

# Constraining Dark Matter Interpretations of the Galactic Center Excess

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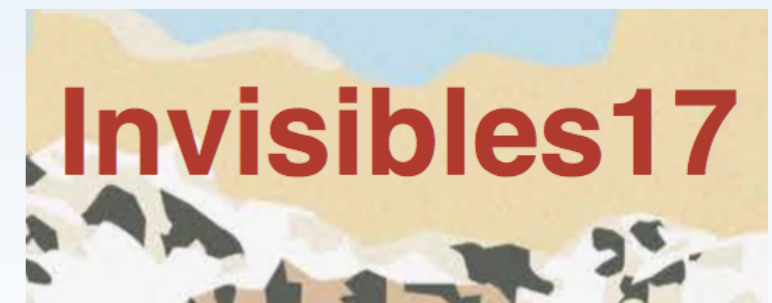
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Invisibles Workshop



# Approach

Using simplified models, can we generically assess the viability of a dark matter interpretation of the GC excess, and identify the parameter space that needs to be probed by future searches

Models: (1) s-channel spin-0 mediator; (2) s-channel spin-1 mediator

(3) t-channel to  $b\bar{b}$ ; (4) Hidden Sectors

(5)  $DM + DM \rightarrow DM + h/Z$  [recently considered for GC + anti-proton]

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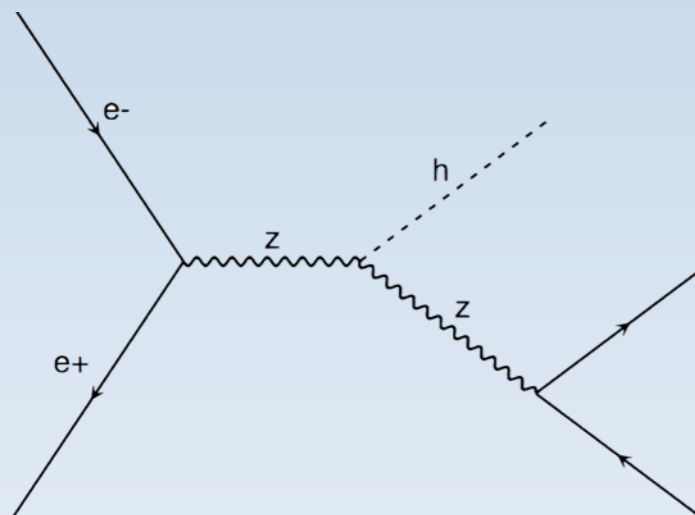
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**LEP-II**  $m_{\text{med}} \in [10 \text{ GeV}, 100 \text{ GeV}]$



Only probe SM couplings

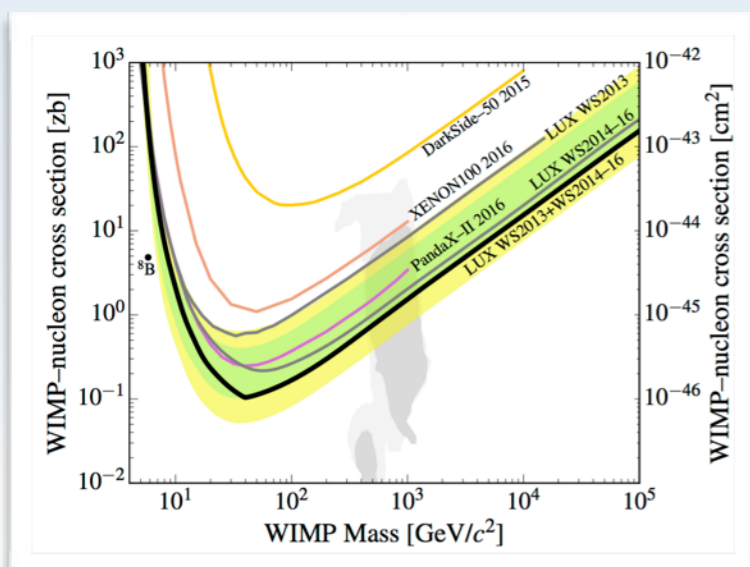
**BaBar**

$m_{\text{med}} \in [1 \text{ GeV}, 10 \text{ GeV}]$

$$\Upsilon \rightarrow \gamma + \text{Scalar}$$

(some searches)

