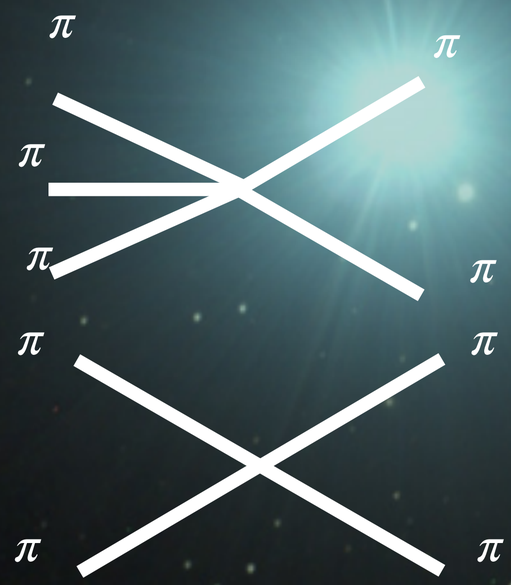
A portal to the SM for resonant SIMPs

Luca Marsili (IFIC-University of Valencia) in collaboration with Camilo Garcia-Cely, Giacomo Landini, Oscar Zapata, based on **2508.21121** (Submitted to JHEP)

DESY Theory Workshop 2025

CSIC Consejo Superior de Investigaciones Científicas
Vniversitat de València
IFIC Institut de Física Corpuscular
Excelencia Severo Ochoa

Strong Interacting Massive Particles



Correct DM abundance

Self-Interactions

$$\sigma/m \sim 1 - 10\,\mathrm{cm}^2/\mathrm{g}$$

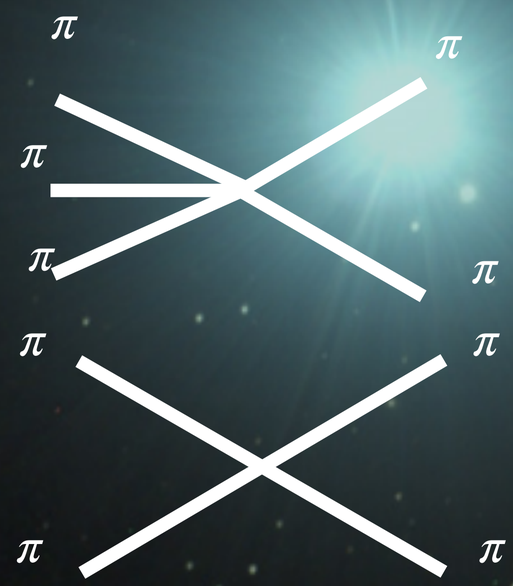
$$m \sim 1 - 100\,\mathrm{MeV}$$

Y. Hochberg, E. Kuflik, T. Volansky, Jay G. Wacker [1402.5143]

See also: Y. Hochberg, E. Kuflik, H. Murayama,T. Volansky, Jay G. Wacker [1411.3727], H. M. Lee, M. S. Seo [1504.00745], Y. Hochberg, E. Kuflik, H. Murayama [1512.07917], A. Katz, E. Salvioni, B. Shakya[2006.15148], A. Kamada, H. Kim, T. Sekiguchi [1704.04505], …

Strong Interacting Massive Particles

$$\mathscr{L} = -\frac{1}{4}F^2 + \bar{q}\, i\gamma^\mu D_\mu q - \left(\bar{q}_L M q_R + \mathrm{h.c.}\right).$$



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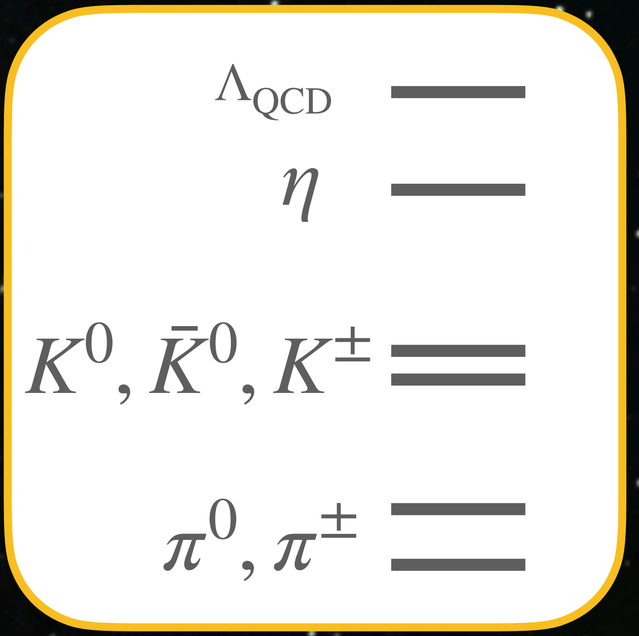

