Dark matter cosmology

from the early universe to near field

Vera Gluscevic

University of Southern California

In collaboration with

Karime Maamari

Adam He

Wendy Crumrine

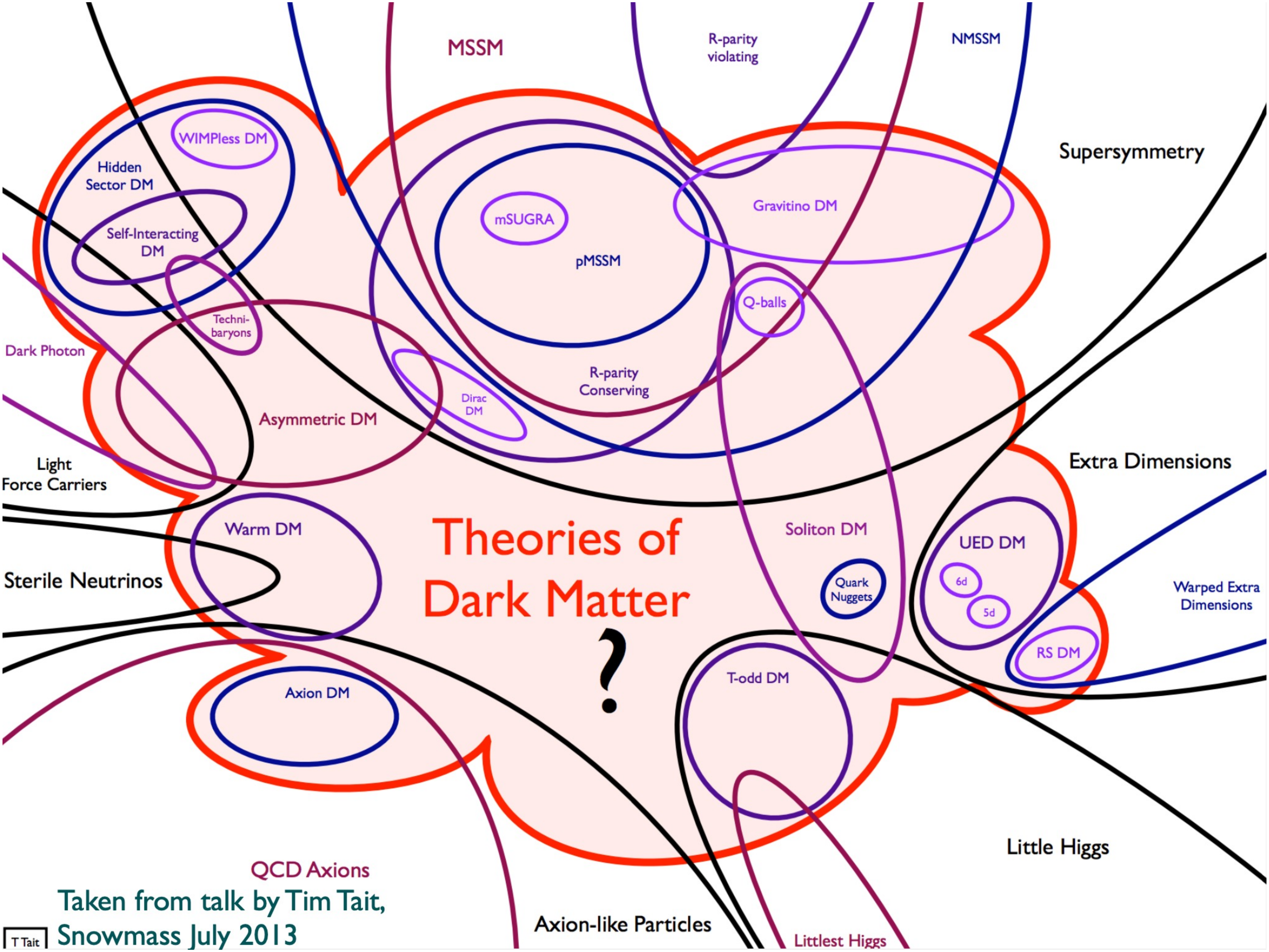
Trey Driskell

arxiv
2301.08299
2301.08260
2010.02936
2008.00022
1904.10000

Rui An

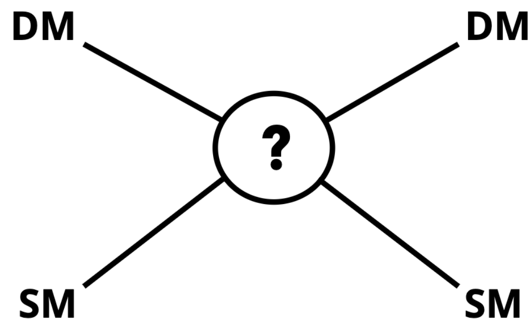
Ethan Nadler

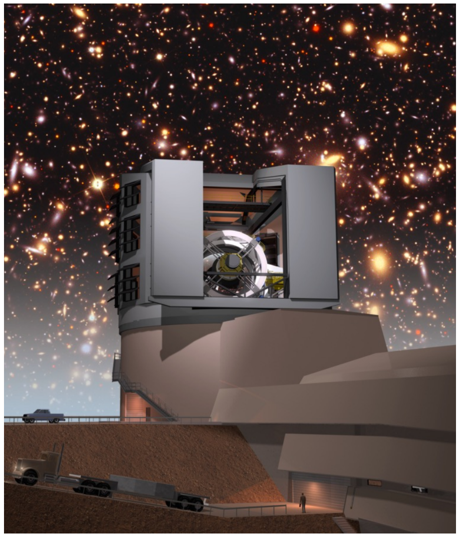
Also: Mikhail Ivanov, Jordan Mirocha, Yue Zhang, Kim Boddy, Andrew Benson, Risa Wechsler, +DES and ACT Collaborations.

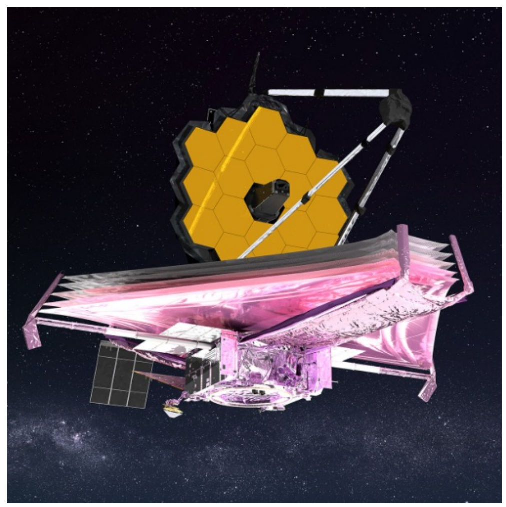


Taken from talk by Tim Tait,
Snowmass July 2013

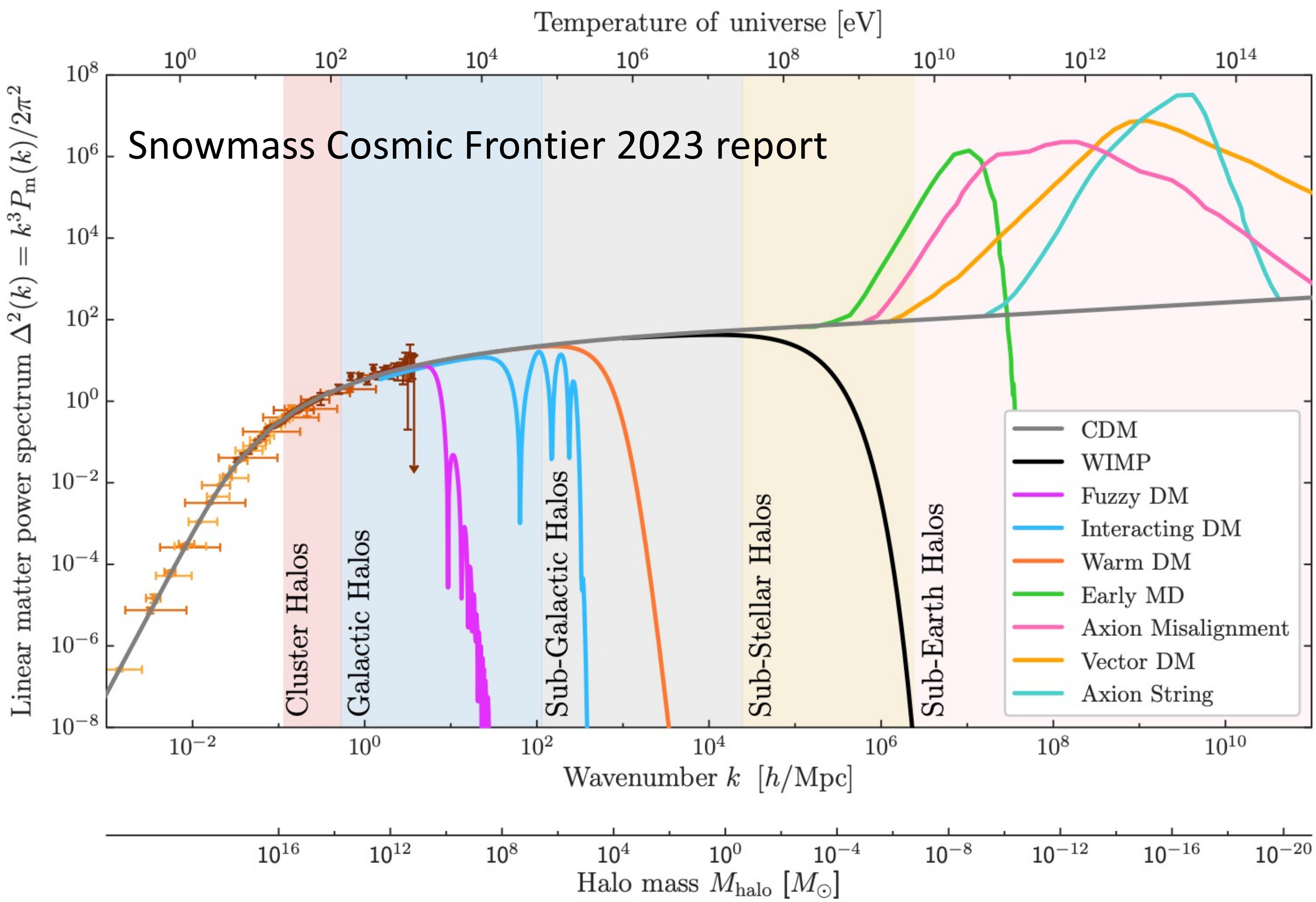
Cosmology x DM physics







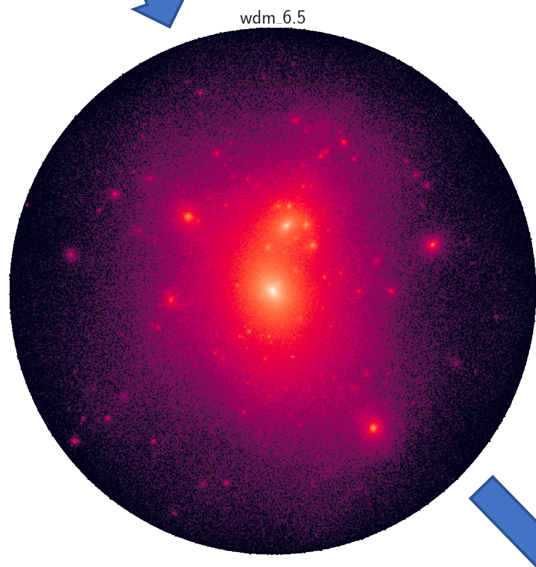
DM microphysics at the small-scale frontier



Lyman-alpha forest, dwarf galaxies, stellar streams, galaxy clustering, strong and weak lensing, intensity mapping, etc.

