Studies of x-ray binary systems Michiel Baldur Maximiliaan van der Klis
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CHAPTER 6

LOW MASS X-RAY BINARIES

6.1 THE X-RAY FLUX VARIATIONS OF CYGNUS X-2
6.2 X-RAY OBSERVATIONS OF BRIGHT GALACTIC BULGE SOURCES IN THE VICINITY OF GX 5-1
The X-ray Flux Variations of Cygnus X-2

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Summary. Results of a 47 d observation of Cygnus X-2 by the COS-B X-ray experiment are presented. The observed variability of the X-ray intensity is investigated for the presence of modulation at either the 9.843 optical period or the 11.23 X-ray period claimed for this source. Upper limits are given to pulse amplitudes for periods between 1 d and 200 s.

Clear dips were observed during the time of highest source intensity, with transitions of up to 40% in the source flux in less than 1-2 10^3 s. It is suggested that the dips may be connected to the reported UV flaring activity.

Key words: X-ray sources - Cygnus X-2 - COS-B

Introduction

The X-ray source Cyg X-2 was associated, at an early time, with the variable star V1341 Cyg (Giacconi et al., 1967). Extensive search for periodicities from optical photometry has lead to the proposal of periods ranging from 0.9 to 14 d (Chevalier et al., 1976; Wright et al., 1976; Basko, 1977), while a convincing 9.8% orbital period was more recently determined on the basis of optical line velocities (Cowley et al., 1979).

The X-ray source is found to vary between a typical low and high state. The presence of a 9.8% X-ray modulation was claimed in low state (Marshall and Watson, 1979; Ilovaisky et al., 1979), but was not confirmed from long baseline observations which seem to indicate an 11.2 d period instead (Holt et al., 1979). The nature of the source is still a matter of strong debate with two contradictory models, one involving a degenerate dwarf at 250 pc (Branduardi et al., 1980), the other a neutron star at 8 kpc (Cowley et al., 1979).

Previously published X-ray observations were made with a relatively sparse daily coverage (Parsonaut and Grindlay, 1978; Holt et al., 1979; Branduardi et al., 1980). We report here on a 47 d COS-B X-ray observation of the source with continuous 100 s resolution coverage of the source flux over periods of 30 h.

Observations

The COS-B X-ray detector is an 80 cm² collimated proportional counter with an energy range of 2-12 keV (see Boella et al., 1974). Cygnus X-2 was in the 10° FWHM field of view of this detector permanently between June 2nd and July 19th, 1981; it was observed at a geometrical efficiency of 0.6. SS Cyg (4U2140+33) was also in the detector field at an efficiency of somewhat less than 0.5; at maximum intensity (Bradt et al., 1979) it would have contributed about 1 c/s to the total counting rate. Due to the high apogee (10^3 km) of the orbit of the COS-B satellite, the X-ray experiment is characterized by a high charged particle background. Most of this background is eliminated onboard by anti-coincidence and pulse-shape discrimination. The residual background is subtracted by means of its relation to the near-simultaneously measured charged particle rate, as known from pointings to fields empty of detectable X-ray sources. This relation is usually reproducible to ~1 c/s from one observation to another but we cannot exclude systematic effects due to changes in the mean properties of the charged particles within one observation. During the observation of Cygnus X-2, the charged particle background varied between 55-65 c/s on a typical time scale of 10 d. After the background subtraction and correction for aspect, the resulting X-ray counting rate, shown in Fig. 1, is in the 20-50 c/s bracket. This corresponds to a flux of 5.2 to 13 10^{-9} erg cm^{-2} s^{-1} (2-12 keV) for an assumed 5 keV bremsstrahlung spectrum (Branduardi et al., 1980), consistent with a low to moderate intensity level of Cyg X-2 (Bradt et al., 1979).

The data gaps in Fig. 1 are the result of periodic satellite switch-off upon entry of the radiation belts (once every 36 h) and rejection of data because of occasional charged particle storms. Each 2048 s bin corresponds to the average of 20 equally spaced 256 measurements, statistical error per bin is about 0.7 c/s. The signal is variable on all time scales from 10 d (not correlated to the background variability) down to the 100 s temporal resolution of the data. Sudden transitions in the intensity of up to 40% and numerous dips of similar depth, all uncorrelated to the particle background, are visible throughout the observation, superposed to a smoother flux variation.

