The Non-thermal of a Large Solar Flares Associated with High Energy of Solar Burst Type III on 4\textsuperscript{th} September 2017

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Abstract. On 4\textsuperscript{th} September 2017, the largest solar flare ever recorded this year saturated the GOES satellite X-ray detectors, making an assessment of its size difficult. We report a large solar flare that produces a hydrodynamic blast wave, moving out through interplanetary space with velocities of 573.6 km/sec and densities 18.1 protons/cm\textsuperscript{3} of protons. The type III burst with split band and herring bones has been recorded from the Kangarlussuaq, Greenland site. It shows a signature of propagating beams of nonthermal electrons with a large and complex structure. During that time, R1-R2 (Minor-Moderate) radio blackouts have occurred on 4 September, 2017; with sunspot number and radio flux is 96 and 120 respectively. The active region, RGN 2673 is a magnetically complex and compact sunspot group that has produced numerous C-class flares and occasional M-class flares on 4 September; the largest thus far was an M5 (R2-Moderate) event at 2033 UTC (1633 ET). Meanwhile, the active region, RGN 2674 is not as magnetically complex and has been relatively inactive. However, due to the development of mixed polarities within RGN 2673, its continued growth, and activity trends, the forecast now calls for expected R1-R2 events the remainder of 4\textsuperscript{th} September on into 5 September.

1. Introduction

Classification of solar flare can be divided into two regions depending on whether the electron energy input goes into radiation or explosive heating [1]. There are 5 classes of solar flare (A, B, C, M and X). Class A flares have purely thermal, compact sources while Class B flares are impulsive bursts which show double footpoints in hard X-rays. Class C flares have gradually varying hard X-ray and microwave fluxes from high altitudes and show hardening of the X-ray spectrum through the peak and on the decay [2]. During solar flares, the X-ray flux received at the Earth increases dramatically, often within a few minutes, and then decays again in times ranging from a few tens of minutes to several hours [3]. The X-rays radiation from solar flares ionize the neutral atmosphere at D region heights greatly increasing the electron densities there and thus markedly lowering the effective VLF reflection height [4]. Previous studies shown that the energy input to the radiative quasi-equilibrium region agrees with the observed flare energy output in optical, UV, and EUV radiation. The energy of solar flare dependence of the decrease may go inversely with particle rigidity, or it may be flatter, depending on the details of the magnetic configuration in and around the blast wave [5, 6]. Detailed analysis on the temperature of the underlying loops increased toward higher altitudes, while the temperature of the coronal source increased toward lower altitudes [7]. The previous results of the
analysis indicate that (1) most of the flare plasma was at temperatures between 3 and 10 million degrees; (2) the peak temperature decreased with time from about $8 \times 10^8$ K to $5 \times 10^8$ K over a period of 3.5 hours; (3) the differential emission measure steadily decreased with time at nearly all temperatures; (4) both radiation and conduction were important cooling mechanisms for the plasma at $T > 10^5$ K; and (5) a substantial amount of energy, of the order of $3 \times 10^{31}$ ergs [8]. A time-intensity profiles for solar proton events are analyzed with respect to the acceleration of energetic particles from the ambient solar wind by an interplanetary shock [9]. The uncertainty in the determination of the level of the primary electron bremsstrahlung as well as the lack of measurements on the $\gamma$-ray emission above 100 MeV combine to allow rather a wide range of energy distribution parameters [10]. Some of these variations were irreversible, occurred in the vicinity of magnetic neutral lines, and likely were related to magnetic energy release in the flare [11]. It is shown that Sweet’s mechanism is much more effective in a highly compressible medium if the merging magnetic fields are exactly antiparallel [12].

Meanwhile, the type III solar burst is a common signature of near-relativistic electrons streaming through the background plasma of the solar corona and interplanetary space, offering a means to remotely trace these electrons [13]. This burst shows the coalescence of electron plasma waves from a nonthermal distribution with electron plasma waves from the distribution of thermal charge fluctuations [14, 15]. It is estimated that the total number of electrons $\gtrsim 22$ keV required to produce a type III burst is $\lesssim 10^{34}$ [16, 17]. This burst can occur singularly, in groups, or storm. This fast drift burst is the most common of the meter wavelength bursts [18].

