Transient Luminous Events observed by a pinhole camera

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Abstract: The next generation of experiments devoted to study extreme energy cosmic rays will be at space platforms. Recent experiments have shown that the UV light background is more complex than previous models. Therefore, the observation of transient luminous events(TLE) at the upper atmosphere will be important. Information about the time and space evolution of this very fast events may need to be recorded, this impose requirements of a wide field of view and the largest focus depth. The simplest optical design: a pinhole camera fulfils this characteristics. This pinhole camera have a multianode photomultiplier (64 pixels) that allow us to register 2-d images of TLEs. In this work we present the observations of some events recorded from Sierra Negra Volcano in Mexico and its capabilities in order to use it as a monitoring device.

Keywords: atmosphere, background, pinhole, MaPMT, flashes, fluorescence, images, ultraviolet, space.

1 Introduction

One of the important phenomena in night atmosphere, directly related to UHECR measurement, are TLE (transient luminous events) characterized by very bright (energy in UV up to 0.1-1 MJ) short (duration of 1-100 ms) flashes [3][4]. The first global measurements of UV flashes were done by the Tatiana space detector [5][6] but still the important characteristics: the lateral distribution of UV glow in one flash and the energy spectrum of flashes are not measured. In this project we present a new method of TLE measurement by the imaging pinhole camera. The presented pinhole camera is planned for operation in space experiments devoted to study of processes of electron acceleration in the atmosphere electric discharges and relativistic electron precipitation to the atmosphere from the magnetosphere among others.

2 Pinhole camera

The Camera obscura detector is the one of best optical imaging designs due to their simplicity, wide field of view and large deep field. We plan to operate it onboard a space mission satellite planed to orbit the earth at 700 Km height. The camera obscura it will be used to explore the eventual creation of perturbations near to the event that may should trigger some TLEs. This perturbation was considerate as background noise in the tracking of the cosmic ray original particle. The high brightness of TLE may allow us to use the simplest pinhole optics for measuring the image in pixels of UV detector. The optimal imaging quality in a pinhole camera is achieved if the hole size is equal to the detector pixel size. Our aim is to measure not only the TLE image but also the temporal profile of the image with time resolution of about ms. Today such a fast photo detector is available only as a Multi-Anode Photomultiplier Tube (MaPMT) with some number of pixels. The size of the pixel in MaPMT is of about 2-3 mm. Assuming the camera hole equal to this size and taking the TLE UV intensity and time duration from [3] it is possible to estimate the signals in the pixels of the pinhole camera. Efficiency of the MaPMT pixels to UV is around 20% for wavelengths λ=300-400 nm and decreases below λ=300 nm. For estimate of the TLE image signals the lateral distribution of UV intensity during the event is needed. We assume that UV flash images cover a circular area of some tens of km diameter (as it was measure in a typical TLE by video cameras figure 1 with uniform intensity over the circle. So the total UV energy Euv radiated by the TLE correspond to the number of photons of wavelength λ=300-400 nm. To improve the detection of TLE, for this project we considered the configuration where the TLE whole area is observed by all pixels, in this setup a detailed image of the UV flash in space and time is obtained as it was suggested in [1][2] for EAS Cherenkov light observations. A scheme of the designed camera obscura it is shown in Figure 2. In our case the design and construction of the camera obscura was made with the following technical parameters: One photo receivers MaPMT model H7546B (Hamamatsu) a matrix of 8 by 8 pixels with a pixel size of 2x2 mm. The pinhole have the same size, the focal distance f considered is f=200 mm. In the test and developing process of the camera obscure detector, as a first stage, we have performed several measurements at the Sierra Negra Volcano (4300 m.a.s.l) in Puebla-Mexico due to the small light pollution and less atmospheric absorption.

3 Camera electronics

The figure 3 shows the block diagram used to the signal processing of MaPMT when a luminous event will appears. The block diagram has as a main processor a FPGA Xilinx XCV100 series. This FPGA control the multiplexing and the digitalization of the 64 analog signals from each MaPMT. Also control and monitored the high voltage supplied to the MaPMT in order to protect it if a bright or long lasting event appears. The FPGA stores all the configuration and operation parameters from the PC/OBC and communicate it thru comunication port. The command controls of FPGA are defined by the user by software graphic programmable interface LabView. With the same software we construct a data base in order to process and plot the regis-

