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The Progression of Active Region with the Formation of Group and Complex Solar Radio Burst Type III on 31st August 2015

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ABSTRACT

In this event, a solar radio burst in the range of 45-165 MHz with energy of $2.982\ x\ 10^{-26}$ to $1.093\ x\ 10^{-25}$ Joule with 0.8 MHz/ second have been correlated with the optical solar prominence. In combination of the optical, radio and X-ray observation, the occurrence of the event has been proposed. The active region of the prominence was AR2403. An individual type III burst was observed at 19:40 UT. The burst lasts for 15 minutes with a drift rate of 0.8 MHz/s. This burst was recorded by the Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) at Almaty Site. From 29th August 2015 onwards, the total magnetic flux increases gradually to over four-fold the initial value during development and levels off around 29th August 2015. It was found that B3 solar flare, followed by a slow coronal mass ejection (CME), is released from NOAA 2403 on 31st August 2015. The region is beyond -30° longitude at the time of the flare, making it impossible to reliably measure any magnetic properties involving gradients. The overall increase of B_{eff} prior to the flare is indicative of an increase in polarity mixing within the AR, which has been shown to be related to flaring. Understanding of the exact nature of the initiation of these events is still incomplete.

***Keywords*:** solar prominences; complex solar radio burst; type III; AR2403; e CALLISTO

1. INTRODUCTION

An active regions, also known as sunspots, appear within 40° of the solar equator and can cultivate to cover 1% of the solar disk. Sunspots are regions of kilo-Gauss magnetic fields which emerge from the sub-surface of the sun and expand rapidly into the solar atmosphere [1]. Their global structure and evolution is governed by photospheric and sub-surface flows. The strong magnetic fields present in active regions inhibit the convective flows causing a reduction in temperature compared to the surrounding regions [2]. The dark interior of a sunspot is known as the umbra and thelighter area surrounding this is known as the penumbra.

The penumbra consist of nerlaments which point radially away from the umbra in simple sunspots. Current prediction techniques of extreme solar events such as solar flares and CMEs, are based on a regions classification and the historical likelihood of these events originating from such regions [3]. Each classification technique attempts to characterise the complexity of active regions into sub-groups [4]. Much work has been done to couple these classifications with physical parameters (area, total magnetic field, etc) to increase the accuracy of the historical prediction methods [5-7]. The McIntosh classification system is a 3-component system, which uses a modified Zurich Sunspot classification for it's first entry. The Mount Wilson method, introduced in 1919, outlines the classification of sunspot groups based on the sunspot configuration and characteristics. Each region is coded with a combination of designations which are based on the unipolar (α), bipolar (ß) or multipolar (γ) nature of the spots. The second component is descriptive of the largest spot in the group and the last entry details the degree of spottiness in the interior of the sunspot group.

Table 1. Mount Wilson Sunspot Magnetic Classification.

Class	Description
α	A unipolar sunspot group
ß	A bipolar sunspot group with a clear, simple division between the polarities
γ	A complex region of positive and negative polarities, a salt and pepper distribution, too complex to classify it as a ß
δ	A qualier to magnetic classes indicating that the umbrae separated by less than 2 degrees within one penumbra have opposite polarity.

In 1963, Wild [8] was the first person to introduced that solar radio burst type III is the most dominant with solar flare phenomenon with the range of frequency of 500-10 MHz [9-11]. This type of solar radio burst produced from energetic particles that released along open magnetic field lines [12]. Type III burst is also known to occur when there is a bright active region on the surface of the sun that is visible and indicates the increased in solar activity [13, 14]. This solar burst type events have fast drift frequency versus time. When the density scale heights lower in the atmosphere are smaller, the drift rates are faster in higher frequency. Type III also known to have the fastest burst's drift rates at metric wavelength and this burst's beams of electrons of energies up to tens of keV. The electron beams are the producers of electrostatic Langmuir waves . At very low corona with corresponding densities, these electron beams can be detected and moves through the SRBS frequency range out to 1 AU where the spacecraft can detect the solar wind [15]. Type III solar radio burst can occur singly, groups or even in storms. Besides that, this burst type are produced at a speed of c/3 with approximately 30 keV kinetic energy that are produced by low energy electron beams [16-18]. In some flare with limited number of energy components which is propagate into kinetic energy, plasma strong radiation and also energetic non-thermal particles, they can exchange in excess magnetic energy of 10^{32} ergs into heated plasma, accelerated particles and ejected solar material [19, 20].

