Cosmological Constraints on Light (but Massive) Relics

CMB-S4 Summer 2021 Meeting

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with Nick Deporzio, Julian Muñoz, & Cora Dvorkin

[2006.09395, 2006.09380 & 2107.09664]



Harvard University → UC Berkeley/LBNL

Introduction

Matter content of the universe

- "Light" : Visible, ordinary particle content $\sim 15\%$
- "Dark" : Invisible, feebly-interacting particle content $\sim 85\%$
  - Most of it needs to be mostly cold and collisionless

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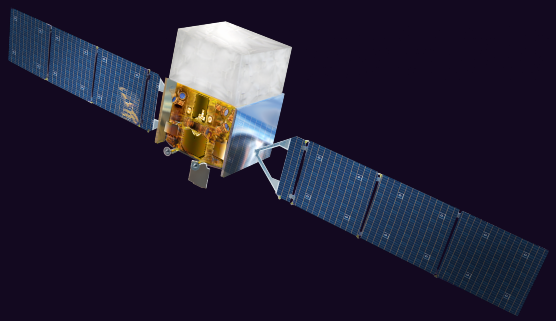

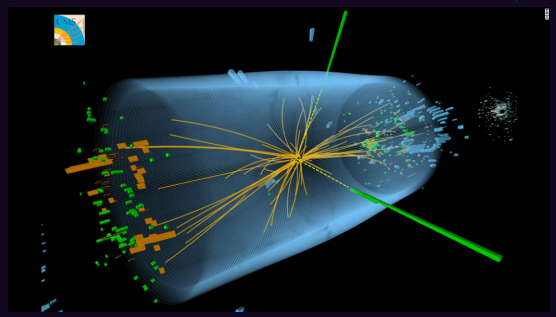

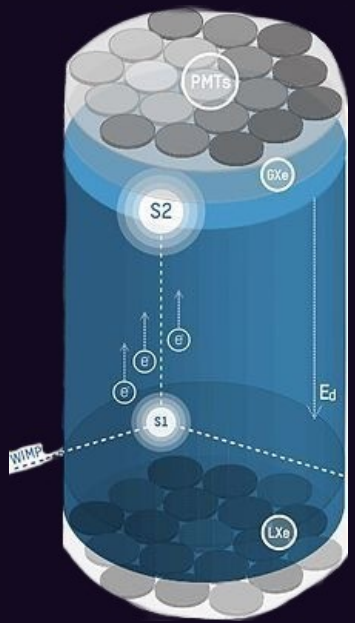

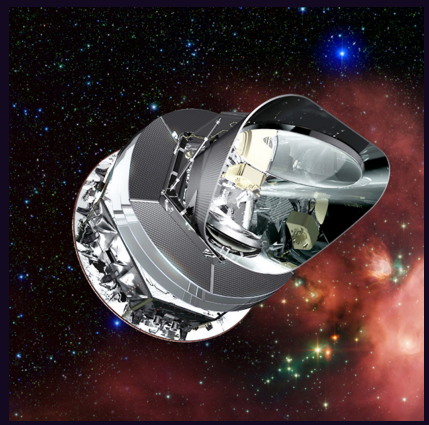

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  - Most of it needs to be mostly cold and collisionless
  - Some fraction can be not that
    - Neutrinos definitely exist, other light relics might too
    - We stand a chance to detect them

Light but Massive Relics

Particles that were in thermal contact with SM at early universe, were relativistic at decoupling, but behaves like matter today.

Light but Massive Relics (LiMRs)

