The WIMPless Miracle

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  - 0803.4196, 0806.3746, 0808.4151, 0908.1768, 1002.3366, 1004.4573

The WIMP miracle

- non-relativistic thermal dark matter → $\rho \propto \langle \sigma_A v \rangle^{-1}$
- to get observed DM density need σ_A ~ 1 pb
- stable matter with coupling and mass of the electroweak theory would have about right relic density for dark matter
  - WIMP miracle
- one of the best theoretical ideas for dark matter
- guide for most theory models and experimental searches
- but is this miracle really so miraculous?
  - is it really a WIMP miracle?

A new dark matter scenario…

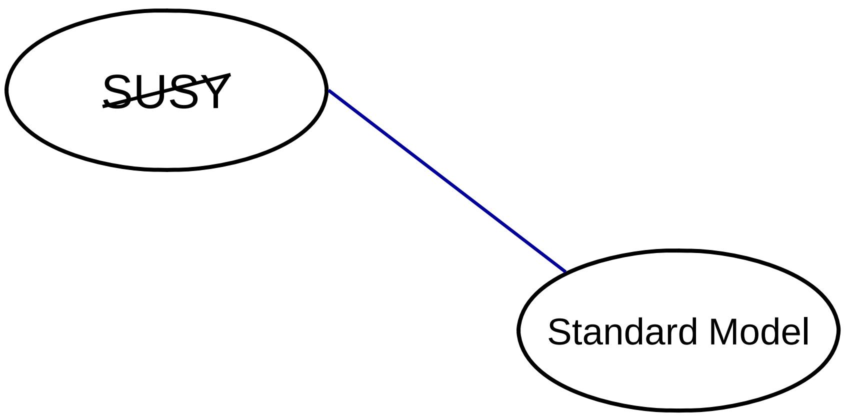
- common feature of beyond-the-Standard-Model physics
  - hidden gauge symmetries, particles

- possible dark matter candidates?
  - can get left over symmetries which stabilize particles
    - discrete, global, gauged?
  - if stable, they contribute to dark matter
    - could be either good, or bad

- what are the dark matter implications for this scenario?

Setup

- the standard "low-energy SUSY" setup (GMSB)
  - one sector breaks supersymmetry
  - an energy scale is generated in Standard Model sector by gauge-mediation from the SUSY-breaking sector
  - this sets the mass of the W, Z, Higgs, etc.



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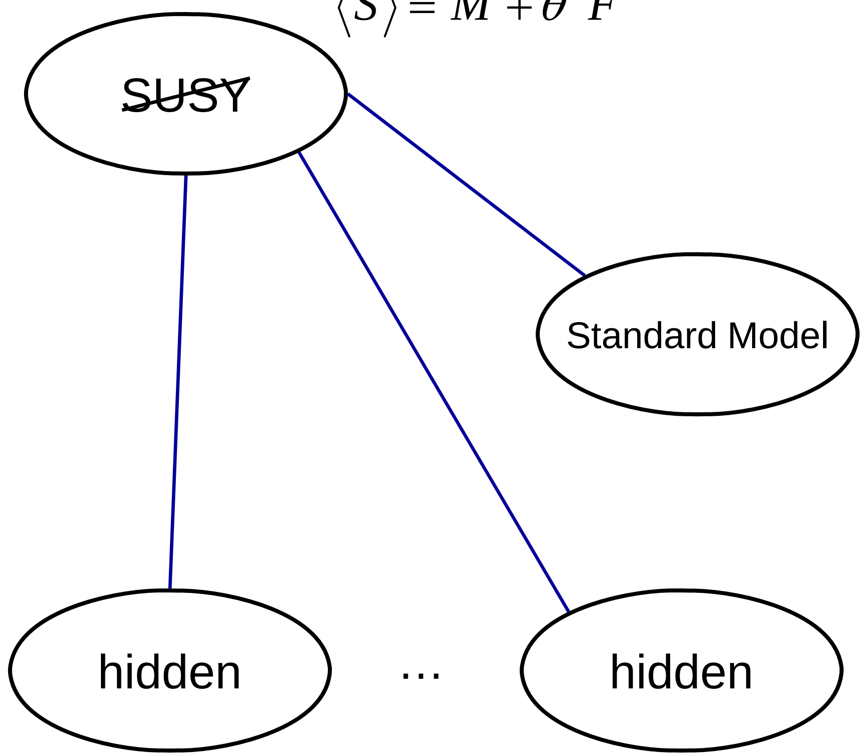
- we add to this extra gauge sectors, which behave in a qualitatively similar way
  - symmetry stabilizes particle at SUSY-breaking scale

