THE ASTROPHYSICAL JOURNAL, 292:148–154, 1985 May 1

THE YOUNG OPEN CLUSTER STOCK 16: AN EXAMPLE OF STAR FORMATION IN AN ELEPHANT TRUNK?

DAVID G. TURNER
Department of Astronomy, Saint Mary's University, Halifax, Nova Scotia
Received 1984 August 6; accepted 1984 November 13

ABSTRACT

UBV photometry is presented for 33 stars in the young open cluster Stock 16 lying in the H II region RCW 75, and these observations are used to obtain new values for the reddening ($E_{B-V} = 0.49 \pm 0.01$), distance (1.90 ± 0.08 kpc), and age ($3\text{–}5 \times 10^6$ yr) of the cluster. The nearby Cepheid V378 Cen and the W-R stars MR 44 and MR 45 are confirmed as nonmembers of Stock 16, although the latter may be members of an anonymous background association which lies at a distance of 3.6 kpc. The relationship of Stock 16 to nearby members of Cen OB1 and Cen R1 is discussed, and arguments are presented for the origin of this sparsely populated cluster from a now-truncated elephant-trunk structure visible in RCW 75. Numbers of faint stars found just within the eastern boundaries of RCW 75 are suggested to be low-mass pre–main-sequence stars formed from the interaction of the ionization/shock front from RCW 75 with the adjacent gas and dust complex. Stock 16 and RCW 75 otherwise constitute what appears to be a rather passive star-formation complex.

Subject headings: clusters: open — stars: Cepheids — stars: formation — stars: Wolf-Rayet

I. INTRODUCTION

This paper presents the results of a new photometric study of the poorly populated open cluster Stock 16 and explores its possibly unique relationship to the surrounding gas and dust complexes. Stock 16 (C1315−623, $l = 306^\circ.11$, $b = +0^\circ.14$) lies in Centaurus just east of the Coal Sack in Crux, and its brightest stars ($V < 12$) have been observed photoelectrically previously by Lyngå (1970*a*) and Crampton (1971) on the *UBV* system, and by Lundström and Stenholm (1980) on a narrow-band system similar to that used by Smith (1968) to study Wolf-Rayet stars. It is a very young cluster lying at a distance of 2 kpc, and sits at the heart of the H II region RCW 75 (Rodgers, Campbell, and Whiteoak 1960). A photographic *RGU* survey of the cluster to $G = 17$ has been published by Fenkart *et al.* (1977), but the data yield little additional information on its distance, age, and stellar content. MK spectral classifications for the brightest cluster stars have been published by Lyngå (1970*a*) and Crampton (1971), and the most luminous cluster member has been identified by Walborn (1973) as a hot O7.5 III((f)) star which, with other bright cluster members, is the source of illumination for RCW 75.

RCW 75 lies at the western edge of a prominent dust complex which extends for more than a degree along the galactic plane in Centaurus. The situation is illustrated schematically in Figure 1, although a complete discussion of the details in this diagram is deferred until § VI. The emission nebulosity associated with RCW 75 is not very noticeable on blue plates of the region, and as a consequence the dust filaments on its eastern edge were mistakenly identified as a fossil H II region by van den Bergh and Herbst (1975). These dust filaments contain a number of B-type stars which illuminate reflection nebulosity and which constitute the heart of the R association Cen R1 (Herbst 1975). A probable association of these objects with the OB association Cen OB1 has also been noted by Herbst (1975), so that from all appearances Stock 16 lies at the active center of an interesting star-formation complex with which it is intimately associated. It is the cluster's role in the star-formation sequence which we wish to examine here.

In addition to the objects mentioned above, the surroundings of Stock 16 also contain three noteworthy stars which previously have been briefly investigated as possible outlying cluster members. Two of these are the W-R stars MR 44 and MR 45 (WR 50 and WR 51 of van der Hucht *et al.* 1981), which seem certain to be background objects seen in projection against the cluster corona (Crampton 1971; Lundström and Stenholm 1980). The third is the $6^d.46$ Cepheid V378 Cen, which probably lies foreground to Stock 16 (Lyngå 1970*a*). It was our original intention in reobserving Stock 16 to examine the case for cluster membership of V378 Cen in more detail. The results of this investigation are included in this study.

II. OBSERVATIONS

Photoelectric *UBV* observations of Stock 16 stars were obtained on four nights in 1976 February/March, three nights in 1977 August, and three nights in 1981 May using the University of Toronto's 0.6 m telescope in Chile at the Las Campanas Observatory of the Carnegie Institution of Washington. Measurements were made using a single-channel, pulse-counting photometer equipped with a dry-ice cooled 1P21 photomultiplier and standard *UBV* filters, and have internal and external errors in the magnitudes and colors which are virtually identical to those cited in a similar study of Stock 14 (Turner 1982*a*). The magnitudes and colors found here for stars in Stock 16 are presented in Table 1, with the stars identified according to the numbering system of Figure 2 (Plates 3 and 4).

The data in Table 1 are closely tied to the *UBV* system through observations of standard stars obtained at the same time as the observations of cluster stars. However, because a number of stars in Stock 16 have been observed by other authors, a comparison of the present photometry with previously published data, as given in Table 2, is instructive. It can be seen from Table 2 that the present *V* magnitudes for Stock

