Investigating the assumptions of the EFTofLSS

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Cosmology from Home, 2023

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500 Mpc/h
[Millenium Simulation Project]

[Millenium Simulation Project]

small-k (large scales)

large-k (small scales)

k_{H} k k_{NL}

Perturbation Theory (PT)

1) Assumption of PPF
2) Includes $k > k_{\mathrm{NL}}$

N-body simulations

1) Macroparticle assumption
2) Limited dynamic range

Effective Field Theory of Large-Scale Structure

[Baumann et al 2012, Carrasco et al 2012]

Goal: Address the shortcomings of PT and extend its reach

1. Introduce a cutoff scale Λ
2. Solve the coarse-grained equations
3. Dependence on $k > \Lambda$ encoded in unknown 'Wilson coefficients'
4. Parameter estimation is done by estimating the coefficients from data

Flavours of EFTs

Top-down

1) Small-scale physics is known

2) EFT coefficients are calculated from small-scale theory (for the EFTofLSS, we use N-body simulations)

Bottom-up

1) Small-scale physics is unknown

2) EFT coefficients are calculated by matching observables to data

Motivation (Karandikar, Porciani, Hahn; in prep)

Design the simplest universe in which the bottom-up and top-down EFTs can be compared

Setup: 1D, Einstein de Sitter

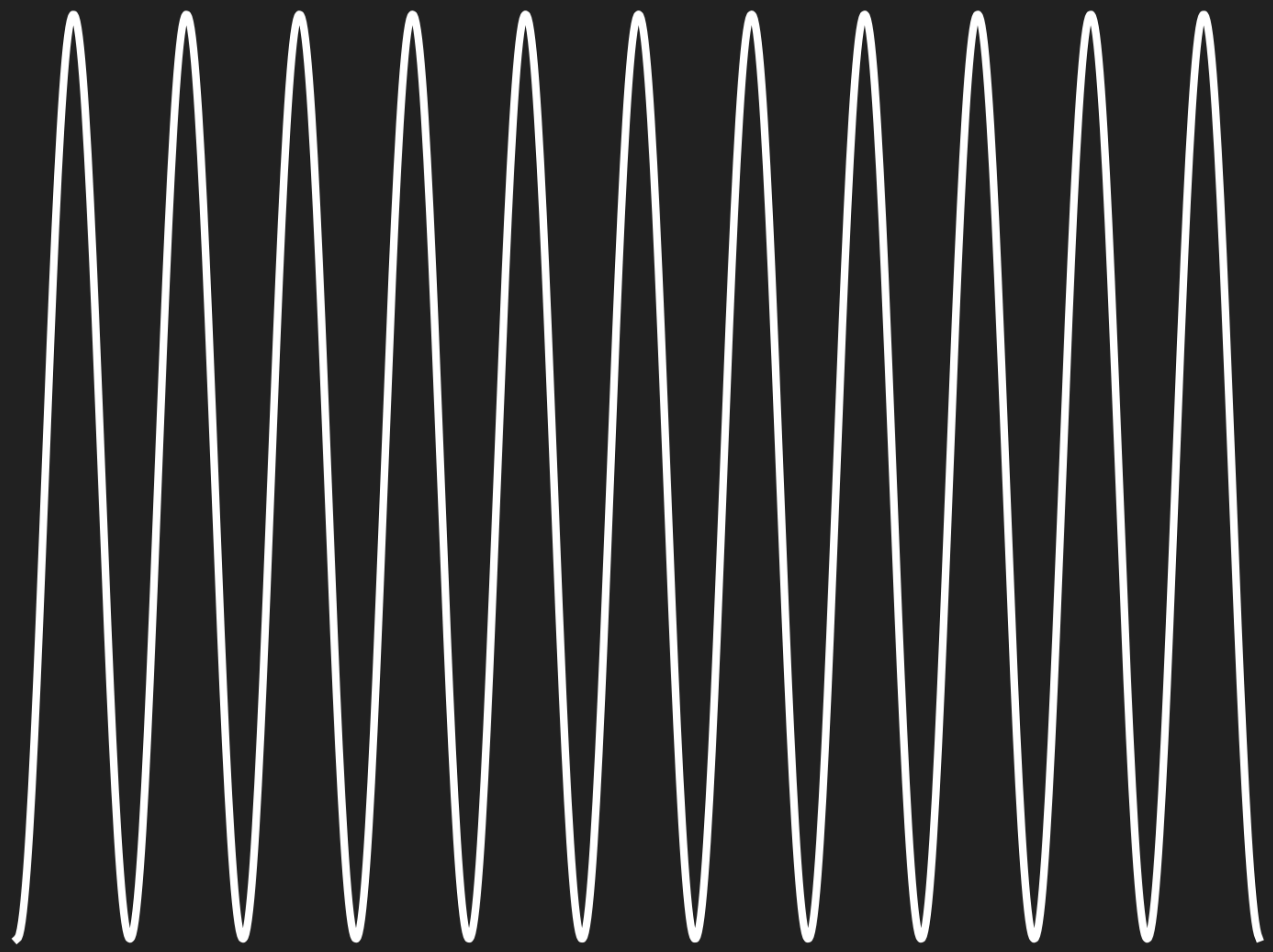
long-wavelength mode

$$k = k_{\mathrm{f}}$$

Setup

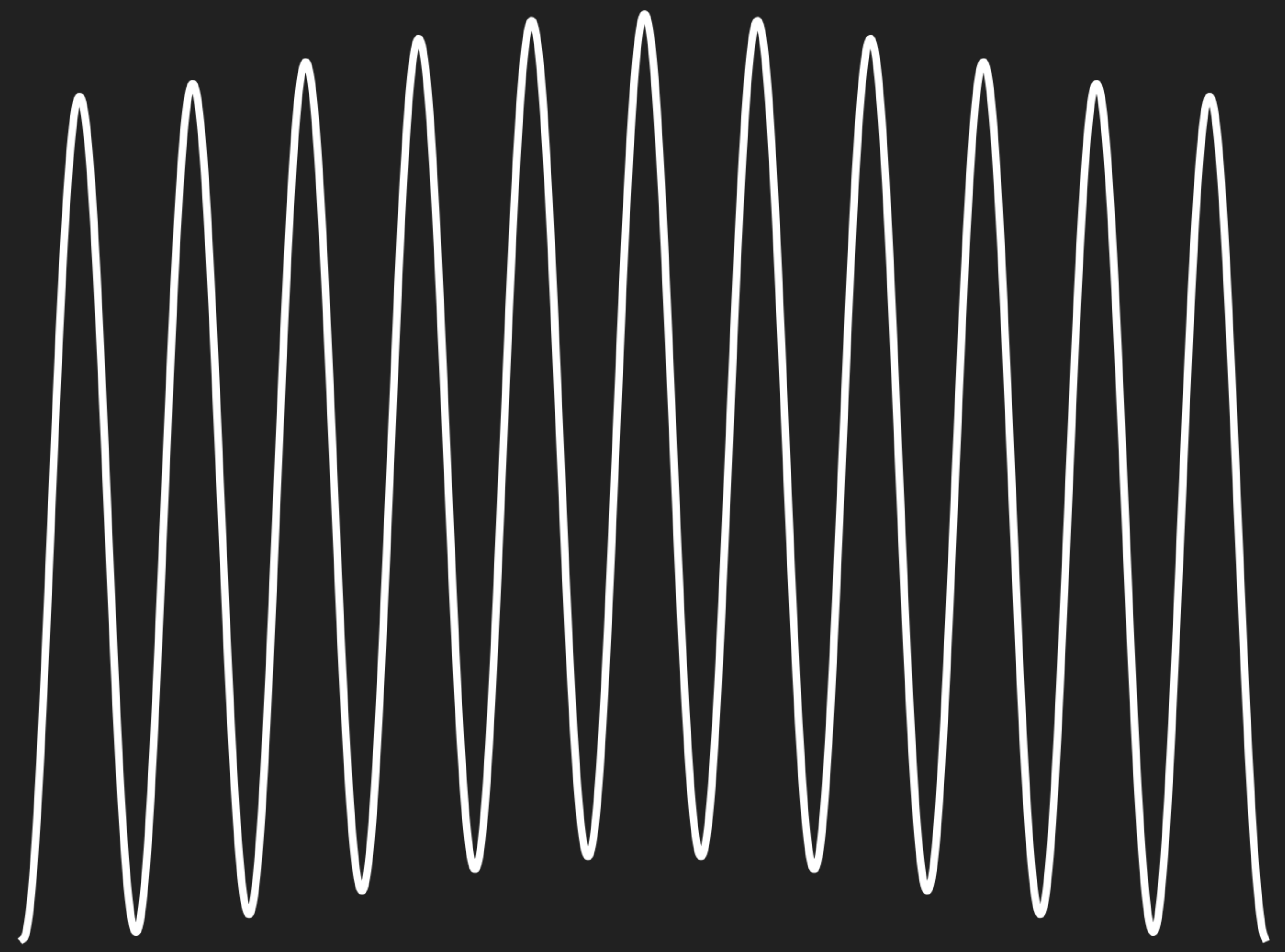
short-wavelength mode

$$k = 11\,k_{\mathrm{f}}$$



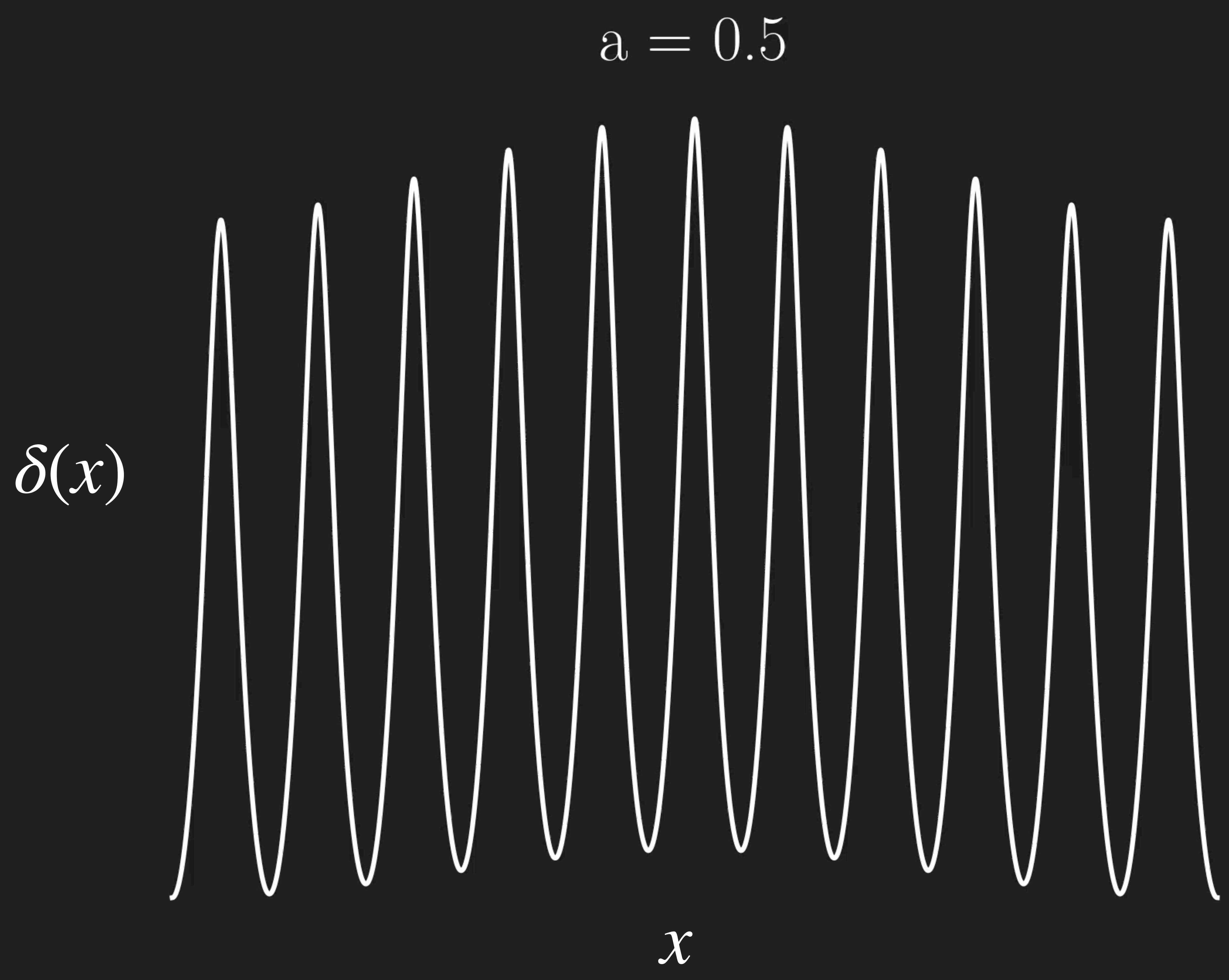
