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TRUMPLER 27: A HEAVILY REDDENED YOUNG OPEN CLUSTER WITH BLUE AND RED SUPERGIANTS*

A. F. J. MOFFAT
Astronomisches Institut der Ruhr-Universität Bochum

AND

M. PIM FITZGERALD† AND P. D. JACKSON†
Astronomy Program, University of Waterloo
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ABSTRACT

Trumpler 27 is a heavily reddened cluster of earliest spectral type O9. It contains six blue supergiants, one yellow supergiant, and one red supergiant, CD −33°12241. The yellow supergiant, of type G0 Ia, lies at the luminous blue edge of the Cepheid instability strip. Two Wolf-Rayet stars are probable members. Tr 27 is 2.1 ± 0.2 kpc from the Sun, on the basis of mean spectroscopic parallaxes of 16 members and Zero-Age Main Sequence fitting. Fifty probable members are identified on the basis of spectra and *UBV* photoelectric and photographic photometry complete to $V \approx 14.8$. The visual extinction ranges from 3 to 8 magnitudes and varies systematically across the face of the cluster. This leads to a value of $R = A_V/E_{B-V} = 3.3 \pm 0.3$. There is no tendency for the intrinsically more luminous stars to be more heavily reddened than stars of lower luminosity.

Subject headings: clusters: open — stars: early-type — stars: spectral classification — stars: supergiants — stars: Wolf-Rayet

I. INTRODUCTION

The open cluster Trumpler 27 (Tr 27; $\alpha_{2000} = 17^h36^m.2$, $\delta_{2000} = -33°29'$; $l = 355°.1$, $b = -0°.7$) has been a recent source of interest because the very red star CD −33°12241 is probably a member (Thé and Stokes 1970; Albers 1973, 1974; Imhoff and Keenan 1976). Thé and Stokes (TS), who made the first useful photometry of Tr 27, claimed that CD −33°12251 is a heavily reddened early-type star. Based on TS's photometry and his own near-infrared, low-dispersion (700 Å mm^{-1}) spectroscopy, Albers (1974) found it to be a G or K supergiant. From two coudé spectrograms in the red region obtained with the Palomar 5 m telescope, Imhoff and Keenan classified it M0: Ia, which, on the basis of TS's results, puts the star behind the cluster. However, the results of TS are subject to improvement since they are based on *photographic UBV* photometry in a relatively crowded star field. Furthermore, the interstellar extinction is large and variable ($A_v \approx 2$ to 7 magnitudes), and no spectral types for the possible members were available to them. For these reasons we initiated a detailed study of the cluster in 1975 using photoelectric *UBV* photometry and MK spectroscopy.

Tr 27 has a diameter of 8′ (Trumpler 1930). Its Trumpler type is I2p, implying a compact but relatively poorly populated cluster containing stars with moderate dispersion in apparent magnitude. Its appearance as a cluster on blue plates is not outstanding, but it is much more obvious on red plates. There is a knot of about a dozen moderately bright stars in a region of diameter 1′ near CD −33°12241. TS pointed out that Tr 27 represents a group of stars encircled by a curious "kink" in Barnard's (1927) dark cloud No. B271. The distance of 1.08 kpc derived by TS places Tr 27 on the extreme outer edge (i.e., on the galactic anticenter side) of the next inner spiral arm − I (Becker and Fenkart 1970). Comparison with the catalog of Luminous Stars in the Southern Milky Way (Stephenson and Sanduleak 1971) shows a coincidence of Tr 27 with eight luminous stars. Furthermore, Tr 27 appears to be located near the center of an impressive concentration of an additional 30 luminous stars in a region of diameter ~0°.9.

II. THE OBSERVATIONAL DATA

We have obtained photoelectric *UBV* photometry for 39 stars using the 61 cm Bochum telescope located on La Silla and the 1.5 m telescope on Cerro Tololo, Chile. The photometry with the 61 cm was obtained by A. F. J. M. using standard stars from the lists of Johnson and Morgan (1953), Johnson and Harris (1954), Cousins (1973), and Gutiérrez-Moreno *et al.* (1966). The photometry with the 1.5 m telescope

