Title: Thermal Dark Sectors in the Early and Late Universe

Speakers: Linda Xu

Series: Particle Physics

Date: December 01, 2020 - 1:00 PM

URL: http://pirsa.org/20120013

Abstract: One of the puzzles that the newly data-rich fields of cosmology and astrophysics are most advantaged to tackle is the nature of the dark sector. In particular, a dark sector that thermalizes with the SM bath at some epoch has present-day observable properties that are directly tied to early-universe interactions. In this talk I survey some recent work on detecting different types of thermal dark particles by leveraging different cosmological and astrophysical datasets. I discuss the utility of each of these different probes, the implication for particle theories, and prospects for the future.

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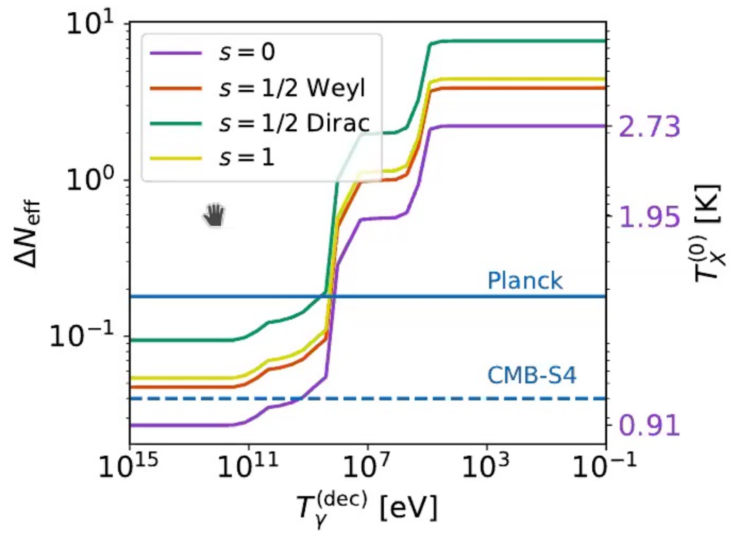
Model Assumptions

Free Parameters: $\{m_X, T_X^{(0)}, g_X\}$

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



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

[redacted]

Why Large-Scale Structure

Google Chrome
BSM PANDEMIC: Oops all Job Talks
calendar.google.com
2pm – 3pm
Activate Settings

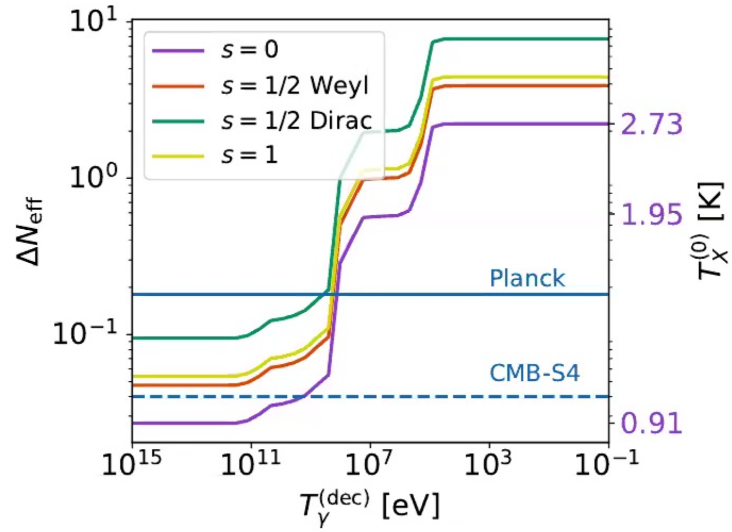
- LSS has modes that CMB does not
- Relatively late transition between radiation & matter
- Cosmological abundance of radiation
- Impact of matter [during matter domination]
- Doesn't require much abundance or *any* present-day interactions

[redacted]

Key Quantities

- While relativistic, contributes to ΔN_{eff}

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



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

Key Quantities

- Transition from radiation to matter $\rightarrow$ free-streaming $k_{\mathrm{fs},X}$

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

Key Quantities

- As matter today, present-day abundance ω_X

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

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- As matter today, present-day abundance ω_X

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

Non-relativistic today $\Longrightarrow$ $m_X \gtrsim 0.1$ meV
Overclosure $\omega_X < \omega_{cdm}$ $\Longrightarrow$ $m_X < 100$ eV for X Weyl

Imprint on Large-Scale Structure

Galaxies are biased tracers of clustering matter

$$P_g \propto b \cancel{P_m} P_{cb}(k, z) \qquad \delta_m = \delta_{cb} + \delta_\nu + \delta_X$$

