An Analysis of Active Region as a Trigger of Solar Flares

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Abstract. Sunspot number, solar radio flux and solar wind involve in interpreting the movements of CMEs and solar flare. Rotating sunspots are an extremely efficient way to inject energy into the magnetic field of the sun's atmosphere. A solar flare is essentially a blast on the surface of the sun going from minutes to hours long. Therefore, the objective of this study is to state that the active region sunspot waves as a trigger solar flare. Equally important, the energy efficiency associated with solar flares may take several hours or even days to build up, but most flares take only a matter of minutes to release their energy. Detailed analyzed of solar flare event on 2016 and 2017 based on e-CALLISTO, the higher the number of active region sunspots, the higher the class of flares produced and released. Four classes of solar are observed in categories of frequency, interplanetary magnetic field and sunspot number emitted by the solar. By using the interplanetary magnetic field data, the magnetic energy contained in the active region sunspots has been calculated which this magnetic energy triggered the emission of solar flare. This study exposed us to analyze the active region waves as a trigger of solar flares and also the factor influenced by it. The physical element that triggers the solar flare by measuring the magnetic energy in the flaring site.

Key words. Sun; Active region; Sunspot; Solar Flare; Data analysis

1. Introduction

In the past, researcher had more focus on the mechanism of the solar flare and nuclear fusion, but rejected due to the low densities in upper chromosphere or lower corona. The positive sunspots, composed of proton particles, and the negative sunspots composed of electron particles, are produced and ejected from tachocline zones, then appearing on the solar surface and moved towards the polar region. However, it processes takes a longer period of time, the nuclear fusion occurred along the first or multiple inner orbits of gyrating protons, depends on the magnitude of producing external magnetic field [1]. Therefore, the objective of this study is to state that the active region sunspot waves as a trigger solar flare. Sunspot number, solar radio flux and solar wind involves in interpreting the movements of CMEs and solar flare [2]. Solar flares are greatly related to the sunspot appearance, it is also found that flares usually occur near and along the dividing line (neutral line) between areas of oppositely directed magnetic fields of sunspots and the development of flares [3].

2. Literature Review
The disturbed area around and above the bipolar sunspot pairs or groups which are highly magnetized is called an active region. A solar flare is essentially a blast on the surface of the sun going from minutes to hours long. Flares occur when the magnetic fields in and around the sun reconnect. There are 5 classes of solar flare (A, B, C, M and X) [4]. They are typically connected with active regions, frequently observed as sun spots, where the magnetic fields are strongest. Solar flare and Coronal Mass Ejections (CMEs) are well known as one of the most massive eruptions which potentially create major disturbances in the interplanetary medium and initiate severe magnetic storms when they collide with the Earth's magnetosphere [5]. Flares and CMEs do not occur when potential magnetic field is in stable equilibrium (a) state because there is no free energy that can be released [6]. Sheared magnetic fields or flux ropes that store free energy when in metastable state (b) and loss-of-equilibrium or loss-of-stability can occur owing to some disturbances [7]. By storing more free energy, the system moves to an unstable equilibrium state (c). Finally, the system reaches the non-equilibrium state (d), and the system cannot stay in a static state any longer and moves to a dynamic state. In this case, sheared magnetic arcades reconnect owing to emerging flux or horizontal motion in the photosphere, and flux ropes suddenly rise upward if the system reaches the loss-of-equilibrium state; then, flares and CMEs occur. Interference with convection magnetic field darkening the sunspots. The spikes clustered around the magnetic field region develop into loops connecting regions of magnetic polarity at active region. The surface horizontal rotational flows could provide sufficient magnetic helicity and energy to produce solar flares [8]. Explosive events such as solar flares can be generated by changing the magnetic field causing by the magnetic reconnection caused by the transverse compressible wave [9].

Rotating sunspots are an extremely efficient way to inject energy into the magnetic field of the sun's atmosphere. Magneto hydrodynamic (MHD) waves play an important role because waves are natural carriers of energy, momentum and data. 3-min oscillation over sunspots are one of the most distinct wave phenomena at chromospheric level and assumed to be related to slow magneto acoustic waves[10]. Class X flares are the strongest types of solar flares that can erupt from the sun. There are also two weaker categories: Class M flares, which are medium strength, but still powerful, and Class C flares, which are the weakest storms from the sun. Class A flares have purely thermal, compact sources while Class B flares are impulsive bursts which show double foot points in hard X-rays. It is widely accepted that solar flares are explosive phenomena that free the magnetic field energy kept in the solar corona mainly as thermal and kinetic energy of the plasma [11]. The typical spatial size, duration and released energy of a flare is about $10^9$ cm, $10^3$ sec and $10^{28}$ erg respectively.

Detailed analyzed of solar flare event on 2016 and 2017 based on e-CALLISTO, the higher the number of active region sunspots, the higher the class of flares produced and released. The sunspot number played an important role in the release of the solar flares. There are 85 numbers of sunspots on 5th May 2005 and on this day X class flare was released which is the highest class of flare. The cooler temperatures result in increased magnetic activity which allows the charged particles to escape from the sun’s atmosphere because of their increased activity. The solar radio bursts are the results of solar flares take place on the surface of the Sun [12].

