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An Analysis of the Electron Density and Drift Rate of Solar Burst Type III During 13^{th} of May 2015

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ABSTRACT

During 13^{th} of May 2015, the solar wind is very high velocity, which is 733 kms^{-1} as compared to 367.5 kms^{-1}. It is believed that the plasma–magnetic field interactions in the solar corona can produce suprathermal electron populations over periods from tens of minutes to several hours, and the interactions of wave-particle and wave-wave lead to characteristic fine structures of the emission. An intense and broad solar radio burst type II was recorded by CALLISTO spectrometer from 20-85 MHz. Using data from a the Blein observatory, the complex structure of solar burst type III can also be found in the early stage of the formation of type III solar burst type event due to active region AR 12339. The drift rate of solar burst type III exceeds 1.0 MHz/s with 6.318 x10^{12} e/m^{3} a density of electron in the solar corona. There were also 2 groups of solar radio burst type III were observed. This CME was detected at 08:36 UT which is 1and ½ hour after the solar burst detected. This event shows a strong radiation in radio region, but not in X-ray region.

***Keywords*:** Sun; solar burst; type III; radio region; X-ray region; solar flare; Coronal Mass Ejections (CMEs)

1. INTRODUCTION

The Sun produces a very high energy deep within its core. The temperature in this region is approximately 15 000 000 C and a pressure (340 billion times Earth's air pressure at sea level) is so intense that nuclear reactions take place. Because of this reaction, one alpha particle or helium nucleus which consists of four protons to fuse together. Alpha particle is 7 %, massive than the four protons because the difference in mass is expelled as energy. The energy is carried to the surface of the Sun in the form of light and heat, through a process known as convection. Its mass is 1.989×10^{30} kg and its luminosity is 3.85×10^{26} W [1].

It is well known that the solar activity is due to large and changing magnetic fields threading the outer regions from Convective zone to Corona and produce the sunspots, solar flare and Coronal Mass Ejections phenomena. It refers to the phenomena that naturally occur within the outer atmosphere of the sun when it magnetically heated [2]. Solar activity generated due to the strong magnetic field and a chaotic dynamo near the surface of the sun which caused a smaller magnetic fluctuation.

During solar activity the energy particle of the Sun released due to solar flares, coronal mass ejection (CME), coronal heating as well as sunspot. This sunspots occur by high concentrations of the magnetic field which inhibit the flow of heat to the surface from the convection zone below. One still unresolved puzzle about the chromospheres is why at some frequencies (at least 10-100) GHz the polar coronal holes appear brighter than the rest of the quiet Sun due to corresponds to an elevated temperature in the upper chromosphere in coronal holes relative to the normal quiet Sun [3].

The Coronal Mass Ejections (CMEs) ejected from the sun are one of the main solar phenomena and the Earth-directed CMEs were very important, since they can produce geomagnetic storms. There is a crucial link between activities in the sun to the earth. Geomagnetic storms can excite if a CME collides with the earth. The higher speed of solar wind enhances magnetic field and generate geomagnetic storm that involves reconnection with the Earth’s magnetosphere [4]. Geomagnetic storms can cause electrical power outages and damaged communications satellite. Besides, it also will produce energetic particles that give damages to the electrical equipment and astronauts. Meanwhile, ionosphere and the radio communications at the earth can be directly affected by solar flares. Also, solar flare release energetic and non-thermal particles into the space [5]. An understanding of both CMEs and flares are required to understand and predict the space weather and its effects to the climate of the earth [6-15]. It is necessary to study the initial stage of CME of their kinematics and the other features. For many CMEs, with the use of data from various instruments, time profiles of velocity, acceleration and geometric characteristics of CMEs immediately after their initiation were obtained in any wavelength [16,17].

