ON A POSSIBLE CARBON-STAR MEMBER OF THE OLD OPEN CLUSTER TRUMPLER 5*

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ABSTRACT

A very red ($B - V \approx 6.1$) object, V493 Mon, is identified as a carbon star. The possibility of its membership in the old open cluster Trumpler 5 is discussed.

Subject headings: carbon stars — open clusters

I. INTRODUCTION

A very red object found during iris photometry of plates of the open cluster Trumpler 5, and later identified in the *General Catalog of Variable Stars* (Kukarkin *et al.* 1970) as V493 Mon, has been observed using photographic photometry (V and B), photoelectric photometry (V, R, and I), and spectrophotometry (from 6250 to 8250 Å). V493 Mon ($\alpha = 6^h35^m10\overset{s}{.}2$, $\delta = +9°26'56''$ [1975.0]) was originally discovered by Maffei (1966) during a photographic search for long-period variables in Monoceros. However, the small plate scale used and the rich star field precluded an accurate determination of the true nature of the star. The data presented here, however, make possible an estimate of the energy distribution of V493 Mon and identify it as a carbon star. We apply provisional values for the distance modulus and reddening of Trumpler 5 (Kalinowski 1975) to V493 Mon and discuss its possible cluster membership.

II. OBSERVATIONS

Figure 1 (plate L3) is a reproduction from V and B plates of V493 Mon and Trumpler 5. A summary of the broad-band observations is presented in table 1. Entries for the first three observing sessions are provisional photographic data from plates taken at the Cassegrain focus of the 82-inch (2.1 m) telescope of the McDonald Observatory. Mean magnitudes are given where possible, and the number in parentheses indicates the number of plates used in determining each value. We estimate the accuracy of these magnitudes to be approximately ± 0.05 in V and ± 0.10 in B.

TABLE 1
BROAD-BAND OBSERVATIONS OF V493 MONOCEROTIS

Date	V	$B-V$	$V-R$	$V-I$
1968 December.....	14.77 (2)	...	...	...
1970 January......	14.40 (1)	...	...	...
1970 December.....	13.46 (3)	6.13 (4)	...	...
1974 March........	13.63	...	3.84	5.62
(Unreddened)....	12.19	5.65	3.49	4.88

The 1974 March V, R, and I magnitudes are photoelectric data also obtained with the 82-inch telescope at McDonald Observatory. R and I magnitudes, utilizing BL Ori and BS 2467 as standards (Iriarte *et al.* 1965), were obtained on March 27 (UT), while V was measured on March 29 (UT). The photometry, hampered by Moon, poor weather, and the low altitude of the star, is not first-class; but the errors (estimated as ± 0.07 mag) are acceptable for this initial investigation.

The photographic data indicate an observed range of $\Delta V \approx 1.3$ for V493 Mon. Maffei's (1966) infrared magnitudes, derived from an N plate + RG 5 filter combination, show a brightness range of $\Delta m_{ir} \approx 1.6$ over a 3-year baseline, but are also too sparse to justify assignment of a period or amplitude to the star. His blue measures are contaminated by neighboring stars.

The last line of table 1 lists the unreddened values of the V-magnitude and colors of V493 Mon assuming a normal reddening law ($R = 3.0$) and adopting $E(B - V) = 0.48$, our provisional value for Trumpler 5. Since, as Fernie (1963), Schmidt-Kaler (1961), Honeycutt (1972), and others have pointed out, late-type stars show less color excess than blue stars for the same amount of interstellar material, these unreddened values may represent an overcorrection. Nevertheless, we adopt them for use in the later discussion as representative of the treatment normally employed in interstellar extinction corrections. The observed and unreddened spectral energy distributions of V493 Mon derived from the broad-band data are compared in figure 2 with those of other stars, including T Lyr, the reddest star (in $B - V$) in the list of Mendoza and Johnson (1965).

