Is dark energy dynamic?

Martin Kunz
University of Sussex, Brighton

& B.A. Bassett, E.J. Copeland, P.S. Corasaniti,
D. Parkinson, J. Silk and C. Ungarelli

outline

- Why dark energy?
- What is it?
- Can we say anything about its nature?
- Conclusions

why dark energy?

Why do we want to consider something with negative pressure? Ever seen such a thing?!
(apart from British showers...)

Count the energy density in the universe:

- radiation: CMB-temp ⇨ $\Omega_\gamma \approx 5x10^{-5}$

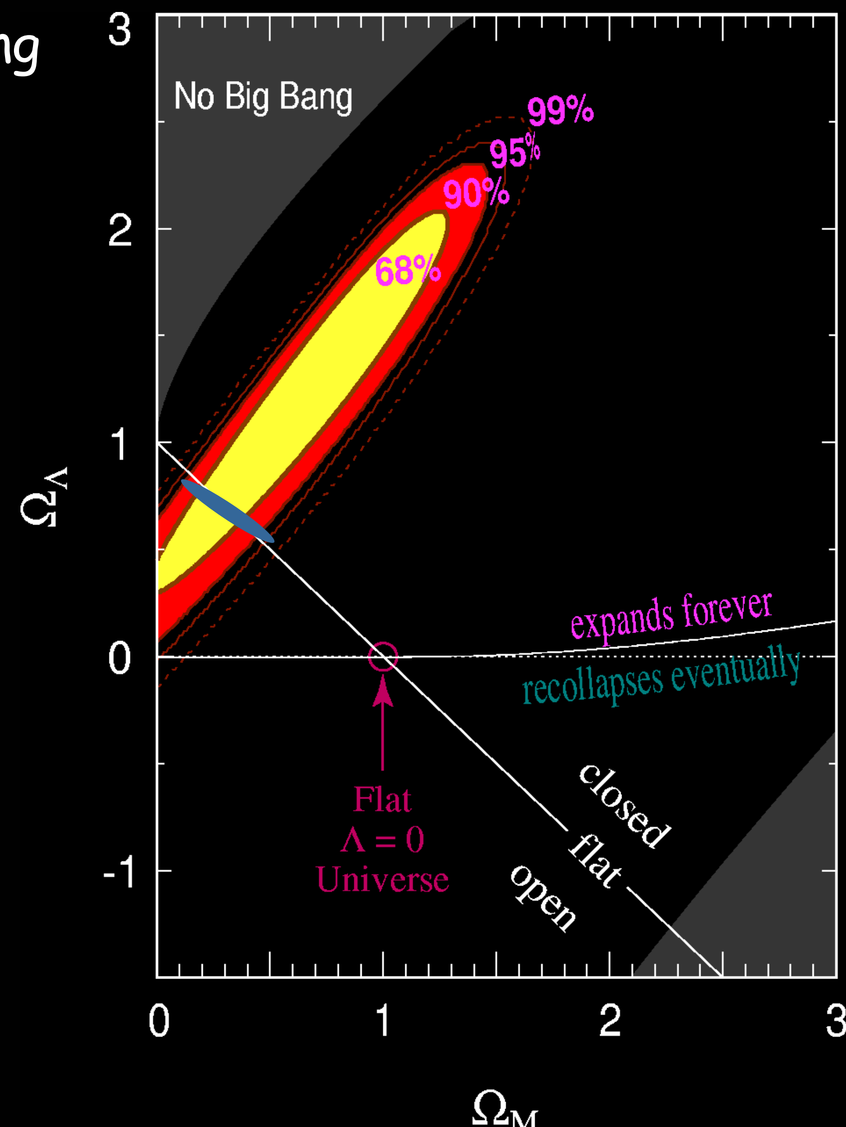
- matter: LSS ⇨ $\Omega_m \approx 0.3$

Do we live in a low density universe?

