Title: 2+1dimensional gauge gravity duality

Date: Dec 10, 2008 11:10 AM

URL: http://pirsa.org/08120056

Abstract: I discuss our recent investigations into 2+1 dim Chern-Simons theories with gravity duals that have reduced supersymmetry. Many new phenomena such as fractional statistics arise in 2+1 dim field theory that make this duality interesting and subtle. I focus on our work involving an example of such a duality with minimal supersymmetry and propose a field theoretic dual for a long known vacuum of gauged supergravity on AdS_4. I also argue that 2+1 dim duality might present a favorable landscape for constructing non-supersymmetric conformal fixed points at large but finite N.

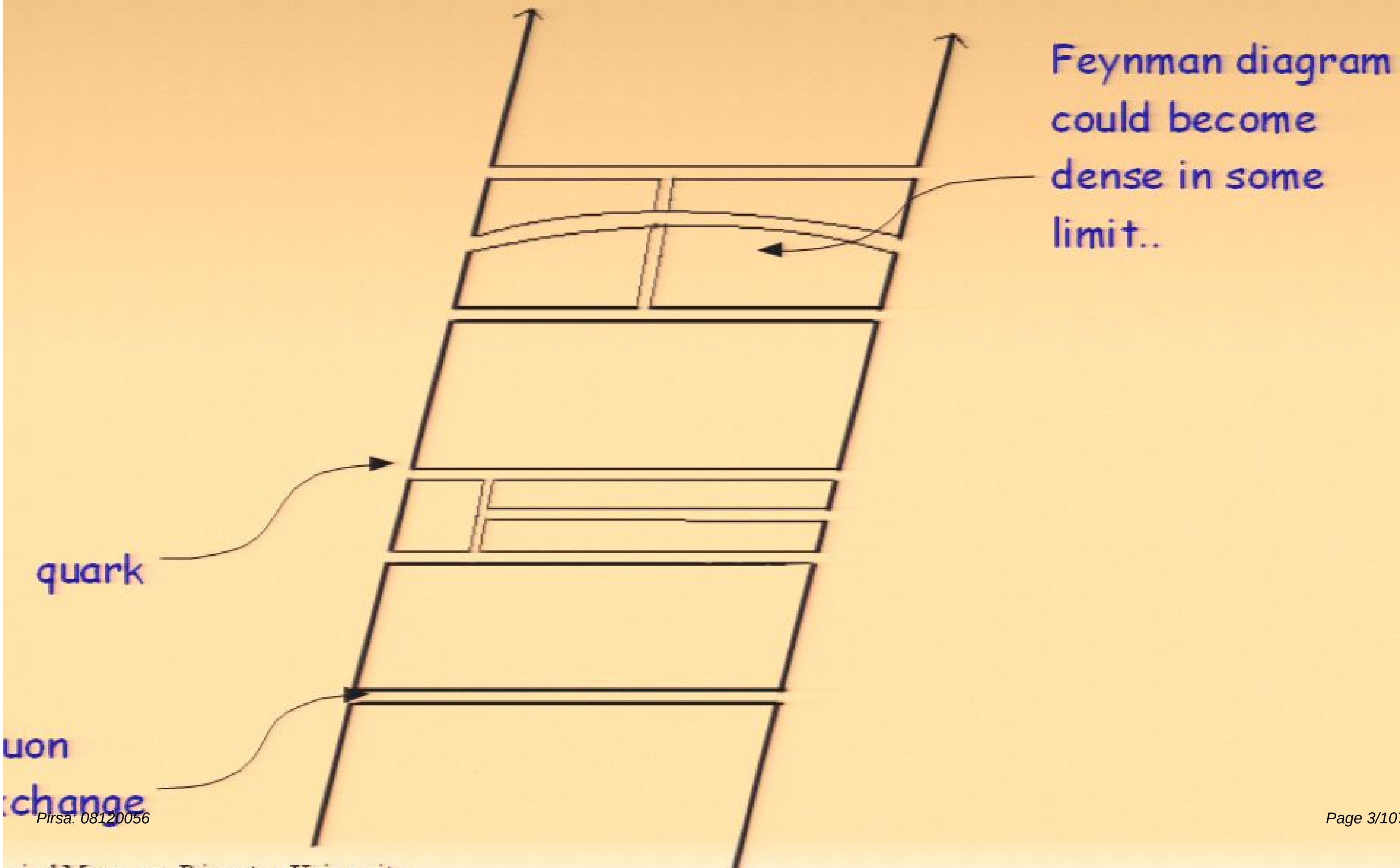
Gauge-Gravity duality
in
2+1 dimensions

Arvind Murugan
Princeton University

Work done with I.Klebanov, T.Klose arXiv:0809.3773
I.Klebanov (in progress)

['t Hooft 1974]

Gauge Gravity duality - origins



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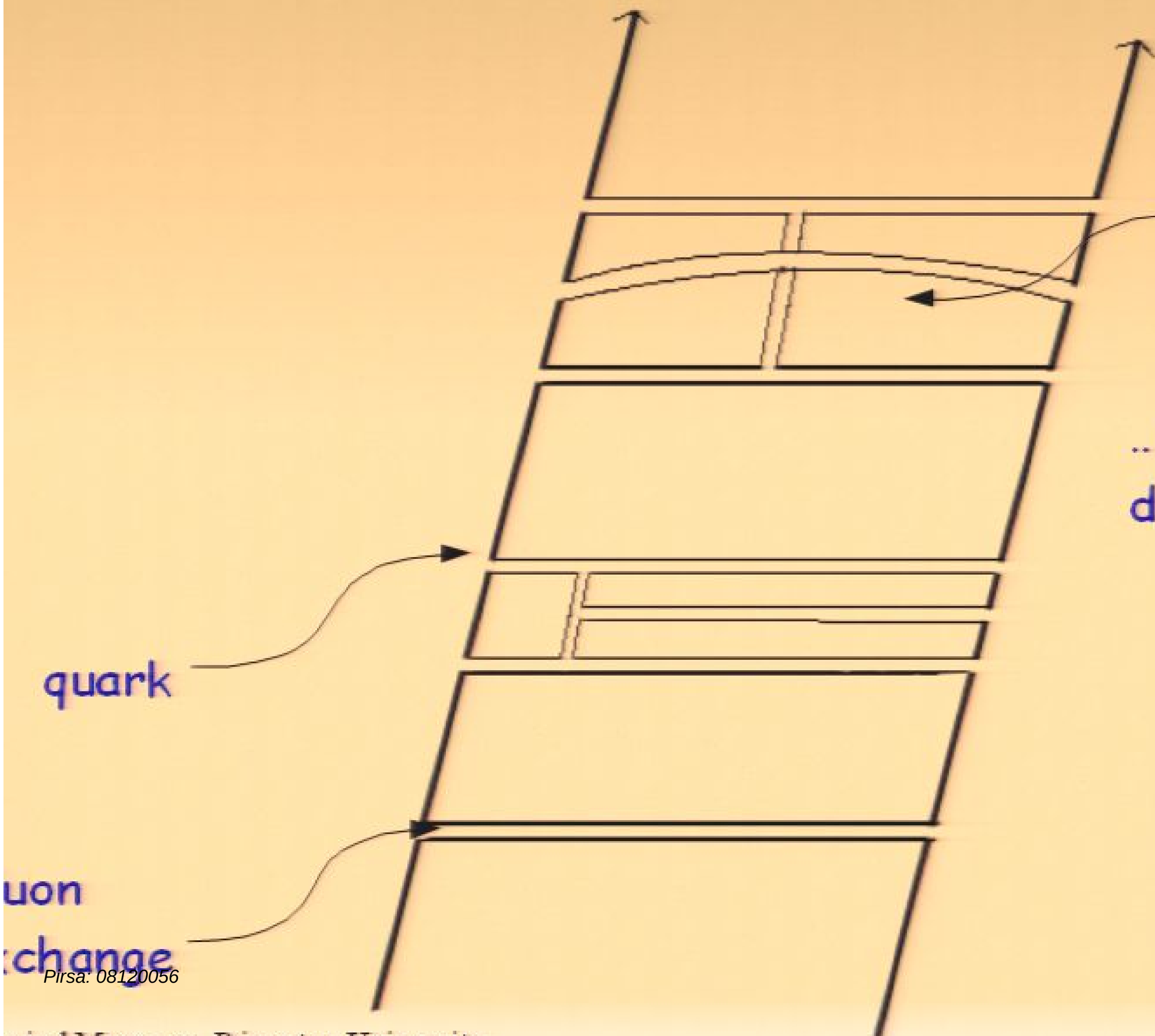

Feynman diagram could become dense in some limit..

.. would look like a two dimensional surface...

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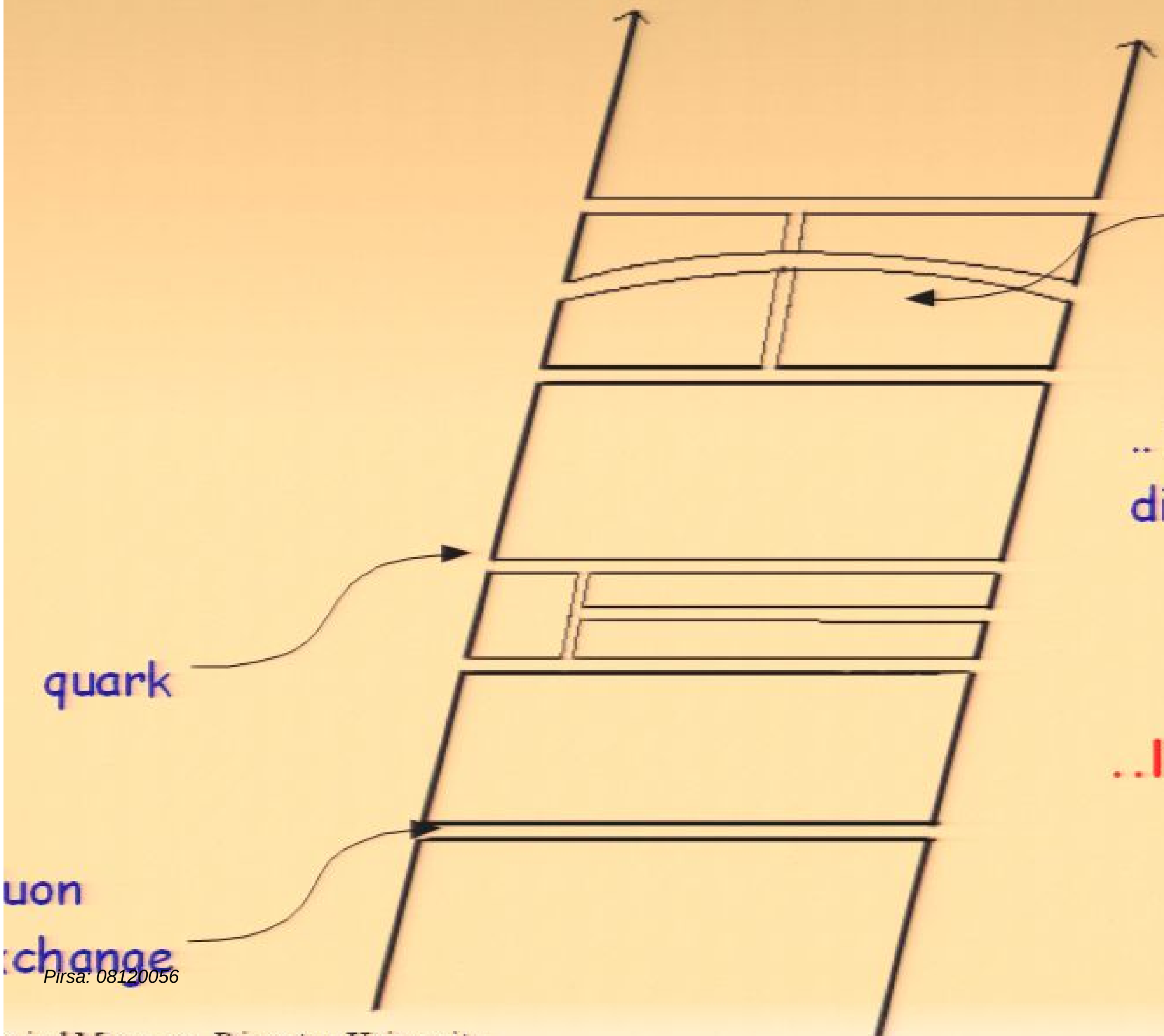

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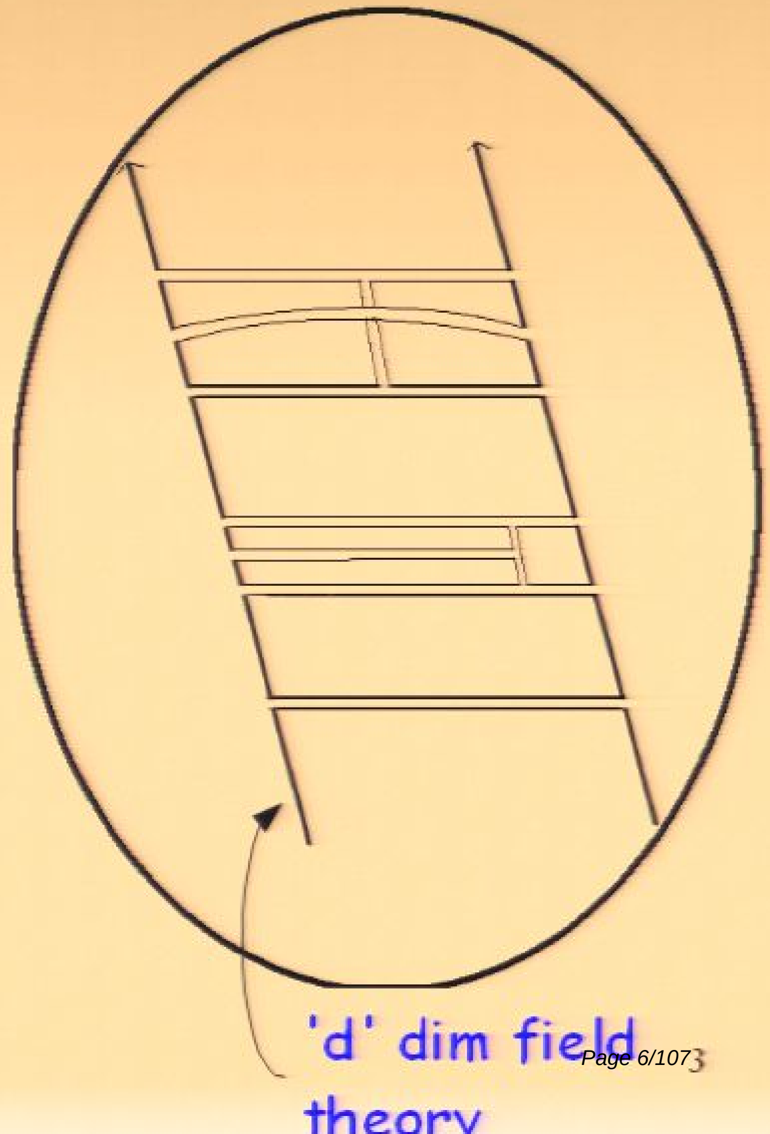
[Polyakov 1981]

Gauge Gravity duality - origins

Strings in non-critical dimensions generate an extra 'Liouville' dimension



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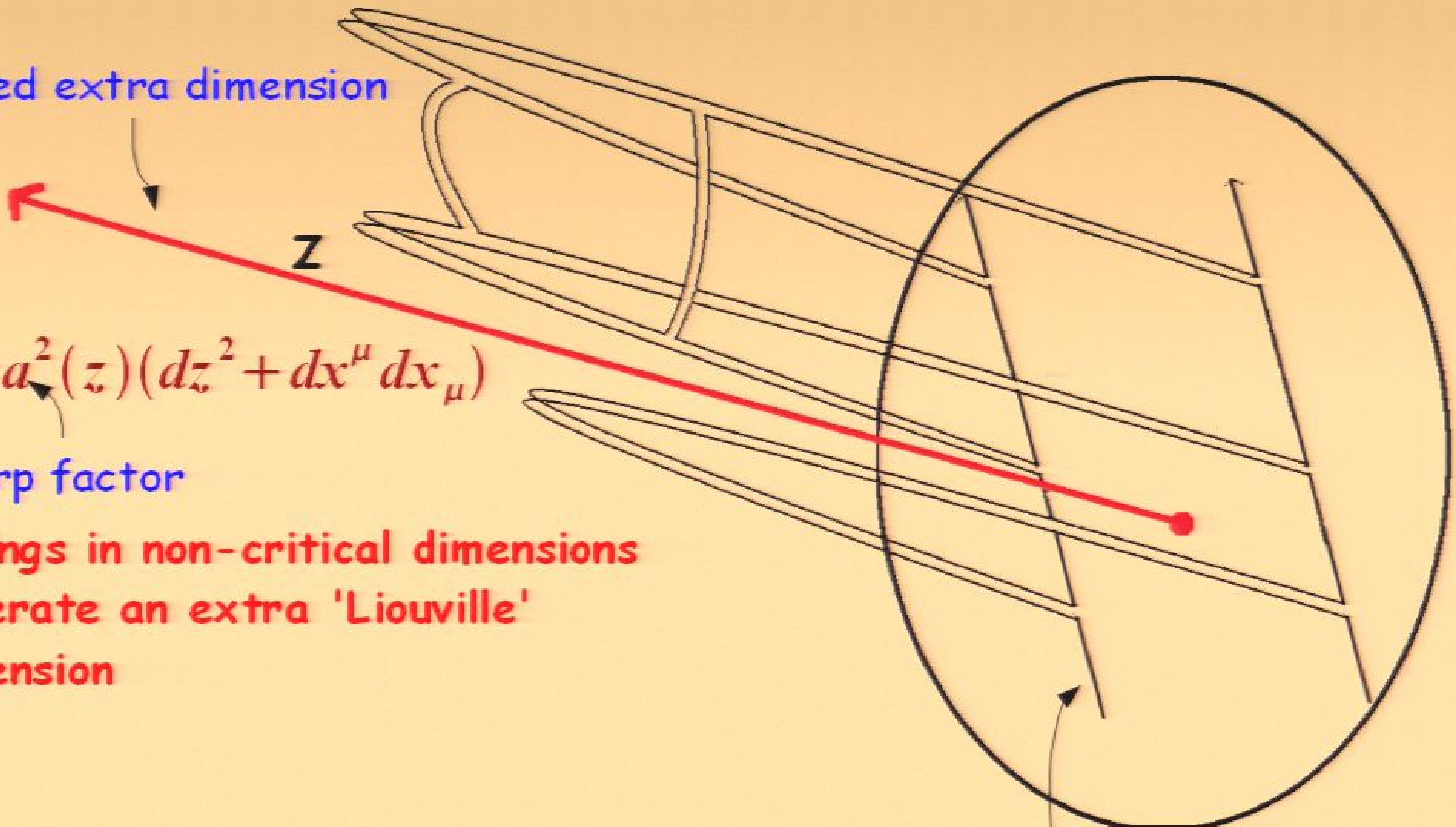

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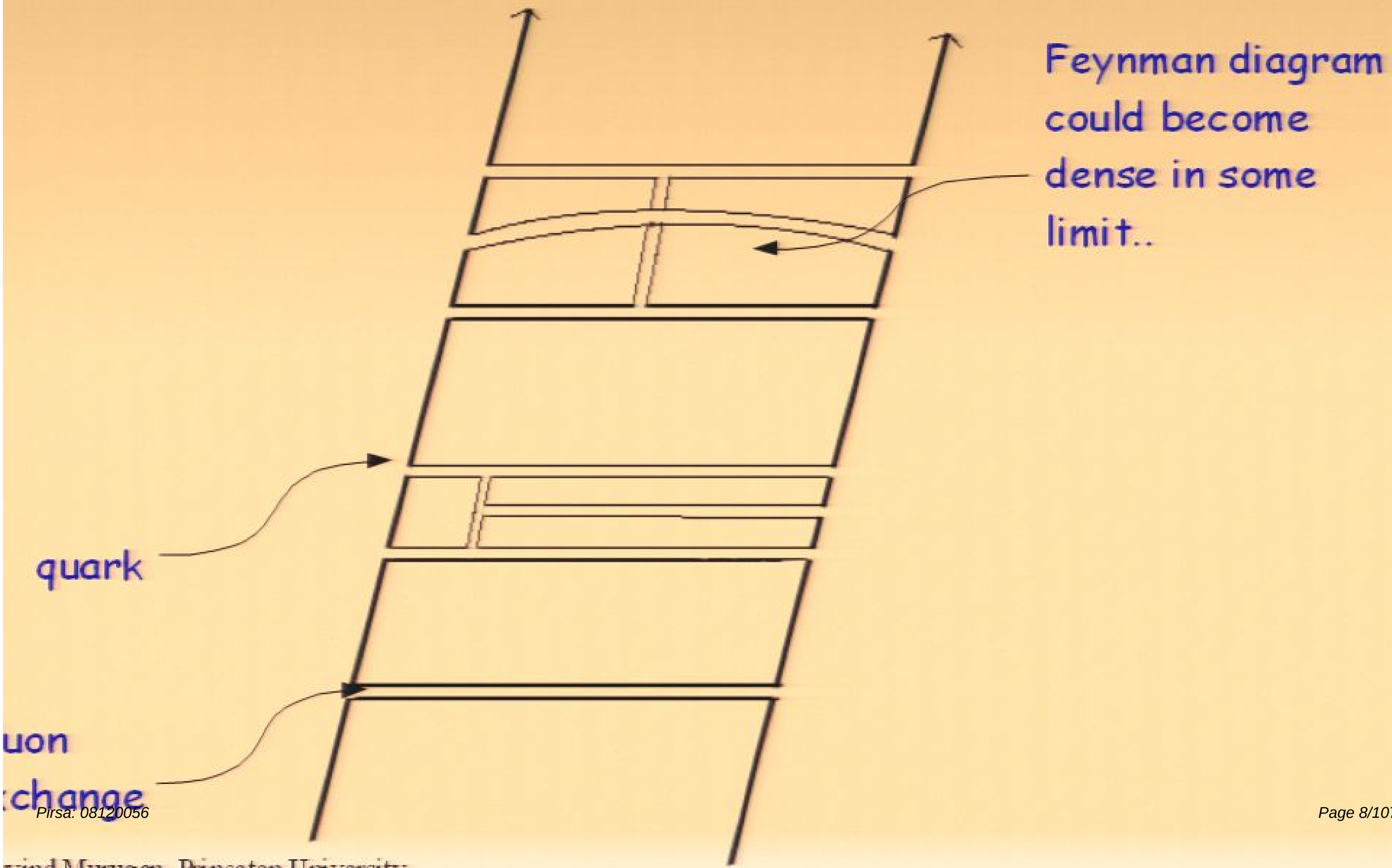

