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THE GAMMA-RAY OBSERVATORY: AN OVERVIEW

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ABSTRACT

The Gamma-Ray Observatory (GRO) is a 16,000 kg spacecraft containing four instruments which span almost six decades of energy from about 50 KeV to about 30 GeV. It will provide the first opportunity to make simultaneous observations over such a broad band of gamma-ray energies. GRO is assembled and undergoing testing prior to its scheduled June 4, 1990 launch aboard the Space Shuttle. The orbit will be circular with an altitude of 450 km and with an inclination of 28 degrees. Data will be recorded at 32 kilobits per second and dumped once per orbit via the Tracking and Data Relay Satellite System (TDRSS). The spacecraft is three-axis stabilized and timing will be maintained to .1 ms. The Observing schedule will begin with an all sky survey, consisting of 30 two week pointings, covering the first 15 months of science operations. Following observations will emphasize source studies and deep searches. Originally selected as a Principal Class spacecraft with a two year mission, extension of the mission to six to ten years makes a vigorous Guest Investigator Program both possible and desirable. Such a program will be fully in place by the third year of the mission, with limited opportunities earlier. Each of the four instruments has a capability for observing both gamma-ray bursts and solar flare gamma-rays, and there is some solar neutron capability. Correlated observations with those at other wavelengths is also receiving considerable attention in the mission planning.

INTRODUCTION

The Gamma-Ray Observatory (GRO) was announced in 1977 as an opportunity for gamma-ray experiments to be included on a free-flying observatory to be launched aboard the space shuttle. The mission was planned as a 3-axis stabilized platform containing four instruments with a planned two year lifetime on orbit. A 1983 launch was anticipated. GRO was envisioned to be the first of a series of five astrophysical missions emphasizing gamma-ray astronomy, x-ray astronomy and cosmic-ray astrophysics.

The GRO is a 16,000 kg spacecraft (Figure 1) which provides an oriented platform for a complement of four instruments to make observations of the gamma-ray sky spanning 6 decades of energy, from 30 KeV to 30 MeV (Figure 2). The very wide dynamic range requires the use of different instruments with a number of detection techniques. Specifics of the instrument capabilities, especially with regard to solar flare observations, will be given in separate papers in later sessions.

The Z-axis of the spacecraft may be pointed to any region of the sky at any time. However, once chosen, the X-axis must be selected to satisfy sun angle constraints which affect the power from the solar panels and the thermal environment of various spacecraft components.

As GRO developed, it became clear that the science return could be significantly enhanced by extending the duration of orbital operations. By the time such an option was considered, the development of the instruments had already begun , and the design of the spacecraft was underway. Studies showed that the only consumable quantity preventing a lifetime of from six to ten years, without major changes to the design and some existing hardware, was the propellant gas required to maintain the operational orbit in the face of atmospheric drag. A decision was made to provide GRO with a dedicated launch so that it could be taken directly to its operational altitude of 450 kilometers at the beginning of the mission. This provides sufficient fuel savings to allow the orbit to be maintained between 440 and 450 kilometers for up to ten years.

