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Near Infrared Night Sky Background

M. Harwit, K. Fuhrmann and M. Werner

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Near infrared night sky background

By M. Harwit, K. Fuhrmann and M. Werner
Cornell-Sydney University Astronomy Center, Cornell University, Ithaca, New York

1. Introduction

We have carried out near infrared observations on wide fields of the sky, using both a rocket-borne telescope and ground-based equipment. The rocket observations covered the spectral range of 1 to 8 μm. The ground-based observations were carried out in a narrow spectral region around 1·085 μm.

The rocket observations give increased sensitivity over a previous flight carried out by one of us in collaboration with D. P. McNutt, K. Shivanandan and B. J. Zajac of the U.S. Naval Research Laboratory. We observe a general signal which would not have been detected in our previous flight. This new signal appears to be genuine, but because of a number of difficulties, mainly associated with vent gases, we prefer not to trust these signals until we have been able to carry out a confirming flight. We will, in the present paper, use the observed fluxes as an upper limit to the near infrared radiation incident on the top of the atmosphere.

The ground-based observations corroborate our rocket results, although at the moment they are not quite as sensitive. The ground-based observations were a side product of work not directly related to the study of the sky background, and it is quite likely that improvements could be obtained.

In general we feel it to be important to carry out ground-based observations wherever the atmosphere permits comparison between ordinary and rocket observations.

2. Rocket observations

On 2 March 1967, at 21.20 M.S.T., we launched an Aerobee-borne payload designed to observe diffuse and homogeneous radiation fields and any other sources that might be present in our fields of view. Our telescope was liquid nitrogen cooled. Its design was similar to that flown earlier by Harwit, McNutt, Shivanandan & Zajac (1966*a*, *b*). Three different detectors, indium arsenide (InAs), indium antimonide (InSb) and gold-doped germanium (Ge:Au) were flown. These detectors, preceded by a silicon transmission filter, respectively responded to three spectral ranges, 1 to 3, 1 to 5·5 and 1 to 8 μm. Each detector viewed the same 5° diameter field of view through an $f/1$ telescope with effective aperture 130 cm^2. With three exceptions, preflight and inflight calibrations were similar to those described earlier (1966*a*, *b*). The first difference involved a zero calibration repeated throughout flight at 5 s intervals; this served to define any drifts in the zero signal levels and gave greater confidence in the observed signal strength. The second difference involved a greater concern with the spectral sensitivity of our detectors. We discuss this feature below. Thirdly, detector stability was checked with greater care, both on a day-to-day basis, under a variety of differing conditions, and in terms of drifts over periods comparable to the duration of a flight.

An attitude control system (ACS) incorporating a roll-stabilized platform pointed the payload at three different portions of the sky: a field of view centred on the Orion nebula, a field of view in Leo Minor centred at r.a. $10^{\mathrm{h}}\ 13{\cdot}3^{\mathrm{m}}$ and decl. $+30^{\circ}\ 49'$ (the location of one of the brighter objects listed by Ulrich *et al.* (1966)) and a field of view centred on the Crab nebula. Finally the telescope performed a slow scan along the Milky Way and dipped down to cross the horizon. At the end of the flight the payload descended on a parachute and was recovered. A number of post-flight checks gave normal results.

Our flight represented the first attempt to launch an infrared astronomical payload incorporating an attitude controlling device; and we ran into some technical difficulties which we had not anticipated.

(1) The attitude control system incorporates thruster jets using the same compressed helium that forces fuel and oxidizer into the rocket's thrust chamber during powered flight. The jets which control the rocket's roll are situated directly below the payload section. During flight some of the aniline propellant can work its way into the helium storage tank and be vented in the roll control jets. Toward the end of the flight we observe a signal on our detectors every time the roll jet valves are opened. In addition, there is a period of slowly increasing signal strength detected by all three detectors during the 50 s preceding this set of 'jet' signals. At the moment we suspect that these two phenomena are related, and we therefore restrict our report to the first two fields of view listed above.

