Press-Schechter Mass Function in Dynamical Quintessence Fields

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Introduction

Context: SNIa data $\longrightarrow$ accelerated expansion (dark energy; dynamical origin?=quintessence)

Goal: Extend [Mainini *et al*. 2003, Nunes & Mota 2004, Solevi *et al*. 2004] studies of impact of quintessence scenarii (dark energy) $\longrightarrow$inhibition on dark matter halo formation

I. Homogeneous models

II. Non-linear collapse models

III. Mass Functions

I-a Background evolution

in the presence of homogeneous
dark energy component

Einstein's Equations - FLRW model:
with critical energy density
Homogeneous model:

quintessence = homogeneous scalar field Q

- (Klein-Gordon eq.)

$$\ddot{Q} = -3\frac{\dot{a}}{a}\dot{Q} - d_Q V(Q)$$

- scale factor a evol.: Friedmann eq.

$$\left(\frac{\dot{a}}{a}\right)^2 = H^2 = \frac{8\pi\mathcal{G}c^2}{3}\rho$$

$$\rho = \rho_b + \rho_\gamma + \rho_\nu + \rho_{CDM} + \rho_Q$$

$$\rho_Q = \frac{1}{2}\dot{Q}^2 + V(Q)$$

Hypotheses: Flat universe ($\Omega_{k_0} = 0$), Q fluctuations neglected on structures scales [Ma *et al*. 1999, for linear evolution] (homogeneity: threshold model to ascertain impact of Q on NL collapse).

