

Relation between coronal type II bursts, associated flares and CMEs

George Pothitakis¹, Panagiota Preka-Papadema¹,
Xenophon Moussas¹, Constantine Caroubalos²,
Constantine Alissandrakis⁴, Panagiotis Tsitsipis³,
Athanasios Kontogeorgos³ and Alexander Hillaris¹

¹Department of Physics, University of Athens, 15784 Athens, Greece

²Department of Informatics, University of Athens, 15783 Athens, Greece

³Department of Electronics, Technological Education Institute of Lamia, Lamia, Greece

⁴Department of Physics, University of Ioannina, 45110 Ioannina, Greece

Abstract. We study a sample of complex events; each includes a coronal type II burst, accompanied by a GOES SXR flare and LASCO CME. The radio bursts were recorded by the ARTEMIS-IV radio spectrograph (100-650 MHz range); the GOES SXR flares and SOHO/LASCO CMEs, were obtained from the Solar Geophysical Data (SGD) and the LASCO lists respectively. The radio burst-flare-CME characteristics were compared and two groups of events with similar behavior were isolated. In the first the type II shock exciter appears to be a flare blast wave propagating in the wake of a CME. In the second the type II burst appears CME initiated though it is not always clear if it is driven by the bow or the flanks of the CME or if it is a reconnection shock.

Keywords. Sun: coronal mass ejections (CMEs), Sun: flares, Sun: radio radiation

1. Introduction

The MHD shock radio signatures, in the interplanetary medium and the solar corona, are the kilometric type II bursts and the metric type II radio emissions respectively. Though the former have been, unambiguously, identified with shocks piston-driven by CMEs, the exciter of the latter is somewhat more controversial as it can be either a blast-wave or a CME driven shock. Only the CME driven shocks are expected to propagate into interplanetary space; the blast-waves are damped with distance and, probably, rarely escape the lower corona (cf. Gopalswamy 2006, Pick *et al.* 2006, and references therein). This ambiguity about the exciter of coronal type II bursts has initiated a number of publications (cf. Kahler *et al.* 1984, Claßen & Aurass 2002, etc.) in which the CME, flare and type II parameters are compared. In this report we examine a set of complex events in search of groups with similarities as regards the relationship of type II burst-flare-CME characteristics; each is expected to represent a different shock generation processes.

2. Data Selection and Analysis

The ARTEMIS IV radiospectrograph (Caroubalos *et al.* 2001) observed 40 type II and/or IV radio bursts (1998-2000) which were published in the form of a catalogue (Caroubalos *et al.* 2004). The gross spectral characteristics of these events, and the associated CME and flare parameters were summarized in this catalogue; here we adopted the same numbering of events.

Table 1. Characteristic Parameters of Each Event in the Data Set

Event	$\delta\tau$ (min)	V_r	D (min)	V_{II} (km/sec)	ΔT (min)
Group I					
19	-22	3.12	3	1213	-4
24	-12	2.50	3	1940	-5
25	-32	1.77	1	1477	-4
Average	-22 ± 5.2	2.5 ± 0.4	2.33 ± 0.67	1543 ± 212	-4.3 ± 0.33
Group II					
08	2	0.38	11	416	-1
21	-10	0.95	3	430	-1
23	20	0.80	11	806	-1
27	9	1.07	1	375	-1
30	17	1.73	3	737	0
32	17	0.82	4	442	0
39	2	0.65	7	494	-1
40	19	1.12	6	598	-2
Average	9.5 ± 3.8	0.9 ± 0.14	5.8 ± 1.3	537 ± 57	0.9 ± 0.2
Unclassified					
06	-13	1.00	10	940	-5
33	-4	1.02	5	1300	-3
36	22	0.85	17	1430	-3
Overall Average	1.1 ± 4.6	1.27 ± 0.20	6.1 ± 1.24	900 ± 132	-2.2 ± 0.5

From the original catalogue we selected fourteen events; (Table 1); they all include flares associated with a type II ARTEMIS-IV metric burst and a SOHO/LASCO CME.

The parameters used in our study were:

- The Type II speed, V_{II} , in km/sec. They were calculated from the frequency drift rate of the type II bands, assuming a Newkirk (Newkirk 1961) corona and radial propagation of the MHD shock.
- The ratio of the Type II speed to the CME speed, $V_r = V_{II}/V_{CME}$. V_{CME} was obtained from the on line LASCO lists
- The time interval, $\delta\tau$, between the CME liftoff and the flare onset from the extrapolated value cited in the LASCO lists and the GOES SXR profiles respectively.
- The Type II duration in minutes, D , from the ARTEMIS-IV dynamic spectra.
- The time interval, ΔT , between the Type II launch time and the flare onset. As the emission starts some minutes after the onset of the flare impulsive phase, back-extrapolation of the emission lanes in the ARTEMIS-IV spectra was used to estimate the type II launch time.

