RECENT VERY BRIGHT TYPE IV SOLAR METRE-WAVE RADIO EMISSIONS

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INTRODUCTION

Stewart et al. (1978) have reported moving Type IV solar metre-wave radio outbursts with brightness temperatures between 10^8 and 10^{10} K. We now report Culgoora radioheliograph observations of four more Type IV radio sources, some moving, some stationary, but all with brightness temperatures above 10^9 K, and one with a brightness temperature above 10^{13} K. We also describe one of the previously reported events (that of 1977 September 20) in more detail. The interest of these events is that their high brightnesses place great strain upon the gyro-synchrotron theory of radio emission.

OBSERVATIONS

Details of the outbursts are shown in Table I. Brightness and

TABLE I

Brightness temperature (T_b), polarization, and motion of the Type II and Type IV phases of four recent intense solar metre-wave radio outbursts.

Date	Type II max. phase at 43 MHz		Type IV					Moving or Stationary
			Max. phase at 80 MHz			Max. phase at 43 MHz		
	UT	$\log_{10} T_b$	UT	$\log_{10} T_b$	Pol. %	UT	$\log_{10} T_b$	
1977 Sept.7	2241	10.7	2259	9.2	40 R	2310	9.3	Slowly M
1977 Sept.16	2244	10.2	2307	10.3	60 R	2333	9.9	S
1978 May 7	-	<12.7	0341	12.0	20 R	0334	13.7	M
1979 Feb.16	0156	11.8	0214	9.5	0 L	0230	9.9	M

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polarization are tabulated for the time of maximum brightness at the stated frequency. No Type II was seen to precede the Type IV of 1978 May 7; a Type II during the Type IV would not have been seen unless it had been brighter than about $10^{12.7}$ K. We see that in all events the brightness temperatures at 43 and 80 MHz exceeded 10^9 K and that in one event, 1978 May 7, the brightness temperature at 43 MHz exceeded 10^{13} K.

Spectral plots for these four events are given in Figure 1. The

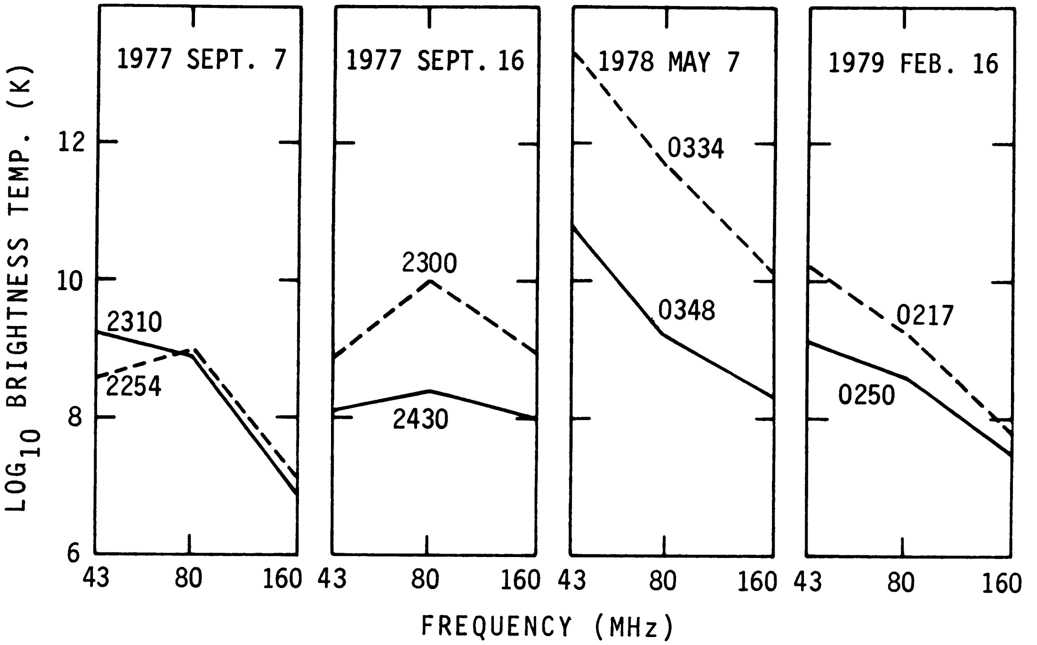

Fig. 1 - Brightness temperature versus observing frequency. Dashed and solid lines respectively refer to the earliest and latest times that the sources were visible at all three radio frequencies. The latest time was usually set by the disappearance of the source at 160 MHz. The apparent coronal height of the sources was often different at different frequencies.

stationary source seen on 1977 September 16 showed a moderately flat spectrum. The moving sources seen on the other dates had steeper spectra, with spectral indices between -4 and -5.

Table I shows also the circular polarization of the Type IV radio sources at 80 MHz at the time of maximum brightness at 80 MHz (the heliograph cannot measure polarization at 43 MHz). These four events showed polarizations of from 0% to 60%; another event seen on 1977 September 20 and described later, showed a polarization, at the time of maximum brightness, of 100%. The polarization increased after the time of maximum brightness in all events except those of 1978 May 8, where the polarization remained steady, and 1977 September 20, where the polarization, having reached 100%, could rise no higher.

Type IV sources, that is sources which emit broad-band long-lived continuum, may be divided into two broad classes: those continuum sources which remain stationary at normal coronal heights and those continuum sources which move progressively outwards to very great coronal heights. The latter have often been considered to be isolated plasmoids carrying their own magnetic field and energetic electrons, and emitting by gyro-synchrotron emission. The four events listed in Table I almost certainly include examples from both classes.