I-b Tracking potentials

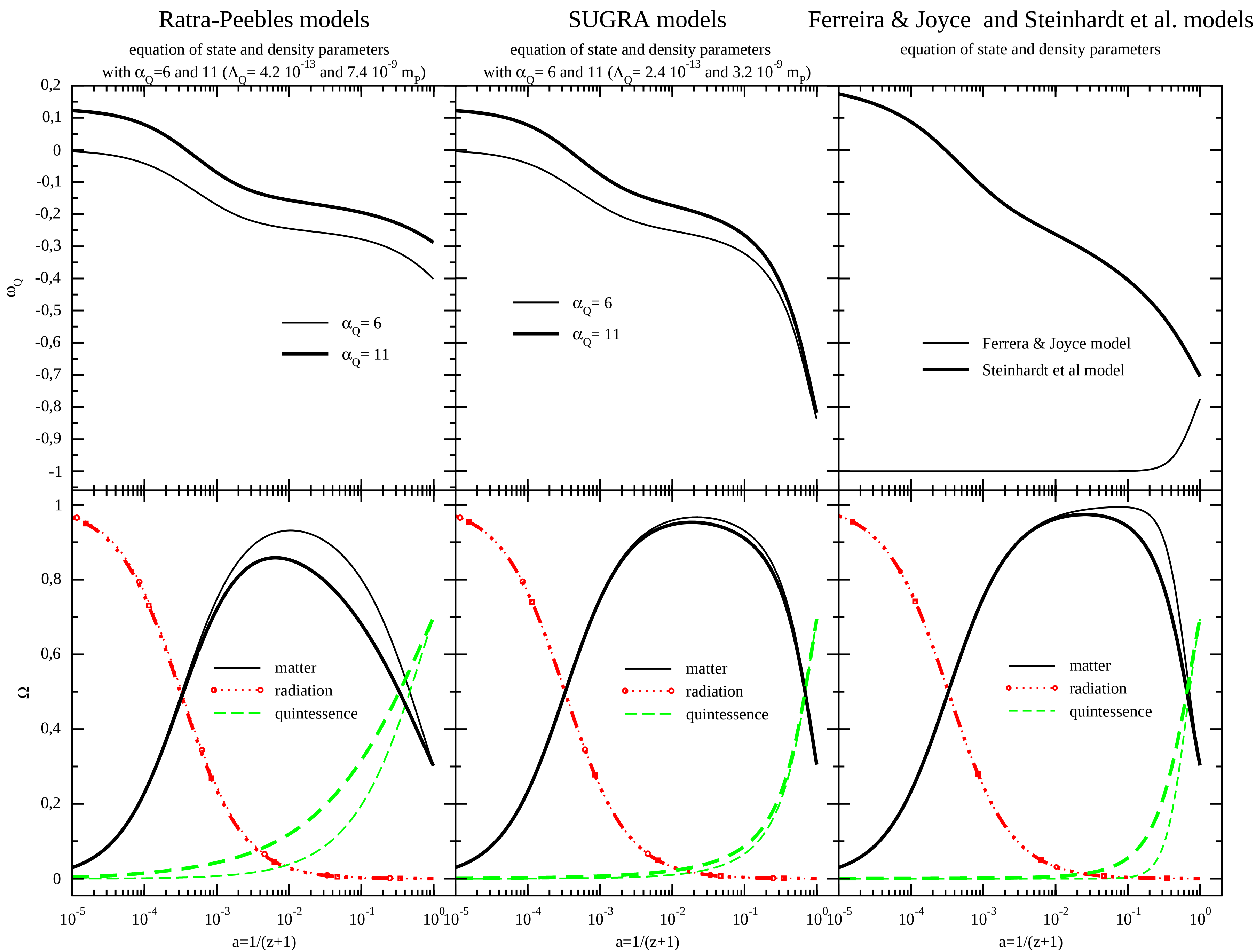
study for various models

Many forms of potentials with tracking properties during radiation

Model	Potential V
R.P. [Ratra & Peebles 1988]	$\frac{\Lambda_Q^{4+\alpha_Q}}{Q^{\alpha_Q}}$
SUGRA : [Brax & Martin 2000]	$\frac{\Lambda_Q^{4+\alpha_Q}}{Q^{\alpha_Q}} e^{\kappa \frac{Q^2}{2}}$
Ferreira & Joyce 1998	$\Lambda_Q^4 e^{-\lambda Q}$
Steinhardt *et al.* 1999	$\Lambda_Q^4 e^{\frac{1}{Q}}$

R.P. and SUGRA compared here with $\alpha_Q = 6$ and 11 [following Brax *et al.* 2000], Ferreira & Joyce with $\lambda = 10$.

I-c Inhibition epochs and ω_Q (equation of state)

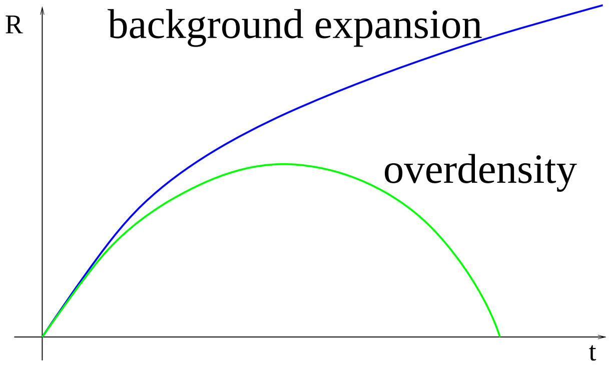


II-a
Non-linear collapse model (overdensity)

in the presence of a homogeneous
dark energy component

Einstein's Equations - **with Birkhoff's Theorem**

FLRW model with "Top hat" model



Halos formation dynamics

Spherical symmetry: non-linear collapse $\Rightarrow$

Friedmann sphere with higher, varying, Ω_{k_0}:

Raychaudhuri equation for s, defined as

$r = s.r_{initial}$

$$\ddot{s} = -\left[\Omega_{r_0} a^{-4} + \frac{4\pi G}{3\mathcal{H}_0^2}(3P_Q + \rho_Q)\right] s - \frac{\Omega_{m_0} a_i^{-3}(1+\Delta_i)}{2s^2},$$