$$W = \lambda S \overline{\Phi} \Phi + \lambda_X S \overline{\Phi}_X \Phi_X$$

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



The energy scale

- gauge interactions determine energy scale in a known way
- F, M_{mess} set by dynamics of supersymmetry-breaking
  - same for all sectors
- in each sector, ratio of coupling to mass is approximately fixed
- same ratio determines annihilation cross-section
  - determines relic density (Scherrer, Turner; Kolb, Turner)
  - if WIMP miracle gets it right, so does every other sector
  - really a WIMPless miracle!

$$m^2_{scalar} = \frac{g^4 N_{mess.}}{(4\pi)^4}\left(\frac{F}{m_{mess.}}\right)^2$$

see G. Giudice, R. Rattazzi (1998)

$$\frac{g_h^4}{m_h^2} \propto \left(\frac{m_{mess.}}{F}\right)^2 = const.$$

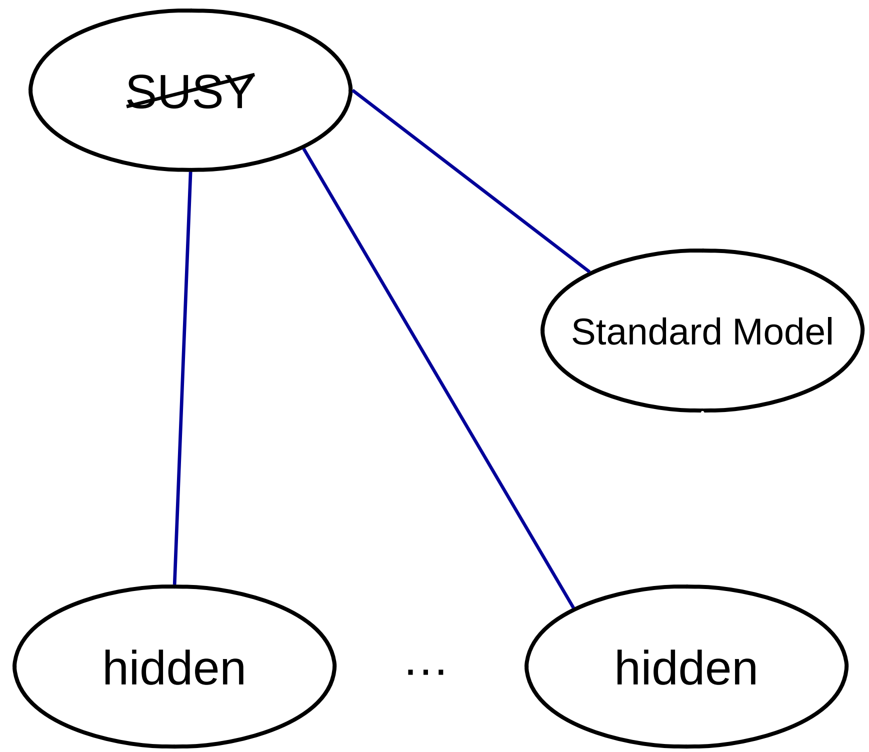
$$\Omega \propto \frac{1}{\langle \sigma v \rangle} \propto \left(\frac{g_h^4}{m_h^2}\right)^{-1} \propto \left(\frac{F}{m_{mess.}}\right)^2$$

Upshot

- a new, well-motivated scenario for dark matter (scalar or fermion)
- natural dark matter candidates with approximately correct mass density
- unlike "WIMP miracle" scenario, here dark matter candidate can have a range of masses and couplings
- opens up the window for observational tests, beyond standard WIMP range
- implications for collider, direct and indirect detection strategies

