Observation of Solar Radio Bursts by CALLISTO Radio Spectrometer in Ibaraki University

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1 Introduction

Solar radio bursts occur due to solar activity such as solar flares. They are categorized by some types from cause of solar radio bursts. Type-III bursts were emitted by high-energy electron streams accelerated by solar flares. They appear in the frequency range between several kHz and several GHz, and they are characterized by a rapid frequency drift from high to low, respectively.

We have been joined the e-CALLISTO network since 2016. We have developed a solar radio observation system using the CALLISTO spectrometer in the Mito campus of Ibaraki University in order to explore the process of generation of high-energy electrons.

A type-III bursts concerned with the C8 class flare occurred on April 2nd 2017 2:45 (UT) observed. This is the first observation of our CALLISTO spectrometer. These burst data have been compared with the burst taken with the Yamagawa solar radio observatory of the National Institute of Information and Communications Technology (NICT), and other flare data. In this paper, the velocities of electrons are calculated from frequency drift and acceleration of electrons is discussed.

2 Observation Summary

- Location Mito Campus of the Ibaraki University (latitude 36.40 N$^\circ$, 140.44 E$^\circ$, altitude 32 m)
- Observation time Everyday 1:00-6:00 (UT) , since August 2016
- The antenna is not tracking the Sun.

Table 1 show that specifications of instruments

Instruments	Maker	Parameter	Range
CALLISTO spectrometer	IHY2007, ISW (ETH Zurich)	Observation band	100 - 850 MHz (187 - 242 MHz is attenuated notch filter)
		Time resolution	0.5 s
		Observation channel	400
		Frequency interval	Non unifomed
Log - periodic antenna	Creative Design Corp. CLP 5130-1	Receivable frequency band	50 - 1300 MHz
		Beam half power angle	70 - 60 $^\circ$
Notch filter	Japan Communication Equipment Corp.	Attenuated frequency	207 - 222 MHz (- 50 dB)
		Guard band	187 - 207 MHz, 222 - 242 MHz
Preamplifier	Mini-circuit Corp. (ZRL-700+)	Gain	30 dB
Attenuator	Mini-circuit Corp. (UNAT-20+)	Attenuated	-20 dB

Table 1: Specifications of instruments

3 Data analysis

Figure 3.1 show that the typical intensity changes of electromagnetic waves that emitted from typical flare. In this research, our observation data were compared with data NICT Yamagawa solar radio observatory. Our data were also compared with other electromagnetic waves data (GOES x - ray, Hida Observatory SMART Hα, SDO AIA 171 Å, 94 Å, Nobeyama radio polarimeter). Also, high energy electron velocities were calculated by using the equation of plasma frequency and electron density, and solar model.

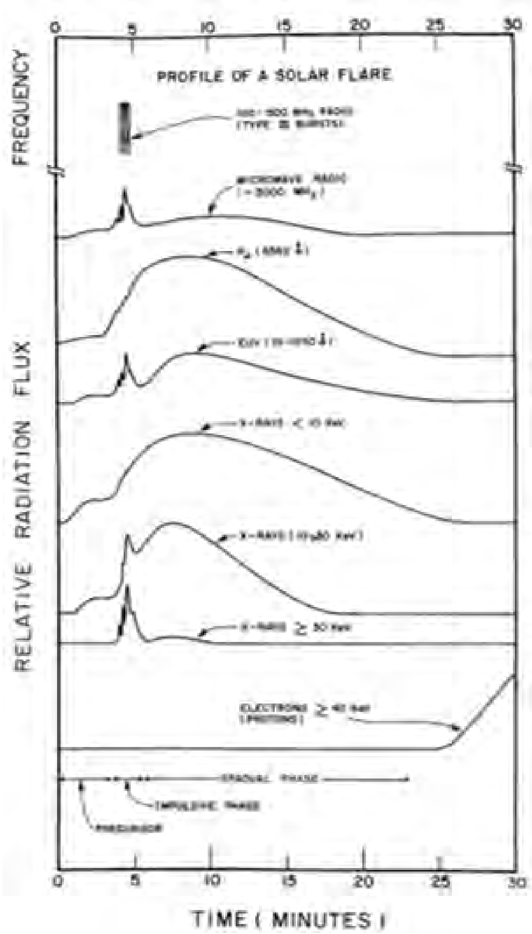

Fig. 3.1: Typical intensity changes of electromagnetic waves that emitted from typical flare. (kane 1974 IAU symp., 57 105)

