Testing for a super-accelerating phase of the Universe (w<-1)

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Dark energy essentials

- Want to know
  - how much, Ω_{DE}
  - equation of state, $w=p/\rho$
- Equation of state w may vary with time
  - $w=w(z)$
  - difficult to measure
- w(z) and Ω_{DE} are difficult to disentangle

  - eg. Maor et al. 2002

The effective equation of state

- Measure $D_L(z)$
  - eg. SNAP
- Fit a constant w model $\rightarrow w_0$
  - eg. assume $\Omega_m=0.3$
- How is w_0 related to w(z)?
  - given that the true w may vary with time..

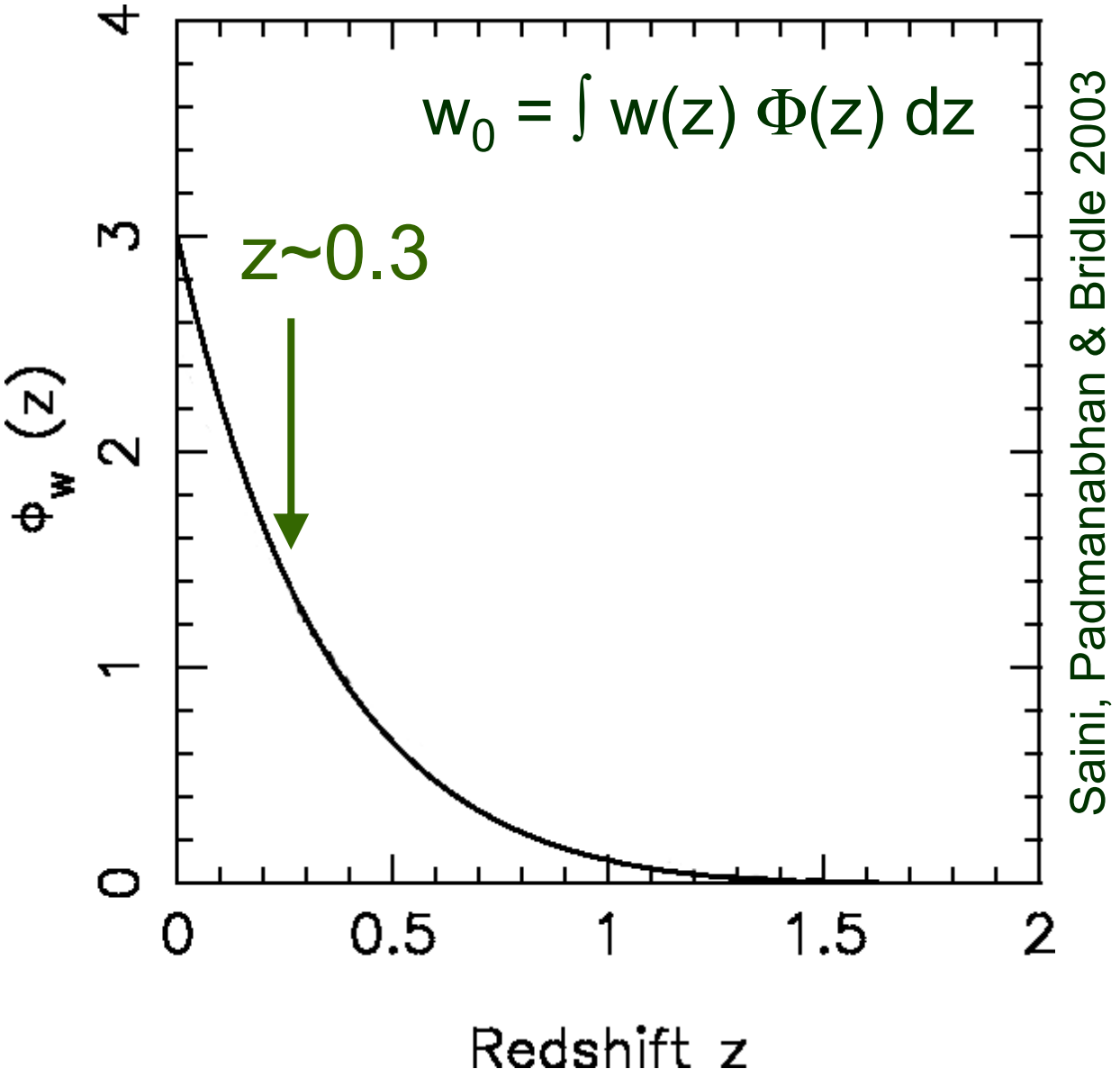
A weighted average?