Type II burst is confined to frequencies $\leq$ 150 MHz, although occasionally that are observed at higher frequencies [18]. Type II bursts typically occur at around the time of the soft X–ray peak in a solar flare and are identified by a slow drift to lower frequencies with time in dynamic spectra, the frequent presence of both fundamental and second–harmonic bands (with a frequency ratio of 2), and splitting of each of these bands into two traces [19-21]. Basically there are seven types of SRBT II, which are Narrow Bandwidth, Band Splitting, Multiple Band, Compound Type III-II Burst, Herring Bond Structure and Other Fine Structure.

2. SOLAR BURST OBSERVATION

CALLISTO spectrometer designed and built to detect the intensity of electromagnetic radiation at radio frequencies between 45-870 MHz. It consists three main components which are the receiver, a linear polarized antenna and control/logging software. Due to the development of the technology, more advanced system was implemented to the system includes a tower-mounted preamplifier or low noise amplifier, additional antennas and a focal plane unit (FPU) with antenna polarization switching and noise calibration capabilities [22,23].

3. RESULTS AND ANALYSIS

Important parameters that have been taken into account are such burst duration, drift rate, energy of the photon, and harmonic structure of the burst. The current conditions of space weather were taken from the space weather website provided by NASA and the images of the structure of sunspot on the Sun, data and other images revealed by SOHO Observatory, Solar Monitor, SWPC and CACTUS which also have a collaboration with NASA.

Here, we considered event is the event is on the 1st of Jun 2014. The occurrence of the event is interesting in many aspects which is also in Blein. From the dynamic spectra of the CALLISTO, it can be observed that there are two types of Solar Radio Burst emitted from the Sun which are SRBT III and followed by SRBT II. Type III that appears is single SRBT III for approximately 4 minutes at 13.32UT till 13.36UT. This burst duration is longer compared to the other events.

There were also 2 groups of solar radio burst type III were observed. However, it the current condition of the Sun is quite differs from the observation on 9th of May. Whereby, the solar wind is very high velocity, which is 733 km/s as compared to 367.5 m/s. Same goes to the solar wind density whereby, it is low which is 1.8 protons/cm3as compared to 4.1 protons/cm^3.

Table 1. The current condition of the Sun (Credit to spaceweather.com).

Parameter	Value
Solar Wind Speed	733.5 km/s
Proton Density	1.8 protons/cm^3
Interplanetary Magnetic Field	3.6 nT

First SRBT III occurred less than 30 seconds within 06.49UT and 06.50 UT. Then, it is followed by second SRBT III seems to be occurred within 06.50 UT to 06.52 UT for approximately 1 minute. Both of the SRBT III is drifted also from 80MHz to 20MHz.

