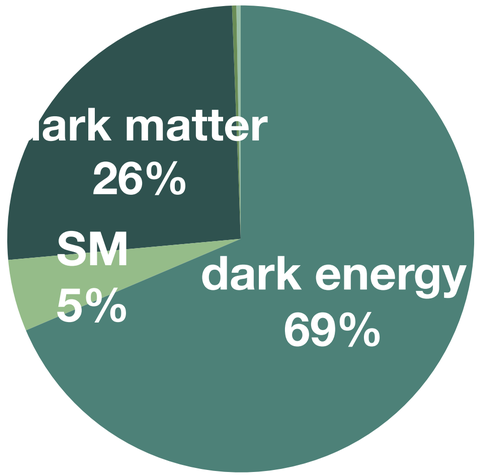
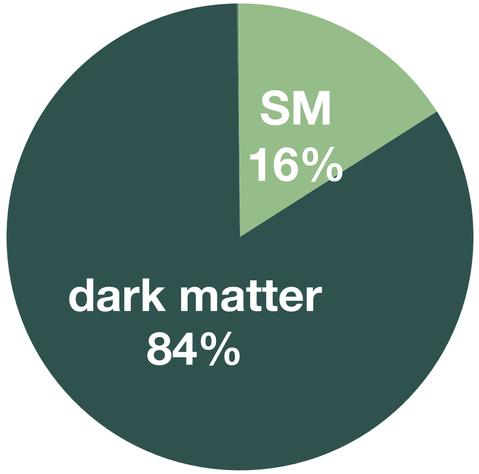
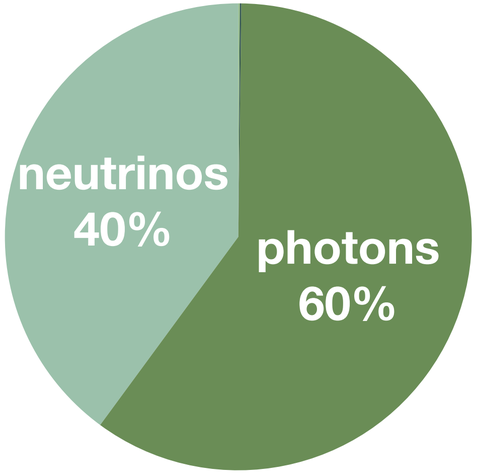
Cosmological Signatures of Interacting Dark Sectors

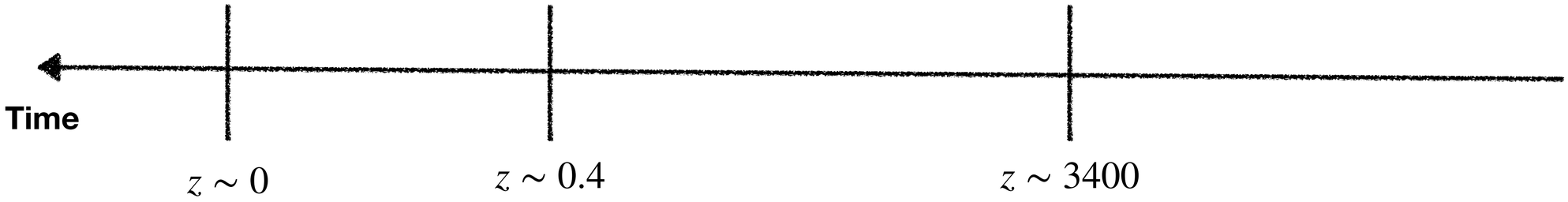
Melissa Joseph
University of Utah

Mostly Dark Universe



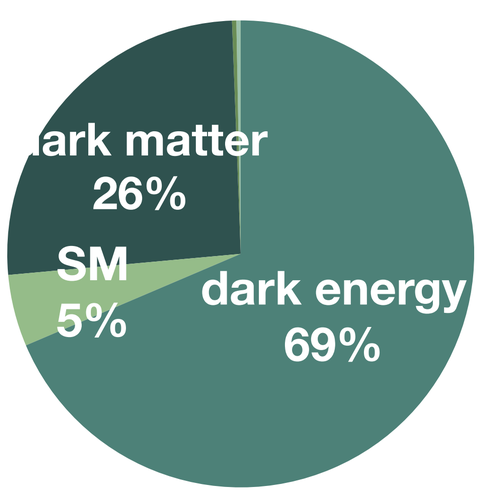


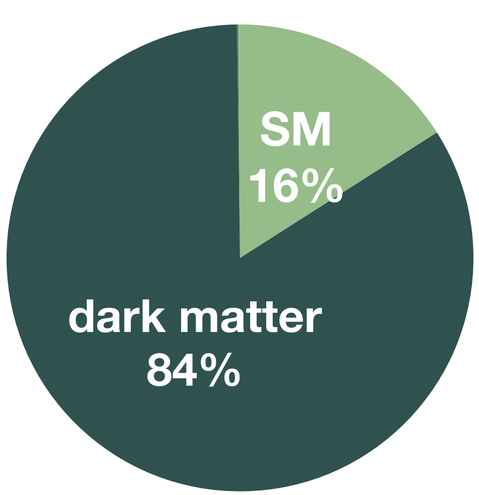




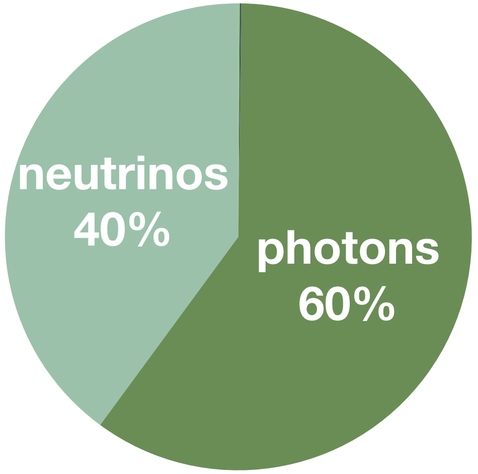
Mostly Dark Universe

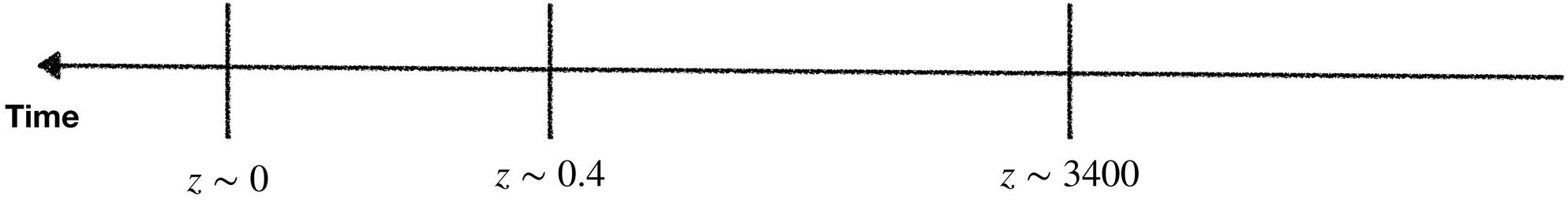
DM Interactions or multiple particles?