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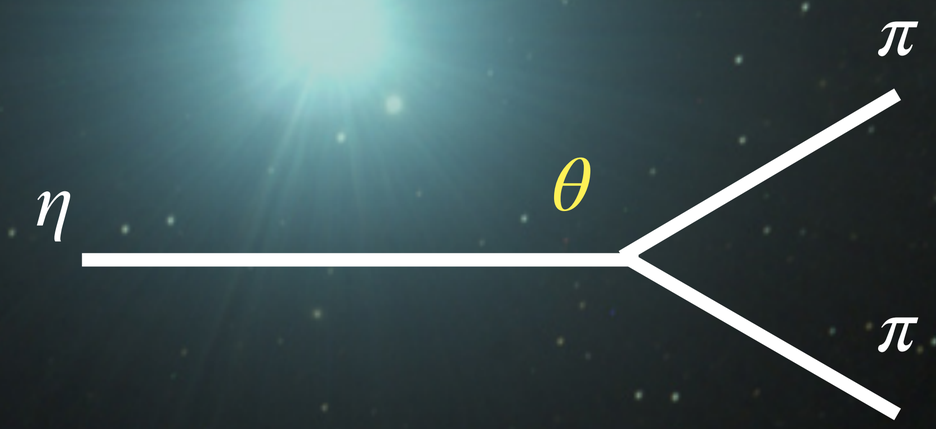
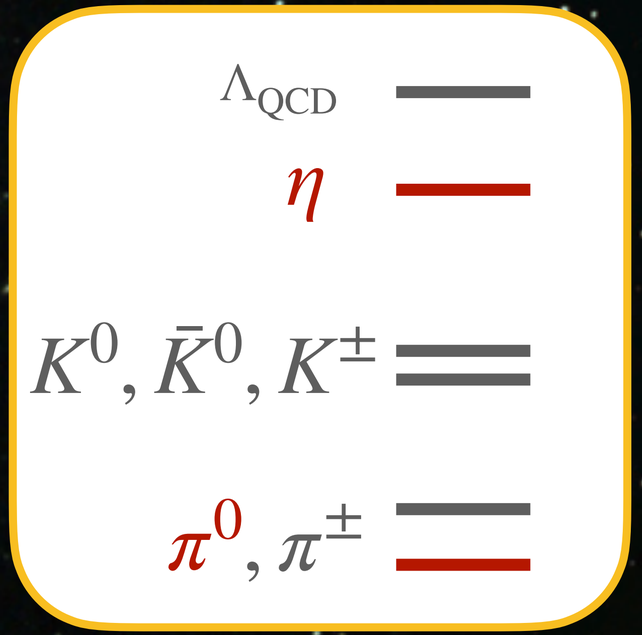
Strong Interacting Massive Particles with $\theta \neq 0$

$$\mathscr{L} = -\frac{1}{4}F^2 + \bar{q}\, i\gamma^\mu D_\mu q - \left(\bar{q}_L M q_R + \text{h.c.}\right) + \frac{g^2\theta}{32\pi^2}F\tilde{F}$$





C. Garcia Cely, G. Landini, O. Zapata[2405.10367]

$$m_\eta/m_\pi^0 = 2 + v_R^2/4$$

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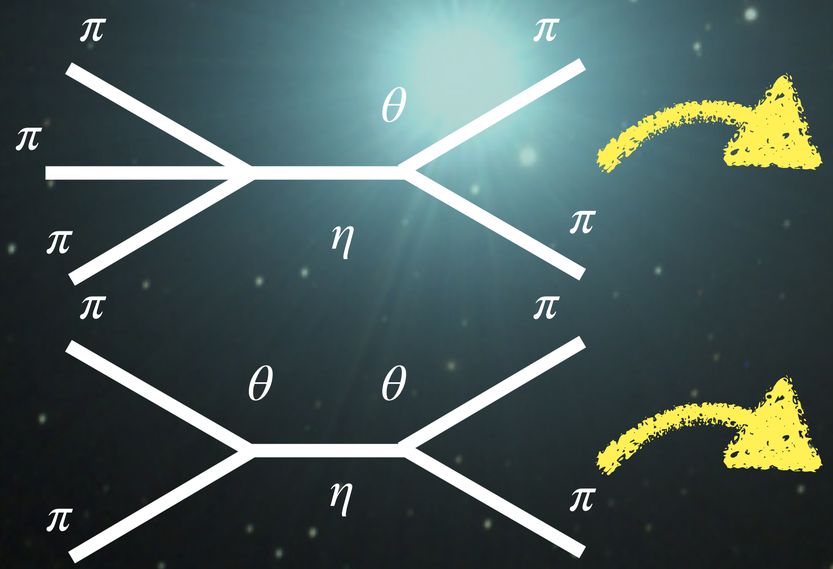
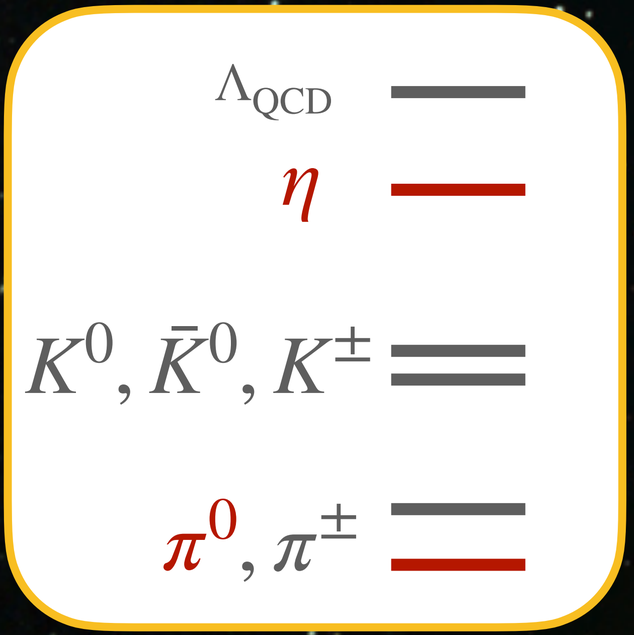


