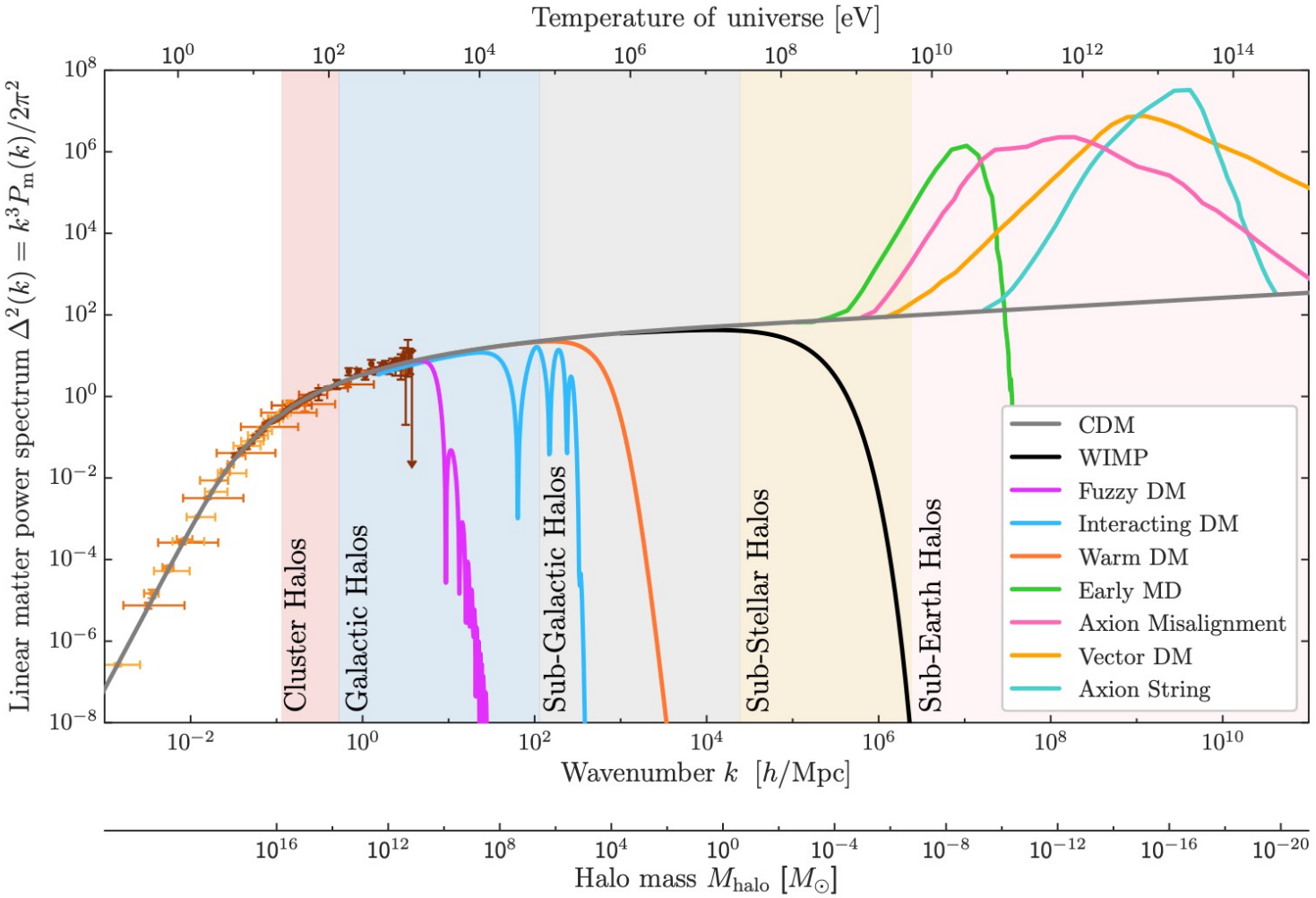
Dark matter and neutrino probes across scales

Vera Gluscevic

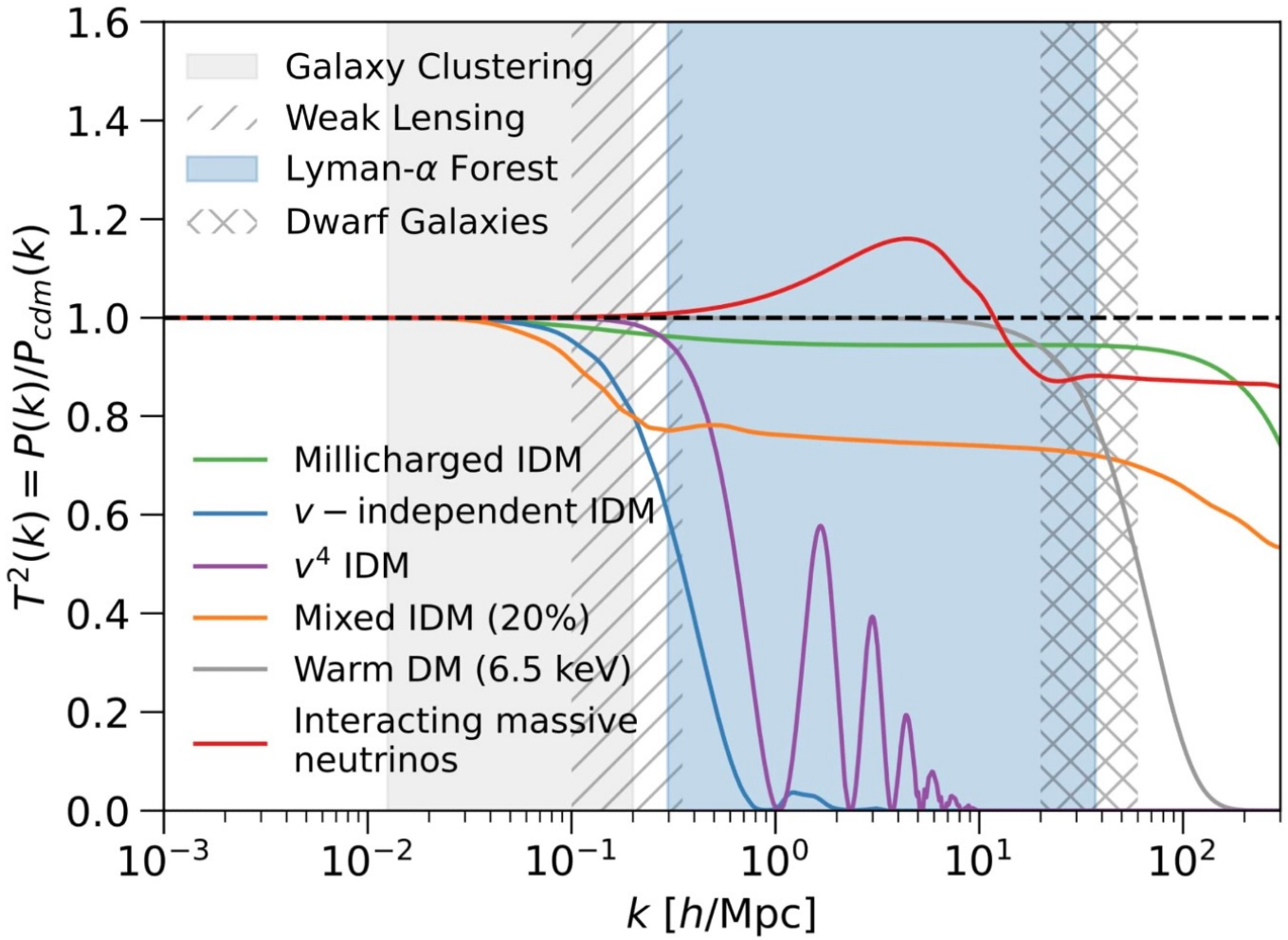
University of Southern California

What's the right solution – across scales?



Snowmass Cosmic Frontier
2023 Report

What's the right solution – across scales?

