

Type II and IV radio bursts in the active period October-November 2003

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Abstract. In this report we present the Type II and IV radio bursts observed and analyzed by the radio spectrograph ARTEMIS IV¹, in the 650-20MHz frequency range, during the active period October-November 2003. These bursts exhibit very rich fine structures such fibers, pulsations and zebra patterns which is associated with certain characteristics of the associated solar flares and CMEs.

Keywords: Solar activity; Corona; Radio; Radiation and spectra; Solar electromagnetic emission
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INTRODUCTION

The active period from 20 October to 5 November 2003 has attracted considerable attention ([5], [8], [10], [11], [6], [12], [13]) because of its abundance in of powerful flares and large coronal mass ejections (CMEs) as well as by strong space weather disturbances. This activity was associated with the appearance of a global complex consisting of three large, remote but connected active regions (AR): AR 484 (Carrington coordinates, N04; L = 354), AR 486 (S15; L = 283) and AR 488 (N08; L = 291) (cf. [5]); while in the visible hemisphere of the sun, this complex, produced 8 X-class and 12 M-class flares.

The Artemis IV solar radio-spectrograph operating at Thermopylae since 1996 ([2]) 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 ([3], [9]). 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.

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),

¹ Appareil de Routine pour le Traitement et l' Enregistrement Magnetique de l' Information Spectral

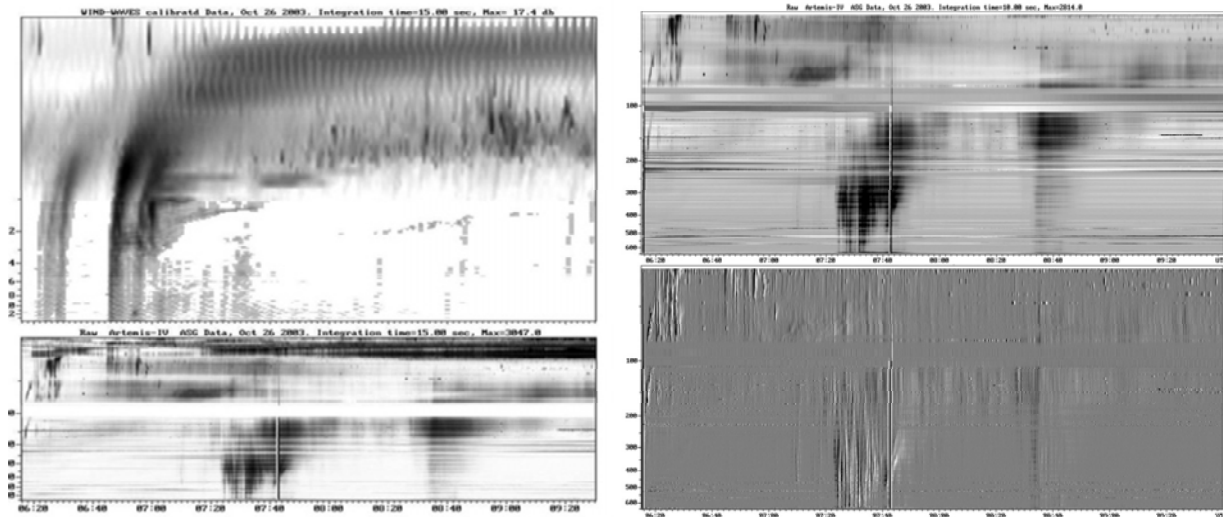


FIGURE 1. LEFT: Combined ARTEMIS-IV and WIND-WAVES spectra of the October 26, 2003 event. RIGHT: ARTEMIS-IV spectra in the frequency range 20–650 MHz; Intensity (top) and its time derivative (bottom), enhancing fine temporal details

