Rapid Fluctuations in the High Energy X-Ray Flux from a Source in Crux

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CSR-P-71-58 March, 1971

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ABSTRACT

On October 15-16, 1970, 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}=300.7±0.5, b^{II}= -2.2±2.7°. Several flares with rise and decay times of a few minutes were recorded. A flux change of about a factor of five was recorded in 2.5 minutes. The highest flux observed in the energy range from 15-32 keV was $\sim$ 10 keV $cm^{-2} sec^{-1}$ and the lowest, $\sim$ 2 keV cm^{-2} sec^{-1}. We also observed a source at ℓ^{II}= 303.8±0.8°, b^{II}=-1.2±2.5°. 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 was observed earlier (Lewin, Clark and Smith 1968a,b). We used a 45 cm^2 NaI(Tℓ) scintillation detector, surrounded by a NaI(Tℓ) anti-coincidence jacket, mounted in an altazimuth configuration. The slit field of view had an angular width

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of 1.5° x 13° FWHM. The length direction was tilted at an angle of 20° to the horizon.

A 34 million ft^3 balloon manufactured by Winzen Research, Incorporated carried the instruments to an altitude of ∿ 147,000 ft. The data were both recorded on board and transmitted to a ground base station. X-rays were recorded in 8 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 # 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 ∿ 40.8°* and an azimuth of ∿ 151°. 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 ∿ 113,000 ft (∿5.3 g/cm^2) to ∿ 140,000 ft (∿2.0 g/cm^2). Later in the flight (between October $15^d23^h39^m$ and $16^d00^h33^m$ UT), we again observed the 2 sources. During this scan (#2), the balloon had reached an altitude of ∿ 147,000 ft (∿1.5 g/cm^2), and the telescope was oriented at a zenith angle of ∿32.6°* and an azimuth of ∿156°*. 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.

*see next page

Footnote

*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 $\sim 0.5°$. This motion caused a measurable modulation in the X-ray counting rate from strong sources such as GX 301-2, reported here.

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

$\ell^{II} = 300.7 \pm 0.5°$, $b^{II} = -2.2 \pm 2.7°$ (our designation: GX 301-2)

$\ell^{II} = 303.8 \pm 0.8°$, $b^{II} = -1.2 \pm 2.5°$ (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 cross-hatched) in Fig. 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 cross-hatched) 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 cross-hatched diamonds are more likely to contain the source locations than the other two, since sources have been previously reported near the cross-hatched areas (Lewin et al 1968a, Lewin et al 1971 previous paper).

Fig. 2 shows the counting rate versus Universal Time as measured during our Scan # 2. Fig. 2a covers only the period during which GX 301-2 was in the field 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 $23^h 43.5^m$ and $23^h 46^m$. The telescope oscillations as mentioned earlier in this paper (see footnote) have a small effect on the measured counting rate fluctuations as presented here, since the plotted counting rates in figure 2a 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 to 32 keV between $15^d 23^h 42^m 42^s$ and $15^d 23^h 43^m 42^s$ UT. This is about twice the flux from Tau X-1 in the same energy range. A mimimum flux of $\sim$ 2 keV cm^{-2} sec^{-1} was measured about 2.5 minutes later. 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%.

During Scan # 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 (previous paper). On April 16, 1969, they observed a variable X-ray flux from $\ell^{II} = 301 \pm 3°$, $b^{II} = -2 \pm 3°$.

Fig. 2b shows the counting rate during Scan # 2 between October $15^d 23^h 39^m$ and $16^d 00^h 56^m$ UT. Each data point represents the average counting rate during a 2 minute period. The triangle is the approximate collimator response to a non-varying point source (of the approximate strength of 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% higher.

Previously, a variable high-energy source has been observed at $\ell^{II} = 304.8 \pm 1.5°$, $b^{II} = -1.5 \pm 2°$ (Lewin, Clark and Smith 1968a, 1968b; Lewin, McClintock and Smith 1970; see also preceding paper). Also, a low-energy (2.4-6.9 keV) source has been observed recently by Uhuru at $\ell^{II} = 303.7 \pm 0.5°$*, 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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*This longitude was estimated by us from Fig. 4 of the AS&E paper.

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Figure Captions

Figure 1: Positions of Sources GX 301-2 and GX 304-1. Four pairs of lines define the cross-hatched error boxes. The lines are determined by the uncertainty in the location of the peaks in the two scans. The arrows indicate the motion of the field of view relative to the stars as a result of the diurnal motion of the earth.

