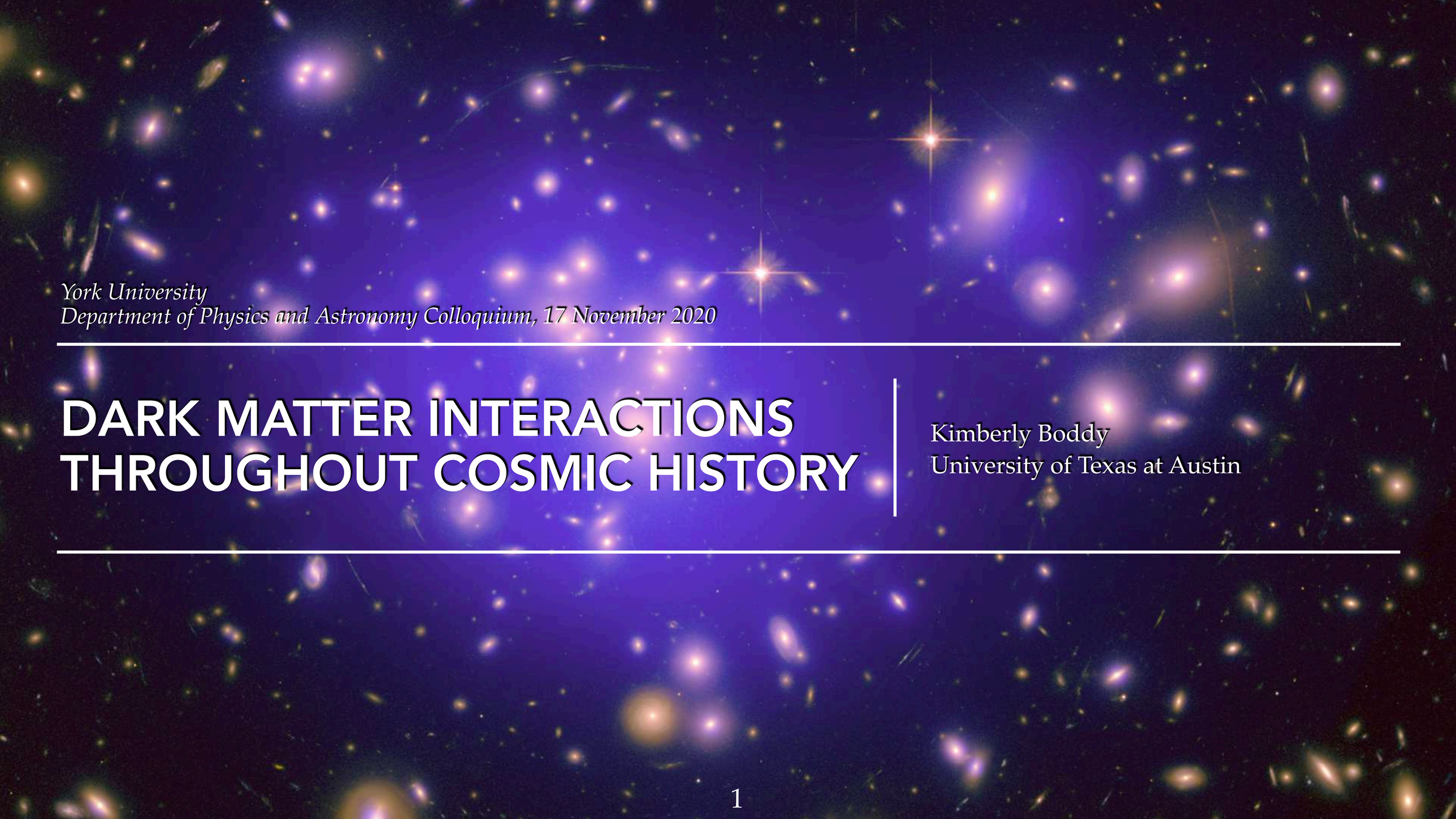
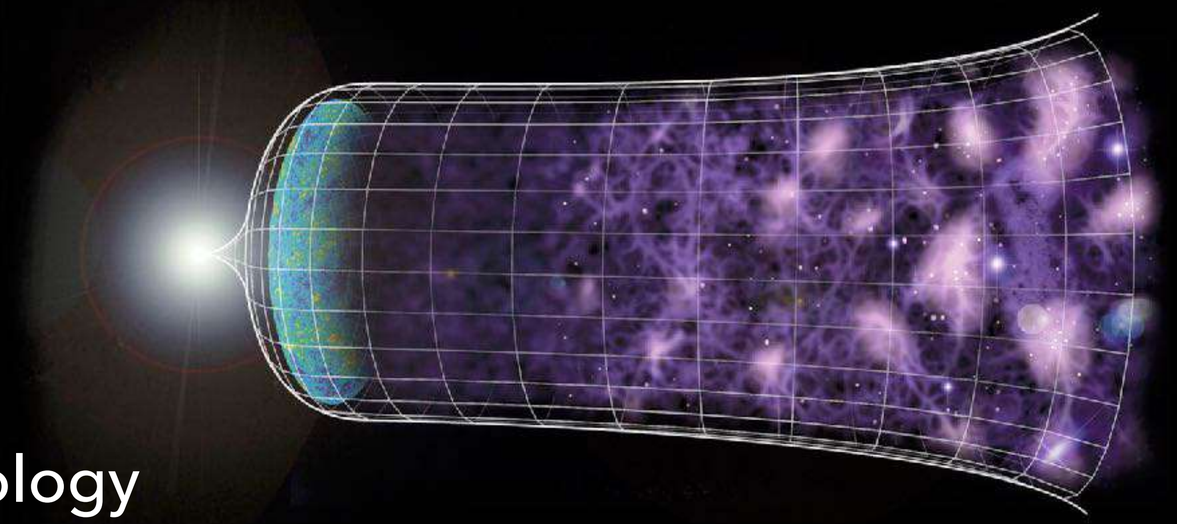


York University
Department of Physics and Astronomy Colloquium, 17 November 2020

DARK MATTER INTERACTIONS THROUGHOUT COSMIC HISTORY

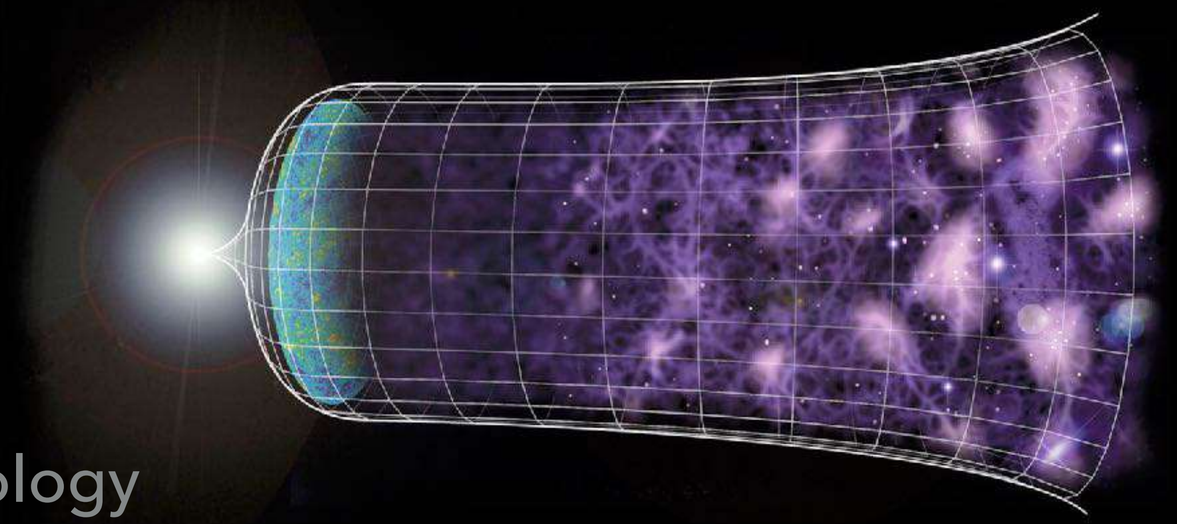
Kimberly Boddy
University of Texas at Austin

Outline



- Role of standard dark matter
- Effects of dark matter physics in cosmology
- Tests of dark matter scattering
- Future prospects

