A Unified Description of Screened Modified

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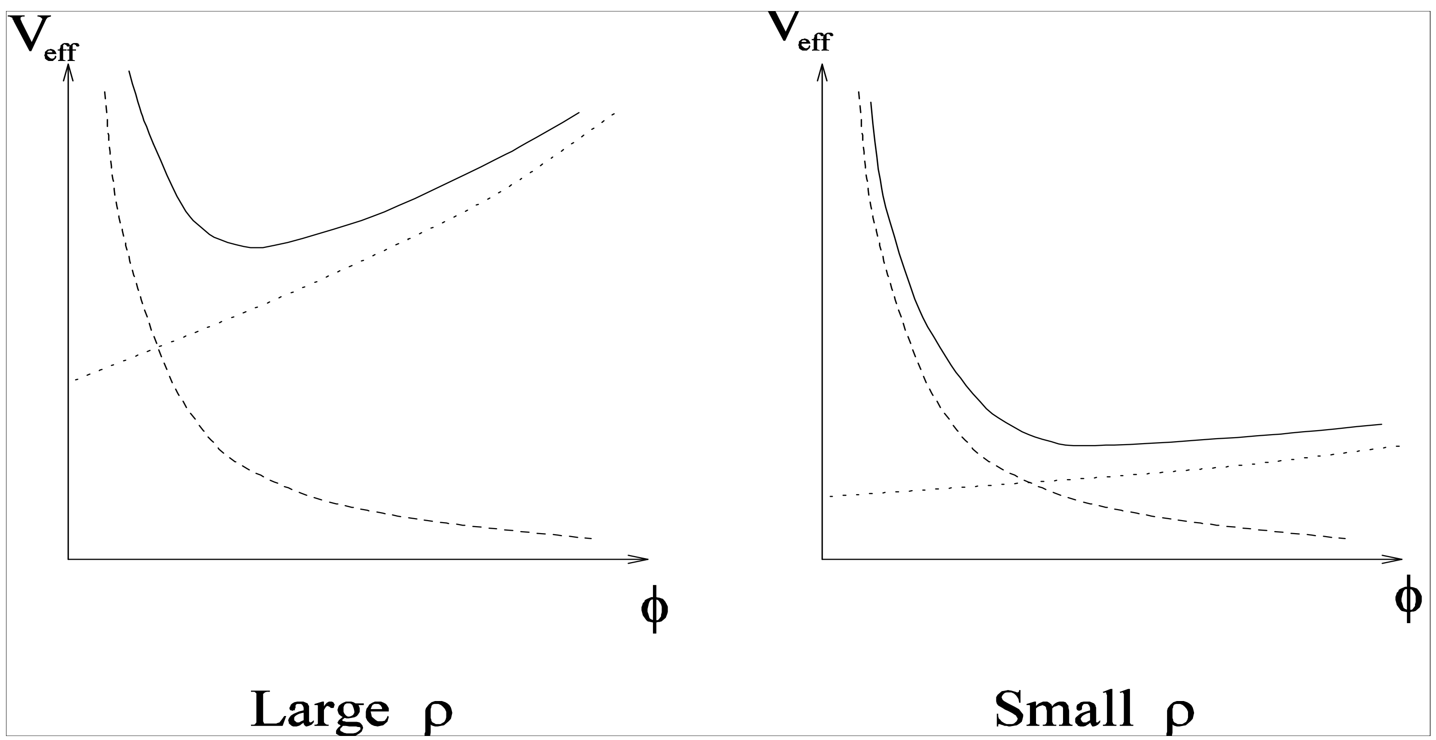
1203.4812; 1206.3568

Outline

- Introduction
- Screened Modified Gravity
- Unified Description - chameleons, symmetrons and dilatons
- Linear and non-linear regime
- N-body plots for symmetron and dilaton

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{16\pi G_N}R - \frac{1}{2}(\partial\phi)^2 - V(\phi)\right) + \mathcal{S}_m(\psi_m, A^2(\phi)g_{\mu\nu}))$$

$$V_{eff}(\phi) = V(\phi) + \rho_m A(\phi)$$



Dilaton

$$V(\phi) = V_0 e^{-\alpha\phi}$$

where the parameters are derived from string theory. The coupling to matter is given by

$$A(\phi) = 1 + \frac{A_2}{2}(\phi - \phi_\star)^2$$

see (Brax et al 1005.3735) for full cosmological behaviour, local constraints and linear perturbation

Screening

since the field has to be at the min of the effective potential by BBN we deduce

$$\phi(a) = \phi_i + \frac{3}{m_{\rm Pl}} \int_{a_i}^{a} da \frac{\beta(a)\rho(a)}{am^2(a)}$$

$$V(a) = V_i - \frac{3}{m_{\rm Pl}} \int_{a_i}^{a} da \frac{\beta^2(a)\rho^2(a)}{am^2(a)}$$

the full non-linear dynamics can be constructed from this the mass and coupling parameter as a function of redshift the screening condition becomes

$$\int_{a_{\rm in}}^{a_{\rm out}} \frac{\beta(a)}{am^2(a)}\rho_m(a){\rm d}a \ll \beta_{\rm out} m_{\rm Pl}^2 \Phi_N;$$

we can apply this to all the models

in addition we can study the growth of structures in the linear and nonlinear regime