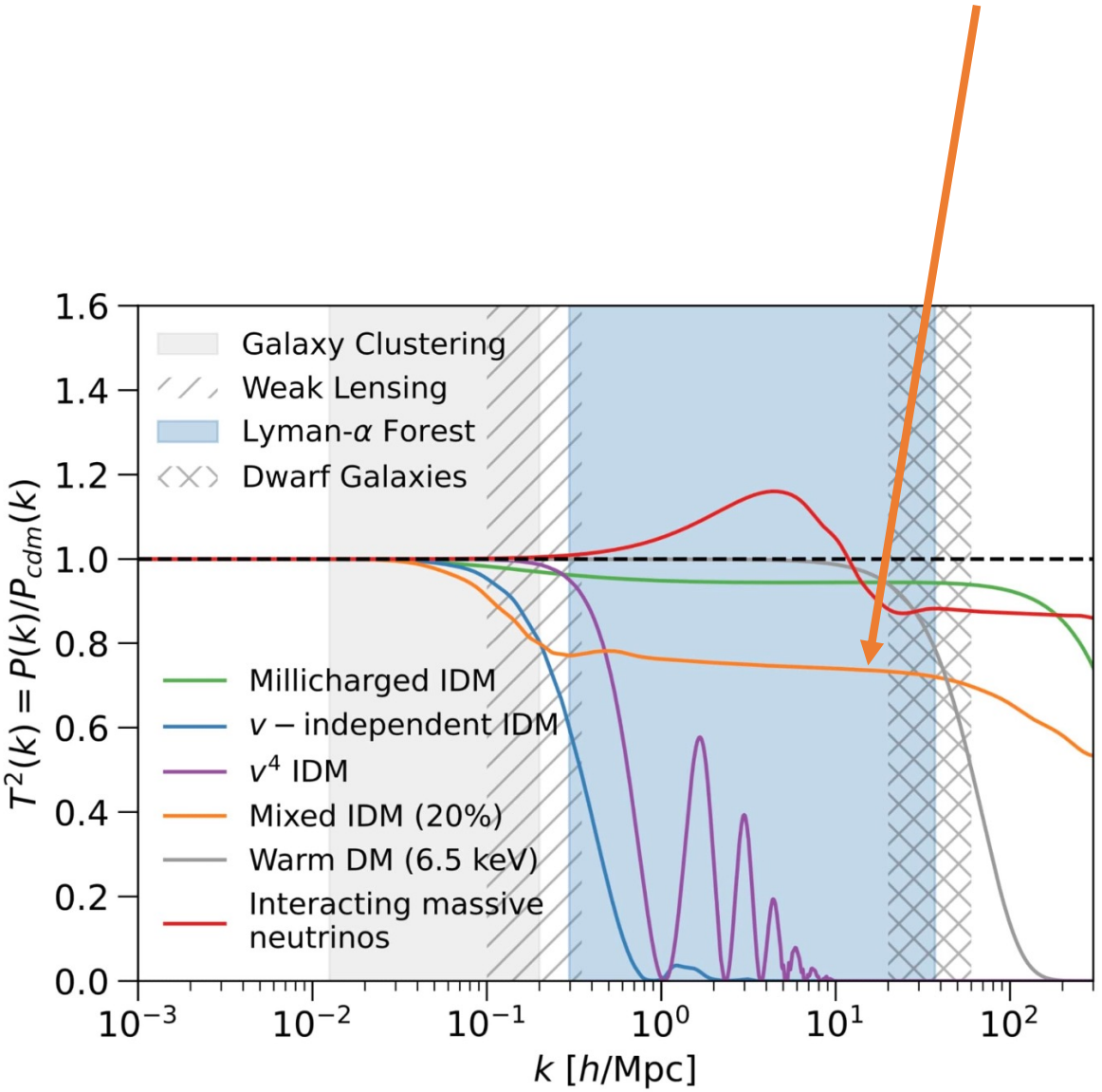


Plot by A. He

Dark matter and neutrino physics

$\sigma_{MT} = \sigma_0 v^n$

Example 1: mixed DM elastically scattering with protons.



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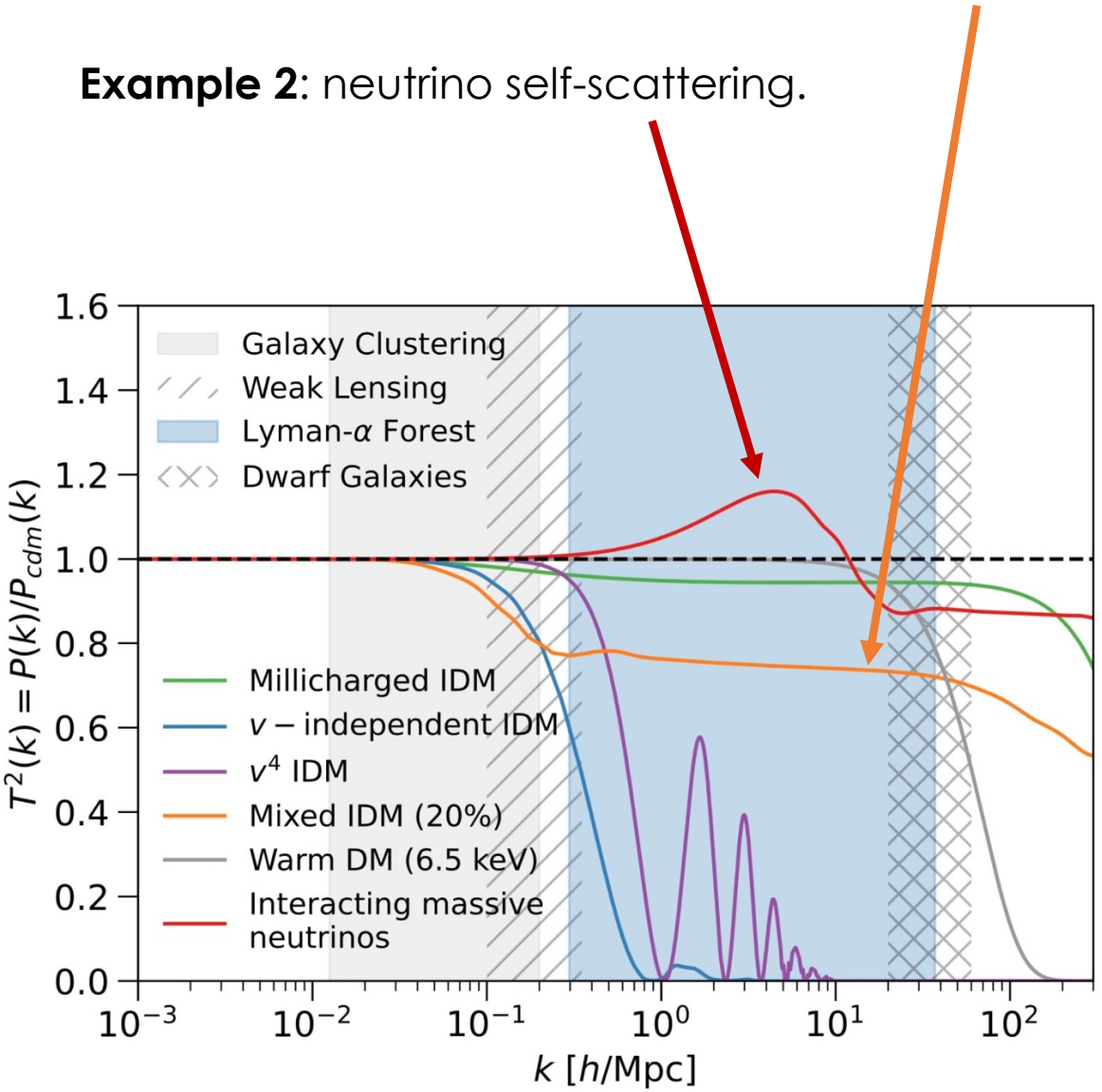
Dark matter and neutrino physics

$\sigma_{MT} = \sigma_0 v^n$

$\mathcal{L}_{\rm int} = g_{ij}\bar{\nu}_i\nu_j\varphi$

Example 1: mixed DM elastically scattering with protons.

Example 2: neutrino self-scattering.



Plot by A. He

Dark matter and neutrino physics

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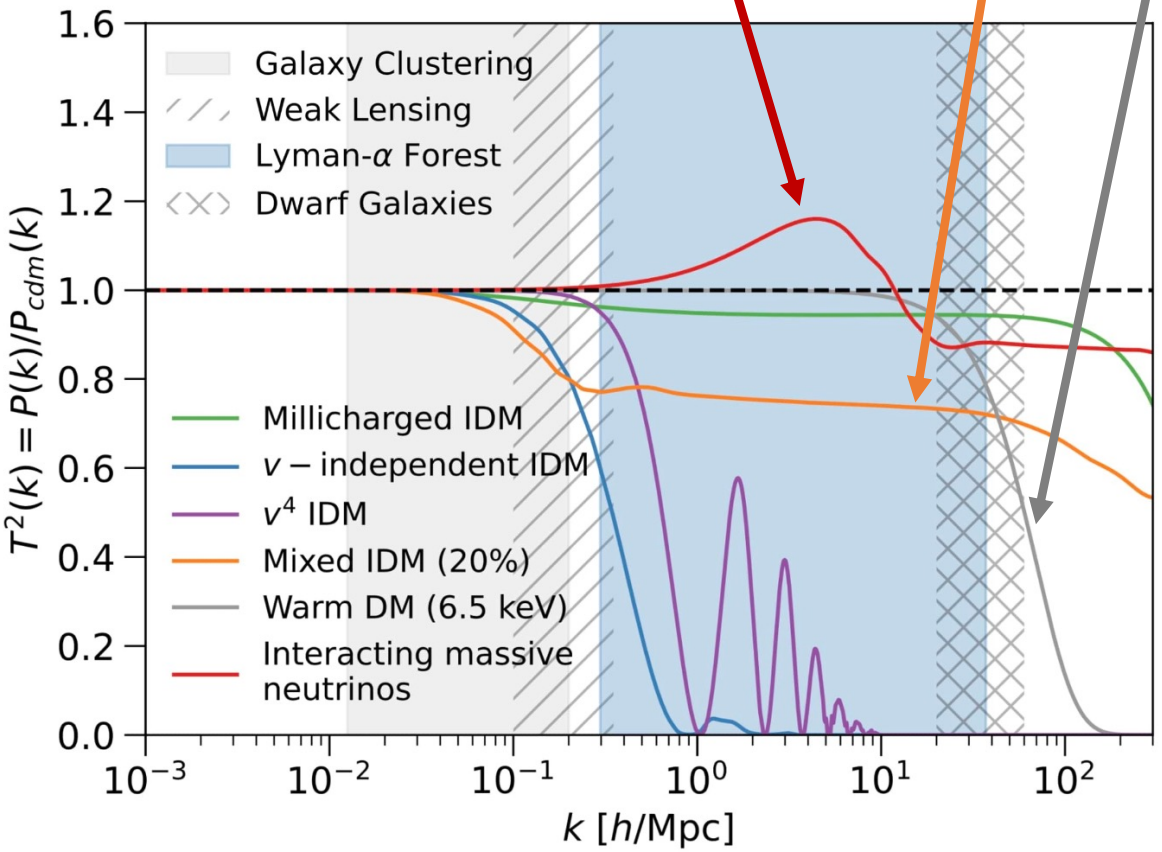
Example 1: mixed DM elastically scattering with protons.

