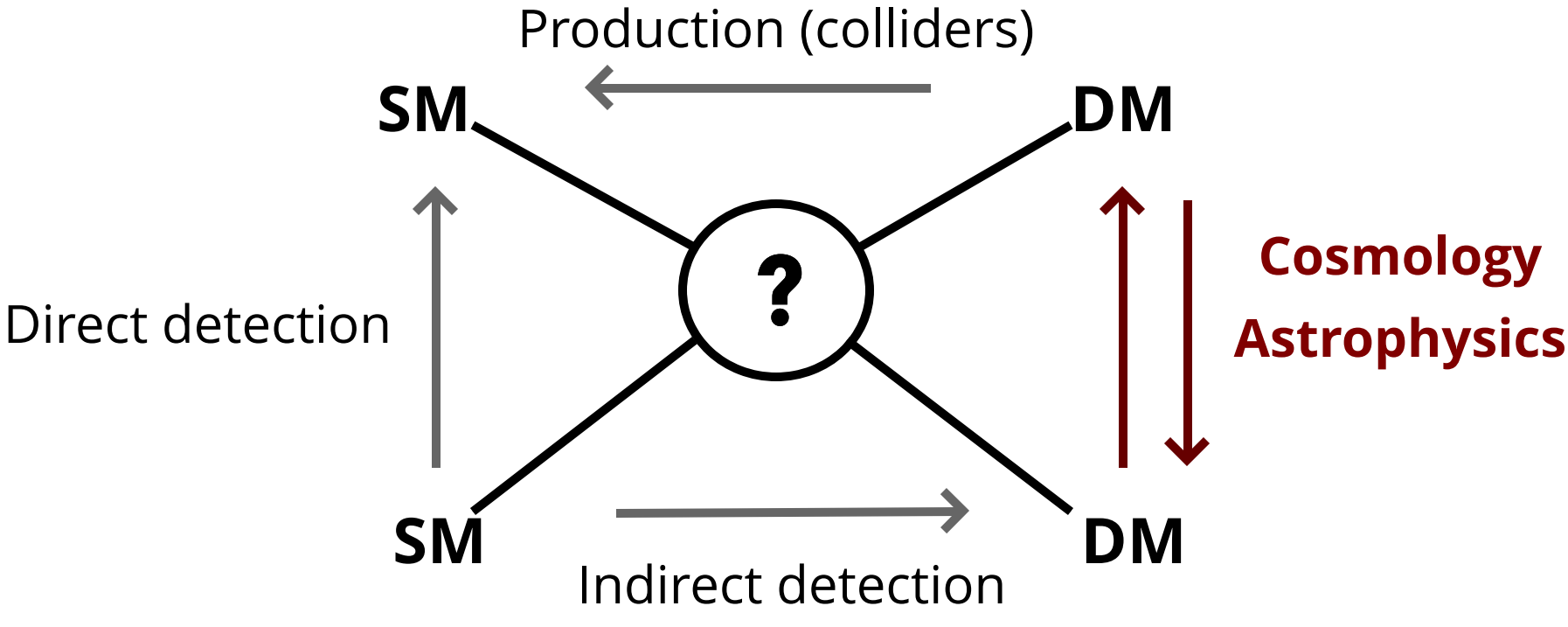
Dark Matter
throughout cosmic history

Vera Gluscevic

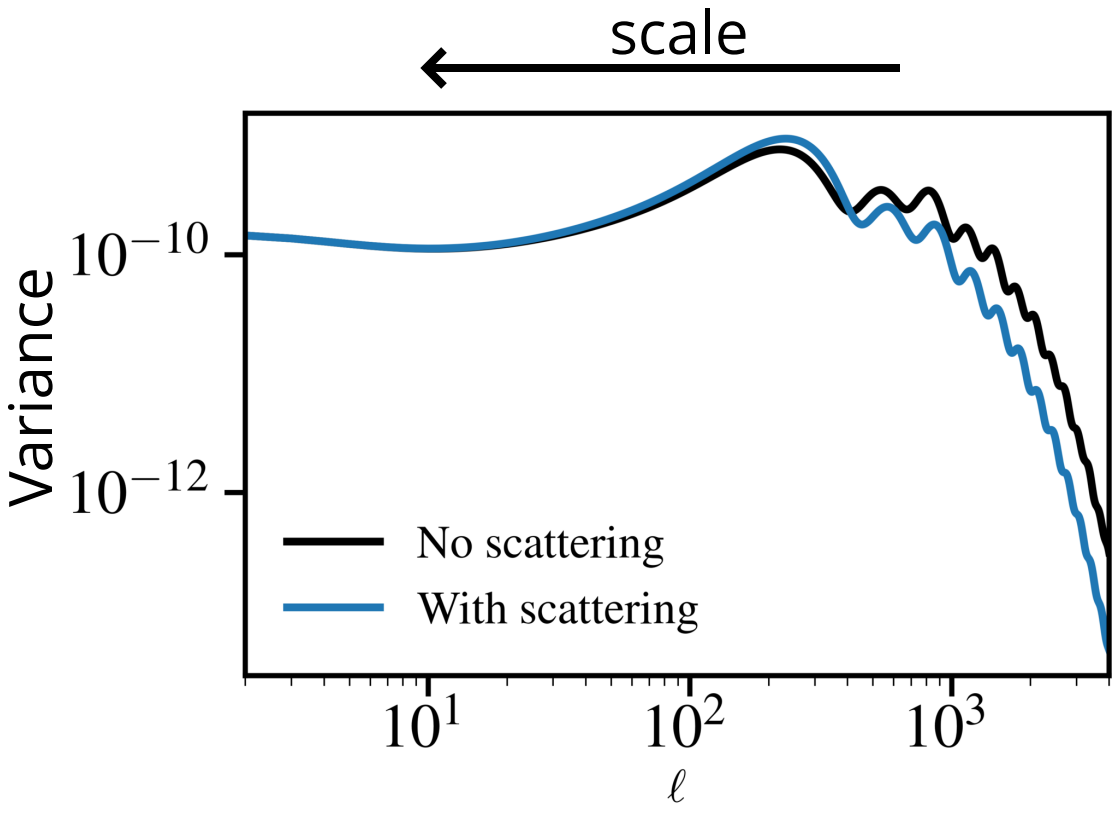
University of Southern California (USC)

COSMO19 - September 2, 2019.

Cosmic direct detection



Dark matter interactions suppress structure on small scales.



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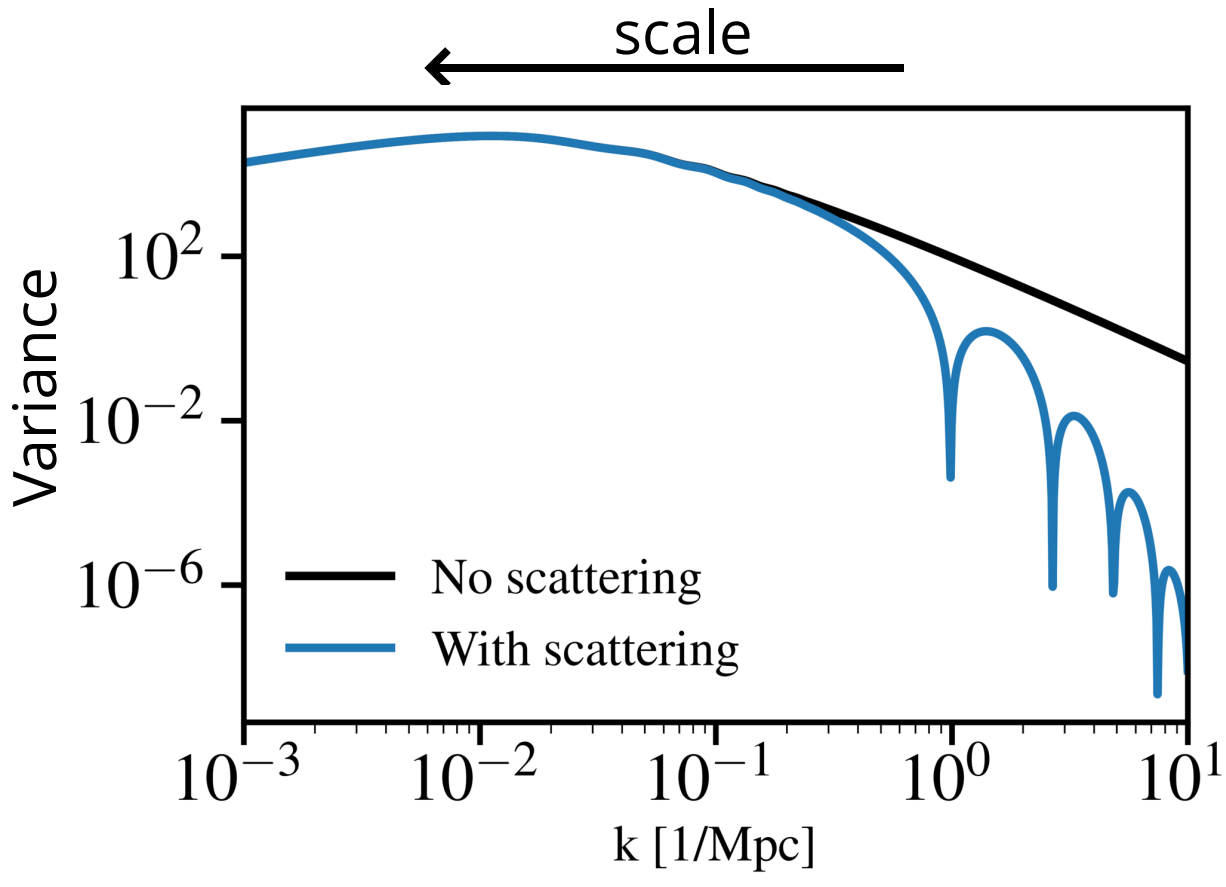
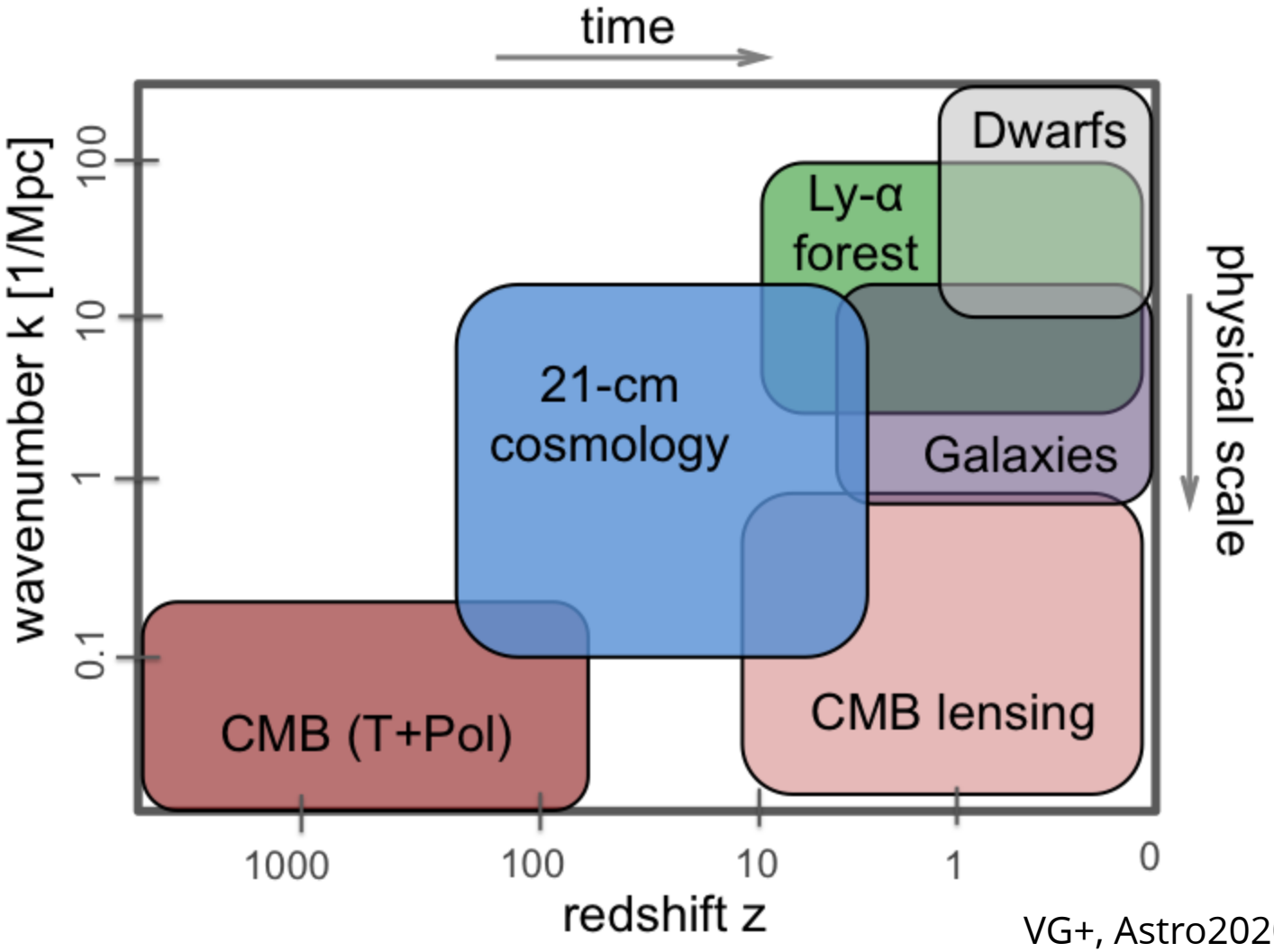


