

Title: A Composite Model of Dark Matter

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URL: <http://pirsa.org/11090116>

Abstract: We describe a model of composite dark matter, bound by an asymptotically free gauge interaction. This leads to a novel relic history and to an enhancement of the present-day dark matter annihilation cross section. Potential indirect detection signals are discussed.

A Composite Dark Matter Sketch

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work with Pospelov, Sharman
arXiv:who.knows

Outline

- Briefly mention the (publication) history
- Describe model of DM confined by $SU(N)$
- (Cosmological) history
- Annihilation
- Direct Detection
- Conclusions

Nonabelian Cosmology

- Been covered by a large number of authors in either QCD or nonabelian dark force cases
- Received attention in split SUSY, or in scenarios with colored, long-lived NLSP
- Increased annihilation at QCD confinement transition caused otherwise stringent constraints to be weakened

Nonabelian Cosmology

Arvanitaki, Davis, Graham, Pierce, Wacker '05

Kang, Luty, Nasri '06

Jacoby, Nussinov '07

Alves, Behbahani, Schuster, Wacker '09

Arkani-Hamed, Finkbeiner, Slatyer, Weiner '09

Falkowski, Juknevich, Shelton '09

Arvanitaki, Dimopoulos, Dubovsky, Graham,

Harnik, Rajendran '09

Kribs, Roy, Terning, Zurek '09...

Motivation

- We'd like to see if DM can follow a similar story
- Can hope for a boost factor in DM annihilation below the confinement transition

A “Model”/Sketch

- We imagine heavy “quarks” Q , with TeV-scale masses coupled to a new $SU(N)$ with a confinement scale $\Lambda \ll M_Q$
- The “quarks” are stabilized by some symmetry

Cosmological History

- At $T \sim M_Q/20$ the “quarks” perturbatively freeze out, with a relic density given by

$$\Omega h^2 \sim 0.1 \left(\frac{\text{pb}}{\langle \sigma v \rangle_{\text{pert.}}} \right) \sim 0.1 \left(\frac{N}{2} \right)^{-1} \left(\frac{\alpha_D(M_Q)}{0.04} \right)^{-2} \left(\frac{M_Q}{\text{TeV}} \right)^2$$

- At $T \sim \Lambda$ bound states, (QQ) , $(\bar{Q}\bar{Q})$, $(Q\bar{Q})$ form, with $(Q\bar{Q})$ decaying to, e.g., dark glue

Cosmological History (cont'd)

- Potential depletion of quarks through re-arrangement $(QQ) + (\bar{Q}\bar{Q}) \rightarrow 2(Q\bar{Q})$

$$\sigma_{\text{r.a.}} v \sim a_{\text{Bohr}}^2 \frac{1}{M_Q a_{\text{Bohr}}} \sim \frac{1}{M_Q^2 \alpha (M_Q \alpha)}$$

- Requiring that this depletion is not important (does not catch up with Hubble rate) requires

$$\Lambda \lesssim 50 \text{ MeV} \left(\frac{M_Q}{\text{TeV}} \right)$$

Cosmological History (cont'd)

- This gives an “effective” depletion $d(N) \sim 1/2$ for $N = 2$
- Difficult to estimate for higher N
- The upper bound on Λ translates to a lower bound on the perturbative density of (QQ) :

$$\Omega h^2 \gtrsim 0.1 d(N) \left(\frac{N}{2}\right) \left(\frac{M_Q}{\text{TeV}}\right)^2$$

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Pitfalls

- Annihilation of $(Q\bar{Q})$ produces glueballs with masses of a few Λ , could be cosmologically relevant
- If we introduce another light state q with a mass a bit larger than the lightest glueball, gauged under $SU(N)$ and a new $U(1)$ that mixes with the photon, then glueballs can decay somewhat efficiently