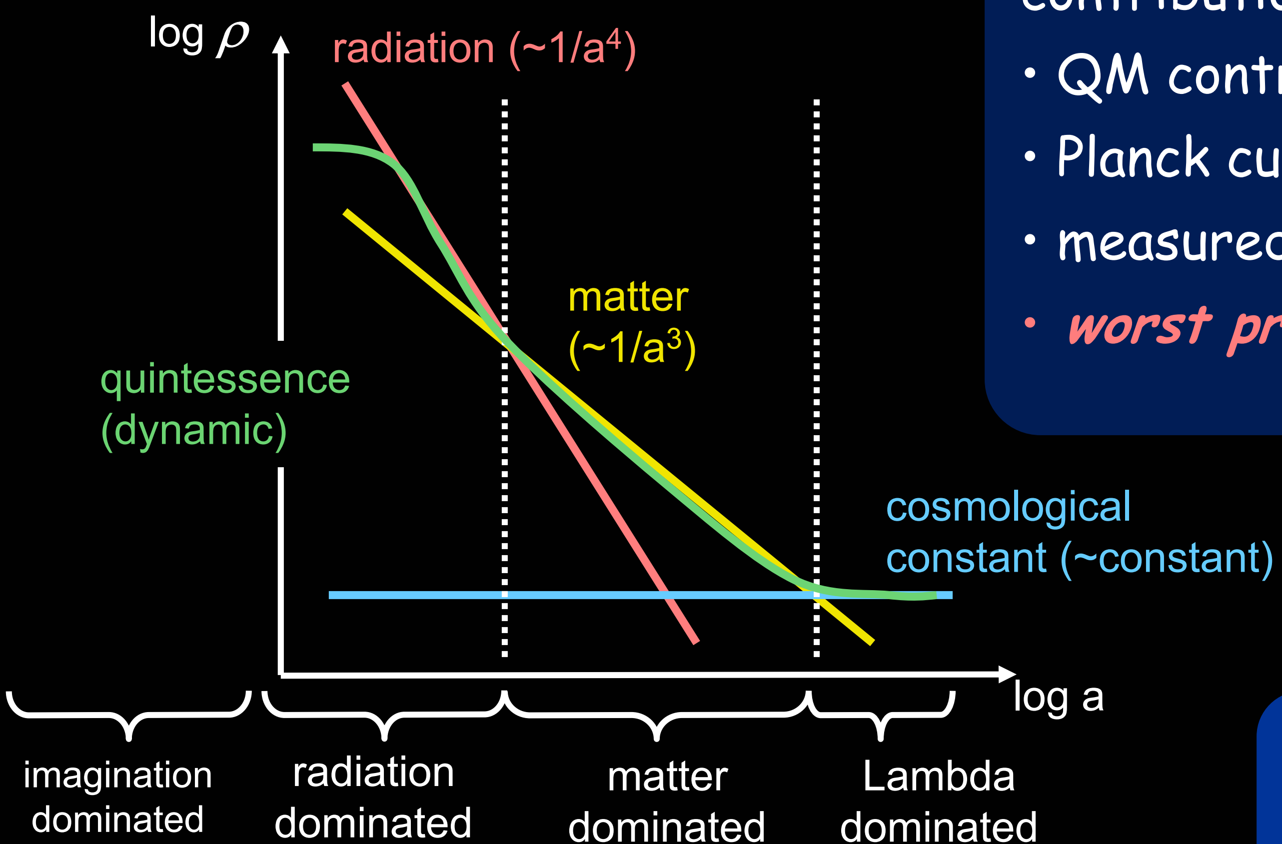
SN-Ia: rather not

CMB anisotropies: NO!

- cosmological const.: ⇨ $\Omega_\Lambda \approx 0.7$



what is it?



Let's guess the size of the contribution by Λ:

- QM contribution ~ k^4.
- Planck cutoff: $\Lambda \approx 10^{76}$ GeV^4
- measured: $\Lambda \approx 10^{-47}$ GeV^4
- *worst prediction* ever?

equation of state:

$p = w\,\rho$

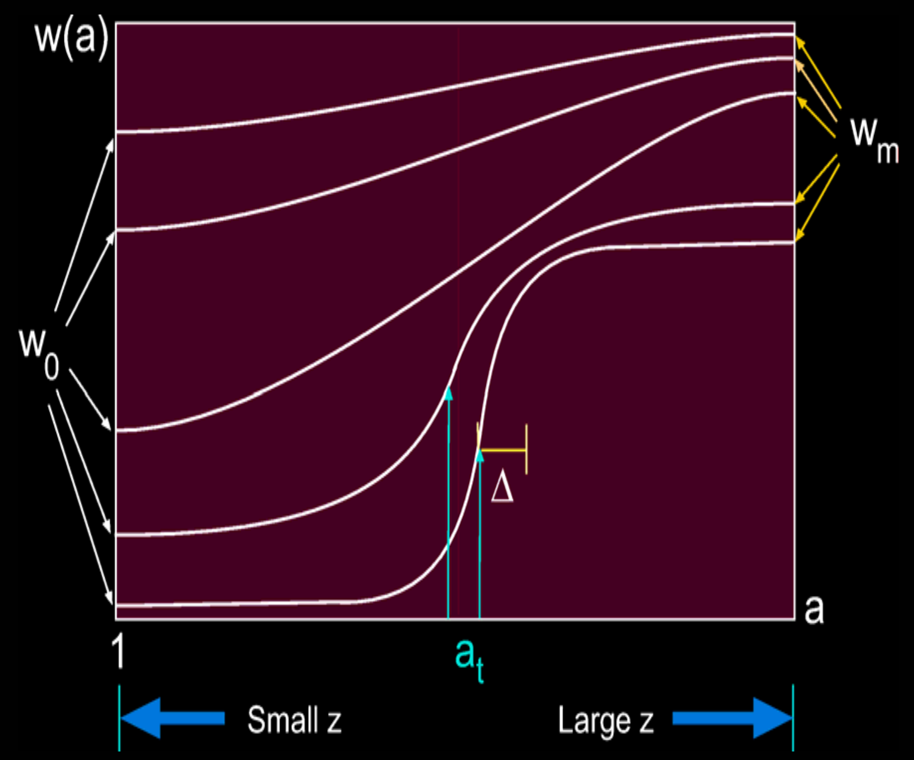
$\rho(a) \sim a^{-3(1+w)}$

the essence of quintessence

We impose an equation of state w(z) which captures the essential features of quintessence and derive an effective potential.

typical expectations:

- recent acceleration
  ➲ $w_0 < -1/3$
- avoid fine tuning the initial energy density
  ➲ $w_m > -1/3$
- there is a transition at a given redshift z_t with a given width Δ.
- Λ corresponds to $w_0 = -1$ and either $w_m = -1$ or $z_t \gg 1$.



outline of the analysis

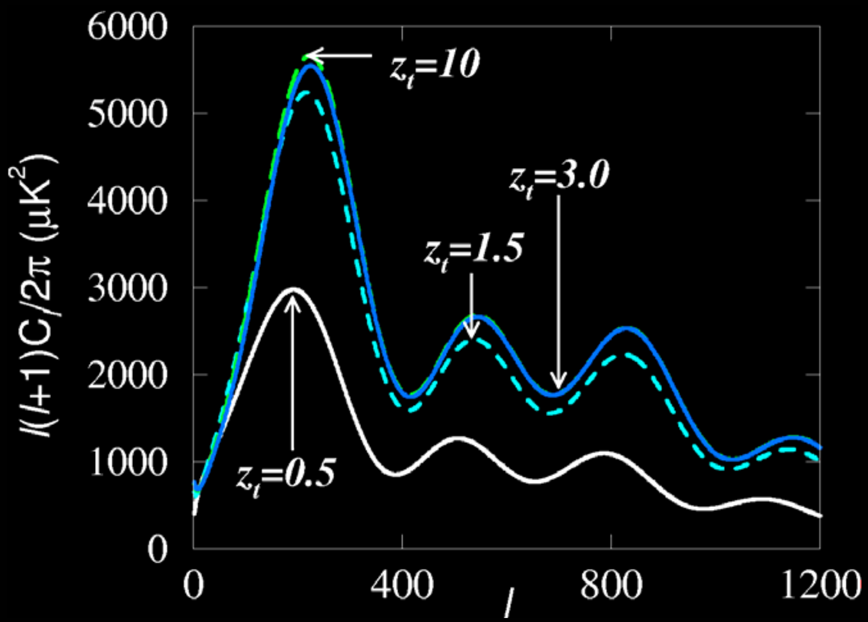
General strategy:

- compute predictions for many models with different parameters (we vary H_0, Ω_Q, Ω_b,, n_s, τ and the normalisation as well as a_t, w_0, w_m, Δ)
- compare with data sets (we use WMAP + SN-Ia)
- derive constraints on the parameters (Markov-Chain Monte Carlo code with modified cmbfast)
- draw conclusions about the physical nature of whatever it was that created the data

influence of w(z) on the CMB

rapid transition :

- late onset of expansion changes ISW effect which acts at large l
- peak lower after COBE normalisation



- Cosmic variance makes the effect hard to observe, especially for models with slowly varying equation of state.
- A data set which connects large and small angular scales is crucial for a correct normalisation ← WMAP.

