ZEBRA PATTERN FLUX DENSITY OBSERVATION DURING THE TYPE IV BURST ON OCTOBER 12, 1981

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Abstract. A new quantitative zebra pattern observation is reported. The mean amplitude ratio of the emission and absorption features of the irregular zebra pattern observed simultaneously with and related to an increased continuum is $\bar{Q} = 3$. This is not contradictory to a zebra pattern model in terms of whistler soliton propagation throughout the source of continuum emission.

1. Introduction

The zebra patterns are a well known and often observed and identified fine structure phenomenon on the background of a type IV-m and dm continuum (Elgaroy, 1961; Slottje, 1972, 1981; Chernov *et al.*, 1975). Several possible emission mechanisms have been developed to explain the more or less regular pattern of emission ridges and absorption gaps (Chiuderi *et al.*, 1973; Zheleznyakov and Zlotnik, 1975a, b; Kuijpers, 1975; Fedorenko, 1975; Chernov, 1976a, b; Fomichev and Fainstein, 1981). A principal and as yet unresolved problem of the theory is the discussion of the flux level during zebra patterns.

The few published observations of time and frequency profiles of zebra patterns give

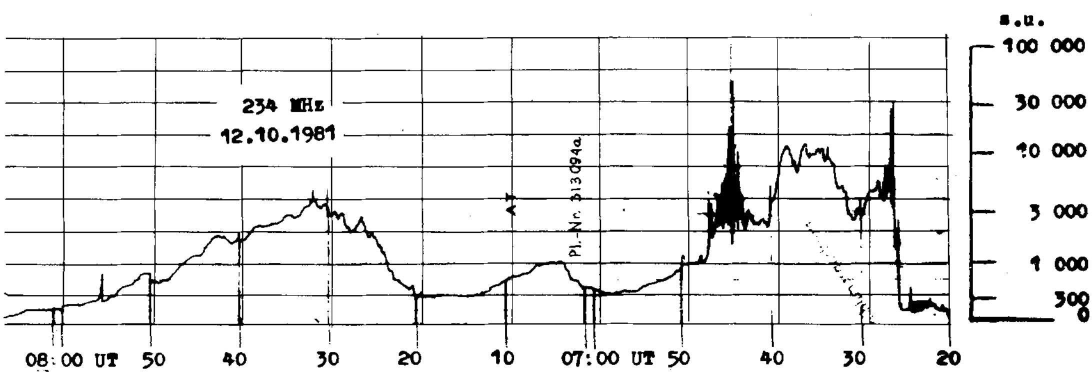

Fig. 1. Low time resolution record of the part of the strong type IV burst on October 12, 1981, with the zebra patterns, at 234 MHz ZISTP (HHI); (s.u. = solar units).

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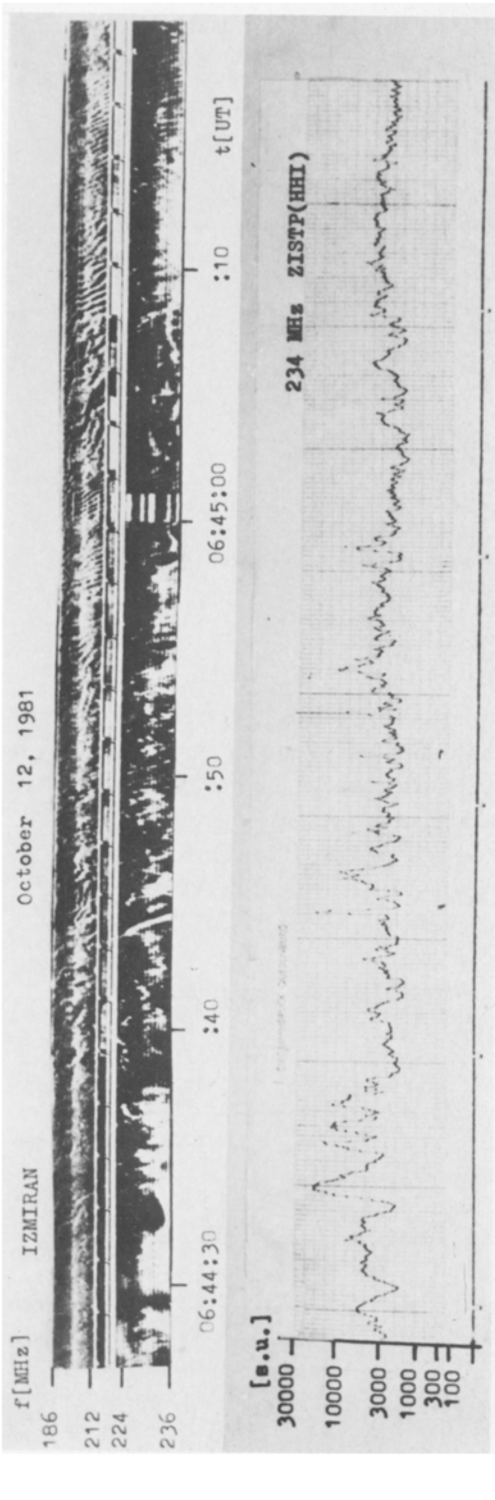

