Cross-correlation of WMAP7 and the WISE Full Data Release

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Overview

Dark Energy (DE) may leave a signal in the secondary anisotropies that are imprinted on the Cosmic Microwave Background radiation (CMB). The Integrated Sachs-Wolfe effect (ISW, Sachs & Wolfe 1967) is an example of a secondary anisotropy: CMB photons passing through a changing gravitational potential become slightly hotter or colder. In a Universe dominated by DE there is a net energy difference between entering and leaving a potential well due to the decay. Thus, the detection of the linear ISW effect provides direct evidence for dark energy in the ΛCDM model. The typical ISW significance in former papers is around 2-3σ (Giannantonio et al. 2012 for review).

Motivation

The Wide-field Infrared Survey Explorer (WISE) all-sky survey is an attractive dataset for ISW studies. The survey effectively probes low redshift $z < 0.3$ with a high source density. We followed Goto et al. (2012) who cross-correlated a WISE preliminary data release (PDR) galaxy sample - covering 10,000 sqr deg. - with the Cosmic Microwave Background. We aim to produce the ultimate ISW cross-correlation analysis with the WISE full data release (FDR).

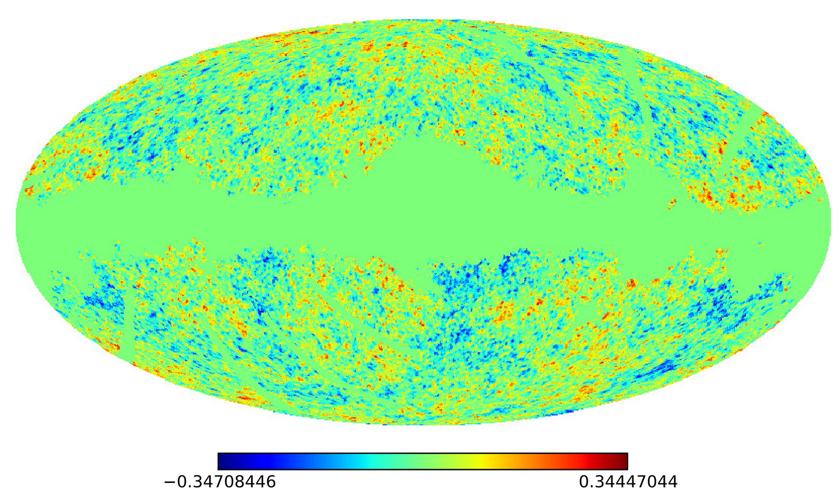

Figure: We used the CMB Extended Temperature Mask and the foreground reduced version of Q, V, and W maps.

WISE galaxies

Things to do:

1. download WISE data at four wavelengths
2. perform star-galaxy separation
3. estimate galaxy bias
4. obtain the redshift distribution

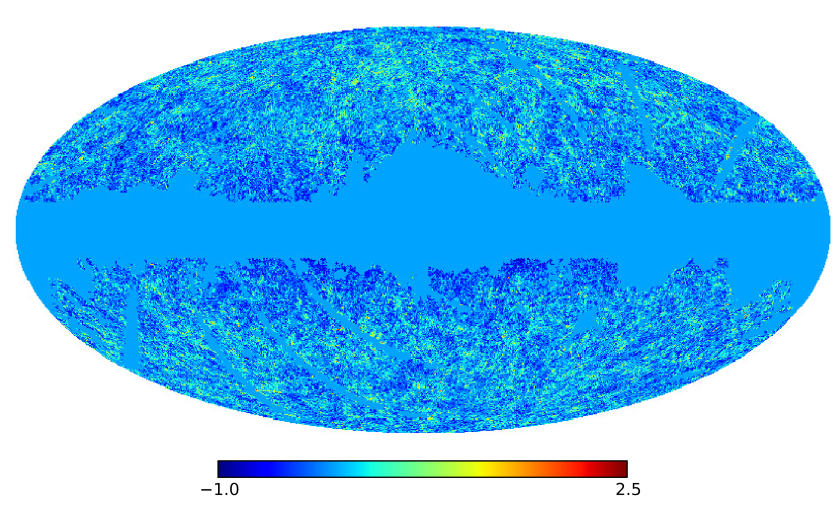

Figure: WISE allsky galaxy sample, together with our mask that includes stripes and WMAP's mask area.

