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ASTRONOMICAL OBSERVATIONS WITH THE UNIVERSITY COLLEGE LONDON BALLOON BORNE TELESCOPE

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ABSTRACT

Since 1970 the U.C.L. balloon borne telescope had made fourteen flights in different parts of the world. Some of the features of the detection system used are described together with examples of the different types of astronomical observations that have been made.

INTRODUCTION

The telescope system was designed and built by the engineering group in the physics department at University College. The timing was most opportune, coming as it did just when the early observations by F.J. Low from aircraft and W.F. Hoffmann from balloons were showing the importance of making observations in the far infrared ($\sim 100 \mu$m) where many objects, principally HII regions, were radiating most of their power, amounting to as much as 10^5 to 10^8 times the energy from the sun. The great advantage of the system was its ability to point, by means of a star tracker, to better than a minute of arc enabling the identifications of sources to be made with little change of ambiguity.

All our photometric observations have used the same broad band of wavelengths, from 40 to 350μm. The short wavelength 'cut on' is determined by the quartz Fabry lens and black polythene filter mounted on the base of the cryostat together with the rigidex entrance window (see Fig.2). The long wavelength limit is determined by diffraction effects. The detector used is a 1mm square gallium doped germanium bolometer (Infra-red Laboratories Inc.). The system's relative response is known from laboratory measurements in a vacuum tank using a Michelson interferometer and this is put on an absolute basis by observing a suitable planet during flight. The aperture stop most frequently used is 5 arc min.

FEATURES OF THE DETECTION SYSTEM

It is hoped that a brief mention of one or two particular features will be of interest to other experimenters.

(i) Chopping System

Two types of chop have been employed, both oscillating the secondary mirror. The mirror is supported by a phosphor bronze disc with a rod some 20 cm in length firmly attached to the back of the secondary mirror mounting. The type of chop is determined by the movement given to the further end of this rod.

A 'circular chop' has been used for a number of flights and the phase sensitive detection (P.S.D.) performed parallel to and perpendicular to the direction of scan. The resulting infra-red signals – INFRARED A and INFRARED B respectively – are shown in Fig.1, which shows the signals recorded while calibrating on Saturn.
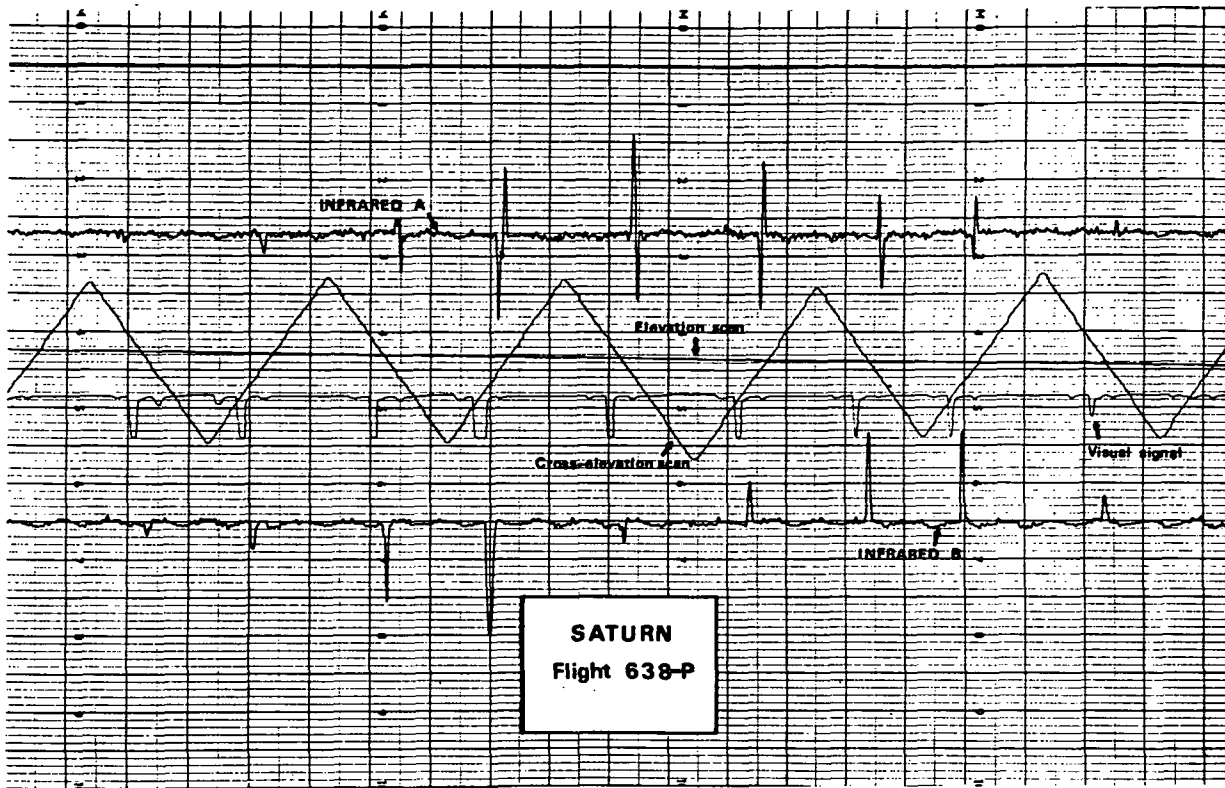
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Figure 1. Signals Recorded while Calibrating System.

