Toward a Theory of The QCD String

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w Victor Gorbenko, 1511.01908

earlier work:

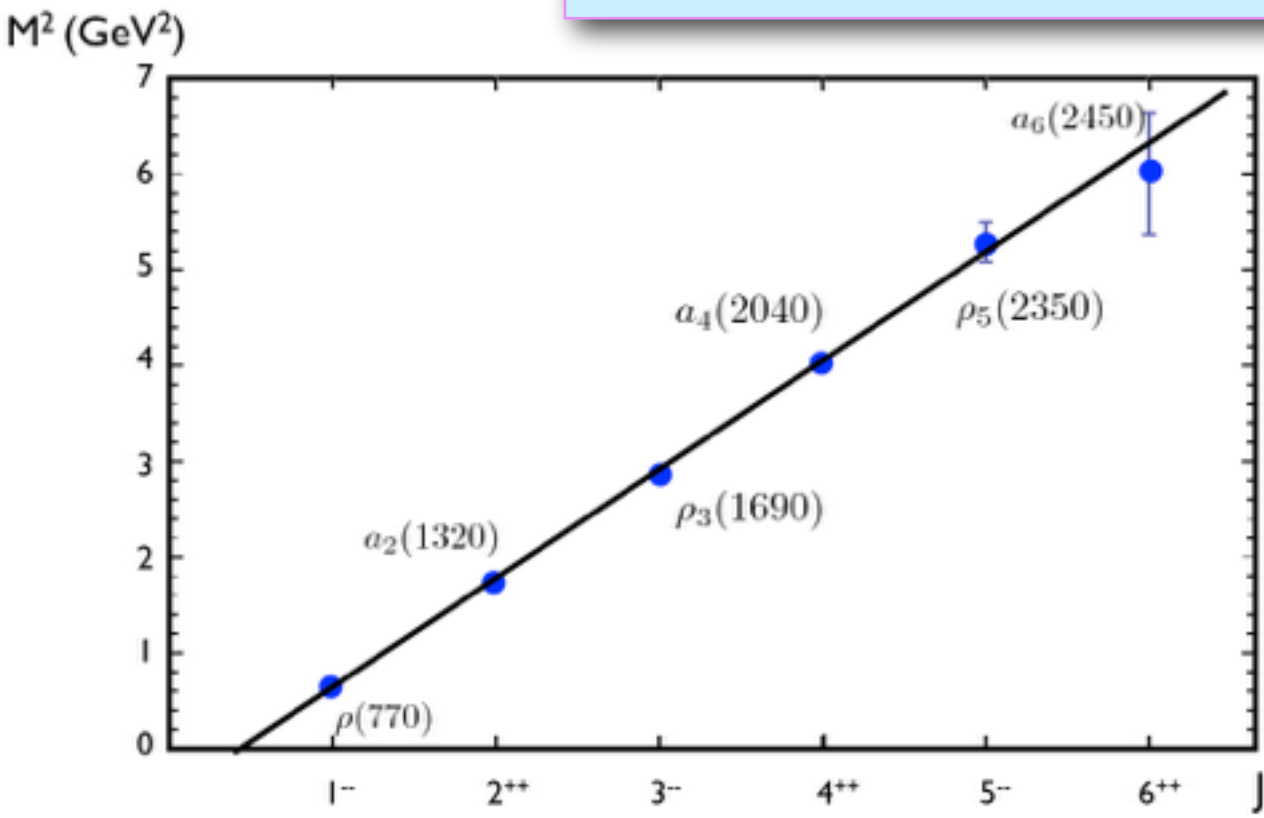
w Raphael Flauger, Victor Gorbenko, 1203.1054, 1205.6805, 1301.2325, 1404.0037
w Patrick Cooper, Victor Gorbenko, Ali Mohsen, Stefano Storace 1411.0703

