Cosmological probes of dark matter interactions

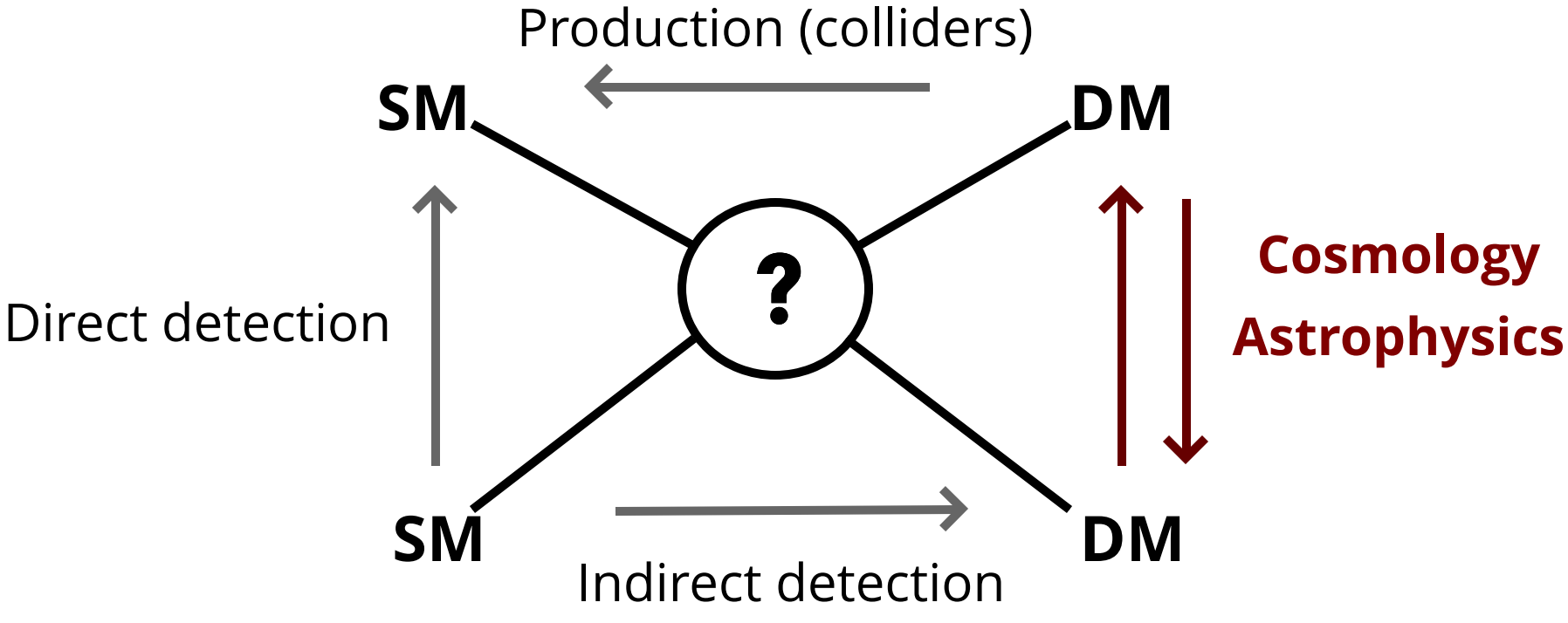
Vera Gluscevic

University of Southern California

LSST Dark Matter Workshop

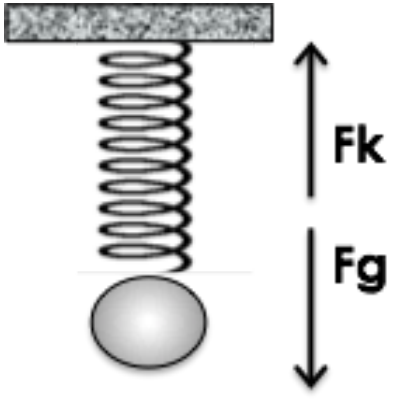
Chicago (August 5, 2019)

Cosmic direct detection



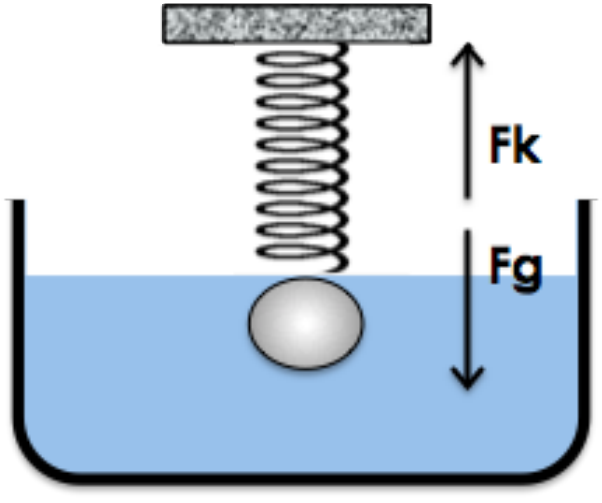
DM-baryon scattering in the early universe

fluids + gravity = baryonic acoustic oscillations

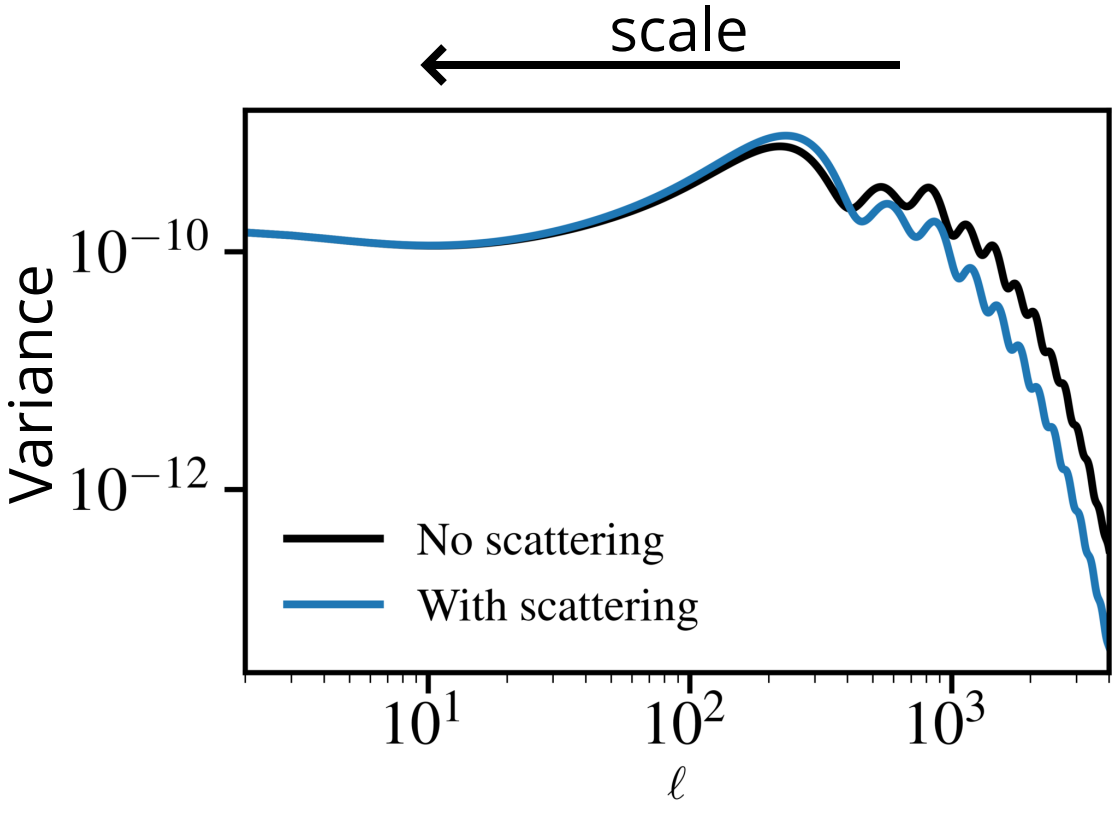


DM-baryon scattering in the early universe

fluids + gravity **+ drag** = **damped** baryonic acoustic oscillations



Dark matter interactions suppress structure on small scales.



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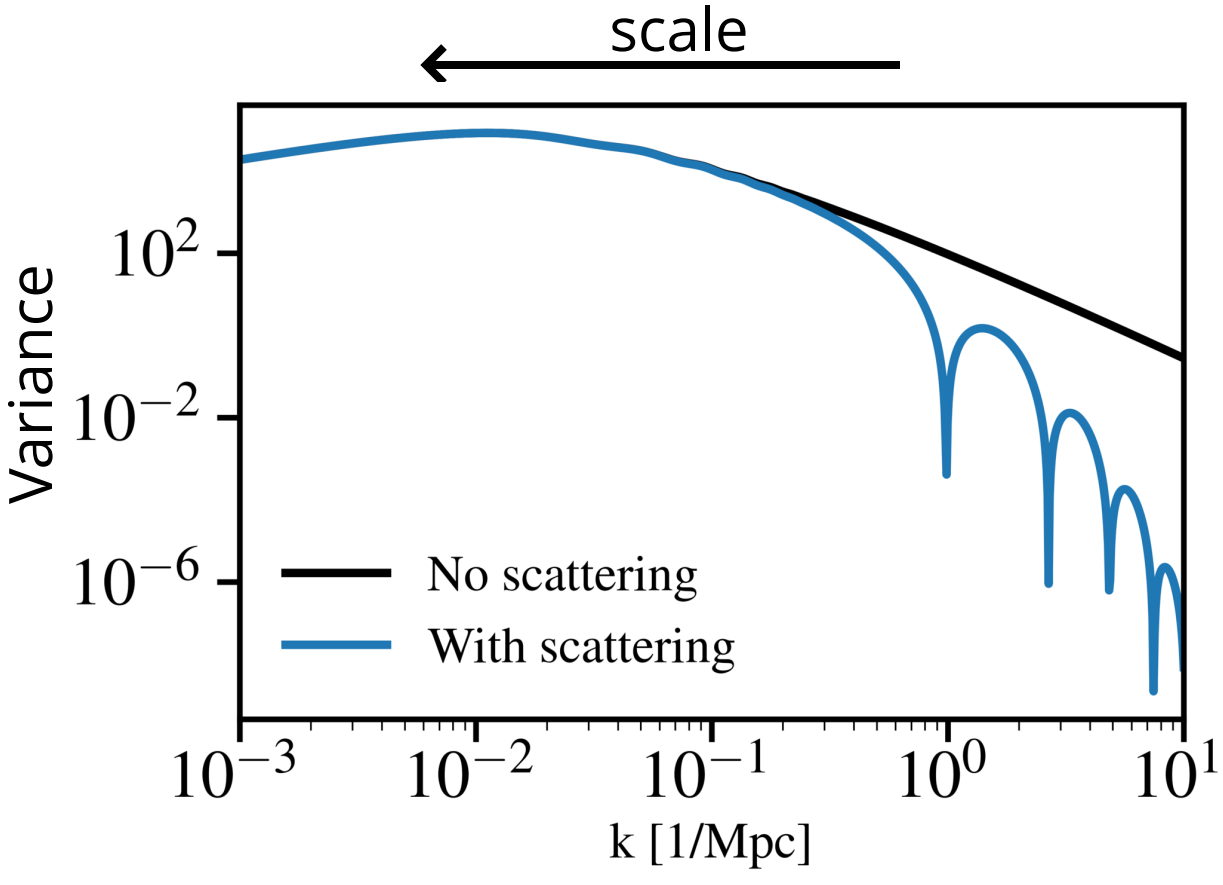
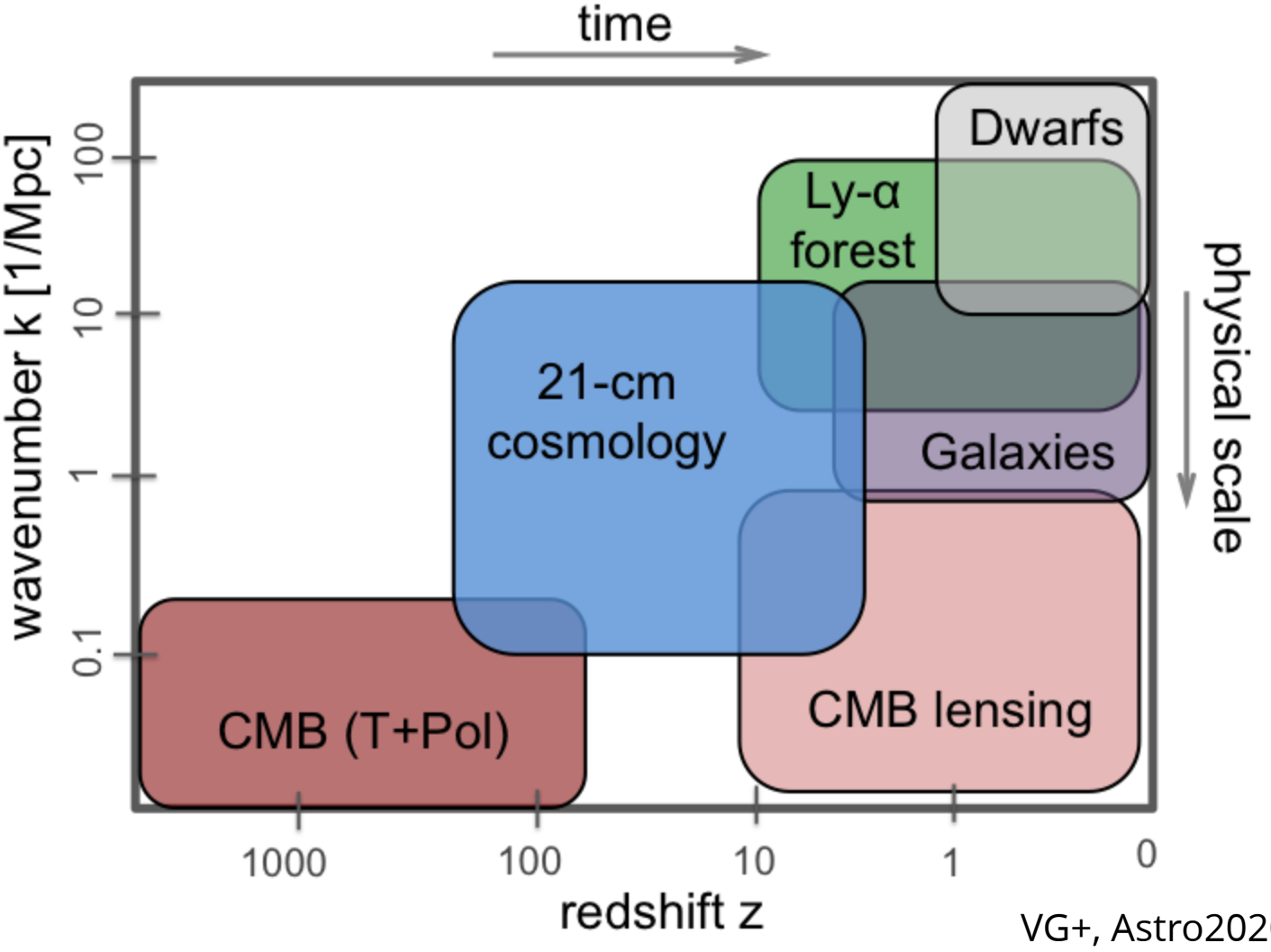


