Viability of a quintessence model with inverse power law potential as a dark energy candidate

E. Almaraz & A. de la Macorra

Instituto de Física, Universidad Nacional Autónoma de México (UNAM)

ealmaraz@fisica.unam.mx , macorra@fisica.unam.mx — (5255) 5622-5140

Abstract

We explore the predictions of a cosmological model where the dark energy is described by a scalar field with inverse power law potential obtained from the dynamics of a dark gauge group. The model (ϕCDM) has two free parameters: the scale factor at which the field condensates (a_c) and the density parameter of the field at that moment (Ω_X^c). Using WMAP9yr data, we found $10^6 a_c = 0.258 \pm 0.146$ and $\Omega_X^c = 0.258 \pm 0.146$. We also found $h = 0.75 \pm 0.03$, $\Omega_X^0 = 0.762 \pm 0.029$ and $w_X^0 = -0.964 \pm 0.027$. As far as the CMB data is concerned, the constraints of this model are in agreement with those of the ΛCDM one. We set the road to extend our analysis to include other types of observations.

The model

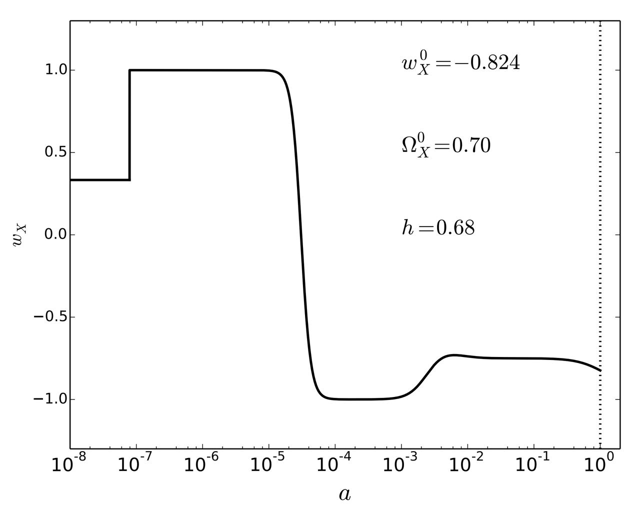
1. Starting from the unification scale, the fields of the SM and those of a dark gauge group SU(N_c) redshift as radiation until a condensation scale Λ_c is reached. Below that threshold, the fields of the dark group are no longer free and have to be described by means of an effective field ϕ whose inverse power law potential $V = \kappa\Lambda^{4+\alpha}\phi^{-\alpha}$ can be obtained from the Affleck-Dine-Seiberg superpotential [1]
2. Gauge coupling unification restriction + BBN bounds $\Rightarrow \alpha = 2/3$ & $\Lambda_c \sim 50$ eV [2, 3]
3. Free parameters: $\Omega_X^c \rightarrow$ density parameter of the dark group at a_c
   $a_c \rightarrow$ scale factor of the field's condensation

Background evolution

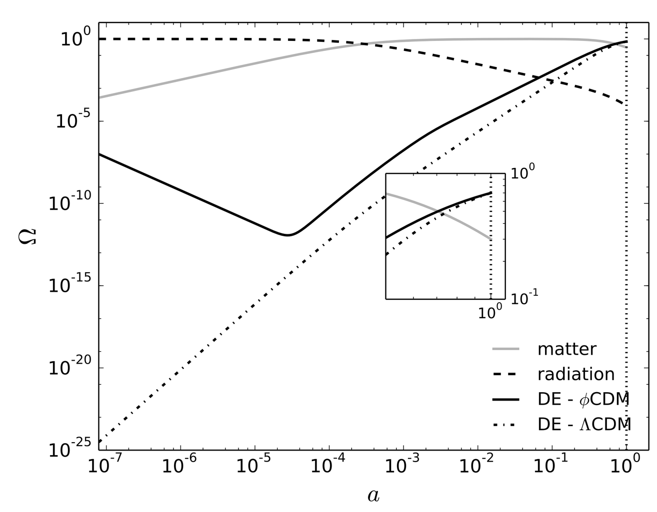
$$H^2 = \frac{8\pi G}{3}(\rho_r + \rho_m + \frac{1}{2}\dot{\phi}^2 + V) \tag{1}$$

$$\ddot{\phi} + 3H\dot{\phi} + V' = 0, \quad \text{where} \quad V' \equiv \frac{dV}{d\phi} \tag{2}$$