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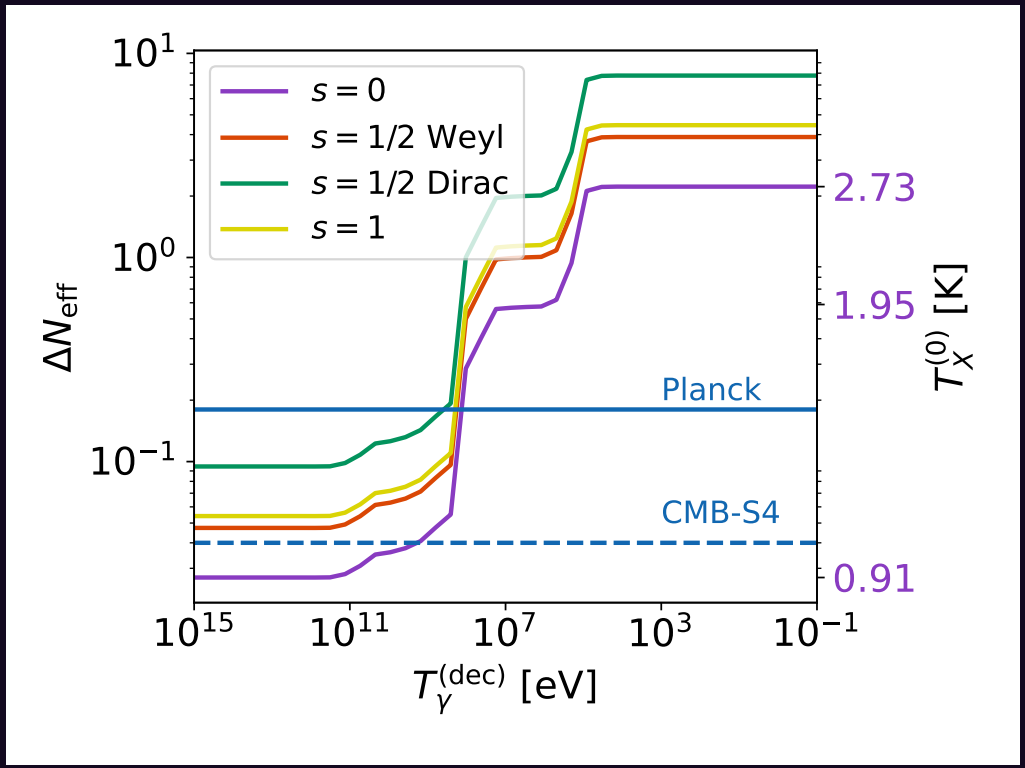
Light but Massive Relics