In addition, there are other types of solar burst which are type II, IV, V and U with the sub-types that are related to the production of type III [21]. These type can be differentiate by the time type III occurred either before or after the other burst. This burst can relate to type U [22], type IV [23], type V [24] and type II burst [25].

2. METHODOLOGY

Figure 1. Solar Telescopes at the Telok Kemang Solar Observatory, Malaysia

We used two types of instruments used to obtain the data which were Lunt Solar 100 mm H-Alpha telescope and the CALLISTO spectrometer. The solar monitoring was carried out at the Telok Kemang Solar Observatory, Port Dickson, Malaysia. In thi system, Lunt Solar with hydrogen alpha filter was used to get the optical data of the solar prominences. We also used a CCD camera (ZWO ASI120MM or DMK 21 AU04) was attached to the Lunt Solar 100 mm H-Alpha telescope and linked to a software to see the images of the sun. A setting of the camera was set in the software such as the frame number and color setting. Then, searched for the desired images, for example the solar flares, sunspots, filaments or solar prominences and started capturing the images.

The captured images, then will be edited by using AutoStakert, RegiStax and Adobe Photoshop to get the best image result of the sun. After the images were processed, all the data of the solar prominences was collected (sunspot number, solar wind, etc). Then, the images of solar prominences by using an optical telescope was compared with the radio telescope images of the type of burst produced. Figure 1 shows the Solar Telescopes at the Telok Kemang Solar Observatory, Malaysia.

It is planned to carry out co-ordinated radio spectral observations of the solar corona from various locations around the world during the International Heliophysical Year (IHY) 2007 [26]. A new generation of broad-band radio spectrometer is currently designed and built to provide high-dynamic-range imaging capabilities superior to that of existing instruments.

The Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) has been described in detail by [27]. With these solar instruments in radio wavelength, a more accurate determination of the specific frequency of energy become feasible due to high time resolution [28]. CALLISTO was considered as a global network of spectrometer system with the purpose to observe the Sun's activities located in different regions of the Earth [29].

ETH Zurich has developed a number of solar radio spectrometers since 1980s [30-36]. It will convert the high-frequency electromagnetic signals into a form convenient for detecting and measuring the incoming radio emission. With large instantaneous bandwidths and high spectral resolutions, these instruments will provide increased imaging sensitivity and enable detailed measurements of the dynamic solar burst.

3. RESULTS AND ANALYSIS

We analyse the time evolution and flare productivity of the sunspot groups that emerge as NOAA 2403, 2405, 2406. Active region NOAA 243 rotates onto the visible solar disk on 31st August 2015 at heliographic latitude -25◦. At this point, AR2403 is mature and decaying, having emerged and evolved on the far side of the Sun.

On 30th August 2015, a new bipolar structure rapidly emerges in the extended plage of the trailing (positive) polarity. National Oceanic and Atmospheric Association (NOAA) switches the 2403 designation to this newly emerged bipole several days later. As the bipole evolves it develops a strong double polarity separation line (PSL) by merging with the decayed flux. It produces many C and B-class flares and several X-class flares. The sunspot group progresses around the visible disk, eventually returning as NOAA 2406.

Figure 2. Prominences during 31st August 2015 (Credited to Telok Kemang Solar Observatory, Malaysia)

