

ASPECTS OF CONFINING STRINGS

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FLUX TUBES IN PURE SU(N) YANG MILLS

The vacuum is trivially gapped

[Athenodorou, Teper '21,
....]

Lightest glueball 0^{++}

$\mathbb{Z}_N^{(1)}$ one-form symmetry

[Gaiotto, Kapustin, Seiberg,
Willet' 14]

Believe that confining strings in YM attract and form bound states


2 NGBs and a Pseudoscalar Axion as the lightest massive excitation

[Dubovsky, Flauger, Gorbenko' 12], [Athenodorou, Dubovsky, Luo, Teper ' 24]

These are important data points, essentially numerical since pure YM
is strongly coupled. We do not have an analytic understanding of
answers to these questions !

ABRIKOSOV-NIELSEN-OLESEN (ANO) VORTEX STRINGS

SUPERCONDUCTING
STRINGS
(Magnetic)


Electric Magnetic duals
of each other
(‘tHooft-Mandelstam)

CONFINING STRINGS
(Electric)

Abelian Higgs Models
(AHMs)

Dual Abelian Higgs
Models

Made precise in
Deformed SW theory

Simple Abelian models are good labs for studying string properties
and asking non-universal questions.

WHY SEIBERG WITTEN THEORY?

$\mathcal{N} = 2$ SYM



$\mathcal{N} = 1$ SYM

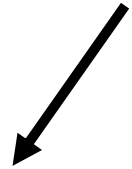


Pure YM

Weakly deform SW theory and restrict our analysis to $\mathcal{N} = 1$ theories

Explicit realization of dual superconductivity (dual Abelian Higgs model) with electric flux tubes instead !

PROPERTIES OF STRINGS



PHASES OF GIANT
FLUX TUBES

EFFECTIVE ACTION
OF LONG STRINGS

1. Magnetic Vortex strings in minimal AHMs
2. Confining Strings in Deformed SW

LARGE FLUX TUBES

MAGNETIC FLUX TUBES IN MINIMAL AHMS

[Dumitrescu, AG
2511.20527]

$$U(1)_m^{(1)}$$

Magnetic flux
symmetry

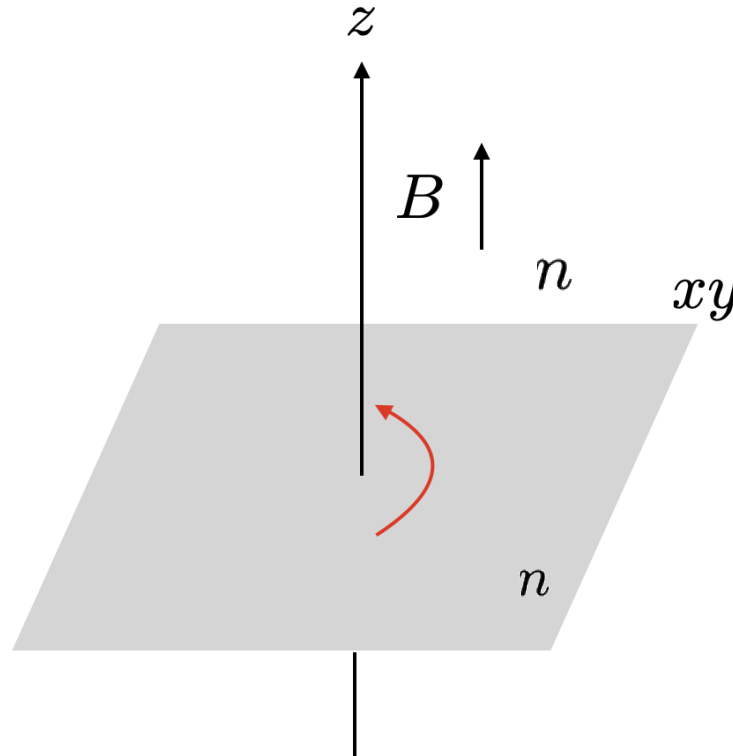
$$\mathcal{L} = -\frac{1}{4e^2} f_{\mu\nu} f^{\mu\nu} - |(\partial_\mu - ia_\mu)\phi|^2 - V(\phi)$$

Admits a Higgs vacuum !

$$n = \frac{1}{2\pi} \int f^{(xy)}$$

$$n \gg 1$$

Simplifying Assumption :
Axially symmetric Strings !



