MINISTERO DELL' ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA
PRIN "The consequences of flavor"

Dark 5th Forces from Linear Cosmology

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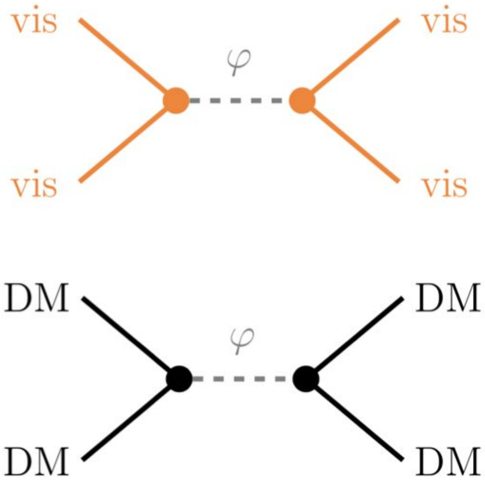
(Scuola Normale Superiore, INFN Pisa)

based on WIP

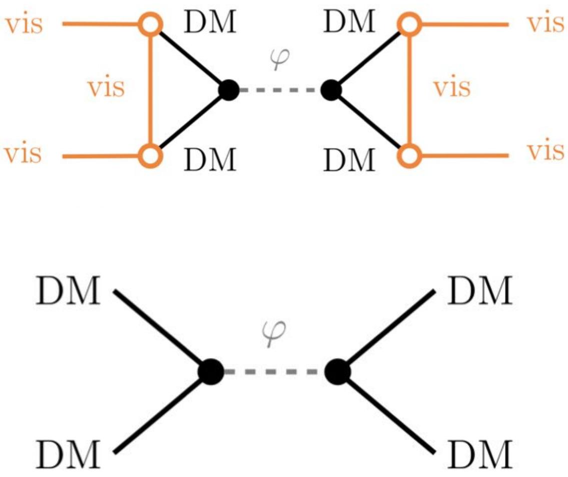
In collaboration with S.Bottaro, E.Castorina, D.Redigolo, E.Salvioni

Dark “Fifth Force” Scenario

Typical 5F scenario



Dark 5F scenario



EP Violation

Introducing the models

$$\mathcal{L}_\chi = -\frac{1}{2}\partial_\mu\chi\partial^\mu\chi - \frac{1}{2}m_\chi^2(1+s^n)\chi^2$$

$$\mathcal{L}_s = -\frac{1}{2G_s}\partial_\mu s\partial^\mu s - \frac{1}{2G_s}m_\phi^2 s^2$$

Cold Scalar DM χ

Scalar mediator s
attractive long range: $m_\phi \lesssim H_0$
subPlanckian strength: $\beta \ll 1$
(never in thermal contact)
5F scenario: $\Omega_s \ll 1$

$$\beta = G_s/G_N$$

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Background evolution

$$\bar{s}'' + 2\mathcal{H}\bar{s}' + \cancel{G_s a^2 V_{s,s}} + G_s a^2 \bar{\rho}_\chi \frac{\partial \log m_\chi(s)}{\partial s} = 0$$

$$\bar{\rho}_\chi' + 3\mathcal{H}\bar{\rho}_\chi = \bar{\rho}_\chi \frac{\partial \log m_\chi(s)}{\partial s}\bar{s}'$$

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$$\bar{\rho}'_\chi + 3\mathcal{H}\bar{\rho}_\chi = \bar{\rho}_\chi \frac{\partial \log m_\chi(s)}{\partial s}\bar{s}'$$

