

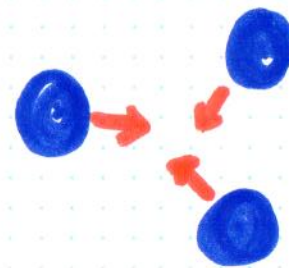
The large Scale structure of the Universe and Cannibals

with

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M. Schmalz (BU)



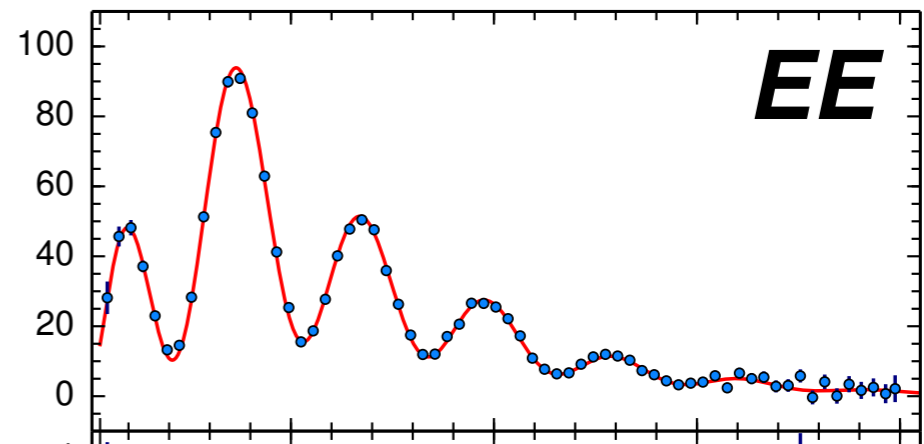
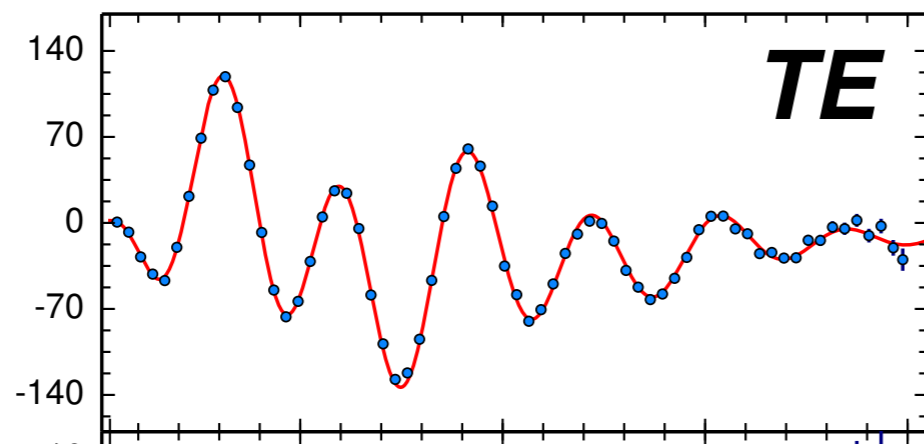
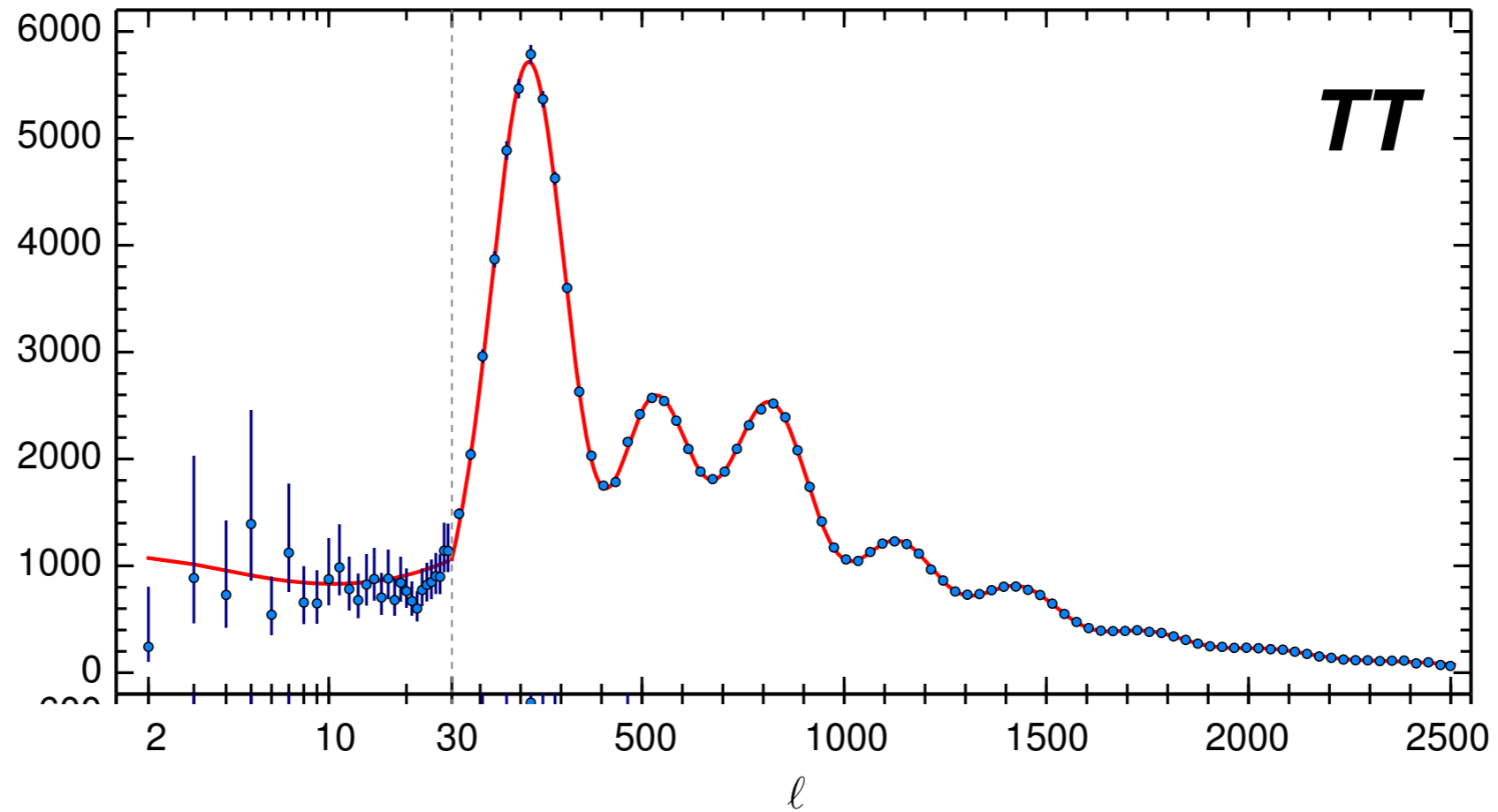
to appear...



