SUSY and non-SUSY analysis of truly confining gauge theories

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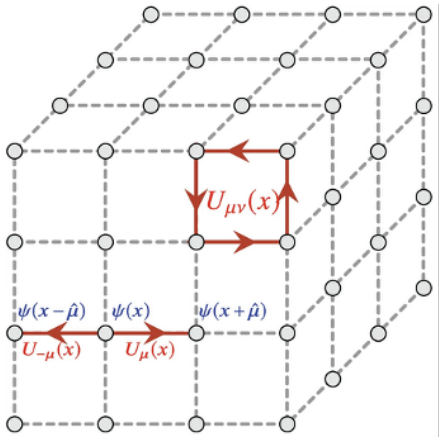
Contents

- **Background**
  QCD $\supset$ confinement $\supset$ dual Meissner
- **Purpose**
  show condensing operator in truly confining phase
- **Method**
  group theory + SUSY QCD + AMSB
- **Result**
  SUSY and non-SUSY

Background: **QCD** ⊃ confinement ⊃ dual Meissner

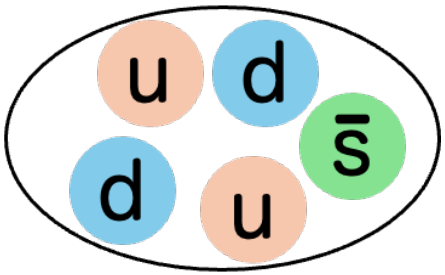
QCD

Kaczmarek(2022)

