Title: PSI 2015/2016 More/Beyond Standard Model - Lecture 9

Date: Mar 03, 2016 09:00 AM

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Abstract:

$$\hat{Q} = (\tilde{Q}, Q, F_Q) = (3, 2, \tfrac{1}{6})$$

$$\hat{U}^c = (\tilde{u}_R^*, u^c, F_{u^c}) = (\bar{3}, 1, -\tfrac{2}{3})$$

$$\hat{D}^c = (\tilde{d}_R^*, D^c, F_{D^c}) = (\bar{3}, 1, \tfrac{1}{3})$$

$$\hat{L} = (\tilde{L}, L, F_F) = (1, 2, -\tfrac{1}{2})$$

$$\hat{E}^c = (\tilde{e}_R^*, E^c, F_{E^c}) = (1, 1, 1)$$

$$\hat{H}_u = (H_u, \tilde{H}_u, F_{H_u}) = (1, 2, \tfrac{1}{2})$$

$$\hat{H}_d = (H_d, \tilde{H}_d, F_{H_d}) = (1, 2, -\tfrac{1}{2})$$

$W_{MSSM} =$

$-\mathcal{L}_{int}$

$$W_{MSSM} = y_u\, \hat{Q}\cdot \hat{H}_u\, \hat{U}^c - y_d\, \hat{Q}\cdot \hat{H}_d\, \hat{D}^c - y_e\, \hat{L}\cdot \hat{H}_d\, \hat{E}^c - \mu\, \hat{H}_u\cdot \hat{H}_d$$

$$-\mathcal{L}_{int} \supset \sum_{ij} \frac{\partial^2 W}{\partial \Phi_i \partial \Phi_j}\bigg|_{\Phi\to\phi} \psi_i \psi_j + \sum_i \left|\frac{\partial W}{\partial \Phi_i}\right|^2_{\Phi=\phi}$$

$$y_u\, Q U^c \cdot H_u$$

$$= y_u\, \bar{u}_R Q_L H_u$$

$$\hat{Q} = (\tilde{Q}, Q, F_Q) = (3, 2, \tfrac{1}{6}) \quad -1$$

$$\hat{u}^c = (\tilde{u}_R^*, u^c, F_{u^c}) = (\bar{3}, 1, -\tfrac{2}{3}) \quad -1$$

$$\hat{D}^c = (\tilde{d}_R^*, D^c, F_{D^c}) = (\bar{3}, 1, \tfrac{1}{3}) \quad -1$$

$$\hat{L} = (\tilde{L}, L, F_F) = (1, 2, -\tfrac{1}{2}) \quad -1$$

$$\hat{E}^c = (\tilde{e}_R^*, E^c, F_{E^c}) = (1, 1, 1) \quad -1$$

$$\hat{H}_u = (H_u, \tilde{H}_u, F_{H_u}) = (1, 2, \tfrac{1}{2}) \quad +1$$

$$\hat{H}_d = (H_d, \tilde{H}_d, F_{H_d}) = (1, 2, -\tfrac{1}{2}) \quad +1$$

$W_{MSSM} =$

$-\mathcal{L}_{in}$

$$W_{MSSM} = y_u \hat{Q}\cdot\hat{H}_u \hat{U}^c - y_d \hat{Q}\cdot\hat{H}_d \hat{D}^c - y_e \hat{L}\cdot\hat{H}_d \hat{E}^c - \mu \hat{H}_u\cdot\hat{H}_d$$

$$-\mathcal{L}_{int} \supset \sum_{ij} \frac{\partial^2 W}{\partial\Phi_i \partial\Phi_j}\bigg|_{\Phi\to\varphi} \psi_i \psi_j + \sum_i \left|\frac{\partial W}{\partial\Phi_i}\right|^2_{\Phi\to a}$$