Outline

1. **data** matter power spectrum σ_8
2. **model** partially cannibalistic dark matter

CMB - Planck 2015



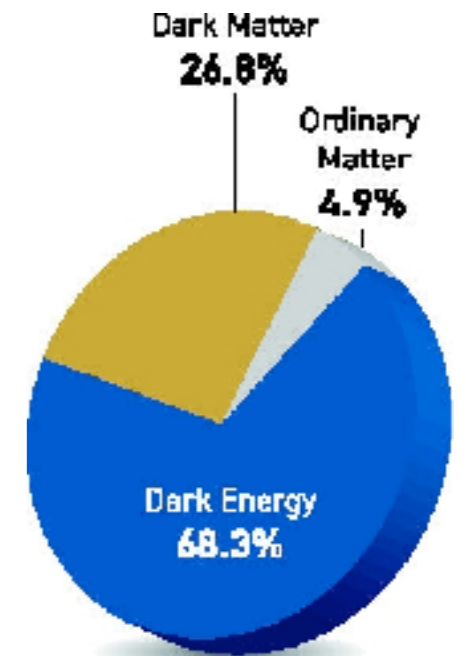
Planck 2016

(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

σ_8 0.831 ± 0.013



possible discrepancy:

matter power spectrum (σ_8)



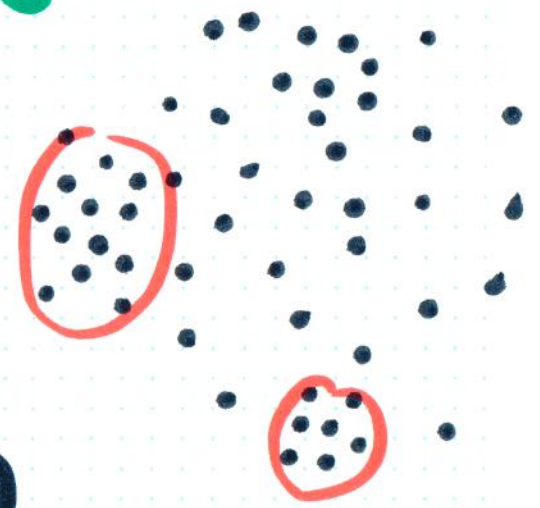
energy density fluctuations

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

Fourier transform $\rightarrow \delta(\vec{k}, t)$
 \swarrow alt)

