

NEW MULTIFREQUENCY MEASUREMENTS OF THE SPECTRUM OF THE COSMIC BACKGROUND RADIATION

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ABSTRACT

New measurements of the Cosmic Background Radiation temperature at 12 cm, 6.3 cm, 3 cm, 0.9 cm and 0.3 cm have been made in July 1982 from the White Mountain High Altitude Research Station. The results are presented and the existence of spectral distortions discussed.

KEYWORDS

Cosmic Background Radiation; Spectral Distortions; 3K Blackbody; Primordial perturbations; Cosmology

Small departures of the spectrum of the cosmic background radiation (CBR) from an exactly Planckian shape may be expected for a variety of physical reasons. The detection of these small departures and the determination of their amplitude and spectral characteristics, particularly in the Rayleigh-Jeans region, would be extremely informative on the evolution of primordial perturbations responsible for the observed structure of the universe. On the other hand, previous measurements in the low frequency range ($\lambda > 0.35$ cm), all made more than 15 years ago, employed quite different techniques and are of varying quality; thus they are not adequate to set very stringent limits on distortions. In addition evidence for a non-thermal spectrum at millimeter and submillimeter wavelengths has been reported by Woody and Richards (1981); improved work at longer wavelengths would then also allow to perform a critical test of the various explanations proposed for this result. New observations have been therefore carried out by our collaboration (Smoot and colleagues, 1983).

An accurate measurement of the temperature of the CBR requires careful accounting of all radiation entering the antennas and an understanding of all systematic effects. These requirements dictated the design of the experiment. All radiometers use Dicke-switched superheterodyne receivers with low sidelobe corrugated antennas. The antennas are all of the same design and are nearly scaled duplicates of each other. All five radiometers used the same cold load reference for calibration. They were mounted in separate movable carts. The carts were able to roll along a 20 meter length of rails. At the center of the rails, and suspended below them, was the liquid helium cold load calibrator. When a radiometer was to be calibrated, it was positioned directly above the calibrator. One antenna of the radiometer was rotated to a straight down orientation and mated to the top of the calibrator with a mechanical interface.

Data were taken on the nights of July 5th and July 6th 1982, from the White

Mountain High Altitude Research Station, of the University of California. Even at this elevation, (3800 meters above sea level), the atmosphere is the largest source of extraneous emission, which must be subtracted from the desired signal. For the two shortest wavelengths (0.3 and 0.9 cm) radiometers, the atmospheric emission is more intense than the cosmic background radiation. This emission was measured by performing zenith scans, by moving large reflectors which directed the antenna beams toward positions in the sky at different zenith angles. In the three long wavelength (3.0, 6.3, 12 cm) radiometers the antennas themselves were directed toward different zenith angles. Because the atmosphere is a large source of systematic errors at all wavelengths, one radiometer, operating at 3.2 cm wavelength, was dedicated to measuring the atmospheric emission very accurately, while the other instruments measured the cosmic background temperature. It did this in an automated fashion using an elliptical reflector to make a nine position zenith scan.

Other sources of background radiation must either be suppressed or measured and subtracted out. These include emission from galactic synchrotron and HII sources, and from the ground and other nearby objects. In addition, many other systematic effects, including magnetic field sensitivity and gravitational torques on radiometer components, must be taken into account. Extreme care and testing reduced these effects to minimal levels. Figure 1 shows the values of thermodynamic temperature we got. They are in good agreement with the previous ones as summarized by Weiss (1980); at the same time the accuracy of our data in the Rayleigh-Jeans region is, on the average, a factor of about 2 higher. In addition, because we made measurements of the spectrum at five wavelengths at the same time, with similar radiometers, a single liquid helium calibrator and simultaneous monitoring of the atmospheric emission, the magnitude of many systematic errors is substantially reduced.