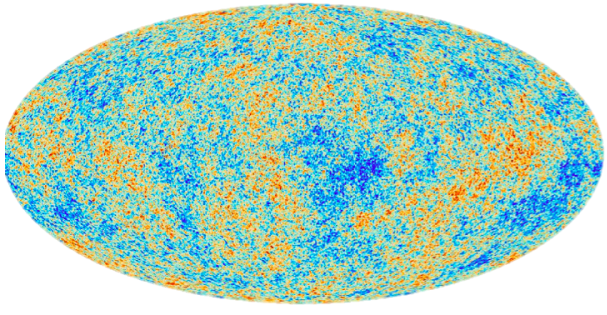
Observables



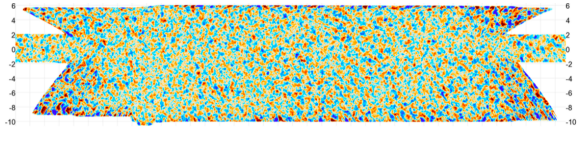
VG+, Astro2020 (2019)

arxiv:1903.05140

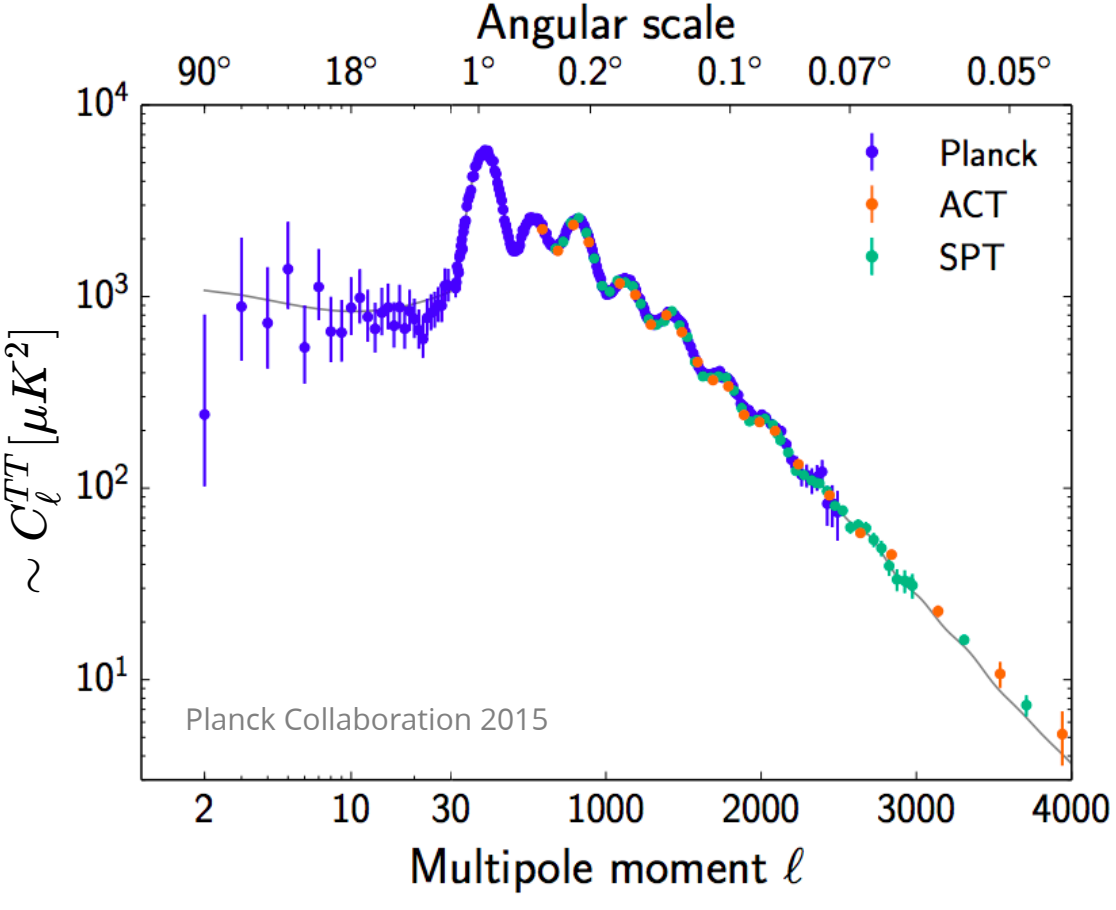
CMB power spectrum



Planck Collaboration 2015

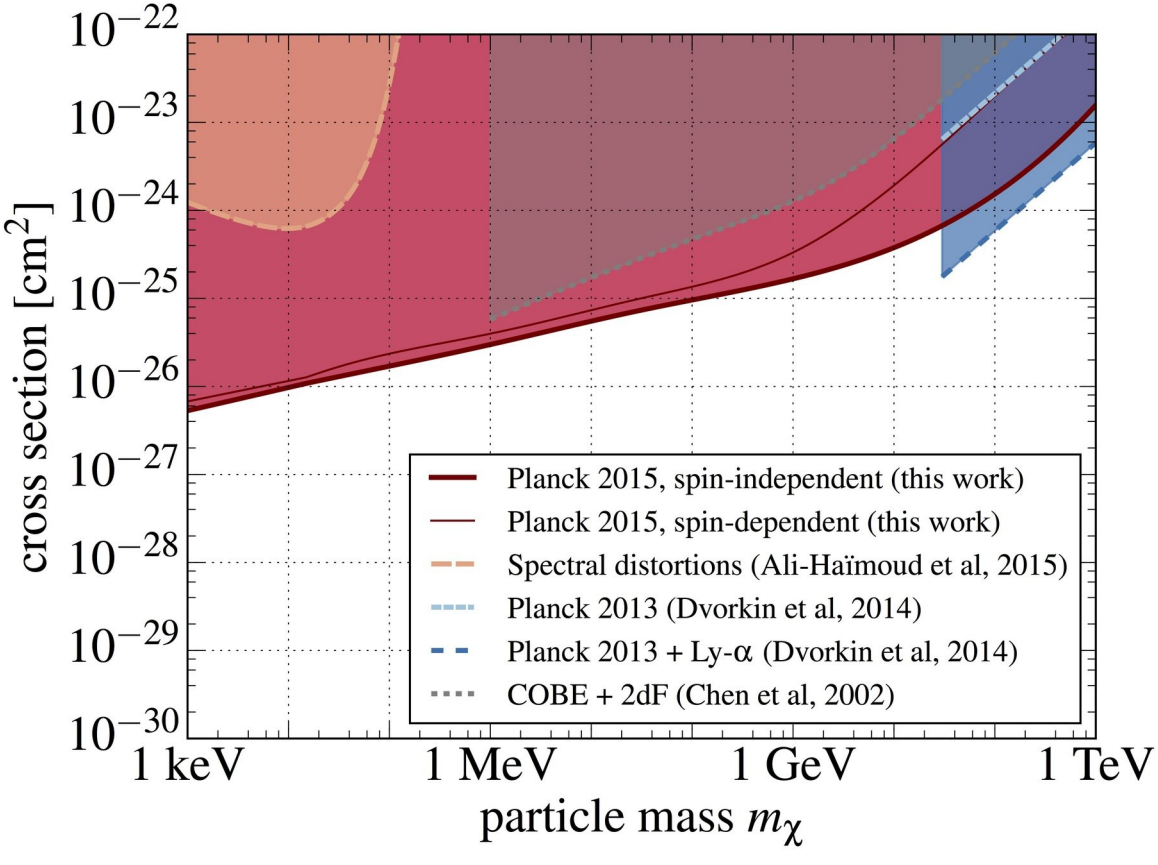


Actpol Collaboration 2016



Planck limits on DM-proton scattering

[velocity-independent spin-independent interaction]

