COMPLEX SOLAR EVENTS OBSERVED WITH THE ARTEMIS-IV RADIO-SPECTROGRAPH IN OCTOBER/NOVEMBER 2003

C. E. Alissandrakis[1], A. Nindos[1], A. Hilaris[2], C. Caroubalos[2], and the ARTEMIS team[2]

[1]University of Ioannina, GR-45110 Ioannina, Greece, Email: calissan@cc.uoi.gr
[2]University of Athens,GR-15784 Athens, Greece, Email: ahilaris@phys.uoa.gr

ABSTRACT

We present dynamic spectra of three out of six complex events observed in the period October 23 - November 3 with the radio-spectrograph ARTEMIS-IV, operating at Thermopylae, Greece. Combined with data from WIND-WAVES, these observations provide a complete view of the radio emission induced by shock waves and electron beams from the low corona to about 1 A.U. We also use data from TRACE, EIT and LASCO for the associated flare and CME activity.

Key words: Metric Radio Bursts, CMEs.

1. INTRODUCTION

Radio emission at metric and longer waves is a powerful diagnostic of disturbances, mainly electron beams and shock waves, formed in the process of energy release and magnetic restructuring of the corona and propagating from the low corona to interplanetary space. The period of the end of October and the beginning of November 2003 was one of intense activity originating in active regions 484, 486 and 488; while in the visible hemisphere of the sun, they produced 8 X-class and 12 M-class flares

2. OBSERVATIONS

The Artemis IV solar radio-spectrograph operating at Thermopylae since 1996 (Caroubalos *et. al.*, 2001a) consists of a 7-m parabolic antenna covering the metric range, to which a dipole antenna was added recently in order to cover the decametric range. Two receivers operate in parallel, a sweep frequency analyser (ASG) covering the 650-20 MHz range in 630 data channels with a cadence of 10 samples/sec and a high sensitivity multichannel acousto-optical analyser (SAO), which covers the 270-450 MHz range in 128 channels with a high time resolution of 100 samples/sec.

Events observed with the instrument have been described, e.g. by Caroubalos *et. al.* (2001b, 2004). In October-November 2003 ARTEMIS-IV observed six major events on October 23 (08:24 UT), October 25 (05:20 UT), October 26 (06:16 UT), October 28 (11:02 UT), November 2 (a behind-the-limb event, 09:20 UT) and November 3 (09:49). Out of those, we selected three events to give an overview here.

3. SELECTED EVENTS

3.1. The Event of October 25, 2003

A peculiar emission was recorded by ARTEMIS on October 25, between 05:20 and 05:36 UT (Fig. 1). A slow drift loop-like structure appeared in the frequency range 75 to 30 MHz, accompanied by moving Type-IV emission in the 360-120 MHz band, starting around 05:24 and extending to about 05:55.

Apparently the disturbance was confined to relatively low heights; there is no trace of the emission in the WIND data (Fig. 2) and no associated CME. We note that a CME, associated with an earlier M1.2 flare starting at 04:17, was detected by LASCO (first image at 05:18), but there is no apparent association with the event we are describing. New flare activity, starting around 05:45 north-northeast of the post-flare arcade, produced strong type III activity, extending from 400 MHz down to 150 kHz (Fig. 2).

Lower in the corona, the only noteworthy activity between 05:20 and 05:36 is the brightening of an arcade of sheared loops in Active Region 486; this was first detected in a TRACE image at 05:11, after a data gap of 23 min (Fig. 3, top). Later on, a spectacular dark feature appeared in the EIT difference image between 06:00 and

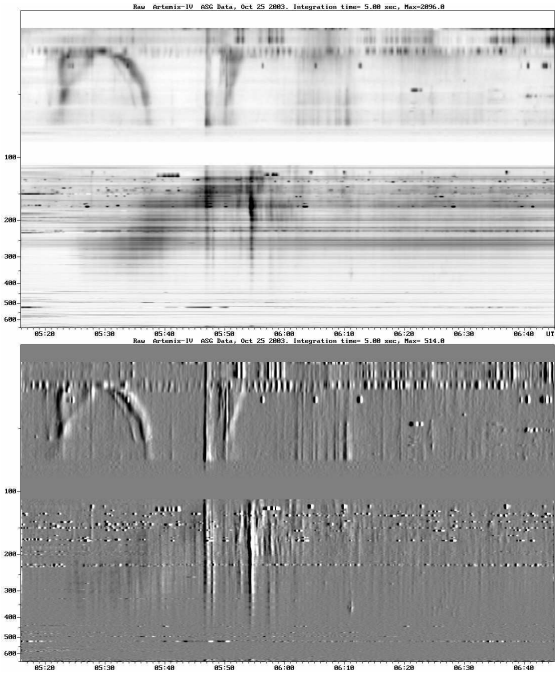

Figure 1. ARTEMIS-IV spectra of the October 25, 2003 event in the frequency range 20-650 MHz; Intensity (top) and its time derivative (bottom), enhancing fine temporal details

