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Comparison of the Optical Image of the Solar Prominence with the Formation of Solar Radio Burst Type III on 3rd September 2015

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ABSTRACT

Solar radio burst in the range of 220 - 400 MHz have been correlated with the optical solar prominence phenomena covering the presence sunspot minimum. In combination of the observation in radio emission and the basis of this study, the occurrence of the event has been proposed. The active region of the prominence was AR2407. An individual type III burst was observed at 08:21 UT. The burst lasts for 20 seconds with a drift rate of 4.25 MHz/s. This burst was recorded by the Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) at Switzerland. The CALLISTO spectrometer is a spectrometer system that has been installed all around the world to observe the activity of the sun for 24 hours. The activation may be

caused by shock waves issuing from prominences and solar flares. The loop prominences can be observed by using the optical telescope and is the initiates points of the following important flare that exist for 6 hours. The active region on the Sun experience the gradual build up of the magnetic field which gives rise to the sunspots, prominences and loops in the corona and produce the powerful outburst explosions.

***Keywords*:** solar prominences; solar radio burst; type III; AR2407; e CALLISTO

1. INTRODUCTION

Prominences are anchored to the Sun's surface in the photosphere, and extend outwards into the Sun's corona. While the corona consists of extremely hot ionized gases, known as plasma, which do not emit much visible light, prominences contain much cooler plasma, similar in composition to that of the chromosphere. Prominences end their lives either through a slow process of decaying emission, or through a more sudden disappearance (disparitions brusques) triggered by a thermal or dynamical instability. The decay of emission can also be transient: the disappearance of a filament in a monochromatic image sampling the cool plasma (Hα for example) can be the result of the change of its temperature as a consequence of a transient heating injection. Thus, the filament will become visible in the hotter EUV lines, but eventually will go back to its original thermal condition. The solar prominences classification is illustrated in Figure 1.