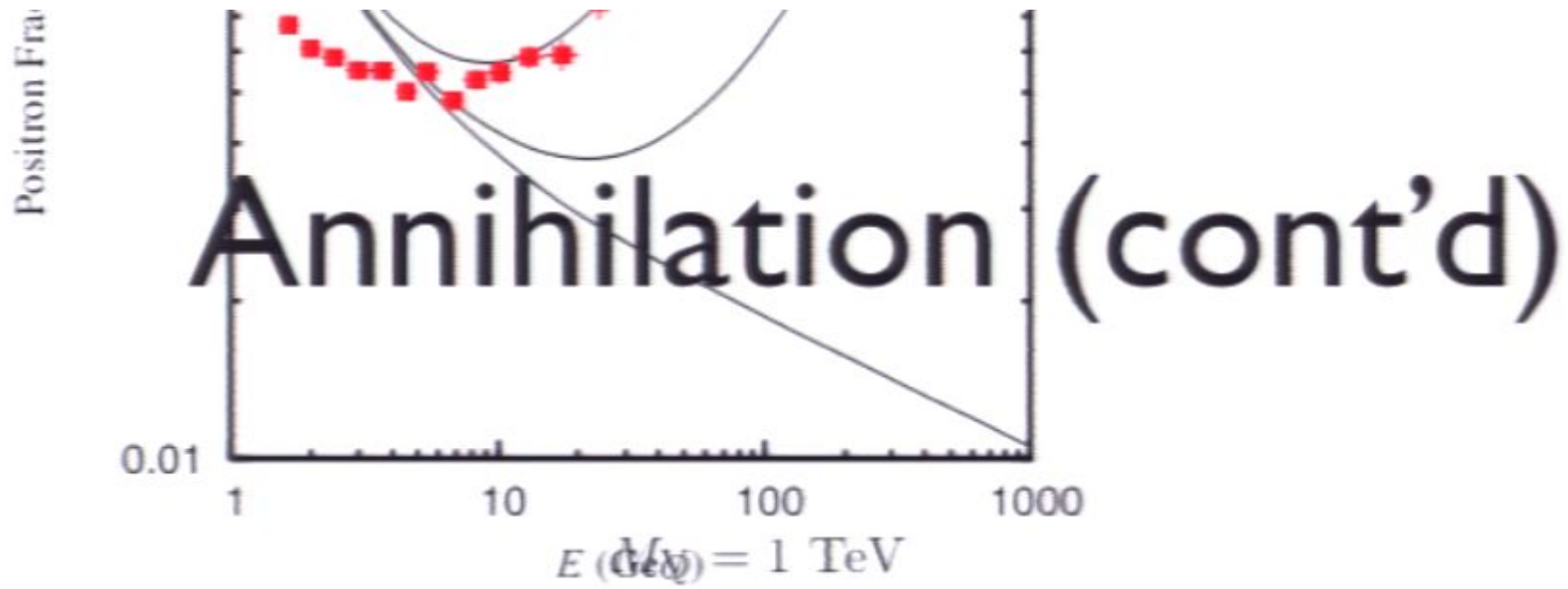
$$\Gamma(\text{glue} \rightarrow VV) \sim 10^{12} \text{ s}^{-1} \left(\frac{\alpha_D}{0.1}\right)^2 \left(\frac{\alpha'}{0.01}\right)^2 \left(\frac{\Lambda}{50 \text{ MeV}}\right) \left(\frac{\Lambda}{m_q}\right)^n$$

Pitfalls (cont'd)

- What are the consequences of these new light states?
- Judicious choice of representation could allow some potential problems to be side-stepped
- ...

Annihilation

- If there is no further depletion of (QQ) at the confinement transition, there will be a boost factor $\langle \sigma_{\text{r.a.}v} \rangle / \langle \sigma_{\text{pert.}v} \rangle \sim \alpha^{-3}$
- The branching to e^+e^- pairs can proceed through decays to glue and then to V (effective boost factor can be tuned)



$$\alpha_D(M_Q) = 0.04$$

$$\frac{\Omega_Q}{\Omega_{DM}} = \frac{1}{2}$$

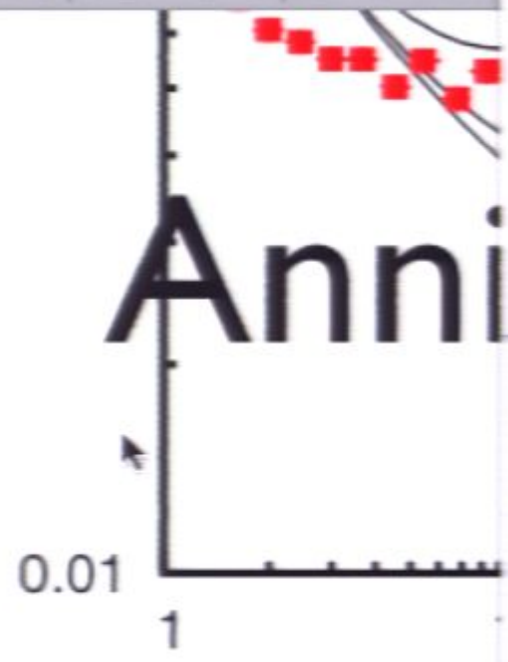
$$M_Q = 1.5 \text{ TeV}$$

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Slides

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Effect: Order:

