Is there something missing in the MSSM?

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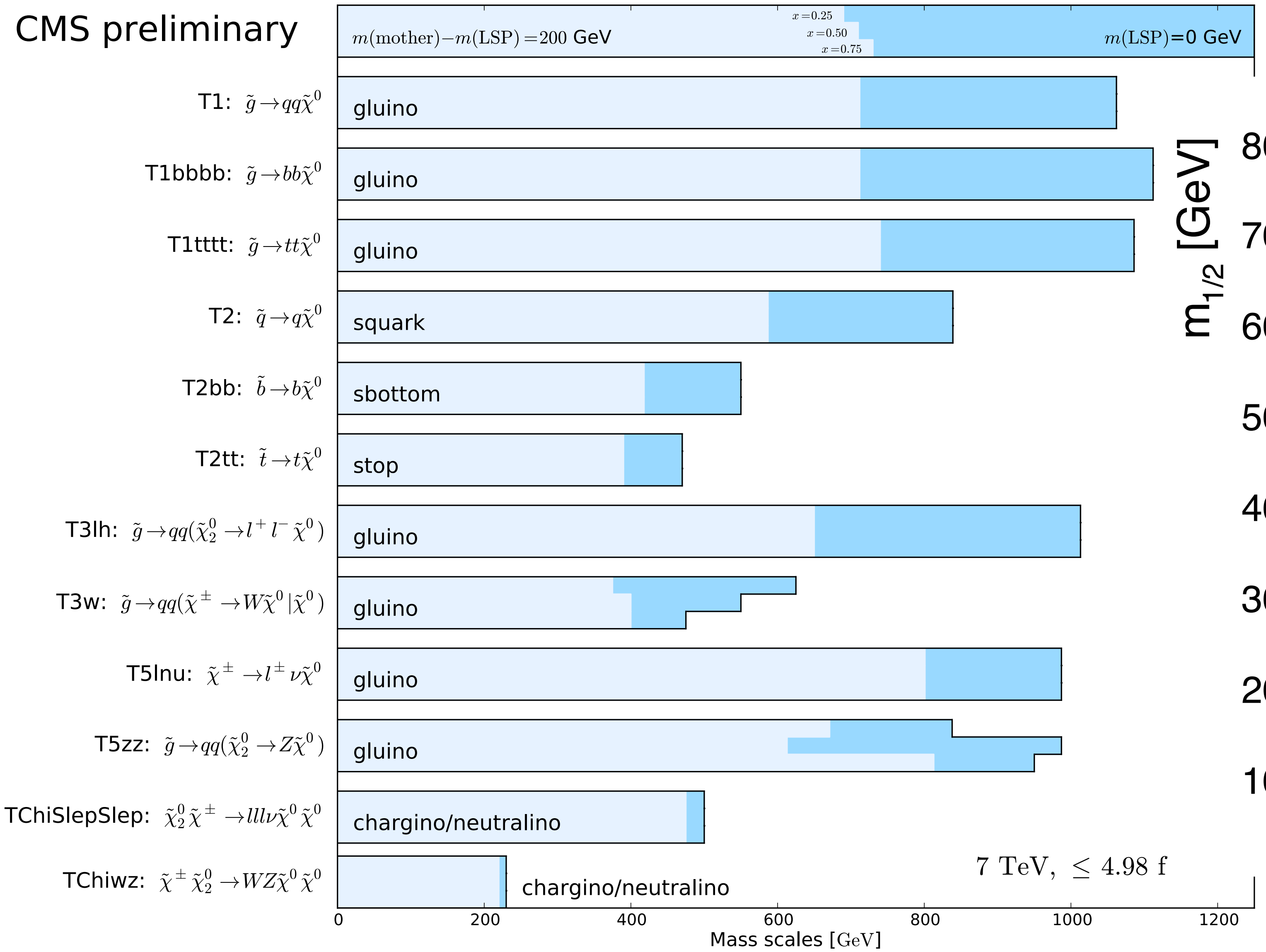