The star tracker is locked on to Saturn and the main telescope is being commanded to make a small raster scan about the planet. Whilst a chart record is sufficient during the flight, data on tape is used for the final analysis.

For detailed mapping of regions we prefer to use a linear chop in which the secondary is rocked from side to side (by solenoids operating on the top end of the bar). The resulting movement, as determined by a laser shining onto a mirror attached to the back of the secondary mirror, is a fair approximation to a square wave.

(ii) Importance of Phasing in Flight

We phase sensitively detect at the balloon end and find that it is important to be able to adjust the phase of the reference sugnal to the P.S.D. system during flight, by repeated observations of a bright object (planet). This applies particularly to the linear chop, where the optimum phase has been found to be as much as 30° different to what was thought to be the optimum on the ground - an awkward adjustment to make without special equipment.

(iii) "Red Button"

To offset residual mismatch of telescope radiations between the two parts of the chop, we make use of a simple sample and hold circuit immediately prior to the D.C. amplifiers. By command, it samples the D.C. signal immediately after the P.S.D. and applies it to the other side of the operational amplifier in the first D.C. stage.

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It is called a 'Red Button' because we heard that a ground based observatory made use of such a device of that name - only to find later that they had never heard of it !

(iv) Visual Maps

The beam out of the telescope is separated into its infra-red and visual components by means of a dichroic mirror as shown in Fig.2.
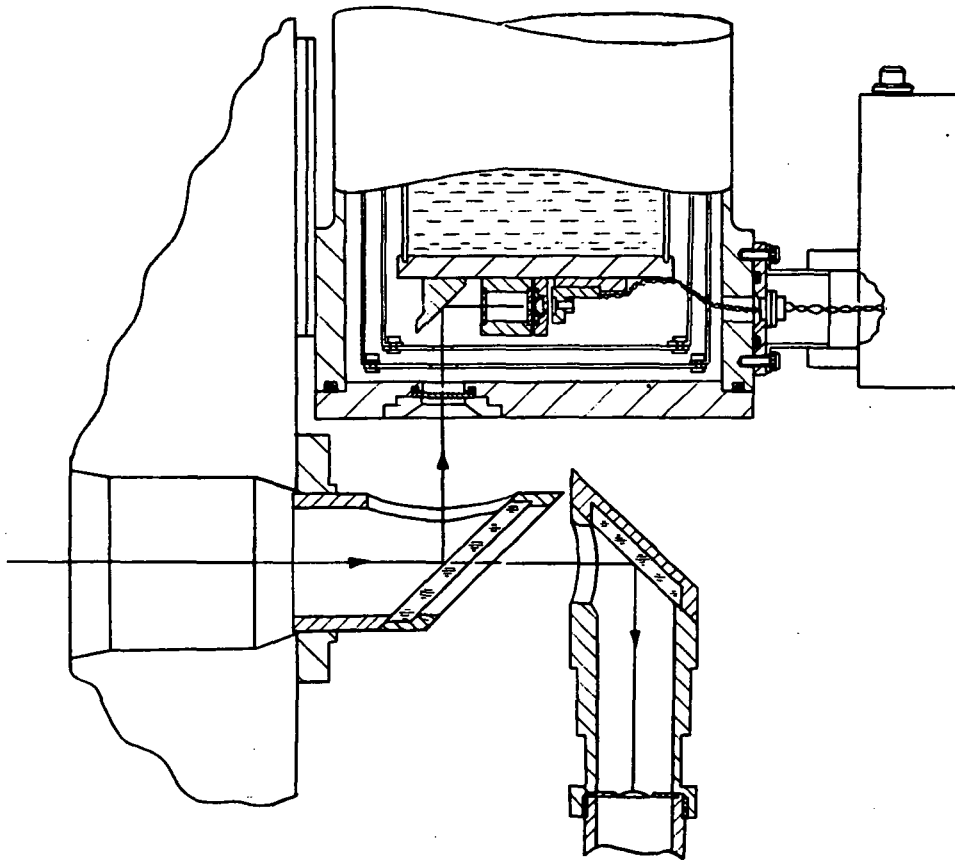

