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LOCALIZATION AND SPECTRUM OF THE X-RAY TRANSIENT SOURCE GRS 1915+105

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ABSTRACT

The observation of the recently discovered X-ray transient source GRS 1915+105, carried out by the SIGMA telescope on board *GRANAT*, has significantly improved the accuracy of determination of the source position. The analysis of the 40–70 keV image provides localization of the source at $\alpha = 19^h12^m51^s$, $\delta = 10°51'.4$ (1950 equinox) with an error circle with radius of $3'.0$ (90% confidence). In this observation on 1992 September 23–24, the source flux was detected at the level of 150 ± 20 mCrab in the 35–70 keV energy range. The spectrum of GRS 1915+105, measured by SIGMA in the 35–250 keV energy domain, can be approximated by a power law with a photon index of -2.5 ± 0.3.

No evidence for association of GRS 1915+105 with the Soft Gamma Repeater (SGR) B 1900+14 has been found in the SIGMA data. The position of GRS 1915+105 is $\sim 1^\circ.7$ apart from the nearest point of SGR's 2 σ error box, obtained by the VENERA/KONUS experiment (E. Mazets, private communication). No soft γ-ray bursts were also detected by SIGMA during 20 hours of observations of the Aquila field. The sensitivity of the GRB-cell to the SGR-type bursts is $\sim 1/10$ of the brightness of the weakest burst, observed by the KONUS experiment in 1979, and $\sim \frac{2}{3}$ of the weakest burst, detected by BATSE in 1992.

Subject headings: gamma rays: bursts — novae, cataclysmic variables — stars: individual (GRS 1915+105) — X-rays: stars

1. INTRODUCTION

A new X-ray transient in the Auila constellation was discovered by the WATCH all-sky monitor on board *GRANAT* on 1992 August 15 (Castro-Tirado et al. 1992). The source position, determined by the WATCH instrument, was $\alpha = 19^h14^m.9$, $\delta = +10°19'$ (1950 equinox) with an error circle radius of $0^\circ.5$. The analysis of BATSE/CGRO data revealed an outburst of hard X-ray emission from this source: it was first detected on June 16–24 between 20 and 230 keV with a flux of 90 ± 10 mCrab, continued to increase in July, and stabilized at the maximum level of 300 mCrab by mid-August (Harmon et al. 1992). Simultaneously with the flux increase BATSE observed changes in the source spectrum. The power-law fit to the source spectrum in the 20–120 keV band indicated an evolution of the spectral index from -2.0 (in June) to -2.8 (in September) (Harmon et al. 1992).

2. INSTRUMENTS AND OBSERVATIONS

The SIGMA coded mask telescope on board the *GRANAT* observatory operates in the 35–1300 keV energy range. It is capable of obtaining images of an $18^\circ.0 \times 16^\circ.7$ (full width at zero response) field of view (FOV). The central $4^\circ.7 \times 4^\circ.3$ rectangle of the telescope's FOV is a fully coded area, where the sensitivity is maximal and constant. Although coded mask pixel size corresponds to 13', the accuracy of a point-source localization is much better and ranges between $0'.5$ and a few arcminutes, depending upon the brightness of the source and the number of observations. A detailed description of the telescope and its in-flight performance was given by Paul et al. (1991).

An observation of GRS 1915+105 was performed by SIGMA on 1992 September 23–24 and lasted 20 hours. A total of 16 hours of scientific data was accumulated. During this observation the telescope was operating in the Spectroscopy/Imaging mode, in which images are recorded in the onboard memory in 95 energy channels with $3'.2$ pixel size. Another type of data, used in the present analysis, is the overall detector count rate in four broad energy bands with 4 s time resolution.

3. IMAGE OF THE AQUILA REGION IN THE HARD X-RAY BAND

The 40–70 keV image of a $4° \times 4°$ region of the sky in the Aquila constellation, including the WATCH error circle of the transient source localization, is shown on Figure 1. The only statistically significant (7 σ) source of hard X-ray emission, detected by SIGMA in this area of the sky, is clearly seen on the image. The source position, as determined from this image is

$$\alpha = 19^h12^m51^s$$

$$\delta = 10°51'.4$$

(1950 equinox) with an error circle radius of $3'.0$ (90% confidence).

The nearest known X-ray source 1E 1912.3+1038 (Hertz & Grindlay 1984) is located 14' apart from the peak centroid