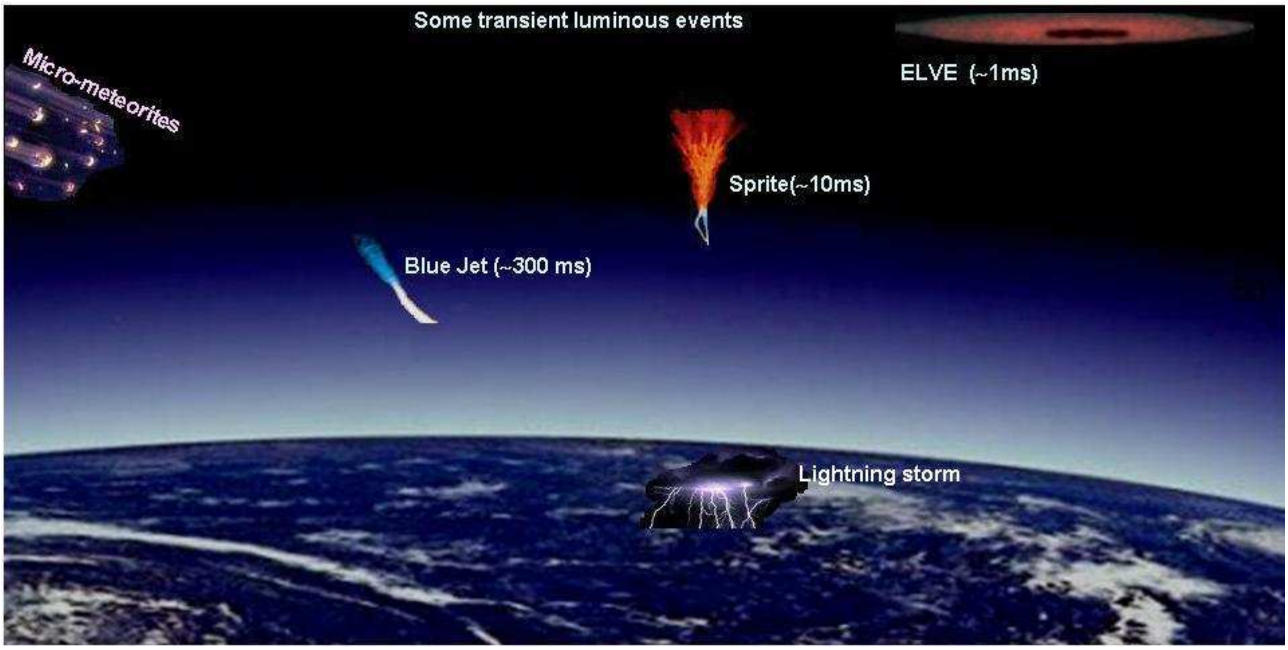

Figure 1: Some transient luminous events measured by video cameras.

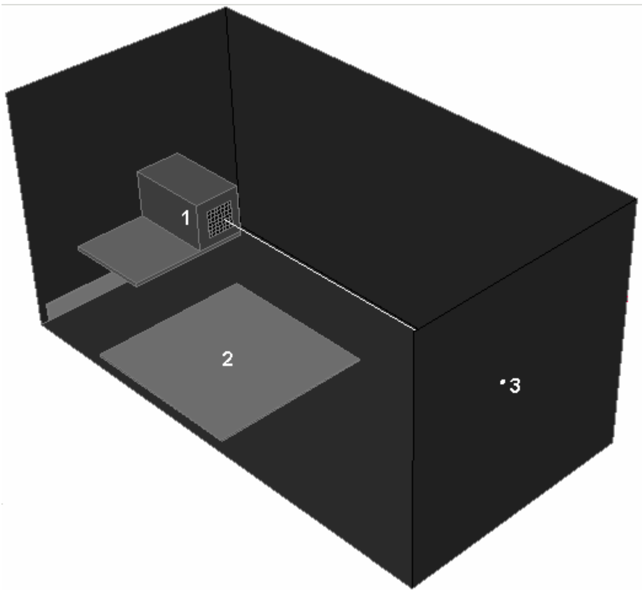

Figure 2: Camera obscura: 1.- Photo receiver. 2.- Electronic Board. 3.- pinhole. The dimensions are 15x15x30 cm^3.

tered events. The 64 pixels of MAPMT are digitalized with only one ADC. For this we use an array of four multiplexers of type ADG706 where each multiplexer selects 1 signal from its 16 input signals according to digital signals applied for control multiplexing.

4 Camera testing

As a first step in the calibration process of the Camera Oscura, it is necessary to measure the response to a single photo-electron by the MaPMT [8], and use it to convert the signal to physical photon flux. To obtain the single photoelectron response, we have found the optimal operative voltage for PMT. To do this, we checked the single photoelectron (SPE) spectrum as a function of supplied voltage with a controlled LED pulse. With a value of 950V as operative voltage and from the analysis of some events, we found the mean charge produced by a single photo-electron response (SPE) and the SPE pulse amplitude distribution as show in figure 4.