Outline



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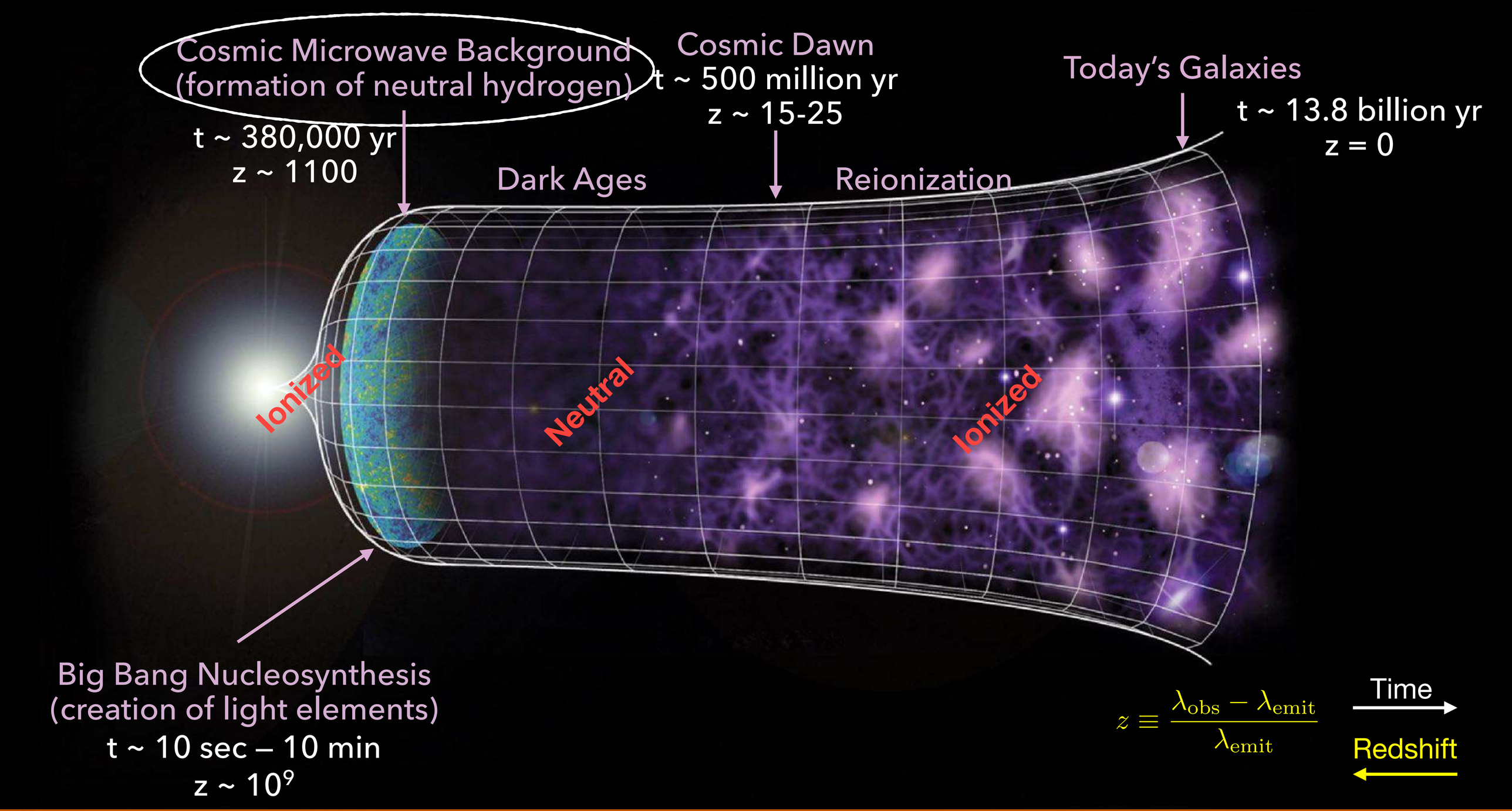
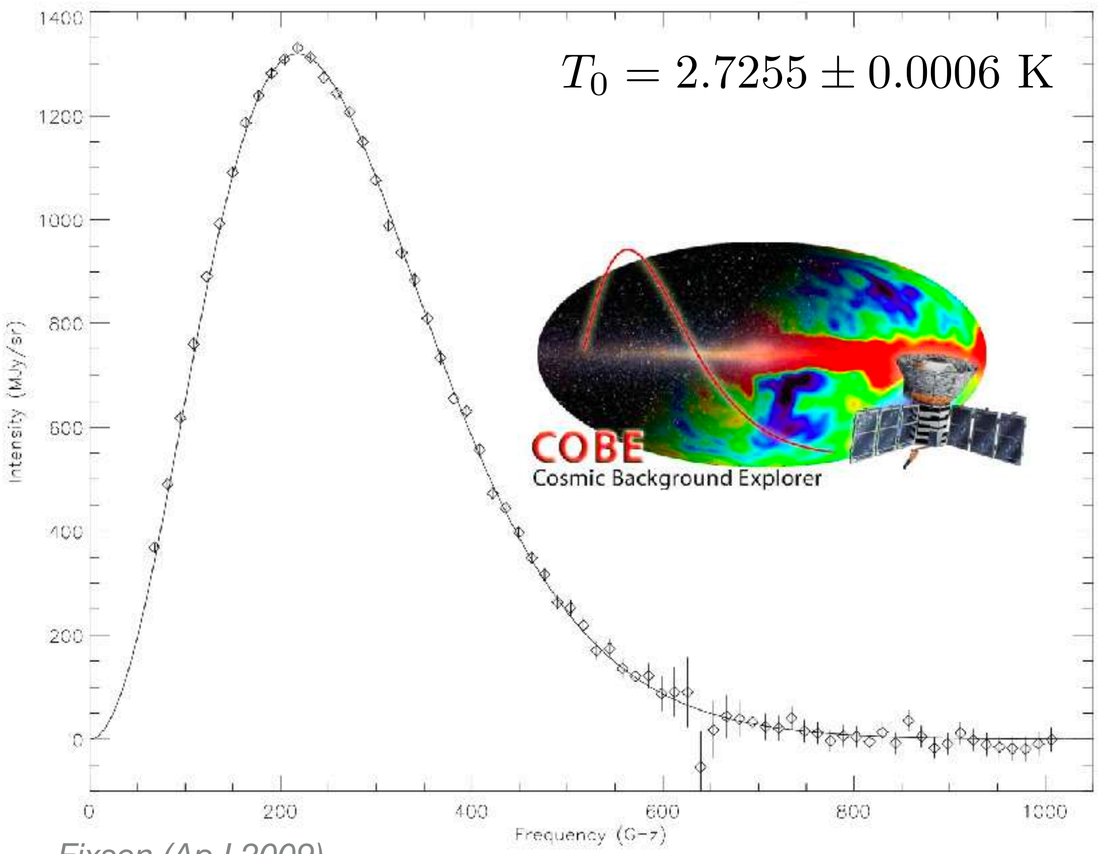
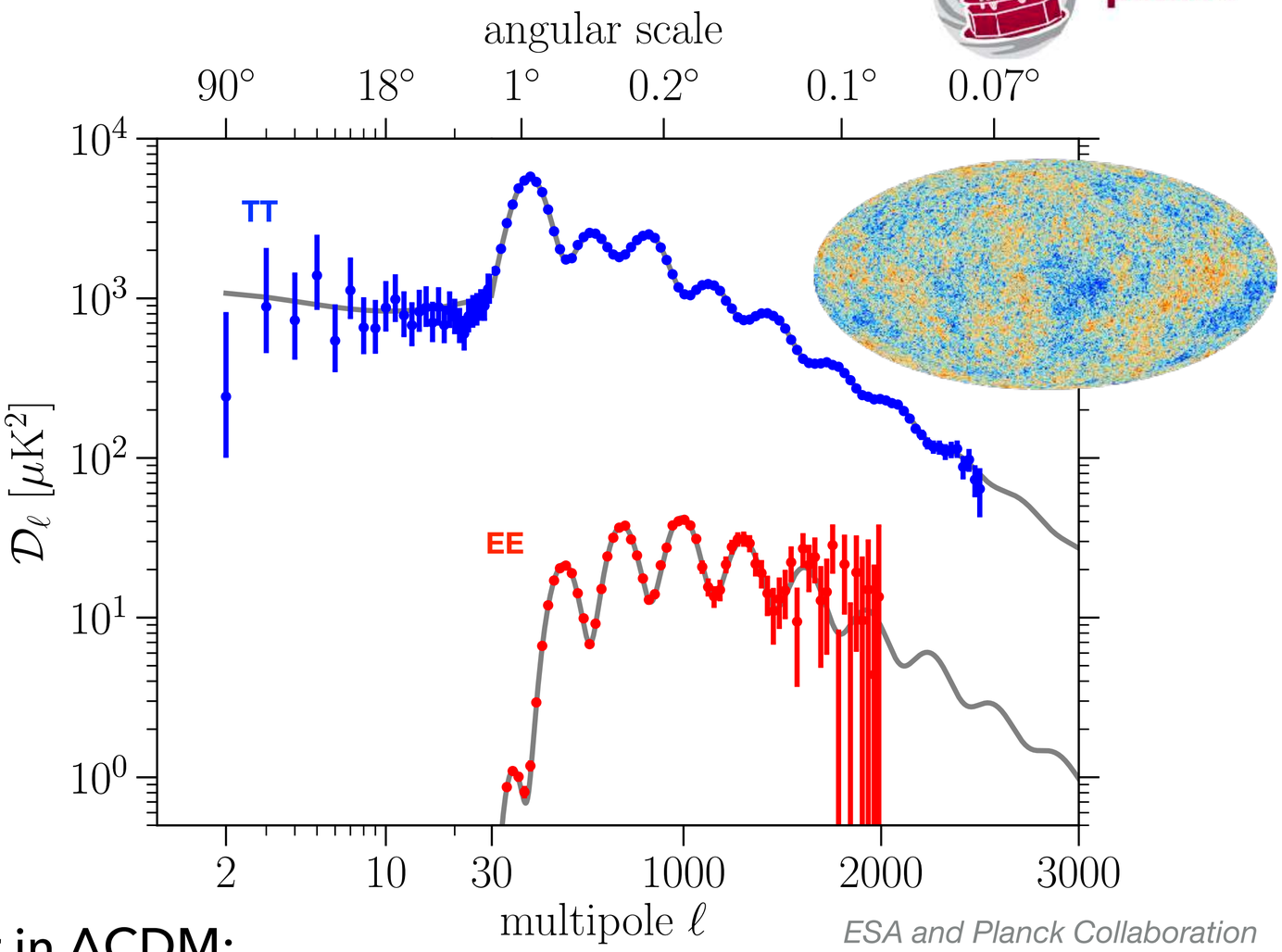

Cosmic Microwave Background
(formation of neutral hydrogen)
t ~ 380,000 yr
z ~ 1100
Cosmic Dawn
t ~ 500 million yr
z ~ 15-25
Today's Galaxies
t ~ 13.8 billion yr
z = 0
Dark Ages
Reionization
Ionized
Neutral
Ionized
Big Bang Nucleosynthesis
(creation of light elements)
t ~ 10 sec – 10 min
z ~ 10^9
$z \equiv \frac{\lambda_{\rm obs} - \lambda_{\rm emit}}{\lambda_{\rm emit}}$
Time
Redshift

Cosmic Microwave Background



Fixsen (ApJ 2009)



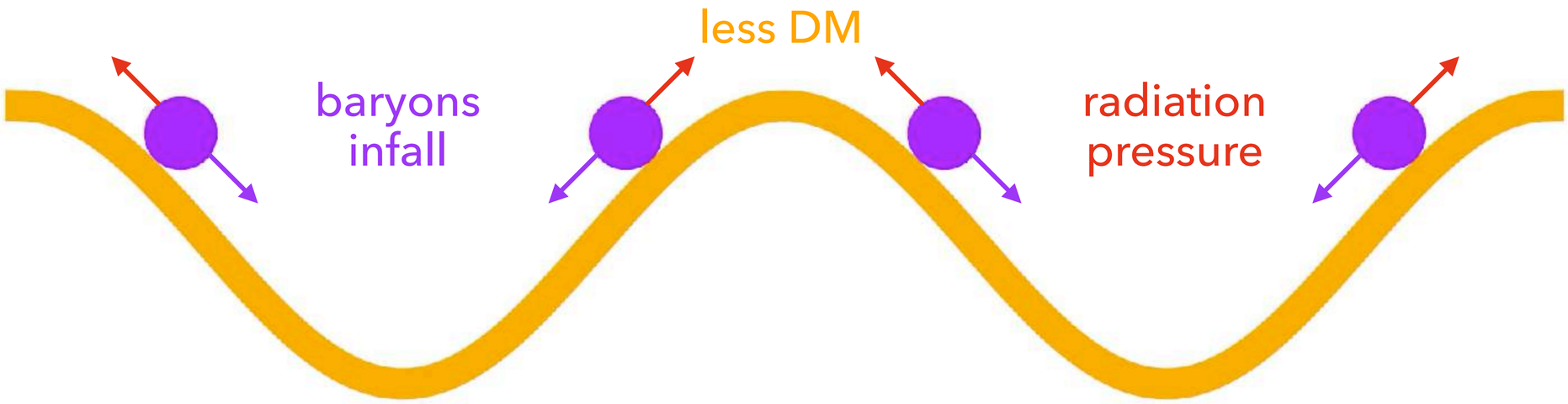
ESA and Planck Collaboration

Dark matter in ΛCDM:

- cold, collisionless
- ~6x more abundant than baryons

"baryons" = protons + helium + electrons

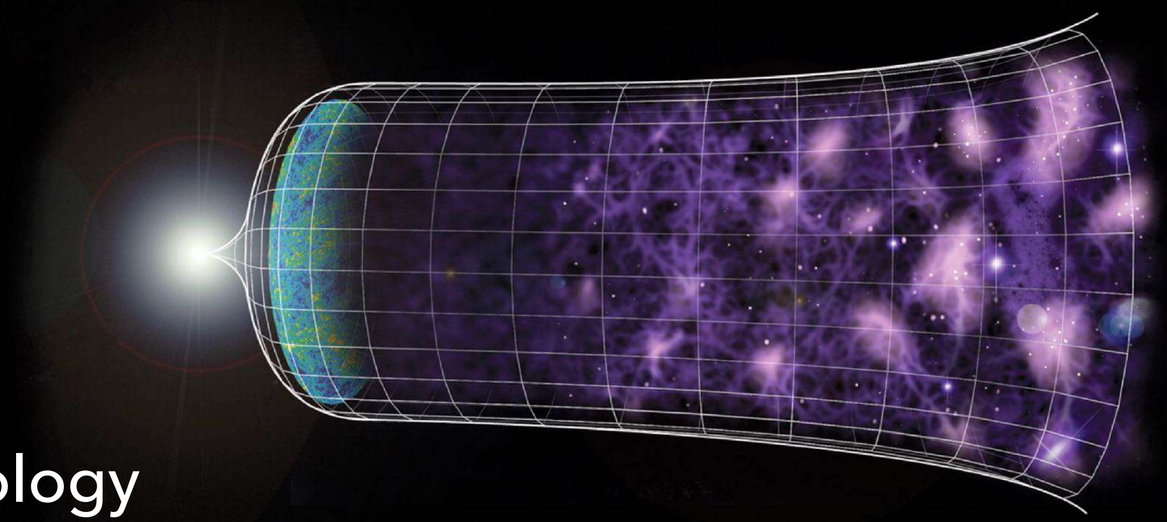
Acoustic Oscillations



more DM
(creates potential well)

simple harmonic oscillators of various frequency and wavelength (Fourier-space description)