Direction: Duration:

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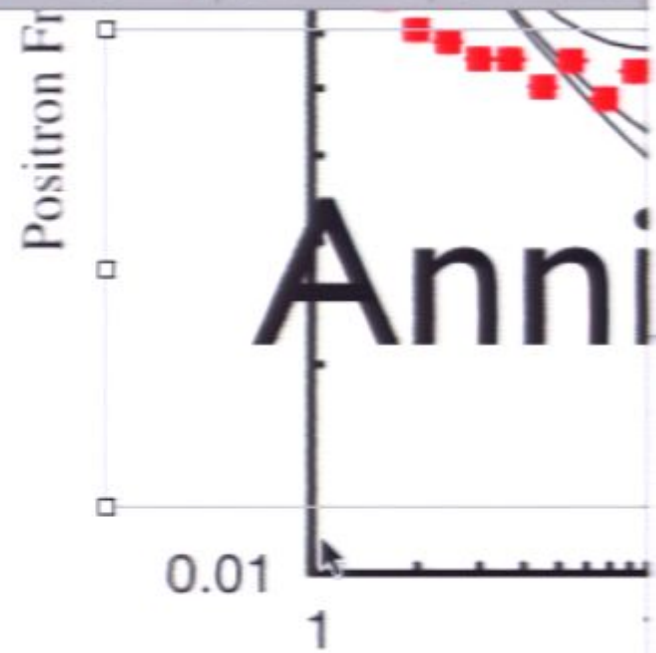
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Navigation and formatting toolbar including icons for New, Play, View, Guides, Themes, Masters, Comment, and Text Box. Text formatting options for Gill Sans, Regular, 84, and bold/italic/underline buttons.

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Slides panel showing a list of slide thumbnails numbered 6 through 15.



Build panel with a preview window showing a slide titled 'Annihilation (cont'd)'. Below the preview are controls for 'Build In', 'Build Out', and 'Action'. The 'Action' dropdown is set to 'None'. Other controls include 'Effect', 'Order', 'Direction', and 'Duration'. An 'Add Action' button and a 'More Options' button are also present.

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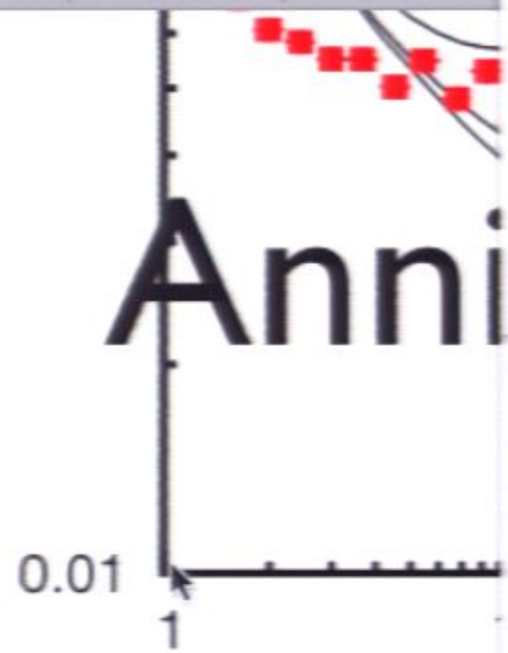
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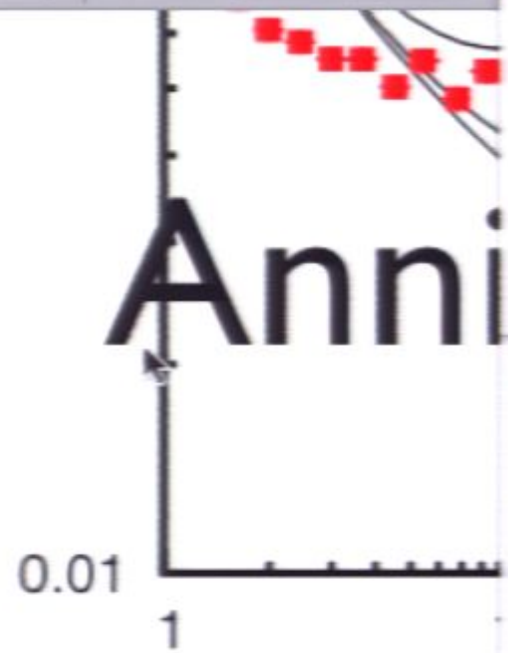
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Slides