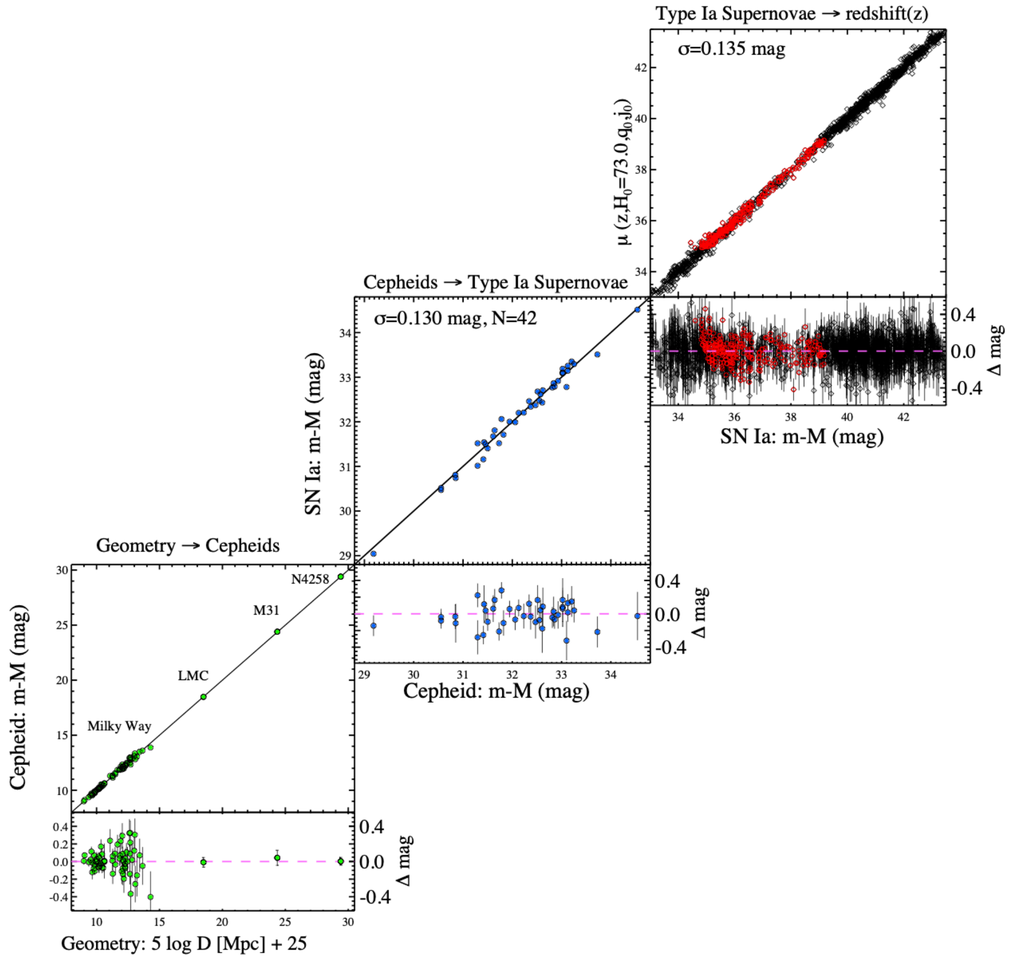


Can some fraction correspond to other dark sector particles?

