Nonlinearities can filter dark energy models

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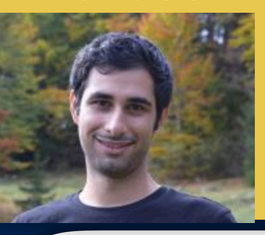

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Action

$$S = \frac{1}{16\pi G}\int \sqrt{-g}Rd^4x + \int \sqrt{-g}P(X,\varphi)d^4x \quad X = -\frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi$$

Equations of motion

$$\zeta \equiv \pi' + \mathcal{H}\pi - \Psi$$

$$\zeta' - 3w\mathcal{H}\zeta + 3c_s^2\left(\mathcal{H}^2\pi - \mathcal{H}\Psi - \mathcal{H}'\pi - \Phi'\right) - c_s^2\nabla^2\pi$$

Non-linear terms

$$+\vec{\nabla}\left[2(c_s^2-1)\zeta + c_s^2\Phi - \Psi\right]\cdot\vec{\nabla}\pi + \left[(c_s^2-1)\zeta + c_s^2\Phi - c_s^2\Psi\right]\nabla^2\pi$$
$$+\frac{\mathcal{H}}{2}\left[(2+3w+c_s^2)(\vec{\nabla}\pi)^2 + 6c_s^2(1+w)\pi\nabla^2\pi\right] - \frac{c_s^2-1}{2}\nabla_i\left(\nabla_i\pi(\vec{\nabla}\pi)^2\right) = 0$$

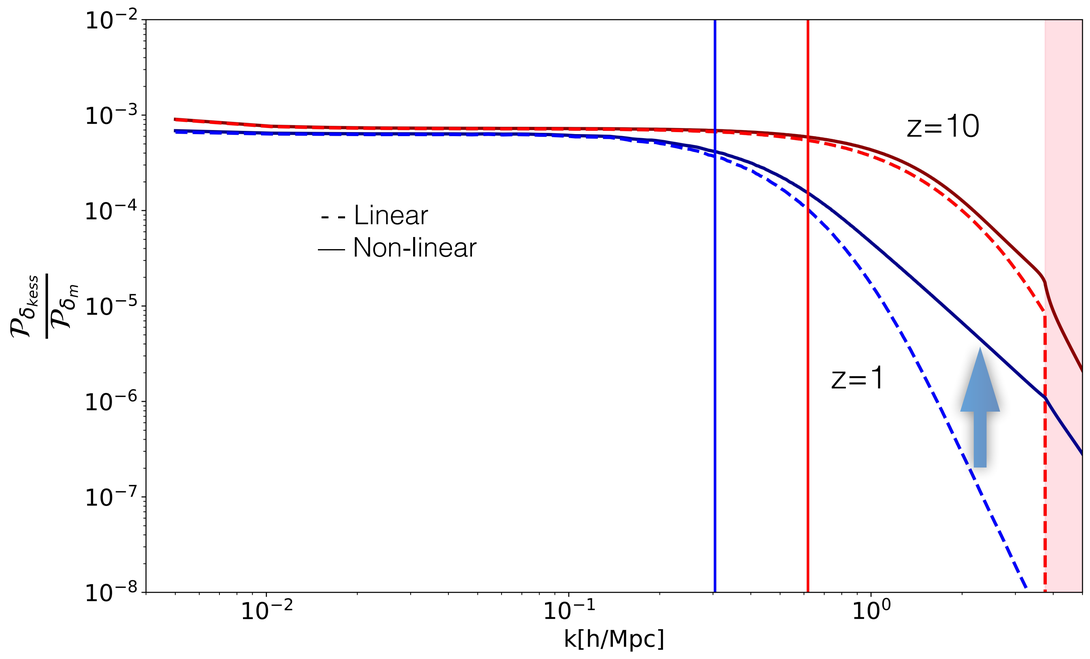
K-essence Stress tensor

$$T_0^0 = -\rho + \frac{\rho+p}{c_s^2}\left[3c_s^2\mathcal{H}\pi - \zeta - \frac{2c_s^2-1}{2}(\vec{\nabla}\pi)^2\right]$$

$$T_i^0 = -(\rho+p)\left[1 - \frac{1}{c_s^2}\left(3c_s^2(1+w)\mathcal{H}\pi - \zeta + c_s^2\Psi\right) + \frac{c_s^2-1}{2c_s^2}(\vec{\nabla}\pi)^2\right]\partial_i\pi$$