3. Experimental

The CALLISTO (Compound Low Cost-Low Frequency for Transportable Observatories) system is one of the most outstanding project under ISWI with there are more than 80 instruments in more than 43 locations with users from more than 116 countries consist of indoor amplifier, CALLISTO.
Receiver, and computer [13, 14]. This network systems are widely used for continuous data collection of solar activities every day through the internet connection and stored in the central database in the computer [15]. At the beginning, the CALLISTO spectrometer was covering a frequency range from 45MHz to 870MHz with the nearness of log-periodic antenna and has a full scope of frequency at Blein Radio Observatory around 50km west of Zurich [16]. The other frequency range can be seen by exchanging in a heterodyne up and down converter. The radiometric bandwidth around 300 KHz given by ceramic band pass channel, while the programmable step measure in frequency is 62.5 KHz. Callisto has constructed precisely for radio spectrometer and focusing on solar flare radio. Noted that all the sites are less suffering from local Radio Frequency Interference [17].

4. Result and Discussion

Four classes of solar flare were observed in categories of frequency, interplanetary magnetic field and sunspot number emitted by the solar. Such in solar flare class B which is the highest frequency is 900 MHz on 19/4/2016 which released energy value is $5.963 \times 10^{-31}$ MeV while on 27/5/2017 the highest frequency is 70 MHz however it rising on 9/6/2017 to 360 MHz.

Table 1: Data energy emitted in solar flares

| Date       | Burst Duration (Minute s) | Lowest Frequency (MHz) | Highest Frequency (MHz) | Drift Rate | Energy at Lowest Frequency (MeV) | Energy at Highest Frequency (MeV) |
|------------|--------------------------|------------------------|-------------------------|------------|----------------------------------|----------------------------------|
| 19/4/2016  | 2                        | 200                    | 900                     | 5.8        | $1.325 \times 10^{-31}$           | $5.963 \times 10^{-31}$            |
| 21/4/2016  | 1                        | 65                     | 160                     | 1.6        | $4.307 \times 10^{-32}$           | $1.060 \times 10^{-32}$            |
| 27/5/2017  | 2                        | 20                     | 70                      | 0.4        | $1.325 \times 10^{-32}$           | $4.368 \times 10^{-32}$            |
| 9/6/2017   | 2                        | 110                    | 360                     | 2.1        | $7.289 \times 10^{-24}$           | $2.385 \times 10^{-21}$            |

Active Region 2529 just produced a moderately strong B9 solar flare peaking at 23:00 UTC (April 19th). Solar activity has been at very low levels for the past 24 hours. There are currently 2 numbered sunspot regions on the disk Solar activity is expected to be low with a slight chance of an M-class flare on day one (20th April) and expected to be very low with a chance for a C-class flares and a slight chance for an M-class flare on day two (21st April) and expected to be very low with a slight chance of a C-class flare on day three (22nd April).

For class B solar flare, the highest frequency which is 500 MHz with $3.31 \times 10^{-31}$ MeV was started on 28\textsuperscript{th} March 2016 and on 25\textsuperscript{th} July 2016 stated the lower frequency among the highest frequency, 90 MHz with $4.64 \times 10^{-32}$ MeV.
Figure 1: The location of the active region AR2529 which release the B9 flare The location of the active region AR2565 which release the C1

Table 2 Data energy emitted in solar flares

| Date       | Burst Duration (Minutes) | Lowest Frequency (MHz) | Highest Frequency (MHz) | Drift Rate | Energy at Lowest Frequency (MeV) | Energy at Highest Frequency (MeV) |
|------------|--------------------------|------------------------|-------------------------|------------|----------------------------------|-----------------------------------|
| 19/4/2016  | 2                        | 200                    | 900                     | 5.8        | 1.325x10^-31                    | 5.963x10^-31                     |
| 21/4/2016  | 1                        | 65                     | 160                     | 1.6        | 4.307x10^-32                    | 1.060x10^-32                     |
| 27/5/2017  | 2                        | 20                     | 70                      | 0.4        | 1.325x10^-32                    | 4.368x10^-32                     |
| 9/6/2017   | 2                        | 110                    | 360                     | 2.1        | 7.289x10^-32                    | 2.385x10^-31                     |

The largest solar event of the period was a C1 event observed at Region 2567. There are currently no sunspot regions on the disk. The solar activity is expected to be very low with a chance for a C-class flares and a slight chance for an M-class flare on day one (26th July) and expected to be very low with a slight chance of a C-class flare on days two and three (27th July, 28th July).

By using the interplanetary magnetic field data, the magnetic energy contained in the active region sunspots has been calculated which this magnetic energy triggered the emission of solar flare. The highest data obtained was when 27th May 2016 and 12th February 2016 which the magnetic field was 21.9 nT and 17.4 nT respectively. By this, the magnetic energy contained in the active region sunspots valued were 6.85 x 10^80 ergs on 12th February 2016 and 1.09 x 10^81 erg on 27th May 2016 but this only determined the magnetic energy stored in active region sunspots and does not relate heavily to the triggered of solar flares.

5. Conclusion

As a conclusion, solar flares are produced from the active region sunspots, based on a few factors such as the magnetic field energy contained in the sunspots, level of energy released which can be calculated from the frequency data obtained from the e-CALLISTO software which is updated daily and can be observed from the software and its websites. And the most important factor that triggers the solar flares based on their level of strongest are from the origin which is the number of sunspots. The higher number of sunspots on the surface of the Sun, the higher the class of flares. The explosion of solar flares has potential to interrupt GPS system, the power grid and also other telecommunication systems. We have highlighted the knowing the importance active region sunspots in the energy release in the explosion of solar flares.
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