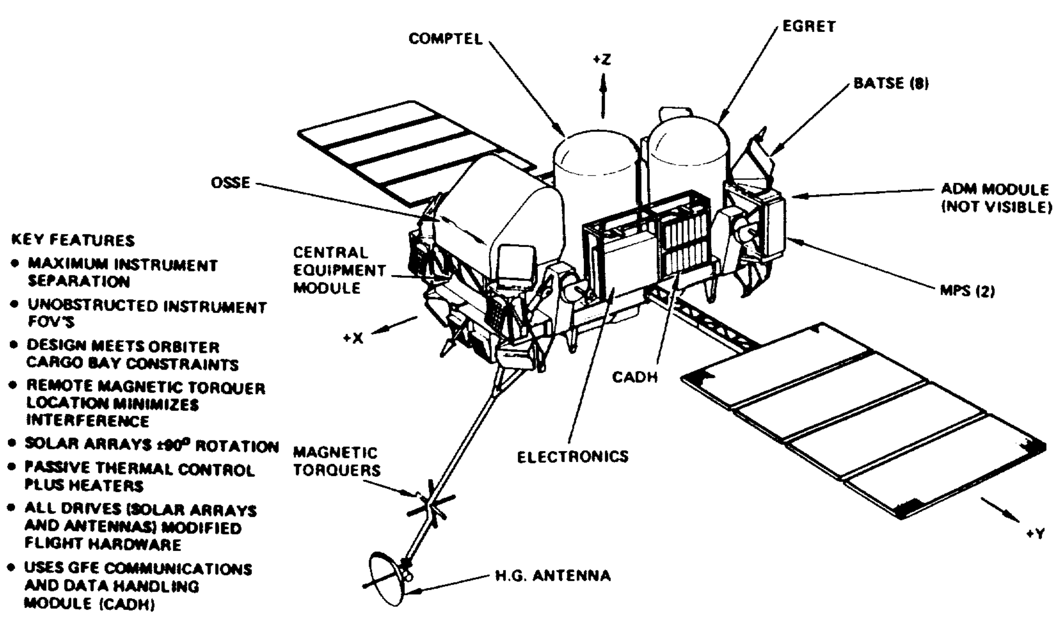


Figure 1. The Gamma-Ray Observatory

The extension of the mission lifetime not only makes it possible, but indeed very desirable to expand the scientific involvement beyond the original Principal Investigators (PIs) and their Co-Investigators. This not only spreads the access to the data and observing opportunities, but it also enhances the scientific return by the infusion of ideas from a broader community. However, since the data analysis systems were designed for a PI class mode of operation, a program to involve those from outside the PI teams must be done in a manner that carefully considers the difficulties in analyzing and interpreting the data, with care to ensure that reliable results are obtained. The program must at the same time provide access to the data for qualified researchers. In this paper, I will briefly describe the mission, the Guest Investigator Program and the organizational structure that is planned to manage the Project during the operations and to implement the Guest Investigator Program.

