GOLDILOCKS COSMOLOGY

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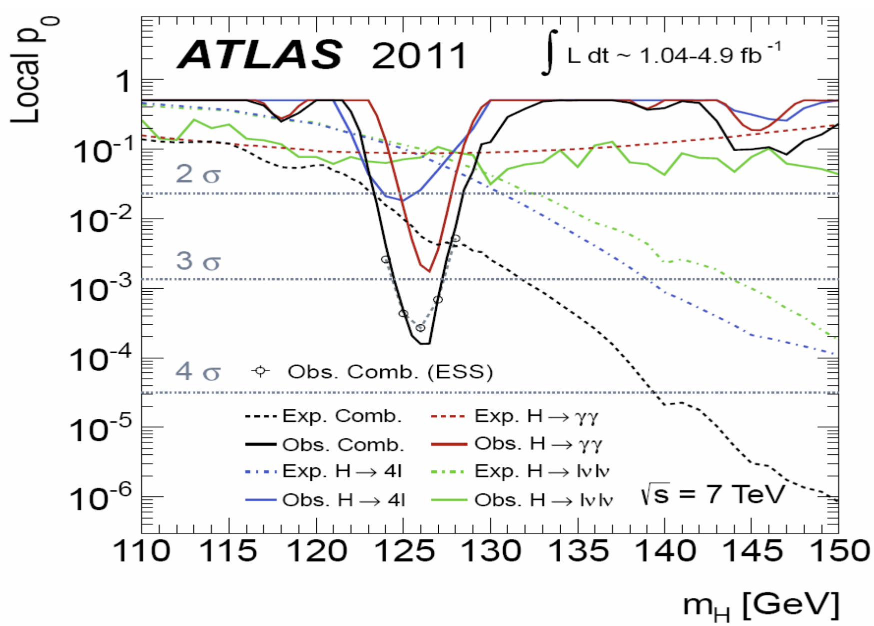
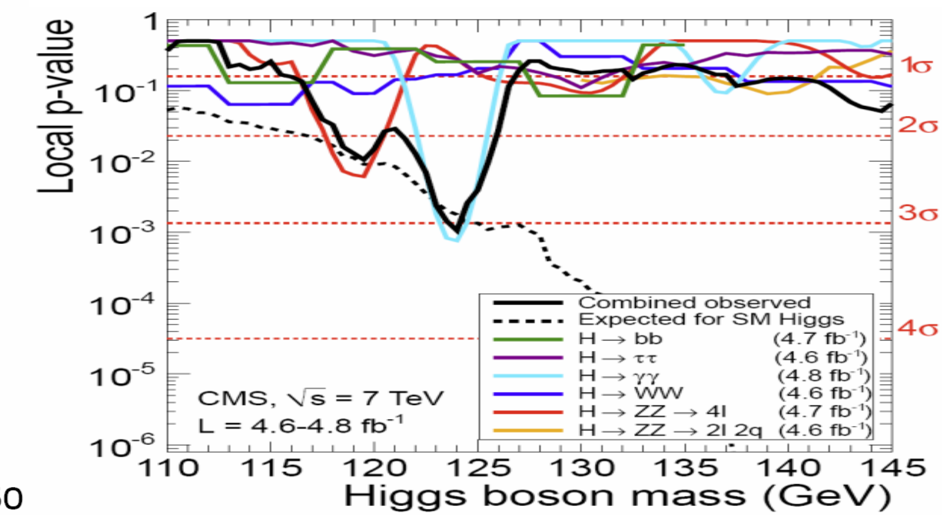
KICP, University of Chicago, 23 May 2012

HIGGS BOSONS AT LHC

- Tantalizing hints in the 2011 data

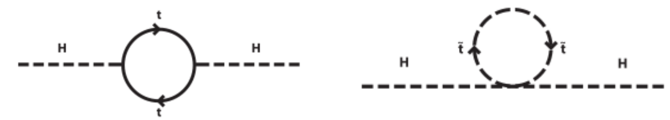




- ~3σ (local significance) signals at 126 GeV (ATLAS), 124 GeV (CMS)
- Light Higgs windows: 117.5 – 118.5 GeV and 122.5 – 127.5 GeV
- Consistent with SM Higgs couplings

