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(NASA-CR-157356) JOINT OBSERVATIONS OF  
4U1223-62 BY THE SAS-3 SATELLITE AND  
COLUMBIA UNIVERSITY PROPORTIONAL COUNTER  
EXPERIMENT ON NASA ROCKET 26.054 UH Final  
Report, 1 Aug. 1977 - 31 Jul. 1978 (Columbia G3/43

N78-29539

Unclas  
28523

CAL-1405

**FINAL TECHNICAL REPORT**

NASA Grant Number NSG-5200

*TITLE OF RESEARCH:*

**Joint Observations of 4U1223-62 by the SAS-3 Satellite  
and Columbia University Proportional Counter  
Experiment on NASA Rocket 26.054 UH**

*PERIOD OF RESEARCH:*

**August 1, 1977 -- July 31, 1978**

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**AUGUST 1978**

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## 1. DESCRIPTION OF RESEARCH

### 1.1 INTRODUCTION

Recent studies have shown that many compact X-ray sources exhibit a variety of complex spectral and temporal behavior. Such sources are generally believed to be binary star systems composed of a collapsed star accreting matter from a normal companion. Short time-scale fluctuations in intensity and spectra reflect processes close to the collapsed star. In the case of some systems such as Cyg X-1 and Cir X-1, millisecond time variations have been interpreted in terms of turbulence in the innermost accretion disk surrounding a black hole (Rothschild *et al.* 1974; Toor 1977), or an extreme manifestation of general shot noise behavior found to be characteristic of Cyg X-1 (Weisskopf and Sutherland 1978). In the case of many other binaries where periodic pulsations have been detected, pulse-phased or intrapulse behavior can be used to understand physical processes close to the rotating magnetic neutron star believed to be the accreting clock (Rappaport and Joss 1977).

Comparatively few observations of the pulsating X-ray binary 4U1223-62 (GX301-2, Wray 977) have been made. It is a weak *Uhuru* source (40 counts, Forman *et al.* 1977) with strong emission above 10 keV (Ricker *et al.* 1973). It is known to be a highly self-absorbed source which exhibits large intensity variations in common with many other X-ray binaries. Iron absorption edges, iron emission lines, and other spectral anomalies have been reported (Swank *et al.* 1976; Swank 1977). A pulsation period of 696 s has been identified with the system (White *et al.* 1976). No other regular periodicities have been found for the system although orbital periods on the order of 10 to 20 days have been suggested from optical studies of the main sequence Be companion, Wray 977 (Mauder 1974; Bord *et al.* 1976; Hammerschlag-Hensterg *et al.* 1977). No high time-resolution studies of the source from 2 to 15 keV have been made although two previous searches at higher energies had yielded null results (Ricker *et al.* 1973, 1976).

We report here on coordinated observations of 4U1223-62, observed by the Massachusetts Institute of Technology instrumentation on the SAS-3 satellite and by the Columbia University proportional counter experiment on NASA rocket 26.054 UH. A second target, 4U0900-40 (Vela X-1), was observed by the Columbia rocket experiment. The observations were directed toward searching for spectral and intensity variations in these sources down to 1 ms sensitivity.

## 1.2 OBSERVATIONS

The Columbia University observations were made from an Aerobee-200 rocket (NASA 26.054 UH) launched from Woomera, Australia, at 1439 h, 15 February 1977 (UT). The payload instrumentation consisted of a bank of 50  $\mu$  beryllium window, xenon-filled proportional counters, sensitive in the energy range from 1.5 to 27 keV with 1200 cm<sup>2</sup> total open area, and another bank of 1  $\mu$  polypropylene window, argon flow proportional counters, sensitive in the energy range from 0.5 to 8 keV with 560 cm<sup>2</sup> of total open area. The xenon counters were placed behind a set of 5.6  $\times$  6.2 egg-crate type collimators, while a similar set of 8.9  $\times$  8.9 collimators defined the field of view of the argon counters. These collimators were coaligned with an aspect camera which provided pointing information accurate to better than a minute of arc every 6 s.