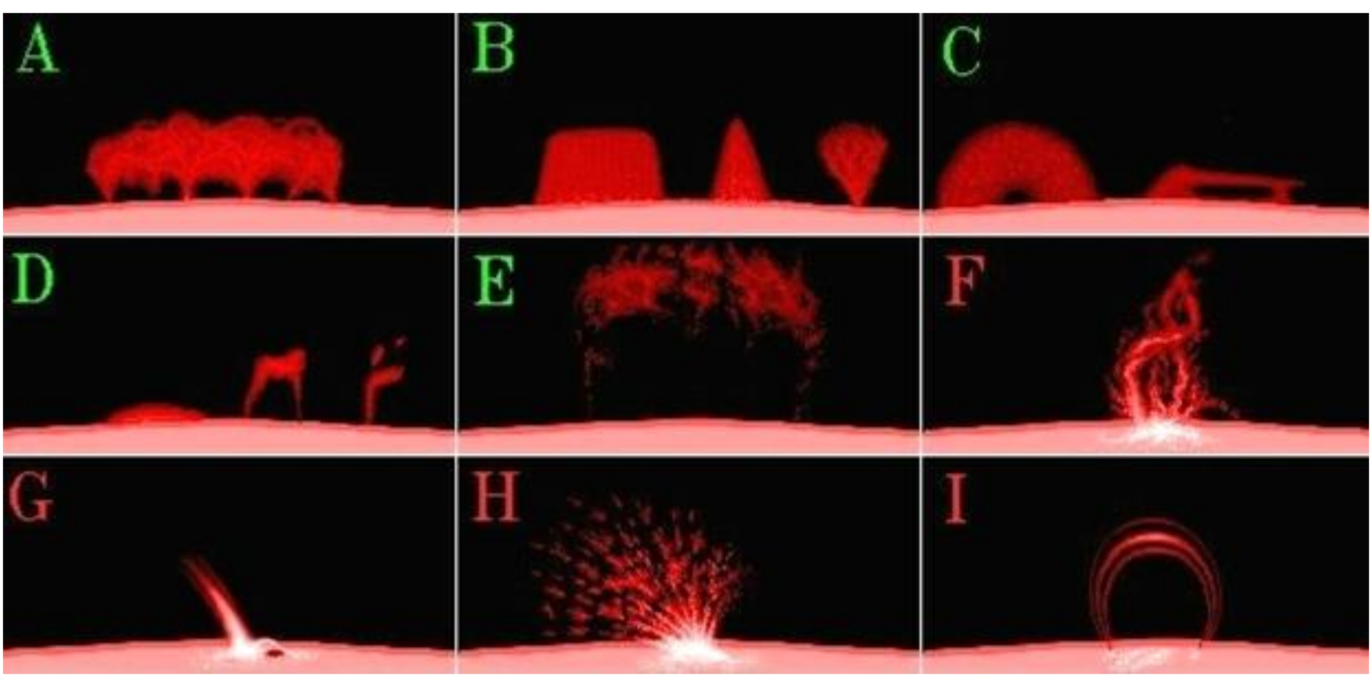

Figure 1. The solar prominences classification.

The prominences are observed beyond the Sun's limb as bright arches against a dark background and when projected on the disk they appear as dark filaments against the background of the disk. Imbedded in the hot corona (~10^6 K), a prominence is a cool gaseous formation (~10^4 K) standing almost vertically on the Sun's surface and measuring 20000 to 200000 km long, 20,000 to 50,000 km high, and about 5000 km thick.

The prominence is always formed in the spot belts, sometimes close to the spots, sometimes in regions without spots. Prominence destabilization has been observed in connection with several phenomena, including magnetic flux emergence, local and large scale photospheric motions with their transport of magnetic flux, and a remote flare that initiates wave disturbances. Partial or failed eruptions of prominences have an initial phase similar to that of a full prominence eruption up to the acceleration phase, which lasts for a shorter time.

The prominence is then observed to decelerate, reaching a maximum height, while prominence material simultaneouly drains back to the solar surface. Failed eruptions sometimes are associated with CMEs. In this case the remaining filament reforms soon, to finally be completely ejected in the CME (Zhou et al., 2006). Other times there is no sign of a CME or opening of the coronal magnetic field. Often these events are associated with compact flares. Similar to full prominence eruption, failed eruptions show properties that can be reproduced by models that use different destabilizing mechanisms