Figure 2. Dichroic mirror reflecting the infra-red beam up into the cryostat and passing the visual beam, which is then reflected into the photomultiplier.

Thus in effect an infra-red map is recorded over which can be laid the corresponding visual map. By superimposing the visual signal on the X-Y plotter, which is used to indicate the telescope position relative to the guide star, a visual map as shown in Fig.3 can be produced. In practice it is far more accurate

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to use the digitised coordinates off tape when use is being made of the visual
signals in the analysis. In practice better use can be made of the observing
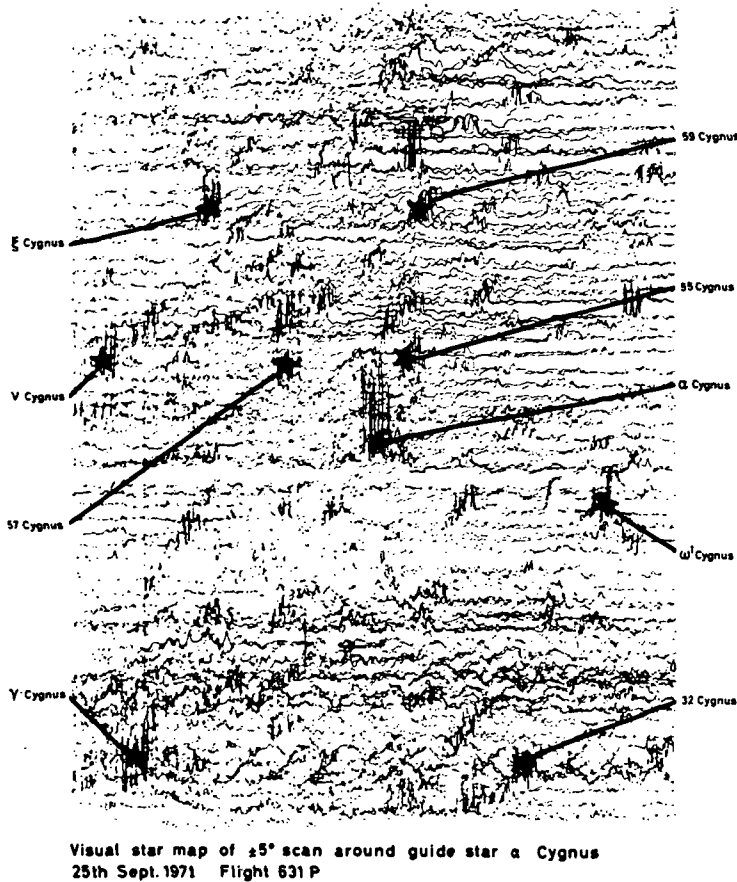time by only scanning limited regions.

Visual star map of ±5° scan around guide star α Cygnus
25th Sept.1971   Flight 631 P

Figure 3. Visual record of stars around guide star.

OBSERVATIONS

Rather than attempting to present a comprehensive account of our observ-
ations to date, examples of the different types of measurement which have been
made with the U.C.L. system will be given.