Spectrophotometric observations of V493 Mon were made on March 13 and 14, 1974 with the Goethe Link 36-inch reflector and the Indiana rapid scanner (Honeycutt, 1971) operated in the photon counting mode. The spectral range covered was from 6250 to 8250 Å. The mean of the two nights' observations is shown in figure 3 along with two comparison stars. No extinction or instrumental response corrections have been made, as our aim was simply to distinguish among a reddened early-type star, an M star, and a carbon star. In V493 Mon the red-degraded $\Delta \nu = 3$ band sequence of CN (Phillips and Leung 1973; Faÿ and Honeycutt 1972) is easily seen. Photon statistics make the detection of
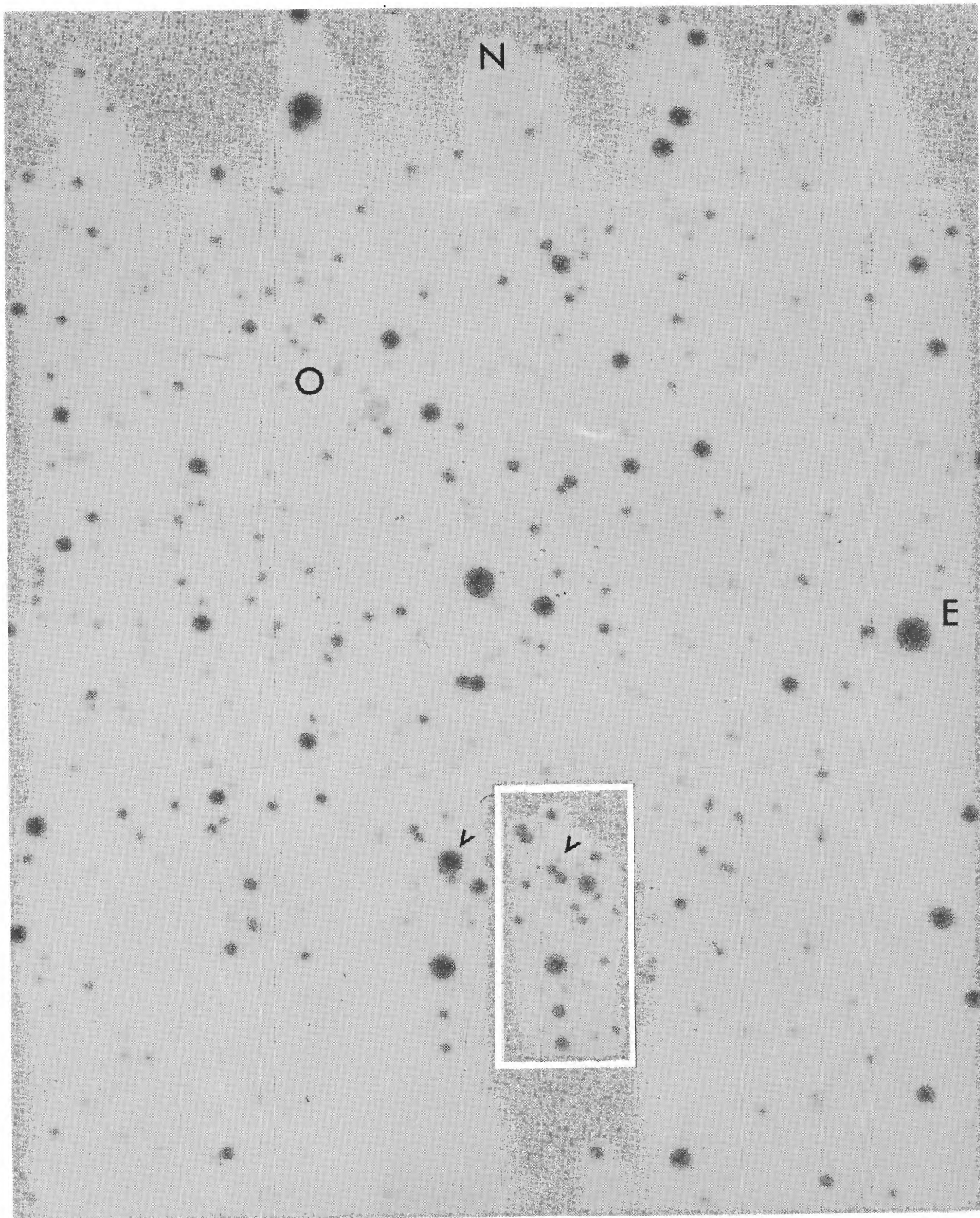
Fig. 1.—V493 Mon and Trumpler 5. Exposures were two hours in *V* and *B* (*insert*). Plates were taken with the 82-inch telescope of the McDonald Observatory. V493 Mon is at the apex of the pointers. The circle marks the approximate center of Trumpler 5, 2.5 from V493 Mon.
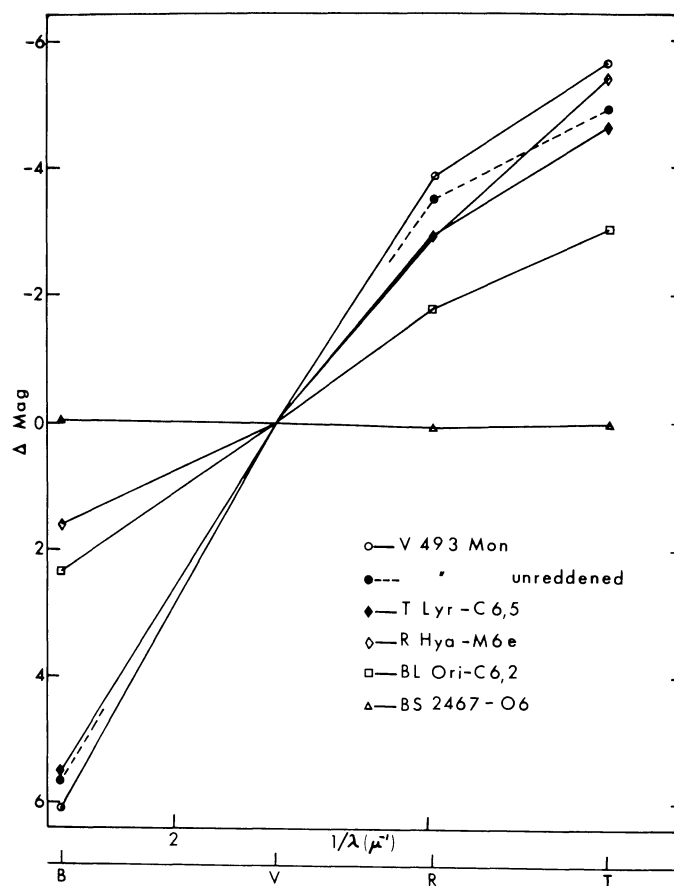
Kalinowski *et al.* (*see* page L77)