HIGGS RESULTS AND SUSY

- 30,000 foot view: great for SUSY



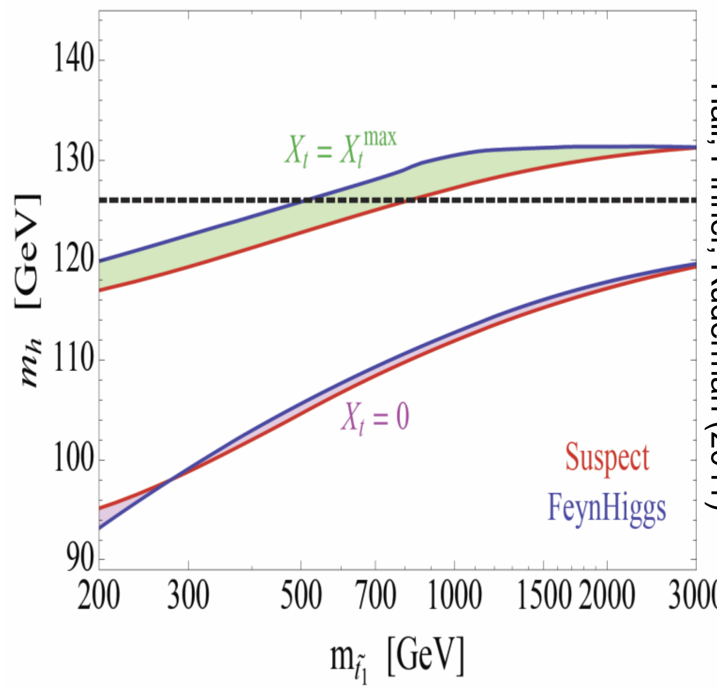
- Closer view: challenging for SUSY
  - Tree-level: $m_h < m_Z$
  - Higgs mass requires large loop-level corrections from heavy top squarks

Tree-level

$\sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$

Left-right mixing

$$m_h^2 = m_Z^2 c_{2\beta}^2 + \frac{3m_t^4}{4\pi^2 v^2}\left(\log\left(\frac{M_S^2}{m_t^2}\right) + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right)$$



Hall, Pinner, Ruderman (2011)

- But naturalness requires light top squarks. This tension motivates reconsideration of many SUSY models

GOLDILOCKS SUSY

Feng, Smith, Takayama (2007); Feng, Surujon, Yu (2012)
Kitano, Low (2005); Ibe, Kitano (2007)

- Let's reconsider gauge-mediated supersymmetry breaking: a beautiful framework that suppresses flavor violation

- In GMSB, Higgs is a special problem: X_t is small → heavy top squarks

Draper, Meade, Reece, Shih (2011); Evans, Ibe, Shirai, Yanagida (2012)

- But GMSB also has other difficulties:

  EDMs
  - GMSB suppresses flavor, but not CP violation (e.g., from μ, $M_{1/2}$ phase difference)
  - Electron EDM → selectrons > 2 TeV, GMSB relations → squarks > 5 TeV

  Dark Matter
  - No WIMP miracle: neutralinos decay to gravitinos
  - keV gravitino DM not viable: $\Omega_{\tilde{G}}\, h^2 \approx 0.1\, (m_{\tilde{G}}$ / 80 eV), but Lyman-α → $m_{\tilde{G}} > 2$ keV

Viel et al. (2006); Seljak et al. (2006)