Much of our observing time has been spent in determining the far infra-
red flux of HII regions known or expected to be bright in this wavelength
region. Data from considerably more than fifty objects has now been obtained
many of which have not previously been measured in the far infra-red. A
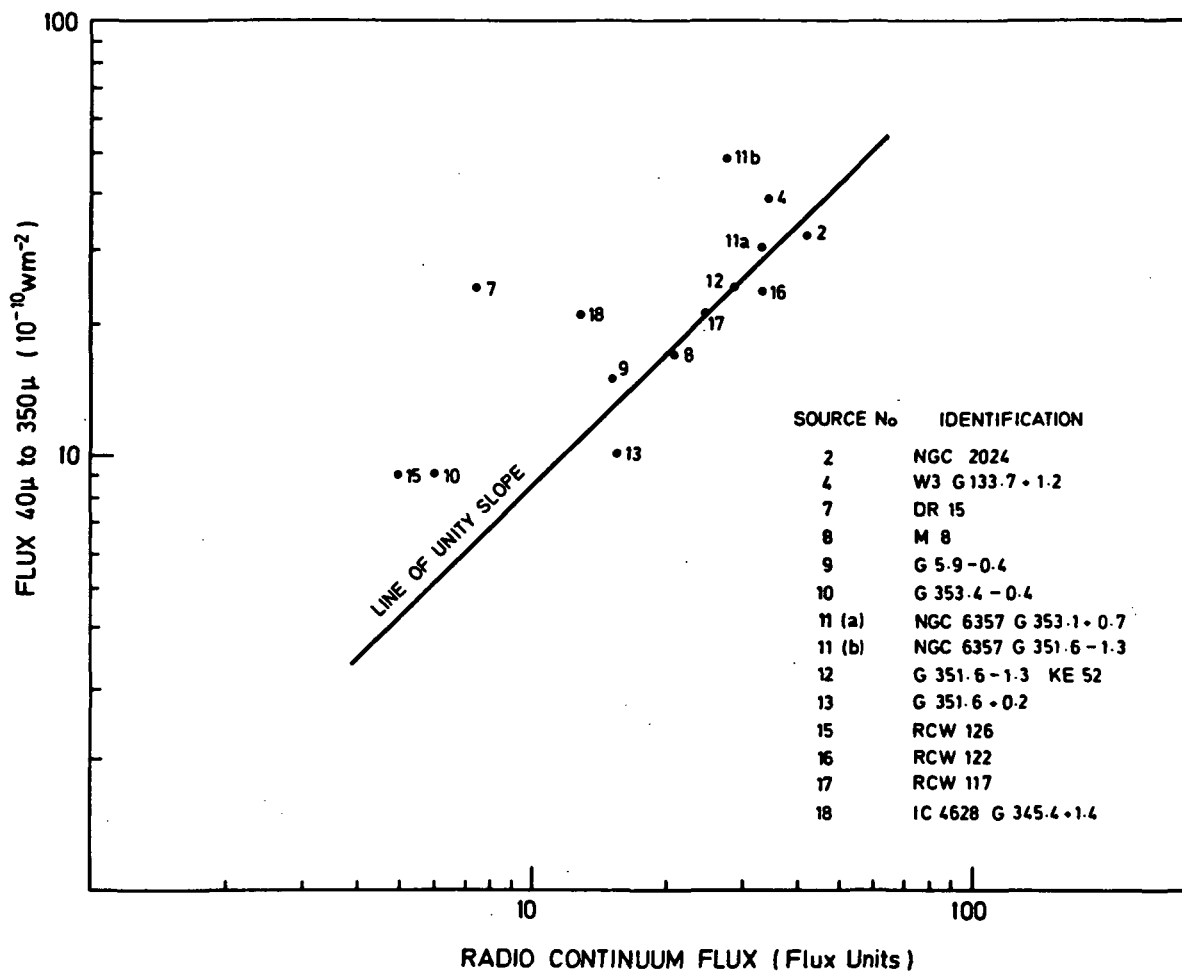sample of the results is shown in Fig.4. (overleaf).

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Figure 4. Plot of far infra-red flux against radio-continuum flux.

In general there is a close correlation between the infra-red flux and the radio continuum flux but there are a number of exceptions. At the present time there is considerable interest in explaining exactly what is happening in these complex regions. The far infra-red flux gives a good measure of the energy output of the exciting star(s) but the mechanism by which the radiating dust is heated is not fully understood and is the subject of a number of theoretical studies.

