Large Scale Structure and Cannibal Dark Matter

Manuel Buen-Abad, BU
Razieh Emami, HKUST
Martin Schmaltz, BU

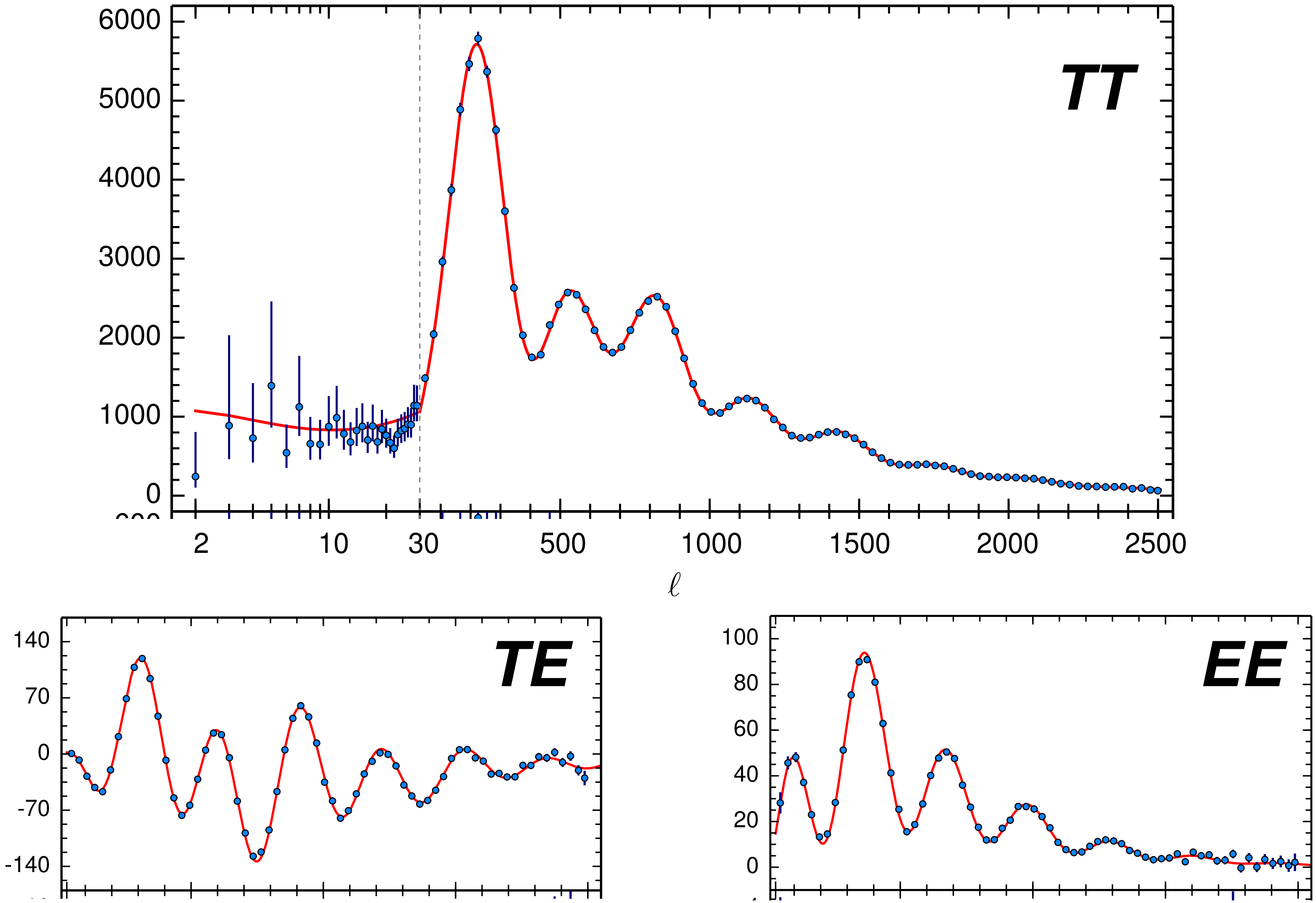
1803.08062

Outline

1. **data** matter power spectrum σ_8

2. **model** partially cannibalistic dark matter

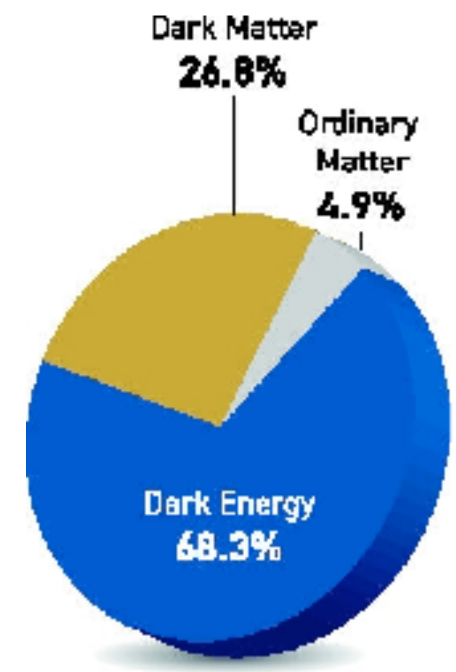
CMB - Planck 2015



Planck 2016 (TT,TE,EE,LowP)

"Cosmic Concordance"

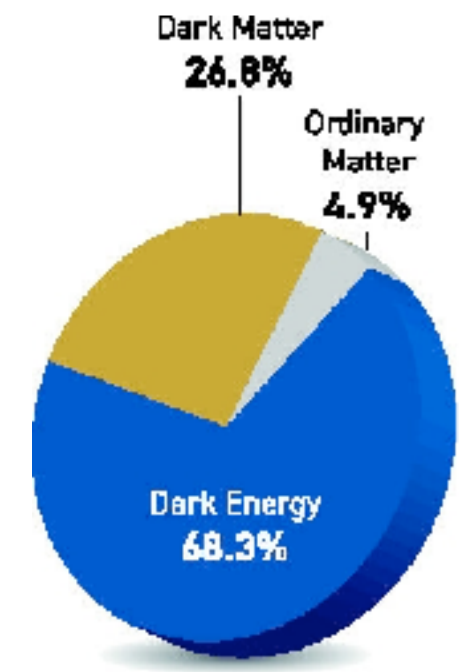
$\Omega_b h^2$	0.02225 ± 0.00016
$\Omega_c h^2$	0.1198 ± 0.0015
$100\theta_{MC}$	1.04077 ± 0.00032
τ	0.079 ± 0.017
$\ln(10^{10} A_s)$	3.094 ± 0.034
n_s	0.9645 ± 0.0049
H_0	67.27 ± 0.66



Planck 2016 (TT,TE,EE,LowP)

"Cosmic Concordance"

$\Omega_b h^2$	0.02225 ± 0.00016
$\Omega_c h^2$	0.1198 ± 0.0015
$100\theta_{MC}$	1.04077 ± 0.00032
τ	0.079 ± 0.017
$\ln(10^{10} A_s)$	3.094 ± 0.034
n_s	0.9645 ± 0.0049
H_0	67.27 ± 0.66

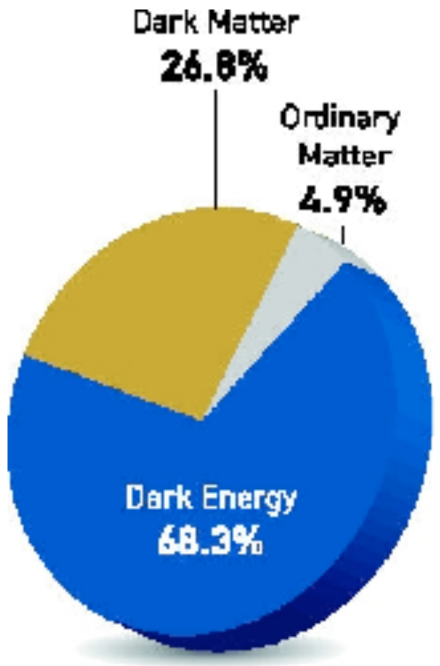


$$\boxed{H_0 = 73.24 \pm 1.74 \text{ (\textit{Riess})}}$$

Planck 2016 (TT,TE,EE,LowP)

"Cosmic Concordance"

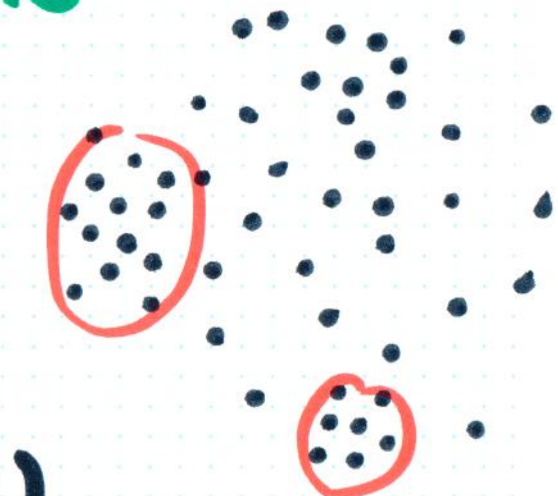
$\Omega_b h^2$	0.02225 ± 0.00016
$\Omega_c h^2$	0.1198 ± 0.0015
$100\theta_{MC}$	1.04077 ± 0.00032
τ	0.079 ± 0.017
$\ln(10^{10} A_s)$	3.094 ± 0.034
n_s	0.9645 ± 0.0049
H_0	67.27 ± 0.66
σ_8	0.831 ± 0.013



