Weak lensing forecasts for dark energy, neutrinos and initial conditions

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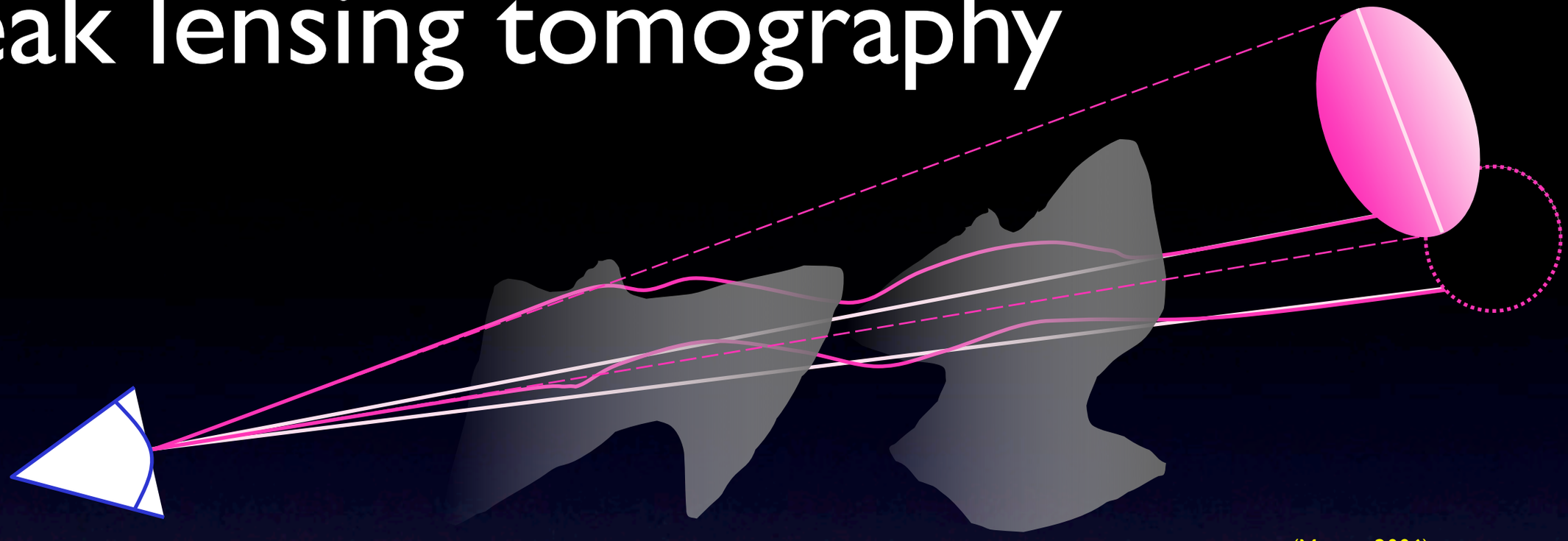
- How well can we constrain cosmological parameters using a future weak lensing experiment?
- Do the error bars depend on the theoretical model?
- How can we improve constraints by combining experiments?

Weak lensing tomography



(Massey 2006)

Geometry

Lensing correlation for redshift bins i and j

$$C_\ell^{ij} = \int \mathrm{d}z \frac{H}{D_A^2} W_i(z) W_j(z) P(k = \ell/D_A, z),$$

Matter power spectrum

$$F_{\alpha\beta} = \sum_\ell \left(\frac{1}{\Delta C_\ell}\right)^2 \frac{\partial C_\ell}{\partial p_\alpha} \frac{\partial C_\ell}{\partial p_\beta},$$

Cosmological parameters

Fisher matrix

$$\Delta C_\ell = \sqrt{\frac{2}{(2\ell+1) f_{\mathrm{sky}}}} \left(C_\ell + \frac{\sigma_\gamma^2}{2 n_g}\right)$$

Error on lensing power spectrum

Survey parameters

Cosmological model

Parameters	w_0	w_a	$\Omega_{\rm DE}$	Ω_m	Ω_b	h	σ_8	n_s	α	β	m_ν	N_ν
Fiducial values	-0.95	0	0.7	0.3	0.045	0.7	0.8	1	0	0	0.66	3