The instrument view axis acquired the first target, 4U1223-62, 104 s into the flight and held on target for 115 s. The second target, 4U0900-40, was acquired 15 s later and held for 95 s. The view axis was then pointed toward a region of the sky devoid of known X-ray sources for a 30 s background calibration. The rocket performed perfectly, pointing to within 0.6 of the first target and 1.1 of the second. While on target, the pointing jitter was less than 5'.

Valid X-ray events from each counter bank were digitally encoded according to pulse height (16 energy bins) and arrival times (50  $\mu$ s time resolution). This information was telemetered down to ground and analyzed for possible flaring, quasiperiodic and periodic pulsations, and other nonstatistical behavior in the source using a Cooley-Tukey fast Fourier transform program (FFT) and an autocorrelation program. The pulse height information was used to derive the source spectrum as a function of time.

For several hours 4 days before and after the rocket flight, the SAS-3 satellite performed a series of scans of the galactic plane centered on the region  $l^{\text{II}} = 300$ ,  $b^{\text{II}} = -2$  to identify the sources in the vicinity of 4U1223-62 and their intensities and to provide positional accuracy of 0.25 for sources with intensity greater than 10% of 4U1223-62.

### 1.3 RESULTS

We observed 4U1223-62 near the main peak of its pulsation period (phase = 0.83 to 1.00) as defined by SAS-3 (Rappaport *et al.* 1977). The orbital phase at the time of the observation is not defined. We have analyzed 14 bins of pulse height data from the xenon counters. The data are well fitted from 2.3 to 27 keV by a simple power law function with a photon power index of  $0.76 \pm 0.09$  (reduced  $\chi^2_{\min} = 0.9$ ; see Figure 1). Two-parameter thermal bremsstrahlung or blackbody models are not permitted by the data. There is no evidence for a spectral feature although nearly twice as many photons were received from this source as from Vela X-1. Source confusion in this rich galactic plane region could have been a problem, but coordinated observations by SAS-3 indicated that this was not the case within the  $\sim 6^\circ$  field of view of the xenon counters (Rappaport *et al.* 1977). The argon counters with their larger field of view were probably source confused and were therefore ignored for spectral analysis.

The average intensity observed,  $0.19 \text{ photons (cm}^2 \text{ s)}^{-1}$  from 3 to 20 keV, is within the 5:1 range of intensity fluctuations reported for 4U1223-62 (Ricker *et al.* 1976). We see no evidence for a significant low-energy cutoff, in agreement with Coe *et al.* (1976) and Swank (1977), but in disagreement with the highly absorbed spectra observed by Jones (1977) and Swank *et al.* (1976). Our data place a  $3 \sigma$  upper limit to the absorption column density of  $4 \times 10^{22}$  atoms  $\text{cm}^{-2}$ . To search for fast time variability of the spectrum, we partitioned our data into 15 s time intervals and fitted each segment to two-parameter power law functions. No significant variations were found.

We have also searched both sets of data from the xenon- and argon-filled counters for significant periodic or quasiperiodic behavior. No periodic component was found. Our data place a  $3 \sigma$  upper limit to periodic pulsations from 2 ms to 20 s of 5% of the total flux from the source. Autocorrelation analysis shows evidence for some nonstatistical time behavior for times less than 10 s (see Figure 2). A 2-times enhancement in the flux occurred once near pulse phase 0.95 with a rise and fall of 5 s (see Figure 3). This is responsible for most of the positive correlation. With this "flare" removed, no significant aperiodic behavior on time scales of 0.1 s to 10 s is evident.