3.1 Comparison with radio wave and other electromagnetic waves data

Our data were compared with x - ray, Hα, UV (171 Å, 94 Å) and microwave (1, 2, 3.75, 9.4, 17, 34 GHz). The data of Hα and UV are image data, so the pixel value of the range of flare occurred were added up respectively. This value were defined the intensity change. Figure 3.2 show that the range of flare each image.

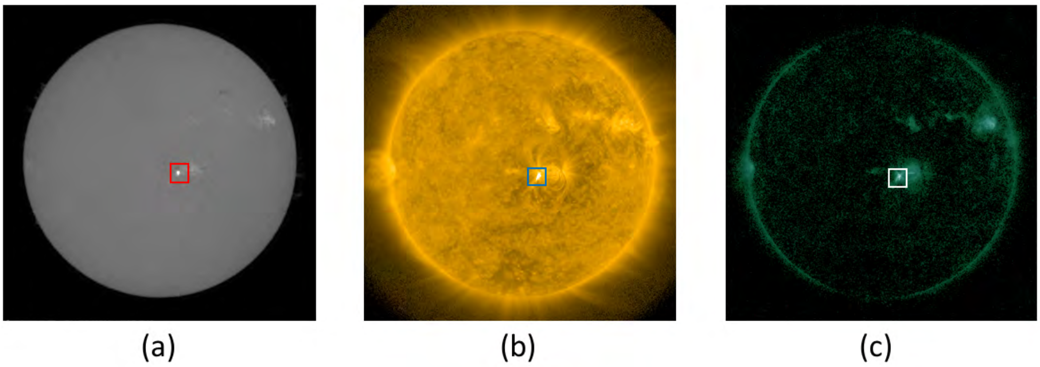

Fig. 3.2: The range of flare each image. (a)Hida observatory SMART Hα (b) SDO AIA 171 Å (c) SDO AIA 94 Å

3.2 Calculation of electron velocities

In this study, electron speeds were calculated as following.

- Confirm the frequency and time at the burst start and end (Point A and B of figure).
- The electron density is calculated by using the equation of plasma frequency and electron density : $F = 9\sqrt{n_e}$ [F : Frequency (kHz) , n_e : Electron density (cm^{-3})]
- Baumbach - Allen model (Cox 2000) is the formula of electron density and height of solar surface :

$$n_e = 10^8[2.99(\frac{R}{R_\odot})^{-16} + 1.55(\frac{R}{R_\odot})^{-6} + 0.036(\frac{R}{R_\odot})^{-1.5}]$$

[n_e : Electron density (cm^{-3}) R : distance from core $R_\odot$: radius of the Sun]
Coefficient of this formula depend on the event target (i.e. quiet regions or active regions). The coefficient of this case is 10 since the density in active region is high. Baumbach - Allen model (Coefficient = 10) is applied to Figure .

4 Result

4.1 Comparison with NICT Yamakawa observatory

Figure 4.1 and 4.2 show the type-III solar radio burst that was observed at NICT Yamagawa radio observatory and Ibaraki Univ. respectively. The time resolution of the NICT data is adjusted 1s from 8ms, and frequency resolution is also adjusted 1MHz from 31.25 kHz. Several bursts occurred in 30 seconds, and frequency drifts are seen each bursts. Box 1, 2 and red box in Figure shows different behavior with Ibaraki Univ. and NICT. Figure 4.3 shows that typical flare model and radio wave spectra. Like ”<” structure seen in spectra and this structure shows the loop top of the flare. Although this ”<” structure and type - II burst were seen in NICT data, they were not seen in Ibaraki Univ. data (figure 4.4) .