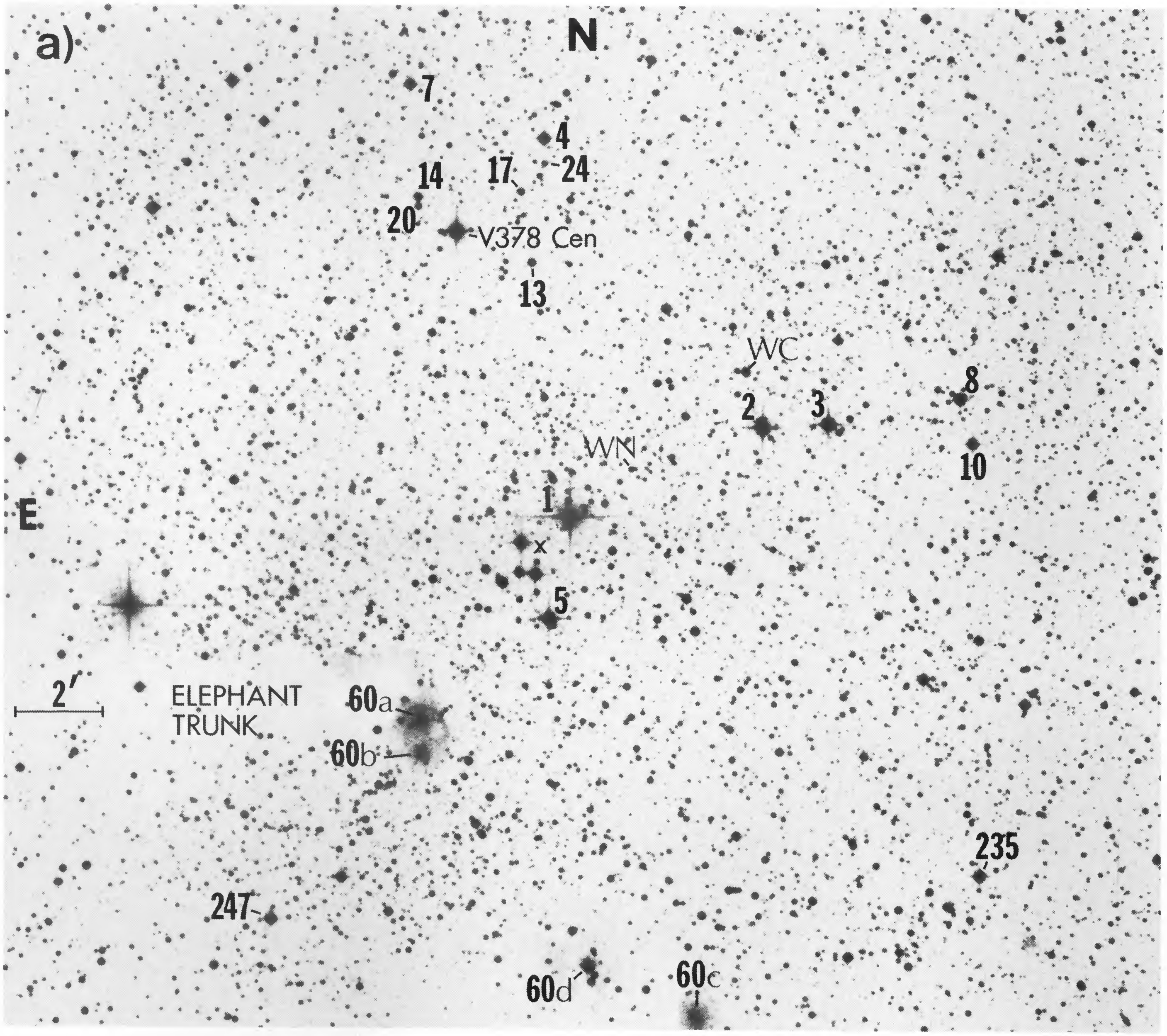

FIG. 2.—Identification chart for (*a*) the Stock 16 region, and (*b*) the cluster nuclear region as reproduced from the ESO B Survey plate (*copyright European Southern Observatory*). Stars 1 to 33 are from Table 1, 60a, b, c, and d are from van den Bergh and Herbst 1975, and 235 and 247 are from Lyngå 1970*a*. The two W-R stars in the region are identified as WC (MR 44) and WN (MR 45), and X denotes the location of the cluster center found from star counts.

TURNER (*see* page 148)

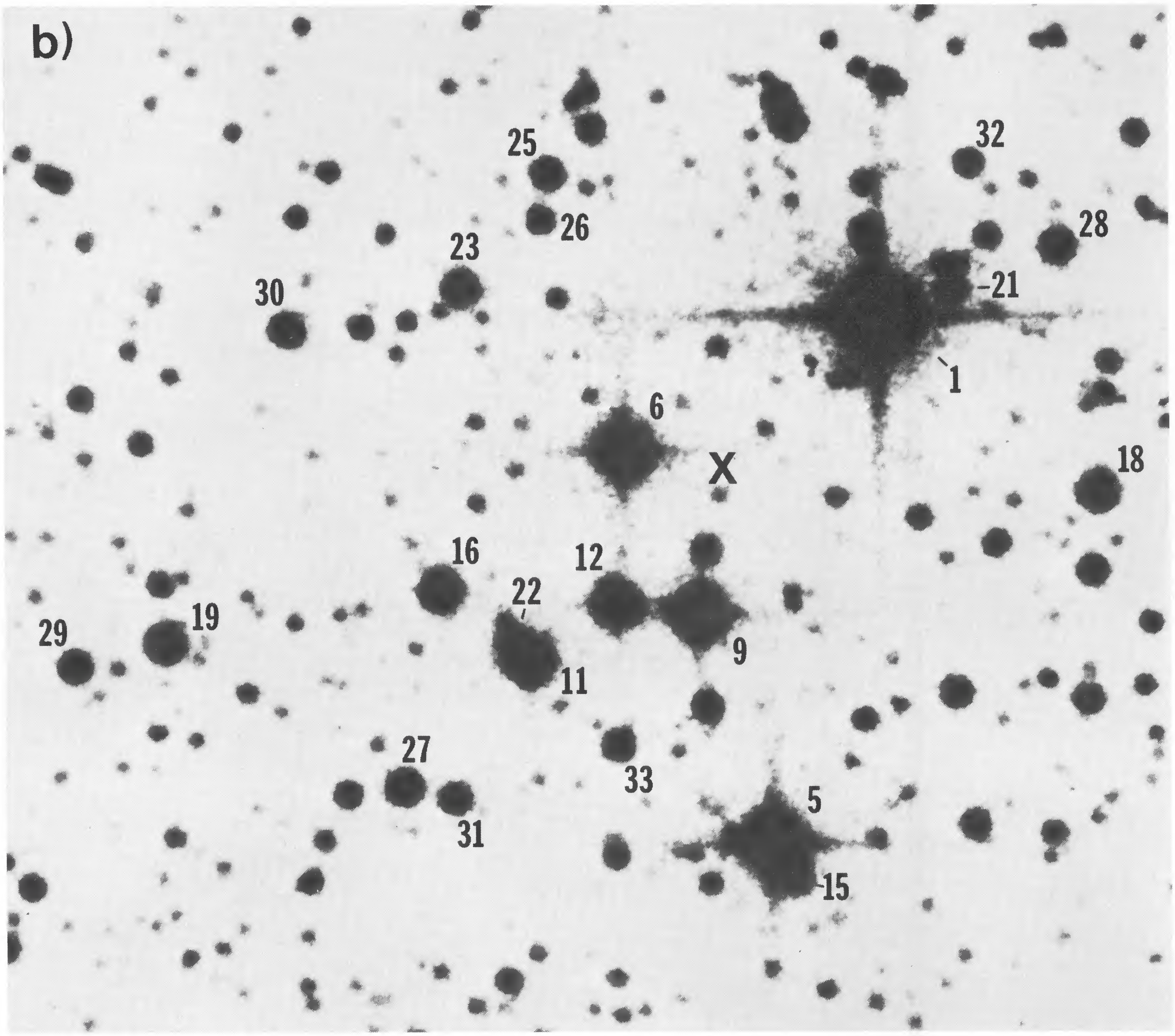

FIG. 2*b*

TURNER (*see* page 148)