**Direct Detection (LUX 2016)**



**CMS & ATLAS**

$m_{\text{med}} \in [100 \text{ GeV}, 1 \text{ TeV}]$

- Search strategy depends on model
  - Monojet + MET
  - Dijet resonances
  - Di-lepton resonances
  - Di-tau resonances
  - Sbottom searches

## S-channel, spin-1 mediator, spin-1/2 DM

$$\mathcal{L} \supset \left[ a\bar{\chi}\gamma_{\mu}(g_{\chi v} + g_{\chi a}\gamma^5)\chi + \sum_f \bar{f}\gamma_{\mu}(g_{fv} + g_{fa}\gamma^5)f \right] V_{\mu}$$

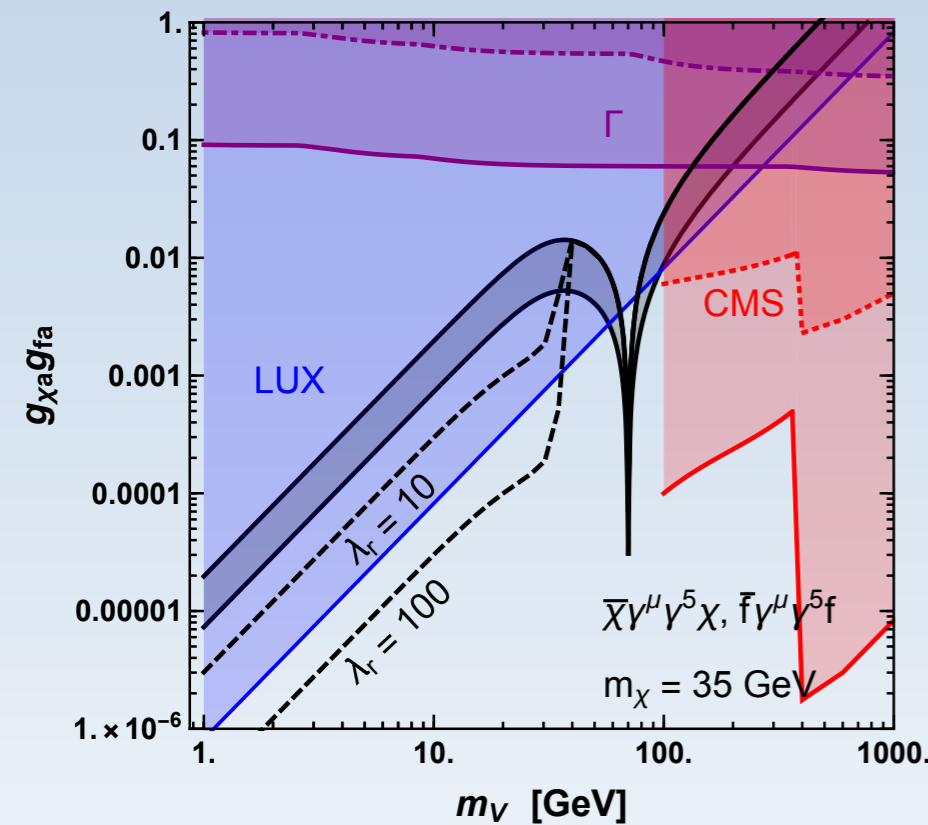
- Start with generic MFVM (all SM couplings equal)
- Is annihilation cross section s-wave?
- What changes are needed for models to survive?