Outline



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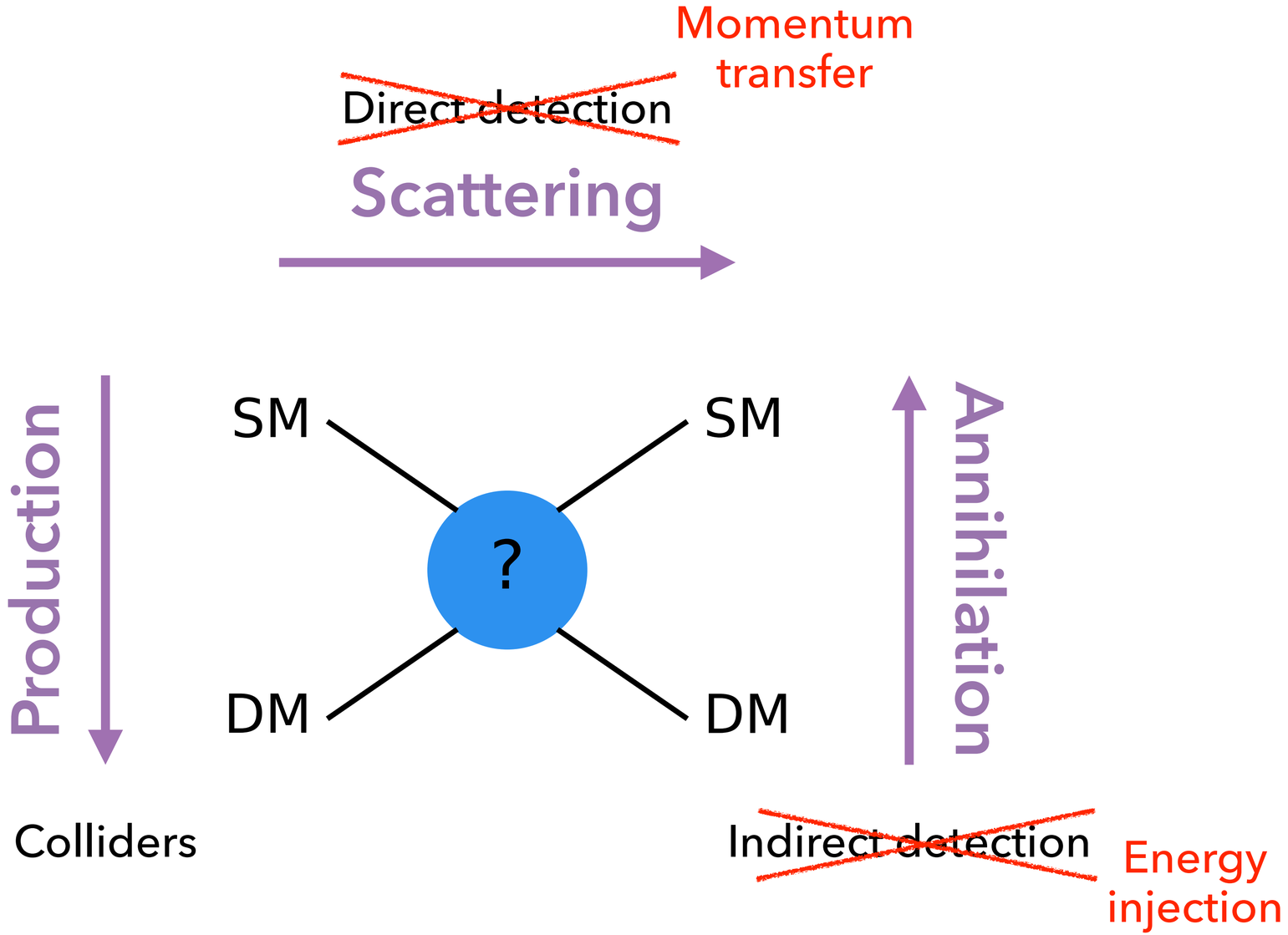
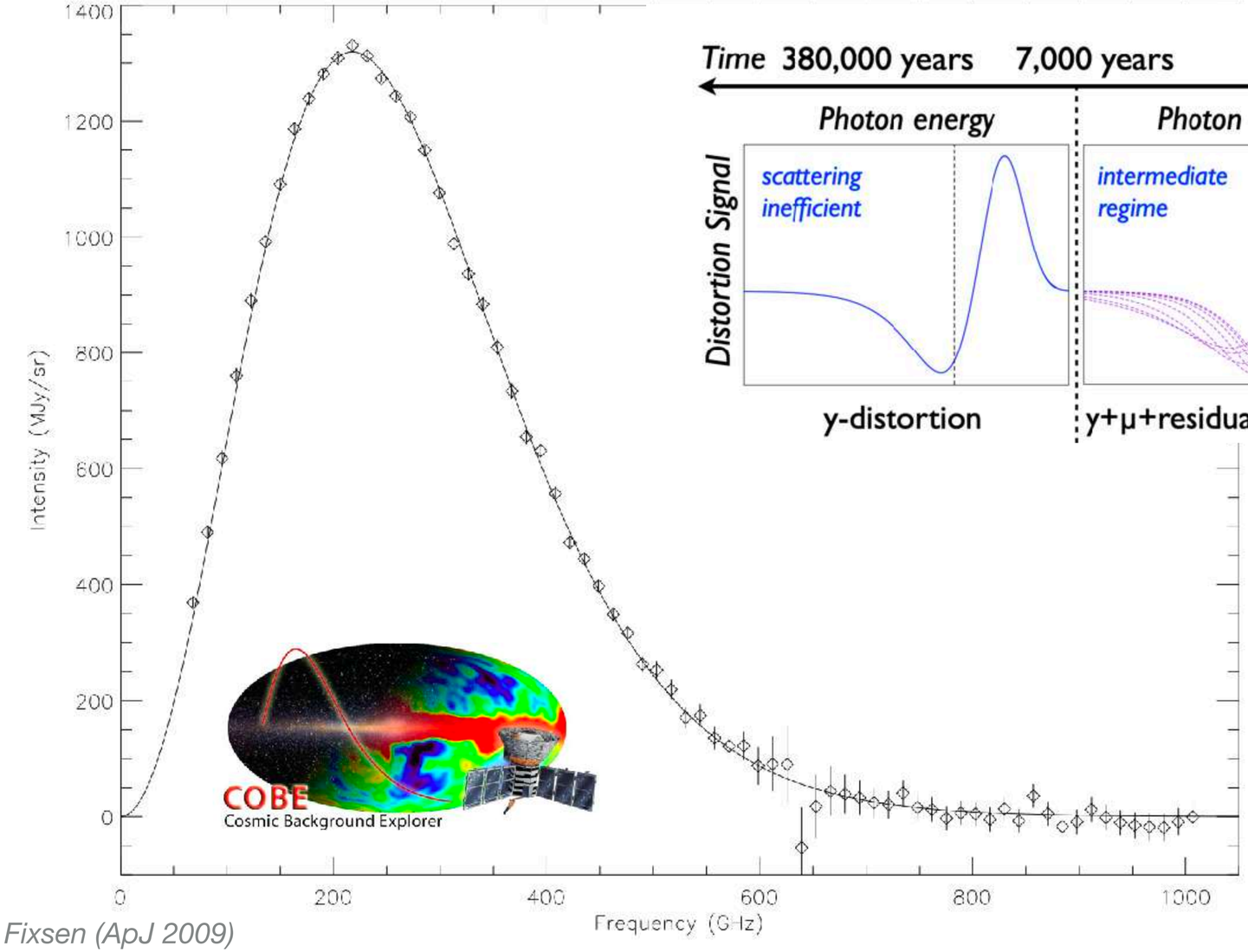
Weakly Interacting Massive Particle (WIMP) Searches