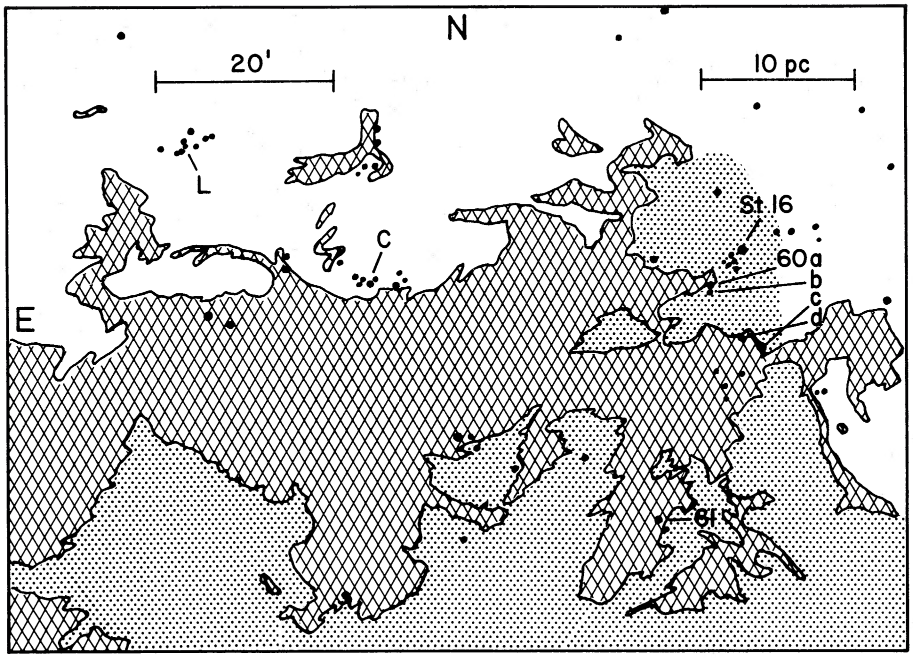

FIG. 1.—Schematic illustration of the Stock 16 region showing the prominent dust concentrations (*cross-hatching*) and emission nebulosity (*dots*). Symbols denote the stars in Cen R1 (60a, b, c, d, and 61), Stock 16 (St 16), and the star chain (*C*) and anonymous cluster (*L*) discussed in § VI.

16 stars are in reasonably good agreement with those published by other authors, while both our $B-V$ and $U-B$ colors tend to be bluer, on average. On the other hand, there is no compelling reasons to make corrections to the data of Table 1.

As noted by Turner (1981), a detailed analysis of *UBV* photometry for stars in open clusters requires confirmation that the photometric data are indeed on the *UBV* system, and that the adopted reddening relation is appropriate for cluster stars. As noted in § I, a few of the bright cluster members have MK spectral types. Therefore it is possible to use these stars to establish the slope of the reddening line, E_{U-B}/E_{B-V}, which would yield unreddened colors for these stars in agreement with their expected intrinsic colors. The appropriate value of E_{U-B}/E_{B-V} which applies to each of the photometric sources in Table 2 is given in its last column. The range of values, from 0.64 to 0.84, is rather extreme, and we note with some interest that the value which applies to the present photometry, $E_{U-B}/E_{B-V} = 0.73$, is in excellent agreement with the value expected from the cluster's galactic location (Turner 1976).

These results can be viewed as a test of the photometric colors for cluster stars, in which case there is no reason to suspect the presence of any sizable systematic errors in the photometry of Table 1. On the other hand, the data of Lyngå (1970*a*) and Schild, Garrison, and Hiltner (1983) do appear suspicious on the basis of the reddening-line test, and one could argue for the presence of zero-point errors in their photometry. A rather large zero-point error in the $U-B$ colors of Schild *et al.* would appear to be indicated, at least in their photometry for stars in Stock 16. Schild *et al.* found good overall agreement of their *UBV* photometry with that of Klare and Neckel (1977) for stars observed in common. Thus the reason for this discrepancy is not readily identified.

III. THE OPEN CLUSTER STOCK 16

Figure 3 is a color-color diagram for Stock 16 constructed from the data of Table 1. Likely cluster members are denoted by filled circles, while open circles denote probable foreground and background stars. O-type and early B-type members of Stock 16 can be identified by their location in Figure 3 close to the intrinsic relation for main-sequence stars reddened by $E_{B-V} = 0.49$, and we have identified a few late B-type members by similar means. All other objects appear unlikely to be cluster members on the basis of their derived location in the cluster color-magnitude diagram.

Figure 4 is a reddening-free color-magnitude diagram for likely members of Stock 16, derived using an adopted reddening relation of slope $E_{U-B}/E_{B-V} = 0.73$ and a local value of $R = A_V/E_{B-V} = 3.0$ (Jackson 1976; Turner 1976). Also included in Figure 4 are similar data for stars belonging to Cen OB1 and Cen R1 which lie within 30′ of Stock 16. The data for these objects are summarized in Table 3. The luminosities of stars in this table have been estimated from their spectral types, from Hβ photometry (Jackson 1976; Klare and Neckel 1977), or from zero-age main-sequence (ZAMS) fitting, and uncertain values are bracketed. The derived distance modulus for Stock 16 from a ZAMS fit to the five apparently single main-sequence stars is $V_0 - M_V = 11.39 \pm 0.09$ (σ), while the 10 Cen OB1 and Cen R1 members in Table 3 with reliable luminosities have a distance modulus of $V_0 - M_V = 11.38 \pm 0.28$. The corresponding distances are 1.90 ± 0.08 kpc and 1.88 ± 0.24 kpc respectively. The extremely close agreement in these two estimates is convincing evidence for a close spatial coincidence of Stock 16 with Cen OB1 and Cen R1. There is also a close agreement in the location of Stock 16 stars with those of Cen OB1 and Cen R1 members in the H-R diagram of Figure 4, so these groups must also be similar in age.