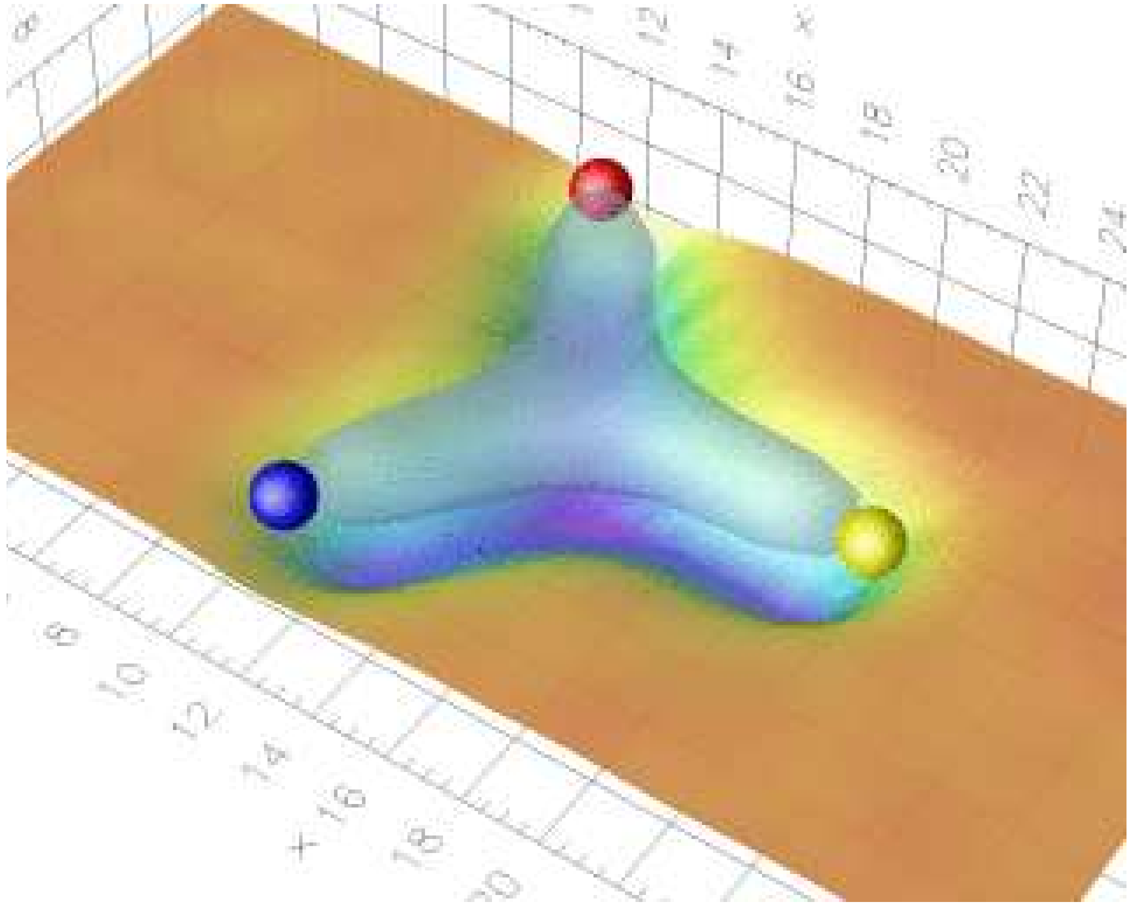
The major question:

What is $SU(\infty)$ Yang-Mills?

Old, fascinating and famously hard. Will try to convince you that it may be the right time to think about it.

QCD is a theory of strings





Bissey et al, hep-lat/0606016

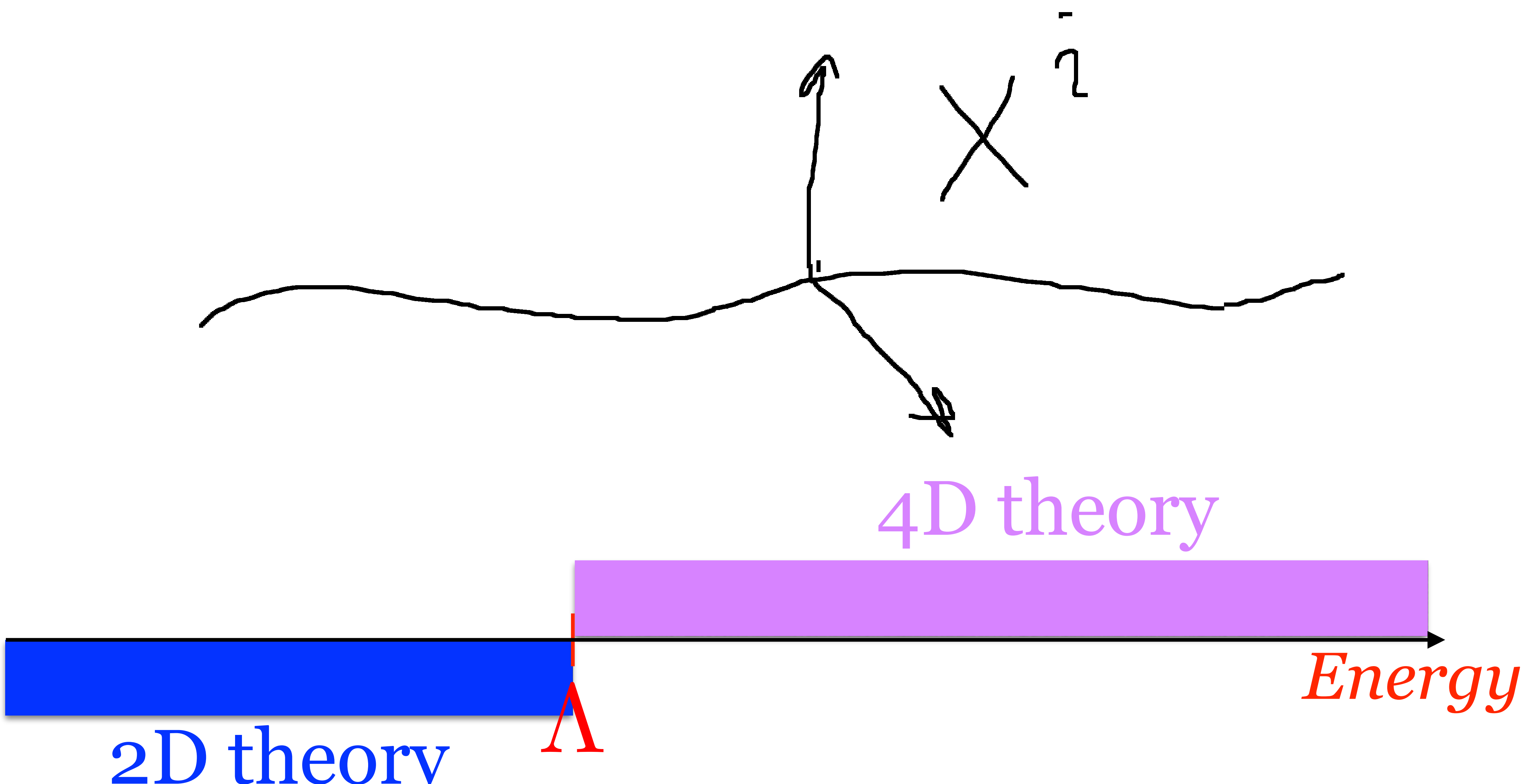
Large N QCD is a theory of free strings

Can we solve this free string theory?

