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Cosmic ray effect on the X-ray Trigger Telescope of UFFO/*Lomonosov* using YSO scintillation crystal array in space

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UFFO Burst Alert and Trigger telescope (UBAT) is the X-ray trigger telescope of UFFO/*Lomonosov* to localize X-ray source with coded mask method and X-ray detector. Its X-ray detector is made up of 36 8×8 pixels Yttrium OxyorthoSilicate (Y2SiO5:Ce, YSO) scintillation crystal arrays and 36 64-channel Multi-Anode PhotoMultiplier Tubes (MAPMTs) for space mission. Its effective detection area is 161cm^2 and energy range is several keV to 150 keV. It was successfully launched in April 28, 2016. In several calibration run, we got several X-ray background data. We already knew X-ray background flux is 2-3 counts/cm^2/sec in space. However our X-ray background data shows approximately 7-8 times higher than what we know. There are many candidates to explain high X-ray background count in space. One of candidates

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is cosmic ray. We will report cosmic ray effect on the X-ray detector using YSO scintillation crystal arrays in space.

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1. Introduction

We developed Ultra-Fast Flash Observatory (UFFO) – pathfinder to observe Gamma-Ray Bursts (GRBs)[1]. It is made up of data acquisition system (UDAQ) and 2 telescopes.

One is Slewing Mirror Telescope (SMT) which consisits of slewing mirror systsem, 100mm aperture Ritchey-Chrétien telescope, Intensified CCD (ICCD) and readout electronics. Its purpose is GRB targeting and tracking within a few seeconds with slewing mirror system and measuring UV/optical signal from GRBs[2,3].

The other is UFFO Burst Alert and Trigger telescope (UBAT) which localizes GRB with coded mask method and gives GRB location to SMT [4]. It consists of external structure, so-called hopper, X-ray detector and electronics. X-ray detector is made up of 36 8×8 pixels Yttrium OxyorthoSilicate (Y_2SiO_5:Ce, YSO) scintillation crystal arrays and 36 64-channel Multi-Anode PhotoMultiplier Tubes (MAPMTs). YSO scintillation crystal array has many advantages. First it dosen't have intrincsic background. It means we can detect low energy X-ray withount internal noise. And it has high light yield and high spatial resolution by adopting pixelized crystals. An effective detection area of UBAT flight model is 161cm^2 and energy range is several keV to 150 keV.

UFFO-pathfinder/*Lmonosov* was successfully launched on April 28, 2016 and we are calibrating our instrument in space.

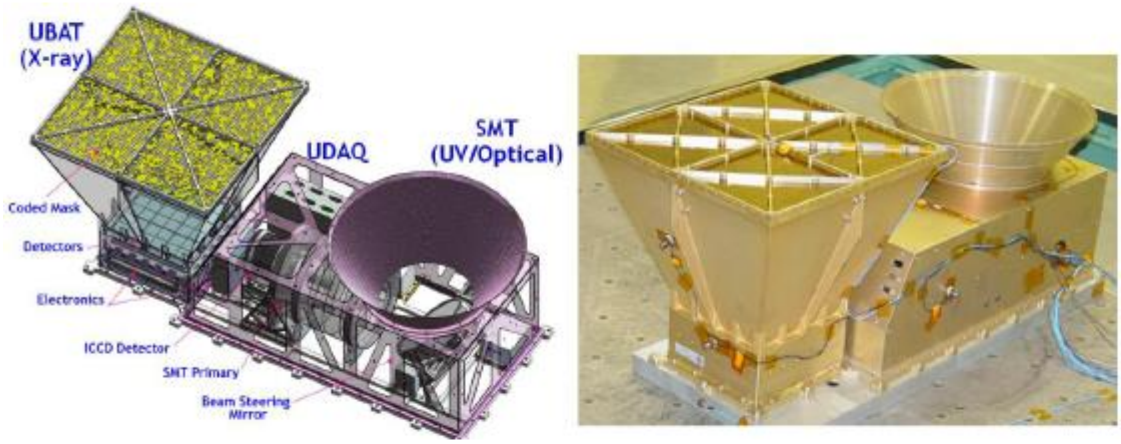

Figure 1: A composition of UFFO-pathfinder (left) and assembled flight model (right)[1]

2. Performance of UBAT in space

After launch, we started telescope calibration in space. During that time, the X-ray trigger telescope (UBAT) took several data.

