CORONAL DENSITY STRUCTURES IN REGIONS OF TYPE III ACTIVITY

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Abstract. The Mauna Loa K-corona data were examined to determine the density in regions of type III activity which were observed during March and April, 1971, at Clark Lake Radio Observatory. It is found that these regions avoided the centres of dense structures in the corona. Both the K-corona data and the radio data indicated densities characteristic of the 'quiet' corona. The density gradients determined from the K-corona and the radio data agreed to within their formal errors.

1. Introduction

It is generally accepted that type III burst exciters travel along neutral sheets in the coronal field, which correspond to the densest parts of streamers (e.g., Wild and Smerd, 1972; McLean, 1970; Sturrock, 1972). Smith and Pneuman (1972), in a theoretical study, point out that the particles responsible for type III bursts cannot travel in the densest part of a coronal streamer due to the transverse magnetic field in the neutral sheet. Some evidence has been presented that not all type III exciters travel at or near the centre of streamers (Kai and Sheridan, 1974; Kuiper, 1973a). In this paper, we present further evidence supporting the latter point of view.

Recently, Kuiper (1973a) analyzed isolated type III bursts observed at Clark Lake Radio Observatory during March and April 1971. By noting the day of transit of the region and comparing the east-west position of the burst at the limb passages, it was possible to deduce the longitude and latitude of the region (see Kuiper, 1973c, Ch. V). It was shown that the bursts occurred in discrete regions corotating with the Sun. By the temporal association of type III bursts with Hα activity, the active regions generating the type III exciters were identified and it was shown that the type III burst regions occurred, on the average, radially above these active regions which are identified. On the basis of the computed coronal potential field and the presence or absence of dark filaments in the plages, it was argued that the bursts occurred only when the field was open, or diverging whereas an arcade-like closed structure, which is often associated with the lower part of a streamer, is unfavourable for the escape

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of the exciters. In this paper, we examine the density of the corona over these active regions. We have used the same radio data, together with the daily white light coronal observations obtained with the High Altitude Observatory K-coronameter at Mauna Loa, Hawaii. The intensity profiles and the synoptic maps derived from the K-corona data allow us to distinguish between dense structures and low intensity regions. A deconvolution technique developed by Leblanc *et al.* (1970) is applied to calculate the electron density of these structures. For the low intensity regions, van de Hulst's (1950) method has been used to compute the electron density of models.

2. The Density in the Regions of Type III Activity

The K-coronameter measures the scattered light by making concentric small-aperture scans around the Sun at selected heights above the limb. In 1971, the heights of the observations were $3\farcm6$, $5'$, $9\farcm1$, and $13\farcm1$. As the electron density is closely related to the intensity of the scattered light we were able, by means of isophotal maps at each height and day to day intensity profiles, to distinguish between dense coronal structures and low intensity regions.

In Table I, we give the central meridian passage (CMP) of each active region above which isolated type III bursts occurred, its limb passages (as the K-corona observations are made at the limb), and the K-corona feature at that position. The identification is generally made at the limb passage of the region, as shown in Figure 1. In a

TABLE I

Active regions above which isolated type III bursts occurred (March–April 1971)

McMath region	CMP	Latitudinal position	East limb passage	K-corona feature	West limb passage	K-corona feature
11174	2 March	24°–26° N	22 February	EDS	9 March	EDS
11176	3–4 March	7°–8° N	24 February	LDR	10 March	LDR
11189	10–11 March	8°–10° S	3–4 March	LDR	17 March	LDR
11191	13 March	16°–17° S	6 March	(LDR)	19 March	LDR
11192	15 March	18°–20° N	8 March	EDS	22 March	no obs. (EDS)
11207	appears on 16th March	6° S	–	–	22 March	no obs.
11209	22 March	15°–20° S	15 March	EDS	23 March	no obs. (EDS)
11221	31 March	16°–18° S	24 March	LDR	6 April (and 10 March)	no obs. (EDS)
11249	16 April	4°–5° S	9 April (and 13 March)	LDR	23 April (and 27 March)	no obs.
11250	16–17 April	4°–5° S	9 April (and 13 March)	LIS	23 April (and 27 March)	no obs.
11256	18 April	20°–22° N	11 April (and 15 March)	LIS	25 April (and 29 March)	no obs.

EDS: edge of dense structure.
LDR: low density region.
LIS: low intensity structure.