The designed pinhole camera was tested and calibrated measuring the Moon luminosity [7][9]. By positioning the camera for observing the Moon image by MaPMT it is easy to measure the reference Moon luminosity in intensity. The MaPMT registering Moon light start working with a constant anode current defined by the ADC code recorded N of ten bits (the maximal code value is 1024). When the code N is greater than a reference then the current decreases (by less than a factor of 10) in inverse proportion to the square root of the mean value of the anode current. In these operating conditions, one encounters the additional problem of how to control and monitor the gain of the MaPMT to register the most very bright (powerful) phenomena (TLE). The FPGA controls the MaPMT high voltage power supply by using an eight-digit digital to analog converter (DAC). The supply voltage is proportional to the DAC control code M. The maximal code value is 128, corresponding to a voltage of 1000 V. Every minute the automatic control circuit controls the voltage (gain) of MaPMT in correspondence with the illumination of the MaPMT.

A useful way to test and calibrate the performance of the pinhole camera, consist in to record the transit of the Moon image crossing every pixel. A telescope mounting base was used to fix the pinhole camera in order to point and track the moon image into a given pixel. Was obtained that crossing time by the MaPMT, will be shorter: 25 s., the signal from Moon will rise and fall continuously having maximum when the moon image is fully inside the limits of the pixel area.

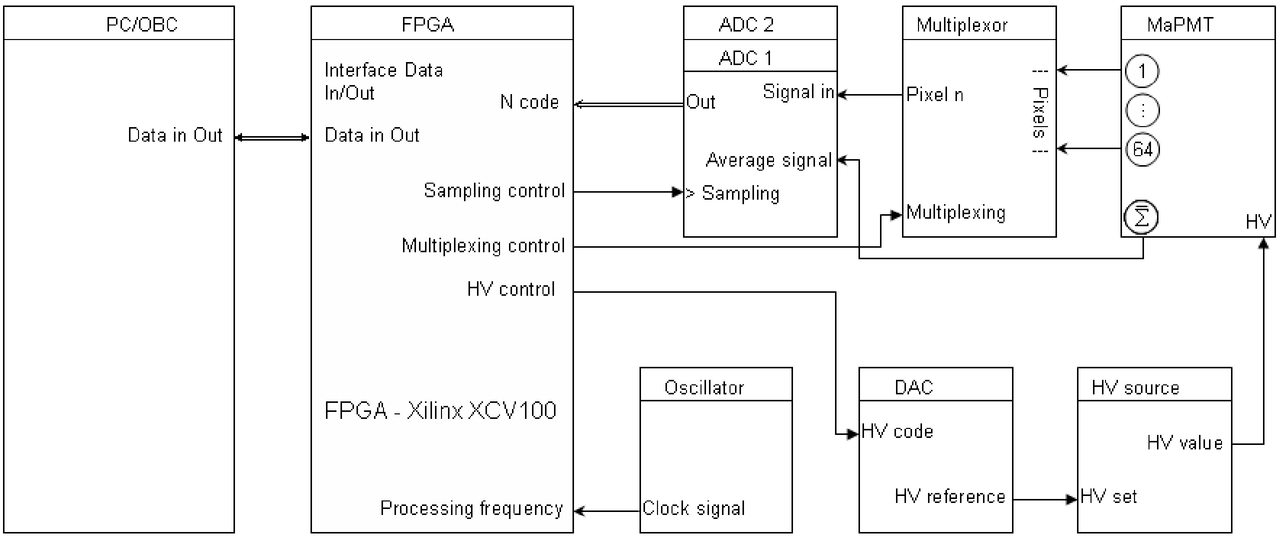

Figure 3: Block diagram of the pinhole camera electronic.

