Cosmic probes of dark matter physics

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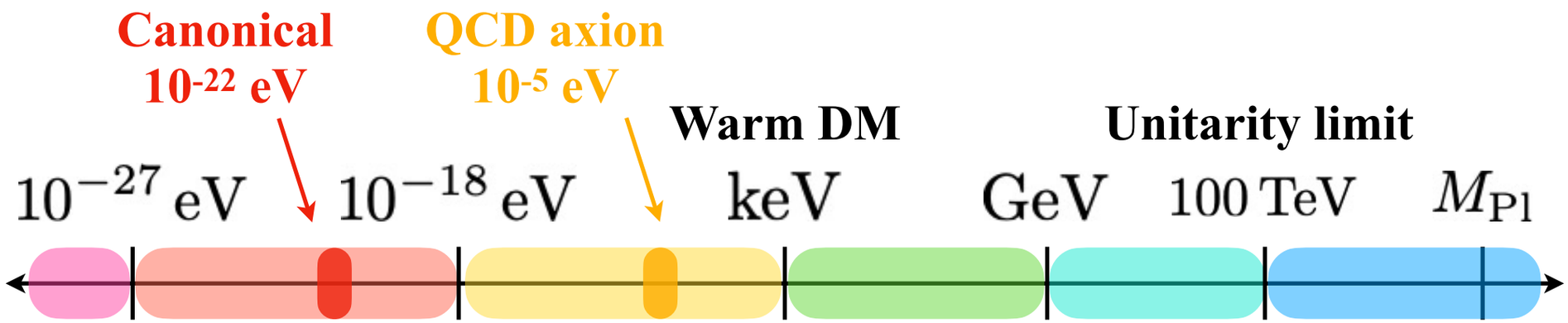
Dark matter candidates well-motivated at many masses



ULA dark energy | **Ultra-light axion DM** | **Axion-like particles** | **Light DM** | **WIMP** | **Composite DM**

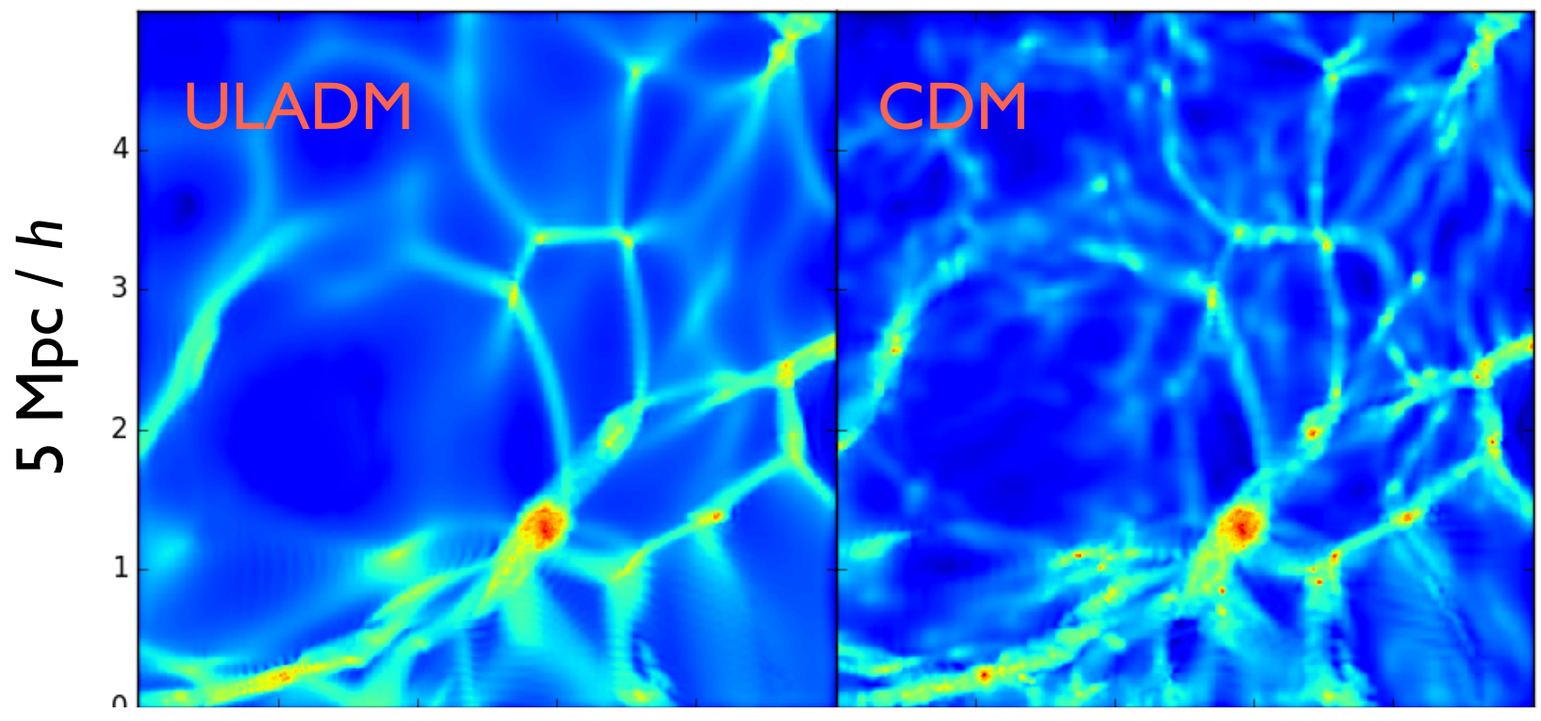
Ultra-light axion is a compelling dark matter candidate

