MONGOLIAN ACADEMY OF SCIENCES
MONGOLIAN JOURNAL OF ASTRONOMY AND GEOPHYSICS

Volume.11 No.1
Page: 7-12

Dependence of drift rate of radio bursts on frequencies for the period of solar activity 2019-2020

Batmunkh Damdin[1*], Batbayar Batmunkh[1], and Christian Monstein[2]

[1]Institute of Astronomy and Geophysics, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia
[2]Instituto ricerche solari Aldo e Cele Daccò (IRSOL), Faculty of Informatics, Università della Svizzera italiana (USI), CH-6605 Locarno, Switzerland
[*]batmunkh@iag.ac.mn,

Received: 2024-10-20, Accepted: 2024-11-05, https://doi.org/10.5564/mjag.v11i1.4183

Abstract

In this paper, we calculated the frequency drift rate (df/dt) of radio bursts observed at the minimum of solar activity of the 25th cycle. The observational spectra of radio bursts from the "CALLISTO network" database were used. The calculation was carried out for the spectra recorded on April 13, 2019 and March 8, 2020. The calculated frequency drift rate were described as $\frac{df}{dt} \simeq af^b$ and the code nonlinear least-squares fit "Marquardt's method" as used to determine the constants (a,b). It is shown that these parameters can be used to determine the electron density of the solar corona.

Keywords: Solar corona, Type III radio bursts, CALLISTO Data

1. Introduction

Solar radio bursts are one of the non-stationary phenomena on the Sun, but their number varies like the number of sunspots. One of the observed parameters is their frequency drifts, which are caused by changes of the electron density in the solar corona. From this data, the frequency drift rate (FDR) can be calculated. The calculation of the FDR is carried out in different ways, which differ significantly from each other due to the inaccuracy of the resolution of the observational spectra, as well as the complexity of the behavior of the dependence in different ranges of the spectrum. Some authors using the drift rate of the type III burst onset and some authors using the drift rate of the type III burst peak flux, and (Alavarez, 1973) have used the rise time of type III bursts (Reid & Ratcli, 2014). For example, in (Alavarez, 1973) FDR was obtained as $0.01f^{1.84}$, and in (Aschwanden et al., 1995) as $0.1f^{1.4}$. And in other works (Stanislavsky, 2017; Melnik et al., 2024; Meléndez et al., 1999; Stähli & Benz, 1987) similar results are given. Deep solar activity continued from mid-2019 to early 2020, during which time no sunspots or radio bursts were observed. In this paper, we calculated the FDR of radio bursts observed at the minimum of solar activity of the 25th cycle. The observational spectra of radio bursts from the "CALLISTO network" database Callisto were used. The calculation was carried out for the spectra recorded on April 13, 2019 and March 8, 2020.

