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Stable and metastable vacua in SQCD

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Abstract

We study deformations of $N = 1$ supersymmetric QCD that exhibit a rich landscape of supersymmetric and non-supersymmetric vacua.

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1. Introduction

In this paper we study the low energy dynamics of supersymmetric QCD (SQCD) in the presence of certain F-term deformations. The starting point of our analysis is an $N = 1$ supersymmetric gauge theory with gauge group $SU(N_c)$ and $N_f > N_c$ flavors of chiral superfields in the fundamental representation of the gauge group, Q_i^α, $\tilde{Q}^i_\alpha$ ($\alpha = 1, \dots, N_c$; $i = 1, \dots, N_f$). This theory has a global symmetry

$$SU(N_f) \times SU(N_f) \times U(1)_B \times U(1)_R \tag{1.1}$$

and a non-trivial moduli space of vacua, which has been extensively studied and is rather well understood; see, e.g., [1–6] for reviews.

A natural question is what happens when we deform the theory by adding a general superpotential that preserves a particular subgroup of the global symmetry (1.1), such as the non-chiral

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subgroup $SU(N_f)_{\mathrm{diag}} \times U(1)_B$. A class of superpotentials with this property is

$$W_{\mathrm{el}} = \sum_{n=1}^{n_0} \frac{1}{n!} m_n \operatorname{Tr} M^n, \tag{1.2}$$

where the meson field

$$M_j^i = \tilde{Q}^i Q_j \tag{1.3}$$

is an $N_f \times N_f$ matrix (the color indices are summed over in (1.3)). Terms with $n > 1$ in (1.2) are non-renormalizable, which is reflected in the fact that the couplings m_n have dimension $[m_n] = 3 - 2n$ at the free fixed point. One can think of the superpotential (1.2) as providing an effective description below a certain energy scale.

In the case $m_n = m_1\delta_{n,1}$ (1.2) is a mass term for Q, $\tilde{Q}$. It has been known for a long time that the resulting theory has N_c supersymmetric vacua, in accordance with the Witten index. More recently, it was found [7] that for $N_c < N_f < \frac{3}{2}N_c$ and small m_1 there are metastable non-supersymmetric ground states as well. Such states might be useful for describing supersymmetry breaking in nature.

The purpose of this paper is to study more general superpotentials of the form (1.2). We will mainly discuss the case where only the two lowest terms in (1.2) are non-zero, i.e.,

$$W_{\mathrm{el}} = m_1 \operatorname{Tr} M + \frac{1}{2} m_2 \operatorname{Tr} M^2 \tag{1.4}$$

but will also comment on higher order superpotentials. We will see that such superpotentials lead generically to a rich landscape of supersymmetric and non-supersymmetric vacua, and explore some of their properties. Related works include [8–18].

Like in [7], we will find it useful to utilize the Seiberg dual description of SQCD, in which the gauge group is $SU(N_f - N_c)$, and the meson (1.3) becomes a gauge singlet field. We will analyze the dynamics in both the electric and the magnetic descriptions and compare them.

The deformed SQCD with superpotential (1.4) has a simple embedding in string theory, along the lines of [19–30]. In a companion paper [31] we describe the relevant string construction, and in particular its connection to the gauge theory results of this paper. We find that the brane description provides a complementary picture to the gauge theory one.

The plan of the paper is as follows. In Section 2 we construct the supersymmetric ground states of the theory (1.4), and verify that the electric and magnetic descriptions give rise to the same vacuum structure once all the relevant quantum effects have been included. In Section 3 we describe metastable states in this theory. In Section 4 we discuss our results and comment on generalizations.

2. Vacuum structure of deformed SQCD

2.1. A first look at the vacuum structure

The $N = 1$ supersymmetric Yang–Mills theory with gauge group $SU(N_c)$ discussed in the previous section, which we will refer to as the electric theory, is equivalent in the infrared [32] to another gauge theory, which we will refer to as the magnetic theory. The latter has gauge group $SU(N_f - N_c)$ and the following set of chiral superfields: N_f fundamentals of the gauge group, q^i, $\tilde{q}_i$, $i = 1, \ldots, N_f$, and a gauge singlet M_j^i which, as suggested by the notation, is identified with the gauge invariant meson field (1.3) in the electric theory.