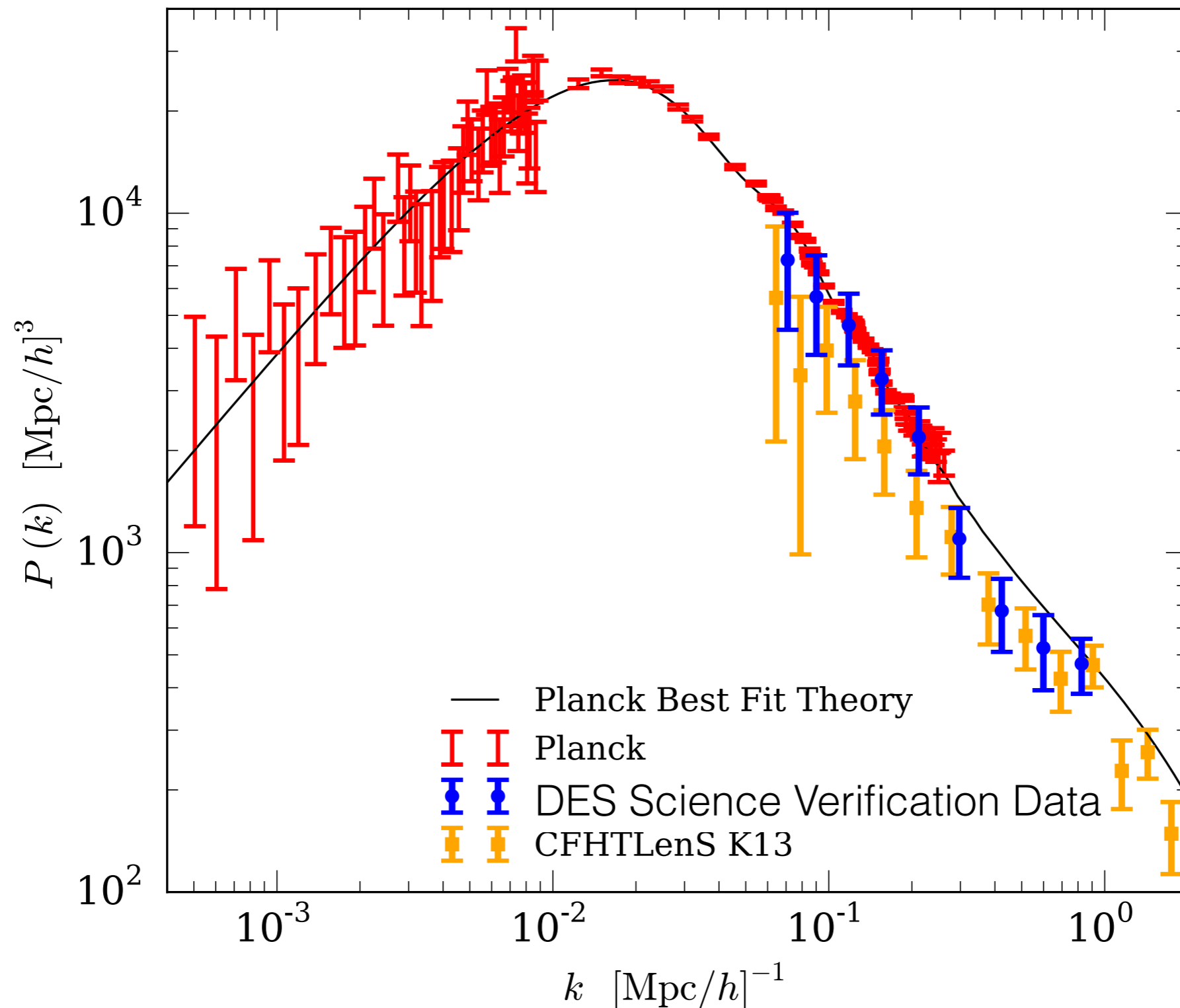
Matter power spectrum

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

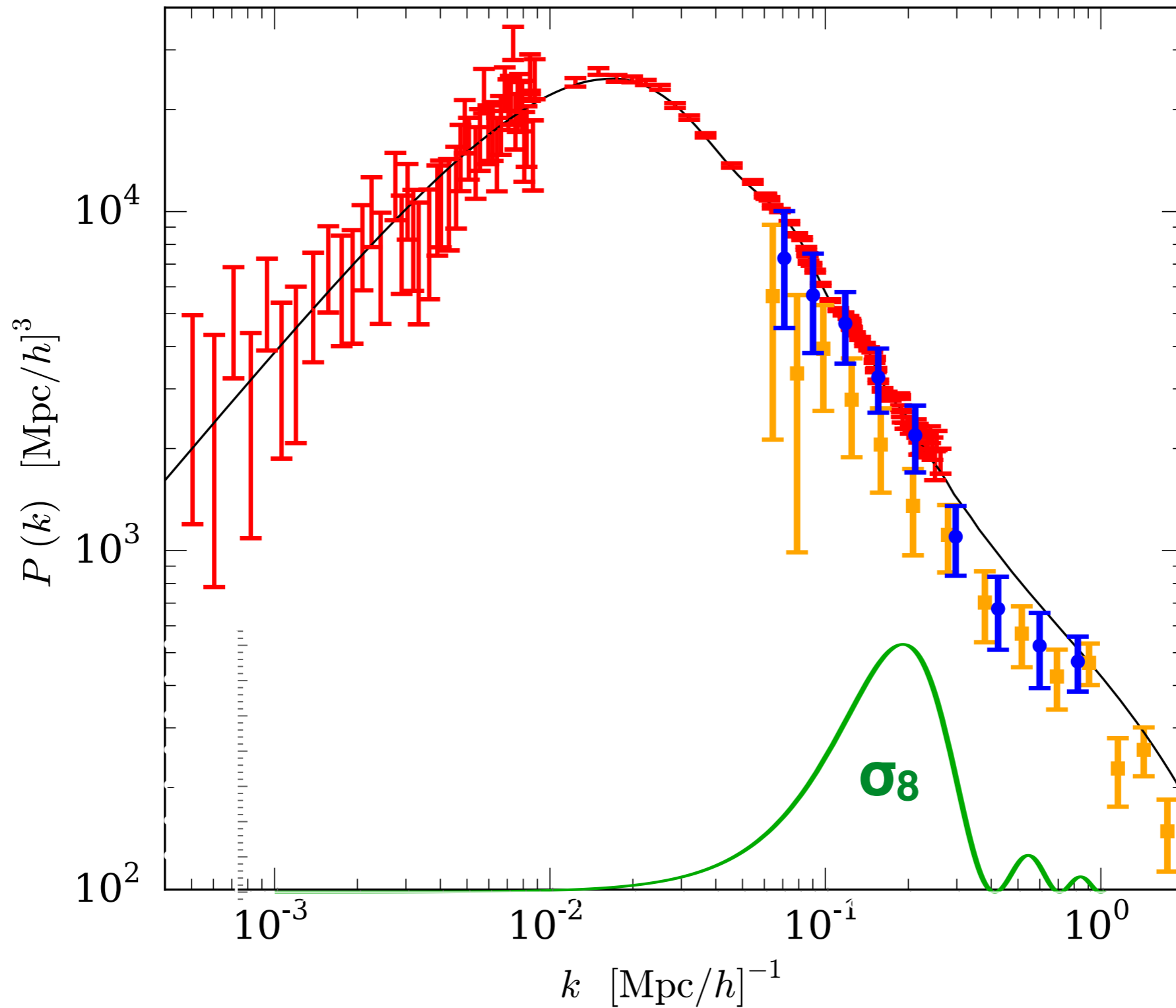


Matter power spectrum from weak lensing

DES astro-ph/150705552

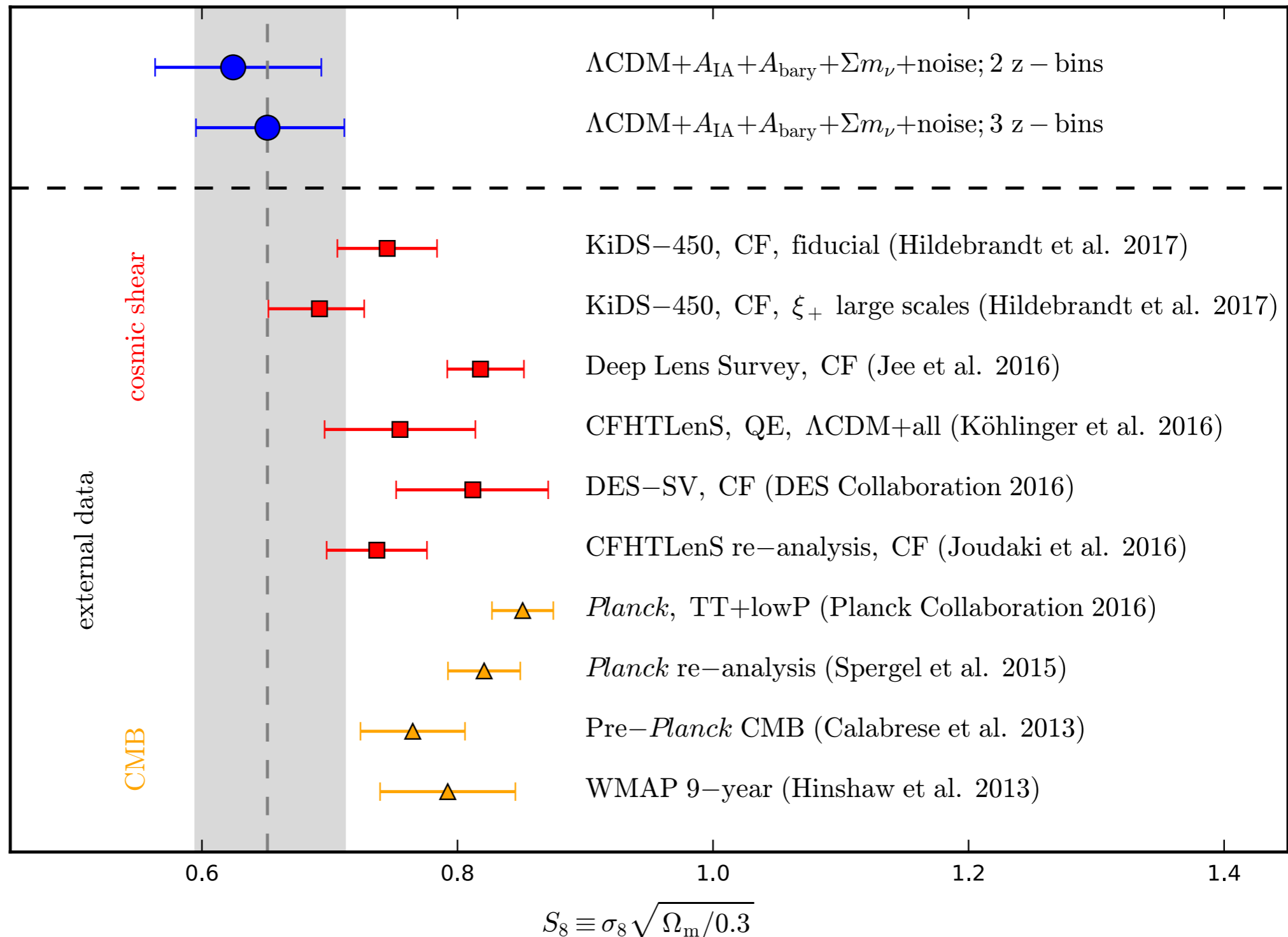


Matter power spectrum $\rightarrow \sigma_8$

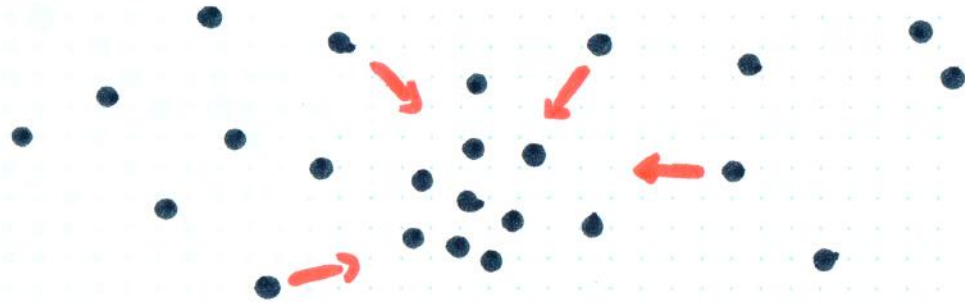


KiDS-450: *weak lensing* power spectrum

1706.02892v1 [astro-ph.CO] 9 Jun 2017



Predicting the matter power spectrum

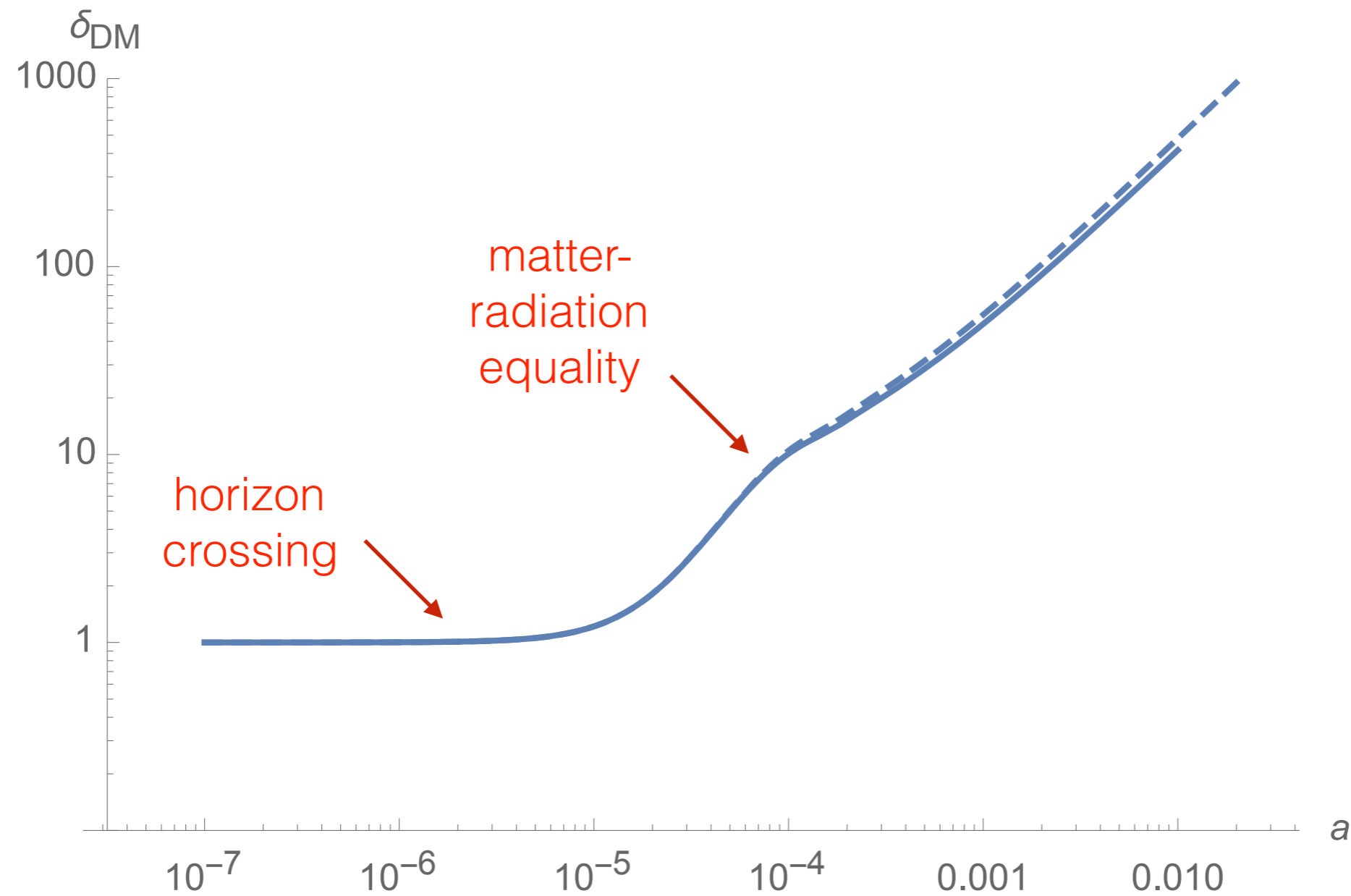


DM is a gravitating fluid, GR fluid equations

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

growth of perturbations

$k=0.2 \text{ Mpc}^{-1}$



MPS



- sensitive to new long range interactions (another talk)
- DM must be cold to cluster

