NEW MEMBERS OF THE ASSOCIATION VI CYGNI. II

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Received February 3, 1958; revised March 3, 1958

ABSTRACT

The existence of twelve additional reddened early-type stars in the O-association VI Cygni has been confirmed by (U, B, V) photoelectric observations with the 82-inch McDonald telescope. This brings to thirty-one the total number of such stars, determined either from slit spectrograms or photoelectrically.

INTRODUCTION

The present paper represents a continuation of work described in Paper I (Schulte 1956*a*) and Paper II (Schulte 1956*b*). Paper I dealt with an experimental technique, adapted from the work of Morgan, Meinel, and H. M. Johnson (1954), of very low-dispersion spectral classification; the technique is designed to be efficient in the recognition of early-type stars and particularly so in the important case of distant O–B association members which have suffered reddening due to interstellar selective absorption. That this was true was illustrated by the reinvestigation of the central regions of the highly reddened association known as VI Cygni; to the list of seven stars published by Morgan *et al.* (1954), ten additional suspected members were added in Paper I.

Paper II described, in part, observations of five members of the seven-star list mentioned above; colors and magnitudes were measured on the (U, B, V) system, using the McDonald Observatory 82-inch telescope and photoelectric photometer. For four of the five stars, the ($B - V$) and ($U - B$) colors indicated that the predictions of their being of early type were correct; the fifth, from its faintness in the ultraviolet, appeared to be a late-type star.

RECENT OBSERVATIONS

On the nights of July 26–27 and 27–28, 1957, the seventeen stars referred to by Morgan *et al.* and in Paper I were observed photoelectrically in U, B, and V with the 82-inch reflector of the McDonald Observatory. The photometric equipment used was designed by Hiltner; the 1P21 photomultiplier was unrefrigerated. The author wishes to express his thanks to Dr. Hiltner for the use of the photometer and for the amplifier calibration and also to Dr. Blaauw, who shared his last two observing nights in order that these observations would not be completely clouded out. Because of the higher sensitivity of the photometer amplifier, it was not possible to use the same primary standard stars as in Paper II; instead, two stars from Johnson and Morgan's (1953) "Fundamental Stellar Photometry"—β Cygni B and HR 6806—were used to transfer to the U, B, V system. Regular observations of previously measured stars within the association were also made during the course of the two nights to check the accuracy of the observations, as discussed below.

The first four columns of Table 1 list the present status of the VI Cygni photometric data. The observations for known association members numbered 1–11 were obtained by H. L. Johnson and Morgan (1954); the values for No. 12 are by Sharpless (1957), and the author's 1957 determinations are listed in the case of suspected members numbered 14–30. The probable foreground star No. 13 was omitted. Numbers 14–17 show systematic differences between the 1957 observations and those of Paper II, averaging

1958ApJ...128...41S

0.06 mag. in V, 0.04 mag. in $(B - V)$, and 0.06 mag. in $(U - B)$; the 1957 values, however, have estimated probable errors of not more than 0.03, 0.02, and 0.03 mag., respectively; most of stars 14–30 are represented by at least two 1957 observations.

DISCUSSION

Before the remainder of Table 1 is discussed, attention is called to the $(B - V)$ versus $(U - B)$ color diagram, Figure 1, in which all the Table 1 stars except No. 12 are plotted, along with a number of standard stars to delineate the unreddened main sequence. The lines labeled "O8," "B0.5," "B2," and "B5" represent "reddening paths" along which stars of corresponding spectral types should lie when subjected to different degrees of interstellar absorption. The work of Hiltner and Johnson (1956) suggests that this family of reddening paths is well represented by the parabola