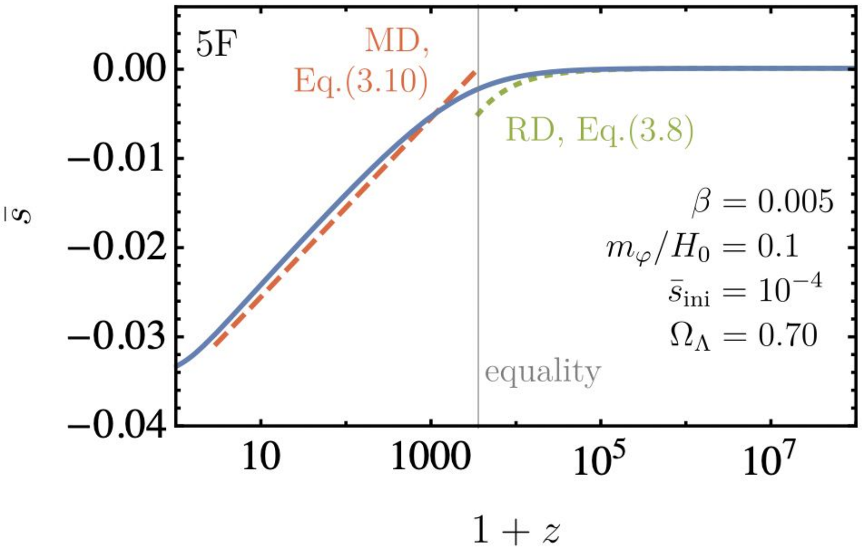
$$s \sim \mathcal{O}(\beta)$$

The prototype: Yukawa interaction $s\chi^2$

- Small s_{ini} : $\dfrac{\partial \log m_\chi(s)}{\partial s} \simeq 1$

$$\bar{s} \simeq \bar{s}_{\text{eq}} - 2\beta \frac{\partial \log m_\chi(s)}{\partial s} f_\chi \log \frac{\tau}{\tau_{\text{eq}}}$$

non trivial attractor



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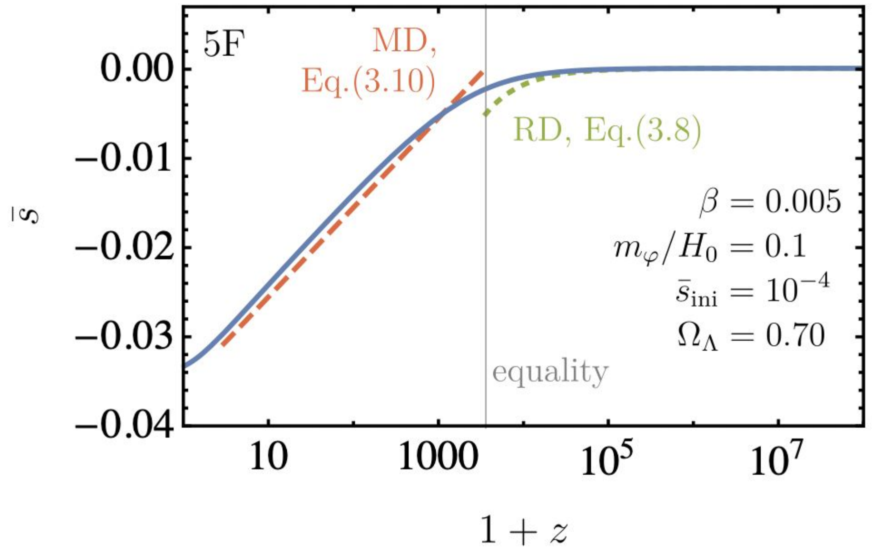
non trivial attractor

- Large $s_{\rm ini}$: $\dfrac{\partial \log m_\chi(s)}{\partial s} \simeq 1/s_{\rm ini}$

Ansatz: $\bar{s} = s_{\rm ini} + \Delta$



We recover small $s_{\rm ini}$ scenario

Perturbation evolution

$$\delta'_\chi + \theta_\chi + 3\Phi' - \frac{\partial \log m_\chi(s)}{\partial s}\,\delta s' - \frac{\partial^2 \log m_\chi(s)}{\partial s^2}\bar{s}'\delta s \ = 0$$

$$\theta'_\chi + \left(\mathcal{H} + \frac{\partial \log m_\chi(s)}{\partial s}\,\bar{s}'\right)\theta_\chi - k^2\left(\Psi + \frac{\partial \log m_\chi(s)}{\partial s}\,\delta s\right) \ = 0$$