Setup

superposition



Setup

sim_1_11



https://bitbucket.org/ohahn/cosmo_sim_1d

Coarse-grained equations

$$\frac{\mathrm{d}f}{\mathrm{d}t} = 0 \xrightarrow[\text{with } \Lambda]{\text{coarse-grain}} \frac{\mathrm{d}f_l}{\mathrm{d}t} = 0 \xrightarrow[\text{moments}]{\text{take momentum}} \int \mathrm{d}p\, p^n \frac{\mathrm{d}f_l}{\mathrm{d}t} = 0$$

Coarse-grained equations

$$\dot{\delta}_l + \frac{1}{a}\partial_x[(1+\delta_l)u_l] = 0$$

mass-conservation

$$\dot{u}_l + Hu_l + \frac{1}{a}u_l\partial_x u_l + \frac{1}{a}\partial_x\phi_l + \frac{1}{a\rho_l}\partial_x\tau = 0$$

momentum-conservation

$$\partial_x^2\phi_l = 4\pi G a^2\bar{\rho}\delta_l$$

gravitational coupling

Effective stress

$$\tau = \tau_{\mathrm{k}} + \tau_{\mathrm{g}}$$

kinetic

$$\tau_{\mathrm{k}} = \Xi_l - \rho_l u_l^2$$

gravitational

$$\tau_{\mathrm{g}} = \frac{1}{8\pi G a^2}\left\{\left[(\partial_x\phi)^2\right]_l - \left(\partial_x\phi_l\right)^2\right\}$$

Effective stress

$$\tau = p_{\mathrm{b}} + \rho_b c_{\mathrm{s}}^2 \delta_l - \rho_b c_{\mathrm{v}}^2 \theta_l + \ldots$$

$$c_{\mathrm{tot}}^2 \equiv c_{\mathrm{s}}^2 + c_{\mathrm{v}}^2$$

EFTofLSS corrections

At the power spectrum level,

$$P_{\text{EFT}} = \underbrace{P_{11} + P_{12} + 2P_{13} + P_{22}}_{\text{tSPT}-4} + 2\alpha_c k^2 P_{11}$$

$$\alpha_c = \frac{1}{a}\int_0^a \mathrm{d}a'\, G(a,a')\, c^2_{\text{tot}}(a')\, a' \qquad G(a,a') = \frac{2}{5H_0^2}\left[\left(\frac{a'}{a}\right)^{3/2} - \frac{a}{a'}\right]$$

(EdS)