Fig. 2a. Interval I (06:44:30–06:45:10 UT).

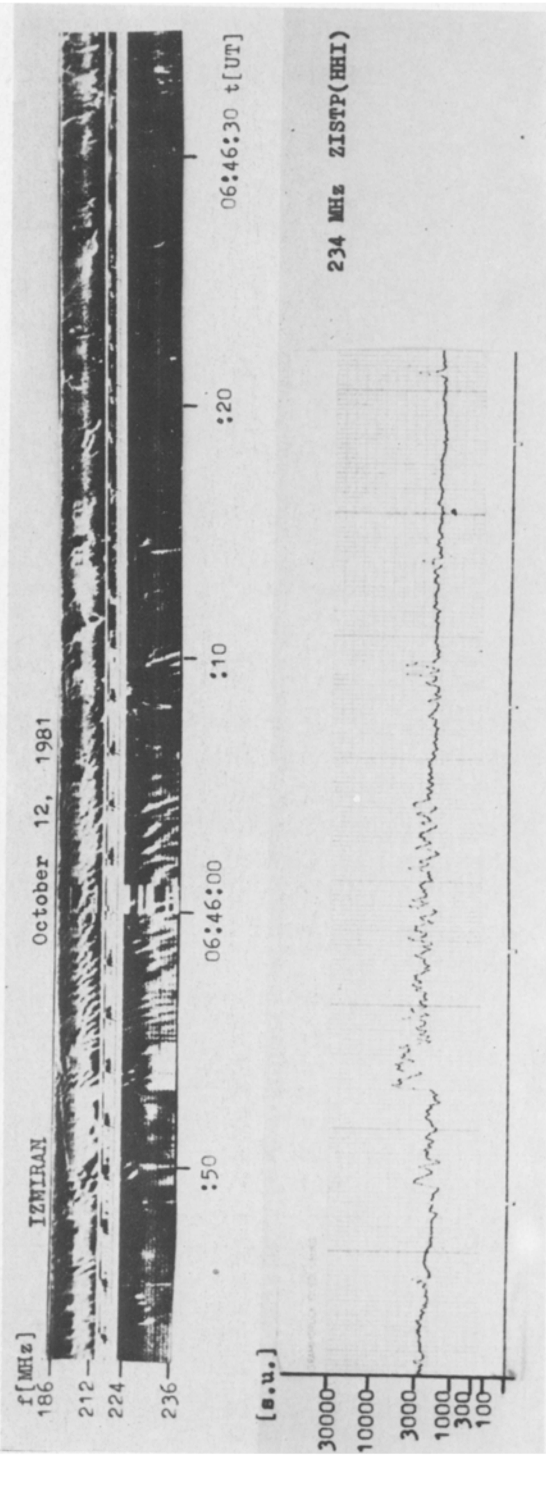

Fig. 2b. Interval II (06:45:50–06:46:15 UT).

