DM from Dynamical SUSY breaking

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Motivation

- Leading paradigm for the origin of DM is the thermal freezeout of stable massive particle.

Relic abundance of cold DM is determined by

Only the ratio is fixed!

$$\langle \sigma v \rangle = \frac{1}{8\pi} \boxed{\frac{\kappa^4}{m_{DM}^2}}$$

$$m_{DM} \qquad \longleftarrow (100\,GeV - 1\,TeV) \longrightarrow (10 - 100\,TeV)$$

$$\kappa \qquad \longleftarrow (0.1 - 1) \longrightarrow (\sqrt{4\pi} - 4\pi\,)$$

$$\begin{array}{cc} \downarrow & \downarrow \\ WIMP & ? \end{array}$$

Feng, Kumar 0803.4196

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$$\begin{array}{lll} m_{DM} & (100\,GeV - 1\,TeV) \longrightarrow & (10 - 100\,TeV) \\ \kappa & (0.1 - 1) \longrightarrow & (\sqrt{4\pi} - 4\pi) \end{array}$$

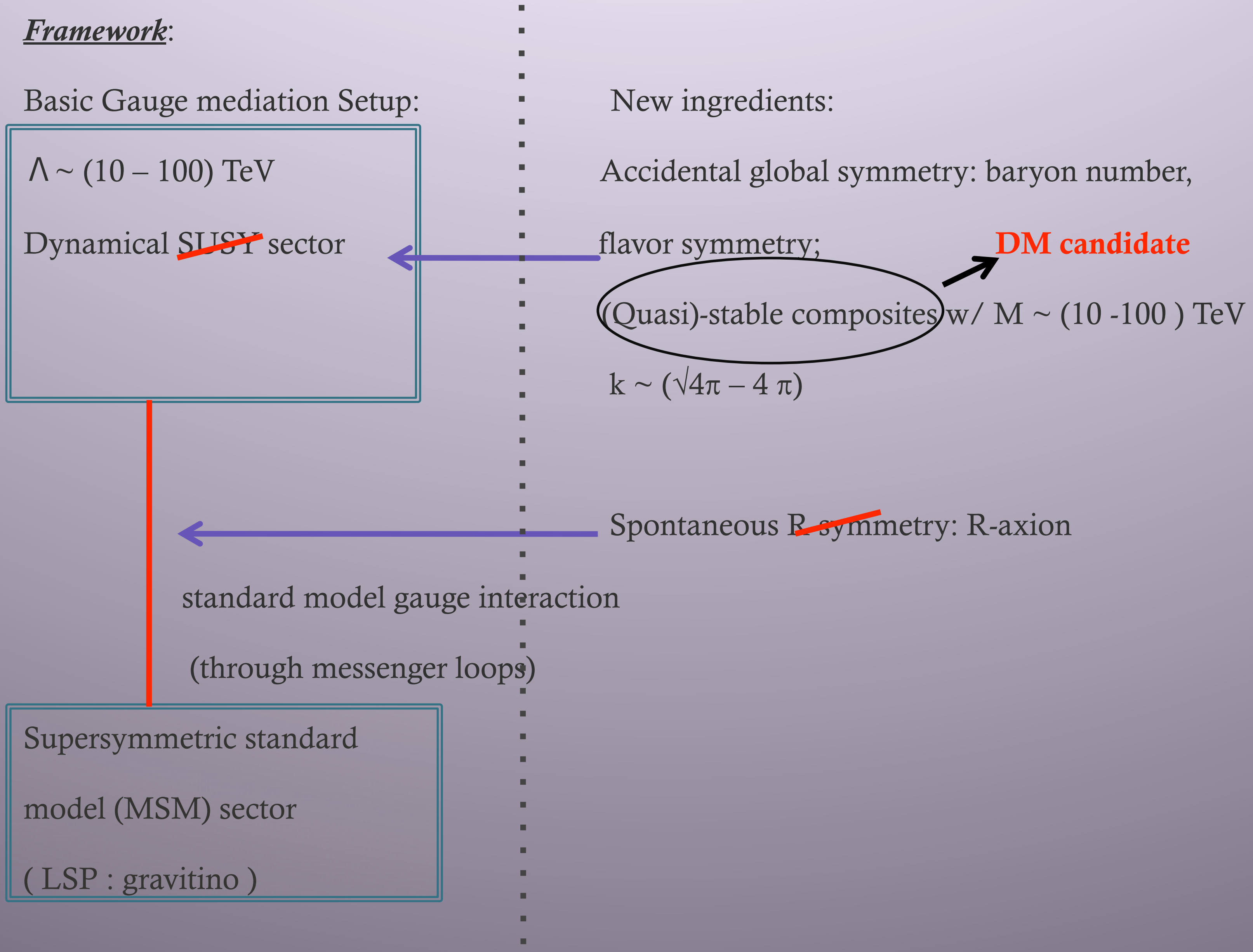
$$WIMP$$

Strongly-coupled

low-scale dynamical SUSY breaking in gauge mediation

(always don't have a viable cold DM in the visible sector)