$$w_0 = \int w(z)\, \Phi(z)\, dz$$

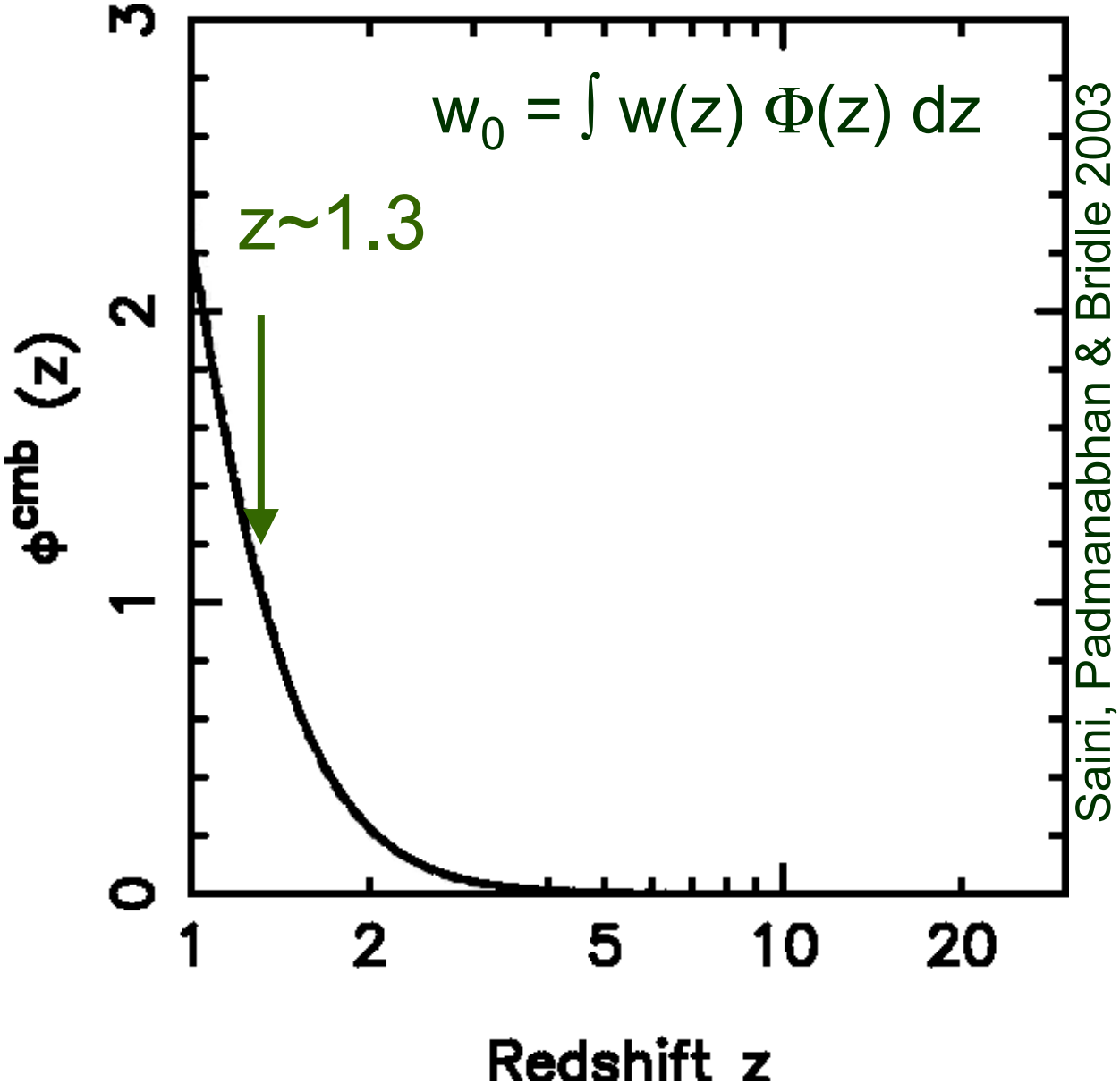
- Yes!
- To a very good approximation (~1%)