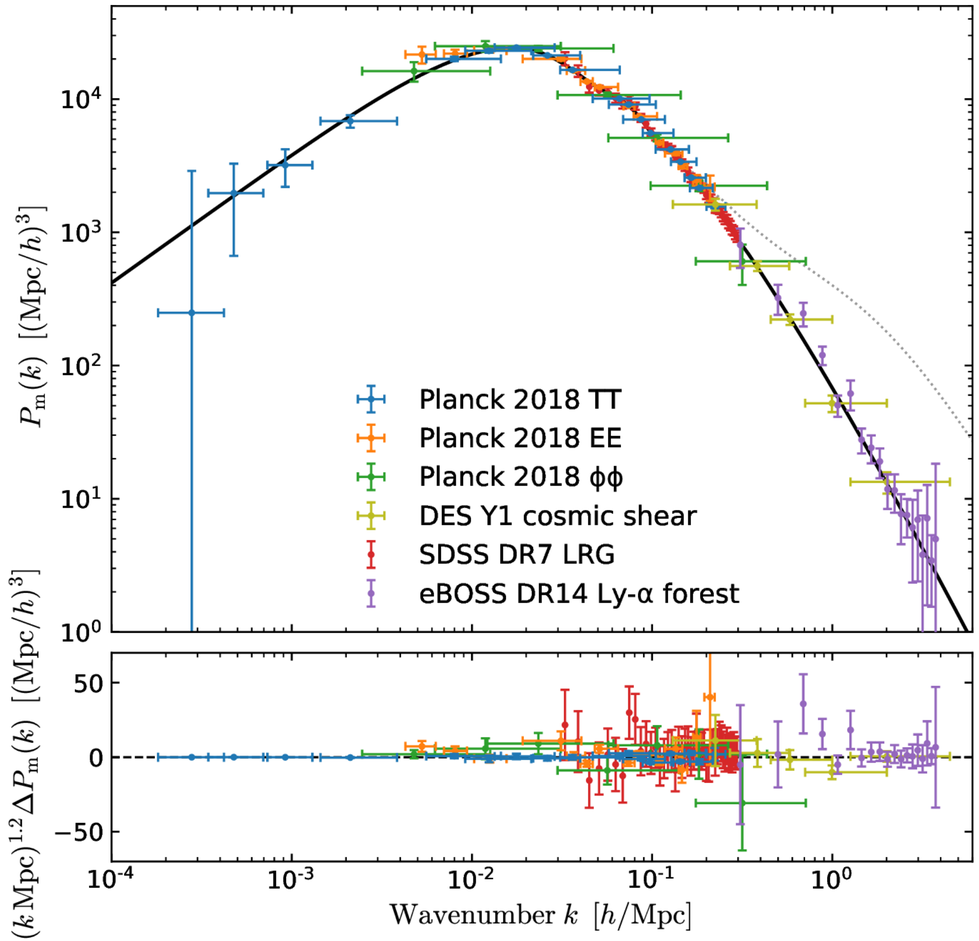




Tensions



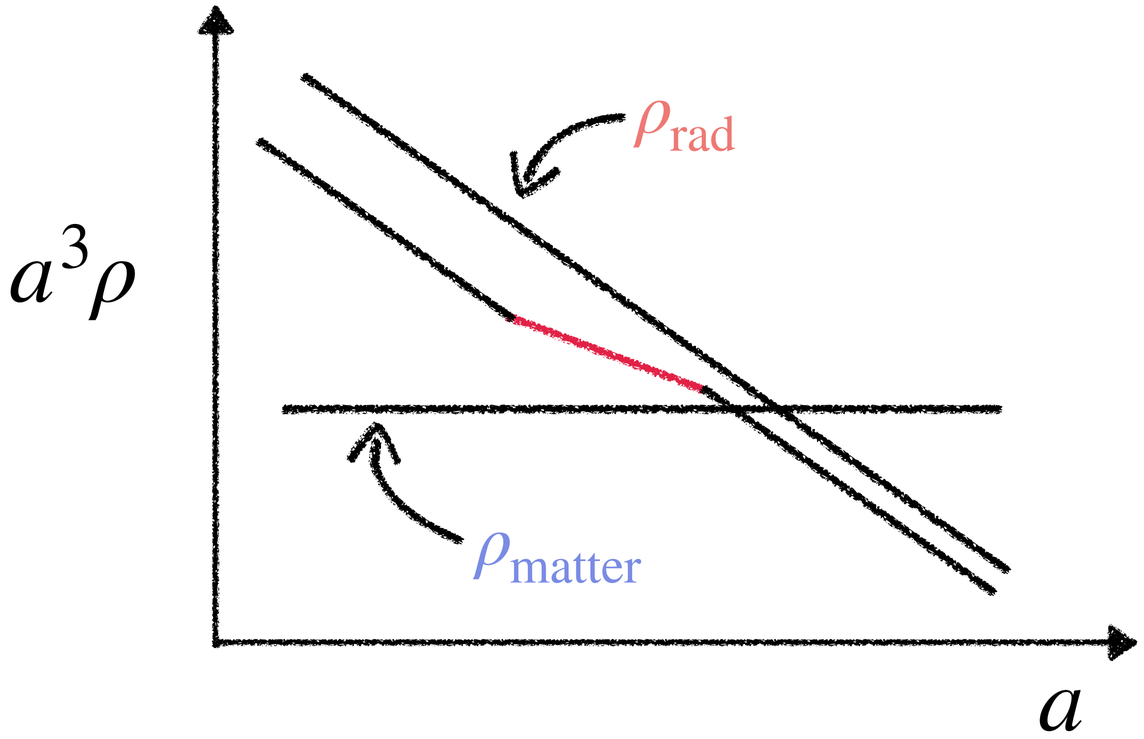
Credit: Riess et al (2021)



Chabanier, Millea, Palanque-Delabrouille 2019

Stepped Radiation

Aloni, **Joseph**, Schmaltz, Weiner arXiV: 2111.00014



Massless fermion ψ

Light scalar ϕ

Stepped Radiation

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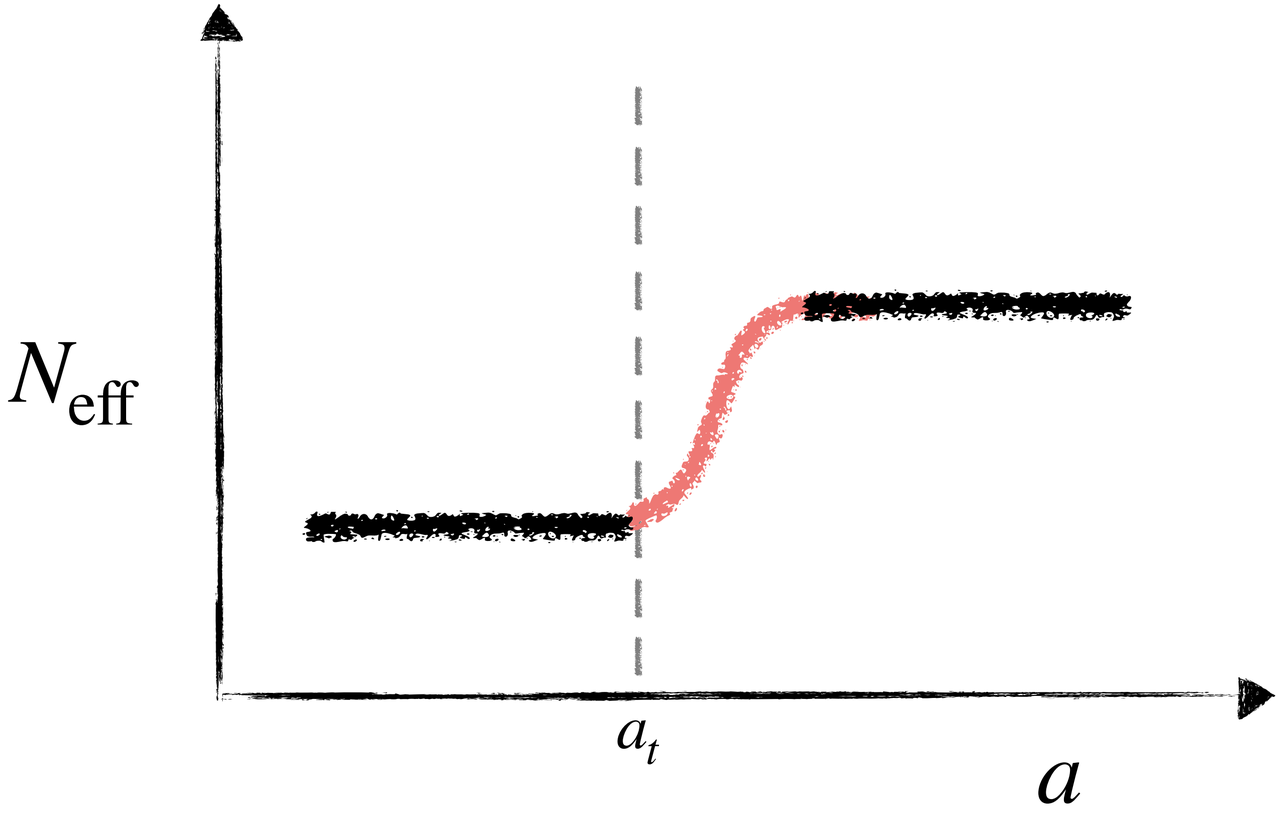
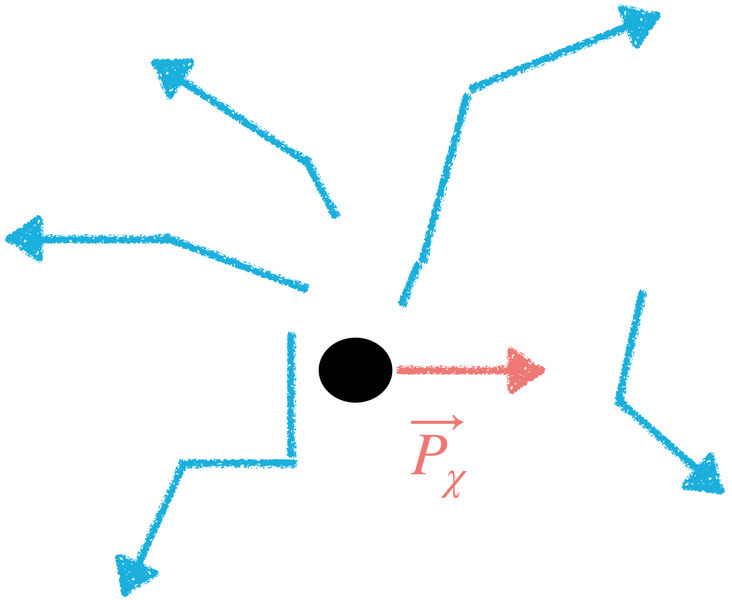


