# Building a SUSY model II: using superfields

Seminar on Supersymmetry and its breaking

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## Main points of the talk

- Apply the superspace formalism and show why it is useful to build SUSY theories
- Principles to construct SUSY lagrangians
- SUSY gauge theories: QED and QCD
- SUSY predictions: particles, interaction, masses, ...

# D and F terms of the superfields

Chiral superfields

$$\Phi(x,\theta,\bar{\theta}) = \phi(x) + i\bar{\theta}\bar{\sigma}^\mu\theta\partial_\mu\phi(x) + \frac{1}{4}\theta\theta\theta\dagger\bar{\theta}\partial_\mu\partial^\mu\phi(x) + \sqrt{2}\theta\psi(x)$$
$$-\frac{i}{\sqrt{2}}\theta\theta\bar{\theta}\bar{\sigma}^\mu\partial_\mu\psi(x) + \theta\theta F(x)$$
$$\Phi^* = blablabla$$

A priori $\Phi$ and $\Phi^*$ (hence the components) are independent.
Vector superfields

$$V(x,\theta,\bar{\theta}) = longstuff$$

Note that

$$\delta_\epsilon F = \delta_\epsilon F' = \delta_\epsilon D = 0$$

$\Rightarrow$ Use F terms of chiral superfields and D terms of vector superfields to build SUSY invariant lagrangians!

## Chiral and vector superfields from chiral superfields

Two ways to combine chiral superfields

1. $\Phi^*\Phi \longrightarrow$ Forms a new vector field because $(\Phi^*\Phi)^* = \Phi\Phi^* = \Phi^*\Phi$
2. $\Phi\Phi \longrightarrow$ Forms a new chiral field because $\bar{D}_{\dot{\alpha}}\Phi\Phi = (\bar{D}_{\dot{\alpha}}\Phi)\Phi + \Phi(\bar{D}_{\dot{\alpha}}\Phi) = 0.$
   In general any analytic function of $\theta$ (or $\bar{\theta}$ ) would still be a chiral superfield.

# Naive combination of the fields

Let us try, very naively, to take a product of the first type

$$\Phi(x,\theta,\bar{\theta}) = \phi(x) + i\bar{\theta}\bar{\sigma}^{\mu}\theta\partial_{\mu}\phi(x) + \frac{1}{4}\theta\theta\bar{\theta}\bar{\theta}\partial_{\mu}\partial^{\mu}\phi(x) + \sqrt{2}\theta\psi(x)$$
$$-\frac{i}{\sqrt{2}}\theta\theta\bar{\theta}\bar{\sigma}^{\mu}\partial_{\mu}\psi(x) + \theta\theta F(x)$$
$$\Phi^*\Phi = \dots$$

and "select" the SUSY invariant component

$$\begin{aligned}[\Phi^*\Phi]_D &= \int d^2\theta d^2\bar{\theta}\ \Phi^*(x,\theta,\bar{\theta})\Phi(x,\theta,\bar{\theta}) \\ &= -\partial^{\mu}\phi^*\partial_{\mu}\phi + i\psi^{\dagger}\bar{\sigma}^{\mu}\partial_{\mu}\psi + F^*F + \text{total derivative}\end{aligned}$$

Note how mentally easy it was to derive this lagrangian, and how the Grassman formalism allows us to choose the SUSY invariant component via simple integration.

# Full Wess-Zumino model

How can we introduce produts of the second type?
Remeber that analytic functions of a chiral superfield is in turn a chiral superfield $\Rightarrow$ define a function via power series

$$W(\{\phi_i\}) \equiv a_i\phi_i + \frac{1}{2}m_{ij}\phi_i\phi_j + \frac{1}{3!}y_{ijk}\phi_i\phi_j\phi_k$$

Higher order terms lead to non-renormalisable theories!
$\rightarrow$ "select" $F$ term $\Rightarrow$

# Frame Title

Qua ci va tutta la parte normale di derivazione di roba

# Another point of view on what we have done

$\Omega$ has 8+8 particles content $\Phi, \Phi^+$ have 2 particles content each: a boson and a left (right) chiral fermion each, F is unphysical