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TABLE 1

PHOTOMETRIC AND SPECTROSCOPIC DATA FOR STARS OBSERVED IN THE REGION OF Tr 27

TS No.	V	$B-V$	$U-B$	n	Source	LSS*	Spectrum	Source	$E_{B-V}(UBV)$	E_{B-V}(B0)†	Membership	Adopted $\mathrm{Sp}[M_v, (U-B)_0]$
1......	8.79	3.12	+3.32	3	1, 2	...	M0Ia	a	1.43:	1.75:	m	?
1a.....	12.70	1.55	+0.28	1	2	...	...	...	1.9:	1.9:	m	ob
2......	10.55	1.28	+0.18	2	1	4253	O9Ia:	a	1.48	1.50	m	b1 Ib
3......	13.16	1.17	+0.19	1	2	...	...	...	1.43	1.44	m	b2 V
4......	11.93	0.59	+0.16	2	1	...	...	...	...	...	n	...
5......	12.16	1.23	+0.08	1	2	...	...	...	1.55	1.55	m	o9 V
6......	11.68	1.30	+1.24	2	2	...	K5: III	e	...	...	n	...
7......	12.80	2.46	...	4	3	...	M2	d	...	...	n	...
8......	11.88	1.66	+0.56	2	2	...	OB	c	1.84	1.87	m	b2 Ib
9......	12.38	0.70	+0.12	1	2	...	Not OB	c	...	...	n	...
10......	12.12	1.64	+0.76	4	3	...	OB−, M2	c, d	1.76:	1.79:	m:	b7 II
11......	12.34	0.96	+0.03	4	3	...	B5: III:	e	1.21	1.22	m	b2 V
12......	12.05	1.57	+0.48	4	3	...	OB	c	1.81	1.83	m	b2 II
13......	11.78	0.96	−0.01	2	1	4264	B2 V	e	1.22	1.23	m	b1 V
14......	11.12	1.18	+0.15	2	1	4262	B0 Ib	a	1.41	1.42	m	b2 II
15......	13.41	0.68	+0.42	4	3	...	Not OB	c	...	...	n	...
16......	10.74	1.09	−0.01	2	1	4263	O9.5 II:	a	1.35	1.36	m	b1 II
17......	13.08	0.54	+0.17	4	3	...	Not OB?	c	...	...	n	...
18......	12.01	3.16	...	4	3	...	M0:	d	...	...	n	...
19......	12.74	1.03	+0.06	1	2	...	OB−	c	1.29	1.30	m	b2 V
20......	13.63	0.81	−0.16	4	3	...	OB−:	c	1.08	1.09	m	b1 V
21......	12.59	0.90	−0.06	1	2	...	OB−	c	1.17	1.18	m	b1 V
22......	11.48	1.17	+0.74	1	1	...	Not OB	c	...	...	n	...
23......	10.11	1.43	+0.37	2	1	4266	B0.5 Ib	a	1.57	1.60	m	b2 Iab
24......	10.76	1.00	+0.69	1	1	...	G0:	e	...	...	n	...
25......	11.42	1.41	+0.34	2	1	...	OB	c	1.65	1.66	m	b2 II
26......	11.34	0.72	+0.20	2	1	...	F7 V	a	...	...	n	...
27......	13.31	2.16	+0.74	4	3	...	...	...	2.5:	2.5:	m	ob
28......	13.38	1.77	+0.86	2	1	4261	WN5	d, f	1.96	1.96	m	?
29......	13.94	2.04	...	4	3	...	...	...	...	...	n:	...
30......	13.79	1.48	+0.65	4	3	...	OB−:	c	1.65	1.70	m:	b5 V
31......	13.59	0.71	+0.27	4	3	...	Not OB	c	...	...	n:	...
32......	12.98	1.07	−0.18	4	3	...	OB−:, M8	c, d	1.4:	1.4:	m	ob
33......	14.06	1.36	...	4	3	...	Not OB?	c	...	...	n:	...
34......	12.94	1.03	+0.03	2	1	...	B1: V:	b	1.30	1.31	m	b1 V
35......	13.86	0.95	+0.32	4	3	...	Not OB?	c	...	...	n:	...
36......	13.18	1.08	+0.16	4	3	...	OB−:	c	1.32	1.33	m	b2 V
37......	13.99	1.13	+0.30	4	3	...	...	...	1.33	1.35	m	b3 V
38......	13.72	0.41	+0.16	4	3	...	Not OB?	c	...	...	n	...
39......	13.55	0.99	+1.31	4	3	...	Not OB	c	...	...	n	...
40......	13.88	0.79	+0.14	4	3	...	...	...	0.95	0.97	m:	b6 V
41......	14.05	0.87	+0.18	4	3	...	...	...	1.04	1.06	m:	b6 V
42......	14.22	1.23	+0.16	4	3	...	...	...	1.51	1.52	m	b0.5 V
43......	10.48	1.99	+1.06	2	1	4256	B9 Ia	g	1.99	2.05	m	b9 Ia
44......	12.11	0.92	−0.10	2	1	...	B1: II::	b	1.20	1.21	m	b0.5 V
45......	13.52	2.37	...	4	3	...	...	...	...	...	n:	...
46......	8.79	1.60	+0.65	4	1	4255	B9 Ia(+ ?)	a	1.61	1.66	m	b9 Ia
46a.....	11.54	1.73	+0.77	2	1	...	...	...	1.80	1.84	m	b7 Ib
46b.....	12.98	1.34	+0.30	2	2	...	...	...	1.61	1.62	m	b1 V
46c.....	13.28	1.45	+0.33	2	2	...	...	...	1.74	1.75	m	b0.5 V
47......	14.34	1.86	+0.95	1	2	...	...	...	2.05	2.08	m:	b5 V
48......	14.41	1.24	+0.68	4	3	...	...	...	...	...	n	...
49......	14.32	1.54	+0.69	1	2	...	...	...	1.72	1.74	m:	b5 V
50......	14.69	1.77	...	4	3	...	...	...	...	...	?	...
51......	14.69	1.31	...	4	3	...	...	...	...	...	?	...
52......	14.14	1.24	+0.27	1	2	...	...	...	1.49	1.50	m	b2 V
53......	14.10	1.64	+0.50	4	3	...	...	...	1.93	1.94	m	b0.5 V
54......	14.71	1.17	...	4	3	...	...	...	...	...	?	...
55......	14.43	1.06	+0.13	4	3	...	...	...	1.31	1.32	m	b2 V
56......	14.18	1.01	+0.74	4	3	...	...	...	...	...	n	...
57......	14.75	1.84	...	4	3	...	...	...	...	...	?	...
58......	14.67	...	...	4	3	...	...	...	...	...	?	...
59......	14.63	0.74	+0.79	4	3	...	...	...	...	...	n	...
60......	14.55	0.88	+0.43	4	3	...	...	...	...	...	n	...
61......	13.90	1.09	+0.24	4	3	...	...	...	1.30	1.31	m	b3 V
62......	14.28	0.82	+0.11	4	3	...	...	...	1.00	1.01	m:	b5 V
63......	14.24	1.15	+0.54	4	3	...	...	...	...	...	n	...
64......	14.95	1.36	+0.42	4	3	...	...	...	1.59	1.60	m	b3 V
65......	14.0	0.9	+0.2	2	4	...	...	...	1.1:	1.1:	m:	ob
66......	14.15	1.09	+0.51	4	3	...	...	...	...	...	n	...
67......	14.68	...	...	4	3	...	...	...	...	...	?	...
68......	14.33	0.95	+0.18	4	3	...	...	...	1.14	1.15	m:	b5 V

