X-693-74-1
PREPRINT

NASA TM X- 70567

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JANUARY 1974

GSFC
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ABSTRACT

It is shown that magnetic bottles as the sources of moving metric type IV bursts are not responsible for the development of geomagnetic storms, despite the fact that shock waves producing type II bursts are the sources of the interplanetary shock waves, which produce SSC's on the geomagnetic field. These magnetic bottles, in general, tend to move in the solar envelope with the speed of several hundred Km sec^{-1} at most, which is much slower than that of the motion of type II radio sources.

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expected to be explicable for the [illegible] mentioned above:

[illegible], these speeds are two or three times smaller

For many years since it became known that solar flares accompanying wide-band type IV radio bursts were usually followed by SSC geomagnetic storms at the earth, it has been thought that magnetic bottles or clouds, identified as the sources of these bursts, are ejected by the flares and then, one to several days later, would be the sources for SSC storms (e.g., Morrison, 1956; Sinno and Hakura, 1958; Parker, 1958; Gold, 1959, 1962; Sinno, 1962). Nishida (1964) has found that the total flux of metric type IV bursts is correlated with the total energy of these magnetic clouds; his results suggested that these clouds were directly responsible for the onset of geomagnetic storms, since it seemed that shock fronts responsible for the onset of SSC's are formed in front of these clouds while expanding into interplanetary space. In fact, it was thought that these clouds expanded into this space after ejection from the flare regions and then, produce geomagnetic storms (e.g., Akasofu and Chapman, 1971).

The recent observational data on the movement of type IV radio sources at metric frequencies, however, show that their moving speeds are much lower than those

expected to be explicable for the idea mentioned above: that is, these speeds are two or three times smaller than those necessary to explain the time delay from flares to SSC geomagnetic storms (Sakurai and Chao, 1974a). It is known that, in general, these speeds are decreased while the type IV radio sources are moving in the solar envelope (Kai, 1973). Furthermore, we have evidence that, for some cases, type IV radio sources cease to move beyond several solar radii or more distant from the flare regions (Warwick, 1969; Schatten, 1970; Sakurai and Chao, 1974b). These results suggest that type IV radio sources do not move just behind the front of shock waves responsible for the emission of type II radio bursts.

Until recent time, however, it has been thought that magnetic bottles or clouds, being stretched outward from the flare regions, expand into interplanetary space, and, sometimes, produce geomagnetic storms, as mentioned earlier in this paper. Furthermore, forerunning shock waves are thought to be responsible for the onset of SSC's of geomagnetic storms (e.g., Akasofu and Yoshida, 1967; Hirshberg, 1968). These waves are also identified as those which propagate in the solar corona as exciting type II radio

bursts. It seems reasonable, therefore, that magnetic bottles or clouds expand into interplanetary space, following shock waves mentioned above. When we refer to our recent results (Sakurai et al., 1974a; Sakurai, 1973), it becomes clear that the statement given above is not correct for the association of shock waves with magnetic bottles in interplanetary space, for, in fact, the moving speed of magnetic bottles is usually much lower than that of shock waves, as shown in Fig. 1.

The mean speed of the interplanetary shock waves has been estimated for eleven cases (Sakurai et al., 1974a). We have examined the relation between this speed and the moving speed of type II radio sources in the solar corona (Fig. 2). This result shows that the observed speed (V_I) is much lower than the observed speed (V_{II}) of shock waves responsible for type II bursts. This suggests that, in general, deceleration must have taken place for these waves during propagation in interplanetary space. Therefore, we may say that shock waves generated in the flare regions tend to propagate in this space as being decelerated Furthermore, their propagation is independent of the

motion of the magnetic bottles in the solar envelope. This results suggests that the source of flare-ejecta cannot be identified as these magnetic bottles, although this identification has long been believed as correct by many peoples, as has been mentioned earlier.

We do not know as yet what the source of flare-ejecta is, despite the fact that the development of geomagnetic storms is often observed several hours after the onset of SSC's. By referring to the results mentioned above, we here would like to propose a model about the origin of flare-ejecta. Our model is as follows: as mentioned earlier in this paper, magnetic bottles move with slow speed of several 100 Km sec^{-1} in the solar envelope. While moving in this region with deceleration, these bottles seem to push away plasma gases overlying the flare regions from their original location. According to the action similar to piston, these gases are given inertiae and then move outward as being accelerated by ambient high-speed outgoing plasma flow produced as a result of heating by the passage of shock waves. This flow seems to drive away these gases into interplanetary space. Thus, these gases would become "flare-ejecta,"

which produce geomagnetic storms following the onset of SSC's. This means that the source of flare-ejecta is identified as the matters ambient in the upper chromosphere and the lower corona above the flare regions.

