COSMIC MICROWAVE BACKGROUND FLUCTUATION SEARCHES ON 5° to 10° SCALES

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ABSTRACT. Deep observations of the cosmic microwave background (CMB) have been made at 10 GHz with beamwidths of 5° and 8° using a triple-beam technique, which greatly reduces atmospheric effects. Significant signals are detected with an rms of $\Delta T/T \sim 4\times10^{-5}$. These signals could be intrinsic to the CMB and are providing fundamental information about galaxy formation in the early universe. A component of this 10 GHz emission may be coming from galactic synchrotron features. This galactic contribution will be elucidated in forthcoming 15 and 30 GHz observations.

1. INTRODUCTION

We review the current status of the search for fluctuations in the CMB by the group at Jodrell Bank, by our collaborators at the Instituto de Astrofisica de Canarias in Tenerife, and by the Mullard Radio Astronomy Observatory in Cambridge. These searches began with observations at Jodrell Bank, essentially a sea-level site, using the Mk II telescope at 5 GHz to set limits on fluctuations on angular scales in the range of 10 to 60′ (Lasenby and Davies 1983). At this frequency and resolution, the fluctuation limits are set by galactic emission and extragalactic sources. Two further series of 5 GHz observations are continuing at Jodrell Bank, both employing interferometry, which reduces the degrading effects of the atmosphere. The first uses the Lovell-MkII broad-band interferometer to study structure on scales of 18 to 60 ″. The second uses a short-baseline interferometer to investigate structure on scales of ~2°; this series is an important adjunct to the high-frequency program described below, as it provides a direct measure of the galactic radio source contributions. In its own right, this experiment has already set limits of $\Delta T/T < 10^{-4}$ on scales of 2°.

Further significant progress in setting limits on fluctuations on the cosmologically important degree scales necessitated a move to a high, dry site (Teide Observatory, Tenerife, at 2300 m) with higher frequency equipment. Data taken at 10.4 GHz in beamswitching mode on an 8° scale showed structure. This observation has been followed up with an independent experiment on a 5° scale.

2. RESULTS OF 10 GHz BEAMSWITCHING OBSERVATIONS

The 8° experiment, now complete, included 24 h RA observations at declinations in the range of −15° to 45°, with deep observations at Dec = 0° and 40°. An analysis of a section of the Dec = 40° deep survey showed significant fluctuations at $\Delta T/T = 3.7\times10^{-5}$ (Davies et al. 1987). This result was confirmed by observations at adjacent declinations of 35° and 45°.

As a result of these positive detections of structure in the background, the observing system was substantially modified to give a beamwidth of 5°. Observations were concentrated in the Dec = −5°, −2.5°, 0°, 2.5°, 5°, 35°, 37.5°, 40°, 42.5°, and 45°. Mapping of sensitivity

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comparable to that with the 8° beam was achieved. Structure was found at similar positions, thus confirming the original detection.

A third beamswitching experiment used a 3° beam provided by a 0.9 m paraboloid, which again was wagged to give the triple-beam response that has been so successful at minimizing atmospheric effects when observing with the 8° and 5° equipment.

3. IMPLICATIONS OF THE RESULTS

The major result of the 8° and 5° experiments is the detection of significant sky fluctuations with an rms value of $\Delta T/T \sim 4\times10^{-5}$. The most clearly detected feature lies at RA $= 15^h$, Dec = 40°, although other weaker features have been found. The fundamental question raised by these results is whether the fluctuations discovered here are intrinsic to the CMB or whether they originate in the foreground and are composed of galactic emission and/or the sum of extragalactic sources.

The synchrotron galactic contribution can be estimated from the published surveys at 408 and 1400 MHz. With a brightness temperature spectral index of −3.0, the expected fluctuations are ~50 μK. Although this amplitude approaches that observed (100 μK rms), the 10 GHz observations do not match the predictions from lower frequencies. It is possible, of course, that the spectral index varies with angle so that no match would be expected. However, our 5 GHz data show no emission with an amplitude sufficient to explain the 10 GHz signals.

The thermal emission from high-latitude galactic HII regions will also contribute to the galactic background. The faint Hα emission of the type detected by Reynolds (1984) may amount to as much as 20–30 μK in an 8° beam at 10 GHz (Davies 1989, in preparation).

The other contribution to observed background fluctuations is the sum of extragalactic radio sources. From the known log N-log S distributions at 5 and 10 GHz, we estimate that the rms fluctuation in an 8° beam is 20 μK.

The astronomical implications of our 10 GHz results to the understanding of the origin of the CMB fluctuation are considerable. Even on the assumption that the detected signal is galactic in origin and thereby provides an upper limit to the CMB fluctuations at $\Delta T/T \sim 3\times10^{-5}$, adiabatic scenarios of galaxy formation with baryonic densities less than the closure density are ruled out, as are a range of isocurvature scenarios. On the other hand, Cold Dark Matter (CDM) scenarios can be accommodated within this upper limit. However, if fluctuations detected are indeed primordial CMB fluctuations, then the CDM scenario for galaxy formation is ruled out when this result is taken in conjunction with the observations of large-scale streaming motions in the universe (Staveley-Smith and Davies 1989).

Of highest priority is the extension of this work to higher frequencies where the galactic and radio source contributions will be less. We are now preparing equipment at 15 and 30 GHz.

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