Perturbation evolution

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potentials: do not affect subhorizon physics

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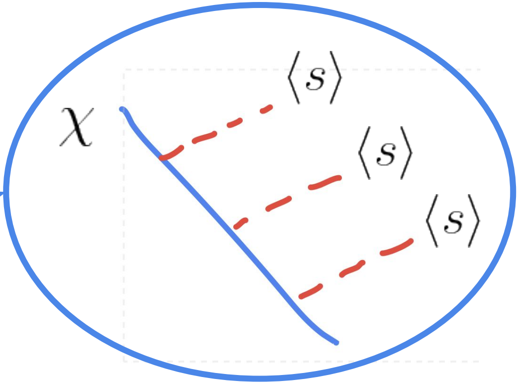
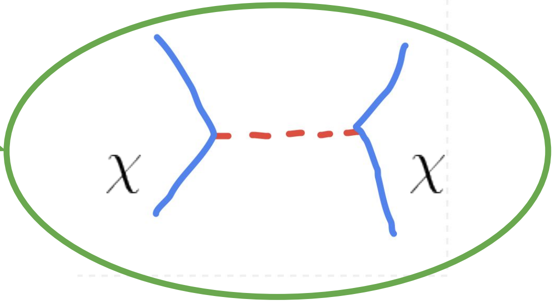


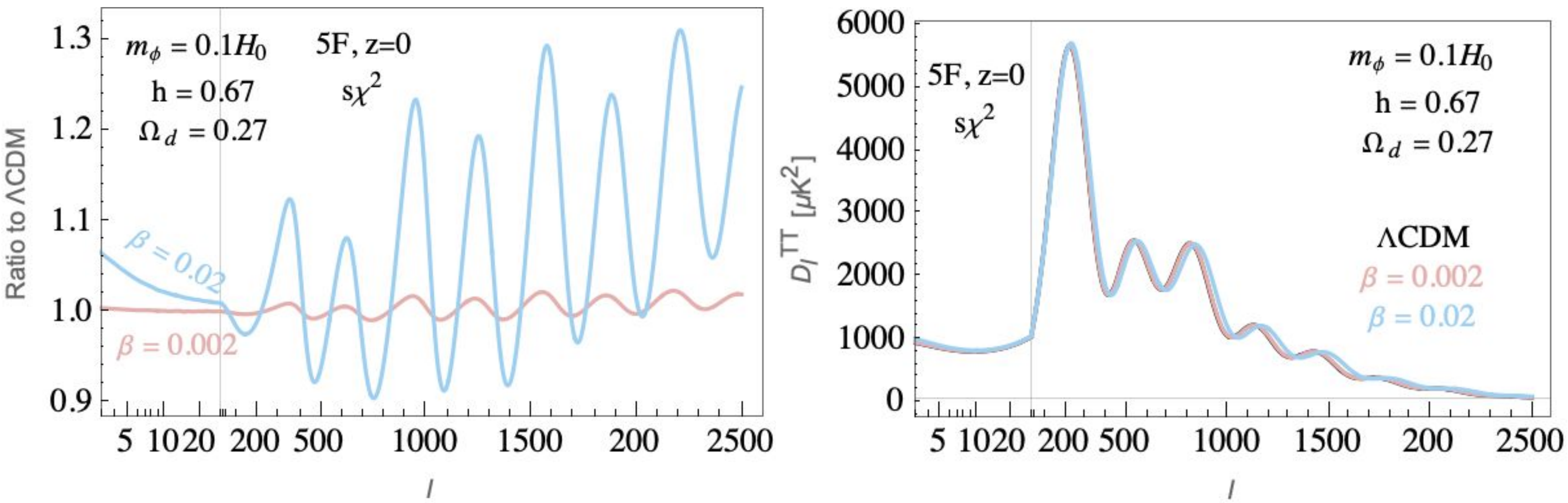


large s_{ini} rescaling: $\beta_{\mathrm{eff}} = \beta\left(\frac{\partial \log m(s)}{\partial s}\right)^2$