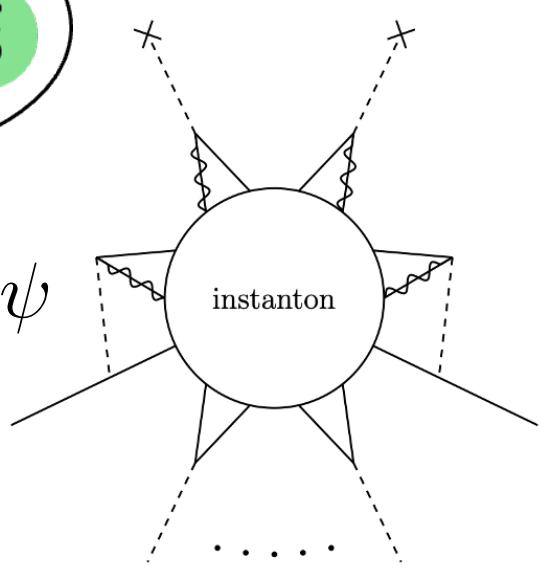


lattice theory

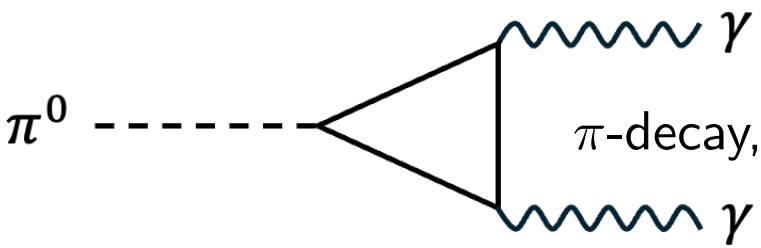
hadron



$$\mathcal{L} = -\frac{1}{4}F^2 + i\bar{\psi}D\psi$$



instanton

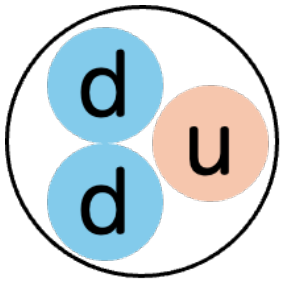


π-decay, anomalies

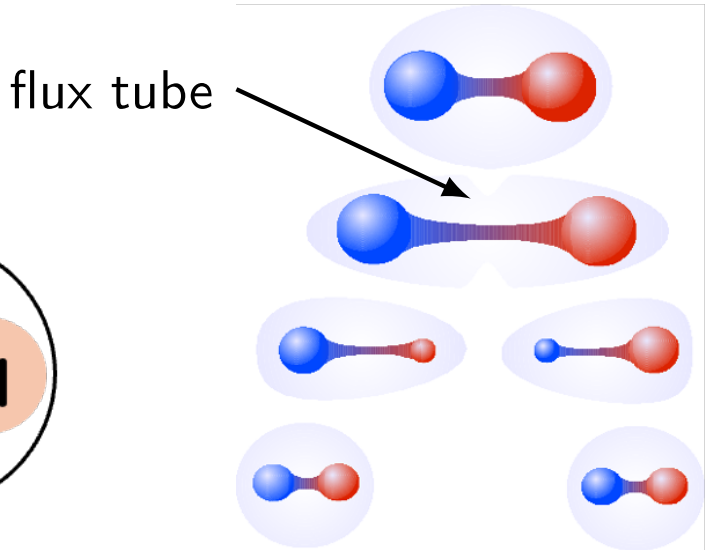
Background: QCD ⊃ **confinement** ⊃ dual Meissner

