Early Dark Energy

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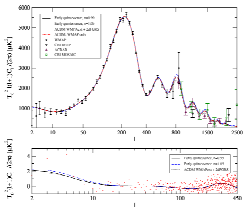
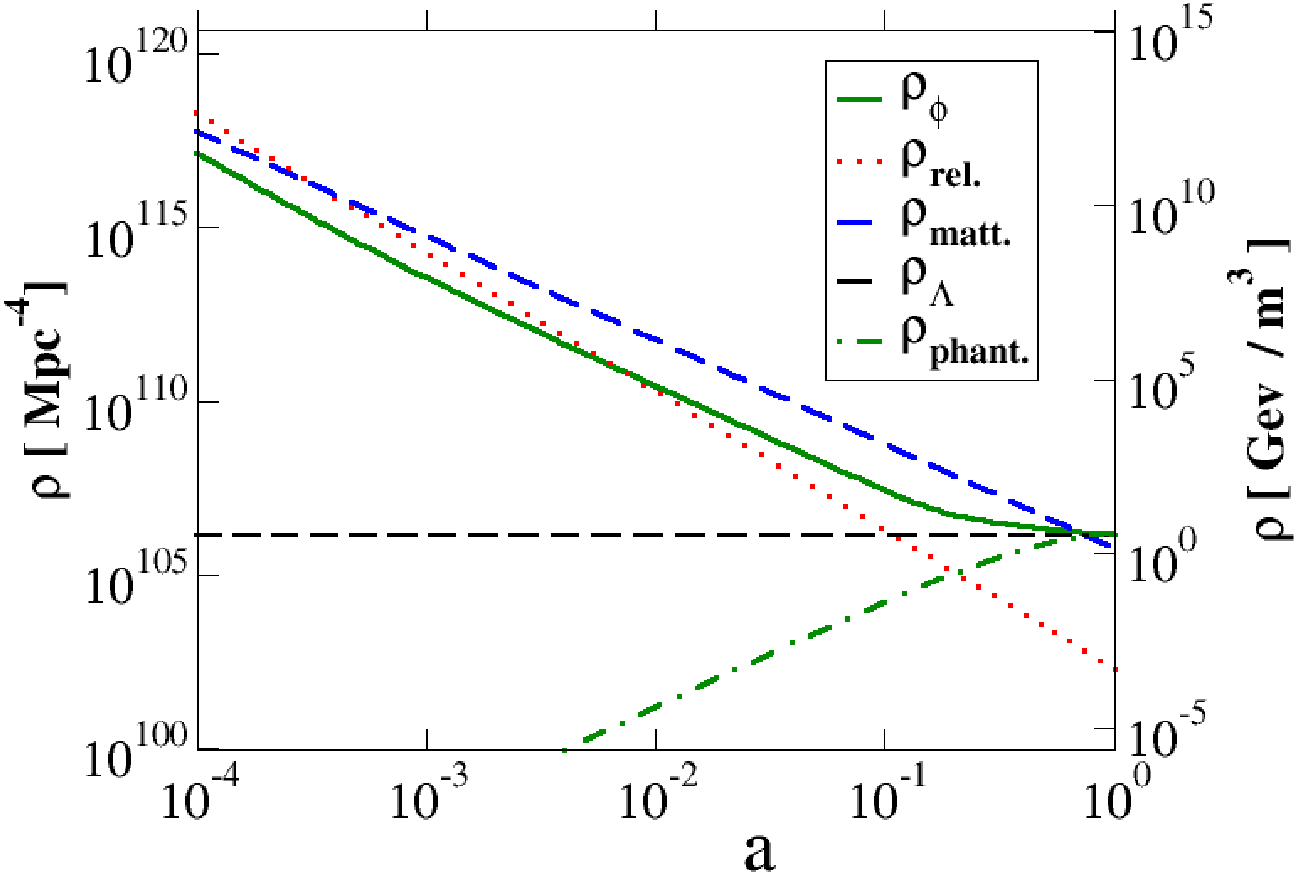
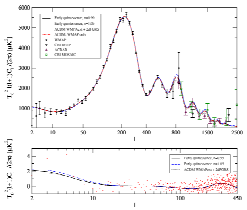


Dark energy (a.k.a. quintessence)





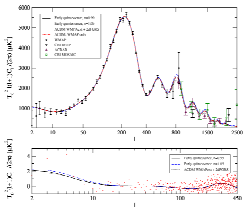
K. Freese et.al. (1987), C. Wetterich (1988), B. Ratra & P.J. Peebles (1988), R. R. Caldwell et. al. (1997), P. G. Ferreira & M. Joyce (1997), R.R. Caldwell (1999)

What is *early* dark energy ?