cosmological parameters

- limits slightly wider, but no clear difference
- **no new degeneracies!**
  (except maybe τ)

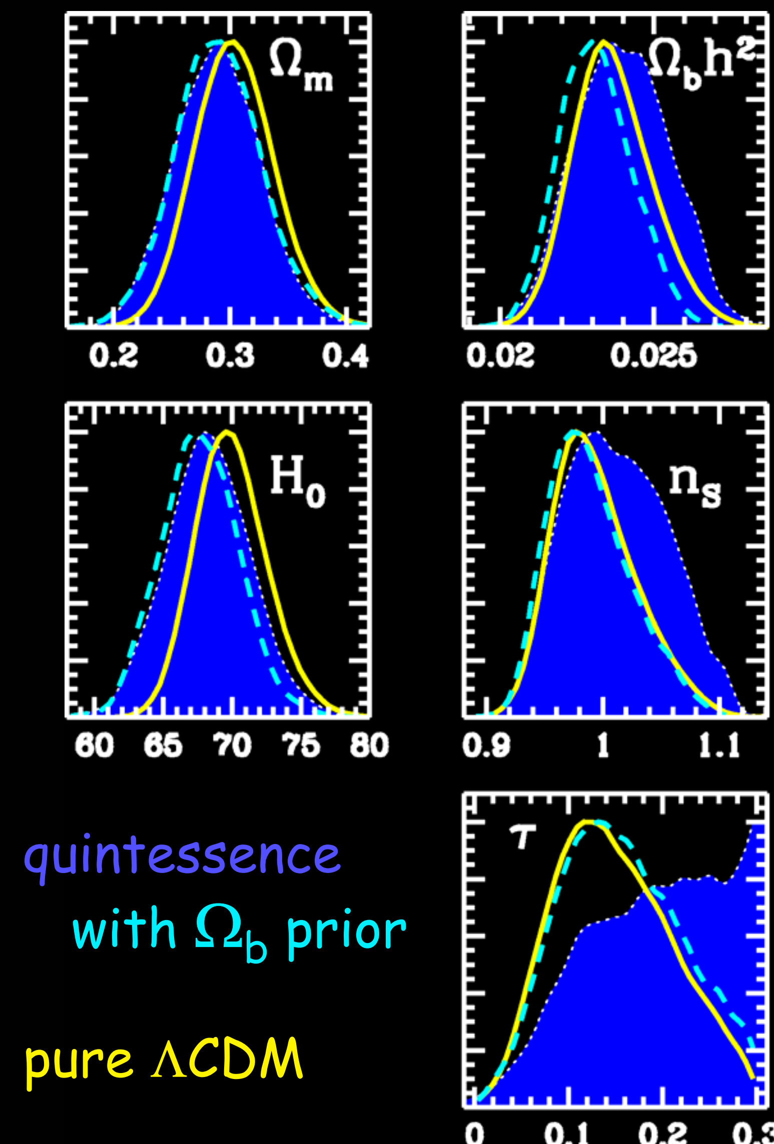
Ω_m = 0.29 ± 0.04

$\Omega_b h^2$ = 0.0240 ± 0.0015

H_0 = 68 ± 3

n_s = 1.01 ± 0.04

τ = 0.19 ± 0.07



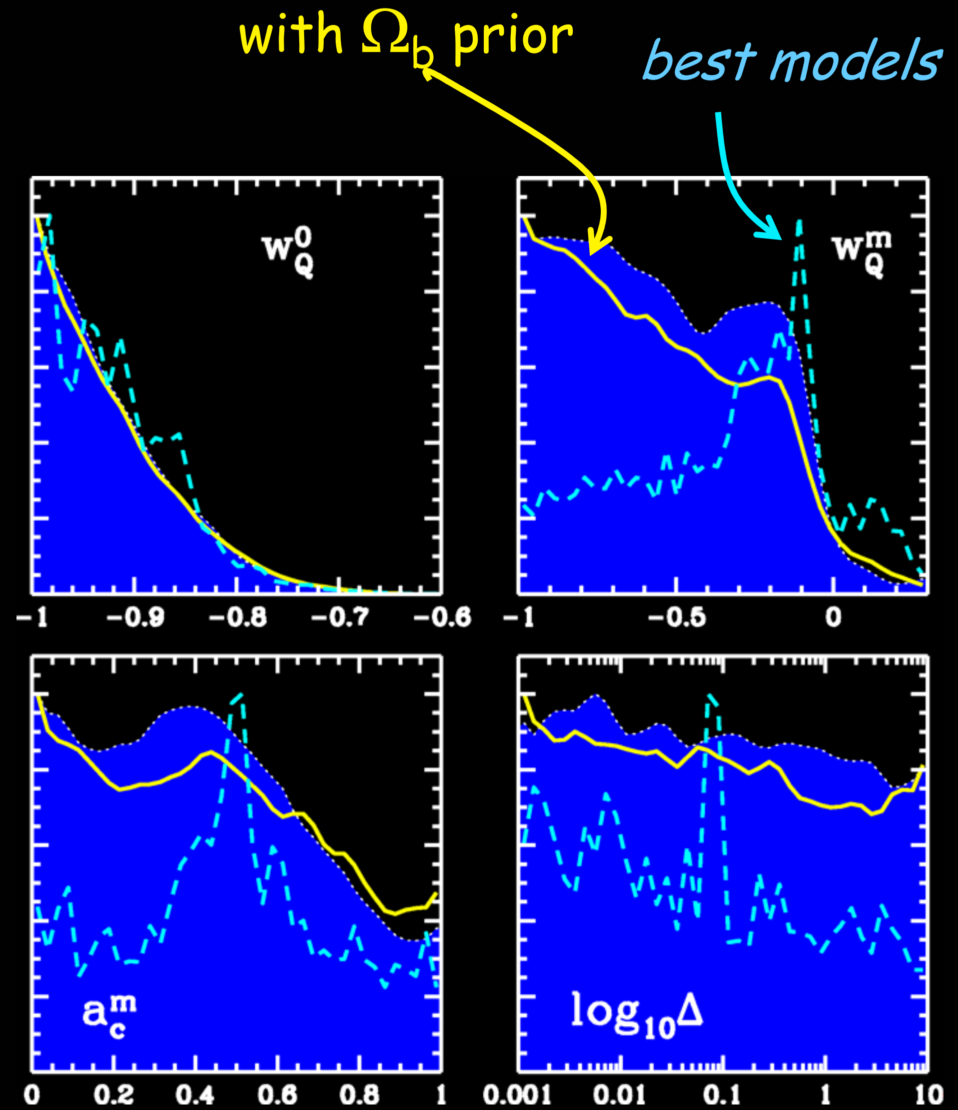
dark energy parameters

$w_0 < -0.80$ at 95% CL
$z_t > 0.6$ (fast transitions)

best-fit quintessence model:

- $w_0 = -1$
- $w_m = -0.13$
- $a_t = 0.5$ ($z_t = 1$)
- effective $\chi^2 = 1603$

