Available online at www.worldscientificnews.com

World Scientific News

WSN 46 (2016) 19-35 EISSN 2392-2192

Coronal Electron Density Distribution Estimated from Meter Type II Radio Bursts and Coronal Mass Ejections

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ABSTRACT

In this paper, we investigate the characteristic coronal mass ejection and Type II radio burst, we calculated the drift rate of Type II Radio burst and determined the electron density distribution from a Coronal Mass Ejections. The data were taken from website e-CALLISTO, Space Weather, SolarHam and also from the Langkawi National Observatory, National Space Agency, Langkawi Kedah, Malaysia. All the data collected on 15th March 2015, 4th November 2015 and 16th December 2015. On 16 March 2015, the events were associated with slower C9 solar flare and CME. For this week, the events were causing radio blackouts on Earth. On 4 November 2015, the events were associated with M1.9 solar flare, CME and Solar burst Type II. The value of the solar wind was 570.4 km/Sec and value for radio sun was 124 sfu. For drift rate, we calculated the value for sites in Sri Lanka (ACCIMT-SRI), Ooty, India (OOTY), Indonesia (INDONESIA) and Kasi, South Korea (KASI) at between 0324 to 0328 UTC. In South Korea was highest drift rate, which is 1.397 MHz/s. Also, at HB9SCT, Switzerland (HB9SCT), Humain, Belgium (Humain), Daro, Germany (Daro-VHF) and TCD in Birr, Ireland (BIR), we calculated the drift rate of solar burst Type II between 1200 until 1203 UTC. In Belgium had the highest value of the drift rate to compare at other sites. Harmonic pattern was also appeared for all these sites. On 16th December 2015, this event associated with C6.6 solar flare and CME. These events give an impact on the earth geomagnetic field which is formed of aurora because of the combination of both events that trigger geomagnetic storming.

Keywords**:** coronal mass ejection; Type II radio burst; electron density distribution; e-CALLISTO

1. INTRODUCTION

Based on astrophysicists, the Sun as a star at middle age because the characteristic of the sun such as brightness, temperature and average size [1]. The Sun is a ball of furiously raging plasma and it is mostly hydrogen and it blazes with an acetylene- torch brilliance. The structure of the sun can be divided by five sections which are the interior, thermonuclear fusion, the surface atmospheres, the inner corona and the outer corona [2]. The interior of the sun includes the core, radioactive layer and convective layer. The thermonuclear fusion, where occur in the core Sun, changes hydrogen nuclei into helium nuclei that release prodigious quantities of energy. Meanwhile, at the surface atmosphere, consists of photosphere and chromosphere [3]. Photosphere can be seen with our eyes and light from orange, red layer and chromosphere usually weak to be seen and should never look at directly anyway. The chromosphere can be divided by two which are upper and lower and chromosphere [4].

The sun consists of sunspot, magnetic field, and filament [5]. These are important elements of the phenomena and surface activity in the Sun which is phenomena prominence, solar flares and Coronal Mass Ejections as shown in Figure 1. The prominence associated with the sunspot which sun spot consists of North Pole and South Pole and occur bright feature extending outward from the Sun [6]. Meanwhile, solar flare is a magnetic storm on the Sun which appear very bright spot and gas surface eruption. Coronal Mass Ejections (CMEs) are huge explosion of plasma and magnetic field the Sun corona [7].

Coronal Mass Ejections (CMEs) was discovered since early 1970s by using coronagraph observation, this is a phenomena happened at solar outer atmosphere where there are flare thermal energy and plasma kinetic energy from magnetic energy, and the sun have losses, mass erratically and appear with events occurring during lower down in the atmosphere, propagate up into the corona with solar flare and appear white light [8-10]. Characteristics of regions coronal holes is low density that associated with high speed solar wind, open magnetic fields [11]. The changing structure of the corona because of CMEs can cause solar wind disturbances. Fast mode MHD shocks with interaction of CMEs with solar wind, which accelerates charged particle with very high energies [12]. From sunspot region, the CMEs associated with interplanetary type II burst, solar energetic particles and shock driving CMEs [13].

Solar burst can be divided into five groups which are Type I, Type II, Type III, Type IV and Type V [14]. The type II burst is the result from plasma emission mechanism [15,16].

The electron beam excited the waves and produced in propagating shock, thus converted waves into escaping radio waves. The characteristics of Type II are usually happening in slow frequency drift burst with strong intensity second harmonic and usually associated with flare, proton emission, magnetohydrodynamic shock waves [17,18]. The duration of burst usually is about 3 minutes to 30 minutes and the range of frequency is about 80-200 MHz. Type II radio bursts (Decameter – hectometric) wavelengths indicate powerful MHD shocks, leaving the inner solar corona and entering the interplanetary medium. All these bursts associated with wider and faster than average CMEs [11]. Flares that associated with CMEs and Type II burst more energetic and impulsive to compare flare without CMEs.

