

Analysis of Solar Events in 2015 with the HAWC Gamma Ray Observatory

E. Tirado¹, E. Moreno¹ and A. Lara² for the HAWC Collaboration

¹ Meritorious University Autonomous of Puebla

² Institute of Geophysics UNAM, Department of Space Sciences

E-mail: etb.tirado@gmail.com, emoreno.emb@gmail.com and alara.unam@gmail.com

Abstract. The work consists in finding and analyse solar events, such as the solar flares and coronal mass ejections and study the variation in the data counting, which can be observed by the high - rise light Cherenkov in water “HAWC” observatory, consist of 300 tanks of ultrapure water, where each of them has 4 photomultiplier tubes. HAWC is dedicated to the observation of gamma and cosmic rays with energies of TeV and has an opening that covers more of 15 % of the sky. With its wide field of view, the observatory is exposed two - thirds of the sky during each 24 hours cycle. The detector has to main data acquisition systems: the particular event and the total sum or Scalers, in this work is will make use of the counting system called TDC Scaler, which records the count rate of the number of particles which impacted on the detector in a time range.

1. Introduction

The High Altitude Water Cherenkov (HAWC) observatory is an air-shower array composed of 300 water Cherenkov detectors (WCDs) currently totally constructed within the Pico de Orizaba National Park (México) by a Mexican-United States collaboration. The main purpose of HAWC is to observe gamma rays and cosmic rays between 100 GeV and 100 TeV, TeV gamma rays are the highest energy photons ever observed.

Milagro was the first generation experiment that operated at a lower altitude of 2630 meters close to the Los Alamos, New Mexico. The pool design of the Milagro experiment has been replaced in the HAWC experiment by a modular design (array of WCDs). The WCD is designed to detect the Cherenkov light produced by secondary particles using photomultipliers tubes (PMTs) immersed in water.

¹ Avenida San Claudio y 18 Sur, Colonia San Manuel, Edificio FM5-206, Ciudad Universitaria, C.P. 72570, Puebla, México.

² Instituto de Geofísica, Circuito de la Investigación Científica s/n, Ciudad Universitaria, Del. Coyoacán, C.P. 04150, Ciudad de México.



The Sun is the closest star to Earth, and because of this is the only star that can be seen with spatial, temporal and spectral resolution without comparison in Astronomy. For this reason the sun is the laboratory base to study and understand the physical phenomena occurring in other stars of similar characteristics.

The Sun is also an active star in whose atmosphere occur violent and energetics events, called solar flares and coronal mass ejections. During this events the Sun emits radiation at very high energies, the particles are accelerated, and a huge amount of material is ejected to the interplanetary medium.

These remainder of the solar activity reaches the Earth and other planets, their atmospheres and magnetosphere. The origin of this active phenomena is closely related to the existence of localized areas of intense magnetic fields referred to as active regions.

For this reason in this work we study the variation of the scaler counting during solar events registered in 2015, and specially during a Forbush Decrease (FD) event generally indicates a decrease in the cosmic-ray count rate caused by transient interplanetary events which are strictly related to a solar mass ejection activity (Cane 2000).

2. Methodology

To observe the effects of solar modulation of galactic cosmic rays, we revised the PMTs scaler rates considering the effect of pressure variability. The correction used is described by the following equation

$$R_{corr} = R_{meas} - Rp + \langle R_{meas} \rangle \quad (1)$$

where R_{corr} is the corrected scaler rate, R_{meas} is the single PMT measured rate and $Rp = a*P + b$ is the linear function used to describe the relation between the scaler rate and the measured atmospheric pressure (P).

For the realization of this work it will be used the software called Python, together with specialized library for solar issues called Sunpy, which helps to acces to the public data of the GOES Observatory of the NASA (NationalAeronautics and Space Administration). With these data, we can know which of the solar events registered in 2015 are interesting for studying in the HAWC Observatory.

Table 1. Solar flares of great intensity in 2015.

