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THE 35-d X-RAY PROFILE OF HER X-1

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Following the report from Ariel-5[1] of substantial X-ray emission from Her X-1 midway through the extended low-state portion of its 35-day cycle, Jones and Forman[2] have reported a similar feature during another cycle measured from UHURU. They further suggest that this feature should occur regularly, consistent with models for the mass accretion disc which are inclined with respect to the binary orbital plane.[3,4] We report here the results of the analysis of >500 days of Ariel-5 All-Sky Monitor data, which support the view that the feature occurs regularly in the 35-day cycle.

The Ariel-5 All-Sky Monitor is barely sensitive to Her X-1 under the most favorable of viewing constraints (see ref. 5 for a complete experiment description). Its sensitivity for accumulation times $\lesssim$ 1/2-day is no better than $\sim$ 0.1 the intensity of the Crab nebula (approximately the maximum intensity of Her X-1), so that considerations such as occultation by the earth make the average sensitivity of the experiment even poorer. During the total duration of observation reported here (16 October 1974 through 16 April 1976), a total of 803 data accumulations of $\lesssim$ 1/2-day, for which Her X-1 was not either outside or at the very edge of the experiment field-of-view, have been obtained. Only 24 of these allow intensity definition at the 2-σ level (corresponding to $\sim$ 3-σ detection of a positive signal above background). Of these 24 measurements, all but one were within the "on-time" of the 35-day cycle, and fully 1/3 were obtained from a single cycle during which the viewing constraints were rear-optimum. It is important to note that the same maximum source intensity produces, for average viewing conditions, less than a 1-σ signal.

We can, however, take advantage of the fact that we can differentiate between null statistical results under optimum viewing conditions (corresponding to a knowledge that the source was not at maximum intensity), and those at more unfavorable conditions (for which no such knowledge can be gleaned). All the data were, therefore, normalized to the same viewing constraints, with individual negative measurements of the intensity relative to background initially defined to be zero. These 803 points, excluding those measurements centered within 7% of the 1.7-d Her X-1 eclipse minimum, were then folded at various trial periods near 35 days. As exhibited by Figure 1, where we have plotted the total variance for a 15-bin light curve compared to the average value (essentially equivalent to a χ^2-test against the hypothesis of a constant source intensity), the 35-day modulation of the normalized record is apparent. Figure 1 alone prescribes a period of 34.7$\pm$.3-d (where the width of the variance peak is consistent with the overall sample duration), in agreement with the 34.88$\pm$.12-d of ref. 6. A comparison of the shape and phase of the on-state portion of the light curves obtained here with those of ref. 6 clearly favors a value of 34.9 $\pm$ .1-d.

The 34.9-d light curve is exhibited in Figure 2, where the negative-intensity measurements are now properly included in the folding procedure (allowing both consistent error estimates and a zero baseline intensity to be obtained). In addition to the characteristic reproduction of the on-state portion of the cycle (bins 1-5), bin 11 contains a > 3-σ excess relative to the surrounding off-state intensity. This feature does not arise primarily from the single high-statistical-significance off-state measurement, as that datum contributes to bin 12. Jones and Forman have reported that the analagous feature they observed in UHURU data near 1 Jan 1972 represented approximately 30% of the maximum intensity, with a duration of $\sim$ 15% of the 35-day cycle (between ϕ = .45 and ϕ = .6 relative to ϕ = 0 at maximum). The present data agree with the magnitude of the effect, but differ somewhat in phase and duration. In the Ariel-5 data, the feature is centered at ϕ = .55 $\pm$ .05 relative to maximum, with an apparent duration of $\lesssim$10% (at an intensity $\gtrsim$ 1/4 of maximum). The agreement in magnitude of the present feature with that obtained from UHURU, coupled with the fact that it is never statistically detectable in an individual measurement, strongly implies that it occurs regularly in every cycle at $\sim$ 1/3 of maximum.

Jones and Forman have attempted to refine model disc geometry parameters on the basis of the UHURU data, but the present measurements are obviously too crude to sensibly revise their estimates. Clearly, a high-sensitivity measurement of this portion of the light curve is required, and our results would suggest that this experiment is possible during any Her X-1 cycle.