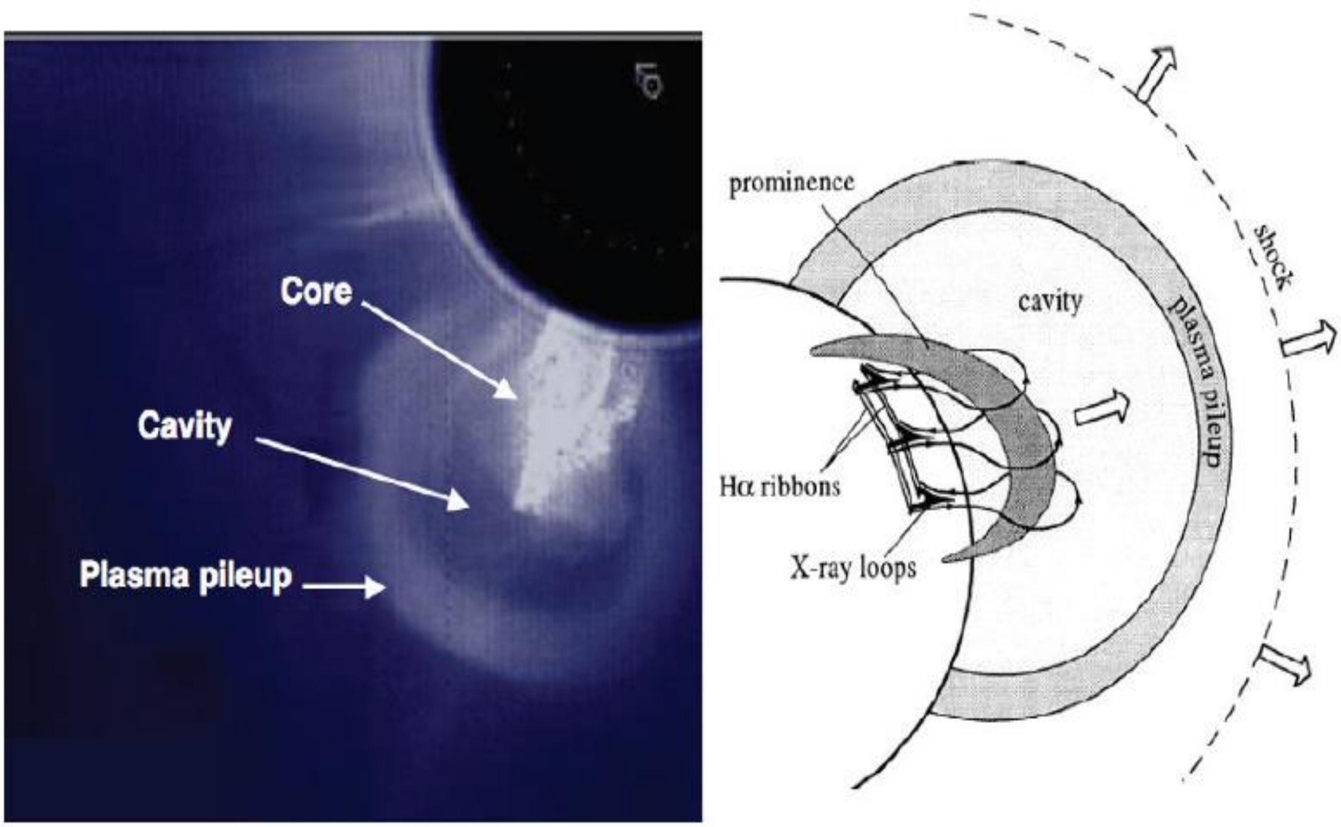

Figure 2. The schematic diagram of the position of the prominence of the Sun structure.

In general, the prominences near sunspots vary rapidly in form,whereas those away from sunspots grow greatly in length and are stable. They often tend to incline slightly away from the active regions near which they occur. A prominence first appears probably by the condensation out of the hotter, but more rarefied coronal material with the assistance of a magnetic field that also support it. The activation of a prominence increase of internal motion, which can continue for several hours to days. To assess how much of the coronal environment is involved in the prominence eruption, how the destabilization is triggered, and how it evolves, we need good time sampling of the event at multiple wavebands. Figure 2 shows the schematic diagram of the position of the prominence of the Sun structure.

In 1963, Wild [1] 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 [2-4]. This type of solar radio burst produced from energetic particles that released along open magnetic field lines [5]. 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. 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 [6]. 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 [7-9]. 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 [10,11].

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 [12]. 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 [13], type IV [14], type V [15] and type II burst [16].

2. METHODOLOGY

There are two types of instruments used to obtain the data which were Lunt Solar 100 mm H-Alpha telescope and the CALLISTO spectrometer. The observation was carried out at the Telok Kemang Solar Observatory, Port Dickson, Malaysia. Lunt Solar with hydrogen alpha filter was used to get the optical data of the solar prominences. A CCD camera (ZWO ASI120MM or DMK 21 AU04) was attached to the Lunt Solar 100mm 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).

Figure 3. Solar Telescopes at the Telok Kemang Solar Observatory, Malaysia.