Dark energy

$$w(a) = w_0 + w_a(1-a)$$

(Chevallier & Polarski, 2001; Linder, 2003)

CDM+baryons

Neutrinos

$$m_\nu = N_\nu m_i$$

Initial conditions

Power law: tilt

$$\mathcal{P}_\chi(k) = A_s \left(\frac{k}{k_{s0}}\right)^{n_s-1}$$

+ running

$$n_s(k) = n_s(k_0) + \frac{1}{2}\frac{\mathrm{d}n_s}{\mathrm{d}\ln k}\bigg|_{k_0} \ln\left(\frac{k}{k_0}\right)$$

$$\alpha = \mathrm{d}n_s/\mathrm{d}\ln k|_{k_0}$$

+ `running of the running'

$$\beta = \mathrm{d}^2 n_s/\mathrm{d}\ln k^2|_{k_0}$$

$$n_s(k) = n_s(k_0) + \frac{1}{2!}\alpha \ln\left(\frac{k}{k_0}\right) + \frac{1}{3!}\beta \ln\left(\frac{k}{k_0}\right)^2$$

Parameters	w_0	w_a	$\Omega_{\rm DE}$	Ω_m	Ω_b	h	σ_8	n_s	α	β	m_ν	N_ν
Fiducial values	-0.95	0	0.7	0.3	0.045	0.7	0.8	1	0	0	0.66	3
QCDM	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
QCDM + α	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
QCDM + α + β	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
νQCDM	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓
νQCDM + α	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
νQCDM + α + β	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Six parameter sets

$$\text{Fractional change in error} = \frac{\Delta p_{\rm ext} - \Delta p_{\rm QCDM}}{\Delta p_{\rm QCDM}},$$

