Interacting Dark Sectors: a tale of two components

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Pheno 2017 Symposium

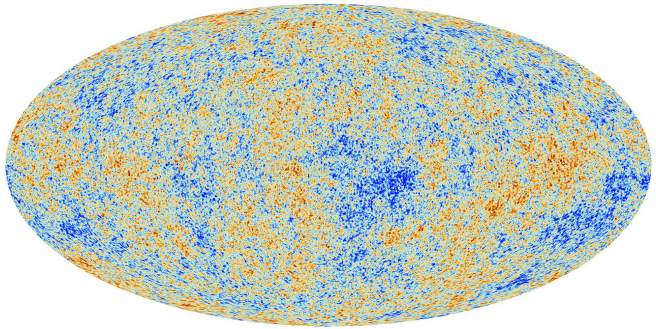
Outline

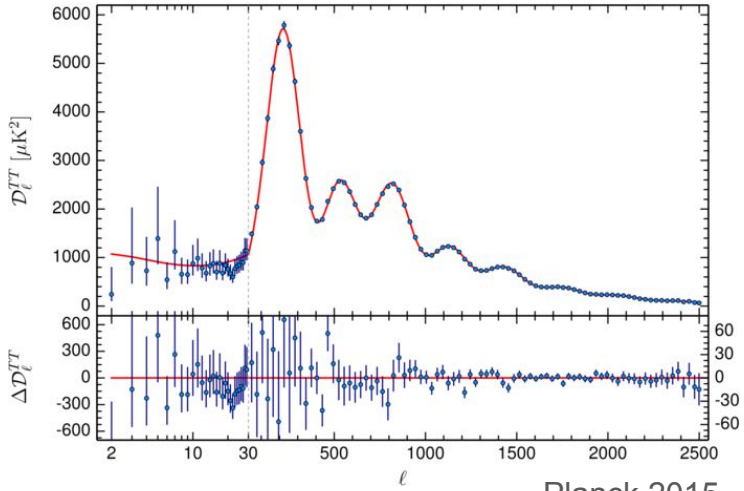
I. Introduction
II. Cosmic Discordance
III. The Model
IV. Results
V. Conclusions

- arXiv:1505.03542
- arXiv:1507.04351
- arXiv:1705.XXXXX

I. Introduction

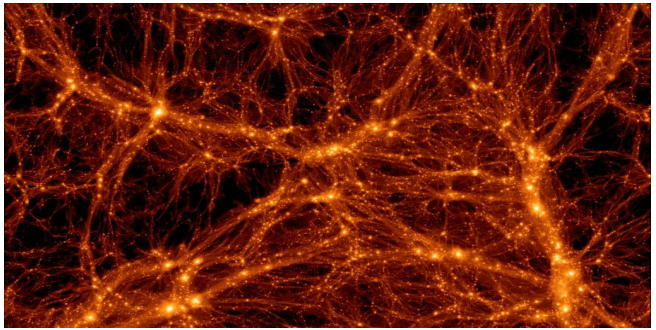
CMB

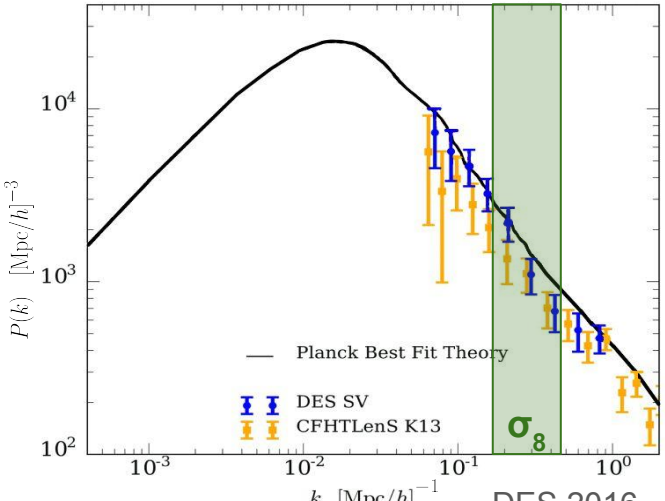




Planck 2015

Structure (MPS)





DES 2016

ΛCDM

$$\rho_{tot} = \rho_{cdm} + \rho_b + \rho_\gamma + \rho_\nu + \rho_\Lambda$$

$$\delta_i = \delta\rho_i/\rho_i$$

CDM linear pert. eqns.

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

$$\dot{\theta}_{\rm cdm} = -\mathcal{H}\theta_{\rm cdm} + k^2\phi$$

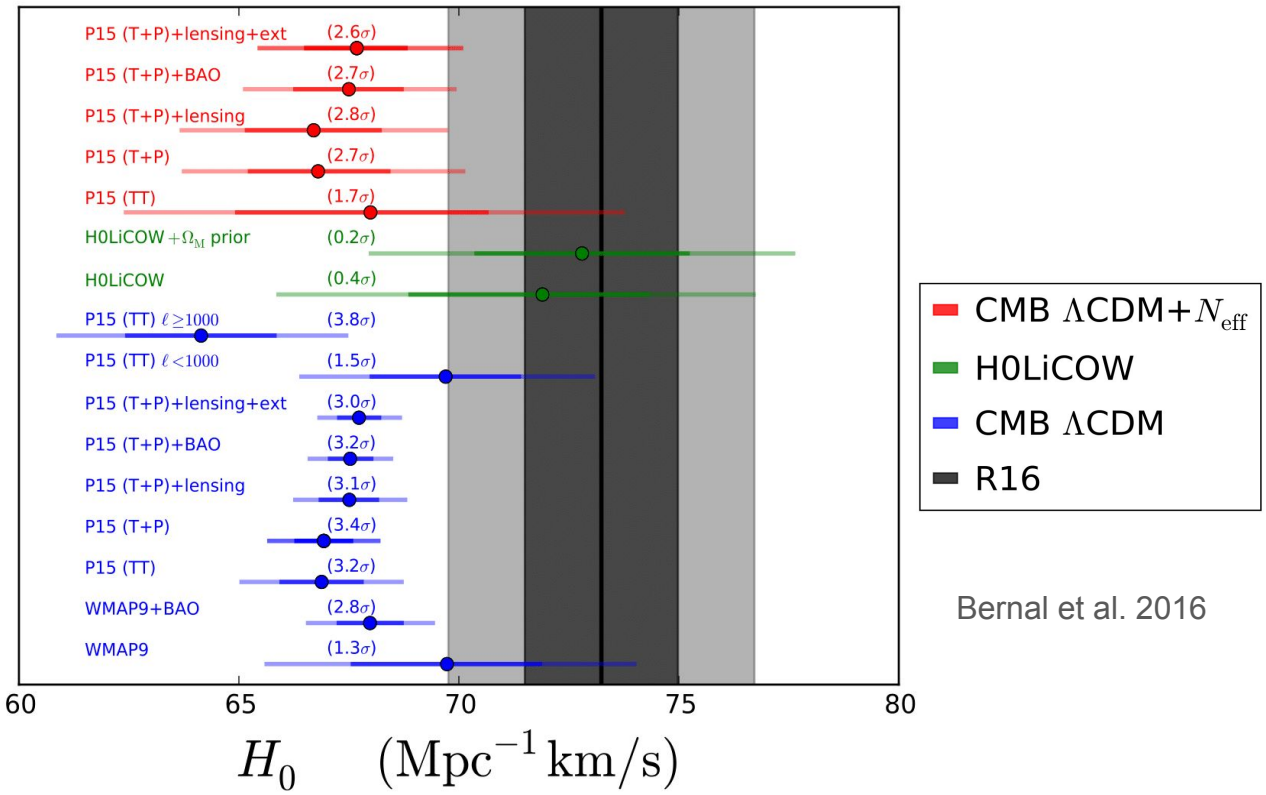
Ma & Bertschinger (1995)

