HARD X-RAY IMAGING SURVEY OF THE GALACTIC PLANE WITH THE CALTECH GAMMA - RAY IMAGING PAYLOAD GRIP-2

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ABSTRACT

In a recent balloon flight on October 6-7, 1995, the Caltech coded aperture Gamma-Ray Imaging Payload (GRIP-2) imaged numerous fields in the Galactic plane and center in the 25 keV - 600 keV energy band. GRIP-2's large phoswich detector (3830 cm^2), 15° (FWHM) field of view, 30′ angular resolution and 6′ point source localization ability make it ideally-suited for surveying the accreting binary population of the Galaxy at high energy. We present a brief description of the instrument and we also report preliminary imaging results from our recent Southern hemisphere campaign and show the capabilities of this balloon-borne coded aperture telescope for hard X-ray/gamma ray imaging. Several galactic sources have so far been detected above 25 keV with GRIP-2: 1E 1740.7-2942, GRS 1758-258, Cyg X-1, GX 339-4, GX 354-0, GX 1+4, GRS 1915+105, Cyg X-3, 4U 1700-377, 4U 1702-429, Terzan 2 and the Crab pulsar.

Keywords: surveys; stars: binaries; Galaxy: center

1. INTRODUCTION

The Galactic center region was first imaged with a coded aperture telescope at energies greater than 30 keV by the Caltech Gamma Ray Imaging Payload (GRIP). It has shown that the "microquasar" 1E 1740.7-2942 (Mirabel et al. 1992) was the dominant source above 30 keV in this region (Cook et al. 1991). Previous observations from Spacelab 2 (Skinner et al. 1987) showed that 1E 1740.7-2942 was also the strongest source in the energy band 19 - 30 keV. Since then the SIGMA telescope onboard the GRANAT satellite has been producing interesting imaging and spectral observations (Vargas et al. 1996) of some regions of the Galactic plane over a 6 years lifetime. GRIP observed the Galactic center region in 1988 and 1989 (Cook et al. 1991; Heindl et al. 1993).

2. THE GRIP-2 INSTRUMENT

The Gamma Ray Imaging Payload (GRIP-2) (Schindler et al. 1996) is a balloon borne coded aperture telescope designed for imaging observations of galactic and extragalactic gamma-ray sources. The telescope uses a large-area position sensitive phoswich detector to record the energy and interaction position of gamma-rays which pass throught a rotating hexagonal uniformly redundant array (HURA) coded aperture mask.

The GRIP-2 detector is a large-area imaging phoswich detector, which provides a substantial collecting area and sensitivity improvement over the original GRIP detector. The NaI(Ti)/CsI(Na) detector is optimized for imaging observations in the energy range 25 keV to 600 keV, with usable sensitivity up to 2 MeV. The 1.5 cm thick NaI(Ti) detection element is fabricated from a single crystal, while the CsI(Na) Compton shield backing the NaI is composed of a mosaic of hexagonal scintillator pieces.

The detector is instrumented with 119 photomultiplier tubes which view the scintillator through a lead glass optical window. The lead glass reduces the rate of low energy events in the CsI, easing the requirements on the electronics for phoswich discrimination. The PMT's are mechanically constrained against the lead glass window by a rigid aluminium strong back structure, assuring a uniform optical coupling between the PMT's and the glass. Sixty-nine light fibers, each coupled to an individual LED are symmetrically located in the strong back. These provide a programmed sequence of individual light pulses over the full active area of the detector for both ground and in-flight calibration of the instrument (Schindler et al. 1996).

3. SURVEY OF THE GALACTIC PLANE

The Galactic plane was observed on October 6 and 7 1995, during our last Southern hemisphere campaign from Alice Springs, Northern Territory, Australia. The GRIP-2 instrument also had a successful initial flight on September 14 and 15, 1993 from Ft. Sumner, New Mexico, USA. We are now processing the science data for this entire flight. There