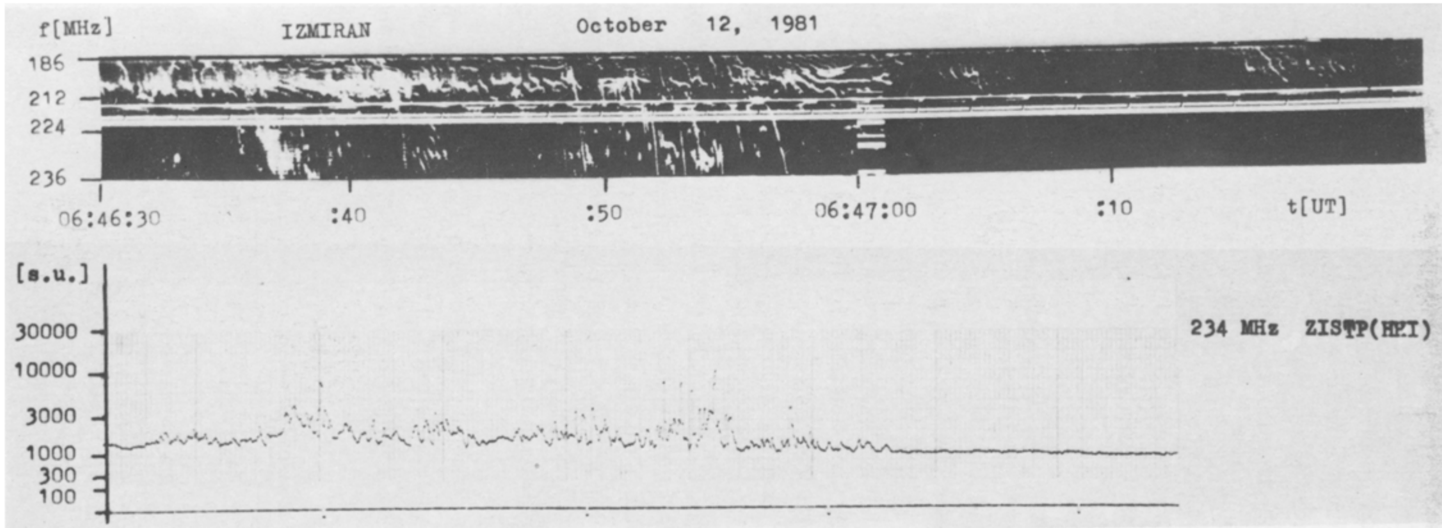

Fig. 2c. Interval III (06:46:30–06:47:10 UT).

Fig. 2a-c. Dynamic spectra in the range 186–236 MHz (IZMIRAN) and high time resolution single frequency records at 234 MHz (ZISTP (HHI)). The time-parallel lines on the spectra are TV station disturbances. The spectrograph sensitivity is smaller on higher frequencies. The timescales on the spectra and the 234 MHz records are only approximately identical.

the following information concerning the dynamics of the effect (Chernov *et al.*, 1975; Chernov, 1976a):

– the absorption bands are an only slightly depressed continuum (up to about $\frac{1}{3}$ of the instantaneous continuum flux density);

– the emission ridges may be several times stronger than the continuum background.

Very rough theoretical flux density estimates have been derived so far, only (Zheleznyakov and Zlotnik, 1975a, b; Chernov, 1976b). The present work deals with the results of new detailed time profile observations of zebra patterns in the course of the strong type IV event on October 12, 1981 (Figure 1). Thereby the authors presume that the time profiles show the zebra pattern behaviour as well as frequency profiles.

2. Observations

Simultaneous observations have been carried out at two widely separated stations (IZMIRAN Moscow, spectrograph working in the range 186–236 MHz (Markeev and Chernov, 1970) and Tremsdorf solar radio observatory of the ZISTP (HHI) near Potsdam, high time resolution single frequency flux record at 234 MHz). The solar origin of the effect is definitely confirmed by the detailed 100% correlation of the spectrum and the single frequency record (Figures 2a, b, c). Three time intervals have been chosen for undertaking a statistical treatment (interval I see Figure 2a, 06:44:30–06:45:10 UT; interval II see Figure 2b, 06:45:50–06:46:15 UT; interval III see Figure 2c, 06:46:30–06:47:10 UT). All the extreme flux values during these intervals form an ensemble of 221 pairs of maximum and minimum flux values (in solar units with a relative error of about 5%). The information has been transformed into a set of histograms (Figure 3a: maximum flux values $x_{i\,\mathrm{top}}$; Figure 3b: minimum flux values $x_{i\,\mathrm{dip}}$; Figure 4: ratio $Q_i = x_{i\,\mathrm{top}}/x_{i\,\mathrm{dip}}$). It is important to note that all the values x_i are measured with respect to the quiet but enhanced mean flux level before and after the zebra pattern.

Mean parameters of the ensemble are shown in Table I. The histograms reveal a decline in time of the flux values together with the continuum level combined with a rise of the Q ratio from 2.7 to 3.4. Further Figure 2 evidences an enhanced mean continuum

TABLE I

Parameters of the zebra pattern maximum and minimum flux values ensemble

Sample	Level (s.u.)		Maxima (s.u.)			Minima (s.u.)			$\overline{Q} = \bar{x}_{\mathrm{top}}/\bar{x}_{\mathrm{dip}}$
	before	after	N	$\bar{x}_{\mathrm{top}}$	s_{N-1}	N	$\bar{x}_{\mathrm{dip}}$	s_{N-1}	
I	1780	1780	92	2010	1190	93	730	680	2.7
II	1580	1580	53	1160	800	54	390	430	3.0
III	1440	860	76	1330	1050	77	390	550	3.4
IV	1780	860	221	1500	1210	224	500	630	3.0

N – number of samples, $\bar{x}$ – mean value, s_{N-1} – mean square deviation.