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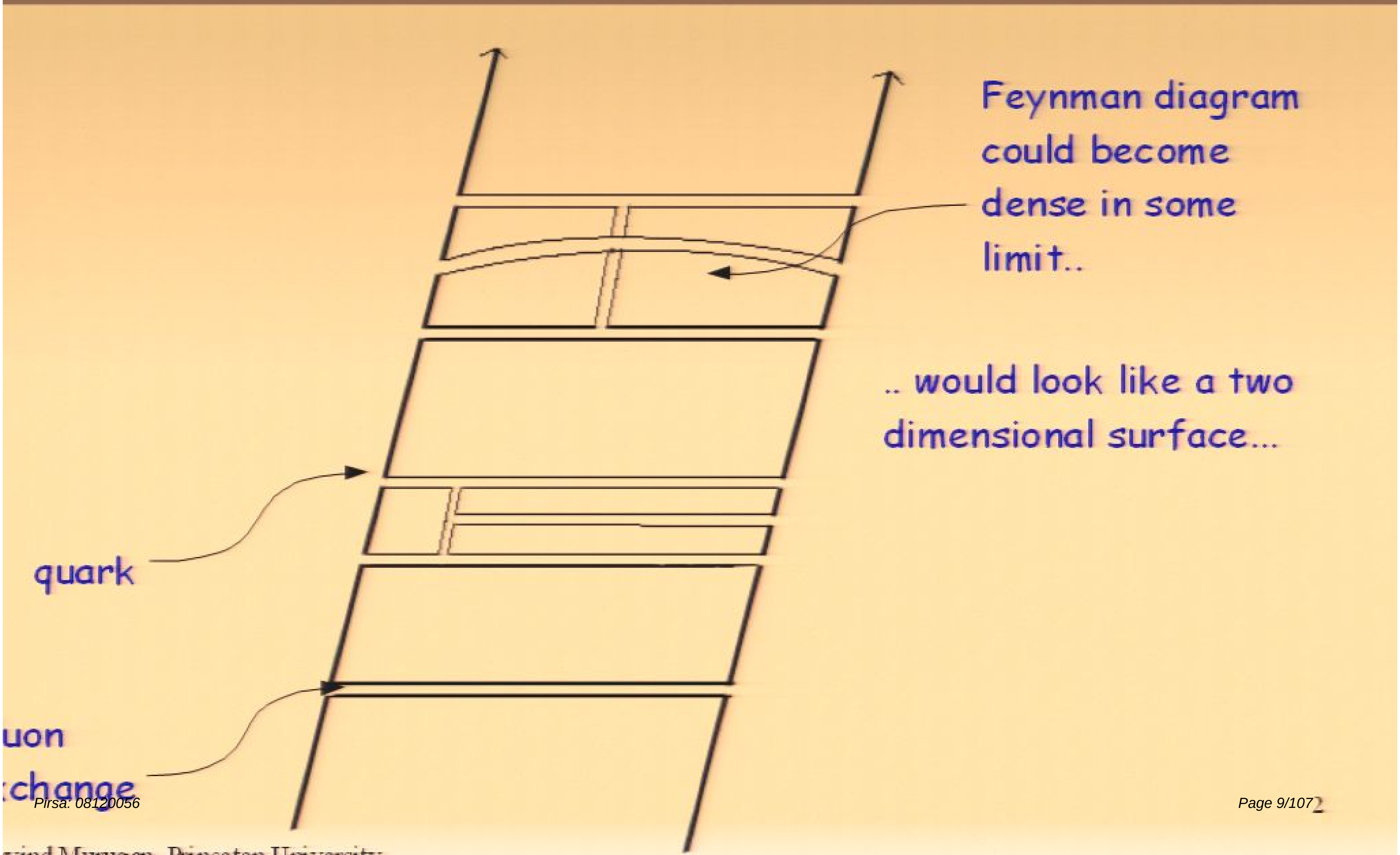

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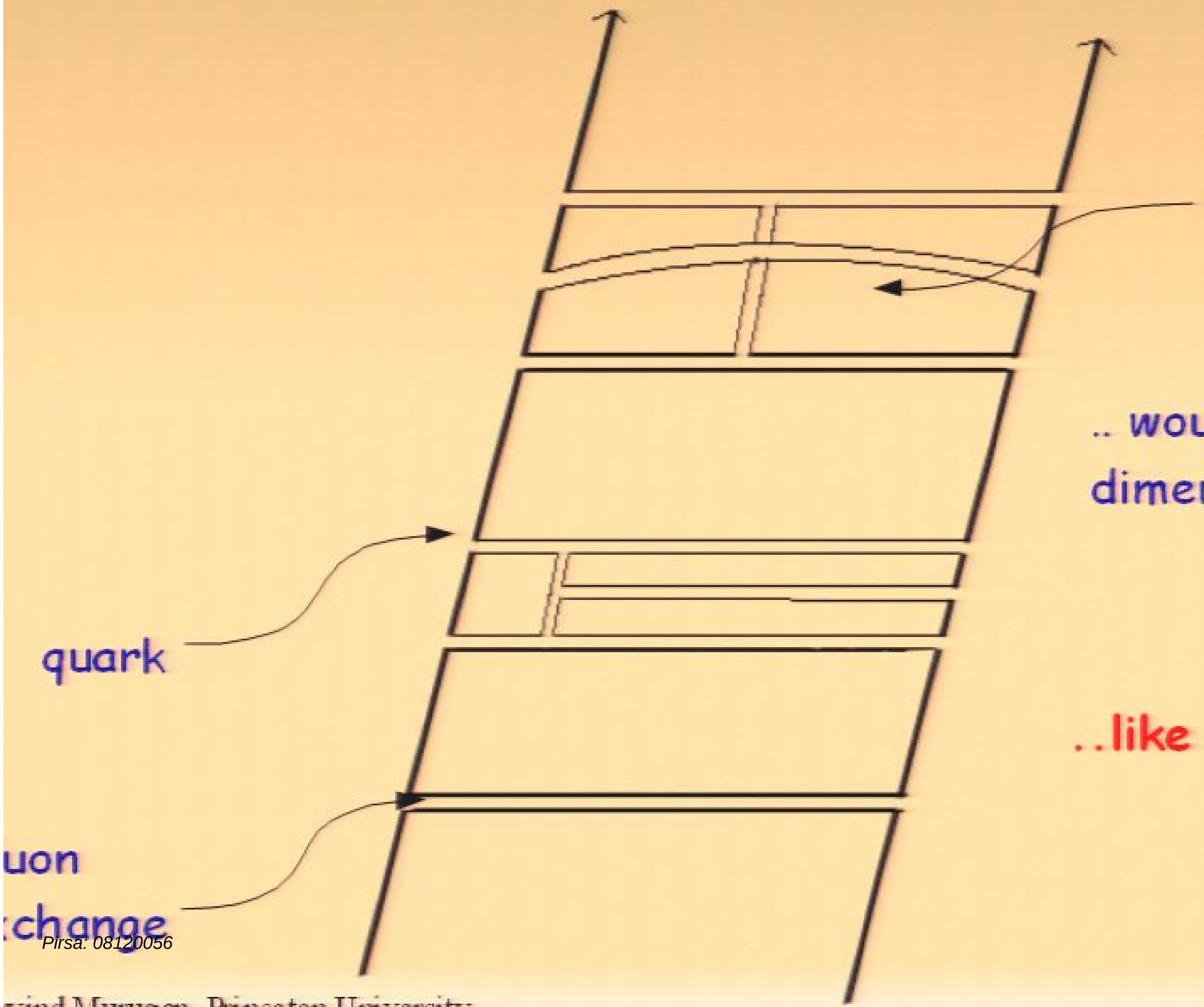

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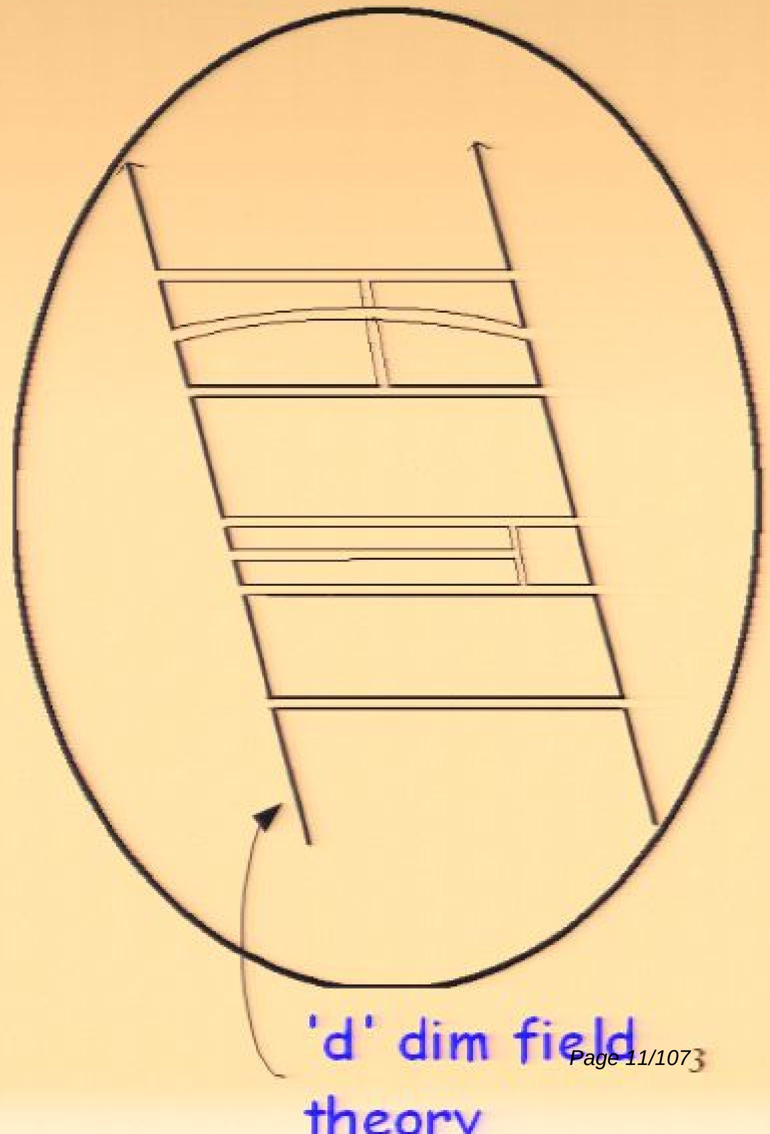

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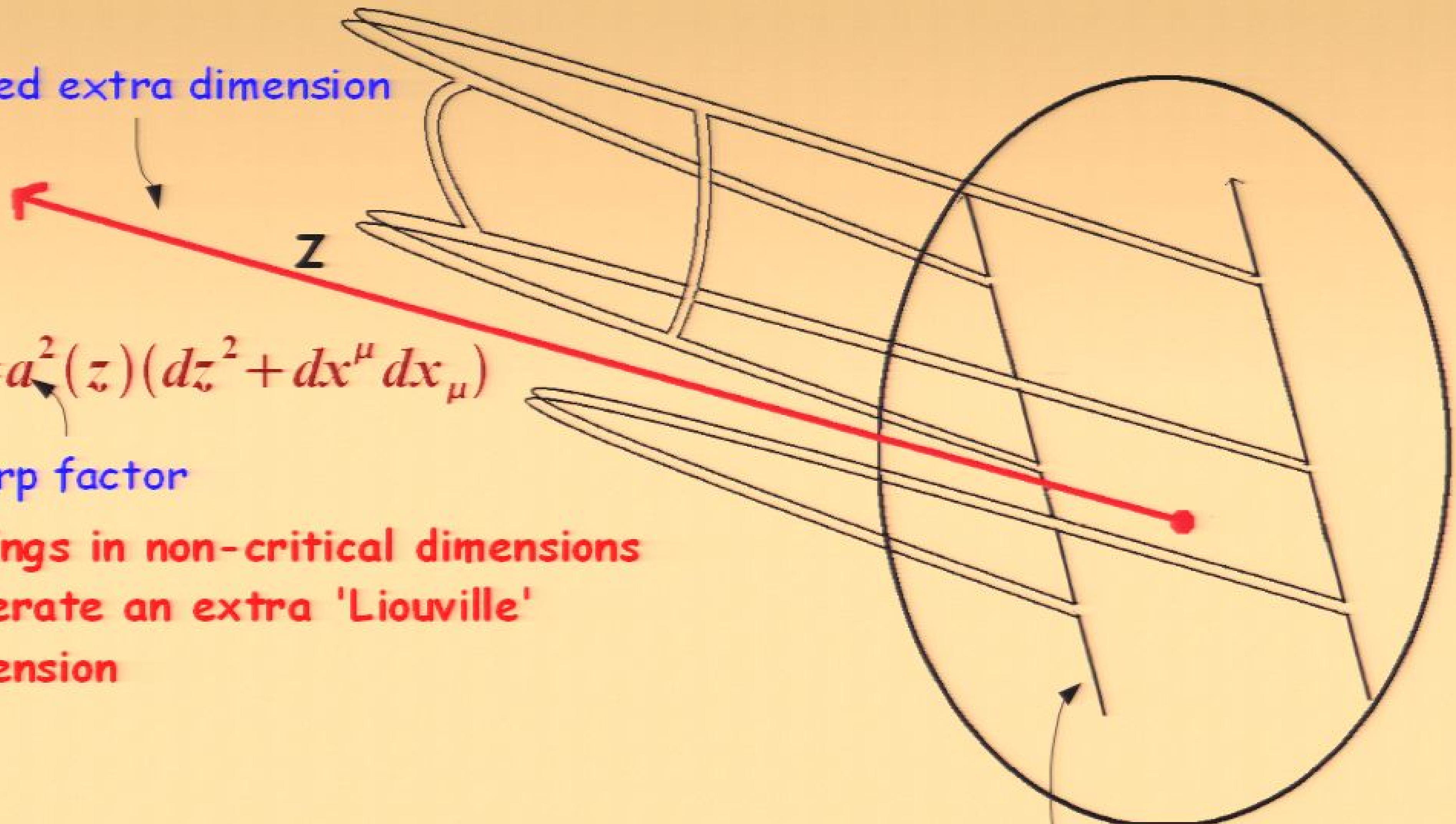

$s^2=a^2(z)(dz^2+dx^\mu dx_\mu)$

warp factor

Strings in non-critical dimensions
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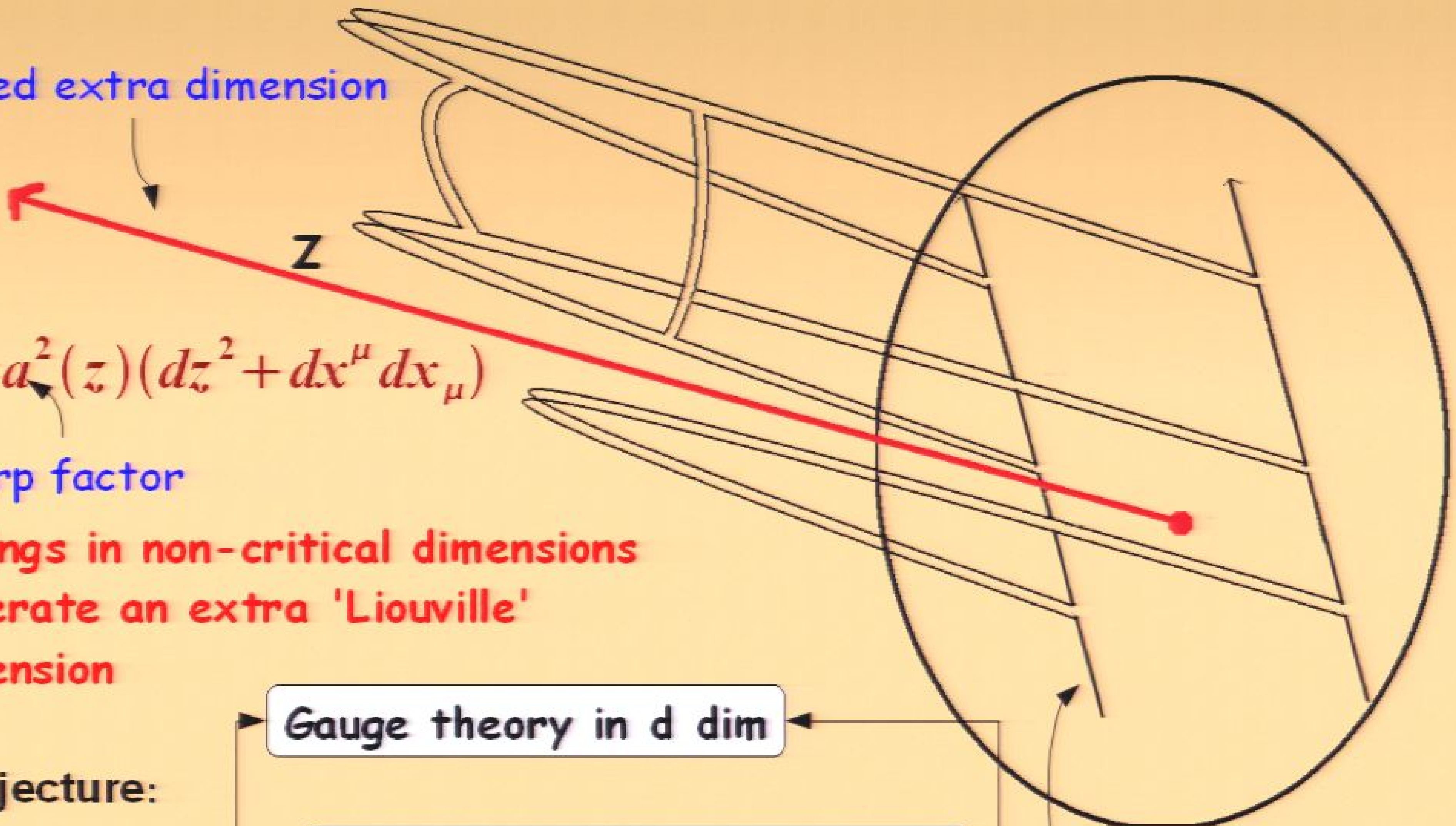
[Polyakov 1981]

Gauge Gravity duality - origins

'arped extra dimension



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Conjecture:

Gauge theory in d dim ⟷ Strings in d+1 warped dim

[Polyakov 1996]

'd' dim field
theory

vind Murugan, Princeton University

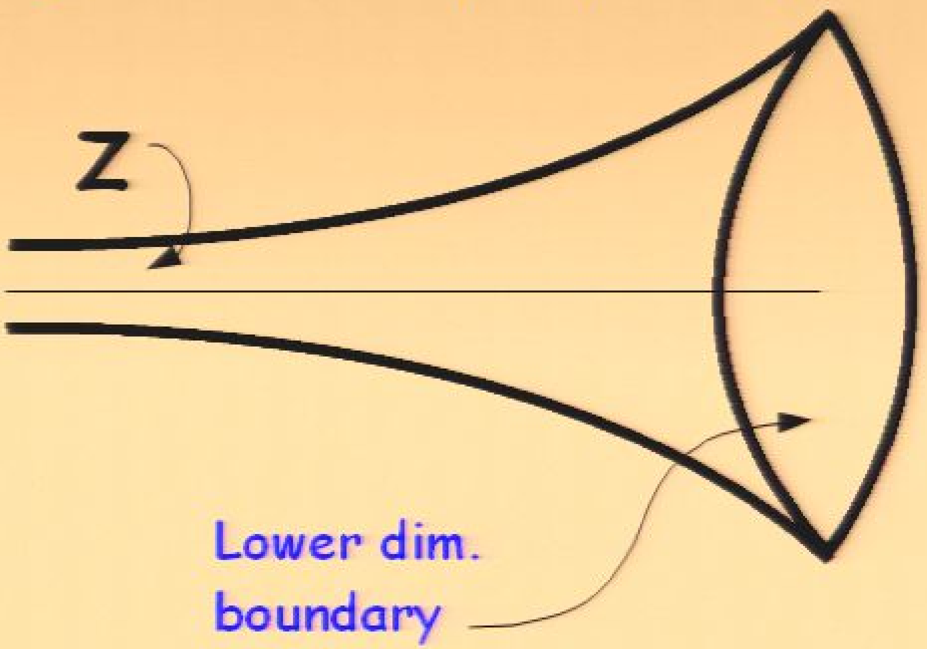
AdS / CFT duality

[Maldacena] [Gubser, Klebanov, Polyakov] [Witten]96

Earlier ideas realized concretely using branes and supersymmetry.

Anti de Sitter space

$$ds^2 = \frac{1}{z^2}(dz^2 + dx^\mu dx_\mu)$$



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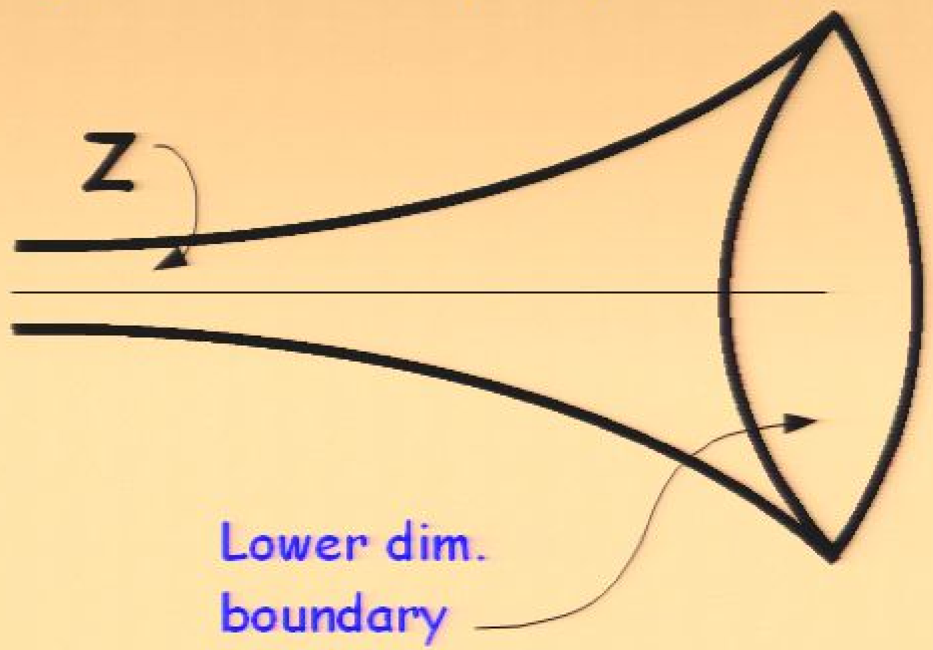

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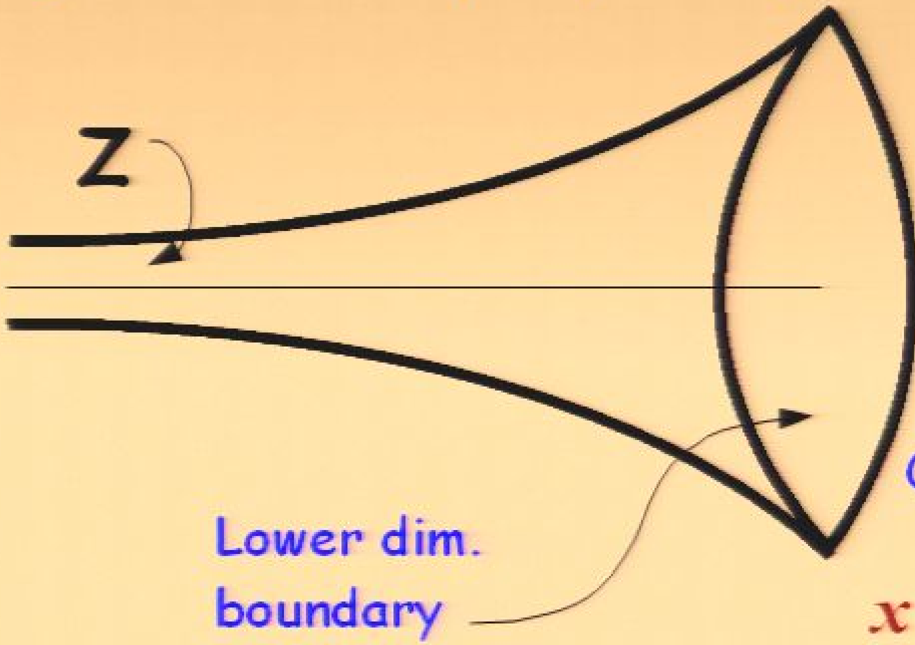