Saini, Padmanabhan, Bridle 2003

The weighting function for SNAP



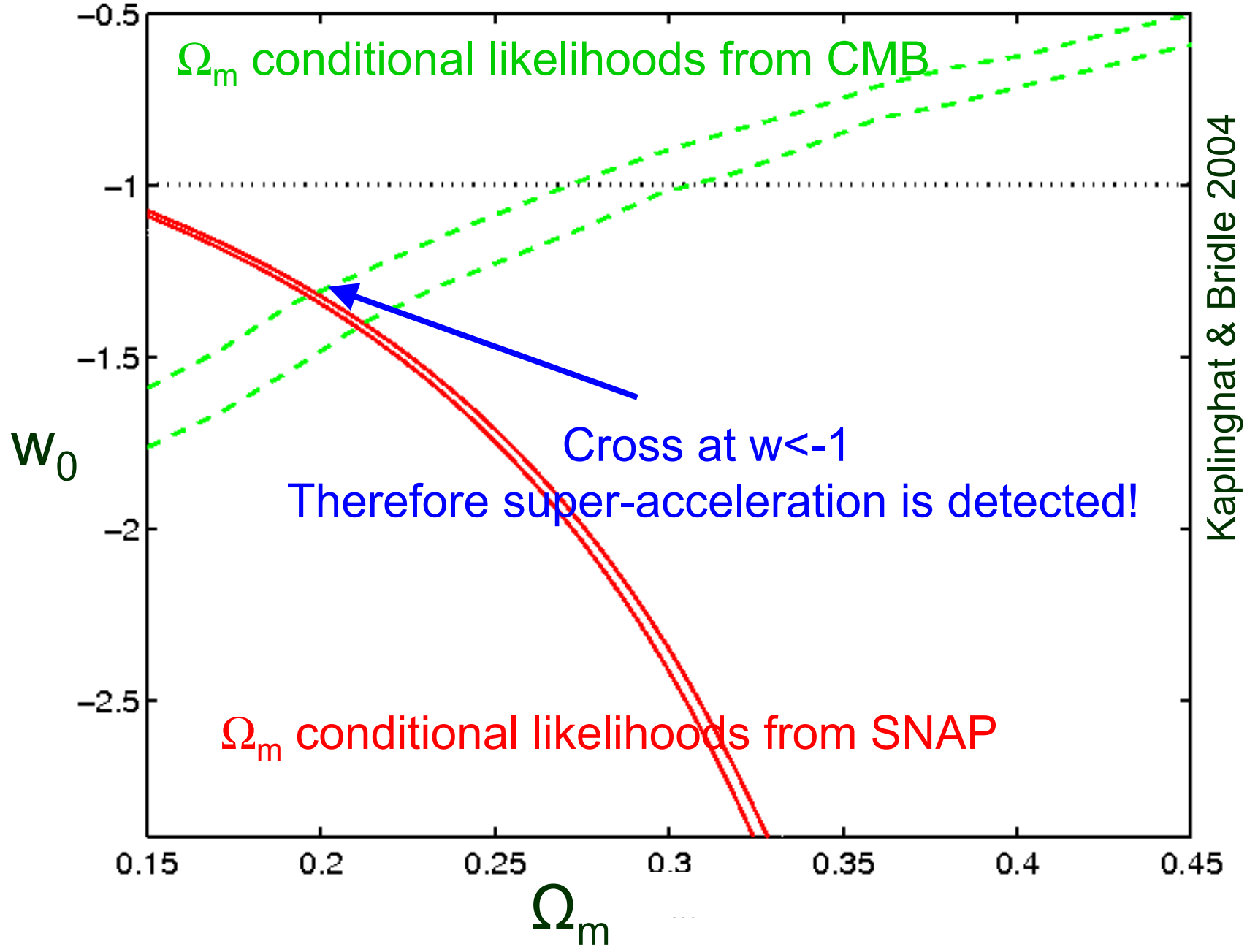
The weighting function for CMB

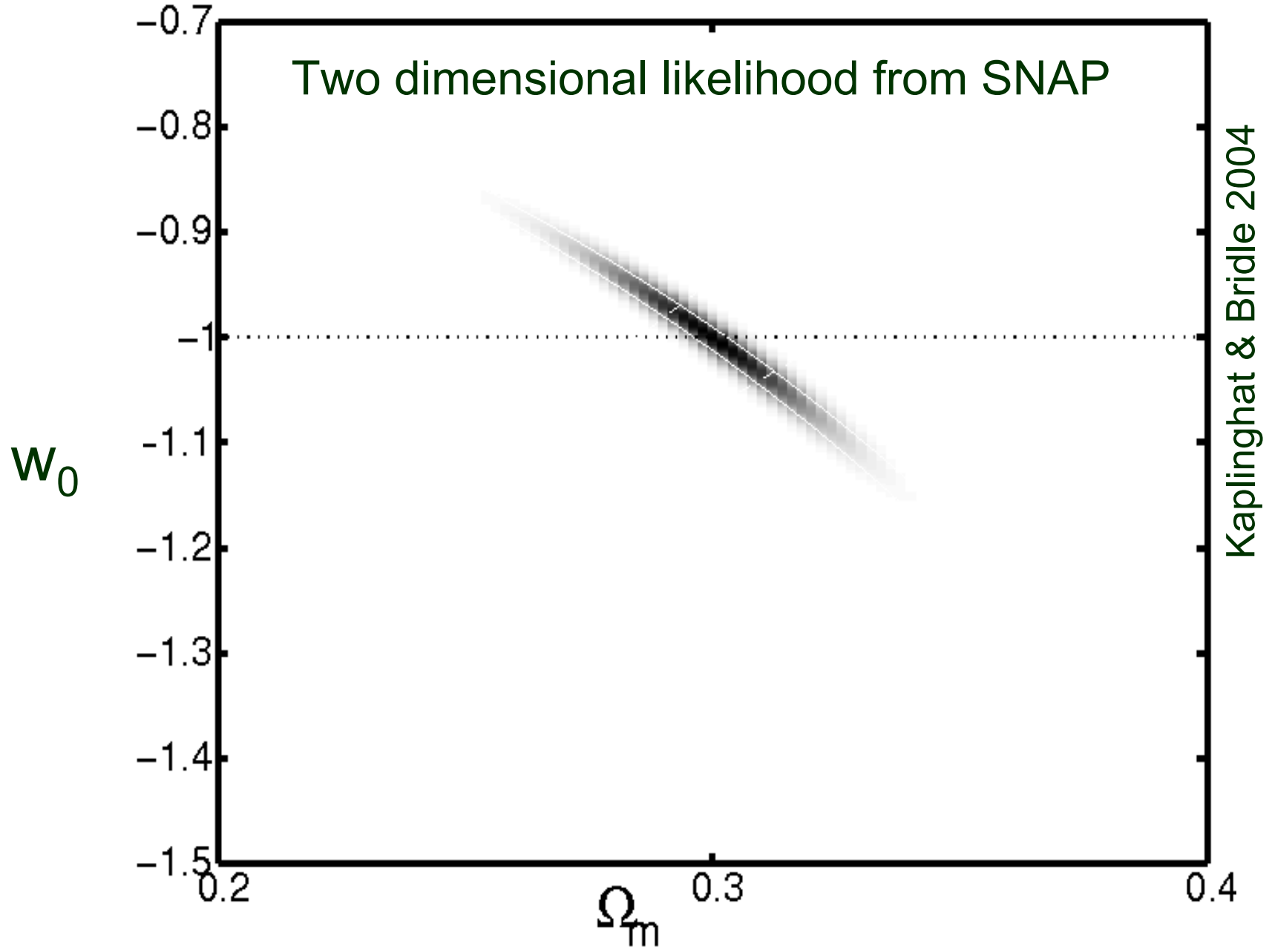


Did the universe undergo super-acceleration (w<-1)?

- Sounds impossible to answer
  - given difficulty of measuring w_1, w_2 …
- Turns out to be possible to answer
  - if the universe super-accelerated enough

Kaplinghat & Bridle 2004


Ω_m conditional likelihoods from CMB
Cross at w<-1
Therefore super-acceleration is detected!
Ω_m conditional likelihoods from SNAP
w_0
Ω_m
−0.5
−1
−1.5
−2
−2.5
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Kaplinghat & Bridle 2004


