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RAPID FLUCTUATIONS IN THE HIGH-ENERGY X-RAY FLUX FROM A SOURCE IN CRUX*

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ABSTRACT

On 1970 October 15–16 we carried out balloon X-ray observations from Australia (energies above 15 keV). We detected a rapidly varying flux from a source at $l^{II} = 300^\circ.7 \pm 0^\circ.5$, $b^{II} = -2^\circ.2 \pm 2^\circ.7$ (GX 301−2). Several flares with rise and decay time of a few minutes were recorded. A flux change of about a factor of 5 was recorded in 2.5 minutes. The highest flux observed in the energy range from 15 to 32 keV was ~10 keV cm^{-2} sec^{-1}. This is at least a factor of 35 higher than the average flux from this region of the sky measured on 1969 March 20 by Lewin, McClintock, and Smith. The lowest flux measured from GX 301−2 during the 1970 October observation is ~2 keV cm^{-2} sec^{-1}. In the same energy range we also observed a source at $l^{II} = 303^\circ.8 \pm 0^\circ.8$, $b^{II} = -1^\circ.2 \pm 2^\circ.5$ (GX 304−1). The flux from this source was about 1 keV cm^{-2} sec^{-1}.

During a balloon flight from Mildura, Australia, on 1970 October 15–16, we carried out X-ray observations of a region of the sky from which a strong X-ray flux had been previously observed (Lewin, Clark, and Smith 1968*a*, *b*). We used a 45 cm^2 NaI(Tl) scintillation detector, surrounded by a NaI(Tl) anticoincidence jacket, mounted in an altazimuth configuration. The field of view of the slit had an angular width of $1^\circ.5 \times 13^\circ$ full width at half-maximum. The length direction was tilted at an angle of 20° to the horizon.

A balloon with a volume of 34 million cubic feet, manufactured by Winzen Research, Incorporated, carried the instruments to an altitude of ~147000 feet. The data were both recorded on board and transmitted to a ground-base station. X-rays were recorded in eight energy channels covering the range from 15 to ~150 keV. Thus far, we have analyzed only data obtained in a "sum channel" which groups the first three energy channels covering the range from ~15 to 32 keV.

During scan No. 1, (between October $15^d22^h07^m$ and $15^d23^h10^m$ UT), we detected two sources. During this scan the telescope was oriented at a zenith angle of ~$40^\circ.8$ and an azimuth of ~151°.[1] A point source would move through our field of view in about 25 minutes as a result of the diurnal motion of the Earth. During the period when the two sources were observed the balloon ascended from ~113000 feet (~5.3 g cm^{-2}) to ~140000 feet (~2.0 g cm^{-2}). Later in the flight (between October $15^d23^h39^m$ and $16^d 00^h33^m$ UT), we again observed the two sources. During this scan (No. 2), the balloon had reached an altitude of ~147000 feet (~1.5 g cm^{-2}), and the telescope was oriented at a zenith angle of ~$32^\circ.6$ and an azimuth of ~156°.[2] A point source would move through our field of view during this scan in about 30 minutes as a result of the diurnal motion of the Earth.

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[1] During the observation the telescope oscillated about the mean values of zenith angle and azimuth as given here. The period of the oscillations was about 30 seconds. The resulting amplitude of the motion of a source relative to our field of view in the direction perpendicular to the slit was ~$0^\circ.5$. This motion caused a measurable modulation in the X-ray counting rate from strong sources such as GX 301−2, reported here.

[2] See n. 1.

In Figure 1 we show the most probable locations for the two sources in the sky. The source positions are

$$l^{\mathrm{II}} = 300^\circ\!.7 \pm 0^\circ\!.5\,, \quad b^{\mathrm{II}} = -2^\circ\!.2 \pm 2^\circ\!.7 \quad \text{(our designation: GX 301}-2)\,,$$

$$l^{\mathrm{II}} = 303^\circ\!.8 \pm 0^\circ\!.8\,, \quad b^{\mathrm{II}} = -1^\circ\!.2 \pm 2^\circ\!.5 \quad \text{(our designation: GX 304}-1)\,.$$

These positions should be regarded as preliminary. Since our error boxes are "diamonds" rather than rectangles, the areas of the two error boxes (shown crosshatched) in Figure 1 are smaller than the errors quoted above might imply. It seems unlikely to us that the sources are located in the other two (not crosshatched) diamonds, although we cannot exclude this possibility. Furthermore, we cannot exclude the possibility of a variety of sources in all four diamonds. However, if one assumes that only two sources are responsible for the detected X-ray flux, we believe that the two crosshatched diamonds are more likely to contain the source locations than the other two, since sources have been previously reported near the crosshatched areas (Lewin *et al.* 1968*a;* Lewin *et al.* 1971 [preceding paper]).

