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UFFO Burst Alert & Trigger Telescope (UBAT): a new instrument for GRBs detection

J.M. Rodrigo[1], J.M. Macián[1], J.T. Biosca[1], M. Reina[2],
L. Sabau-Graziati[2], and V. Reglero[1]

[1] Image Processing Laboratory University of Valencia PO BOX 22085, E-46071, Valencia, Spain
[2] INTA - Area de Cargas Utiles, Dpto. de Programas y Ciencias del Espacio, Ctra. Ajalvir Km 4, E-28850 Torrejón de Ardoz (Madrid), Spain

Abstract. By using techniques developed on High Energy Gamma rays detection from the LEGRI Instrument on board Spanish MINISAT-01 satellite, and, the experience acquired with the INTEGRAL payloads, the scientific and technical team of IPL-INTA is involved in developing a new instrument which will detect early Gamma Ray Burst event: the goal of the Ultra Fast Flash Observatory (UFFO) telescope will be to locate GRBs and measure its UV/Optical photons in short time scales less than one minute even sub-second timescales. To prove that this technological challenge is to successfully achieved, UFFO collaboration has developed the UFFO Pathfinder space mission to be launched on board Lomonosov satellite in November 2011. It consists of two instruments: The UFFO Burst Alert & Trigger Telescope (UBAT) devoted to the location of the GRB, and the Slewing Mirror Telescope (SMT) for the UV/Optical afterglow observation, upon triggering by UBAT. University of Valencia and INTA team collaborates in the UBAT Imaging System, Mechanical Housing and Thermal Control Hardware, as weel as in the On Board and Trigerring software developing, design and manufacturing or programming. In this paper we will present UFFO UBAT Telescope design.

1. Introduction

Gamma Ray Bursts (GRBs) are the most energetic events in the Universe emitting high energy photons up to 10^{51}Hz in time period of few tens of second, and they also posses a wide range of redshift factors. These properties provides great leverage in time (GRBs could be a "standard candle" which would make them useful as a cosmological prove of the very high readshift of the Universe, see Jung et al. 2011), in wavelenght (burst and afterglow span some nine order of magnitude in photon energy, for highly synoptic observations), and in information (allowing multimesseger astrophysics where the exploxion can be observed in photon, neutrinos, and gravitational waves). One of the most powerful and distant GRBs is the GRB090423 with redshift of 8.2 ocurred about 630 million years after the Big Bang. This observation allows us to begin exploring the last blank spece on our map of the Universe.

In the begining GRBs were clasified in two unique groups based on their gamma-X emissions alone: a shorter, hard spectrum burst,

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Send offprint requests to: J.M. Rodrigo

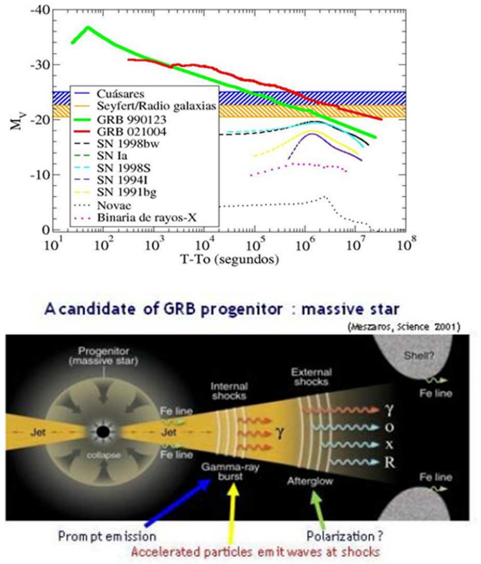


Fig. 1. Up: GRBs light curve vs. other stellar bodies. Down: GRB afterglow.

with duration of gamma-X emission less than two seconds, and longer, soft burst, with duration of gamma-X emissions up to100 seconds. In any case the origin of both types remains unknown although there has been much progress thanks to SWIFT satellite observations. After 476 events detected by SWIFT Burst Alert Telescope (BAT) in five years, the above classification can not be validated: there are many types of difenret light curves, and they are complex, with decays, plateaus, changes in slope, and other features that are not yet understood (Park et al. , 2009). Unfortunately the accuracy in the measurement of the rising phase is not enough to understand the physics in this regime and the observations of GRBs are limitated to their afterglows due to the lack of ability to shorten the response time. To determine whether these GRB models are correct, observation of the phenomenum prompt signals is indispensable, and in particular, we need: larger statistics with wider FoV & higher sensitivity, higher redshift with large aperture, wider band in wavelenght (if possible together with neutrinos) and faster response measurements for early prompt protons measurement.

