FLARE-PUFFS AS A CAUSE OF TYPE III RADIO BURSTS

By R. G. Giovanelli*

[*Manuscript received April* 17, 1958]

Summary

An analysis has been made of the association of type III solar radio bursts with flares which show sudden bright expansions, or " puffs ". Type III bursts occur within ± 2 min of the times of two-thirds of the puffs ; by comparison, they occur during the whole lifetimes of about one-quarter of flares of all types (Loughhead, Roberts, and McCabe 1957). Most if not all puffs are followed by surges, and hence it appears that the same explosion yields two quite different ejections ; one, at velocities of the order of one-fifth that of light, is responsible for the burst, and the other, at velocities of the order of 100 km/sec, is the surge.

I. Introduction

In a solar radio burst of type III (Wild, Roberts, and Murray 1954) the frequency of maximum intensity decreases rapidly in a few seconds, the accepted cause being a disturbance ejected at velocities of the order of one-fifth that of light through the solar corona.

Loughhead, Roberts, and McCabe (1957) found that 60–70 per cent. of type III bursts occur during lifetimes of flares of apparent area (i.e. uncorrected for any foreshortening) exceeding about 20×10^{-6} of the Sun's hemisphere. However, rather less than one flare in four is associated with a type III burst. This low figure indicates that there are differences of degree or type between various flares ; as over two-thirds of the type III bursts are associated with tiny flares of apparent area below 40×10^{-6} of the Sun's hemisphere, flare size alone is not the determining factor.

It is well known that some flares are associated with other types of ejection. In particular, surges dark in Hα sometimes appear on the disk during or after flares. These have outward velocities of the order of only 100 km/sec, and cannot themselves be the disturbances directly responsible for type III bursts, though the chances of a surge accompanying a flare are about the same as those of a type III burst.

Recently, Giovanelli and McCabe (1958) have shown that the first trace of a surge is usually the ejection from the flare of diffuse matter, brighter than the chromosphere, which fades and disappears by becoming transparent, though it can be detected if the ejection crosses the limb. The dark surge subsequently appears close to the flare and travels outwards in the same direction. The basic feature of the event is the emission of a substantially continuous particle stream having different appearances at different stages.

* Division of Physics, C.S.I.R.O., University Grounds, Chippendale, N.S.W.

Close examination of films of flare-surges shows that some of the flares, but not all, appear to be of an explosive character. Within a minute or so the flare may expand rapidly (e.g. Giovanelli and McCabe 1958, Plate 1, Figures 1 and 2; Plate 2, Figure 2; Plate 3, Figure 1). Usually, but not always, this expansion or "puff" occurs at the outbreak of the flare. However, the initial bright expansion is much more diffuse and indefinite in some of the other flare-surges (e.g. Giovanelli and McCabe 1958, Plate 2, Figure 1), and these are not included here as "puffs".

Its violent and sudden nature suggests that a puff is the identifiable flare characteristic most likely to be associated with type III bursts. The following account describes an investigation to establish whether or not this is so. It is found that there is a very strong and significant association, and that the times of type III bursts and puffs are closely identical.

II. Observations and Analysis of Results

The flare observations were made with the Sydney Hα flare-patrol camera, 16 mm diameter photographs of the Sun being obtained on Eastman Kodak IV E film, usually at 0·5 min intervals. These have been examined in projection. Type III burst data obtained with the Dapto radiospectrograph have been provided by Mr. J. P. Wild.

The analysis covers observations made in 1956–1957, from which there has been prepared a list of flares showing clear, indisputable puffs occurring during the times of radiospectrograph observation. The list is small (27 flares) and incomplete, but the events are reasonably well distributed over the 2-year period. Times of puffs have then been compared with times of type III bursts.

Table 1

ASSOCIATION OF TYPE III BURSTS WITH FLARE PUFFS

Apparent area (10^{-6} hemisphere)		0–40	41–80	>80	Total
Number of flare puffs		14	6	7	27
Puffs with coincident type III bursts	(a) Total	11	4	3	18
	(b) Cases with non-puff flares beginning at puff time ± 4 min	2	2	1	5

Results are summarized in Table 1, which gives (i) the numbers of flare-puffs grouped according to apparent flare area, (ii) the number of these with a type III burst occurring within ± 2 min of the time of the puff, and (iii) the number of the latter group in which puffs occurred within ± 4 min of the beginning of another flare. With one exception, all the above flares produced dark surges.

Table 1 shows that 18 of 27 puffs, or 67 per cent., coincided with type III bursts to within ± 2 min. Most of the flares were of class 1 —, 20 having apparent areas below 80×10^{-6} of the Sun's hemisphere. The apparent decrease in frequency of association as the flare area increases is not statistically significant.

The analysis of Loughhead, Roberts, and McCabe has shown that type III bursts occur during the lifetimes (± 2 min) of only about 22 per cent. of all flares. There is therefore negligible chance of the close association found between puffs and type III bursts being fortuitous. Loughhead, Roberts, and McCabe have also shown that in 50 per cent. of associations the type III bursts occur within ± 2 min of the beginning of the flare. In five of the present cases non-puff flares began within the rather larger limits of ± 4 min of the time of the puff. At most, these would be expected to produce only about one association, insufficient to affect the conclusions.

The present investigation establishes that there is a close and significant association between flare-puffs and type III bursts, two-thirds of the flare-puffs producing bursts within ± 2 min of the time of the puff. No significant dependence on flare size has been established.

III. Discussion

The question naturally arises whether the flare-puff is the only flare phenomenon which produces type III bursts. It is not possible to answer this as yet, for the small size of the majority of flares makes it very difficult to distinguish puffs on the small-scale flare-patrol photographs. However, it is of interest that Loughhead, Roberts, and McCabe (1957) reported an investigation in which 48 flare-surges were studied, type III bursts being found to occur during 29 per cent. of them, whereas such bursts occurred during 18 per cent. of 246 flares not accompanied by observed surges. Their data were insufficient to establish that flare-surges are more likely to be associated with type III bursts than flares not ejecting surges. But, from the relatively low rate of association with flare-surges as a whole, it appears that type III bursts are much more likely to be associated with flare-surge events showing rapid expansions (puffs) than with those where the initial bright expansion is more diffuse and indefinite.

The present conclusions add appreciably to our knowledge of the flare-surge event. As shown by Giovanelli and McCabe, puffs, in common with other flare expansions, are the first stages in the ejection of particle streams with velocities of the order of 100 km/sec; in Hα, these streams are bright, transparent, or dark against the Sun's disk, depending on excitation conditions which vary with time along the stream. Within about a minute or so, i.e. effectively simultaneously, the same explosions eject at velocities of the order of one-fifth that of light the high speed disturbances responsible for type III bursts.

IV. Acknowledgments

The flare observations described here were made under the supervision of Miss Marie K. McCabe; details of burst observations have been provided by Mr. J. P. Wild.

V. References

Giovanelli, R. G., and McCabe, Marie K. (1958).—*Aust. J. Phys.* **11**: 191.
Loughhead, R. E., Roberts, J. A., and McCabe, Marie K. (1957).—*Aust. J. Phys.* **10**: 483.
Wild, J. P., Roberts, J. A., and Murray, J. D. (1954).—*Nature* **173**: 532.