Warm dark matter: overview

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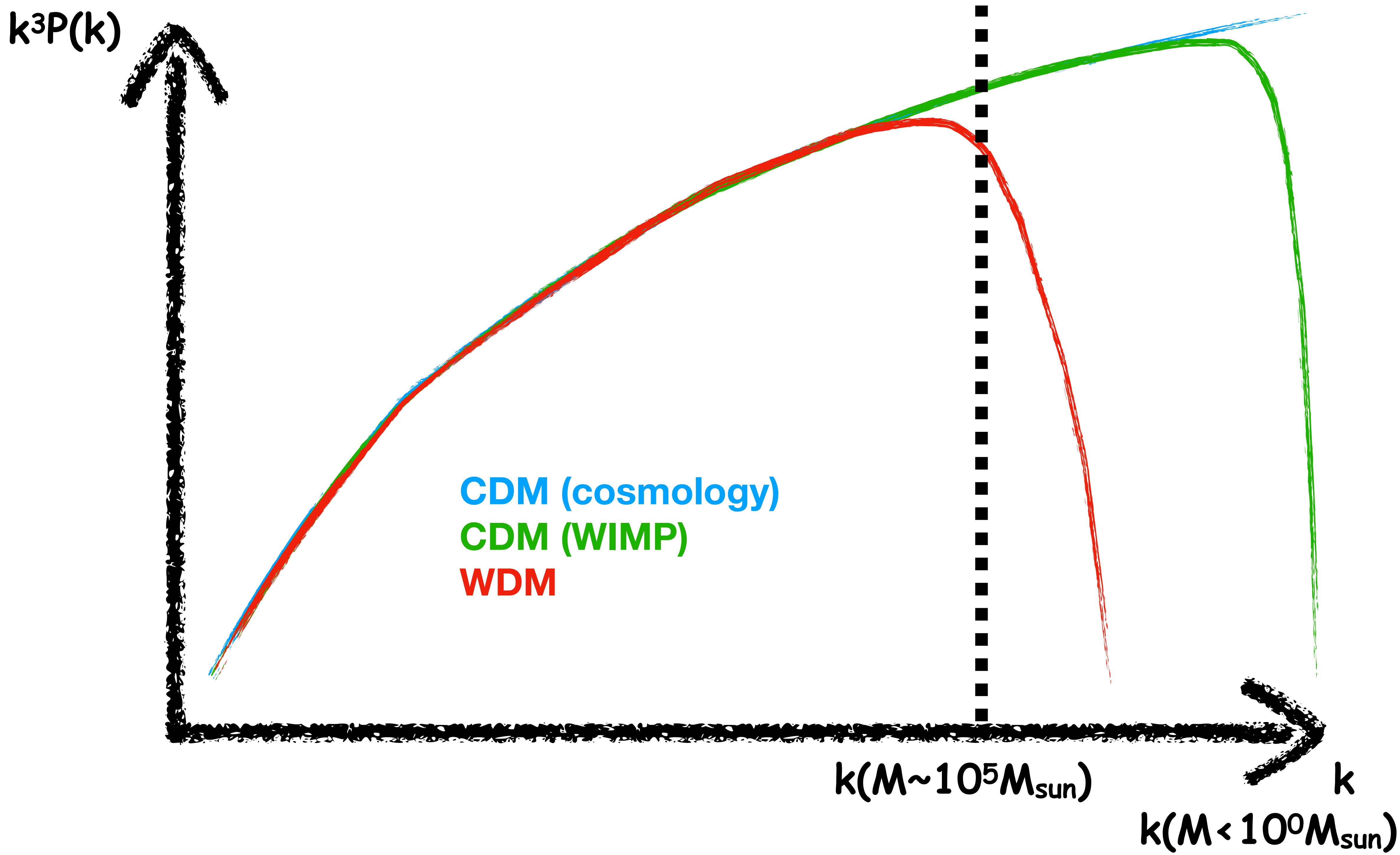
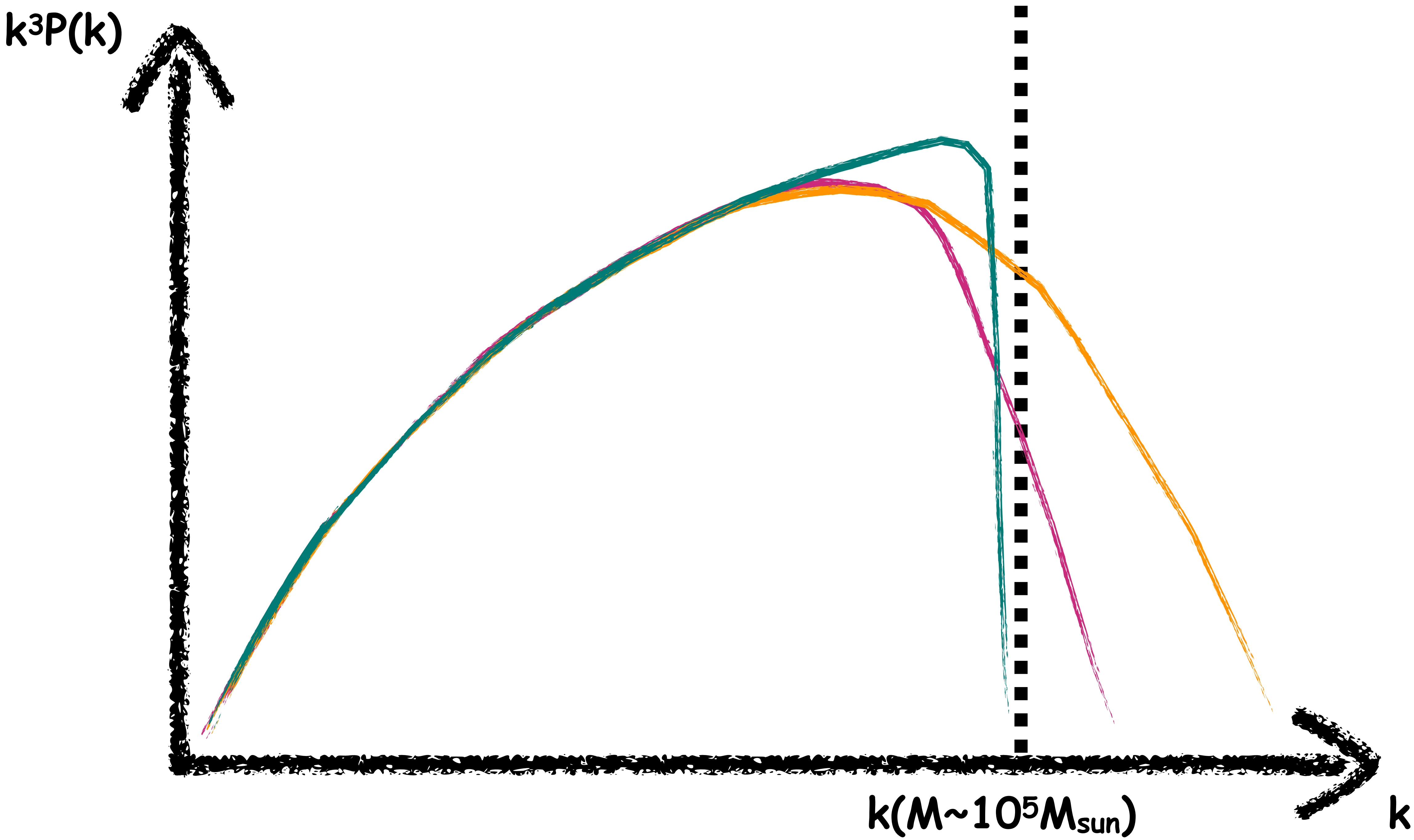
What is warm dark matter?
— Cosmology



What is warm dark matter?
— Cosmology, N.B.



M. Lovell, HÍ & Durham

Reykjavík, 30/09/19

What is warm dark matter?
— Particle physics

- Gravitino
- Sterile neutrino — non-resonant
- Sterile neutrino — resonantly produced
- Sterile neutrino — heavy scalar decay

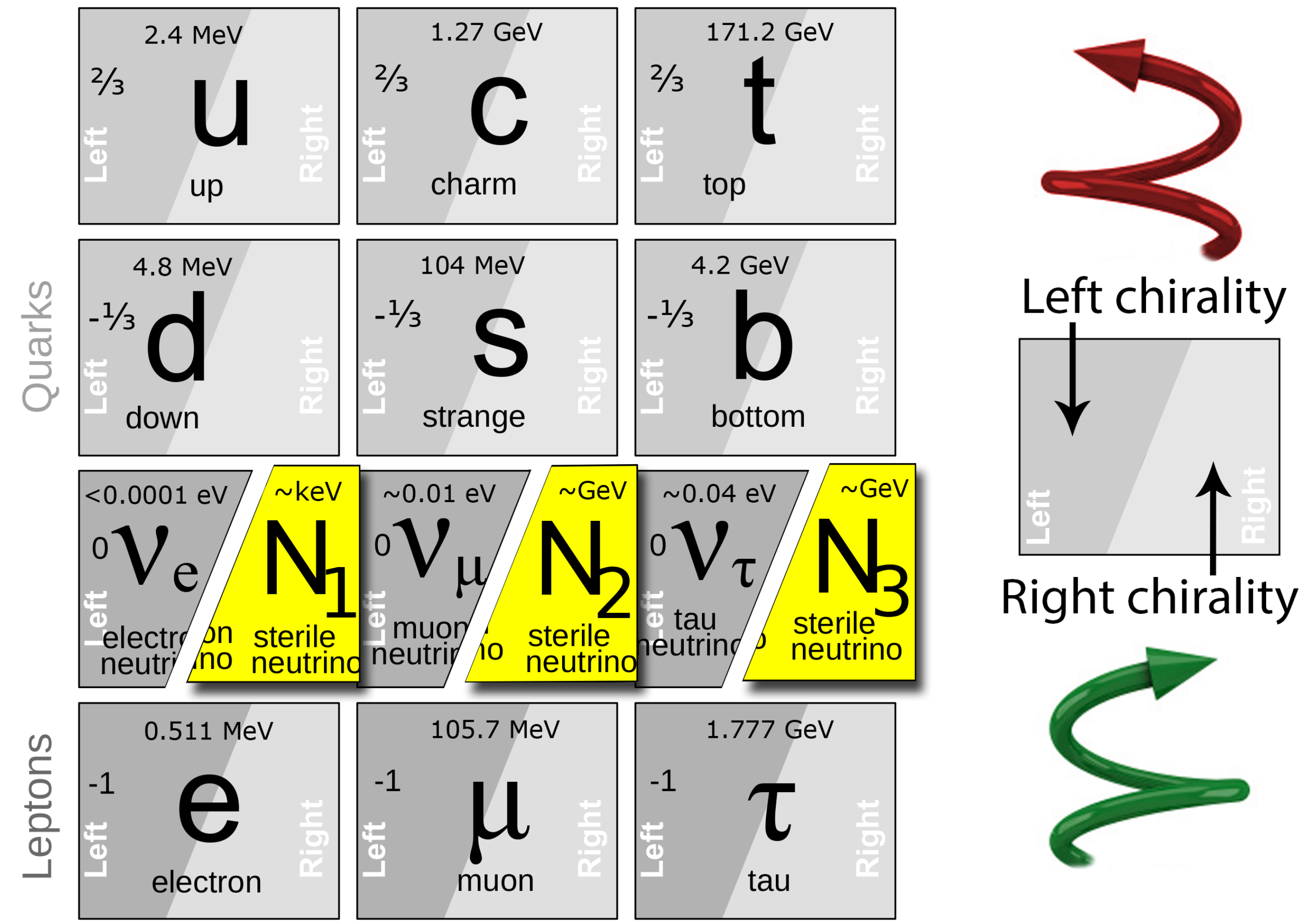
Gravitinos

- Panels & Primack 1982
- In supersymmetry, gravitino can be massive
- In order to close the Universe and freeze-out within thermal equilibrium, require $m_{grav} \leq 1$keV: very-WDM
- For $m_{grav} \sim [1\text{-}100]$keV, require decay of thermalised sparticles (Giudice & Rattazi 1999), sensitive to the temperature post inflation.