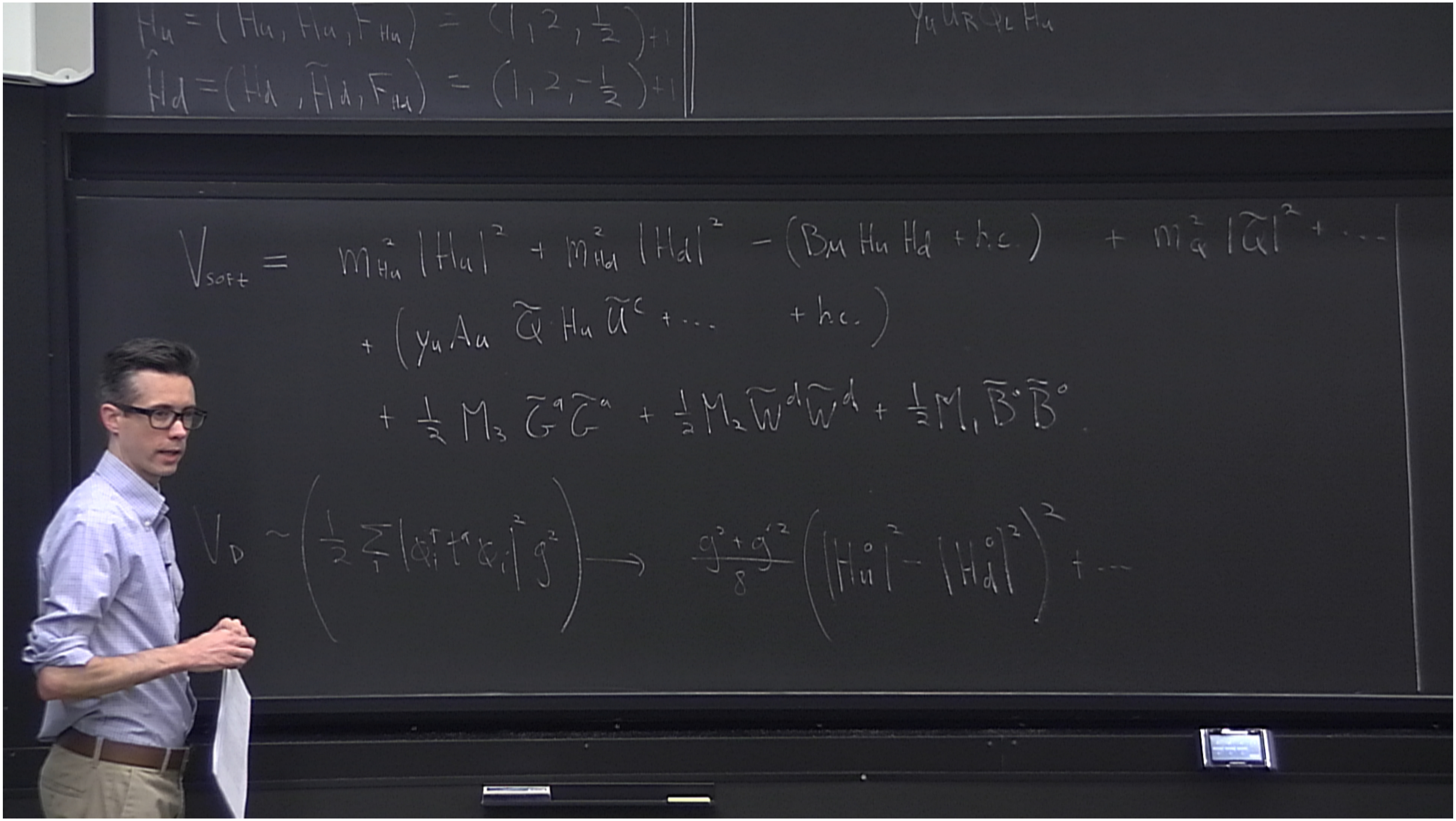
$$y_u Q U^c H_u$$

$$\parallel$$

$$y_u \bar{u}_R Q_L H_u$$

$$\underset{-1}{L}\cdot\underset{+1}{H_u},\quad \underset{-}{U^c}\underset{-}{D^c}\underset{-}{D^c},\quad \underset{-}{Q}\cdot\underset{-}{L}\,\underset{-}{D^c},\quad \underset{-}{L}\,\underset{-}{L}\,\underset{-}{E^c}$$

$$P_R$$



$\hat{H}_u = (H_u, \tilde{H}_u, F_{H_u}) = (1, 2, \frac{1}{2})_{+1}$
$\hat{H}_d = (H_d, \tilde{H}_d, F_{H_d}) = (1, 2, -\frac{1}{2})_{+1}$
$y_u u_R q_L H_u$
$V_{soft} = m_{H_u}^2 |H_u|^2 + m_{H_d}^2 |H_d|^2 - (B\mu H_u H_d + h.c.) + m_Q^2 |\tilde{Q}|^2 + \ldots$
$+ (y_u A_u \tilde{Q} \cdot H_u \tilde{u}^c + \ldots + h.c.)$
$+ \frac{1}{2} M_3 \tilde{G}^a \tilde{G}^a + \frac{1}{2} M_2 \tilde{W}^a \tilde{W}^a + \frac{1}{2} M_1 \tilde{B}^0 \tilde{B}^0$
$V_D \sim \left(\frac{1}{2}\sum_i |\phi_i^\dagger t^a \phi_i|^2 g^2\right) \longrightarrow \frac{g^2+g'^2}{8}\left(|H_u^0|^2 - |H_d^0|^2\right)^2 + \ldots$