- Axion-like particles are low-mass bosons abundantly produced in BSM theories, e.g., string theory axiverse

$$10^{-27}\,\mathrm{eV} < m < 10^{-18}\,\mathrm{eV}$$

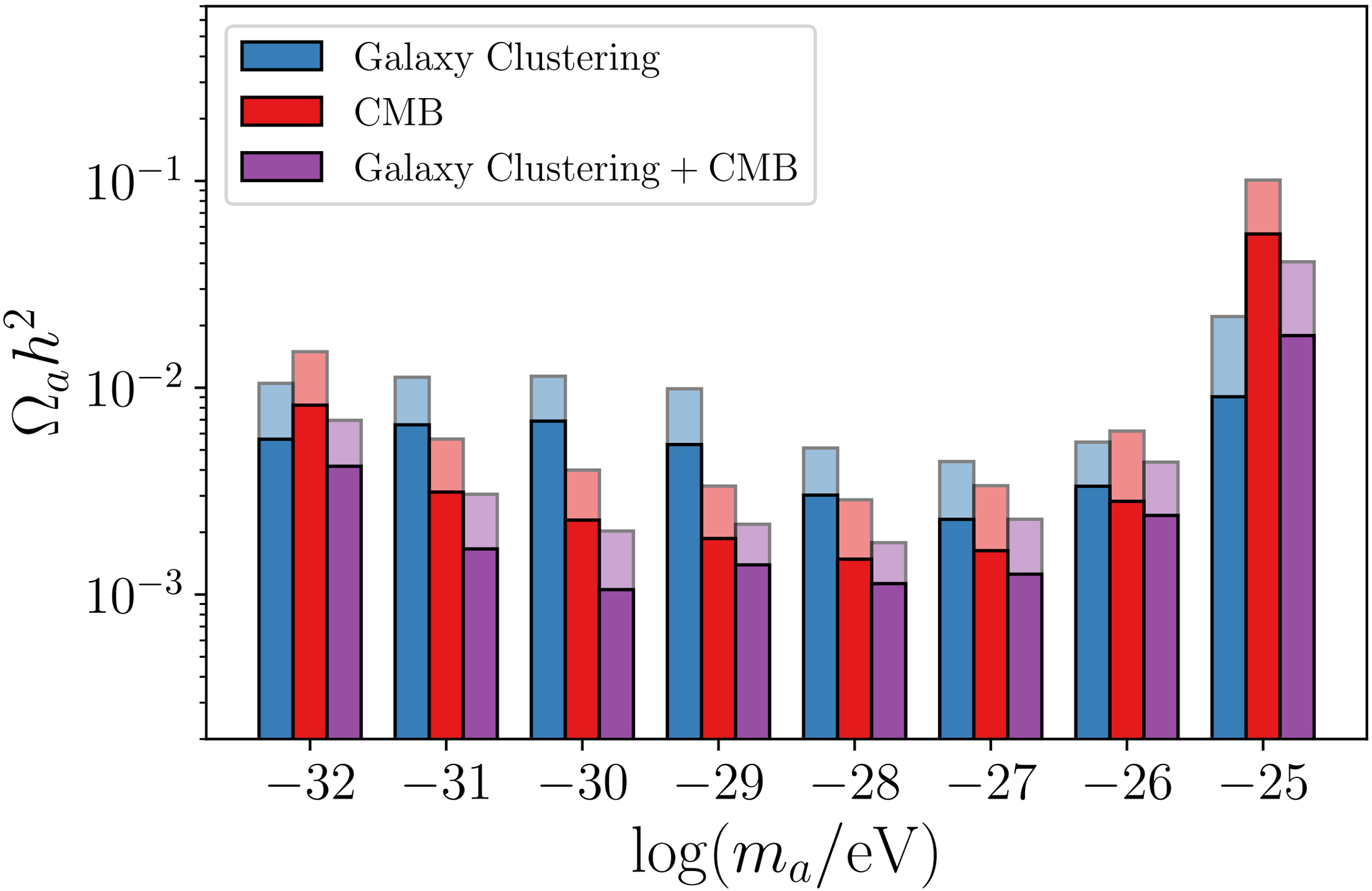
- New physics to resolve cosmological model tensions

