Cosmology With Low-Redshift Observations:
No Signal For New Physics

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Abstract

We analyse various low-redshift cosmological data for ΛCDM and different dark energy models and find out that the ΛCDM still gives the best fit to the data with H_0= $70.3^{+1.36}_{-1.35}$ Km/s/Mpc(at 1σ). This value is in 2σ or less tension with various low and high redshift measurements for H_0 including SH0ES, Planck-2018 and the recent results from H0LiCOW-XIII. The derived constraint on S_8 from our analysis is $S_8 = 0.76^{+0.03}_{0.03}$, fully consistent with direct measurement of S_8 by KiDS+VIKING-450+DES1 survey. We hence conclude that the ΛCDM model with parameter constraints obtained in this work is consistent with different early and late Universe observations within 2σ. We therefore, do not find any compelling reason to go beyond concordance ΛCDM model.

Introduction

Different cosmological observations of the last couple of decades have surprised us with extraordinary results and puzzles. Also, It has shown serious tension for ΛCDM model when the Local measurement of the expansion rate of the universe (SH0ES project) by Riess et al. are taken into account. Their model independent measurement of the Hubble parameter at present is H_0 = 74.03 ± 1.42 Km/s/Mpc which is in 4.4σ tension with the result H_0 = 67.4 ± 0.5 Km/s/Mpc from the latest Planck-2018 compilation for a concordance ΛCDM model. Therefore, we reanalyze the available low-redshift observational data assuming different dark energy models which affects only the late time cosmology. Our aim is to examine if low-redshift data (without local measurement of H_0) also exhibit significant tensions in measured values of different cosmological parameters.

Models Used

To begin with, we assume spatially flat FRW cosmology for the background universe. We consider the following dark energy models for our background cosmology:

- **ΛCDM model** with the Hubble parameter $H(z)$,

$$\frac{H^2(z)}{H_0^2} = \Omega_{m0}(1+z)^3 + (1-\Omega_{m0}). \tag{1}$$

- **wCDM model** with dark energy model of a constant equation of state w and the Hubble parameter $H(z)$,

$$\frac{H^2(z)}{H_0^2} = \Omega_{m0}(1+z)^3 + (1-\Omega_{m0})(1+z)^{3(1+w)} . \tag{2}$$

- **CPL model**: Dark energy model with an equation of state $w(z) = w_0 + w_a(1-a) = w_0 + w_a\frac{z}{1+z}$ where w_0 and w_a are two arbitrary constants

$$\frac{H^2(z)}{H_0^2} = \Omega_{m0}(1+z)^3 + (1-\Omega_{m0})f(z), \tag{3}$$

where $f(z) = \exp\left(3\int^z \frac{(1+w(x))}{1+x}dx\right)$.

- **Pade Model for dark energy**:

$$\frac{H^2(z)}{H_0^2} = \Omega_{m0}(1+z)^3 + (1-\Omega_{m0})\mathcal{P}(z) , \tag{4}$$

where

$$\mathcal{P}(z) = \frac{1+P_1z+P_2z^2}{1+Q_1z+Q_2z^2} , \tag{5}$$

Priors Used

Parameter	Models	Prior (uniform)
Ω_{m0}	All	[0.1, 0.9]
H_0	All	[50, 90] Km/s/Mpc
σ_8	All	[0.6, 1.0]
r_d	All	[130,170]
w	$wCDM$,	[-1.9, -0.4]
w_0	CPL	[-1.9, -0.4]
w_a	CPL	[-4.0, 4.0]

Table I: Parameters used in different models and their prior.

Data Sets Used

- Isotropic and Anisotropic BAO measurements.
- BAO measurement by BOSS-DR12 using Lyman-α samples
- Angular diameter distances measured using water megamasers under the Megamaser Cosmology Project.
- Strong lensing time-delay measurements by H0LiCOW experiment.
- Latest Pantheon data for SNIa in terms of H(z)/H0
- OHD data for Hubble parameter as a function of redshift using cosmic chronometers.
- "Gold-17" sample for fσ_8 measurements.

Results:

Best-fit values of parameters for ΛCDM

ΛCDM			
Parameters	BASE	+CC	$+f\sigma_8$
Ω_{m0}	$0.29^{+0.014}_{-0.014}$	$0.29^{+0.013}_{-0.013}$	$0.29^{+0.013}_{-0.013}$
r_d (Mpc)	$141.72^{+4.55}_{-4.56}$	$144.66^{+2.81}_{-2.83}$	$144.71^{+2.9}_{-2.9}$
H_0 (Km/s/Mpc)	$71.74^{+2.22}_{-2.22}$	$70.26^{+1.38}_{-1.37}$	$70.3^{+1.36}_{-1.35}$
σ_8	—	—	$0.77^{+0.03}_{-0.03}$
$S_8 = \sigma_8\sqrt{\Omega_{m0}/0.3}$	—	—	$0.76^{+0.03}_{-0.03}$

TableII :These are Best-fit values of parameters for ΛCDM. Correspondingly, we find constraints for all other models taking different data combinations as well. (please refer paper.)