Stuff that clusters ↔ Stuff that expands

Neutrinos & LiMRs

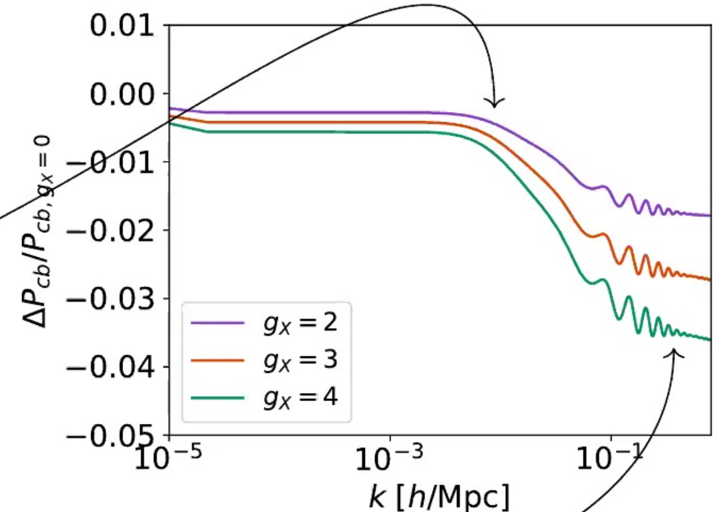
[redacted]

Imprint on matter fluctuations

Stuff that clusters ↔ Stuff that expands

Neutrinos & LiMRs

- Structure suppressed at small scales
- Scale $\propto k_{fs,X}$
- Amplitude $\propto \omega_X/\omega_m$



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

Imprint on the halo bias

Stuff that clusters ↔ Stuff that expands

Neutrinos & LiMRs

- Growth-Induced Scale Dependent Bias (GISDB)

$$b(k,z) = 1 + b_L(z)\ f(k,z)$$

[RelicCLASS: github.com/wlxu/RelicClass]

[RelicFast: github.com/JulianBMunoz/RelicFast]

Imprint on the halo bias

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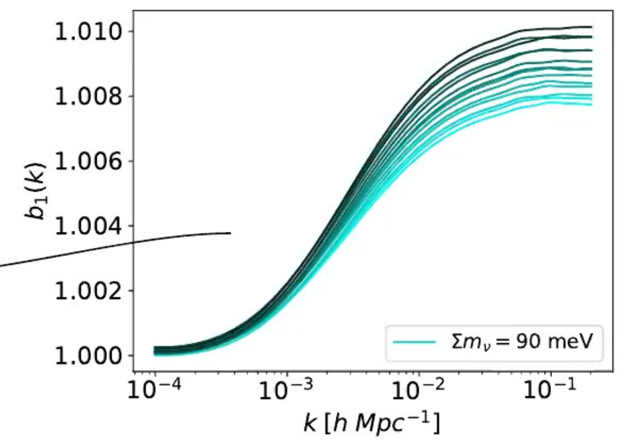
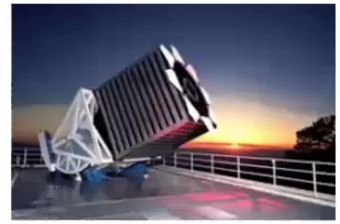


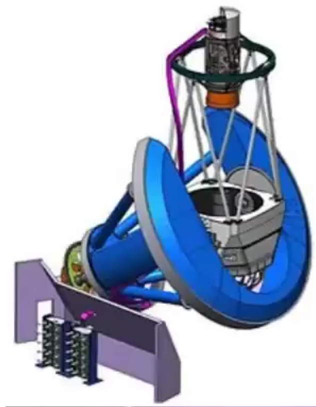
[RelicCLASS: github.com/wlxu/RelicClass]

[RelicFast: github.com/JulianBMunoz/RelicFast]

[redacted]

