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Propagation of type II burst shock waves along the radial magnetic field in the solar corona

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Abstract. We present an analysis which indicates that in several cases coronal holes exist in the vicinity of the active regions producing type II bursts. It is inferred that shock waves which produce type II bursts essentially travel along the coronal magnetic field.

Key words : type II bursts—coronal holes—the sun

1. Introduction

Type II radio bursts are due to a disturbance travelling out through solar corona (Wild *et al.* 1953). It is now generally accepted that the disturbance responsible for type II bursts is a collisionless MHD shock wave (Uchida 1974). The magnetic field and density distribution are highly inhomogeneous in the solar corona. Therefore, it is expected that these inhomogeneities affect the propagation of shock front which produces type II bursts. There is some evidence in the literature implying that the shock waves follow a curved path from the flare to limb.

For the first time an attempt has been made here to point out that in several instances the coronal holes exist in the vicinity of active regions which produce shock waves leading to type II bursts. Since coronal holes are situated along open-lined radial field structures, we infer that shock waves which produce type II bursts travel along the radial magnetic field in the solar corona.

2. Observational data

The correspondence between active regions producing a number of type II bursts, their shock waves and positions of coronal holes is examined. All the 183 type II bursts recorded during the period 1977 January to 1978 June are taken from the Solar-Geophysical Data. Out of these type II bursts, only about 84 type II burst events could be obtained for which there were H-alpha solar flare reports in the Solar-Geophysical Data. From these flare reports, 33 active regions were picked up

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in which the above said 84 types II bursts occurred and are listed in table 1. The positions of these active regions and nearby coronal holes as judged from the KPNO helium 10830 Å synoptic maps (which are expected to have a close correspondence with emissions from coronal holes, *cf.* Harvey *et al.* 1975) are reproduced in figure 1. In figure 1 active regions are shown hatched while the coronal holes are shown by solid lines (indicating well-defined boundaries) and dashed lines (indicating ill-defined boundaries).

3. Results and discussion

An inspection of table 1 reveals that a few active regions are most prolific for the production of type II bursts. McMath region 15266 (rotation 1667) which gave rise to two decimetric, ten metric and one decametric bursts in rotation 1667, three metric and one decametric bursts in rotation 1668 (region 15314) and two metric bursts in rotation 1669 (region 15368) is the best example. Other such active regions can be found in table 1.

An examination of figure 1 reveals that type II bursts rich active regions are located in the vicinity of coronal holes except for eight active regions which do not show a nearby coronal hole (one region has no data for holes). The remaining 25 active regions have a nearby coronal hole located at a heliographic longitudinal distance (minimum edge-to-edge separation) of about 0.8° to 10°. The maximum number (*i.e.* 11) of active regions of the present study are, however, located 1.6° away from the coronal holes. Over this 18 months period 24 type II bursts occurred in these regions out of a total of 84 type II bursts events.

There have been attempts to study the propagation of type II bursts relative to magnetic field. In one case Kai (1969) drew attention to the fact that the shock front had been stopped or reflected by the strong field behind the flare. On the other hand there have been reports of four type II bursts arising due to behind-the-limb flares (Smerd 1970; McLean & Nelson 1977; Nelson & McLean 1977; Gergeley & Kundu 1976) and one event due to near-the-limb flare (Markeev *et al.* 1983), which implies that the shock waves must have followed a curved path from the flare. From his discussion of the event on 1969 March 30, Smerd (1970) concluded that the shock wave was either guided along the coronal magnetic field or got refracted by suitable structures in the corona. For this event Dulk *et al.* (1971) have shown that the shock path was along the coronal magnetic field, whatever be the cause of the curved path. It may be remarked that such evidence provides an observational basis for the notion that shock waves can be channelled along paths of weak magnetic field which may, in general, be curved.

Furthermore, Dulk *et al.* (1971) examined the data for a number of other bursts for eliciting information about the direction of motion relative to the magnetic field but were unable to arrive at any concrete conclusion. However, they did give other arguments which suggest that shock waves which produce type II bursts may travel approximately along the magnetic field : often the positions of type II bursts coincide with the positions of associated type III bursts, and the latter are certainly guided along the magnetic field. In addition, type II bursts which extend to very low frequencies (say < 20 MHz) move approximately radially.

