UCSB HEMT-ACME
South Pole 1990-91 Results[a]

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INTRODUCTION

We report further results from the University of California at Santa Barbara program to measure anisotropy in the Cosmic Background Radiation (CBR) at angular scales near 1°[1]. We used the University of California at Santa Barbara Advanced Cosmic Microwave Explorer and a wide band 30 GHz High Electron Mobility Transistor (HEMT) amplifier to gather data. The data presented here represent 64 of the total of 500 hours acquired with this system during the 1990-91 season. The data have a statistical error of 13.5 μK per pixel, the smallest error bars of any data set of this type to date. The data contain a significant signal with a maximum likelihood $\Delta T/T = 8.6 \times 10^{-6}$, where the model sky has a Gaussian auto-correlation function with a coherence angle of 1.5°. The amplitude of this signal appears to fall with increasing frequency, but is less than 2σ away from the spectrum expected of primordial fluctuations in the CBR. If the source of the fluctuations is primordial, then the data are approximately consistent with Cold Dark Matter (CDM) scenarios[2].

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THE INSTRUMENT

The University of California at Santa Barbara Advanced Cosmic Microwave Explorer (ACME)[3] is a one meter F1 off axis Gregorian telescope. The off axis Gregorian design was used with a greatly under-illuminated primary to create a 1.5° beam with very low sidelobes. The ellipsoidal secondary oscillated sinusoidally at 8 Hz, resulting in maximum sensitivity to signals separated by 2.1°.

We used a cryogenic HEMT amplifier[3], operating from 25 to 35 GHz. This wide band, coupled with the very low noise temperature of 30 K, gives a theoretical noise of 0.6 mK in one second. We achieved a noise of 1 mK$\sqrt{\text{sec}}$ on the sky. The full band is sub-divided into 4 bands of nominal 2.5 GHz bandwidths. We used these sub-bands to flatten the gain of the amplifier for the largest effective bandwidth. In addition, these bands gave limited spectral resolution to distinguish foreground sources.

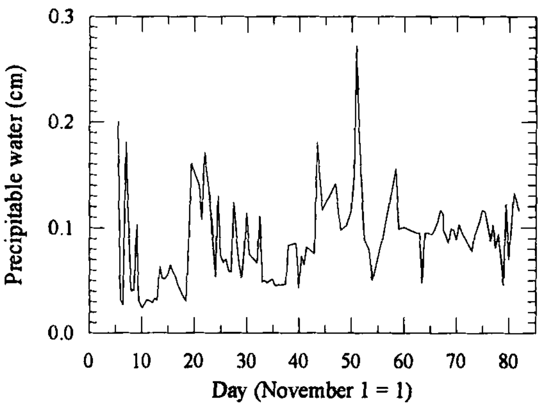

Figure 1: precipitable water for November, December, and January, 1990-91.

THE SITE

It is well known that the primary advantage of South Pole observing is the high altitude and very cold, dry air. Precipitable water was below 1 mm for most of the data taking period (see figure 1). This offered many sections of continuous high stability data that were longer than 24 hours. Perhaps less well known are the geometrical advantages afforded South Pole observers. The site eliminates the problems of sky rotation that are common to most other measurements, significantly simplifying the analysis. The long, continuous integrations allow checks of systematics not available on experiments of shorter duration.

OBSERVATION STRATEGY

We used the 408 MHz Haslam map and the 100 μ IRAS map to determine a region relatively free from synchrotron and dust contamination. In this region we acquired 500 hours of data[4]. The data are separated into 8 data sets at 6 separate elevations and centered on three distinct right ascensions. Each of these data sets consists of a set of sky temperature differences separated by 2.1°. Pointing and calibration were verified using the moon, galactic center, and Large Magellanic Cloud. Calibrations were performed approximately once daily by inserting a black body target into the beam.

The data presented here consist of 13 sky temperature differences, centered at 2^h right ascension. All points are at declination -63°. The data were acquired as 526 single scans, performed over a period of 64 hours.

DATA REDUCTION

We removed data acquired while the telescope was not pointed at the desired right ascension and declination, data taken during calibrations, errors in the beam modulation, and other errors. We then removed an offset and linear drift in time from each scan. An rms and average were calculated for each 20 point bin. At this point we removed scans that showed excess structure due to atmospheric emission. This resulted in removal of 5-

