

TYPE III RADIO BURSTS AND SOLAR ENERGETIC PARTICLES

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INTRODUCTION

In the current paradigm for the production of large SEP events the shocks driven by CMEs are considered to be of prime importance in accelerating the particles. Other processes, in particular those related to flares, are considered to be of little importance. Although large-scale shock acceleration can explain many of the characteristics of SEP increases there are some puzzles. Various arguments suggest that the shocks are not extensive enough to be responsible for the so-called "solar component" i.e. the early particles which at high energies disappear into the background long before any interplanetary shock passes the spacecraft.

Recent observations combining radio and particle data provide evidence that the early particles have their origins in flare events that occur in association with the eruption of the associated CMEs. Essentially every SEP event is associated with a type III radio burst. The drift rates of the bursts at

the lowest frequencies (<100 kHz) indicate that the causative electrons do reach the observer even when there is nominally very poor magnetic connection. The delays in the starts of the lowest frequency radio emissions are matched by delays in the arrival of the electrons AND protons. The delays increase with the angular distance between the flare location determined from H- α observations and the nominal magnetic connection of the observer and the maximum intensities show proportional decreases. The radio data show that the delays occur in the interplanetary medium and indicate that some lateral transport must be occurring.

SUGGESTION: The solar component of SEP events cannot be shock accelerated because the shocks are not in the required location.

ARGUMENT 1:

From a statistical analysis at 1 AU it has been found that interplanetary shocks have angular extents of at most 180°. In contrast particles can be seen over a longitudinal extent of over 200° within one hour and over a longitudinal extent of nearly 300° within 5 hours. FIGURE 1 shows the distribution of onset delays for high energy events seen on Helios 1, 2 and IMP 8 as a function of "connection angle". Lines connect points for the same event. The delays are measured using anticoincidence guards which provide count rates, with high statistics, of mainly ~>60 MeV protons (other species also contribute).

ARGUMENT 2:

Comparing different events the shock speeds do not organise the data; the flare position does. FIGURES 2A and 2B show data for two events in 1979 with very similar relative locations of the spacecraft. The relative particle profiles are also very similar except that the event occurs with less delay at Helios 2 for the March event consistent with its better connection in this event relative to the February event (-77° versus -101°). Helios 1 had connections of -39° and -44° and IMP 8 had connections of -119° and -118° . Shock passages are indicated below the proton intensities. It is clear that the February shock was faster than the March shock but the particle delays are not shorter.

SUGGESTION: The solar component of SEP events is accelerated in the flare events that accompany CME eruptions.

In a recent study (Cane, Erickson and Prestage, *J. Geophys. Res.*, in press, 2002) of the flare events associated with >20 MeV proton events in the time frame 1997-2001 it has been found that long lasting type III bursts accompany major proton events. These type III bursts are often not reported because of the over emphasis on type II bursts, which are shock related. An example of a complete dynamic spectrum (2 GHz to 20 kHz) of the radio emission associated with a major proton event is shown in Figure 3. Type III bursts indicate the presence of open field lines along which flare particles escape to the interplanetary medium. In subsequent work it has been found that the delays of the start of the radio emission at 1 AU relative to the time of the start of the emission at the Sun show the same organisation with connection longitude, see FIGURE 4 (right panel), as do proton delays (see Figure 1). Furthermore, the early ~25 MeV proton intensities decrease as the radio delays increase, as seen in the left panel of Figure 4, implying a coupling between the delay and the intensity. This is what is expected for interplanetary scattering where a smaller and smaller number of particles end up on field lines distant from the solar source region. The rapid decrease in intensity with increasing connection angle seen in multi-spacecraft studies is not what is expected for shock acceleration in which one expects a uniformly strong shock of some 100° in longitude.