Constraints on a steep EoS for the Dark Energy using BAO

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Abstract

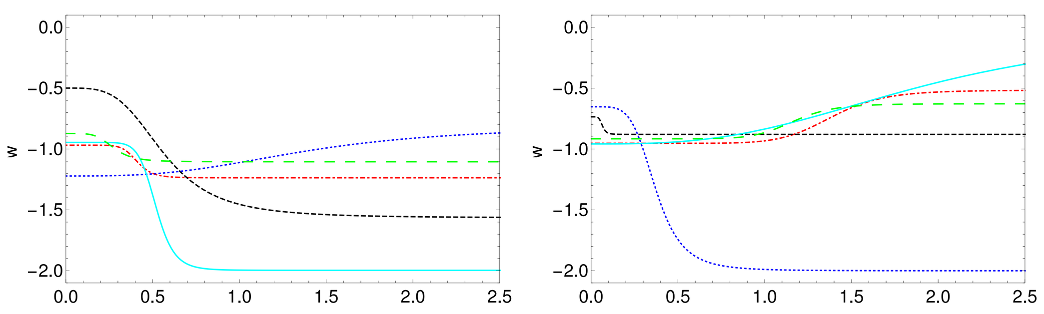
We present a parametrization for the Dark Energy (DE) Equation of State "EoS" that has a transition at pivotal redshift z_T between the present day value w_o to an early time w_i and the steepness of this transition is given in terms of the q parameter. We study if a late time transition is favored by BAO measurements and Planck priors. According to our results, an EoS with a present value of $w_0 = -0.91$ and a high redshifts value $w_i \equiv w(z \to \infty) = w_a - w_o = -0.62$, featuring a transition at a redshift of $z_T = 1.16$ with an exponent $q = 9.95$ is a good fit to the observational data. We found good agreement between the model and the data reported by the different surveys. The constraints imposed by the available BAO measurements and its physical behavior are discussed.

Parametrization of the DE EoS

We are modeling the DE equation of state (EoS) with the following parametrization:

$$w_{de}(z) = w_0 + (w_i - w_0)\frac{(\frac{z}{z_T})^q}{1+(\frac{z}{z_T})^q} \quad (1)$$

where w_i and w_0 represent the value for $w(z)$ at large redshifts and at present day, respectively whereas z_T represents the transition redshift in between both values with its steepness modulated by q. This transition is motivated by scalar field dynamics such as for example quintessence models.



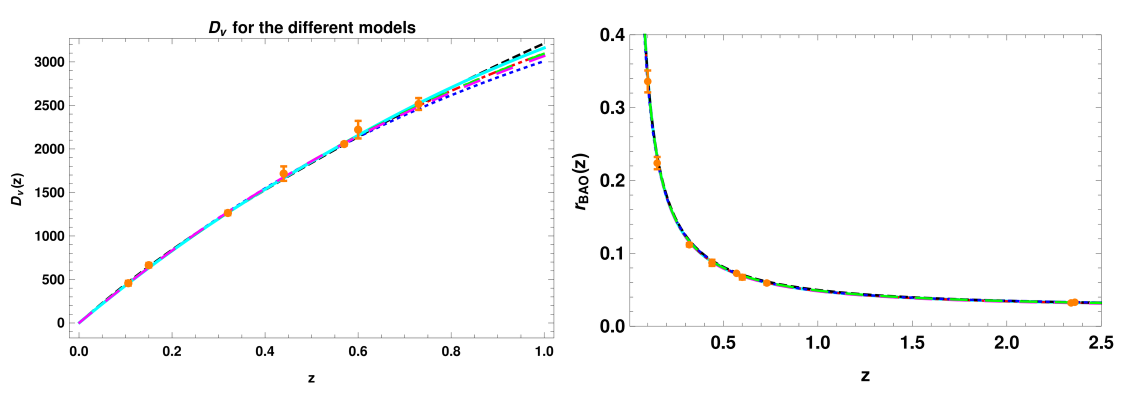
(a) Using $D_V(Z)$ data (b) Using $r_{BAO}(z)$ data

Figure: Evolution of the EoS for the best fit models found by minimizing the χ^2 function for different data sets and intervals for the parameters minimized.

