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MOTION OF METRIC TYPE IV RADIO SOURCES AND ITS RELATION TO SHOCK WAVES RESPONSIBLE FOR TYPE II RADIO BURSTS

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ABSTRACT

Both type II and type IV radio bursts are often produced by the same solar flares, but their moving speeds are generally quite different from each other. In particular, the speed of type II radio sources is much higher than that of type IV sources except for a few cases. This results indicates that the motion of type IV sources is independent of that of type II sources. Furthermore, whenever type IV sources are generated in proton flares, the moving speed of these sources is always much slower than that of type II sources. It seems that there are two kinds of the emission processes for type IV bursts. The one is associated with the expanding shock waves, while the other is accompanied by expanding magnetic bottles. The latter are always associated with proton flares.

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Solar flares are often associated with type II and type IV radio bursts. At present, it is thought that type II radio bursts are generated as a result of the excitation of plasma waves by shock waves propagating in the solar corona, whereas type IV radio bursts at metric frequencies are emitted from relativisitic electrons due to their interaction with sunspot magnetic field lines expanding through the solar corona (e.g., Takakura, 1961; Kundu, 1965; Wild and Smerd, 1972). Type IV radio bursts consist of several spectral components as classified to IVμ, IV dm, IVmA and IVmB, for instance (e.g., Wild, 1962; Kundu, 1965; Sakurai, 1974). Among them, the complex bursts consisting of both type IVμ and IVdm bursts are stationary in the solar atmosphere near the flare regions and the range of emission frequencies is usually higher than 500 MHz, whereas the source of type IVmA bursts at metric frequencies moves away from the flare region with speed of some 100 $Kmsec^{-1}$. The IVmB component at metric frequencies is also stationary which is generated after the parent flare fades away. In this paper, the relation of the motion of type IVmA sources with shock waves responsible for type II bursts will be considered using the observed data for these two radio sources.

The difference of the emission mechanisms between type II and type IVmA bursts suggests that the moving speed of the shock waves mentioned above is not necessarily equal to that of metric type IV sources. By analyzing the observed data on the speeds for both type II and type IV sources, Sakurai and Chao (1973a) have recently found that these two sources usually tend to move with speeds different from each other. Sometimes, we observe that the sources for type IV bursts decelerate and later often cease to move in the solar envelope (e.g., Warwick, 1969; Schatten, 1970; Sakurai and Chao, 1973b). The observational results on the moving speeds for these type II and type IV sources are summarized in the following papers: Dulk (1970, 1971), Dulk and Altschuler (1971), Sakurai and Chao (1973a), Smerd (1971), Smerd and Dulk (1971), Wild (1969) and Wild et al. (1968).

When we plot the relation between these speeds for these two sources by using the observational results, it follows that, except for three cases, the speeds of shock waves are usually higher than those of type IV sources, as shown in Fig. 1. In this figure, we see that, in case of solar proton flares, the moving speeds of type IV sources are much slower than those of shock waves. As is well known, the emission flux of type IV bursts at metric frequencies, associated with proton flares, is usually very high (e.g., Castelli et al., 1967; Sakurai, 1969). However, the moving speed of the sources for these bursts is much slower than that of type II sources; that is, the motion of type IV sources is independent of that of type II sources. Thus we cannot say that these type IV sources later become flare ejecta responsible for geomagnetic storms, although the latters are described as propagating with magnetic bottlelike structure in interplanetary space.

It is thought at present that shock waves which produce type II bursts are responsible for generation of geomagnetic SSC events (e.g., Akasofu and Chapman, 1971; Hundhausen, 1972). This means that these waves are able to propagate in interplanetary space without serious dissipation. According to Pinter (1973) and Sakurai et al. (1973a), however, they are slowed down during propagation in this space, but their speeds at the earth's orbit are still higher than those of type IV sources as seen in the solar atmosphere. This fact emphasizes that interplanetary shock waves do not propagate together with type IV sources.

As shown in Fig. 1, type IV sources sometimes propagate with shock waves in almost the same speed. However, these are not associated with intense emission of the microwave component of type IV bursts and high energy protons. This fact suggests that some shock waves can produce high energy electrons responsible for the emission of type IV bursts. Three cases shown in Fig. 1 indicate that, while propagating in the solar corona, the shock waves produced these electrons in the region just behind these waves. Although the emission mechanism for these cases is identified as gyro-synchrotron mechanism, the mechanism for generating high energy electrons may be completely different from the cases as seen in proton flares, shown in Fig. 1.

In the case of proton flares, the moving sources of type IV bursts, identified as IVmA, must be produced independently of the generation of shock waves. It seems that the formation of these sources is closely related to the acceleration of high energy protons and electrons in the flare regions; these particles would then produce magnetic bottle-like structure while stretching outward sunspot magnetic field lines in the flare regions (Sakurai, 1973). The process associated with the formation of type IV sources may be related to the cause of slow-speed motion.

