SEP Event Onsets: Far Backside Solar Sources and the East-West Hemispheric Asymmetry

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ABSTRACT

Prompt onsets and short rise times to peak intensities Ip have been noted in a few solar energetic (E > 10 MeV) particle (SEP) events from far behind the west limb (WL). We discuss 15 archival and recent examples of these prompt events, giving their source longitudes, onset and rise times, and associated CME speeds. Their timescales and CME properties are not exceptional in comparison to a larger set of SEP events from behind the WL. A further statistical comparison of observed timescales of SEP events from behind the WL with events similarly poorly magnetically connected to the eastern hemisphere shows longer timescales of the latter group, a result due to neither solar rotation nor faster CMEs.

Background

Based on > W140º sources of E > 10 MeV proton SEP events in 1966, 1967, and 1971, Cliver (1982) argued that the SEP sources must be shock waves broad enough to generate SEPs over a large longitudinal region. Cliver et al. (2005) inferred a W180º source location for a large SEP event on 2001 August 16 and argued that the prompt arrival of E > 400 MeV protons was caused by a shock sweeping around to the front side of the Sun from its distant backside origin. These "extreme propagation" (EP) (Cliver et al.,1995) proton and electron events observed on Helios 1/2 and IMP-8 included 1 to 3 MeV electron onsets within 2 hours for longitudinal separations up to 150º. Here we add more recent examples of far backside SEP events (Table 1) and then compare their parametrized timescales with those of a large sample of SEP events from > W100º.

Cliver et al. (1995) did not find east/west differences in the propagation of Hα waves or in the efficiency of SEP acceleration at the inferred shock fronts. We compare statistically the onset and rise times of ~ 20 MeV proton events for far eastern and western longitude ranges compiled by Kahler (2013).

Table 1: SEP Events at Longitudes >115° With Prompt Onsets.

Year	Date	Long.	CME Onset T	SEP Onset T	TO hrs	TR hrs	Vcme km/s	Ip pfu
1966	16 Jul	W172°	20:50	22:30	1.7	4.0	NA	1.1
1971	1 Sep	W120°	19:35	21:00	1.4	1.5	NA	300
1984	16 Feb	W130°	08:58	09:35	0.6	0.4	NA	660
1996	13 Aug	W150°	14:15	17:00	2.7	3.0	620	<0.1
2001	18 Apr	W117°	02:12	03:00	0.8	4.0	2465	321
2001	16 Aug	W180°	15/23:41	01:00	1.3	1.5	1575	493
2004	3 Sep	W120°	2/23:46	03:00	3.2	0.5	751	<0.2
2005	29 Aug	W148°	10:47	13:00	2.2	4.0	1600	1.0
2011	21 Mar	W138°	02:12	04:00	1.8	2.6	1341	14
2011	3 Nov	E152°	22:13	23:30	1.3	1.5	991	3
2012	26 May	W116°	20:42	23:00	2.3	2.0	1966	14
2012	8 Sep	W145°	09:26	12:00	2.6	1.5	734	1.0
2013	21 Apr	W124°	07:13	10:00	2.8	1.5	919	3
2013	24 Apr	W175°	21:45	23:00	1.3	4.0	594	0.7
2013	28 Dec	W130°	17:15	18:40	1.4	2.3	1118	29

Selection of Prompt Backside SEP Events

We surveyed the literature to compile a list of SEP events, all in the range of 10 to 50 MeV for protons, with prompt onset intensity profiles and source locations at least 25º behind the WL. All TO, the times from flare peak or CME launch to SEP onset, are ≤ 3.2 hrs. All TR, the times from onset to half the peak intensity Ip, are ≤ 4.0 hrs. Those 15 events are listed in Table 1. The SEP event of 2011 November 3 was outstanding for the very rapid rises to peak intensities at STEREO A, B, and ACE, despite the wide separation of the three spacecraft (Mewaldt et al., 2013). Its associated CME was the only one observed off the east limb of the Sun. Figure 1 shows intensity profiles of that event in addition to the earlier 2001 August 16 and recent 2013 December 28 SEP events of Table 1.

Prompt Backside Versus All Backside SEP Events

We compare in Figure 2 the TO and TR values of events in Table 1 with those of a similar larger group of ≥ W100º (WL) events from the survey of Kahler (2013). The larger WL group satisfy only the longitude condition of ≥100º. The median longitude of the Table 1 SEP events is W138º, probably only slightly greater than those of the larger WL group. The four events common to both groups are shown as prompt events. The main result of this comparison is that the Table 1 backside SEP events with prompt onsets at Earth are not distinguished from the class of all backside SEP events in terms of their onset times TO and rise times TR.