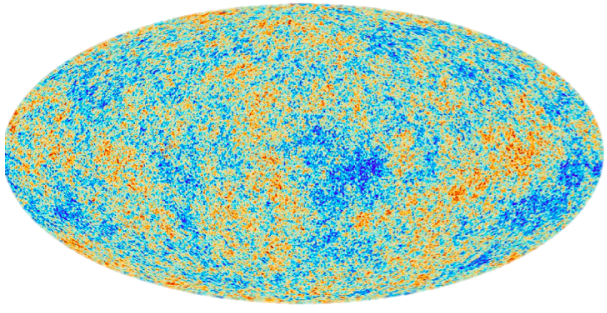
Observables



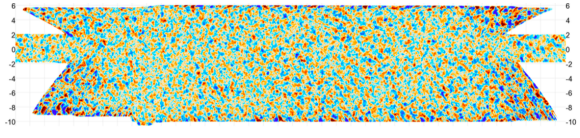
VG+, Astro2020 (2019)

arxiv:1903.05140

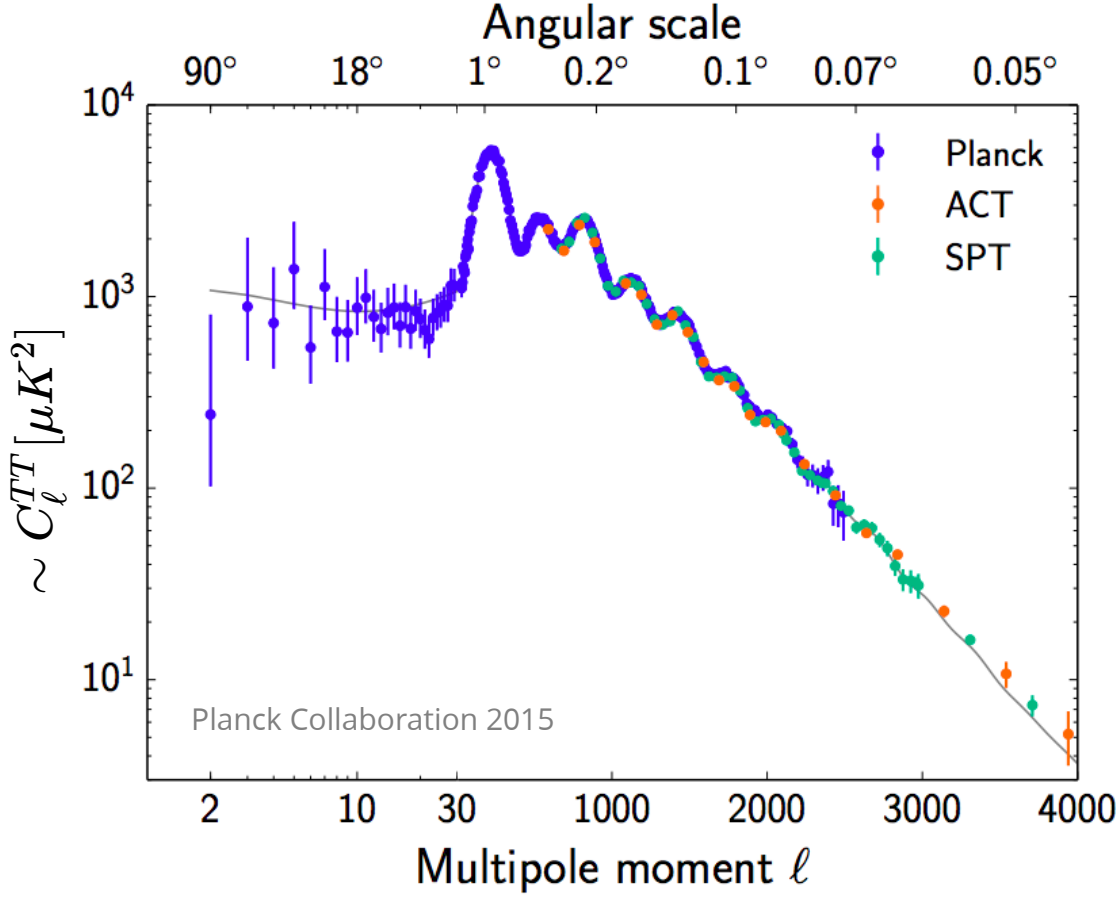
CMB power spectrum



Planck Collaboration 2015

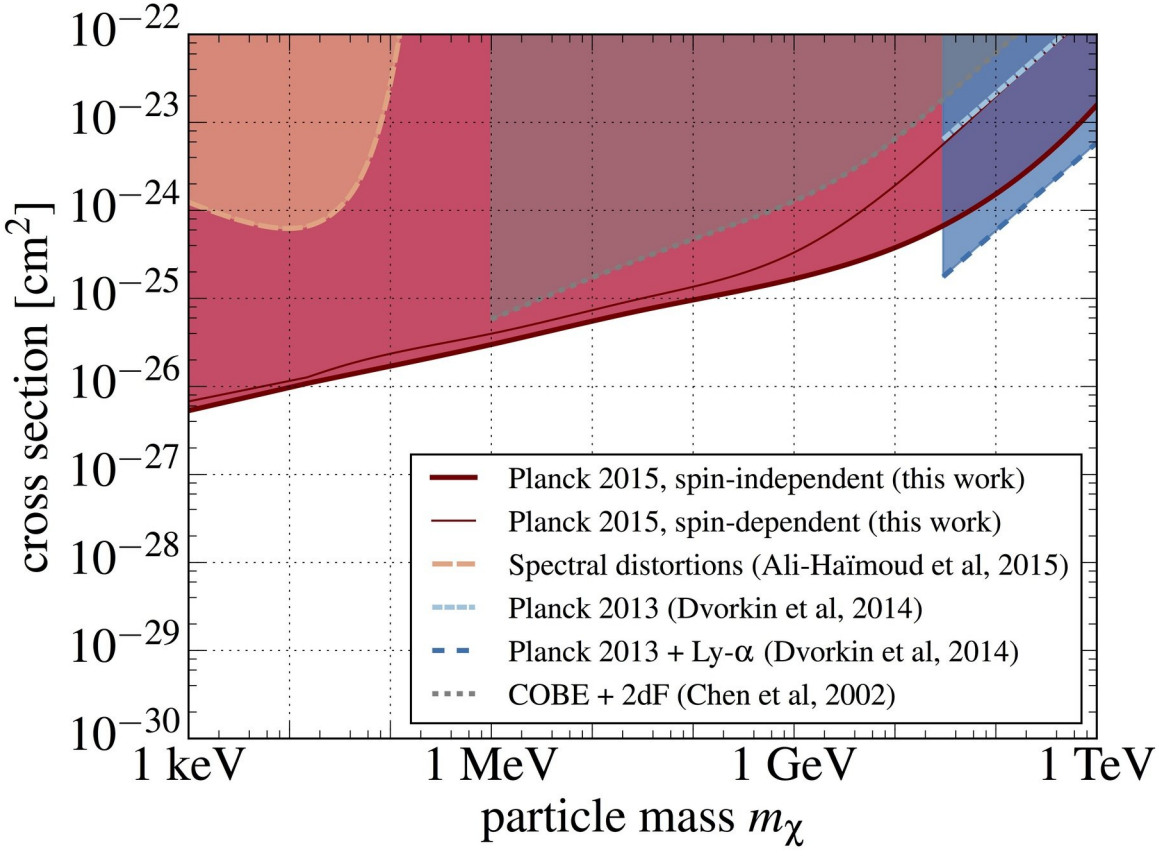


Actpol Collaboration 2016



Planck limits on DM-proton scattering

[velocity-independent spin-independent interaction]