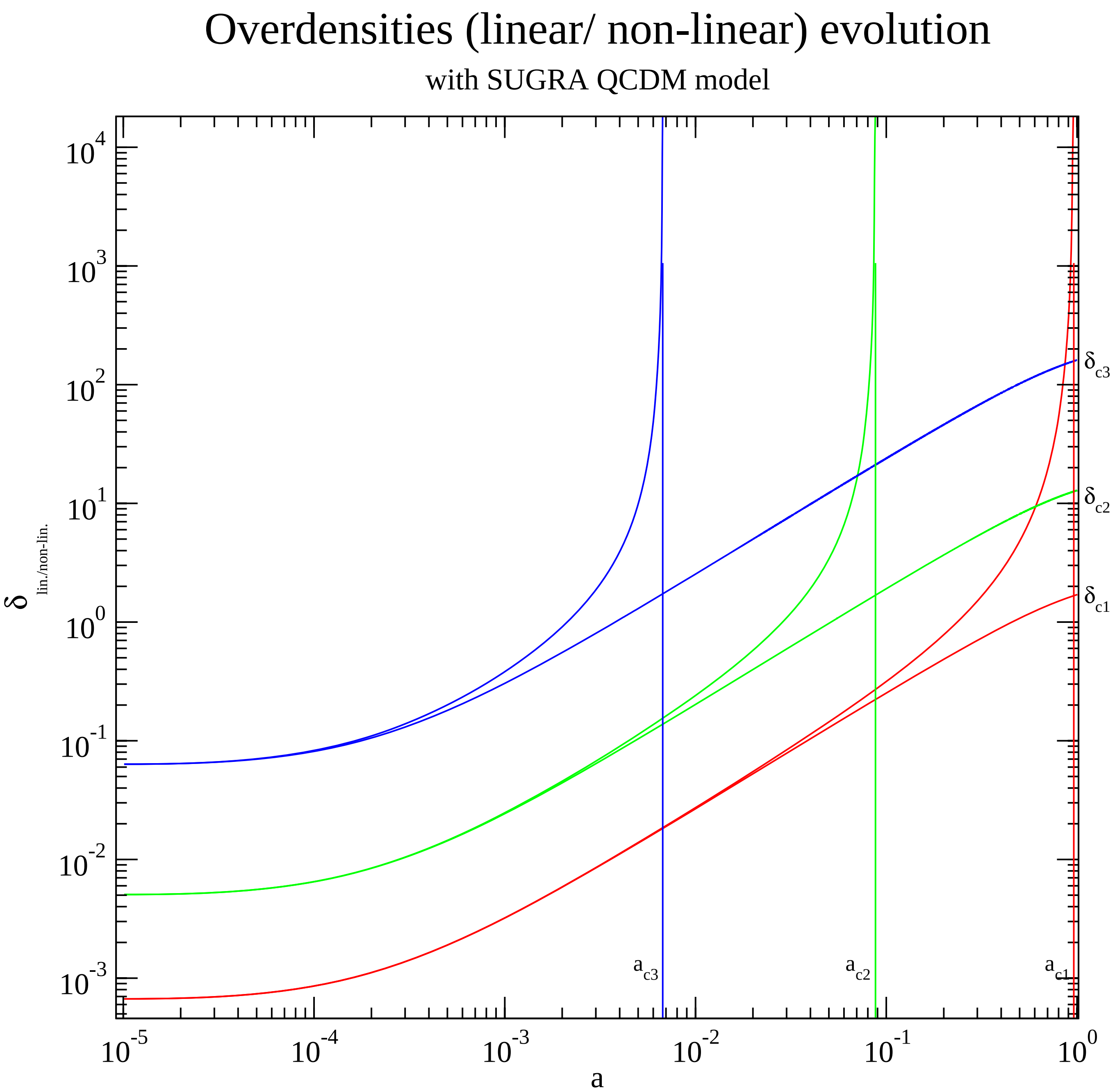
$$3P_Q + \rho_Q = 2\left(\dot{Q}^2 - V(Q)\right),$$

with nonlinear and linear overdensity:

$$\delta = (1+\Delta_i)\left(\frac{a}{a_i s}\right)^3 - 1,$$

$$\ddot{\delta}_L + 2\frac{\dot{a}}{a}\dot{\delta}_L = \frac{3}{2} H_0^2 \Omega_{m_0} a_i^{-3} \delta_L.$$