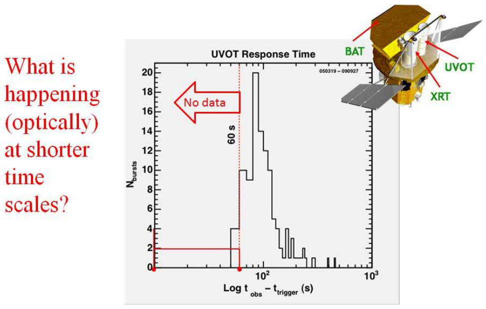


Fig. 2. GRB spectrum measured by SWIFT

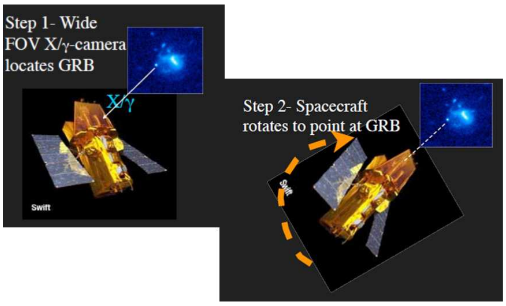


Fig. 3. SWIFT GRB detection methodology

2. UFFO Mission

Previous mission devoted to the GRBs study have limited response speed just in the time after the burst (there are few data with time below 60 seconds after gamma-X ray signal. This is because first satellite detecs the gamma-X ray signal using the burst alert telescope (BAT in the case of SWIFT) which is able to locate the origin of the event by using a standard coded mask technique, and later, the satellite should rotate to point the GRB using UV and Optical telescope (UVOT in the case of SWIFT). After slewing, a period time aproximately of 100 seconds is need for satellite stabilization and then is when the telescope start to observe.

UFFO collaboration propose a new technology approach which allows to measure early optical photon from GRBs to subsecond time scale for better understanding of GRB mechanism and potentially find GRBs with readshift up to z=10 for the first time (Park et al. , 2009). UFFO will redirect the optical path of the incoming GRB beam instead of

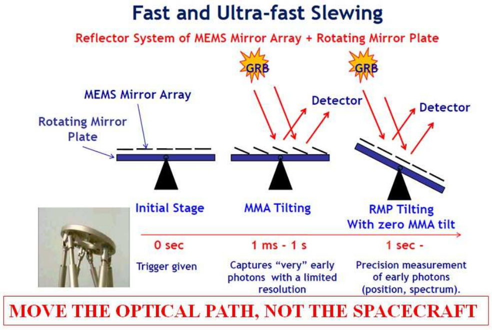


Fig. 4. UFFO mission GRB detection approach

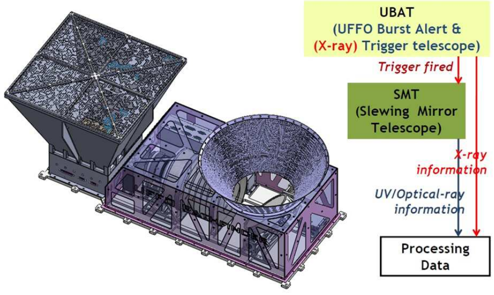


Fig. 5. UFFO mission

the entire spacecraft using the Micro Electrical Mechanical System (MEMS) to built Mirror Array (MMA). On other words, each pixel of mirror is controled by a nano-fabricated micro-motor and redirect the photons beam in the new angle within mseconds times.

In order to undertake this challenge, scientist and engineers from many countries have joined the UFFO consortium in 2010: The Korean team centered around the Ewha Women's University Research Centre for MEMS Space Telescope, has been spearheading in applying MEMS technology to satellite telescopes in the past ten years; the US team is headed by Prof. George Smoot of UC Berkeley; the Russian team at the Moscow State University has dedicated the past several decades perfecting the satellite telescope launching missions; the European team has extensive experience in satellite telescope projects and on the GRBs studies, Denmark and France team are expertises in space detectors, Poland team is devoted to space power supply units, Taiwan team are expertise in particle astrophysiscs, high energy experimentation, numerical analysis and sowftare development, and the Spanish team has dedicated in the past two decades to the design and development of the imaning systems and associated on board and trigger software for high energy instruments in space enviroment.

