TRANSITION BETWEEN TYPE I AND TYPE III BURSTS IN CLOSED OR OPEN MAGNETIC FIELD LINES

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When studying the propagation of accelerated electrons outwards in the corona, we have shown that the perpendicular momentum of the electrons remaining after the type I process is transformed into parallel momentum during the propagation along the decreasing magnetic field, and that type III emission can occur when the parallel velocity component reaches a critical value. With this model we explain in particular the low frequency cut-off of type I emission, the characteristics of the type III bursts near their starting frequency and the transition between type III- and type I-like decameter emission observed in few cases.

This transition has been studied in two different cases. First in events where type III-like emission is followed by type I emission. Secondly in the more well known association of metric type I and decametric type III storms.

1. TYPE I AND TYPE III-LIKE EMISSIONS IN A MAGNETIC ARCH.

Two type II-type IV events observed at Nançay in the 25-70 MHz frequency range appear with quite striking fine structures (Figure 1). These structures are drifting positively (towards high frequencies) in the low frequency range and negatively (towards low frequencies) in the high

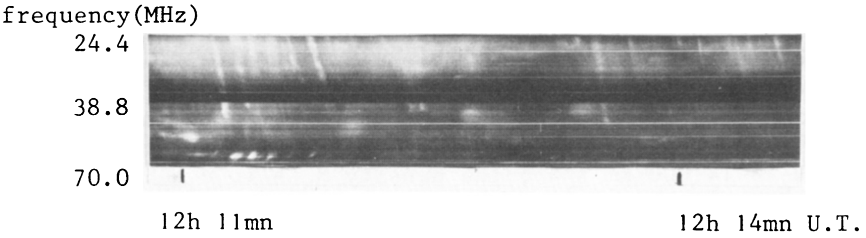

Figure 1. Part of the Nançay 73.09.07 event.

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frequency range (which is opposite to the so-called "herring bone" structures. In several other examples the positively drifting structures (p.d.s.) were only present, superimposed on the continuum type IV emission : these p.d.s. recall curiously type III's with reversed drift-rates.

The interpretation of these structures has been guided by several indications which suggest that we are dealing with an arch configuration, probably trans-equatorial, since the two events were associated with active centers in the equatorial region, and loop-shaped transients were observed by the Skylab coronograph. It is known that the transient event tears open the closed field lines and a solar wind expansion is set up which extends well out in the corona. Just before the reconnection of the magnetic field, the upward mass flow is very enhanced and this material will be captured in the closed loops and compressed downwards in the corona. Then it is probable that local accelerations at the top of the loop are set up since the magnetic field changes drastically in the region located near the neutral point while the reconnection goes up.

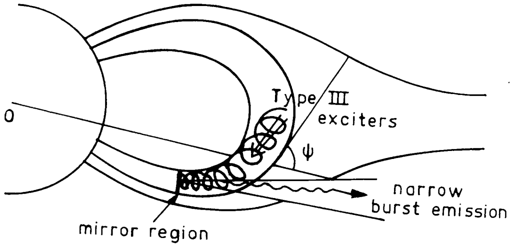

Figure 2. Physical representation of the two emissions in an arch magnetic field configuration.

The accelerated beams of electrons propagate downwards (Figure 2) and excite at each level a plasma emission which gives rise to a type III burst drifting positively. As the magnetic field B is increasing the parallel velocity component ($v_{//}$) decreases and the perpendicular one ($v_{\perp}$) increases. When $v_{//}$ is such that there is no more positive slope in the velocity dispersion function, then the plasma type III emission disappears (Figure 3).

From two approaches, we derived the parameters of the beam and of the medium. We first used the observed high-frequency cut-off of the type III emission. This condition gives us $v_{//f}$, the average parallel component of the velocity at the altitude where the type III-like emission stops. We find that this value is independent of the initial total energy. Second, we compute from the frequency-drift of the type III bursts (B(r) and $v_{//}(r)$) in the studied region ($2.15 < r < 3R_{\odot}$) and particularly we deduce $v_{//f}$. The comparison of the two values of $v_{//f}$ obtained from these two independent approaches allow us to conclude that in the beam : the initial energy $U_0 \geq 0.46$ c (or 63 keV) ; the velocity dispersion $V_b \simeq 2 V_e = 14\ 000$ km s^{-1} ; the density $N_b \simeq 10^{-5} N_o$.

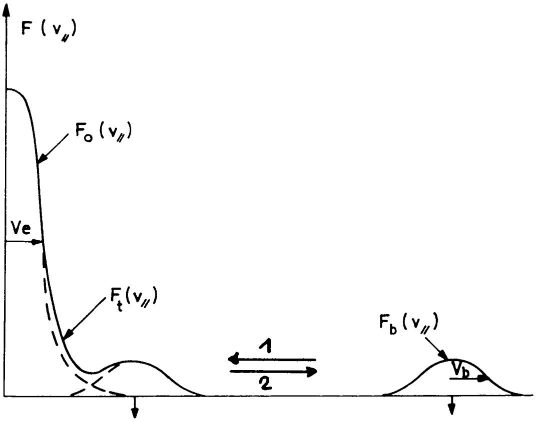

Figure 3. Evolution of the velocity distribution function of the medium $F_O(v_{//})$ and of the beam $F_b(v_{//})$ showing $v_{//f}$ when the positive slope disappears (§ 1) or appears (§ 2).

The electrons still go down in the corona with $v_{//}$ decreasing as B increases until they are reflected in a mirror region. Then they will propagate upwards and soon after reflection, the beam is such that $v_\perp >> v_{//}$. We have shown that the conditions in the medium as well as in the beam are such that a cyclotron beam plasma instability according to Mangeney and Veltri's theory (1976a, b) can occur. This emission gives rise to short lived narrow-band bursts the characteristics of which are in agreement with the "negative drifting structures".