TABLE 1—*Continued*

TS No.	V	$B-V$	$U-B$	n	Source	LSS*	Spectrum	Source	$E_{B-V}(UBV)$	E_{B-V}(B0)†	Member-ship	Adopted Sp[M_v,$(U-B)_0$]
69......	14.23	0.96	+0.20	4	3	...	...	...	1.15	1.17	m:	b5 V
70......	14.53	1.45	...	4	3	...	...	...	...	...	?	...
71......	14.66	...	...	4	3	...	...	...	...	...	?	...
72......	14.01	3.10	...	4	3	...	...	...	...	...	n:	...
80......	14.80	1.40	...	1	2	...	...	...	...	...	?	...
81......	16.32	1.19	...	2	2	...	...	...	...	...	?	...
82......	17.29	1.22	...	2	2	...	...	...	...	...	?	...
102......	8.39	1.94	+1.71	2	1	...	G0 Ia	a	1.27:	1.40:	m	?
103......	10.69	0.99	−0.07	2	1	4240	B1 II	a	1.28	1.29	m	b0.5 II
104......	10.69	0.79	−0.29	2	1	4271	O9 III	a	1.10	1.10	m	o9 V
105......	11.85	1.37	+0.49	2	1	4282	WC7–N6	f	1.55	1.55	m:	?
106......	11.43	1.02	+0.07	2	1	4259	B2 III:	e	1.28	1.29	m	b2 V
107......	11.46	0.94	−0.16	2	1	4257	B0 V	e	1.25	1.25	m	o9 V

* LSS refers to the catalog of Stephenson and Sanduleak (1971).

† The reddening derived from the photometry, $E_{B-V}(UBV)$, has been converted to the equivalent reddening for a B0 V star, E_{B-V}(B0).

NOTES TO TABLE 1

Source of photometry:

1—Photoelectric (Bochum 61 cm telescope).
2—Photoelectric (Tololo 1.5 m telescope).
3—Photographic (TS transformed to the system of 1 and 2).
4—Photographic (visual estimate from direct plates taken with the Curtis Memorial Schmidt telescope on Cerro Tololo: the TS colors for star no. 65 are suspect).

Source of spectral types:

a—130 Å mm^{-1} Garrison image-tube spectrograph on the 61 cm telescope of the David Dunlap Observatory, University of Toronto, at Las Campanas, Chile.
b—70 Å mm^{-1} image-tube spectrograph on the 1 m Yale telescope at Cerro Tololo, Chile.
c—Thin-prism plate (1360 Å mm^{-1} at Hγ) taken with the Curtis Schmidt using a baked IIIa-J plate with UG5 filter.
d—Thin-prism plate taken with ammonia-sensitized IN plate + RG 695 filter. The spectra are unwidened and the classification technique is that of Nassau and Velghe (1964).
e—280 Å mm^{-1} (at Hγ) objective-prism plates taken as above, in the blue.
f—From Smith (1968*a*).
g—47 Å mm^{-1} image-tube spectrograph on the 2.1 m telescope at Kitt Peak National Observatory.

Individual Stars:

1—E_{B-V} obtained from observed colors and intrinsic colors of Lee (1970).
1a—Very crowded by star no. 1; the Bochum photometry gave V = 13.8;, $(B-V)$ = 1.2:, $(U-B)$ = −0.0:.
10—M2 type probably from a very near visual companion.
19—Close double.
23—Spectrum has strong O II λ4415 for its type.
28—WR star. E_{B-V} obtained by converting Smith's (1968*b*) values using $E_{B-V} = 1.2\,E_{b-v}$.
30—Foreground B star?
32—OB−: from IIIa-J + UG5 objective prism plates; M8 from IN + RG8 plates. No evidence for a visual companion.
47—Foreground B star?
49—Foreground B star?
102–107—Bright stars located immediately around Tr 27.
105—WR star; treated as for star 28.

obtained by M. P. F. was reduced using a program prepared by Herbst (1974) and standards taken from Johnson and Morgan (1953) and Landolt (1973). Both sets of standards ranged from O5 to M2. The photometry from the two telescopes agrees well. Comparison of our photoelectric photometry with the photographic photometry of TS indicates only the small mean differences (in the sense this paper minus TS)

$$\Delta V = -0.05\ \mathrm{mag}\,, \qquad \Delta(B-V) = -0.03\ \mathrm{mag}\,,$$
$$\Delta(U-B) = -0.05\ \mathrm{mag}\,,$$

with a standard deviation of ~0.09 mag in each for the 24 stars in common that are not either crowded or suspected of variability. These corrections have been added to TS's values, if not observed by us photoelectrically. The resulting magnitudes and colors for all stars considered are given in Table 1. In this table the numbering system is that of TS with some additions. For clarity we show a blue chart in Figure 1, with an ultraviolet insert of the central region. In addition we show a red chart in Figure 2 which clearly depicts the cluster and delineates the dust in the region quite strikingly.