- Most dynamical models of dark energy have a non-constant equation of state $w \equiv p/\rho = w(z)$
- In principle, a change between $w_0 \approx -1$ today and different value $w_{early} \approx 0$ at early times conceivable A. Hebecker & C. Wetterich (2000)
- If cross over to $w_{early} \sim [0, \frac{1}{3}]$,

$$\Omega_{early} \sim few\ \%$$

seems “natural” R.R. Caldwell et. al. (2003)

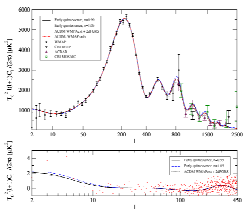


Many Parameterizations of w(z) ...

Many parameterizations on the market:

$w(z) = w_0$	ancient
$w(z) = w_0 + z w^{(1)}$	ancient
$w(z) = w_0 + w^{(e)} \frac{z}{1+z}$	E. V. Linder (2002)
...	...

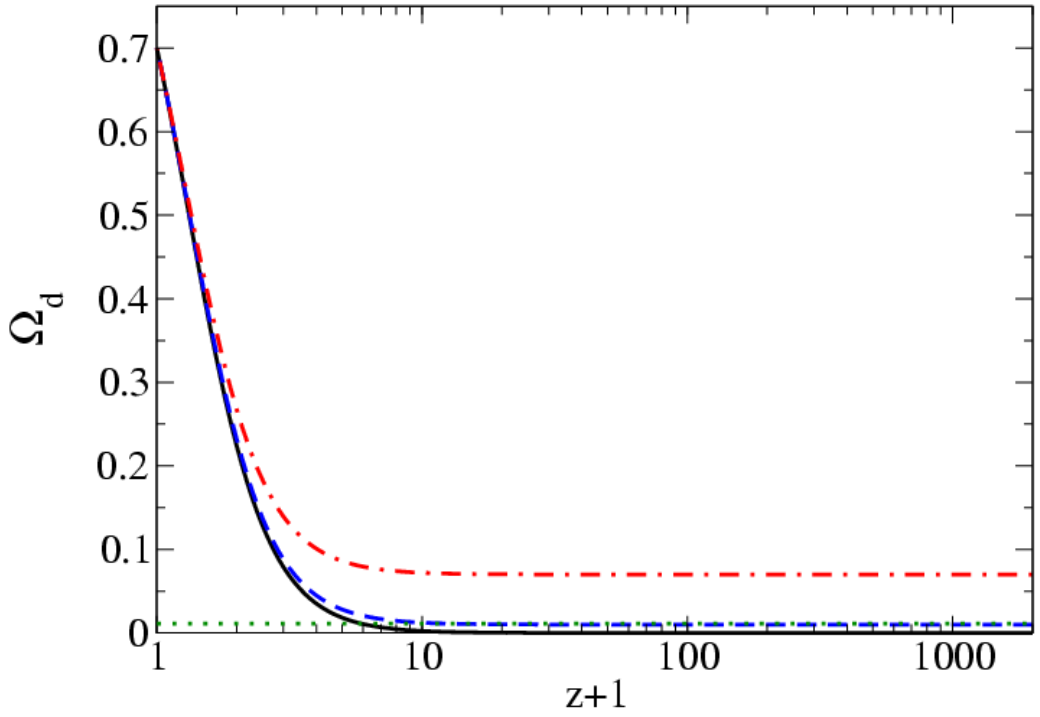
$$w(a) = w_0 + (w_m - w_0) \frac{1+e^{\frac{a_c}{\Delta}}}{1+e^{-\frac{a-a_c}{\Delta}}} \frac{1-e^{-\frac{a-1}{\Delta}}}{1+e^{\frac{1}{\Delta}}}$$

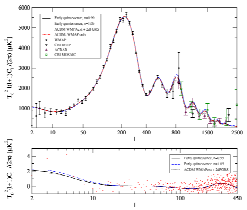


P.S. Corasaniti, E.J. Copeland (2002)