Lensing: Marginalised errors

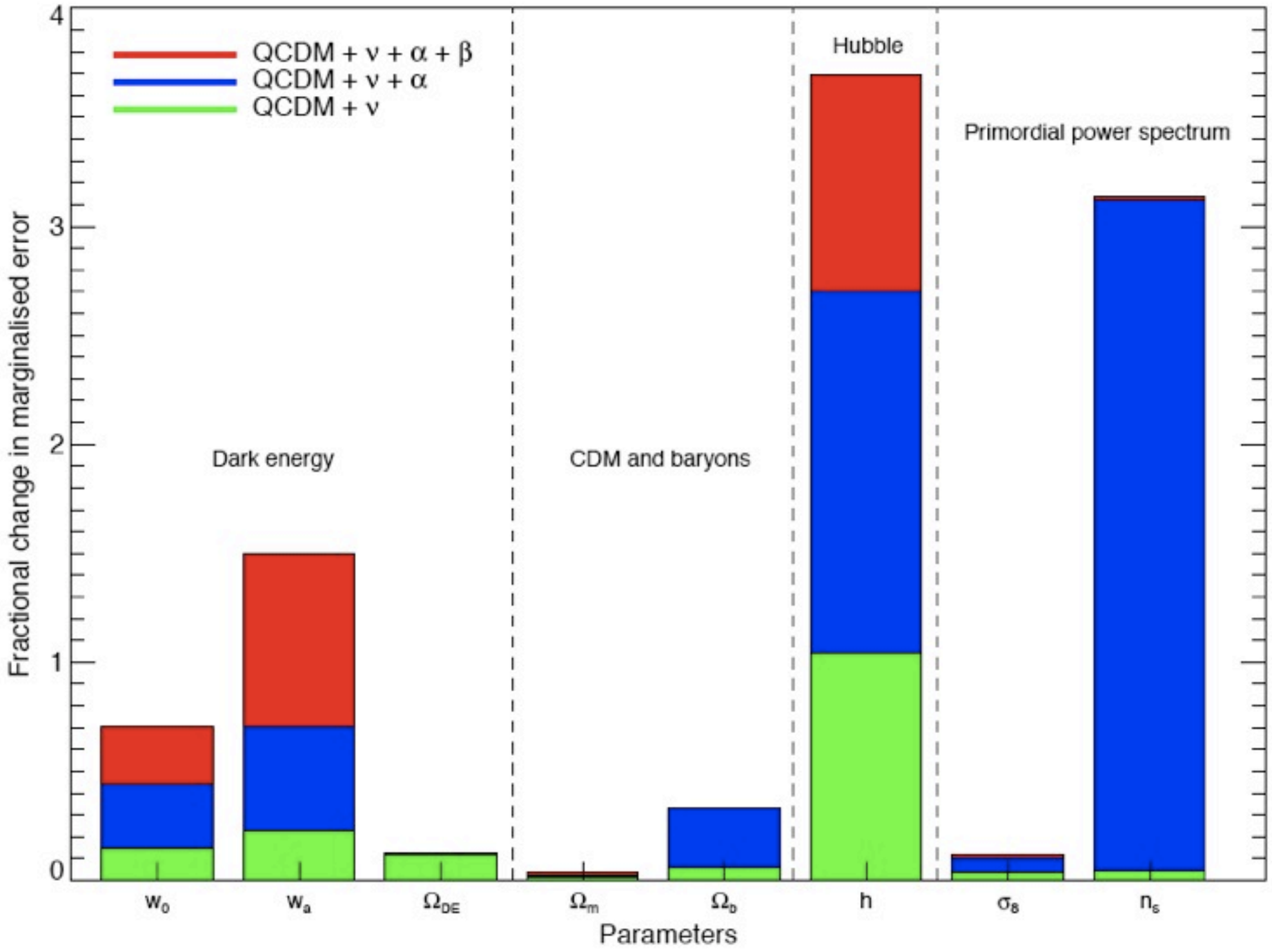
Parameter	QCDM	νQCDM	QCDM $+\alpha$	QCDM $+\alpha+\beta$	ν QCDM $+\alpha$	νQCDM $+\alpha+\beta$
w_0	0.05633	0.06443	0.05740	0.06583	0.08099	0.09608
w_a	0.19297	0.23674	0.21567	0.24988	0.32904	0.48144
$\Omega_{\rm DE}$	0.05214	0.05841	0.05287	0.05297	0.05842	0.05856
Ω_m	0.00731	0.00742	0.00731	0.00752	0.00749	0.00756
Ω_b	0.02411	0.02558	0.02544	0.02981	0.03200	0.03201
m_ν/eV		1.10229			1.19614	1.51694
N_ν		3.27380			3.81643	11.12214
h	0.11337	0.23176	0.18660	0.24691	0.41999	0.53253
σ_8	0.01184	0.01230	0.01185	0.01268	0.01307	0.01319
n_s	0.02904	0.03038	0.08662	0.11158	0.11969	0.12003
α			0.04378	0.05661	0.06556	0.07137
β				0.02574		0.08479
FOM	130.99	79.69	114.86	97.59	56.36	38.02

~ 10%

~ 200%

~ 10%

Fractional error change: lensing only



- Neutrino & primordial PS & DE degeneracy
- Solution: Combine with constraints from CMB

Marginalised errors: Lensing + CMB (Planck)

