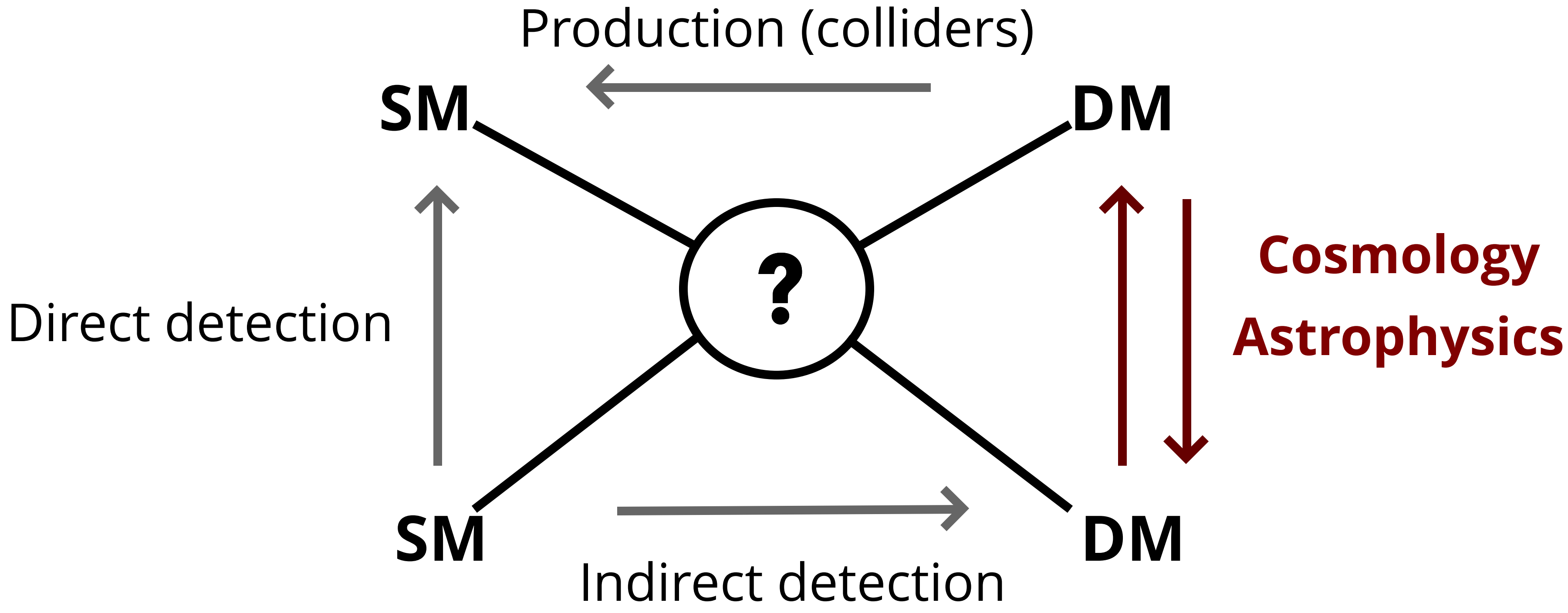
Dark Matter
throughout cosmic history

Vera Gluscevic

University of Southern California (USC)

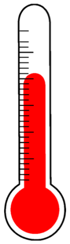
2nd Global 21cm Workshop - McGill University - October 7, 2019.

Cosmic direct detection



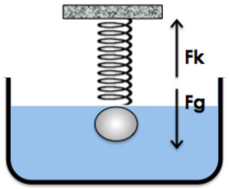
Cosmological probes of DM-baryon scattering

momentum + heat transfer



Thermal history of the Universe

$$\dot{T}_\chi = -2\frac{\dot{a}}{a}T_\chi + 2R'_\chi(T_b - T_\chi)$$



Cosmological perturbations

$$\dot{\delta}_\chi = -\theta_\chi - \frac{\dot{h}}{2}, \ \dot{\delta}_b = -\theta_b - \frac{\dot{h}}{2}$$

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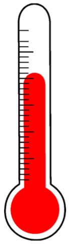

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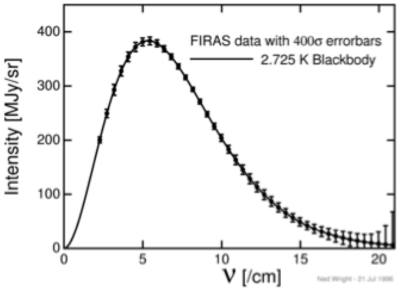

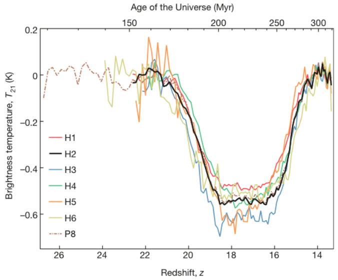

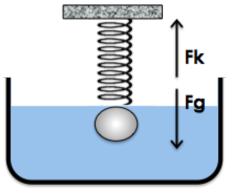

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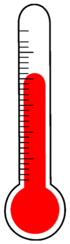

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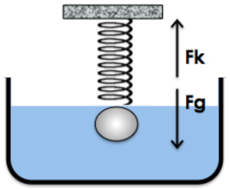

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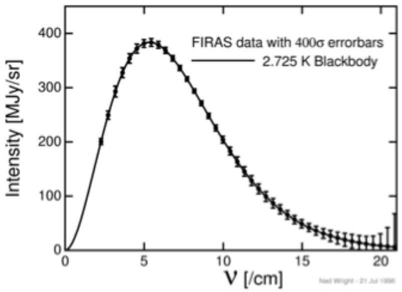
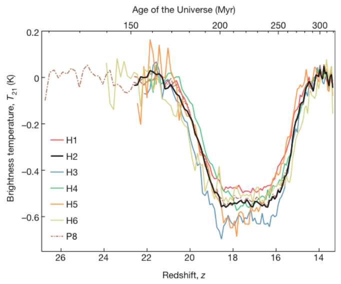
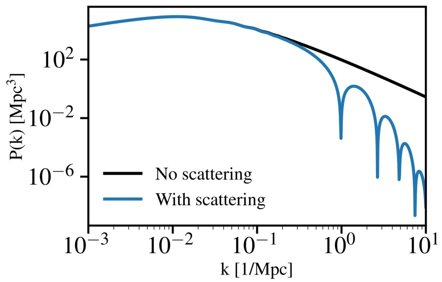
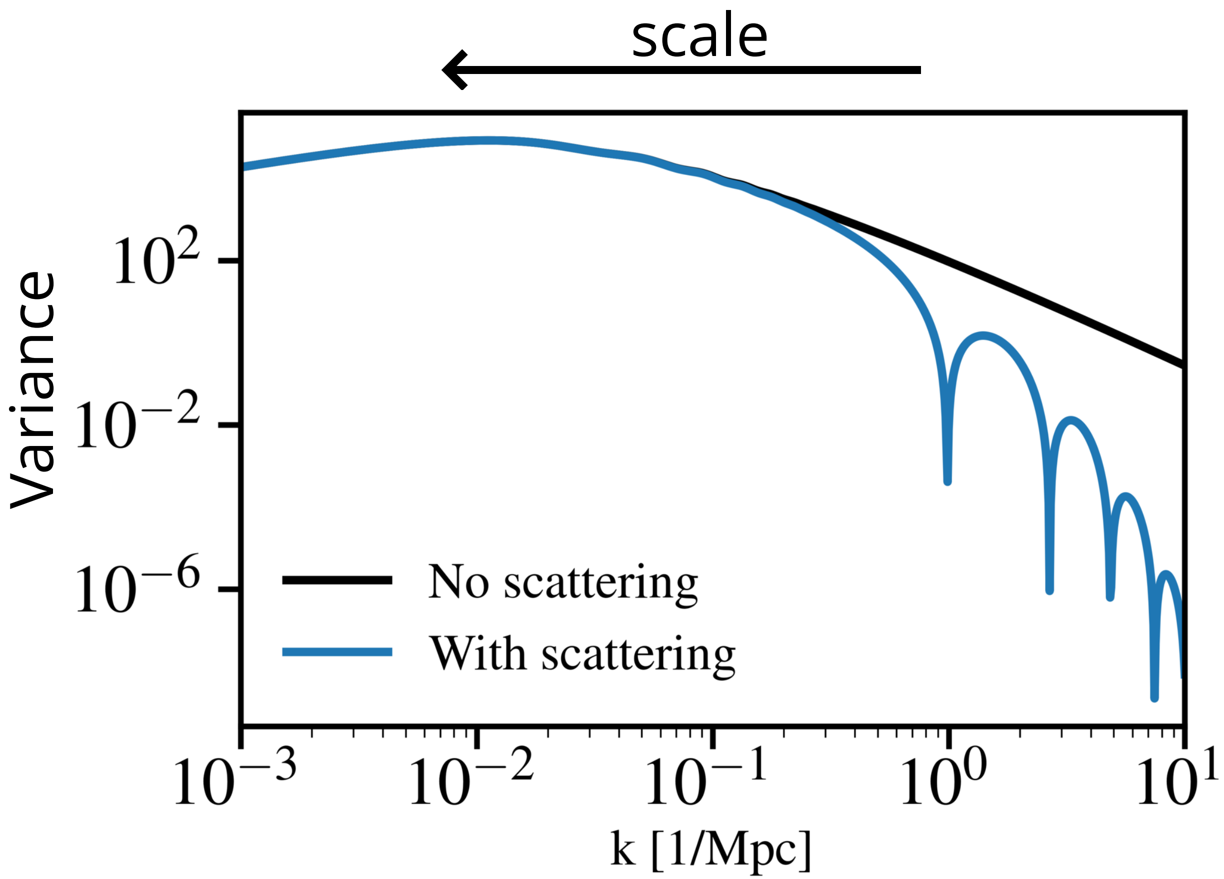






Dark matter interactions suppress structure on small scales.