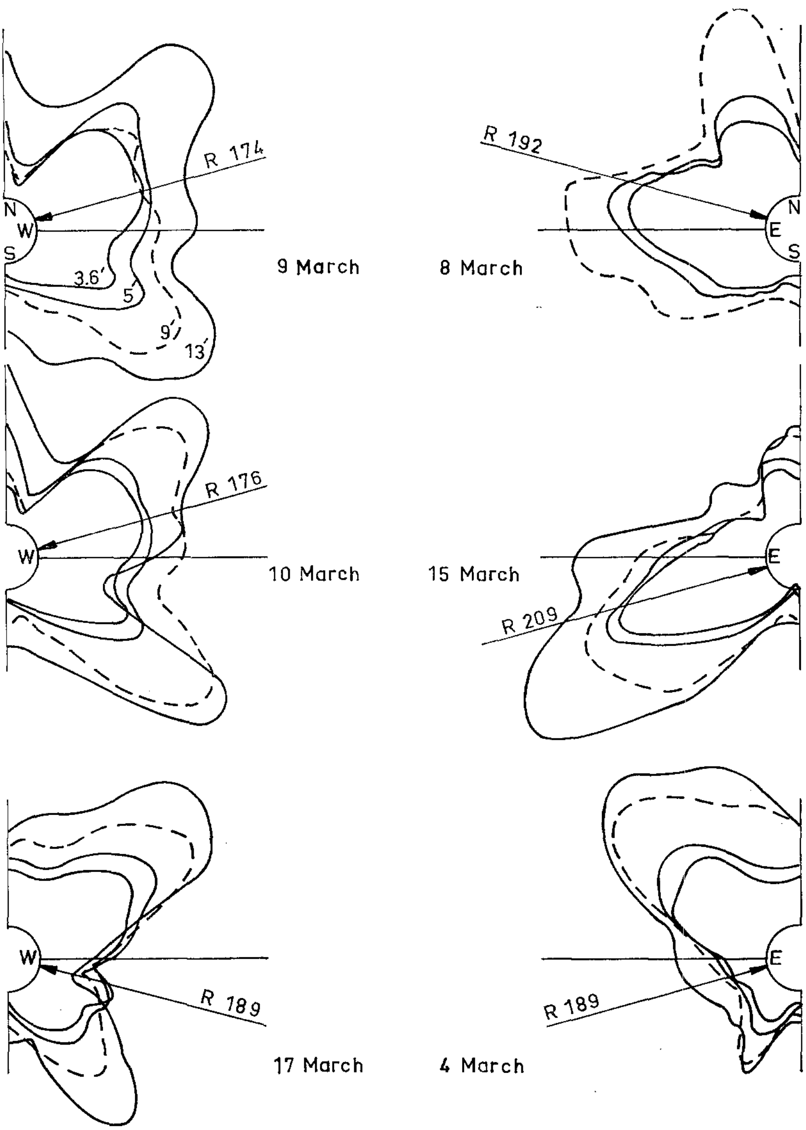

Fig. 1a.

few cases, when no observations were made on the day of limb passage, observations were made for most of these a few days before and after limb passage. In such cases, it was possible to determine the nature of the corona from the synoptic map in Figure 2. It can be seen from Table I and Figures 1 and 2 that most of the active regions (11189, 11176, 11191, 11249, 11221, 11250) associated with emission of isolated type III bursts avoided the coronal high density regions, a few centres (11174, 11192, 11209) appeared adjacent to high density regions, but not any active region associated with type III bursts is on the axis of a large coronal density structure.