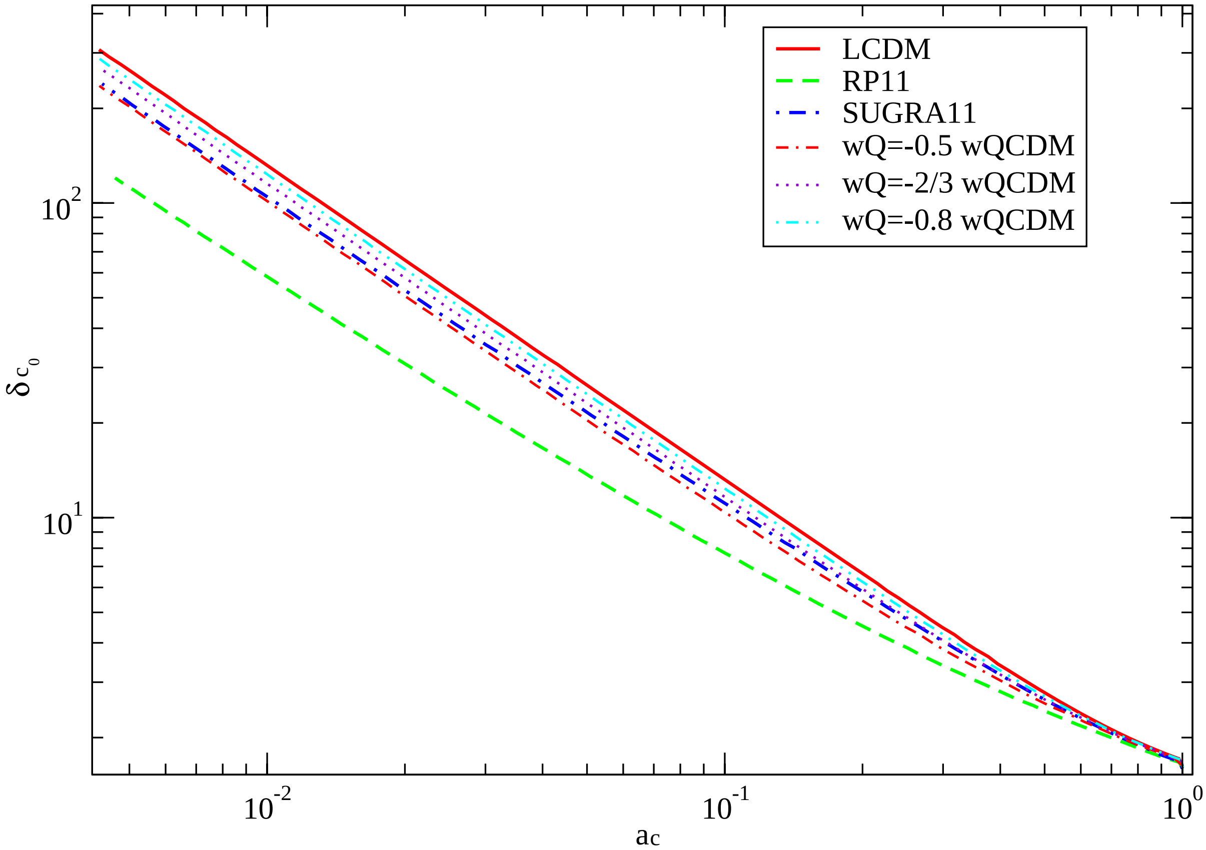
II-b "Top hat" collapse and overdensities