SETUP

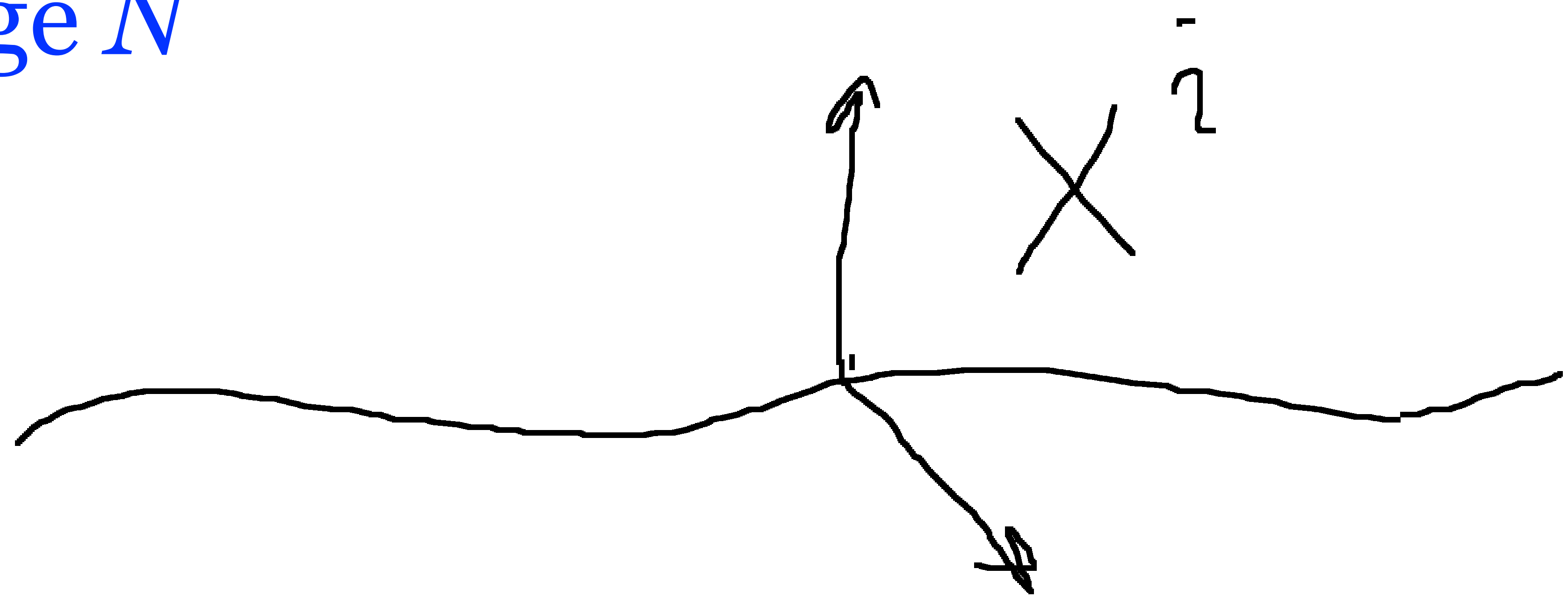
✓Confining gauge theory with a gap Λ

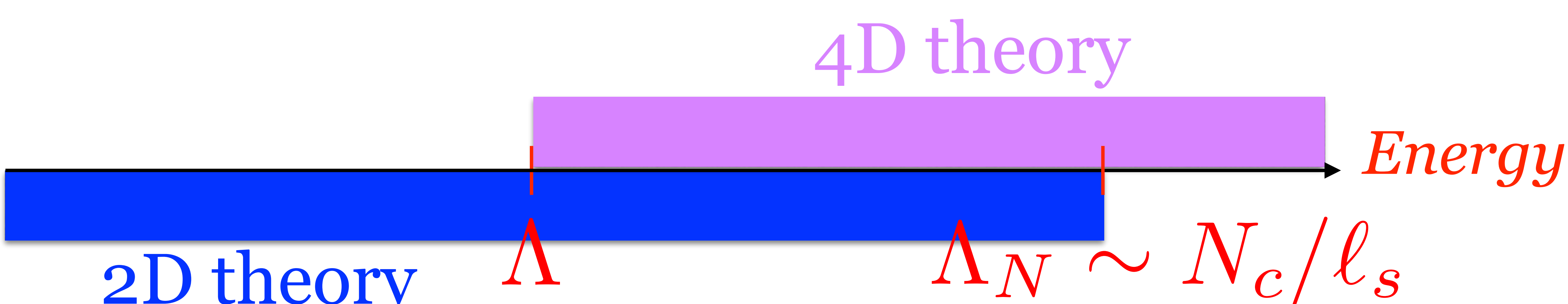
✓Unbroken center symmetry