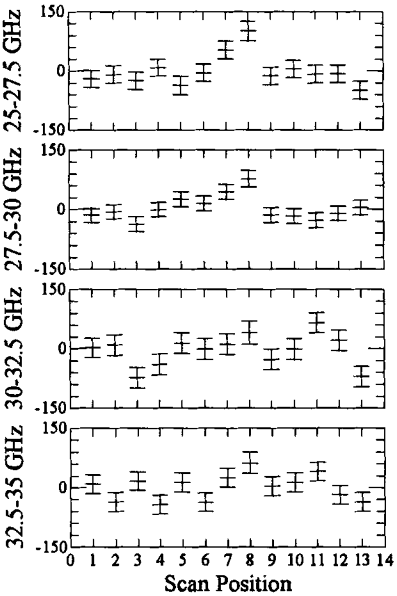

Figure 2a: Single band data

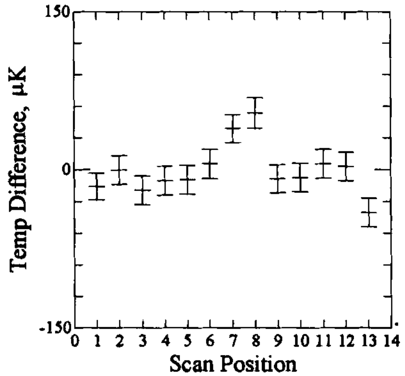

Figure 2b: Full band data

Figure 2: Sky temperature differences for points separated by 2.1°

10% of the scans, depending on the band. No cuts based solely on the rms of a complete scan were done. Data closer than 65° to the sun were determined from other data to be potentially contaminated, and to be conservative they were removed. The averages, weighted by their individual variances, were added together. The results at this point are shown in figure 2a. Data from the four channels were combined to create the final data set shown in figure 2b. The per-pixel error bars are 13.5 μK, the lowest of any data set of this type published to date. The data show a clear detection, most of which is confined to points 7 and 8.

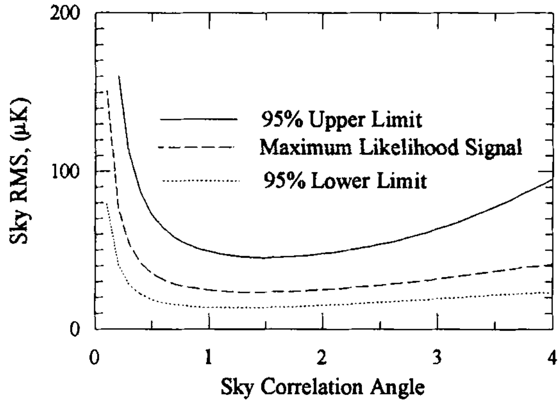

Figure 3: upper and lower limits and maximum likelihood detection using an assumed Gaussian sky autocorrelation function

ANALYSIS AND RESULTS

For comparison to other results, we chose to compute limits using a Gaussian correlated sky. Figure 3 shows the limits and maximum likelihood detection as a function of the sky correlation angle. The data set a 95% confidence upper limit of $\Delta T/T \leq 1.6 \times 10^{-5}$. The maximum to the likelihood is at $\Delta T/T = 8.6 \times 10^{-6}$, which is approximately what one would expect from most standard CDM theories. However, it is not clear from the data whether the signal is CBR or a foreground contaminant. The upper limit is consistent with the previously published one of Gaier et al.[5] The data were also reduced in azimuthal coordinates, and no contamination was found at the level of the observed signal.

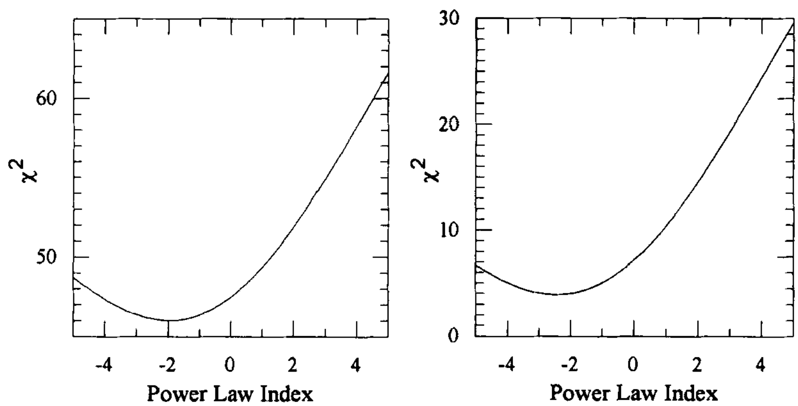

Figure 4a: full 13 point data set

Figure 4b: points 7 and 8 only

Figure 4: χ^2 of residuals of best fit power law spectrum, for the entire data set and points 7 and 8 separately

The four channels allowed a limited amount of spectral analysis. A best fit signal, assumed to be a power law, $T \propto \nu^{\beta}$, was found to have a spectral index β of -2 +1.5, -1.75 (see figure 4a). An identical analysis was applied to points 7 and 8, where most of the signal detected lies. The remaining eleven points defined a baseline, which we subtracted. This yielded an index of -2.5 +1.3, -1.5 (see figure 4b). A thermal spectrum, expected for most CBR anisotropies, would have an index of 0 if the effects of changing beam size with increasing frequency are ignored.

If the signal in points 7 and 8 is hypothesized to be foreground, which the data only suggest and do not prove, and therefore these points are eliminated from the data set, the upper limit set by the remaining points is $\Delta T/T \leq 8 \times 10^{-6}$.

CONCLUSION

We have presented further results of data taken at the Amundsen-Scott South Pole station. Using the high sensitivity of a HEMT amplifier and the long integration times available for Antarctic observations, we obtained an extremely sensitive data set, with per pixel 1σ errors of 13.5 μK. The thirteen data points we presented here set an upper limit of $\Delta T/T \leq 1.6 \times 10^{-5}$. The data show a clear detection at the level of 8.6×10^{-6}, a value consistent with CDM theories. However, the source of the signal is not uniquely identified solely using its spectrum. The spectrum is more suggestive of emission from bremstralung or synchrotron processes than it is of a CBR signal. If points 7 and 8 are hypothesized to be contaminated and removed, the result is an upper limit of $\Delta T/T \leq 8 \times 10^{-6}$.

Because we are close to being able to distinguish between the these possibilities, more data are needed, and we plan a return to the South Pole in late 1993. Work is also continuing to analyze the entire data set in the context of structure formation theories.

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