TWO CLASSES OF SOLAR ENERGETIC PARTICLE EVENTS ASSOCIATED WITH IMPULSIVE AND LONG DURATION SOFT X-RAY FLARES

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ABSTRACT

Solar energetic particle events observed in space have different properties depending on the class of associated flare. Impulsive flares, which occur low in the corona in regions of high energy density, are associated with particle events which are deficient in protons. These events are rarely associated with coronal mass ejections and interplanetary shocks. The vast majority of large, high energy proton events are associated with long duration flares, many of which are also associated with fast coronal mass ejections and strong interplanetary shocks. Such flare events originate relatively high in the corona.

1. Introduction. Recently it has been pointed out from two different viewpoints that there may be more than one class of interplanetary solar energetic particle (SEP) event. In the first study [1] it was found that there were SEP events which showed high abundances of electrons relative to protons at energies near 35 MeV and which were well correlated with gamma ray events. Previously it had been found that there was a poor relationship between particle fluxes inferred from gamma ray observations and fluxes measured in space [2,3]. In another study [4] a few examples of SEP events were found which were not associated with coronal mass ejections(CMEs). In this work it was noted that these rare events were associated with impulsive flares. It had been previously established that the flares associated with CMEs and interplanetary shocks (and by inferrence SEPs) [5,6,7,8] tend to be predominately of a different class, namely 'long duration'. A study in 1977 [9] showed that impulsive and long duration flares, as observed in soft X-rays, occurred in different regions of the corona. Long duration flares occur higher in the corona than impulsive flares.

We have made a study of SEP events and find that there are two classes. Although in one class the events tend to be 'proton poor' and are not, in general, associated with CMEs, the important distinguishing feature is their association with impulsive flares.

2. The Data. We have used data from Goddard Space Flight Center detectors on IMP-8 and ISEE-3 to assemble a list of solar flare events which produced relativistic electrons (>3 MeV) above approximately 5x10-4 electrons/(cm2.ster.sec.MeV) during the interval September 1978 to December 1983. Only events with a confident source association were included. For the majority of the events, this meant that there were H-alpha, soft X-ray and

metric radio phenomena that occurred at the same time. The events were divided into two classes depending on the durations of the associated (1-8 A) soft X-ray events.

We term "long duration" those particle events associated with soft X-ray flares which lasted for more than 1 hour at greater than 10% of the peak intensity. "Impulsive events" were associated with X-ray flares with a duration of less than 1 hour at greater than 10% of the peak intensity. Four further events without X-ray observations were included in this group on the basis of the short duration of the associated H-alpha activity. It is important to note that the terminology "impulsive" and "long duration" refers to the soft X-ray profiles and not to the particle time histories. However, the SEP events associated with impulsive flares do tend to have short durations relative to 'normal' proton events as can be seen in Figure 1.

The 73 events of our study are listed elsewhere [10] along with a more detailed description of the selection criteria. There are two lists corresponding to the two classes. The information provided is as follows; a) flare timimg and location, soft X-ray intensity and duration; b) timings and intensities of associated metric bursts of Types III, II and IV; c) average speed to earth of any associated interplanetary shock; d) electron onset and peak fluxes in two energy bands (~1 and 10 MeV); e) peak proton fluxes

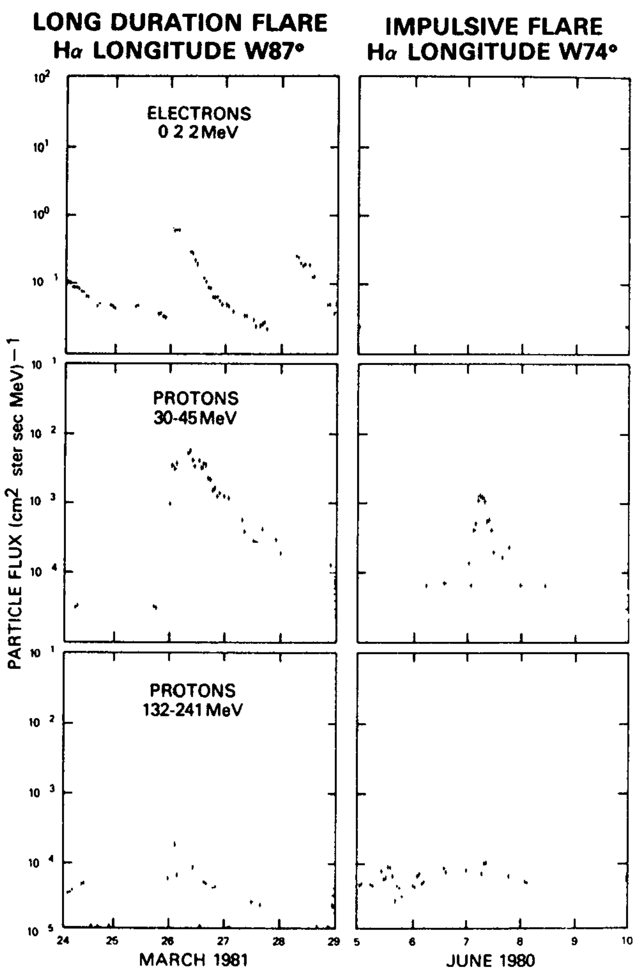

Fig.1 Proton and electron fluxes as a function of time for three events. There were two events on June 07, 1980 but they are unresolved in these figures.