Detection scenarios

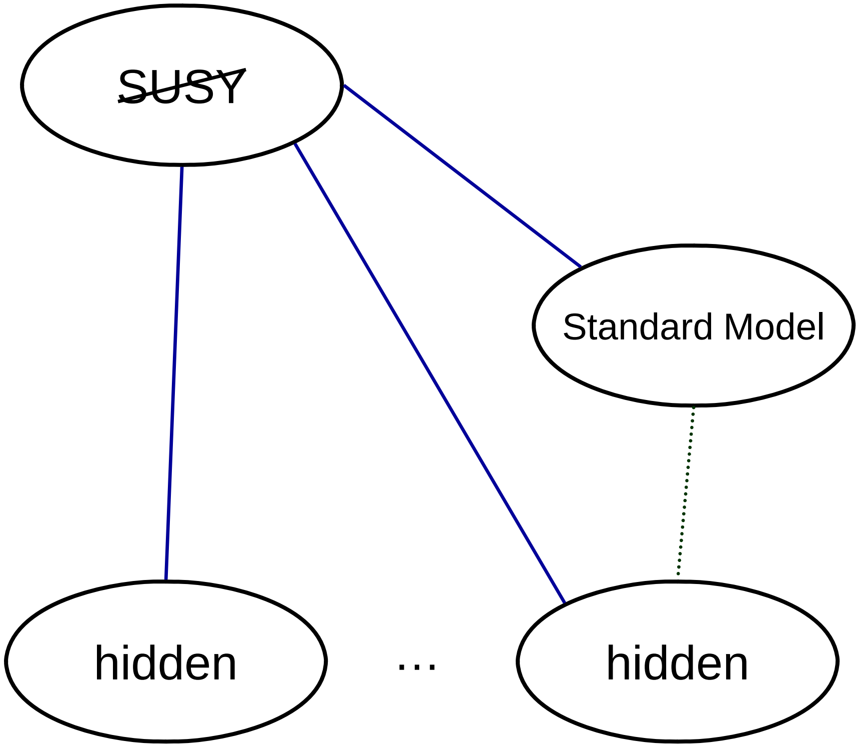
- if no connection between SM and hidden sector…
  - no direct, indirect or collider signature
  - only gravitational



Detection scenarios

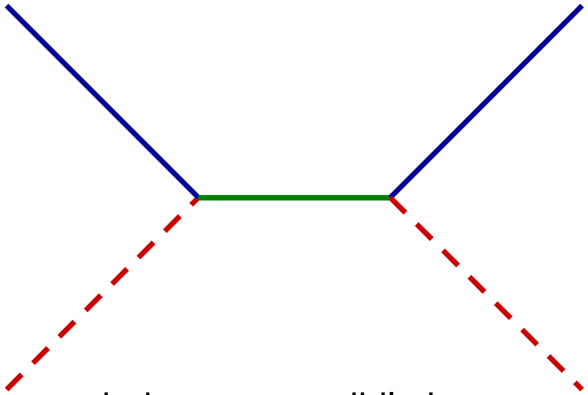
- if no connection between SM and hidden sector…
  - no direct, indirect or collider signature
  - only gravitational

- but could have connectors between those sectors
  - exotics charged under both SM and hidden sector

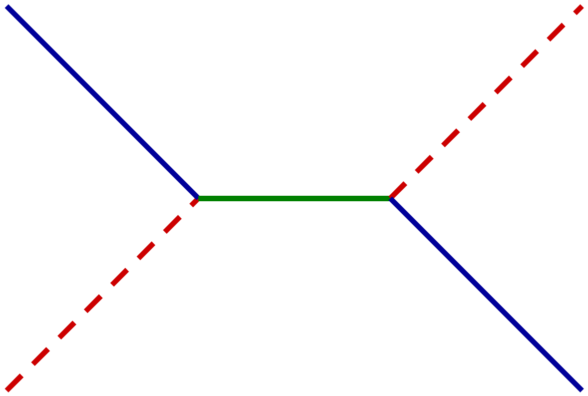


Yukawa coupling

- $W = \lambda X Y_L f_L + \lambda X Y_R f_R + m Y_L Y_R$
- f is a SM multiplet
- $Y_{L,R}$ are exotic 4th generation connector particles
- allows both annihilation to and scattering from SM particle f