Perturbations

linear regime

$$\Delta_m'' + \frac{a'}{a}\Delta_m - \frac{1}{2}\frac{\rho_m}{m_{\rm Pl}^2}a^2\Delta_m\left[1+\frac{2\beta^2(a)}{1+\frac{a^2m^2(a)}{k^2}}\right]=0,$$

for chameleons

$$m = m_0 a^{-r}, \beta = \beta_0 a^{-s}$$

In general

r <3/2 -- dilaton

3/2 < r < 3 --chameleon

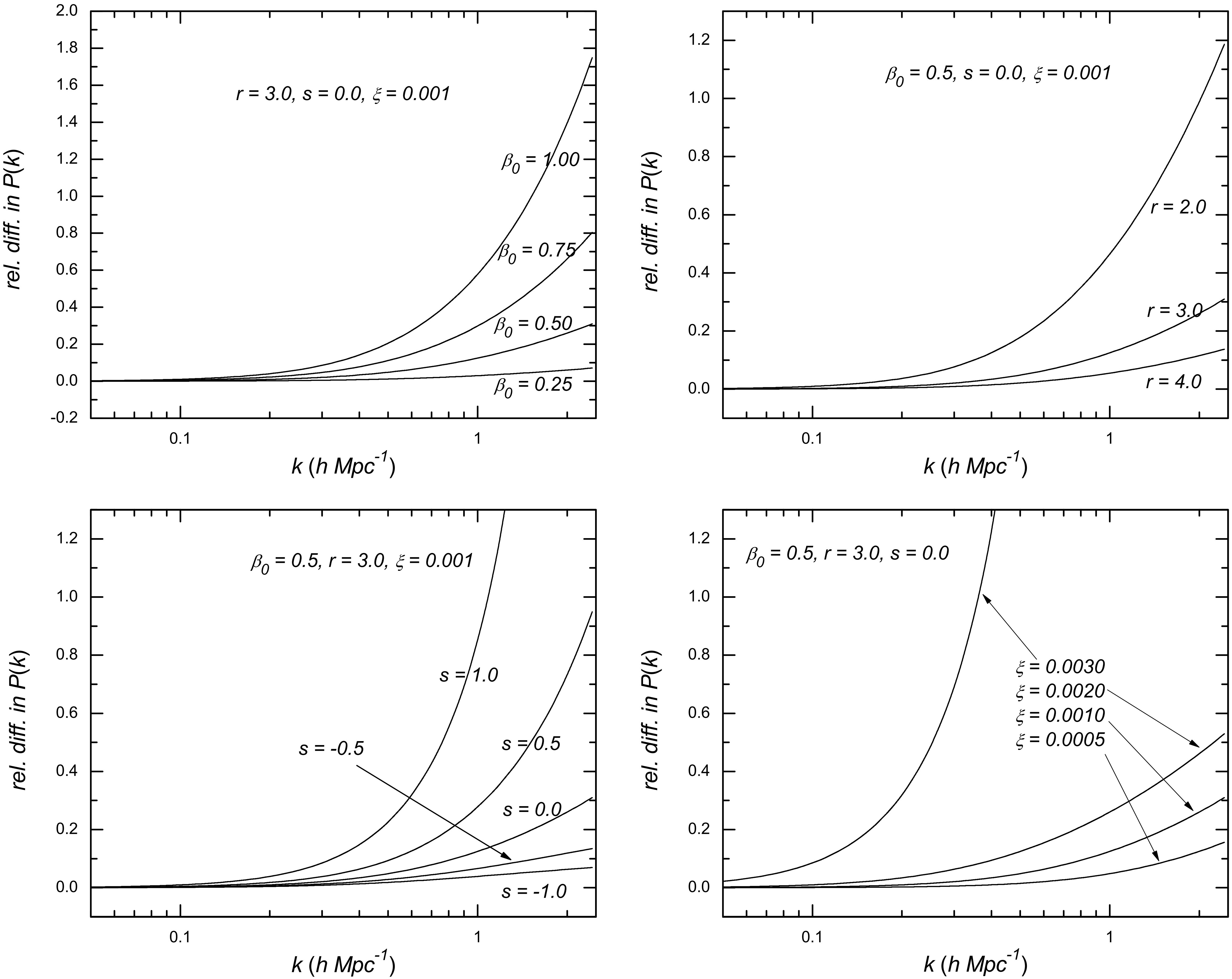
3 < r - large R f(R)

what about the symmetron?

$$m(a) = m_\star \sqrt{1 - \left(\frac{a_\star}{a}\right)^3}. \qquad \beta(a) = \beta_\star \sqrt{1 - \left(\frac{a_\star}{a}\right)^3},$$