Other interactions

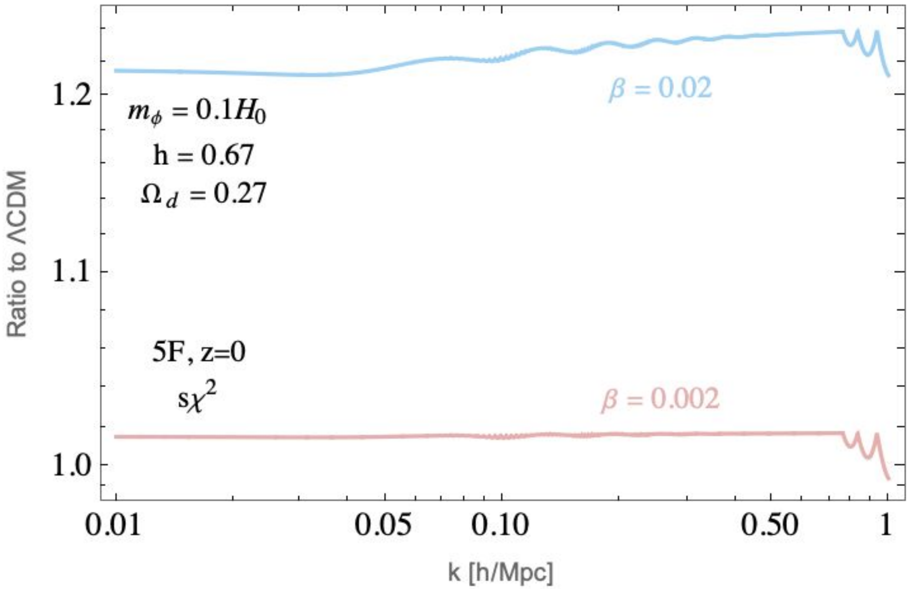
Model	$\dfrac{\partial \log m(s)}{\partial s}$	Small $s_{\rm ini}$	Large $s_{\rm ini}$
$s\chi^2$ (super-renormalizable)	$\dfrac{1}{1+2s}$	1	$1/s_{\rm ini}$
$\dfrac{1}{2}s^2\chi^2$ (marginal)	$\dfrac{s}{1+s^2}$	s	$1/s_{\rm ini}$
$\dfrac{1}{n!}s^n\chi^2$ (non-renormalizable)	$\dfrac{ns^{n-1}}{2(1+s^n)}$	s^{n-1}	$1/s_{\rm ini}$