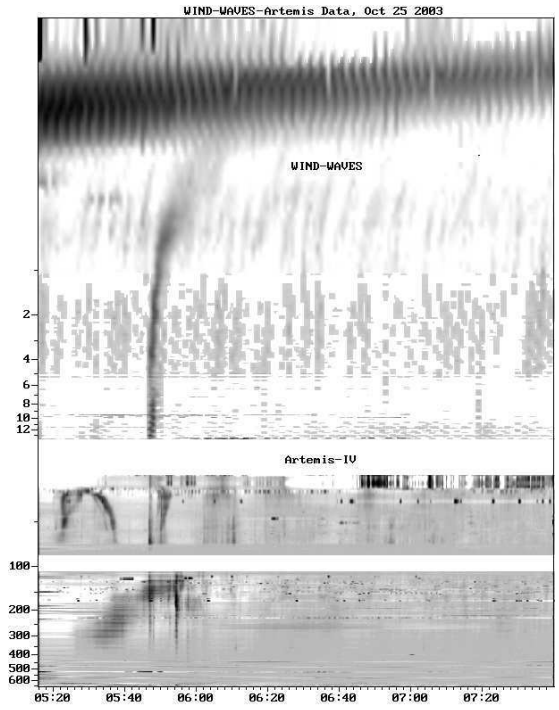

Figure 2. Combined ARTEMIS-IV and WIND-WAVES spectra of the same event

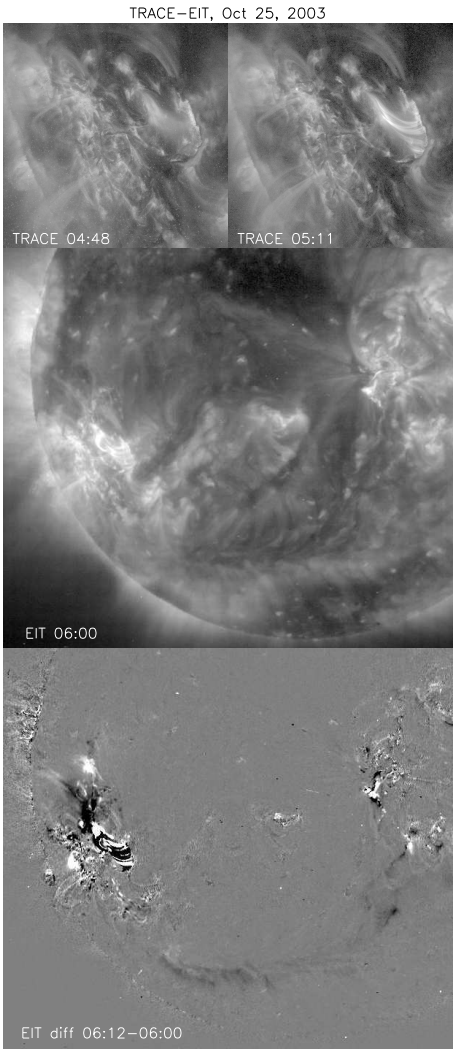

Figure 3. TRACE and EIT images of associated coronal activity

06:12 (Fig. 3, bottom); it is very large, extending over more than a solar radius.

3.2. The event of October 26, 2003

The ARTEMIS spectra show a nice type II with fundamental/harmonic emission, starting around 06:16 (Fig. 4). High frequency type IV emission started around 06:20 at high frequencies and at around 06:44 at low frequencies. There is more high frequency continuum emission at 07:20 and at 08:35 UT, with considerable fine structure.

