Image Processing of Case Study of Solar Radio Burst Type III and Type IV Burst Using Sunpy

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Abstract. Solar radio burst at low-frequency lies in the fact that they originate in the same layers of the solar atmosphere in which geo-effective disturbance probably originate Type III bursts have consistently the fastest drift rates of bursts at metric wavelengths and was created by an electron beam through plasma emission. Meanwhile, type IV burst is broadband quasi-continuum features associated with the decay phase of solar flares. A geomagnetic storm is a major disturbance of Earth's magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding Earth. The aim of this study is to find out whether type III bursts preserved energy to solar bursts type IV thus led to the formation of geomagnetic storm. The solar radio burst type III and IV were observed by CALLISTO Spectrometer. CALLISTO is an acronym from Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory. The Sunpy by Python was used to analyze the spectrogram image by eliminate the unwanted signal or noise in the image which is in the presence of noise, the spectrum gives inaccurate reading of frequency and time. Although the study did not show much correlation between bursts type IV and type III in producing these storms, there are several possible explanations from this result. It may be the case that solar events such as solar flare, CMEs and active region ejected from the solar disc is not heading towards Earth and the energy has eventually disperses into the interplanetary medium.

1. Introduction

One of the main reason detecting solar radio burst because it is the important tool for specifying magnetic, thermal and density structures at the time. Solar radio burst at low-frequency lies in the fact that they originate in the same layers of the solar atmosphere in which geo-effective disturbance probably originate [1]. This is where the solar flares and coronal mass ejections (CME) are believed to be launched. Solar flare is sudden large energy releases in the magnetic active region are the most active manifestation of solar activity [2, 3]. It might define as a rapid brightening in H alpha, but simultaneously can have manifestations right across the electromagnetic spectrum and might eject the high energy particles and blobs plasma into the solar wind. Coronal mass ejections (CMEs) are huge explosions of magnetic field and plasma from the Sun's corona [4]. A CME is a large scale coronal...
structure ejected from the Sun and propagate into the interplanetary space [5]. Certain CMEs may intercept the Earth orbit if they move toward the direction of the Earth, causing space weather. Fast CME eruptions are often accompanied with flares and filament eruptions [6].

This study was focused on solar burst type III and type IV in relation to solar activities [7]. Solar burst type III is the radio signatures of the solar flare accelerated electron beams ejected into the corona and interplanetary medium which are characterized by very fast frequency drifts in the dynamic spectra [3]. Another potential use of type III burst is that they always have a significant relationship with solar flare events [8]. Type III bursts have consistently the fastest drift rates of bursts at metric wavelengths and was created by an electron beam through plasma emission [9]. The radio emission tracks the electron beam as it travels through the decreasing plasma density of the solar corona and solar wind.

Meanwhile, type IV burst is broadband quasi-continuum features associated with the decay phase of solar flares [10]. Solar burst type IV always related to the development of sunspot groups [11]. It has been well established that type IV bursts have a high probability of being followed by geomagnetic disturbance [12]. It generally believed to be synchrotron radiation from relativistic electrons spiraling in magnetic fields and results from trapped electron populations [13]. There are several subclasses of type IV bursts, the type most tightly coupled to flares is called type IV continuum. The centimeter-wavelength bursts, particularly the intense ones, are closely associated with solar flares [14].

The Earth’s surrounding known as a Space Weather is the conditions of the solar wind speed and density, magnetic field strength and orientation and energetic particle levels [15]. The high energies and magnetic field strengths from the Sun travelling at up to thousands of km s⁻¹ impact the Earth’s magnetosphere that might be harmful to the Earth technology [16]. The correlation of solar radio burst with solar activity play an important role in space weather study. The information gathered from the relation of solar burst type III and type IV with solar activity may be useful. The relationship between solar radio burst type III and IV being followed by geomagnetic disturbance cannot be denied anymore [17]. The authors mention the significant relationship between type IV burst and geomagnetic storm. But, does the presence of burst type III preceded type IV burst affect the production of geomagnetic storm? The valuable information may be obtained from this study regarding the occurrence of geomagnetic storm with solar radio burst type III. In addition, such information may also be very important and useful for solar monitoring.

2. Geomagnetic Storm

A geomagnetic storm is a major disturbance of Earth’s magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding Earth [18]. These storms result from variations in the solar wind that produces major changes in the currents, plasmas and fields in Earth’s magnetosphere. The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several to many hours) periods of high-speed solar wind. Geomagnetic storm is defined by changes in disturbance storm time (Dst) index, has been used to characterize the size of a geomagnetic storm. However, there are currents produced in the magnetosphere that follow the magnetic field and connect to intense currents in the auroral ionosphere. These auroral current produce large magnetic disturbances on the ground used to generate a planetary geomagnetic disturbance index called Kp. This index is used globally to describe space weather that can disrupt systems on Earth. The mean planetary Kp index for geomagnetic storm is nT with interval for 3-hours. The Kp-index ranges from 0 to 9, where a value of 0 means very little geomagnetic activity and a value of 9 means an extreme geomagnetic storm. For geomagnetic storm, it has 5 indexes of Kp started from level G1 (minor storm), G2 (moderate storm), G3 (strong storm), G4 (severe storm) and G5 (extreme storm).

3. Methodology

The radio spectrometer of the CALLISTO (Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory) was used in this research for monitoring the solar radio burst [19]. The instruments observe automatically, their data is collected every day via
internet and stored in a central database. The ‘burst mode’ can be triggered from the spectrograph of CALLISTO automatically [20]. The e-CALLISTO system has already proven to be a valuable new tool for monitoring solar activity and for space weather research [21].

