charge distributions in ^{152}Sm and ^{154}Sm. Fortunately, there are at least two rather direct approaches open to test our $E4$ moments. First, according to the trend of the $E4$ moments indicated by other results[11] and by calculations,[14] effects on the cross sections due to these moments should be small in the Yb-W region so that measurements there should agree with the calculations without any significant ambiguity due to $E4$ contributions. The second approach is to use slightly heavier ions in order to excite higher states. The size of the $E4$ effects relative to the multiple $E2$ processes goes down with increasing projectile charge, but up strongly with the spin of the excited state. For example, with Li projectiles (if breakup can be avoided) it should be possible to observe the decay of the 6^+ state, where $E4$ effects of about 50% are expected to occur in these samarium nuclei. Effects of around a factor of 2 should be observable in the excitation of the 8^+ state with boron projectiles. Although many other effects become important with heavier ions, making the interpretation more difficult, the expected $E4$ effects are large and this approach seems very promising. It is, therefore, unlikely that the present uncertainties about these $E4$ moments will persist for long.

We are indebted to Dr. K. Alder and Dr. R. Roesel for their calculations of the quantal effects relevant to these experiments. We have also benefitted from many discussions with, and help from, Dr. N. K. Glendenning. One of us (F.S.S.) wishes to acknowledge the hospitality of the physics section of the University of Munich during the preparation of this manuscript.

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Measurement of the Far-Infrared Background Radiation in the Night Sky*

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A rocket-borne radiometer measurement of background radiation in the spectral range from 6 to 0.08 mm has yielded a flux which corresponds to an equivalent backbody temperature of $3.1_{-2.0}^{+0.5}$ K.

A superfluid-helium–cooled rocket-borne far-infrared radiometer was launched from the Kauai Test Range Facility, Kauai, Hawaii, at 00:48 HST, 29 May 1971. Photometric measurements of the night-sky background were successfully made in two of the three spectral regions in which measurements were attempted. The present paper describes the results in the passband between approximately 6 and 0.8 mm. The results obtained in the other passband, centered at 100 μm, will be discussed in a separate publication.

The proposed 2.7-K blackbody cosmic radiation[1] has been the subject of many experimental investigations during the past six years. Many ground-based radiometric measurements supporting the existence of this background have been made on the long-wavelength side of the 2.7-K Planck curve, which has its peak at ~1.5 mm. Direct measurements near the peak and on the short-wavelength side are not possible, however, unless one makes the observations from an altitude above most of Earth's atmosphere. Observations of this kind have been made with rocket-borne radiometers[2] and a balloon-borne radiometer,[3] and have yielded background fluxes higher than that expected from an isotropic 2.7-K blackbody radiation, although the data from the balloon experiment are not inconsistent with a 3-K blackbody background upon which is superposed a strong line between 0.8 and 1.0 mm. Measurements of intensities of interstellar optical absorption lines[4] do not rule out such a nonthermal background.

The radiometer used in the present experiment was similar to an earlier one described in the literature.[5] Briefly, the instrument consisted of three separate bolometers, operated at a bath temperature of approximately 1.5 K, with different radiation filters for each bolometer. The transmittance of the 6–0.8-mm filter is shown in Fig. 1. The response of the Ge bolometer sensor itself is approximately flat over the passband. Since the radiometer was designed to provide information on the integrated background, the sensors had the relatively large cross-sectional area of 4×4 mm^2, and the cone optics had a field

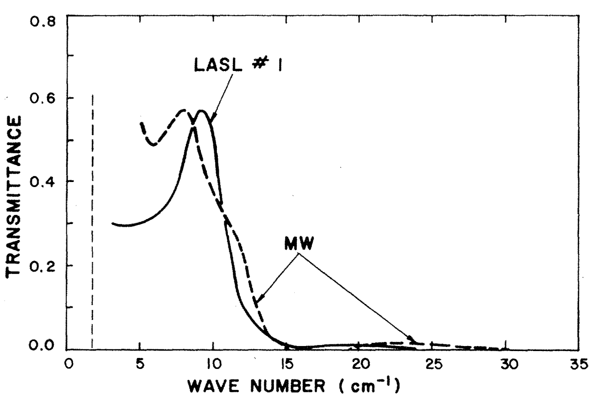

FIG. 1. Measured transmittance of radiation filter for bolometer 1, labeled LASL 1. A waveguide-imposed cutoff in the optics is indicated by the dashed line at 1.7 cm^{-1}. For comparison, the curve labeled MW shows the response of the radiometer flown by Muehlner and Weiss (Ref. 3) with filter SR-2 in position, normalized to the transmission of LASL filter 1 at its peak.

of view of about 0.1 sr. The entire optical system was normally cooled to superfluid-helium temperatures.

