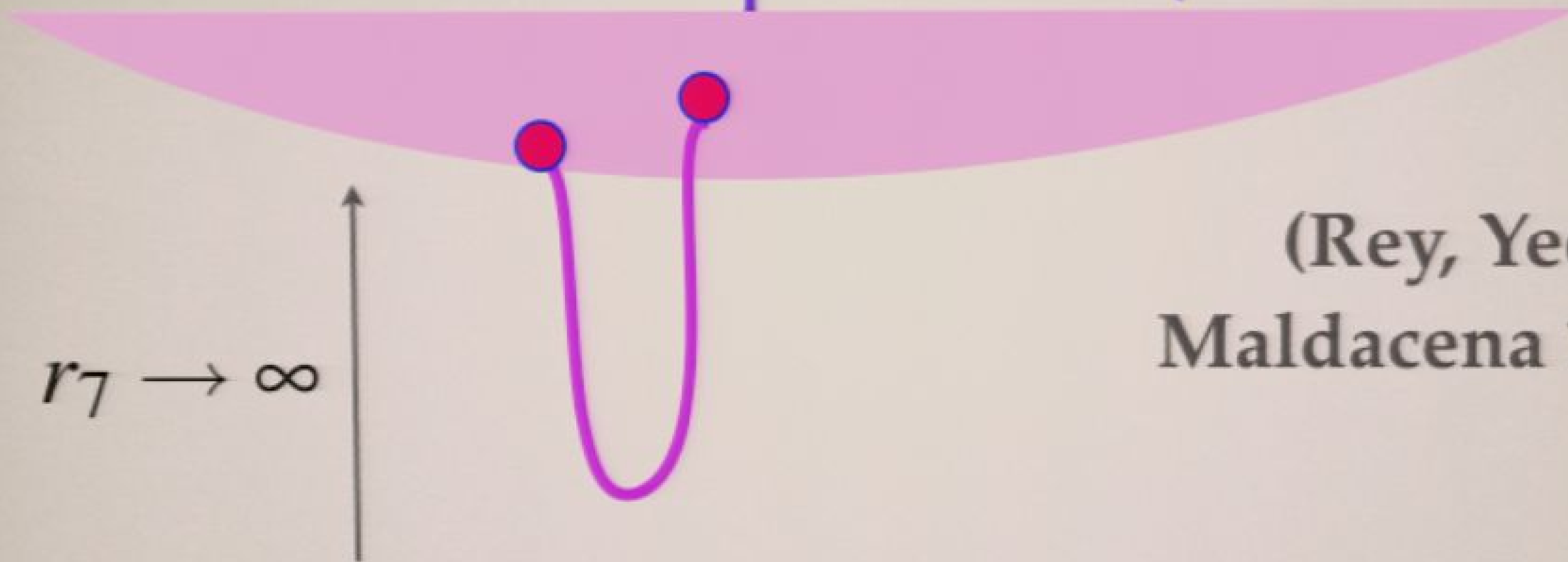

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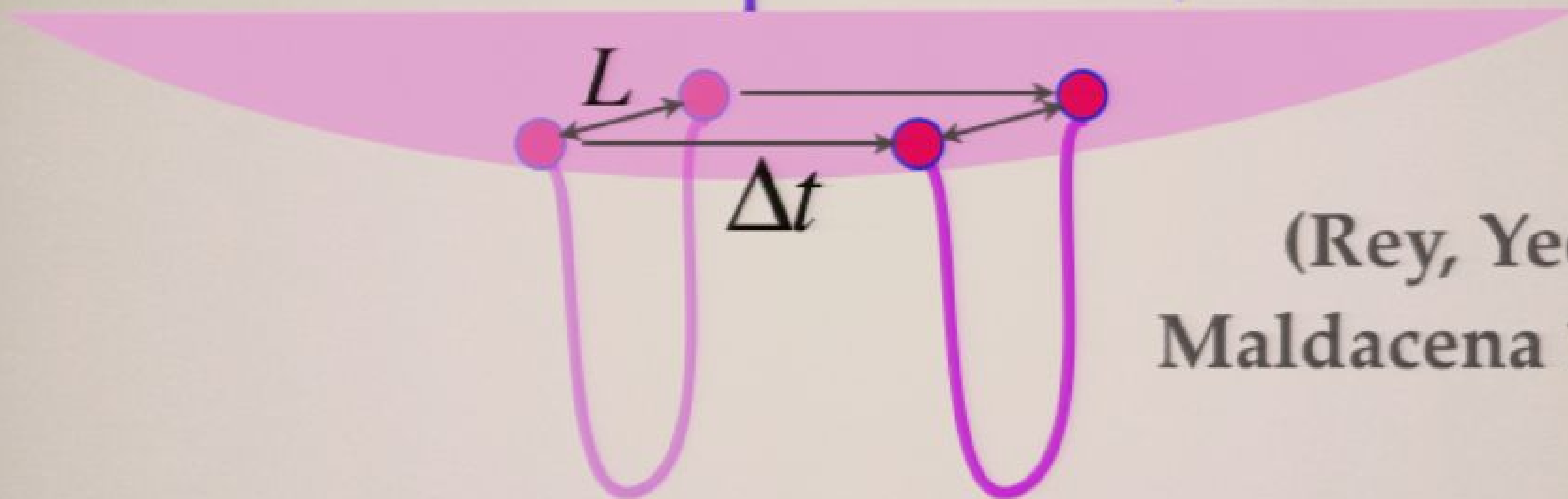

(Rey, Yee;
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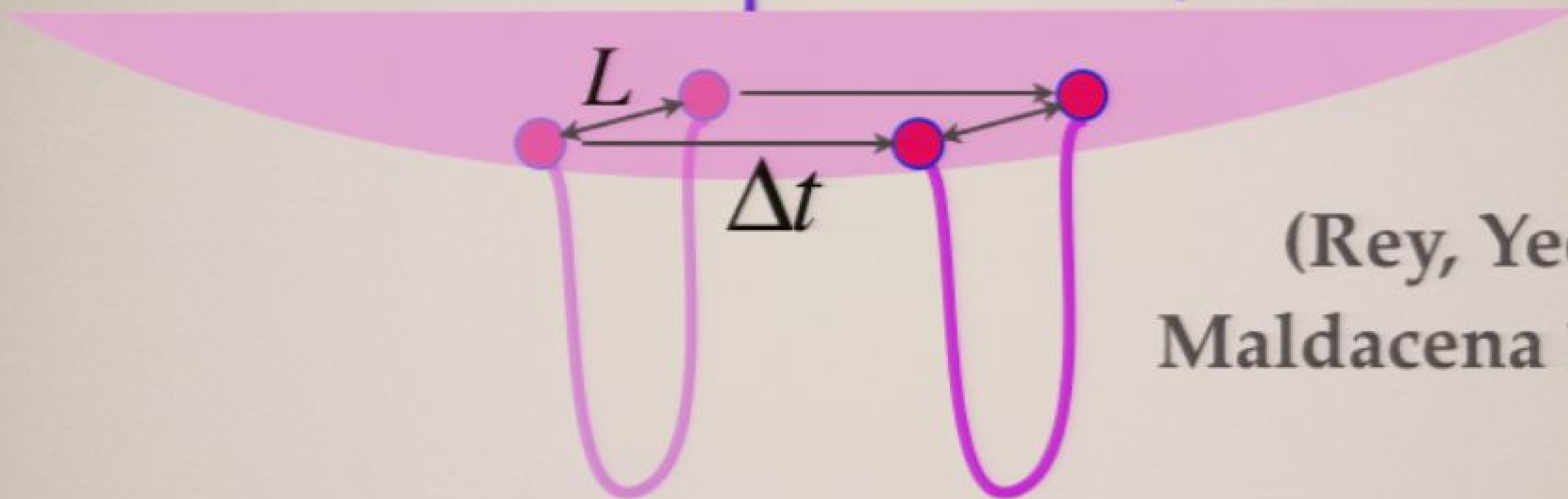
$$< W(C) > = e^{iS}$$

Wilson loops in AdS / CFT



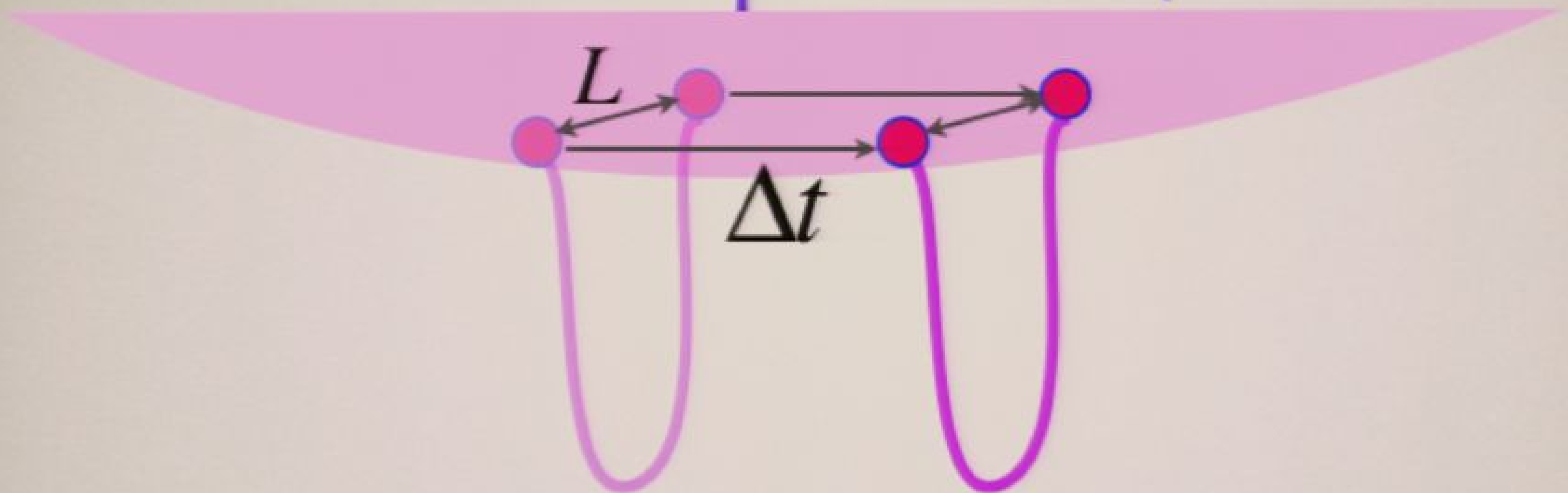
(Rey, Yee; Maldacena 1998)

$$< W(C) >= \mathrm{e}^{iS}$$

$$S_{NG} = -\frac{1}{2\pi\alpha'}\int d^2\sigma\sqrt{G}$$

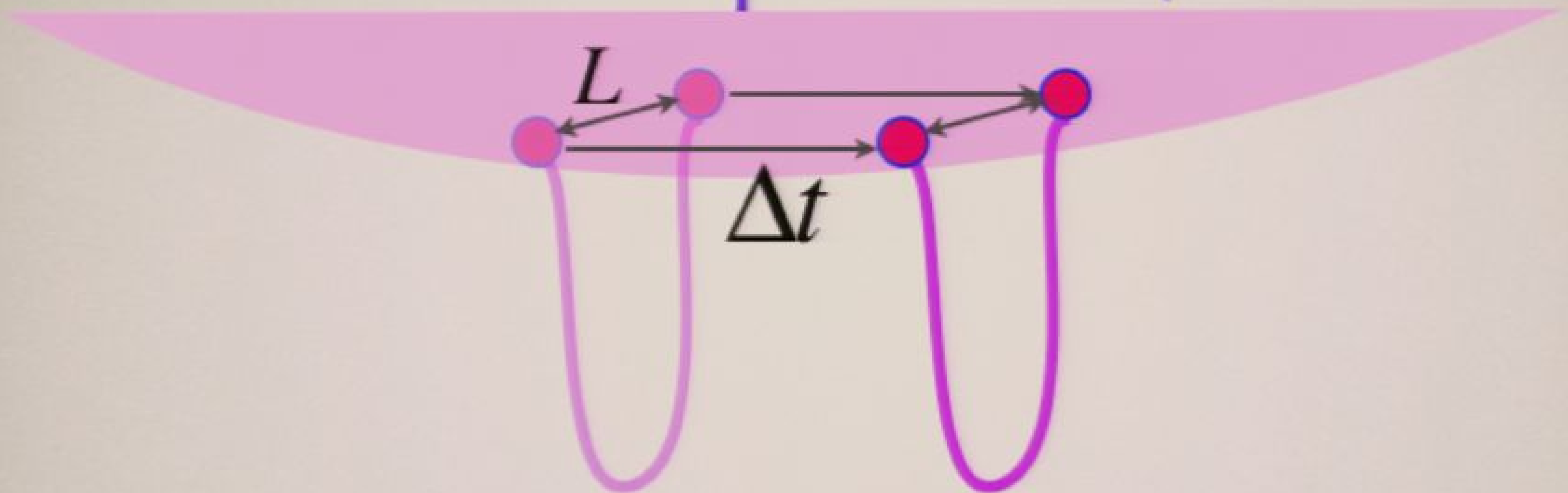
where $G = \det\left[g_{\mu\nu}\frac{\partial x^\mu}{\partial\sigma^\alpha}\frac{\partial x^\nu}{\partial\sigma^\beta}\right]$

Wilson loops in AdS / CFT



$$S \longrightarrow E$$

Wilson loops in AdS/CFT

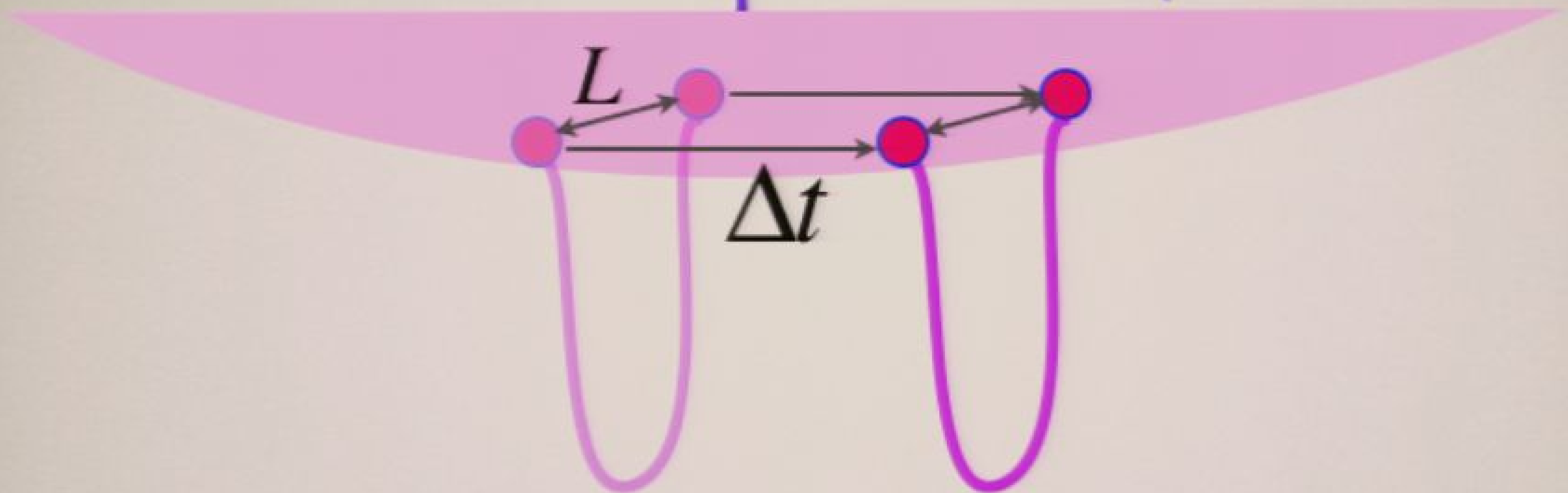


$$S \longrightarrow E$$

$$\downarrow$$

Equations of motion $\longrightarrow E \sim -\dfrac{\sqrt{g_{YM}^2 N}}{L}$

Wilson loops in AdS / CFT



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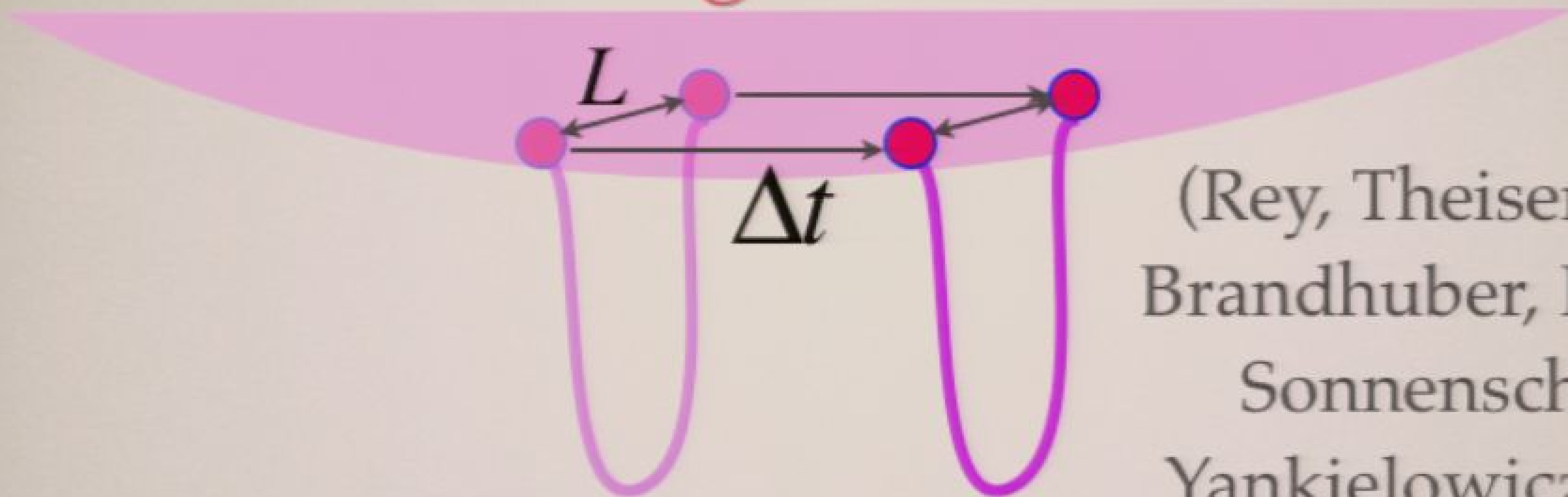
Coulombic interaction

Turning on the heat



(Rey, Theisen, Yee; Brandhuber, Itzhaki, Sonnenschein, Yankielowicz 1998)

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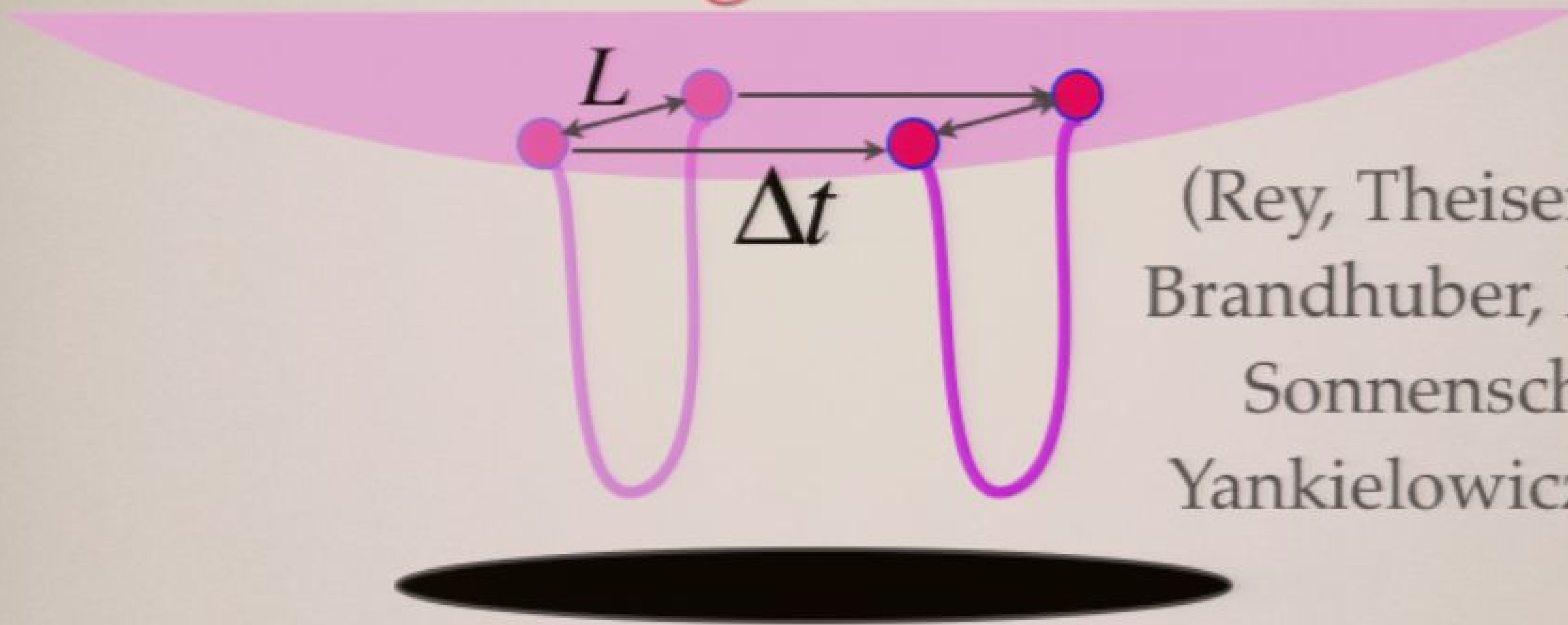

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$$E \sim -\frac{\sqrt{g_{YM}^2 N}}{L}\left[1 + c(TL)^4 + \cdots\right]$$

AdS black hole metric:

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

$$\text{where } f(r) = 1 - \frac{(\pi R^2 T)^4}{r^4}$$

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Relating distance and time in each theory:

$$\Delta x_i^{4d} = \Delta x_i^{\text{SUGRA}}$$

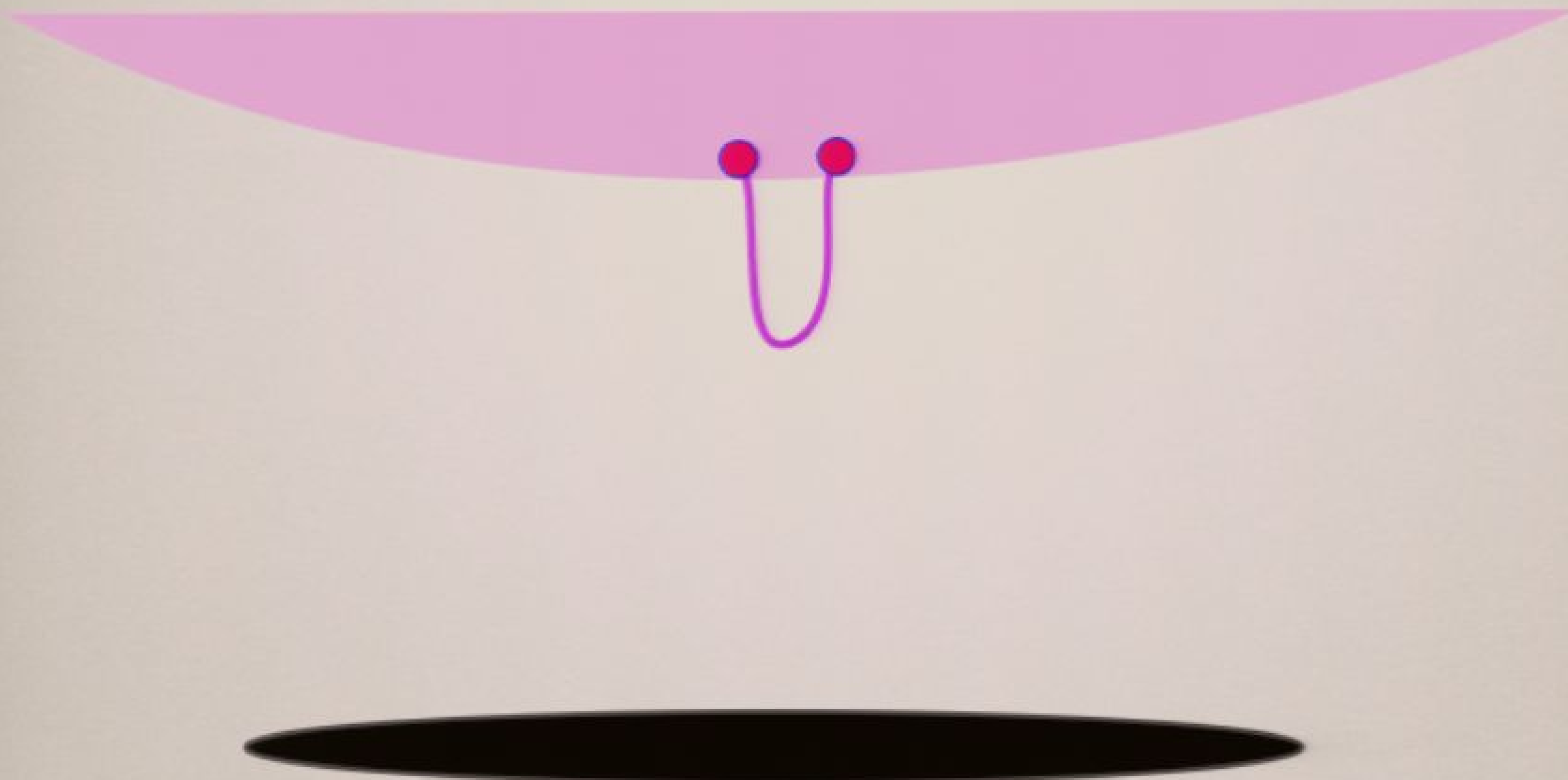
$$\Delta t^{4d} = \Delta t^{\text{SUGRA}} \sqrt{f(r_7)}$$

To determine the g factor :

Do strong-coupling calculation in YM theory
such as the correlation function

$$< O(x_1)\, O(x_2) >$$

String on background of AdS black hole



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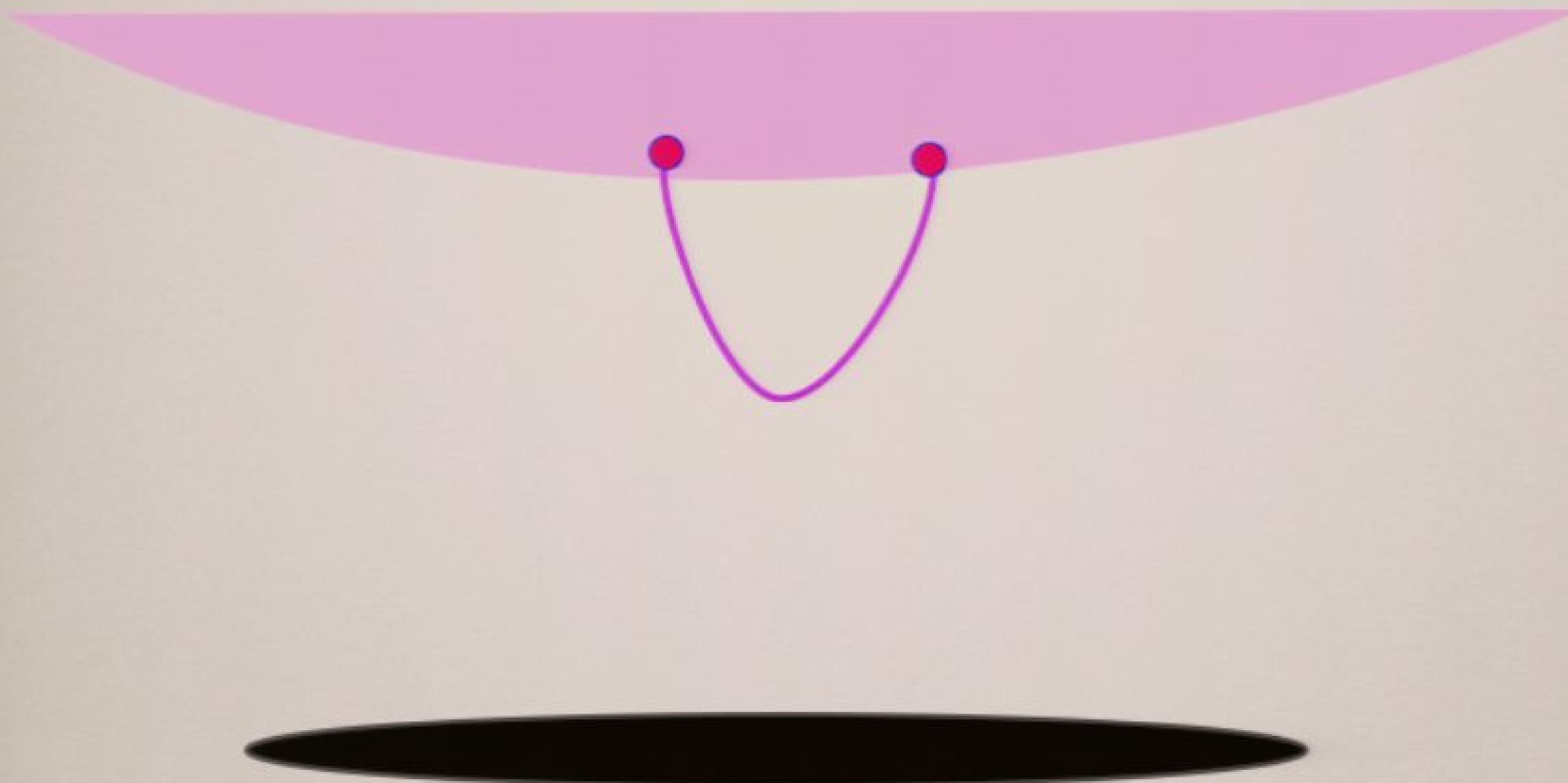

