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THE ENVIRONMENT OF THE SUN DURING THE EXPLOSION OF CORONAL MASS EJECTIONS (CMEs) ON 2nd MAY 2016

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ABSTRACT

Coronal Mass Ejections (CMEs) have been studied has become the most important phenomena of solar activity because it is the most energetic phenomena on the Sun. Concerning the importance of the impact of solar radio burst, we study the selected event of CMEs to observe the environment of the atmosphere of the Sun. It was found that the geomagnetic field was at active to severe storm conditions due to continued activity from the active region. The sunspot number is 76 and radio flux exceeds 92 sfu. There are eight sunspots and with a density of 2.9 proton/ cm^3. During that event, solar wind also reached up to 540.6 $kmsec^{-1}$. It is recommended to collect data for 5 years and above in order to observe the trend of the graph between SRBT II and the speed of CMEs.

Keywords: sun; environment; atmosphere; Coronal Mass Ejections (CMEs); solar radio burst type II.

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1. INTRODUCTION

1.1. Coronal Mass Ejections (CMEs)

Generally, the phenomena of Coronal Mass Ejections (CMEs) occur in closed magnetic fields that contain one or more neutral line (polarity dividing lines) in the photospheric magnetic flux where the magnetic field that produce a flare or CME which is literally consist of one or more closed magnetic dipoles [1]. In the atmosphere of corona, it composed of protons, electrons and uncertain amount of helium nuclei and a small portion of highly ionized heavier atoms. The total shape of the corona varies with the solar [26] cycle, near sunspot maximum. These CMEs can strike into Earth's magnetic fields producing currents that drive the particles down toward Earth's poles, which then react with oxygen and nitrogen. The effect of this phenomena creates the aurora which also known as the Northern and Southern Lights. The major problem of this study is the understanding of the phenomena CMEs and the related consequence of the phenomena which is solar radio burst [2]. This phenomenon occurs in a very short time and every time it occurs, new parameters might be collected as CMEs is a non-static process developed by the Sun. Therefore, there are large scales of parameters that can be chosen and used to relate to the study. Moreover, the observations of CMEs that driving the solar burst cannot be taken directly due to limited instruments and obviously telescope is a quite high cost instrument. The massive magnetized plasma structure of the CME was ejected from close magnetic field regions of the Sun. CME often occurs on solar disk, which is close to the central meridian, got attention from space weather [24] since they are prone to interact with the Earth's space environment.

The CME can be divided into two classes which are (i) flare-related CME events that usually occur in young active regions consisting of sunspots and (ii) CME associated with filament eruption that are perfectly reflected in the evolution of active regions, which then will become dominant as the magnetic flux of the active region getting scattered [3]. Thus, monitoring their observations through the solar radio spectrometers website is the most significant in this study.

1.2. Solar Radio Burst Type II

In this study, the occurrence of solar radio burst and Coronal Mass Ejection is important in solar physics. Focusing on the slow-drift bursts (Type II), it is a slow frequency-drifting form of radio emission and has been explained as a trademark of the magneto hydrodynamic (MHD) shock propagating outward through the solar corona (1−5 $R_\odot$) [4]. The multiples of type II burst caused by a single shock travelling through the different coronal structure as there are no multiple disturbances [5]. It contains a variety of bands with different frequency drift rates and frequency bands that are different from the normal fundamental-harmonic or band-split relationship [6]. There are many possible parameters that can be obtained, especially the speed of the solar burst as time can be measured [7].

The band splitting of type II burst shows in both (i) fundamental and (ii) harmonic bands. The plasma emission from the upstream and downstream shock regions gives out the band splitting. The frequency difference between these bands can be related to the shock comprehension which provides an estimate of the Alfvén Mach number. However, the band-split type II in “classical” proves that the two emission lanes show similar morphologies, similar intensity variations and correlated frequency drift, indicate the emission comes from a common radio-source trajectory [8].