Flavours of EFTs, revisited

Top-down

Estimate c_{tot}^2 from simulations, then calculate α_c

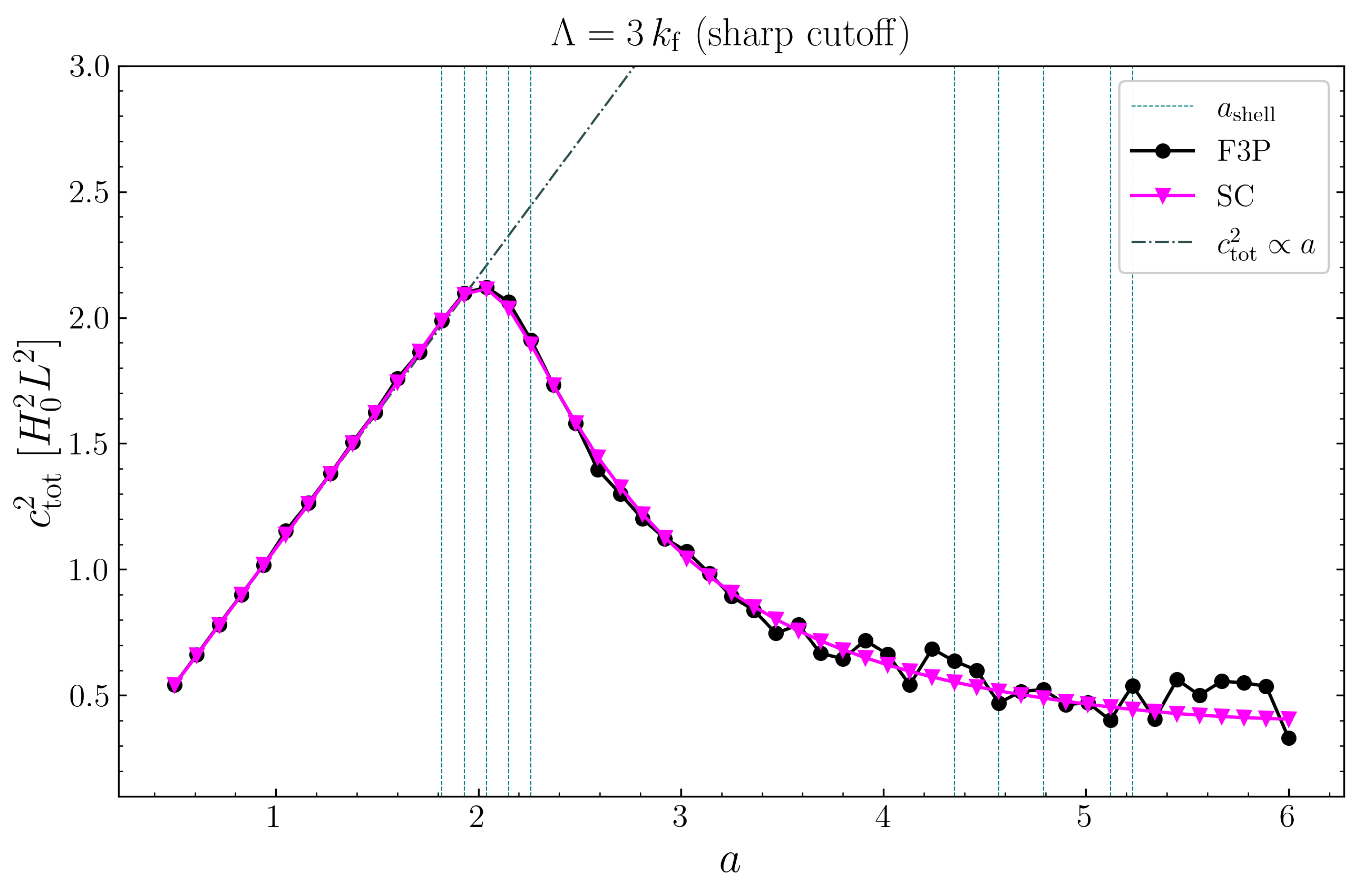
1) Take spatial correlations of τ with δ_l, θ_l: SC
2) Fit measured τ with δ_l, θ_l: F3P