Two dimensional likelihood from SNAP
w_0
−0.7
−0.8
−0.9
−1
−1.1
−1.2
−1.3
−1.4
−1.5
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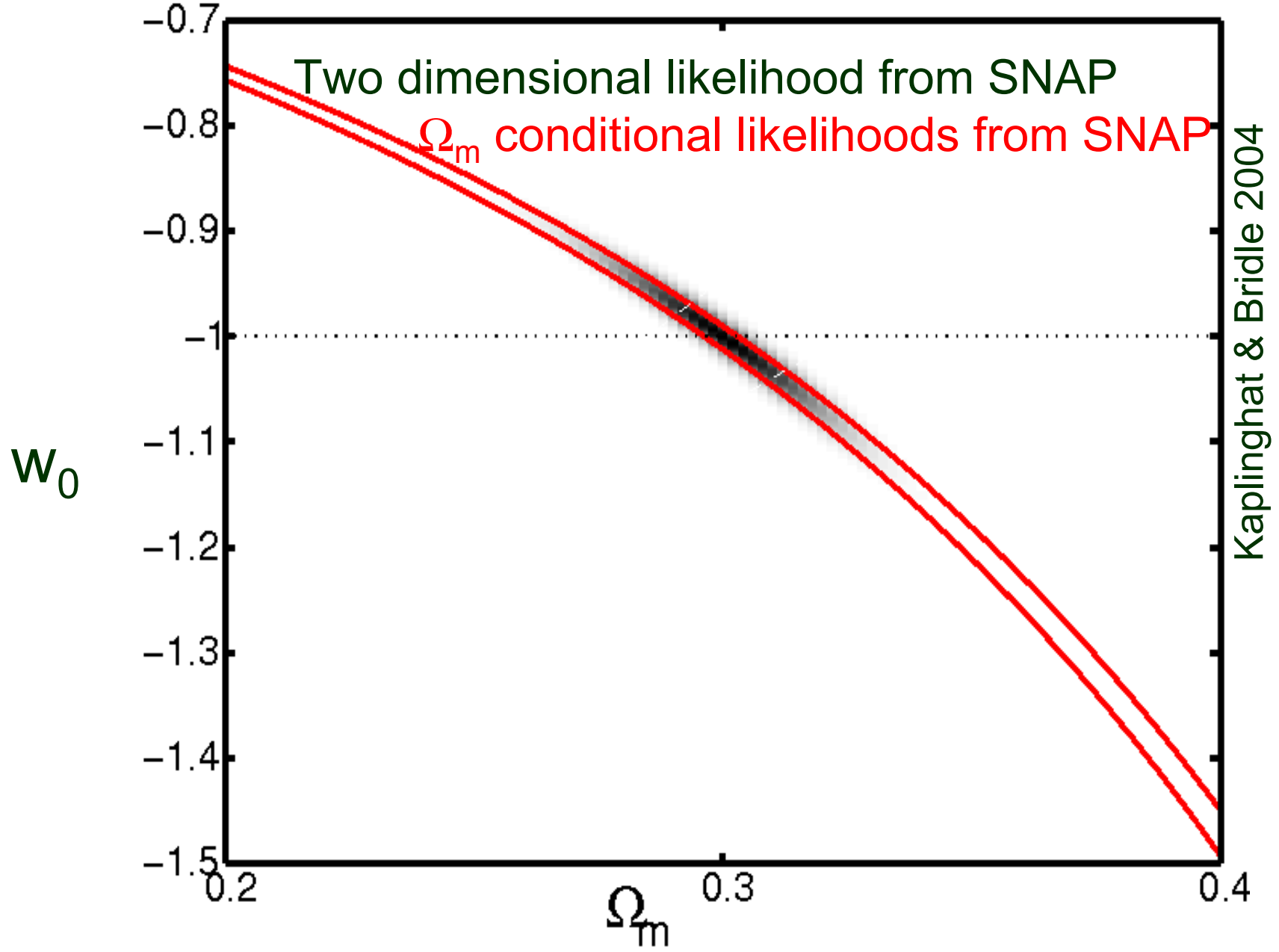
Ω_m
Kaplinghat & Bridle 2004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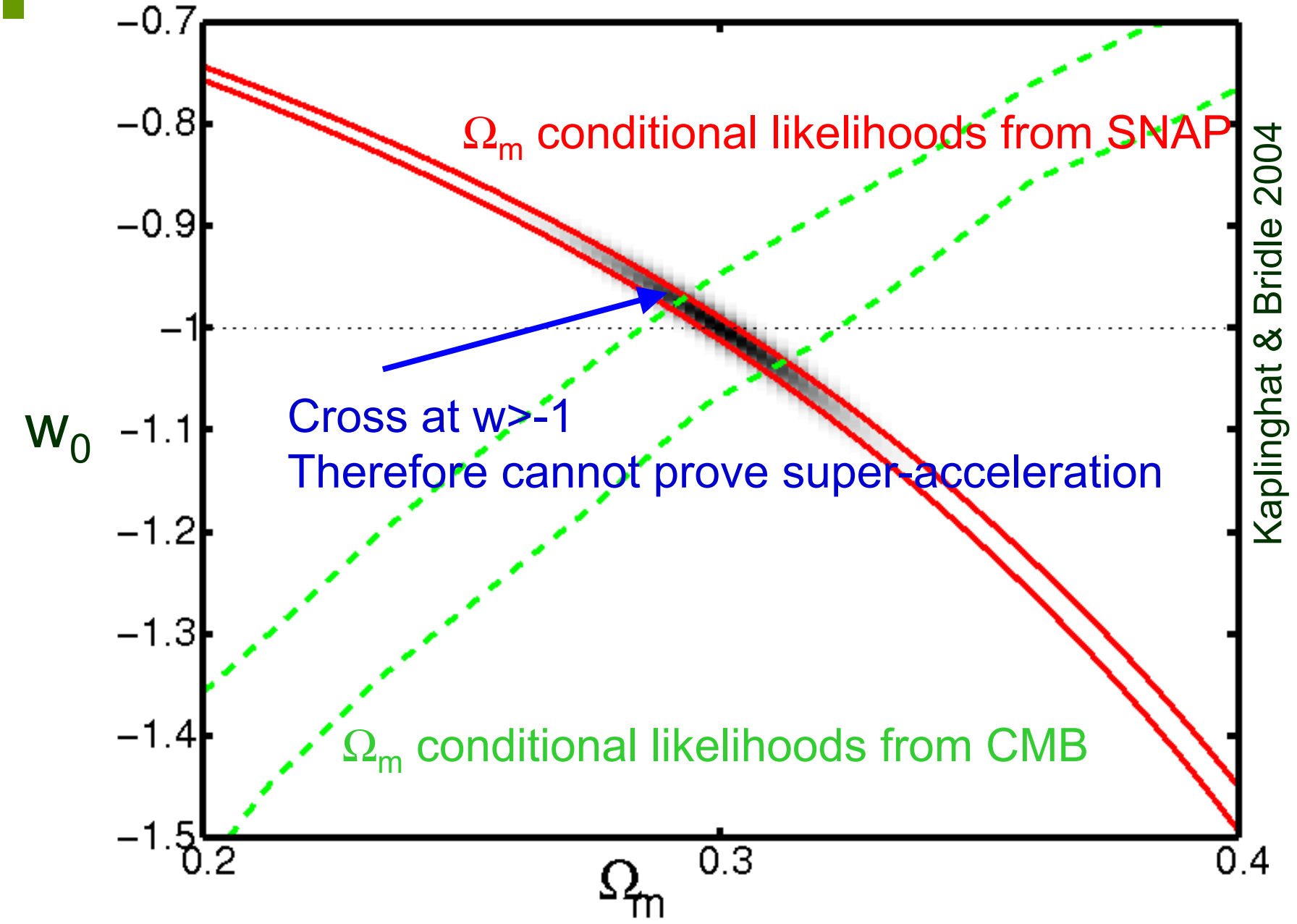
Kaplinghat & Bridle 2004