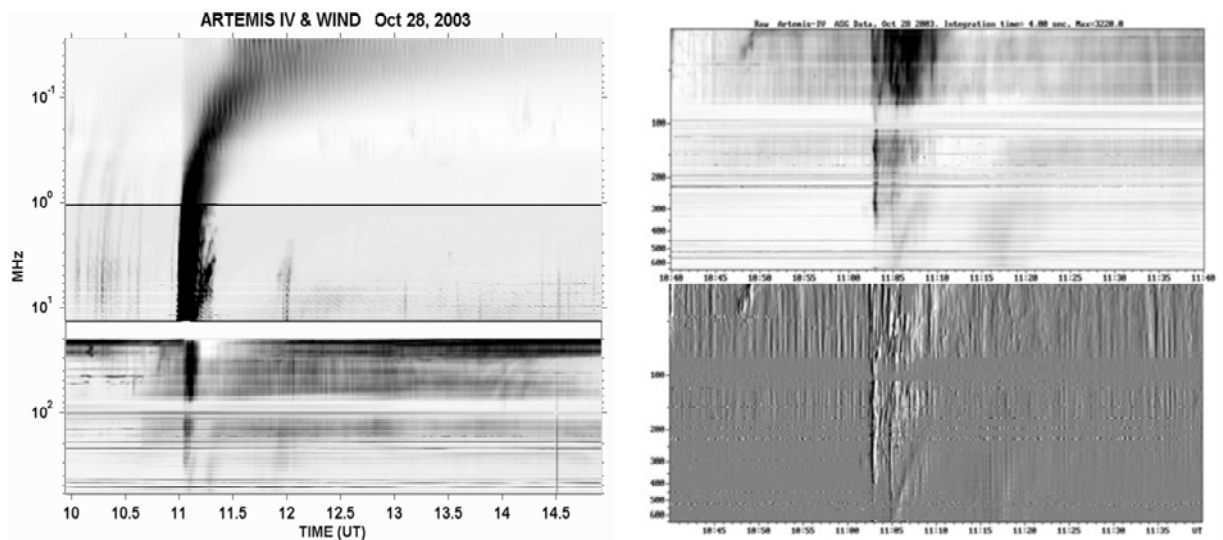


FIGURE 2. LEFT: Combined ARTEMIS-IV and WIND-WAVES spectra of the October 28, 2003 event. RIGHT: ARTEMIS-IV spectra in the frequency range 20–650 MHz; Intensity (top) and its time derivative (bottom), enhancing fine temporal details

November 2 (a behind-the-limb event, 09:20 UT) and November 3 (09:49); Combined with data from WIND-WAVES ([1]), 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. Out of those, we selected three events to give an overview here.