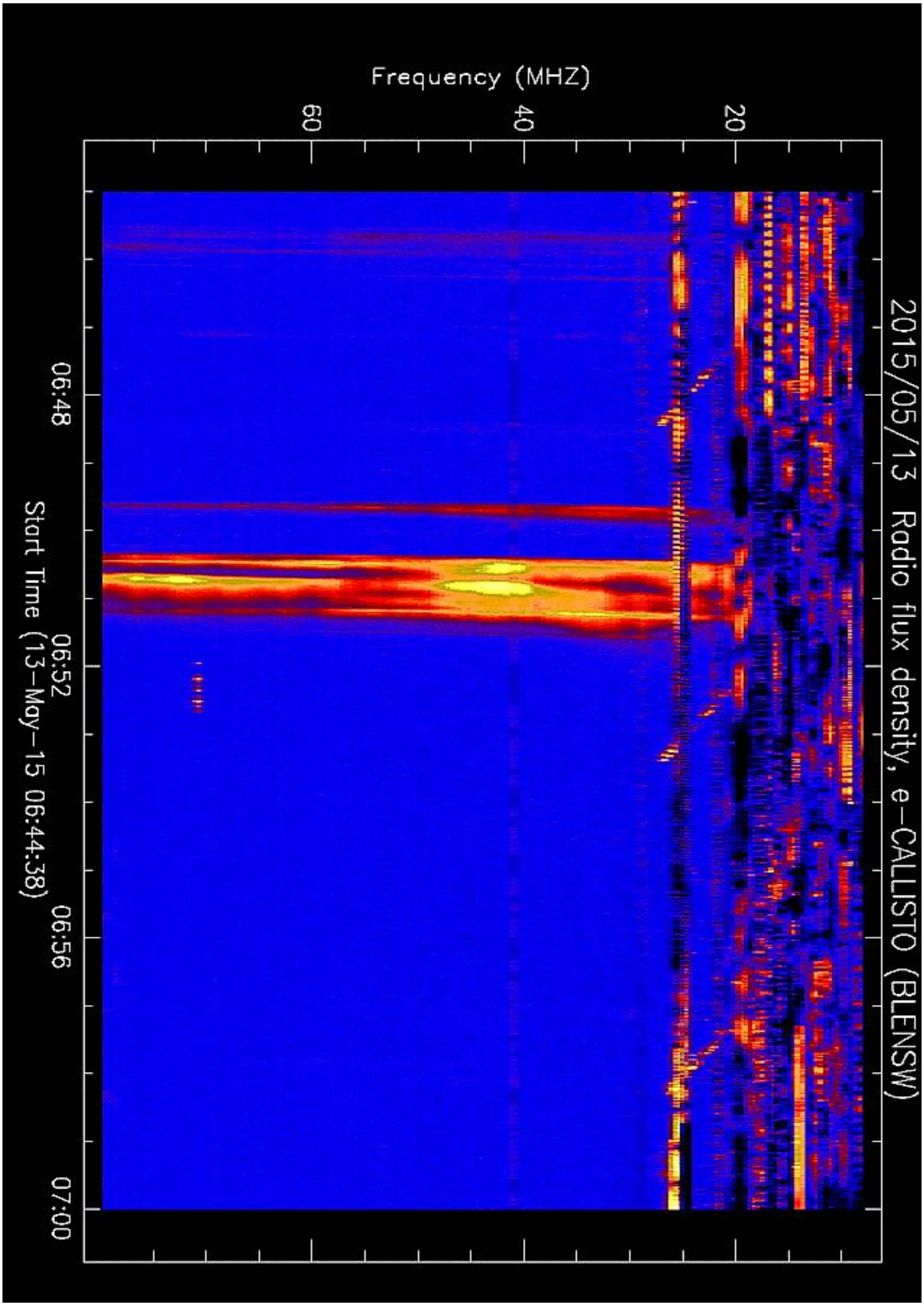

Figure 1. SBRT III and II on 13th of May 2015 (Credit to e-CALLISTO).