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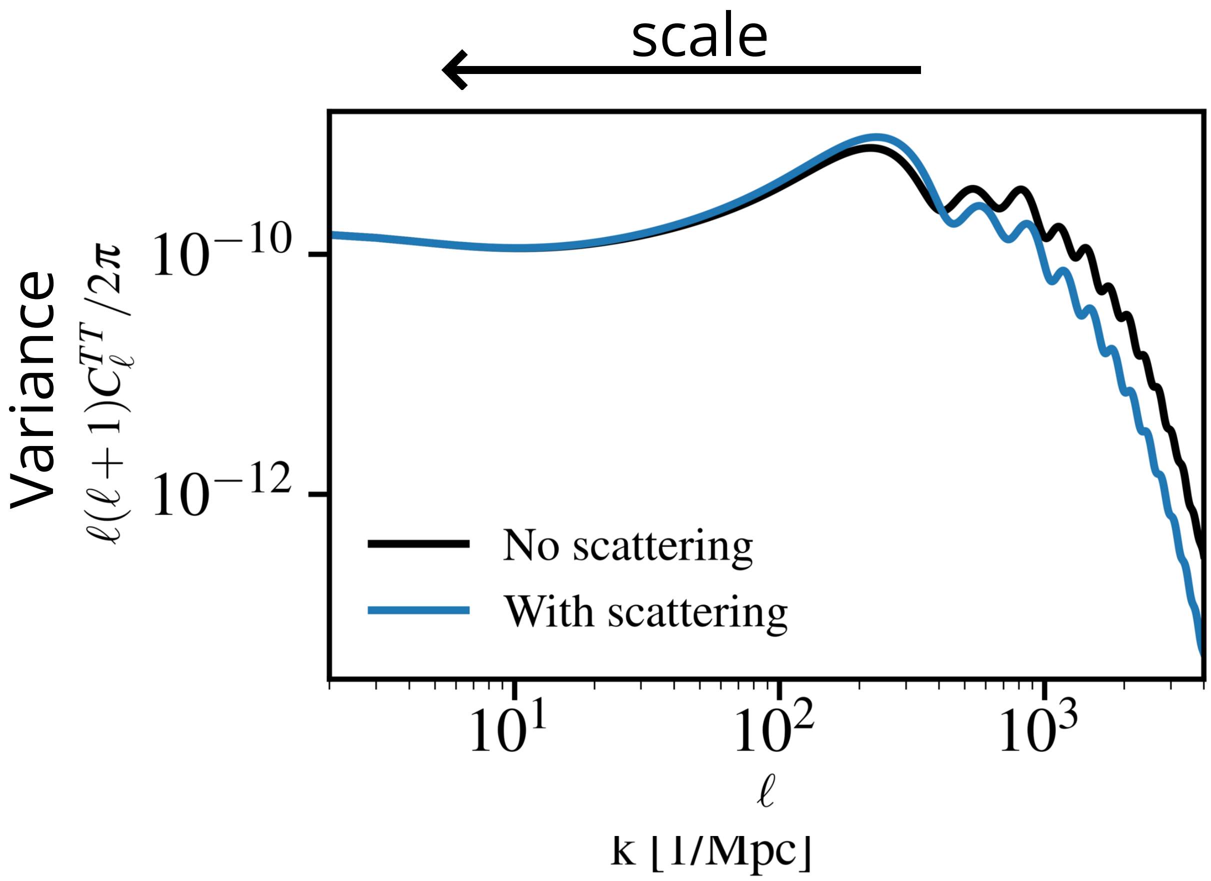
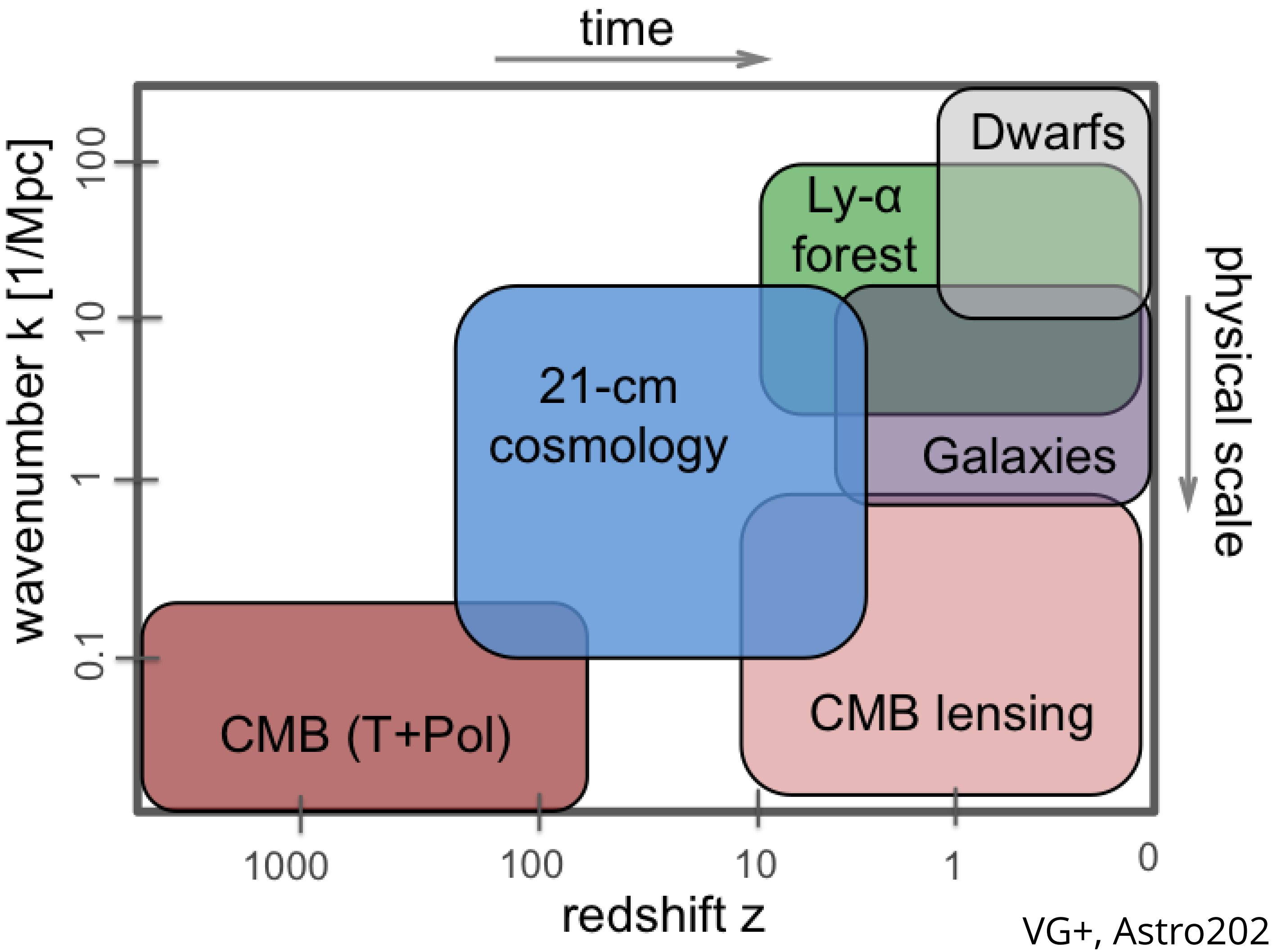


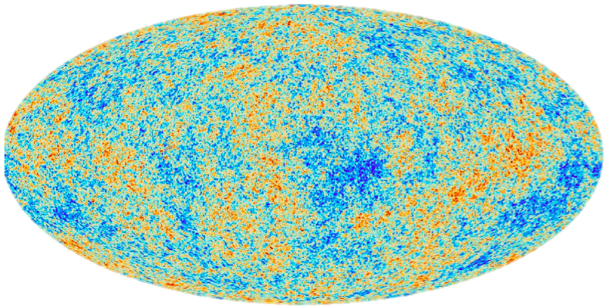
Observables



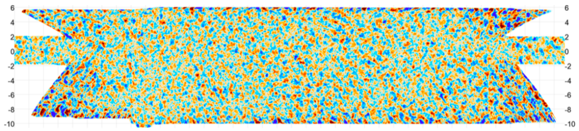
VG+, Astro2020 (2019)

arxiv:1903.05140

CMB power spectrum



Planck Collaboration 2015



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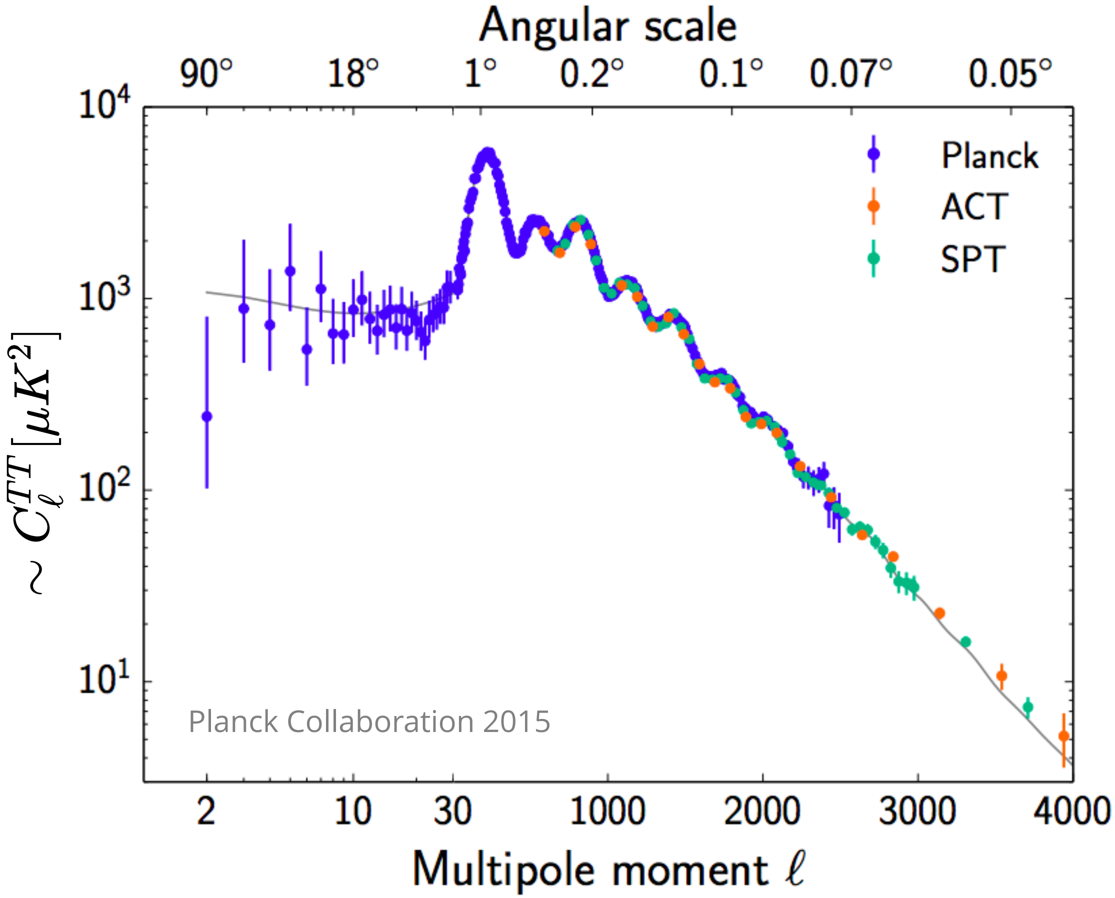
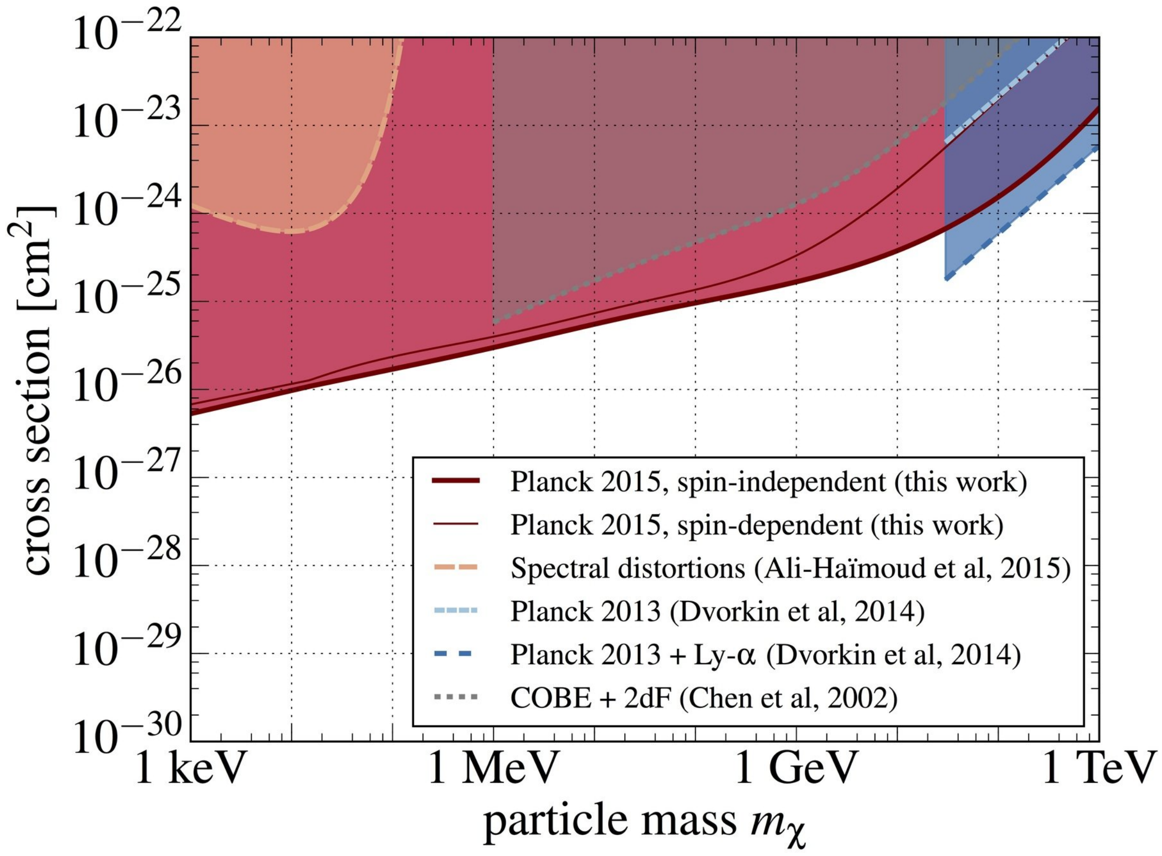


Planck limits on DM-proton scattering

[velocity-independent spin-independent interaction]



VG and Boddy, PRL (2018)

See also: Boehm+ (2002), Chen+ (2002), Dubovsky+ (2004), Sigurdson+ (2004), Dvorkin+ (2014), etc.