2. Experimental

We use the Compound Astronomical Low cost, Low frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) as a main system of solar radio bursts and RFI-monitoring for astronomical science and education [19-21]. The e-CALLISTO is the worldwide network connected via internet [22, 23]. This system can cover 24 hour data of solar burst, which operates identical spectrograph in different locations around the world. It is more than 133 instruments in more than 67 locations with users from more than 132 countries [24, 25].

However, it solar burst can be detected only after they have travelled far enough from the Sun [15, 26]. In Malaysia, we used 5.5 meters Log Periodic Dipole Antenna with a gain of 6 dB. The timing of the CALLISTO is controlled by a GPS clock in which the relative timing is accurate to within less than one millisecond, whereas the absolute time is uncertain to within a few milliseconds due to internal delays. This system has an individual channel has 300 kHz bandwidth and can be tuned by the controlling software in steps of 62.5 kHz [27].

3. Results and Discussion

Figure 1 shows the type III burst with split band and herring bones from the Kangarlussuaq, Greenland site. It shows a signature of propagating beams of nonthermal electrons in the solar atmosphere. This fast drift burst has a very different physical origin that produces such different properties. This event produces a type III burst with a large and complex structure. Figure 2 shows the GOES X-ray Flux data starting from 2nd to 4th September 2017. The Type III radio burst is used as the indicator of the starting point of the magnetic reconnection. Strong evidence for the escape of energetic electrons would be presence of radio burst Type III. The subject of nonlinear wave-wave interaction which involving interaction of electrostatic electron plasma that called as Langmuir waves.
Figure 1. Strange group of type III solar radio bursts observed by Callisto in Kangarlussuaq, Greenland (credited to: e-CALLISTO data) and GOES X-ray Flux data starting on 2nd to 4th September 2017 (credited to: Solar monitor)

Table 1 shows the solar parameters during the explosion of solar flare. The active region AR2673 expanded more than 10-fold in a single day. Huge sunspot AR2673, which materialized with shocking speed over the few days period, is seething with activity. We can observe clearly the plasma currents surging inside the sunspot's magnetic canopy-apparently on the verge of an explosion in optical observation. It is then suddenly becomes one of the largest sunspots of the year. It has a 'beta-gamma' magnetic field that harbors energy for strong M-class solar flares. Any such explosion today would be geoeffective as the active region is directly facing Earth. Possible outcomes include moderately-strong shortwave radio blackouts, Earth-directed Coronal Mass Ejections (CMEs) and geomagnetic storms later this week.

Table 1. Solar Parameter during the explosion of solar flare

| Parameter             | Value          |
|-----------------------|----------------|
| Solar wind speed      | 573.6 km/sec   |
| Density Proton        | 18.1 protons/cm³ |
| Sunspot number        | 96             |
| 10.7 cm flux          | 120            |
| Interplanetary Mag. Field, B_{total} | 6.1 nT          |
| Interplanetary Mag. Field, B_{z}          | 0.5 nT north   |

During that time, R1-R2 (Minor-Moderate) radio blackouts have occurred on 4 September, 2017. The active region, RGN 2673 is a magnetically complex and compact sunspot group that has produced numerous C-class flares and occasional M-class flares on 4 September; the largest thus far was an M5 (R2-Moderate) event at 2033 UTC (1633 ET). Meanwhile, the active region RGN 2674 is not as magnetically complex and has been relatively inactive. However, due to the development of mixed polarities within RGN 2673, its continued growth, and activity trends, the forecast now calls for expected R1-R2 events the remainder of 4th September on into 5th September.
4. Conclusion

The eruption mechanism of solar flares and radio burst Type III are currently an extremely active area research, especially during the solar cycle is towards maximum. It is normally found at the pre-flare stage that could be a signature of electron acceleration. Solar radio burst type III potentially reveals about the acceleration site of the particles from the Sun to the Earth during large solar flare. In this case, the solar flare is one of the largest solar flare that occurred in 2017 due to the active region RGN 2673.

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