# HIGHLIGHTS FROM THE GAMMA RAY OBSERVATORY MISSION

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**ABSTRACT.** The Gamma Ray Observatory was launched on April 7, 1991 for a mission expected to last several years. Its four instruments are designed to study gamma ray emission over a wide energy regime from 0.02 to over 30,000 MeV. Following a brief description of the capabilities of each instrument and their status, the viewing program and is discussed, and some very early results are presented.

## 1. Introduction

The Gamma Ray Observatory (GRO) is the second in a set of four 'Great Observatories' planned by NASA. It was launched by the Shuttle Atlantis on April 7, 1991, and after a period of activation and testing, scientific observations were begun on May 12, 1991. The propulsion system is capable of maintaining the orbit for over 13 years, and it is expected that useful observations will be continued for several years.

At this early stage, the few results that are available are quite preliminary. The instrument teams are still involved in analyses to verify the instrument response functions and analysis software systems. This report will include some of these preliminary, as yet unpublished results, following a brief discussion of the observatory and instrument capabilities and an outline of the viewing program in the next 15 months.

## 2.0 Description of the Gamma Ray Observatory

The Observatory, shown in Figure 1, contains a set of four instruments that designed to study gamma ray emission over a broad energy range from 50 keV to 30 GeV. The Observatory provides electrical power, command and data handling services, timing, orbit maintenance, and stabilized to the instruments. Information on position to within 30 Km, and aspect to within 2 arcmin are a part of each instrument. Event timing to an absolute accuracy of 100 micros is furnished by the spacecraft. For more detailed descriptions of the observatory, the instruments, the data analysis systems, and the expect scientific investigations, see reference 1.

The Burst and Transient Source Experiment, BATSE, is comprised of eight modules that together view the entire sky. This instrument is designed to measure burst time profiles and energy spectra of gamma ray transients in the energy interval from 20 keV to 20 MeV for transients as short as 0.2 msec. The modules are arranged at the four upper and four lower corners of the platform and together they form an regular octahedron. Since each module views a full hemisphere, a burst is detected in four of the modules, and the relative arrival times can locate the source direction to within 5 to 10 degrees. BATSE provides a burst signal to the other instruments that permits them to initiate special burst modes of operations.



*J. Bergeron (ed.), Highlights of Astronomy, Vol. 9,* 255–259.

The Oriented Scintillation Spectrometer Experiment (OSSE) is sensitive to gamma rays from 50 keV to 10 MeV and has a second mode covering 20 MeV to 150 MeV. The detectors are shielded NaI, CsI phoswich with an energy resolution of 4 to 8% depending on energy. Each of its four modules has a passive collimator of 5 x 11 degrees. The modules can be oriented through an angle of 192 degrees in the X-Z plane in Fig. 1. Generally, two detectors are viewing a source while the other two are sampling nearby background. The ability to orient gives OSSE the flexibility to view alternate targets when the earth is occulting the pointing axis direction.

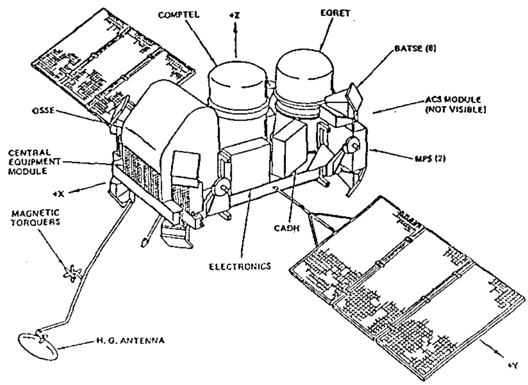


Figure 1. The Gamma Ray Observatory

The Compton Telescope (COMPTEL) detects gamma rays by two Compton scattering interactions. COMPTEL covers the energy range from 1 to 30 MeV with a wide field of view of over 40 degrees half angle. It has an energy resolution of 5 to 8% for each photon, and can image a source to within 0.1 to 0.5 degrees depending on its intensity and the duration of the exposure. Based on pulse-height analysis, COMPTEL can also detect neutron events, and its NaI crystals and large anticoincidence counters are useful in studying burst time profiles and monitoring rates for transients.

The Energetic Gamma Ray Experiment Telescope (EGRET) detects gamma rays using the pair production process in a spark chamber to image each event. EGRET is sensitive to gamma rays from 20 to 30,000 MeV within a large field of view of half angle 35 degrees. A NaI crystal is used to absorb the event and provide a measure of the energy with a resolution of about 18%. Sources of gamma rays are imaged to within 0.2 to 0.5 degrees depending on intensity for a typical 2 week exposure. The NaI is also used to provide spectra of bursts and solar flares. The NaI crystal and the large anticoincidence dome provide time profiles of rates at a variety of energy thresholds.

