LOW RESOLUTION SPECTRUM OF THE ORION NEBULA IN THE 60–300 μ RANGE

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Abstract. Airborne observations of the Trapezium region of the Orion Nebula in the 60–300 μ range have been made from 13.7 km altitude using a Michelson interferometer with the Rice University 12-in. Flying Infrared Telescope. Fourier analysis of five interferometer scans provided spectra with resolution ranging from 7 cm^{-1} to 20 cm^{-1}. These spectra were compared with lunar spectra taken with the same instrument at the same altitude to correct for instrumental and atmospheric effects. A weighted combination of these scans provides a low resolution spectrum. The radiation per unit frequency interval at 190 μ was found to be at least 40% of that measured between 75 and 90 μ. Neglecting possible features in the spectrum, its general shape is consistent with a blackbody near 70 K. The resolution is inadequate to resolve spectral lines.

Broadband observations of the Trapezium region of the Orion Nebula made by Low and Aumann (1970) revealed a large amount of radiation in the far infrared which was peaked near 70 μ. Their observations were made with a 31-cm open port telescope (Low *et al.*, 1970) on board a NASA Lear jet flown at an altitude of 13.7 km to eliminate most of the atmospheric water vapor absorption. To determine the spectral shape of the radiation we have added a Michelson interferometer to the airborne telescope to perform Fourier spectroscopy beyond 50 μ. The measurements described here result in a crude spectrum of a four arc minute diameter (estimated FWHM) portion of the Trapezium region of the Orion nebula from 60 to 300 μ.

A schematic diagram of the apparatus is shown in Figure 1. Light enters the Cassegrain telescope (Dall-Kirkham optics, Cervit primary with aluminum coating and aluminized silicon secondary) and then passes through a l-mm white polyethylene window into an evacuated chamber which contains a Michelson interferometer developed by Augason and Young (1971) and since modified for airborne use. The interferometer employs a 12.5 μ mylar beam splitter with gold coated plane mirrors. The detector is a gallium-doped-germanium bolometer cooled to 2 K and filtered to transmit at wavelengths longer than 50 μ. Actually we found that there was some leakage at shorter wavelengths. This was measured in the laboratory and appropriate small corrections were applied to the spectra obtained from the Lear jet.

In order to cancel radiation emitted by the sky and other sources such as the telescope, the signal is modulated by oscillating the secondary mirror horizontally. This permits the detector to view either of two 4′ diameter fields or 'beams' separated by 12′ and located symmetrically to the right and left of the axis of the primary mirror. To remove any 'offset signal remaining due to residual asymmetries in the system, signals can be recorded with the object in each of the two beams. The AC signal produced by the oscillating secondary mirror is amplified by a preamplifier and subsequently by a phase-lock amplifier synchronized with the secondary mirror drive signal. The output

Greenberg and Van de Hulst (eds.), Interstellar Dust and Related Topics, 453–457.

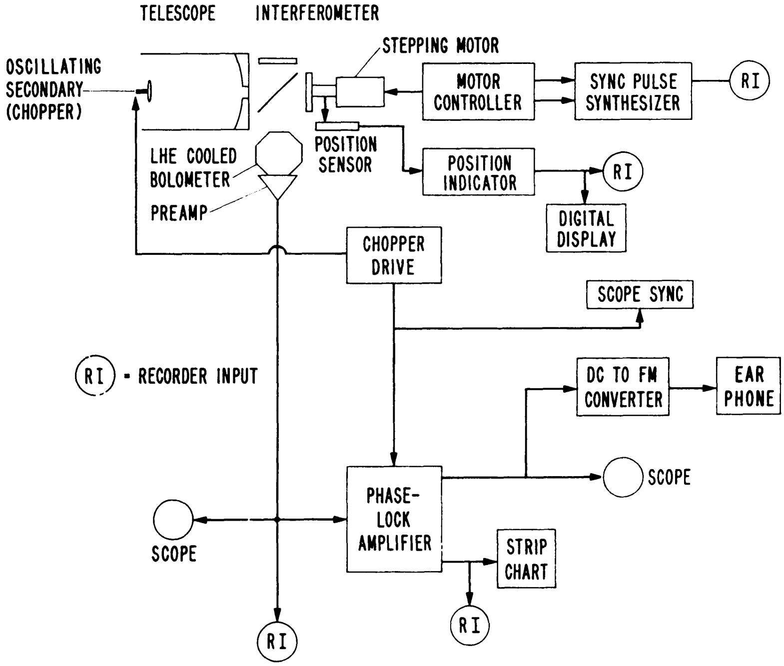

Fig. 1. Interferometer electronics block diagram.

