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Calculation the Properties of recorded on 06th September 2017 type II Solar Radio Burst with CME using Matlab.

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Abstract

Solar radio burst is an arrangement of a frequency space that varies with time. Solar radio frequency is ranging from 70 MHz to 2.2 GHz and most of the radio burst can be identified in low-frequency range (<200 MHz) Type II solar radio bursts are the most common radio burst and are slow frequency drift bursts. Most of the time they are accompanied by a second harmonic as well. The Type-II solar radio burst recorded on 06th September 2017 at12.00 pm by the Austria-Unigraz solar observatory was engaged to investigate the properties of type II solar radio burst with CME(Coronal Mass Ejection). Math lab software and mathematical models were used to analysis type II solar radio burst. The frequency distribution of type II bursts was approximated as an exponential and low drift rate value could be seen. The correlation coefficient between model frequency vs frequency was 0.973803. Newkirk model was used to estimate the drift velocities and electron density of the solar radio bursts. Although the special origin of the solar radio burst is not known clearly we assumed. Most of solar radio bursts were originated within the solar radius of 0.9 - 1.3 range from the photosphere. Further analysis also showed that the flux density of the burst was varying between $1.32 \times 10{-}22 Wm^2Hz^{-1}$ to $0.42 \times 10{-}22 Wm^2Hz^{-1}$. The average plasma velocity of type II solar radio bursts was determined as 1168.16 km s^{-1}. Therefore, we could say that in this case, CME was used to increase the plasma velocity of solar burst type II and flux density.

Introduction

Solar activity is one of the most significant events take place in the climate of the solar system which is unpredictable. Solar activities include solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles(Behlke 2001; National Aeronautics and Space Administration 2015; J.V Wijesekera1, K.P.S.C Jayaratne2 2018). Solar radio burst (SRB) is an arrangement of a frequency space that variation with time(White 2007)(Anon)(Ii n.d.).Most of radio burst can be identified in low frequency range such as below 200 MHz and depending on frequencies. Solar radio bursts were the first phenomenon identified in the field of radio astronomy field. Solar radio frequency range is from 70 MHz to 2.2 GHz (.Hanslmeier, A., & Messerotti 1999; IPS AUSTRALIA 2009)(Monstein 2015). Most of the radio burst can be identified in low frequency range below 200 MHz. Type II solar radio bursts are the most common radio burstand are slow frequency drift bursts. Most of the times they are accompanied by a second harmonic as well. Time duration of these types of bursts are between 3 min to 30 min. Frequency range between 20 MHz 250 MHz (Hanslmeier, A., & Messerotti 1999). Occasionally type II solar radio bursts associated with Coronal Mass Ejection (CME). Coronal mass ejections (CMEs) are magnetized structures, which can affect the heliospheric conditions, producing large fluctuations in the