### 3.0 The Viewing Program

During the first 15 months (Phase I), COMPTEL and EGRET will perform an all-sky survey in 33 viewing periods of 14 days each. The survey will catalog interesting sources for further study in subsequent years, and will be used to map the diffuse galactic and extra-galactic gamma ray emissions. At the same time, OSSE will undertake observations on a large number of target sources. Targets of Opportunity may interrupt the planned program in which case it will be completed in the following phase. The program was interrupted already in period 2 to view the Sun during it unusually activity in early June. Beyond Phase I, the viewing plan will focus on interesting targets discovered in Phase I, especially those that may be time varying, and there will be longer duration exposures to weak sources of interest. The Phase I viewing plan is given in Table I.

### 4.0 Present Status and Preliminary Results

The BATSE instrument (ref. 2) reports that 75 cosmic bursts have been detected in the first 77 days. An additional 123 bursts triggered by solar flares with photons above 60 keV were also observed. On July 11, 1991, a cosmic burst with duration of only 10 milliseconds was observed. This is believed to be the shortest burst ever recorded. The data from 5 detectors indicate a point source in the direction of the constellation Hydra. The instrument is operating well.

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OSSE (ref. 3) has determined that the background is close to what was expected, and that it can operate close to a 50 keV threshold. The Crab nebula and pulsar, and a 1.6 msec pulsar, 1957+21, were observed. During viewing period 2 when the solar activity was high, OSSE detected emission in 4 flares. In two of these, the detectors were pointed to the Sun following a trigger signal from BATSE. Nuclear line emissions including lines at 2.23 MeV from neutron capture, lines at 4.4 and 6.1 MeV associated with carbon and oxygen, and positron annihilation were seen. Supernova 1991T in Virgo was observed in period 2 in an effort to detect Cobalt-56, and a search for Cobalt-57 in supernova 1987A will be made in period 6. The galactic center region will be searched for evidence of positron annihilation in periods 4 and 5.

Table I. The GRO Phase I Viewing Plan

| Nbr | Target | Start Date | Galactic Coordinates Z-Long. | Z-Lat. | X-Long. | X-Lat |
|---|---|---|---|---|---|---|
| 1 | CRAB PULSAR | 16-MAY-1991 | 190.92 | -4.74 | 100.06 | -10.31 |
| 2A | CYG X-1 | 30-MAY-1991 | 73.28 | +2.56 | 162.60 | -14.79 |
| 2B | SUN | 08-JUN-1991 | 194.87 | -7.29 | 104.63 | -1.91 |
| 3 | SN 1991 T | 15-JUN-1991 | 299.76 | +65.46 | 211.38 | -0.74 |
| 4 | NGC 4151 | 28-JUN-1991 | 156.19 | +72.08 | 161.97 | -17.84 |
| 5 | G CENTER 0+0 | 12-JUL-1991 | 0.00 | -4.00 | 0.00 | +86.00 |
| 6 | SN 1987 A | 25-JUL-1991 | 278.00 | -29.32 | 229.73 | +49.85 |
| 7 | GAL 025-14 | 08-AUG-1991 | 25.00 | -14.00 | 25.00 | +76.00 |
| 8 | VELA PULSAR | 22-AUG-1991 | 262.94 | -5.67 | 328.85 | +76.33 |
| 9 | HER X-1 | 05-SEP-1991 | 59.67 | +40.28 | 205.41 | +44.29 |
| 10 | FAIRALL 9 | 19-SEP-1991 | 294.32 | -54.85 | 284.89 | +34.79 |
| 11 | 3C 273 | 03-OCT-1991 | 294.25 | +63.67 | 4.35 | -9.56 |
| 12 | CEN A | 17-OCT-1991 | 310.71 | +22.21 | 84.25 | +59.34 |
| 13 | GAL 335-83 | 31-OCT-1991 | 335.00 | -83.50 | 335.00 | +6.50 |
| 14 | ETA CAR | 14-NOV-1991 | 285.04 | -0.74 | 15.03 | +0.20 |
| 15 | NGC 1275 | 28-NOV-1991 | 152.63 | -13.44 | 63.78 | +4.80 |
| 16 | SCO X-1 | 12-DEC-1991 | 0.00 | +20.29 | 0.00 | -69.71 |
| 17 | SN 1987 A | 26-DEC-1991 | 283.21 | -31.62 | 9.52 | +5.97 |
| 18 | M 82 | 09-JAN-1992 | 137.47 | +40.48 | 49.35 | -2.20 |
| 19 | GAL 058-43 | 23-JAN-1992 | 58.15 | -43.00 | 58.15 | +47.00 |
| 20 | SS 433 | 06-FEB-1992 | 39.70 | +0.76 | 39.70 | -89.24 |
| 21 | NGC 1068 | 20-FEB-1992 | 171.52 | -53.90 | 4.38 | -35.41 |
| 22 | MRK 279 | 05-MAR-1992 | 115.35 | +44.88 | 123.69 | -44.81 |
| 23 | CIR X-1 | 19-MAR-1992 | 322.14 | +3.01 | 322.14 | -86.98 |
| 24 | MRK 335 | 02-APR-1992 | 108.77 | -41.42 | 238.48 | -35.91 |
| 25 | GAL 009+57 | 16-APR-1992 | 9.53 | +57.15 | 118.41 | +11.80 |
| 26 | MCG +8-11-11 | 30-APR-1992 | 164.06 | +7.90 | 85.92 | -55.96 |
| 27 | GAL 224-40 | 14-MAY-1992 | 224.00 | -40.00 | 139.44 | +6.45 |
| 28 | CAS A | 28-MAY-1992 | 108.75 | -2.37 | 198.56 | +4.42 |
| 29 | NGC 2992 | 11-JUN-1992 | 252.41 | +30.65 | 183.98 | -31.81 |
| 30 | ESO 141-55 | 25-JUN-1992 | 335.10 | -25.56 | 255.63 | +20.92 |
| 31 | GAL 225+02 | 09-JUL-1992 | 225.46 | +1.95 | 323.60 | +76.50 |
| 32 | PKS 2155-304 | 23-JUL-1992 | 13.11 | -53.32 | 267.65 | -11.23 |
| 33 | MCG +5-23-16 | 06-AUG-1992 | 196.66 | +45.66 | 299.00 | +11.80 |

