A closer look to the sgoldstino interpretation of the diphoton excess

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Based on 1603.05682

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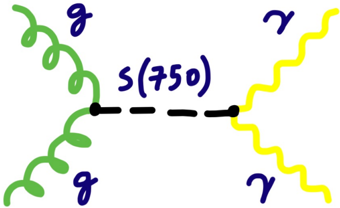
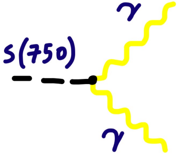
$\sigma(pp \to s \to \gamma\gamma)$



$$\sigma = \frac{\sum_{\mathcal{P}} C_{\mathcal{P}\overline{\mathcal{P}}}\Gamma(s \to \mathcal{P}\overline{\mathcal{P}}) \times \Gamma(s \to \gamma\gamma)}{m_s \Gamma_s E_{cm}^2}$$

Assuming that $\Gamma(s \to gg)$ dominates the width, one finds that the cross section is proportional to the photon width...

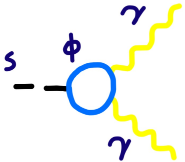
$$\sigma \approx \frac{C_{gg}\Gamma(s \to \gamma\gamma)}{m_s E_{cm}^2}$$



$$\Gamma_{\gamma\gamma} \approx 0.3 MeV \quad (\sigma = 6fb)$$

minimum $\Gamma_{\gamma\gamma}$ compatible with observations

Difficult to achieve in perturbative renormalizable models (Salvio Staub Strumia Urbano 1602.01460)



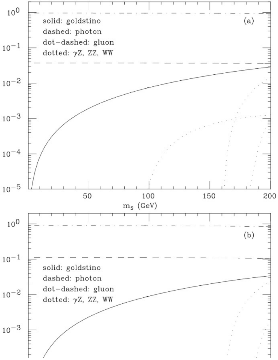
- low masses of the mediators
- large charges
- large number of mediators
- large Yukawa's
- large scalar trilinears (instabilities)

Sgoldstino

Superpartner of the goldstino. Phenomenological analysis have long history

LEP signatures

Perazzi Ridolfi Zwirner '00



$$X = S + \sqrt{2}\theta\psi + \mathcal{F}$$

sgoldstino (S), goldstino (ψ)

Why the sgoldstino? Supersymmetry, if present, must be broken spontaneously $\Rightarrow$ Presence of massless goldstino; its superpartner is not protected, but theorems guarantee its tree level masslessness in a broad context (e.g. Komargodski Shih '09)

Effective theories with MSSM $+ \psi + S$

In a wide class of models, gauginos acquire Majorana mass from supersymmetry breaking

$$\frac{1}{2}M_a\lambda_a\lambda_a + h.c.$$

Supersymmetry dictates that it should come together with other operators

$$\frac{M_a}{2F}\int d^2\theta X \mathcal{W}_a^\alpha \mathcal{W}_a^\alpha =$$

$$= \frac{1}{2}M_a\lambda_a\lambda_a + \frac{M_a}{2\sqrt{2}F}\left(sG_a^{\mu\nu}G_a^{\mu\nu} - aG_a^{\mu\nu}\tilde{G}_a^{\mu\nu}\right) + \ldots$$

Nonzero Majorana masses imply nonzero trilinear couplings $s\gamma\gamma$ and sgg

$$\Gamma_{\gamma\gamma} = \frac{m_s^3 M_\gamma^2}{32\pi F^2} \quad \Rightarrow \quad \sqrt{F} \approx 4\,TeV \left(\frac{M_\gamma}{200\,GeV}\right)^{1/2} \left(\frac{6fb}{\sigma_{\gamma\gamma}}\right)^{1/4}$$

UV Completion

Gauge mediation $\rightarrow$ we add messenger fields that will eventually

- generate MSSM masses
- mediate the resonance decay

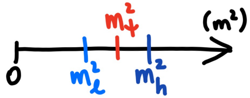
We also want to respect unification (main achievement of MSSM) $\Rightarrow$ we add messengers in complete SU(5) multiplets, with total Dynkin index $N \lesssim 5$

$F \ll \lambda M^2$

$$\mathcal{L}_\Phi = \lambda \int d^2\theta X \Phi \bar{\Phi} + h.c.$$

$$\langle X \rangle = M + \theta^2 F$$

$\mathcal{L}_\Phi$ provides masses for the messenger multiplet and trilinear couplings between them and the sgoldstino



$$m_\Psi = \lambda M$$
$$m^2_{h/l} = \lambda^2 M^2 \pm \lambda F$$

The decay width into photons and the MSSM masses (we consider M_3) are predicted to be