During launch, a decrease in gain of the bolometer amplifiers occurred. However, periodic on-board radiation calibrations[5] satisfactorily established their new (constant) gains during the remainder of the flight, and also verified the linearity of their response. At an altitude of 120 km the nose cone of the payload was ejected, after which the payload axis was tipped to 11° east of the zenith, and a scan of the night sky in an approximate north-south path was initiated. The scan dipped to about 65° from the zenith at each end, passing approximately through the galactic center toward the south end. A total of nearly two complete (round-trip) scans were performed. Data were accumulated starting at an altitude of 185 km, through apogee at 340 km, and down to 420 sec. Recovery of the payload was unsuccessful.

Figure 2(a) shows the temperature behavior at three key locations in the radiometer during the relevant portion of the flight. The bolometer bath temperature remained very close to the desired temperature of 1.5 K. The figure also shows that the upper part of the optical system warmed up as the radiometer scan approached the horizon, and also during the time when heat was supplied to the on-board calibrators, but when the scan passed close to the zenith the temperature of the upper optics dropped below 2 K.

The data from the bolometer are presented in Fig. 2(b) as a 10-sec moving average (plotted at 2-sec intervals) of the phase-lock–detected signal from the bolometer amplifier. The fluxes observed at closest approach to the horizon were somewhat higher than anticipated, probably because the radiation filters had more band-stop leakage than we had suspected. The data were averaged over the periods indicated in the figure, corresponding approximately to the central 50° section of each scan, where the bolometer signal appears to have bottomed out. A total observing time of 110 sec is included in this average. The average signal obtained is equivalent to that from an isotropic blackbody with a temperature of $3.1^{+0.5}_{-2.0}$ K. To present the results in another manner, we suppose that all the observed flux is in a spectral line near 9 cm^{-1}, where the peak transmission of the filter occurs. Corresponding to the upper limit of the radiation temperature of 3.6 K, this assumption yields a value of 1.5×10^{-10} W cm^{-2} sr^{-1} for the flux falling on the radiome-

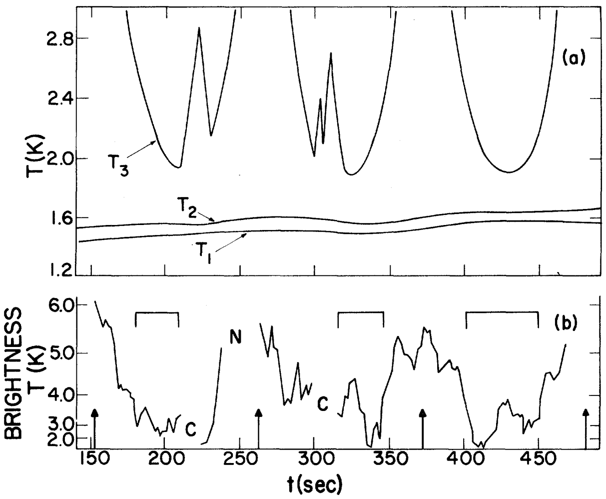

FIG. 2. (a) Temperature versus time after liftoff, as measured by thermometers 1, 2, and 3, located within the superfluid He bath, at the outside top surface of the superfluid He vessel (the location of the radiation choppers), and at the top of the entire optical system, respectively. Since the measurements begin to lose accuracy at about 3 K, T_3 is not plotted for higher temperatures; however, at the closest approaches of the scan to the horizon, T_3 reached approximately 5 K. (b) Signal from bolometer 1 medium-gain amplifier over the same portion of the flight. The ordinate relates the linear voltage signal to the equivalent blackbody background temperature. The calibrate signals, several times stronger than the background signals, have been eliminated from the data at locations C; the gap in the data marked by N corresponds to a period of excessive noise in the bolometer signal. Vertical arrows show the times of closest approach of the scan to the horizon, as obtained from gyro platform readout data. The inverted brackets indicate those periods of time over which signal levels were averaged to obtain the radiation temperature reported in the text. The structure of the signal during the bracketed periods is representative of the (somewhat high) noise level of this amplifier channel during flight; the rms noise for the 110 sec of data enclosed by the brackets is equivalent to an incident flux of 3×10^{-11} W cm^{-2} sr^{-1}.

ter. The above results are based upon calibration of the entire radiometer with a laboratory blackbody source held at various cryogenic temperatures,[5] combined with the measured filter transmittance.[6]

In prelaunch laboratory evaluations of the instrument, capping the optical system so that no net flux fell on the radiometer yielded a bolometer signal corresponding to a flux of $(0\pm2)\times10^{-11}$ W cm^{-2} sr^{-1}; there was no shift of this zero level on a long time basis. Other checks established that there was a short (<5-sec) recovery time of the radiometer output to this zero level after it had been subjected to large fluxes such as those falling on it at the closest approaches of the instrument scan to the horizon. In the actual flight configuration of the instrument package, there was an uncertainty of the zero level in this detector channel caused by cross talk between the bolometer and the chopper signals. This cross talk signal appeared with a phase of $85\pm5°$ from the true signal, introducing an uncertainty of $^{+0}_{-5}\times10^{-11}$ W cm^{-2} sr^{-1} in the zero level of this detector during flight. The bounds on the observed radiation temperature take into account this cross talk uncertainty, the rms radiometer noise, nonlinearities in the electronics and telemetry, and an estimated calibration uncertainty of 40%