Sterile neutrino — resonant production

- Three new, sterile neutrinos
- Two explain baryogenesis, neutrino oscillations. Unstable.
- Third is dark matter candidate:
- Lifetime of 10^{28}s = 3.2×10^{20}yr = 2.3×10^{10} age of the Universe

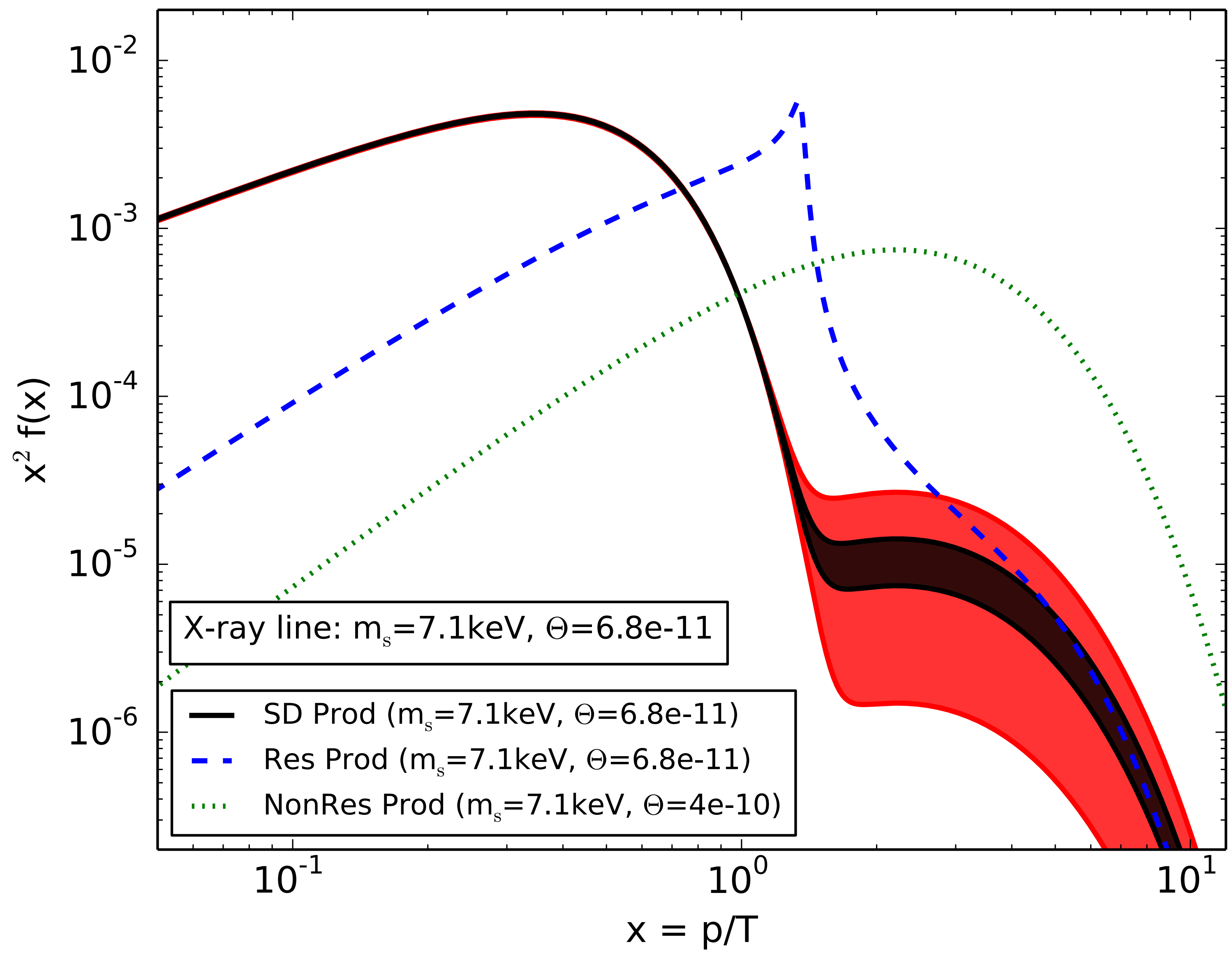
- Non-resonant: production in absence of lepton asymmetry.
- Ruled out by X-ray observations



Sterile neutrino — heavy scalar

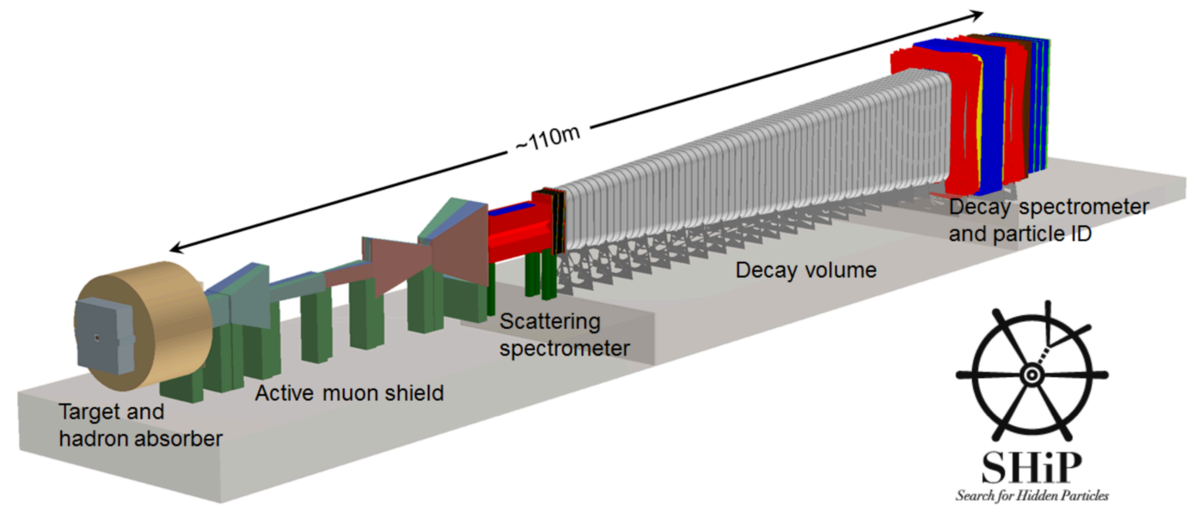
- Generate sterile neutrino through two mechanisms: non-resonant + decay of heavy scalar into two sterile neutrinos. Add together for total dark matter abundance
- Non-resonant component very warm, scalar component almost cold

Merle & Schneider +15

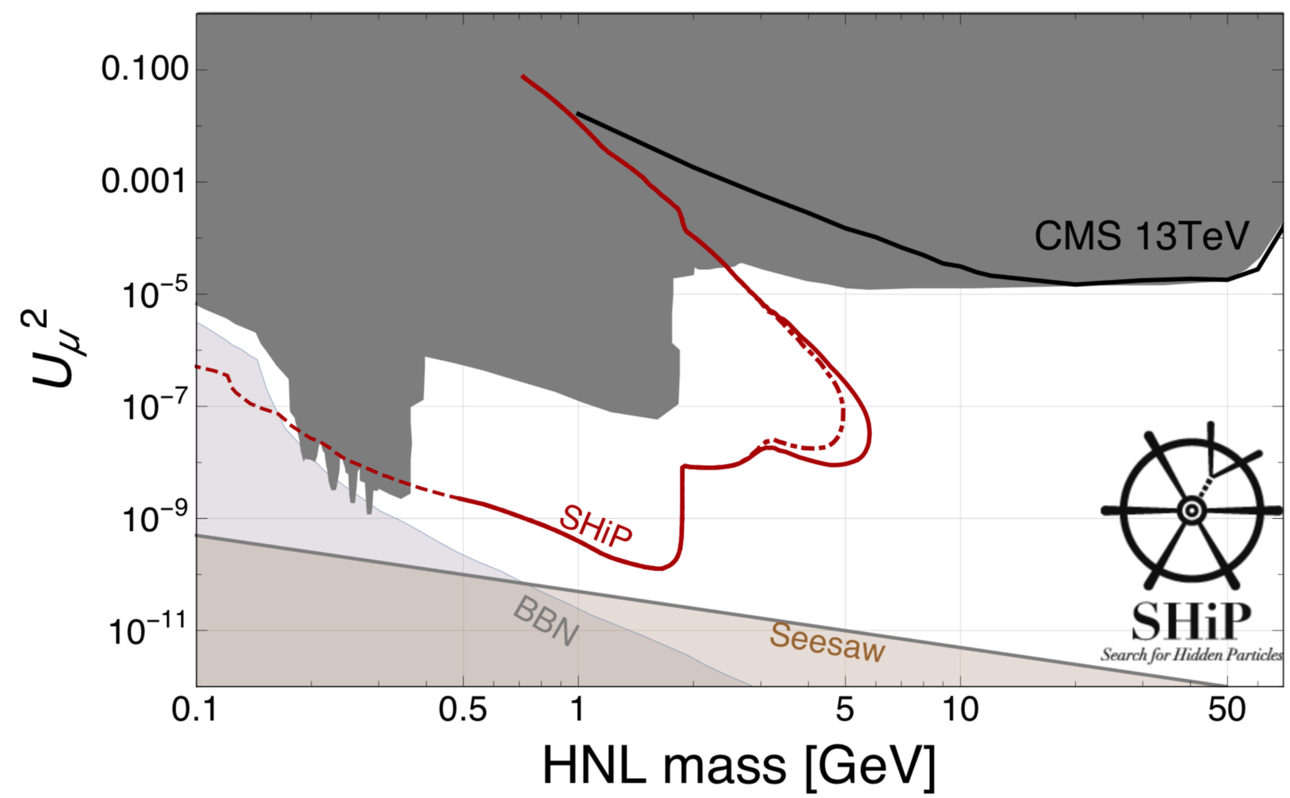


Sterile neutrino — probes

Sterile neutrino — detection with SHiP

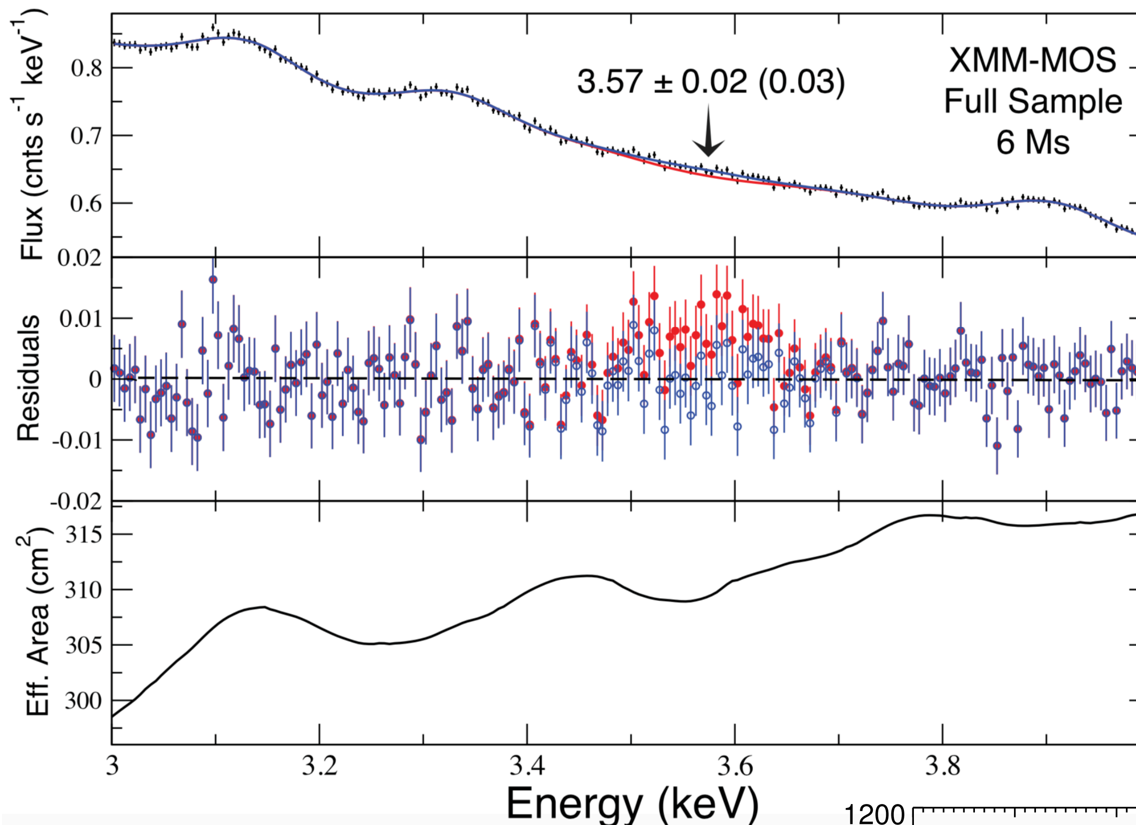


- The two GeV sterile neutrinos could be detected at the SHiP experiment
- Produced in rare decays of mesons
- If approved, will start taking data in 2026 at the earliest



