# EAST-WEST ASYMMETRY OF MAGNETIC BOTTLE EXPANSION AND ITS RELATION TO SHOCK WAVES PROPAGATING IN THE SOLAR ATMOSPHERE

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**Abstract** (*Solar Phys.*). It is known that the sources of metric type IV radio bursts generally move outwards with speed of a few to several hundred km $s^{-1}$ in the solar atmosphere and envelope (e.g., Kundu, 1965; Smerd and Dulk, 1971; Wild and Smerd, 1972). These sources consist of magnetic lines of force being stretched out from the flare regions and relativistic electrons being trapped by these field lines. They are often observed as expanding magnetic bottles (e.g., Smerd and Dulk, 1971). As a result of this expanding motion, the frequency range of type IV burst extends with time to lower frequencies, because of the decrease of both magnetic field intensity and energy of radiating electrons (Dulk, 1970; Sakurai, 1973a). By considering the observed expansion rate of emission frequency range, it seems possible to estimate the pattern of expansion of these radio sources: in doing so, we have analyzed the onset time differences between microwave and metric emissions of type IV bursts by referring to the longitudinal positions of parent solar flares on the solar disk, since the dependence of these differences on parent flare positions in the solar longitude seems to give a clue to estimate a general pattern of the expansion of magnetic bottles. The result thus analyzed is shown in Figure 1. Furthermore, peak flux intensities at metric frequencies for these type IV bursts have been also analyzed as a function of the longitude positions of parent flares (Figure 2). The results shown in Figures 1 and 2 are explained by assuming that, while moving outwards, the magnetic bottle tends to expand a few 10 deg east of the meridian plane which crosses the flare region (Sakurai, 1973a).

The expansion speed of these type IV sources is always much slower than that of type II radio sources, except for a few cases (see, Sakurai and Chao, 1974; Kai, 1973). Recently, Dulk *et al.* (1971) have shown that shock waves responsible for type II radio bursts usually propagate along the magnetic field lines above and near the flare regions. With the results shown in Figures 1 and 2, their analysis suggests that these shock waves tend to expand independently of the magnetic bottles in the solar atmosphere (e.g., Sakurai, 1973a).

The slow speed expansion of type IV radio sources strongly suggests that flare-ejecta observed behind interplanetary shock waves are completely different from magnetic bottles identified initially as the sources of metric type IV bursts (Sakurai

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and Chao, 1974). However, these interplanetary shock waves seem to have been formed as a result of the latter expansion of shock waves responsible for type II bursts (e.g., Burlaga, 1974; Sakurai, 1973b).

As has been mentioned above, the magnetic bottles as metric type IV radio sources