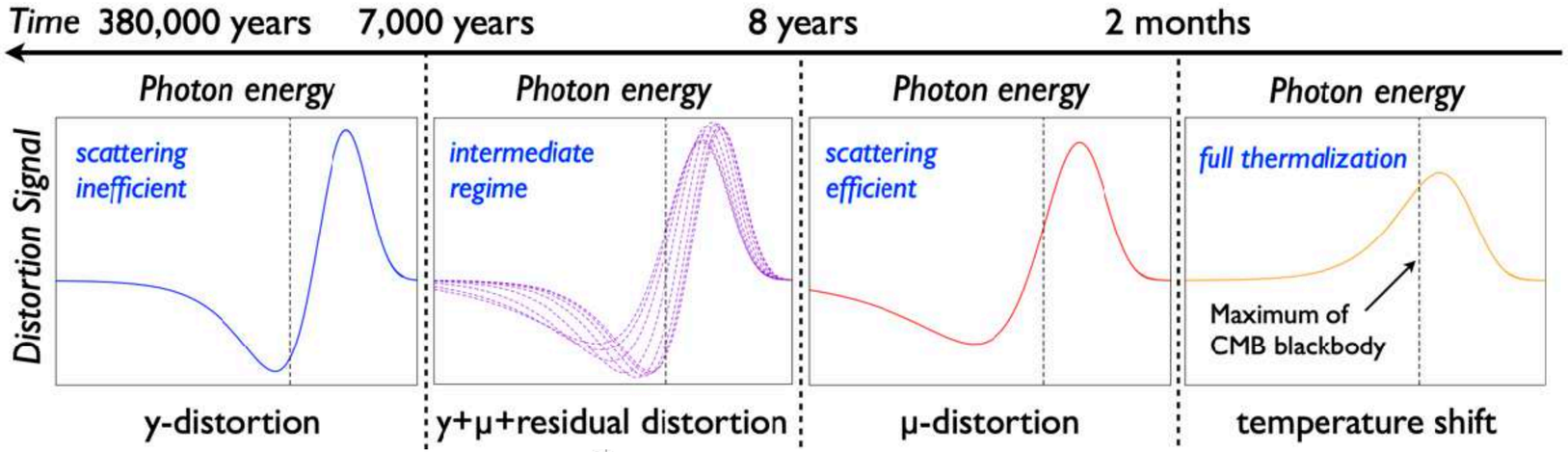


Spectral Distortions of CMB Blackbody

$$T_0 = 2.7255 \pm 0.0006 \text{ K}$$

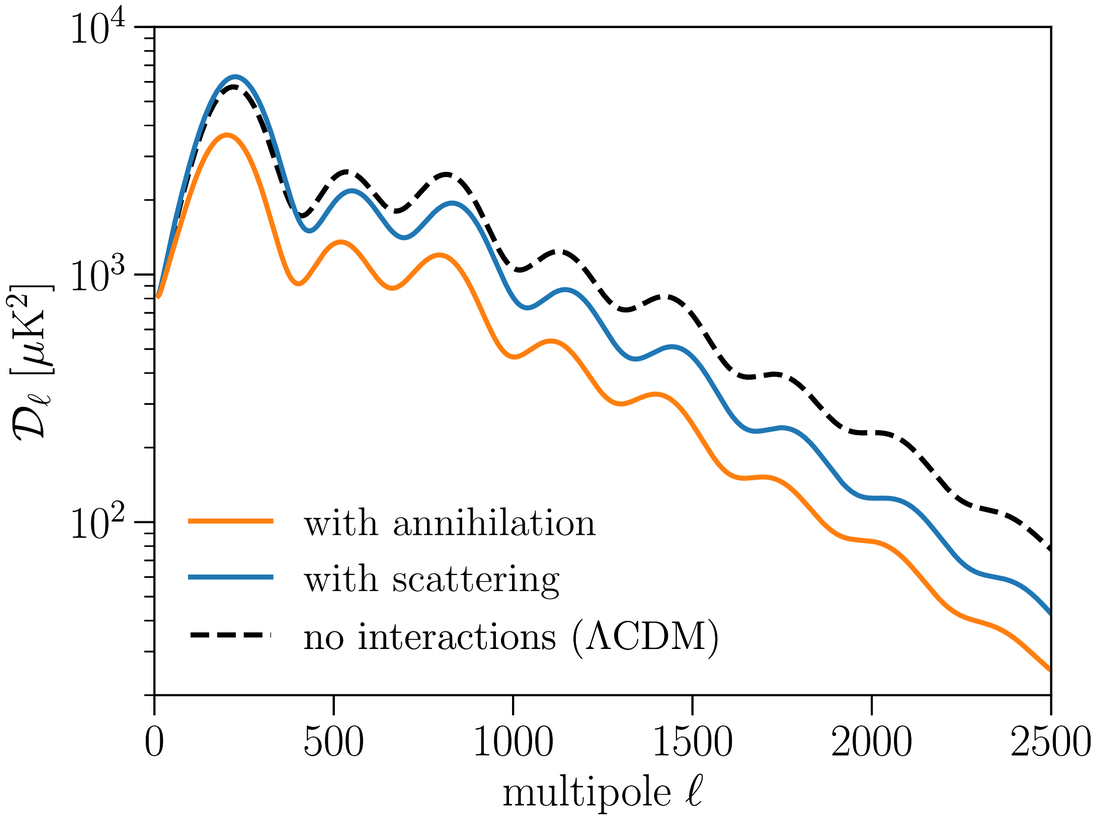


Fixsen (ApJ 2009)



Astro2020 white paper
Chluba+ (1903.04218)

Suppression of CMB Anisotropies



DM annihilation
- suppression across (mostly) all scales

DM-baryon scattering
- suppression at small scales

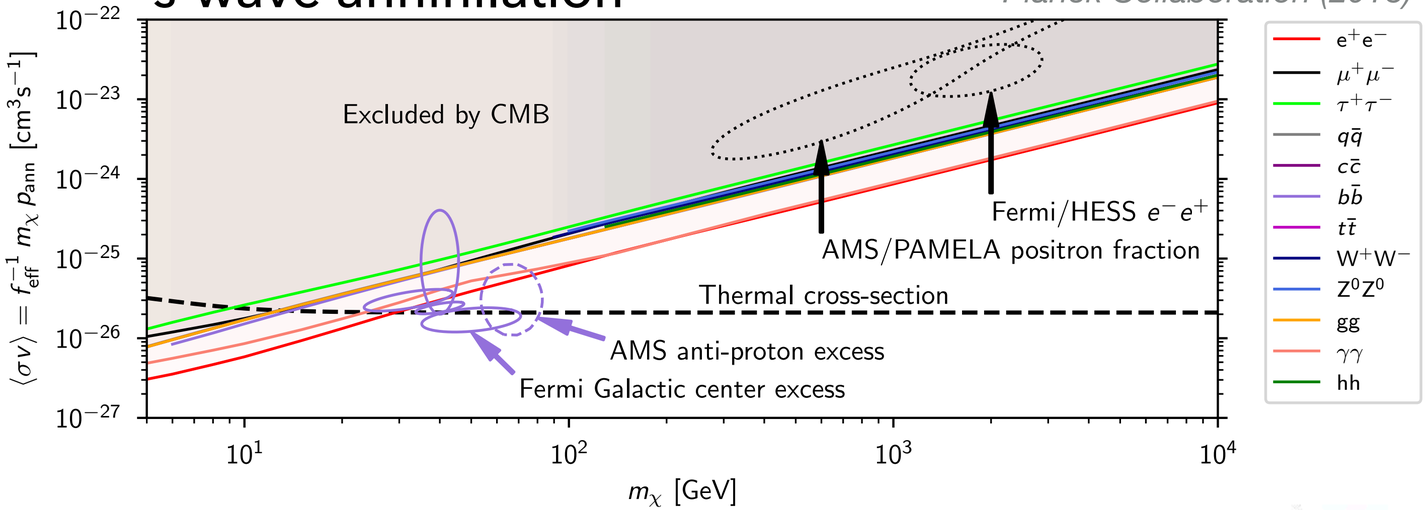
Effects of annihilation and scattering are distinguishable

*Li, Gluscevic, **KB**, Madhavacheril (PRD 2018)*

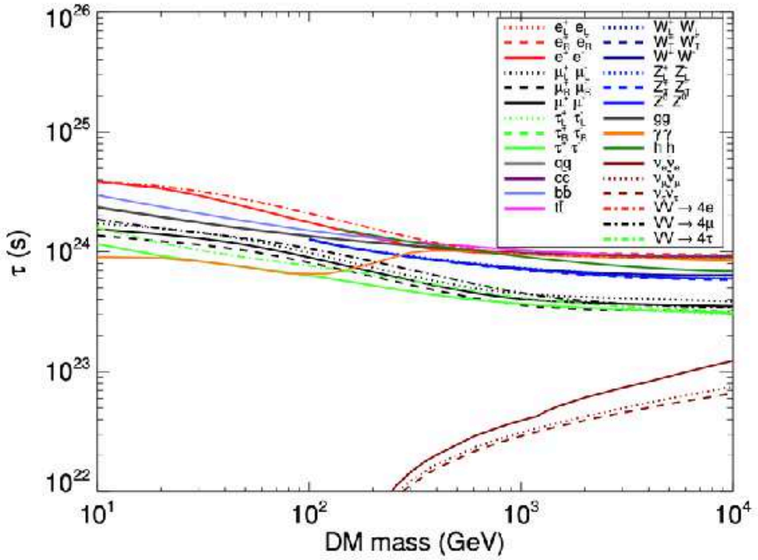
Annihilation and Decay Constraints

s-wave annihilation

Planck Collaboration (2018)



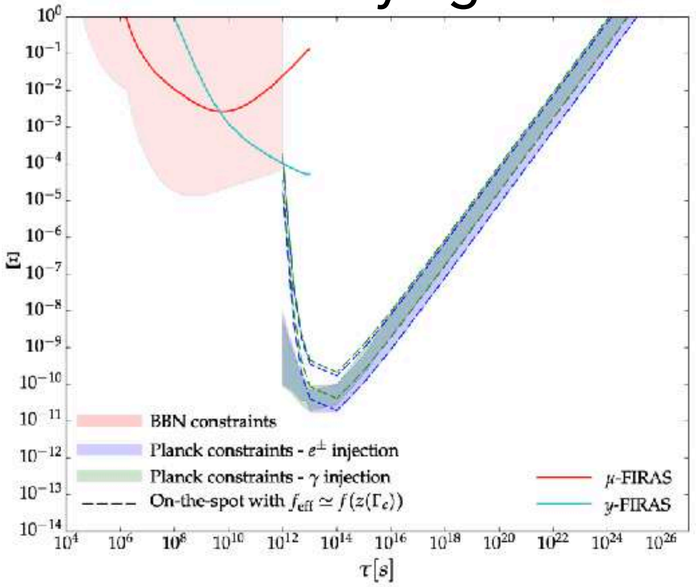
decay



Slatyer and Wu (PRD 2017)

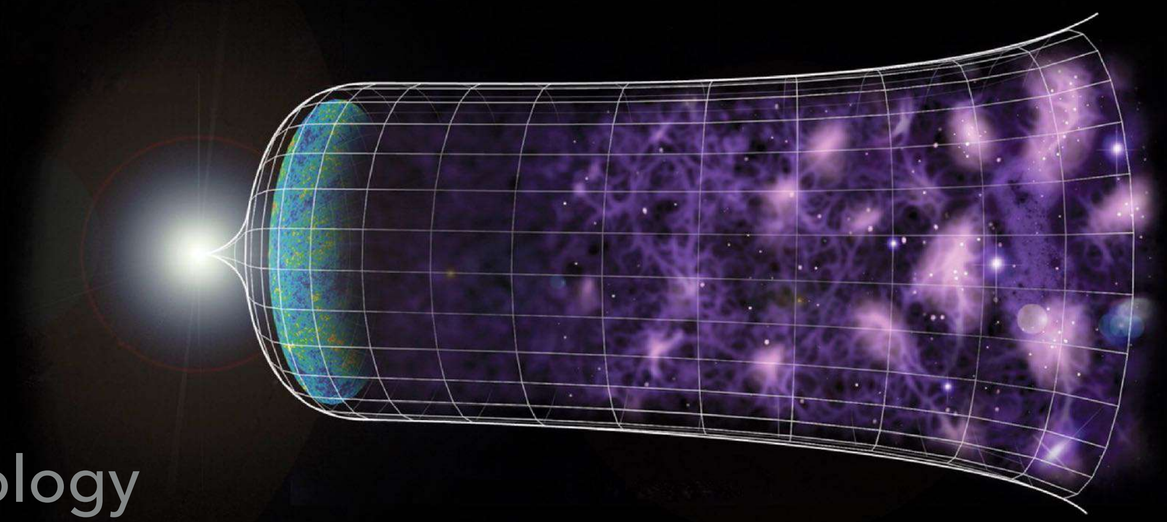
Anisotropies most sensitive at
z~600 (annihilation)
z~300 (decay)

decaying fraction



Poulin, Lesgourgues, Serpico (JCAP 2017)

Outline



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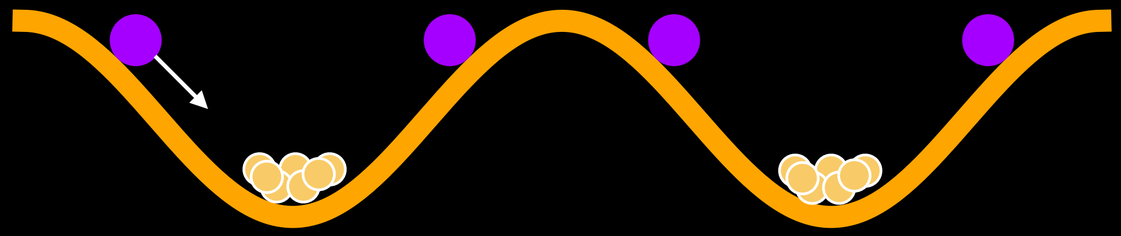
Small-Scale Suppression



Interactions can destroy
small, weakly-bound structures

Test with CMB

Momentum Transfer

- Parameterize scattering:

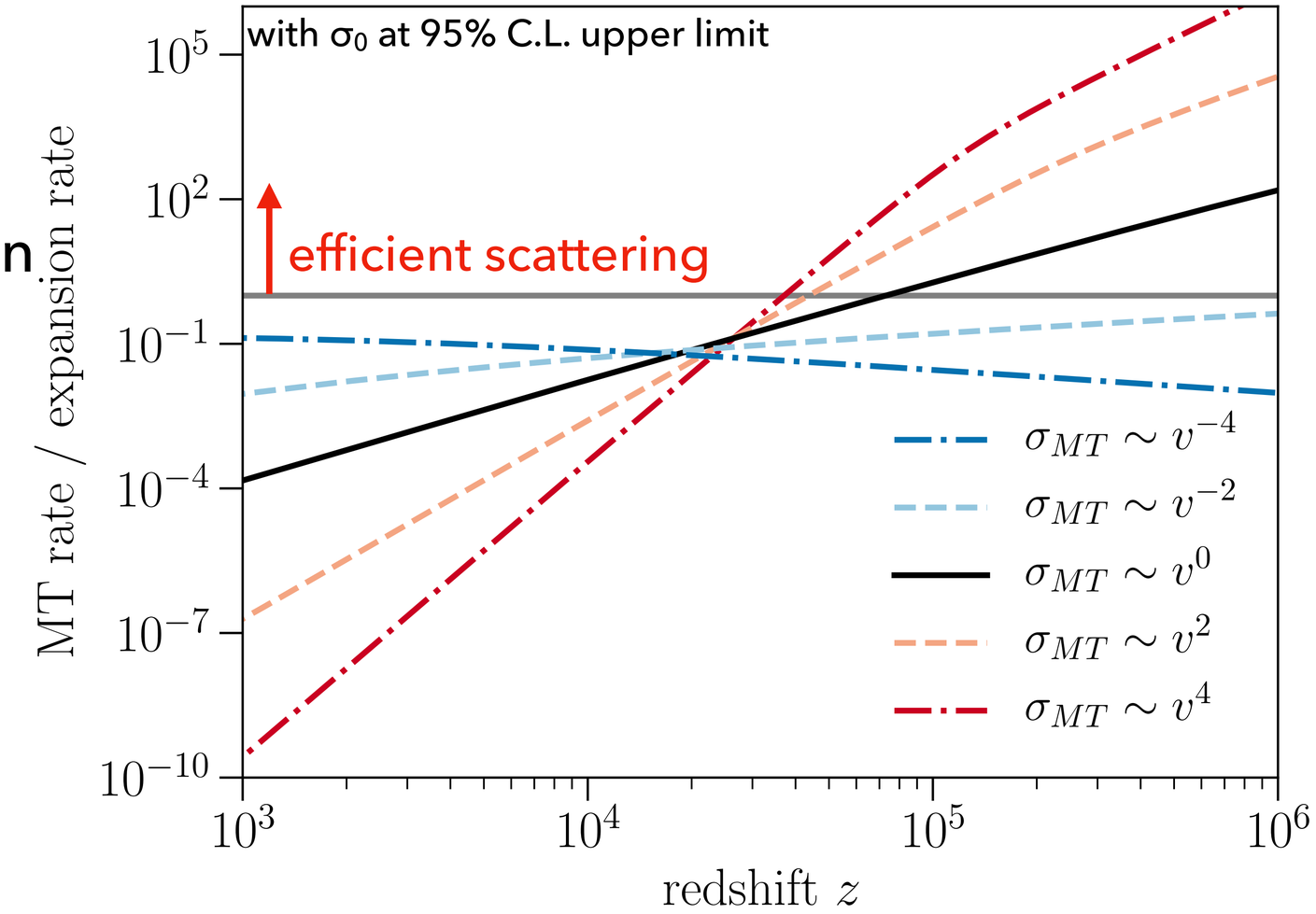
$$\sigma_{MT}(v) = \sigma_0 v^n$$

- Relates to:
  - EFT formalism in direct detection
  - Very light mediator models
- Thermal dispersion

$$v_{\rm th} = \sqrt{\frac{T_b}{m_b} + \frac{T_{\rm DM}}{m_{\rm DM}}}$$

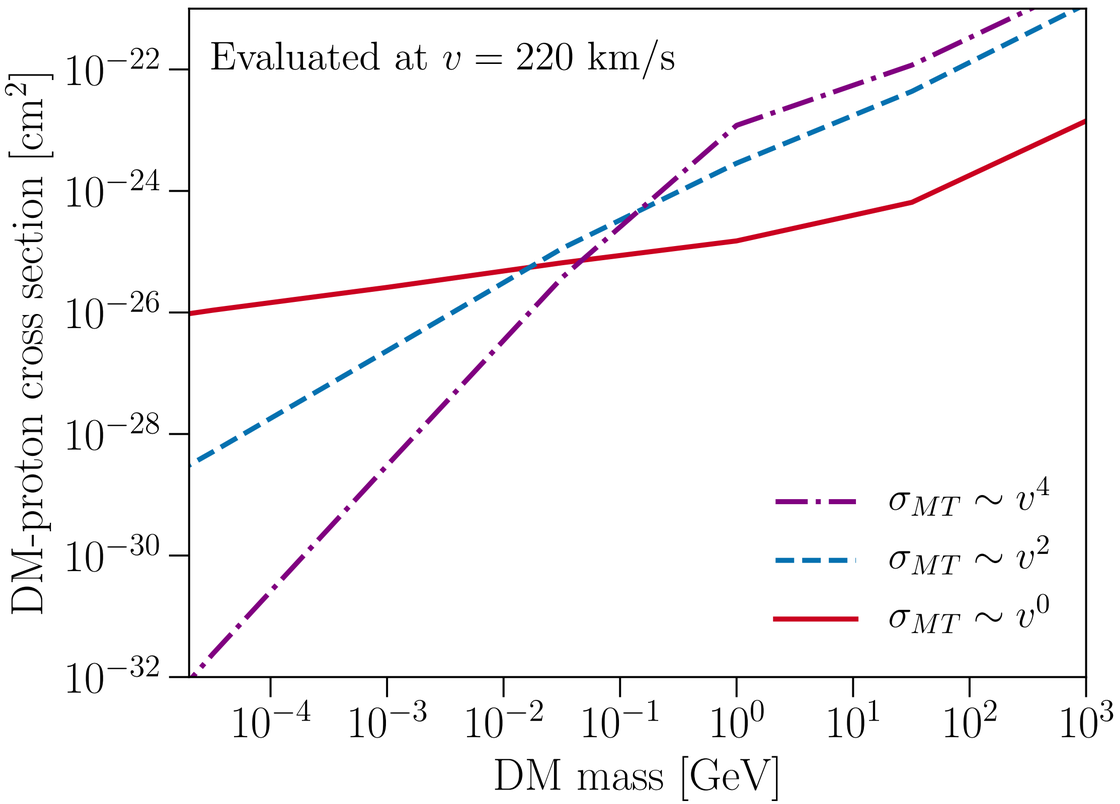
- Relative bulk velocity

$$\vec{V} = \vec{V}_b - \vec{V}_{\rm DM}$$

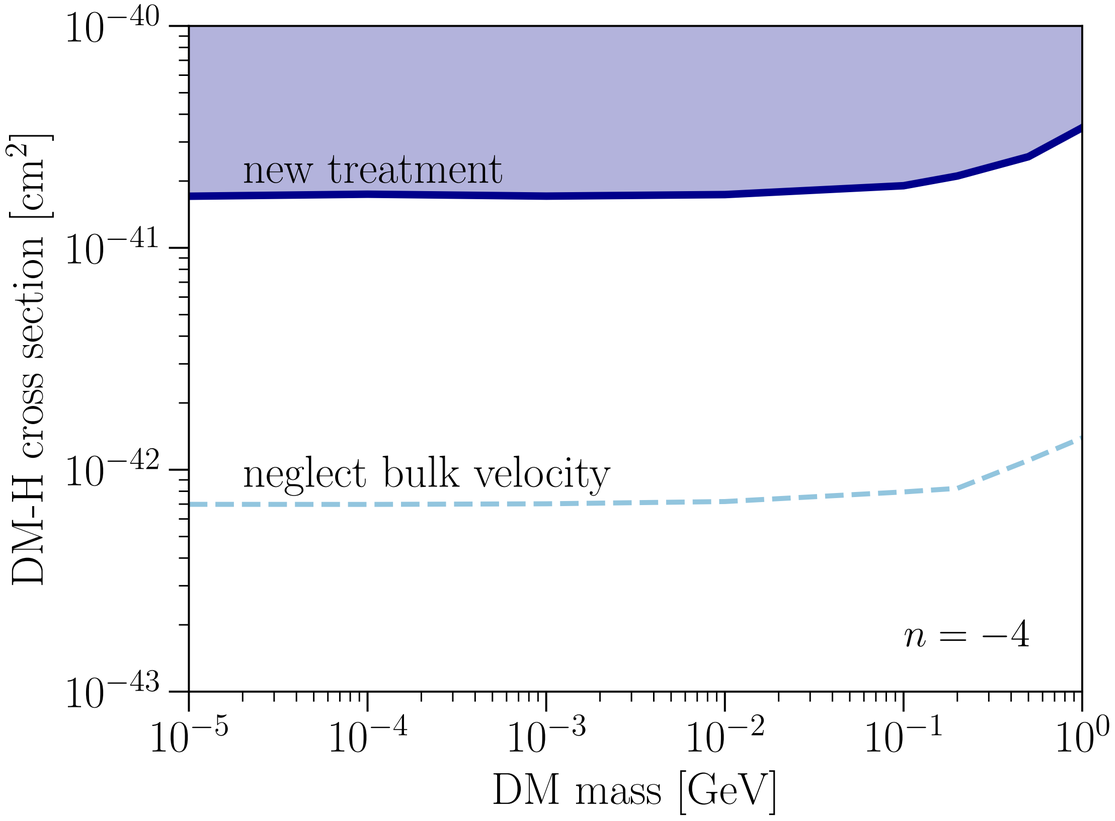


*for n≥0: **KB**, Gluscevic (PRD 2018) and Gluscevic, **KB** (PRL 2018)*
*for n<0: **KB**, Gluscevic, Poulin, Kovetz, Kamionkowski, Barkana (PRD 2018)*

Scattering Constraints



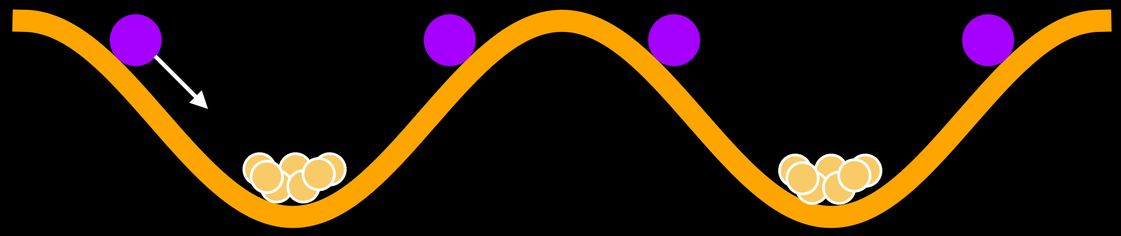
***KB**, Gluscevic (PRD 2018)*



***KB**, Gluscevic, Poulin, Kovetz, Kamionkowski, Barkana (PRD 2018)*

implications for EDGES, see
*Kovetz, Poulin, Gluscevic, **KB**, Barkana, Kamionkowski (PRD 2018)*