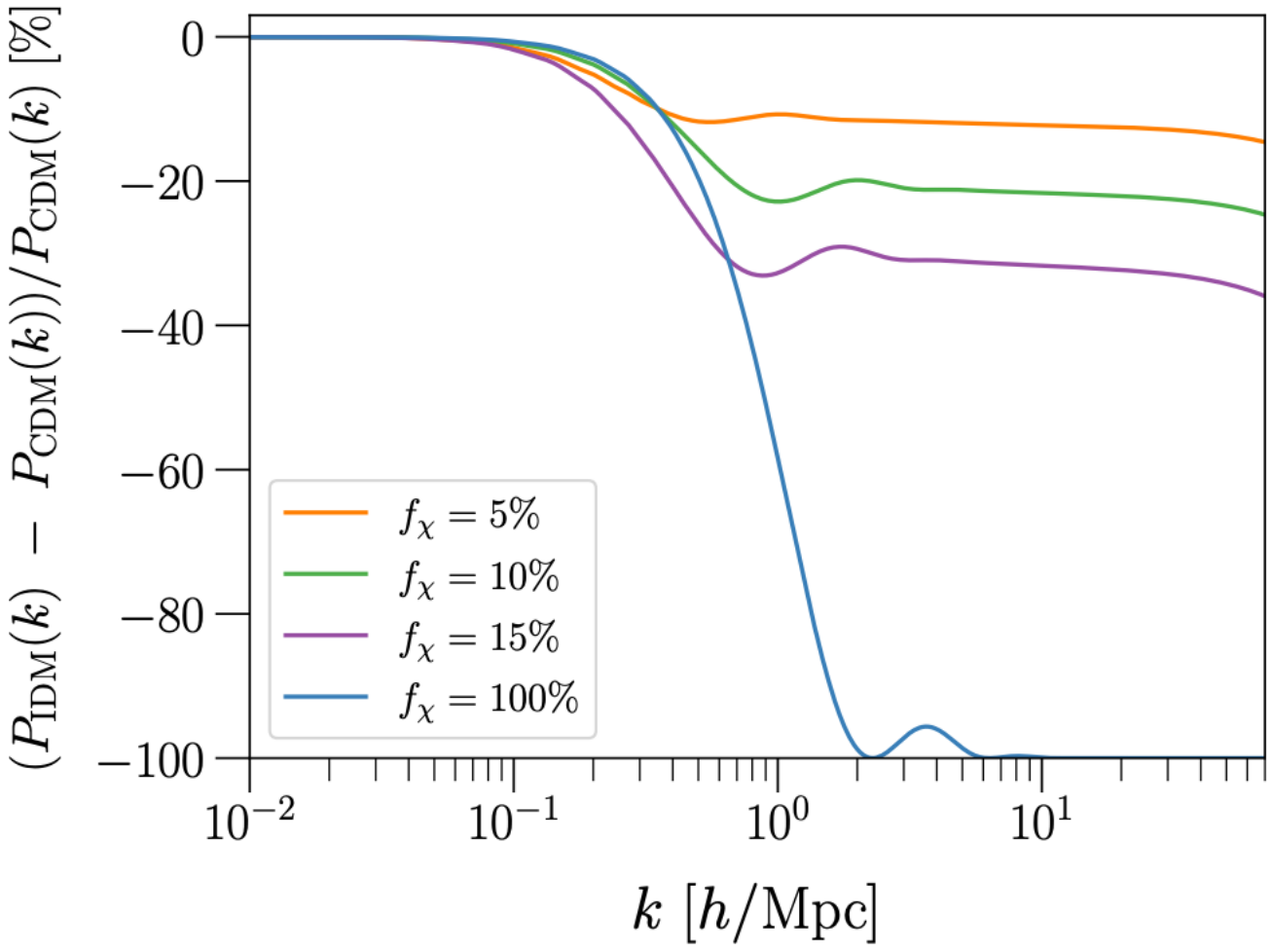
Example 2: neutrino self-scattering.

Example 3: warm, non-thermal relic (sterile neutrino)



Plot by A. He

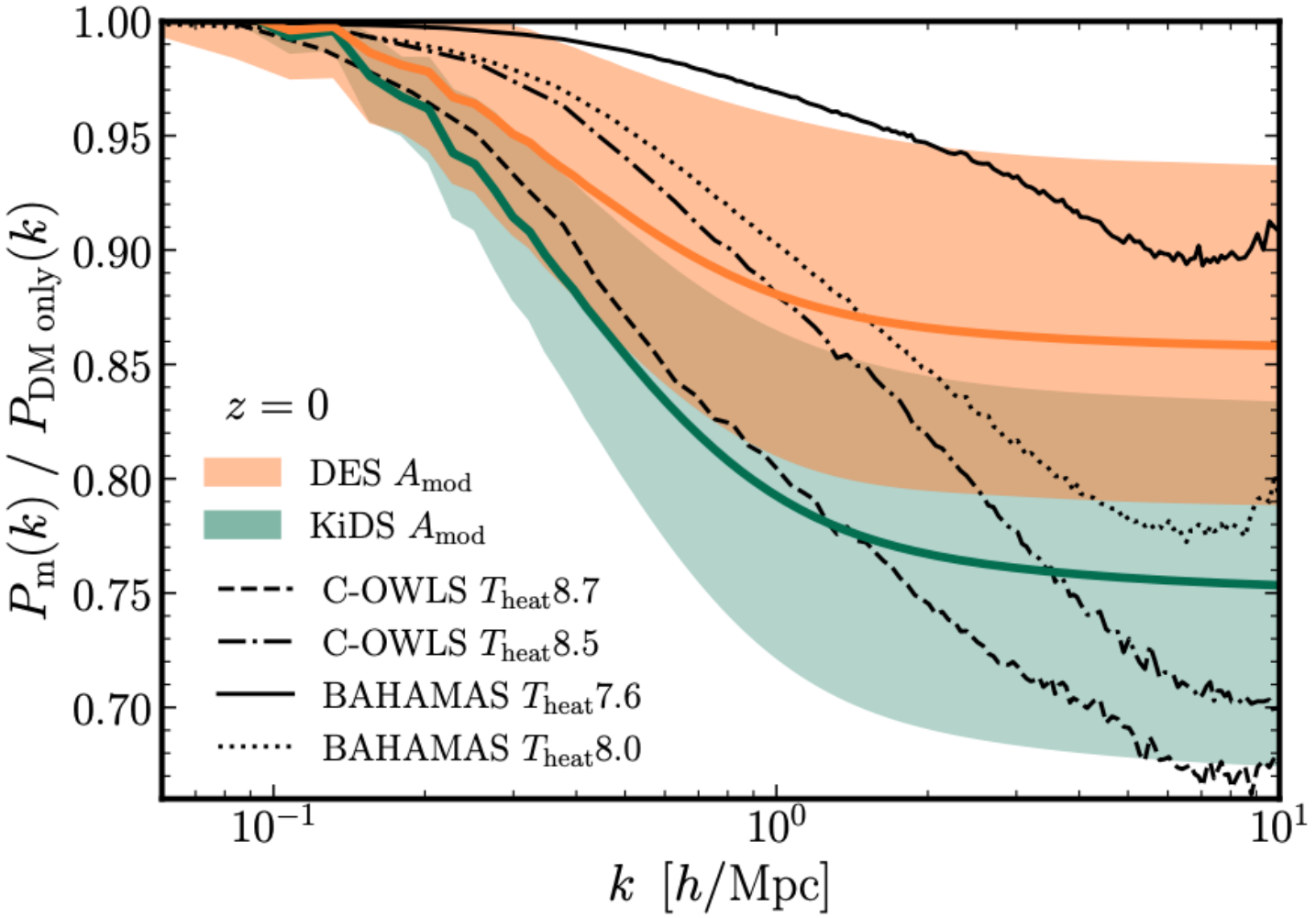
Example 1: Mixed interacting DM (scattering with protons)