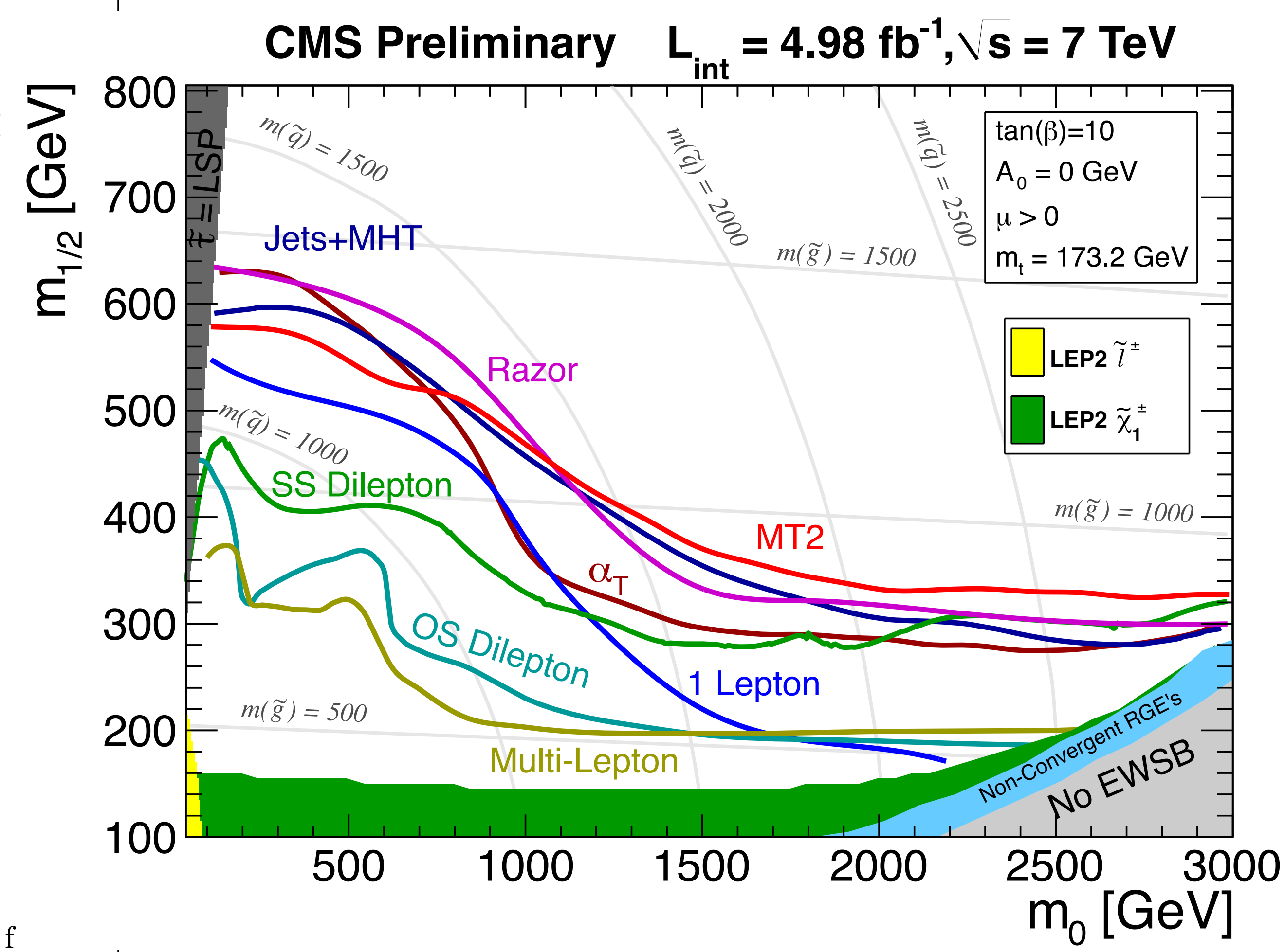
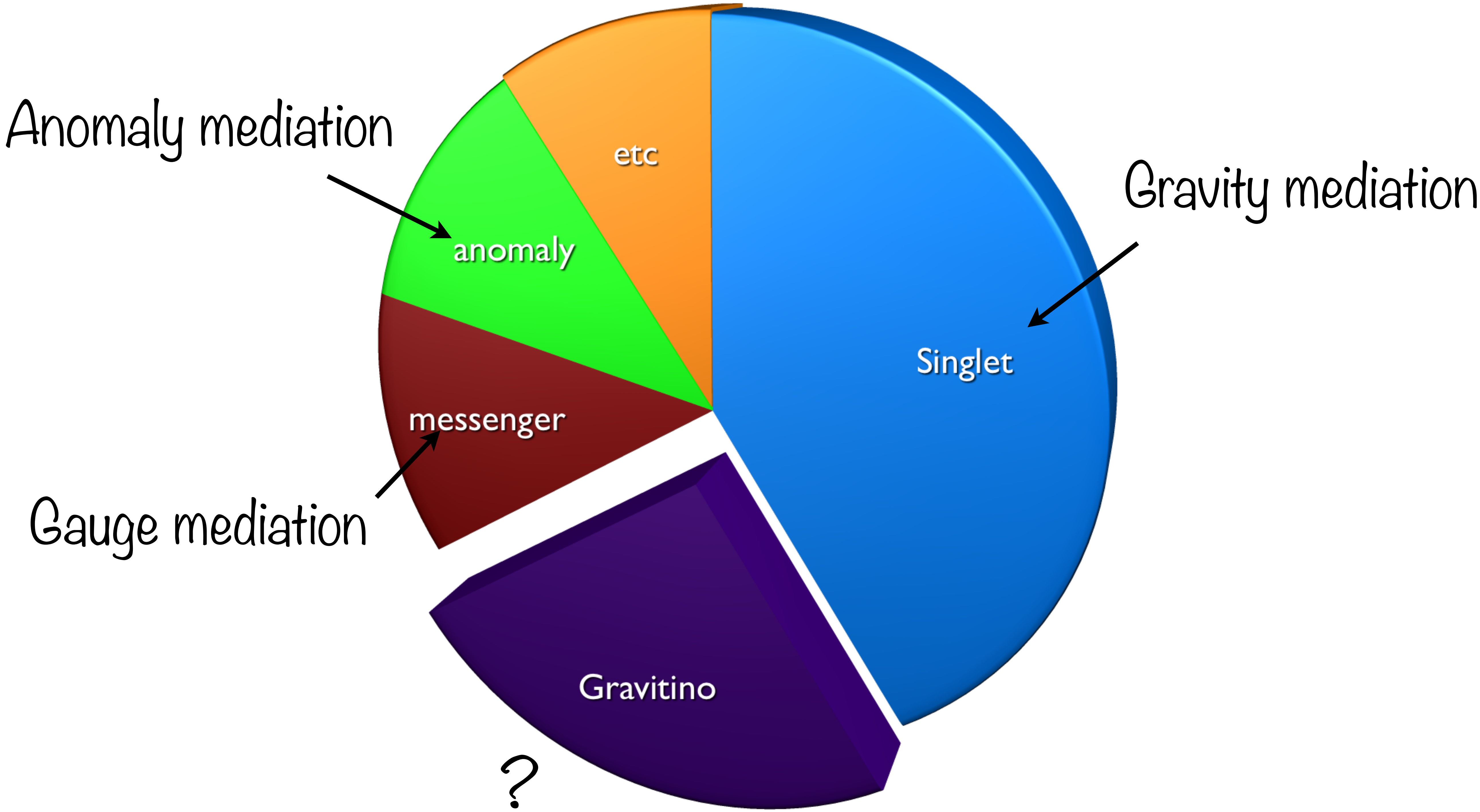


