Table I. Potential energy of O^{16} for Yale potential.

State	nl	NL	Matrix element First order (MeV)	Second order (MeV)	Weight factor	Contribution to the potential energy (MeV)
$^3S_1$	00	00	−2.02	−6.98	3	−27.0
$^3S_1$	00	01	−2.02	−6.74	9	−78.8
$^3S_1$	00	02	−2.02	−6.53	15/2	−64.1
$^3S_1$	00	10	−2.02	−6.57	$\frac{3}{2}$	−12.9
$^3S_1$	10	00	−0.66	−6.97	$\frac{3}{2}$	−11.4
$^1S_0$	00	00	−8.03	⋯	3	−24.1
$^1S_0$	00	01	−8.03	⋯	9	−72.3
$^1S_0$	00	02	−8.03	⋯	15/2	−60.2
$^1S_0$	00	10	−8.03	⋯	$\frac{3}{2}$	−12.0
$^1S_0$	10	00	−7.24	⋯	$\frac{3}{2}$	−10.8
$^1P_1$	01	00	4.86	⋯	6	+24.2
$^3P_0$	01	00	−1.63	⋯	6	−9.8
$^3P_1$	01	00	2.70	⋯	18	48.6
$^3P_2$	01	00	−0.84	⋯	30	−25.2
$^1D_2$	02	00	−0.50	⋯	15/2	−3.8
$^3D_1$	02	00	1.08	⋯	$\frac{3}{2}$	1.6
$^3D_2$	02	00	−2.01	⋯	$\frac{5}{2}$	−5.0
$^3D_3$	02	00	0.07	⋯	$\frac{7}{2}$	0.2
					Total =	−337.8

about 6.5 MeV per particle after correcting for the Coulomb energy and the center-of-mass motion. Results of Hartree-Fock calculations using the harmonic-oscillator basis will be reported shortly as well as further calculational details. We want to emphasize at this stage that in the framework of our theory we have already obtained reasonable values for the binding energy, spin-orbit splittings, and the p-shell effective interaction.

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COSMIC BACKGROUND RADIATION AT 3.2 cm – SUPPORT FOR COSMIC BLACK-BODY RADIATION*

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Dicke *et al.*[1] have suggested that the universe may be filled with black-body radiation which originated at a time when the matter and radiation were in a hot, highly contracted, state – the primordial fireball. As the universe expanded, the cosmological red shift would have cooled the cosmic black-body radiation to the extent that one should now look for it in the microwave band. Concurrent with this suggestion, Penzias and Wilson[2] reported the discovery of an excess background radiation at a wavelength of 7.35 cm. The measurement of the spectrum of this new microwave background provides a severe test of the cosmic black-body-radiation hypothesis. This Letter reports a measurement of the microwave background at a wavelength of 3.2 cm; the flux found is that which would be emitted by a black body at 3.0 ± 0.5°K. A more complete description of the experiment will appear elsewhere.

Figure 1 shows a schematic diagram of the instrument. It is a Dicke-type radiometer[3] in which the receiver input is periodically switched between a horn antenna and a reference source (cold load). The output of the receiver at the switching frequency is synchronously detected and recorded. The record is a measure of the difference between the temperature of the reference source and the apparent temperature of the radiation collected by the antenna. The horn antenna is shielded to exclude radiation from the ground and has a main lobe half-angle (10 dB down) of 10°. The cold-load termination is immersed in liquid helium to es-

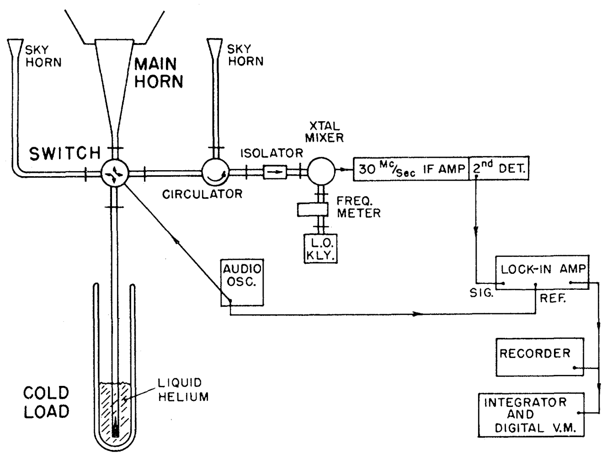

FIG. 1. The Princeton radiometer. The sky horns are simply a convenient means of getting cold terminations. The main horn is about 2 feet long and has an aperture of 9×10.

tablish a reference temperature, and the length of wave guide between the termination and the switch is kept short in order to minimize radiation from the wave-guide walls. The radiometer is calibrated by replacing the main horn antenna with a termination at room temperature.