σ_8 = moment of the matter power spectrum

energy density fluctuations

$$\rho(\vec{x},t) = \bar{\rho}(t)\left(1+\delta(\vec{x},t)\right)$$



Fourier transform $\longrightarrow$ $\delta(\vec{k},t)$

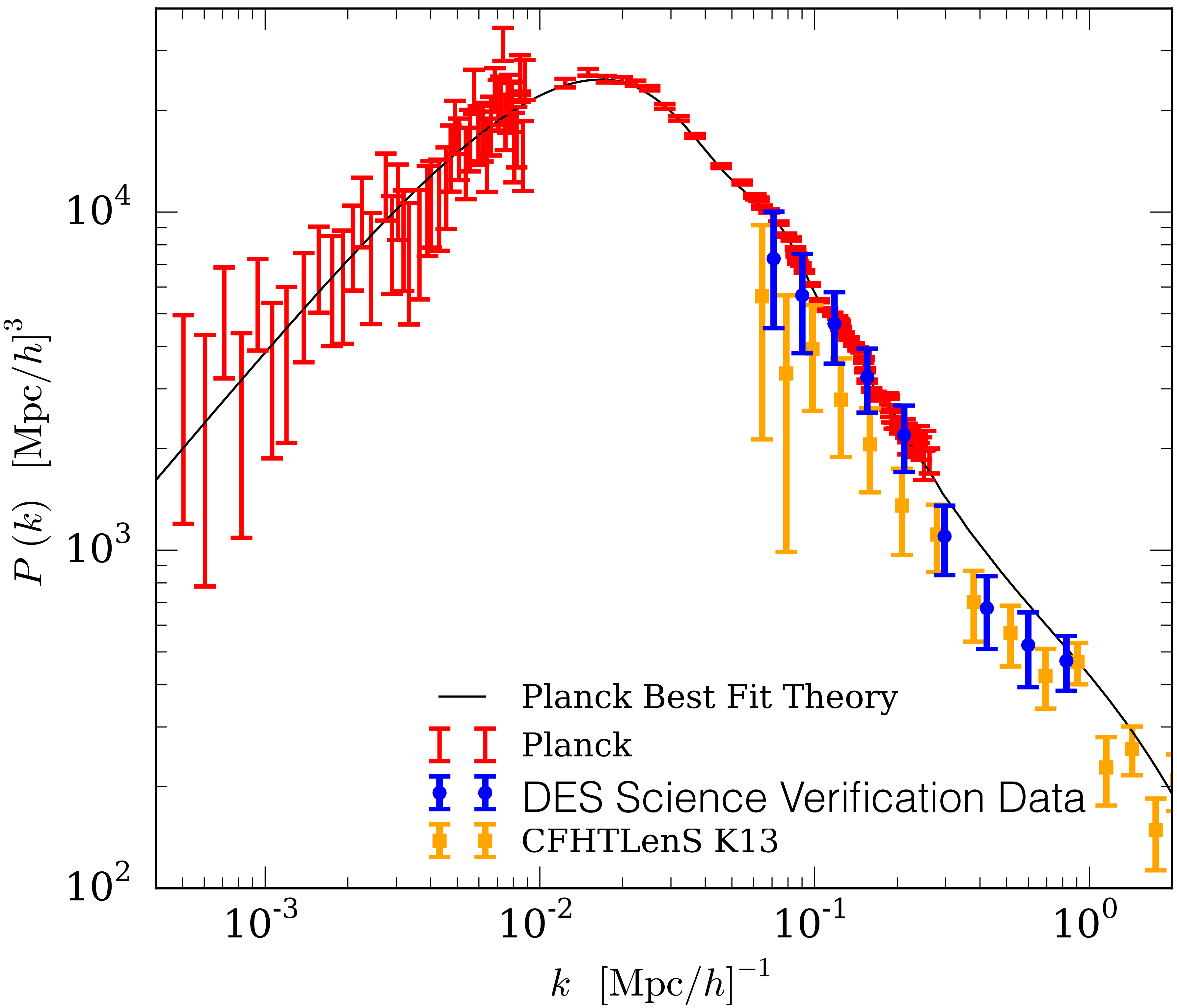
$a(t)$

Matter power spectrum

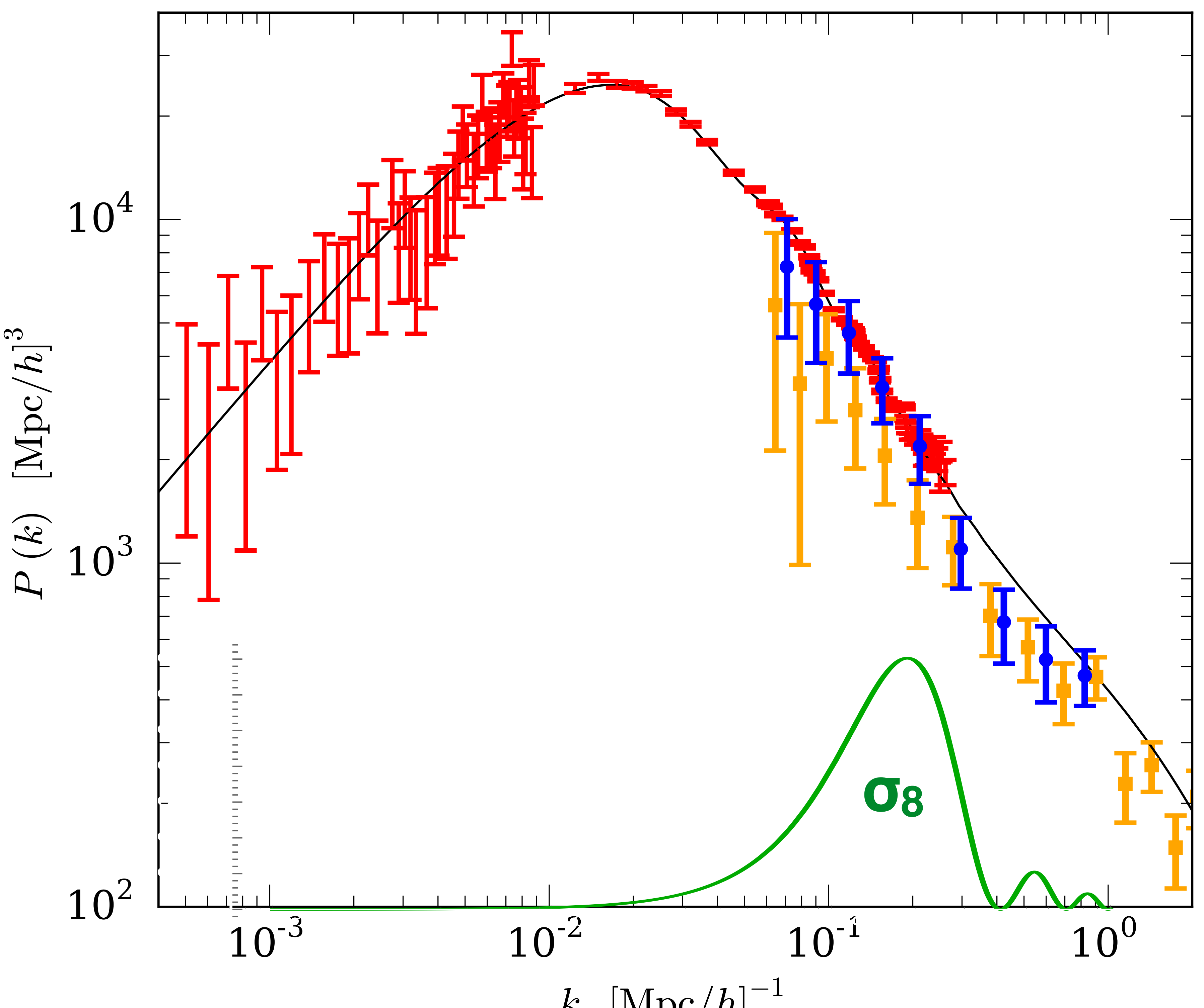
$$\langle \delta \delta \rangle \equiv P(k,a)$$

