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# A Measurement of the Brightness Temperature of the Sun in the Range 65 to 180 cm $^{-1}$

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# A measurement of the brightness temperature of the Sun in the range 65 to 180 $cm^{-1}$

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The Bilderberg continuum atmosphere (B.c.a.) model of the Sun (Gingerich & de Jager 1968) has a temperature minimum of 4600 K between the photosphere and low chromosphere, which is based mainly on observations in the ultraviolet. This layer of the solar atmosphere is observable in both the ultraviolet and infrared spectral regions. However, at the time that the B.c.a. model was developed, there were no absolute measurements of the brightness temperature between 12 μm and 1 mm although there was some evidence to indicate the shape of the expected minimum in this spectral region. Since then several experiments have been performed from aircraft and high altitude balloons with the object of measuring the brightness temperature of the sun at long infrared wavelengths.

The measurement described in this paper made use of a Michelson interferometer employing Fourier transform multiplex techniques and was flown from a balloon to a height of 32.6 km from the N.C.A.R. Balloon Flight Station, Texas, U.S.A., in September 1969. The beam splitter consisted of a stretched film of Melinex 8 μm thick and the detector used was a Golay cell. Radiation of wavelengths shorter than about 45 μm was completely attenuated by optical filtering with black Melinex, polyethylene loaded with a uranium salt and by the quartz window of the detector. The Michelson interferometer was used with a continuous movement of one of its mirrors at 4 $\mu m\,s^{-1}$ and further shortwave attenuation was achieved by suitable electrical filtering of the signal frequencies in the resulting interferogram.

The spectrometer was mounted in a modified solar pointing platform which was initially built for the Science Research Council by the Hi-Altitude Instrument Co. Inc., Denver. At altitude the platform 'locked' onto the sun to better than 6′, sufficient to ensure that the aperture which selected the central part of the solar disk was uniformly illuminated. No significant fluctuations in signal between interferograms was observed indicating that the guidance was adequate; a closer guidance system would, of course, have been preferred.

During the flight the solar radiation was 'chopped' against that from the sky, both beams including the main black Melinex filter stretched over the input mirror. For a short period the platform was offset from the sun and interferograms taken which measured the effect of any unbalance in the chopping system, the resulting 'sky' spectrum being subtracted from the 'solar' spectrum (see figure 1). After the flight the system was calibrated against a known source in an evacuated chamber.

One problem with the type of platform used was the crossing of the input beam by support cables, in particular the one which carried telemetry leads. To overcome this difficulty a large number of short interferograms were recorded and, as expected, due to the rate of rotation of the outer part of the gondola becoming very slow at altitude, it was possible to select many of

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these interferograms which had not been affected by a crossing cable. The appearance of a set of averaged spectra is shown in figure 1, at a resolution of about 10 $cm^{-1}$ (after apodization). The effect of the instrument profile has not been removed from these spectra, and the strong attenuation of the radiation towards the shorter wavelengths is clearly seen.

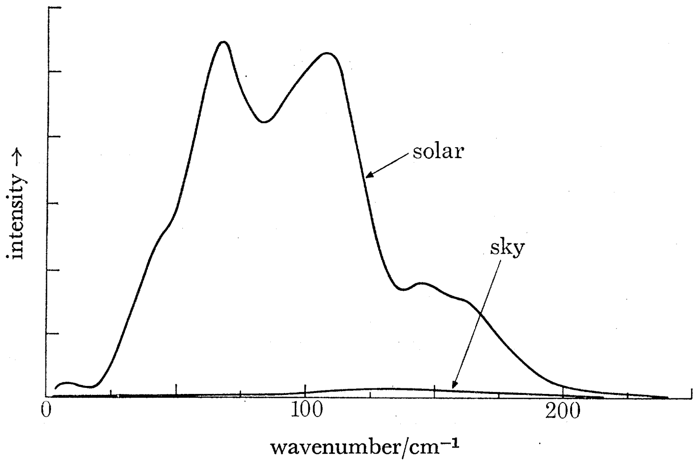


FIGURE 1. Low resolution (~ 10 $cm^{-1}$) solar and sky spectra.