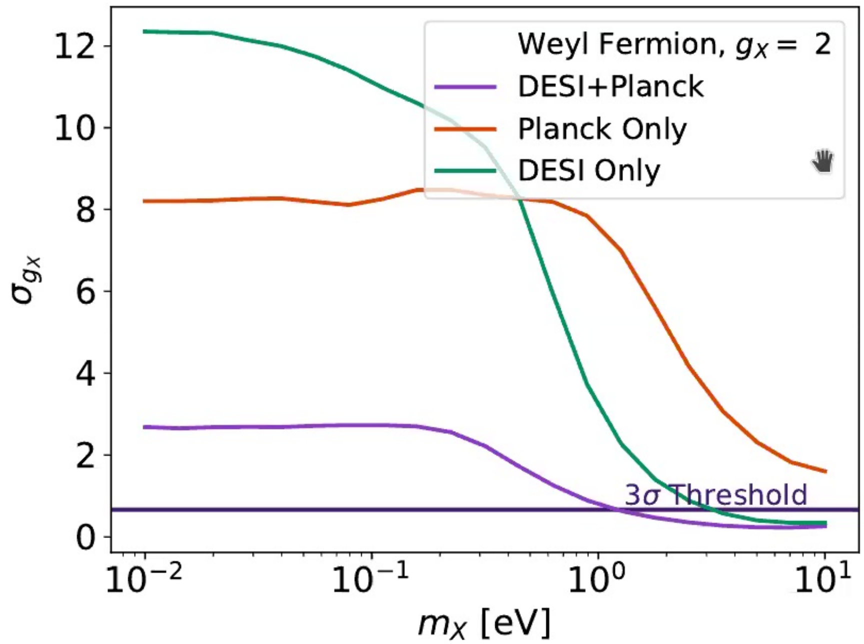
Data/Experiments





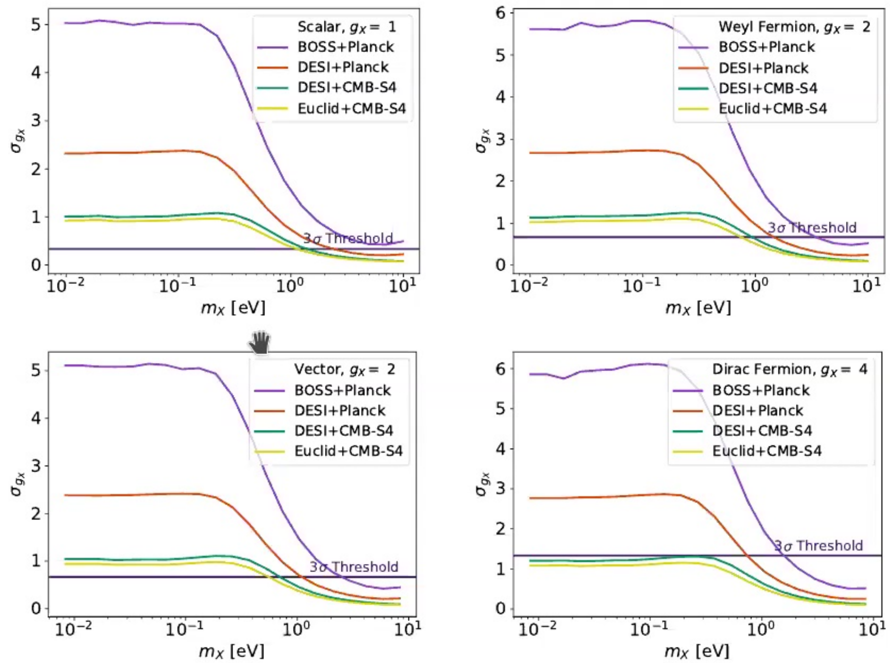
- Planck, CMB-S4 $+\tau$
- LSS single tracers
  - BOSS
    $\mathcal{O}(100)/\Delta z/$deg^2 LRGs
  - DESI
    $\mathcal{O}(1000)/\Delta z/$deg^2 ELGs
  - Euclid
    $\mathcal{O}(5000)/\Delta z/$deg^2 H$\alpha$s

Detection Prospects: $\{m_X\}$



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380, Minimal temperature $T_X = 0.91$ K]