Figure 2 shows the counting rate versus Universal Time as measured during our scan No. 2. Figure 2*a* covers only the period during which GX 301−2 was in the field

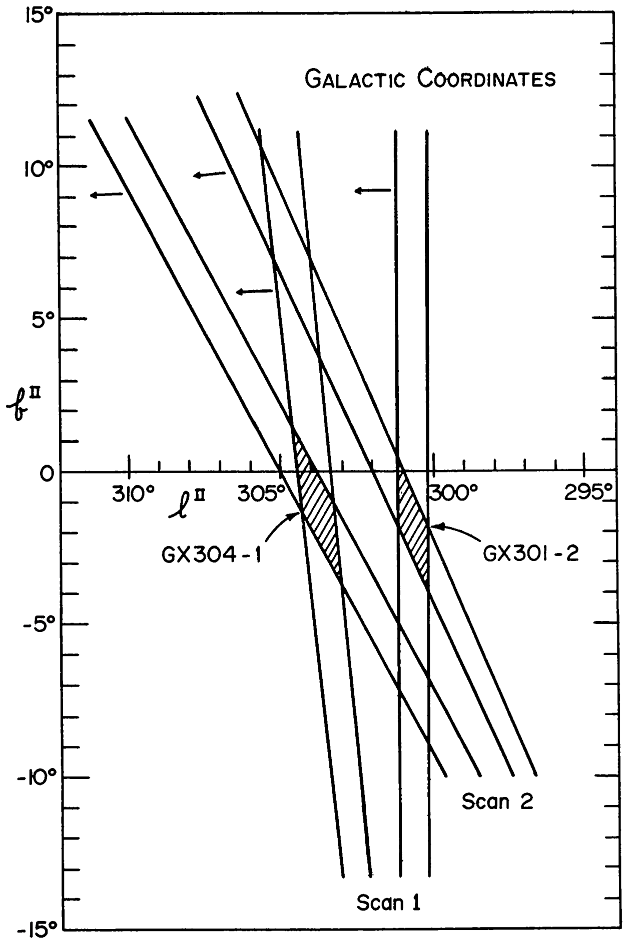

FIG. 1.—Positions of sources GX 301−2 and GX 304−1. Four pairs of lines define the crosshatched error boxes. The lines are determined by the uncertainty in the location of the peaks in the two scans. The four arrows indicate the motion of the field of view relative to the stars as a result of the diurnal motion of the Earth.