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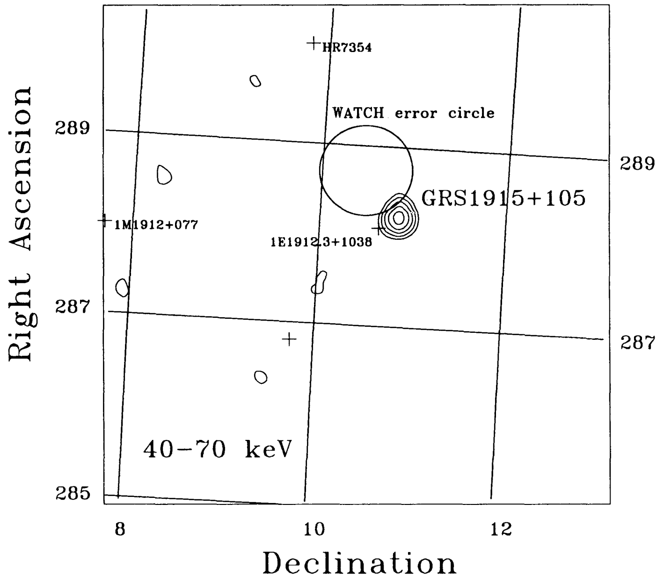

FIG. 1.—The 40–70 keV SIGMA image of the Aquila region including the error circle of GRS 1915+105 reported by the WATCH instrument (*solid line*). Contours are 3, 4, 5 ... standard deviations.

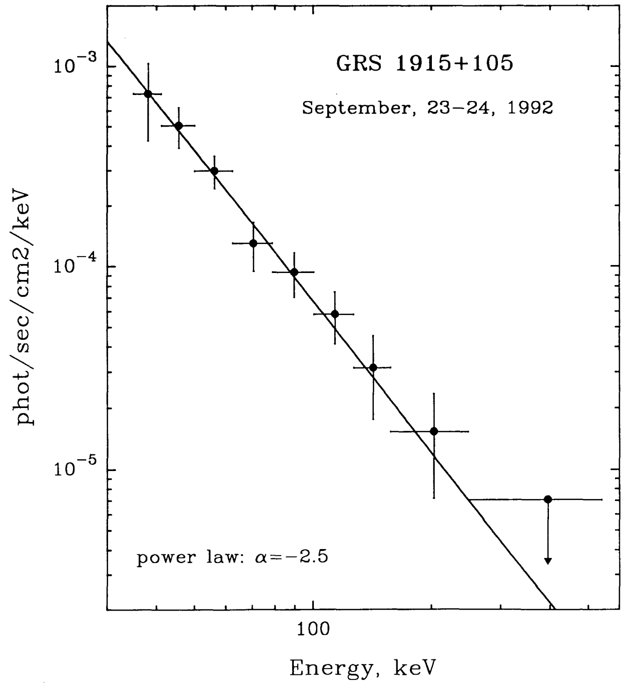

FIG. 2.—The spectrum of GRS 1915+105, obtained by SIGMA during 1992 September 23–24. The solid line corresponds to the best-fit power-law spectrum.

(Fig. 1), that is, well outside of the GRS 1915+105 error box. Due to a good angular resolution of the SIGMA telescope, the mutual contamination of these two sources is not strong (30% in this energy band). To estimate an impact of 1E 1912.3+1038, we determined the intensities of the two sources in the 40–70 keV energy band with positions at the ones of 1E 1912.3+1038 and GRS 1915+105, respectively. The intensities obtained are $(32.6 \pm 4.2) \times 10^{-4}$ counts s^{-1} cm^{-2} at the GRS 1915+105 position and $(-3.7 \pm 4.2) \times 10^{-4}$ counts s^{-1} cm^{-2} at the position of 1E 1912.3+1038. Therefore, a possible contribution of 1E 1912.3+1038 to the observed hard X-ray emission can be neglected.

4. THE SPECTRUM OF GRS 1915+105

The spectrum of GRS 1915+105, derived at the above position, is shown in Figure 2. The hard X-ray flux from the source was detected by SIGMA up to ~150–200 keV. The spectrum in the 40–250 keV energy range is well fitted by a power-law model with a photon index of -2.5 ± 0.3 and a spectral flux at 100 keV (F_{100}) of $6.9 \pm 1.0 \times 10^{-5}$ photons s^{-1} cm^{-2} keV^{-1} (reduced χ^2 equals to 0.25 for 6 d.o.f.). The energy flux from the source during the SIGMA observations was $1.12 \pm 0.14 \times 10^{-9}$ ergs cm^{-2} s^{-1} (150 ± 20 mCrab) and $7.6 \pm 1.3 \times 10^{-10}$ergs cm^{-2} s^{-1} (100 ± 20 mCrab) in the 35–70 and 70–150 keV energy bands, respectively. A bremsstrahlung fit to the data gives the temperature $kT \sim 80$ keV (reduced χ^2 is 0.47 for 6 d.o.f.). Low significance of high-energy points have not allowed us to set up an upper limit for the temperature in the Comptonized disk model (Sunyaev & Titarchuk 1980). The lower limit on the disk temperature is 37 keV (67% confidence).

Transient annihilation features have been detected by SIGMA in the spectra of two black hole candidates: 1E 1740.7−2942 (Sunyaev et al. 1991; Bouchet et al. 1991; Churazov et al. 1993), Nova Muscae (Sunyaev et al. 1992a; Goldwurm et al. 1992), and the Crab Nebula (Sunyaev et al. 1992b). Nothing similar was found in the spectrum of GRS 1915+105 during this observation. The 3 σ upper limit on the 300–600 keV flux from the source is 5.8×10^{-3} photons s^{-1} cm^{-2}. The upper limit on the flux in a narrow emission line anywhere in the 450–550 keV energy domain is 3.6×10^{-3} photons s^{-1} cm^{-2}.