The technology needed is reasonably mature, the challenge, however is the uniformity of the MEMs array for large area mirrors, and, faster data processing. With these science and technical motivations in mind, the Taiwan and Korea members of the present UFFO collaboration initiated the Prompt Observations of Energetic Transients satellite (POET) in 2008 but it was later aborted. Afterwards a scaled model of this telescope called UFFO Paithfinder was proposed in 2009 in response to an opportunity afforded by available space on board Lomonosov Space Mission scheduled for Launch in November 2011.

3. UFFO Pathfinder

It consists of two instruments: the UFFO Burst Allert and Trigger Telescope (UBAT) for the detection of the GRBs location, and Slewing Mirror Telescope (SMT) for the UV/optical afterglow observations, upon triggering by UBAT. The goals were clear: the scaled model mass should be less than 20 kg mass, power budget less than 20 wats and the the instrument should be ready in two years from the date of definition. Having these simple principles in mind, the team start to work with a very simple design, using commercially available components, and fortunatelly the UFFO Pathfinder has now entered the final stage of preparation before it is launched in November 2011 (Park et al. , 2009).

Because the time constrain, the SMT telescope will not use the MEMS mirror array. Instead a Ritchey-Chretien telescope with monitorized mirror plate, with 10 cm in diameter and the FoV of 17 x 17 arcmin. SMT can redirect the incoming GRB light path within

Table 1. UFFO Paithfinder SMT Technical specification

Telescope	Ritchey-Chretien + monitorized mirror plate
Aperture	10 cm diameter
F-number	11.4
Detector and/Operation	Intensified CC with MCP / Photon Counting
Field of View	17 x 17 arcmin
Detection Element	256 x 256 pixeles
Telescope PSF	1 arcsec at 350 nm
Pixel scale	4 arcsec
Location Accuracy	0.5 arcsec
Wavelength Range	200 nm - 650 nm
Color Filters	8
Sensitivity	B=19.5 for white light in 100 sec
Bright Limit	mv=6 mag
Data taking start time after trigger + location	¡ 1 s
Date Rate	1 GB/day
Mass, Power, consumption, size	11.5 kg, 10 W, 20 cm x 20 cm x 80 cm

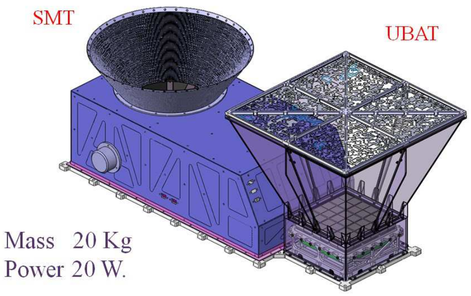
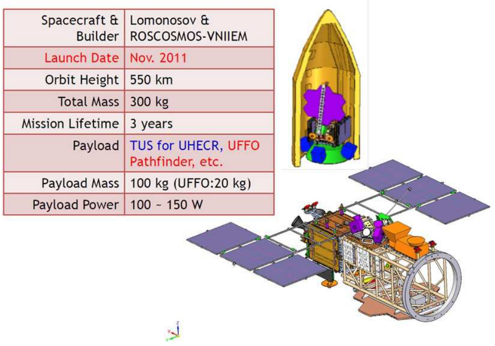


Fig. 6. UFFO Pathfinder set up



Spacecraft & Builder	Lomonosov & ROSCOSMOS-VNIIEM
Launch Date	Nov. 2011
Orbit Height	550 km
Total Mass	300 kg
Mission Lifetime	3 years
Payload	TUS for UHECR, UFFO Pathfinder, etc.
Payload Mass	100 kg (UFFO:20 kg)
Payload Power	100 ~ 150 W

Fig. 7. UFFO Pathfinder platform: Lomonosov Satellite

1 second. Other technical specifications of the SMT are given in Table 1.

Details on the instrument UBAT design are the reason of this paper and they are given in separate section.

4. UFFO Burst Alert and Trigger Telescope (UBAT)

The instrument design will follow the SWIFT Burst Alert Telescope X-gamma trigger camera, its main scientific propouse is to detect as faster as possible the GRBs position in the sky and trigger to SMT for GRB subsecond spectrum characterization. This is achieved by selecting detector type with high quantum efficiency, selecting as large detector area as realistic on the Lomonosov satellite, and using a coded mask aperture camera scheme for good position detection for transients and triggering the SMT.