We have considered that these type IV sources themselves are not identified as flare-ejecta which are ejected from the sun in association with flares. However, it seems likely that their motion in the solar envelope plays an important role to produce flare-ejecta, since part of the solar plasma concentrated above the flare active regions may be squeezed away, by the motion of type IV sources, into interplanetary space. Intense emission of type IV bursts at metric frequencies is always associated with solar flares which produce solar cosmic rays and SSC geomagnetic storms (e.g., Sinno, 1961; Sakurai, 1969). This fact suggests that these storms are produced as a result of the interaction of the earth's magnetic field with flare-ejecta, even if we are unable to identify the source of these ejecta. Therefore, it is necessary to inquire this source by investigating the physical processes associated with the expansion of type II and type IV radio sources in the solar atmosphere. In particular, the slow-speed motion of metric type IV radio sources may be very important to understand what these processes are. If we could interpret these series of events, the formation of non-spherical helium-enriched shells propagating interplanetary space would be reasonably understood (Sakurai and Chao, 1973c). It seems likely that these shells are generated as a result of the interaction of magnetic bottles with the helium-enriched regions above the flare region in the lower solar corona.

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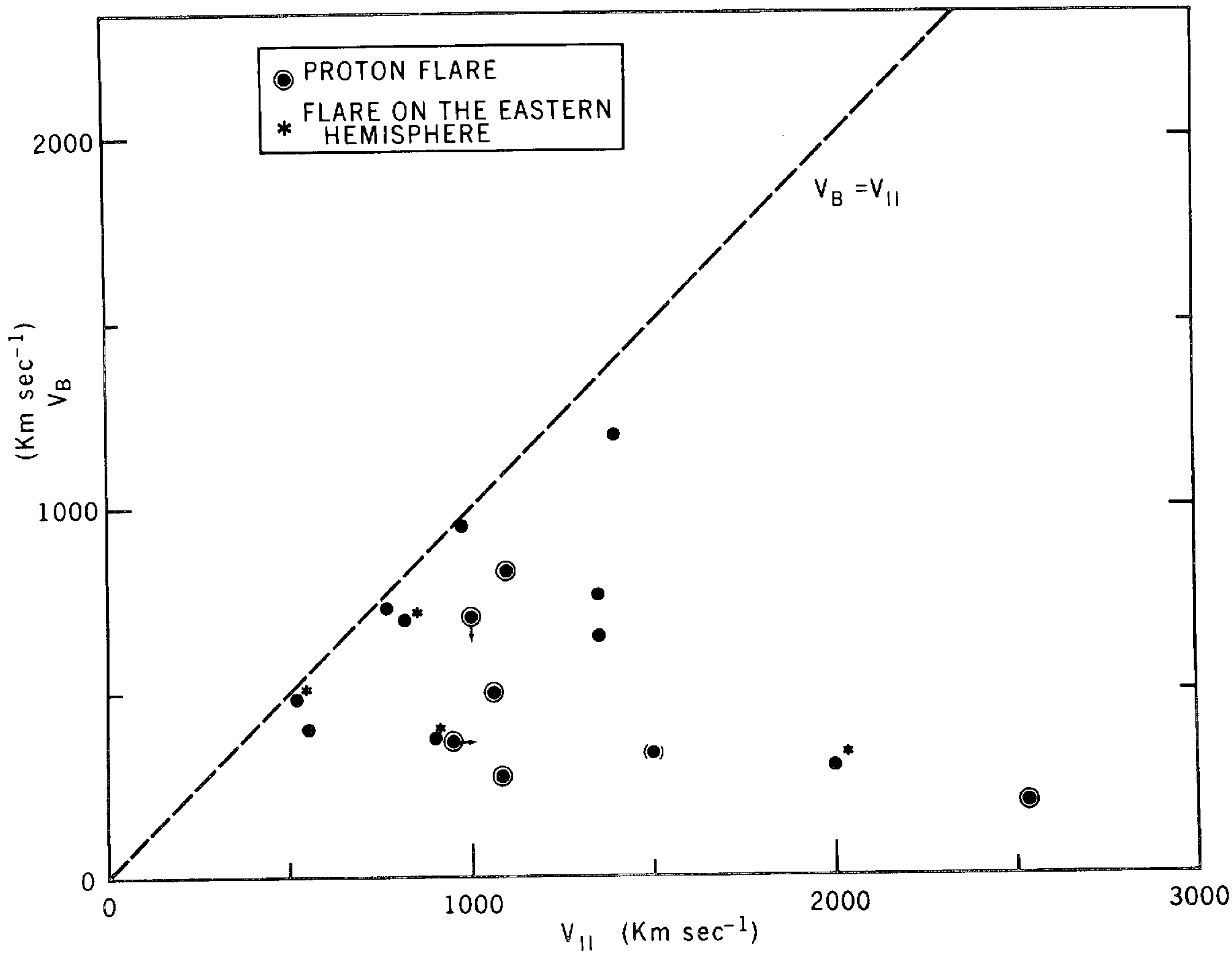
Caption of Figure

Fig. 1 - The relation between the moving speeds of type II and type IV radio sources, which are shown with V_{II} and V_B, respectively.


PROTON FLARE
FLARE ON THE EASTERN HEMISPHERE
$V_B = V_{II}$
2000
1000
0
V_B (Km sec^{-1})
0
1000
2000
3000
V_{II} (Km sec^{-1})