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The half power beam width of 3.5 arc min unfortunately means that sizes can only be determined to ∿ arc minutes and better angular resolution is required to decide whether or not a significant fraction of the radiation is being emitted from outside the HII region. Whilst agreement with the radio position was in all cases within 3 arc minutes it is not yet possible to say whether there is any real displacement between the centres of the infra-red and radio sources.

A second type of measurement which gives far more information is to closely scan a region so that a contour map in the infra-red can be constructed and compared with the corresponding radio map. A number of such maps have now been completed, in particular of NGC 6357 and NGC 6334, the latter being shown in Fig.5.
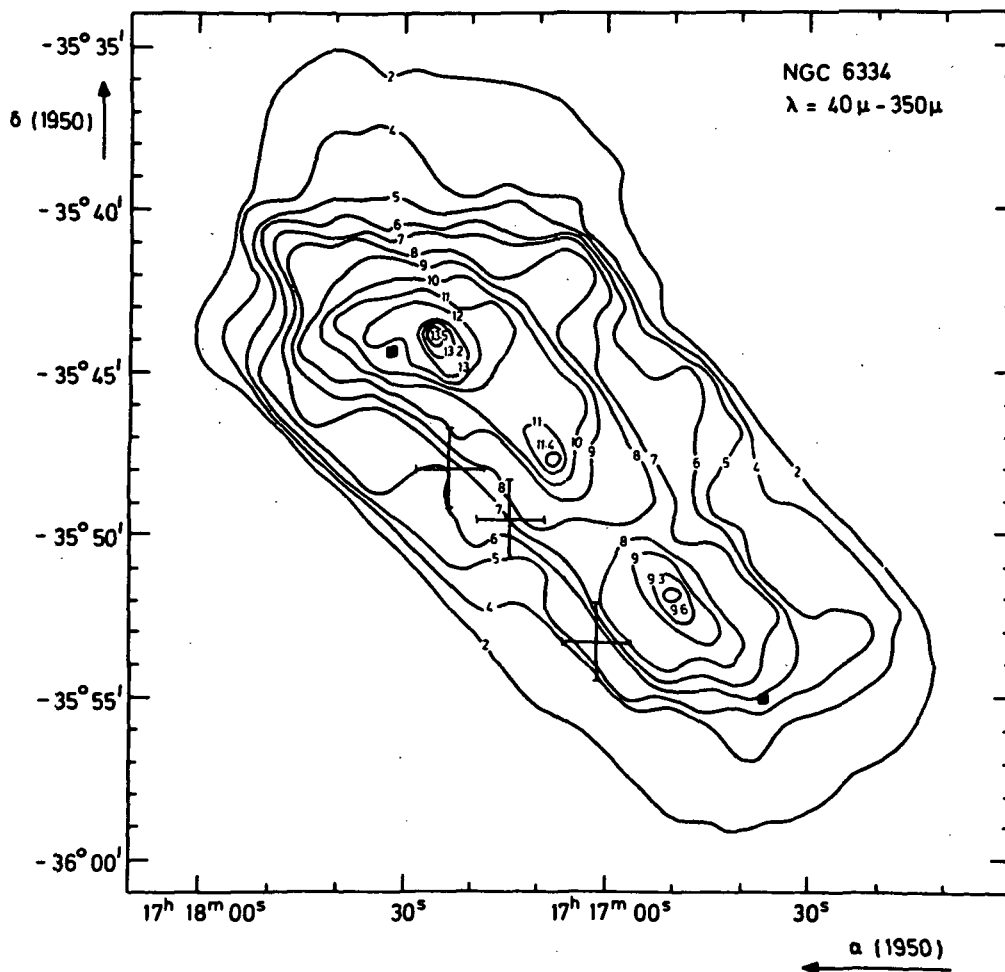

Figure 5. Far infra-red map of NGC 6334. Contour units are 2.3 x 10^{-10} wm^{-2}

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The three crosses marked indicate the position of the three radio peaks and, in view of the positional accuracies of the infra-red peaks and the radio peaks no special significance is attached to their relative displacement. However, no convincing correlation between them all can be obtained by adjusting their position and it appears that the brightest infra-red component corresponds to the OH maser source, whose position is marked with a square, while the other two infra-red peaks correspond to the radio sources, the central infra-red peak being double but unresolved in our beam. Confidence that this is a correct interpretation is strengthened by the immediate correlation of the radio and infra-red peaks in the case of NGC 6357 (not shown). NGC 6334 obviously requires further study but at the present time the observations could be interpretated in terms of a massive protostar to explain the northern infra-red peak.