Figure 2: Counting Rate vs 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 approximate collimator response to a point source of the appropriate intensity at $\ell^{II} = 304°$, $b^{II} = -1°$.

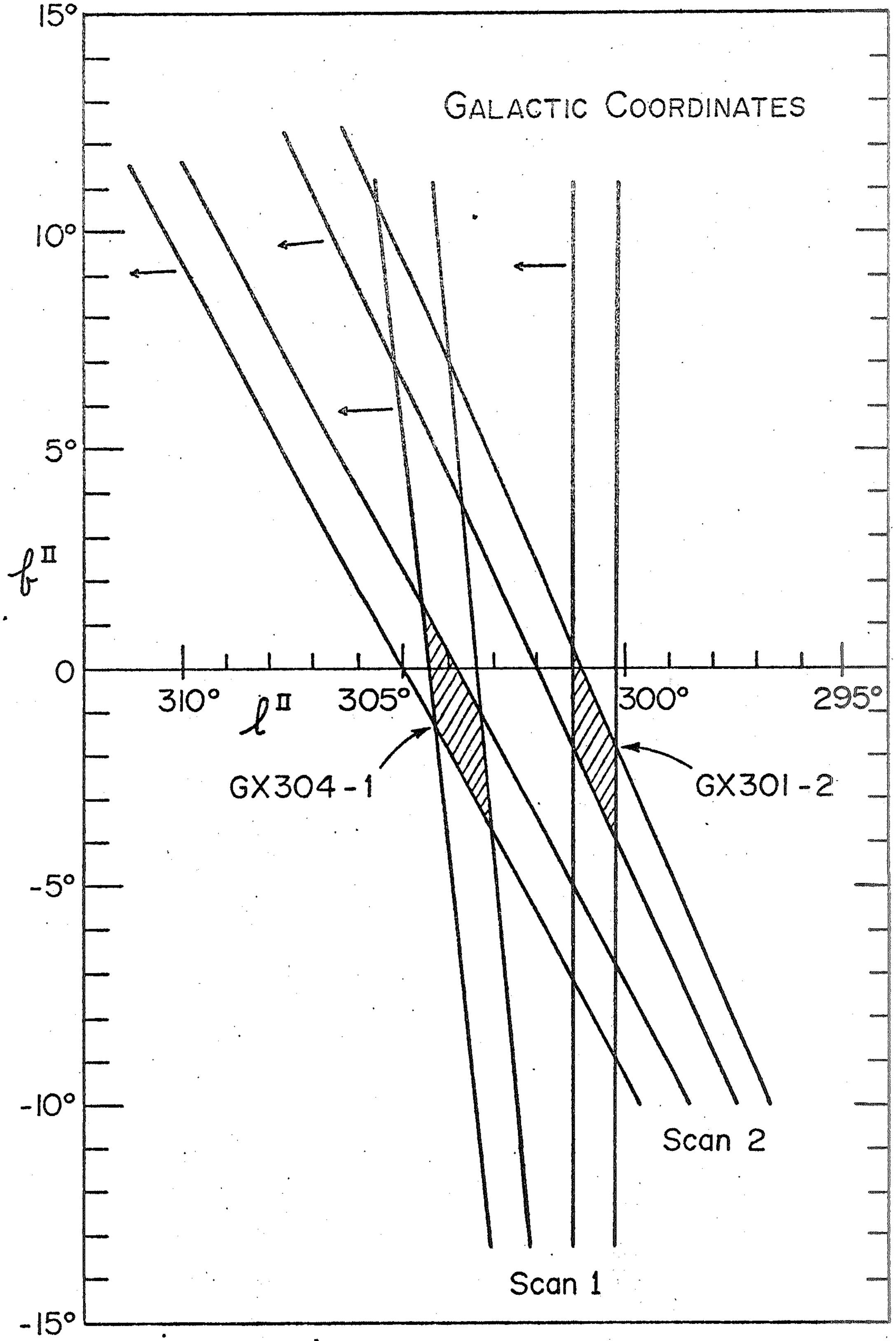
GALACTIC COORDINATES
15°
10°
5°
0
-5°
-10°
-15°
b^{II}
l^{II}
310°
305°
300°
295°
GX304-1
GX301-2
Scan 2
Scan 1

