

UHURU AND ARIEL V OBSERVATIONS OF 3U 1630-47: A RECURRENT TRANSIENT X-RAY SOURCE

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Received 1976 June 14; revised 1976 August 13

ABSTRACT

We have analyzed *Uhuru* and *Ariel V* observations of 3U 1630-47 from 1970 December to 1976 May. During this time the X-ray source underwent four transient-like outbursts separated by approximately 600 days. This is the first example of a transient X-ray source exhibiting separate, regularly spaced outbursts. The observed features of the light curve can be applied to a model employing a collapsed object in a highly eccentric system as described by Avni, Fabian, and Pringle to predict an eccentricity ≥ 0.65 .

Subject headings: X-rays: variable — X-rays: sources

I. INTRODUCTION

Uhuru observations of "transient" behavior in 3U 1630-47 were reported by Forman, Jones, and Tananbaum (1976). The first observed outburst occurred between 1970 December and 1971 March. A second outburst was observed in 1972 October-November, and a third in 1974 March-May. The source 3U 1630-47 was next observed above background by *Ariel V* in 1976 January. In this *Letter* we present detailed observations of these outbursts and discuss the eccentric binary model for transient X-ray sources described by Avni, Fabian, and Pringle (1976).

II. OBSERVATIONS

We have analyzed *Uhuru* observations of the X-ray source 3U 1630-47 from 1970 December to 1973 February. The analysis technique is described by Forman, Jones, and Tananbaum (1976). Briefly, we superposed repeated scans of a band of the sky while the satellite spin axis location remained relatively fixed (typically for 1 day). An average intensity (or upper limit) was calculated for each day of 3U 1630-47 observations. We have examined additional *Uhuru* data for observations of 3U 1630-47 between 1973 April and 1974 June. In 1973 April the bearings isolating the stabilizing rotor from the satellite failed and the transmitter degraded. Therefore, all observations made subsequent to 1973 April consist of a few hundred seconds of data per day with a satellite spin rate of approximately 5° per second. Intensities from individual source sightings were corrected using the necessarily rough aspect information.

We have also analyzed *Ariel V* observations of 3U 1630-47 made between 1974 November and 1976 May. The observations were made with the experiment B sky survey detectors and yield source intensities

averaged over several days. The intensities and upper limits from both the *Uhuru* and *Ariel V* observations are shown in Figure 1. Two outbursts occurring in early 1971 and late 1972 and separated by ~ 600 days are clearly visible. The peak rates in the first two outbursts are about $150 \text{ Uhuru cnt s}^{-1}$ (2-6 keV), more than an order of magnitude above the intervening upper limits. During the first outburst, the source intensity increased by at least 50% in 50 days, and then declined by a factor of 3 in 30 days. We do not have continuous observations during either outburst, so that the maximum intensity could have been greater than was observed. The third outburst, centered in 1974 April, is not as well defined due to the greater uncertainties in the intensities resulting from the failure of certain satellite components. The fourth outburst observed by *Ariel V* is also clearly visible in Figure 1, and although the turn-on was not observed, the data illustrate the decay. We note that on 1975 March 3-4, observations by the ANS satellite did not detect X-ray emission from 3U 1630-47 with a 3σ upper limit of $25 \text{ Uhuru cnt s}^{-1}$ (Schreier and Parsignault 1976), which is also shown in Figure 1.

The average spectrum from each day of *Uhuru* observations was analyzed and compared with the average spectrum of this source from the survey of Jones (1976), who characterized this source with $\alpha = 4.0 \pm 0.6$ and $E_a = 4.5 \pm 0.3 \text{ keV}$ for a fit to a power law with energy index α and cutoff E_a . All fits were consistent with these average values, and the data were equally well fitted by exponential spectra with $kT = 2.0 \pm 0.5 \text{ keV}$ and $E_a = 3.6 \pm 0.4 \text{ keV}$.

III. DISCUSSION

The X-ray source 3U 1630-47 exhibits repetitive X-ray outbursts. Several authors (Avni, Fabian, and Pringle 1976; McCluskey and Kondo 1971; Tsygan 1975; Pacini and Shapiro 1975) have suggested that