Results:

- color-color plots for selection
- galaxy map with $\sim 2 \cdot 10^6$ objects
- galaxy auto-correlation and bias
- median redshift, $\bar{z} \approx 0.15$

Theory, measurements, and simulations

We derived the expected correlations and galaxy bias using WMAP7 best-fit ΛCDM cosmological parameters. We measured power spectra using SpICE (Szapudi et al. 2001). The cross-spectrum of a galaxy map and the CMB is given by

$$C_l^{gT} = b_g \frac{6 \cdot T_{CMB}\, \Omega_m\, H_0^2}{\pi\, c^2} \int dk\, k^2\, P_k \cdot \int dr\, j_l(kr) \frac{d(1+z)\ D_1(z)}{dr} \int dr'\, j_l(kr')\, \phi(r')\, r'^2$$

where $D_1(z)$ is the linear growth factor, $\phi(r) \propto \frac{dN(r)}{dz}\frac{dz}{dV}$ is a comoving coordinate with a normalization relation $\int \phi(r) r^2 dr = 1$, and j_l is a spherical Bessel function.

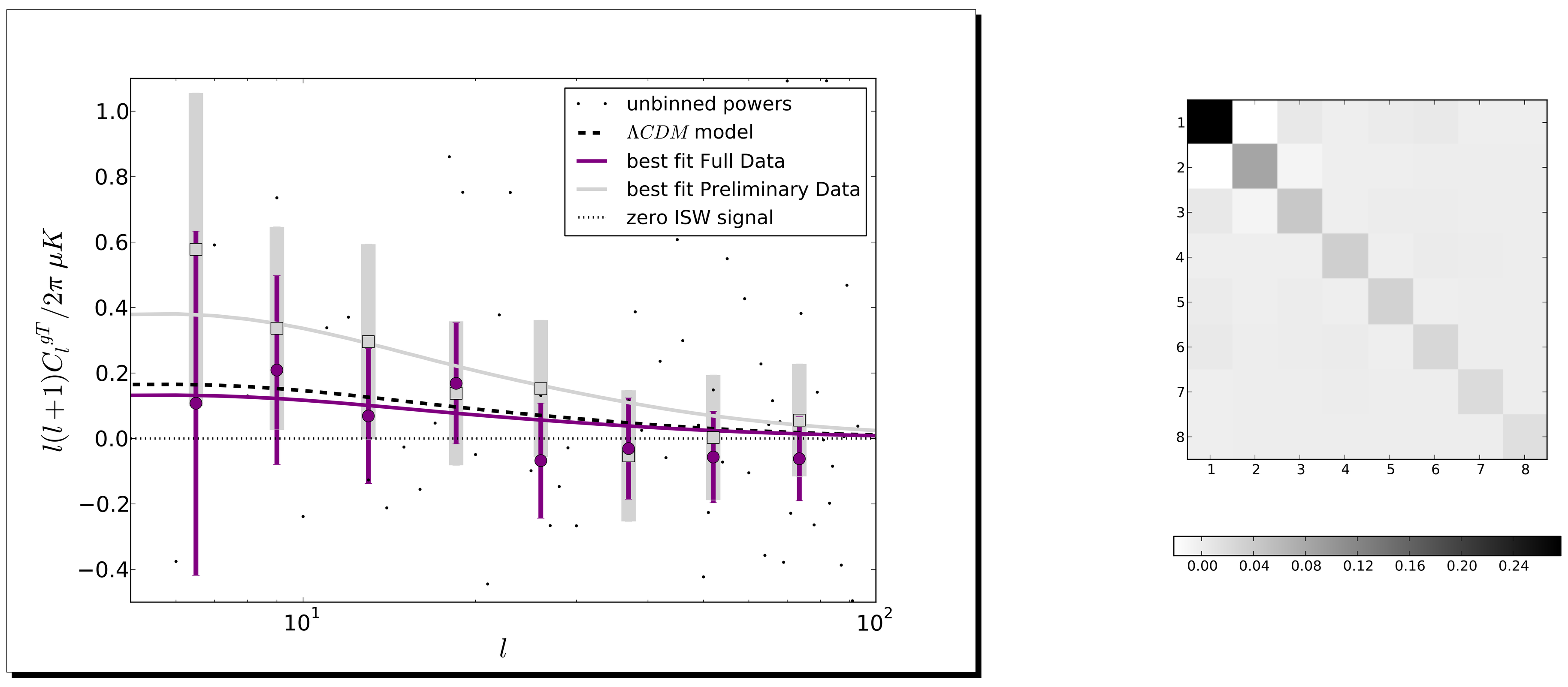

Figure: Cross-correlation power spectra of WMAP7-WISE datasets using our $|b| > 20$ mask, and expectations for ΛCDM cosmology and zero ISW detection. We estimated the covariance matrix using 1000 CMB simulations.

χ^2 statistics

We evaluate a χ^2 statistic for each hypothesis which is the following:

$$\chi^2 = \sum_{i,j} d_i C_{ij}^{-1} d_j$$

where $d_i = (C_{d,i}^{gT} - C_{t,i}^{gT})$ and C is the covariance matrix. Index i labels the bins we use in the cross-spectrum.