SETUP

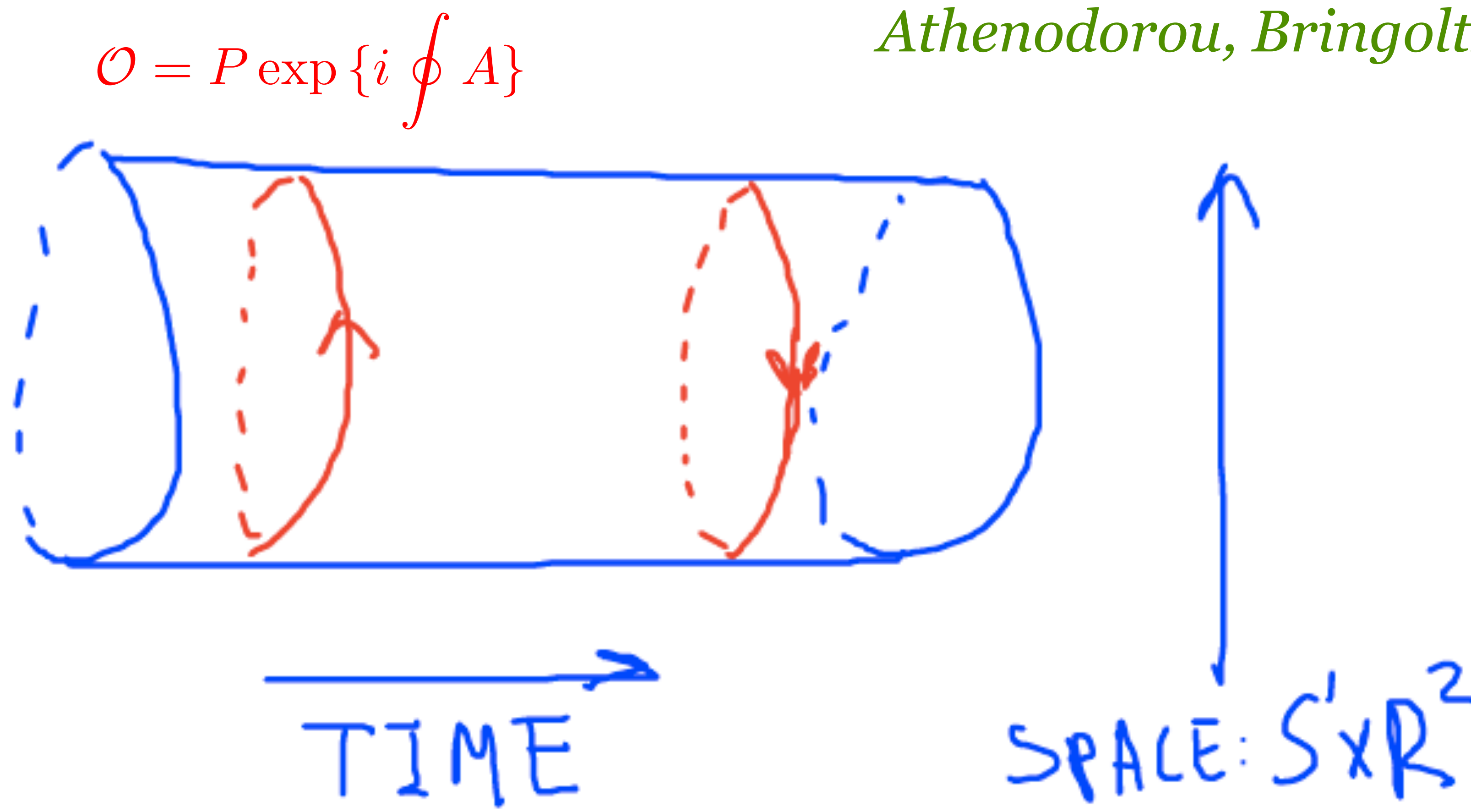
- ✓ Confining gauge theory with a gap
- ✓ Unbroken center symmetry
- ✓ Large N