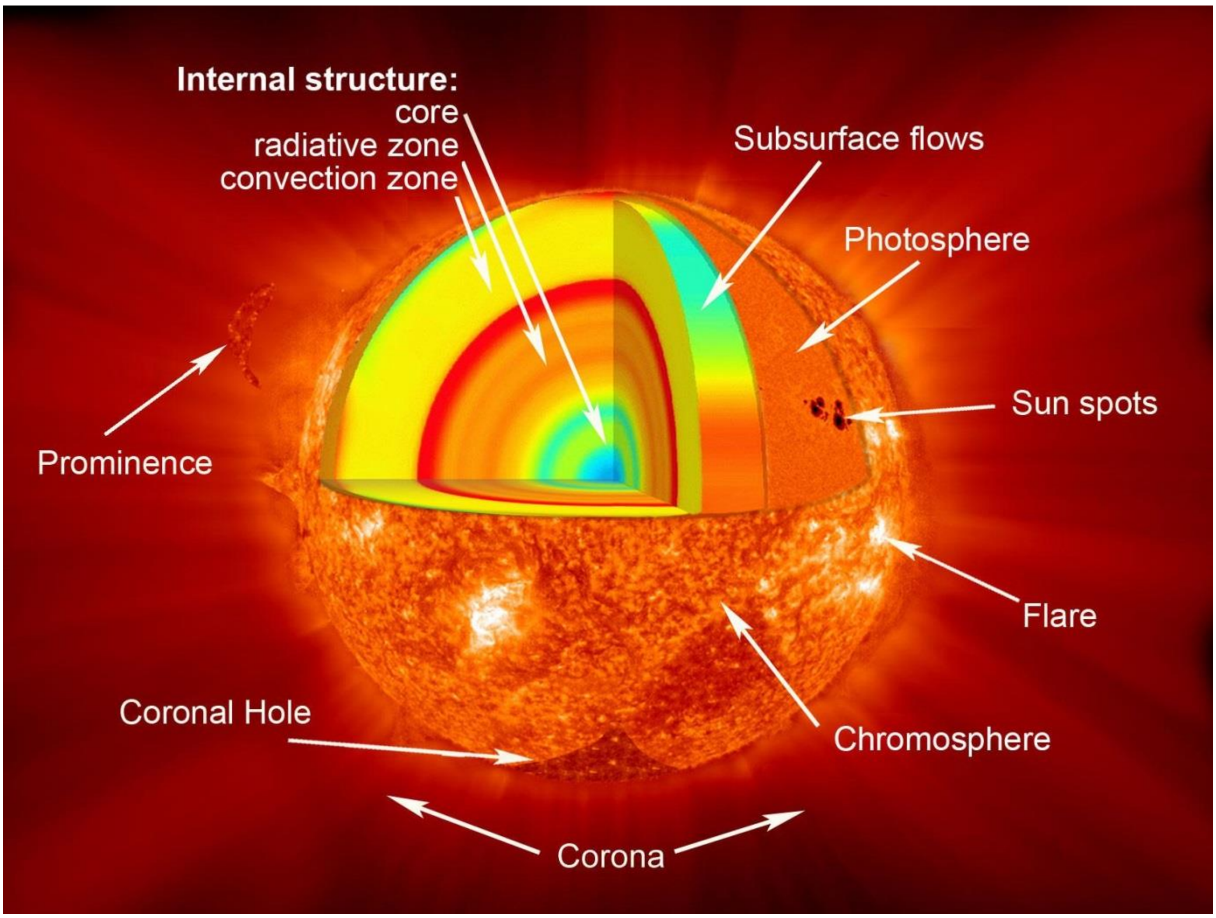


Figure 1. The structure of the Sun.

The most important parameter that's used in astrophysical and laboratory plasmas are the electron density (Equation 1) and temperatures of various plasma structures of the corona, active region - flare and coronal mass ejections. The energy of phenomena we can calculate by using formula:

$$\mathbf{E} = \boldsymbol{hf}$$

where $\boldsymbol{h}$ is plank's constant
$\boldsymbol{f}$ is frequency

Electron density

$$\mathrm{Ne} = \frac{\mathrm{v_p}^2 4\pi\epsilon_0 \mathrm{m_e}}{\mathrm{e}^2}$$

the plasma frequency

$$\mathrm{v_p} = \sqrt{\frac{\mathrm{e}^2\mathrm{Ne}}{4\pi\epsilon_0 \mathrm{m_e}}} \tag{1}$$

The decreasing of the frequencies can be effected to the decreasing of the drift rate where the drift rate of the solar burst can be calculated using Equation 2 [19]. The drift rate (displacement of the peak in frequency per unit time) was determined by taking the value of start frequency to end of the frequency and taking the value of start the time until the end of the time of solar burst. The frequency drift rate of the solar burst also can be known a power law in the frequency of emission.

$$\text{Drift Rate} = \frac{df}{dt} = \frac{(f_e - f_s)}{(t_e - t_s)} \left(\frac{MHz}{s}\right) \tag{2}$$

where f_e = frequency of end times

f_s= frequency of start time

t_e= end time

t_s= start time

From different spectral domains [metric (m), decameter-hemotrometric (DH) and kilometre (km) wavelength], this power law can be used from different or same events [2]. The resulting of bursts from characteristics of speed shock related to the drift rate of the type II burst [3].

2. METHODOLOGIES

In this paper, we investigate coronal electron density from meter, type II and Coronal Mass Ejections because of the previous study it was noticed that during the period of high solar activity, it was noticed that the CME energy is more correlated to the X-ray flux of the associated flares. However, it is only barely understood how the distribution of the electron density and the behaviour of coronal mass ejections and solar flare in the corona.

We calculated the coronal electron density distribution from characteristics of coronal mass ejection of the Sun, calculated the drift rate of solar radio burst type II, and determined the others characteristic of coronal mass ejection and Type II burst. The event of this phenomenon was collected from the CALLISTO system [20]. The CALLISTO Spectrometer is a programmable heterodyne receiver by former Radio and Plasma Physics Group (PI Christian Monstein) build on the framework of IHY2007 and ISWI. This application most to monitor of Radio Frequency Interference (RFI) and observation of solar radio burst for astronomical science, education and outreach [21].

The data obtained from CALLISTO is FIT files with to 400 frequencies per sweep and transferred via a RS-232 cable to the computer and saved.

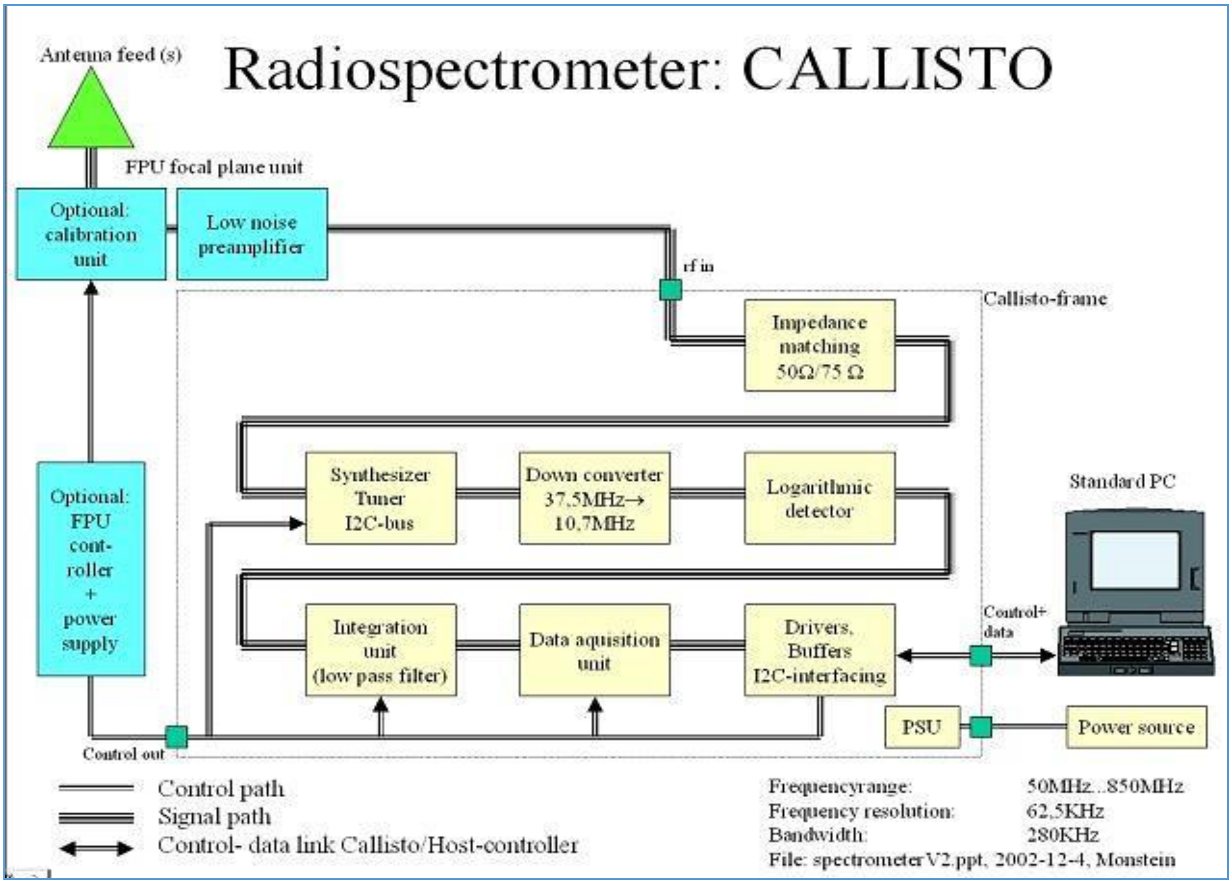


Figure 2. The flow of the process Radio Spectrometer CALLISTO (credited to e- CALLISTO

Figure 3. The TMB 152/1200 APO and other telescopes on paramount-ME as viewed inside the LNSO Dome (credited to Langkawi Observatory).

