ENERGETIC PROTONS FROM A DISAPPEARING SOLAR FILAMENT

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ABSTRACT

A solar energetic ($E > 50$ MeV) particle (SEP) event observed at 1 AU began about 1500 UT on 1981 December 5. This event was associated with a fast coronal mass ejection observed with the Solwind coronagraph on the P78-1 satellite. No metric type II or type IV burst was observed, but a weak interplanetary type II burst was observed with the low frequency radio experiment on the ISEE-3 satellite. The mass ejection was associated with the eruption of a large solar quiescent filament which lay well away from any active regions. The eruption resulted in an Hα double ribbon structure which straddled the magnetic inversion line. No impulsive phase was obvious in either the Hα or the microwave observations. This event indicates that neither a detectable impulsive phase nor a strong or complex magnetic field is necessary for the production of energetic ions.

1. Introduction. The conventional view of energetic (tens of MeV) solar particle acceleration is that it occurs only during flares in active regions (see Svestka (1981) for a general review). In many flares impulsive hard X-ray and microwave bursts indicate a rapid acceleration of electrons to energies of tens of keV. The γ-ray observations from the Solar Maximum Mission have shown that MeV ion production can also occur during the impulsive phase (Forrest and Chupp 1983). Acceleration of ions to tens of MeV then sometimes occurs in a subsequent "second phase" characterized by metric type II and type IV radio bursts and long-enduring soft X-ray and microwave events. The active regions producing these energetic flares are characterized by strong and complex magnetic fields, and the flares themselves are usually Hα double ribbon structures (Svestka 1981).

Some exceptions to this conventional picture are known. The most convincing published example of a nonflare source for a prompt SEP event was discussed by Sanahuja et al. (1983). They attributed a $1 < E < 15$ MeV SEP event to the disappearance early on 1979 April 23 of a large filament

*Also: University of Maryland, College Park, Maryland 20742 USA at least partially located in a small and weak active region. A pair of double-ribbon flares, one in McMath region 15956, accompanied the filament disappearance. However, they argued that the filament eruption, rather than the flares, was the important factor in this SEP event.

2. Observations. The SEP event of 1981 December 5 was observed with the GSFC cosmic ray experiment on the ISEE-3 spacecraft (Figure 1). The MeV electron onset was between 1415 and 1430 UT, followed by the proton onset between 1500 and 1530 UT. The velocity dispersion and rapid rise to maximum are evidence of an impulsive injection of particles from a well connected solar longitude. The 11-22 MeV proton flux measured by the Helios 1 spacecraft (~ 13° behind the west limb) on December 6 was a factor of 10 lower than that measured simultaneously by the GSFC experiment on IMP-8 at the Earth, consistent with our association of the SEP event with the disappearance of the disk filament, rather than with a source from behind the limb.

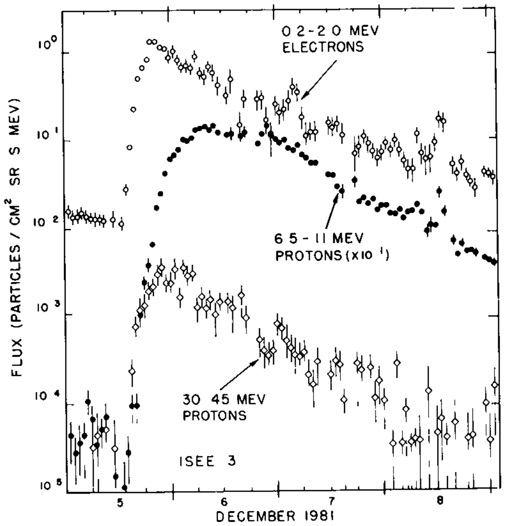

Figure 1. Flux-time plots of energetic particles for the SEP of 1981 December 5.

Several Hα filtergrams obtained by the Haute Provence Observatory (provided courtesy of P. Simon) and reproduced in Figure 2 show the key times in the eruption of a large filament on 1981 5 December. The filament, located at ~ W35-45°, N15-30° became active and began to erupt at ~ 1215 UT. Hα brightenings were first observed at 1315 UT, forming a classic double-ribbon pattern along the filament channel. The filament was not at the location of a former active region, and it lay at least 25 heliographic degrees from the nearest plage region.

Figure 3 shows the ejected filament and coronal material observed by the NRL white-light coronagraph (SOLWIND) on the P78-1 satellite. The first of these difference images shows that the coronal disturbance was not yet visible at 0658 UT, but was in progress during the next available image at 1447 UT. At this time the leading edge of the coronal material was already located at 6.2 R_O in the northwest quadrant while the much smaller prominence was near the edge of the occulting disk at 2.5 R_O. During the subsequent images the ejected coronal material left the 2.5-10.0 R_O field of view, and the prominence moved uniformly outward in the plane of the sky. Its apparent latitude 30° north of west is consistent with the original location of the filament on the disk. From these observations, we found that the prominence was moving with a speed of 305 ± 20 km/s in the plane of the sky. Extrapolated back to the 0.65 R_O location of the disk filament, this speed gives a starting time of 1329 ± 0010 UT, or approximately 1 hr after the disk filament began to disappear. This 1-hr time delay suggests that the erupting filament accelerated during the first hour after its initial disappearance from the Hα spectral bandpass, as is usually observed for erupting prominences.