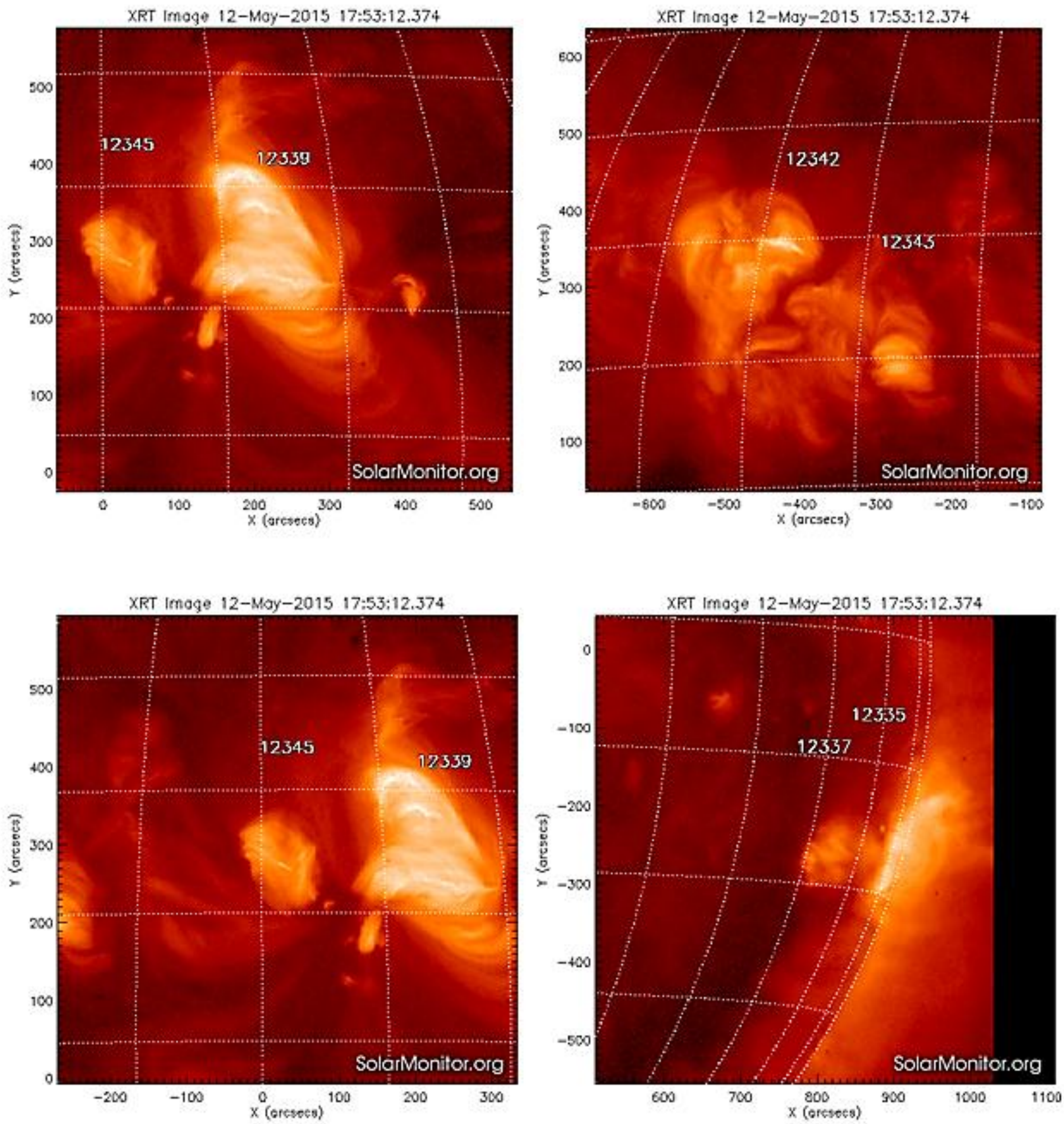

Figure 2. Images of AR that producing flares on 12nd of May (Credit to Solar Monitor).

However, the time duration of the appearance of the second SRBT III is really closed from the first, differ from the observation on 9th of May where it takes about 10 minutes for the second SRBT III to appear and the intensity of the second SRBT III is brighter as compared to the first. During the day, it was observed that there are 12 solar active regions, however only four of them actively produce classes of flare. The table shows the details of flares that produced by each active region

Table 2. Active Region and their type of flares on 13rd of May(Credit to SolarMonitor).

AR 12339	C1.2, C1.7
AR 12342	C1.9
AR 12345	C9.2, C2.2, C1,7, C3.0
AR 12337	C2.6

Based on the X-ray Flux data below, it can be observed that only C type of flare was observed. Whereby, the highest class was C.92 and the lowest one was C 1.2.