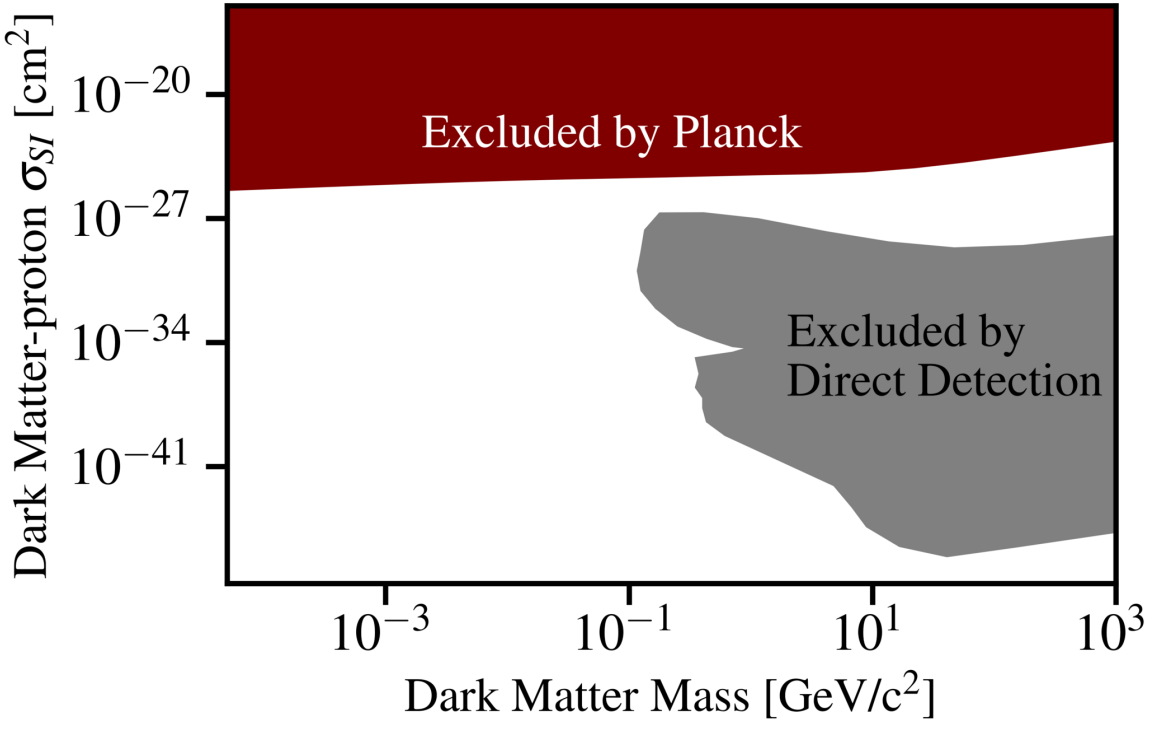


VG and Boddy, PRL (2018)

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

Planck limits on DM-proton scattering

[velocity-independent spin-independent interaction]



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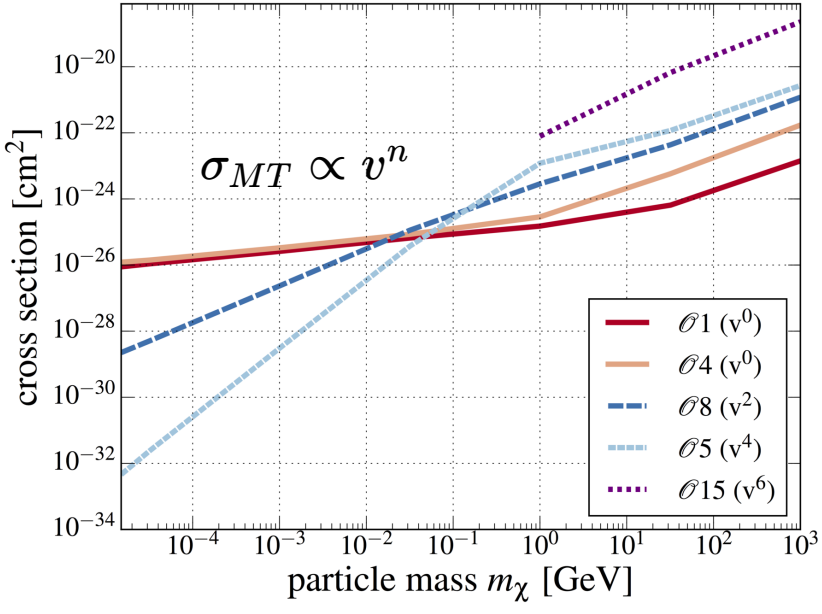
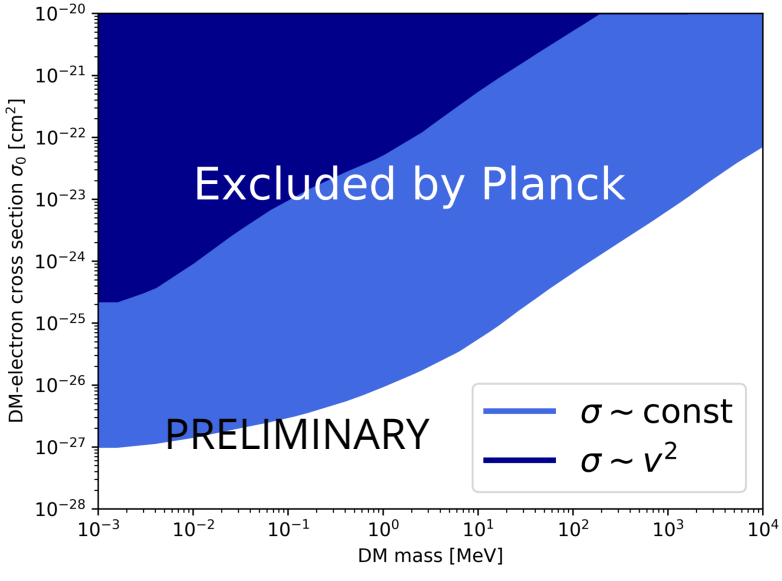
And beyond...



DM effective theory

(Boddy and VG, 2018)

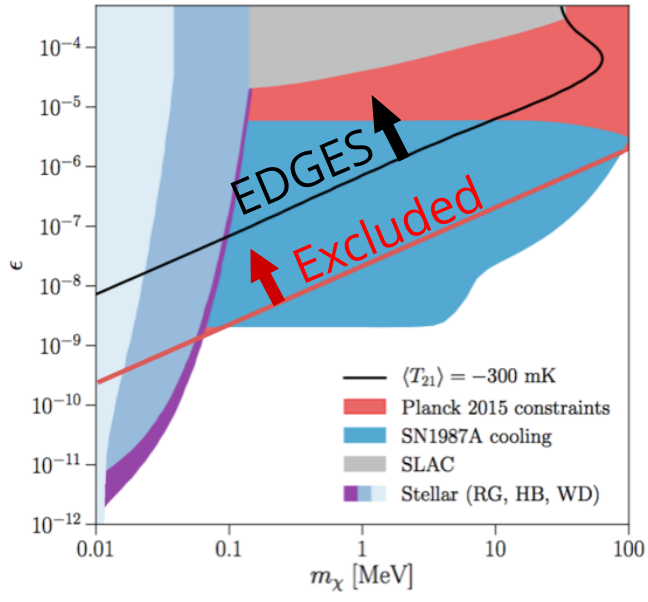
Age of the Universe ~1000 years: less than 1 in 100 000 scatterings is with DM.



Scattering with electrons

(VG and Boddy, in prep.)

And beyond...

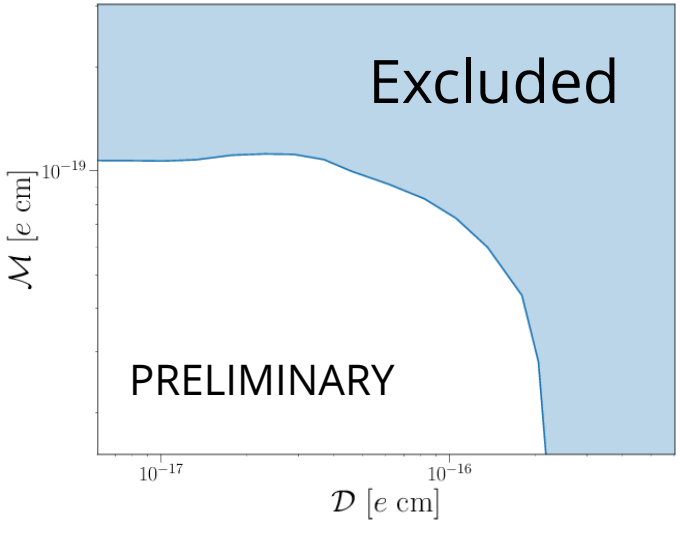


Limits on millicharge

(Boddy, VG, + 2018

Kovetz, Poulin, VG, + 2018)