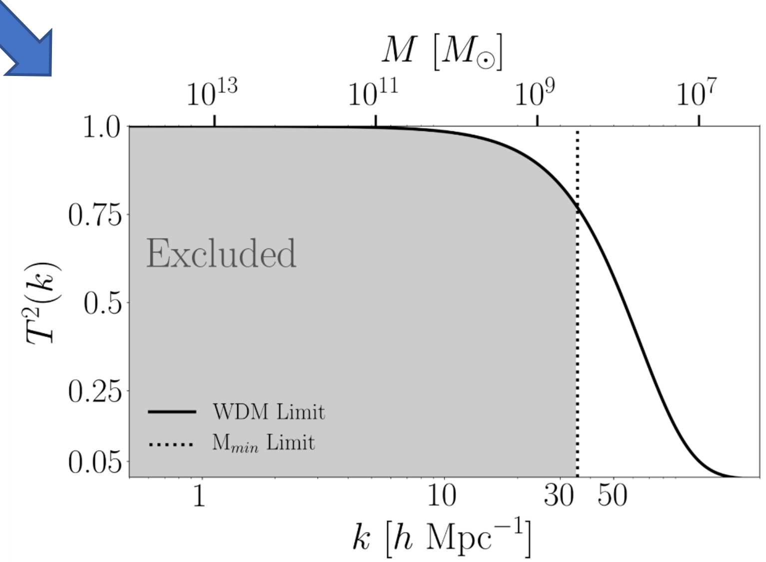
Near-field Cosmology

Known MW satellites from DES + PanSTARRS + SDSS



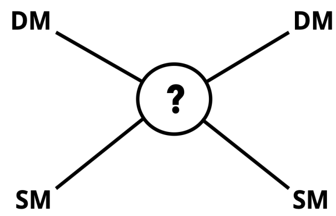
galaxy-halo connection model
(Nadler+ 2018)
+
mock observations

>6.5keV

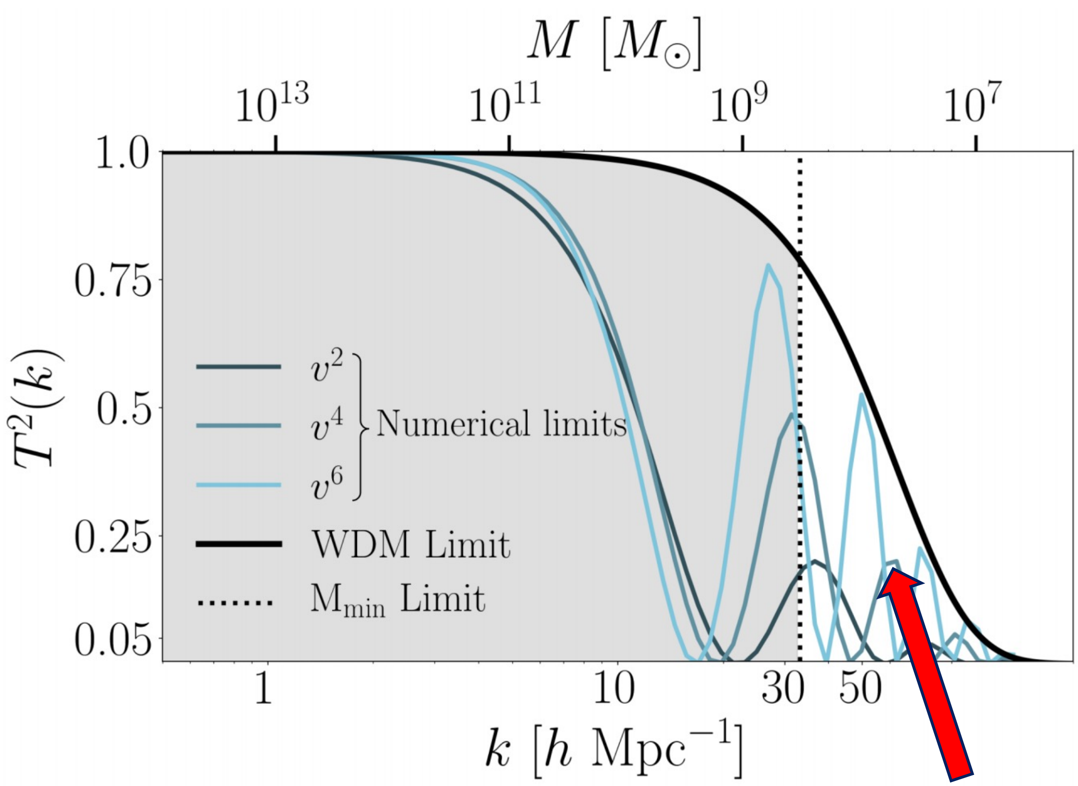


Nadler, Gluscevic, Boddy, Wechsler (2019)
DES+ (2020)

Interactions of sub-GeV DM with the Standard Model



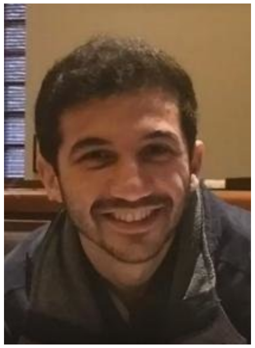
$$\sigma_{MT} = \sigma_0 \upsilon^n$$



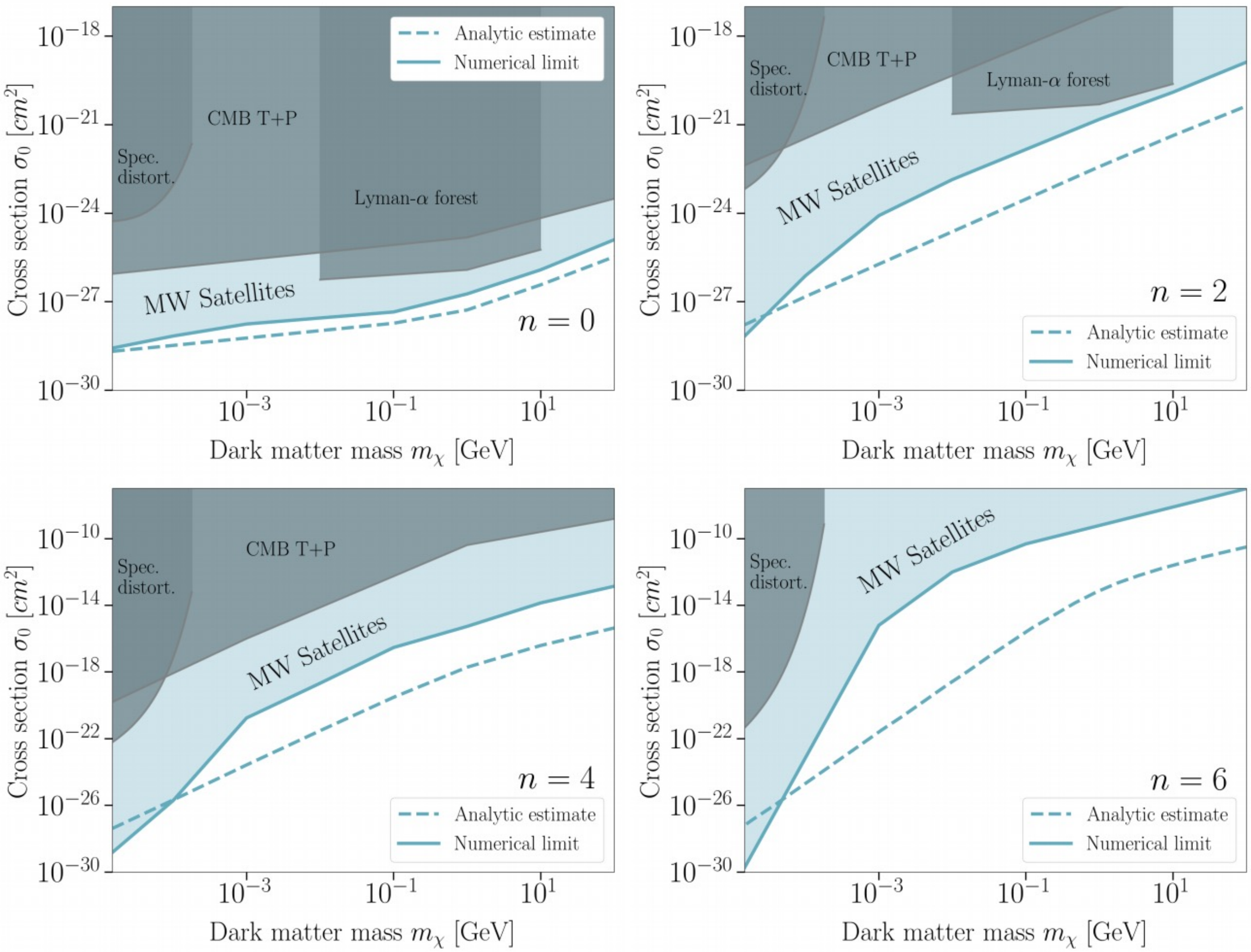
inconsistent

Maamari, Gluscevic,+ (2021), arXiv:2010.02936

DM-proton scattering bounds



Karime Maamari
(USC)