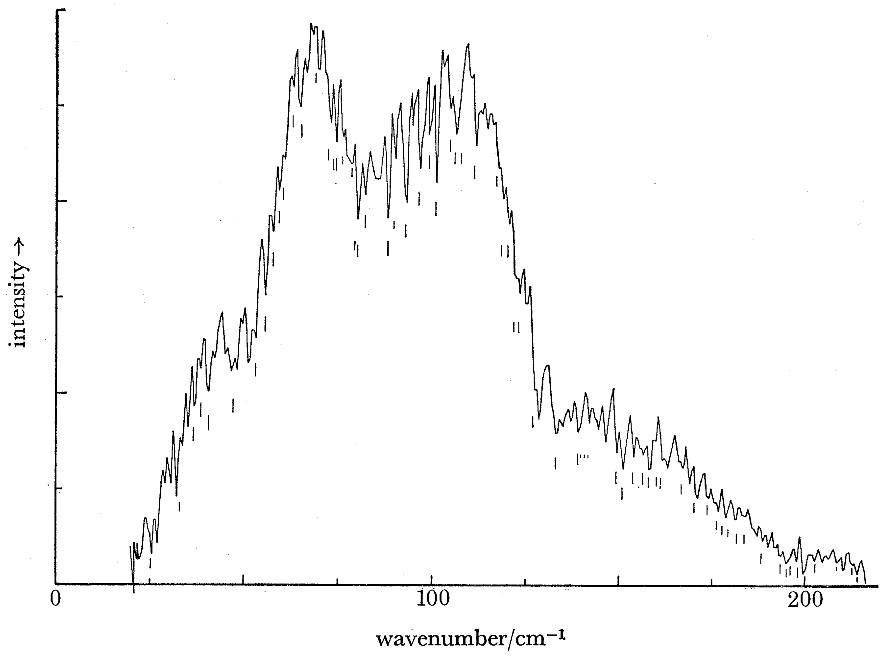


FIGURE 2. Solar spectrum at resolution ~ 1 $cm^{-1}$. Vertical dashes indicate the positions of water vapour absorption lines.

Longer interferograms were also recorded and give a resolution of about 1 $cm^{-1}$ but require correction for cable crossings. One spectrum which has been partially corrected is shown in figure 2, and clearly indicates the presence of water vapour in the path, the absorption lines being in agreement with those given by Turon-Lacarrieu & Verdet (1968), the positions of which are indicated by vertical dashes. Our spectrum also has a number of other interesting features which require further study.


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When the calibration spectra were being measured a high resolution spectrum was also obtained. This showed a similar amount of water vapour absorption to that observed in the solar spectrum and, to date, no relative correction has been applied; it will in any case be small.

The brightness temperature of the Sun was obtained from the average of seventeen solar spectra at low resolution and is shown plotted on figure 3 (labelled U.C.L.) together with the results of Gay *et al.* (1968), Eddy, Léna & MacQueen (1969), Léna (1970) and Mankin & Strong (1970, M. & S.). The prediction according to the Bilderberg model (B.c.a.) is also plotted; it shows the very broad minimum in the temperature distribution in this spectral region.

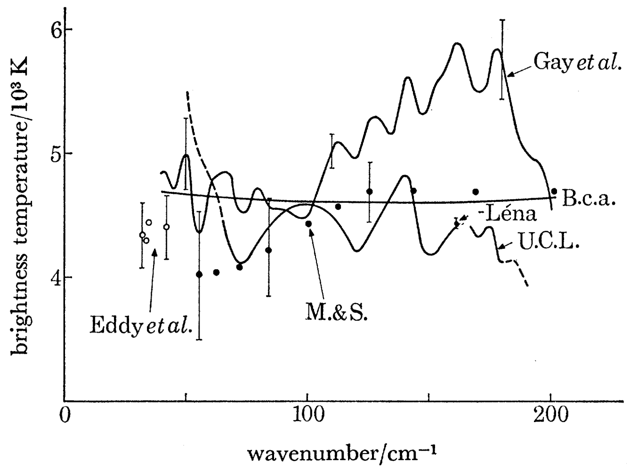


FIGURE 3. Solar brightness temperature.

The results of both Gay *et al.* and Mankin & Strong show a decreasing temperature with decreasing wavenumber. While our results do not indicate this trend so strongly, they are nevertheless very compatible with the values of Mankin & Strong between 70 and 140 cm$^{-1}$.

The fluctuations in temperature which we observe are probably instrumental. Their origin is so far unknown and consequently it has not been possible to calculate error bars for this curve. The standard deviation corresponding to the spread of the individual spectra about their mean is far less, amounting to only 2 % between 75 and 160 cm$^{-1}$. The parts of the temperature curve which can only be determined at a lower accuracy, due for instance to the steep slope of the spectra in that region, have been shown by a dashed line.

Our experiment was originally intended to give only relative values but we have nevertheless endeavoured to put our results on an absolute basis. As we cannot do this with any great confidence it is very reassuring to find that our curve passes close to the well-defined point at *ca.* 160 cm$^{-1}$ given in the paper by Eddy *et al.*—see also Léna (1970). We wish to think of this point as normalizing our results at an average temperature some 200 K below the B.c.a. prediction.

This paper is a preliminary report of our results, the analysis of which is continuing. The work will form the subject of a Ph.D. thesis to be presented by Mr G. R. Courts.

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Watts in the preparation and testing of the payload was greatly appreciated. We are also very indebted to Dr D. A. Walmsley for his help with a preliminary flight of this equipment.

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