Macroscopic Supersymmetry

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Lecture 3

(Supplementary Material)

NLSP Decays to the Goldstino

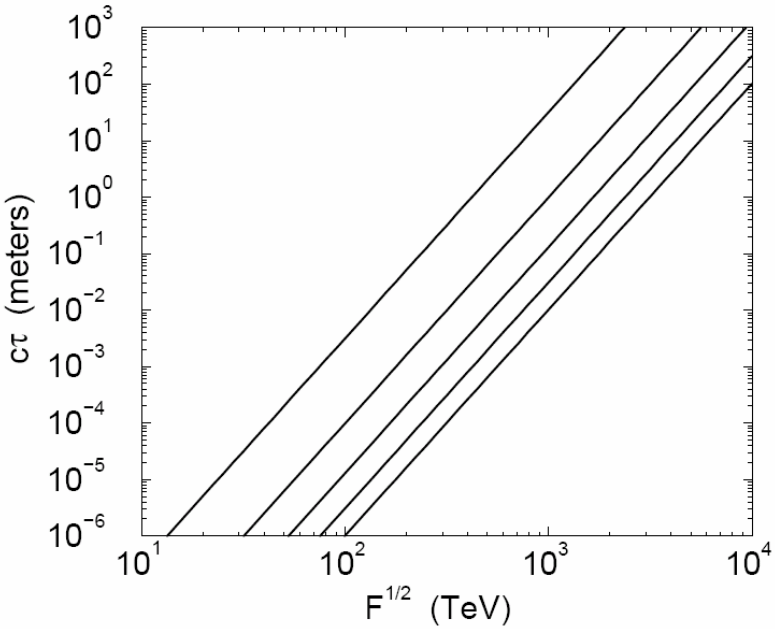

FIGURE 2. NLSP decay length, $c\tau(\widetilde{X} \to X\widetilde{G})$, in meters, as a function of the supersymmetry breaking scale, $\sqrt{F}$, in TeV. From top to bottom the lines are for an NLSP mass $m_{\widetilde{X}} = 50$, 100, 150, 200, 250 GeV and with $m_X = 0$ and $\kappa = 1$.

TABLE 1. Decay modes to the Goldstino in various NLSP scenarios.

NLSP	Decay to the Goldstino
Bino-like Neutralino	$\widetilde{\chi}_1^0 \to \gamma\, \widetilde{G}$
Higgsino-like Neutralino	$\widetilde{\chi}_1^0 \to (h, Z, \gamma)\, \widetilde{G}$
Stau	$\widetilde{\tau} \to \tau\, \widetilde{G}$
Slepton Co-NLSP	$\widetilde{\ell} \to \ell\, \widetilde{G}$
Squark	$\widetilde{Q} \to (q, q'W)\, \widetilde{G}$
Gluino	$\widetilde{g} \to g\, \widetilde{G}$

Exercises: Lecture 3

1. Consider a region of the MSSM parameter space in which a neutralino is the lightest supersymmetric particle. If R-parity is conserved at the renormalizable level the neutralino is a possible dark matter candidate since it is stable against decay through renormalizable interactions. However, if R-parity is broken by dimension five superpotential operators the neutralino is unstable. Find a typical decay mode from such interactions, and estimate the neutralino lifetime if the scale of the dimension five operator is of order the GUT scale. Is a neutralino with such decays stable enough to survive as dark matter? Estimate the lifetime if the neutralino can decay only through a GUT scale dimension six operator. Is a neutralino with such decays stable enough to survive as dark matter?

2. In the rigid supersymmetry limit the operator coupling the SUSY breaking and visible sectors which gives rise to a soft scalar mass for a visible sector chiral multiplet Φ from F-term breaking is

$$\frac{1}{M^2}\int d^4\theta\ \mathcal{Z}^\dagger \mathcal{Z}\Phi^\dagger\Phi$$

where

$$\mathcal{Z} \supset \sqrt{2}\theta^\alpha G_\alpha + \theta^2 F$$

is the linear combination of SUSY breaking sector chiral superfields which have non-zero auxillary F-components. Show that the Weyl fermion G transforms inhomogeneously under supersymmetry transformations and is therefore the massless Goldstino. Calculate the soft mass squared of the visible sector scalar. From the above operator calculate the interaction of the Goldstino with the visible sector chiral multiplet. Assume the visible sector fermion is massless. Calculate the decay rate for the process

$$\phi \to \psi G$$

Show that this agrees with the decay rate calculated from the derivative form of the Goldstino coupling

$$\frac{1}{F}\,\partial_\mu G^\alpha j^\mu{}_\alpha \ +\ \text{h.c.}$$

where

$$j^\mu{}_\alpha = \sigma^\nu_{\alpha\dot\alpha}\bar\sigma^{\mu\dot\alpha\beta}\psi_\beta D_\nu\phi$$

is the supercurrent