# Artificial Radiation Observed with Ginga Satellite

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**Summary:** The X-ray astronomy satellite Ginga detected radiation of artificial origin with the Gamma-ray Burst Detector (GBD). The transient events of non-cosmic origin appeared in February 1987 when the GBD observations started, and disappeared in June 1988. The typical event consists of the two successive bursts separated by a few min. The burst pair has approximate reflection symmetry; the first burst has a slow rise and a rapid decay, the second has a rapid rise and a slow decay. The geographical distribution of the events and their spectra revealed that they were due to geomagnetically trapped electrons.

Key wards—radiation belt, space reactor, gamma-rays.

## 1. INTRODUCTION

It is well known that energetic particles were injected into radiation belt by the nuclear explosion of July 1962. For upto eight years they produced an enhancement of the trapped electron population of many orders of magnitude (Stassinopoulos, 1989). Short term contaminations of the outer belt were also observed depending on injection latitude and altitude (Stassinopoulos and Verzariu, 1971). The existence of artificial radiation at lower altitude was classified until August of 1988. The gamma-ray detector onboard the Solar Maximum Mission (SMM) satellite has detected bursts of annihilation gamma-rays, bremsstrahlung gamma-rays and electrons since 1982. These events triggered the detection system for cosmic gamma-ray observation. These false bursts saturated the available SMM memory capacity and prevented true cosmic bursts from being recorded.

The GBD aboard the Ginga satellite has also detected similar events which have disturbed cosmic gamma-ray burst observation. Although we have not yet finished our analysis, we present preliminary results on these unusual events.

## 2. X-RAY ASTRONOMY SATELLITE GINGA

The Ginga satellite was launched on February 5th, 1987 from Kagoshima Space Center and injected into an orbit of 505.5 km perigee height, 673.5 km apogee height and 31.1 degree inclination. The total mass of the satellite is 420 kg. The rectangular main body

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measures 1 m × 1 m × 1.5 m. The four deployable solar paddles are 1.7 m long and 0.7 m wide.

Ginga carries three scientific instruments, the Large Area proportional Counters (LAC), All Sky x-ray Monitor (ASM) and Gamma-ray Burst Detector (GBD) (Makino and Astro-C Team, 1987). The LAC is the main instrument. It consists of eight identical proportional counters. The total effective area is 4,000 $cm^2$ and the instrument is sensitive to x-rays from 1.5 keV to 35 keV (Turner et al. 1989). The field of view of the LAC is 1 degree by 2 degrees FWHM. The ASM consists of six Xe-filled proportional counters, each with a separate collimator of 1 degree by 45 degree (FWHM) field of view. The ASM collimators are arranged symmetrically about the z-axis of the spacecraft in six different slant-angle positions (Tsunemi et al. 1989).

The GBD consists of a NaI (Tl) scintillation counter and a Xe-filled proportional counter. The NaI (Tl) scintillator is 8.7 cm in diameter and 1 cm in thickness and detects gamma-rays in the energy range from 20 keV to 400 keV. The effective area of the proportional counter is 63 $cm^2$. It is sensitive to x-rays from 2 keV to 30 keV (Murakami et al. 1989). No collimator is employed for the NaI (Tl) counter or the proportional counter. The signals from the GBD are stored in two memory systems. One is a continuously sampling slow memory and the other is a fast memory triggered by the rise of the burst and is frozen until read out by command from the ground station. Only one burst can be recorded in the fast memory.

## 3. Bursts Of Artificial Origin

The operation of the GBD started on 26 February 1989. The first cosmic gamma-ray burst was detected on 3 March 1989 and was also observed by PVO satellite (Yoshida et al. 1989). However, many mysterious bursts were observed every day beginning with 27 February 1989.

### 3.1 Time Profile

The time profiles of these unusual bursts were clearly different from those of normal cosmic bursts. Most cosmic bursts had multi-peaked irregular time profiles, while these non-cosmic bursts had regular shape. Typical events consisted of two successive bursts as shown in Fig. 1. The first burst rises slowly with an exponential time constant of about 15 s and then falls sharply in 1 s. The second burst is a mirror image of the first burst, in time, with a 1 s rise and a 15 s exponential decay. The interval between bursts of the pair ranged from 1 min. to 5 min.