But we use direct parameterization of $\Omega_{d.e.}(z)$

$$\Omega_{d.e.}(a) = \frac{\Omega^0_{d.e.} - \Omega^{early}_{d.e.}(1 - a^{-3w_0})}{\Omega^0_{d.e.} + \Omega^0_m a^{3w_0}} + \Omega^{early}_{d.e.}(1 - a^{-3w_0})$$



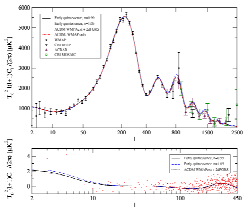


What can early dark energy do for you ?

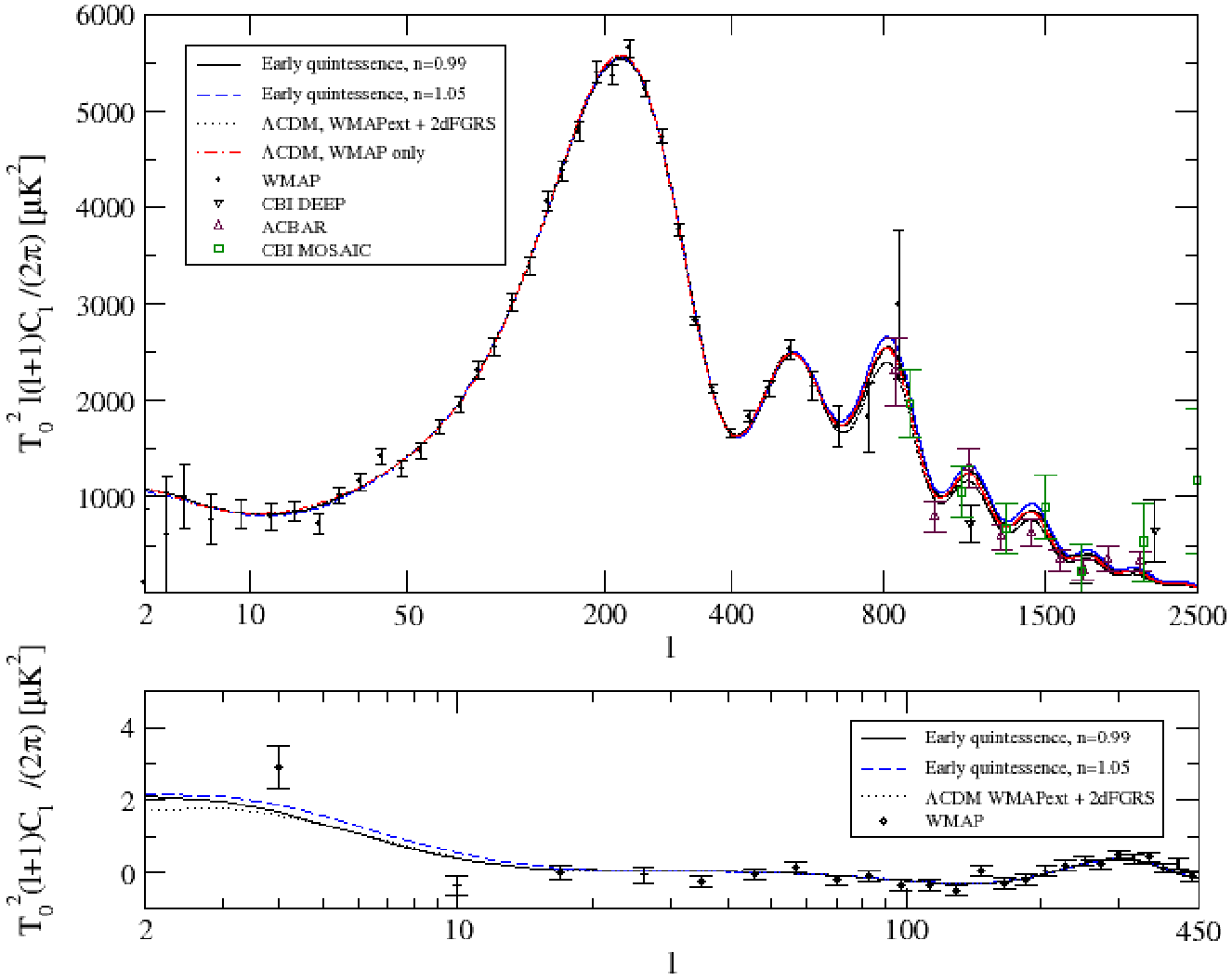
- Attractor in the early universe like $V \sim \exp(-\varphi)$
- Modes entering horizon after z_{equ} are suppressed by the presence of dark Energy
  P.G. Ferreira & M. Joyce (1997), J. Schwindt (2001), M.D et. al. (2001)