II. Cosmic Discordance

H_0

- H_0 = **67.27 ± 0.66 Mpc^{-1} km/s (Planck 2015)**
- H_0 = **73.24 ± 1.74 Mpc^{-1} km/s (Riess et al. 2016)**

Solution? ΔN_{eff}

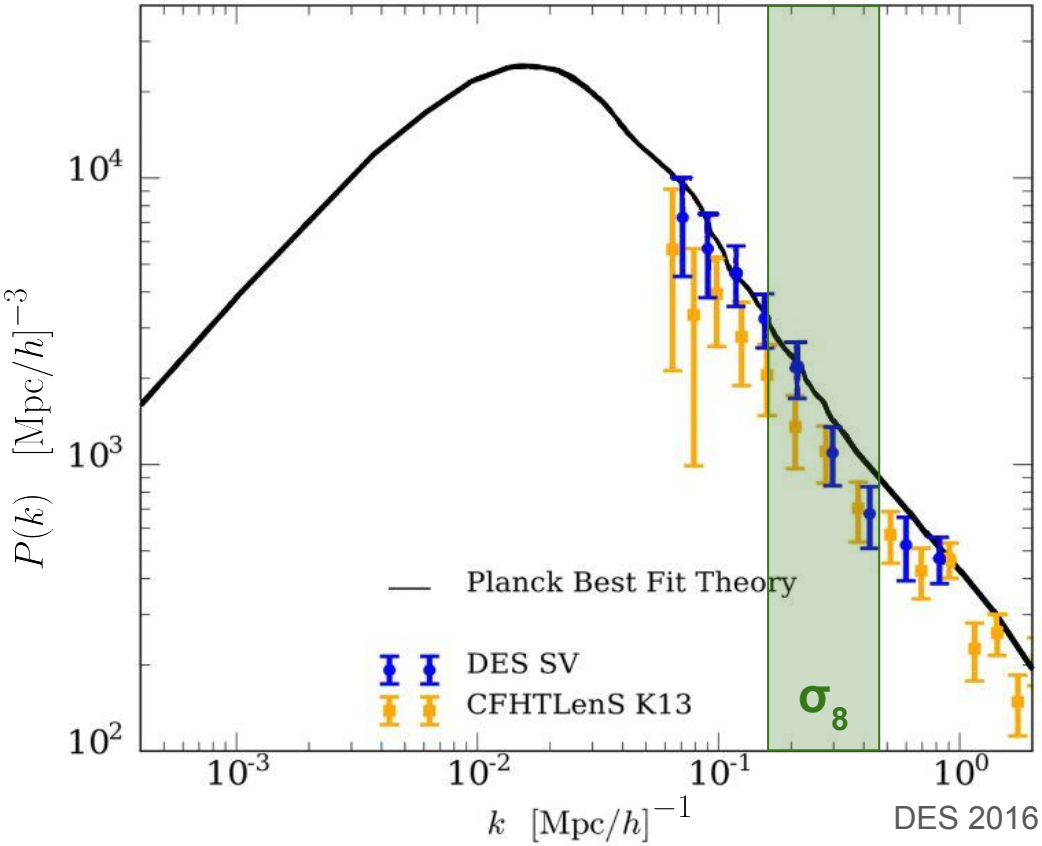


Bernal et al. 2016

σ_8

- σ_8 = 0.831 ± 0.013 (Planck 2015)
- $\sigma_8 (\Omega_m/0.27)^{0.48}$ = 0.768±0.037 (CFHTLens, MacCrann et al.)
- Planck SZ clusters, Planck gravitational lensing, KiDS-450, …