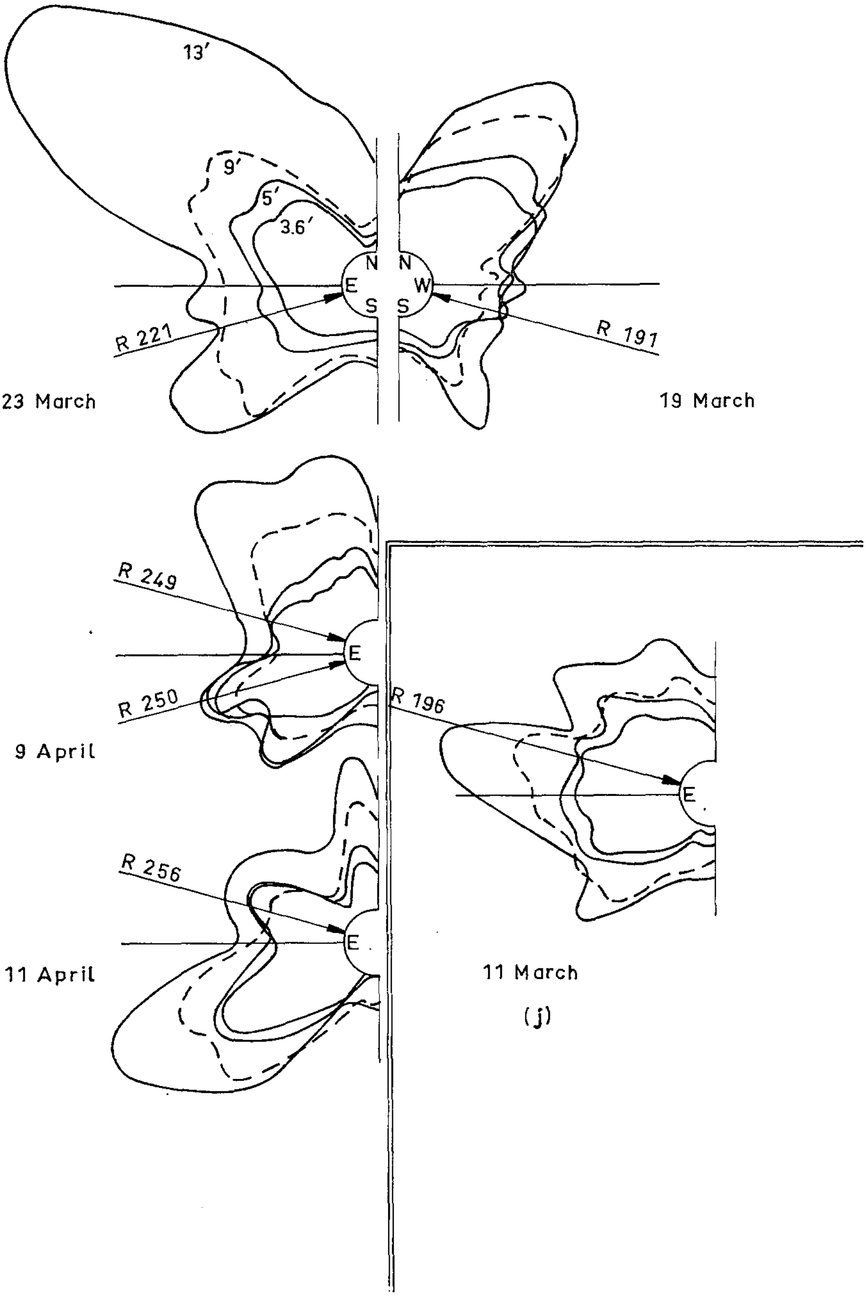

Fig. 1b.

Fig. 1a–b. K-corona observations: Intensity profiles obtained at four heights. The dashed line indicates the intensity at 9′ above the limb. The position of the McMath region associated with the solar burst region is shown by an arrow. (j) Region 196 which did not show any type III activity.

It is of interest to consider McMath 196. While it showed considerable Hα activity, no type III bursts were associated with this region. On the basis of the closed structure associated with it in the calculated potential field as well as a prominent dark filament, Kuiper (1973a) concluded that this region probably had a closed-over, streamer-like field configuration. We see in Figure 2 that this region is associated with a high density structure.

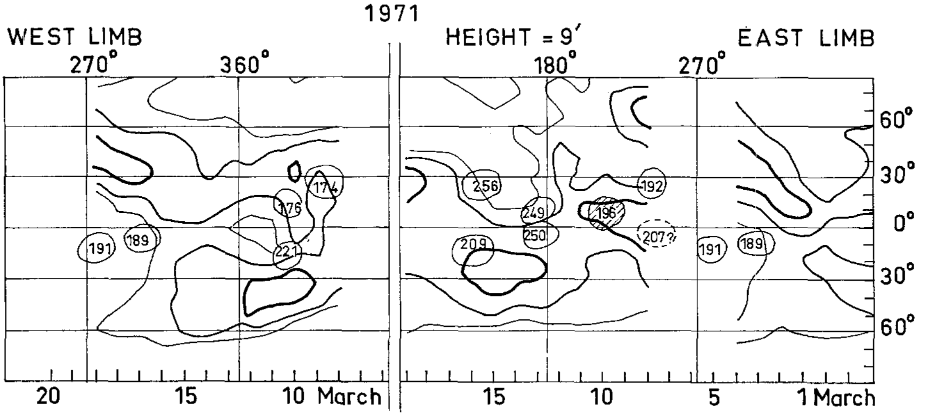

Fig. 2. K-corona observations: synoptic maps. The numbers represent MacMath regions associated with the solar burst regions. The intensity levels are in arbitrary units and represent: —— very low; —— low; ▬▬ high intensity.