TABLE 1

PHOTOELECTRIC UBV PHOTOMETRY FOR STARS IN STOCK 16

Star	V	$B-V$	$U-B$	n	Spectral Type[a]	Comments[b]
1......	7.97	0.18	−0.78	13	O7.5 III((f))	m, vv, HD 115455, LSS 3019
2......	9.05	0.19	−0.37	3	B8	nm, HD 115345
3......	9.32	0.19	−0.73	3	B0 Vn	m, vv, HD 115316, LSS 3010
4......	9.45	1.71	+1.95	1	...	nm, CPD −61°3577
5......	9.52	0.21	−0.68	7	B0.5 V	m, vv, CPD −61°3576
6......	10.12:	0.23	−0.61	6	B0:-B2 V	m, vv, LSS 3022
7......	10.13	1.23	+0.84	1	F5 Ib	nm, LSS, 3029
8......	10.32	0.43	+0.34	1	...	nm, CPD −61°3560
9......	10.47	0.21	−0.66	4	B2 V	m, vv, LSS 3021
10......	10.58	0.26	−0.51	2	...	m, CPD −61°3559
11[c].....	11.56:	0.32	−0.30:	8	...	m, CPD −61°3583
12......	11.60	0.25	−0.47	8	...	m, CPD −61°3580
13......	12.20	1.08	+1.08	1	...	nm
14......	12.32	0.49	+0.37	5	...	m?
15......	12.32	1.78	...	3	...	nm
16......	12.48	0.30	−0.19	3	...	m
17......	12.54	1.35	+1.04	1	...	nm
18......	12.68	0.37	−0.19	4	...	m
19......	12.80	0.37	+0.02	5	...	m
20......	13.18	0.66	+0.18	5	...	nm
21......	13.19	0.96:	+0.48:	2	...	nm
22......	13.35	0.50	−0.18::	2	...	nm?
23......	13.38	0.45	+0.28	5	...	m
24......	13.40	1.57	...	1	...	nm
25......	13.49	0.97	+0.50	1	...	nm
26......	13.50	1.04	+0.57	3	...	nm
27......	13.51	0.38	+0.04	4	...	m
28......	13.55	0.36	+0.15	5	...	nm?
29......	13.74	0.58	+0.40	3	...	m
30......	13.76	0.36	+0.17	4	...	nm?
31......	13.84	1.00	+0.88	1	...	nm
32......	13.84	1.41	+1.24:	2	...	nm
33......	14.37	0.45	+0.32	2	...	m

[a] Spectral types from Walborn 1973 for star 1, Crampton 1971 for stars 5, 6, and 9, Lyngå 1970*a* for stars 6 and 9, Henry Draper Catalogue for star 2, Stephenson and Sanduleak 1971 for star 7, and this paper for star 3.

[b] Letters m = probable cluster member, vv = velocity variable, nm = nonmember.

[c] Star 11 is variable. $V = 11.38$ in 1977 August.

Members of Stock 16 are clearly quite young, and only the most luminous cluster member, of spectral type 07.5 III((f)), shows evidence of having evolved away from the ZAMS. We estimate the cluster age to be $\sim 3 \times 10^6$ yr based on a comparison of the data for this star with the theoretical evolutionary tracks for massive stars published by Maeder (1981). If the effects of mass loss and core overshooting are included (Doom 1982*a*, *b*), the derived age would be $\sim 5 \times 10^6$ yr. Nearby members of Cen OB1 and Cen R1 seem to exhibit a spread in their ages from $\sim 10^6$ yr to 5×10^6 yr based on the models of Maeder (1981), and from $\sim 10^6$ yr to 8×10^6 yr based on the models of Doom (1982*a*, *b*).

The core cluster of Stock 16 appears to be extremely rich in the proportion of binary systems among member stars. All four of the brightest cluster members in Figure 4 are spectroscopic binaries according to the work of Lyngå (1970*a*) and Crampton (1972), and five of the nine fainter cluster members lie well above the ZAMS. In fact, one of the latter (star 11) varies in brightness, and may be an eclipsing system. It is difficult to distinguish pre–main-sequence stars from unresolved

TABLE 2

MEAN DIFFERENCES WITH RESPECT TO OTHER AUTHORS

Present Data Minus	ΔV	$\Delta(B-V)$	$\Delta(U-B)$	n	E_{U-B}/E_{B-V}
Lyngå 1970*a*	+0.015	−0.027	+0.027	8	0.64
Crampton 1971	−0.009	−0.042	−0.010	6	0.69
Moffat 1975	−0.016	−0.025	−0.015	4	0.72
Jackson 1976	−0.011	−0.027	−0.016	2	0.73
Klare and Neckel 1977	−0.035	−0.031	−0.036	2	0.74
Schild *et al.* 1983	+0.005	−0.006	−0.066	2	0.84
Present data					0.73

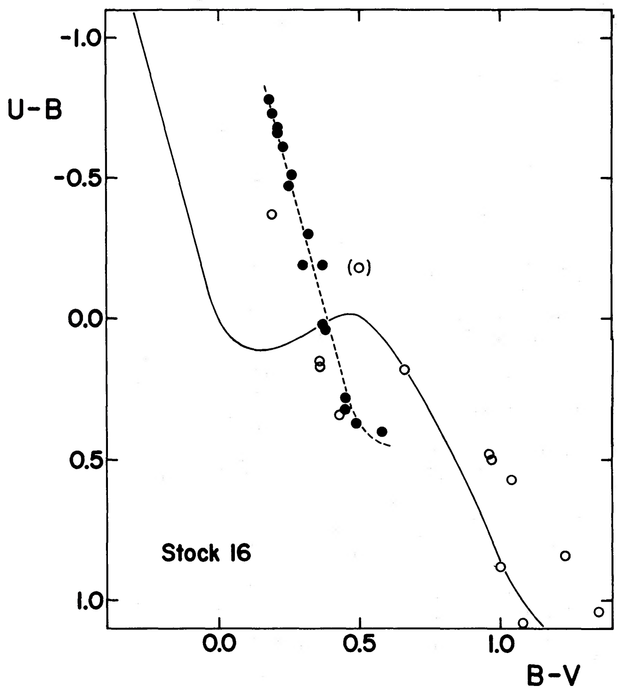

FIG. 3.—Color-color diagram for Stock 16, with likely cluster members denoted by filled circles. The dashed line represents the location of the intrinsic relation for main-sequence stars (*solid line*) reddened by $E_{B-V} = 0.49$.

binaries in Figure 4 for $V_0 > 11.2$, but at least six of the eight stars, or 75%, brighter than this are indicated by the data to be unresolved binary systems. Clearly, it would be desirable to investigate the faint cluster members by spectroscopic means in order to test whether or not the binary frequency in Stock 16 is really as high as 75%.