Massless fermion ψ

Light scalar ϕ

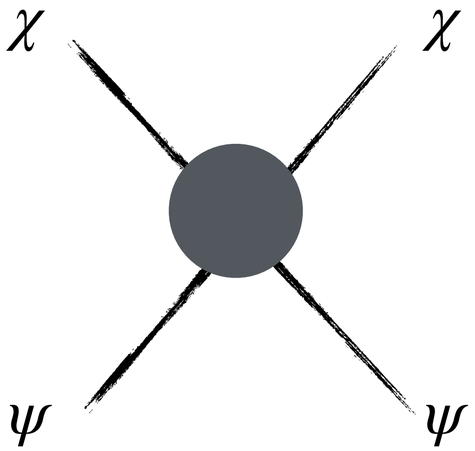
DM-DR Interactions: Structure Formation



DM interactions with radiation gives the DM additional pressure

This can suppress the growth of perturbations at scales relevant for S_8

DM Fluid Equations



$$\dot{\delta}_{DM} = -\theta_{DM} + 3\dot{\phi}$$

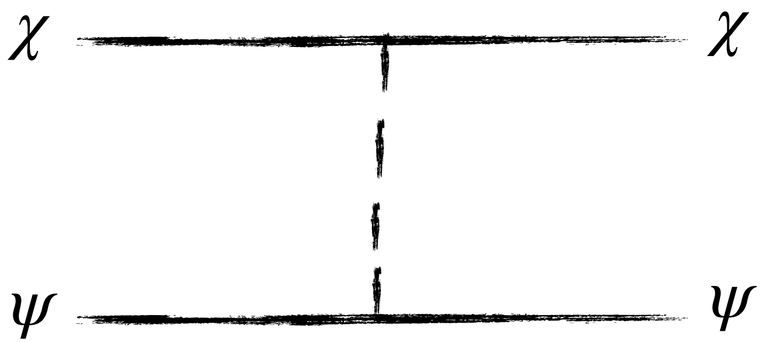
$$\dot{\theta}_{DM} = -\mathcal{H}\theta_{DM} + k^2\psi$$

$$\dot{\theta}_{IDM} = -H\theta_{DM} + k^2\psi + a\Gamma\left(\theta_{WZ} - \theta_{IDM}\right)$$

Couples dipole moments of DM and DR

DM-DR Interactions: Weakly Interacting

Before the mass threshold

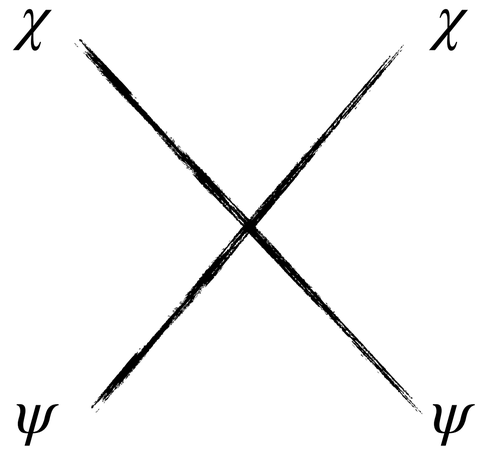


$$\Gamma \propto \frac{T_d^2}{M_\chi}$$

$$H \sim \frac{T^2}{M_{pl}}$$

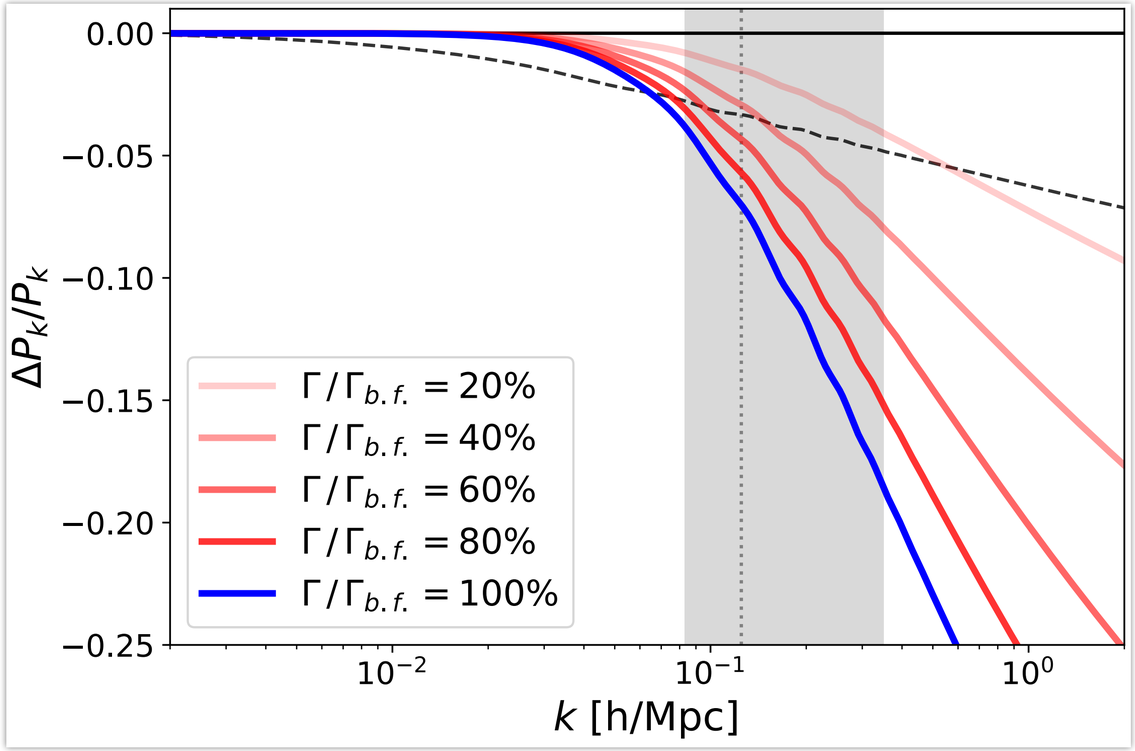
(Radiation dominated)