Punchline : The large flux limit
is a tractable limit and the
physics of the giant strings gets
simplified.

MAGNETIC FLUX TUBES IN MINIMAL AHMS

[Dumitrescu, AG 2511.20527]

$$\mathcal{L} = -\frac{1}{4e^2} f_{\mu\nu} f^{\mu\nu} - |(\partial_\mu - ia_\mu)\phi|^2 - V(\phi)$$

$n \gg 1$

PHASES OF GIANT STRINGS

Scaling of **size** and **tension** with flux.

$$V(\phi) \sim |\phi|^2 (|\phi|^2 - 1)^2$$

**DOMAIN WALL
PHASE**

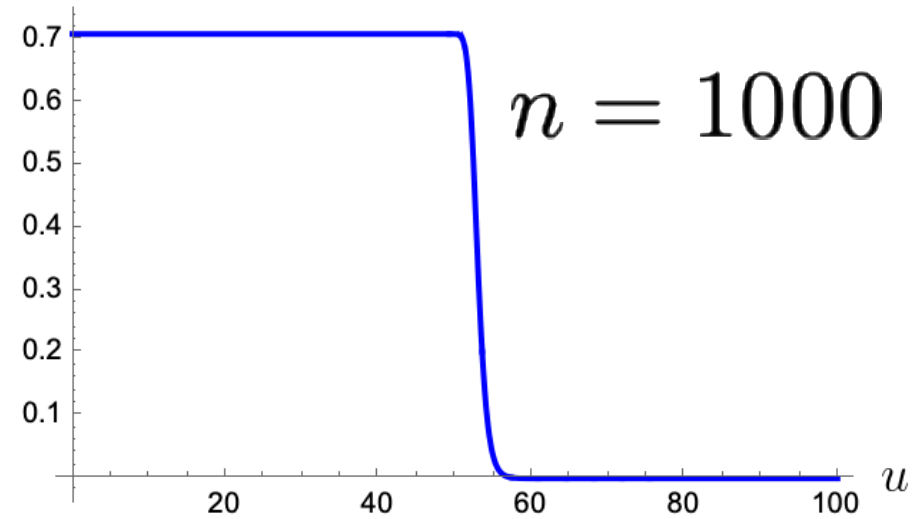
$$T_n \sim n^{2/3}$$

$$V(\phi) \sim (|\phi|^2 - 1)^2$$

**BULK
PHASE**

$$T_n \sim n$$

Magnetic field B



CONFINING STRINGS IN SOFTLY DEFORMED SU(2) SW THEORY

$U(1)_e^{(1)}$ Electric flux
symmetry

To appear [Dumitrescu, AG]

$$\mathcal{L} = -\frac{1}{4e^2} f_{\mu\nu} f^{\mu\nu} - |(\partial_\mu - ia_\mu)m|^2 - |(\partial_\mu + ia_\mu)\tilde{m}|^2 - \frac{|\partial_\mu a_D|^2}{e^2}$$

Monopole fields

Neutral Scalar

$$-\frac{e^2}{2} (|m|^2 - |\tilde{m}|^2)^2 - 2|a_D|^2 (|m|^2 + |\tilde{m}|^2) - e^2 |\sqrt{2}m\tilde{m} + \xi + 2\alpha_2 a_D + 3\alpha_3 a_D^2|^2$$

**DUAL ABELIAN HIGGS
MODEL !**

Deformation
parameters !

$\mathcal{N} = 1$ Model with fermions turned off

Weakly coupled theory of monopoles and photons !