With the antenna pointing at the zenith, the radiometer output, ΔT, is given by

$$\Delta T = T_{\mathrm{CL}} + T_{\mathrm{SW}} - [T_{\mathrm{HL}} + T_{\mathrm{ATM}} + T_{\mathrm{BG}}],$$

where T_{CL} is the apparent temperature of the radiation entering the switch from the cold load, T_{SW} is an instrumental asymmetry arising from unequal insertion losses in the two arms of the switch, T_{HL} is the apparent temperature of the radiation from the walls of the antenna (horn loss), T_{ATM} is the apparent temperature of the atmospheric radiation at 3.2 cm, and T_{BG} is the temperature of the background radiation at this wavelength. In order to determine T_{BG}, each of the other quantities in the equation must be measured. T_{CL} is determined by measuring the temperature distribution along the cold-load wave guide and computing the wall absorption and radiation, which is then added to 4.2°K. T_{SW} is measured periodically by interchanging the cold-load and antenna connections and taking the mean of the resulting ΔT's. T_{HL} is measured by heating the walls of the horn to a known temperature and measuring the increase of the wall radiation with the radiometer. T_{ATM} is measured by tipping the horn to various zenith angles and measuring the additional radiation resulting from the longer path through the atmosphere.[4]

The results of 11 runs made at Princeton are shown in Table I. Averaging the last column in the table gives $T_{\mathrm{BG}} = 3.0\pm0.5$°K, where the uncertainty represents the estimated limit of systematic error. The standard error of the mean of the 11 measurements of T_{BG} is ±0.06°K and this is a measure of the random errors in the result due to errors in measuring T_{SW}, T_{ATM}, and ΔT. Possible systemat-

Table I. The results of 11 runs with the Princeton radiometer. The final result is given in the text.

Run No.	Date	R.A.[a]	T_{CL} (°K)	T_{SW} (°K)	T_{HL} (°K)	T_{ATM} (°K)	ΔT (°K)	T_{BG} (°K)[b]
1[c]	9/29/65	14^h20^m	10.66 ±0.35[d]	−3.67 ±0.20[e]	1.12 ±0.15[d]	3.2 ±0.2[e]	−0.36 ±0.05[e]	3.07
2	10/31/65	23^h40^m	6.71	3.90	1.08	2.9	3.36	3.32
3	10/14/65	10^h10^m	6.66	3.51	1.09	3.2	3.03	2.89
4	10/19/65	15^h	6.90	3.91	1.11	3.1	3.62	3.02
5	10/19/65	18^h30^m	6.77	3.80	1.09	3.2	3.52	2.80
6	10/19/65	1^h	6.80	3.76	1.08	3.0	3.36	3.16
7	11/14/65	17^h	6.78	4.11	1.08	2.9	3.97	2.98
8	11/14/65	20^h30^m	6.98	4.20	1.08	2.9	4.48	2.76
9	11/15/65	18^h10^m	6.86	3.77	1.08	3.1	3.37	3.12
10	11/29/65	4^h20^m	6.82	3.67	1.07	2.9	3.78	2.78
11	12/1/65	19^h30^m	6.79	3.52	1.07	2.9	3.24	3.14

[a]Declination = +40°.

[b]Corrected for absorption in atmosphere and horn by multiplying by $[1+(T_{\mathrm{ATM}}+T_{\mathrm{HL}})/290°\mathrm{K}] \approx 1.013$.

[c]Run No. 1 was taken with a precision attenuator in series with the cold load and with switch connections reversed.

[d]Estimated limit of systematic error.

[e]Typical statistical standard deviation in measurement of one run.

ic errors stem from inaccurate knowledge of the wall radiation in the horn antenna and cold load. The error quoted for T_{HL} (see Table I) is the estimated limit of error as a result of uncertainties in the wall heating experiments mentioned above. The estimated limits of error in T_{CL} are based upon bench measurements of the cold-load wall losses at room temperature and at 77°K, and upon wall heating experiments similar to those employed to measure T_{HL}.

The result of this experiment is shown in Fig. 2 along with the results of Penzias and Wilson.[2] It is seen that the measurements to date of the microwave background are consistent with a cosmic black-body radiation temperature of 3°K. Also, the brightness of the microwave background is about 100 times greater than that expected by extrapolating long-wavelength measurements[5] of the galactic and extragalactic background. On the basis of the measurements at 7.35- and 3.2-cm wavelength, the spectral index (brightness = const $\times \lambda^{\alpha}$) of the microwave background is found to be $-2.4 \leq \alpha \leq -1.4$. This should be compared with $\alpha = -2.0$ for black-body radiation in this wavelength range, and with $0.5 \leq \alpha \leq 1.0$ for most nonthermal radio sources.[6,7] Thus the results of measurements of the microwave background at wavelengths of 7.35 and 3.2 cm lend support to the cosmic black-body radiation hypothesis and, at the very least, indicate a new source of cosmic microwaves.

The proposed cosmic black-body radiation is expected to be isotropic, and so T_{BG} was measured with the antenna pointing in various directions along the +40° celestial parallel (see column 3 in Table I). The results indicate that T_{BG} is the same in these directions to within ±10%. Isotropy measurements are continuing at Princeton.

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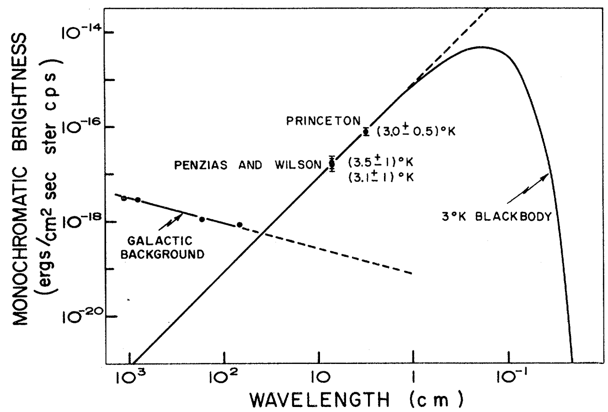

FIG. 2. Measurements to date of the microwave background radiation. The galactic radio background is extrapolated with a spectral index of $\alpha = 0.5$. This figure due to P. J. E. Peebles.

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