## S-channel, spin-1 mediator, spin-1/2 DM

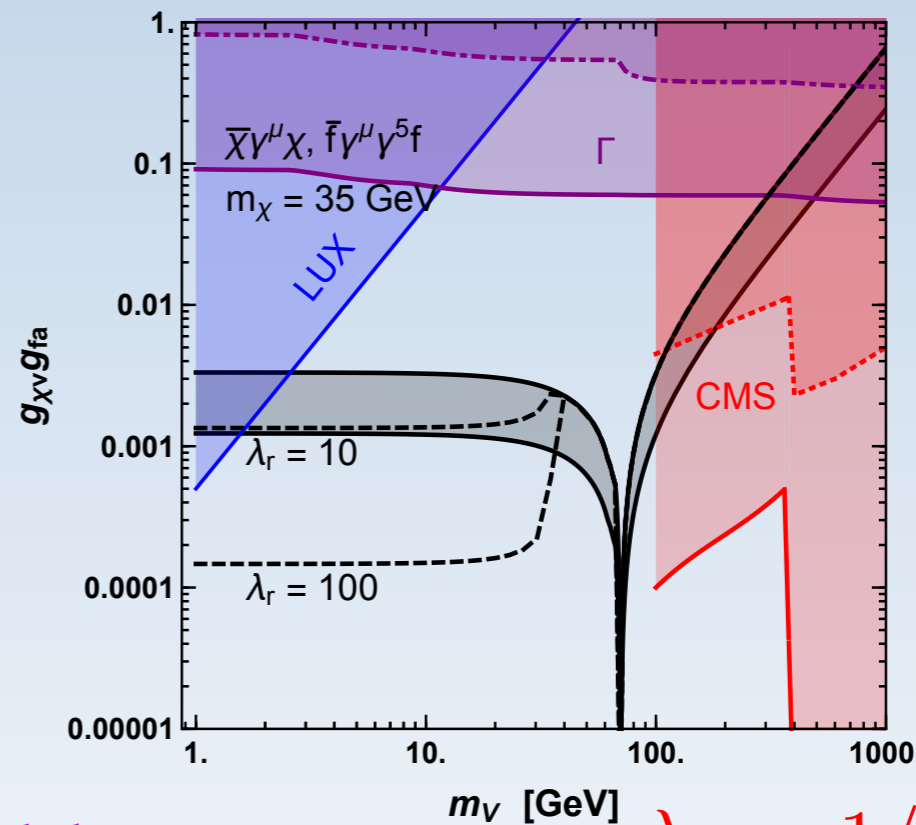
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$$\lambda_r = \lambda_{\text{DM}} / \lambda_b$$



LHC:  
Di-lepton  
Monojet +MET



Note that loop suppressed SI interactions may enhance DD bounds... (but model dependent!)

Breakdown of model

$\lambda_r = 1/3$  (Solid)