of the phase-lock amplifier is recorded as a function of the position of the movable interferometer mirror. This mirror is moved in 9.6 μ steps. When looking at a bright extended source such as the Moon, the interferometer may be stepped automatically every one-half second or less, and as many as 256 steps are taken in a single scan. When looking at fainter sources, the interferometer mirror is not moved until the signal level is clearly established in both the left and right beams. This process is slow, so that during a single flight there was time for only 30 to 70 steps when observing the Orion Nebula. The resulting interferograms are then Fourier analyzed to yield unapodized spectra.

The spectrum obtained from a single two minute, 256 step lunar scan is shown in Figure 2. Its resolution is approximately 2.5 cm^{-1}. The main sharp features are due to telluric water vapor absorption. The overall shape is determined by the filter cut-on near 200 cm^{-1}. the beam splitter function and the blackbody character of the lunar emission. An average of five spectra of the Trapezium region is shown in Figure 3. The resolution is 10 cm^{-1} and the line lengths indicate two standard deviations. To correct the Trapezium spectrum for telluric absorption and instrument effects we have divided the spectrum in Figure 3 by the lunar spectrum in Figure 4 which was degraded to the same resolution. The result is then multiplied by a 360 K balckbody function which we considered appropriate (Kopal, 1969) for the obliquely illuminated portions of the moon which we observed. The result appears in Figure 5. Since it is not possible to take both lunar and Orion spectra simultaneously and usually not even the same night,

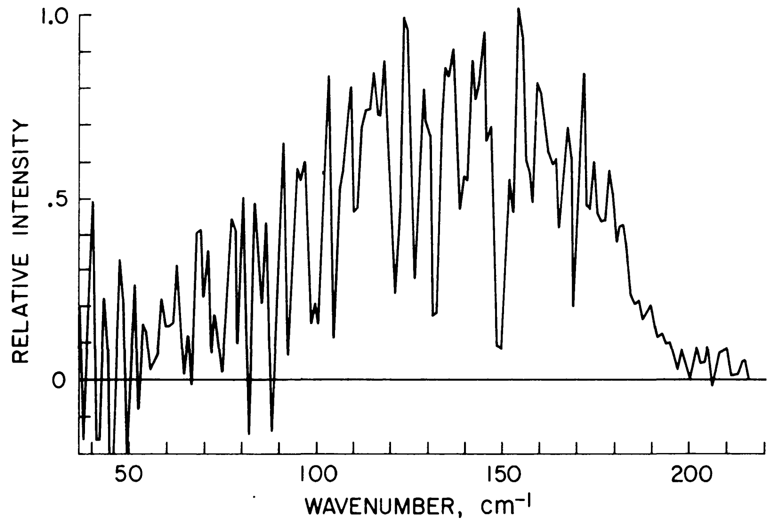

Fig. 2. Moon spectrum not corrected for atmospheric absorption and instrument efficiency.

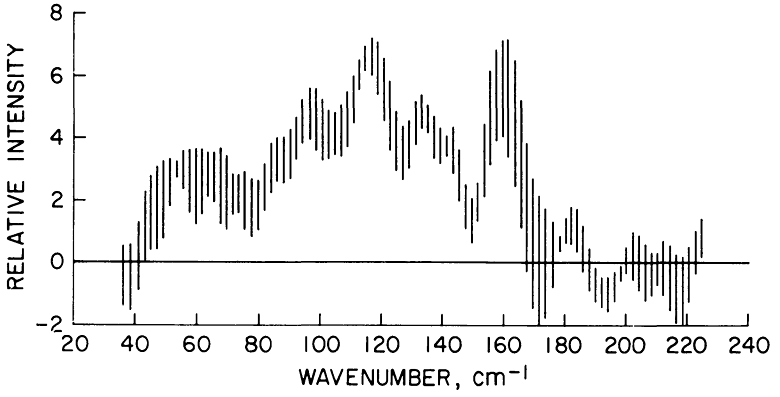

Fig. 3. FIR spectrum of Orion Nebula-Trapezium region uncorrected for atmospheric absorption and instrument efficiency. The calculated resolution is 10 cm^{-1}.