For $z_T = q = 1$ Our parametrization reduces to the Taylor expansion EoS $w = w_o + w_a(1-a)$ widely used used in many cosmological observational analysis. The value of w_o is restricted by observations to be close to -1 ($w = -1.55^{+0.58}_{-0.48}$ according to the 95% limits imposed by Planck TT, TE, EE latest measurements [Ade et al., 2015]). Nevertheless, the behavior and properties at different cosmic epochs is much poorly constrained by current observations.

Observational Data: BAO

We made use of the observational points from the six-degree-field galaxy survey (6dFGS [Beutler et al., 2011]), Sloan Digital Sky Survey Data Release 7 and 11 (SDSS DR7 [Ross et al., 2015] and SDSS DR11 [Anderson et al., 2014]), the WiggleZ dark energy survey ([Kazin et al., 2014]) and the Lymann α Forest (Lyα-F) measurements from the Baryon Oscillation Spectroscopic Data Release 11 (BOSS DR11 [Font-Ribera et al., 2014], [Delubac et al., 2015]) as analyzed and reported by Gong *et al* 2015 [Gong et al., 2015]. Additionally to the free parameters in the equation 1 we also investigate the constraints on Ω_m and H_0 (or equivalently h), resulting in the set $\theta = \{w_0, w_i, z_t, q, \Omega_m, H_0\}$. Using this data sets we minimized the relative χ^2 function. When including the information from Planck $\pm 1\sigma$ in the limits to constrain Ω_m and H_0, we labeled those results as "BAO + Planck", otherwise they were labeled "BAO".



(a) Using $D_V(Z)$ data (b) Using $r_{BAO}(z)$ data

Figure: Fitting to the observational data points by the resulting best fit models.

Constraints

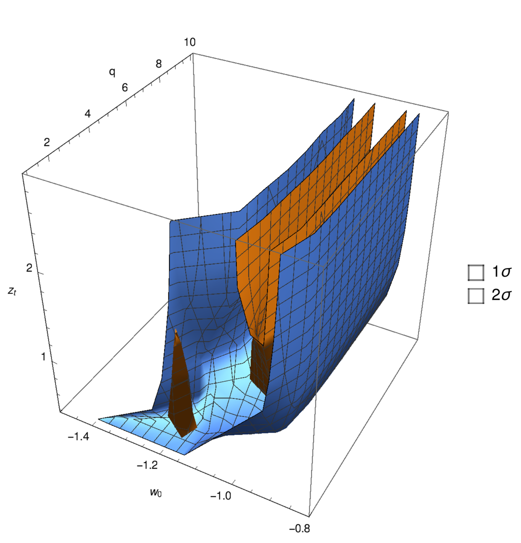
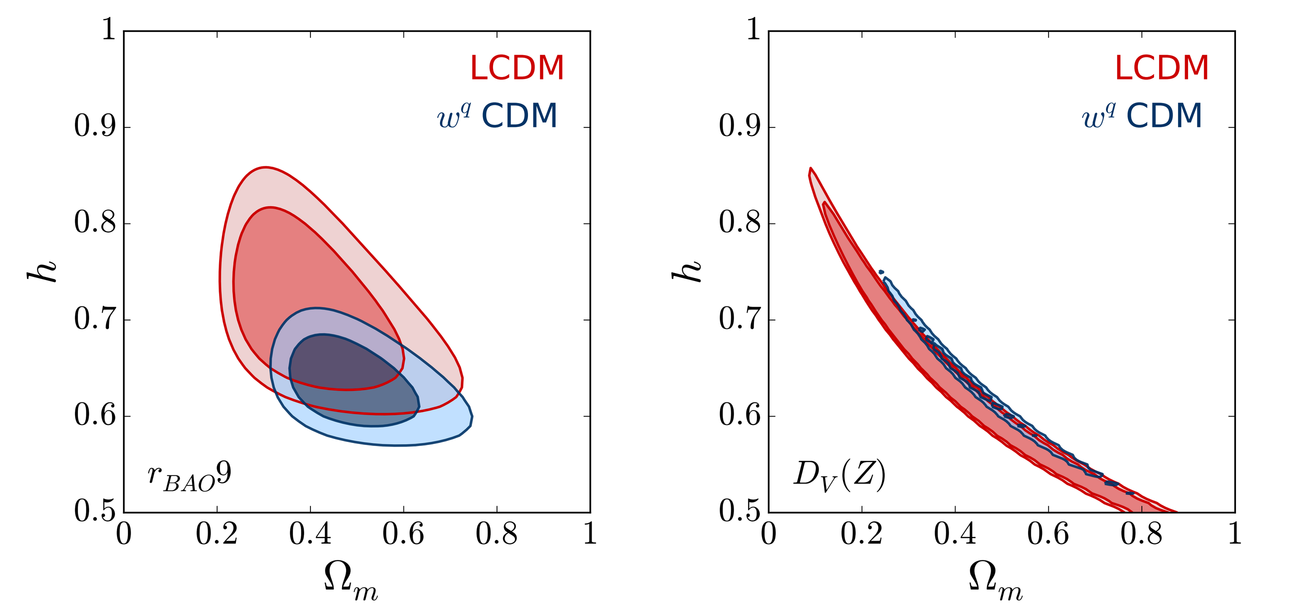