Bottom-up

Match the EFT and N-body spectrum to get α_c

$$\alpha_c = \frac{P_{N-\text{body}} - P_{\text{tSPT}-4}}{2k^2 P_{11}}$$

Results: Estimated $c^2_{\rm tot}$

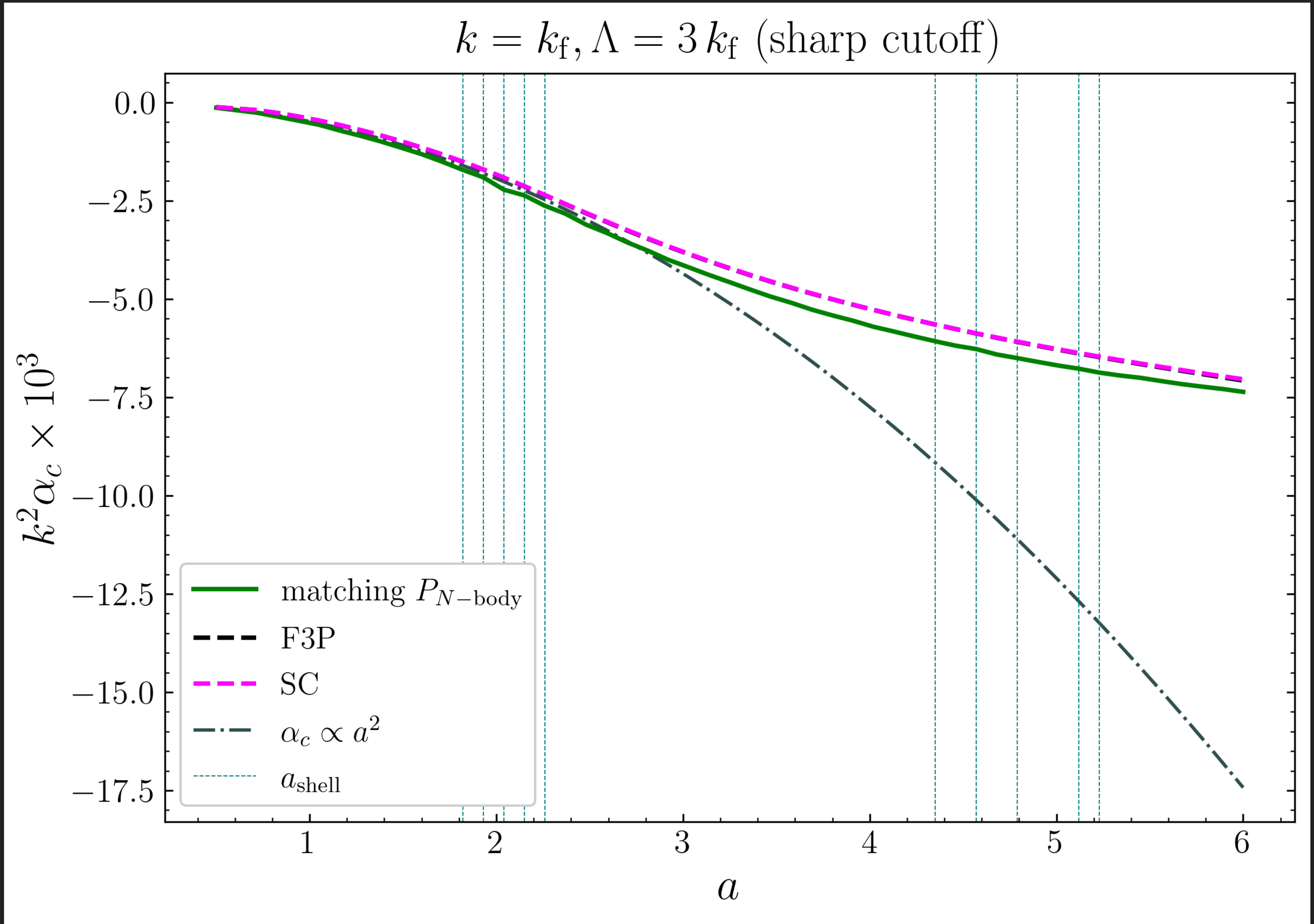


$a_{\rm shell}$: shell-crossing times

F3P: 3-parameter fit

SC: estimate from spatial correlations

