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Paper 2.10

SKY SURVEY AT FAR INFRARED WAVELENGTHS USING A BALLOON-BORNE TELESCOPE

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ABSTRACT

Localised sources of far infrared radiation ($\lambda \geq 50\mu$) have been detected during a high altitude balloon flight with a 40 cm telescope and silicon detectors. The flight system is described and preliminary results are presented.

I. INTRODUCTION

A large area of the sky has been scanned for localised sources of far infrared radiation, using a balloon-borne system that was sensitive to wavelengths beyond about 55 microns. Two Molectron silicon bolometers were used, with a Newtonian telescope having a 40 cm primary. The telescope was driven in azimuth at a fixed elevation; this mode of scanning was carried out for the duration of each of two balloon flights from the N.C.A.R. Balloon Facility in Palestine, Texas, in September 1973. The flight system is described in this paper, and preliminary scientific data will be presented at the meeting.

II. FLIGHT SYSTEM

a) Optics.

The primary mirror had a diameter of 40 cm and a focal length of 100 cm; the flat secondary was used as the chopper and was rocked at about 8 Hz. The dewar with the detectors was located at the one side of the telescope, with focus in the entrance plane of two brass light-pipes. The field of view is defined by the ratio of the focal length of the primary and the front aperture of each light pipe, and is a rectangle of 0.65° in azimuth and 1.0° in elevation. The amplitude of the chopping motion was adjusted so that the two fields of view that were to be compared were separated by 1.0°

Each light-pipe was of square cross-section, starting with 1.8 cm side and tapering over a length of 10 cm to a square exit aperture with 0.5 cm sides, leading to a spherical cavity of 0.95 cm diameter, in which the silicon chip was suspended. The light-pipe assemblies were made of brass; the spherical housing and a mounting plate were made of oxygen-free copper, and mounted to the underside of the liquid-helium container. The two light-pipes were arranged with the one beneath the other. The silicon detector elements were each 5 x 5 x 0.4 mm, manufactured by Molectron Corporation.

Wavelength selection was set by the filters: 2 mm crystal quartz on the dewar (0.5 mm of clear polyethylene was used for one flight); 1.8 mm of teflon on the aperture in the radiation shield within the dewar; and 2 mm of crystal quartz plus 6 mil black polyethylene at the entrance to the light-pipes. The overall spectral response of the system was compared to a Golay cell at the University of Missouri-Rolla, using a Fourier-transform spectrometer. The response is fairly flat from 60 microns to the longest wavelength checked, 600 microns; the response falls to half by about 55 microns and is not measurable below 50 microns. A preliminary estimate yields 10% as the overall transmission of the filter combination at 100 microns and 20% for $\lambda \gtrsim 200\mu$.

b) Orientation

The telescope was locked at 26.5° elevation, and then driven continuously in azimuth during the flight. The instantaneous direction of the telescope was obtained through the use of a magnetometer and sky cameras. A Schonstedt magnetometer was used as a sensor to serve two cameras to continuously follow Polaris. These cameras were operated with open shutters and continuously-moving film, so that Polaris was recorded as a trace. (Time markers were supplied by an Accutron watch.) The azimuthal difference between the cameras and the telescope was monitored with a 9-bit shaft encoder, and corrections were later included based on the actual position of the Polaris trace, the local time, and the balloon drift in longitude. The moon was detected by the bolometers several times in each flight, and these sightings provide a calibration of the co-ordinate measurement. The accuracy of other source positions is then about 0.4° in azimuth and ± 0.5° in elevation; the corresponding uncertainties in R.A. and declination vary somewhat in different parts of the sky but generally do not exceed ± 0.5°.

c) Signal Processing

The preamplifiers were located in a shielded box immediately adjacent to the dewar. The output of the preamps was both telemetered directly and also processed further on board after which it was recorded on-board and telemetered. On-board, lock-in amplifiers were used in conjunction with a reference signal provided by the chopper, and each detector output was recorded in high-gain and low-gain channels. The on-board recording was intended as a back-up system, and consisted of the continuous photographing of meters that displayed the outputs. In parallel, these outputs were telemetered via the NCAR FM/FM system.