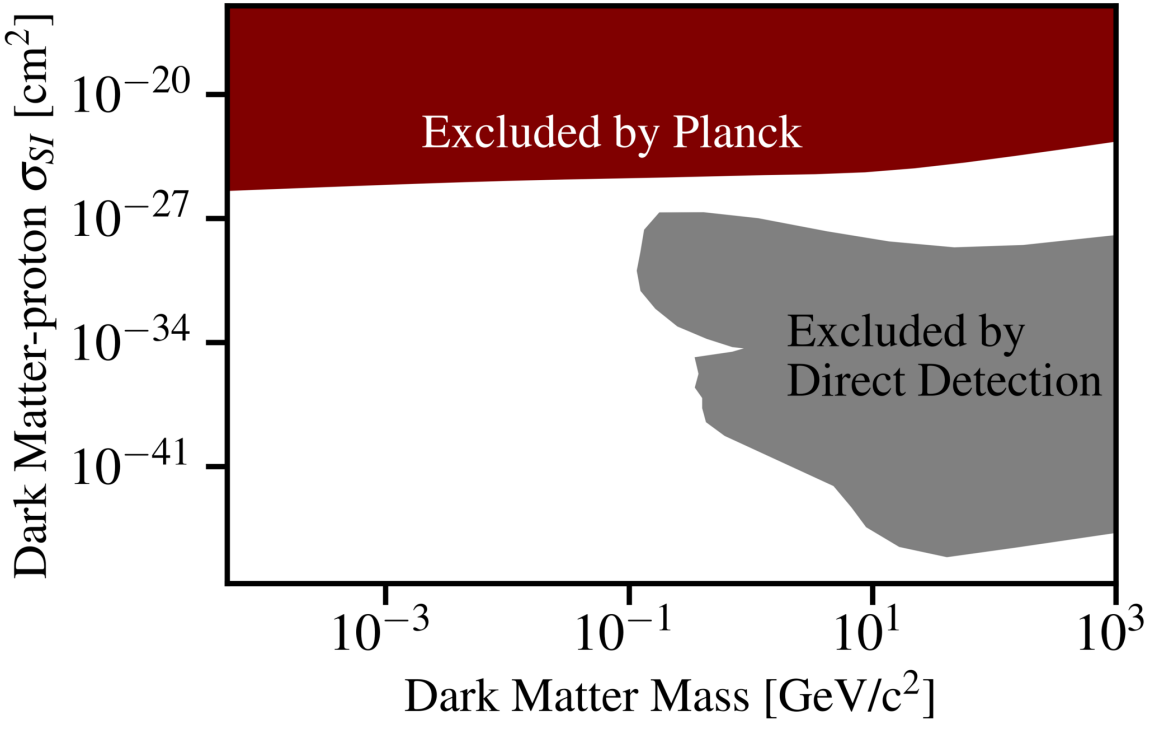


VG and Boddy, PRL (2018)

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

Planck limits on DM-proton scattering

[velocity-independent spin-independent interaction]



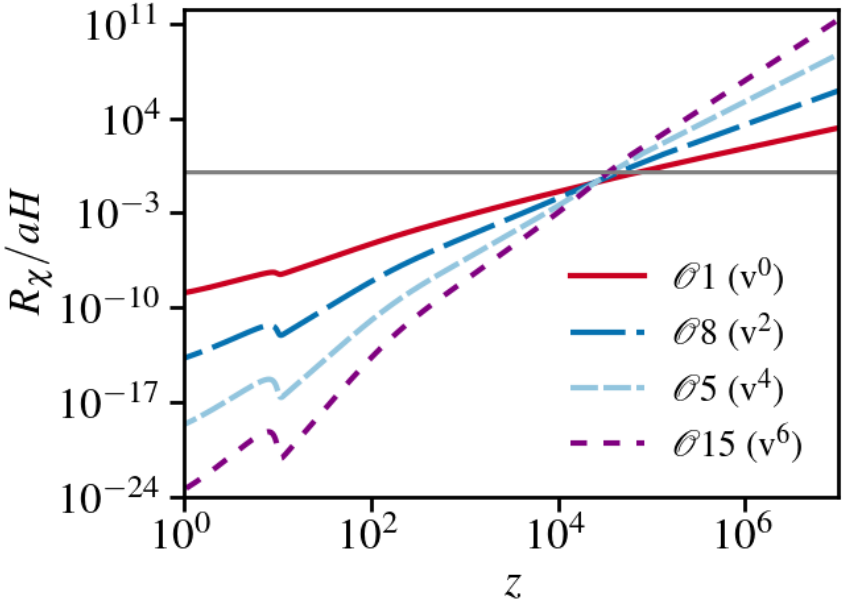
VG and Boddy, PRL (2018)

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

And beyond...

Interactions in cosmological context

momentum-transfer rate



time

Boddy and VG (2018)

see also: Sigurdson+ (2002), Dvorkin+ (2014), etc.

momentum-transfer cross section

momentum-transfer rate

$$\sigma_{MT}(v^n) \longrightarrow R_\chi$$

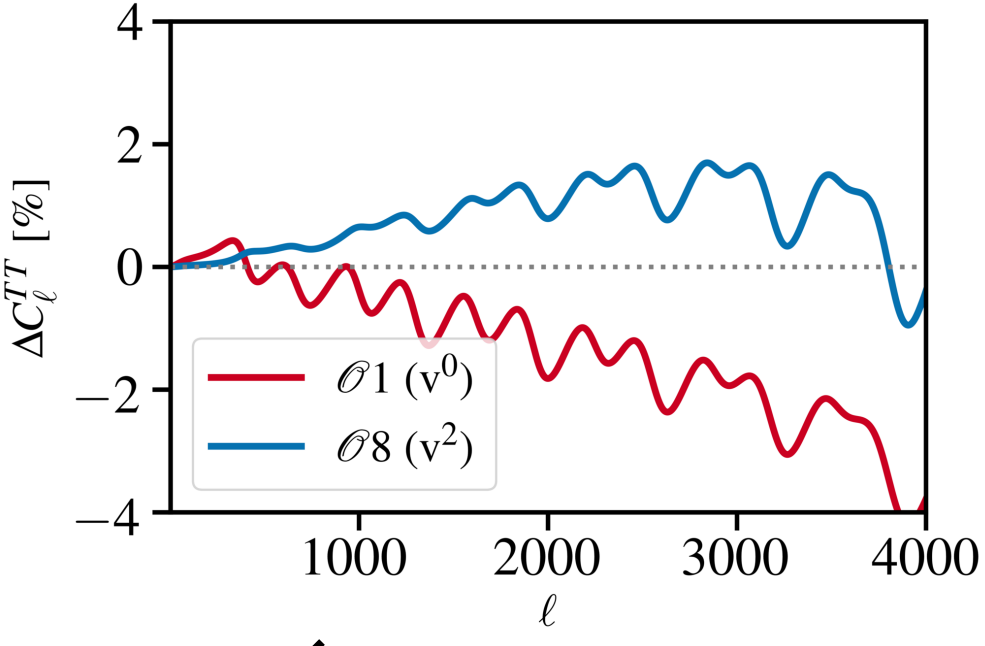
momentum dependance of the interaction operator

Interactions in cosmological context

operator **signal**

$$\mathcal{O}_i \longrightarrow C_\ell(m_\chi, c_i)$$

signal shape

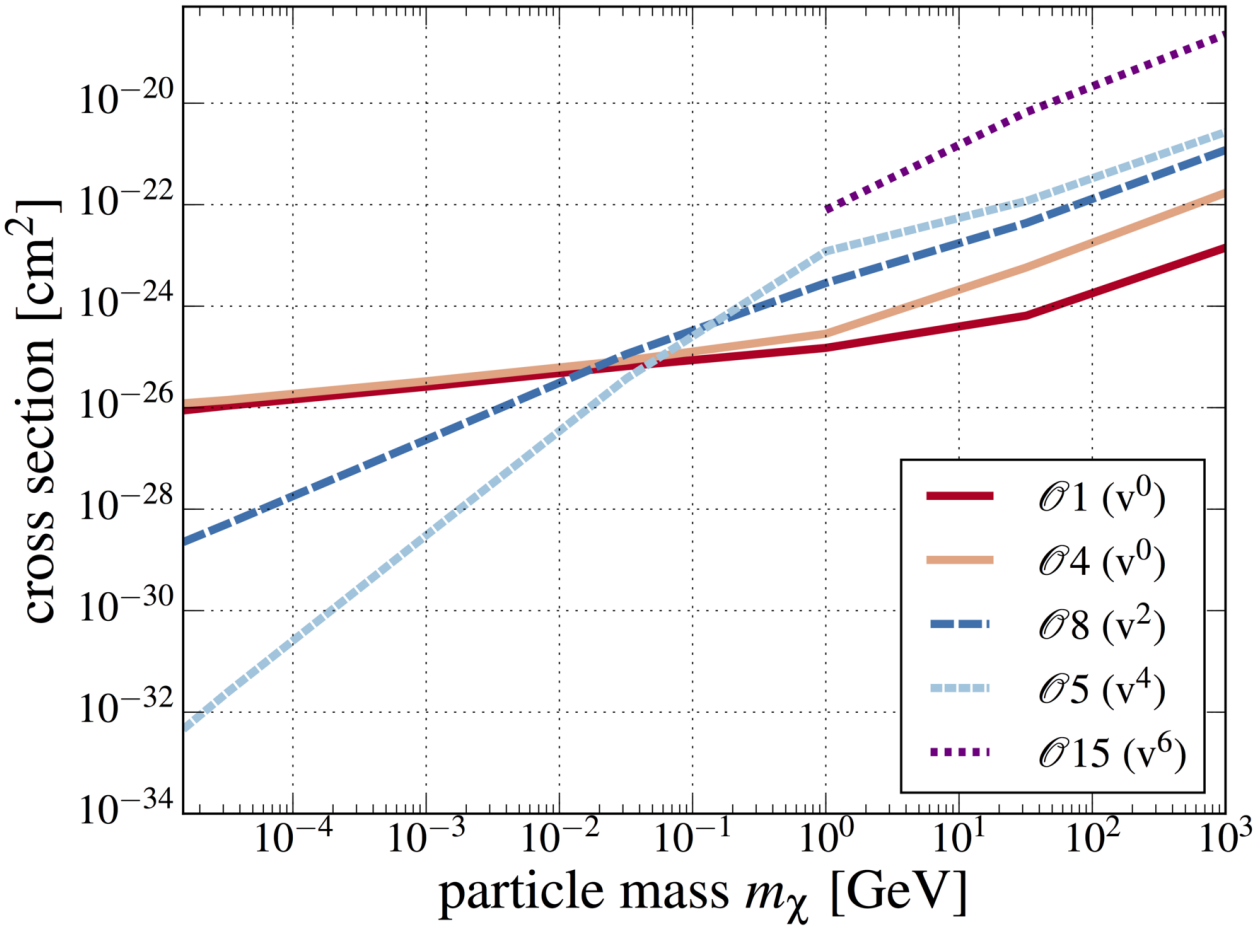


angular scale

Fan et al, 2010; Fitzpatrick et al, 2012; Anand et al, 2013

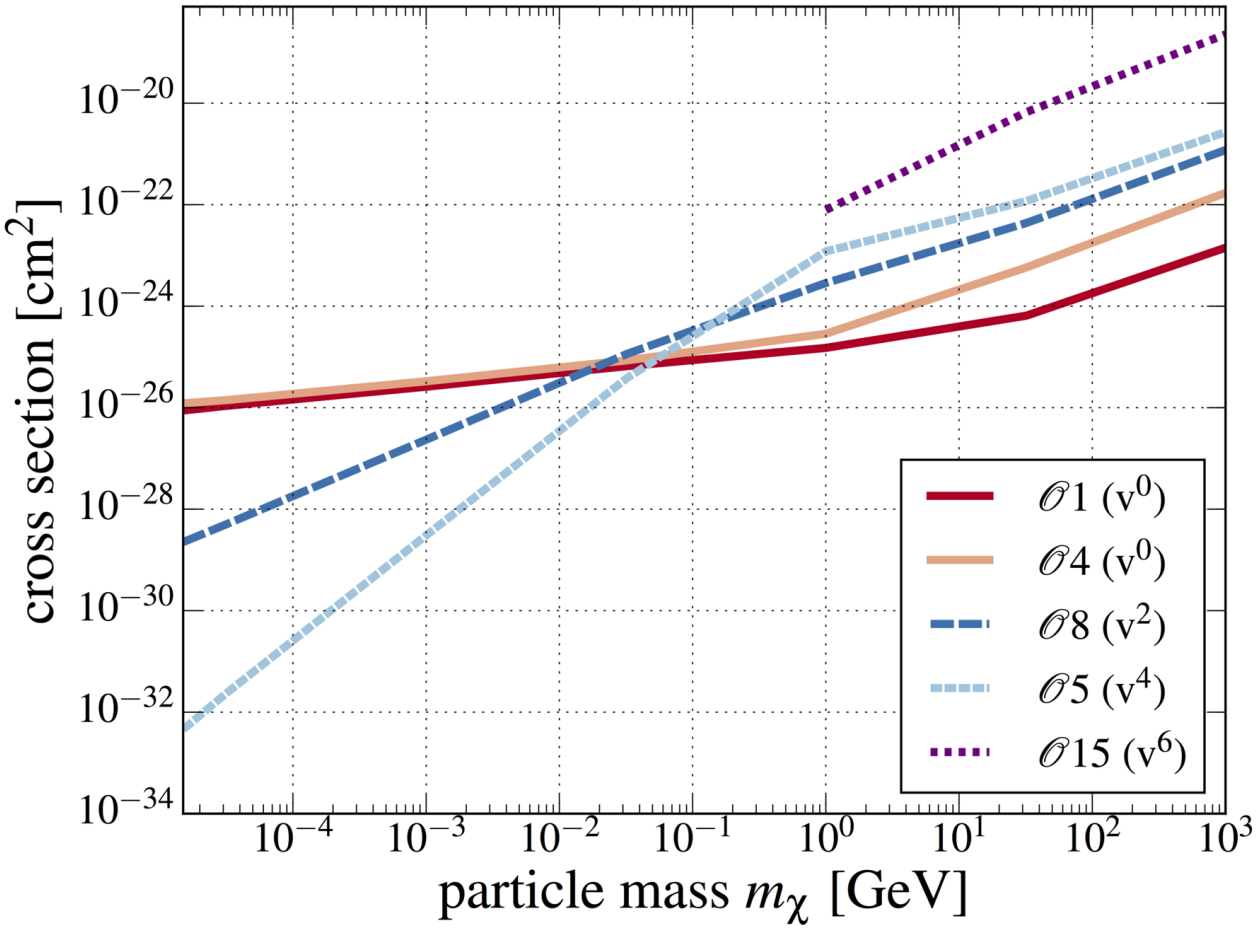
Boddy and VG (2018)