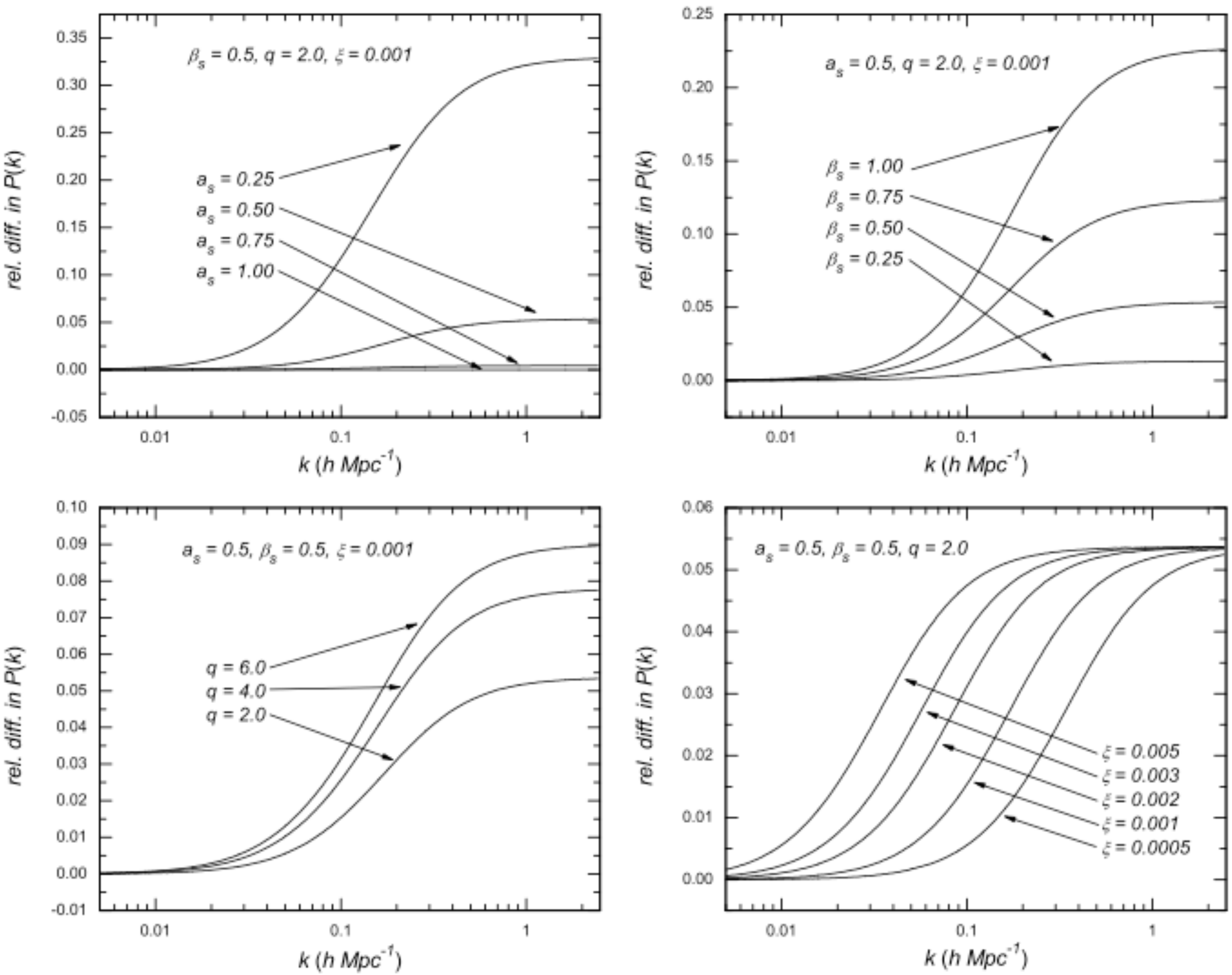
generalised symmetron

$$m(a) = m_\star \left[1 - \left(\frac{a_\star}{a}\right)^3\right]^{1/p}; \qquad \beta(a) = \beta_\star \left[(1 - \left(\frac{a_\star}{a}\right)^3\right]^{1/q},$$



r = 3.0, s = 0.0, ξ = 0.001
β0 = 1.00
β0 = 0.75
β0 = 0.50
β0 = 0.25
rel. diff. in P(k)
k (h Mpc-1)
β0 = 0.5, s = 0.0, ξ = 0.001
r = 2.0
r = 3.0
r = 4.0
β0 = 0.5, r = 3.0, ξ = 0.001
s = 1.0
s = 0.5
s = -0.5
s = 0.0
s = -1.0
β0 = 0.5, r = 3.0, s = 0.0
ξ = 0.0030
ξ = 0.0020
ξ = 0.0010
ξ = 0.0005

