SUSY breaking from monopole condensation

Yuri Shirman

with D. Curtin, C. Csaki, J. Terning, and V. Rentala

arXiv:1108.4415 [hep-th] 7/5/12

Descriptions of dynamical SUSY breaking

- Instantons
- Gaugino condensation
- Confinement
- Dual gauge dynamics in the IR

- Models with global or local SUSY breaking minima

Our Goal:

Models where SUSY breaking is triggered by monopole condensation

Outline

- Monopoles in $\mathcal{N} = 1$
  - $SU(2)^2$ model
  - $SU(2)^3$ model
- SUSY breaking
  - The model
  - Coleman-Weinberg potential
  - More examples
- Conclusions

Monopoles in $\mathcal{N}=1$

Monopoles in $SU(2)\times SU(2)$ with two bifundamentals

Intriligator and Seiberg

- Moduli space

$$M_{fg}=Q_f\cdot Q_g\equiv Q_{f,c_1c_2}Q_{g,d_1d_2}\epsilon^{c_1d_1}\epsilon^{c_2d_2}$$

- Low energy physics at large M_{11}:
  - $SU(2)^2$ broken to $SU(2)_D$ and with a triplet ϕ and a singlet.
  - An approximate $\mathcal{N}=2$ theory. At a generic point on the moduli space, $\mathrm{Tr}\phi^2\neq 0$, unbroken gauge group is $U(1)$.
  - Singularity at $\mathrm{Tr}\phi^2=\Lambda_L^2$. Monopoles become massless. Kahler potential for the moduli is known.
- $\mathcal{N}=2\ \rightarrow \mathcal{N}=1$ breaking suppressed by powers of $M_{11}\sim v^2$. Kähler potential modified

Monopoles in $\mathcal{N} = 1$

Monopoles in $SU(2) \times SU(2)$ with two bifundamentals

Intriligator and Seiberg

- Holomorphy, symmetries and weakly coupled limits give solutions everywhere on the $SU(2)^2$ moduli space
- Monopoles are massless on singular submanifolds

$$W = (\det M - U_+)\tilde{E}_+ E_+ + (\det M - U_-)\tilde{E}_- E_-$$
$$U_\pm = (\Lambda_1^2 \pm \Lambda_2^2)^2$$

- Kähler potential for moduli is regular on the singular submanifold but generically receives large strong coupling corrections

Monopoles in $\mathcal{N} = 1$

Monopoles in $SU(2)^3$ model

CEFS

	$SU(2)_1$	$SU(2)_2$	$SU(2)_3$
Q_1	$\square$	$\square$	1
Q_2	1	$\square$	$\square$
Q_3	$\square$	1	$\square$

- Moduli

$$M_i = \det Q_i \equiv \tfrac{1}{2} Q_{i,c_1 d_1} Q_{i,c_2 d_2} \epsilon^{c_1 c_2} \epsilon^{d_1 d_2}$$

$$T = \tfrac{1}{2} Q_{1,c_1 d_2} Q_{2,c_2 d_3} Q_{3,c_3 d_1} \epsilon^{c_1 d_1} \epsilon^{c_2 d_2} \epsilon^{c_3 d_3}$$

  - Symmetry breaking: $SU(2)^3 \to SU(2)_D \to U(1)$
- Singular submanifold

$$\Lambda^4 (M_1 + M_2 + M_3) - M_1 M_2 M_3 + T^2 \pm 2\Lambda^6 = 0$$

- Monopole superpotential

$$W_{eff} = \sum_{\pm} \left[\Lambda^4 (M_1 + M_2 + M_3) - M_1 M_2 M_3 + T^2 \pm 2\Lambda^6 \right] E_\pm \tilde{E}_\pm ,$$

SUSY breaking

$$
\begin{aligned}
W &= \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} \\
&\quad - \mu^2 M_1 + m_Y Y M_3 + m_Z Z T \\
&\quad + \lambda M_2 \phi_1 \phi_2 + \tfrac{m_2}{2}\phi_2^2 + m_1 \phi_1 \phi_2
\end{aligned}
$$

- Require massless monopoles

$$\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6 = 0$$

- Irrelevant terms must remain irrelevant
- Tadpole for $M_1 \rightarrow$ monopole condensate $\rightarrow$ tadpole for M_2
- O'Rafeartaigh sector Shih sector