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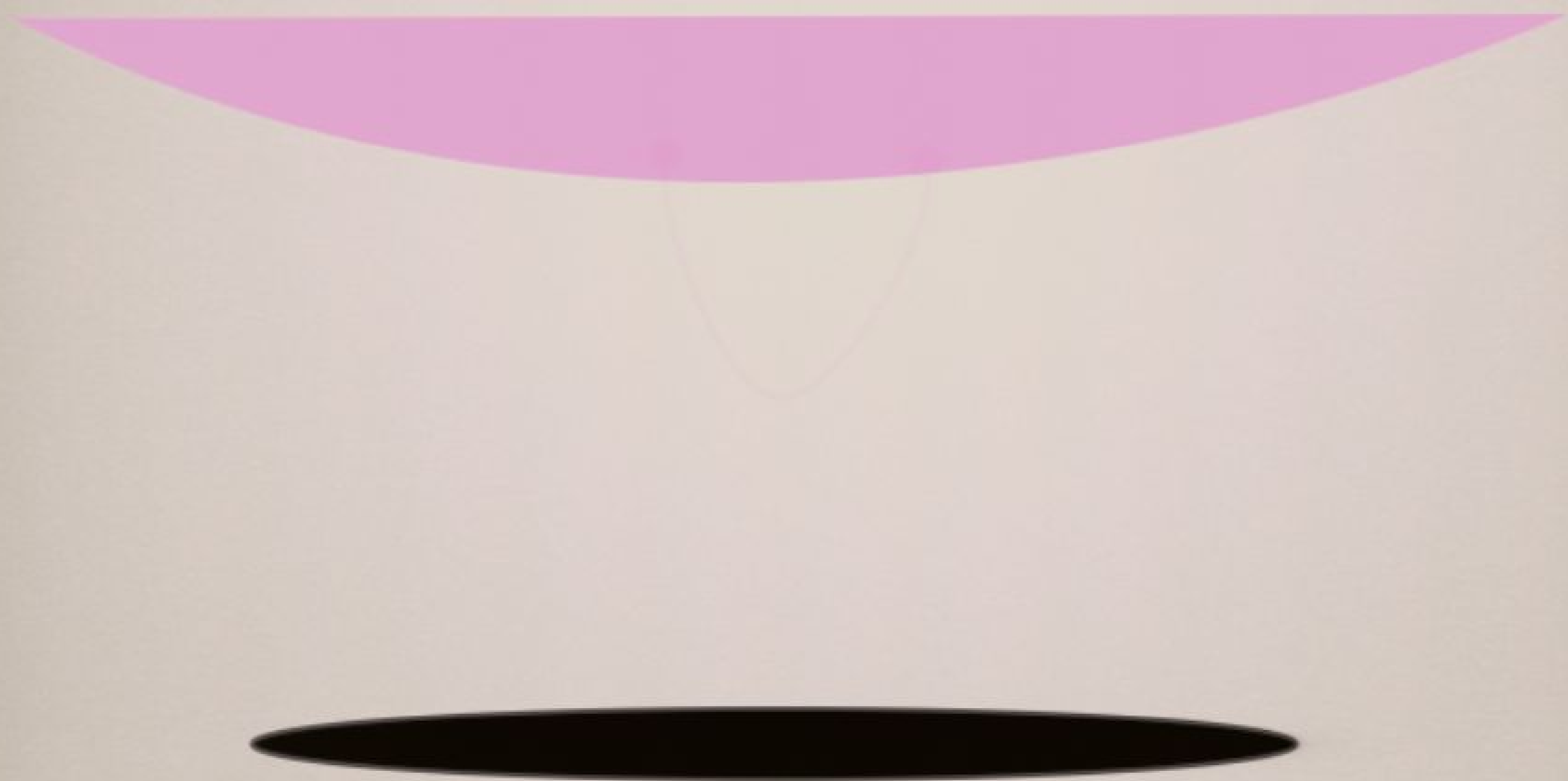

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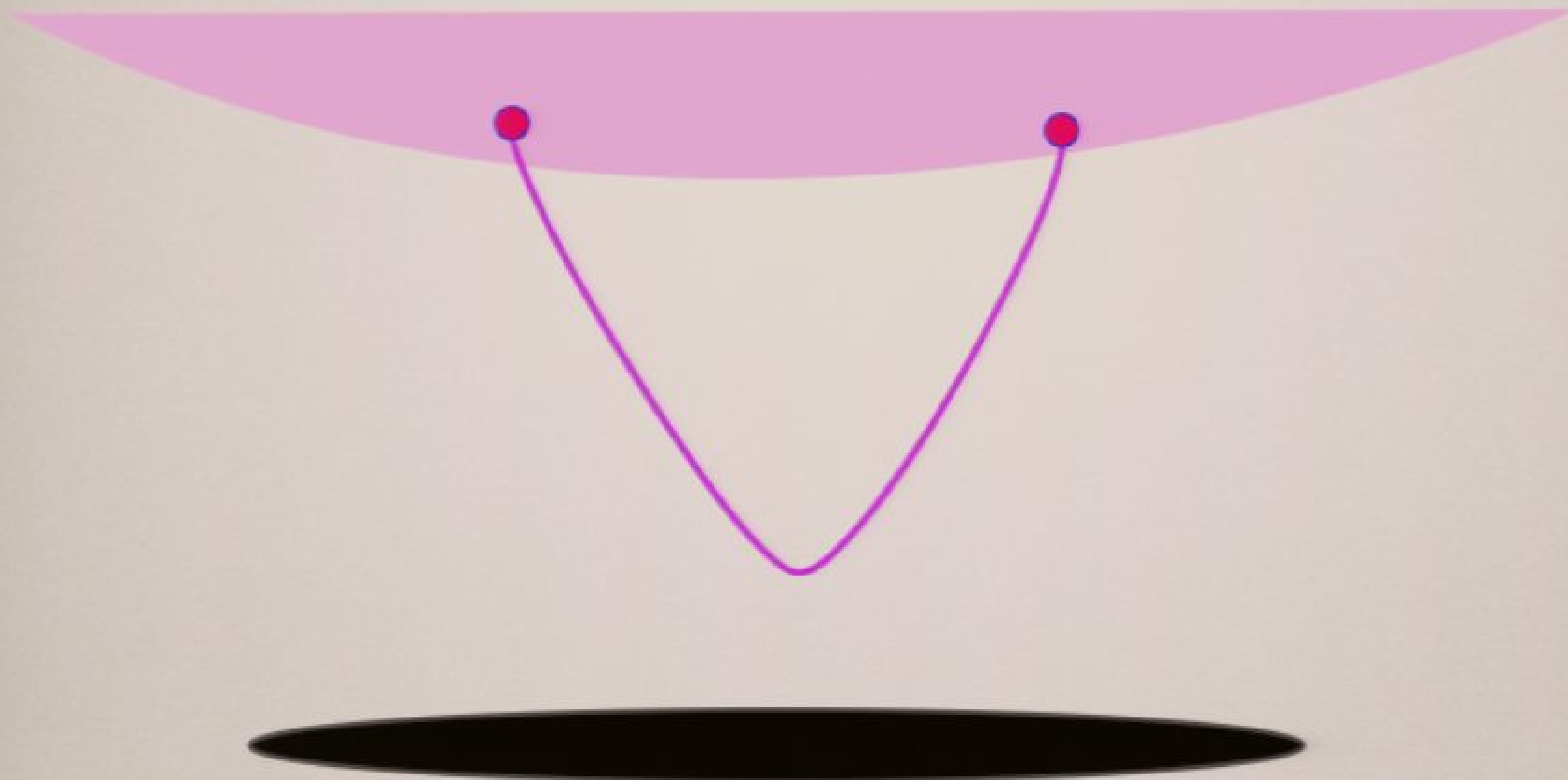

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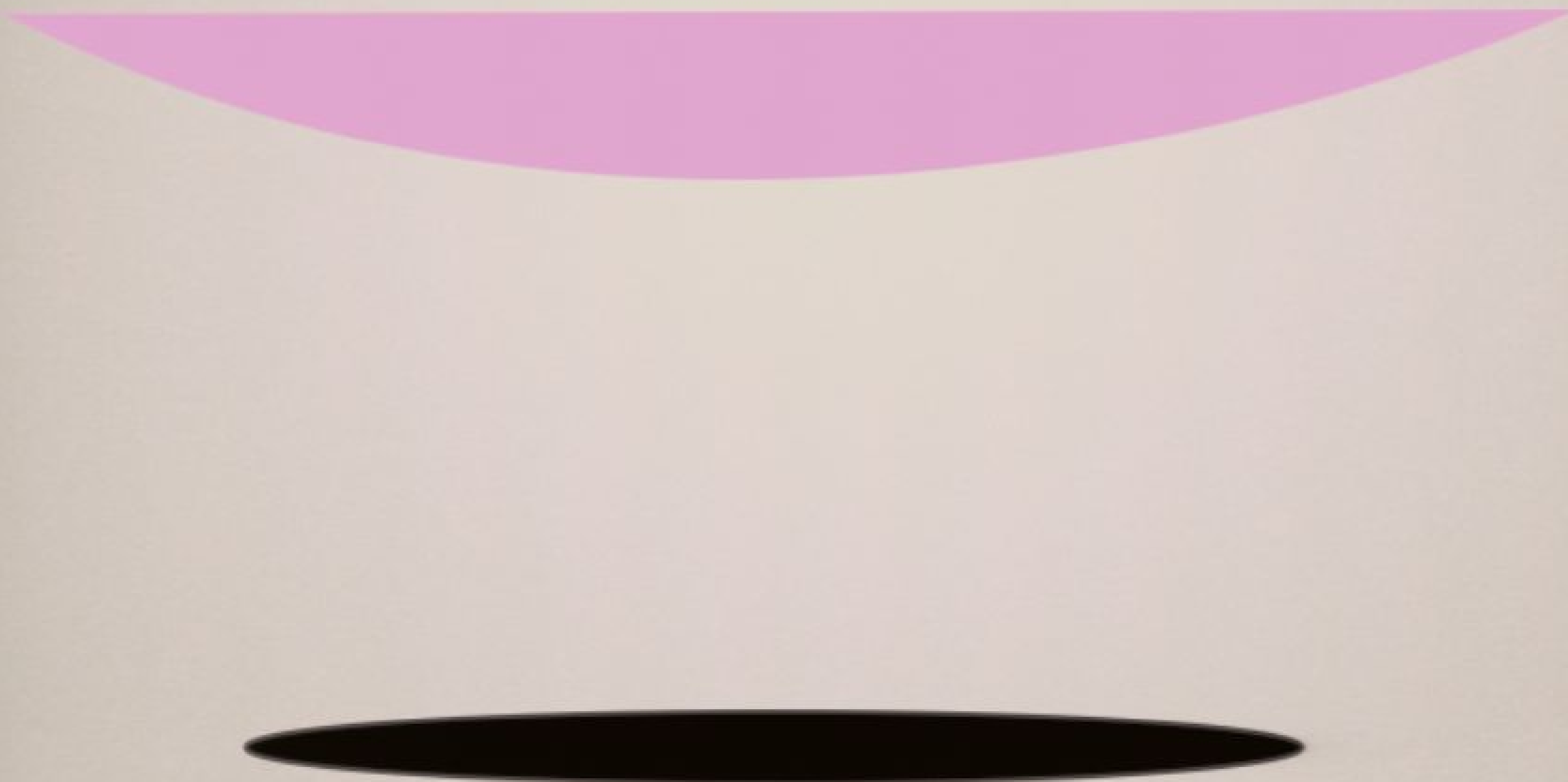

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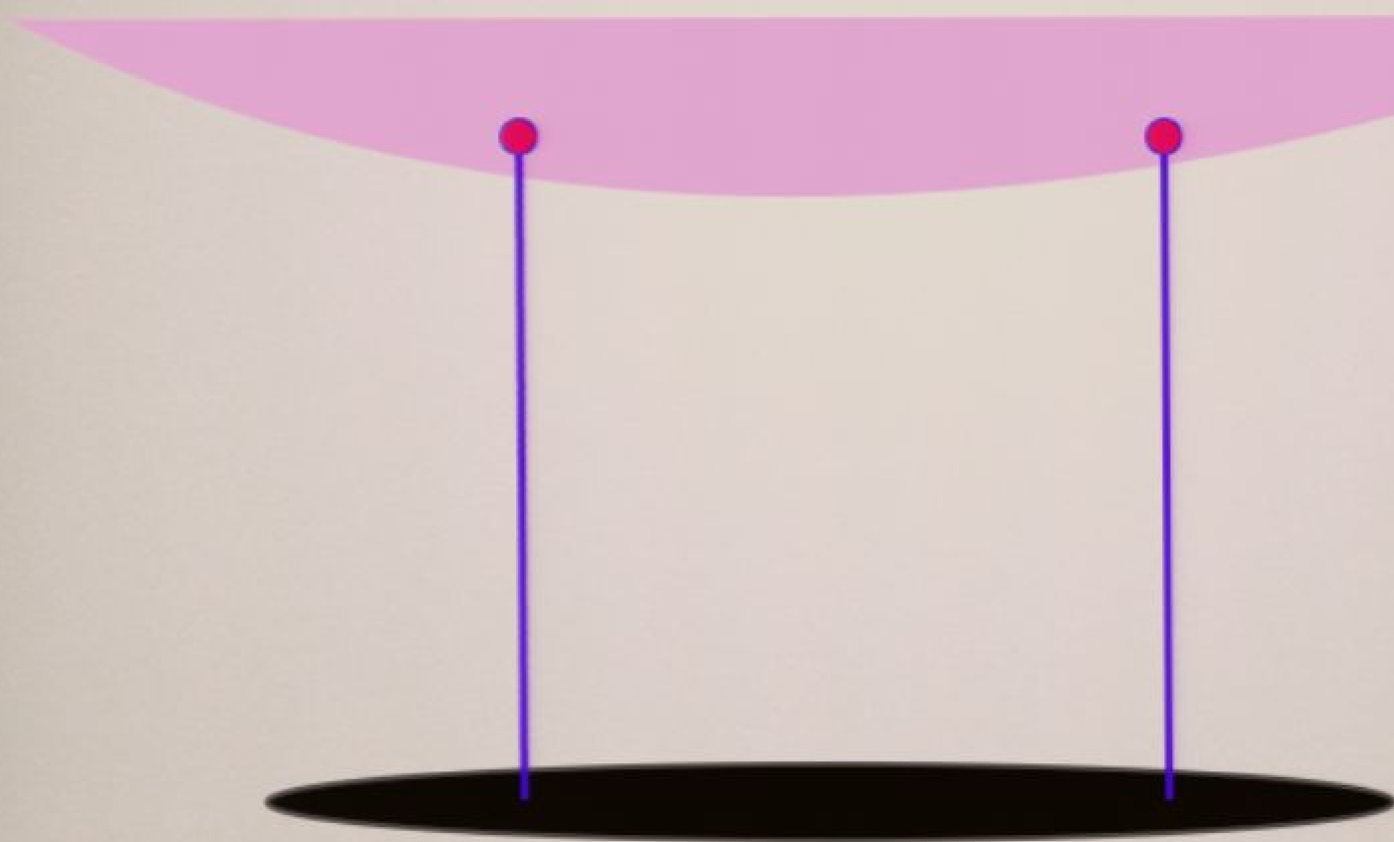

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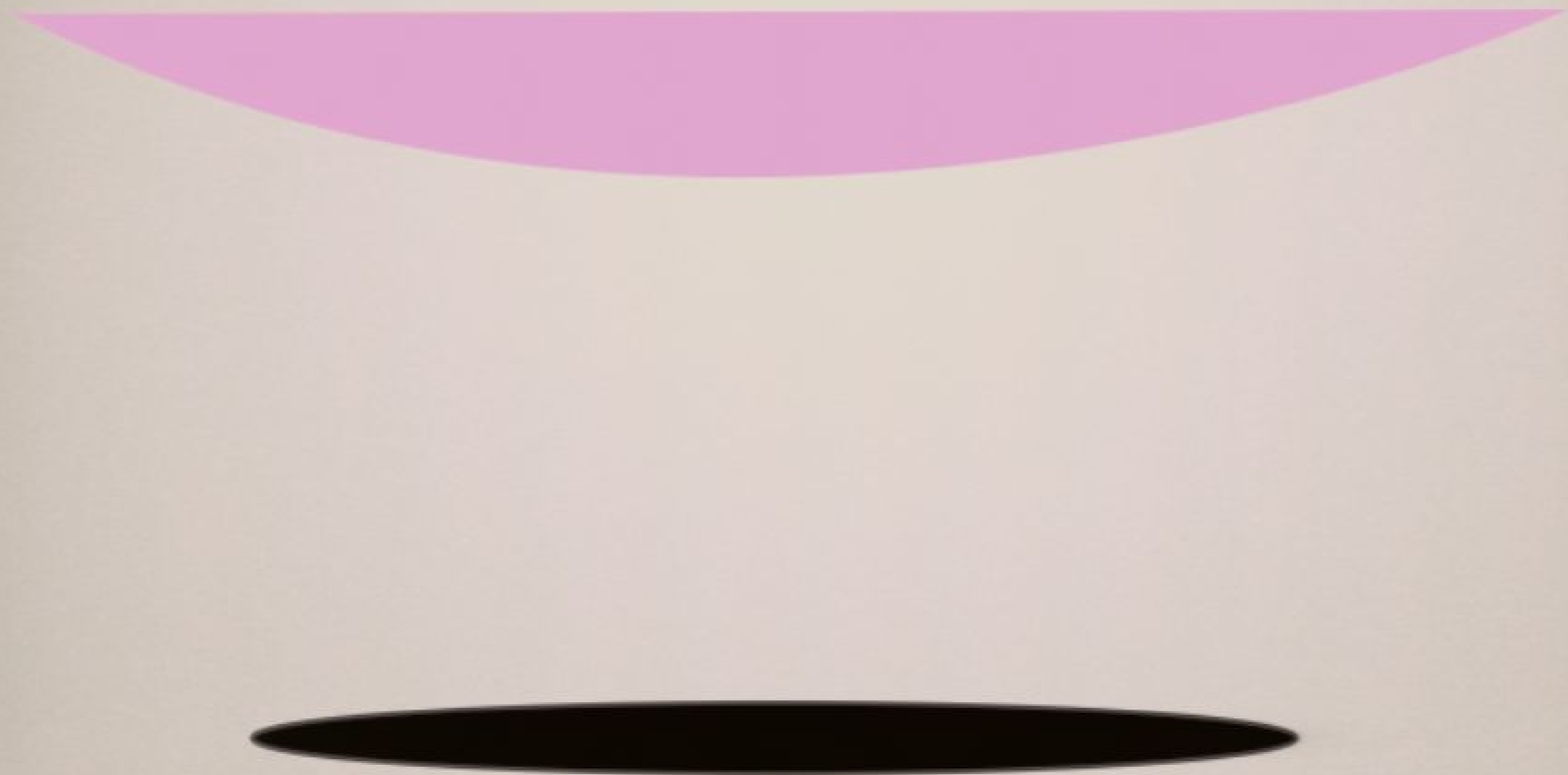

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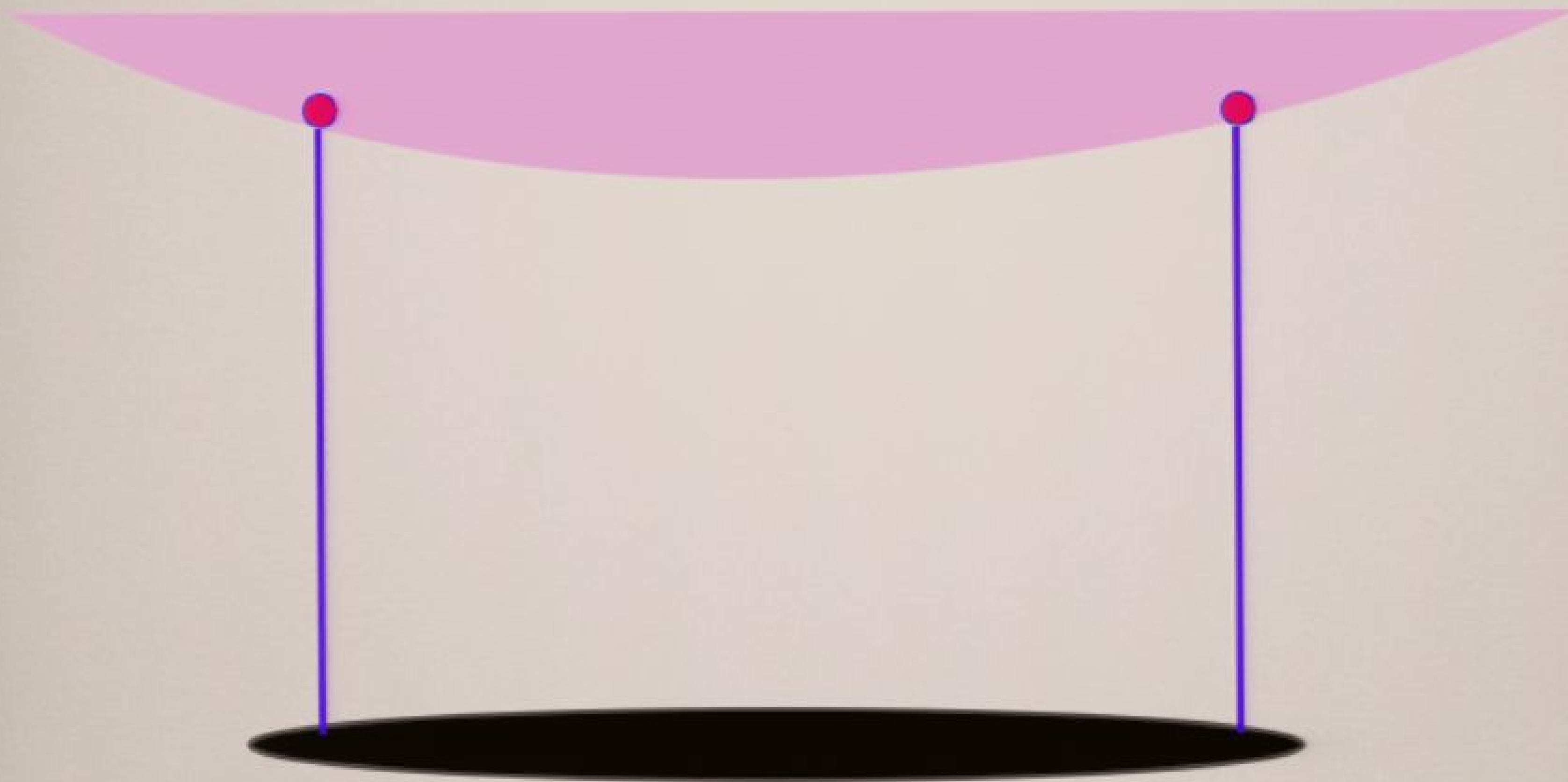

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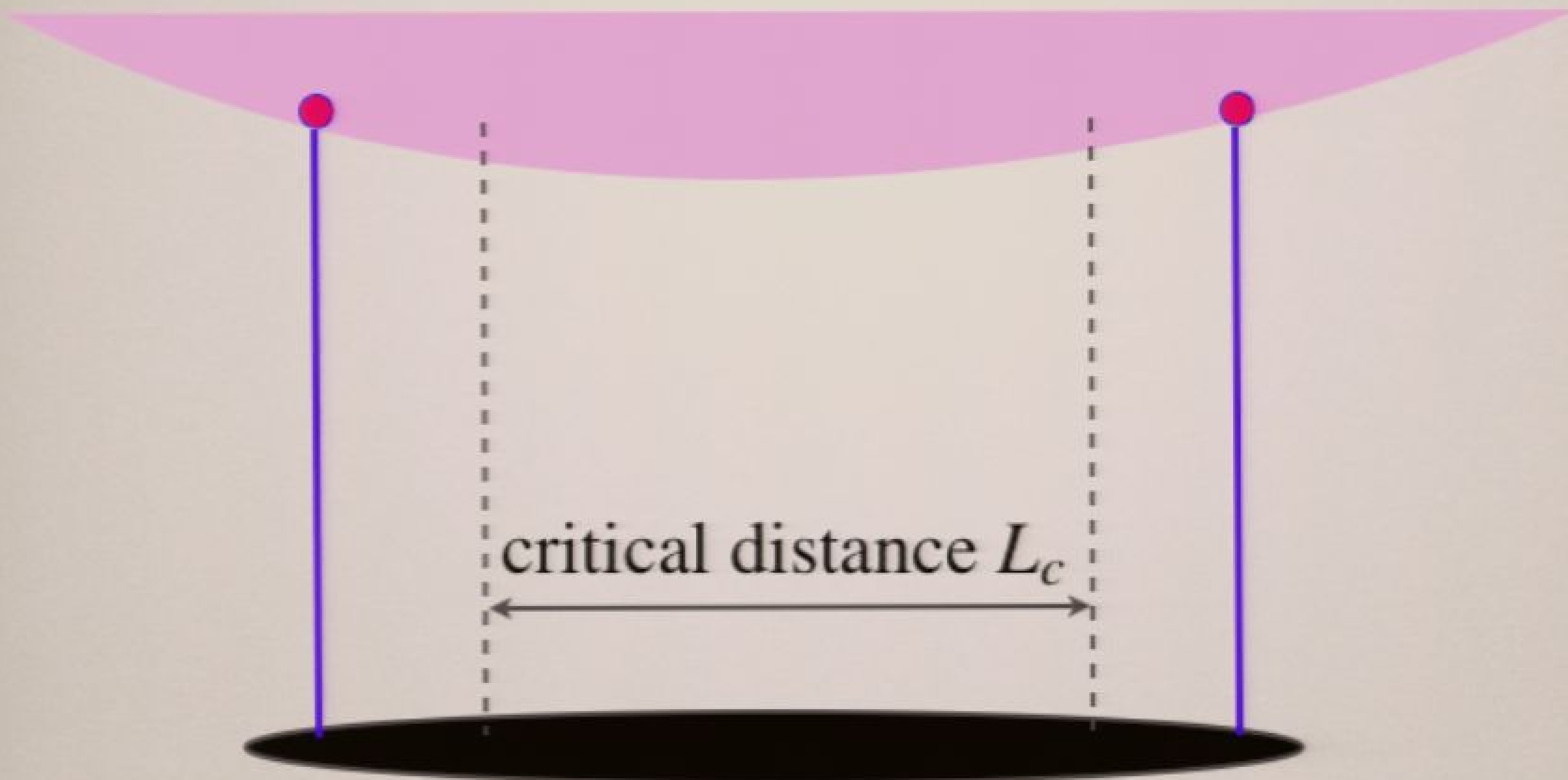

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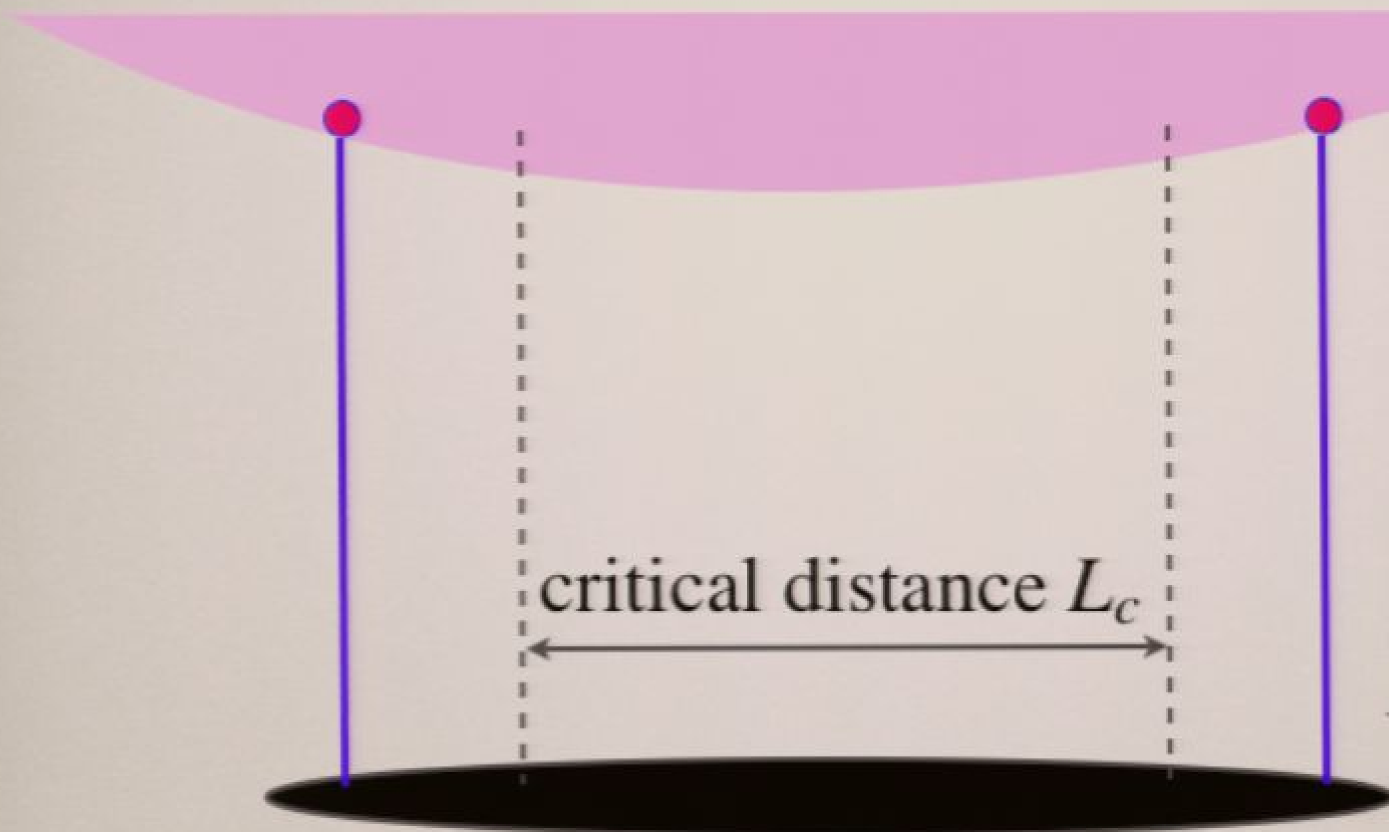

$$L_c \approx \frac{0.4}{T}$$

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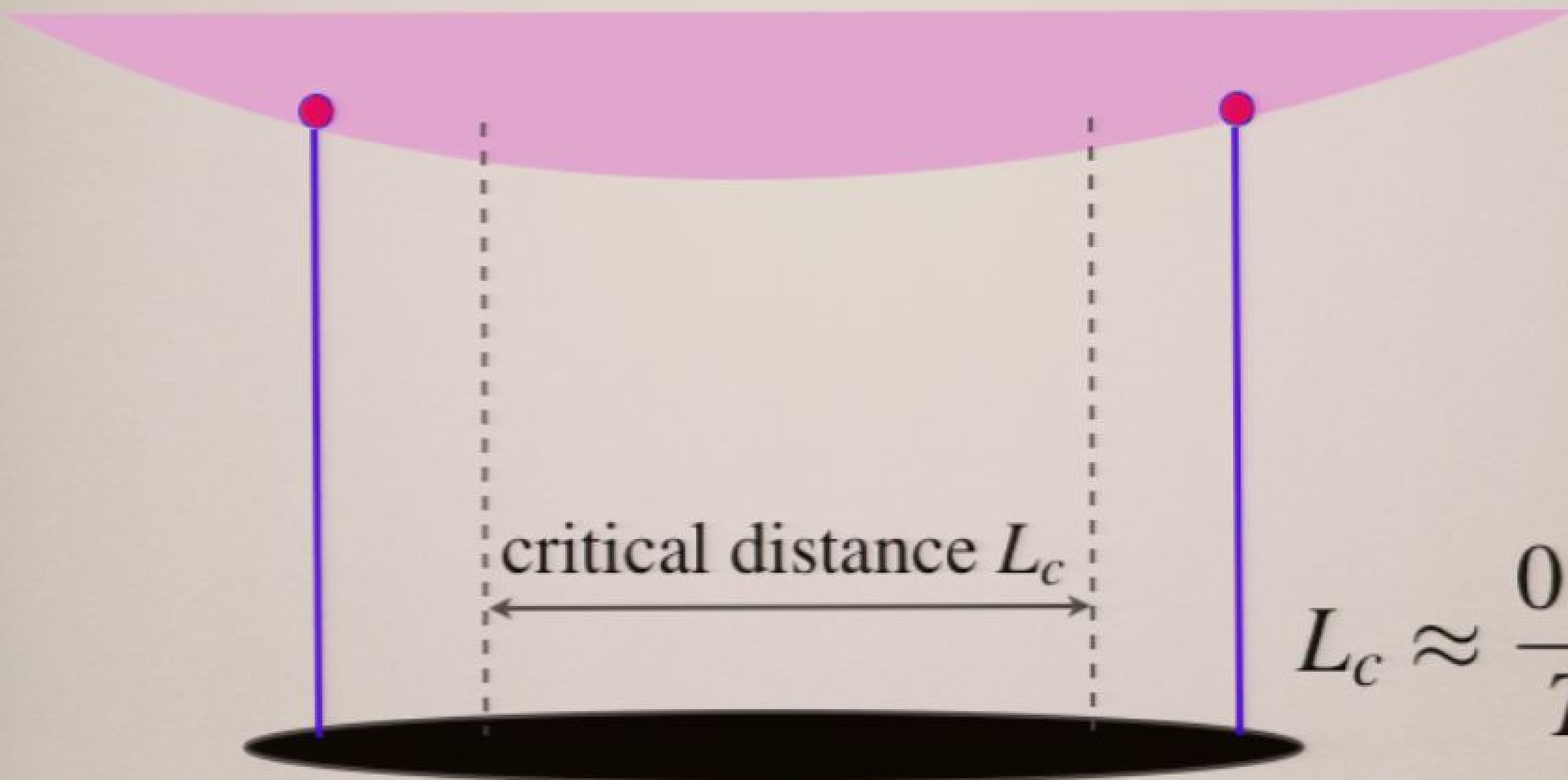