FIG. 2.—The spectral energy distribution of V493 Mon compared with other stars. T Lyr and R Hya are from Mendoza and Johnson (1965); BL Ori and BS 2467 from Iriarte *et al.* (1965).

individual CN bands in V493 Mon difficult, but the overall depression in the region of the band sequence matches the CN absorption spectrum well. M supergiants can also show CN bands in this spectral region, but the observed strength of the CN absorption, along with the absence of TiO and the star's strong blue deficiency (table 1) combine to make the identification of V493 Mon as a carbon star secure.

III. DISCUSSION

The statistical probability that the location of V493 Mon, only 2.5 from the center of Trumpler 5 ($l \approx 203°$, $b \approx +1°$), is a chance superposition can be estimated from Westerlund's (1971) catalog of carbon stars in the southern Milky Way, used here because its limiting I-magnitude is about 12.5 and the survey is confined to the galactic plane. This probability is less than 0.015. There is thus a good probability that the star is a member of Trumpler 5.

Adopting provisional Trumpler 5 parameters, $(m - M)_0 = 12.3 \pm 0.1$ and $E(B - V) = 0.48$, the absolute magnitudes of V493 Mon, from table 1, are $M_V = -0.1$, $M_B = 5.5$, $M_R = -3.6$, and $M_I = -5.0$. (Note that use of the 1970 December mean V and the same colors

will brighten all these values by 0.2 mag.) The above absolute visual magnitude is somewhat fainter than the mean values assigned to N-type carbon stars in the literature (cf. Gordon 1968; Richer 1971). There appears, nevertheless, to be considerable scatter about these mean values. Gordon's (1968) data on individual stars contain several values of M_V that are near to or greater than zero.