$$\lambda_{\mathrm{QP}} \propto m_{\mathrm{a}}^{-\frac{4}{9}}$$



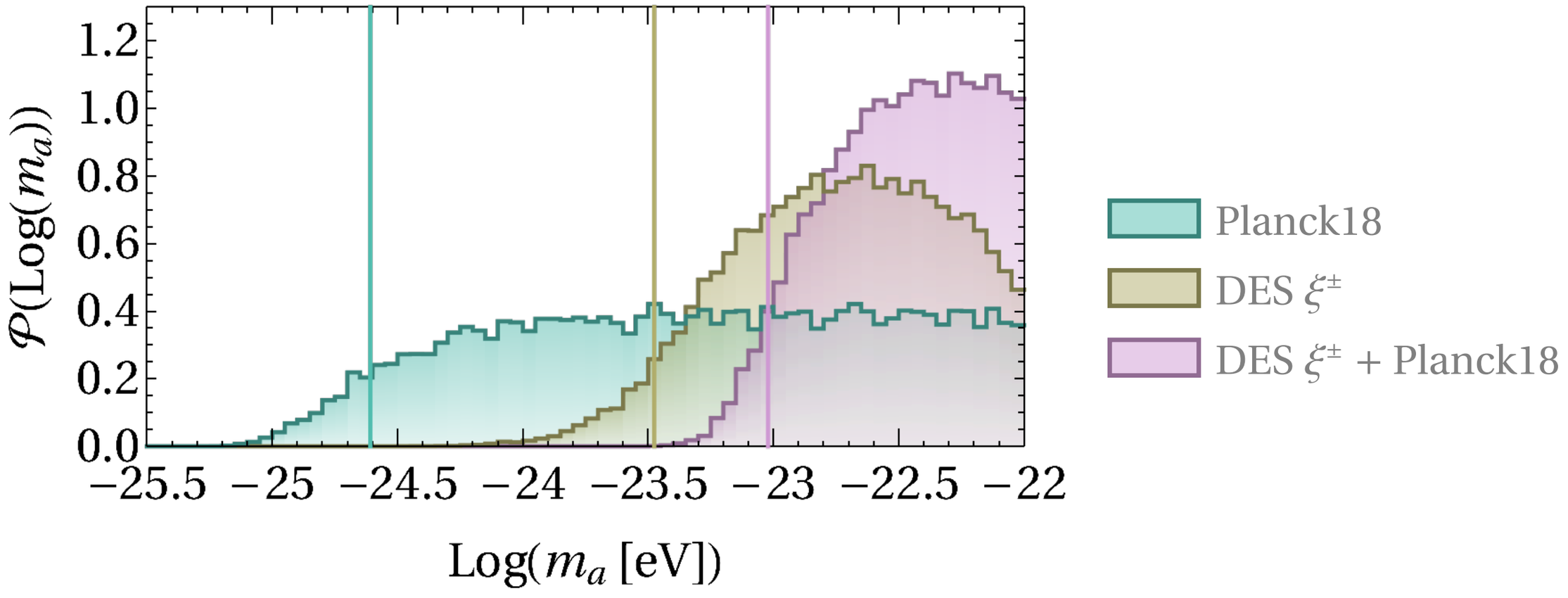
Hui et al. (2017); Allali et al. (2021); Blum & Teodori (2021); Armengaud et al. (2017)

Combining galaxy clustering from BOSS with *Planck* CMB improves bound by up to 4.5 x



Laguë, Bond, Hložek, Rogers, Marsh, Grin (2021, in review)

Joint CMB & galaxy weak lensing bounds



Dentler, Marsh, Hložek, Laguë, Rogers, Grin (2021, in review)

Ultra-light axions are invoked to resolve so-called cold dark matter "small-scale crisis"