Modern semiconductor detectors based on Cd and Te compounds or LYSO crystals offers many advantages for X and Gamma ray detection in spece enviroment because the have high stopping power due to its high density, they can operate close to room temperature and do not require cryogenic cooling systems as required by conventional Si and Ge detectors, high spatial resolution by adoptin pixeled detector plane, and high light yield together with fast decay time.

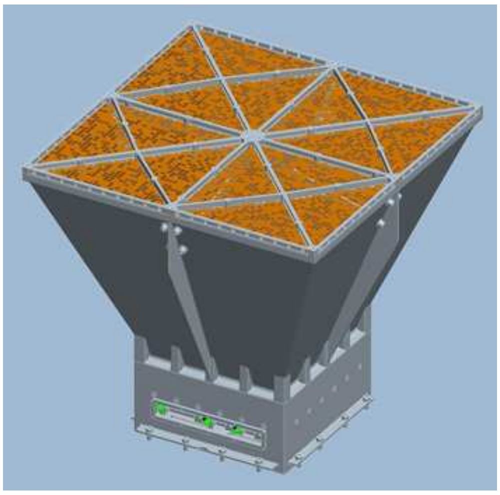


Fig. 8. UFFO Burst Alert Telescope (UBAT)

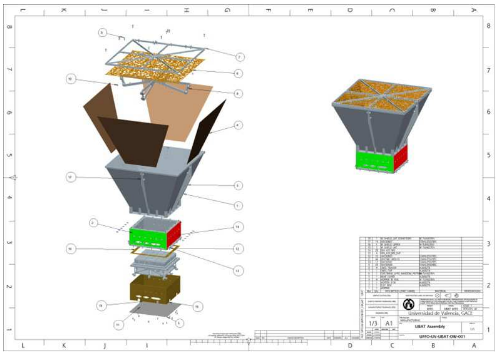


Fig. 9. UFFO Pathfinder Burst Alert Telescope Assembly Drawing

UBAT detects the GRBs photons in the energy range of 5 to 200 KeV. The LYSO scintillation crystal covers the X and Gamma ray photons to UV photons, which eventually become electrical pulsess through the chain of multi-anode photomultipliers and pulse shaping electronics. The electrical pulses are recorded with a period of 2.5 nanoseconds.

The UBAT Detector Module (DM) includes the LYSO crystal, MAPMTs, analog and digital boards, high voltage boards, and the support structure. When the Gamma and X ray photons come on the DM, it produces UV photons by scintillation in proportion to the energy of the event- These UV photons are converted into electrons, which are multiplied by the MAPMTs and fed into analog boards. The signals are then processed at the digital boards where the trigger algorithm is also performed. For a more detailed explanation see Jung et al. (2011)

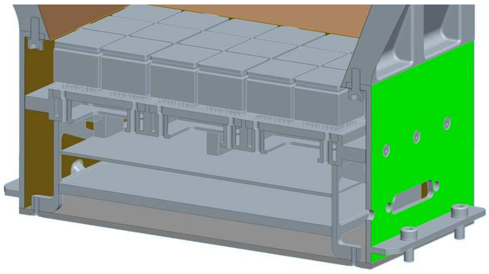


Fig. 10. Pictorical representation of UBAT DM into electronic box

Therefore the core of the UBAT instrument is the DM, but it is also important the Imaging system composed by coded mask subassembly and hopper which determines the FoV of the telescope, and the mechanical housing for the DM named electronic box which provides interfaces to the satellite platform.

A Coded Mask is a optical len for high energy composed of pixels that either block protons or allow them to pass through intercepts the incident gamma beam coming from GRB located in the field of view of the instrument. Once the mask has coded the beam, it reaches the pixelized DM and projects on it the coded mask shadowgram characteristic of the sources located in the observed region. The disposition of the mask pattern, pixel size and geometrical shape is such that each shadowgram is independent from the other through an auto correlation function.