Solution? Suppress MPS

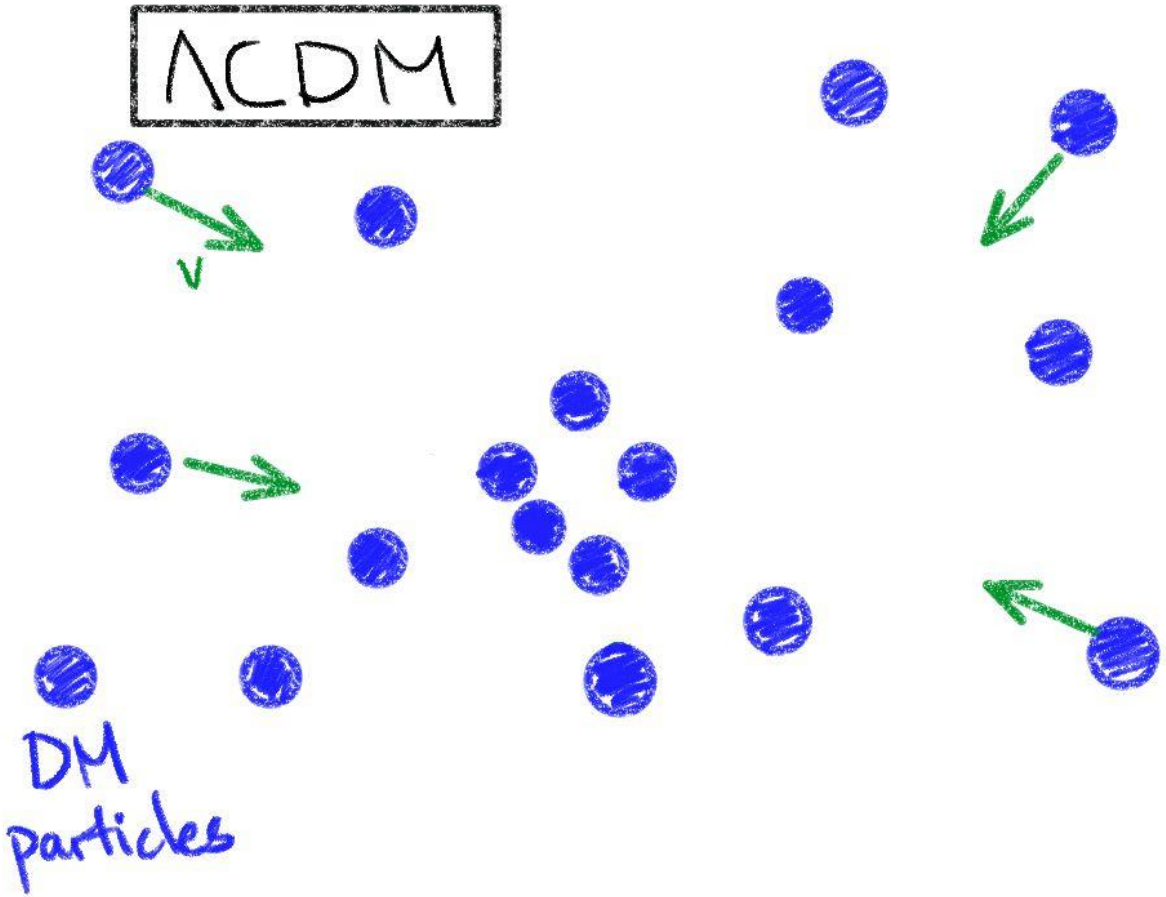


III. The Model

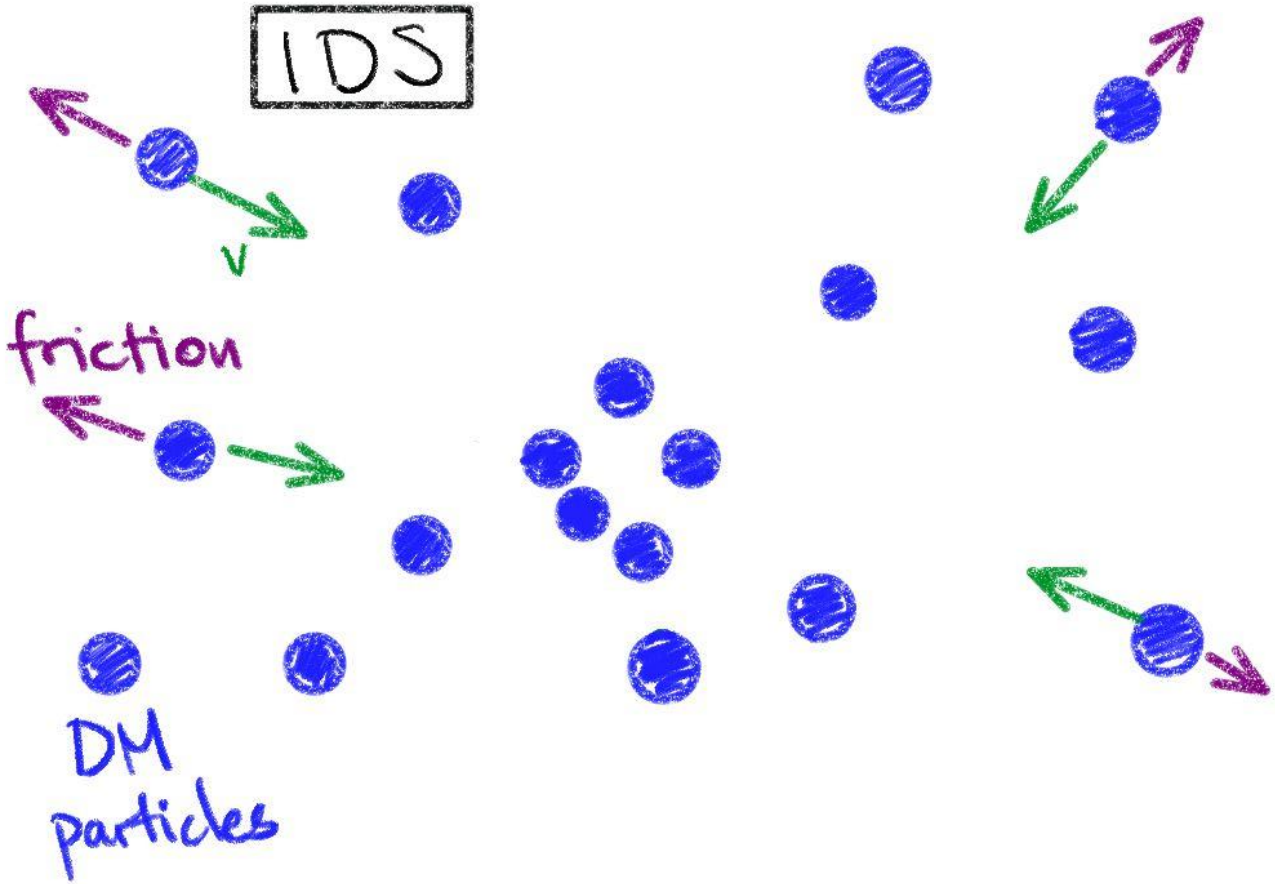
IDS

$$\rho_{tot} = \rho_{cdm} + \rho_b + \rho_\gamma + \rho_\nu + \rho_\Lambda + \rho_{idm} + \rho_{dr}$$

$\rho_{idm} + \rho_{dr}$: Γ



Structure Formation: Microscopic Picture



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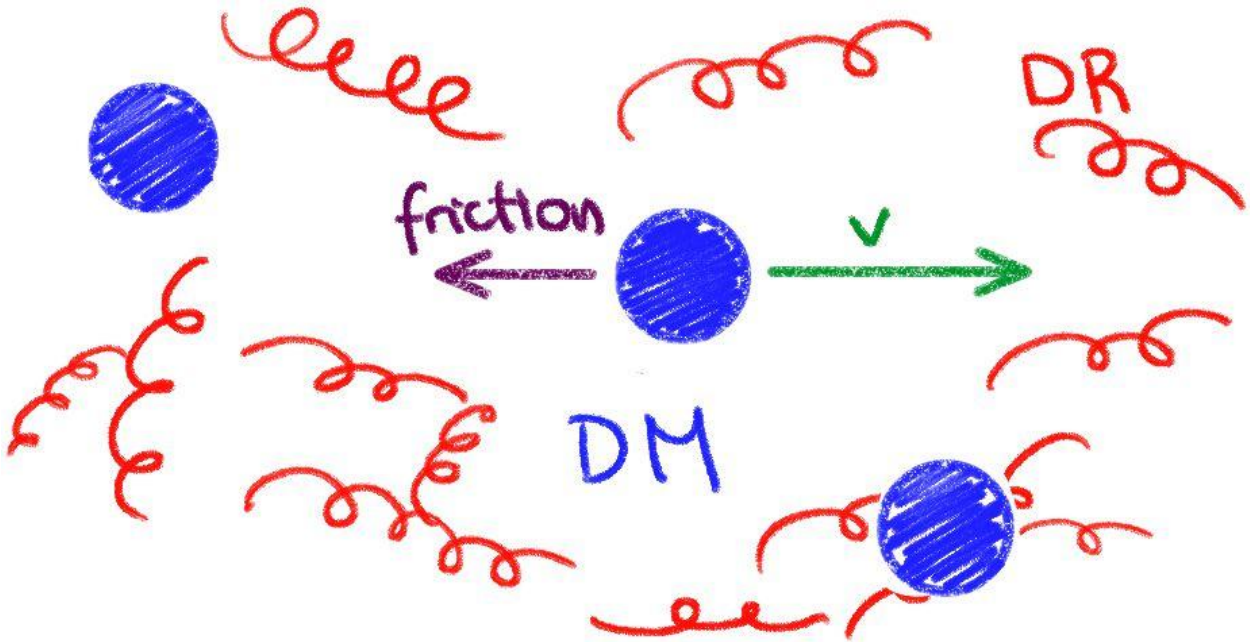


Friction

IDS lin. pert. eqns.