We checked detector performance through diffused X-ray data analysis. UBAT takes 700 frames data and it is divided 5 sessions. We are able to adjust exposure time of each session by commend. Table 1 shows default value of number of frame and exposure time in each session. We set the default value of exposure time and took a data on July 5, 2016. Figure 2 shows its results.

It is 1 of 700 frames X-ray data. A white color means X-ray was detected and a black color means no X-ray on detector. (a) and (b) were set 100ms exposure time and (c) and (d) were set 500ms exposure time. (c) and (d) have many X-ray hits in comparison with (a) and (b). It means our session setting is working well.

Table 1: Default value of number of frame and exposure time

Session Number	Number of frame	Exposure time per 1 frame (sec)
1	200	0.1
2	300	0.1
3	100	0.5
4	50	0.5
5	50	0.5
Total	700	150

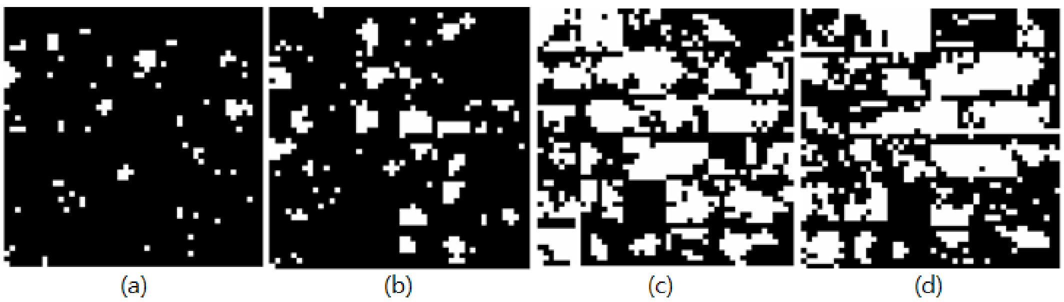

Figure 2: X-ray telescope(UBAT) detector data in space, 48channel x 48channel. (a) and (b) are 100mse c exposure time and (c) and (d)are 500msec exposure time.

In Figure 3, red points were divided 2 groups because of exposure time setting. We set 100-msec exposure time from data taking start to 50 seconds and 500 msec exposure time 51 seconds to 150 seconds. Also, we calculated count rate using this data. It is approximately 21.3 cnts/cm^2/sec. We already known counts of diffused X-ray background is 2~3 cnts/cm^2/sec up to 15 keV. This value is from *swift* which is NASA mission to observe GRB [5]. Our value is about 7 times higher than well-known value. We suggest 3 candidates of reason which are crosstalk effect, low energy sensitivity and cosmic ray effect. In section 3, we discuss cosmic ray effect on the UBAT using beam test results.

