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CONSTRAINS ON DARK ENERGY WITH COSMOLOGICAL PROXIES

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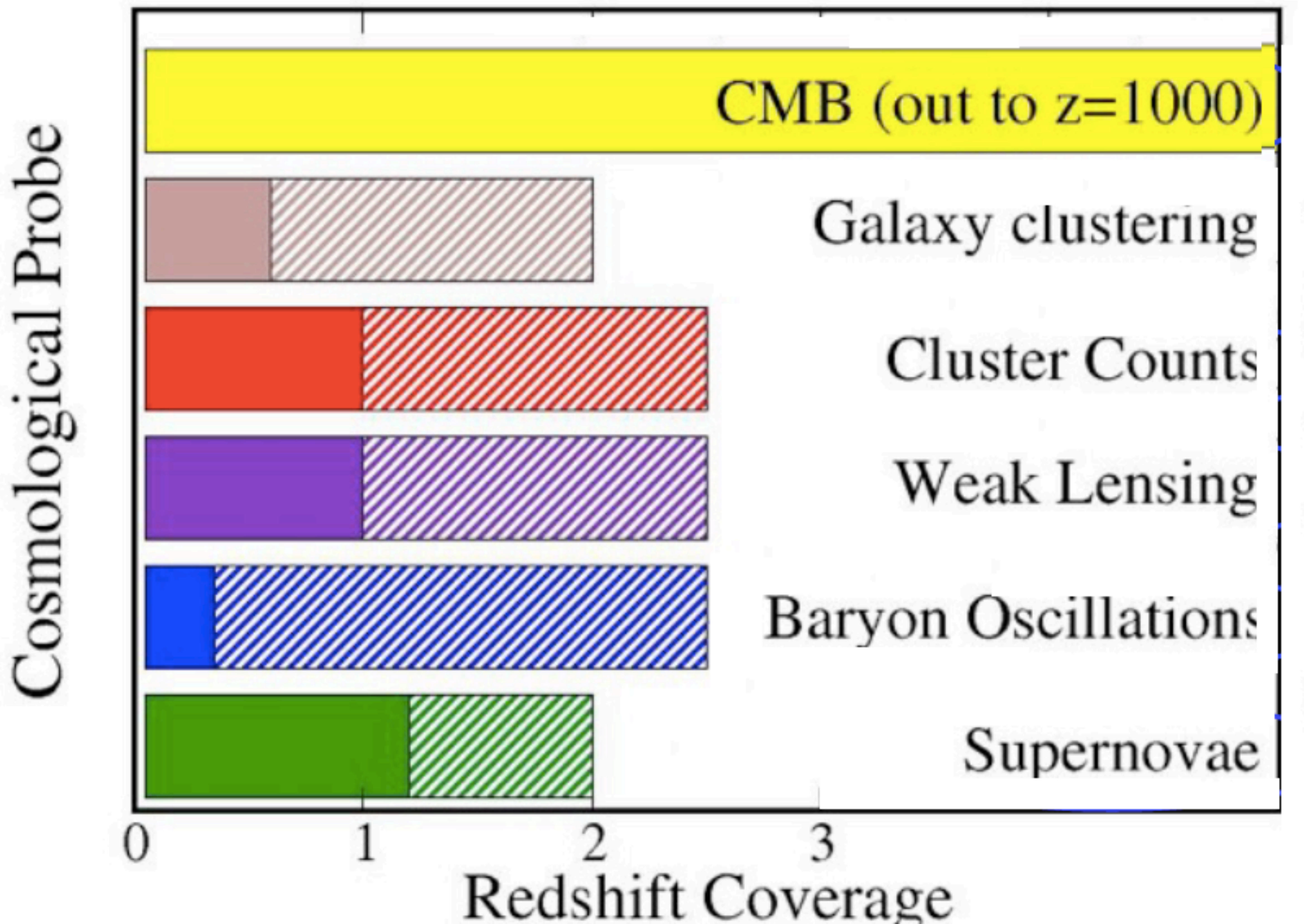
COSMOLOGICAL PROXIES TO TEST DARK ENERGY

K-ESSENCE, FREE PARAMETERS OF THE MODEL AND RESULTS WITH MCMC

PARAMETERS ESTIMATION WITH MONTEPYTHON

POWER SPECTRA ANALYSIS

COSMOLOGICAL PROXIES TO TEST DARK ENERGY (AND SURVEYS TO WORK WITH)



CMB (out to z=1000)
Galaxy clustering
Cluster Counts
Weak Lensing
Baryon Oscillations
Supernovae
Cosmological Probe
0
1
2
3
Redshift Coverage

Luminosity distances of the SNIa

$$d_L(z) = \frac{c(1+z)}{H_0} \int_0^z \frac{dz'}{B(z')}$$

$$B(z') = (\Omega_{\phi 0} f(z'; m, z_*) + (1 - \Omega_{\phi_0})(1+z')^3)^{1/2}$$

$$\mu = m - M = 5(\log_{10} d_L(z) - 1)$$

Supernova Cosmology Project Union2.1 (Amanullah et al. 2010, Rubin et al. 2014)

JLA (Joint Light-curve Analysis)

$$5 \log_{10}\left[\frac{H_0}{c}\, d_L(z_i, \mathbf{p})\right] = m_i + \alpha\, s_i - \beta\, C_i - \mathcal{M}$$

where $m_i,\ s_i,\ \text{and}\ C_i$ are the observed peak magnitude, stretch, & color of the $i^{\rm th}$ SN (proper to the light-curve fitting analysis)

$\alpha,\ \ \beta,\ \ \text{and}\ \ \mathcal{M}$ are "nuisance" parameters

$$\mathcal{M} \equiv M + 5 \log_{10}\left[\frac{c}{H_0 \times 1\ \text{Mpc}}\right] + 25$$

SDSS-II and SNLS supernova samples (Betoule et al. 2014)

BAO (baryon acoustic oscillations)

$$r_s = \int_0^{t_*} \frac{c_s}{a(t)}\, dt = \frac{c}{\sqrt{3}} \int_0^{a_*} \frac{da}{a^2 H(a) \sqrt{1 + \frac{3\Omega_b}{4\Omega_\gamma}\, a}}$$

$$\Delta\theta_s = \frac{r_s}{d_A(z)} \quad \text{(transverse modes)}$$

$$D_V(z) \equiv \left[(1+z)^2 d_A(z) \frac{cz}{H(z)} \right]^{1/3}$$

BOSS -Baryon Oscillation Spectroscopic Survey- (Anderson et al. 2014)

6dF Galaxy Survey (Beutler et al. 2011)

Cluster Count

$$\frac{d^2N}{d\Omega\, dz} = n(z)\,\frac{r(z)^2}{H(z)}$$

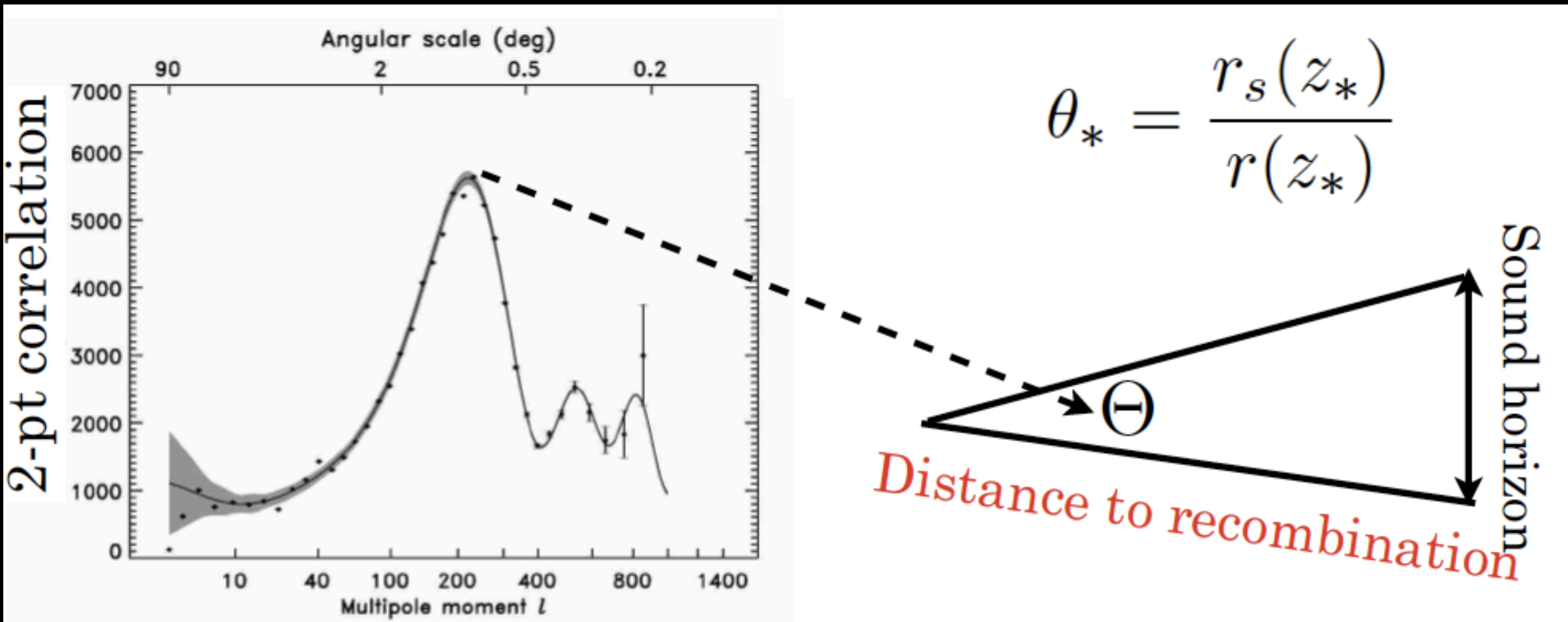
cluster number (measured)