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

natural dark matter

\Rightarrow Cannibals

dark matter mass $M \ll M_{\text{planck}}$

a naturalness problem!



$$M \ll M_{pl.}$$



1. M connected to scales of the SM, e.g.

WIMP

RHV

GUT

2. independent scale from dimensional transmutation

$$M \sim M_{pl.} e^{-\frac{1}{\alpha}}$$



Simplest natural dark matter

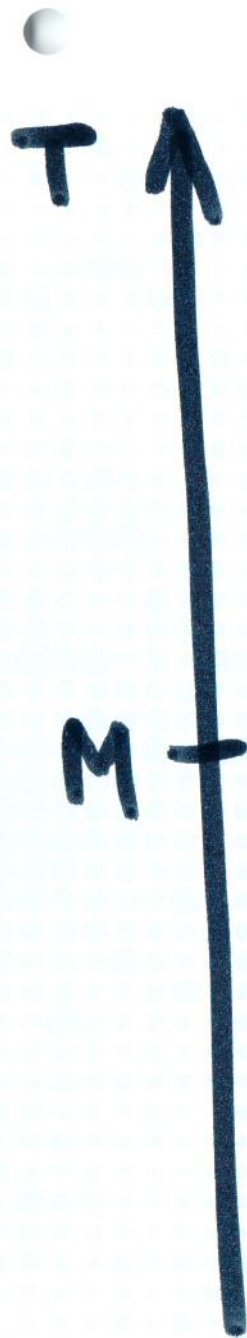
non-Abelian gauge sector

$$\mathcal{L}_0 \sim \frac{1}{g_0^2} F_0^2 + \frac{H^\dagger H F_0^2}{M_{\text{Pl}}^2} + \dots$$

↑
no "flavors" for
simplicity

↑
no relevant couplings
to SM \Rightarrow very "dark"





dark gluons "radiation"

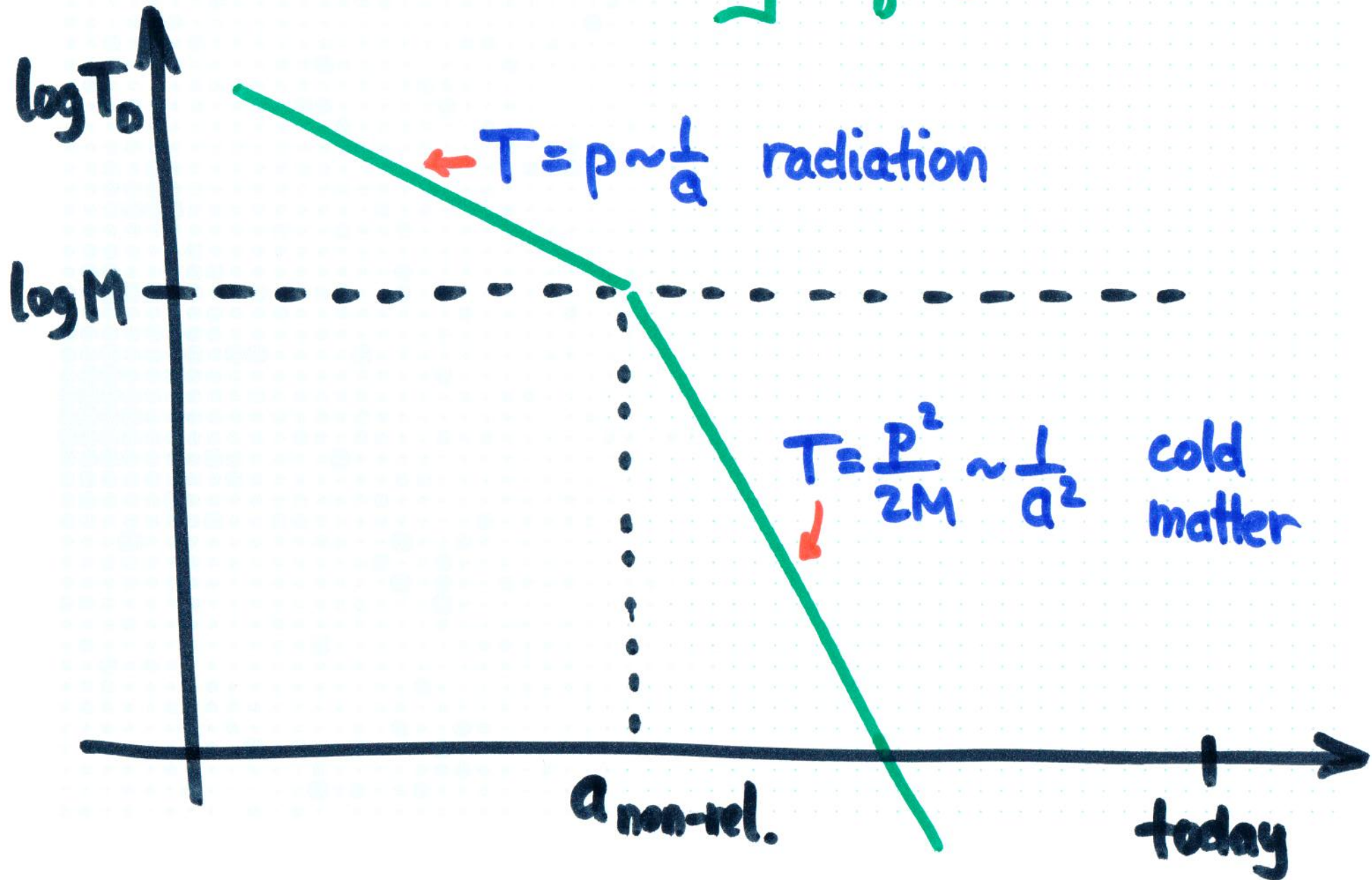


glueball masses

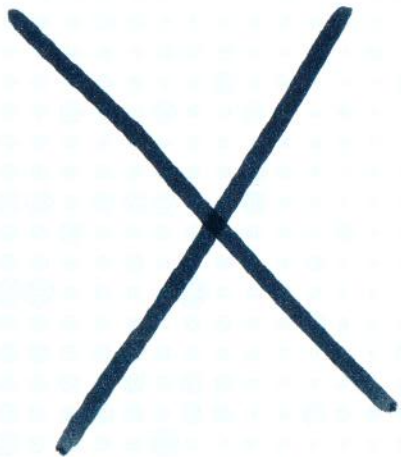
dark glueballs "matter"