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

$$\dot{\theta}_{\text{idm}} = -\mathcal{H}\theta_{\text{idm}} + k^2\psi + a\Gamma(\theta_{\text{dr}} - \theta_{\text{idm}})$$

$$\dot{\delta}_{\text{dr}} = -\frac{4}{3}\theta_{\text{dr}} + 4\dot{\phi}$$

$$\dot{\theta}_{\text{dr}} = k^2\left(\frac{\delta_{\text{dr}}}{4} + \psi\right) - a\Gamma R_{\text{idm-dr}}(\theta_{\text{dr}} - \theta_{\text{idm}})$$

$$R_{\text{idm-dr}} \equiv \frac{3}{4}\frac{\rho_{\text{idm}}}{\rho_{\text{dr}}}$$

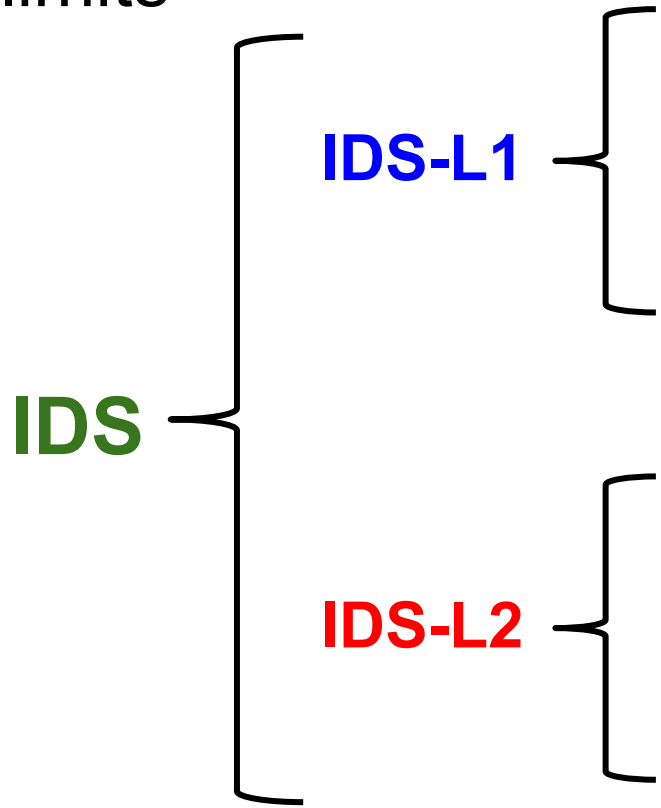
Parameters

$$\Gamma$$

$$\Delta N_{\mathrm{eff}}$$

$$f \equiv \frac{\rho_{\mathrm{idm}}}{\rho_{\mathrm{dm\ tot}}}$$

Two limits



IDS-L1

f=1, Γ << H:

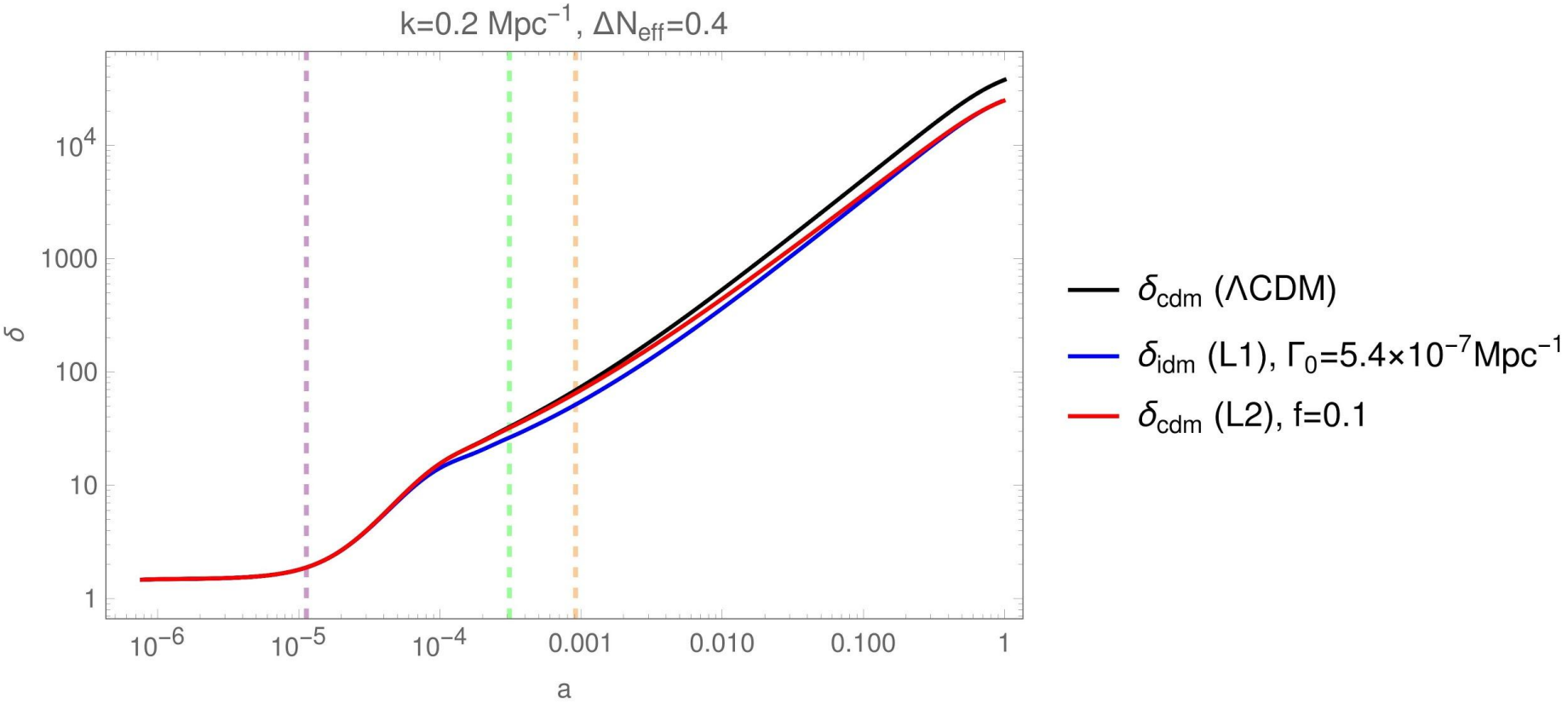
All DM is IDM and feels friction

IDS-L2

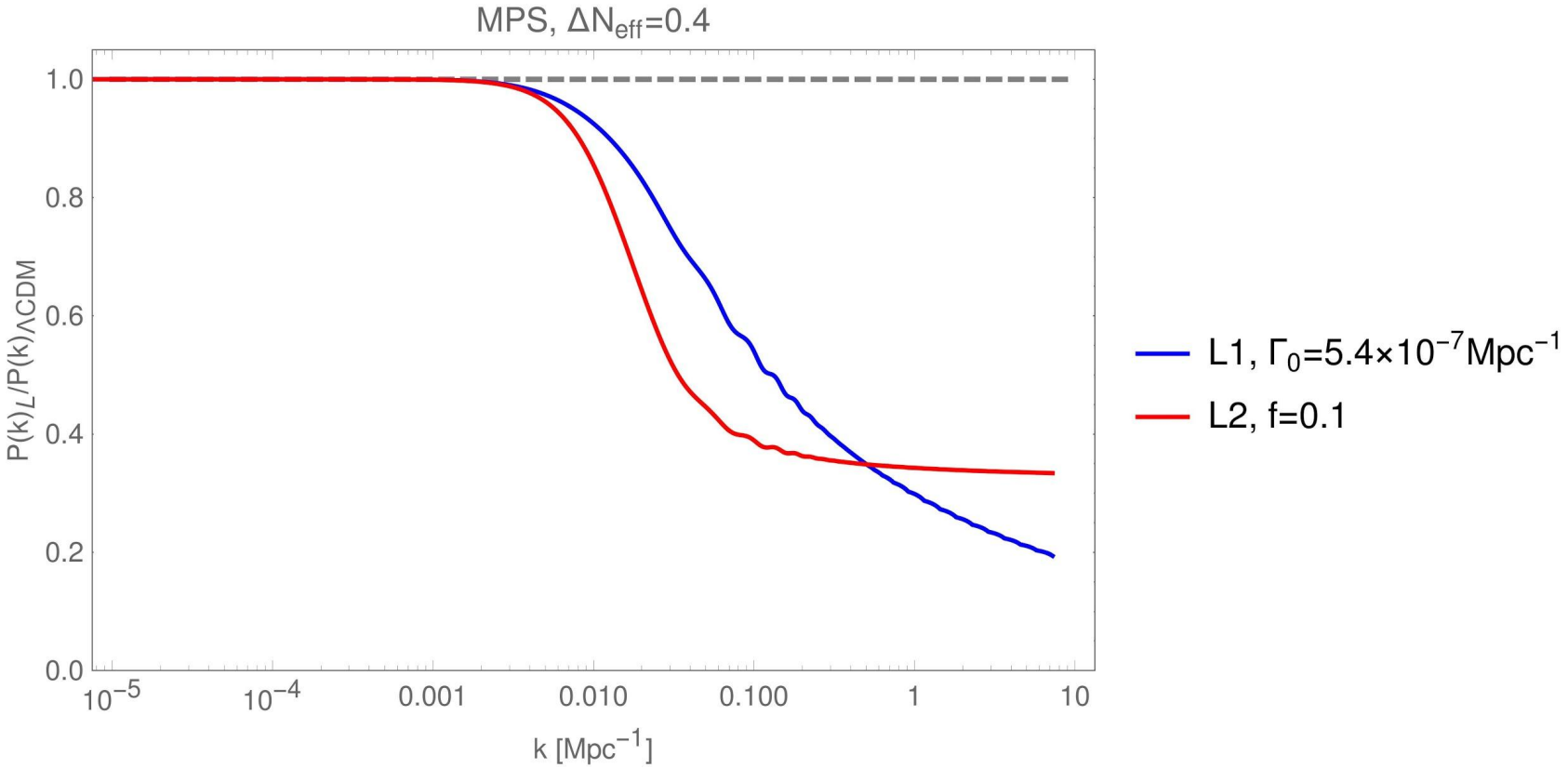
f<<1, Γ >> H:

Part of DM is IDM large friction ⇒ tightly coupled to DR: Dark Plasma

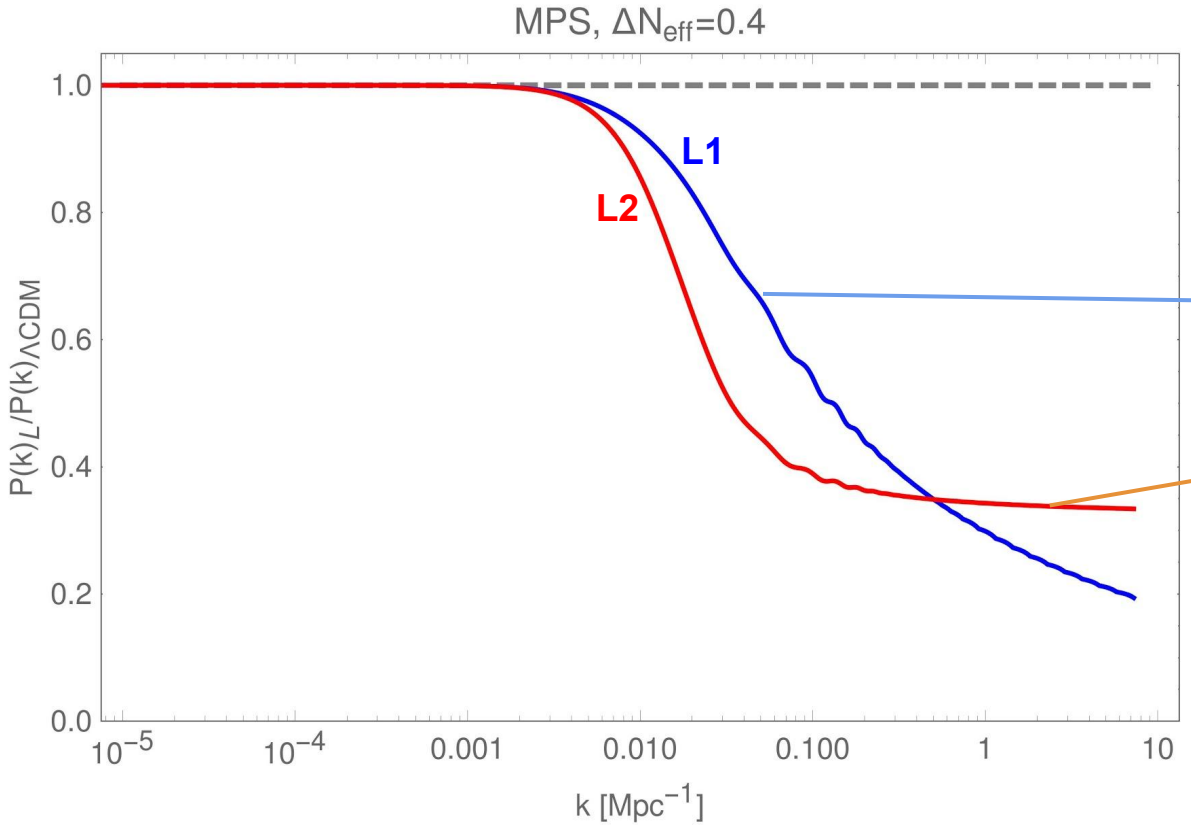
Chacko et al. 2016



DM perturbations


MPS, ΔN_eff=0.4
P(k)_L/P(k)_ΛCDM
1.0
0.8
0.6
0.4
0.2
0.0
10^-5
10^-4
0.001
0.010
0.100
1
10
k [Mpc^-1]
L1, Γ_0=5.4×10^-7 Mpc^-1
L2, f=0.1