II-c Collapse overdensities

Critical overdensity vs collapse scale

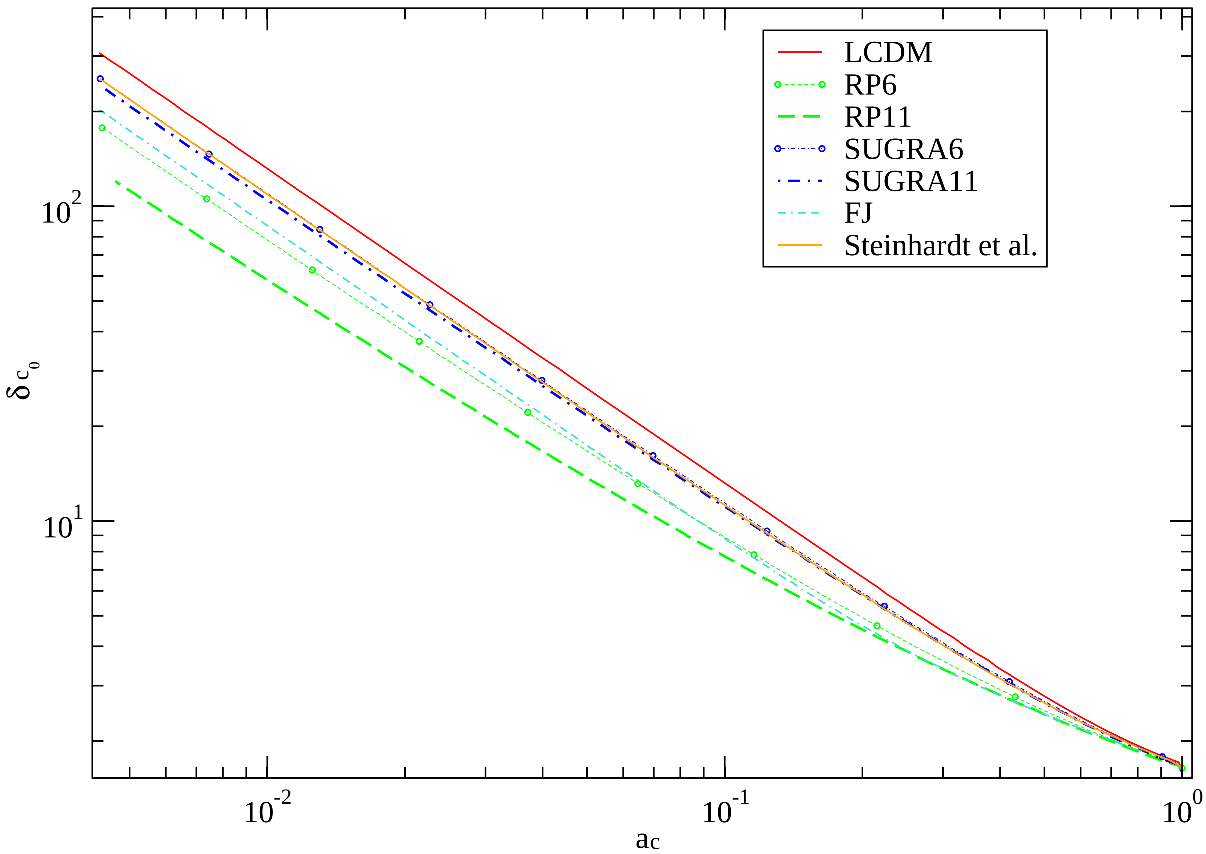
with various QCDM and pseudo-QCDM models



for collapse in pseudo-quintessence, see [Lokas *et al.* 2004]

Critical overdensity vs collapse scale

with various QCDM models



III-a Press-Schechter scheme

Semi-analytical prescription decoupling the collapse's nonlinear dynamics (here: $\delta_c \equiv \delta_{c_0}$) and the initial distribution of mass fluctuations (represented by σ).

Differential mass function (Gaussian overdensity fluctuations - nonlinear collapse from the "top hat" model)