After the mass threshold

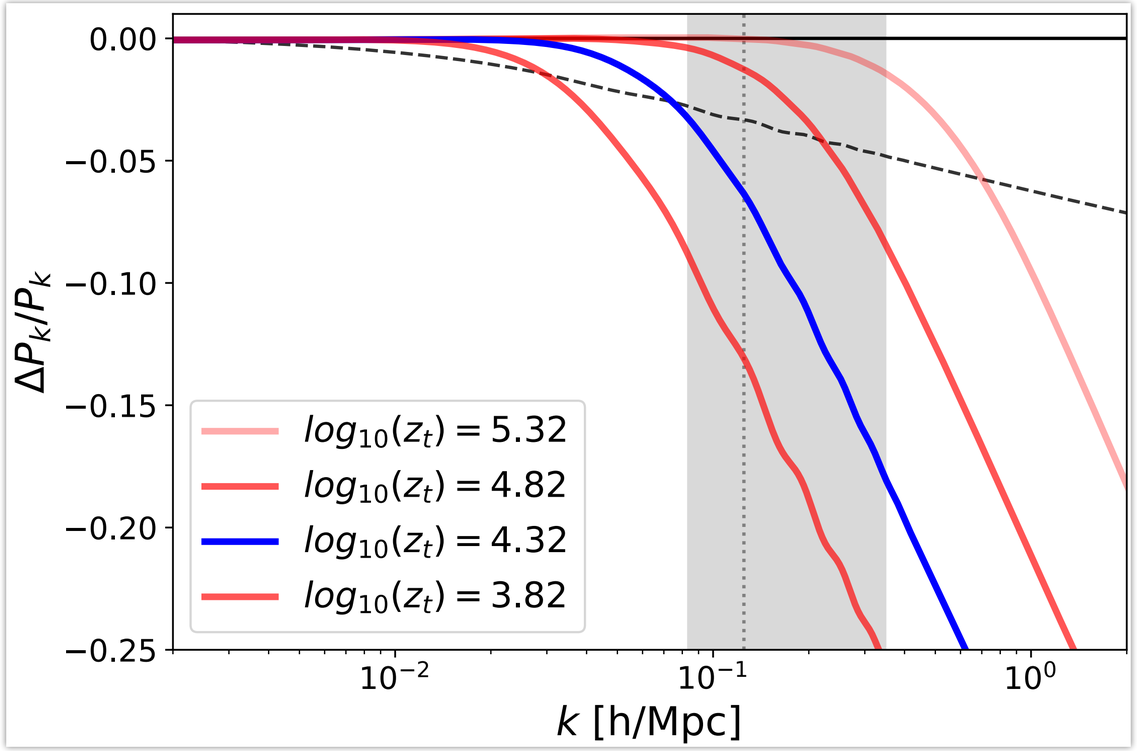


$$\Gamma \propto \frac{T_d^2}{M_\chi} \left(\frac{T_d}{m_\phi} \right)^4$$

vs no DM-DR interaction



vs no mass threshold

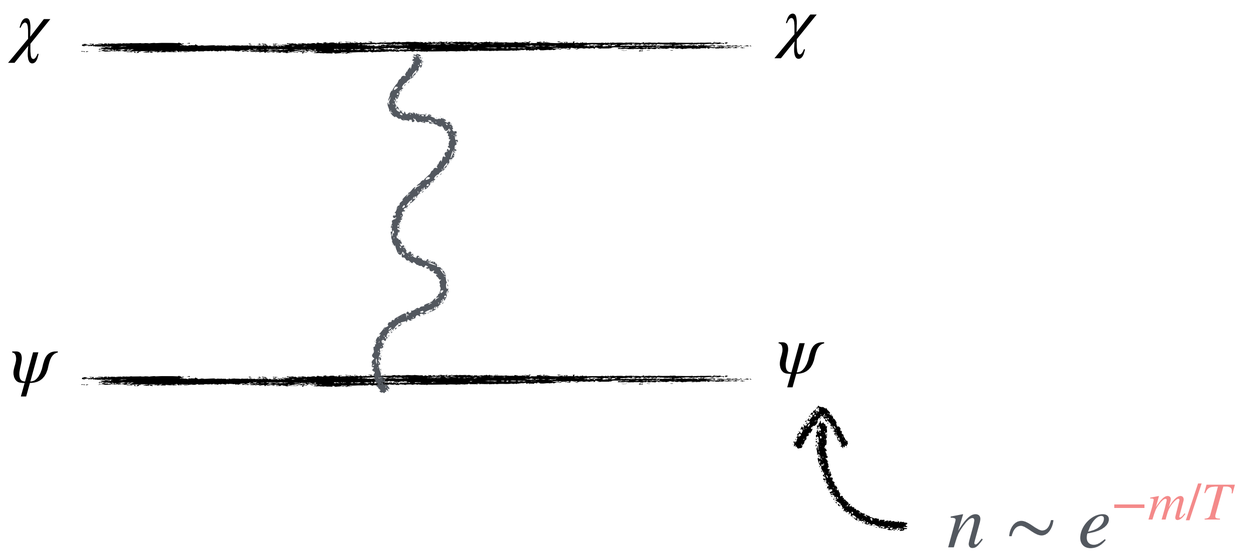


$$\frac{P \text{ interacting}}{P_{\text{not-interacting}}} \simeq \begin{cases} 1 & k \ll k_{s.o.} \\ 1 - \sqrt{2}\,\frac{\Gamma}{H} \times \log k/k_{s.o.} & k \gg k_{s.o.} \end{cases}$$

Smooth suppression in log k due to weak coupling

DM-DR Interactions: Strongly Interacting

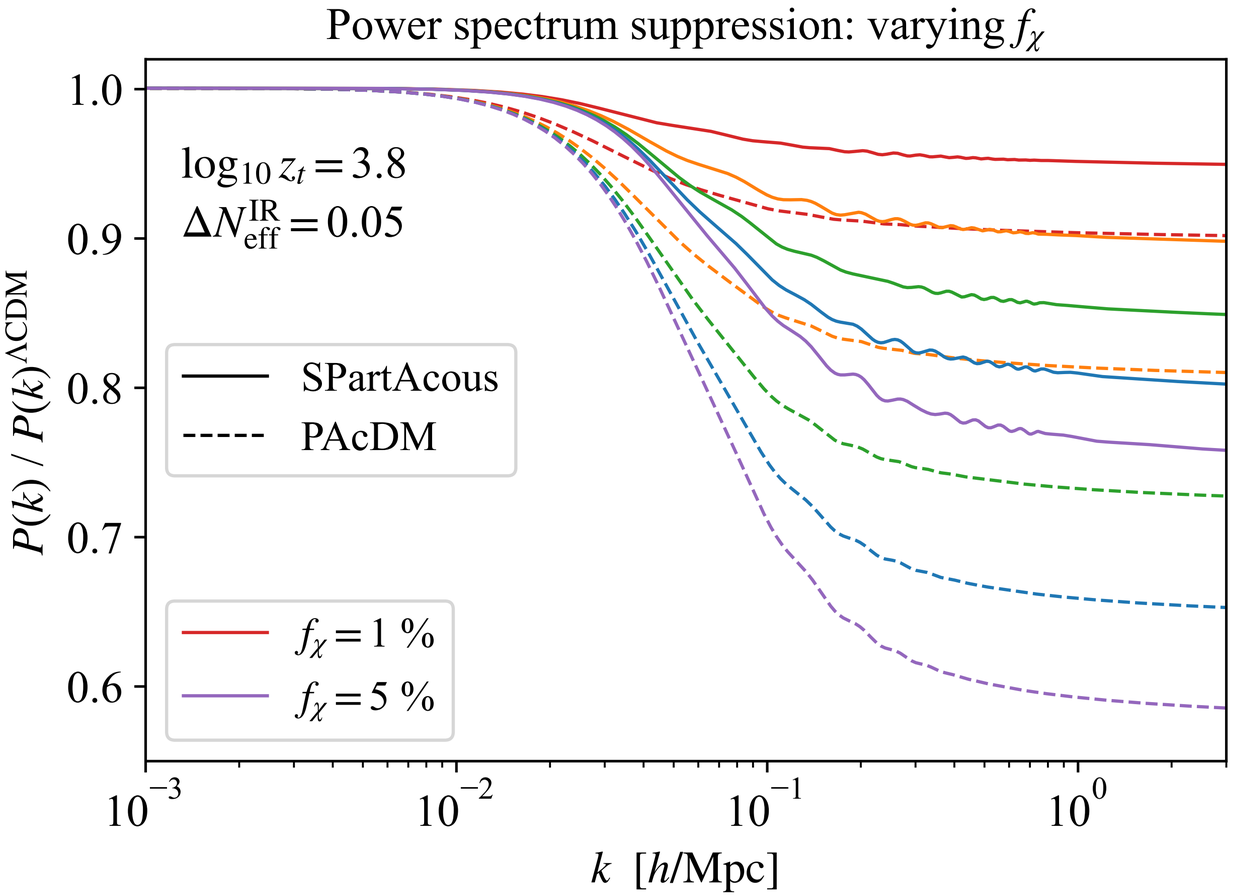
Buen-Abad et al, arXiV: 2208.05984, 2306.01844



