COSMIC BACKGROUND ANISOTROPY STUDIES AT 10° ANGULAR SCALES WITH A HEMT RADIOMETER

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ABSTRACT

An expedition to the Amundsen-Scott South Pole Station was recently mounted to measure medium to large angular scale fluctuations in the cosmic background radiation (CBR) at 15 and 25 GHz. Preliminary results are reported in this paper. No fluctuations have been detected as yet and data analysis is proceeding using likelihood ratio tests to set upper limits of $\Delta T/T$ for models which may be constrained by this experiment.

INTRODUCTION

The cosmic background radiation (CBR) is presently believed to be highly red-shifted photons from the era of matter-radiation decoupling when the universe was at a temperature $\approx 4000K$. The visible universe is highly non-uniform with density fluctuations in the form of galaxies and galactic clusters, and the CBR should contain information about density perturbations in the early universe which led to the inhomogeneities observed in the present day matter universe. CBR photons have been travelling unimpeded since the time of decoupling and so serve as an excellent measure of conditions of the universe at the time of decoupling.

To date measurements of angular fluctuations of the CBR have shown that the background is highly uniform. The only definite exception to this homogeneity is a dipole anisotropy of amplitude 3 mK which is believed to be the result of the peculiar motion of our galaxy and not intrinsic to the CBR. Recently two groups have reported controversial detections of anisotropy in the CBR. With the exception of these results, the CBR has been measured to have a temperature 2.75 K which is uniform to $\Delta T/T < 10^{-4}$. Our experiment is most sensitive to fluctuations at angular scales of 4-20 deg and is capable of measuring fluctuations of $\Delta T/T < 10^{-5}$.

OBSERVING STRATEGY AND THE INSTRUMENT

Each system in the radiometer uses low noise cryogenic HEMT amplifiers and a cryogenic latching Dicke-switch to achieve a total system noise of $\approx 3 - 4mK/\sqrt{Hz}$. Cryogenic requirements for the instrument were satisfied with a closed-cycle helium gas refrigerator, which only needs electricity to operate, allowing extended runs without liquid cryogens. Figure 1 is the schematic of the instrument.

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When making ground based measurements, the atmosphere can be a formidable problem to deal with adding unwanted noise and signal. For this reason we chose to make our measurement from the Amundsen-Scott South Pole Station. By making zenith scans atmospheric temperatures (radiometric) of $2.78 \pm .35K$ at 15 GHz and $5.5 \pm .25K$ at 25 GHz were measured. Figure 2 shows these scans and the appropriate fit. In addition to choice of site, observing techniques can reduce the effects of atmospherics. We employ in our system, a slow second chop or "wobble" which measures differences on shorter time scales making the system less prone to long term instabilities which include the atmosphere. Figure 3 shows the FFT of a data scan of a single sky position. The 1/f knee occurs at about 400 sec. Subtraction of these chop states also makes the experiment less sensitive to atmospheric gradients.