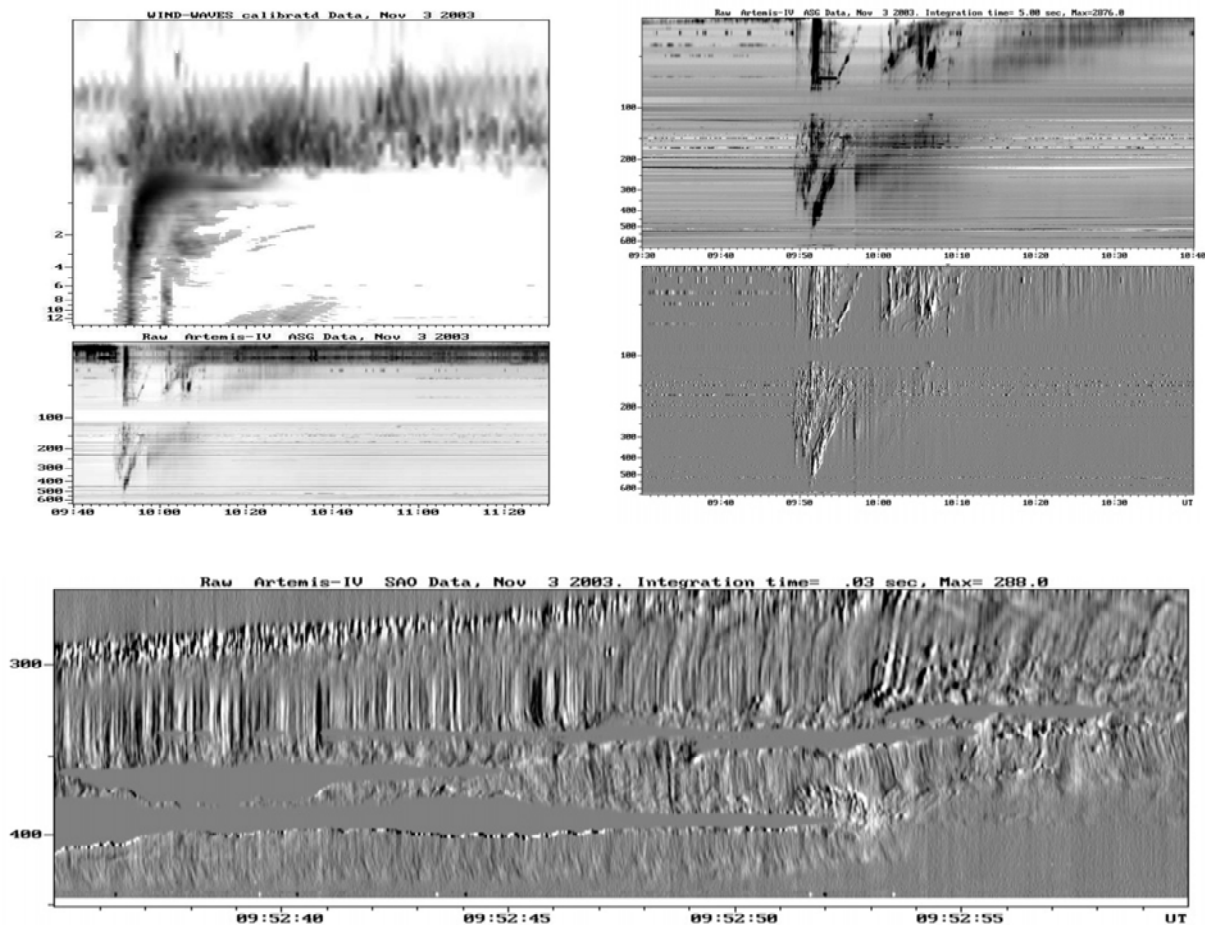


FIGURE 3. UPPER LEFT: Combined ARTEMIS-IV and WIND-WAVES spectra of the November 3, 2003 event. UPPER RIGHT: ARTEMIS-IV ASG Spectra in the frequency range 20–650 MHz; Intensity (top) and its time derivative (bottom), enhancing fine temporal details. BOTTOM PANEL: Differential SAO Spectrum with high (0.03 sec) resolution of a part Type II lane, showing U-shaped *herringbone* structures.

SELECTED EVENTS DESCRIPTION

Event Overview

The event of October 26, 2003

A type II with fundamental–harmonic emission, starts at 06:16 followed by high frequency type IV emission starting at 06:20 (high frequencies) and 06:44 (low frequencies); follows high frequency continuum emission at 07:20 and at 08:35 UT, with considerable fine structure (cf. figure 1).

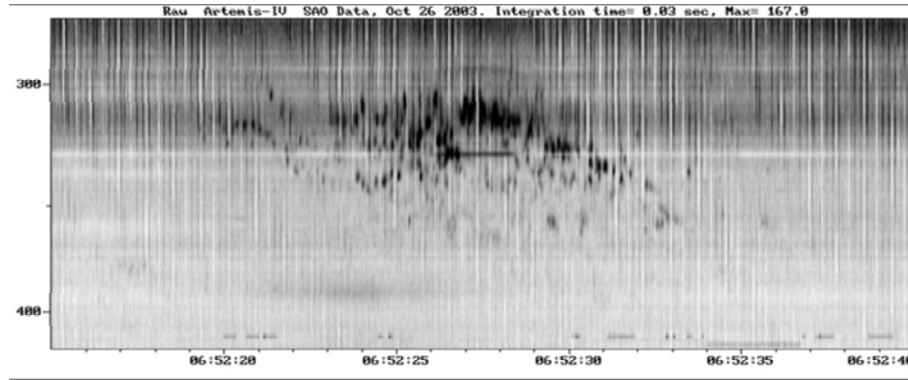


FIGURE 4. ARTEMIS-IV SAO differential spectrum, in the frequency range 270–450 MHz, of Narrowband Spikes (26 October 2003)