$$\lambda_{\rm dB} \sim {\rm kpc}$$

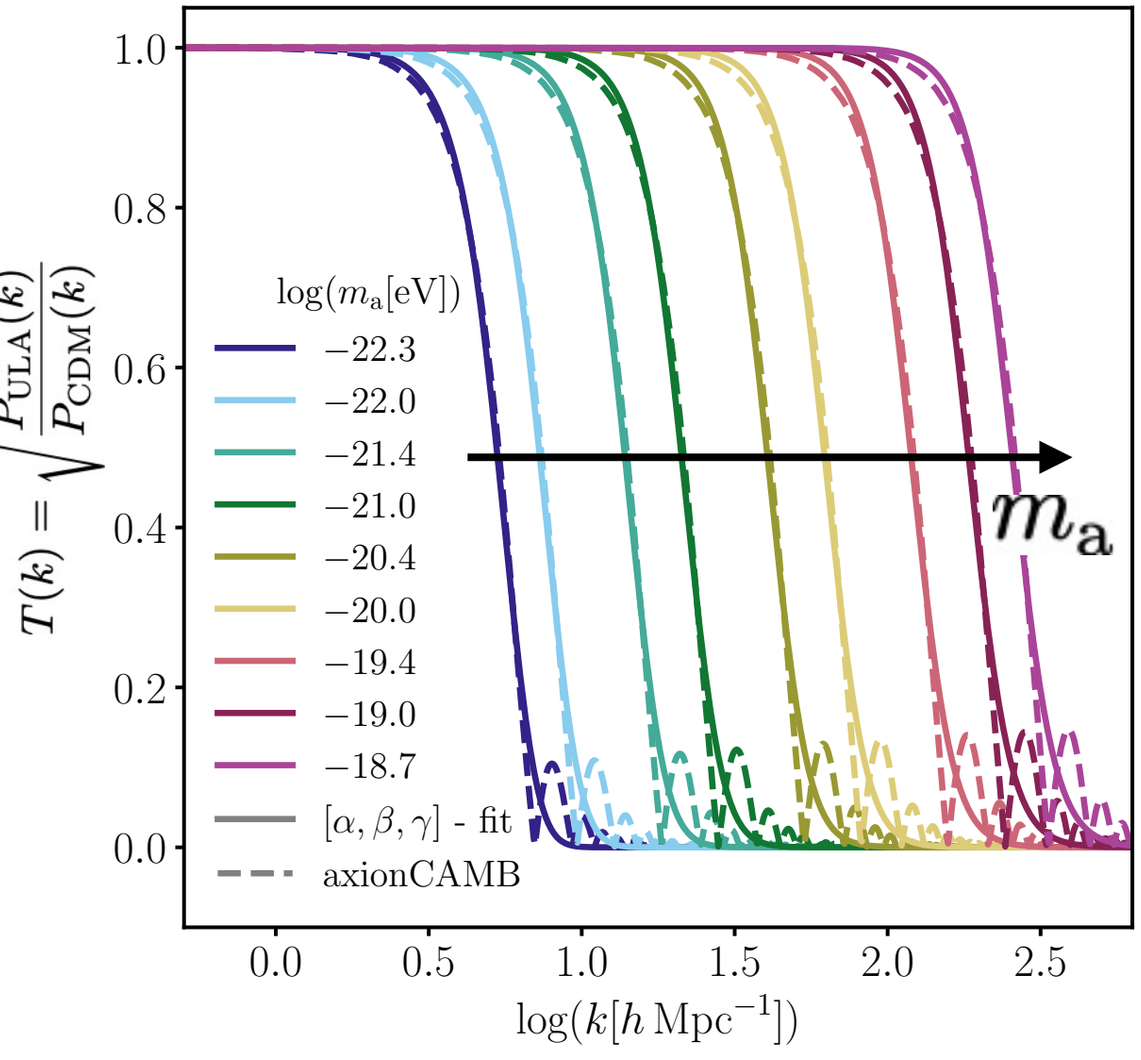
$$\lambda_{\rm QP} \sim {\rm Mpc}$$

CDM "small-scale crisis" prefers DM **mass scale ~ 10^{-22} eV**

Lyman-alpha forest traces ultra-light axion dark matter cut-off

$$k_{\frac{1}{2}} \propto m_{\rm a}^{\frac{4}{9}}$$

Hu et al. (2000)



- Ly-alpha forest traces linear, high-redshift ($z \sim 5$), small-scale density perturbations

