SUSY Hidden Dark Photon

- **SUSY:** \( m_{A'} \sim \min \{ \sqrt{\epsilon m_Z}, \epsilon m_{\text{MSSM}} \} \)
  
  [Arkani-Hamed+Weiner 2008; Cheung et al. 2009; DM, Poland, Zurek 2009; ...]

- **Hidden Higgs fields spontaneously break the U(1)'**.

\[
\mathcal{L} \supset \int d^2 \theta \left( \frac{\epsilon}{2c_w} B^\alpha X_\alpha + \mu' HH' \right) + (h.c.)
\]

- **Physical states:**
  - 1 \( A' \) massive hidden photon
  - 3 \( \chi_{1,2,3}^x \) hidden fermion “neutralinos” (lightest is stable)
  - 2 \( h_{1,2}^x \) hidden scalar Higgs bosons
  - 1 \( \alpha^x \) hidden pseudoscalar Higgs boson
Experimental Signals of the Theory

• Depend mainly on how the hidden photon decays. This is determined mostly by the mass spectrum.

• Four main cases:
  • A: \( A' \rightarrow SM + SM \), similar to visible vector portal
  • B: \( A' \rightarrow \chi_1^x + \chi_1^x \), similar to dark vector portal
  • C: \( A' \rightarrow h_1^x + a^x \), not much attention [Schuster, Toro, Yavin 2009]
  • D: \( A' \rightarrow \chi_1^x + \chi_2^x \), new!

• Focus on cases C and D. [DM, Spray 2014]
\( h_1^x, a^x, \chi_2^x \) are typically long-lived.
Case C - Limits

[Image of a 2D graph with axes labeled $m_{\chi}$ (GeV) and $\epsilon$, showing various shaded regions and contours representing different experimental limits and theoretical predictions.]
Case D - Limits

[DM, Spray 2014]
Warped Dark Photon

- Warping (compositeness) can also produce a light $A'$.  
  
- Setup:

  $z = 1/k$
  
  $z = R_1$
  
  $z = R_2$

- Dark photon Kaluza-Klein partners, $n = 1, 2, 3, \ldots$

  \[
  m_n \sim n m_x / \sqrt{\ln(M_{\text{Pl}}/m_x)}, \quad \epsilon_n \sim \epsilon / \sqrt{n \ln(M_{\text{Pl}}/m_x)}
  \]
Warped Dark Photon

- Other dark states: [McDonald, DM 2011]
  - dark IR brane Higgs
  - dark bulk radion + KK modes
  - dark-localized graviton KK modes
- Higher KK modes cascade down giving multi-body signals. e.g.