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Build

Annihilation (cont'd)

Build In Build Out **Action**

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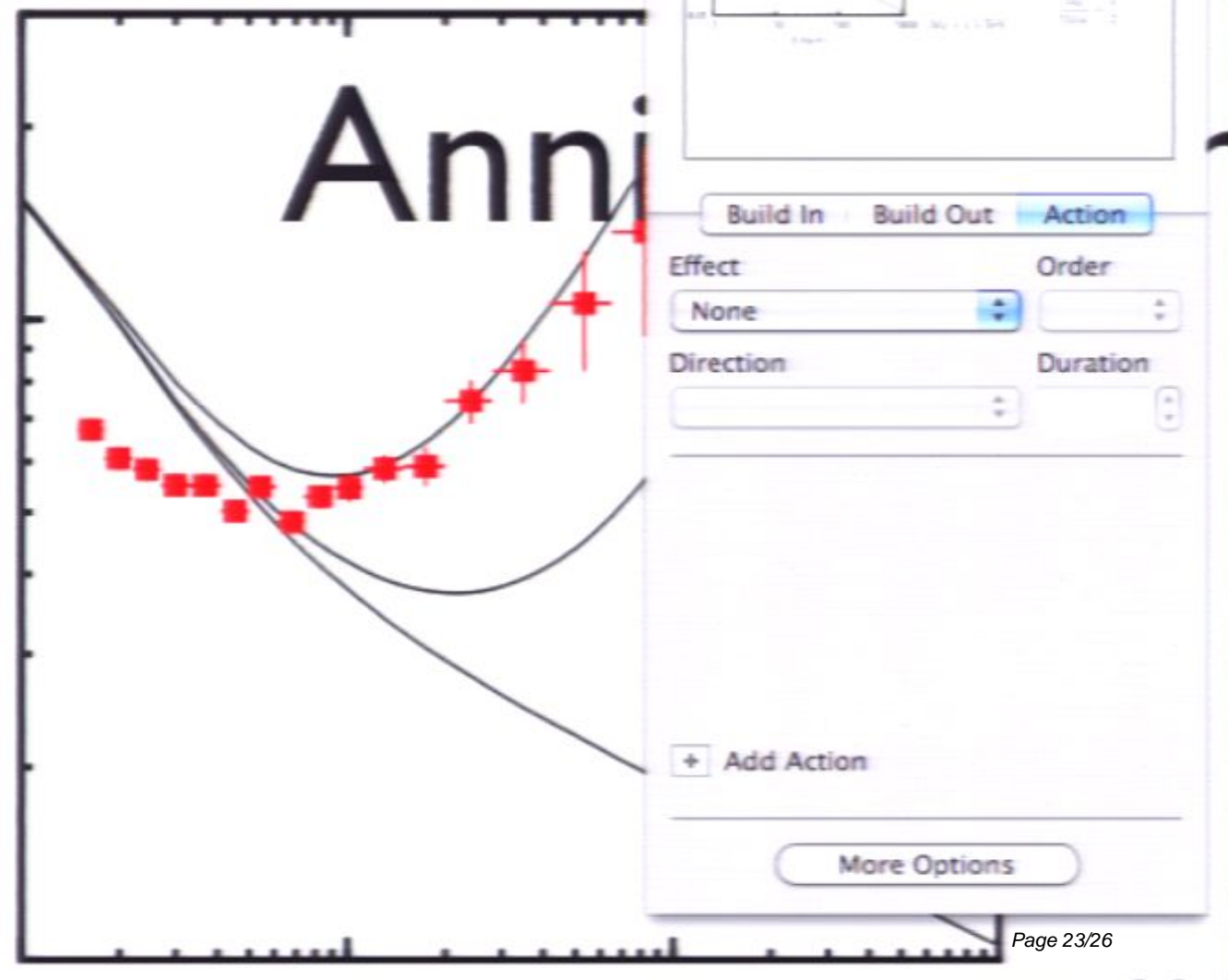
More Options