$\sigma_{MT} = \sigma_0 v^n$

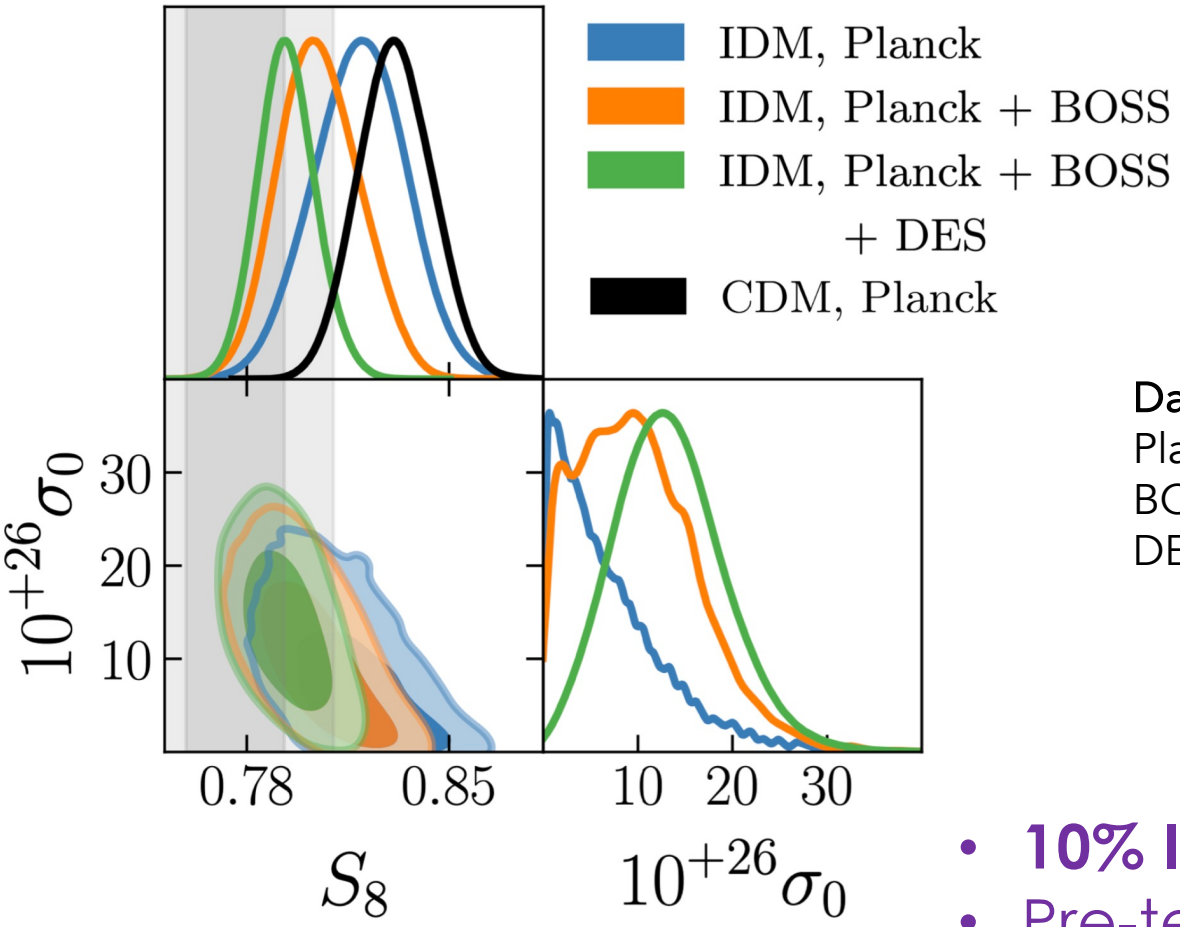
He, Ivanov, An, Gluscevic (2023)

S8 tension = k-dependent suppression?



Amon and Efstathiou 2023

Example 1: Mixed interacting DM (scattering with protons)



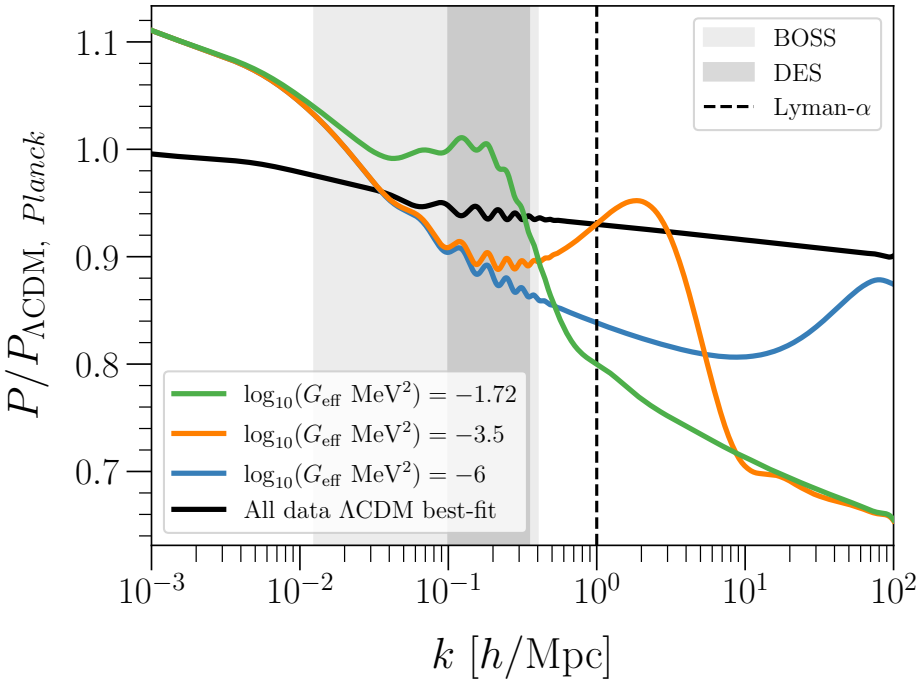
Adam He

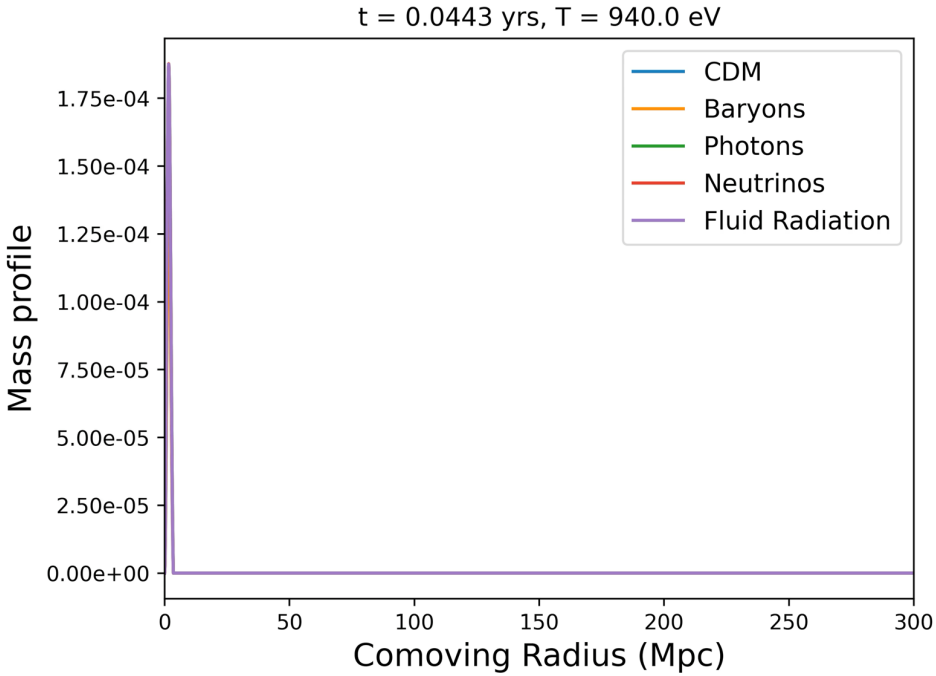
Data:
Planck primary and lensing
BOSS galaxy clustering (full-shape)
DES weak lensing S8 prior

- **10% IDM alleviates S8 tension**
- Pre-tension physics
- Consistent across data
- Soon/already falsifiable?

He, Ivanov, An, Gluscevic (2023)

Example 2: Self-interacting neutrinos





$$\Gamma_\nu \propto G_{\rm eff}^2 T_\nu^5$$

$$\mathcal{L}_{\rm int} = g_{ij}\bar{\nu}_i\nu_j\varphi$$

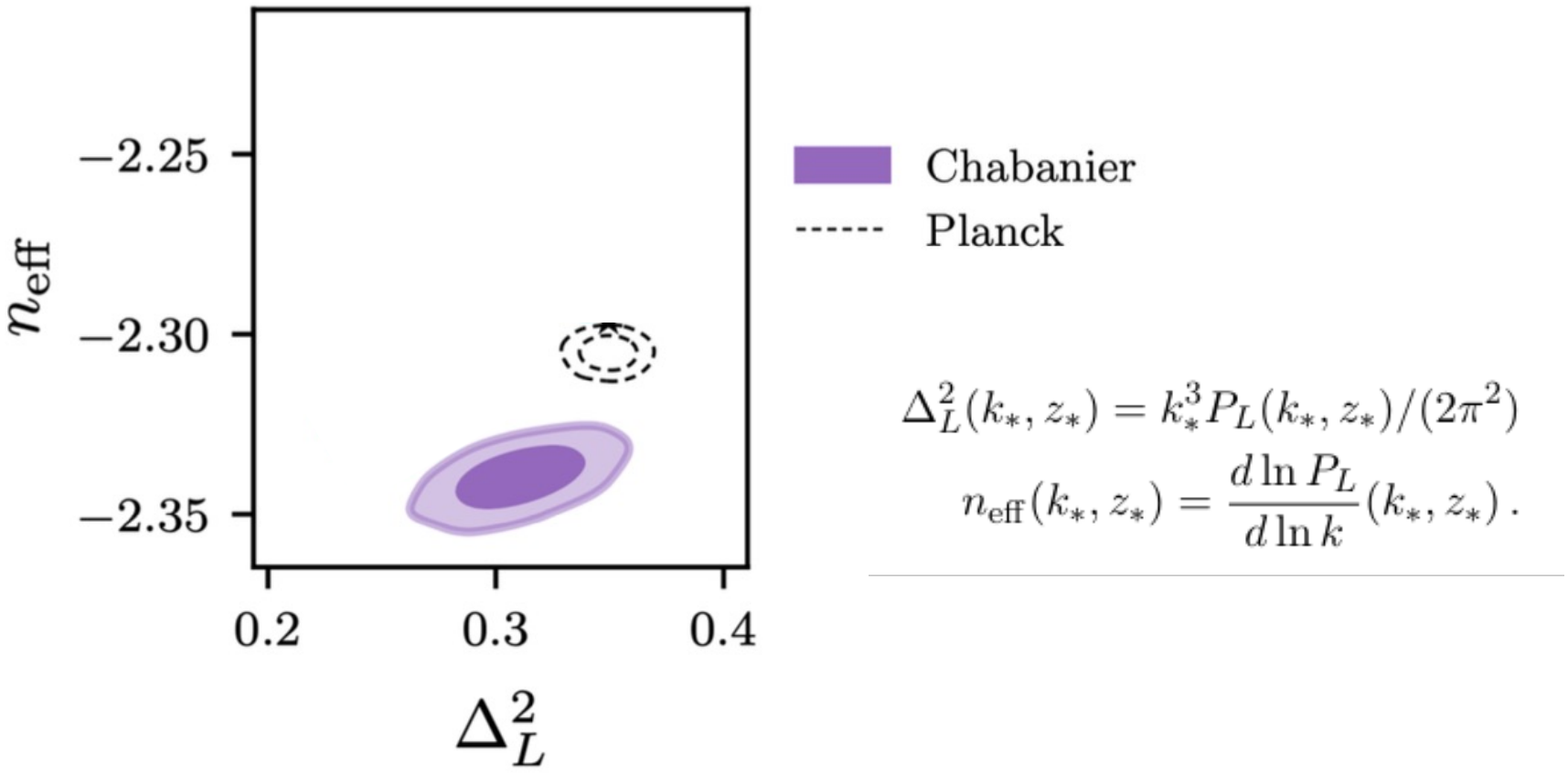
Plot by Murali Saravanan (UW)