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

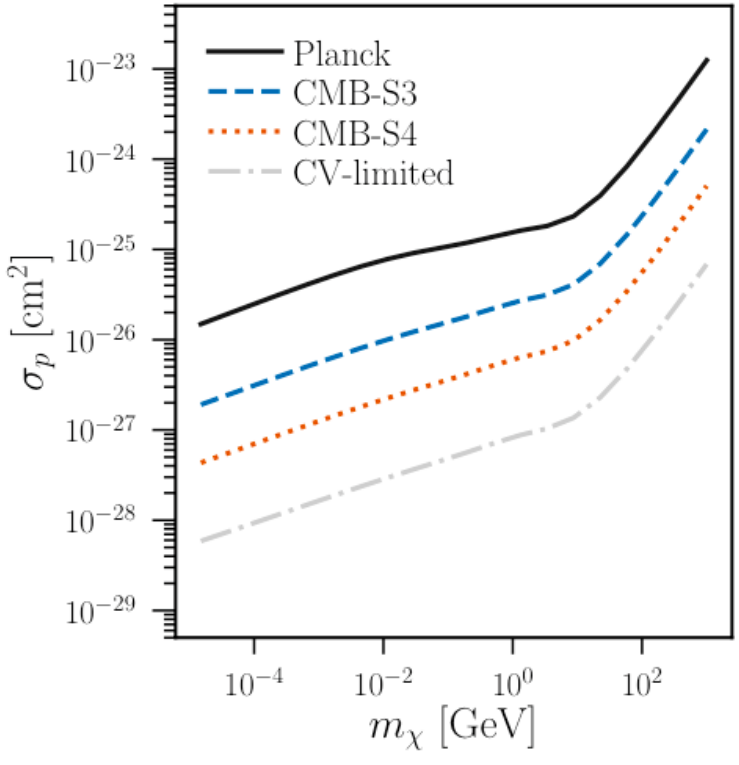


Limits on Dipole DM

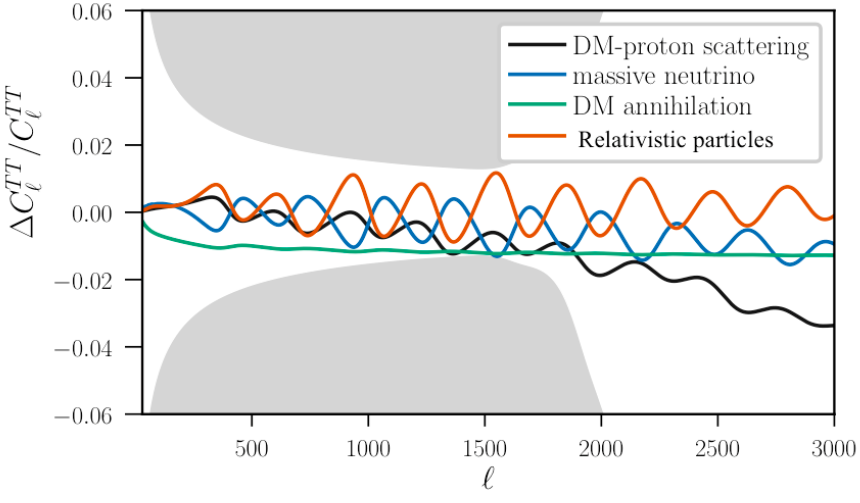
(Pfeffer, in prep.)

Next-generation ground-based CMB

(Simons Observatory, CMB-S4)

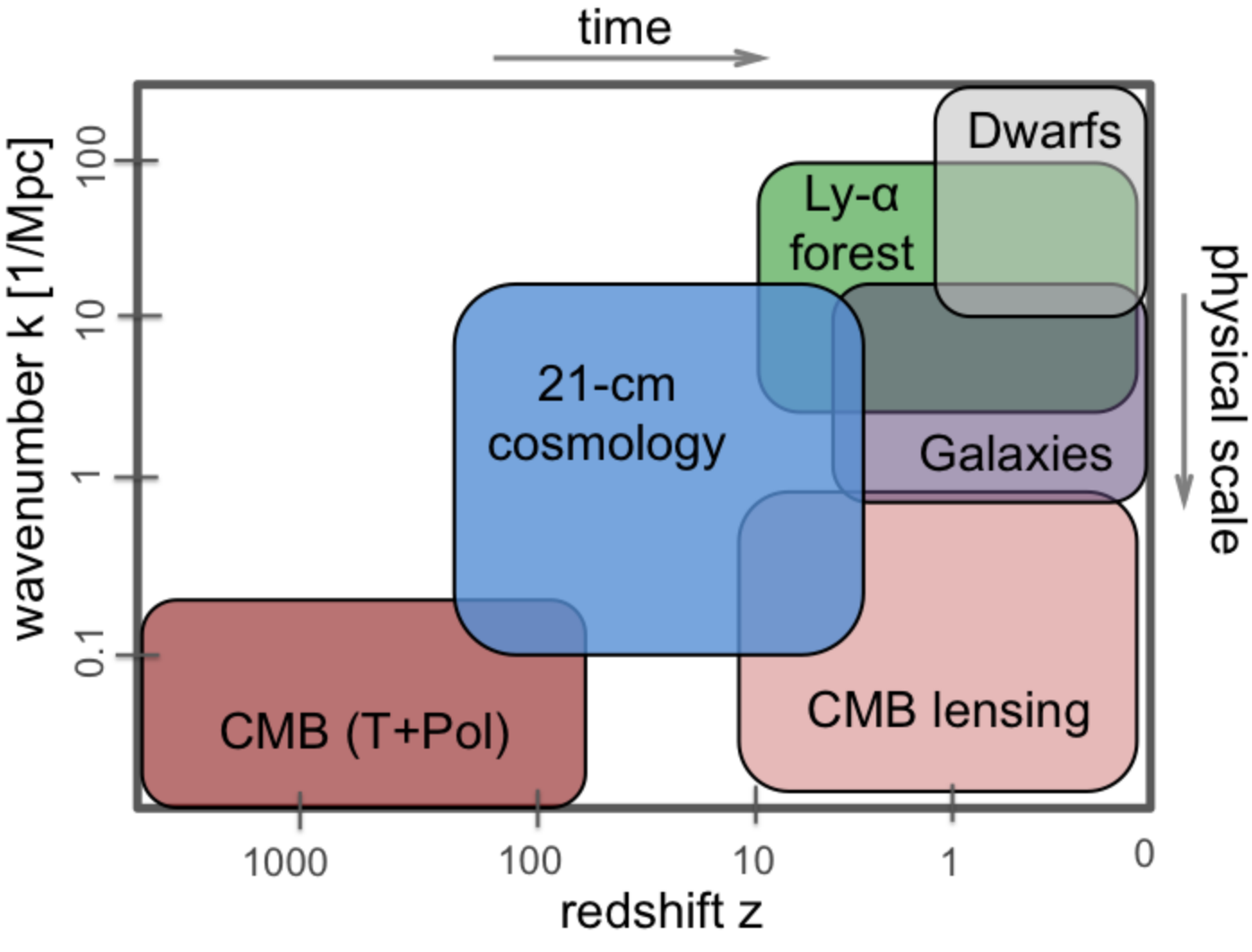


DM interactions do NOT look like other science targets, given well-measured CMB lensing.



Li, VG, + (2018)