MINIMAL GMSB

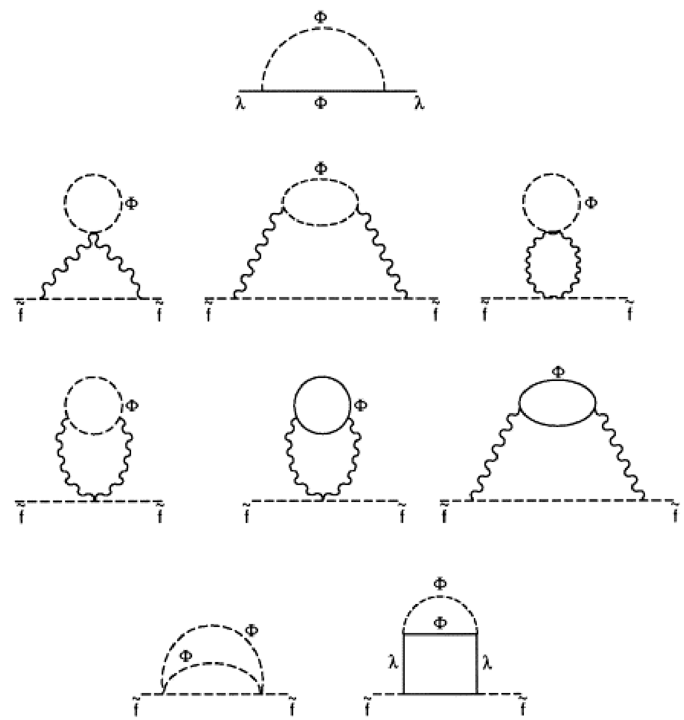
- Let's simply close our eyes, take all the data at face value, and see where it leads us. For simplicity, consider minimal GMSB
- 5 parameters: $m_{\tilde{G}}$, Λ, $\tan\beta$, N_5, sign(μ); set $N_5 = 1$, $\mu > 0$

$$\boxed{m_{\tilde{G}} = \frac{F}{\sqrt{3} M_*}}$$

$$\Lambda = F/M_m$$

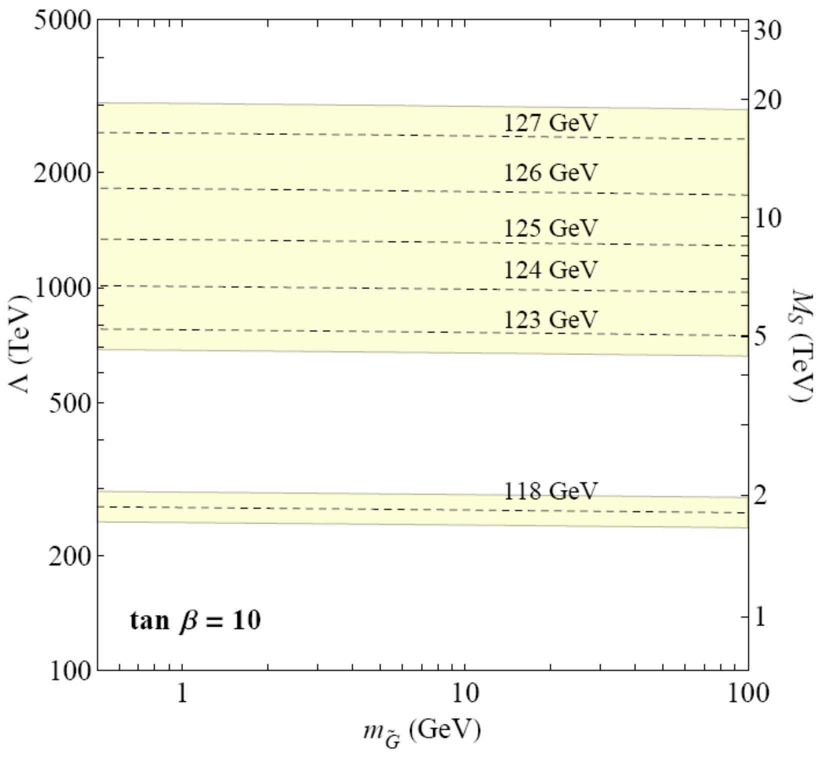
$$m^2_{\tilde{f}}(M_m) = 2 N_5 \Lambda^2 \sum_{a=1}^{3} C_a^f \left[\frac{\alpha_a(M_m)}{4\pi} \right]^2$$