Detection Prospects: $\{m_X, g_X\}$



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

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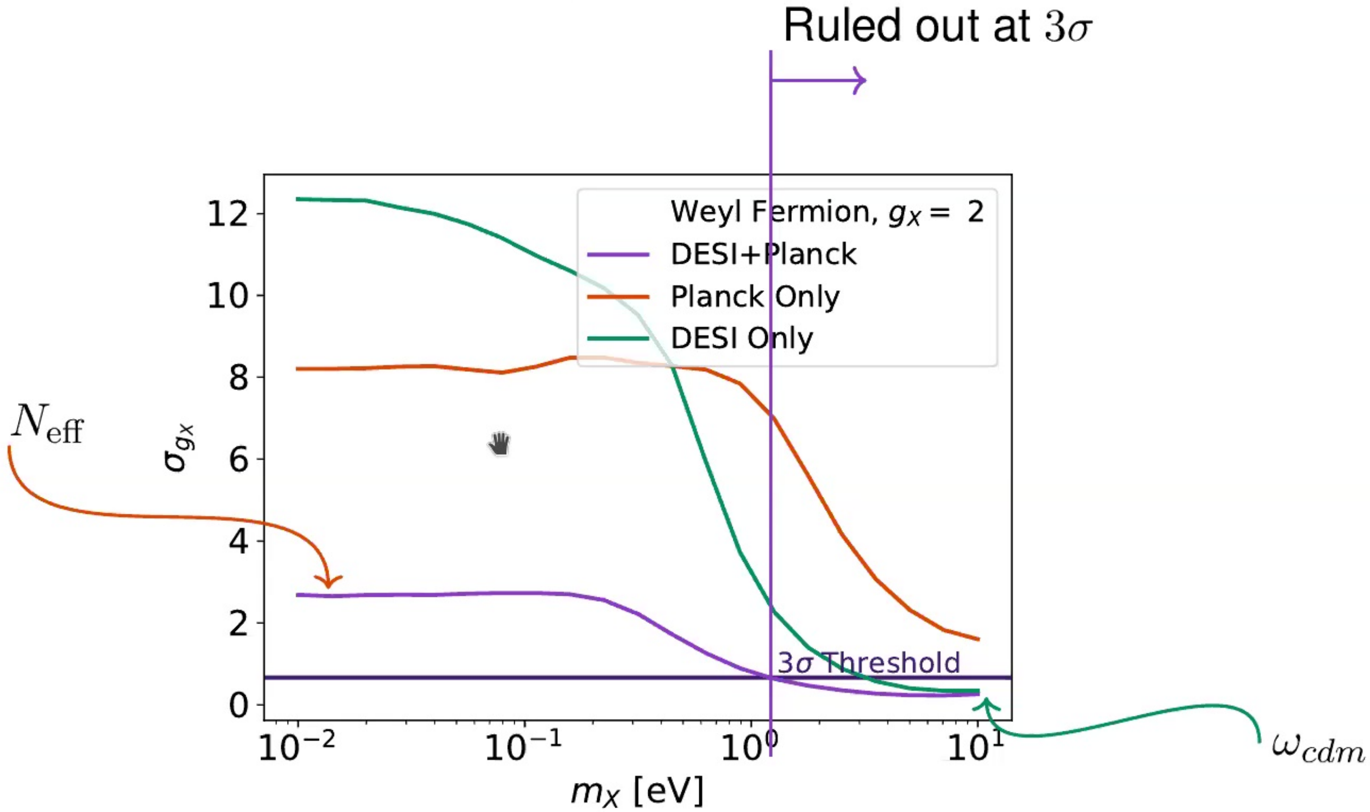