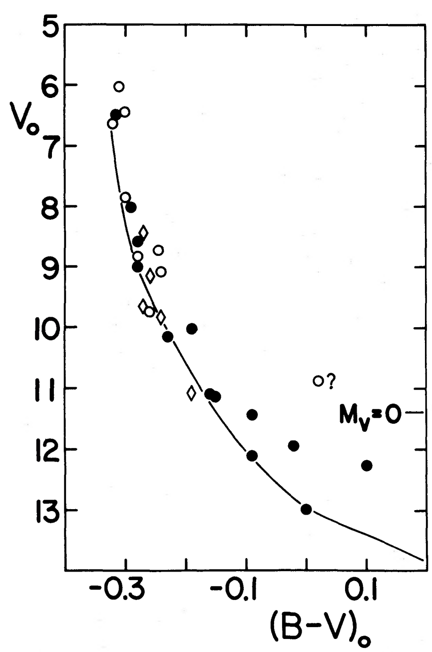

FIG. 4.—Reddening-free color-magnitude diagram for Stock 16 and its neighboring complex. Members of the cluster nucleus are indicated by filled circles, while open symbols denote nearby members of Cen OB1 (*circles*) and Cen R1 (*diamonds*).

IV. STARS IN THE REGION OF STOCK 16

As noted in § I, the region immediately adjacent to Stock 16 contains three objects of particular interest as possible cluster members, namely the Cepheid V378 Cen and the two W-R stars MR 44 (= WR 50, spectral type WC6 + abs) and MR 45 (= WR 51, spectral type WN4). The observed magnitudes and colors for these two W-R stars, combined with their likely intrinsic parameters as inferred from the work of van der Hucht *et al.* (1981) and Turner (1982*b*), produce fairly large values for their color excesses and distances ($E_{B-V} > 1.0$, $d \approx 3.9$ kpc, see Table 3). Star 7 in Table 1 (= LSS 3029, Stephenson and Sanduleak 1971) also has a large reddening [E_{B-V}(B0) = 0.85, B-star equivalent] and distance based upon its objective-prism classification of F5 Ib. Finally, Table 3 contains four other objects (LSS 3031, 3033, 3035, and 3040) which, on the basis of their distance moduli, are clearly indicated to be background objects to Stock 16 and Cen OB1. Two of these stars, LSS 3033 and 3035, have been identified by Jackson (1976) as likely members of a newly-discovered OB association centered at $l = 305°.81$, $b = +1°.11$, and lying at a distance of 3.58 kpc. Jackson identified 12 objects in the region of Stock 16 as possible members of this association, but one of these, star 3, in Table 1, is almost certainly a member of Stock 16. The mean distance modulus for the four likely association members in Table 3 which have reliable luminosity estimates is $V_0 - M_V = 12.79 \pm 0.10$, which corresponds to a distance of 3.60 ± 0.16 kpc.

These findings suggest that the volume of space immediately background to Stock 16 and Cen OB1 is relatively devoid of luminous objects for ~1.7 kpc. The color excesses of stars near Stock 16 which belong to the background OB association range from 0.69 to 1.58, and much of this differential reddening must originate with dust in the immediate vicinity of association members. In support of this suggestion we note that both MR 44 and MR 45 seem likely to be association members, yet their color excesses are dramatically different ($E_{B-V} = 1.13$ and 1.58) despite their close proximity in the sky (see Fig. 2). The reddening of (foreground) Stock 16 members near these W-R stars is remarkably constant at $E_{B-V} = 0.49 \pm 0.01$ m.e., and the excess reddening observed for both MR 44 and MR 45 must originate from dust clouds which lie in close proximity to these W-R stars.

The light-curve parameters for V378 Cen taken from Schaltenbrand and Tammann (1971) are $\langle V \rangle = 8.46$, $\langle B \rangle - \langle V \rangle = 1.03$, and $P = 6^d.45930$. If the Cepheid were associated with Stock 16, it would have a derived luminosity of $\langle M_V \rangle = -4.41 \pm 0.09$. Typical Population I Cepheids of this period, however, have luminosities almost a full magnitude more positive ($\langle M_V \rangle \approx -3.5$), and have ages (cf. Kippenhahn and Smith 1969) of $\sim 5 \times 10^7$ yr, which is a factor of 10 larger than the age calculated for Stock 16. It seems certain from both discrepancies that V378 Cen cannot be a member of Stock 16.

The space reddening of V378 Cen can be estimated from its probable location foreground to Stock 16 (by perhaps 700 pc). On this basis, the Cepheid's color excess must be no larger than E_{B-V}(B0) = 0.49. Cluster star 14, which lies a little more than 1′ northeast of V378 Cen, may be an outlying member of Stock 16, but its data are also consistent with it being a foreground star of similar reddening. An analysis of the tabulated data for likely foreground objects in Table 1 suggests that most of the foreground reddening to Stock 16 occurs within 500 pc of the Sun, a finding supported by the results of Neckel and Klare (1980). The space reddening of V378 Cen can therefore be

TABLE 3

OBSERVATIONAL DATA FOR LUMINOUS STARS WITHIN 30′ OF STOCK 16

Star[a]	V	$B-V$	$U-B$	Reference[b]	Spectral Type	Reference	E_{B-V}	$V_0 - M_V$
LSS 2998	7.94	0.20	−0.72	1, 2, 3	O9-B0.5 Vn	1, 4	0.50	11.13
LSS 3003	10.10	1.05	−0.12	1, 5	O9 III	1	1.36	11.42
LSS 3013	11.87	0.81	−0.07	6	WC6 + abs	7	1.13	(13.07)
LSS 3017	13.55	1.14	+0.12	6	WN4	7	1.58	(12.86)
LSS 3031	10.29	0.80	−0.15	1, 8	B2 Ib	1	0.98	12.75
LSS 3033	8.08	0.44	−0.59	2, 3, 5	B0.5 Ia	4	0.69	12.91
LSS 3035	10.89	0.78	−0.35	5	...	...	1.10	(12.32)
LSS 3040	11.87	0.87	−0.31	5	...	...	1.19	12.80
LSS 3045	11.31	0.26	−0.55	5	...	...	0.52	11.65
LSS 3052	10.09	0.83	−0.31	5	...	...	1.15	11.14
KS 806	10.18	0.17	−0.68	2, 3	...	...	0.45	11.52
Ly 235	10.26	0.27	−0.49	1	B1 Vn	1	0.51	10.99
SRN 60a	10.74	0.27	−0.54	1, 8, 9	B1-B2 V	1, 9	0.53	11.05
SRN 60b	12.70	0.35	−0.28	9	...	...	0.54	11.73
SRN 60c	12.02	0.49	−0.32	9	...	...	0.73	11.35
SRN 60d	10.63	0.46	−0.43	1, 9	...	...	0.73	(10.57)
SRN 61	10.73	0.09	−0.71	9	B1 V	9	0.36	11.78
St 16−7	10.13	1.23	+0.84	10	F5 Ib	10	0.85	12.68

[a] Star numbering from Stephenson and Sanduleak 1971 = LSS, Klare and Szeidl 1966 = KS, Lyngå 1970*a* = Ly, van den Bergh and Herbst 1975 = SRN, and Table 1 = St. 16.