- Mass m_X
- (present-day) Temperature $T_X^{(0)}$
- Thermalized dofs g_X

LiMRs : the Light part

$$g_{*S}^{(dec)} \propto (T_X^0)^{-3}$$



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

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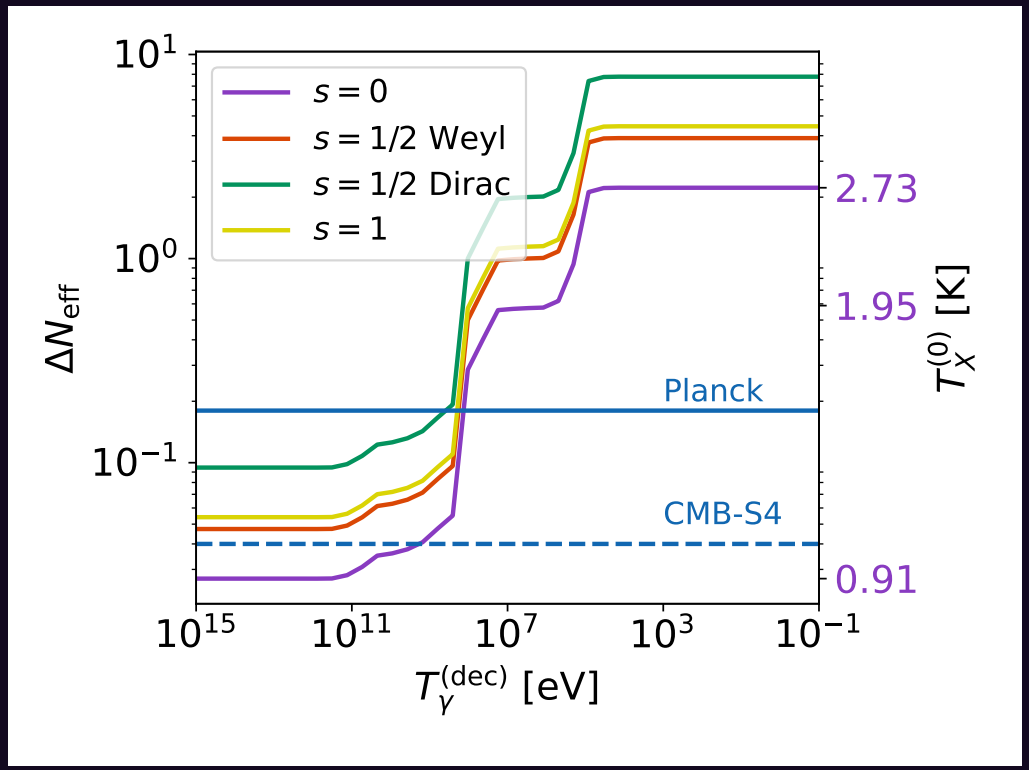
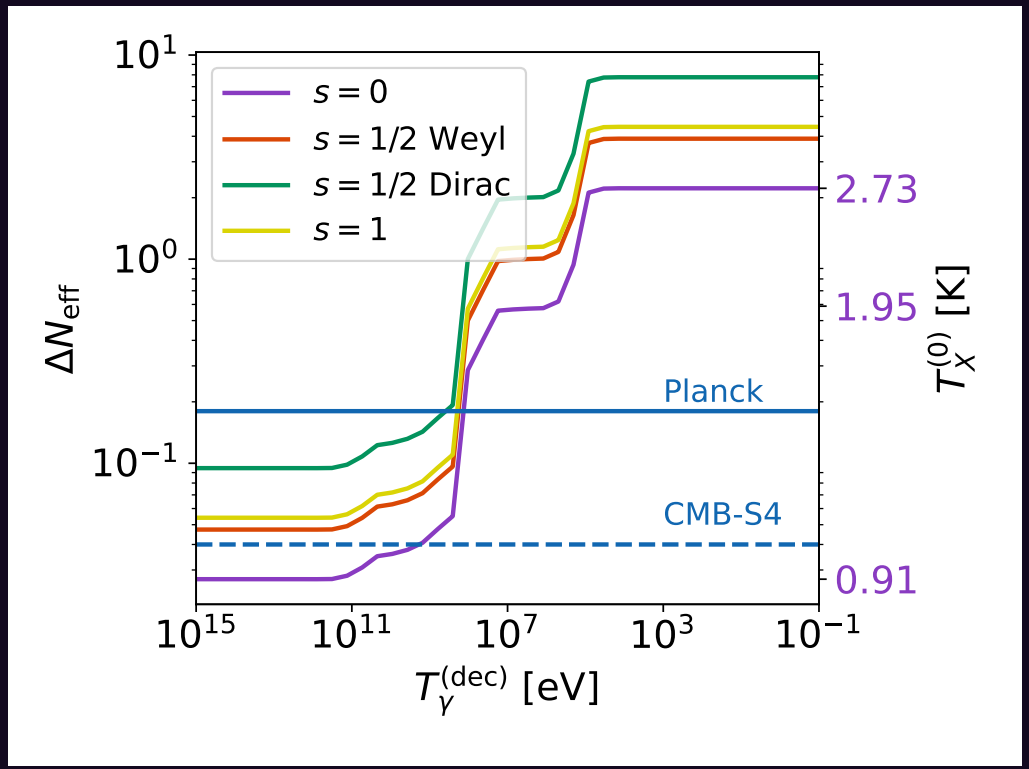


Minimal extensions $\Longrightarrow$ $T_X^0 \geq 0.91$ K.