The average height of the type III bursts gave us a measure of the coronal density. In order to determine the height of the radio bursts, we compared the east-west positions of this activity. All the events occurring in a single region in one day were averaged together. For all the days for which we had such data, it was found that the east-west positions of the bursts at 60 MHz were, on the average, 1.55 ± 0.10 larger than the east-west positions of active regions. As we already pointed out, the regions of type III activity were centered radially above their corresponding active regions. (Note that this statement refers to the centres, and not the individual bursts). Consequently, the apparent height of the type III bursts at 60 MHz was 1.55 $R_\odot$. When refraction and scattering effects were taken into account (Leblanc, 1973), the true height at 60 MHz was found to be 1.4 $R_\odot$. By virtue of the observed density gradients (see next section), the height 1.5 $R_\odot$ corresponds to a type III burst frequency of 50 MHz. Since we do not know in what ratio the observed bursts were fundamental or harmonic emission, we estimate the electron density at 1.5 $R_\odot$ to be in the range $0.7\text{–}3.0 \times 10^7$ cm^{-3}.

These values are less higher than the electron density derived from others radio observations (Wild *et al.*, 1963) which generally favoured a high density model (twice Newkirk's model). The discrepancy between these and our own results may be explained by the fact that scattering effects were not taken into account. It has been demonstrated (Riddle, 1972; Leblanc, 1973) that, due to scattering, the apparent height of type III bursts (fundamental emission) is higher than the real one, and must

TABLE II

Density gradients

McMath region	$g_R = \beta/\varrho = d(\log N_e)/d\varrho$ ($\varrho = 1.5\,R_\odot$)	$g_K = d(\log N_e)/d\varrho$ ($\varrho = 1.5\,R_\odot$)	N_{eK} ($\times 10^7$ cm^{-3})
11174	?	$\approx 4.5 \pm 1$	2.2 and 3.3
11176			2.6
11189	8^{+4}_{-2}	$\approx 6.3 \pm 1$	0.8–0.5
11191			0.7–1
11192			0.8
11207		no obs.	no obs.
11209	?	$\approx 4.5 \pm 1$	4
11221	$3.1^{+0.7}_{-0.5}$	$\approx 4.1 \pm 1$	1.7
11249	$3.6^{+0.5}_{-1}$	$\approx 5.3 \pm 1$	1.4
11250			1.7
11256			1.5