[b] *UBV* photometry adjusted according to the results of Table 2.

REFERENCES.—(1) Lyngå 1970*a*. (2) Klare and Neckel 1977. (3) Schild *et al.* 1983. (4) Garrison *et al.* 1977. (5) Jackson 1976. (6) Moffat 1975. (7) van der Hucht *et al.* 1981. (8) Crampton 1971. (9) Herbst 1975. (10) Table 1.

established to be at least as large as that of star 14, but no larger than that of Stock 16. The implied color excess is $E_{B-V}(\mathrm{B0}) = 0.49$, which corresponds to $E_{B-V} = 0.46$ for V378 Cen. Dean, Warren, and Cousins (1978) derived a similar value of $E_{B-V} = 0.49$ for this Cepheid using $B-V$ and $V-I$ observations with an adopted intrinsic color relation.

V. DID STOCK 16 FORM FROM AN ELEPHANT TRUNK?

An extremely peculiar property of the cluster Stock 16 is revealed by star counts, which are illustrated in Figure 5. The counts reproduced here were made off a print obtained from the ESO B Sky Survey plate of the region (see Fig. 2), and include strip counts (using strip dimensions of 3′.0 × 0′.5) made along a line joining the center of the elephant-trunk structure southeast of Stock 16 with cluster star 1, and three similar strip counts made perpendicular to this relation—one through the cluster center (see Fig. 2) and the other two through points located 3′ on either side of the cluster center. Two sets of counts are presented—a bright set to a limit of $B \approx 15$, and a faint set to $B \approx 18$—with results discussed below.

The cluster Stock 16 stands out clearly in the bright set of star counts as a reasonably-symmetric, Gaussian-shaped distribution of star densities with a radius of $\sim 2'.5$ about the cluster center depicted in Figure 2. The corresponding cluster radius of ~ 1.4 pc is small by cluster standards, and it is perhaps as a consequence of the high frequency of stellar encounters between cluster members that are expected in such circumstances (Wielen 1971) that the cluster has developed such a large proportion of close binary systems (cf. Dokuchaev and Ozernoy 1981) among its present population.

The faint set of star counts is more interesting, and it should be evident from Figure 5 that the cluster nucleus is no longer prominent below $B \approx 15$. Rather, there is an unusual peak in star density to the northwest of star 1 which seems to represent the faint clumpings of stars visible $\sim 2'$ north and west of this star in Figure 2. We tentatively identify the location of these

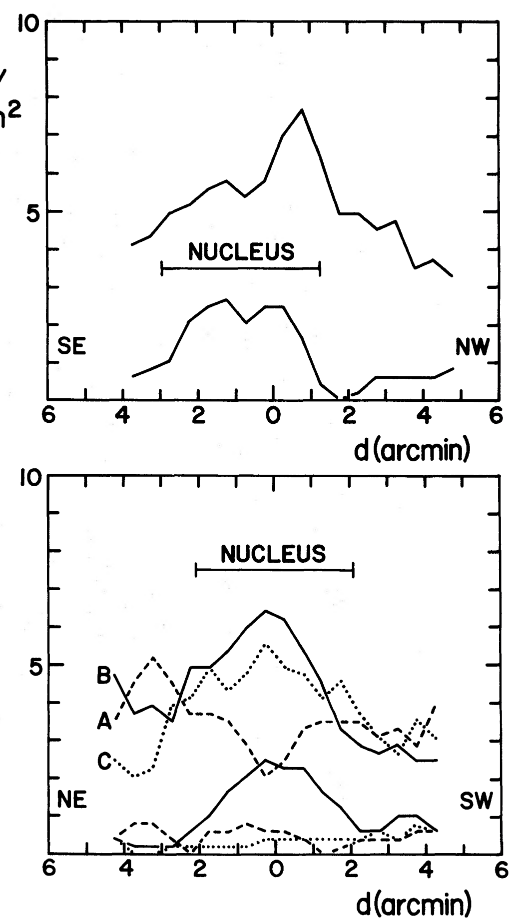

FIG. 5.—Strip counts for Stock 16 as described in the text. The upper relation in each section represents star densities above $B \approx 18$, while the lower relation is for a limit of $B \approx 15$. The three relations in the lower section are for strips 3′ southeast of the cluster center (*A*), through the cluster center (*B*), and 3′ northwest of the cluster center (*C*).

clumps as the former leading edge of the now-truncated elephant-trunk structure lying 5′ southeast of Stock 16.

The data in Figure 5 confirm the existence of additional concentrations of faint stars along both sides of the cluster lying parallel to the line joining it to the elephant trunk. A close inspection of Figure 2 also reveals enhancements in the density of faint stars all along the inside edge of the dust clouds which represent the region of interaction of the H II region with the dust complex. It seems unlikely that concentrations of faint stars in these particular locations are due to a fortuitous spatial coincidence of Stock 16 and its surrounding dust complex with background star clusters. A more reasonable explanation is that these concentrations represent real clumpings of low-mass, low-luminosity stars belonging to the Stock 16 complex. Such objects would all be fainter than $M_V \approx +3$ if they are at the same distance as Stock 16, and would be pre–main-sequence stars if they are of comparable age to the cluster. Quite possibly they are analogous to the small dark Bok globules which are seen in the Rosette Nebula in projection against the inside edge of the surrounding dust complex (cf. Herbig 1974). Presumably, large numbers of such objects could have been created from the pinching off and subsequent contraction of low-mass Rayleigh-Taylor instabilities which formed along the eastern edge of the ionization/shock front of RCW 75 as it expanded into the dust cloud from which it was spawned. Herbig (1974) has argued that the small dust globules in the Rosette Nebula are *not* examples of protostars, since their calculated mean lifetimes of only $\sim 10^4$ yr preclude the possibility of star formation. Nevertheless, the faint stellar objects which lie along the eastern borders of RCW 75 could provide rather convincing evidence for just such a possibility, provided that their pre–main-sequence status can be confirmed. A program of photographic observation of the Stock 16 complex to search for T Tauri–type variability in these faint objects would be a relatively simple means of testing this suggestion.