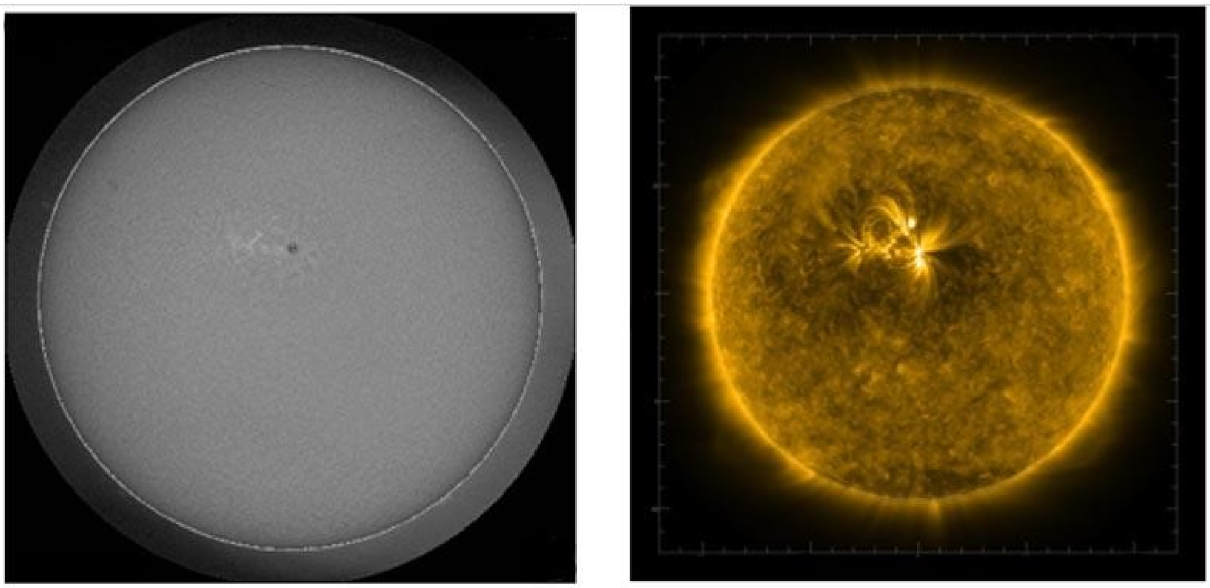

Figure 1. Images of the chromosphere in the H_α line (GONG H-Alpha data, left) and the corona in the $171 A^\circ$ line (SDO AIA, right) taken on April 13, 2019.

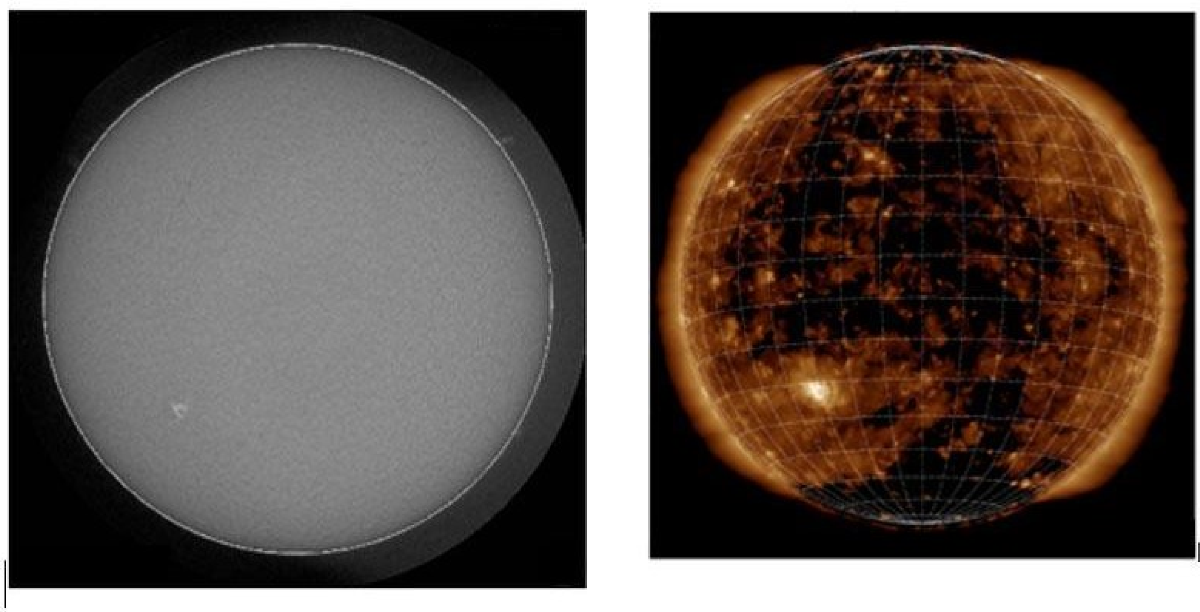

Figure 2. The same as in Figure.1 (March 08, 2020).