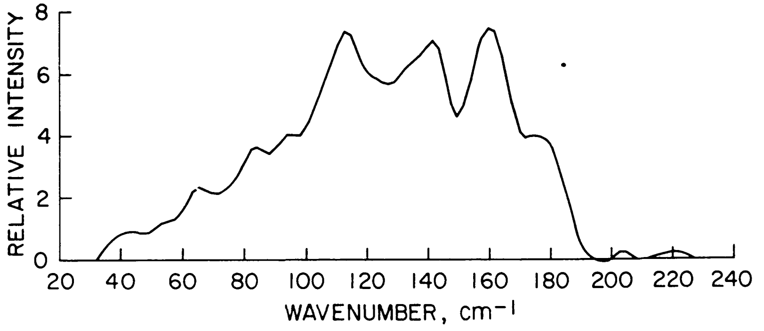

Fig. 4. Degraded moon spectrum uncorrected for atmospheric absorption and instrument efficiency.

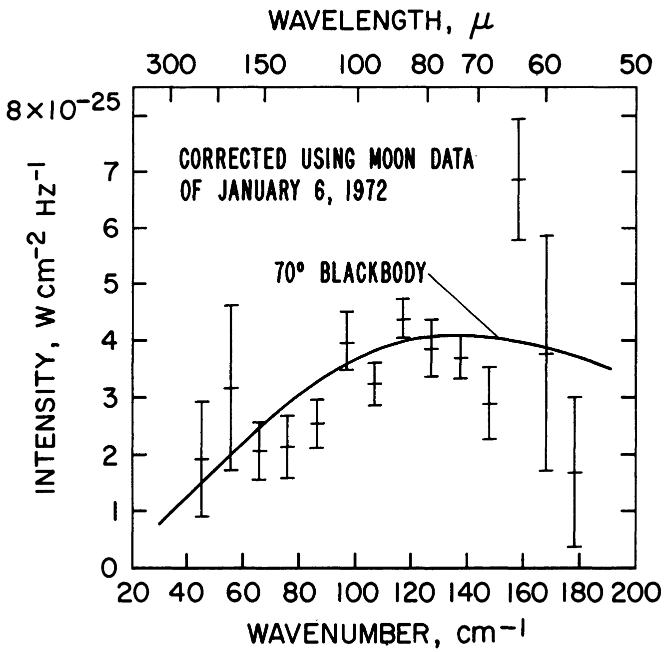

Fig. 5. FIR spectrum Orion-Trapezium region.

the water vapor correction may be different on different nights. We used an average of five Orion scans and an average of five lunar scans to obtain our results. Use of a different average of five lunar scans obtained in August 1971 gave nearly identical results.

The intensity scale was adjusted so that the overall flux in the 60 tp 300 μ range is normalized to Low and Harper (1971) measurement. The error bars indicate ± 1 standard deviation from the mean. A 70 K blackbody curve, normalized to the same total flux, is shown for comparison. Earlier work (Low and Aumann, 1970) indicated a blackbody behavior from 10 to 100 μ, and an extrapolation between 100 μ and 1 mm suggested a $\nu^{3.5 \pm 0.5}$ behavior at longer wavelengths. Figure 5 shows that the blackbody shape extends out to 200 μ.

Resolution and signal to noise were insufficient to detect lines having intensities predicted by Petrosian (1970). The two strongest lines predicted in the observed spectral range are the O I line at 63 μ and the O III line at 88 μ. While there are apparent peaks in Figure 5 at these wavelengths, the large standard deviations (determined directly from the spread in the five measured spectra) precludes a positive identification. The instrument used in these measurements is capable of better resolution and with sufficient integration time should be capable of producing a more accurate spectrum.

Acknowledgements

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