Spectrum requires  $\sim 35$  GeV DM

$\Gamma / m_A = 0.1$

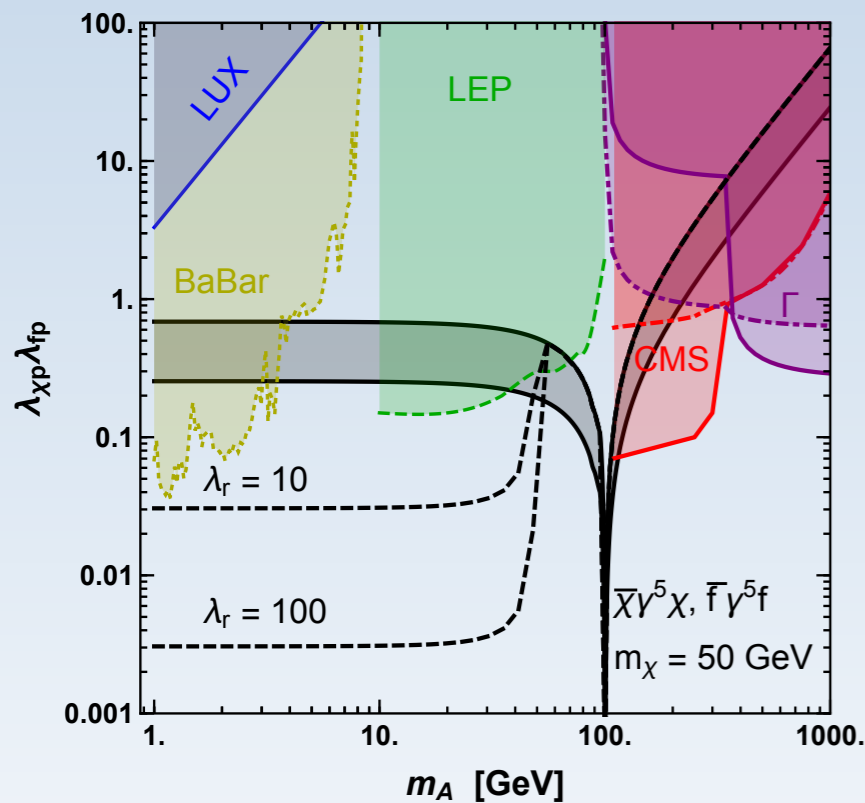
$g_\chi = 1$  (i.e.  $\lambda_r \gg 1$ , dotted)

Such models are heavily constrained and don't look promising...  
but can increase viability if e.g. mediator only couples to 3rd generation

# S-channel, spin-0 mediator, spin-1/2 DM

$$\mathcal{L} \supset \left[ a\bar{\chi}\lambda_{\chi p}i\gamma^5\chi + \sum_f y_f\bar{f}(\lambda_{fs} + \lambda_{fp}i\gamma_5)f \right] A$$

As Belen has previously pointed out in this conference, these terms don't respect gauge invariance. **However**, interpreting the GC excess in the context of more complete models can lead to a phenomenology primarily dictated by these interactions (see refs below). Thus using this simplified model may allow for generic and conservative statements about potential viability of a pseudoscalar interpretation.