Planck limits on EFT



Boddy and VG (2018)

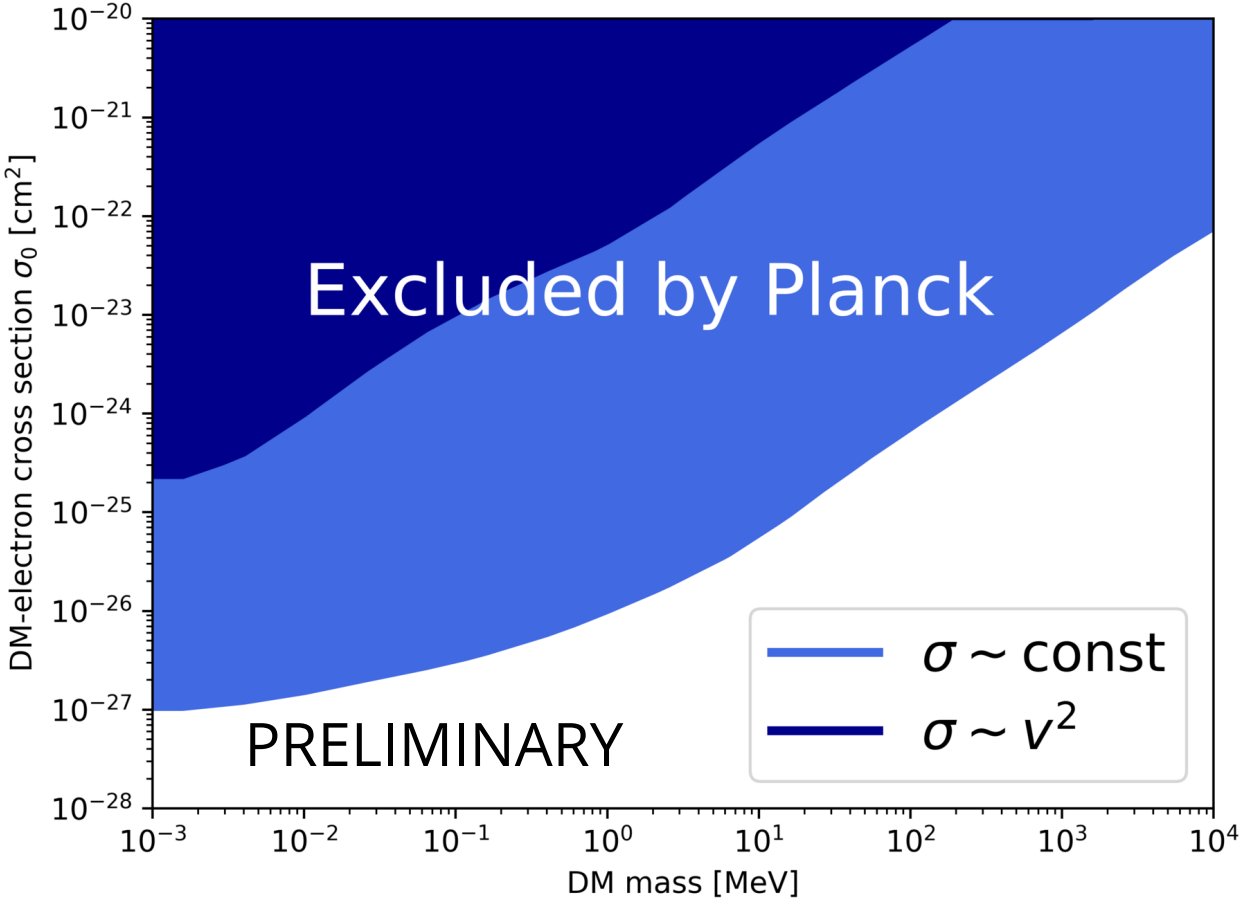
Planck limits on EFT



Age of the Universe ~1000 years: Boddy and VG (2018)

less than 1 in 100 000 scatterings is with DM.

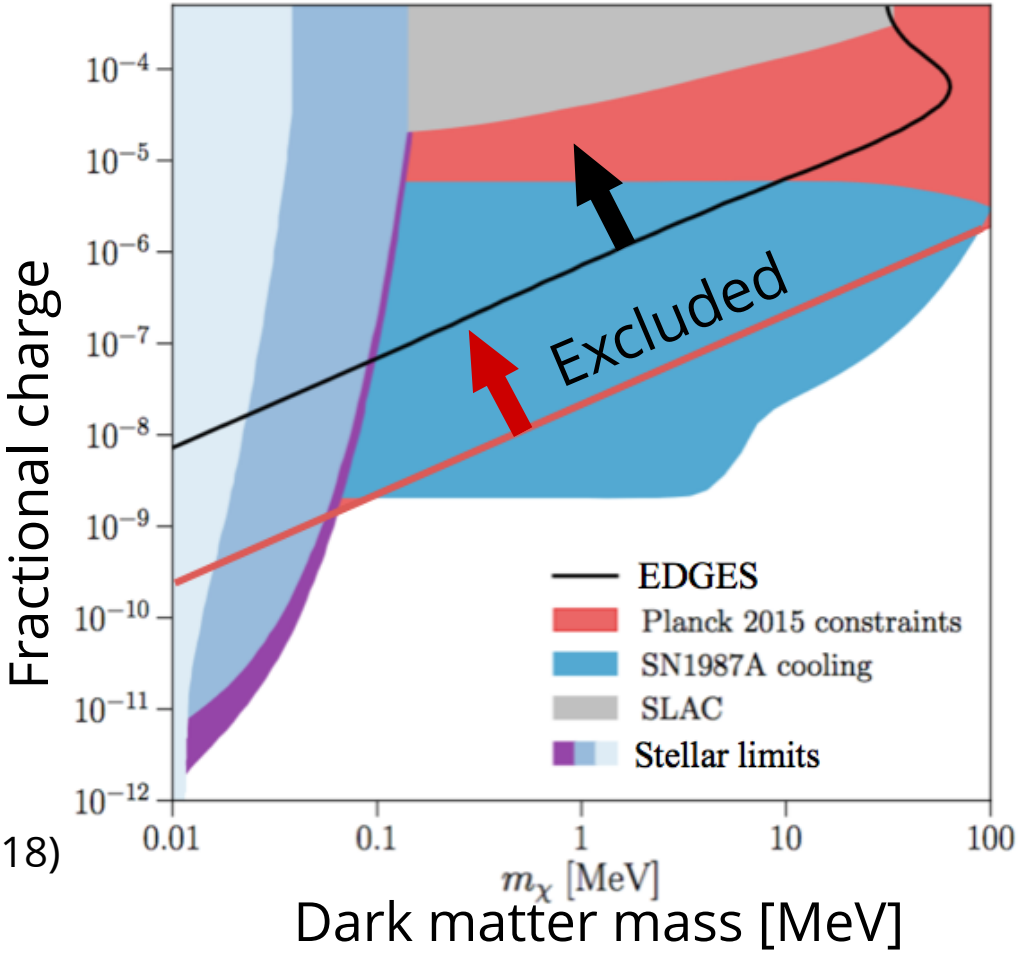
Planck limits on DM-electron scattering



Boddy and VG, in prep. (2019)

Planck limits on millicharge

$$\sigma(v) \sim v^{-4}$$

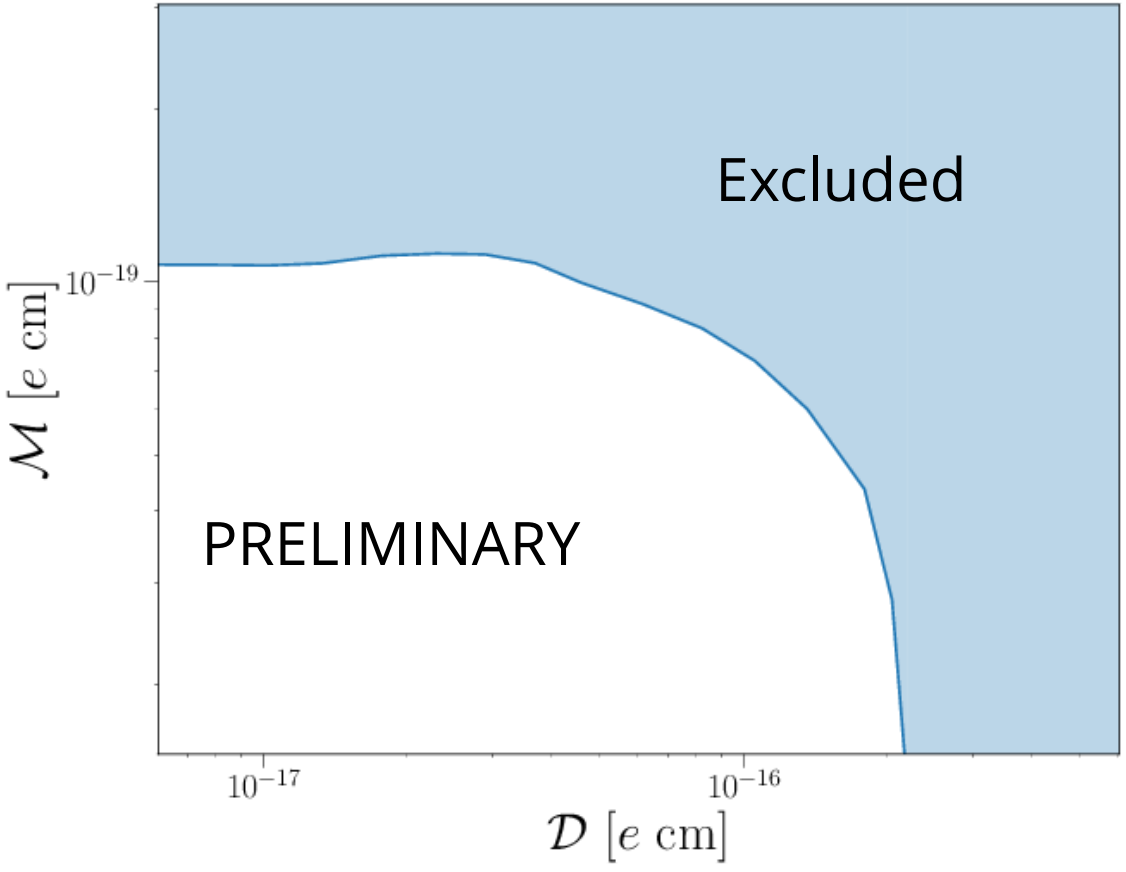


Boddy, VG, + (2018)

Kovetz, Poulin, VG, + (2018)

See also: Xu, + (2018); Slatyer, + (2018); Wu, + (2018); Dvorkin, + (2014).