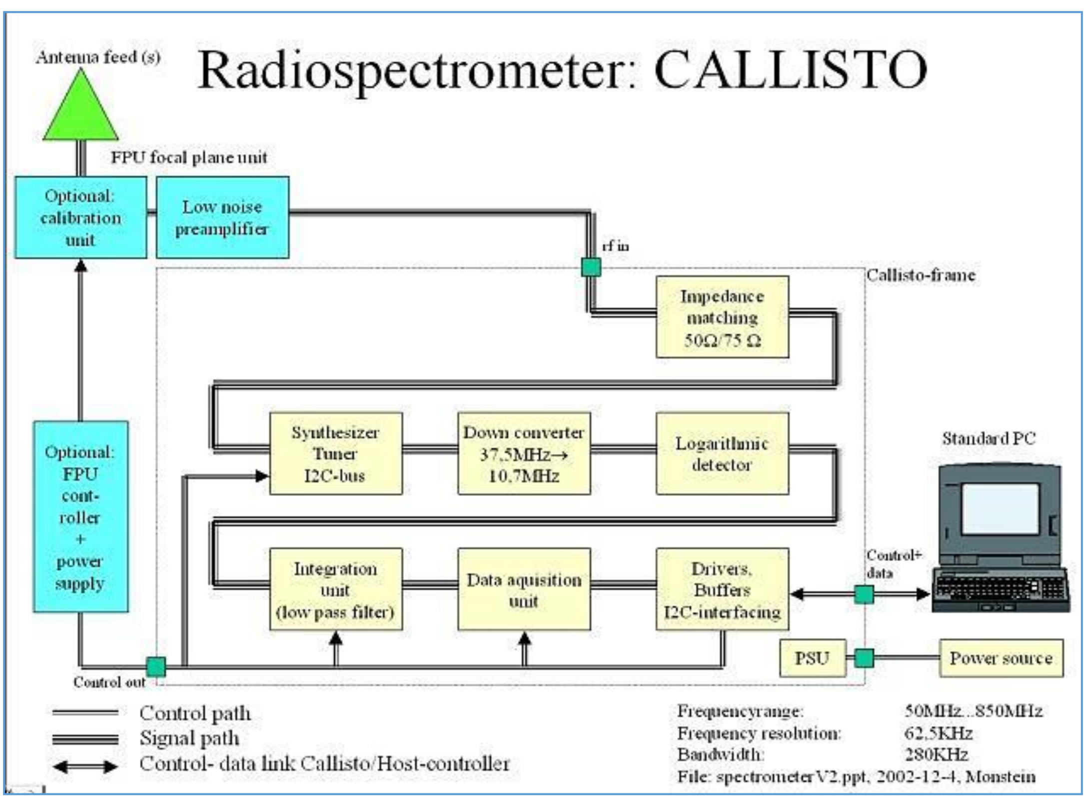

Figure 4. CALLISTO System (Credited to e-CALLISTO

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 3shows the Solar Telescopes at the Telok Kemang Solar Observatory, Malaysia

The CALLISTO spectrometer is a programmable receiver built to observe or detect solar radio burst that occur at a particular time and location. This program is applied to observed solar radio burst and Radio Frequency Interference (RFI) that is used to monitor for astronomical science, education and others. CALLISTO operates between the frequencies of 45MHz to 870 MHz using a modern, commercially available broadband cable TV tuner having a frequency resolution of 63.5 KHz. There are a lot of CALLISTO instruments have been deployed in Malaysia, Indonesia, Australia, Switzerland, Russia, South Africa and many more.

3. RESULTS AND ANALYSIS

Figure 5 shows three sunspots, which were known as AR2406, AR2407 and AR2409. The great 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 single type III burst. Figure 4 showed the prominence that occurred on 3rd September 2015 at 08:20 [UT]. 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 and shown in Figure 6. The solar radio burst was recorded by e-CALLISTO system using HB9SCT which is the test site of Christian Monstein located in Switzerland.

