FINE STRUCTURE IN SOLAR TYPE III RADIO BURSTS SPECTRA

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Abstract

The new digitalized polarispectrometer IKARUS (Perrenoud, 1979) at ETH, Zürich gave the possibility for a more detailed investigation of the solar type III spectral evolution.

Analysis of a number of type III events showed a surprising variety of so far undescribed spectral structures among individual bursts in the frequency range between f = 200 and 450 MHz. Despite the "normal" type III bursts obeying a very high drift speed and traversing the entire solar corona from high frequencies to low ones around 10 MHz which presumably belong to electron beams propagating up to the interplanetary space at 1 AU (Lin et al., 1973, Alvarez et al., 1975., Gurnett et al., 1977, 1978), we found an entirely different behaviour for a large group of type III bursts observed above 200 MHz with respect to their drifts as to their spectra. These bursts show an abrupt change in their drift speeds when propagating outward to lower frequencies. Their spectral index $n = -\log I/\log f$ is $20 < n < 30$, one order of magnitude higher than for normal type III bursts. The correlation between the change in drift and spectral intensity is expressed by a potential law $I \propto (df/dt)^{-p}$ with $2 < p < 3$. The change in the drift speed is a steep function of frequency, $df/dt \propto f^s$, $s \simeq 9$, yielding $I \propto f^3$. It reflects part of a smooth transition from enhanced Cilié-Menzel chromospheric to Baumbach-Allen coronal density models describing a more active sun. A simple model calculation on the basis of local pressure equilibrium $d(NT)/dr = mNg$ (N, T, m, g are the respective electron density, temperature, mass and solar gravitational acceleration), taking into account the drift change, led to a suggestive profiling (Fig. 2) of the transition in both density and temperature. The best fit was found for the beam velocity $v_B = 2.5 \times 10^4$ km/s.

Bursts with radially outward increasing drift rates, indicating subsequent electron beam acceleration, and of bursts obeying both normal and reversed drifts, have been observed. The latter should be injected simultaneously in and outward from a source situated at the base of the

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corona. In most cases the inward injected burst part ceased very rapidly. Generally the polarisation of the analysed bursts is low. There are however cases of rather high polarization up to 70%. Change of polarisation in the course of propagation to lower frequencies have been found several times.

