PRELIMINARY OBSERVATIONS OF THE FAR-INFRARED NIGHT-SKY BACKGROUND RADIATION

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We have carried out far-infrared rocket observations in the spectral range from 0.4 to 1.3 mm and have detected a flux of 5×10^{-9} W/cm^2 sr, with an uncertainty of a factor of 2. The flux is nearly two orders of magnitude greater than that to be expected from a 3°K black cosmic background in this spectral range; its equivalent blackbody temperature would correspond to $8.3°\mathrm{K}_{-1.3}^{+2.2}°\mathrm{K}$.

On 29 February 1968 an Aerobee rocket launched from the White Sands Missile Range, at about 8:30 MST, carried a liquid-helium-cooled telescope to an altitude of 170 km. Four different solid-state detectors were flown to span the spectral range from 5 μ to 1.3 mm. Copper-doped germanium and gallium-doped germanium photoconductors (with infrared filters to define three broad spectral bands) were used to cover the range 5-120 μ. The results obtained with these detectors (Houck and Harwit[1]) and a description of the cryogenically cooled telescope (Harwit, Houck, and Fuhrmann[2]) will be presented elsewhere.

In this Letter we wish only to present the results obtained with an n-type InSb detector (Kinch and Rollin[3]). Except for a strongly filtered intrinsic response near 5 μ, the detector has a flat response from about 400 μ to longer wavelengths. The long-wavelength response was limited by a wire mesh filter. The InSb detector has a very fast response; it was, therefore, compatible with our other detectors which had to be operated at a minimum chopping frequency of 150 cps to avoid serious low-frequency noise problems.

The object of the experiment was to measure the detector's response to a liquid-helium-cooled environment and then to open the telescope to expose the detector to the night sky's radiation. The telescope had a 5° field of view. The detectors were housed in a reflecting cavity which had a 1.1-cm-diam circular aperture in the focal plane of the telescope's $f/0.9$, 17-cm primary mirror. A 150-cps tuning fork chopped the light entering the cavity. Prior to launch, and during powered flight, the top of the telescope was covered by a set of reflecting beryllium copper strips constituting a baffle system which was kept cold through good thermal contact with the rest of the telescope. The InSb detector, therefore, saw nothing but thermal emission from the blackened walls of the liquid-helium-cooled telescope. After powered flight, the baffles remained closed until the rocket reached an altitude of 130 km, where there was no possibility of atmospheric gases condensing on the telescope's components. The telescope's vacuum cover was then ejected, and the folded baffles sprang open so that radiation from the sky could enter the telescope; a significantly larger signal was then detected by the Rollin detector as indicated in Fig. 1.

Just prior to launch, the entire system was at 4.2°K. But during powered flight, the telescope cooled down to about 2.35°K, because we were unsuccessful in keeping the pressure above the liquid helium reservoir at 1 atm—one of our pressure valves apparently did not function properly. Nevertheless, the "zero" signal levels obtained at these two temperatures are almost identical and give a median value close to 0 V on our 0- to 5-V telemetry readout. The corresponding readout, after the telescope cover was removed, was about 0.7 V—a very clear difference.

The main question then concerns the origin of this signal, not whether a signal was actually detected. A number of possible sources can be eliminated:

(1) The signal is unlikely to originate within the telescope itself. The temperature of the telescope interior was very carefully monitored with carbon resistance thermometers, placed at a number of key locations. They all remained well below 3°K throughout the useful observing period. Stray, multiply reflected radiation from warm parts of the telescope can be excluded as a possible source because the Ge:Ga detector, which has a peak response at 100 μ, would have been affected much more severely by such radiation. The same is true of stray, multiply reflected thermal

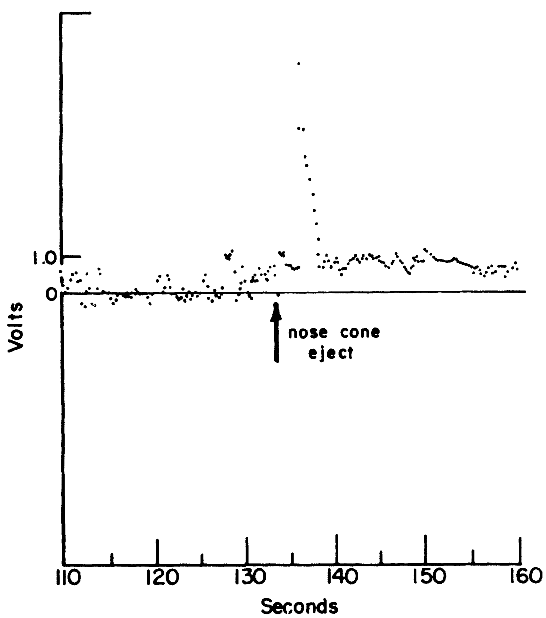

FIG. 1. Data points obtained just prior to and after ejection of the telescope cover and nose cone. The big signal just after ejection is produced by the warm nose cone. However, this signal goes away as the telescope's viewing direction is moved. As shown in Fig. 2, the direction of nose-cone ejection was deliberately kept remote from the objects to be viewed in the later portion of the flight. The data points are obtained after the signal has gone through a logarithmic amplifier, so that the voltage scale is not linear in signal strength.

emission from the earth which is far stronger in the 50- to 120-μ region than in the submillimeter range; for the Ge:Ga detector responds much more strongly to atmospheric temperature blackbody radiation than does the InSb.