best ΛCDM : $\chi^2 = 1606$



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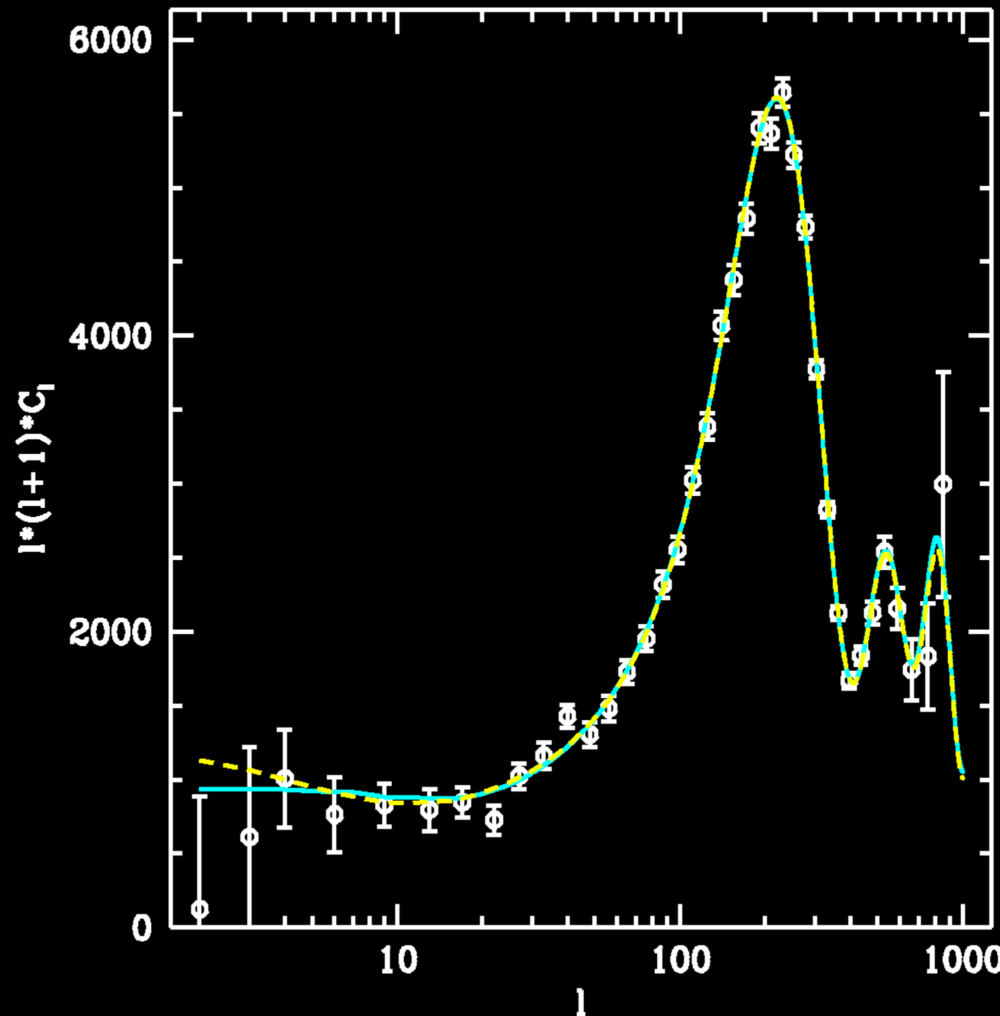
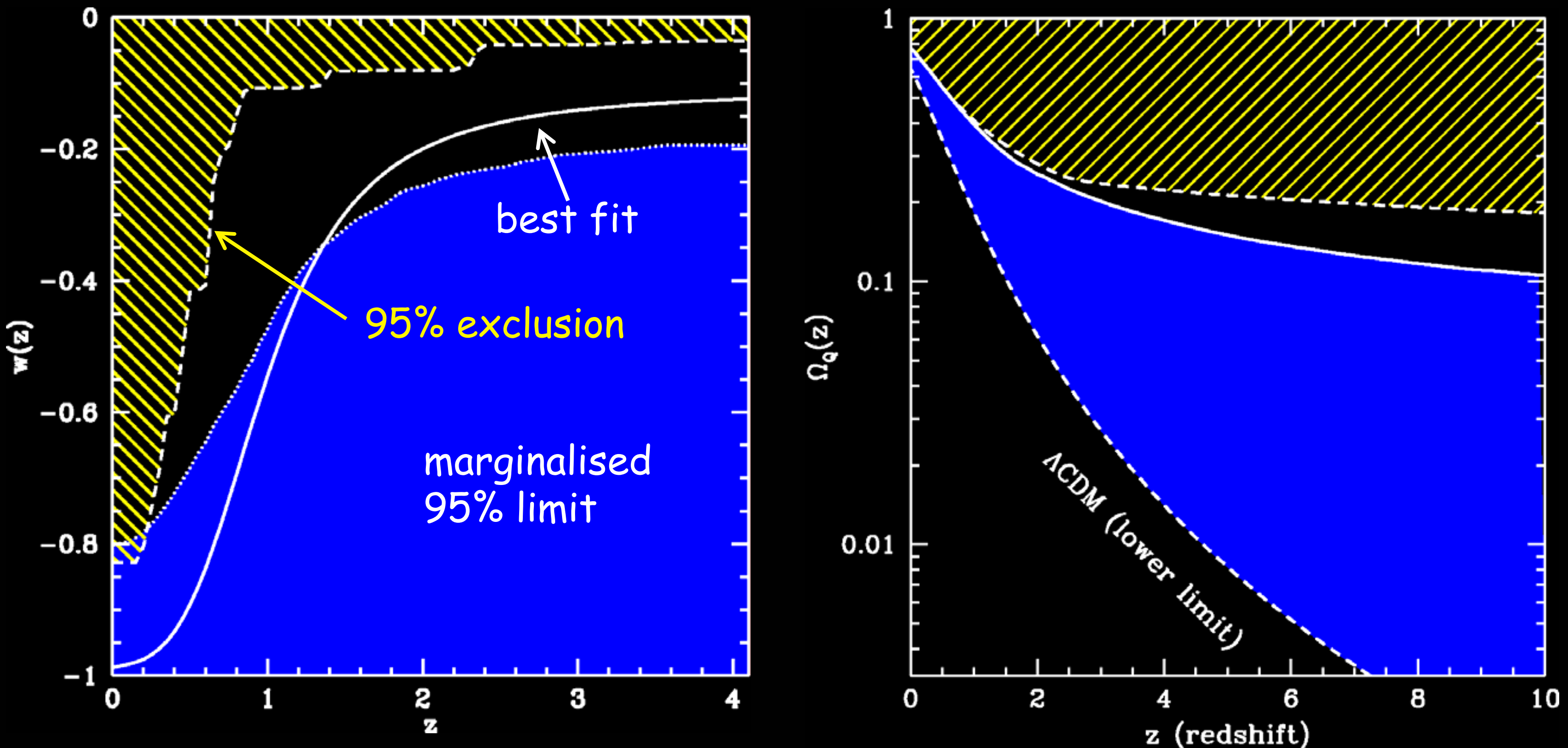