The coverage of the Ginga was interrupted by the South Atlantic Anomaly (SAA), by earth occultation, and by the limitation of the memory capacity. One of the pair of bursts was sometimes missed due to incomplete coverage. The number of sharp rise bursts was larger than that of sharp fall bursts. We detected 35 burst pairs, 12 sharp fall bursts and

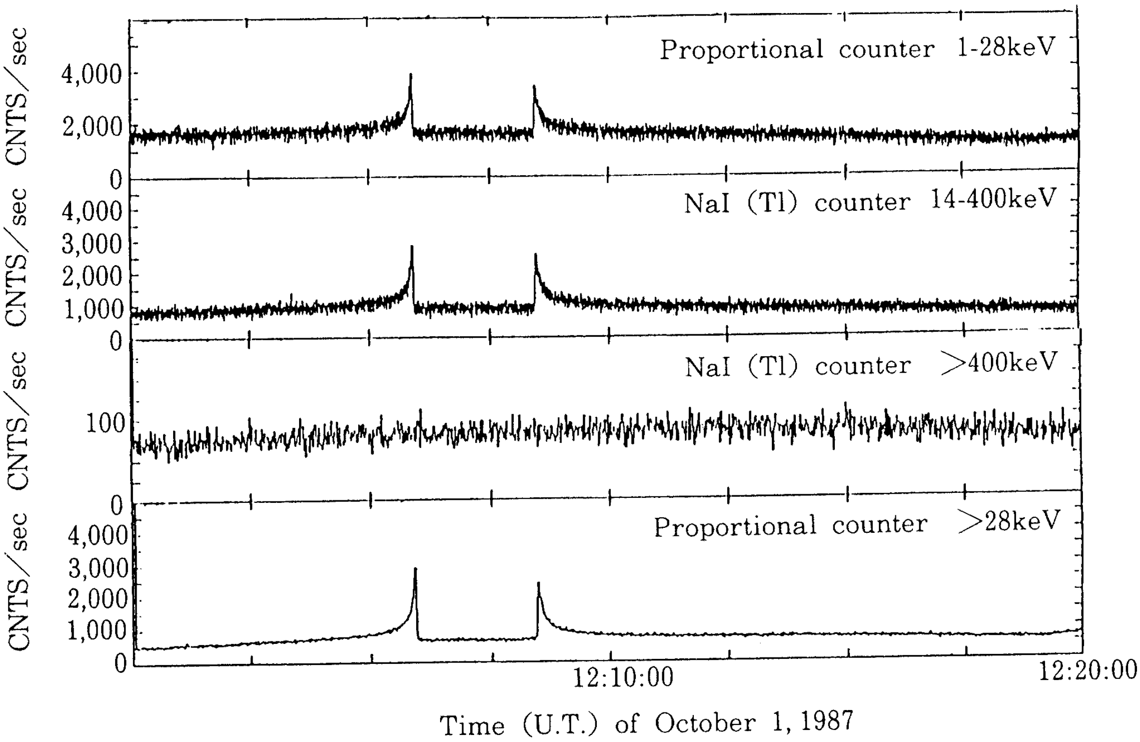


Fig. 1. A typical burst pair observed with the GBD of Ginga.

57 sharp rise bursts from 27 February to 27 April 1987. The excess of the sharp rise burst suggests that there exists at least single sharp rise bursts which are similar to the x-ray bursts from cosmic x-ray sources. But these could not be cosmic x-ray bursts or solar flares because hard x-rays are not emitted from cosmic x-ray bursts (e.g. Lewin and Joss, 1983) and the occurrence does not depend on day time or night time.

