Model of Composite B-L Asymmetric Dark Matter

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Shin Kobayashi

ICRR, the Univ. of Tokyo

In collaboration with

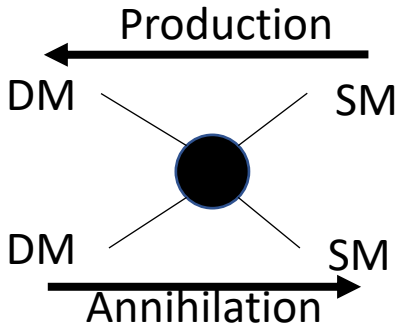
M. Ibe (ICRR, IPMU), A. Kamada (CTPU), and W. Nakano (ICRR)

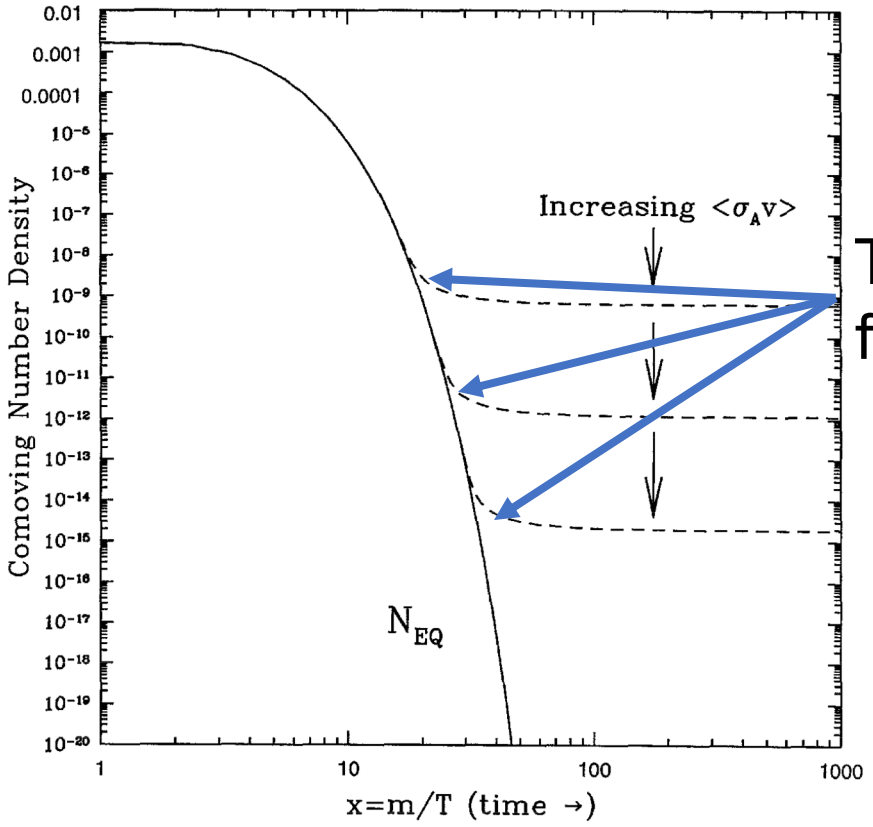
Contents

Coincidence Problem I (origin of DM)

- Weakly Interacting Massive Particle: WIMP
- WIMP scenario: DM abundance is explained from thermal freeze-out.