Bassett & Hlozek 2009
Eisenstein et al. 2007
See also: Brinckmann+ 2020, Loverde+ 2022
Berryman+ 2022; Kreisch+ 2020;
Ivanov 2024, Bird+ 2024.

Reduced Lyman-alpha likelihood: **a fresh look**

He, Ivanov, Bird, VG (2503.15592)

(See also Ivanov 2024, Bird+ 2024)



$$\Delta^2_L(k_*, z_*) = k_*^3 P_L(k_*, z_*)/(2\pi^2)$$

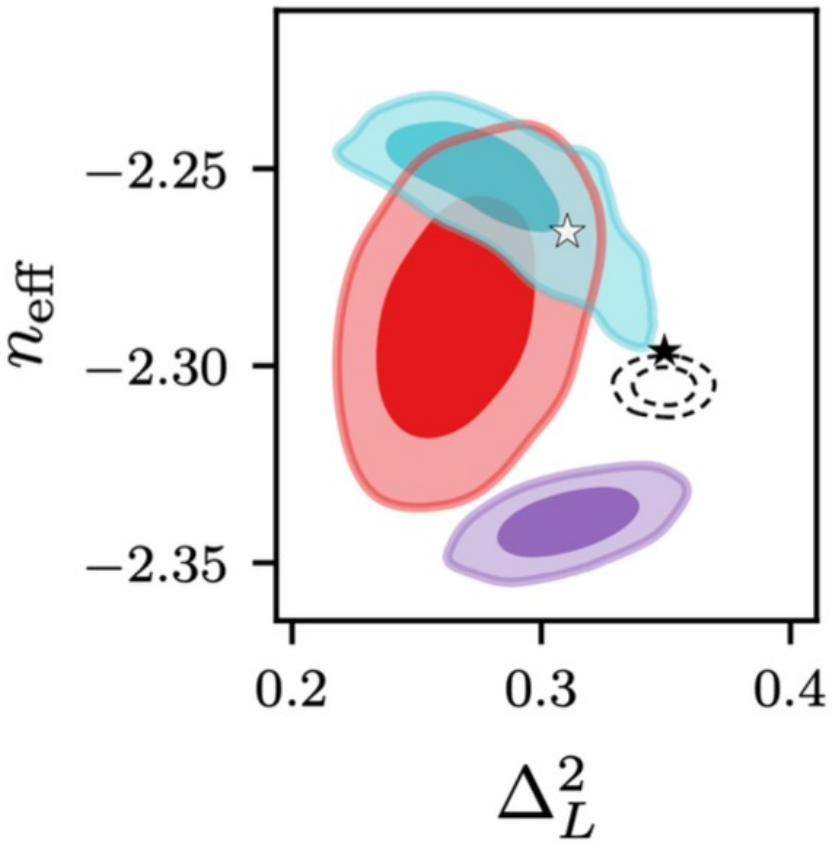
$$n_{\rm eff}(k_*, z_*) = \frac{d\ln P_L}{d\ln k}(k_*, z_*)\,.$$

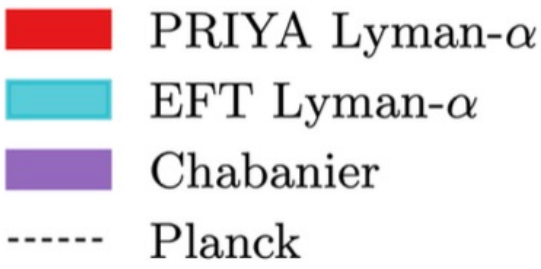
eBOSS Lya likelihood was in tension with Planck.

Reduced Lyman-alpha likelihood: **a fresh look**

He, Ivanov, Bird, VG (2503.15592)

(See also Ivanov 2024, Bird+ 2024)





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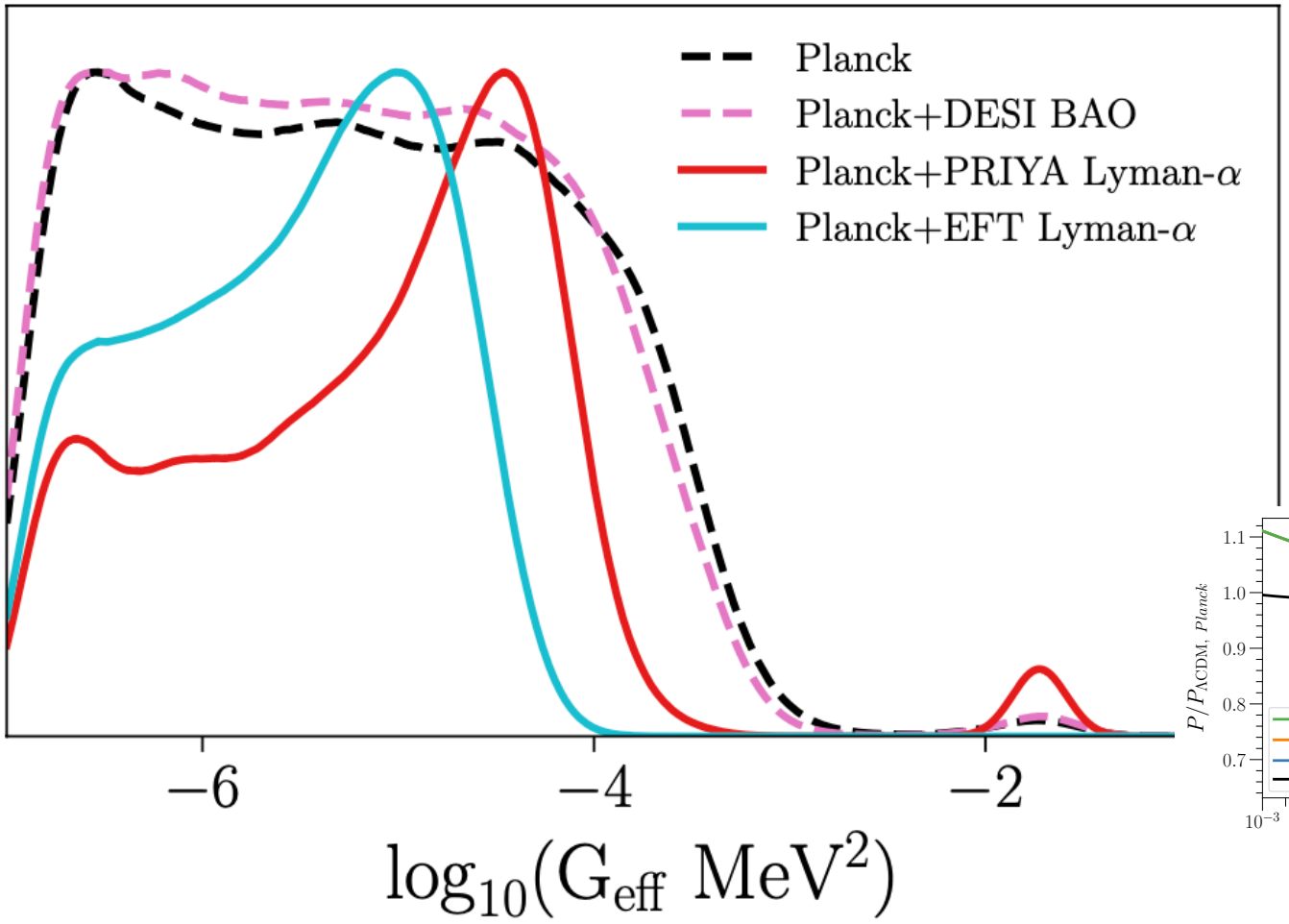
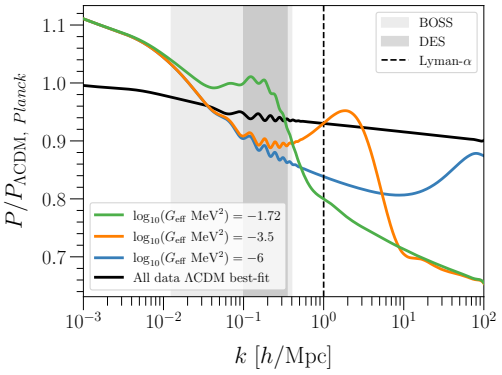
* EFT likelihood with priors from **Sherwood** simulation
* compressed likelihood from an emulator of **PRIYA** simulation