The event of October 28, 2003

The events start with a type II burst starting at 10:47 in ARTEMIS-IV lower frequencies, and extending into the WIND-WAVES range. Follows a complex event, comprising an intense type III group, a type II with fundamental-harmonic structure followed by a type IV continuum; all extend into the WIND-WAVES range. (cf. figure 2)

The event of November 3, 2003

The events starts at 09:49 UT with weak type III bursts, followed by a very strong type III group extending down to 150 kHz. Follows a type II, displaying fundamental-harmonic structure. There is an indication of multiple shocks since three lanes appear on the spectra; firstly a fast type II, probably fundamental, followed by the fundamental-harmonic pair; these shocks were associated with a coronal wave by [12]. The event extends into the high frequency part of the WIND-WAVES spectrum, down to about 9 MHz. A type IV continuum follows the type II, also extending into the WIND-WAVES band range (cf. figure 3 upper panels).

The SAO recordings of the type II harmonic, with high resolution, exhibit *herringbone* structure, resulting from *type III-like* emissions due to electron populations accelerated by the MHD shock. In this recordings however the spectral shape of the *herringbone* is *type U-like*, thus indicating the presence of some type of magnetic confinement for the exciter (cf. figure 3 lower panels).

Fine Structure

The high sensitivity and time resolution of the SAO facilitated an examination on fine structure within the three studied periods; all exhibited rich fine structure embedded in the Type-IV continua. In our analysis, the continuum background is removed by the use

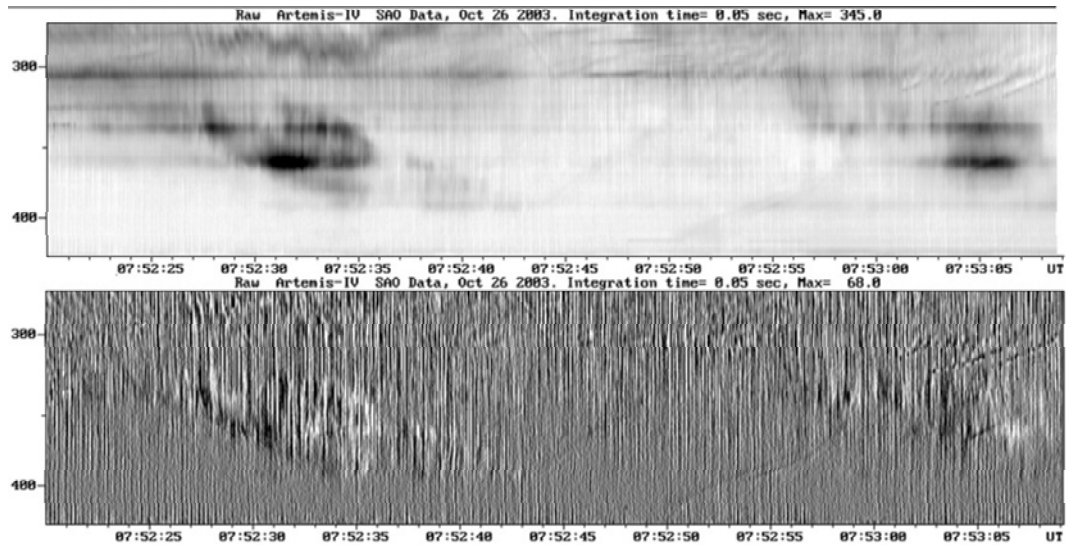


FIGURE 5. ARTEMIS-IV SAO spectra, in the frequency range 350–450 MHz, of Slowly Drifting Bursts (cf. [7] their figure 7) and fibers overlaid on a pulsating structure (26 October 2003). Top: Intensity Spectrum, Bottom: Differential Spectrum.