The CALLISTO process between 45 MHz and 870 MHz by a modern, broadband cable TV tuner CD1316 with frequency resolution of 62.5 KHz. CALLISTO also had a link to website Space Weather News and information about the Sun- Earth environment, SolarHam Amateur Radio Station. All the data and events, we had collected from e-CALLISTO, Space Weather and SolarHam.

The data also collected from the Langkawi National Observatory, National Space Agency (ANGKASA), Malaysia. This observatory located at Empangan Bukit Malut, 07000 Bukit Malut, Langkawi Kedah, Malaysia. The telescope in Langkawi Observatory was designed to observe the full disk of the Sun in Continuum and Hydrogen – Alpha with optical tube, 3.5” Starlight focuser, Set CNC tube rings, 2”/1.25” adapter and 50 mm finder bracket.

3. OBSERVATIONS AND ANALYSIS

3. 1. Event on 15th MARCH 2015

On 15th March 2015, at 00:45 and 02:00 UT, from region sunspot AR2297 (Figure 3) a magnetic filament erupted with a slow C9- class solar flare. At 02:13 UTC (March 15), a long duration C9 flare may have produced a coronal mass ejection (CME) . Sunspot AR2297 has beta - gamma delta magnetic field that harbors energy for x - class solar flares. For much of the past week, sunspot AR2297 also was causing radio blackouts on Earth and on 12 march the sunspot did the opposite.

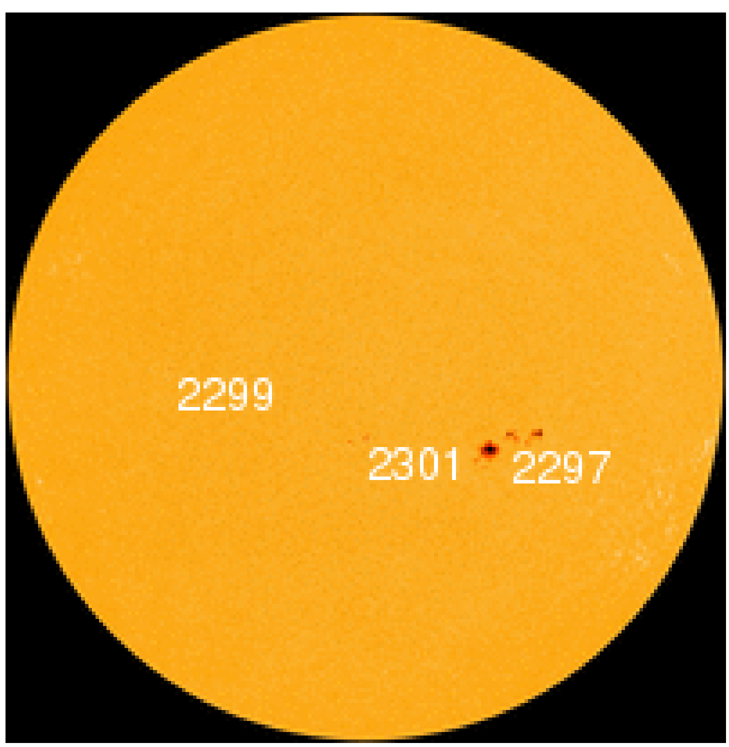


Figure 3. Active Region AR2297 on 15 March 2015 (credited to SpaceWeather)

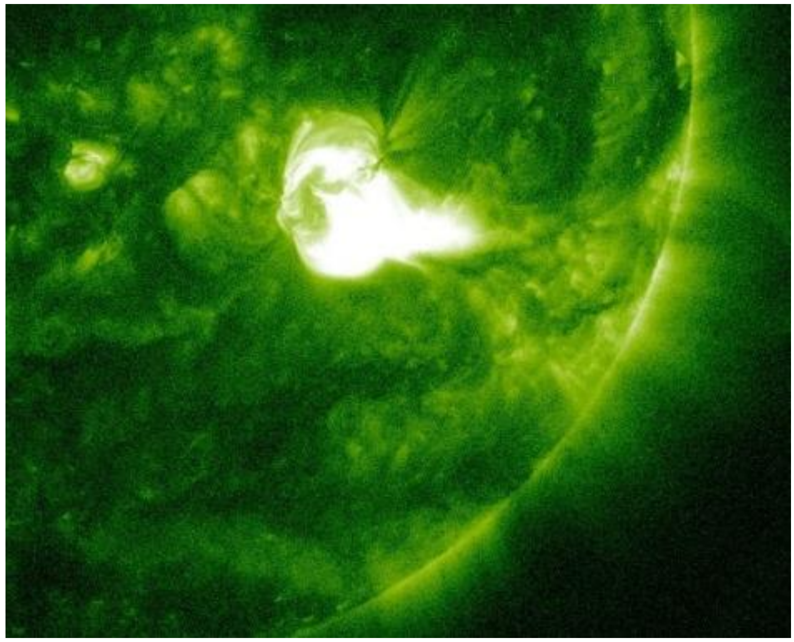


Figure 4. Coronal mass ejection on 15 March 2015 at 02:13 UTC using Solar Dynamic Observatory (SDO) of the 94 angstroms channel (credited to SOLARHAM)

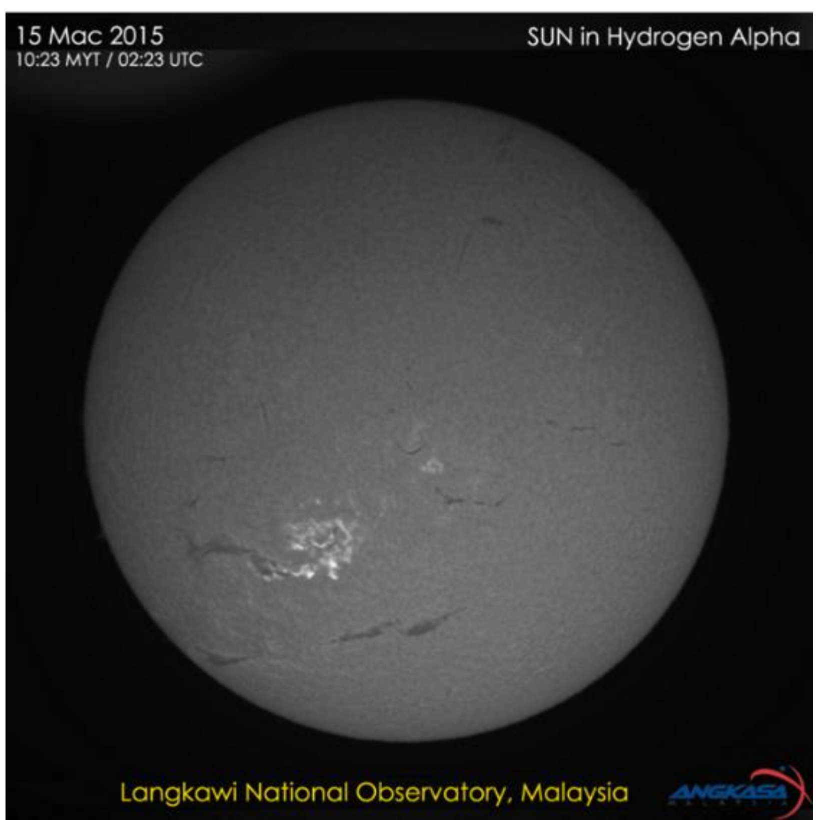


Figure 5. Sun in Hyrogen Alpha on 15 March 2015 (credited to Langkawi Observatory)

3. 2. Event on 4th NOVEMBER 2015

During 4th November 2015, the active region 2445 (Figure 6) at 03;26 UTC solar activity was increased to moderate levels with M1.9 solar flare. The flare was associated with a Type II radio emission and associated estimated velocity of 790 km/s. A coronal mass ejection (CME) was appeared to be directed to the west and away from the earth.