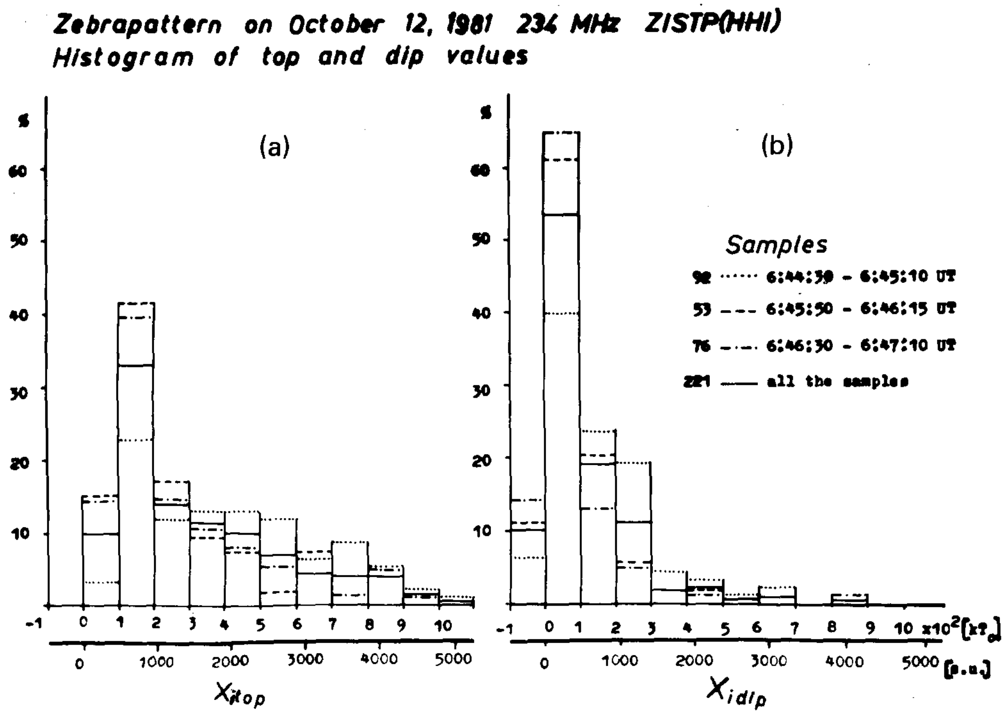

Fig. 3. Histogram of maximum (a) and minimum (b) flux values. (x_i (s.u.) = cx_i (kT_0); c – calibration factor; k – Boltzmann's constant; T_0 – ambient temperature).

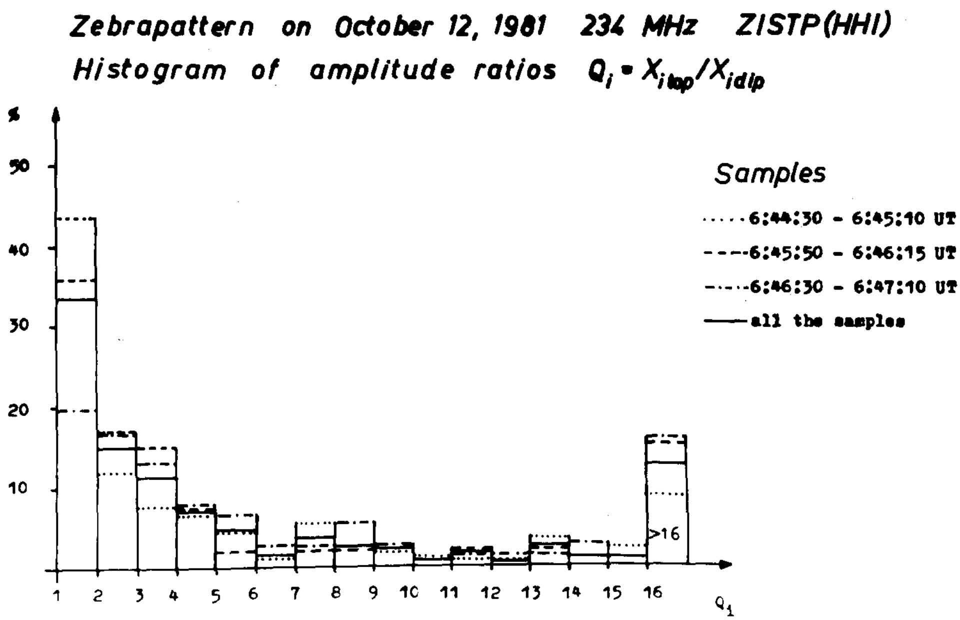

Fig. 4. Histogram of the Q_i ratios.