The motion of the shock through the radial plasma density profile can be observed based on the decreasing of the signal in frequency. One can deduce the propagation speed of the driving shock wave from eruption region. SRBT II were first identified by [9] and also discovered by [10] and classified as a broadband lasting from 20 minutes to a few hours. Thus the CME kinetic energy is the indicator of the life time of the type II bursts [11]. This burst usually distinguishes from the fast-drifting type III bursts and could be produced by synchrotron radiation by electrons spiraling in a magnetic field [12]. It exhibits considerable individual variation discovered in the dynamic spectra as slowly drifting bands, often in pairs differing in frequency by a factor ≈ 2 [13]. They were quickly interpreted in terms of a coronal shock wave accelerating electrons, driving Langmuir waves near the electron plasma frequency fp and producing radio emission near fp and $2f_p$ [13-14]. The development of SRBT II is often accompanied by a richness which may take the form of multiple independent drifting bands or other forms of fine structure. The main band is split into two sub-bands because of the effect of magnetic splitting, analogous to the Zeeman Effect. Therefore, the slowly drifting feature in dynamic spectrum can be observed. It also widely known that the radio emission it occurs as a final step in a series of physical processes: initiation of the shock, particle acceleration, generation of plasma waves and finally conversion of plasma waves into electromagnetic waves and the process of the magnetic reconnection [15-16]. The shocks basically formed when the seed of the driver exceeds the wave propagation speed in the ambient medium called *Alfven* in which is governed by both the magnetic field and plasma density. This origin of metric SRBT II is still under debate. Magnetic [27] splitting in some cases require unacceptably high speeds relative to the ions in a laminar shock model.

2. METHODOLOGY

Compound Astronomical Low cost, Low frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) is the main applications of solar radio bursts and RFI-monitoring for astronomical science and education [17-18]. The instrument itself called CALLISTO, but the e-CALLISTO is the worldwide network connected via internet [19-20]. The coverage is 24 hours, which operates identical spectrograph in different locations around the world. It is more than 133 instruments in more than 67 locations with users from more than 132 countries [21-22]. The disk CMEs in white light is hard to detect since they are ejected at large angles from the sky plane and they are blocked by the occulting disk of the coronagraphs. However, it can be detected only after they have travelled far enough from the Sun [23].

In order to setup the hardware of the system, it has been operated with a 5 meters parabolic reflector (from 80 MHz to 800 MHz) near the Institute in Zurich with a log-periodic dipole antenna (gain 6 dB) in the full frequency range at the Bleien Radio Observatory about 50 km west of Zurich. The total cost is less than one percent of the components for Phoenix-2. The timing of the CALLISTO is controlled by a GPS clock in which the relative timing is accurate to within less than one millisecond, whereas the absolute time is uncertain to within a few milliseconds due to internal delays. The total frequency range is from 45-870 MHz where an individual channel has 300 kHz bandwidth and can be tuned by the controlling software in steps of 62.5 kHz. The instrument can easily be duplicated for more channels or be used at higher frequencies by down-converting to the above intrinsic frequency range.

It is distributed on a RISC processor ATmega16 and a standard PC or laptop. The program that built in the RISC, the driver, buffer and interfacing software is in C++ using an interrupt-driven state machine concept. The host software on the PC is also in C++ and operates under Windows 2000 and XP. The relevant parameters are stored in a text file, which can be easily adapted to other observing configurations. In order to communicate with an extended GPS system and external temperature and humidity sensors, additional RS232 ports are preconfigured. A file-controlled scheduler starts and stops measurements in relation to local PC time (UT). The scheduler is automatically repeated every day and can be changed on-line and remotely.

3. RESULTS AND DISCUSSION

On this date, the principal angle detected was 48° while the angular width was 38° which were considered small. The median velocity collected was 294 km/s. Thus, this CME can be categorized as gradual CME. From the picture it is clearly shown that there is no muzzle flash of solar flare. This means the CME was associated with prominence. Although it has lower speed, the acceleration is large. Typically, the CME will expand in size as they propagate outward from the Sun as the magnetic field embedded in the CME is stronger than the background field of the solar wind. The consequence of this bigger size of CMEs cause the speed getting slower that can take between 24 to 36 hours to pass over the Earth [25]. As they reached Earth, the acceleration will be so large. Fig. 1 shows the type II burst with split band and herring bones from the Greenland site.