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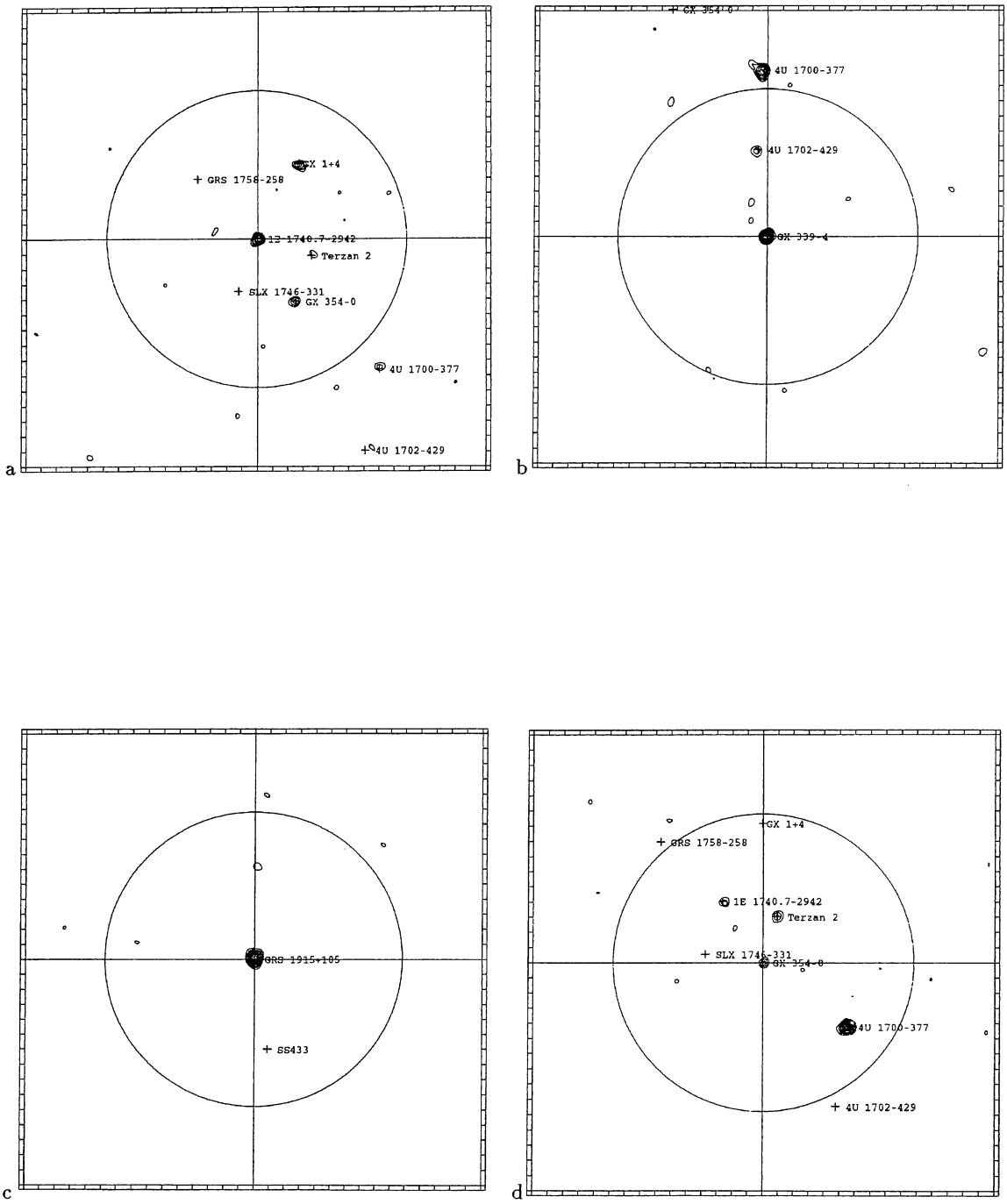

