nature astronomy

SUPPLEMENTARY INFORMATION

DOI: 10.1038/s41550-017-0216-z

In the format provided by the authors and unedited.

Dynamical dark energy in light of the latest observations

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Dynamical dark energy in light of latest observations (Supplementary Information)

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This document contains three supplementary tables and five supplementary figures.

Acronym	Meaning	References
P15	The *Planck* 2015 CMB power spectra	1
JLA	The JLA supernovae	2
6dF	The 6dFRS (6dF) BAO	3
MGS	The SDSS main galaxy sample BAO	4
$P(k)$	The WiggleZ galaxy power spectra	5
WL	The CFHTLenS weak lensing	6
H_0	The Hubble constant measurement	7
OHD	$H(z)$ from galaxy age measurements	8
gBAO-$3z$	3-bin BAO from BOSS DR12 galaxies	9
gBAO-$9z$	9-bin BAO from BOSS DR12 galaxies	10
LyαFB	The Lyα forest BAO measurements	11
B	P15 + JLA + 6dF + MGS	
ALL12	The combined dataset used in Zhao *et al.*, (2012)[12]	
ALL16-$3z$	B+$P(k)$+WL+H_0+OHD+gBAO-$3z$+LyαFB	
ALL16	B+$P(k)$+WL+H_0+OHD+gBAO-$9z$+LyαFB	
DESI++	P15 + mock DESI BAO[13] + mock SNe[14]	

Supplementary Table 1. The datasets used in this work.

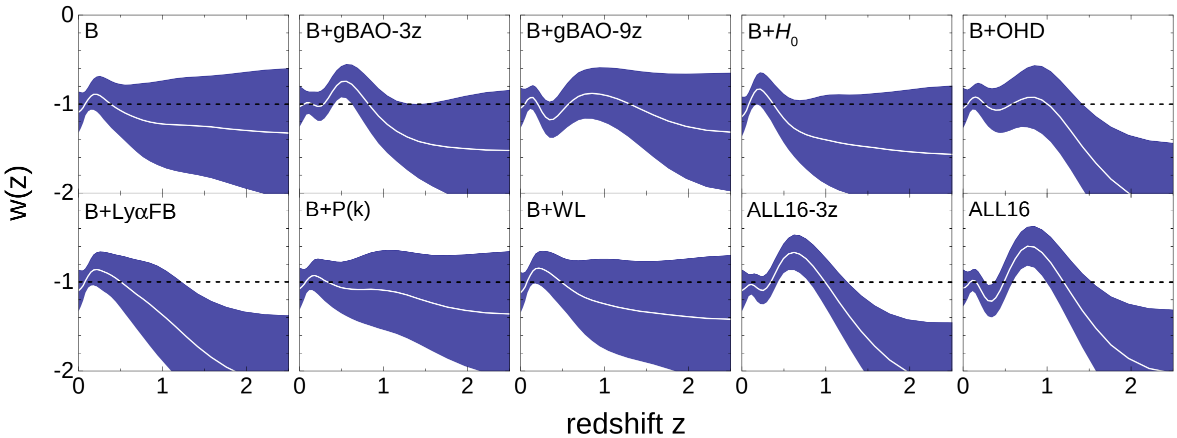
	ALL12	ALL16
SNe	SNLS3 (472) [15]	JLA (740) [2]
gBAO	BOSS DR9; $z_{\rm eff} = 0.57$ [16]	BOSS DR12; nine $z_{\rm eff} \in [0.2, 0.75]$ [10]
LyαFB	none	BOSS DR11; $z_{\rm eff} = 2.34$ [11]
H_0 [km s^{-1} Mpc^{-1}]	74.2 ± 3.6 [17]	73.24 ± 1.74 [7]
CMB	WMAP7 [18]	*Planck* 2015 [1]

Supplementary Table 2. Comparing ALL12 and ALL16 datasets.

