LOW ENERGY GAMMA RAY IMAGER (LEGRI)

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Abstract. The Low Energy Gamma Ray Imager (LEGRI) will be one of the three instruments carried by the first MINISAT mission. LEGRI aims to demonstrate the technological feasibility of a new generation of low energy gamma-ray telescopes with imaging, medium resolution spectroscopy and high continuum sensitivity in the 20-200 keV spectral region, based on HgI_2 solid state detector technology.

The data supplied by LEGRI will allow us to investigate HgI_2 detectors in astrophysics by examining semiconductor stability, radiation damage and survival capability under space conditions. Furthermore, LEGRI will provide a good scientific output in the very interesting low energy γ-ray/hard X-ray domain.

LEGRI was accepted by the MINISAT consortium in March 1993. The delivery is scheduled by September 1995 and the MINISAT-01 launch at the mid of 1996 with a nominal life of 2 years.

1. Scientific and technological background

Imaging combined with high continuum sensitivity is a prime requirement for high energy astronomy. Accurate positioning of the gamma-ray point sources and imaging for the extended sources have been identified as key issues for the GRO and SIGMA successors.

Precise location of the gamma-ray emitters is crucial to identify X-ray, optical, infrared and radio counterparts, while mapping diffuse Galactic emission and extended sources will be crucial in understanding the interstellar processes working in space and the injection of heavier elements by the supernova explosions. Extragalactic gamma-ray astronomy is also potencially a very rewarding discipline. Accurate measurements of gamma-ray

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AGN's and their relation with X-ray extragalatic emitters is a priority for future high energy missions. The extension of AGN spectra from the X-ray range to higher energies is fundamental to the understanding of the nature of powerful mechanisms acting on these objects.

In this framework the 20-200 keV spectral region has a particular importance. Unique astrophysical information regarding nuclear excitation process, radioactivity, cyclotron emission and line formation is contained in this region of the electromagnetic spectrum. For many astronomical objects it is very important to determine the end of their X-ray tails and the possible extension of their spectra to gamma-ray energies. Despite the importance of this energy range, a significant data gap actually appears at the 20-200 keV region. Efficiencies of currently available and new generation CCD X-ray detectors drop abruptly at 20 keV and many scintillator based instruments have been limited to operation above 100 keV. LEGRI aims to fill in this gap performing high sensitivity measurements and continuous monitoring of hard X-ray/low energy gamma emitters.

HgI_2 detectors will be used to fill in this vital energy gap. HgI_2 presents a greater resistance to radiation damage than other semiconductors which can be used in this spectral range such as Ge, Si and CdTe. They have been tested under fluences of 40 keV photons with counting rates up to 10^{12} ph cm^{-2} sec^{-1} without any significant deterioration [1]. It has also been demonstrated that HgI_2 detectors can endure doses of 10^{14} neutrons cm^{-2} and 10^{12} protons cm^{-2} of 10 MeV without suffering any damage. The above referred resistance to proton radiation damage is particularly important for space borne gamma-ray instrumentation which may have to pass through regions of extreme high energy particle fluxes.

Detectors based on HgI_2 technology do not show evidence of internal worsening over periods of seven years, working efficiently at room temperature. They provide medium energy resolution with a spectroscopic performance which is intermediate between Ge and scintillation devices while avoiding the complexity of the cooling systems necessary for Ge. For all these reasons, low energy gamma-ray detectors based on this technology are extremely promising devices to develope low gamma-ray astronomy in the space.

The technology and expertise required to fabricate HgI_2 crystals are not extensively available. A few laboratories in the world can produce suitable sensors, mainly for laboratory purposes. Over the last five years, the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) in Spain, has carried out a development program on this material with successful results and a production line is now available.

2. The Low Energy Gamma Ray Imager

2.1 LEGRI PERFORMANCE

LEGRI on board of the MINISAT-01 (INTA) mission has been partially conceived as a technology demonstration model for a new generation of gamma-ray telescopes based on the use of solid state HgI_2 detectors.

LEGRI is a gamma-ray imager with moderate resolution (2.2°) and good point source location capability (20'), providing medium resolution spectroscopy (4 keV at 30 keV) and high continuum and broad line sensitivity at 20-200 keV. The estimated continuum sensitivity of 3 mCrab at 30 keV will allow survey to be made of selected areas and deep measurements of specific fields. A summary of LEGRI key performance parameters can be found in Table 1. In Figure 1 we present the estimated continuos LEGRI sensitivity by comparison with the currently operational space missions SIGMA and OSSE [2,3].

ENERGY RANGE	20-200 keV
CONTINUUM SENSITIVITY	3 mCrab at 30 keV and 10^5 s (3σ)
SPECTRAL RESOLUTION	E/ΔE = 8% at 30 keV
ANGULAR RESOLUTION	2.2°
POINT SOURCE LOCATION CAPABILITY (PSLC)	20'
FULLY CODED FOV	11°
DETECTORS	10x10 1cm² HgI_2 crystals array 0.5 mm thick
MASS	30 kg.
POWER	20 W

TABLE 1. LEGRI key performance parameters.

