Two loop effective action in $N = 2$ $d = 3$ chiral superfield model

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Motivation

- dualities between three dimensional supersymmetric models and certain superstrings or supermembranes on some backgrounds
- some supermembranes can be described by three dimensional supersymmetric sigma-models
- quantizing three dimensional supersymmetric sigma-models may help to understand quantum aspects of supermembranes

Problem

- to study low-energy effective action in $N = 2$ $d = 3$ supersymmetric sigma model with one chiral superfield

Note: the problem in $N = 1$ $d = 4$ was solved by

I. Buchbinder, S. Kuzenko and A. Petrov, Phys. Lett. B321 1994

I. Buchbinder and A. Petrov, Phys. Atom. Nucl. 63 (9) 2000

Model

General chiral superfield model

$$S[\varphi,\bar\varphi] = -\int d^7z K(\varphi,\bar\varphi) - \int d^5z W(\varphi) + \int d^5\bar z \bar W(\bar\varphi)$$

$K(\varphi,\bar\varphi)$ - Kähler potential, $W(\varphi)$ - chiral potential

Effective action

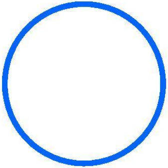
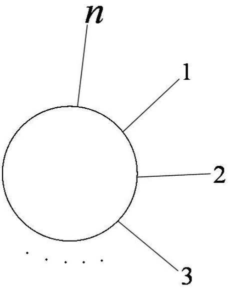
$$\Gamma = S + \hbar\Gamma^{(1)} + \hbar^2\Gamma^{(2)} + \dots$$

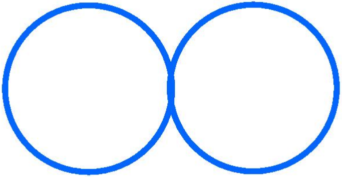
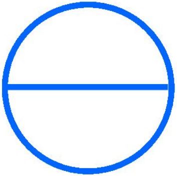
$\Gamma^{(1)}$ - one loop effective action, $\Gamma^{(2)}$- two loop effective action

Our aim: effective potential

$$\Gamma[\phi,\bar\phi] = -\int d^7z K_{eff}(\phi,\bar\phi) - \int d^5z W_{eff}(\phi) + \text{c.c.}$$

Feynman graphs

$\Gamma^{(1)} =$  $= \sum_{n=2}^{\infty}$ 

$\Gamma^{(2)} = -\frac{1}{8}$  $-\frac{1}{12}$ 

Matrix superpropagator

Propagator

Formal definition of the full propagator

$$\mathbf{G} = -\left(S''[\phi, \bar{\phi}]\right)^{-1}$$

Here ϕ and $\bar{\phi}$ are classical background fields

Explicit form

For the constant background fields we have

$$\mathbf{G}(z_1, z_2) = \frac{1}{K^2_{\phi\bar{\phi}}\Box + |W''|^2} \begin{pmatrix} \bar{W}''\delta_+(z_1 - z_2) & -\frac{K_{\phi\bar{\phi}}}{4}\bar{D}^2\delta_-(z_1 - z_2) \\ -\frac{K_{\phi\bar{\phi}}}{4}D^2\delta_+(z_1 - z_2) & -W''\delta_-(z_1 - z_2) \end{pmatrix}$$

One loop effective action

$$\Gamma^{(1)} = \frac{i}{2}\mathtt{tr}\ln \mathbf{G}$$

Note: there is **no UV divergences in** $\Gamma^{(1)}$ **in** $\boxed{d = 3}$

One loop effective potential

One loop chiral effective potential

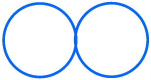
$$\boxed{W^{(1)}_{eff}(\phi) \equiv 0}$$

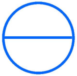
One loop Kähler effective potential

$$\boxed{K^{(1)}_{eff}(\phi, \bar{\phi}) = \frac{1}{4\pi}\sqrt{W''(\phi)\bar{W}''(\bar{\phi})}}$$

Two loop chiral effective potential

Remark

$d = 3$  $\rightarrow W^{(2)}_{eff}(\phi)$

$d = 4$  $\rightarrow W^{(2)}_{eff}(\phi)$

Exact superpropagator

$\bar{\phi} = 0$ $\qquad$ $\phi = \text{const}$

$$\mathbf{G}(z_1, z_2) = \begin{pmatrix} 0 & \frac{1}{K_{\phi\bar{\phi}}\Box}\frac{\bar{D}^2 D^2}{16}\delta^7(z_1 - z_2) \\ \frac{1}{K_{\phi\bar{\phi}}\Box}\frac{D^2\bar{D}^2}{16}\delta^7(z_1 - z_2) & -\frac{1}{4K^2_{\phi\bar{\phi}}\Box}[W''(z_1)\frac{\bar{D}^2}{K^2_{\phi\bar{\phi}}\Box}\delta^7(z_1 - z_2)] \end{pmatrix}$$

Two loop chiral effective potential

$$W^{(2)}_{eff}(\phi) = \frac{\bar{W}^{(4)}}{64\cdot(4\pi)^3}\left(\frac{W''}{K^4_{\phi\bar{\phi}}}\right)^2$$

Conclusion

Results

- one loop effective Kähler potential is found
- two loop effective chiral potential is computed

Open problems

- two loop effective Kähler potential
- two loop effective action in three dimensional supersymmetric electrodynamics