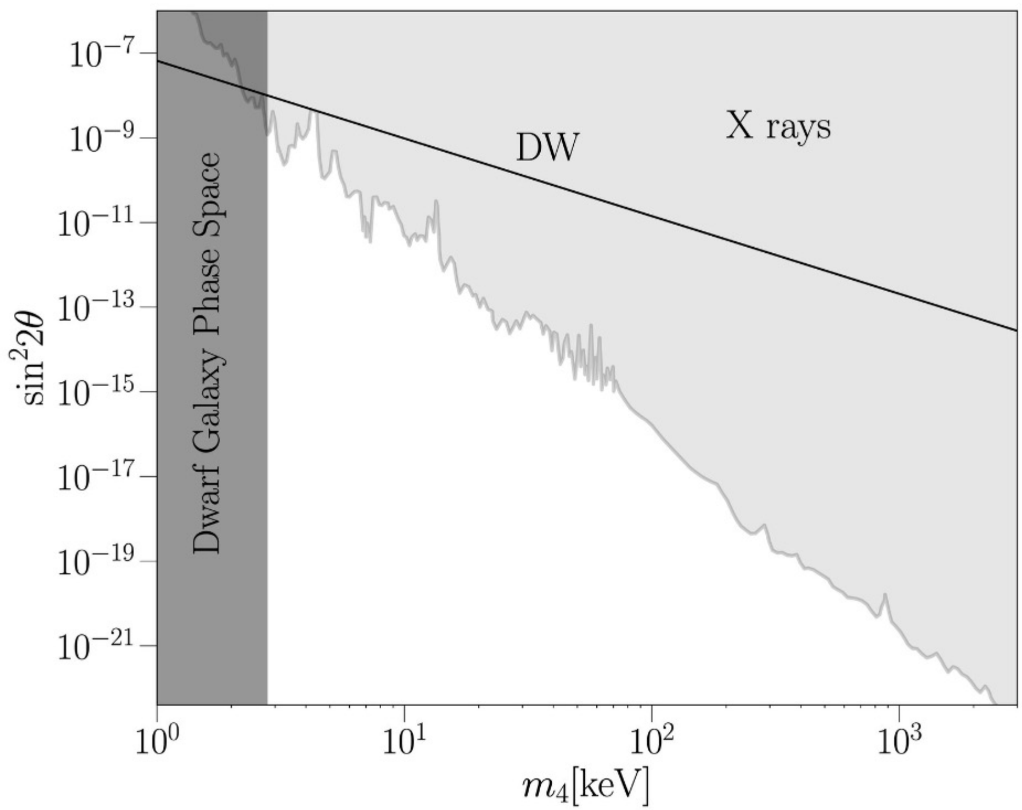


=> **3-5 OOM improvement.**

Maamari, Gluscevic,+ (2021), arXiv:2010.02936

Dodelson-Widrow sterile neutrinos:

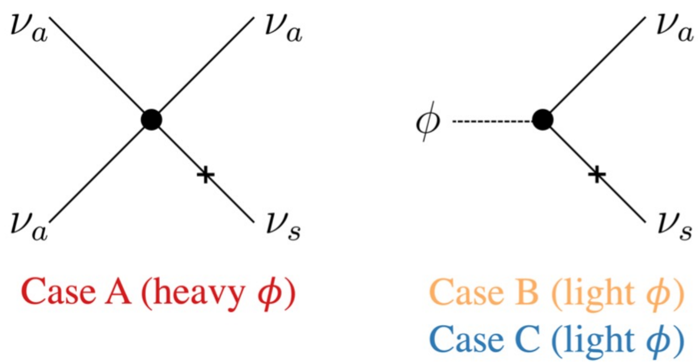
$$\nu_4 = \cos\theta\,\nu_s + \sin\theta\,\nu_a$$

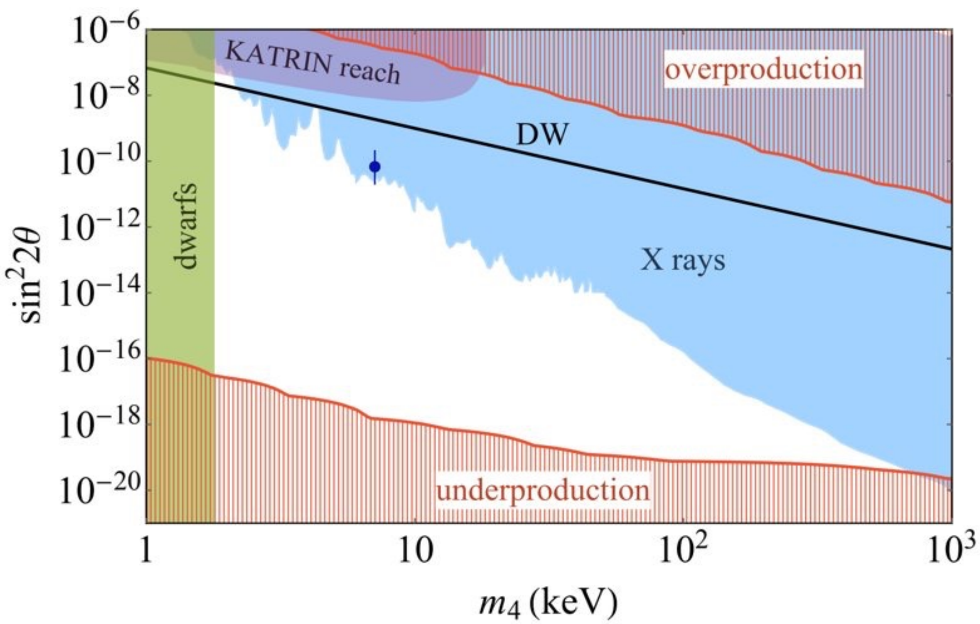


Problem: sterile nus decay and produce observable X-rays.

Sterile neutrinos + **neutrino self-interactions**

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

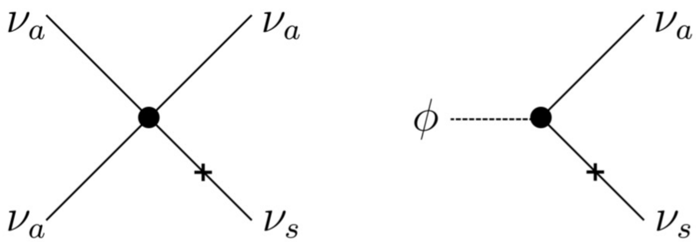




de Gouvea + (2019), etc.

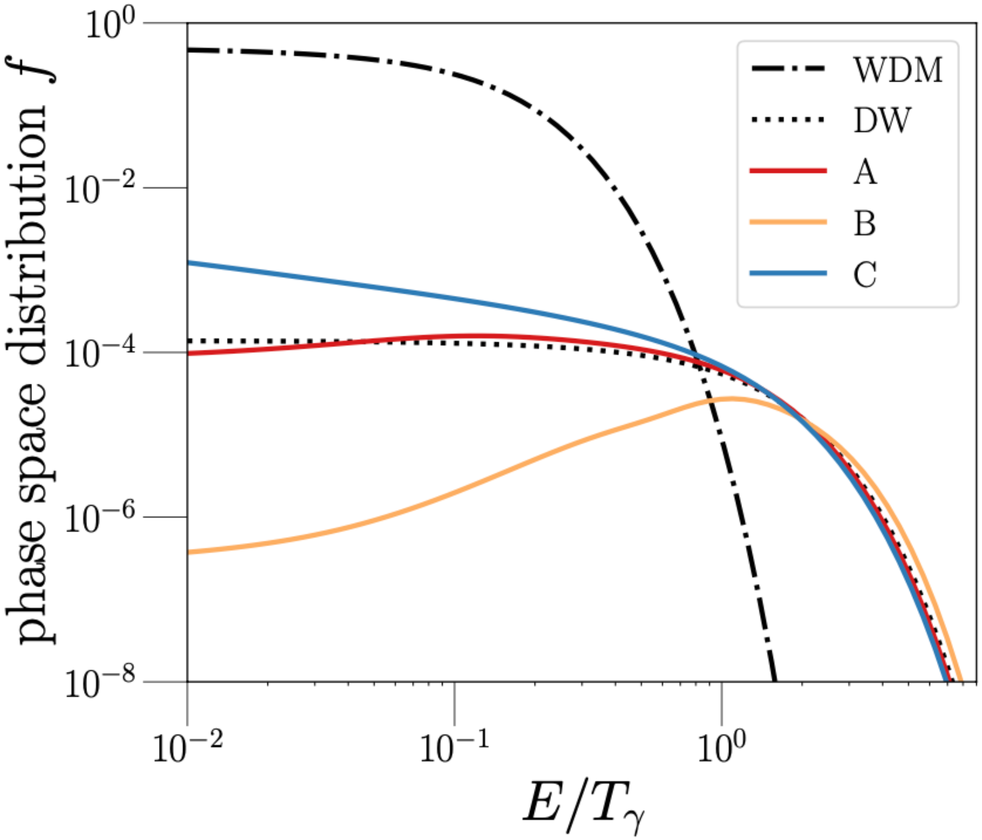
Sterile neutrinos + **neutrino self-interactions**

Rui An



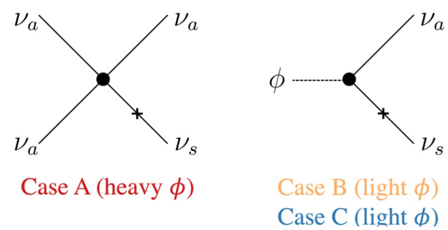
Case A (heavy ϕ)

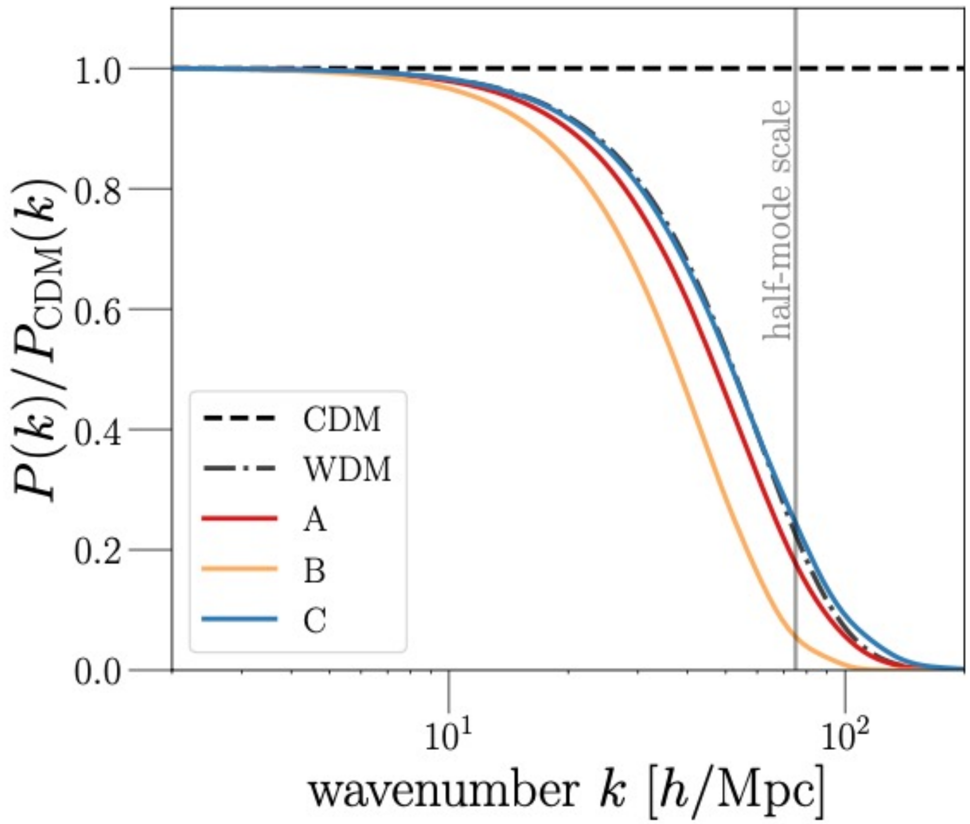
Case B (light ϕ)
Case C (light ϕ)