2. Observations and determining the frequency drift rate

Flares (Table. 1) were not observed at that time (April 13, 2019 at the end of the previous cycle and March 8, 2020 at the beginning of the next cycle), and deep activity minima continued at different depths of the atmosphere, that is, in the chromosphere and corona (Figure.1 and 2). But there was a strong radio burst (Figures.3 and 5 show the CALLISTO data spectra selected for this calculation), and with confidence we can say that it is not associated with flares. The article (Juha et al., 2021) presents three type III solar bursts which were observed

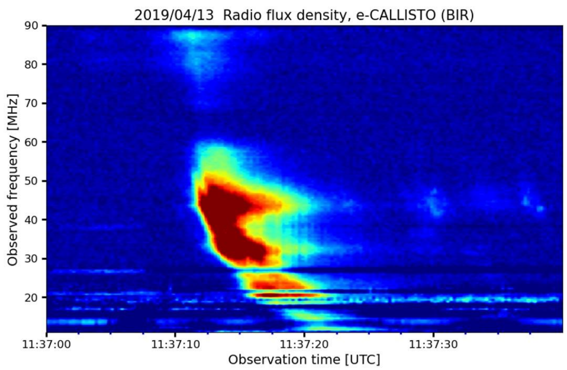

Figure 2

Figure 3. Spectrum of the type III solar radio burst observed at Bir castle, Ireland on April 13, 2019.

in May and June 2020 at radio frequencies between 18 – 90 MHz and obtained FDR 11.7-4.2 MHz/s.

A. Chromosphere and Corona

Figures. 1 and 2 show images of the quiet chromosphere and corona on days when radio bursts occurred. Complex type III bursts are due to near-relativistic electrons accelerated either by the solar flare reconnection process or by the SEP shocks (Thejappa Golla, 2018), but flares above class B were not observed at that time (Table. 1).

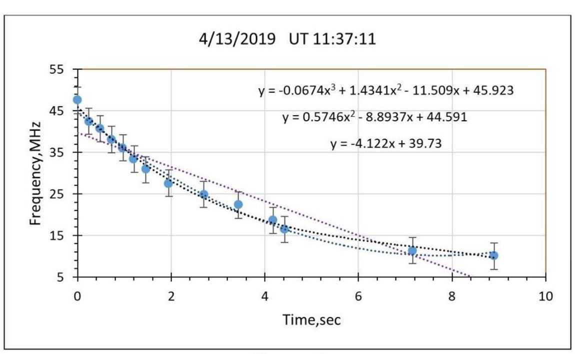

Figure 3

Figure 4. Measured frequency values versus time (Figure. 3) and their polynomial approximation with n=1,2,3.

Table 1. The number of radio bursts that occur during the solar minimum in the period 2019-2020.

Date	Start UT (h:m)	GOES	Radio Burst]
13-Apr-2019	11:30	<C	1
20-Mar-2020	13:30	-	6
20-Mar-2020	14:15	-	
20-Mar-2020	15:30	-	
20-Mar-2020	16:30	-	
20-Mar-2020	20:30	-	
20-Mar-2020	21:15	-	
29-May-2020	10:45	C9.4	3
29-May-2020	11:15	C1.1	
29-May-2020	16:45	M1.2	
02-June-2020	15:00	-	1
04-June-2020	12:15	-	1
05-June-2020	05:15	-	3
05-June-2020	09:29	-	
05-June-2020	23:00	-	
06-June-2020	02:30	-	1
07-June-2020	00:15	-	1
09-June-2020	06:46	-	3
09-June-2020	08:00	-	
09-June-2020	09:00	-	

B. Radio burst April 13, 2019

The radio burst spectra obtained with the "CALLISTO" radio spectrometer were used to calculate the FDR. We used the drift rate of the type III burst onset, since the spectrum was clearer and the time behavior of the spectrum can be seen with some error. The software code RAPPViewer in e-Callisto was used

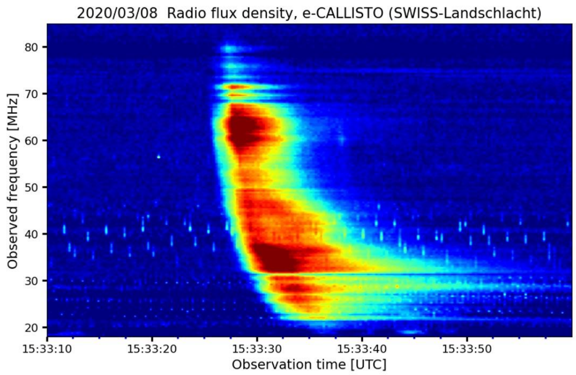

Figure 4

Figure 5. Spectrum of the type III solar radio burst observed at Bir castle, Ireland on April 13, 2019.