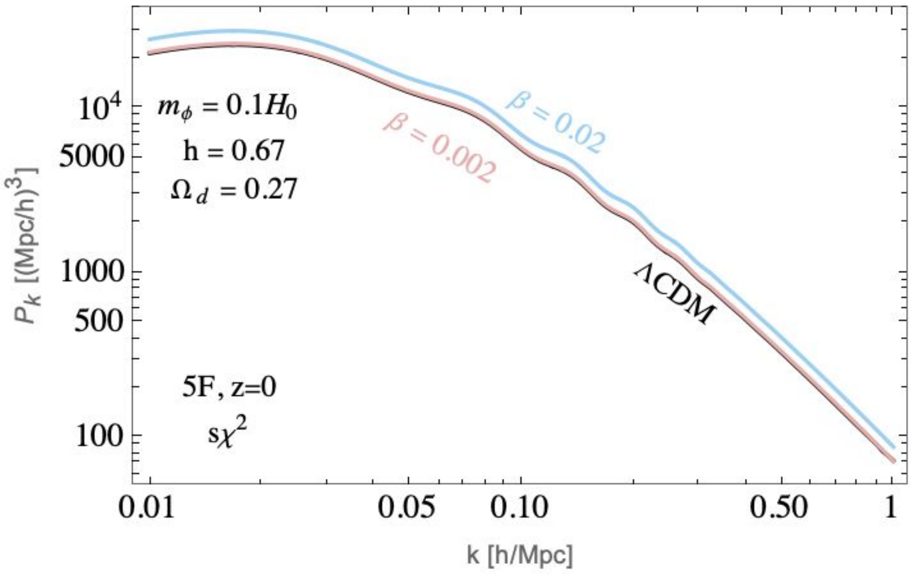
Effect on CMB



ISW **shift**

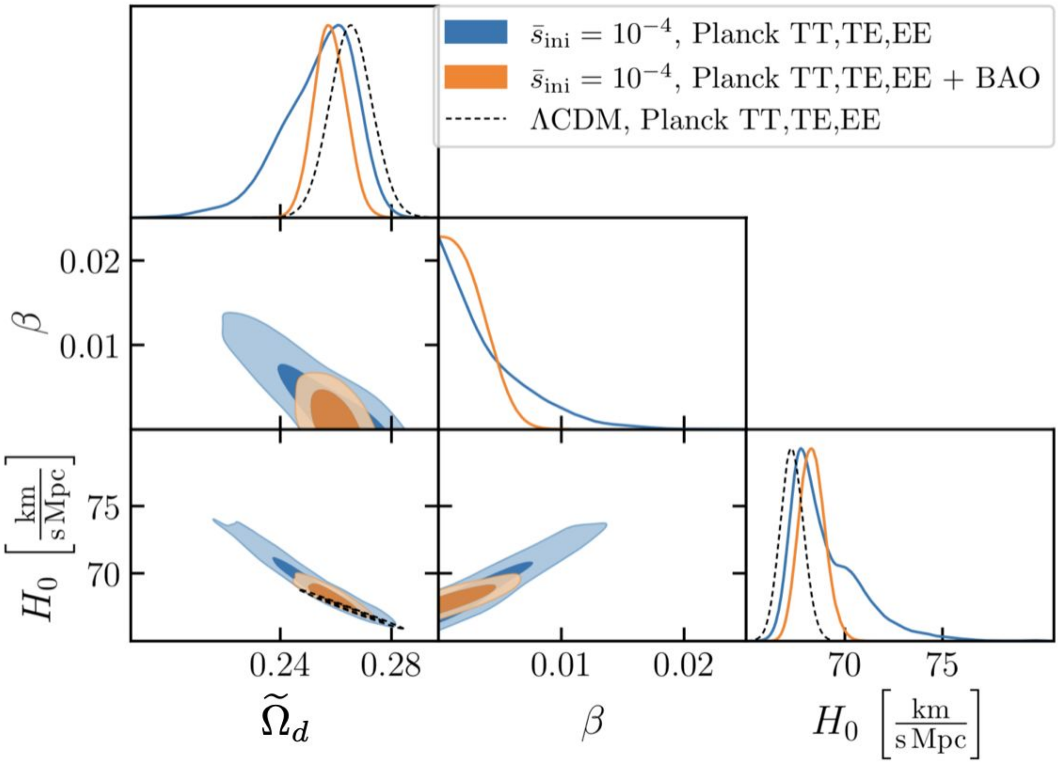
Effect on P(k)





No new BAO phases

Final results (yukawa)



