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Modular X and gamma rays sensor, a space-based instrument for transient lighting events in high atmosphere

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Abstract. Doing application of the techniques developed on High Energy Gamma rays detection for LEGRI mission of MINISAT satellite, and the experience acquired with INTEGRAL payloads. The scientific and technician team of INTA-GACE is involved into a international consortium, on developing an instrument to detect High Energy Events of very short time duration, similar to Gamma ray burst. Transient Lighting Events (TLEs), which are present on Terrestrial high atmosphere, and being object of research recently. A space base instrument, to be located on International Space Station (COLUMBUS module), will be enjoy of a superbly location to monitor the earth atmosphere in order to detect those rare events. At same time new detectors and technical challenges are front the team. This article exposes the actual design status and solutions in the MXGS instrument, to give support to gamma sensors.

Key words. Atmosphere: TGF – Atmosphere: TLE – Space: Gamma instrument – Space: Gamma sensors – Sensors: CZT – Sensors: BGO – Thermal: LHP – Thermal: AGP – Space: ISS

1. Introduction

The world of science has shown repeatedly, as different disciplines and science branch may be interrelated, or as field technologies could be profitable in others.

Along years the space missions on gamma astronomy, as the Compton Gamma Ray Observatory (CGRO - Figure 1), observing astronomical sources, has been detecting gamma photons burst from an unexpected direction, the Earth.

Instruments as BATSE (20 keV-100 MeV)on CGRO has detected gamma burst similar in spectrum to the astronomical sources (Figure 2), but coming from a direction where the instrument shielding was reduced.

Others space missions as RHESSI, FERMI (GLAST instrument from 8 keV to 40 MeV), AGILE have adding data to the Earth gamma burst detection.

One possible source for this detected events, is on the Earth atmosphere. From 1990, with video registered, by Franz and al. of very fast events named sprites. The scientific com-

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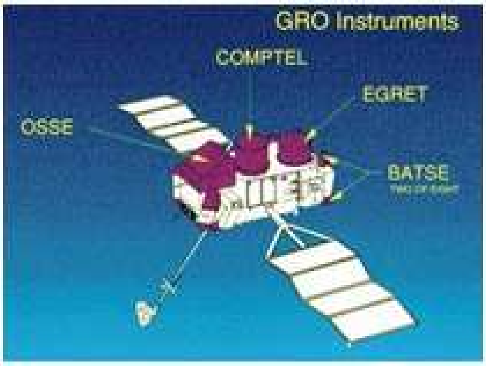

Fig. 1. Instruments of CGRO - COMPTON spacecraft

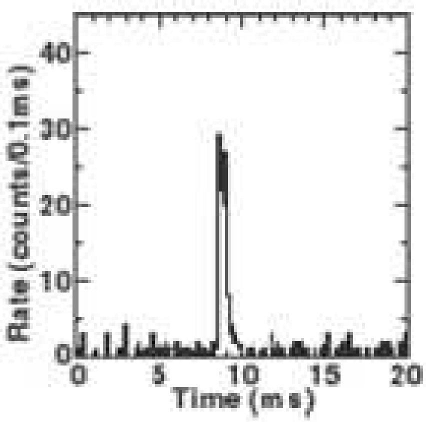

Fig. 2. gamma burst detected by BATSE

munity has included new founds about high energy phenomena in the higher atmosphere. Lighting storms are powerful events which deploy energies of GW with high intensity electrical fields, which in combination with Earth magnetic field can accelerate electrons and ions (Figure 3).

These phenomena shown in the visible spectrum different shapes as sprites, blue jets, with time duration from ms to seconds (Figure 4). They are known as Terrestrial lighting Events or TLE. And it seems to be associate whit gamma burst known as Terrestrial gammary flashes of TGF.

Apparently exist a geographical relation between the Thunderstorms and the TGF, as could be shown through the data collected by the FORMOSAT-2 payload ISUAL (Figure 5), compared with the data from the Optical Transient Detector of the NASA (Figure 6).

Both figures were obtained by space missions, which show as privigelate is that location for Earth observation.