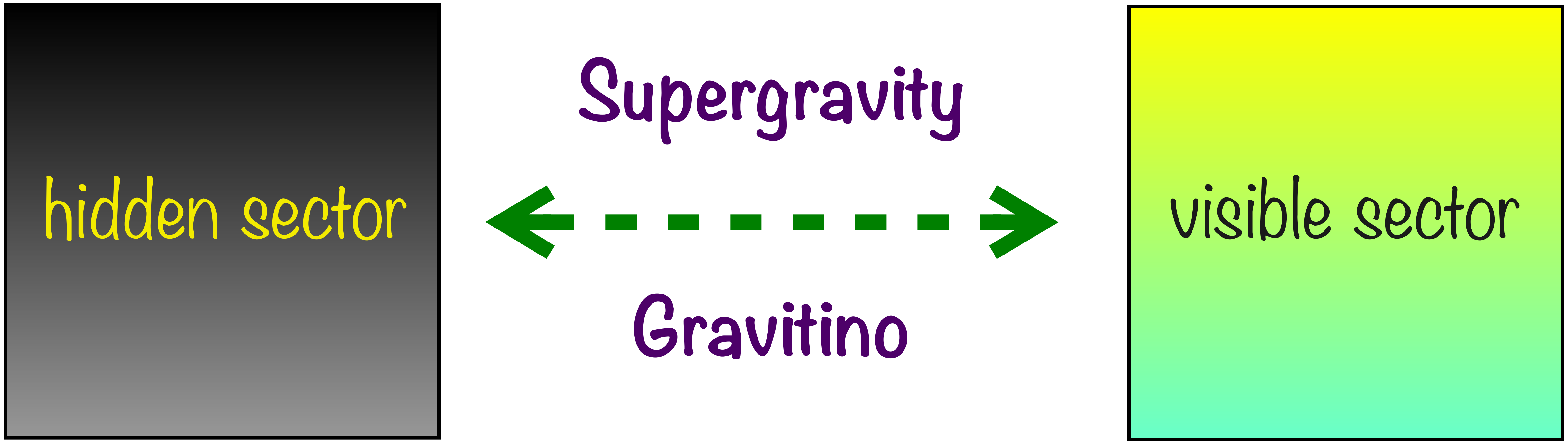


``Where is susy?''

Current Situation of Low-energy Supersymmetry

Contributions to soft mass





- gauge field of local supersymmetry transformations.
- massive ☜ “supersymmetric Higgs mechanism”.
- no gauge coupling for local supersymmetry.

gravitino kinetic term :

$$\mathcal{L}_{3/2} = \frac{1}{\kappa^2}\Big[\frac{i}{2}\varepsilon^{\mu\nu\rho\sigma}\, {}^*\Psi_\mu \gamma_5 \gamma_\nu \partial_\rho \Psi_\sigma + i m_{3/2}\, {}^*\Psi_\mu \Sigma^{\mu\nu} \Psi_\nu + \frac{i}{2}\alpha_s\, {}^*\Psi \cdot \gamma\, \partial\!\!\!/\, \gamma \cdot \Psi\Big].$$

massive gravitino propagator :

$$\frac{i}{\kappa^2}\langle \Psi_\mu {}^* \Psi_\nu \rangle = P^{3/2}_{\mu\nu}\frac{1}{m_{3/2} + \partial\!\!\!/} + \sum_{i,j}(P^{1/2}_{ij})_{\mu\nu}\big[\alpha_{ij}(\Box)\partial\!\!\!/ + \beta_{ij}(\Box)\big],$$

with

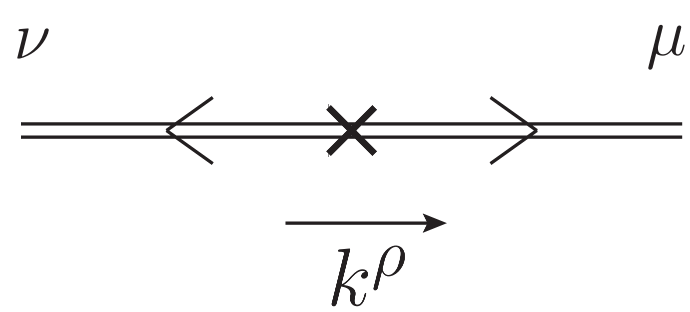
$$P^{3/2}_{\mu\nu} = \theta_{\mu\nu} - \frac{1}{3}\hat{\gamma}_\mu \hat{\gamma}_\nu,$$

$$(P^{1/2}_{11})_{\mu\nu} = \frac{1}{3}\hat{\gamma}_\mu \hat{\gamma}_\nu, \qquad (P^{1/2}_{12})_{\mu\nu} = \sqrt{\frac{1}{3}}\hat{\gamma}_\mu \omega_\nu,$$

$$(P^{1/2}_{21})_{\mu\nu} = \sqrt{\frac{1}{3}}\omega_\mu \hat{\gamma}_\nu, \qquad (P^{1/2}_{22})_{\mu\nu} = \frac{1}{3}\omega_\mu \omega_\nu,$$

$$\omega_\mu \equiv \frac{\partial_\mu \partial\!\!\!/}{\Box}, \quad \hat{\gamma}_\mu \equiv \gamma_\mu - \omega_\mu, \quad \theta_{\mu\nu} \equiv \eta_{\mu\nu} - \omega_\mu \omega_\nu.$$

chirality-flipping propagator (in two component notation)



$$\langle \psi_\mu \overline{\psi}_\nu \rangle_{\frac{3}{2}} = (-i)\kappa^2 \Big[\eta_{\mu\nu} - \frac{1}{3}\Big(\sigma_\mu \bar{\sigma}_\nu - \frac{k_\nu \sigma_\mu k \cdot \bar{\sigma}}{k^2} - \frac{k_\mu k \cdot \sigma \bar{\sigma}_\nu}{k^2} + 4\frac{k_\mu k_\nu}{k^2} \Big) \Big] \frac{m_{3/2}}{k^2 + m_{3/2}^2}$$