time behaviour of the DE

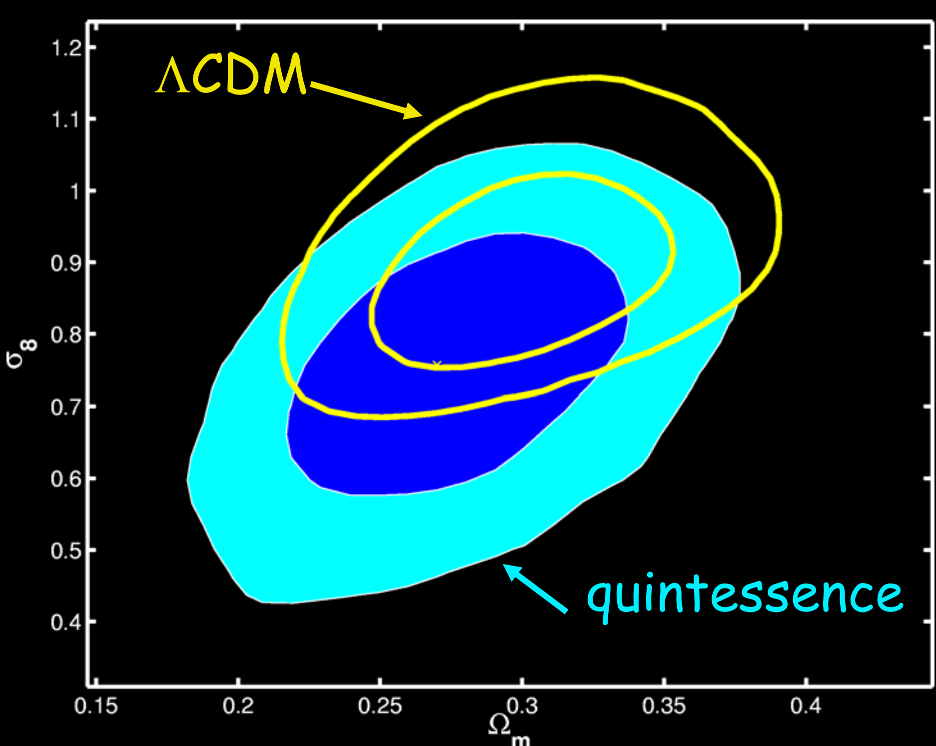


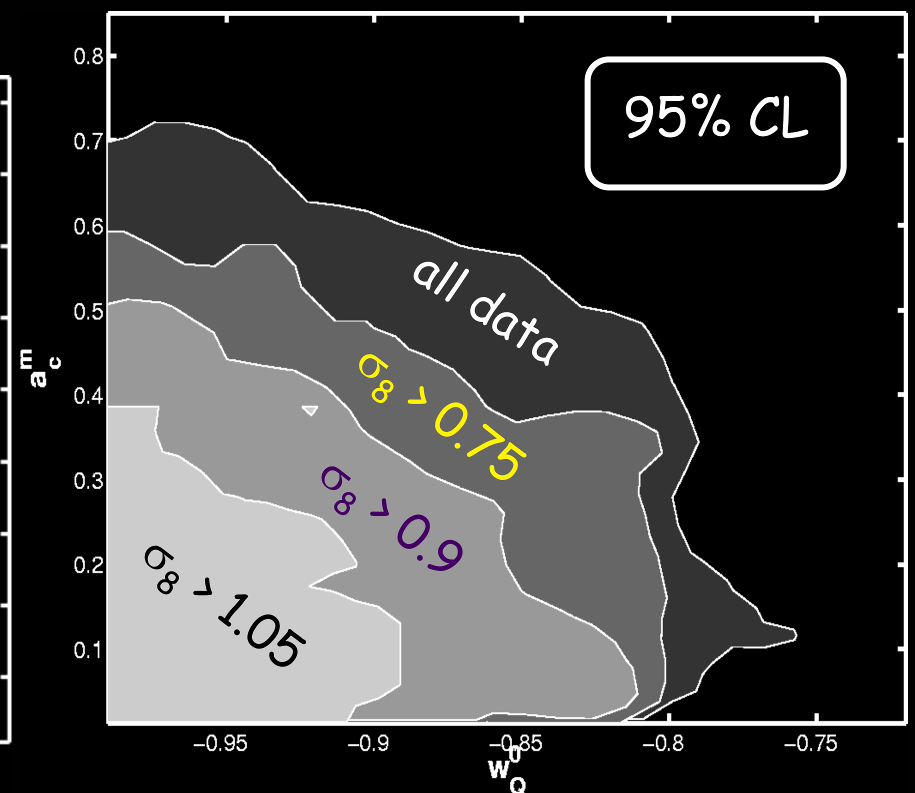
- really strong constraints on w only for z < 0.2
- w < 0 for z < 5 (matter e.o.s. / tracking)
  ➲ this might spell trouble for exponential potentials…
- dark energy becomes quickly subdominant in the past

the clustering behaviour

- the ISW changes the overall normalisation
- this in turn changes the normalisation of the matter P(k)