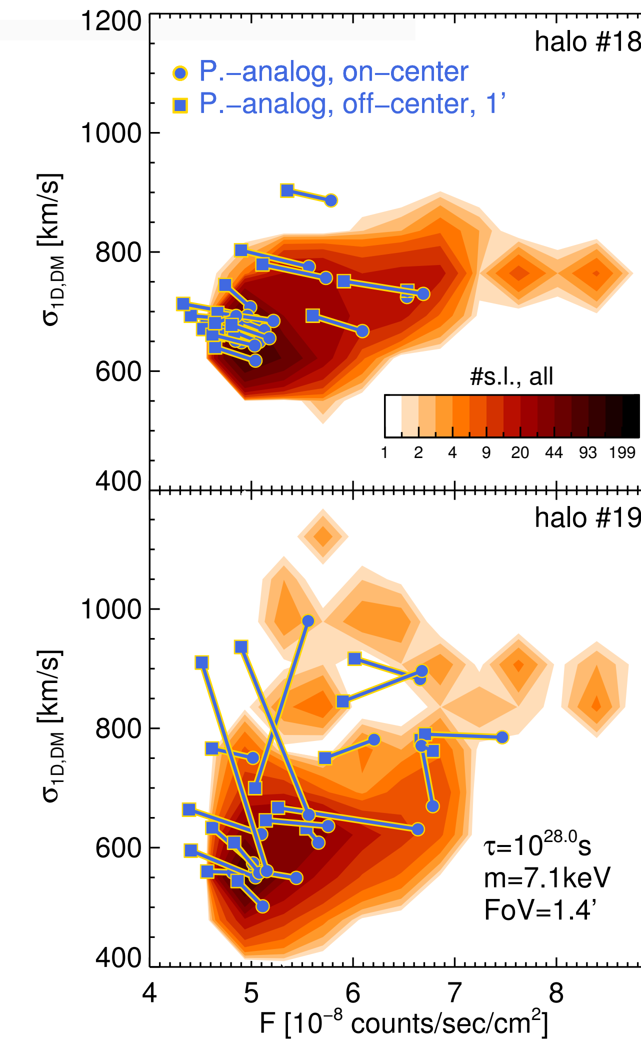
Sterile neutrino — X-ray decay

- Claims of X-ray detection in clusters and some galaxies at an energy of 3.55keV
- Discussion mostly centres on modelling the background
- Two tests:
- All claimed detections must agree on the DM mass and mixing angle
- Velocity dispersion in clusters must be >600km/s (gas <200km/s)

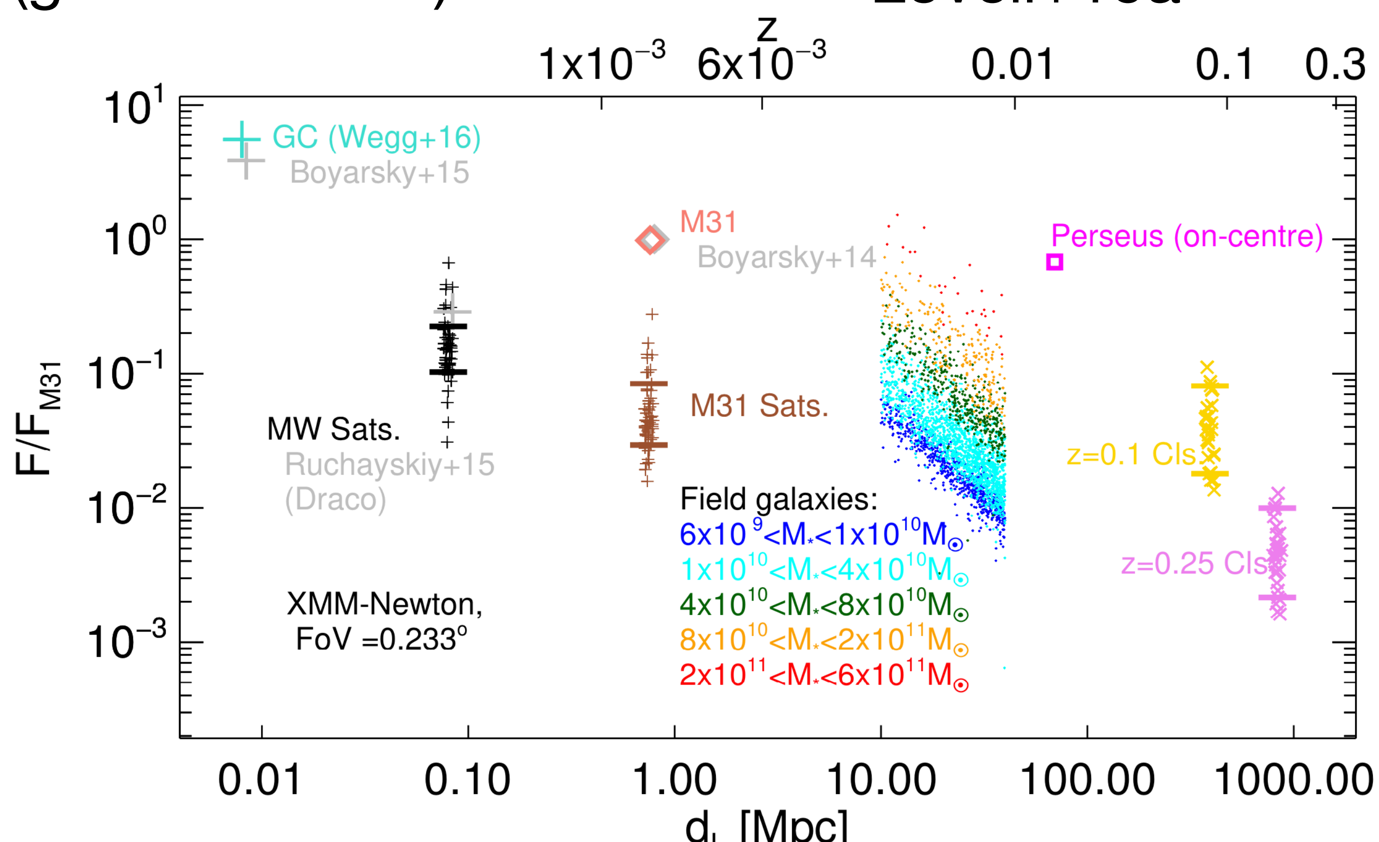


Bulbul+14

Lovell+19c



Lovell+19a



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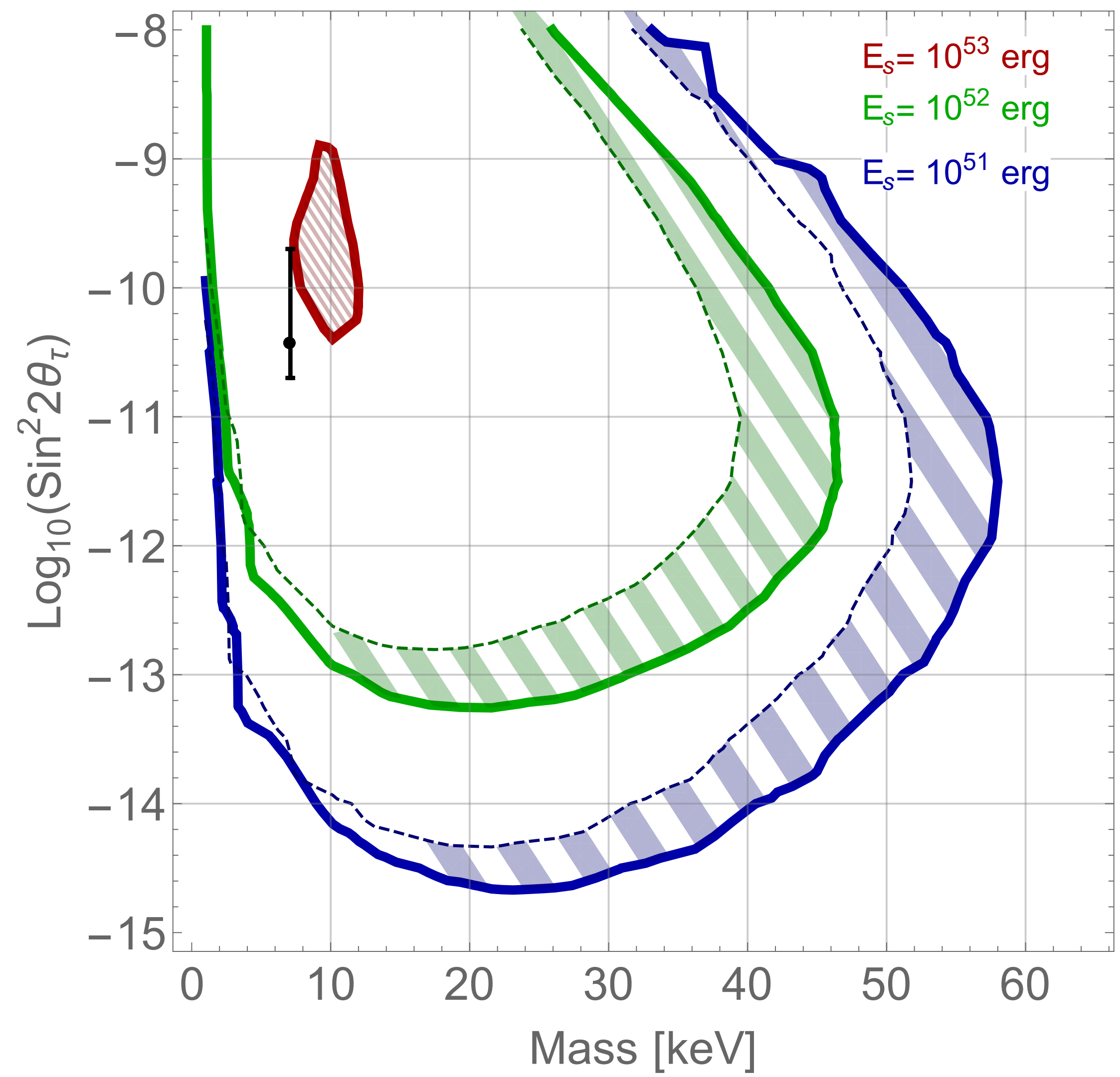
Sterile neutrino — supernova effects

- Sterile neutrinos can be generated in supernova explosions
- For the 3.55keV line-compliant 7keV sterile neutrino, >10^{52}erg could be emitted in sterile neutrinos per explosion
- Major uncertainty: temperature of supernova core