	ΛCDM			$w(z)$CDM		
$10^3\Omega_b h^2$	22.4 ± 0.13	22.5 ± 0.16	22.4 ± 0.14	22.3 ± 0.15	22.4 ± 0.21	22.5 ± 0.17
$10^3\Omega_c h^2$	118.4 ± 0.9	121.9 ± 2.4	118.4 ± 1.0	119.2 ± 1.4	120.4 ± 2.6	117.7 ± 1.5
$10^3\Theta_s$	1041 ± 0.3	1041 ± 0.4	1041 ± 0.3	1041 ± 0.3	1041 ± 0.4	1041 ± 0.3
$10^2\tau$	7.9 ± 1.6	8.2 ± 1.7	4.4 ± 1.8	6.9 ± 1.7	7.3 ± 1.8	4.5 ± 1.9
$\ln(10^{10}A_s)$	3.1 ± 0.03	3.1 ± 0.04	3.0 ± 0.04	3.1 ± 0.03	3.1 ± 0.04	3.0 ± 0.04
$10^2 n_s$	96.8 ± 0.4	97.5 ± 0.6	96.8 ± 0.4	96.6 ± 0.5	96.9 ± 0.8	97.0 ± 0.5
M_ν (eV)	0.06	< 0.19	0	0.06	< 0.25	0
$N_{\rm eff}$	3.04	3.27 ± 0.14	3.04	3.04	3.14 ± 0.16	3.04
$A_{\rm Lens}$	1	1	1.17 ± 0.07	1	1	1.17 ± 0.07
$10^3\Omega_m$	307 ± 5.3	304 ± 5.8	301 ± 5.6	289 ± 11.2	290 ± 11.3	285 ± 10.9
H_0	67.9 ± 0.40	69.1 ± 0.85	68.5 ± 0.44	70.2 ± 1.3	70.5 ± 1.4	70.2 ± 1.3

Supplementary Table 3. Constraints on cosmological parameters.

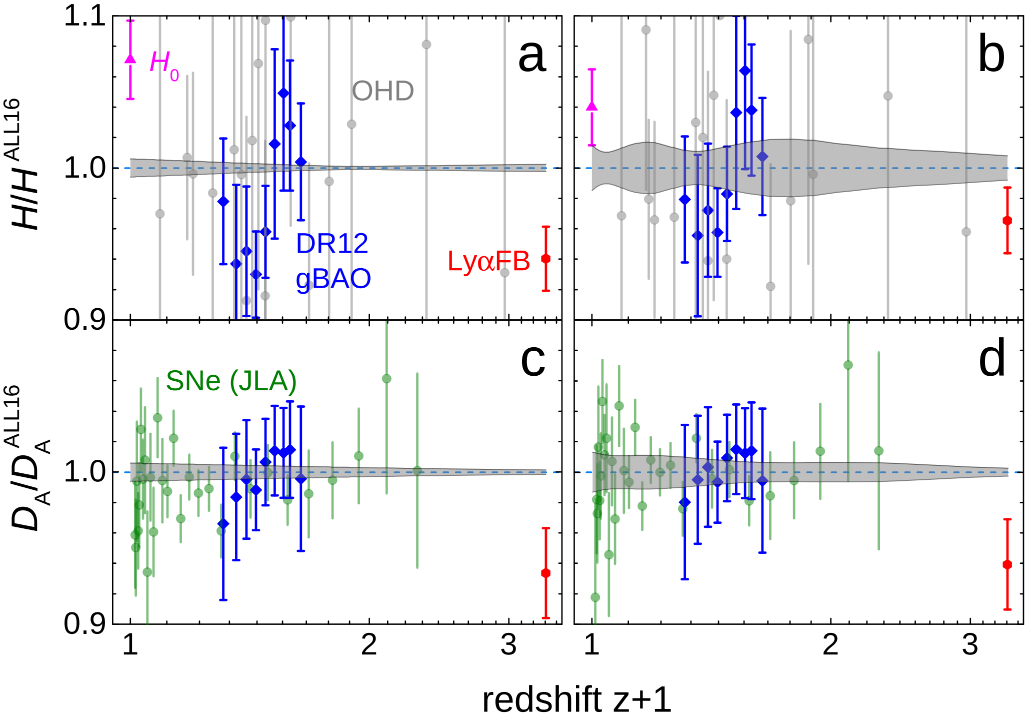
The mean and 68% CL uncertainty on cosmological parameters in both ΛCDM (left) and $w(z)$CDM (right) models. For the neutrino mass, the 95% CL upper limit is quoted instead. The unit of the Hubble parameter H_0 is km s^{-1} Mpc^{-1}.



Supplementary Figure 1. The reconstructed evolution history of the dark energy equation of state using ten different data combinations.