[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

LiMRs : the Light part

$$\Delta N_{\rm eff} \propto g_X (T_X^0)^4$$



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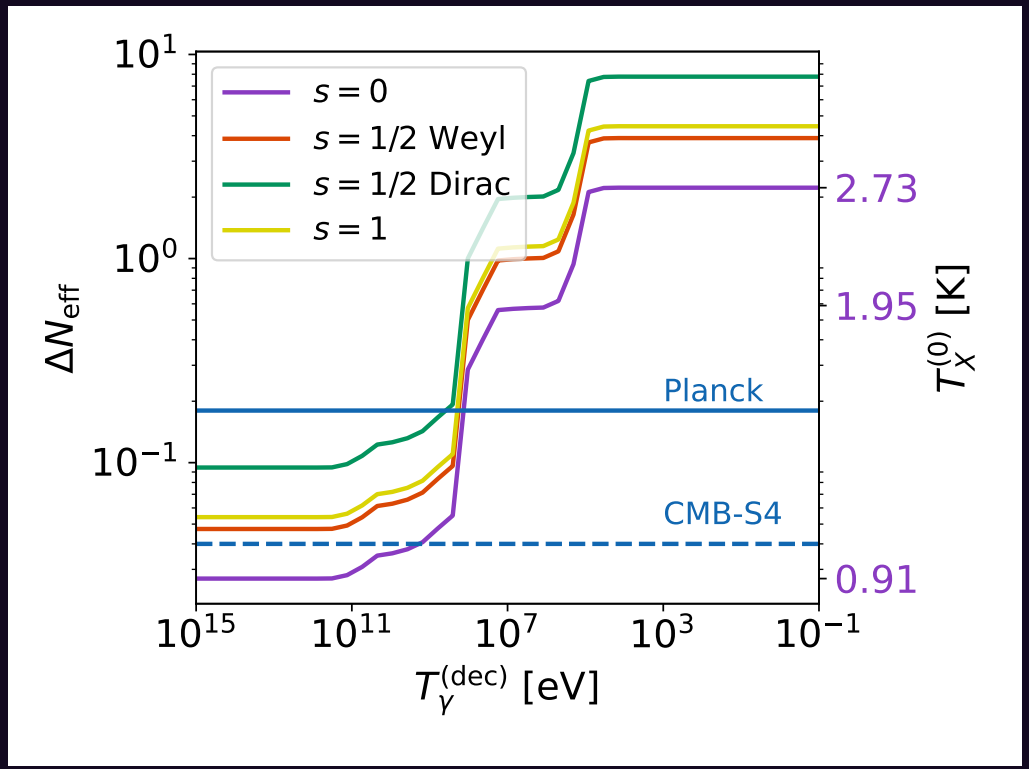

Planck $\Delta N_{\rm eff} \leq 0.36 \implies T^0_{\rm Weyl} \leq 1.5$ K

CMB-S4 $\Delta N_{\rm eff} \leq 0.06 \implies T^0_{\rm Weyl} \leq 0.96$ K

[95% CL]

[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

LiMRs : the Massive part

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$$\omega_X \propto g_X m_X (T_X^{(0)})^3$$

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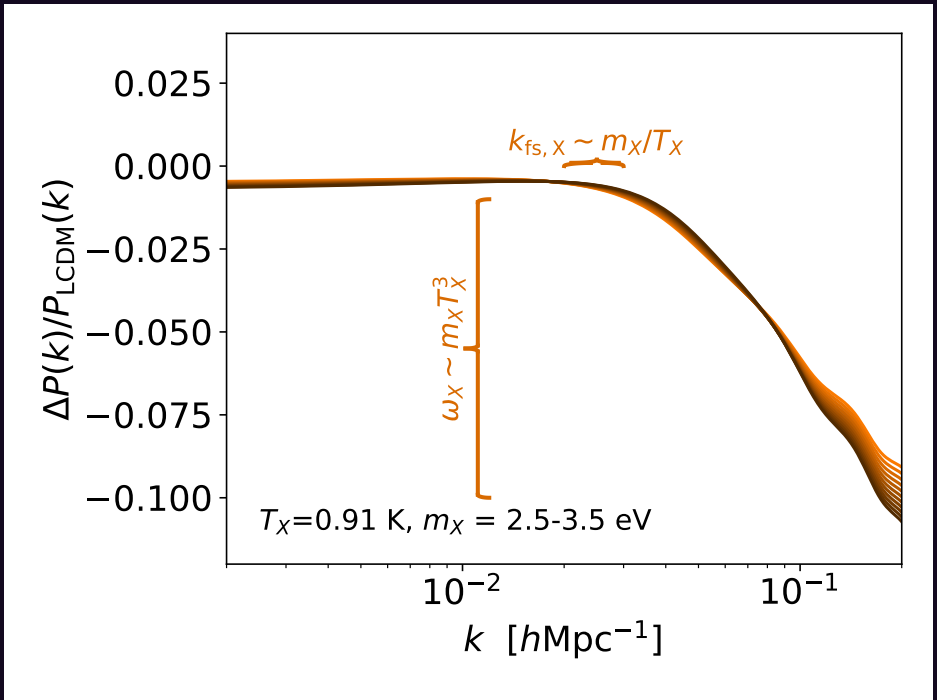
$$\omega_X \propto g_X m_X (T_X^{(0)})^3 \qquad k_{\mathrm{fs},X} \propto \frac{m_X/T_X^{(0)}}{\sqrt{1+z}}$$