Matter power spectrum from weak lensing

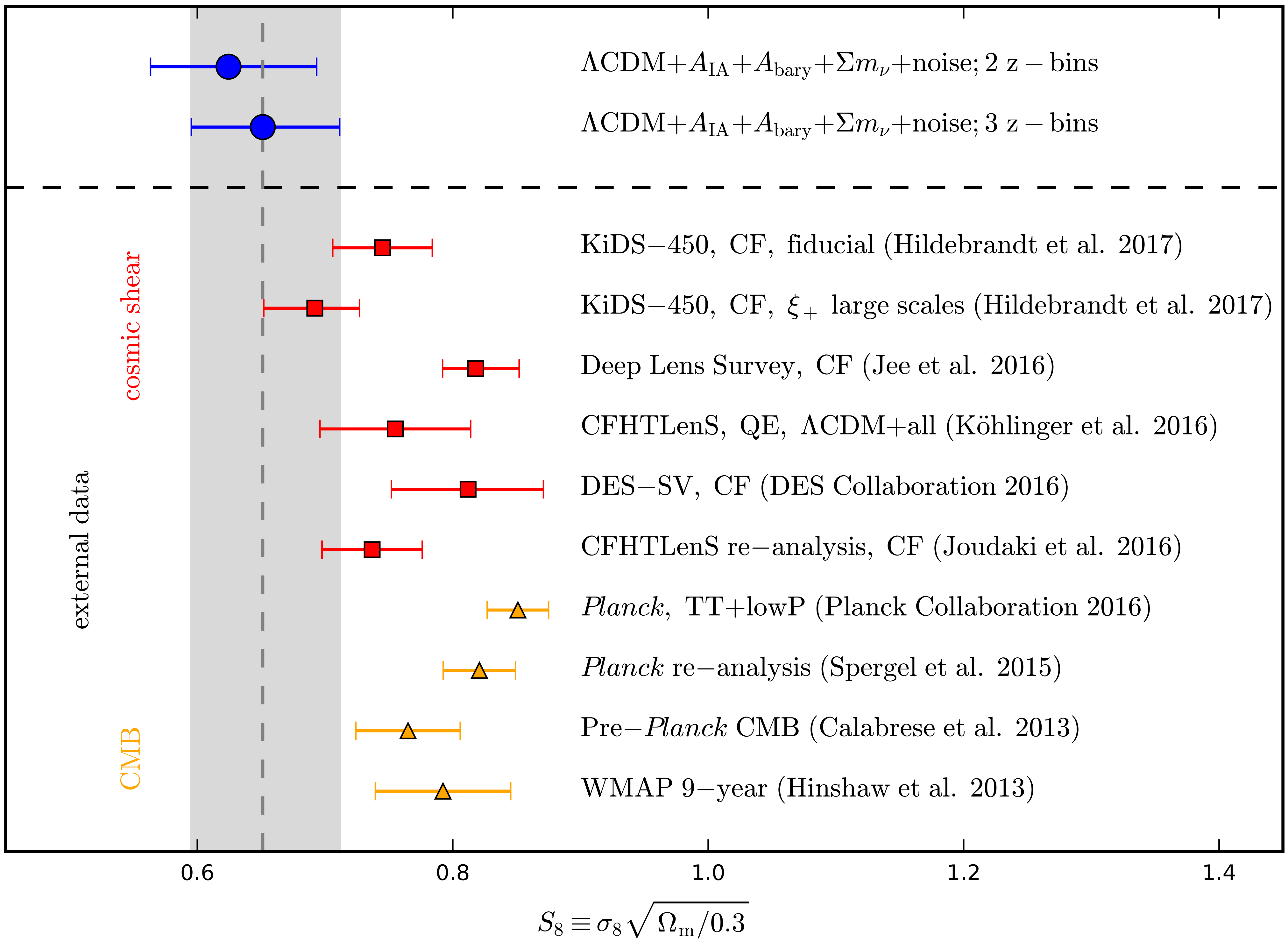
DES astro-ph/150705552



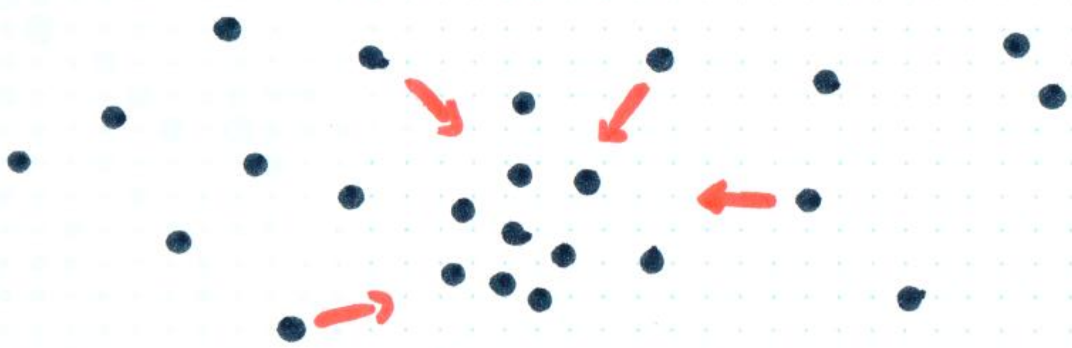
Matter power spectrum —> σ_8



KiDS-450: weak lensing power spectrum



Predicting the matter power spectrum

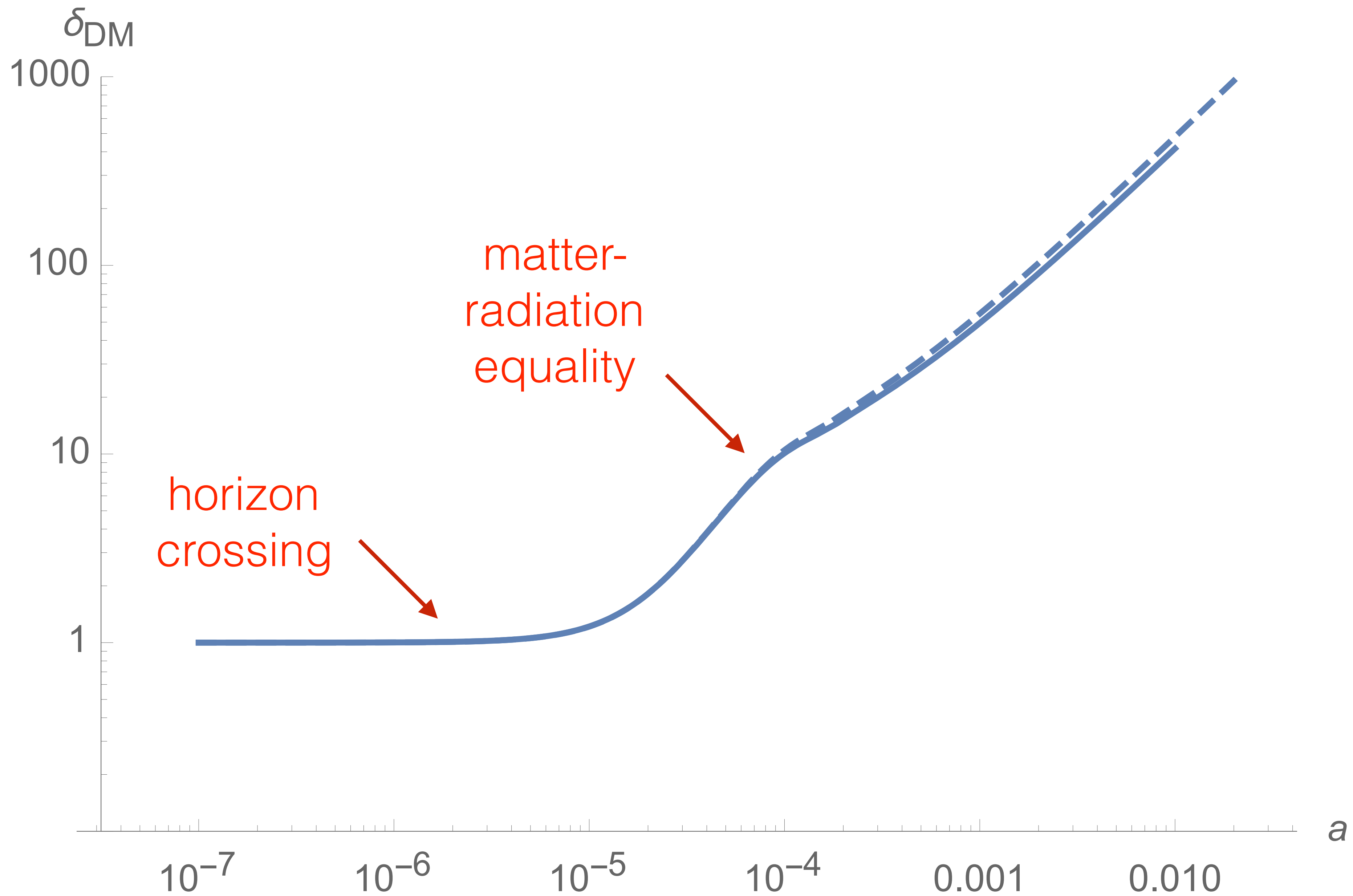


DM is a gravitating fluid, GR fluid equations

δ small $\xrightarrow{\text{linearize}}$ different k decouple

growth of perturbations

k=0.2 Mpc^{-1}



MPS

- sensitive to new long range interactions (another talk)

- DM must be cold to cluster

$$\frac{T}{M} = v^2 \ll v_{escape}^2$$

DM naturalness problem

- particle DM
- abundance determined by standard mechanism

$$\left.\begin{array}{l}\text{particle DM}\\ \text{abundance determined}\\ \text{by standard mechanism}\end{array}\right\} M_{DM} \ll M_{Planck}$$

Solutions:

1. M_{DM} related to scales of "SM": WIMP
   m_ν
   GUT ...

2. new scale from dimensional transmutation:

$$M_{DM} \sim M_{pl}\, e^{-1/\alpha}$$

Simplest natural dark sector

non-Abelian (pure) gauge theory

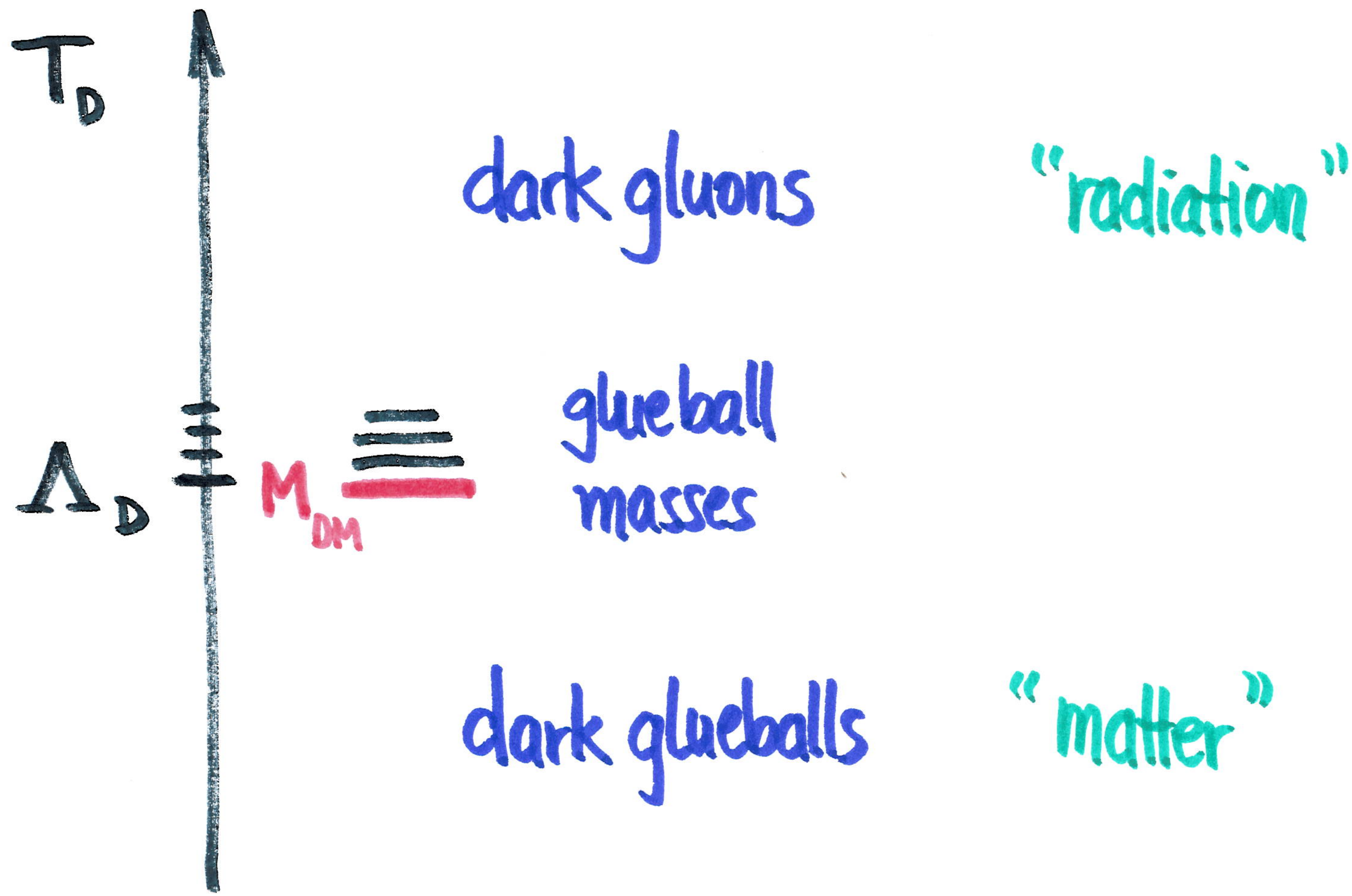
$$\mathcal{L}_D \sim \frac{1}{g_D^2} F_D^2 + \frac{H^\dagger H F_D^2}{M_{pl}^2} + \ldots$$