Spectral types were estimated for about half the stars in Table 1. The various instruments used are noted at the foot of the table. In particular, types for 10 stars were estimated from slit spectra obtained using the Garrison image-tube spectrograph attached to the Toronto 61 cm telescope on Las Campanas. These spectra were compared with spectra of standard stars selected from lists of Keenan and Morgan (1951) and Hiltner, Garrison, and Schild (1969). Most standard MK types between O and B9 and

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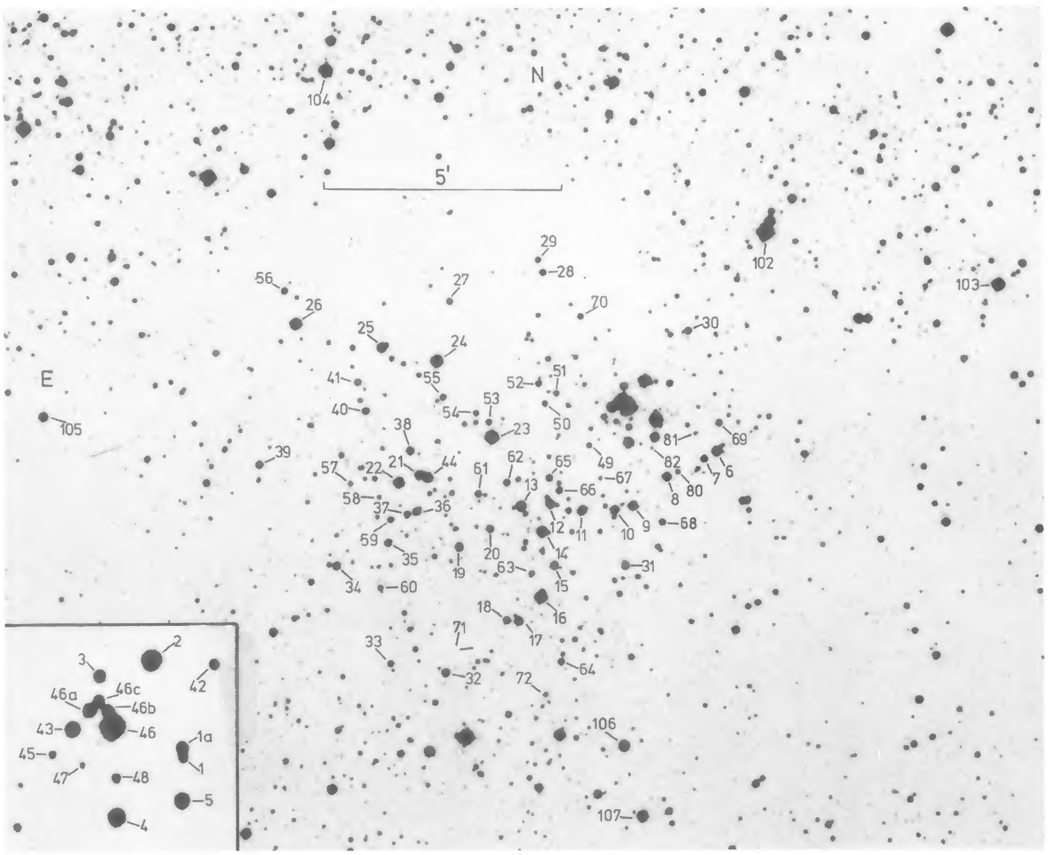

FIG. 1.—Blue (Kodak IIIa-J baked emulsion + GG 385 filter) chart of Tr 27 prepared from a Curtis Schmidt plate. The central area is that of Trumpler 27, and the outer region includes the other adjacent luminous stars observed. The insert on the lower left shows an enlargement in ultraviolet (IIIa-J sensitized + UG2 filter) of the region around star nos. 43 and 46.

