An Analysis on the Formation of Solar Radio Burst Type II, III and IV by Using e-CALLISTO, IUGONET and Space Weather Data

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Abstract. The study of the radio solar burst data on 30th March 2018 and 31st March 2018 are essential for the understanding of type II, type III and type IV nature. Through this paper, the relationship of these three types of solar radio burst can be studied. The necessary data were collected from the free online websites which includes the Space Weather Website, e-CALLISTO and IUGONET metadata database. From this study, the occurrence of solar radio burst type II, III, and IV showed that there was the production of solar flares and Coronal Mass Ejections (CMEs) where it contributed to the geomagnetic disturbances to the Earth. On 30th March 2018, the Sun produced C-class flares with C4 value while the next day, the sun had B1 solar flares’ event. The planetary K-index for both days were 2 (30th March 2018) and 3 (31st March 2018) respectively.

1. Introduction
The Sun is our nearest star to the Earth with the distance of 1AU. When the activity of the Sun is active, the Sun will produce a fast-moving solar wind that eventually will cause the effect to the surrounding interplanetary space. Basically, when the sun is very active, they will produce intense magnetic field which then will trigger the formation of solar flares or another powerful phenomenon which is known as Coronal Mass Ejection (CME).

Type II solar radio burst has slow drift bursts where they drift from high to low frequencies at the rates of about ¼ Mc per sec per sec [1] where the drift rate decreasing when the wavelength is decreasing [2, 3]. This kind of solar radio burst type are released in second harmonic and fundamental bands as proposed by Murray, Wild and Rowe that the drift of the frequency is caused by the excitation in the plasma oscillation of the coronal gas where the frequency decreases with time. It is due to the exciting activity travels to the region of decreasing electron density. The metric of type II burst is produced by the Coronal Mass Ejections, flares and also different types of ejecta that is considered as drivers of the MHD shocks [4-6]. Solar radio burst type II was identified and discovered by Payne Scott et al. [7] and Wild and McCready [8] respectively. They are categorized by the broadband and have time duration of about 20 minutes to a few hours.

Solar radio burst type III is a fast drift burst and most common to be found in meter wavelength bursts with the frequency range of 10 MHz to 500 MHz. This type of solar radio burst was introduced by Wild [9] and can be occurred singly, in group or in the storm. The intensity of the signal may vary
for type III burst with the frequency. The duration of type III burst can exceed 30 minutes [10]. The electron plasma waves of type III burst are coalescence from the nonthermal distribution with the thermal distribution charge fluctuations [11, 12]. Type IV solar radio burst shows the formation of new active region [13, 14]. Some of type IV burst will come before type II burst at meter wavelength. This type of bursts is related to the production of the sunspot group. It is also well known to be followed by the geomagnetic disturbance [15].

2. Methodology and Observation
All the data for this study was collected from the Space Weather Website, IUGONET and e-CALLISTO. CALLISTO is the abbreviation for Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory where currently there are more than 150 instruments at more than 90 locations worldwide. CALLISTO is design for solar radio burst and RFI monitoring for education and astronomical science purpose [16] and is a global network that is connected via the internet [17]. The data collected for solar radio burst were from BLENSW, GREENLAND and BLEN5M site. BLENSW and BLEN5M are the observatory from Switzerland while GREENLAND is from the ISR Observatory, Greenland. The magnetic field data was taken from the IUGONET metadata database and other parameters of the sun such as the speed, density, and radio sun were collected from the Space Weather Website. All data then were analysed to see their relationship to each other.

3. Discussion
The tables and figures provide the data and information about solar radio burst type II, III, and type IV.

Table 1. Sun’s current conditions on 30th March 2018 (Credit: Space Weather)

| Parameter                  | Value      |
|----------------------------|------------|
| Solar Wind                 | 454 km/sec |
| X-ray Solar Flares         | C4         |
| Sunspot no.                | 0          |
| Radio Sun                  | 10.7 cm flux: 69 sfu |
| Planetary K-index          | Kp = 2 (quiet) |
| Interplanetary Magnetic Field | B<sub>total</sub>: 8 nT | B<sub>Z</sub>: -4 nT South |

Table 2. Probabilities of Geomagnetic Storms at High-latitudes (Credit: Space Weather)

|       | 0-24 hr | 24-48 hr |
|-------|---------|----------|
| Active| 20%     | 15%      |
| Minor | 25%     | 20%      |
| Severe| 20%     | 15%      |

Figure 1. The Sun surface for sunspot and coronal hole region on 30th March 2018.(Credit: SDO/HMI/AIA)
Table 1 above shows the condition on the Sun’s surface on 30th March 2018. The solar wind was a bit high with the speed of 454 km/sec although the sunspot number was 0. But, as can be seen from Figure 1 of coronal holes structure, we can observe that solar wind stream was high as the temperature and densities of this region was very low. Thus, the area is thin and make it easy for solar wind to break through it. We are reaching the solar minimum as the spotless days of the Sun can be seen for the past 2 years. From the X-ray solar flares recorded, the flare was classified to be in the C-class with the indication of giving few visible consequences to the Earth. C-class flare ranging from $10^5 \leq 1 < 10^6$.