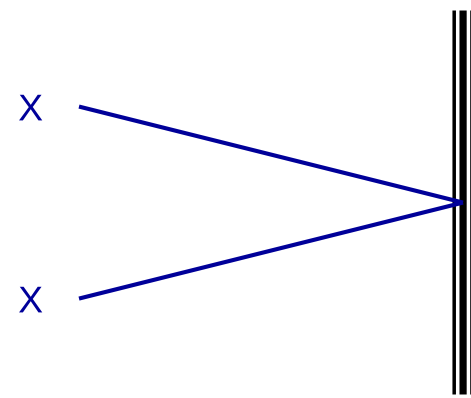
dark matter annihilation



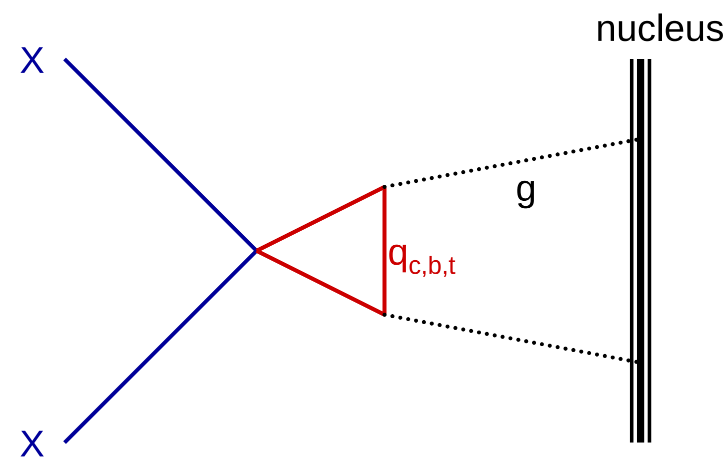
dark matter-nucleon scattering

Nuclear scattering

- couple to light or heavy quarks
  - heavy quark loop couples to gluons
  - can compute coupling to heavy quarks via conformal anomaly (Shifman, Vainshtein, Zakharov)



- assume WIMPless DM couples to one quark gen.
  - simple FCNC solution
  - 3rd generation may be motivated by observed hierarchy



Scalar or fermion → features

- scalar WIMPless DM
  - can have larger σ_{SI}
  - for σ_{SI}, need to couple to $f^{\dagger}_L f_R$
    - need SM mass or squark mixing insertion (dim. 6)
    - chirality suppression
  - with scalar DM, chirality flip from m_Y (dim. 5)
    - not suppressed
- Majorana fermion WIMPless DM
  - scattering from SM quarks is s-, u-channel, not t-channel
  - for Majorana fermion DM, $\sigma_{SI}=0$, but σ_{SD} is non-zero
  - only way to access is through detectors sensitive to σ_{SD}
  - most models will be seen first through σ_{SI}, σ_{SD} can confirm
  - Majorana fermion WIMPless DM is only found through σ_{SD}

Novel detection prospects....

- direct detection
  - DAMA can be matched with low-mass particle with $\sigma_{SI} \sim 10^{-2-5}$ pb
  - CoGeNT has a signal which can fit the same region
  - hard to fit with neutralino models (σ_{SI} suppressed, mass larger)
  - WIMPless DM scalar fits the bill ($\lambda_b \sim 0.7$, $m_X \sim 9$ GeV, $m_Y \sim 400$ GeV)
- indirect detection (neutrino)
  - excel at low mass (Super-K) and σ_{SD} (IceCube)
  - Super-K can make model-independent check of DAMA/CoGeNT (soon!)
  - may get signals at IceCube/DeepCore from σ_{SD} of Majorana DM
    - annihilation to superpartners
- Tevatron/LHC
  - can produce YY pairs through QCD processes
  - missing E_T signal
  - results with short-term data (including most of DAMA/CoGeNT)

Conclusion

- new theoretical scenario for dark matter
  - large range of masses and couplings
- possible explanation for results of DAMA/LIBRA, CoGeNT
- interesting searches at Tevatron and LHC
- signals possible at Super-Kamiokande and IceCube/DeepCore

Mahalo!