Looks hopeless to solve without experimental data

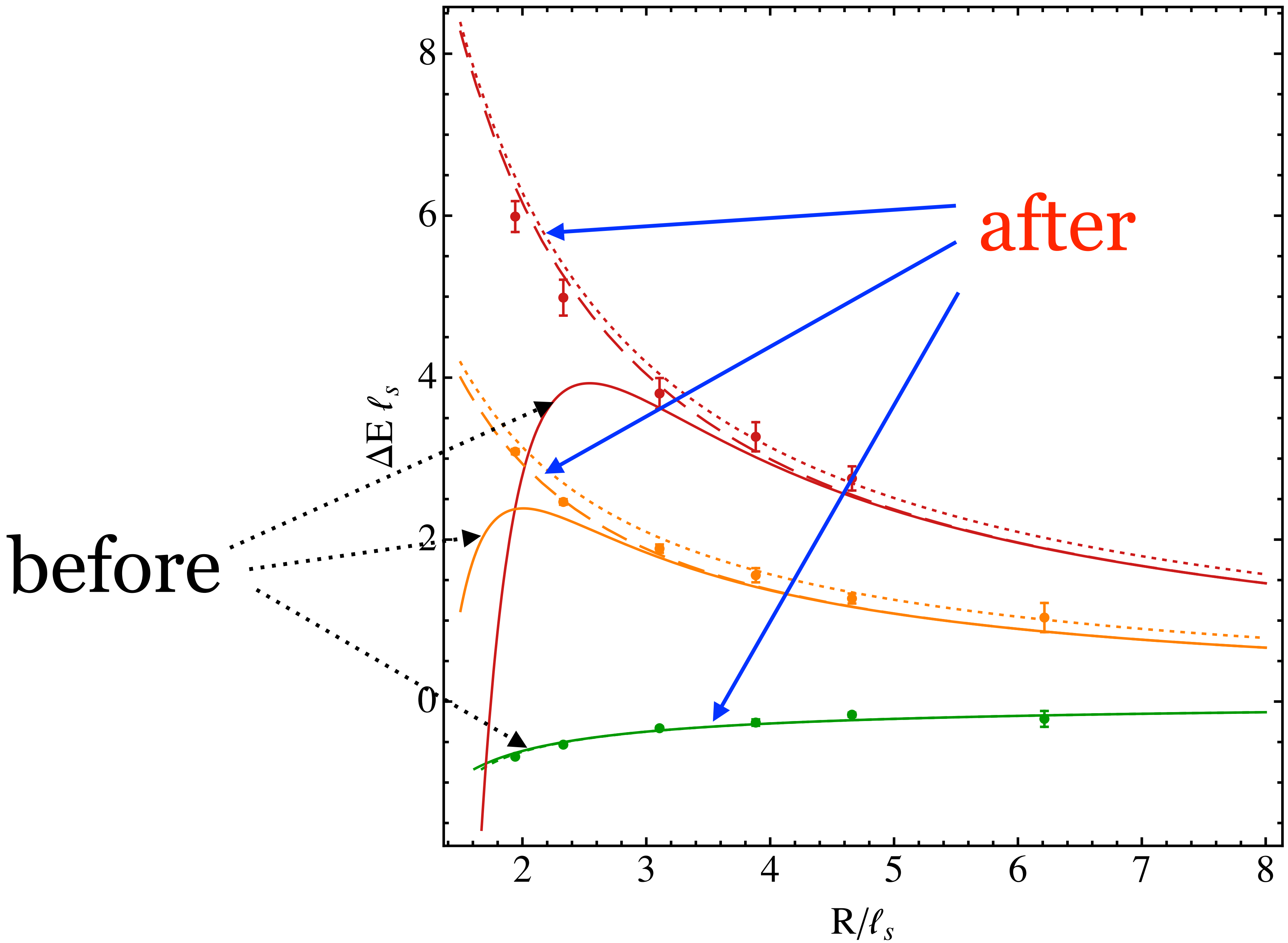
all the data from the papers by Athenodorou, Bringoltz and Teper



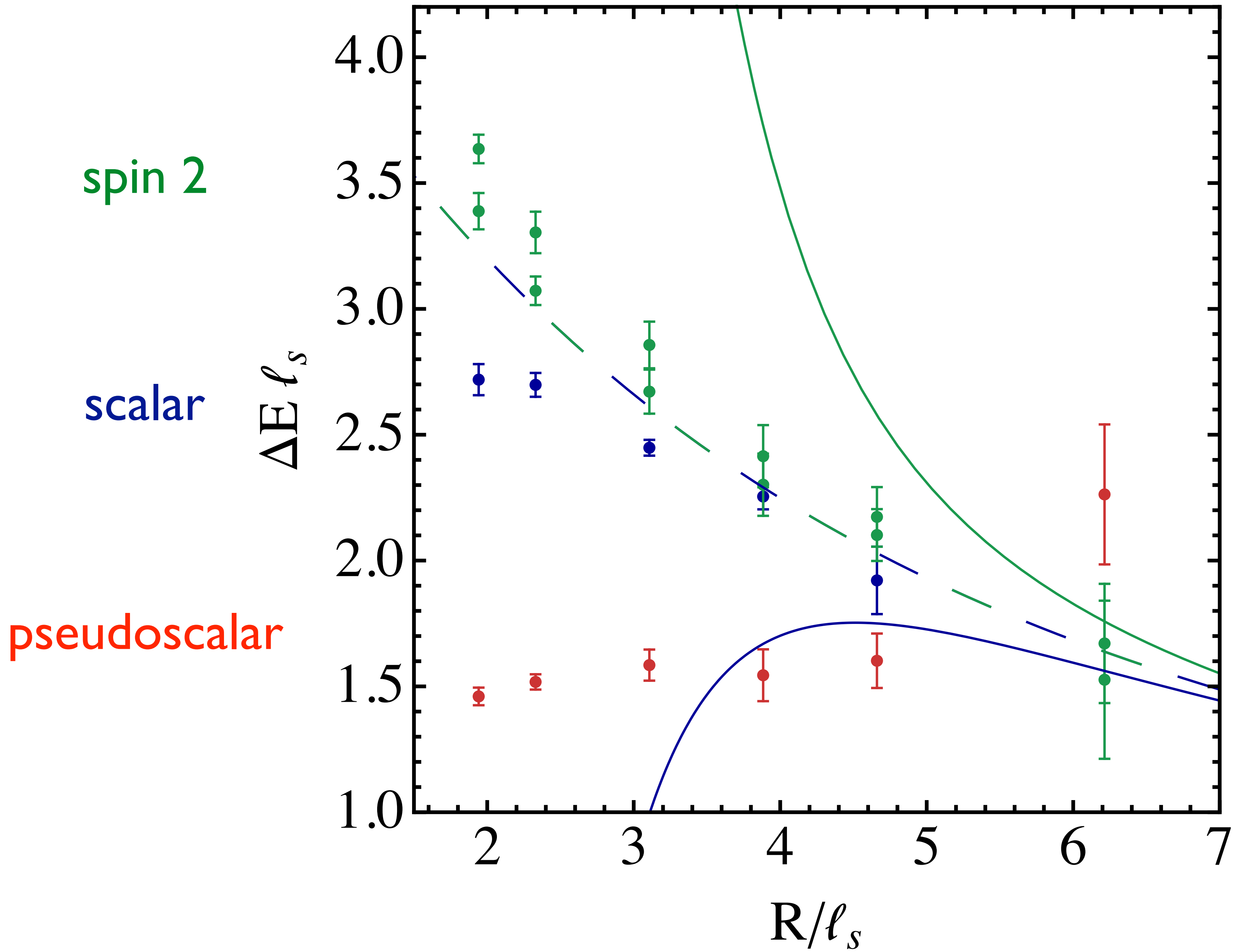
$$\int \mathcal{D}A e^{-S_{YM}} \mathcal{O}(0)\mathcal{O}^\dagger(t) \to e^{-E_{\mathcal{O}} t} + \ldots$$