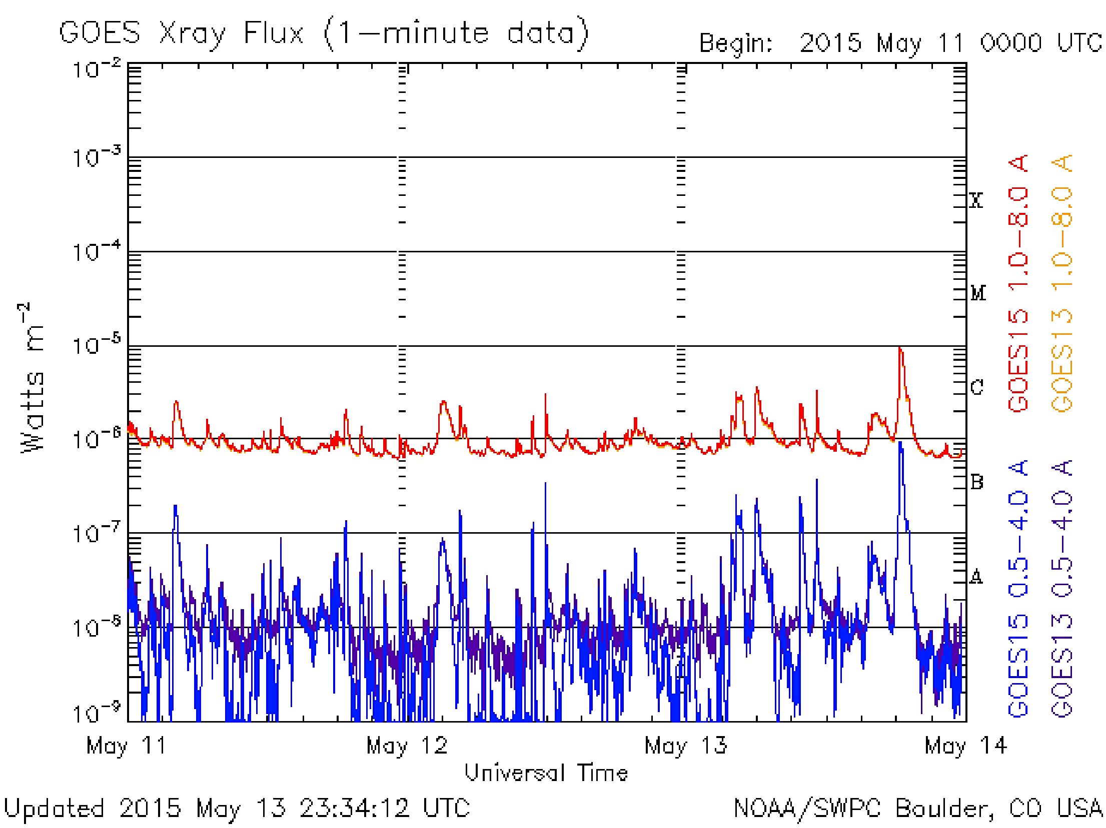

Figure 3. GOES X-ray Flux Data starting on 11th to 14th of May (Credit to Solar Monitor).

A medium CME was also detected during that day with the height f 4.5 Rs. This CME was detected at 08:36 UT which is 1and ½ hour after the solar burst detected.

