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GEOMAGNETIC STORM RELATED TO INTENSE SOLAR RADIO BURST TYPE II AND III DUE TO M3.9 CLASS FLARE AND CORONAL MASS EJECTIONS

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ABSTRACT

The strong energetic particles ejected during sun's activity will propagate towards earth and contribute to solar radio bursts. These solar radio bursts can be detected using CALLISTO system. The open website of the NASA provides us the data including CALLISTO, TESIS, solar monitor, SOHO and space weather. The type III and II solar radio burst on 9th November 2015 due to M3.9 class solar flare and coronal mass ejections event has expected to cause the geomagnetic storm on 11th November 2015. The geomagnetic storm reached the Earth a day earlier than expected date due to high speed coronal mass ejections that more than 950 km/s and high energy of ejected particle that causes the M3.9 class flare and coronal mass ejections. The geomagnetic storm luckily does not give high impact on earth because the event on sun, which triggered this storm not heading toward earth.

Keywords: solar radio burst; coronal mass ejections; geomagnetic storm; solar flare.

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1. INTRODUCTION

The Sun is the nearest star which consists of hot gaseous with 92% Hydrogen and about 8% Helium. The structure of the Sun can be categorized into two layers; inner and outer layer. Inner layer consists of core, radiative zone and convective zone. While, outer layer consists of photosphere, chromosphere and corona. Usually, activities of the Sun such as solar flare, solar prominence and Coronal Mass Ejections (CMEs) take place on the surface of corona. The Sun is our main source of energy.

Normally, the activity of the Sun will eject the energetic particle and some of them can propagate towards the Earth. Since 1960s, the solar radio burst has been classified into five types at frequency of below few hundreds MHz [1-2]. All the types of solar radio burst have their characteristics. The type I solar radio bursts are non-flare related phenomenon, consisting of a continuum components and a burst component [1]. Type II burst is due to Coronal Mass Ejections, while type III and IV usually related with solar flare. For type V, it is usually accompanied by type III [3].

There are different types of CMEs. They are classified according to the activities take place before forming the CMEs. The first type is flare-related CMEs while the second type is CMEs associated with filament eruption.[4-5]. The flare related CMEs potentially formed the CMEs during solar flare events. This type of CMEs is due to magnetic [23] flux in active region, which potentially observed the CMEs during solar flare events. Normally, the SRBT III and II could be formed on spectrograph during this event [6, 4]. For the second category, it could lead to SRBT IV and II due to evolution of sunspot where the filament eruption also can form CMEs.

The mechanisms responsible for the CMEs explosion can be categorized into three a) gradual CMEs b) impulsive CMEs c) CMEs related to SRBT IV [7-8]. The gradual CMEs usually formed when prominences and their cavities rise up from below coronal streamers with speed in range 400-600 km/s before leaving 30RΘ [4, 9]. While for impulsive CMEs, it is closely related to flares and Moreton waves. This Moreton wave is an intimation of the CMEs with the detonation drive directly across the 2-30 RΘ at speed reach more than 750 km/s. It is very dangerous if the CMEs pointed towards the Earth [4, 10], which will give high impact to the

Earth for example geomagnetic disturbance on the Earth, which can have a serious effect on power system. The final mechanism is affiliated to the burst type IV contemplate s third stage of the flare evolution, which is only acquire a larger event contributed to the expulsion of proton flares during explosive phase [7, 11].

Indirectly, explosion of solar radio burst possibly bring out many negative impacts to the Earth. By very extreme energy particles exonerate from intense solar radio burst can be detrimental to the humans as lower the lower energy radiation from nuclear explosion. These energetic particles due to solar [22] activities also give an impact toward our satellites [12] and also power grid system.

The different method used to obtain all the results. The solar radio burst can be detected using CALLISTO system consist of hardware and software. The main instruments of CALLISTO system is antenna, Low Noise Amplifier (LNA) and CALLISTO spectrometer. However, the CALLISTO system has been successfully installed in more than 38 countries all over the world and they provide the data for future used on CALLISTO website. In Universiti Teknologi MARA (UiTM) Shah Alam, we still in progress for installing the CALLISTO system and contribute data to the website.