Further details of both the photometric measurements and the infra-red maps are given in a paper by Emerson, Jennings and Moorwood 1973, which also has the relevant list of references.

Finally, we have made some preliminary spectral measurements, using a Michelson interferometer. For various reasons progress has not been as rapid as hoped but low resolution spectra have been obtained of two objects, Saturn and W51. The spectrum of Saturn is shown in Fig.6.
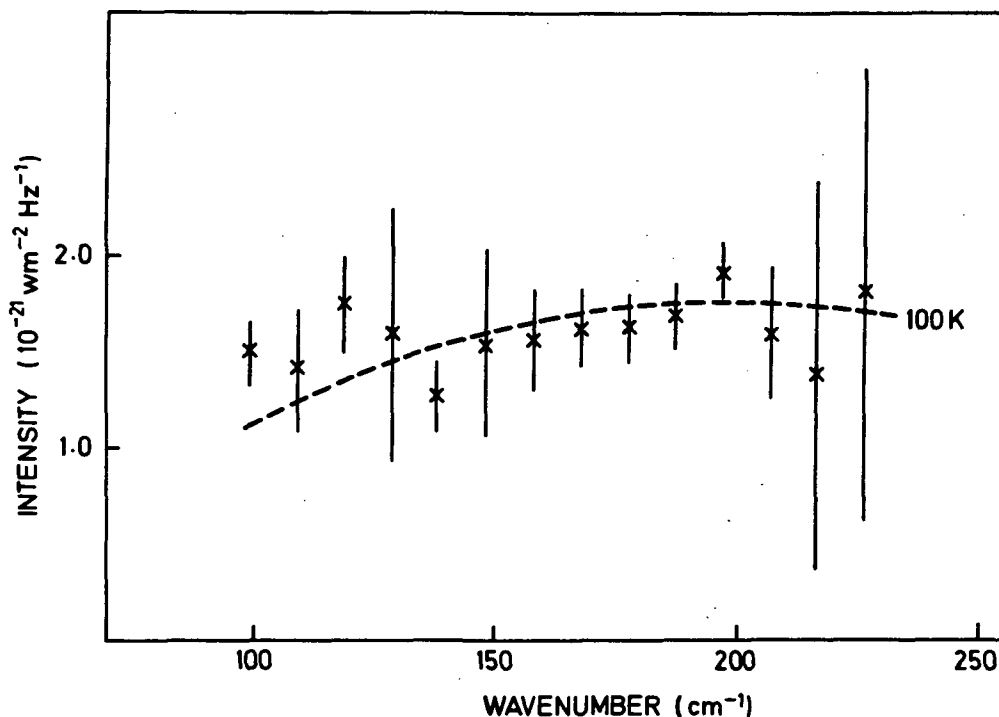

Figure 6. Spectrum of Saturn.

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Saturn was not the prime object and the interferograms were obtained in nine minutes. The spectrum was calibrated photometrically with respect to Jupiter. The brightness temperature is 100K at about 100 cm^{-1} and it is of interest to note that the brightness temperature tends to increase with wavelength in this region as found by Armstrong, Harper and Low 1972. The 100K curve shown corresponds to the colour temperature which gives the best fit. The angular resolution was insufficient to separate the contribution from the disc and rings.

It is intended to continue to develop this type of instrument for spectral measurements of continuous sources and also, hopefully, to detect line emission in the far infra-red.

ACKNOWLEDGEMENTS

REFERENCES

Emerson, J.P., Jennings, R.E. and Moorwood, A.F.M., 1973. Far infra-red observations of HII regions from balloon altitudes. Ap.J., 184:401-414.

Armstrong, K.R., D.A. Harper, Jr. and Low, F.J., 1972. Far infra-red brightness temperatures of the planets. Ap.J., (Letters), 178:L89-L92.

DISCUSSION SUMMARY — PAPER 1.3

The telescope was 15 inches in diameter. A beam size of five arcminutes was used and the detector NEP was 10^{-13} watts/Hz$^{1/2}$ with a one-second integration time. Observations of Saturn using this system and an interferometer yielded a signal-to-noise ratio of about two.