Evidence for dark energy: Cross-correlating SDSS5 with WMAP3

A.Cabré, E.Gaztañaga, M.Manera, P.Fosalba & F.Castander

1. Institut de Ciències de l’Espai (CSIC/IEEC), Campus UAB, F. de Ciències, Torre C5 par-2, Barcelona 08193, Spain
2. INAOE, Astrofísica, Tonantzintla, Puebla 7200, Mexico

Abstract. We cross-correlate the third-year WMAP data with galaxy samples extracted from the SDSS DR5 (SDSS5) covering 16% of the sky. These measurements confirm a positive cross-correlation, which is well fitted by the integrated Sachs-Wolfe (ISW) effect for flat LCDM models with a cosmological constant. The combined analysis of different samples gives $\Omega_\Lambda = 0.79 - 0.83$ (68% Confidence Level, CL) and $\Omega_\Lambda = 0.75 - 0.85$ (95% CL).

1. Introduction

Dark Energy models with late time cosmic acceleration, such as the $\Lambda$-dominated CDM model, predict a blueshift in the temperature anisotropies of CMB produced by photons coming from last scattering surface that pass through matter potentials evolving with time. It is the integrated Sachs-Wolfe (ISW) effect which is important at large scales. We can detect the ISW effect through the cross-correlation of temperature fluctuations with local tracers of the gravitational potential such as galaxies. A positive cross-correlation between the 1yr WMAP data (WMAP1) and galaxy samples from the Sloan Digital Sky Survey data release 1 (SDSS1) was first found by Fosalba, Gaztañaga & Castander (2003), FGC03 from now on, and Scranton et al. (2003). WMAP1 has also been correlated with the APM galaxies (Fosalba & Gaztañaga 2004), infrared galaxies (Afshordi et al. 2004), radio galaxies (Nolta et al. 2004), and the hard X-ray background (Boughn & Crittenden, 2004). Here we want to check if these results can be confirmed to higher significance using the SDSS data release 5 (SDSS5) which covers 3 times the volume of SDSS1. For details see Cabré et al 2006 who has done a similar analysis with DR4.

2. Results

In order to trace the changing gravitational potentials we use galaxies selected from the SDSS5 (Adelman & McCarthy 2007) (16% of the sky). We have selected subsamples with different redshift distributions to check the reliability of the detection and to probe the evolution of the ISW effect. We use a slice with apparent magnitude $r = 20 - 21$ and a selection of high redshift galaxies (LRG). For the CMB temperature fluctuations we take the 3rd year WMAP data (WMAP3).

We define the cross-correlation function as the expectation value of galaxy density fluctuations $\delta_G$ and temperature anisotropies $\Delta_T = T - T_0$ (in $\mu$K)
at two positions \( \hat{n}_i \) and \( \hat{n}_j \) in the sky. To estimate the cross-correlation from the pixels maps we average over all pixels \( N_{i,j} \) separated an angle \( \theta \pm \Delta \theta \), i.e.,

\[
w_{RG}(\theta) = \sum_{i,j} \Delta T(\hat{n}_i)DG(\hat{n}_j)/N_{i,j}.
\]

We use \( \sigma_8 = 0.75 \) as given by WMAP and obtain \( b\sigma_8 \) from the galaxy autocorrelation function. We fit the cosmological models to the cross-correlation measurement. Results are shown in fig. 1.

![Figure 1](image_url)

Figure 1. a,b) The continuous line with errorbars shows the WMAP3-SDSS5 angular cross-correlation for the \( r = 20 - 21 \) sample and the LRG sample. The dashed lines show the \( \Lambda CDM \) model with \( \Omega_\Lambda = 0.81 \) (best overall fit) scaled to the appropriate bias and projected to each sample redshift. c) Probability distribution for \( \Omega_\Lambda \) in the \( r = 20 - 21 \) sample (short-dashed line), the LRG sample (long-dashed line) and the combined analysis (continuous middle curve). The range of 68% and 95% confidence regions in \( \Omega_\Lambda \) are defined by the intersection with the corresponding horizontal lines.

We find that a \( \Lambda CDM \) model with \( \Omega_\Lambda \simeq 0.81 \) successfully explains the ISW effect for both samples of galaxies without need of any further modeling. The best fit for \( \Omega_\Lambda \) for each individual sample are very close, as seen in SDSS4-WMAP3. This is significant and can be understood as a consistency test for the \( \Lambda CDM \) model.

Acknowledgments

This work was supported by the European Commission’s ALFA-II programme through its funding of the Latin-american European Network for Astrophysics and Cosmology (LENAC).

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