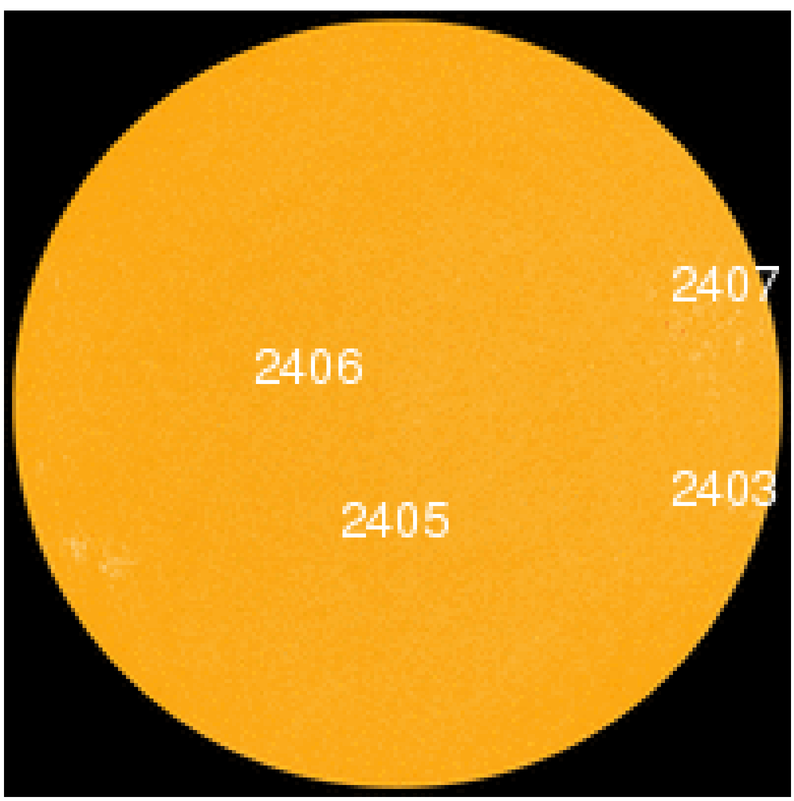

Figure 3. Group of active region during 31st August 2015 (Credit: SDO/HMI)

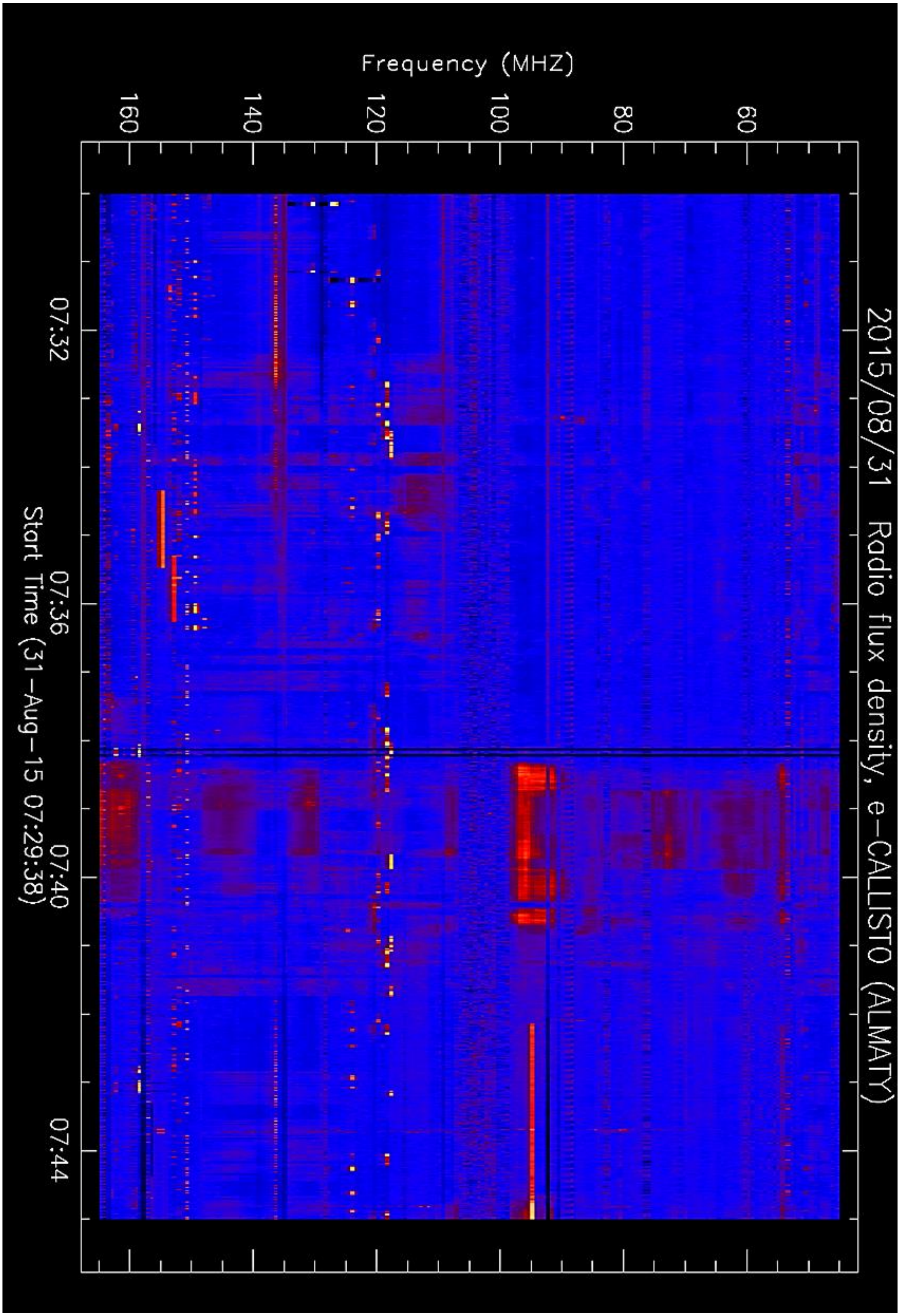

Figure 4. The solar radio burst type III during 31 August 2015 (Credited to e-CALLISTO)

