A NEW PLASMA EMISSION MODEL FOR BRIGHT, SLOWLY MOVING TYPE IV SOLAR RADIO BURSTS

B. Kliem
Zentralinstitut für Astrophysik der AdW der DDR,
Sonnenobservatorium Einsteinturm, Telegrafenberg,
DDR-1500 Potsdam

ABSTRACT. As a model of bright, slowly moving type IV bursts, coalescence of oblique Bernstein models into predominantly o-mode waves is proposed. Bernstein mode instability is supposed in an adiabatically compressed plasma within the current sheet associated with the underlying traveling coronal disturbance.

НОВАЯ ПЛАЗМЕННО/ЭМИСНАЯ МОДЕЛЬ ДЛЯ МОЩНЫХ МЕДЛЕННО ДВИЖУЩИХСЯ ВСПЛЕСКОВ IV ТИПА: Излучение мощных медленно движущихся всплесков IV типа, интерпретируется как результат слияния волн Бернштейна в преимущественно обыкновенную электромагнитную волну. Волны Бернштейна распространяются под углом к внешнему магнитному полю. Предполагается, что возбуждение волн Бернштейна происходит в адиабатически сжимающейся плазме токового слоя, возникающего во фронте коронального транзиента.

NOVÝ PLAZMOVO-EMISNÝ MODEL PRE JASNÉ A POMALY SA POHYBUJÚCE RÁDIOVÉ ZÁBLESKY IV TYPU: Žiarenie jasných a pomaly sa pohybujúcich zábleskov typu IV je možné interpretovať ako výsledok kumulácie Bernsteinových v́ln a to najmä do elektromagnetickej vlny. Bernsteinove vlny sa šíria šikmo k smeru vonkajšieho magnetického poľa. Nestabilita vedúca k vzniku Bernsteinových vĺn je spôsobená adiabatickou kompresiou plazmy v prúdovej vrstve. ktorá vzniká vo fronte koronálneho tranzienta.

1. INTRODUCTION

Solar moving type IV bursts (abbreviated as IV Mo) are a manifestation at long radio wavelengths of disturbances traversing the corona. They possess

a wide scatter in properties from event to event, being connected with coronal transients of different forms and/or shock waves, or H_α ejecta in a range of apparent velocities between 20 and 1500 km s^{-1}. Brightness temperatures range from the thermal coronal level up to $\sim 10^{10}$ K with differing polarisation characteristics (but always o-mode dominance according to the leading spot hypothesis). The large elevation of the source in comparison to the plasma level of the undisturbed corona represents one common propertly of these bursts, it has, however, been shown to be consistent with the enhanced plasma levels inside the associated, cospatial coronal mass ejection in the few occasions of simultaneous observation. It appears questionable that an unique model may account for this bursts class.

If one follows Duncan (1981) who regards the existing observations as giving evidence against the interpretation of the majority of moving type IV bursts as synchrotron emission, then one is left with only one detailed model of IV Mo plasma emission (by Vlahos et al., 1982). This model supposes super--Alfvenic upward propagation of a magnetic loop and explains the type IV emission in a convincing way as harmonic plasma emission of streaming and trapped electrons inside the loop, which had been accelerated by the shock wave at the contact surface (though not all details were analysed in that paper). A significant fraction of IV Mo is ascending with sub-Alfvenic velocities, however. In fact, the IV Mo - velocity distribution peaks at $u_R \approx 400 \ldots 600$ km s^{-1} (cf. Kai, 1979; add there 8 events reported by Duncan, 1981), which may be in the range of coronal Alfven velocities or even less. The brightness temperature of slowmoving type IV bursts ($M_A = u_R/v_A < 1$) may reach $T_b \approx 10^{10}$ K-comparable to the brightest fast IV Mo reported so far. The event of 20/21 Febr. 1979 may be considered as an extreme example with $u_R \approx 20$ km s^{-1}, $T_b \approx 10^{10}$ K and ~ 50 % o-mode polarization (cf. Duncan, 1981). Here I propose a new plasma emission model for the subclass of bright (nonthermal), slowly moving type IV bursts.