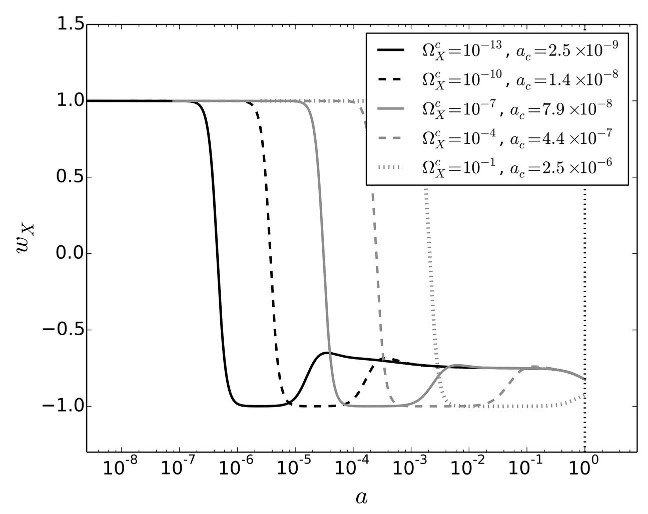
Equation of state



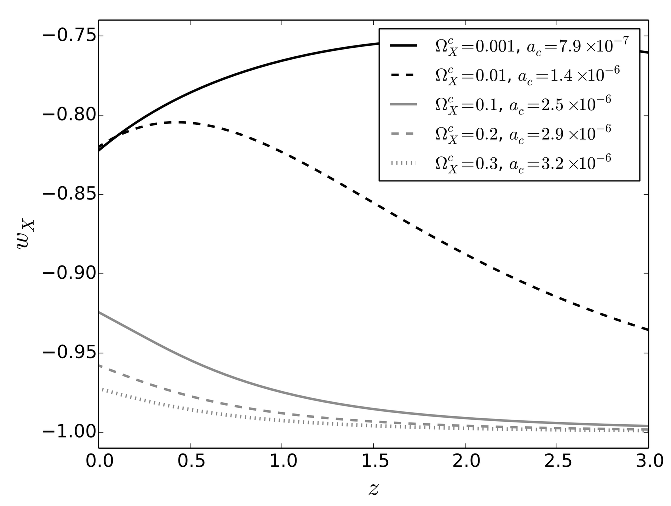
Density parameter



Initial conditions