- we can detect this if we know the amplitude of P(k) or σ_8
- **BUT:** we can only observe galaxies

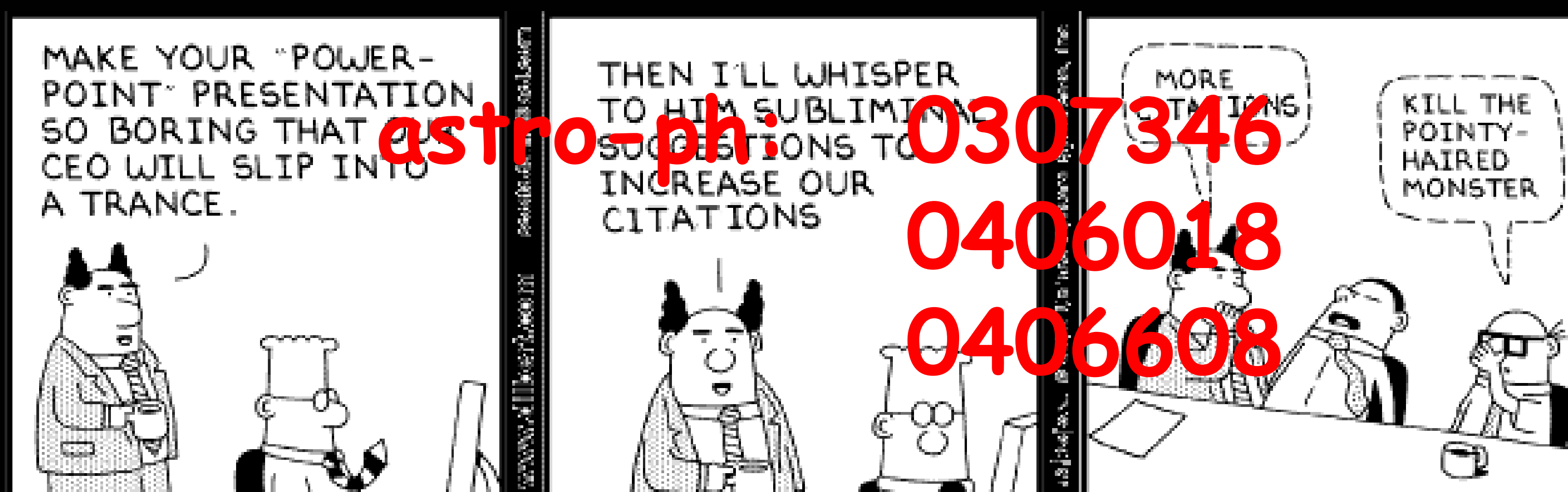
➲ we don't know σ_8 very well!





conclusions

- no strong change in w for $z < 0.5$
- eq of state today: $w_0 < -0.80$
- the clustering is different from ΛCDM (can mimic running n_s or massive ν)
- but: **no need for anything beyond Λ !**



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