The UBAT FoV is defined by the distance between coded mask and DM, and the relation between the area of the coded mask and the area of the detector window. Therefore, all these values are the drivers for the hopper or collimator design. For UBAT is important to reduce the count rate cause by the background specially in the lower energy range (up to 100 KeV), and for this reason the detector is sourrounded by a passive shielding in order to pro-

Table 2. UBAT Technical Specifications

Field of View	Aprox. 1.8 sterad (90.2 x 90.2)
Point Spread Function	Less or equal to 10 arcmin
Detector	LYSO + MAPMT
Detector Energy Range	5 - 200 KeV
Number of Pixels	48 x 48
GRB detection rate	Aprox. 34 GBRs/year
Pixel size	1.2 x 1.2 x 1 mm^3
Effective Area	191.1 cm^2
Energy Resolution	¡ 20% at 60 KeV
Quantum efficiency	99 % at 100 KeV
Sensitivity	310 mCrab with 10 seconds exposure at 5.5 sigma for 4 to 50 KeV
Passive shielding composition	0.1 mm W + 3 mm Al
Passive shielding absortion	100 % at 4- 50 KeV
UBAT total mass	10 Kg
UBAT Detector Module mass	2.6 Kg
Coded Mask pattern	Pattern W alloy of 1 mm thickness
Coded Mask size	400 x 400 x 1 mm^3
Mask to DM distance	280 mm
Volume	400 x 400 x 365 mm^3
Power consumption	10 W

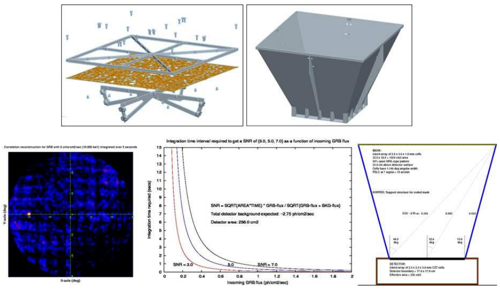


Fig. 11. UFFO UBAT Telecope Imaging System

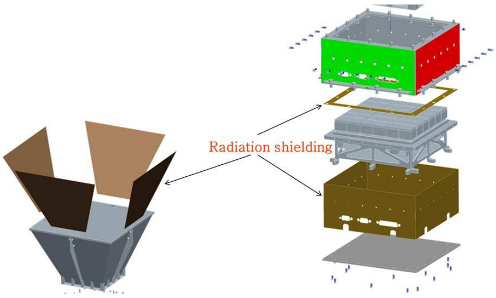


Fig. 12. UBAT Passive shielding

tect it against the radiation coming out of the FoV.

Finally the primary structure of the UBAT telescope is made uo of a mechanical housing for DM integration with the Hopper and Coded Mask including the passive shielding as shown in Figure 12.

5. Conclusions

Currently the UFFO collaboration is exceiting workin in the UFFO Pathfinder manufacturing in order to lunch the instrument on board Lomonosov satellite in November 2011. In parallel, the team is also exploring the next step, a more ambitious project named UFFO-100 and it will be based on the same design principle but with larger total mass of 100 Kg and power consumption of aproximately 100 W (thus the name UFFO-100).This would affoird a 30 cm aperture SMT and 1024 cm^{2}CZT X-ray camera. The goal is to finally integrate the MMA technology into a motorized slewing mirror. The key components and the dimensions for the big brother of UFFO Pathfinder in shown in figure hereafter. It is foreseen to lauch UFFO-100 in 2015 by the Soyuz Launcher.

Therefore, we can concluded that the absence of the Earth bounded enviromental influence in the space improve the space tele-

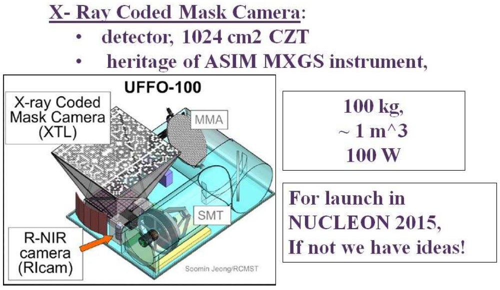


Fig. 13. A rendering of the UFFO-100 GRB Telescope

scopes performances and then they detect signal originated from much deeper space, thereby providing us a better understanding of the early Universe. A major part of the High Astrophysics satellites are observing the cosmos in its large-scale structure, but new missions becames to look for more localized and extreme astrophysical transient phenomena, and these efforst should be complementary because only the combined knowledge of both studies will give us the complete picture of our Universe (see Gehrels et al. 2004).

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