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Relaxation of magnetic field relative to plasma density during solar flares

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Abstract. We investigated the variations of 74 microwave ZP structures observed by Chinese Solar Broadband Radio Spectrometer at 2.6–3.8 GHz in 9 solar flares, found that the ratio between the plasma density scale height L_N and the magnetic field scale height L_B in emission source displays a tendency of decrease during the flaring process, indicates that L_B increases faster than the L_N during solar flares. The detailed analysis of the step-wise decrease of L_N/L_B in three typical X-class flares reveals the magnetic field relaxation relative to the plasma density.

Keywords. Sun: flares — Sun: magnetic topology — Sun: radio radiation

1. Introduction

Zebra pattern (ZP) is an intriguing spectral structures in the solar radio emission (Elgaröy 1959; Chernov 2006), which consists of a number of almost parallel and equidistant stripes superimposed on the type IV radio burst in dynamic spectrum, providing a unique diagnostics of the magnetic field and ambient plasma around the source (Tan, *et al.* 2012). It is generally considered that the emission of microwave fine ZP structures requires high density and high temperature (Bastian *et al.* 1998), implies that the source of microwave ZP may be located very closed to the flare core region where the magnetic energy is released. From the double plasma resonance model, we may obtain the intrinsic information of the flare core region by calculating the ratio of scale lengths of plasma density and magnetic field (L_N/L_B) (Kuznetsov & Tsap 2007).

2. Observations and Results

Table 1 listed 74 ZPs in 9 solar flares from 1997 to 2006, whose L_N/L_B can be calculated (Fig. 1). We found: (1) During the flaring processes, the ratio is mainly in the range

Table 1. The list of flare events with microwave ZPs at 2.6–3.8 GHz from 1997 to 2006

Flare				ZP							
Event	Class	AR NOAA	SXR peak UT	Start UT	End UT	f GHz	Δf MHz	Pol	No	Ns	S
09.04.2000	M3.1	8948	23:42	23:35:12	23:35:18	2.60-3.10	20-40	STRONG R	1	3	◇
29.10.2000	C4.4	9209	01:57	02:06:32	02:35:05	2.60-3.10	65-80	R	17	3-7	△
24.11.2000	X2.0	9236	05:02	04:59:56	05:01:57	2.60-3.80	55-60	L&R	4	3	□
25.11.2000	M8.2	9240	01:31	00:59:19	01:09:30	2.60-3.80	50	L&R	4	5-6	◆
19.10.2001	X1.6	9661	01:05	00:51:00	01:19:55	2.60-3.00	55-75	R	18	3-8	×
21.04.2002	X1.5	9906	01:50	01:45:40	02:01:45	2.60-3.80	30-70	L	10	10-34	+
18.11.2003	M3.9	10501	08:31	08:22:42	08:26:50	2.60-3.50	30-50	STRONG R	3	3-5	▲
09.07.2005	M2.8	10786	22:06	22:03:16	22:04:53	2.60-3.50	50-80	L&R	6	8	■
13.12.2006	X3.4	10930	02:40	02:22:30	03:03:00	2.60-3.80	50-250	R	13	3-6	∗

Notes.— Start (UT)– time of the first ZP in the event; End (UT)– time of the last ZP in the event; AR NOAA– number of NOAA active region; SXR peak (UT)– time of soft X-ray peak; f (GHz)– frequency range of ZPs; Δf (MHz)– frequency separation of adjacent stripes; Pol– left- or right-handed circular polarization; No– number of ZPs; Ns– stripes number in a ZP event; Ref– reference; S– the symbols used in Figure 1 (Yu *et al.* 2012).

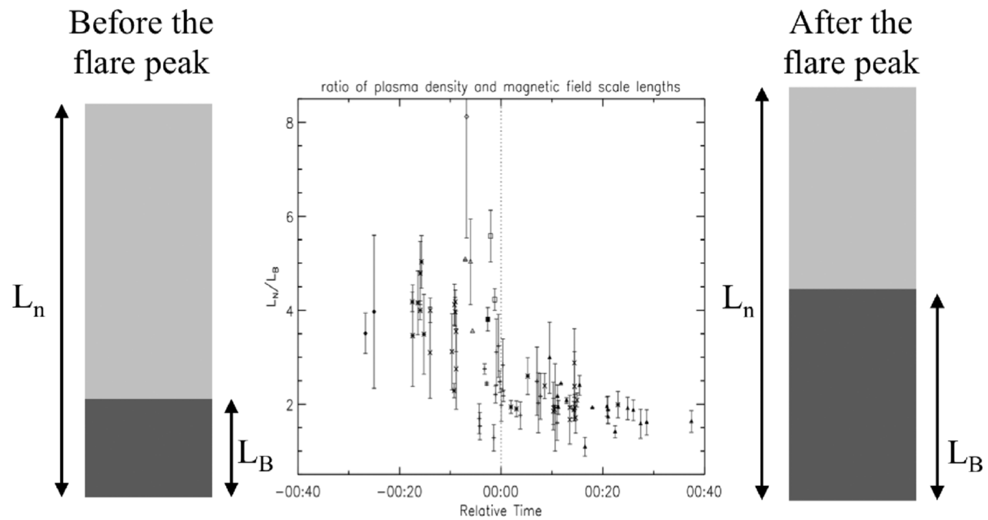

Figure 1. L_N/L_B estimated from 74 microwave ZPs in the 9 flare events listed in Table 1, are plotted against the time relative to the GOES soft X-ray flaring peaks (*vertical dotted line*) of each flares. The symbols used to denote the ratio L_N/L_B are also listed in Table 1 (Yu *et al.* 2012).

of between 1.5 and 5. Before the flaring peak, the ratio is mainly in range of 3–5, and after the peak the ratio decreases to 1–3, which indicates that L_B increases faster relative to the L_N (cartoon in Fig.1). (2) The smaller these absolute values L_N and L_B are, the more stripes can be realized in certain frequency range. The absolute values of L_N and L_B varied in different events as the numbers of zebra stripes varied (Tabel.1), whereas the ratio L_N/L_B is mainly in the range of 1.5–5, independent from the varied absolute values. (3) Among the listed 9 events, we found 3 typical flares that ZPs appeared in both of before and after the soft X-ray flaring peaks. The ratio displays a step-wise decrease during the processes of topological changes of magnetic fields in flaring regions.

3. Conclusions

(1) The magnetic field scale height increases faster relative to the plasma density scale height during the flaring process.

(2) The L_N/L_B variation is due to the topological change of flare core region where the main part of the magnetic energy is released.

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