Orientifold QCD, duality and planar equivalence
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Non-Supersymmetric Seiberg Duality in orientifold QCD and Non-Critical Strings

Dan Israël, IAP

Liverpool Workshop, March 08

A. Armoni, D.I., G. Moraitis and V. Niarchos, arXiv:0801.0762
D.I., V. Niarchos, arXiv:0705.1240

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  ➡ Phenomenological string models need spontaneous or explicit breaking of (global) susy, but at high mass levels the theory is approximately supersymmetric

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- These two issues are related by gauge/string correspondences

➡ Are there examples for which they can be addressed alltogether?

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Outline

1. Orientifold QCD, duality and planar equivalence
2. Seiberg duality at finite N: a conjecture
3. Non-critical type 0' strings
4. OQCD in non-critical strings and duality

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Planar equivalence
orientifold QCD

Seiberg duality in SQCD

- IR dynamics of $\mathcal{N}=1$ QCD is well understood   *(Seiberg 94)*

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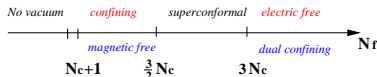orientifold QCD

Seiberg duality in SQCD

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- $SU(N_c)$ "electric" SQCD with N_f $\square$, $\bar{\square}$ flavors has a dual "magnetic" description with gauge group $SU(N_f\text{-}N_c)$ and an extra meson chiral multiplet ➡ provides a weakly coupled description of the strongly coupled dynamics

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- For $\frac{3}{2}N_c < N_f < 3N_c$: *conformal window* $\rightarrow$ interacting IR fixed point for both electric and magnetic Lagrangians

➡ numerous checks thanks to super(conformal) symmetry

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- One would like to extend this analysis to non-supersymmetric gauge theories ➡ in QCD, only the upper bound of the conformal window is known   (Banks, Zaks 82)

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- Planar equivalence provides exact non-perturbative results for (a restricted class of) non-susy gauge theories

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➤ OQCD-AS with N_c=3, $\mathrm{N}_f = 0$: one flavor QCD!

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- Similarly, an orientifold "magnetic" theory can be defined for $N_c, N_f \to \infty$, N_f/N_c fixed
- Predicts a non-supersymmetric Seiberg duality in OQCDs in this large N limit

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Seiberg duality at finite N: a conjecture

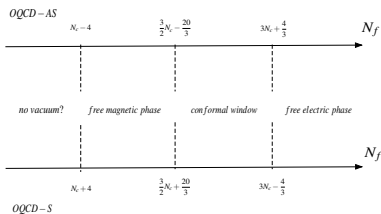- We propose that (N_c, N_f) OQCD-S/OQCD-AS is dual to a "magnetic theory" with $(N_f - N_c \mp 4, N_f)$ for any N_f and any $N_c > 5$ *(Armoni, DI, Moraitis, Niarchos 08)*

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- 't Hooft anomaly matching is satisfied for any finite N_c, N_f
  ➥ good consistency check but not powerfull enough

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- This duality if true predicts the following phase structure, with a conformal window $\frac{3}{2}N_c \pm \frac{20}{3} < N_f < 3N_c \mp \frac{4}{3}$:

➤ more evidence comes from a string theory construction

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- One expects a string theory realization of OQCD to be tachyon-free and without space-time fermions (no fermionic gauge-inv. operators) ➡ *do such string theories exist ?*

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- Sagnotti orientifold of type 0B (type 0'B) is tachyon-free but RR tadpole ➟ add D9-branes, NSNS tadpole left   *(Sagnotti 95)*

$$\Omega' \; : |0\rangle_{\text{NS}} \to -|0\rangle_{\text{NS}} \; , \;\; \psi_r^i \bar{\psi}_r^j |0\rangle_{\text{NS}} \to \psi_r^j \bar{\psi}_r^i |0\rangle_{\text{NS}}$$

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- Only such string theories known with full tree-level consistency: *non-critical type 0' strings*   *(DI, Niarchos)*

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- Start e.g. with type 0A on $\mathbb{R}^{3,1} \times [\mathcal{N} = 2 \text{ Liouville}]$
  ➡ non-chiral GSO projection, contains a tachyon sector + doubling of the RR forms

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  $$m^2 = p_\mu p^\mu + p_\phi^2 + \tfrac{1}{4} + \tfrac{1}{2}(n_x + w_x)^2 + \cdots - \tfrac{1}{2}$$
  ➡ not enough to lift the tachyon

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- Crosscap wavefunction can be determined by modular bootstrap from the Möbius amplitude:
  $$\text{Tr}_{\text{OPEN}, |B\rangle} \left(\mathcal{P} e^{-\pi t H_o} \right) = \sum_{\text{closed}} \langle B | \mathcal{P} e^{-\frac{4\pi t}{H_c}} | \mathcal{C}_{\mathcal{P}} \rangle$$
  ➡ Needs $\mathcal{P}$-matrix elements for $\mathcal{N} = 2$ characters ($\tau \to -\frac{1}{4\tau}$)

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  ➥ Needs $\mathcal{P}$-matrix elements for $\mathcal{N} = 2$ characters $(\tau \to -\frac{1}{4\tau})$
- Closed string tachyon is projected out, while no tadpole is generated (RR tadpole is massive) ➥ perturbatively stable

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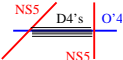OQCD in non-critical strings

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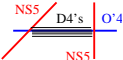 ➡ OQCD realized as some sort of "near-horizon" Hanany-Witten (HW) construction

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- RR charge jump of the orientifold across the NS5-branes accounted for by the crosscap state found ➥ extended orientifold (FZZ-like) contains a localized piece (ZZ-like) with opposite RR-charge

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Color and flavor branes for OQCD

- D-branes boundary states same as the NSNS part of their type IIA analogues ➡ the latter realize $\mathcal{N} = 1$ SQCD

  (Fotopoulos Niarchos Prezas; Ashok Murthy Troost 05)

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- Localized D4-branes near the Liouville wall (ZZ-like): color degrees of freedom ➡ with the Möbius amplitude contributing to the open RR sector, symmetric or antisymmetric fermions

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- Localized D4-branes near the Liouville wall (ZZ-like): color degrees of freedom ➡ with the Möbius amplitude contributing to the open RR sector, symmetric or antisymmetric fermions

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- Realize "electric" OQCD-S/OQCD-AS ➡ leading order backreaction (holographic β-function) suggests that the gauge theory has a quartic coupling, also for SQCD model: $\int \mathrm{d}^2\theta \, Q\tilde{Q}Q\tilde{Q}$.

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- Due the orientifold, only $\mu \in \mathbb{R}$ allowed ➥ one goes through strong coupling $\mu = 0$, creating ± 4 extra color branes
  ➥ however no extra stringy dynamics at $\mu = 0$ is expected to affect the gauge theory IR dynamics

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Conclusions

- String theories with only bosonic degrees of freedom and full tree-level stability (tachyon- and tadpole- free) are very rare

- On the gauge theory side, few non-susy models inherit properties of susy theories through planar equivalence

- Not surprisingly one can engineer such gauge theories (orientifold QCD) in such string theories (non-critical 0'A)

- The string theory picture strongly supports a Seiberg duality in OQCD at finite N, and predicts an exact conformal window

- A genuine holographic duality pair could be constructed if one knew how to include D-brane and orientifold backreaction properly