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AN UPPER LIMIT ON OPTICAL PULSATIONS FROM PSR 1913+16*

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ABSTRACT

A region of the sky covering the 2' by 2' error box of PSR 1913+16, a radio pulsar in a binary system, was searched for optical pulsations at the known pulsar frequency and none were observed. We place an upper limit of 18.2 magnitudes on any such pulsations. Within the smaller error box which has recently been suggested for this object, the limit is 19.2 magnitudes.

*This work was performed under the auspices of the United States Energy Research and Development Administration.

I. INTRODUCTION

The recently discovered (Hulse and Taylor 1975) radio pulsar PSR 1913+16 ($\alpha_{1950.0}=19^h13^m13^s\pm4^s$, $\delta_{1950.0}=+16^o00'24''\pm60''$) is an extremely interesting astronomical object by virtue of its location in a highly eccentric, short period binary system and its high pulsation frequency (16.9 Hz). Any optical pulsations that might be observed from the region defined by the above coordinates could help to establish the optical counterpart of this object, and could conceivably provide a valuable probe of the binary system as well (as in the case of HZ Herculis - Hercules X-1 (Middleditch and Nelson 1973, Middleditch 1975)). Between October 18, 1974 and November 10, 1974 we searched this region for optical pulsations having the same time-dependent frequency as the radio pulsar in a series of four photometric runs at the 61-cm telescope of the University of California's Lick Observatory.

II. EXPERIMENTAL PROCEDURE

Photons from an area of the sky defined by a 128" diaphragm were counted using an unfiltered EMI 9658R photomultiplier. Data consisted of the numbers of photons arriving in contiguous 4-ms or 10-ms time bins and were stored on magnetic tape for later analysis. Three runs consisted of 2^{20} bins; one run, which used a 59" diaphragm, consisted of only 2^{18} bins. A total of 5.5 hours of data was collected. Coverage of the four runs is indicated in figure 1. Uncertainties in positioning the diaphragm led to an error of ±5" in the diaphragm center coordinates.

Since the signals from the radio pulsar have a significant Doppler shift varying on a time scale of the same order as the duration of our runs, the usual data analysis by means of discrete Fourier transforms was inappropriate: any signal would have been smeared over many frequency bins and its significance lost. Instead, the data were signal averaged by a computer program that changed the signal averaging period 1024 times per binary period (or every 27.25 sec of data) in a manner dependent upon the elements of the orbit in order to compensate for the changing Doppler shift. The accuracy and sensitivity of the signal averaging program were confirmed using data from the HZ Her - Her X-1 system and also using simulated data corresponding to a system having orbital parameters similar to those of PSR 1913+16. The uncertainties in the orbital parameters were shown to have a negligible effect on the accuracy of this program.

III. RESULTS

Because of the complex nature of the data analysis, only those optical pulsations having the same time-dependent frequency as the radio pulsar were considered in this experiment. In each of the four runs the measured pulsation amplitude was consistent with the random noise level present in the run. Upper limits for these pulsations (assumed to be sinusoidal), together with details of each of the four runs, are given in table 1. The upper limits were established at the 90% confidence level by calculating that signal amplitude which would have been reduced by a noise fluctuation to less than or equal to the observed amplitude with a probability of 10%.

Recent radio observations (van Someren Greve et. al. 1975), made since our experiment was performed, suggest a considerably reduced error box for this object, $\alpha_{1950.0}=19^h13^m12^s.0\pm0.3^s$, $\delta_{1950.0}=+16^\circ00'18''\pm18''$. This error box lies entirely within our region No. 1, for which the upper limit on the pulsations in question is 19.2 magnitudes. We plan a substantially more sensitive search of this region during the next observing season.

We would like to thank Dr. J.H. Taylor for supplying detailed parameters of the pulsar prior to publication.

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Middleditch, J., and Nelson, J. 1973, Astrophys. Letters, 14, 129.

van Someren Greve, H. W., van der Laan, H., and Baars, J. W. M. 1975, I. A. U. Circ. No. 2741.

TABLE 1

UPPER LIMITS ON OPTICAL PULSATIONS FROM PSR 1913+16

Region No.	Coordinates of center (1950.0)	Diaphragm diameter	Date (Start of run)	Initial mean anomaly[1]	Bin width	Number of bins	Upper limit (90% confidence) on magnitude of pulsations[2]
1 (SW)	$\alpha=19^h13^m12.3^s\pm0.3^s$ $\delta=16^\circ00'02''\pm5''$	128"	18 Oct., 1974 2442338.6188 JD	$74.7^\circ\pm0.8^\circ$	10 ms	2^{20}	19.2 magnitudes
2 (NE)	$\alpha=19^h13^m14.4^s\pm0.3^s$ $\delta=16^\circ00'51''\pm5''$	128"	9 Nov., 1974 2442360.6229 JD	$117.9^\circ\pm0.8^\circ$	4 ms	2^{20}	18.2 magnitudes
3 (NW)	$\alpha=19^h13^m07.7^s\pm0.3^s$ $\delta=16^\circ01'15''\pm5''$	128"	10 Nov., 1974 2442361.5972 JD	$123.7^\circ\pm0.8^\circ$	4 ms	2^{20}	18.5 magnitudes
4 (SE)	$\alpha=19^h13^m17.0^s\pm0.3^s$ $\delta=15^\circ59'38''\pm5''$	59"	10 Nov., 1974 2442361.6583 JD	$191.8^\circ\pm0.8^\circ$	4 ms	2^{18}	18.6 magnitudes

(1) The uncertainty in the initial mean anomaly is due primarily to a ±1 min uncertainty in the initial time of the run.
(2) The magnitude of pulsations refers to the time-averaged contribution of that light corresponding to the second term in the assumed intensity, $I = I_0 + I_1(1-\cos(\omega t))$.