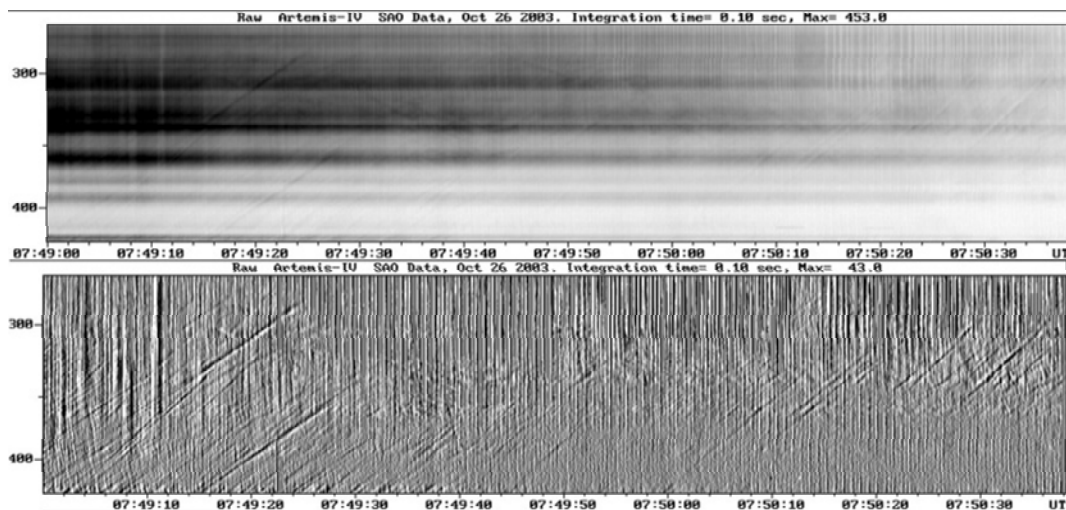


FIGURE 6. ARTEMIS-IV SAO spectra, in the frequency range 270–450 MHz, of Pulsations and Fibers (26 October 2003). Top: Intensity Spectrum, Bottom: Differential Spectrum.

of high-pass filtering on the dynamic spectra (differential spectra in this case).

We present certain examples, which are divided according to a published morphological classification scheme ([7]) based on Ondrejov Radiospectrograph recordings in the 0.8–2.0 GHz range. In our recordings we have detected narrow band spikes (figure 4), Slowly Drifting Bursts (figure 5), fibers (figures 5,6), Narrowband Type III Bursts (figure 8), laces (figure 7), zebra patterns (figure 8), and isolated broadband pulses (figure 9). An EEL type emission ([4]) was found to border a pulsating structure (figure 9).