See also 1808.07445


time
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Ly-α
forest
21-cm
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Galaxies
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wavenumber k [1/Mpc]
100
10
1
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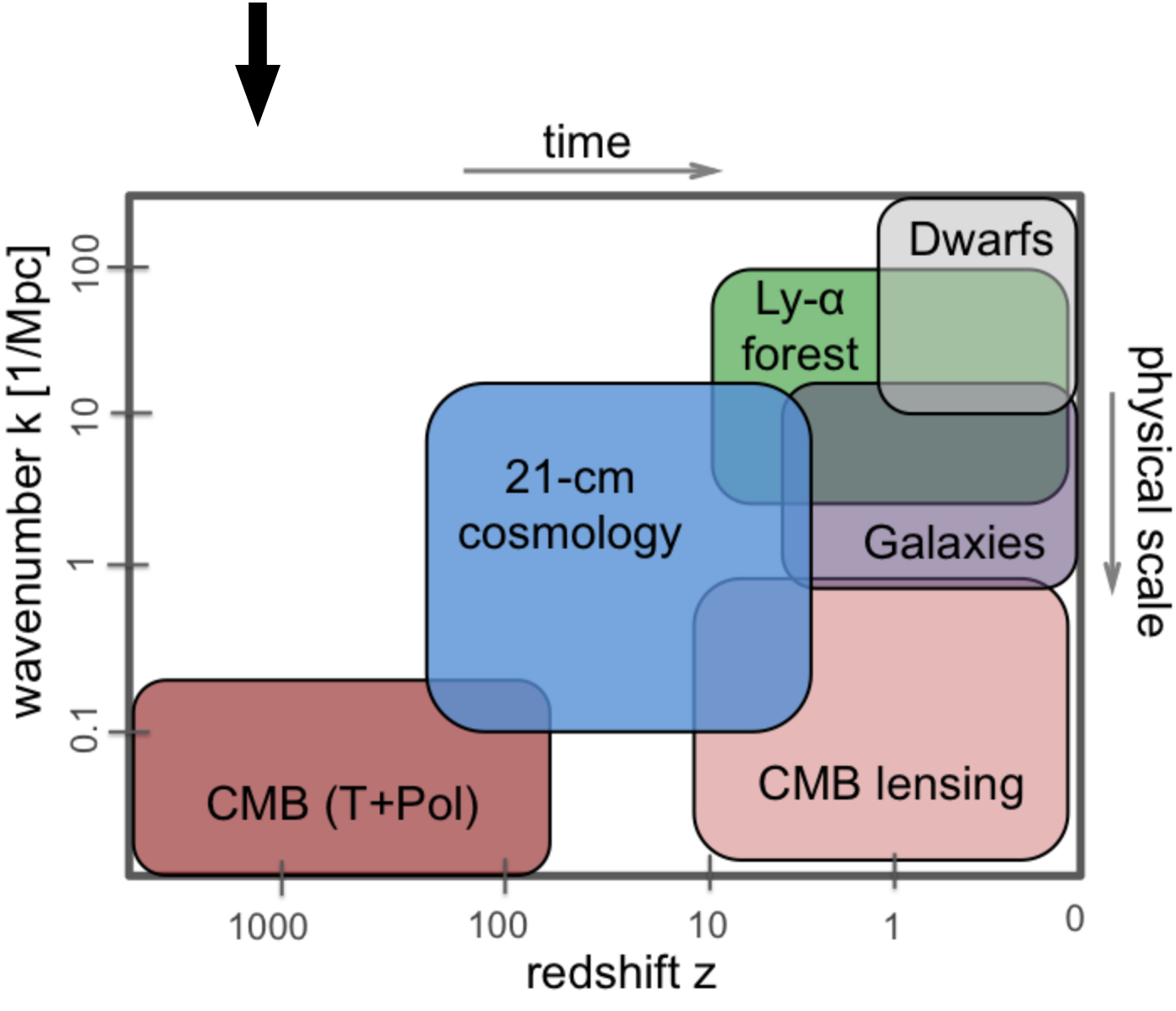
1
0
redshift z
physical scale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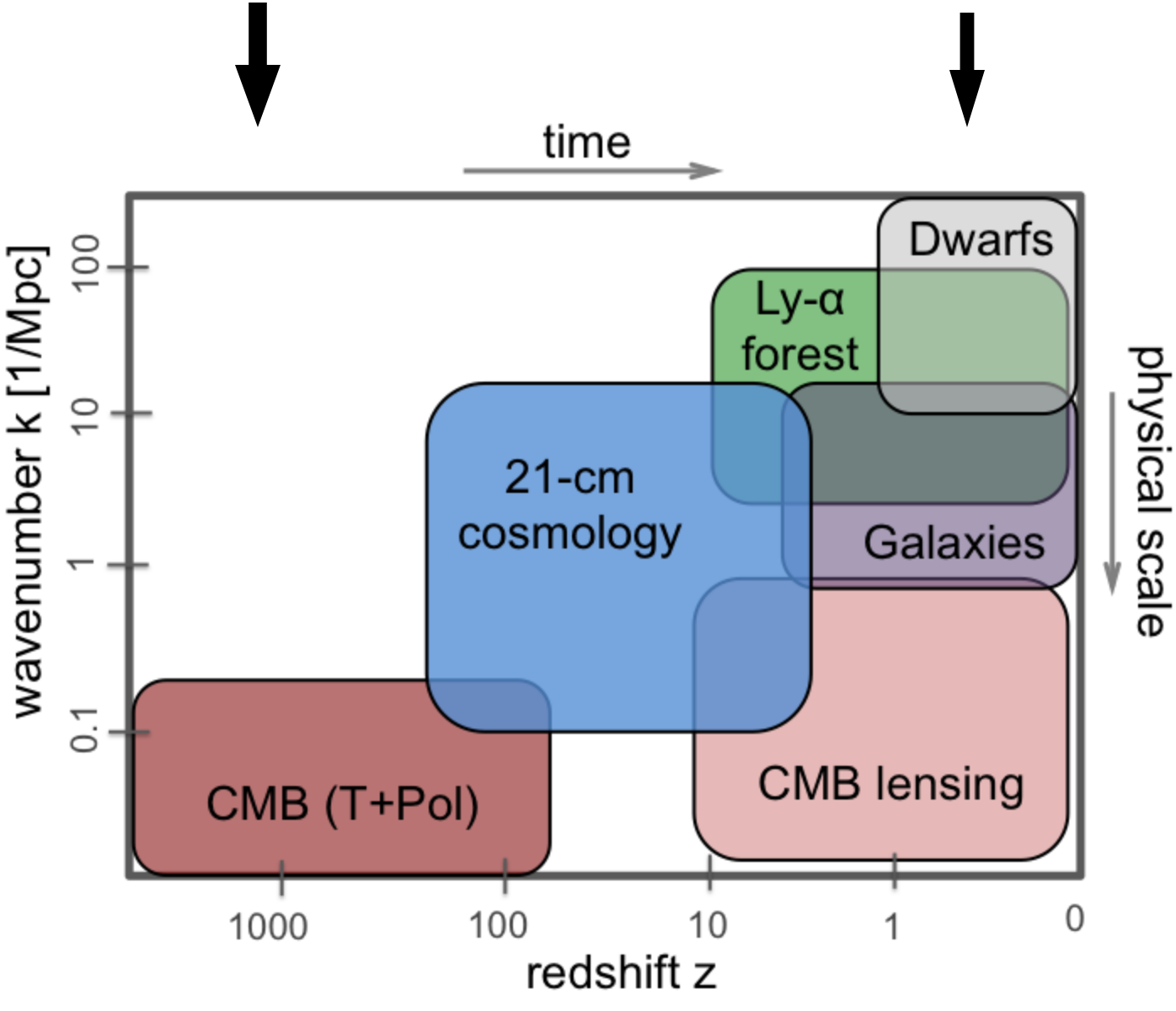
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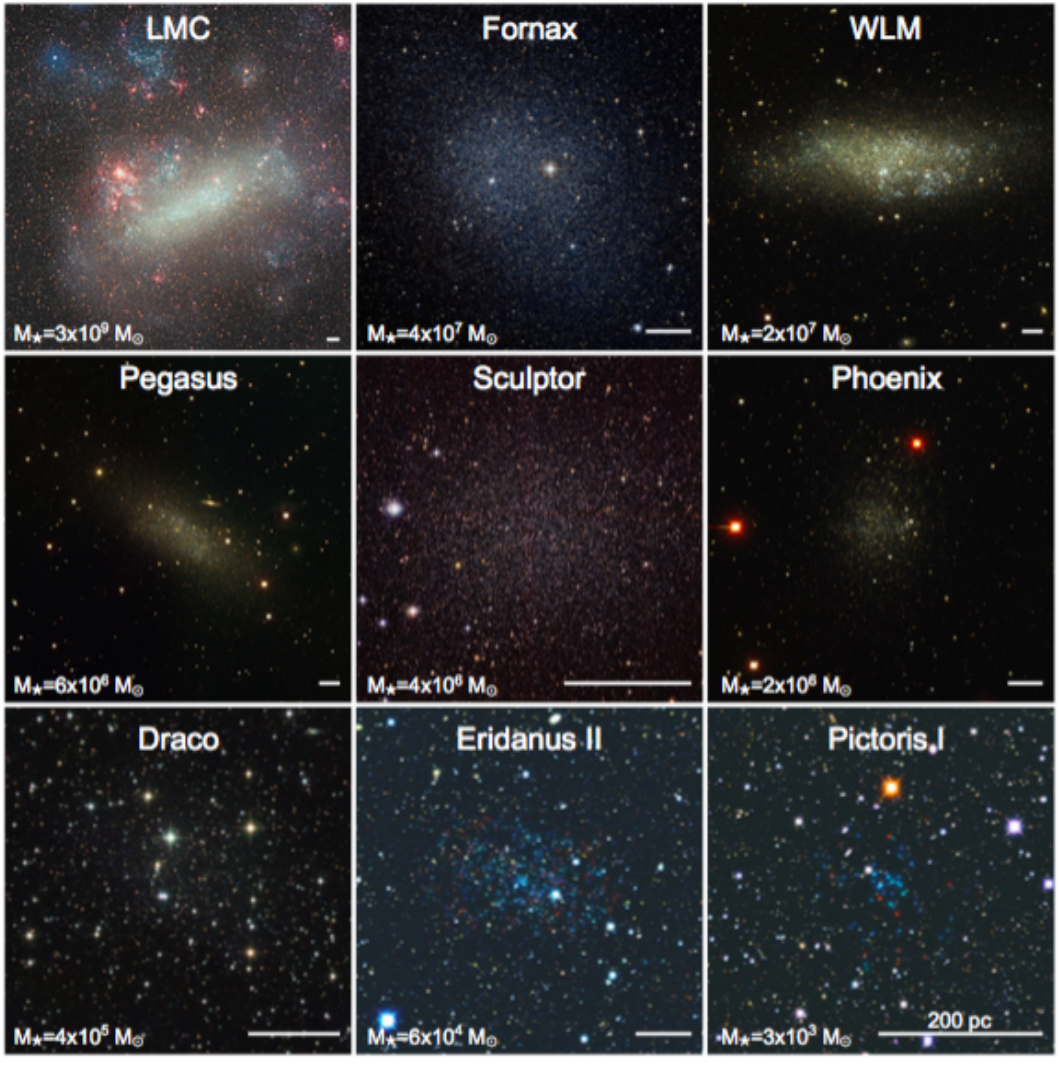
Near-field cosmology

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



Bullock and Boylan-Kolchin (2017)

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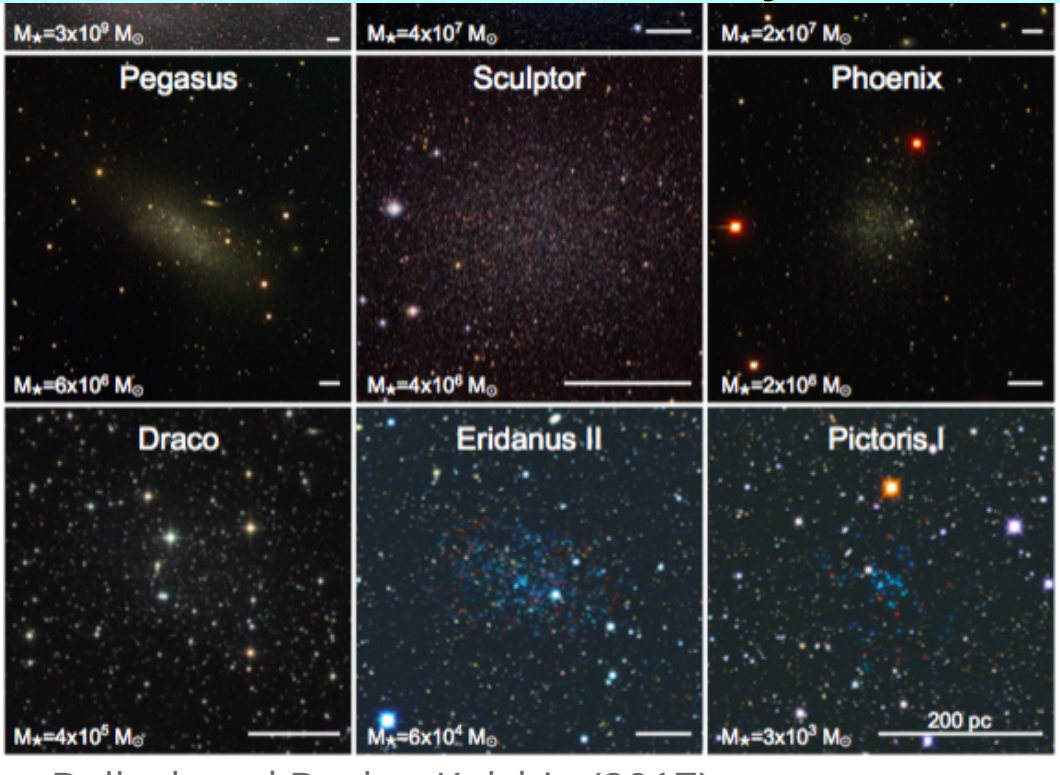
Big Question:

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



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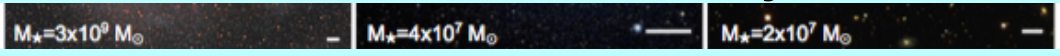
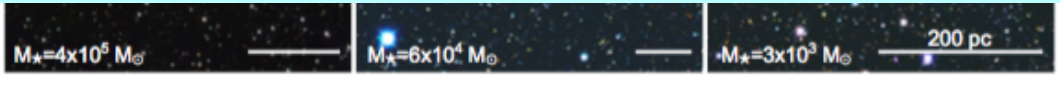


Challenges:



Bullock and Boylan-Kolchin (2017)

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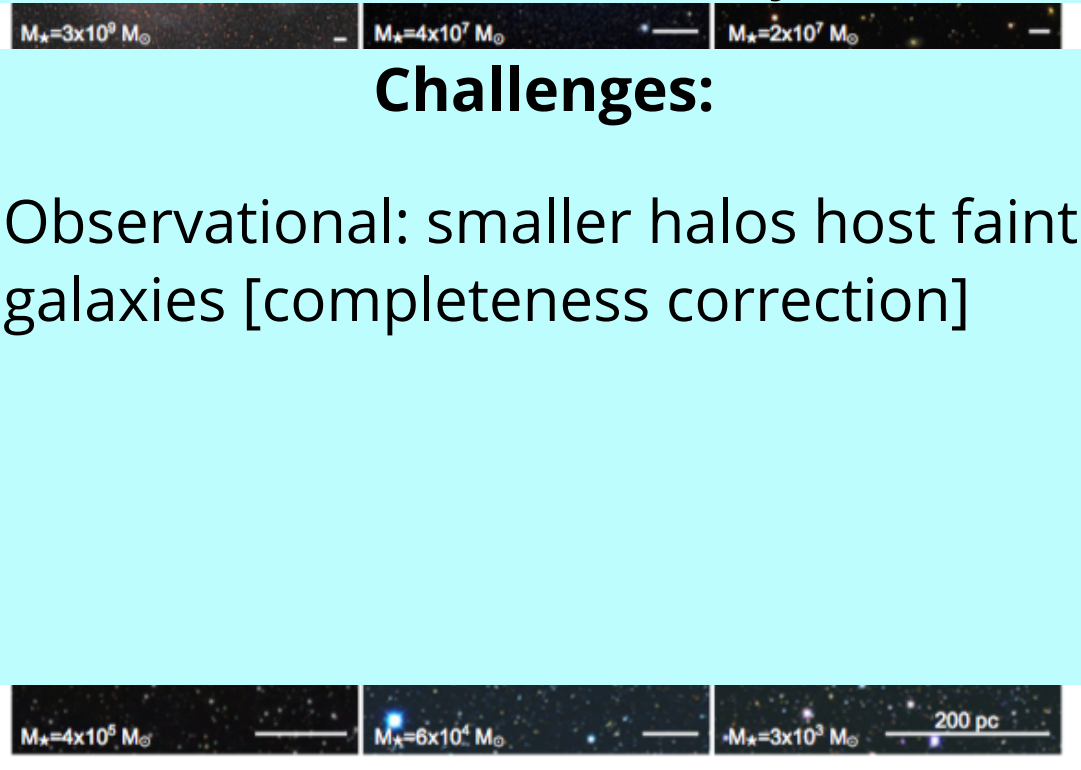

Challenges:

- Observational: smaller halos host fainter galaxies [completeness correction]

Bullock and Boylan-Kolchin (2017)

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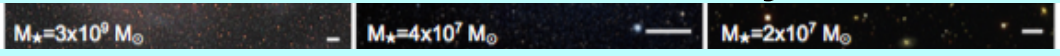
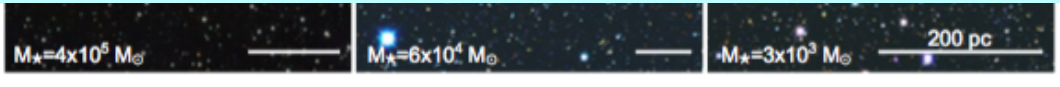


Challenges:

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



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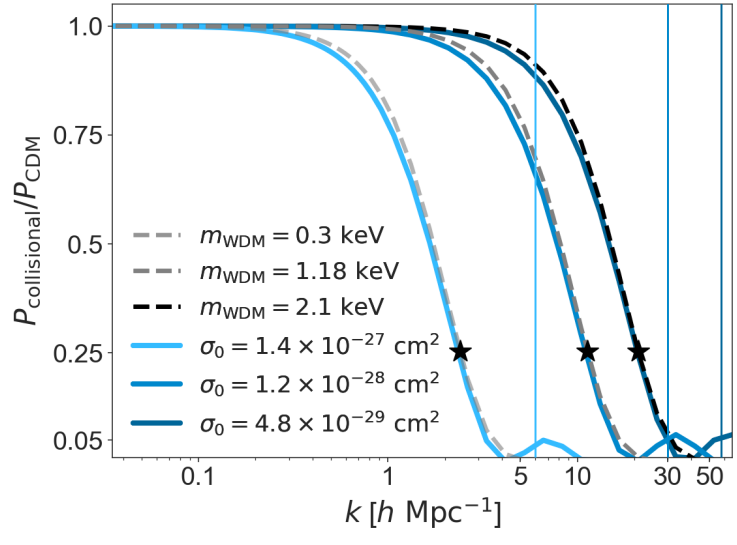
Limits from Milky Way Satellites

Momentum transfer (σ_0, m_χ) = Hubble rate



Limits from Milky Way Satellites

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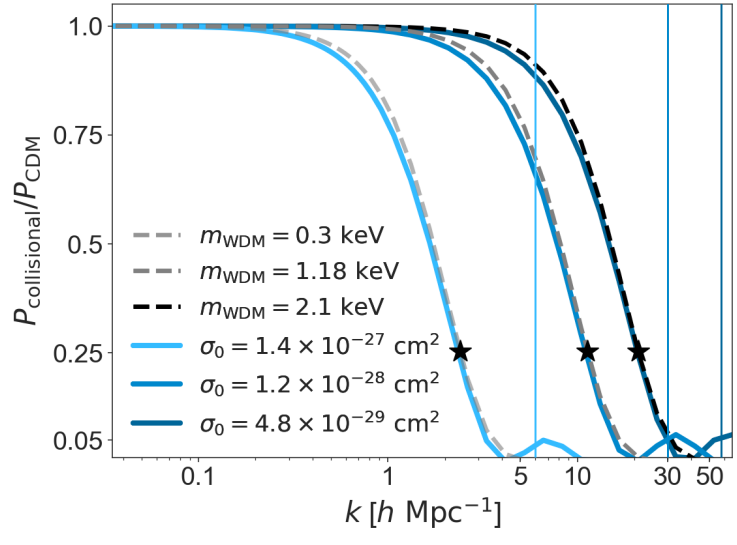
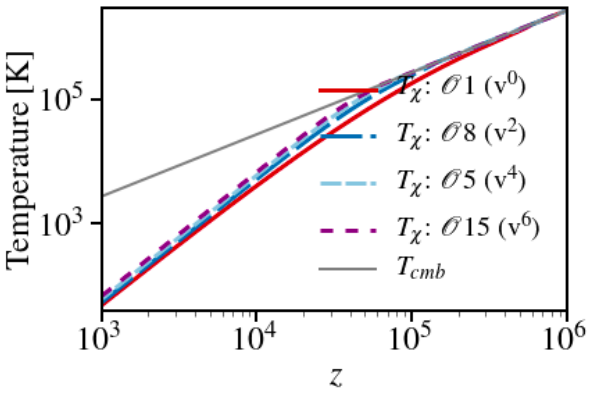
$$R_\chi \sim n_\chi \sigma_0 v$$



Limits from Milky Way Satellites

thermal history



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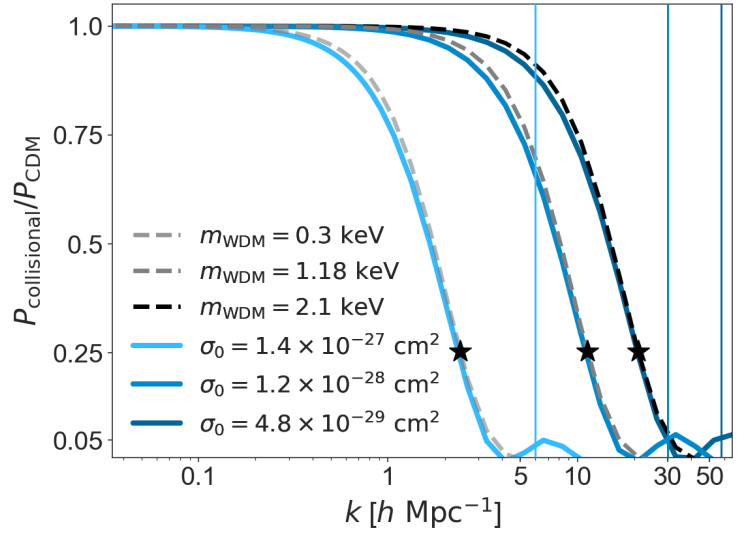