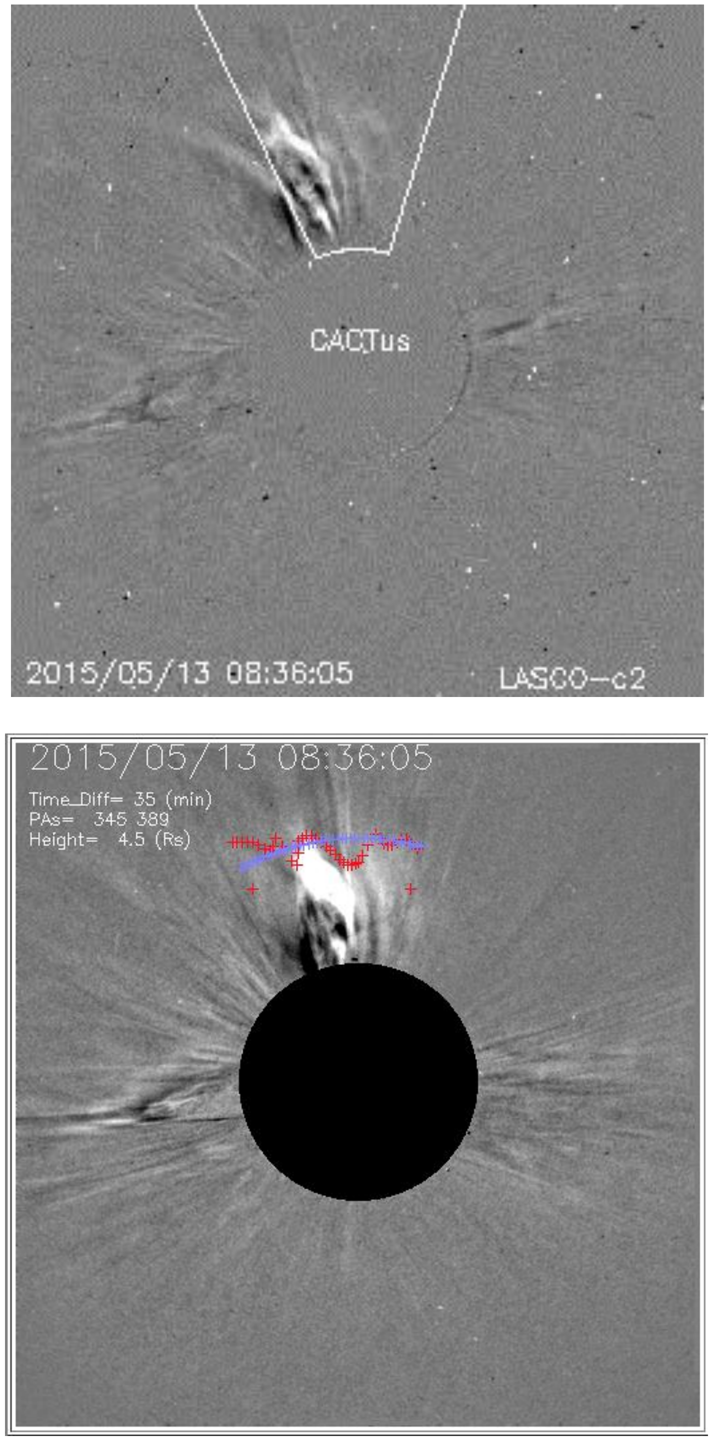

Figure 4. Image of CME on 13th of May 2015

The wind speed during the day quite high, and the high-speed stream solar wind is buffeting Earth's magnetic field, and this is causing geomagnetic storms around the poles (Spaceweather.com). This shows that, wind velocity will contribute to the increasing velocity of the flare so it can disturb the magnetic field of the earth.

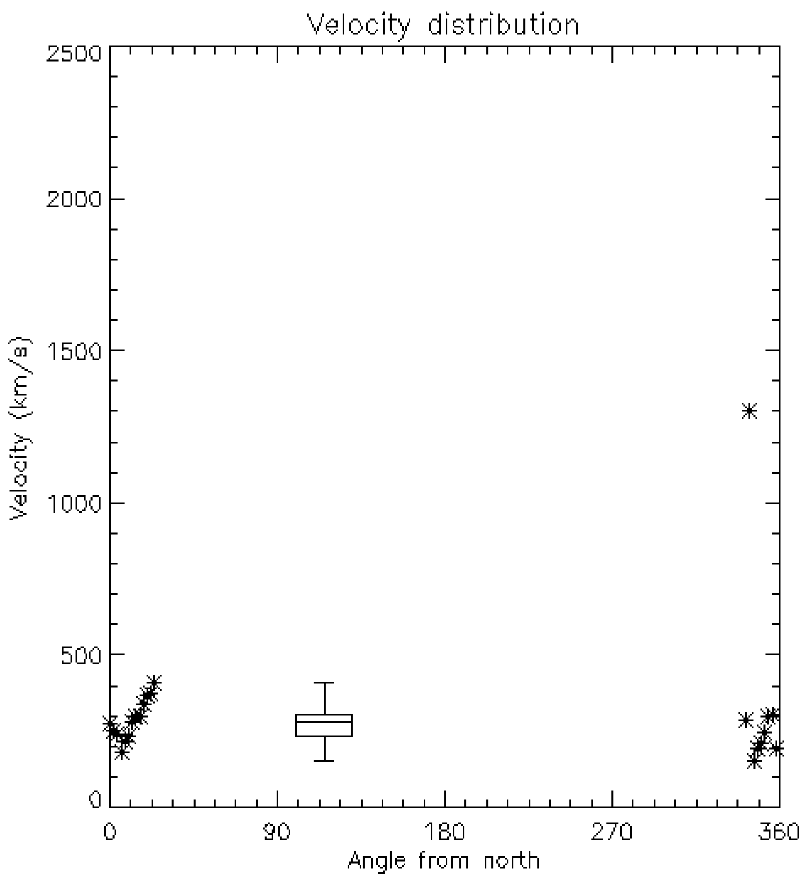

Figure 5. Velocity of CMEs on 13rd of May 2015(Credit to CACTUS)