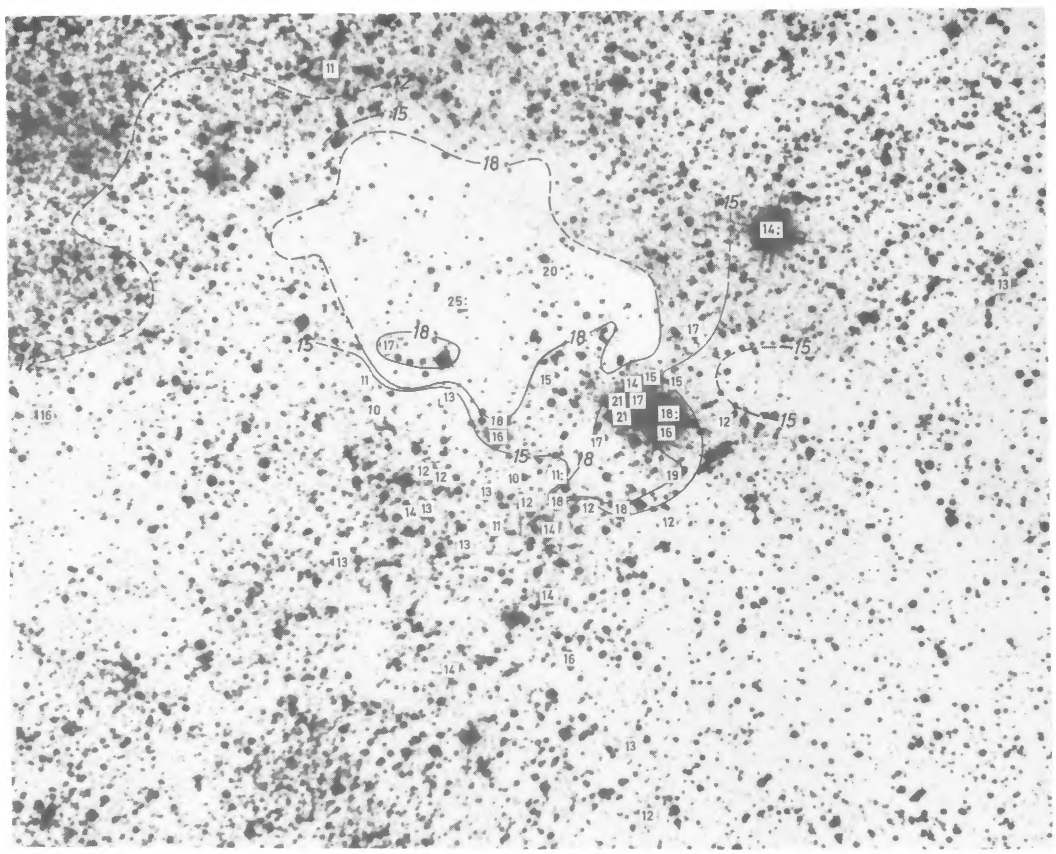

FIG. 2.—Red (Kodak 098–04 sensitized + RG2 filter) chart of Tr 27, showing lines of equal color excess. The numbers indicated are color excesses, in units of one-tenth of a magnitude, for an equivalent B0 star taken from Table 1. A similar figure without lines and excesses is given by Imhoff and Keenan (1976).

TABLE 2

Deduced Parameters for Cluster Stars with MK Spectral Types

TS No.	Sp	M_v	$(B-V)_0$	$(U-B)_0$	E_{U-B}/E_{B-V}	V_0-M_v
1.......	M0 Ia	−7:	+1.69	+1.91	0.99:	10.9:
2.......	09 Ia:	−6.2:	−0.26	−1.11	0.84	11.9:
11.......	B5: III:	−2.2:	−0.18	−0.60	0.55:	10.9:
13.......	B2 V	−2.5	−0.26	−0.87	0.70	10.5
14.......	B0 Ib	−5.8	−0.23	−1.07	0.87	12.5
16.......	O9.5 II:	−5.8	−0.29	−1.11	0.80	12.2
23.......	B0.5 Ib	−5.8	−0.22	−1.03	0.85	11.7
34.......	B1: V:	−3.6:	−0.28	−0.95	0.75:	12.2:
43.......	B9 Ia	−7.0	0.00	−0.57	0.82	11.1
44.......	B1: II::	−5.0:	−0.26	−1.00	0.76:	13.4:
46.......	B9 Ia(+ ?)	−7.0	0.00	−0.57	0.76	10.7:
102.......	G0 Ia	−8.0	+0.67	+0.49	0.96:	12.2:
103.......	B1 II	−5.0	−0.26	−1.00	0.74	11.8
104.......	O9 III	−5.7	−0.31	−1.12	0.75	12.0
106.......	B2 III:	−3.6:	−0.24	−0.90	0.77	11.0:
107.......	B0 V	−4.2	−0.30	−1.08	0.74	11.8
Mean...						11.7 ± 0.2 (s.e. mean)

Note.—The reddening results shown come from the observed *UBV* colors and intrinsic colors taken as a function of spectral class from Schmidt-Kaler (1965).

about half those between A0 and M5 are available on our set of plates taken with the Toronto telescope. The remaining types were obtained by comparing the spectra with prints from the MK Atlas (Morgan, Keenan, and Kellman 1943) and *An Atlas of Low-Dispersion Grating Stellar Spectra* (Abt *et al.* 1968).

III. CLUSTER DISTANCE

In order to investigate the nature of interstellar extinction in Tr 27 we show in Figure 3 a plot of color excess in $(U-B)$ versus that in $(B-V)$ for the 16 cluster members with MK types. The data are listed in Table 2. Intrinsic colors and absolute visual magnitudes as a function of spectral luminosity class were taken from Schmidt-Kaler (1965), except for star 1, whose intrinsic colors were adopted from Lee (1970). The positions of the early-type stars of class II to V in Figure 3 show compatability with the reddening lines of Serkowski (1963). The colors for the blue supergiants put them below Serkowski's reddening lines. This may partly be due to the fact that he related the reddening line variation to $(B-V)_0$, whereas the variation of reddening line slope is more accurately related to $(U-B)_0$ (Golay 1963; FitzGerald 1970). However, use of reddening lines as a function of $(U-B)_0$ still requires an increase in the slope X of $\sim$0.1 to fit the supergiant data where

$$E_{U-B}/E_{B-V} = X + 0.06\, E_{B-V}\,.$$

The reason for this discrepancy is not known, but could result from one or a combination of any of the following: a lack of heavily reddened *UBV* standards to calibrate the photometry; improper spectral classification; incorrect intrinsic colors or reddening lines for supergiants. In view of the above circumstances we have adopted Serkowski's reddening line slopes for *all* stars in Tr 27 as a function of the star's class V $(B-V)_0$ index. These slopes are close to those given by FitzGerald (1970) as a function of $(U-B)_0$. Using these reddening lines and the intrinsic colors of Schmidt-Kaler (1965), we have derived the reddening for each suspected cluster member. For stars whose location in the color-magnitude diagram lay in the class II to Ia region we used the appropriate intrinsic color relations. For the remaining stars of class III to V we used the intrinsic class V colors. The derived photometric color excesses $E_{B-V}(UBV)$ are listed in Table 1.