The solar radio burst type III and IV were observed by CALLISTO Spectrometer. CALLISTO is an acronym from Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory. The CALLISTO spectrometer was designed by an electronics engineer, Christian Monstein from the Institute for Astronomy of the Swiss Federal Institute of Technology Zurich (ETH-Zurich). The radiometric bandwidth is about 300 kHz and the integration time for this spectrometer is 1 msec with 0.25 sec time resolution of 200 channels per spectrum (800 pixels per second). The instruments were placed at a low-level noise location to reduce system noise and the preamplifier was connected to the spectrometer to amplify a gain. In term of the sensitivity, it is depending on the instrument whether it connected to the small or the large antenna.

The Sunpy by Python was used to analyze the spectrogram image by eliminate the unwanted signal or noise in the image which is in the presence of noise, the spectrum gives inaccurate reading of frequency and time. In order to remove the unwanted signal, the important thing needs to consider is to ensure the valuable signal not removed. Thus, give a quality data that has not affected the value of the data. Reduced the noise while maintaining its spectral characteristics. This problem can be overcome by adjusting the $V_{\text{min}}$ to normalize the colour.

%%%%EXAMPLE FROM LOCAL FOLDER

```python
from matplotlib import pyplot as plt
from matplotlib import cm
import sunpy
from sunpy.spectra.sources.callisto import CallistoSpectrogram
image = CallistoSpectrogram.read("M:\MyPython\BLEN7M_20120813_123000_24.fit.gz ")
image = image.linearize_freqs(1)
nobg = image.subtract_bg()
nobg.plot(cmap=cm.gist_ncar,vmin=5)# cm.hot, cm.spectral, cm.gist_ncar, cm.jet
plt.ylabel("Frequency [MHz]"")
plt.xlabel("Time [UT]"")
plt.title("Bleien Switzerland")
plt.show()
```

Figure 1. Coding of sunpy for data analysis

4. Results and Discussions

The 3rd August 2011 solar burst event showed a type IV burst was preceded and followed by type III burst. A group of solar radio burst type III at 0817-0818 UT from the frequency range of 60-70 MHz that was detected by BIR station. Two hours later, a smooth continuum moving type IV with strong structure appear at 1030-1349 UT at the frequency range of 160-900 MHz that were detected from BLEN7M, HUMAIN, INPE and MRO stations. This type IV burst then was followed by single burst type III which is occur above 30-700 MHz at 1200-1904 UT. A single type III burst were recorded at BIR, BLEN7M, and OOTY stations.

There was a flare M6-class at 1348 UT blast from sunspot 1261. The magnetic storm associated with this complex radio activity had level G4 from 2000 to 2400 UT are about 48 hours later. A CME produced by this event is heading directly toward Earth as recorded by SOHO. It was travelling slowly with speed 356 km/s with 122 sfu radio flux. The number of sunspot is 98 and the interplanetary
magnetic field is 3.0 nT appear at 00:30:05 and onset at 21:28:51 UT with mass 7.20e+13 g. There are 3 sunspot during this event which are AR1263, AR1261 and AR1260.

Figure 2. Solar Radio Burst Type IV on 3th August 2011 and a group of solar radio burst type III from 13:32 UT to 13:44 UT.

The event was associated with M6 class flare erupted from AR1261 active region. The type IV burst stop almost exactly at the time of the soft X-ray peak at 1348 UT, regarded as the time at which energy release in the flare ends. As CME travelling towards Earth with speed 296 km/s, it reached Earth 48 hours later. In addition, severe geomagnetic storm level G4 and strong storm level G3 were recorded from 1800 UT to 0000 UT on 5 August 2011. There are 5 Active Region recorded during this event with 98 sunspot number. It was reported an ionospheric waves and VHF radio noise from the listening station above the Arctic Circle in Norway. The M1 class eruption from the active region AR1261 was observed by three spacecraft: SOHO, STEREO A and STEREO b. It was also recorded that the CME elfit the Sun with the speed of 900 km/s and reach the Earth on 5 August 2011. A mild moderate geomagnetic storm are detected on 5\textsuperscript{th} and 6\textsuperscript{th} of August 2011.
The data of geomagnetic storms was obtained from website Laboratory of X-Ray Astronomy of the Sun, LPI (link: http://www.tesis.lebedev.ru/en/). The TESIS is a set of solar imaging instrument developed by the Lebedev Physical Institute of the Russian Academy of Science and launched aboard the Russian spacecraft CORONAS-PHOTON in January 30, 2009. It showed the data from the last 3 days of magnetic storms with three indicators such as geomagnetic calm, geomagnetic disturbances, and geomagnetic storm. Other than, the data of geomagnetic storm from WDC for Geomagnetism, Kyoto also collected for comparison.

**Figure 3.** Solar Radio Burst Type IV on 3th August 2011 and a group of solar radio burst type III from 13:32 UT to 13:44 UT after using Sunpy

**Figure 4.** The geomagnetic storm on 5th August 2011

5. Conclusions
In this study several solar and geomagnetic activity indices were analyzed along with the events of solar, solar wind and magnetospheric origin. It has been showed that type IV bursts have a high probability of being followed by geomagnetic disturbance. The occurrence of type IV alone (without type III) is not enough, since the corresponding solar plasma cloud behind the shock front has too week a particle density to cause an observable geomagnetic effect. Similarly, the occurrence of a type III without type IV burst may not be sufficient to influence the geomagnetic activity, since it has no shock front associated with it. This association between type III and type IV solar radio burst can be explained by the fact that both of this solar radio burst are generated by fast electrons. The disturbance which gives rise to type III bursts have high velocities and may be either streams of electrons or fast, transverse shock. While, the electrons which give rise to type IV are principally have a similar velocity range.

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