Example 2: Self-interacting neutrinos

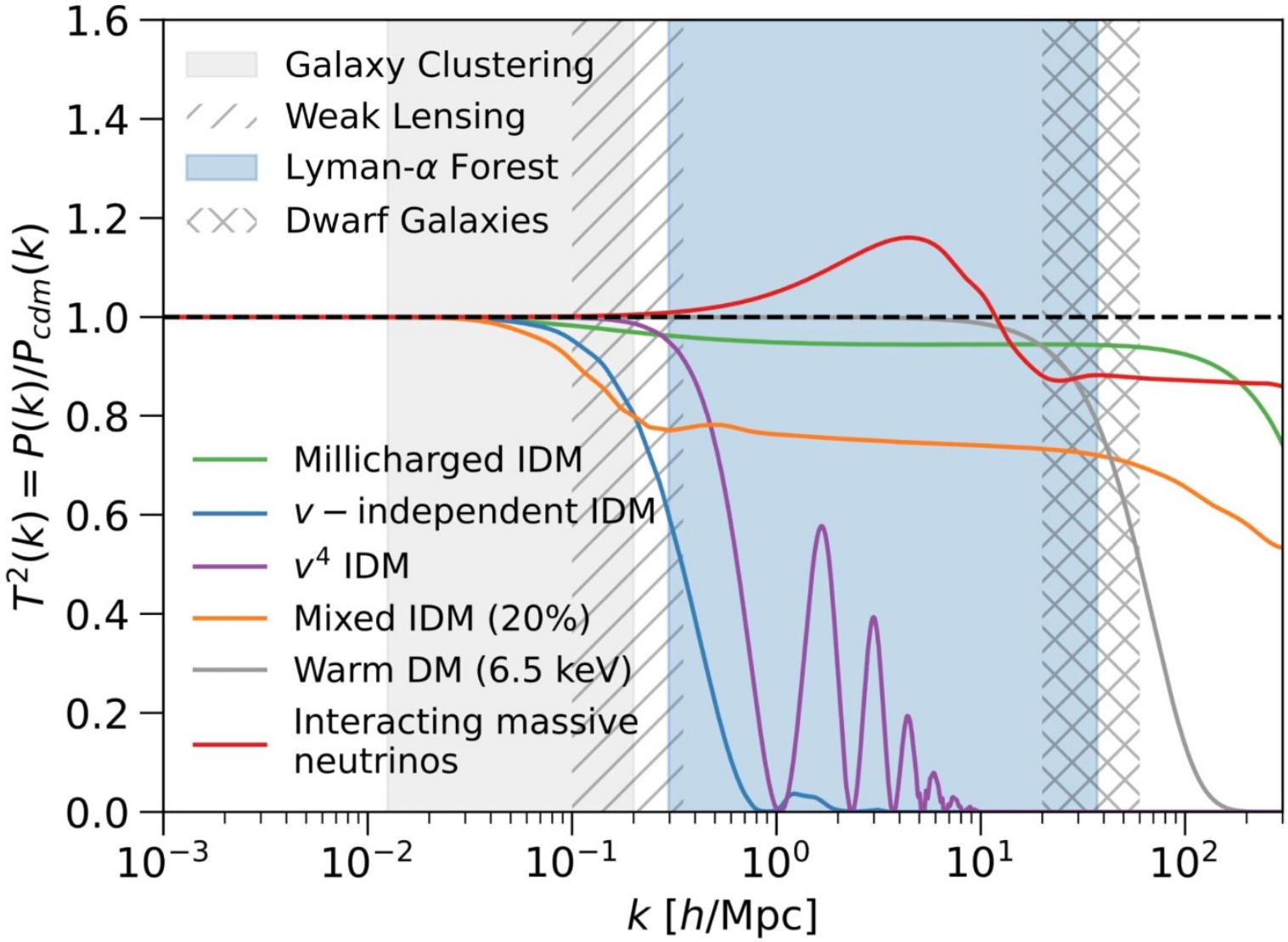
Adam He

He, Ivanov, Bird, VG (2503.15592)





Example 3: Sterile neutrinos

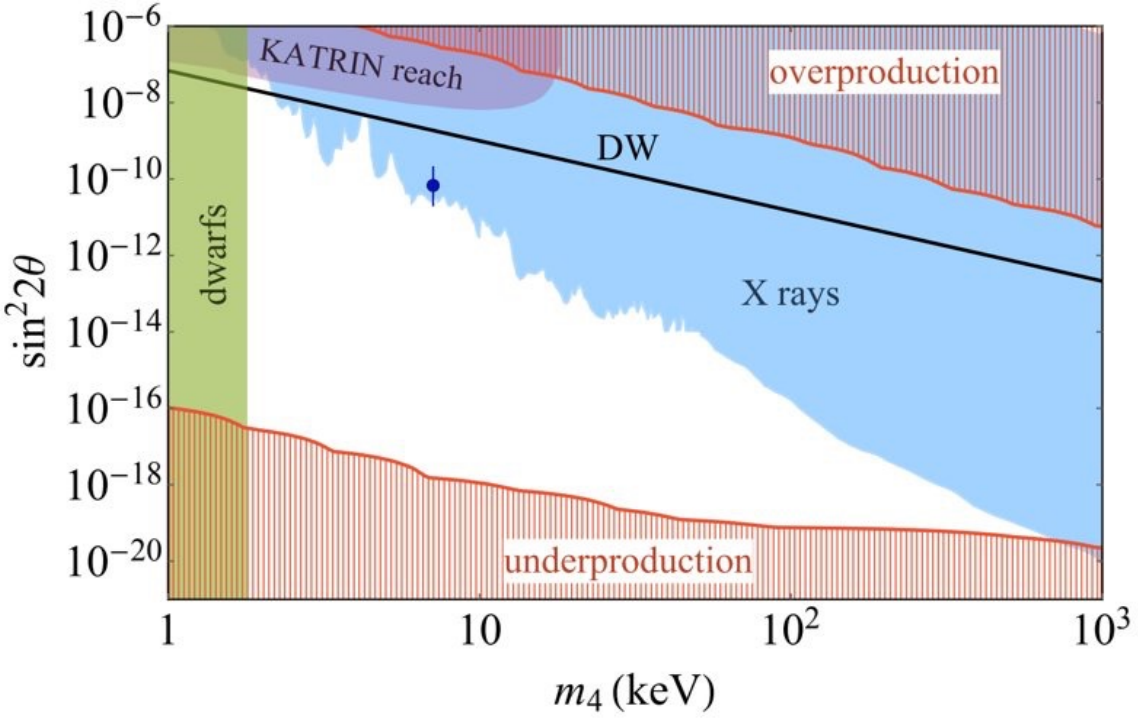


Plot by A. He

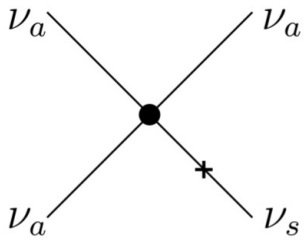
Example 3: Sterile neutrinos

$$\nu_4 = \cos\theta\,\nu_s + \sin\theta\,\nu_a$$

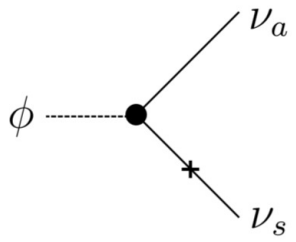
DM = Fourth, heavy (~keV) neutrino that doesn't talk to the SM, but mixes with active neutrinos.



$$\mathcal{L} \supset \frac{\lambda_\phi}{2}\nu_a\nu_a\phi + \text{h.c.}$$



Case A (heavy ϕ)

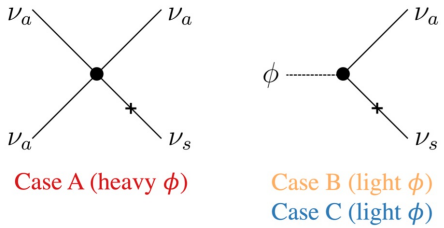


Case B (light ϕ)
Case C (light ϕ)

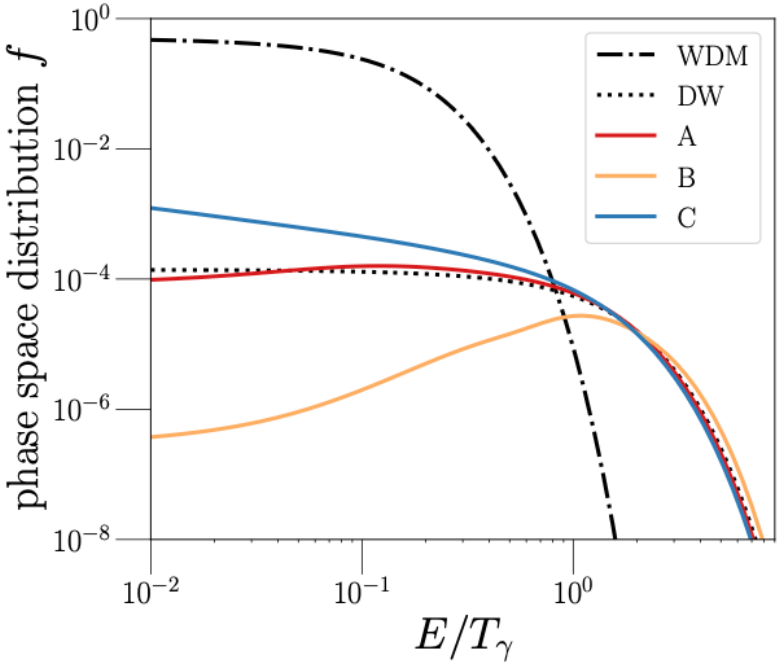
de Gouvea + (2019), etc.