$$\Gamma_A \gtrless H$$





Thermal freeze-out

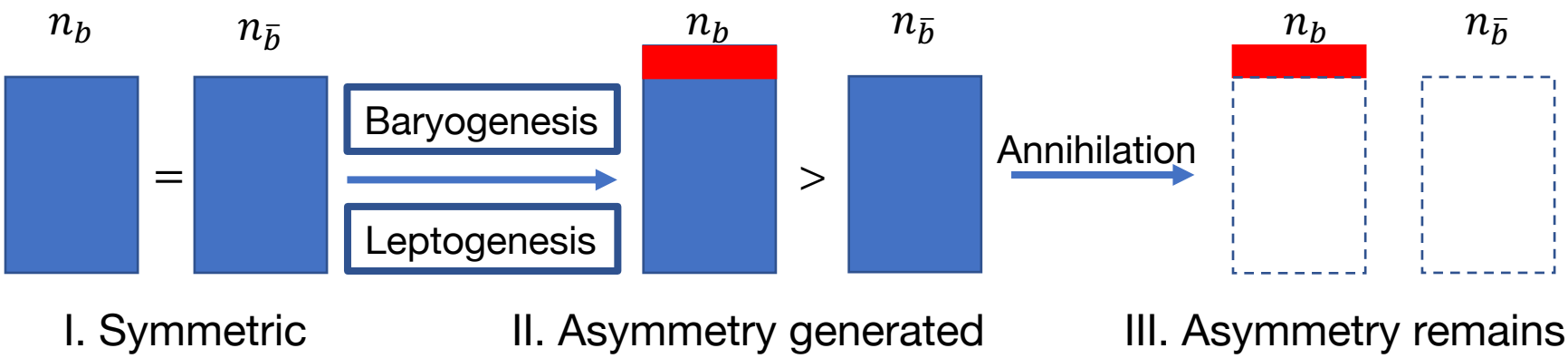
Fig: G. Jungman, M. Kamionkowski and K. Griest, Physics Reports 267(1996)

Coincidence Problem II (origin of baryon)

If there is no asymmetry generation in baryon sector

$$\frac{n_B^{\rm predict}}{n_B^{\rm obs}} < 10^{-10}$$

Baryo-genesis (lepto-genesis) recovers this 10^{-10} discrepancy



Coincidence Problem III

Even after 10^{-10} discrepancy recovored…

The Universe @ Today

$$\frac{\Omega_{\mathrm{DM}}}{\Omega_{\mathrm{B}}} \simeq 5 = \mathcal{O}(1)$$

Question

- Is there any mechanism that solve this problem?

⟶ Asymetric Dark Matter!

Asymmetric Dark Matter (ADM)

Ω_B:Baryogenesis or Leptogenesis
Ω_{DM}:~~Thermal freeze-out~~
Baryogenesis or Leptogenesis

Originate from the ~~Independent~~ Process
Same

↓

~~Difficult to~~ Solve Coincidence Problem!
Naturally

Basic Idea of ADM

Contents

Model Building

What we need for ADM Model

- $B - L$ charged DM ← Ω_{DM} from Baryogenesis
- $B - L$ portal interaction ← Distribute $B - L$ asym. between SM and Dark Sector (DS)
- Large enough σ_{ann} of DM ← Annihilate symmetric component of DM

Model Building

Why Composite?

1. Recall what we need for ADM model…

- $B - L$ charged DM
- $B - L$ portal interaction
- Strong DM annihilation ← Obtained by confinement!

2. DM mass

ADM mass is typically $1 \sim 10$ GeV.

Obtained by QCD′ dynamics!

$$\Lambda_{\mathrm{QCD}'} = 10 \times \Lambda_{\mathrm{QCD}} \sim 1\mathrm{GeV}$$

Model Building

Components of Dark Sector (DS)

- DS has $SU(3)_D \times U(1)_D$ symmetry.
- 2-flavor dark quarks are charged under this symmetry and $B - L$

	$\mathrm{SU}(3)_D$	$B-L$	$\mathrm{U}(1)_D$
Q_1	$\mathbf{3}$	$1/3$	$2/3$
$\bar{Q}_1$	$\bar{\mathbf{3}}$	$-1/3$	$-2/3$
Q_2	$\mathbf{3}$	$1/3$	$-1/3$
$\bar{Q}_2$	$\bar{\mathbf{3}}$	$-1/3$	$1/3$

$$SU(3)_D \longrightarrow \mathrm{QCD}' \qquad U(1)_D \longrightarrow \mathrm{QED}'$$

+ Dark Higgs to make dark photon massive

Model Building

$B - L$ portal interaction

$B - L$ asymmetry: Generated from Leptogenesis.