Returning our attention to the cluster proper, it can be noted in Figure 5 that the cluster nucleus is not nearly so striking in the faint set of strip counts as it is in the bright set. This can be interpreted as evidence for a deficiency of low-luminosity cluster-nuclear members, possibly as a consequence of the preferential evaporation of low-mass stars through stellar encounters (Wielen 1971). Such an explanation for the unusual stellar density variations appearing in the star-count data for Stock 16 is reasonable from a dynamical standpoint and would also help to explain the unexpectedly high proportion of binary systems found among the bright cluster members.

Several lines of argument indicate that Stock 16 cannot represent the first generation of stars produced from the nearby gas and dust complex. For example, cluster members are slightly younger than several nearby luminous stars belonging to Cen OB1. Also, RCW 75 is moderately well evolved in terms of the "blister" model of H II region development (Tenorio-Tagle 1979), with its interior regions well purged of dust grains (witness the absence of differential reddening for Stock 16 members) and its peak radio continuum originating from the head of the ionization/shock front (Haynes, Caswell, and Simons 1978) at a point roughly coincident with the easternmost portions of the elephant trunk. The cluster seems to fit quite well into the scheme of sequential star formation proposed by Elmegreen and Lada (1977), but its peculiar location at the end of a truncated elephant-trunk structure and its poor nature in terms of member stars argue that it was created from the pinched-off portion of what must originally have been a larger elephant trunk protruding into a less evolved RCW 75. The implosion mechanism described by Blitz and Thaddeus (1980) might have been the triggering mechanism which led to star-cluster formation in this instance. Stock 16 therefore seems to present rather graphic evidence that star formation *is* possible within the high-density portions of elephant trunks.

The immediately preceding generation of OB stars whose radiation supplied RCW 75 with the motive power necessary to develop Stock 16 from an elephant trunk are not easily identified in the field of this cluster. A logical site for their location would seem to be in the region north of cluster stars 3 and 10, but there is only marginal evidence in the star counts for a cluster at this position. Perhaps the original OB-type cluster which led to the development of RCW 75 has already dispersed over much of the field of this H II region, with stars 3 and 10 representing merely its sparse remains. Proper-motion data for the OB stars in this region would seem to be essential for further investigation of this suggestion.

The site of the next generation of stars in this complex should lie in the dense dust clouds located along the eastern (ionization-bounded) edge of RCW 75. In fact, the four stars in this part of the complex which are involved in reflection nebulosity—SRN 60a, b, c, and d—do lie along the optical boundaries of the ionization/shock front and could be newly formed objects, albeit with masses typical of main-sequence stars of spectral type B1–B3. Chu (1983) has in fact demonstrated that SRN 60a (= LSS 3027) lies in a small H II region of medium electron density. On the other hand, the radio continuum peak is located at the easternmost terminus of the prominent elephant-trunk structure, and it is tempting to view this region as the logical site of current star formation. The entire Cen OB1 region has been surveyed for OH masers by Caswell and Haynes (1985), but there are only two candidates for membership in the Stock 16/RCW 75 complex. Both lie $\sim 30'$ south of Stock 16, and seem to be unrelated to the expansion of RCW 75 into its adjacent dust complex. It would seem that further progress in the study of star formation in this region must await the results of infrared and CO studies of the region.

VI. THE GALACTIC NEIGHBORHOOD OF STOCK 16

For purposes of examining the relationship of the Stock 16/RCW 75 complex to its surroundings, it is necessary to return to the schematic mapping of the $\sim 1^\circ\!.5$ section of the galactic plane lying immediately east of Stock 16 that is presented in Figure 1. The region is seen to be dominated by an extensive, ~ 60 pc long, segment of continuous dust obscuration which presumably delineates most of the giant molecular cloud from which the Stock 16/RCW 75 complex was created. There are a few stellar concentrations (C and L in Fig. 1) lying spatially just north of the region of heavy dust obscuration which might be similar in some respects to Stock 16—that is, recently created star clusters formed from density enhancements along the edge of the giant molecular cloud. Stellar concentration L is an anonymous cluster of B-type stars studied by Lodén (1971), and its derived distance of ~ 2 kpc (Lodén 1971), or ~ 1.8 kpc from an independent ZAMS fit made here, makes it spatially coincident with the dust complex. Stellar concentration C is a star chain which forms part of a loose clustering of B, A, and later-type stars denoted as 807 in the lists of Lodén (1977). Photometric observations of the stars in this clustering have been obtained by Lodén (1977) and Hidayat and Wiramihardja (1978), and it appears that there may be several different distance groups present along the line of sight, with the main group concentrated at a distance of ~ 1 kpc. A few of the stars in this chain may lie at the same distance as the molecular-cloud complex, but they do not appear to represent a star cluster.

The north and east sides of the molecular cloud therefore contain only a few poorly populated clusters, four stars embedded in reflection nebulosity, and a small number of OB stars belonging to Cen OB1. The south side of the cloud is more complex since it lies projected against the outlying portions of the m Cen emission nebula. This extensive H II region appears to contain a few outlying members of Cen OB1 (Lyngå 1970*b*; Jackson 1976) and has a kinematic distance from Georgelin and Georgelin (1970) which is almost identical to that of RCW 75 ($d_{\rm kin} = 1.75$ kpc for m Cen, $d_{\rm kin} = 1.80$ kpc for RCW 75). The m Cen nebula covers 2°5 of sky south of the dust clouds which form its northern edge, and if, as seems likely, it belongs to the same star-formation complex as Stock 16 and RCW 75, it would extend the optical dimensions of this complex to at least 3°5, or ~ 120 pc. Stock 16 and RCW 75 therefore represent merely a small indentation in the northwest corner of an extensive complex which covers much of the galactic plane between $l = 305°5$ and 308° from $b = +0°5$ to $-2°8$. The region has not yet been mapped extensively at infrared or molecular-line wavelengths, but is covered in radio continuum (Haynes, Caswell, and Simons 1978) and OH maser (Caswell and Haynes 1985) surveys. Unfortunately, the only objects in the region which appear to represent star-formation centers are a compact H II region (and associated OH maser) 35′ south-southeast of Stock 16 and an OH maser (and associated H_2O maser) 30′ south-southwest of Stock 16. Only the former has an LSR velocity comparable to those of RCW 75 and the m Cen nebula.