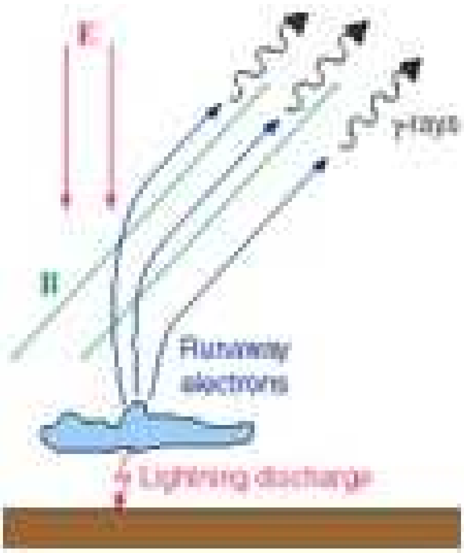

Fig. 3. physical model

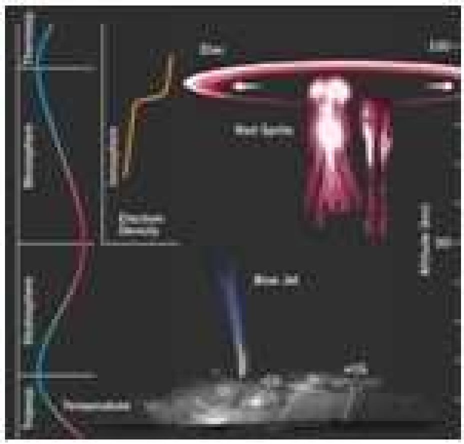

Fig. 4. Terrestrial lighting Events

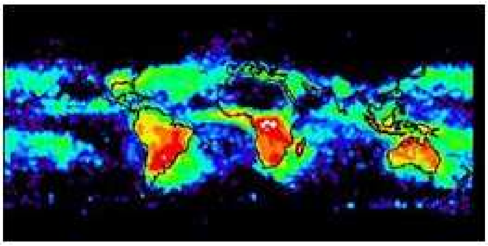

Fig. 5. Gamma burst distribution

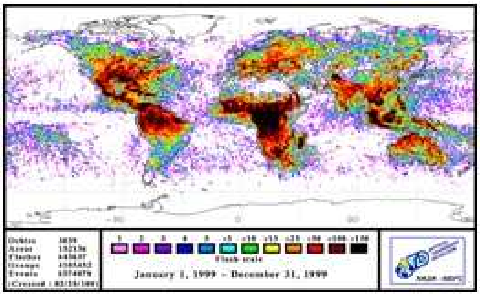

Fig. 6. Lightning distribution

2. ASIM mission and MXGS instrument

2.1. Driver parameters

In order to research in the above possible interrelation, between TLEs and TGFs, a multi spectral instrument is needed, where visible and gamma instrument works together, from a space orbit. The previous data show that we would expect fluxes of 50 TGFs by month, with a gamma detector area of 1024 cm2. With a energy range between 100 keV to 30 MeV. The instrument need to has the capability to manage around 1000 counts/msc during a TGF. And to obtain the maximum profit of the spectra bandwidth (visible and gamma), the gamma detector shall have the capability to locate the gamma source. For that, not only the sensitivity if not energy resolution, and a code mask need to be defined and used, assuming the photon losses due to the code mask.

2.2. Project members

An international consortium was create to develop a space mission from the International Space Station (ISS), with the goal to gather observation data of the above mentioned events during at least two years. That mission is the Atmosphere Space Interaction Monitor (ASIM). With two instruments, the MMIA in the visible, and the MXGS for gamma rays. ASIM mission was granted with funds by European Space Agency (ESA), with the objective to do use of one of the COLUMBUS external payload facilities (COLUMBUS is the European module of ISS). The responsible of ASIM mission project is the Danish enterprise TERMA. The ASIM scientific consortium is led by the Danish Technical Institute (DTU - Denmark), with collaboration of University of Bergen (Norway), and the Image Processing Laboratory of Valencia University (IPL- GACE).

In MXGS INTA and IPL-GACE works together. IPL-GACE on scientific group and the structural design, and INTA on the thermal control and integration and test activities. Whitin of the spanish group, others institutions as the Carlos III University of Madrid, the Instituto de Astrofsica de Andalucia and the Universidad Politcnica de Catalua are part of the science group. DTU is the responsible of the System engineering tasks, and the developing the Digital Process Unit, while the University of Bergen is the responsible for the detectors sensors.

DTU, GACE and INTA were partners in INTEGRAL. DTU has experience with CZT sensors, while GACE has experience with gamma code mask in LEGRI instrument of INTA satellite MINISAT, and on INTEGRAL mission also.

2.3. ASIM description

ASIM is compound of two kind of sensors. Visible cameras named MMIA, and the gamma and X ray monitor, the MXGS, subject of this paper (Figure 7). MXGS is looking to Nadir, the Earth suborbital point with a 80 grades field of view. They are two MMIA, one look-

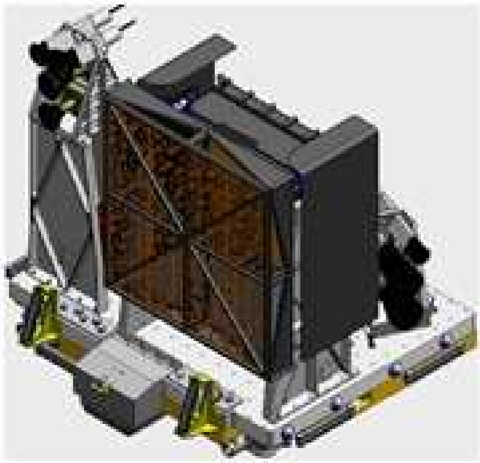

Fig. 7. ASIM instruments on CEPF

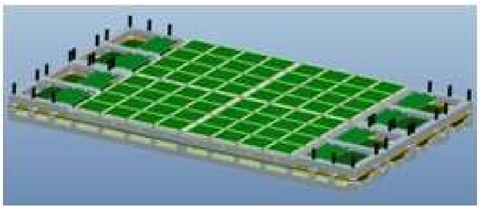

Fig. 8. Low energy CZT detector plane

ing to NADIR as MXGS, and another looking to the limb. MMIAs and MXGS with a power unit, and a Control unit are mount on the CEPF, a standard plate made by Carlo Gavazzi, which does the mechanical interface with the COLUMBUS external facility.