thermal history $T_0(a)$



a mistake: forgot glueball interactions



thermal equilibrium



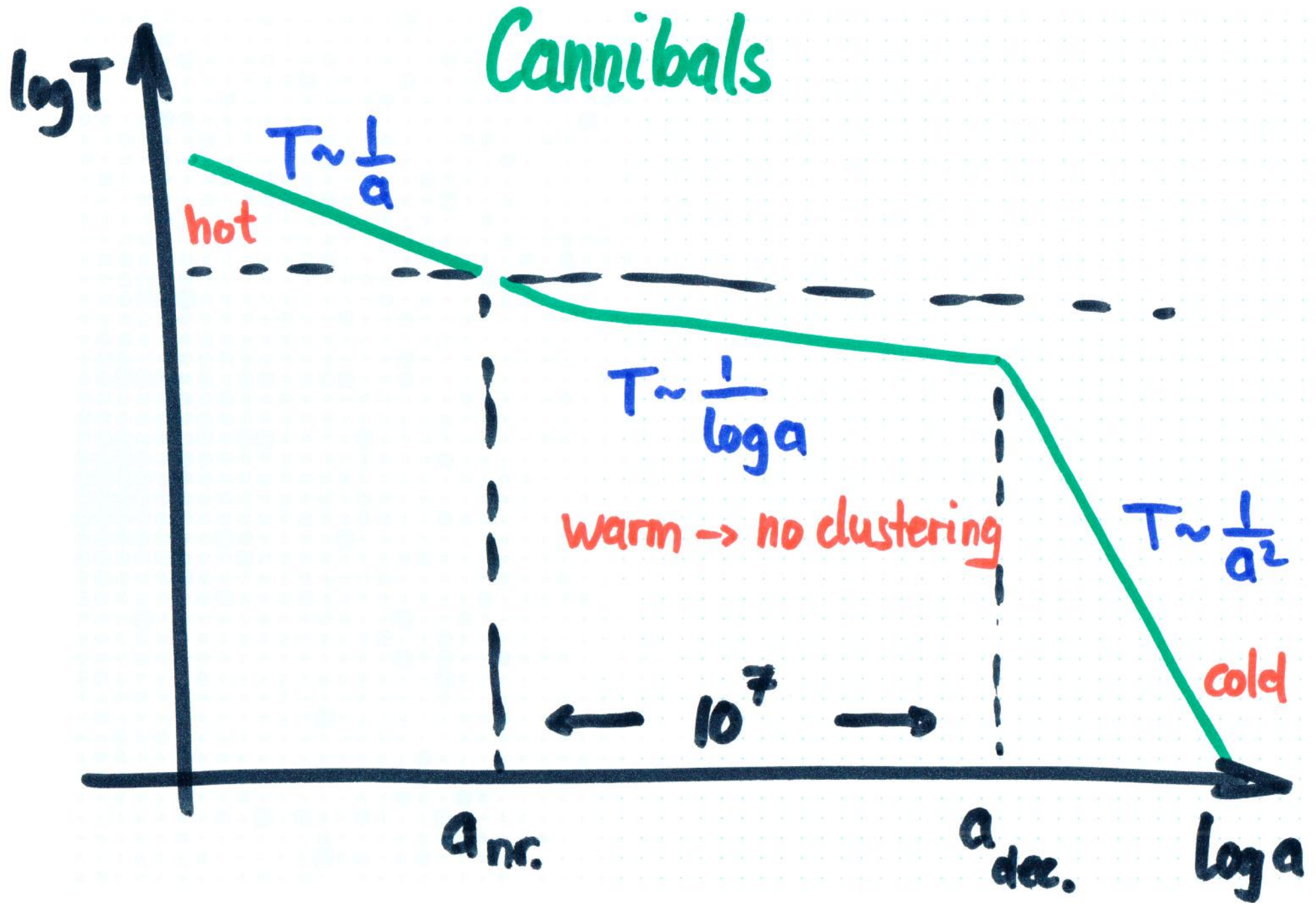
$$\sim \frac{1}{M}$$

chemical equilibrium

cannibals

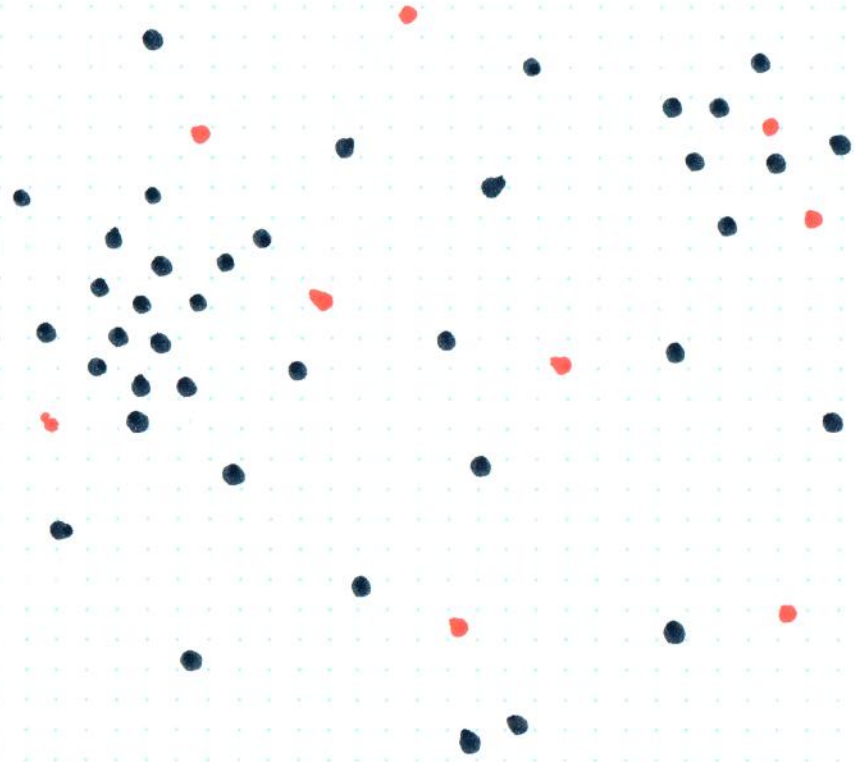
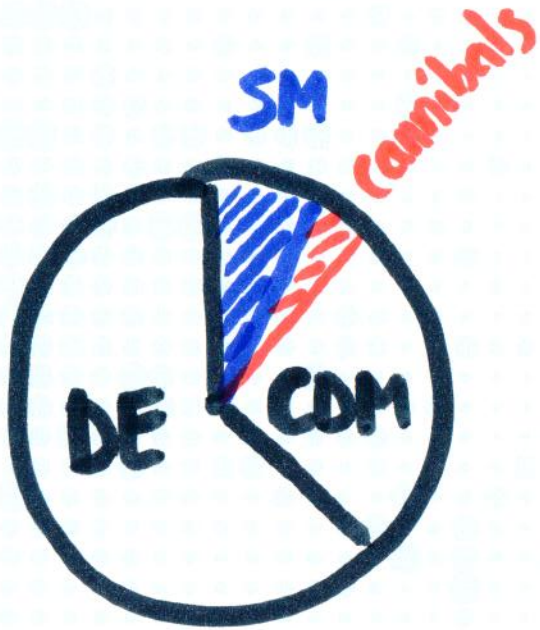