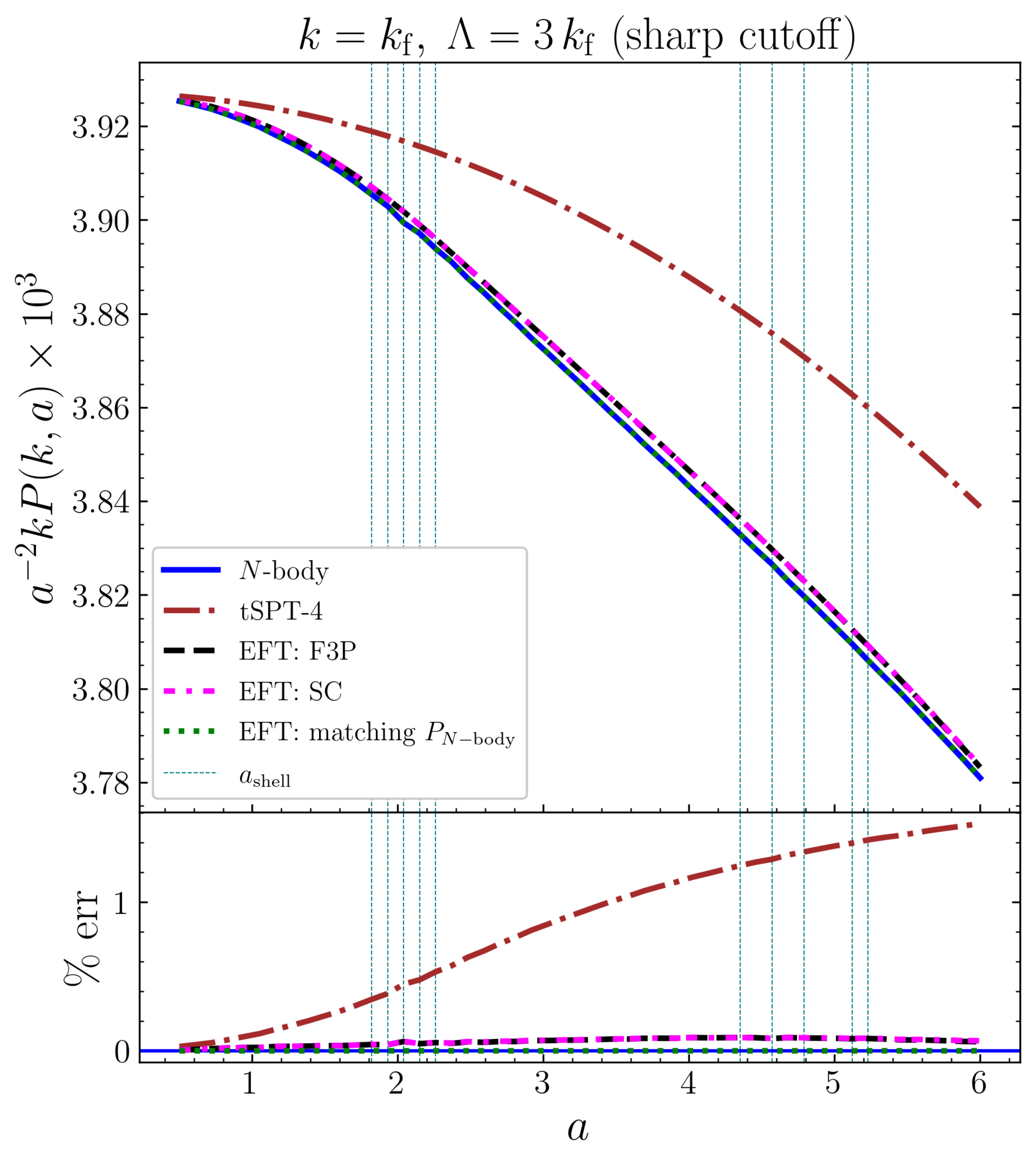
Results: α_c



top-down: dashed lines

bottom-up: solid line

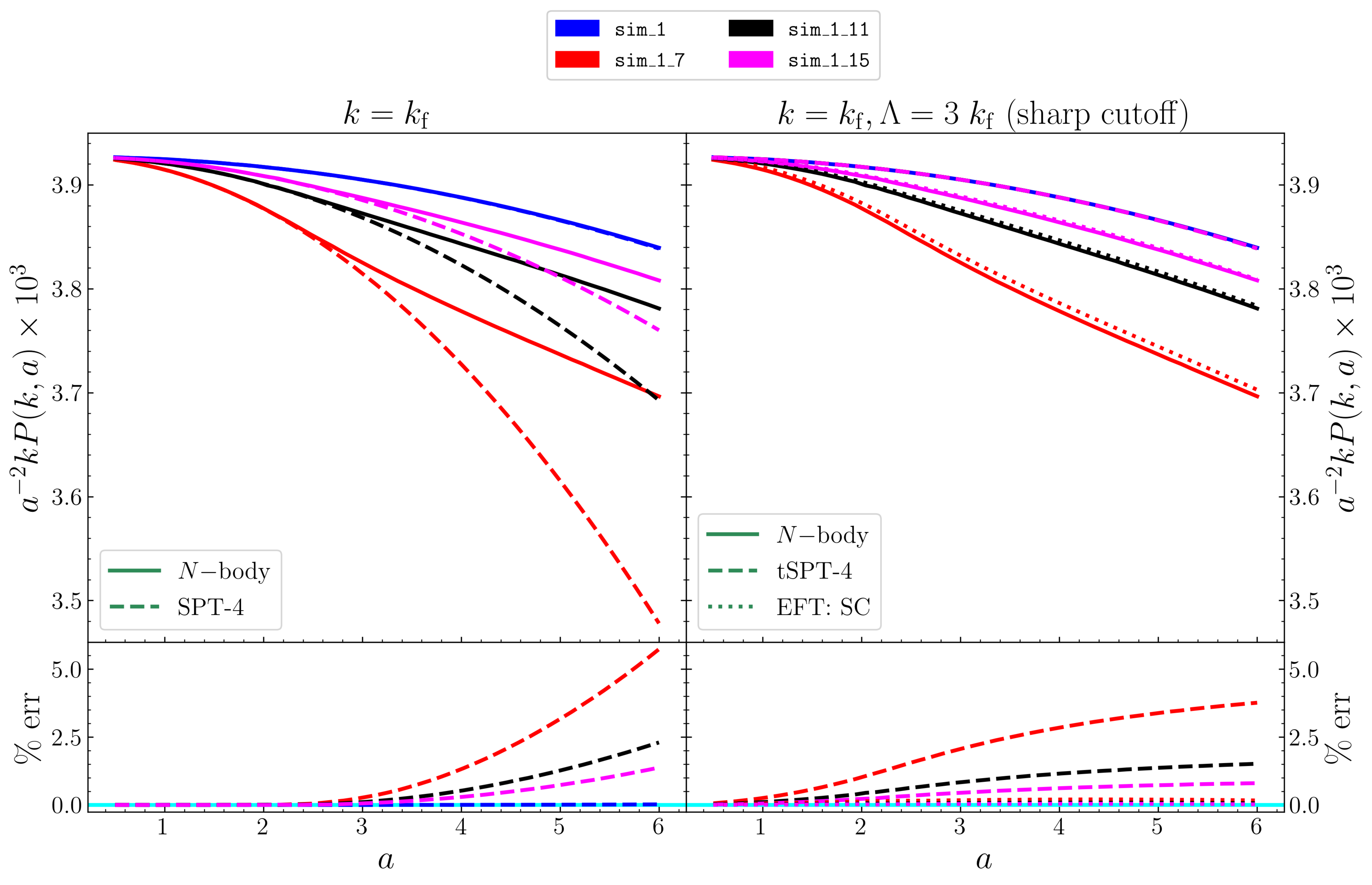
Results: Power in $k = k_\mathrm{f}$



top-down: dashed lines

bottom-up: dotted line

Results: Dependence on separation of scales



Summary

- c^2_{tot} deviates from linear evolution after shell crossing
- The bottom-up and top-down estimators agree, providing a consistency check on the EFTofLSS
- The EFT predictions are robust to changes in scale separation

Summary

The bottom-up and top-down estimators agree, providing a consistency check on the EFTofLSS

For more details, see: (Karandikar, Porciani, Hahn; in prep)