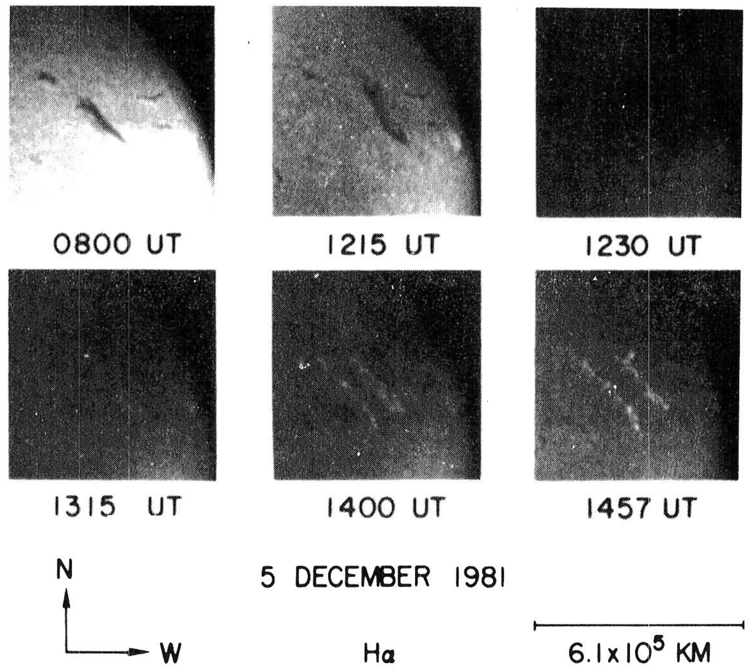

Figure 2. Hα images from the Haute Provence Observatory showing the filament disappearance (top) and subsequent two-ribbon brightening (bottom) on 1981 December 5. Comparison of the top three images shows a clear outward motion of the northernmost part of the filament.

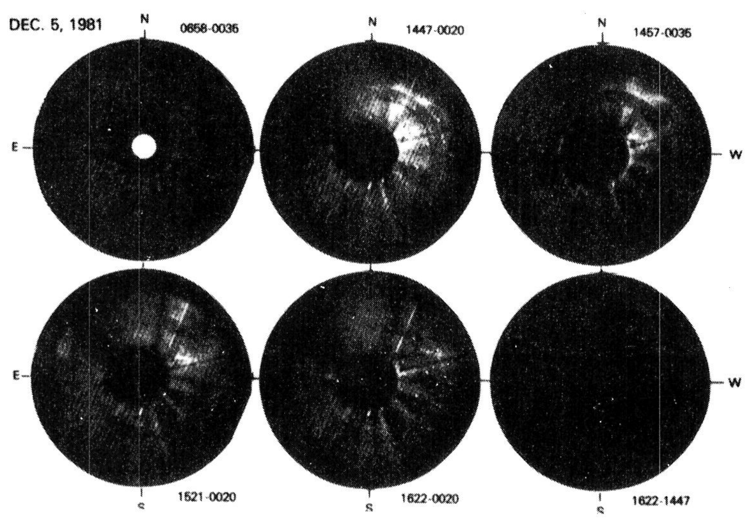

Figure 3. Subtracted images from the NRL Solwind coronagraph showing the CME of December 5. The Hα filament can be seen as the small bright structure at the inner core of the CME.

No impulsive microwave or hard X-ray bursts accompanied the filament disappearance. There were, however, weak gradual soft X-ray and microwave events that appeared to accompany the eruption. A faint and very gradual GOES 1-8 Å enhancement began shortly after 1300 UT, rising from a C2.5 background to a peak level of only C3.5 at 1430-1450 UT. A gradual rise-and-fall event was observed in the Sagamore Hill Observatory 4995 MHz record beginning at ~ 1300 UT with a peak flux of 21 ± 3 s.f.u. at ~ 1400 UT. Metric type III bursts observed from 1316 to 1326 UT were also detected in the ISEE-3 radio data, but these were not due to the filament activity because the deduced position of the 1980 kHz position was east of central meridian. An apparent shock-associated (SA) event (Cane et al. 1981) was observed at 1980 kHz in the ISEE-3 radio data from the end of the type III emission at about 1328 UT until 1352 UT. By tracking the centroid of the emission out to about 0.7 AU, we estimate that the source longitude for this event was in the range W10°- W40°, indicating a spatial as well as temporal association with the filament disappearance and CME. The SA event was followed by a weak interplanetary type II burst (Cane 1985).

3. Discussion and Conclusion. The E > 50 MeV SEP event of 1981 December 5 has been associated with a filament disappearance well removed from any active region. The motion of the filament was observed in Hα as shown in the second and third images of Figure 2 and later in the coronagraph images shown in Figure 3. Besides the filament disappearance, the prominent solar signatures of the December 5 event were the Hα double-ribbon emission shown in Figure 2 and the accompanying weak gradual thermal soft X-ray and microwave event. The Hα ribbons appear to be the footpoints of cool loop arcades overlain by hot soft X-ray loops.

In addition, we found no evidence of any impulsive phase microwave emission from this event. This indicates that neither active regions nor obvious impulsive phase phenomena are necessary for energetic particle production (cf. Cliver et al. 1983). The good association of SEPs with Hα flares and with flare impulsive phase bursts is most likely not a direct cause-and-effect relationship but rather a manifestation of the Big Flare Syndrome (Kahler 1982), which states that, statistically, energetic flare phenomena are more intense in larger flares, regardless of the detailed physics.

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