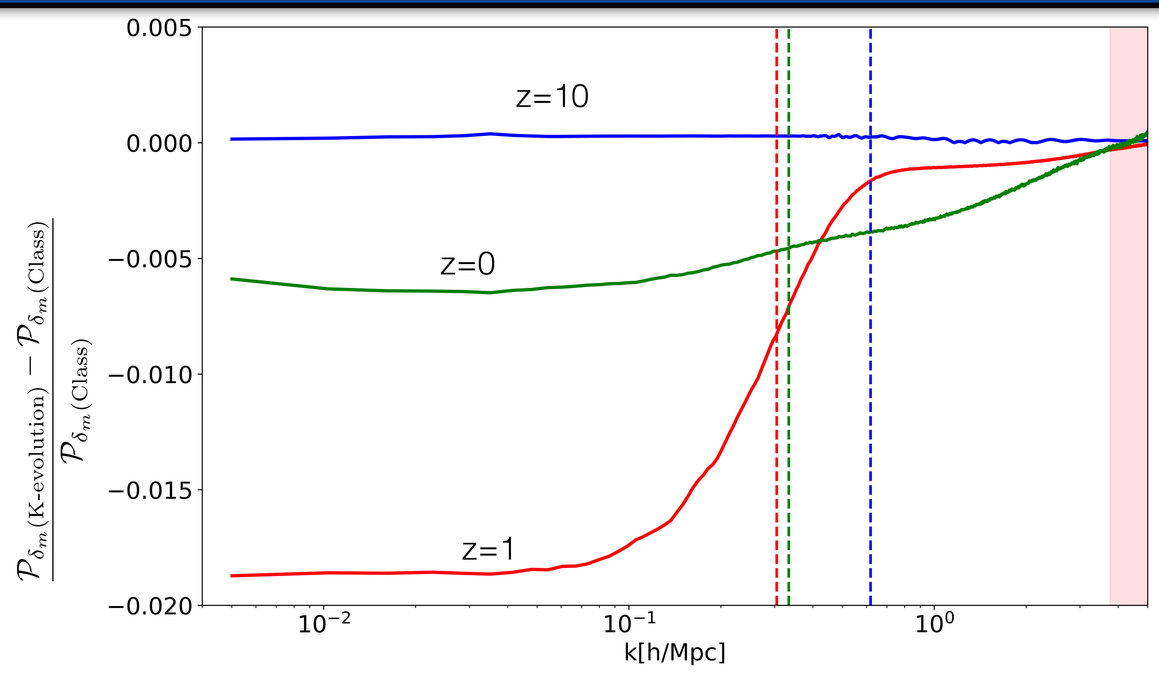
$$T_j^i = p\delta_j^i - (\rho+p)\left[3w\mathcal{H}\pi - \zeta + \frac{1}{2}(\vec{\nabla}\pi)^2\right]\delta_j^i + (\rho+p)\delta^{ik}\partial_k\pi\partial_j\pi$$