Table 1. Active regions giving type II bursts

Sl No.	Rotation	Region	Coordinates		Separation from the hole (degrees)	Number of type bursts			Dates of type II event
			Lat.	Long.		Deci-metric band	Metric band	Deca-metric band	
1.	1653	14726	S22	18	3.2	0	2	0	1977 Apr. 16, 21
2.	1654	14771	S24	15	3.2	0	1	0	1977 May 19
3.	1656	14815	S23	203	1.6	0	1	0	1977 Jun. 23
4.	1658	14915	S25	98	2.5	0	1	0	1977 Aug. 26
5.	1659	14943	N08	192	0.8	0	4	2	1977 Sept.09, 16 19, 20
6.	1660	14967	N31	341	10	0	2	0	1977 Oct. 06
7.	1660	14979	N13	204	8	0	1	1	1977 Oct. 12
8.	1661	15017	N22	250	No data	0	1	0	1977 Oct. 31
9.	1661	15016	S23	267	No hole	0	1	1	1977 Nov. 07
10.	1662	15049	S23	194	1.6	0	1	1	1977 Dec. 06
11.	1662	15061	N27	86	8.0	0	0	3	1977 Dec. 08, 09
12.	1662	15056	S25	134	1.6	0	1	2	1977 Dec. 09 10, 17
13.	1662	15067	N17	43	3.6	0	1	1	1977 Dec. 10, 17
14.	1663	15074	S28	358	No hole	0	3	1	1977 Dec. 26, 27
15.	1663	15081	S19	202	10	0	5	2	1977 Dec. 28, 30 1978 Jan. 01, 08, 09
16.	1663	15083	S19	179	1.6	0	1	1	1977 Dec. 31 1978 Jan. 03
17.	1663	15092	N17	113	No hole	0	1	0	1978 Jan. 11
18.	1664	15139	N17	30	1.6	0	4	2	1978 Feb. 09, 13 15, 17
19.	1665	15161	N23	225	1.6	0	3	1	1978 Feb. 25, 26
20.	1665	15172	N21	72	No hole	0	1	0	1978 Mar. 06
21.	1666	15198	N17	177	No hole	0	1	0	1978 Mar. 28
22.	1666	15214	N23	78	1.6	0	1	0	1978 Apr. 08
23.	1666	15221	N21	30	No hole	0	1	0	1978 Apr. 08
24.	1667	15231	N17	338	1.6	0	1	0	1978 Apr. 10
25.	1667	15235	N17	282	8	2	6	0	1978 Apr. 11, 12, 14, 16, 18, 20
26.	1667	15266	N24	68	0.8	2	10	1	1978 Apr. 28, 30 May 01, 02, 07, 08, 09
27.	1668	15280	S27	351	20	0	4	0	1978 May 02, 11, 14
28.	1668	15294	N20	264	3.2	0	2	2	1978 May 10, 11
29.	1668	15291	N17	293	1.6	0	1	1	1978 May 16
30.	1668	15301	S28	195	No hole	0	2	1	1978 May 22, 24
31.	1668	15314	N18	79	1.6	0	3	1	1978 May 31 Jun. 01, 02
32.	1669	15368	N19	79	10	0	2	0	1978 Jun. 22
33.	1669	15375	S20	50	1.6	1	4	2	1978 Jun. 26, 27, 28

Uchida *et al.* (1973) suggest that a type II burst occurs when the shock front proceeds into low-Alfven velocity region. Further, Uchida (1974) has shown that the propagating shock wave is refracted by magnetic and density structures of the