Interaction between SM and N_R

$$\mathcal{L}_{N\text{-SM}} = \frac{1}{2} M_R \bar{N}_R \bar{N}_R + y_N H L \bar{N}_R + \text{h.c.}$$

Interaction between DS and N_R

$$\mathcal{L}_{N\text{-}D} = \frac{1}{M_*^2} \left(\bar{Q}_1 \bar{Q}_2 \bar{Q}_2\right) \bar{N}_R + \text{h.c.}$$

At T $< M_R$,

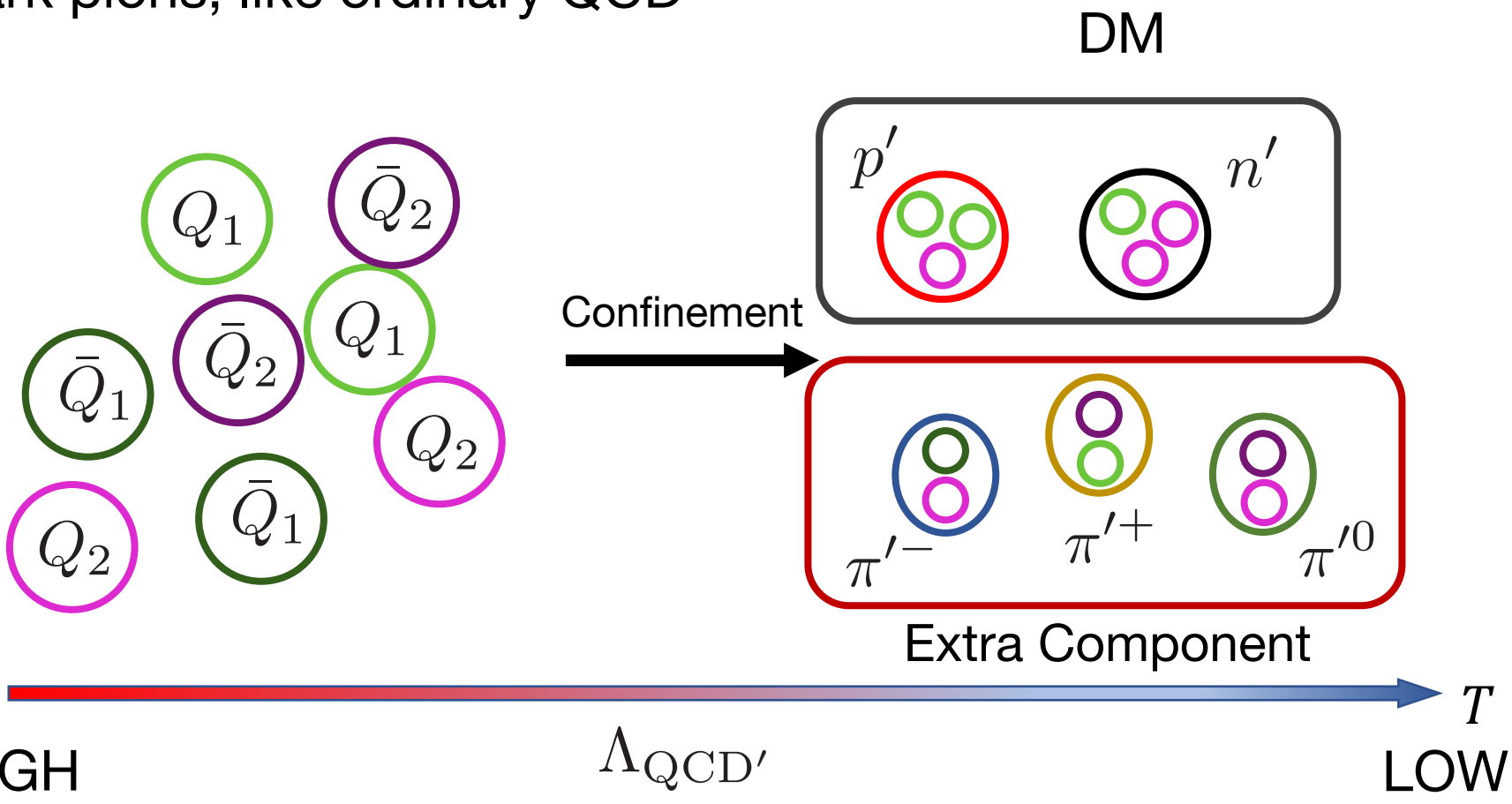
$$\mathcal{L}_{B-L\text{portal}} = \frac{y_N}{M_*^2 M_R} \left(\bar{Q}_1 \bar{Q}_2 \bar{Q}_2\right) L H + \text{h.c.} = \frac{1}{\Lambda_*^3} \left(\bar{Q}_1 \bar{Q}_2 \bar{Q}_2\right) L H + \text{h.c.}$$