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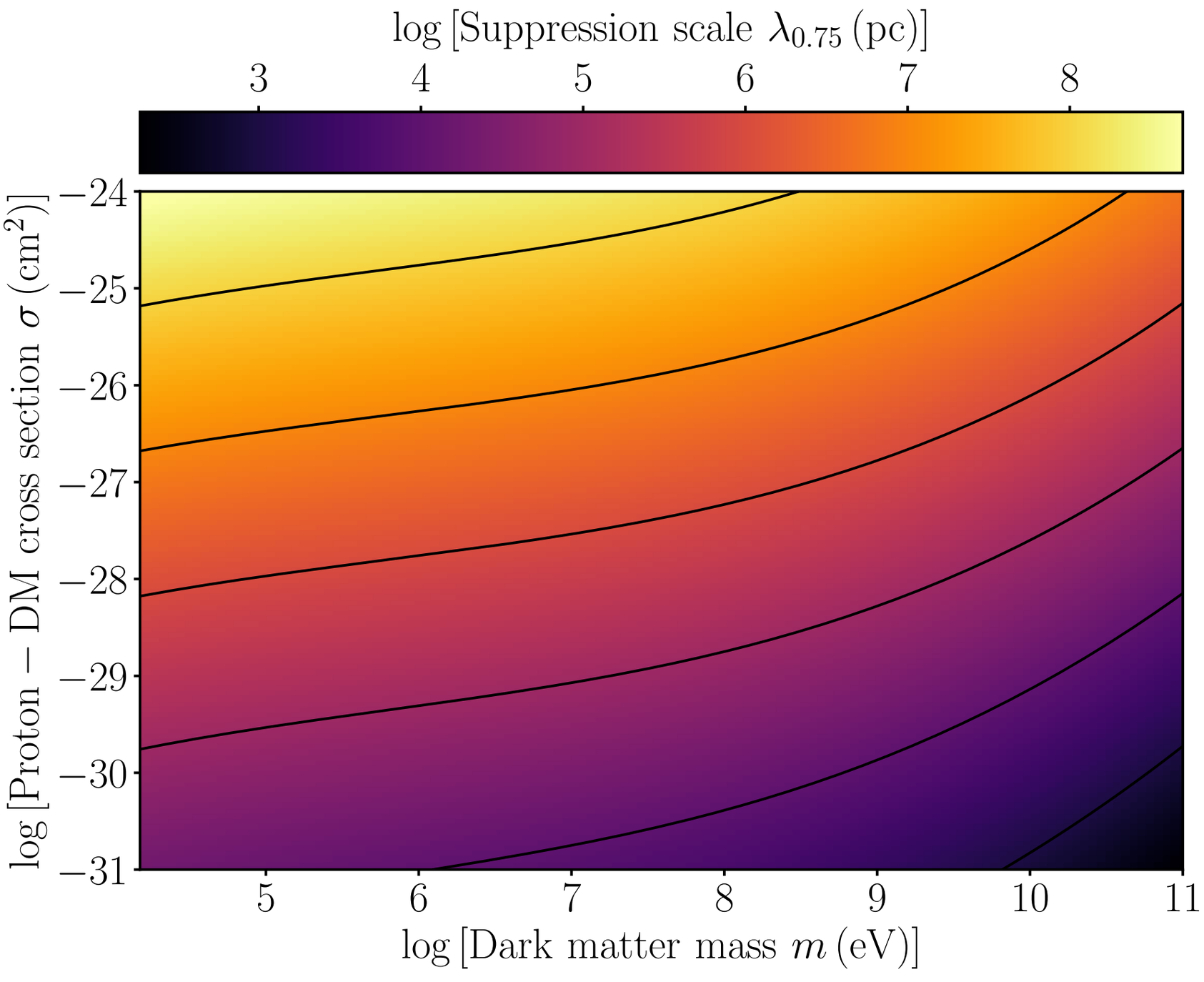
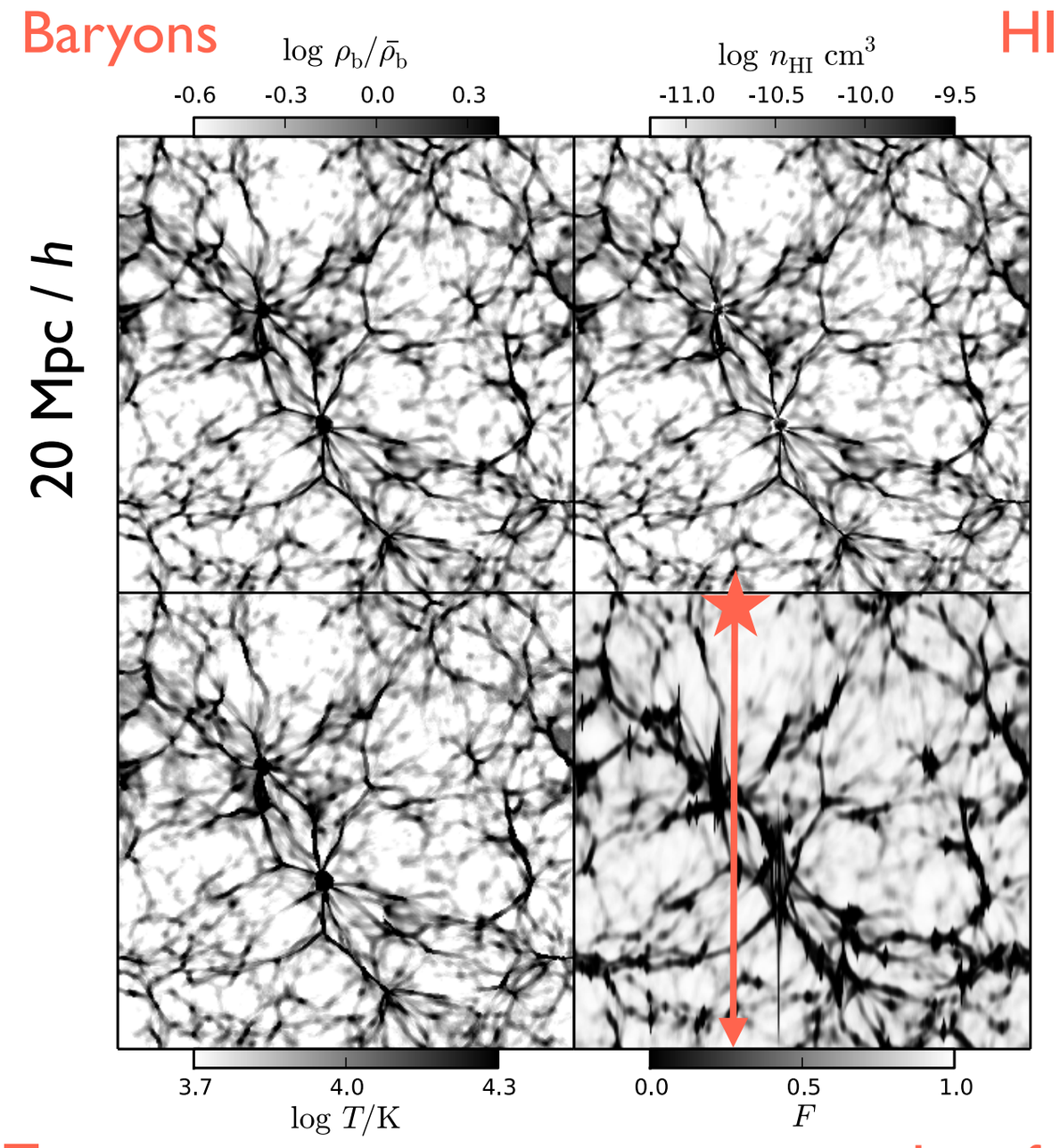
Rogers & Peiris (2021ab, Phys. Rev. Lett., Phys. Rev. D)

Smaller cosmological scales probe light DM that cannot be directly detected



Rogers et al. (2021, in review)

Dark matter bounds must marginalise astrophysics



- Ly-alpha forest traces DM & intergalactic medium astrophysics
- ~ 3000 CPU-hours per simulation in 12-D parameter space
- ⇒ need ML-accelerated "emulator"

Lukić et al. (2015); Rogers et al. (2019, JCAP); Rogers & Peiris (2021, Phys. Rev. D)