Effect of non-linearities on linear k-essence field



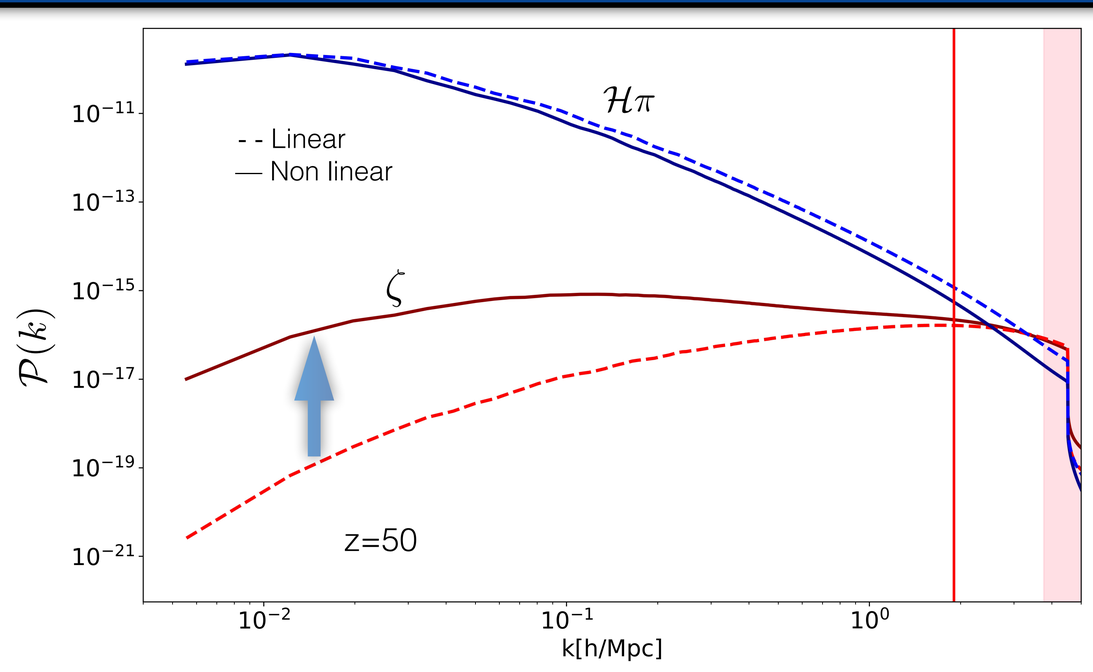
- The non-linear Φ, Ψ and Φ' in k-evolution source linear $\delta_{\text{k-essence}}$
- The equations used for the scalar field in k-evolution are linear

Effect of linear k-essence field on matter power spectrum



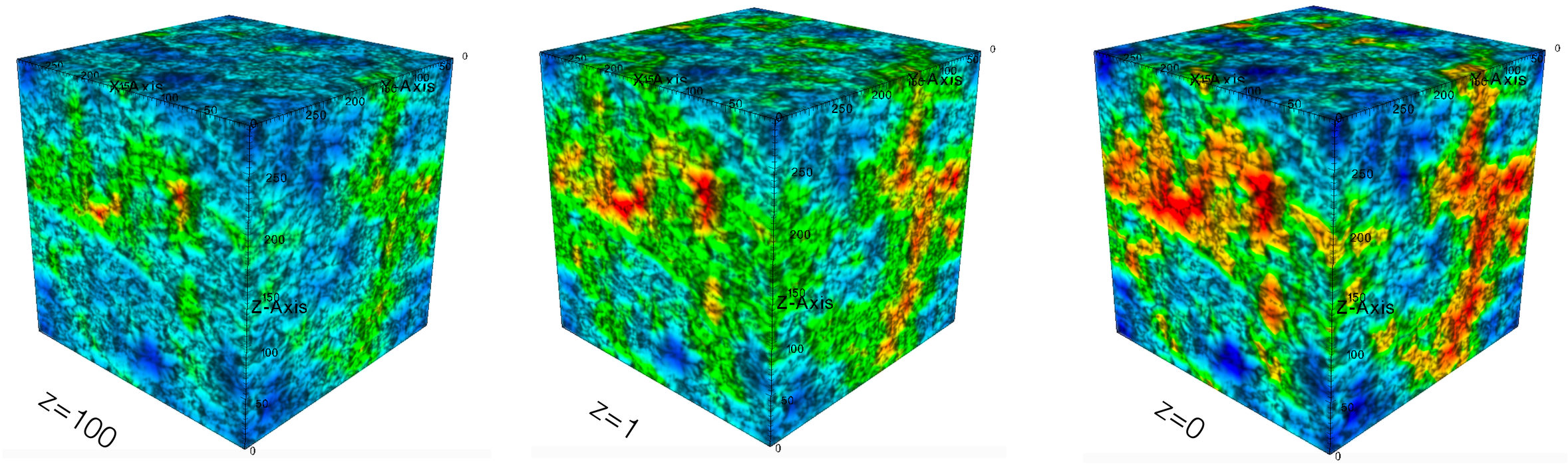
- The non-linearities affect k-essence field clustering and therefore resulting in different matter power spectrum
- Φ' which is more important at large scales is the source of ζ which changes total stress tensor and reduces the matter clustering at large scales

Can non-linearities filter dark energy models?



- Adding non-linearities can make the system unstable
- $\mathcal{H}\pi$ decays but ζ grows and $\delta_{\text{k-essence}}$ becomes large which causes the particles speed up

K-essence field clustering



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