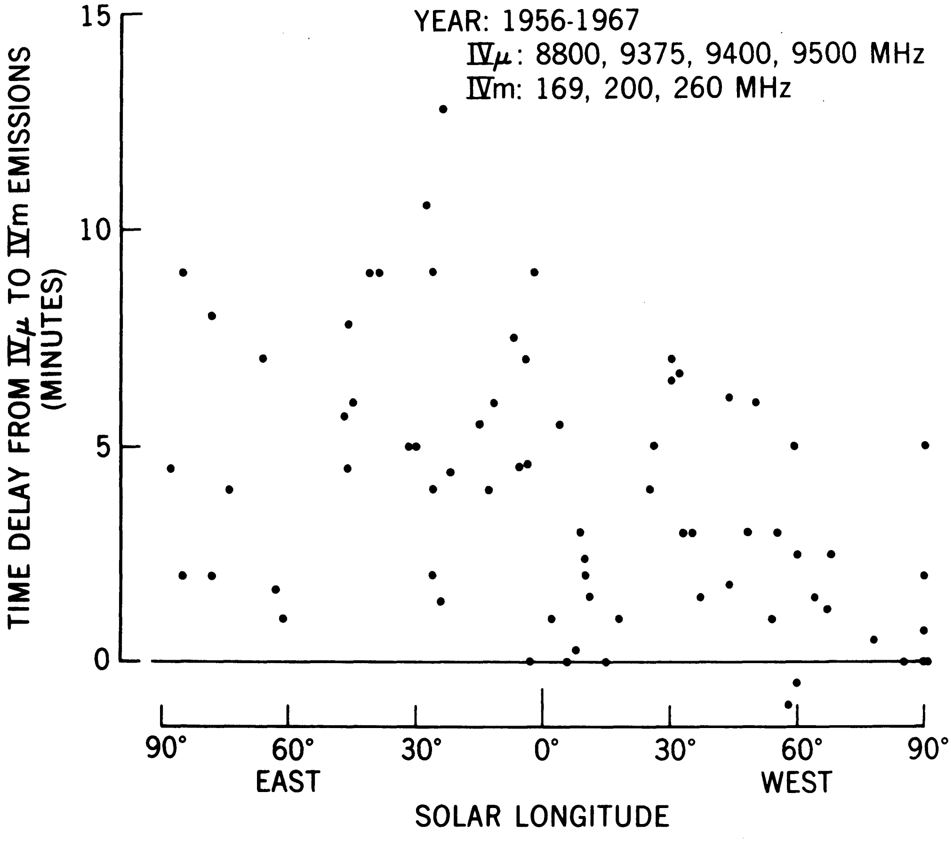


Fig. 1. Relation of the onset time differences between microwave and metric type IV radio emissions to the longitudinal positions of parent flares.

usually expand with slow speed into the solar envelope. Furthermore, they seem to push away the atmospheric gases overlaid on themselves into outer space. If this is the case, it is likely that these bottles are responsible for the ejection of the helium-enriched shells, which are observed at the Earth's orbit. These shells have been detected by Hirshberg *et al.* (1972) based on the analysis of satellite plasma data at the Earth's orbit.

The thickness of these shells is dependent on the longitudinal positions of parent flares (Figure 3). The origin of this property seems to be strongly related to the ex-