Bayesian Evidence Results:

	ΛCDM	$wCDM$	CPL	PADE
$Ln\mathcal{Z}$	-60.59	-69.08	-63.24	-63.38

Bayesian Evidence for different dark energy models.

Constraints on H_0 value

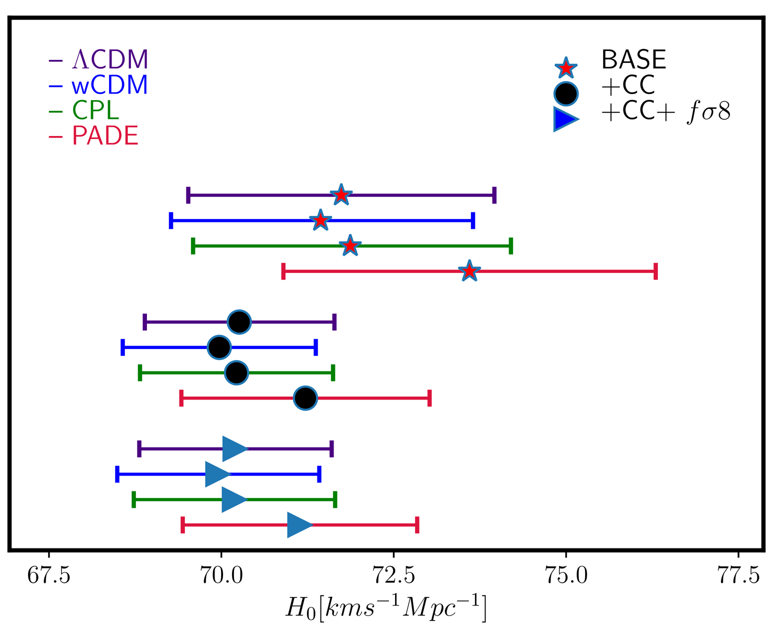

Figure 1: Values of H_0 with 1-σ error for several models studied in the work. The results are shown for different combinations of data-sets studied.

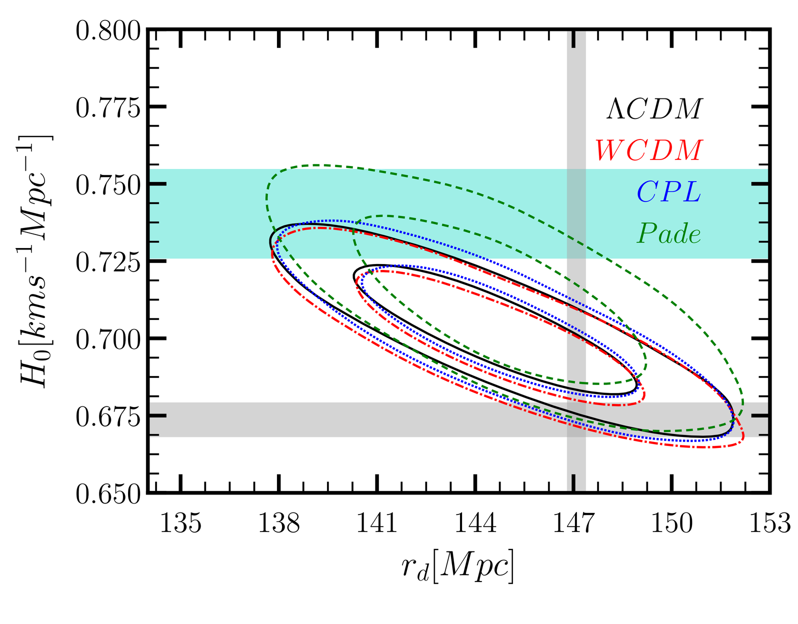

Figure 2: 1σ and 2σ constrained contours in H_0r_d parameter plane. The horizontal green band is 1σ constraints on H_0 by R19. The horizontal (vertical) grey band is constraint on H_0 (on r_d) from Planck-2018. Here the "BASE+CC+fσ_8" data sets is used.