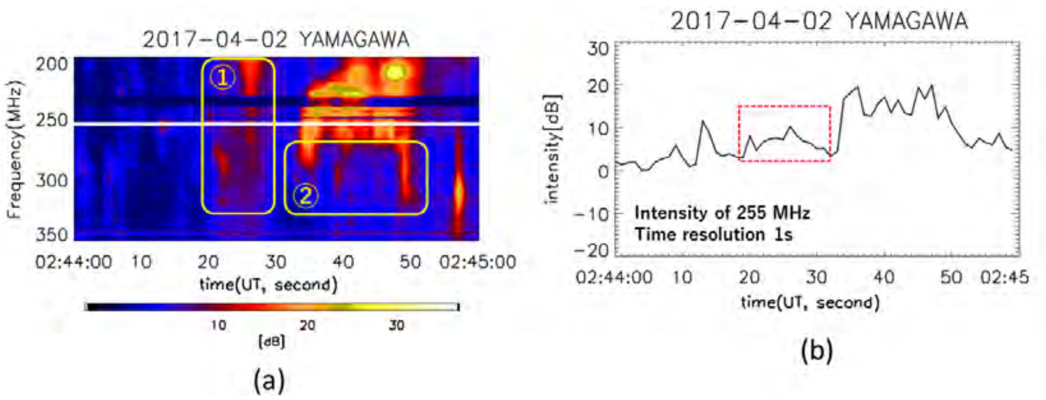

Fig. 4.1: (a) Observation result of NICT Yamakawa radio observatory. White line shows 255 MHz. (b) Intensity of 255 MHz in (a).

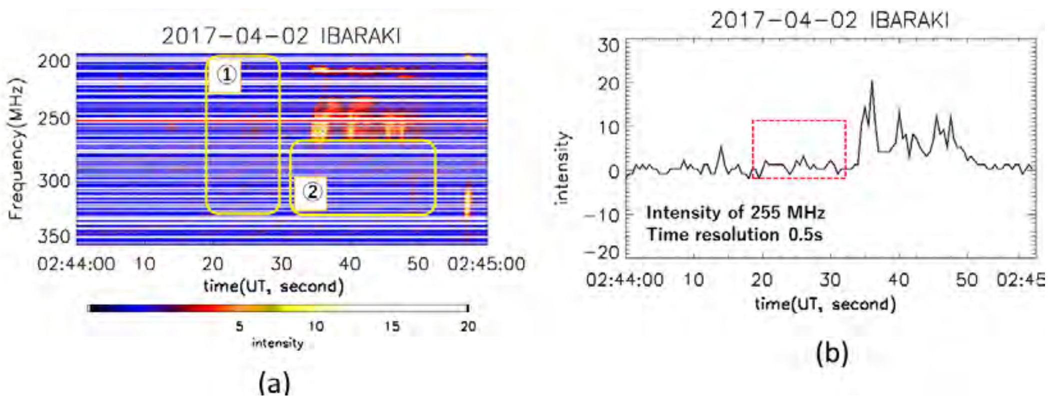

Fig. 4.2: (a) Observation result of Ibaraki Univ.. White line shows 255 MHz. (b) Intensity of 255 MHz in (a).