An examination of the data of Mendoza and Johnson (1965) suggests that the V-magnitude of V493 Mon may, in fact, be atypically depressed. Of the 22 carbon stars in their list with $R - I$ colors between ~ 1.0 and 1.8, none has $V - R$ and $V - I$ colors as red as those of V493 Mon. Of those having $R - I \approx 1.4$, not one comes within ~ 0.8 mag of being as red as V493 Mon in $V - R$ or $V - I$. It may be that the extremely high absorption found in the ultraviolet and blue spectral regions of some carbon stars extends into the visual wavelengths of the spectrum of V493 Mon. Baumert (1974) has recently questioned the meaningfulness of carbon-star absolute visual magnitudes in view of the fact that the magnitudes are functions not only of distance and interstellar reddening, but also of stellar temperature and C_2 absorption. Thus the possibility
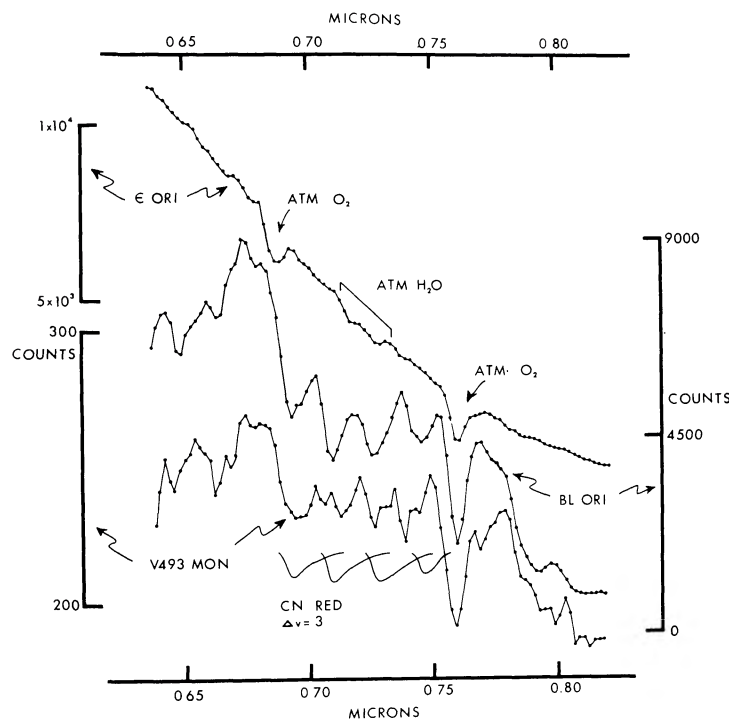
FIG. 3.—Photoelectric scans of V493 Mon and two comparison stars. The wavelength range is 6250–8250 Å, the spectral resolution is 40 Å, and the data spacing is 20 Å. Epsilon Ori is spectral type B0 Ia, and BL Ori is C6, 2.

that V493 Mon has a depressed visual magnitude but a normal bolometric luminosity seems plausible.

Baumert (1974) has ranked variable carbon stars in the order Lb, SRb, Mira, SRa in terms of increasing mean brightness at 1.04 μ and cites the good agreement of his $\langle M(104)_{max}\rangle = -5.5$ with Barnes's (1970) measure of $\langle M_I \rangle = -5.18$ for carbon Miras at maximum light. Though his data were somewhat incomplete, Maffei (1966) found no firm evidence for periodicity in the star's infrared variability. It would seem that either the SRb or Mira classification agrees well with the M_I magnitude of V493 Mon if .it is at the distance of Trumpler 5.

In brief, no presently available datum precludes the membership of V493 Mon in Trumpler 5. Further observations over a long period of time and a longer wavelength range seem appropriate.

Previously published works have considered evidence for carbon stars in the open clusters NGC 7789 (Gaustad and Conti 1971) and NGC 2260 (Hartwick and Hesser 1973), for which membership yields values of $M_V \approx -2.0$. As discussed by Hartwick and Hesser, the data imply masses for these carbon stars of $\approx 1.8 \mathfrak{M}_\odot$ and

suggest that both are in a post–helium-flash evolutionary stage. If V493 Mon is a member of Trumpler 5, its assignment to a similar evolutionary stage seems appropriate, since Trumpler 5 is an apparently very old cluster possessing a well-defined subgiant branch (Kalinowski 1975). A provisional estimate for the mass of a star at the main sequence turnoff of Trumpler 5 (assuming roughly solar metallicity) is $\mathfrak{M} \leq 1.4 \mathfrak{M}_\odot$.

Unfortunately, the kinematic association of V493 Mon with Trumpler 5 will be difficult to establish. Radial-velocity measurements do not seem promising unless the cluster's orbital velocity presently includes a significant component toward or away from the galactic center. A proper-motion study will similarly be difficult because of the cluster's distance and probable Z velocity (≤ 100 km s^{-1}). Noting Trumpler 5's age, however, a proper motion study of the cluster's general stellar membership seems desirable. One of us (J.K.K.) would appreciate information on any existing astrometric plates of the cluster region.

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