cluster number density (sims)

distances (modeled)

Planck Collaboration XXIV. Cosmology from Sunyaev-Zeldovich (Ade et al. 2018)

CMB (Cosmic Microwave Background)



$$R \equiv \sqrt{\Omega_m H_0^2}\, r(z_*)$$

WMAP Collaboration (Komatsu et al. 2014), Planck Collaboration (Ade et al. 2015),

SPT (Schaffer et al. 2011)

Other cosmological probes

clustering (DM)

Weak gravitational lensing:

$$P_{\mathrm{shear}} \simeq \int_0^\infty W(r) P_{\mathrm{matter}}(r) dr$$

distances

H_0 prior

$$\rho_c = \frac{3H_0^2}{8\pi G}$$

$$\Omega \equiv \frac{\rho}{\rho_c} = \frac{8\pi G \rho}{3H_0^2}$$

For instance, Riess et al. 2016

but also,

- Gal-gal lensing
- Strong lensing
- RSD
- Peculiar velocities
- Hubble constant
- Cosmic voids
- Shear peaks
- Galaxy ages
- Redshift drift
- GRB & quasars

K-ESSENCE, FREE PARAMETERS OF THE MODEL AND RESULTS WITH MCMC

K-essence scalar fields —-> K-inflation model proposed by Armendariz-Picon et al. (1999,2001).

However, the idea was extended to describe a dynamical dark energy contribution with a non-canonical kinetic term.

With this scheme, it is possible to avoid the fine-tuning of the initial values of the field and its velocity.

$$S = \int d^4x\sqrt{-g}\left(\frac{R}{2\kappa^2} + p(\phi, X)\right) + S_B$$

$$p(X,\phi) = K(\phi)L(X)$$

$$X = -\frac{1}{2}\nabla^\alpha\phi\nabla_\alpha\phi$$

$$K(\phi) > 0$$

↓

$$p(v,\phi) = K(\phi)Q(v)$$

$$v = \frac{d\phi}{dt} = \sqrt{-2X} > 0$$

We propose an effective parametrisation for the equation of state that satisfies the attractors of the dynamical system and evolves from radiation to this cosmological time.

$$\omega_\phi(z) = \frac{4/3}{\left(\frac{1+z_d}{1+z}\right)^m + 1} - 1$$

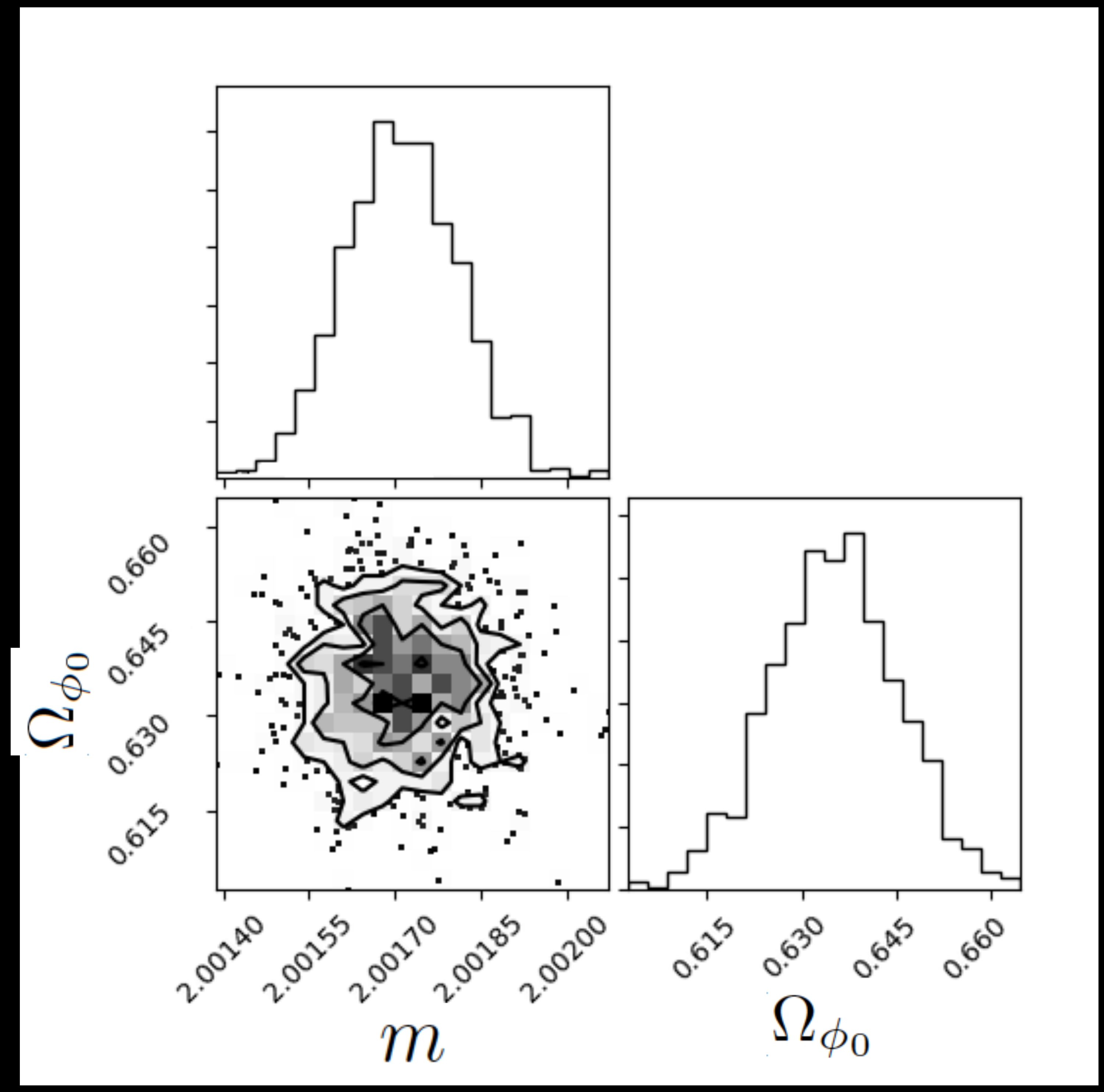
$$0 < z < 10^{15}$$

The inflection of the function occurs at a given redshift during matter domination epoch:

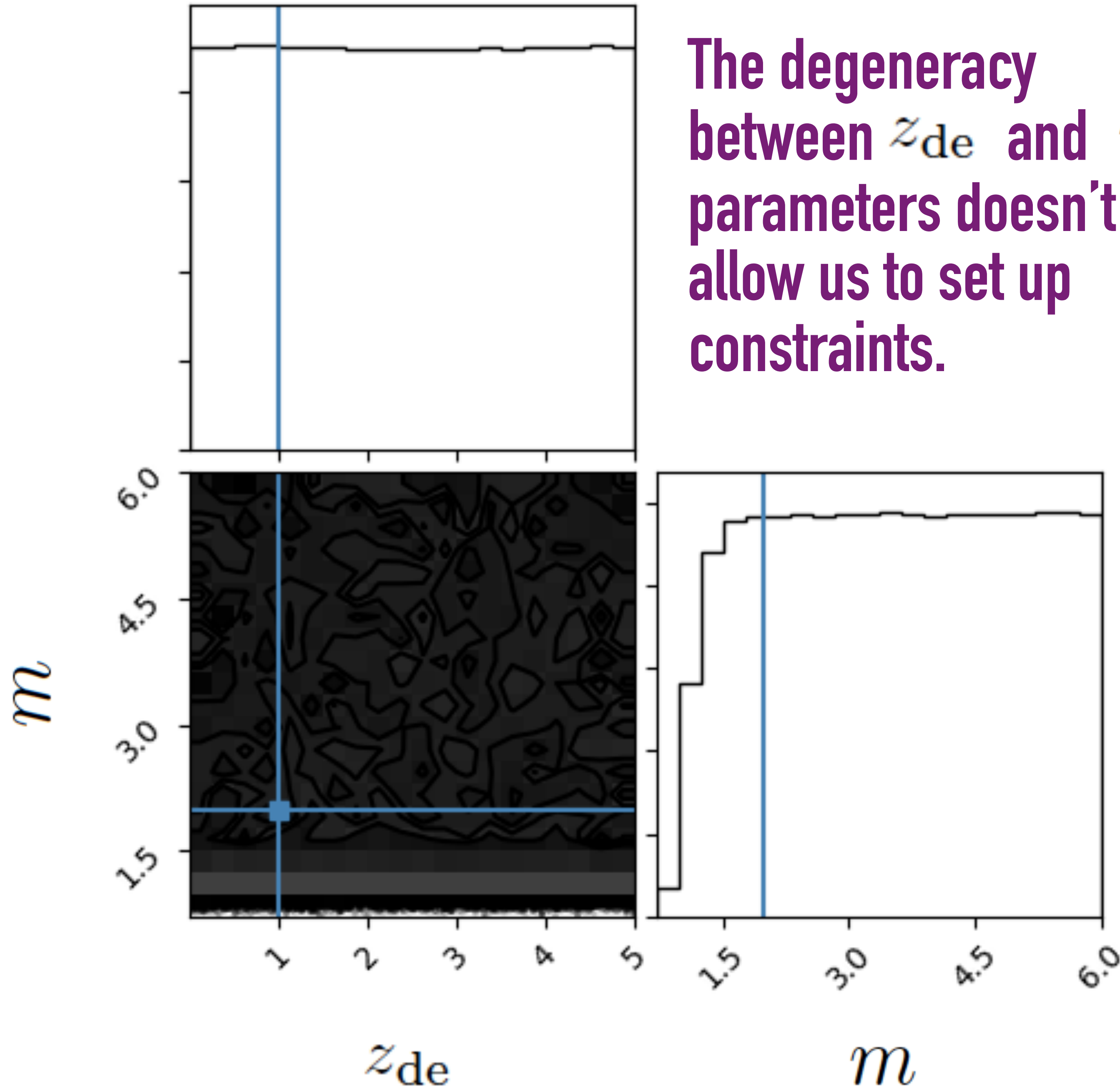
$$z_d = \frac{z_{eq} + z_{\rm de}}{2}$$

z_{eq} Radiation – matter equality

$z_{\rm de}$ Matter – DE equality



0.660
0.645
0.630
0.615
Ω_{ϕ_0}
2.00140
2.00155
2.00170
2.00185
2.00200
m
0.615
0.630
0.645
0.660
Ω_{ϕ_0}



The degeneracy between $z_{\rm de}$ and m parameters doesn't allow us to set up constraints.

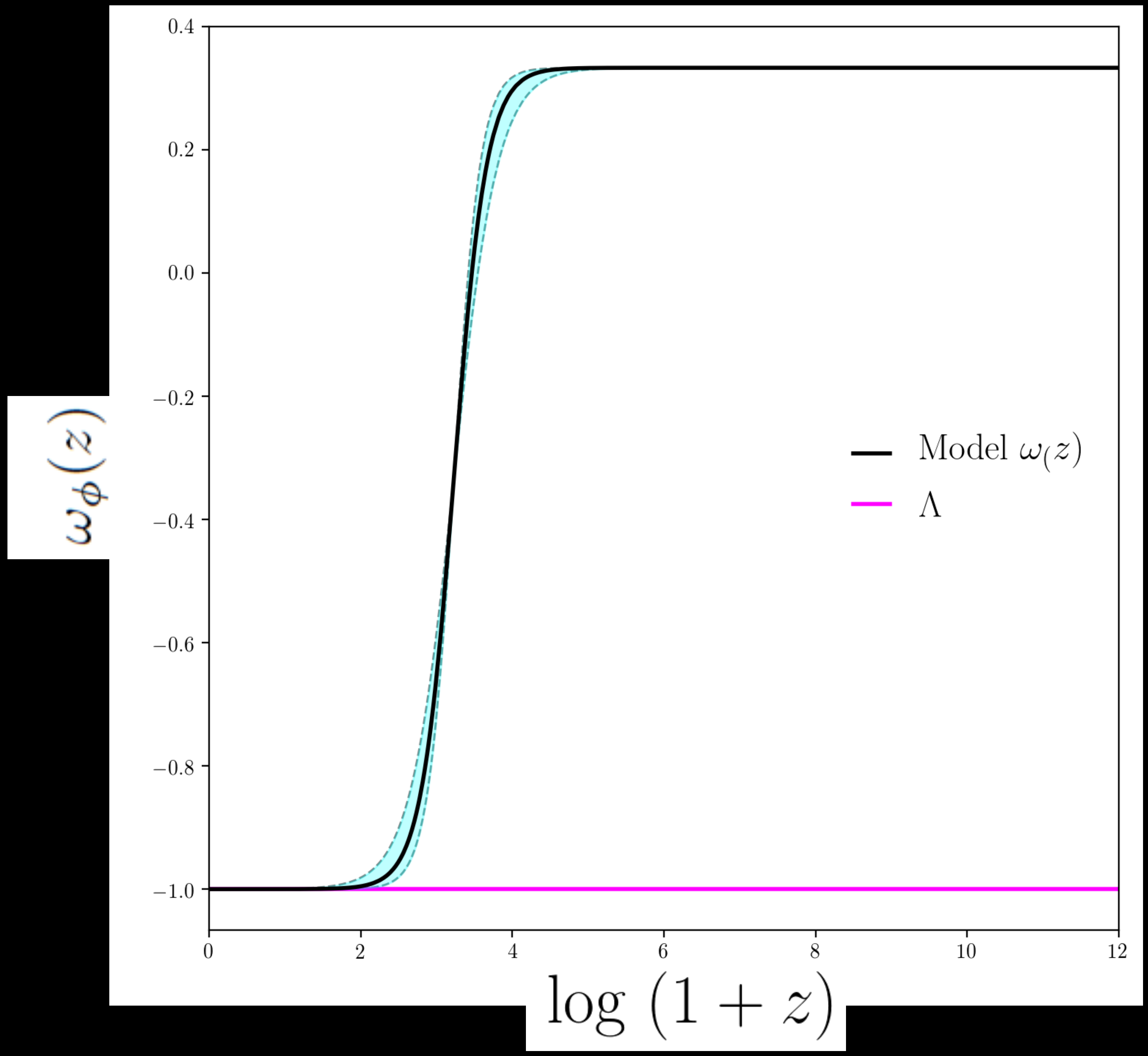
$$q(z_{\rm de}) = 0$$

For this model, the previous condition entails:

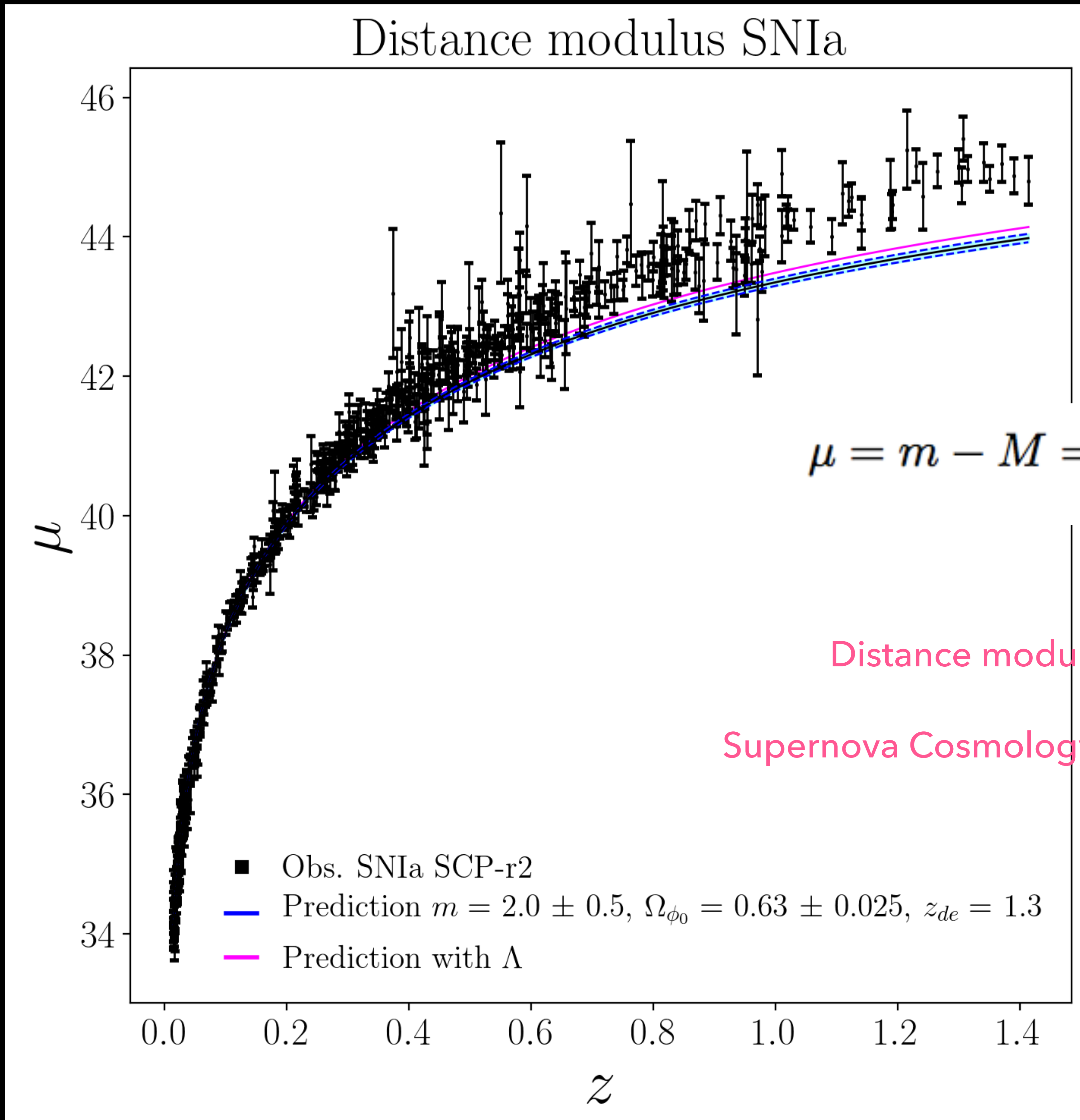
$$q(z_*) = \frac{H_0}{2} \frac{4\Omega_{\phi 0} f(z_*) \frac{1}{\left(\frac{1+z_d}{1+z_*}\right)^m + 1} + (1-\Omega_{\phi 0})(1+z_*)^3}{(\Omega_{\phi 0} f(z_*) + (1-\Omega_{\phi 0})(1+z_*)^3)^{1/2}} - 1 = 0.$$

Solving numerically the equation for the deceleration parameter:

$$z_{\rm de} = 1.3 \pm 0.1$$



With best fitting parameters $\{\Omega_{\phi_0}, m, z_{\rm de}\} = \{2.0 \pm 0.5,\ 0.630 \pm 0.025,\ 1.3 \pm 0.1\}$



$$\mu = m - M = 5(\log_{10} d_L(z) - 1)$$

Distance modulus of the SNIa from the survey

Supernova Cosmology Project Union2.1 (Rubin et al. 2014)

$$R = (\Omega_m H_0^2)^{1/2} \int_0^{1089} \frac{dz}{H(z)},$$

Huang et al. 2015 inferred a value from parameters of the Planck Collaboration 2015 and the definition of R made by Bond et al. 1997, Efstathiou et al 1998.

$$R = 1.7496 \pm 0.005$$

$$R_{\mathrm{cal}} = 1.8733 \begin{smallmatrix} +0.0602 \\ -0.0667 \end{smallmatrix}$$

Take away I

The model with the set of parameters given by $\{\Omega_{\phi_0}, m, z_{\rm de}\}$:

- ★ $z_{\rm de}$ and m are largely degenerated.
- ★ $z_{\rm de}$ has to be constrained with the deceleration parameter.
- ★ Ω_{ϕ_0} is smaller than the value reported by Planck in the standard model.

PARAMETERS ESTIMATION WITH MONTEPYTHON

DE models CPL Chevallier-Linder-Polarski

with a equation of state $w = w_0 + (1 - a)w_a$

Using CLASS and Montepython

* Convergence criterium: Gelman-Rubin
* 100000 steps with Metropolis-Hastings algorithm
* Likelihoods pre-computed from different experiments.

$$\mathcal{L} \propto e^{-\chi^2_{tot}/2}$$

Likelihoods

$$\chi^2_{tot} = \chi^2_{CMB} + \chi^2_{JLA} + \chi^2_{BAO} + \chi^2_{CC}$$

name	description	type	LU	D	reference(s)
bao	6dFGS BOSS DR9, SDSS DR7	BAO	1.1	SC	[43] [44] [45]
bao_boss	6dFGS, BOSS DR10&11: LOWZ, CMASS, SDSS DR7: MGS	BAO	2.0	SC	[43] [52] [45]

$$\mathcal{L} \propto e^{-\chi^2_{tot}/2}$$

Likelihoods

name	description	type	LU	D	reference(s)
hst	Hubble Space Telescope	H_0 prior	3.0	SC	[67]
JLA	full JLA likelihood	Supernovae	2.1	D	[70]
Planck_SZ	Planck 2015: SZ cluster counts as $\Omega_m^\alpha \sigma_8$ prior	Cluster Count	2.2	SC	[77]
sn	Union2	Supernovae	1.0	SC	[84]
spt	SPT DR1	CMB	1.0	SC	[85]

Forecast likelihoods

name	description	type	LU	D	reference(s)
fake_desi	DESI	BAO: d_A/r_s	3.0	M	[30]
fake_planck_bluebook	Planck 2015 est.: TTTEEE	CMB	2.0	M	[95]

Model 1: SN (SCP 2.1 + JLA)

Model 2: SN + CMB (SCP 2.1 + JLA + fake Planck bluebook)

Model 3: SN + CMB (SCP 2.1 + JLA + SPT)

Model 4: SN + CC (SCP 2.1 + JLA + Planck SZ)

