PLASMA DIAGNOSIS BY MEANS OF FIBER BURSTS

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ABSTRACT. During the type IV solar radio burst on August 19, 1981 a lot of fiber bursts were observed. One of them is used for plasma diagnostic in the source volume. The great frequency extension of the considered fiber burst allows to estimate the height dependence of the plasma parameters.

ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ ПЛАЗМЫ АНАЛИЗОМ ВОЛОКНИСТЫХ СТРУКТУР: Спектрографишеские наблюдения вплеска 19-ого августа 1981 г показывают многие волокнистые структуры. Одно волокно использовано, чтобы определить параметры корональной плазмы. Выражения для вариации параметров плазмы определены для большого интервала высоты в короне.

URČENIE PARAMETROV PLAZMY Z ANALÝZY VLÁKNITÝCH ŠTRUKTÚR RÁDIOVÉHO SPEKTRA: Dynamické spektrum rádiového záblesku z 19. augusta 1981 obsahuje väčší počet vláknitých štruktúr. Pre detailnú analýzu bolo vybrané jedno vlákno. Veľký frekvenčný rozsah uvažovaného vlákna (a z toho plynúci veľký rozsah výšok) umožnil určiť výškovú zmenu parametrov plazmy.

Fine structures of solar radio bursts are important for plasma diagnosis in the burst source volume. This allows to get a better physical information on the flare process.

The spectrographic records of the event on August 19, 1981 observed by the radio spectrograph at the ETH Zurich show many fine structures typically for type-IV fine structures. They were extensively describes by Karlicky

(1986). A typical one of the fiber bursts started at 14:12:16.5 UT is used to diagnose the plasma in the burst source volume.

This event was connected with an 1B flare located at S 16° E 28° and observed between 12:39 UT and 14:17 UT (NOAA Solar Geophysical Data).

The main properties of the analyzed fiber burst are listed in Table 1. This fiber burst show an approximately constant instantaneous bandwidth b_f of 8 MHz over the whole frequency extent (656 MHz - 515 MHz).

Table 1

Drift rates of the fiber burst at different frequencies

f(MHz)	D_f(MHz.s^{-1})
656	- 26.3
610	- 22.6
515	- 17.3

We intend to estimate the plasma parameters by means of Kuijpers' (1975) fiber burst model. According to this model the fiber bursts arise by coalescence of packets of whistler solitons propagating along the magnetic field in a coronal loop and Langmuir waves into electromagnetic waves. Therefore, the fiber bursts radiate at frequencies of $\omega = 2\pi f = \omega_L + \omega_W$ with $\omega_L \approx \omega_{pe}$ (ω_L - frequency of the Langmuir waves, ω_W - the whistler frequency, ω_{pe} - the local electron plasma frequency). According to Elgarøy (1982) the whistler frequency f_W can be estimated by the instantaneous bandwidth of the fiber burst $f_W = b_f = 8$ MHz ($\omega_W = 2\pi f_W = 50.3\ 10^6 s^{-1}$). Thus, the 656 MHz - and 515 MHz-level is connected with an electron particle density of $52.1\ 10^8$ cm^{-3} and $31.9\ 10^8$ cm^{-3}, respectively.

Because the whistler waves propagate with group velocity $v_G = 2c(\omega_{ce}/\omega_{pe})(x(1-x)^3)^{1/2}$ ($x = \omega_W/\omega_{ce}$, ω_{ce} - electron cyclotron frequency) we find

$$\frac{1}{N_e}\frac{dN_e}{ds} = \frac{2\pi D_f}{c\,\omega_W}\sqrt{\frac{x}{(1-x)^3}} \qquad (1)$$

(N_e - electron particle density, c - velocity of light) from the usual definition of the drift rate D_f, where d/ds denotes the derivative along the propagation direction (along the magnetic field in a coronal loop according to Kuijpers (1975)). D_f and x vary with N_e. Thus, the equation (1) represents an ordinary differential equation of N_e. In order to estimate the right hand side of the equation (1) we look to the variations of the x-values. Whistler solitons propagating along the external magnetic field are only generated for $x > 0.25$ under coronal conditions (supersonic whistler group velocity) (Karpman and Washimi 1977, Spatschek et al. 1979). Because cyclotron damping becomes important for $x > 0.5$ under coronal circumstances (Kuijpers 1975), we find for the x-values at the 656 MHz- and the 515 MHz-level (x_s respective x_e)