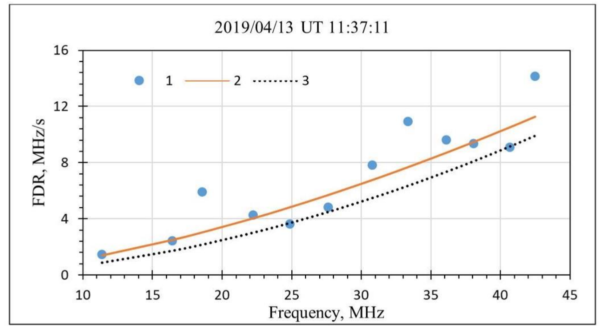

Figure 6

Figure 7. Calculation of FDR depending on the frequency and their approximation as af^b. 1- Calculation of FDR from observations, 2- a=-0.03,b=1.59 (2019/04/13), 3- (Alavarez, 1973).

for the measurements. The observed spectrum (Figures. 3 and 5) was used to determine the frequency-time dependence, which was described by polynomials of degrees n=1,2,3 both for averaging and for calculating the derivative (Figures. 4 and 6).

3. Results

The calculated frequency drift rate were described as $\frac{df}{dt} \simeq af^b$ and the code nonlinear least-squares fit "Marquardt's method" was used to determine the constants (a,b) (NRF). The derivative is calculated in two ways: the first is $f'_{(k+1)} = \frac{(f_{(k+2)} - f_k)}{(t_{(k+2)} - t_k)}$, the second, it can be taken directly from the approximation expression and their results are almost the same. Table. 2 shows the results of the calculation to determine the constants (a,b) of the approximation $\frac{df}{dt} \simeq af^b$. From this it can be seen that the calculation from the observed spectrum and the calculation from the approximation with n=3 are in sufficient agreement with each other. The approximation for n=2 differs significantly from the value determined from observations. Thus, the frequency shift in time is complex and can be associated with a variable change in the electron density of the solar corona. As a result of the fitting solution, $\frac{df}{dt} = -0.03f^{1.59}$ for April 13, 2019 and $-0.04f^1$.45 for March 8, 2020. These results are shown in fig.7 and 8. The choice of the position of the beginning of the spectrum was more subjective; for the spectrum on April 13, 2019, the spread was greater. But on March 8, 2020, the beginning of the spectrum was clear and changed smoothly and, accordingly, the spread was smaller. What is the meaning of these coefficients **a** and **b**? In fact, they are not constant, and the physical states of the corona in which the radio bursts originate are different. From the expression given in (Batmunkh & Damdin, 2020), it is clear that a directly depends on the speed of the electron beam, the angle between the direction of the beam and the vertical, and is inversely proportional to

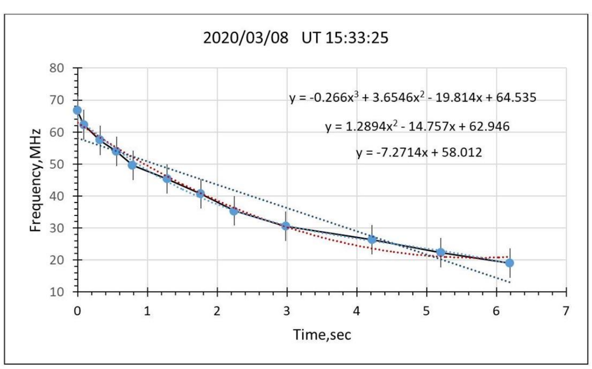

Figure 5

Figure 6. Measured frequency values versus time (Figure. 5) and their polynomial approximation with n=1,2,3.