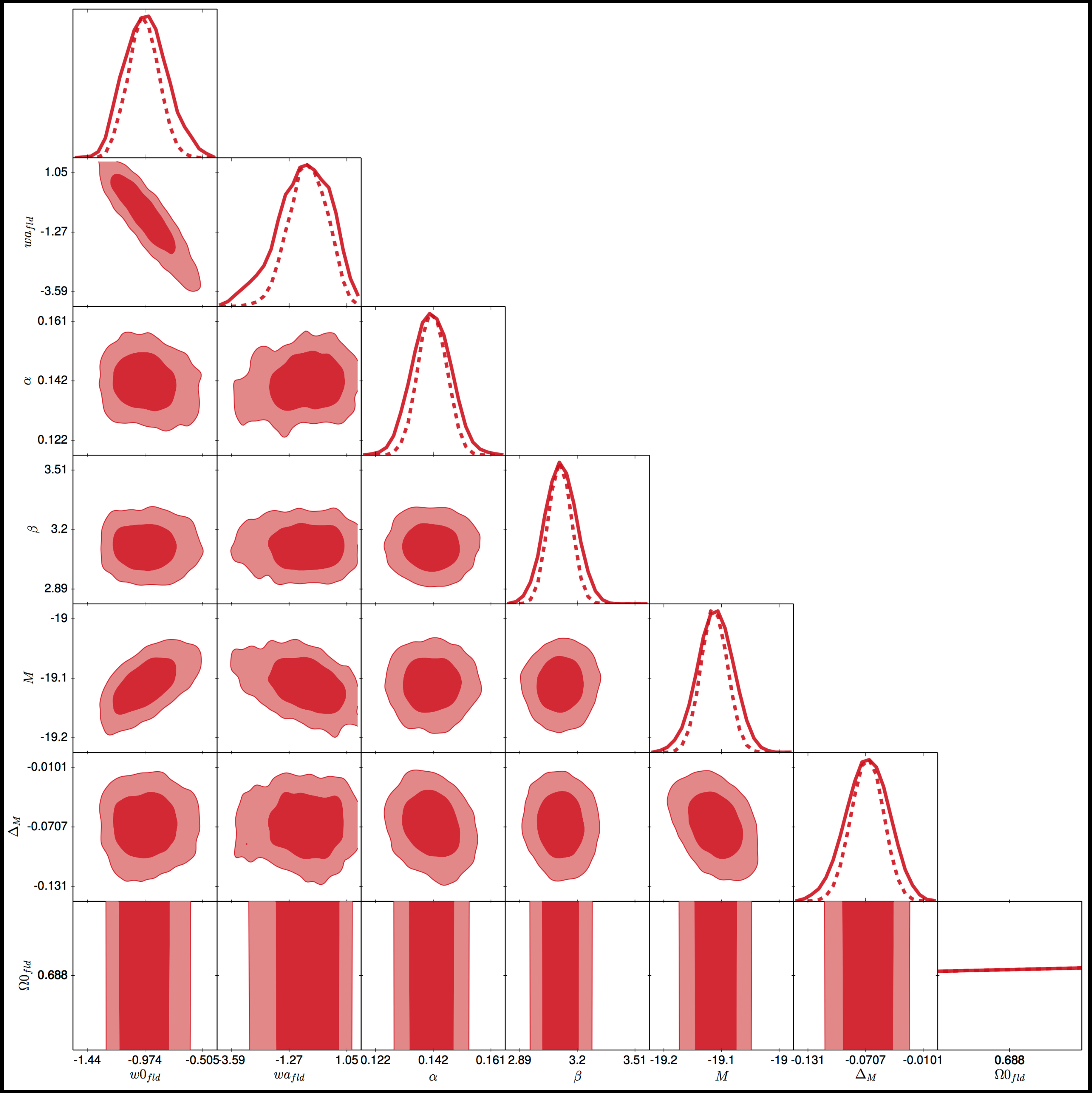
Model 5: SN + BAO (SCP 2.1 + JLA + 6dFGS + BOSS DR9 +SDSS DR7)

Model 6: SN + BAO_ BOSS (SCP 2.1 + JLA + 6dFGS + BOSS DR10&11 +SDSS DR7:MGS + LOWZ + CMASS)

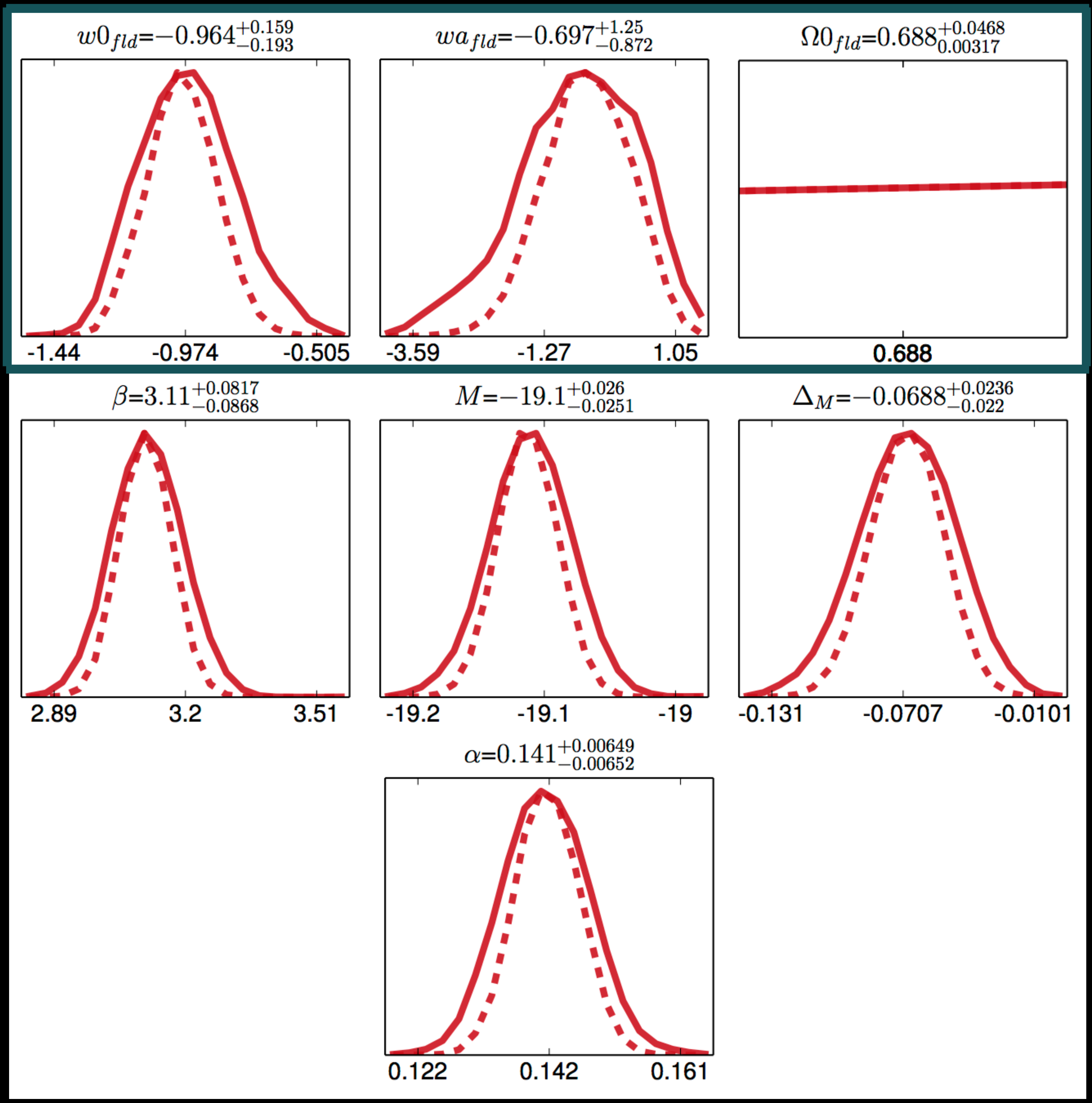
Model 7: SN + BAO (SCP 2.1 + JLA + fake DESI)

Model 8: SN + H_0 (SCP 2.1 + JLA + HST)

Model 1: SN (SCP 2.1 + JLA)



Model 1: SN (SCP 2.1 + JLA)