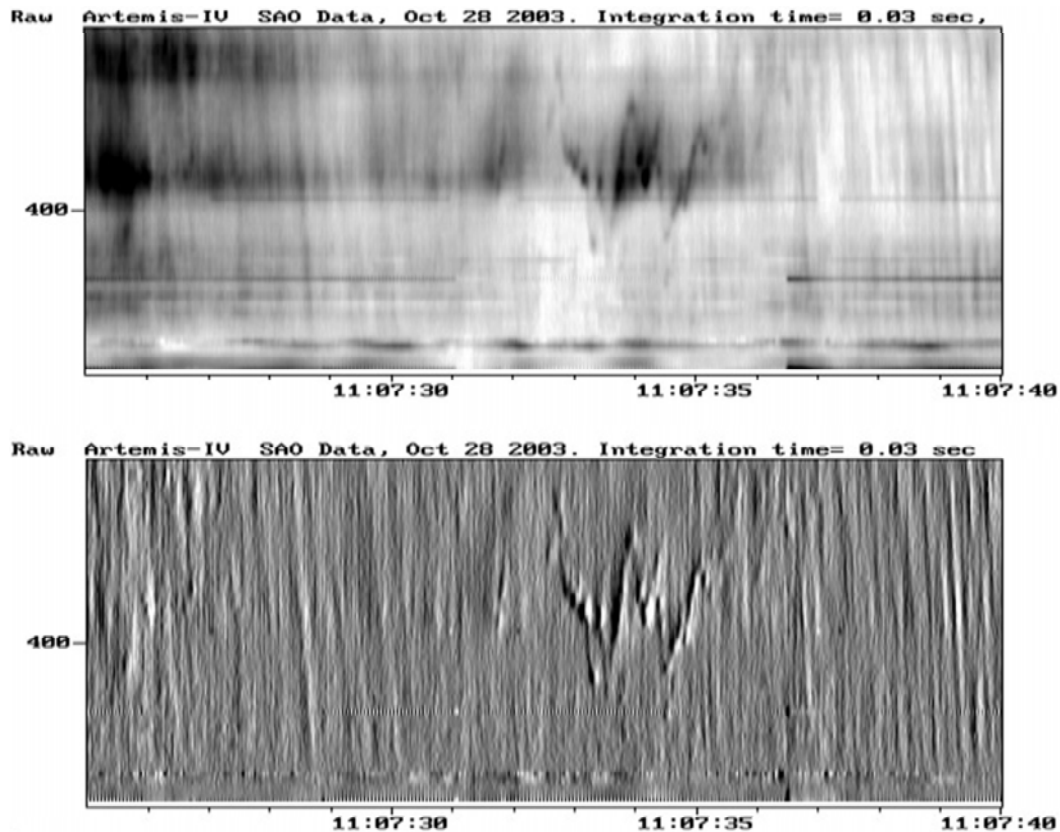


FIGURE 7. ARTEMIS-IV SAO spectra (28 October 2003), in the frequency range 270–450 MHz, of a lace type structure (cf. [7] their figure 11) overlaid with spikes. Top: Intensity Spectrum, Bottom: Differential Spectrum.

DISCUSSION & CONCLUSIONS

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; three of them were presented here. WIND-WAVES data complement nicely the ARTEMIS data and trace the radio emission from the middle corona all the way to almost 1 A.U. The high resolution SAO recordings on the other hand reveal a variety of fine structure which, almost, matches the comprehensive Ondrejov Catalogue ([7]). This last, although it refers to the spectral range 0.8–2 GHz, seems to produce similar fine structure with the metric range.

Further analysis of the metric radio bursts fine structure is in progress.

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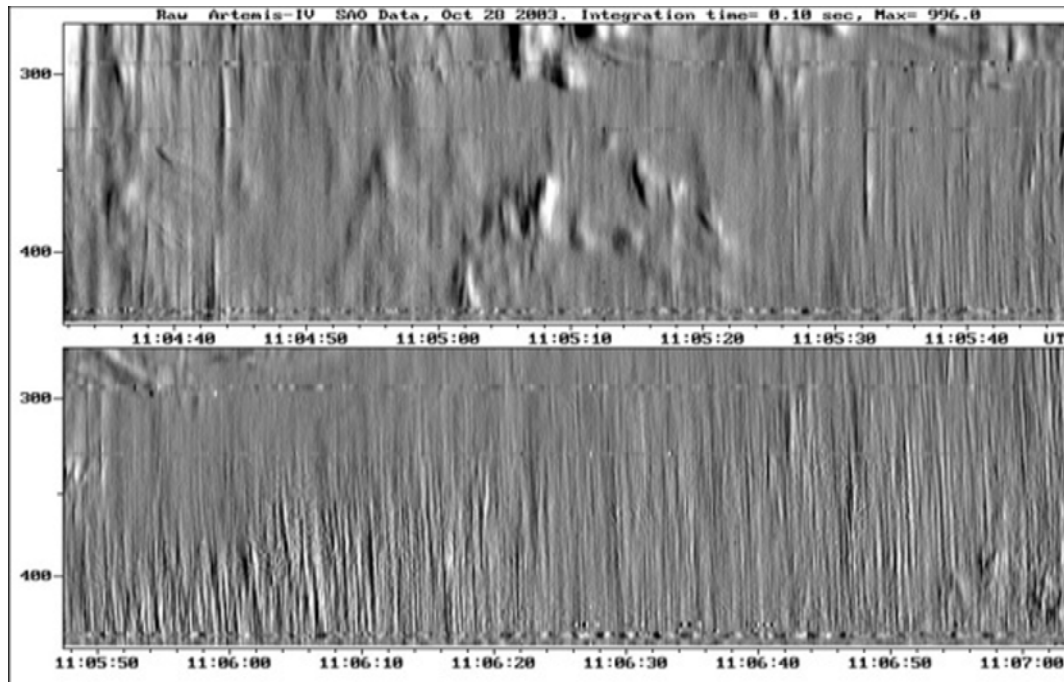


