SEPARATION AND ANALYSIS OF TEMPORAL AND SPATIAL VARIATIONS IN THE 10 APRIL 1969 SOLAR FLARE PARTICLE EVENT

R. Reinhard
Space Science Dept. of ESA
ESTEC
2201 AG Noordwijk
The Netherlands

E. C. Roelof and R. E. Gold
Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20707
USA

ABSTRACT:

We analysed the 10 April 1969 energetic particle event with five spacecraft separated over 180° in azimuth. The particle fluxes are mapped back to the coronal injection longitudes which are estimated from the instantaneous solar wind velocities and connected at the same time of observation to give the longitudinal particle gradients. Cutting these gradients at representative longitudes gives the temporal variations at fixed coronal longitudes which turn out to be power-law decays. This shows that the exponential rise and decay observed by spacecraft is due to the spatial gradient sampled by the spacecraft as the connection longitude changes due to the Sun's rotation.

1. INTRODUCTION

In terms of energetic charged particle propagation, a spacecraft in interplanetary space is connected to the Sun by the spiral magnetic field lines. Due to the Sun's rotation, the connection longitude continuously shifts eastward in the Sun's reference frame and the observed temporal flux variation at a single spacecraft is a mixture of a spatial azimuthal and a true temporal variation. Only with several spacecraft well distributed in azimuth is it possible to disentangle the spatial and temporal variation. The last opportunity for multiprobe observations of that kind was in April 1969 when a major flare - the second largest of the previous solar cycle - was observed by five spacecraft distributed over 180° of solar azimuth (Table 1).

In order to make use of multiprobe observations, the experiments on the various spacecraft have to be intercalibrated, correcting for the different energy channels and electron sensitivities. This was done in a very careful manner by selecting time periods in late 1968 and March 1969 when Pioneer 9 and Explorer 34 were <5° separated in azimuth. We find that the differences in the electron sensitivity
Table 1

<table>
<thead>
<tr>
<th>spacecraft</th>
<th>azimuthal separation from flare</th>
<th>heliocentric distance (10^8 Km)</th>
<th>energetic particle detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explorer 34 (IMP 4)</td>
<td>114°</td>
<td>1.5</td>
<td>&gt; 10 Mev</td>
</tr>
<tr>
<td>Pioneer 6</td>
<td>-36°</td>
<td>1.45</td>
<td>7.4-44 MeV</td>
</tr>
<tr>
<td>Pioneer 7</td>
<td>20°</td>
<td>1.68</td>
<td>7.2-47.4 MeV</td>
</tr>
<tr>
<td>Pioneer 8</td>
<td>89°</td>
<td>1.57</td>
<td>7.4-38.5 MeV</td>
</tr>
<tr>
<td>Pioneer 9</td>
<td>146°</td>
<td>1.13</td>
<td>7.4-38.5 MeV</td>
</tr>
</tbody>
</table>

and the energy thresholds partially cancel each other so that only a correction factor of ~20% should be applied, which is negligible compared to the much larger spatial and temporal variations we find in this event and, therefore, we decided not to apply any correction factors.

The most likely location of the flare site is N22 E114 with 11 UT on 10 April 1969 for the time of particle acceleration. The time-intensity profiles of the 10 April particle event observed by the five spacecraft (Fig. 1) rise and decay exponentially and show several kinks. The event has a number of unusual features:

1) the fluxes rise rapidly at Pioneer 6 and Pioneer 7, while the rise is delayed by a day at the other three spacecraft;
2) at Pioneer 7 two peaks are observed with the second rise starting on 11 April;
3) after 12 April the fluxes at Pioneer 8, Explorer 34 and Pioneer 9 are 1 to 3 orders of magnitude higher than at Pioneer 6 and Pioneer 7, which are better connected to the flare site;
4) the intensity difference persists until very late in the event in contrast to conventional views of diffusive equilibrium (the whole solar system being uniformly filled with particles late in the event)

Note that the last two features could only be detected by multi-spacecraft observations.