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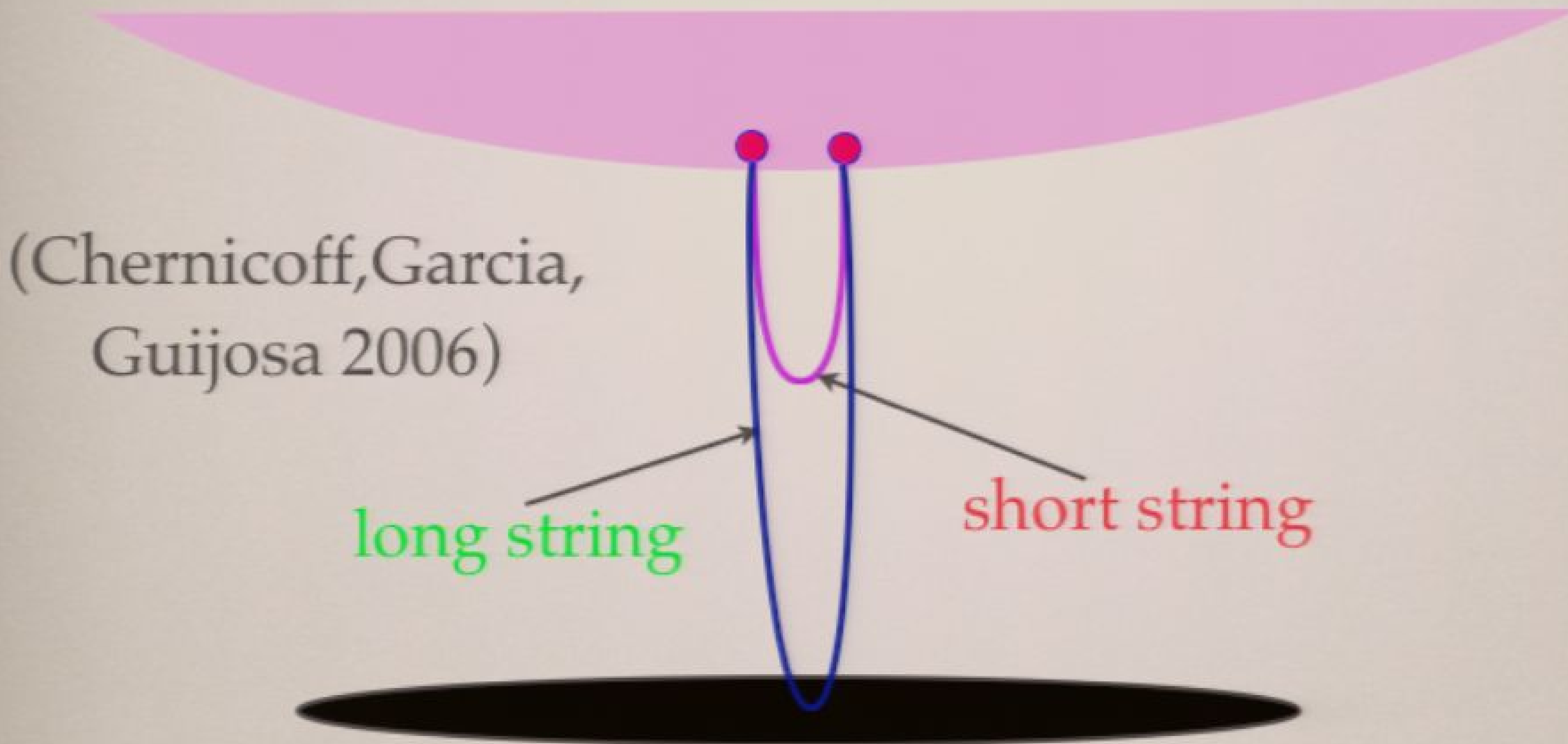
screening length is $g(g_{YM}^2 N, T)\, L_c$

Two strings for a given $L < L_c$



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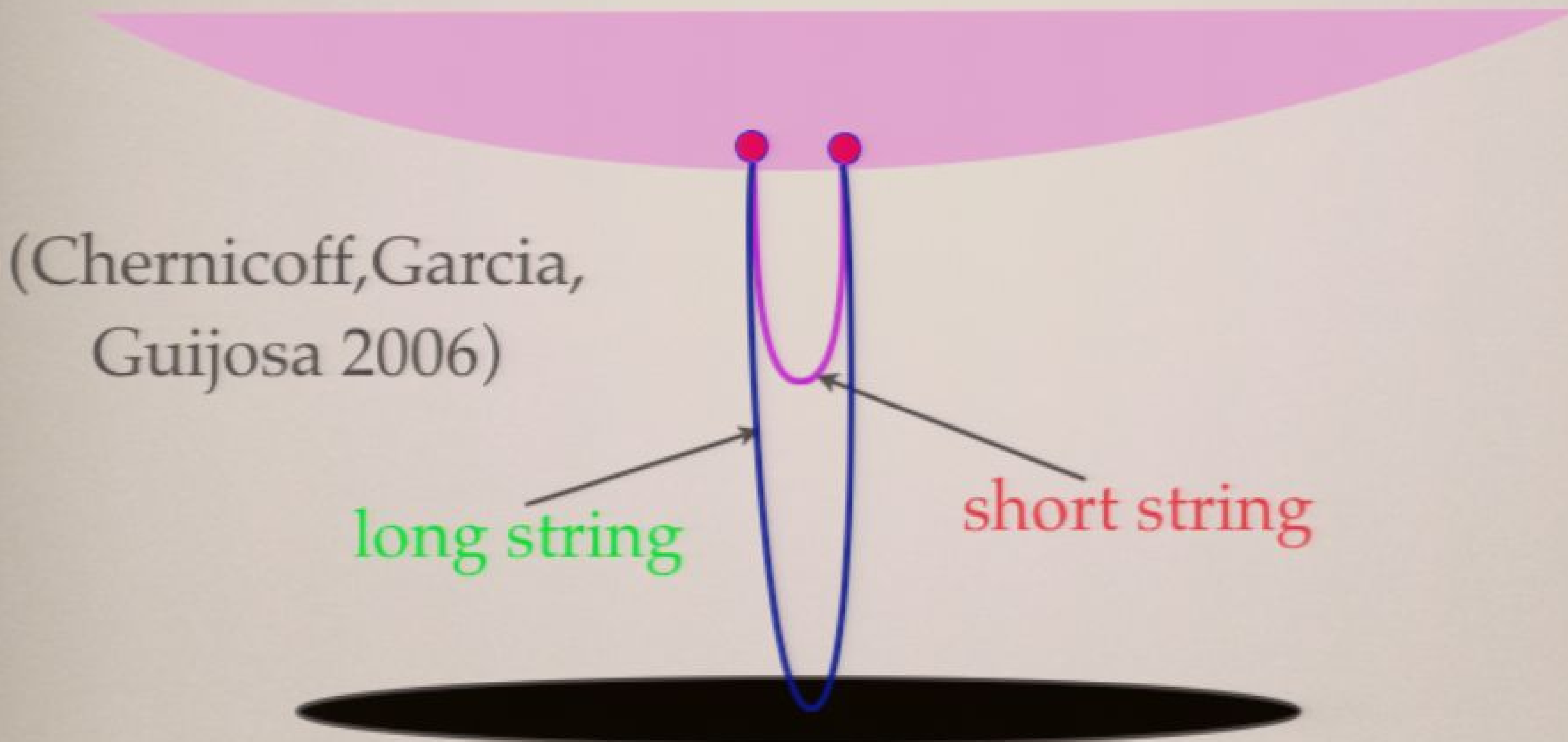

Long string is unstable and decays into short string

(Argyres,Edalati,V-P;
Friess,Gubser,Michalogiorgakis,Pufu 2006)

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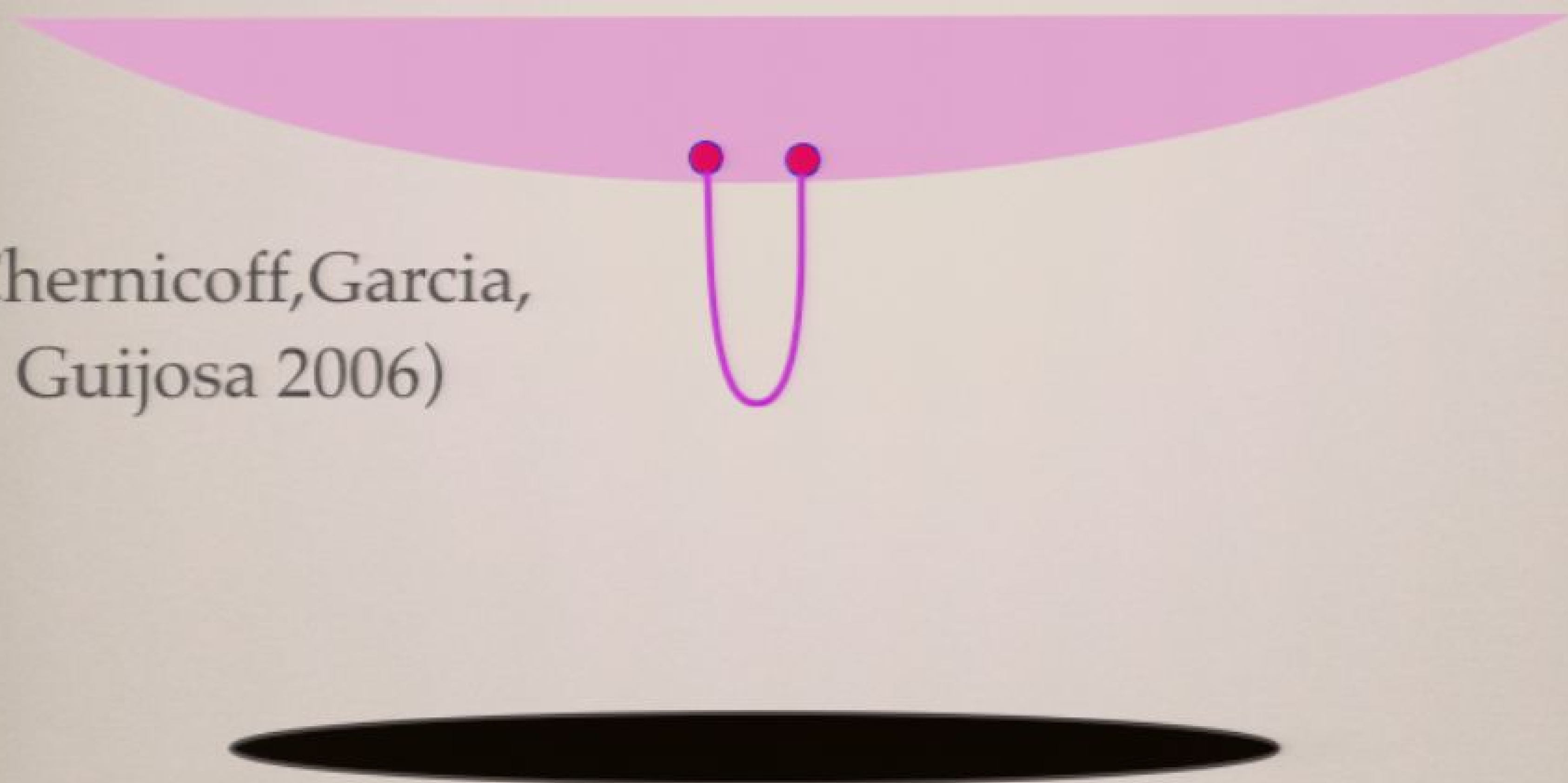

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Steadily moving string

Embedding: $t=\tau,\ x=v\tau,\ y=\sigma,\ z=0,\ r=r(\sigma)$

Boundary conditions: $r\left(\pm\frac{L}{2}\right)=r_7$

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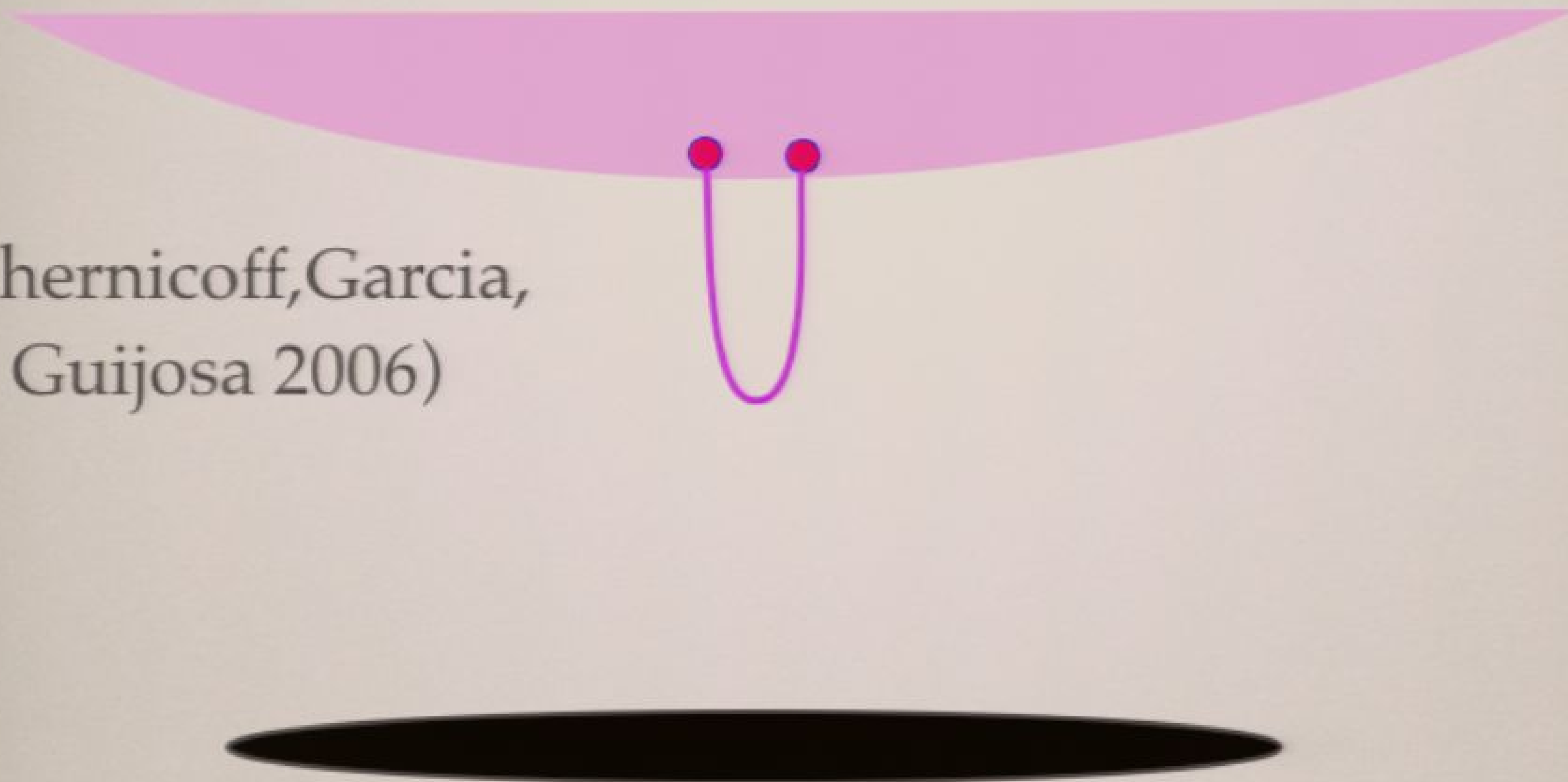

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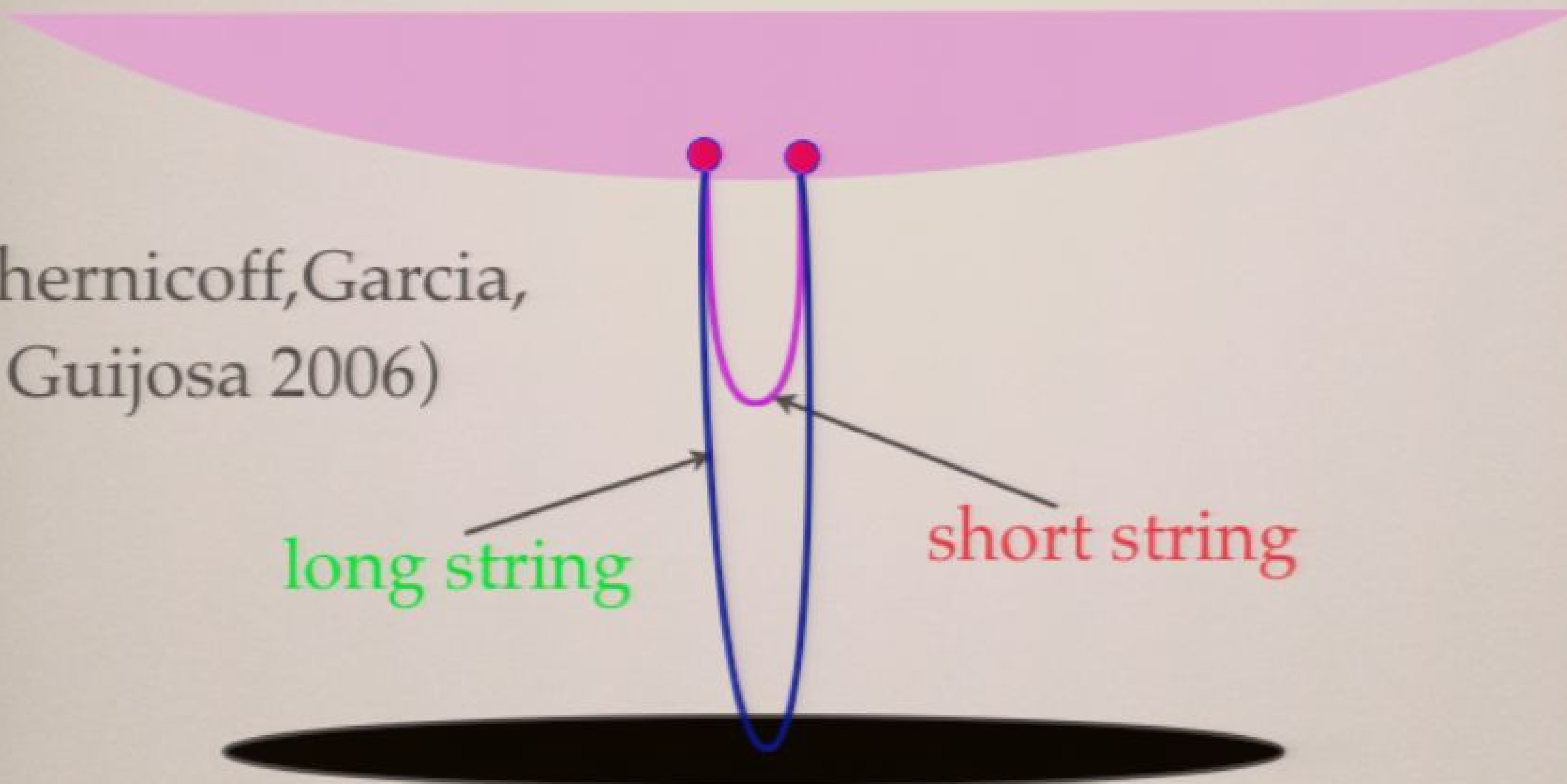

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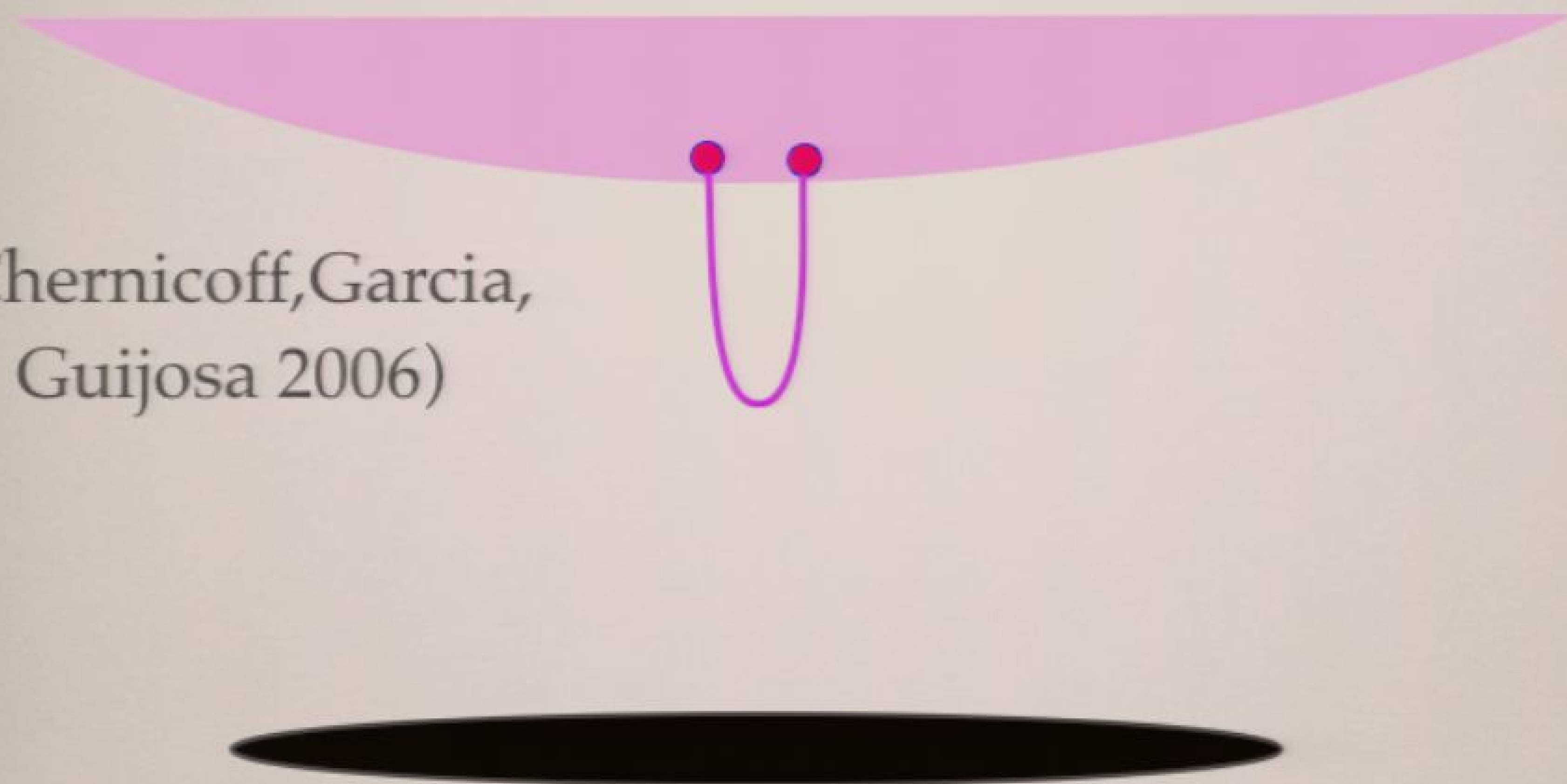

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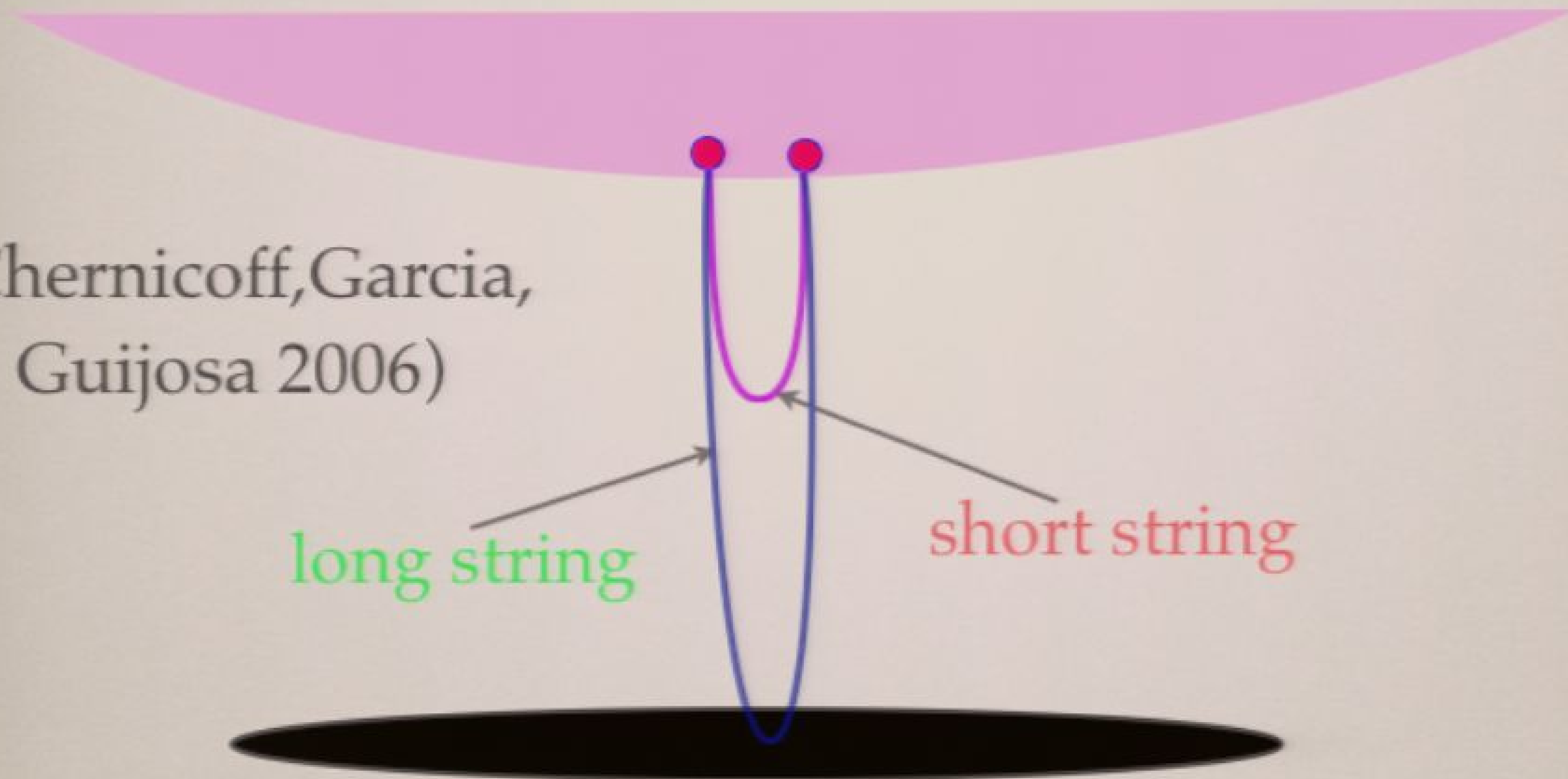

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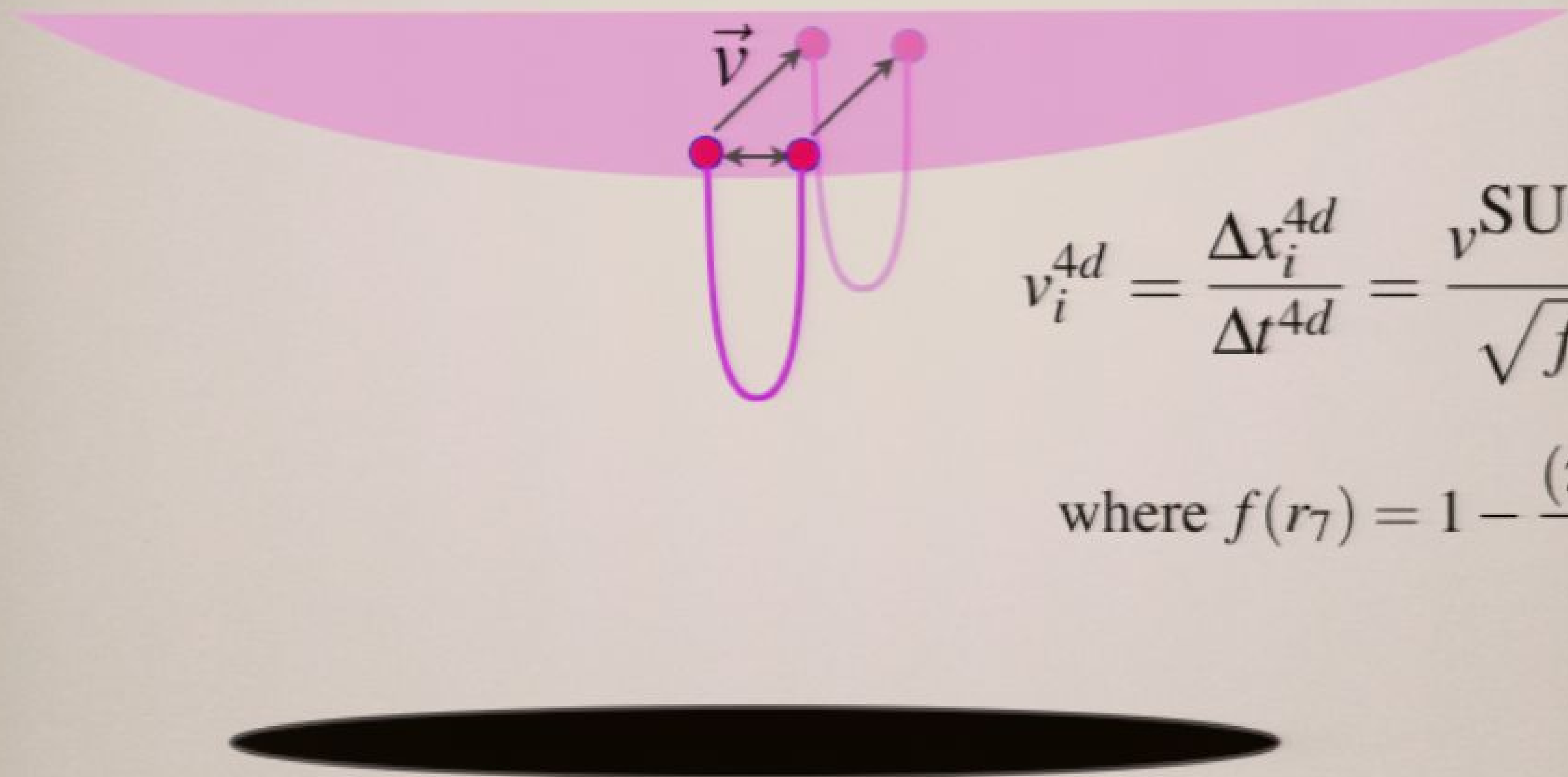
String never reaches event horizon

Steadily moving short string with $\vec{v}_\perp$



$$v_i^{4d} = \frac{\Delta x_i^{4d}}{\Delta t^{4d}} = \frac{v^{\text{SUGRA}}}{\sqrt{f(r_7)}}$$

where $f(r_7) = 1 - \dfrac{(\pi R^2 T)^4}{r_7^4}$

(Argyres, Edalati, V-P)