no flavors

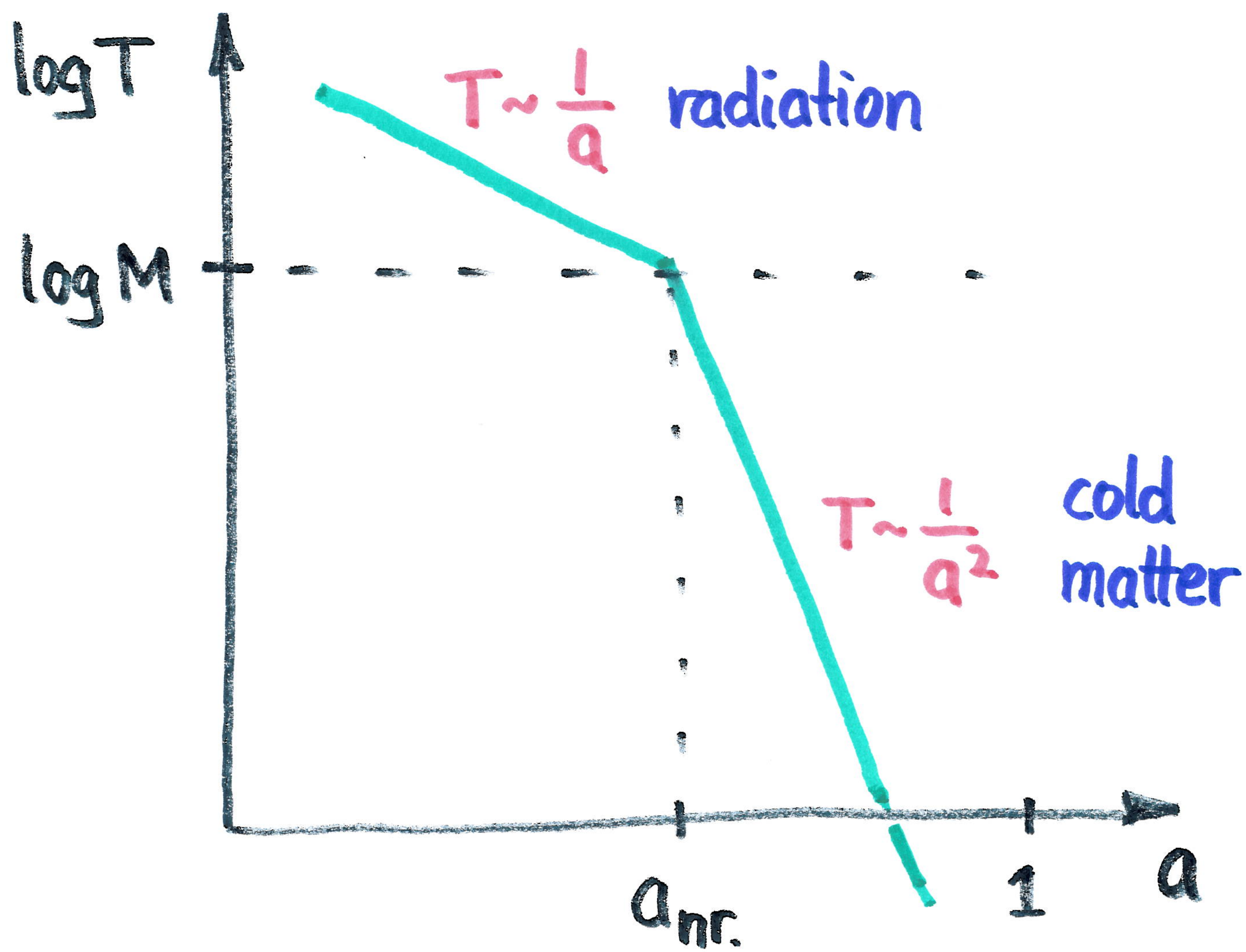
dim ≥ 6

automatically decoupled from SM

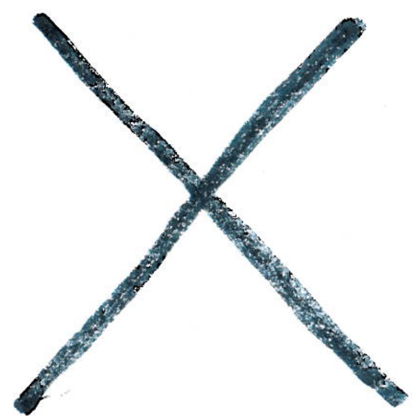
dark dynamics



massive particle thermal history



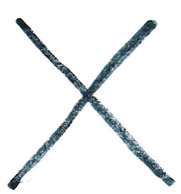
mistake: ignored interactions of glueballs



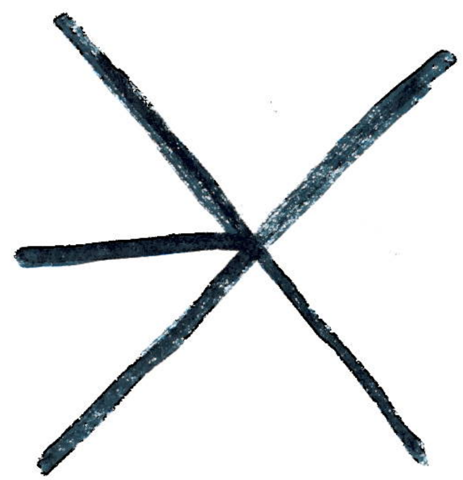
$$\sim \langle \sigma v \rangle \underline{n}$$