Correct DM abundance

Resonant self-interactions



C. Garcia Cely, G. Landini, O. Zapata[2405.10367]

C. Garcia Cely, X. Chu, H. Murayama [1810.04709]

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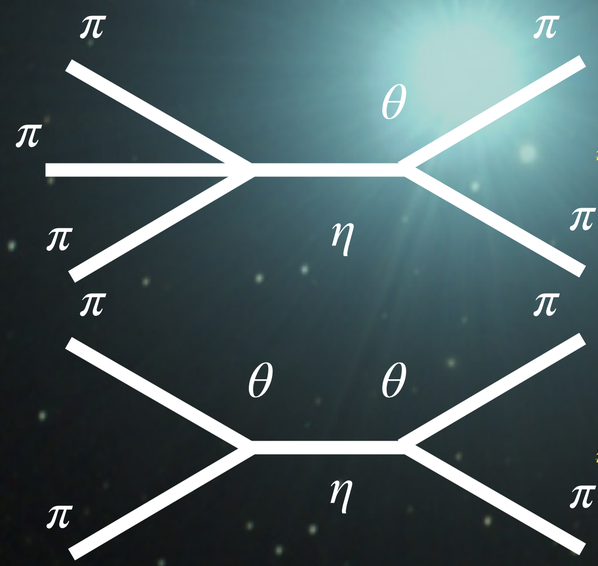

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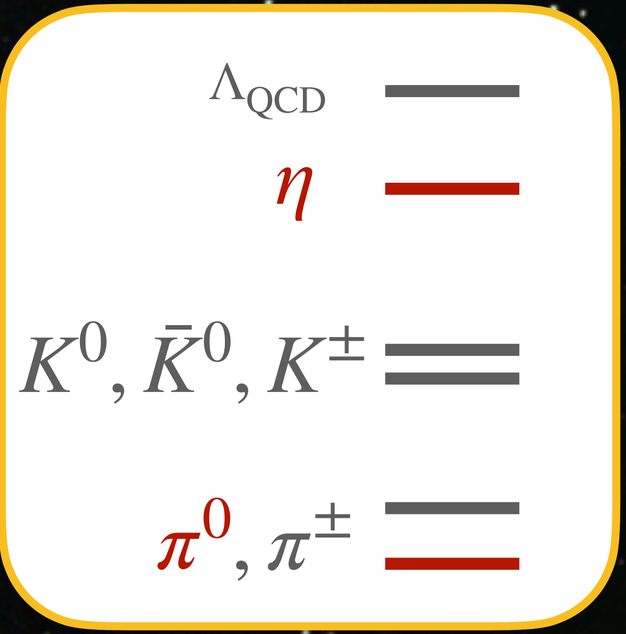

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C. Garcia Cely, X. Chu, H. Murayama [1810.04709]

Velocity dependent self interactions

Strong Interacting Massive Particles with $\theta \neq 0$

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Interactions with Standard Model particles

?

Resonant self-interactions

η

$K^0, \bar{K}^0, K^\pm$

$\pi^0, \pi^\pm$

C. Garcia Cely, G. Landini, O. Zapata[2405.10367]

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Interactions with Standard Model particles ?

Thermalisation

DM Stability

C. Garcia Cely, G. Landini, O. Zapata[2405.10367]

C. Garcia Cely, X. Chu, H. Murayama [1810.04709]

Velocity dependent self interactions

Thermalisation

π^0 $\pi^+\pi^-$ K^-K^+ $K^0\bar{K}^0$ η

Thermalisation

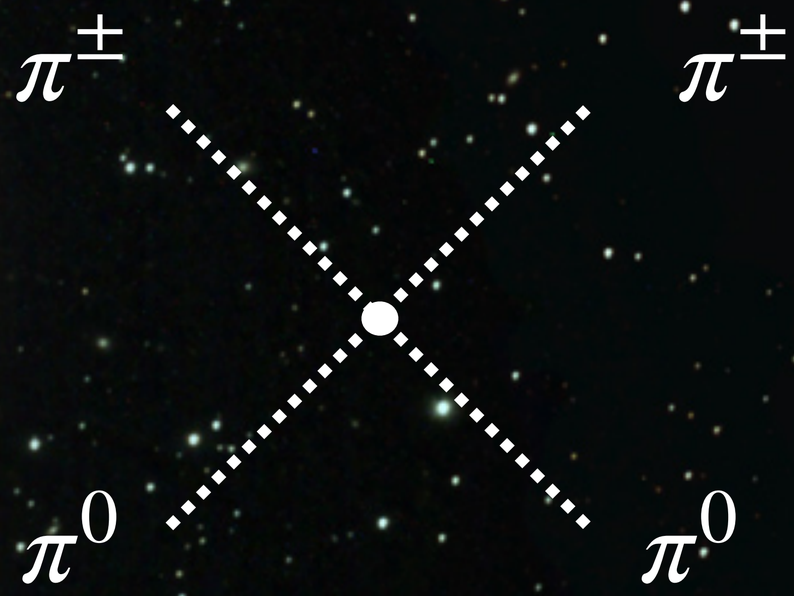
$$\overbrace{\pi^0\ \pi^+\pi^-}^{U'(1)}\ K^-K^+\ K^0\bar{K}^0\qquad \eta$$