LiMRs : the Massive part

Stuff that clusters $\leftrightarrow$ Stuff that expands

Neutrinos & LiMRs



[WLX, Mũnoz, Dvorkin 2107.09664]

Data/Experiments

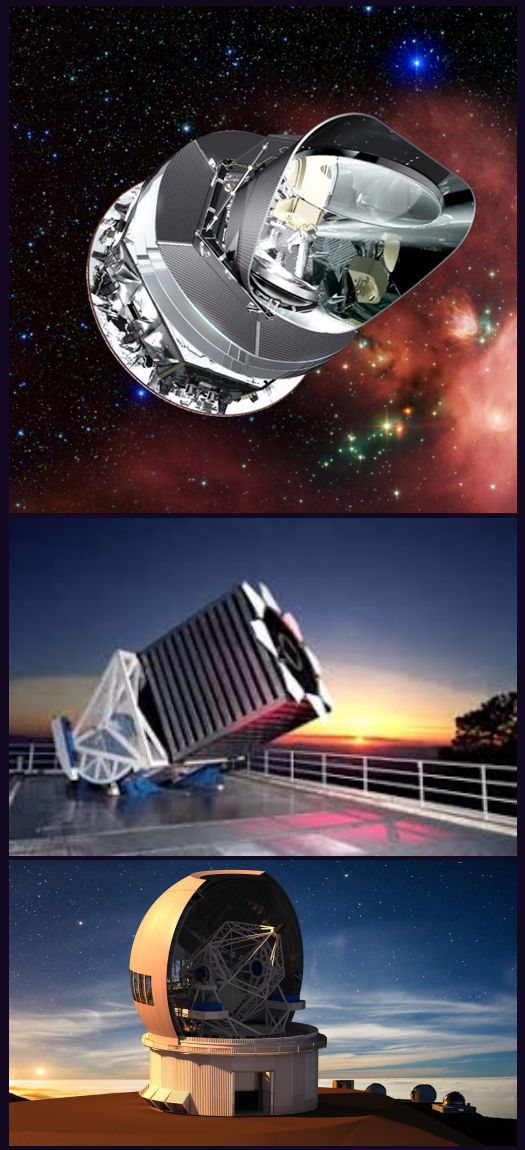
- Markov Chain Monte Carlo

  $\{\omega_b, \omega_{cdm}, h, n_s, A_s, \tau, \sum m_\nu\}$

  $+\{m_X, T_X^{(0)}\}$

- {Scalar, Weyl, Vector, Dirac}

- Planck 2018 TT+TE+EE +Lensing
- CFHTLens
- BOSS DR 12 (CLASS-PT)



[Chudaykin, Ivanov, Philcox, Simonović, 2004.10607]

Results

So, are there LiMRs in our universe?