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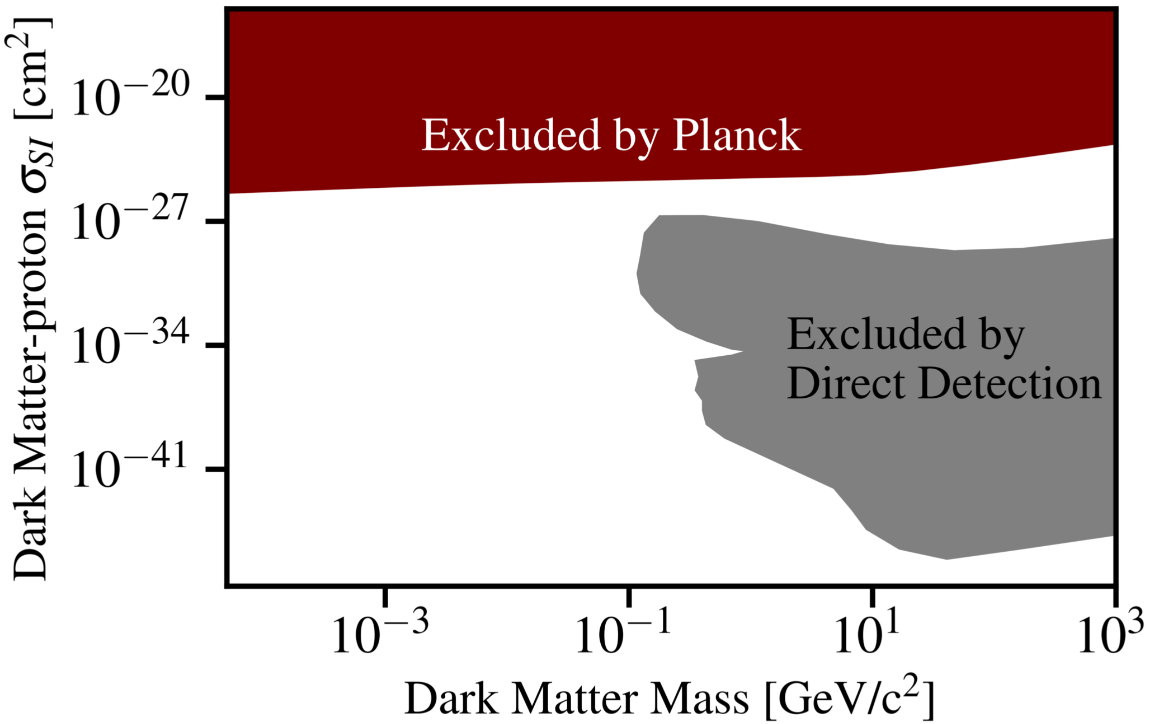

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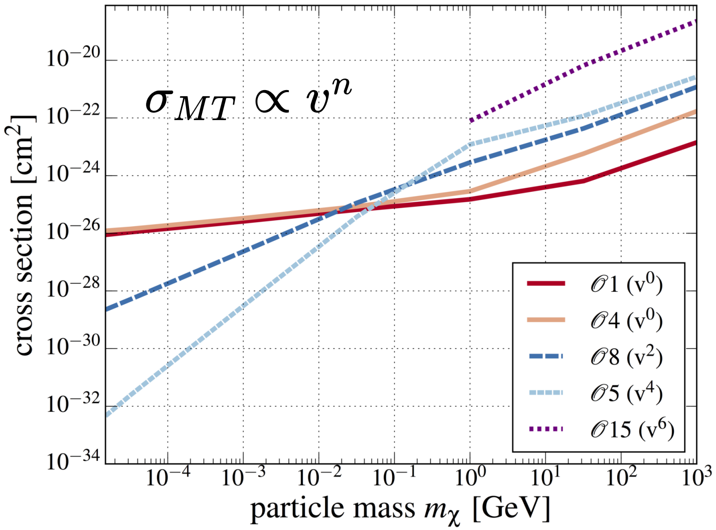
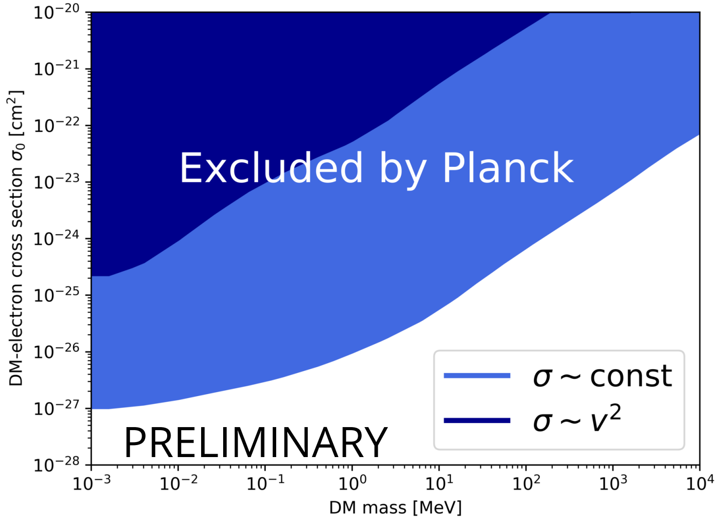
And beyond...



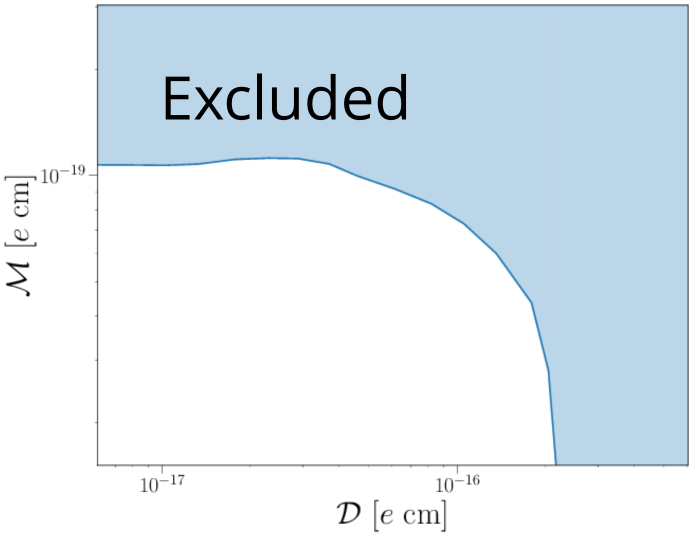
DM effective theory

(Boddy and VG, 2018)



Scattering with electrons

(VG and Boddy, in prep.)



Dipole DM

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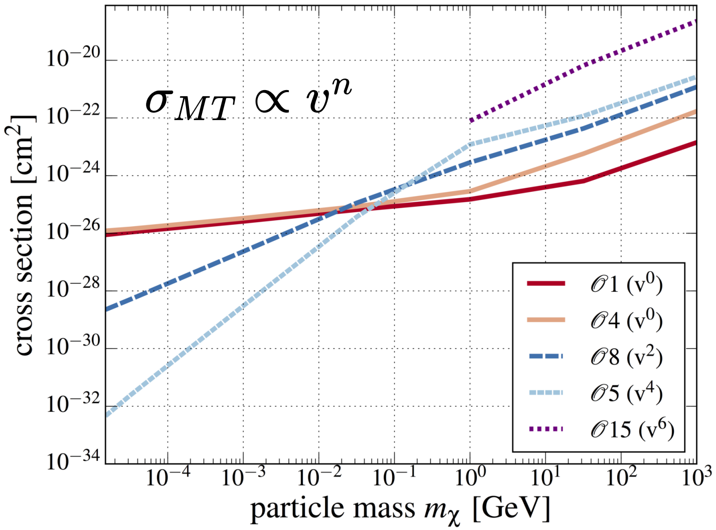

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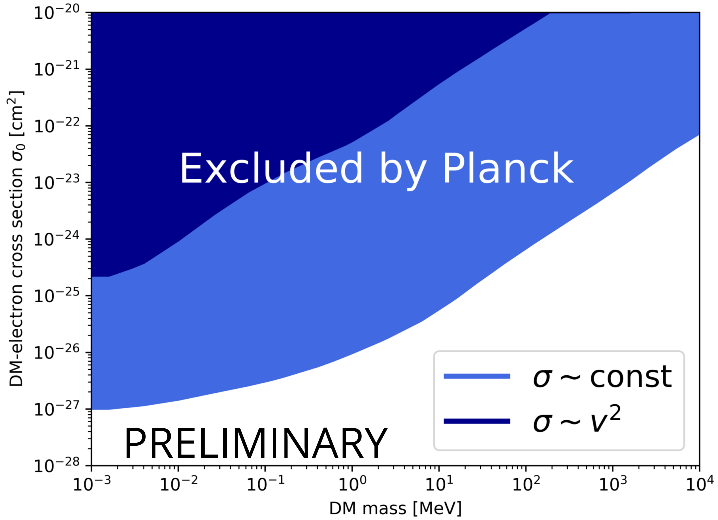

Scattering with electrons

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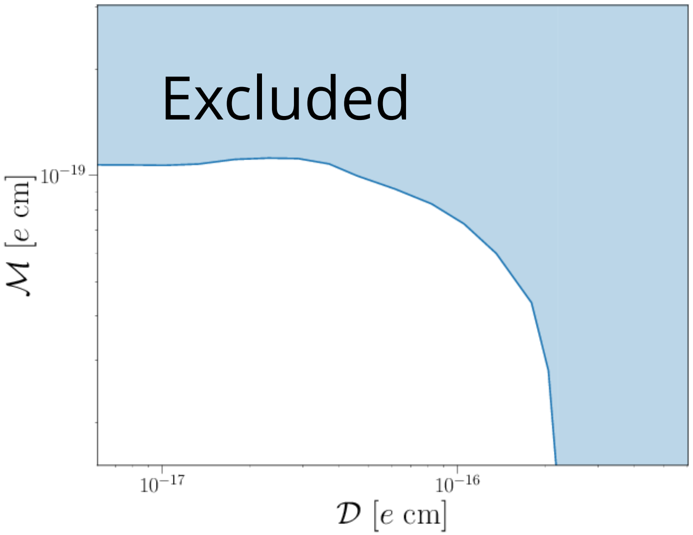
Age of the Universe ~1000 years: less than 1 in 100 000 scatterings is with DM.