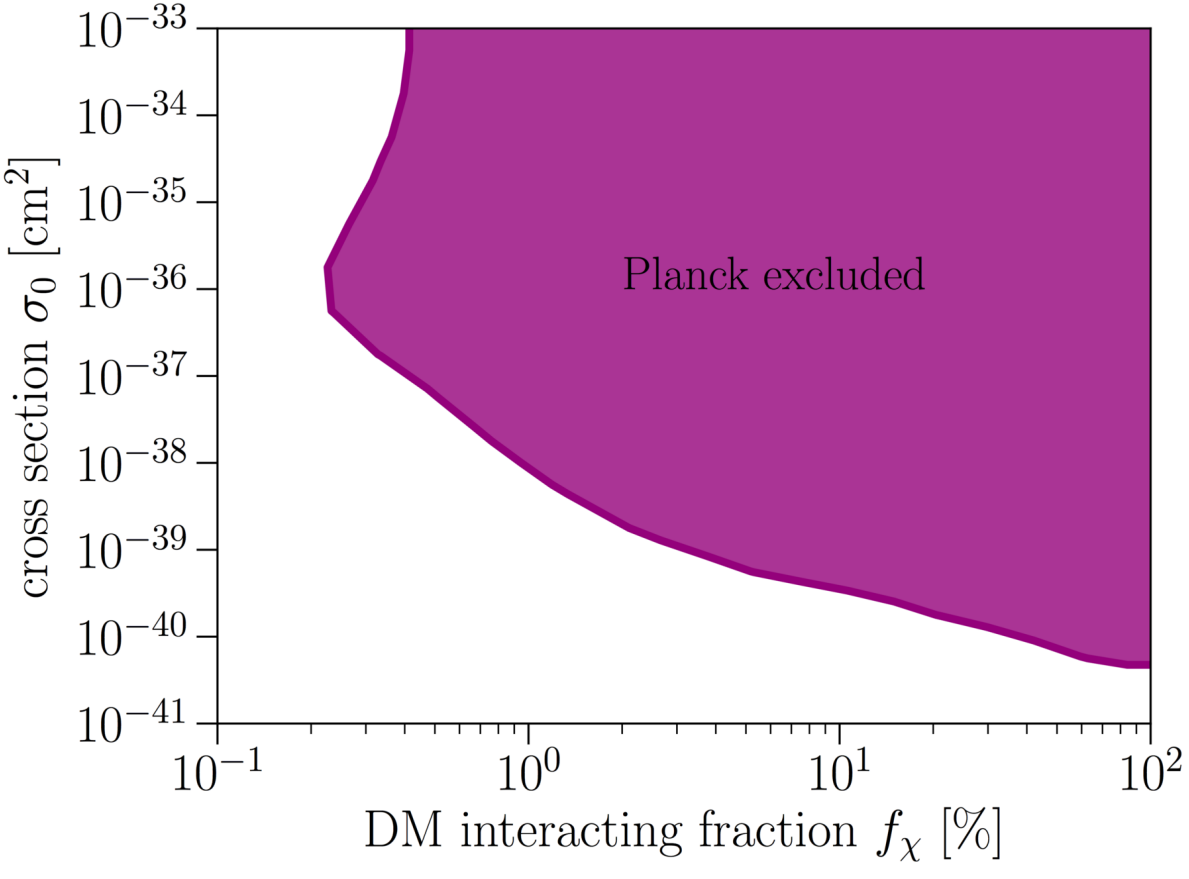
Planck limits on dipole DM



Plot by Daniel Pfeffer

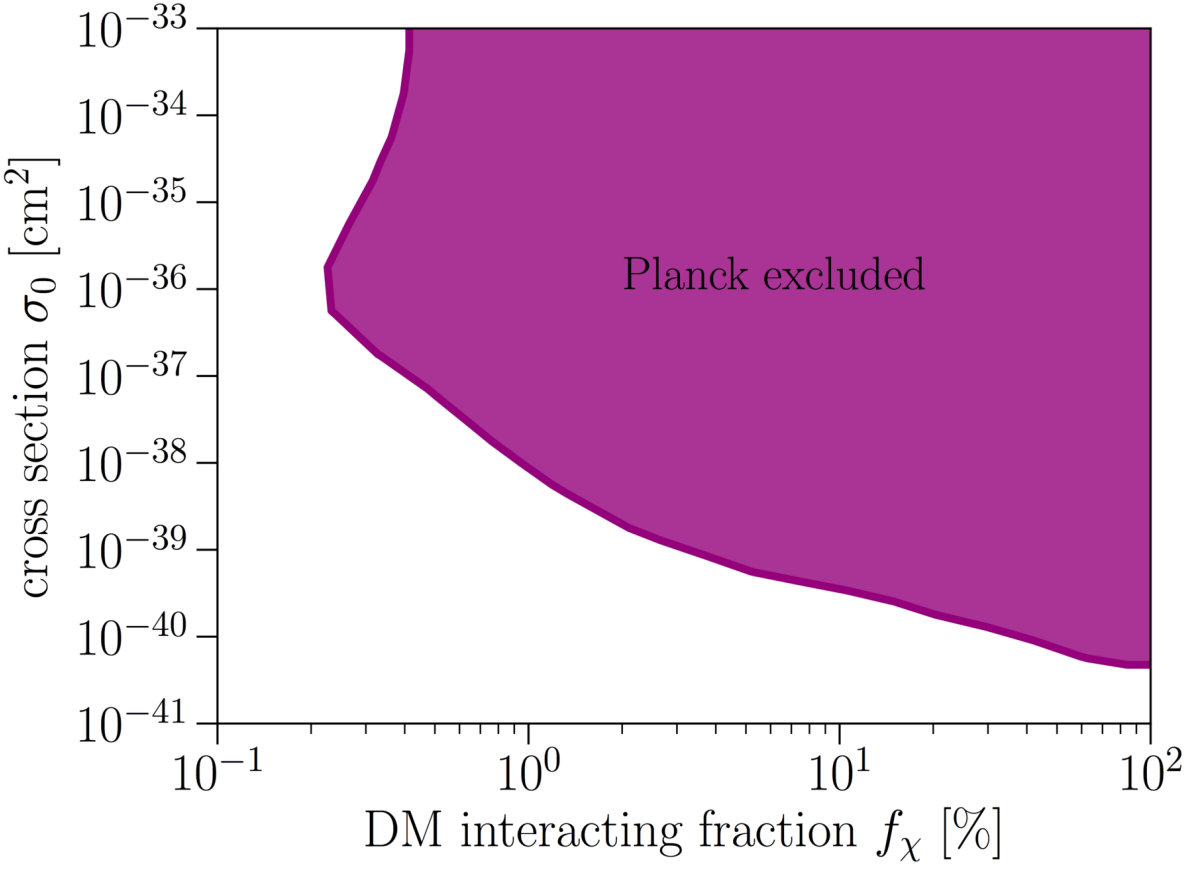
Pfeffer, Boddy, Poulin, VG (in prep.)

Limits on interacting sub-component



Boddy, VG, + (2018).

Limits on interacting sub-component



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

Boddy, VG, + (2018).

Next-generation ground-based CMB observatories

=> high resolution measurements.

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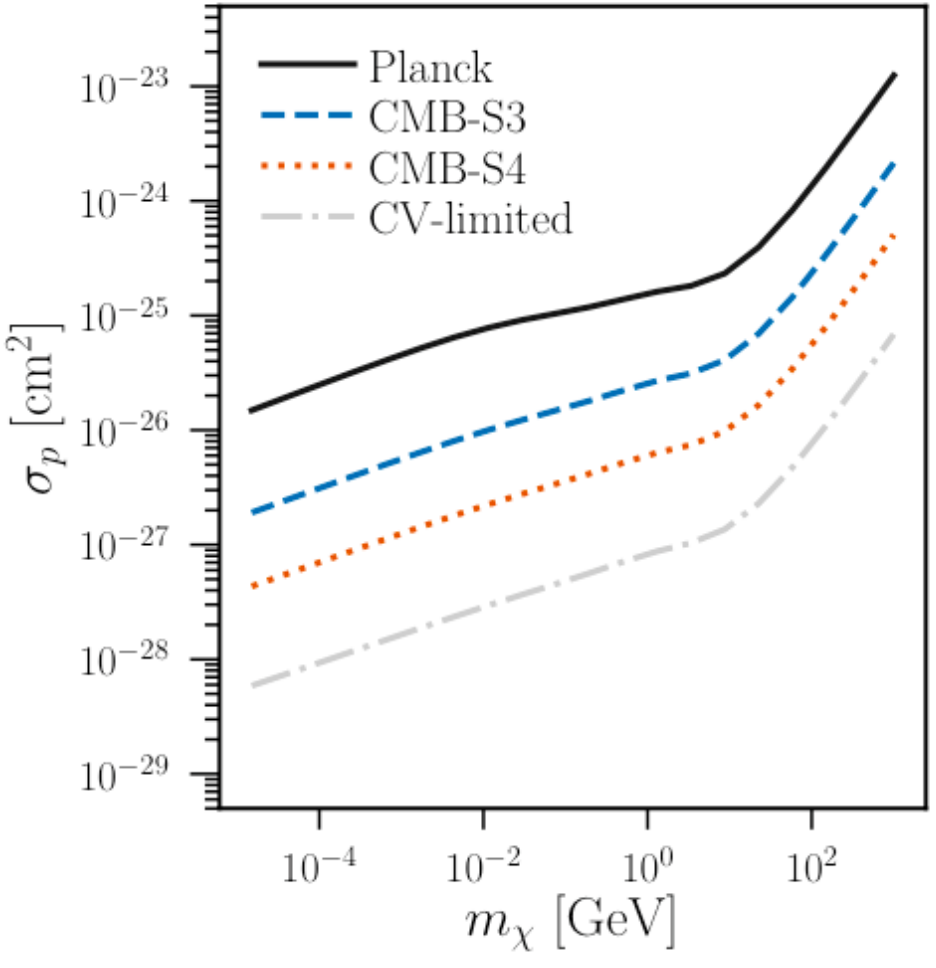
=> high resolution measurements.

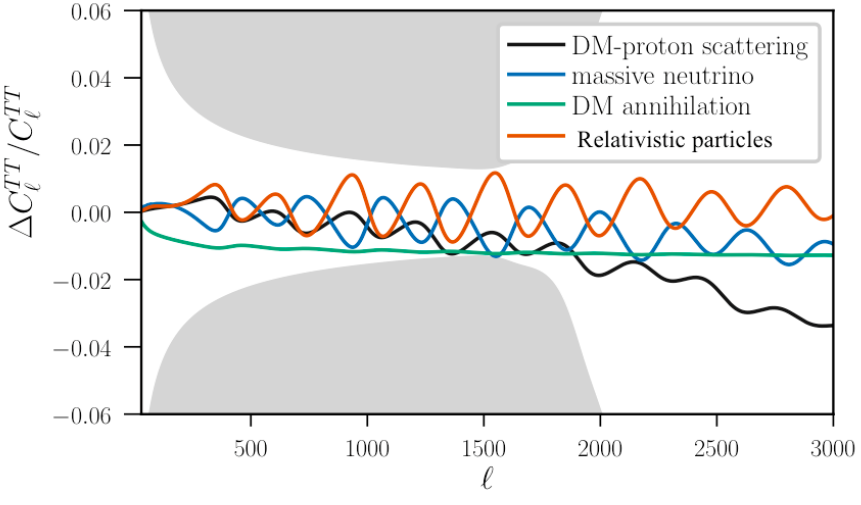
CMB-S4 (proposed) and Simons Observatory