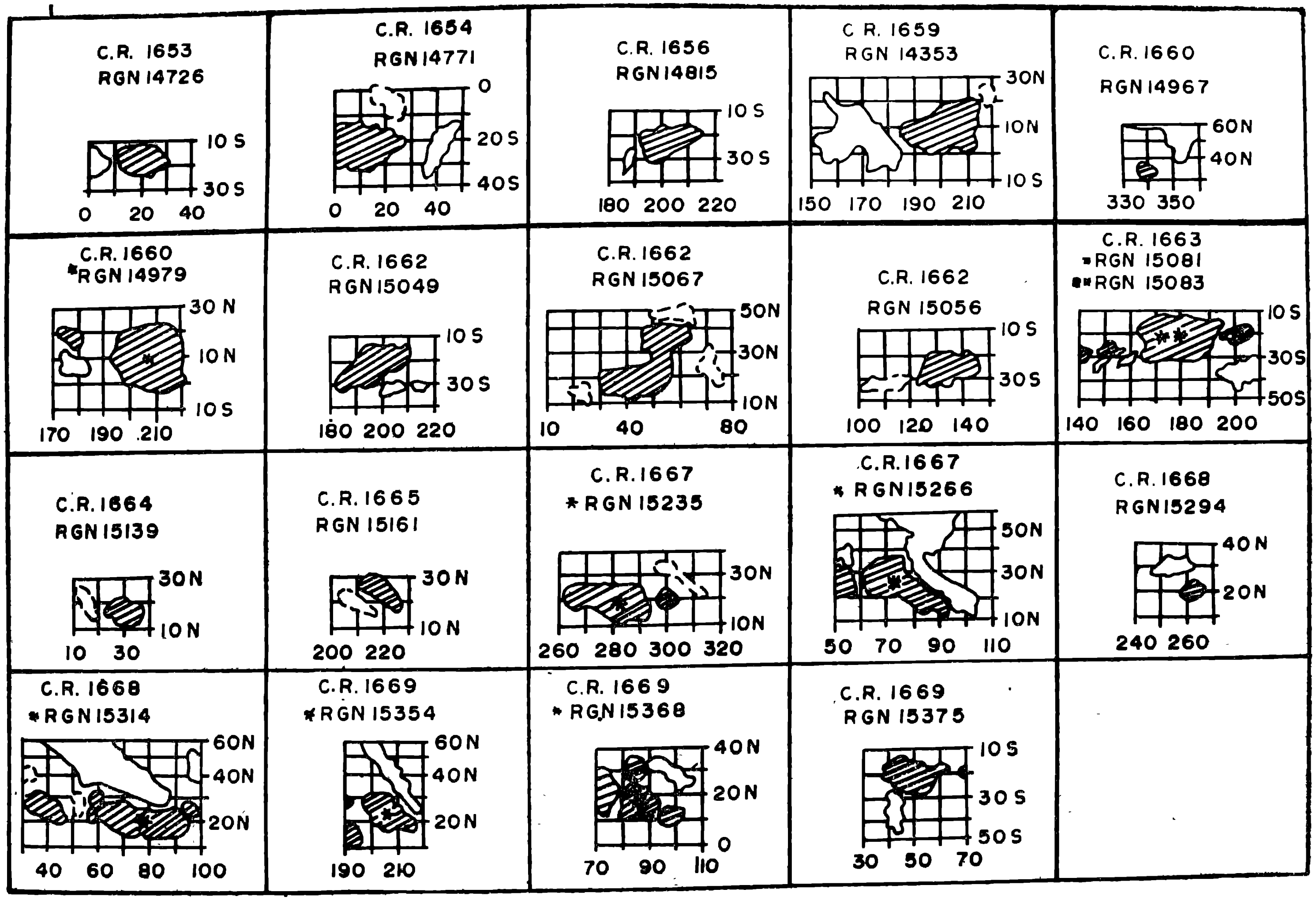

Figure 1. The positions of active regions and nearby coronal holes. Active regions are shown hatched while the coronal holes are unhatched regions with solid and dashed boundaries.

corona towards the pre-existing low-Alfven velocity regions; and the shock strength builds up above a certain value due to focusing effect by refraction and lowered Alfven speed.

Our study, which shows the presence of coronal holes in the neighbourhood of active regions producing larger number of type II bursts, provides useful comparison with Uchida's theory. Coronal holes occur over regions of relatively weak magnetic fields of predominantly one polarity surrounded by regions of stronger fields. The photospheric magnetic fields underlying a hole diverge outward from the sun as 'open' rather than closed field lines. Because of the higher fields, the ratio of kinetic to magnetic pressure would be even smaller in the regions surrounding a hole than that in the coronal hole (Steinlofson & Tandberg-Hanssen 1977). This indicates that coronal holes are the regions of low-Alfven velocity through which magnetic field lines are stretched radially outward. If such a coronal hole is in the vicinity of the shock wave source (active region), there seems to be considerable chance that the shock front sweeps along the low-Alfven velocity structures of a coronal hole and propagates radially along the open magnetic field configuration of the coronal hole.

4. Conclusions

Our study shows that in most of the case the type II bursts-rich active regions have a nearby coronal hole. Open lined magnetic flux of coronal holes may provide sites for type II bursts, since such structures provide lower Alfven velocity regions into which propagating MHD fast-mode waves tend to get refracted and in which the wave energy tends to get focused. The shock is variously affected in a coronal hole, depending on how low the Alfven wave velocity (V_A) in the hole is. If $-(\Delta V_A)L$ is large enough along the path, the hole may trap the wave which is then guided into the hole. The strength of the shock, which is otherwise weak, is significantly enhanced in the coronal hole as the wavefront proceeds into such structures and presumably radiates the strongest emission from there. The type II bursts sources may be identified with such low-Alfven velocity regions illuminated by such enhanced shocks.

Wild & Smerd (1972) noted that regions of low-Alfven velocity exist along essentially radial cores of coronal streamers. They cite this circumstance in favour of shock waves travelling essentially parallel to the magnetic field. The proximity of the coronal holes to type II burst-rich active regions leads us to infer that the shock waves which produce type II bursts travel along the magnetic field. However, theoretically a fast wavefront can propagate almost isotropically under coronal conditions, and therefore it seems that the wave is not strictly guided along the open flux in the coronal holes but is compelled to become inclined to get directed into such regions.

We may suggest a method for the verification of the hypothesis that the shock wave penetrates into the coronal hole regions from the close-by active regions. The build up of the shock waves in the coronal holes will certainly affect the coronal and/or chromospheric emissions during the type II bursts. If that is the case then during the type II bursts the coronal holes would show regions of higher electron densities and higher kinetic temperatures which can be inferred from the emission line strengths.

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