Analysis and Results

Period Search

The data have been investigated for periodic intensity modulations using both folding and FFT techniques. Possible modulations at the 11.23 ASM X-ray period (Holt et al., 1979) and the 9.843 spectroscopic optical period (Cowley et al., 1979) could not have been discovered from the present 47 d observation. To test whether a modulation at either of these periods can be found back
in the observed X-ray variability, the signal was folded according to the corresponding ephemerides: \( T = JD 2443000.9 + 11.23 \) E and \( T = JD 2443166.7 + 9.843 \) E (predicted X-ray phase). The resulting light curves are given in Fig. 2. It should be kept in mind, that these light curves could be spurious, resulting from irregular flux variations. Indeed, the charged particle background, when folded, shows "light curves" of similar modulation depth (but of different shape and phase) as the X-ray flux.

The 11\,523 light curve resembles the "sawtooth" shaped one seen in the ASM data, with the maximum occurring about 0.06 (ASM: 0.07) later in phase than midway between the minima, and a best fit sinusoidal amplitude of 9.0\% (ASM: 7.2\%). The epoch of the minimum of the best-fit sine wave is JD 2444780.6 ± 0.6, halfway between the predicted minima. This corresponds to a correction to the 11\,523 period of plus or minus 0.03 ± 0.01, consistent with the 0.03 error quoted by Holt et al. (1979). The trace resulting from the 9\,5843 folding has its minimum at JD 2444780.1 ± 0.8, close to the value of JD 2444781.0 ± 0.4 predicted for the X-ray star superior conjunction (Cowley et al., 1979). The relative full amplitude from a sine fit to the modulation

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**Fig. 1.** The counting rate from Cygnus X-2 after background subtraction and aspect correction. Statistical error on each 34 min bin is about 0.7 c/s. Strong dips are visible and marked by vertical lines (see also Table 2)

**Fig. 2a.** The Cygnus X-2 counting rate folded using the predicted X-ray ephemeris of Cowley et al. (1979) with a period of 9\,5843. Formal error per bin is less than 0.5 c/s

**Fig. 2b.** Same as a, with the folding period of 11\,523 from the ephemeris of Holt et al. (1979)
Fig. 3. The Cygnus X-2 power spectrum. The low frequency part of the spectrum is shown, with the power normalized to 1 in the high frequency part. The complex structure around 1.55 (n ~ 50) corresponds to the satellite orbital period. Peaks at 1506 (n ~ 73) and 3.52 (n ~ 24) (marked by arrows) are not found in the background transform.

Table 1. Upper limits for coherent pulsations in Cygnus X-2

<table>
<thead>
<tr>
<th>Period range</th>
<th>Highest relative semi-amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 - 0.26 d</td>
<td>4 %</td>
</tr>
<tr>
<td>0.26 - 0.19 d</td>
<td>2 %</td>
</tr>
<tr>
<td>0.19 - 0.065 d</td>
<td>0.8 %</td>
</tr>
<tr>
<td>0.065 - 0.035 d</td>
<td>0.5 %</td>
</tr>
<tr>
<td>0.035 d - 200 s</td>
<td>0.2 %</td>
</tr>
</tbody>
</table>

