

The Nelson-Seiberg theorem revised

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Strings 2013, 27 June 2013

Based on [arXiv:1209.1059] (with Zhaofeng Kang and Tianjun Li)
and some earlier works.

the Nelson-Seiberg theorem

The theorem

- ▶ Generically, F-type SUSY breaking at the global minimum “ \Rightarrow ” W has an R-symmetry, “ \Leftarrow ” the R-symmetry is spontaneously broken. (Nelson & Seiberg 1993)
- ▶ “Generic” means no fine-tuning for parameters.

Applications

- ▶ Model building: R helps SUSY breaking in the hidden sector.
- ▶ Approximate R \Rightarrow metastable SUSY breaking.

Complexities and defects

- ▶ “ \Rightarrow ” and “ \Leftarrow ” claims are separate.
- ▶ Using “ \Leftarrow ” requires solving the vacuum.

Proof of the Nelson-Seiberg theorem

Proof.

- ▶ Solving $\partial_i W = 0 \Leftrightarrow N_{\text{equations}} = N_{\text{variables}}$.
- ▶ With R, the form of W is constrained (with field redefinition):

$$W = xf(y_1, \dots, y_{d-1}), \quad x = z_d^{2/r_d}, \quad y_i = z_i/z_d^{r_i/r_d}.$$

- ▶ If $x \neq 0$ then solving $f = 0, \partial_{y_i} f = 0 \not\Leftarrow N_{\text{equations}} > N_{\text{variables}}$.
- ▶ $x = 0$ singular, solutions unclear.
- ▶ Notice $r_d \neq 0, x \neq 0$ breaks the R-symmetry.
- ▶ So SUSY breaking " \Rightarrow " R, " \Leftarrow " spontaneously broken R. \square

Issues in the proof

- ▶ Field redefinition singular at $x = 0 \Rightarrow$ all complexities and defects. Need revision?

A “ \Leftrightarrow ” condition for SUSY breaking

Proof.

- ▶ Without field redefinitions, W has the general form:

$$W = X_i f_i(Y_j) + W_1,$$

$$W_1 = \mu_{ijk} X_i X_j A_k + \nu_{ijk} X_i A_j A_k + A_i A_j (\kappa_{ij} + \lambda_{ijk} Y_k + \xi_{ijk} A_k),$$

$$r(X_i) = R(W)(= 2), \quad r(Y_j) = 0, \quad r(A_k) \neq R(W) \text{ or } 0.$$

- ▶ To satisfy $\partial_i W = 0$ and $W = 0$, one can solve

$$f_i(Y_j) = 0, \quad X_i = A_k = 0.$$

- ▶ $N_Y \geq N_X \Rightarrow$ SUSY (check all R-charge assignments).
- ▶ $N_Y < N_X$ and $X = A = 0 \Rightarrow$ SUSY breaking.
- ▶ $X \neq 0$ or $A \neq 0 \Rightarrow$ R breaking \Rightarrow SUSY breaking (by N-S).
- ▶ Without R \Rightarrow SUSY (by N-S).
- ▶ So SUSY breaking \Leftrightarrow an R symmetry and $N_Y < N_X$. □

Results

The Nelson-Seiberg theorem revised

- ▶ Generically, F-type SUSY breaking at the global minimum \Leftrightarrow W has an R-symmetry and $N_Y < N_X$ for any consistent R-charge assignment. (Sun 2012)

Application: SUSY breaking vacua in model building

- ▶ Low energy EFT for dynamical SUSY breaking models.
- ▶ Bonus: A 's are essential for spontaneous R-breaking.

Application: SUSY vacua in string phenomenology

- ▶ R-symmetries and $N_Y \geq N_X \Rightarrow$ SUSY vacua with $W = 0 \Rightarrow D_i W = 0$ and $V = 0$ in SUGRA.
- ▶ String (flux) models, discrete R-symmetry, arrange $N_Y \geq N_X$.