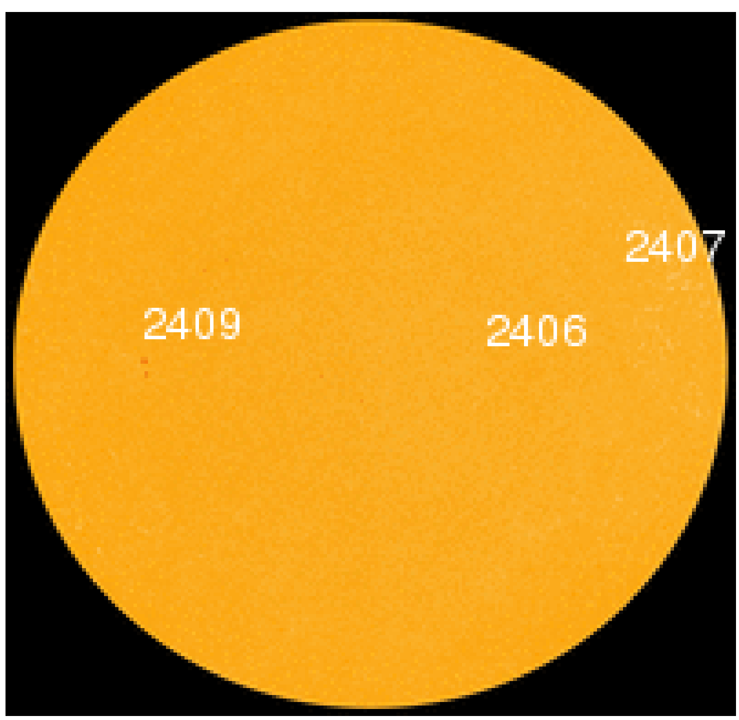

Figure 5. The location of AR2406, AR2407 and AR2409 on 3rd September 2015 (Credit: SDO/HMI)

Figure 6. The prominence that occurred at 0820 UT
(Credited to Telok Kemang Solar Observatory, Malaysia)

Table 1. The condition of the sun on 3rd September 2015 (Credited to Space Weather).

Parameter	**Value**
Radio sun	10.7 cm flux: 88 sfu
X-ray solar flare	6-hr max: B2 2253 UT Sep 03
	24-hr: C1 1137 UT Sep 03
Planetary K-index	Now:K_p = 2 quiet
	24-hr: K_p = 3 quiet
Interplanetary magnetic field	B_{total}: 11.7 nT
	B_z: 8.1 nT south