thermal equilibrium

mistake: ignored interactions of glueballs

 $\sim \langle \sigma v \rangle \underline{n}$

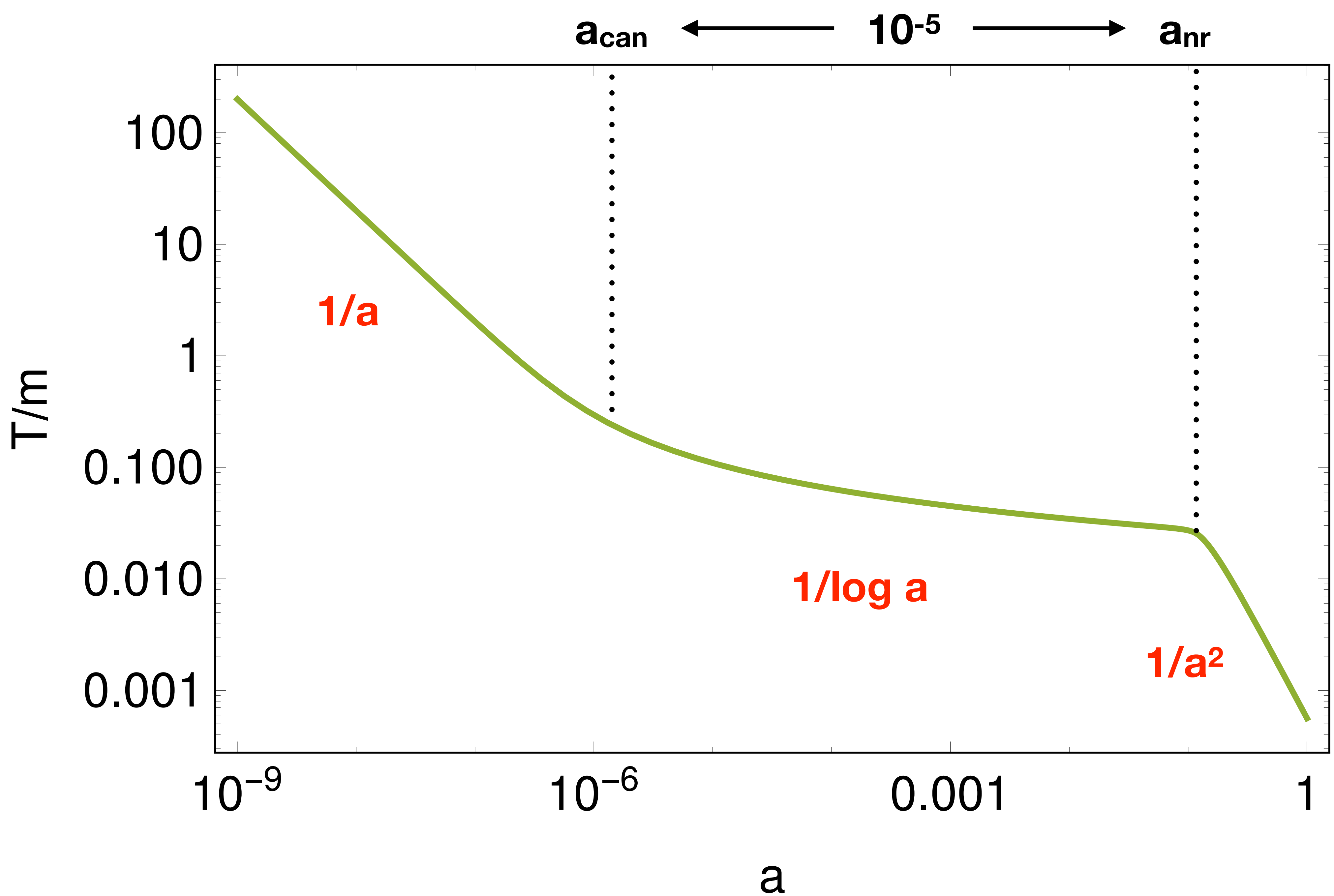
thermal equilibrium

 $\sim$ "σv" $\underline{\underline{n}}^2$

"cannibalism" heat source

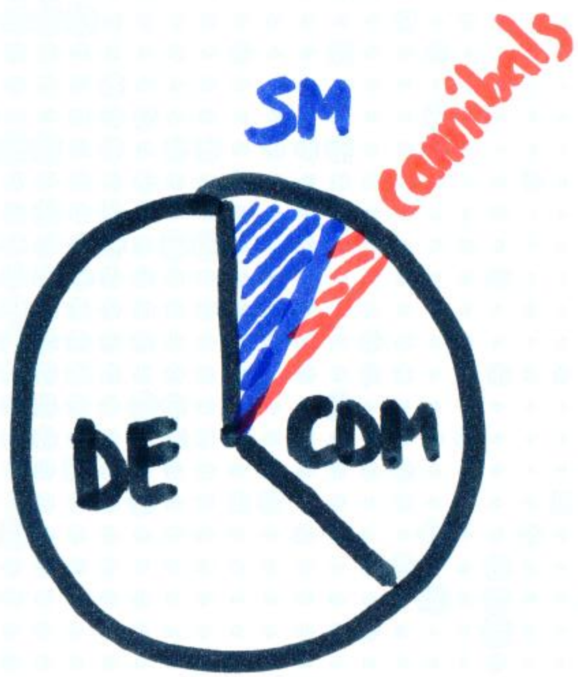
$\Longrightarrow$ chemical equilibrium

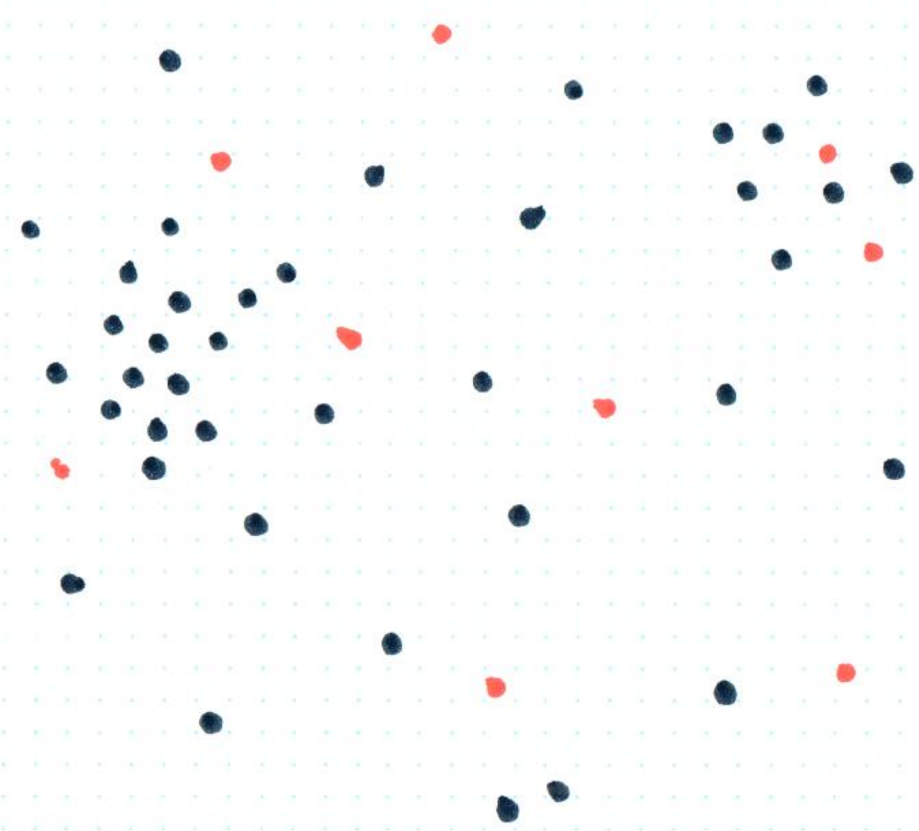
Cannibal thermal history