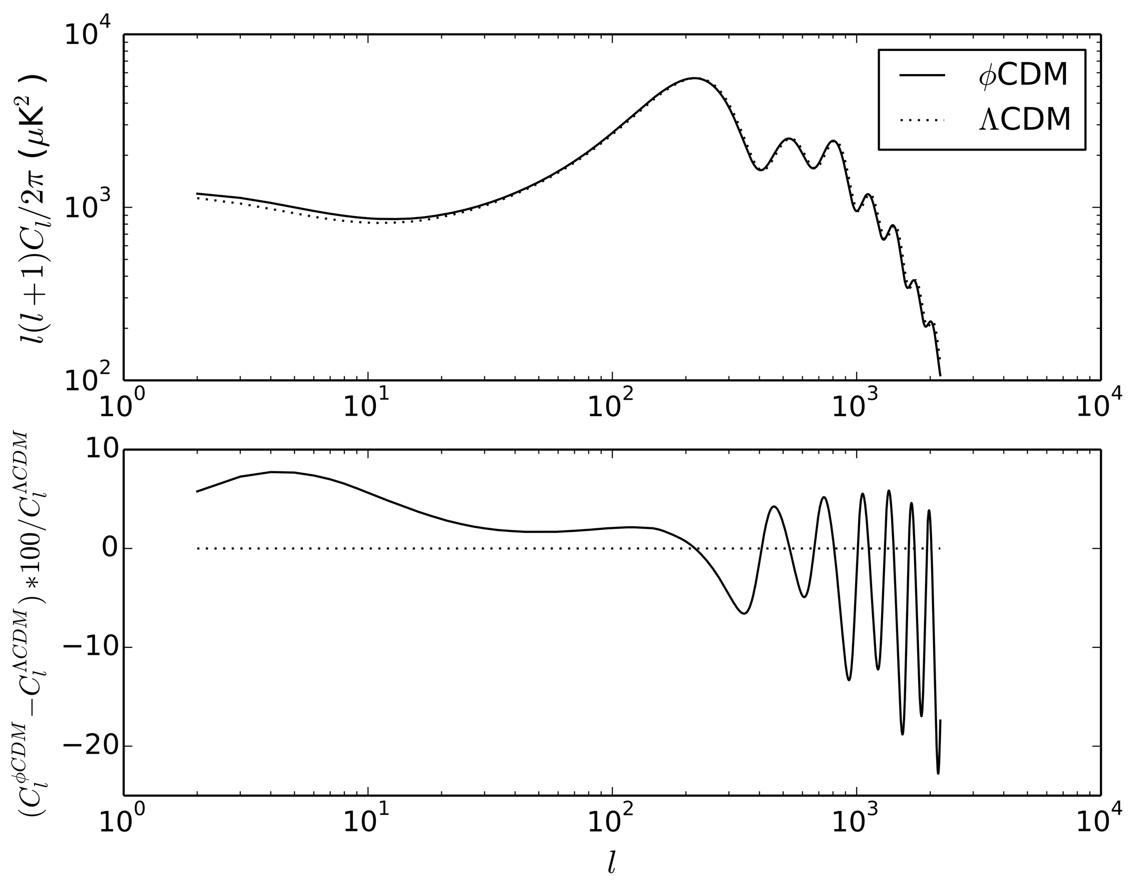


Late-time evolution



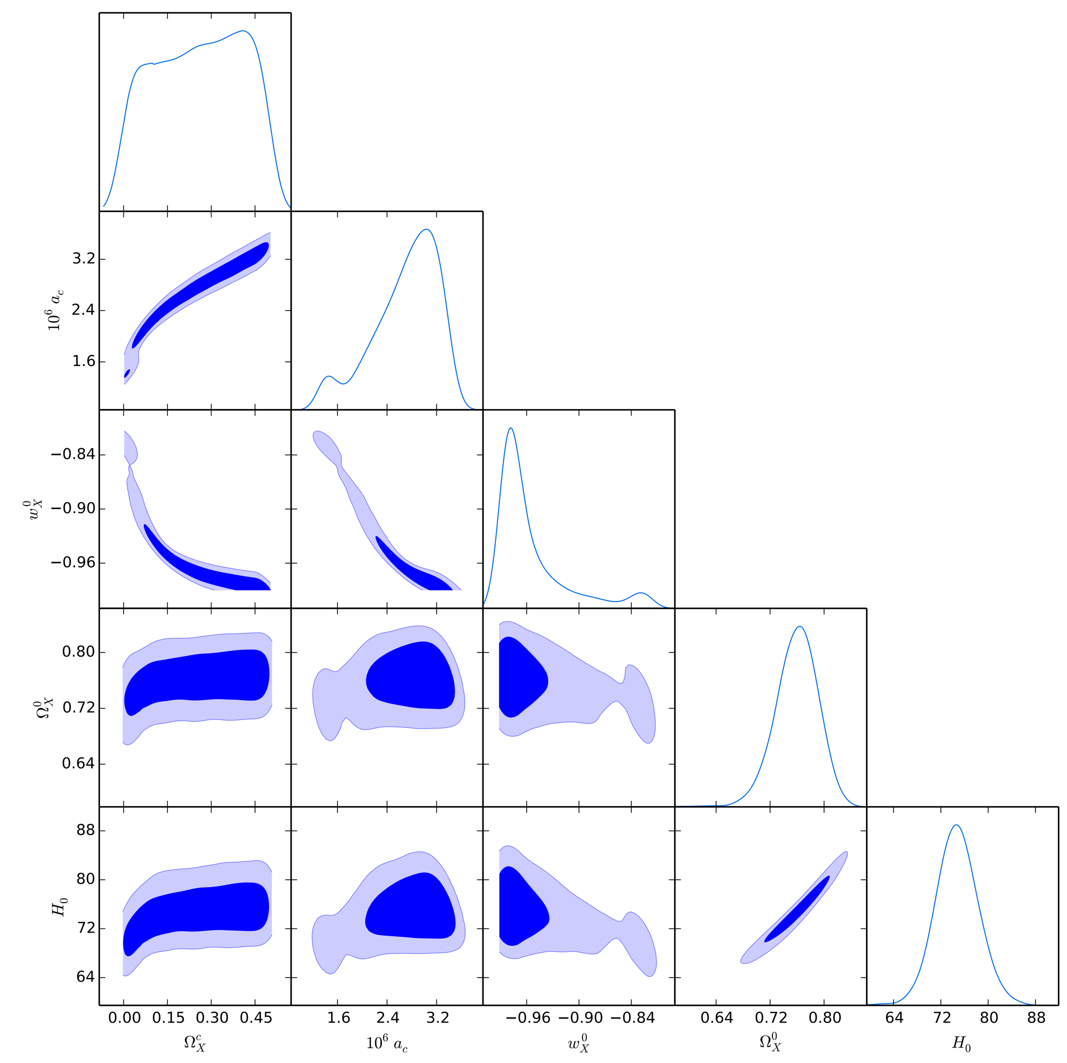
Perturbations

$$\ddot{\delta\phi} + 2\mathcal{H}\dot{\delta\phi} + (k^2 + a^2 V'')\delta\phi = -\frac{1}{2}\dot{\phi}\dot{\gamma} \qquad \text{(synchronous gauge)} \tag{3}$$