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Only a(z) which has dilation symmetry:

$$x \to \lambda x,\; z \to \lambda z \longrightarrow ds^2 \to ds^2$$

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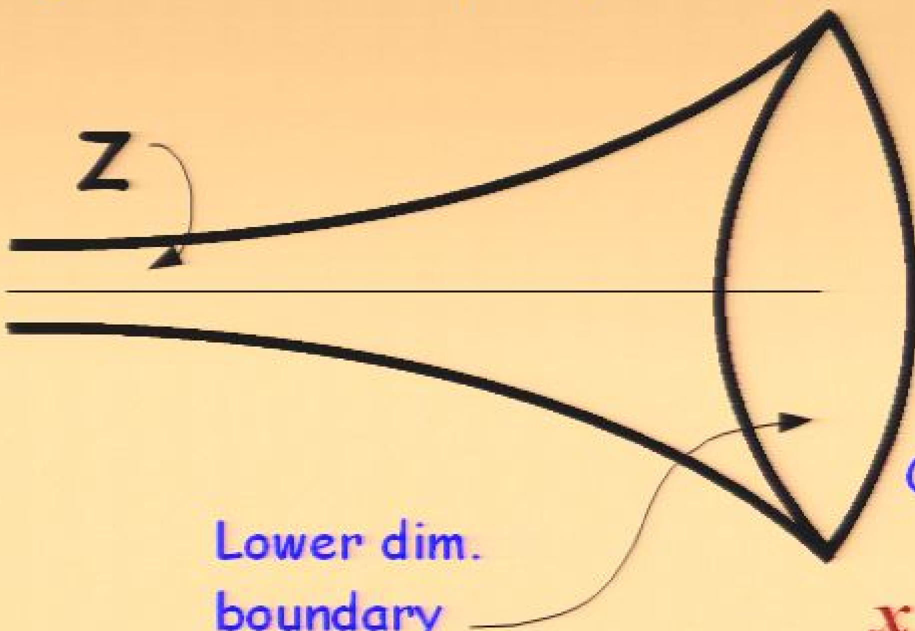

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$$a^2(z) = \frac{1}{z^2} + \frac{a_1}{z^n} + \cdots$$

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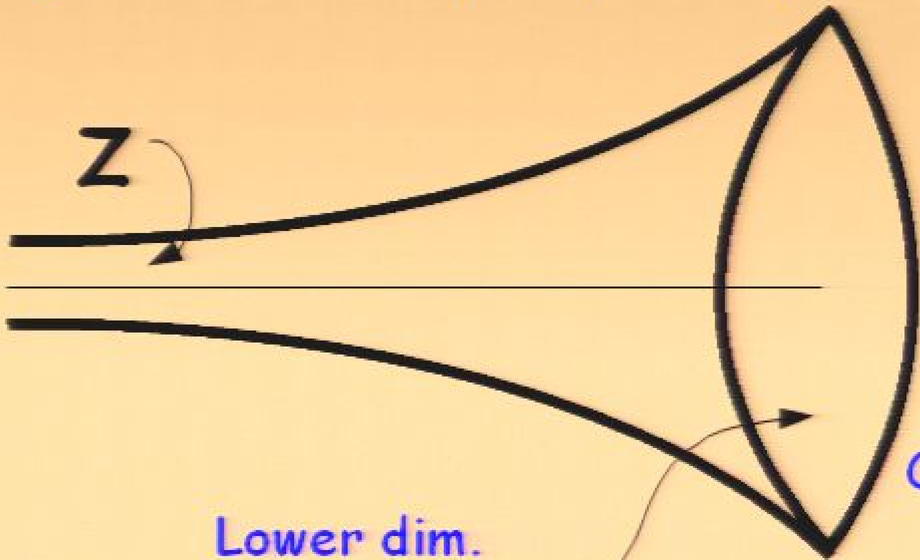

Lower dim. boundary

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Introduces length scale
Non-trivial RG flow

AdS / CFT duality

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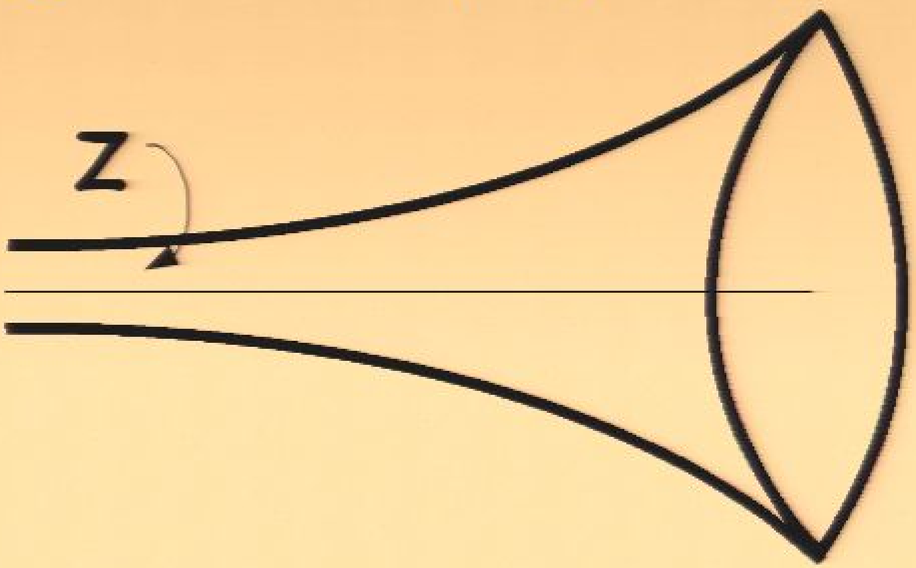
$$AdS_4 \times X^7$$



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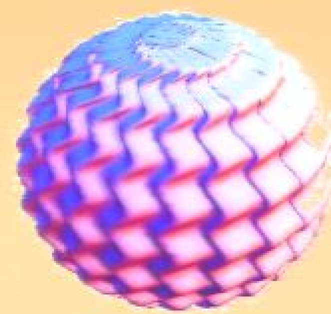

Superstrings require 10 or 11 dimensions (M theory)

internal space decides details of dual field theory

- Gauge symmetry
- Global symmetry
- Supersymmetry
- Matter content

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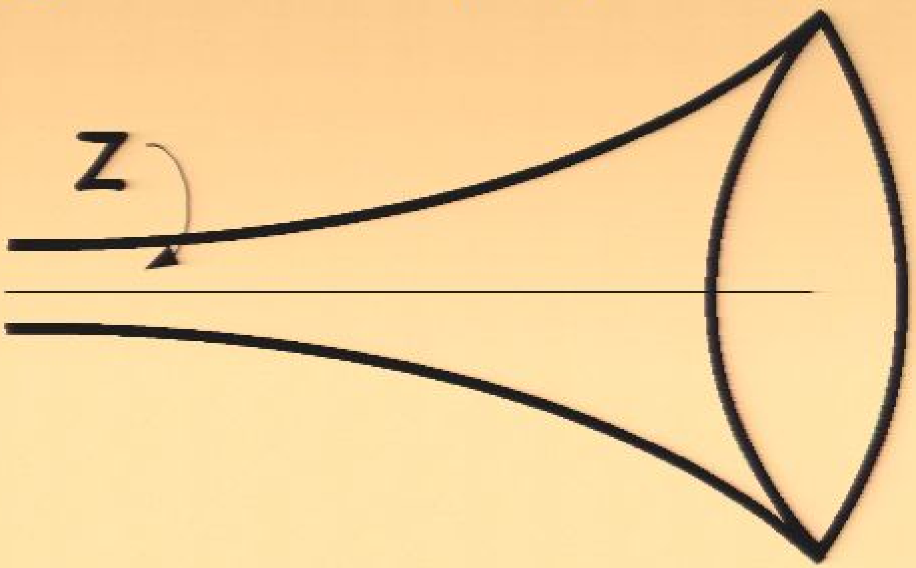

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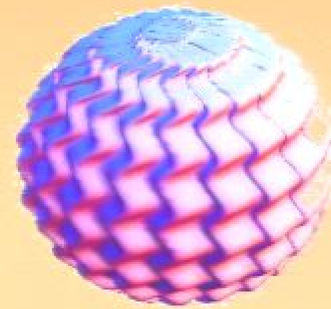

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Maximally Supersymmetric Duals

[Aharony, Bergman, Jafferis, Maldacena 2008]

$$AdS_4 \times S^7$$

What is the 2+1 field theory dual?

Most (super) symmetric space

Maximally Supersymmetric Duals

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Gauge group: $U(N) \times U(N)$

gauge fields not dynamical.

$$Tr\, F \wedge * F$$

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$$W_i \quad (N, \overline{N}) \longrightarrow W_i T(x) \quad (\overline{N}, N)$$

Minima of Gauged SUGRA

Spaces like $AdS_4 \times S^7$ were studied extensively in the 80s...

.. through an effective theory on AdS_4

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Come with varying amounts of SUSY

Arvind Murugan, Princeton University

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[Warner 1983]

.. but the potential has 5 other extrema (with some min. symmetry).

EMAINING SYMMETRY IS AT LEAST SU(3)

CALAR, DOSCALAR MIXTURE	COSMOLOGICAL CONSTANT, Λ	REMAINING GROUP SYMMETRY	REMAINING SUPRSYMMETRY
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S	$-2\times 5^{3/4}g^2$	$SO(7)^+$	None
M	$-7.1916g^2$ approx.	G_2	None
P	$-6g^2$	$SU(4)^-$	None
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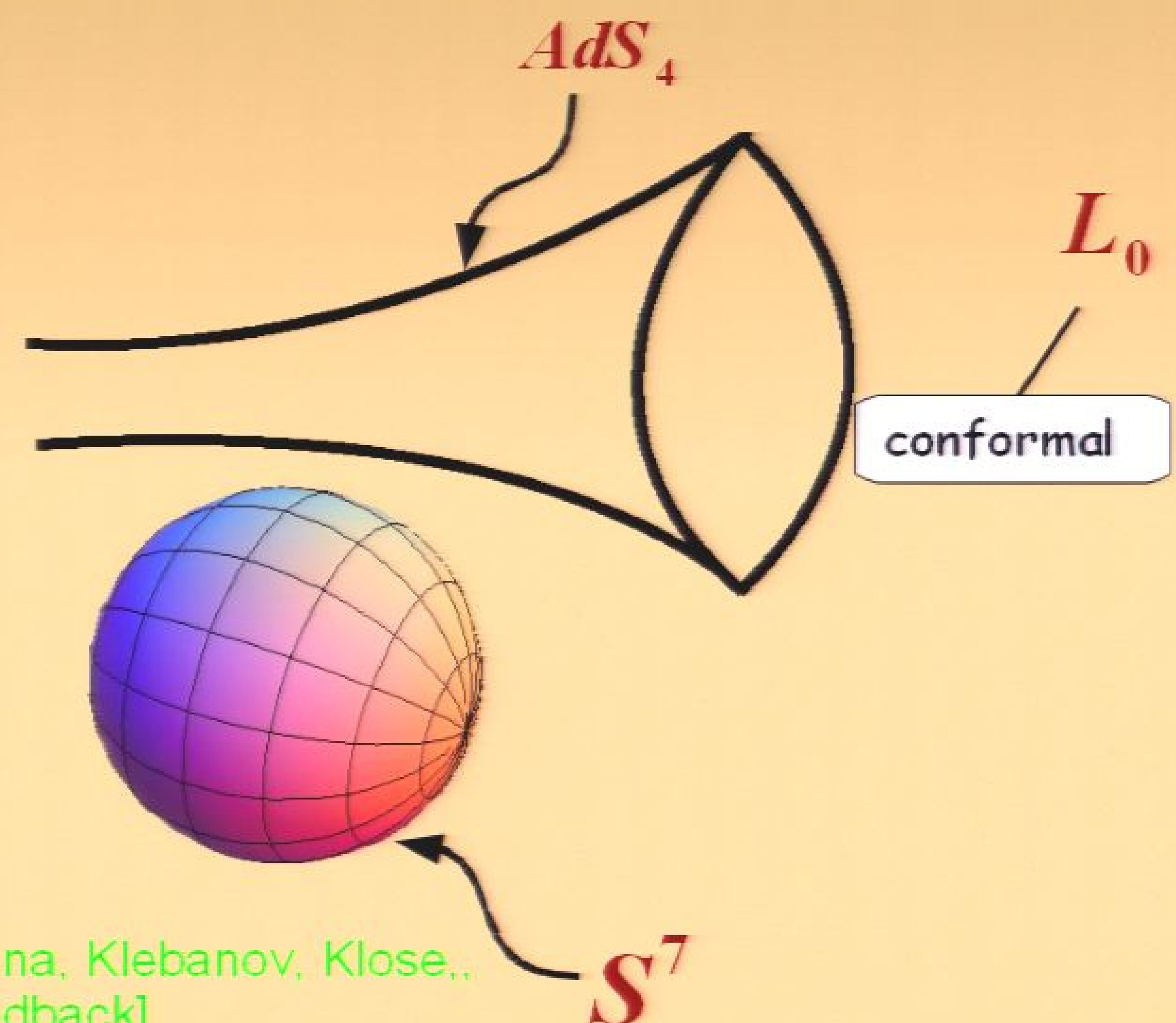
[W

na (wi

What is the gauge dual of this low SUSY vacuum?

Adding a mass term



[Benna, Klebanov, Klose,, Smedback]

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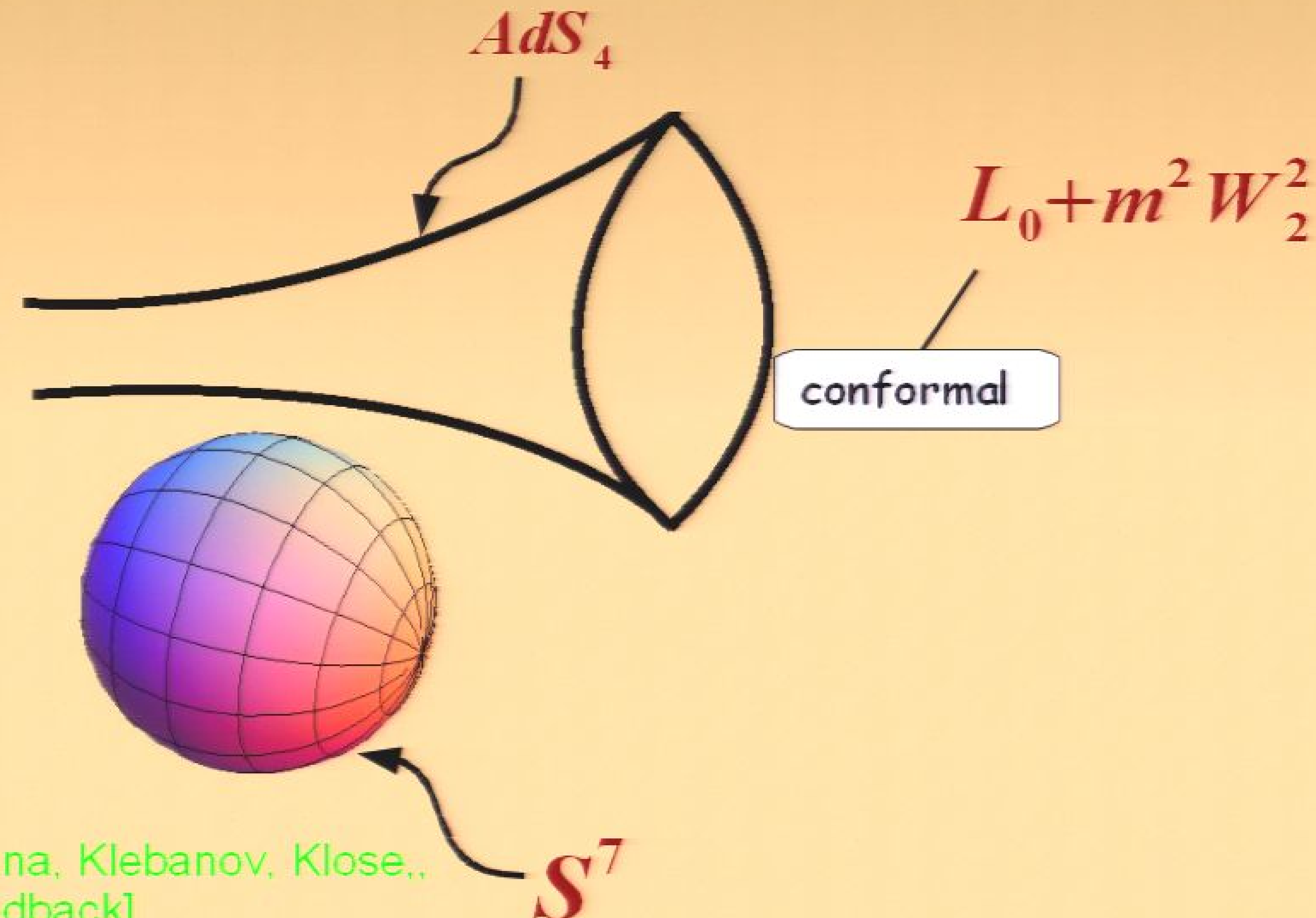

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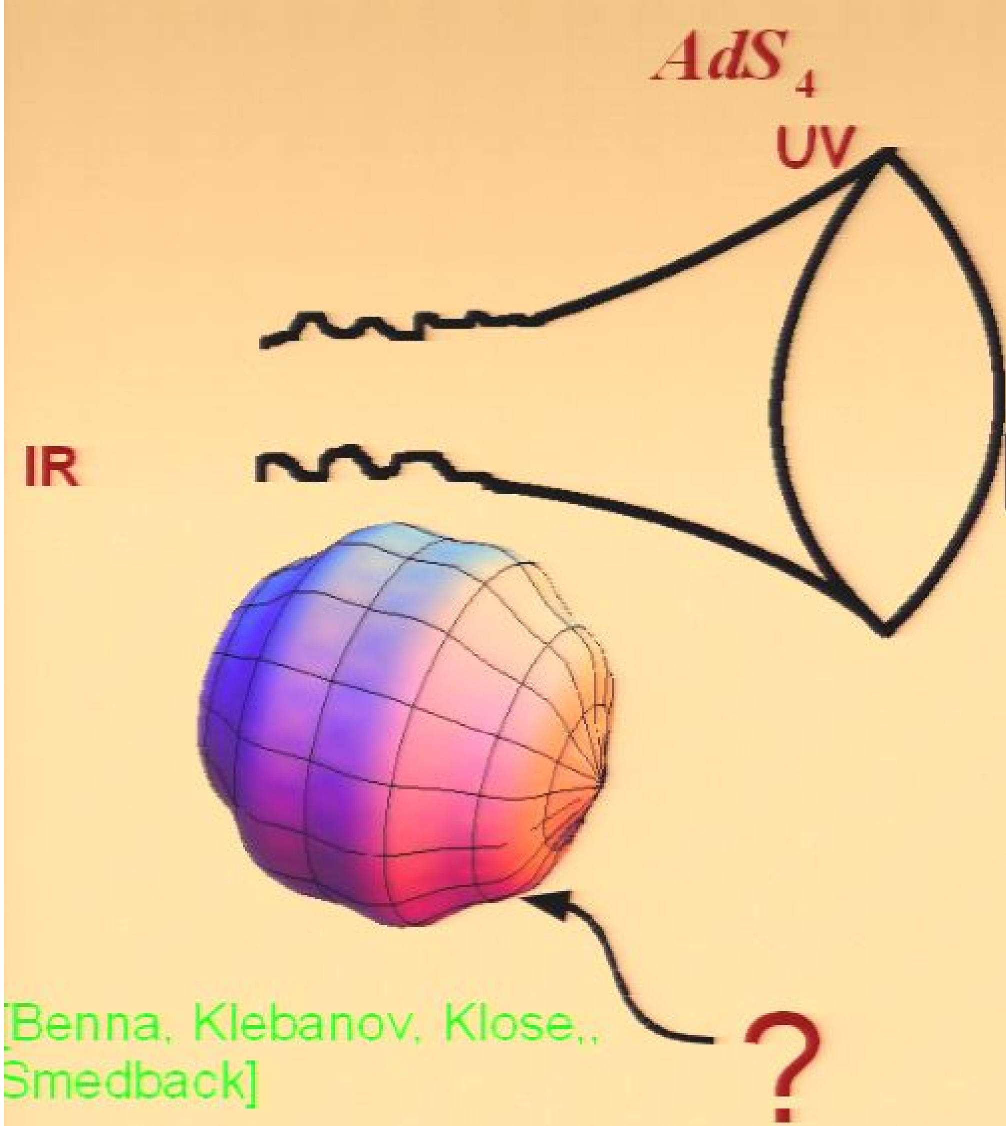


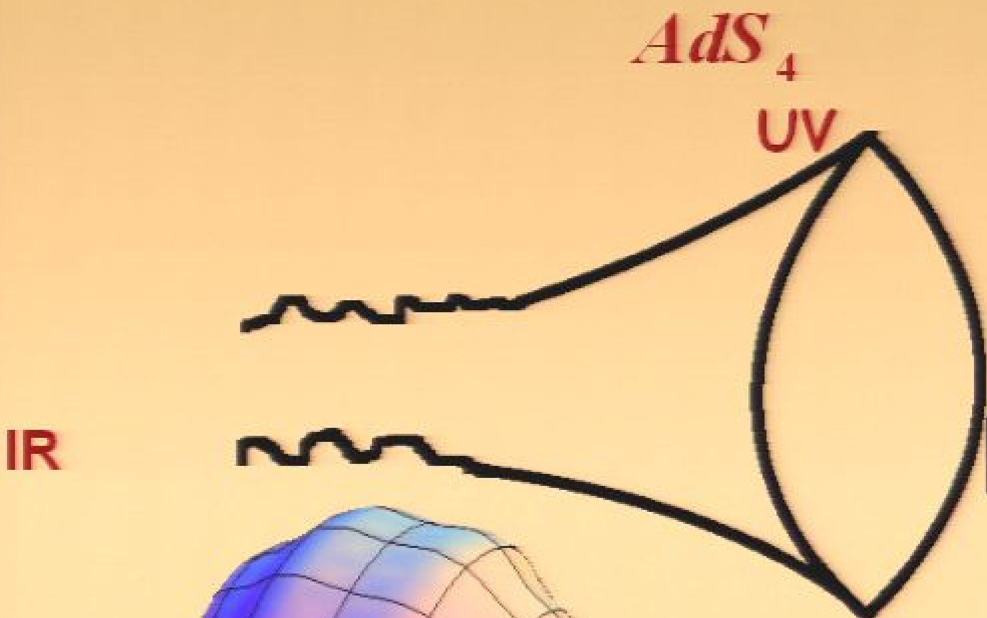
[Benna, Klebanov, Klose,, Smedback]

$$L_0 + m^2 W_2^2$$

conformal

- Breaks conformality
- Induces RG flow
- Does not affect UV (high energies)
- Changes IR physics
- Breaks parity

Adding a mass term



Needs monopole operator for gauge invariance

$$L_0 + m^2 W_2^2$$

conformal

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[Benna, Klebanov, Klose,, Smedback]

Field theory analysis

$$W \sim Tr(Z_1 W_1 Z_2 W_2 - Z_1 W_2 Z_2 W_1) \; + m W_2^2$$

Write in terms of Zs using monopole opeartors for convenience..

$$W \sim T^2 \, Tr(Z_1 Z_3 Z_2 Z_4 - Z_1 Z_4 Z_2 Z_3) + m T Z_4^2$$

$\Rightarrow$ $Z_4 \sim T \, \epsilon^{abc} Z_a Z_b Z_c$ Integrating out massive field..

$$\boxed{W \sim T^3 (\epsilon^{abc} Z_a Z_b Z_c)^2}$$

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SU(3) symmetric

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Integrating out massive field..

$$W \sim T^3 (\epsilon^{abc} Z_a Z_b Z_c)^2$$

SU(3) symmetric

Sextic superpotential.. each Z must have dimension 1/3 for W to be marginal.