We have evidence to support this model since the helium-enriched shells are usually observed behind the shock waves producing SSC's at the earth (Sakurai and Chao, 1973). As shown by Sakurai et al. (1973), the formation of these shells is closely related to the opening-up of closed sunspot magnetic field lines above the flare regions, as discussed by Valdez and Altschuler (1970). This process seems to be responsible for the ejection of helium-enriched gas, a part of flare-ejecta, into interplanetary space. The plasma gases blown up outward by the action being pushed by magnetic bottles, the sources of type IV radio bursts at metric frequencies are, therefore, identified as the flare-ejecta producing the main part of geomagnetic storms at the earth.

I wish to thank Drs. J.K. Chao and L.F. Burlaga for their helpful comments.

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Caption of Figures

Fig. 1 - The relation between the speeds of shock waves responsible for the emission of type II radio bursts (V_{II}) and of the sources of type IV radio bursts at metric frequencies (V_B).

Fig. 2 - The relation between the speeds of shock waves responsible for the emission of type II radio bursts (V_{II}) and the mean speeds of interplanetary shock waves (V_I). Double circles indicate these waves associated with solar proton flares.

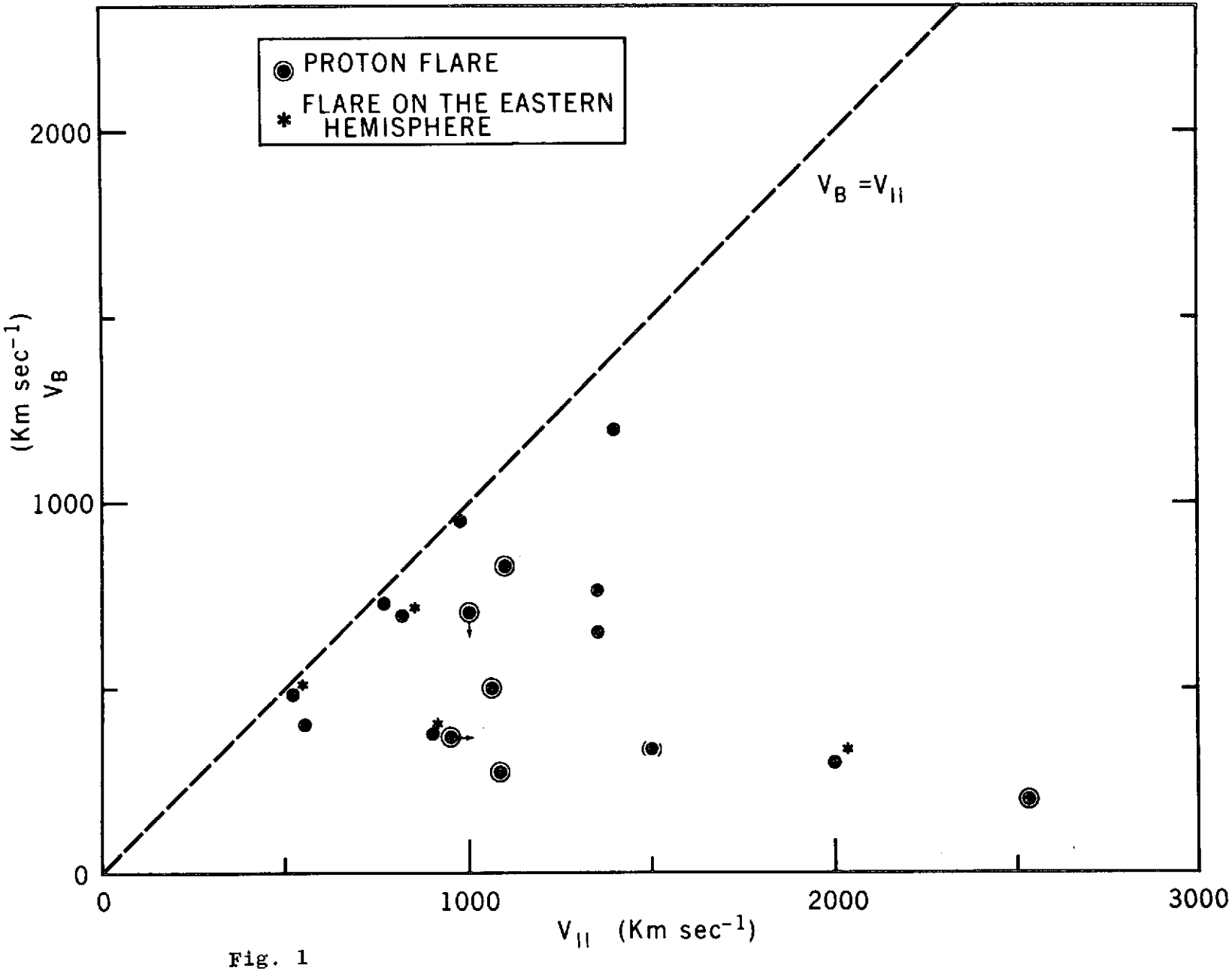
PROTON FLARE
FLARE ON THE EASTERN HEMISPHERE
$V_B = V_{II}$
2000
1000
0
0
1000
2000
3000
V_B (Km sec^{-1})
V_{II} (Km sec^{-1})