$$\langle \psi_\mu \overline{\psi}_\nu \rangle_{\frac{1}{2}} = (-i)\kappa^2 \Big[\frac{1}{3}\Big(\sigma_\mu \bar{\sigma}_\nu - \frac{k_\nu \sigma_\mu k \cdot \bar{\sigma}}{k^2} - \frac{k_\mu k \cdot \sigma \bar{\sigma}_\nu}{k^2} + \frac{k_\mu k_\nu}{k^2} \Big) \beta_{11} + \frac{k_\mu k_\nu}{k^2} \beta_{22}$$
$$+ \frac{1}{\sqrt{3}} \Big(\frac{k_\nu \sigma_\mu k \cdot \bar{\sigma}}{k^2} - \frac{k_\mu k_\nu}{k^2} \Big) \beta_{12} + \frac{1}{\sqrt{3}} \Big(\frac{k_\mu k \cdot \sigma \bar{\sigma}_\nu}{k^2} - \frac{k_\mu k_\nu}{k^2} \Big) \beta_{21} \Big]$$

interaction between gravitino and gaugino

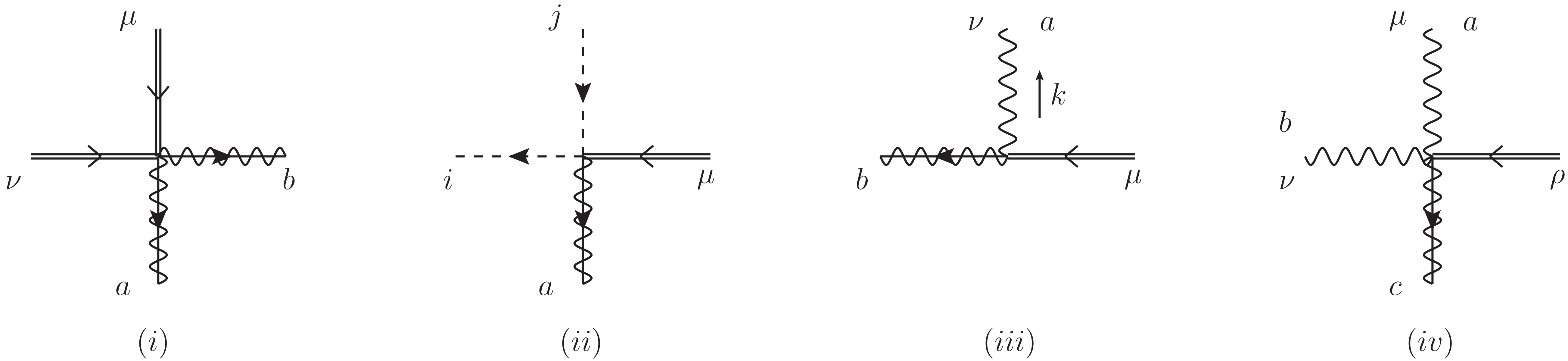
$$\mathcal{L}_{\rm sugra} \supset \mathcal{L}_i$$

$$\mathcal{L}_1 = \frac{1}{16}[\lambda^a \lambda^a \bar{\psi}_\mu (3g^{\mu\nu} - 2\bar{\sigma}^{\mu\nu})\bar{\psi}_\nu + \bar{\lambda}^a \bar{\lambda}^a \psi_\mu (3g^{\mu\nu} - 2\sigma^{\mu\nu})\psi_\nu],$$

$$\mathcal{L}_2 = \frac{1}{2}[\bar{\psi}_\mu \bar{\sigma}^\mu \lambda^a + \psi_\mu \sigma^\mu \bar{\lambda}^a] \sum_{i,j} A_i^* (T^a)^i_j A_j,$$

$$\mathcal{L}_3 = \frac{i}{2}[\partial^\mu \mathcal{A}^{\nu c} - \partial^\nu \mathcal{A}^{\mu c}]\Big[(\psi_\mu \sigma_\nu \bar{\lambda}^c - \bar{\psi}_\mu \bar{\sigma}_\nu \lambda^c) - \frac{i}{2}\varepsilon_{\mu\nu\rho\kappa}(\psi^\rho \sigma^\kappa \bar{\lambda}^c + \bar{\psi}^\rho \bar{\sigma}^\kappa \lambda^c)\Big],$$