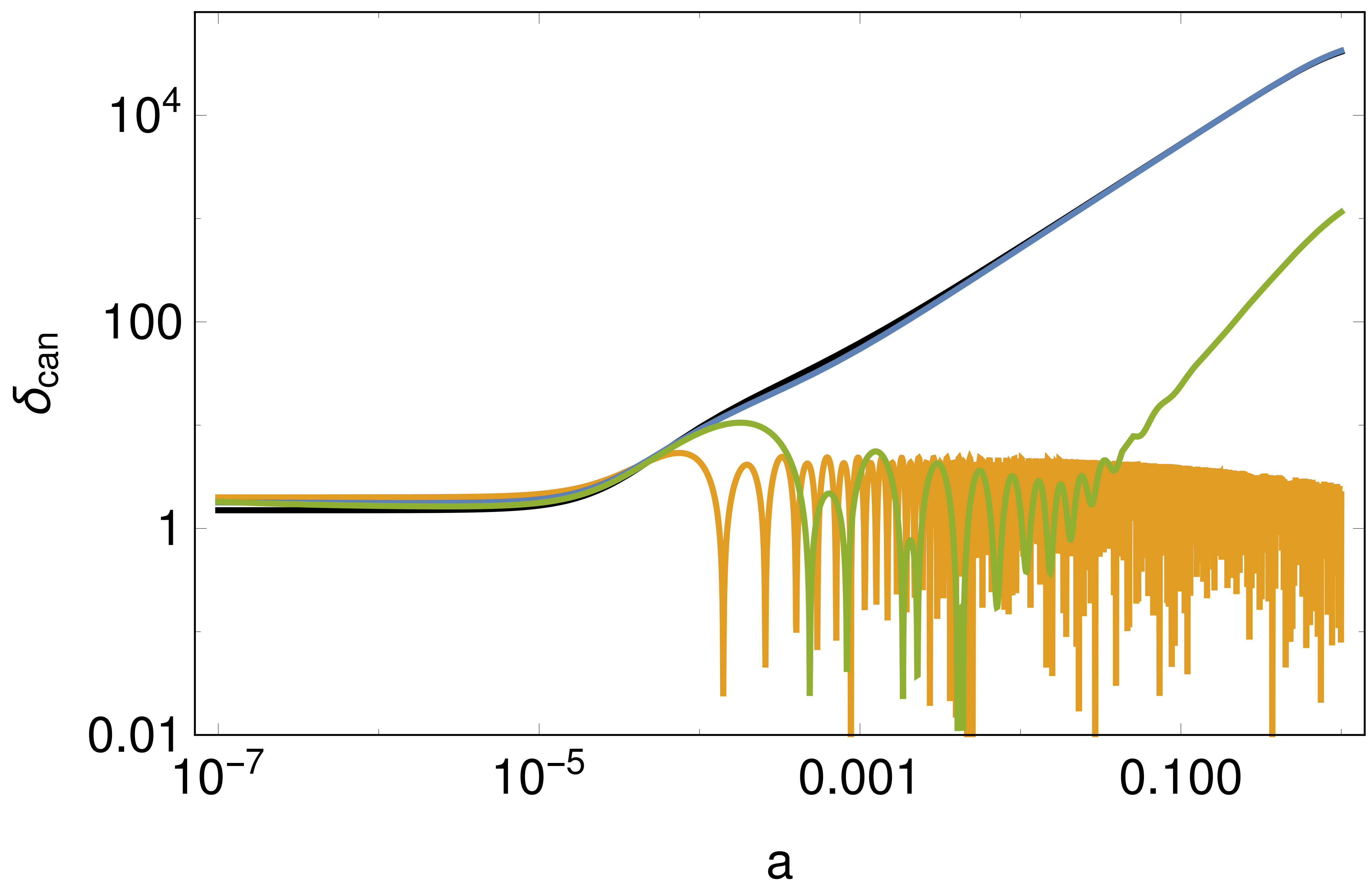
natural cannibals do not cluster

⟹ cannot be all DM



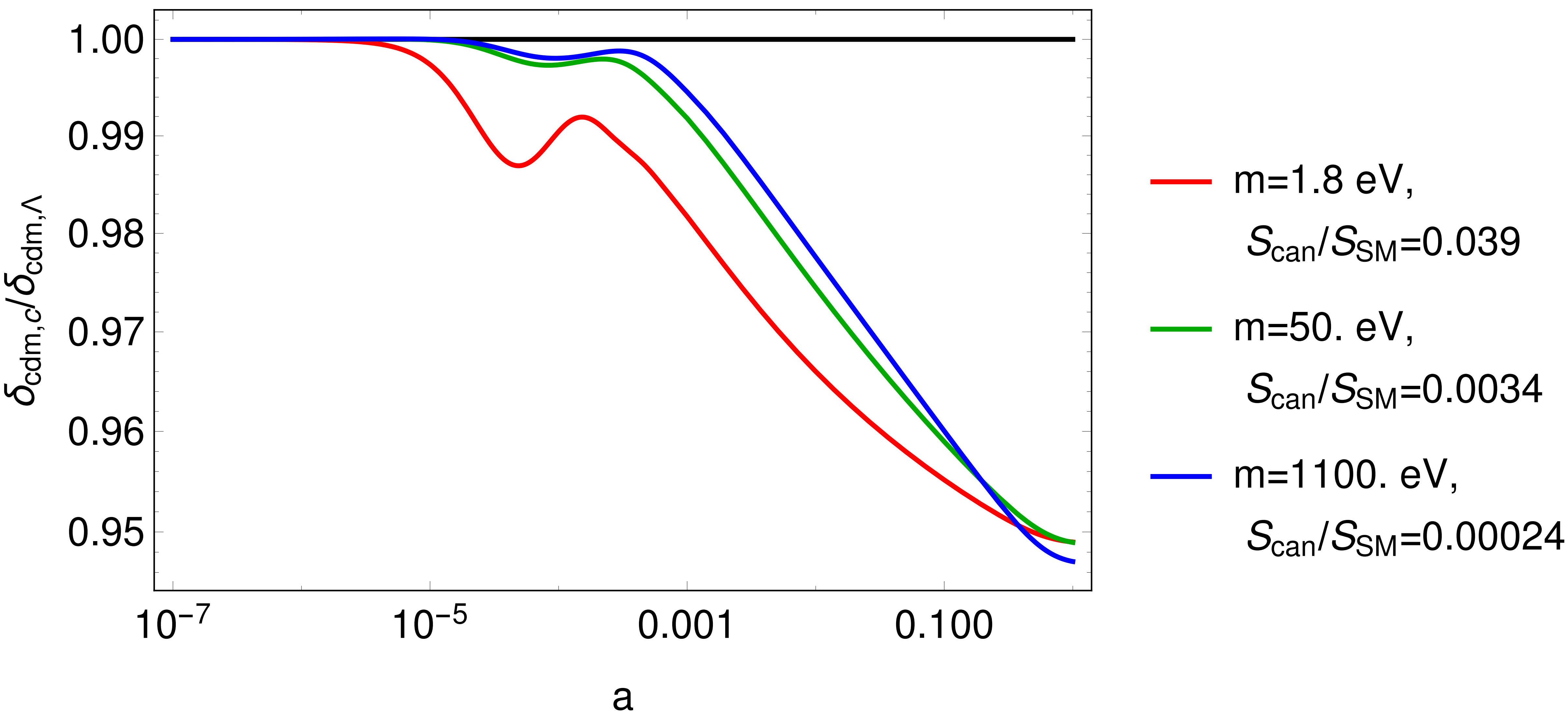


growth of perturbations in cannibals

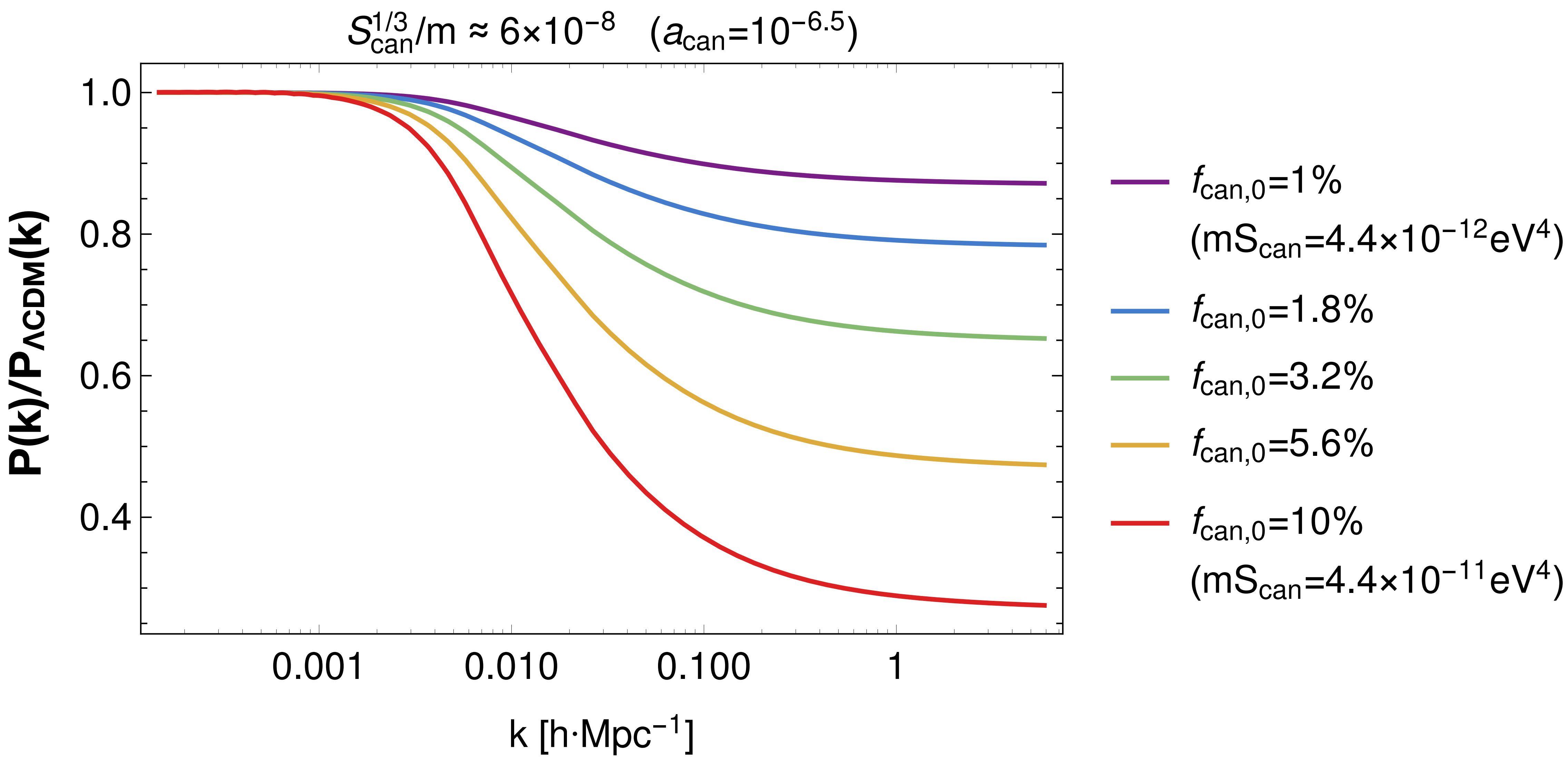


$$\ddot{\delta}_{\rm can} + \mathcal{H}\dot{\delta}_{\rm can} + k^2 c_s^2 \delta_{\rm can} = -k^2\psi$$

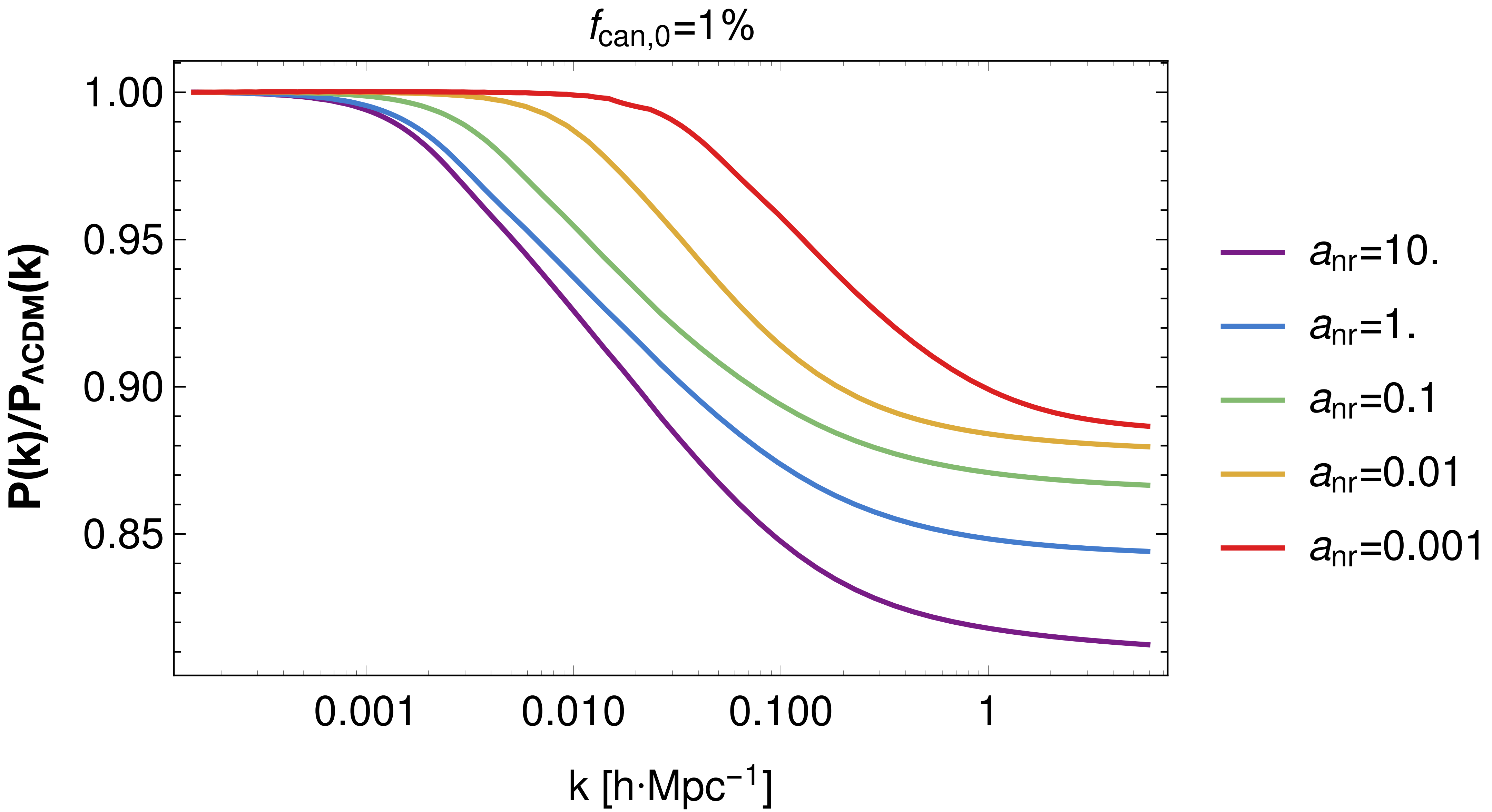
growth of DM perturbations in presence of cannibals