  ➡ The sooner a mode enters the horizon, the sooner it "feels" this presence

Less power on small compared to large scales!



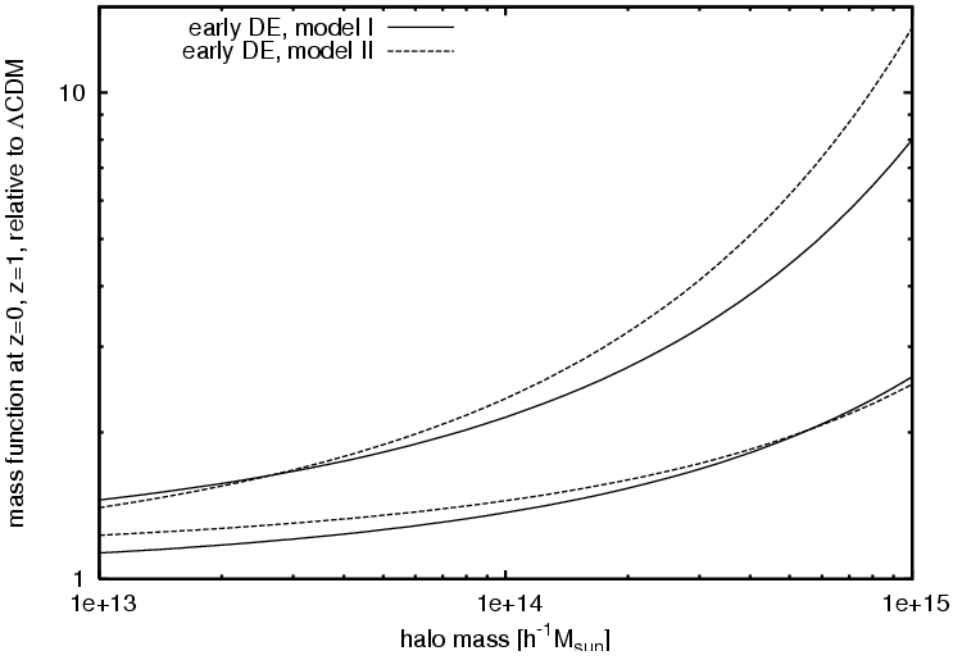
So CMB spectra show a tilt…

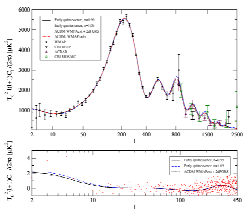


R.R. Caldwell et. al. (2003)

But it can do more …

- As linear structure growth is slowed down, collapsed objects must have formed earlier.
- So early dark energy predicts more structure at higher redshifts compared to standard cosmological constant. M. Bartelmann, M.D., C. Wetterich (2005)





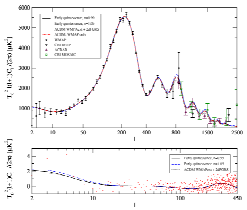
But that's not all…

• Change in scalar quintessence field evolution may be linked to change in fundamental constants.
T. Damour (2002), C. Wetterich (2002), K.A. Olive et. al (2002), H.B Sandvik et. al (2002), D. Parkinson et.al (2002)

• A change in fine structure constant α may have been meassured M.T. Murphy et.al. (2001). [However: H. Chand et.al. (2004)]