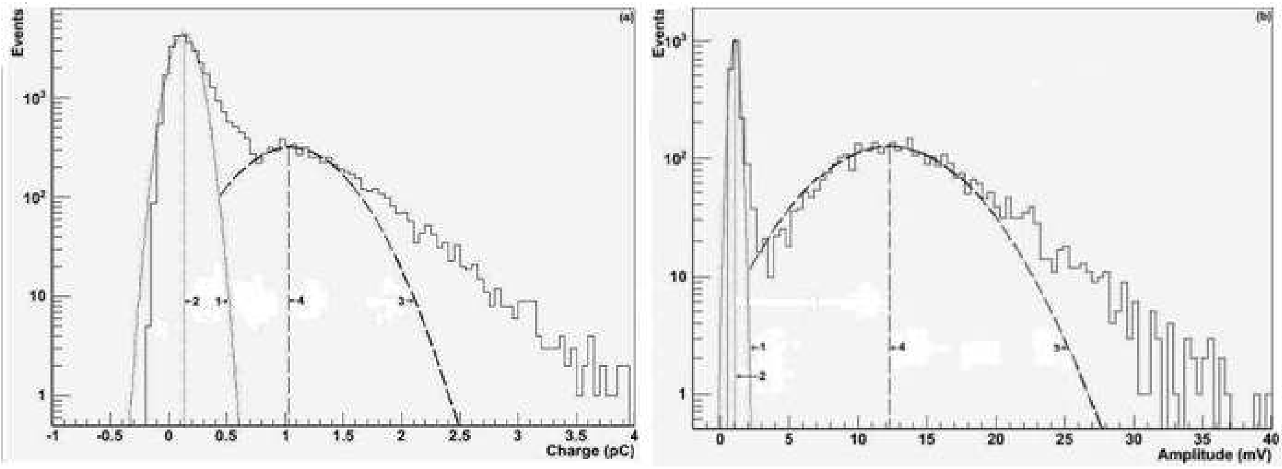

Figure 4: Single photo-electron spectra MaPMT. a) Charge spectra. b) Amplitude spectra. 1-The distribution of the baseline, 2-The mean of the baseline. 3-The SPE distribution. 4-The mean of a SPE.

Example of UV TLE event registered (on July 24, 2010 at 2:55 am Mexico time) at mountain Sierra Negra-Mexico (4300 m.a.s.l) is shown in figure 5. The event was registered on a storm developed at a distance of some kilometers from camera obscura position, the instrument was observing at 20^o from the zenith and around 4pi. The frequency of multiplexed pixels was of 500 microseconds, then the total samplings of 64 pixels were 32 milliseconds, this last time correspond to the sample frequency of a pixel. Considering the SPE amplitude spectra, for the maximum amplitude of the event, the number of photons recorded aproximately 20 photons, and for the integration of 64 pixels signal, the number of photons registered are around 290 photons UV.

Also camera obscura registered the trace of a micrometeorite (on October 22, 2010 at 3:20 am Mexico time) at mountain Sierra Negra-Mexico. The instrument was observing at 10^o from the zenith. The frequency of multiplexed pixels was of 1 ms, the total samplings of 64 pixels were 64 milliseconds, this last time correspond to the sample frequency of a pixel and of each slide. In figure 6 we can see that this cosmic object was registered in four slides, the duration of the moving object in the field of view of the instrument was of 256 milliseconds. Some other recently registered TLEs and trace of a micrometeorites, will be presented in the poster.

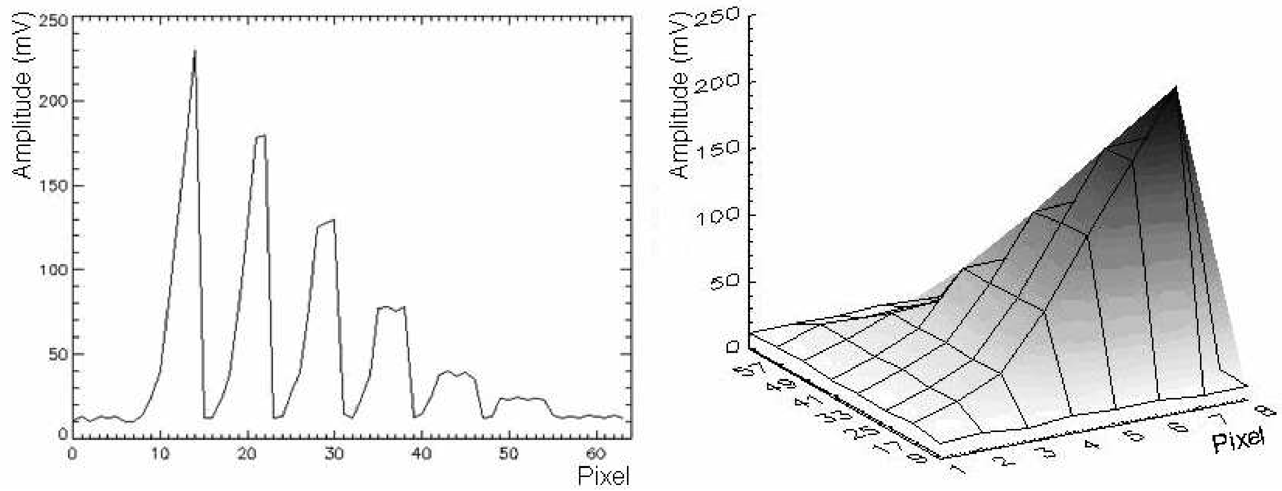

Figure 5: UV TLE registered with pinhole camera. a). Temporal profile reconstructed with the sequence of 64 pixels multiplexed. b) Image reconstructed according the distribution and amplitude registered for each pixels of MaPMT.