Varying parameters: Fraction of DM that cannibalizes



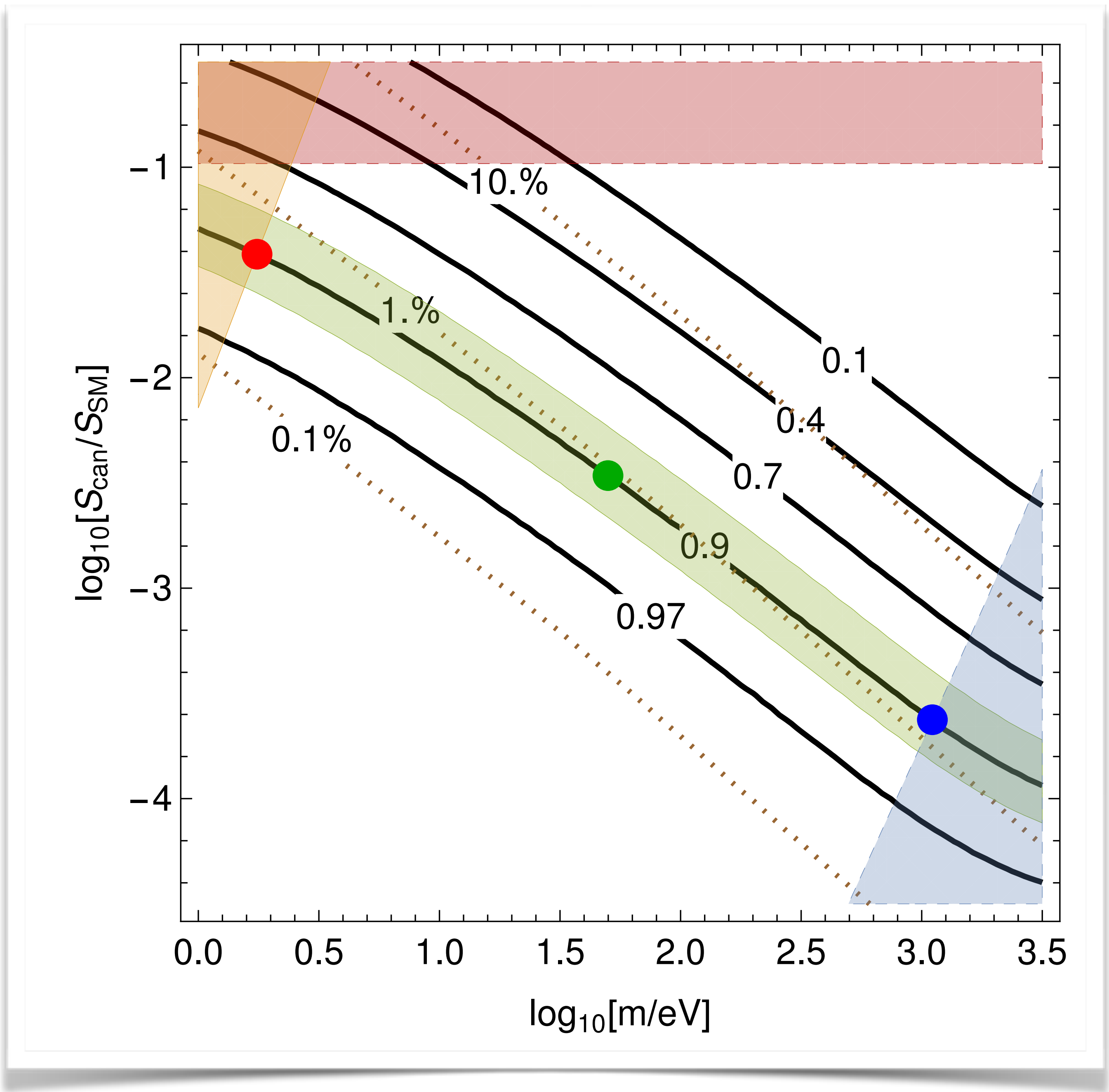
Varying parameters:
When cannibalism stops



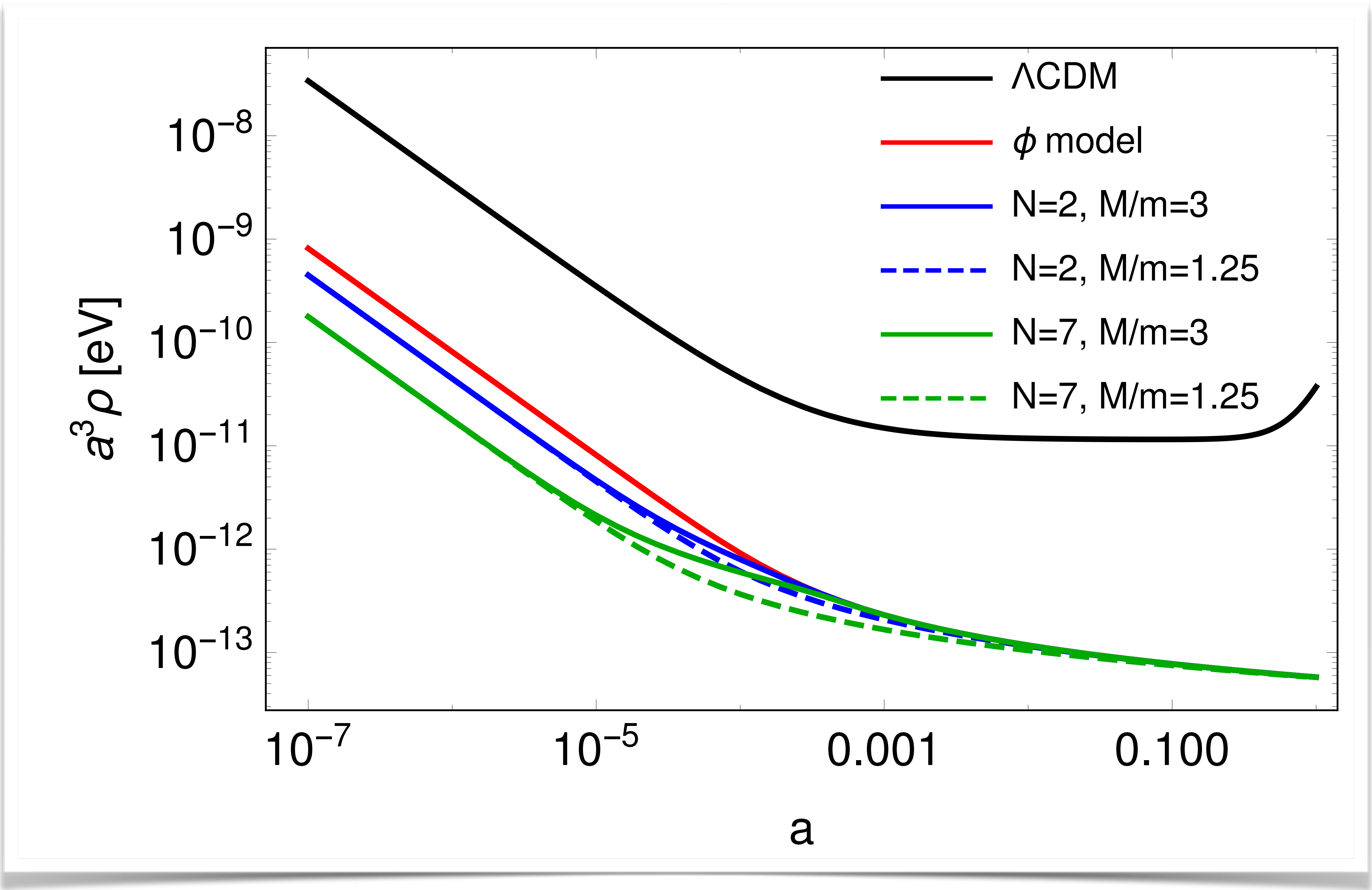
issues not discussed

- $M, T \sim S^{1/3}$ parameter space
- glueball spectrum dependence
- global fit: CLASS, MontePython