QCD

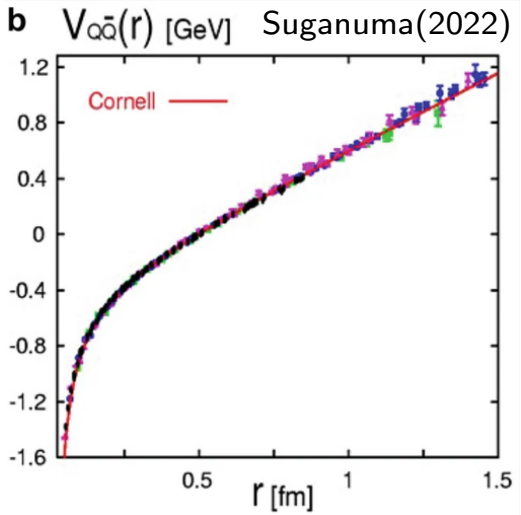
confinement



quark unobservability

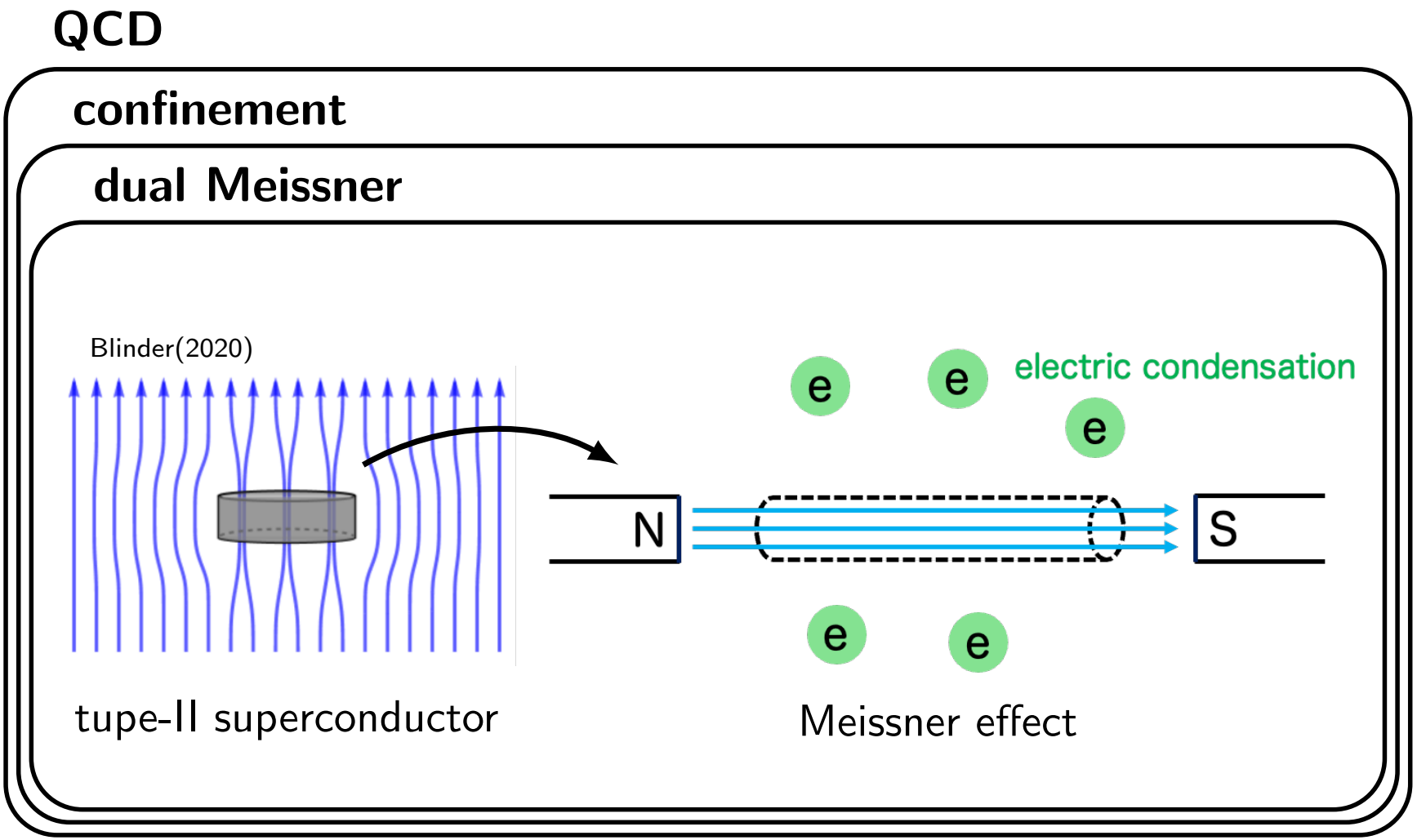


Schwinger mechanism

