CME event produced along with solar flares and its relation with the magnetic field

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Abstract. The magnetic field of the Sun plays the main role in the production of the solar flares until the enormous coronal mass ejections. The magnetic field can be observed from the sunspots on the Sun’s surface. This paper is focusing on the production of the coronal mass ejection and solar flare based on the solar radio burst type II and III that occurred on 2nd April 2017 which were recorded by BLENSW site in Switzerland. The active region (AR) 2644 on the sun’s surface that day had produced the M-class flare with the value of M5.3 which peaked at 0802 UTC. The region of 2644 had a magnetic classification of the beta-gamma spot where it contributes to the energy of the M class flare. The velocity of the flare moving through the interplanetary space was 588 km/sec. During that day, three significant shortwave radio blackouts affected the Indian and Pacific regions oceans. The coronal mass ejection produced was not facing the Earth and Kp index of 3 and the total interplanetary magnetic field with 5 nT were recorded. All data were collected from e-CALLISTO, CACTUS, Space Weather Live and Space Weather website.

1. Introduction
Coronal mass ejections (CMEs) and solar flares are among the significant events that creates on the Sun’s surfaces. The energetic solar flares and Earth directed CMEs were always in observation as they can cause the disruption on the magnetic field of the Earth thus causing the geomagnetic storms. When this happens, the satellites, navigation systems and electrical power grid are going to be disturbed. The magnetic field is enhanced by the higher solar wind speed and hence create the geomagnetic storm which includes the reconnection with the magnetosphere of the Earth [1, 2].

In order to know more about the magnetic field of the Sun, it is better to know about the McIntosh system. This system focuses on the sunspot where the changes in the magnetic field can be observed. McIntosh system classified the sunspot into few categories which are Z, p and c. Z here means the Zurich class, p is the penumbra of principal spot and c is the distribution of the spot. In addition, the Mount Wilson class which contains of α, β, γ, and δ can be used to categorize the sunspot too. Based on the size of the spot, its relation to the magnetic energy and magnetic field is directly proportional to each other where, when the size is increased, the magnetic field and its energy will increase [3]. For the overview, when there is sunspot on the Sun surfaces, there is also magnetic field. Coronal mass ejection usually occurs when the magnetic field on the sunspot get highly twisted, become stressed and reconstructed into less tense configuration which is known as magnetic reconnection. The highly tangled and twisted magnetic field then spews away from the sun’s surfaces and carries with it the plasma.

The formation of coronal mass ejections usually associated with the solar radio burst type II [4]. This burst happens when the accelerated electrons are at the outward propagating of the coronal shock front [5]. CMEs can be classified into two categories; (1) flare related CME and (2) CME that is related to the filament eruption [6, 7]. The first category theoretically shows the formation of the CMEs throughout the solar flares where it is due to the magnetic flux in the active region. The second category, the focus is on the sunspot evolution as it can produce solar radio burst type II and type IV, which the CMEs can be produced by the eruption of the filament. Knowing type II burst could give the information of the shocks associated with geomagnetic storms [8]. Type II occurs because of the vigorous eruptions in the atmosphere of the Sun where it tells us about the coronal mass ejection that is associated with the flare. The magnetic field that is not stable caused the production of solar flare and followed by the coronal mass
ejection. The emitted signal from the flare produces a wave and mass acceleration which is the main factor for radio burst.

Solar radio burst type III usually related to the solar flares [9]. The strong magnetic fields that have denser and hotter active regions compared to the surroundings will enhance the radio burst type III normally from 10 to 100 minutes [10]. The characteristic of type III bursts is that they drift from high to low frequencies and have been detected at kHz [11] until 8 GHz frequencies [12] even though the typical frequency of the occurrence is less than 150 MHz [13].

2. Method

For this study, the data from a few sources was used such as e-CALLISTO data for radio burst analysis. CACTus online database to study coronal mass ejections and other parameter values were from the Space Weather Live and Space Weather website courtesy. CALLISTO stands for Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory where it is a system that observed the Sun for 24 hours per day and has a network that connected via the internet which is known as e-CALLISTO [14, 15]. Until today, the system has been installed at more than 90 locations around the globe. The data obtained was from BLENSW. The BLENSW site is from Bleien Observatory, Switzerland with 7-meter parabolic dish to track the Sun in radio frequency. CACTus database is a software that detects the coronal mass ejections in image sequences from LASCO.