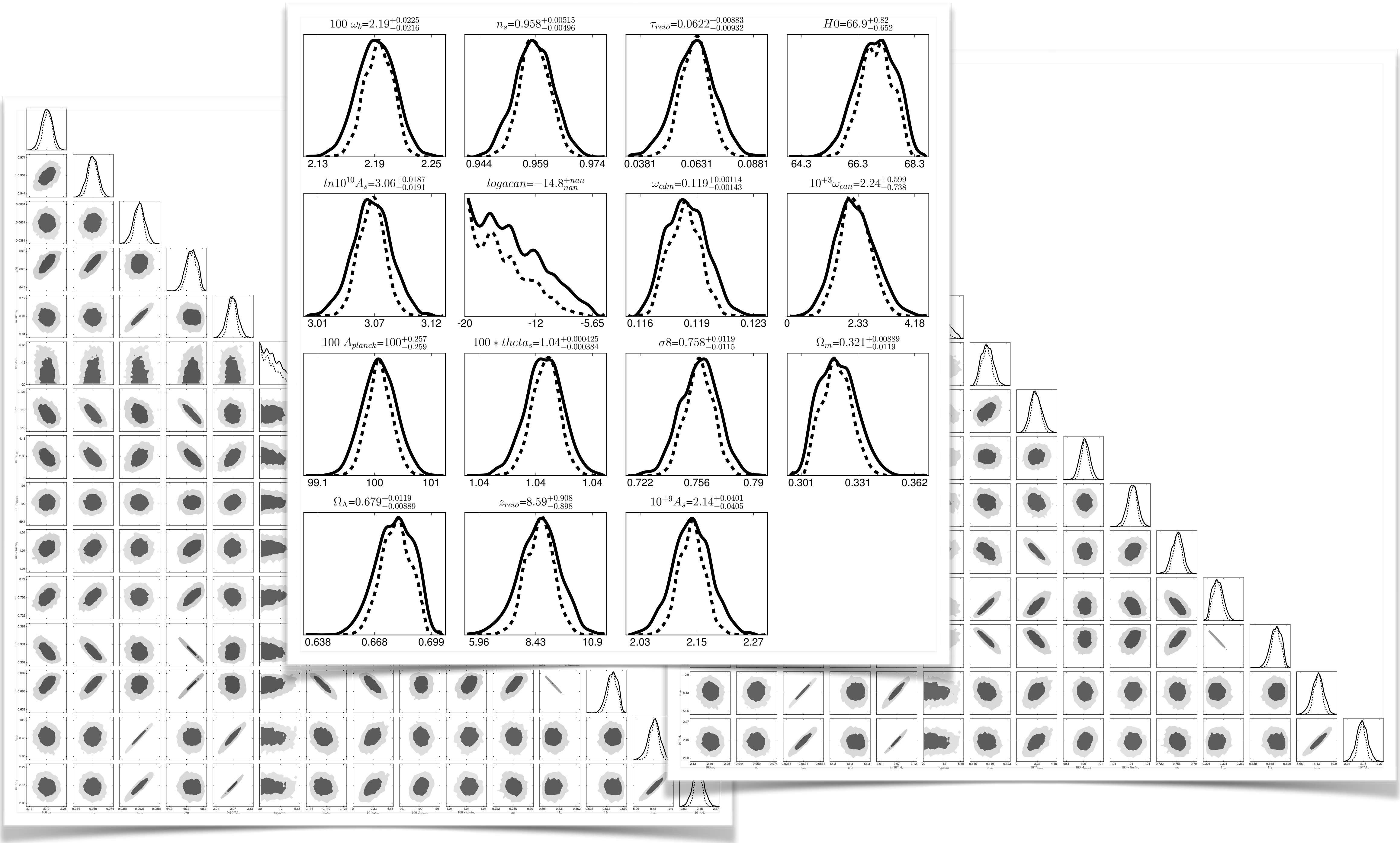
• $M, T \sim S^{1/3}$ parameter space



- glueball spectrum dependence

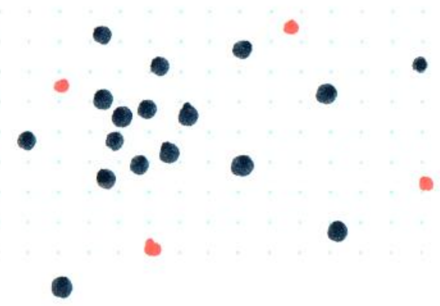


- global fit: CLASS, MontePython



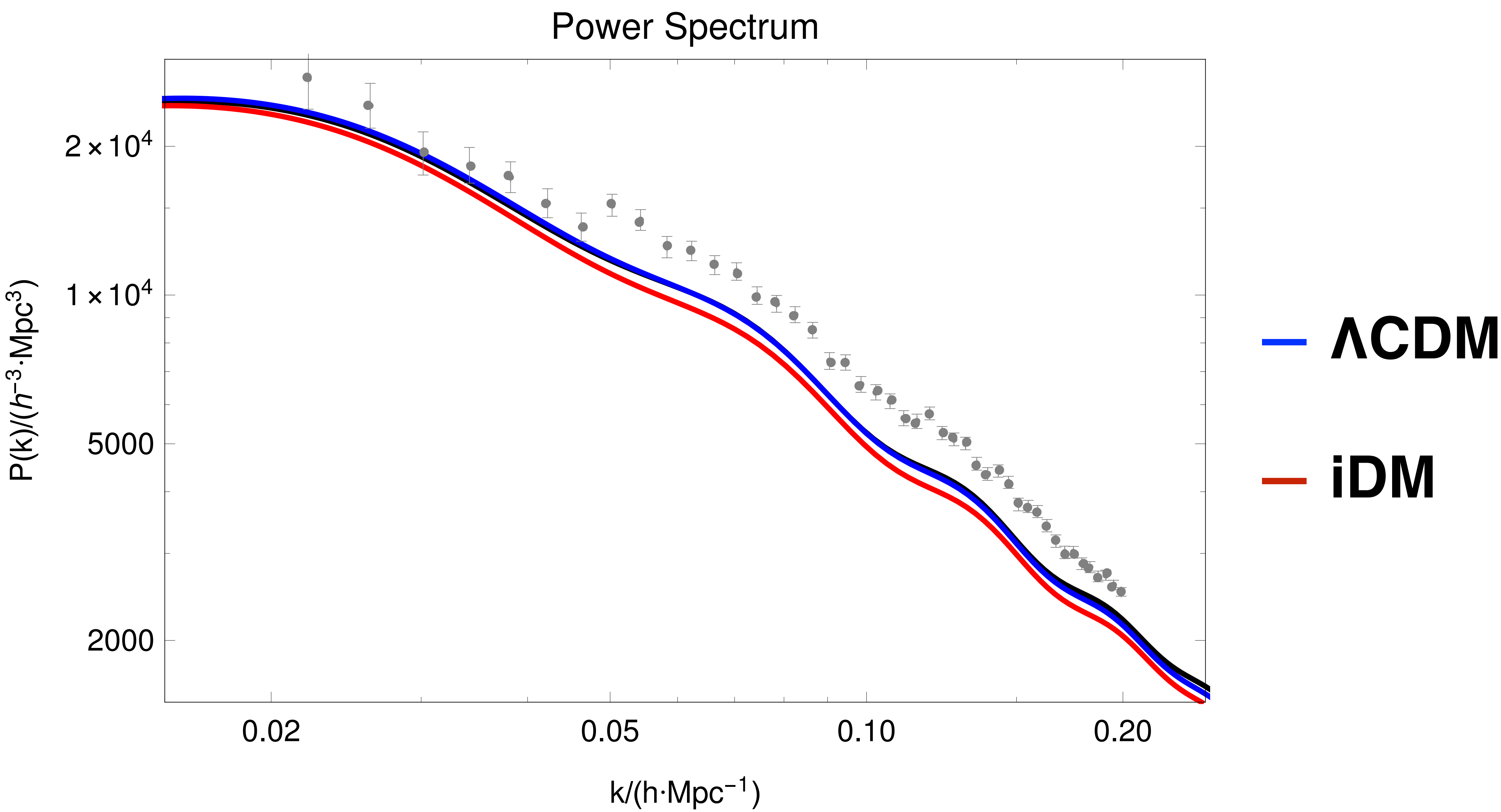
Conclusions

- future MPS measurements are precision tests of ΛCDM
- non-standard DM models can predict different MPS shapes
- partially cannibalistic DM suppresses MPS
  → solution to σ_8 problem ?



back up!

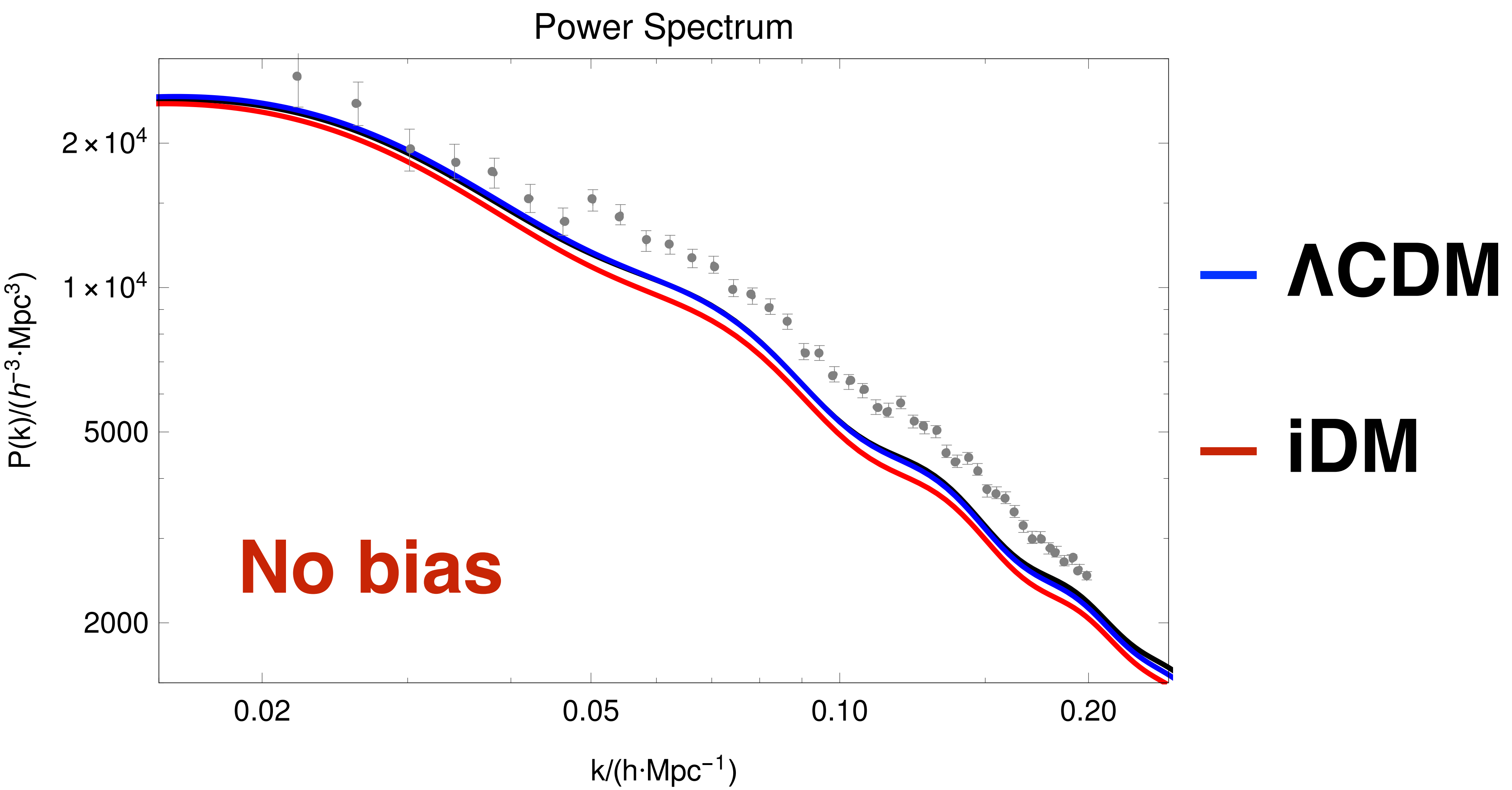
Galaxy Power Spectrum, SDSS-DR7, "straight up"



Galaxies don't track dark matter perfectly

"Galaxy bias"

$$P_{DM}(k) = P_{gal}(k)\,(a + b\,k + c\,k^2)$$



Galaxy Power Spectrum, SDSS-DR7