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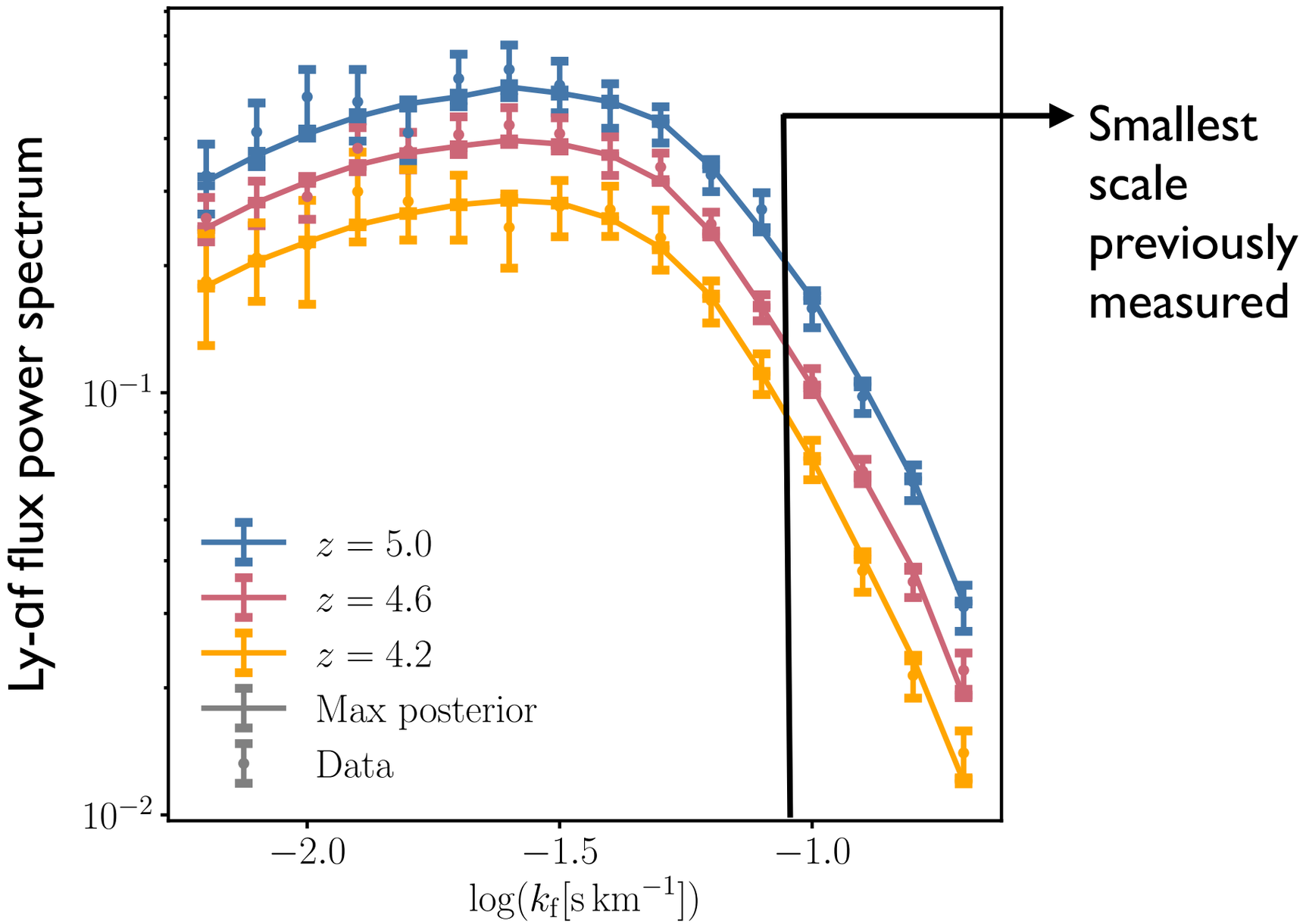
STRONG BOUND ON ULTRA-LIGHT AXION DARK MATTER

Phys. Rev. Lett., 126, 071302, 2021
Phys. Rev. D, 103, 043526, 2021
with Peiris

Dark matter bound driven by new small-scale data



Data: Boera et al. (2019)

