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CONNECTION BETWEEN THE SHOCK WAVE SPEED AND II TYPE RADIO BURSTS DRIFT VELOCITY

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ABSTRACT. The substantial arguments of strong connection between shock wave speed and drift velocity of II type radio bursts in 25-180 MHz range are presented. The studied sample has included 112 proton events that were accompanied with coronal shock waves. To evaluate drift velocity and shock wave speed there was used original records of dynamic spectra from radio spectrograph in 25-180 MHz range. The velocities of shock waves were evaluated with the power mode model of solar corona density falloff.

Keywords: drift velocity, shock wave, II type radio bursts

1. Introduction

Urgency of the study of the shock waves is straight connected with the decision of the problem of the acceleration of solar cosmic rays (Tsap et al., 2012; Tsap et al., 2013). The most reliable indicator of the shock waves are II type radio bursts. It is known that for their generation is responsible the plasma mechanism of radio radiation (Cairns, et al., 2003). It is considered that meter range bursts of II type are connected with shock waves, appearing in flares (Wagner et al., 1983; Vrsnak et al., 1995), but bursts in decameter-hectometer range are connected with propagation the interplanetary shock waves, generated by CME (Classen et al., 2002; Gopalswamy et al., 1998).

Earlier in work (Galanin et al., 2015) it was shown that there is a fairly strong relationship between the drift velocity and shock wave speed calculated using Newkirk model (Newkirk, 1961). The Newkirk model is often used for finding of electron density in active area of the solar corona. However, Newkirk model has some restrictions. First, value of electron density when the height of the source R are equal to Sun radius Sun $R = R_{\odot}$ cannot be more than 1.7×10^{9} sm^{-3}. Secondly, this model gives an averaged distribution of density for active area when distribution of density can greatly differ for miscellaneous events. The model with exponential density falloff, just allows finding distribution of density for each concrete event that allows obtaining the best coincidence to theoretical model with observations. In this connection we researched the relationship between the drift velocity and shock wave speed compute by means of exponential model of density falloff in solar corona.

2. Raw data, methods of the processing and results of the study

For study the relationship between the shock wave speed and drift velocity bursts of II type were used the original record dynamic spectrum, got on radio spectrograph SRS (Solar Radio Spectrograph) within the range of 25-180 MHz (http://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-radio/rstn-spectral/) figure 1.
An example of dynamic spectrum of the radio burst of II type of the event 31.05.2003 is showed on figure 1. As it is seen, it is possible to select two bands, corresponding to main and the second harmonica. They are enough well approximated by functions of the type (1) (the light lines on figure 1).

$$\log_{10} f_{ij} = -\gamma_j \cdot \log_{10} t_i + f_{0j} \quad \text{or} \quad f_{ij} = f_{0j} \cdot t_i^{-\gamma_j} \qquad (1),$$

where t_i – time, corresponding to maximum intensity of the hits II type on frequency f_{ij}, γ_j and f_{0j} – a coefficients to linear regression, i=1, 2…n – a number counting out, j=1,2 – a number of the harmonica. The zero-point counting out time for all events corresponded to the beginning of the first harmonica on frequency 180 MHZ.

The main frequency plasma radiation f_{i1} is proportional to electron density $\sqrt{N_{i1}}$ (2).

$$f_{i1} = \sqrt{\frac{e^2 N_{i1}}{\pi m_e}} = 8.98 \cdot 10^{-3} \sqrt{N_{i1}} \ \text{МГц} \qquad (2)$$

So, using empirical dependence of the frequency from time f_i (1) and approaching model of coronal electron density N_i (3), it is possible to calculate the distance R_i (4) of the front of the shock wave.

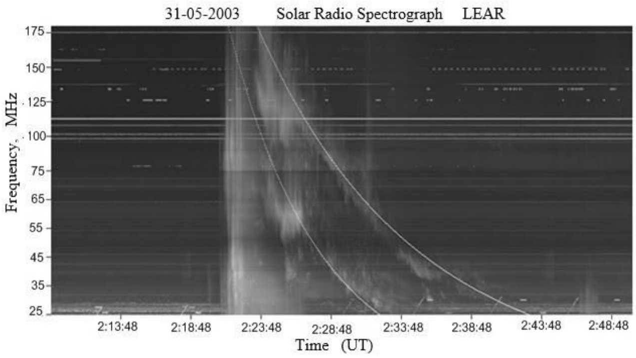

Figure 1: Dynamic spectrum of radio burst of II type of the proton event 31-05-2003

$$N_i = N_0 \cdot R_i^{-\delta}, \qquad (3)$$
$$R_i = \frac{N_0}{N_i}^{\frac{1}{\delta}}, \qquad (4)$$

where N_0 and N_i – initial and the current values of electron density, R_i – a distance of the shock wave front in Sun corona at moment of time t_i , δ – a exponent of density falloff. From expression (4) it is seen that to define the distance R_i it is necessary to find δ. Since for given moment of time t_i corresponds the definite value of the distance R_i and electron density N_i, then dependencies of density falloff N_0/N_i from distance and from time must be alike. From observations, is possible to find the dependence of the concentration falloff from time. So, knowing dependence of the frequency from time (1) from expression (2), it is possible to define the concentration N_i (5), and, consequently, the dependence of the concentrations falloff from time t_i (6).

$$N_i = \left(\frac{f_i}{0.898 \cdot 10^4}\right)^2, \qquad (5)$$
$$\log_{10} N_i = -\beta \cdot \log_{10} t_i + N_0 \quad \text{or} \quad \frac{N_0}{N_i} = t_i^{\beta}, \qquad (6)$$

where N_0 and β – a coefficients to linear regression (6).