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FIGURE CAPTION

Figure 1. An enlargement of the red print of the Palomar Sky Survey (copyright by The National Geographic Society) corresponding to the field of PSR 1913+16; north is at the top, east to the left. The regions of the sky searched for optical pulsations are outlined by circles, numbered as in table 1. The four points, $\alpha_{1950.0}=19^h13^m13^s\pm4^s$, $\delta_{1950.0}=16^\circ00'24''\pm60''$, are indicated by crosses. The error box of van Someran Greve et. al. is not shown but lies entirely within circle 1. (Reproduction permission granted by the Hale Observatories.)

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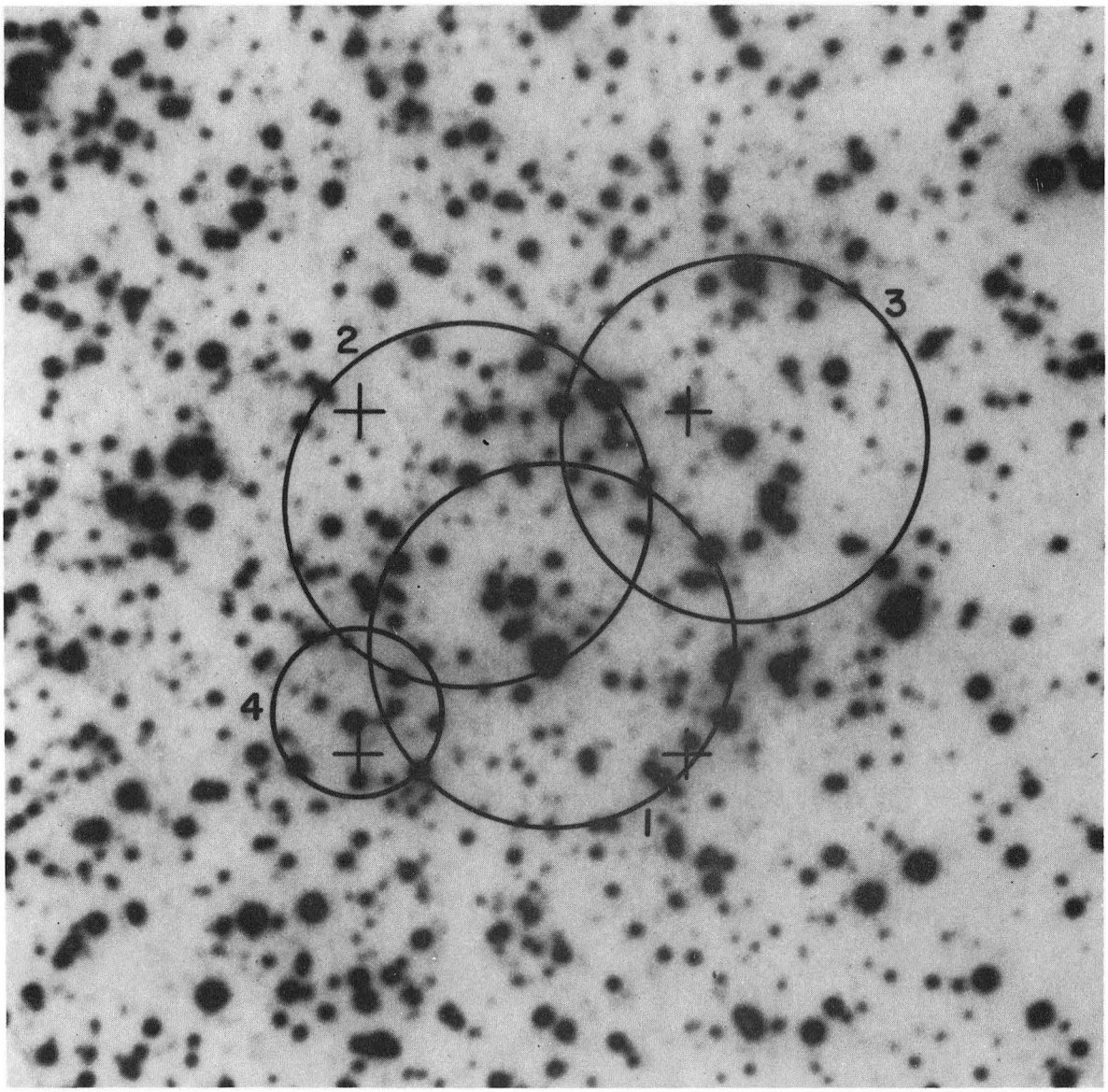

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Fig. 1

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