(2) The InSb detector has an intrinsic absorption near 5 μ. However, this part of the spectrum was strongly blocked by a filter and the residual sensitivity in this range was an order of magnitude less than that of a Ge:Au detector flown in a March 1967 flight. That detector, which operated over a spectral band of 1 to 7.5 μ, had failed to establish the existence of a definite cosmic flux (Harwit, Fuhrmann, and Werner[4]). Moreover, the InSb detector registered only a small signal increase when the telescope pointed close to the horizon, while the Ge:Ga channel was driven well into saturation with a signal about 10^3 times greater than that seen near zenith (cf. Houck and Harwit[1]). We, therefore, exclude the possibility that the InSb detector could have been responding to radiation in the near-infrared part of the spectrum, when the telescope was pointed at the zenith.

(3) The possibility of atmospheric emission cannot be completely rejected. In a recent review, Dalgarno[5] discusses the pure rotation spectrum of N_2O, CO, and NO. These atmospheric constituents emit in the range from 100 to 600 μ. However, at these wavelengths it seems very unlikely that the night-time emission above 170 km would be of the order of 0.1 erg/cm^2 sec.

Water vapor carried aloft with the rocket could also produce detectable thermal emission, but this radiation should have affected the Ge:Ga far more strongly than the submillimeter detector, and we see no evidence of such an effect.

We know of no interplanetary source that could produce the observed signals. Neither thermal radiation from dust, nor plasma emissions are predicted to be strong in this spectral range.

Different regions of the sky were scanned by the telescope as shown in Fig. 2. One cannot state that the observed signal is isotropic, but our results would certainly be consistent with such a flux distribution. We saw no signal increase near the ecliptic plane, the galactic plane, the Pleiades, the Crab nebula, or the Orion nebula.

The strength of the observed signal is about 5 $\times 10^{-9}$/cm^2 sr. This corresponds to a blackbody signal at 8.3°K. The uncertainty in our absolute detector calibration may give an error amounting to as much as a factor of 2. This would make the signal consistent with a blackbody tempera-

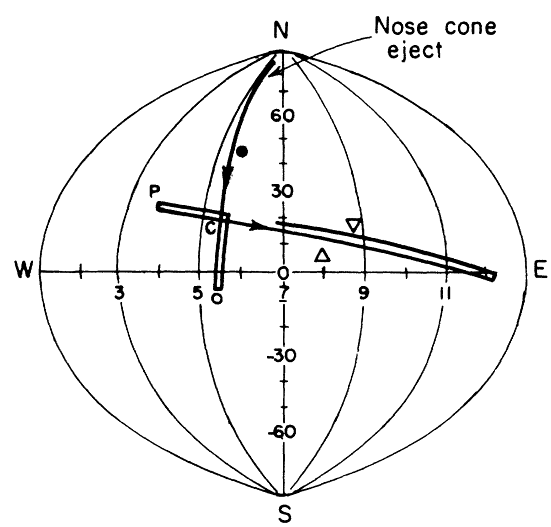

FIG. 2. Scan of the different portions of the sky. O represents the Orion nebula, P the Pleiades, and C the Crab nebula. The nose cone was ejected at the north end of the scanning path. Horizon approach occurred in the east. Scans ∇ and Δ are along the ecliptic.

ture lying between 7 and 10.5°K.

Our calibrations were obtained in the following way. A spectral calibration was obtained both at 4.2 and at 2.2°K with a Michelson interferometric spectrometer. It showed the response to be nearly flat from 0.4 to 1.3 mm at both temperatures.

The detector's absolute sensitivity was determined by means of blackbody calibrations. The black body covered the entire entrance aperture of the telescope. To test the blackness of the emitting surface, a cavity was constructed by placing a perforated copper plate in front of the black body. The intensity of radiation emanating from the perforations was compared to the intensity given off by the unmasked black body. Within experimental error the ratio of observed signals was the same as that of the geometric areas of the perforations and the entire black body. Since the cavity radiation could only be "blacker" than that of the plain black body, we concluded that the black body, in fact, was black. The detector's response was measured for blackbody temperatures in the range of 16 to 78°K. The relative response obtained at different blackbody temperatures gives confirming evidence for the correctness of the spectral curve measured with the Michelson interferometer. An independent absolute sensitivity measure also was obtained with a 0.9-mm microwave source of known power. All these calibrations were in satisfactory agreement.

We can interpret our observations in a number of different ways: If the flux is to be consistent with microwave observations made at longer wavelengths (cf. Penzias and Wilson,[6] as well as others), it cannot be black at 8.3°K. However, a dilute blackbody spectrum at a temperature of $3n$°K, with a dilution factor of $n > 3$, would be consistent both with the microwave observations and our present results. Houck and Harwit's[1] observations made with a Ge:Ga detector, flown on the same flight, are consistent with $n \leq 6$. In any case, the actually observed radiation is a factor of 30 greater than the total radiation expected in a 3°K cosmic flux. The radiation density of the universe, therefore, could be comparable to the mass energy density if the observed flux is cosmic. Our observations, if representative of a cosmic flux, might lead to inconsistencies with current theories on the origin and distribution of cosmic rays (cf. Greisen[7] and Stecker[8]). We emphasize, therefore, that we have greater confidence in the detected signal than in the nature of its source. There are arguments that can be presented against atmospheric, solar system, and cosmic origins. Only further observations will clarify this problem.

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