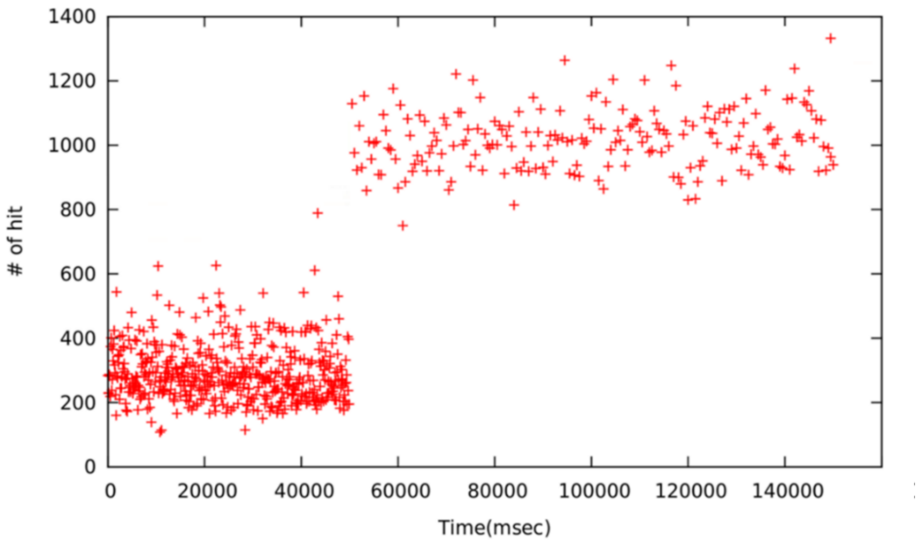

Figure 3: Number of hit of each frame on July 5,2016 data

3. Cosmic ray effect

3.1 CERN beam test with mini UBAT detector

We tested our X-ray detector with heavy incident heavy ion beam at European Organization for Nuclear Research (CERN) to confirm X-ray detector of UBAT resopose when comsic ray pass through UBAT. We prepared a mini X-ray detector of UBAT for ground test. It consists of only one analog electronics and 2 YSO scintillation crystals and MAPMTs set (see Figure 4).

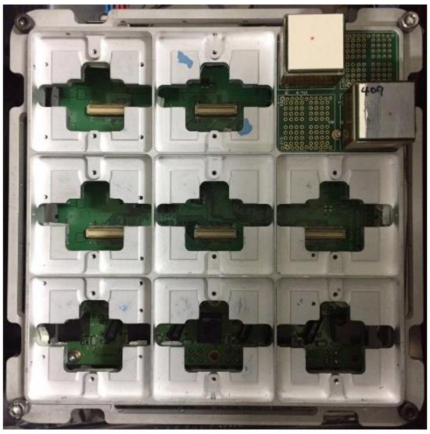

Figure 4: The mini X-ray detector of UBAT for ground test. There is an analog electronics, 2 YSO scintillation crystals and MAPMTs set on right-upper side of the UBAT detector structure.

We used H4 beam line at CERN. Heavy ions have a momentum of 60 GeV/c per nucleon and A/Z = 2.0. We put 20cm thickness of lead between beam line and our detector to produce fragmented particles like cosmic ray. And we made dark box to protect X-ray detector from light and put X-ray detector in the dark box. It was placed on the table in front of beam line. Test facility and set-up shown in Figure 5.

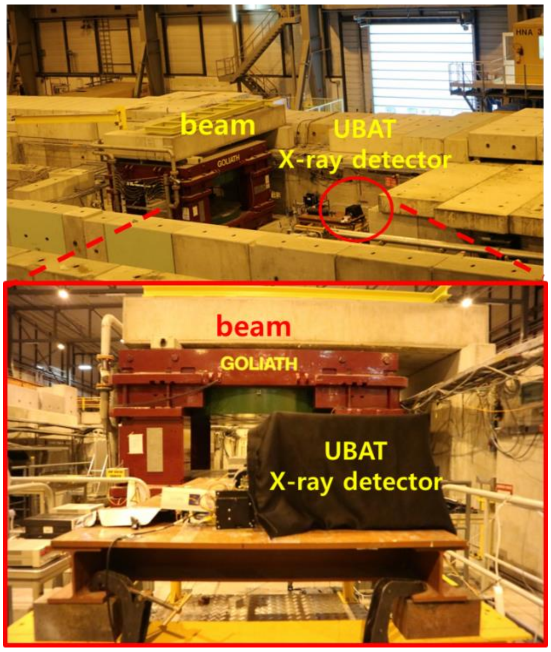

Figure 5: Test set up at H4 beam line of CERN. The dark box which includes X-ray detector is placed in front of beam line.

UBAT has 6×6 MAPMT and YSO scintillation crystal sets. One square is one set and mini UBAT has only 2 sets, (1,5) and (2,6) location. We set exposure time is 6msec for all frames of data, total duration time of a data is 4.2 seconds. When we took a data without any beam in the ground, we didn't see big clusters in each frame. However, we can see big clusters with heavy ion beam in Figure 6 and almost frames have big clusters. It means any charged particles make cluster on our detector and cosmic rays can make clusters.

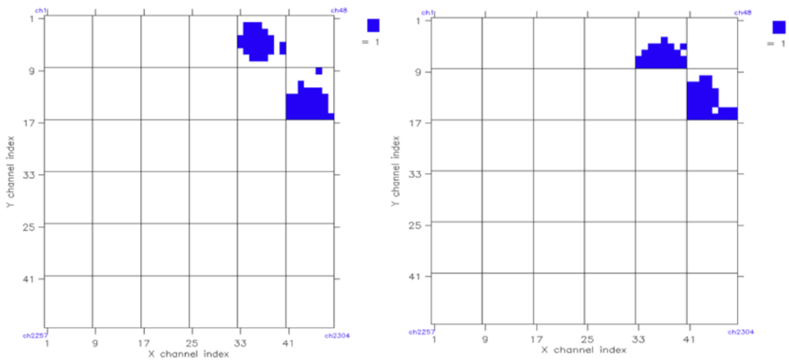

Figure 6: Each is one of frames response from beam test. It takes 6msec to take a frame data. UBAT has 6×6 MAPMTs originally but mini UBAT has only 2 MAPMTs. Its locations are (1,5) and (2,6). Blue color is response for any particles and white color is no response.