$$\Delta(Z_a) = \frac{1}{3}$$

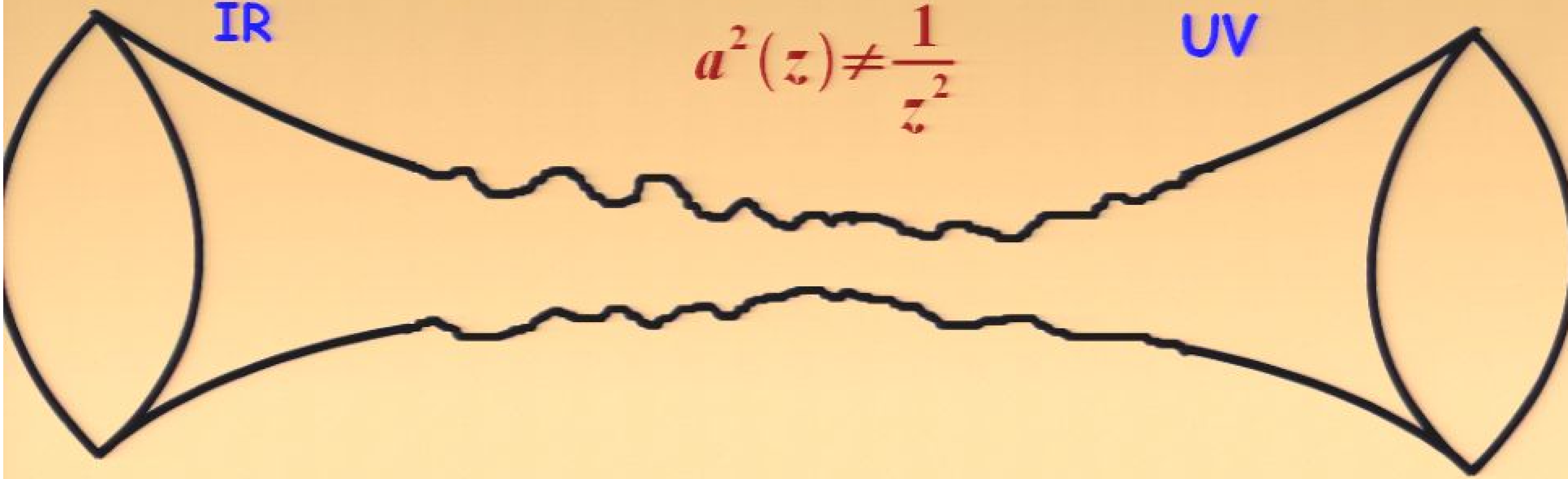
RG Flow

[Nicolai, Warner], [Corrado, Pilch, Warner] [Ahn,Rey]

IR

$$a^2(z) \neq \frac{1}{z^2}$$

UV

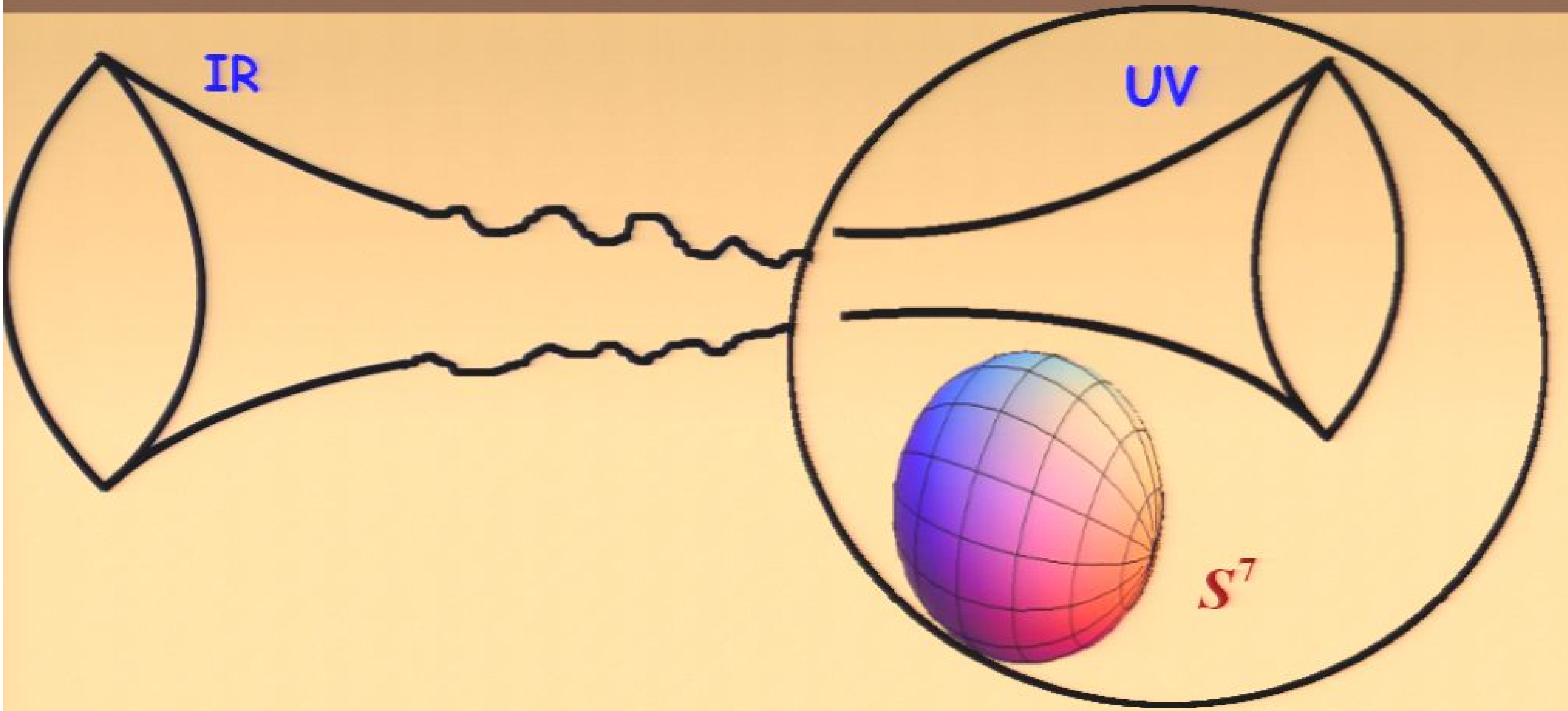


$$a^2(z) = \frac{1}{z^2} \qquad \longleftarrow \qquad a^2(z) = \frac{1}{z^2}$$

A background with two AdS throats had been already been worked out.

RG Flow

[Nicolai, Warner],
[Corrado, Pilch, Warner]
[Ahn,Rey]



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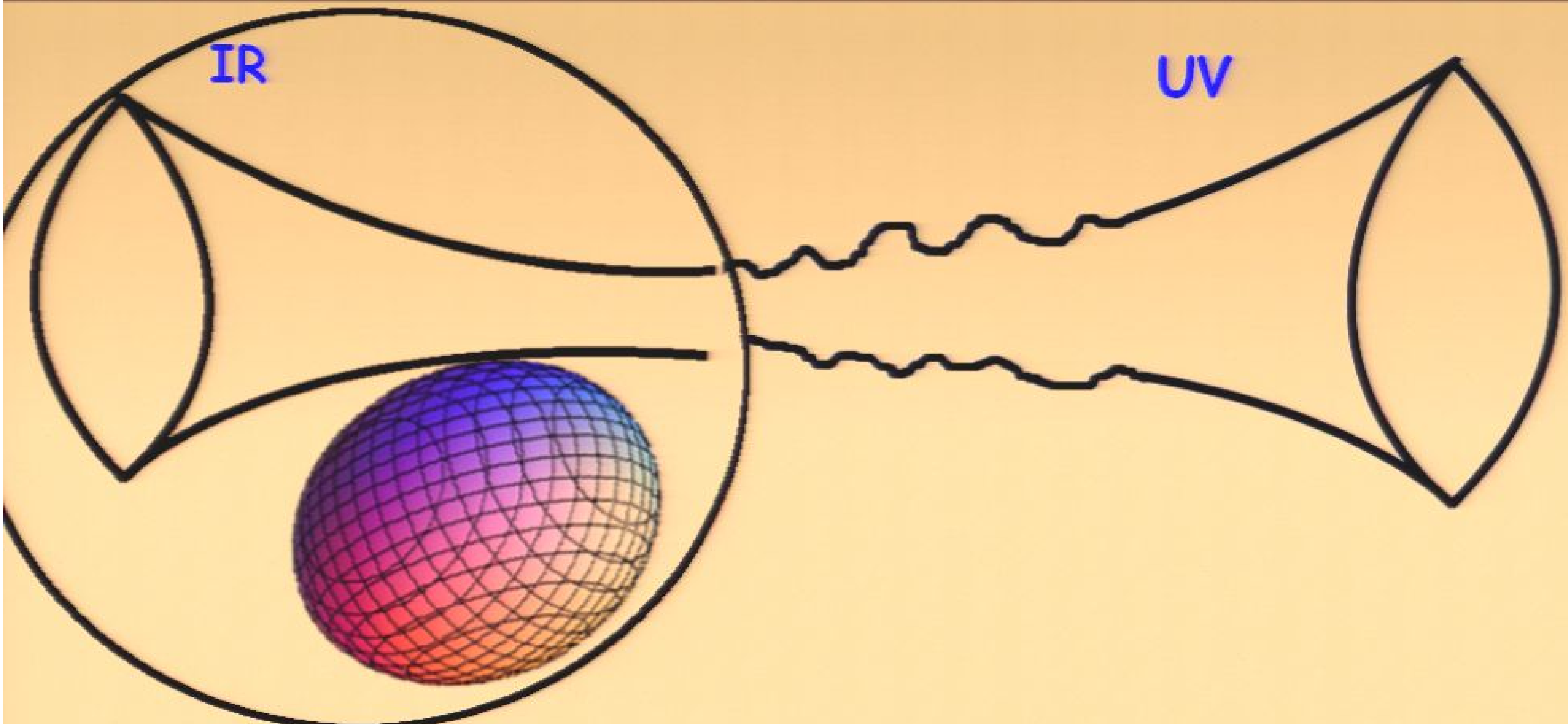

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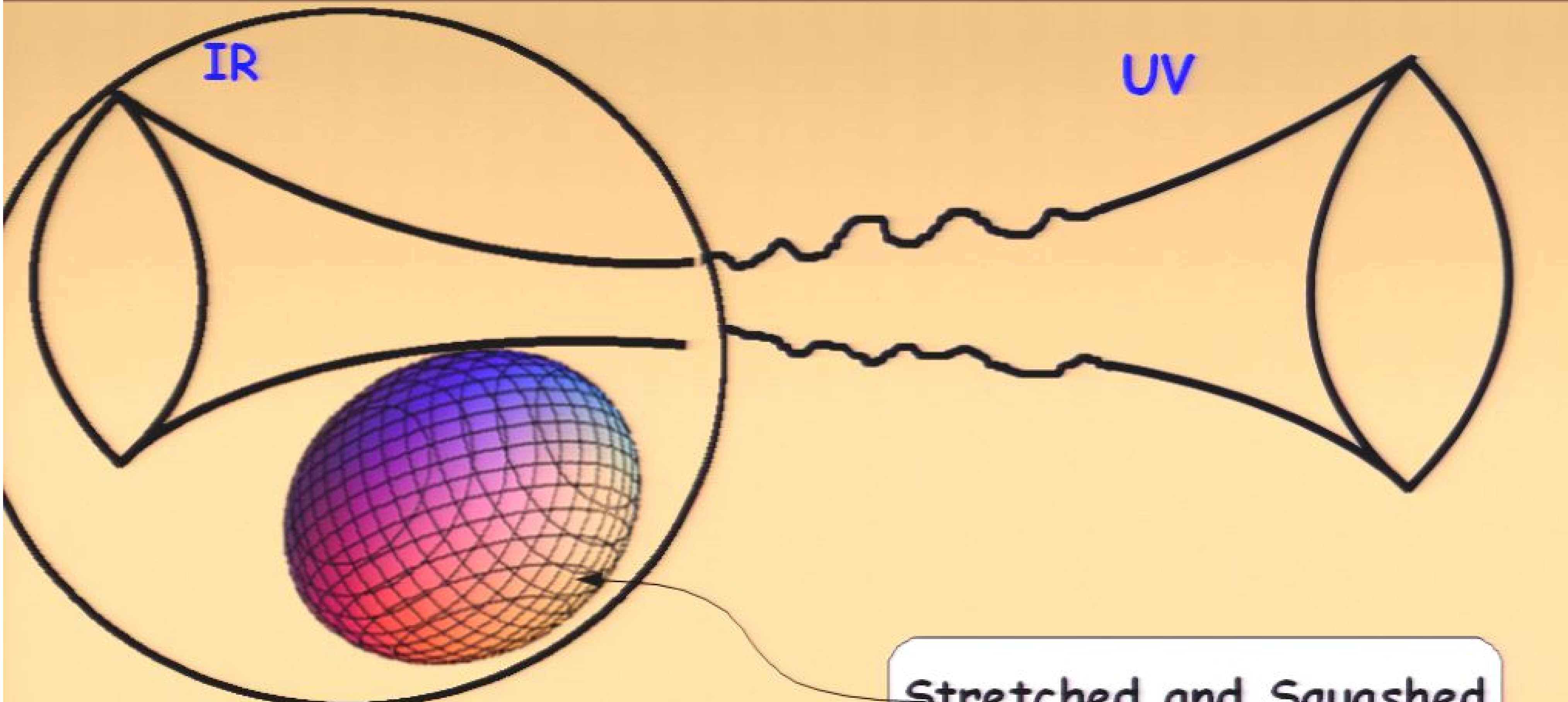

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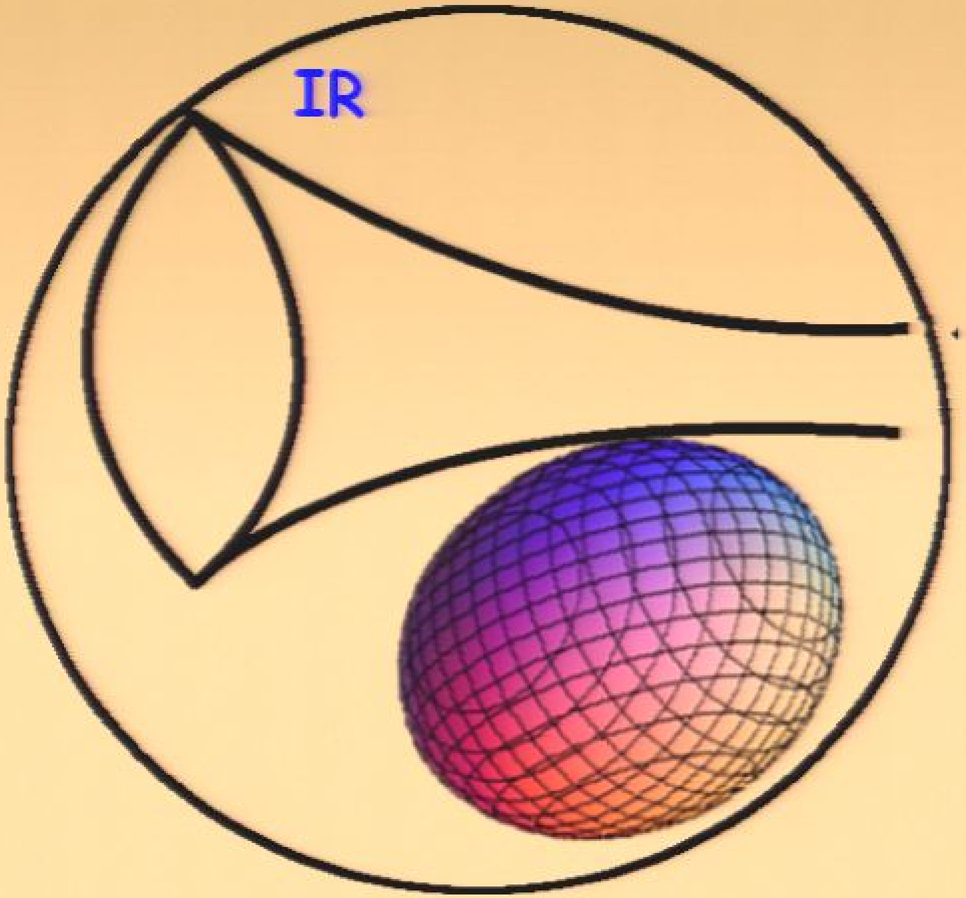

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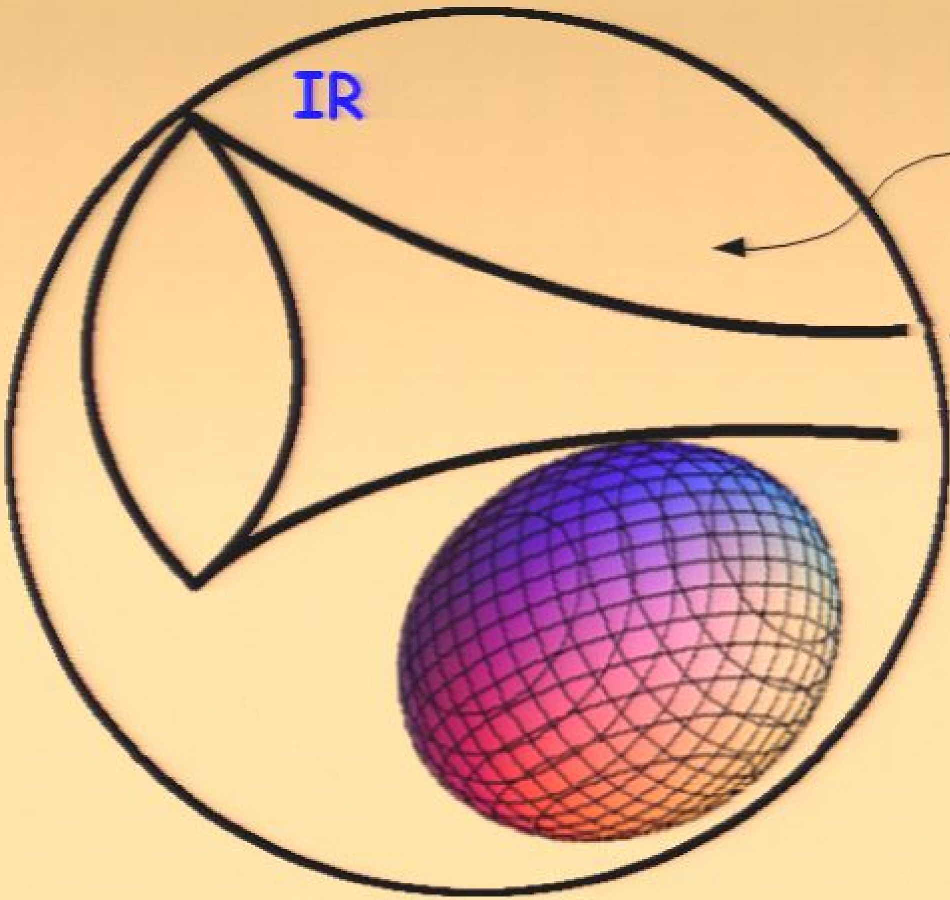

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AdS metric is warped by function 'h' on internal space

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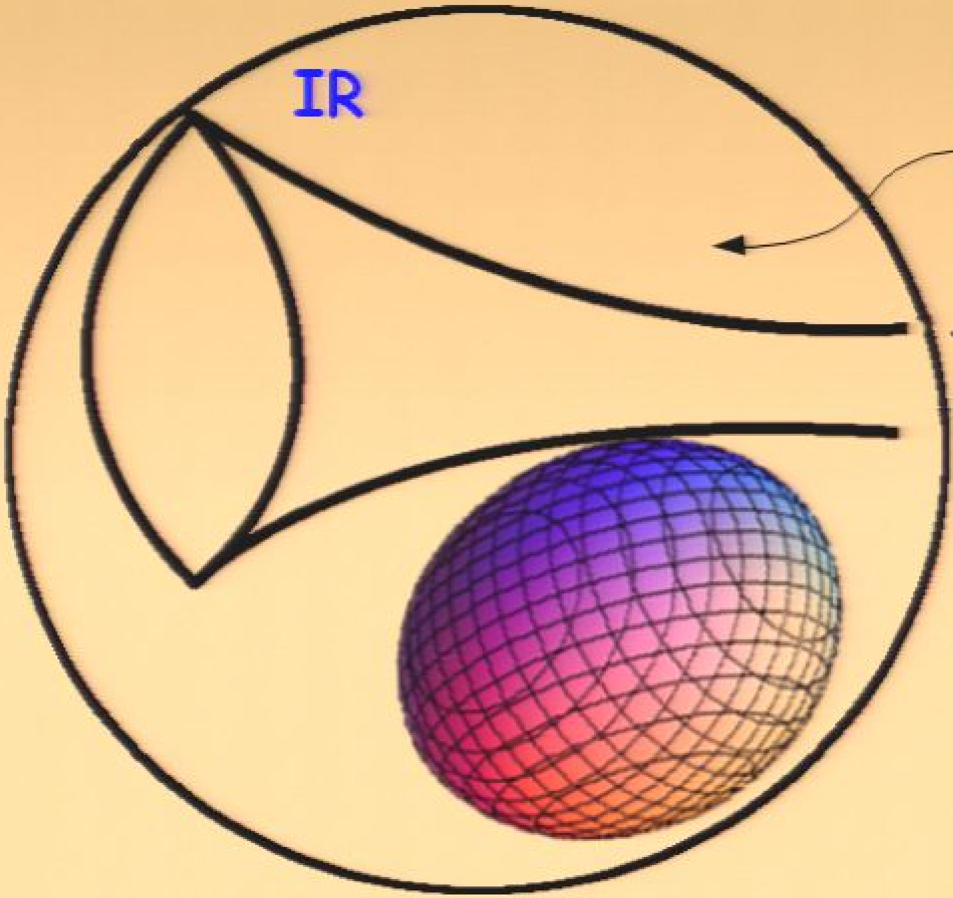

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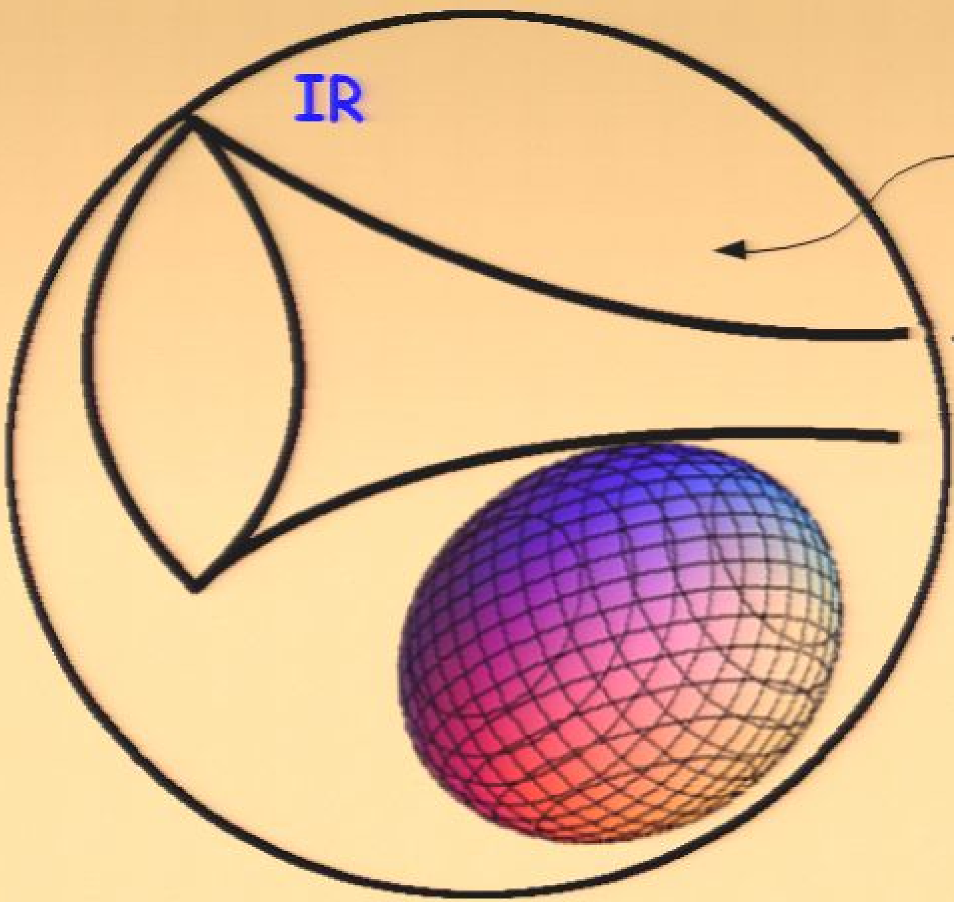