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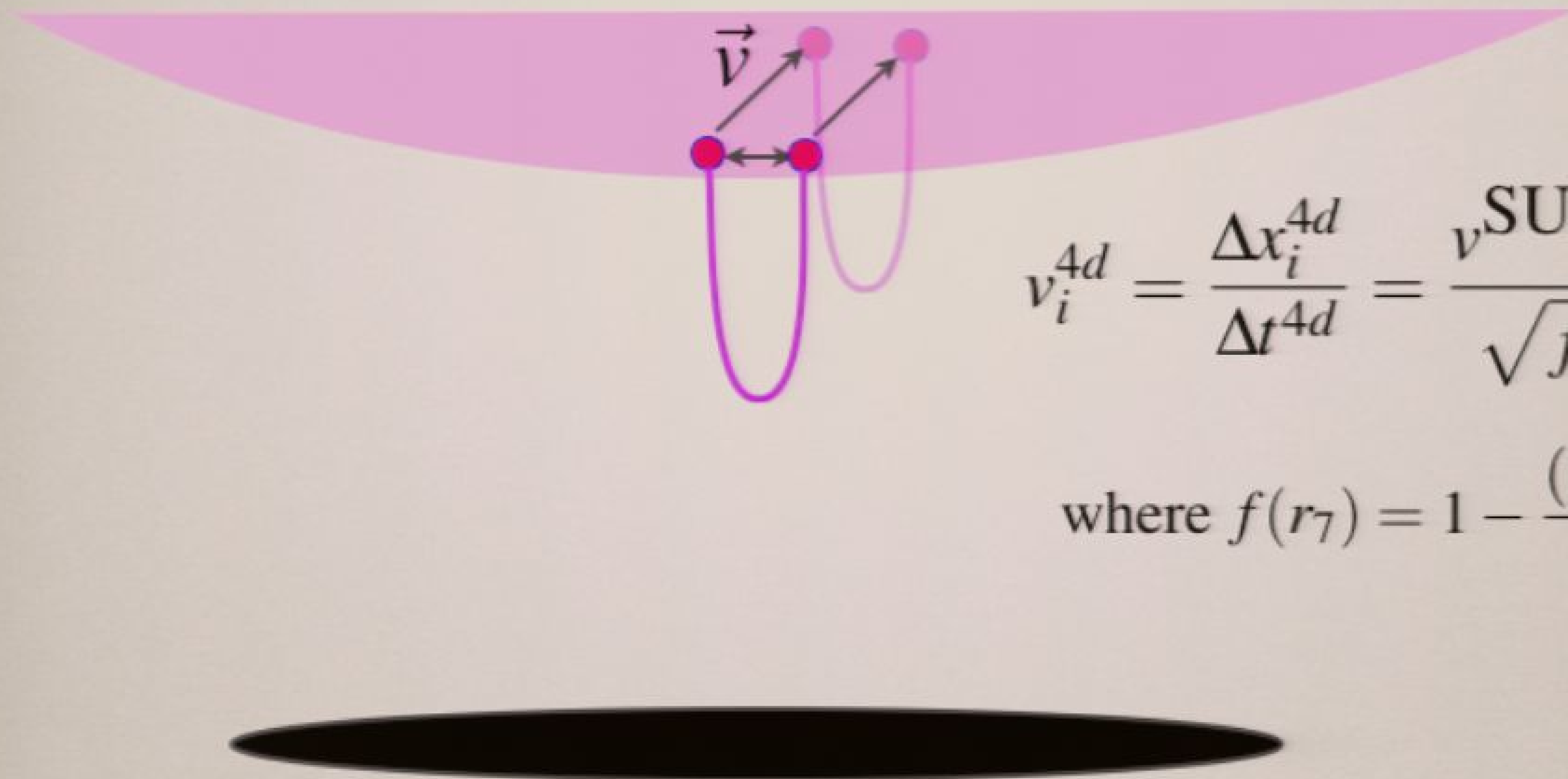

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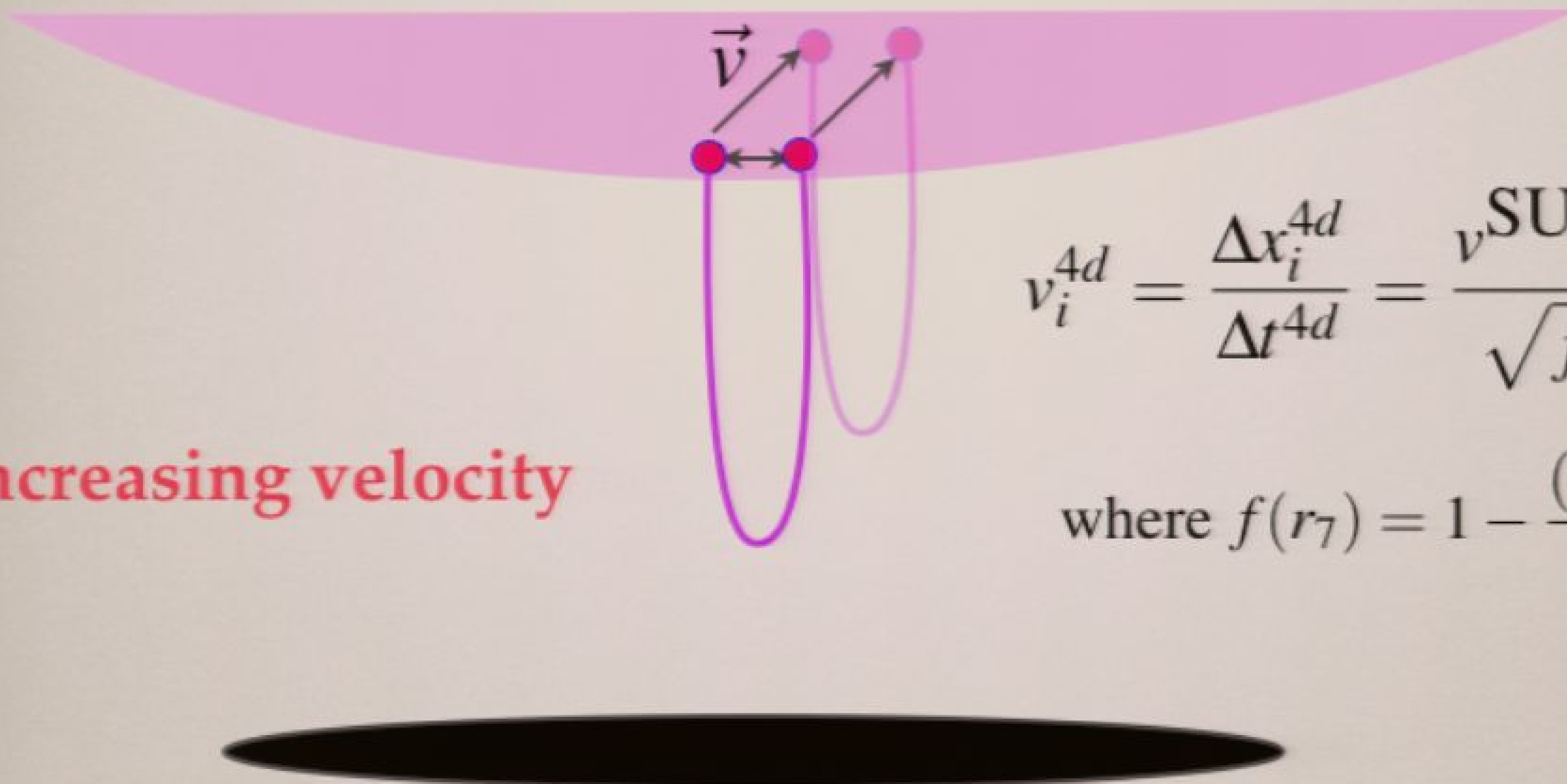

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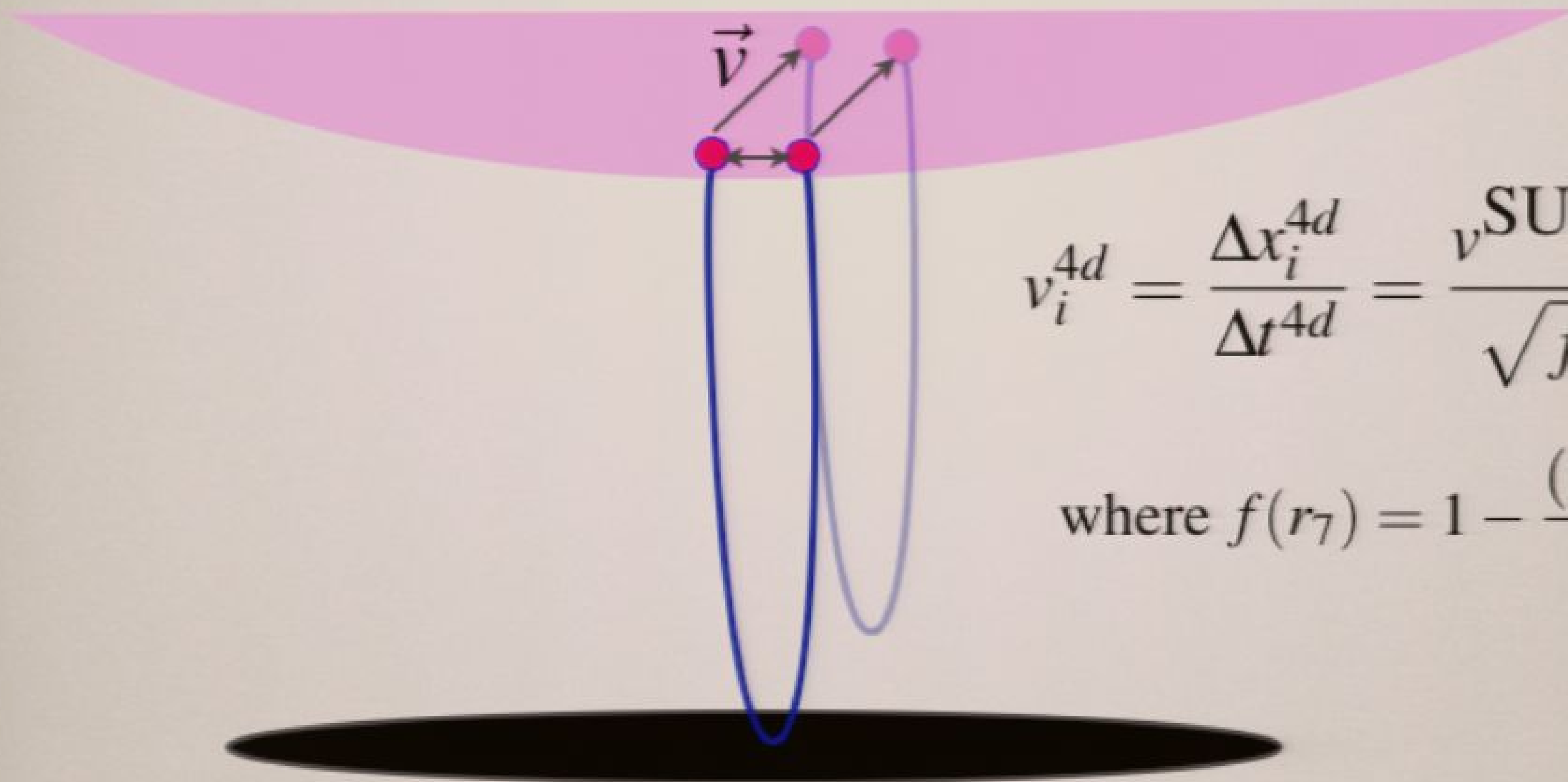

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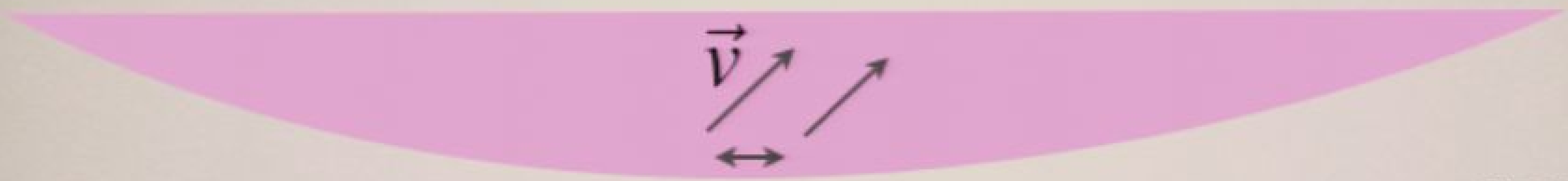

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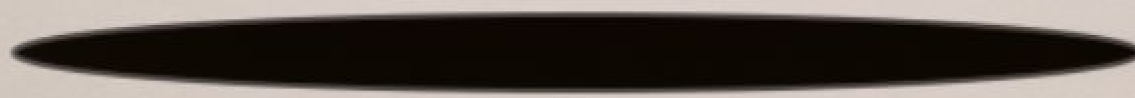

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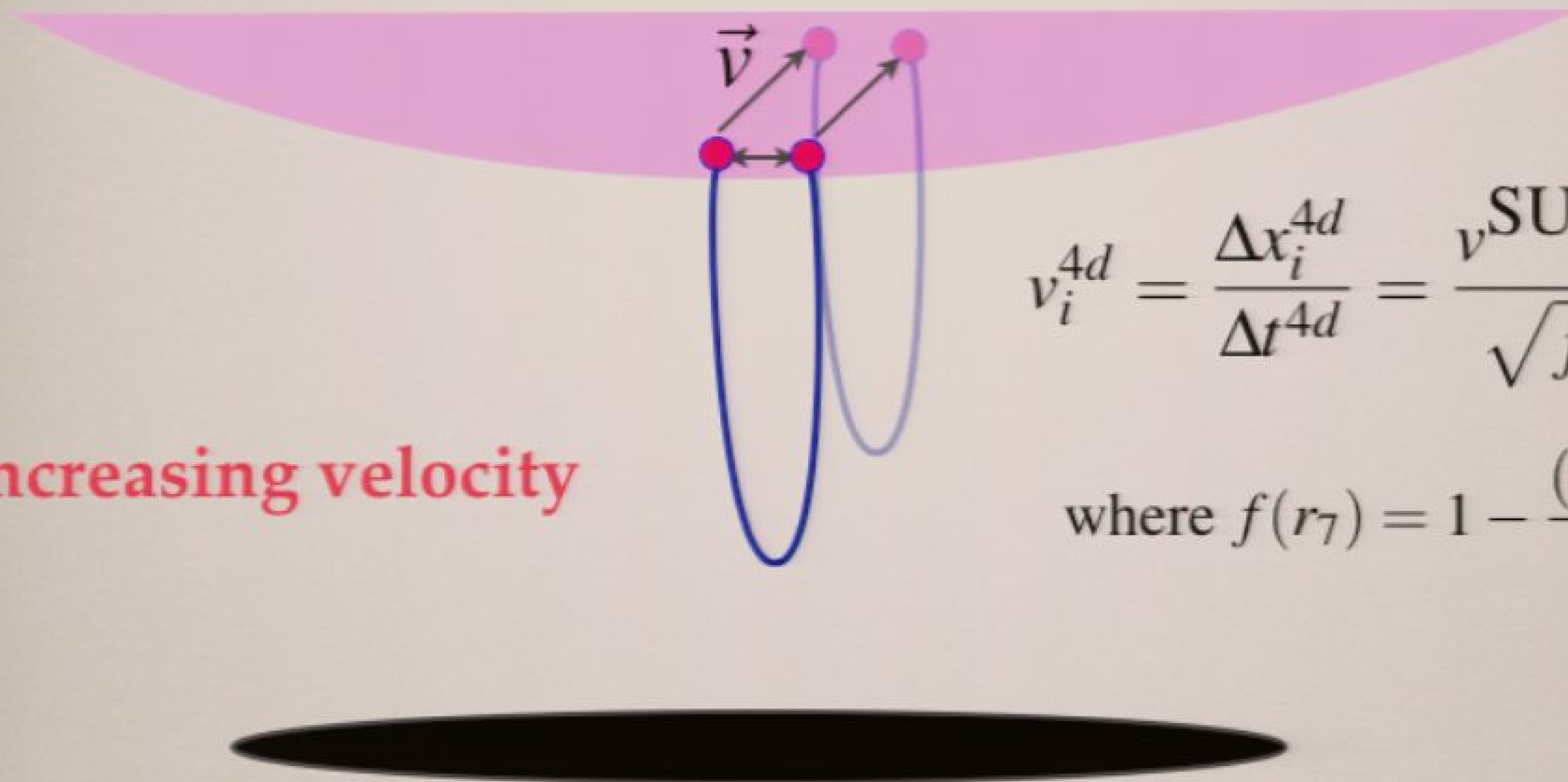

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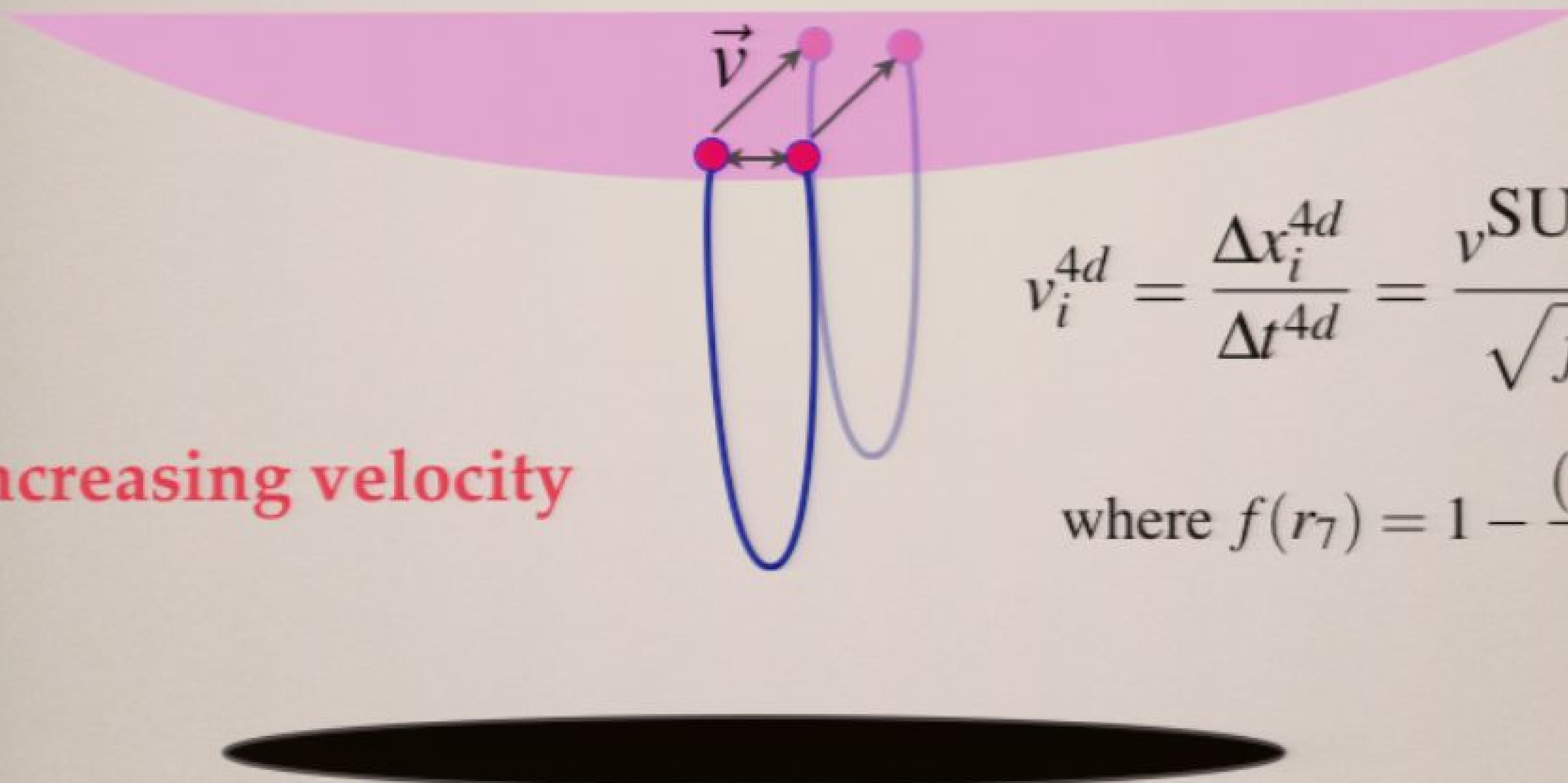
Increasing velocity

$$\text{where } f(r_7) = 1 - \frac{(\pi R^2 T)^4}{r_7^4}$$

Steadily moving strings with $\vec{v}_\perp$



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As in the static case, the long string is unstable

(Argyres, Edalati, V-P; Friess, Gubser, Michalogiorgakis, Pufu 2006)

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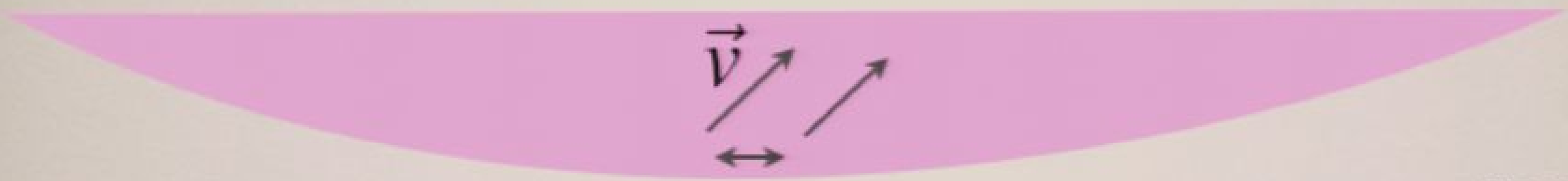

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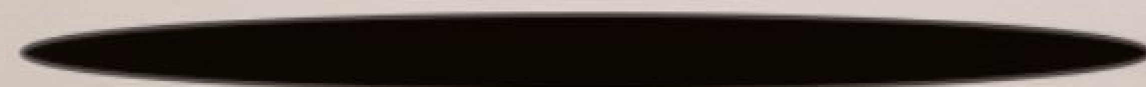

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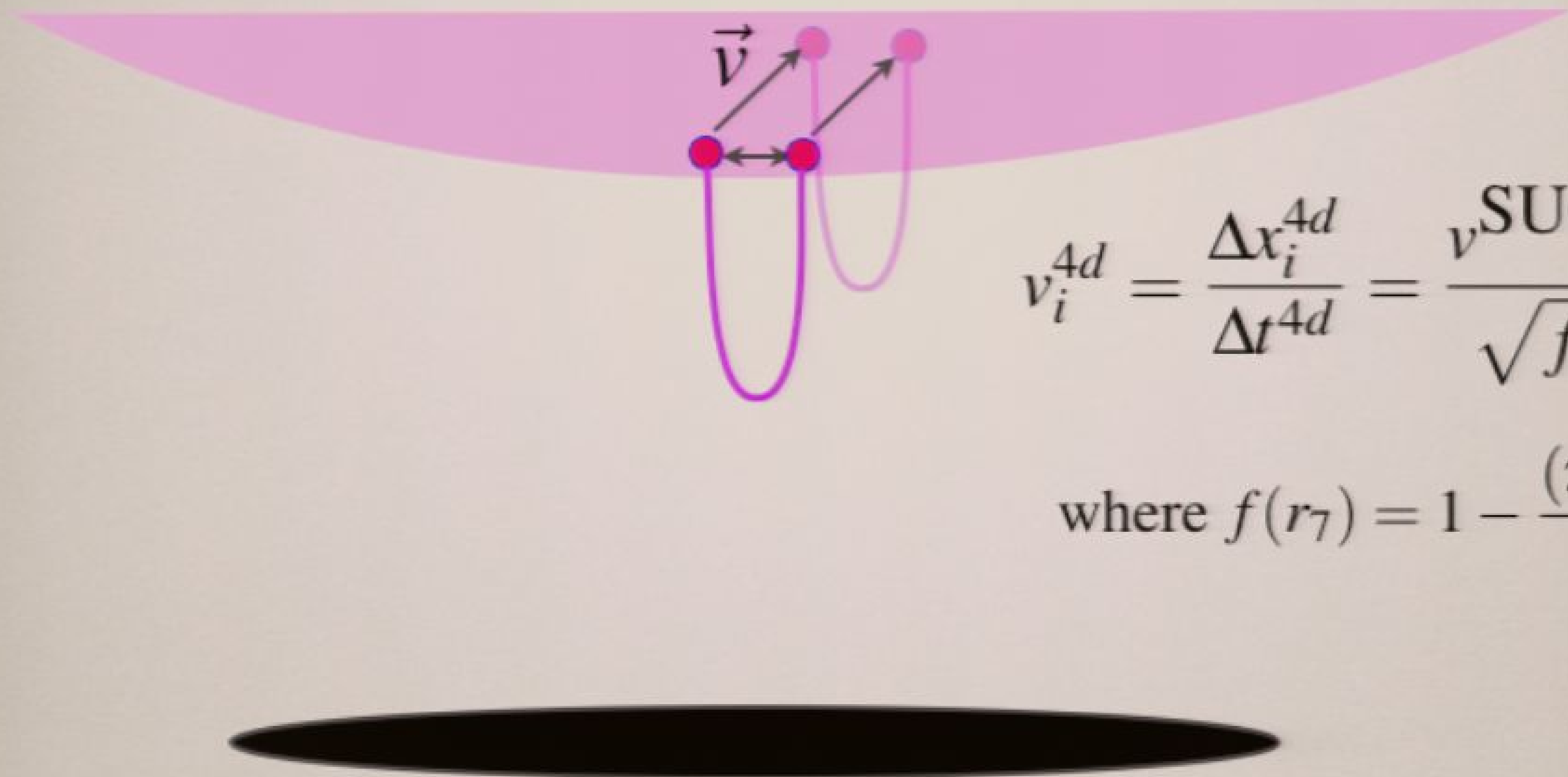

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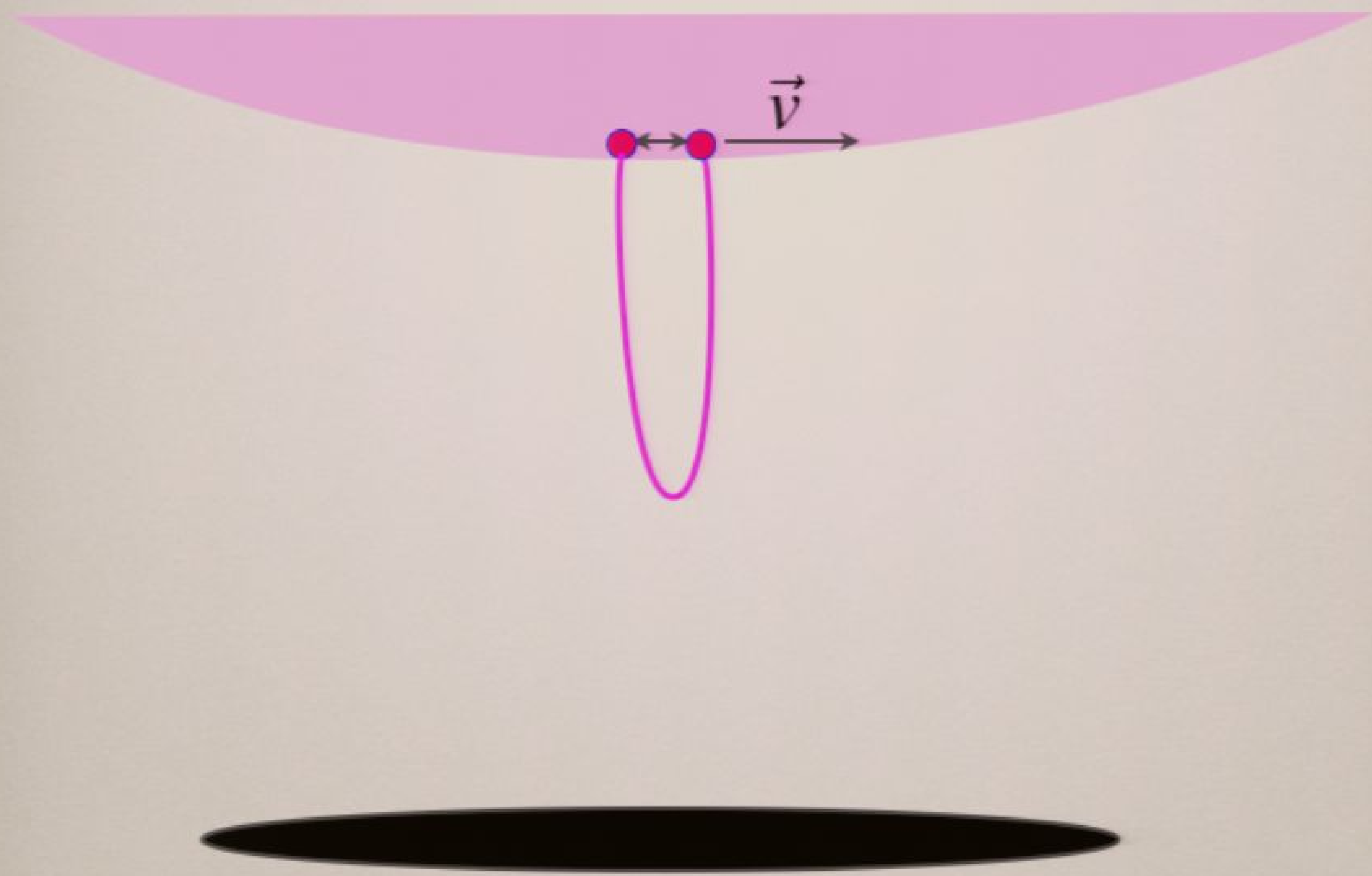

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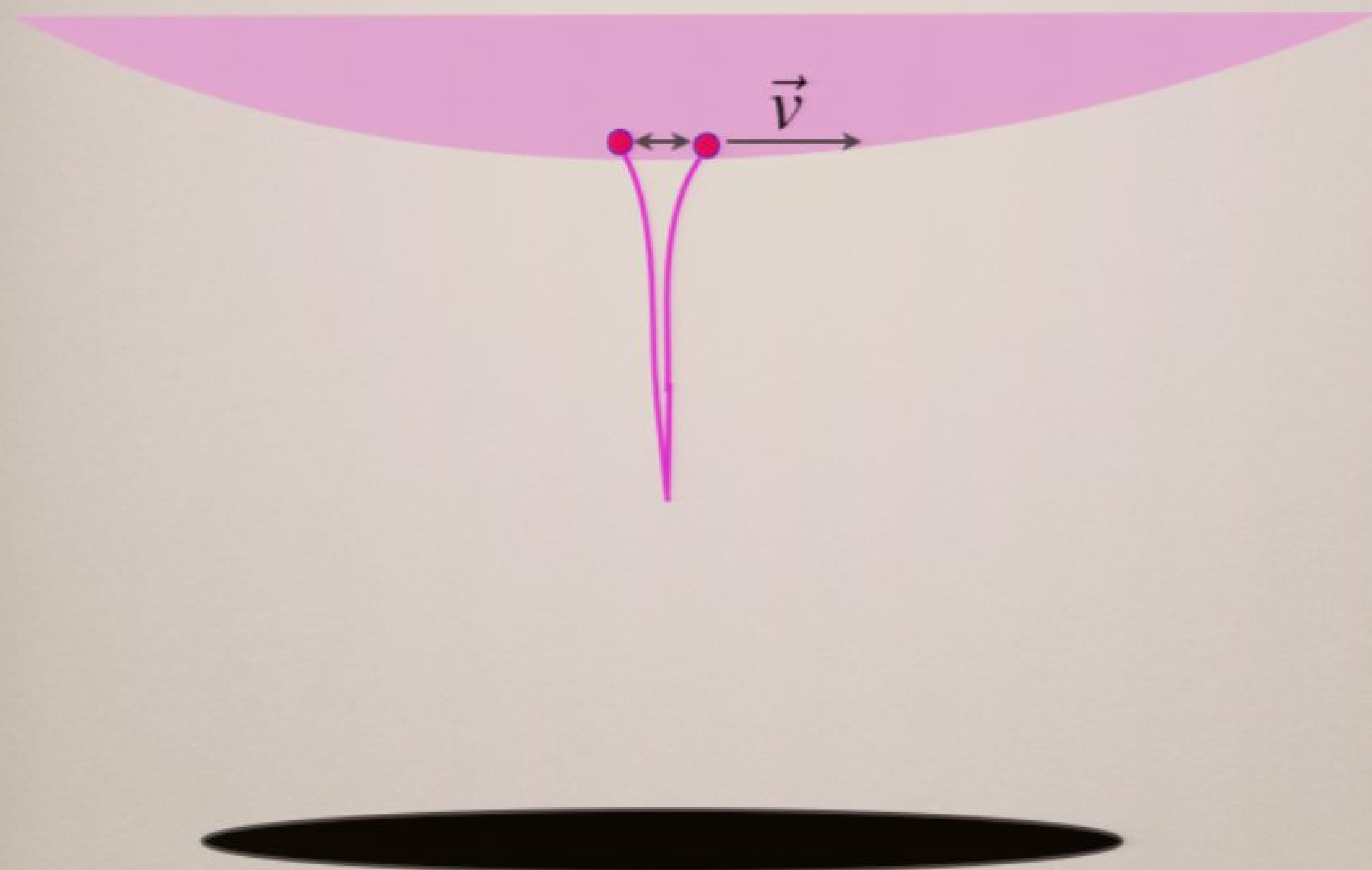