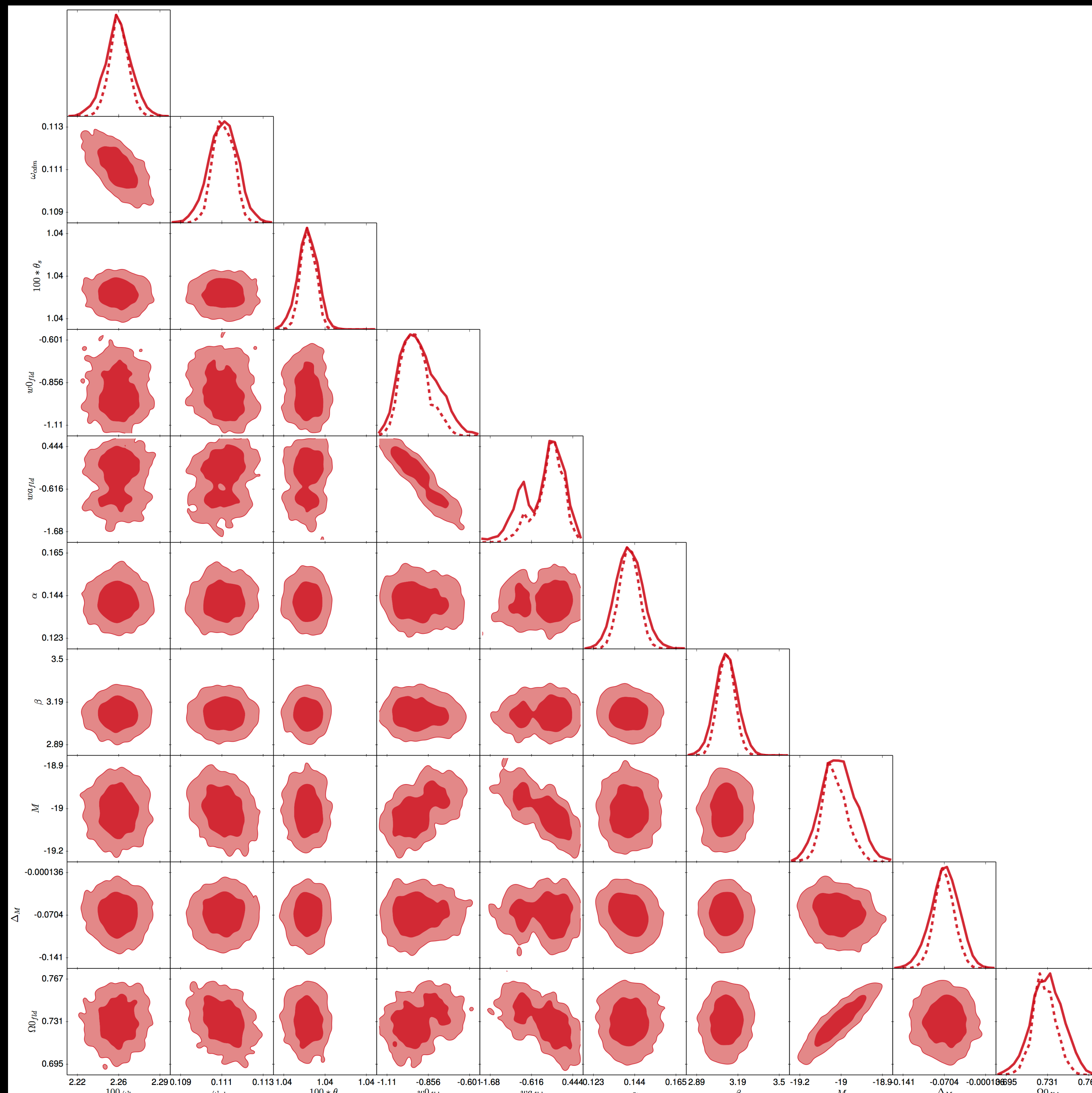


Inferred parameters

“Nuisance” parameters (JLA modeling)

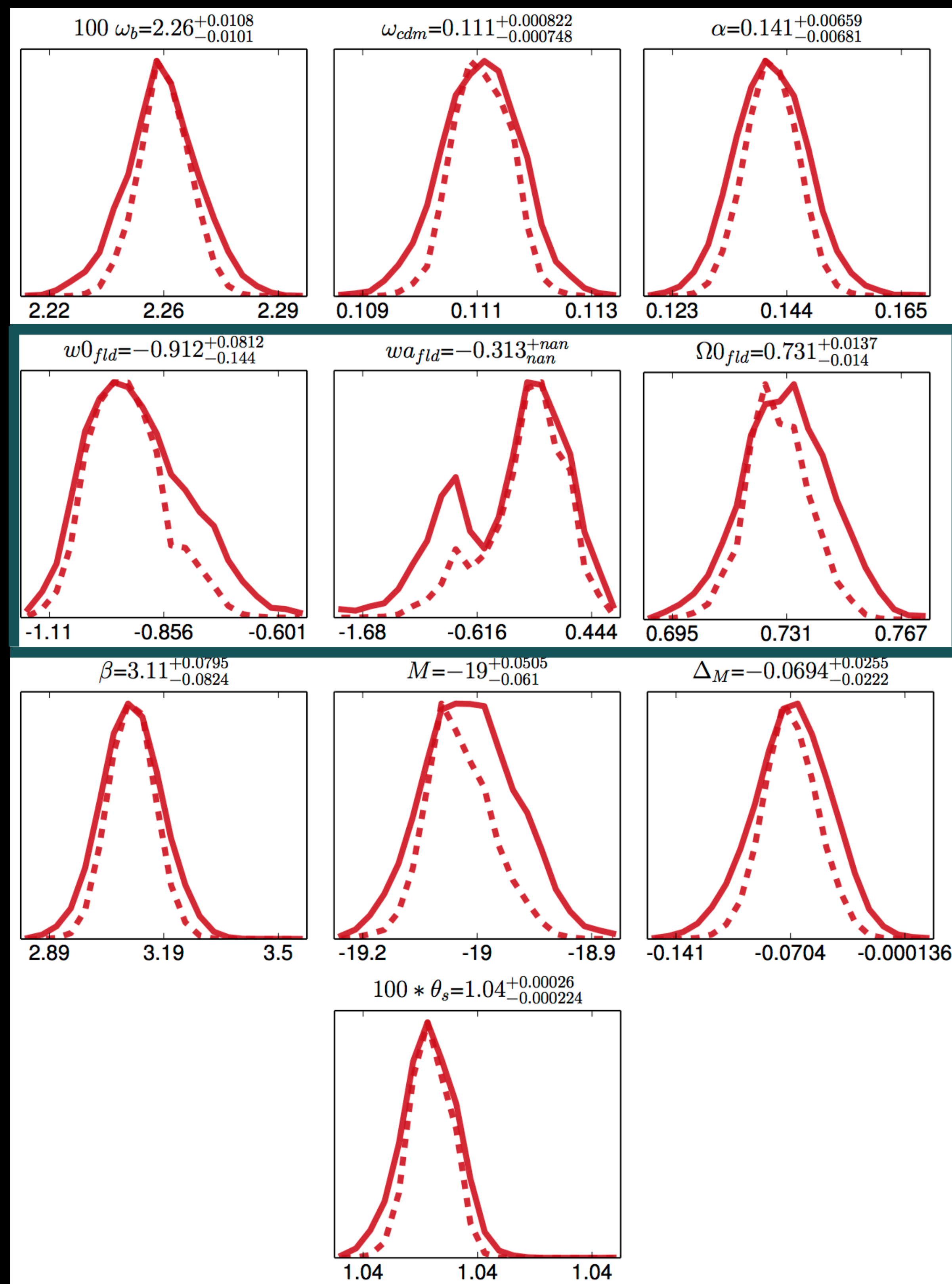
Model 2: SN + CMB

(SCP 2.1 + JLA + fake Planck bluebook)



Model 2: SN + CMB

(SCP 2.1 + JLA + fake Planck bluebook)