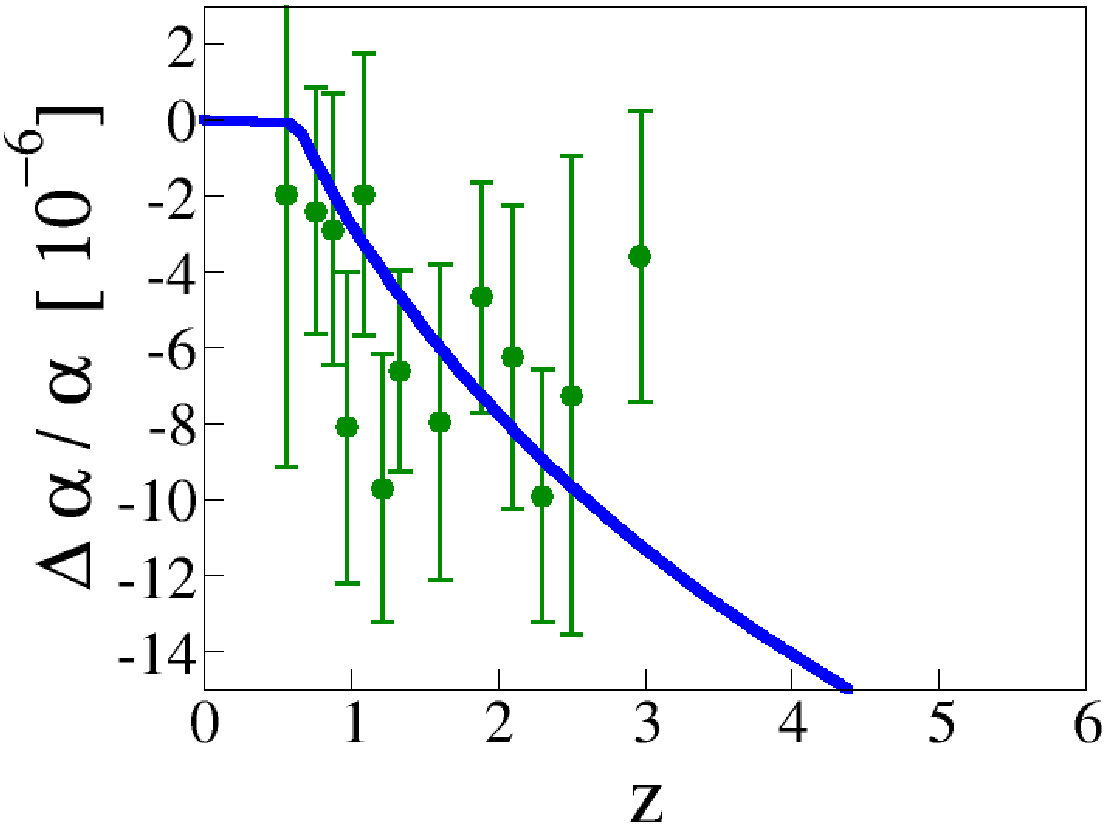
• Take for instance

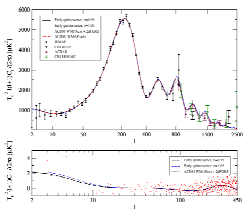
$$\alpha(z) = \alpha_0 + \alpha_{(1)}[\varphi(z) - \varphi_0] + \dots$$