There were five active regions on the sun’s surfaces, but the one that produced the strong M class flare was active region 2644 which occurred at 2033 UT. Based on the data from Space Weather Services from Australian Government, Bureau of Meteorology, on April 2017 alone, there were 65 events related to type III solar radio burst, one type II burst, four type IV bursts, two events of type V bursts and other continuum with 23 events. In this paper, the focus is on type II and III solar radio burst events and how the sunspot harvests its energy in the production of the solar flares and coronal mass ejections.

![Figure 1](https://example.com/figure1.png)

**Figure 1.** The spectrogram of type III solar radio burst from the BLENSW site (Credit: e-CALLISTO) and GOES X-ray Flux data (Credit: Solar Monitor)

The production of solar radio burst type III as shown in Figure 1 occurred between 0754 UT and 0757 UT with three minutes duration. As we know, type III is related to fast drift burst and shows the production of solar flares and indicates the beginning of the magnetic reconnection [16]. The first one minute showed the group of type III burst while the last two minutes, a single type III was produced. From the GOES X-ray data shown, the M class flares happened for four times on 2nd April 2017. The maximum speed of solar wind reached the peak of 588 km/sec, while the total interplanetary magnetic field had the value of 5 nT. The southward component of magnetic field reached the -3 nT where when this value is much lower, the chances for the aurora activity is very high.
Figure 2. Type II solar radio burst recorded from a BLENSW site on CALLISTO system (Credit:e-CALLISTO) and the CME production (Credit: LASCO-c2)

After 13 minutes type III burst occurred, type II burst followed. Type II slow drift burst with fundamental was detected between 0811 UT until 0816 UT, lasting for about five minutes. The radio burst type II occurrence denoted the production of coronal mass ejections. However, the coronal mass ejection was not facing the Earth as it was located at N14W55 (West limb of the Sun).

| Table 1. Parameter value of the Sun on 2nd April 2017 |
|----------------------------------|----------|
| Parameter                        | Value    |
| Sunspot number                   | 75       |
| Radio sun 10.7 cm flux           | 112 sfu  |
| K-index                          | 3 (quiet)|
| Radio blackout                   | R2 (moderate) |

| Table 2. Solar Parameter of Active Region 2644 |
|-----------------------------------------------|----------|
| Parameter                                     | Value    |
| Number of sunspots                            | 12       |
| Size                                          | 210      |
| Magnetic classification of sunspot            | $\beta - \gamma$ |
| Class spot                                    | EKC      |
| Location                                      | N14 W55  |

Figure 3. The image of a) shows the AR on the Sun’s surface and b) shows the AR in magnetogram image

The M-class solar flare occurrence with the reading of M 5.3 had caused the moderate R2 radio blackout affecting the area of Pacific and Indian oceans. The Earth’s upper atmosphere have been ionized by the
ultraviolet (UV) radiation from the flares which then altered the normal propagation of radio waves around the Earth.

From the image b) of Figure 3, the magnetogram shows the different color in certain areas of the active region 2644. It indicates the strength of the magnetic field on the sunspot. The yellow region indicates the positive (North) polarity that pointed out from the Sun while the red shows the strongest fields. The blue is the South or negative polarity with green region is the strongest. So, by looking at the magnetogram image, the red and green region dominated the sunspot area, hence, shows that the area had a strong magnetic field.

The active region 2644 has a beta-gamma magnetic field where that is one of the main points the M class flares were produced. This bipolar sunspot had compact distribution and a size of 210. The strength of the magnetic field is related to the area of sunspot group and the ambient magnetic energy of the total active region may produce a large explosion [3]. This is proven as the active region 2644 produced four M class flare of M5.7, M5.3, M2.3, and M2.1 which considered large explosion from the Sun.

3. Conclusion
The production of solar radio burst type II is usually related to the formation of the coronal mass ejections, while the solar radio burst type III is related to the solar flares. In this study, solar flare that produced by active region 2644 lead to the production of M 5.3 class flare where there was a radio blackout occurred with R2 value. From the result, we can say that the production of the coronal mass ejection was caused by the solar flares.

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