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Argonne/Fermilab
Oct 628
2009

Cosmic Signals from the Hidden Sector

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0905.3149
+ followup...

(Gravitational Evidence for DM overwhelming, $\Omega_{DM} \sim 0.2$)

What is DM? (axion, WIMP.)

Particle: Mass? Couplings?

Cosmic Ray Anomalies! PAMELA, FERMI, HESS.

Annihilation
or
Decay of DM in Milky Way Halo...

(Excited about cross checks of this interpretation,
neutrinos, gamma rays, WMAP/Fermi Haze.
DM models become plausible if models are plausible,
so let's start with theory bas.)

Weak Scale Supersymmetry!

DM $\rightarrow$ LSP but... gravitino overproduction
(low reheat temp, non-standard cosmology)

Keep gravitino in ^{thermal} contact with SM

$$m_{3/2} \lesssim 10 \text{ eV}$$

But no more LSP DM!

Low Scale Gauge Mediation

$$m_{3/2} \sim \frac{F}{M_{Pl}} \Rightarrow \sqrt{F} \sim 10-100 \text{ TeV}$$

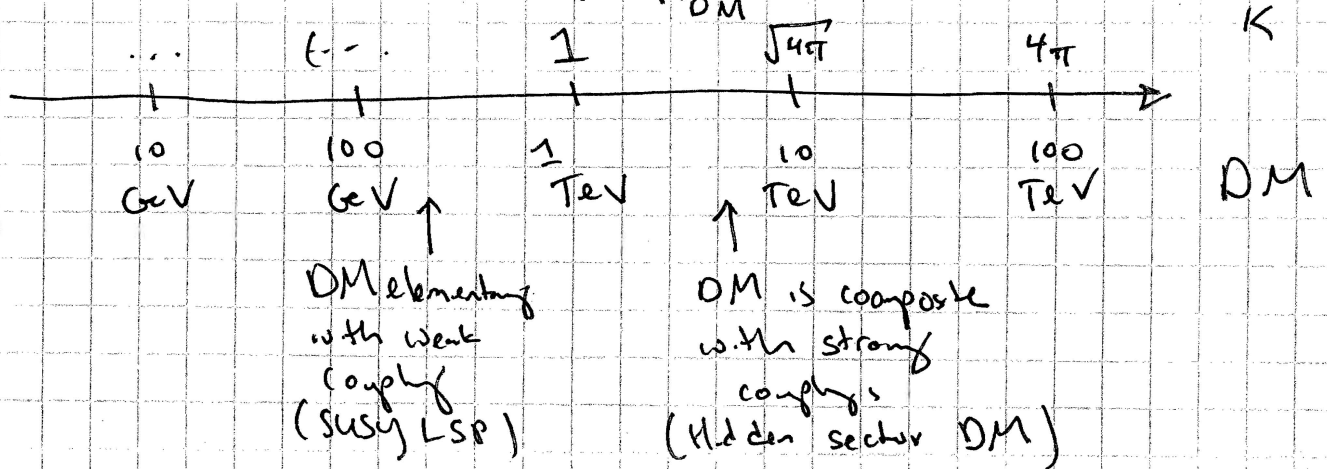
↳ suggests strongly interacting sector near TeV scale!

Very natural to have...

DM in the hidden sector!

Still preserves WIMP miracle

$$\langle \sigma v \rangle \sim \text{pb} \sim \frac{1}{8\pi} \frac{K^4}{m_{DM}^2}$$



(This alone is not enough, nor is it new.)

Dimopoulos, Gurdice Parnell 1996

Key addition:

Heavy composite DM interacting
with light axion-like state.

↳ beautifully explains CR data!

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Strong Dynamics @ 10-100 TeV

(need not be SUSY, could be technicolor-like thing)

→ Quasi-stable states

Baryon # or
Flavor sym. $\Rightarrow$ DM candidate
 $m_{DM} \sim 10 \text{ TeV}$

$d=6$ violation
@ $M_{\text{UV}} \sim M_{Pl}$ $\Rightarrow$ $\tau_{DM} \sim 10^{26} \text{ sec}$
(needed for CR)