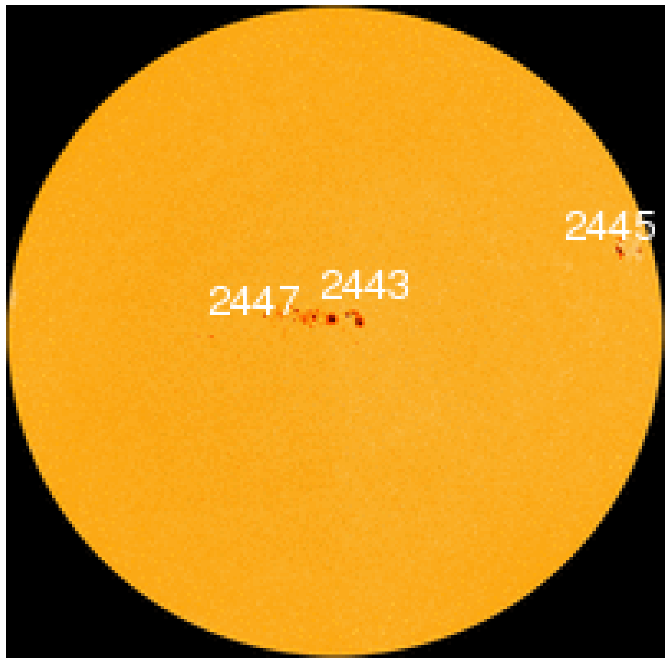


Figure 6. Active Region AR 2445 on 4 November 2015 (credited to the SpaceWeather)

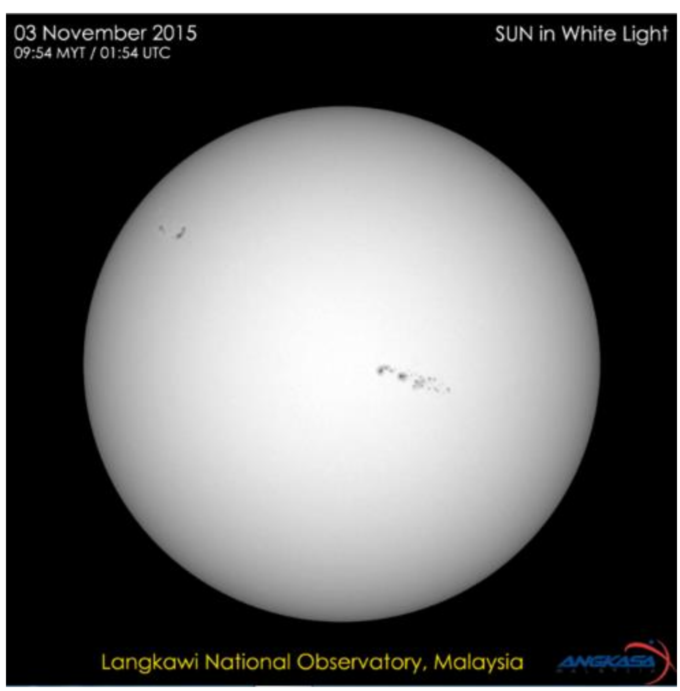


Figure 7. Sun in white light on 3rd November 2015 (credited to the Langkawi Observatory)

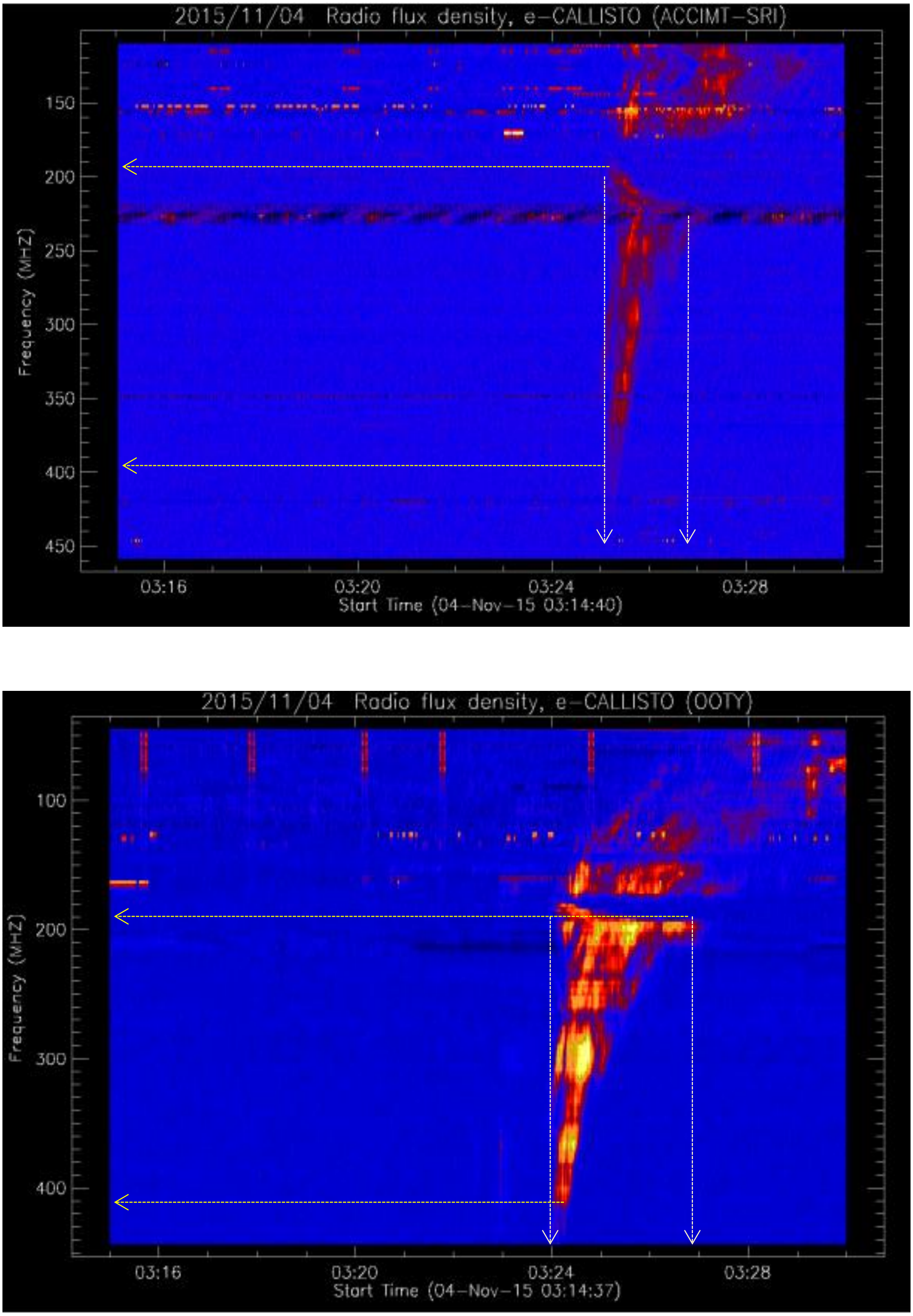


Figure 8. The comparison of solar burst Type II on 4th November 2015 at 0324 UTC (credited to e-CALLISTO)

