CONTRIBUTIONS

Radio Studies of the Quiet Sun at Decimetre and Metre Wavelengths

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It is known that in the radio spectrum the limb of the quiet sun is brighter in the equatorial regions than near the pole. But most of the available theoretical calculations[1] of the brightness distribution over the quiet sun have been made with the assumption of spherical symmetry. We have therefore calculated two-dimensional distributions at several decimetre and metre wavelengths, taking account of the observed asymmetry in the north-south direction. Newkirk's[2] method of ray-tracing was used, the calculations being made with a CDC 3600 computer. Some of the preliminary results (particularly for a sunspot minimum period) are presented here; they indicate that the electron temperature of the solar corona has a value of about 1 to 1.5×10^6 °K.

For the quiet solar corona the electron densities in the equatorial and polar directions were assumed to be the same as in the model of van de Hulst[3] for a sunspot minimum period; some maps were also derived for the case when the above densities are multiplied by constant factors K_e and K_p respectively. For other directions on the Sun, electron densities were calculated by assuming that the surfaces of constant electron density are ellipsoidal in shape and symmetrical about the Sun's axis of rotation.

The calculated two-dimensional map at 214 MHz for $K_e = K_p = 1$ and an assumed electron temperature of the corona of 10^6 °K shows limb brightening of about 60% and ellipticity of 12%. The Fourier transforms of the one-dimensional strip scans in the east-west and north-south directions derived from the calculated map at 214 MHz are compared in Figure 1 with the visibility functions measured

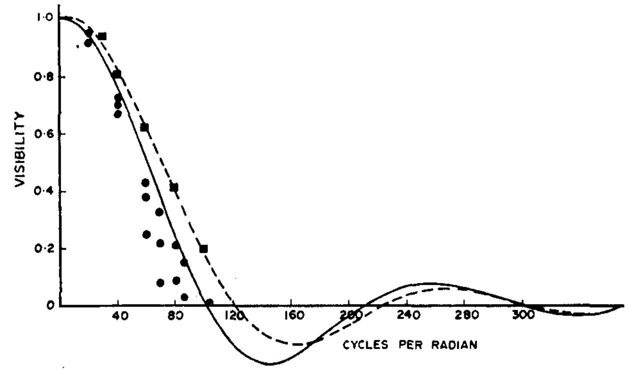

Figure 1. One-dimensional Fourier transform of theoretical brightness distribution at 214 MHz (—— equatorial scan, – – – polar scan; ● values observed by O'Brien in equatorial direction, ■ values observed by O'Brien in polar direction).

by O'Brien.[4] A reasonable agreement is seen up to the maximum spacings of the 2-aerial interferometer used by O'Brien but for the east-west scan the calculated Fourier transform is somewhat broader than the observed one.

Moutot and Boischot[5] have derived a value of 5.8×10^{-22} W/m^2 Hz for the flux density of the quiet sun at 170 MHz from observations made during the rising phase of the last solar cycle. According to Fokker's[6] calculations this value of flux-density requires an electron temperature of 650 000 °K. As seen from Table I, however, our detailed calculations require a value of about 1×10^6 °K. The derived value of temperature would be lower if the electron densities were much higher during the period of the above observations.

Table I

Calculated Solar Flux at 170 MHz for Different Temperatures using van de Hulst's N_e Model

Coronal Temperature (10^6 °K)	Solar Flux (10^{-22} W/m^{2}Hz)	
	$K_e = 1.0, K_p = 1.0$	$K_e = 1.25, K_p = 1.25$
0.75	4.94	5.40
1.00	5.63	6.40
1.25	6.03	7.17
1.50	6.23	7.70

A calculated two-dimensional distribution at 610 MHz has been presented earlier.[8] Its east-west strip scan was found to be in good agreement with the observations made during June-July 1965. In Figure 2 is shown a north-

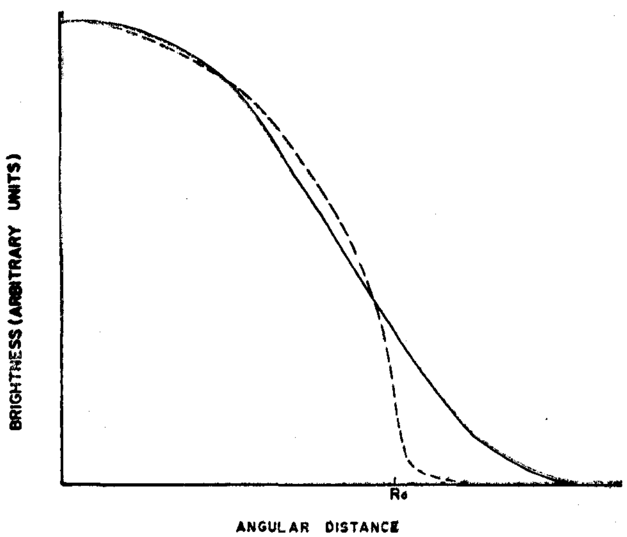

Figure 2. One-dimensional brightness distribution of Sun in polar direction: —— observed in November 1965; – – – theoretical.

south strip scan of the quiet sun observed at 610 MHz with a 5′.7 beam in November 1965. The theoretical strip scan shown in the figure, if smoothed by the beam of the antenna, agrees reasonably with the observations although the latter still shows a somewhat higher tail. This broadening could be caused by scattering of radio waves by irregularities in the solar corona[7] but the possibility of its arising from higher side lobes of the antenna cannot be eliminated.