The present result, consistent with a 2.7-K blackbody background, when compared to the results of Houck, Harwit, and collaborators,[2] suggests that there may be a strong source of background radiation between 12 and 23 cm^{-1}. There is a disagreement between our results and those of Muehlner and Weiss (MW).[3] Figure 1 shows that the high-frequency cutoffs of our radiometer and that of the radiometer of MW with filter SR-2 in position are quite similar. However, MW obtained a signal for this configuration corresponding to an 8-K blackbody background; allowance for the maximum possible radiative contribution from other sources[7] reduces this value to approximately 6 K. Clearly, additional experiments are required to establish the spectrum of the submillimeter background radiation.

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Determination of the Real Part of the ρ-Nucleon Forward Scattering Amplitude and the Relative ρ-ω Production Phase

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The real part of the ρ-nucleon forward scattering amplitude has been obtained by a measurement of the photoproduction of asymmetric electron-positron pairs from a carbon target. A determination of the relative ρ-ω production phase is also made. At a mean incident photon energy of 4 GeV the ratio of the real to the imaginary part of the ρ-nucleon amplitude is found to be -0.28 ± 0.12.

The idea that ρ-nucleon (ρN) forward scattering does not proceed by a purely absorbtive mechanism was suggested[1] as a possible explanation for the difference between the values of the ρ-photon coupling constant obtained from ρ-photon production data[2] and colliding beam experiments.[3] In order to bring the photoproduction value into reasonable agreement with colliding beam results, it was necessary to use a value of $\alpha_{\rho N}$, the ratio of the real to the imaginary part of the ρN forward scattering amplitude, as large as -0.45 at an incident energy of 5–6 GeV.

The present experiment was carried out primarily to measure the phase of the coherent ρN forward scattering amplitude by a direct method if vector dominance is assumed, using the process

$$\gamma + A \to A + \rho, \quad \rho \to e^+e^-,$$

where the resultant electron pairs are detected asymmetrically. In addition, the experiment will give an independent determination of the ρ-ω production phase previously measured with our symmetric configuration.[4]

In the invariant-mass region of the ρ meson, the amplitude for the photoproduction of electron pairs consists of contributions from the Bethe-Heitler (BH) process, the Compton process including ρ and ω mesons,[4,5] and possible incoherent processes. As a consequence of charge-conjugation invariance, the cross section arising from the interference between the BH and Compton amplitudes involves only electron pairs in which the electrons have unequal four-momenta. A measurement of asymmetric electron pairs, therefore, provides a means of obtaining the relative phase of these amplitudes, and hence, since the BH amplitude is real, the phases of the ρ-nucleus and ω-nucleus forward scattering amplitudes.

The differential BH-Compton interference cross section is written

$$\frac{d\sigma_I}{dp^+dp^-d\Omega^+d\Omega^-} = \frac{Z\alpha^{5/2}}{\pi^2}\frac{\epsilon^+\epsilon^-}{M}\frac{G_E(t)e^{-bt/2}}{t}\frac{1}{\gamma_\rho}\left(\frac{m_\rho}{m}\right)^2\left(\frac{d\sigma_{\gamma A}}{dt}\bigg|_{t=0}\right)^{1/2} K_I(p^+,p^-,\epsilon^+,\epsilon^-)$$
$$\times \mathrm{Re}\left\{ i\exp(i\varphi_{\rho A})\left[\frac{1}{m^2-m_\rho^2+im_\rho\Gamma_\rho(m^2)}+\left(\frac{\gamma_\rho}{\gamma_\omega}\right)^2\left(\frac{m_\omega}{m_\rho}\right)^2\frac{\exp(i\varphi_{\rho\omega})}{m^2-m_\omega^2+im_\omega\Gamma_\omega}\right]\right\},$$

where $\Gamma_\rho(m)$ has the usual Jackson[6] form and $K_I(p^+,p^-,\epsilon^+,\epsilon^-)$ is a kinematic factor. Also Z, M, and $G_E(t)$ are the respective nuclear charge, nuclear mass, and the electric form factor of the target; $\epsilon^\pm$ and $p^\pm$ are the energies and four-momenta of the pair electrons, respectively; t is the square of the four-momentum transfer to the nucleus; m_V and Γ_V are the mass and width of vector meson V; $em_V^2/2\gamma_V$ is the photon–vector-meson coupling constant; m_π is the pion mass and m is the invariant pair mass. The relationship between the phase angles $\varphi_{\rho A}$ and $\varphi_{\omega A}$ of the coherent ρ- and ω-nucleus amplitudes is $\varphi_{\omega A}=\varphi_{\rho A}+\varphi_{\rho\omega}$, where $\varphi_{\rho\omega}$ is the phase angle between the ρ and ω photoproduction amplitudes.