Interact with the **dark photon**

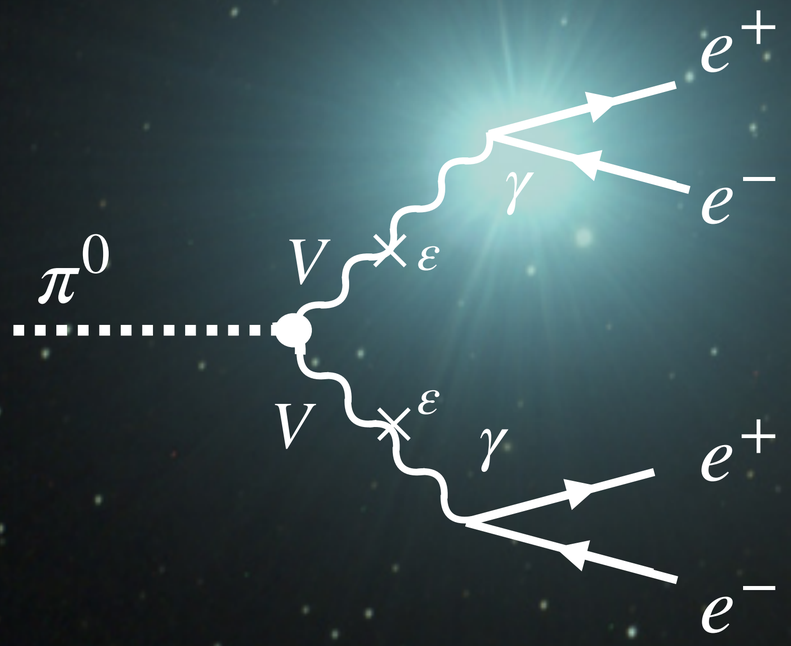
Thermalisation

I

II



DM Stability

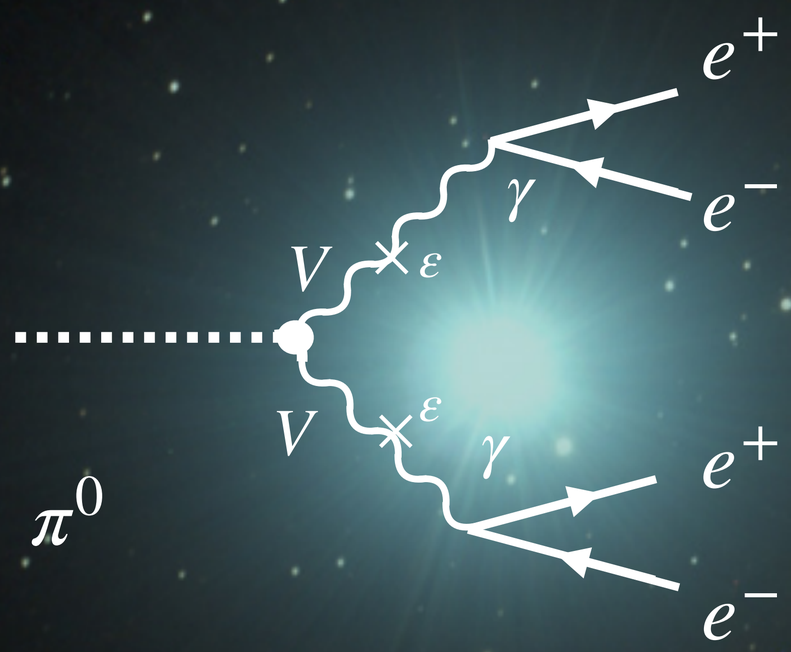


Pions **decay**
when they **interact** with SM

Interactions have to be **very weak** and a
"**dark pion**" would be **metastable**

Y. Hochberg, E. Kuflik, H. Murayama [1805.09345]
A. Katz, E. Salvioni, B. Shakya [2006.15148]

DM Stability



Heating of **gas-rich dwarf galaxies** (Leo-T)

$$\tau_{\rm DM} \gtrsim 10^{26}\ \text{sec}$$

Wadekar, Zhang [2111.08025]

$$\tau_{\rm DM} \sim 1.4\times 10^{29}\ \text{sec} \left(\frac{0.1}{\sin\theta_{\pi\eta}}\right)^2 \left(\frac{10^{-3}}{\alpha_d}\right)^2 \left(\frac{5\times 10^{-4}}{\varepsilon}\right)^4 \times \left(\frac{m_V}{0.5\,\text{GeV}}\right)^8 \left(\frac{20\ \text{MeV}}{m_{\rm DM}}\right)^9 \left(\frac{0.5}{m_{\rm DM}/f_\pi}\right)^6$$

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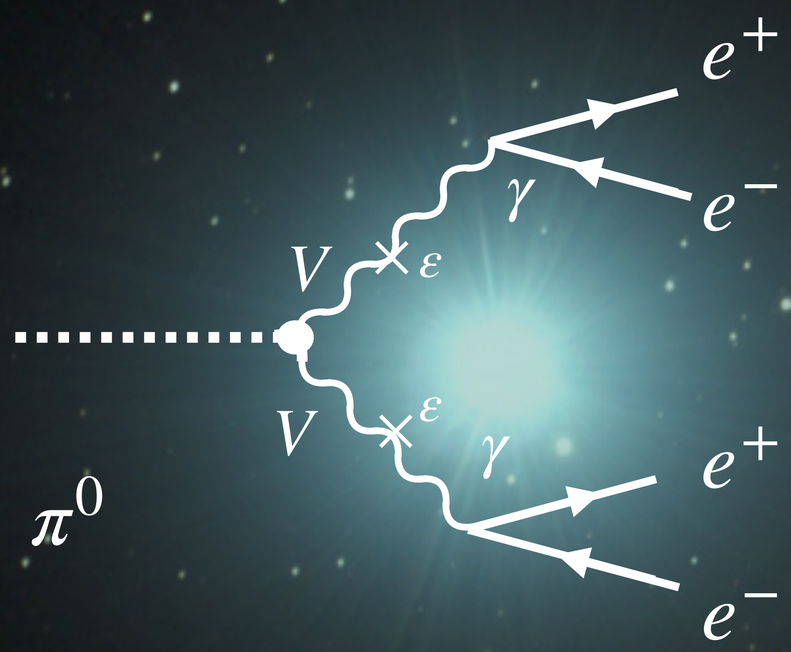