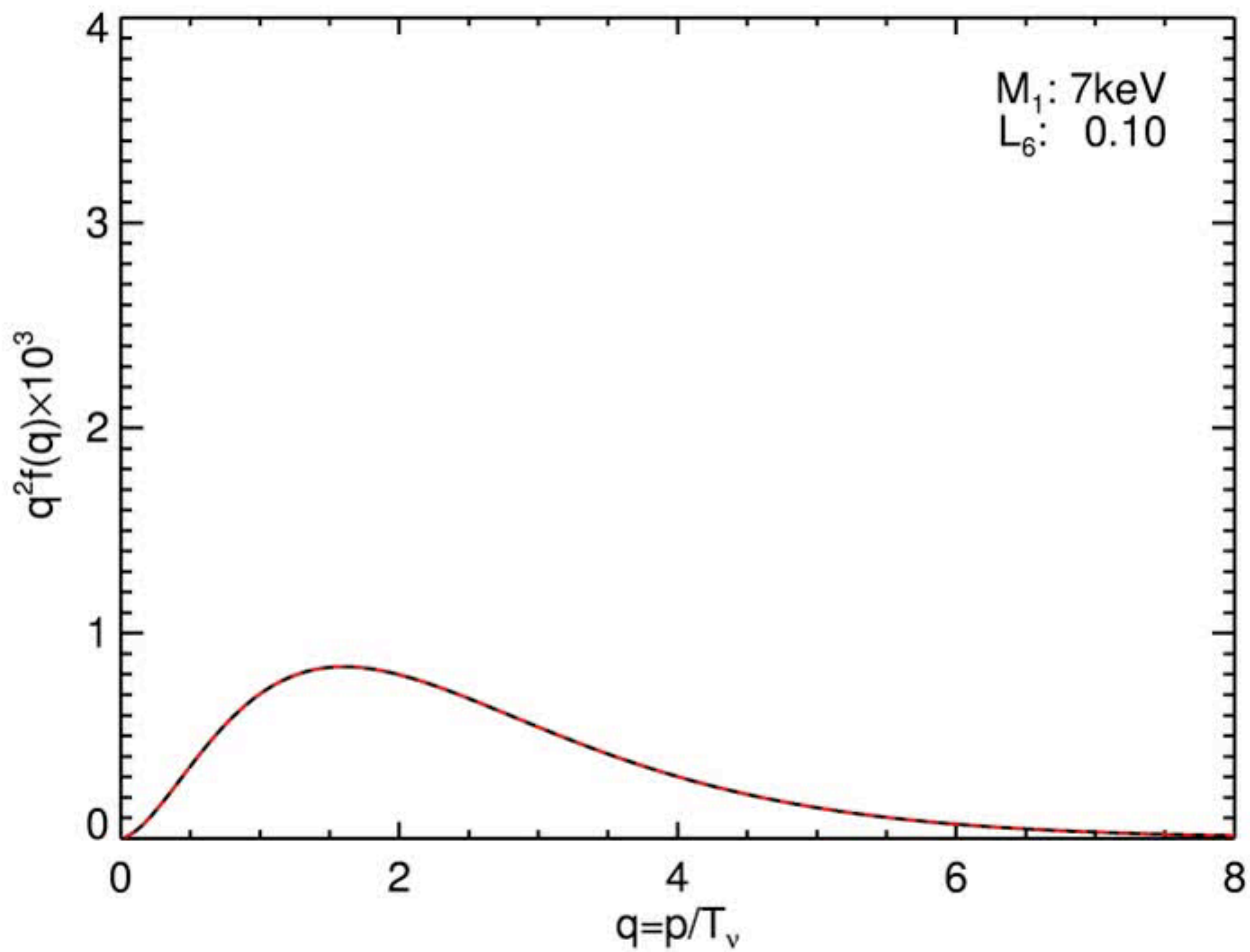
Syvolap, Ruchayskyi & Boyarsky 2019
(see also Suliga, Tamborra & Wu 2019)

Sterile neutrino —
as warm dark matter

Sterile neutrino — resonant production

- Resonances preferentially generate sterile neutrinos at particular energies — freeze-in
- Momentum and amplitude of resonances increases with lepton asymmetry, L_6
- Momentum distribution maximally cold at L_6=8 (25) for 7keV (2keV) mass.

Momentum distribution functions



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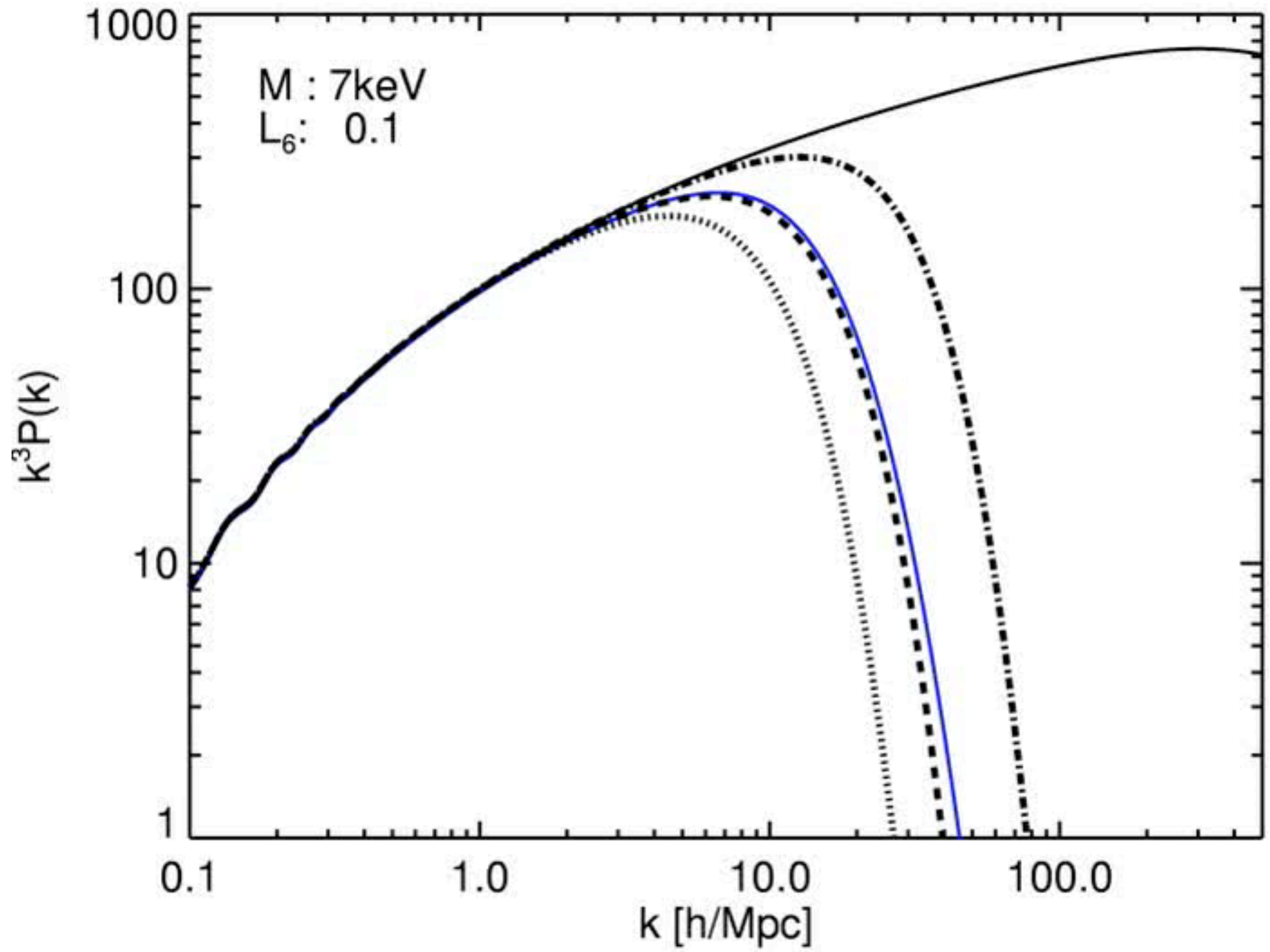
Linear matter power spectra



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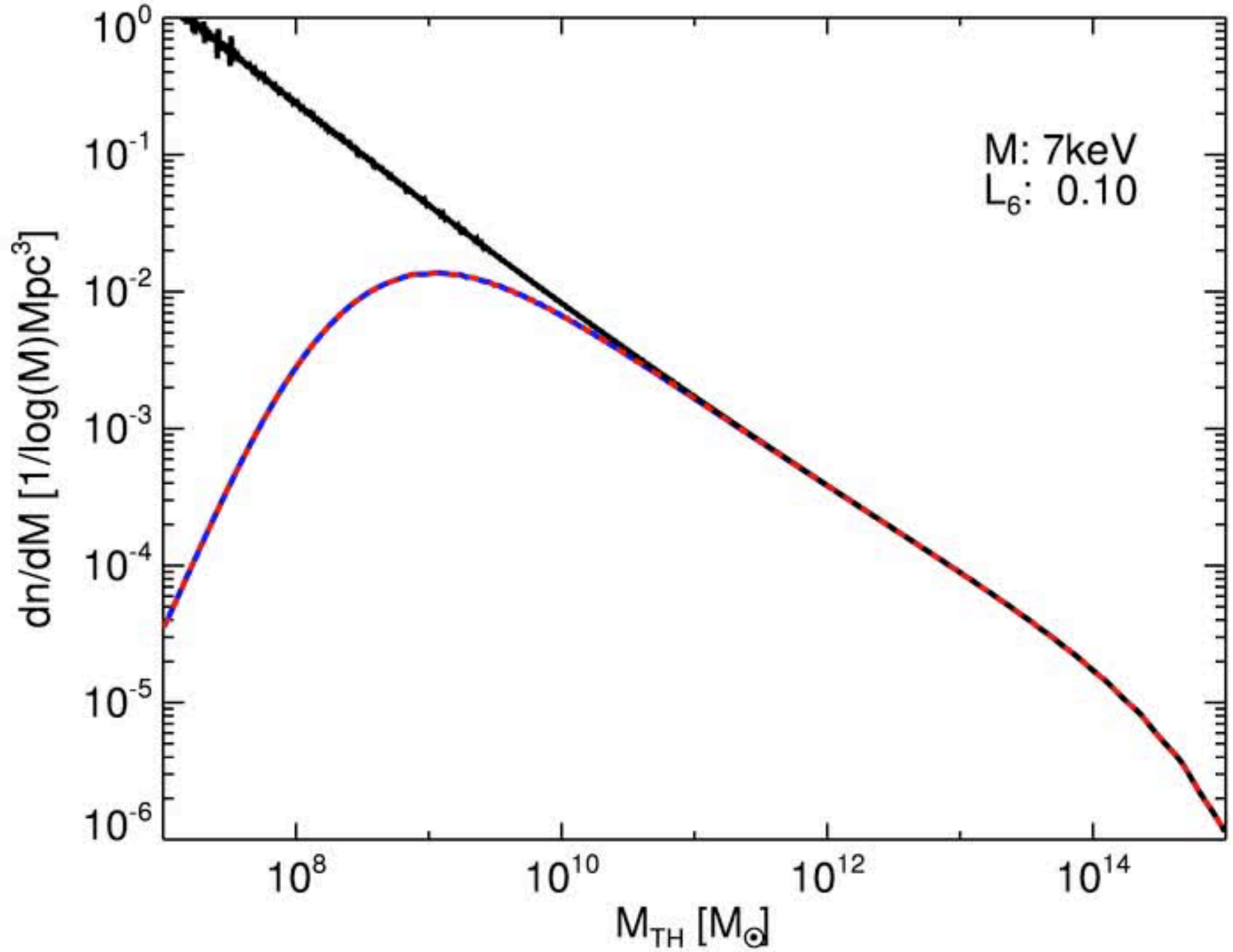
EPS mass functions



