Comment on "Interplanetary shocks unconnected with earthbound coronal mass ejections" by T. A. Howard and S. J. Tappin

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Received 18 October 2005; revised 17 February 2006; accepted 20 March 2006; published 15 June 2006.

Citation: Gopalswamy, N., S. Akiyama, S. Yashiro, and J. Kasper (2006), Comment on ''Interplanetary shocks unconnected with earthbound coronal mass ejections'' by T. A. Howard and S. J. Tappin, *Geophys. Res. Lett.*, *33*, L11108, doi:10.1029/2005GL024983.

1. Introduction

[1] Recently, *Howard and Tappin* [2005] (hereinafter referred to as HT) reported on a set of 7 interplanetary (IP) shocks, apparently not connected with any detectable coronal mass ejection (CME) activity along the Sun-Earth line and concluded that there was no evidence to associate 6 of them with corotating interaction regions (CIRs); they were uncertain about one event. Based on these results, HT put forth a proposal that the 6 shocks were associated with ''erupting magnetic structures'' or EMSs and that EMSs rather than CIRs are the dominant cause of IP shocks that cannot be associated with halo CMEs. Our analysis of these events does not agree with these conclusions due the following reasons: (1) the Solar and Heliospheric Observatory (SOHO) mission had a data gap for one event , and (23 October 1998), so the CME association could not be checked; (2) the 18 May 1999 and 23 December 2001 shocks were likely CIR-related; (3) the remaining 4 shocks were CME-related, two (7 April 1998 and 9 November 2002) reported in the published literature [*Manoharan et al.*, 2004] and the other two (both on 23 August 1999) were associated with two successive CMEs from the same region ejected off the Sun-earth line. Therefore, we do not see any basis for invoking anything other than CIRs and CMEs. In the following, we revisit the source of each of the 7 shocks.

2. Event 1: 7 April 1998

[2] This is a shock followed by ejecta [*Manoharan et al.*, 2004, event #12]. SOHO's Extreme-ultraviolet Imaging Telescope (EIT) observations show a clear dimming from AR 8190 (S23E23) with an accelerating CME of speed 155 km/s. The width was at least 48 degrees. This was the only major active region on the Sun, and at the right location. The measured sky-plane speed is likely to be an underestimate and the observed acceleration implies increased speed at larger distances from the Sun. The 1-AU shock speed was $\sim$367 km/s and the IP CME (ICME) speed was 325 km/s, both of which are consistent with an accelerating disk CME. Therefore, one cannot rule out this CME as a source for the 7 April shock. Note that while most Earth-impacting CMEs are halos, non-halos also arrive at Earth as magnetic clouds or ejecta [*Gopalswamy et al.*, 2000, 2001b].

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0094-8276/06/2005GL024983$05.00

3. Event 2: 23 October 1998

[3] A type II burst (20 October 1998 at 23:20 UT) is indicated by the authors near the estimated onset of the CME. Type II bursts are indicators of energetic (faster and wider on the average) CMEs [see, *Gopalswamy et al.*, 2005]. Therefore, the type II burst can be taken as evidence for a CME at the appropriate time. Observing this CME was not possible because, there was a SOHO data gap from 15 October 1998 20:50 UT to 21 October 19:35 UT, so one cannot conclude that there was no associated CME.

4. Event 3: 18 May 1999

[4] This event with a forward-reverse shock pair is a classic example of CIR-related shocks. Because of its conspicuous nature, this event has been listed in the SOHO/MTOF page as an example of CIR related shock pair (http://umtof.umd.edu/pm/fig49c.gif). The solar source is clearly a huge low-latitude coronal hole crossing the central meridian around 13 May. HT also suspect that this IP shock was of CIR origin.

5. Events 4 and 5: 23 August 1999

[5] The two shocks are separated by $\sim$4 hours. At the Sun, there were two fast CMEs: a fast (631 km/s) and wide (94 deg.) CME at 18:50 UT on 20 October, followed by another fast (812 km/s), and wide (76 deg.) CME at 23:26 UT (see http://cdaw.gsfc.nasa.gov/CME_list). The CMEs originated from AR 8673 when it was at S23E66 (producing an M1.2 flare) and S25 E64 (producing an M9.8 flare). Both CMEs drove shocks, as evident from metric type II bursts at 18:39 and 23:17 UT. Given the above-average width of these shock-driving CMEs and the fact that the shocks are much more extended than the CMEs at large distances from the Sun [*Burlaga*, 1995], it is very possible that the western flanks of the shocks crossed the Sun-Earth line to be detected at 1 AU.