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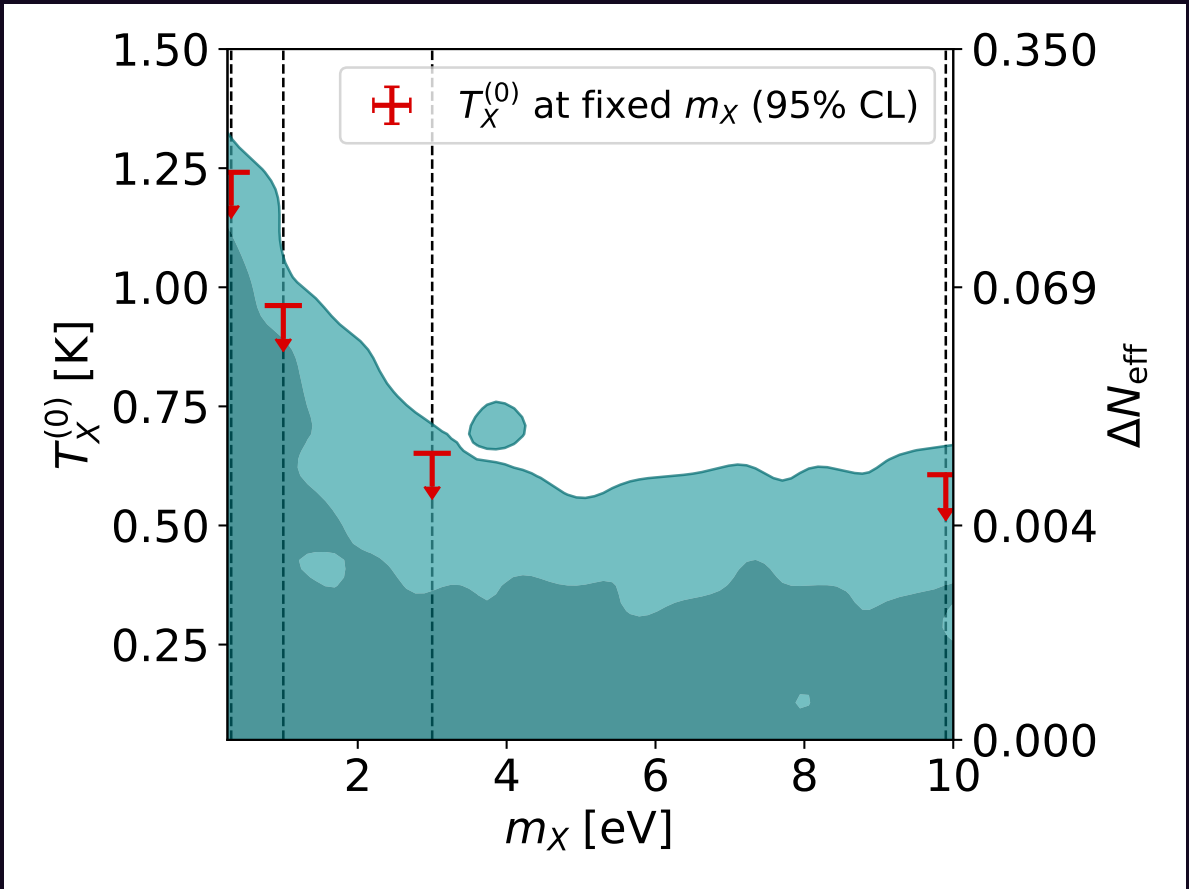
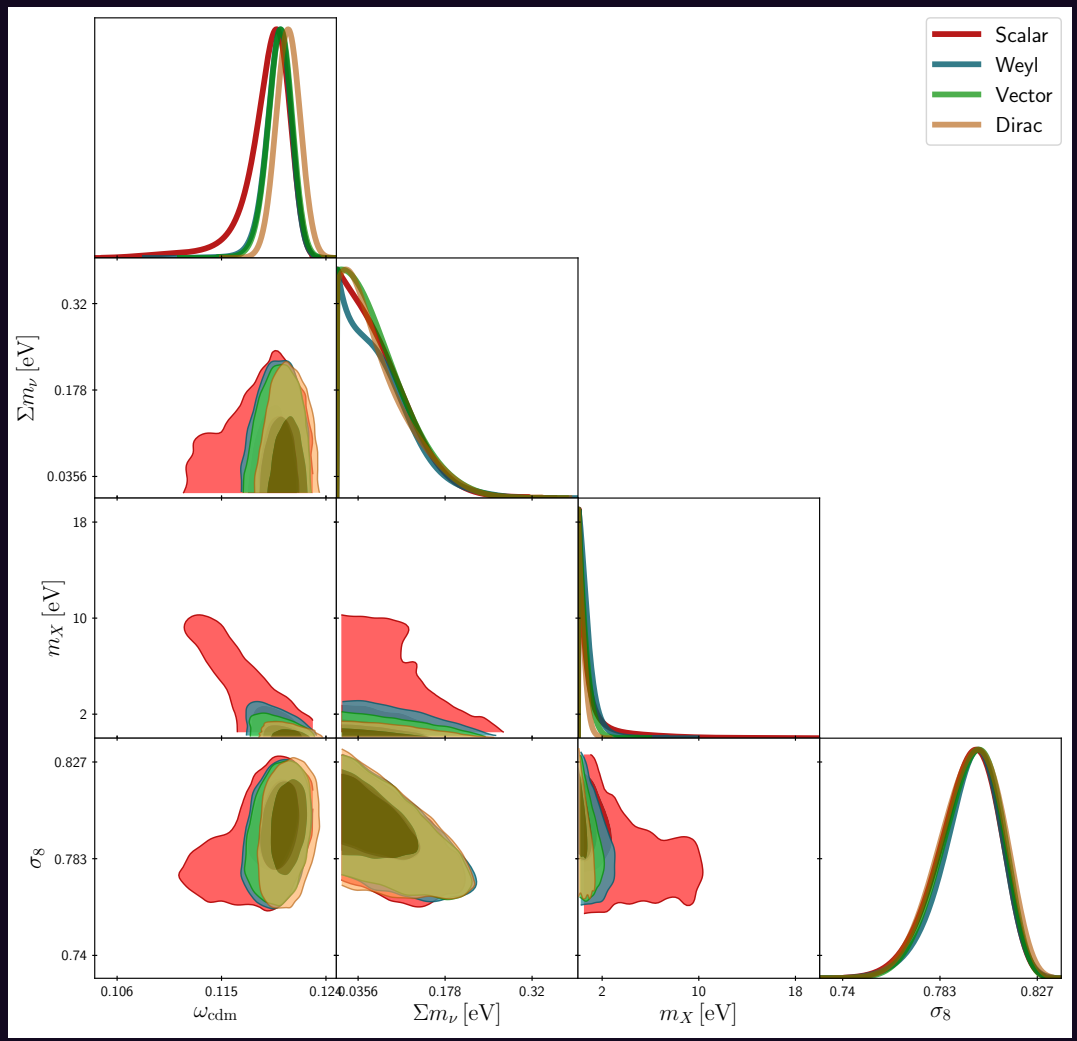