Fig. 1

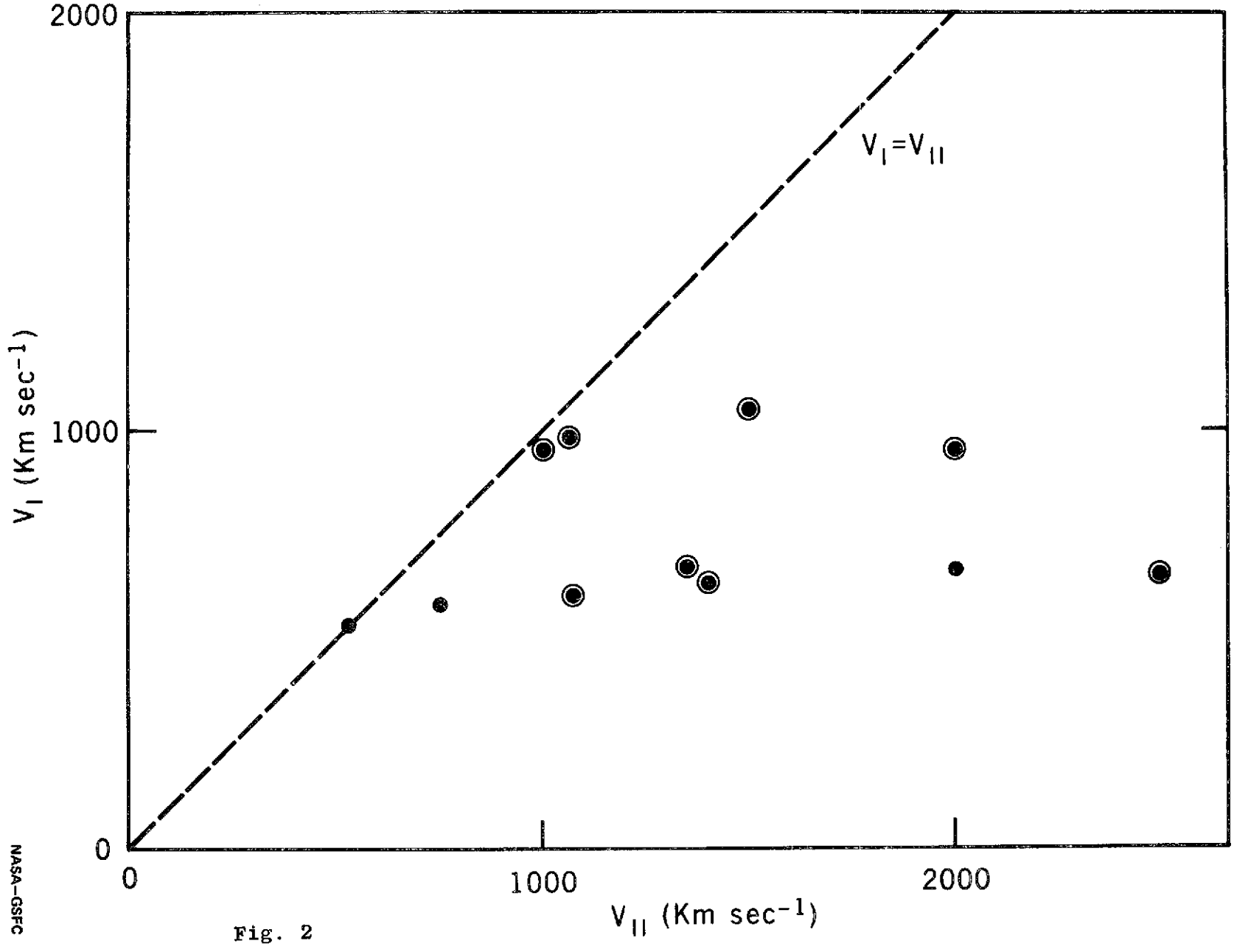

Fig. 2