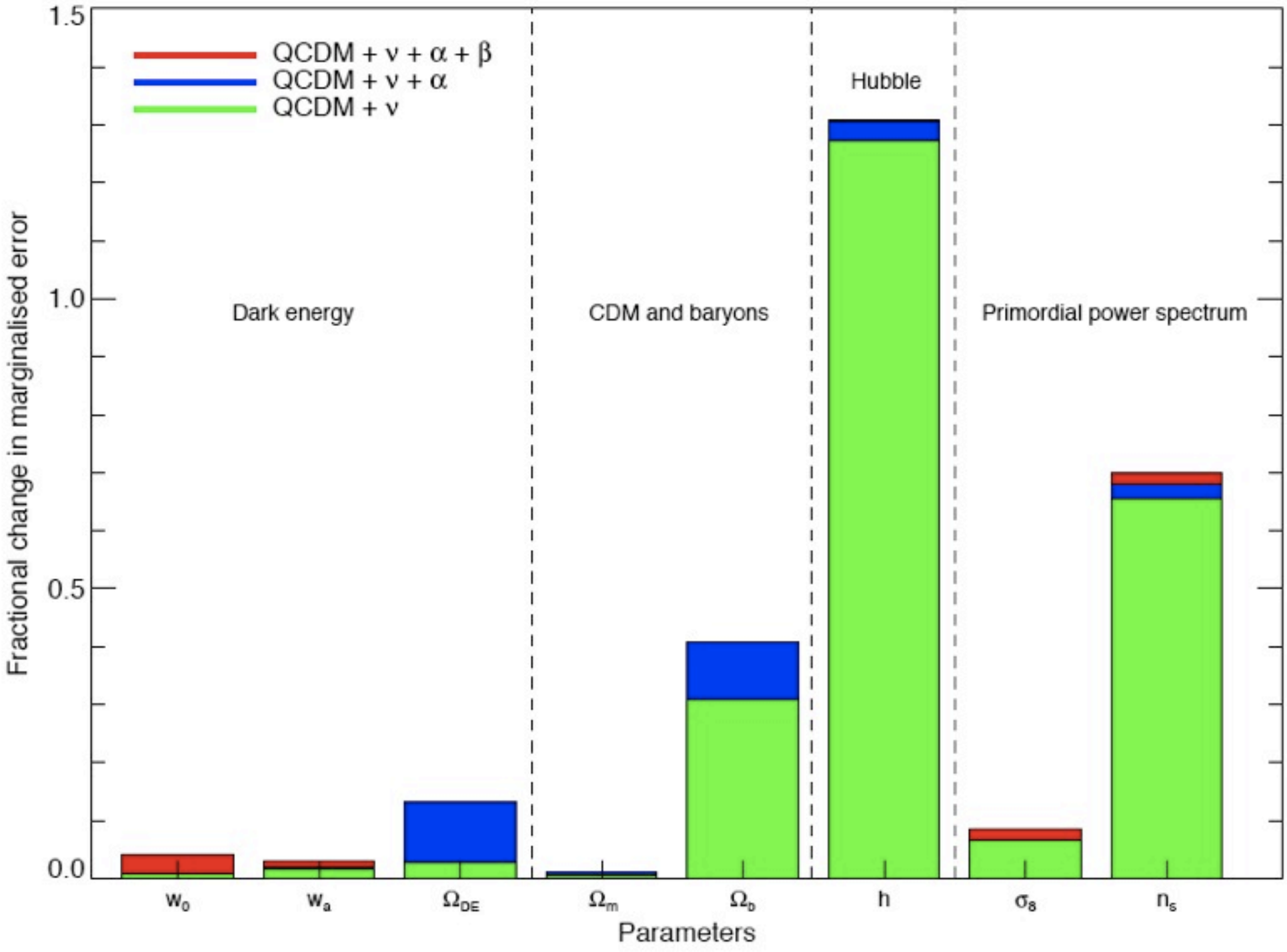
Parameter	QCDM	νQCDM	QCDM $+\alpha$	QCDM $+\alpha+\beta$	ν QCDM $+\alpha$	νQCDM $+\alpha+\beta$
w_0	0.04942	0.04984	0.04943	0.05055	0.04987	0.05142
w_a	0.17943	0.18231	0.17946	0.18260	0.18275	0.18482
$\Omega_{\rm DE}$	0.00644	0.00661	0.00721	0.00722	0.00730	0.00730
Ω_m	0.00389	0.00391	0.00391	0.00391	0.00393	0.00393
Ω_b	0.00091	0.00119	0.00101	0.00101	0.00128	0.00128
$m_\nu/{\rm eV}$		0.14172			0.14172	0.14176
N_ν		0.11694			0.11821	0.11924
h	0.00599	0.01360	0.00625	0.00625	0.01381	0.01382
σ_8	0.00461	0.00491	0.00467	0.00470	0.00492	0.00501
n_s	0.00332	0.00549	0.00356	0.00360	0.00557	0.00563
α			0.00515	0.00519	0.00545	0.00545
β				0.01779		0.01834
FOM	357.12	258.40	357.01	348.70	251.51	240.59