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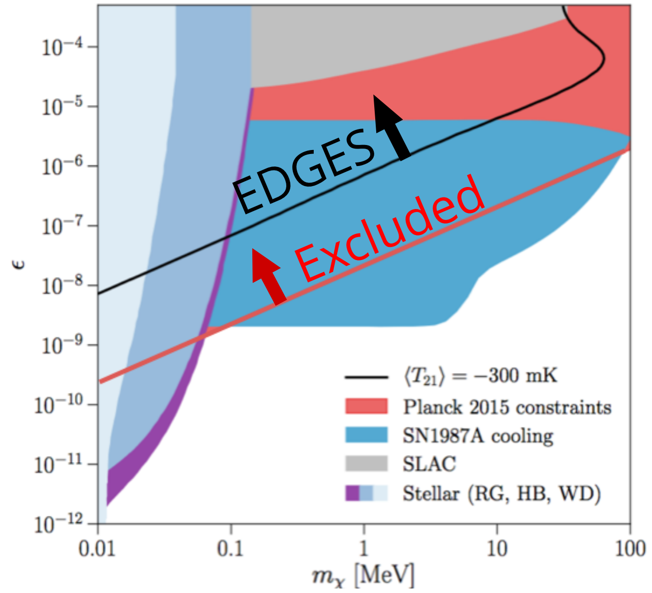
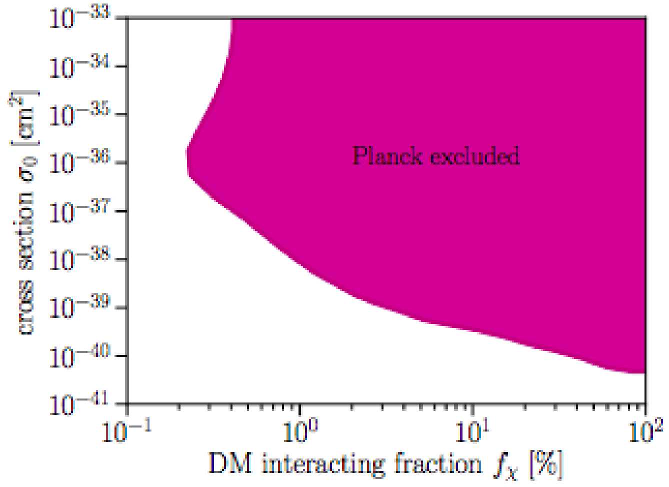
What about millicharge?

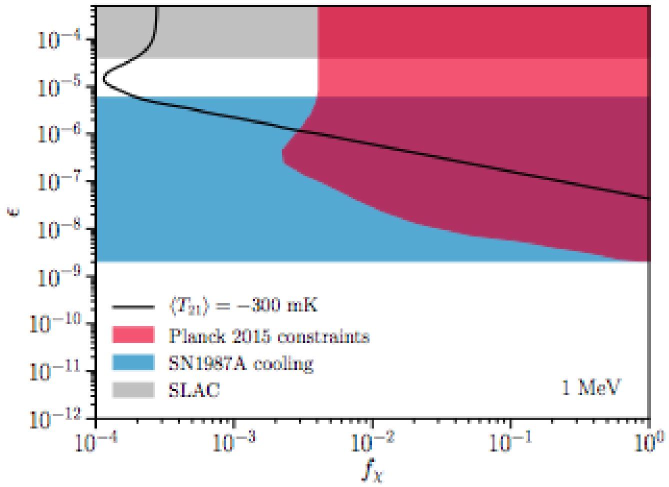




Boddy, VG, + 2018

Kovetz, Poulin, VG, + 2018

(see also Slatyer+ 2018, Xu+ 2018)



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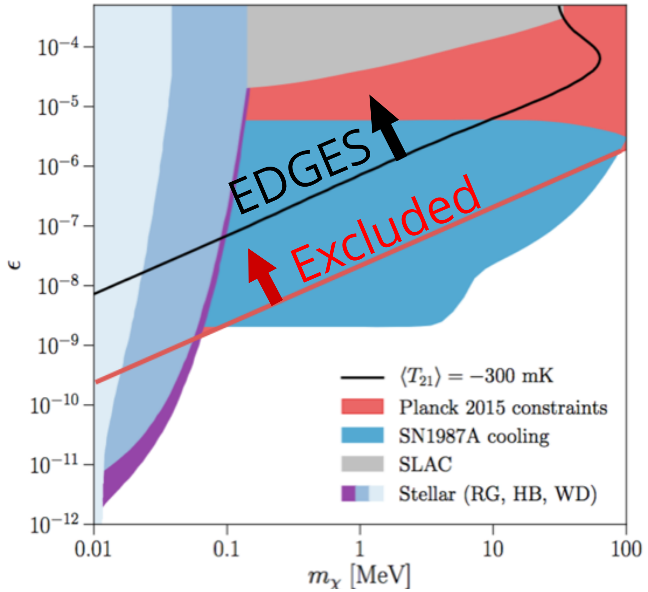

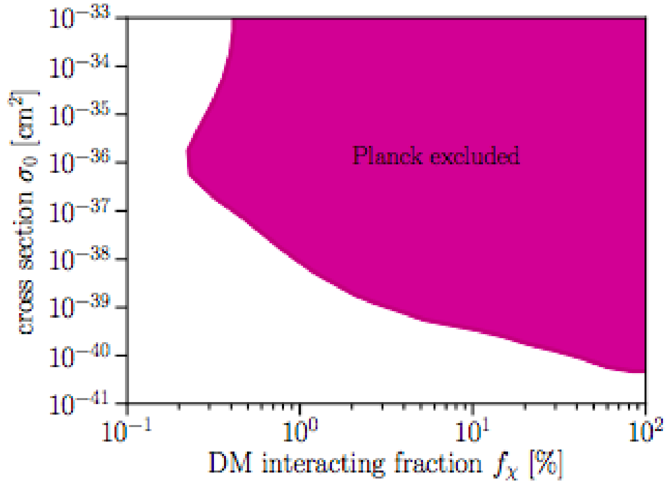

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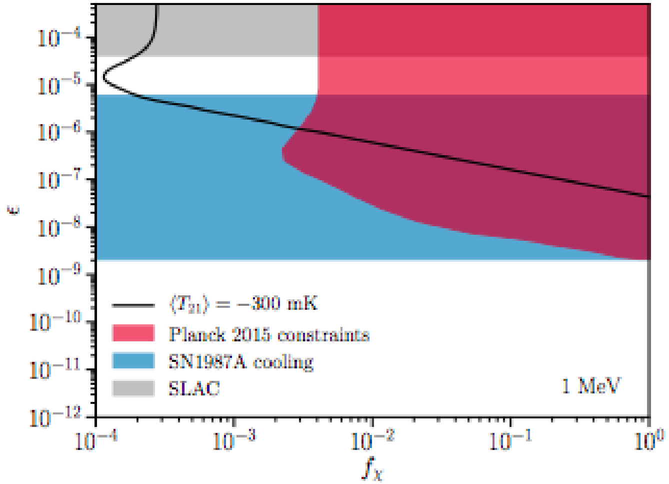

Planck is inconsistent with EDGES, if more than 0.5% of DM is millicharged.

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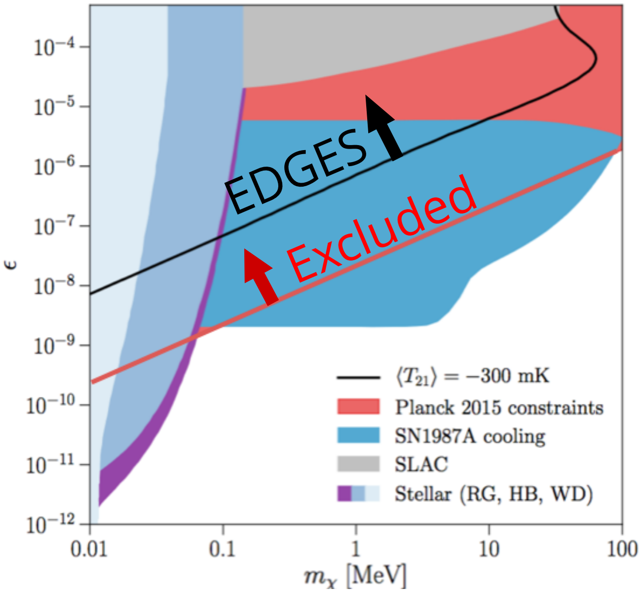

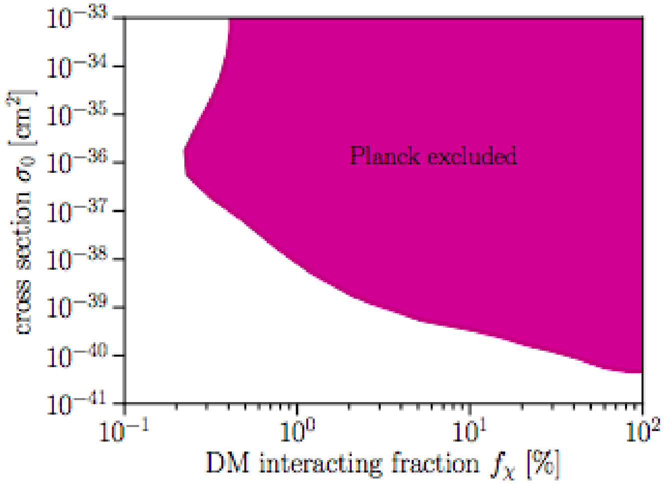

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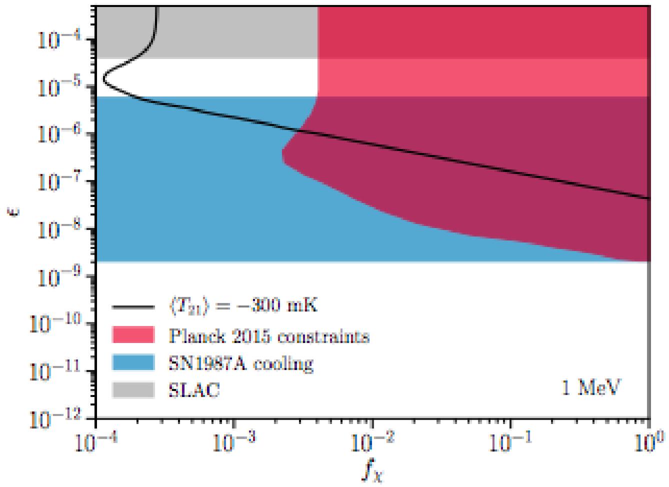