symmetron

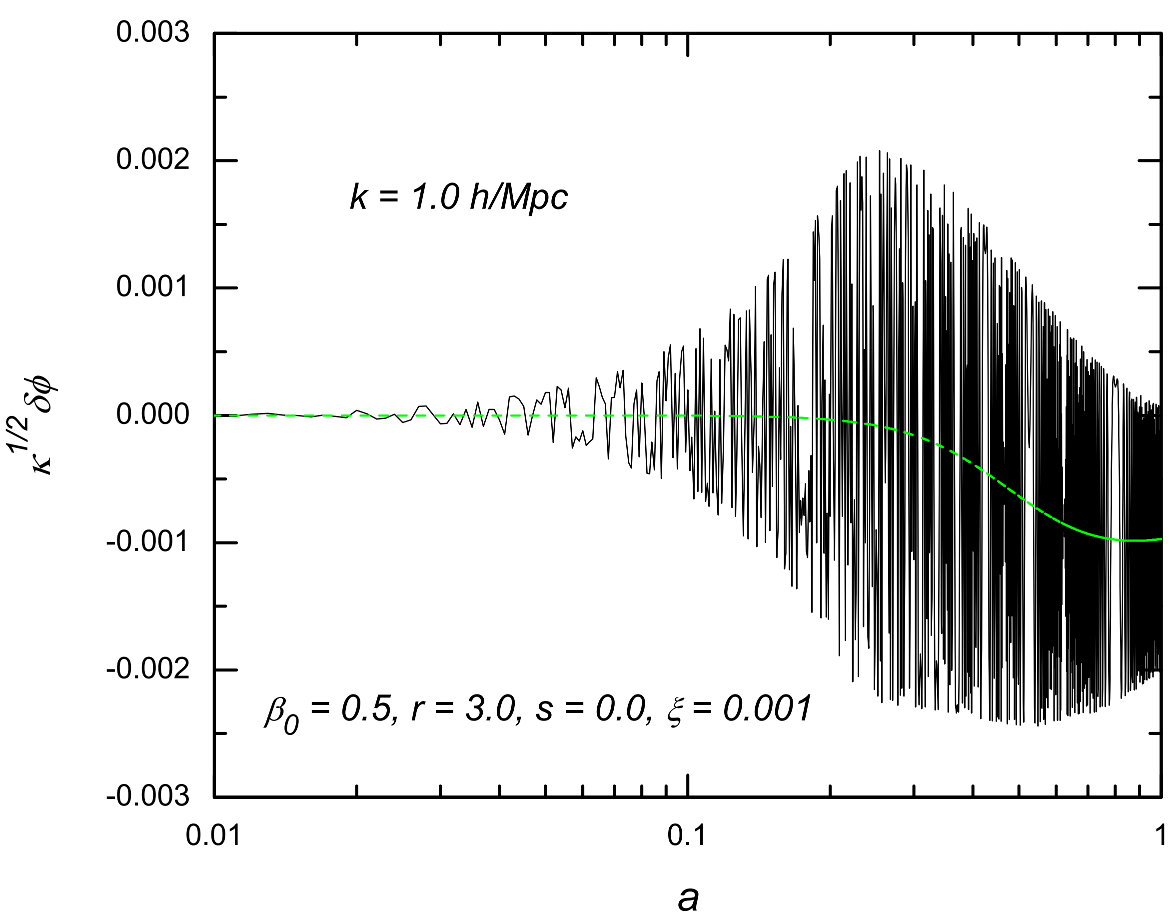


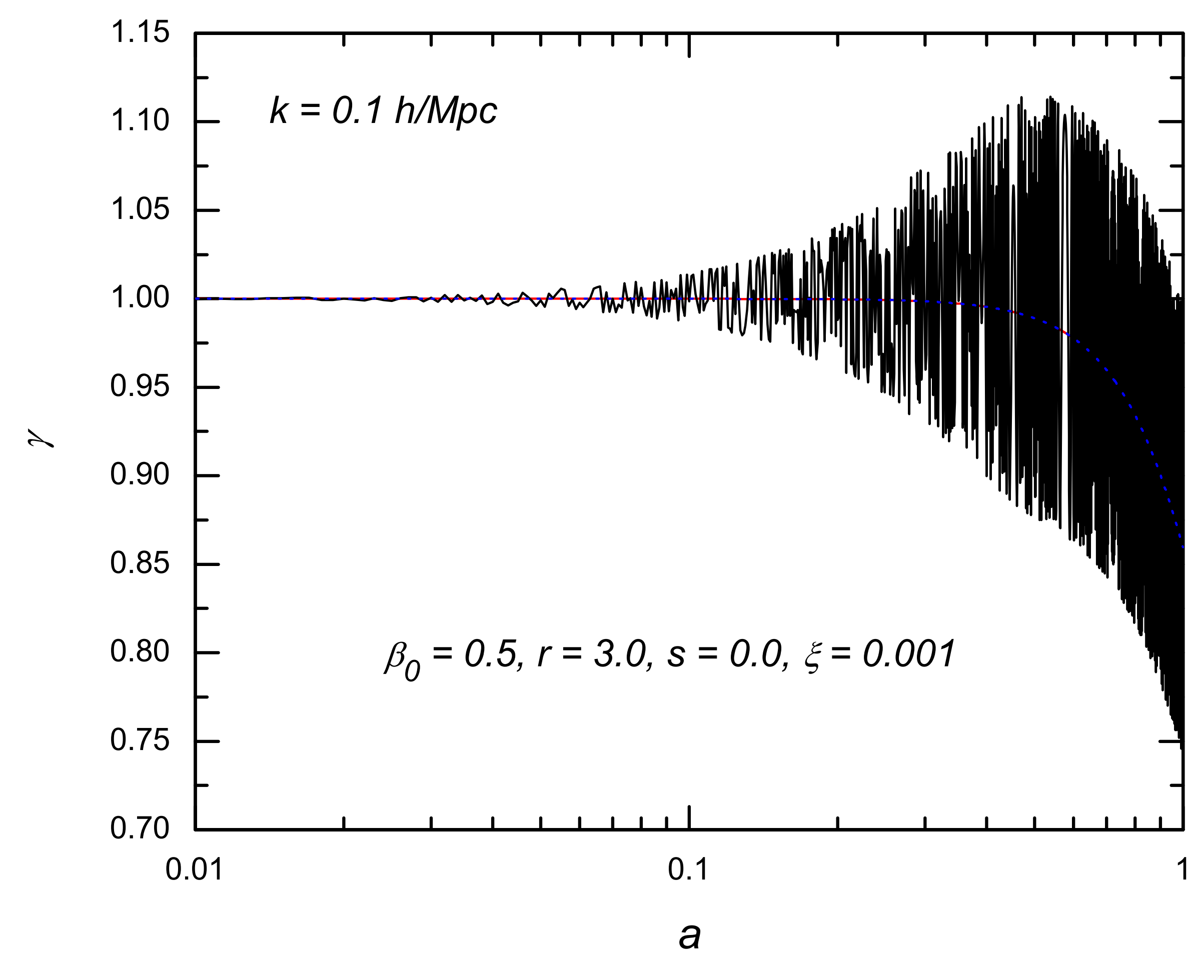
β_s = 0.5, q = 2.0, ξ = 0.001
a_s = 0.25
a_s = 0.50
a_s = 0.75
a_s = 1.00
rel. diff. in P(k)
k (h Mpc^-1)
a_s = 0.5, q = 2.0, ξ = 0.001
β_s = 1.00
β_s = 0.75
β_s = 0.50
β_s = 0.25
rel. diff. in P(k)
k (h Mpc^-1)
a_s = 0.5, β_s = 0.5, ξ = 0.001
q = 6.0
q = 4.0
q = 2.0
rel. diff. in P(k)
k (h Mpc^-1)
a_s = 0.5, β_s = 0.5, q = 2.0
ξ = 0.005
ξ = 0.003
ξ = 0.002
ξ = 0.001
ξ = 0.0005
rel. diff. in P(k)
k (h Mpc^-1)

In Jordan frame the usual param is

$$\Phi = \gamma(k, a)\Psi$$

for comparison, this param is fine in linear regime, but doesn't capture the full nonlinear dynamics of screened models