During the first flight, a major DC offset was observed which was attributed to differences in emissivity of the two fields that were viewed during the successive halves of the chopping cycle. Before the second flight, all parts of the telescope that could be 'seen' by the light-pipes were covered with aluminum foil; these included the areas behind the primary mirror and on the inside of the telescope tube behind the secondary and directly opposite the entrance of the light-pipes. The result was a noticeable reduction in offset for the second flight. The offset was still large, but some celestial sources could still be seen on both flight records.

Electronically, the saturation effects of the large DC offset occur in the lockin amplifier, and these could be obviated after the flight. A new lockin amplifier was constructed; the inputs for this were the directly telemetered preamp output and the reference signal (both of which had been recorded). Far larger signals could not be handled, although the lunar signals still completely saturated the system.

Two further electronic filters were introduced and proved to be of major use in cleaning up the signals. These comprise our 'notch' filter: one pass-band is centered at the chopping frequency of 8.3 Hz and the other at 3.1 Hz. At the lower frequency, persistent noise had been detected, and was attributed to beating from the chopping of the secondary mirror.

The post-flight record shows an average noise level recorded at 60 $nv/Hz^{1/2}$. Extensive pre-flight calibration of the detector had yielded a value of 50 Kv/watt responsitivity. With 20% as the filter transmission, this leads to a minimum detectable signal of $\sim 6 \times 10^{-12}$ watt at the entrance to the light-pipe, or an incident intensity $\sim 10^{-23}$ $W/m^2.Hz$.

It should be pointed out that the minimum detectable signal could be considerably reduced if an oriented system were used. This would permit a much smaller field of view with consequent smaller apertures in the dewar and radiation shield.

d) Scanning Mode

It was decided to adopt the unusual arrangement of the two detectors to allow a check on the sighting of celestial objects. If an infrared source is detected in the east it may first be seen by the lower detector. Four minutes later, when the gondola has returned to the same azimuth, the source will have risen in the sky and should be observed in the upper detector. For a source first seen in the west, the order of sighting in the two detectors will be reversed. Without repeated sighting of an object, there will usually be a residual suspicion that one might instead have noted an instrumental glitch, and the two-detector system is designed to obviate this problem. It might, of course, happen that a source is first viewed in the upper detector but this should happen only for those objects that are already too high to be seen with the lower detector, and one might then expect to observe such objects twice more (one with each detector) later in the flight.

The elevation angle of the telescope is adjustable on the ground, and was set at 26.5° for the September flights, to give us the possibility of sweeping through the galactic center.

The rate of scanning was chosen at 4 minutes per revolution, and the drive system was provided by NCAR.

e) Balloon flights.

Both flights were successfully carried out from N.C.A.R.-Palestine, in September 1973. Data for the second flight (Sept. 20-21) is being analysed first because of the reduced offset problem. Both flights were at float altitudes of about 97,000 ft, for about 9 hours.

III. RESULTS

Only preliminary results were available at the time of the meeting. The upper detector record shows a total of 82 events that at first sight appear to be possible signals, while the lower detector show 78 such events. With only a preliminary analysis so far available, detailed listings of possible sources and their locations are not being included with the present paper. Even at this early stage, it can be seen that the moon was detected four times and that these observations provide a calibration of the co-ordinate measurements. Several other sources were seen more than once. Small corrections in co-ordinates still need to be included.

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The discussion was concerned with the identification and intensities of the sources observed in the Washington University investigation.

It was reported that the stronger sources observed had intensities of 10,000 to 20,000 flux units. Some sources observed were within one or two degrees of known pulsars but it will be necessary to process the photographs from the onboard star camera before identification is completed.