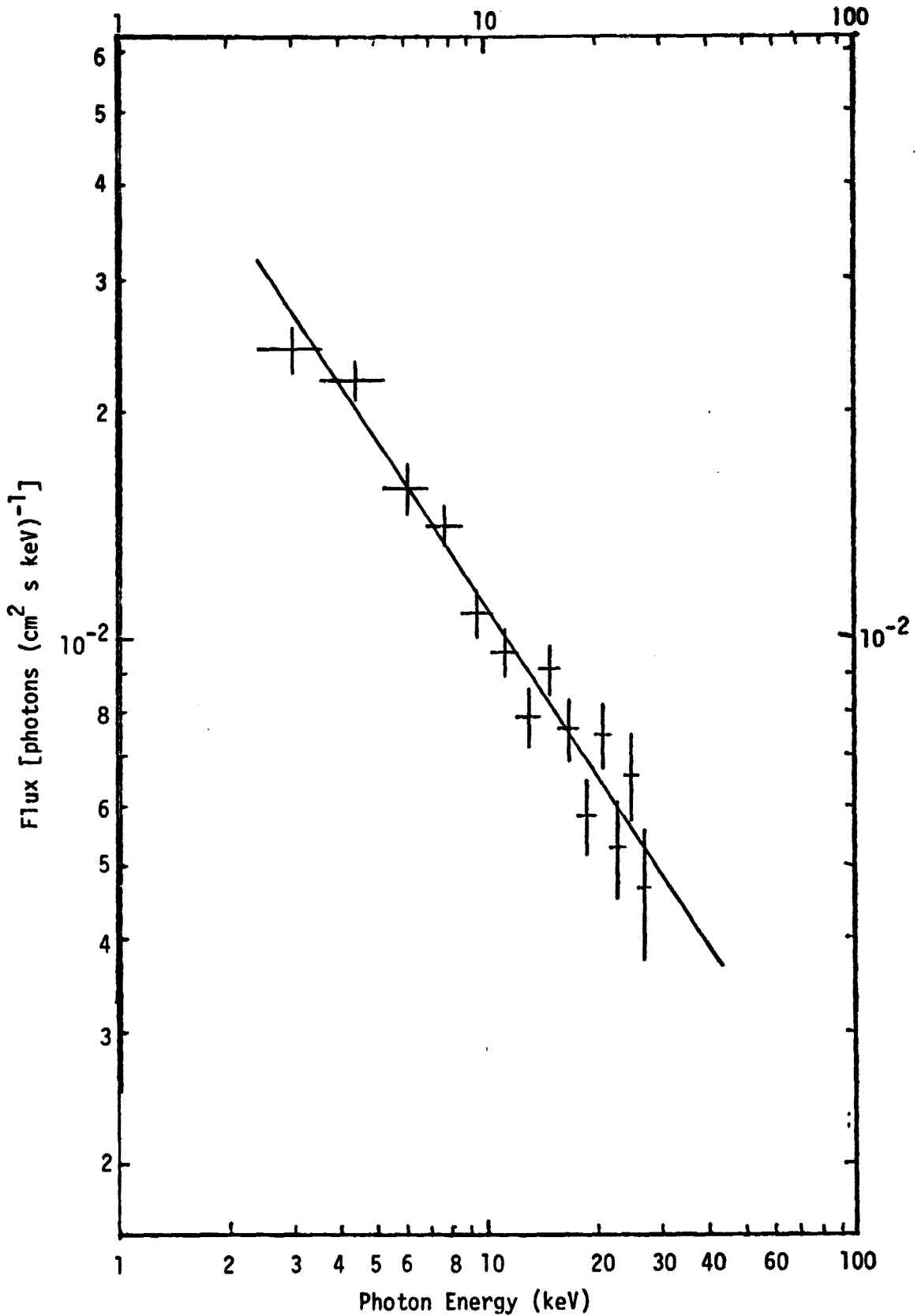


FIG. 1. — Photon spectrum of 4U1223-62 obtained between 104–219 s after launch by the set of xenon proportional counters. The best-fit function shown is  $0.061 E^{-0.75}$ .