Framework:



Basic Gauge mediation Setup:

$\Lambda \sim (10 - 100)$ TeV

Dynamical ~~SUSY~~ sector

standard model gauge interaction

(through messenger loops)

Supersymmetric standard

model (MSM) sector

(LSP : gravitino)

New ingredients:

Accidental global symmetry: baryon number,

flavor symmetry;

(Quasi)-stable composites w/ M ~ (10 -100) TeV

DM candidate

$k \sim (\sqrt{4\pi} - 4\pi)$

Spontaneous ~~R-symmetry~~: R-axion

(Quasi-stable) states

- Lightest states charged under some unbroken global symmetries are cold DM candidates;
- Accidental global symmetries could be broken at high scale, e.g., unification/Planck scale. Dim-6 operators leads to a DM lifetime:

$$\tau_{DM} \sim 8\pi \frac{M_*^4}{m_{DM}^5} \sim 2 \times 10^{25} sec \left(\frac{M_*}{10^{17}\, GeV} \right)^4 \left(\frac{10\, TeV}{m_{DM}} \right)^5$$

Required lifetime to explain electon/positron anomalies in cosmic rays!

(Arvantitaki, Dimopoulos, Dubovsky, Graham, Harnik and Rajendran

0812.2075, 0904.2789…)

Portal to the MSM:

R- axion

- Spontaneous R breaking is always associated with SUSY breaking . e. g. : ADS criteria
- R – axion keeps DM in thermal equilibrium with MSM
- R-symmetry breaking is also essential to generate gaugino masses in MSM

- R-axion mass:

From supergravity:

$$m_a^2 \sim \frac{\Lambda^3}{M_{Pl}} \sim (10\,MeV)^2 \left(\frac{\Lambda}{100\,TeV}\right)^3$$

From additional explicit breaking:

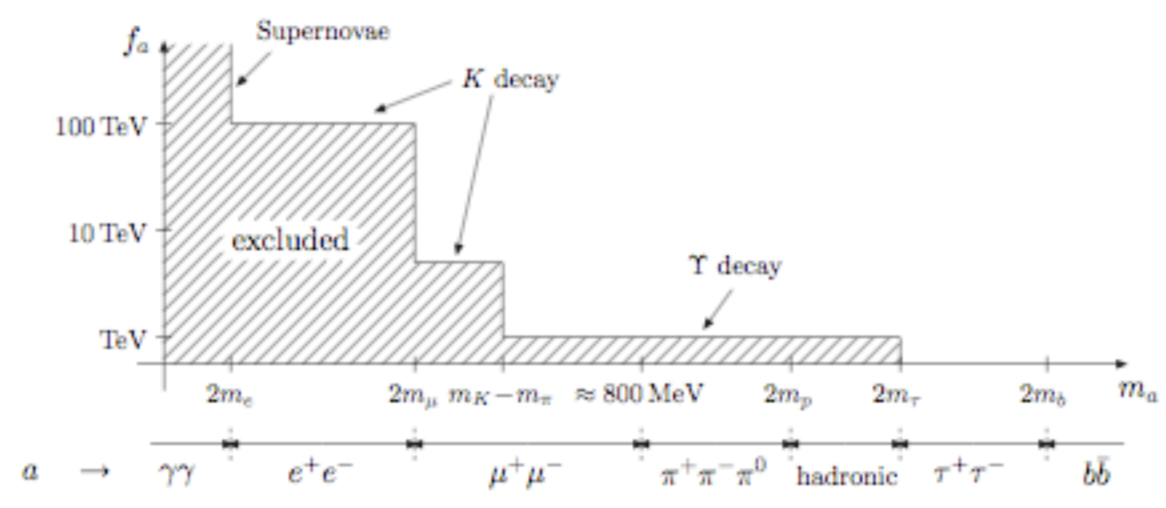
Dim-5 ops suppressed by (10^9-10^{18}GeV)

m_a ~ (1 MeV – 10 GeV)