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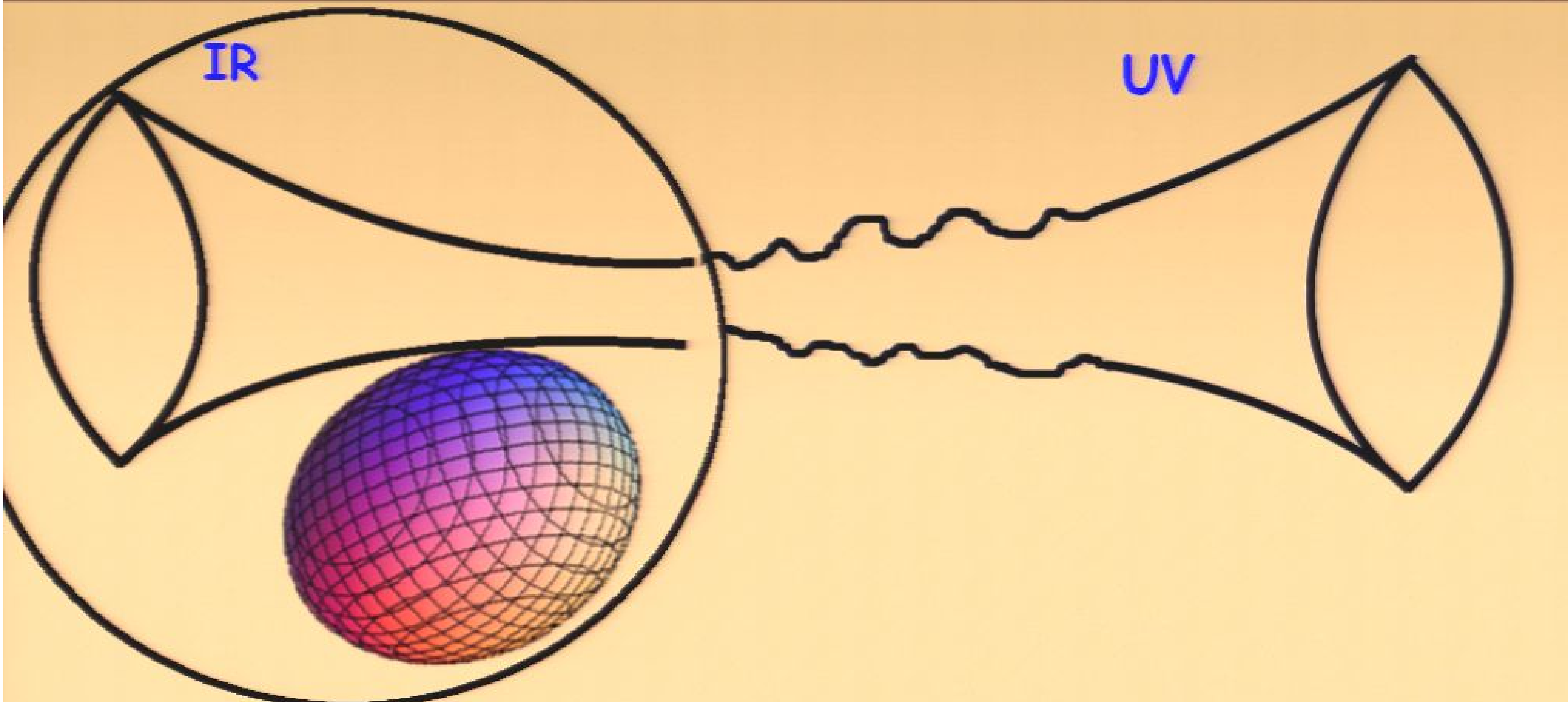

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SU(3) x U(1) symmetry

Field theory analysis

$$W \sim Tr(Z_1 W_1 Z_2 W_2 - Z_1 W_2 Z_2 W_1) + m W_2^2$$

Write in terms of Zs using monopole opeartors for convenience..

$$W \sim T^2\, Tr(Z_1 Z_3 Z_2 Z_4 - Z_1 Z_4 Z_2 Z_3) + m T Z_4^2$$

$$Z_4 \sim T\, \epsilon^{abc} Z_a Z_b Z_c$$

Integrating out massive field..

$$W \sim T^3 (\epsilon^{abc} Z_a Z_b Z_c)^2$$

SU(3) symmetric

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Sextic superpotential.. each Z must have dimension 1/3 for W to be marginal.

$$\Delta(Z_a) = \frac{1}{3}$$

RG Flow

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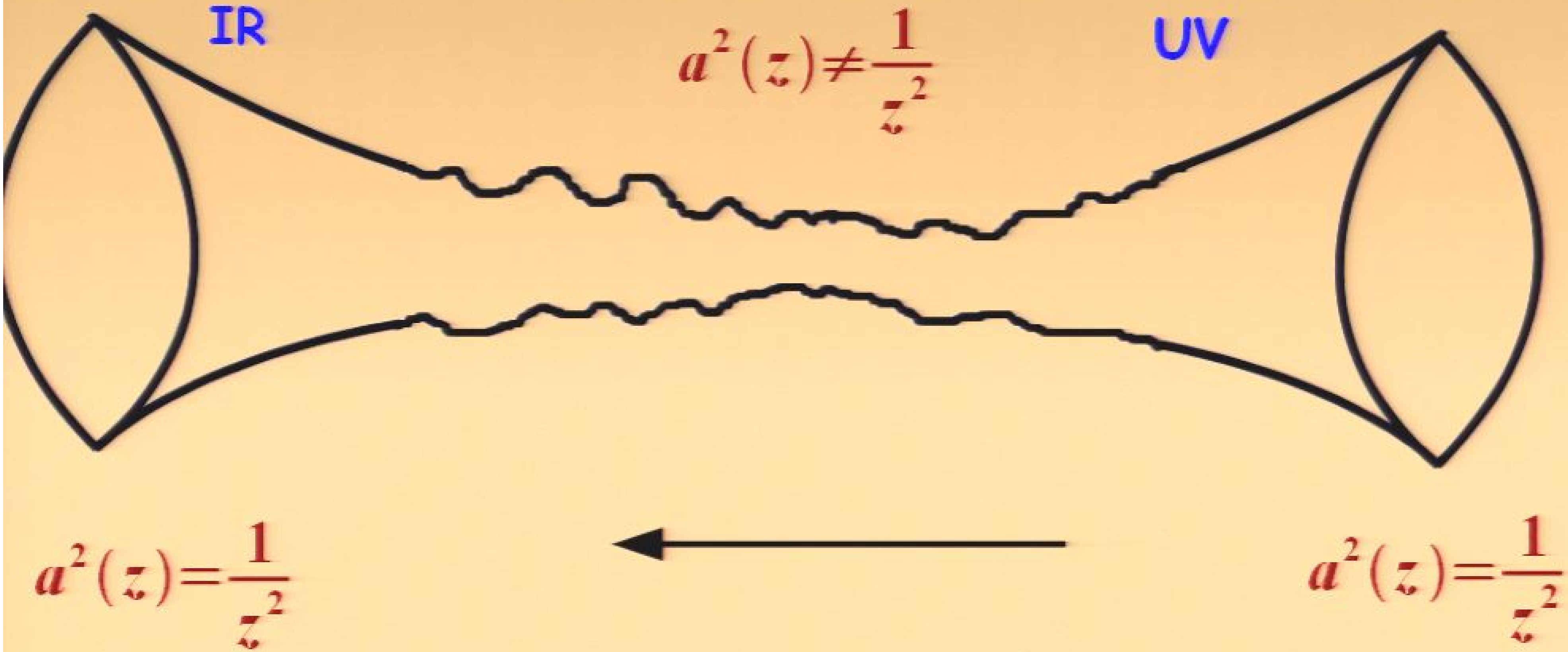

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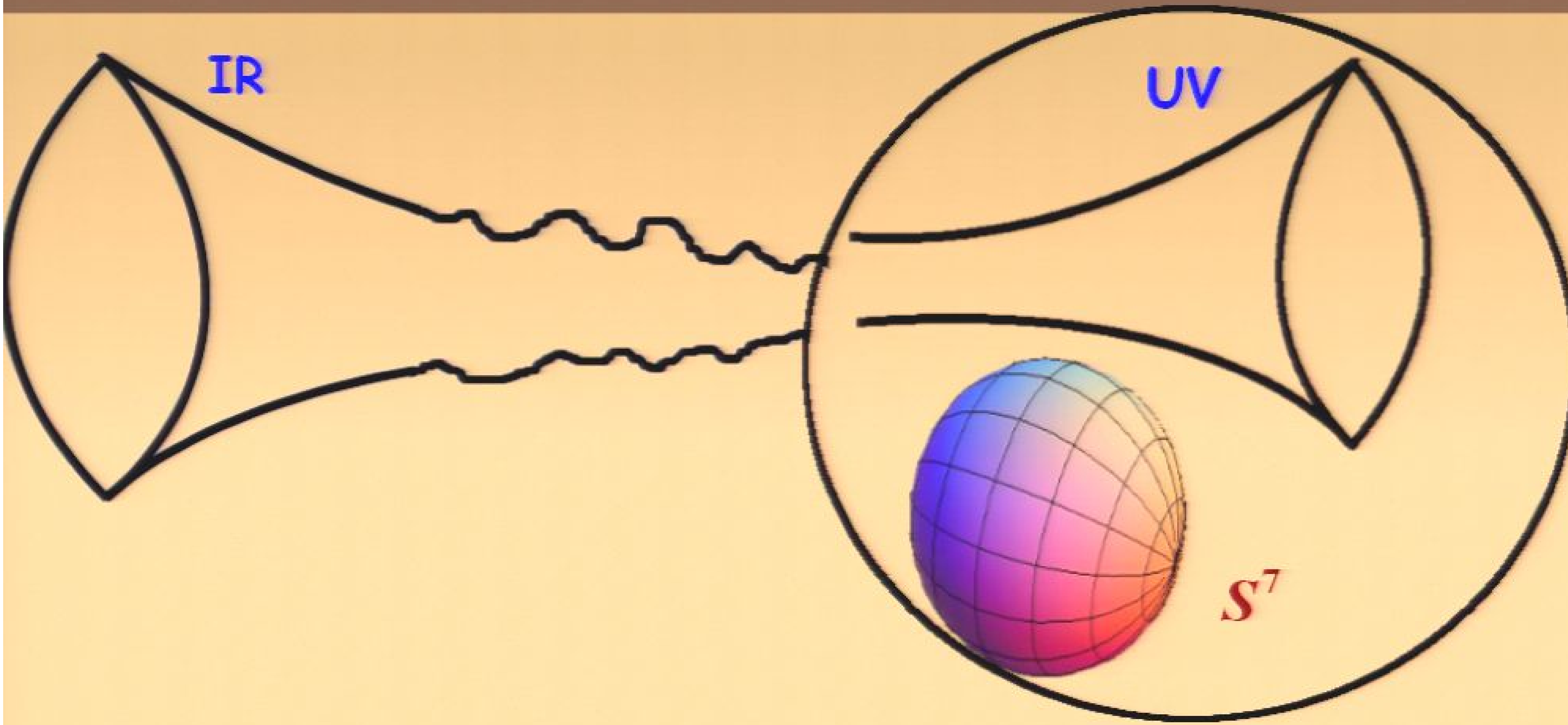

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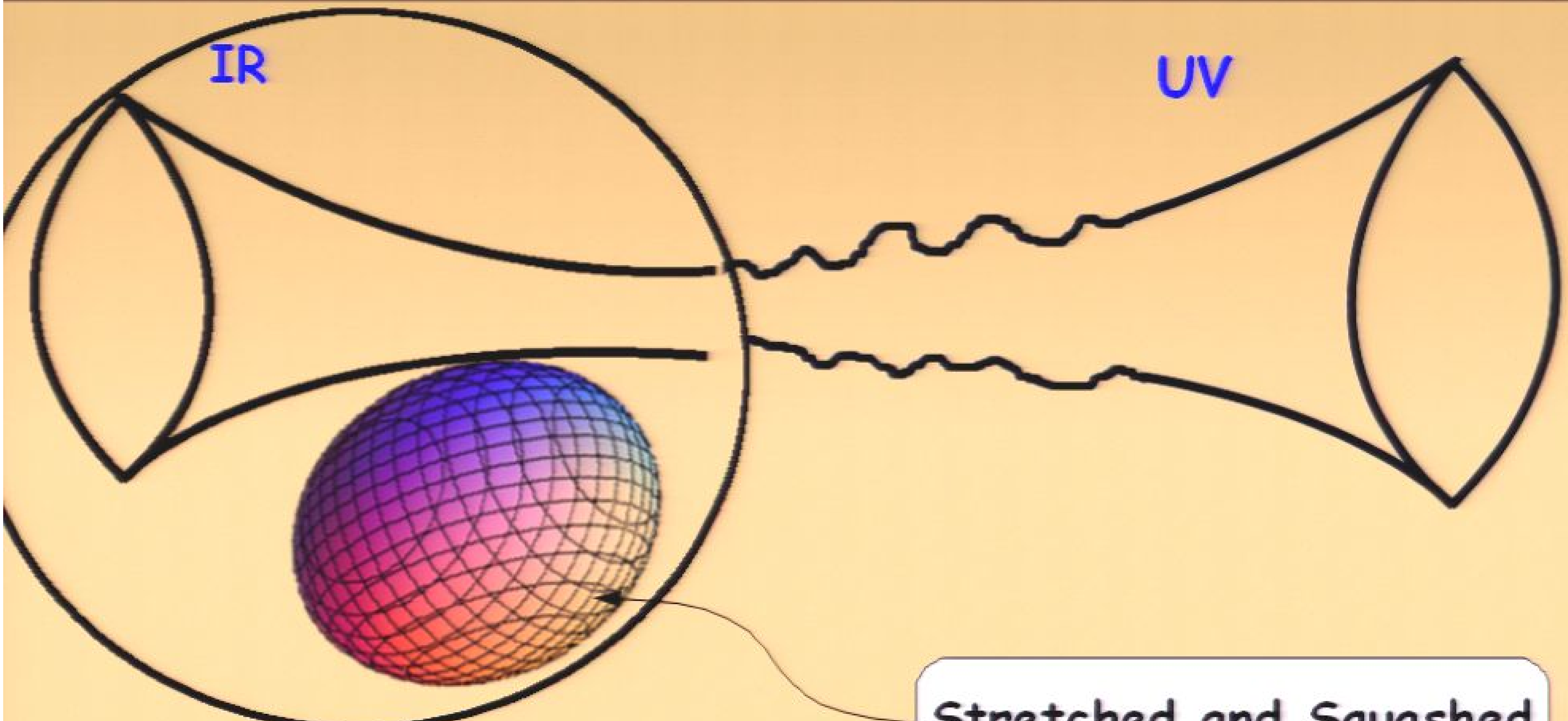

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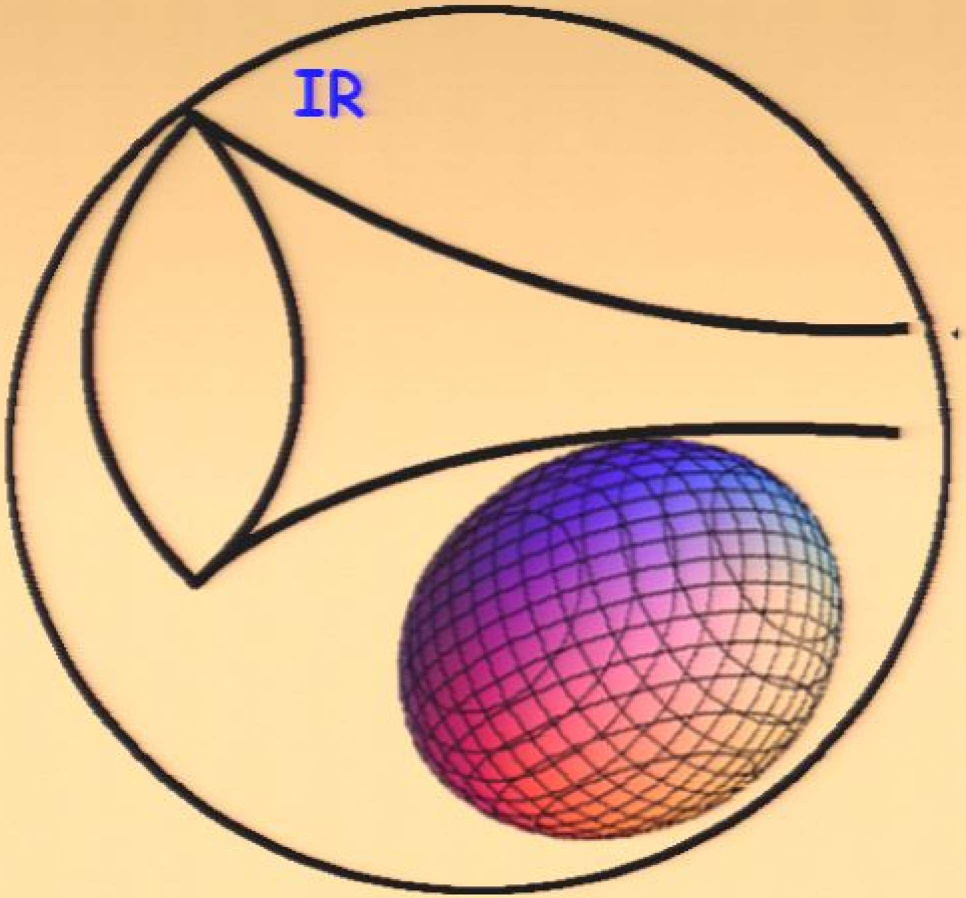

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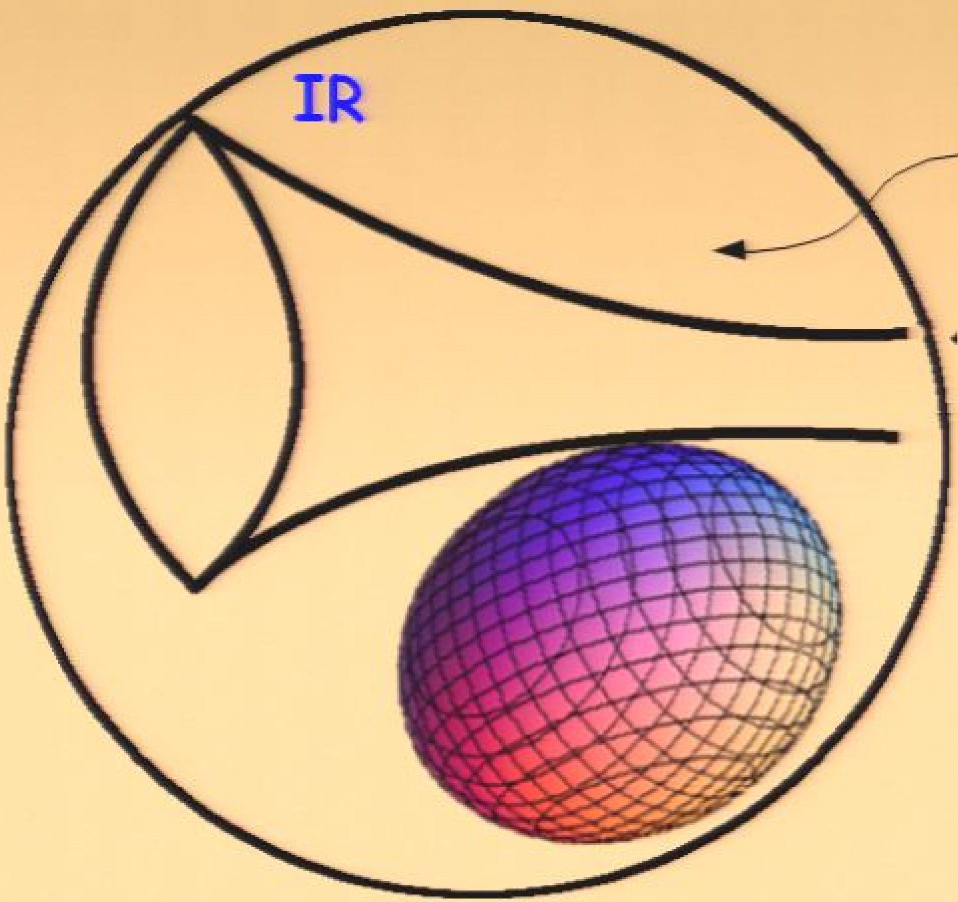

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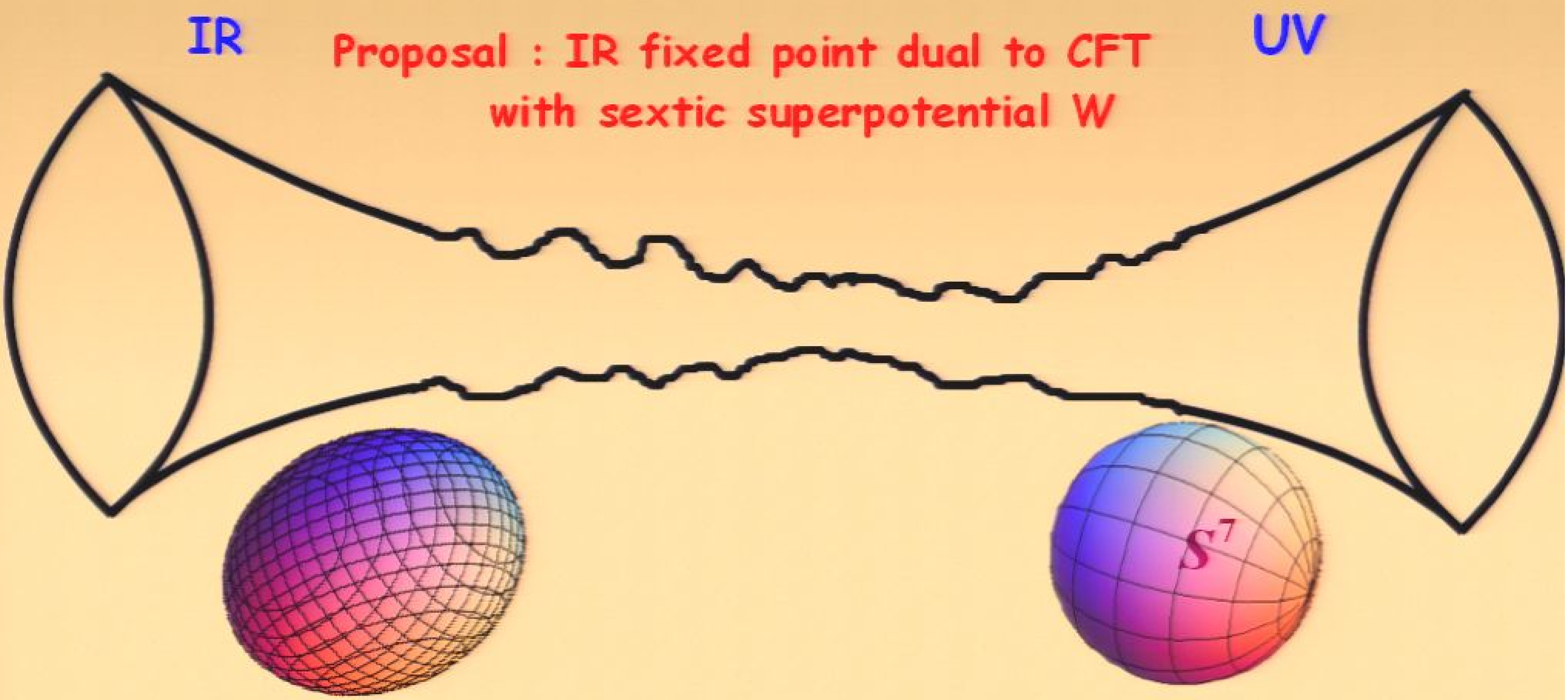