Warm dark matter — effects

- Halo abundance
- Halo collapse time
  - Halo mass
  - Halo concentration

Warm dark matter — effects

- **Halo abundance**
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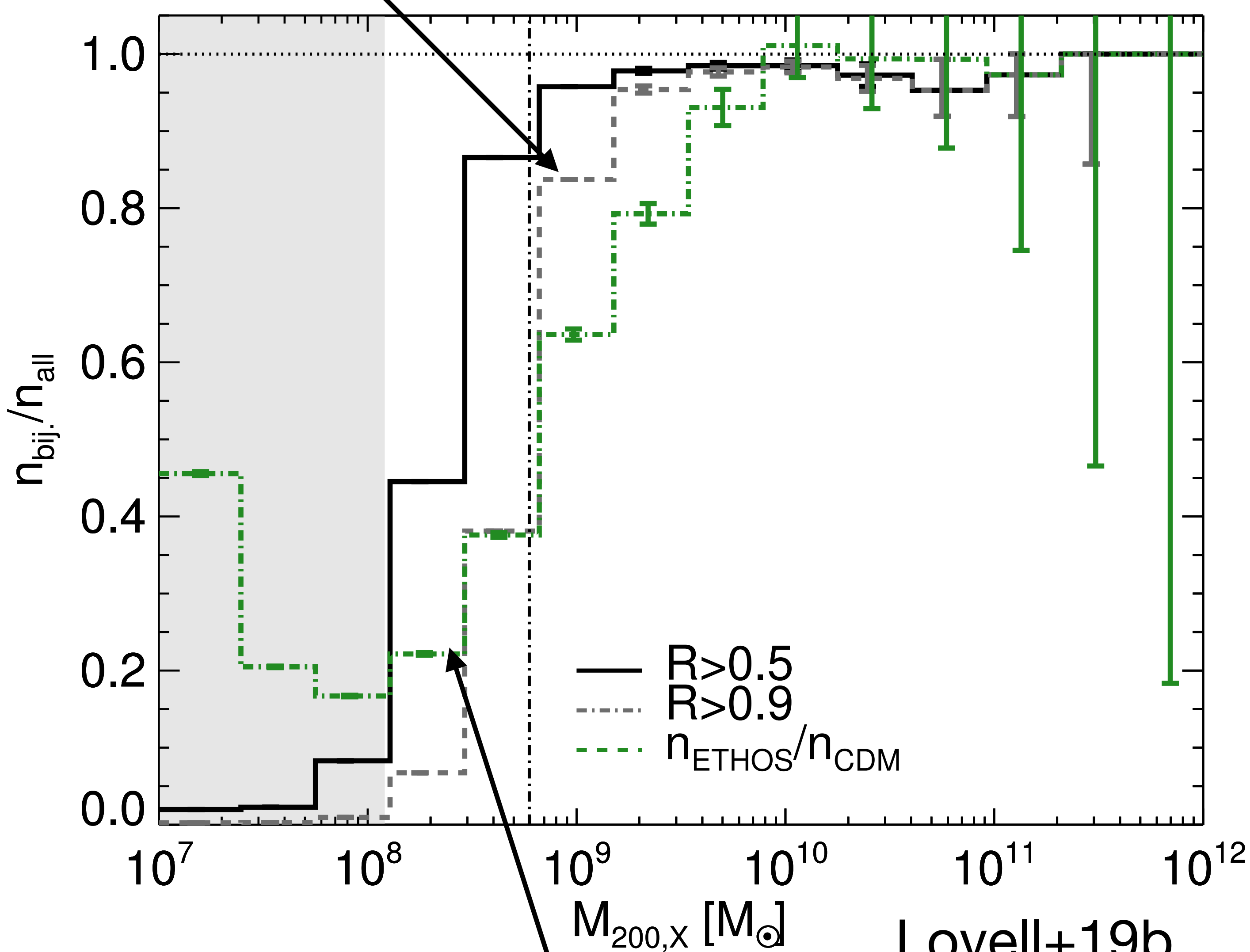
Fraction of CDM haloes reproduced in ETHOS4



Ratio of ETHOS-to-CDM mass functions

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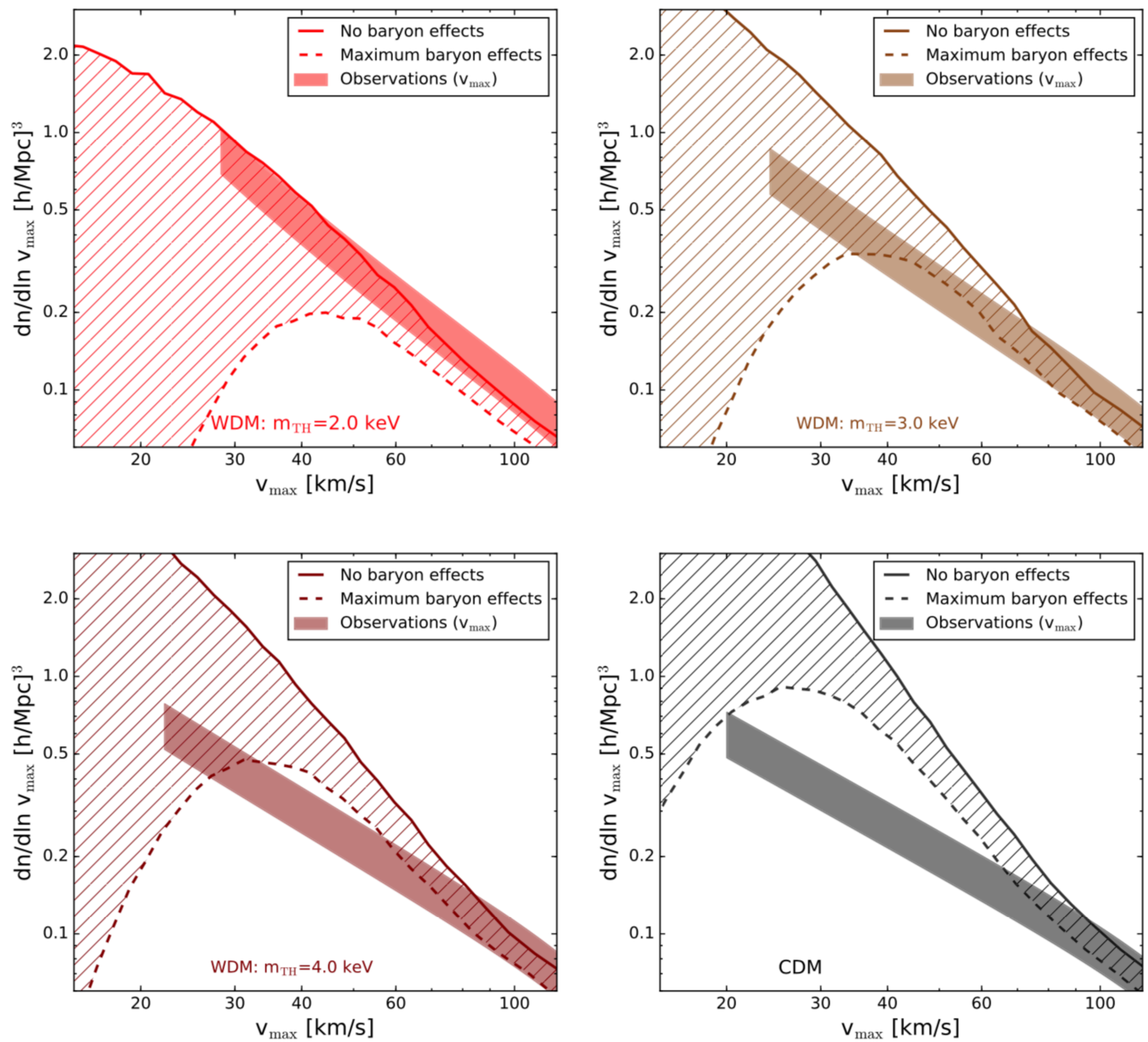
HI velocity functions



Schneider+2017 (also considers mixed-DM, SIDM)

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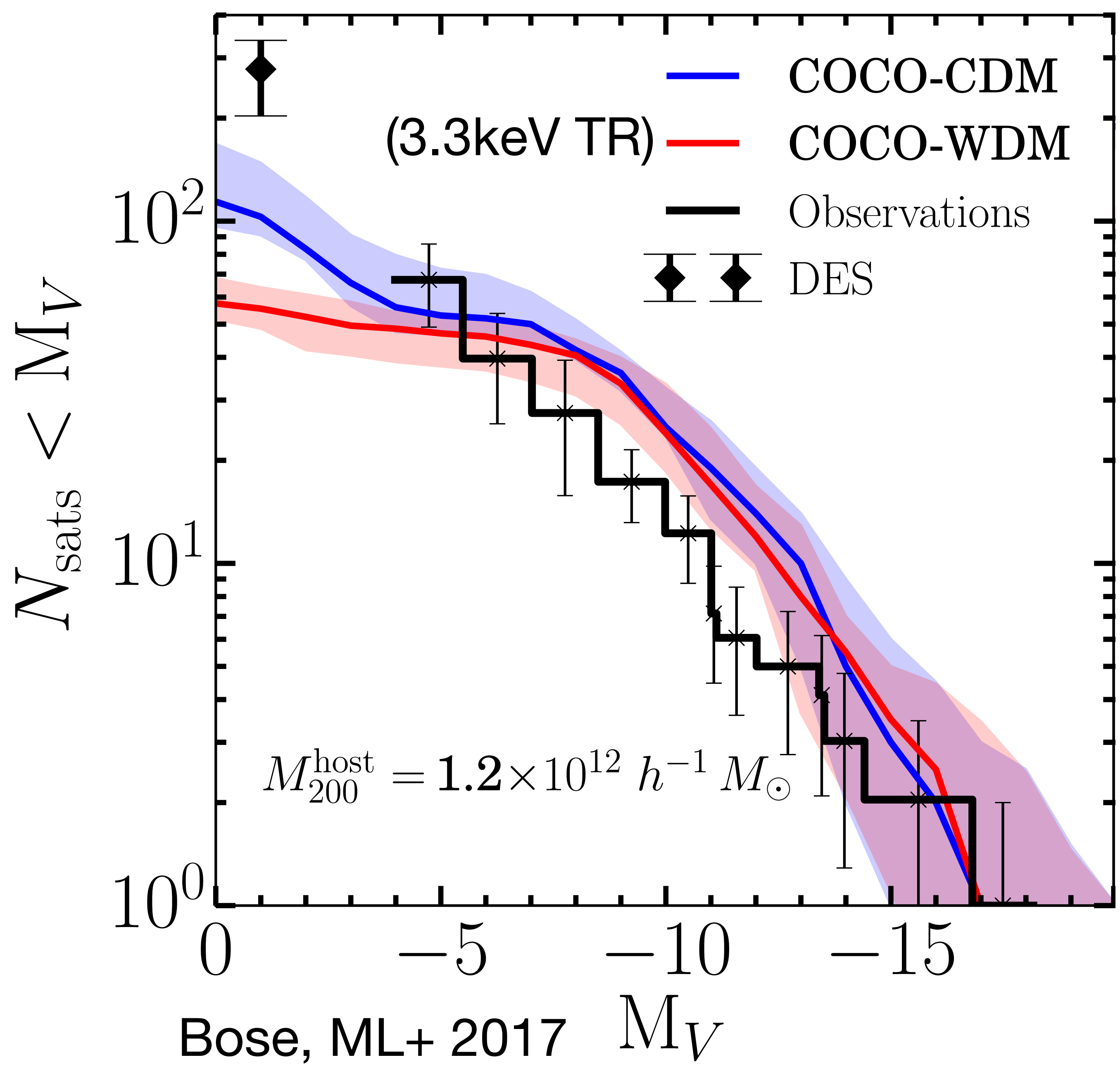
MW satellite counts



Bose, ML+ 2017
(see Collins talk)

(see also Cherry & Horiuchi, 2017)

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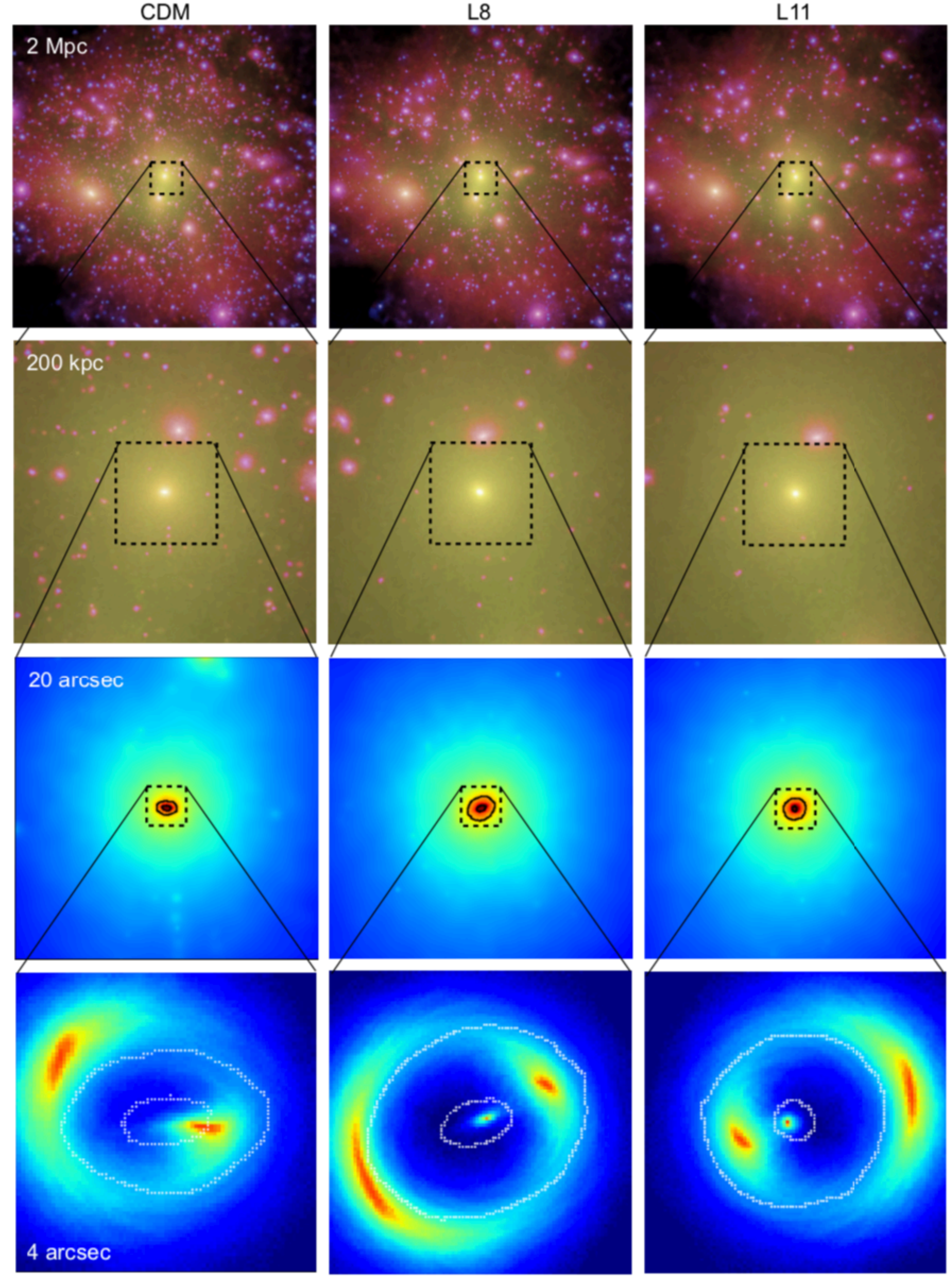
Lensing arcs