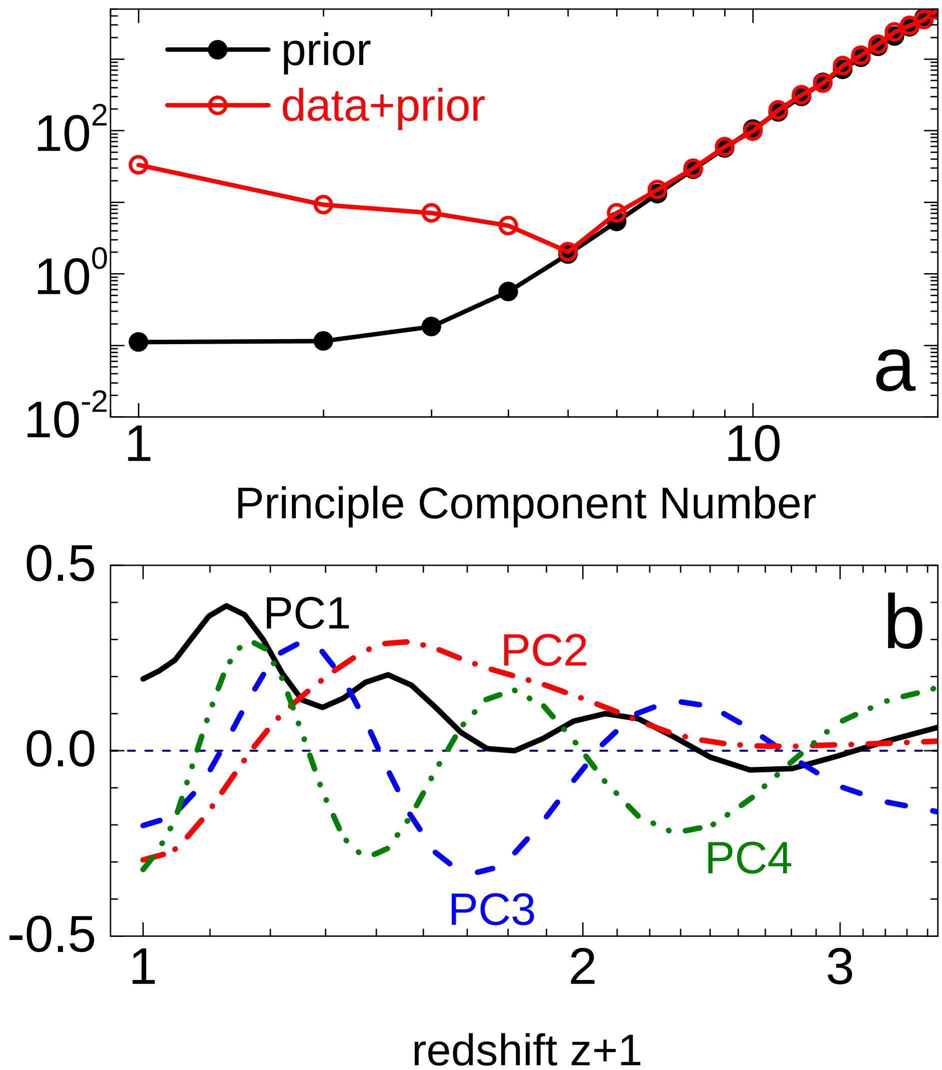
The reconstructed $w(z)$ (white solid line) and the 68% CL uncertainty (dark blue shading) from different data combinations shown in the legend. The correlated prior parameters are $a_c = 0.06$ and $\sigma_{\rm m} = 0.04$.

One can note that the dip in $w(z)$ at $z \sim 0.4$ is more pronounced for ALL16 compared to ALL16-$3z$, thanks to BAO-$9z$ being more informative than BAO-$3z$. As we will see shortly, this makes the ALL16 result more consistent with the $w(z)$ reconstructed in Zhao *et al.* (2012)[12] using a different combination of data (ALL 12).