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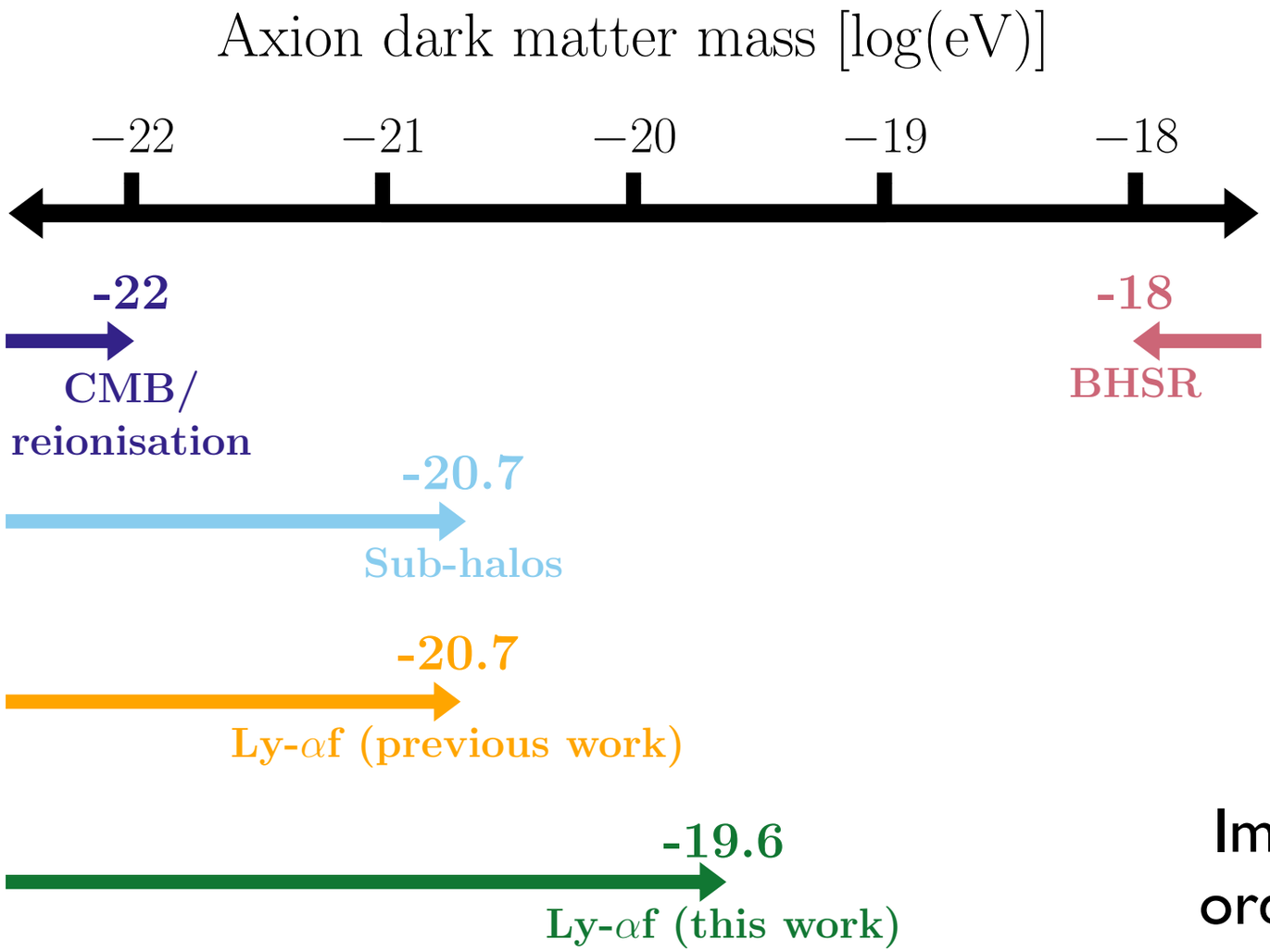
Rogers & Peiris (2021ab, Phys. Rev. Lett., Phys. Rev. D)

"Canonical" 10^{-22} - 10^{-21} eV ULA DM is strongly disfavoured by new bound



Improve bound by order of magnitude

$$m_{\rm a} > 2 \times 10^{-20}\,{\rm eV}$$

Rogers & Peiris (2021ab, Phys. Rev. Lett., Phys. Rev. D)

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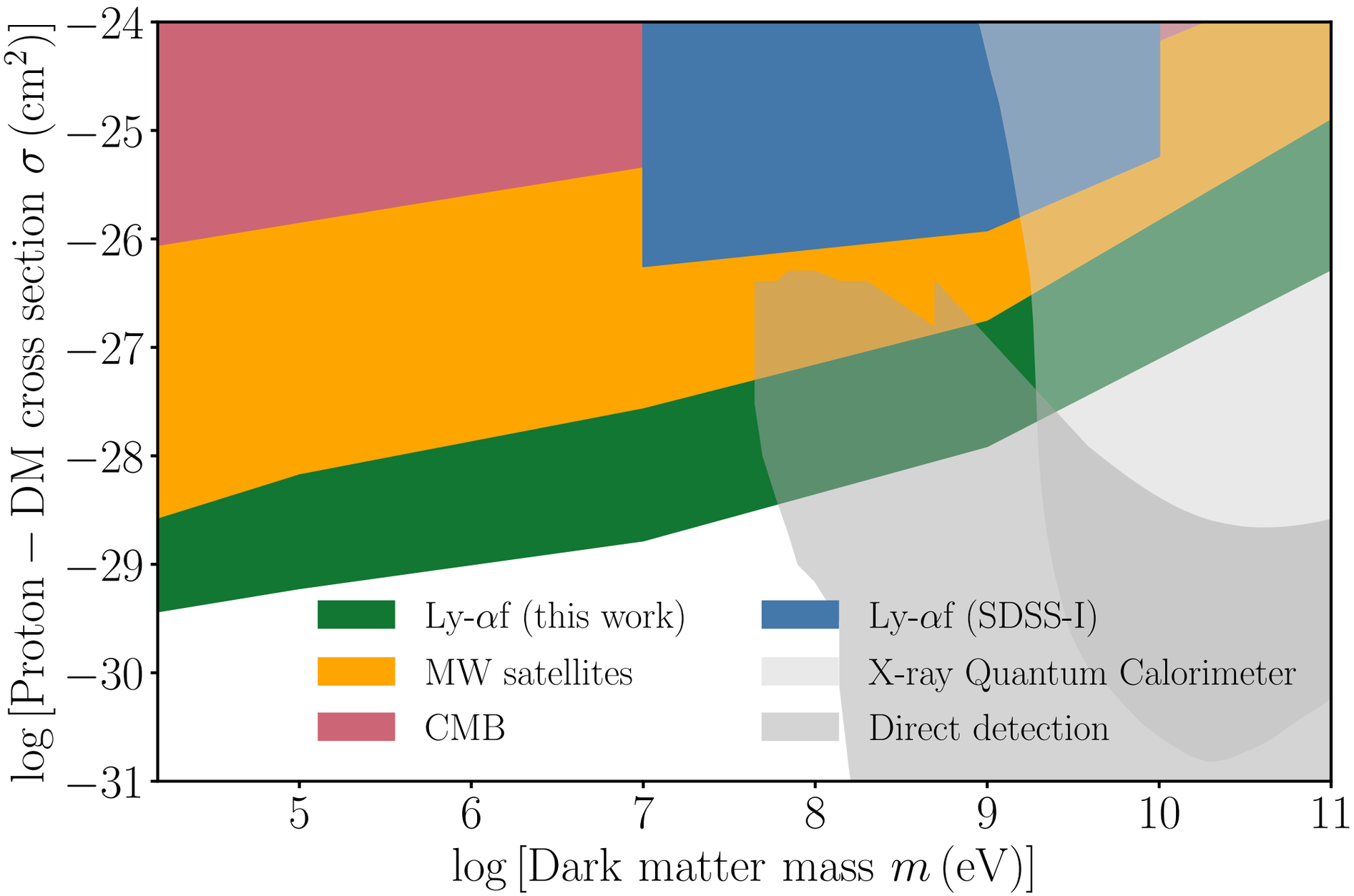
New limits on light dark matter