Despali, ML+2019

Warm dark matter — effects

QSO flux ratio anomalies

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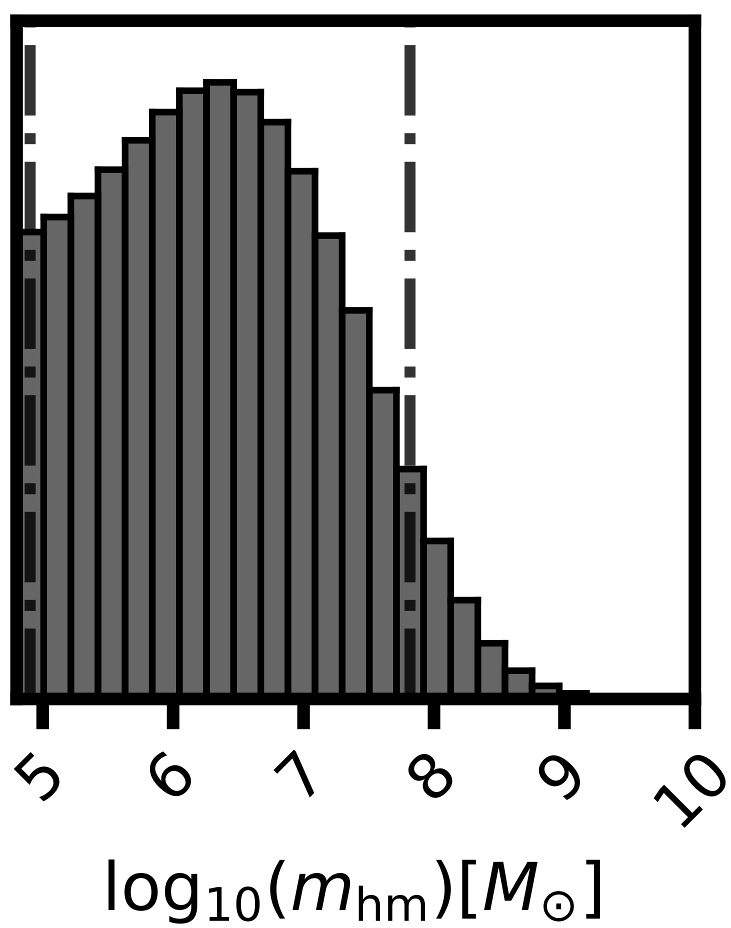

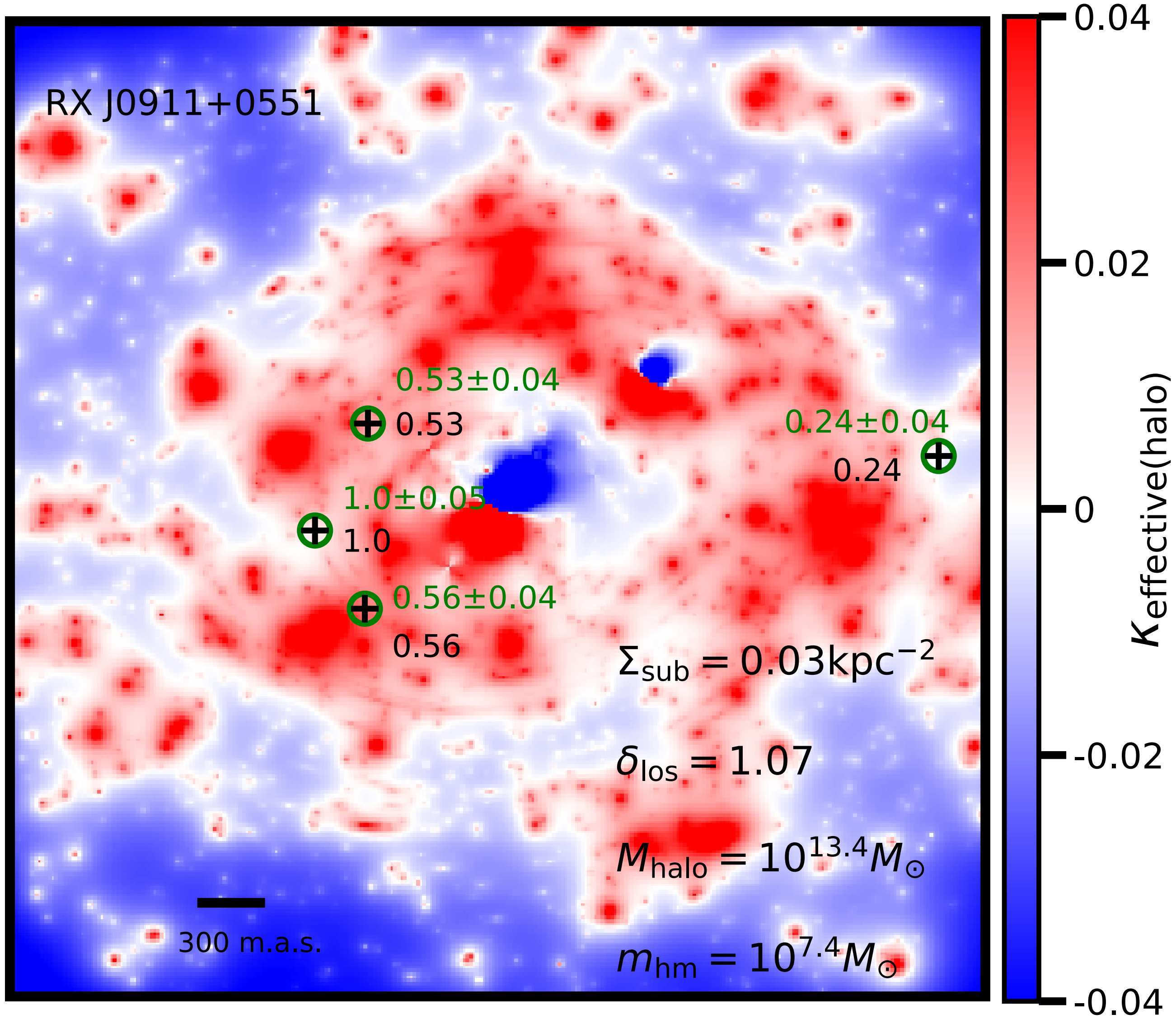

Gilman+2019
(see also Hsueh+2019)

Warm dark matter — effects

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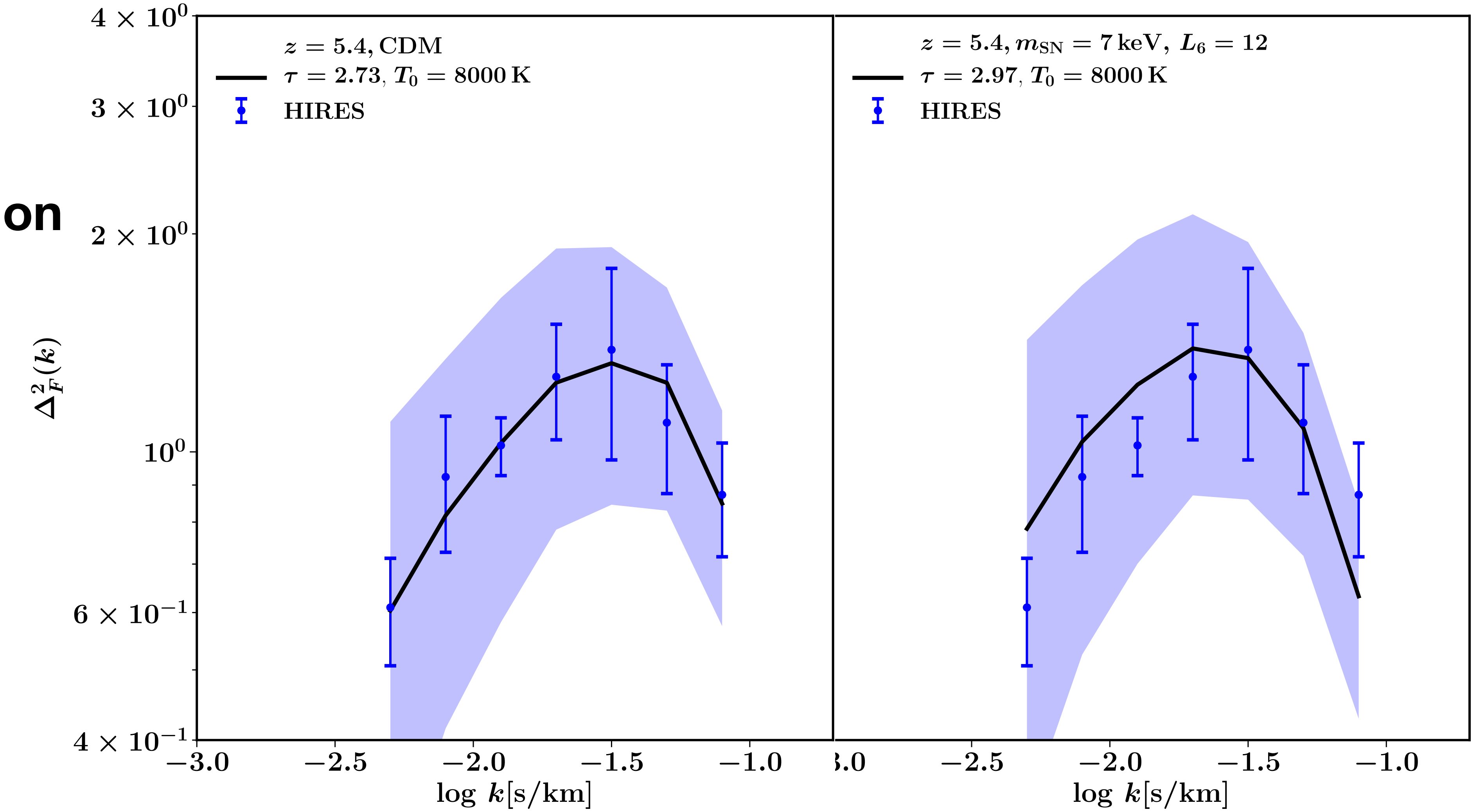
Lyman-α forest



Garzilli+2019
(see Irsic talk)