N-body Simulations

dilatons

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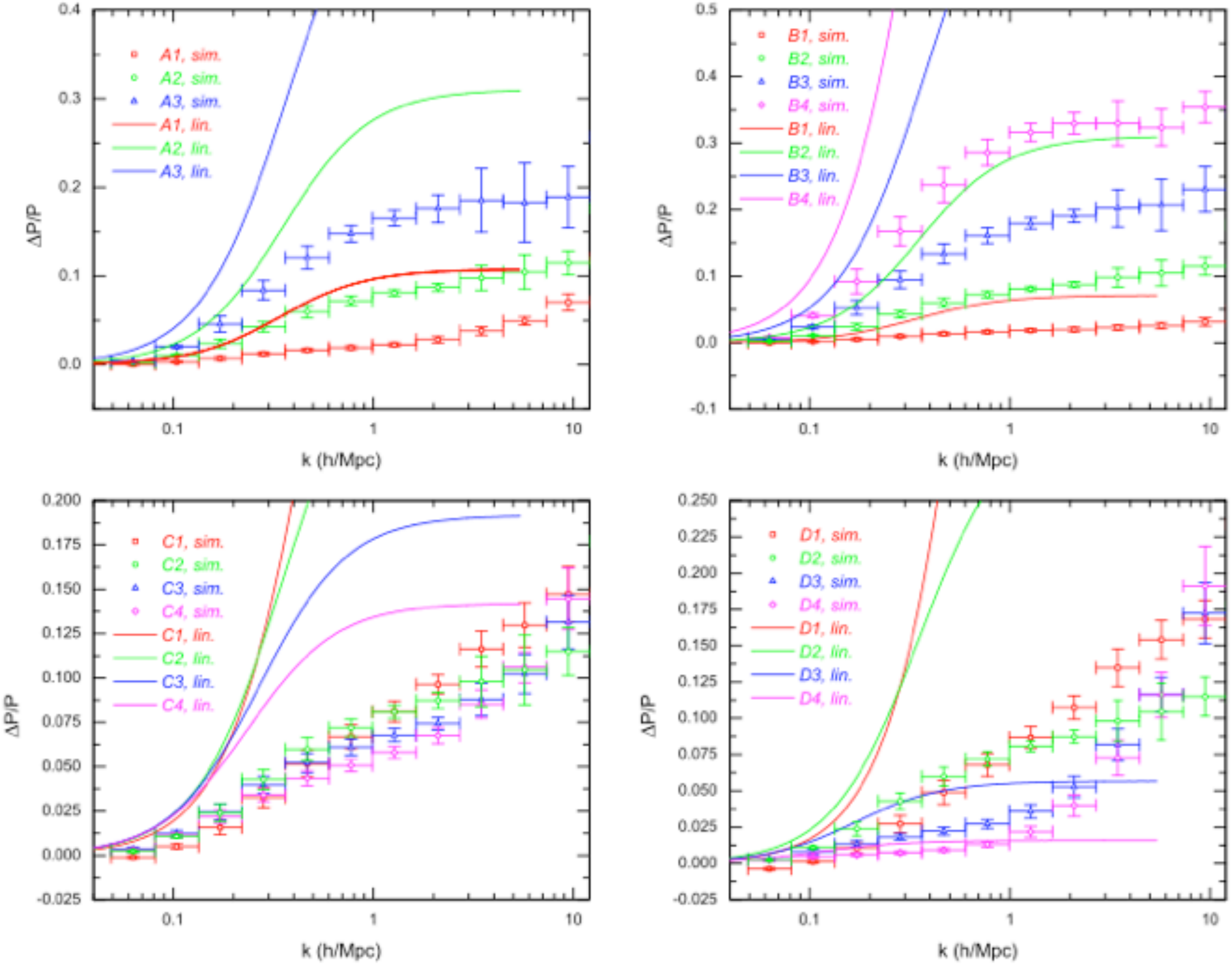
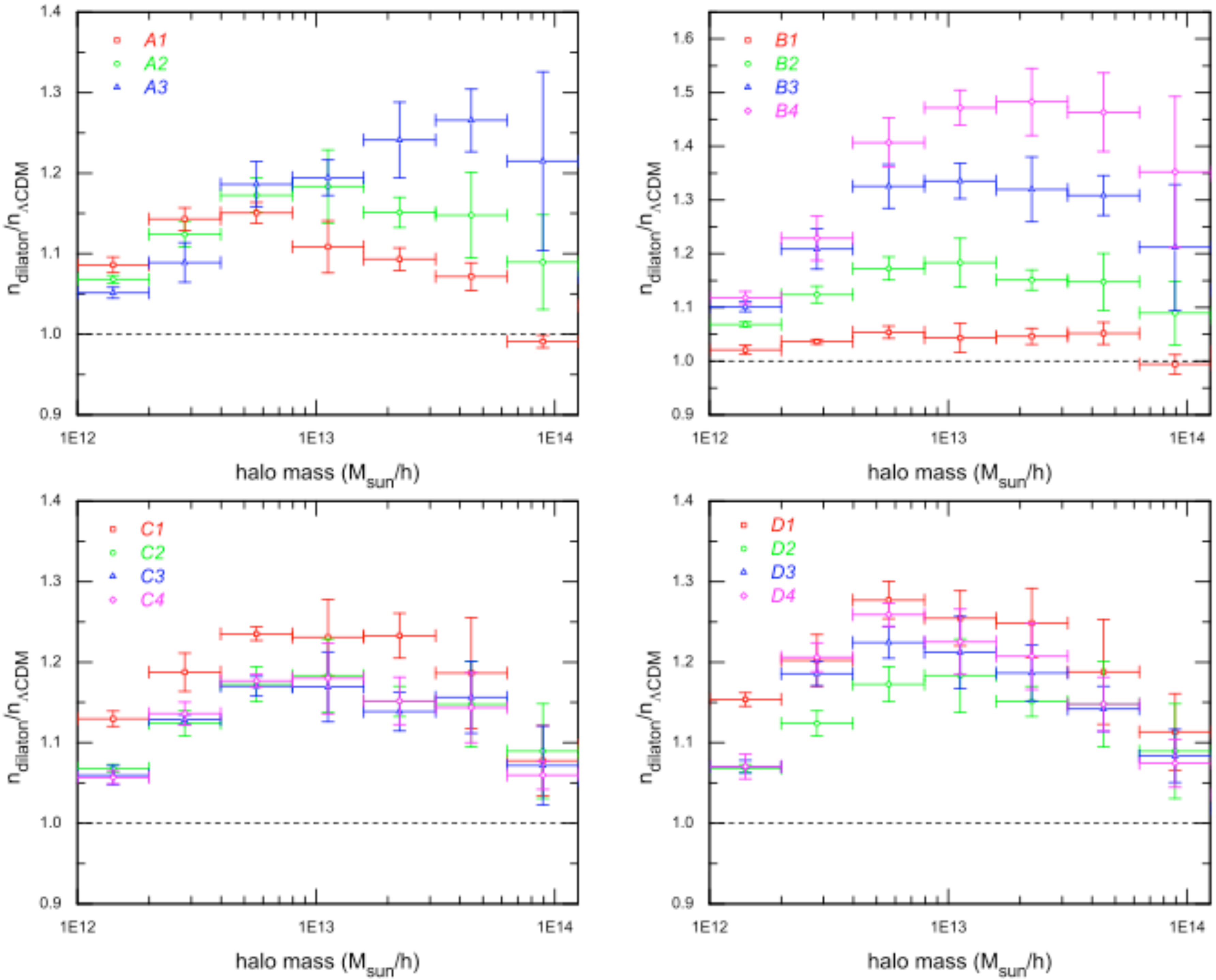