Isloor (unpublished) has studied many isolated sources of the slowly varying component at 610 MHz during 1965-1966. The highest values of brightness temperature were found to be 1×10^6, 1.1×10^6. 1.5×10^6 and 1.7×10^6 °K for regions with central meridian passage of 1966 September 28, 1965 October 3, 1966 April 2 and 1966 March 21 respectively. It is known that the electron temperature of the corona has a higher value near the active regions than in the quiet parts. But because the above sources at 610 MHz have a rather large size of 10′, 6′.6, 7′.3 and 7′.3 respectively it seems reasonable to assume that the peak observed value of about 1.5×10^6 °K represents the electron temperature of the quiet rather than the active solar corona. This value is in agreement with that derived by Moutot and Boischot[5] and Christiansen and Mathewson.[9]

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Observations of the Sun with the Molonglo Cross

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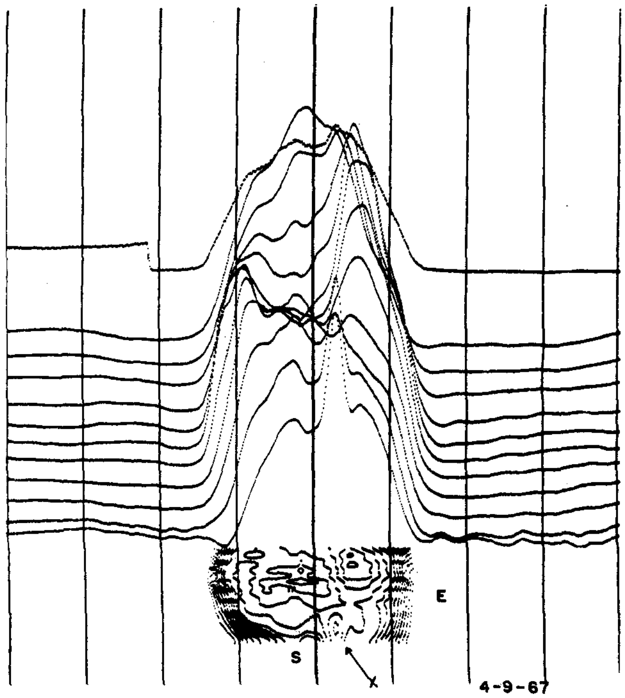

Figure 1. A record of the Sun showing the eleven beams. The top record is of the east-west total power; the bottom section shows the contour map of the Sun which is produced at the same time. The small bright region marked with a cross was not present the previous day.

Transit observations of the Sun can be made with the Molonglo radio telescope[1] which is now in full operation at 408 MHz. Thus the Sun can be scanned once per day by eleven separate beams evenly spaced in declination. Because of foreshortening of the north-south arm with increasing zenith angle, the total coverage varies and in winter about 28′ arc can be covered by the eleven beams, whereas only 15′ is covered in mid-summer. This also means that the beamwidth in declination changes from 2′.9 at the zenith to about 5′.8 for the mid-winter sun. The beam is 2′.8 wide in right ascension. A further complication is the fact that the positions of the eleven beams cannot be chosen arbitrarily but can only be selected from a predetermined set of beam positions. These latter have been fixed by the phasing connections built into the telescope and cannot be changed easily. Hence for all the above reasons the strip of Sun which can be scanned will vary from day to day.

So far only 6 days' observations have been made with the full instrument. These have been recorded in two ways. Firstly an analog record was made using an eleven-channel recorder as shown in Figure 1. The total power for the east-west arm is also displayed on a twelfth channel. As well as these a section of the chart is given over to an automatic contour plot of the Sun as it goes past the telescope. This is extremely useful for rapid analysis but as it is not corrected for different channel gains or zeros it is used mainly as a guide in the analysis of the analog records. To this end the data is also recorded digitally on magnetic tape which can then be fed into the KDF9 computer for processing. It is the intention to program the computer to produce accurate contour maps but at present this is not available. The digital equipment has therefore been used to produce sampled data for hand analysis.

Turning now to the observations, two aspects will be discussed. Firstly, the way in which the intensity falls off at the limb is of considerable interest because of the possibility of limb brightening, and, secondly, the positions, intensities and sizes of the bright regions are of importance. With so few observations it will not be possible to give definitive answers but from what is available a few things are of interest. For example, referring back to Figure 1, it will be noticed that the edge of the radio sun is fairly sharply defined. In order to examine this more closely, contour maps of the Sun for the 6 days were drawn and a scan along the equatorial direction was determined from these. Thus after rejecting two of these because of bright regions, the way in which the radiation varies from the centre of the Sun was determined as an average of 10 centre-to-edge scans and is shown in Figure 2. The mean brightness temperature at the centre was 0.97×10^6 °K. For comparison, a theoretical curve for infinite resolving power due to Smerd[2] is shown dotted.

There is some smoothing due to the 3′ beam so that any sharp peak at the edge will be reduced. Even allowing