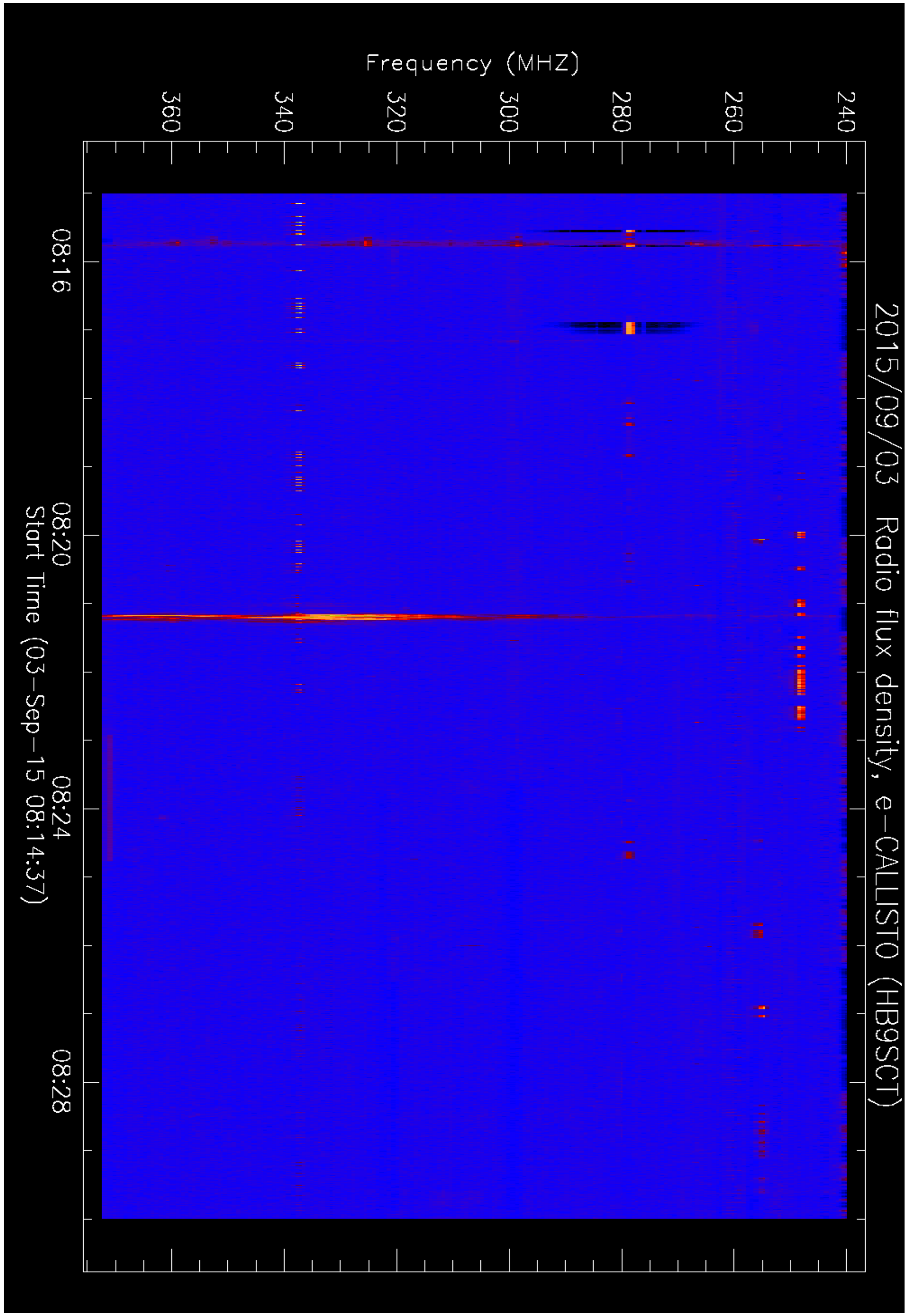

Figure 7. The solar radio burst type III at 08:20 UT (Credited to e-CALLISTO)

The graph showed the single radio burst located at several points. The event occurred at a frequency of 285 MHz and ended at 370 MHz, which lasts for about 20 seconds. The minimum energy for the starting frequency was 1.888 x 10^{-25} J and maximum frequency was 2.452 x 10^{-25} J at the ending frequency. Based on the calculation, the drift rate was 4.25 MHz/s and the solar wind recorded for this event was 440.6 km/sec and has proton's density of 8.1 protons/cm^3. This prominence was detected as active prominences as it occurred at active region of AR2407.

Consequently, this type III burst provide information on electron acceleration and transport, and the conditions of the background ambient plasma they travel through. The eruption agree that a formed flux rope erupts once it exceeds the instability threshold, which forces the overlying magnetic field to open. However, they differ in the location where the different events happen, as well as their temporal sequence (the formation of a current sheet, for instance). Magnetic equilibrium is eventually recovered as a consequence of reconnection in the current sheet.

One of the key approaches to answering this question depends on our ability to identify the location and timing of the optical image of the prominence brightening in H-alpha and Calcium filter. Their position within the magnetic structure, inferred from the photospheric magnetic field and its extrapolation, can help distinguish among the various magnetic models for the eruption.

The active region on the Sun experience the gradual build up of the magnetic field which gives rise to the sunspots ,prominences and loops in the corona and produce the powerful outburst explosions. Eruptive prominences are one of the type of solar outburst. They begin as a normal prominences, dense curtains of gas at a relatively cool temperature about 10000 K and hanging high up in the much hotter corona. The magnetic field will change it structure and shape within a few minutes. As it twists and tears itself from the Sun at the end, the magnetic field catapults the prominence gas's out into space.

4. CONCLUSION

The activation may be caused by shock waves issuing from prominences and solar flares. The loop prominences can be observed by using the optical telescope and is the initiates points of the following important flare that exist for 6 hours. Type III burst can be observed when there is bright active region on the sun's surface. This type of burst can occur singly, in group or storm. Based on the solar radio burst recorded by e CALLISTO on 3rd September 2015, type III radio burst was detected. The burst was a single burst with duration of 20 seconds and drift rate of 4.25 MHz/s. The event occurred at 285 MHz and finished at 370 MHz, which lasts for about 20 seconds. The energy, calculated were between 1.888 x 10^{-25} J and 2.452 x 10^{-25} J. This indicates that the burst occurred because of the active region of AR2407.

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