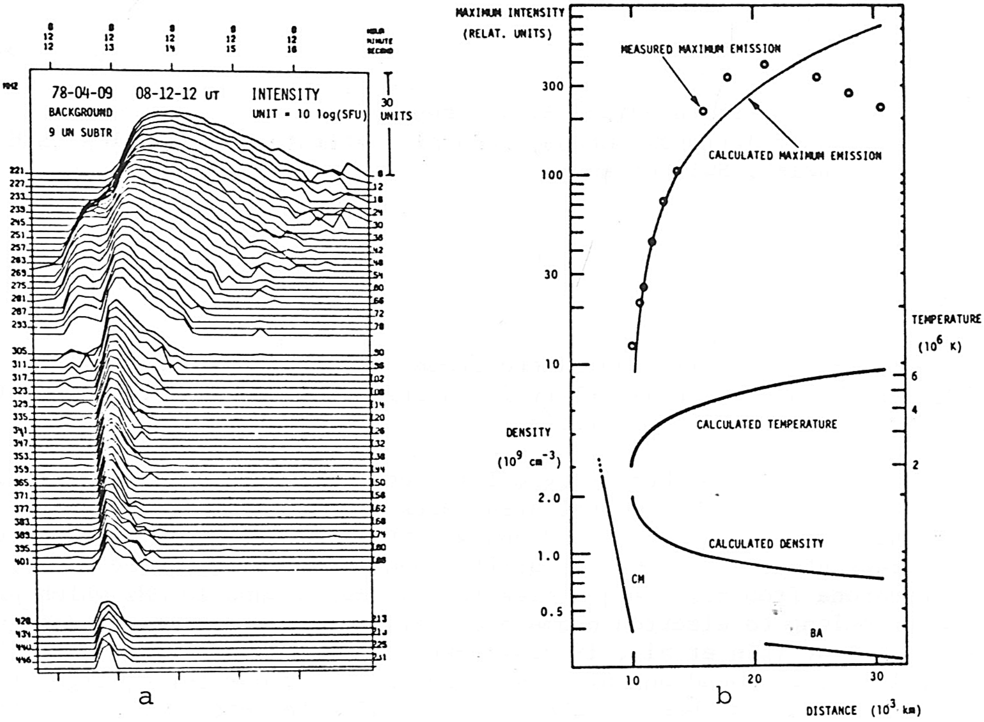

Fig. 1a. Frequency-time diagram of the type III burst of April 4, 1978 at 08.12.12 UT, recorded in Zürich. Fig. 1b, lower part: Model of the lower corona density and temperature in dependence on the height above the photosphere, calculated from drift measurements of the burst in Fig. 1a and compared with the chromospheric and coronal models of Cilié-Menzel (CM) and Baumbach-Allen (BA) for the quiet sun. Upper part: Comparison between the measured spectrum and the calculated emission, based on the assumption of constant emissivity per volume.

A slowly drifting intensity gap has been detected in a burst with radial drift around 10 MHz/s. The drift of the main burst amounts to 300 MHz/s. A classical density model of Newkirk gives drift velocities around 5.10^3 km/s near the local magnetosonic velocity, suggesting a moving magnetohydrodynamic structure. The spectrum of the burst obeys a radially outward decaying modulation of the intensity of a wavelength near 40 MHz corresponding to $2x10^4$ km or less. The maximum amplitude is 5 dB. The oscillation damps away over little more than one wavelength. This burst was strongly polarized.

A large number of type III do obviously not reach the interplanetary space but relax in the deeper coronal layers. Starting from the deeper corona they rapidly leave the regime of strong plasma turbulence and will not become nonlinearly stabilized. This goes on account of the steep plasma gradients in the transition region. The ceasing time of the "decaying" burst is less than or of the order of 1 s. The wave energy is concentrated in a region of $\Delta f < 40$ MHz at ~ 300 MHz, too large to be explained by quasilinear plateau formation (qpf) (Vedenov et al., 1976). In an inhomogeneous medium as the solar atmosphere, however, the conditions for nonlinear beam stabilization by the oscillating two-stream instability (oti) worsen with increasing radius. The beam escapes from the strong turbulent regime, and the oti stops at a distance, where $W_\ell/NT_e < 6(k\lambda_d)^2$. From competition of qpf and oti using $\Delta v_B \sim v_B/3$ (Papadopoulos, 1975, Papadopoulos and Freund, 1979), one obtains a critical beam velocity $(v_B/v_e)_c = 2(6)^{-1/4}\ (m/M)^{1/8}\ (N/N_B)^{3/8}$ at which beams begin to escape from the corona. With $N_B/N < 10^{-2}$ we have $v_{Bc} > 10\ v_e$.

The drifting intensity reduction can be explained using the concept of lower-hybrid soliton formation on a magnetohydrodynamic scale (Treumann, 1978). Langmuir waves, traversing the soliton gradient will tunnel (Melrose, 1979) the soliton, thereby converting into the ordinary mode at the fundamental. This mode is strongly polarized as has been observed.

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DISCUSSION

Maxwell: Did I hear you say you assume the emission was fundamental?

Treumann: I have not argued that the emission is actually at the fundamental. On the contrary, since the burst is essentially unpolarized, we believe it is second harmonic. But the assumption of emission at the fundamental and harmonic influences the further calculation only by a numerical factor of order one, which shifts a little bit higher the curves in the figure showing the temperature and density model. This is fully covered by the assumption of the initial values of temperature and density at the starting point of the burst.

Slottje: The remark made earlier by the Australians (see discussion following the paper presented by M. Pick and A. Raoult) that fundamental type III bursts hardly if at all appear above 160 MHz is at variance with our observations of type III bursts with a high "polarization nose" (Slottje, 1973) which have also been observed by Santin (1977). This phenomenon can only be explained by fundamental radiation. Such bursts have been observed fairly frequently between 160 and 320 MHz with the high resolution Dwingeloo spectrograph.

Dulk: In the study by Suzuki and me, we found only 4 of about 1000 type III bursts had fundamentals at frequencies higher than 160 MHz. However, our study concentrated on classical III's, on open field lines, that continued to the lowest frequency observable, 20 MHz. We missed, or ignored, very short sharp bursts and those confined to high frequencies. It is certainly true that some of those could be fundamentals.