~ 5%

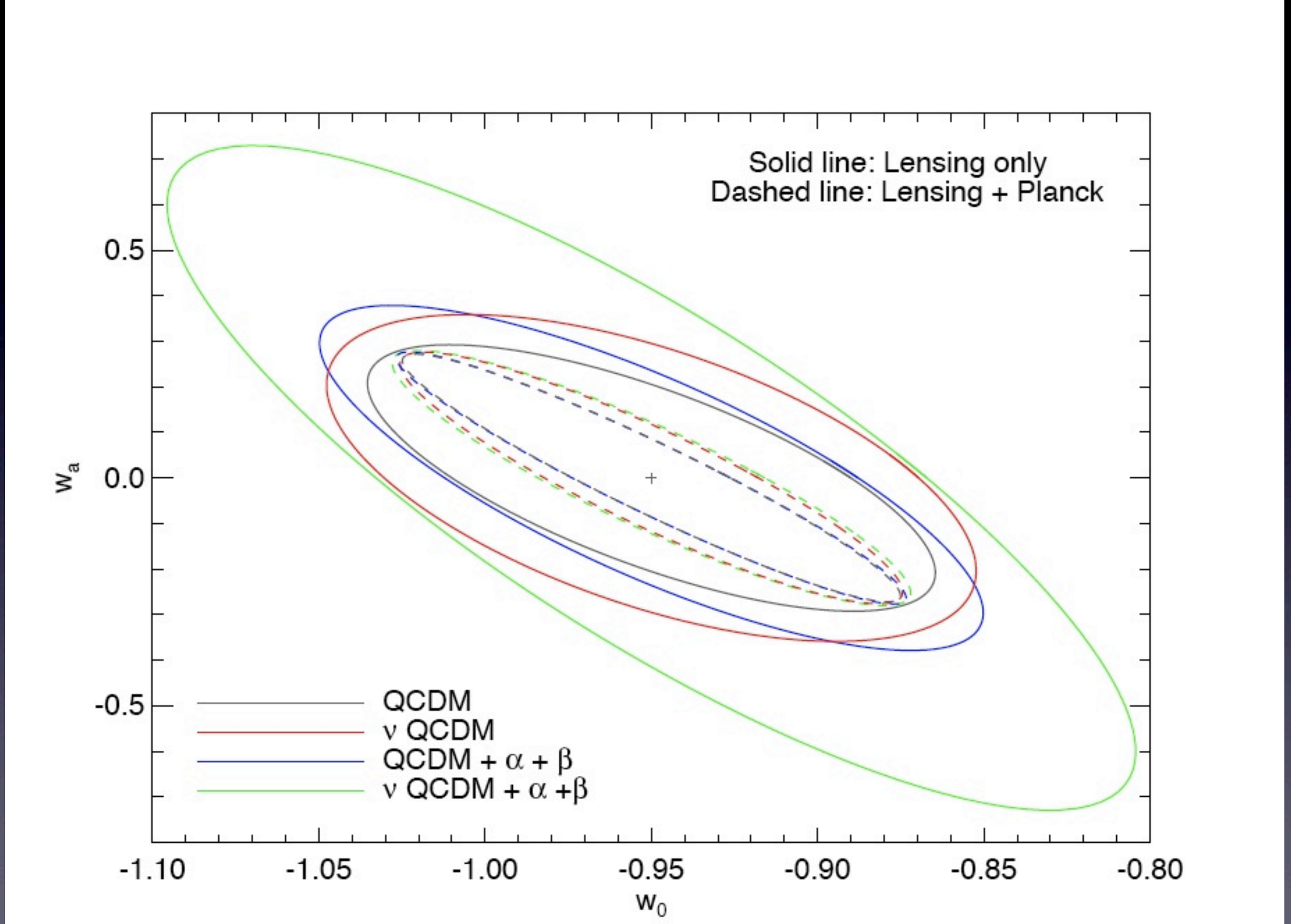
~ 25 %

~ 0.5 %

Fractional error change: lensing + CMB



Dark energy EOS error ellipses



Conclusion

- Lensing can constrain DE, and other parameters: Neutrinos, primordial power spectrum
- Need to:
  - Minimise systematics in lensing
  - More accurate power spectrum calculation (baryon wiggles, DE perturbations, neutrino mass parameterisation...)
    - Obtain tighter constraints:
    - e.g Δm_ν=0.78 eV (lensing) Δm_ν=0.12 eV (lensing+Planck)
- Combine with other probes: CMB, BAO, SNe