Table 2. Characteristics of the Cygnus X-2 dips

<table>
<thead>
<tr>
<th>Date (JD 2444000.0)</th>
<th>Source int. (c/s)</th>
<th>Dip rel. ampl. (%)</th>
<th>Dip width FWHM (h)</th>
<th>Trans. time (h)</th>
<th>Phase*</th>
</tr>
</thead>
<tbody>
<tr>
<td>762.23</td>
<td>28.5</td>
<td>18.6</td>
<td>0.25</td>
<td>0.14</td>
<td>0.61</td>
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<tr>
<td>764.31</td>
<td>32.8</td>
<td>19.5</td>
<td>0.48</td>
<td>0.21</td>
<td>0.82</td>
</tr>
<tr>
<td>768.47</td>
<td>27.7</td>
<td>16.9</td>
<td>0.27</td>
<td>0.14</td>
<td>0.24</td>
</tr>
<tr>
<td>776.65</td>
<td>40.2</td>
<td>18.6</td>
<td>1.21</td>
<td>1.80</td>
<td>0.22</td>
</tr>
<tr>
<td>777.80</td>
<td>47.2</td>
<td>20.3</td>
<td>3.12</td>
<td>1.70</td>
<td>0.17</td>
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<tr>
<td>789.02</td>
<td>38.1</td>
<td>22.3</td>
<td>2.16</td>
<td>1.30</td>
<td>0.31</td>
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<td>782.25</td>
<td>37.0</td>
<td>22.9</td>
<td>4.32</td>
<td>2.72</td>
<td>0.64</td>
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<tr>
<td>784.17</td>
<td>44.7</td>
<td>14.3</td>
<td>0.96</td>
<td>0.42</td>
<td>0.84</td>
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<tr>
<td>785.33</td>
<td>41.7</td>
<td>21.8</td>
<td>0.48</td>
<td>0.28</td>
<td>0.95</td>
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<td>785.47</td>
<td>41.9</td>
<td>30.5</td>
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<td>0.97</td>
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<td>786.76</td>
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<td>2.16</td>
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<td>0.10</td>
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<tr>
<td>787.05</td>
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<td>0.72</td>
<td>0.35</td>
<td>0.13</td>
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<td>787.33</td>
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<td>27.1</td>
<td>1.97</td>
<td>0.71</td>
<td>0.24</td>
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<td>13.2</td>
<td>0.51</td>
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<td>793.30</td>
<td>38.9</td>
<td>13.6</td>
<td>1.22</td>
<td>0.21</td>
<td>0.76</td>
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<tr>
<td>796.16</td>
<td>33.6</td>
<td>12.5</td>
<td>0.89</td>
<td>0.35</td>
<td>0.06</td>
</tr>
<tr>
<td>797.82</td>
<td>35.1</td>
<td>15.1</td>
<td>1.23</td>
<td>0.85</td>
<td>0.22</td>
</tr>
</tbody>
</table>

* Phases are computed according to the following ephemerides:
Spectroscopic phase: \( T = 2443161.68 + 9.843 \, {\text{E}} \) (Cowley et al., 1979) (spectroscopic phase, corresponding to X-ray phase 0.52);
X-ray phase: \( T = 2443000.9 + 11.23 \, {\text{E}} \) (Holt et al., 1979)
Dips in the Cyg X-2 Flux

Illovaiskyy et al. (1979) reported the occurrence of X-ray dips and a deep (14 h) minimum at X-ray phase 0.5. In the present data, similar but slightly less deep minimums are visible at various phases (see at JD 2444770.0, 79.0, and 80.0 in Fig. 1). The nearly continuous recording of the X-ray flux with the COS-B experiment allows the study of flux variations as short as a few minutes, but no spectral information is available.

A set of 19 clear dips (duration less than 0.05) in the X-ray intensity was selected and studied in a detailed way (see Table 2). Most of the dips (12) occur between JD 2444775.0 and JD 2444789.0, during the time of highest source intensity (see Fig. 1). They are variable in strength and shape, with relative amplitudes ranging from 12 to 40%, half-maximum widths from 15 min to 4 h and transition times from 8 min to 2 h.

A few of these transitions are shown in more detail in Fig. 4. Even for the deepest dips, the intensity can drop or recover very quickly, within 1-2 10^-3 s (compare Illovaisky et al. 1979).

