Asymmetric Accidental Composite Dark Matter

based on 2104.14244

S.Bottaro, M.Costa, O.Popov

Outline

1) Review of Accidental Composite Dark Matter (ACDM) models
2) Asymmetrizing ACDM models
3) Benchmark model and implementation
4) Conclusion

Review of ACDM models

Review: Accidental Composite Dark Matter

- New confining SU(N) dark color group.
- Elementary dofs: QCD-like fundamentals of DC, SM charged

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Requests

- DCquarks SU(5) GUT fragments
- Neutral/Weakly interacting DM bound state
- Accidental Stability: U(1)

M.Costa, SNS and INFN Pisa

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SU(5)	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$	charge	name
1	1	1	0	0	N
$\bar{5}$	$\bar{3}$	1	1/3	1/3	D
	1	2	-1/2	0,1	L
10	$\bar{3}$	1	-2/3	-2/3	U
	1	1	1	1	E
	3	2	1/6	2/3,-1/3	Q
15	3	2	1/6	2/3, -1/3	Q
	1	3	1	0,1,2	T
	6	1	-2/3	-2/3	S
24	1	3	0	-1,0,1	V
	8	1	0	0	G
	$\bar{3}$	2	5/6	4/3,1/3	X
	1	1	0	0	N

Antipin et al. 1503.08749

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DCq content	Allowed N_{DC}	DM candidates
$N_{\mathrm{DF}} = 3$		
$\Psi = V$	3	VVV =3
$\Psi = N \oplus L$	3,...,14	$N^{N_{\mathrm{DC}}*}$
$N_{\mathrm{DF}} = 4$		
$\Psi = V \oplus N$	3	VVV, VNN =3, VVN =1
$\Psi = N \oplus L \oplus \tilde{E}$	3,4,5	$N^{N_{\mathrm{DC}}*}$=1
$N_{\mathrm{DF}} = 5$		
$\Psi = V \oplus L$	3	VVV =3
$\Psi = N \oplus L \oplus \tilde{L}$	3	$NL\tilde{L}$=1
=	4	$NNL\tilde{L}$, $L\tilde{L}L\tilde{L}$=1
$N_{\mathrm{DF}} = 6$		
$\Psi = V \oplus L \oplus N$	3	VVV, VNN =3, VVN=1
$\Psi = V \oplus L \oplus \tilde{E}$	3	VVV =3
$N \oplus L \oplus \tilde{L} \oplus \tilde{E}$	3	$NL\tilde{L}$, $L\tilde{L}\tilde{E}$=1
=	4	$NNL\tilde{L}$, $L\tilde{L}L\tilde{L}$, $N\tilde{E}L\tilde{L}$=1
$N_{\mathrm{DF}} = 7$		
$\Psi = L \oplus \tilde{L} \oplus E \oplus \tilde{E} \oplus N$	3	LLE, $\tilde{L}\tilde{L}\tilde{E}$, $L\tilde{L}N$, $E\tilde{E}N = 1$
$\Psi = N \oplus L \oplus \tilde{E} \oplus V$	3	$VVV, VNN = 3, VVN = 1$
$N_{\mathrm{DF}} = 9$		
$\Psi = Q \oplus \tilde{D}$	3	$QQ\tilde{D} = 1$
$N_{\mathrm{DF}} = 12$		
$\Psi = Q \oplus \tilde{D} \oplus \tilde{U}$	3	$QQ\tilde{D}$, $\tilde{D}\tilde{D}\tilde{U} = 1$

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Asymmetrizing ACDM models

Asymmetrizing ACDM: generating the asymmetry

Asymmetric DM

- more particles than antiparticles
- Different phenomenology

  (bound states, ID bounds,...)
- Different abundance/mass relation
- Possibly link to baryon asymmetry

(for future works…)

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Sakharov conditions

1) U(1) breaking

careful: stabilizing symmetry

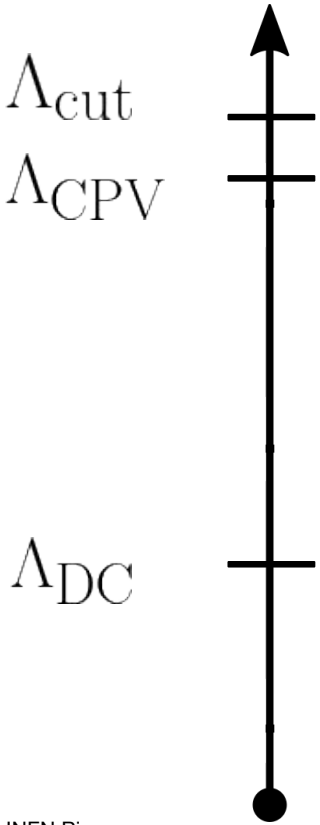
2) CP violation

Needs physical phases

3) Out-of-equilibrium process

QCD-like theory NOT enough!

