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Optical Pulsations from 4U0900-40: Do they Exist?

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ABSTRACT

A search for optical pulsations from 4U0900-40 (HD77581) was made using H_{β} interference filters in 1977-1978. No pulsations were detected above 10^{-3} of the observed flux. This contrasts with Steiner's (1977) detection of pulsations at the 2% level. Ariel V data covering both ours and Steiner's observations show that X-ray variability does not support this discrepancy.

I. INTRODUCTION

The discovery of X-ray pulsations from 4U0900-40 by McClintock et al., (1976) has produced increased interest in the search for optical pulsations from the visual counterpart, the 6.88 magnitude B0 supergiant, HD77581. The parameters of the binary system have been refined by Ogelman et al. (1977) who found an orbital period of 8.9643 days and an eclipse duration of 1.90 days. A shorter eclipse duration of 1.69 days has been reported by Watson and Griffiths (1977). The pulse period of 282.9 seconds appears to both speed up and slow down, but according to Becker et al., (1978) the X-ray pulsar has a long term spin up with $\dot{P} = -1.0 \times 10^{-9}$. From the observed Doppler shift of these pulsations, the length of the semi-major axis was determined to be $asini = 113(4)$ lt-s (Ogelman et al. 1977).

In 1976 a search for broadband optical pulsations was made by Nelson et al. (1978) who reported pulsed fraction upper limits as low as 2×10^{-4} . Charles et al. (1978) have also reported broadband upper limits of $\sim 8 \times 10^{-3}$. More recently, a positive detection of optical pulsations using H_{β} interference filters was reported by Steiner (1977). These pulsations were reported to be present at all observed binary phases, including the X-ray eclipse, with a fractional modulation of up to 2%.

If this result is confirmed, a study of the optical pulsation period as a function of time may reveal details of neutron star structure (Lamb, Pines, Shaham 1978) as well as improved physical parameters for the binary system components (Middleditch and Nelson 1976). A study of the spectrum of the optical pulsations along with the spectrum of the X-ray pulsations could provide insight into the physical processes which produce this modulation.

In an effort to confirm the results of Steiner (1977) a search for optical pulsations from 4U0900-40, using H_{β} interference filters, was undertaken by the authors. Steiner's results were not confirmed; on 5 nights of observations no pulsations were seen, with pulsed fraction upper limits of $\sim 10^{-3}$, a factor of 20 lower than that reported by Steiner.

The X-ray satellite Ariel V has been continuously monitoring 4U0900-40 since 1974. Results of this survey (Holt et al., 1978, Holt 1978) suggest that intrinsic X-ray variability is not the source of the discrepancy between ours and Steiner's measurements; the average X-ray intensity during Steiner's observations is the same as the average X-ray intensity during our observations.

The details of our observations are discussed in this Letter.

II. THE OBSERVATIONS

Observations of 4U0900-40 using the CTIO 0.9m telescope were made by one of us (FC) on 1977 November 9 and 10. By use of a dichroic filter, the light beam was split so that simultaneous measurements through a narrow ($25 \text{ \AA}$) and a wide ($175 \text{ \AA}$) H_{β} filter were made. The counts were recorded in 0.5 second intervals for subsequent analysis.

On 1978 February 2,3, and 4 observations of this source were obtained (by JN) using the KPNO 0.9m telescope. These data were obtained using either a narrow ($30 \text{ \AA}$) or wide ($170 \text{ \AA}$) H_{β} filter and recorded in 0.1 second intervals for analysis. A summary of the observations is given in Table I.

Both sets of data were analyzed in a similar fashion. Each observation was fitted with a low order polynomial and the occasional points which deviated widely from this fit (caused by guiding errors) were replaced by their respective polynomial values. The polynomials were then subtracted from the data streams. The resulting smoothed data streams were Fourier transformed and their power spectra were examined for signals at the expected pulsation frequency and its low harmonics. No obvious signals were seen. As a result of the detrending process, the power spectra were flat, even for the low frequencies of interest, so reliable estimates of the statistical uncertainties were obtained. The upper limits derived from the observations (90% confidence level) are typically $\sim 0.1\%$ pulsed fraction and are given in Table I.

III. INTERPRETATION

Our results are in clear disagreement with those of Steiner (1977). Since Steiner saw pulsations at all observed phases and our observations cover a range of binary phases, it is unlikely that a model invoking a pulsed intensity which varies with binary phase can explain the discrepancy.

Since the X-ray flux from the source is variable, another possible explanation is that when Steiner's observations were made, the X-ray flux was much greater than during our observations. Data from the Ariel V X-ray satellite spanning 1974 to 1978 (Holt et al., 1978, Holt 1978) were examined to check this possibility. Using intensities averaged over one binary cycle, no systematic difference is seen. The averaged intensity covering Steiner's observations can be no more than 50% higher than the averaged X-ray intensity covering our observations; thus long time scale X-ray variability cannot be the source of the discrepancy. 4U0900-40 is also known to exhibit short time scale variability. Watson and Griffiths (1977) describe the variability of this source on a short time scale (~ 2 hr resolution) covering 19 binary cycles. Their most extreme flare is 10 times the average X-ray intensity. Thus, even if all of Steiner's observations were made during intense X-ray flares, and all of our observations were made during periods of average X-ray intensity, a factor of two discrepancy remains.

Theoretical models producing continuum optical pulsations by re-processing the X-ray flux in the atmosphere of the companion star (Chester 1978) predict pulsation amplitudes $\lesssim 0.2\%$ for this object. If the pulsations are actually in lines, as is implied by Steiner's results and not in the continuum, then a different pulsation mechanism is needed. Until a detailed pulsation model exists, no certain relation between X-ray pulsed intensity and optical pulsed intensity can be made.

An additional possibility for explaining the discrepancy exists. The relatively well studied optical pulsations in HZ Her-Her X-1 (Middleditch and Nelson 1976) reveal that the optical pulsation strength varies over the 35 day cycle, but mostly in a quite different fashion than the observed hard X-rays. It is thought that shadows cast by the accretion disk in the direction of the non-degenerate companion produce this apparent non-correlation between the pulsed optical and X-ray fluxes. If one could invoke a similar mechanism in 4U0900-40, then perhaps one could explain the wide range of optical pulsation strengths reported in spite of the relative constancy of the X-ray flux detected at the earth.

The resolution of this perplexing issue clearly requires additional optical observations.

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Table I

<u>Time of observation</u> <u>JD-2443450 (3 Nov 77)</u>	<u>Duration of</u> <u>run (seconds)</u>	<u>Binary</u> <u>phase</u>	<u>H_β</u> <u>filter</u>	<u>counts/s</u> <u>from star</u>	<u>Pulsed fraction</u> <u>upper limit 90%</u> <u>confidence level</u>
6.875	1160	94°-95°	N	4850	2.9 x 10 ⁻³
			W	14500	2.9 x 10 ⁻³
7.792	6000	131°-133°	N	4500	0.8 x 10 ⁻³
			W	13500	0.6 x 10 ⁻³
91.789	7000	264°-267°	N	10000	1.2 x 10 ⁻³
92.775	8627	304°-308°	W	90000	1.3 x 10 ⁻³
93.750	10945	343°-348°	N	10000	1.0 x 10 ⁻³

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