The picture which consistently emerges of the Stock 16/RCW 75 region is that of a rather subdued star-formation complex. It appears to be almost passive in comparison with the rich Carina Nebula complex 20° further to the west, which has been demonstrated by Turner *et al.* (1980) to be a region of extremely vigorous, ongoing star-forming activity involving several pairs of rich, young OB-type clusters created during various past episodes of star formation. The star-formation activity in the Stock 16/RCW 75 region appears in contrast to involve both fewer and relatively less massive stars than in the Carina complex, and may not contain sufficient momentum at present to prevent the process from simply dying away. It would be of considerable interest in this regard to map the area at infrared and molecular-line wavelengths in order to obtain additional details on the obscured portions of the complex, where star formation may be continuing undetected. Based on such studies it should be possible to obtain a clearer picture of the dimensions of this molecular cloud complex and to determine a better estimate of the extent to which star formation has proceeded in the region.

This investigation was supported by research grants to the author awarded through the Natural Sciences and Engineering Research Council (NSERC) of Canada, and was completed during tenure of an NSERC University Research Fellowship. I am grateful to Jim Caswell for supplying an up-to-date picture of the radio observations available for the Stock 16 region. I would also like to thank Paul Ford, Peter Leonard, and Brian Bourdon who, as summer students in recent years, made valiant efforts to obtain and decipher the star-count data for Stock 16. Their results provided the first clues concerning the true nature of the Stock 16 complex.

REFERENCES

Blitz, L., and Thaddeus, P. 1980, *Ap. J.*, **241**, 676.
Caswell, J. L., and Haynes, R. F. 1985, *Australian J. Phys.*, in press.
Chu, Y.-H. 1983, *Pub. A.S.P.*, **95**, 873.
Crampton, D. 1971, *A.J.*, **76**, 260.
———. 1972, *M.N.R.A.S.*, **158**, 85.
Dean, J. F., Warren, P. R., and Cousins, A. W. J. 1978, *M.N.R.A.S.*, **183**, 569.
Dokuchaev, V. I., and Ozernoy, L. M. 1981, *Soviet Astr. Letters*, **7**, 52.
Doom, C. 1982*a*, *Astr. Ap.*, **116**, 303.
———. 1982*b*, *Astr. Ap.*, **116**, 308.
Elmegreen, B. G., and Lada, C. J. 1977, *Ap. J.*, **214**, 725.
Fenkart, R. P., Binggeli, B., Good, D., Jenni, D., Labhardt, L., and Tschumi, A. 1977, *Astr. Ap. Suppl.*, **30**, 307.
Garrison, R. F., Hiltner, W. A., and Schild, R. E. 1977, *Ap. J. Suppl.*, **35**, 111.
Georgelin, Y. P., and Georgelin, Y. M. 1970, *Astr. Ap.*, **6**, 349.
Haynes, R. F., Caswell, J. L., and Simons, L. W. J. 1978, *Australian J. Phys., Ap. Suppl.*, No. 45, p. 1.
Herbig, G. H. 1974, *Pub. A.S.P.*, **86**, 604.
Herbst, W. 1975, *A.J.*, **80**, 212.
Hidayat, B., and Wiramihardja, S. D. 1978, *Astr. Ap. Suppl.*, **34**, 73.
Jackson, P. D. 1976, Ph.D. Thesis, University of Maryland.
Kippenhahn, R., and Smith, L. 1969, *Astr. Ap.*, **1**, 142.
Klare, G., and Neckel, T. 1977, *Astr. Ap. Suppl.*, **27**, 215.
Klare, G., and Szeidl, B. 1966, *Veröff. Landesternwarte Heidelberg-Königstuhl*, **18**.
Lodén, L. O. 1971, *Astr. Ap.*, **15**, 332.
———. 1977, *Astr. Ap. Suppl.*, **29**, 31.
Lundström, I., and Stenholm, B. 1980, *Repts. Obs. Lund*, No. 16.
Lyngå, G. 1970*a*, in *IAU Symp. 38, The Spiral Structure of Our Galaxy*, ed. W. Becker and G. Contopoulos (Dordrecht: Reidel). p. 270.
———. 1970*b*, *Astr. Ap.*, **8**, 41.
Maeder, A. 1981, *Astr. Ap.*, **102**, 401.
Moffat, A. F. J. 1975, Ruhr Univ. Bochum, unpublished observations.
Neckel, T., and Klare, G. 1980, *Astr. Ap. Suppl.*, **42**, 251.
Rodgers, A. W., Campbell, C. T., and Whiteoak, J. B. 1960, *M.N.R.A.S.*, **121**, 103.
Schaltenbrand, R., and Tammann, G. A. 1971, *Astr. Ap. Suppl.*, **4**, 265.
Schild, R. E., Garrison, R. F., and Hiltner, W. A. 1983, *Ap. J. Suppl.*, **51**, 321.
Smith, L. F. 1968, *M.N.R.A.S.*, **141**, 317.
Stephenson, C. B., and Sanduleak, N. 1971, *Publ. Warner and Swasey Obs.*, **1**, No. 1.
Tenorio-Tagle, G. 1979, *Astr. Ap.*, **71**, 59.
Turner, D. G. 1976, *A.J.*, **81**, 1125.
———. 1981, *A.J.*, **86**, 222.
———. 1982*a*, *Pub. A.S.P.*, **94**, 655.
———. 1982*b*, in *IAU Symp. 99, Wolf-Rayet Stars: Observations, Physics, Evolution*, ed. C. W. H. de Loore and A. J. Willis (Dordrecht: Reidel), p. 57.
Turner, D. G., Grieve, G. R., Herbst, W., and Harris, W. E. 1980, *A.J.*, **85**, 1193.
van den Bergh, S., and Herbst, W. 1975, *A.J.*, **80**, 208.
van der Hucht, K. A., Conti, P. S., Lundström, I., and Stenholm, B. 1981, *Space Sci. Rev.*, **28**, 227.
Walborn, N. R. 1973, *A.J.*, **78**, 1067.
Wielen, R. 1971, *Ap. Space Sci.*, **13**, 300.

DAVID G. TURNER: Department of Astronomy, Saint Mary's University, Halifax, Nova Scotia, B3H 3C3, Canada