THE GAMMA-RAY OBSERVATORY MISSION

The Gamma-Ray Observatory is now totally integrated and is under-

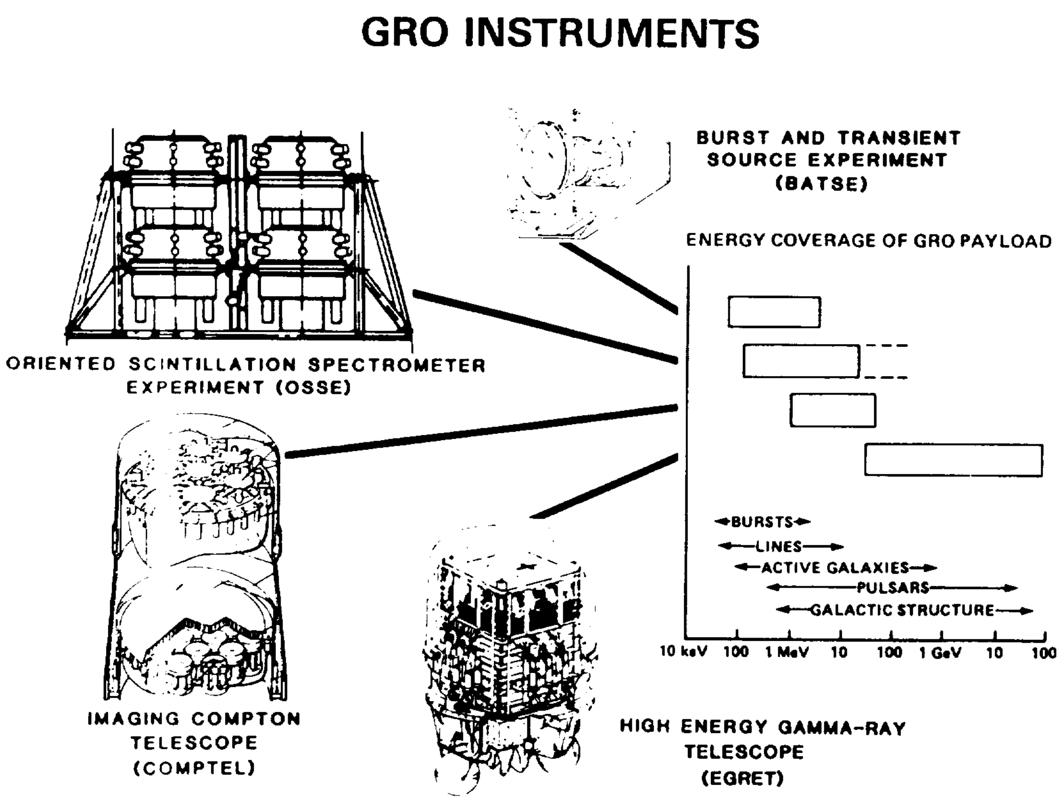


Figure 2. Energy Coverage of the GRO Experiments

going Observatory environmental testing at the Mission Contractor facility. GRO is scheduled for launch in June 1990. GRO will be carried directly to its operational altitude of 450 km. Although the orbital altitude is degraded by atmospheric drag, it will be maintained between 440 and 450 km (Figure 3) by the on-board propulsion system. At the end of the mission the spacecraft will either be retrieved by the Space Shuttle, or will receive a controlled reentry, using the propulsion system .

During the orbit operations data will be recorded at a 32 kilobit per second data rate, and these data will be telemetered via the Tracking and Data Relay Satellite (TDRS) once every two orbits at a 512 kilobit rate. Uplink commanding of both the experiments and the spacecraft will also be sent during these TDRS contacts. The mission operations profile is indicated in Figure 4. The Control Center will be at the Goddard Space Flight Center. Data will be received in packetized form with all ancillary information required to analyze the data already inserted on board the spacecraft. Time ordering, overlap elimination and quality checks will be done on ground before the data are forwarded, within 48 hours of receipt, to the experiment data analysis facility sites.

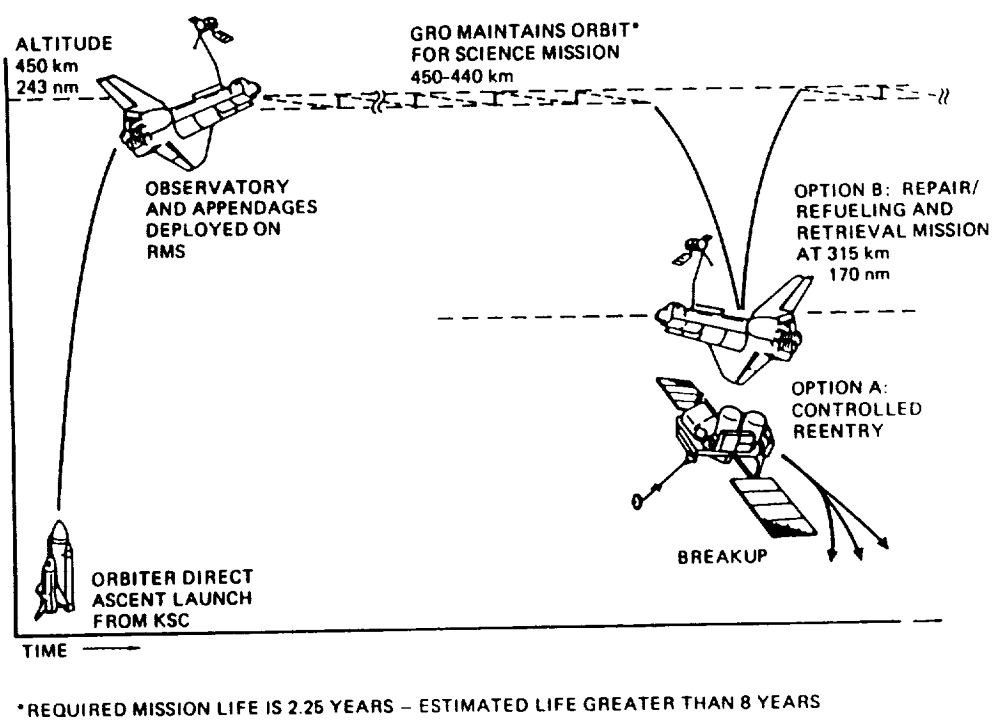


Figure 3. The GRO Mission Profile

The viewing program for the first 15 months will consist of a nearly-uniform full sky survey of two weeks exposures for the two wide field instruments (EGRET and COMPTEL). The narrow aperture instrument (OSSE) will select 30 primary and secondary targets for discrete source studies during this 15 month period, and, of course, the burst instrument (BATSE) covers the entire unocculted sky at all times. The viewing program will be discussed in detail in a later paper.