Small-Scale Suppression

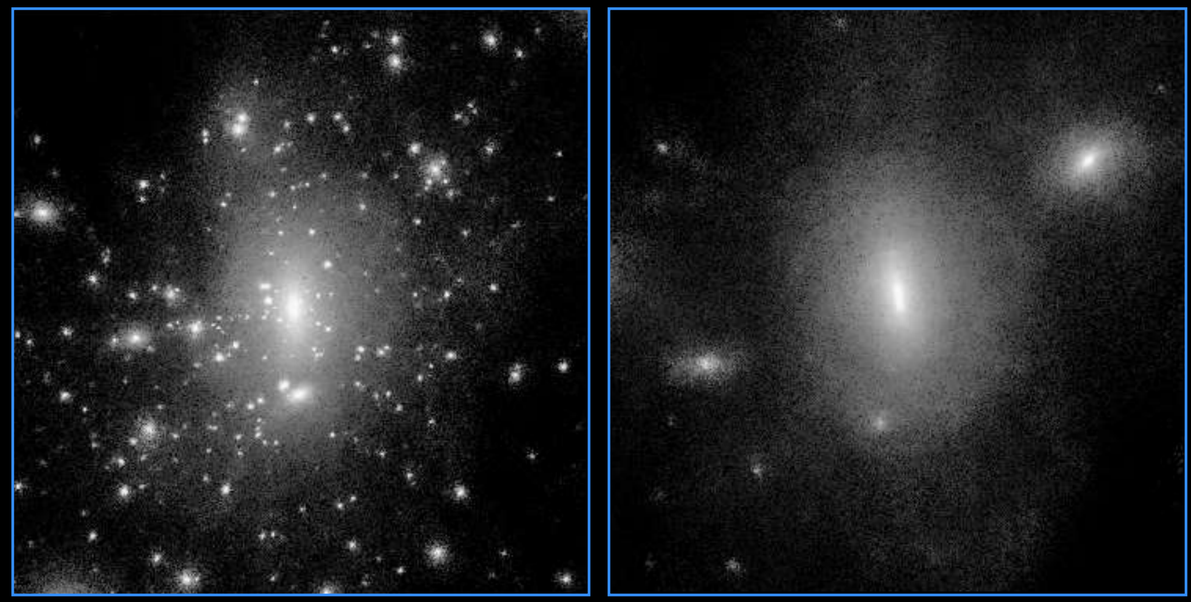


Interactions can destroy
small, weakly-bound structures

Test with CMB

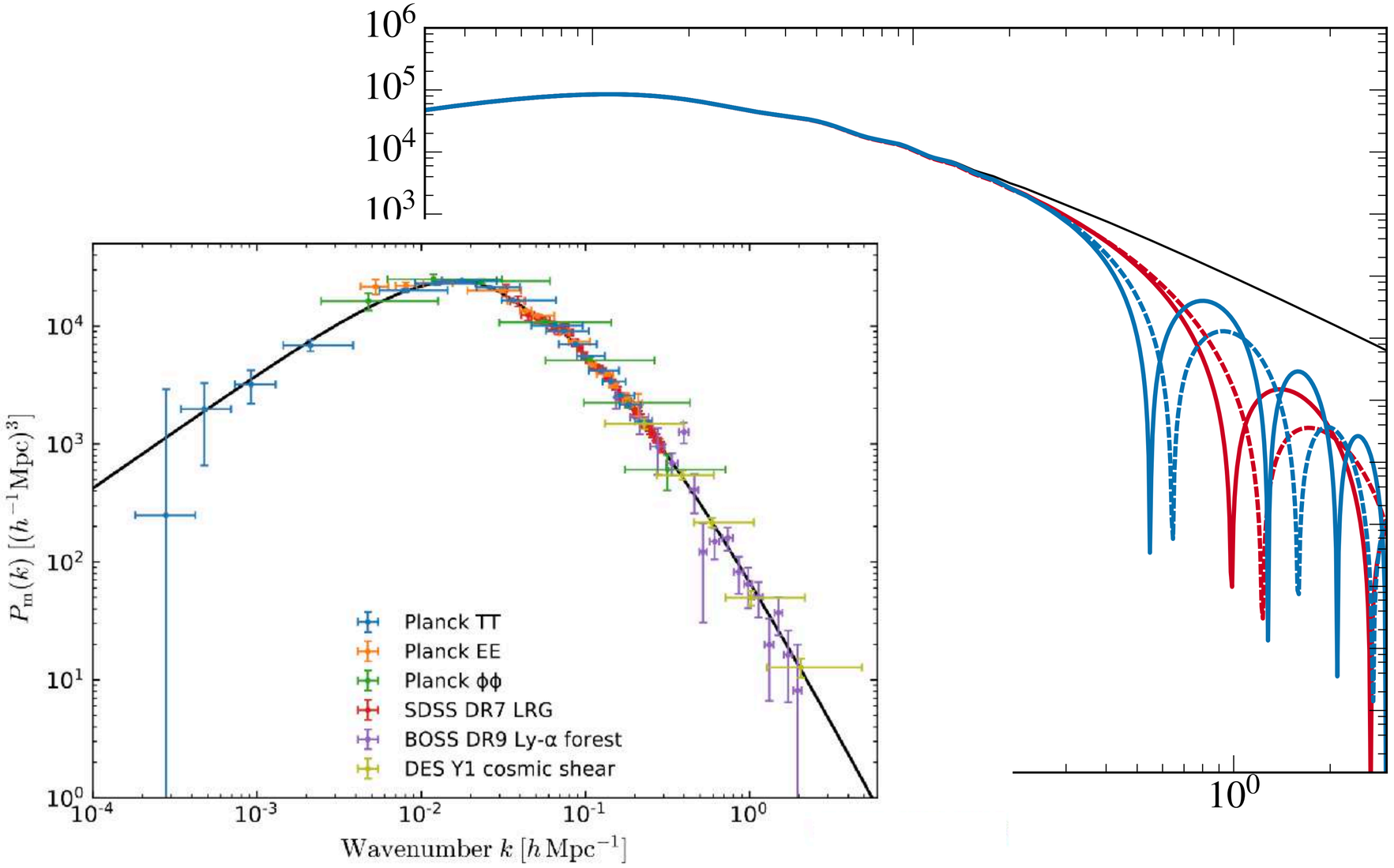
Very small galaxies
might not form

Test with galaxy surveys



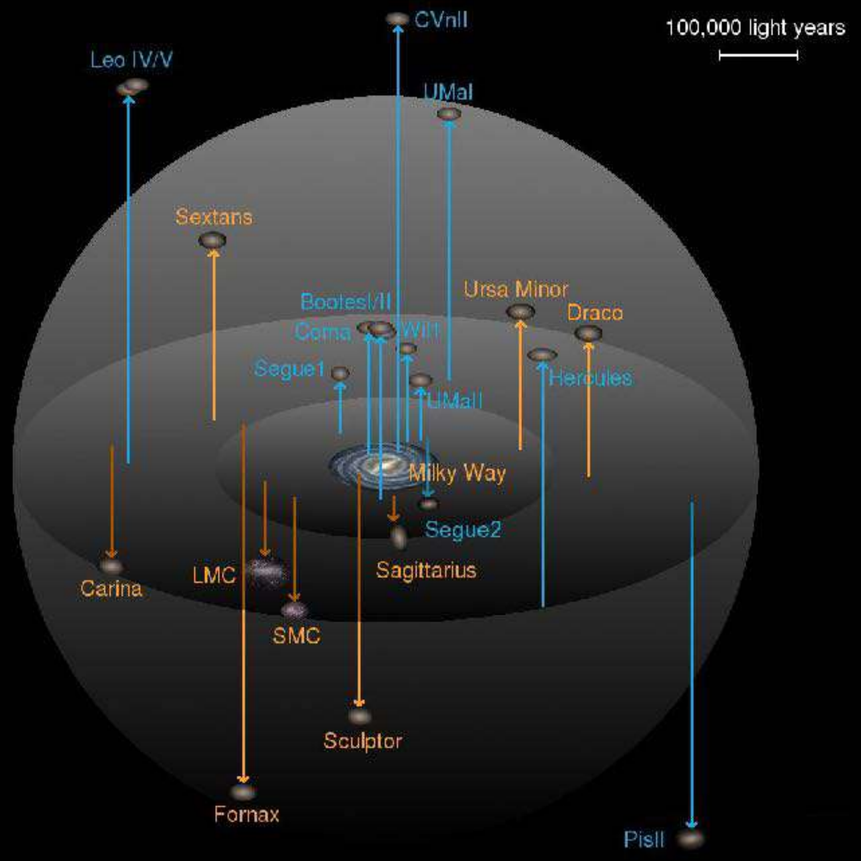
Moore+ (MNRAS, 1999)

