ON THE DETERMINATION OF CURVATURE AND DYNAMICAL DARK ENERGY

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Constraining simultaneously the Dark Energy equation of state and the curvature of the universe is difficult due to strong degeneracies. To circumvent this problem it is quite usual to assume flatness to constrain Dark Energy, or conversely, to assume a cosmological constant to constrain curvature. In this study, we show the dangers to use such assumptions. In this end, we simulate data for type Ia Supernovae (SN), the Cosmic Microwave Bacground (CMB) and the Baryonic Acoustic Oscillations and test the above assumptions.

1 Introduction

In order to break the degeneracy between the curvature of the Universe and the Dark Energy dynamics, it's quite usual to assume flatness to constrain Dark Energy, or to assume a cosmological constant to constrain curvature. The aim of our analysis is to quantify the bias involved by such assumptions if they are not true. For that, we simulate type Ia supernovae magnitudes, the Cosmic Microwave Background shift parameter[1], R, and the Baryonic Acoustic Oscillations reduced parameter[2], A, for the next generation of surveys. Then we test the above assumptions.

2 Reconstruction of Dark Energy dynamics with a wrong assumption on curvature

In this section we want to test the effect of a wrong assumption of flatness on the determination of the DE equation of state parameters[a]. For that purpose, we simulate a non flat Universe, with a curvature Ω_T between 0.9 and 1.1, with a cosmological constant. In the fit, we assume a flat Universe ($\Omega_T = 1$) and we determine the DE equation of state parameters. The aim is to check if the fitted Dark Energy is equivalent to the fiducial one, namely the cosmological constant. To detect the wrong assumption, we define a detectability criterion by a χ^2 test. In practice, if $\chi^2 > 2N_{dof}$, we consider that the wrong assumption is detected. This test allows to discriminate some biased models with fiducial curvature Ω_T less than 0.97 and more than 1.07. But what about the models with a low χ^2 ? We define a biased model if : $|w_0 + 1| > \sigma(w_0)$ and $|w_a| > \sigma(w_a)$. The results show many biased models with fiducial curvature between 0.97 and 0.99 and between 1.01 and 1.08. For these tested models the cosmological constant is confused with a dynamical Dark Energy. This confusion is not detectable by the χ^2 and is only due to the wrong assumption of flatness. This phenomenon is a danger in case of real data.

[a] For the simulation and the fit we use the DE equation of state : $w(z) = w_0 + w_a z/(1+z)$

3 Reconstruction of the curvature with a wrong assumption on Dark Energy

Now we will investigate the biases introduced in the most common strategy which is to pin down the curvature of the Universe when assuming that DE is a cosmological constant (ΛCDM hypothesis). The simulation is computed for a non flat Universe with a dynamical DE. In the fit we assume a cosmological constant to extract the curvature of the Universe. Actually, two studies are realized in order to answer to different questions. Firstly, we want to test if the fitted curvature may be confused with a flat Universe due to the wrong assumption. Secondly, we will verify if the fitted curvature corresponds or not to the fiducial one.

The detectability criterion allows to discriminate many biased models. Then we define the confusion with a flat Universe if : $|\Omega_T - 1| < \sigma(\Omega_T)$ and test the models for which the fit seems good. For some of these, it exists a confusion of a non flat Universe with a flat Universe. For open models with curvature Ω_T between 0.97 and 0.99, this confusion appears especially for DE models with $w_0 < -1$ and $w_a > 0$. For closed models with curvature between 1.01 and 1.02, it appears especially for DE models with $w_0 > -1$ and $w_a < 0$. These results mean that a non flat Universe can be confused with a flat Universe only due to the wrong assumption of cosmological constant and this confusion is not detectable in case of real data. On the other hand, we define a valid model, if $|\Omega_T - \Omega_T^F| < \sigma(\Omega_T)$ where ^{F} means fiducial, namely if the fitted curvature corresponds to the fiducial one.

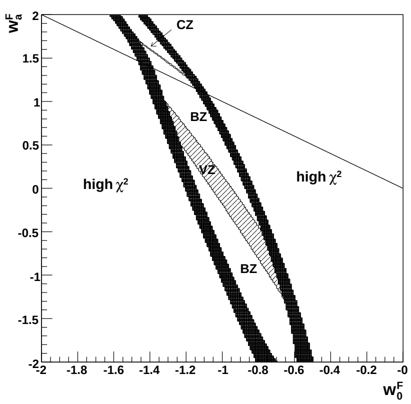

Figure 1: Fiducial cosmology : $\Omega_M = 0.25, \Omega_X = 0.7$

The figure 1 illustrates this study for an open Universe ($\Omega_T = 0.95$) in the fiducial plane (w_0, w_a). Each point of the plane corresponds to a tested DE model. Black contour gives the goodness of the fit, wherein the fit seems good. One can see the confusion zone (CZ) which includes all the DE models which can be confused with a flat Universe. The VZ area is the "validity zone" and contains models where the curvature is well reconstructed. All of the other models inside the black contour are biased and this bias is not detectable, even if statistics is high.

4 Conclusion

In summary, assuming flatness or a cosmological constant implies some important biases and confusions. A more detailed study was made,[3] notably with a different statistical scenario but the conclusions are the same. We have also studied the errors of the fitted values with or without the wrong assumptions. Comparison between these errors in a combined analysis SN, CMB, BAO shows small gain to assume flatness or/and a cosmological constant. Consequently, combined analysis should be performed without assumptions on curvature or DE dynamics. This has a small impact on the constraints and it avoids serious potential misinterpretation of the data.

References

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