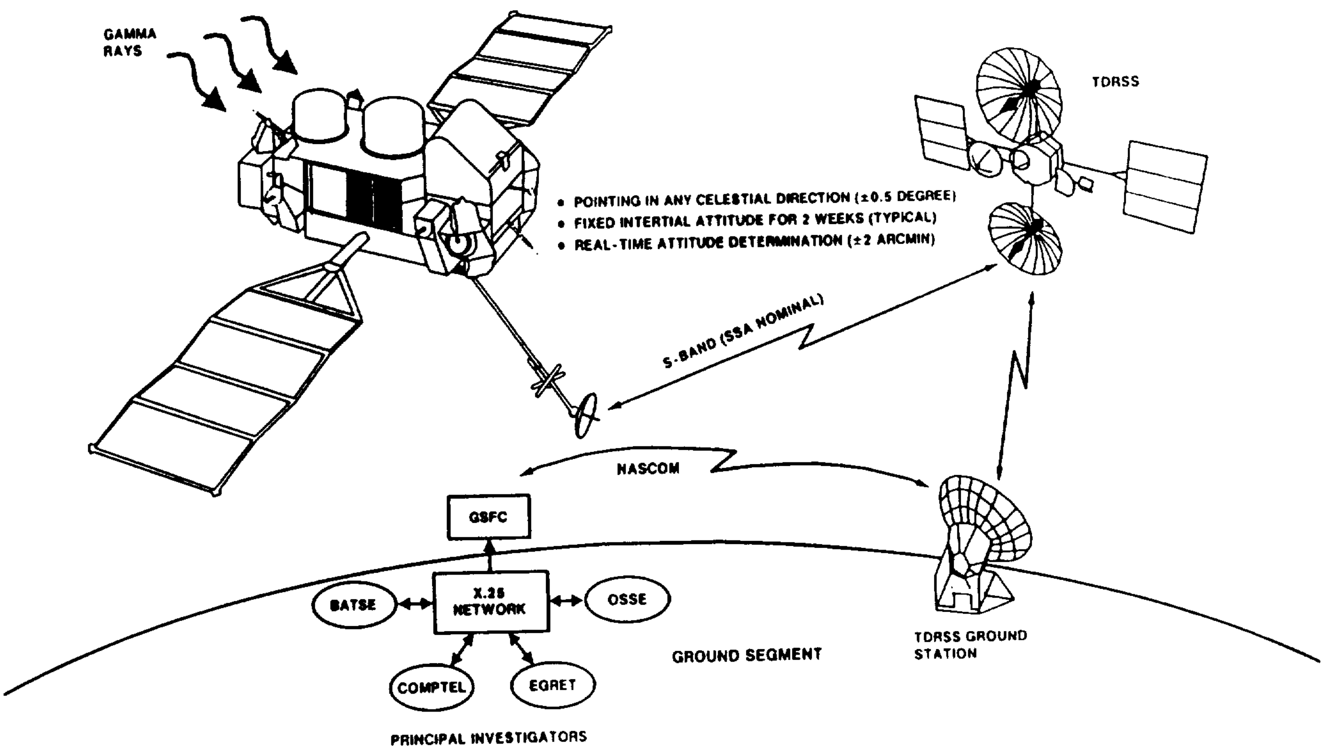


Figure 4. GRO Mission Operations

THE GUEST INVESTIGATOR PROGRAM

As discussed above, the extended GRO mission presents an opportunity for expanded participation beyond that of the Principal Investigators and their Co-Investigator teams. Recognizing the value of increasing the involvement of the broader scientific community NASA plans to implement a vigorous GRO Guest Investigator Program, which will be phased in starting in the first year of the mission, and reaching the full level in the fourth year of the mission when Guest Investigators will have access to about half of the viewing time.

NASA is planning to release a NASA Research Announcement for the first phase of the Guest Investigator Program later this year. This phase will involve limited opportunities with two of the GRO Instruments. In the second phase, opportunities will include about 30 percent of the viewing time, and the opportunity to work with data a various levels of processing as the proposer desires. The Investigator will be able to visit one of the GRO PI institutions and work for an extended period of time with the PI teams, or he can choose to work independently with higher level archival data products. There will also be opportunities for coordinated observations and for theoretical studies related to GRO.

THE SCIENCE SUPPORT CENTER

The central point of contact for Guest Investigator support will be the GRO Science Support Center, located on-site within the Laboratory for High Energy Astrophysics at the Goddard Space Flight Center. The Center will be a source of information for potential users at all stages of their involvement, from the preproposal stage, through the analysis phase. The Center will provide information on the availability and timing of opportunities, and give technical support in the implementation of the contract with the Guest Investigator.