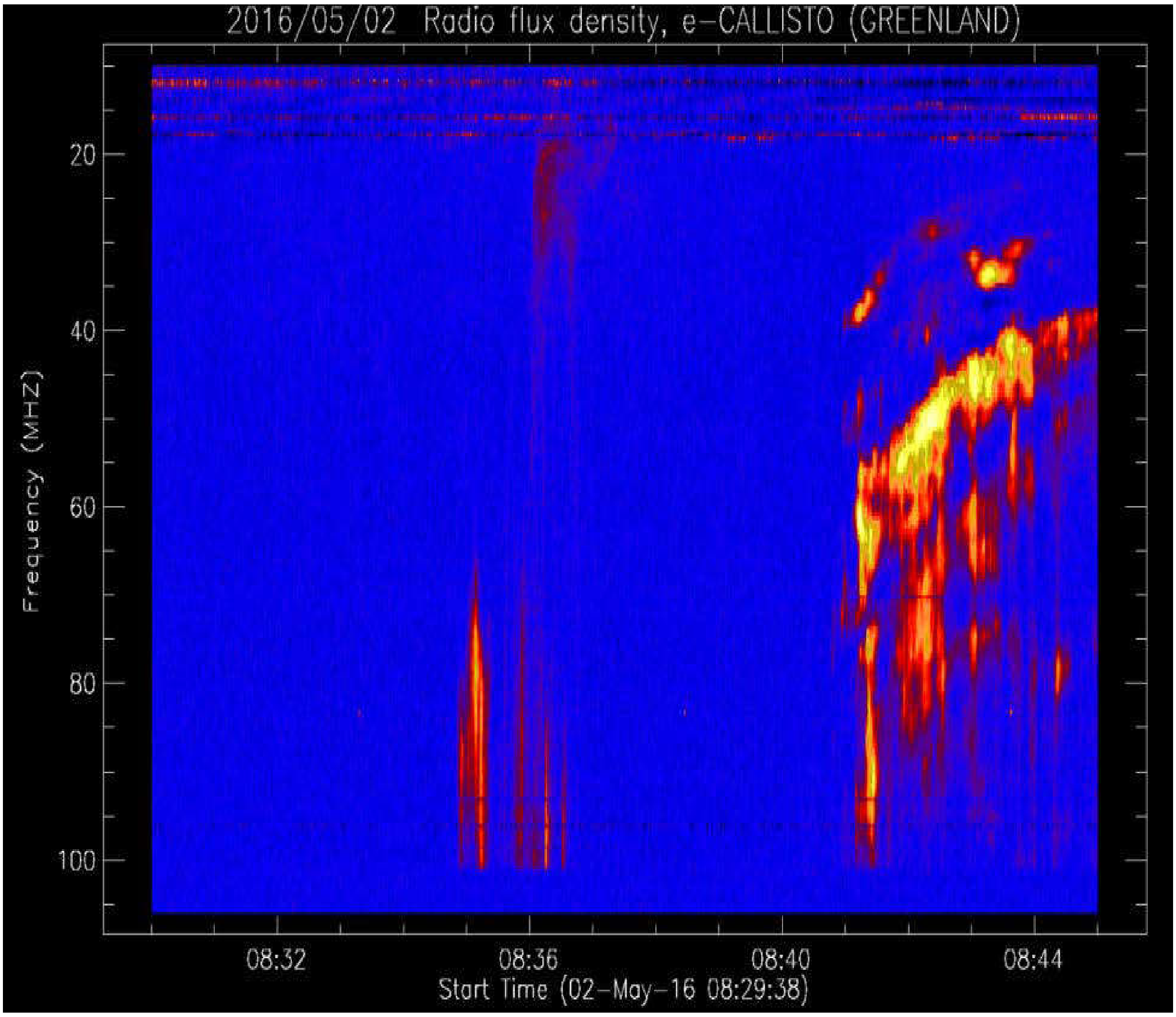

Fig.1. Type II burst with split band and herring bones

Not all sites can observe this burst due to the visibility of the Sun above horizon. Therefore, different places are important to confirm and select a best data. Furthermore, it could not be denied that radio frequency measurements are almost always subject to some level of RFI and background noise. In order to solve such problem, it is strongly suggested that solar monitoring should be consistent been done in order to avoid irrelevant data while doing observations. There are many different methods for both determining and removing the presence of RFI in an observation and also for removing it. These include online techniques where the correction is applied in real time as the signal is received, detected, integrated and offline techniques with the correction occurring after the signal has been recorded. However, the growing number of radio applications had deteriorated the radio frequency spectrum every year. The structure of the Coronal Mass Ejections and the environment of the Sun can be seen very clearly in Fig. 2.