In order to quantify similarities between each pair (i,j) of events we computed, a *proximity measure* in the form of *Standard Euclidean Distance*, d_{ij} ; the smaller the index d_{ij} between a pair the more its members resemble each other. We define d_{ij} as:

$$d_{ij} = \sqrt{[V_{IIi} - V_{IIj}]^2 + [V_{ri} - V_{rj}]^2 + [D_i - D_j]^2 + [\delta\tau_i - \delta\tau_j]^2 + [\Delta T_i - \Delta T_j]^2}$$

Each coordinate (parameter) in the sum of squares is inversely weighted to the standard deviation of that coordinate. The *proximity measure* (d_{ij}) between pairs of events is used as a criterion for the identification of clusters within our data set. Certain groups of *similar* events emerge thus and are summarized in Table 1:

- Group I (Events 25, 19 & 14). Events in this group exhibit a close time relationship between the type II launch and the flare onset (average $\Delta T=-4.3\pm 0.3$ min); the type IIs are fast (average $V_{II}=1543\pm 212$ km/sec) while the CME launch precedes the

flare by 22 ± 5.2 minutes and the CME speed is almost half the shock speed (average $V_r = V_{II}/V_{CME} = 2.5 \pm 0.4$). This suggests that the type II radio source is located behind the leading edge of the CME and that the associated shock was probably ignited by the flare and was propagating through the transient disturbance at the wake of the CME. This is consistent with the scenario proposed by Wagner & MacQueen (1983) for the 17 April 1980 type II burst and Vršnak *et al.* (2006) for the 3 November 2003 event (cf. also Vršnak & Cliver (2008) for a review). Two of the three events lack interplanetary type II in the WIND/WAVES reports, the only exception being Event 25.

- Group II (Events 21, 30, 39, 32, 40, 27, 08, & 23). Here the type II launch time is well associated with the flare onset (average $\Delta T = -0.90 \pm 0.20$ min) and the CME launch which is about 9.5 ± 3.8 minutes after the flare. The type II speeds (average $V_{II} = 537 \pm 57$ km/sec), on the other hand, are equal or less to the CME speeds (average $V_r = V_{II}/V_{CME} = 0.9 \pm 0.14$); the type II duration (average 5.8 ± 1.3 min) more often than not exceeds the typical values for coronal type IIs. It is expected that the type II are driven by CME bow shocks (when $V_r \approx 1$) or CME flanks, or are reconnection shocks induced by the CME liftoff. Three of the Events (39, 08 & 23) have an interplanetary type II as is often the case with shocks driven by CME front or flanks. For the rest (21, 27, 30, 32 & 40) no interplanetary type II was reported.

The association between the events 33, 06 & 36 remains at present uncertain, however they are characterized by fast CMEs and long duration type II shocks.

3. Discussion & Conclusions

We have studied fourteen complex events, each includes a coronal type II burst a GOES SXR flare and a LASCO CME; certain parameters, related to shock & CME kinetics and radio bursts-flare-CME timing were compared. Uncertainty factors were:

- Projection Effects: They introduce inaccuracies in the CME speed calculation; the errors are minimal in the case of limb CMEs.
- Take off Time: Both CME onset and Type II start are estimated from backward extrapolation neglecting possible acceleration.
- Type II Speed: The calculations rely heavily on the coronal model adopted; this can be resolved in the case of radio images of limb events.
- SXR Flare Onset: Depends on the detection threshold used.

Despite the uncertainties, it was found that most of the events may be grouped together based on their similar behavior; for each group we have conjectured a different shock generation processes, as various mechanisms exist (Vršnak & Cliver (2008)). Further study, with a larger data set of, preferably, limb events, will provide improved results as regards the coronal type II drivers.

References

- Caroubalos, C., Hillaris, A., Bouratzis *et al.*, 2004, *A&A*, 413, 1125
 Caroubalos, C., Maroulis, D., Patavalis *et al.*, 2001, *Exp. Astron.*, 11, 23
 Claßen, H. T. & Aurass, H., 2002, *A&A*, 384, 1098
 Gopalswamy, N., 2006, *AGU Geophysical Monograph Series*, 165, 207
 Kahler, S., Sheeley, Jr., N. R., Howard *et al.*, 1984, *Solar Phys.*, 93, 133
 Newkirk, G. J., 1961, *ApJ*, 133, 983
 Pick, M., Forbes, T. G., Mann *et al.*, 2006, *Space Sci. Revs*, 123, 341
 Vršnak, B. & Cliver, E. W., 2008, *Solar Phys.*, 142
 Vršnak, B., Warmuth, A., Temmer, *et al.*, 2006, *A&A*, 448, 739
 Wagner, W. J. & MacQueen, R. M., 1983, *A&A*, 120, 136