Cosmological history



New completion ⟶

Asymmetry generation

U(1) violation

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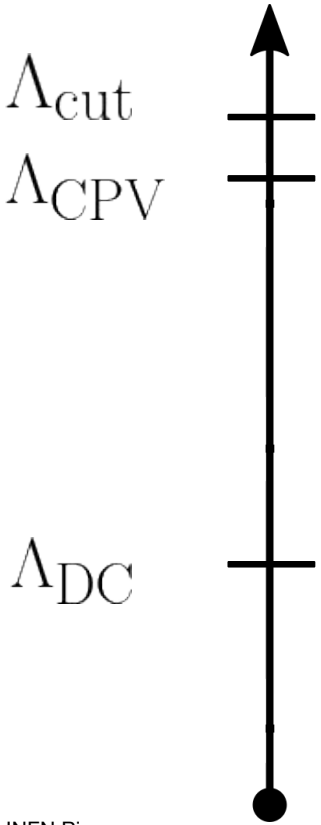

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U(1) violation

U(1) accidental symmetry

asymmetry conserved

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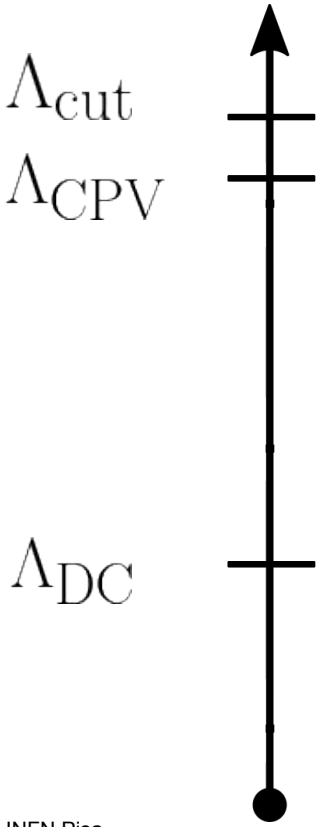