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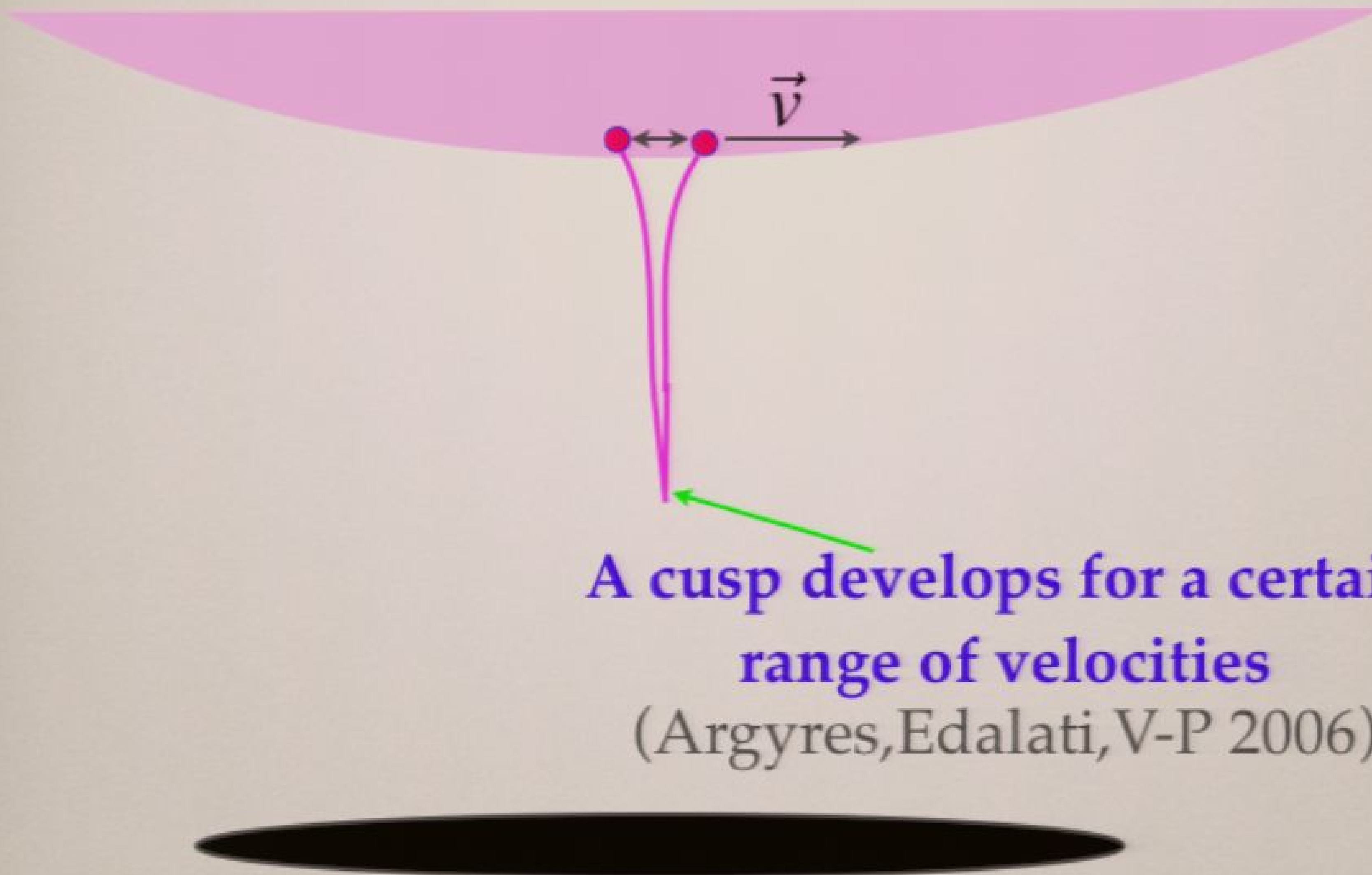

A cusp develops for a certain range of velocities

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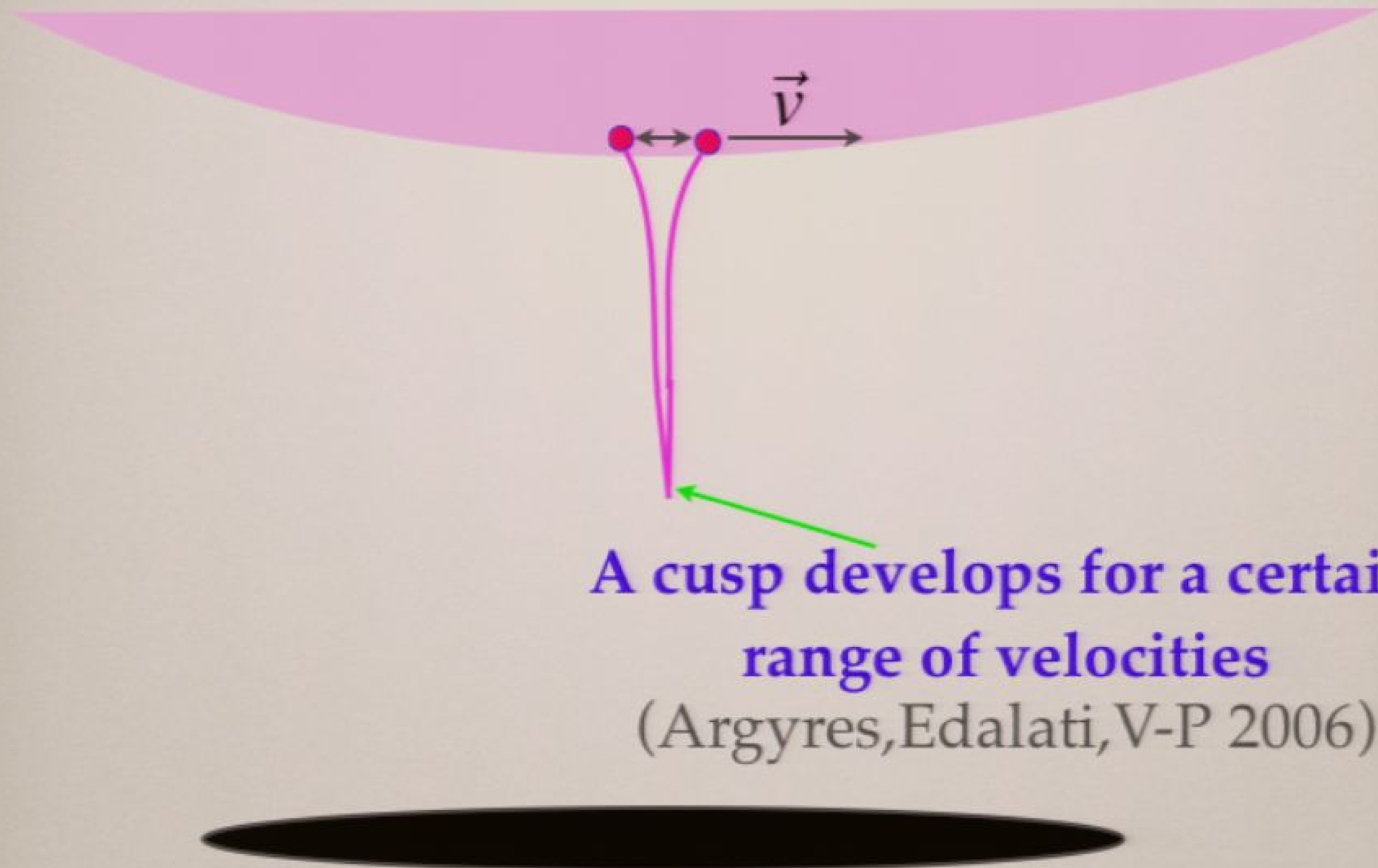

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Indicates breakdown in our description

Extracting the friction coefficient

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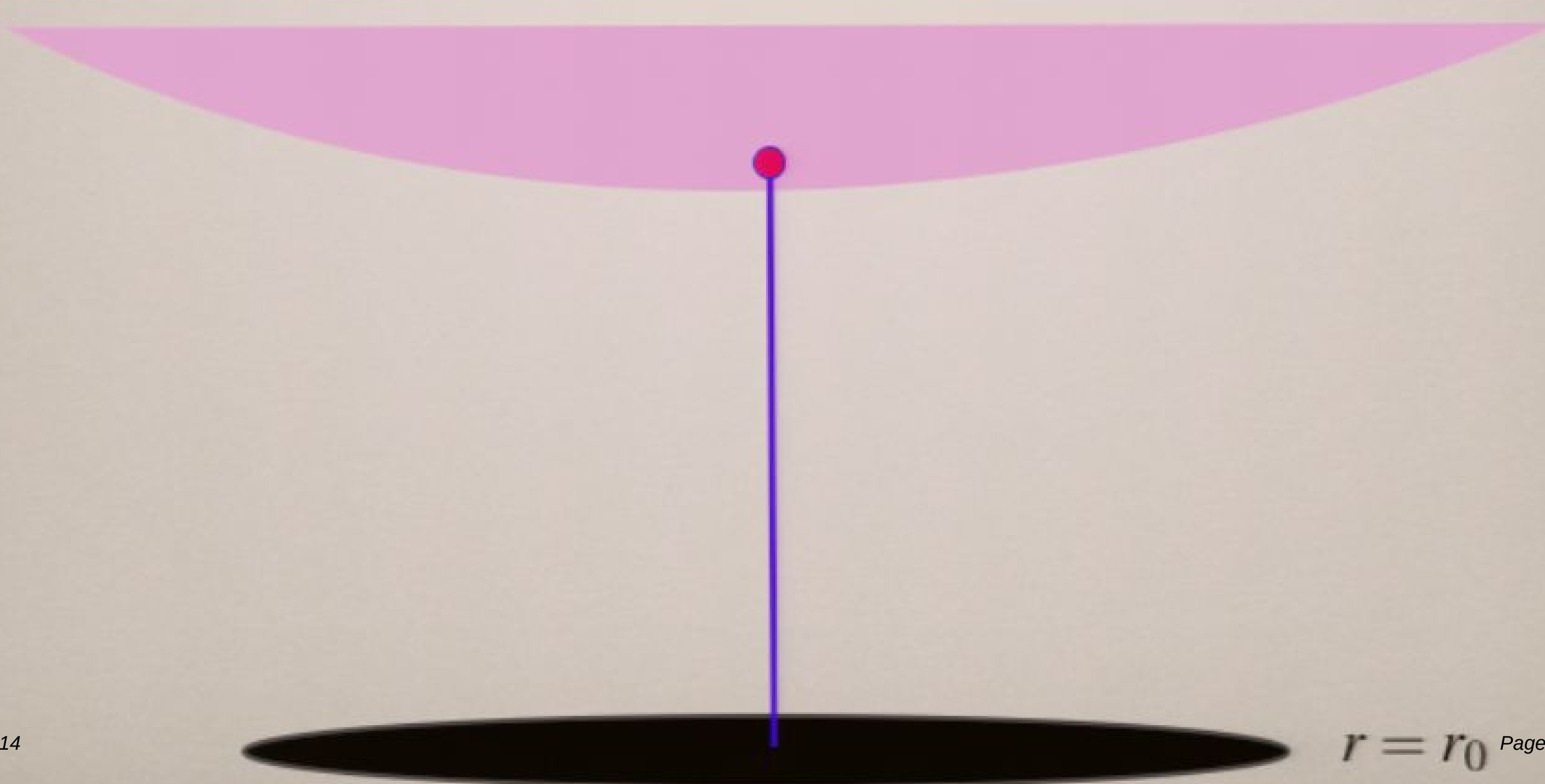

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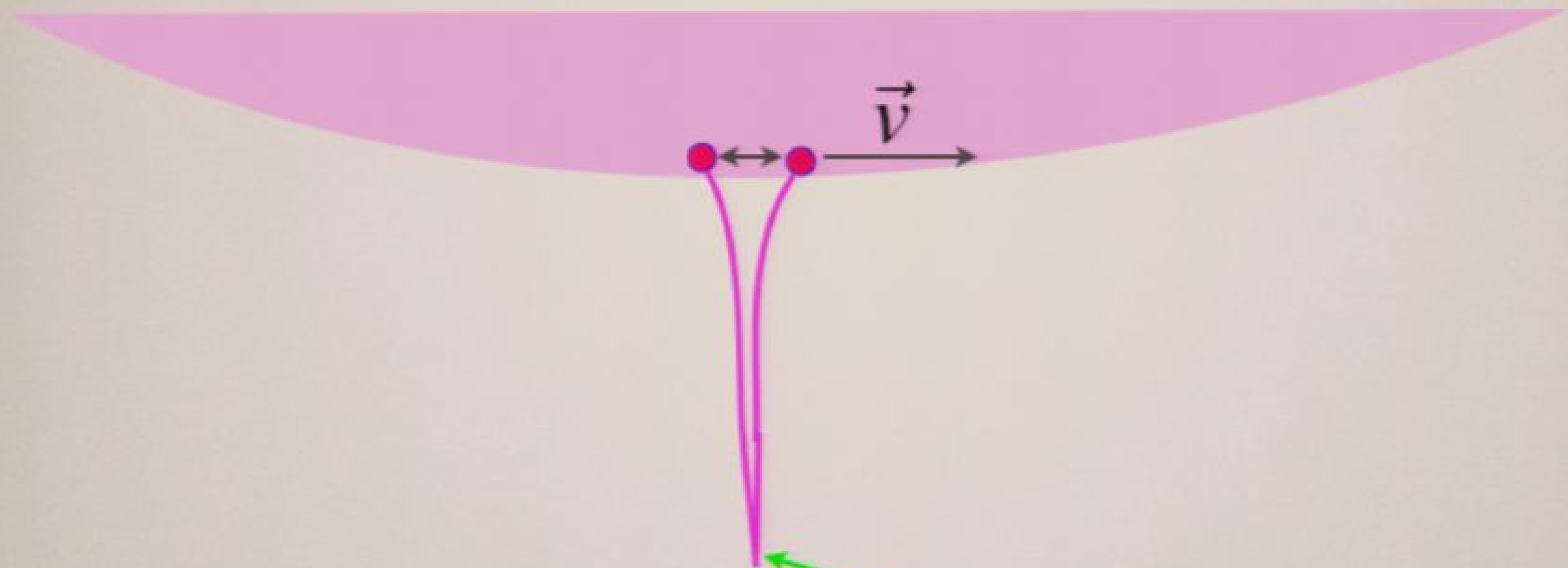

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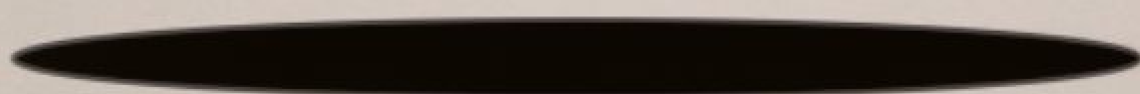

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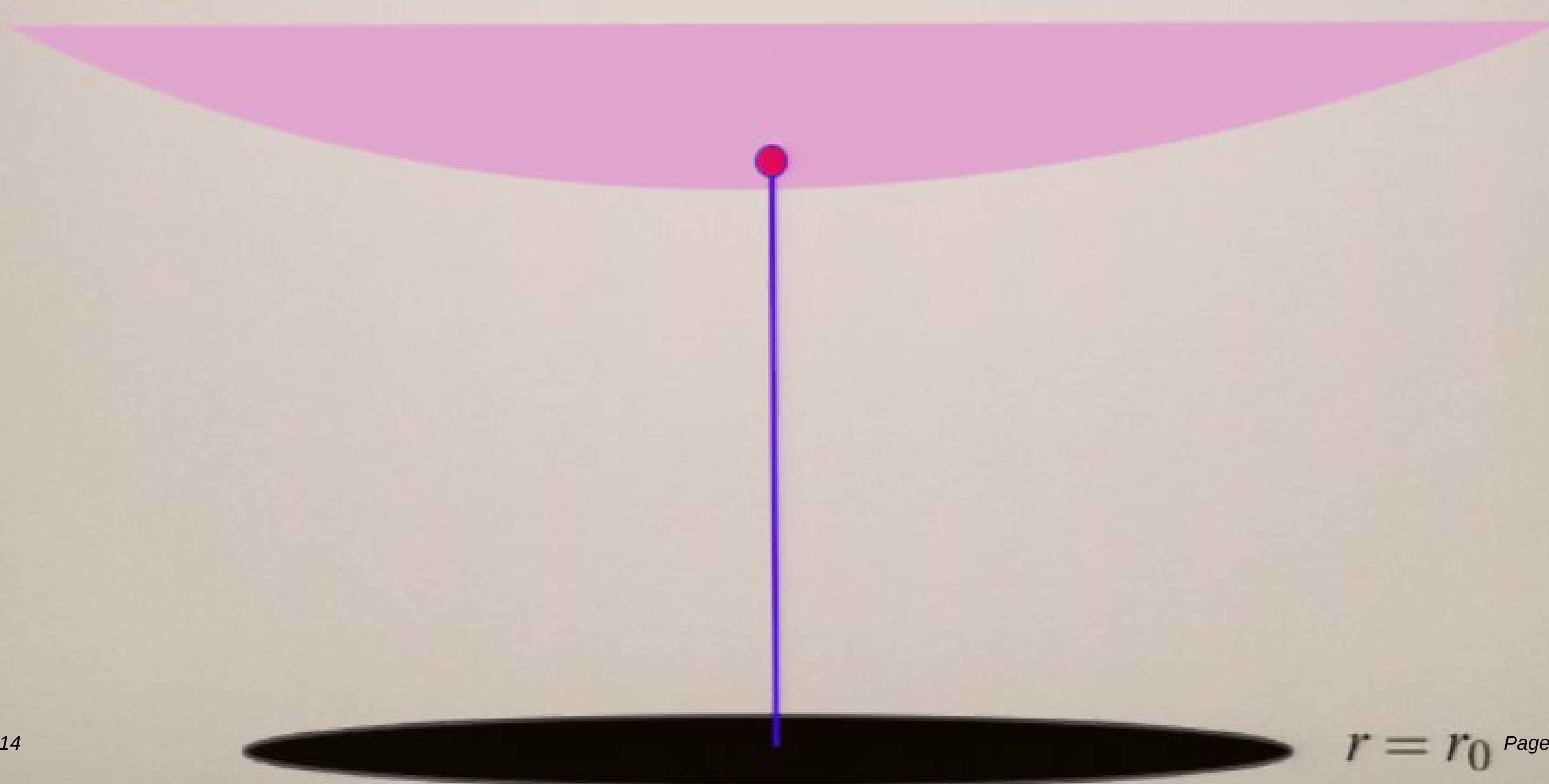

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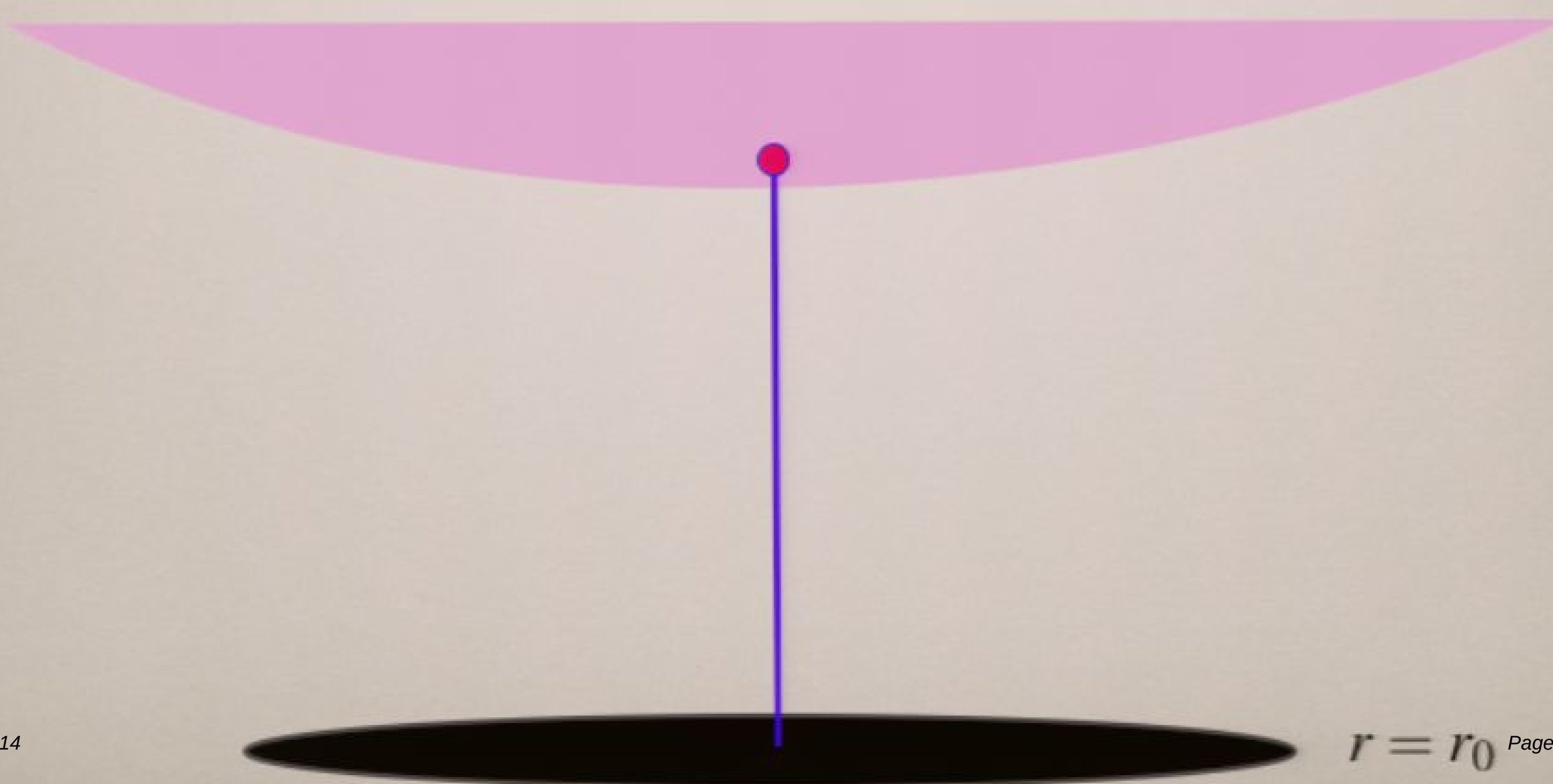

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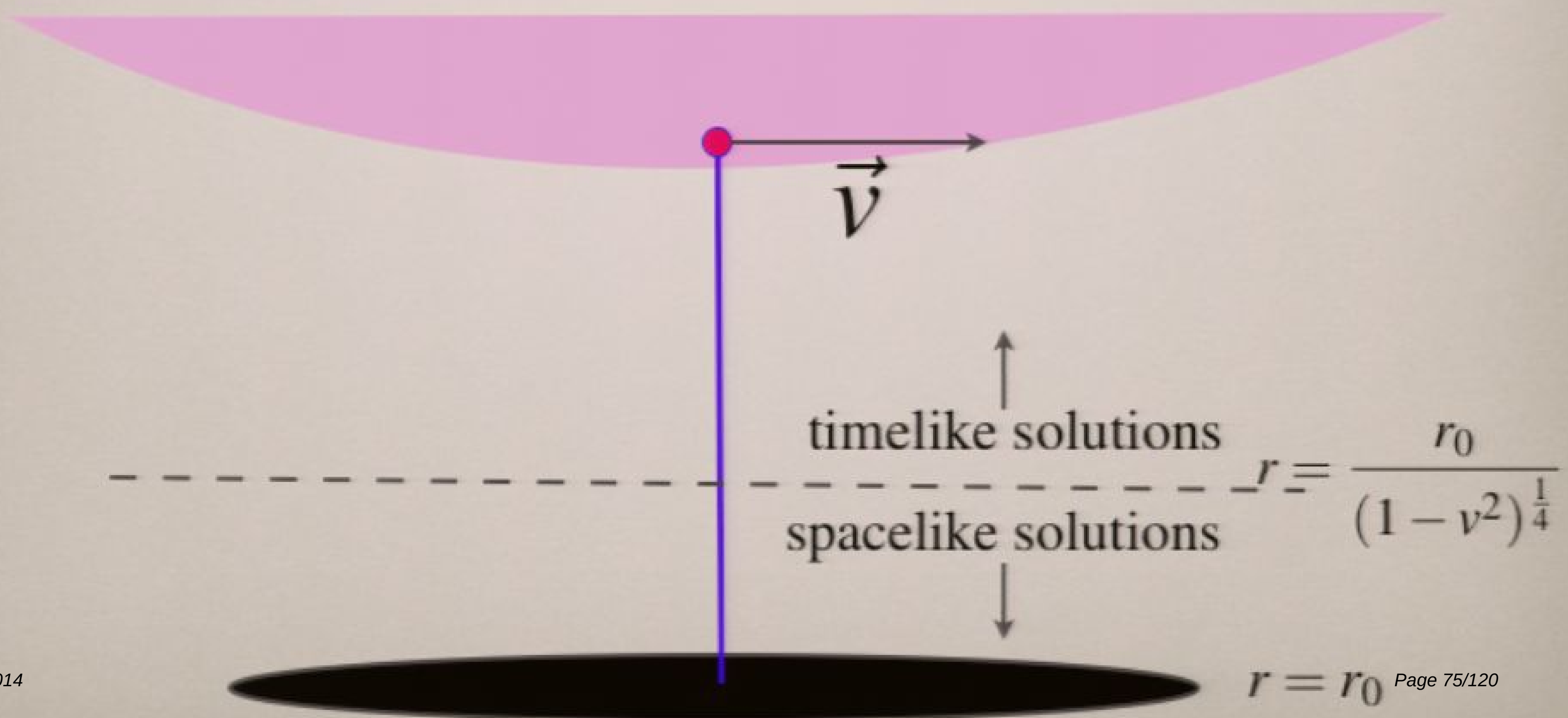

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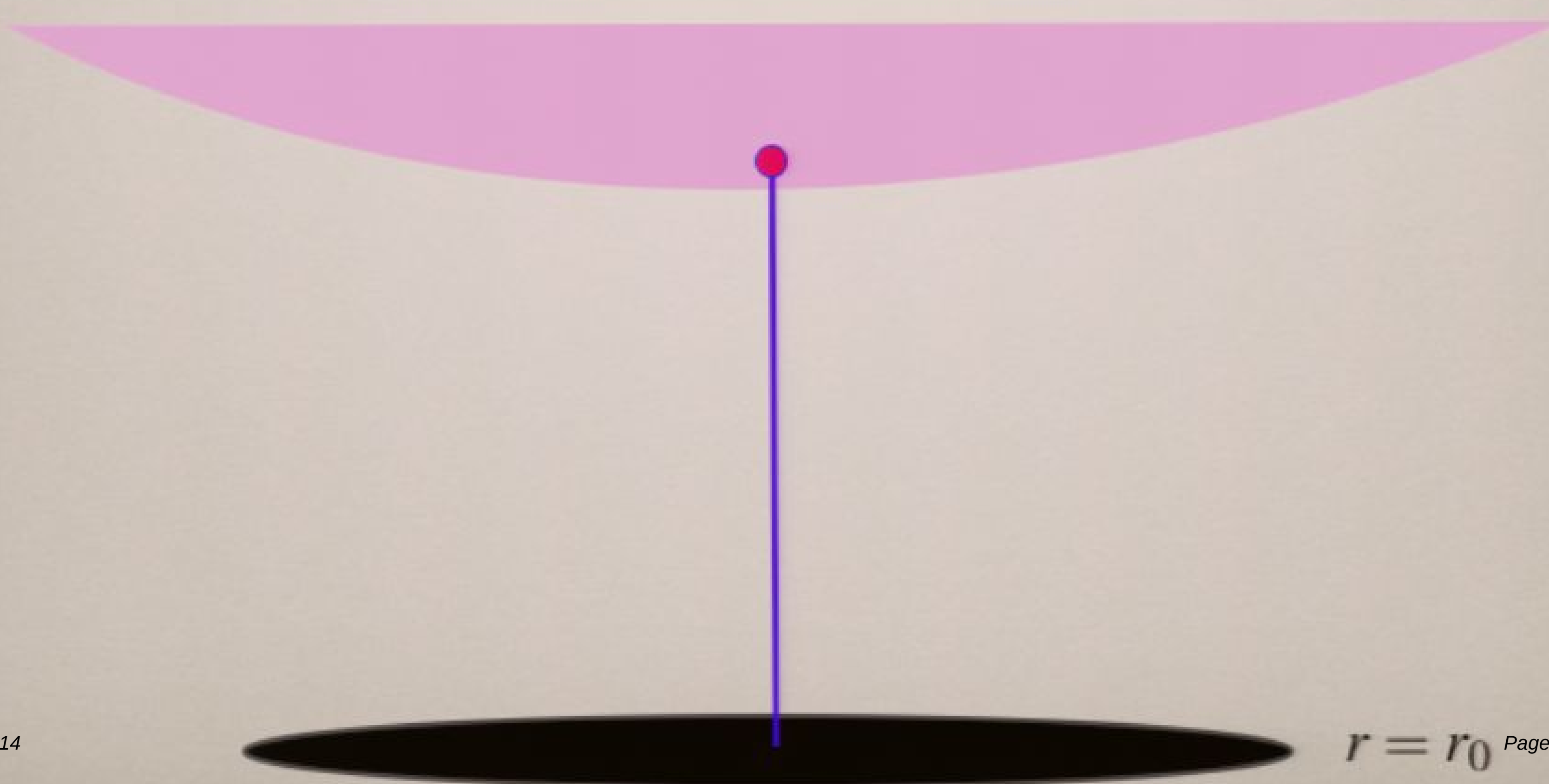