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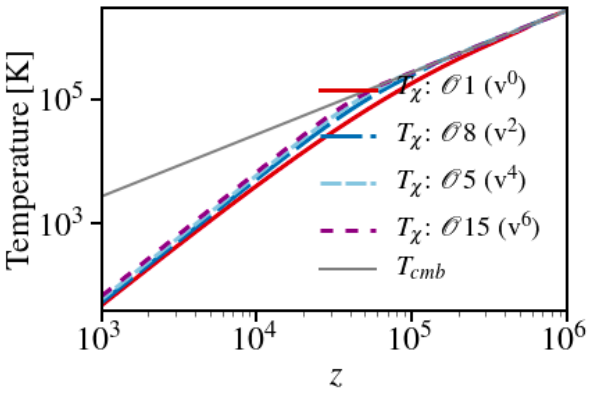

Momentum transfer (σ_0, m_χ) = Hubble rate

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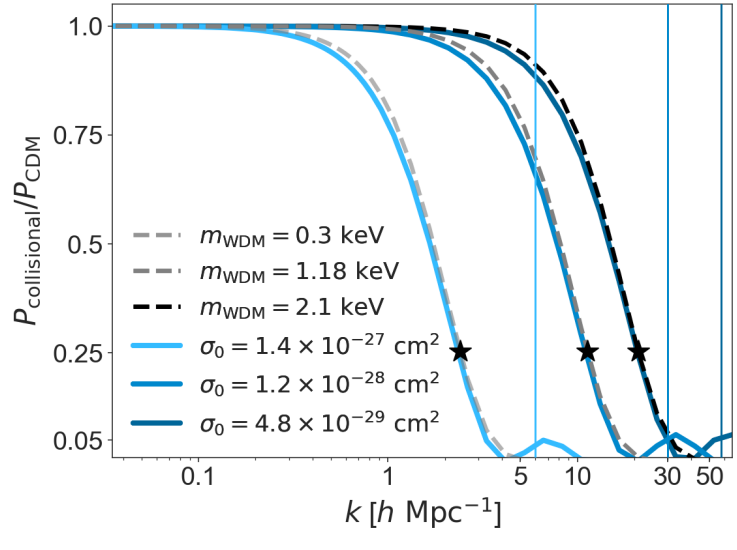
z_{crit}



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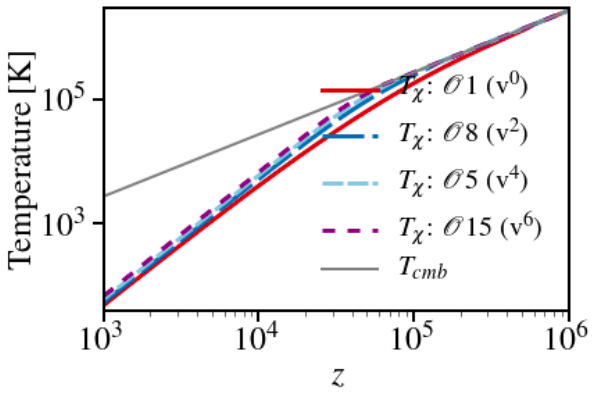

Momentum transfer (σ_0, m_χ) = Hubble rate

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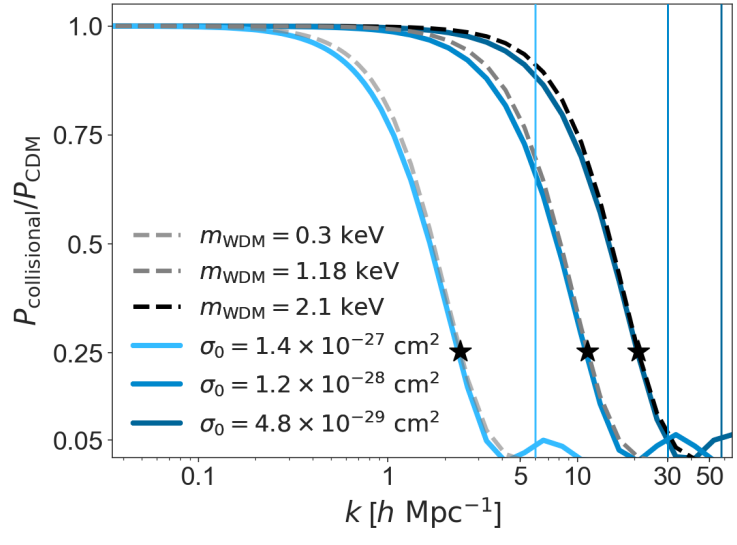
↓

z_{crit}

↓

Horizon size (z_{crit}) $= 2\pi / k_{crit}$



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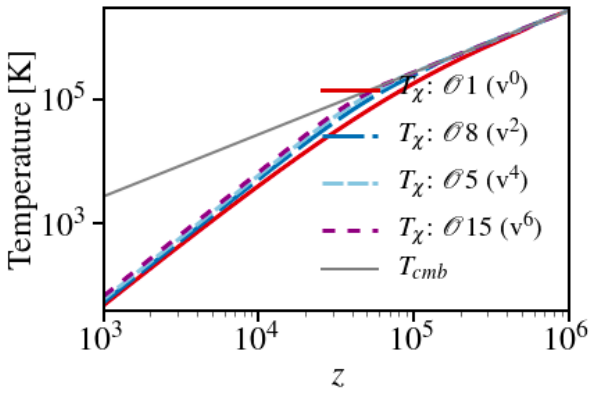

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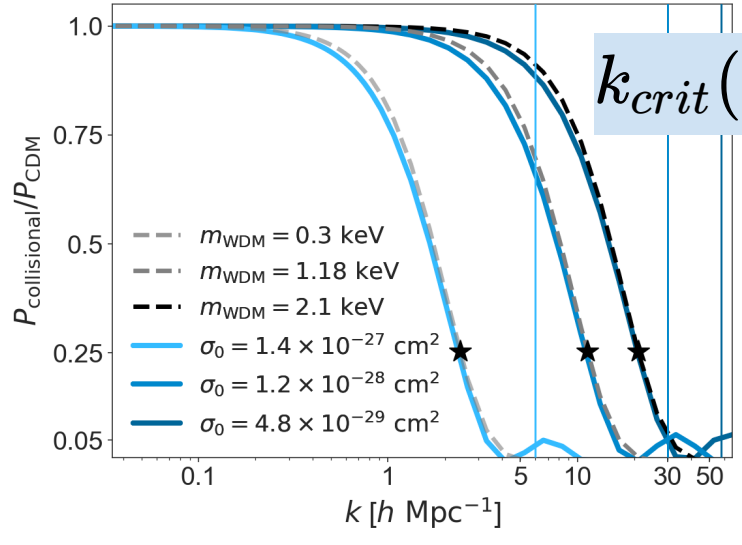

$k_{crit}(\sigma_0, m_\chi)$

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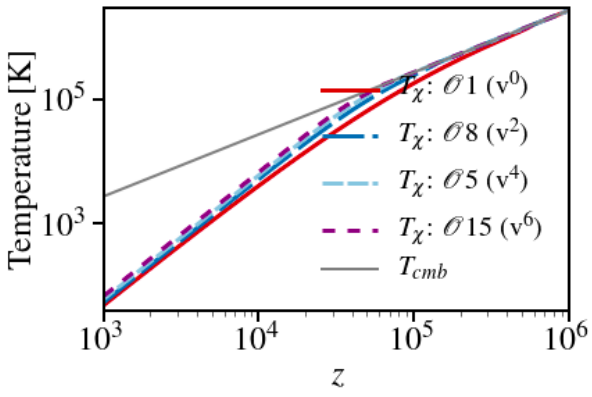

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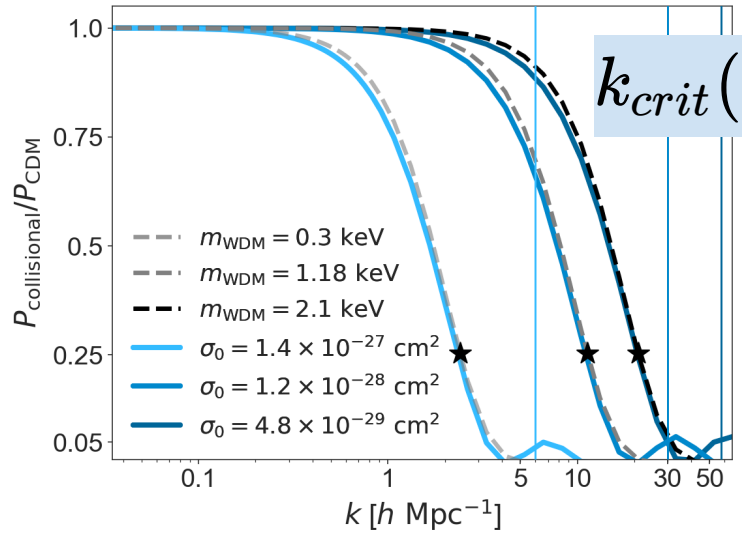
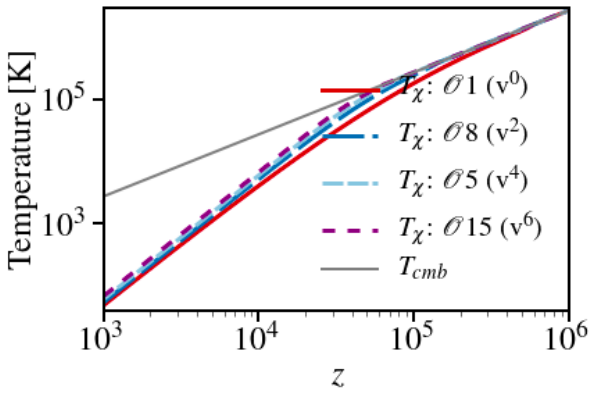