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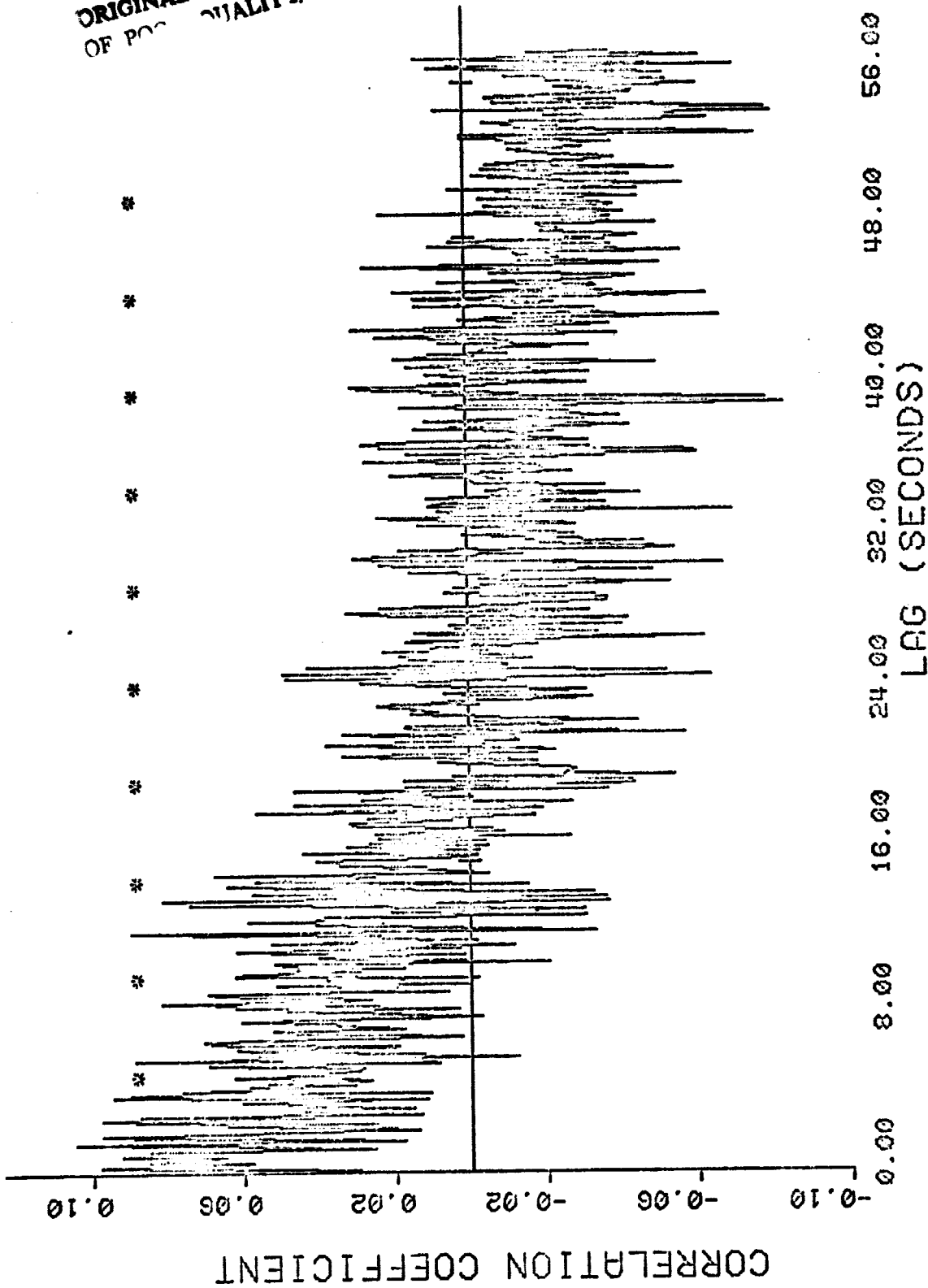


FIG. 2. - Autocorrelation function of 4U1223-62 data collected by the xenon counters for time intervals of 0.1 s. The asterisks (\*) indicate 3x the nominal standard deviation of the correlation coefficient.