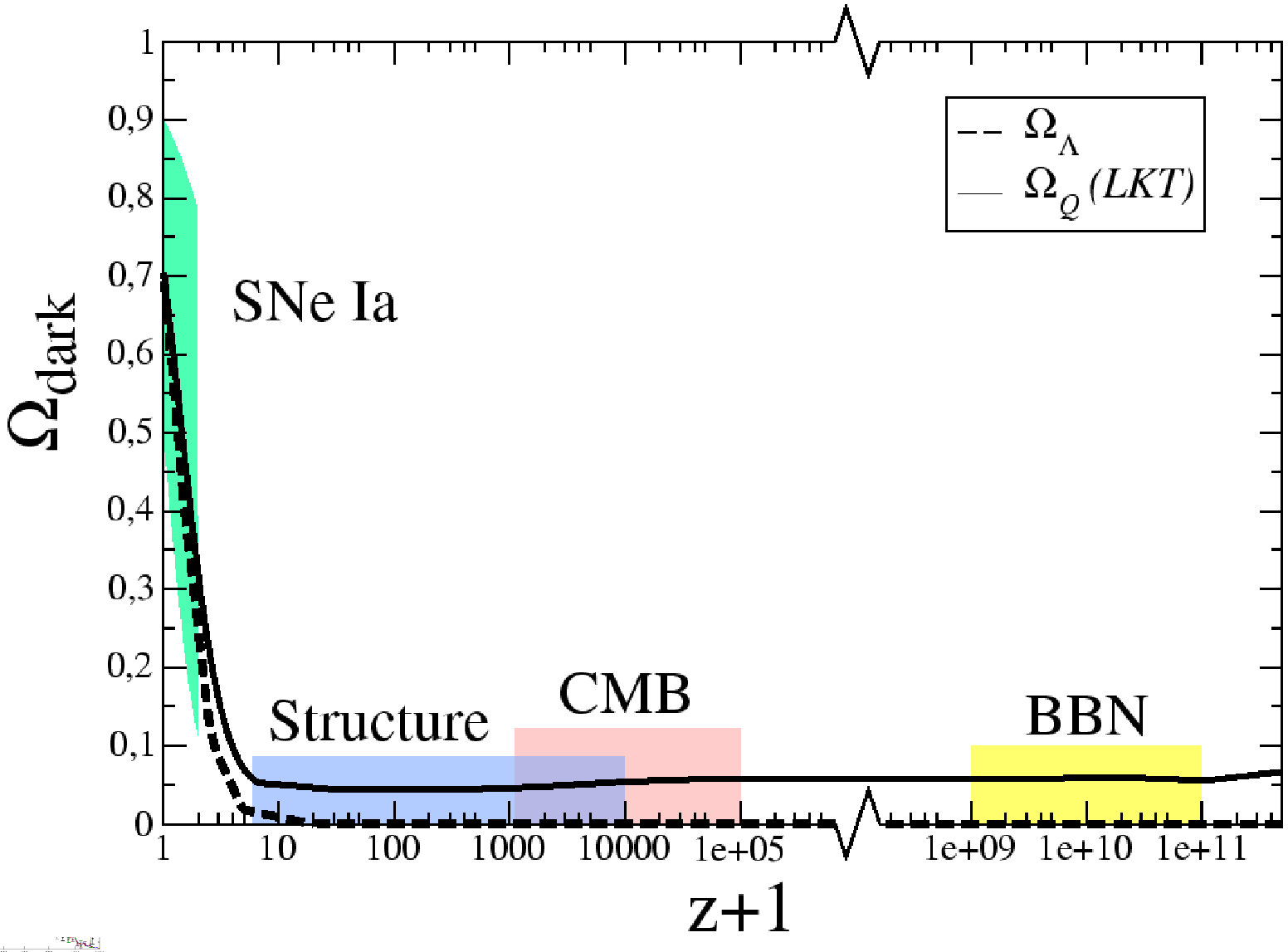
… maybe ‘constants’ not *so* constant

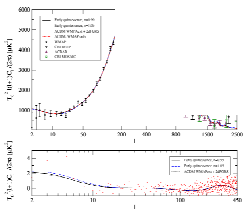
- Oklo restricts change of α for recent times,
  - freeze of φ
  - freeze in kin. E.
  - $w \rightarrow -1$
- Conversly, change of α at high redshifts
  - $\varphi \rightarrow evolv.$
  - $w \neq -1$
  - cross-over