Figure: The q-z_t-w_0 space of parameters.

When using the BAO measurements we got a reduced chi-squared function of $\chi^2_{red} = 0.95$ and parameters $\theta = \{w_0 = -0.91, w_i = -0.62, z_T = 1.16, q = 9.95, \Omega_m = 0.3247, H_0 = 66.67\}$. We found weak constraints on the value for the new parameters z_T and q as shown in this 3D contour plot displaying the 1σ(orange)-2σ(blue) contours around the minimum.

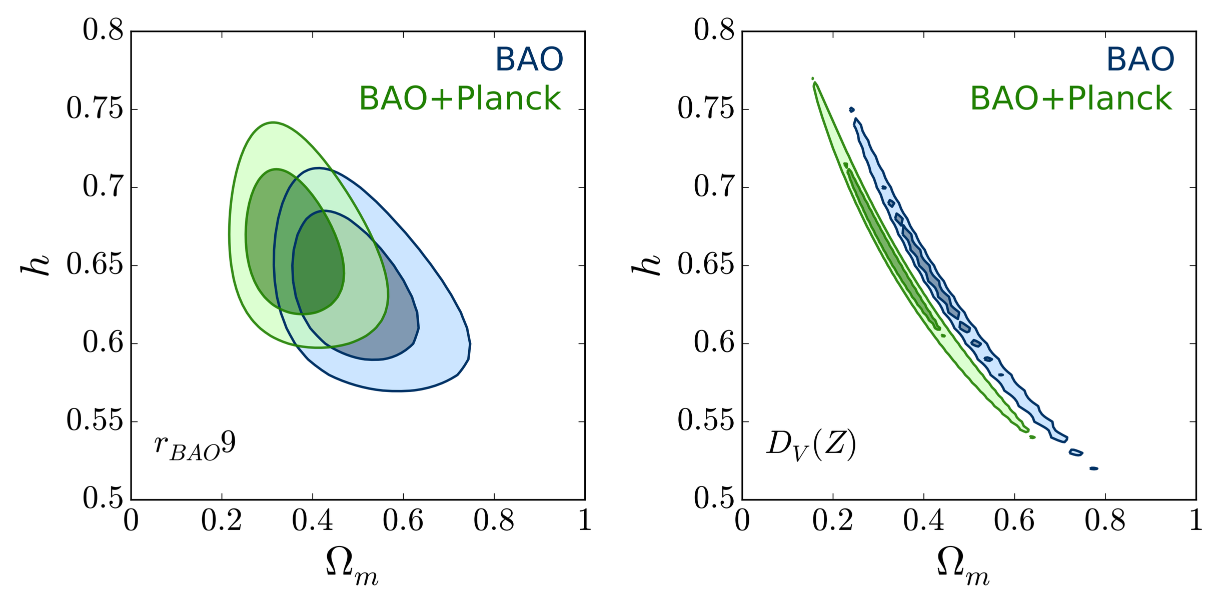
Comparison to LCDM



(a) (b)

Figure: Figure (a) shows the contours corresponding to $r_{BAO}(z)$ measurements while (b) corresponds to $D_V(z)$ data. In blue we portrait the contours corresponding to the BFM and the LCDM contours are shown in red.

