

LXeGRIT: The Prototype of a New Gamma Ray Telescope

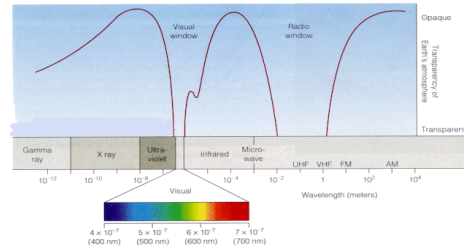
<http://www.astro.columbia.edu/~lxe/lxe-grit/>

Introduction To Gamma-Ray Astronomy

Gamma-Ray Astronomy is a relatively new field of astronomy which has developed during the last few decades. As early as the late 1940s, scientists began to hypothesize that there were processes in the universe that would create these high energy waves. It was not until the 1960's that they developed adequate technology to detect them. Since the first γ -ray detection by the Explorer XI Satellite in 1961, which detected fewer than 100 cosmic γ -ray photons, the technology has developed significantly. Although γ -rays can pass through most materials, cosmic γ -rays are absorbed by the Earth's atmosphere. Therefore all γ -ray detectors must be brought to a level above most of the atmosphere for meaningful measurements, either on satellites or, as in the case of LXeGRIT, on balloons.

Gamma-Rays are electromagnetic waves with energies greater than about 100 keV, or wavelengths 100,000 or a million times shorter than optical light. They are the most energetic type of light wave. Gamma-rays are created by many important processes that occur in the universe, e.g., radioactive decay, deceleration of ultra-fast electrons, or interactions of cosmic rays with interstellar gas. They reveal the physics of supernovae and very compact objects such as neutron stars and stellar black holes, or giant black holes in the centers of active galaxies. They provide important clues on how the chemical elements are being formed through stars, and have puzzled scientists with energetic flashes, so-called Gamma-Ray Bursts, which are the most energetic celestial events we know. To study these topics, we have to create maps of the γ -ray sky, and measure the 'colors' and changeability of its sources.

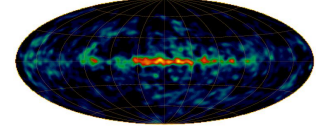
Transparency of the Earth's Atmosphere



This figure illustrates the varying opacity of the Earth's atmosphere, depending on the light's energy, or wavelength. While the atmosphere is transparent in some important windows, especially in the optical regime and at radio wavelengths, it blocks out most other wavelengths of light. Gamma-rays can therefore only be measured from the top of the atmosphere, where only balloons and satellites can reach.

THE GAMMA-RAY SKY

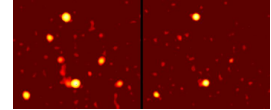
The Radioactive Sky



ABOVE: Map of radioactive Aluminum-26 in the Milky Way. This radionuclide marks the sites of current star formation in our galaxy.

BELOW: Gamma-Ray sources can also fluctuate greatly in short periods of time. The pictures below are of the same γ -ray sources at the Galactic Center, taken at different times to illustrate the large variations.

The Ever-Changing Sky



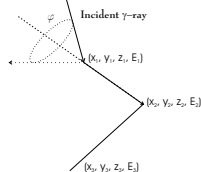
LXeGRIT: Liquid Xenon Gamma Ray Imaging Telescope

At the heart of LXeGRIT is a sophisticated γ -ray detector filled with liquid xenon, called Liquid Xenon Time Projection Chamber or LXeTPC. Xenon is the heaviest stable noble gas, and in its liquid form, it is very dense. As a result, it is well suited to stop the penetrating γ -rays, which lose their energy mainly through the Compton scattering process, before being absorbed. Each interaction in the liquid generates an electric charge cloud and a flash of scintillating ultraviolet light. The LXeTPC gathers both light and charges, to accurately measure the locations and energy losses of each interaction. Combining all information, we can generate a map of the γ -ray sky and determine its γ -ray 'colors'. How this is done in detail, is explained in the following.

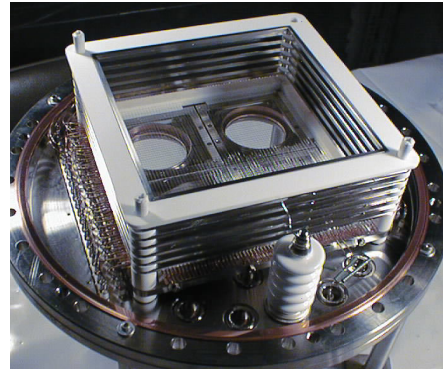
Compton Scattering:

As the γ -ray travels through the liquid xenon, it collides with an electron at a position (X_1, Y_1, Z_1) and transfers some energy E_1 . Usually, a γ -ray undergoes several scatterings before eventual absorption. From the positions of the first two scatterings and from the energy deposits, which determine the angle ϕ by which the γ -ray was deflected, one can reconstruct a circle of possible source locations. Several γ -rays from the same celestial source

describe different circles, which all intersect in one point - the source location.

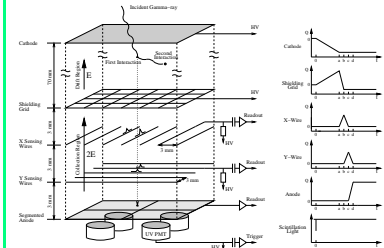


The Time Projection Chamber



ABOVE: The LXeTPC seen from the top, with the cathode removed to allow for viewing the inside of the chamber.

Measurement Principle



- An incoming γ -ray enters the detector and loses its energy in multiple steps of Compton scattering and is then photoabsorbed.
- Light created by the γ -ray's loss of energy is detected by Ultraviolet Photomultiplier Tubes (UV PMTs) at the bottom of the detector. Because the photons travel at the speed of light, this information is used to determine the time of the interaction.
- In each interaction, the fast primary electron generates a dense cloud of secondary electrons, which drift downwards in the detector until they pass through wire grids which determine the X-Y-coordinates. The drift time with respect to the light signal provides the Z-coordinate.
- The energy is measured on a segmented anode at the bottom, where the charges are collected.

The LXeGRIT Team at Columbia

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University of New Hampshire, Durham, USA
INFN - University of Padua, Italy

October 2000 Flight

On October 4, 2000, the LXeGRIT payload was launched from Ft. Sumner, New Mexico. The balloon stayed afloat for 26.5 hours until it landed about an hour outside of Phoenix, AZ. While data were recorded from all sources that passed through the instrument's large field-of-view within about 45° from the zenith, the Crab Nebula was the main focus of this flight.

The Crab Nebula in optical light



The Detector on the Balloon Gondola



The Payload Ready to be Launched