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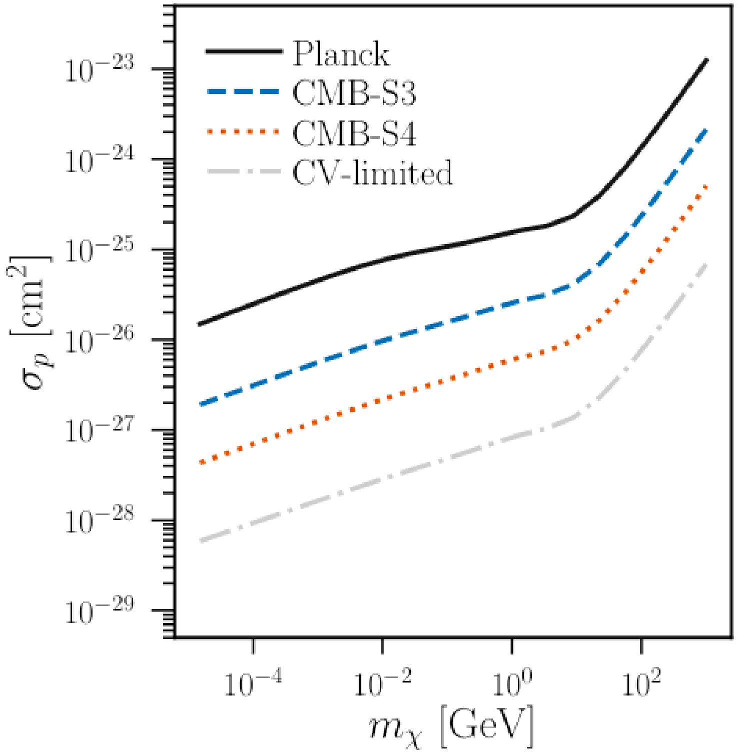
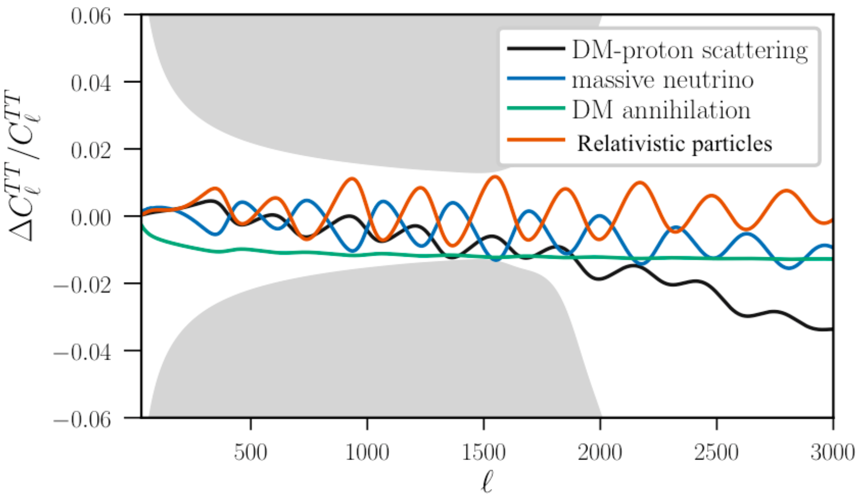
NB: Bulk relative velocity matters at late time!

Next-generation ground-based CMB

(Simons Observatory, CMB-S4)



DM interactions do NOT look like other science targets, given well-measured CMB lensing.



Li, VG, + (2018)

See also 1808.07445

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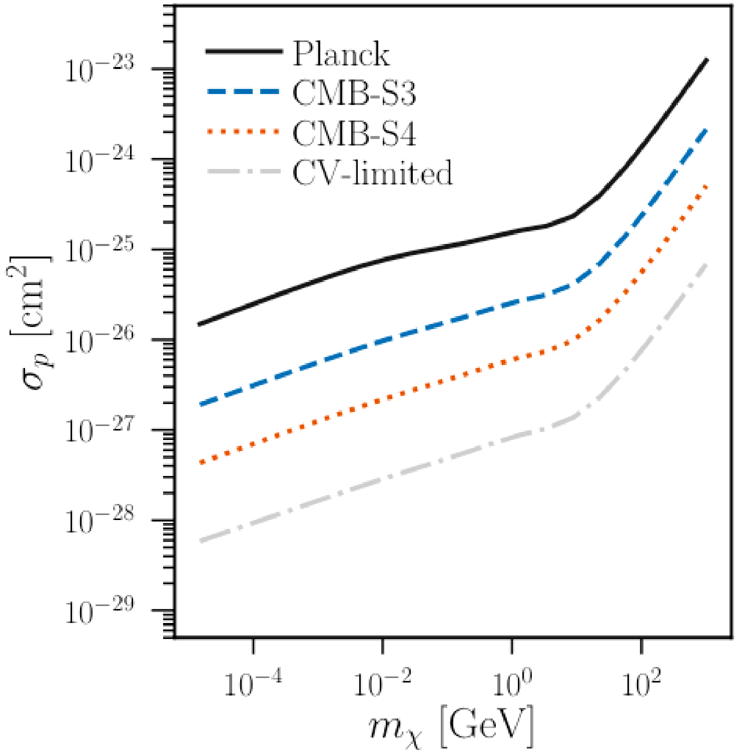

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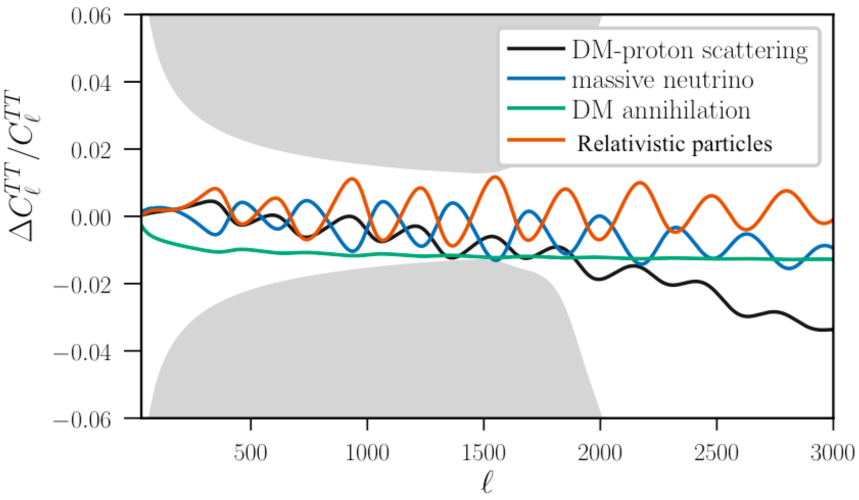