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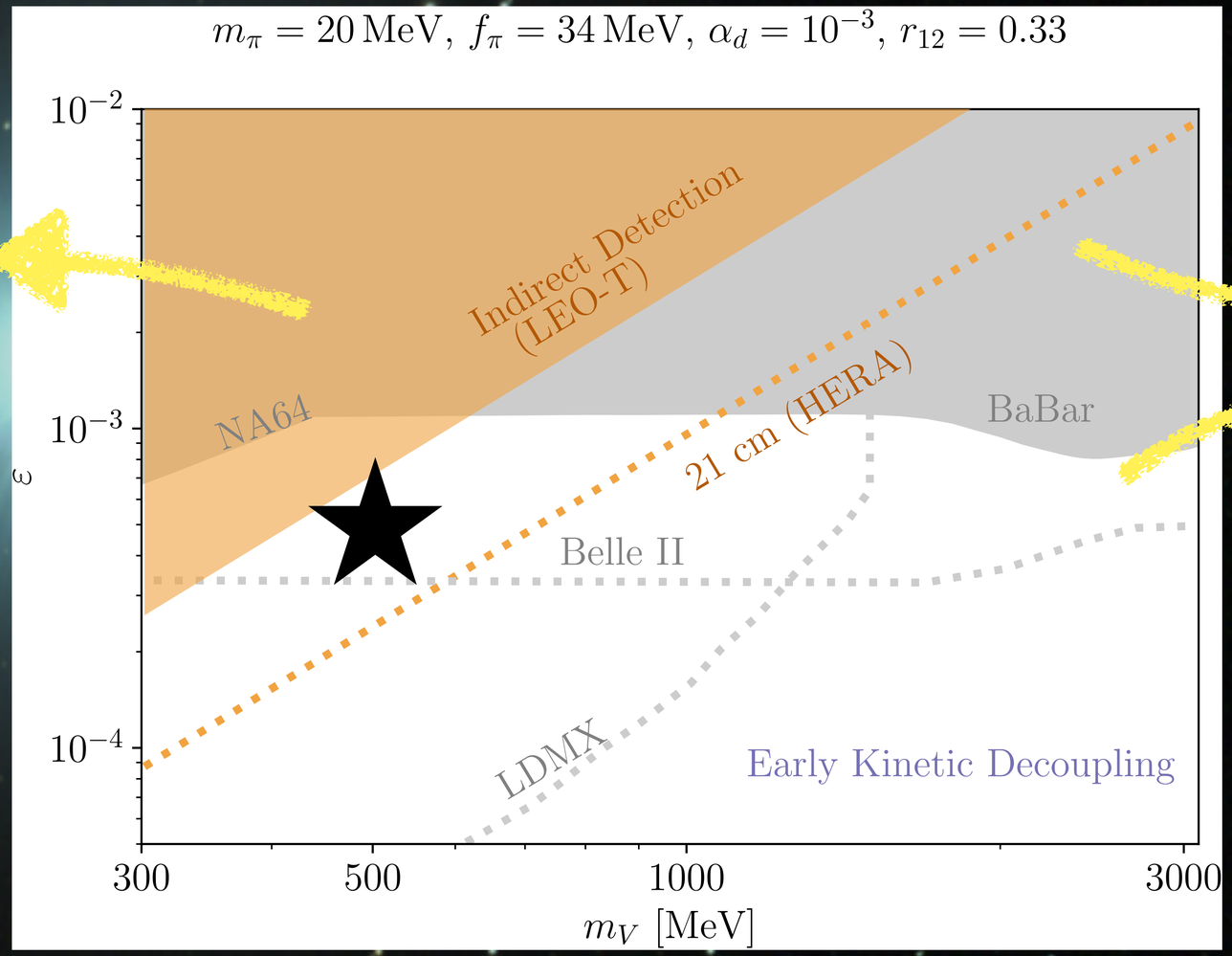
*10-50 MeV **mass scale** for DM*