3 → 2 heat glueball plasma

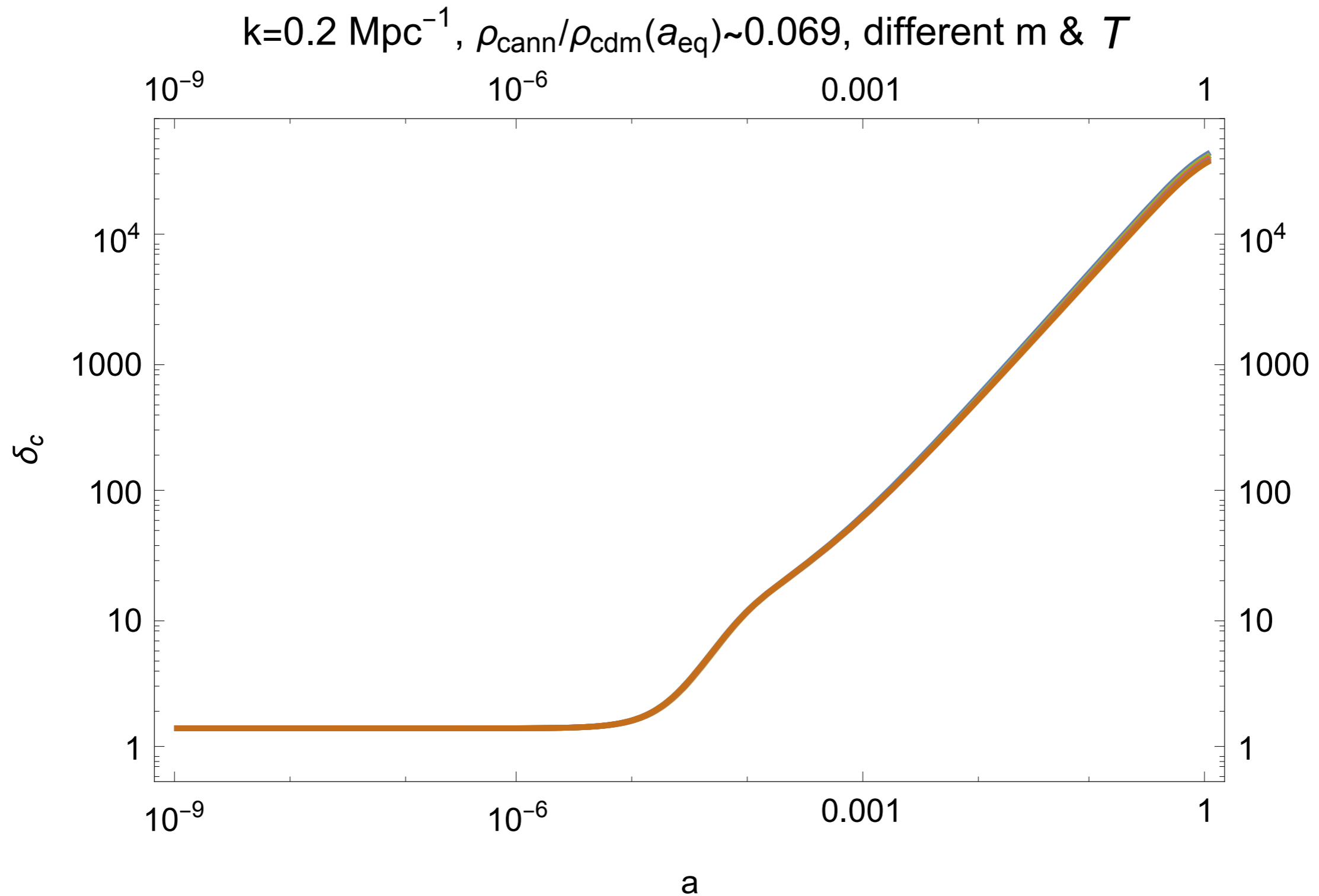


natural cannibals do not cluster

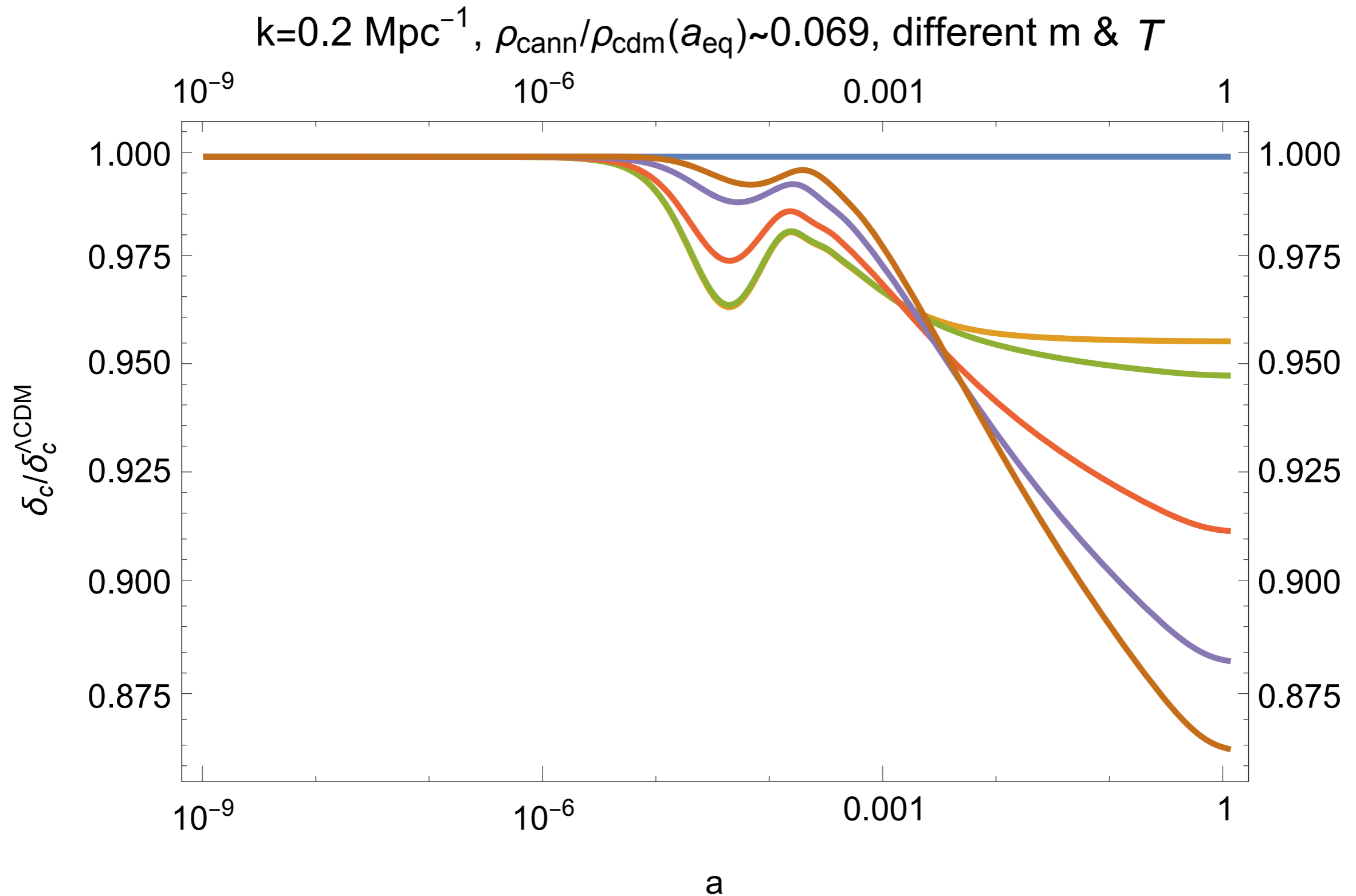
⇒ cannot be all DM



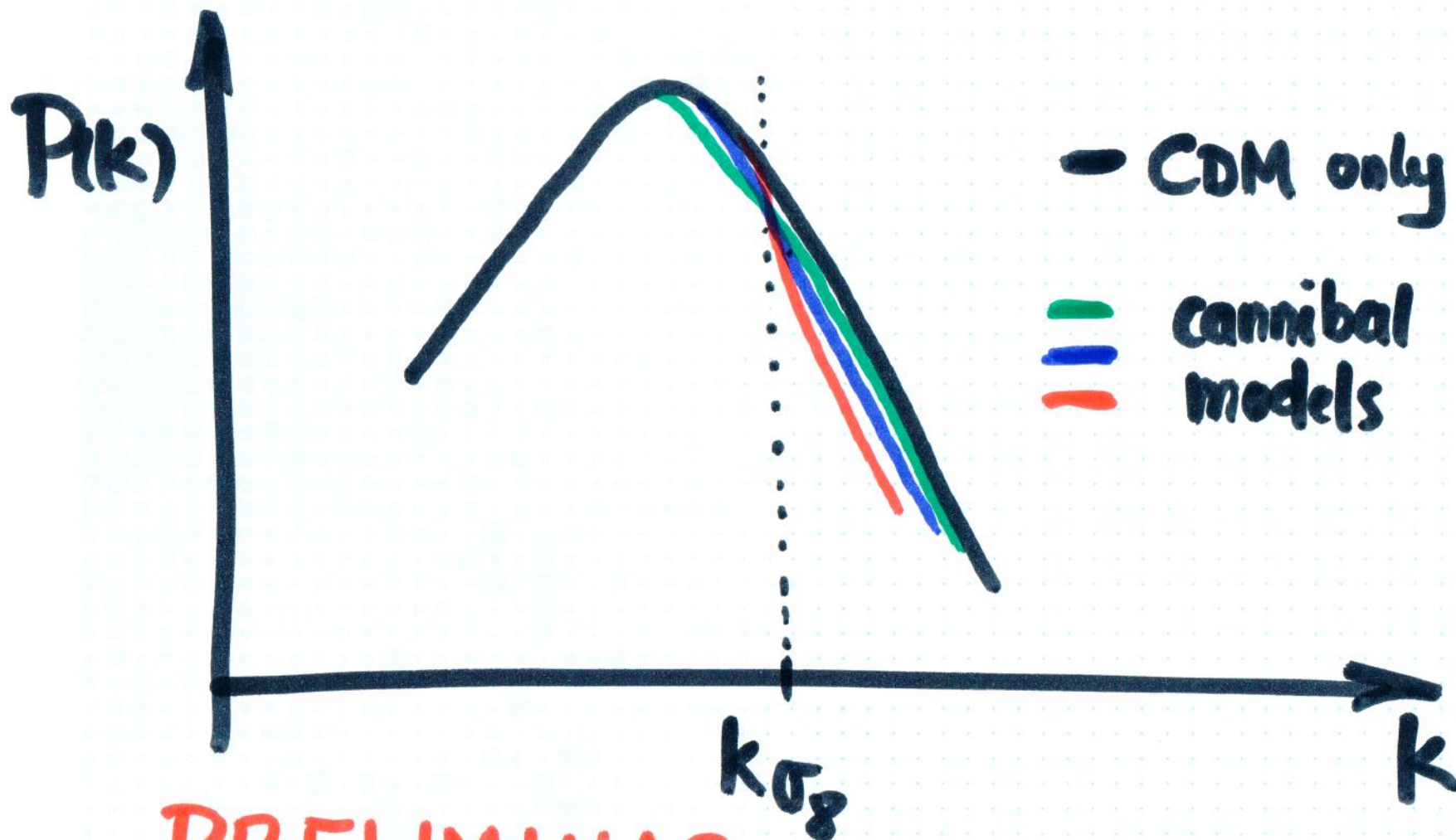
DM perturbation growth with 7% cannibal DM



DM perturbation spectrum with 7% cannibal DM relative to no cannibal DM