$$M_a(M_m) = N_5 \Lambda \frac{\alpha_a(M_m)}{4\pi}$$

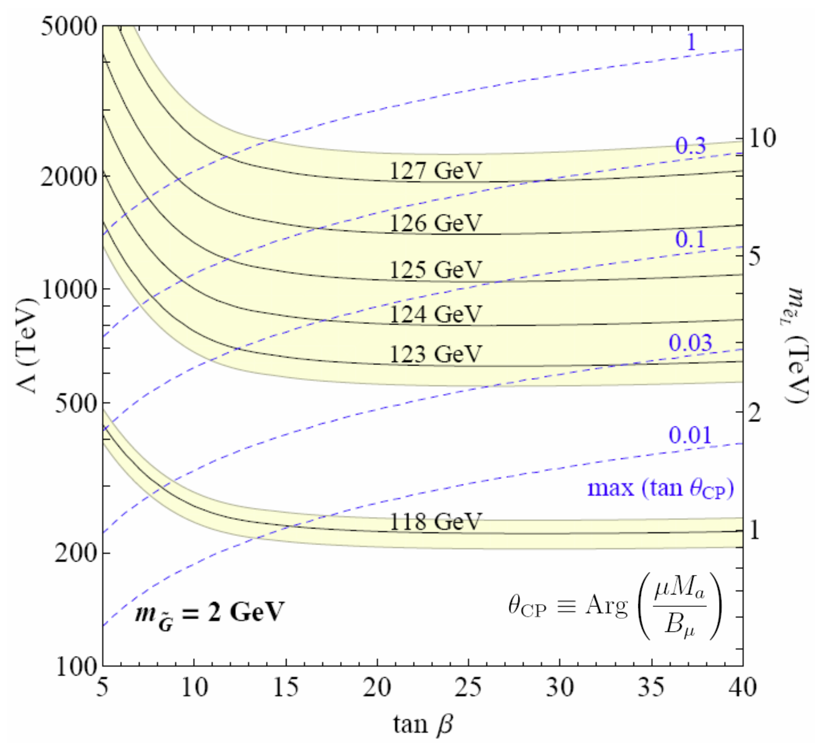


HIGGS AND EDMS

- Higgs Mass



- Electron EDM

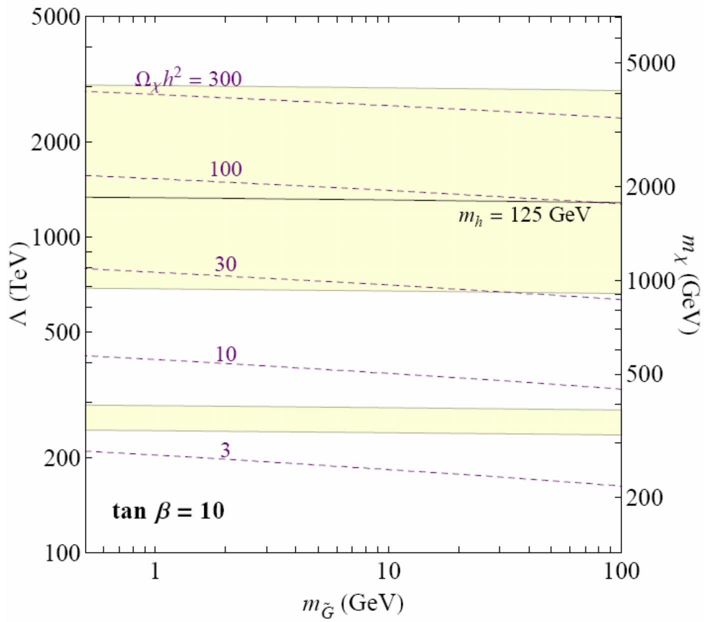


- The Higgs and EDM constraints both point to the same region of parameter space

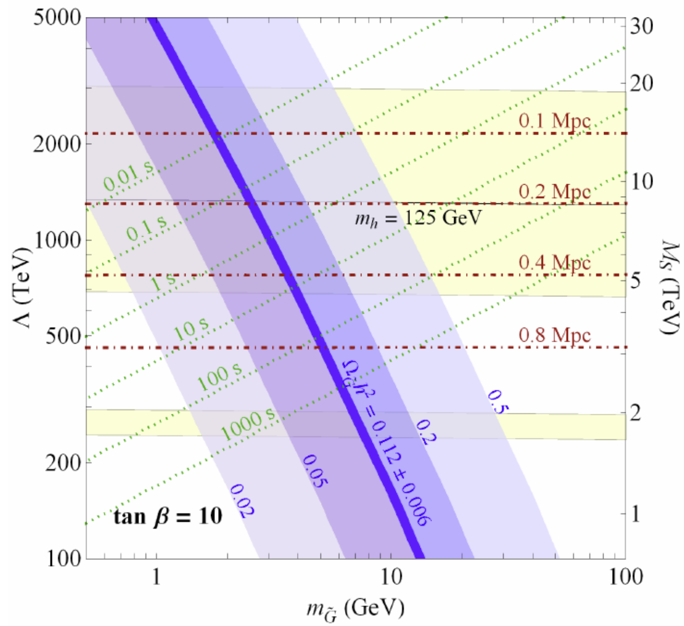
DARK MATTER

- Such large masses → TeV neutralinos are vastly over-produced in the early universe with Ωh^2~100. But then they decay to GeV gravitinos that have the right relic density!