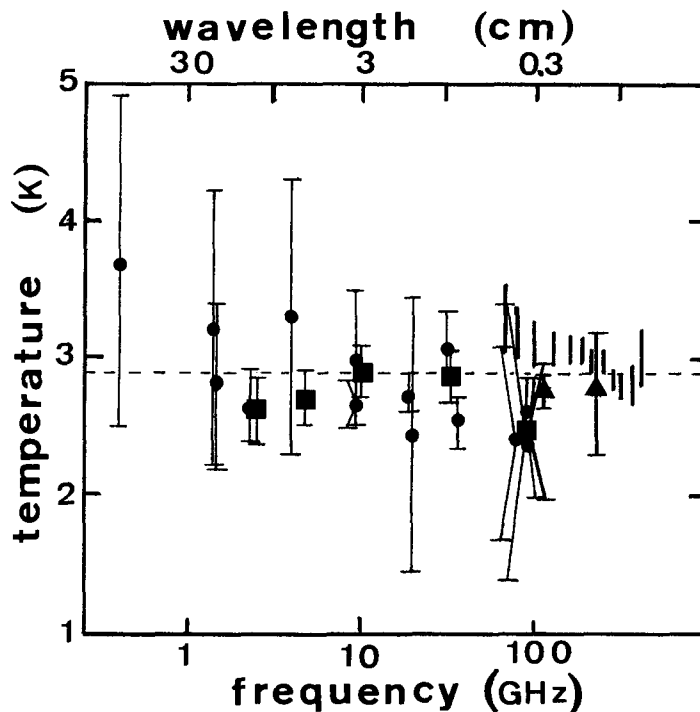


Fig. 1. Measured Values of the Thermodynamic Temperature of the CBR
 ● previous ground based data, (see Weiss, 1980); ■ present data
 ▲ Cyanogen data, ||| Woody and Richards, (1981) data

A standard statistical analysis yields:

- Best fit blackbody temperature

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|-------------------------------|-----------------------|
| our data only | $T = 2.78 \pm 0.10$ K |
| all ground based measurements | $T = 2.74 \pm 0.05$ K |
| all available data | $T = 2.90 \pm 0.03$ K |

- Fit to a Bose-Einstein spectrum with chemical potential μ :

| | | | | |
|---------------------------------|--------------------------|-------------------------------------|------------------------------|---------------------------------------|
| ground based measurements only: | $T = (2.77 \pm 0.06)$ K, | $\mu = 1.1 \cdot 10^{-3}$ | $(+3.0, -1.1) \cdot 10^{-3}$ | $(\Omega = 0.1)$ |
| | $T = (2.77 \pm 0.06)$ K, | $\mu \leq 7 \cdot 10^{-3}$ | $(\Omega = 1)$ | $(\Omega = \text{density parameter})$ |
| all available data | $T = (2.92 \pm 0.03)$ K, | $\mu = 5.2 \cdot 10^{-3}$ | $(+3.0, -2.8) \cdot 10^{-3}$ | $(\Omega = 0.1)$ |
| | $T = (2.92 \pm 0.03)$ K, | $\mu = (1.4 \pm 0.9) \cdot 10^{-2}$ | $(\Omega = 1)$ | |

- Fit to a comptonized spectrum (all data)

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|--|-----------------------|--|
| $T = (2.90 \pm 0.03)$ K, | $u = 2 \cdot 10^{-3}$ | $(+7 \cdot 10^{-3}, -2 \cdot 10^{-3})$ |
| $u = \text{comptonization parameter.}$ | | |

In summary there is no significant evidence of deviations from a Planck spectrum in the Rayleigh-Jeans region. Ground based measurements, however, yield a brightness temperature lower than that reported by Woody and Richards at the peak, the difference being significant at about 3σ level. If such difference is interpreted as an excess at the peak the data entail: $\mu \leq 4 \cdot 10^{-3}$ ($\Omega = 0.1$) or $\mu \leq 7 \cdot 10^{-3}$ ($\Omega = 1$) and $u \leq 0.01$ (1σ limit). Alternatively part of the difference may be due to a non-zero chemical potential.

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