$$\Lambda_* = \left(M_*^2 M_R / y_N\right)^{1/3}$$

Cosmology

Confinement of DS

QCD′ components confine to compose dark nucleons and dark pions, like ordinary QCD



Cosmology

Entropy transportation through Dark photon

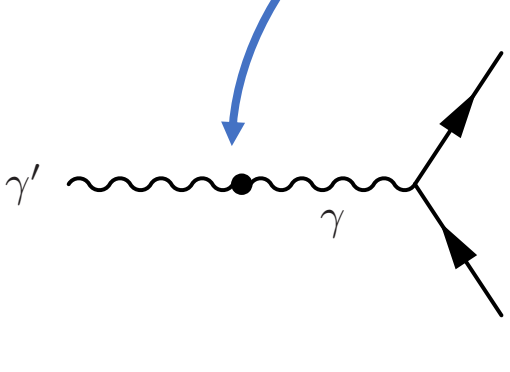
Dark pions annihilate or decay into dark photon γ'

$$\pi^-\pi^+ \to 2\gamma' \qquad \pi'^0 \to 2\gamma'$$

γ' can decay into electron pair through kinetic mixing

$$\mathcal{L}_{A'-A} = \frac{\epsilon}{2} F_{\mu\nu} F'^{\mu\nu} + \frac{1}{2} m_{\gamma'}^2 A'_\mu A'^\mu$$

Kinetic mixing term



$$\Gamma_{\gamma'} = N_{\rm ch} \frac{1}{3} \epsilon^2 \alpha m_{\gamma'}$$

$$\simeq 0.3\,{\rm s}^{-1} \times N_{\rm ch} \left(\frac{\epsilon}{10^{-10}}\right)^2 \left(\frac{m_{\gamma'}}{100\,{\rm MeV}}\right)$$