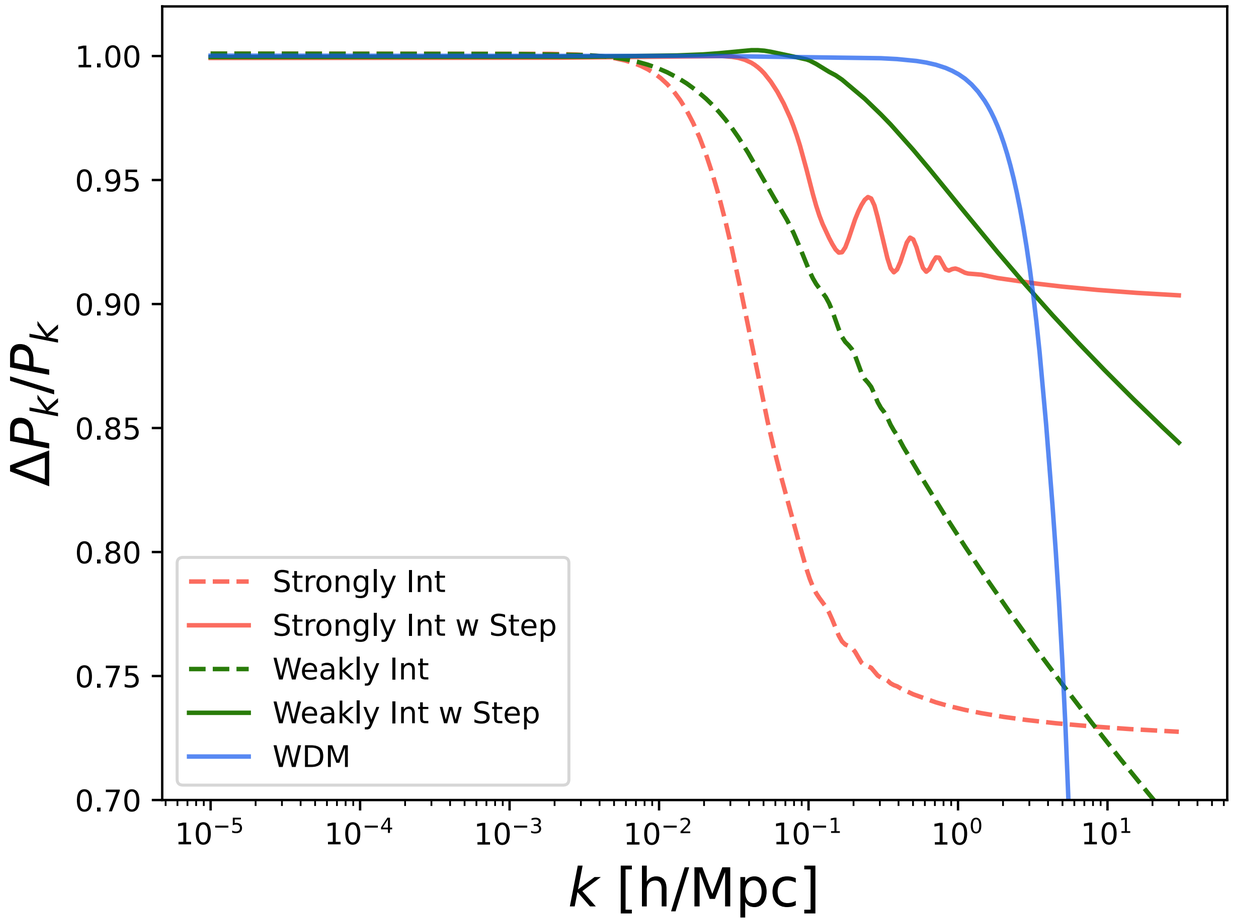
Light fermion ψ

Gauge boson A_μ

DM-DR Interactions: Strongly Interacting



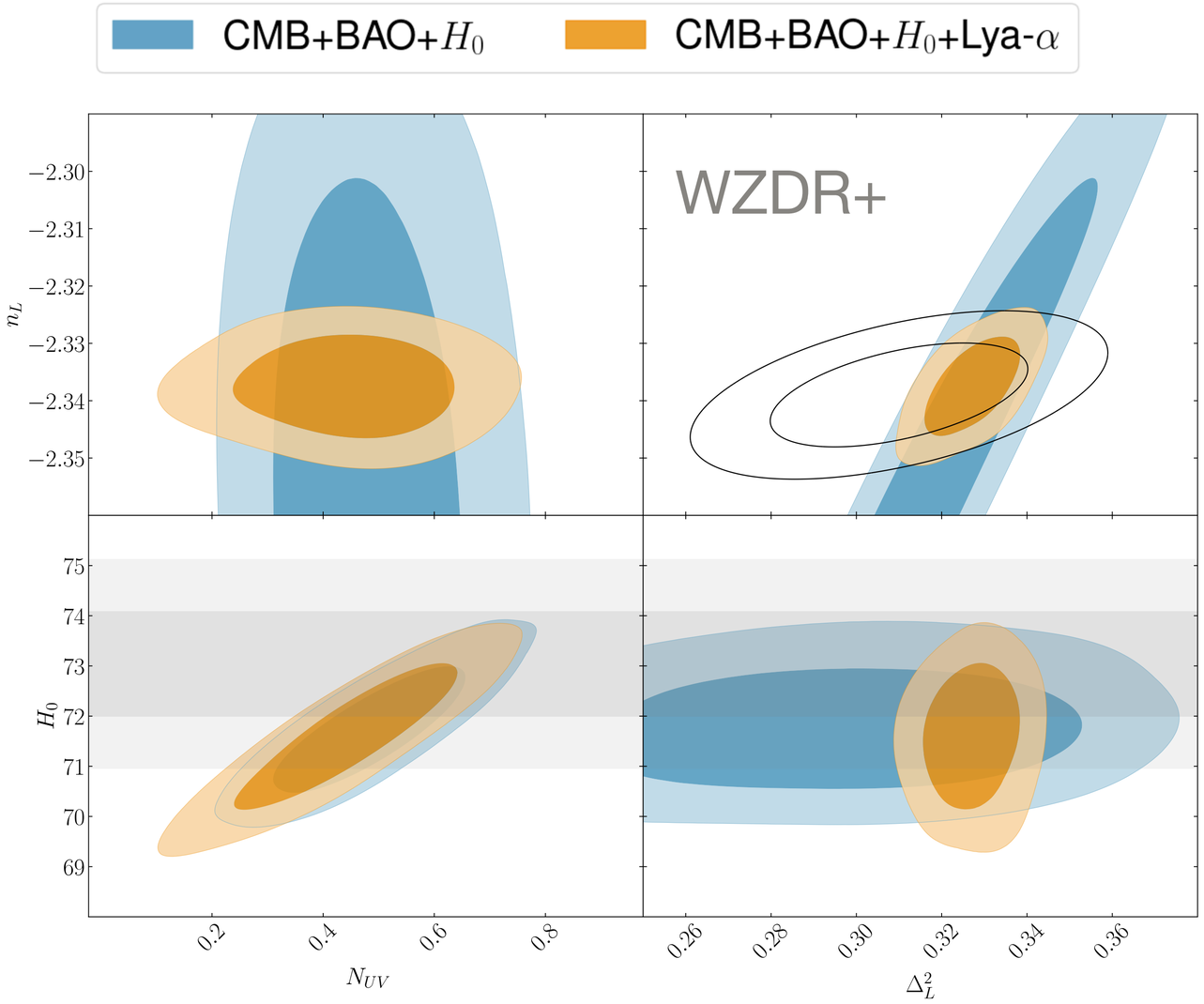
- Fraction of DM is strongly interacting - dark acoustic oscillations
- Exponential shut-off of DM-DR interactions after mass threshold (at z_t)