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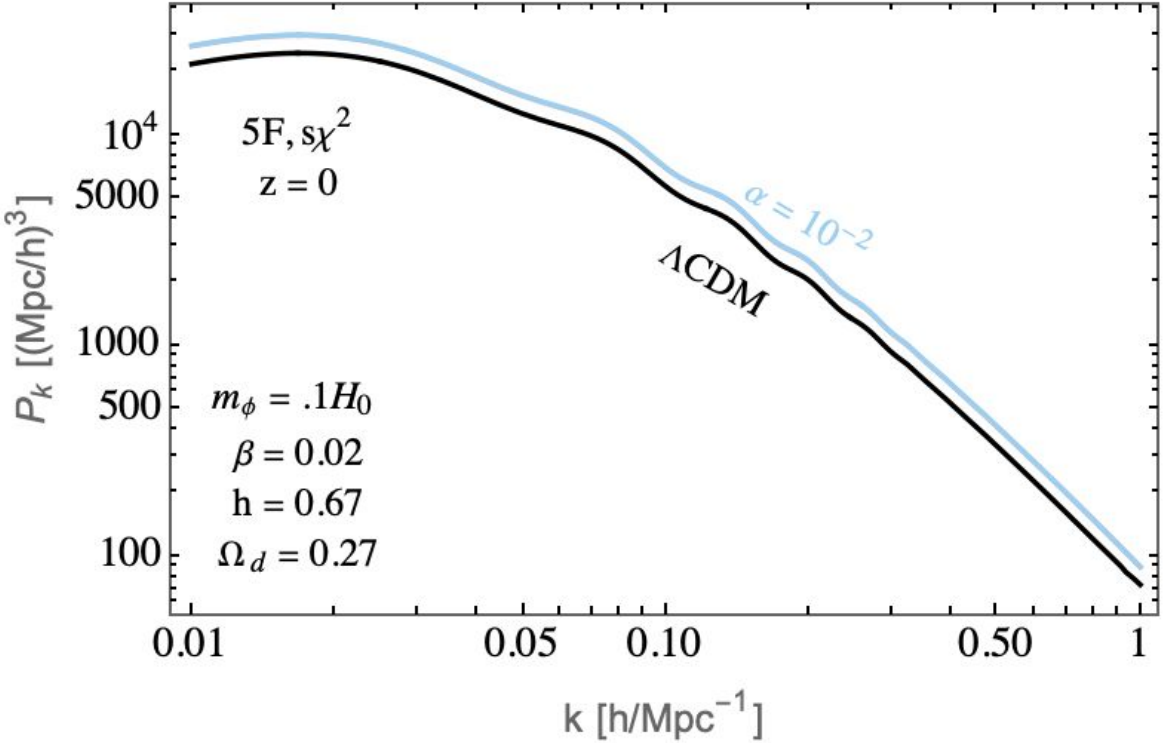
Conclusions

- Presence of long range force in Dark Sector modifies distances and falling
- Small $s_{\rm ini}$: Yukawa has **non trivial attractor** in s background, other interactions undistinguishable from ΛCDM
- Large $s_{\rm ini}$: **universal behaviour**, like rescaled Yukawa
- CMB: effect on low *l* through ISW, shift of peaks (distance modification)
- Pk: enhancement (also in velocity pert.), no new phases