Most of the data for CME, flares and geomagnetic storm were obtained from the website as there are some limitations and impossible to get the optical data from the surface of the Earth of Sun's activity. So, the satellites under NASA's project were launched to capture the image of activity on the Sun and the data are open to all researchers.

The event on 9th November 2015 showed the M3.9 class flare with high speed of CMEs lead to Solar Radio Burst Type III and II. The high speed of CME was targeted to reach the Earth on 11th November 2015. However, the CMEs reach the Earth on 10th November 2015 and caused geomagnetic storm even though it was not directed towards the Earth. This expectation due to high speed of CME, which is can reach more than 950 km/s.

Geomagnetic storm is the effect of solar wind shock wave, which causes a temporary disturbance on Erath's magnetosphere. The power will be disturbed when there are geomagnetically induced current (GIC) impelled by the electric field carry out by the magnetic field variations that appear during a geomagnetic disturbance. Current induced in power lines flow to ground through substation transformers. This will lead to saturation of the transformer core, which bring out to variety of problems. Increasing heat of transformer is the purpose of burning out. It is costly involvement in fixing the problem for not only destruction of equipment, but also the loss of income from sale power. It was recorded in 13th March 1989, Quebec was experience for over 9 hours without power due to geomagnetic disturbance. The Quebec blackout on 13th March 1989 had a total cost about 13.2 USD with harmful equipment about 6.5 million USD. The transformer of nuclear generation station at Salem, New Jersey were cost several million dollars to replace after burnt out during the same geomagnetic disturbance on 13th March 1989 and the acquisition of replacement power from neighboring utilities cost about 17 million USD. The high cost required to replace the breakdown system and delivery time also take long period to recover usually one year.

Geomagnetic storm also affected the satellite and spacecraft. It was recorded the G5 geomagnetic storm in 2003 called Halloween storm causes the failure of Solar and Heliospheric Observatory (SOHO) satellite. The Halloween CME strike the Earth's magnetic field on 29th October 2003 with G5 (extreme) geomagnetic storm, which lasted for twenty-seven hours. The CMEs left the Sun on 28th October 2003 and zap not only the atmosphere on 29th October 2003, but interfere with vital communications network. This geomagnetic storm was one of the largest ones of the past half-century with X45 class solar flare and has believed to be responsible for complete loss of the 640 million USD on ADEOS 2 spacecraft along with its 150 million USD NASA Seawinds instrument. It also triggered the Global Positioning System (GPS) disruptions to Federal Administration Aviation navigation system.

2. RESULTS AND DISCUSSION

On 9th November 2015 an intense Solar Radio Burst Type (SRBT) III and II were recorded by CALLISTO in Glasgow. The time interval within these two burst are only in short period of time, which is 3 minutes and 55 seconds. This event is one of the notable event in 2015 with related to both M3.9 class flare and intense Coronal Mass Ejections.