6. Event 6: 23 December 2001

[6] This seems to be a CIR shock, as illustrated in Figure 1. The solar wind speed, east-west flow angle (EW), proton temperature, proton density, magnetic field magnitude, and alpha-to-proton ratio are plotted in Figure 1

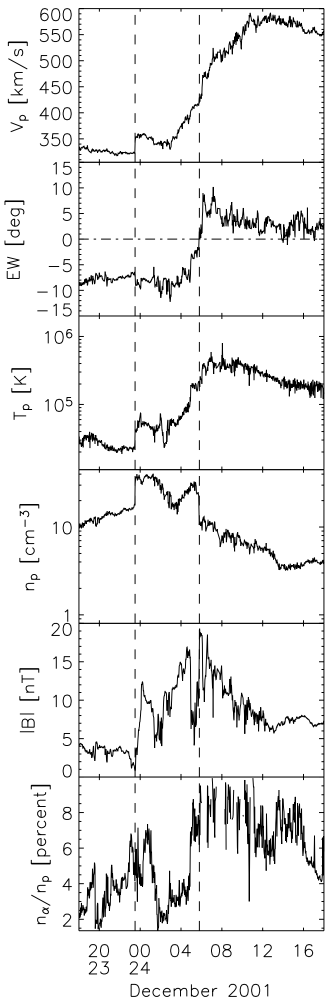

Figure 1. Flow speed (V_p), east-west flow angle (EW), proton temperature (T_p), proton density (n_p), Magnetic field magnitude, and the ratio of alpha-proton density ratio , and (n_α/n_p) from the Wind spacecraft observations of the 23 December 2001 shock. The shock is indicated by the first vertical dashed line. The stream interface can be seen at ~05:00 UT on 24 December, as marked by the second vertical dashed line.

for a 24 h period from 21 December 2001 18:00 UT to the same time next day. Expansion of the compression region at the leading edge of a high speed stream (~600 km/s) seems to be responsible for this shock. The stream interface is marked by the density spike and the east-west deflection (transverse flow generally changes from west to east at the interface) [e.g., *Gosling*, 1996]. The SOHO/EIT image in the 284 Å wavelength shows a dark low-latitude coronal hole that was present close to the disk center at the appropriate time (see Figure 2). The high speed stream most likely originated from this hole. The coronal hole was visible in the previous and next solar rotations, moving toward the equator. High-speed solar wind was also detected in the previous and next rotations.

7. Event 7: 9 November 2002

[7] This is also a shock previously studied by , and *Manoharan et al.* [2004, event #91]. The associated CME

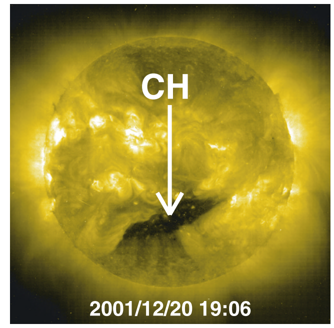

Figure 2. The Coronal hole (CH) responsible for the 23 December 2001 shock. This is a SOHO/EIT image at 284 Å taken on 20 December 2001 at 19:06 UT.

was fairly wide (102 deg.) and of above average speed (485 km/s) lifting off around 05:06 UT from AR 0180 (S13E13) on 6 November. The CME and the associated disk features in EIT are shown in Figure 3. There was also an associated metric type II burst from 05:38 to 05:48 UT reported by Culgoora (not considered by HT), confirming that the CME is driving a shock near the Sun. Therefore, this is not a case of an EMS driving shock only close to 1 AU.

[8] To summarize, shocks 1 and 7 were associated with white light CMEs (see also Figure 3) according to published literature. Shock 2 originated during a SOHO data gap, so the CME association cannot be checked. Shocks 3 and 6 have been shown to be CIR-related shocks. It is possible to associate the two shocks (4 and 5) on 23 August 1999 with two successive fast CMEs ejected to the east of the Sun-Earth line. It is likely that these are the western flanks of the CME-driven shocks. Apart from the CIR shocks, all other interplanetary shocks are associated with regular CMEs. Even those shocks, which appear to have no drivers behind them, are known to be associated with CMEs moving at large angles with respect to the Sun-Earth line [*Gopalswamy et al.*, 2001a]. HT also point out that there were non-halo CMEs (width $\leq$ 120 deg.) during the days leading up to the shocks. Non-halo CMEs can also drive shocks. Therefore, we conclude that (1) there is no observational basis for invoking "invisible CMEs" to explain "Interplanetary shocks unconnected with earthbound coronal

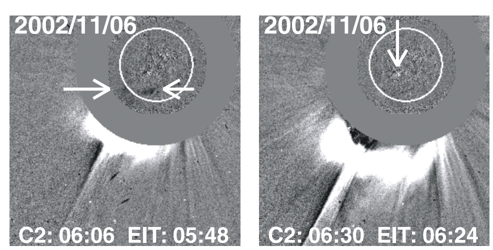

Figure 3. Two SOHO/LASCO images showing two snapshots of the 2002 November 06 CME responsible for the IP shock on 9 November 2002. SOHO/EIT difference images (at 195 Å) are superposed to indicate the disk activity. (left) The extent of dimming in the EIT 195 Å difference image is shown by two arrows. (right) The active region from which the CME originated is indicated by an arrow.

mass ejections'', and (2) all the shocks in question can be explained by the two known shock drivers, viz., CMEs and CIRs.

[9] **Acknowledgments.** We thank R. Kataoka for discussions. SOHO is a project of international cooperation between ESA and NASA. This work was supported by NASA's LWS TR&T and SR&T programs.

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