Add CMB data

- Simulated Planck data
  - Use only l>50 to avoid perturbations
- Marginalise over h, Ω_b, A_s, n_s, z_{re}
  - Use CosmoMC code http://cosmologist.info/cosmomc
- Fix $\Omega_k=0$, $A_t=0$, $m_\nu=0$
- Basically use peak position ie. $D_A(z=1100)$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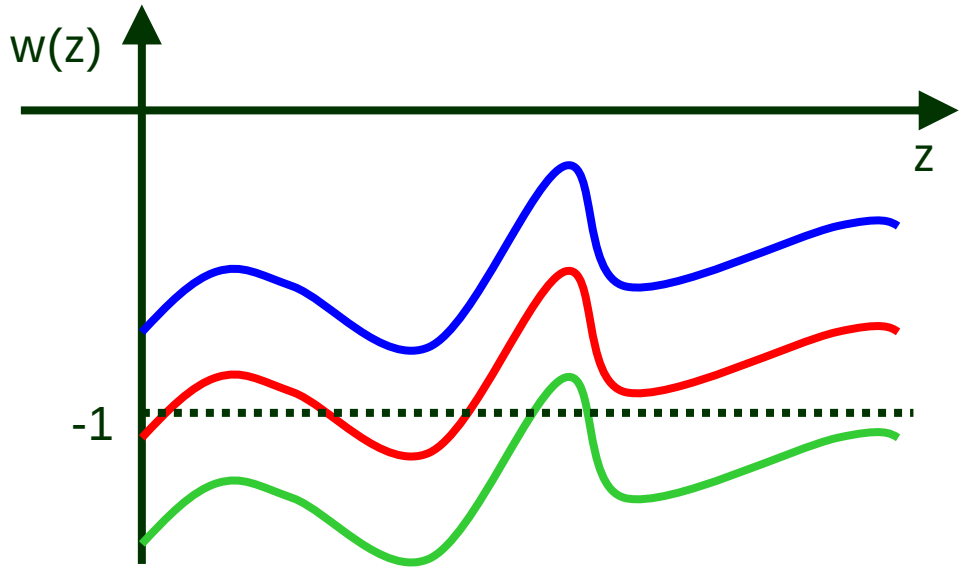
Ω_m
Ω_m conditional likelihoods from SNAP
Cross at w>-1
Therefore cannot prove super-acceleration
Ω_m conditional likelihoods from CMB
Kaplinghat & Bridle 2004

Why does this work?

- SN and CMB measure a weighted average of the true w(z) (given Ω_m)