TABLE 1

SPECTROSCOPIC AND PHOTOMETRIC DATA

Star No.	V	$B-V$	$U-B$	MK	$E_{(B-V)}$	M_v
1	11 09	+1 42	+0 31	O9 *V*	1 73	−5 0
2	10 61	+1 15	+ 13	B1 I*b*?	1 41	−4 5
3	10.22	+1 61	+ 47	O9?	1 92	−6 4
4	10 22	+1 17	+ 09	O8	1.48	−5 1
5	9 1 (var.)	+1 67	+ .55	O7f	1 99	−7 1
6	10 67	+1 22	+ 18	O8 *V*	1 53	−4 8
7	10.50	+1 44	+ 30	O6f	1 76	−5 7
8A	8 98	+1 29	+ 14	O6f	1 61	−6 8
8B	10 31	+1 35	. . . . .	O8?	1 66	−5 6
8C	10 08	+1 35	+ .10	O6?	1 66	−5 8
8D	11.93	+1.43	+ 30	O9?	1 74	−4.2
9	10 80	+1.93	+ .65	O5f	2 26	−6 9
10	9.88	+1 52	+ 40	O9.5 I*a*	1.83	−6 5
11	10 04	+1.43	+ .25	O6f	1 75	−6 1
12	11.47	+3 19	+2 01	B5 I*a*?	3 35	−9.5
14	11 61	+1 23	+ .14		1 53:	−3 9:
15	11 28	+1 19	+ .09		1 49:	−4 1:
16	11.00	+1 17	+ .06		1 47:	−4 3:
17	11 75	+1 36	+ .23		1 66:	−4 2:
18	11 09	+1 91	+ .65		2 21:	−6 4:
19	11 06	+1 60	+ .37		1 90:	−5 5:
20	11 62	+1 12	+ 03		1 42:	−3 5:
21	11 50	+1 02	− .07		1 32:	−3 4:
22	11 68	+2 01	+ .70		2 31:	−6 2:
23	12 61	+1 49	+ 14		1 79:	−3 7:
24	11 97	+1 60	+ 35		1 90:	−4 6:
25	11 74	+1 55	+ .44		1 85:	−4 7:
26	11 87	+1 61	+ 41		1 91:	−4 7:
27	12.25	+1 62	+ 50		1 92:	−4 4:
29	12 04	+1 47	+ 22		1 77:	−4 2:
30	12 36	+1 58	+0 68		1 78:	−3 9:

$$(U-B)_{\text{obs}} = (U-B)_{\text{int}} + 0.72E_{(B-V)} + 0.05\,[E_{(B-V)}]^2 ,$$

in which $E_{(B-V)}$ is the color excess, $(B - V)_{\text{obs}} - (B - V)_{\text{int}}$. Table 2 lists the intrinsic $(B - V)$ and $(U - B)$ colors which were used to define the four curves in Figure 1.

In Figure 1, VI Cygni stars numbered 1–11 (except No. 2) are plotted as open circles. They are all of spectral type O5–O9.5; the column headed "MK" in Table 1 gives Morgan's spectral types from 82-inch spectra taken by Bidelman (Johnson and Morgan 1954).

The crossed circle is the B1 *Ib* star, No. 2. The half-filled circles represent Nos. 14–30, for which slit spectra are as yet unavailable. With the exception of No. 30, which lies between the B2 and B5 curves, stars 14–30 fall in the region in the two-color diagram where reddened stars of types earlier than B1 are predicted to fall.

Morgan, Harris, and Johnson (1953) give -0.32 to -0.28 as the range of intrinsic $(B - V)$ colors between spectral types O7–B0.5. If the assumption is correct that stars