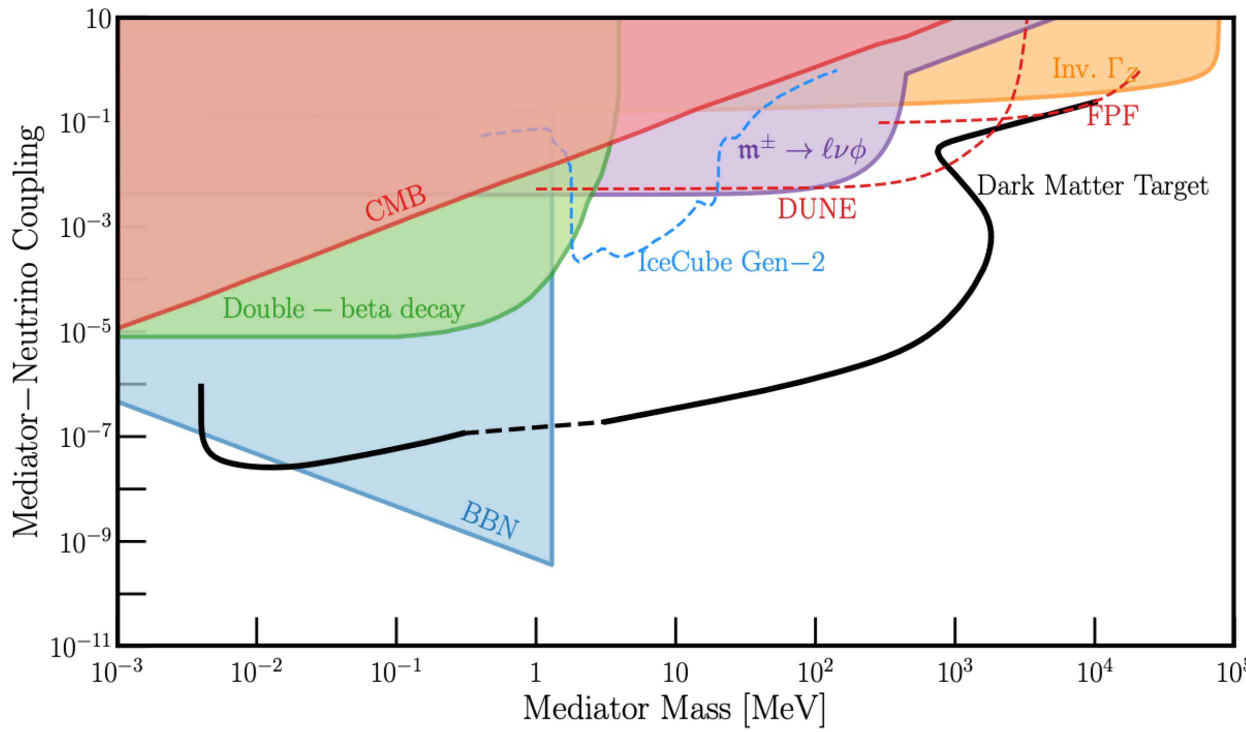
Power suppression from sterile neutrino free streaming:

Rui An





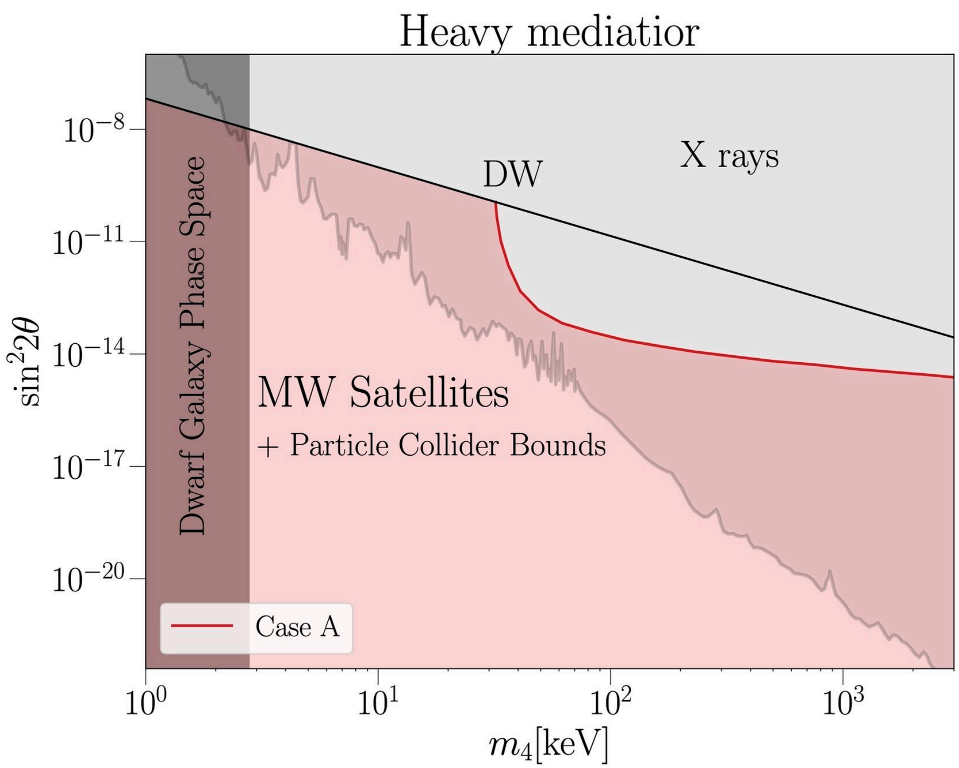
Lab bounds on neutrino self-interactions:

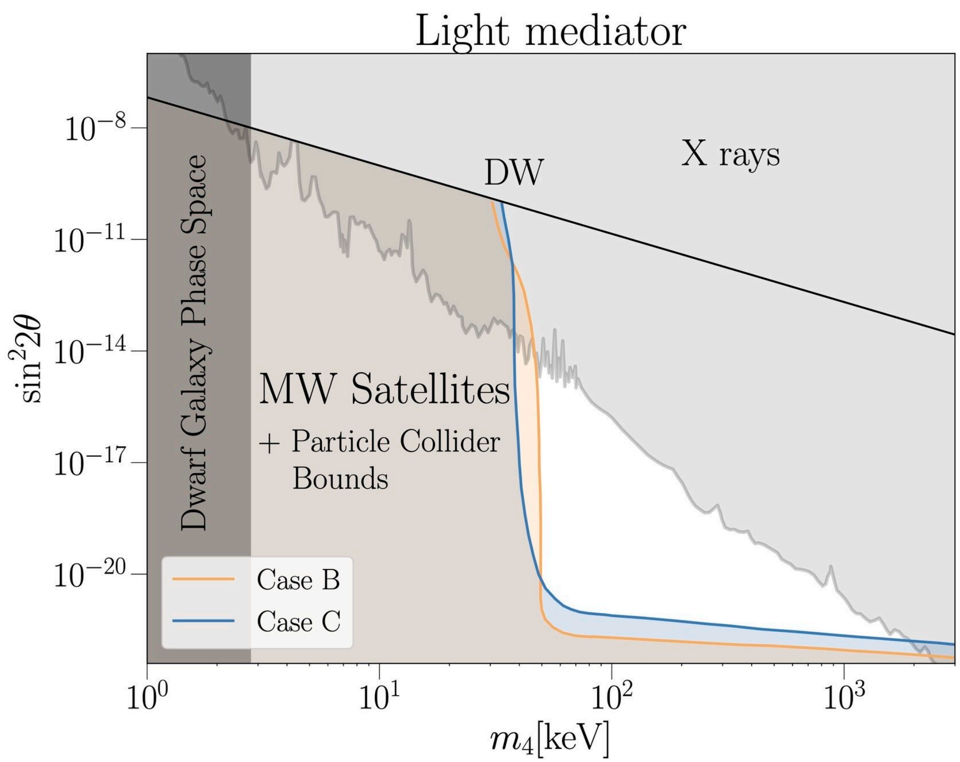


https://arxiv.org/pdf/2203.01955.pdf

Mediators > 1GeV are ruled out.

Rui An

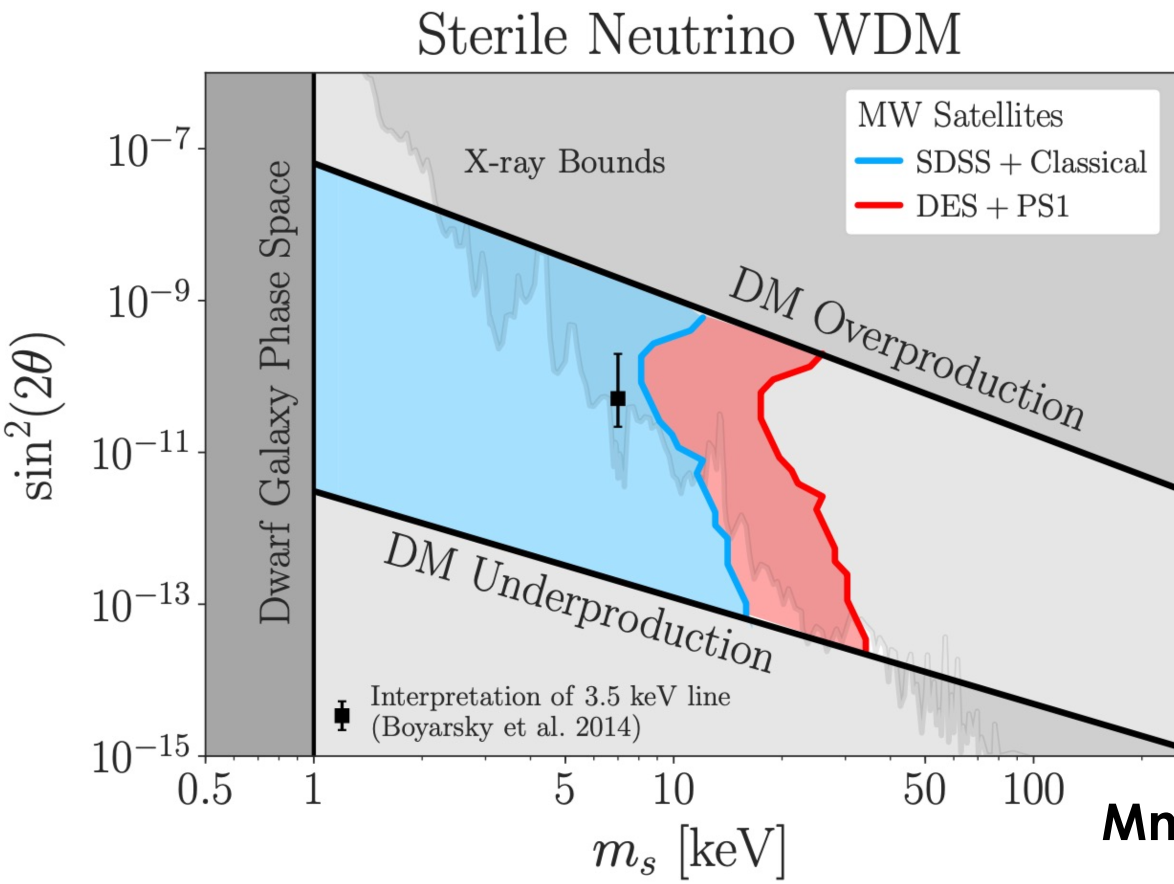




An, Gluscevic, Nadler, Zhang (2023)