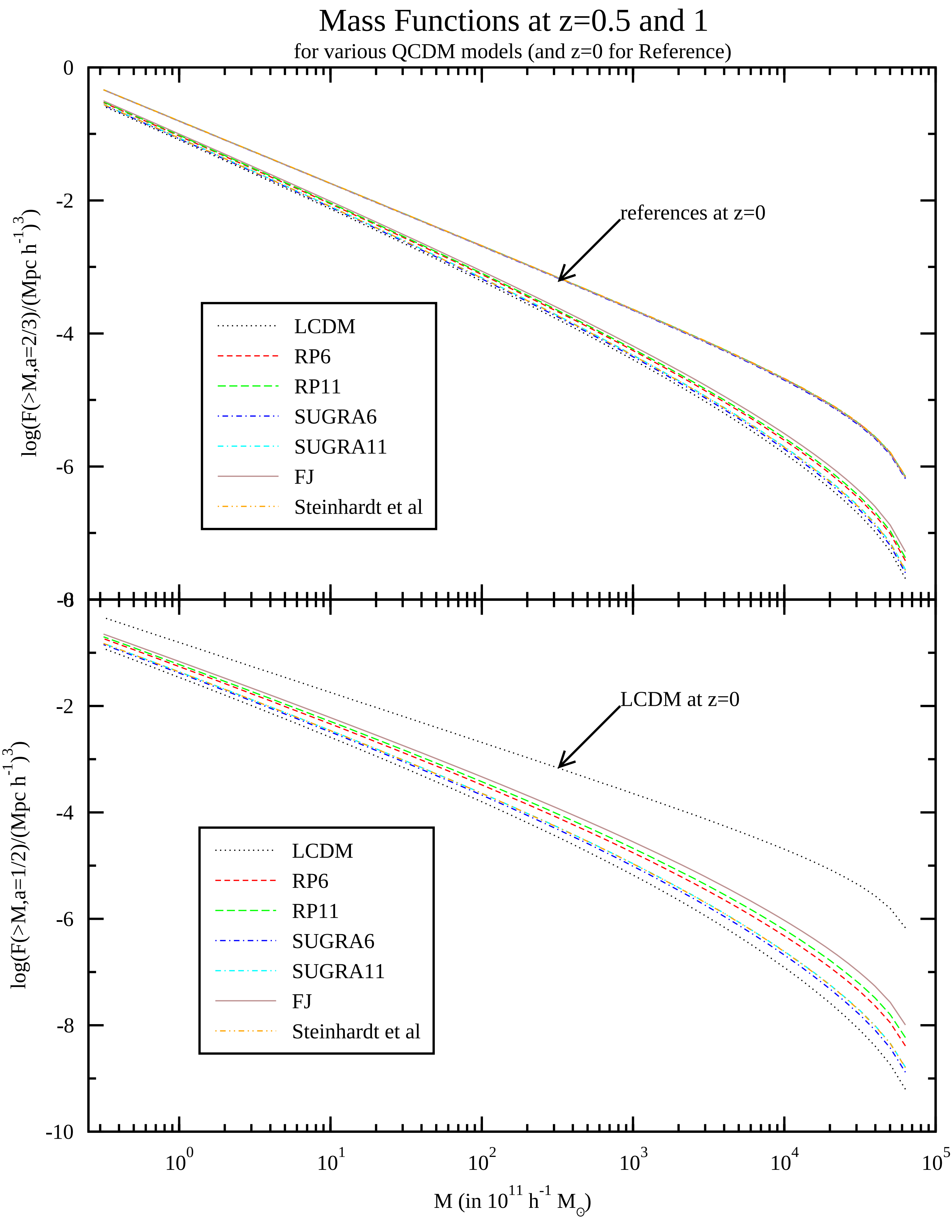
$$dN/dM(M,a) = (2/\pi)^{1/2} \times$$
$$\times\, (\rho_m \delta_c / M\sigma^2)(d\sigma/dM) \times \exp(-\delta_c^2/2\sigma^2)$$

here $\delta_c = \delta_c(a)$, $\rho_m = \rho_m(a)$ and $\sigma = \sigma(M)$ [using Bond & Efstathiou 1980].

Cumulative mass function : fraction in mass of the universe collapsed in structures with masses $> M$

$$F(> M) = \int_M^\infty dN/dM.dM$$

III-b Comparison of the mass functions at z=0, z=0.5 and z=1 (RP, SUGRA FJ and Steinhardt *et al.*)



Conclusions

Results:

- Extended [Mainini *et al*. 2003, Nunes & Mota 2004, Solevi *et al*. 2004] evidence of quintessence models impact on dark matter halo formation via mass function evolution to array of models,
  - effects on clusters scales ($\sim 10\%$ at $z \sim 1$ for $10^{14}\,h^{-1}M_{\odot}$) $\rightarrow$ precision cosmology (weak lensing, South Pole Telescope SZ survey).
- Emphasized ω_Q role for structure formation
  - ω_Q very variable ($\rightarrow$JDEM-SNAP).
  - impact of ω_Q dominates,

Caveats:

- Q homogeneity ($\rightarrow$Clustering),
- Geometric effects [Solevi *et al.* 2004, Solevi *et al.* 2005] ($\rightarrow$ bias-geometry dependence [Kaiser 1984] should break degeneracy)

Developments: extention of array of models to

- Other models
- Clustering DE
- Interacting DE
- Confirm bias-geometry
- Use ω_Q predominance

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