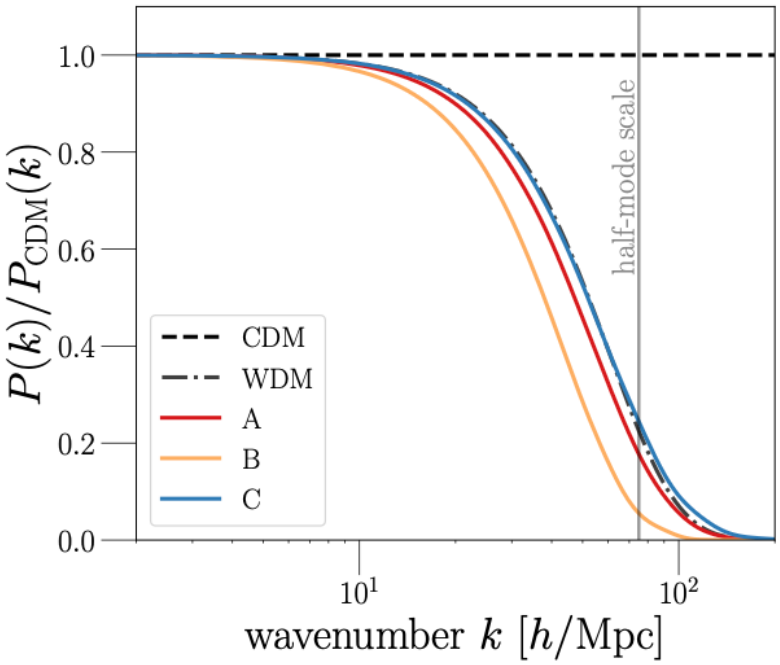
Example 3: Sterile neutrinos

Rui An



=> a cosmology were DM free streams out of grav. potentials.

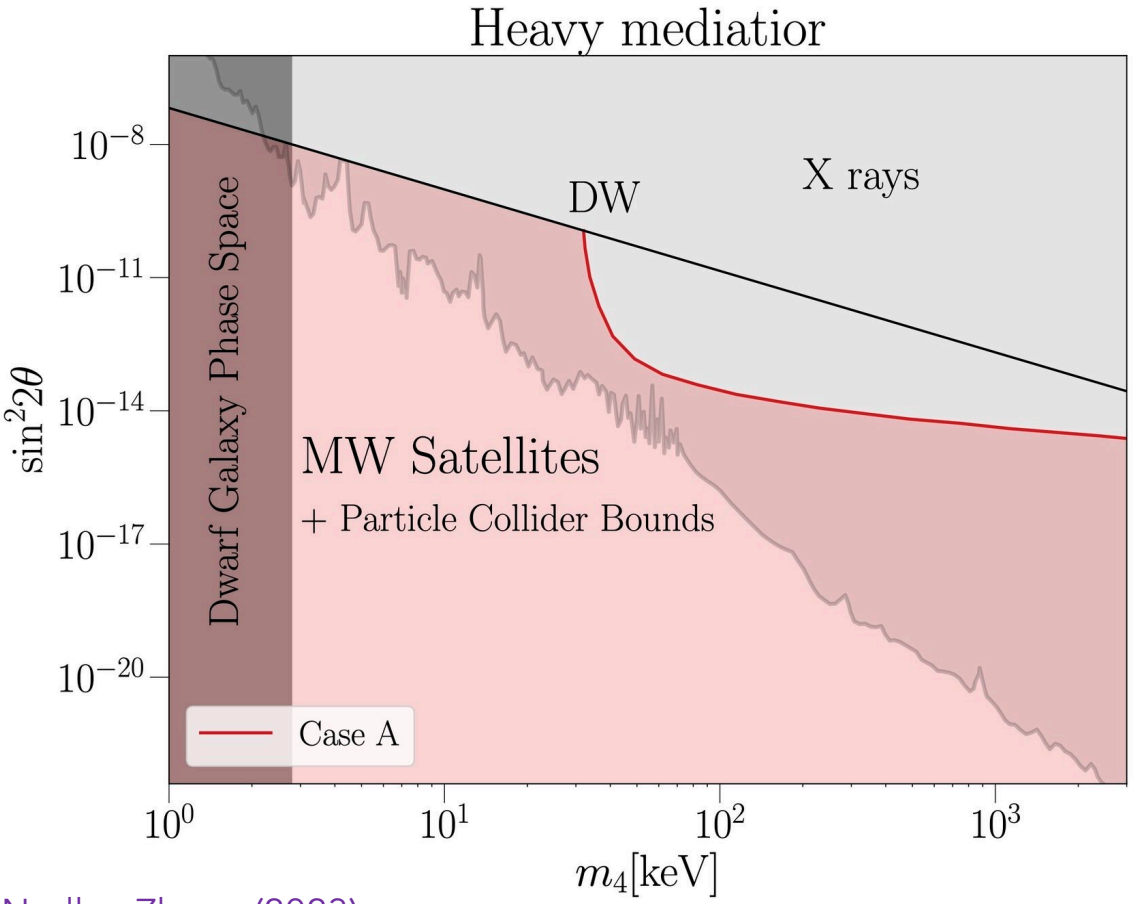




Example 3: Sterile neutrinos

Rui An

Combined bounds: sky + lab

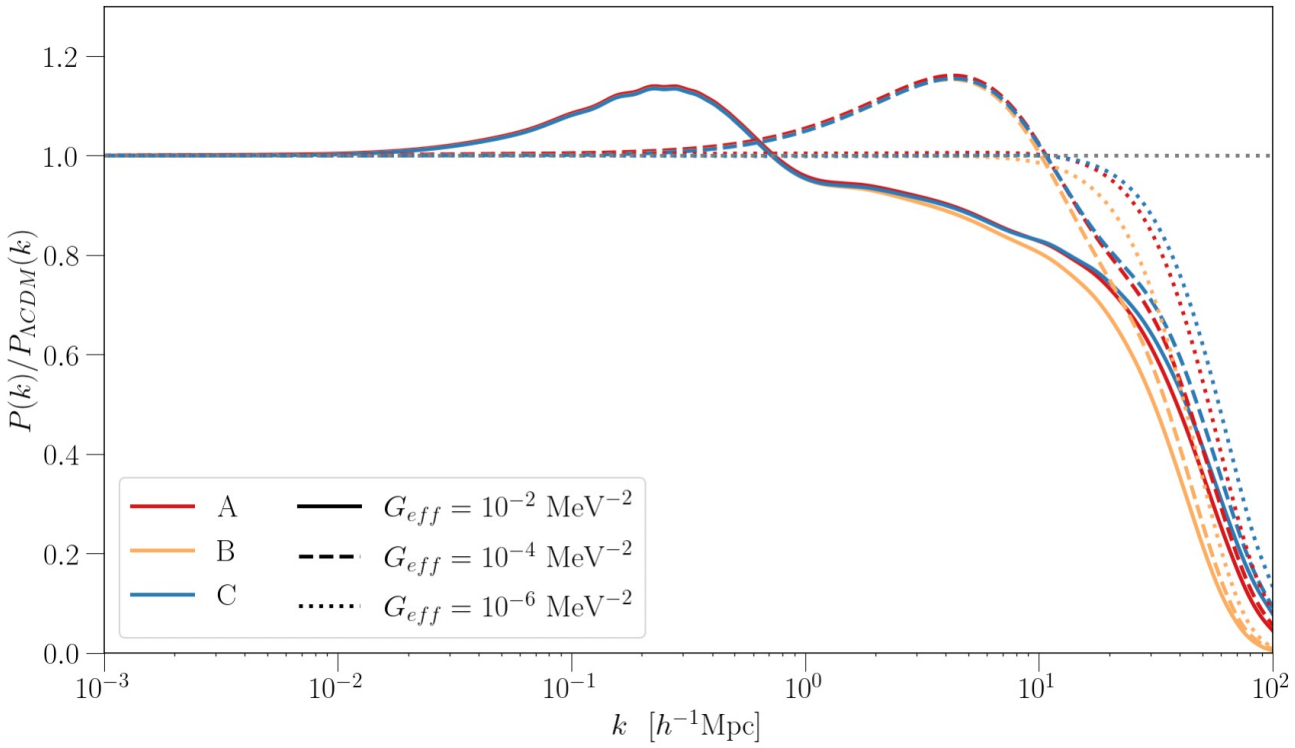


An, Gluscevic, Nadler, Zhang (2023)

Mediators > 1GeV are ruled out.

Putting it together:
Interacting neutrinos + sterile neutrino DM.