The Science Support Center will be a source for technical information on the GRO instruments, for scientific and technical information on the GRO spacecraft and mission, for catalogs of data on GRO and other astrophysics and astronomy observations, for the status of GRO observations, for availability of useful analysis software, and other such information of use for GRO investigations.

The Center will come under the GRO Project Scientist, and will provide support to him and the Assistant Project Scientist in promoting the greatest possible scientific return from the mission. The Chief Scientist will also act as a science spokesman for GRO.

THE SCIENTIFIC OUTLOOK FOR GRO

The Scientific Objectives of the Gamma-Ray Observatory are:

A study of discrete objects such as black holes, neutron stars, and objects emitting only at gamma-ray energies.

A search for evidence of nucleosynthesis - the fundamental process in nature for building up the heavy elements and other gamma-ray lines emitted in astrophysical processes.

The exploration of the Galaxy in gamma rays to study the origin and dynamic pressure effects of the cosmic-ray gas and the structural features revealed through the interaction of the cosmic rays with the interstellar medium.

A study of the nature of other galaxies as seen at gamma-ray wavelengths, with special emphasis on radio galaxies, Seyfert galaxies, and quasi-stellar objects.

A search for cosmological effects through observations of the diffuse gamma radiation and for the possible primordial black-hole emission.

Observation of gamma-rays bursts, their luminosity distribution, the spectral and temporal characteristics, and their spatial distribution.

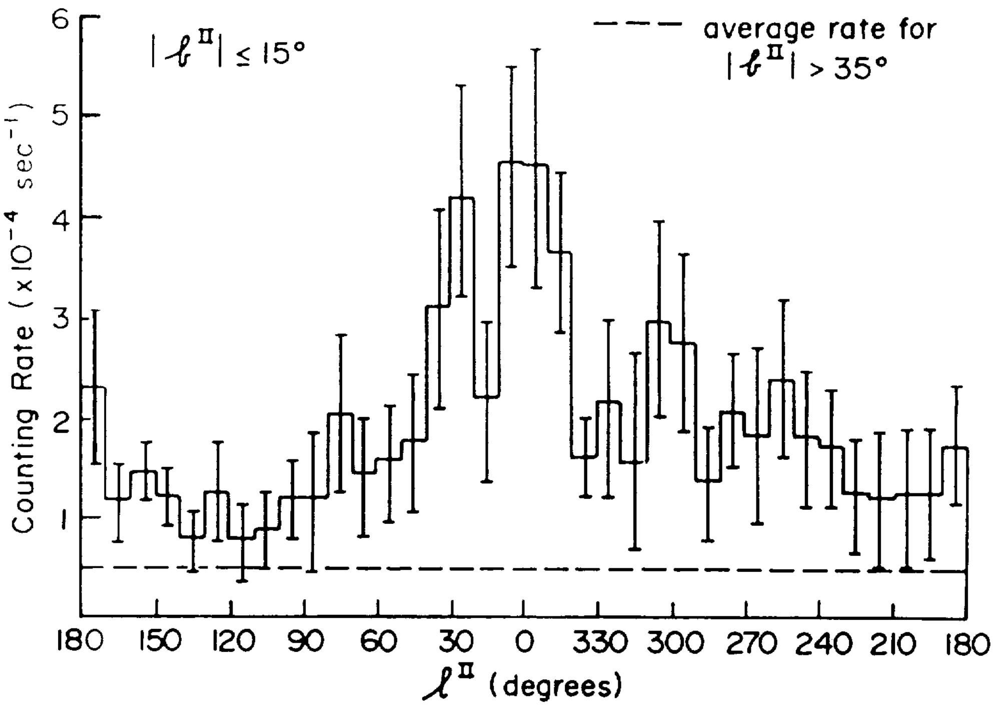
These objectives cover a very wide range of outstanding problems in astrophysics, from local sources to extragalactic sources of both localized and extended emissions, involving the most massive and dynamic objects and most energetic astrophysical processes known. The relative immaturity of observations at these wavelengths makes the potential for new knowledge commensurate with the large increase in observing capability.