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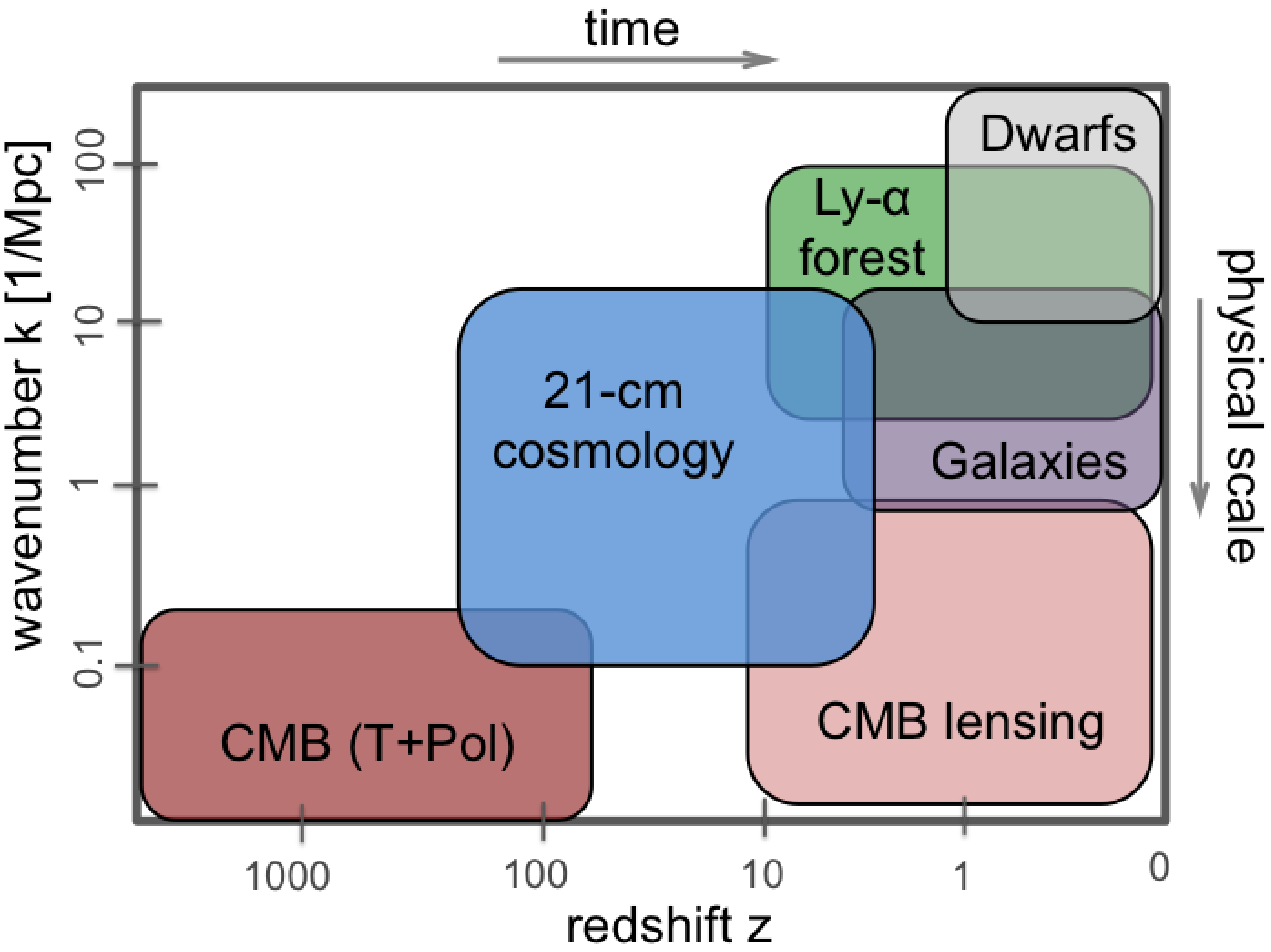
CMB: independent of cosmology, robust to confusion with other physics.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Dwarfs
Ly-α
forest
21-cm
cosmology
Galaxies
CMB (T+Pol)
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wavenumber k [1/Mpc]
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1
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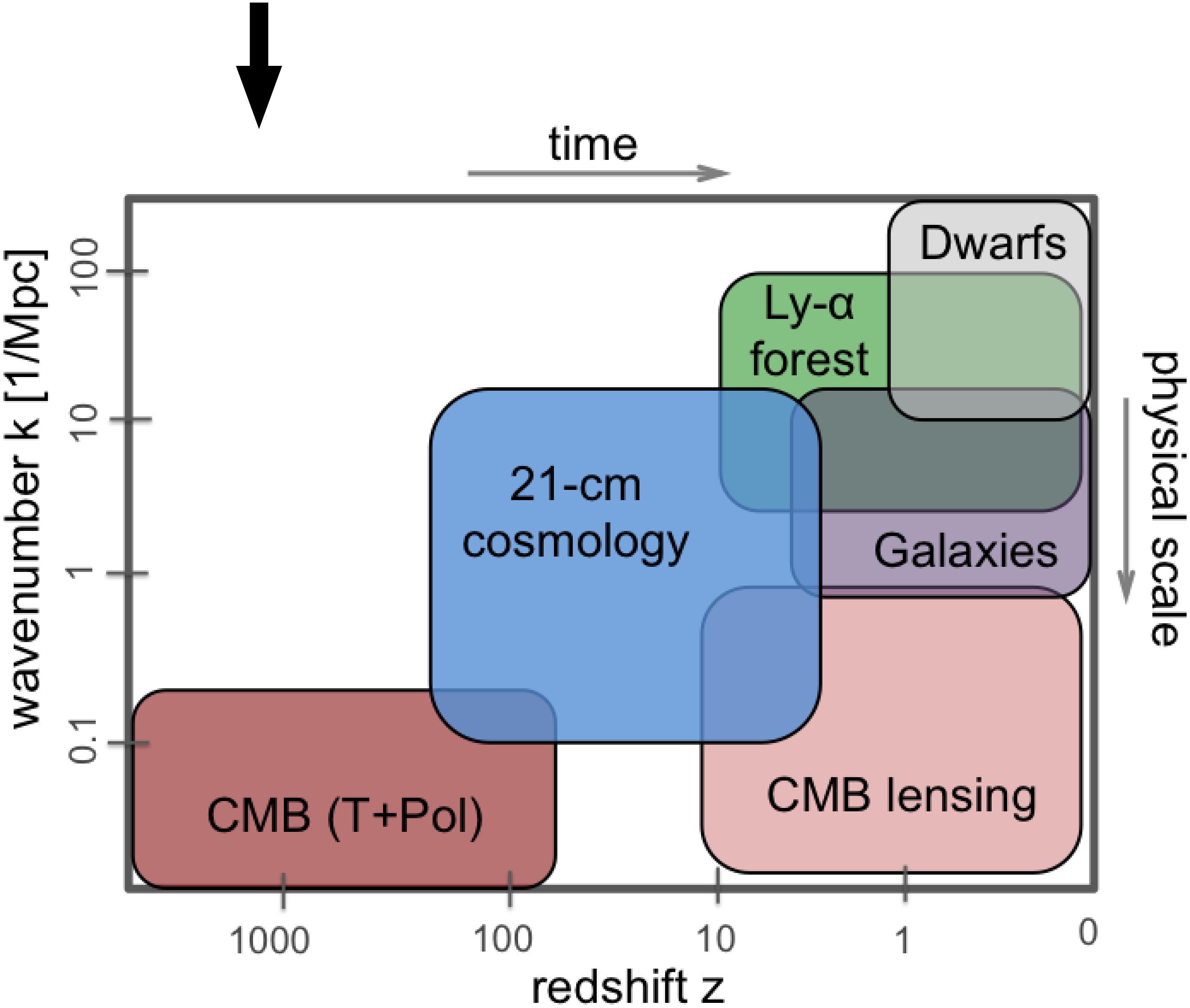
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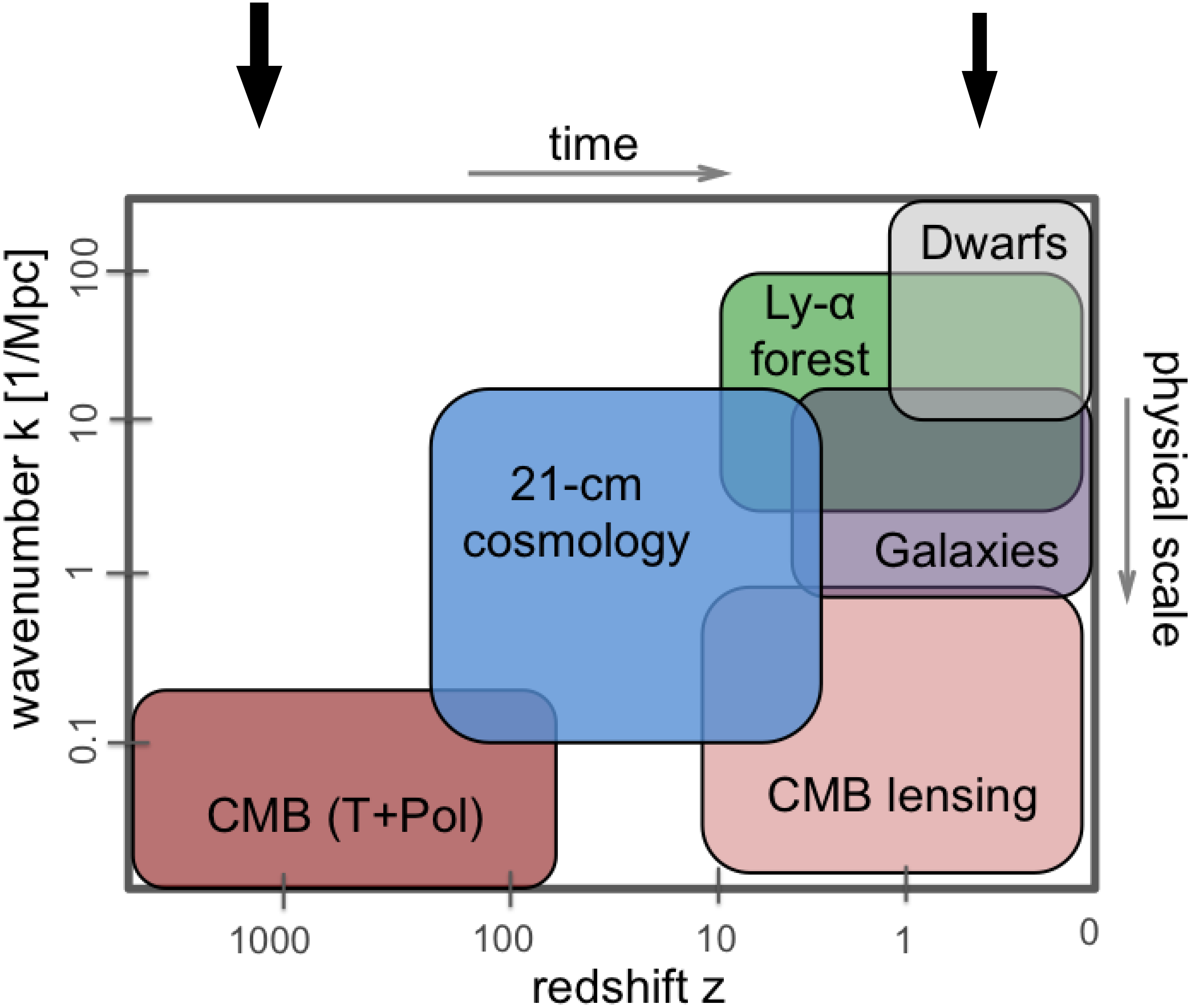
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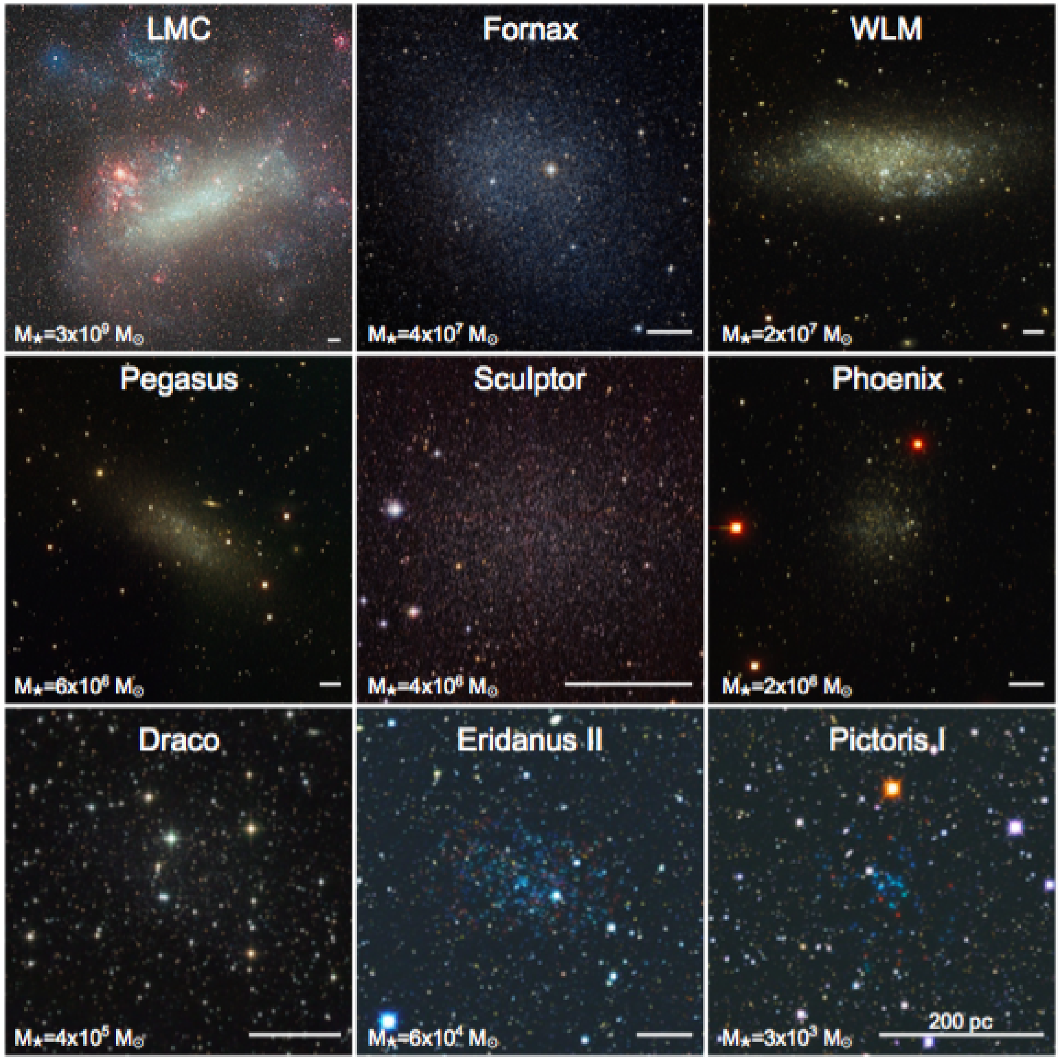
Near-field cosmology

Galaxy surveys: **SDSS, DES;** Upcoming: **LSST,DESI,...**



Bullock and Boylan-Kolchin (2017)

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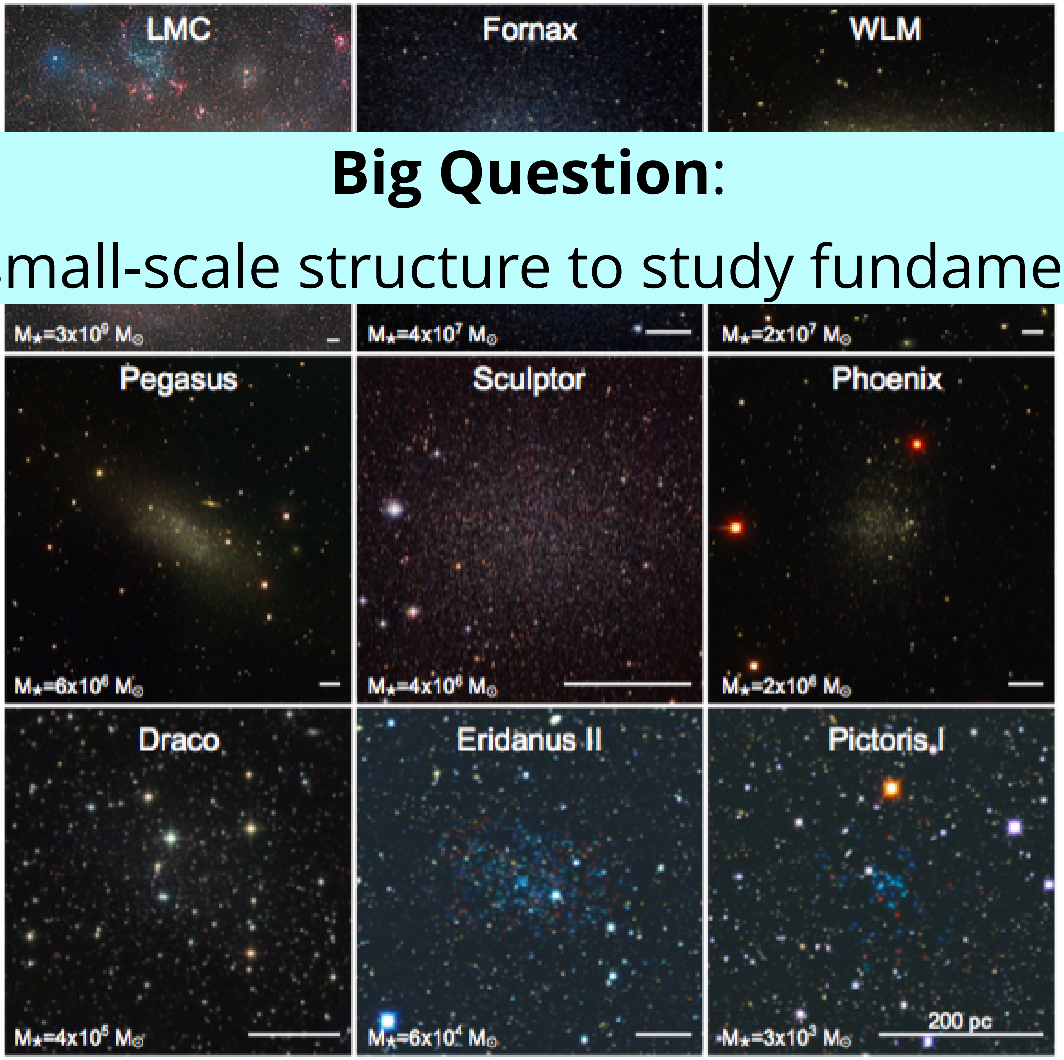

Big Question:

Can we use small-scale structure to study fundamental physics?