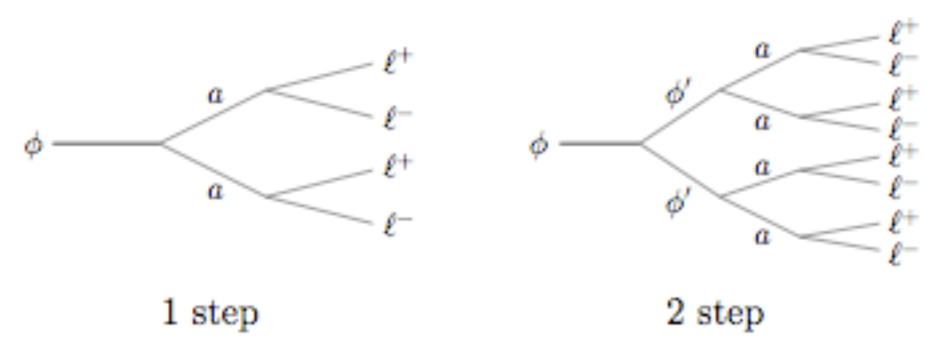
- R-axion coupling

$$\mathcal{L} = -i\frac{m_u \cos^2\beta}{\sqrt{2}f_a}\, a\, \bar{\Psi}_u \gamma_5 \Psi_u - i\frac{m_d \sin^2\beta}{\sqrt{2}f_a}\, a\, \bar{\Psi}_d \gamma_5 \Psi_d - i\frac{m_e \sin^2\beta}{\sqrt{2}f_a}\, a\, \bar{\Psi}_e \gamma_5 \Psi_e,$$

- R-axion allowed parameter space (Mardon, Nomura and Thaler 0905.3749)



- Lepto-philic DM decays through R-axion portal

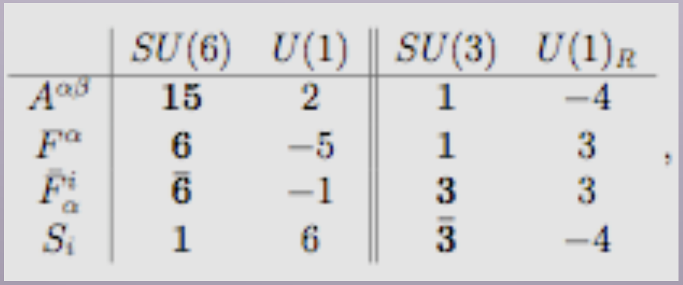


Recap:Minimal requirements for DM from dynamicl SUSY breaking

- An (approximate) unbroken global symmetry under which DM is charged
- A spontaneously broken R- symmetry, resulting in an R-axion

A model

- DSB with a dynamical superpotential: e.g, 3-2 model, 4-1 model (w/o any DM candidate in the DSB sector)
- Needs to extend the global symmetry structure to allow for a DM
- Setup (a 6-1 model)



	$SU(6)$	$U(1)$	$SU(3)$	$U(1)_R$
$A^{\alpha\beta}$	$\mathbf{15}$	2	$\mathbf{1}$	-4
F^{α}	$\mathbf{6}$	-5	$\mathbf{1}$	3
$\bar{F}^{i}_{\alpha}$	$\bar{\mathbf{6}}$	-1	$\mathbf{3}$	3
S_i	$\mathbf{1}$	6	$\bar{\mathbf{3}}$	-4

,

SU(3) → SU(2)

- Add superpotential $W_{cl} = \lambda\epsilon_{123}A^{\alpha\beta}\bar{F}^1_\alpha\bar{F}^2_\beta + \eta_1 F^\alpha(\bar{F}^1_\alpha S_1 + \bar{F}^2_\alpha S_2) + \eta_3 F^\alpha \bar{F}^3_\alpha S_3,$
- Below SU(6) dynamical scale, the gauge singlet composites are

$$\begin{array}{rcl} X \sim SF\bar{F} & : & (\bar{\mathbf{2}}+\mathbf{1})_2 \\ H \sim A\bar{F}\bar{F} & : & (\bar{\mathbf{2}}+\mathbf{1})_2 \\ Y \sim F\bar{F}\,\mathrm{Pf}\,\mathrm{A} & : & (\mathbf{2}+\mathbf{1})_{-6} \end{array}$$

In composites, full superpotential is

$$W = \tilde{\lambda}\Lambda^2 H_3 + \tilde{\eta}_1 \Lambda^2 \left(\frac{X_1^3 Y^1 + X_2^3 Y^2}{Y^3} \right) + \tilde{\eta}_2 \Lambda^2 X_3^3 + \frac{\alpha \Lambda^4}{\sqrt{Y H}},$$

added

dynamical generated

E.o.ms cannot be satisfied simultanenously: ~~SUSY~~

R-charged composites get VEVs: ~~R~~

DM candidates: lightest composites charged under the unbroken global SU(2)

NDA tells: couplings ~ 4 π

mass ~ Λ

- DM could also arise from other DSB scenario: e.g, vector-like model with a quantum moduli space.
- We have focused on one-scale DSB model: DM mass is comparable to the dynamical scale;

  There are DSB models containing stable states parametrically lighter than the DSB scale, e.g., pseudo-GB or pseudo moduli. It's hard to achieve right amount of relic abundance for those states.

Conclusion and Outlook

- An alternative mechanism that gauge mediated SUSY breaking could have cold DM candidate: DM from the DSB sector
- Minimal requirements to realize the mechanism already requires non-trivial structure of DSB sector; necessary to develop more tools to understand strongly-coupled SUSY theory.
- Additional probe of the dark sector from the light R-axion state