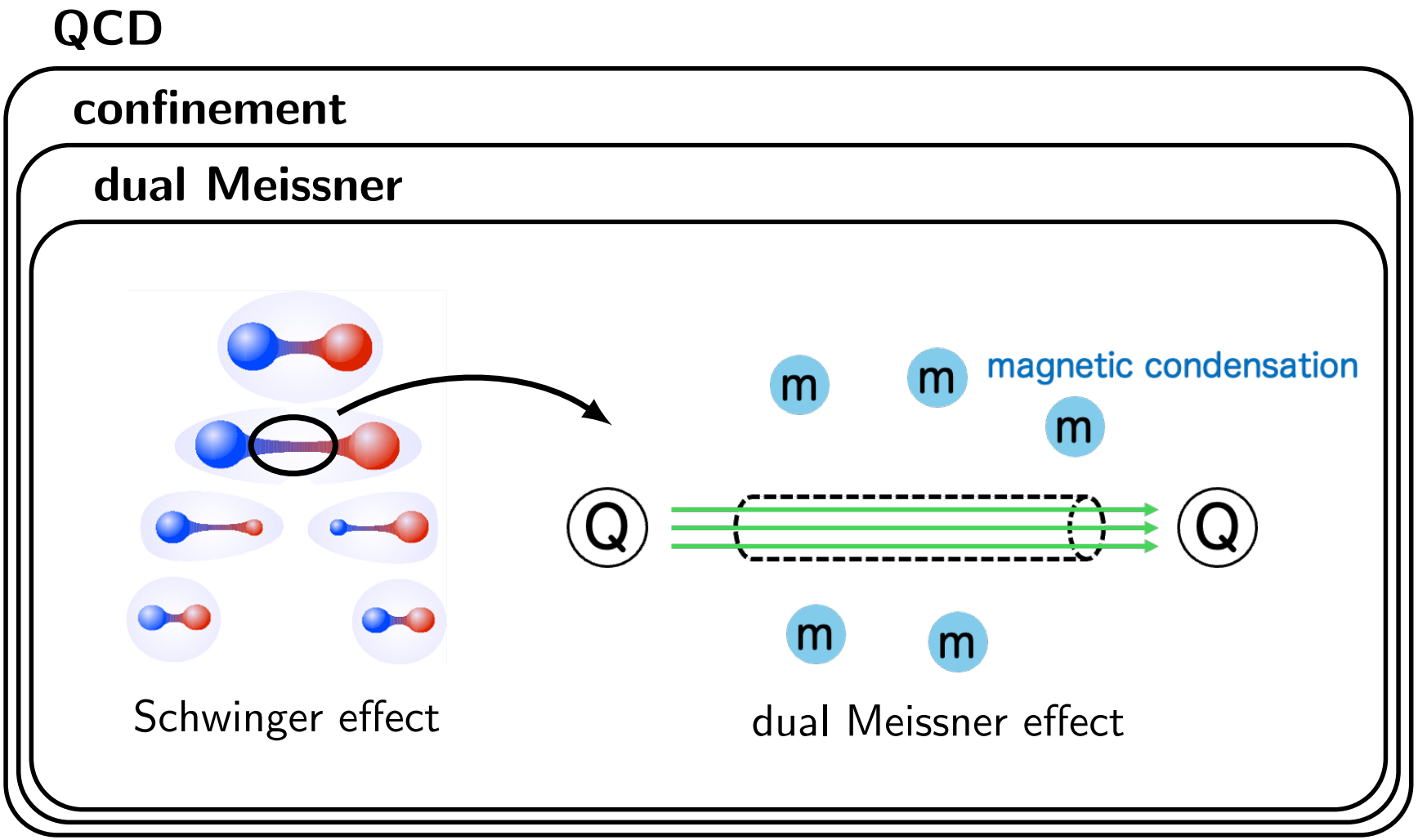


linear potential

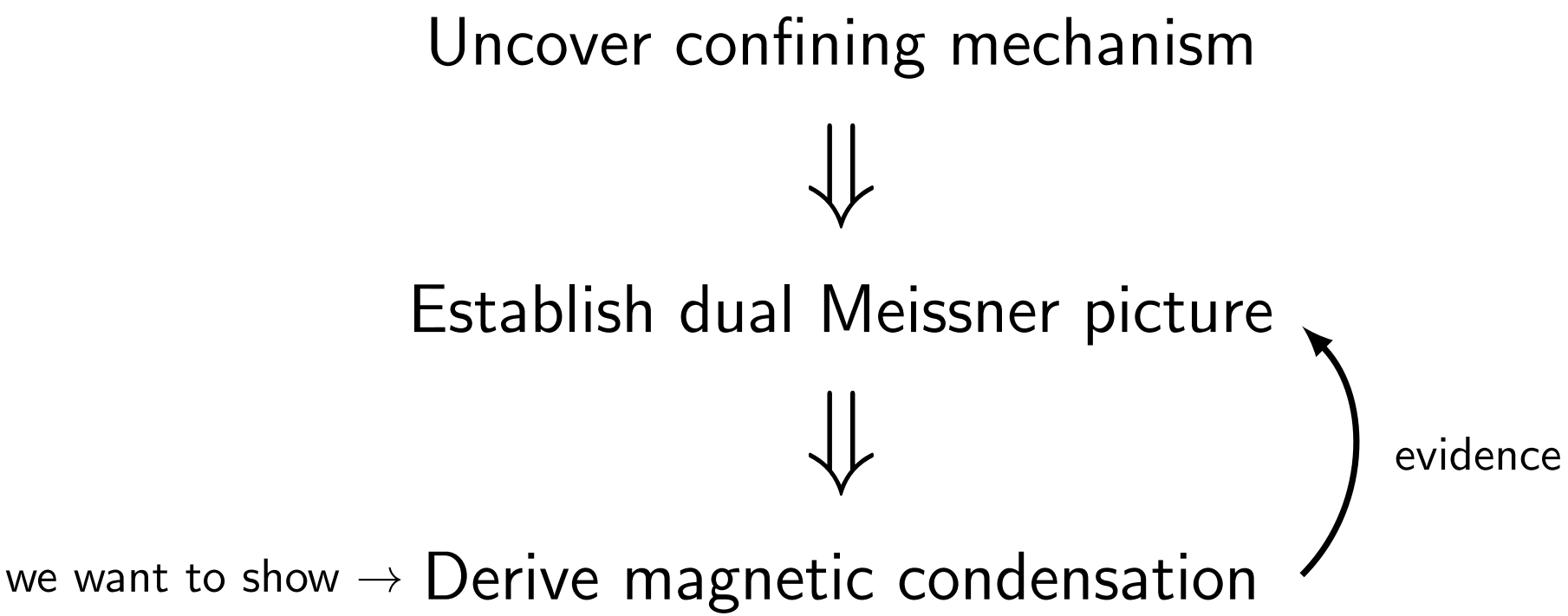
Background: QCD ⊃ confinement ⊃ **dual Meissner**