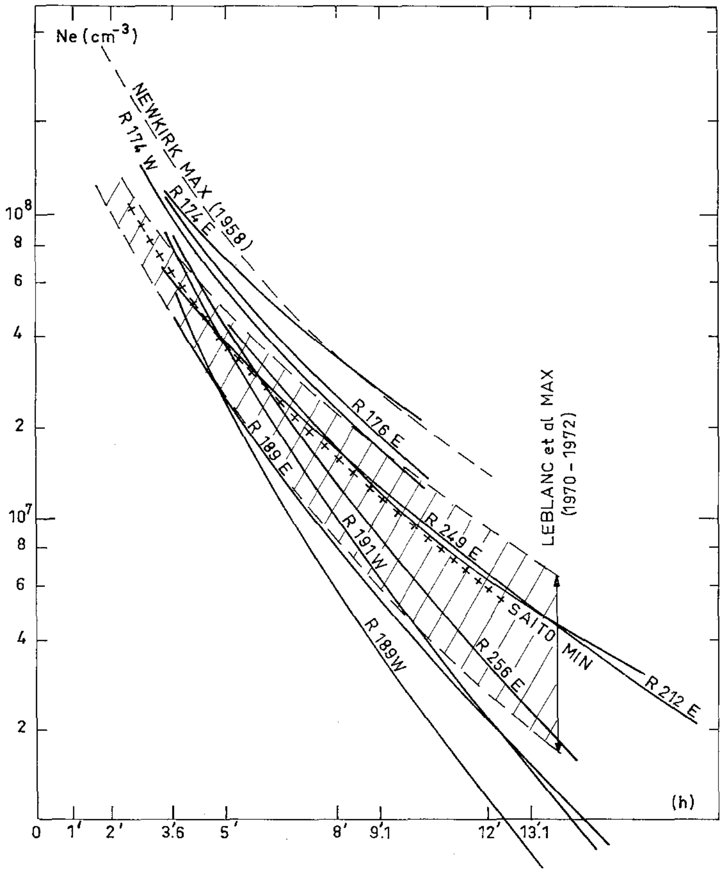

Fig. 3. Calculated electron density models. For comparison, we also give Newkirk's (1967) model for the 1956–1958 solar maximum, Saito's (1970) average model for solar minimum, and the range of values for the quiet corona determined by Leblanc *et al.* (1973) for the 1970–1972 maximum (hatched region).

coincide with that of the harmonic emission; this means that the electron densities derived by assuming an emission at the fundamental frequency will be about four times too large at each level.

In Table II, the densities at 1.5 $R_\odot$, as determined from the K-corona observations, are given for the corona above the type III-associated active regions. The densities range from 0.7 to 4×10^7 cm^{-3}. Thus, there is quite good agreement between the radio and optical determinations of the density. The results are also consistent with the values determined for the quiet corona at solar maximum obtained by Newkirk (1967) and Leblanc *et al.* (1973):

Newkirk	(1958 maximum)	3×10^7 cm^{-3}
Leblanc et al.	(1971 maximum)	0.9–2.5 $\times 10^7$ cm^{-3}.

The coronal density at different heights, as determined from the K-corona scans, is given for the various type III-active regions in Figure 3.

3. The Density Gradients in the Regions of Type III Activity

The density gradient of some regions of type III activity was determined from the radio data by a method described by Kuiper (1973b). The density of the corona was assumed to be of the form $N \sim \varrho^{-\beta}$, where ϱ is the height measured from the centre of the Sun. Not all regions had enough bursts to give a statistically meaningful result. Consequently, it was necessary to group together a number of nearby regions, and even then, only three sets of data gave meaningful results. The results of the analysis are listed in Table II.

In the K-corona analysis, a density model of the form $N \sim \exp(-K/\varrho)$ was assumed. The gradient was determined for five regions, including the three used in the radio analysis. The results are given in Table II.

Because of the different models assumed in the two analyses, a parameter

$$\begin{aligned} g_\mathrm{K} &= -\,d(\log N)/d\varrho = K/\varrho_\mathrm{K}^2 \\ g_\mathrm{R} &= \beta/\varrho_\mathrm{R} \end{aligned}$$

was defined, where ϱ_K and ϱ_R are the mean heights at which the K-corona and radio burst density gradients were determined. The values of g for both analyses can be compared directly in Table II. It is seen that the agreement is reasonably good.

4. Discussion

We have examined the coronal density above active regions which showed type III activity during March and April of 1971. We recapitulate our findings:

(1) The centres of type III activity avoided the regions of high density in the corona, the centres occurring either in regions of low density or, in a few cases, to the side of dense structures. On the other hand, a particularly flare-active region which occurred under a dense structure had no associated type III activity.

(2) The average height of the type III bursts during this period, when corrected for the effects of refraction and scattering, was consistent with the densities derived from the K-corona data, and both were characteristic of the 'quiet' corona at solar maximum.

(3) The density gradients derived from the radio data and the K-corona data agreed to within their observational uncertainties.

We conclude that the observed isolated type burst exciters did not travel in coronal streamers. It is interesting to note that Caroubalos *et al.* (1974) reach the same conclusion to explain the directivity of fundamental and harmonic sources observed during the Stereo experiment (Steinberg and Caroubalos, 1970).

Particularly in view of the theoretical study of Smith and Pneuman (1972), we caution against attaching undue significance to those centres of activity which occurred to the side of dense structure. We have dealt here with the average properties of regions of type III activity, and not individual bursts. The characteristics of individual bursts (position, height, frequency drift) vary significantly among the bursts in a given center (e.g. McLean, 1969, 1970; Palmer and Lin, 1972; Kai and Sheridan, 1974). Also, the bursts at these frequencies are large, possibly due to the effects of scattering. In these instances where the regions of activity occurred to the side of dense structures, we point out merely that they did not occur near the centres of these structures.

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