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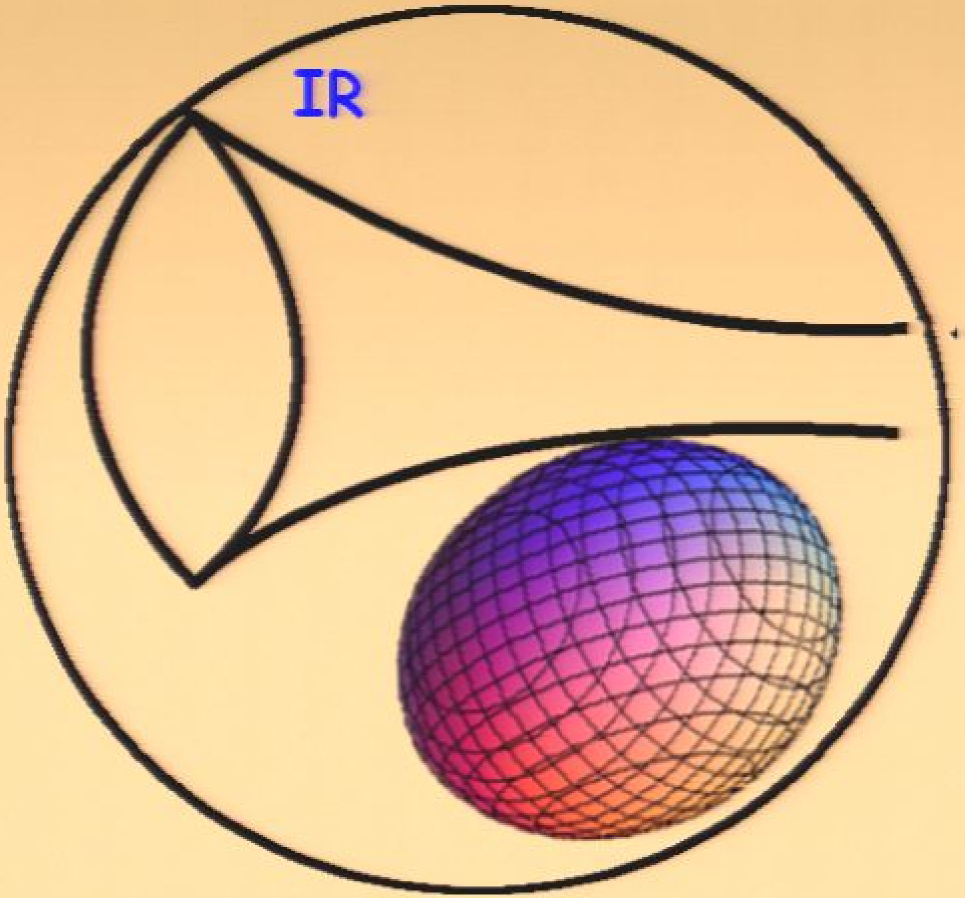

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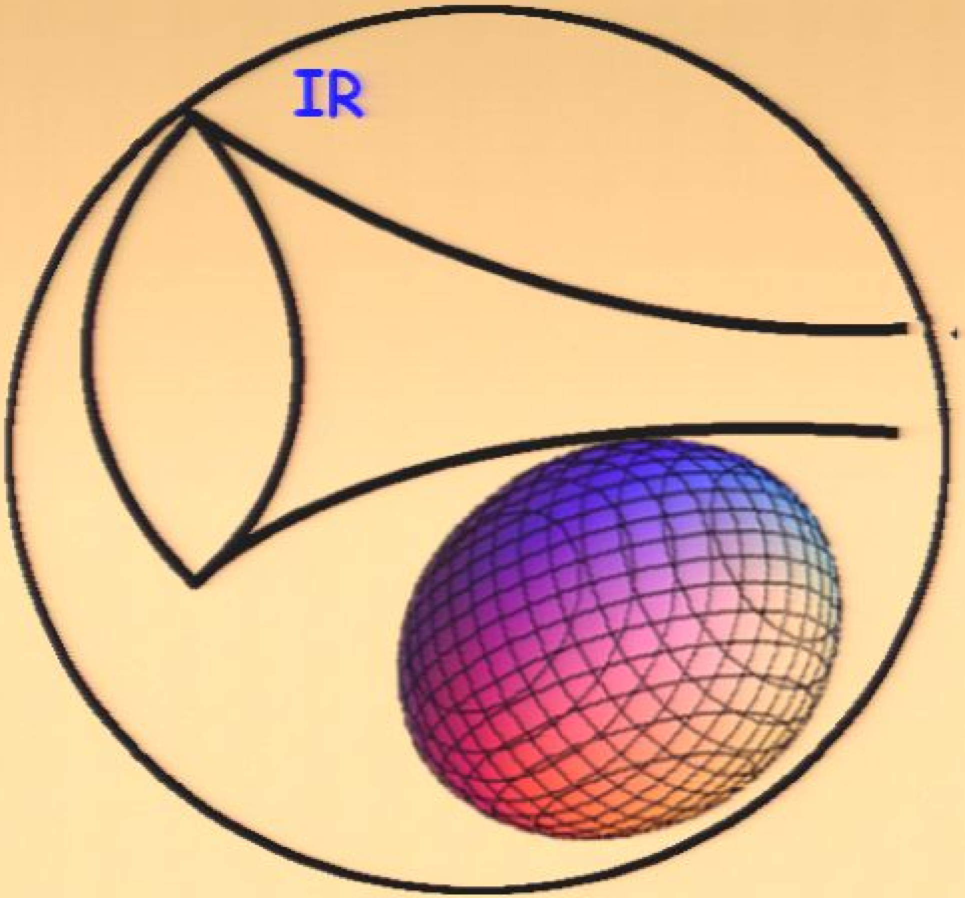

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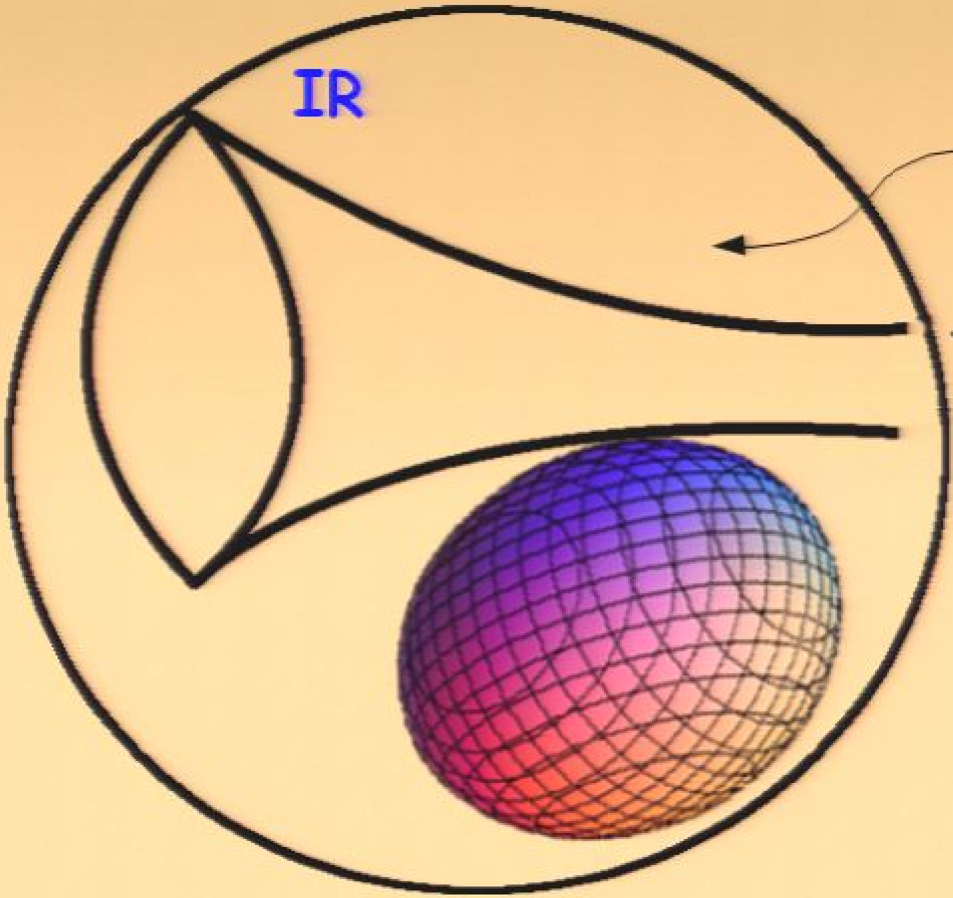

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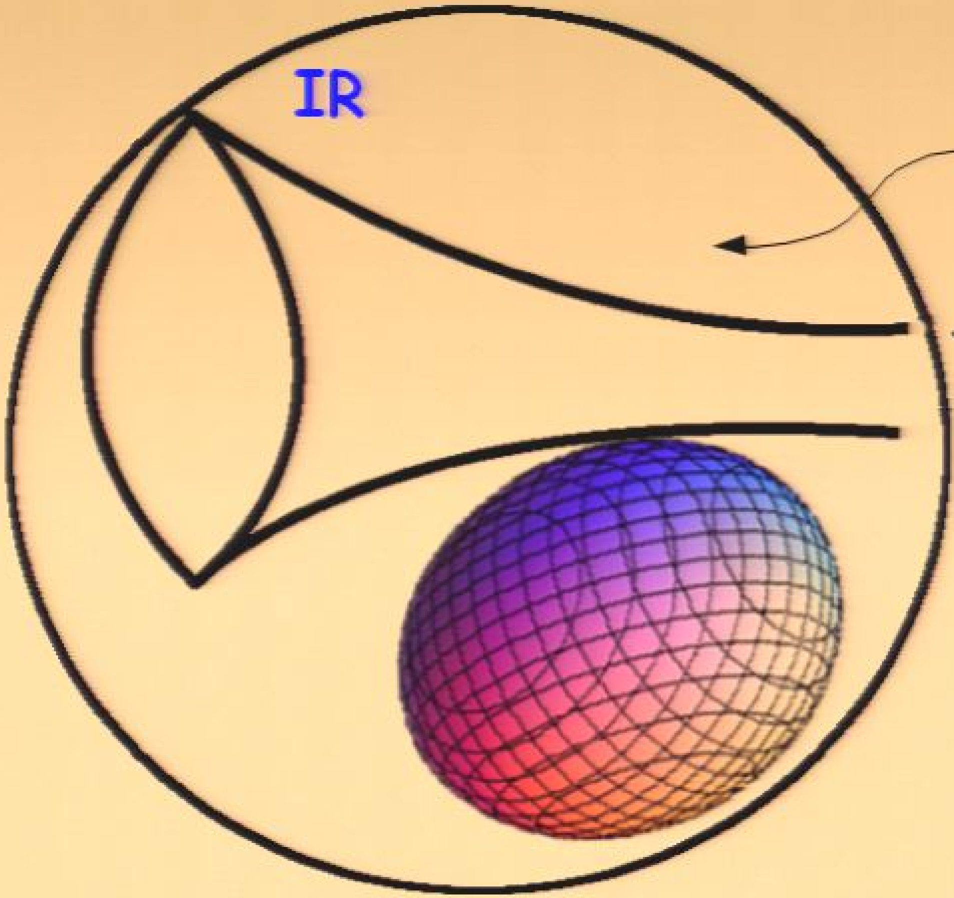

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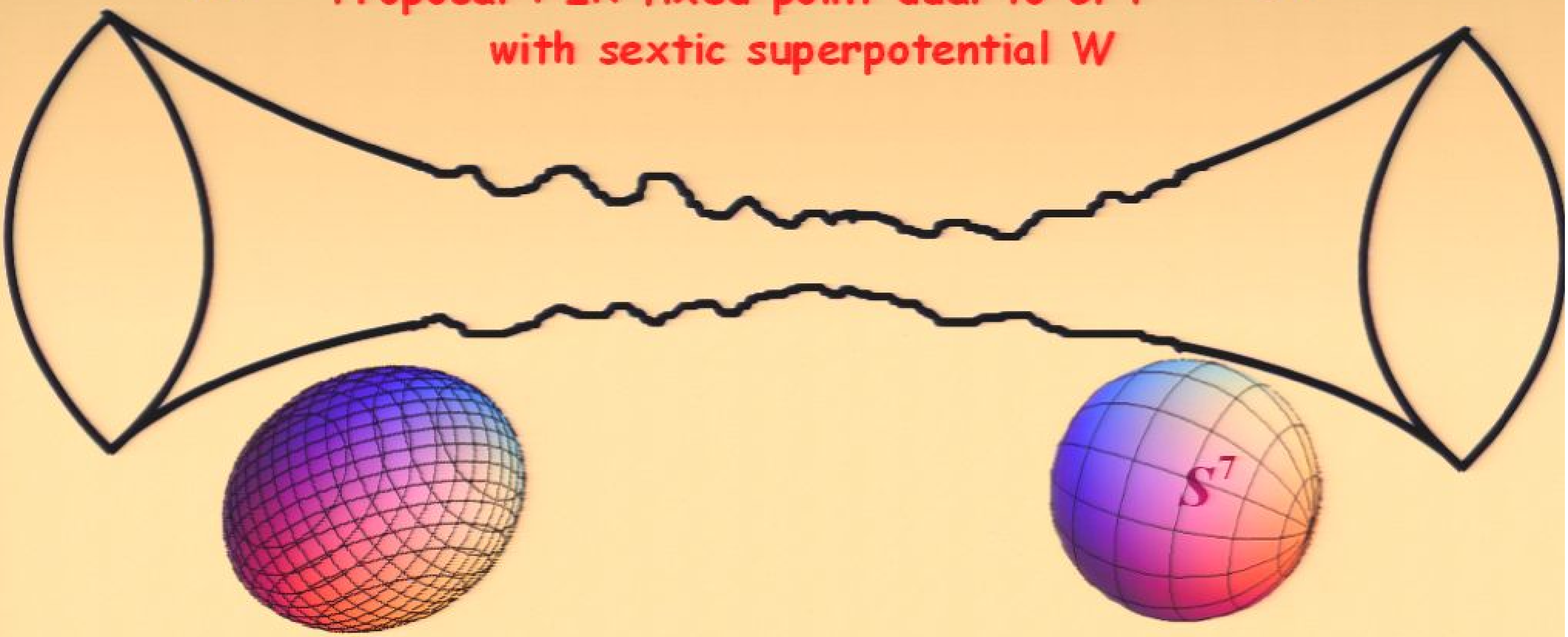
Proposal : IR fixed point dual to CFT
with sextic superpotential W



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RG flow → Break SO(8) to SU(3)

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• 0	.. + $3+\underline{3}+1+1+$ ..

Choice of $U(1)_R \subset SO(8)$ →

Spin	SU(3) x U(1) rep
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But SUSY relates R charge of fermions and bosons

Gravity spectrum, the easy way

Vary choice of $U(1)_R \subset SO(8)$

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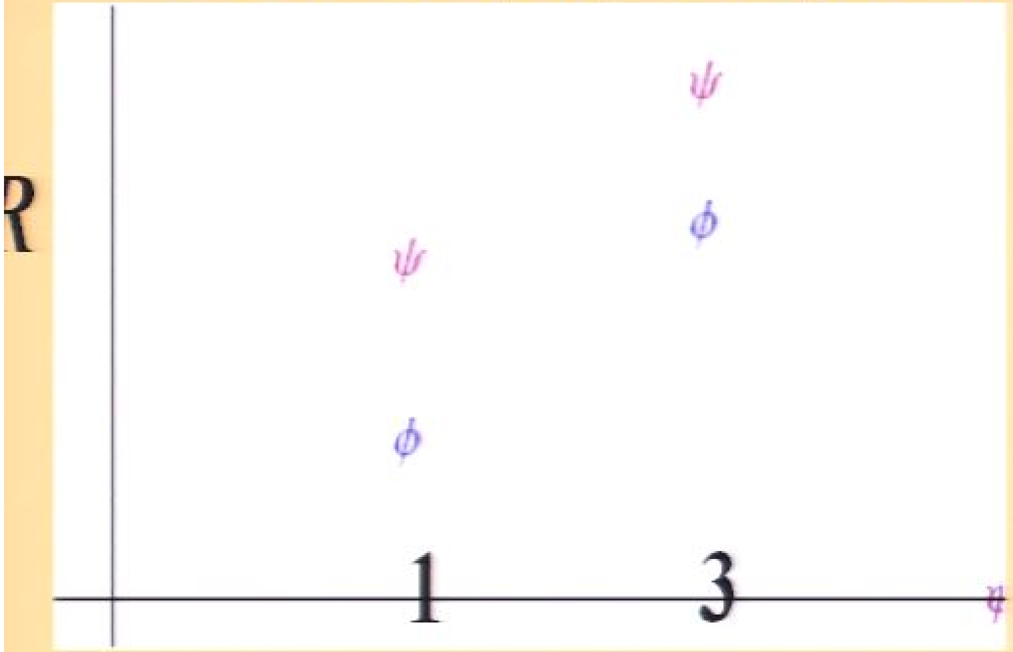
SUSY : If Spin ½ and Spin 0 are to form a hypermultiplet, **a – b = 1**



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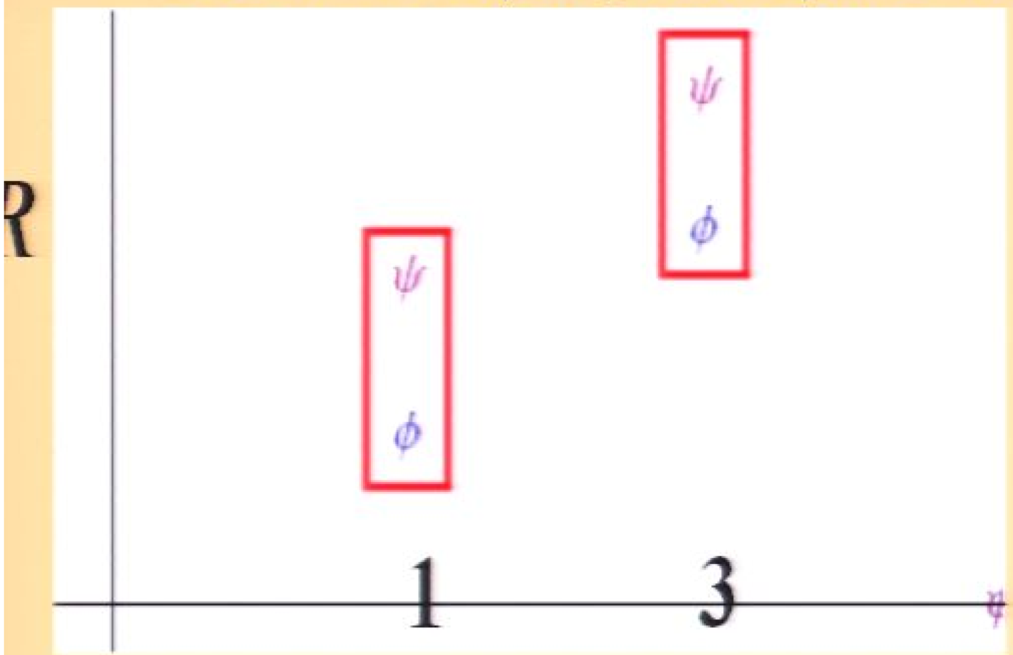

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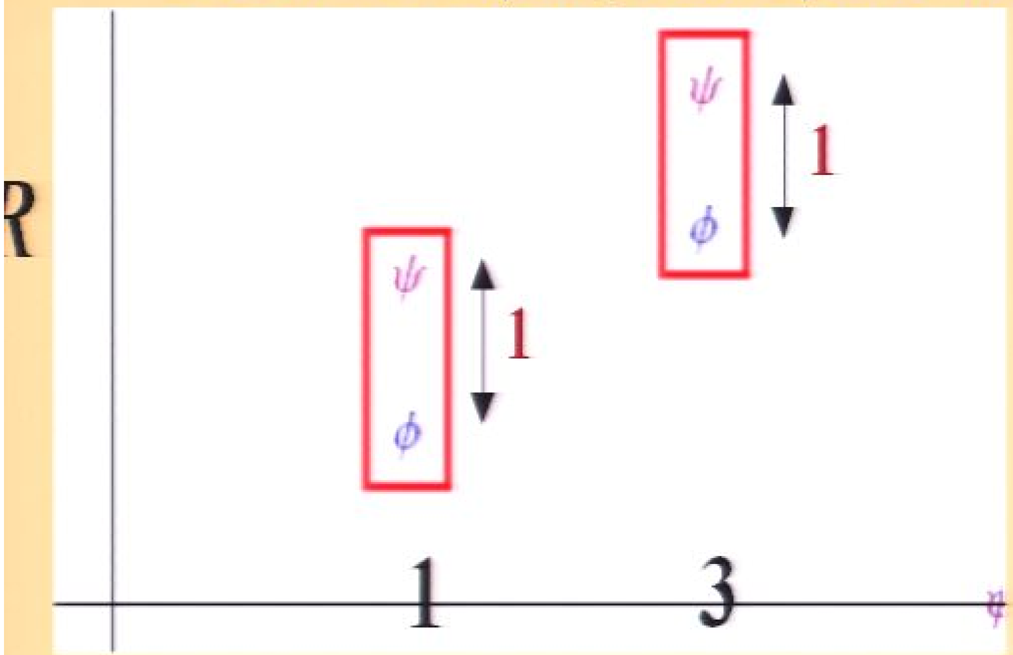

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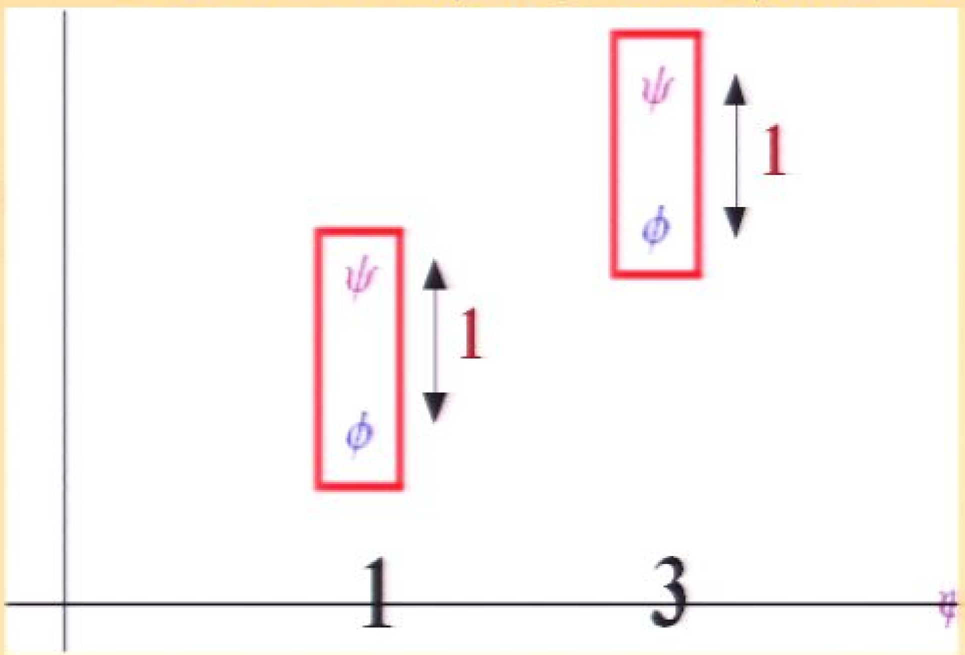