Figure 1

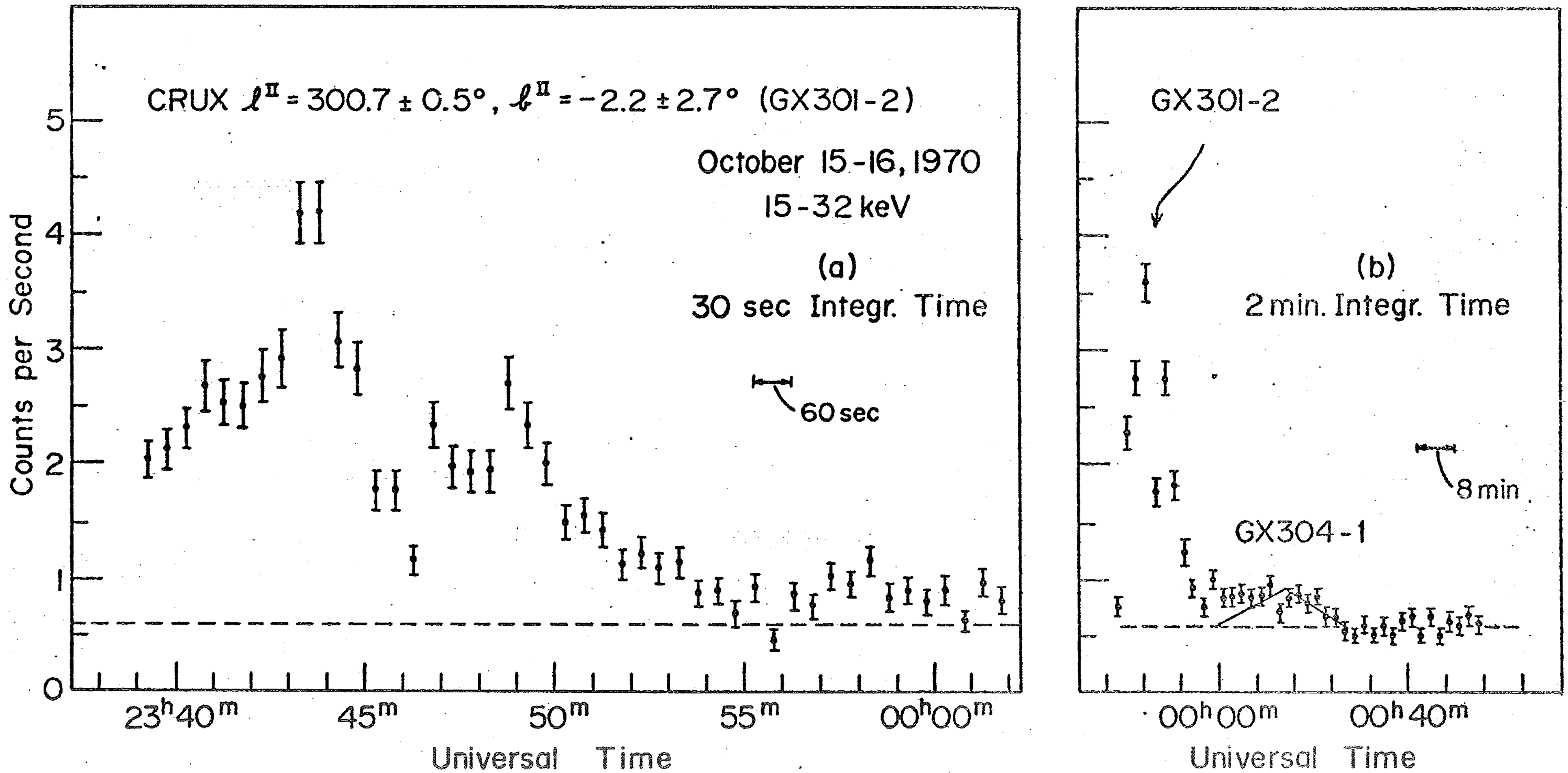
CRUX ℓ^{II} = 300.7 ± 0.5°, b^{II} = −2.2 ± 2.7° (GX301-2)
October 15-16, 1970
15-32 keV
(a)
30 sec Integr. Time
60 sec
Counts per Second
0
1
2
3
4
5
23h40m
45m
50m
55m
00h00m
Universal Time
GX301-2
(b)
2 min. Integr. Time
8 min
GX304-1
00h00m
00h40m
Universal Time

Figure 2

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