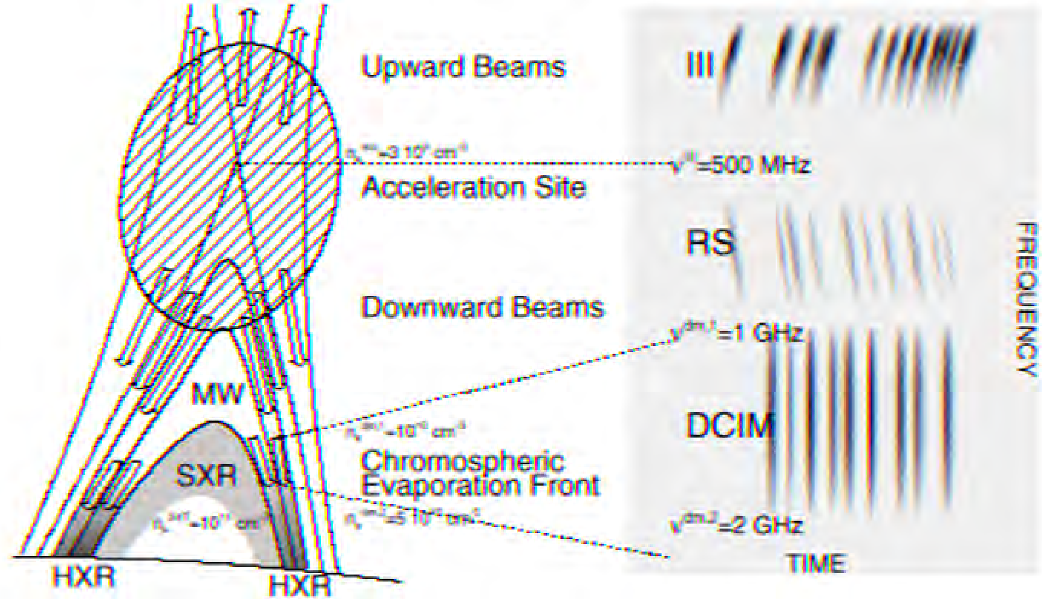

Fig. 4.3: Typical flare model and radio wave spectra. Like "<" structure seen bordering 500 MHz. (Aschwanden and Benz 1997, fig. 10)

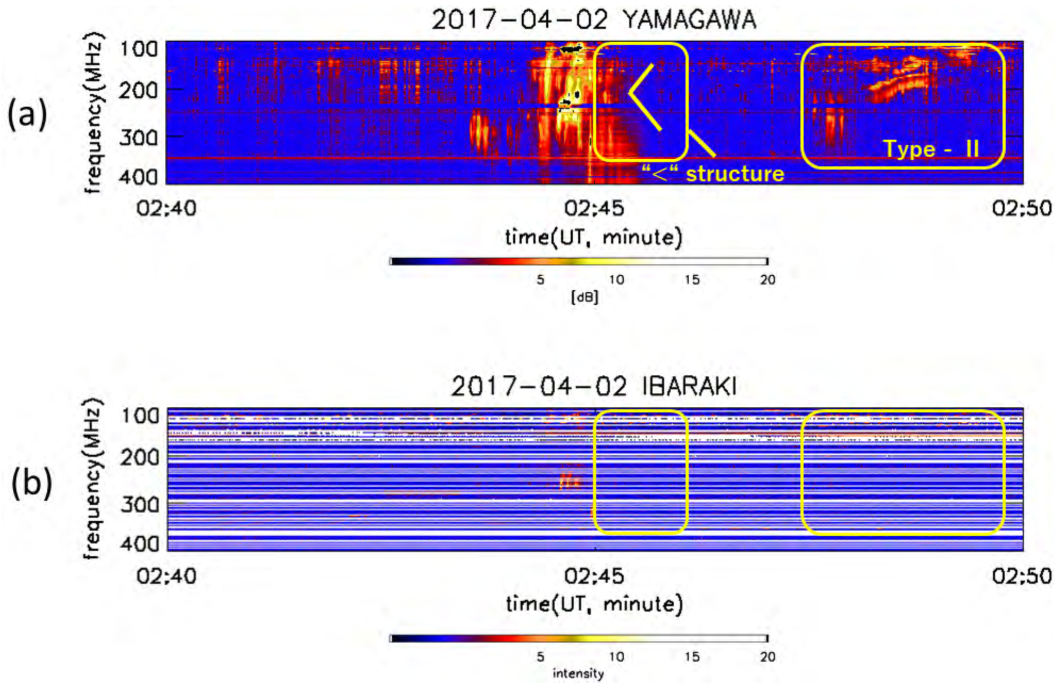

Fig. 4.4: (a) "<" structure and type - II burst that observed NICT. (b) Observation result of Ibaraki Univ.. Yellow boxes show that the time of "<" structure and type - II were seen in NICT data.