We have looked for regularity in the occurrence of the dips with respect to the periods of 9% and 11523 claimed for the source. The phases of the dips are indicated in Table 2. We note that the strongest dips occur predominantly in a (0.0-0.3) phase interval of the 9% period, with all but one being in the (0.0-0.3) interval (phase 0.0 corresponding to the optical star superior conjunction, or X-ray phase 0.52). However the restricted sample does not clearly establish this effect; in particular, as the two proposed periods are nearly in phase during the observing period, a similar but less impressive clustering is also observed for the 11523 period. The optical star, V 1341 Cyg, exhibits erratic variations on timescales of minutes of several tenths of a magnitude (Kristian et al., 1967), which can be interpreted as UV flaring activity, preferentially occurring in the same 9% phase interval (0.6-0.3) (Cowley et al., 1979). If the clustering of the X-ray dips is real, this would relate the two phenomena. Since L_0/L_max ~ 100-450 (Badt et al., 1979), this suggests that the X-ray flux during the dips may be reprocessed into UV with an efficiency of the order of a percent. Simultaneous observations are indicated to check for time coincidence of these events.

Acknowledgements. The authors thank J. van Paradijs for reading the manuscript. M. vdK acknowledges financial support by the
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Marshall, N., Watson, M.G.: 1979, IAU Circ. 3318
6.2 X-RAY OBSERVATIONS OF BRIGHT GALACTIC BULGE SOURCES IN THE VICINITY OF GX 5-1

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SUMMARY

Results are presented for 44 days of pointed COS-B X-ray observations of the galactic center region around GX 5-1. It is found that GX 5-1 exhibits relatively rapid (~ 10\textsuperscript{3} s) intensity transitions as well as flaring events with a typical time scale of ~ 10\textsuperscript{4} s. Neither GX 5-1, GX 3+1 nor GX 9+1 shows evidence of periodic intensity modulations due to orbital motion on time scales from minutes to fractions of a day. These results are discussed in the context of proposed models for bright galactic bulge sources.

KEY WORDS: X-ray binaries - bright galactic bulge sources - type II X-ray sources

I. Introduction

The galactic bulge contains about 15 persistent X-ray sources with an X-ray flux exceeding 100 \(\mu\)Jy, among which are some of the brightest sources in the galaxy (see, e.g., Bradt et al. 1979). Observationally, these objects belong to the type II X-ray sources (see, e.g., Canizares 1975), generally characterized by the absence of pulsations and eclipses, by soft X-ray spectra and high ratios of X-ray to optical luminosity. Binary models which have been proposed for this class of objects rely on a weak magnetic field, or on one that is aligned with the rotation axis of the compact object (see, e.g., Cominsky et al. 1980), a small mass ratio \(M_\text{opt}/M_X\) (Joss and Rappaport 1979) and the presence of a thick accretion disk (Milgrom 1978) to explain many of the observed characteristics.

For the lower luminosity type II sources (\(L_X < 10^{36}\) erg s\textsuperscript{-1}) the mass transfer could be driven by gravitational radiation in a highly compact binary containing a main sequence dwarf (Rappaport, Joss and Webbink 1982). In the case of the higher luminosity galactic bulge sources, magnetic braking effects in a compact binary (Verbunt and Zwaan 1981), mass transfer from a red giant (Webbink, Rappaport and Savonije 1982) and mass transfer from a helium main sequence star (Savonije 1982) have recently been proposed to explain the high luminosity of the observed sources. The main observational differences between these models, apart from the obvious differences in appearance of the donor star (if it is visible) would be the binary period: ranging from \(> 10\) d for a red giant, to \(< 1\) h for a lobe-filling helium main sequence star. However, in view of the lack of quantitative evidence, it is probably fair to say that the bright galactic bulge sources remain something of a mystery.

Previous observations of bright galactic bulge sources for durations of longer than one day (Forman, Jones and Tananbaum 1976, Mason et al. 1976, Parsignault and Grindlay 1978) yielded X-ray light curves of typically a few tens of measurements per day. From these observations, it became clear that the sources generally have a variability factor of less than 3, and do not exhibit periodic pulsations above the level of a few percent. Ponman (1981), on the basis of Ariel V RMC observations with 100 mfn resolution, suggests the existence of regular variations with periods of several days in three galactic bulge sources.
In the present paper, data are presented which provide nearly continuous coverage (with 100 s resolution) over intervals of 25 h, of the X-ray flux from a field in the galactic bulge probably dominated by the brightest of the bulge sources, GX 5-1. These data were obtained during two pointed observations with a total duration of 44 d.