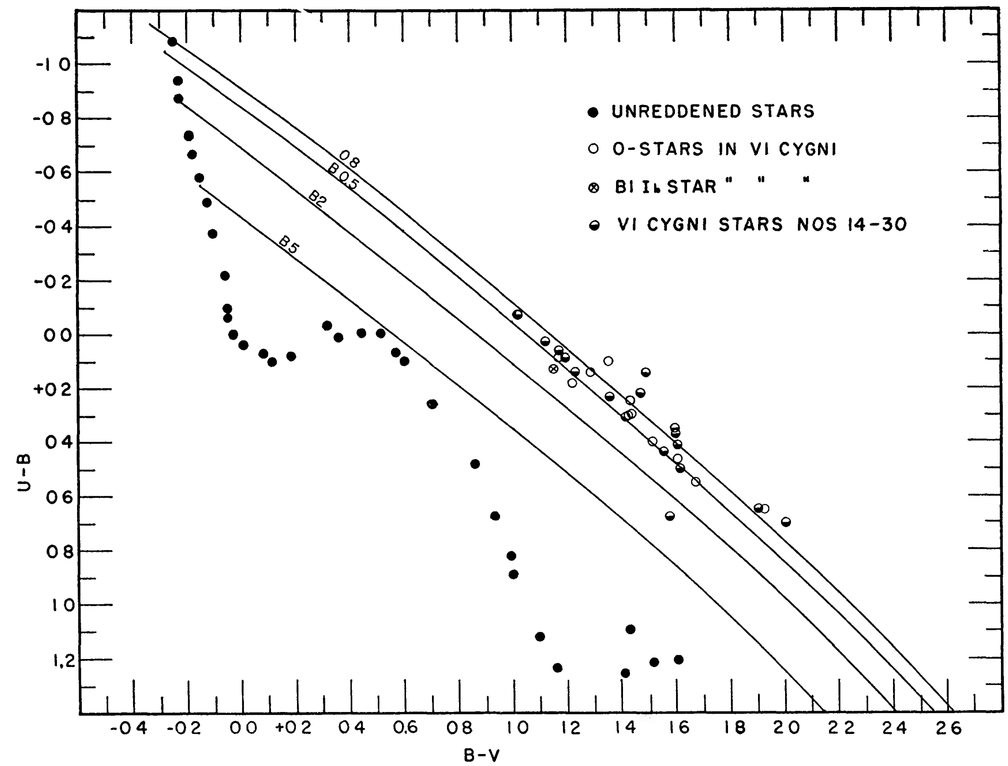

FIG. 1.—Two-color diagram of unreddened standard stars and of stars in VI Cygni

TABLE 2

INTRINSIC COLORS

MK	$(B-V)$	$(U-B)_{int}$	MK	$(B-V)_{int}$	$(U-B)_{int}$
O8	−0 32	−1 17	B2	−0 24	−0 88
B0 5	−0 28	−1 06	B5	−0 15	−0 55

14–29 are of types earlier than B1, then an average intrinsic $(B - V)$ of -0.30 assigned to them should not be too much in error and will enable an approximate determination to be made of their absolute magnitude and color excess. The sixth column of Table 1 lists the resultant color excesses, along with previously determined values for Nos. 1–12. An intrinsic color of -0.20 was assumed for No. 30. The total visual absorption, $3E_{(B-V)}$, combined with the V magnitudes and a distance modulus of 10.9 for the association, yielded the absolute magnitude values in the seventh column. The latter, even in the case of Nos. 1–11, are, of course, subject to systematic error if the original mean distance modulus should be found to need revision.

CONCLUSIONS

Figure 2 is a diagram of the center of VI Cygni, measuring approximately 100 square parsecs in cross-sectional area at the assumed distance of 1500 parsecs. The color excesses