3.2 Cosmic ray effect on UBAT in space

UFFO-pathfinder took several diffused X-ray background data during calibration in space. Each data has different exposure time setting. Therefore, we checked 1msec per a frame data of all data because if exposure time is long, some small clusters gather and make big cluster and our minimum settable exposure time is 1msec for X-ray detection. Also, when a cluster includes more than 30 X-ray hitting pixels, we defined it is made by cosmic ray. Figure 7 shows diffused X-ray background data from space. In diffused X-ray background data by our detector, approximately 5% of total frames have big cluster like Figure 7. As we ignore frames which include big cluster and calculate count rate again, we are able to get about 12.3 cnts/cm^2/sec. This value is 1.7 times less than previous value.

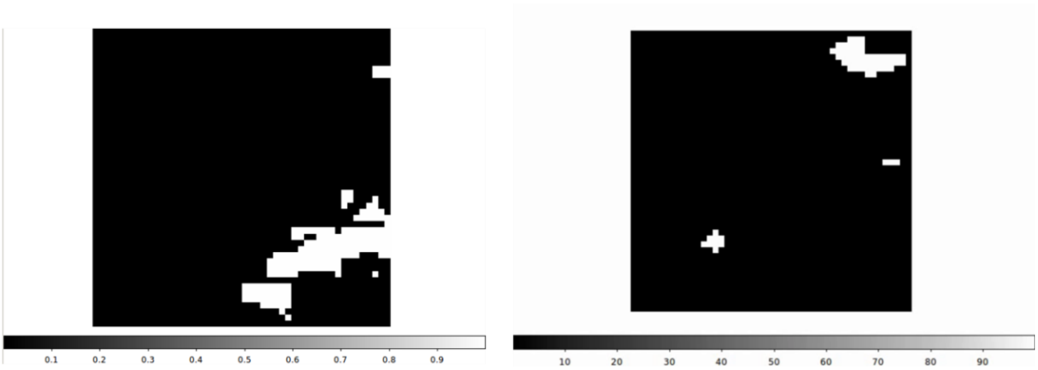

Figure 7. 48×48 channels X-ray hitmap in space. A white color is X-ray hitting channel and black is no X-ray channel. Left: One of 700 frames data on Sep.29,2016. Exposure time is 1msec. Right: One of 700 frames data Nov.24, 2016. Exposure time is 1msec.

4. Conclusions

UFFO Burst Alert & Trigger telescope (UBAT) is X-ray telescope of UFFO/*Lomonosov* to detect X-ray and localize Gamma-Ray Bursts (GRBs). Its detector was made up of YSO scintillation crystal arrays and MAPMTs. They are the first materials as X-ray detector in space, we confirmed that they are suitable for space mission.

After launch, UBAT got several diffused X-ray background data in space during calibration. X-ray count rate is 7 times higher than as we expected from *swift* results. We assumed several candidates to find reason of high count rate. One of candidates is cosmic ray effect on UBAT because X-ray hitmap of several data frames has big clusters it cannot be from X-ray. We tested our X-ray detector at CERN to confirm cosmic ray effect on ours. We set proper beam and test condition to make charged particles. We confirm that charged particles made big clusters on our detector.

UBAT doesn't have any cosmic ray counter to distinguish it. So, as hitmap of a frame has big clusters which are connected more than 30 pixels, we defined it is from cosmic ray. We calculated how many big clusters are detected. Approximately 5% of all frames of 1msec exposure time have it. As we remove big cluster, X-ray count rate is ~12.3 cnts/cm^2/sec. Cosmic ray effect reduce about 40% of X-ray count. In our following paper, we will report for low energy sensitivity and crosstalk effect on UBAT.

Acknowledgements

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