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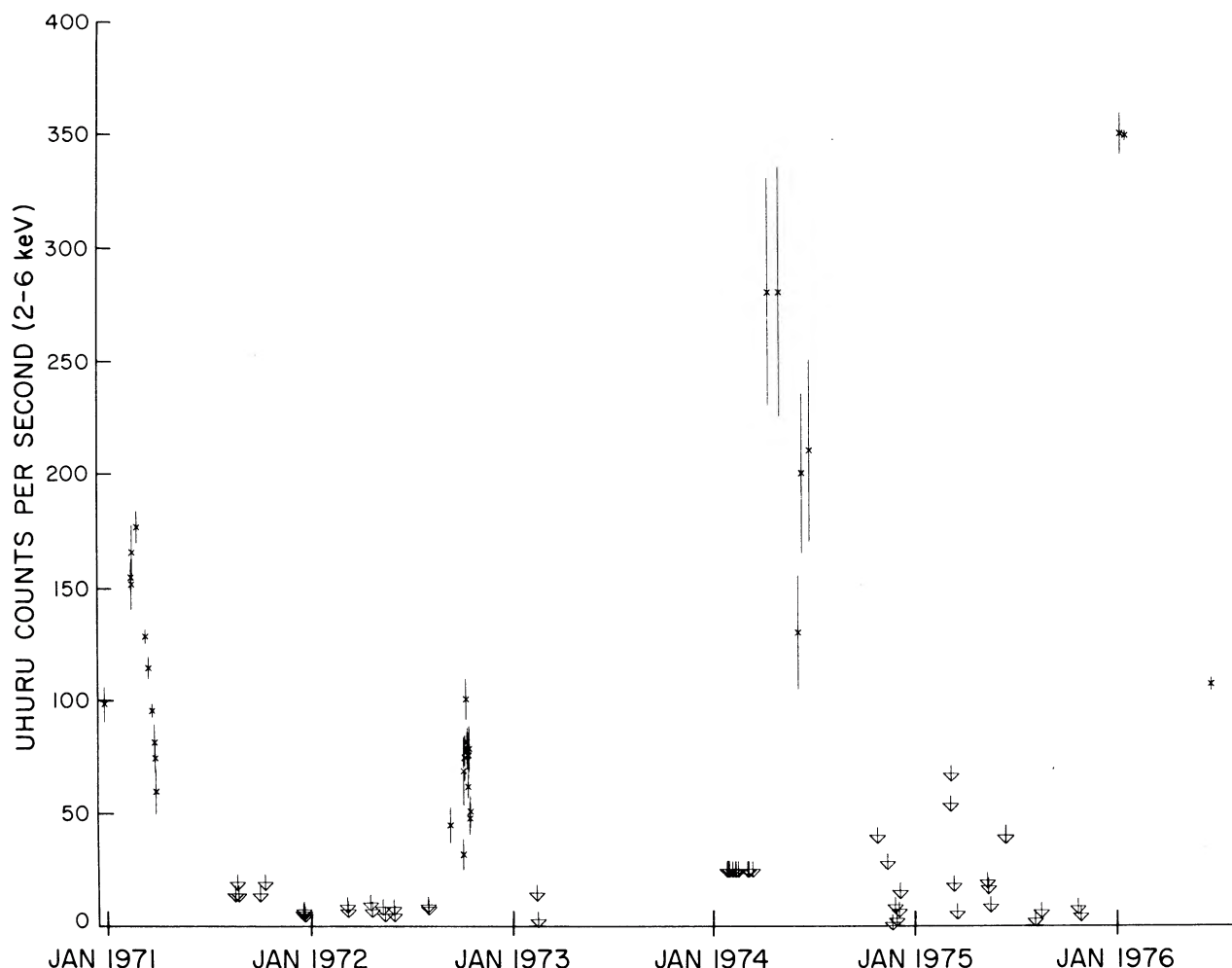


FIG. 1.—The light curve (2–6 keV) of 3U 1630–47 covering 5½ years of observations, shows four outbursts separated by about 600 days. The upper limits shown are 3σ . The large upper limits result when the source was not well centered in the collimator fields of view.

transient X-ray sources occur in binary systems in which the matter accretion rate varies greatly due to an eccentric orbit. Avni, Fabian, and Pringle (1976) derive relationships between the eccentricity and period of the orbit, the ratio of maximum to minimum intensity, the rise or decay time of the intensity variation, and the fraction of the interval for which the source is observed. The four outbursts we observed are separated by ~ 600 days, and no X-ray emission is observed in the intervening periods. If the eruptions are periodic and last more than 50 days (the minimum length of all the observed outbursts), our observations eliminate all of the possible periods less than 600 days. If we require that all the positive sightings occur at a particular phase different from all the upper limits, we find that the observations are best fitted by a period of 615 ± 5 days.

If 3U 1630–47 is in a binary system with a 600 day period, the fraction of the period for which we observe the source is ≥ 0.17 and ≤ 0.34 , and the ratio of maximum to minimum intensity is ≥ 30 . In a binary system where the primary star loses mass by a stellar wind,

these parameters imply an orbital eccentricity ≥ 0.65 (Avni, Fabian, and Pringle 1976). If we extrapolate the decay of the source and assume that the source has a rapid turn-on characteristic of transient sources, then the source is ON for $\sim 20\%$ of its period and would have an eccentricity ≥ 0.85 . Avni, Fabian, and Pringle point out that mass loss by Roche lobe overflow implies a larger orbital eccentricity than in the stellar wind loss system.

The pulsating X-ray transient source A0535+26 observed by *Ariel V* and SAS-3 in 1975 April to June (Rosenberg *et al.* 1975; Bradt *et al.* 1976) was observed to have a subsequent outburst in 1975 November (Joss 1975). A0535+26 was also observed by *Uhuru* in 1970 December (Forman, Jones, and Tananbaum 1976) and again in 1971 April at an intensity of 20–40 *Uhuru* cnt s⁻¹. Unlike 3U 1630–47, the A0535+26 observations may indicate irregular variability as has been observed for the transient source 3U 1543–47 (Li, Sprott, and Clark 1976) and for 3U 0115+63 (Forman, Jones, and Tananbaum 1976).

The observations of 3U 1630–47 presented here

represent the first example of regularly spaced multiple outbursts of a transient X-ray source. The X-ray source 3U 1630-47 may belong to a class of transient X-ray sources which consists of compact objects in long-period, highly eccentric binary systems.

We wish to thank Dr. D. Kniffen for facilitating our use of the GSFC computer facilities which enabled us to process the *Uhuru* data.

We thank J. Billings and M. Twomey for help with the preparation of this manuscript. This work is supported under NASA grant NAS5-20048 and by the Science Research Council.

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