GRO represents a great step in sensitivity, over and order of magnitude improvement over previous observations, and with much greater exposure to the entire celestial sphere. There is a hope for a mission lifetime greater than any previous gamma-ray mission, and great improvements in angular resolution will be made across the spectrum. Coordinated Observations , already planned by observers at many other wavelengths, will bring the very great advantages of synergism to all of the observations. So, in this context of great expectations, let us revisit the historical record for a moment.

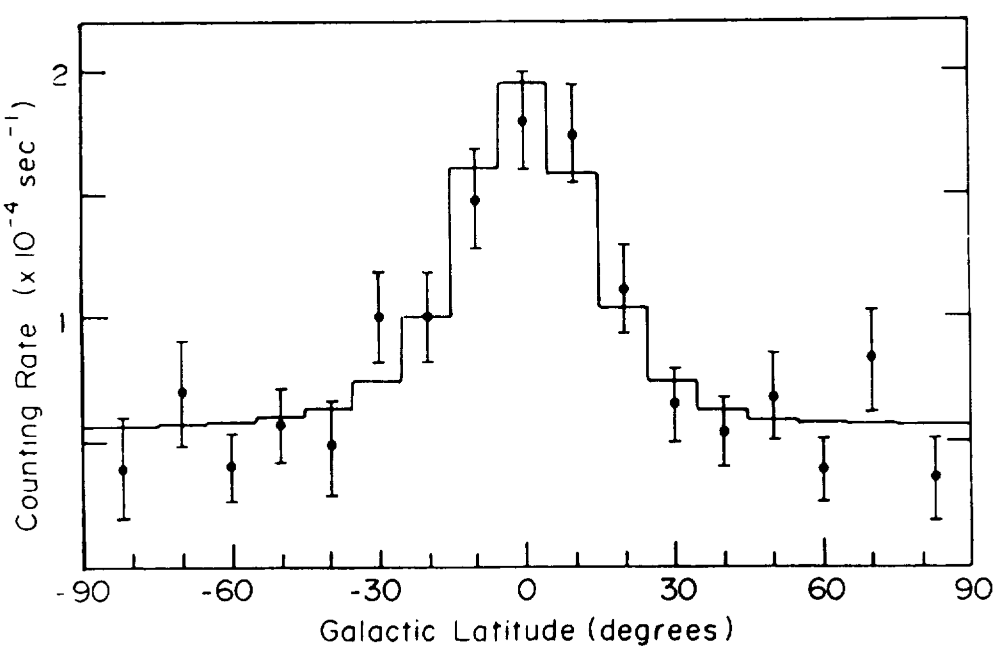
The first great milestone of observational gamma-ray astronomy occurred in 1968 with the launch of the OSO-3 satellite with gamma-ray spectrometer experiment of Kraushaar et al. (1972). This pioneering experiment gave us the first unambiguous observation of the diffuse gamma-ray emission from the plane of our galaxy. As shown in Figure 5, both the observed longitude and latitude distributions gave clear indications of this dominating feature of the gamma-ray sky. Although the angular resolution of the instrument was limited, the emission was clearly resolved in longitude. The discrete source contribution, if any, could not be discerned, but it was concluded that a major portion of the observed emission resulted from the decay of neutral pions resulting from the interaction of galactic cosmic rays with the interstellar gas.

Observations with much better resolution followed with the spark chamber instruments flown aboard SAS-2 (Fichtel, et al.,1975) and COS-B (Mayer-Hasselwander, et al., 1982) (Figure 6). Now clear evidence for many local variations in the central galactic enhancement can be seen, some due to known discrete sources, some to as yet identified local excesses. These may be additional point sources, or indications of localized enhancements in matter, cosmic rays, or both. Better resolution and sensitivity is required to resolve these questions, and the GRO observations will provide this. However, the most significant conclusion of the comparison of the OSO-3 and COS-B figures is the significant improvement in the detail of our knowledge of the emission from such regions that comes with major increases in observational capability. While COS-B represented increase in effective area of about a factor of five compared to OSO-3, the GRO EGRET instrument provides almost a factor of 40 increase over COS-B. Improvements in spatial and spectral resolution and dynamic range are equally dramatic. Considering the improvement in detail COS-B provided, the implications for GRO on this and other observations are enormous.