II. Observations

The X-ray detector onboard the COS-B satellite (Boella et al. 1974) is a proportional counter with 80 cm$^2$ effective area in the energy range 2-12 keV. The collimator provides an approximately trapezoidal angular response curve with a nearly flat top of 1.1° and a FWHM of 10°. The sensitivity is essentially zero beyond 10.5° from the center of the field.

During the 33 d of the first observation, from September 17 to October 20, 1975, the center of the circular field of view gradually drifted from α = 269.4°, δ = -25.1° to α = 268.4°, δ = -24.1°; during the second observation, February 24 to March 7, 1977 (11 d), the drift was from δ = -25.2° to -24.9° at a constant α = 270.0°. Short term pointing jitter was damped to better than 1'.

Figure 1 shows a map of the observed region with the detector field of view during the 1975 observation superimposed. It is clear that there were a number of sources within the field of view; however, on the basis of the luminosities quoted in the catalogues of Forman et al. (1978) and Bradt et al. (1979), and under the assumption that no transient sources were active, only three of these sources, GX 5-1, GX 3+1 and GX 9+1, are likely to have contributed appreciably (>5%) to the total counting rate (Table 1). The contribution of GX 5-1 was very likely to have been between 25 and 65% of the total.

Figure 2 shows the behaviour of the counting rate during both observations, together with an observation of the Crab nebula which was made just before the 1975 GX 5-1 observation. For these plots, the original data, consisting of ~25 s integrations of the X-ray flux alternated with ~75 s of background measurements every 102.4 s, have been averaged into 1024 s bins. A charged particle background of approximately 100 c/s has been subtracted. The typical statistical error per bin is 1 c/s (1σ). Gaps in the data are due to passage of the satellite through the radiation belts of the Earth, once per 1.5 d orbit, and to occasional charged particle 'storms'.

The first frame of Figure 2, containing the Crab data, shows a nearly steady flux. A small downward trend in the counting rate is due to the pointing drift. From this observation it is deduced that 1 COS-B c/s corresponds to 12.6 μJy (2-11 keV mean) for a Crab-type spectrum. This observation also clearly demonstrates the stability of the detector as well as the constancy of the non-X-ray background.

The change in counting rate behaviour on day 16, after slewing to the GX 5-1 field, is readily evident. The total counting rate increases by a factor of about two over that of the field containing the Crab nebula. The appearance of the count rate plot is dominated by flaring behaviour and relatively abrupt changes in intensity with an amplitude of ~40 c/s; these have a characteristic time scale of a few thousand seconds. Together with some slower transitions of similar amplitude, these combine to yield an erratic temporal behaviour which shows no apparent periodicities.

The same type of behaviour is visible in the second observation (last frame of Fig. 2), more than a year later.

III. Analysis

In a search for periodicities with small amplitude which might underlie the irregular variability of the signal, the data have been subjected to a Fourier analysis. A 2$^{15}$-point fast Fourier transform yielded a power spectrum with a frequency resolution of 0.3 μHz and a Nyquist limit corresponding to 200 s (Figure 3). None of the peaks in the power spectrum corresponding to periods shorter than about 1 d is significant. For periods longer than one day, the power spectrum is much enhanced by the effect of the 1.5 d satellite period and the
intrinsic source variability that is apparent in the data. Accordingly, many of the low frequency amplitudes exceed the 99% confidence upper limit for statistical fluctuations due to photon noise. The same is also true for the transform of the 'window'-function and for transforms of data obtained during other observations. The significance of any peak in this region is therefore difficult to evaluate from our data alone.

Taking into account the excess variability in the signal at low frequencies, we quote upper limits (99% confidence) on periodic variability for the various sources within the field of view. The upper limits for the individual sources in Table 2 are given for the (worst case) assumption, that they were at their lowest luminosity thus far observed. Apart from the DC component, the highest peak in the power spectrum (of marginal significance), corresponds to a period of $6.5 \pm 1.0$ d and a full amplitude of 13 c/s (see Fig. 3). This peak is probably caused by recurring 1-2 d episodes of lower average flux visible in the data around days 21, 27, 32, 39 and 47.