→ Light axion-like states

Spontaneously broken
R or PQ $\Rightarrow f_a \sim 1-100 \text{ TeV}$

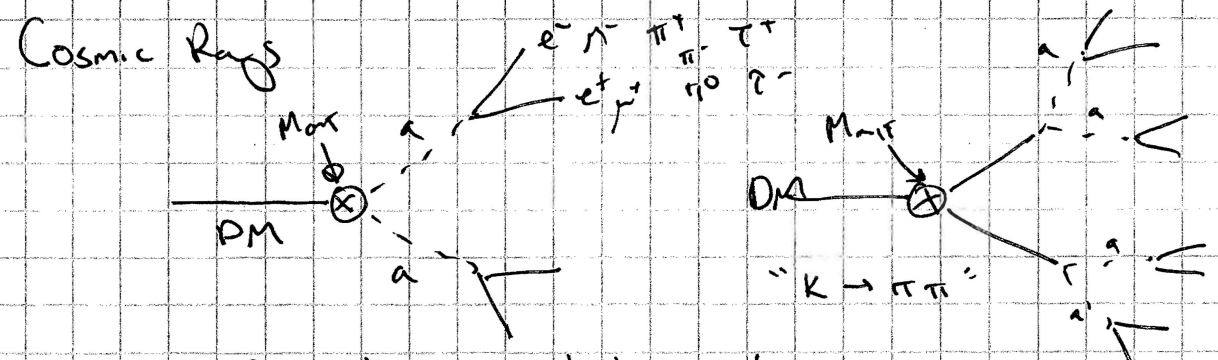
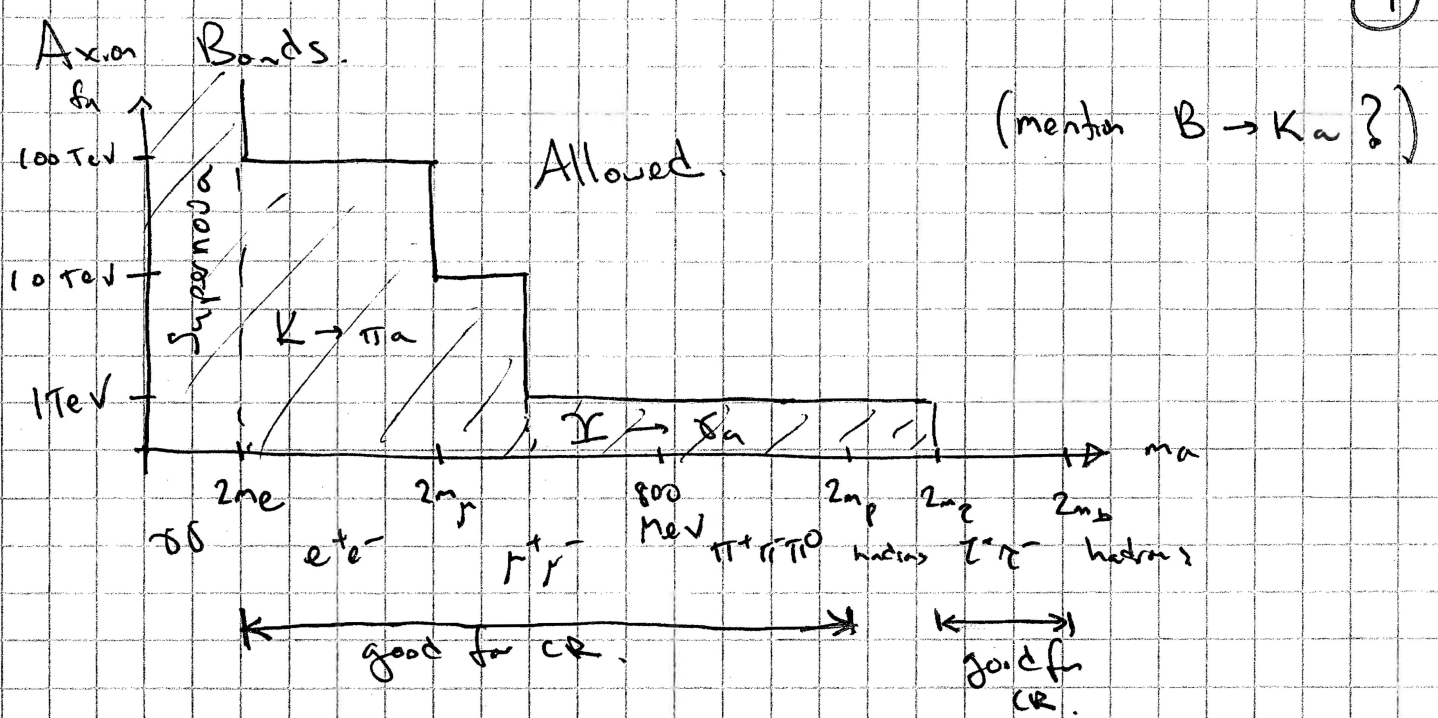
SUGRA effects or
 $d=5$ violation @ M_I $\Rightarrow m_a \sim 1 \text{ MeV} - 10 \text{ GeV}$

→ Coupled to the Higgs

h, h_c charged under R or PQ

$a \rightarrow \text{SM SM.}$

(Talk about model building in a second, first signatures)



DM decay is lepton rich.

Beautiful fit to PAMELA, HESS, FERMI
(fits FERMI better than ATIC...)

$\mu, \pi, \tau \rightarrow \text{neutrinos}$ (safer than annihilation b/c decay $\sim p$ ann.h. $\sim p^2$)
 $\pi, \tau \rightarrow \pi^0 \rightarrow \gamma\gamma$ (safe from GC bounds)

Predicts diff γ ray flux at FERMI.

Collider experiments.