2. COALESCENCE INSTABILITY IN CORONAL CURRENT SHEETS AND TEMPERATURE ANISOTROPY

If a disturbance-presumably a loop-ascends with $M_A < 1$, a current sheet forms at its contact surface with the surrounding medium due to the very high electrical conductivity (e.g. Pneuman, 1974). The current sheet is unstable against tearing mode perturbations. Taking into account the stabilizing influence of streaming out along the sheet of plasma that had been convected towards the sheet with velocity u_R (in the sheet-rest frame) by demanding that the tearing mode growth time $\tau_T \sim \tau_A^{2/3} \tau_r^{1/3}$ be less than the convection time $\tau_{HD} \sim L\, u_{out}$. one can derive $M_A \ll (1/6)\, \beta^{5/6}$ for tearing to occur (τ_A, τ_r, τ_{HD} - Alfvenic, resistive, and convective time scales, respectively; L-sheet length; β ($\ll 1$)-plasma beta). Here anomalous resistivity is assumed in τ_r. The row of current filaments produced by the tearing mode is again unstable with respect to coalescence. If the magnetic field is nearly antiparallel on both sides of the sheet, then the plasma in and between the current filaments is compressible, and coalescence may proceed on the fast time scale τ_A involving adiabatic compression of plasma perpendicular to the magnetic field in and between filaments (Tajima et al., 1982). This compression will be sufficiently rapid to produce anisotropic temperature ($A = T_\perp/T_\parallel > 1$) of bulk plasma if filament diameters $l \ll 8\beta^{-1/2} l_{mfpi}$ are involved (l_{mfpi}-ion mean free path). Compression factors $\lesssim 50$ have been found in numerical simulation (Tajima et al., 1982). Already for $A \gtrsim 3$ electrostatic electron cyclotron harmonic waves (e.s. ECW) will grow immediately, first of all in the lowest harmonic band $(0.5 < \omega/\omega_{ce} < 1)$ at $0.1 \lesssim k_\perp r_{ce} \approx |k_\parallel| r_{ce} \lesssim 1$, $r_{ce} = (T_\perp/m_e)^{1/2}/\omega_{ce}$, and will reach the saturation level $E^2/(8\pi n T_\perp) \sim 6.10^{-4}$ in a few cyclotron periods (Gitomer et al., 1972).

3. RADIOEMISSION

Fulfilment of the resonance conditions

$$\underline{k} = \underline{k}_1 + \underline{k}_2 , \quad \omega^{\sigma}(\underline{k}) = \omega^{\sigma'}(\underline{k}_1) + \omega^{\sigma'}(\underline{k}_2)$$

for coalescence of two e.s. ECW, $\omega^{\sigma'}(\underline{k}_{1,2})$, into radio emission $\omega^{\sigma}(\underline{k})$, σ = o; x, seems possible at first sight (and may be verified exactly using numerically obtained dispersion curves). It relies on the fact that the e.s. ECW are excited with cylindrical symmetry as well as in both regions $k_{1\parallel} \lessgtr 0$. So it is easy to find pairs with $\underline{k}_2 \approx -\underline{k}_1$ and $\omega^{\sigma'} \approx \omega^{\sigma}/2$. This is an advantage of the proposed mechanism. On the other band, $\omega^{\sigma}_{cut} < 2\,\omega^{\sigma'} < 2\,\omega_{ce}$ is required, where $\omega^{\sigma}_{cut}(0, P = \omega_{pe}^2/\omega_{ce}^2)$ is the cutoff frequency of mode σ. One has $\omega^{o}_{cut}(\pi/2, P) = P^{1/2}\omega_c$, $\omega^{o}_{cut}(0,P) = \omega_1 = ((1 + 4P)^{1/2} - 1)\omega_c/2$, $\omega^{x}_{cut} = \omega_2 = \omega_1 + \omega_c$ and finds $P < 6(4)$ for parallel (perpendicular) o-mode escape and $P < 2$ for x-mode escape, which explains the o-mode dominance. These conditions are rather stringet and appear to conflict with average coronal models of density and field strength, but they may just be produced by the compression which lowers P. With compression factors of 5-10, twice the Newkirk (1967)-density, and field strengths near the upper limit of the spread in Dulk and McLean (1978), o-mode emission at 80 MHz can be obtained at heights $h \lesssim 2R_s$ above the photosphere, consistent with observations.

Since both coalescing waves possess a high, nonthermal level of electric energy density, the observed brightness temperatures are readily explained. I derive $T_b < 10^{12}$K in the companion paper (Kliem 1986). Consequently, aalowance is made for rather dilute sources that contain only a number of coalesced filaments, each one radiationg a few collision times only, being convected away along the sheet and refreshed by new elementary coalescence events of old or new filaments below the instrumental resolution.

ACKNOWLEDGEMENT

I am indepted to L. Mollwo And A. Krüger for numerous discussions and constructive criticism of the present ideas.

REFERENCES

Dulk, G.A., McLean, D.J.: 1978, Solar Phys. 57, 279.
Duncan, R.A.: 1981, Solar Phys. 73, 191.
Gitomer, S.J., Forslund, D.W., Rudsinski, L.: 1972, Phys. Fluids 15, 1570.
Kai, K.: 1979, Solar Phys. 61, 187.
Kliem, B.: 1986, these proceedings.
Newkirk, Jr., G.: 1967, Ann. Rev. Astron. Astrophys. 5, 213.
Pneuman, G.W.: 1974, in Coronal Disturbances, (ed. G. Newkirk, Jr.), IAU-Symp. No. 57, Reidel, Dordrecht, p. 35.
Tajima, T., Brunel, F., Sakai, J.: 1982, Astrophys. J. 258, L45
Vlahos, L., Gergely, T.E., Papadopoulos, K.: 1982, Astrophys. J. 258, 812.