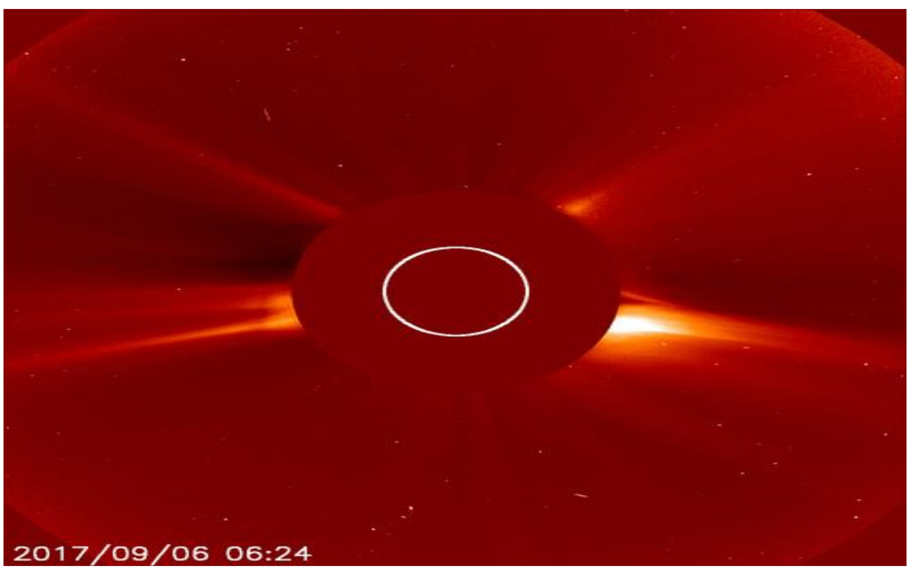

Figure 1 – CME ejection with solar flare, extracted from Space weather

heliospheric magnetic field (Zainol et al. 2015). Because of that it will help to increase ejection speed of solar radio bursts.Velocity of type II is above 200 km/sec and sometime if CME associate with solar radio bursts speed is goes to half of the speed of light (Behlke 2001). The relationship between CMEs, flares and type II bursts is still a matter of debate. Type-II radio bursts show a slow drift in time from high to low frequency with a drift rate typically ≤ 0.5 MHz S^{-1}(Behlke 2001). Ejection of CME with flare is illustrated as in figure 1

The CALLISTO spectrometer is a programmable heterodyne receiver built in the framework of IHY2007 and ISWI by former Radio and Plasma Physics Group at ETH Zurich, Switzerland. The instruments observe automatically, its data is collected every day via internet and stored in a central database. There are many solar radio stations combine with the e-CALLISTO system (Monstein n.d.)

In this paper will be calculated frequency drift rate, drift velocities, the electron density of the solar radio bursts and ejection height during the occurrence of solar radio bursts oftype II phenomenon. Only Mathematical model and Math lab software were used thoroughly to calculate above mentioned parameters (J.V Wijesekera1, K.P.S.C Jayaratne2 2018).

1.1 *Event Description.*

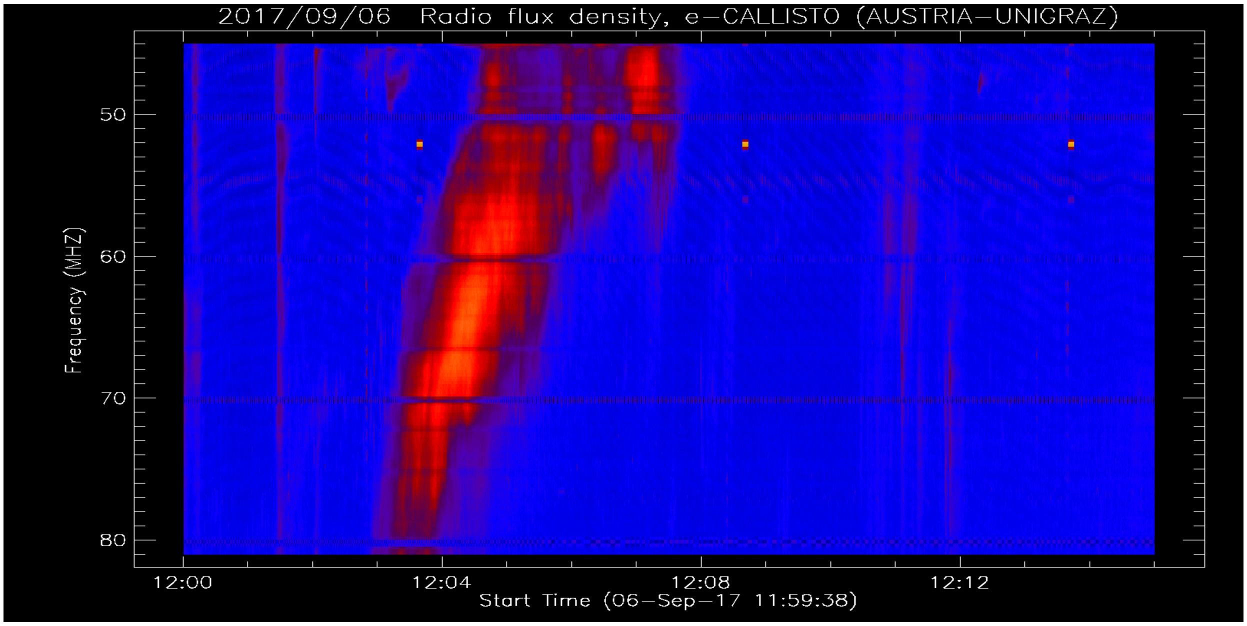

Figure 2- Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-Unigraz solar observatory

The Type-II solar radio burst recorded on 06th September 2017 at12.00 pm is shown in figure 2 and it recorded by the Austria-Unigraz solar observatory was engaged to investigate the properties of type II solar radio burst with CME.