Matter Power Spectrum



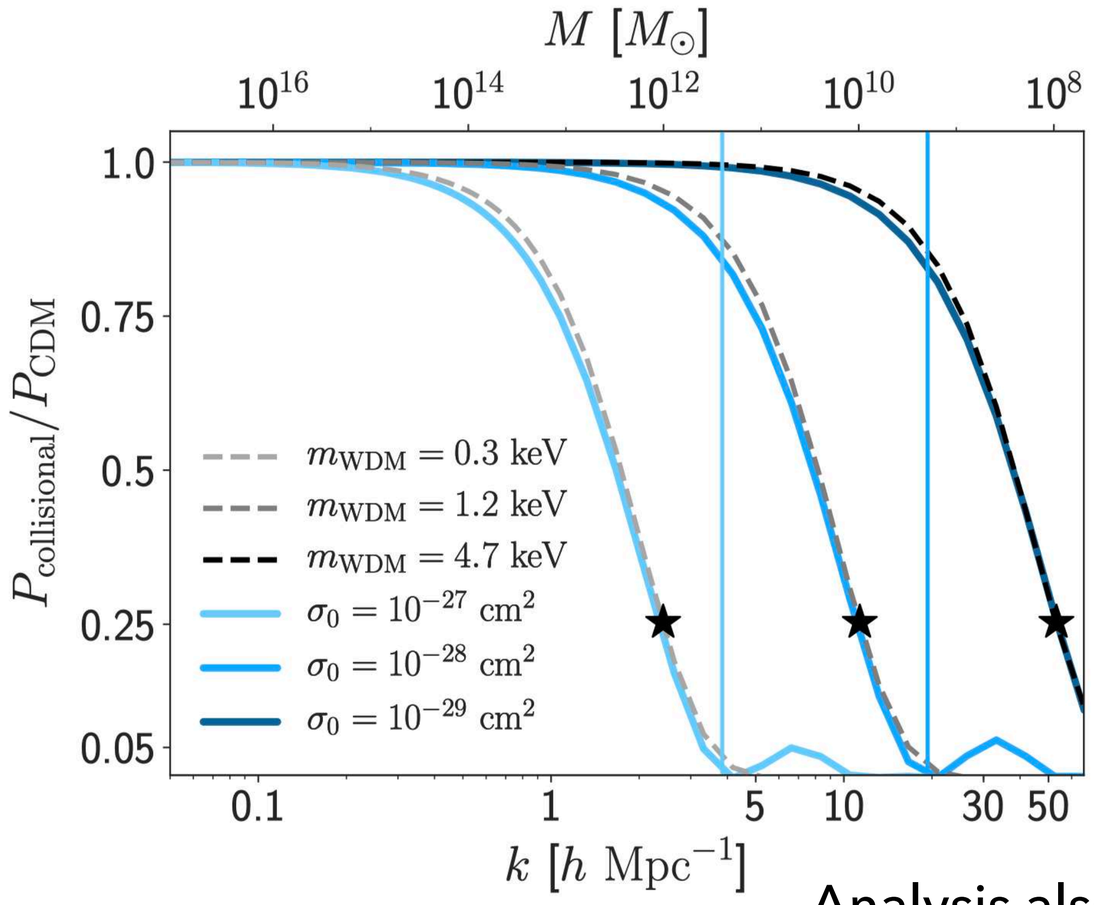
KB *and Gluscevic (PRD 2018)*

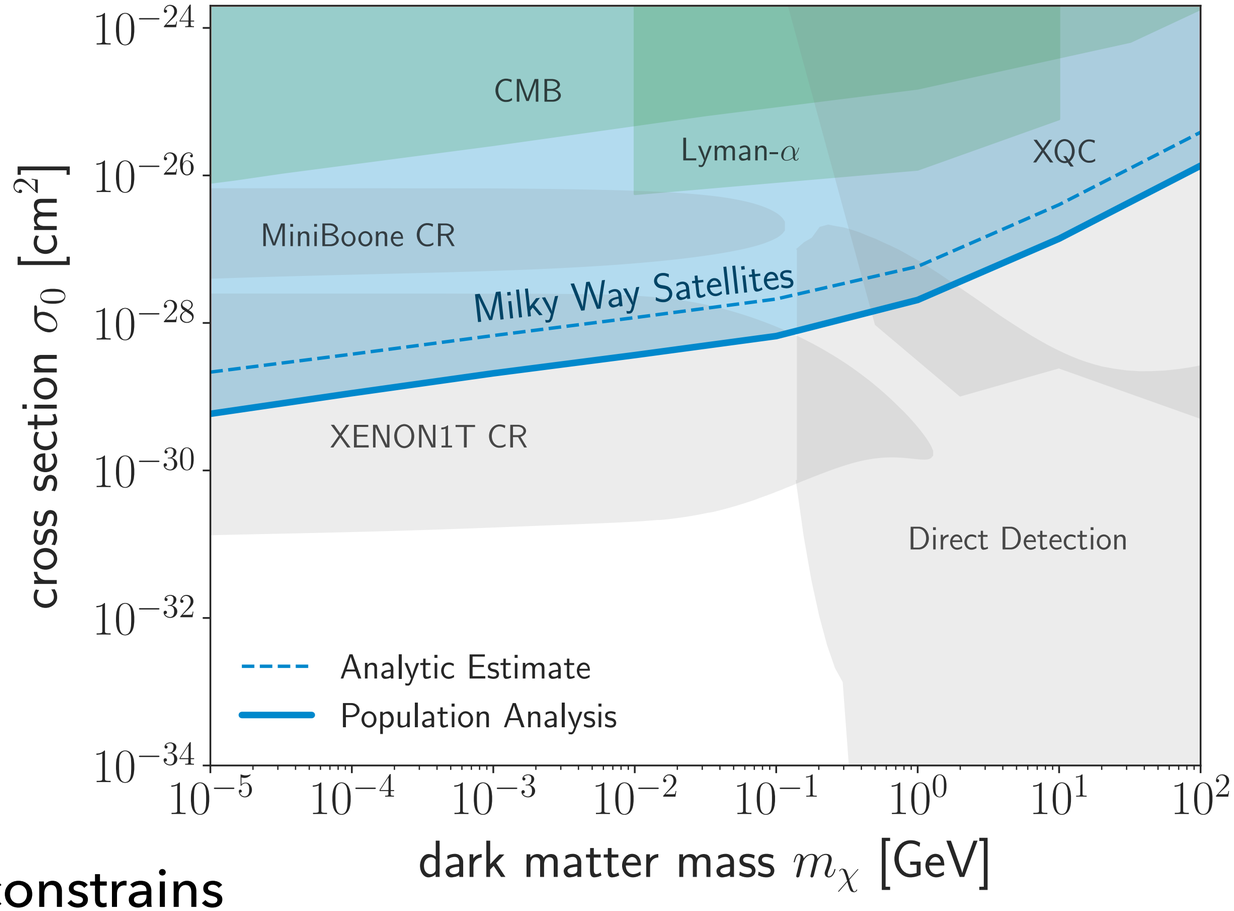
Milky Way Satellites



Classic dwarfs
SDSS-identified dwarfs

Constraints with SDSS + Classical



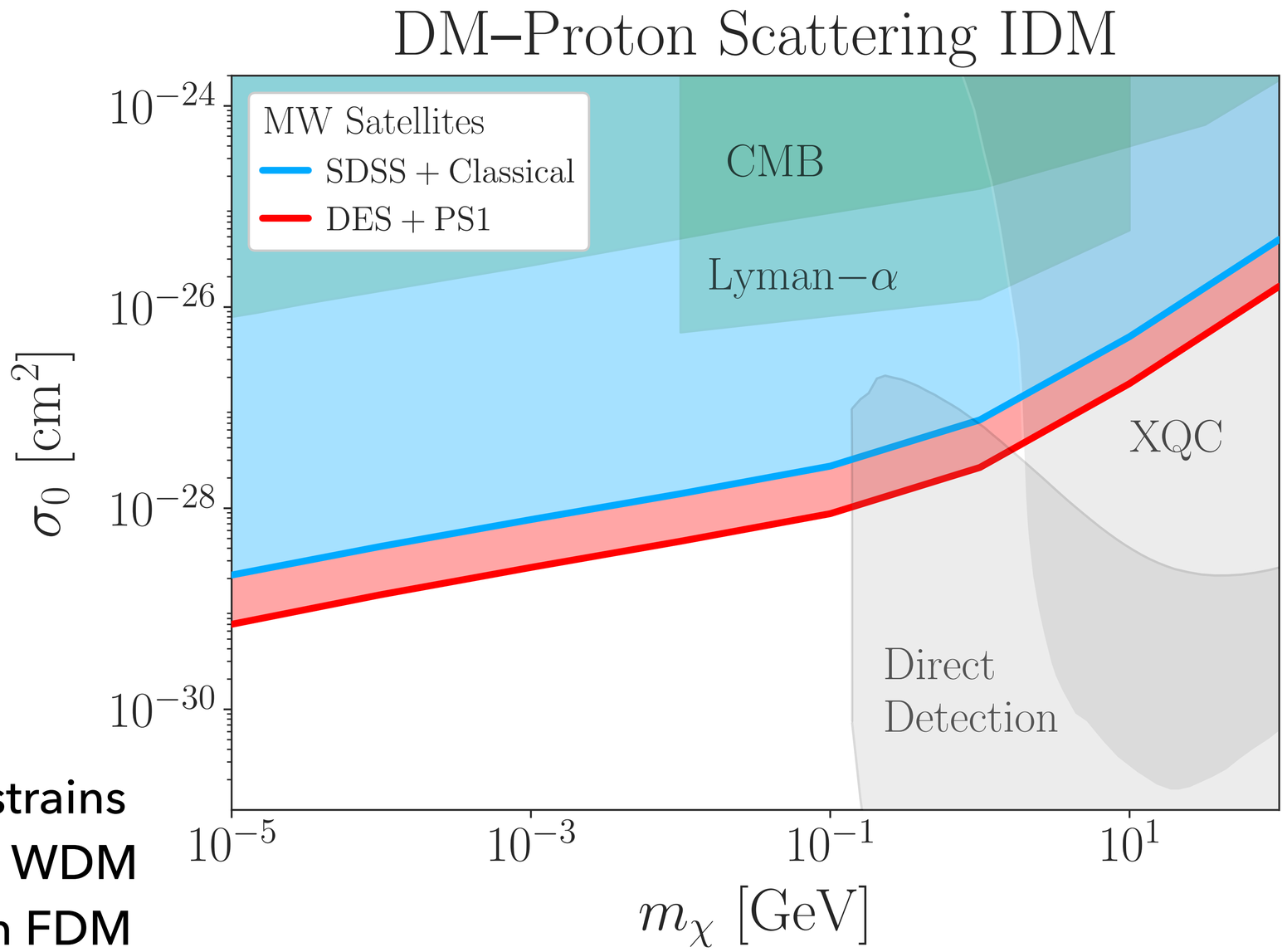


Analysis also constrains

- Warm DM: m > 3.3 keV
- Fuzzy DM: m > 3 × 10^{-21} eV

*Nadler, Gluscevic, **KB**, Wechsler (ApJL 2019)*

Constraints with DES + Pan-STARRS1

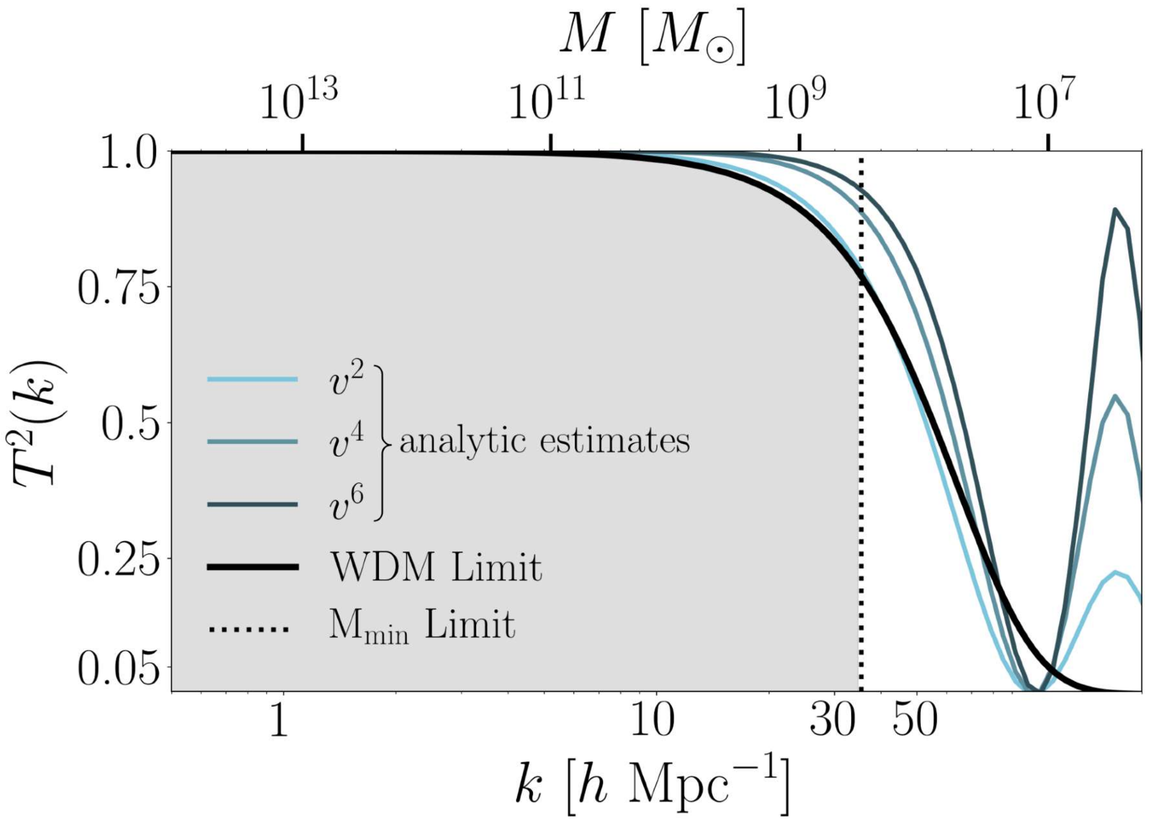


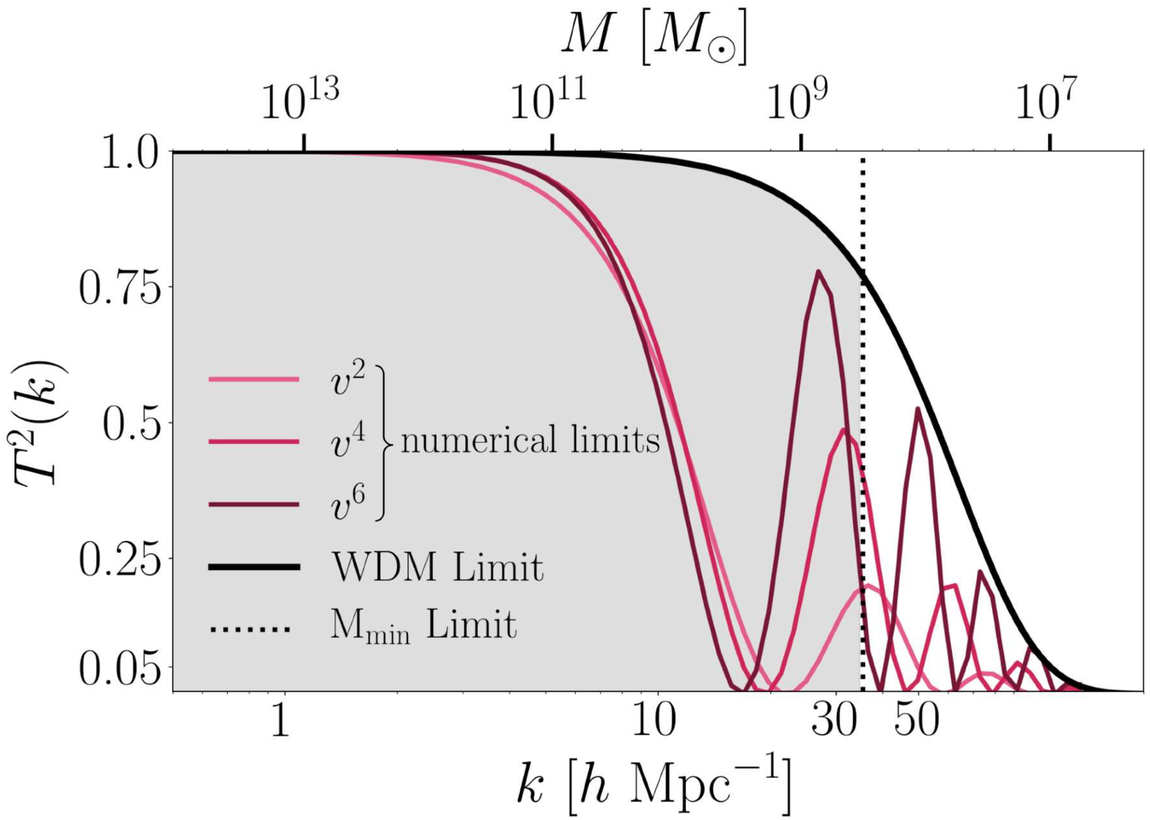
Analysis also constrains

- Sterile neutrino WDM
- Ultra-light axion FDM

DES Collaboration, incl. ***KB*** *(2008.00022)*

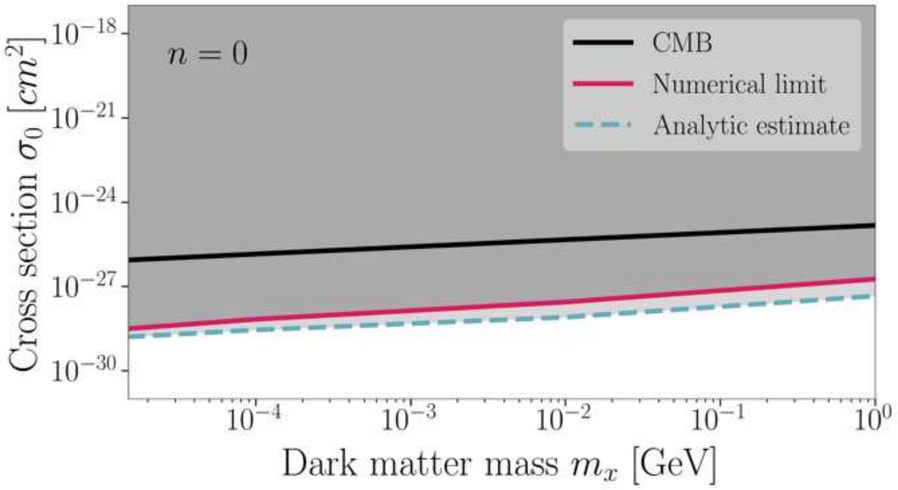
Constraining Velocity-Dependent Models

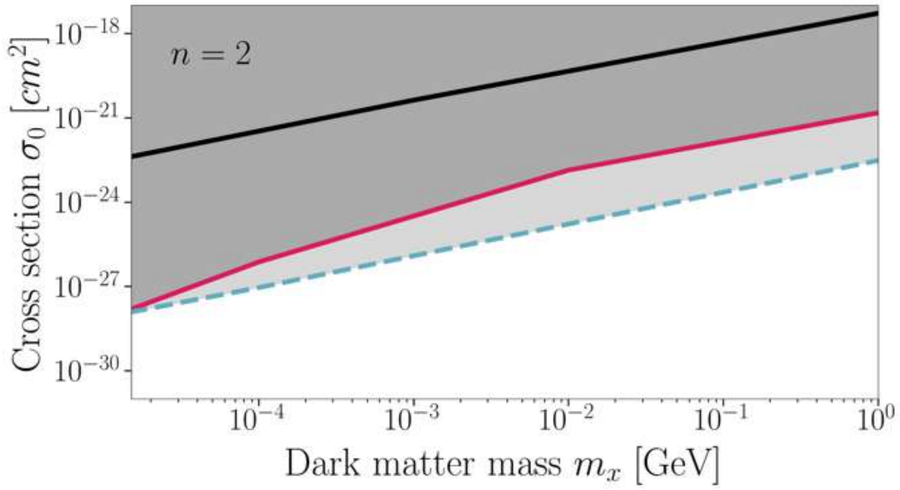