Using SUSY and group theory

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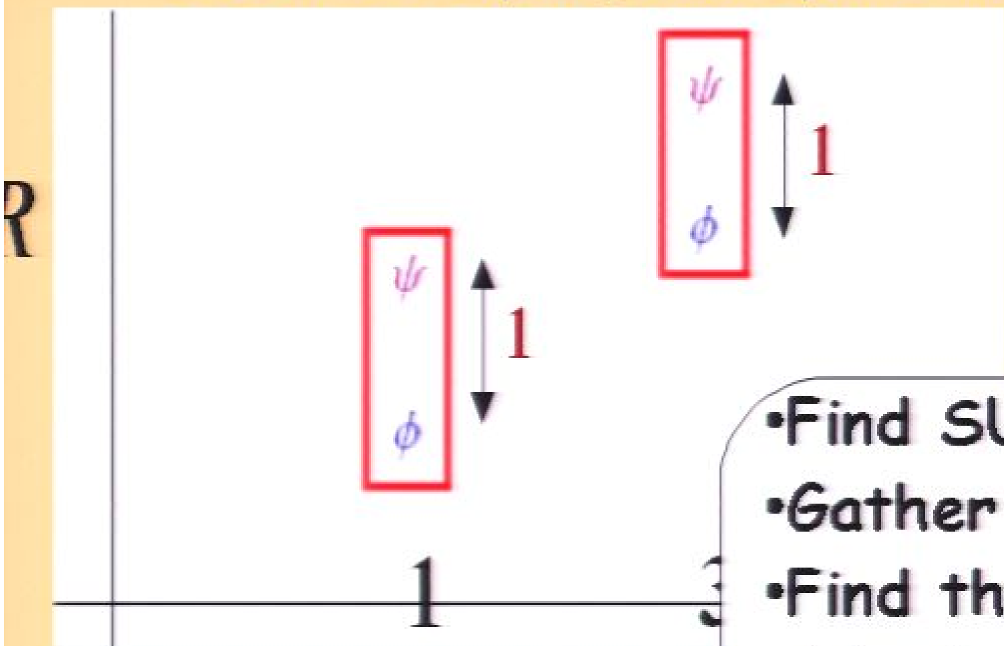

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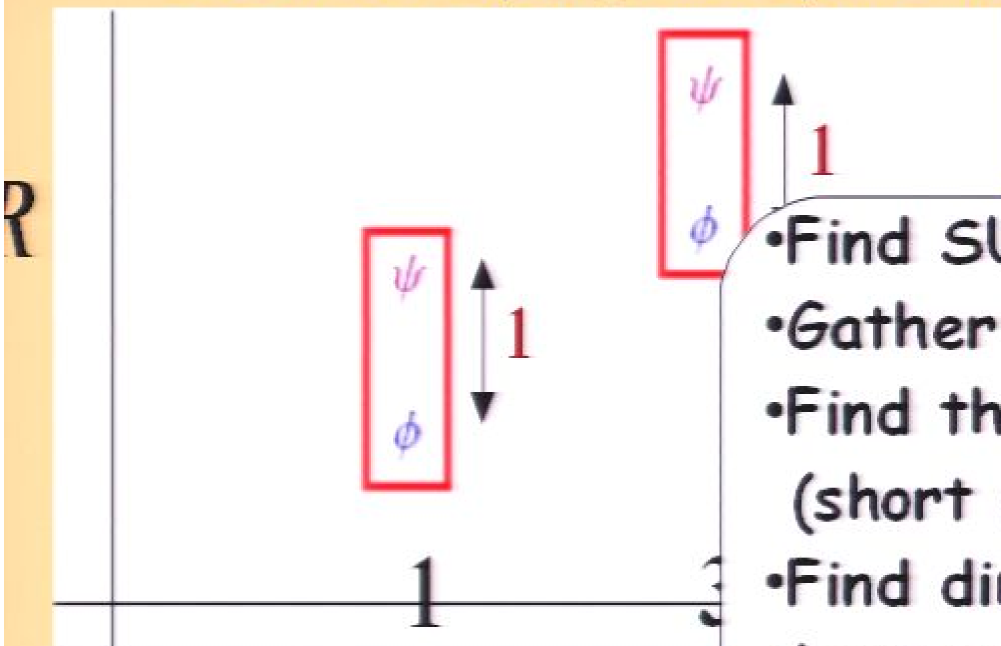

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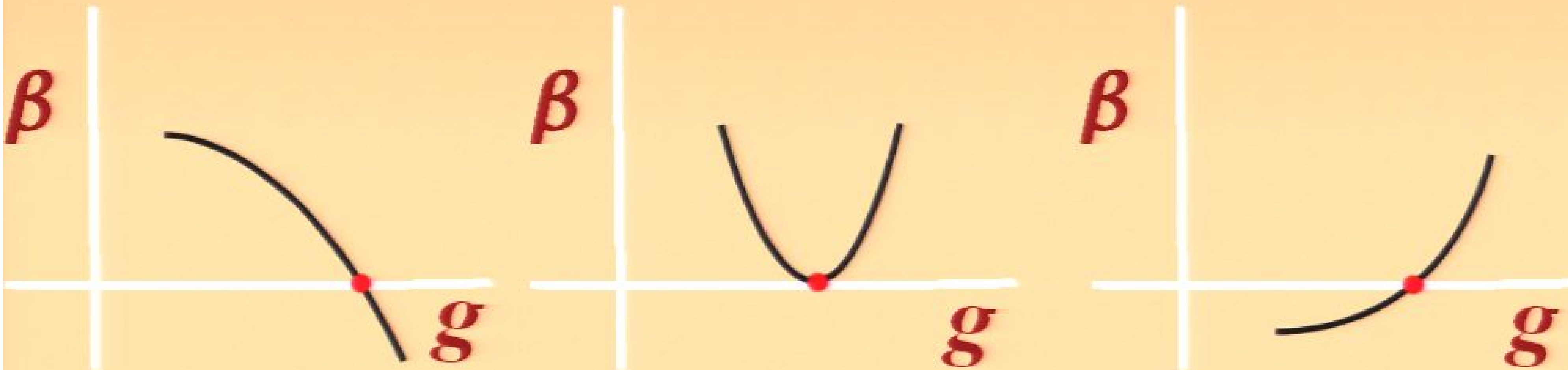
Non-supersymmetric CFTs?

Three kinds of operators at a conformal fixed point

Relevant	Marginal	Irrelevant



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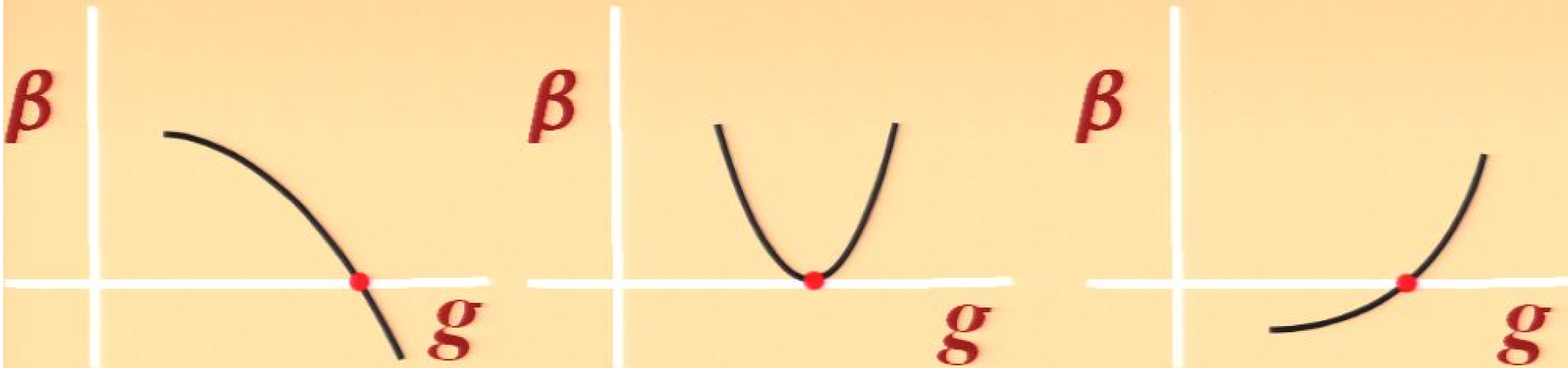

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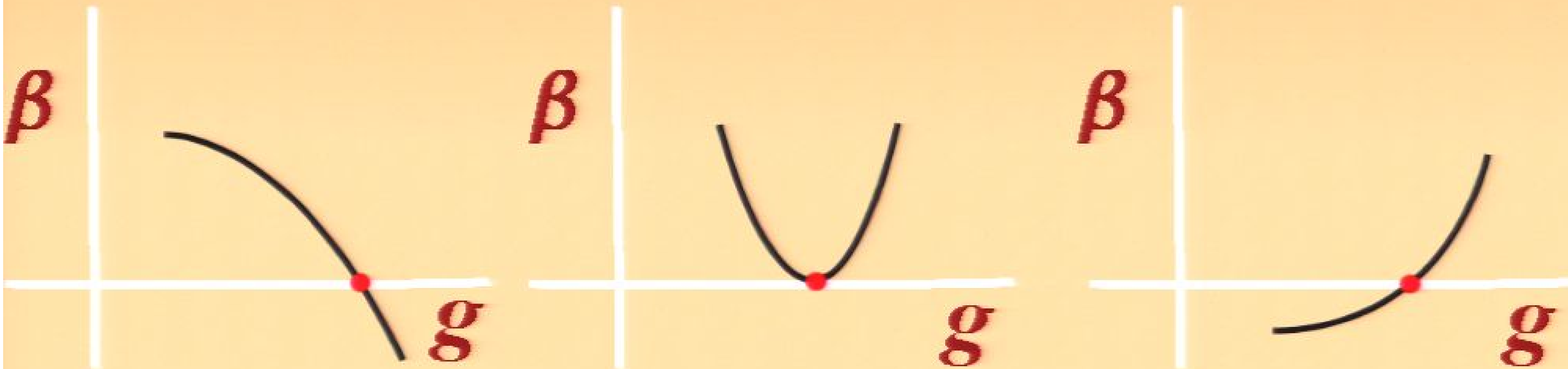

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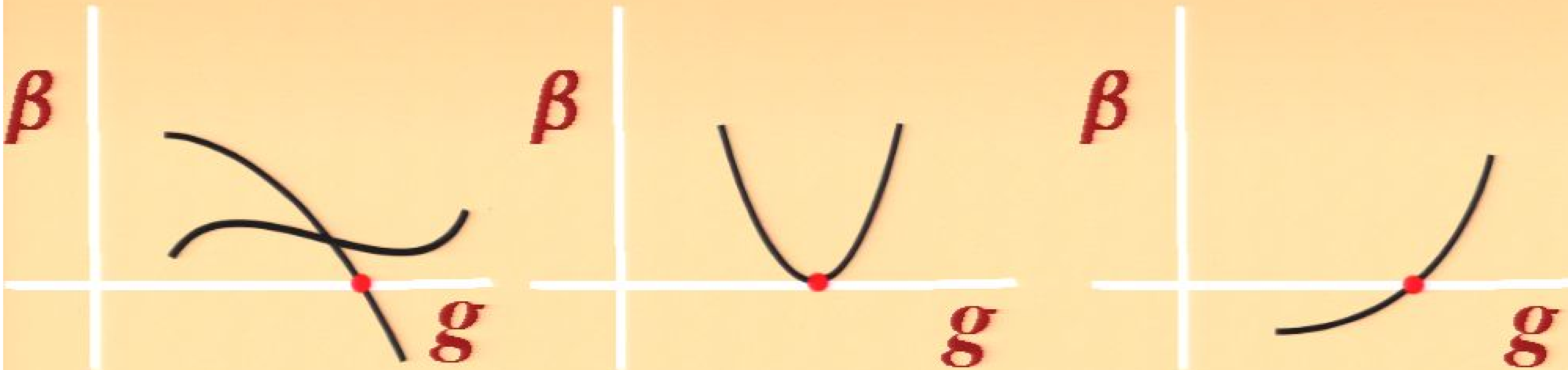

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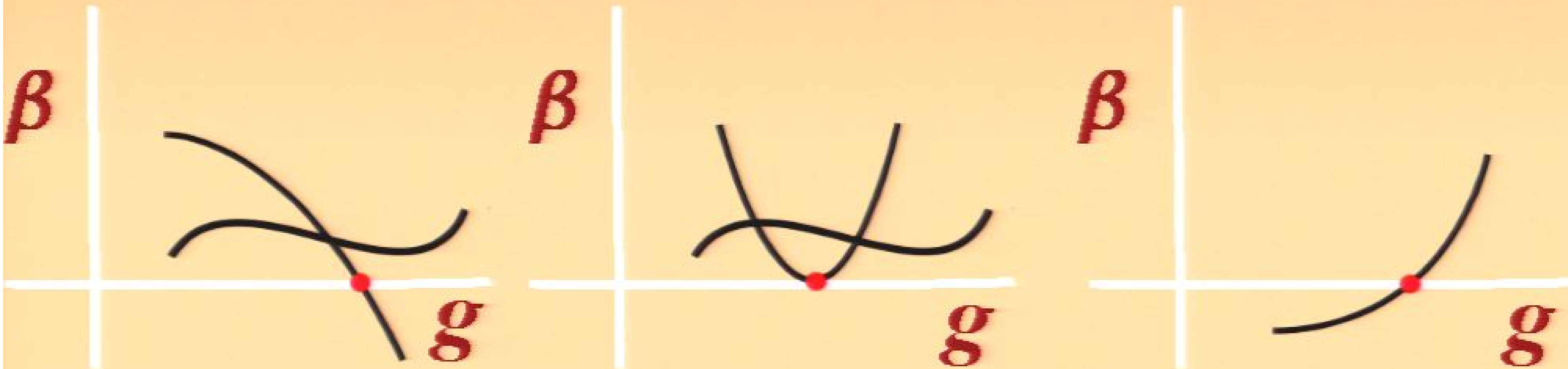

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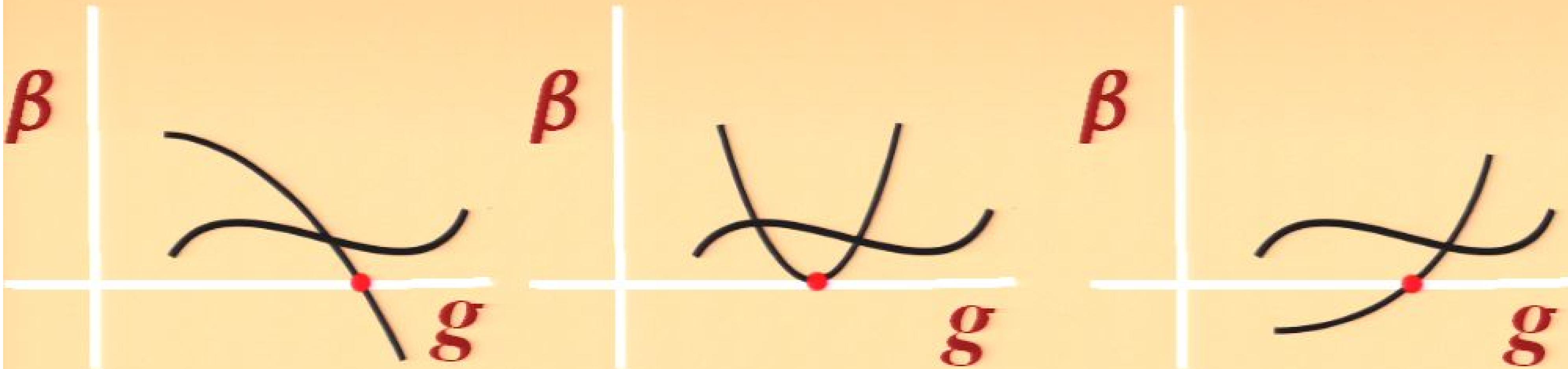

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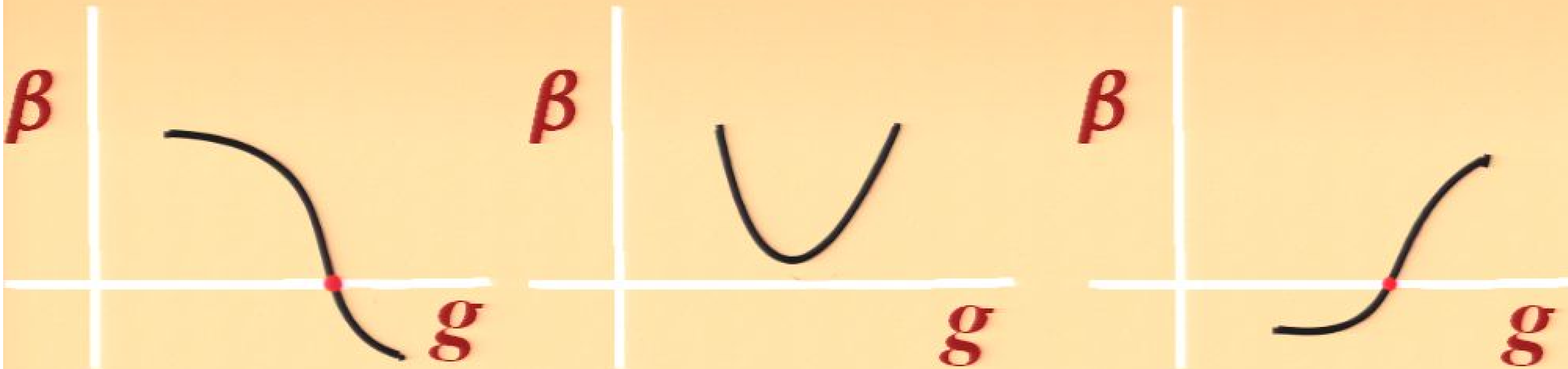

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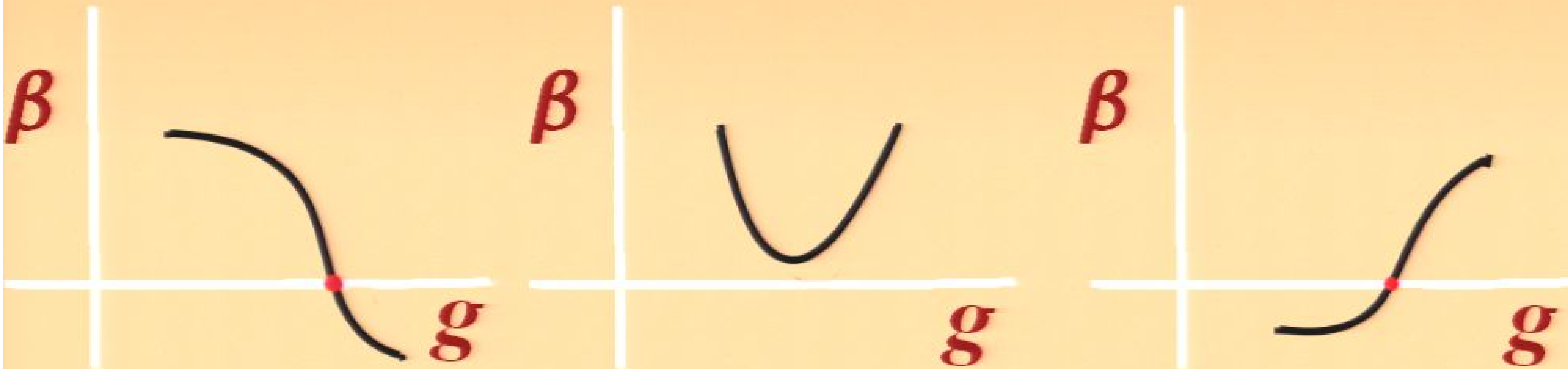

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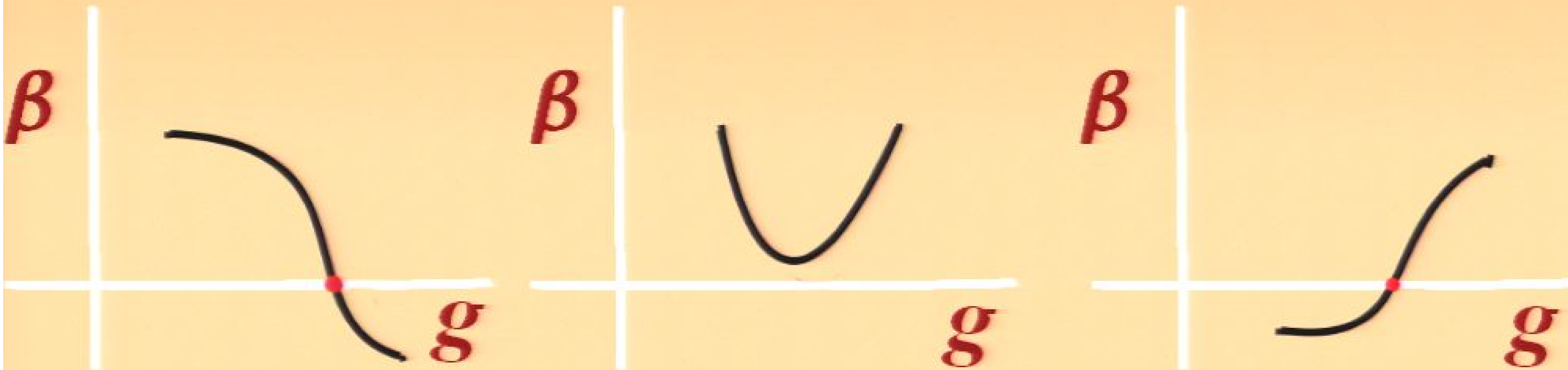

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$AdS_5 \times X^5$ non-SUSY

$\frac{1}{g^2} Tr\, F \wedge * F$ Gauge coupling is always marginal

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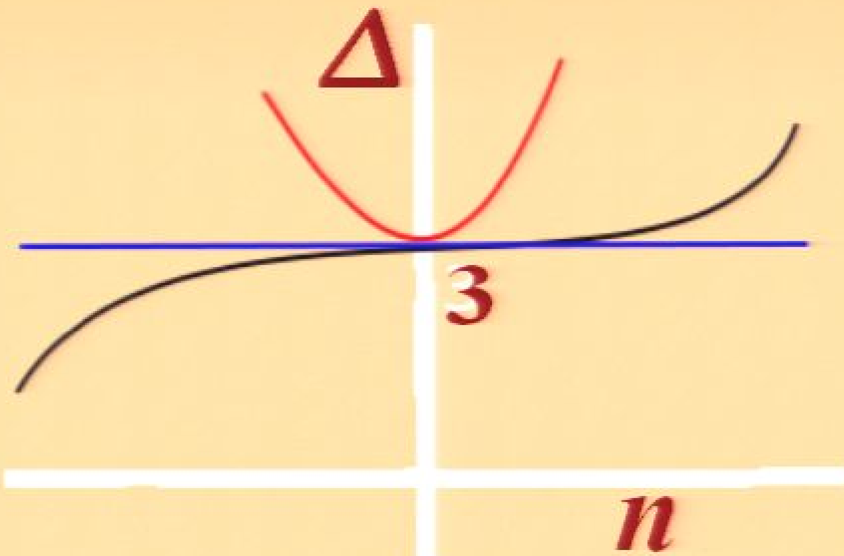

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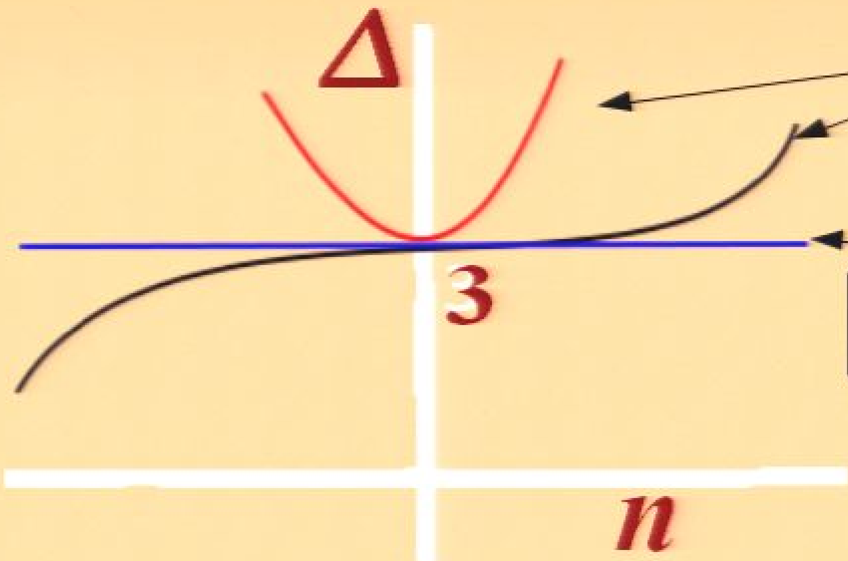
$$AdS_4 \times X^7(n)$$

Any non-SUSY family.
Let n=0 be SUSY.