FIGURE 8. ARTEMIS-IV SAO differential spectrum, in the frequency range 270–450 MHz, of Narrowband Type III Bursts ([7] their figure 6) Pulsations and Fibers (28 October 2003). Zebra patterns are superposed on the fibers and the pulsating structure.

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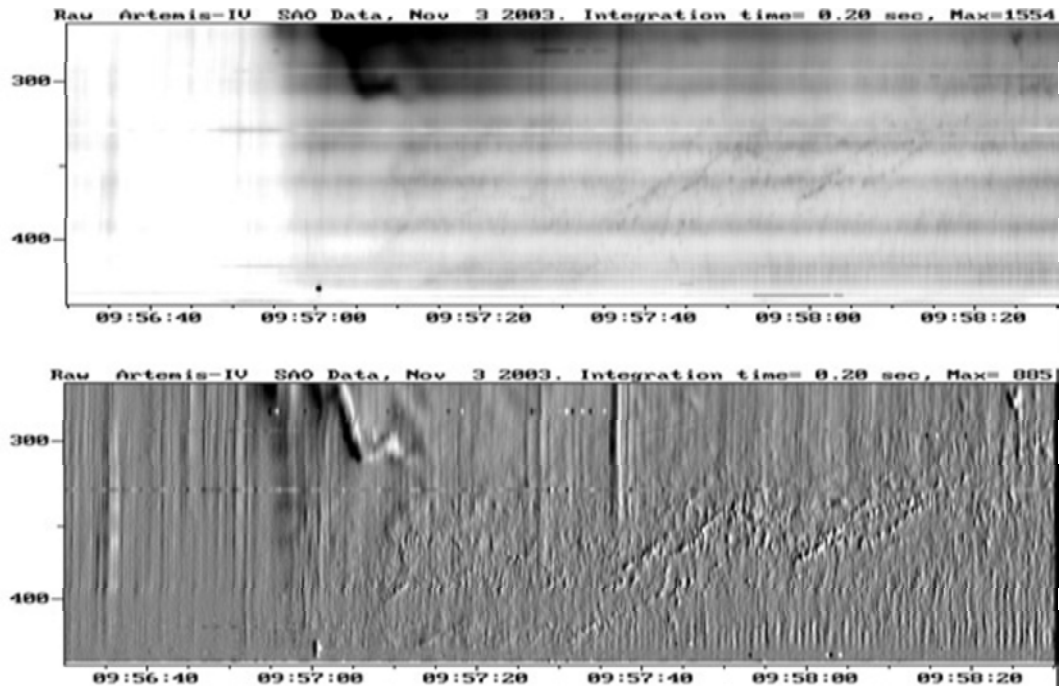


FIGURE 9. ARTEMIS-IV SAO spectra (03 November 2003), in the frequency range 270–450 MHz, of Isolated Broadband Pulse ([7] their figure 4); in the lower frequency part of the spectrum the lower part of a pulsating structure with an EEL-type form([4] their figure 1) appears. Top: Intensity Spectrum, Bottom: Differential Spectrum.

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