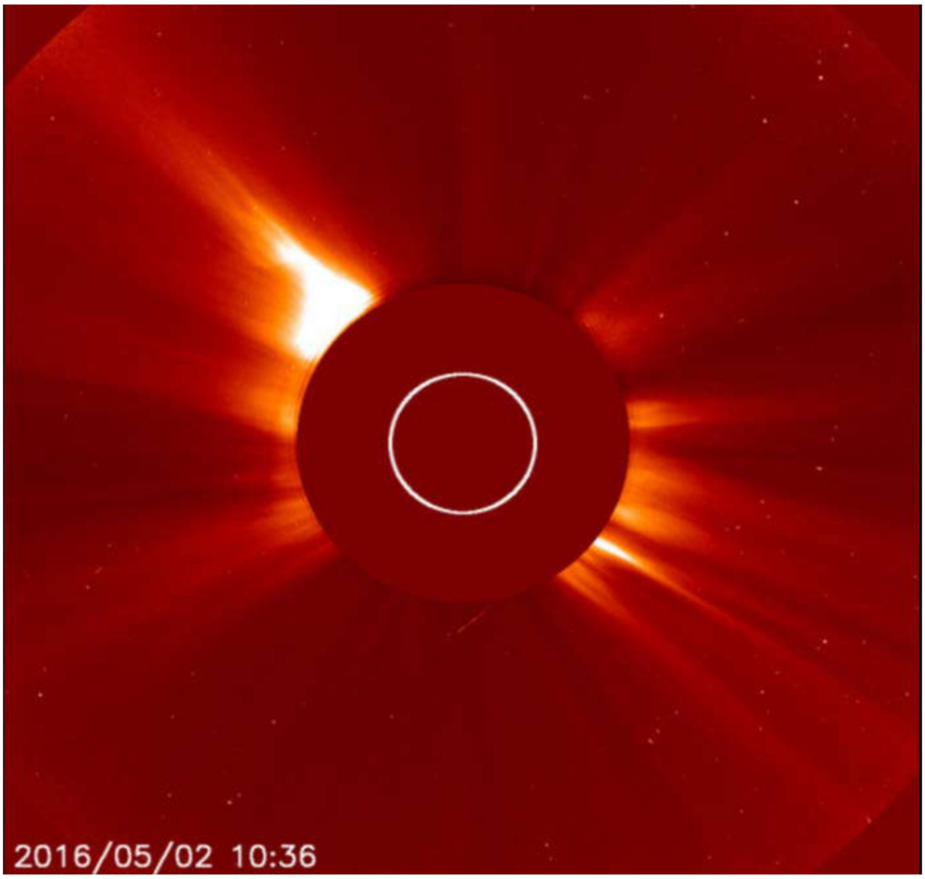

Fig.2. A spectrograph of CME on 2nd May 2016

Based on the Fig. 3, the distribution of CME shown the minimum velocity was 166 km/s and the maximum velocity that could be reached was 428 km/s. The most distributed occurrences of CMEs were in the range between 280-350 km/s, which was approximately 50%. The parameter of solar radio burst type II is tabulated in Table 1.

Table 1. The parameter of solar radio burst type II

Date	Drift Rate	Electron Density, N_e (10^{13} e/m^3)	Height (10^8 m)	E = hf ($\times 10^{-26}$ J)
2nd May 2016	0.13	0.989	0.761	1.98 (min)-6.63(max)

It was found that the geomagnetic field was at active to severe storm conditions due to continued activity from the sheath region associated with the 2nd May 2016 of CME. Unfortunately, we could not obtain the data during that period because our system is suddenly switched off due to high voltage. The distribution of the velocity of CMEs is illustrated in Fig. 3.