$$|^2 + \cdots$$

$$V_H = V_F + V_D + V_{soft}$$

$$= \left(m_{H_u}^2 + |\mu|^2\right)|H_u^0|^2 + \left(m_{H_d}^2 + |\mu|^2\right)|H_d^0|^2 - \left(B_\mu H_u^0 H_d^0 + h.c.\right)$$

$$+ \frac{g^2 + g'^2}{8}\left(|H_u^0|^2 - |H_d^0|^2\right)^2$$

$$\langle H_u^0 \rangle = v_u = v \cdot \sin\beta \geq 0$$

$$\langle H_d^0 \rangle = v_d = v \cos\beta \geq 0$$

$$\sqrt{v_u^2 + v_d^2} = 174 \text{ GeV}$$

$$\tan\beta = \frac{v_u}{v_d}$$

≥ 0

≥ 0

$$m_Z^2 = \frac{m_{H_u}^2 - m_{H_d}^2}{\cos 2\beta} - m_{H_u}^2 - m_{H_d}^2 - 2|\mu|^2$$

8 : $H_u^0,\ H_u^+,\ H_d^-,\ H_d^0$

5 $\hookrightarrow$ $h^0,\ H^0,\ A^0,\ H^\pm$

$$m_{h^0} \leq m_{H^0}$$

$$m_h^2 \leq m_Z^2 \cos^2 2\beta$$

(tree level)

$$\left(|H_u^0|^2 - |H_d^0|^2\right)^2 + \cdots$$

$\lambda_{eff}/4$

$= 0$ for $|H_u^0| = |H_d^0|$

↳ D-flat

$$m_Z^2 = \frac{m_{H_u}^2 - m_{H_d}^2}{\cos 2\beta} - m_{H_u}^2 - m_{H_d}^2 - 2|\mu|^2$$

8 : $H_u^0,\ H_u^+,\ H_d^-,\ H_d^0$

5 ↳ $h^0,\ H^0,\ A^0,\ H^\pm$

$m_{h^0} \le m_{H^0}$

1-loop

$$m_h^2 \le m_Z^2 \cos^2 2\beta \left(1 + \frac{y_t^2 m_t^2}{(4\pi)^2} \ln\left(\frac{m_{\tilde t}^2}{m_t^2}\right)\right)$$

(tree level)

$$\Delta m_{H_u}^2 \sim \frac{y_t^2 m_{\tilde t}^2}{(4\pi)^2} \ln\left(\frac{m_{\tilde t}^2}{m_t^2}\right)$$

$\tilde H_u^0, \tilde H_d^0, \tilde W^3, \tilde B^0 \to \chi_1^0, \chi_2^0, \chi_3^0, \chi_4^0$

"neutralinos"

$\tilde H_u^+, \tilde H_d^-, \tilde W^\pm \to \chi_1^\pm, \chi_2^\pm$

"charginos"

$$\tan\beta = \frac{v_u}{v_d}$$

$m_{h^0} \leq m_{H^0}$

1-loop

$$m_h^2 \leq m_Z^2 \cos^2 2\beta \left(+ \frac{y_t^2 m_t^2}{(4\pi)^2} \ln\left(\frac{m_{\tilde{t}}^2}{m_t^2}\right)\right)$$

(tree level)

$\tilde{H}_u^+, \tilde{H}_d^-, \tilde{W}^\pm$

$\tilde{G}$ = gravitino

"Gravity Mediation" $\quad m_{soft} \sim \frac{F}{M_{Pl}} \to$ mSUGRA

CMSSM

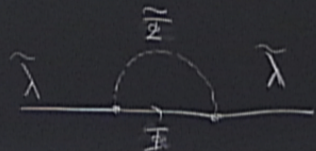
"Gauge Mediation" $\quad W \supset M_* \bar{\Phi}\Phi + \lambda X \bar{\Phi}\Phi$

