

THE FLARE ORIGIN OF FORBUSH DECREASES NOT ASSOCIATED WITH SOLAR FLARES ON THE VISIBLE HEMISPHERE OF THE SUN

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1. Introduction. Previous investigations (e.g. /1/) have shown that Forbush decreases (Fds) are produced by the propagation into the interplanetary space of a strong perturbation originating from a solar flare (Sf) accompanied by Type IV radioemission. As the front of the perturbation propagates into the interplanetary space, the region in which the galactic cosmic rays are modulated (Fd-modulated region) rotates westward with the Sun and is generally included between two boundary streams /2/; therefore the Fds not associated with observed Type IV Sfs (N.Ass.Fds) are likely to be produced by Type IV Sfs occurred on the Sun's backside; these events can be observed when the Earth crosses the corotating Western boundary of the modulated region. The main purpose of this paper is to support our empirical Fd-model by studying the origin of N.Ass.Fds and the corotation of the boundary streams.

2. Data analysis. It is very likely that the strong active regions (SAR) producing great flare-associated Fds during their passage on the visible hemisphere of the Sun can flare up further Type IV Sfs when they are located on the Sun's backside; a N.Ass.Fd should be observed when the Western edge of a modulated region produced by the flares from one of these active zones encounters the Earth. We think that this is the case for the majority of N.Ass.Fds. In order to test this statement we plotted in Figure 1 the distribution of the onset-times of all (~140) N.Ass.Fds (amplitude $\geq 1.5\%$ in the polar nucleonic intensity over the period 1957-1979 /1,3,4/) with respect to the central meridian passage (CMP) of 120 SAR /5/ producing large Fds (amplitude $\geq 3\%$ for Type IV Sfs located between E90-W45 and $\geq 1.5\%$ for W45-W90 /1/). We notice that, over a random distribution, large peaks come out between -4 and +2 days from the 27-day recurrences of the CMP of SAR; i.e. these N.Ass.Fds are found to begin some days before the magnetic field line connected with the SAR crosses the Earth. The peak at +27 days appears to be the most pronounced as expected, while the peak amplitude at the CMP of SAR is reduced by the occurrence of large Fds, produced by Type IV Sfs in the Eastern quadrant, which mask the contemporary presence of N.Ass.Fds. Moreover we found that ~60% of the ~140 N.Ass.Fds are related with the CMP of SAR or its +27-day recurrence; on the other hand 58% of the 120 SAR analyzed are related to a N.Ass.Fd occurring near the +27-day CMP recurrence, while for 23% of them the possible N.Ass.Fds are masked by the occurrence of flare-associated Fds.

In conclusion it seems that the majority of N.Ass.Fds ($\geq 60\%$) are produced by intense Type IV Sf activity from long-living SAR; therefore we may expect that most of the remaining N.Ass. Fds could be produced by energetic Type IV Sfs occurring on the Sun's backside in active regions not included in SAR.

Figure 2 shows a Bartels display of CMP dates of SAR (\bullet) together with their 27-day recurrences (\circ); the arrows indicate the N.Ass.Fd onset-times. The time interval between the +27-day recurrence of CMP of SAR and the beginning of N.Ass.Fds may be explained by two effects: the heliographic distance between the active region and the solar source of the Western stream and the speed of the Western stream itself. The Table shows that, as an average, the more the N.Ass.Fd onset-time (t_1) precedes the CMP or its +27-day recurrence (t_0), the more the solar wind speed at the Fd-onset is found to increase. This result may account for about a half of the broadening of the recurrent peaks; therefore

the solar source of the Western stream seems to be located, from case to case, between $\sim 40^\circ$ and $\sim 75^\circ$ in the West of the active region which is, as expected, the half longitudinal extension of the Fd-modulated region.	$t_1 - t_0$ (days)	V (km/s)	Number of Events
	$-4 \div -2$	570	13
	$-2 \div 0$	465	17
	$0 \div +2$	380	10

The corotation with the Sun of the Fd-modulated region is better shown if the boundary streams are found to recur. The interplanetary data /6/ are used to investigate the recurrence of these perturbations. Periods of enhanced magnetic field intensity ($B \geq 10nT$), not associable either with interaction regions between high-speed streams ejected from coronal holes and the ambient solar wind, or with interplanetary perturbations produced by energetic Type IV Sfs in the visible hemisphere of the Sun, have been identified. The average behaviour of the interplanetary magnetic field intensity B and proton density N for 160 of those perturbations are shown in Figure 3 together with the average behaviour of B and N about ± 27 days (b) and ± 54 days (c). The day of the sharp increase in B was chosen as epoch-time. The results show that there is a high probability that these interplanetary structures corotate with the Sun, being the lifetime ≥ 2 solar rotations.

3. Conclusions. The parent active regions of most N.Ass.Fds are found to be the ones showing an intense Type IV Sf activity during their passage on the visible hemisphere of the Sun, namely those which are most likely able to produce Type IV Sfs also on the Sun's backside. Type IV Sfs emitted at different times by the same active region will depress the cosmic ray intensity in the same portion of the interplanetary space corotating with the Sun; therefore the Fd-effect will be observed also in the interplanetary regions which were not swept by the front of the perturbation, as it should happen for the N.Ass.-Fds. These results give a further support to the experimental

Fd-model developed by our group (e.g./2/).

References.

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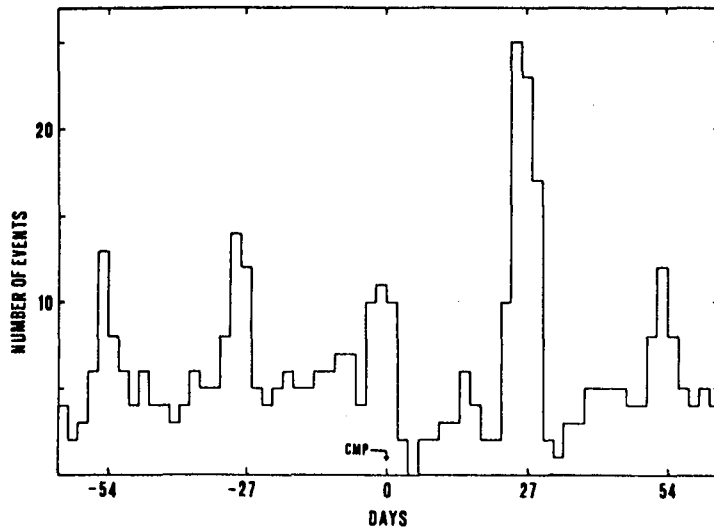


Figure 1: Distribution of the onset times of the N.Ass.Fds with respect to the Central Meridian Passage (CMP) of the active regions producing energetic Type IV Sfs and associated with great Fds (see the Text).

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Figure 2: Bartels display of IMF data of SAR (●) together with their 27-day recurrences (○); the arrows indicate the N.Ass.Fd onset-times.

Figure 3: (a)- Superposed epoch analysis of the interplanetary magnetic field magnitude and proton density for 160 interplanetary perturbations during 10 days centered about the time t_0 of the sharp increase in B which is chosen as epoch time; (b)- the same as in (a) using as epoch time: $t_0 \pm 27$ days; (c)- the same as in (a) using as epoch time: $t_0 \pm 54$ days.

