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Physical Parameters of Shock-accelerated Electron Region Estimated from Observations of Solar Metric Band-split Type II Burst

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This study presents the analysis of a solar split-band type II radio burst observed on November 3, 2010 ($\sim$ 10:17:14 UT) by CALLISTO-BR (Compound Astronomical Low frequency Low Cost Instrument for Spectroscopy and Transportable Observatory) spectrometer operating in the frequency range of 45-870 MHz. Among the physical parameters determined for the shock propagation region are: source speed of the order of 1033 km s^{-1}; electron number density of $\sim 8.6 \times 10^8$ cm^{-3}; Alfvén speed of the order of 2007 km s^{-1}; Mach number of $\sim 1.09 - 1.33$; magnetic field strength of $\sim 7 - 177$ G and temperature of the order of 6.0×10^6 K. The outcomes, compared to those reported in the literature, are consistent, taking into account the fact we are dealing with an atypical type II radio burst, namely, one with high starting frequency, what accounts for the very high Alfvén speeds estimated for the initial altitudes of propagation of the shock through the solar corona.

I. INTRODUCTION

Although the solar type II radio bursts are known as signatures of magnetohydrodynamic (MHD) shocks propagating outward through the solar atmosphere [1], which accelerate electrons that excite plasma waves that, in turn, convert into escaping radio waves [2], there are long-standing controversies about how such shocks are brought forth. While some works suggest the solar flares as their origin, others indicate the coronal mass ejections (CME) as their most likely driver, especially in the meter wavelength range [3, 4].

II. METHODOLOGY

The main criteria employed in determining the observational parameters, from which the physical ones were estimated, were the half power width on time and spectral profiles, and the mode. The chief observational parameters are: frequency drift rate ($d\nu/dt$); starting time (t_i); end time (t_f); duration (Δt); starting frequency (ν_i); end frequency (ν_f); total frequency band ($\Delta\nu$), instantaneous bandwidth ($\Delta\nu_i$); and instantaneous band-splitting (DB_i).

The physical parameters, determined for the type II emitting source and its region are: source speed (υ_s); electron number density (n_e); density jump across the shock (X_n); magnetic field strength (B); Mach number (M); Alfvén Mach number (M_A); Alfvén speed (υ_A); and Temperature (T).

III. OBSERVATION AND ANALYSIS

On November 3, 2010, around 10:17:14 UT, CALLISTO-BR recorded a solar type II radio burst whose dynamic spectrum is displayed by Figure 1. The conspicuous presence of two very close main branches in its spectrum is not consistent with the interpretation of them as being the fundamental and harmonic bands ($\nu_H/\nu_F \approx 2$) [5]. A split-band type II radio burst turned out to be the only feasible scenario. As regards the interpretation of the frequency band, the analysis suggests it is the fundamental one.

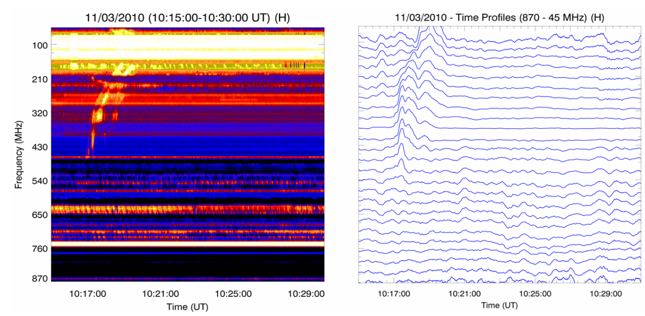

Figure 1: Dynamic spectrum and time profiles (smoothed) of solar split-band type II radio burst recorded on November 3, 2010 ($\sim$10:17:14 UT) by CALLISTO-BR spectrometer.

In order to determine the observational parameters, it was needed to identify the flux intensity peaks through both time and spectral profiles (Figure 2). The frequency drift rate, for instance, was estimated by a linear fit carried out for both branches identified via time profile.

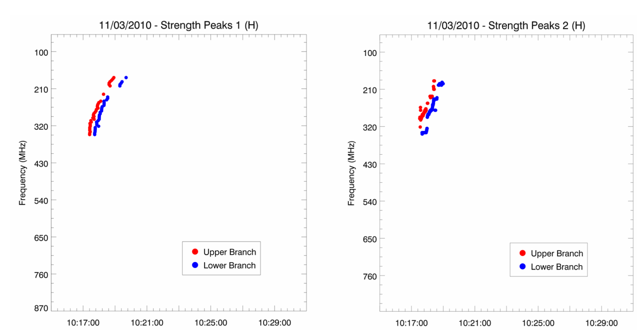

Figure 2: Flux intensity peaks identified via time (1) and spectral (2) profiles, used in determining the observational parameters of the solar type II radio burst on 11/03/2010.

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IV. RESULTS AND DISCUSSION

The frequency drift rate estimated in this study is in agreement with those reported in the literature for solar type II radio bursts with high starting frequencies, as long as the analyzed frequency band is interpreted as the fundamental one [2, 6]. Table I provides the estimated values for the observational parameters and Table II shows some comparisons with previous works.

Table I: Observational parameters of the solar type II radio burst recorded on November 3, 2010 by CALLISTO-BR.

ν_i (MHz)	ν_f (MHz)	$d\nu/dt$ (MHz s^{-1})	$\Delta\nu_i$ (MHz)	$\Delta\nu_i/\nu$	DB_i (MHz)	DB_i/ν
339.9	187.3	-1.69 $\pm$ 0.06	74.2	0.22	20.6	0.07

Table II: Comparison - observational parameters.

Parameter	This study	Literature	
$d\nu/dt$ (MHz s^{-1})	-1.69 $\pm$ 0.06	-1.66	[6]
-	-	-1.46	[5]
$\Delta\nu_i/\nu$	0.22	0.1 - 0.7	[7]
DB_i/ν	0.07	0.05 - 0.60	[5]

The estimated source speed is consistent with the upward movement of matter associated with solar type II radio bursts [8]. However, the mean value obtained for Alfvén speed is atypical [2, 9]. Table III brings out the estimated values for the physical parameters (with reference to the mean frequency, i.e. 263.6 MHz) and Table IV provides some comparisons with previous works.

Table III: Physical parameters of the emitting source for type II event recorded on November 3, 2010 by CALLISTO-BR.

υ_s (km s^{-1})	n_e (cm^{-3})	X_n	B (G)	υ_A (km s^{-1})	M_A	T (K)
1033 $\pm$ 46	8.62×10^8	1.13	27	2007	0.51	6.89×10^6

Table IV: Comparison - physical parameters.

Parameter	This study	Literature	
υ_s (km s^{-1})	1033 $\pm$ 46	1200	[10]
-	-	200 - 2000	[8]
υ_A (km s^{-1}	2007	450 - 1300	[11]
M_A	0.51	1.5 - 2.5	[7]

V. CONCLUSION

This study afforded the development of specific programming tools for reduction and analysis of the CALLISTO-BR data. The outcomes turned out to be consistent with those found in the literature, taking into account that an atypical solar type II radio burst was analyzed, what accounts for the very high Alfvén speeds estimated for the initial altitudes of the shock.

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