Date	Flare Class	Max, UT
03-03-15	M8.2	00:27:00
07-03-15	M9.2	22:22:00
11-03-15	X2.1	16:22:00
05-05-15	X2.7	22:11:00
22-06-15	M6.5	18:23:00

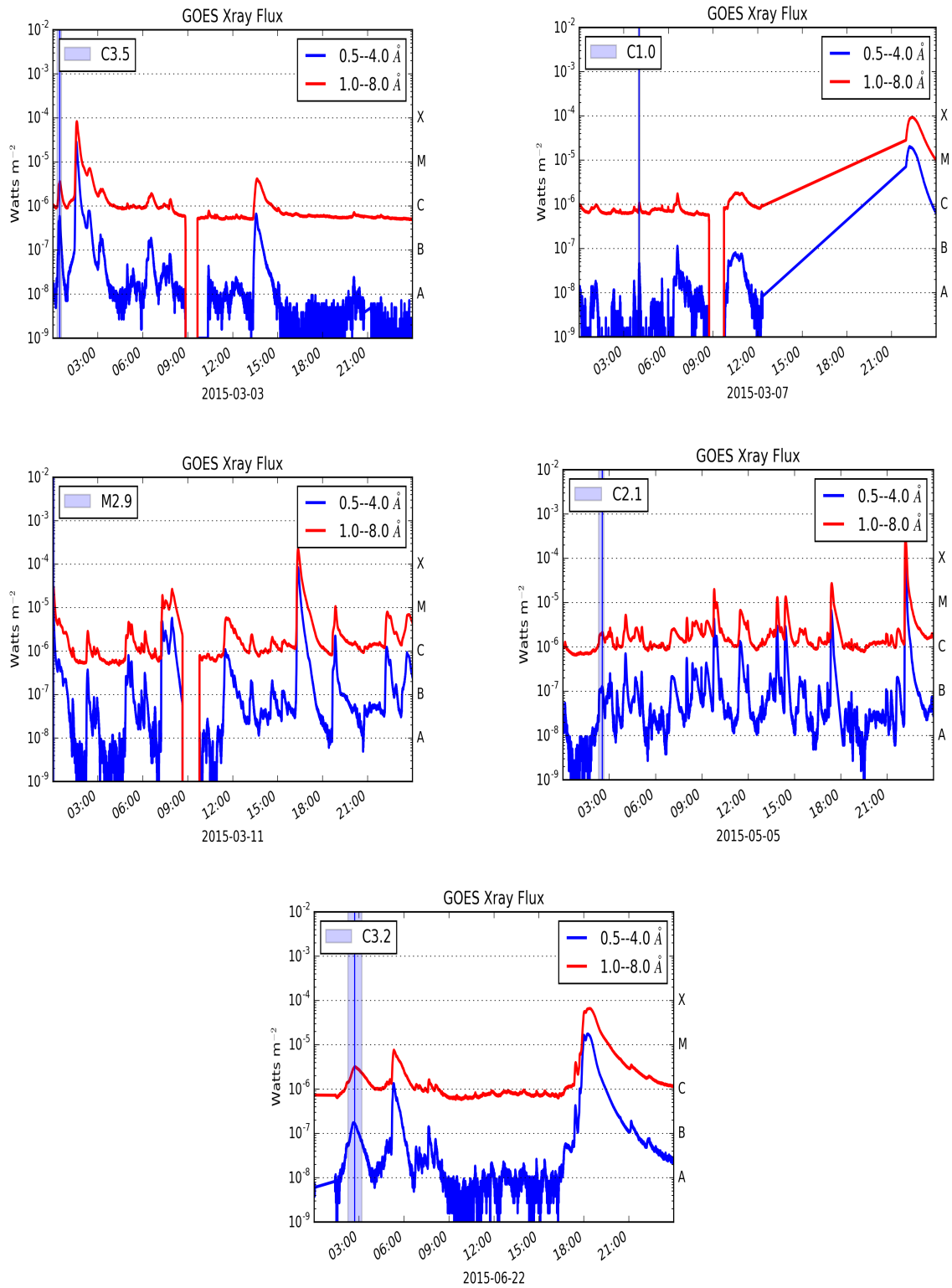


Figure 1: In this figure we show the plots of emission of X Ray flux for each of the solar events shown in Table 1. These graphics are made with public data from the Observatory GOES 15.

3. Discussion and Results

For the analysis of the HAWC observatory data (TDC Scaler). We desing a program in Python, which processes data from the PMTs that are generated every 10 minutes and contain around 60000 measurements for each PMT, and then plot the information obtained to verify the Variation of the scaler counting during a solar event, for example in solar flares and coronal mass ejections are enhancements in the counts for few minutes to hours and in the case of interplanetary coronal mass ejections are decreases in the counts for few hours to days.