Radio sun with 69 s.f.u. shows the correlation with the sunspot number and a number of UV and visible solar irradiance records. The K-index showed the value of 2 which means the sun is in calm condition. The chances for the occurrence of geomagnetic storm at high latitudes of severe rate was low with the reading of 15% for one to two days alert and only 1% at mid-latitudes regions as mentioned in Table 2.

The interplanetary magnetic field of the Sun during that day (30th March 2018) was $B_z = -4$ nT South. It is known that when the value of this magnetic field is lower, the chances for the aurora activity is much higher. Figure 2 shows the magnetic field data from 25th March 2018 until 1st April 2018. The above magnetic field data shows that on 26th, 27th and 28th March 2018, the peak was a bit high in a term of their H, D and z components. This may indicate that the recorded solar bursts from the CALLISTO systems was caused by the sun activities on those days.

**Figure 2.** Magnetic field data with 1sec resolution from the fluxgate magnetometer at Syowa Station, Antarctica (Credited: IUGONET data; National Institute of Polar Research, Japan)
There are two events of solar radio burst data recorded on 30th March 2018 (Figure 3) after a few quiet days of the Sun. The first event of solar radio burst occurred at 08:00 UT while the second event at 13:22 UT. The event on 08:00 UT was producing type III solar radio burst followed with type II burst. Type II burst showed the fundamental (occurs between 20 to 150 MHz) and first harmonic radiation which lasted for ~1 minute. Radio burst type III started at 20 MHz and ended at 70 MHz while type II started at 20 MHz until 60 MHz. From the burst shown, we knew that the sun was experienced solar flare and followed by the production of Coronal Mass Ejection (CME). The next event (Figure 4) at 13:22 UT showed small group of solar radio burst type III with duration of two minutes. It means that, there was another occurrence of solar flares after the event at 08:00 UT. The burst data was obtained at Greenland site of CALLISTO.

Table 3. The condition of the Sun on 31st March 2018 (Credit: Space Weather)

| Parameter                  | Value                     |
|----------------------------|---------------------------|
| Solar Wind                 | 469 km/sec                |
| X-ray Solar Flares         | B 7.1                     |
| Sunspot no.                | 11                        |
| Radio Sun                  | 10.7 cm flux: 69 sfu      |
| Planetary K-index          | Kp = 3 (quiet)            |
| Interplanetary Magnetic Field | $B_{total}$: 7 nT; $B_z$: -5 nT South |
Figure 5. The Sun’s surface showing the sunspot and coronal hole on 31\textsuperscript{st} March 2018. (Credit: SDO/HMI/AIA)

Table 3 above shows the condition of the Sun on 31\textsuperscript{st} March 2018. On that day, there was 11 sunspot numbers that appeared on the Sun’s surface (new sunspot appeared, AR2703) with the radio flux of 69 s.f.u. That day solar flare was recorded and categorized under B1 class which was caused by the AR2703. The solar wind speed on that day was quite high with 469 km/sec. The Kp index was 3 (quiet). This Kp index was recorded by a magnetometer, an instrument that measure the disturbances of geomagnetic field. The data from magnetometer for this 31\textsuperscript{st} March 2018 can be refer from Figure 2. Besides that, the B\textsubscript{z} component value was -5.0 nT pointing to the South and the probability of geomagnetic occurrence was 10% severe for the coming one to two days starting on that day.

Figure 6 above displays the data of solar radio burst type IV which was recorded by the CALLISTO system at site Bleien, Switzerland. As can be seen from the data above, the frequency range were from 300 MHz to 800 MHz with duration of approximately 500 seconds. Usually, type IV occurs after a great outburst which related to solar flares or plasma emissions. Besides, in other word, type IV burst can also occur when there is the formation of the new active region and production of sunspot group where they might yield the geomagnetic disturbance [13-15]. The Sun’s surface on 31\textsuperscript{st} March 2018, showed the appearance of the new active region 2703. This can be a proof of the production of the solar radio burst type IV.

4. Conclusion
From the all the data collected on 30\textsuperscript{th} March 2018 and 31\textsuperscript{st} March 2018, it shows that even the Sun is not active (in terms of the production of the sunspot), we can still get the data which indicates that the sun, somehow, is active for the production of the flares and Coronal Mass Ejection. In addition, the activities from the past days before 30\textsuperscript{th} March 2018 contributed to the production of the solar flares and Coronal Mass Ejections thus enhancing the geomagnetic disturbance.
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