IV. Discussion

The observed irregular intensity transitions occur on a short time scale (a few $10^3$ s). This makes it highly probable that each individual transition is the result of an event in one particular source, rather than the accidental superposition of smaller flux changes from several of the sources in the field of view, all taking place within $~10^3$ s. The amplitude of the flares and transitions, $~40$ c/s, then pinpoints GX 5-1 as the only remaining source with a previously observed flux range large enough to have caused them (Table 1). As they are visible in both observations, separated by 1.5 y, they probably do not originate from a transient source. It should be noted, however, that an origin of this variability in an unknown recurrent transient or in one of the observed 'steady' sources at an unusually high level of variability can not strictly be excluded.

If the rapid irregular variability arises in GX 5-1, this implies that this source frequently changes its intensity with a factor of at least 2 within less than an hour. Within the framework of a binary model with mass accretion, one might attempt to explain the variability in terms of changes in the intrinsic X-ray flux, i.e., in the accretion rate, or as the result of variable extinction or obscuration of the X-rays.

First, consider variable partial obscuration of an extended X-ray source by an accretion disk whose thickness varies with azimuth angle (White and Holt 1982). If the thickness of the disk is some fixed function of the position angle with respect to the symmetry axis of the binary system, (e.g., depends on the angular distance from the impact point of the accretion stream), it would be difficult to understand how such a disk could effectively hide the orbital motion of the system, while causing rapid intensity changes of a factor of $>2$.

Changes in the distribution of absorbing gas structures on the scale of the binary system, moving under the influence of gravitational forces, would occur on time scales similar to the orbital period, and consequently this could only serve to explain the observed flux changes in highly compact systems with periods of the order of 1 h. In larger systems, small absorbing structures would have to be invoked.

The present data do not contain spectral information, but in previous observations (Mason et al. 1976, Parsignault and Grindlay 1978), on somewhat longer time scales than discussed here, a positive correlation between intensity and spectral hardness was observed for GX 5-1 and several similar sources. This is opposite to the inverse correlation that is expected for intensity variations due to changing absorption, and rather points to variations in the accretion rate itself as an explanation for the observed variability. A higher accretion rate could cause spectral hardening by, for example, an increase in absorption close to the compact object (Kylafis et al. 1979 and references therein), or by higher temperatures in the X-ray producing region.

It is possible that the degree of variability in the accretion rate required to explain the luminosity variations is caused by instabilities in the inner region of the accretion disk (Lightman 1974, Pringle 1976). These might be more pronounced in Type II X-ray binaries because of the probable absence of a strong magnetic field, which could allow the disk to

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extend very much closer to the compact object than in Type I sources.

The apparent lack of variability on time scales of hours for GX 5-1, GX 3+1 and GX 9+1 tends to rule against highly compact binary models. It should be noted, however, that the X-ray flux of the 41 min X-ray binary 4U 1626-67 (Middleditch et al. 1981) is not observed to modulate with the orbital period. Furthermore, the 50 min X-ray binary 4U 1915-05 (Walter et al. 1982, White and Swank 1982), which exhibits partial and erratic X-ray eclipses, would exhibit only a small amount of power at 50 min in a Fourier spectrum, and such modulations would have been difficult to detect in any of the sources except for GX 5-1.

