

# Dark Matter Freeze-out via Catalyzed Annihilation

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C.Y.X, Shou-hua Zhu, Phys. Rev. Lett. 127, 061101.







<sup>2</sup>/<sub>Catalyzed freeze-out</sub>

<sup>3</sup> A model & phenomenology

4 Summary

# PART 01

# Introduction



#### How many dark matter are there in the Universe?



arXiv:1807.06209

#### **Freeze-out:** to understand the abundance of dark matter.



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- 1. O(1) coupling. (Weakly interacting)
- 2. 100GeV mass. (massive particles)

# WIMPs



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 2. 100GeV mass.

# WIMPs

Electroweak









Many direct detection experiments are established to search for DM.





PandaX

The null results provide with stringent constraints on WIMPs.

# The WIMP Crisis





 $m_S$ [GeV]

A simple Higgs portal model:

$$\Delta {\cal L} = - rac{1}{4} \lambda H^\dagger H \chi^2 \, .$$

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# The WIMP Crisis







# The WIMP Crisis





# PART 02

# **Catalyzed freeze-out**

## **DM** in a Secluded Sector



Can we reproduce correct abundance in a secluded sector?



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#### Can we reproduce correct abundance in a secluded sector?



## Catalyzed Freeze-out



#### **The Catalyzed Annihilation**



Three 2DM  $\rightarrow$  2Med plus two 3Med  $\rightarrow$  2DM effectively deplete two DM particles.

Mediator is not consumed, like a catalyst.



















#### **Requirements:**

<sup>1</sup>/Secluded sector.

<sup>2</sup>/Long-lived mediator.

<sup>3</sup> DM is slightly heavier than Med.

<sup>4</sup> Annihilation channels.

#### **Requirements:**

- <sup>1</sup>/Secluded sector.
- <sup>2</sup> Long-lived mediator.
- <sup>3</sup> DM is slightly heavier than Med.
- 4 Annihilation channels.

#### Features:

- <sup>1</sup> Polynomially suppressed  $n_{\rm DM}$ .
- <sup>2</sup>/<sub>MeV</sub> TeV DM mass.
- <sup>3</sup> The freeze-out is late.  $x_f \simeq 800$ .

<sup>4</sup> Enhanced indirect detection signals.

## Catalyzed Freeze-out



#### **Varying Mass Ratio**



When the mass ratio is larger than 1.5,  $\Omega h^2$  is rapidly suppressed.

When the mass ratio is close to 2,  $4 \rightarrow 2$  process could be dominant.

# PART 03

# A model & phenomenology

# A Dark Photon Model

#### **Dark Photon Model**

$$\mathcal{L}_{\rm DS} = -\frac{1}{4} F'_{\mu\nu} F'^{\mu\nu} + \frac{1}{2} m_{A'}^2 A'_{\mu} A'^{\mu} + \bar{\chi} (i D \!\!\!/ - m_{\chi}) \chi,$$

$$\mathcal{L}_{\rm mix} = -\frac{\epsilon}{2\cos\theta_W} F'_{\mu\nu} B^{\mu\nu}.$$

 $\chi$ : DM A': Mediator



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$$\begin{array}{c} \chi: \mathrm{DM} \\ A': \mathrm{Mediator} \\ \mu^{0} - 10^{-10} \\$$

#### Summary:



1/WIMP is stringently constrained by direct detections (the WIMP crisis).

2/We proposed novel catalyzed freeze-out paradigm.

3/ The paradigm is realized in the dark photon model.

4 Works to do: 1. new models, 2. kinetic decoupling, 3. entropy dilution, 4. ...

# Thanks.

#### **Chuan-Yang Xing**