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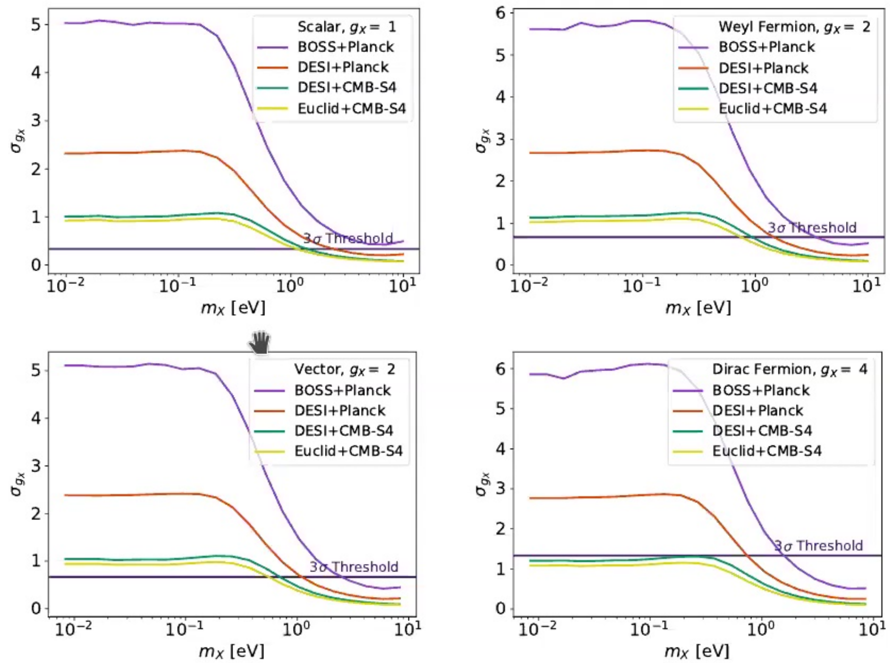
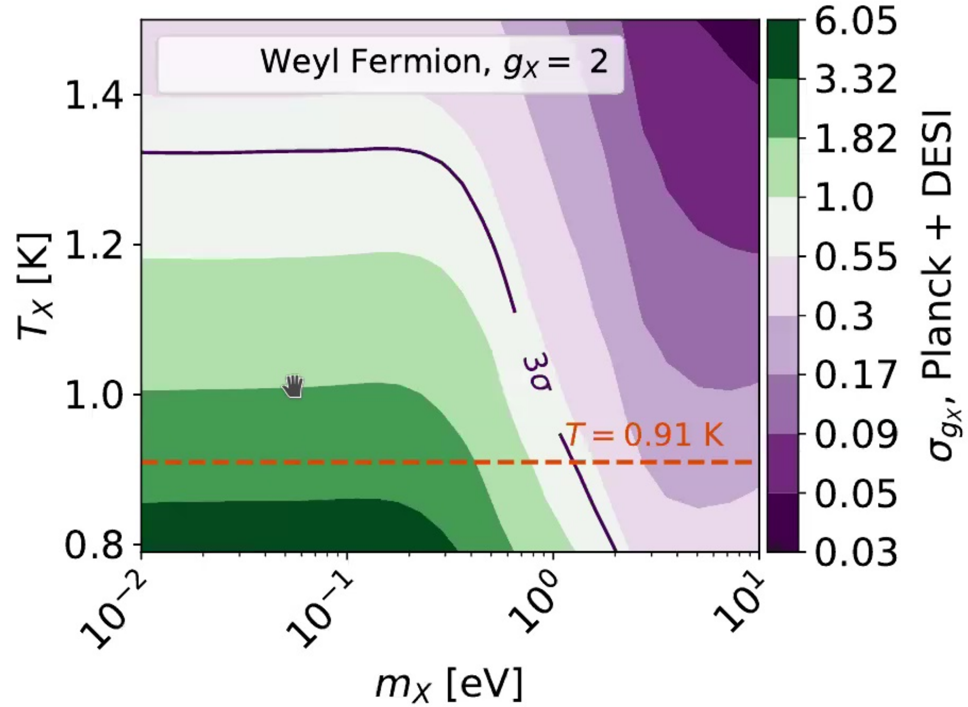


[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

Detection Prospects: $\{m_X, T_X\}$



[Deporzio, WLX, Mũnoz, Dvorkin 2006.09380]

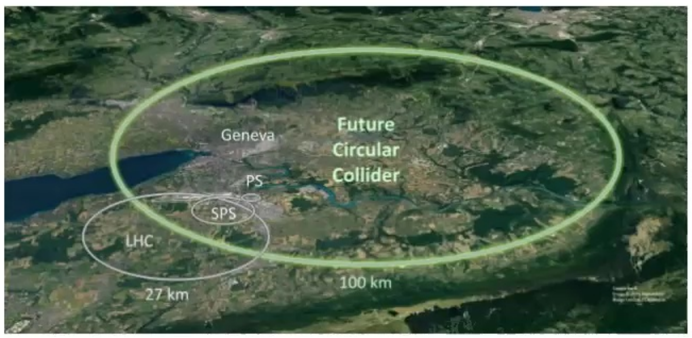
Complementarity

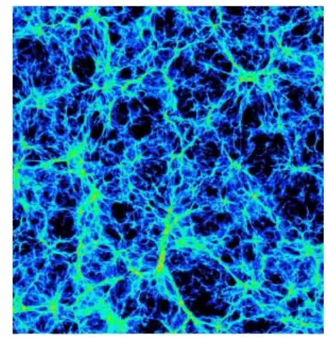
Light gravitinos in gauge-mediated SUSY breaking

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

$$m_X \leq 3 \text{ eV} \implies \Lambda \lesssim 80 \text{ TeV}$$

Compare with FCC reach: $\Lambda \gtrsim 100$ TeV





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Wrap-Up

- There are reasons to care about LiMRs
- If so, LSS is probably the arena with most information
- Significant constraints with DESI/Euclid + S4
- Nontrivial constraints with BOSS +Planck

Overall Landing Points

Dark matter could be anything and come from anywhere

- Thermal dark sectors are important
- Search for properties rather than models
- Examine each aspect separately
- Sythesize information over a span of cosmic history

Specifically

- Cosmic ray $\bar{d}$ for thermal relic/GCE candidates
- CMB for strong elastic scattering
- LSS for LiMRs

are promising avenues for probing dark sector physics

Thank you!