arXiv:2111.10386
with Dvorkin, Peiris

Cosmology probes well-motivated light dark matter that cannot be directly detected



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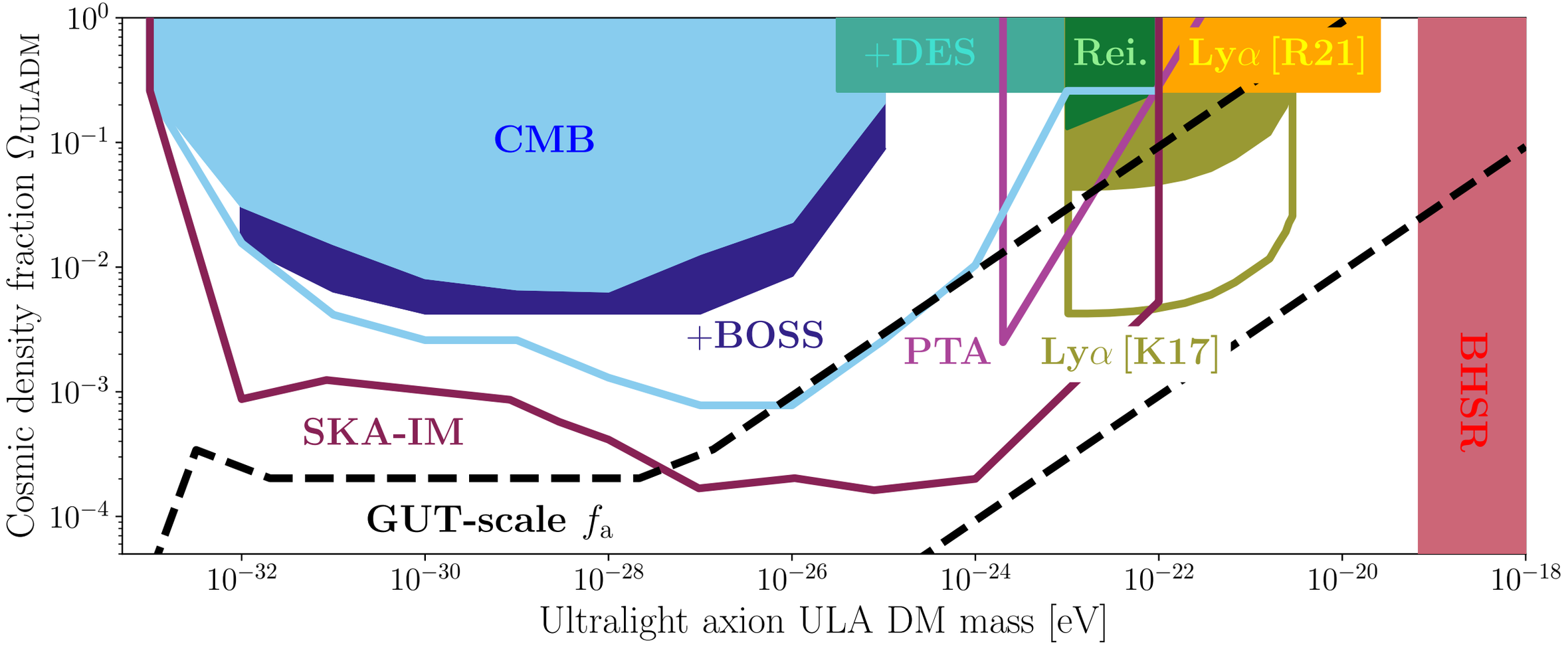
Rogers et al. (2021, in review)

Multi-probe approach to reach GUT-scale physics



Modified from Grin et al. (2019)