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FIGURE CAPTIONS

Figure 1 Variance $\sum_{i=1}^{15} (x_i - \bar{x})^2$ for 15-bin light curves as a function of trial period. The ordinate is normalized to the mean for trial periods 32.0-33.0-d and 36.0-38.0-d.

Figure 2 Her X-1 34.90-d light curve in 15 bins. The ordinate is normalized to approximate UHURU counts for comparison with other measurements. The epoch of the start of bin 1 is JD 2,442,442.0.

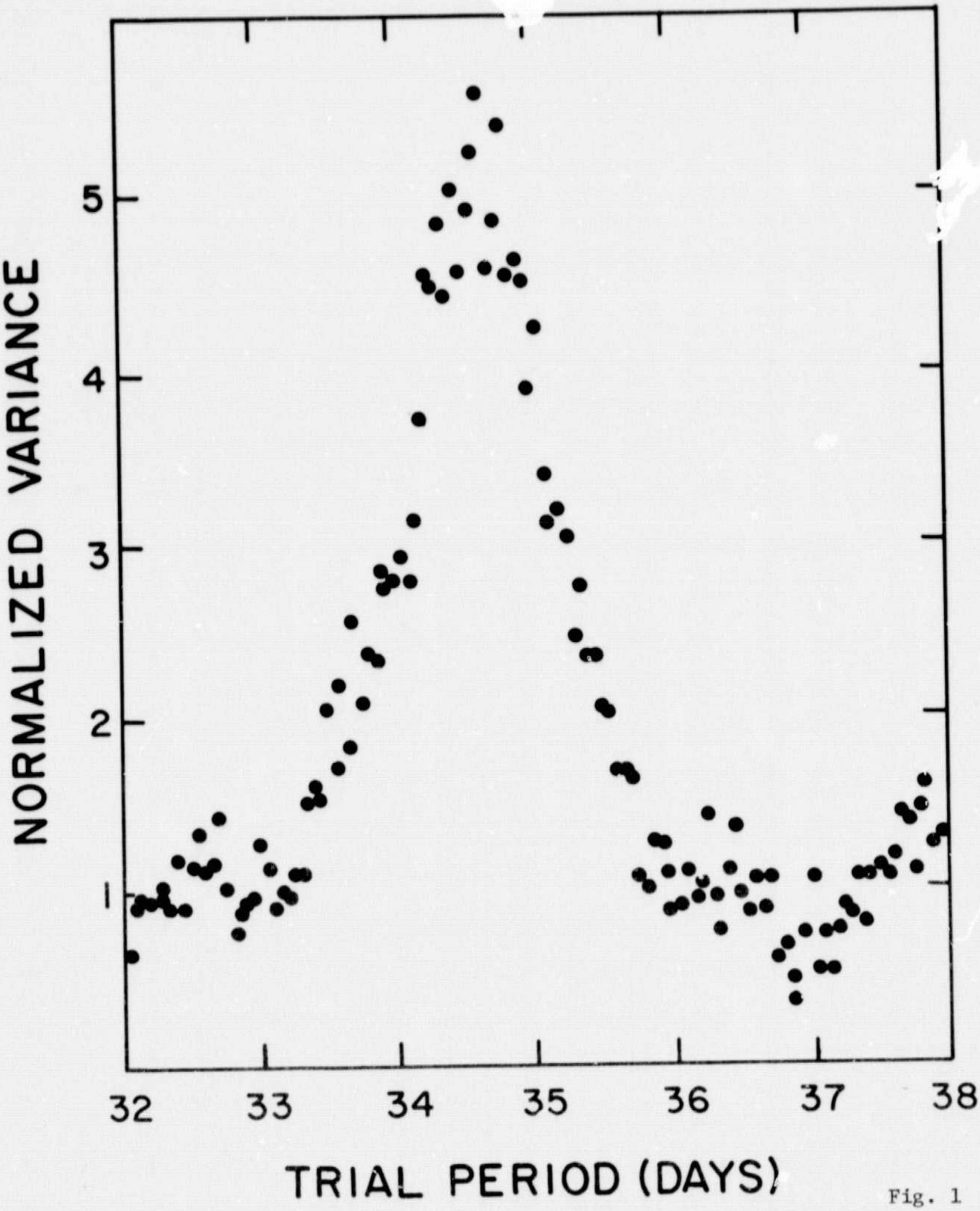
NORMALIZED VARIANCE
5
4
3
2
1
32
33
34
35
36
37
38
TRIAL PERIOD (DAYS)