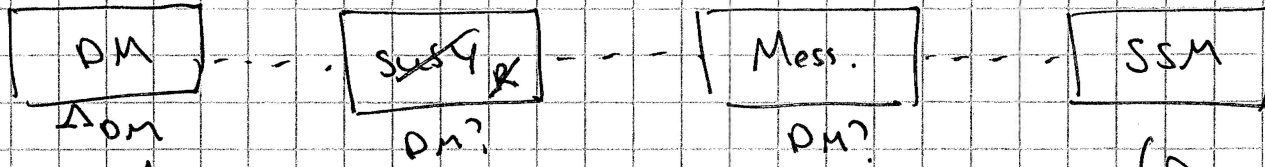
DM too heavy to be produced, but make axion in beam dumps.
 (can't hide the Higgs) $Br \sim 10^{-5}$.
 also $B \rightarrow Ka$.

(5)

Want: Complete Model of low scale gauge mediation.

Dynamic SUSY, composite messengers?, composite SSM?

Right DM properties. (notoriously difficult)



(Discuss parameter tension later if you want.)

Have: Toy Model of DM sector.

B or $[F]$ violated $\Delta=6 @ M_{\text{GUT}}$

spontaneous $[R]$ or PQ explicit breaking $d=5 @ M_1$ or $[SUGRA]$

Focus on DM sector.

SUSY QCD with $N_f < N_c$

$$W = \lambda; S Q_i \bar{Q}_i$$

$\langle S \rangle$ from SUSY sector breaks R symmetry

$$R(Q) = R(\bar{Q}) = 1 - \frac{N_c}{N_f} \quad R(S) = \frac{2N_c}{N_f}$$

Below Δ_{DM}

$$Q_i \bar{Q}_j \rightarrow M_{ij}$$

$$W = m_i M_{ij} + (N_c - N_f) \Lambda^3 \left(\frac{\Lambda^{N_f}}{\det M} \right)^{\frac{1}{N_c - N_f}} \quad (6)$$

$\uparrow$
 $\lambda \langle S \rangle$
 (includes
 axion)

$$\langle M_{ii} \rangle \sim \frac{\Lambda^2}{m_i}$$

$$\langle M_{ij} \rangle = 0$$

Theory has broken R, but unbroken $U(1)^{N_f}$ symmetry

$M_{ij} \ i \neq j$ absolutely stable

$M_{ii} \rightarrow 2a, 3a, a + j\tilde{\tau}$ depending on component.

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$\det M$ terms make M_{ij} good thermal relic.



$$m_{DM} \sim \frac{m_i m_j}{\Lambda}$$

$$K \sim \frac{m_i^2 m_j}{\Lambda^3}$$

Need $\lambda \langle S \rangle \sim \Lambda_{DM}$.

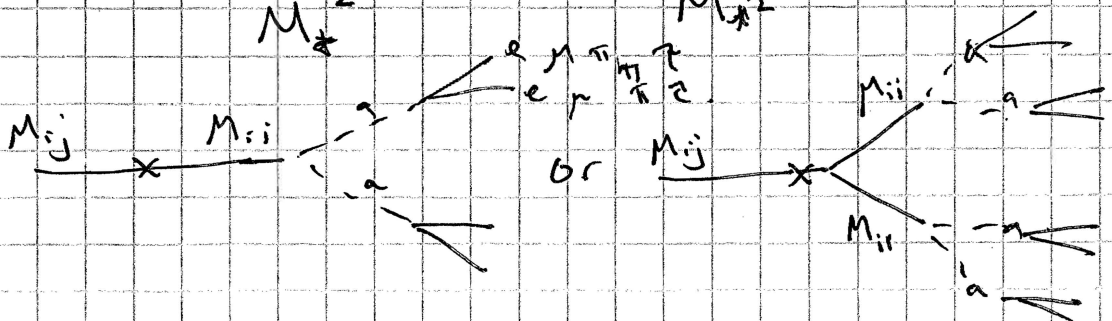
(plausible using dm trans sector)

$$\langle \sigma v \rangle \sim \frac{1}{8\pi} \frac{K^4}{m_{DM}^2}$$

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Straight forward to decay DM

$$K = \frac{Q_i^+ Q_j Q_k^+ Q_l}{M_{*}^2} \Rightarrow \frac{\Lambda^2}{M_{*}^2} M_{ij}^+ M_{kl} \quad \text{flavor violation!}$$



Lot's of Model Building Directions!

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↪ axion ↔ dark photon

↪ "little hierarchy" 10 TeV DM vs. 100 TeV ~~susy~~

→ composite Higgs has 10 TeV dynamical sector.

→ 100 TeV DM with 10 TeV splittings

→ "triggered" sectors.

↪ "complete" model: merge DM ↔ ~~susy~~
or DM ↔ Mess.

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e^+e^- Excess $\Rightarrow$ New Directions for DM

Heavy DM interacting
with light state } fits the data!
could be true!

But why? Ingredients already there!

Heavy DM $\Rightarrow$ composite in hidden sector.

Light state $\Rightarrow$ R-axion.

Compelling construction, independent of CR excess.
(New target for ~~susy~~ model building.)