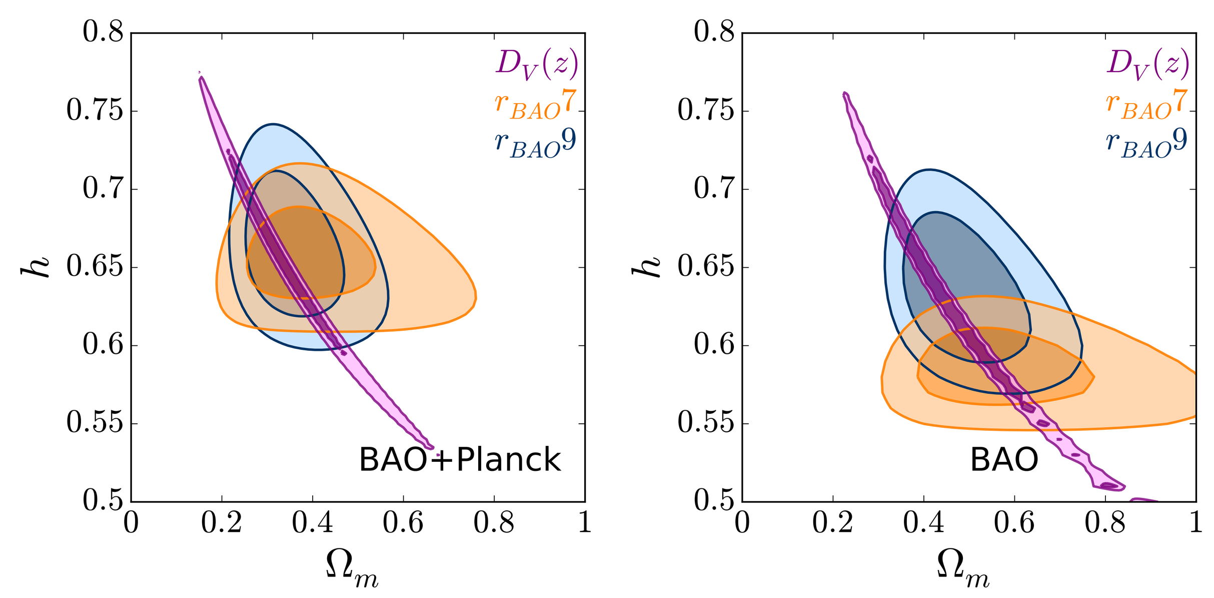
Planck Priors



(a) Using the 9 data points of $r_{BAO}(z)$ measurements. (b) Using the 7 data points of $D_V(z)$ measurements.

Figure: "BAO" contours in blue and "BAO+Planck" in green.

Different data sets



(a) "BAO+Plank" contours (b) "BAO" contours

Figure: Comparison of the different data: $r_{BAO}(z)$ with or without Lyα-F measurements and $D_V(z)$ measurements.

Conclusions

A steep EoS for the DE was favored by the available BAO data when including Planck priors. We obtained good fittings to the observational data and a very steep EoS as result from numerical minimization. We compared the results obtained by using $r_{BAO}(z)$ data including and excluding the Lyα-F measurements and when using $D_V(z)$ measurements instead. The comparison to LCDM model was investigated and some tension was found when $D_V(z)$ data was used. The impact of the priors from Planck was also analyzed and led us to the same conclusion. Finally, the use of the Lyα-F points in $r_{BAO}(z)$ data set was studied and found they restrict tighter the values of h and Ω_m.

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