New completion → Asymmetry generation

U(1) violation

U(1) accidental symmetry

asymmetry conserved

ACDM models → Confinement

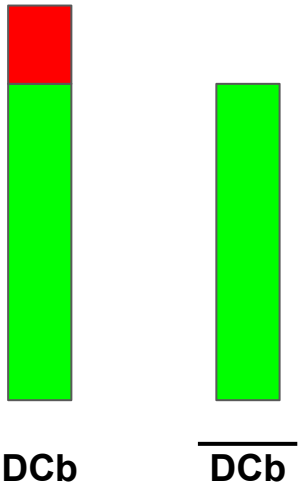
Symmetric annihilation

$\mathrm{DC}\pi$ decay in SM Decay in lightest stable DCb

Asymmetrizing ACDM: annihilating the symmetric part

Non-thermal asymmetric component

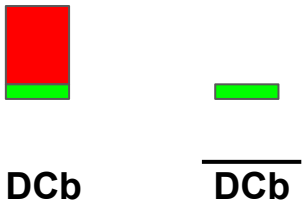
Symmetric component



Asymmetrizing ACDM: annihilating the symmetric part

$$\Omega_{\rm DM} \propto m_{\rm DCb} \eta_{\rm DM}$$

Non-thermal asymmetric component



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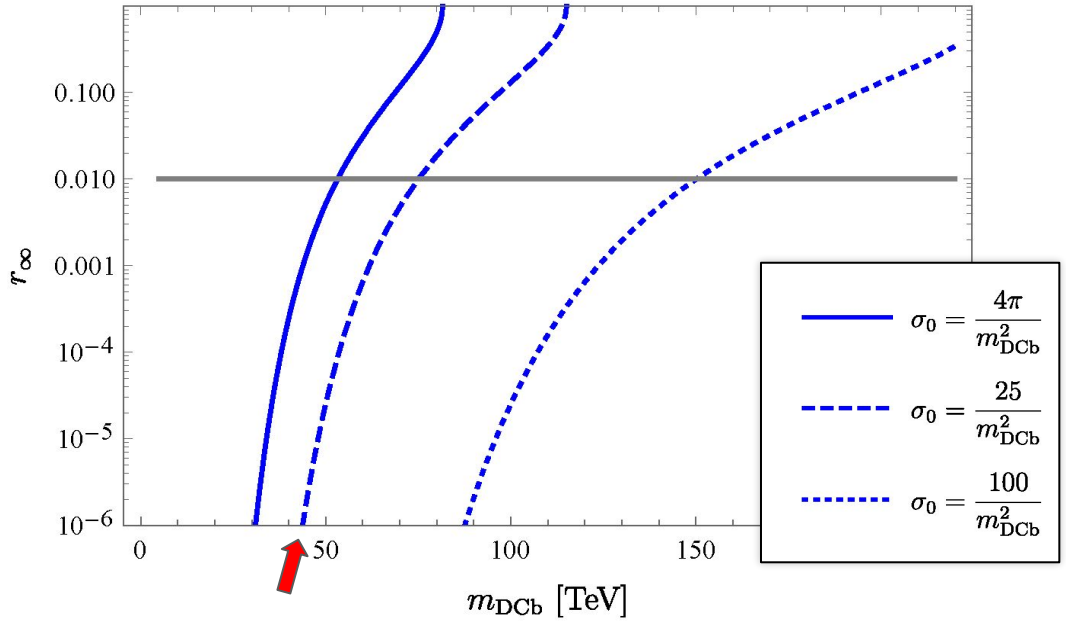
Non-thermal asymmetric component

DCb $\quad$ $\overline{\text{DCb}}$



Asymmetric case:

larger cross section, lighter DM!

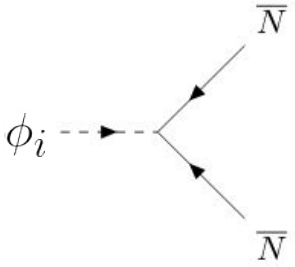
$$r \equiv \frac{n(\overline{X})}{n(X)} \approx \exp\left[-2\left(\frac{\sigma_0}{\sigma_{\rm WIMP}}\right)\left(\frac{1-r_\infty}{1+r_\infty}\right)\right]$$

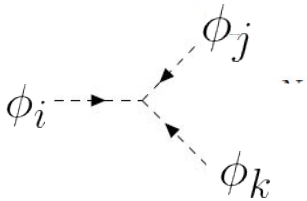
Benchmark model

Benchmark model

Field	$\mathrm{SU(3)_{DC}}$	$(\mathrm{SU(3)}_c, \mathrm{SU(2)}_L)_Y$	$\mathrm{U(1)_{DB}}$ (D)
N	3	$(1,1)_0$	1
ϕ	$\bar{6}$ (sym)	$(1,1)_0$	-2

$$\mathcal{L} = \mathcal{L}_{\rm kin} + y\phi_{ij}N^iN^j + \lambda M_\phi \epsilon^{ijk}\epsilon^{i'j'k'}\phi_{ii'}\phi_{jj'}\phi_{kk'}$$





DCb: N^3 **accidentally stable** $\mathbb{Z}_2$

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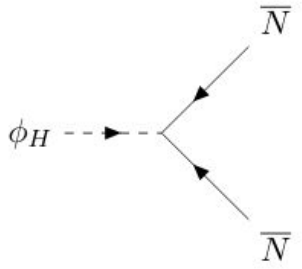
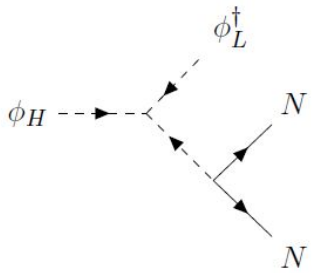
OOE: decay of heavy scalar



$\Delta D = 0$



$\Delta D = 6$

$$\epsilon = \frac{\Gamma(\phi_H \to \phi_L^\dagger NN) - \Gamma(\phi_H^\dagger \to \phi_L \overline{NN})}{\Gamma_H}$$

