MEASUREMENTS OF THE COSMIC BACKGROUND RADIATION SPECTRUM

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Abstract: Measurements of the Cosmic Background Radiation (CBR) temperature have been performed at five wavelengths ranging from 0.33 to 12 cm. The results give a weighted average of 2.72 $\pm$ 0.04 K in agreement with the most recent data at higher frequencies and constrain possible Compton distorsions to less than 5%.

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The CBR spectrum, after its discovery by Penzias and Wilson (1965), was measured in a wide interval of wavelengths ranging from the decametric to the millimetric region.

At the end of the 1970's the observations were in agreement with a black body spectrum of about 2.7 K with a possible excess at its peak where the temperature was measured to be 2.96 K (Woody and Richards, 1979). Theoretical speculations were proposed explaining the apparent departure from a Planckian spectrum at the peak (Negroponte et al., 1981; Aiello et al., 1980).

On the other hand, a substantial body of theoretical work as also available supporting possible distortions of a Planckian spectrum (Illarionov and Sunyaev, 1975; Danese and De Zotti, 1977; Danese and De Zotti, 1982; Sunyaev and

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Zel'dovich, 1970). In a Compton-like distortion, for instance, any release of energy in the early universe ($4x10^4 < z < 10^6$) will result in spectral distortion that makes the CBR cooler in the Rayleigh-Jeans region and hotter in the Wien region; the maximum decrease is expected in the range $\lambda = 3$-10 cm. The detection of such distortions may give information on the epoch of the energy release, the density of the universe and possibly the mechanism that generated the energy release.

Unfortunately the experimental situation was such that, although the average CBR temperature was known with reasonable accuracy, individual measurements in the Rayleigh-Jeans region had much smaller associated accuracies (errors up to $\sim$ 30%) large enough to mask any of the predicted distorsions.

Therefore the need for more accurate measurements suggested a program to measure the low frequency spectrum of the CBR. The new observation runs were performed in July 1982 and September 1983 from the University of California's White Mountain Research Station at 3800 m a.s.l.. These runs involved a collaboration among the authors and institutions mentioned on the title page. The goal was to measure the temperature of the CBR at several wavelengths to an accuracy better than 5% and to eliminate sources of systematic errors.

Five radiometers were used operating at wavelengths 0.33, 0.91, 3.0, 6.3 and 12.0 cm; an additional radiometer working at 3.2 cm was used to monitor atmospheric emission (Smoot et al., 1985; Mandolesi et al., 1984; Mandolesi et al., 1986; Sironi et al., 1984; Sironi et al., 1986; De Amici et al., 1984; De Amici et al., 1985; Partridge et al., 1984; Witebsky et al., 1986).

Table 1 gives our measured values of the CBR antenna temperature $T_{A,CBR}$ and the corresponding thermodynamic temperature T_{CBR}. The weighted average of all our measurements is 2.72 ± 0.04 K (Smoot et al., 1983; Smoot et al., 1985; Partridge et al., 1985). This value and the individual measurements agree well with the interstellar CN data (Meyer and Jura, 1985; Crane et al., 1986) and with the new millimetric ballon borne observations (Peterson et al., 1985).

It is remarkable that all the most recent and accurate results from several types of experiment, involving techniques as different as ground based microwave observations and ballon borne bolometric infrared measurements and UV detections of interstellar CN lines, are now consistent with a Planckian spectrum for the CBR with a temperature of 2.72 ± 0.02 K. In particular the earlier bolometric result of Woody and Richards (1979) has now been revised and the new experimental result (Peterson et al., 1985) is consistent with a black body spectrum of temperature 2.78 ± 0.11 K.

The analysis of the fit of the data to a pure black body spectrum over a wavelength range of about 100 restricts the existence of distortions due to energy release processes in the early universe to 5%. In particular a Bose-Einstein distortion must have a chemical potential $\mu_o < 10^{-3}$ if the density of baryons is high ($\Omega_b = 1.0$), and $< 2\text{x}10^{-3}$ in the more realistic case with $\Omega_b = 0.1$; both values are 1σ limits. Our results also limit Compton distorsion: we find the Compton distorsion parameter $Y < 10^{-2}$. In turn, these results limit the energy release by cosmological processes anywhere in the redshift interval $10\text{-}10^6$ to 3 - 4% of the energy in the cosmic background.

In the future, the greatest improvement in the determination of the nature of the CBR spectrum distorting processes should come from high accuracy absolute measurements as well as from high sensitivity anisotropy measurements in the millimeter and submillimeter regions in satellite borne experiments.

Table 1 - Results of measurements of the CBR (in K) of the White Mountain Collaboration

Wavelength (cm)	Number of Observations	$T_{A,CBR}$	T_{CBR} Thermodynamic	Combined Results
12.0	6	2.48 ± 0.24	2.54 ± 0.24	2.77 ± 0.13
	18	2.81 ± 0.15	2.87 ± 0.16	
6.3	5	2.63 ± 0.21	2.73 ± 0.22	2.70 ± 0.07
	38	2.59 ± 0.07	2.70 ± 0.07	
3.0	82	2.68 ± 0.17	2.91 ± 0.17	2.75 ± 0.08
	59	2.41 ± 0.14	2.64 ± 0.14	
0.91	21	2.10 ± 0.20	2.82 ± 0.21	2.81 ± 0.12
	32	2.09 ± 0.13	2.81 ± 0.14	
0.33	29	1.00 ± 0.57	2.58 + 0.68 - 0.79	2.57 ± 0.12
	49	0.99 ± 0.09	2.57 ± 0.12	

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