$$\lambda_r = 1$$

$$\lambda_r = 10$$

1502.06000,  
Berlin, Gori, Lin, Wang  
Model: MSSM

1404.3176  
Ipek, McKeen, Nelson  
Model: 2HDM

1612.07115  
Butter, Murgia, Plehn, Tait  
Model: MSSM

1405.5204  
Berlin, Gratia, Hooper, McDermott  
Model: NMSSM (Hidden Sector)

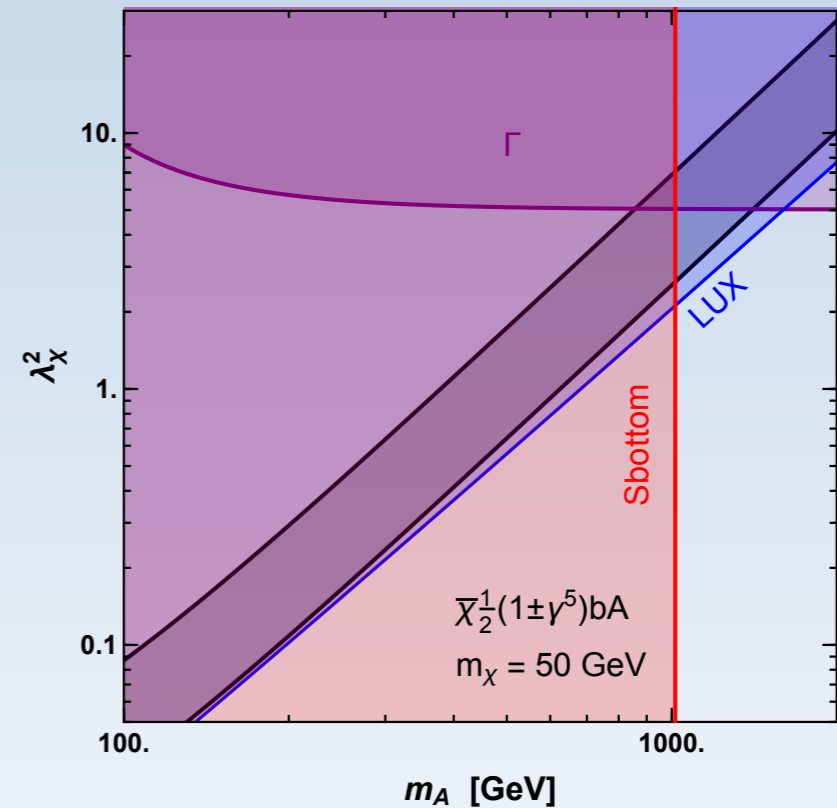
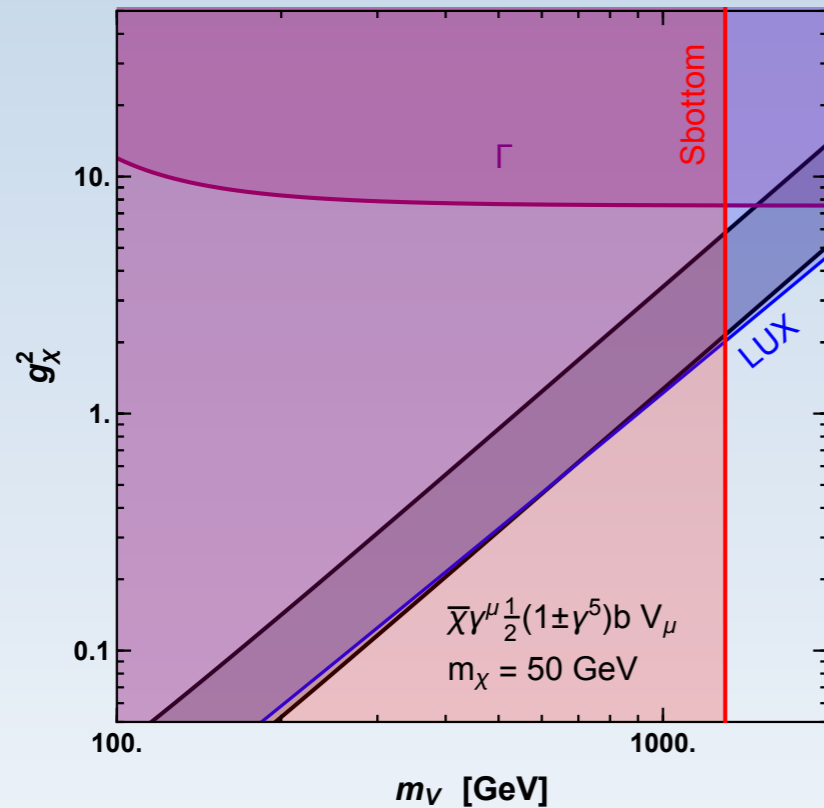
LHC constraints can be reduced/eliminated by introducing asymmetric couplings to up-like and down-like quarks — of order 5 or 10

Spectrum requires ~50 GeV DM

## t-channel annihilation to bb

$$\mathcal{L} \supset g_\chi \bar{\chi} \gamma^\mu (1 + \gamma^5) f V_\mu + g_\chi \bar{f} \gamma^\mu (1 - \gamma^5) \chi V_\mu^\dagger$$

No 'wiggle room' with these models as they predict charged and colored mediators (easy to probe at LHC)



No longer feasible...

# Take-away

- Spin-0 mediated models with PS couplings remain viable and have a significant amount of parameter space, especially if the models deviates from a MFVM
- Spin-1 mediated models can be *effectively* considered ruled out
- t-channel annihilation models are **all** ruled out
- Hidden sector models are extremely difficult to probe, and if excesses are observed in dwarf galaxies in the near future, these models may gain significant interest
  - (see Escudero & SJW 17xx.xxxx for future probes of such models)

## Thank you!

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