Thermalisation and stability

Pions **decay** when they **interact** with SM



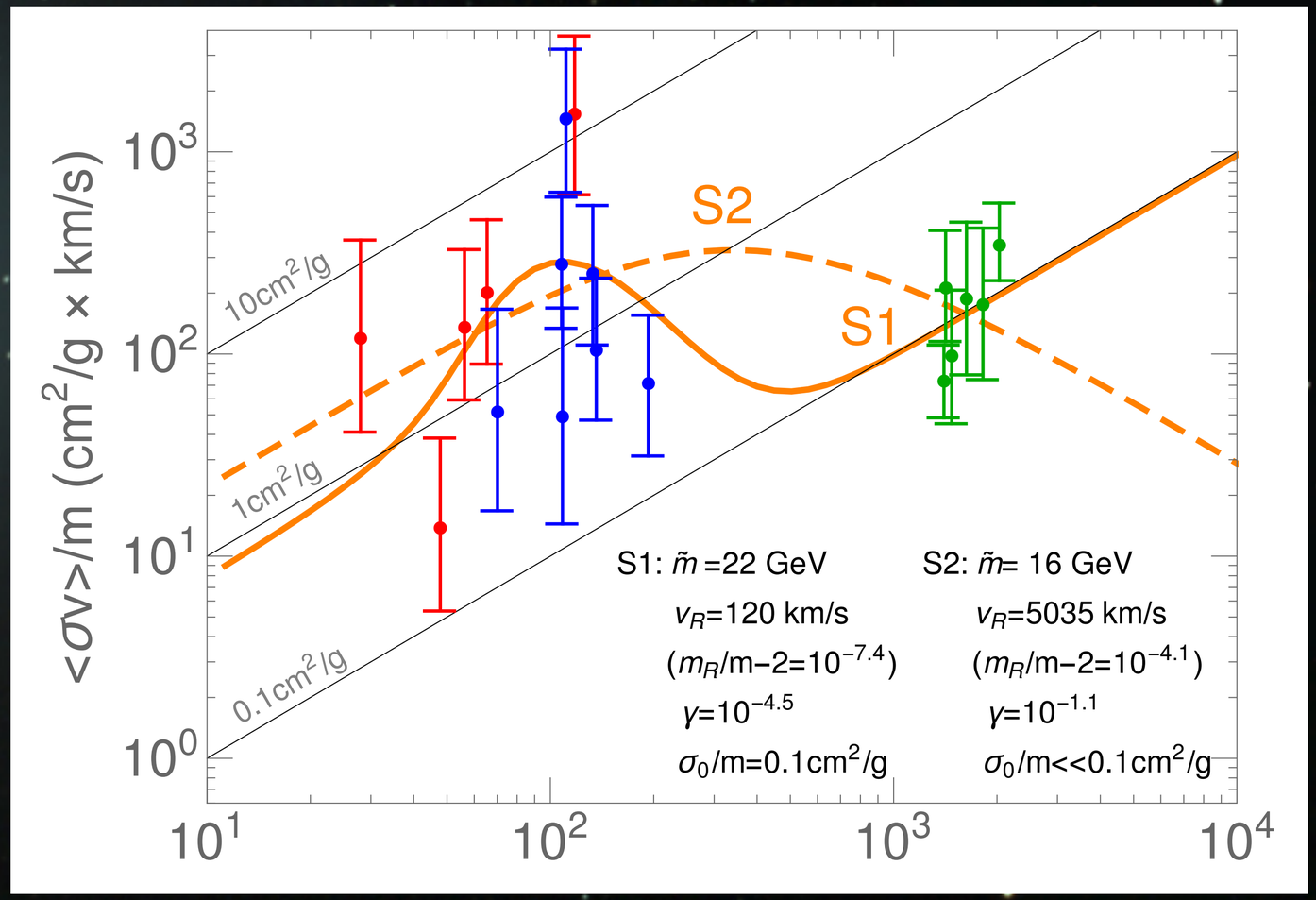
Colliders bounds

$T_{\mathrm{kd}} > T_{\mathrm{fo}}$

Summary and Astrophysical consequences

- **Resonant SIMP** are promising **SIDM candidates**
- Help address tensions **in small scale structure**
- **Velocity-dependent** cross section

M. Kaplinghat, S. Talin, H. B. Yu[1508.03339]



[X. Chu, C. Garcia Cely, H. Murayama, 1810.04709]

Summary and Astrophysical consequences

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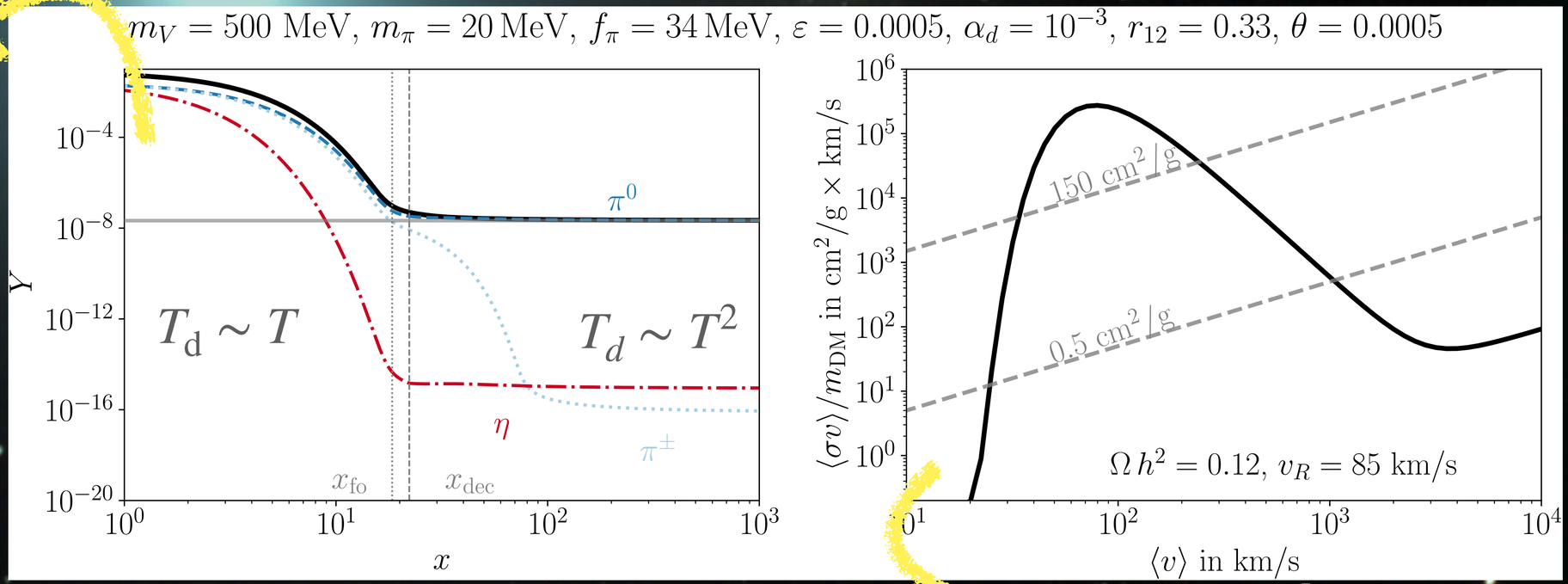