### 3.2 Event Rate

The frequency of the bursts were 0–10 events in a day, uncorrected for coverage factor. The maximum was 11 bursts on 3 March 1987. Five of these were burst pairs and others were all fast rising bursts. Four burst pairs and 5 single bursts were observed from 1 U.T. to 6 U.T. on this date. Some bursts appeared periodically with an interval of the orbital period of the satellite, for a few orbital periods. Some of the burst pairs obtained from 27 March to 21 April 1987 showed 23.5 hour periodicity in a day-by-day basis burst arrival time diagram. The 23.5 hours is the period that the satellite return to same geographical position and was also obtained by the SMM (Rieger et al. 1989). No periodicity was obtained for long term data.

Several bursts were detected on 17 June 1988, but no burst of artificial origin was observed after 18 June 1988 (but see Discussion).

### 3.3 Spectrum

The energy spectra are quite different from those of normal cosmic gamma-ray bursts. An example of the pulse-height distribution from the NaI (Tl) counter and the proportional counter are shown in Fig. 2. The distribution is discontinuous in the overlapping energy region. If the incident radiation is photons, the two spectra should be continuous.

Therefore, the discontinuity is evidence for particle incidence, possibly electron incidence. No difference can be seen between the spectra from each of the pair burst. We have not yet confirmed that all unusual bursts we observed are due to particles.

### 3.4 Geographical Distribution

Geographical positions where the unusual bursts occurred are plotted in Fig. 3. It can be seen clearly that the events are correlated with the geomagnetic equator and are distributed on both sides of the equator. The burst pairs appeared on both side of the