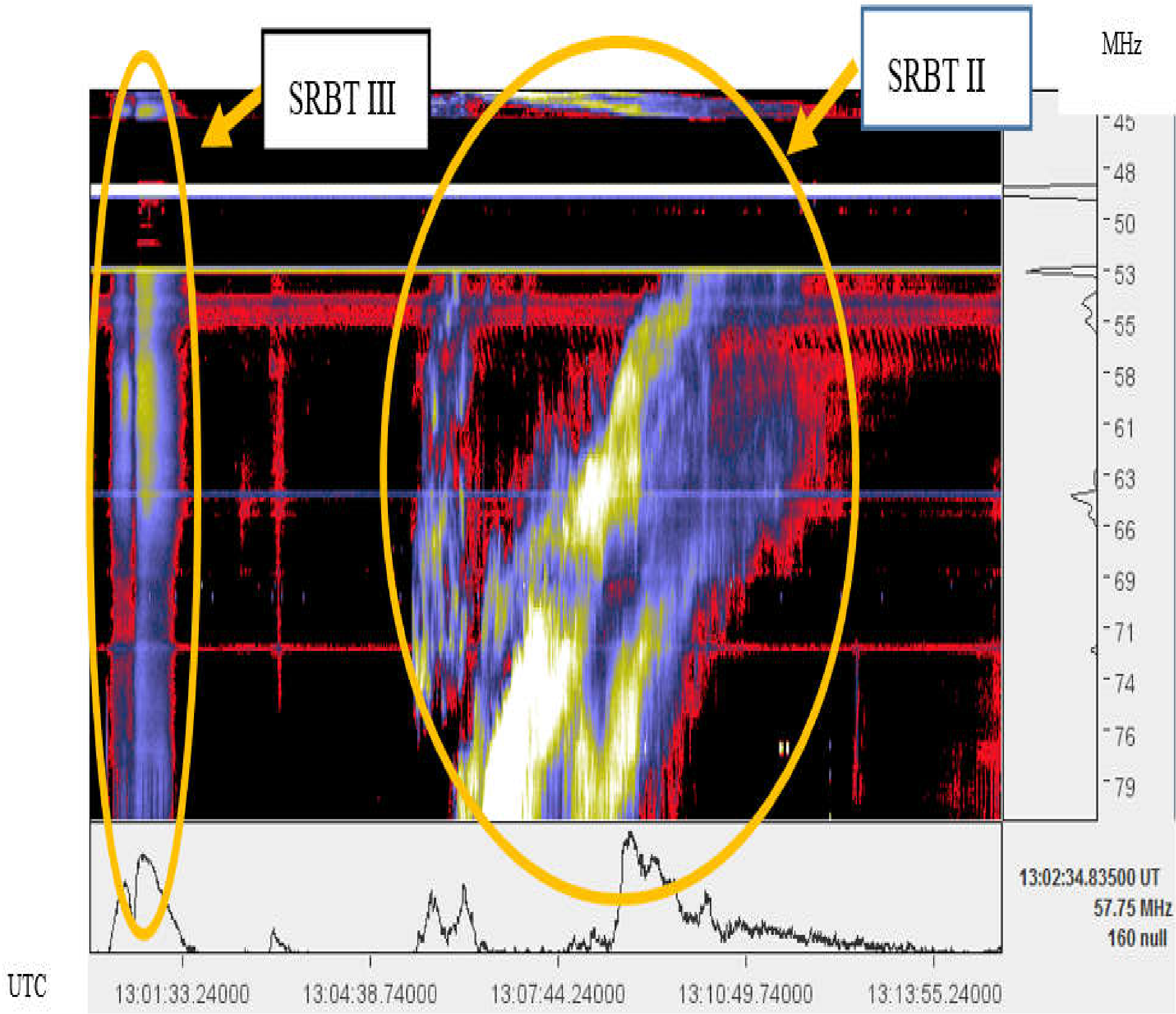

Fig.1. The Type III and Type II Solar Radio Bursts on 9th November 2015

The Solar Radio Burst Type III recorded at time interval of 13:00:15 UT until 13:01:22 UT, while the Solar Radio Burst Type II emerged on spectrograph at 13:05:17 UT until 13:11:48 UT. During this event, the soft X-ray spectrum observed by GOES 15 showed the maximum intensity of 3.964 x 10^{-5} Wm^{-2} at 13:12 UTC and this flare is classified as M3.9 class flare. The intensity of soft x-ray emission starts to increase at 12:15 UTC and takes 20 minutes to reach maximum intensity. The decay of x-ray emission ended at 15:37 UTC and this process takes 2 hours and 25 minutes. The M3.9 flare is medium sized flares usually attack the southern and northern poles of the Earth, which causes the blackout. This M3.9 flare has strong and huge energy, which correlate with gradual CMEs events 30 minutes later [7]. This Gradual CMEs was proved by SRBT II minutes later at spectroscopy. This explosion of solar flare and CMEs observed in sunspot AR 12499.