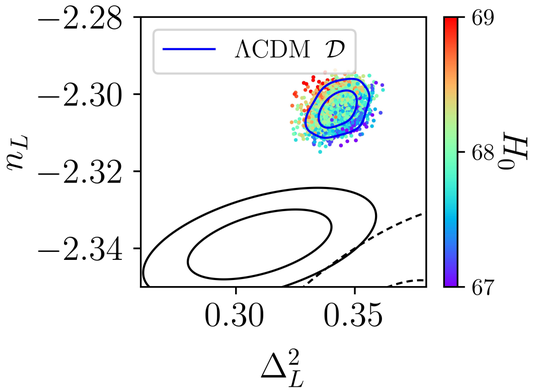


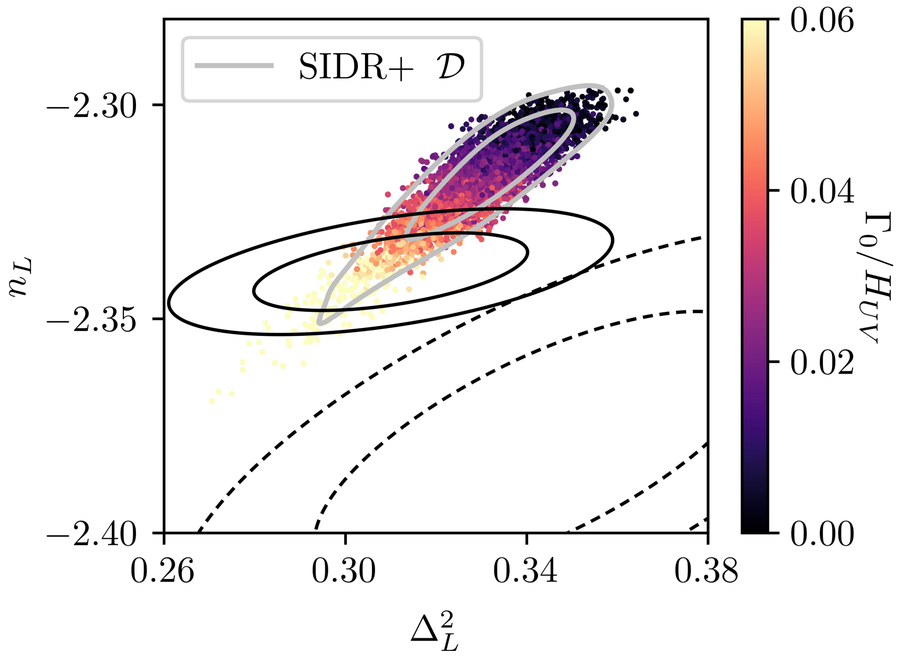
- Deviations from standard assumptions of CDM can leave (non-primordial) imprints in MPS
- Need measurements of power at small-scales to differentiate these models

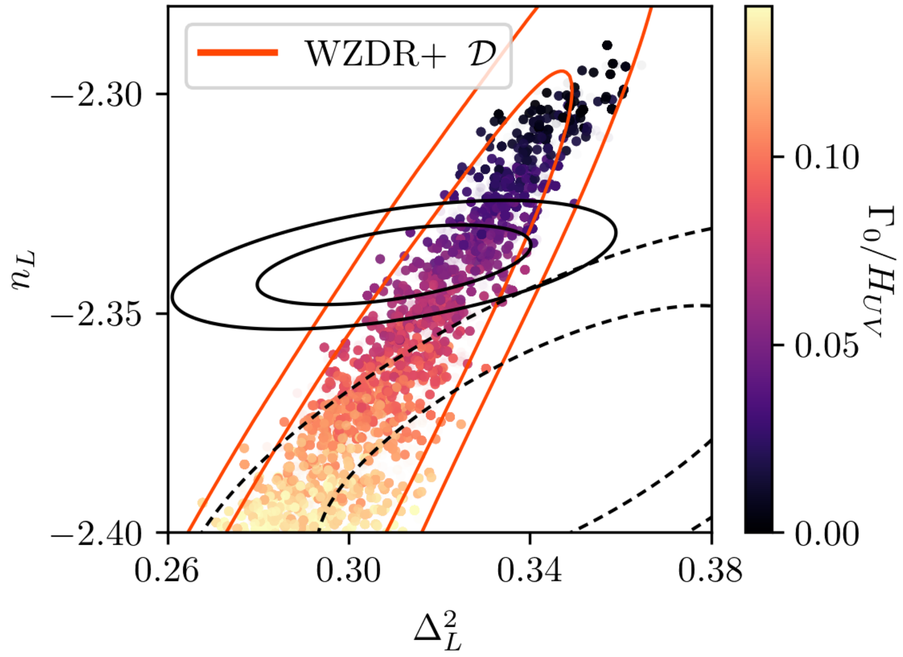
Conclusions

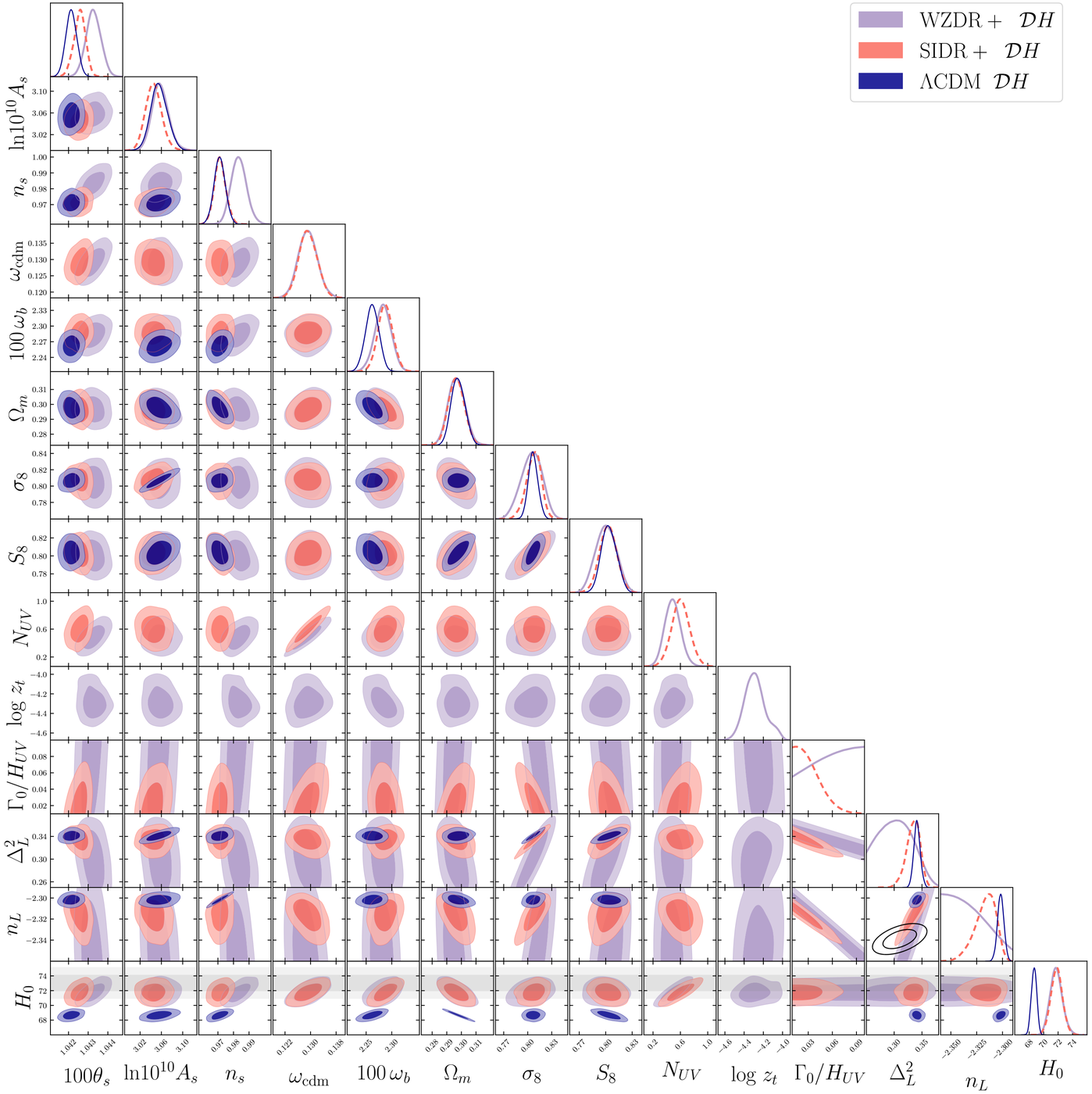
- Interacting dark sector models (stepped dark sectors …) alleviate cosmological tensions while still providing good fits to LSS
- Can provide concrete targets for extensions of LCDM
- Measurements of the MPS at smaller scales will allow us to distinguish between these models