Space does not permit a more detailed discussion of the expected LEGRI scientific scope but the wide range of astronomical objects that can be studied includes pulsars, black hole candidates, X-ray, binaries, supernovae and AGN.

2.2 LEGRI CONSTRUCTION

The LEGRI system will consist of the following units:

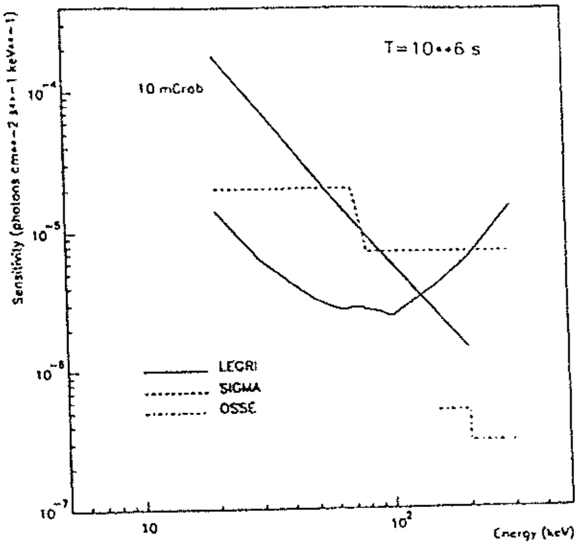

Fig. 1. LEGRI sensitivity at 3σ. Comparison with SIGMA (GRANAT) and OSSE (GRO).

- Detector Unit: This is a position-sensitive gamma-ray detector consisting of an array of 100 HgI_2 detection elements, each 0.5 mm thick, arranged on a 12x12 mm^2 square grid; the associated Front End Electronics, based on a 16 channel low-noise preamplifier chip, using gate array technology and a commercial ADC; a mechanical collimator made of tantalum; and a main mechanical assembly with passive shielding.

- Mask Unit: located at 540 mm from the detector plane and parallel to it, consisting of a static coded aperture mask made from 24x24 mm^2 tungsten elements, 1 mm thick, within a carbon fibre honeycomb plate and support structure.

- Power Supply and Digital Processing Units: which will provide interfaces to the PLM for power, commands and data transmission.

- High Voltage Unit: This will supply the high voltage (500 V) needed to operate the detectors.

- Star Sensor: which will be used to determine with sufficient precision the satellite attitude , allowing for the reconstruction of the gamma-ray images on the ground without spatial blurring caused by platform drift or jitter.

- A Science Operation Center which will be located at Valencia.

In Fig. 2 we show LEGRI's location on the MINISAT-01 payload module, together with the other instruments which will complete this first MINISAT mission.

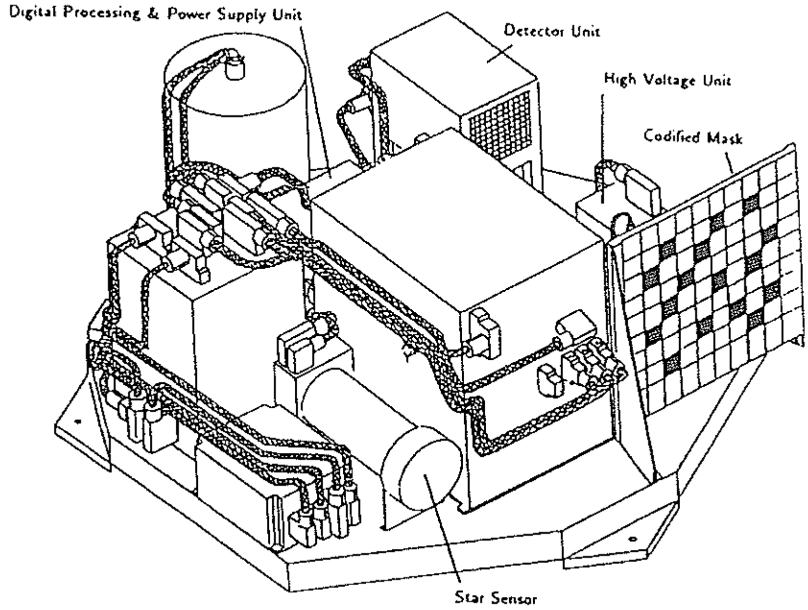

Fig. 2. LEGRI's location on the MINISAT PLM

2.3 LEGRI COLLABORATION

LEGRI is being designed and built by a consortium including the following Universities and Laboratories:

University of Valencia/CSIC/University of Alicante
: Detector Mechanical Assembly and Integration, Coded Mask Assembly, Science Operation Center (SOC)

CIEMAT: HgI_2 Manufacturing and Testing, Detector Matrix Assembly

INTA: Management, Thermal Control, Integration and Test

RAL: Front End Electronics, High Voltage Unit, Star Sensor

University of Birmingham: Digital Processing Unit, Power Supply Unit

University of Southampton: Electrical Ground Support Equipement

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