Literature review

Earlier researchers of solar radio bursts

There are many solar radio burst research projects and most of them are depend on e- CALLISTO system. This system provides various data from multiple servers. The articles "*Coronal Mass Ejections and Solar Radio Emissions*" and *"Large-Scale Simulations of Solar type III Radio Bursts: flux density, drift rate, duration, and bandwidth"* were used to check the validity of this research

Coronal density model

Coronal density models could be used to find the electron density of solar radio bursts. Few basic electron density models for chromosphere, inner corona and outer corona of the sun were considered for admonitory purposes. This was because solar radio bursts are originated near the solar chromosphere in different height levels. In this research Newkirk model was used perfectly to calculate the electron density of solar radio bursts. Though Newkirk model is a simple model, it is perfect for this research.

Methodology

Analysis of drift rates of type II solar radio bursts

Math lab was used to extract the type II solar radio burst “Fit” file taken from the e-Calisto server. Simple binary code used for the analysis of SRB type II image and it helped to separate frequency scale and time scale of chosen flare.Drift rate graphs of solar flares can be plotted by using frequency (which corresponding to highest intensity) with time(J.V Wijesekera1, K.P.S.C Jayaratne2 2018). Moreover, distribution of frequency vs time graph was shown the pattern of our chosen SRB flare and easily found the trend line (model equation) of the graph. In addition, by differentiating graph trend line, we could find the drift rate of SRB flare. After obtaining the derivatives of the trend line, we could see a variation of drift rates. There by finding the mean value of these drift rates, one could obtain an average value for solar radio bursts.

Analysis of electron density and height of solar radio bursts

Finding the electron density on chromosphere in the sun was the major issue of this research and Newkirk model was used to avoid this matter. . Newkirk model could be used reversely to verdict each electron density and height of solar radio bursts. The frequency corresponds to electron densities should be found for calculating a height of each solar radio burst. The electron densities of each radio burst could be introduced by using equation 01(Newkirk 1967; Doddamani et al. 2014; . Hanslmeier, A., & Messerotti 1999).

$$F_{elec} = 8.973 \times 10^{-3}\sqrt{Ne(r)}\ MHz \qquad (01)$$

Where F_{elec} is a plasma frequency in MHz and $\sqrt{Ne(r)}$is the electron density in cm^{-3}

Using the values of electron density we could find the ejection height of SRB flare. For that, Newkirk model equation was appropriated for calculate ejection height of SRB flare and the equation is shown in equation 02, [8], [9]

$$Ne = N_o \times 10^{4.32Ro/R} \qquad (02)$$

Where $N_o = 4.2 \times 10^4\ cm^{-3}$. - Concentration, Ro - solar radius, R - distance from solar center to source of type burst. After getting height values corresponding to electron densities, could plot the graph between electron density vs height.

Analysis of plasma velocity of solar radio bursts

In this research, we had to differentiate each values of electron density vs height graph to calculation of plasma velocity of SRB. These differentiated values were used with equation 3 for calculating plasma velocity.

$$v = \frac{(2\frac{df}{dt}N)}{f\frac{dN}{dr}} \qquad (03)$$

Where

$v - plasma\ velocity\ (km\ s^{-1}), \frac{df}{dt} - drift\ rate(\ (MHz\ s^{-1}),$

$N - electron\ density\ (cm^{-3}),\ \ f - plasma\ frequency\ (MHz)$

$$\frac{dN}{dr} - change\ of\ electron\ density\ with\ respect\ to\ height\ (cm^{-3}{R_o}^{-1}\ )$$

Analysis of flux density of solar radio bursts

Further analysis of in this research, equation 4(Benz 2009) used to determine flux density of SRB type II.

$$I = 1.94 \times 10^{-4} \times R^{1.992}$$

Where

$I - flux\ density\ (Wm^2Hz^{-1}\ \ )\ \ \ R - Height(solar\ radius)$

Results and discussion

According to the recorded type II solar radio burst, we could see some characteristics which belonged to the type II solar radio bursts. In the first part of the research, could see the low drift rate values for recorded type II flare and SRB pattern in frequency vs time graph were observed. There are