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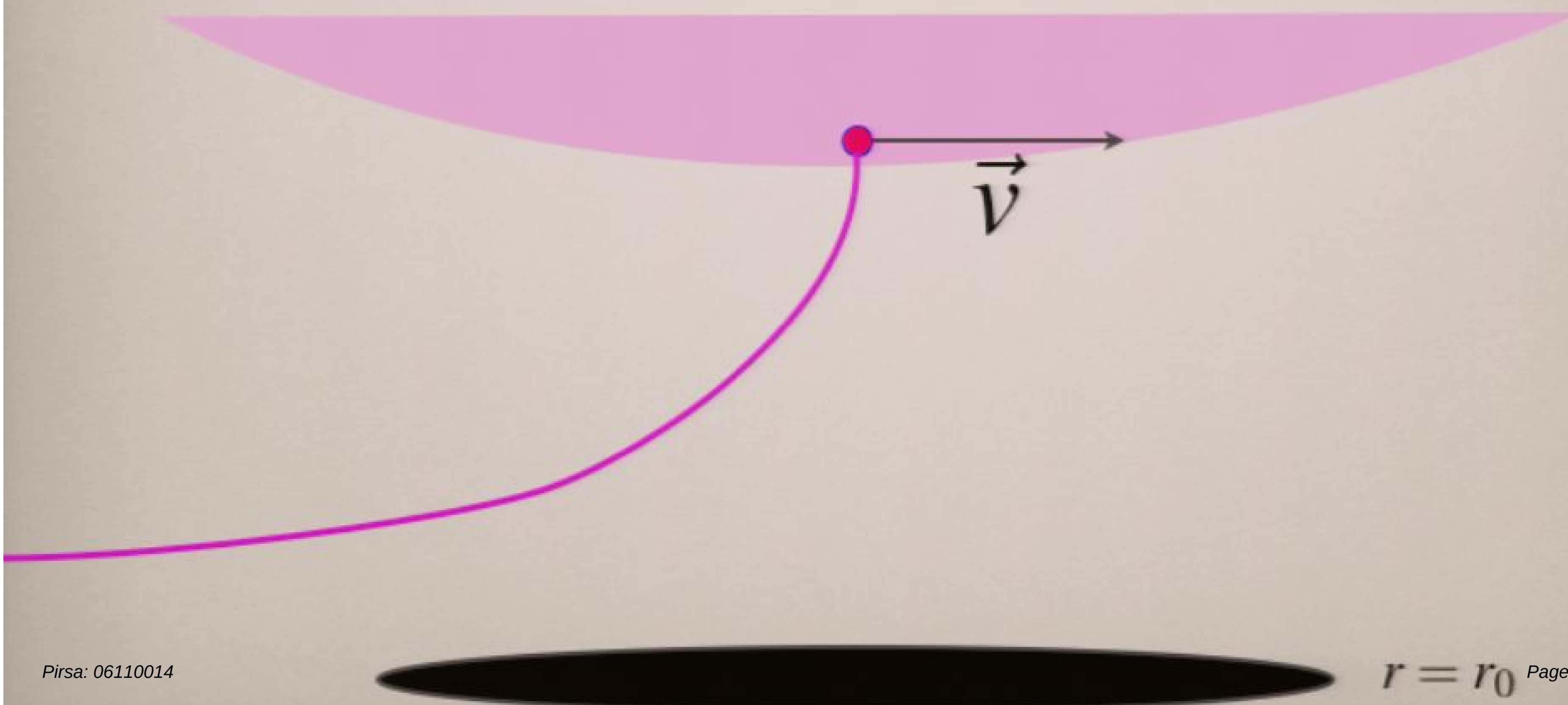

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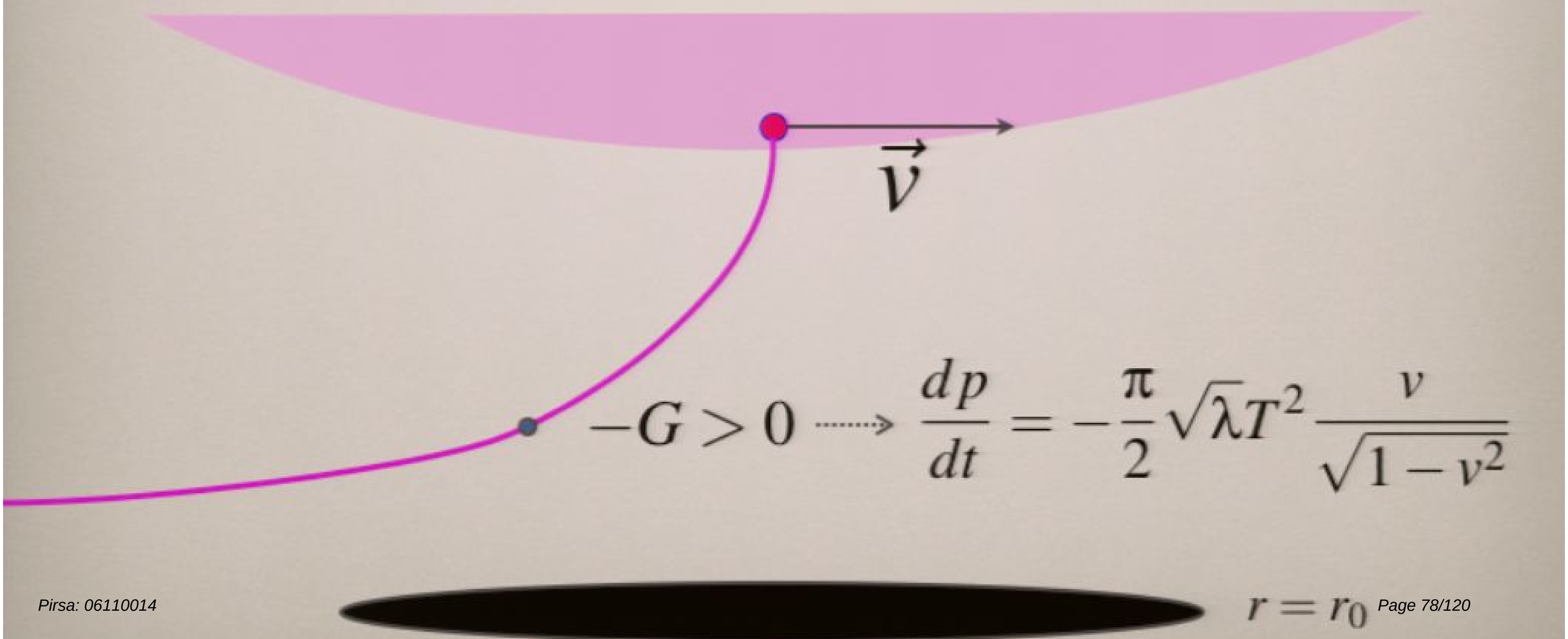

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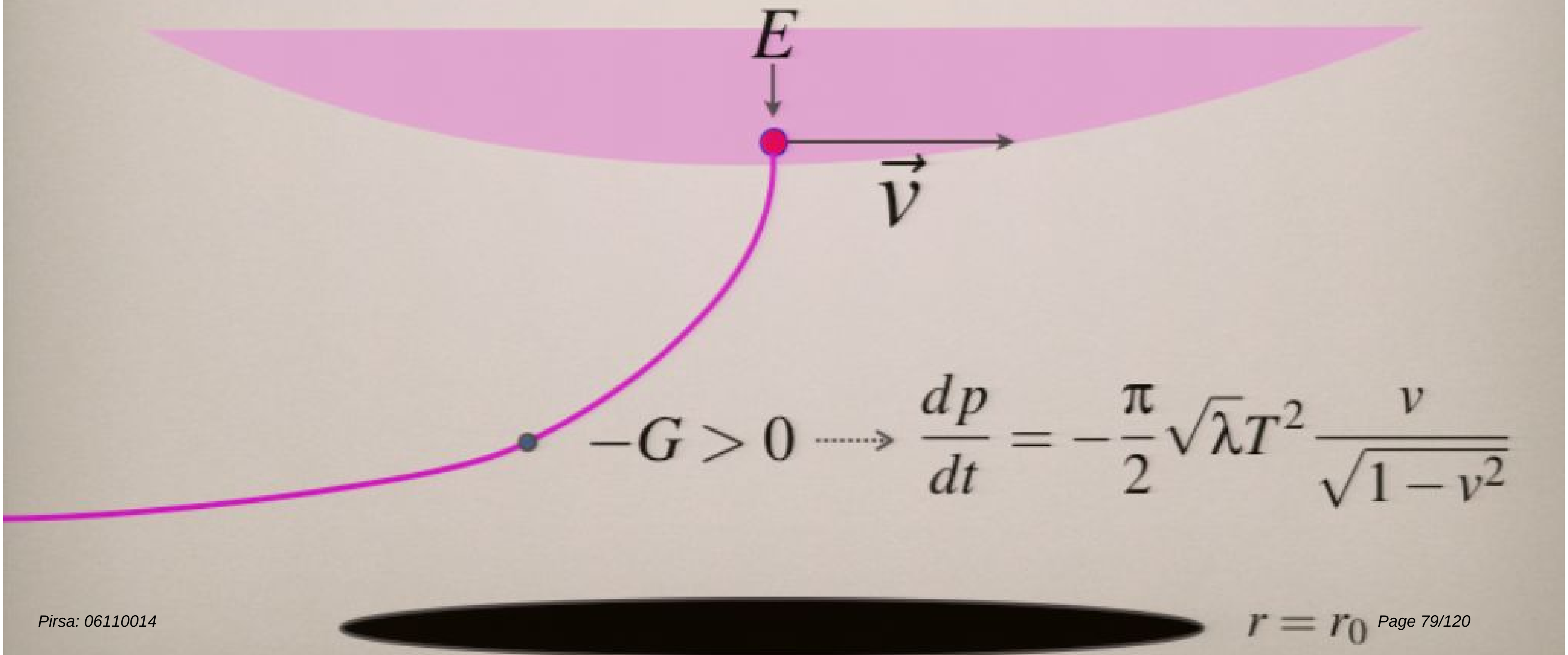

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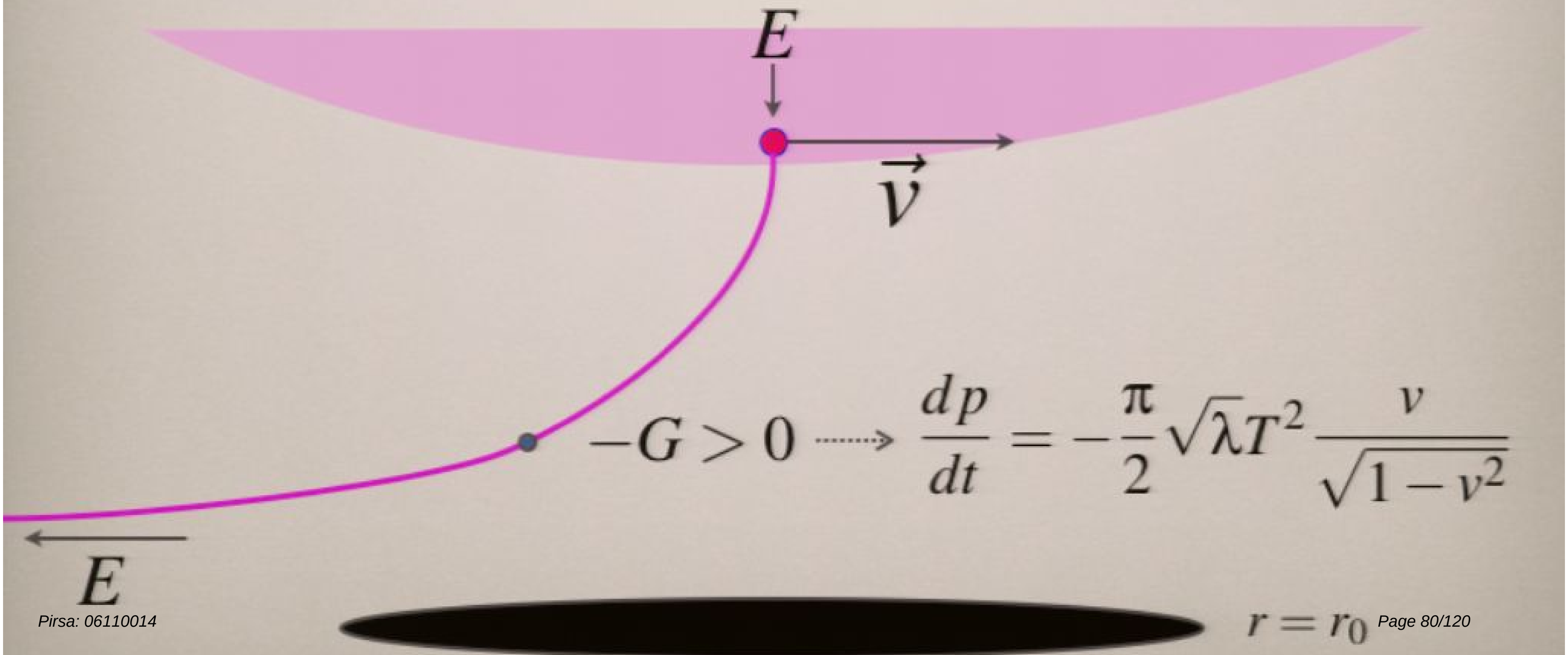

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$$\Pi_x^{\sigma}|_{r=r_0} = \frac{dp}{dt} = -\mu p \longrightarrow \mu = \frac{\pi}{2}\frac{\sqrt{\lambda}T^2}{M_{\text{kin}}(T)}$$

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$$\text{jet quenching parameter } \hat{q} = \frac{2\pi\sqrt{\lambda}T^3}{v}$$

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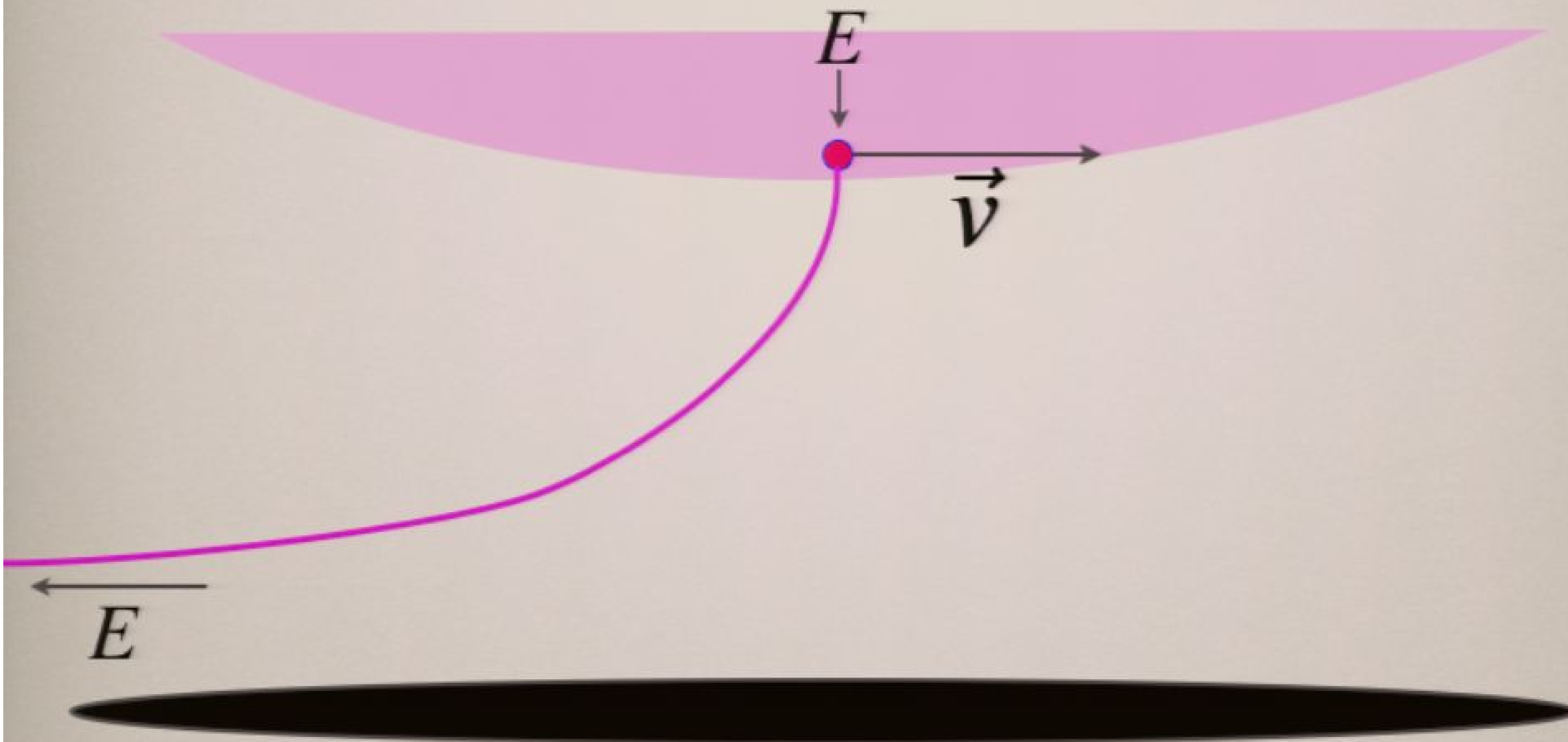
Need to determine before extracting actual value

What is the mechanism for energy loss?



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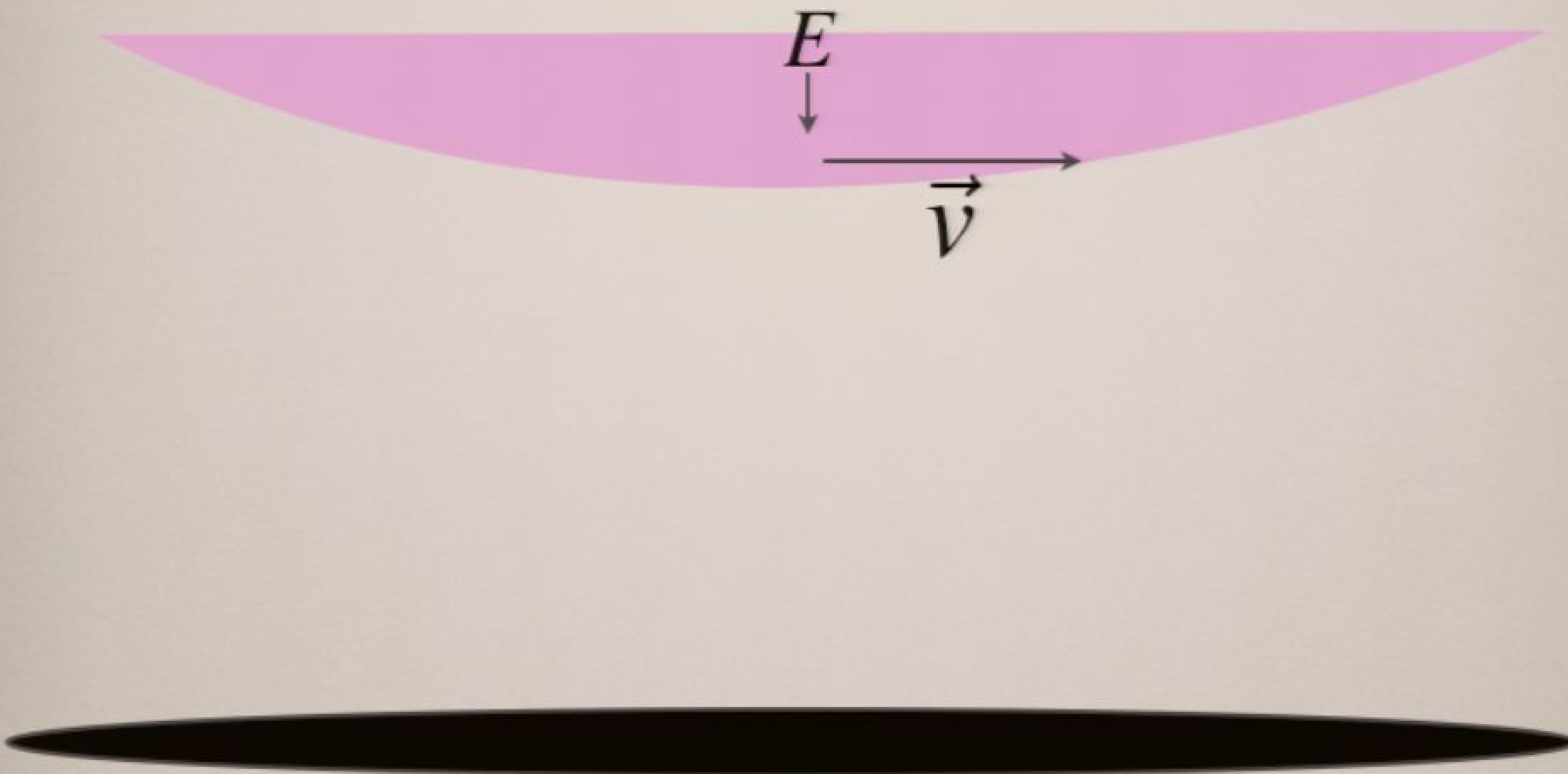

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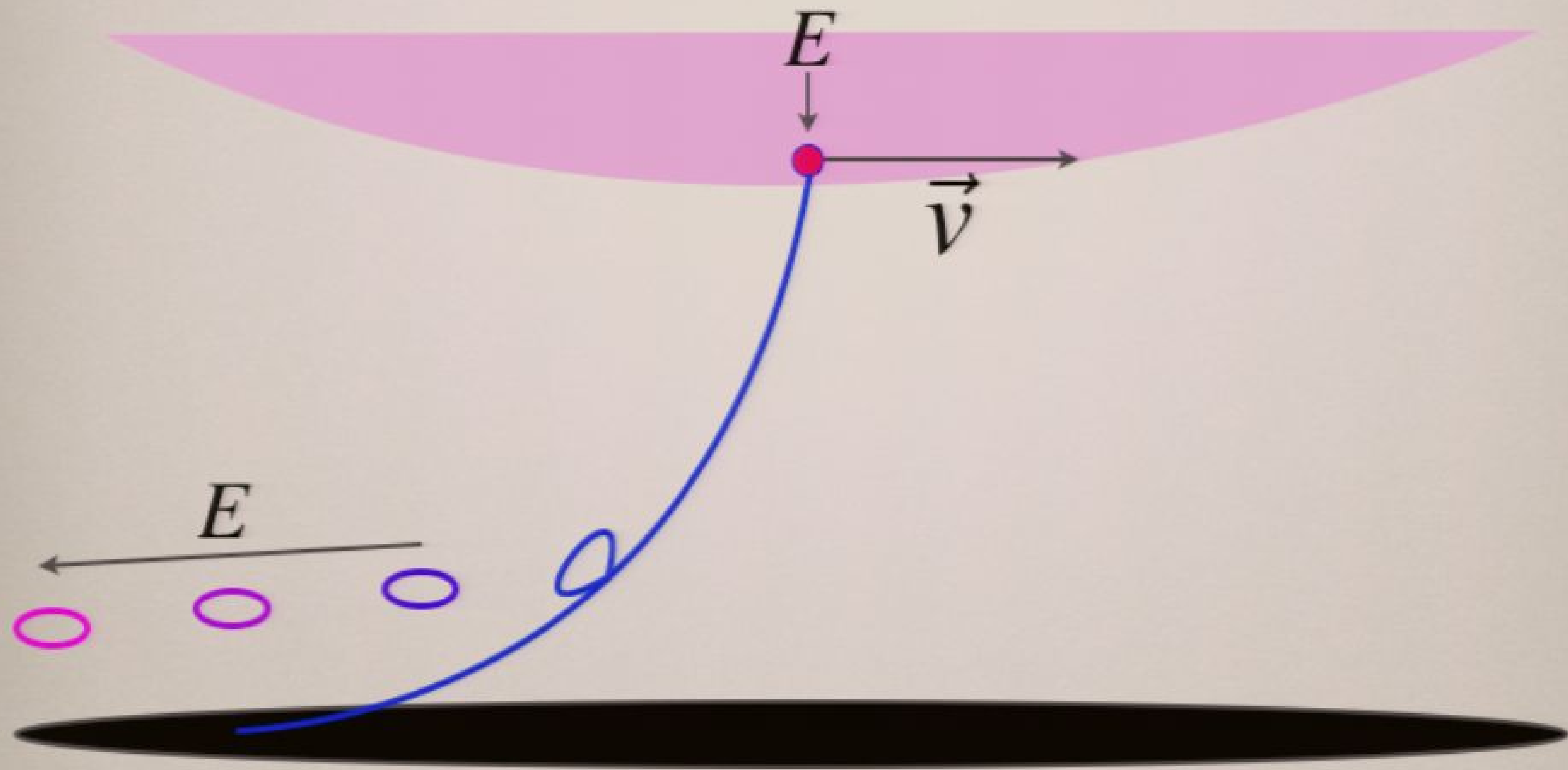

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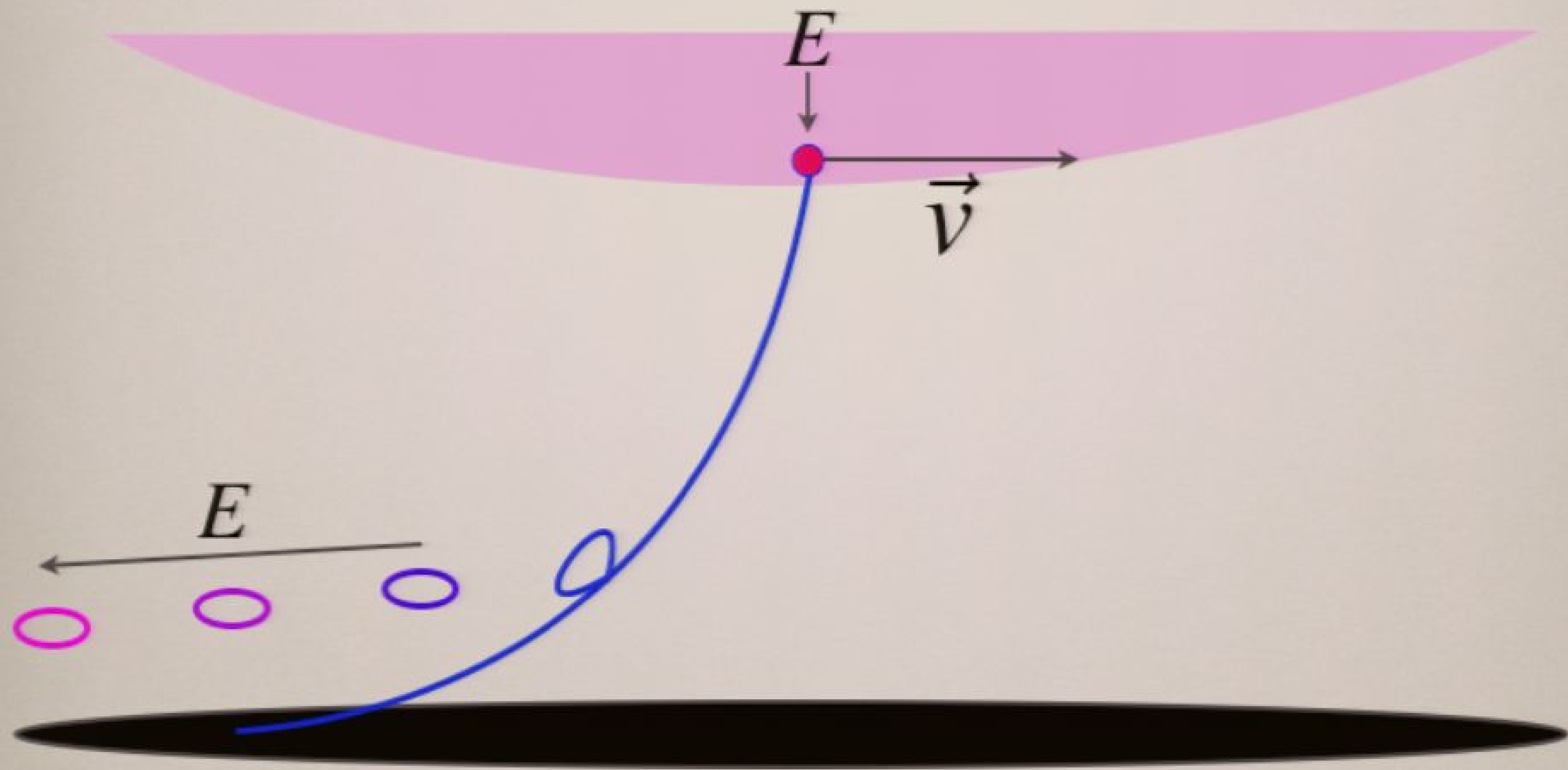

Radiating closed strings?

Extracting the jet quenching parameter in the ultra-relativistic regime

(Liu,Rajagopal,Wiedemann 2006)

$$< W >= \mathrm{e}^{-\frac{1}{4}\hat{q}\Delta t L^2}$$

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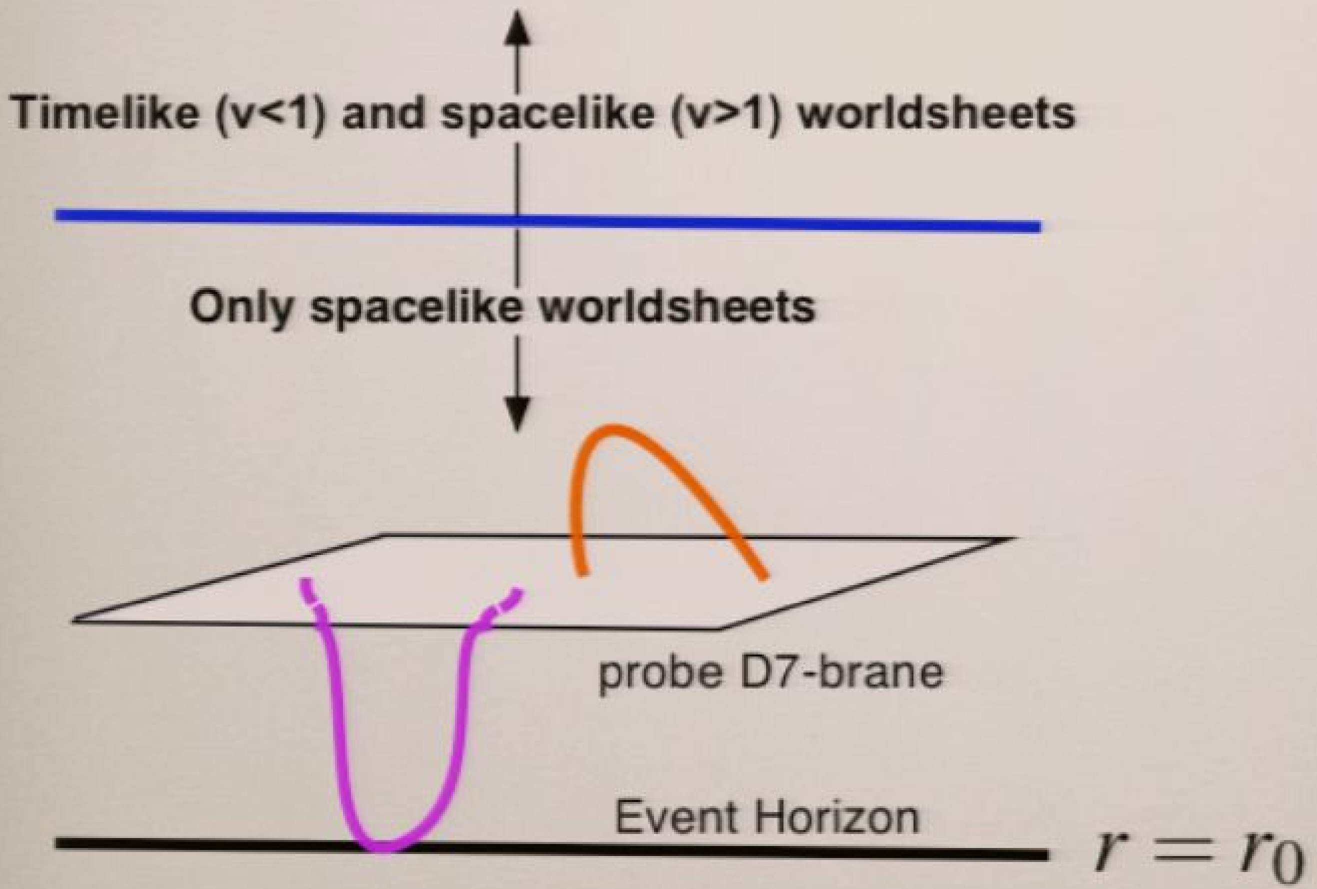
Use spacelike string solution?