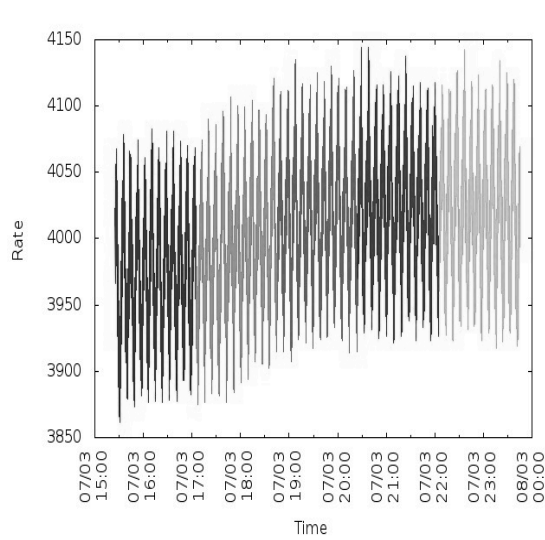


Figure 2a: Plot that show Rate vs. Time of the 07-03-15 solar event.

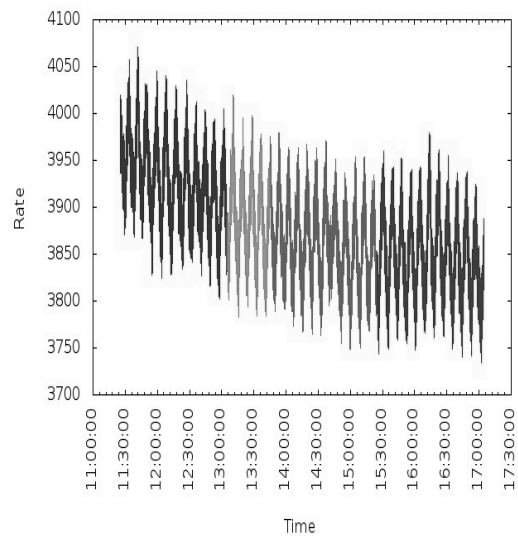


Figure 2b: Plot that show Rate vs. Time of the 11-03-15 solar event.

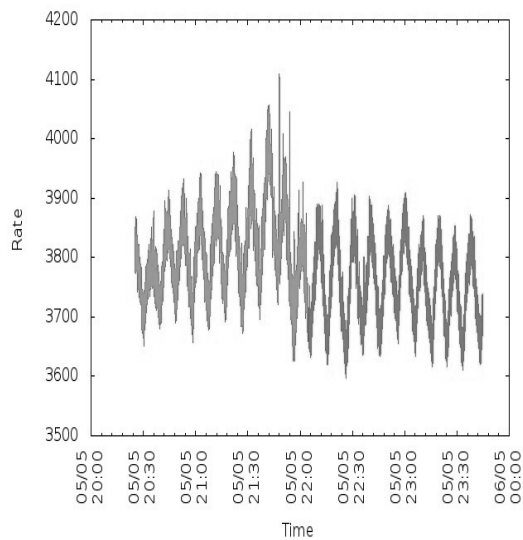


Figure 2c: Plot that show Rate vs. Time of the 05-05-15 solar event.

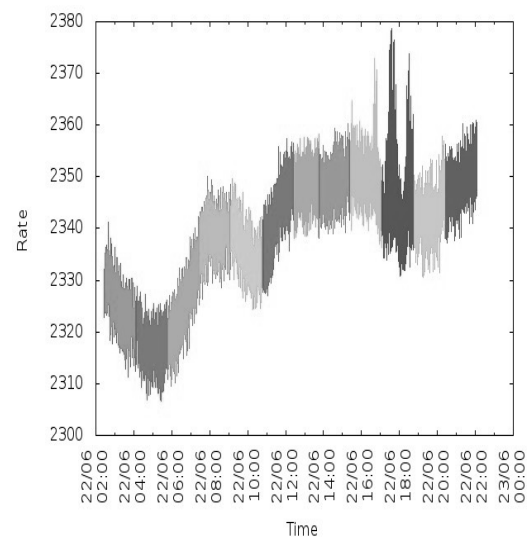


Figure 2d: Plot that show Rate vs. Time of the 07-03-15 solar event.

In Figure 2 we can observe that in the subfigure 2b and 2c we have an enhancement of the counting data, which implies that the solar event we are talking about is solar flare and in figure 2d we can observe that the solar event is an interplanetary coronal mass ejections.

4. Summary and Conclusions

In this work we analyze the HAWC observatory TDC Scaler data to find long transient solar events (solar flares and coronal mass ejections). We studied with the help of the plots obtained for solar events of the days listed above in Table 1 and we can study the variability of the counting data reported by Cane in 2000 with the HAWC Observatory.

5. Acknowledgments

This research has made use of SunPy, an open-source and free community-developed solar data analysis package written in Python.

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