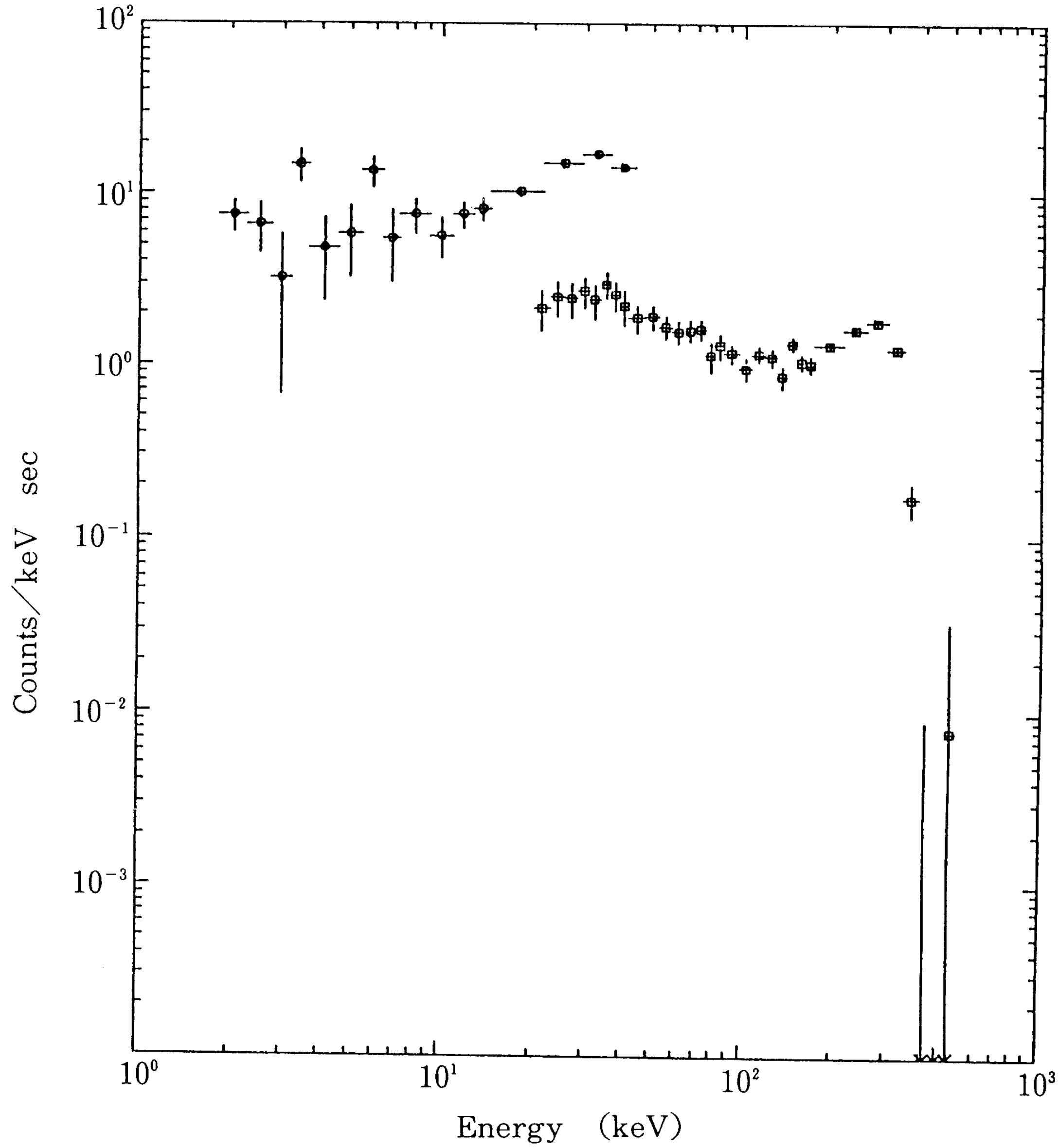


Fig. 2. The energy loss spectrum of the burst of artificial origin. Circles and squares are pulse-height distributions of the proportional counter and the NaI (Tl) counter respectively. Discontinuity around 20 keV is evidence for charged particle incidence.

equator. Most of the single bursts distributed similarly to the pair bursts. This implies that single bursts are essentially same as pair bursts and that one of the pair has been missed. Further analysis show that the intervals of pair bursts depends on the altitude of the satellite. Absence of data points over South America and the Atlantic Ocean is due to the SAA where the high voltage supplies for the detectors were turned off.