Lightlike limit

(regard as formal procedure and see where it leads...)



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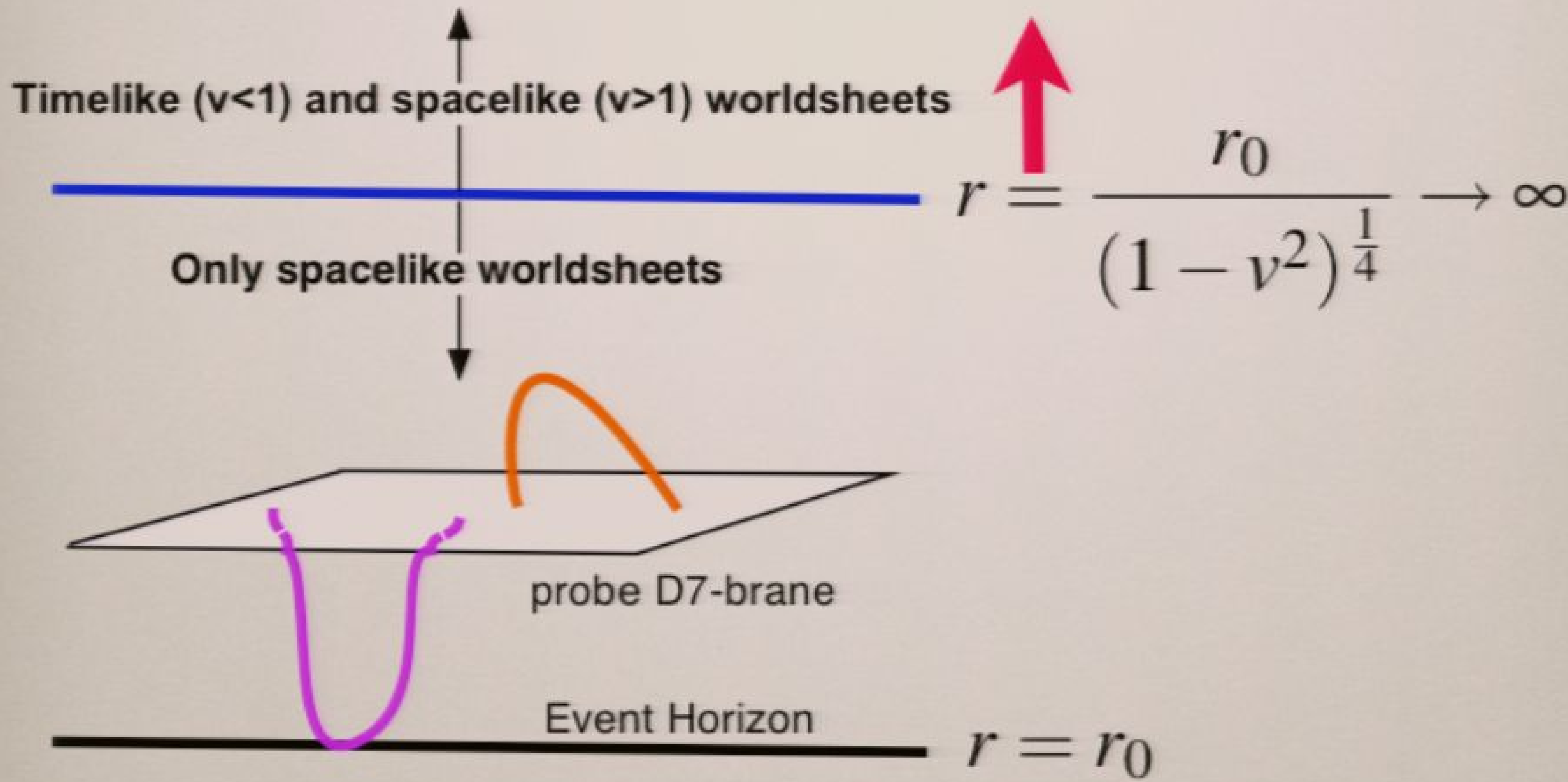

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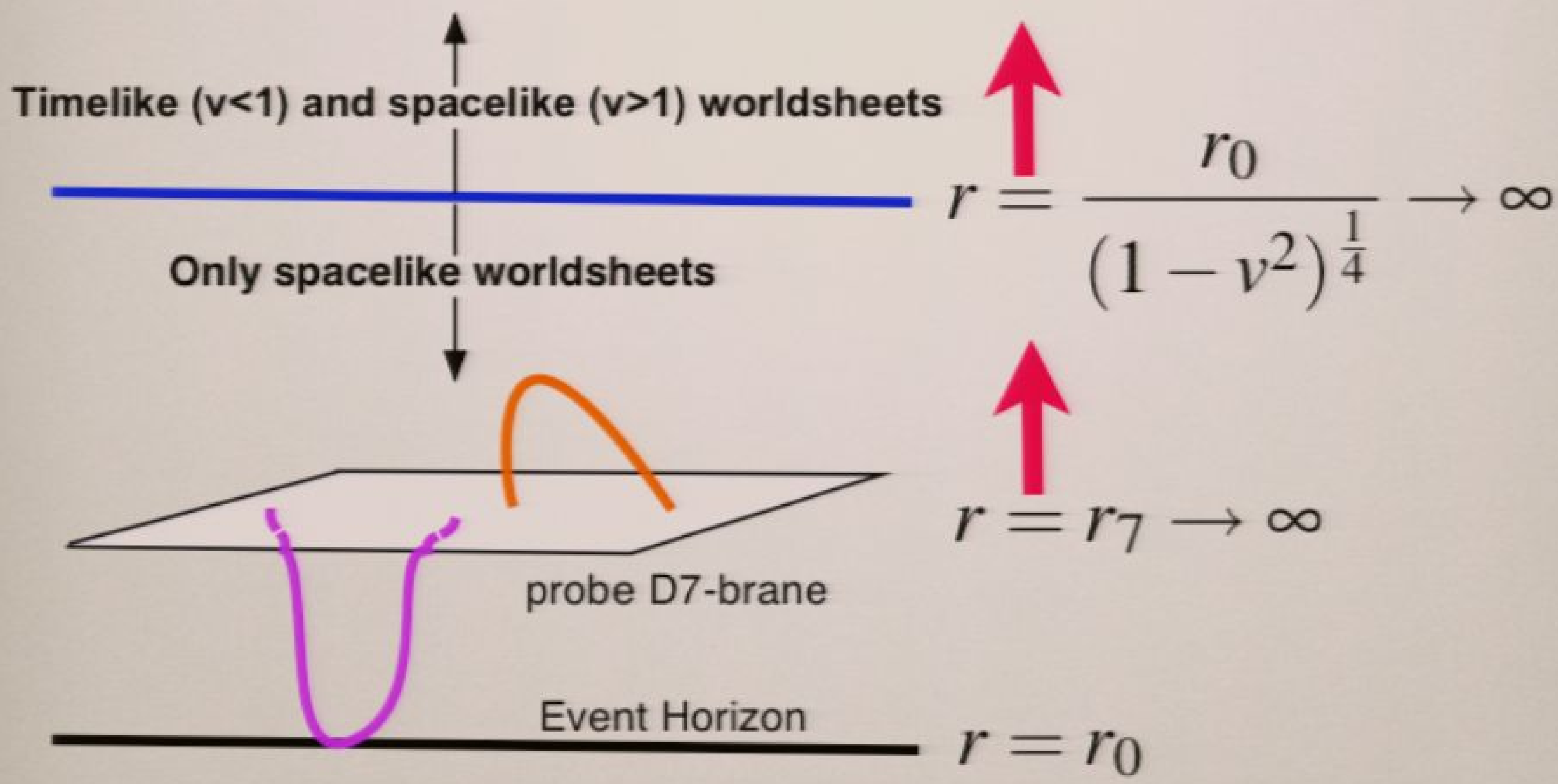

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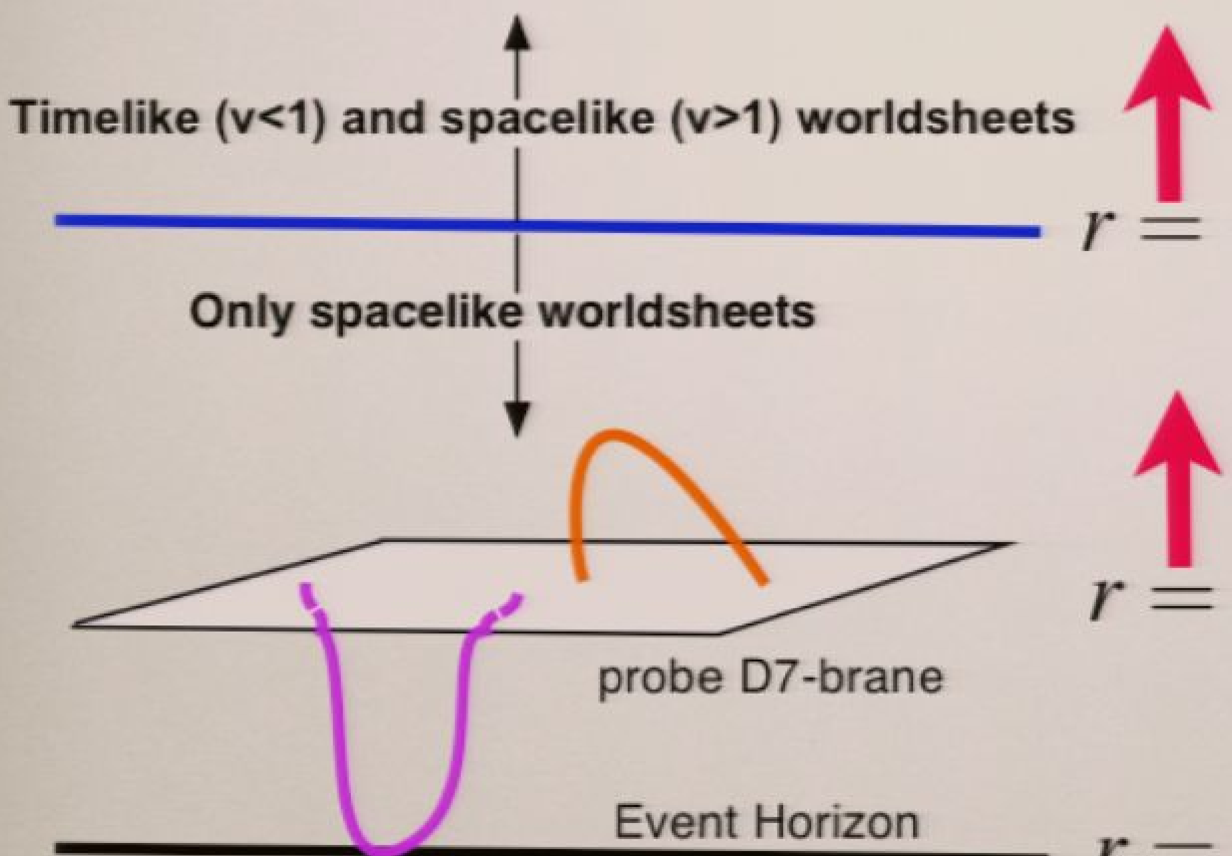


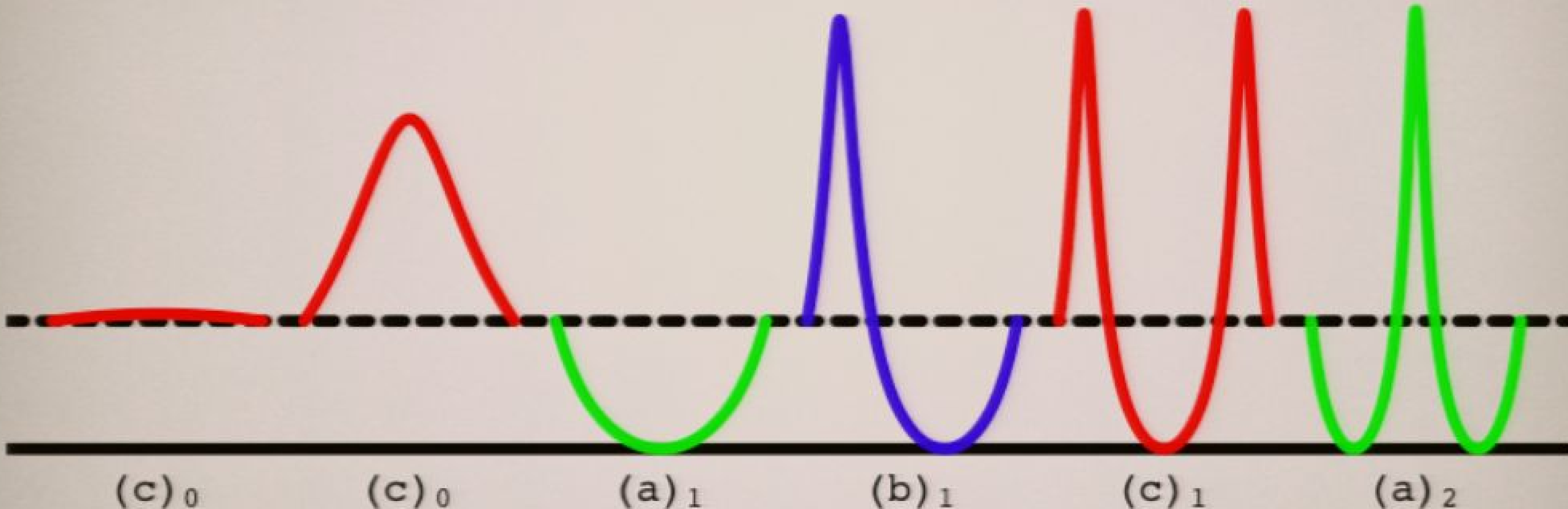
$$r = \frac{r_0}{(1-v^2)^{\frac{1}{4}}} \to \infty$$

$$r = r_7 \to \infty$$

$$r = r_0$$

This limiting procedure is ambiguous

Many branches of solutions



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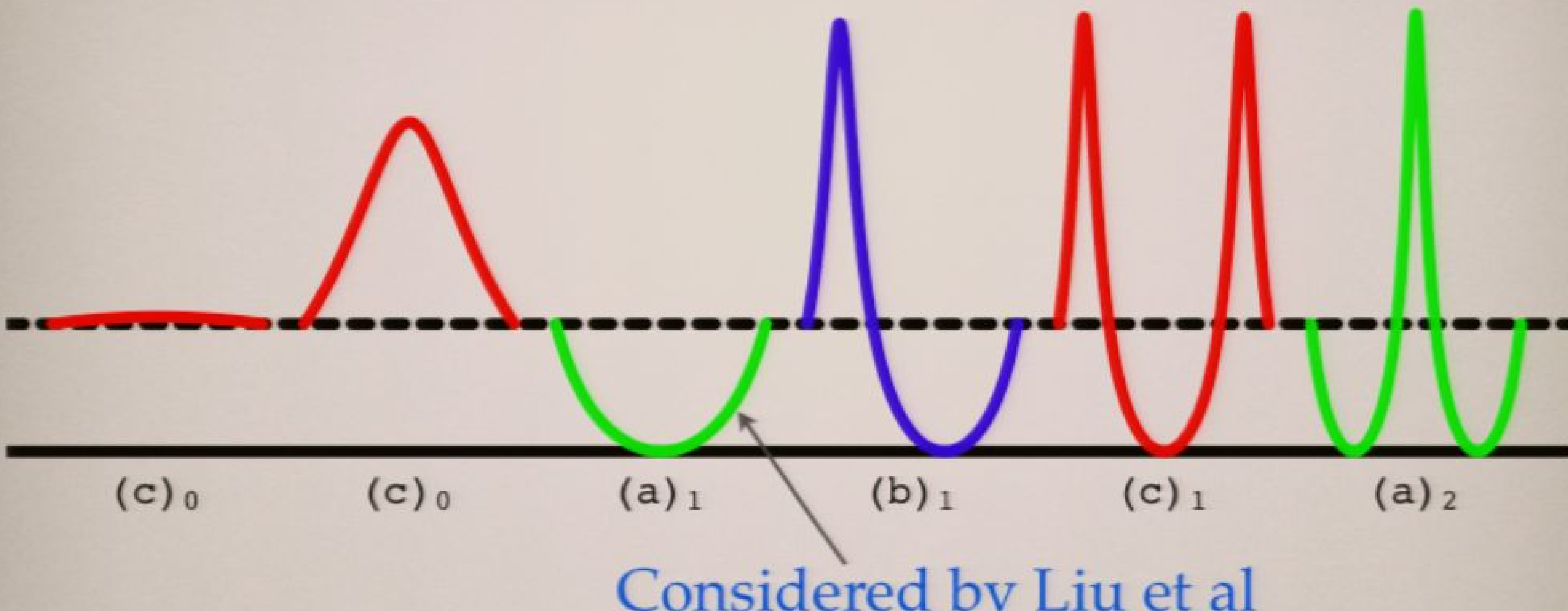

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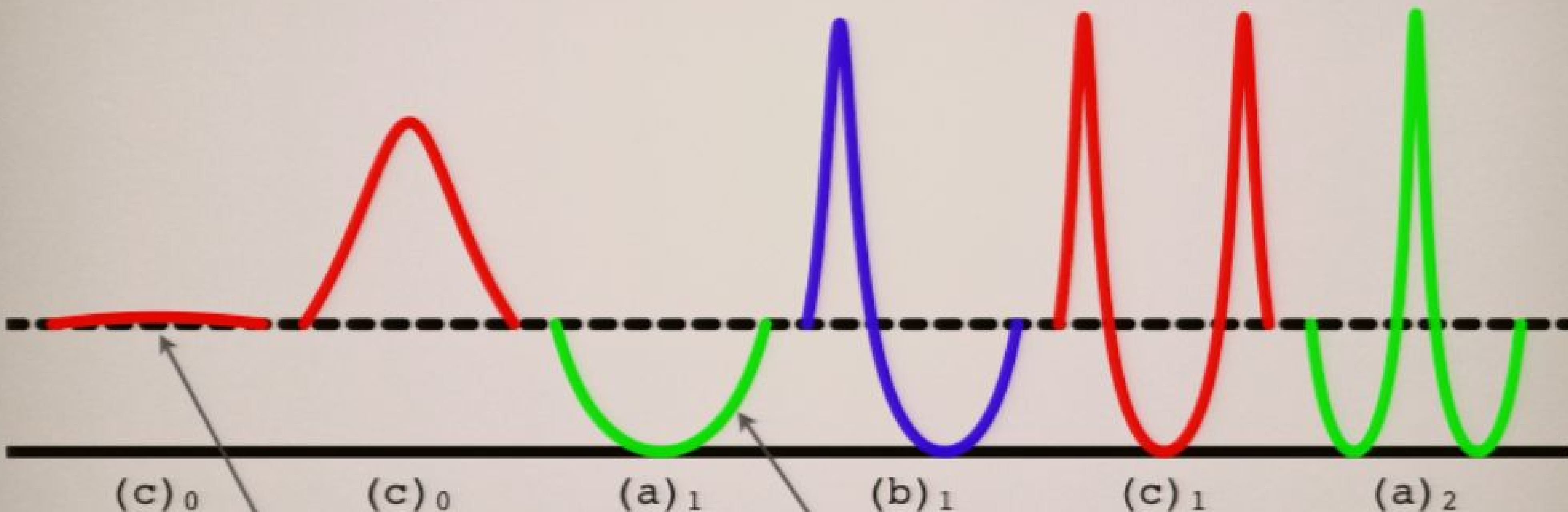

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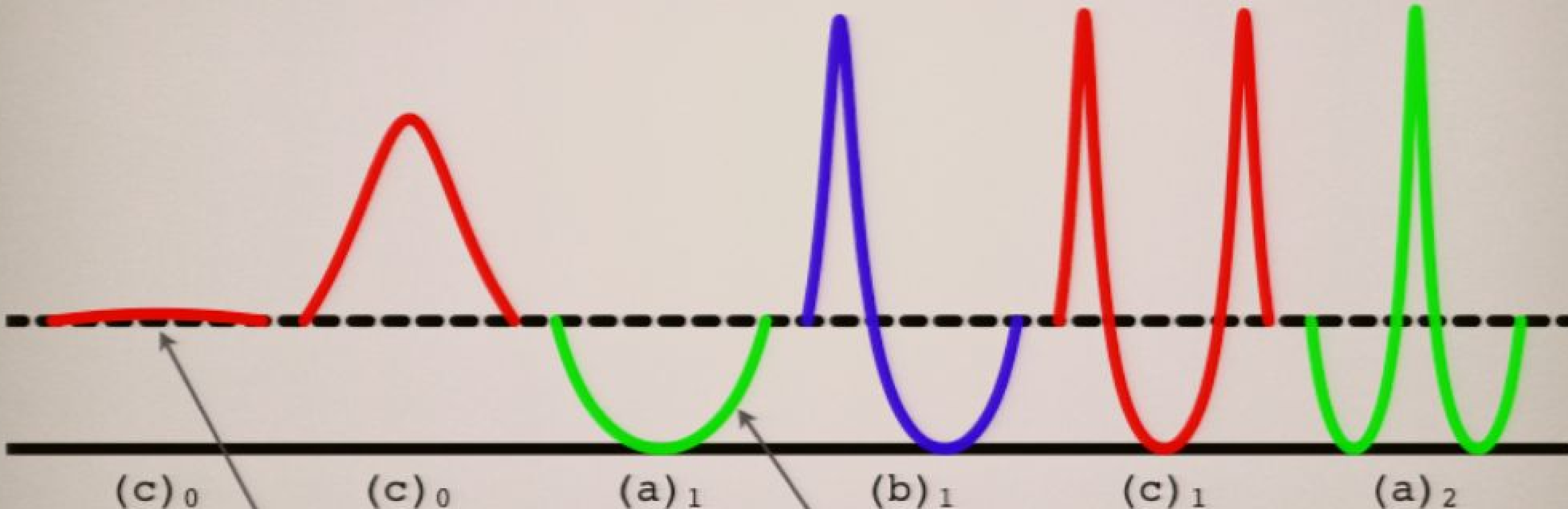

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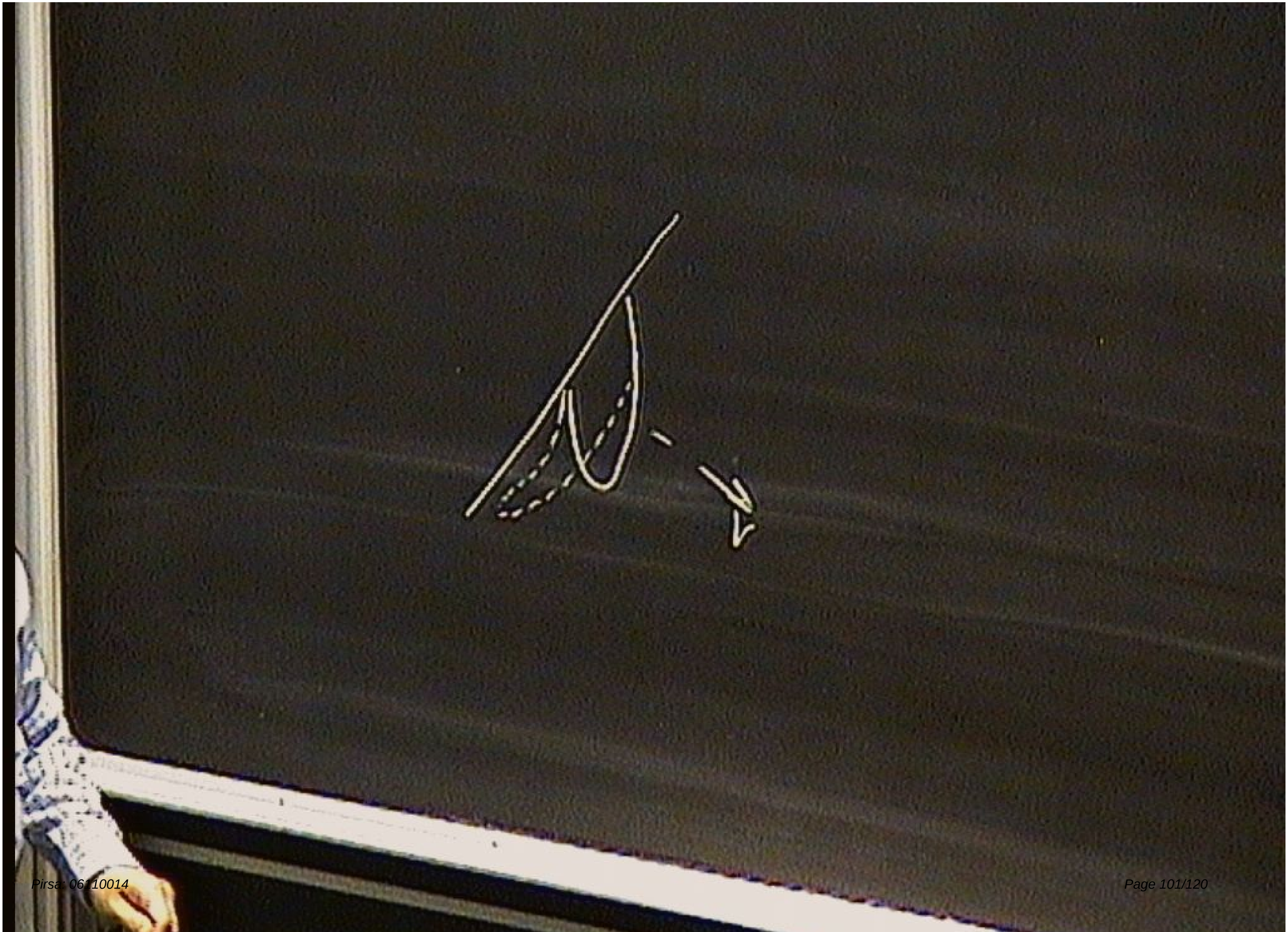

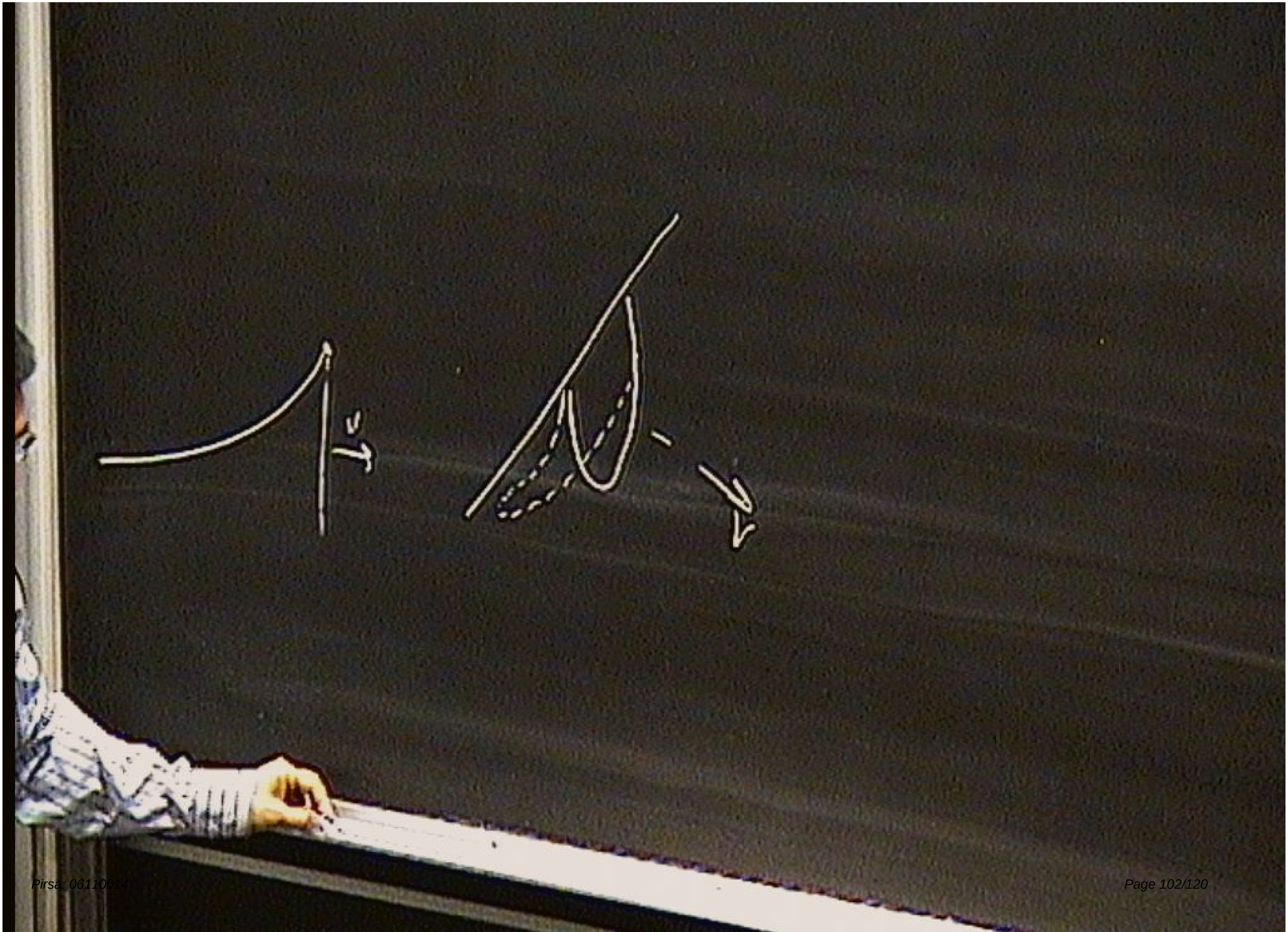

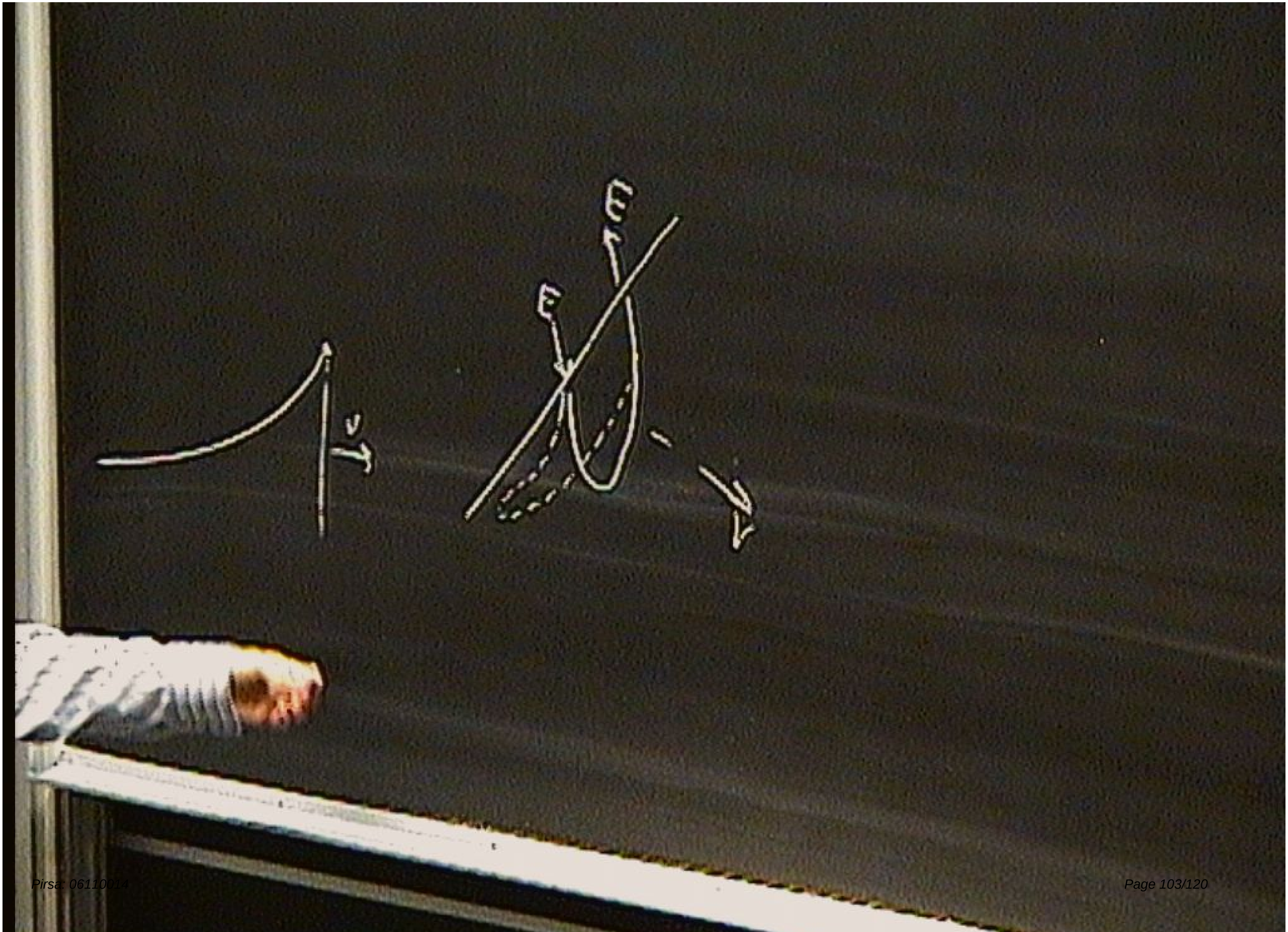

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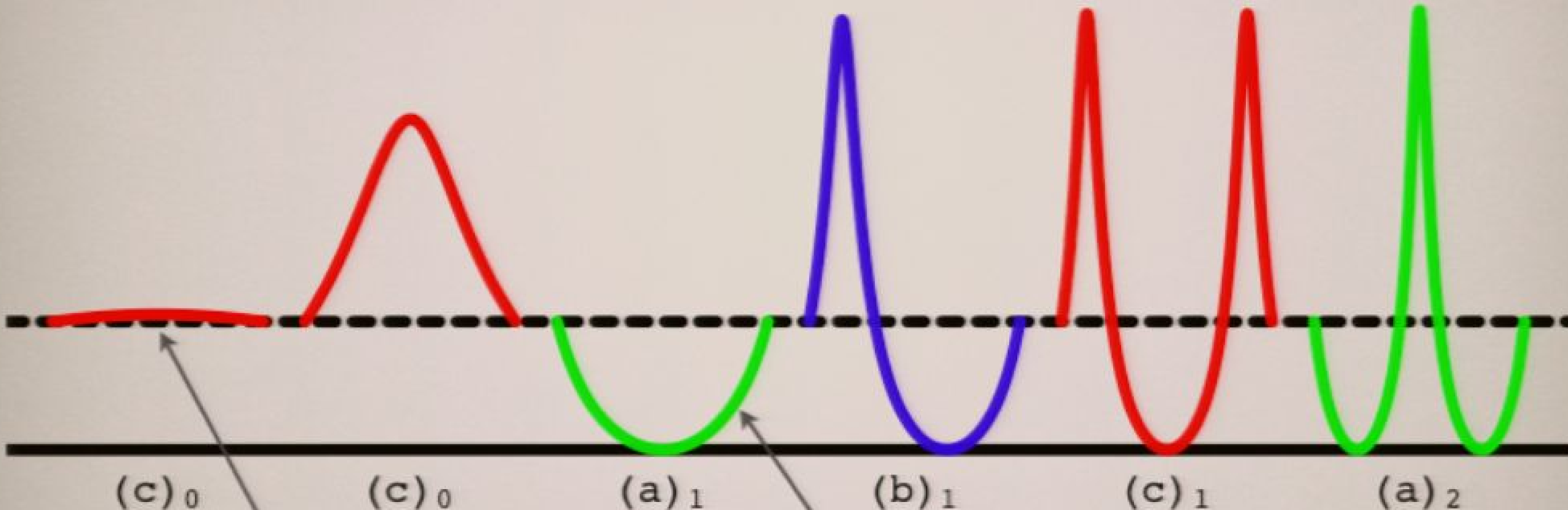