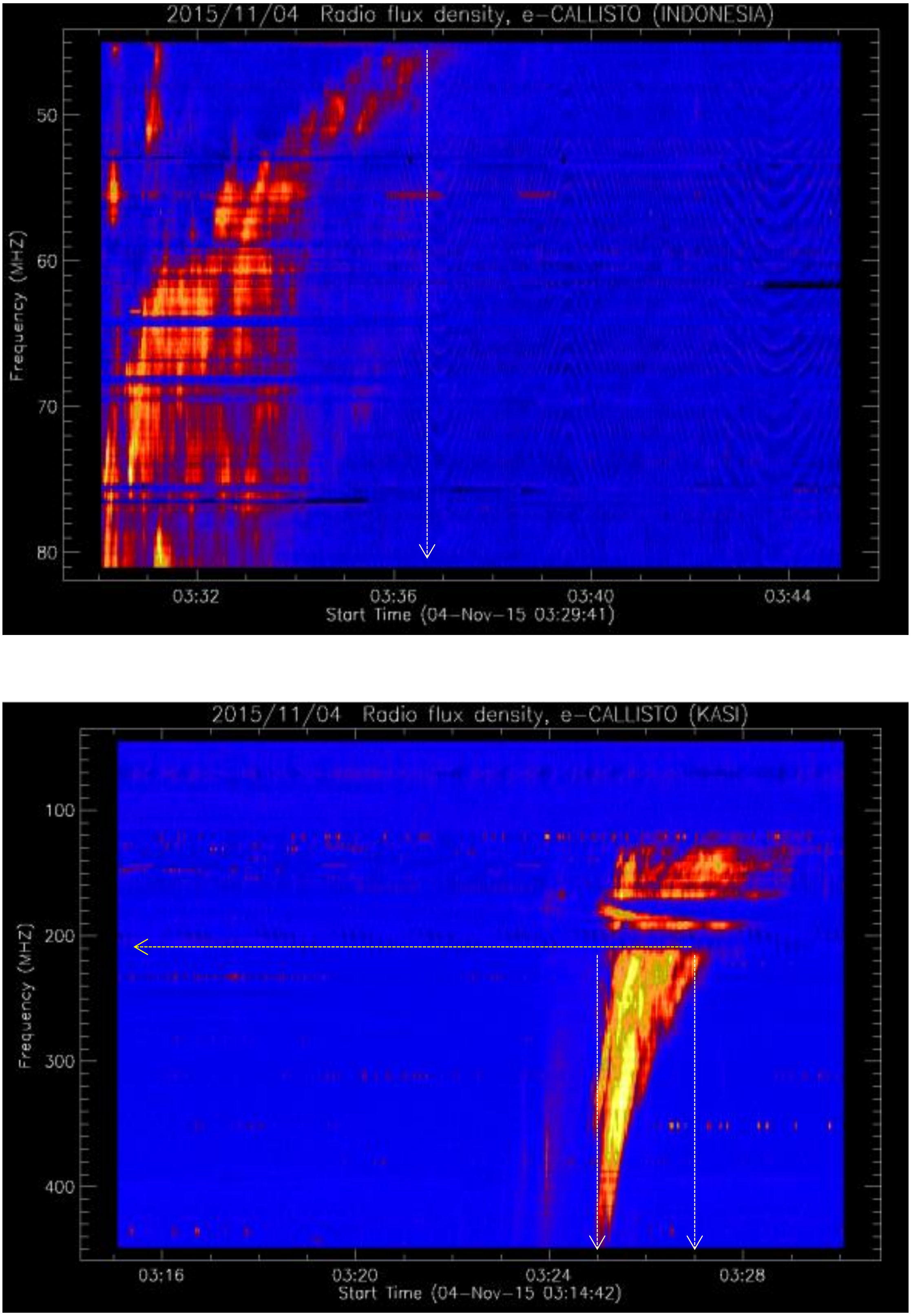
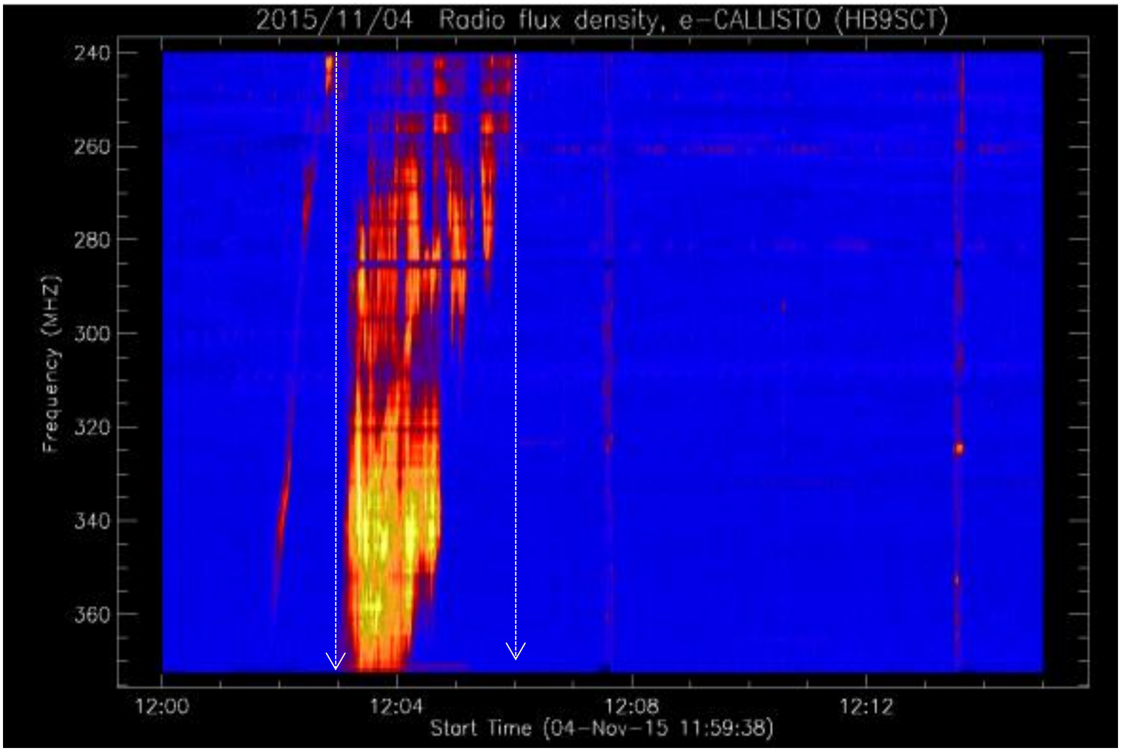