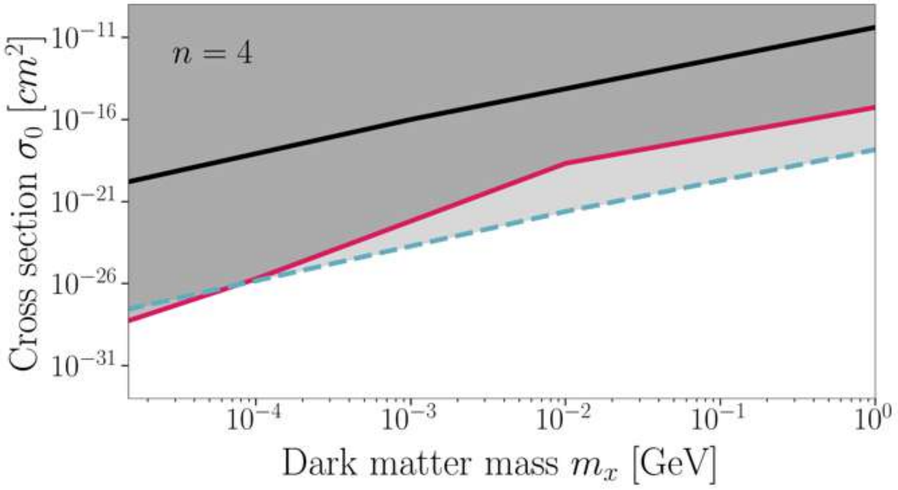


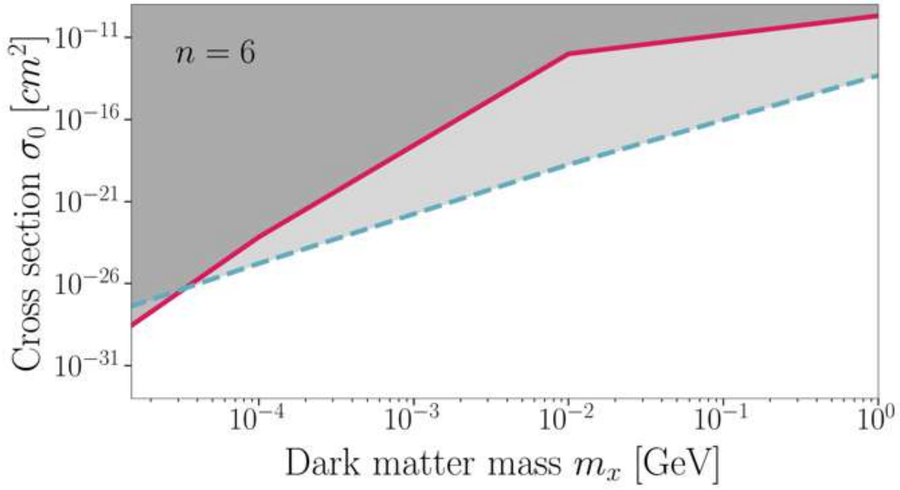
*Maamari, Gluscevic, **KB**, Nadler, Wechsler (in prep)*

Preliminary Results









*Maamari, Gluscevic, **KB**, Nadler, Wechsler (in prep)*

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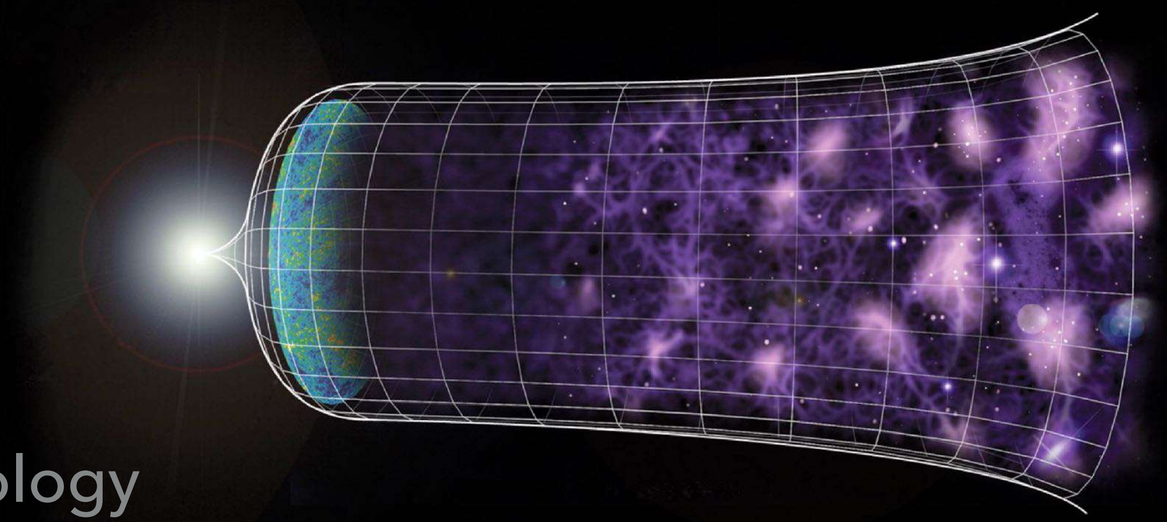

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CMB Experiments

COBE (1992)

Planck (2018)

WMAP (2003)

Simons Observatory

CMB-S4

PICO, CMB-HD

South Pole Telescope

Atacama Cosmology Telescope

Galaxy Surveys

Rubin
Observatory

LSST DM white paper 1902.01055

See also:
DESI, WFIRST, Euclid, …

Cosmological and astrophysical observables provide a unique and rich foundation to address the long-standing dark matter problem.