Restrictions come from …



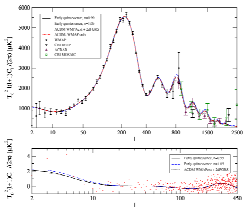


Constraining early dark energy

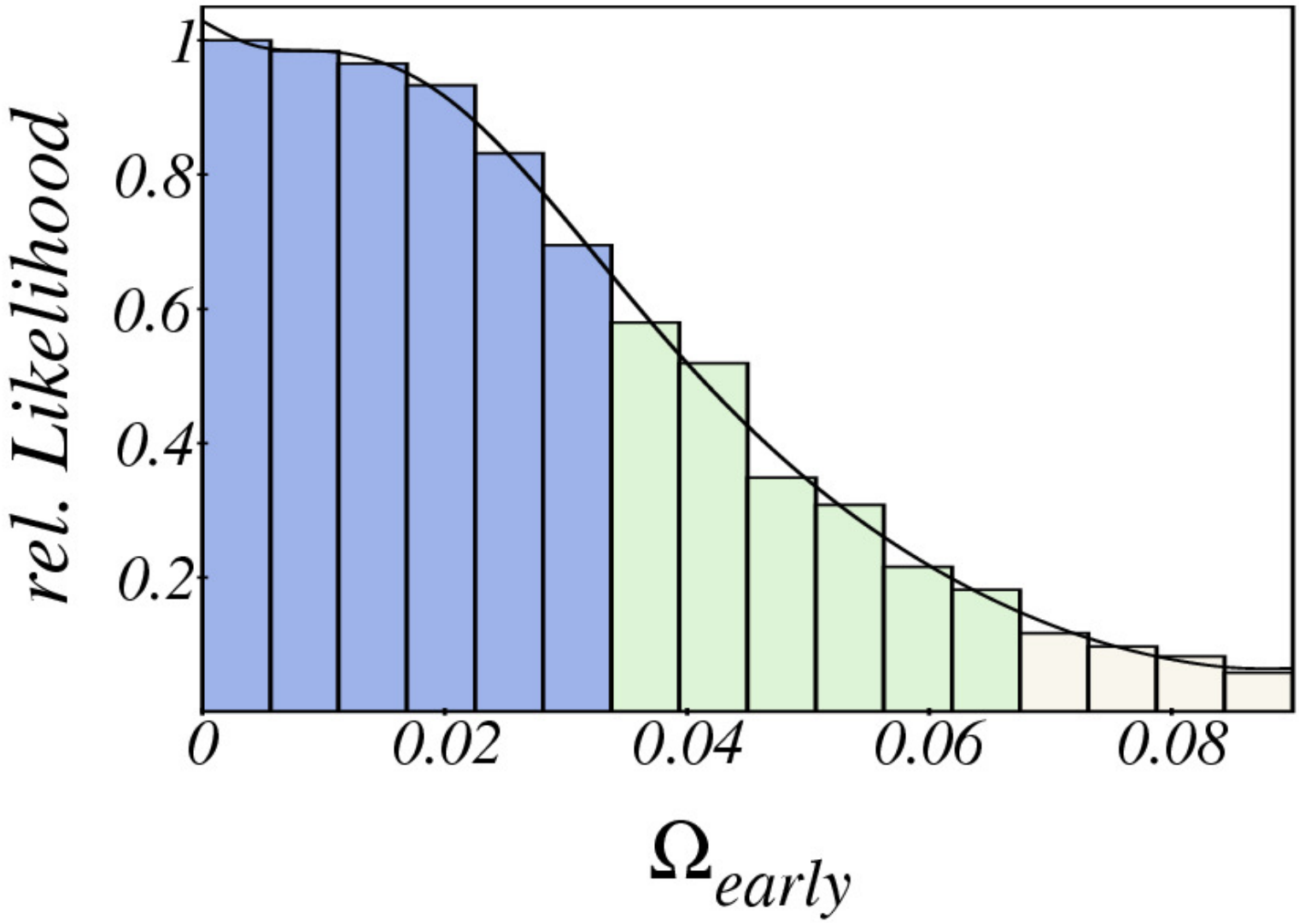
- Scan seven-dimensional parameter space:

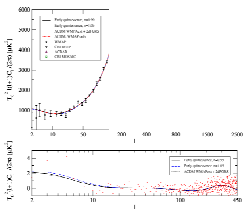
$$\Omega_m h^2,\ \Omega_b h^2,\ h,\ \tau,\ n_s,\ w_0,\ \Omega_{early}$$

- Use Monte Carlo Markov chain from cmbeasy
- Compare to:
  - WMAP [C.L. Bennet et.al (2003)]
  - CBI [A.C.S. Readhead et. al (2004)]
  - VSA [K. Grainge et. al (2002)]
  - SNe Ia [A. Riess et. al (2004)]
  - SDSS [M. Tegmark et. al. (2003)]



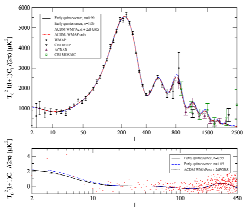
Preliminary constraints on early dark energy





Conclusions

- Early dark energy appealing from "naturalness" point of view
- Predicts more structure at higher redshifts, well testable with future SZ experiments.
- May be linked to running of coupling constants (still hot ?)
- Hypotheses nicely testable
- Detection would kill Λ
- However, more parameters only justified, if data is fit better or theoretical prejudice demands it
- Current constraint* $\Omega_{early} < 8\%$



* Careful: Preliminary Results