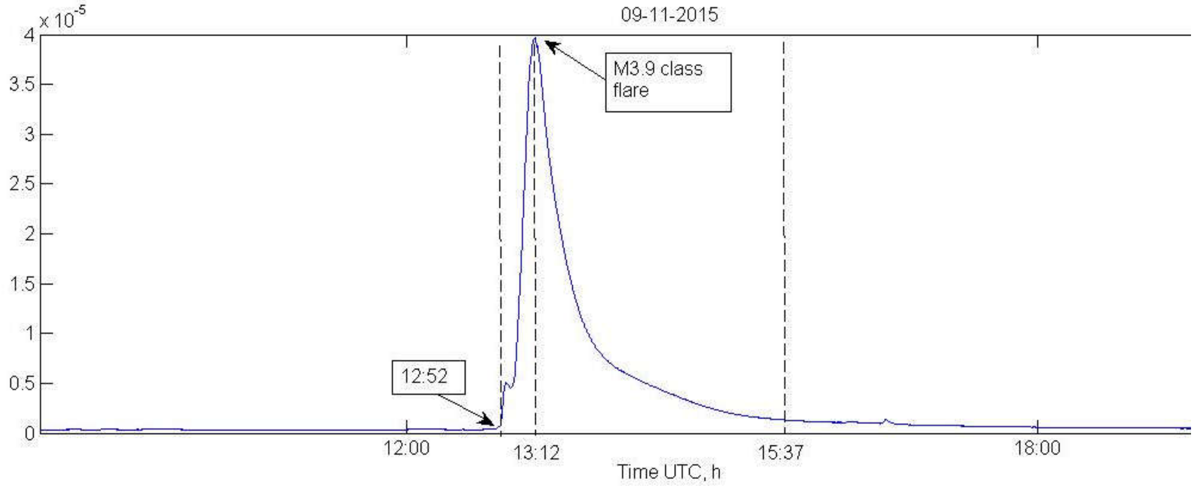

Fig.2. Soft x-ray spectrum obtained from GOES 15 satellite shows maximum intensity at 13:12 UTC

The CMEs triggered at 13:36UT until 15:48UT captured by SOHO with clear helmet streamer structure at 14:00UT. The space weather [20] website reported that the radio emission from shock waves in CMEs reach more than 950 km/s as it left the Sun's surface; lead to geomagnetic storm on 10th November 2015. This CMEs can be classified as flare-related CMEs which causes SRBT III and II, and the mechanism involved for this CMEs is impulsive CMEs explosion as the speed is more than 750 km/s [13].