CONFINING STRINGS IN SOFTLY DEFORMED SU(2)

SW THEORY

To appear [Dumitrescu, AG]

$$\mathcal{L} = -\frac{1}{4e^2} f_{\mu\nu} f^{\mu\nu} - |(\partial_\mu - ia_\mu)m|^2 - |(\partial_\mu + ia_\mu)\tilde{m}|^2 - \frac{|\partial_\mu a_D|^2}{e^2}$$

$$-\frac{e^2}{2} (|m|^2 - |\tilde{m}|^2)^2 - 2|a_D|^2 (|m|^2 + |\tilde{m}|^2) - e^2 |\sqrt{2}m\tilde{m} + \xi + \cancel{2\alpha_2 a_D} + \cancel{3\alpha_3 a_D^2}|^2$$

$$T_k \sim \sin \frac{\pi k}{N}$$

Model admits BPS
strings !

BPS
truncation !

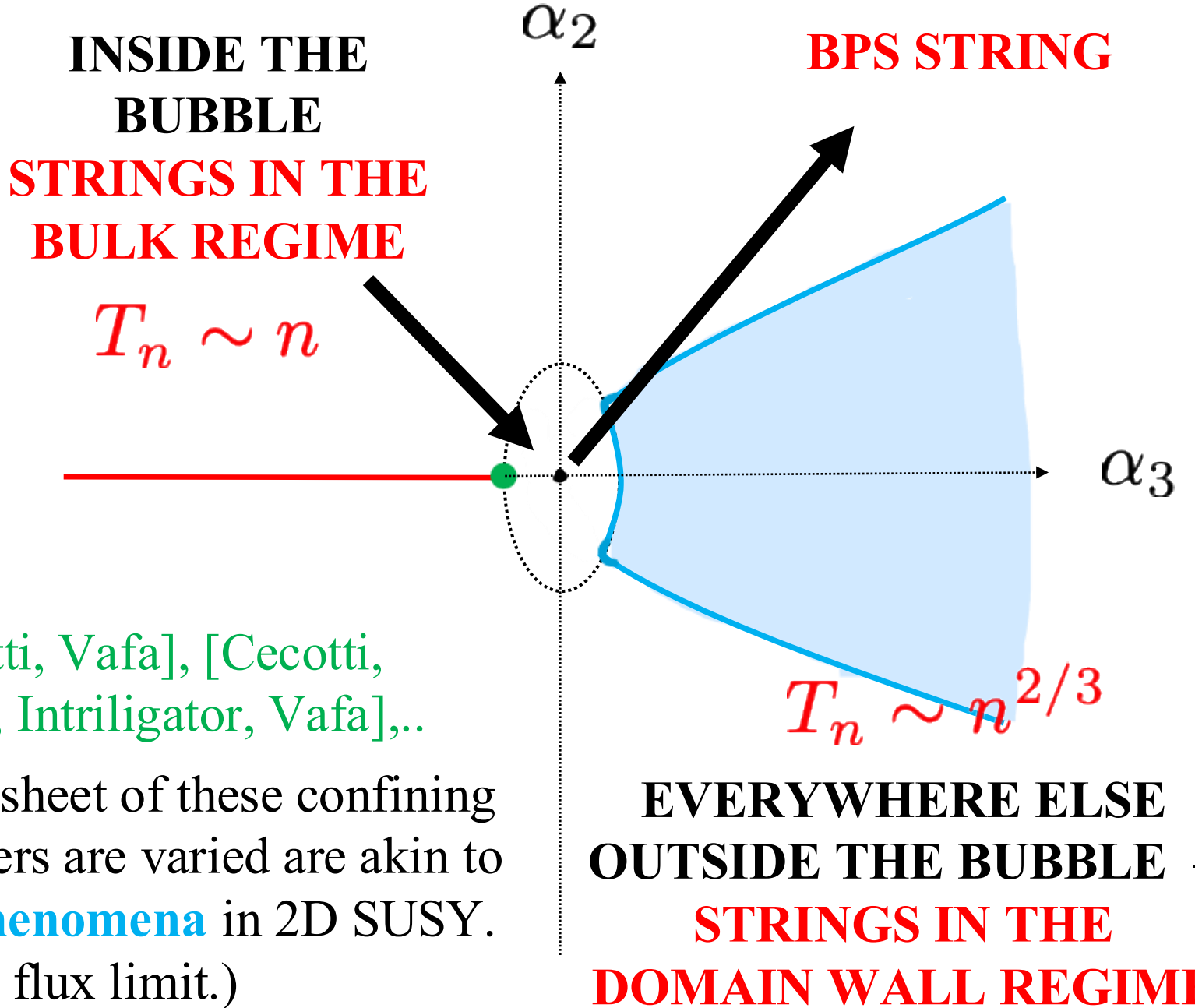
$U(1)_e^{(1)}$ Electric flux
symmetry

Monopole fields

Neutral Scalar

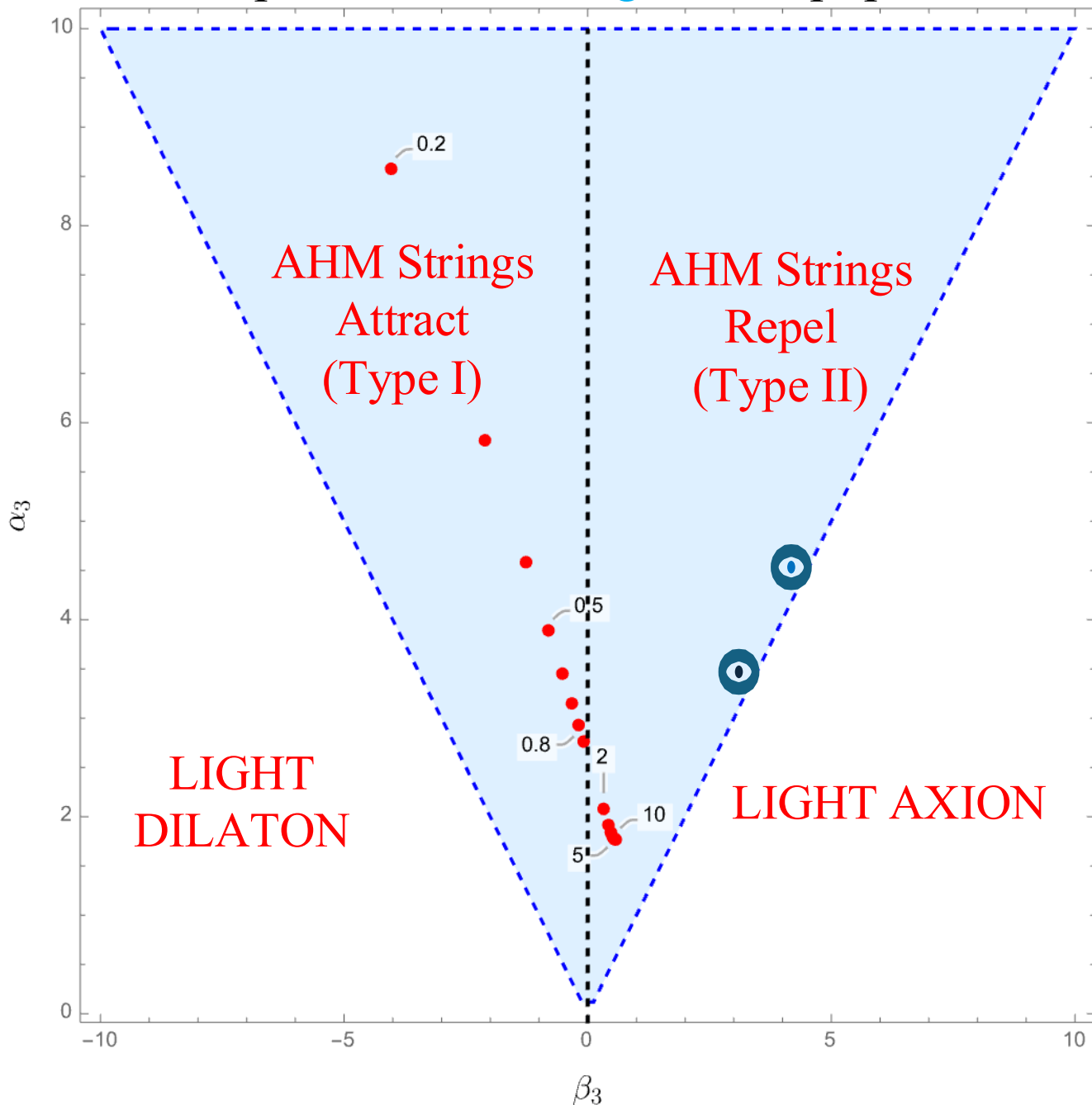
[Douglas, Shenker], [Vainshtein, Yung], [Klebanov, Herzog],
[Hanany, Strassler, Zaffaroni],