Velocity-dependent cross

Conclusions

- SIMP models can provide **velocity dependent self-interactions**
- The presence of a **dark photon** successfully provides a way to **thermalise** the **dark mesons until freeze out**
- The **dark pion DM** would be only **metastable**
- The model is **testable** by future colliders experiments and astrophysical probes, it is **consistent** with all **existing bounds**

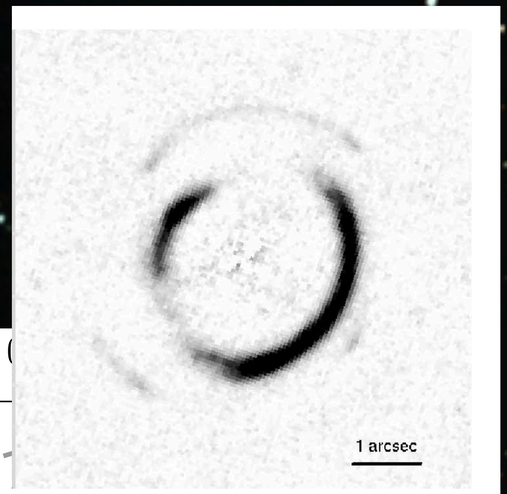
THANK YOU

BACKUP SLIDES

Summary and Astrophysical consequences

Gavazzi et al., 2008

SDSS J0946+1006
Li et al., 2504.11800



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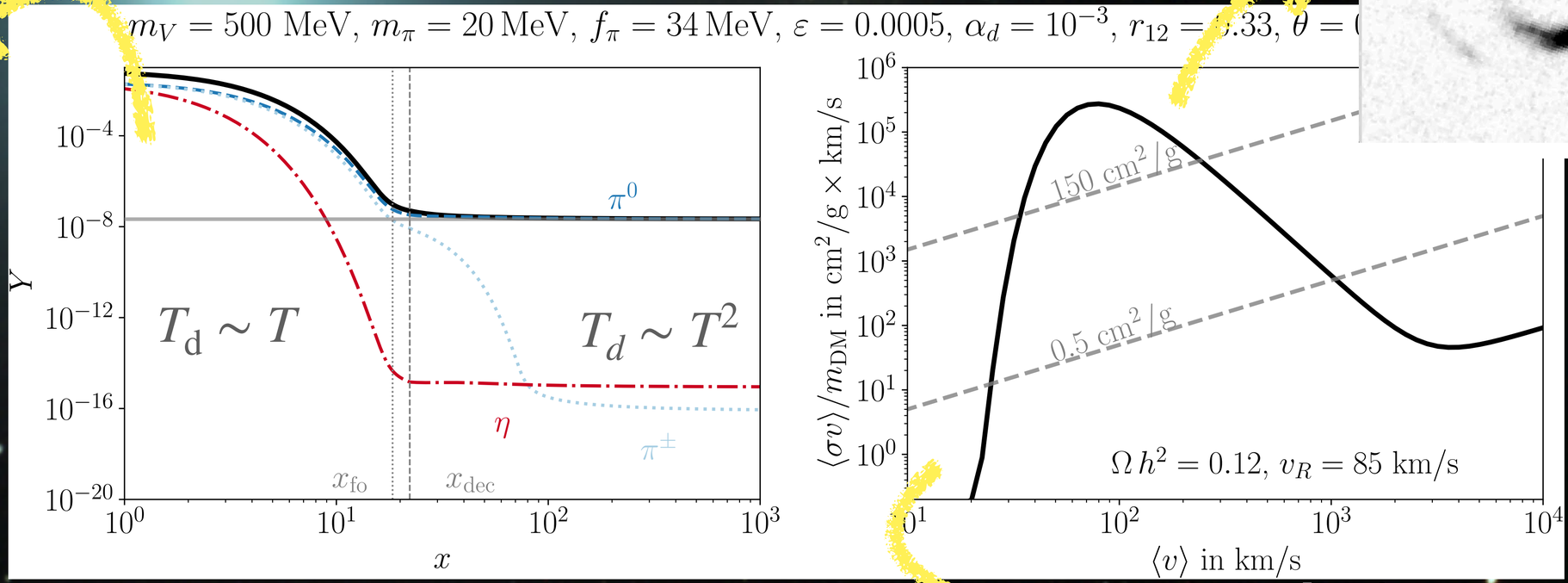