The ratio, R, of total visual extinction to reddening is investigated in Figure 4, following the procedure of Turner (1976), in which apparent distance moduli obtained by assuming all unambiguously reddened O and B stars to lie on the zero-age main sequence (ZAMS) are plotted against reddening. Fitting to the lower envelope of the point distribution yields $R = A_v/E_{B-V} = 3.3 \pm 0.3$ and $V_0 - M_v = 11.5 \pm 0.5$. This R-value is consistent with the normal value $R = 3.20 + 0.21\,(B-V)_0$ (Schmidt-Kaler 1965; Moffat and Schmidt-Kaler 1976), which we use in the rest of this paper.

From Table 2 it is apparent that we are dealing with a group of stars with common distance. A simple or weighted average of the 16 true distance moduli based on MK types and *BV* photometry yields an average distance modulus of 11.7 ± 0.2 (standard error of the mean [m.e.]). The seven supergiants give 11.6 ± 0.3 compared with 11.8 ± 0.3 for the nine nonsupergiants. The standard deviation is $\sim$0.8 mag, consistent with the normal dispersion expected for this technique (cf. Blaauw 1963).

Figure 5 shows a two-color plot of all stars in Table 1. The stars located in a strip between the reddening lines for O5 to B5 V stars are tentatively assumed to be members of Tr 27, as well as stars 1 and 102, the red and yellow supergiants. That most of these stars lie in a cluster sequence is seen in the reddening-free color-magnitude diagram of Figure 6. Fitting the

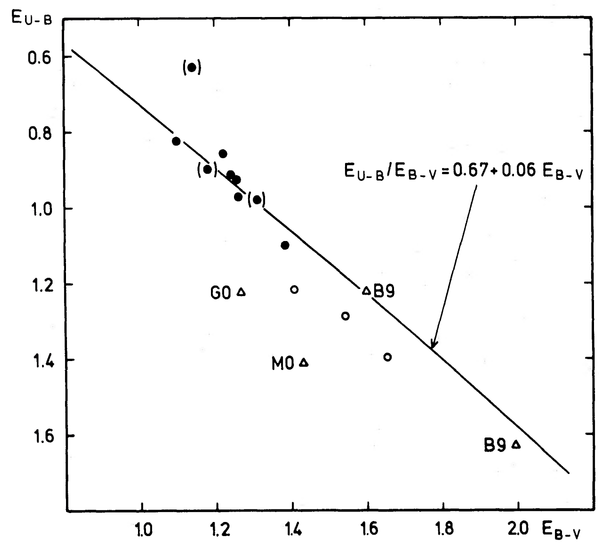

FIG. 3.—Reddening in $(U - B)$ versus reddening in $(B - V)$ for the 16 stars in Table 2 with MK spectral type. Filled circles represent very early nonsupergiants (brackets imply less certain values), open circles very early supergiants, and triangles the remaining supergiants. The reddening line is drawn for a star with $(B - V)_0 = -0.26$ from Serkowski (1963).

ZAMS of Schmidt-Kaler (1965) to the unevolved part of the sequence yields a distance modulus of 11.4 ± 0.2 (estimated m.e.). This overlaps well with the modulus obtained from the spectral types. We adopt an average $V_0 - M_v = 11.6 \pm 0.2$, corresponding to a distance of 2.1 ± 0.2 kpc for Tr 27. This is about twice the distance derived by TS, putting the cluster on the inner edge of the $-$I arm, where other young clusters are known to lie (Vogt and Moffat 1975).

This discrepancy between our distance modulus and that of TS is interesting in view of the fact that there is good agreement between our photometry and their photometry. There are small systematic differences, as shown above (ours is slightly bluer), and the value of R we used (see above) is slightly larger than that of $R = 3$ used by TS. However, both these effects are far from being sufficiently large to explain the discrepancy in distance and, furthermore, they work in opposite directions.

The basic reason for the distance discrepancy appears to lie in the fainter stars chosen as members and subsequently used for the main-sequence fitting. TS rely heavily on stars 4, 9, and 17 for the lower part of the main-sequence fit. If members of Tr 27, these stars would have unusually low reddening ($E_{B-V} \approx 0.7$) for the cluster. Furthermore, these stars have positions in the two-color plot (Fig. 5) which lie very close to the positions of unreddened G-type main-sequence stars. We feel that these stars are consequently F to G field stars.