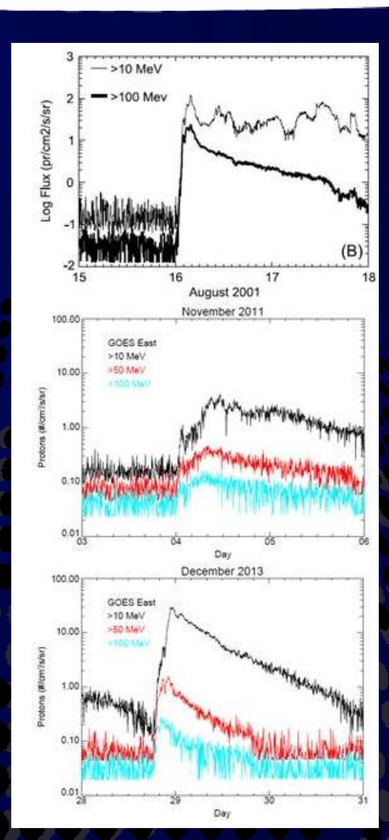


Figure 1. (Left) GOES SEP data from three events of Table 1.

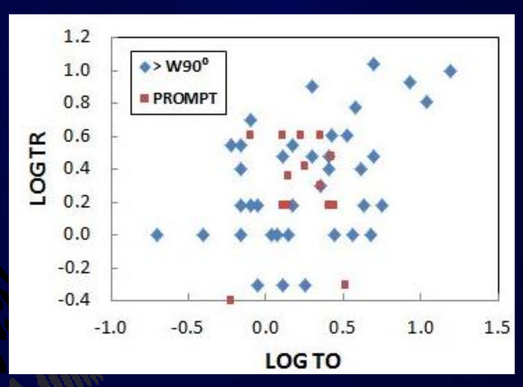
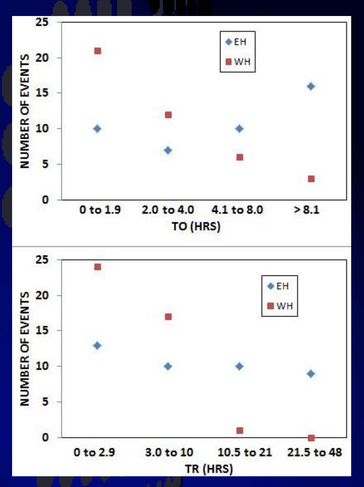


Figure 2. (Above) Comparison of log TR versus log TO for the 15 prompt backside events of this study (red squares) and the 38 ≥ W110º SEP events (blue diamonds) of Kahler (2013). Units of TO and TR are hours.

Eastern Versus Western Hemisphere SEP Events

We examine the observed differences of TO and TR between SEP events roughly equally separated from the eastern and western flanks of the associated CMEs. Taking an average longitude connection of W50º, appropriate for a solar wind speed of ~450 km/s, the longitude ranges of < E00º, i.e., eastern hemisphere, and > W100º, would be well matched for such a comparison. These two ranges compare to the longitude groups of E130º to E06º, and > W100º of the survey of Kahler (2013). In our Figure 3 we compare the number distributions of SEP events versus TO and TR for these EH and WL groups. There is a clear asymmetry in that the EH events are broadly distributed across both time bins while the WL events show sharp decreases with longer timescales.

Figure 3. Comparisons of numbers of SEP events with timescales TO (top) and TR (bottom) for eastern (E130º - E06º, EH, blue diamonds) and western (≥ W100º, WH, red squares) hemispheres. Event times are taken from Table 1 of Kahler (2013).



The two groups profiled in Figure 3 are approximately equally offset from the average optimum magnetic connection of W50º. The symmetry is broken by the solar rotation, which convects the bulk SEP population toward (away from) the near-Earth observer for EH (WL) events. In the ~10 hr timescales encompassing nearly all events of Figure 2, that rotation is < 6º and not a factor. The median CME speed of the EH events, 1374 km/s, exceeds that of the WL events, 1136 km/s by about half a standard deviation. However, TO is not correlated with Vcme for either group, and TR correlates only weakly, but equally, r = 0.32, with each group. Thus the somewhat larger Vcme of the EH group is also not a factor in the different distributions of Figure 3.

Summary

We report 15 SEP events from > W115º with short timescales and show that their timescales are not exceptional when compared to a larger group of SEP events from behind the west limb. The timescales of EH SEP events statistically exceed those of WL events, but the differences are due to neither solar rotations nor CME speed differences.

References

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