Priyank Parashari

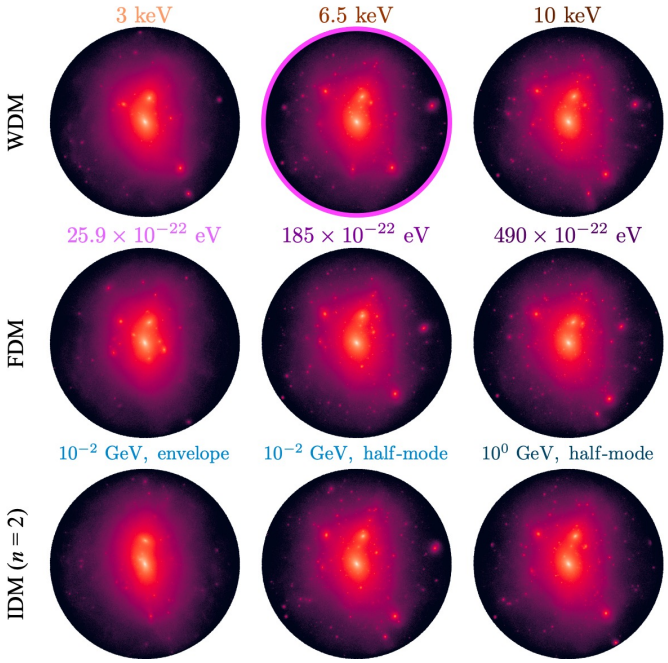


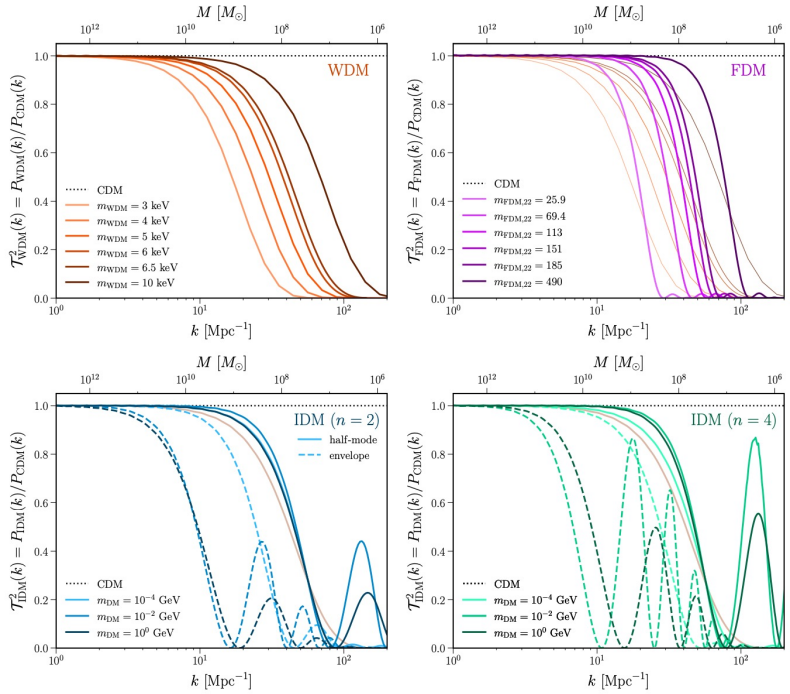
Plot by P. Parashari

Power excess!
Can't use WDM…

Next?

COZMIC: Cosmological Zoom-in Simulations with Initial Conditions Beyond CDM



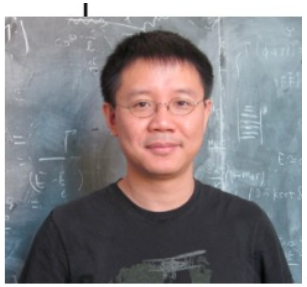


Ethan Nadler
(USC/Carnegie)
→ UCSD

Rui An
(USC)

Daneng Yang
(UCR)

Xiaolong Du
(UCLA)



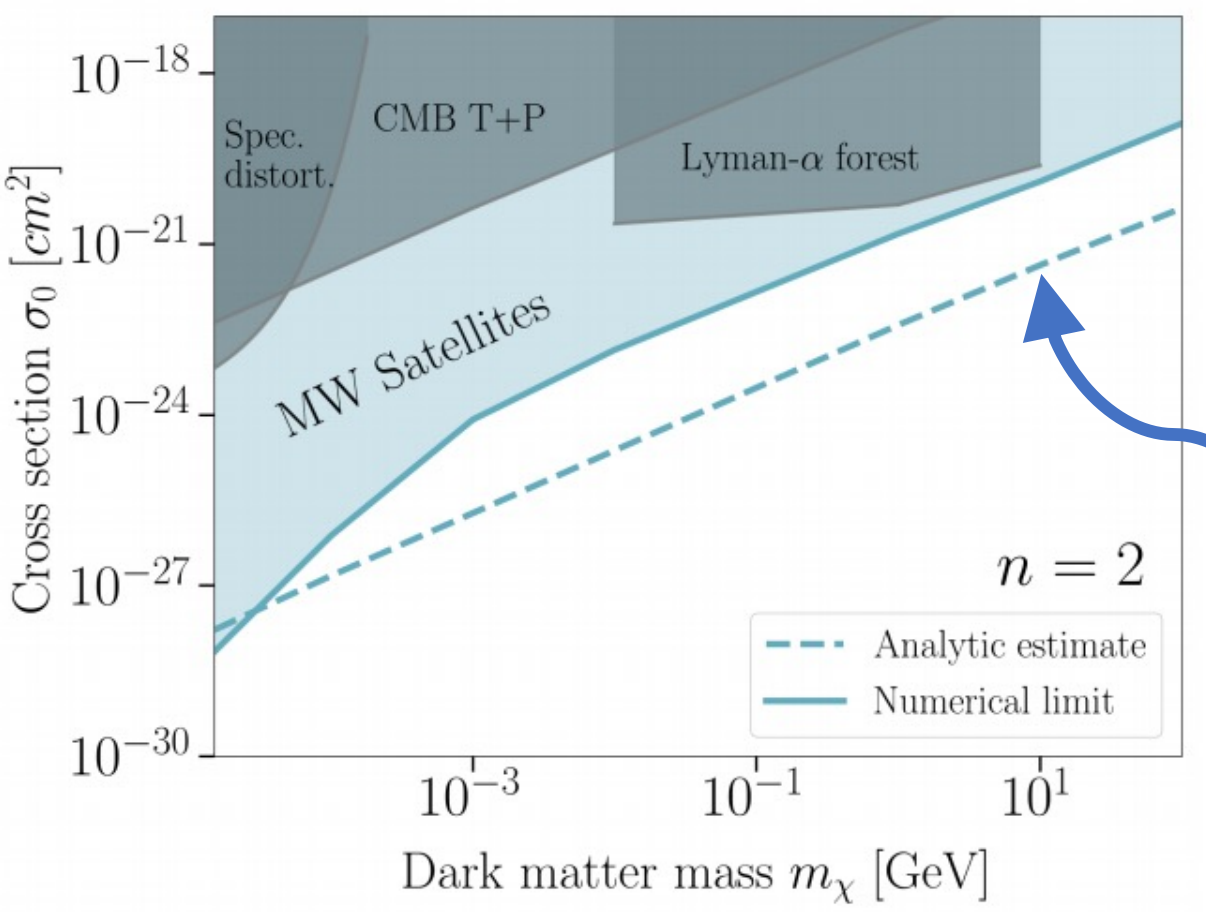
Haibo Yu
(UCR)

Andrew Benson
(Carnegie)

2410.03635; 2411.03431; 2412.13065

DM-proton scattering

$$\sigma_{MT} = \sigma_0 v^n$$



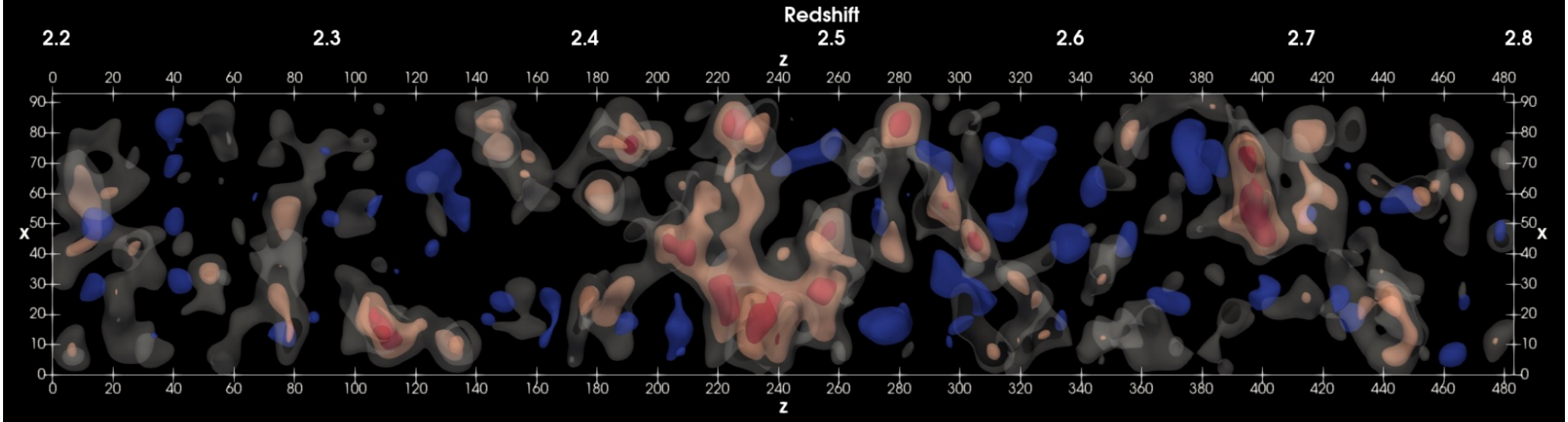
Expected new bound with COZMIC

(e.g. n=2, DM with electric dipole)

Maamari, VG, Boddy, Nadler, Wechsler+ 2020

The future: new tracers of matter distribution

Tomographic reconstruction of the Lya forest



The largest available contiguous map of gas in the intergalactic medium, reconstructed from the LATIS survey (Newman+ 2025)

Summary

- Many new-physics models affect a range of scales, all the way down to satellite galaxies.
- Data is coming from various observations (incl. lya forest) and the bottleneck is forward-modeling of structure in BSM cosmologies.