2.4. MXGS description

MXGS does use of two detector planes. The low energy detector plane (Figure 8), is made of 64 Cadmium Zinc Tellure or CZT crystals, each one coupled to an amplifier and ASIC. Their energy sensitivity varies from 10 keV to 400 keV. They are grouped in four detector units with 16 CZT each one, and digital process board. They are been space proof in previous Gamma space missions as INTEGRAL (ESA) and SWIFT (NASA).

The high energy detector plane (Figure 9) has twelve Bismuth Germanate (BGO) crystals, which energy sensitivity goes from 200 keV to 20 MeV. Each one is coupled to a photo multipliers tube or PMT. The BGO are grouped in four detector units. As was mentioned, the BGO crystals flown in FERMI mission.

Fig. 9. High energy BGO detector plane

Both sensors has an lineal response respect to the temperature. They works between -20°C to +30°C, but their energy resolution decrease very fast with high temperatures, thus their operating temperatures is reduced to 20°C.

The MXGS characteristics are defined on below list.

- Detectors area 1024 cm^2
- Low Energy Detector: 10 - 400 keV
- High Energy Detector: 200 - 20 MeV
- Energy resolution: 10% at 60keV / 15% at 662keV
- Low Energy Detector FOV 80°
- Angular resolution: 3°
- Background: 2 counts/msec
- Time accuracy: 5 s
- Dimension: 763x521x770 mm
- Mass: 138 kg
- Power: 104 W

The sensors with their associated electronics and PMT for BGO detector plane are mounted on an aluminum frame, as structural support and to homogenize the detector plane temperatures, and create a high thermal path for the detector power dissipation. The detector plane normal is looking to Nadir direction (Earth surface). Both detectors need a shielding except the Nadir direction. Thus, a rectangular box with different materials (Stainless Steel, Ta, Sn and Pb) are surrounded they, while a hopper shape made of aluminum and Tungsten define the field of view until the code mask high. This is made of Tungsten.

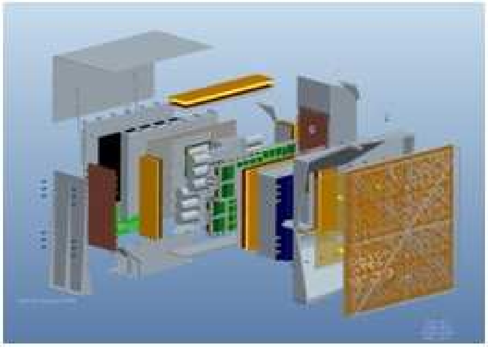

Fig. 10. MXGS elements

The requirements about trigger signal and processing impose us to use an specific devote digital process unit (DPU) close to the detectors. This is located behind and under the detector plane. BGO and CZT need high voltages, at time that front end electronic and DPU does use of low voltages; therefore, a specific Power supply unit (PSU) is attached behind the detector plane.

As is shown in Figure 10, the detector plane is perpendicular to ASIM mounting plane, which is a specific element, the CEPA, designed to be coupled to the external experiment location of COLMBUS module. Two specific support structures and the DPU box is the main structural path of MXGS.

The ISS orbit, their elements and the MXGS power distribution and dissipation, determine the radiators location on MXGS. Two radiators are defined; one is devoted to the detector dissipation. This radiator is closed to one of the support structure, in the RAM direction (ISS velocity vector). Other radiator is defined for the DPU and PSU power dissipation. That radiator has an L shape, cover the top and part of the backside of MXGS

The entire envelope between radiators and code mask shall be cover with multi layer insulation (MLI). The MXGS geometrical configuration; their power dissipation, and the requirements about mass and temperatures; are the reason to select Loop Heat Pipes (LHP) as the thermal means to transport the detector heat dissipation to radiators, with a minimum temperature gradient, and mass. The initial selected working fluid is ammonia. But the great thermal impact of the orbit conditions, with extremes hot and cold cases impose the use of a shut valve between detectors and radiator, in cold case. Under this condition the radiator temperature could be below of the ammonia freezing temperature. A tradeoff between heater power and different working fluid is ongoing. While the final ASIM design review is not closed.

3. Conclusions

MXGS and ASIM mission shows the benefits of the international collaboration, and the interdisciplinary application of technologies. The space is a paramount site to study the earth, and the low orbits (down to 900 km), are comfortable from the thermal point of view. But the system designers need to put attention on the operating temperatures range, at same time that the power dissipation. If they want to reach a simple design.