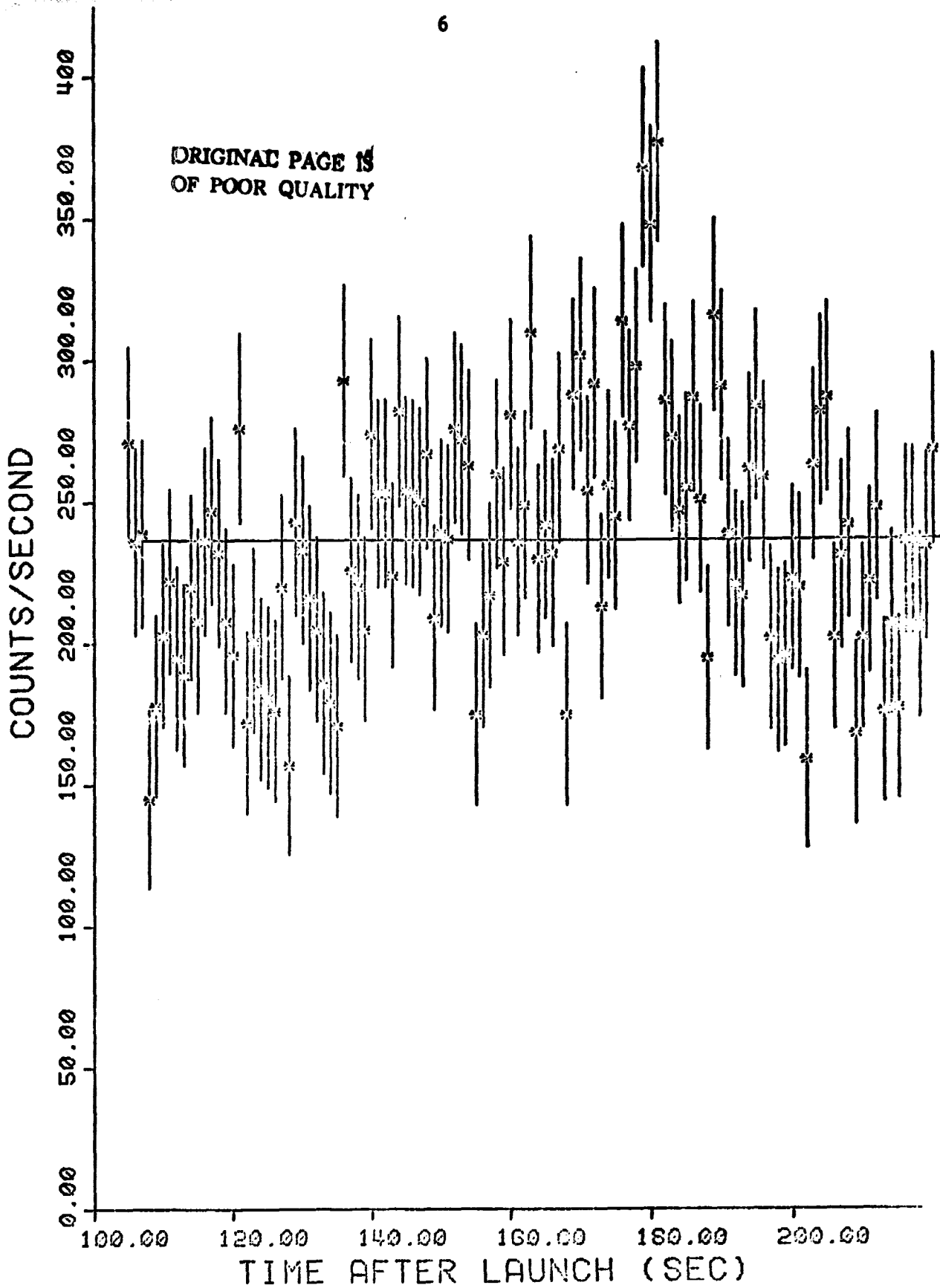


FIG. 3. - The 2-25 keV X-ray light curve for 4U1223-62 from the xenon-filled proportional counter. The horizontal line drawn through the data points indicates the mean rate of  $237 \text{ counts s}^{-1}$ .

#### 1.4 SUMMARY

These observations contribute to the increasingly convincing identification of the rotation of a magnetized neutron star with the measured pulsation period for 4U1223-62. No shorter time scale periodicities, from 2 ms to 20 s have been found for this source. Our spectral data for 4U1223-62, when compared with other observations at different epochs, confirm the large variability in both intensity and spectral character.

Future pulse-resolved studies of binary X-ray sources using instruments with higher sensitivity and better energy resolution, such as gas scintillation proportional counters (Anderson *et al.* 1978), should prove extremely fruitful.

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## 2. PUBLICATIONS

- W. H.-M. Ku and R. S. Wolff, "Observations of Pulsating X-Ray Binaries 4U0900-40 and 4U1223-62," 1978 (in preparation).

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