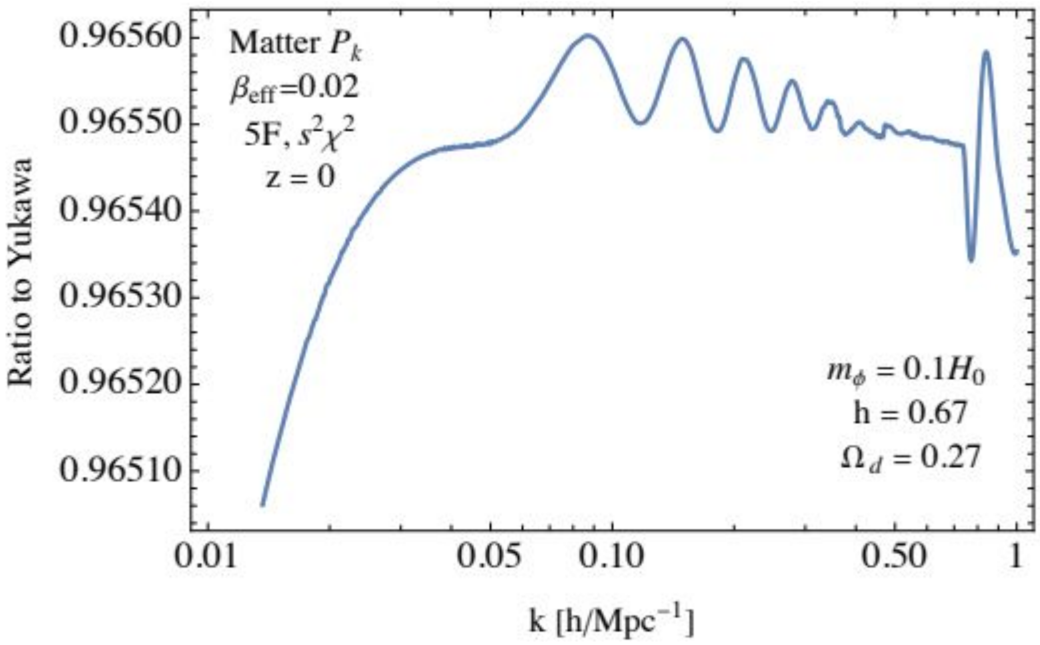
Thanks for the attention!

Backup

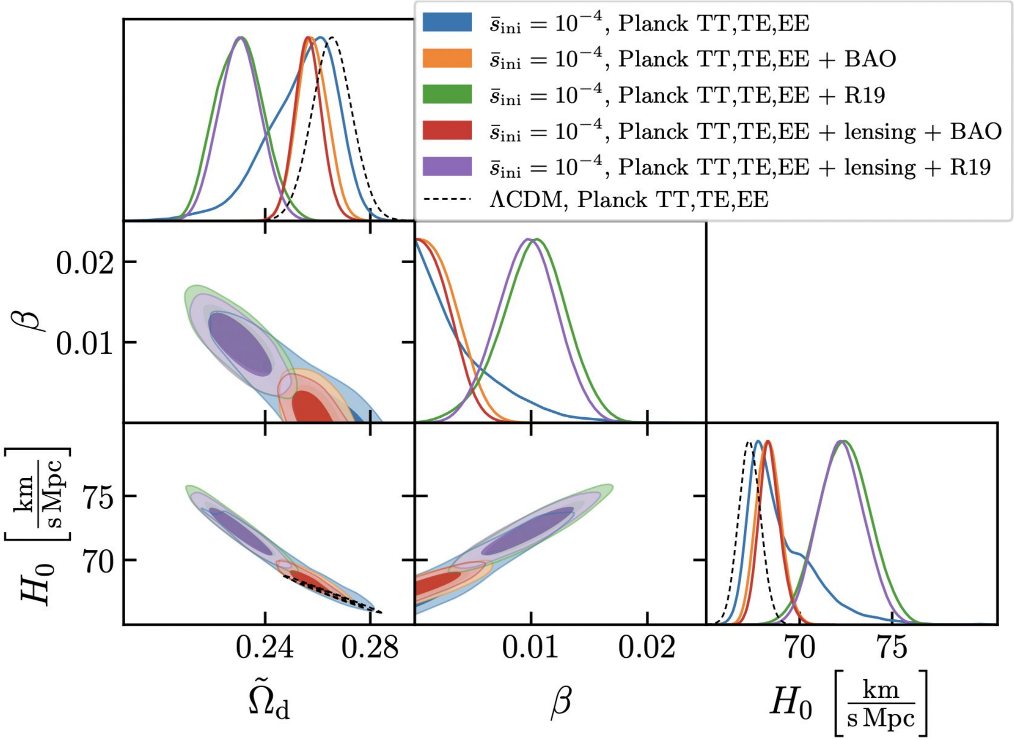
Non adiabaticity



Perturbation rescaling



Final results



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Final results: dilaton