Singular superpotentials and higher-derivative F-terms

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Motivation

Studying non-perturbative aspects of $\mathcal{N}=1$ SUSY gauge theories is important for many reasons:

- Compactification of string theory on certain manifolds gives rise to 4D $\mathcal{N}=1$ SUSY gauge theories.
- ADS/CFT correspondence for $\mathcal{N}=1$ theories.
- 4D $\mathcal{N}=1$ theories are the closest supersymmetric theories to the real world physics.
- Exact results can be obtained in these theories.
- Existence of a wealth of generic non-perturbative phenomena such as dynamically generated superpotential, confinement, deformed classical moduli space, Seiberg duality, etc.

Structure of 4D $\mathcal{N}=1$ SUSY gauge theories

- The basic field ingredients are chiral superfields Φ^i, anti-chiral superfields $\overline{\Phi}_i$ and vector superfields V^a.

- The most general gauge-invariant action for the Φ^i, $\overline{\Phi}_i$ and V^a takes the form

$$\begin{aligned} S &= \int d^4x\ d^4\theta\ K(\overline{\Phi}, e^V\Phi) \\ &+ \int d^4x\ d^2\theta \left(\frac{\tau}{32\pi i}\right) \mathrm{tr}(\mathcal{W}^2) + h.c. \\ &+ \int d^4x\ d^2\theta\ W(\Phi) + h.c., \end{aligned}$$

- Our problem is to find the low energy behavior of these theories, specially, we would like to know W_{eff}.

- The key observation is that W_{eff} can often be determined exactly by symmetry, holomorphicity and smoothness constraints.
  (Seiberg, hep-th/9309335)

Singular superpotentials

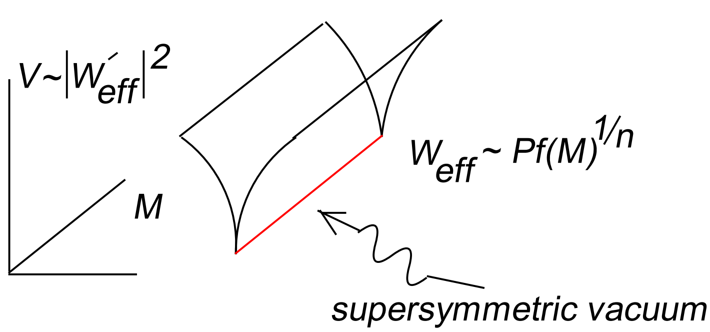
Despite much progress in the effective dynamics of these theories, W_{eff}'s are less understood for a large number of flavors n_f. This is manily because:

- W_{eff}'s are singular when expressed in terms of the local gauge-invariant chiral degrees of freedom.

For example, in SU(2) supersymmetric QCD, we have

$$W_{\text{eff}} \sim (\text{Pf}M)^{\frac{1}{n}} \qquad \text{for} \quad \text{n} = n_f - 2 > 1,$$

and a naive analysis shows that these singular W_{eff}'s cannot correctly describe the moduli space of vacua.

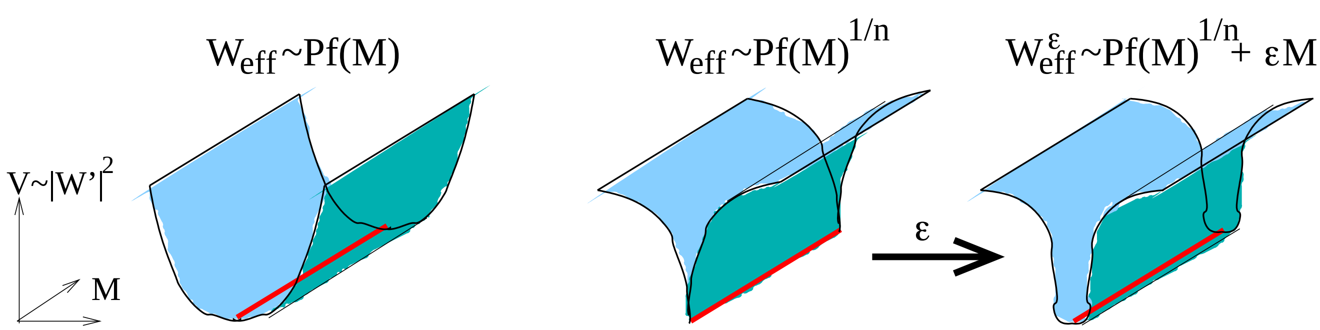


Singular W_{eff}'s; no problem

- Although W_{eff}s' are singular, they have a perfectly well-defined minimum (supersymmetric vacuum).

- W_{eff}s' cusp-like singularity can be regularized by turning on arbitrarily small masses (regularizing papameters).

- We have shown that no matter how the regularizing parameters are sent to zero, these superpotentials always give the correct constraint equation(s) describing the moduli space.
  (P. Argyres and M. E. hep-th/0510020)



(a): n=1 (b): n>1

Higher-derivative F-terms

- Besides correctly describing the moduli space, our W_{eff}'s are also consistent under RG flows and Konishi anomaly equations.

- Also, they pass a different, more stringent, test (P. Argyres and M. E. hep-th/0510020 and 0603025):

  By a tree-level calculation, W_{eff}'s reproduce all the higher-derivative F-terms introduced by Beasley and Witten in hep-th/0409149, upon being expanded around a gerenic ponit on the moduli space.

$$\begin{aligned}\delta S \quad \sim \quad & \int d^4x \; d^2\theta \; \Lambda^{6-n_f} \overline{\mu}^{1-n_f} \mu^{-1} \epsilon^{u_1 v_1 \cdots u_{n_f-1} v_{n_f-1}} \\ & (\overline{D}\delta\overline{M}_{1u_1} \cdot \overline{D}\delta\overline{M}_{2v_1})(\overline{D}\delta\overline{M}_{1u_{n_f-1}} \cdot \overline{D}\delta\overline{M}_{2v_{n_f-1}}) + \cdots .\end{aligned}$$