Exploring the consequences of parameter values in cosmological models with CosmoEJS, an interactive package of Cosmology Java simulations

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Introduction

It is not only important to constrain the parameters of cosmological models with the most recent and precise observational data, but it is also crucial to understand the physical consequences of those parameters for the different cosmological observables. CosmoEJS is an interactive Java package of simulators that allow the user to explore the ramifications of choosing various values for the cosmological parameters of a particular model [1]. Two such simulations now include observations of the growth of structure in galaxies, as well as the expansion history of the universe. Users can visually inspect the plotted theoretical values of their model, compare numerical fitting using all known, calculated and real cosmological values, and finally plot the expansion rate of their models as they evolve in time. The current list of these Java built-in simulations includes a current novel supernovae Type Ia survey, baryon acoustic oscillations (BAO), the cosmic microwave background (CMB) radiation, gamma-ray bursts (GRBs), measurements of the Hubble parameter, H(z), the Alcock-Paczynski (AP) test, and the growth parameter, δc and δm0. The simulations allow for any number of simulations of models, including dark energy, the cosmic-logical constant and modified gravity.

Cosmological Background

The cosmic acceleration can be explained by a cosmological constant, or some other form of repulsive dark energy, i.e., negative pressure of dark energy, or by an extension or modification to gravity at cosmological scales of distance. In the context of general relativity (GR), to account for this dark energy effect, the addition of a term to Einstein’s Field Equations (EFE) can be used to derive equations of motion with a cosmological constant of the desired value consistent with the dynamics of Friedmann-Lemaître-Robertson-Walker (FLRW) universe. We provide a means of using those commonly accepted models of the FLRW universe in a Java environment for large scale observations of the expansion of the universe, thereby enabling the parametrizations for the standard model in cosmology. We have further understood how constraints on parameters of a particular model can be fit to different data sets and evolve dynamically by exploring these models using CosmoEJS.

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References

[3] CosmEJS
[5] TACC

Fig. 2: A zoom version of Figure 1 showing 40% and 5% confidence contours on (0.0, $\Omega_m$), for a complete set of the latest-solved CMB measurements from Planck (Ref. 6).

The Model and Parameters to Fit

As an example, we begin with the general model [2] that allows for varying dark energy and spatial curvature, but can reduce (w = −1.0, $\omega_m$ = 0.0, δm0 = 0.0) to the simple Λ Cold Dark Matter model for constraining matter (Ω) and dark energy (Ω). $\Omega_a = H(1 + 0.0,0.0,0.0,0.0)$: the Hubble Constant parameter; $\Omega_b = 0.05$: the fractional baryon density; $\Omega_c = 0.0$: the fractional cold dark matter density; $\Omega_d = 0.79$: the fractional dark energy density; $\Omega_e = 0.0$: the fractional curvature density; $\Omega_f = 0.0$: the fractional dark energy density; $\Omega_g = 0.0$: the fractional curvature density; $\Omega_h = 0.0$: the fractional dark energy density; $\Omega_i = 0.0$: the fractional curvature density; $\Omega_j = 0.0$: the fractional dark energy density; $\Omega_k = 0.0$: the fractional curvature density; $\Omega_l = 0.0$: the fractional dark energy density; $\Omega_m = 0.0$: the fractional curvature density; $\Omega_n = 0.0$: the fractional dark energy density; $\Omega_o = 0.0$: the fractional curvature density; $\Omega_p = 0.0$: the fractional dark energy density; $\Omega_q = 0.0$: the fractional curvature density; $\Omega_r = 0.0$: the fractional dark energy density; $\Omega_s = 0.0$: the fractional curvature density; $\Omega_t = 0.0$: the fractional dark energy density; $\Omega_u = 0.0$: the fractional curvature density; $\Omega_v = 0.0$: the fractional dark energy density; $\Omega_w = 0.0$: the fractional curvature density; $\Omega_x = 0.0$: the fractional dark energy density; $\Omega_y = 0.0$: the fractional curvature density; $\Omega_z = 0.0$: the fractional dark energy density; $\Omega_0 = 0.0$: the fractional curvature density.

As their choice of free parameters change, Eq. (1) describes different types of evolutions for the universe. The parameter constraints, see Fig. 1 and Fig. 2, are obtained using CosmoMC [3], but CosmoEJS can be used to numerically and visually constrain parameter values that match each data set (and others), thus simulate the dynamical evolution of the universe.

References

[3] CosmEJS
[5] TACC
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GRB (Red): $\chi^2_{DE} = 23.182$

GRB (Red): $\chi^2_{DGP} = 23.305$

Supernovae Type Ia and Gamma-Ray Bursts

SNe (Black): $\chi^2_{DE} = 562.255$

SNe (Black): $\chi^2_{DGP} = 632.873$

Age of Universe$_{DE} = 13.970$ Gyr

Age of Universe$_{DGP} = 13.722$ Gyr

Current $z = 8.301$

Look-back time = 0.618 Gyr

Deriving: $\Omega_k = 1.0 - \Omega_m - \Omega_\Lambda$

$\Omega_0 = 1.000$, universe is currently 'Critically Dense' (Flat Universe).
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