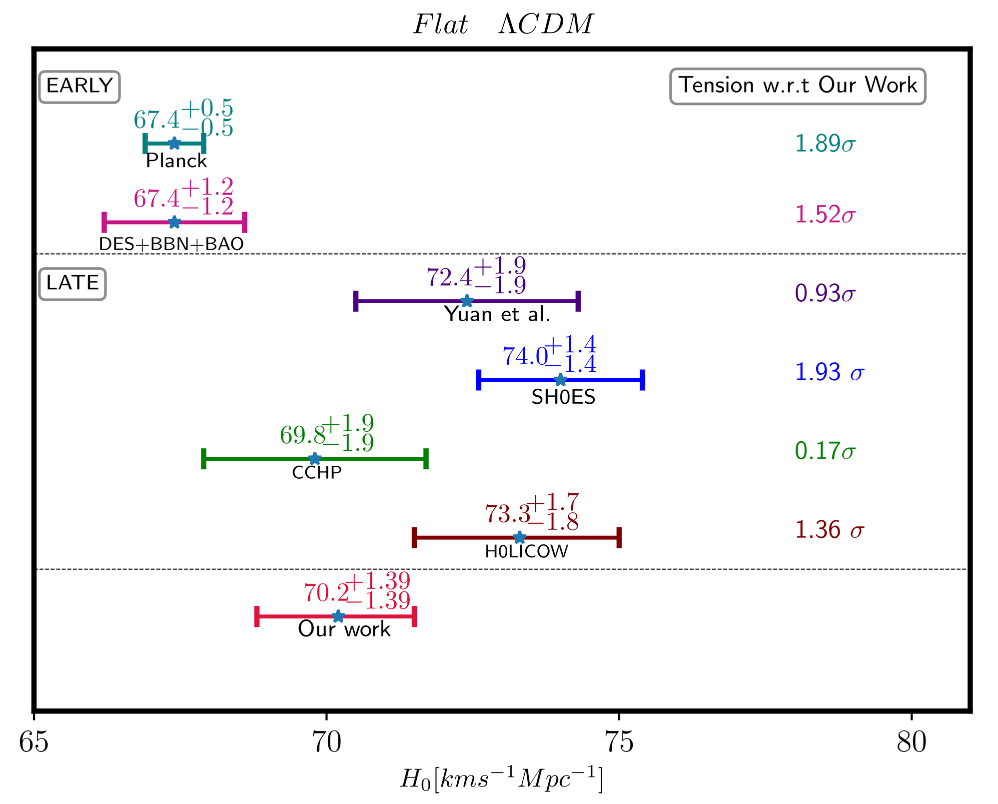

Figure 3: H_0 measurements with 1σ error bars from different observational data including the one reported in this work for ΛCDM model. We also show the tensions in our measurement with low-redshift observations compared to other observations

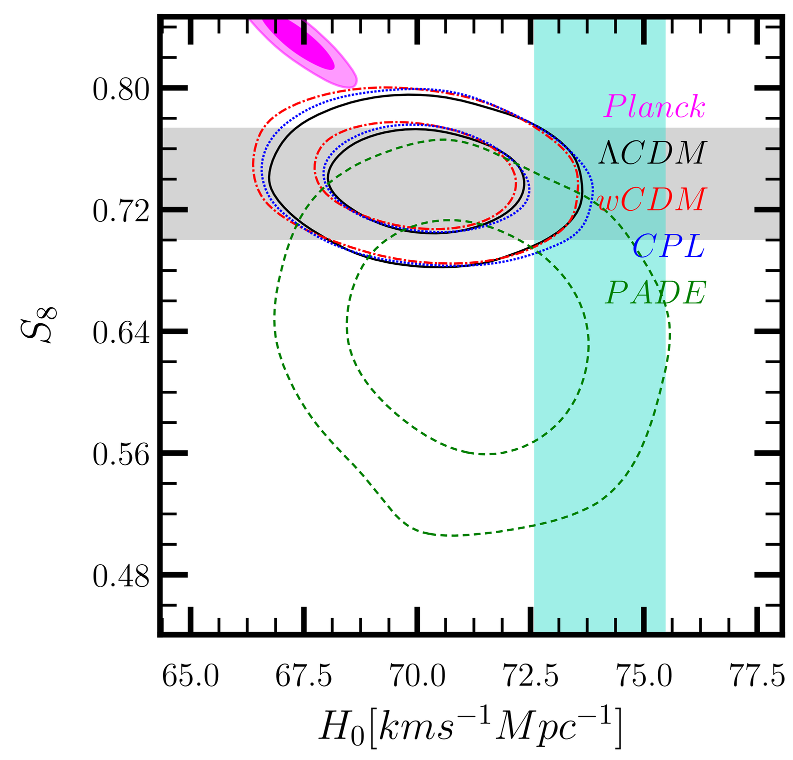

Figure 4: 1σ and 2σ contours in (H_0, S_8) plane. The grey band is 1σ bound for S_8 from KiDS+VIKING-450+DES-Y1 survey results. The green band in the Figure is the 1σ bound on H_0 from R19

Conclusions

To conclude, we revisit the low-redshift observational data "SN+BAO+MASERS+SL+CC+fσ_8" assuming different dark energy models including ΛCDM. The ΛCDM with model parameters as shown in Table II is consistent with R19, F19, Planck-2018, H0LiCOWXIII as well as KiDS+VIKING-450+DES-Y1 and the tensions with each of these observations are always within 2σ or less. Hence ΛCDM model with parameters as mentioned in Table II best represents the current Universe without any significant tension.

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