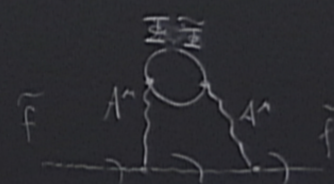
messengers

↳ SM gauge charges

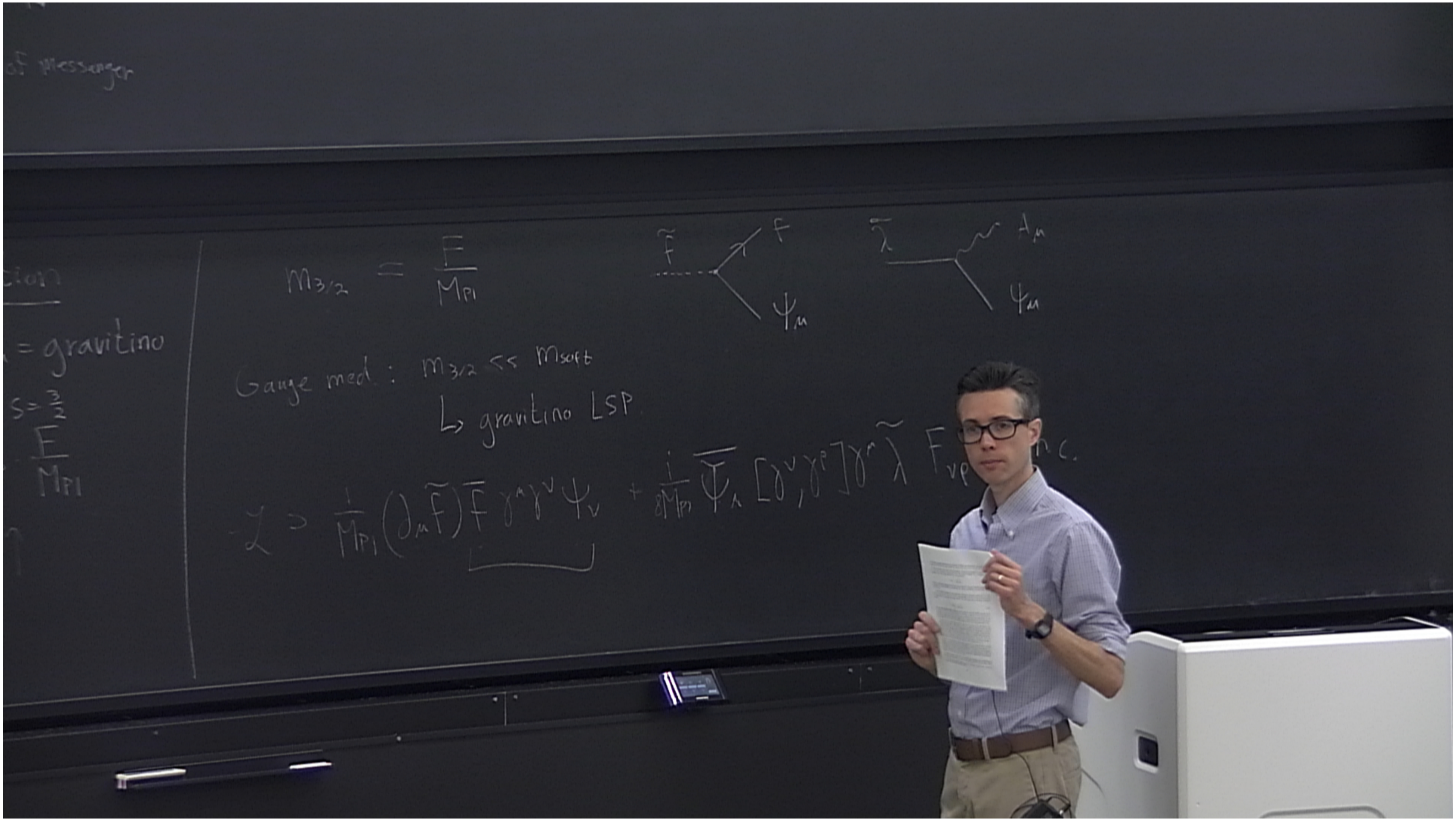
// SUSY breaking, $F_X \neq 0$

$$m_{soft} \sim \frac{g^2}{(4\pi)^2}\frac{F}{M_*}$$





$$m_{soft}^2 \sim \frac{g^4}{(4\pi)^4}\left(\frac{F}{M_*}\right)^2$$


of messenger
= gravitino
Gauge med. : m3/2 << msoft
↳ gravitino LSP
h.c.