~ 7% cannibal DM can give correct σ_8



PRELIMINARY 😊



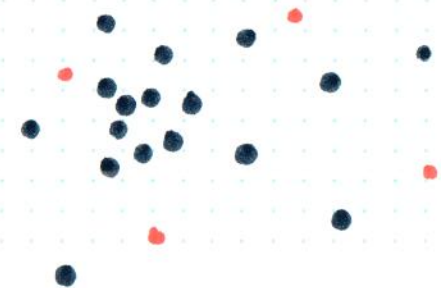
in progress ...

- Study of parameter space M, T_{can} .
- model dependence to glueball spectrum
- precision cosmological fits



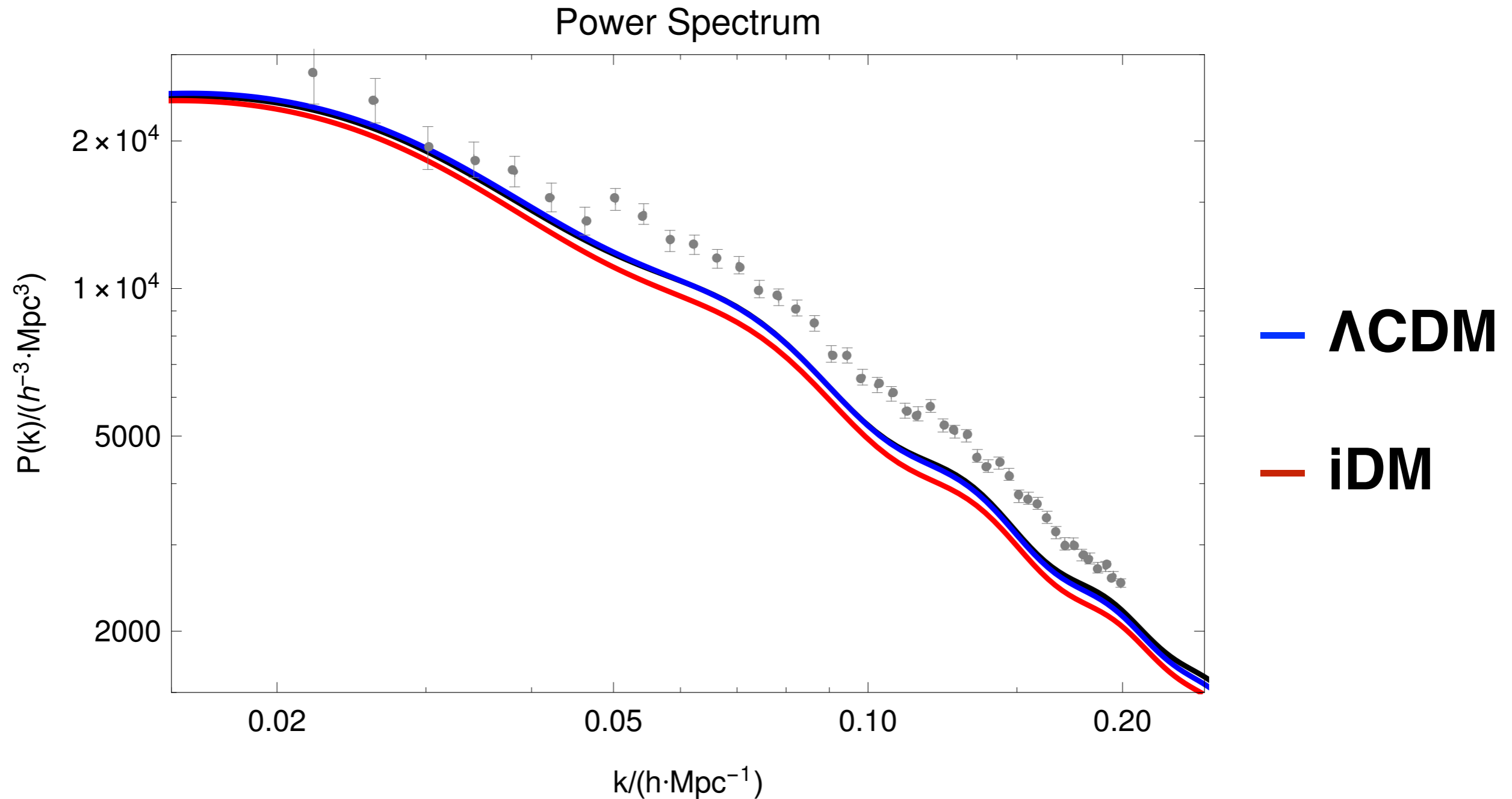
Conclusions

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



back up!