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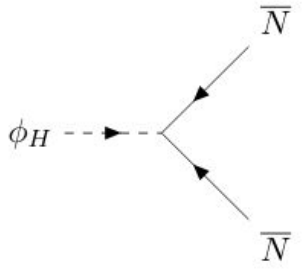
Weak-washout condition:

$$M_\phi \gtrsim 10^{15}\ \mathrm{GeV} \approx M_{\rm GUT}$$



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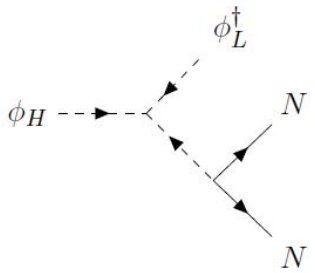

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$$\eta_{\rm DM} \approx 2\frac{\epsilon}{g_*}$$

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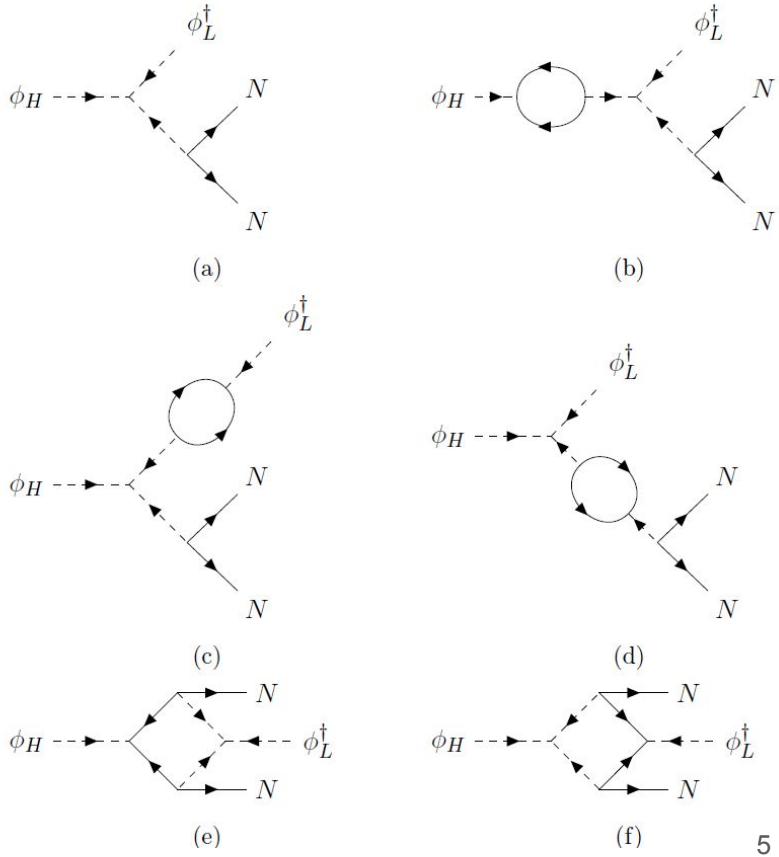
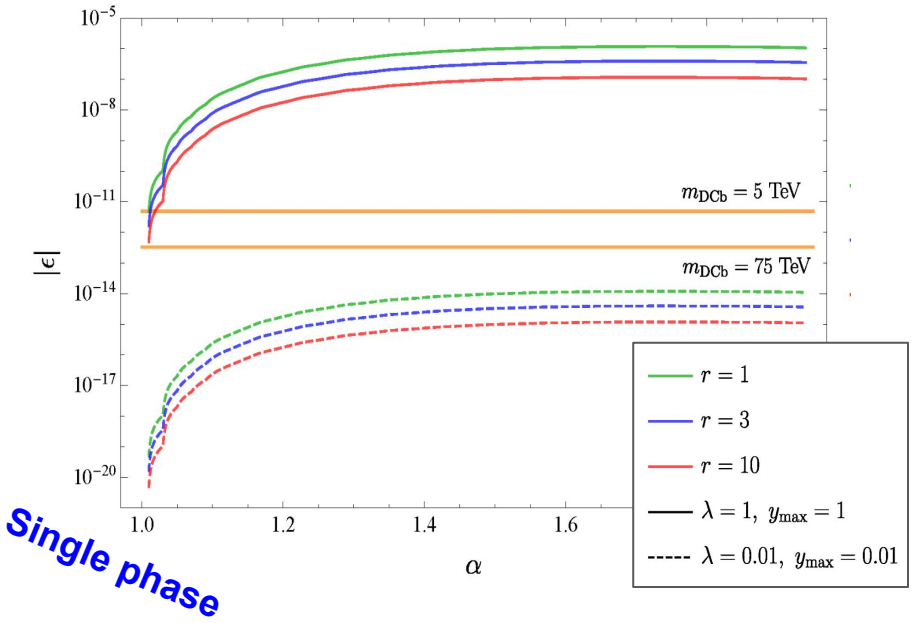
Two flavors to get enough CPV: **3 phases**