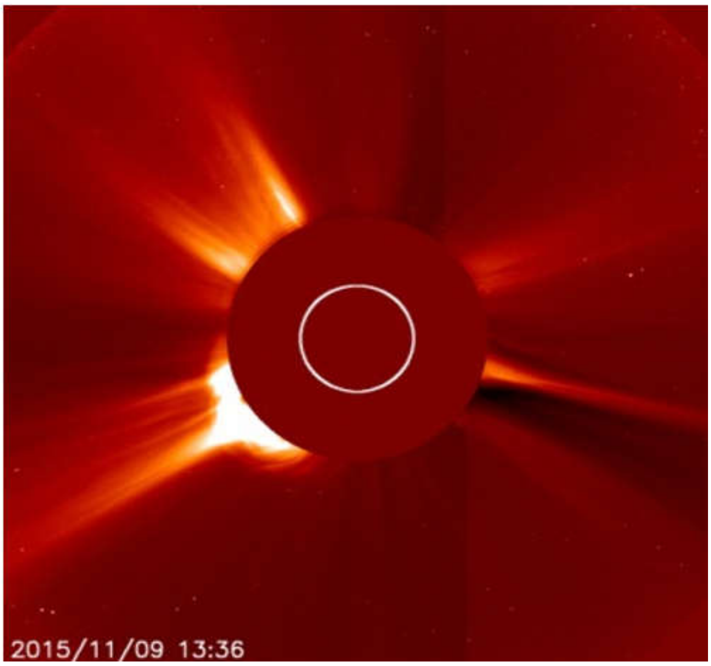

Fig.3. The Coronal Mass Ejections at 13:36 UT

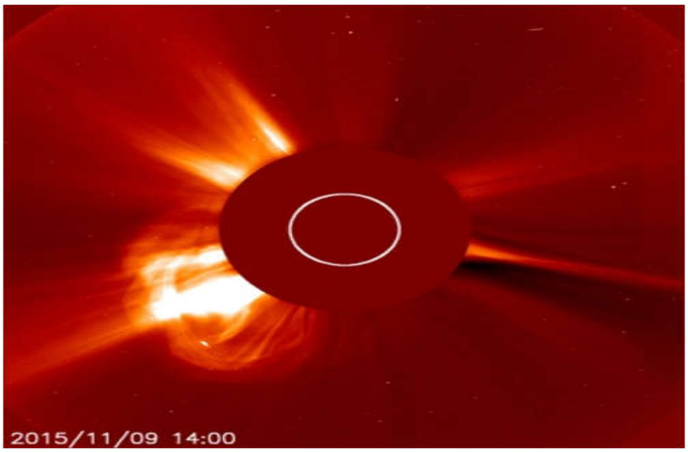

Fig.4. The Helmet Streamer of Coronal Mass Ejections 4 minutes later

The G2 class magnetic storm on 10th November 2015 is due to fast moving stream solar wind pounding the Earth's magnetic field. Although the CMEs is not heading toward the Earth, it will be geoeffective. NOAA forecast models anticipate a glancing blow on 11th November 2015 with G1-class geomagnetic storms likely when the CME arrives. However, the geomagnetic storm occurred earlier than expected date due to faster speed of CMEs.

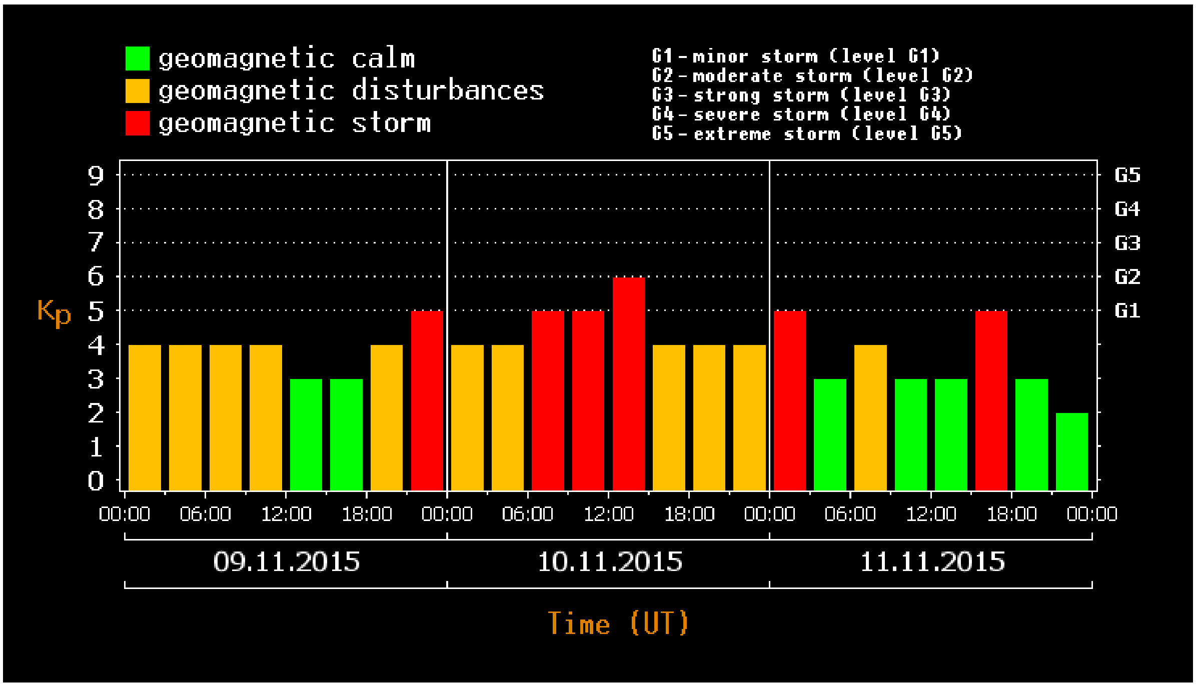

Fig.5. The graph of geomagnetic storm on 9th November 2015

3. METHODOLOGY

The CALLISTO system used to get the data of Type II bursts, which are consist of antenna, Low Noise Amplifier (LNA) and CALLISTO spectrometer. All these instruments linked using coaxial cable for minimum cable loss [14]. CALLISTO itself stand for Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory has been introduced in 1980s and 2000s by Institute of Technology Zurich and established several solar radio spectrometers such as Phoenix and Phoenix II [15-16]. This spectrometer manage to function in frequency range of 45-870 MHz [17]. This is one of ISWI (International Space Weather Initiative) project [14, 18] with goal to study the activity of the Sun within 24 hours per day and has collaborates with several countries to contributes the data in websites. The low-cost instrument, provide worldwide installation and networking, which enhances the observed data [18-19]. The figure below showed the distribution place, which has installed the CALLISTO instruments that consists of 136 instruments in more than 75 locations with users from more than 133 countries. All the data from all sites will update a data per 15 minute.