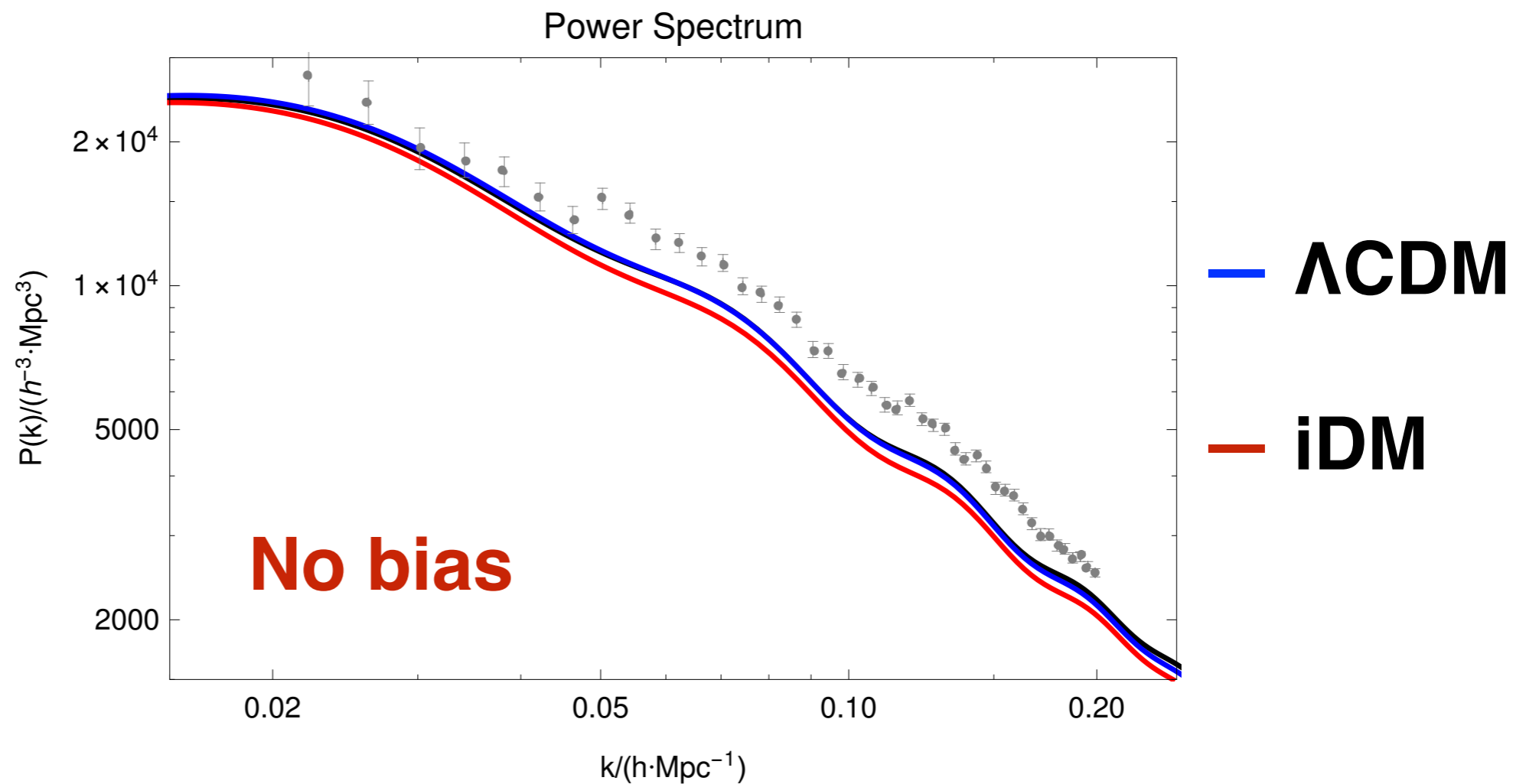
Galaxy Power Spectrum, SDSS-DR7, "straight up"



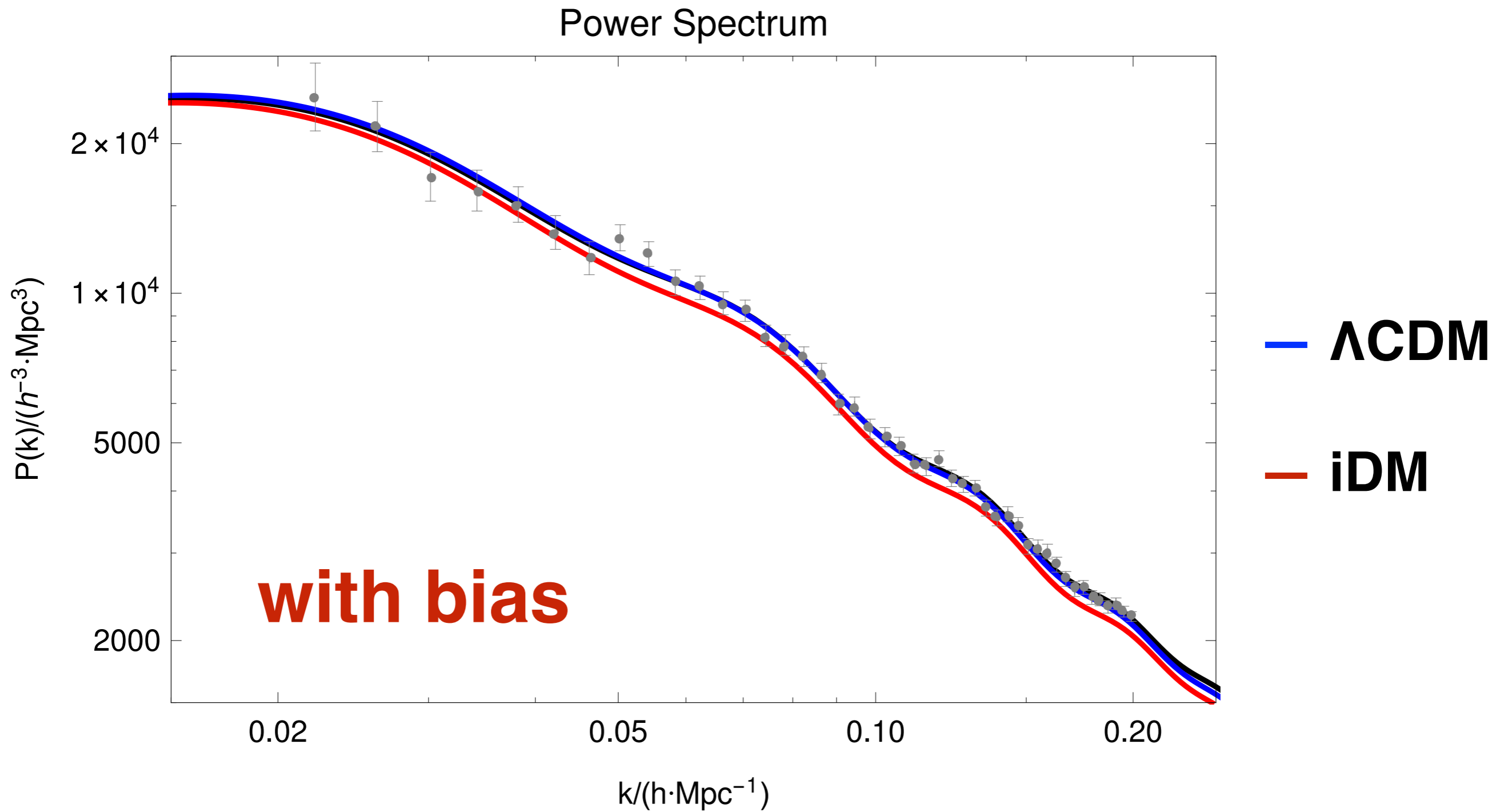
Galaxies don't track dark matter perfectly

"Galaxy bias"

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



Galaxy Power Spectrum, SDSS-DR7



Λ CDM perturbation growth