[WLX, Mũnoz, Dvorkin 2107.09664]

Results

$$T_X = 0.91\ \mathrm{K}$$

m_X (95% CL)	
Scalar	11.2 eV
Weyl	2.26 eV
Vector	1.58 eV
Dirac	1.06 eV



[WLX, Mũnoz, Dvorkin 2107.09664]

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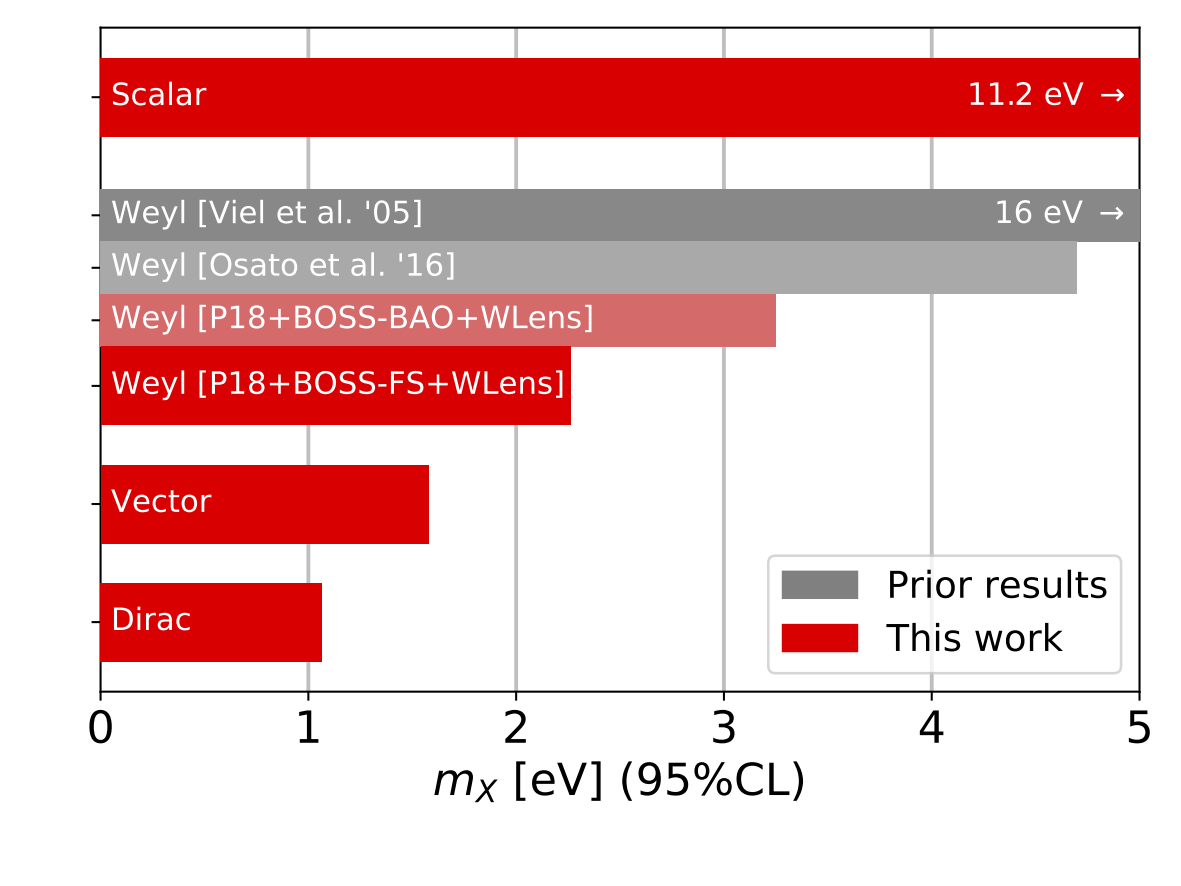