The GRO instrument and science contributions will expand on these points., and so it is only redundant to discuss them further here. The program before us looks very exciting. Those of us who have been involved in the difficult task of building the instruments look forward to hearing the many ideas the community will present on ways to maximize the return on these long and intense efforts. We all look forward to a very stimulating Workshop, and an even more stimulating involvement of astronomy and astrophysics community in the most exciting opportunities that the Gamma-Ray Observatory will provide for all.



(a)



(b)

Figure 5. OSO-3 Longitude (a) and Latitude (b) Distributions of the Galactic Diffuse Gamma-Ray Emission above 100 MeV. (Mayer-Hasselwander, et al., 1982)

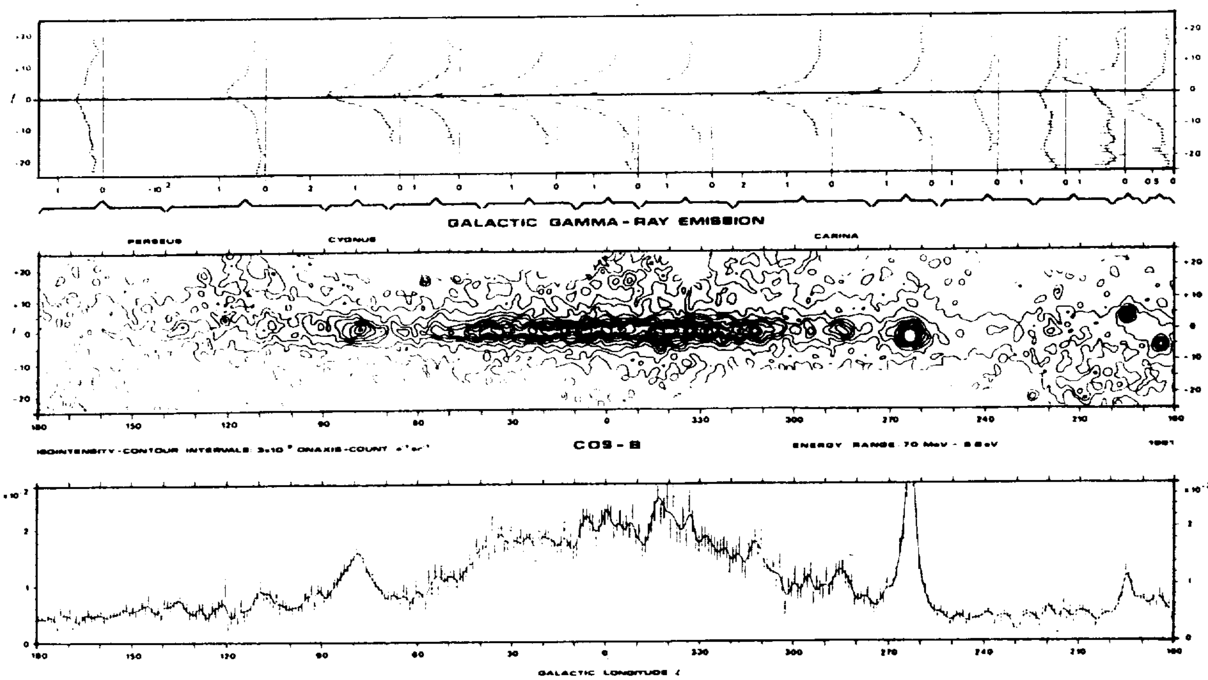


Figure 7. The COS-B Latitude (Top) and Longitude (bottom) distributions and contour plot of the diffuse galactic gamma-ray emission above 70 MeV.

Each of the GRO instruments has a capability for observing solar flare gamma-rays and neutrons, spanning the full range of energies for GRO. The capabilities include good sensitivity and time resolution and good energy resolution throughout the entire spectrum. These capabilities will be discussed in detail in later sessions, but perhaps the most important thing to point out here is that GRO has the capability to point to any region of the sky with the full instrument complement within a few hours. Furthermore the BATSE instrument will provide continuous observations of the Sun for transient events when it is not occulted by the Earth, and with proper advanced planning, the OSSE instrument can be oriented in the spacecraft X-Z plane to view the Sun within three hours.

The great increase in observing capability offered by GRO provides the opportunity for it to be one of NASA's most exciting and productive missions. Our knowledge in all areas of gamma-ray astrophysics will be greatly increased. Our study of the gamma-ray emission from solar flares should teach us much about the process of production, acceleration, storage and propagation of particles in solar flares.

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