Shi-Fuller mechanism is ruled out (for 100% DM)

Ethan Nadler
(USC/Carnegie)



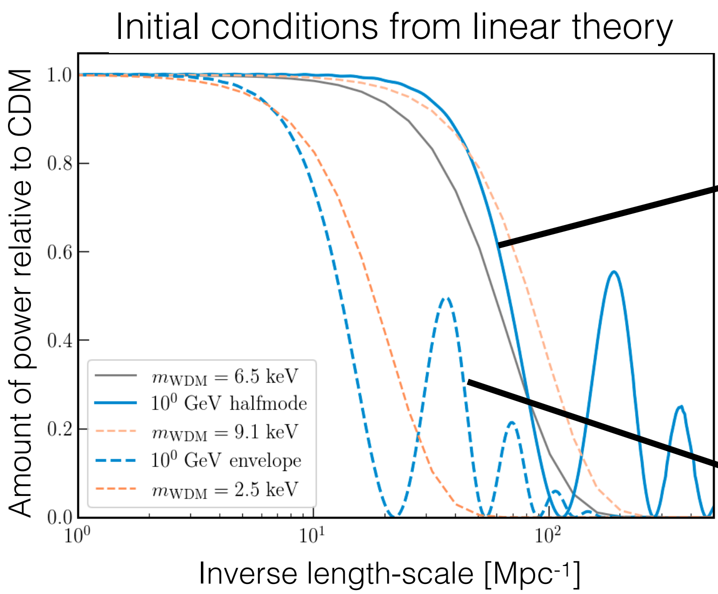
Mmin < 10^8 Msun

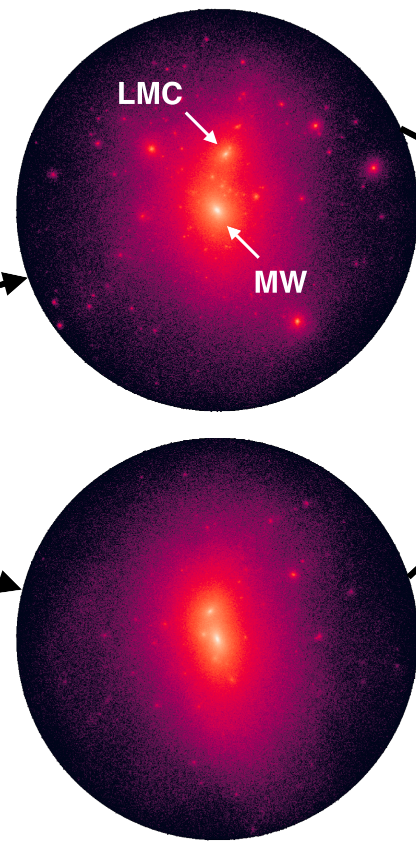
Nadler, DES+ (2020)
2008.00022

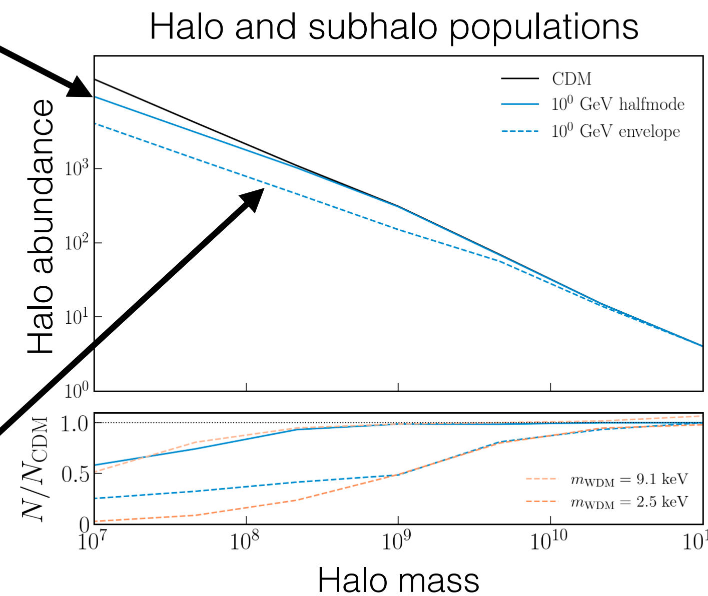
***Including:** realistic modeling of galaxy-halo connection (incl. disruption of subhalos by the Milky Way disk) and mock observations of the satellite abundance (luminosity, size, and radial distribution).

IDM transfer + N-body simulations + galaxy-halo model

PRELIMINARY



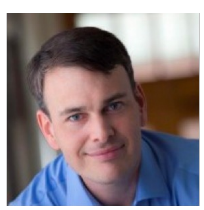




72 cosmological simulations of Milky Way-like systems in various dark matter models: warm, ultra-light, interacting

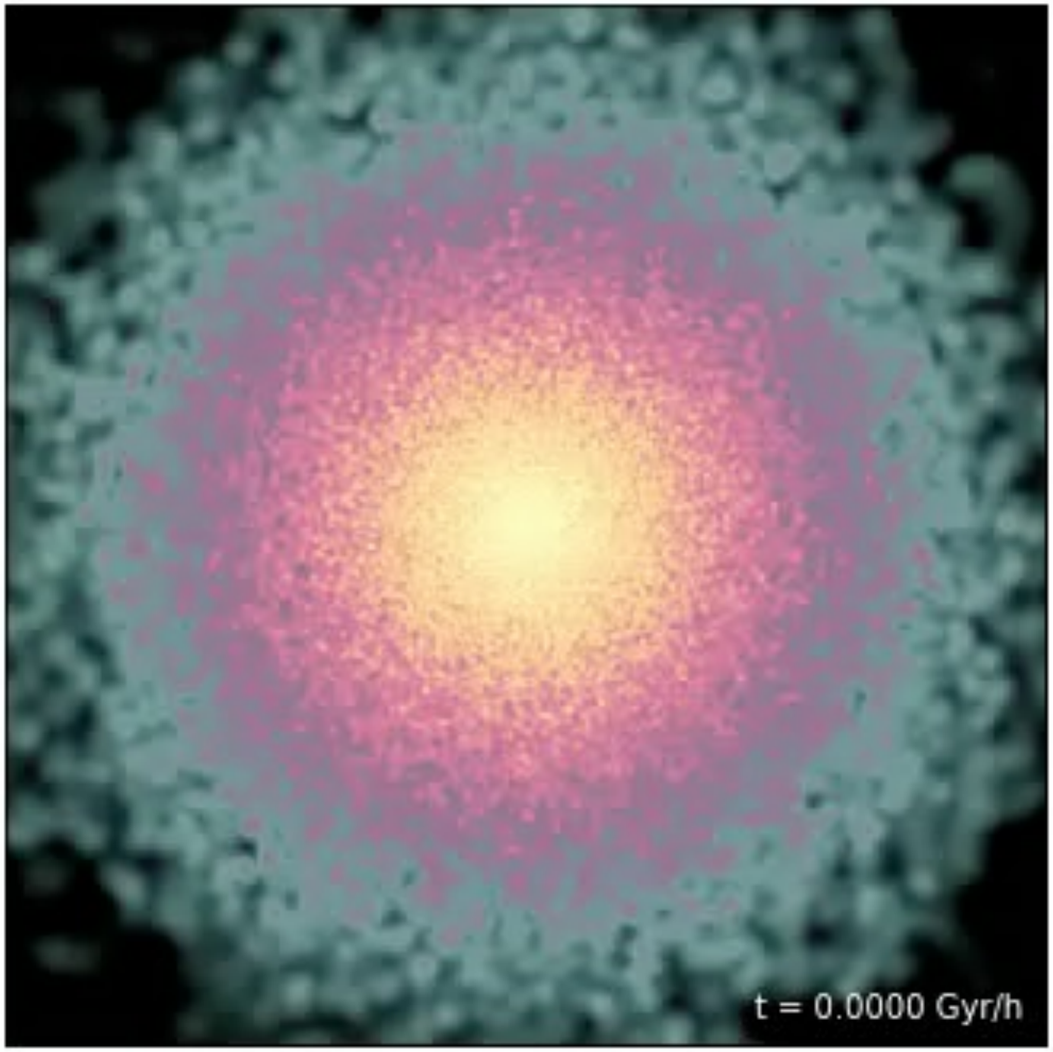
Ethan Nadler

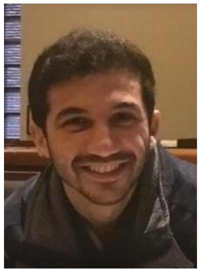
Rui An



Andrew Benson

Next up:
Hydrodynamic simulations with DM-proton scattering





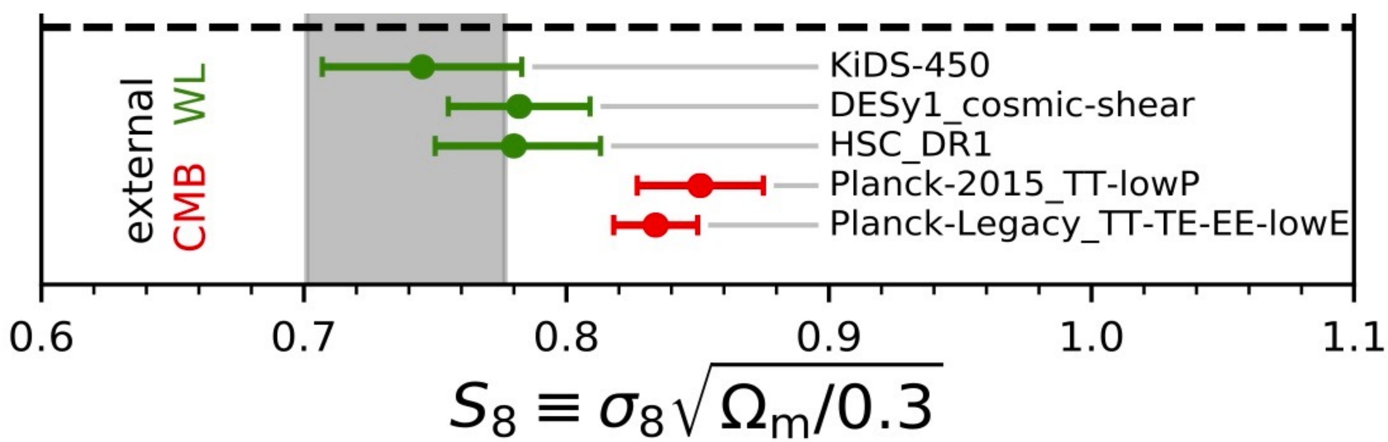
Karime Maamari

Illustration only.