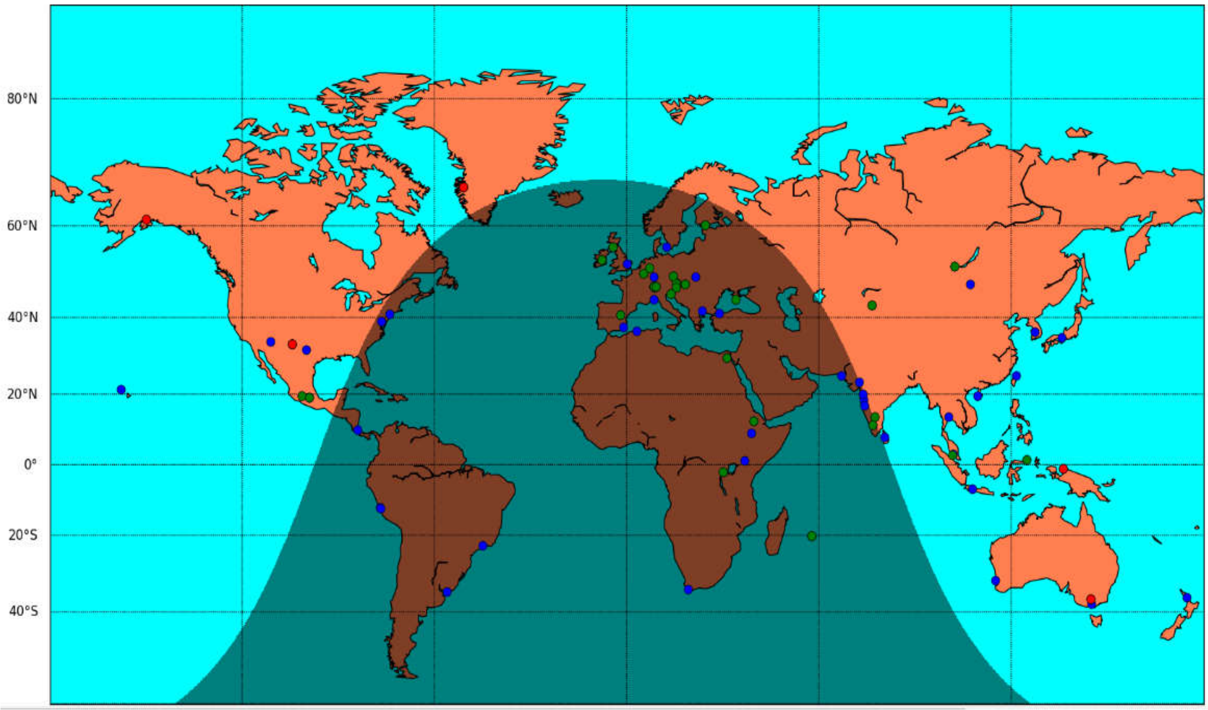

Fig.6. The IDL map of the present distribution of CALLISTO instruments

For the CMEs obtained in this paper, it is from SOHO (Solar and Heliopspheric Observatory) website which is a project of ESA (European Space Agency) and NASA. SOHO was design with intend to study the inner structure of the Sun, its broad outer atmosphere and the origin of the solar wind, the flow of highly ionized gas that blast continuously outward through the Solar System.

4. CONCLUSION

It is important to know the relation of all activities of the Sun as they could give high impact on the Earth. The event on the Sun on 9th November 2015 can be highlight as a huge event, which lead to geomagnetic storm with related to M3.9 class flare and flare-related CMEs contribute to SRBT III and II. The very intense SRBT III and II displayed in spectroscopy due to high energetic particle due to these activity of the Sun. The high speed of CMEs causes the earlier geomagnetic storm than expected date. Although geomagnetic storm has strike the Earth, but it does not give high impact as the CMEs not directed toward the Earth [21].

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