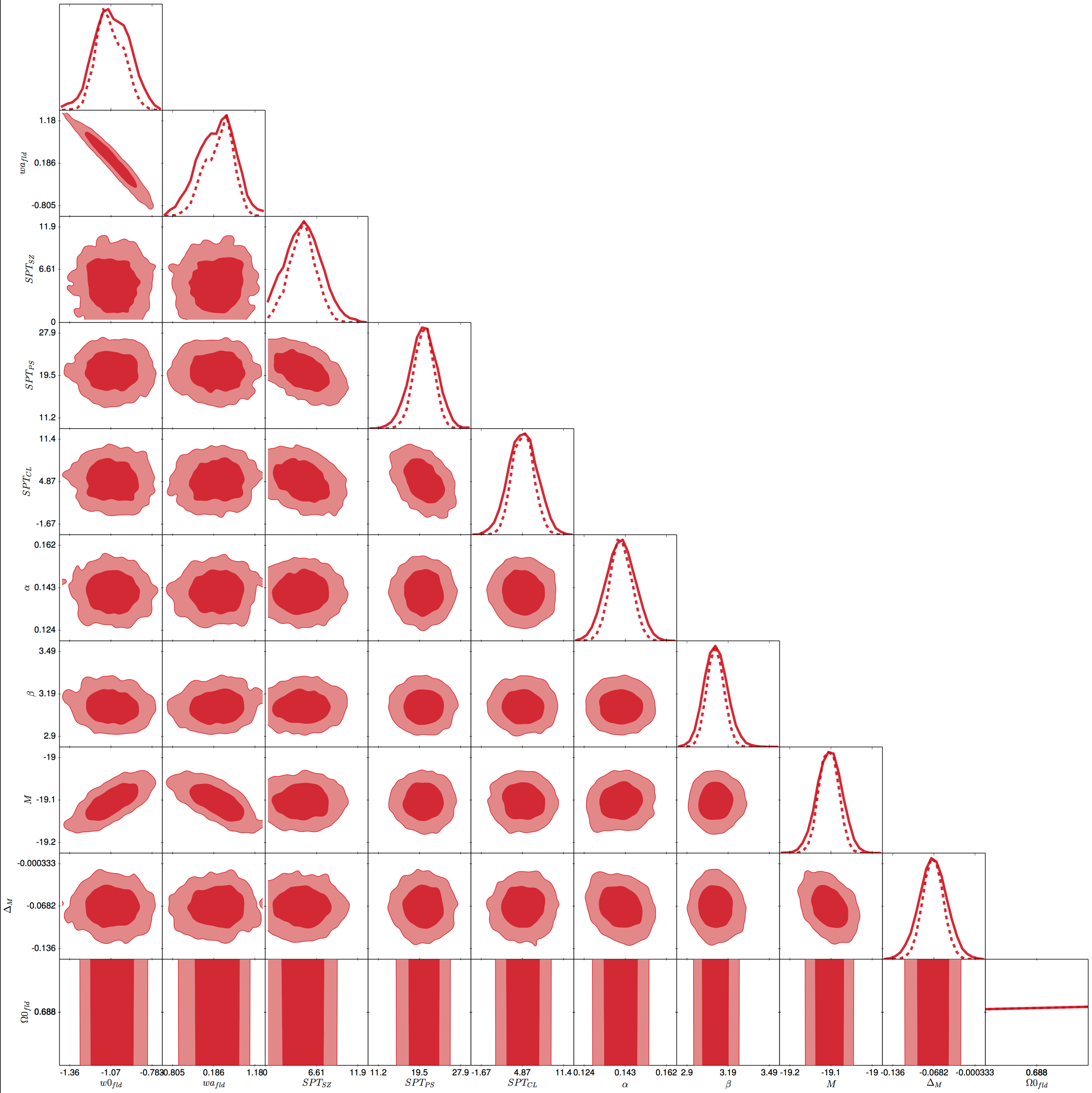
Inferred parameters

"Nuisance" parameters

(JLA modeling)

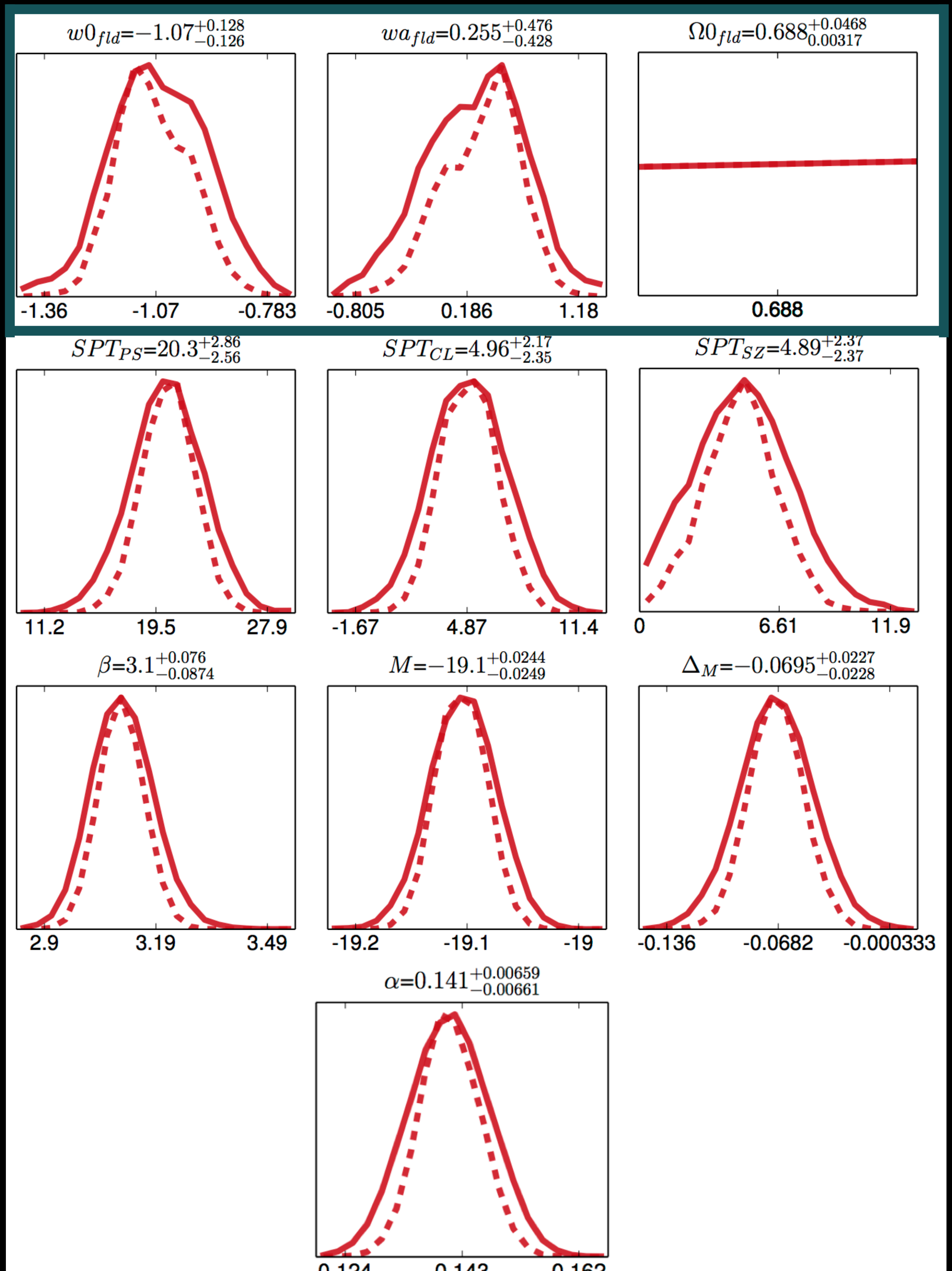
Model 3: SN + CMB

(SCP 2.1 + JLA + SPT)



Model 3: SN + CMB

(SCP 2.1 + JLA + SPT)