SUSY breaking

$$W = \left[\Lambda^4(M_1 + M_2 + M_3) - M_1 M_2 M_3 + T^2 - 2\Lambda^6\right] E\tilde{E}$$
$$- \mu^2 M_1 + m_Y Y M_3 + m_Z Z T$$
$$+ \lambda M_2 \phi_1 \phi_2 + \frac{m_2}{2}\phi_2^2 + m_1 \phi_1 \phi_2$$

- Require massless monopoles

$$\Lambda^4(M_1 + M_2 + M_3) - M_1 M_2 M_3 + T^2 - 2\Lambda^6 = 0$$

- Irrelevant terms must remain irrelevant
- Tadpole for M_1 $\rightarrow$ monopole condensate $\rightarrow$ tadpole for M_2
- O'Rafeartaigh sector Shih sector

SUSY breaking

$$
\begin{aligned}
W &= \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} \\
&\quad - \mu^2 M_1 + m_Y Y M_3 + m_Z Z T \\
&\quad + \lambda M_2\phi_1\phi_2 + \frac{m_2}{2}\phi_2^2 + m_1\phi_1\phi_2
\end{aligned}
$$

- Require massless monopoles

$$\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6 = 0$$

- Irrelevant terms must remain irrelevant
- Tadpole for M_1 $\rightarrow$ monopole condensate $\rightarrow$ tadpole for M_2
- O'Rafeartaigh sector Shih sector

SUSY breaking

$$
\begin{aligned}
W &= \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} \\
&\quad - \mu^2 M_1 + m_Y Y M_3 + m_Z Z T \\
&\quad + \lambda M_2 \phi_1 \phi_2 + \frac{m_2}{2}\phi_2^2 + m_1 \phi_1 \phi_2
\end{aligned}
$$

- Require massless monopoles

$$\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6 = 0$$

- Irrelevant terms must remain irrelevant
- Tadpole for M_1 $\to$ monopole condensate $\to$ tadpole for M_2
- O'Rafeartaigh sector Shih sector

CW potential

For a range of parameters Coleman-Weinberg potential results in a local minimum

- Local minimum if $y = \frac{\lambda\langle\mu^2\rangle}{m_1 m_2} < 1$ (Recall $\langle\tilde{E}E\rangle \sim \mu^2$)
- Minimum at $M_2 = 0$ if $r = m_2/m_1 < 2$
- Minimum at $M_2 \approx \frac{\sqrt{m_1 m_2}}{\lambda}$ if $r > 2$.

Matching parameters between UV and IR descriptions

$$\mu^2 \sim m\Lambda \qquad \lambda = \tilde{\lambda}\frac{\Lambda}{\Lambda_{UV}}$$

$$m_Z = c_Z\frac{\Lambda^2}{\Lambda_{UV}} \qquad m_Y = c_Y\Lambda$$

CW potential vs strong coupling corrections

- Model strongly coupled near $M_1 \approx 2\Lambda^2$.
- Discrete global symmetry restricts form of strong coupling corrections to the Kähler potential
- Require that strong coupling corrections are negligible while conditions for the minimum are satisfied

$$\frac{m_2}{\Lambda} \ll \left(\frac{\Lambda}{\lambda_{UV}}\right)^3$$

$$\frac{\Lambda}{\Lambda_{UV}} \lesssim \left(\frac{m_1}{\Lambda}\right)^2 \frac{\Lambda}{m}$$

Variations of the model

- More calculable model

$$
\begin{aligned}
W &= \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} \\
&-\mu^2 M_1 + m_Y Y M_3 + m_Z Z M_2 \\
&+ \lambda X (T\phi_2 - f^2) + m_1\phi_1\phi_2
\end{aligned}
$$

- More dynamical model

$$
\begin{aligned}
W &= \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} \\
&-\mu^2 M_1 + m_Y Y M_3 + \\
&+ \lambda M_2 T\phi_2 + m_1\phi_1\phi_2
\end{aligned}
$$

Conclusions and questions

- New models of metastable dynamical SUSY breaking based on monopole condensation
- Are there generalizations?
- Application to phenomenological model building?
- Are there limits where SUSY breaking dynamics has more conventional description?