No generically present marginal operator.



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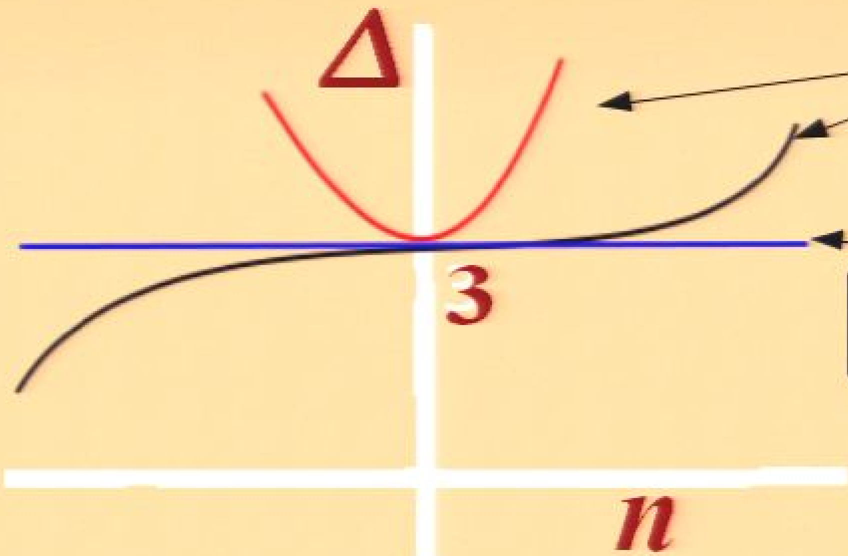

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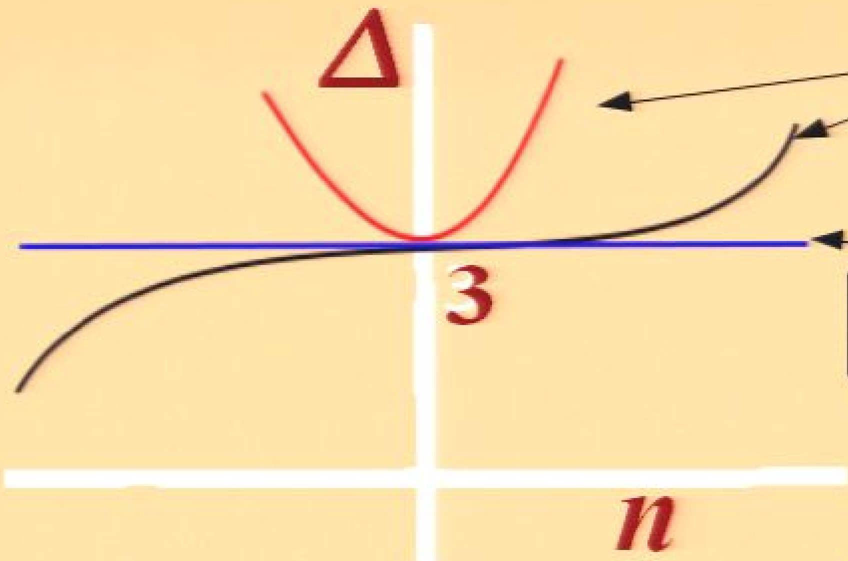

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[Berkooz, Rey; Seiberg]

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Three kinds of operators at a conformal fixed point

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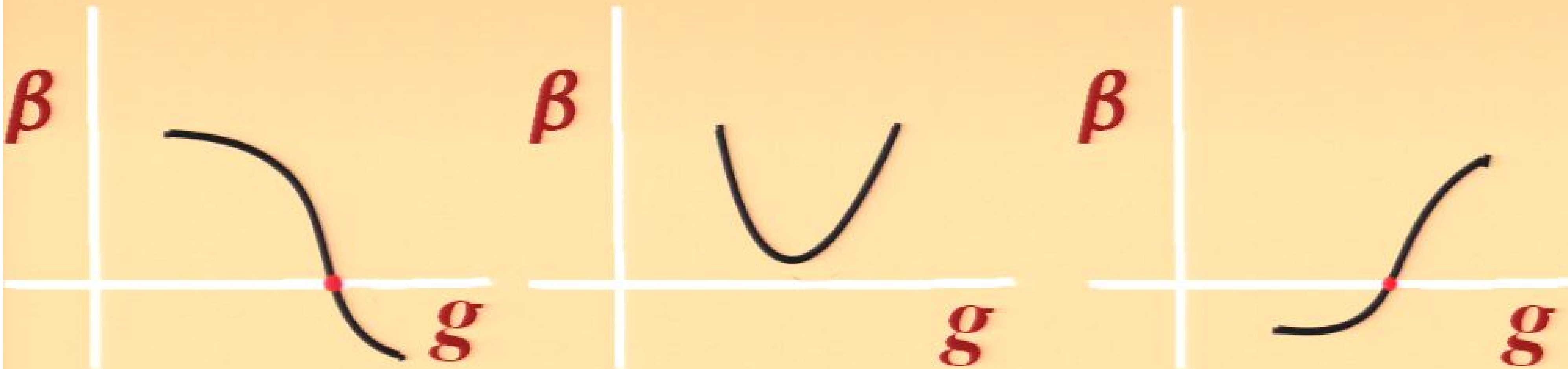

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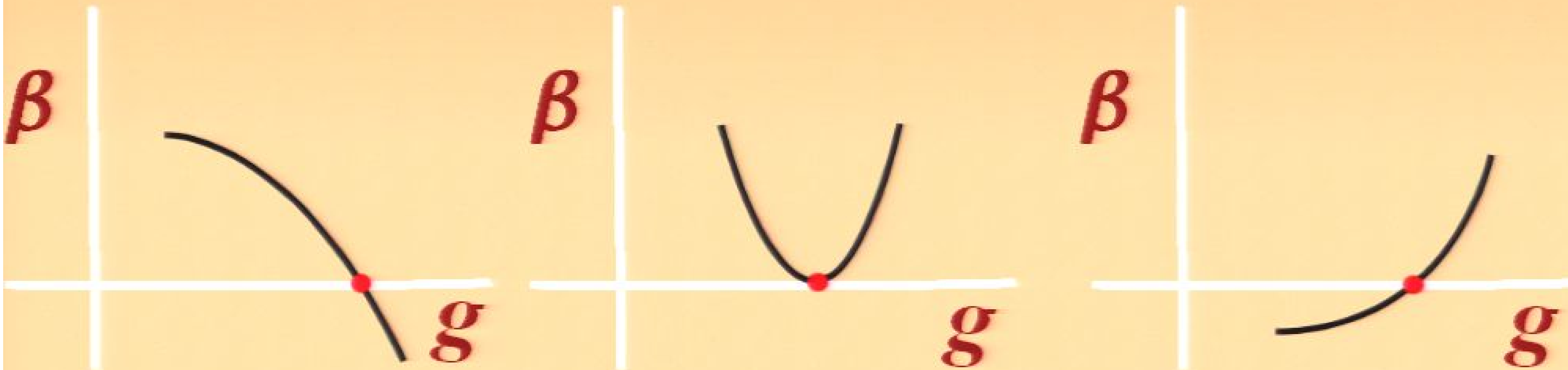

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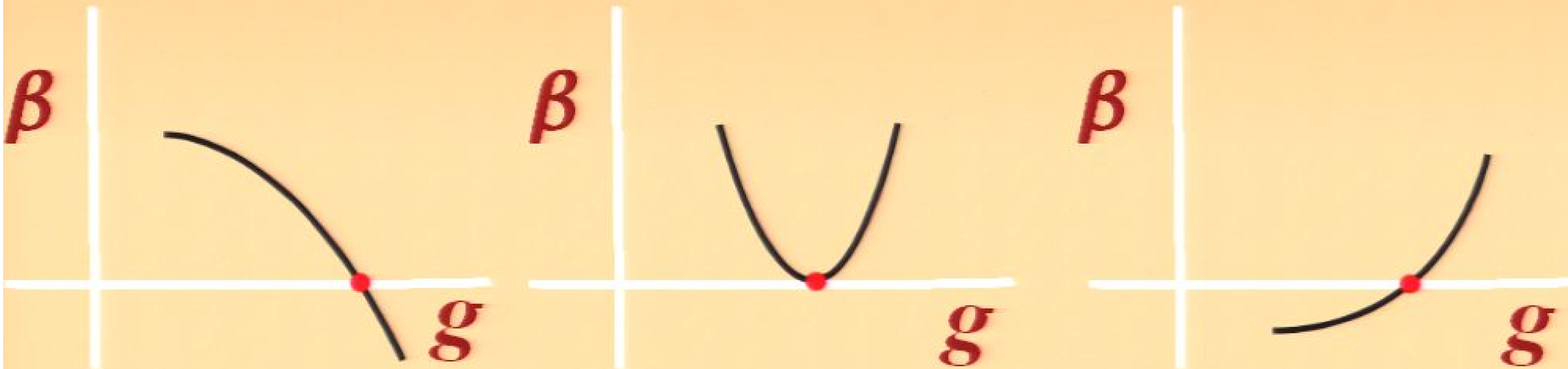

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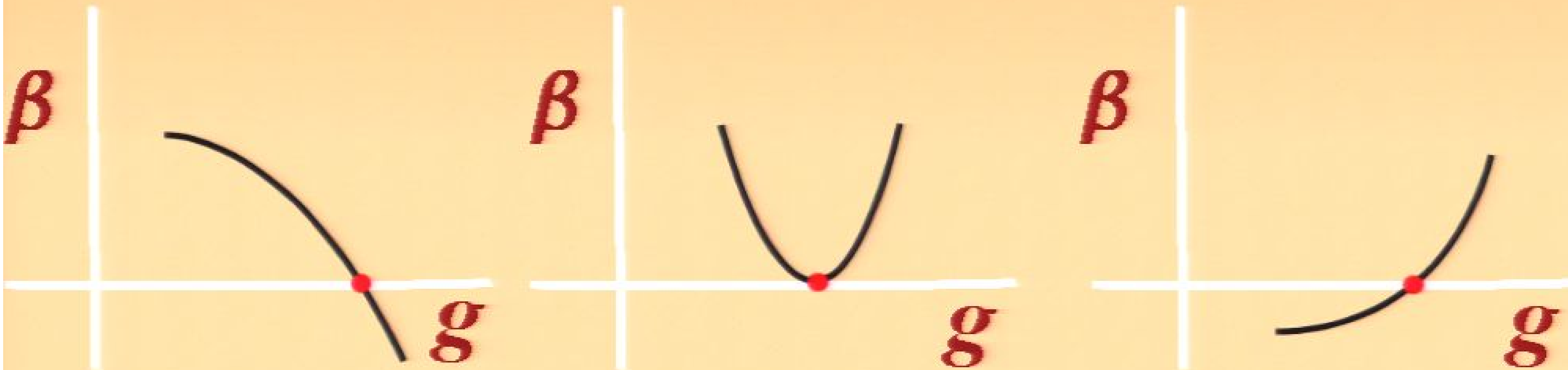

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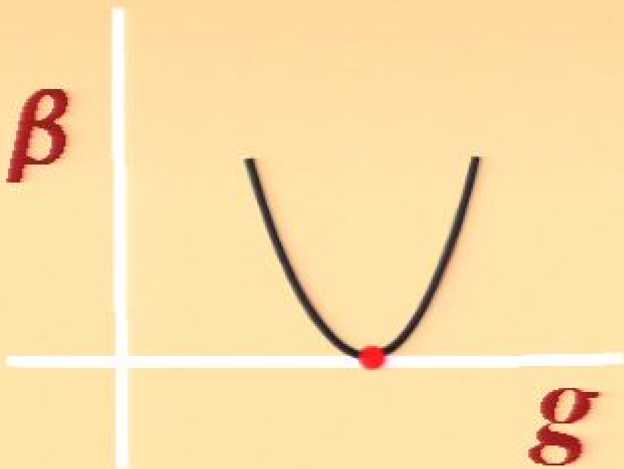

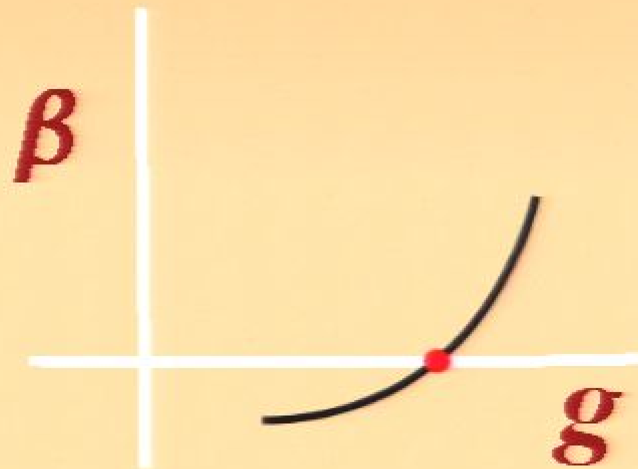

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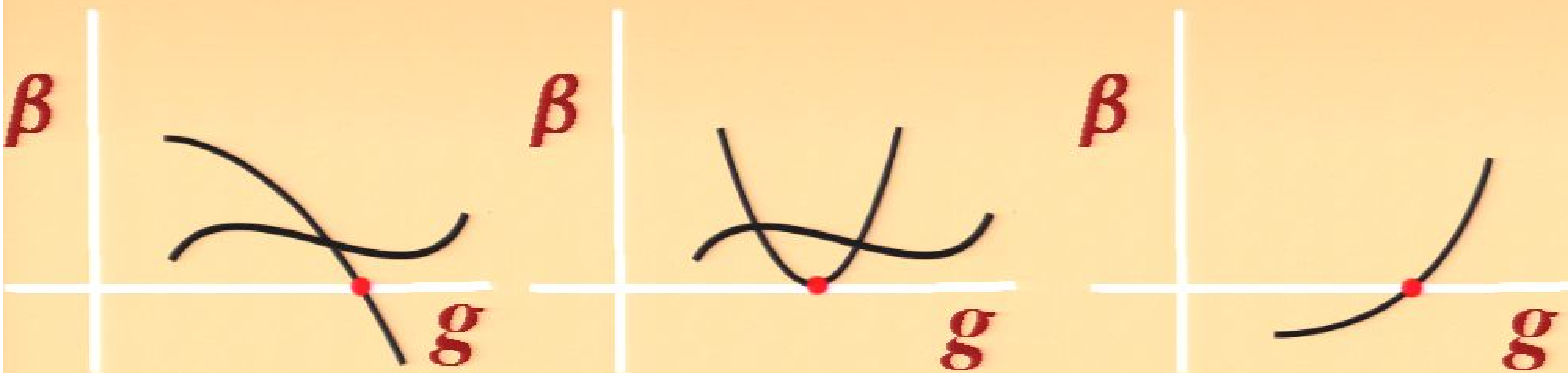

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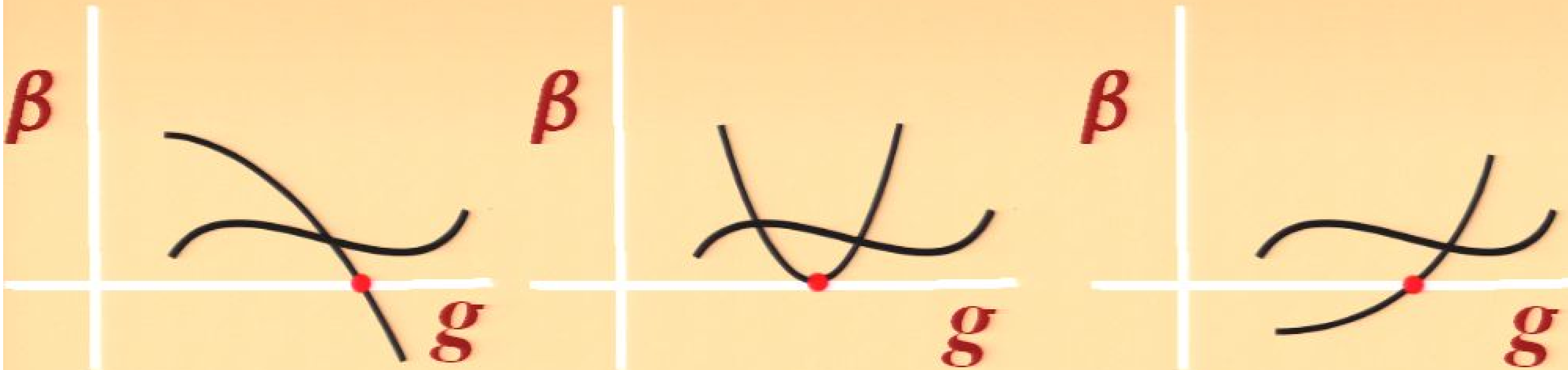

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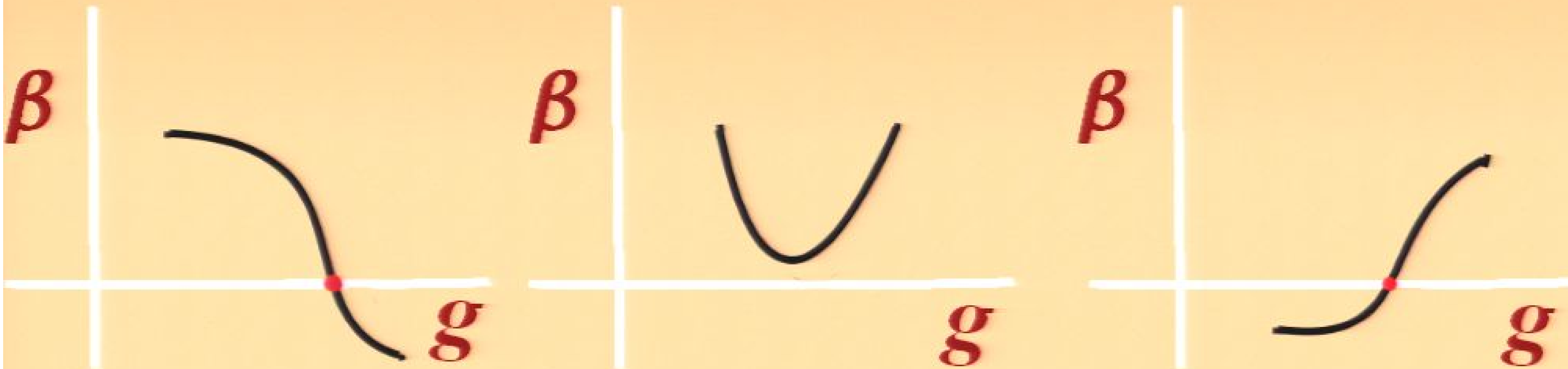

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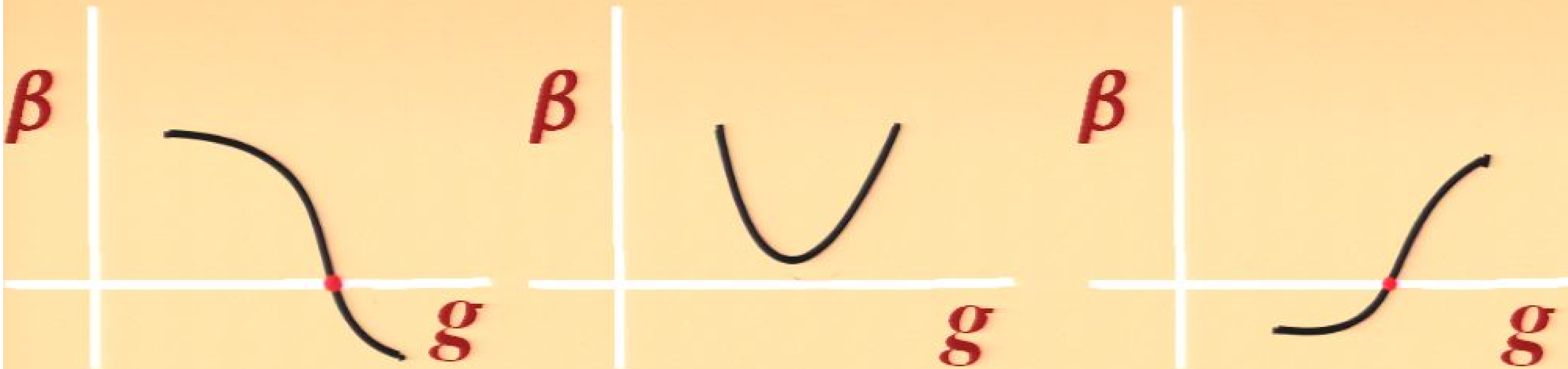

Marginal operators could destroy conformal fixed points.

$AdS_5 \times X^5$ non-SUSY

$\frac{1}{g^2} Tr\, F \wedge * F$ Gauge coupling is always marginal

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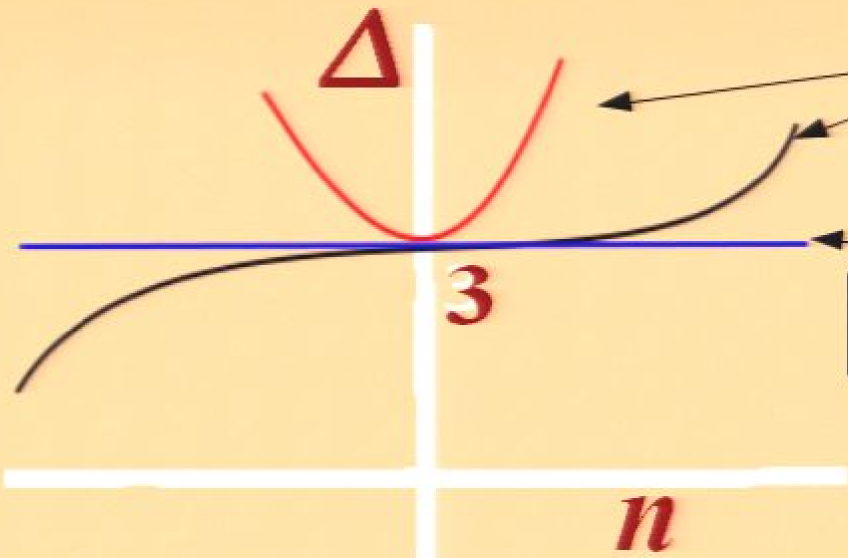

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Future directions

- Hidden SUSY and monopole operators
- Other interesting vacua of SUGRA
- Rich ”landscape” of AdS_4 compactifications.. stable non-SUSY backgrounds?
- Transport coefficients from field theory
- Other condensed matter applications..?