Inferred parameters

“Nuisance” parameters

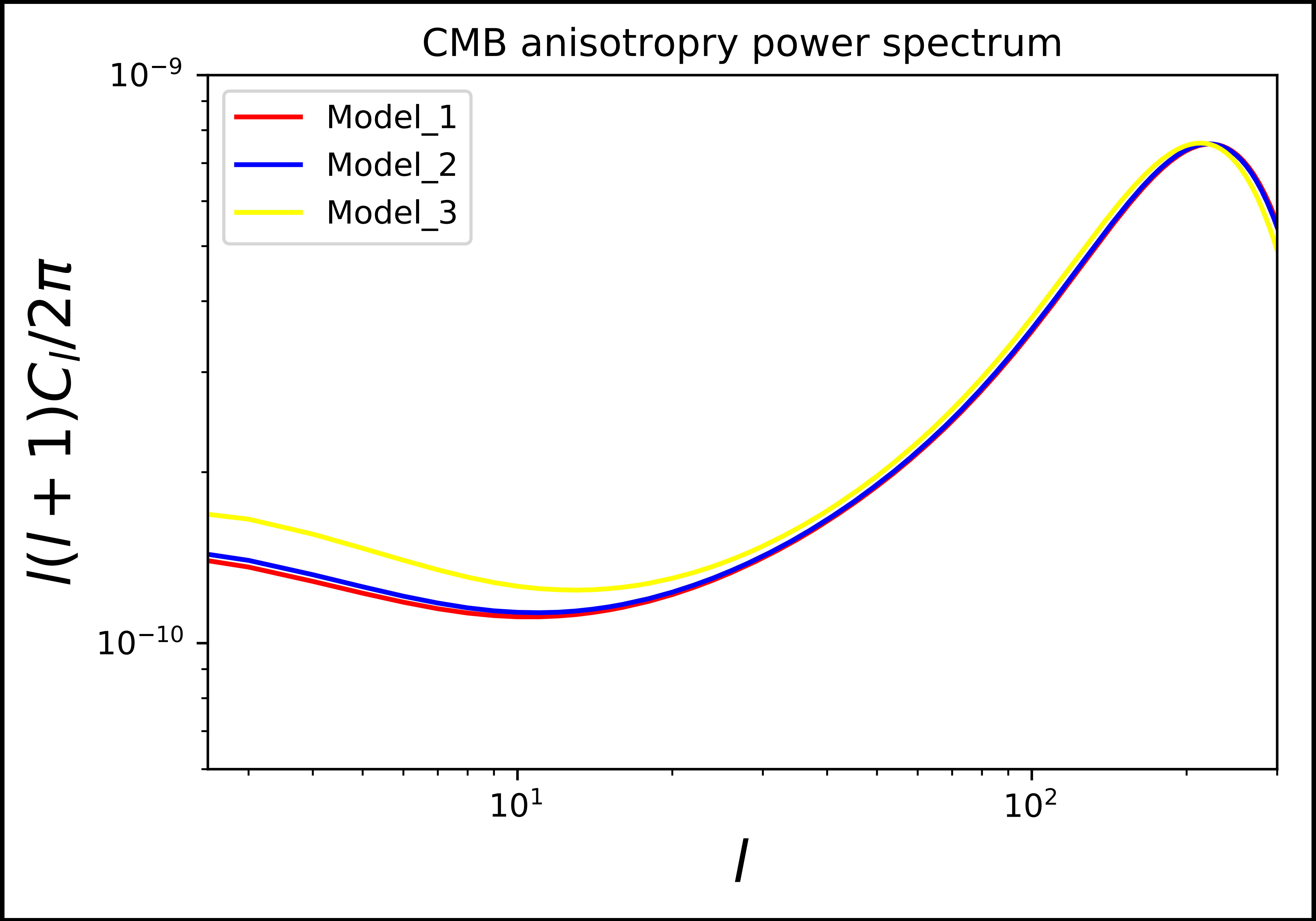
(SPT modeling)

“Nuisance” parameters

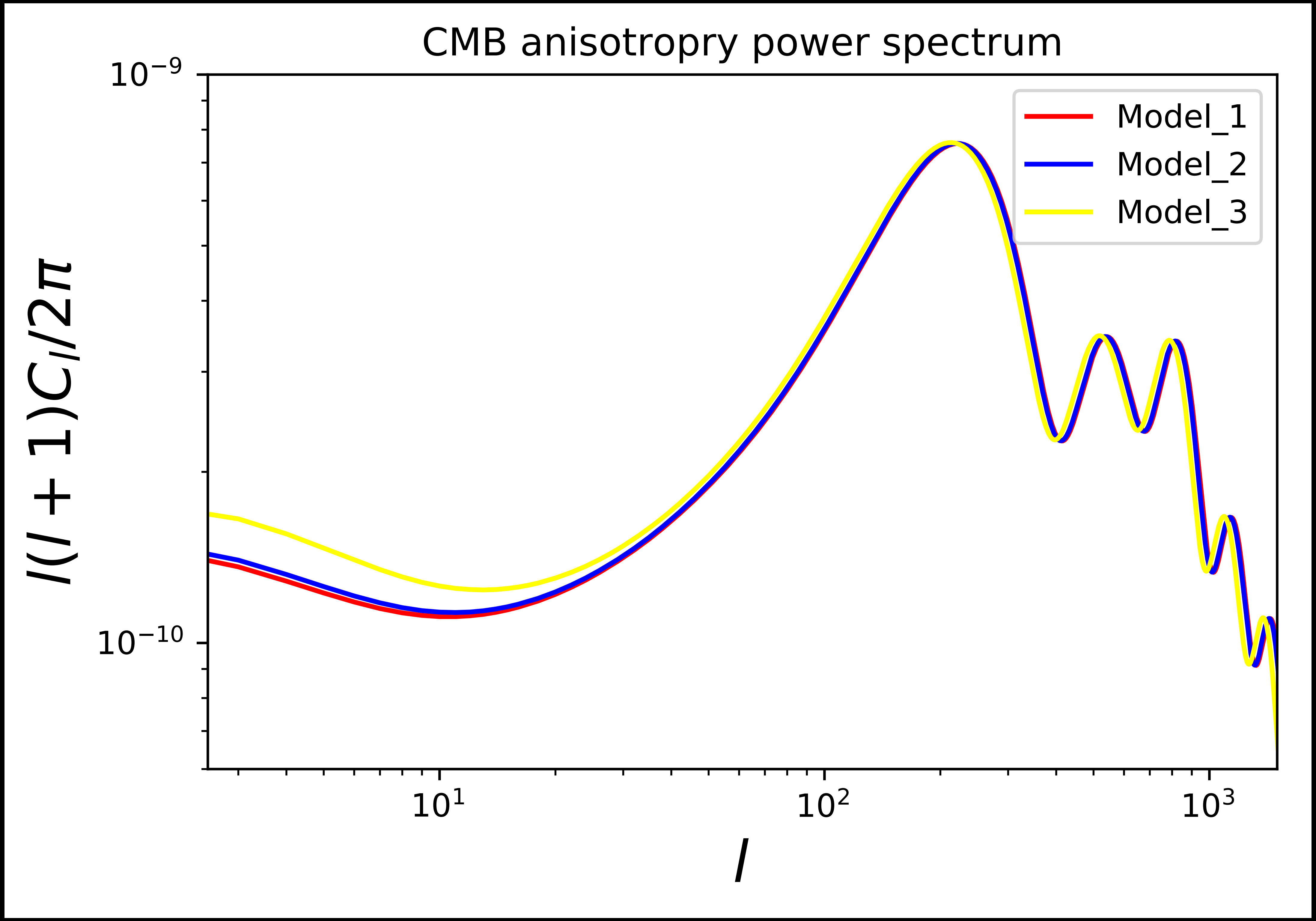
(JLA modeling)

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$w0_{fld}$	$-0,9639^{+0,16}_{-0,19}$	$-0,9118^{+0,081}_{-0,14}$	$-1,066^{+0,13}_{-0,13}$	$-0,9175^{+0,15}_{-0,12}$	$-0,9248^{+0,13}_{-0,15}$	$-0,8896^{+0,13}_{-0,12}$	$-0,8855^{+0,536}_{-0,537}$	$-1,02^{+0,15}_{-0,17}$
wa_{fld}	$-0,6974^{+1,3}_{-0,87}$	$-0,3133^{+0,2}_{0,2}$	$0,2551^{+0,48}_{-0,43}$	$-0,1191^{+0,2}_{0,1}$	$-0,6262^{+0,99}_{-0,79}$	$-0,517^{+0,77}_{-0,88}$	$-0,3817^{+0,54}_{-0,54}$	$-0,369^{+1,1}_{-0,76}$
$\Omega0_{fld}$	$0,6879^{+0,047}_{0,0032}$	$0,731^{+0,014}_{-0,014}$	$0,6879^{+0,047}_{0,0032}$	$0,7413^{+0,021}_{-0,017}$	$0,6879^{+0,047}_{0,0032}$	$0,6879^{+0,047}_{0,0032}$	$0,7522^{+0,0244}_{-0,0247}$	$0,6879^{+0,047}_{0,0032}$

POWER SPECTRA ANALYSIS



CMB anisotropry power spectrum
Model_1
Model_2
Model_3
10^{-9}
10^{-10}
$l(l+1)C_l/2\pi$
10^1
10^2
l


CMB anisotropry power spectrum
10^{-9}
10^{-10}
$l(l+1)C_l/2\pi$
10^1
10^2
10^3
l
Model_1
Model_2
Model_3

TAKE AWAY:

* We studied two models that describe dynamical dark energy: a K-essence scalar field with a non-negligible contribution during radiation domination epoch, through an effective parametrization of the equation of state, and a second model (CLP), with a linear evolution of the equation of state with redshift.

* The number of free parameters has a strong impact on the solution of a given model. DE models with many free parameters present large degeneracies among free parameters.

* The later caveat can be alleviated by introducing as many experiments' likelihoods as possible. Future constraints will be found with SN + BAO + CMB + CC + Ho (as a prior).

* DE models have large impact on low multipoles (l) in the CMB temperature anisotropies power spectrum. At large scales, different models' effect are non-distinguishable.

Thanks for your attention!

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