Looks hopeless to solve without new theoretical tools

TBA technique



Colliding left- and right-movers

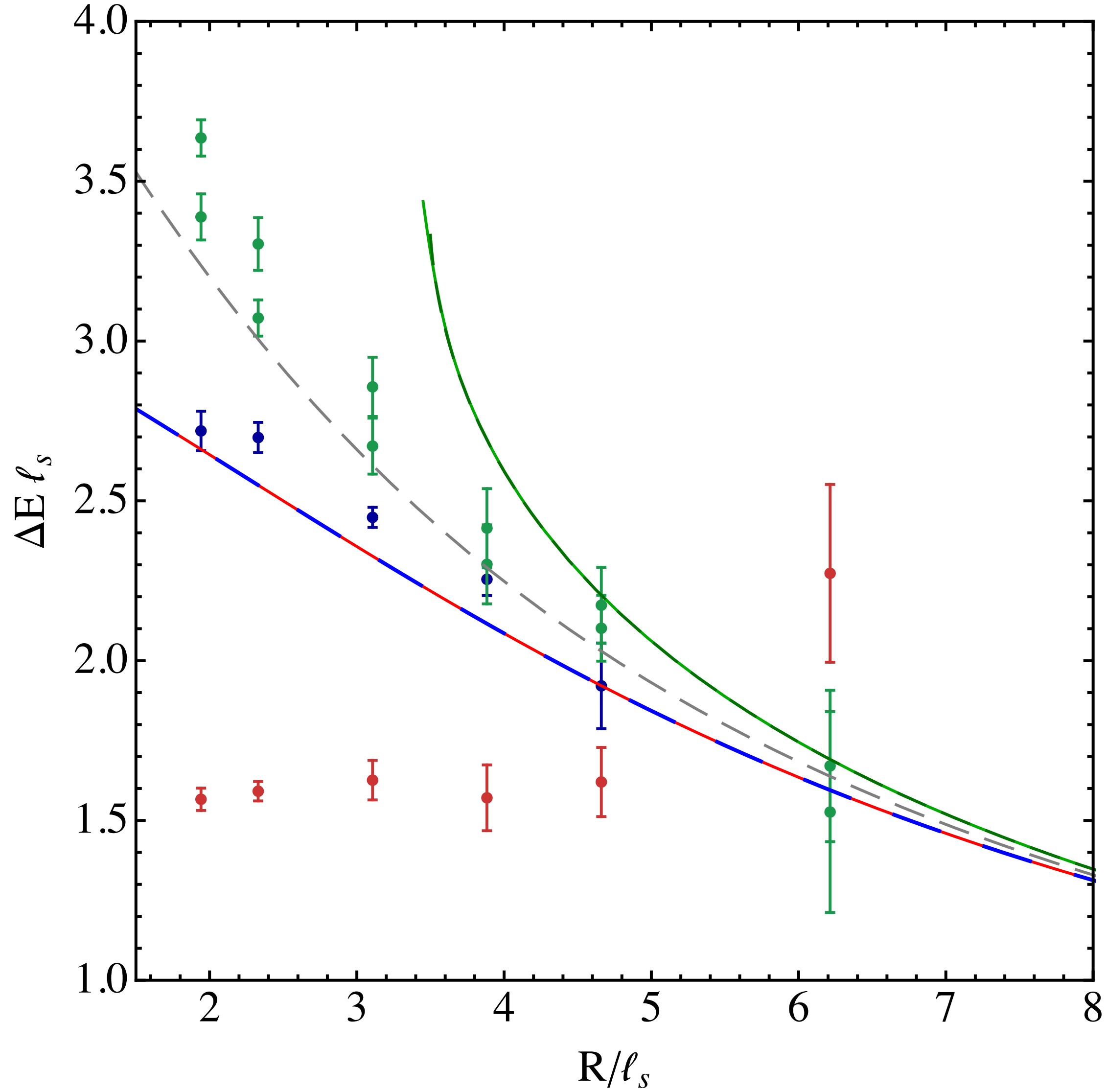


Colliding left- and right-movers

spin 2

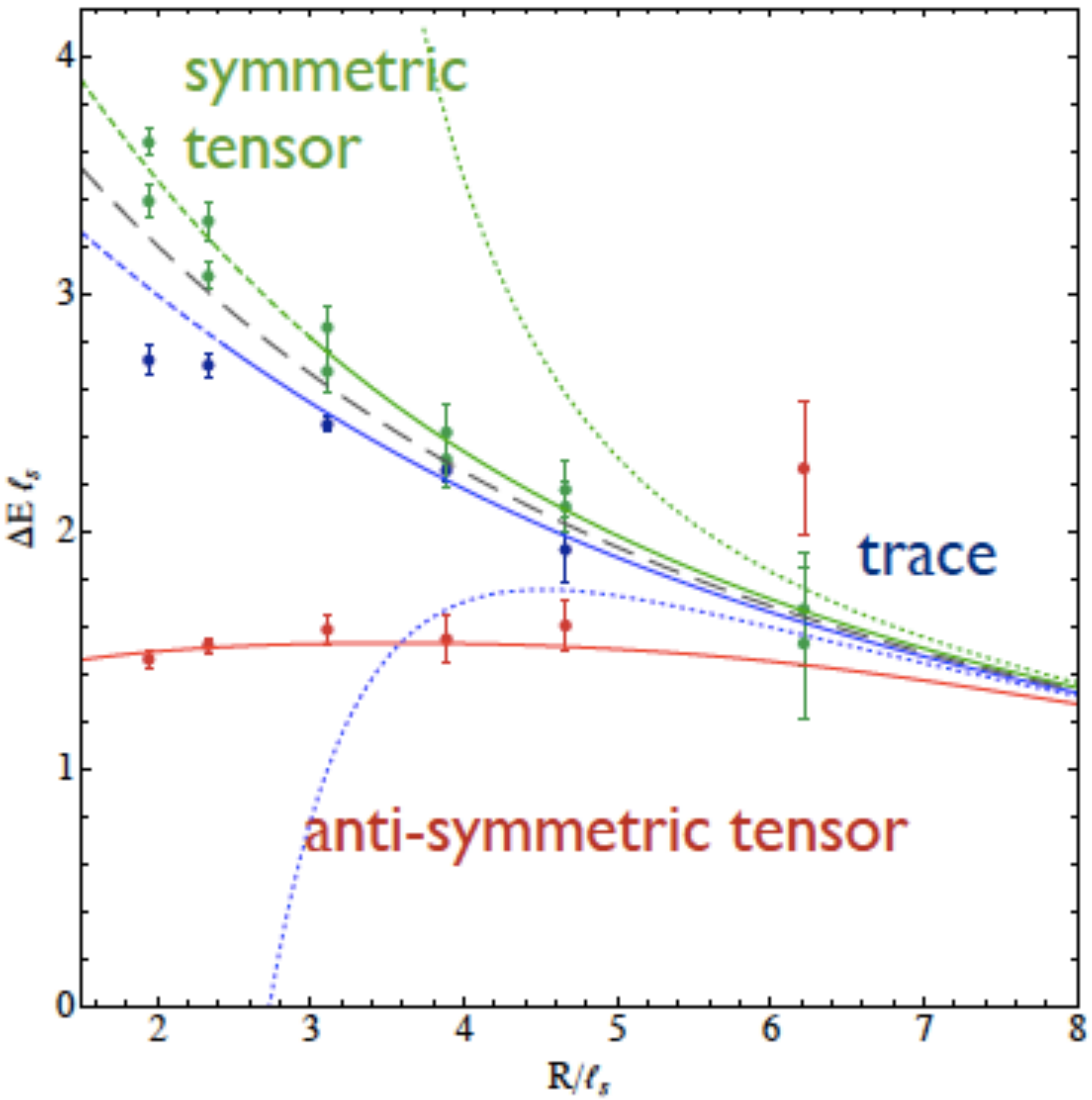
scalar

pseudoscalar



Red points:
A new massive state appearing as a resonance in the antisymmetric channel!