Anomaly Mediation

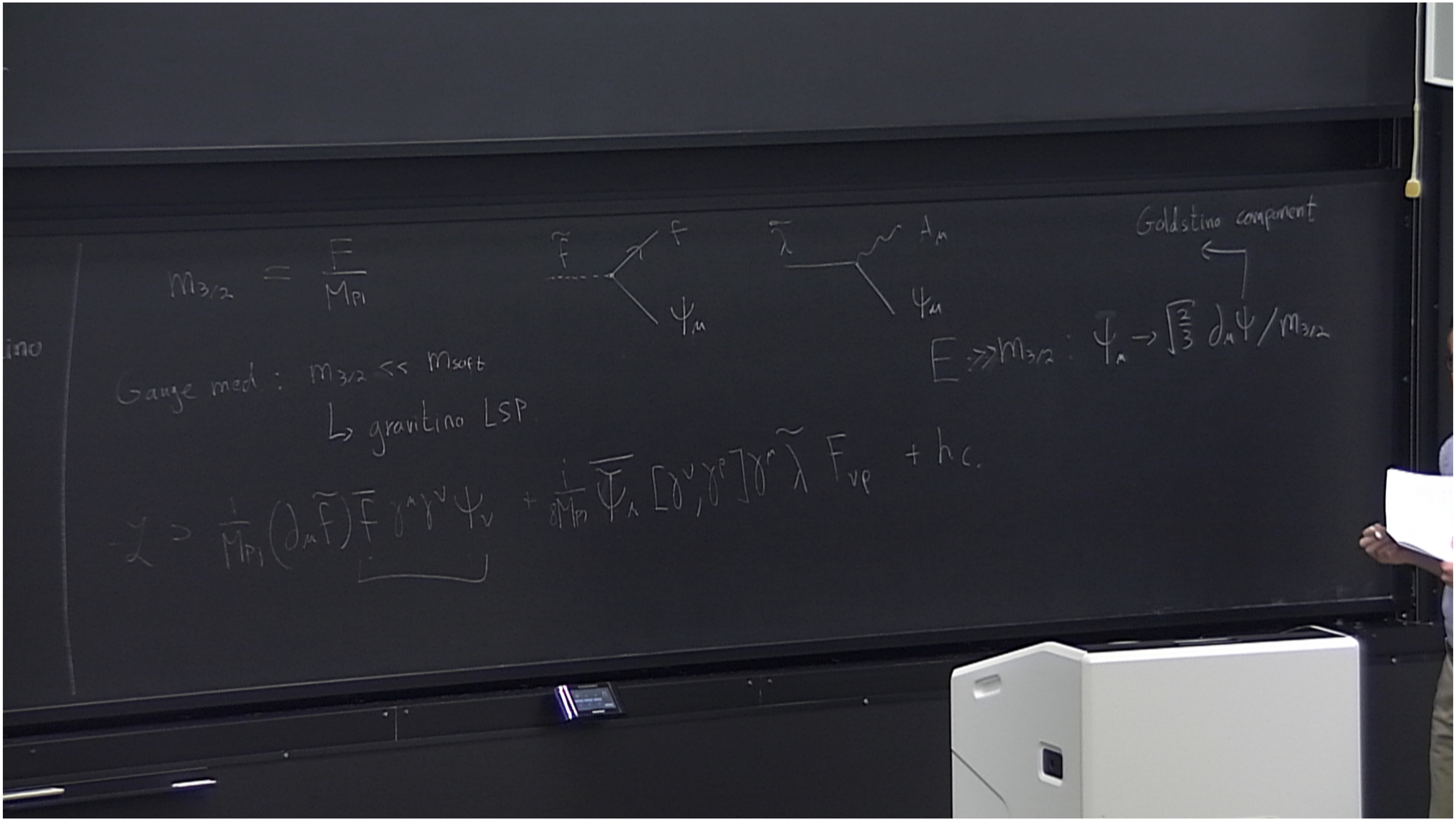
$h^{\mu\nu}$, ψ_μ = gravitino

" $s = \frac{3}{2}$

$$m_{soft} \sim \frac{g^2}{(4\pi)^2} \cdot \frac{F}{M_{Pl}}$$

Ga

$\mathcal{L}$


$m_{3/2} = \frac{F}{M_{Pl}}$
$\tilde{f}$ f ψ_μ
$\tilde{\lambda}$ A_μ ψ_μ
Goldstino component
$F \gg m_{3/2}: \psi_\mu \to \sqrt{\frac{2}{3}}\, \partial_\mu \psi / m_{3/2}$
Gauge med: $m_{3/2} \ll m_{soft}$
↳ gravitino LSP
$\mathcal{L} \supset \frac{1}{M_{Pl}} (\partial_\mu \tilde{f}) \bar{f} \gamma^\mu \gamma^\nu \psi_\nu + \frac{i}{8 M_{Pl}} \bar{\psi}_\lambda [\gamma^\nu, \gamma^\rho] \gamma^\lambda \tilde{\lambda} F_{\nu\rho} + h.c.$