$0.25 < x_s < x_e < 0.5$. Here, the whistler waves are considered to propagate upwards in a coronal loop. Furthermore, we assumed that the Langmuir wave are excited in the whole region between the 656 MHz- and the 515 MHz-level. Supposing $0.25 < x_s < 0.35$ and $0.3 < x_e < 0.5$ (with $x_s < x_e$), we get for the right hand side of the equation (1)

$-(10.35 \pm 1.92) \cdot 10^{-6}\mathrm{km}^{-1}$ and $-(10.35\ {}^{+\,4.06}_{-\,3.61}) \cdot 10^{-6}\mathrm{km}^{-1}$ at the 656 MHz- and the 515 MHz-level, respectively. Using the mean values, the differential equation (1) can be integrated

$$N_e(s) = N_{eo}e^{-a(s-s_o)} \qquad (2)$$

with $a = 10.35 \cdot 10^{-6}\mathrm{km}^{-1}$ and $N_{eo} = N_e(s_o)$. The height scale $a^{-1} \approx 100000$ km is a typical values for an isothermal barometric loop atmosphere with a temperature of $2\ 10^6$ K (Aschwanden and Benz 1985). The loop model by Wragg and Priest (1981) includes such a loop atmosphere.

In order to obtain an approximate value of s_o, we use the eightfold Newkirk (1961) model, which is a radial density model. In the contrary, the equation (2) described the density behaviour in a coronal loop. s_o is determined by the requirement that equation (2) agrees with the eightfold Newkirk model at s_o with the suitably chosen value of $N_{eo} = 40\ 10^8\mathrm{cm}^{-3}$. Thus, we find for $s_o = 42000$ km $= 0.06\ R_S$ above the photosphere (R_S - solar radius). Then, the expression (2) represents the particle density behaviour along the magnetic field in an height range between 17000 km and 63000 km in the coronal lopp, where the fiber burst took place.

The magnetic field strength can be calculated by

$$B = \frac{m_e c\,\omega_W}{ex} \qquad (3)$$

(m_e - electron mass, e - elementary charge). Taking the above ranges of the x-values, a magnetic field strength of (8.8 ± 1.6) G and (7.6 ± 1.9) G is obtained at the 656 MHz- and the 515 MHz-level, respectively. Adopting for the mean electron particle density $N_{eo} = 40\ 10^8\mathrm{cm}^{-3}$, for the mean magnetic field strength 8.2 G, and for the temperature $2\ 10^6$ K, we get a mean ratio of $\omega_{pe}/\omega_{ce} \approx 25$ and a usually defined plasma-beta of 0.8.

Of course, we know that the present results are only estimates. The derived numerical plasma parameters of the burst source volume are only mean values with corresponding errors. But these uncertainties are typically for quantitative estimates in the field of solar radioastronomy. We emphasize that the relative large frequency extent of the investigated fiber burst allows to deduce the plasma parameters over a great height range in a coronal loop.

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DISCUSSION

Yu.M. Rozenraukh

In your consideration you always suggest the presence of isolated whistler soliton. How to explain the quasiperiodical structure of the fiber bursts, as shown on the first picture ?

G. Mann

In my report I only considered an individual fiber for deducing plasma parameters in the burst source volume. The problem of occurence of individual fibers or grouped fibers is the aim of my poster contribution.

Ye.Ya. Zlotnik

How can you explain the absorption ridge at the low frequency side of your fiber-bursts ?

G. Mann

In Kuijper's fiber burst model, the absorption ridge at the low frequency side of a fiber-burst is explained by the relationship between continuum generation and fiber generation. The fibers are produced by coalescence between whistler waves and Langmuir waves into electromagnetic waves. Therefore, Langmuir waves are exhausted for the continuum generation manifested as an absorption at the low frequency side of the fibers. Therefore, the frequency distance between the absorption ridge and the emission ridge is equal to the whistler frequency. Note, that our investigated fiber burst unfortunately shows an absorption ridge. Therefore we estimate the whistler frequency by the instantaneous bandwith according to Elgarøy.