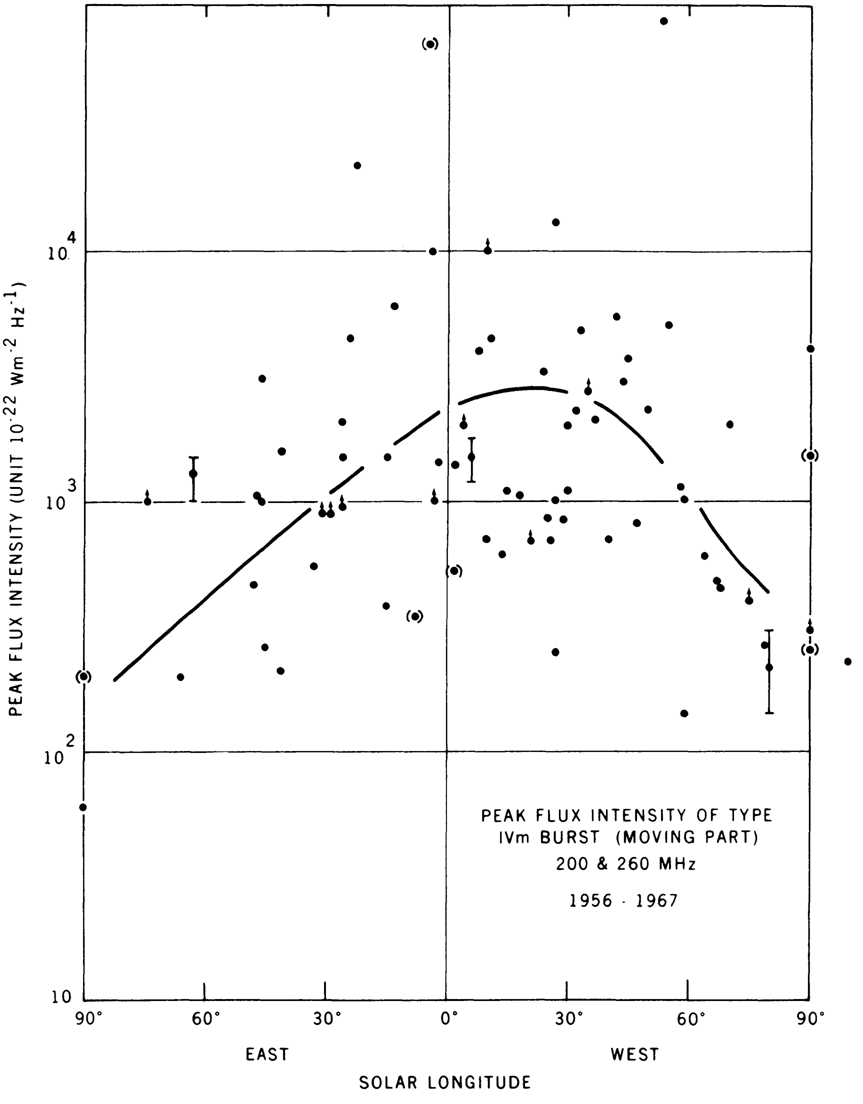


Fig. 2. The peak flux intensity of type IV metric emissions with respect to the longitudinal position of parent flares.

panding pattern of the magnetic bottles near the Sun, because the helium-enriched region is formed in the upper chromosphere and the lower corona, as shown by Brandt (1966) and Nakada (1969, 1970). The eastward expansion of these bottles seems to have produced the east-west assymmetry as seen on the helium-enriched shell. Non-spherical expansion of interplanetary shock waves seems to be also related to the field-aligned propagation of the shock waves near the Sun.

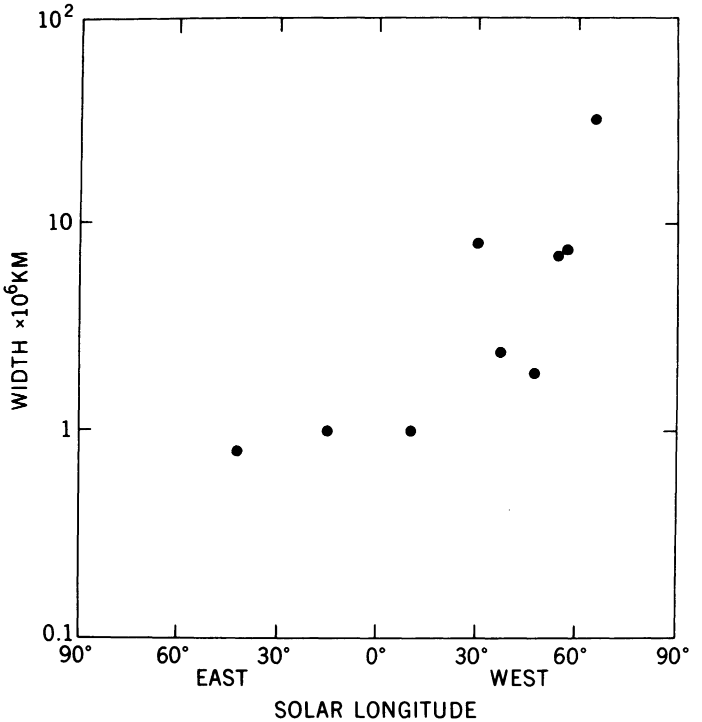


Fig. 3. Relation between the thickness of the helium-enriched shells observed at the Earth's orbit and the longitudinal positions of associated flares.

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## DISCUSSION

*Newkirk:* Your results critically depend upon identifying which flares are to be associated with which radio events. Of all the flares, which might be candidates for a particular event, how did you choose the ones used in your study?

*Sakurai:* The approach was basically statistical.

*Dryer:* Newkirk put his finger on the essential problem. The usual approach is to look in the 'yellow book' for an interesting flare and to pick a 'reasonable' one with large optical importance with, hopefully, type II's and/or IV's. I believe that this was done here.

*Sakurai:* Yes.

*Pick:* Caroubalos showed that the microwave energy was a good indicator of the interplanetary importance. This could be used to determine which flare.

*Sakurai:* Even so, it still does not lead to a clear decision.

*Gotwols:* I wonder if the first slide, which is a scatter plot of time delay vs longitude, really shows a statistically significant trend. It appeares to me that with a mere handful of points added at Western longitudes, no trend would remain in the data.

*Sakurai:* The E–W asymmetry is evident. No statistical test was applied.