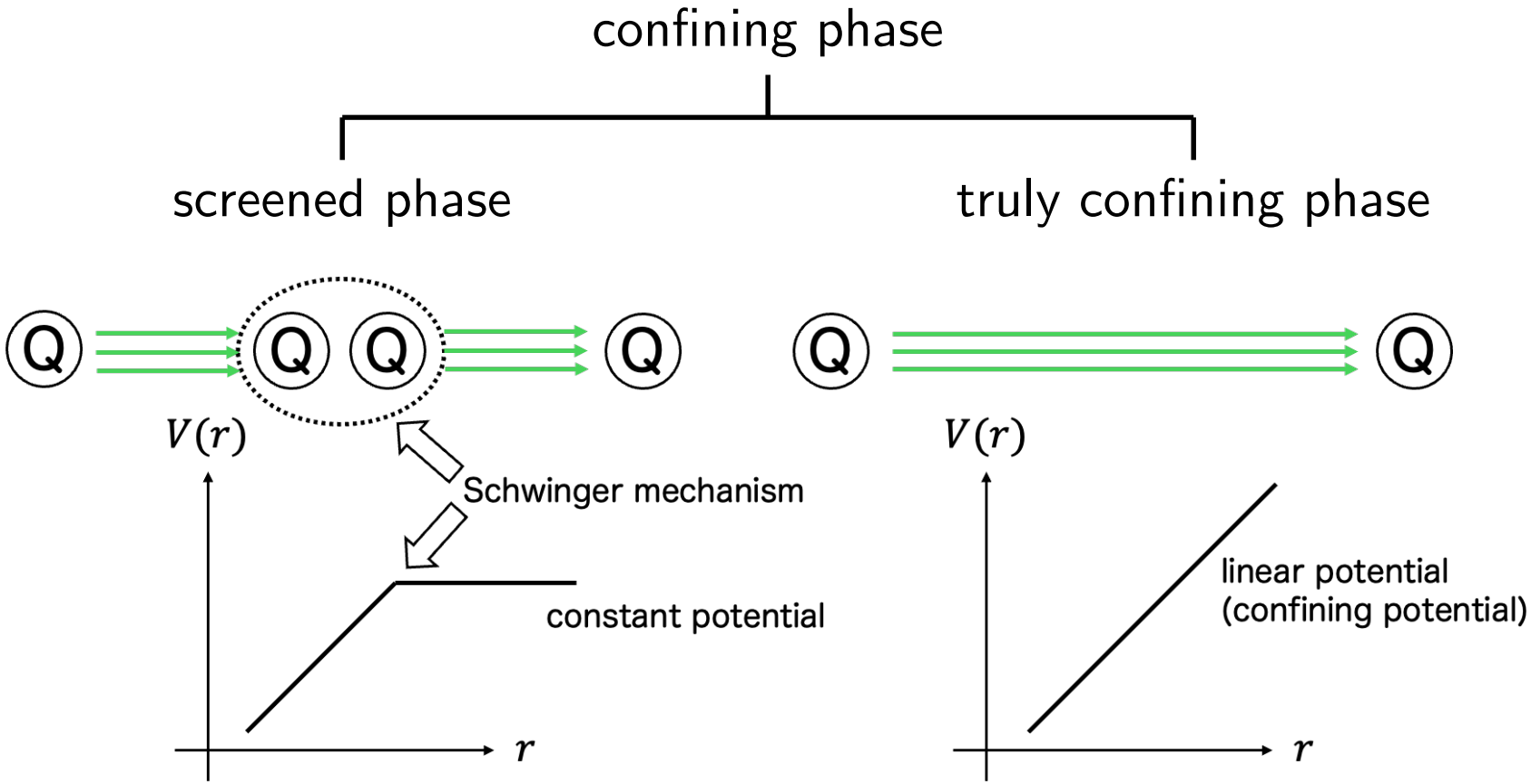
Background: QCD ⊃ confinement ⊃ **dual Meissner**