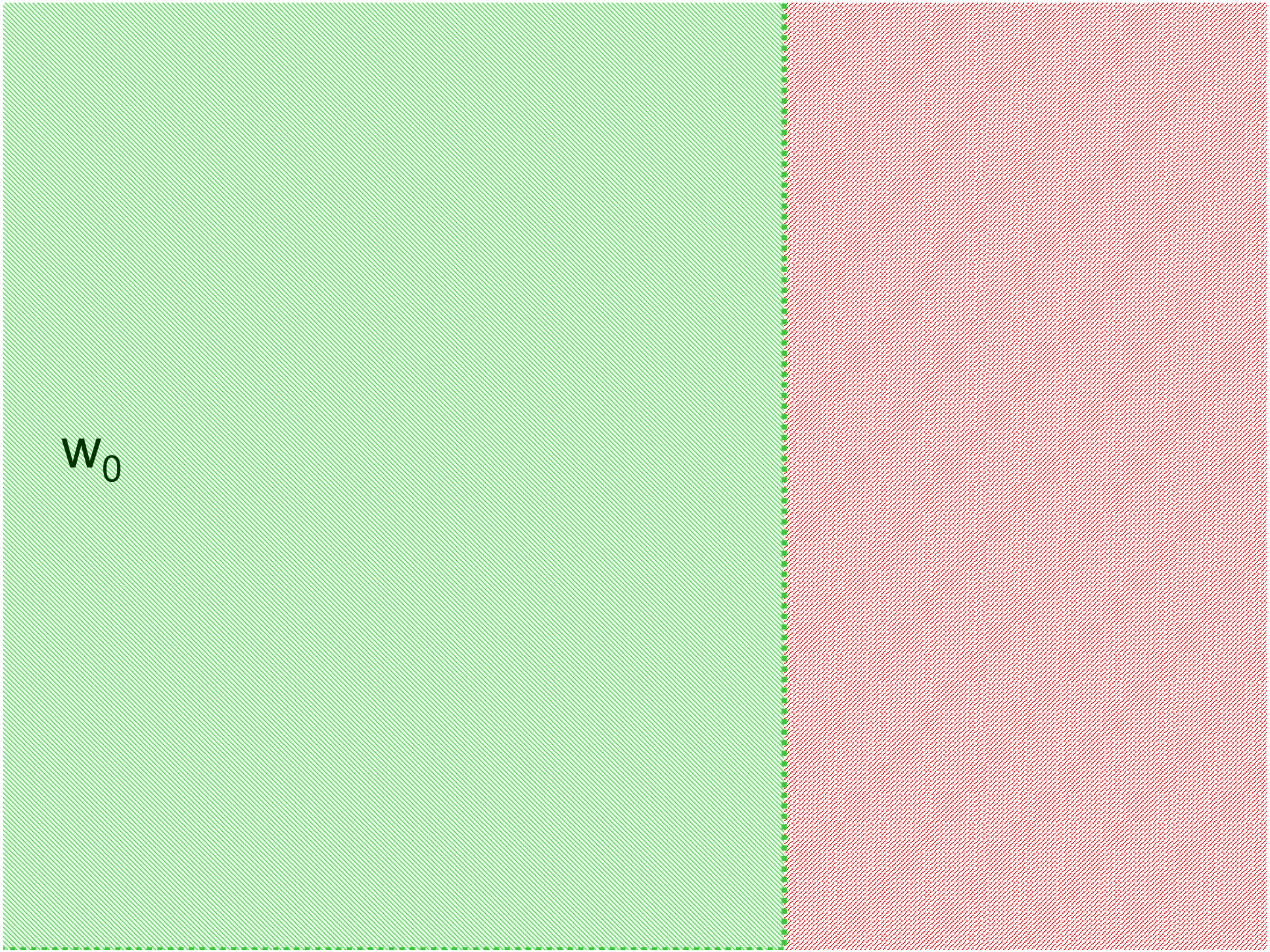


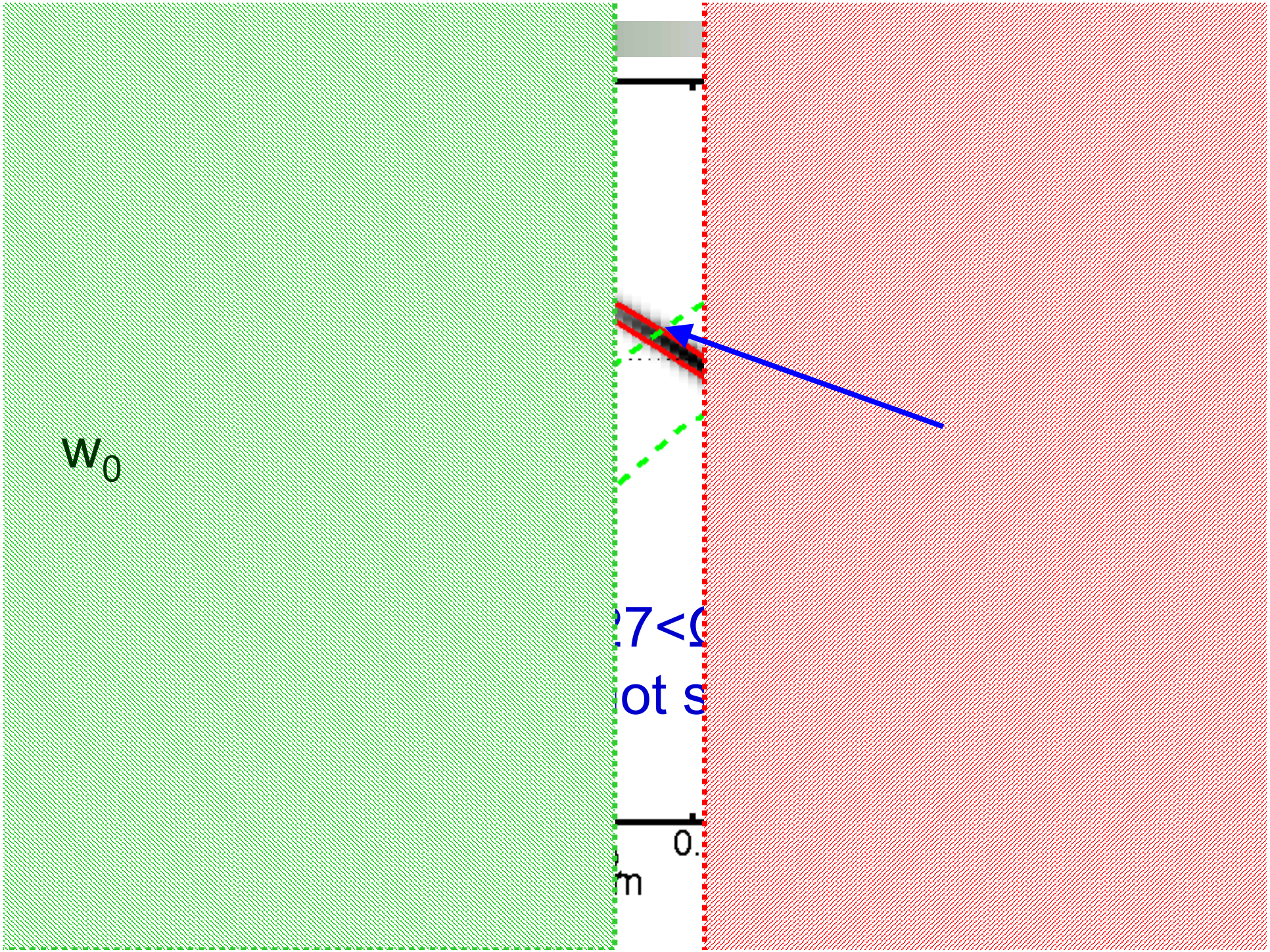
$w_{0\,SN} = -0.6$

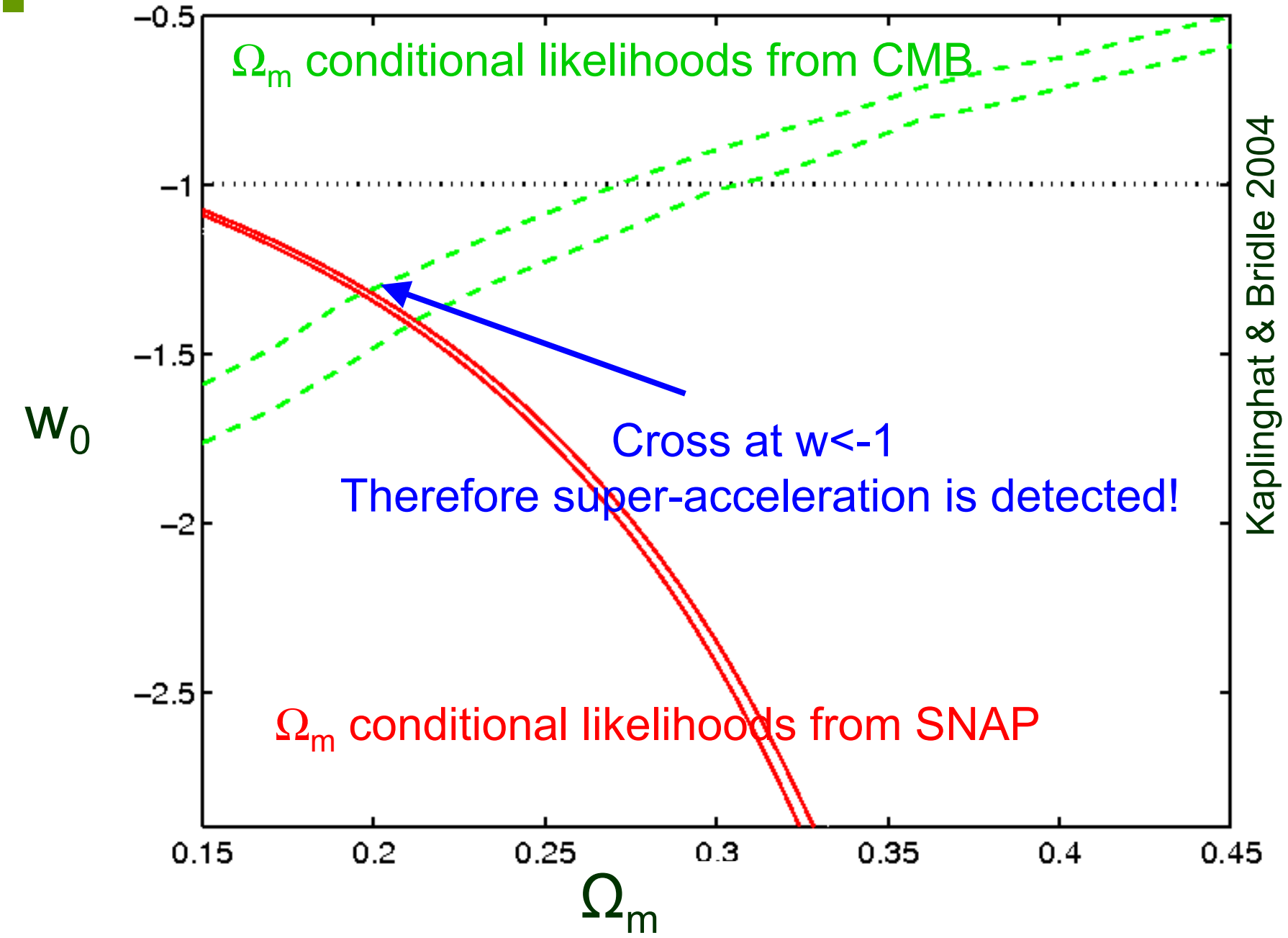
$w_{0\,SN} = -1.0$

$w_{0\,SN} = -1.3$

- If $w_{0\,SN} < -1 \Rightarrow w(z) < -1$ at some z


w_0


w0
0.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Kaplinghat & Bridle 2004

More general results

- Upper contours cross at w_u
  - $w(z) < w_u$ at some z
- Lower contours cross at w_l
  - $w(z) > w_l$ at some z
- Could consider lines that are not horizontal!
  - eg. $w<-1/(3(1-\Omega_m))$

Summary

- Can determine if w<-1 at some z

Without

- Making assumptions about w(z) form
- Making assumptions about Ω_m

Saini, Padmanabhan, Bridle 2003

Kaplinghat & Bridle 2004