The excessive explosion at optical wavelength send the gas and fast electron streaming through the solar system. When the reach to the Earth, the particles produces a group type III burst. Figure 2 showed the prominence that occurred on 31st September 2015. Solar type III radio bursts are an important diagnostic tool in the understanding of solar accelerated electron beams.

Type III solar radio burst was recorded by e-CALLISTO spectrometry. The solar radio burst was recorded by e-CALLISTO system using ALMATY site. The event occurred at a frequency of 45 MHz and ended at 165 MHz, which lasts for about 15 minutes. The minimum energy for the starting frequency was in the range of 45-165 MHz with energy of $2.982x10^{-26}$ to $1.093x10^{-25}$ Joule with 0.8 MHz/ second. This flare was detected at active region of AR2403.

From 29th August 2015 onwards, the total magnetic flux increases gradually to over four-fold the initial value during development and levels off around 29th August. The maximum magnetic field increases abruptly on 29th August and also increases over time, albeit less smoothly than the magnetic flux.

Table 1. The condition of the sun 31st August 2015 (Credited to Space Weather).

Parameter	**Value**
Radio sun	10.7 cm flux: 92 sfu
Solar wind speed	358 km/ second
Proton Density	2.6 protons
Interplanetary magnetic field	B_{total}: 4.3 nT
	B_z: 0.9 nT south

The nonthermal distribution of accelerated electrons believed to produce solar hard X-ray emissions is known to evolve dramatically over the course of a solar flare, from a steep to a flat power-law spectrum as the acceleration process becomes more efficient.

Signatures in the evolution of the magnetic configuration of NOAA 2403 precede its intense coronal activity, indicated by the associated solar burst type III in Figure 3. During 31st of August 2015, the new emergence causes a jump in the main bipole separation line length. As the emergence continues and strong PSLs develop, this length decreases,while the total PSL length increases.

Also, there are signs of gradual helicity injection as the angle between the main bipole connection line and the main PSL grows from near perpendicular (90◦) to around 120° (top panel).

It was found that B3 solar flare, followed by a slow coronal mass ejection (CME), is released from NOAA 2403 on 31st August 2015. The region is beyond -30° longitude at the time of the flare, making it impossible to reliably measure any magnetic properties involving gradients. However, the interval over which the region evolves prior to the eruption (~29th

August 2015 to 1st September 2015) is well observed by SDO/HMI. The magnetic flux and connectivity of the region is also measured at the time of the eruption.

Currently, flares can not be reliably forecasted. This is partially because the mechanisms behind flaring can not be directly observed and are not well understood. Also, since the magnetic field can not be reliably measured in the corona, one must rely on photospheric fields and extrapolations to determine the magnetic structure in the corona. This lack of direct knowledge of what is really going on has resulted in the common use of proxies to indicate the build up of flare energy in a sunspot group. Therefore, determining the statistical relationship between sunspot group properties and flaring has become essential for any flare forecasting system.

Once radio imaging is available, the shock's properties can be studied in detail. By using multi-wavelength imaging observations, in EUV, white light and radio, and radio spectral data over a large frequency range, the triggering and development of a complex eruptive event was analysed.

CONCLUSION

Solar eruptive events occur when magnetic energy stored in the atmosphere of the Sun is released as a mixture of rapidly ejected plasma (coronal mass ejections) and radiation across the electromagnetic spectrum (solar flares). Each of the properties begins to decay at a faster rate after the flare than before the flare, except for effective of the magnetic field, B_{eff} which is increasing slightly prior to the flare. This indicates that after the flare, the active region begins to diffuse and decay faster or that the magnetic fields become oriented further from the line-of-sight direction more quickly. The overall increase of B_{eff} prior to the flare is indicative of an increase in polarity mixing within the AR, which has been shown to be related to flaring. Understanding of the exact nature of the initiation of these events is still incomplete.

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