Figure 1: Different fields imaged with GRIP-2

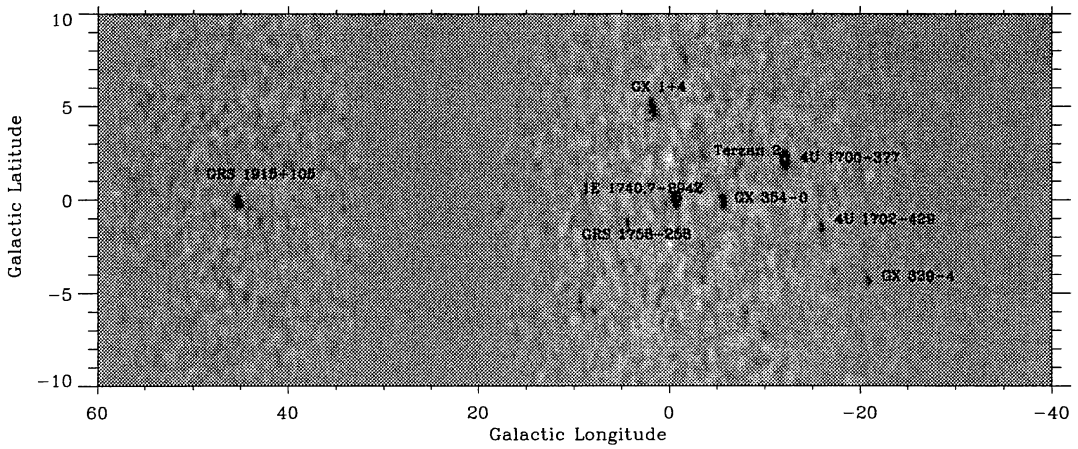

Figure 2: Low energy map: 25 - 70 keV

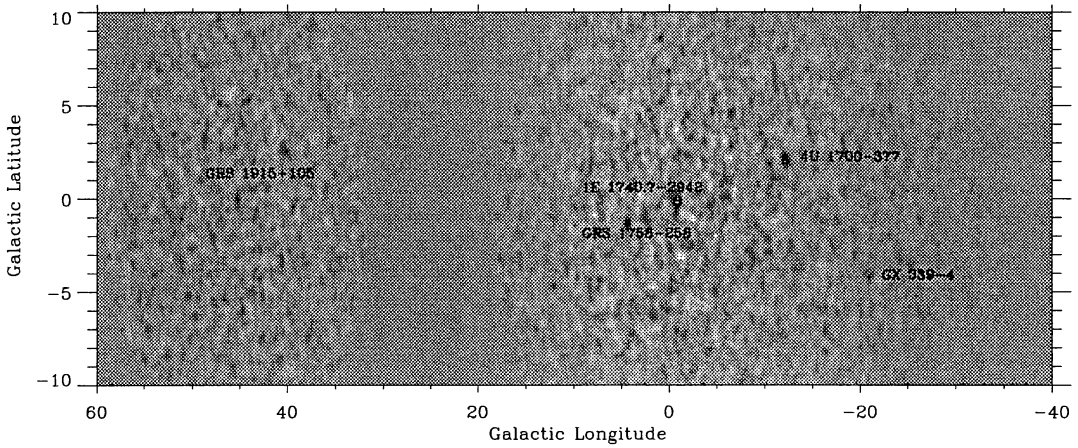

Figure 3: High energy map: 70 - 135 keV

Pointing	Date (U.T.)	Livetime (s)	Mean line-of-sight atmosphere (g cm^{-2})
GX 339-4 (1)	15.99 - 18.16 (1)	7865	5.67
Galactic center (1)	18.18 - 20.22 (1)	6610	4.33
GX 339-4 (2)	20.25 - 22.09 (1)	6223	3.87
GRS 1915+105 (1)	22.12 - 23.53 (1)	4596	4.56
Galactic center (2)	23.56 (1) - 0.40 (2)	2774	4.18
GX 354-0 (1)	16.51 - 17.60 (2)	3890	5.88
GRS 1758-258 (1)	17.61 - 18.53 (2)	3014	4.77
GX 354-0 (2)	18.54 - 19.65 (2)	3645	3.39
4U 1700-377	19.66 - 20.40 (2)	2513	3.03
GRS 1758-258 (2)	20.40 - 20.96 (2)	1786	3.05
GRS 1915+105 (2)	20.99 - 21.62 (2)	2086	4.47

Table 1: Log of the observations

is particular interest in analysis of the GRIP-2 data for LSI 61+303, the Cygnus X-1/X-3 region, the Crab/A0535+26 region, the Galactic center region, 3C273 and in analysis of data from the Virgo region for which OSSE sky maps have been made.

The GRIP-2 1995 flight yielded excellent results, including a rich set of source detections in the Galactic center region. Table 1 summarizes the eleven different pointed observations along the Galactic plane. In Figure 1, we present some fields imaged during this campaign. Figures 2 and 3 are a composite image of these different pointings. The Galactic center sources exhibited variability on many scales. GRIP-2 detected strong emission from the persistent black hole candidates such as 1E1740.7-2942, GRS 1758-258, GX 339-4, Cyg X-1 and GRS 1915+105. There are early indications of significant spectral differences between these sources. Even more exciting is the indication that GRIP-2 achieved sufficient sensitivity to begin to see the hard tails of several LMXBs. Such hard tails were seen earlier from GX 354-0 by GRIP-1 (Cook et al. 1991) and from other LMXBs by SIGMA (Barret et al. 1991; Claret et al. 1994). While some identifications are still tentative, we have indications that we have detected at least 3 LMXBs during the Fall flight: GX 354-0, Terzan 2, and 4U 1702-429.

Our analysis activities have concentrated on energy, efficiency, and pointing calibration of the instrument using pre-flight, flight, and post-flight data. Calibration observations on the Crab pulsar yield good agreement with spectra measured by previous instruments (Schindler et al. 1996). Analysis is continuing and will be concentrated on the spectral evolution of these compact stars. Because of the good time resolution ($\sim$ 1 μs), GRIP-2 can perform valuable complementary studies of time variability, pulse profile and also search for QPOs. Additional observations of Vela X-1, Cen A, the LMC X-1/LMC X-3 region, and SMC X-1 are still in progress.

4. CONCLUSIONS

The power of the GRIP-2 wide-field coded mask imaging technique for observations of bright and faint Galactic sources is demonstrated by these composite images, taken in 13 hours in a 30-hour balloon flight, which is comparable to images made in 1-month integrations by the SIGMA satellite instrument. Thus with GRIP 2, a significant fraction of the Galactic plane can be observed in a single balloon flight with sensitivity sufficient to monitor the state of a large fraction of the sources detected by SIGMA. This is directly demonstrated in these relatively short observations of the Galactic plane regions.

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FIGURE CAPTION

Figure 1: Different fields imaged with GRIP-2 during the Alice Springs campaign (The contours indicate the number of excess counts in a given direction, calibrated in units of the statistical significance of the excess. Contours are spaced by one σ):
a) The Galactic center region (First pointing, contours start at 2.7 σ)
b) The GX 339-4 region (Second Pointing, contours start at 2.5 σ)
c) The GRS 1915+105 region (First Pointing, contours start at 2.8 σ)
d) The GX 354-0 region (Second Pointing, contours start at 2.5 σ)

Figure 2: Low energy map: 25 - 70 keV

Figure 3: High energy map: 70 - 135 keV

Table 1: Log of the observations, (1) October 6, 1995, (2) October 7, 1995