$$S = \int d^2\sigma \frac{1}{2}\partial_\alpha\phi\partial^\alpha\phi - \frac{1}{2}m^2\phi^2 + Q\phi\epsilon^{\alpha\beta}\epsilon_{ij}K^i_{\alpha\gamma}K^{j\gamma}_\beta$$



$$m\ell_s \approx 1.85^{+0.02}_{-0.03} \qquad Q \approx 0.382 \pm 0.004$$

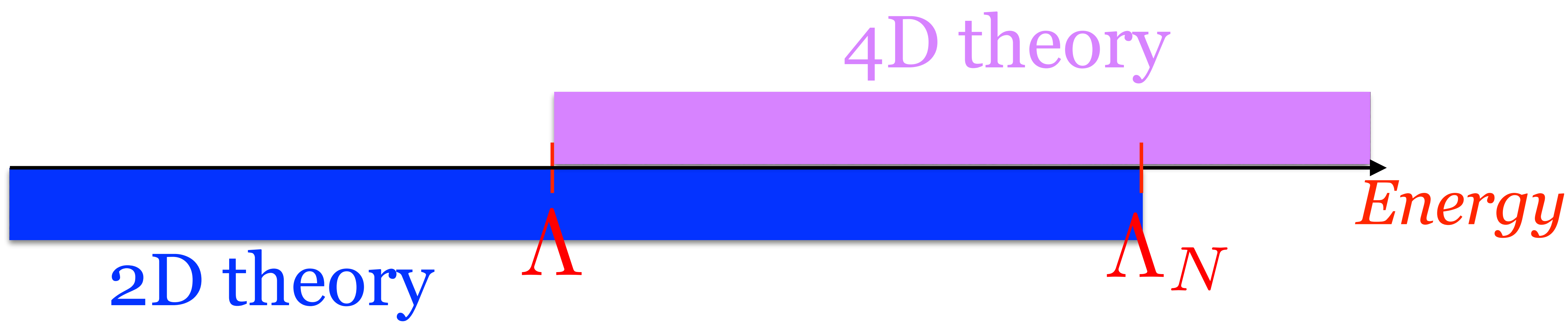
SD, Raphael Flauger, Victor Gorbenko, 1301.2325

More theory questions:

✳Can 2D theory be integrable, at least in the planar limit?