Next-generation CMB: Forecasts

velocity-independent scattering

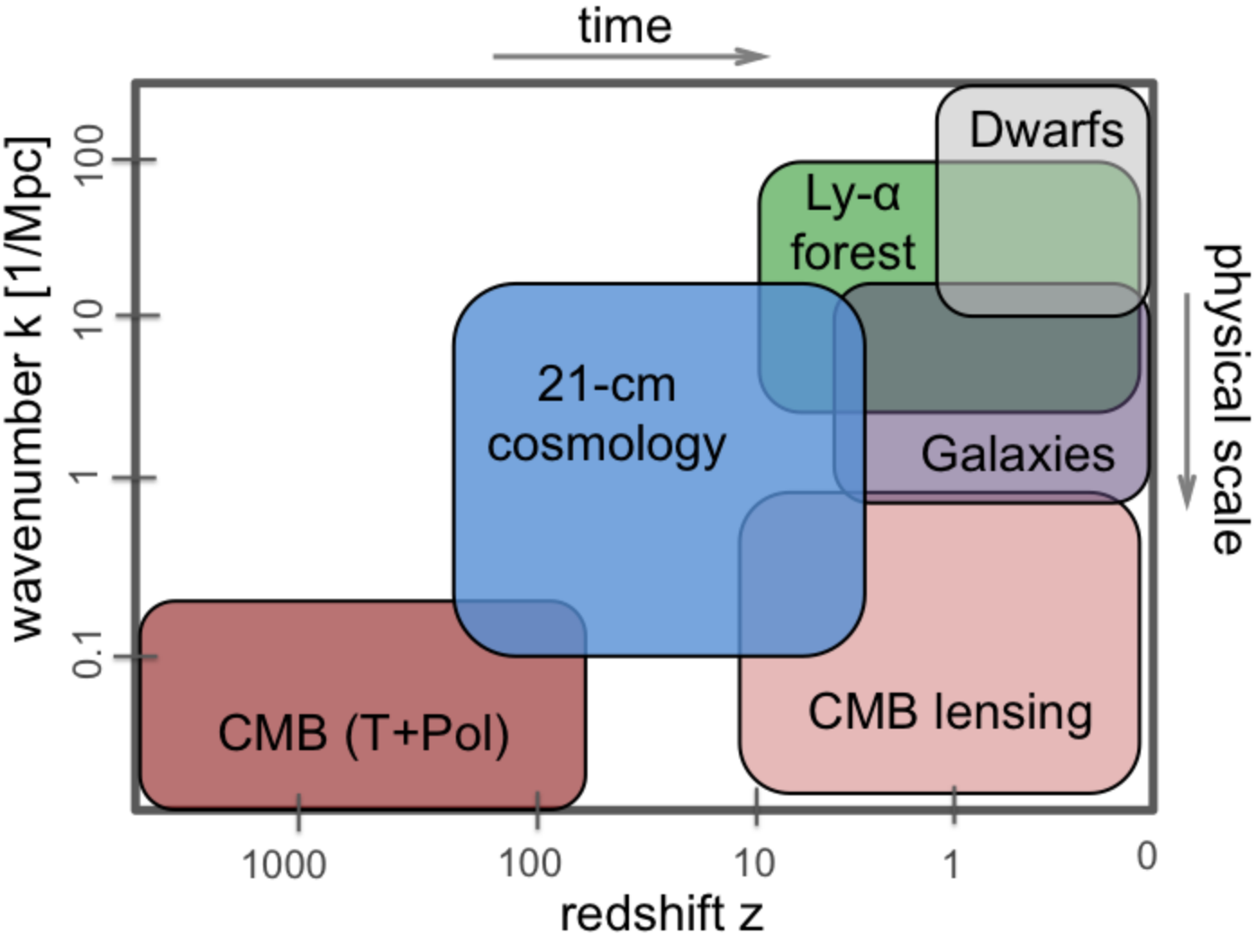


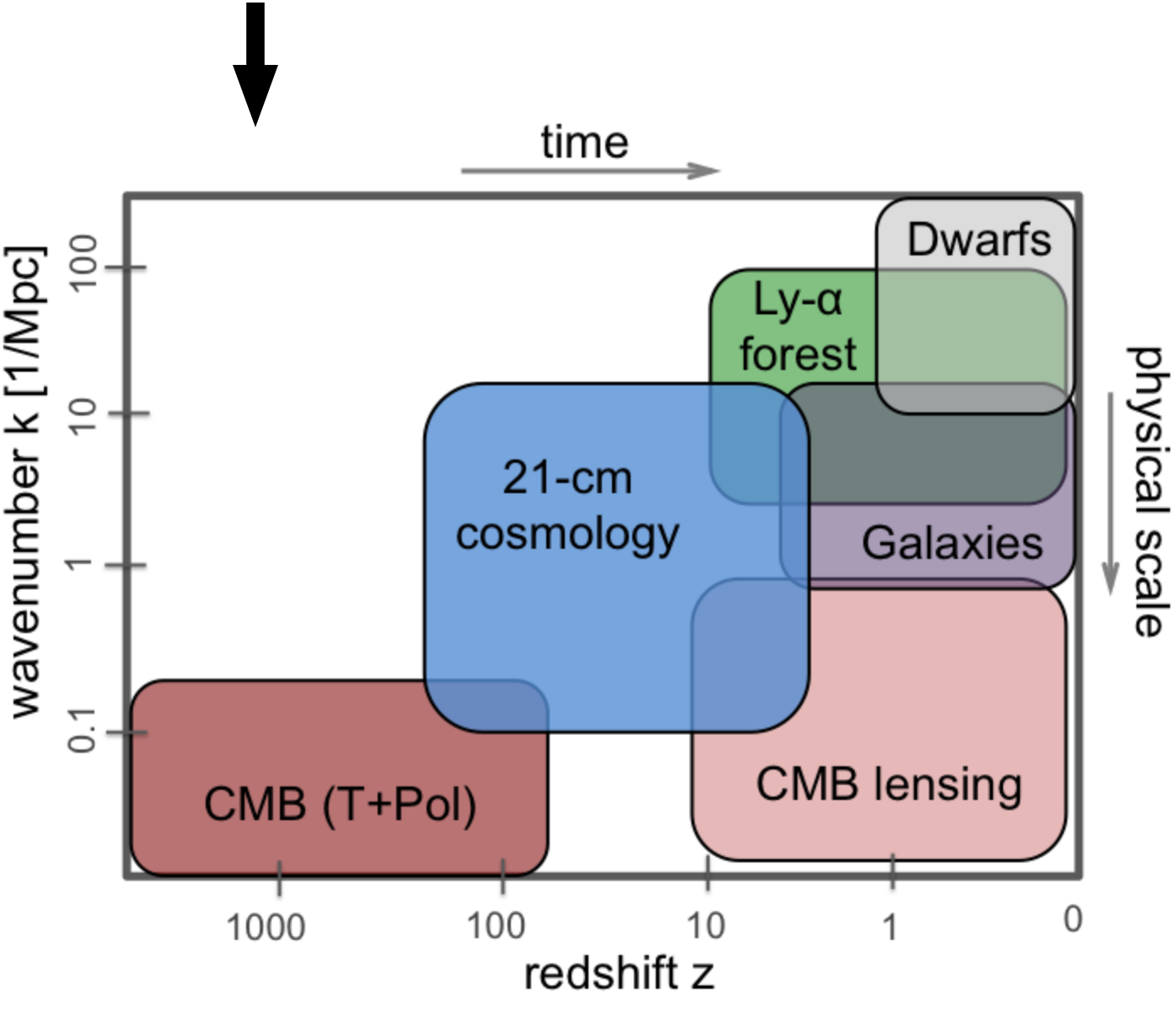
DM interactions do NOT look like other science targets, given well-measured CMB lensing.



Li, VG, + (2018)

See also 1808.07445


time
Dwarfs
Ly-α
forest
21-cm
cosmology
Galaxies
CMB lensing
CMB (T+Pol)
wavenumber k [1/Mpc]
100
10
1
0.1
physical scale
1000
100
10
1
0
redshift z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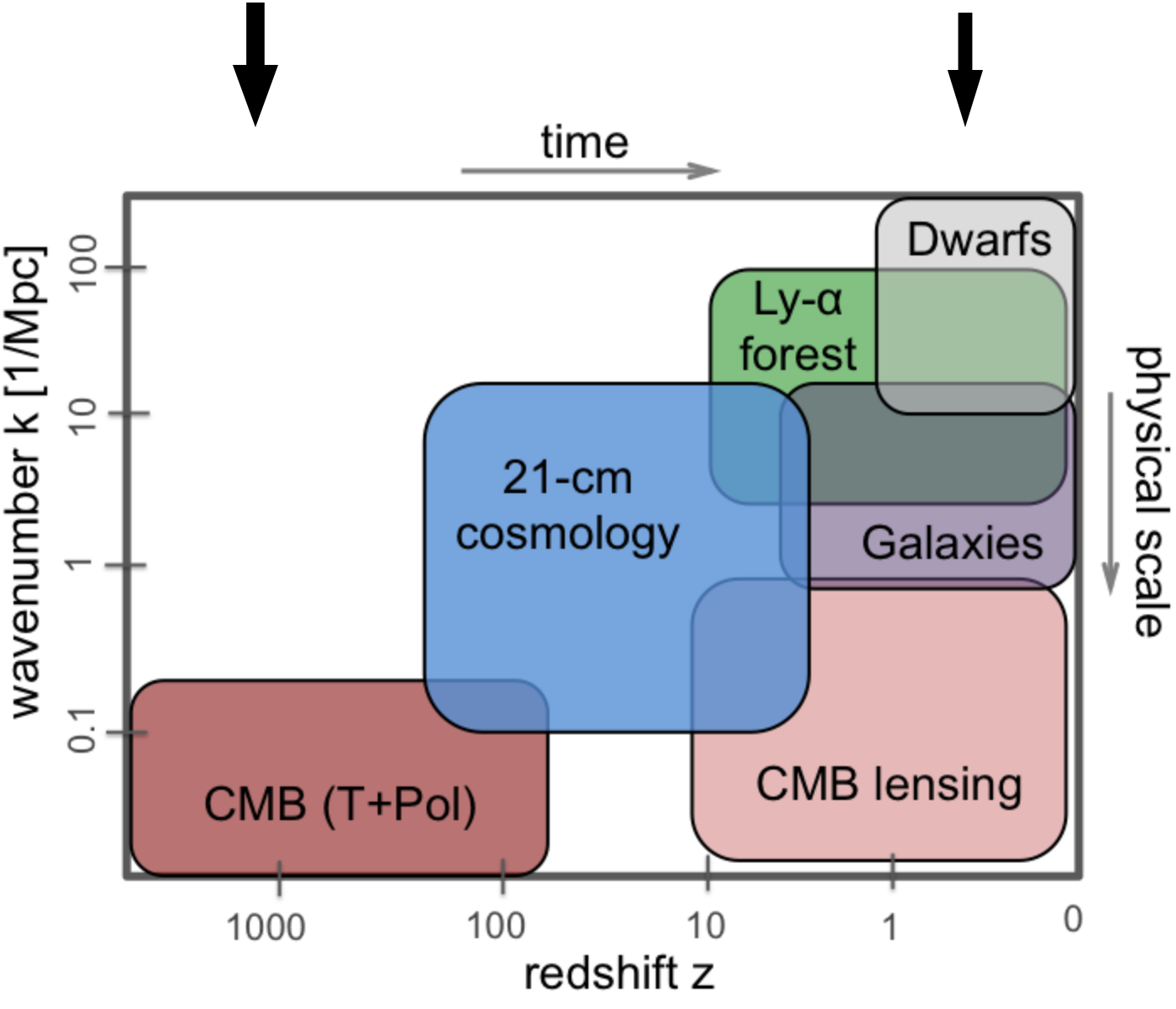
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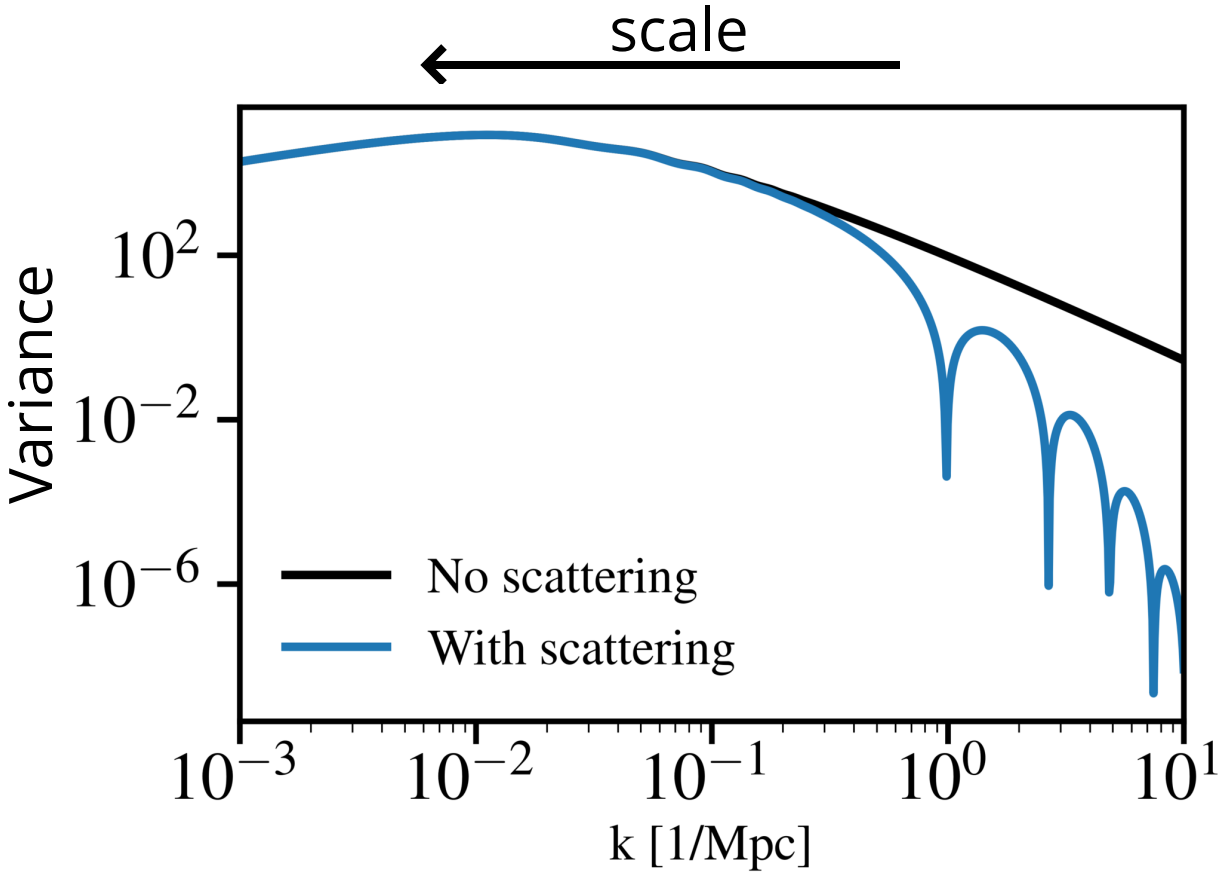
Dark matter interactions suppress structure on small scales.