Figure 8(continue). The comparison of solar burst Type II on 4th November 2015 at 0324 UTC (credited to e-CALLISTO)



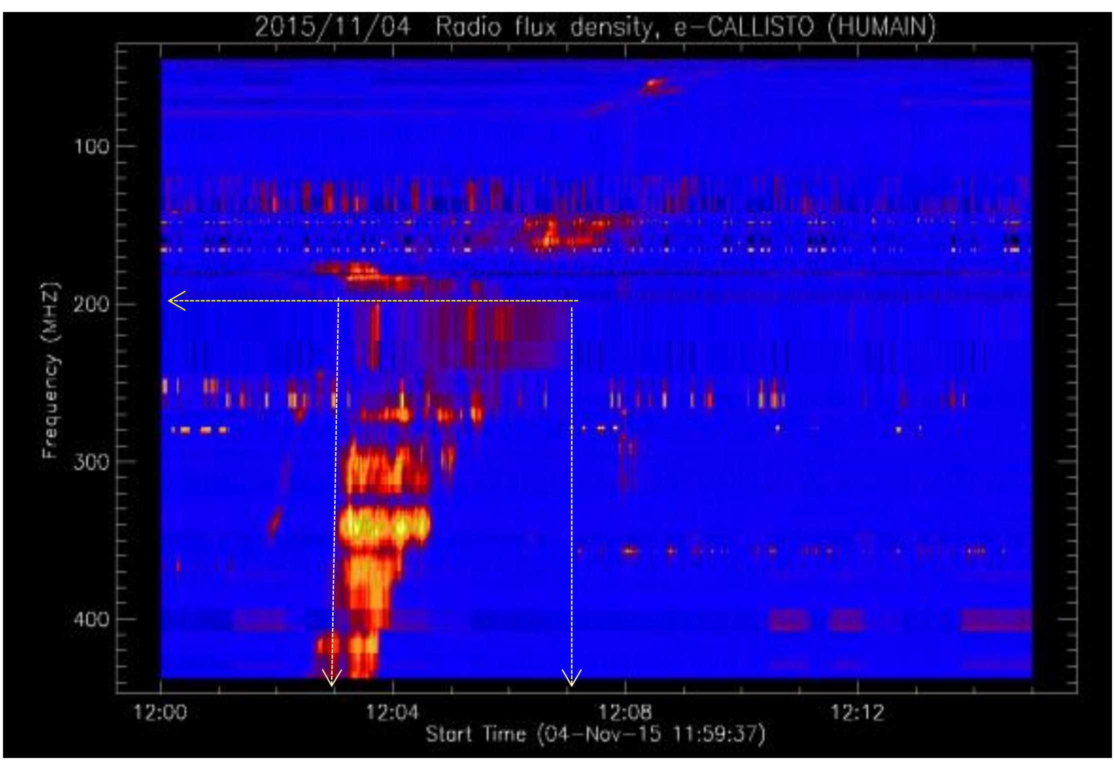
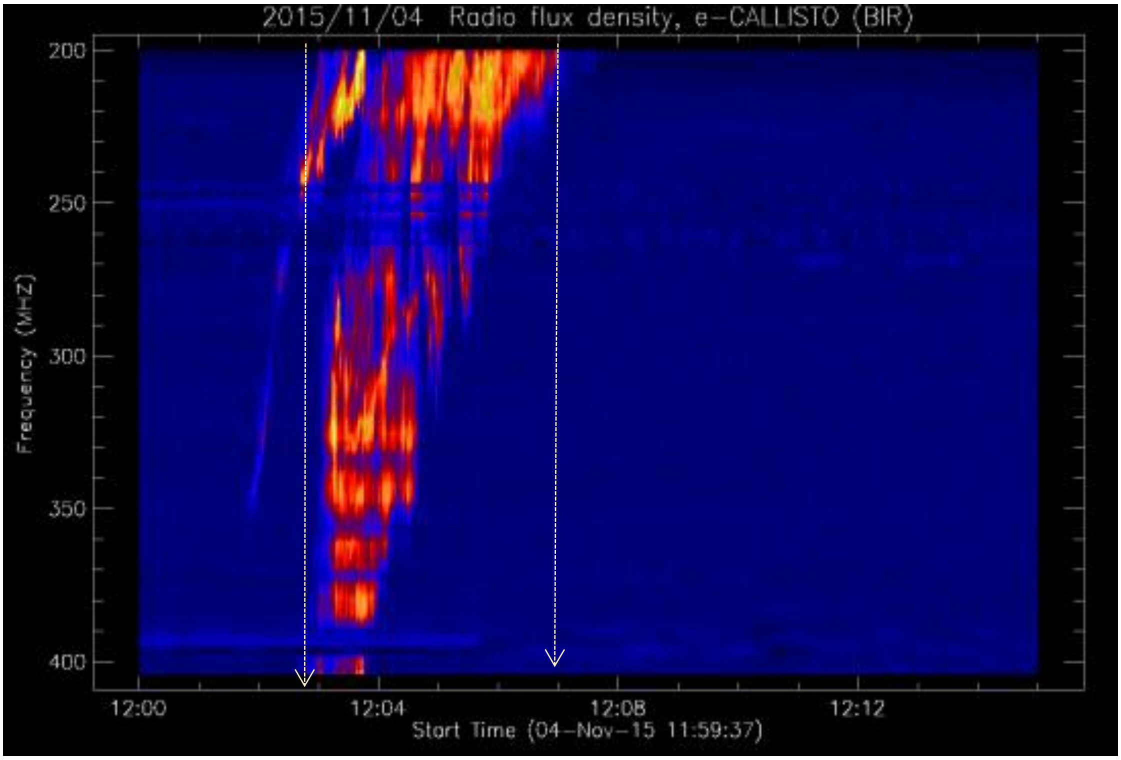


Figure 9. The comparison of solar burst Type II on 4th November 2015 at 1203 UTC (credited to e-CALLISTO