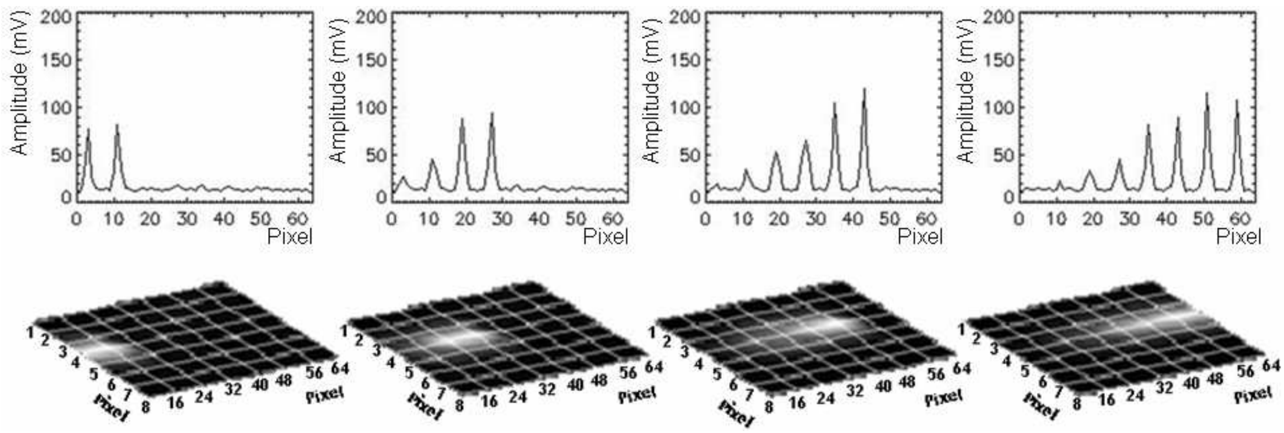

Figure 6: UV trace of a micrometeorite registered in the FOV of the pinhole camera.

5 Conclusions

The pinhole camera design has shown to be a fruitful configuration for start studies of background light level distribution presented in the atmosphere. The calibration and performance test at the Mexican mountain Pico de Orizaba/Sierra Negra shows that its possible to detect with high confidence level the TLE and UV background light.

References

[1] G. K. Garipov and B. A. Khrenov. 1994 J. Phys. 20, 1891.

[2] G. K. Garipov and B. A. Khrenov. 1995 J. Phys. 21, 879.

[3] G. K. Garipov, B. A. Khrenov, M. I. Panasyuk, V. I. Tulupov, A. V. Shirokov, I. V. Yashin and H. Salazar. 2005 Astroparticle Physics. 24, 400.

[4] G. K. Garipov, B. A. Khrenov, B. K. Lubsandorzhie, S. A. Belyanchenko, V. A. Smolitskiy, U. Salazar and E. Fokitis 2005 Instruments and experimental techniques, 48, 92.

[5] G. K. Garipov, M. I. Panasyuk, I. A. Rubinshtein, V. I. Tulupov, B. A. Khrenov, A. V. Shirokov, I. V. Yashin and H. Salazar 2006 Instruments and experimental techniques. 49, 126.

[6] V. Abrashkin, V. Alexandrov, Y. Arakcheev, A. Cordero, J. Cotzomi, M. Finger, G. Garipov, V. Grebenyuk, N. Kalmykov, B. Khrenov, P. Klimov, V. Koval, O. Martinez, E. Moreno, D. Naumov, A. Olshevsky, M. Panasyuk, I. Park, E. Ponce, C. Robledo, S. Sharakin, L. Tkatchev, V. Tulupov, R. Tyukaev, B. Sabirov, H. Salazar, O. Saprykin, A. Shirokov, L. Villasenor, I. Yashin, N. Zaikin and A Zepeda. 2007 Nuclear Physics 166 6871.

[7] E. Ponce, B. Krenov and H. Salazar, 2007 Proc. 30th ICRC HE.1.5 148.

[8] S. Yoshida. 2005 29th ICRC he15.

[9] E. Ponce, B. Khrenov, M. I. Panasyuk, H. Salazar, O. Martinez, G. Garipov and P. Klimov. 2010. Nuclear instruments and methods in physics research section A doi:10.1016/j.nima.2010.10.100.