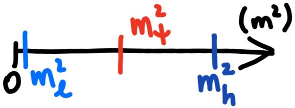
$$\Gamma_{\gamma\gamma} = \frac{\alpha^2}{(8\pi)^3} \frac{m_s^3}{m_\Psi^2} \lambda^2 N_\gamma^2 \implies m_\Psi \approx 1.1\, TeV \left(\frac{\lambda N_\gamma}{16} \right)$$

$$M_3 = \frac{\alpha_3}{4\pi} \frac{F}{M} N_3 \ll \frac{\alpha_3}{4\pi} m_\Psi N_3 \implies m_\Psi \gg 22\, TeV \left(\frac{10}{N_3} \right) \left(\frac{M_3}{1.7\, TeV} \right)$$

$$F \lesssim \lambda M^2$$

In this limit the picture changes

- gauginos get masses from loops of the whole multiplet ($E \sim m_\Psi$)
- the decay into photons is mediated mainly by ϕ_l ($E \sim m_l \ll m_\Psi$)



$$m_l \ll m_\Psi$$

$$\Gamma_{\gamma\gamma} = \frac{1}{36} \frac{\alpha^2}{(8\pi)^3} \frac{m_s^3}{m_l^2} N_\gamma^2 \left(\frac{\lambda m_\Psi}{m_l} \right)^2$$

$$M_3 = \frac{\alpha_3}{4\pi} m_\Psi N_3 \log 4$$

The combination $\lambda m_\Psi / m_l \equiv g_{eff}$ measures the effective strength between sgoldstino and light messengers...

The dynamics governing the light scalars s and ϕ_l is captured by

$$V_{\rm light} = \frac{1}{2} m_s^2 s^2 + m_l^2 |\phi_l|^2 + \sqrt{2} \lambda m_\Psi s |\phi_l|^2 + \ldots$$

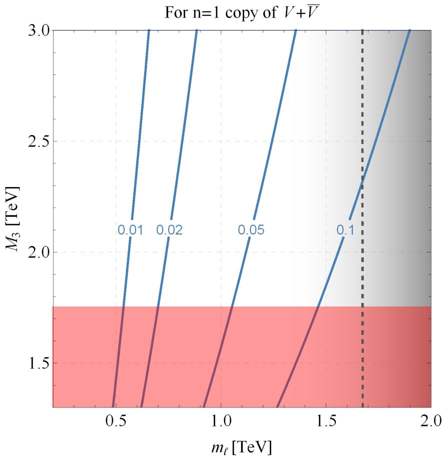
Assuming $m_l \gtrsim m_s$, it is appropriate to express the dimensionful coupling in terms of this mass scale (e.g. to control higher loop contributions)

$$V_{\rm light}^{(3)} = \sqrt{2} \left(\frac{\lambda m_\Psi}{m_l} \right) m_l s |\phi_l|^2 = \sqrt{2} g_{eff} \, m_l s |\phi_l|^2$$

We are considering the limit in which g_{eff} goes strong, *getting therefore a further enhancement of the signal*

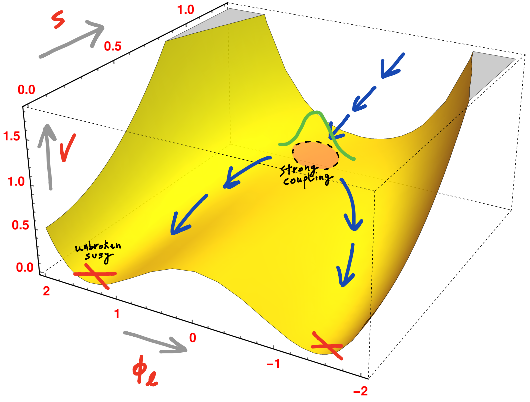
But to trust our loop computations we require $g_{eff} \lesssim 4\pi$

Example



$SU(5)$ adjoint, with $V_{(3,2,-5/6)}$ and $\overline{V}$ becoming light. Notice that N=5

Where did we get?



- We are close to a critical point, where ϕ_l becomes tachionic
- The system $s \times \phi_l$ is strongly coupled
- What is the effective (∞−loop) potential in that region?
- We speculate that a local minimum could develop there, *explaining F.T.*
- Still, the minimal model is unstable (strong trilinear and weak quartic)

Further model building to stabilize the potential

Summary and Outlook

We have considered sgoldstino models, with MSSM masses given by Gauge Mediation

We could fit the signal by stretching a lot the parameters

Optimistic view: We can explain the fine tuning and the potential is stable

Pessimistic view: The potential is unstable, indicating that there are general major difficulties in sgoldstino models

Other possibilities: relax some of the constraints we lived with

- Generate large quartics for the light messenger ϕ_l
- Give masses to MSSM with other mechanism: e.g. Dirac masses to gauginos / tree level masses to sfermions (via an extra U(1)')
- ...