Velocity-dependent cross

Summary and Astrophysical consequences

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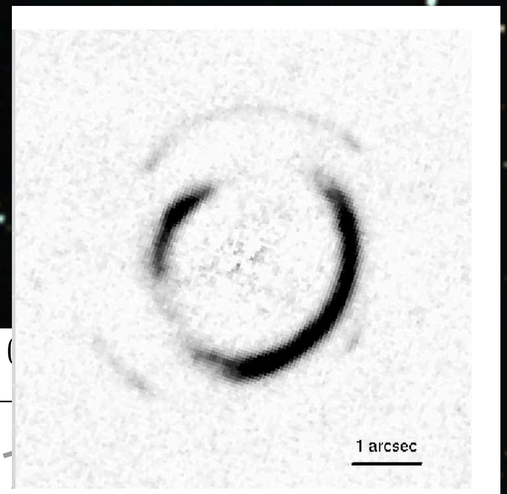
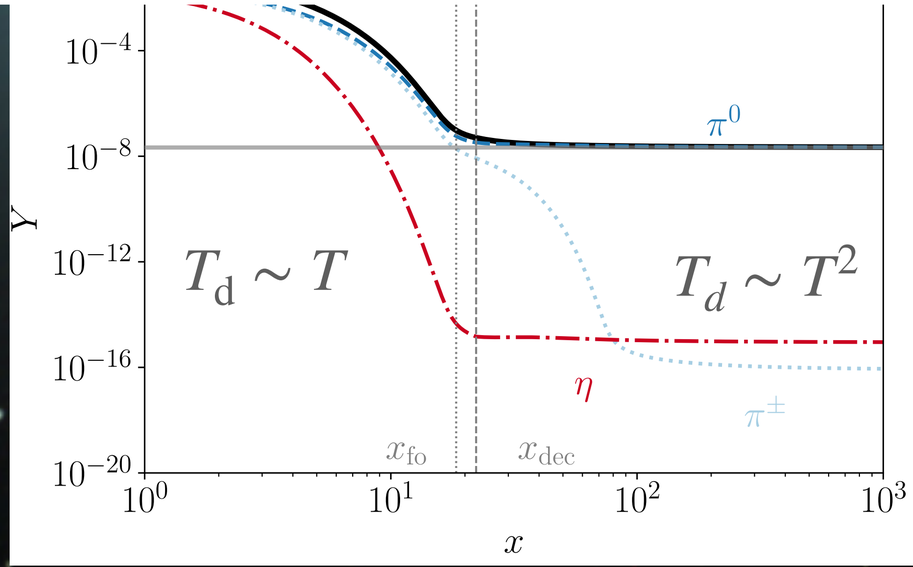
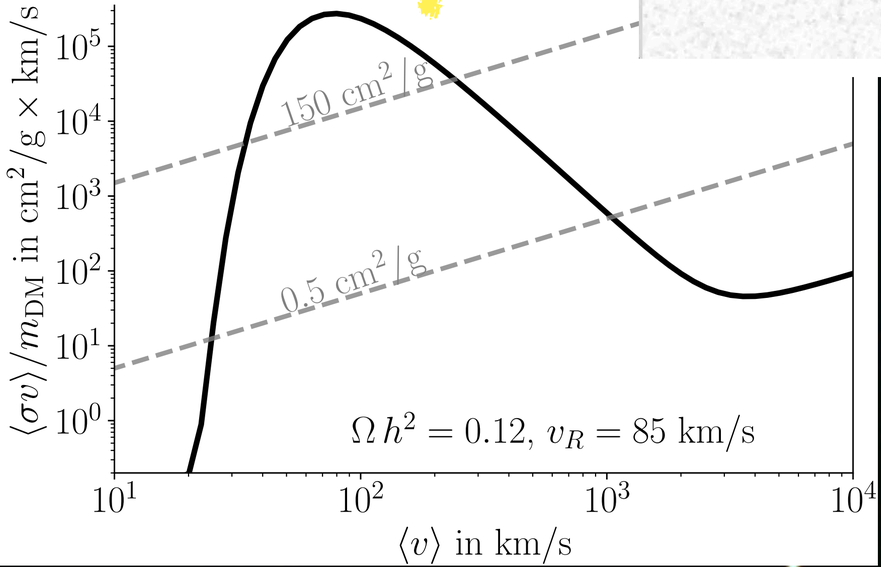


The lensing object **SDSS J0946+1006** **might** be an SIDM halo

Correct DM abundance





Velocity-dependent cross

DM decay

Heating of **gas-rich dwarf galaxies** (Leo-T)

Wadekar, Zhang [2111.08025]

$$\tau_{\rm DM} \gtrsim 10^{26}\ \text{years}$$

CR detection outside solar magnetic field by **Voyager**

Boudad, Lavalle, Salati [1612.07698]

CMB anisotropies, **21cm**, and other methods

Slatyer, Liu [1506.03811], [1803.09739]

The dark photon portal

New $U(1)$ ***group***

Dark photon V

Dark mesons ***couples only*** *with dark photons*

$$\mathscr{L} \subset e_d j_D^{'\mu} V_\mu + e\varepsilon j^\mu V_\mu$$

Standard Model particles ***couples*** *with dark photon trough* ***kinetic mixing***

New interactions *among dark mesons and SM*