Large scale structure

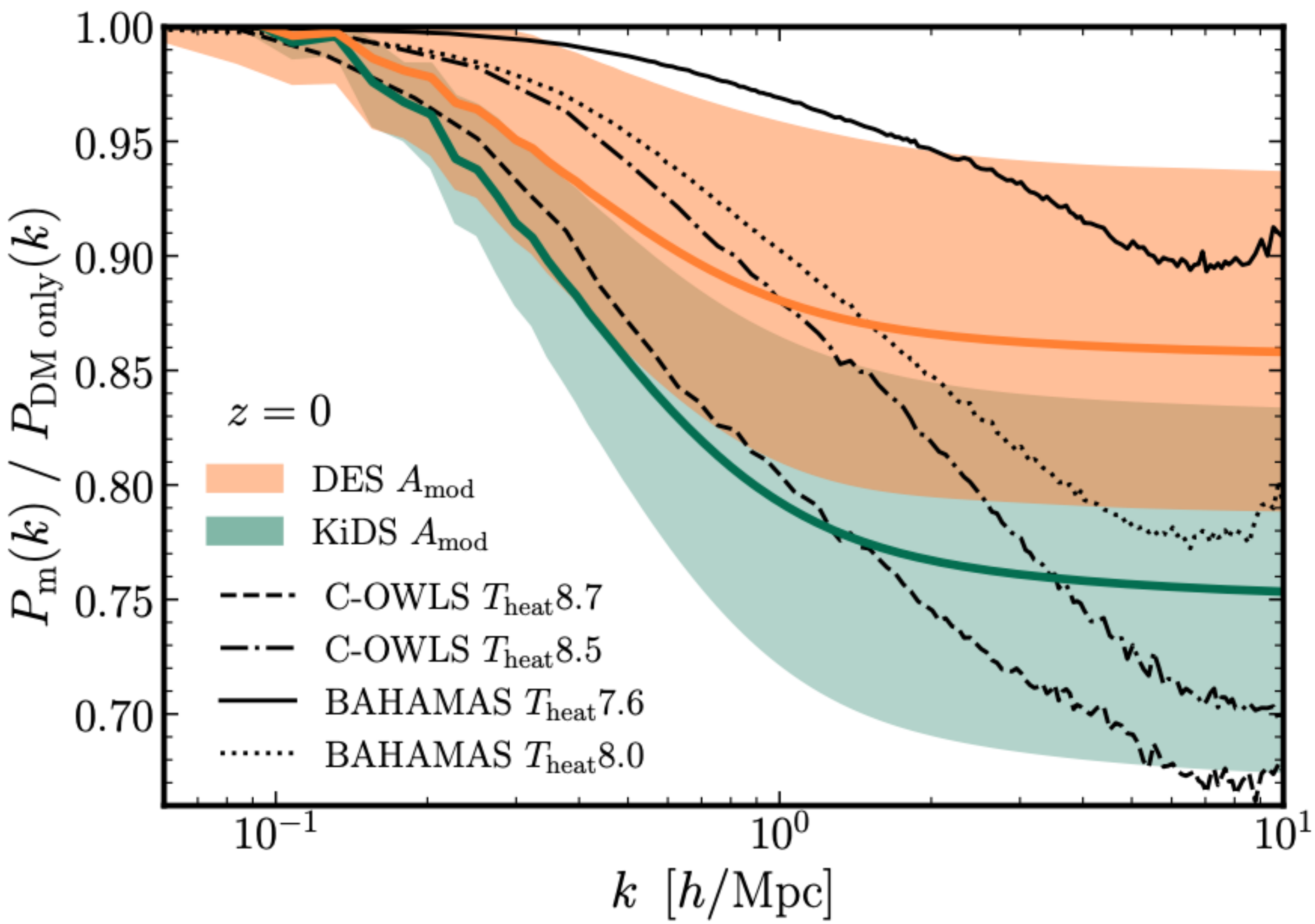
S8 tension

Less matter clustering is measured by weak lensing surveys, than anticipated by CMB + LCDM.



https://arxiv.org/pdf/2203.06142.pdf; Plot by KiDS collab.

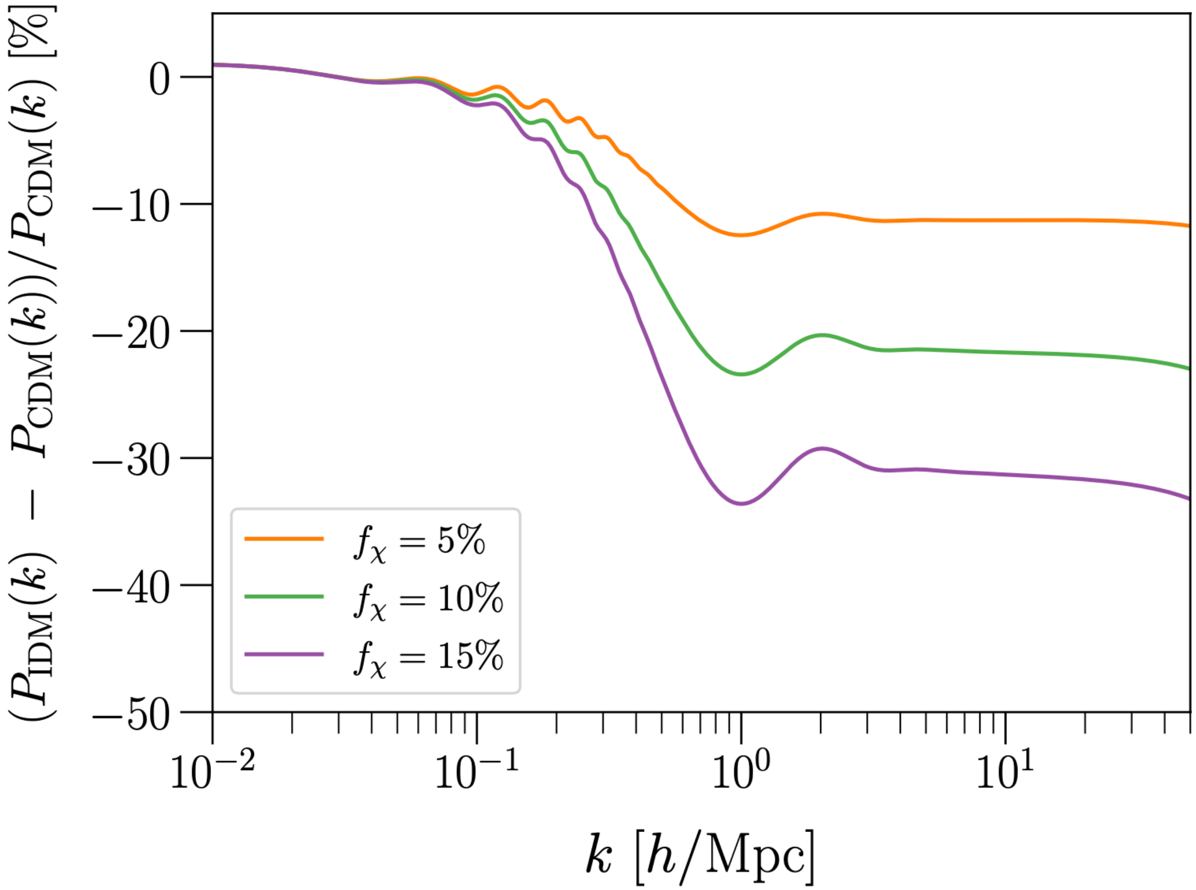
S8 tension = k-dependent suppression?



Amon and Efstathiou (2022), Preston+ (2023)

S8 tension: IDM?

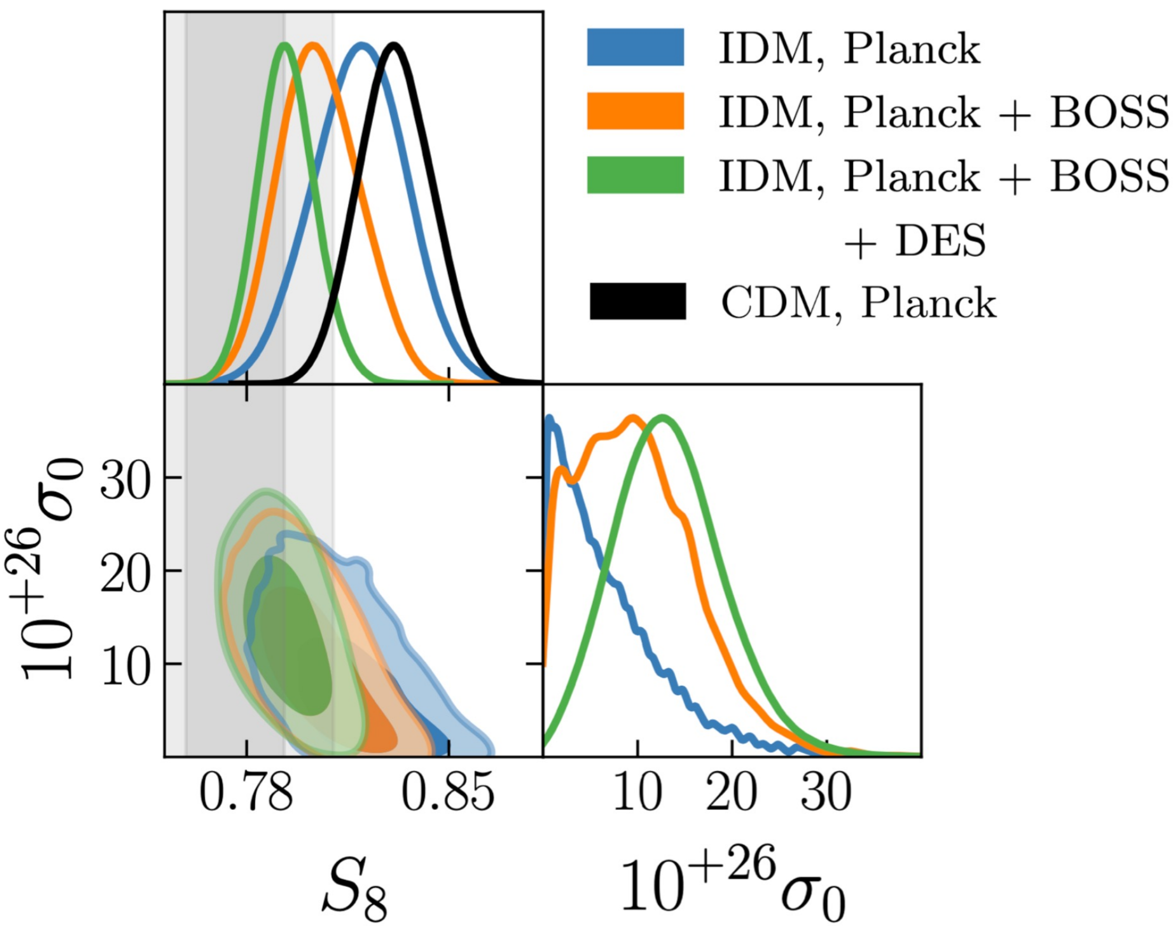
Adam He



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

He, Ivanov, An, Gluscevic (2023)

Does IDM alleviate S8 tension?