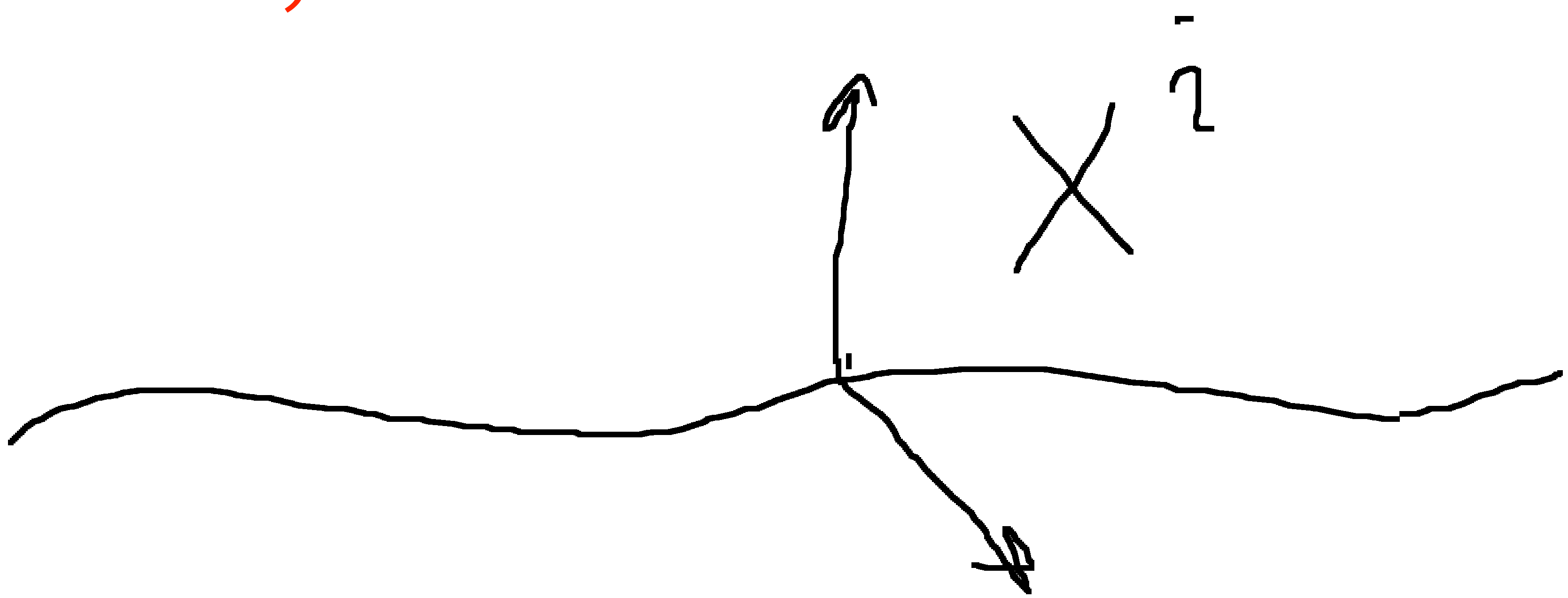
✳Could it be integrable for planar (pure glue)?

✳How to calculate for $\Lambda \lesssim E \lesssim \Lambda_N$ and whether (approximate) integrability may help?



Could QCD string be integrable for pure glue?

NO, at least not at finite N



$$S_{string} = -\ell_s^{-2}\int d^2\sigma\sqrt{-det(\eta_{\alpha\beta}+\partial_\alpha X^i\partial_\beta X^i)}+\mathcal{O}(\ell_s^2)$$

✶Integrable at tree level

✶*Universal* one-loop particle production if $D\neq 26,3$

All these one-loop amplitudes can be explicitly calculated, SD to appear

A simple option to restore integrability:

$$S_{string} = -\ell_s^{-2} \int d^2\sigma \sqrt{-det(\eta_{\alpha\beta} + \partial_\alpha X^i \partial_\beta X^i + \partial_\alpha \phi \partial_\beta \phi)} + Q \int d^2\sigma \phi R[X] + \ldots$$

$$Q = \sqrt{\frac{25 - D}{48\pi}}$$

This is also known as a linear dilaton background

Another simple option to restore integrability:

$$S_{string} = -\ell_s^{-2} \int d^2\sigma \sqrt{-det(\eta_{\alpha\beta} + \partial_\alpha X^i \partial_\beta X^i + \partial_\alpha \phi \partial_\beta \phi)} + Q \int d^2\sigma \phi K \tilde{K} + \ldots$$

$$Q = \sqrt{\frac{25-D}{48\pi}} = \sqrt{\frac{7}{16\pi}} \approx 0.373176\ldots$$

Compare to

$$Q_{lattice} \approx 0.382 \pm 0.004$$

???

What this could mean?

✶Numerology

✶In the planar limit axion becomes massless and the planar QCD string is integrable

✶ This is the UV asymptotics of the planar QCD string