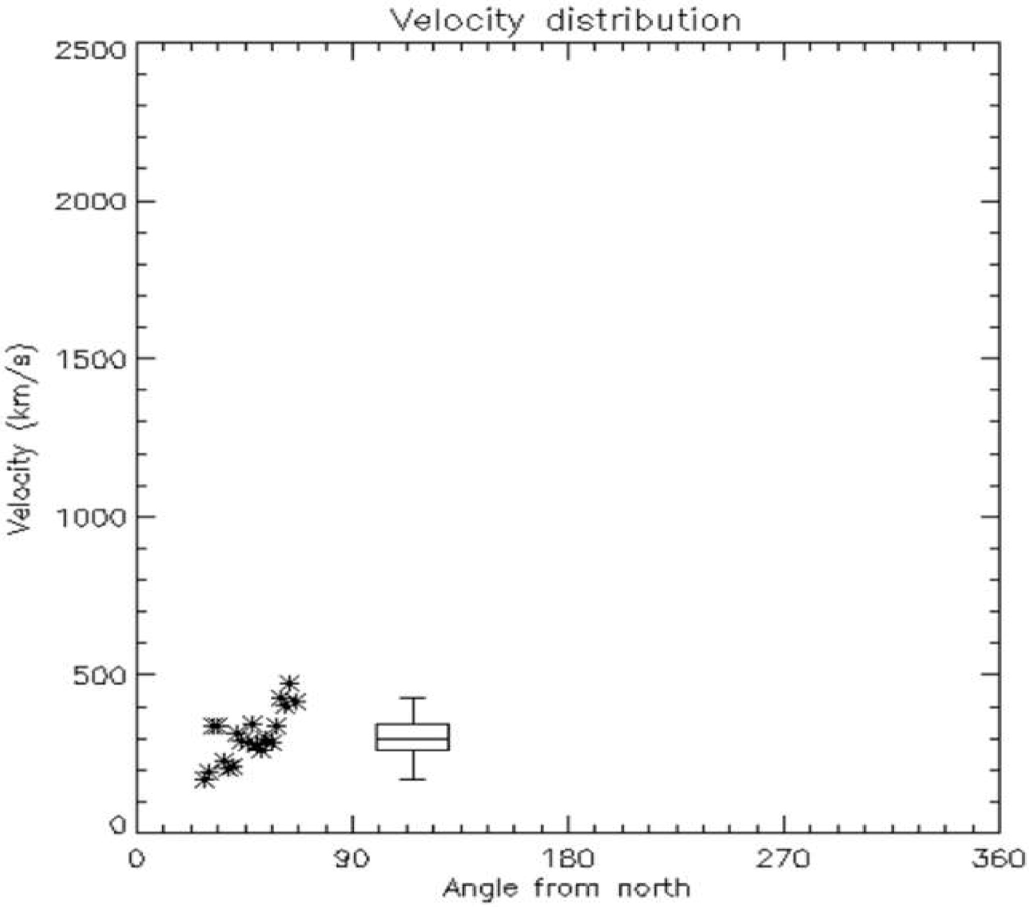

Fig.3. The graph of distribution of CME velocity

From the earliest prediction, there is a possibility a CME will eject directly to the Earth. This is due to a continuous monitoring within a few day period. Based on the results, it is associated with type M class solar flare from active region AR2533, AR 2535, AR 2536, AR 2539 AND AR 2540. It was found that the sunspot number is 76 and radio flux exceeds 92 sfu. There are eight sunspots and with density of 2.9 proton/ cm^3. During that event, solar wind also reached up to 540.6 km sec^{-1}. Those parameters provided an alert with sun's activities. The potential of a big explosion of CMEs is considered very high.

5. CONCLUSION

It must be emphasized that for further research, it is recommended to collect data for 5 years and above in order to see the trend of the graph between SRBT II and the speed of CMEs correlated. It is because the sun activity resets every 11 years and hence the peak activity of the Sun is in the middle of the year 11.

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