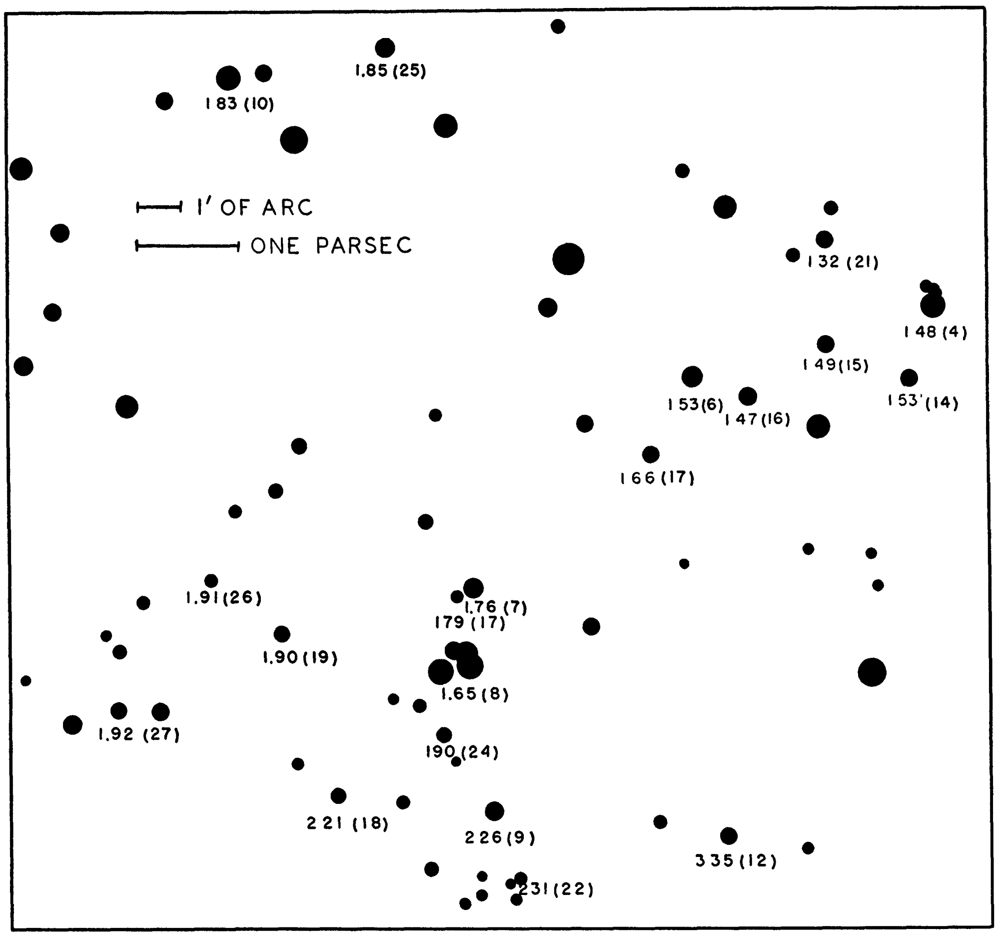

FIG. 2.—Diagram of the central region of VI Cygni; the bright star to the right of the "one parsec" symbol is HD 195988 (1900 co-ordinates 20h29m.4; + 41°7′); north is up; see text for explanation of numbers.

are written directly below the respective Table 1 stars occurring in the area of the diagram. The numbers in parentheses are the stars' designation numbers. It will be seen that the indirectly derived color excesses for Nos. 14–27 seem to be as well correlated with position on the sky as are the stars with directly determined color excesses and known to be association members. The color excesses are smallest in the upper right, are uniformly greater along the left side, and increase rapidly toward the lower right, with a maximum at star No. 12. The correlation can be said at least not to disprove the hypothesis that the stars are all at about the same distance, if they are more or less imbedded in interstellar material. The subjective argument can, of course, be used; a small areal dispersion of early-type stars would not be expected to be accompanied by a large radial dispersion. The volume of space bounded by the limits represented by Figure 2 and by the depth of VI Cygni is approximately 1000 cubic parsecs. The density of stars earlier than B2 in this region is therefore of the order of 0.02 per cubic parsec. The very high density compared to normal associations, as well as its small diameter, makes tempting the thought that VI Cygni may be a nascent association in its very early stages of expansion.

More spectroscopic observations are needed, either with large instruments or by use of techniques such as the infrared spectroscopy employed by Sharpless (1957) on No. 12. Also, a more thorough photoelectric investigation of the entire region might provide valuable statistical information.

The author wishes to thank Drs. A. B. Meinel and W. W. Morgan for their continued interest in and advice regarding this work, and Dr. G. P. Kuiper for the opportunity to use the 82-inch telescope.

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