FINE STRUCTURE IN A METRIC TYPE IV BURST: MULTI-SITE SPECTROGRAPHIC, POLARIMETRIC, AND HELIOGRAPHIC OBSERVATIONS

G. P. CHERNOV
IZMIRAN, 142092 Troitsk, Moscow Region, Russia

K.-L. KLEIN
DASOP, CNRS-URA 1756, Observatoire de Paris, Section d'Astrophysique de Meudon, 92195 Meudon, France

P. ZLOBEC,
Osservatorio Astronomico, via G.B. Tiepolo 11, 34131 Trieste, Italy

and

H. AURASS
Astrophysikalisches Institut Potsdam, Observatorium für solare Radioastronomie, 14552 Tremsdorf, Germany

(Received 20 December, 1993; in revised form 10 August, 1994)

Abstract. The spectral fine structure of solar radio continua is thought to reveal wave-particle and wave-wave interactions in magnetic traps in the solar corona. We present observations of spectra, polarization, and spatial characteristics of combined emission/extinction features ('zebra patterns') during a decimetric/metric type IV event on 5 June, 1990. Very high modulation depths are observed. The size and location of the sources during emission and extinction are determined for the first time. Two remarkable features are found: (1) The sources of emission stripes have finite size, up to nearly 2'; during extinction stripes the brightness is reduced across the whole extent of the unperturbed continuum, which is slightly larger than 2'. (2) During emission stripes the sources drift over distances up to several ×10^4 km, with apparent velocities up to 10^5 km s^{-1}. The observed features are briefly discussed with respect to interpretations based on wave-particle interactions and on the scattering of electromagnetic waves.

1. Introduction

Particles accelerated during flares are partly injected into closed coronal structures where they become trapped. Such configurations likely give place to various instabilities whereby waves are generated, such as Langmuir waves and whistlers, which subsequently interact with the trapped particles and may change the trapping conditions. Various types of fine structure identified in dynamic spectra of decimetric and metric continuum emission ('type IV') have been ascribed to wave-wave and wave-particle interactions in coronal traps (Kuijpers, 1975; Bernold, 1980; Slottje, 1981; Aurass et al., 1987). Among them are drifting bands of combined emission and extinction features. The latter are called fiber bursts or intermediate drift bursts when consisting of a single band with nearly constant drift rate, and zebra pattern when composed of several simultaneous bands with often a time-variable drift rate.

Fiber bursts are generally explained by the coupling of Langmuir waves (l) with whistlers (w), \( l + w \rightarrow t \) (Kuijpers, 1975; Mann, Karlický, and Motschmann, 1987). A widely accepted interpretation of zebra patterns, however, has not yet emerged. They were originally ascribed to be the growth of upper hybrid waves at frequencies where the upper hybrid frequency, \( \omega_{uh} \), is a multiple of the cyclotron frequency, \( \omega_{ce} \), of the electrons (double plasma resonance):

\[
\omega_{uh} = \sqrt{\omega_{pe}^2 + \omega_{ce}^2} = N\omega_{ce},
\]

where \( N = 2, 3, \ldots \), and \( \omega_{pe} \) is the electron plasma frequency. Theories based on this mechanism were proposed by Kuijpers (1975), Zheleznyakov and Zlotnik (1975), Berney and Benz (1978), Mollwo (1983, 1988), Winglee and Dulk (1986), and reviewed by Kuijpers (1980). The occurrence of emission and extinction stripes in both zebra lines and fiber bursts motivates their interpretation in the framework of a unique mechanism. Therefore Chernov (1976, 1990a, b) proposed that zebra lines are generated by whistler wave packets propagating obliquely to the magnetic field, and fiber bursts by whistlers ducted in overdense coronal structures. Thus, zebra stripes are produced when a whistler trajectory intersects a region where the electrons emitting the type IV continuum are trapped.

So far, observations of fiber bursts and zebra patterns have been discussed using dynamic spectra of flux density, and sometimes polarization, without spatial resolution. A statistical study was carried out by Slottje (1981). A detailed analysis of individual events is found, e.g., in Slottje (1972), Chernov, Korolev, and Markeev (1975), Kuijpers, van der Post, and Slottje (1981), Aurass and Chernov (1983). Imaging observations can improve the understanding of spectral fine structures: on the one hand they constrain the association of fine structure features with other types of activity, such as flares or filament eruptions, as well as the magnetic topology of the plasma-magnetic-field configuration near the site of emission. On the other hand they should display details of the source configuration, such as the relative position of sources of continuum and fine structure, which may give deeper insight into the relevant plasma processes. The present paper reports on radio observations which combine for the first time spectrographic, polarimetric, and imaging diagnostics. The observations are presented in Section 2, starting with a brief description of the instruments (Section 2.1). An overview of the active region and of the evolution and structure of the radio sources is given in Section 2.2. Selected fine structures are presented in Section 2.3 with emphasis on the temporal evolution of their flux density spectrum, as well as the position and size of the radio sources during different phases of emission/extinction features.