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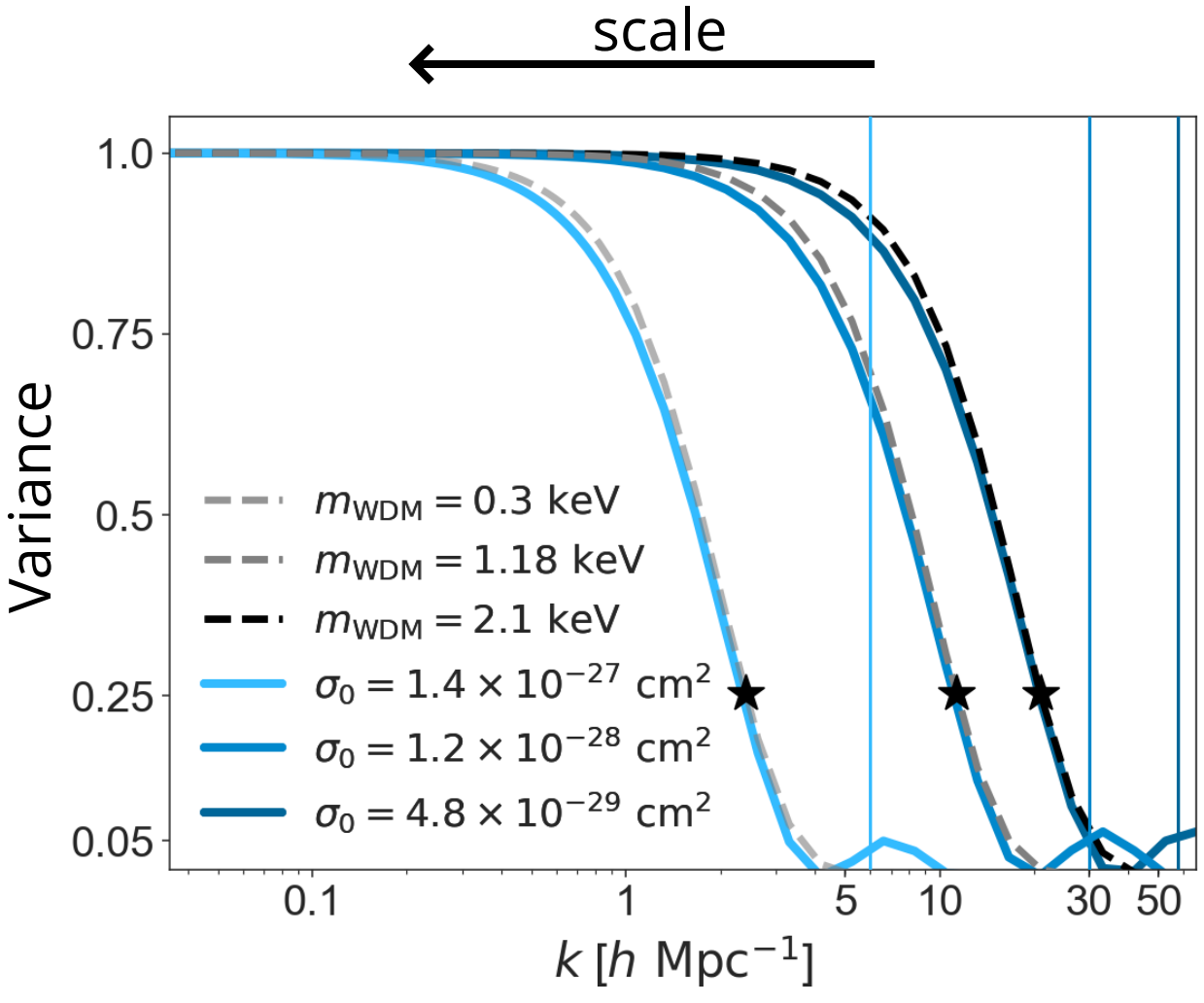
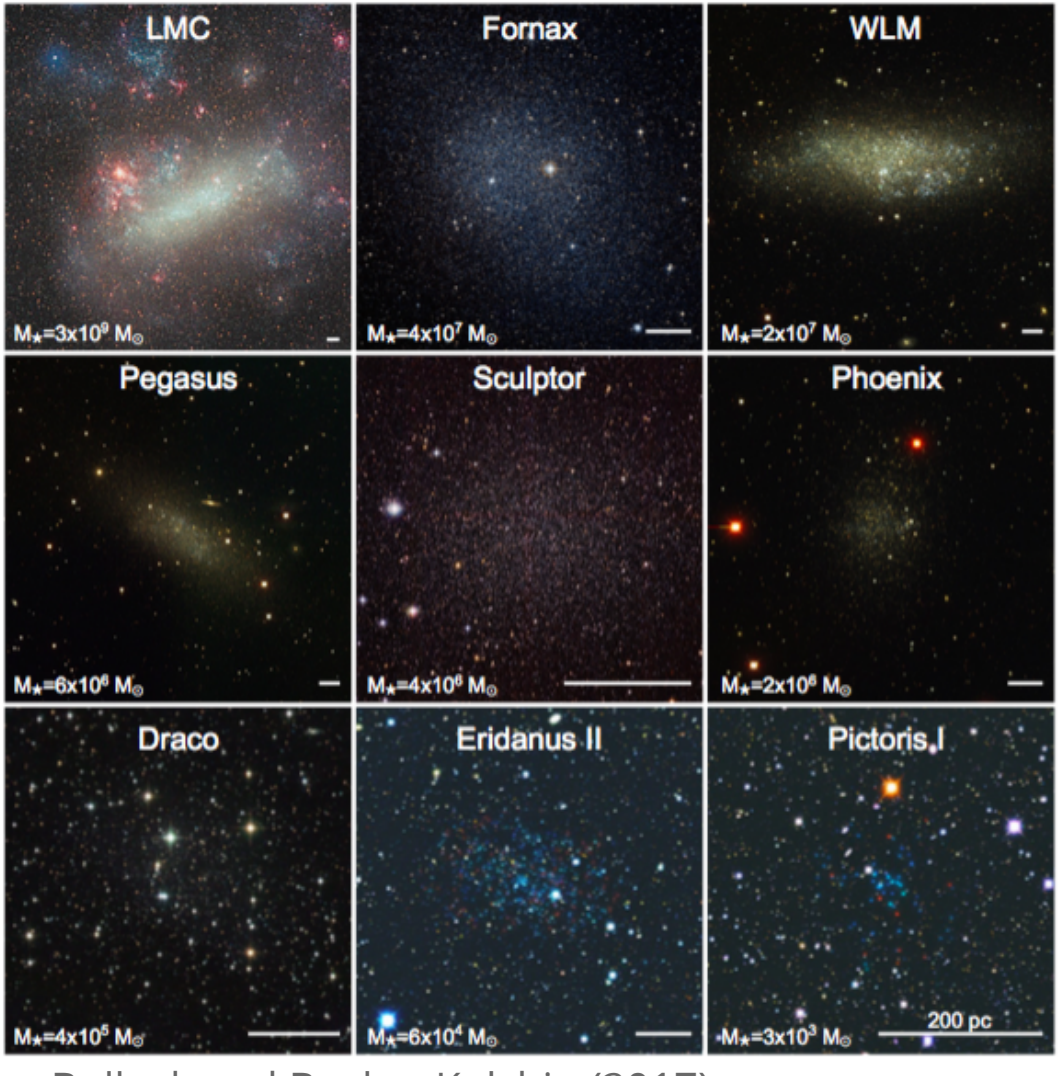