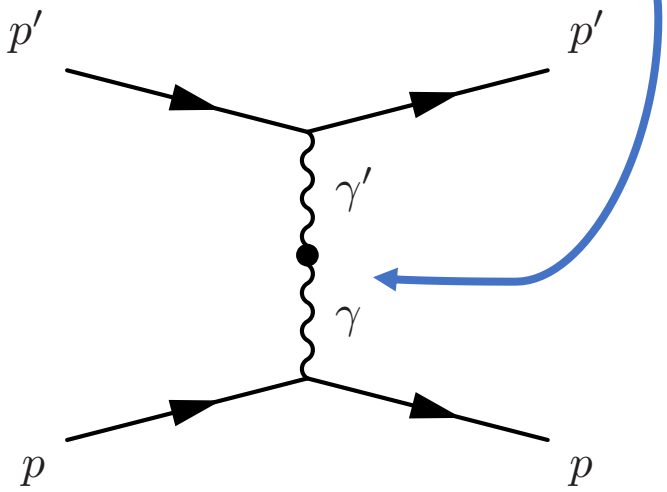
$N_{\rm ch}$: number of decay channels

Direct Detection Constraint

DM-Nucleon Scattering

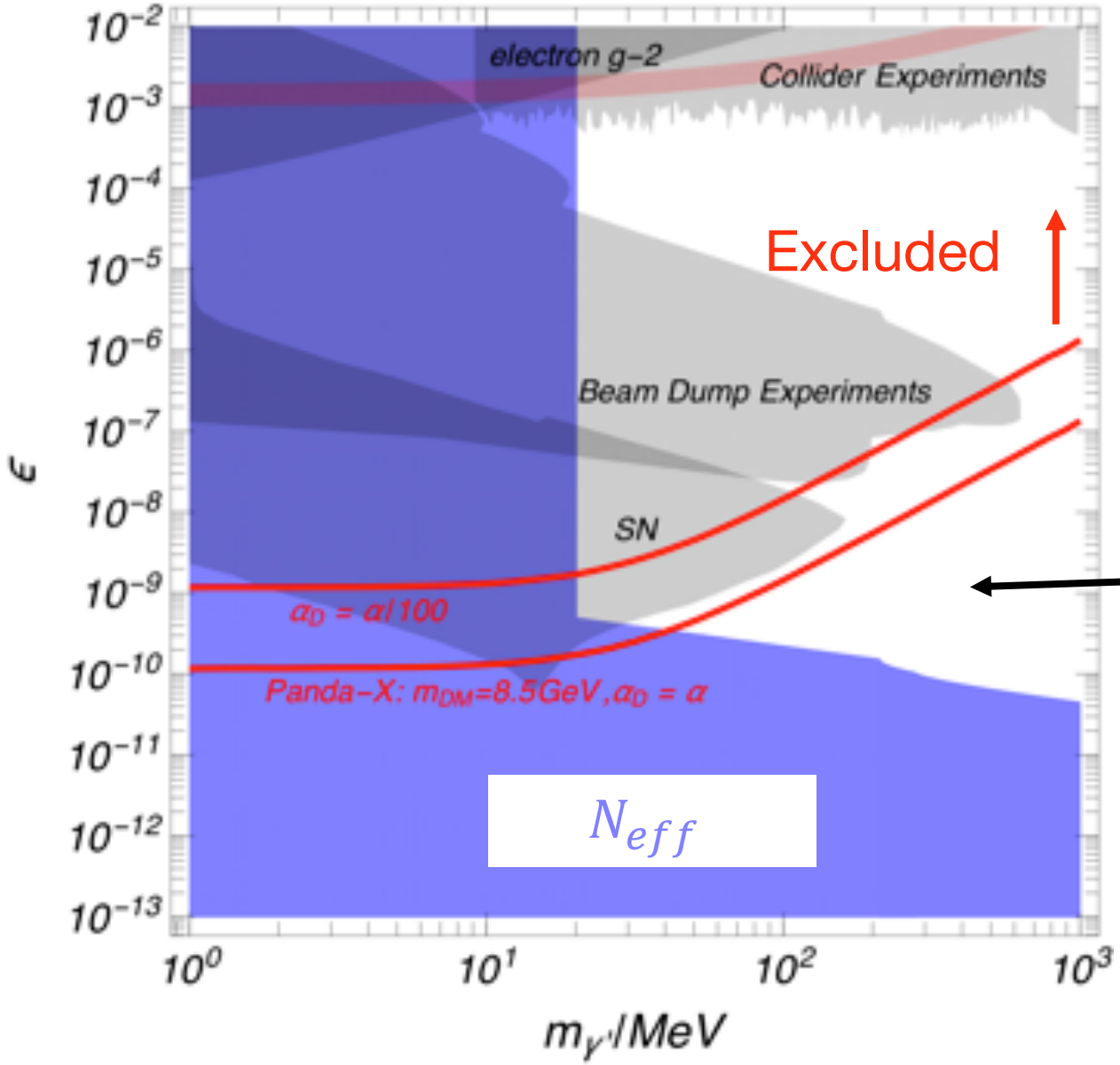
$$\mathcal{L}_{A'-A} = \frac{\epsilon}{2} F_{\mu\nu} F'^{\mu\nu} + \frac{1}{2} m^2_{\gamma'} A'_\mu A'^\mu$$

Kinetic mixing term also induces DM-nucleon scattering



We can detect in direct detection experiments!

Direct Detection Constraint



Excluded

$\alpha_D = \alpha/100$

$\alpha_D = \alpha$

Allowed!

In our model

$m_{\pi'} \sim 1\,\mathrm{GeV}$

$m_{\mathrm{DM}} = 8.5\,\mathrm{GeV}$