A consequence of this study is the determination of the local magnetic field. It is found to be equal to about 9 Gauss between 1.5 and 2 $R_\odot$ in the arch, and to decrease very steeply between 2 $R_\odot$ and 3 $R_\odot$.

Another consequence is that the emission is strongly circularly polarised we expect to verify this prediction with future observations with the large collecting array of Nançay (Decameter Radio Astronomy Group, 1979).

2. TYPE I AND TYPE III CUT-OFF FREQUENCIES.

2.1. Association type I and type III bursts :

- Type III burst storms are associated with the occurrence of type I burst storms at higher frequency and this relationship is so remarquable that Malville (1962), Hanasz (1966) and Boischot (1970) have already suggested the probability of a physical similarity between the two phenomena. Our fixed frequency records confirm this relationship : the type III bursts seem to emerge from type I bursts.
- The cut-off frequency of type I bursts sometimes varies slightly on one day, but usually changes from one storm to another.
- The sense of polarization of storms of type III bursts is the same as that of any time I emission occurring within the same period.

- The probability of occurrence of type I storms increases with the local magnetic field strength.
- Storms of type III bursts are much more polarized than isolated type III bursts.
- Very few observations of the positions of type I and associated type III storms are available. This point is discussed (Aubier et al., 1979).

All these properties support our hypothesis that associated type I and type III storms might be caused by the same beams of electrons.

2.2. Survey of the emission process :

Let us consider an active region with closed and open field lines in which are injected electrons of high energy. Among the different theories of type I emission built on a plasma beam instability, the theory of Mangeney and Veltri (1976 a, b) studies the evolution of a cyclotron beam plasma instability in a weakly turbulent medium. This mechanism implies beams of electrons of large perpendicular velocity component (either produced in the active region or accelerated higher in the corona) and low relative velocity dispersion, gyrating along a strong magnetic field. If the magnetic lines are closed and the arch does not extend very high into the corona, only type I emission occurs and only at high frequencies. But if the magnetic arch is so high that B reaches a low value, then both emissions can occur: type I storms at high frequencies and type III storms at lower frequencies (Figure 4). Indeed, we show (Aubier et al., 1978) that after the generation of a type I burst the remaining perpendicular velocity component of the outward propagating beam diminishes because the magnetic field decreases. Due to the conservation of the particle energy, the parallel velocity component increases and might make possible the emission of a type III burst (Figure 3, i.e. when a positive slope appears in the total velocity distribution function of the medium and of the beam). If we are dealing with an arch structure, the type III emission will present a lower frequency limit where

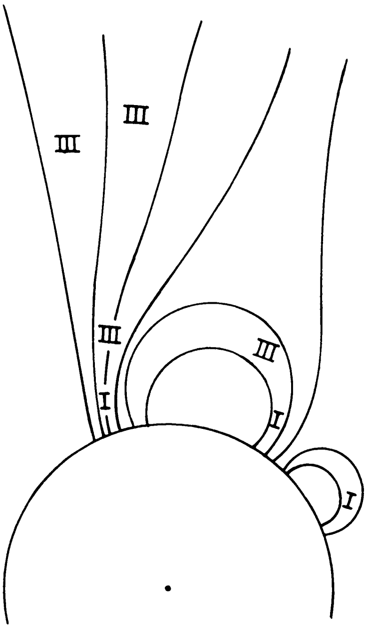

Figure 4. Proposed model of the source region, showing where the type I and (or) the type III storms take place.

the type III bursts very often show J or U forms. Along opened field lines, associated with a high magnetic field, both type I and type III bursts can also be emitted and are polarized in the same sense. Moreover in this case type III storms may extend to very low frequencies, which is impossible in the case of closed field lines.

In a region of weak magnetic field, even if the electrons have a large perpendicular velocity component, type I emission does not take place, but at a given height, the $v_{//}$ of the electrons will be large enough to produce type III emission.

2.3. Consequences for the observations :

- This theoretical interpretation allows us to understand the frequency variation of the transition region within a storm or from one storm to another. The starting frequency is not necessarily the same for all type III bursts, it depends on the energy of the electron beams and on the physical parameters of the corona which vary from one period to another.
- A gap may exist between type I and type III emission. But if the type III emission is radiated on the harmonic mode it may overlap the type I emission.
- Our study shows that the propagation velocity of a type III exciter is not constant but increases just after the starting frequency towards a limit. This property is in fact confirmed by the observations. We have measured different characteristics of type III bursts in the 29.3 - 36.9 MHz frequency range. We found significant differences in the frequency drift and half power duration measurements when the type III bursts are observed close to or far from their starting frequency. This statistic will be improved with further observations at Nançay.

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DISCUSSION

Kundu: Can you predict from theoretical considerations what will be the change-over frequency from type I to type III in open field configurations? I ask this because in an earlier paper you mentioned that the transition takes place at the solar wind acceleration region. If we have a two-dimensional imaging device which can change frequency very fast such as the one we have at Clark Lake, maybe we can test this directly from positional data.

Aubier: We tried to do something along those lines but I don't know the answer yet.

Gergely: Do you have any positional measurements on the different type III bursts in your model? We have observed one case (5 September 1973 flare) where there are a lot of type III bursts. Only one of them cuts off very sharply at ∿ 90 MHz. The position of this burst is very different from all the others and coincides roughly with the direction of motion of an ejected prominence or surge.

Aubier: Yes, on the other hand there are many examples in the literature of type I and type III burst position measurements which agree quite well.