The GOES records give an X1.2-class flare from 05:57 to 07:33 UT, with maximum at 06:54. TRACE images show the brightening of sheared S-shaped loops from 06:10 (Fig. 6, top). The sigmoid to arcade transition occurred

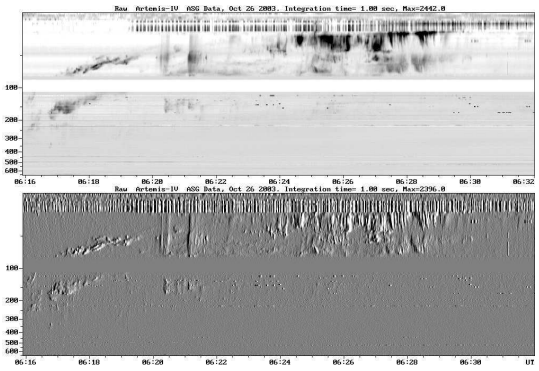

Figure 4. ARTEMIS-IV spectra of the October 26, 2003 event

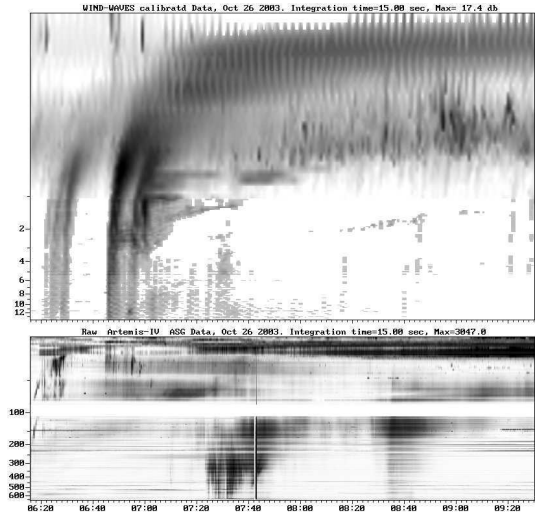

Figure 5. Combined ARTEMIS-IV and WIND-WAVES spectra of the same event

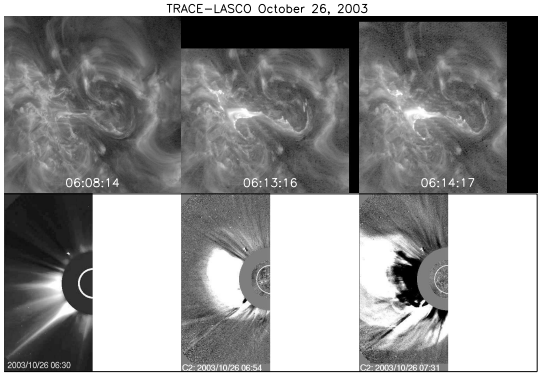

Figure 6. TRACE and EIT images of associated activity

gradually, but even as late as 07:30 the post-flare loops contain a lot of shear.

The associated "partial halo" CME was first recorded by LASCO at 06:54 (Fig. 6, bottom). Backward extrapolation indicates that it was launched around 06:13. The WIND spectra show type II emission extending below 2 MHz, an apparent extension of the type II observed by ARTEMIS (fig. 5). Much stronger emission was recorded in the form of two groups of type IIIs, starting at 06:20 and 06:44; the latter extended from 70 MHz down to 25 kHz.

3.3. The event of November 3, 2003

This event (Fig. 7) was triggered by an X3.9 flare (Fig. 9, top) which started at 09:43 UT, ended around 10:19 UT, with maximum at 09:55. It occurred near the limb (N08W77), in AR488. The associated CME (Fig. 9, bottom) was launched (according to the backward extrapolation) at 09:53 UT.

The EIT images show sheared loops that brighten between 09:36 and 09:48 UT. At 10:00 UT the sheared core of the active region has been covered with very bright emission, causing saturation of the detector; adjacent to the bright core an ejecta is clearly visible, which disappeared in the next image (10:15). Also from 10:00 UT a bright disturbance moving close to the NW part of the limb is visible, probably a coronal wave. Nice post-flare loops appeared after 10:37

The metric emission started at 09:49 UT with weak type III activity, followed by shortly afterwards by a very strong type III group extending down to 150 kHz (Fig. 7 & 8). At the same time a type II started, displaying fundamental/harmonic structure. The harmonic band has considerable structure, probably indicating multiple shocks (better visible in the differential spectrum, bottom of Fig. 7); it extends into the high frequency part of the WIND-WAVES spectrum, down to about 9 MHz (Fig. 8). A moving type IV follows the type II, which also appears to extend into the WIND-WAVES band. At lower frequencies (1.7-3 MHz) WIND-WAVES shows evidence of shocks between 10:00 and 10:32 UT