Fig. 1

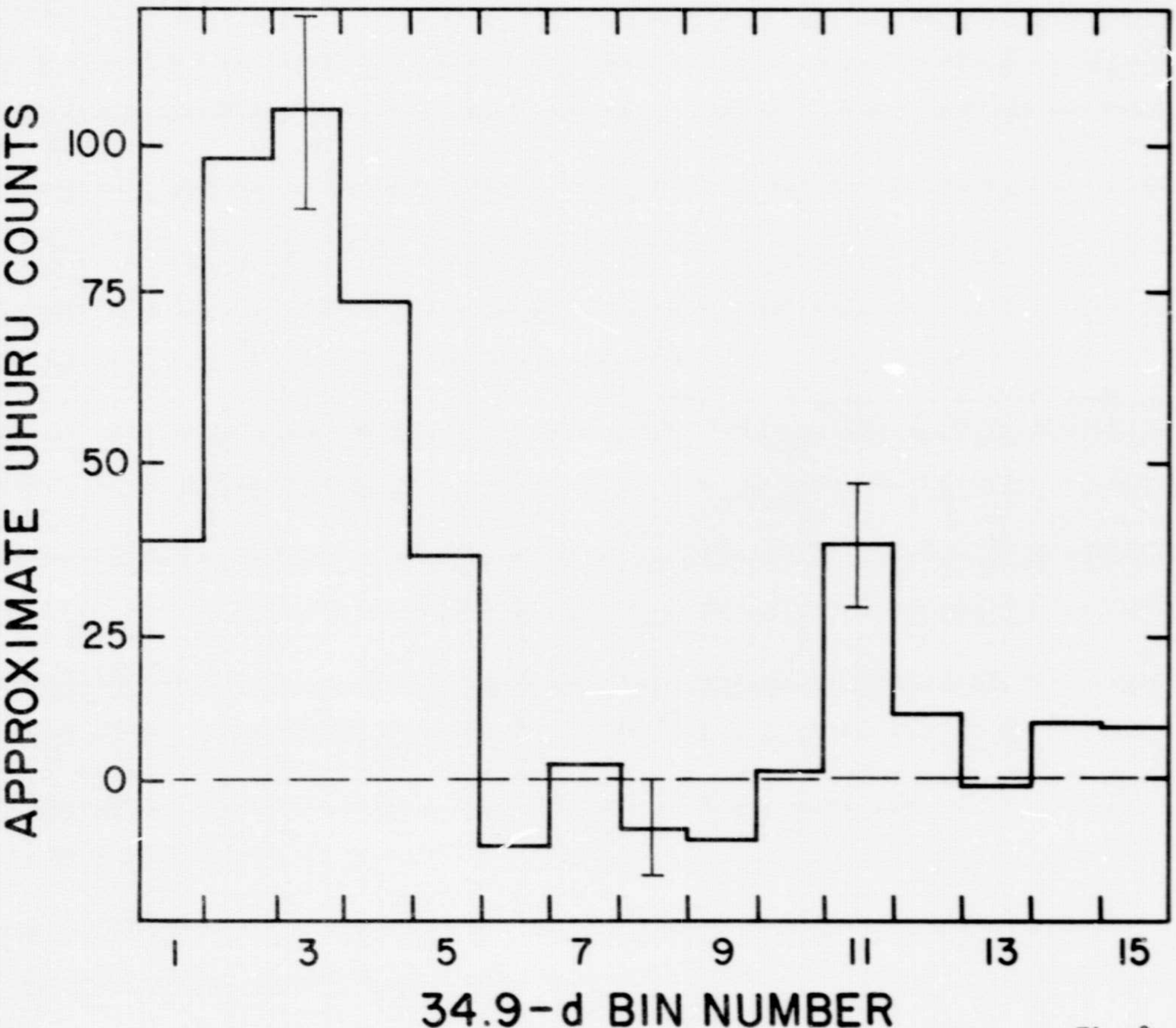
APPROXIMATE UHURU COUNTS
100
75
50
25
0
1
3
5
7
9
11
13
15
34.9-d BIN NUMBER

Fig. 2