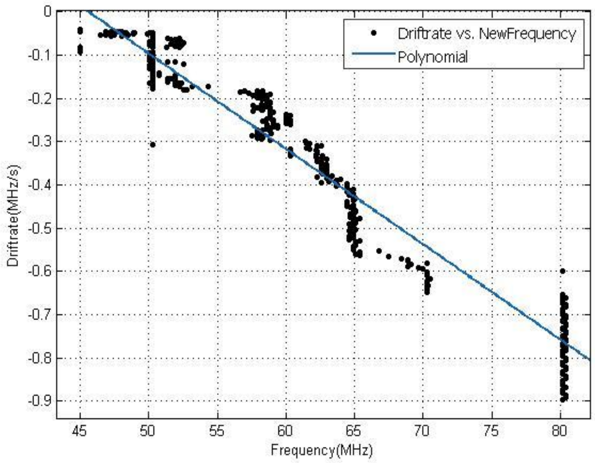

Figure 3- Drift rate vs frequency graph of Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-

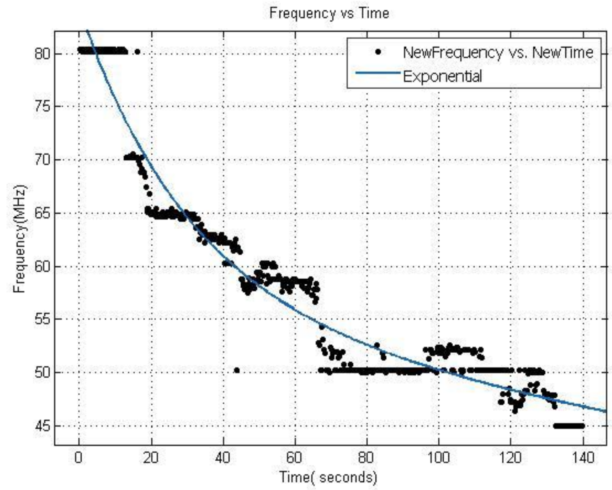

Figure 4- Frequency vs Time graph of Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-Unigraz solar

graphically shown in figure 3 and 4 respectively. Especially we could see the exponential decay type trend line for type II SRB. Furthermore, most of type II solar radio bursts were originated within the solar radius of 0.9 - 1.3 range from the photosphere. It could be seen in figure 5.

But main point was that recorded type II SRB always obey the Newkirk model graph. The results of the research were compared with the data given in the book of MOTIONS IN THE SOLAR ATMOSPHERE to validate. Results of electron density vs height graph always follows power equations in the form of $f(x) = A \times 10^{-bx}$.

Plasma velocity of type II SRB was supposed to be a medium value. According to the G. A. Newkirk model, type II solar radio bursts could get the mean velocities less than 500Km s^{-1} (White 2007; Ratcliffe et al. 2014; Hamidi et al. 2013)

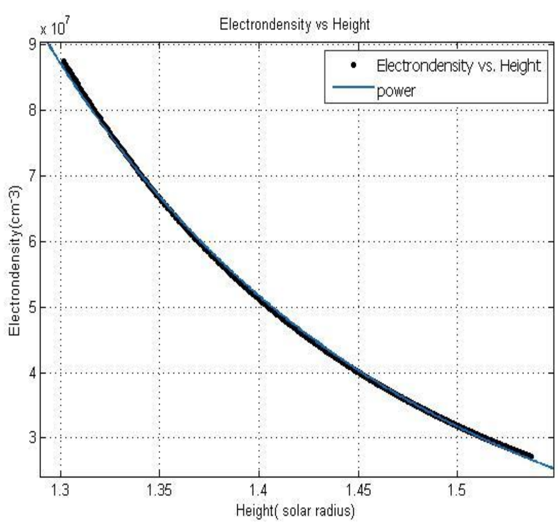

Figure 5- Electron density vs Height graph of Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-Unigraz solar observatorv