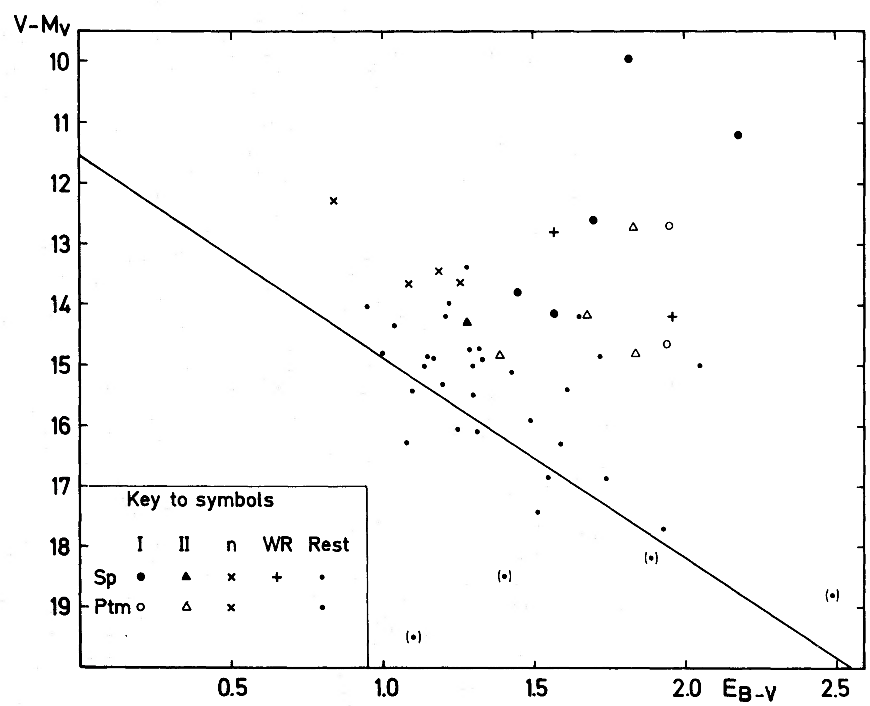

FIG. 4.—Relation between apparent distance modulus $V - M_v$(ZAMS) versus reddening E_{B-V}(ZAMS) for all stars with unambiguous O or B reddening lines. The line corresponds to $R = 3.30$, $V_0 - M_v = 11.5$.

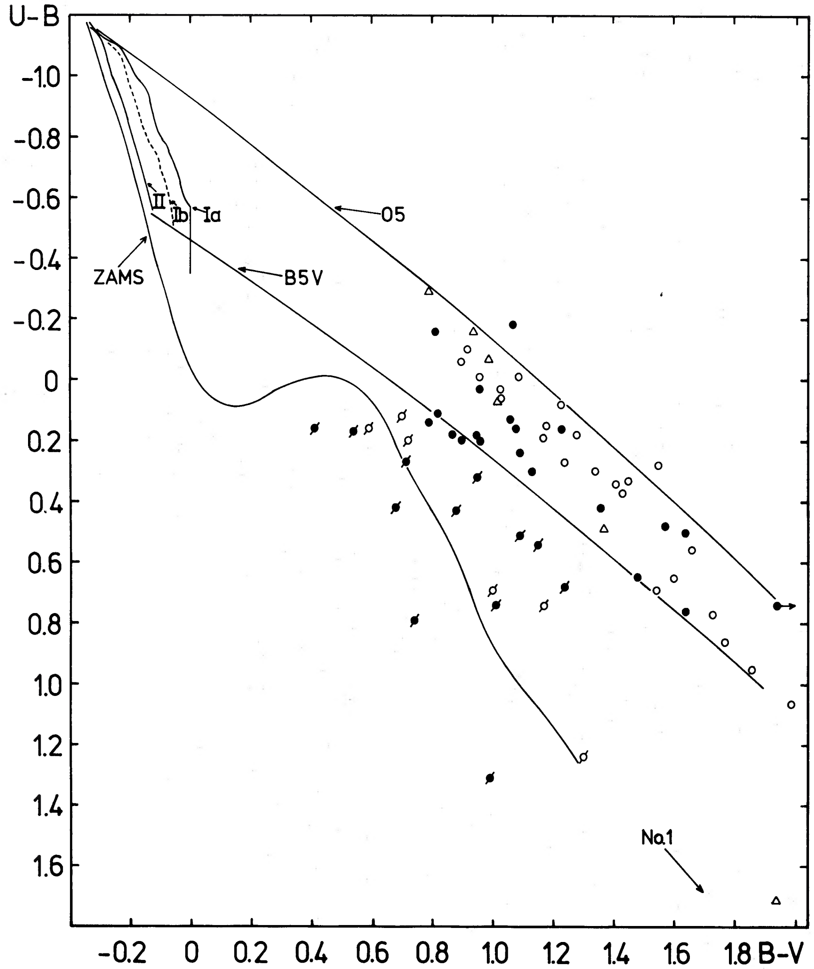

FIG. 5.—Two-color diagram for all stars observed in Tr 27. The zero-age main sequence, class II, Ib, and Ia relations are from Schmidt-Kaler (1965). Reddening lines for O5 and B5 V stars are shown. Suspected nonmembers are stroked out. *Open symbols*, photoelectric, *closed*, photographic; triangles denote stars just outside the obvious cluster region. Stars have been dereddened along the class V reddening lines, to the intersection of the reddening line with the intrinsic color relationship appropriate to their (photometric) luminosity class.

The lower end of the main sequence in Figure 6 consists of stars 20, 37, 40, 41, 42, 52, 55, 61, 62, 64, 68, and 69. Although they were measured by TS, these stars were not included in their analysis since TS, lacking the photoelectric and spectroscopic data available to us, did not analyze stars fainter than $V =$ 13.5. When these stars are dereddened, however, their loci in the two-color diagram all pass at least 0.1 magnitude above the F to G "hump" for unreddened main-sequence stars and reach the B-type main sequence with an average E_{B-V} of about 1.2. Our confidence in considering these stars as main-sequence B stars results from their position in the two-color diagram, the resulting appearance of the color-magnitude diagram (Fig. 6), and the agreement, as shown above, in the spectroscopic and photometric distance moduli.