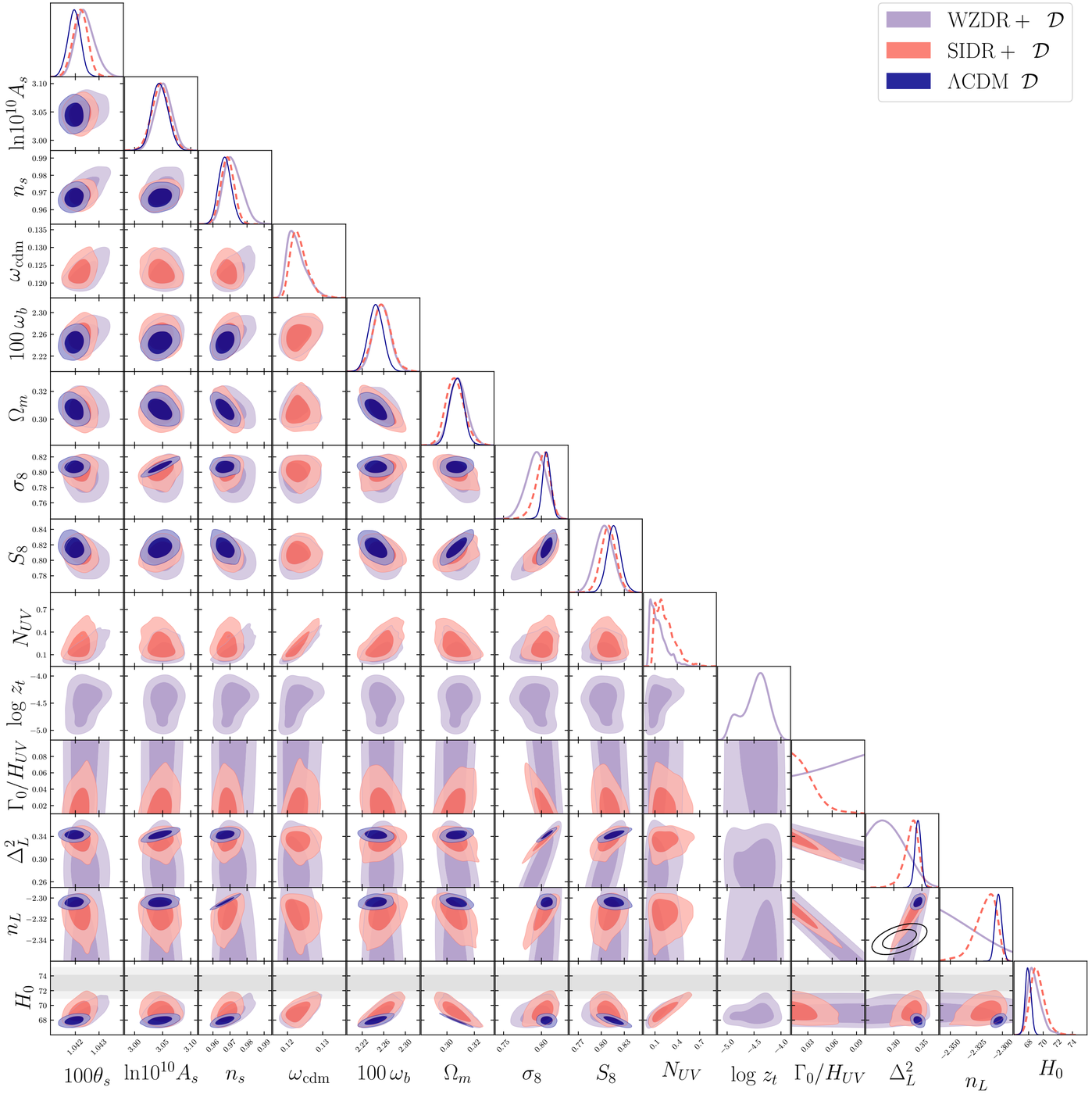

CMB+BAO+H_0
CMB+BAO+H_0+Lya-α
WZDR+
n_L
H_0
N_{UV}
Δ_L^2


ΛCDM $\mathcal{D}$
n_L
H_0
Δ_L^2


SIDR+ $\mathcal{D}$
-2.30
-2.35
-2.40
n_L
0.26
0.30
0.34
0.38
Δ_L^2
0.06
0.04
0.02
0.00
Γ_0/H_{UV}


WZDR+ $\mathcal{D}$
-2.30
-2.35
-2.40
n_L
0.26
0.30
0.34
0.38
Δ_L^2
0.10
0.05
0.00
Γ_0/H_{UV}


WZDR + $\mathcal{D}H$
SIDR + $\mathcal{D}H$
ΛCDM $\mathcal{D}H$
$100\theta_s$
$\ln10^{10}A_s$
n_s
$\omega_{\rm cdm}$
$100\,\omega_b$
Ω_m
σ_8
S_8
N_{UV}
$\log\,z_t$
Γ_0/H_{UV}
Δ_L^2
n_L
H_0


WZDR + $\mathcal{D}$
SIDR + $\mathcal{D}$
ΛCDM $\mathcal{D}$
$100\theta_s$
$\ln10^{10}A_s$
n_s
$\omega_{\rm cdm}$
$100\,\omega_b$
Ω_m
σ_8
S_8
N_{UV}
$\log\,z_t$
Γ_0/H_{UV}
Δ^2_L
n_L
H_0