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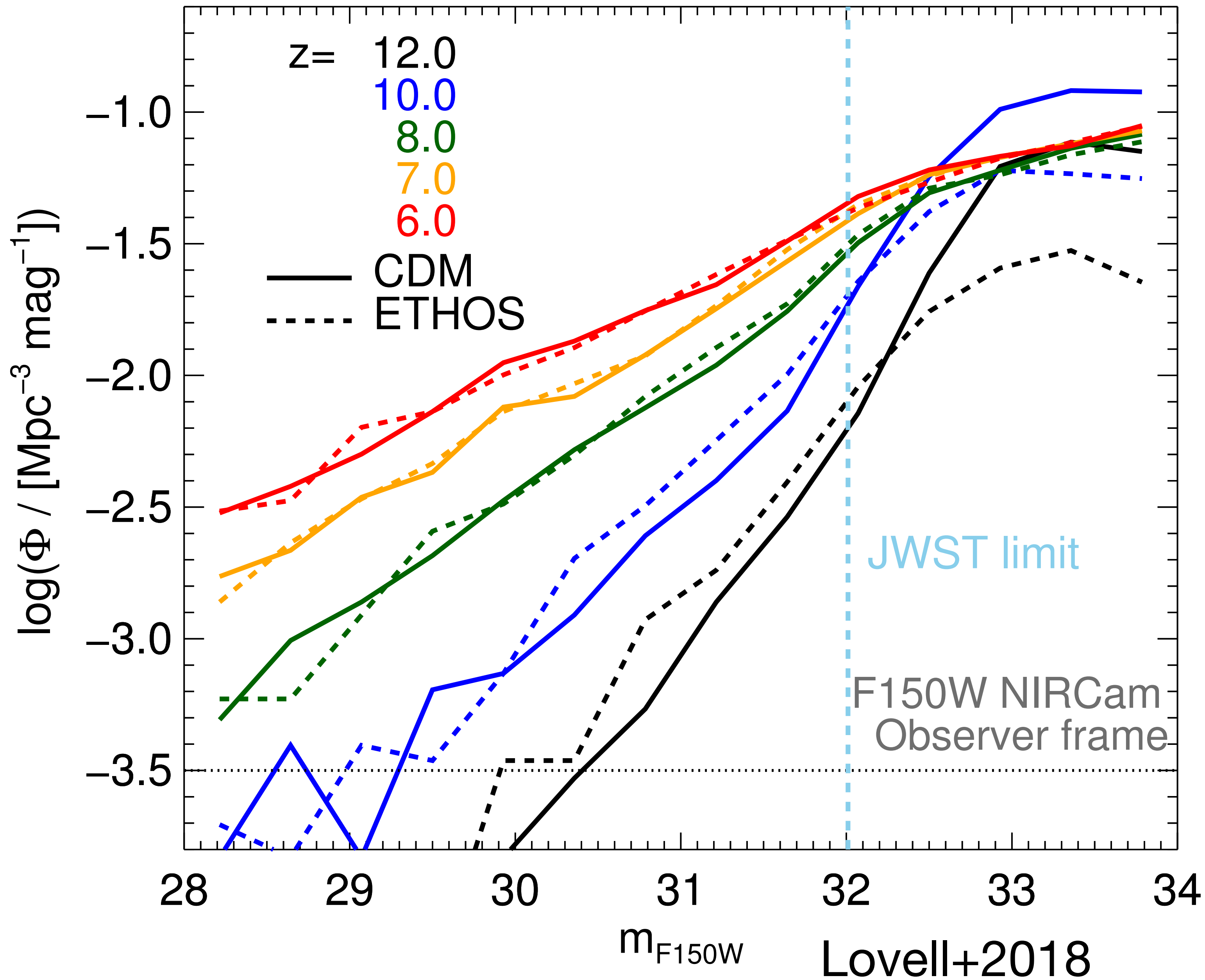
High redshift counts



Lovell+2018

Warm dark matter — effects

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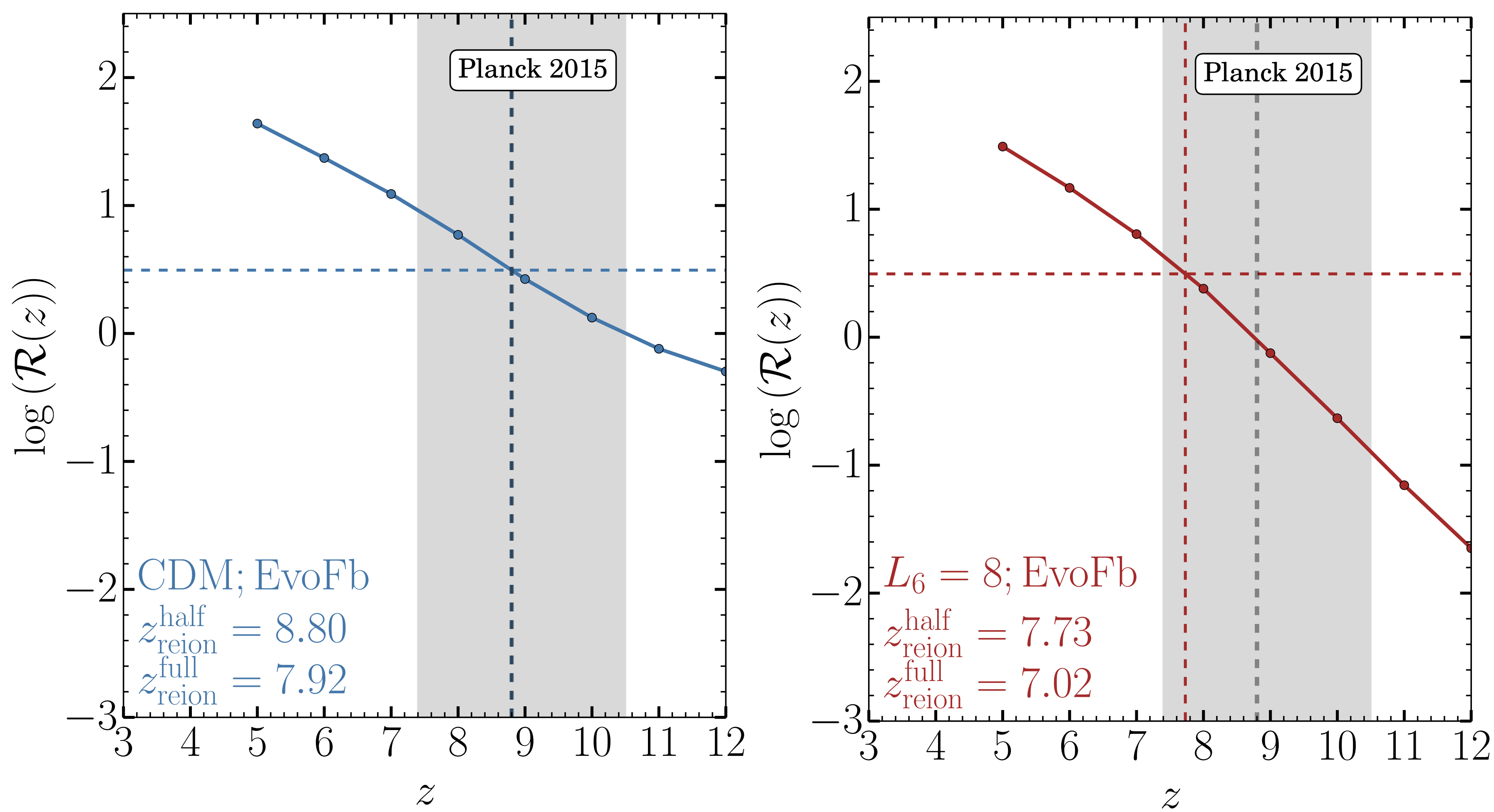
Reionization



Bose, ML+2017

Warm dark matter — effects

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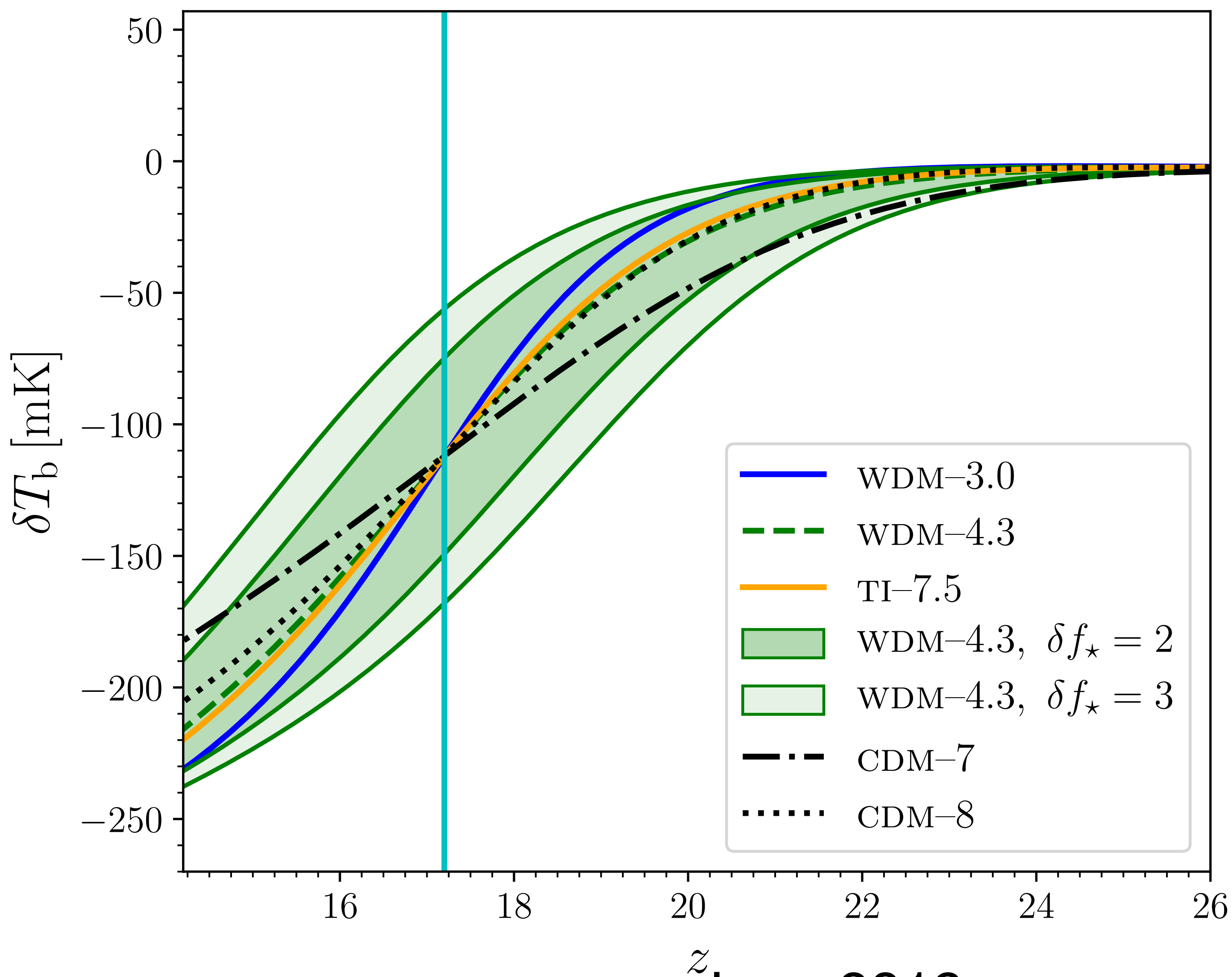
CMB absorption by 21-cm



Leo+2019
(see also Boyarsky, Iakubovskyi+2019)

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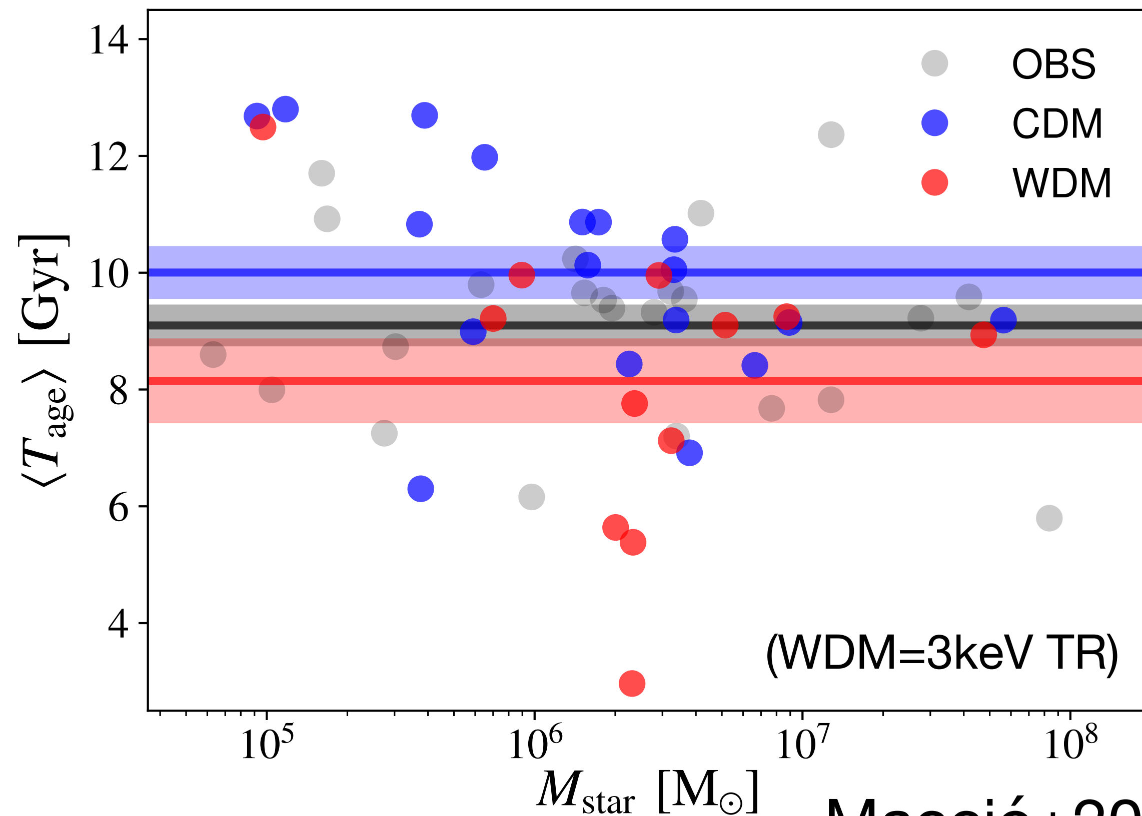
Galaxy ages