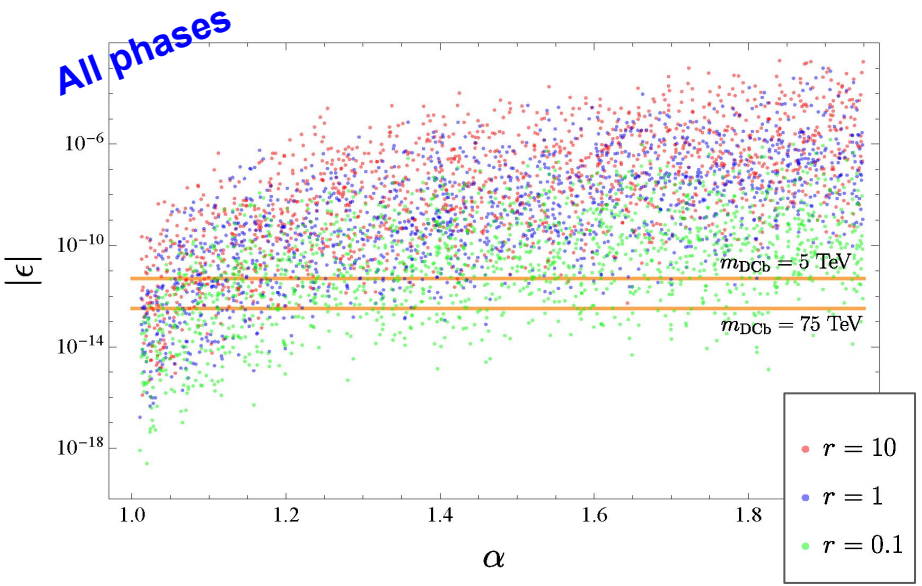


Results

$\alpha = M_H/M_L$ controls phase space



Single phase



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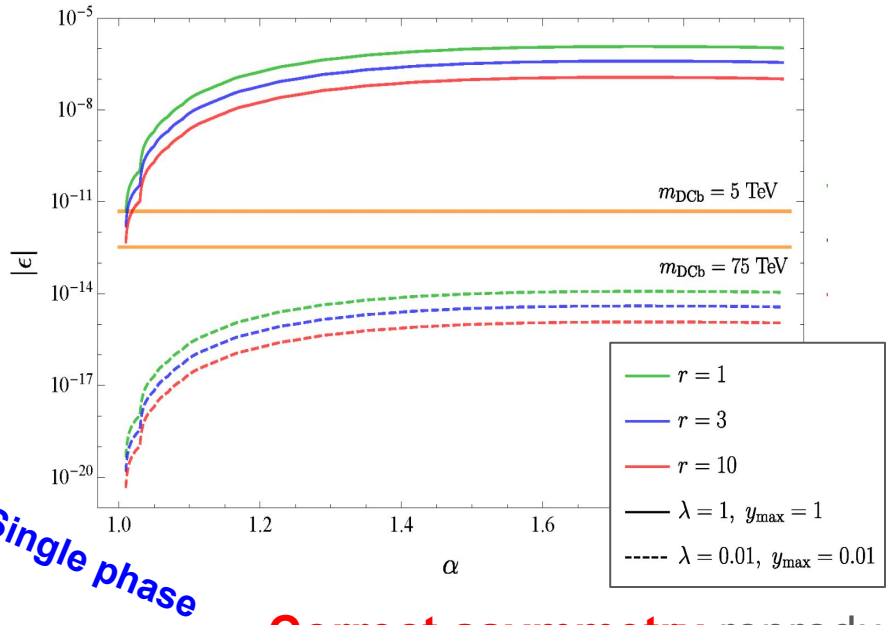