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References

### Table 1 Observed Steady Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Offset (°)</th>
<th>Collimator Transmission</th>
<th>Expected Counting Rate (c/s) Max</th>
<th>Expected Counting Rate (c/s) Min</th>
<th>Expected Percentage Of Total Max</th>
<th>Expected Percentage Of Total Min</th>
</tr>
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<tbody>
<tr>
<td>GX 5-1 (1758-250)</td>
<td>0.2</td>
<td>1.00</td>
<td>111</td>
<td>42</td>
<td>65</td>
<td>25</td>
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<tr>
<td>GX 3+1 (1744-265)</td>
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<td>0.76</td>
<td>40</td>
<td>13</td>
<td>24</td>
<td>8</td>
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<td>GX 9+1 (1758-205)</td>
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<tr>
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<td>0.58</td>
<td>8.3</td>
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<td>4.9</td>
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<td>GCX-3 (1743-288)</td>
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<td>3.8</td>
<td>0</td>
<td>2.3</td>
<td>0</td>
</tr>
<tr>
<td>GCX-1 (1742-294)</td>
<td>5.5</td>
<td>0.47</td>
<td>4.5</td>
<td>1.9</td>
<td>2.6</td>
<td>1.1</td>
</tr>
<tr>
<td>GX 1+4 (1728-247)</td>
<td>5.7</td>
<td>0.45</td>
<td>7.8</td>
<td>1.2</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>NGC 6624 (1820-303)</td>
<td>8.3</td>
<td>0.20</td>
<td>6.5</td>
<td>1.0</td>
<td>3.8</td>
<td>0.6</td>
</tr>
<tr>
<td>GX 13+1 (1811-171)</td>
<td>8.4</td>
<td>0.19</td>
<td>6.8</td>
<td>2.3</td>
<td>4.0</td>
<td>1.3</td>
</tr>
<tr>
<td>1755-338</td>
<td>9.3</td>
<td>0.12</td>
<td>0.9</td>
<td>0.3</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>GX 9+9 (1728-169)</td>
<td>9.5</td>
<td>0.11</td>
<td>2.8</td>
<td>1.5</td>
<td>1.7</td>
<td>0.9</td>
</tr>
<tr>
<td>FIELD TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>225.4</td>
<td>75.0</td>
</tr>
</tbody>
</table>

The non-transient X-ray sources in the field of view of the COS-B X-ray detector. The flux from non-transient, unresolved sources in the galactic center region is estimated to have contributed less than 2 c/s to the total counting rate (Forman et al. 1978). Second column gives the distance of the source from the center of the detector field, third the collimator transmission efficiency at which the source was observed. Maximum and minimum expected counting rates were calculated according to the flux ranges given in Bradt et al. (1979).
## Table 2 Upper Limits to Modulation

<table>
<thead>
<tr>
<th>Source</th>
<th>1.0-0.38 d</th>
<th>0.38-0.16 d</th>
<th>0.16-0.06 d</th>
<th>0.06-0.01 d</th>
<th>0.01-200 s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Count</td>
<td>Rate</td>
<td>Count</td>
<td>Rate</td>
</tr>
<tr>
<td>GX 5-1</td>
<td>14%</td>
<td>7.5%</td>
<td>4.2%</td>
<td>2.1%</td>
<td>0.9%</td>
</tr>
<tr>
<td>GX 3+1</td>
<td>43%</td>
<td>24%</td>
<td>13%</td>
<td>6.6%</td>
<td>2.9%</td>
</tr>
<tr>
<td>GX 9+1</td>
<td>57%</td>
<td>31%</td>
<td>18%</td>
<td>8.8%</td>
<td>3.9%</td>
</tr>
<tr>
<td>GX 13+1</td>
<td>-</td>
<td>-</td>
<td>81%</td>
<td>41%</td>
<td>18%</td>
</tr>
</tbody>
</table>

99% confidence upper limits to periodic modulations. The upper limits were derived from the local mean power for an assumed exponential distribution of power amplitudes. Note that the upper limits for an individual source were calculated from the (worst case) assumption that the source was at its lowest previously observed level.

![Figure 1. Map of the observed region near the galactic center. The geometrical transmission of the detector decreases approximately linearly from the center to the edge of the field of view (large circle).](image-url)
Figure 2. The counting rate from the GX 5-1 field and, for comparison, from the Crab at 1024 s resolution. A charged particle background of about 100 c/s has been subtracted from the signal; statistical error per bin is about 1 c/s. Note that the first three frames are consecutive in time.
Figure 3. The low-frequency part of the power spectrum of the GX 5-1 1975 observation. The power was normalized to a mean value of 1 at high frequencies. The complex appearance of the spectrum around 7.7 μHz (1.5 d) is due to the satellite orbital period. Notice the high power in the 1.8 μHz (6.5 d) bin, marked by an arrow.