We believe that the signals from the first two fields of view are to be viewed with caution but not to be rejected outright. We reason that: (*a*) The anomalous signal observed for the Crab field of view rises monotonically. A backward extrapolation indicates that the onset of this signal coincided with the manoeuvres involved in moving from the second to third target. (*b*) The 'jetting' signal is not seen during the earlier portions of the flight even when the roll jets are on for long time intervals.

(2) Our liquid nitrogen cooling system was designed to direct the vent gases down toward the tail of the rocket. This was intended to produce a small thrust that would keep the liquid coolant gently pressed against the bottom of the telescope-dewar. The technique worked quite well once equilibrium had been reached, but initially, just after the powered portion of the flight was over, liquid was able to come in contact with warm portions at the top of the dewar, and considerable amounts of liquid seem to have spurted out during the time the telescope pointed at Orion. The vented liquid tends to produce nitrogen snow-flakes in a vacuum. We think that some of these snow-flakes passed near the telescope's field of view and produced enough scattered earth light to give strong intermittent signals registered by the Ge:Au and InSb detectors. The InAs detector which is relatively insensitive to the long wavelength radiation emitted by the earth was not affected. This effect subsided after the first source had been viewed, but a recurrence was found each time the telescope was moved to a new field of view. The motion produced centrifugal forces that again caused liquid to be vented. In future flights we expect to use a venting system that eliminates many of these problems.

(3) In addition to these two difficulties we also experienced a weakening of the InSb detector response which unfortunately started just after the telescope's door was ejected and apparently stopped right after the flight.

An intermittent weakening of this kind had been noticed just before flight. In a series of post-flight tests in our laboratory we were unable to make this detector fail. We suspect that the difficulties were due to a poor connexion in a lead that had to be disconnected before the payload was returned to our laboratory. The InSb signals have proved useful in corroborating the evidence of the other two detectors, but their photometric value is limited.

The spectral response of the InAs and Ge:Au detectors is shown in the figure; sensitivity increases toward the bottom of the drawing. Ge:Au has two sensitivity peaks, one at 1·7 and the other at 4·5 μm. The sensitivity is expressed in watts per square centimetre per steradian. The curve Ge:Au (1) reproduces what we consider to be the germanium detector's sensitivity at the beginning of the flight, and Ge:Au (2) the sensitivity at the end. This increased sensitivity, observed as an increased response to the calibration light, has been observed on previous flights and is due to vacuum cooling of the liquid nitrogen coolant.

3. Results

We measure significant signal levels on both detectors from both the Orion region and the region in Leo Minor. Since we do not know in which portion of their sensitive range the detectors respond, we present the results of our observations in terms of the minimum detectable signal (m.d.s.). The m.d.s. is small if the radiation incident on our detectors happens to lie near the peak of the detector's spectral sensitivity curve. Correspondingly the m.d.s. is large if the radiation has a wavelength to which the detector is insensitive. The figure shows that 1 m.d.s. unit (1 m.d.s.u.) corresponds to signals ranging from *ca.* 10^{-10} to *ca.* 10^{-8} W cm^{-2} sr^{-1} in differing portions of the spectral range.

For the Orion region we find that the InAs detector registers a signal of *ca.* 5 m.d.s.u. The gold-doped germanium, as already stated, records what we interpret as occasional spurts of liquid, but during the intervening times the signal level always seems to return to a level near *ca.* 6 m.d.s.u.

For the Leo Minor region the InAs detector registers essentially the same signal as seen in Orion, namely *ca.* 5 m.d.s.u. The Ge:Au detector sees *ca.* 8 m.d.s.u.

We feel that the two InAs signal levels are particularly reliable. Throughout our testing period, InAs showed itself to be highly stable. The Ge:Au signals from Leo Minor also merit confidence. The only way in which a false signal could readily be produced would be through stray radiation emitted near the Earth's horizon and multiply reflected within the telescope. Since our telescope had been carefully baffled, this stray radiation could only have penetrated had there been some malfunction of the system. Our recovered payload gives us no reason for suspicion.