Bullock and Boylan-Kolchin (2017)

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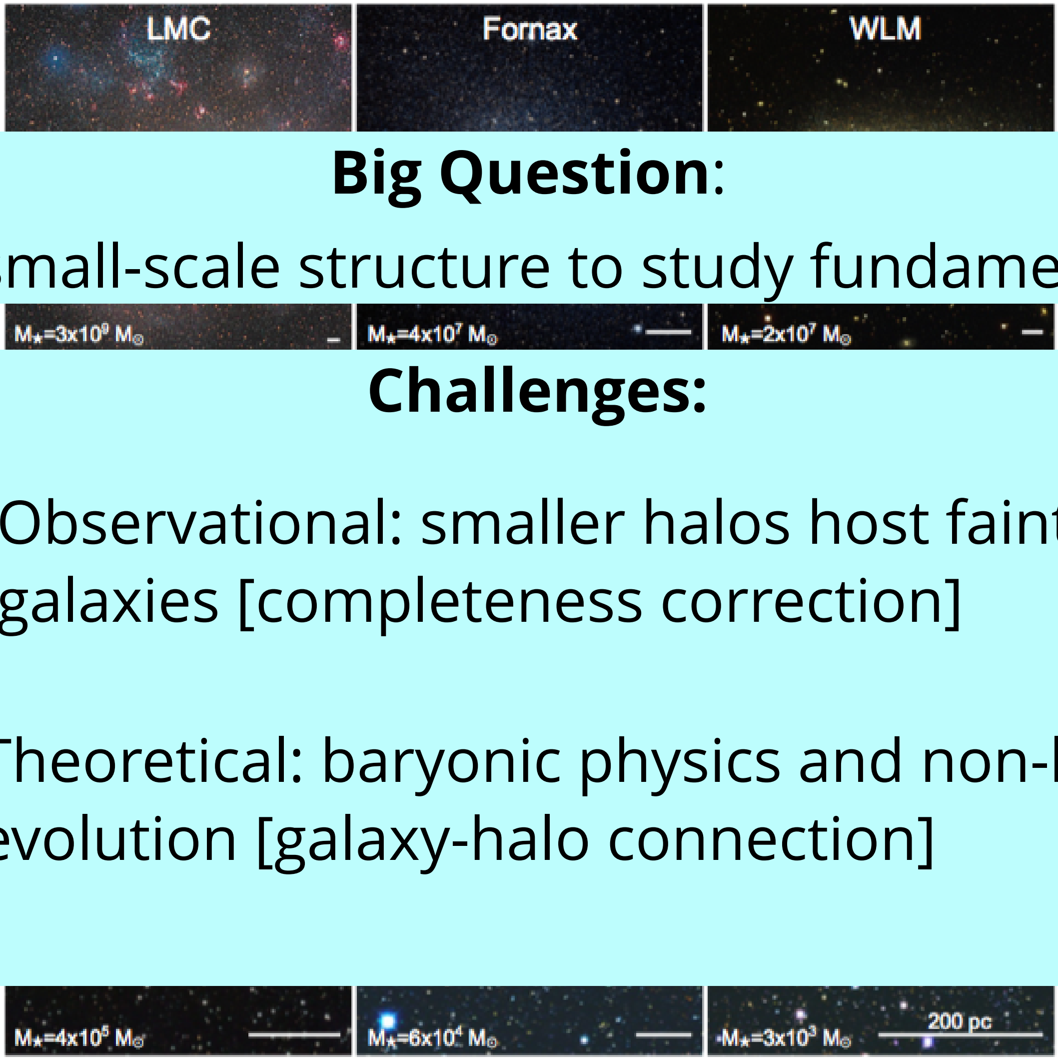


Big Question:

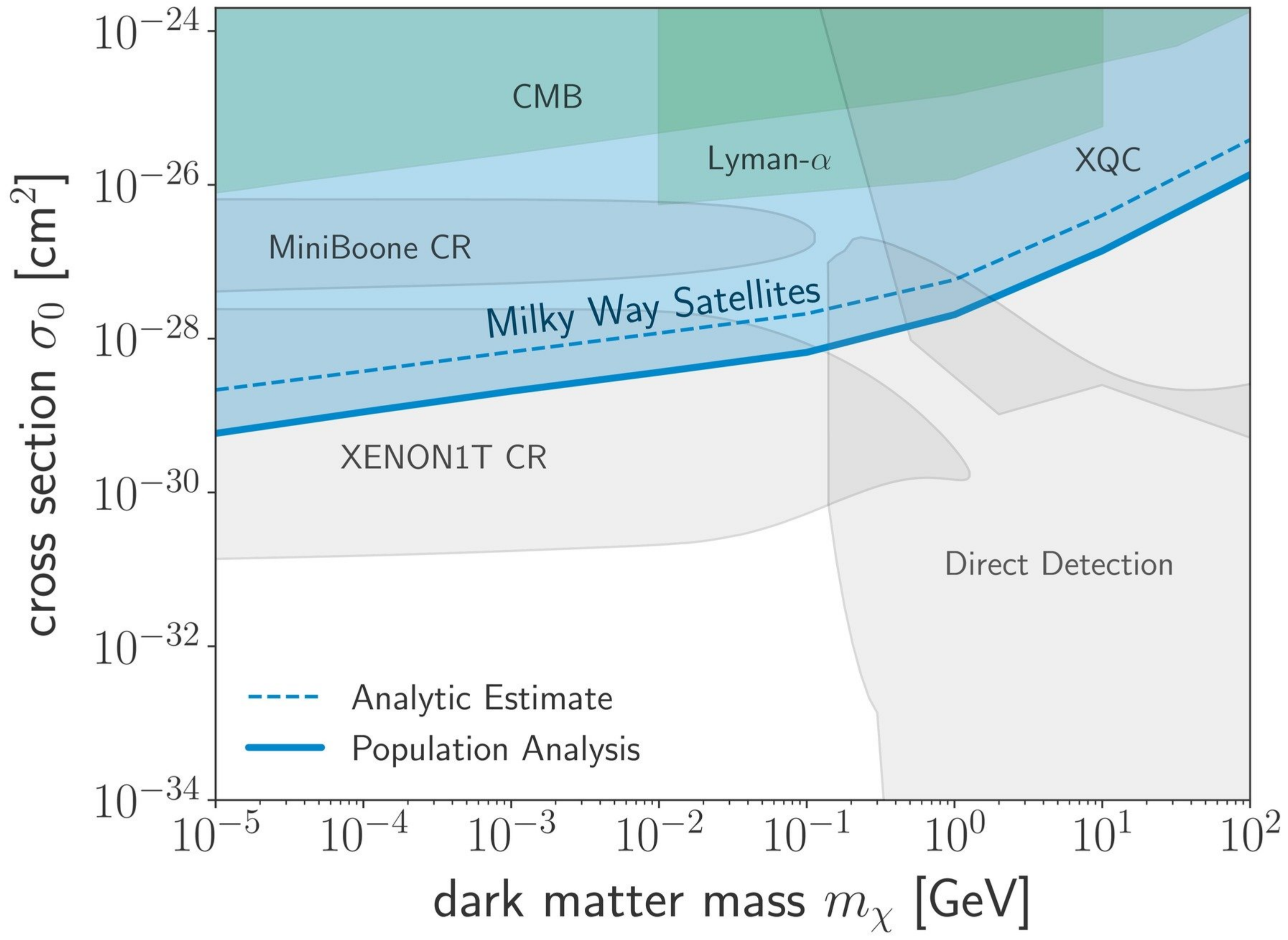
Can we use small-scale structure to study fundamental physics?

Challenges:

- Observational: smaller halos host fainter galaxies [completeness correction]
- Theoretical: baryonic physics and non-linear evolution [galaxy-halo connection]

Bullock and Boylan-Kolchin (2017)

Limits from Milky Way Satellites



Nadler, VG, Boddy, Wechsler (ApJ Letters 2019)