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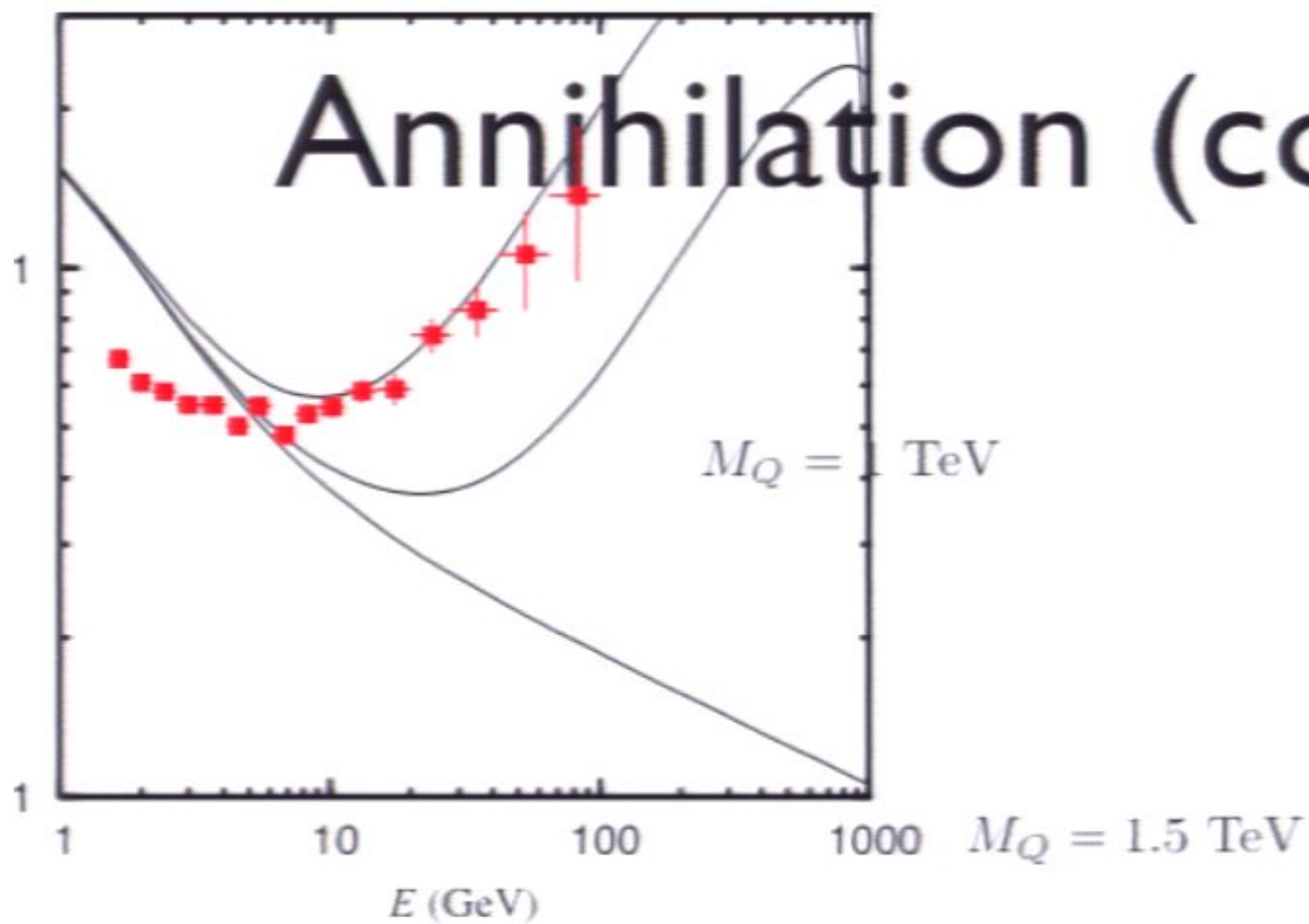
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Annihilation (cont'd)



$$\alpha_D(M_Q) = 0.04$$

$$\frac{\Omega_Q}{\Omega_{DM}} = \frac{1}{2}$$

Scattering

- Loop-suppressed but maybe problematic...
- Could dial down kinetic mixing but possible tension with glueball lifetime

Conclusions

- DM confined by an $SU(N)$ is an interesting possibility, potentially quite rich
- Potential for a boost factor in annihilation
- Quantitative statements are difficult to make