4.2 Comparison with radio wave and other electromagnetic waves data

Figure 4.5 and 4.6 show that intensity change of radio wave and other electromagnetic waves. From these figures, X - ray intensity and Hα intensity changed typically. Although both sharp peak and gentle peak are seen in typical UV intensity change, only one peak was seen in 171 Å intensity and two gentle peak were seen in 94 Å intensity. In typical flare, the peak time of microwave and meter radio burst are same. But in this flare, peak times of microwaves and meter radio type - III burst were not same time. Also, no peak were seen in 17 GHz and 35 GHz.

Figure 4.7 shows that the microwave data of NICT. This figure show that the type - III burst and microwave peak were not same bursts.

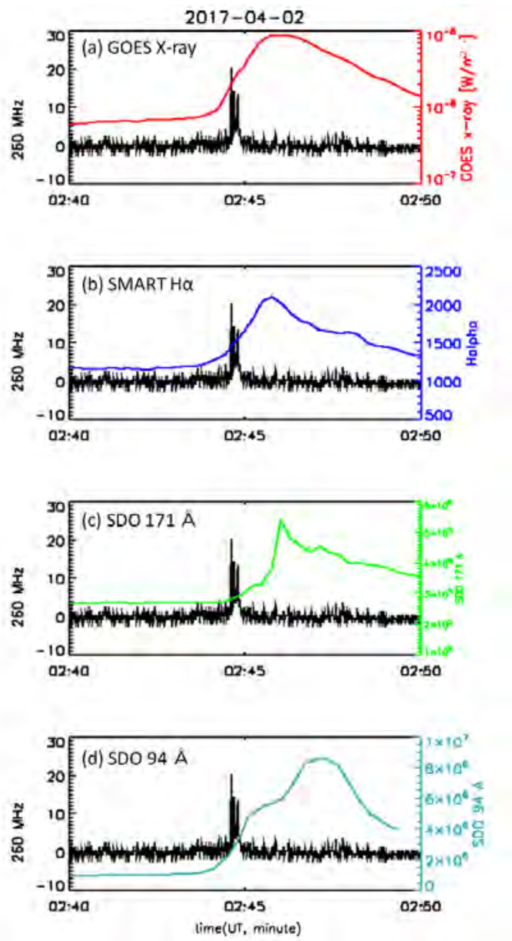

fig. 4.5

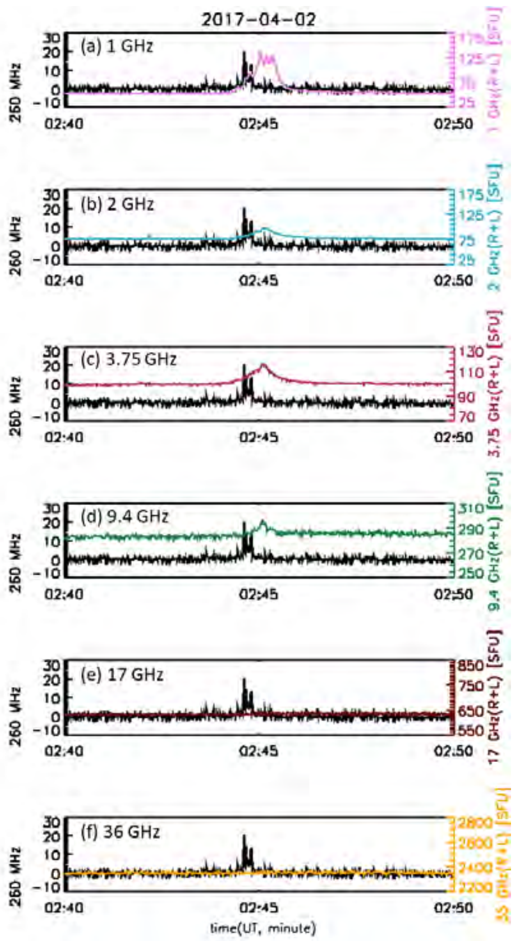

fig. 4.6

Fig. 4.5: Radio wave and other electromagnetic waves intensity. Black line : 260 MHz intensity, color line : other electromagnetic waves intensity. (a) GOES X - ray. (b) SMART Hα. (c) SDO 171 Å. (d) SDO 94 Å.