in two bands (~10 and 60 MeV), f) the ratio of the high energy electron flux to the low energy proton flux; and g) approximate electron and proton spectral indices based on the ratios of the high to low energy fluxes of each specie.

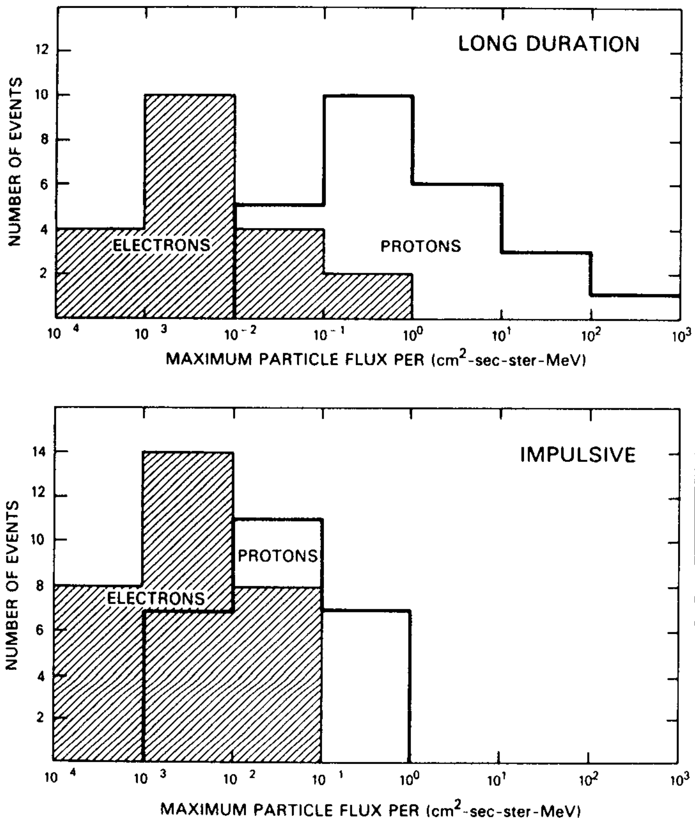

Figure 2 shows event size distributions for electrons (4-19 MeV) and protons (9-23 MeV) for both long duration and impulsive events. Whereas both classes have similar electron events, proton events with peak fluxes above 1/(cm2-sec-ster-MeV) occur only with long duration flares. Additionally high energy proton events occur only rarely with impulsive flares. The particle fluxes show that the impulsive events are 'proton poor'.

The key to understanding our results is in the metric radio bursts. We find that the impulsive flare events of our study produced strong Type III bursts, the majority (77%) including Type V continuum. Conversely the Type III/V burst occurred with only 15% of the long duration flares. Type II bursts occurred about equally (~80%) for both classes. Type IV occurred more frequently with long duration flares (72%) than with impulsive flares (23%).

3. Discussion. Our results, and other recent results, require modifications to many long held ideas about particle acceleration in flares, in particular to the ideas about the two phases. It was originally proposed [11] that in the first phase only non-relativistic electrons were accelerated. Observations of gamma-rays and the association of a class of proton and relativistic electron events with strong Type III bursts show that this is incorrect. Acceleration at coronal shocks was assumed necessary for the production of protons and high energy electrons. Since Type II bursts (the signatures of shocks) always follow

associated Type III bursts it was assumed that the first phase was necessary for the generation of shocks and the subsequent second phase acceleration. We find that there is a good correlation between high energy proton events and Type II and Type IV bursts but note that some events are not preceded by Type III bursts. Proton events with weak impulsive phases have been discussed before [12]. We believe that the relationship between the two phases is the following: A shock can form as a consequence of the initial impulsive energy release in energetic solar events. At essentially the same time beams of high energy particles can be created but the probability is greatest low in the corona. When the coronal shock strengthens (relatively high in the corona) it can accelerate high energy particles which escape to the interplanetary medium. In this scenario there is no relationship between the intensity of the first phase and that of the second. However in very 'big' flares both phases will be strong.

4. Conclusions. Our results suggest that energy releases that take place high in the corona are most likely to be associated with a CME and the particles observed in space may include substantial fluxes of both electrons and protons. Energy releases in the low corona occur rapidly and are most likely to produce fluxes of particles that in the interplanetary medium are deficient in protons.

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