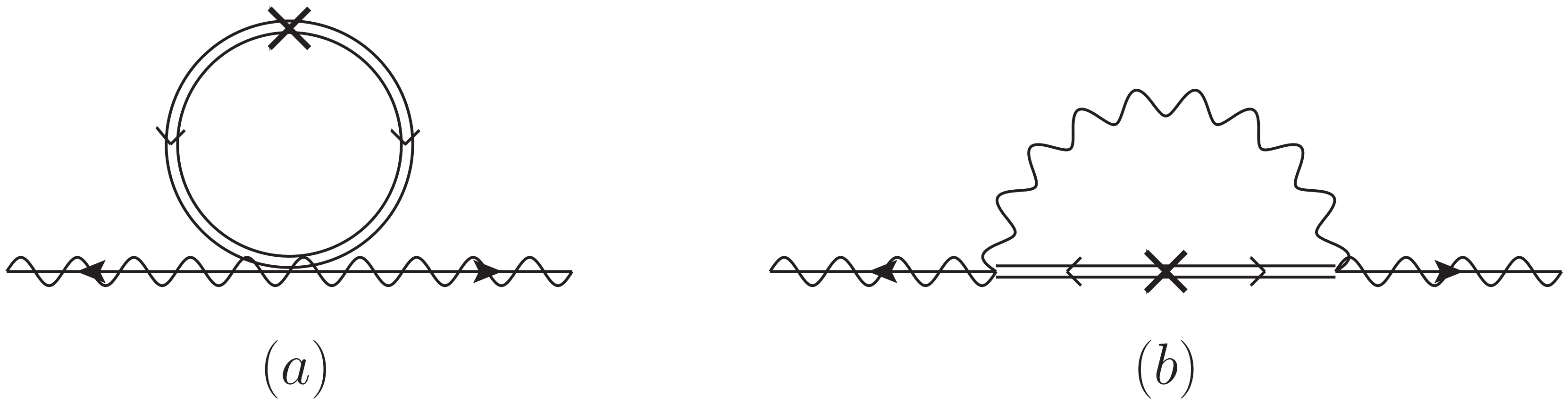
$$\mathcal{L}_4 = \frac{i}{2} g f^{abc} \mathcal{A}^{\mu a} \mathcal{A}^{\nu b}\Big[(\psi_\mu \sigma_\nu \bar{\lambda}^c - \bar{\psi}_\mu \bar{\sigma}_\nu \lambda^c) - \frac{i}{2}\varepsilon_{\mu\nu\rho\kappa}(\psi^\rho \sigma^\kappa \bar{\lambda}^c + \bar{\psi}^\rho \bar{\sigma}^\kappa \lambda^c)\Big],$$



$\mathcal{L}_1$	$\frac{i}{4}[3\eta^{\mu\nu}\delta^{\dot{\alpha}\dot{\beta}} - 2(\bar{\sigma}^{\mu\nu})^{\dot{\alpha}\dot{\beta}}]\delta^{ab}$
$\mathcal{L}_2$	$\frac{i}{2}(T^a)^i_j\sigma^\mu$
$\mathcal{L}_3$	$[\frac{i}{2}(-k_\mu\sigma_\nu + \eta_{\mu\nu}k\cdot\sigma) + \frac{1}{2}k^\rho\varepsilon_{\mu\nu\rho\kappa}\sigma^\kappa]\delta^{ab}$
$\mathcal{L}_4$	$-\frac{g}{2}f^{abc}(\eta^{\mu\rho}\eta^{\nu\kappa} - \eta^{\mu\kappa}\eta^{\nu\rho})\sigma_\kappa + i\frac{g}{2}f^{abc}\varepsilon^{\mu\nu\rho\kappa}\sigma_\kappa$

Table 1: The Feynman rules for the interactions.

Gaugino mass



$$m_{1/2} = \frac{m_{3/2}}{16\pi^2}\Big[\frac{\Lambda^2}{m_P^2} - \frac{m_{3/2}^2}{m_{\rm P}^2}\log\Big(\frac{\Lambda^2}{m_{3/2}^2}+1\Big)\Big],$$

For $m_{1/2} \ll m_P$,

$$\frac{m_{1/2}}{m_{3/2}} \sim \frac{1}{16\pi^2}\frac{\Lambda^2}{m_P^2}.$$

- No gauge or Yukawa couplings show up in the result.

- Different gaugino acquire the same mass from gravitino at one loop.

- Scale dependence stems only from the gaugino mass.

Outlook

- Evaluate sfermion mass from gravitino loops.
- Reproduce anomaly mediation from explicit one-loop effective supergravity lagrangian.