The COMPTEL instrument (ref. 4) is performing very well. All background rejection techniques are working properly, and the background is close to the predicted values. The Crab is evident in the image of the anti-center galactic region, and its intensity is consistent with expectations.
The pulsar light curve was measured with unprecedented time resolution. Two gamma ray bursts and two solar flares have been imaged in the instrument.

The EGRET instrument image of the anti-center region shows two distinct sources, the Crab and Geminga. Figure 2 is a counts map of the region for events above 100 MeV. The location of these sources is consistent with the know position in the case of the Crab, and with the COS-B location (ref. 5) in the case of Geminga. These two sources have significantly different energy spectra as is evident in the contour maps shown in Fig. 4. At low energies, below 100 MeV, the Crab is clearly seen while Geminga is almost absent while at high energies above 1000 MeV Geminga is dominant.

Light curves from the Crab and Vela pulsars are shown in Fig. 3 for energies above 100 MeV. Both sources have a similar features with a sharp main pulse, and a second, broader pulse. The background can be judged from counts near the end-points of the phase interval. The Crab is in a low background region of the plane, and the background in Fig. 3 is seen to be very low. The inter-pulse structure for the Crab is significant. Vela is in a higher background region, and in this case, the interpulse intensity appears to be consistent with background levels.

EGRET has observed bursts triggered by the BATSE detector, in particular, the May 3 event where spectra in time intervals of 1, 2, and 4 seconds of accumulation show gamma rays to over 100 MeV. Solar flare spectra have been obtained in during the period of high activity in early June.

EGRET observed a very significant emission of gamma rays from the quasar 3C279. The emission extends to high energies with a relatively hard spectrum (ref. 7).

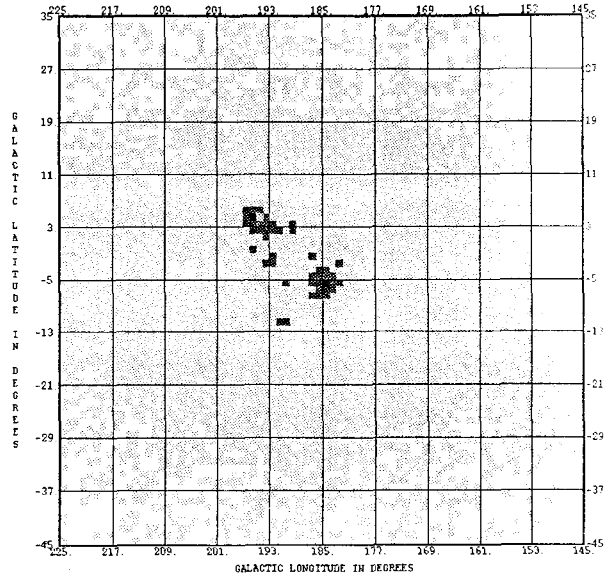


Fig. 2. Gamma Ray Counts map of the Galactic anti-center region for energies above 100 MeV. The Crab is the source in the middle and Geminga is at the upper left. The grid is 8x8 degrees.