Figure shows the graph of CME velocity versus angle from north for 13rd of May 2015. It can be observed that there are 18 CMEs occur on that day and the distributions of CMEs velocity on that day are low. Whereby they are ranging from 100 m/s to 500 m/s and only one of them is 1400 m/s. Thus, the average CME velocity is 300 m/s and make the CME on 13rd of May to be classified in 'gradual CME'.

Calculations

i. The *plasma frequency* is given by;

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

whereby *electron density*;

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

$$= \frac{(40 \times 10^6)^2 \times 4\pi \times (8.854 \times \ 10^{-12}) \times (9.109 \times 10^{-31})}{(-1.602 \ \times \ 10^{\ -19})^2}$$

$$= 6.318 \times 10^{12} \ e/m^3$$

ii. Given that, *drift velocity;*

$$D = \frac{\Delta f}{\Delta t} = \frac{f_{\max} - f_{\min}}{d}$$

where max *f* and min *f* represent the upper and lower limits of the frequency at which the radio emission takes place and *`d'* gives the duration of a burst.

The drift rate for the first SRB is,

$$D = \frac{80MHz - 20\ MHz}{15s} = 4MHz/s$$

and for the second SRB is

$$D = \frac{80MHz - 20\ MHz}{60s} = 1MHz/s$$

iii. Given that the *flare temperature*,

$$T_{CME} = 3 \times \ 10^7 (\frac{\boldsymbol{B}}{50\ G})^{\frac{6}{7}} (\frac{n_0}{10^9 cm^{-3}})^{\frac{-1}{7}} \times (\frac{L}{10^9 cm})^{\frac{2}{7}} K$$

$$= 3 \times \ 10^7 (\frac{3.6 \times 10^{19}}{0.005})^{\frac{6}{7}} (\frac{1.8}{10^9})^{\frac{-1}{7}} \times (\frac{4.5 \times 6.95 \times 10^{10}}{10^9})^{\frac{2}{7}} K$$

$$= 2074\ K$$

iv. Energy of the burst,

$$E = hf_1$$

$$= 6.626 \times 10^{-34} \times 80 \times 10^6$$

$$= 5.301 \times 10^{-26} J$$

$$= 3.309 \times 10^{-7} eV$$

$$E = hf_1$$
$$= 6.626 \times 10^{-34} \times 20 \times 10^6$$

$$= 1.325 \times 10^{-26} J$$

$$= 8.272 \times 10^{-8} eV$$

Based on the calculations that have been made, the electron density for the burst on 13rd of May 2015 is $6.318 \times 10^{12}\ e/m^3$ and the drift velocities for both burst are $4 MHz/s$ and $1 MHz/s$. Besides, the CME temperature on that day is low which is $2074\ K$ and the energy of photon of the burst is ranging from $3.309 \times 10^{-7} eV$ to $8.272 \times 10^{-8} eV$.

4. CONCLUDING REMARKS

This event shows a strong radiation in radio region, but not in X-ray region. Therefore, we an only found a class C-solar flare during the time. However, it is a significant phenomena because there are 18 CMEs occurring that day and the distributions of CME speed are between 200 ms^{-1} to 1100 ms^{-1}. It might due to the unstable 'beta-gamma' magnetic fields that harbor energy for B-class flares. Their presence implies acceleration possibly at the tops of loops. Besides that, they have long been of interest in the Space Weather because they have a high degree of association with solar energetic particle events.

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