Neutralino Ω



Gravitino Ω

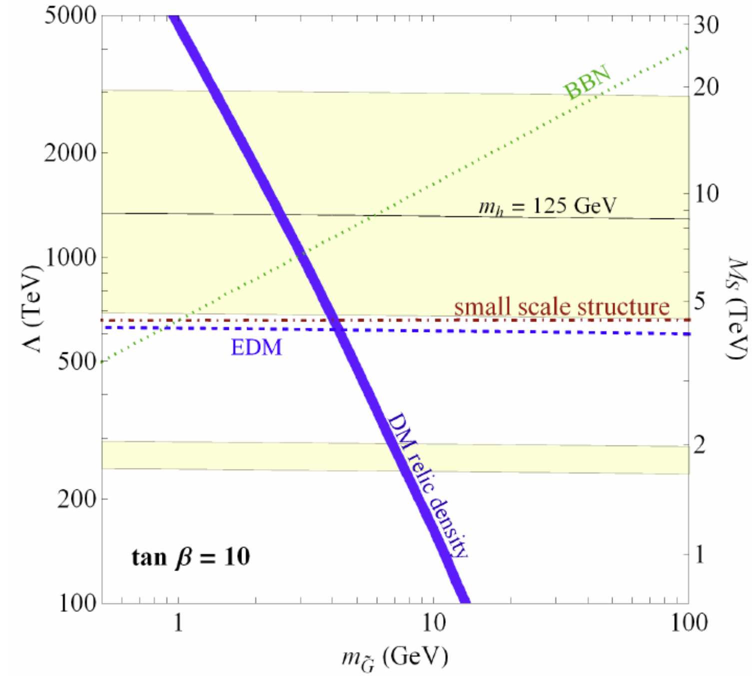


- Why "Goldilocks":
  - Gravitinos are light enough to solve the flavor problem
  - Gravitinos are heavy enough to be all of DM

GOLDILOCKS COSMOLOGY

- Dark matter is non-thermal gravitinos from late decays

- Several constraints
  - Relic density
    $$\Omega_{\tilde{G}} h^2 = (m_{\tilde{G}} / m_\chi) \Omega_\chi h^2$$
  - Decays before BBN (1 s)
    $$\tau_\chi \simeq \frac{48\pi m_{\tilde{G}}^2 M_*^2}{m_\chi^5} \simeq 0.02 \text{ sec} \left(\frac{m_{\tilde{G}}}{1 \text{ GeV}}\right)^2 \left(\frac{2 \text{ TeV}}{m_\chi}\right)^5$$
  - Cold enough ($\lambda_{FS} < 0.5$ Mpc)
    $$\lambda_{\rm FS} \simeq 1.0 \text{ Mpc} \left[\frac{u_\tau^2 \tau}{10^6 \text{s}}\right]^{1/2} \left[1 - 0.07 \ln\left(\frac{u_\tau^2 \tau}{10^6 \text{ s}}\right)\right]$$



- All constraints point to the same region of parameter space
- Naturalness? Perhaps focus point SUSY

Agashe (1999)

SUMMARY

- LHC Higgs results motivate a re-analysis of BSM models
- If the Higgs signal persists, Goldilocks SUSY will be among the simplest explanations
  - Minimal field content, standard cosmology
  - Simultaneously fits Higgs mass, flavor, EDMs
  - Cosmology: non-thermal GeV gravitino DM from late decays
- Implications
  - SM-like Higgs will be discovered at ~ 125 GeV
  - No superpartners at the LHC; no direct, indirect DM detection
  - EDMs just around the corner
  - Warm DM with λ_{FS} ~ 0.1 – 0.5 Mpc