MPS



$$\sim -\left.\frac{\Gamma}{H}\right|_{\mathrm{RD}} \log k$$

$$\sim (1-2f)\left(\frac{a_0}{a_{\mathrm{eq}}}\right)^{-\frac{6}{5}f}$$

Chacko et al. 2016

MPS

IV. Results

Codes

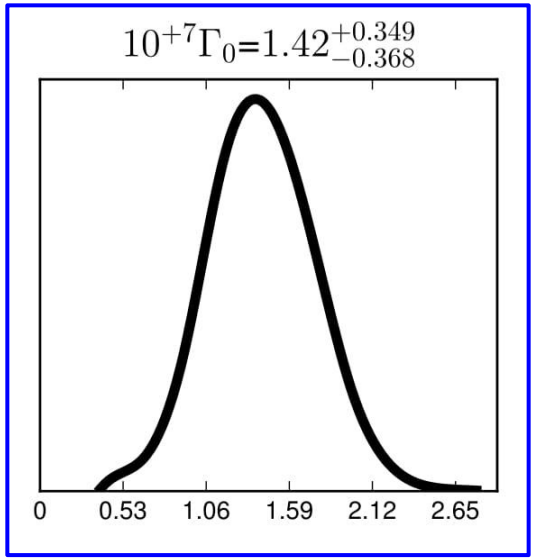
- Boltzmann Code (cosmological eqns.):
  - CLASS
- Fit to data:
  - Montepython

Modified by Lesgourgues, Schmaltz, & MBA.

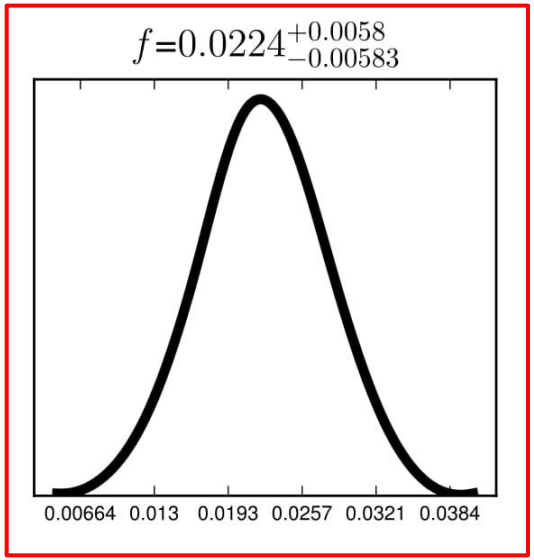
CMB+lensing+BAO+Planck clusters+CFHTLens+SDSS+H_0

$\Delta\chi^2_{L1}$ = -18.4 (3.9σ)

$\Delta\chi^2_{L2}$ = -16.7 (3.7σ)



PRELIMINARY



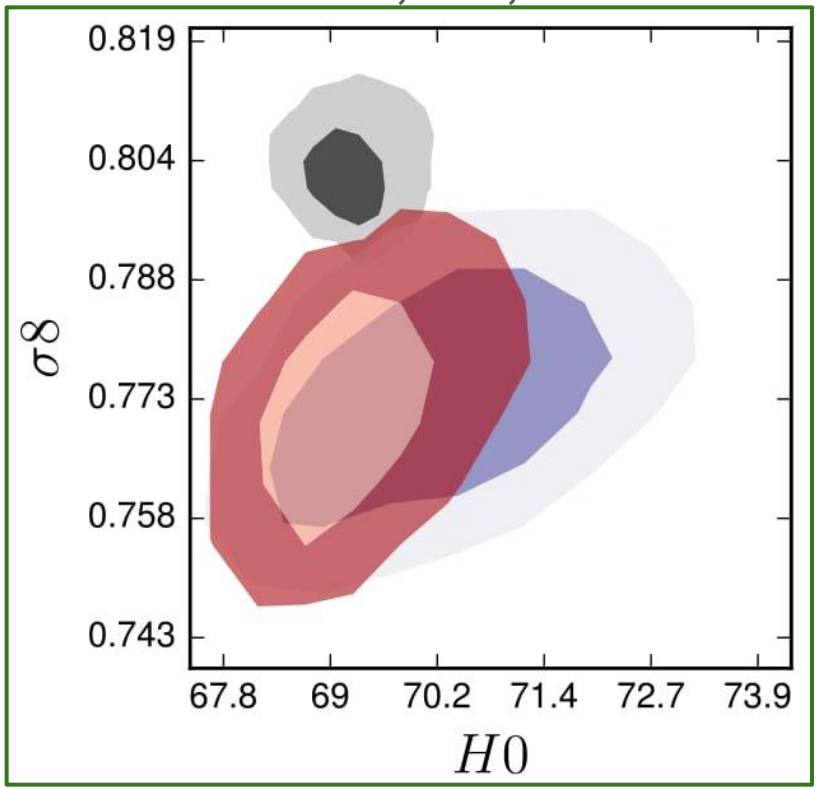
PRELIMINARY

V. Conclusions

Conclusions

- Cosmological data admits the possibility of Interacting Dark Matter.
- New Interacting Dark Sector model eases σ_8 and H_0 tensions (i.e. better global fit).
- Matter Power Spectrum can have different shapes: future observations!