The Ge:Au signals from Orion must be treated with more scepticism, because we do know of interference from what we believe is the above-discussed jetting action of liquid nitrogen. None the less, between spurts of nitrogen, the signal level settles back to essentially the same value each time, and that value is somewhat lower than the signal from Leo Minor.

The stellar sources previously reported by ground-based observers of the two fields of view are not powerful enough to be seen by our small flight telescopes during the 50 s each source is viewed. It is therefore interesting to see whether the interstellar radiation field and zodiacal light alone could account for the observed signals or whether other

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sources have to be invoked. To answer this question, we compare the computed signal strengths (Peebles & Partridge 1967) for Galactic starlight and zodiacal scatter, presented in figure 1, to the spectral response curves of our detectors. A detector will just barely detect a source if the two curves coincide over a bandwidth of 1 μm. If the detector curve dips below the source curve, over a wide enough bandwidth, the situation is even more favourable. In our observations, the situation is rather marginal.

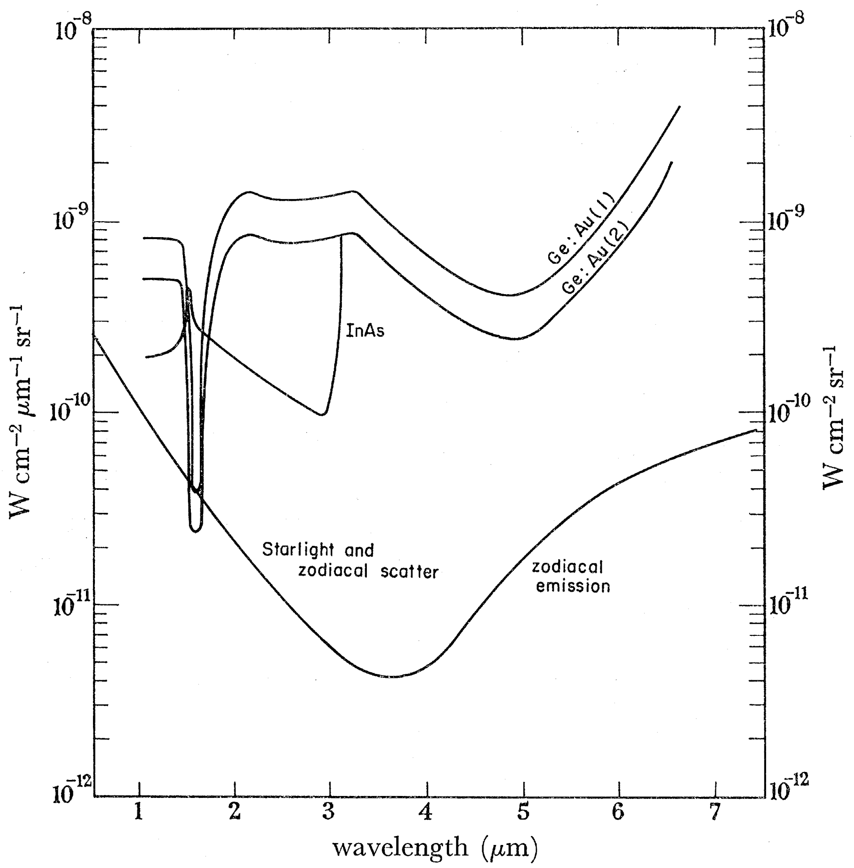

FIGURE 1. The lowest curve is a modified version of slightly updated data presented by Partridge & Peebles. The left half of the curve represents zodiacal scattered light off the ecliptic plane and starlight off the Galactic plane. The right half of the curve represents the contribution of reradiation by zodiacal grains near the ecliptic plane, at an elongation of 90°. The grains are assumed to have diameters which are not small compared to the wavelength radiated. The left-hand scale is to be used with this curve. Curve InAs represents the spectral sensitivity of the indium arsenide detector. Curves Ge:Au (1) and Ge:Au (2) illustrate the increase in sensitivity of the gold-doped germanium detector during flight. The right-hand scale is to be used with these response curves. Increasing sensitivity pushes the detector response curve downward.