5. TIMING ANALYSIS

The 4 s count rates, recorded during this observation, give the possibility of investigating a short-term variability of the source in the 0.001–0.1 Hz frequency range. The timing analysis of the data has not given any positive detection of low-frequency noise or coherent pulsation. The power density spectrum of the source is consistent with the Poissonian noise level with the upper limit on the fractional rms of the flux fluctuations, integrated over 0.001–0.1 Hz range, on the level of 50% (confidence level of 95%). The search for coherent pulsations in the same frequency range gave an upper limit on the fractional rms of coherent pulsations on the level of 12% (confidence level of 95%).

6. GRS 1915+105 AND SGR B 1900+14

On June 19, July 8, and August 19 the BATSE instrument detected three recurrent soft γ-ray bursts (Kouveliotou et al. 1993) similar to those observed by KONUS from the soft γ-ray repeater (SGR B 1900+14) in 1979 (Mazets rt al. 1979). The BATSE error circle (5° in radius) centered at R.A. = 19^h12^m, decl. = +11° includes both the position of the SGR (Mazets et al. 1979) and the position of GRS 1915+105 (measured by SIGMA). Since GRS 1915+105 became bright nearly at the same time, it may be suggested that the GRS 1915+105 could be the source of the recurrent γ-ray bursts, observed by BATSE. The precise (~3′) position of GRS 1915+105 obtained with SIGMA is ~1°.7 apart from the nearest point of 2 σ error box, obtained by VENERA/KNOUS experiment (E. Mazets 1993, private communication), making the association of the source with SGR unlikely (see also paper of Kouveliotou et al. 1993). Therefore, we conclude that GRS 1915+105 and SGT B 1900+14 are different sources.

During the whole observational session on September 23–24 the GRB cell of SIGMA was switched on. Having a sensitivity of 3×10^{-8} ergs cm^{-2} for 0.25 s integration time, it gives the possibility of localizing the GRB events, occurring in the coded field of view of SIGMA, with arcminute accuracy (a description of the SIGMA GRB-cell can be found in Guerry et al. 1986 and Sunyaev et al. 1993). The sensitivity of the GRB-cell to the SGR-type bursts is $\sim\frac{1}{10}$ of the brightness of the weakest burst, observed by the KONUS experiment in 1979, and $\sim\frac{2}{3}$ of the weakest burst, detected by BATSE in 1992. No GRB-cell triggerings occured during SIGMA observation of this region. Of course, it should be noted that the duration of this observation (20 hours) was quite short in comparison with recurrence time of bursts, observed by BATSE in June–August 1992 from this region, $\sim$1 month (Kouveliotou et al. 1993).

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REFERENCES

Bouchet, L., et al. 1991, ApJ, 383, L45
Castro-Tirado, A. J., et al. 1992, IAU Circ. 5590
Churazov, E., et al. 1993, ApJ, 407, 752
Goldwurm, A., et al. 1992, ApJ, 389, L79
Guerry, A., et al. 1986, Adv. Space Res., 6, 103
Harmon, B. A., et al. 1992, IAU Circ. 5619
Hertz, P., & Grindlay, J. P. 1984, ApJ, 278, 137
Kouveliotou, C., et al. 1993, Nature, 362, 728
Mazets, E., Golenetskij, S., & Gur'yan, Yu. 1979, Soviet Astron, Lett. 5, 649
Paul, J., et al. 1991, Adv. Space Res., 11, 8, 289
Sunyaev, R., & Titarchuk, L. A&A, 86, 121
Sunyaev, R., et al. 1991, ApJ, 383, L49
———. 1992a, ApJ, 389, L75
———. 1992b, IAU Circ. 5481
———. 1993, ApJ, 402, 579

Note added in proof—Following the arcminute localization of the new X-ray transient, provided by the *SIGMA* telescope, the search for an optical/radio counterpart was initiated. In radio, GRS 1915+105 was first detected at 20 cm with the Very Large Array (Mirabel, I. F., et al., IAU Circ. 5773 [1993]. In the soft X-rays, it was localized with 10″ accuracy by *ROSAT* at $\alpha = 19^h15^m11^s.8$, $\delta = 10°56'47''$ (equinox 2000.0) (Greiner, J., IAU Circ. 5786 [1993]), and using the 2.2 m telescope (+IRAC 2) at the European Southern Observatory, it was identified as a variable infrared source at $\alpha = 19^h12^m50^s.01$, $\delta = 10°51'27''.5 \pm 1''$ (equinox 1950.0) (Mirabel, I. F., et al., IAU Circ. 5830 [1993]; see also A. Castro-Tirado, IAU Circ. 5830 [1993]) inside the *ROSAT* error circle. All these positions are consistent with that measured by SIGMA.