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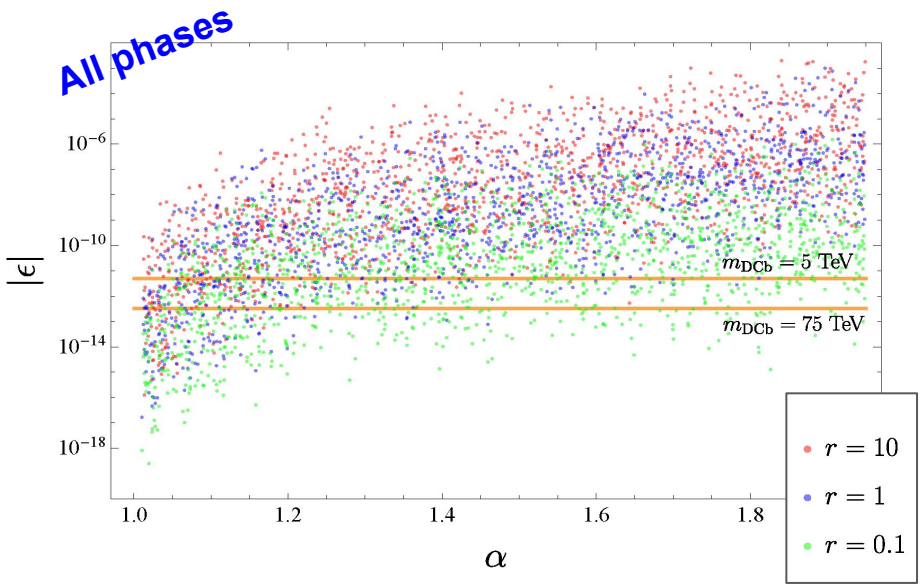

Correct asymmetry reproduced in TeV range with 10% FT!

Implementing the benchmark

Uncolored models

Model	ϕ	Couplings
V		ϕVV
$N \oplus L$		ϕNN
$N \oplus L \oplus \tilde{E}$		ϕNN
$V \oplus L$		ϕVV
$N \oplus L \oplus \tilde{L}$		$\phi NN, \phi L\tilde{L}$
$V \oplus L \oplus N$	$(\bar{6},1,1)_0$	$\phi VV, \phi NN$
$V \oplus L \oplus \tilde{E}$		ϕVV
$N \oplus L \oplus \tilde{L} \oplus \tilde{E}$		$\phi NN, \phi L\tilde{L}$
$L \oplus \tilde{L} \oplus E \oplus \tilde{E} \oplus N$		$\phi NN, \phi E\tilde{E}, \phi L\tilde{L}$
$N \oplus L \oplus \tilde{E} \oplus V$		$\phi NN, \phi VV$
$V \oplus N$	$(\bar{6},1,5)_0$	ϕVV

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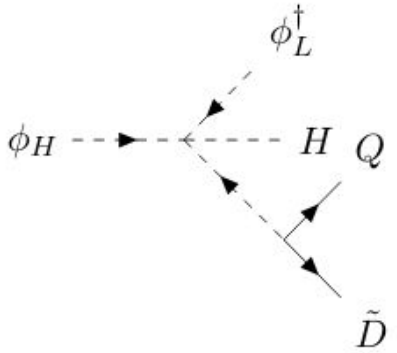
$N \oplus L \oplus \tilde{L} \oplus \tilde{E}$		$\phi NN, \phi L\tilde{L}$
$L \oplus \tilde{L} \oplus E \oplus \tilde{E} \oplus N$		$\phi NN, \phi E\tilde{E}, \phi L\tilde{L}$
$N \oplus L \oplus \tilde{E} \oplus V$		$\phi NN, \phi VV$
$V \oplus N$	$(\bar{6},1,5)_0$	ϕVV

Colored models

$$\phi_{ij,ab} Q^{ia} \tilde{D}^{jb} \qquad \phi \in (\bar{6},\bar{6},2)_{1/6}$$

$$\lambda \epsilon^{abc} \epsilon^{a'b'c'} \epsilon^{ijk} \epsilon^{i'j'k'} \phi_{ii'aa'} \phi_{jj'bb'} \phi_{kk'cc'} H^*$$



Conclusions

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- We have built **asymmetric** extension of Accidental Composite Dark Matter models.
- The symmetric component is annihilated by non-perturbative annihilations. **No extra interactions** needed!
- The asymmetry generation mechanism can produce the **correct asymmetry** without much tuning.
- **Accidental stability** of DM candidate is preserved even in presence of U(1) breaking interactions.
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- Mechanism implemented in **ALL** original model, preserving possibility of SU(5) unifications.
- **To do**: generate simultaneously **SM** and **DS** asymmetry.
- **To do**: other dynamics?

Thanks for the attention!