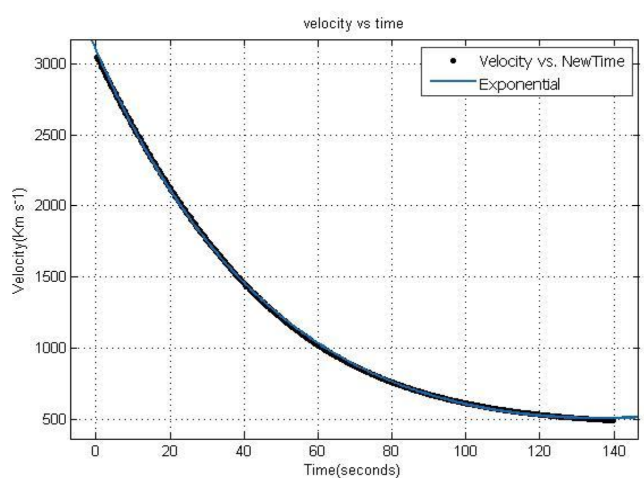

Figure 6- Velocity vs Time graph of Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-Unigraz solar observatory

However, the calculated plasma velocity of type II SRB was shown higher value than the above value. This could be due to the additional force given by CME ejection associated with type IISRB. The final part of this research found the flux variation vs time of recorded type II SRB. It is shown in figure 7 and flux density of the burst was varying between $1.32 \times 10^{-22} Wm^2Hz^{-1}$ to $0.42 \times 10^{-22} Wm^2Hz^{-1}$.

Regression analysis of all above graphs shown in table 1.

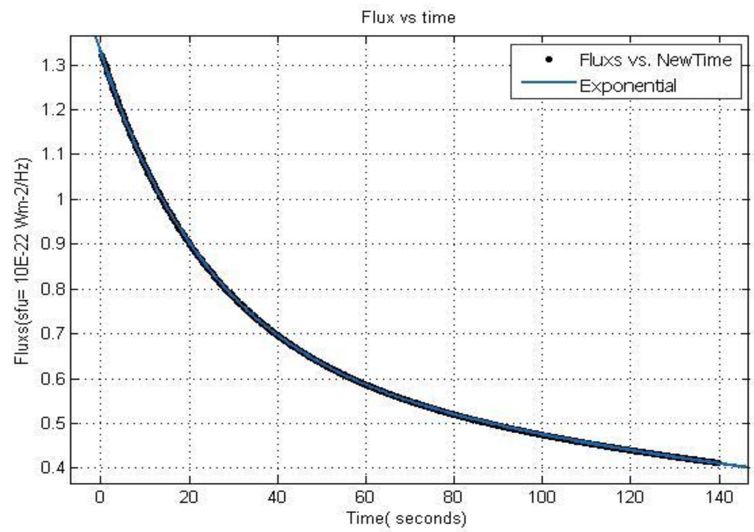

Figure 7- Flux vs Time graph of Type-II solar radio burst recorded on 06th September 2017 extracted from Austria-Unigraz solar observatory

Table 1-Regression analysis

Graph name	Model Equation	SSE	R-square	Adjusted R-square	RMSE
Frequency vs Time	$f(x) = 27.63e^{-0.03292\times x} + 56e^{-0.001401\times x}$	2773	0.9483	0.948	2.235
Drift rate vs Frequency	$f(x) = -0.02204 \times X + 1.004$	1.835	0.9383	0.9382	0.05592
Electron density vs Height	$f(x) = 5.587 \times 10^8 \times x^{-7.085}$	6.269e+13	0.9996	0.9996	3.268e+05
Velocity vs Time	$f(x) = 3045e^{-0.01997\times x} + 51.14e^{0.01312\times x}$	5.095e+04	0.9998	0.9998	9.582
Flux vs Time	$f(x) = 0.6892e^{-0.04063\times x} + 0.6357e^{-0.003164\times x}$	0.0003374	1	1	0.00077

Conclusion

In this research, we thoroughly analyzed properties of type II solar radio bursts. For this, we chose type II solar radio burst that recorded on 06th September 2017 at 12.00 pm and it was recorded by the Austria-Uni Graz solar observatory. According to research, the frequency distribution of type II bursts was approximated as an exponential and low drift rate value could be seen. The correlation coefficient between model frequencies vs frequency was 0.973803. Generally, less than 500 $\mathrm{Km\ s^{-1}}$ velocities can be seen in type II solar radio bursts. However, more than 500 $\mathrm{Km\ s^{-1}}$ velocity could be seen in this research and it was 1168.16 $\mathrm{Km\ s^{-1}}$.

For the reason, Coronal Mass Ejection could be associate with recorded type II SRB. Final part of this research was calculate the flux density of type II SRB. According to that could see the flux density exponentially decreases with time. Most of type II SRB could not damage to the earth magnetic field because its flux density was very low.

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