RevMexAA (Serie de Conferencias), **26**, 121–122 (2006)

POLARIZATION SPECTRUM OF CMB OBTAINED FROM THE COSMIC BACKGROUND IMAGER

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RESUMEN

Presentamos el espectro de potencias angulares estimado de la emisión polarizada CMB usando el intrumento CBI. Se realizaron observaciones dedicadas de septiembre 2002 a abril 2005, las que brindaron suficientes datos para extraer un espectro EE de potencias sin precedentes con detección global de polarización de 10σ. El patrón pico-valle del espectro EE y su corrimiento de fase con el espectro TT de potencias confirman aspectos importantes de la física primordial del universo temprano que se infieren del modelo cosmológico estándar.

ABSTRACT

We present the estimated angular power spectrum of the polarized CMB emission by using the Cosmic Background Imager (CBI). Dedicated CMB observations were carried out from September 2002 to April 2005, providing enough data to extract an unprecedent EE power spectrum with an overall 10σ detection of polarization. The peak-dip pattern of the EE spectrum and its phase shift with the TT power spectrum confirm important aspects of the primordial physics of the early universe as inferred from the standard cosmological model.

Key Words: **COSMIC MICROWAVE BACKGROUND — COSMOLOGY: OBSERVATIONS**

1. INTRODUCTION

The CBI is a 13 element radio interferometer located at the Llano de Chajnantor, Segunda Región, Chile, at 5.080 mts. Its observing frequency band ranges from 26 to 36 GHz and is splitted in 10 bands, one GHz bandwidth each. It was installed by the end of 1999 and originally intended to observe the total intensity of the CMB (Padin 2002). The enormous success of that campaign led to a variety of publications (Mason 2003; Myers 2003; Pearson 2003; Readhead 2004a; Sievers 2003), with a huge impact within the cosmological community.

The natural extension to the original scientific goal was to measure the E-mode polarization of the CMB. Theoretically, the CMB polarization fraction is about 10% of the total intensity and obviously this fact is a difficult challenge to overcome. However, the capability to confirm or refute the *standard cosmological model* lies necessarily in our ability to observe the weakly polarized CMB photons, extract the well known angular power spectra and estimate the cosmological parameters . Therefore, given that we are dealing with fundamental questions of physics, the goal well worth the effort.

This short paper will be organized as follows. First, we will mention how the CBI was prepared to face this challenge. Second, we present the EE spectrum extracted from CBI's extended campaign in polarization mode and finally, some conclusion and comments.

2. POLARIZATION UPGRADE TO THE INSTRUMENT

The upgrade to the CBI to switch the observations from CMB total intensity to polarization was based in three particular items:

• Configuration of the array: it was decided to use a closed pack array because it was expected that most of the power from the CMB polarized emission wouldn't come from lower multipoles. The spatial resolution of the upgraded configuration was $300 < l < 2000$ in multipole scale.

•Amplifiers: The High Electron Mobility Transistors (HEMT) were replaced with a new generation of HEMTs, provided by NRAO, with better noise figures and an improved frequency response, matching the observing frequency band of the receiving system.

•Polarizers: It was found that the quarter wave plates used in the total intensity campaign, to choose the hand of the circular polarization (L or R), were having leakage factors ∼5–15%, too high if the E-

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mode was what we were aiming for. New, software addressable, broadband achromatic polarizers replace the old quarter wave plates with an average leakage factor of ∼1–3%.

For the observations reported here, there were 7 antennae sensitive to LCP and 6 to RCP.

3. EE SPECTRUM

Polarization of the CMB was generated by Thomson scattering of photons at the time of last scattering. The scattered radiation from the electron-incident field interaction is linearly polarized parallel to the incident field polarization, thus, it could be represented with the Stokes parameters Q and U. Fortunately, we can directly estimate those parameters from cross-polar baselines RL and LR, direct output of the analog correlator of our receiving system.

The angular power spectra show the distribution of the variance C_l, usually in μK^2, as a function of multipole number l and is estimated using maximum likelihood procedures. Usually, CMB polarization is represented with the covariances TT, EE, BB and the cross-correlation TE spectra, which are non zero because of parity properties of T (temperature), E (grad-like polarization) and B (curl-like polarization). As a result, TT spectrum from CBI polarization observations agrees very well with previous results and the new data doesn't improve what we already knew about it. BB is far from being detected with current technology, although an upper limit of $5.2\mu K^2$ with an 95% confidence has been reported from this spectrum (Sievers 2006), and TE has a 3.3σ detection, still low to use it for cosmological purposes. The EE spectrum has a 10σ detection of polarization (Sievers 2006), the strongest thus far, that is why we highly focus on it for this publication.

CBI's EE spectrum shows a remarkably good agreement with the fiducial model and a phase shift with TT spectrum of π. This is a fundamental test for the adiabatic standard cosmological model because, as expected from the physics of the primordial acoustic oscillations, the density and velocity of the primordial plasma are completely out of phase, unprecedentedly confirmed with the derived spectra. As shown in fig. 1, there is a big improvement on CBI's results from Readhead 2004b to Sievers 2006, shrinking of the error bars and derived bandpowers are now much more close to the model. This is entirely due to the 54% increase in integration time.

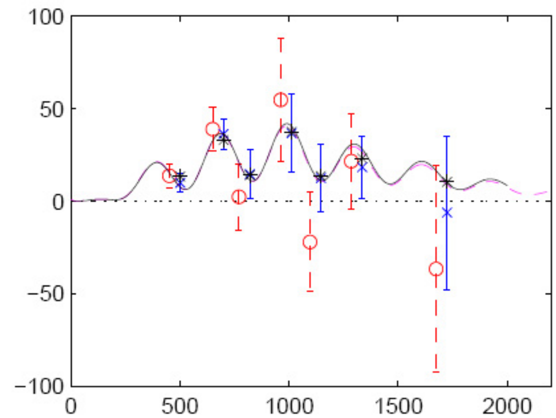

Fig. 1. EE angular power spectrum. Abscissas are multipole numbers and ordinates is variance C_l in μK^2. Red circles are from Readhead 2004b, blue crosses are from Sievers 2006, black asterisks show the expected values from the fiducial model using the window functions, black curve is the fiducial model from a combination of available TT+EE+TE data and magenta dashed curve is a flat power-law ΛCDM model which best-fits the WMAP, CBI, and ACBAR CMB data (Spergel 2003).

4. CONCLUSIONS

In this paper we present the CBI project and its last results from the 2.5 years of dedicated CMB polarization observations. A careful upgrade to the receiving system and a configuration change in the array made all this observations possible. Polarized CMB emission (EE) with maxima phase shifted by π relative to TT, was detected with a 10σ confidence, the strongest result ever published, successfully confirming important predictions of the standard model.

We are grateful to the whole CBI team for their enormous dedication during the project lifetime and to all the institutions that have given their precious support to hold the project running.

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