4. SUMMARY AND DISCUSSION

The ARTEMIS-IV radio-spectrograph, operating in the range of 650-20 MHz, observed 6 complex events during the super-active period of October-November 2003; an overview of three of them was presented here. Combination of the ARTEMIS data with SXR/EUV images provides information about the origin of the disturbances producing the radio emission. LASCO coronagraph images show the corona up to 30 solar radii and help us determine whether CME events are associated with the radio emission. WIND-WAVES data complement nicely

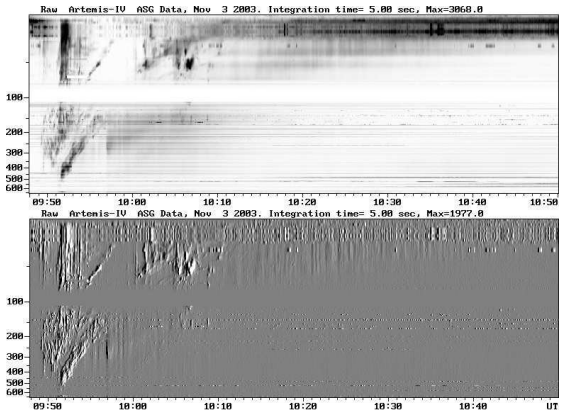

Figure 7. ARTEMIS-IV spectra of the November 3, 2003 event

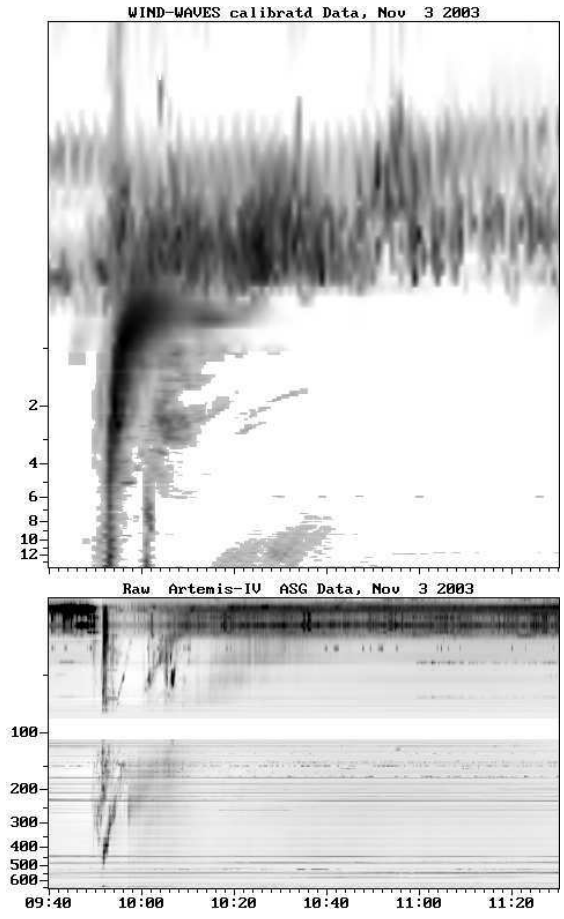

Figure 8. Combined ARTEMIS-IV and WIND-WAVES spectra of the same event

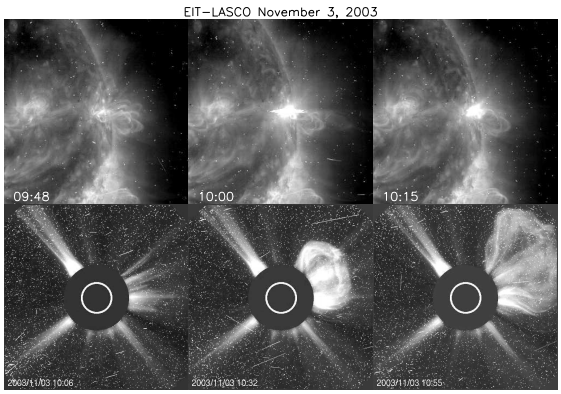

Figure 9. TRACE and EIT images of associated coronal activity

the ARTEMIS data and trace the radio emission from the middle corona all the way to almost 1 A.U.

Our data indicate that the radio disturbances came from eruptions covering spatial scales from the active region size up to almost one solar radius. We plan to further investigate the details of the radio emission and to attempt to determine the heights where the shock waves form.

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