Purpose: show **condensing op.** in truly confining phase



Purpose: show condensing op. in **truly confining phase**



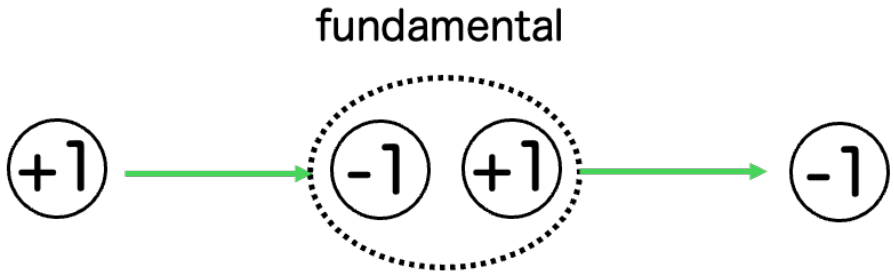
We list and analyze all truly confining theories,
and identify magnetic condensation.

Method: **group theory** + SUSY QCD + AMSB

Gauge theory = Gauge group + Matters (many combinations)

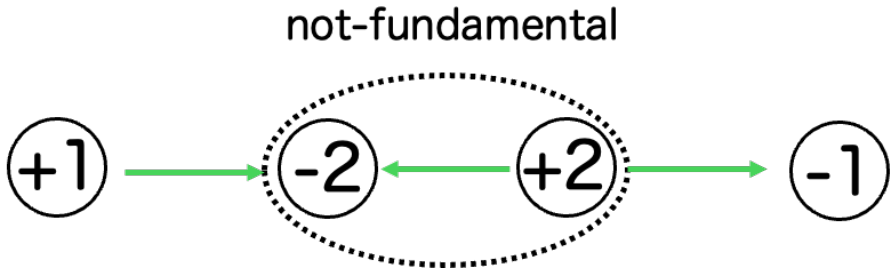
- fundamental rep. is NG

  ∵ all flux tube is screened



- very large rep. is NG

  ∵ no asymptotic freedom

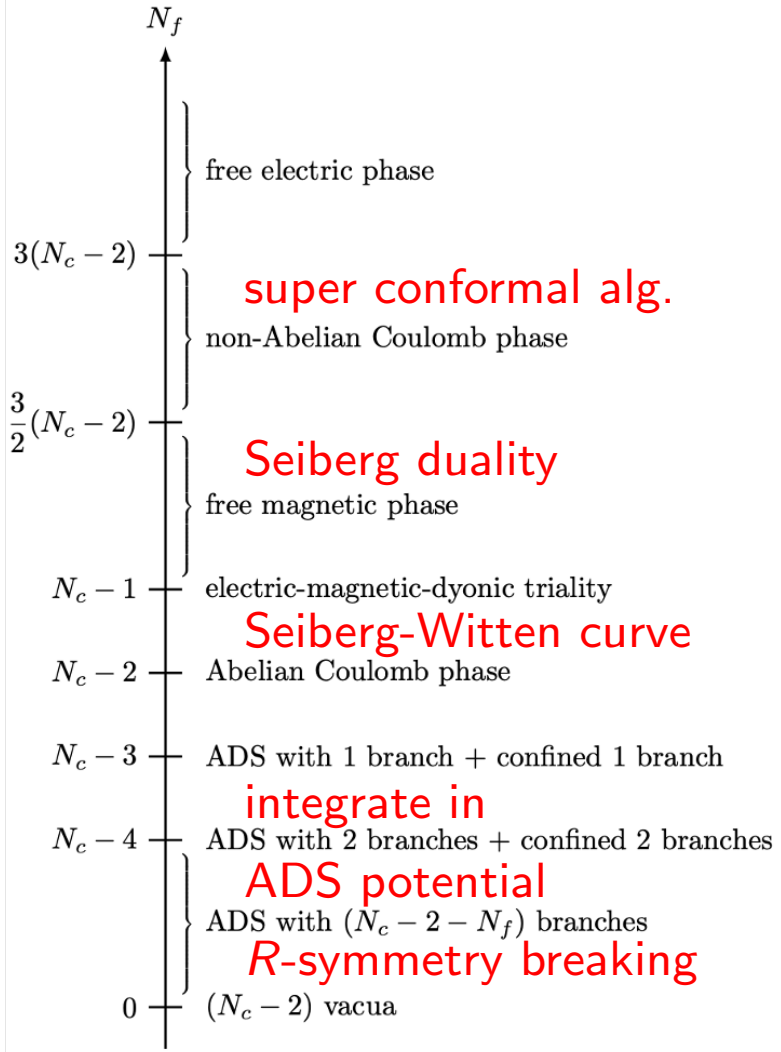


Truly confining gauge theories are classified by 7 types.

Method: group theory + **SUSY QCD** + AMSB

- QCD is difficult ...
- SUSY makes many things possible!
- For example, in $SO(N_c)$ theory ...

quantum and non-perturbative effect are exactly computed!



phase diagram of $SO(N_c)+N_f$ vectors

Method: group theory + **SUSY QCD** + AMSB

Example of finding a condensing operator in $SU(2k) + A + \tilde{A}$.

- add three fundamental quarks (s-confining)

$$SU(2k) + A + \tilde{A} + 3(Q + \tilde{Q})$$

- by mass term $mQ\tilde{Q}$, following operator condensates

$$\tilde{Q}(A\tilde{A})^{k-1}Q$$

- using generalized Konishi anomaly (trivial in Chiral ring)

$$\bar{D}^2(\tilde{Q}E^iQ) = m\tilde{Q}E^iQ + \mathrm{tr}(E^iW^2) \equiv 0$$

- we find a condensing operator

$$\mathrm{tr}\{(A\tilde{A})^{k-1}W^2\}$$

Method: group theory + SUSY QCD + **AMSB**

We used **AMSB (anomaly mediated SUSY breaking)** to get non-SUSY knowledge.