[WLX, Mũnoz, Dvorkin 2107.09664]

Results
& what we can learn from it

Light gravitinos in gauge-mediated SUSY breaking

$$m_X = \frac{\Lambda^2}{\sqrt{3} M_{pl}}, \quad T_X = 0.91 \text{ K}, \quad g_{X,\text{eff}} = 2$$

$$m_X \leq 2.26 \text{ eV} \implies \Lambda \leq 69.1 \text{ TeV}$$

Results
& where we've landed

Dark sectors are worth studying, in whole or in part

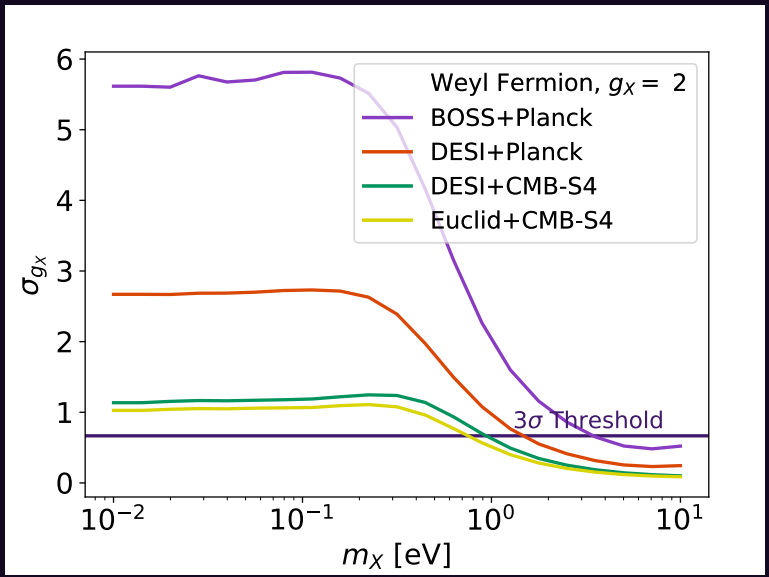
- There are reasons to care about LiMRs
- If so, cosmological data is uniquely powerful
- The first set of comprehensive constraints

Results
& where we're going next

Better data coming soon!

$T_X = 0.91$ K

m_X (95% CL)		
	BOSS + Planck	DESI + S4
Scalar	11.2 eV	0.94 eV
Weyl	2.26 eV	0.58 eV
Vector	1.58 eV	–
Dirac	1.06 eV	–



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

Thank you!

[Estella Lin, 2021]