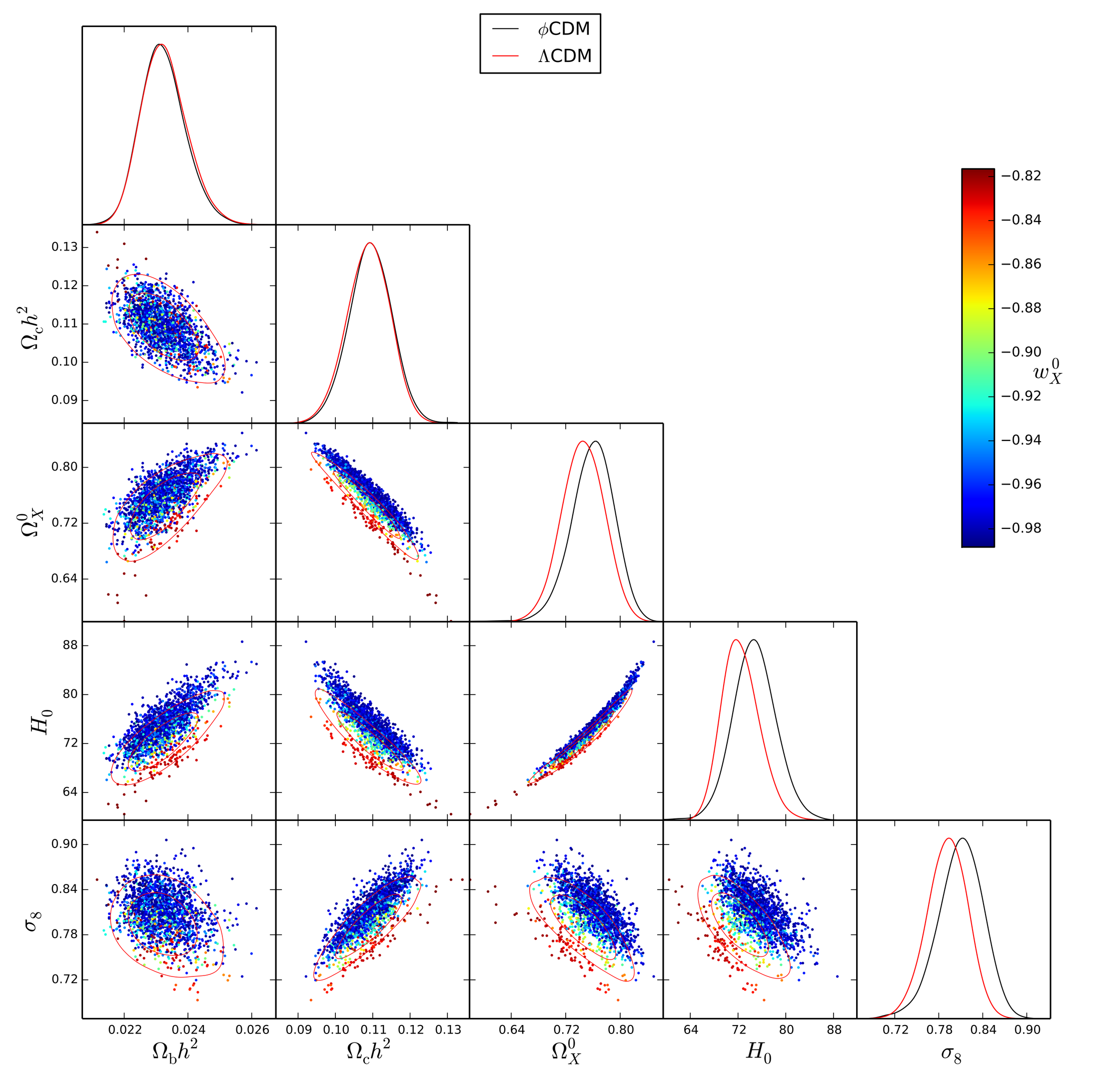
CMB temperature power spectrum

Constraints on quintessence parameters from WMAP9yr



Parameter	Mean $\pm$ Std	Best Fit	Marginal limits 68% lower	68% upper	95% lower	95% upper
Ω_X^c	0.258 ± 0.146	0.212	0.081	0.427	0.010	0.488
$10^6 a_c$	2.69 ± 0.52	2.70	2.17	3.12	1.41	3.41
κ	1.082 ± 0.262	0.926	0.815	1.365	0.543	1.578
w_X^0	-0.964 ± 0.027	-0.966	-0.992	-0.960	-1.000	-0.902
Ω_X^0	0.762 ± 0.029	0.750	0.734	0.793	0.704	0.816
H_0(km s^{-1} Mpc^{-1})	75.18 ± 3.29	73.59	71.55	78.21	68.66	81.92

Comparison with ΛCDM



Forthcoming Research

1. Update to Planck-2013 and Planck-2015
2. Inclusion of BAO and SNeIa measurements

References

[1] A. de la Macorra and C. Stephan-Otto. Quintessence restrictions on negative power and condensate potentials. *Phys. Rev. D*, 65:083520, 2002.

[2] A. de la Macorra. Quintessence unification models from non-abelian gauge dynamics. *JHEP*, 01:033, 2003.

[3] A. de la Macorra. A realistic particle physics dark energy model. *Phys. Rev. D*, 72:043508, 2005.

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