- SUSY lagrangian:

$$\mathcal{L}_{\text{susy}} = \int d^4\theta K(\phi_i) + \int d^2\theta W(\phi_i) + \text{c.c.}$$

- AMSB lagrangian (SUSY breaking term):

$$\mathcal{L}_{\text{tree}} = m\left(\phi_i \frac{\partial W(\phi_i)}{\partial \phi_i} - 3W\right) + \text{c.c.}$$

- SUSY with AMSB is expected to describe non-SUSY QCD!

We want to find non-SUSY stable vacua which continuously connected SUSY vacua.

Result: **SUSY** and non-SUSY

theories	condensation
$\mathcal{N}=1$ YM	◯
$SO(k)+(k-4)V^i$	◯
$SO(k)+(k-3)V^i$	◯
$SU(6)+A^{[ijk]}$	◯
$Sp(k)+A^{[ij]}$	◯
$SU(2k)+A^{[ij]}+\tilde{A}^{[ij]}$	◯
$SO(12)+2S$	◯

Q. Any magnetic condensation?

- for "condensing op.,"
  it exists in all theories!
- for "magnetic op.,"
  it exists in some theories!

Our result support
dual Meissner picture
in a limited sence.

Result: SUSY and **non-SUSY**

theories (with AMSB)	stable vacua
$\mathcal{N}=1$ YM	◯
$SO(k)+(k-4)V^i$	◯
$SO(k)+(k-3)V^i$	◯
$SU(6)+A^{[ijk]}$	◯
$Sp(k)+A^{[ij]}$	◯
$SU(2k)+A^{[ij]}+\tilde{A}^{[ij]}$	◯
$SO(12)+2S$	◯

Our result support
dual Meissner picture
even in non-SUSY vacua.

Summary

- **Background**
  QCD $\supset$ confinement $\supset$ dual Meissner
- **Purpose**
  show condensing operator in truly confining phase
- **Method**
  group theory + SUSY QCD + AMSB
- **Result**
  We find each theory has a *condensing operator* indicating *dual Meissner picture*.

Thank you for your listening!