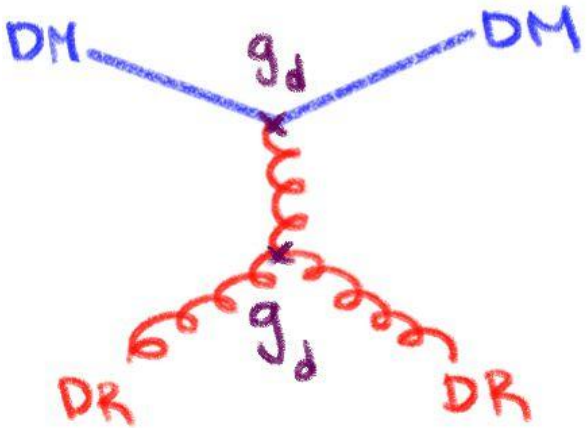
ΛCDM, L1, L2



PRELIMINARY

BACKUP SLIDES

Scattering

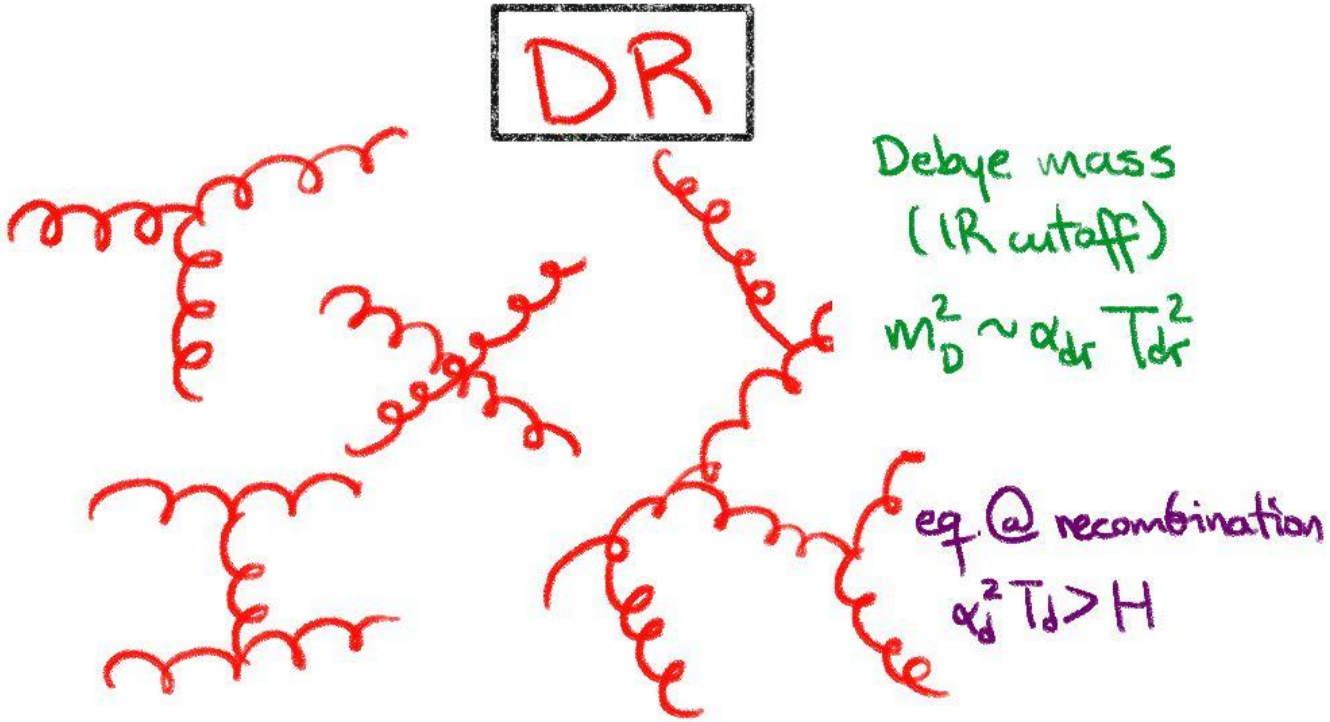


$$\sigma \sim \alpha_d^2 T_{dr}^{-2}$$

$\Rightarrow$ momentum loss rate

$$\Gamma \sim n_{dr} \langle \sigma v \rangle \frac{\Delta p}{p}$$

$$\therefore \Gamma \sim \alpha_d^2 \frac{T_{dr}^2}{M_{dm}} \propto a^{-2}$$



DR self interactions: perfect fluid ($\Pi = 0$)

$c_{eff}^2 = 1/3$, $c_{vis}^2 = 0$

IDS Model

DR: $SU(N)_d$, $\alpha_{dr} \ll 1$ $(\neq \Lambda_d \ll T_{dr,0})$

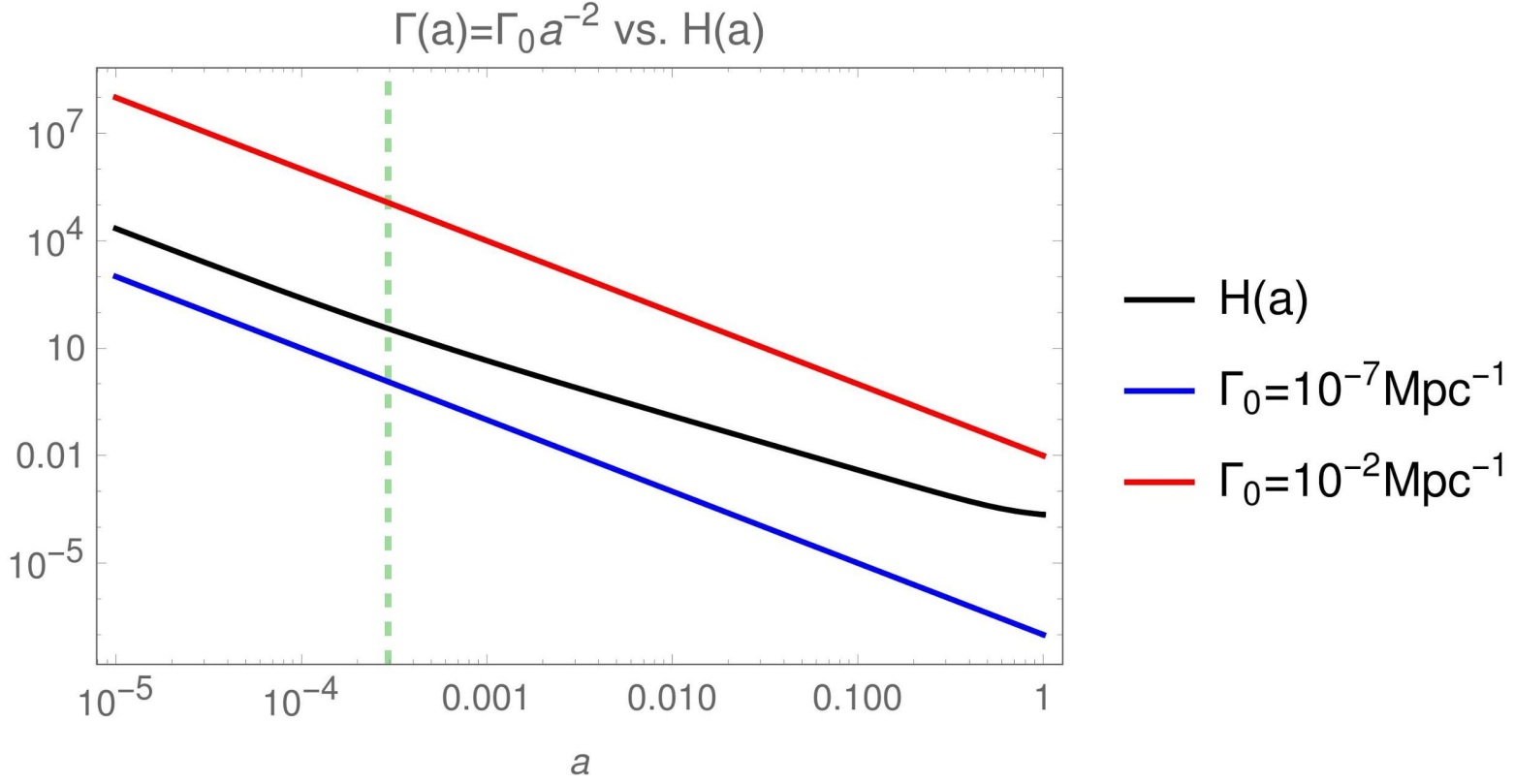
$$\Delta N_{eff} = \frac{8}{7}(N^2-1)(T_d/T_\nu)^4$$