Using expression (4), as well as approximation of the distance R_i for event of the propagation the strong shock wave in ambience with exponential density falloff (Grechnev et. al., 2008) in the manner of

$$R_i = R_0 \cdot t_i^{\frac{2}{5-\delta}} = \frac{N_0}{N_i}^{\frac{1}{\delta}} \cdot h_0 \cdot t_i^{\frac{2}{5-\delta}},$$

it is possible to find δ, where h_0 – a scale of the distances in Sun corona. The Parameters δ, N_0 and h_0 are selected so as compute values of the concentration from time to the best advantage corresponded to observed values of the concentration, i.e. $\frac{N_0}{N_i} = t_i^{\beta}$. On figure 2 is shown dependence of the exponent of density falloff δ from value of the exponent β.

Thereby to define the distance R_i and δ, it is enough to know the dependence of the concentration falloff N_0/N_i from time t_i. Knowing δ it is possible to find the dis tance $R_i = R_0 \cdot t_i^{\frac{2}{5-\delta}}$ and to evaluate the velocity of the shock wave U_i at any time moment t_i (7). But knowing the dependence of the frequency f_i from time $f_{ij} = f_{0j} \cdot t_i^{-\gamma_j}$ it is possible to define the drift velocity V_i (8).

$$U_i = \frac{R_{i+1} - R_i}{t_{i+1} - t_i}, \qquad (7)$$
$$V_i = \frac{f_i - f_{i+1}}{t_{i+1} - t_i}. \qquad (8)$$

To more exactly evaluate the relationship between of the shock wave speed U_i with the drift velocity V_i, were received dependencies U_i and V_i from time t_i in the manner of (9) and (10), accordingly.

$$\log_{10} U_i = \upsilon \cdot \log_{10} t_i + U_0 \quad \text{or} \quad U_i = U_0 \cdot t_i^{\upsilon} \qquad (9)$$
$$\log_{10} V_i = \nu \cdot \log_{10} t_i + V_0 \quad \text{or} \quad V_i = V_0 \cdot t_i^{\nu}, \qquad (10)$$

where U_0, V_0, υ and ν - a coefficients of linear regression, U_0 and V_0 - initial values of the shock wave speed and of the drift velocity, υ and ν - a exponents. Then, with exponents υ and ν, it is possible to judge about change of the drift velocity and of the shock wave speed in the course of time in frequency range 25-180 MHz for all 112 proton events. Result of our study is presented on figures 3 and 4.

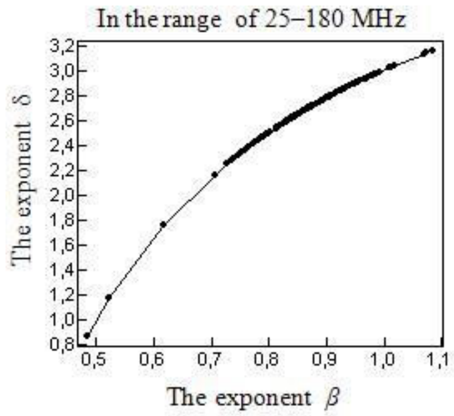

Figure 2: Relationship between δ and β in exponential model of the density falloff

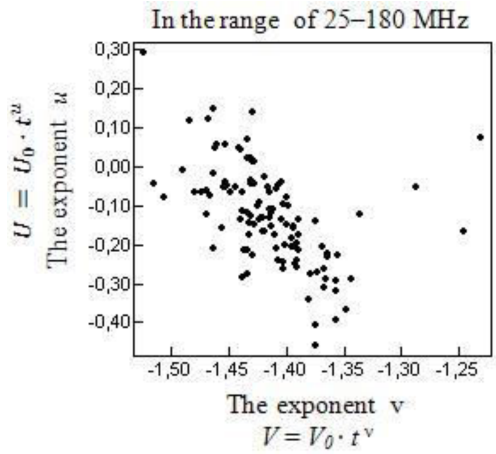

Figure 3: The relationship between the speed of the shock wave and the drift velocity in Newkirk model

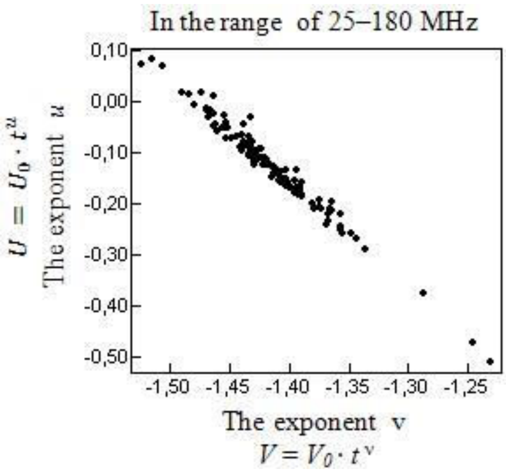

Figure 4: The relationship between the speed of the shock wave and the drift velocity in exponential model. On X axis is the exponent of falloff of the drift velocity ν, on Y axis is the exponent of falloff of the shock wave speed υ

On figure 3 and figure 4 is shown the relationship between of the drift velocity and of the shock wave speed for Newkirk model and exponent model of the density falloff, accordingly. On X axis there is the exponent of the falloff of drift velocity, but on Y axis there is the exponent of the falloff of the shock wave speed. Figure 4 shows that there is a sufficiently strong relation between the shock speed U_i and the drift velocity V_i in exponential model of the density falloff. However relationship of velocity of the shock wave U_i at the drift velocity V_i in Newkirk model vastly worse figure 3. This is connected with that that Newkirk model gives averaged distribution of density in active area. While distribution of density can vastly differ from one event to another.

Conclutions

Comparative analysis showed that there is a fairly strong relationship between the drift velocity and the speed of the shock wave in the range of 25-180 MHz.

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