We chose to observe using drift scans at a few elevations. This involves double-chopping at a given azimuth and letting the earth's rotation change the field of view with time. Because the entire sky is not free of contaminating signals (the galaxy and sun), the instrument was periodically slewed to a different azimuth to increase the amount of integration time at sky positions free from galactic emission and far from the sun. Unfortunately this technique had the effect of causing baseline offsets of $\approx < 1mK$ at different azimuths. These offsets are stable for a given azimuth set position and can be attributed to elevation deviations as a function of azimuth position. In analyzing the data, we only consider drift scans which pass through the galactic plane allowing us to determine offsets with great accuracy. This galaxy information is also useful for frequency scaling of galactic emissions between our two frequencies, which will hopefully increase our effective sky coverage by allowing us to subtract out known galactic sources.
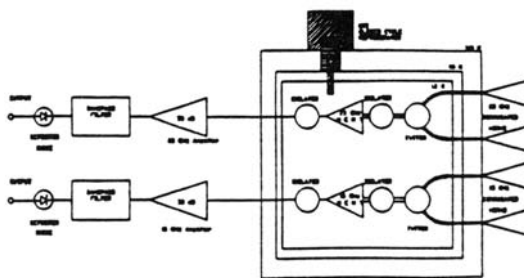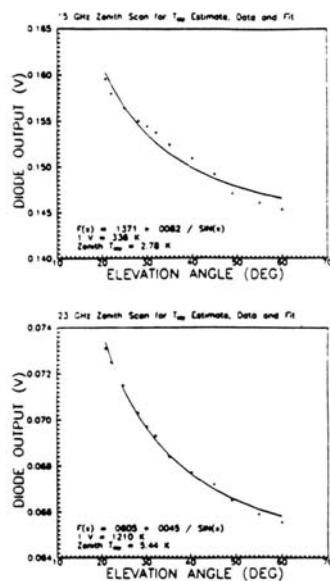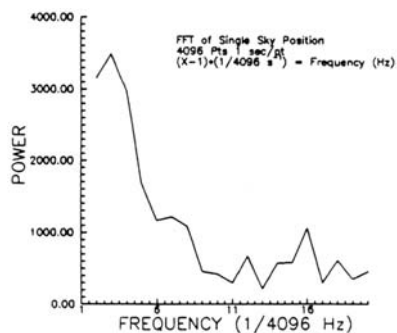

Fig. 1

Fig. 2

Fig. 3

RESULTS

In **Figure 4.** data from scans at $\delta = -60$ are displayed. The data have been binned, double-subtracted, and filtered for display purposes. The only data fitting performed is subtraction of scan offsets. The expected galactic contribution at 25 GHz is also displayed. This galactic contribution is modeled from a 408 MHz map with scaling indices of $\nu^{-2.7}$ and $\nu^{-2.1}$ for galactic synchrotron and HII emissions respectively. These values are not expected to be accurate over such a large range of frequencies and for positions off of the plane. We have not yet analyzed our data at 15 GHz to determine optimum scaling parameters.

Simple statistical tests have been performed on the 25 GHz data. Figure 5 shows a segment of the data with galaxy and dipole components as well as a small residual linear trend removed. The data are grouped into 1/3 beam width bins and slightly oversampled. The reduced χ^2 of this set is about .85 for 14 degrees of freedom or about 60 percent consistent with random noise with this σ. These results are preliminary.
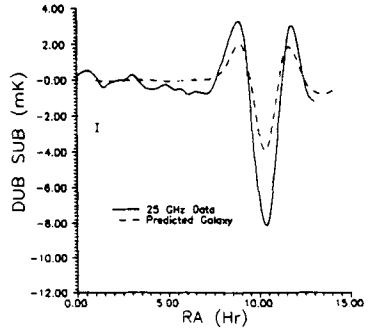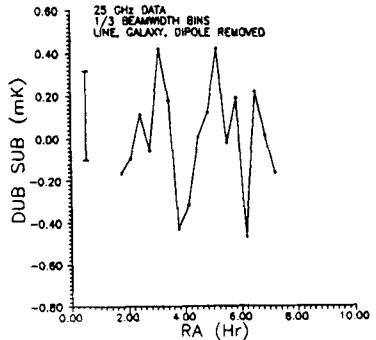

Fig. 4

Fig. 5

CONCLUSION

We have described an instrument designed to make sensitive measurements of the CBR on 10° angular scales. The instrument was operated at the South Pole during the austral summer of 1988-89. Preliminary results reveal no obvious intrinsic structure. The sensitivity was limited by observation time not sytematics.

ACKNOWLEDGEMENTS

REFERENCES

1. F. Melchiorri, B. O. Melchiorri, C. Ceccarelli, and L. Pietranera, *Ap. J.*, **250**, L1 (1981).

2. R. D. Davies, R. Watson, E. J. Daintree, J. Hopkins, A. N. Lasenby, J. Beckman, J. Sanchez-Almeida, and R. Rebolo, *Nature*, **326**, 6112 (1987).

3. C. G. T. Haslam, C. J. Salter, H. Stoffel, and W. E. Wilson, *Astron. Astrophys. Suppl.*, **47**, 1 (1982).