

UPPER LIMITS FOR THE VISIBLE COUNTERPART OF THE HULSE-TAYLOR BINARY PULSAR

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ABSTRACT

The time-averaged intensity of visible pulses from PSR 1913+16 is fainter than $V = 23$ mag. The absence of visible objects at the pulsar position on the *Sky Survey* implies a rough limit of $M > 3$ for the absolute magnitude of the pulsar's binary companion.

Subject headings: pulsars — stars: binaries

Figure 1 (Plate L10) shows the red Palomar Sky Survey plate of the field of the pulsar. The timing position of Taylor *et al.* (1976), which has an accuracy of $0''.2$, is shown by a cross. Its position in Figure 1 was measured by us with respect to four secondary position standards. The positions of these stars, which have an accuracy of order $0''.5$, are given in Table 1. If the accuracy of the timing position is anywhere near the quoted errors, it rules out the presence of any visible star at the pulsar position on either the red or blue Sky Survey plate: the nearest stars are $5''$ away. This sets a limit of $B \geq 21$ mag, $R \geq 20$ mag, for any visible object, whether pulsating or not, associated with the pulsar. In particular, this is the limit for the pulsar's binary companion. This is consistent with an early limit for pulsed visible radiation given by Chanan, Middle-ditch, and Nelson (1975).

For visible pulses, a fainter limit can be obtained from photoelectric measurements made with the 200 inch Hale reflector in 1975 July 3 and 4 and August 2 (UT), using an unfiltered photomultiplier with S20 response. Photomultiplier pulses were (a) synchronously averaged on-line at twice the apparent pulsar period and (b) continuously counted for successive 2 ms intervals, with the raw counts recorded on digital magnetic

tape. Experiments (a) and (b) were done in parallel, with (b) as a backup in the event the ephemeris used for (a) was not accurate enough. The raw data from (b) were later folded over a range of periods near the nominal period of the pulsar. All measurements were made near times of maximum positive pulsar radial velocity, and no attempt was made to correct for period changes within a single run. The duration of each run was 10 minutes or less, and the smearing due to phase slip was at most a few milliseconds.

The ephemeris used in (a) proved to be accurate, and none of the data from (a) or (b) show statistically significant visible pulsations at the pulsar frequency. The area surveyed includes a region 40 arcsec square, centered $3''$ south of the new timing position (as well as the position of the nearby faint source discovered by van Someren Greve, van der Laan, and Baars (1975) and Hjellming and Gibson (1975), which was at the time still considered to be a possible candidate).

The 4 sigma limit for visible pulsations, averaged over time, is $V > 23$ mag, assuming a pulse width of 10 ms.

The distance and visible extinction, both of which are quite uncertain, have been discussed by Davidsen *et al.* (1975). As they point out, the present limit scaled against the Crab is roughly the fourth power of the period ratio. Adopting their value of 3.3 mag of visible absorption and the Hulse-Taylor (1975) estimate of 5 kpc for the distance, the absence of any visible object on the Sky Survey sets a rough limit on the absolute magnitude of the pulsar's binary companion. It must be fainter than $M \sim 3-4$, a number which is clearly uncertain by several magnitudes.

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TABLE 1

POSITIONS OF THE STARS IDENTIFIED IN FIGURE 1

Star	R.A. (1950)	Decl. (1950)
F.....	19 ^h 13 ^m 12 ^s .25	+16°00'36".7
H.....	12.28	01 14.1
J.....	12.89	01 26.7
K.....	09.11	01 31.5
Pulsar*.....	12.48	01 08.4

* Taylor *et al.* 1976.

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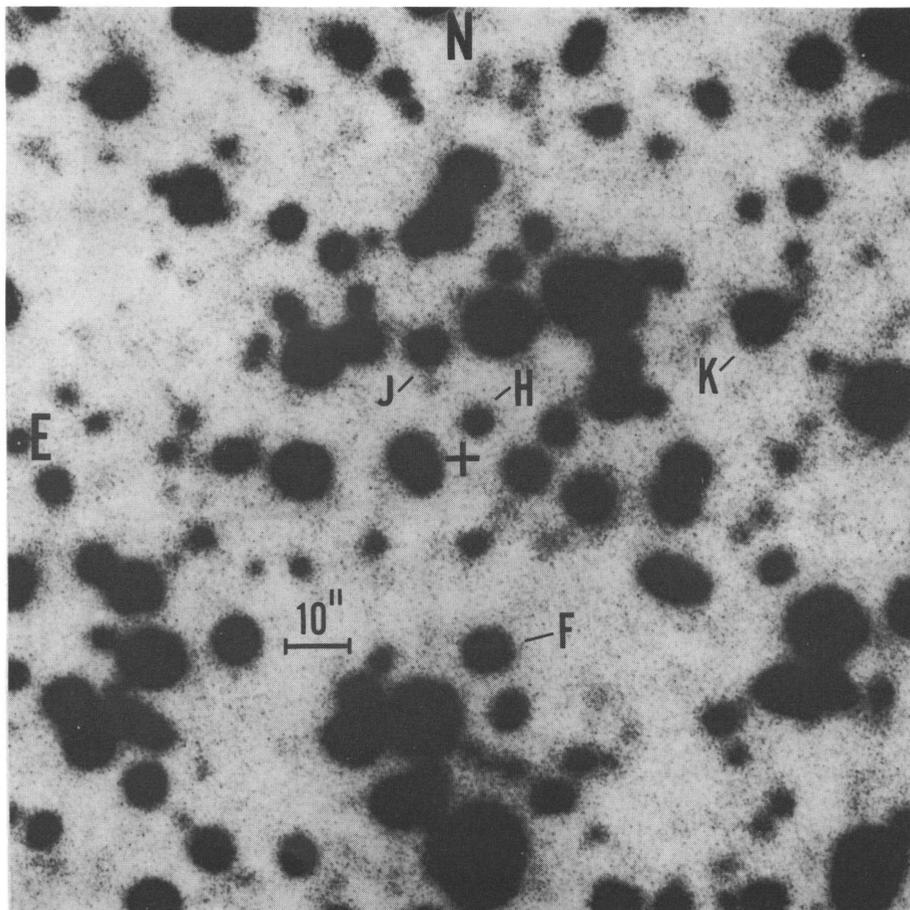


FIG. 1.—Red Sky Survey print of the field of PSR 1913+16. The cross is the pulsar timing position of Taylor *et al.* (1976), accuracy $0''.2$. Stars F, H, J, and K are local position standards measured by us; accuracy of order $0''.5$. All positions are listed in Table 1. Both the red and blue Sky Survey prints are empty at the pulsar position.

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Note added in proof.—Observations in 1976 March suggest a limit 2 mag fainter than that deduced above from the Sky Survey plates. The only candidate visible to the 200 inch plate limit is a faint red star $3''.4$ southwest of the Taylor *et al.* pulsar position.

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