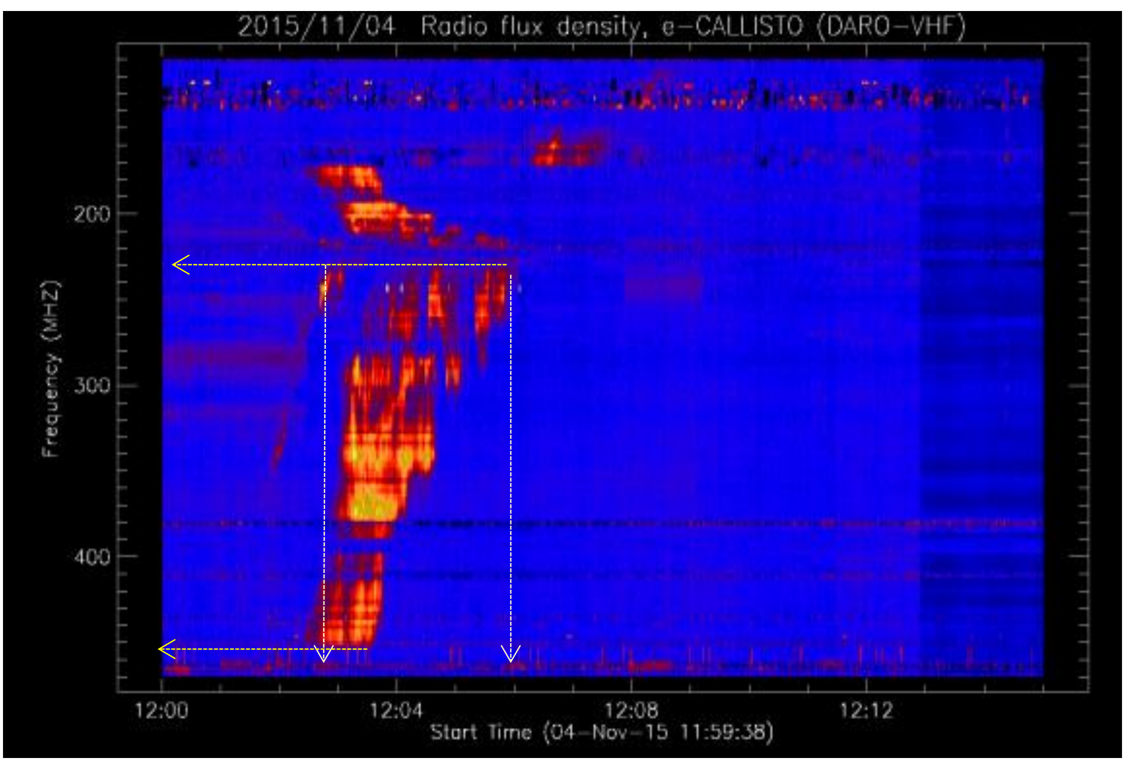


Figure 9(continue). The comparison of solar burst Type II on 4th November 2015 at 1203 UTC (credited to e-CALLISTO)

Thus, the data that we get from the CALLISTO status report #59, we calculated the value of the drift rate of solar burst Type II at different sites which are in Sri Lanka (ACCIMT-SRI), Ooty, India (OOTY), Indonesia (INDONESIA) and Kasi, South Korea (KASI) at between 0324 to 0328 UTC. We found that the value of the drift rate in Sri Lanka was 0.9167 MHz/s. This value also was same in Ooty, India. Meanwhile the value of the drift rate in Indonesia was 1.222 MHz/s and in South Korea was 1.379 MHz/s. We can see that in South Korea was the highest drift rate to compare in the Sri Langka, Ooty India and Indonesia. For all these sites is a harmonic frequency appeared.

Thus, for the sites at HB9SCT, Switzerland (HB9SCT), Humain, Belgium (Humain), Daro, Germany (Daro-VHF) and TCD in Birr, Ireland (BIR), we calculated the drift rate of solar burst Type II between 1200 until 1203 UTC. The value drift rate in Switzerland was 0.75 MHz/s and this value same within Germany. In Ireland the value drift rate was 0.8375 MHz/s and Belgium was 1.125 MHz/s. In Belgium had the highest value of the drift rate to compare at other sites. Harmonic pattern was also appeared for these sites.

3. 3. Event on 16th DECEMBER 2015

On 16th December 2015, there are two coronal mass ejections was happening. First occur at 0903 UTC with of a C6.6 solar flare and appears to have faint full halo characteristic and could give effect to the Earth. Second CME happened at 1345 UTC because of eruptive events along a filament in the southeast quadrant with brighter, full halo coronal mass ejection. These events give an impact on the earth geomagnetic field which is ***formed of aurora*** because of the combination of both events that trigger geomagnetic storming.

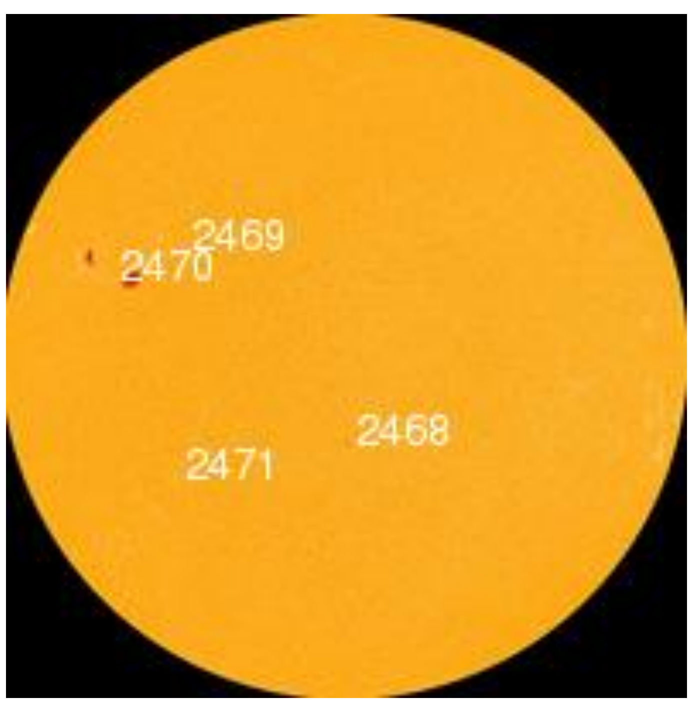


Figure 10. Big Active Region AR2470 poses a slight threat for M class solar flare on 16 December 2015 (credited to Spaceweather)

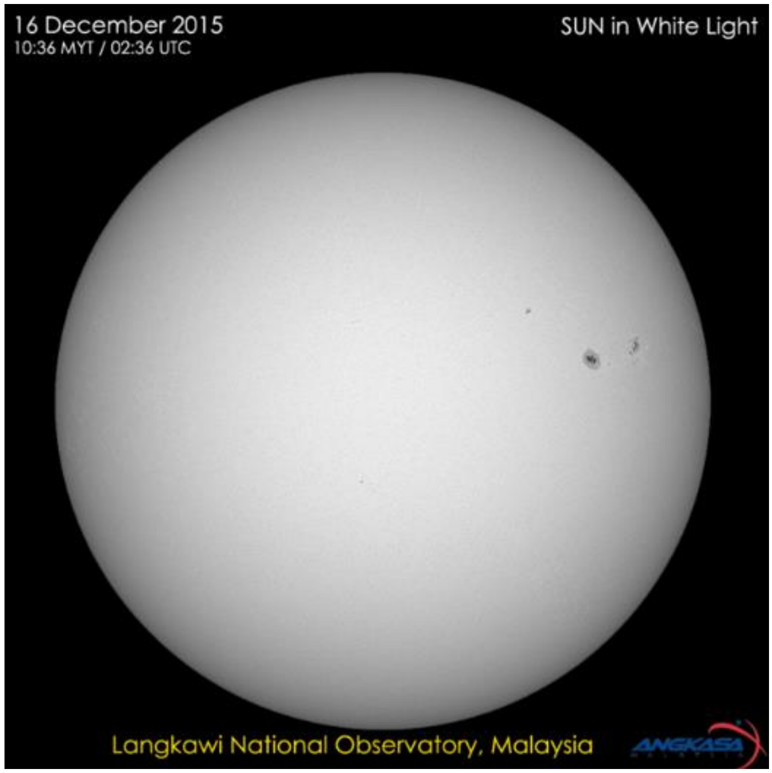


Figure 11. Sun in white light on 16th December 2015 (credited to Langkawi Observatory)

The observation was observed during on 15th November 2015, 4th November 2015 and 16th December 2015.