emission in the course of the zebra patterns (see for instance 06:44:50–06:45:03 UT; 06:45:08–06:45:15 UT; 06:45:52–06:46:06 UT; and 06:46:37–06:46:45 UT). So the absorption dips very seldom cross the undisturbed continuum background level.

3. Discussion

The main points of this paper are:

– We have presented quantitative data describing the amplitude dynamic range of the October 12, 1981 pattern.

– The mean flux ratio $\overline{Q}$ (emission ridge intensity/absorption band intensity) is about 3.

– The important fact to realize is a 'local' continuum enhancement that has been observed together with the zebra pattern. There is no doubt about a strong correlation between the occurence of the emission and absorption ridges and a rise and fall of the continuum emission.

Three theoretical approaches can be quoted to explain a zebra-pattern-like configuration:

(a) The excitation of harmonic waves in a coronal point source volume (Chiuderi *et al.*, 1973; Zheleznyakov and Zlotnik, 1975a, b; Fedorenko, 1975; Fomichev and Fainstein, 1981). Thereby the last cited mechanism (Fomichev and Fainstein, 1981) explains the emission stripes by scattering of nonlinear ionsound waves at fast particles without taking into account the absorption stripe formation.

(b) The excitation of waves at a lot of different coronal hight levels where the double resonance condition of the loss cone instability is fulfilled (Kuijpers, 1975; Zheleznyakov and Zlotnik, 1975b).

(c) The spatial modulation of wave excitation by propagating whistler wave solitons (Chernov, 1976a, b).

The zebra pattern phenomenon is characterized by a colourful morphology. There are events presenting a slow time dependence and well-expressed clean structures. But there are cases showing a high degree of irregularity, too, especially marked by a strong variability of frequency drifts which are definitely caused by a strong dynamic behaviour of the source volume conditions. A split-up or merging of emission ridges is commonly observed in such cases (see Kuijpers, 1975; and our Figure 2a, b near 06:45:05 UT and 06:45:50 UT at about 200 MHz).

The October 12, 1981 burst clearly shows irregular zebra pattern appearing coupled with an enhancement of the background continuum. This effect cannot be explained using models of group (a) which therefore must be excluded for the present event.

In the frame of Kuijpers' model the simultaneous appearence of the zebra patterns and an enhanced continuum is improbable. Besides the continuum enhancement requires an extremely high fractional fast particle density (10^{-2} of the cold plasma density).

In Zheleznyakov and Zlotnik's (1975b) model the formation of zebra stripes is independently treated from the continuum generation for the kinematic instability, and in the relativistic case (zebra pattern in the form of tadpoles), too. Therefore it is difficult to explain the simultaneous continuum enhancement and the zebra pattern appearence with an amplitude ratio of $\overline{Q} = 3$ in the emission and absorption stripes, especially if the flux level in the absorption gaps rests very high.

On the other hand the whistler mode waves inherent in the third kind of zebra models (Chernov, 1976b) cause the continuum level reduction of about $\frac{1}{3}$ at the low frequency edge of the strong emission ridges quite in accordance with our observations. Besides the whistlers more effectively scatter the less energetic part of the fast particle loss cone distribution than the more energetic particles (Melrose, 1975) and produce a positive slope in the fast particle distribution – a so called gap distribution. This is the source of a more effective Langmuir wave excitation in each part of the emission volume.

Therefore the observed background continuum enhancement in the course of zebra pattern occurence with the $\overline{Q}$ ratio near 3 can be explained by nonducted (repeatedly reflected) whistlers propagating with some inclination to the magnetic field. This is the essential difference to the fiber burst interpretation which implies a ducted whistler propagation along the magnetic flux tube (Chernov *et al.*, 1981).

Nevertheless all the present mechanisms are not completely consistent. It is necessary to make simultaneous spectral and intensity observations together with the measurement of source diameters.

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