## 5.0 Summary

The instruments on the Gamma Ray Observatory are all functioning well. Preliminary findings suggest that a large number of very significant results will be forthcoming. A wide range of scientific studies including the nature and distribution of gamma ray bursts, the nature of high energy gamma ray galactic and extragalactic sources, the character of the diffuse galactic and extragalactic emission, pulsars are among some of the topics will be advanced from the observations.

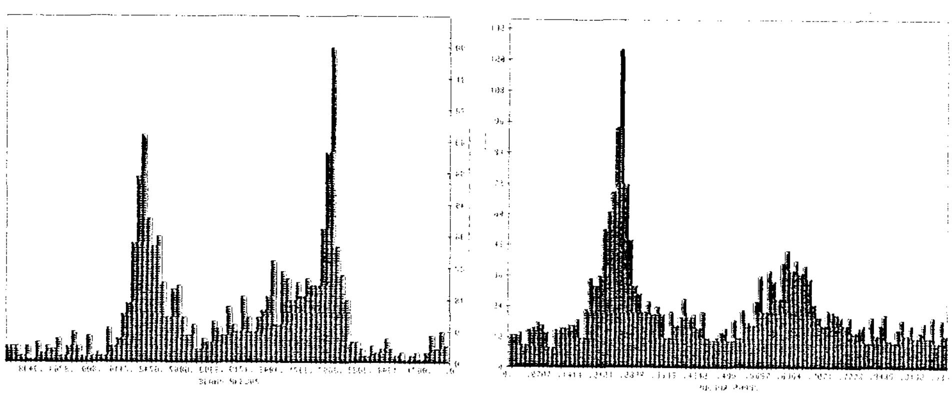

Fig. 3. Phase plots for the Crab (left) and Vela (right) pulsars for energies above 100 MeV. The phase here relative to the radio phase is arbitrary. For the Crab each bin is 300 micros while for Vela, the bins are 1 ms.

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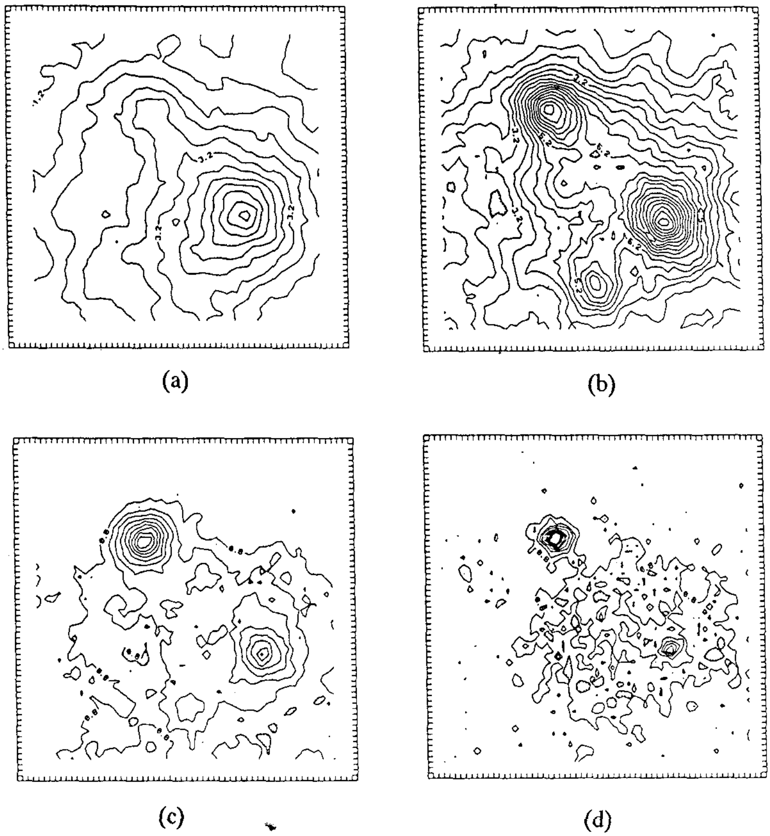


Fig. 4 Contour plots of gamma ray counts for the Galactic anti-center region in four energy intervals as follows: (a) 50 to 100 MeV, (b) 100 to 300 MeV, (c) 300 to 500 MeV, and (d) above 1000 MeV. Each map covers a 30x30 degree interval. The Crab is to the lower right, and Geminga to the upper left. Note that the Crab is stronger at low energies while Geminga dominates at high energies. These plots have not been corrected for instrument response.

**6.0 References**


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