Mask	ISW Model	χ^2	$\Delta\chi^2$	Amplitude	σ
	Zero	3.07	-		
$\lvert b\rvert > 10$	Best-fit	2.20	0.87	0.8 ± 0.9	**0.9**
	ΛCDM	2.26	0.81		
	Zero	2.32	-		
$\lvert b\rvert > 20$	Best-fit	1.63	0.69	0.8 ± 0.8	**1.0**
	ΛCDM	1.74	0.58		
	Zero	5.64	-		
$\lvert b\rvert > 10$	Best-fit	2.91	2.73	2.3 ± 1.2	**1.9**
PDR area	ΛCDM	3.74	1.90		

Systematic effects

- possible color dependence in CMB maps
- gradient in mean galaxy density at $|b| < 20$
- choice of magnitude limit and galaxy mask
- efficiency of star-galaxy separation
- moon-contamination of observations

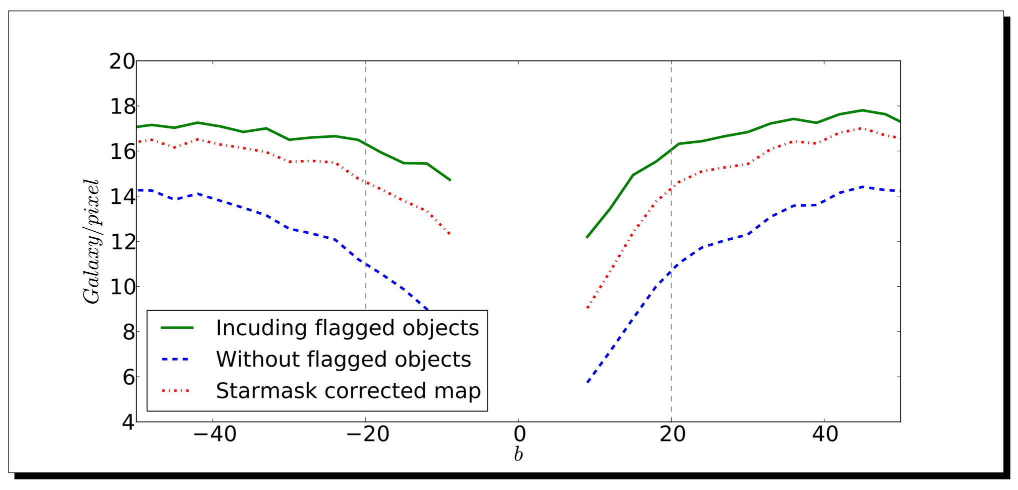

Figure: Gradient in mean galaxy density at $|b| < 20$.

We developed possible corrections and repeated our analysis, but the results appear to be robust against the slight changes in methods.

Conclusions

While some recent studies (Ho et al. 2008, Giannantonio et al. 2012, Goto et al. 2012) measured higher ISW correlations than ΛCDM predictions, we conclude that the robust signal we found is consistent with ΛCDM and previous measurements of similar datasets (Francis & Peacock 2010, Rassat et al. 2007). Our analysis highlighted the importance of cosmic variance.

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