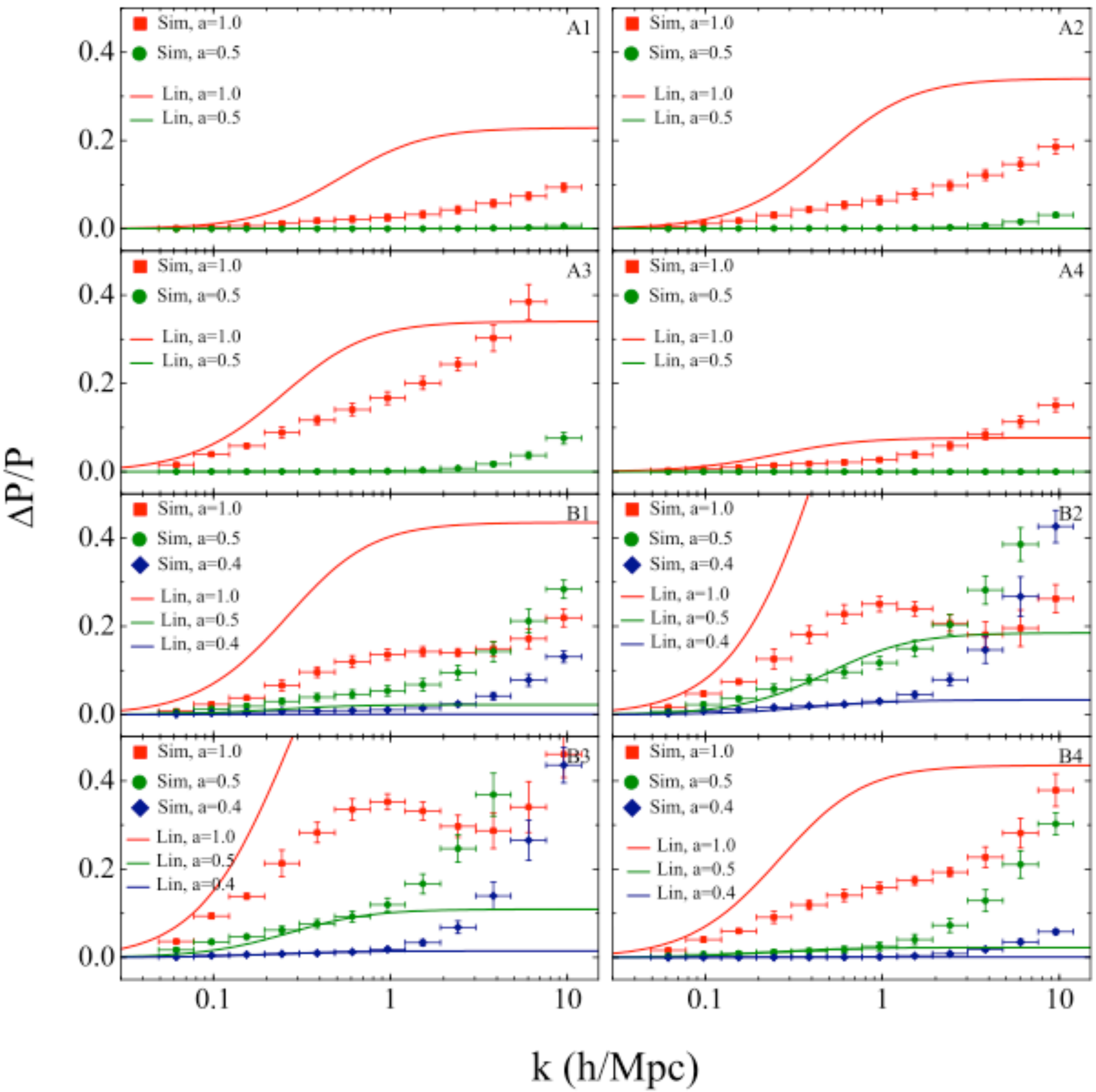
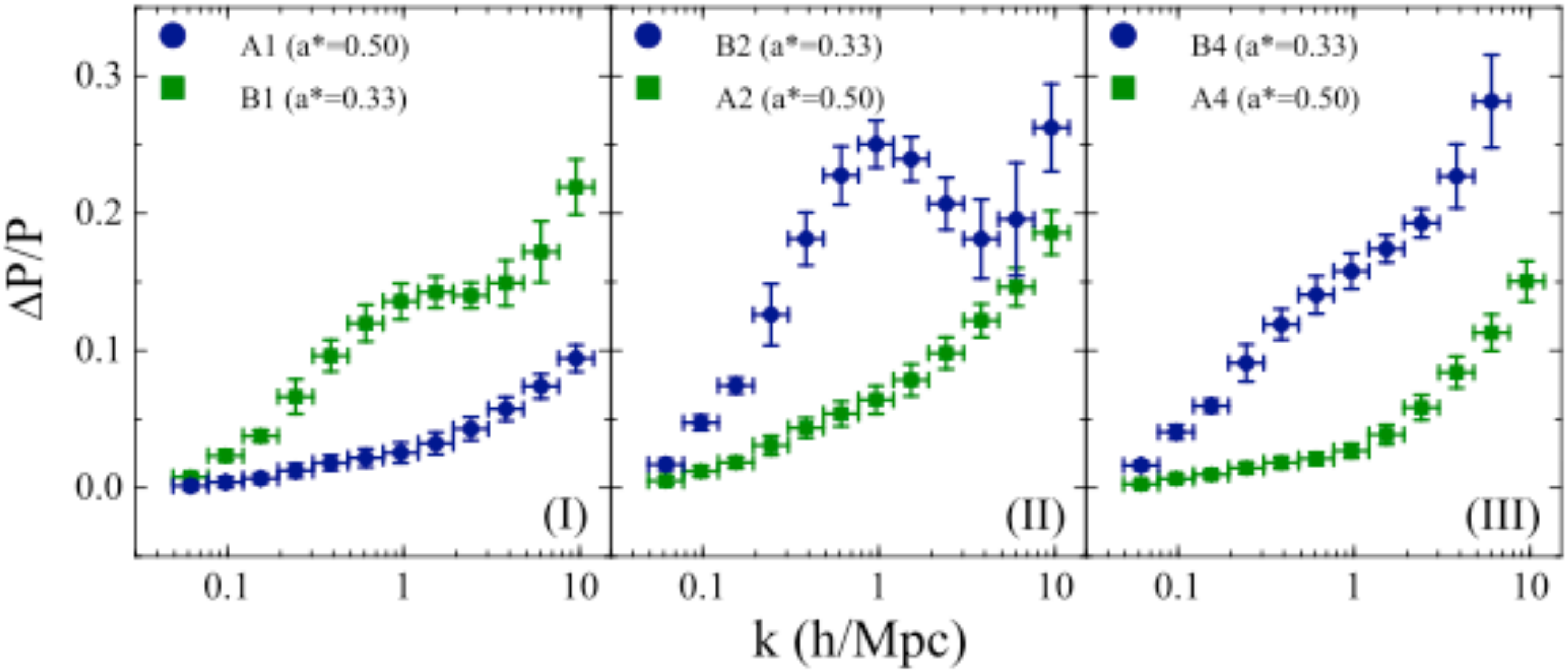