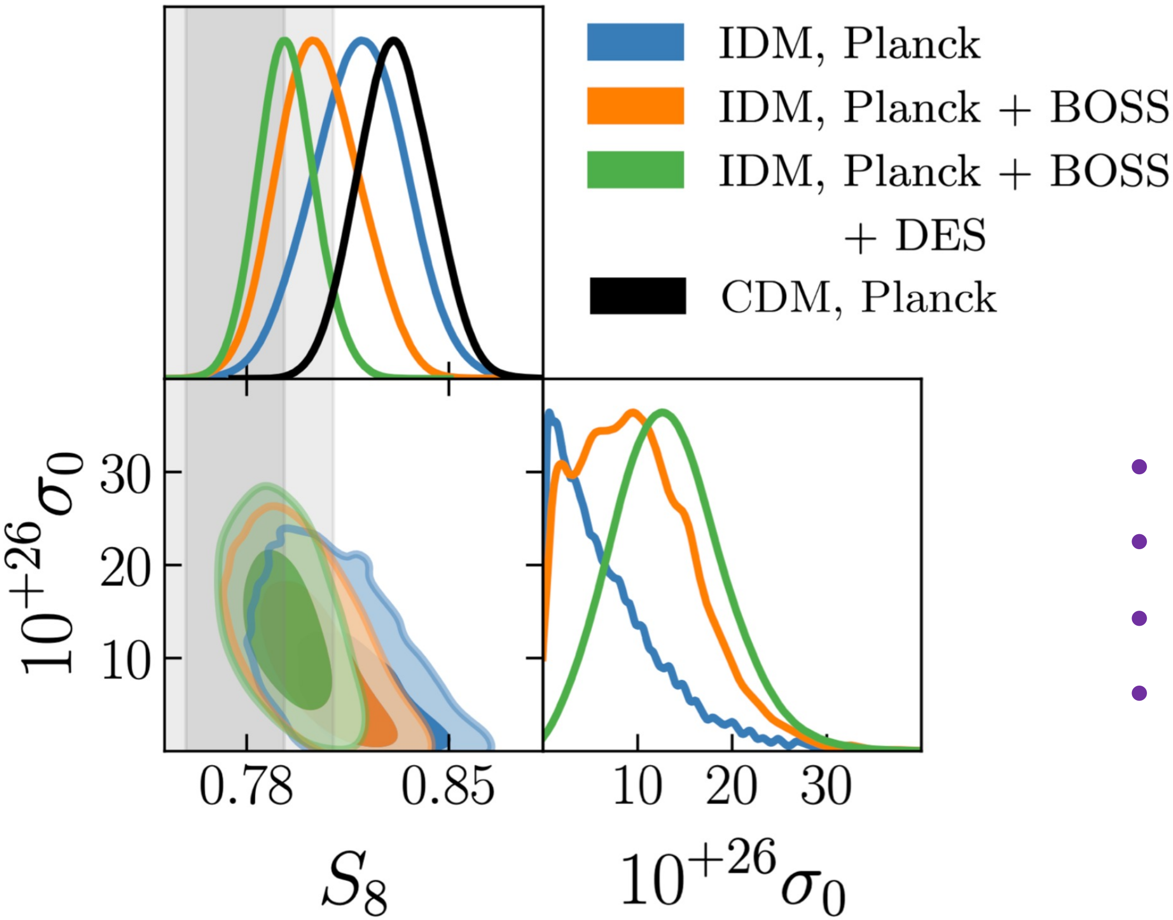


Adam He

He, Ivanov, An, Gluscevic (2023)

Model	ΛCDM, *Planck* + BOSS + DES	IDM, *Planck* + BOSS + DES
σ_0 $[10^{-26}\ \mathrm{cm}^2]$	–	$13.23\ (5.163)^{+5.2}_{-6.5}$
S_8	$0.813\ (0.813) \pm 0.009$	$0.794\ (0.804)^{+0.009}_{-0.01}$
$\Delta\chi^2_{\mathrm{min}}$	–	-6.7

Does IDM alleviate S8 tension?



Adam He

- **Pre-tension physics**
- **Consistent across data**
- **Does not mess up H0**
- **Imminently falsifiable**

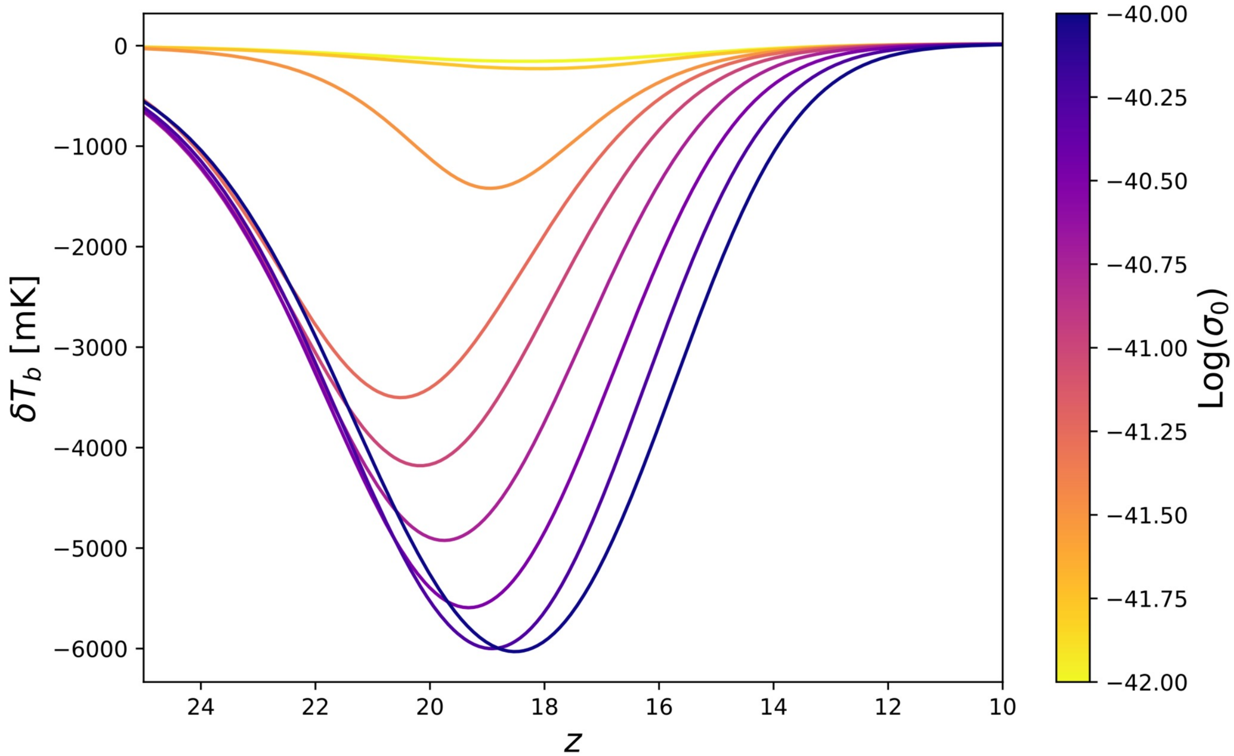
He, Ivanov, An, Gluscevic (2023)

Model	ΛCDM, *Planck* + BOSS + DES	IDM, *Planck* + BOSS + DES
σ_0 [10^{-26} cm^2]	–	$13.23\ (5.163)^{+5.2}_{-6.5}$
S_8	$0.813\ (0.813) \pm 0.009$	$0.794\ (0.804)^{+0.009}_{-0.01}$
$\Delta\chi^2_{\rm min}$	–	-6.7

21- cm cosmology

Global 21-cm signal with IDM

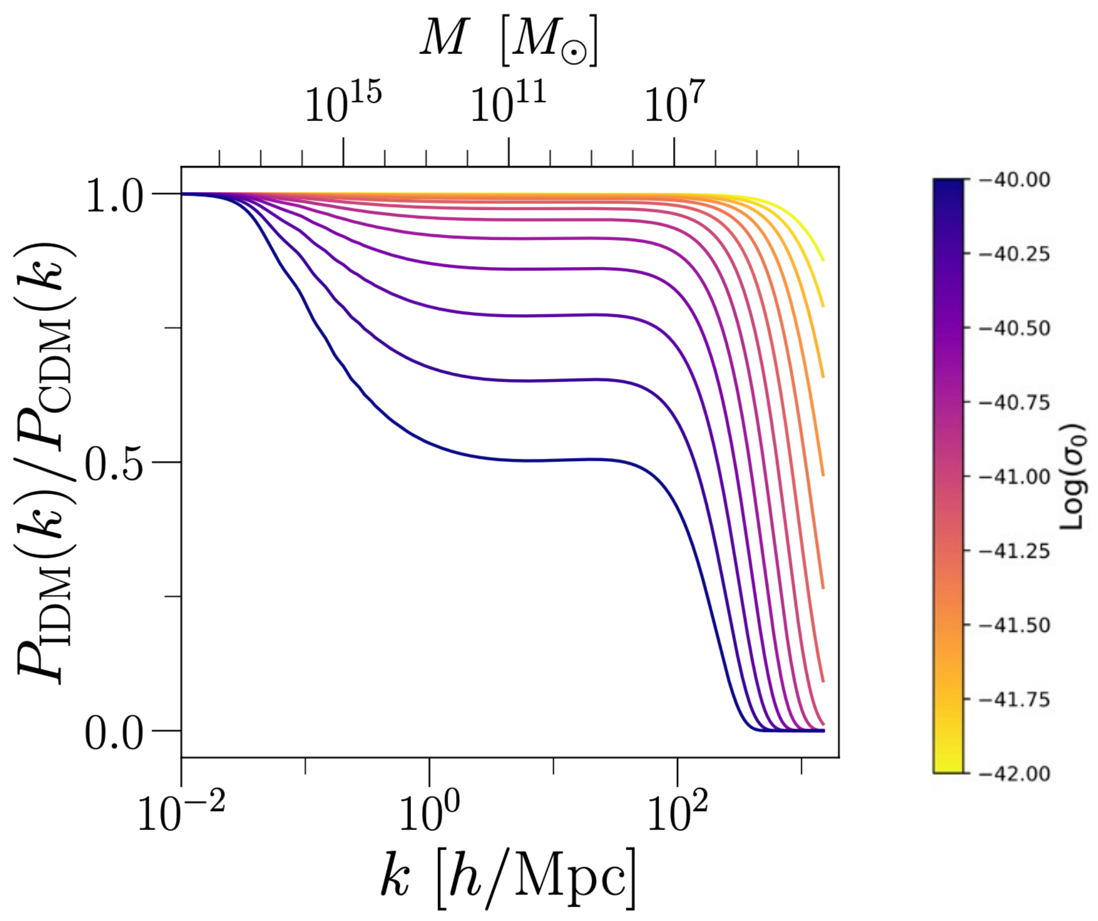
Altered thermal history:



Driskell + (2022)
Munoz+ (2016)
EDGES collab. (2018)

Global 21-cm signal with IDM

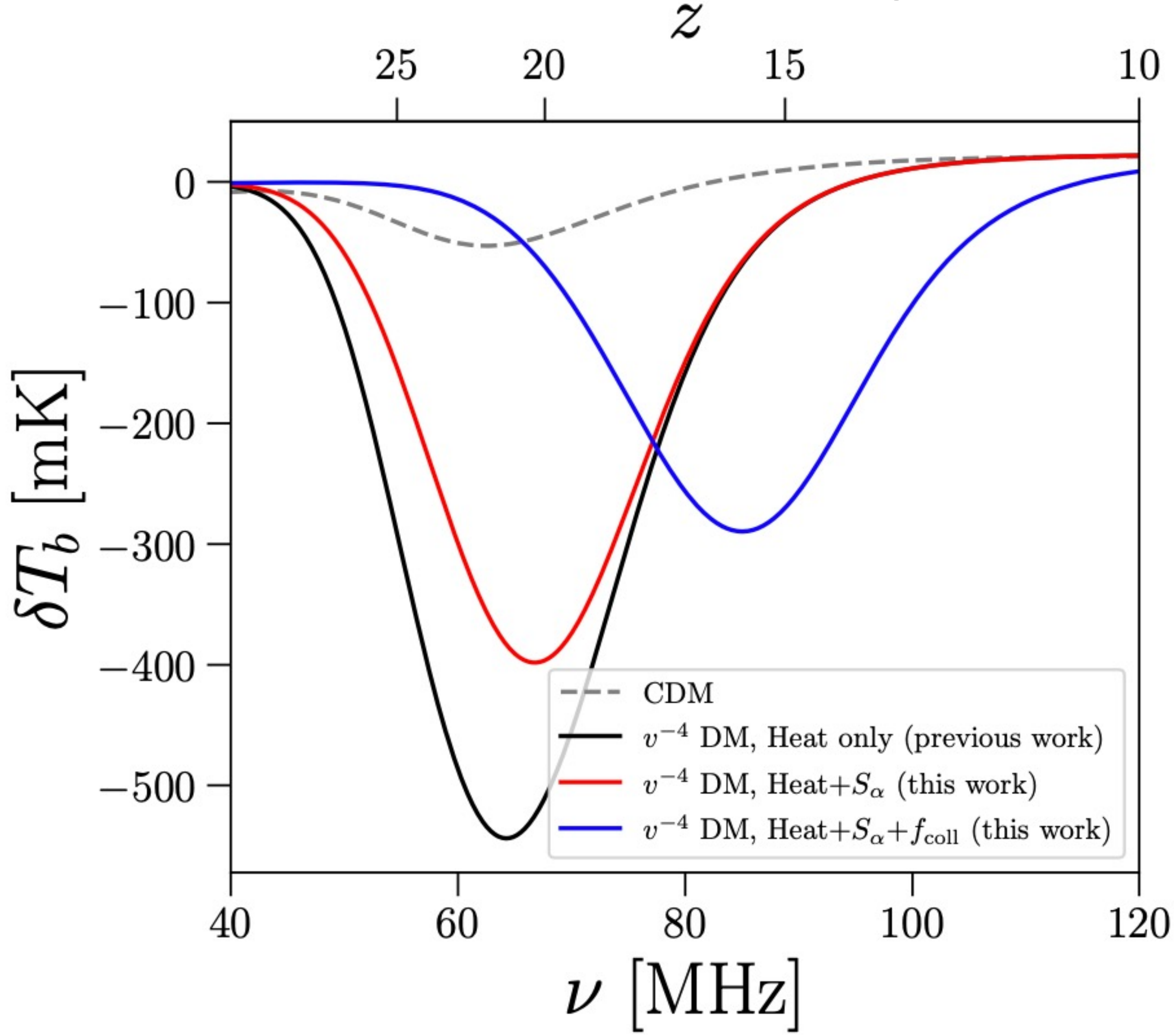
Suppression of structure:
(Not included in previous modeling)

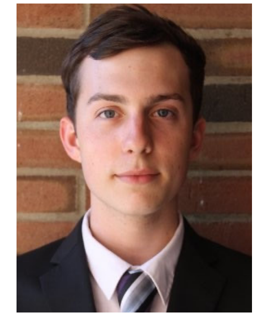


Driskell + (2022)

Global 21-cm signal with IDM

Suppression + cooling





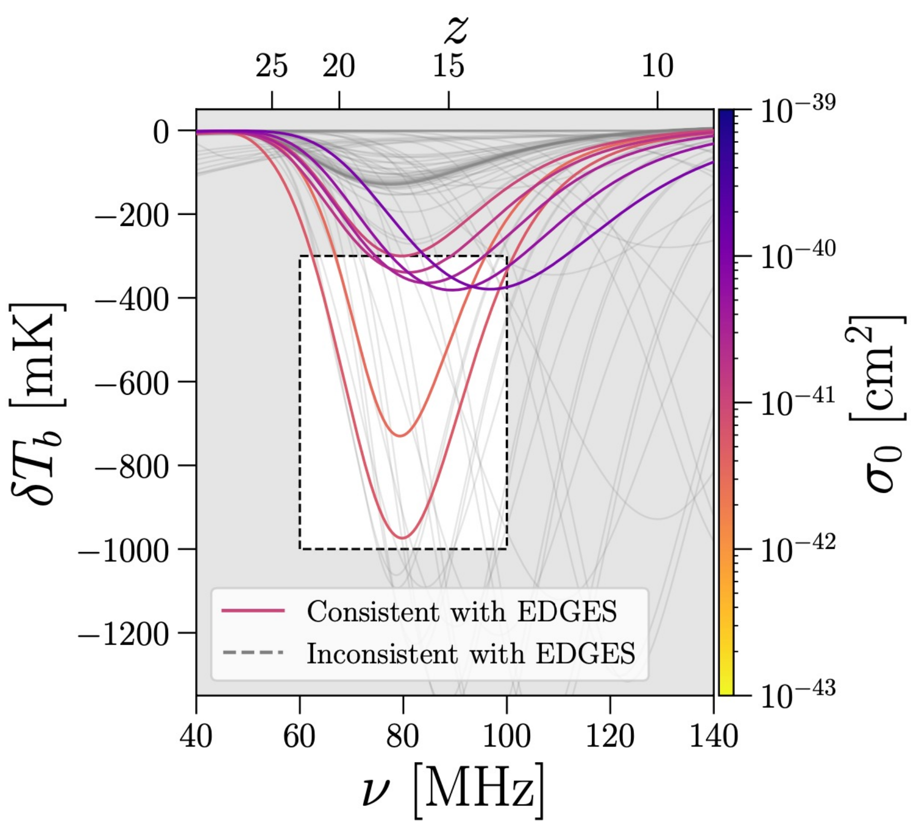
Trey Driskell

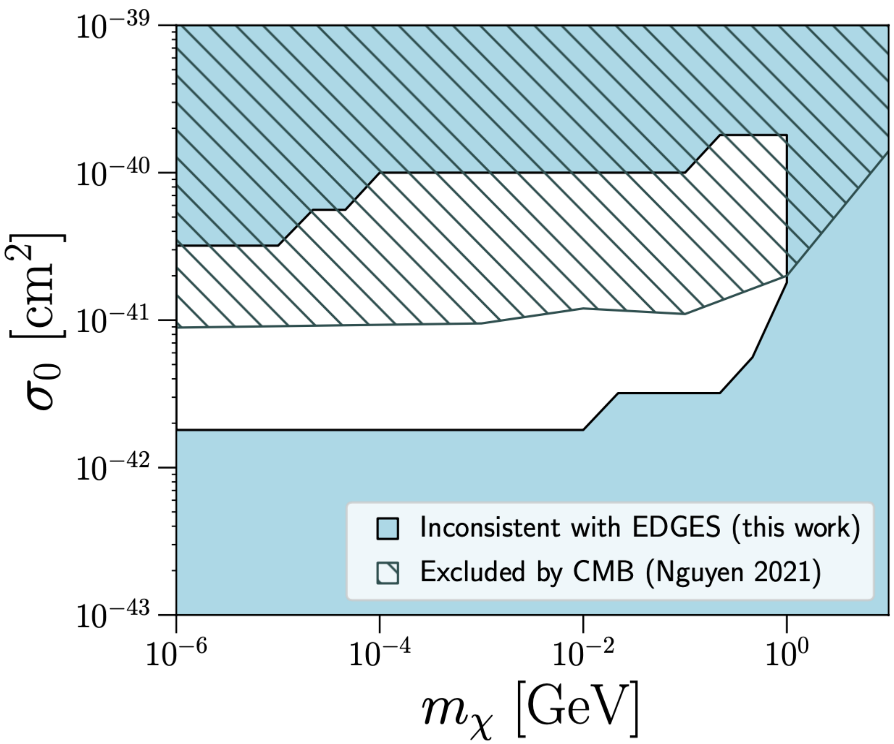
Driskell + (2022)

Global 21-cm signal with IDM

Millicharge cannot explain the EDGES signal.
V^−4 Coulomb-like scattering is further constrained by the timing of the signal.

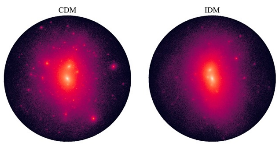
Trey Driskell



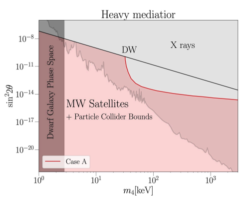


Driskell + (2022)

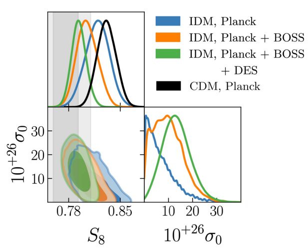
Key Points



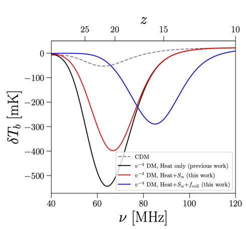
- Small scale structure is sensitive to DM physics. **MW satellites** currently drive a non-CDM frontier.



- **Sterile neutrino** DM is heavily constrained by small scale structure, regardless of the particle spectra.



- **DM-baryon scattering** alleviates S8 tension, through scale-dependent power suppression.



- **21cm signal** requires accurate modeling of structure formation + thermal history.