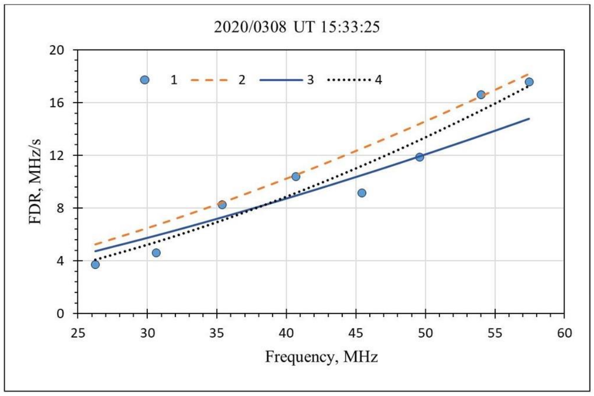

Figure 7

Figure 8. Calculation of FDR depending on the frequency and their approximation as af^b. 1- Calculation of FDR from observations, 2- a=-0.03,b=1.59 (2019/04/13), 3- (Alavarez, 1973).

the temperature of the corona. And b depends on the "scale height" (H), that is, on how it changes with distance. We can assume that b is equal to one when H is constant. This means that a deviation from unity (b>1) shows the inhomogeneity of the medium (barometric law is not respected) in which the waves propagate. Therefore, a more detailed analysis of these coefficients will yield interesting results.

Table 2. Constants a and b for the polynomial at n=1,2,3.

	2019/4/13, 11:37:11		2020/03/08. 15:33:25	
n	a	b	a	b
1	-4.122	0	-7.2714	0
2	-0.0621	1.3479	-0.0848	1.2630
3	-0.0248	1.6360	-0.0404	1.4569
Obs	-0.0295	1.5857	-0.0409	1.4539

4. Conclusions

It should be emphasized that radio bursts occurred at the minimum of solar activity and without any strong flares or other eruptive processes. Type III radio bursts typically occur when beams of fast electrons pass through the corona. Therefore, the source of these radio bursts is not solar flares, but possibly particles from coronal holes and other sources of particle acceleration. The spectra were from 10 MHz to 90 MHz, so the behavior may be different at higher frequencies. But our result is very similar to the result obtained by (Alavarez, 1973) at low spectral frequencies. Within the error of determining the FDR from spectrum observations, the radio bursts discussed above have the same nature. b>1 shows that the electron density in the corona with distance is far from hydrostatic equilibrium.

It can be seen from the calculation that the errors in measuring the frequency-time dependence significantly affect the results of determining the approximation parameters.

The work Batmunkh & Damdin (2020) shows that these constants (a, b), determined from the spectrum of radio bursts, can be used to determine the electron density of the solar corona.

Acknowledgments

The international network of solar radio spectrometers (e-CALLISTO) continuously accumulates a large number of spectra and makes it possible not to miss radio bursts.

References

Alavarez, H., 1973. Solar wind density model from km-wave type iii bursts, *Solar Physics*.

Aschwanden, M. J., Benz, A. O., Dennis, B. R., & Schwartz, R. A., 1995. Solar electron beams detected in hard X-rays and radio waves, *Astrophysical Journal v. 455, p. 347*, **455**, 347.

Batmunkh, B. & Damdin, B., 2020. Electron density in the solar corona from type iii radio bursts, *Proceedings of the Mongolian Academy of Sciences*, pp. 17–24.

Juha, K., McKay, D., & Merja, T., 2021. First type iii solar radio bursts of solar cycle 25, *Solar Physics*, **296**(4).

Meléndez, J., Sawant, H., Fernandes, F., & Benz, A., 1999. Statistical analysis of high-frequency decimetric type iii bursts, *Solar Physics*, **187**, 77–88.

Melnik, V., Brazhenko, A., Dorovskyy, V., Frantsuzenko, A., Shevchuk, M., Yerin, S., & Bubnov, I., 2024. Spectral features of a single type iii burst in the frequency range of 10–70 mhz, *Frontiers in Astronomy and Space Sciences*, **11**, 1369003.

Reid, H. & Ratcli, H., 2014. A review of solar type iii radio bursts, *Astronomy and Astrophys*.

Stähli, M. & Benz, A., 1987. Microwave emission of solar electron beams, *Astronomy and Astrophysics (ISSN 0004-6361), vol. 175, no. 1-2, March 1987, p. 271-276.*, **175**, 271–276.

Stanislavsky, A., 2017. Solar type III bursts with high-frequency cut-off, *Astron. Nachr*.

Thejappa Golla, R. J. M., 2018. Overview of solar radio bursts and the sources, in *Abstract book of American Astronomical Society Meeting*.