The signals registered by the detectors are perhaps a factor of 6 higher than those that could be expected from the combined curves for the Galaxy and zodiacal dust scatter. This may indicate a shortcoming of the theoretical estimates which could be systematically in error. Alternately it might represent a false signal whose origin we do not know. We believe that the signal is real, but prefer to wait for confirmation in a flight with a new payload configuration.

To summarize, we have observed the flux from a region in Orion and a region in Leo Minor with two detectors operating broad band over the spectral ranges 1 to 3 and 1 to 8 μm. The flux detected is a factor of 6 or so higher than one would expect from computed interstellar and zodiacal radiation densities. Since the computations for this region are uncertain and since we experienced a number of difficulties with vent gases during flight, this agreement may be as good as can be expected. We hope to pursue this problem in future flights when some of the technical difficulties encountered in this first attitude controlled flight will have been solved.

Ground-based observations

In the course of an observing programme designed to detect the (2–0) S(5) line of H_2 at 10850 Å, data were taken which give an upper bound on the brightness of the sky in this wavelength range. The measurements were made through a Fabry–Pérot interferometer using an S-1 phototube as a detector. A narrow band interference filter (FWHP ~ 7 Å; transmission ~ 30 %) peaked at 10850 Å was used to isolate one free spectral range of the Fabry–Pérot. Laboratory calibrations using a blackbody source indicated that the entire optical system had a quantum efficiency of $6{\cdot}4\times10^{-6}$ to $1{\cdot}3\times10^{-6}$ in this configuration.

The observations were made with the 24 in. reflector at the Mees Observatory, University of Rochester, in April and May of 1967, and with a 16 in. reflector at Kitt Peak in July 1967.

For each area of the sky observed, 1 min counts were taken at 0·2 Å intervals. Dark counts were taken before, during, and after each run. For each run, the mean number of counts per minute $\overline{C}$ was determined by averaging the counts from 30 spectral intervals. In some cases, an atmospheric OH line at 10842 Å was observed; these data points were excluded from the analysis. Then the mean dark counting rate, $\overline{D}$, was determined for each run. The difference, $(\overline{C}-\overline{D})$, is the counting rate due to the night sky. If we call this difference N, we can compute the night sky flux (W cm^{-2} sr^{-1} μm^{-1}) from the formula:

$$\Phi = \frac{NE}{60}\frac{1}{W}\frac{1}{T}\frac{1}{\Delta\lambda}\frac{1}{A}\frac{1}{\Omega}\ \mathrm{W\,cm^{-2}\,sr^{-1}\,\mu m^{-1}},$$

where $N/60$ is the mean number of counts observed/second, E the energy of each photon (joules), W the system efficiency, T, $\Delta\lambda$ the filter transmission and bandpass, A the area of telescope aperture, and Ω the angular field of view (sr).

Data are available from a total of seven runs, each of which represents about 30 min of observations. The dark counting rates, $\overline{D}$, were typically *ca.* 18 counts/min, and the mean counting rate $\overline{C}$, was of the same order. The largest value of N observed for any region 4 counts/min. For several runs, we found $\overline{D} > \overline{C}$, implying that the signal is effectively zero.

Although the results are uncertain because of the uncertainty in the system quantum efficiency, they do permit us to say that the night sky flux near 10850 Å is

$$< 3\times10^{-8}\ \mathrm{W\,cm^{-2}\,sr^{-1}\,\mu m^{-1}}.$$

The null result obtained for some runs $(\overline{D} > \overline{C})$ suggest that the flux is actually less than 3×10^{-9} W cm^{-2} sr^{-1} μm^{-1}. This is greater by a factor of 3 than the upper limit on the flux in the same spectral region deduced from the rocket observation discussed above However, it should be noted that the regions studied in the ground-based experiment were located in obscured areas near the galactic plane.

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