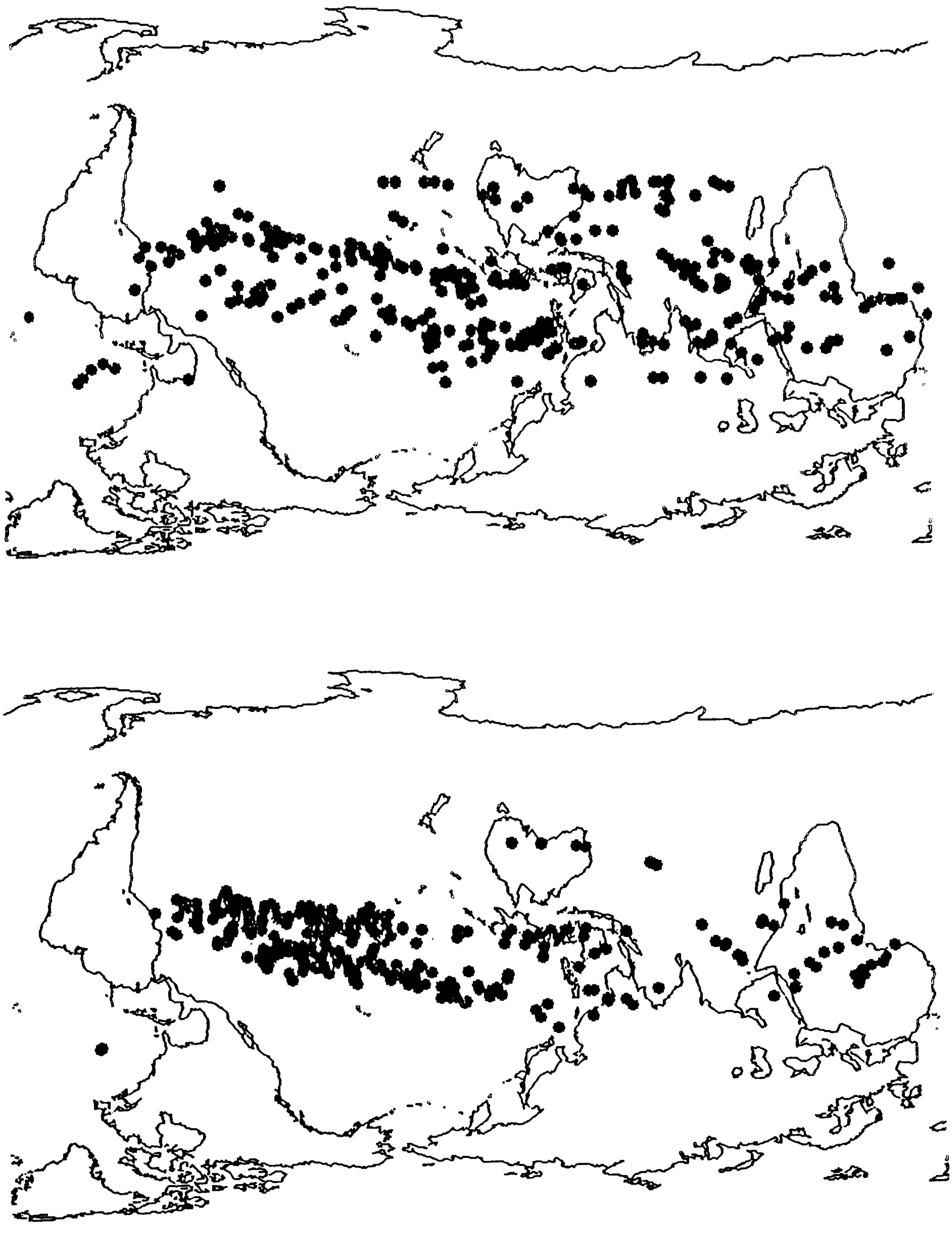

Fig. 3. The geographical distribution of pair bursts (upper figure) and single bursts (lower figure). The bursts appeared on both sides of the geomagnetic equator and no essential difference can be seen between pair burst and single burst distribution.

## 4. Discussion

We concluded immediately from the geographical distribution and spectra of these events that their origin was not cosmic but geophysical. However, it is very strange that these phenomena have never been reported although the intensity was high enough to be detected with a small monitor counter. We concluded that the unusual radiation we observed was the geomagnetically trapped electrons, but we did not successfully interpret the symmetric burst profile.

In August 1988, NASA announced that the Solar Maximum Mission (SMM) satellite detected transient gamma-ray and charged particle events from nuclear reactor on board Soviet satellites (Woldrop 1988). A series of papers on this problem appeared in Science vol. 244 in April 1989. Three types of transient events were observed by SMM from 1980 to 1988 (Rieger et al. 1989). These were, type 1 (0.5 MeV line events, positron events), type 2 (charged particle events) and type 3 (high energy gamma-ray events). Both type 1 and type 2 events exhibited similar time profiles as those observed with Ginga. We have not yet observed positron events. Most of the Ginga events are not enough signal to noise ratio to derive spectra.

Share et al. (1989) proposed a model of charged particle injection from an in-orbit nuclear reactor. The transient events are observed when a detector satellite crosses same magnetic field line as that source satellite crossed. The burst pairs are observed when the detector satellite goes inside of the magnetic shell where the particles are stored and enters into the shell again. The altitude distribution of the particles had a sharp cut off at minimum L-value (which assigns geomagnetic lines of force in the unit of altitude at the geomagnetic equator) of the source satellite. The fast fall and the fast rise bursts correspond to the crossings from the trapped region to lower L region and reentry to trapped region respectively. These occurs before and after crossing the geomagnetic equator where the satellite altitude is lower than that of trapping shell (Share et al. 1989).

Although we have not yet examined the coincidence of L-parameter of Ginga orbit and that of the source satellite when the bursts were detected, we are confident that unusual events observed by Ginga are of same origin as those detected by SMM in the same period.

We would have missed 10–20% of cosmic bursts by false cosmic bursts occupying the fast memory. However, we monitored all the events by continuously sampling the slow memory. Further results on artificial bursts as well as cosmic gamma-ray bursts will be published elsewhere.

We have noted that the bursts of possibly artificial origin have been observed since August 1989. The width of the bursts are narrower than previous bursts. The spectra showed charged particle feature and the 0.5 MeV line feature.

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