Fig. 4.6: Meter radio wave and microwave intensity. Black line : 260 MHz intensity, color line :microwave flux (SFU). (a) 1 GHz. (b) 2 GHz. (c) 3.75 GHz. (d) 9.4 GHz. (e) 17 GHz. (f) 35 GHz.

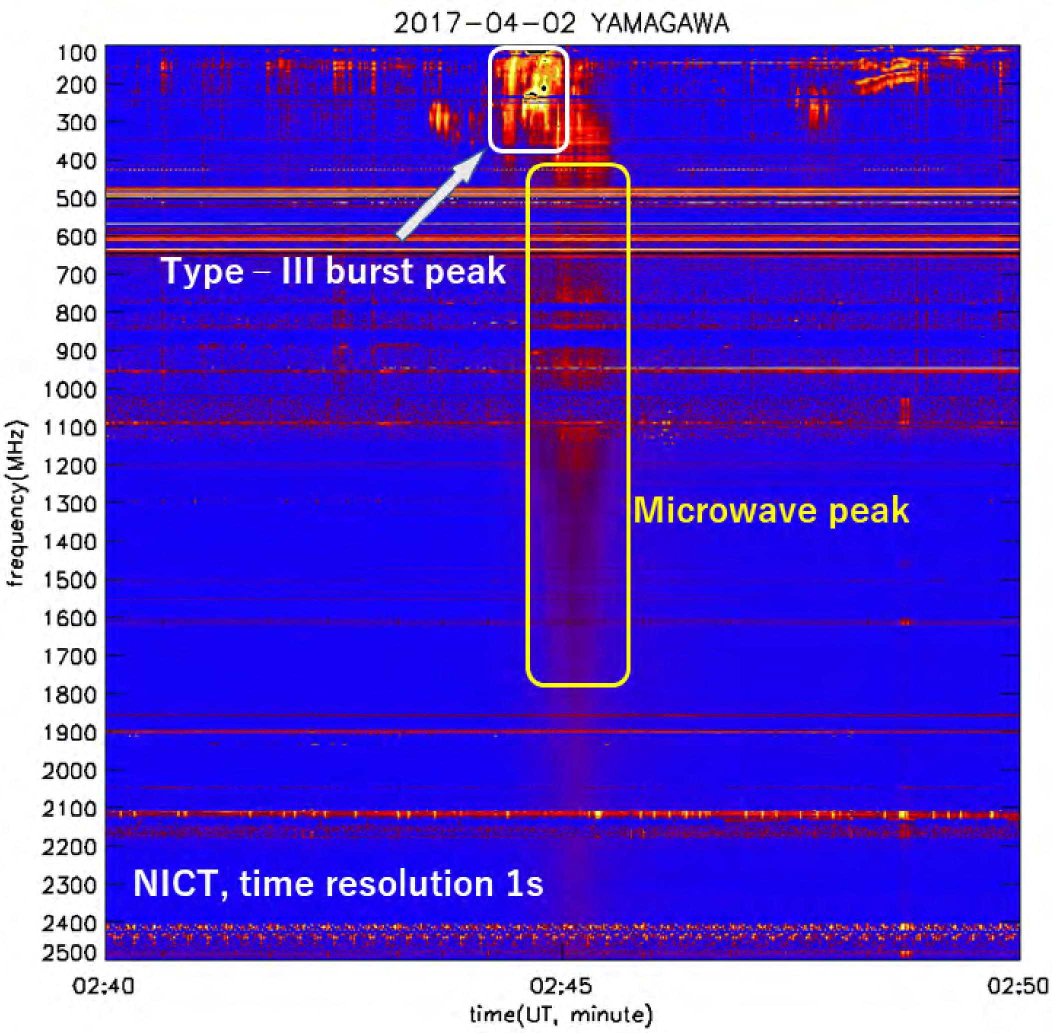

Fig. 4.7: (a) Observation result of NICT Yamakawa radio observatory. White box : type - III burst, yellow box : microwave peak.