Table 1. The data of events on 15 March 2015, 4 November 2015 and 16 December 2015 (credited to Space Weather)

Date	15/03/2015	16/12/2015	04/11/2015
Time (UTC)	2 : 13	9 : 03 13: 45	12 : 04
Solar wind Speed: Density:	322.2 km/sec 7.0 protons/ cm^2	395.4 km/sec 2.6 protons/ cm^2	570.4 km/sec 1.4 protons/ cm^2
X ray Flares 6 hr max : 24 hr :	C7 2256 UT Mar15 C9 0213 UT Mar15	B7 1715 UT Dec16 C6 0903 UT Dec16	C1 1700 UT Nov 04 M3 1353 UT Nov 04
Sunspot number	56	64	95
Radio sun	10.7 cm flux : 116 sfu	10.7 cm flux : 119 sfu	10.7 cm flux : 124 sfu

4. DISCUSSION

From the data that collected from SpaceWeather (Table 1), we want compared relationship the difference of the speed and density on 15 March 2015, 4 November 2015 and 16 December 2015. The density that is given in protons/cm^3, then we assume the proton is approximately with electron. We can see that the increasing the speed wind, the decreasing of electron density. On 4 November 2015, the coronal mass ejection was associated with Type II burst, then, it has the highest of solar wind, which is 570.4 km/sea and the highest of radio flux which is 124 safe to compare the other events. The number of sunspots on 4 November 2015 also have the highest to compare with other events. The higher number of sunspots associated with the occur of the solar burst and CMEs. The primary sources CMEs because of active regions on the Sun that containing sunspots' and plagues [5]. For the highest drift rate of the Type II burst that we compared on 4th November 2015 was occurring in South Korea 1.379 MHz/s. Harmonic pattern was appeared for all burst Type II burst on the sites that we compared.

5. CONCLUSION

In conclusion, although the solar flare, it is possible to form solar radio burst type II that associated with CME event. The frequency ant time that we get from solar burst type II we can find the drift rate of that frequency. We also can determine the characteristic of solar burst Type II. From the events, we can also, find the value of electron density distribution and the energy from the events. To focus on this point, the events of coronal mass ejection and solar burst Type II have been studied as well.

ACKNOWLEDGMENT

We are grateful to CALLISTO network, STEREO, LASCO, SDO/AIA, NOAA, SOHO, SolarMonitor and SWPC make their data available online. This work was partially supported by the 600-RMI/FRGS 5/3 (135/2014) and 600-RMI/RAGS 5/3 (121/2014) UiTM grants and Kementerian Pengajian Tinggi Malaysia. Special thanks to the National Space Agency and the National Space Centre for giving us a site to set up this project and support this project. Solar burst monitoring is a project of cooperation between the Institute of Astronomy, ETH Zurich, and FHNW Windisch, Switzerland, Universiti Teknologi MARA and University of Malaya. This paper also used NOAA Space Weather Prediction Centre (SWPC) for the sunspot, radio flux and solar flare data for comparison purpose. The research has made use of the National Space Centre Facility and a part of an initiative of the International Space Weather Initiative (ISWI) program. We are also thanks to the Langkawi National Observatory,National Space Agency,(ANGKASA), Empangan Bukit Malut 07000 Langkawi, Kedah, Malaysia, for giving us the facility to book and use the discussion room to complete this paper.

References

[1] Aschwanden, M.J., *Physics of the Solar Corona, an Introduction*. 2004, Berlin: Springer.

[2] Benz, A.O., *Solar and Stellar Coronae*. 2002: Kluwer Academic Publishers.

[3] Gary, D.E.K., *Solar and Space Weather Radiophysics { Current Status and Future Developments* 2004, Dordrecht: Kluwer.

[4] Goldman, M.V. and D.F. Smith, *Physics of the Sun*. Vol. 2. 1986: Dordrecht: Reidel.

[5] Labrosse, N., et al., *Physics of Solar Prominences: I - Spectral Diagnostics and Non-LTE Modelling.* Space Sci. Rev., 2010. 151: p. 243-332.

[6] Kundu, W., *Solar and Space Weather Radiophysics*. Vol. 89. 2004, Dordrecht: Kluwer.

[7] Mackay, D.H., et al., *Physics of Solar Prominences: II - Magnetic Structure and Dynamics.* Space Sci. Rev., 2010. 151: p. 333-399.

[8] Klimchuk, J.A., *Theory of Coronal Mass Ejections*, in *Space Weather*, P. Song, Singer, H.J., Siscoe, G.L., Editor. 2001: American Geophysical Union, Washington, DC.

[9] Z.S. Hamidi, et al., *Observations of coronal mass ejections (CMEs) at low frequency radio region on 15th April 2012*, in *PERFIK 2012*, R.Shukor, Editor. 2013, American Institute of Physics: Malaysia. p. 5.

[10] Hamidi, Z., *Probability of Solar Flares Turn Out to Form a Coronal Mass Ejections Events Due to the Characterization of Solar Radio Burst Type II and III.* International Letters of Chemistry, Physics and Astronomy, 2014. 16(1): p. 85.

[11] Hamidi, Z.S., et al., Solar studies in radio emission and optical photometry. Vol. 1. 2013: University of Malaya Publisher.

[12] Hamidi, Z.S., et al., *An X-ray Observations of A Gradual Coronal Mass Ejections (CMEs) on 15th April 2012 International Letters of Chemistry, Physics and Astronomy* 2014. 8(3): p. 13 -19.

[13] Hamidi, Z. and N. Shariff, *The Propagation of An Impulsive Coronal Mass Ejections (CMEs) due to the High Solar Flares and Moreton Waves.* 2014.

[14] White, S.M., *Solar Radio Bursts and Space Weather.* Asian Journal of Physics, 2007. 16: p. 189-207.

[15] Z.S. Hamidi, et al., *Theoretical Review of Solar Radio Burst III (SRBT III) Associated With of Solar Flare Phenomena.* International Journal of Fundamental Physical Sciences, 2013. 3(2): p. 20-23.

[16] Vilmer, N.M., *Energy Conversion and Particle Acceleration in the Solar Corona*, in *Lecture Notes in Physics*. 2003, Springer: Berlin.

[17] Pontin, D.I., *Theory of magnetic reconnection in solar and astrophysical plasmas.* Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2012. 370 (1970): p. 3169-3192.

[18] Joel C. Allred, et al., *Radiative Hydrodynamic Models of the Optical and Ultraviolet Emission from Solar Flares.* ApJ, 2005. 630(1).

[19] Zainol, N., et al., *Investigation of Drift Rate of Solar Radio Burst Type II Due To Coronal Mass Ejections Phenomenon.* 2015.

[20] Z.S. Hamidi, et al., *E-Callisto Collaboration: Some Progress Solar Burst Studies Associated with Solar Flare Research Status in Malaysia.* Malaysian Journal of Science and Technology Studies, 2013. 9(2): p. 15-22.

[21] Hamidi, Z., N. Shariff, and C. Monstein, *Evaluation of Spectral Overview and Radio Frequency Interference (RFI) Sources at Four Different Sites in CALLISTO Network at the Narrow Band Solar Monitoring Region.* 2014.

(Received 18 March 2016; accepted 04 April 2016)