A1
A2
A3
B1
B2
B3
B4
C1
C2
C3
C4
D1
D2
D3
D4
$n_{dilaton}/n_{\Lambda CDM}$
halo mass (M_{sun}/h)
1E12
1E13
1E14

symmetron



A1
A2
A3
A4
B1
B2
B3
B4
Sim, a=1.0
Sim, a=0.5
Sim, a=0.4
Lin, a=1.0
Lin, a=0.5
Lin, a=0.4
ΔP/P
0.0
0.2
0.4
0.1
1
10
k (h/Mpc)



A1 (a*=0.50)
B1 (a*=0.33)
B2 (a*=0.33)
A2 (a*=0.50)
B4 (a*=0.33)
A4 (a*=0.50)
ΔP/P
0.3
0.2
0.1
0.0
(I)
(II)
(III)
0.1
1
10
k (h/Mpc)

One can study the variation in the fine structure constant and variation in particle masses using this parametrisation for all models.

We can use the same parametrisation to investigate the effect of modified gravity on 21cm predictions -- to appear soon (P.Brax and S. Clesse)
and BAO -- to appear shortly (as above + C. van de Bruck and G. Sculthorpe)

- We have presented a simple parametrisation which fully encaptulates the dynamics of screened, modified gravity models (chameleons, symmetrons and dilatons)
- Reconstruct the potential and coupling
- Studied the growth of structures in the linear and nonlinear regime.
- Apply to 21cm cosmology and BAO