However, very high moving Type IV sources can be identified with confidence only if the source lies near the limb and has a component of velocity radially outwards at right angles to the line of sight. Such circumstances prevailed during the event of 1977 September 20 (Stewart et al., 1978; Duncan and Dixon, 1979). This event began with two adjacent and oppositely polarized sources on the limb. The southern source was about 55% left-hand circularly polarized throughout the event. The northern source was about 60% right-hand circularly polarized at the start (0325 UT) of the event, but it rapidly increased in polarization and was approximately 100% polarized at all times after 0329 UT. As shown in Figure 2, the southern partially left-hand-polarized source remained stationary, but the northern totally right-hand-polarized source moved outward at a projected velocity of 710 km s^{-1} and reached a projected radial distance of 3.4 $R_{\odot}$ before fading (Fig. 2). Thus in this event we have a clear example of both a stationary and a moving Type IV radio source, each with a brightness temperature exceeding 10^9 K.

The moving component of the very bright event observed on 1978 May 7 showed only about 20% polarization at the time of maximum brightness. It differed from all the other events listed in Table I in that its polarization did not increase after the time of maximum brightness; in fact, at many times its polarization fell well below 20%. Its projected velocity carried it across the face of the disk, so that we have no way of knowing whether or not it rose to great coronal heights.

DISCUSSION

Moving Type IV sources have often been attributed to gyro-synchrotron emission from sub-relativistic electrons trapped in an isolated moving plasmoid (Dulk, 1973; Kai, 1978). However, the observations reported here and elsewhere (Kai, 1969, 1978; Stewart et al., 1978) throw doubt on this interpretation (cf. McLean, 1974). Because moving Type IV radio emission is usually strongest at low frequencies (Fig. 1) and because it is often substantially circularly polarized, we cannot invoke electrons with energies much above 100 keV (Kai, 1969; Dulk, 1973; Stewart et al., 1978). However, 100 keV electrons are incapable of giving gyro-synchrotron brightness

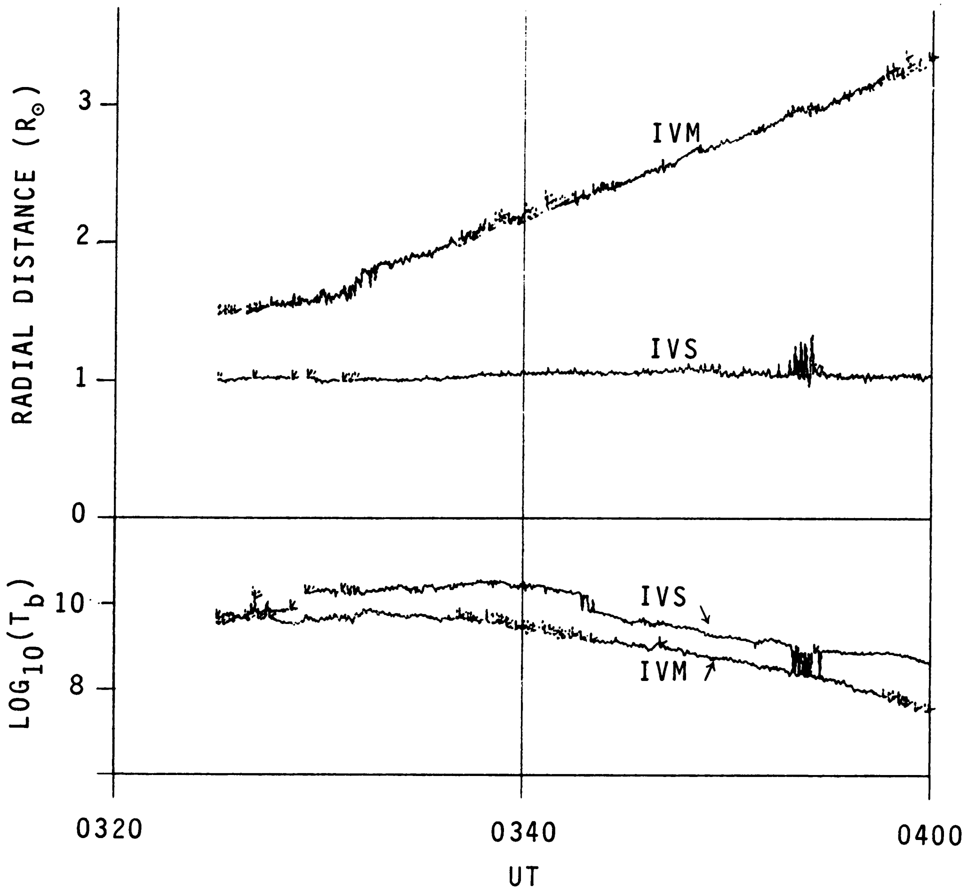

Fig. 2 - Plots of radial distance (top) and brightness temperature (bottom) of the two sources seen on 1977 September 20, both measured at 80 MHz.

temperatures much greater than 10^8 K (Stewart et al., 1978); even if they radiated as a perfect black body they could, from Boltzmann's relation, give a brightness of no more than 10^9 K. Thus, in summary, on the incoherent gyro-synchrotron model the observed spectra and polarization of Type IV radio sources are difficult to reconcile with their observed brightness. The very high brightnesses suggest amplified, or coherent, emission.

A feature of the event of 1977 September 7 suggested coherent plasma emission. During this event Type III emission was seen to come from the same high moving source as Type IV emission. As Type III emission is universally believed to arise through plasma emission this observation implies that - notwithstanding the great height of the source - plasma densities were appropriate for plasma emission. Hence the Type IV also probably arose through plasma emission (Duncan, 1978).

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