Near-field cosmology

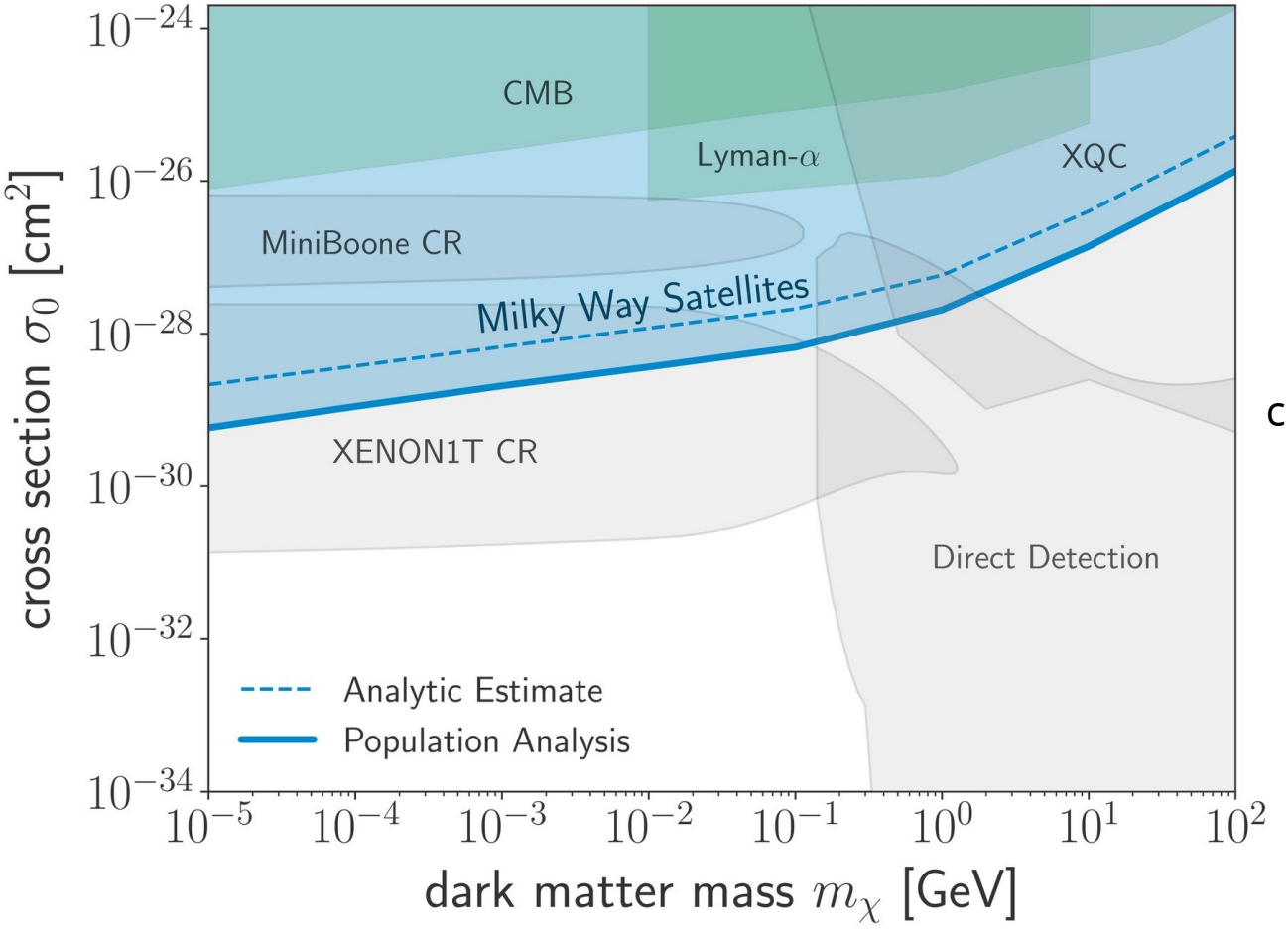
Many more with galaxy surveys like LSST



Bullock and Boylan-Kolchin (2017)

c.f. Ethan's talk on Wednesday

Limits from Milky Way Satellites



c.f. Ethan's talk on Wednesday

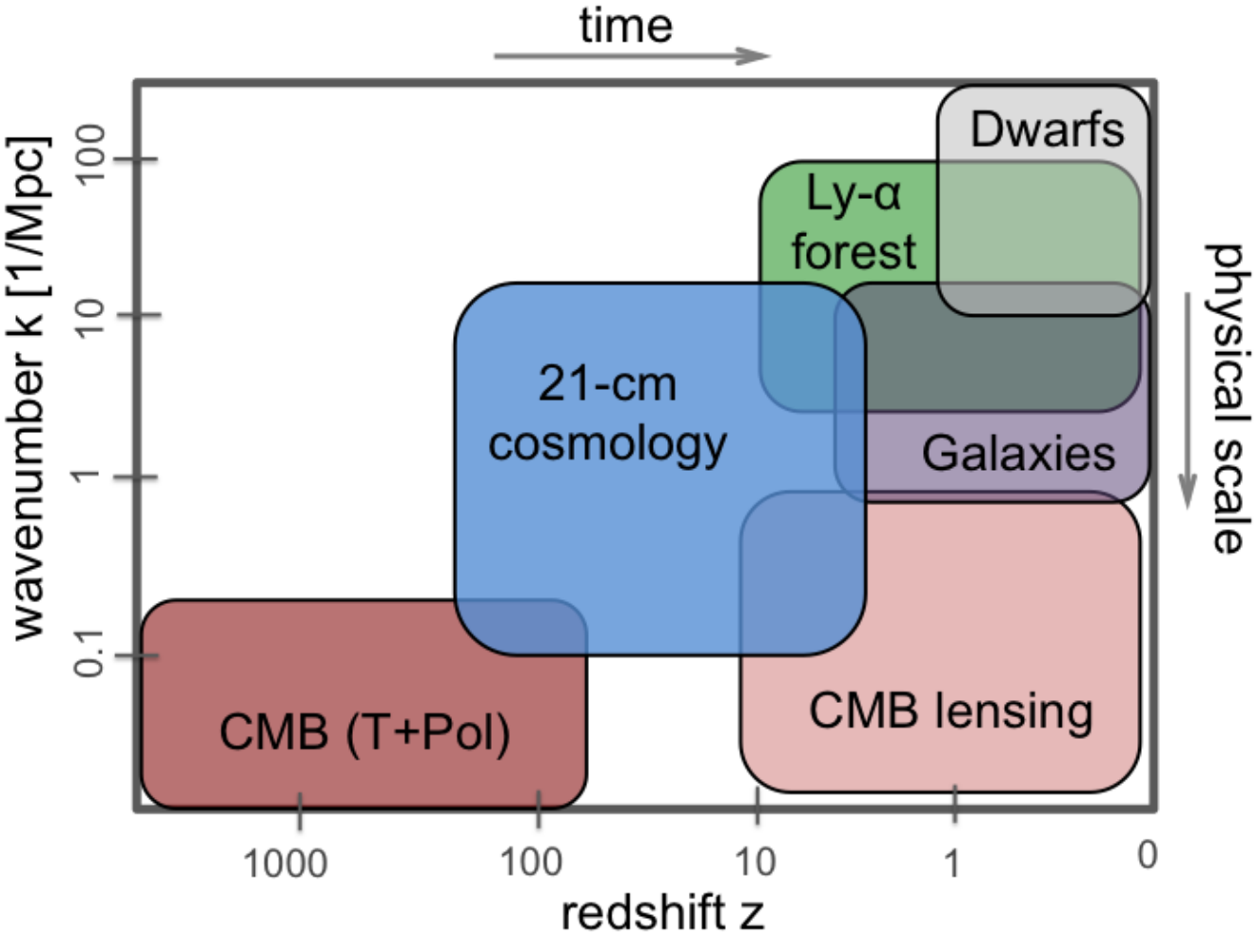
Nadler, VG, Boddy, Wechsler (ApJ Letters 2019)

vel-independent scattering: 3 OOM better than Planck.

Work in progress

- Limits on other scattering models
- Simulations in interacting cosmologies
- Projections for LSST etc.
- Understand degeneracies in DM modeling space
- Understand modeling systematics

Broader scope



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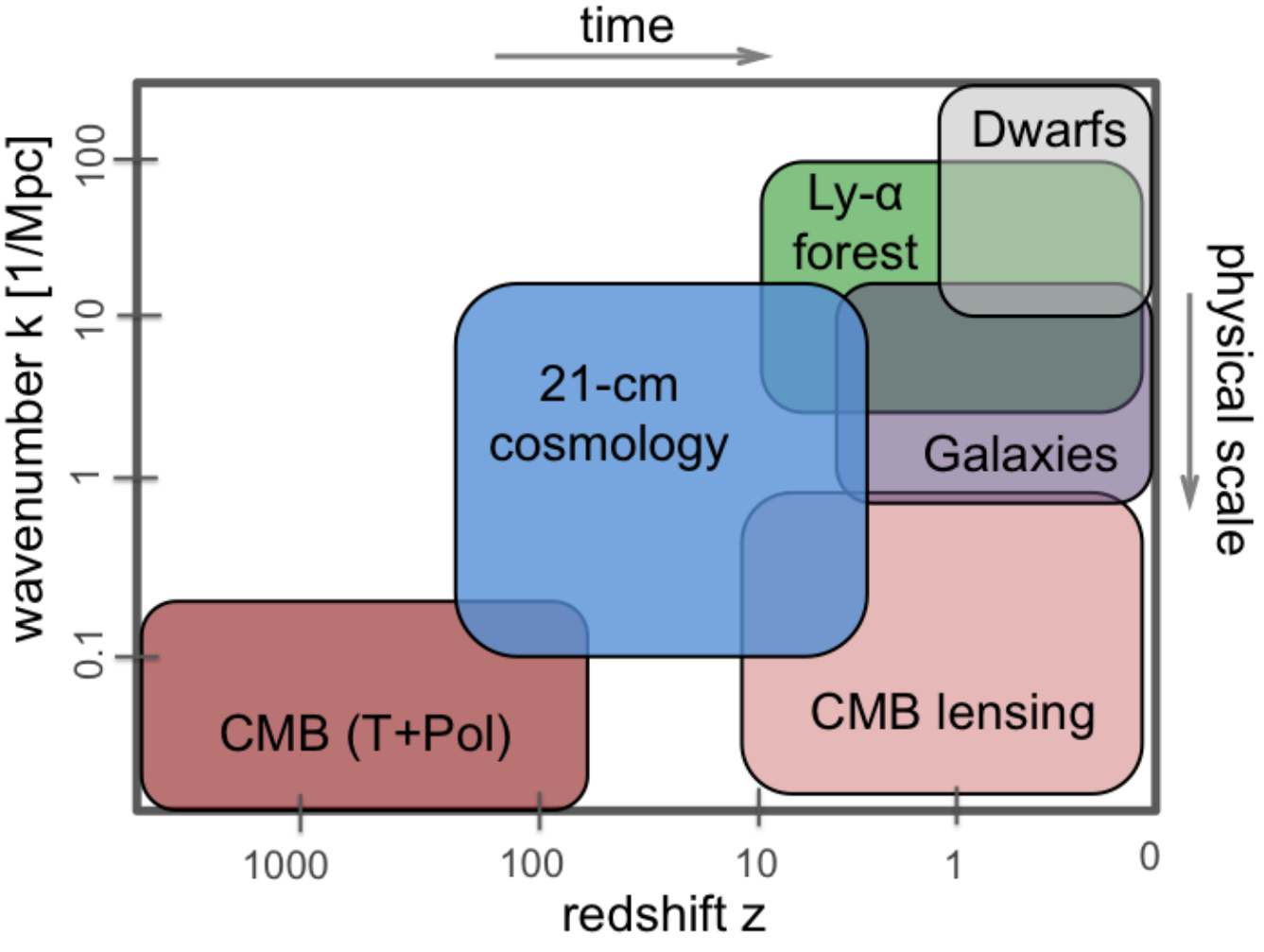
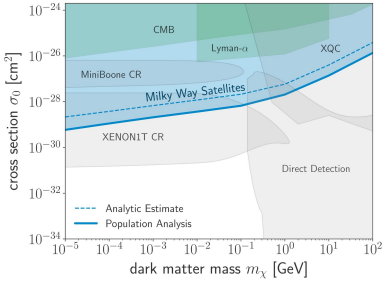
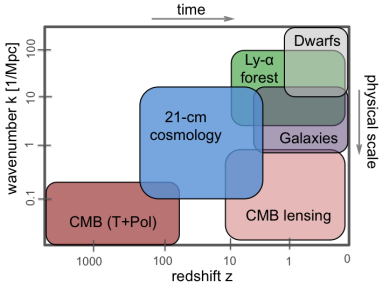


Lots of data coming: Simons Observatory, CMB-S4, LSST, DESI, HERA, SKA, EDGES, SARAS, DD experiments,...

Key points





- CMB already probes new parameter space and new paradigms; near-field cosmology is messier, but very promising [e.g. satellites].
- *LSST/VRO and other data sets in next decade will be goldmine for tests of new physics.*
- **Key for discovery: comprehensive searches and joint analyses.**
- **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**

Towards the future

Astro2020 Science White Paper

Cosmological Probes of Dark Matter Interactions: The Next Decade

Thematic area: Cosmology and Fundamental Physics.

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Endorsers: The full list of names is available at:
https://github.com/veragluscevic/Astro2020-DM-Cosmology-Endorsers

Abstract

Cosmological observations offer unique and robust avenues for probing the fundamental nature of dark matter particles—they broadly test a range of compelling theoretical scenarios, often surpassing or complementing the reach of terrestrial and other experiments. We discuss observational and theoretical advancements that will play a pivotal role in realizing a strong program of cosmological searches for the identity of dark matter in the coming decade. Specifically, we focus on measurements of the cosmic-microwave-background anisotropy and spectral distortions, and tracers of structure (such as the Lyman-α forest, galaxies, and the cosmological 21-cm signal).


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