4.3 Calculation of electron velocities

Figure 4.8 shows the speeds of accelerated electrons originating from the burst. This results show that electrons were accelerated to 3 17 % of light speed. The radio waves were observed in the range of 1.17∼1.21 $R_{\odot}$.

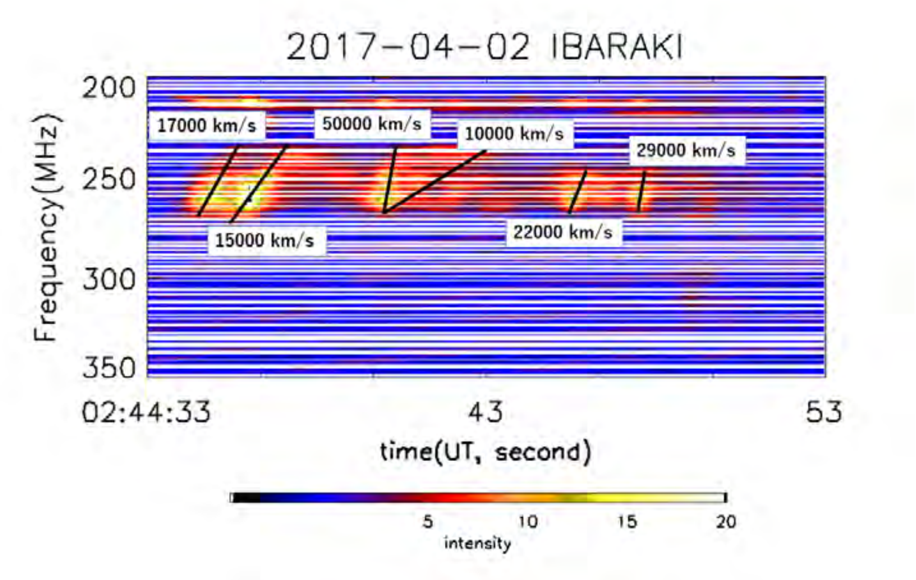

Fig. 4.8: Calculated electron velocities

5 Discussion

5.1 Comparison with NICT Yamakawa observatory

Although our observation system is smaller than other observation system, our observation system could observe some solar radio burst. The differences of NICT data and Ibaraki Univ. come from as follow. (1) Intensity of observed bursts is weaker than the others. (2) The CALISTO monitor at Ibaraki University is more plainness than NICT one. (3) Observable frequency channels of CALISTO of the Ibaraki University is less than NICT one.

5.2 Comparison with radio wave and other electromagnetic waves data

The intensity of X - ray and Hα changed typically, but the intensity of 171 Å and 94 Å didn't change typically. This reason come from the time resolution of AIA : the time resolution of AIA is about 10 seconds, so peaks of 171 Å and 94 Å were not seen.
In this flare, the time of microwave peak and type - III burst are not same because microwave peak and type - III burst are from different bursts. From these researches, it is assumed that the flare occurred April 2nd has complex structure.

5.3 Calculation of electron velocities

Although electrons are accelerated to 10 30 % of light speed driven by solar flare in generally, the result in this case is 3-17 % of light speed. Acceleration in our result shows slightly slower than typical one. This difference of electron acceleration might be attribute of the observation band of Ibaraki University. Further these electron velocities should be calculate with other solar atmosphere model.

6 Conclusion

In this research, the observation system of Ibaraki Univ. can observe solar radio burst, and electron velocities can be calculated from these data. On the other hand, these analysis were qualitative research. In the future, we would like to analysis using simulation model and compare with theoretical value and observation data.

References

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- Cox, A.N.(ed.) 2000, Allen's Astrophysical Quantities

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