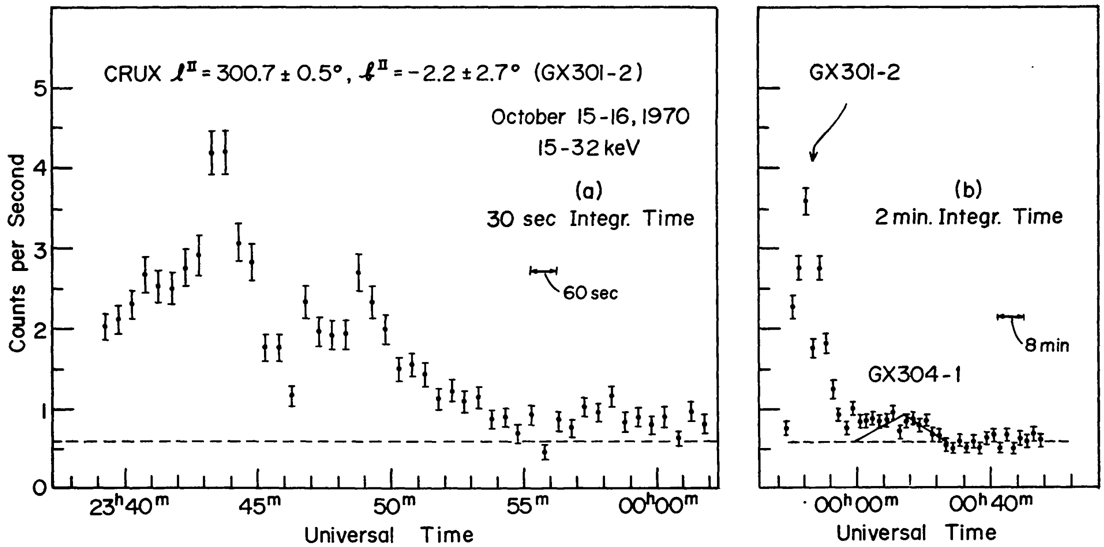

FIG. 2.—Counting rate versus time for scan 2. (*a*) Each data point represents the counting rate observed in a 30-second period ($\pm 1\ \sigma$ error bars). (*b*) Each data point represents the counting rate as observed in a 2-minute period ($\pm 1\ \sigma$ error bars). All data of scan 2 are shown here (compressed time scale). The triangle shows the collimator response to a point source of the appropriate intensity at $l^{II} = 304°$, $b^{II} = -1°$.

of view. Each data point represents the average recorded counting rate over a 30-second period. The X-ray flux varies continuously. Several flares with rise and decay times of a few minutes were recorded. A change in flux of about a factor of 5 was recorded in 2.5 minutes between $23^h43^m.5$ and 23^h46^m. The telescope oscillations mentioned earlier in this paper (see n. 1) have a small effect on the measured counting-rate fluctuations presented here, since the plotted counting rates in Figure 2*a* are average values over a 30-second period which is the approximate period of the oscillations. If the spectra at both maximum and minimum source intensity are similar to that of Tau X-1, then a maximum energy flux of $\sim$10 keV cm^{-2} sec^{-1} was measured in the energy range of 15–32 keV between $15^d23^h42^m42^s$ and $15^d23^h43^m42^s$ UT. This is about twice the flux from Tau X-1 in the same energy range, and it is at least a factor of 35 higher than the average flux from this region of the sky measured on 1969 March 20 (Lewin *et al.* 1970). A minimum flux of $\sim$2 keV cm^{-2} sec^{-1} was measured about 2.5 minutes after the above maximum energy flux was measured. If the energy spectra are of exponential form with a value of $kT \sim 5$ keV, then the numbers quoted here for the energy flux should be increased by about 60 percent.

During scan No. 1 GX 301−2 also showed severe flux changes. These results, final source positions, and spectra as a function of source intensity will be published in detail later. We will also investigate the possibility that the X-ray flux from GX 301−2 was varying periodically. Our time resolution was 1 millisecond.

To the best of our knowledge, GX 301−2 has not been observed from rockets or satellites. The only report of a source in the near vicinity of GX 301−2 was made by Lewin *et al.* (1971). On 1969 April 16 they observed a variable X-ray flux from $l^{II} = 301° \pm 3°$, $b^{II} = -2° \pm 3°$.

Figure 2*b* shows the counting rate during scan No. 2 between October $15^d23^h39^m$ and $16^d00^h56^m$ UT. Each data point represents the average counting rate during a 2-minute period. The triangle is the approximate collimator response to a nonvarying point source (of a strength appropriate to GX 304 − 1) that moves through the center of the field of view as a result of the diurnal motion of the Earth.

If the spectrum from GX 304−1 is like that of Tau X-1, then the energy flux is about 1 keV cm^{-2} sec^{-1}. If the energy spectrum is of exponential form with $kT \sim 5$ keV, then the flux is about 60 percent higher.

Previously, a variable high-energy source has been observed at $l^{II} = 304\overset{\circ}{.}8 \pm 1\overset{\circ}{.}5$, $b^{II} = -1\overset{\circ}{.}5 \pm 2^{\circ}$ (Lewin *et al.* 1968*a*, *b;* Lewin, McClintock, and Smith 1970; see also Lewin *et al.* 1971). Also, a low-energy (2.4–6.9 keV) source has been observed recently by *Uhuru* at $l^{II} = 303\overset{\circ}{.}7 \pm 0\overset{\circ}{.}5$,[3] within a few degrees of the galactic equator (Giacconi *et al.* 1971). It seems quite likely that these were two observations of the GX 304−1 source reported here.

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[3] This longitude was estimated by us from Fig. 4 of the AS & E paper.