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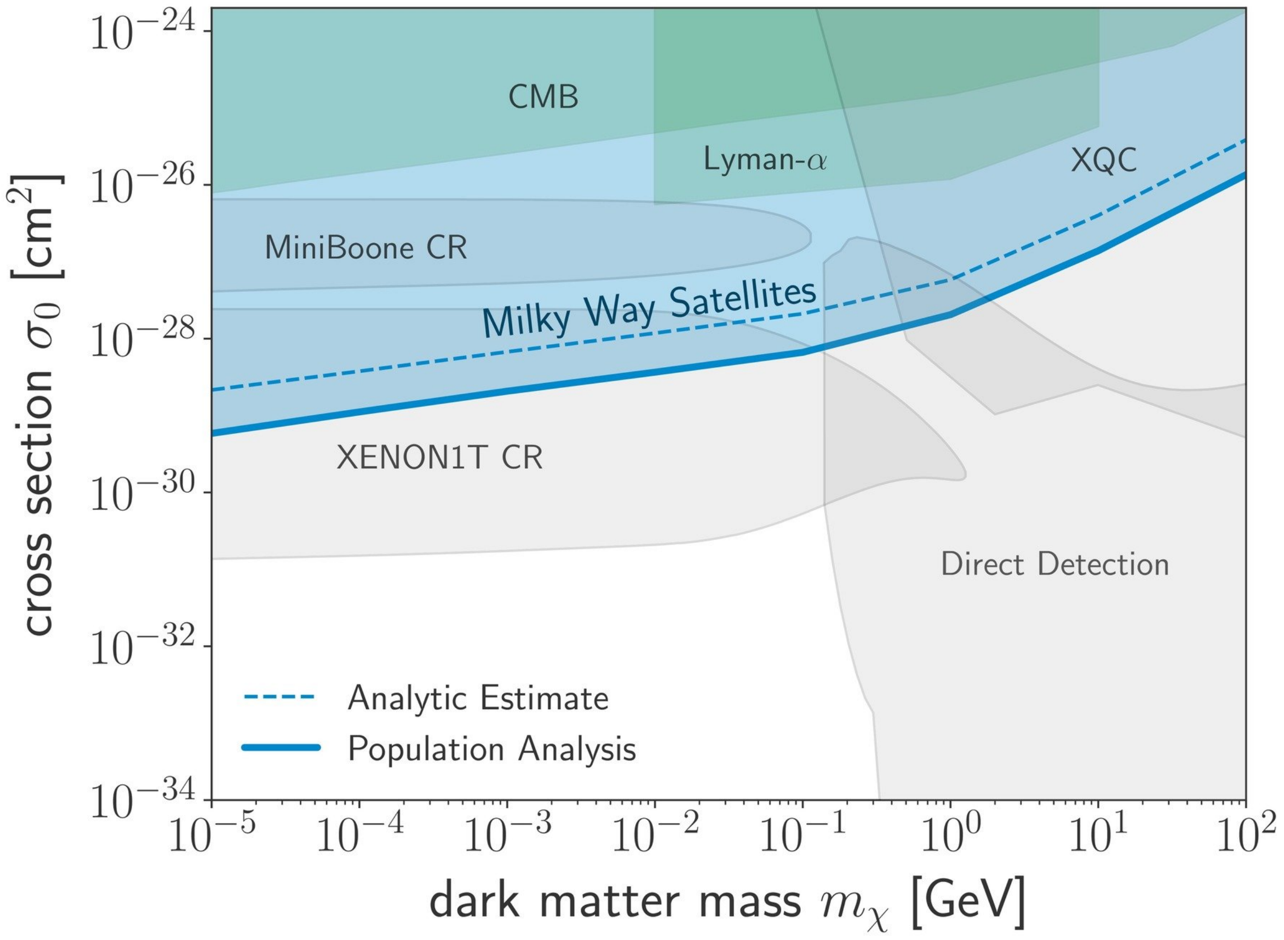
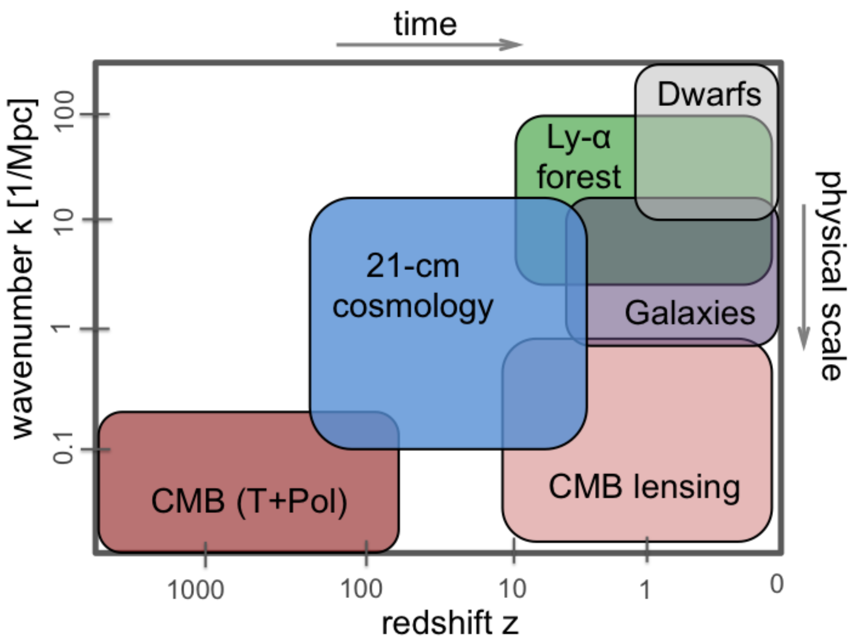


Nadler, VG, Boddy, Wechsler (ApJ Letters 2019)

Caveats: holds for velocity independent scattering, cosmology-dependent.

How does 21-cm fit here?



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arxiv:1903.05140

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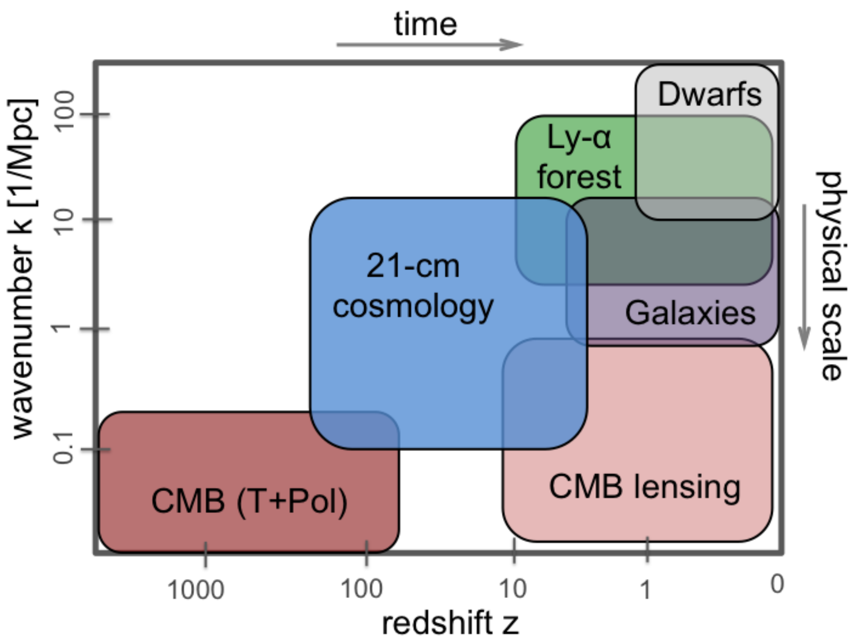

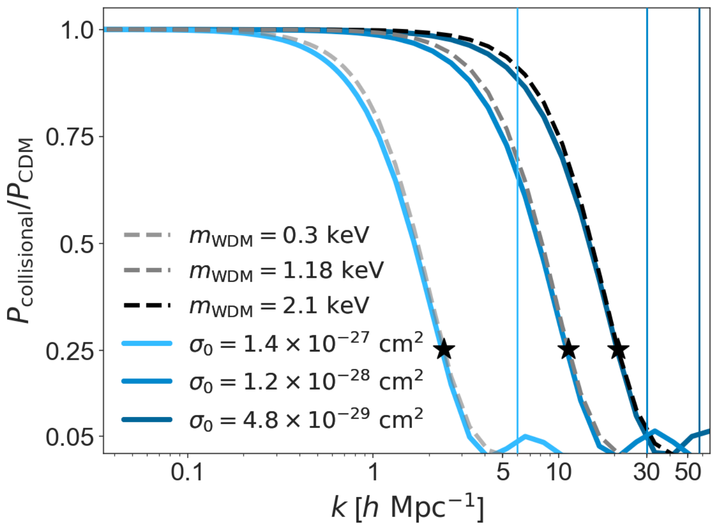

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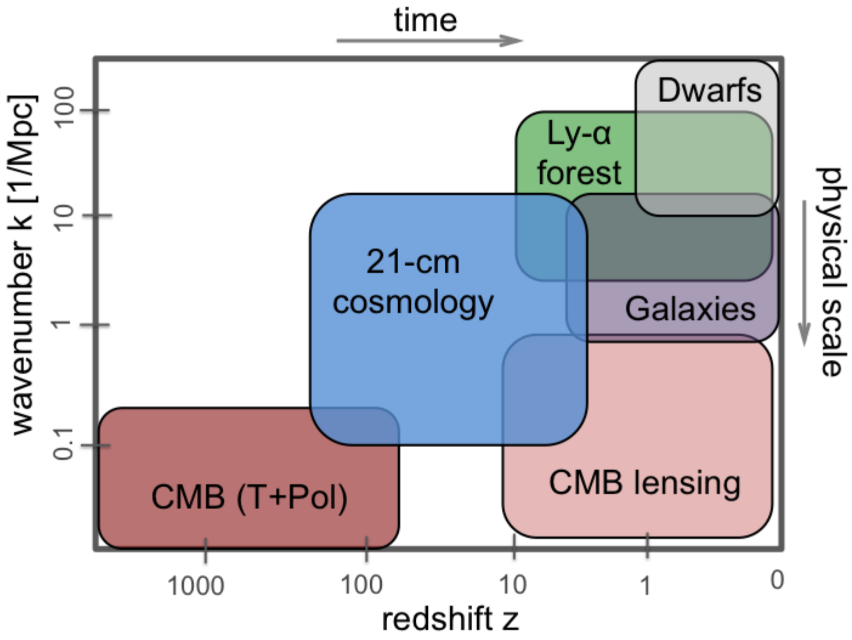

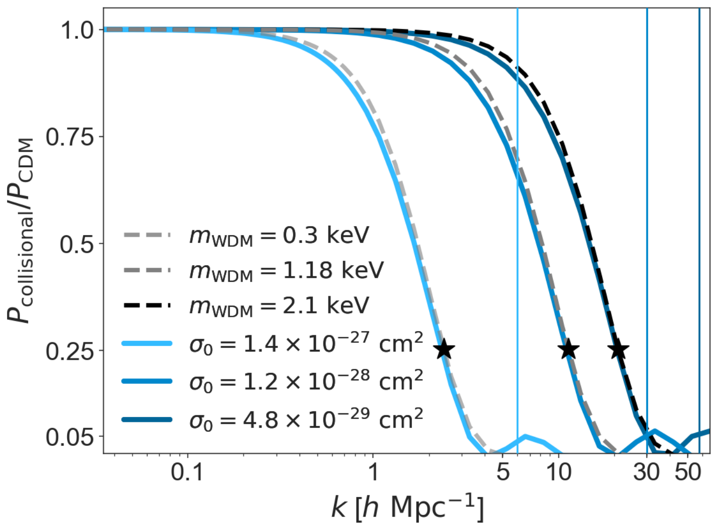

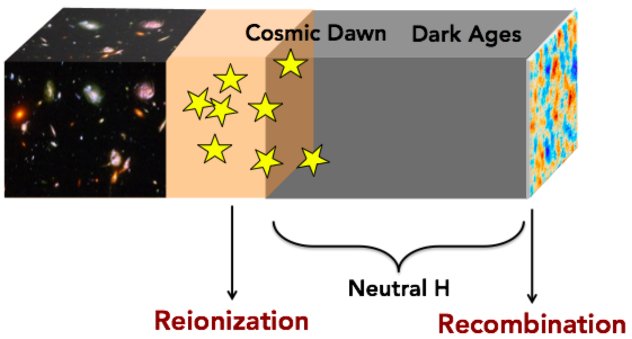

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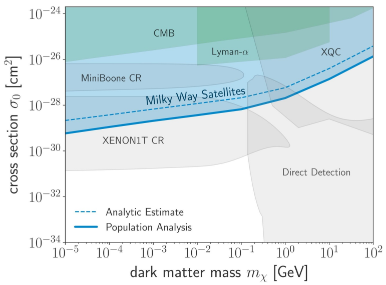
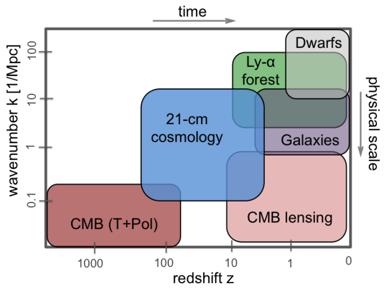
Key points





- CMB already probes new parameter space and new paradigms; near-field cosmology is messier, but very promising [e.g. satellites].
- **Key for discovery: comprehensive searches and joint analyses of all available data.**
- **To address: non-linearities in non-standard cosmologies, frameworks for joint analyses of multiple observables, assessment of limitations and degeneracies in new data sets.**

VG+, Astro2020 (2019) **arxiv:1903.05140**