SUSY breaking from monopole condensation

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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

$$M_{fg} = Q_f \cdot Q_g \equiv Q_{f,c_1 c_2} Q_{g,d_1 d_2} \epsilon^{c_1 d_1} \epsilon^{c_2 d_2}$$

- 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 $\mathcal{N} = 1$

$SU(2)^3$ 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

$$M_i = \det Q_i \equiv \frac{1}{2} Q_{i,c_1 d_1} Q_{i,c_2 d_2} \epsilon^{c_1 c_2} \epsilon^{d_1 d_2}$$
$$T = \frac{1}{2} Q_{1,c_1 d_2} Q_{2,c_2 d_3} Q_{3,c_3 d_1} \epsilon^{c_1 d_1} \epsilon^{c_2 d_2} \epsilon^{c_3 d_3}$$

- 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

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

Mass perturbed $SU(2)^3$

$$W_{eff} = \left[\Lambda^4(M_1+M_2+M_3) - M_1M_2M_3 + T^2 - 2\Lambda^6\right] E\tilde{E} + m_1M_1 + m_2M_2 + m_3M_3$$

Supersymmetric ground state(s):

$$\langle \tilde{E}E \rangle = -\frac{\sqrt{m_1m_2m_3}}{\sqrt{m_1}+\sqrt{m_2}+\sqrt{m_3}}$$

$$\langle M_1 \rangle = \left(\sqrt{\frac{m_3}{m_1}} + \sqrt{\frac{m_2}{m_1}}\right)\Lambda^2$$

$$\langle M_2 \rangle = \left(\sqrt{\frac{m_1}{m_2}} + \sqrt{\frac{m_3}{m_2}}\right)\Lambda^2$$

$$\langle M_3 \rangle = \left(\sqrt{\frac{m_2}{m_3}} + \sqrt{\frac{m_1}{m_3}}\right)\Lambda^2$$

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
- Generate monopole condensate — tadpole for M_2
- O'Rafeartaigh sector Shih sector

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$$
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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

$$\Lambda_{UV} >> \Lambda m_{1,2} >> m$$

$$\left(\frac{\Lambda}{\Lambda_{UV}}\right)^2 \quad \frac{m_2}{\Lambda} \sim \frac{m}{m_2}$$

Variations of the model

- More calculable model

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

- More dynamical model

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

Conclusions and questions

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