IDM: $N \sim SU(N)_d$; $\Gamma \equiv \Gamma_0 a^{-2}$;

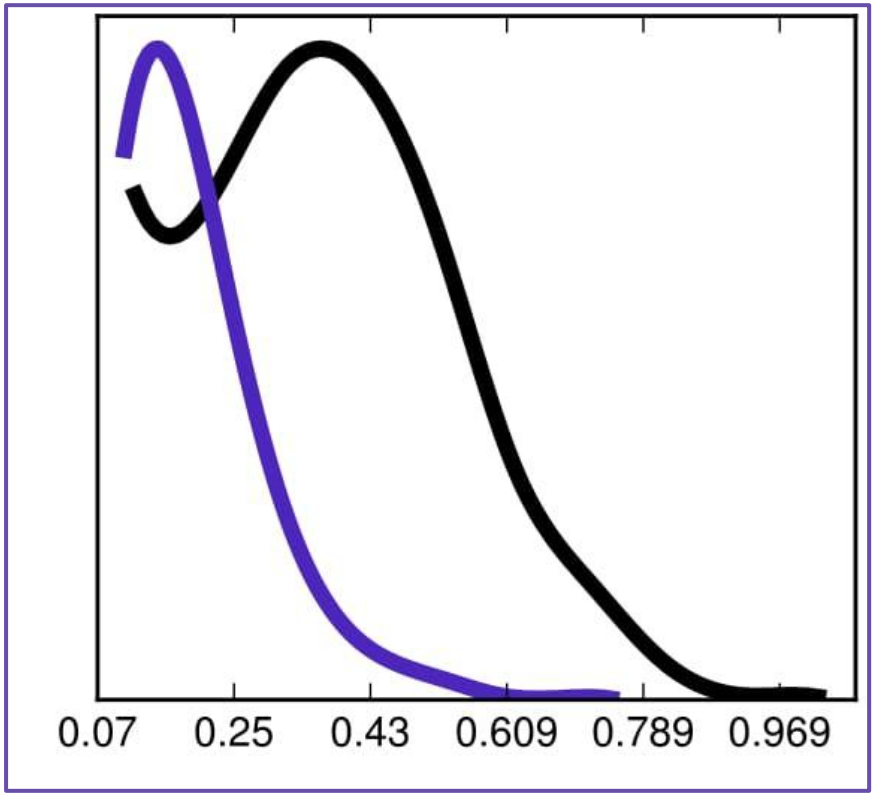
$$\Gamma_0 = \frac{\pi^2}{9}(N^2-1)\alpha_d^2 \log \alpha_d^{-1} \frac{T_{dr}^2}{M_{idm}}$$

$H_0 \simeq 2.4 \times 10^{-4} M_{pl}^{-1}$ (L2: $\Gamma_0 \gg H_0 \Leftrightarrow \alpha_d > 10^{-7}$)

Γ vs. H


Γ(a)=Γ0a−2 vs. H(a)
10^7
10^4
10
0.01
10^−5
10^−5
10^−4
0.001
0.010
0.100
1
a
H(a)
Γ0=10^−7Mpc^−1
Γ0=10^−2Mpc^−1

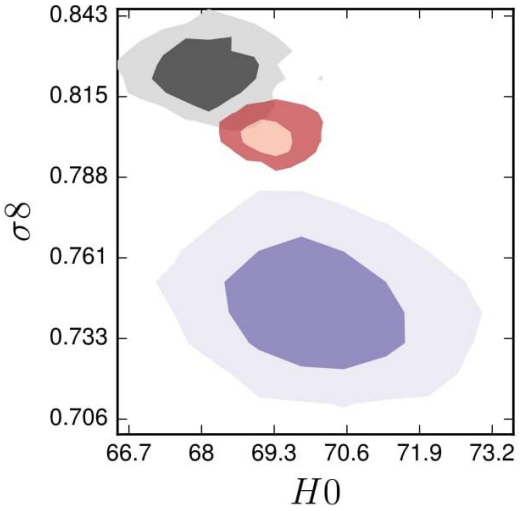
ΔN_{eff}



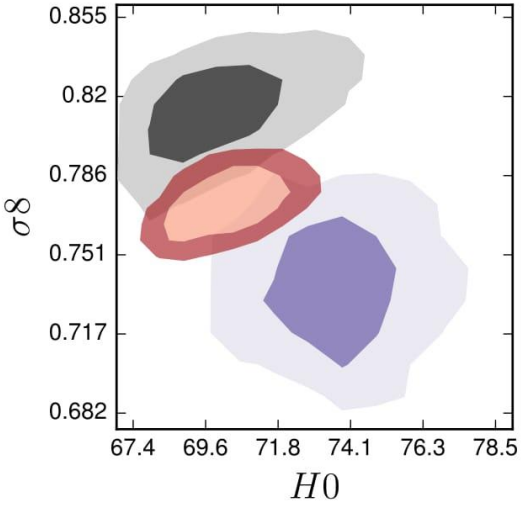
L1, **L2**

PRELIMINARY

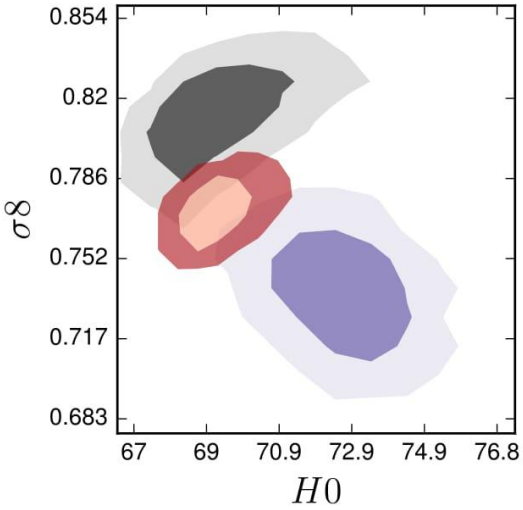
ΛCDM



L1



L2



CMB, **LSS+BAO+H0**, **COMBINED**

PRELIMINARY