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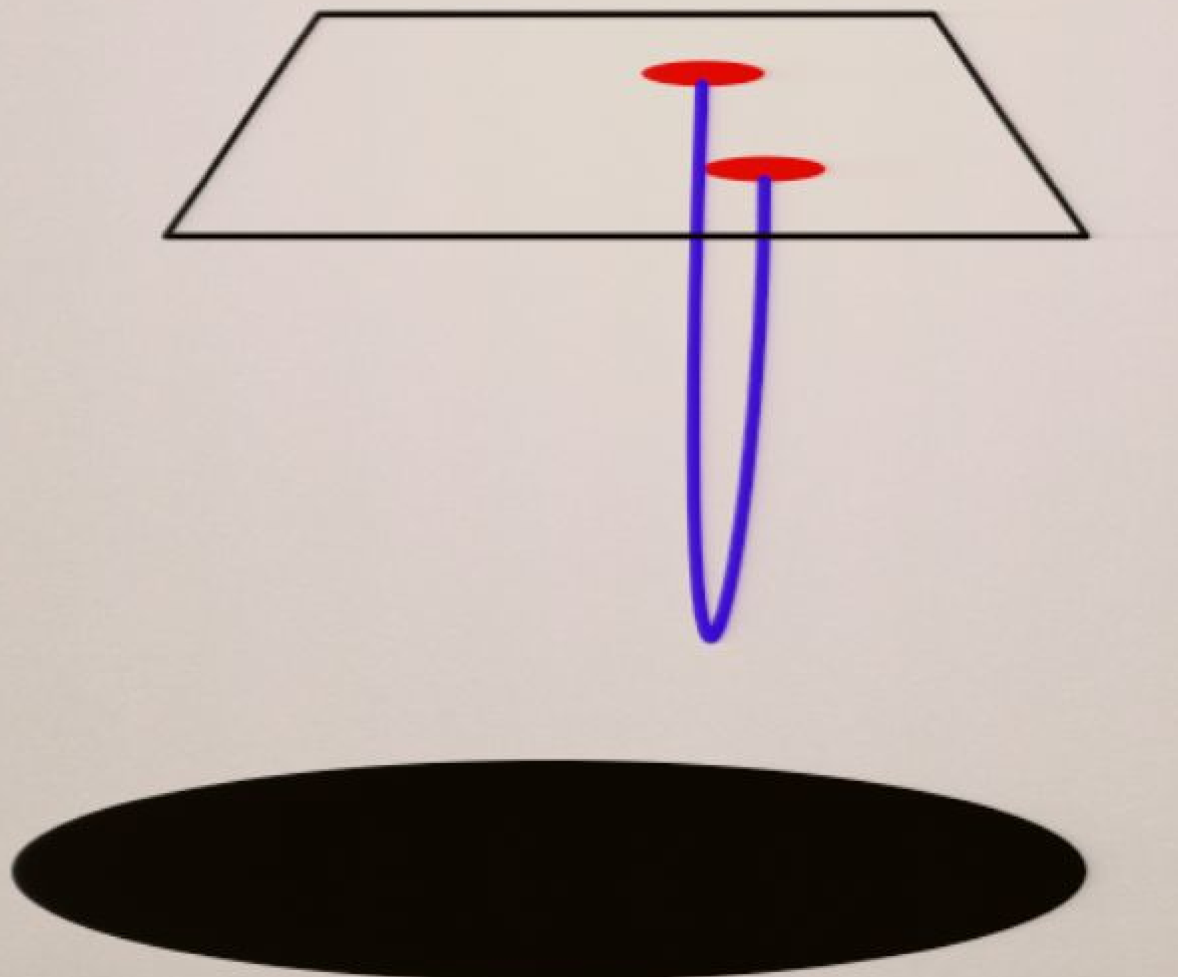

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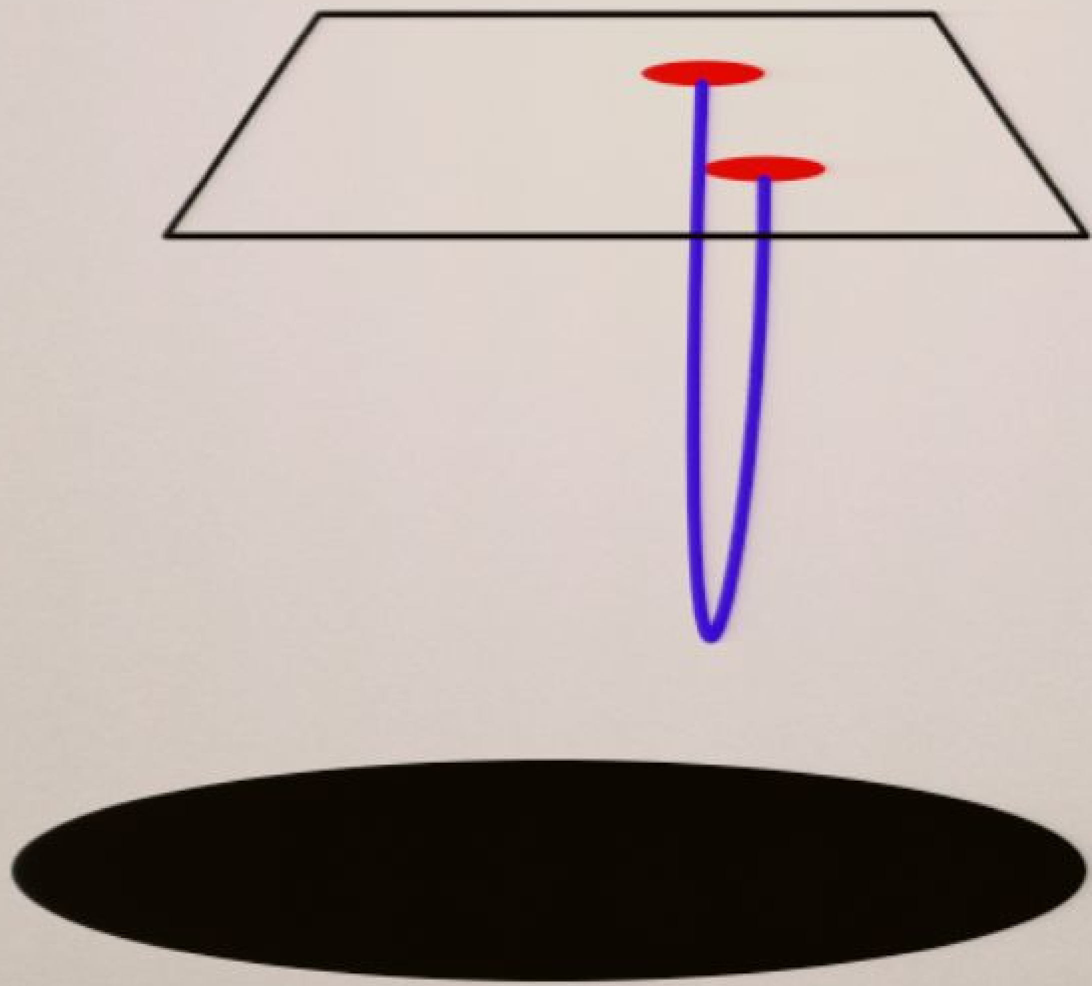

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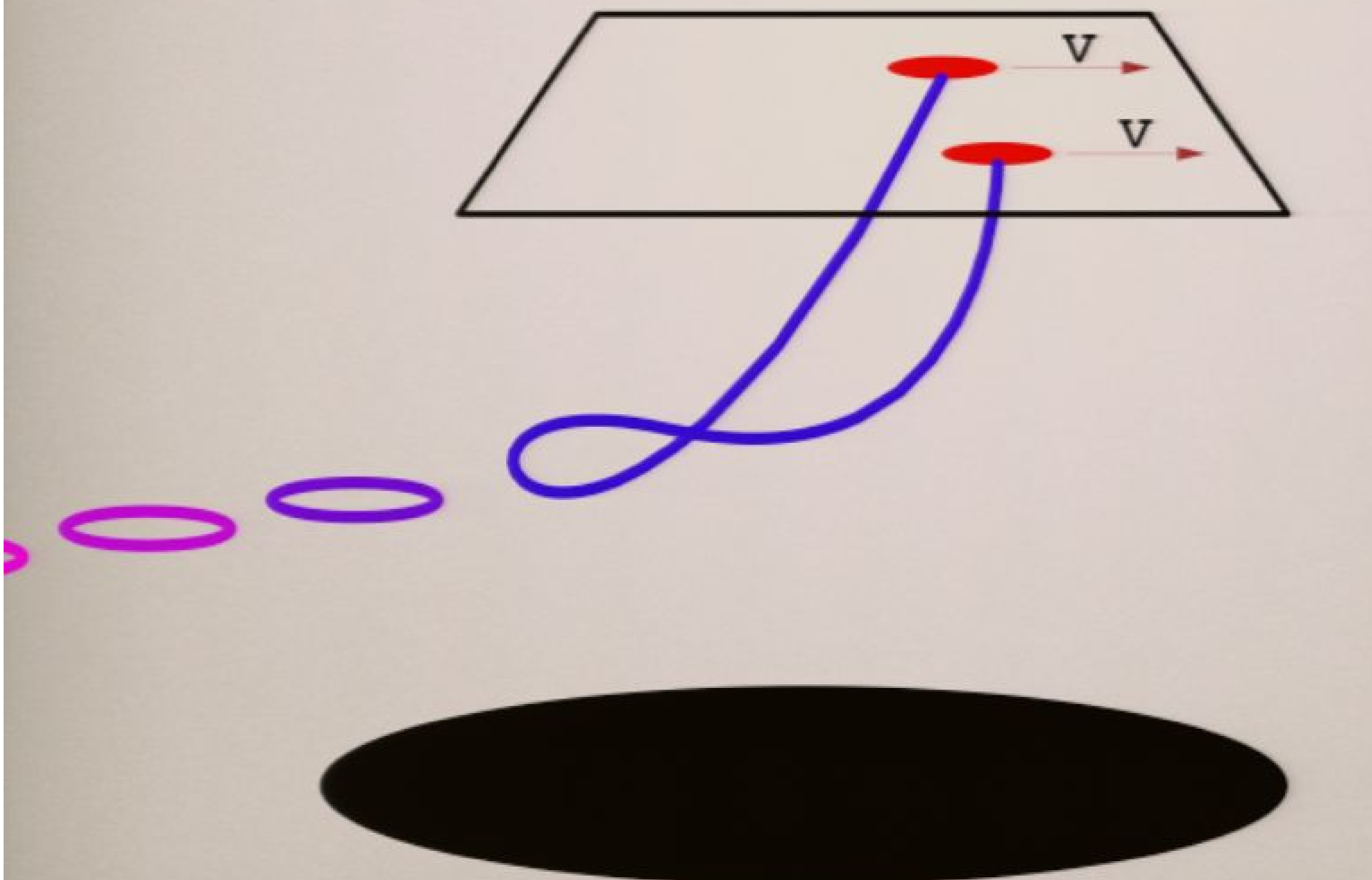

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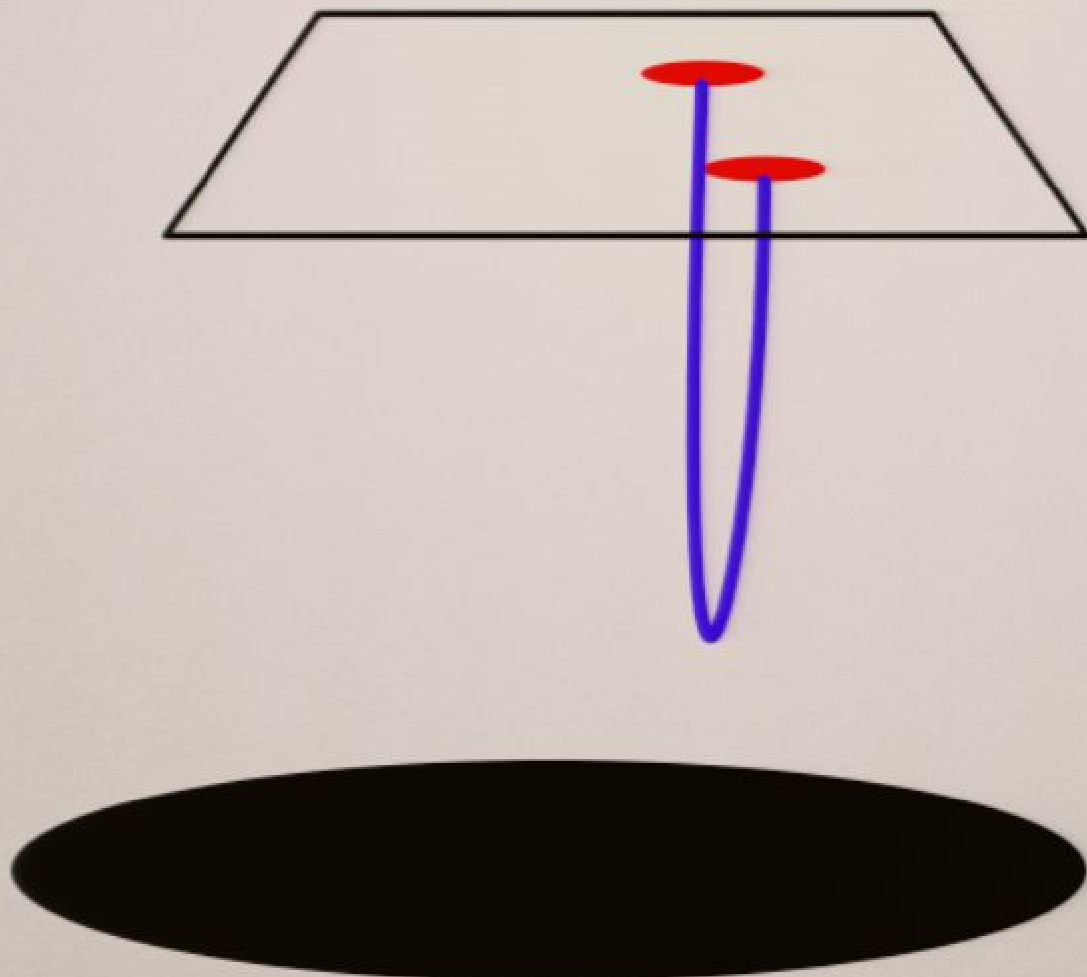

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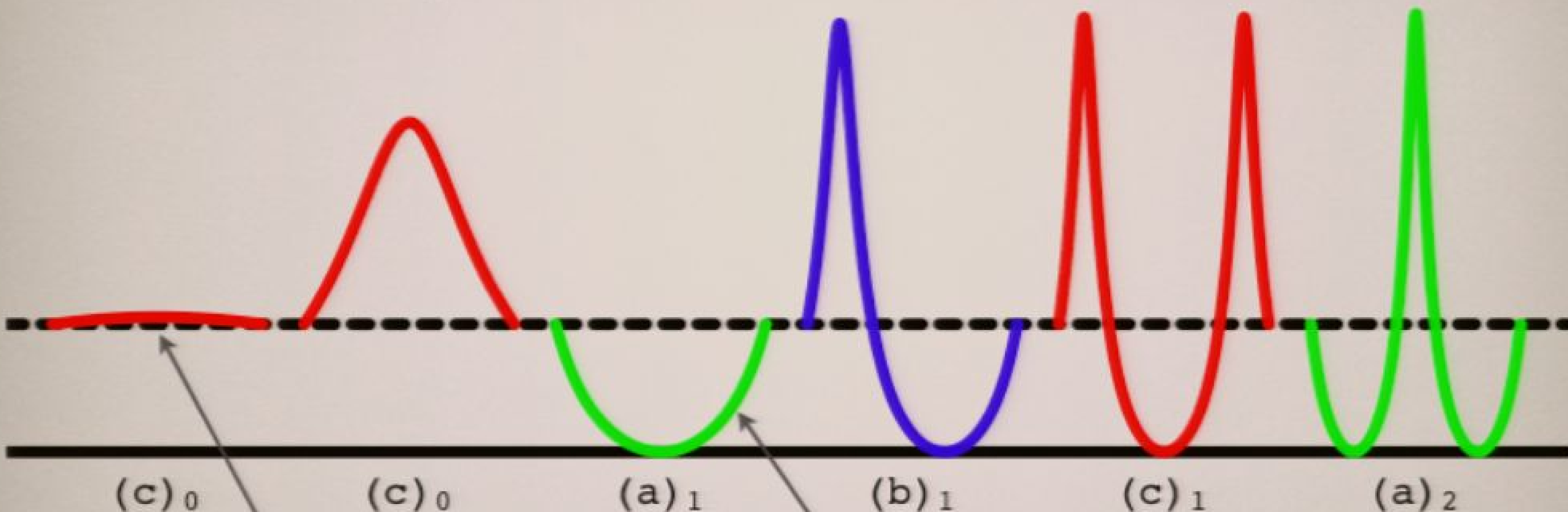

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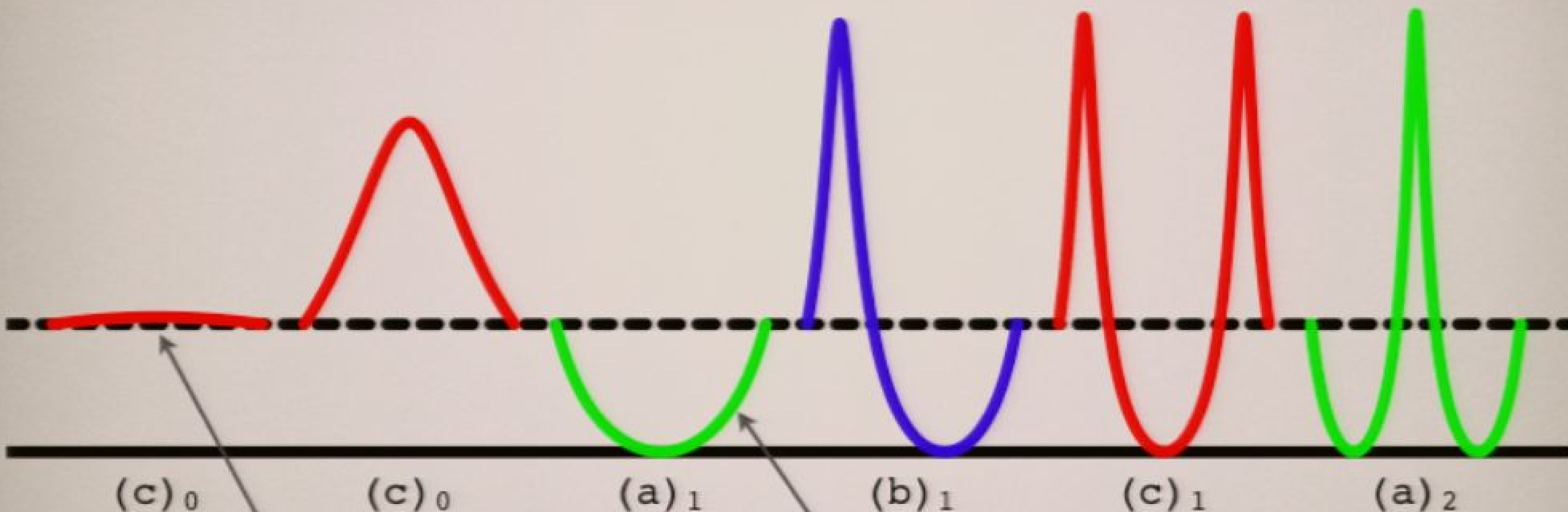

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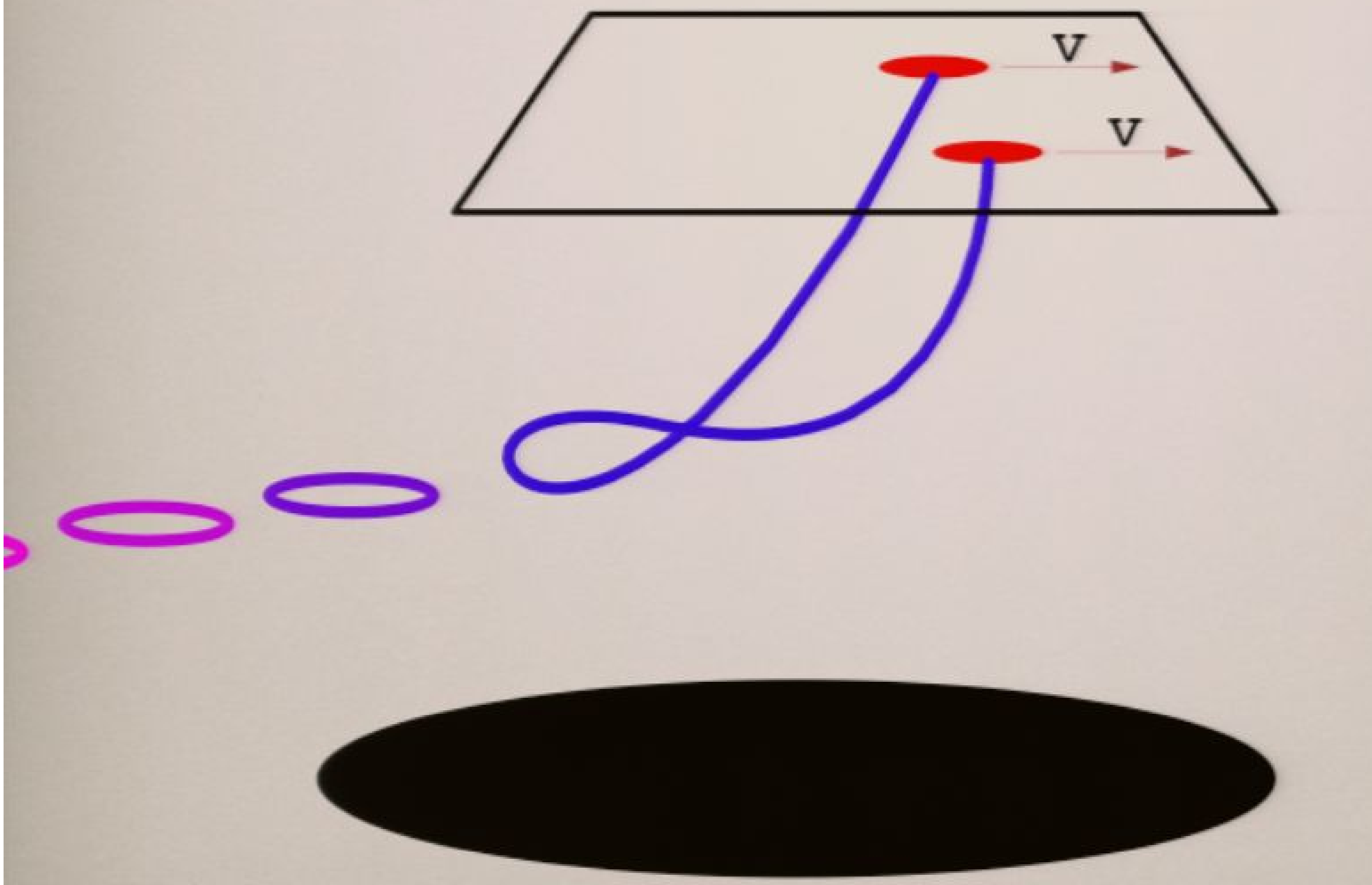

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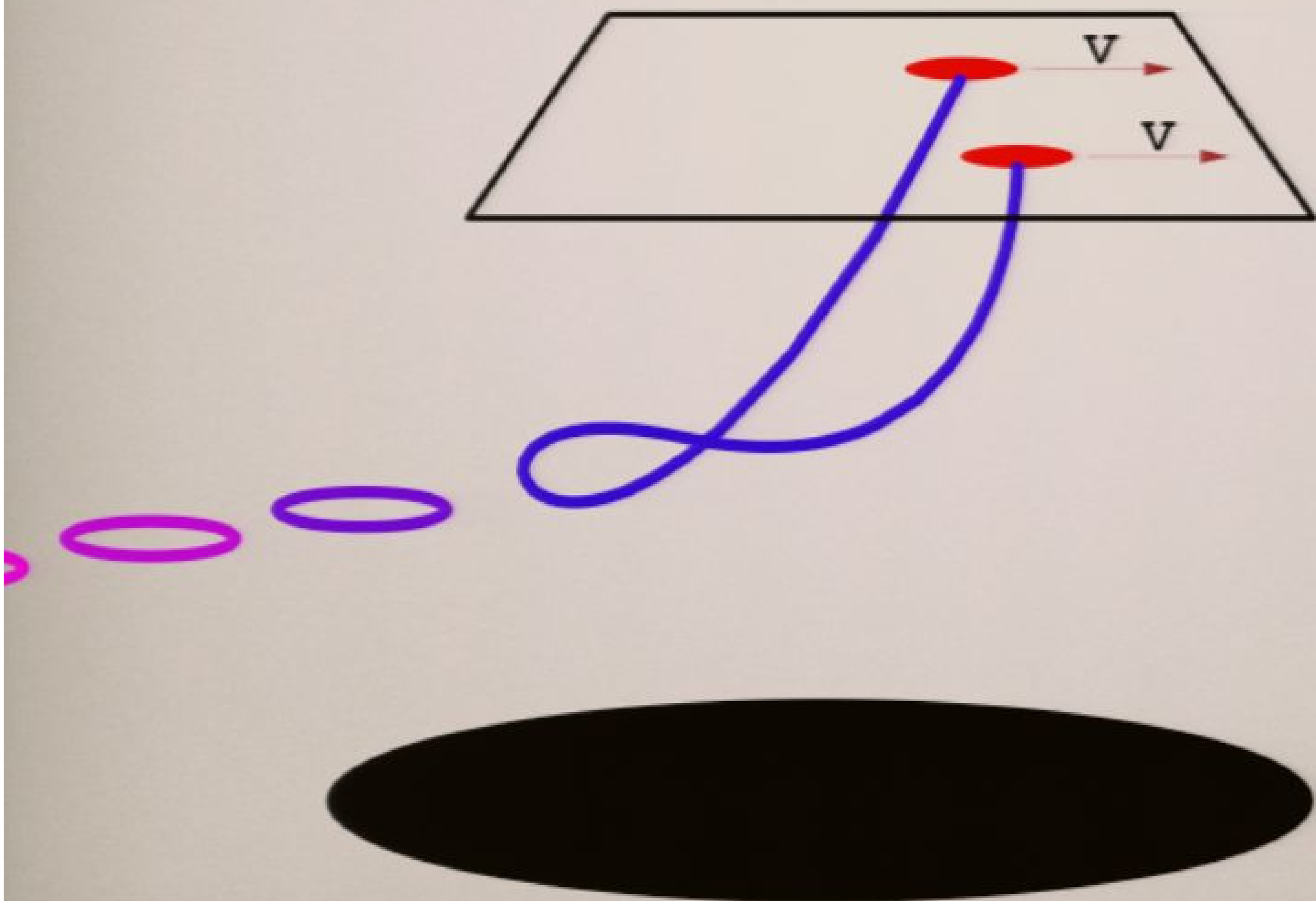

...or else another procedure

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- Resolve ambiguities before extracting certain quantities (compute distance-dependent quantity at strong coupling)

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- Computing ultra-relativistic jet quenching parameter

Calculate jet quenching from realistic gravity duals

(Buchel 2006)

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Numerical generalization of Klebanov-Strassler type solution away from extremality

(Pando Zayas, Terrero-Escalante 2006)

- Find out who said that statement about string theorists

Thanks for listening!