Macció+2019

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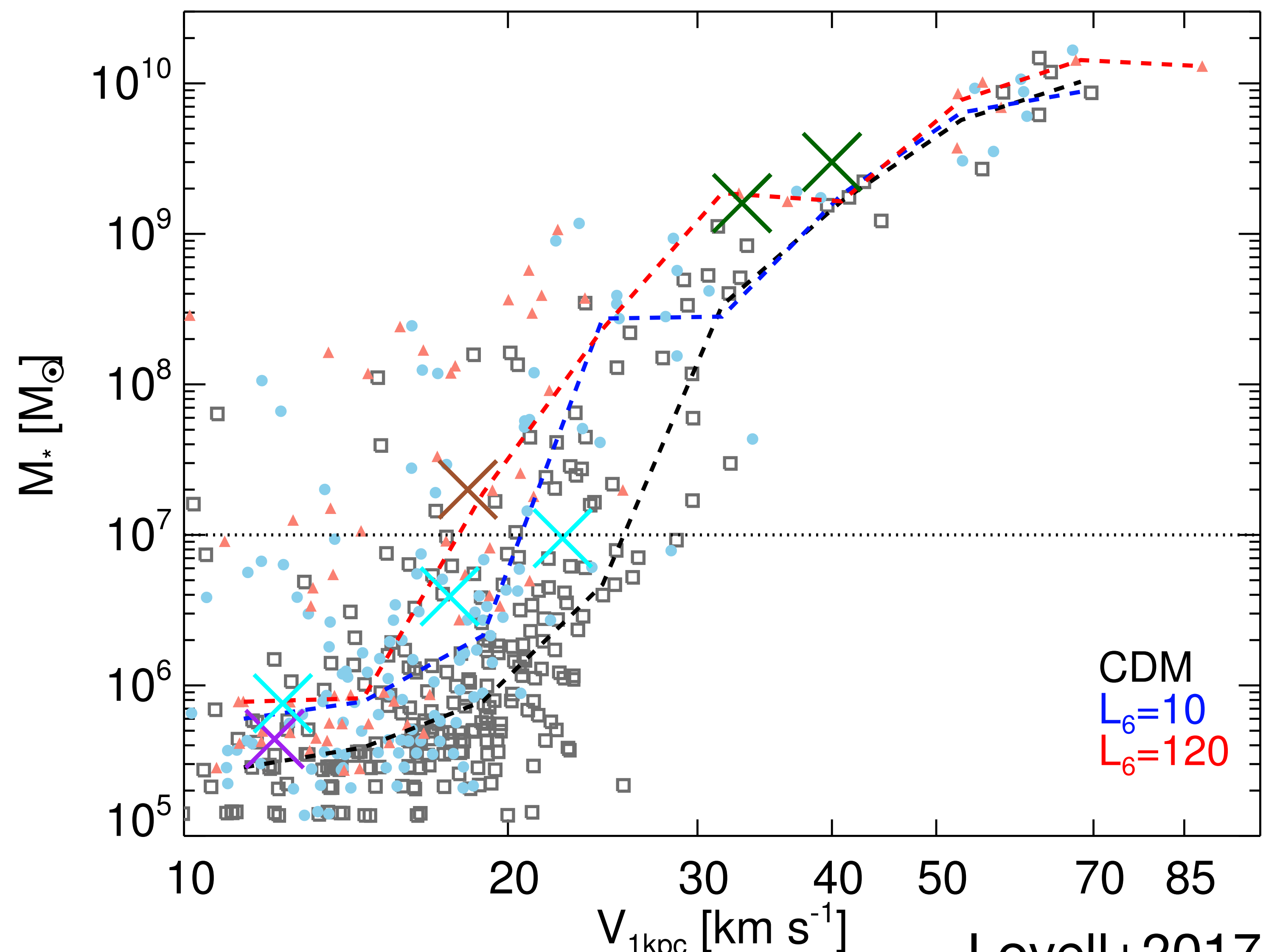
dSph stellar mass-halo mass



Lovell+2017b

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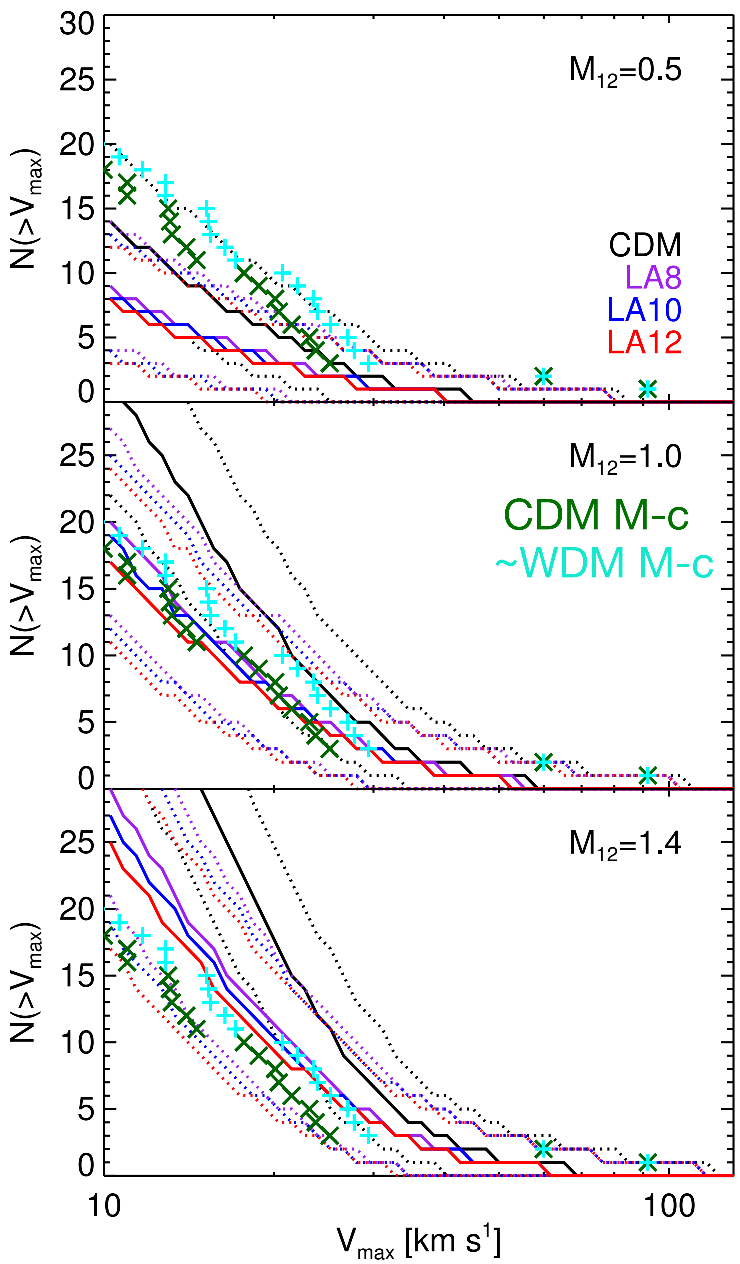
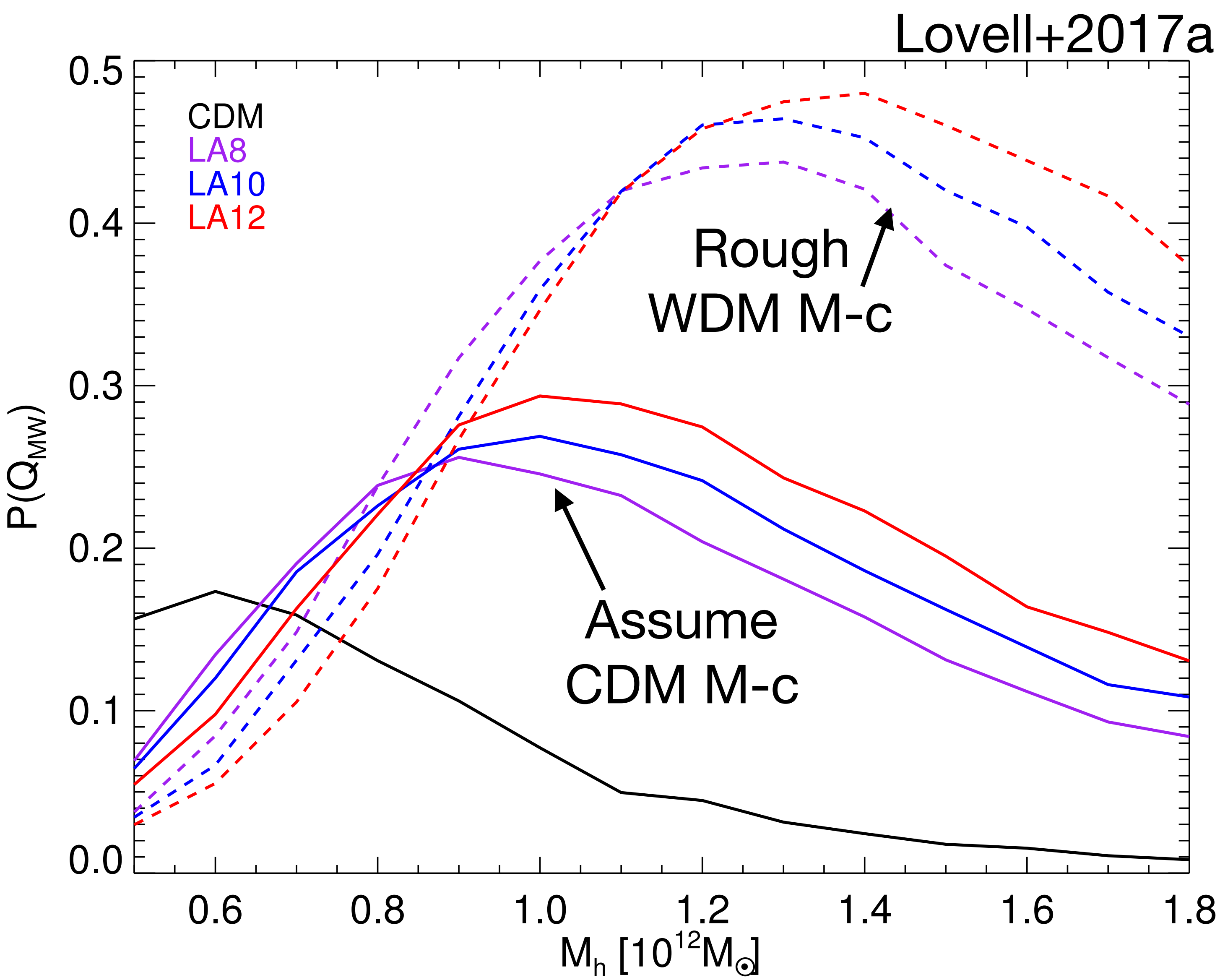


MW satellite Vmax function (TBTF)



Summary

- WDM models derived from comprehensive models of particle physics
- Sterile neutrinos imprinted in particle physics experiments, X-ray observations and supernovae
- WDM properties imprinted on ~11 observables