$k_{crit}(\sigma_0, m_\chi)$

$$M_{crit} = \frac{4\pi}{3}\bar{\rho}(\lambda_{crit})^3$$

Limits from Milky Way Satellites

thermal history



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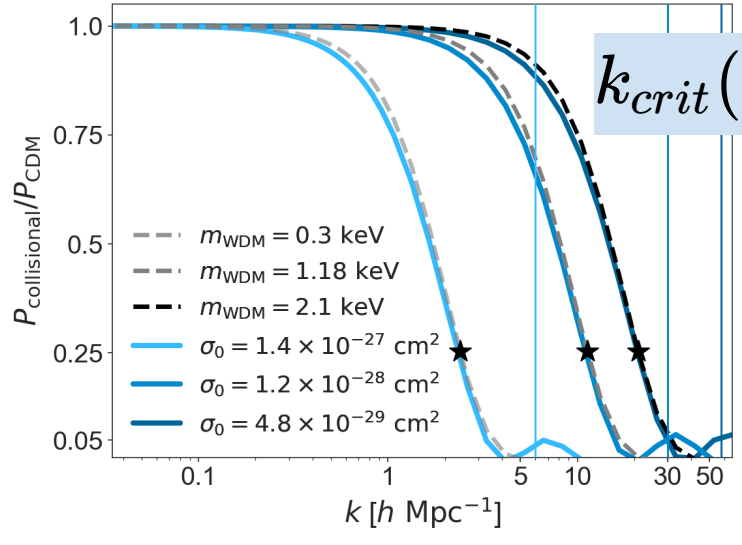

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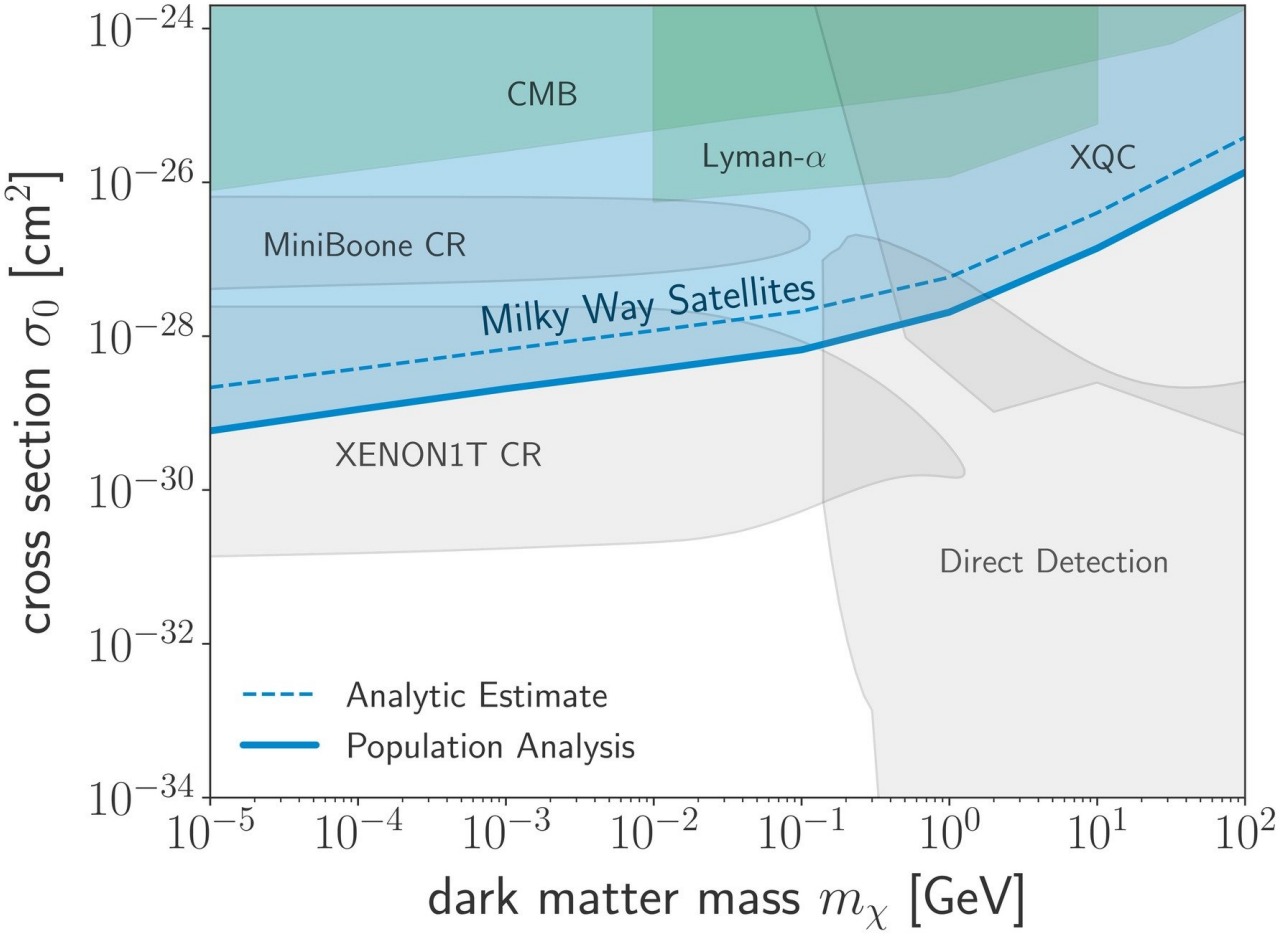

Nadler, VG, Boddy, Wechsler (ApJ Letters 2019)

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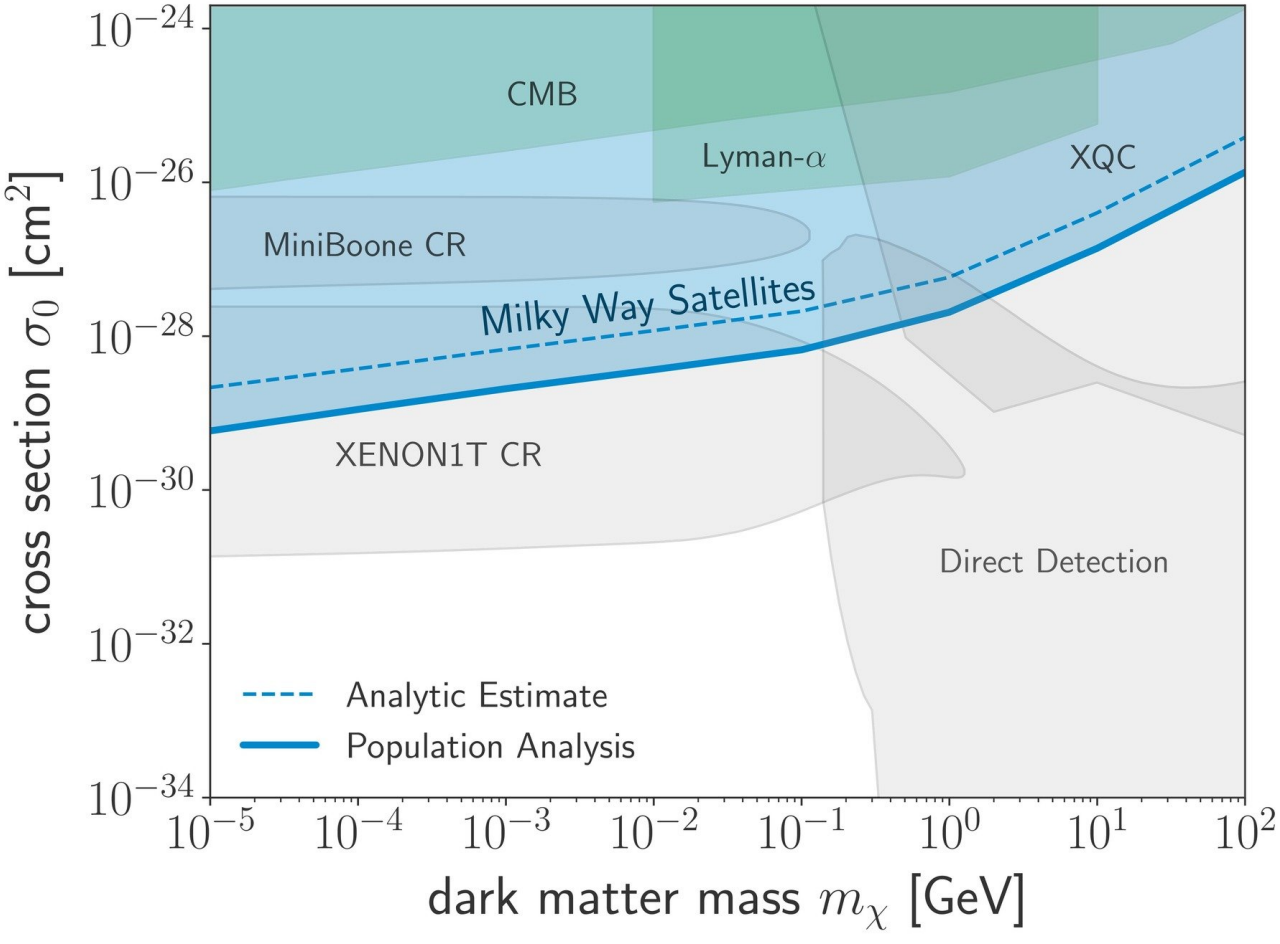

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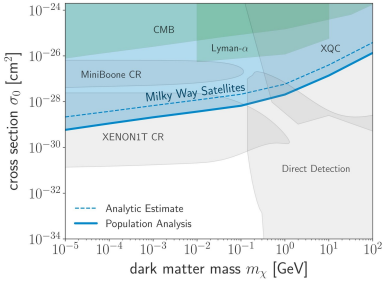
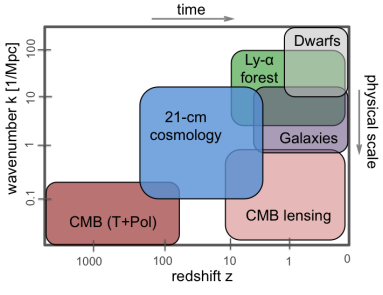
vel-independent scattering: 3 OOM better than Planck.

Key points





- CMB already probes new parameter space and new paradigms; near-field cosmology is messier, but very promising [e.g. satellites].
- **<u>Key for discovery</u>: comprehensive searches and joint analyses.**
- **<u>To-address</u>: 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**