GIANT CONFINING STRINGS



Phase transitions on the world-sheet of these confining strings as deformation parameters are varied are akin to **Cecotti-Vafa wall crossing phenomena** in 2D SUSY.
(Sharp in the large flux limit.)

Bootstrap Plot **allowed region** and population



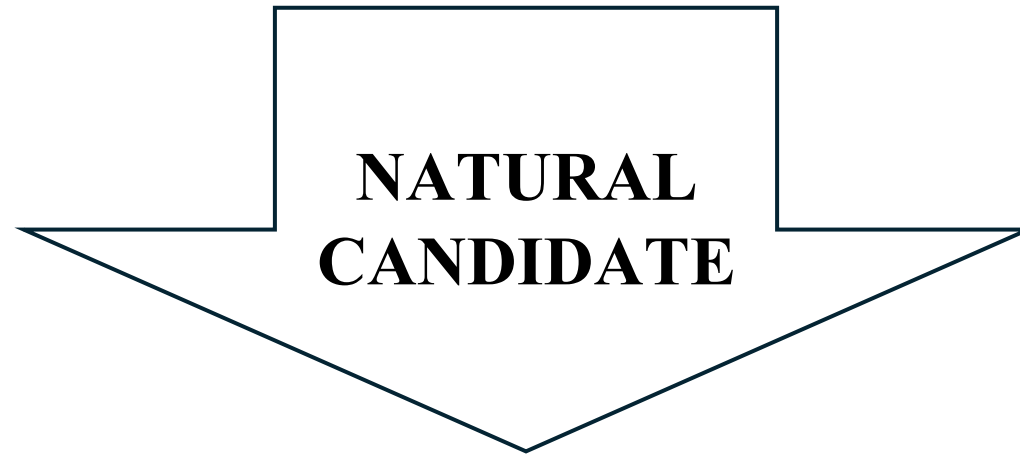
[Miro, Guerrieri], [Miro, Guerrieri, Hebbar, Penedones, Vieira]

- Minimal AHMs
To appear [Dumitrescu, AG, Li]
 $e = 1$
- SU(N=3,5) Yang Mills (lattice)
[Dubovsky, Flauger, Gorbenko, Athenodorou, Teper,..]
- Holographic confining theories
[Aharony, Karzbrun,..]
[Polyakov],...

The axion is light in the regime where AHM strings repel – Opposite to Yang Mills !

MINIMAL AHM IS NOT A
COMPELLING DUAL DESCRIPTION
FOR YM CONFINING STRINGS !

MINIMAL AHM IS NOT A
COMPELLING DUAL DESCRIPTION
FOR YM CONFINING STRINGS !



Deformed SW Theory

SUMMARY

1. **Minimal** Abelian Higgs models (AHMs) **do not** serve as compelling dual descriptions of YM flux tubes !

2. Deformed SW provides a setting where dual superconductivity can be made precise. The minimal AHMs serve as effective toy models to study strings in this richer setting.

3. The large flux limit is a tractable limit and the physics of the giant strings gets simplified.

What is the lightest fluctuation mode around a string background ?

Do separated strings attract or repel ?

Domain Wall Phase

Bulk phase

THANK YOU !