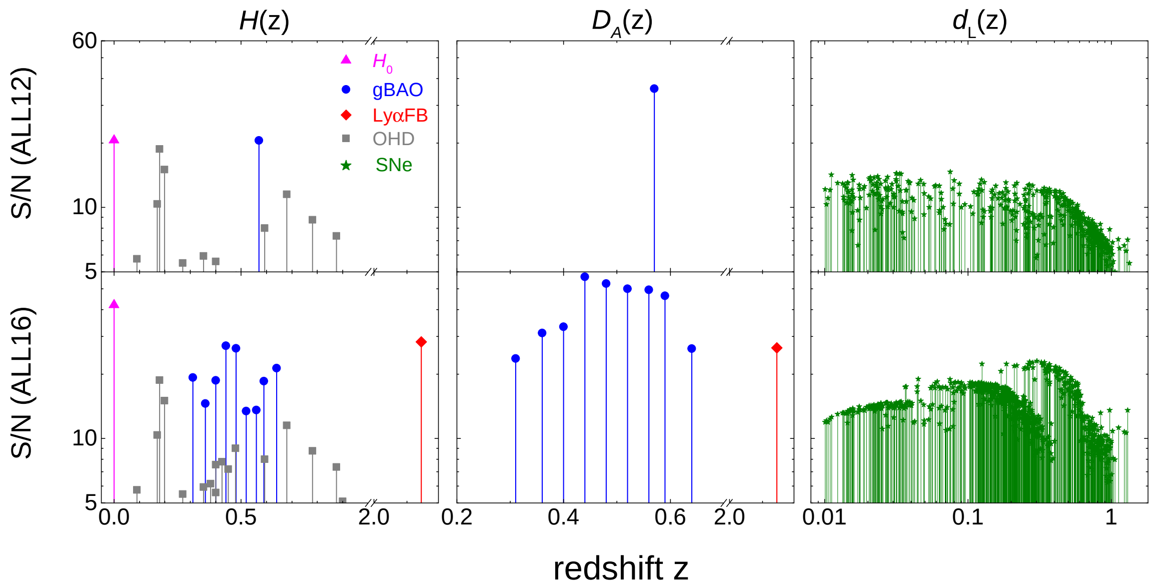


Supplementary Figure 2. A comparison between observations and theoretical predictions in ΛCDM and $w(z)$CDM universes.

The $H(z)$ (panels a, b) and the $D_A(z)$ (c, d) data rescaled by the values derived from the ALL16 best fit ΛCDM (a, c) and $w(z)$CDM (b, d) models. Datasets are labeled by accordingly coloured text, and the shaded bands indicate the 1σ uncertainty in the rescaled $H(z)$ and D_A. The shaded bands indicate the uncertainty in the rescaled $H(z)$ and D_A. One can see that, in the case of $w(z)$CDM, the data points are much more consistent with the corresponding values derived from ALL16, demonstrating the significant reduction in tension.

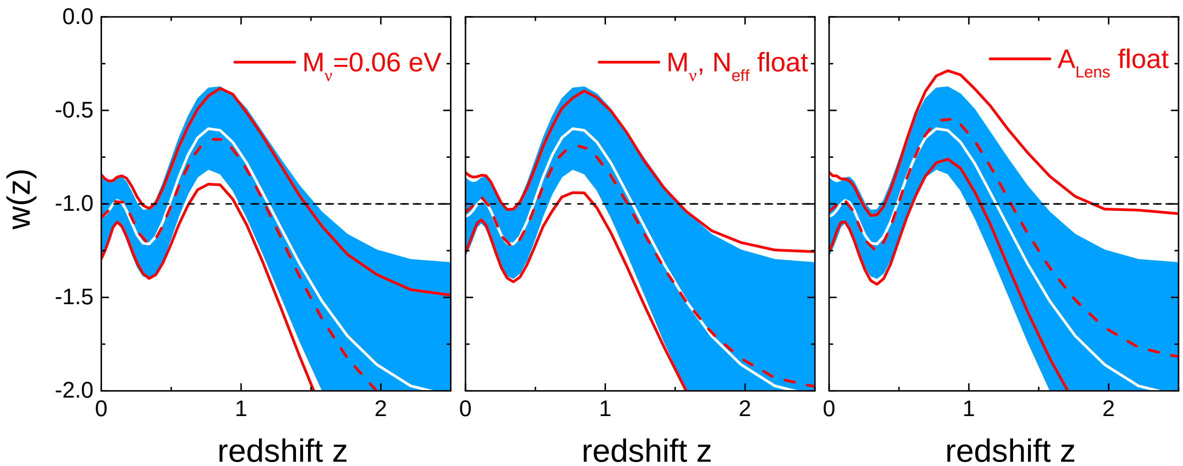


Supplementary Figure 3. A principal component analysis of the $w(z)$ reconstruction result. Panel a: the inverse eigenvalues of the prior covariance matrix (black line with filled dots) and of the posterior covariance (red line with unfilled dots); Panel b: the first four posterior eigenmodes of $w(z)$ for the ALL16 dataset combined with the correlated prior.



Supplementary Figure 4. The signal-to-noise ratio of observables in ALL12 and ALL16 datasets respectively.

The signal-to-noise ratio of the expansion rate of the Universe $H(z)$ (left), angular diameter distance $D_A(z)$ (middle) and luminosity distance $D_L(z)$ for ALL12 (upper) and ALL16 (lower) datasets.



Supplementary Figure 5. The effect of neutrinos and CMB lensing amplitude on $w(z)$ reconstruction. The reconstructed $w(z)$ (red dashed) with 68% CL uncertainty (red solid) in three cases. Left: the sum of neutrino masses M_ν is fixed to 0.06 eV; middle: the neutrino masses M_ν and number of relativistic species $N_{\rm eff}$ are marginalised over; right: the CMB lensing amplitude $A_{\rm Lens}$ is marginalised over. The white line and light blue shaded bands in each panel shows the mean and 68% CL uncertainty of our ALL16 reconstruction, which is shown in Fig. 1 of the Letter using the same colour scheme, for a comparison.

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