From Figure 6, photometric spectral-luminosity classes are derived and listed in Table 1. There is good agreement between these classes and the MK types for the stars of moderately high luminosity, but for the supergiants the photometric types tend to be slightly later. Presumably the reasons for this small discrepancy are connected with the position of the supergiants in Figure 3.

In view of the extremely large and variable reddening, the agreement of the MK types with the positions in the color-magnitude diagram is quite satisfactory. The brightest eight cluster members appear to form an evolved sequence of six blue, one yellow, and one red supergiant of high luminosity. These stars will be discussed in a later section.

The earliest spectral type is O9, and the upper-main-sequence turnoff occurs at about B1 V, corresponding to an age of about 6 million years (Allen 1973).

The parameter A_{12} of Harris (1976*a*) is $-1.13 \pm$ 0.02 for Tr 27, placing it in Group I, the youngest of

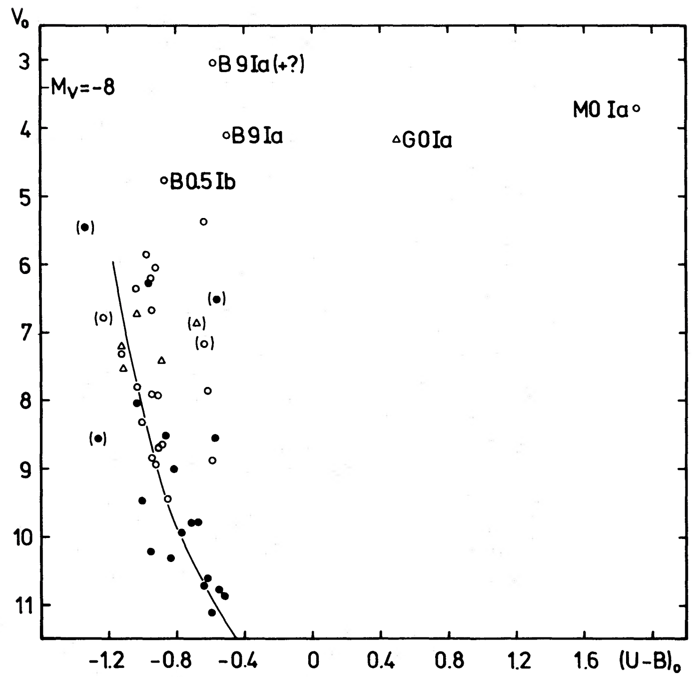

FIG. 6.—Color-magnitude diagram for suspected members of Tr 27. The zero-age main sequence of Schmidt-Kaler (1965) is fitted with true distance modulus 11.4. Symbols are as in Fig. 5. Brackets refer to uncertain values. The effects of interstellar extinction have been removed.

her six age groups of open clusters. For group I membership, the age limits of Harris are 2.5×10^6 years and 6×10^6 years. However, as will be discussed below when the individual supergiants of Tr 27 are considered, there is evidence for a spread in age of the various members of Tr 27 of perhaps 10^7 years.

The Wolf-Rayet stars 28 and 105 appear to be members of Tr 27. They correspond to MR 74 and MR 76, respectively, in the Wolf-Rayet catalog of Smith (1968*a*). From Smith's (1968*b*) narrow-band photoelectric photometry these stars have $v_0 = 7.58$ and 7.35, respectively. This yields $M_v = -4.0 \pm 0.2$ and -4.2 ± 0.2, respectively, assuming our distance modulus of 11.6 ± 0.2. These values are well within the range expected for stars of this type (Smith 1968*c*, 1973): -4.3 for WN 5 and -4.4 for WC 7–N6. Their reddening (cf. Table 1) is also compatible with membership. The adjacent star MR 73 appears to be too distant (7.6 kpc according to Smith 1968*c*), while no parameters have been estimated for MR 75 (OB + WN).

IV. REDDENING STRUCTURE

The large and variable reddening of the members of Tr 27 is undoubtedly a consequence of the patchy dust lanes seen on deep exposures (cf. Fig. 1 and Imhoff and Keenan's Fig. 1). This is borne out in Figure 2, in which approximate lines of equal reddening (all stars reduced to an equivalent B0 star using Fernie's [1963] relation) are indicated. The lines of equal reddening drawn in Figure 2 fit well with the dark lanes and the individual color excesses, suggesting that much of the dust lies in front of Tr 27. If the stars of Tr 27 were embedded *in* the dust, one would expect larger scatter in reddening across the cluster. Especially noteworthy is the large reddening in the NE section in which star 27 and the Wolf-Rayet star 28 are located. The former star suffers 7.8 mag visual extinction, compared with only 3.2 for the least reddened member of Tr 27. Another smaller region of high reddening is located between the knot of stars around star 1 and star 10 to the south.

If we assume that these clouds lie no farther than Tr 27, it is possible to derive an upper limit to their mass. Using an excess reddening for the clouds of 1.0 mag based on a comparison of the reddening of stars behind and beside the clouds, a radius of 2′, and a ratio of gas column density to reddening of 40 $M_\odot$ pc^{-2} mag^{-1} (Savage and Jenkins 1973), we find a total mass of $\leqslant 190\ M_\odot$. The possibility that this is foreground material is supported by the lack of evident H II emission or reflection nebulosity. Furthermore, the cluster contains numerous very luminous stars which have likely had sufficient time to blow away most of the interstellar matter remaining after star formation.

TS noted a correlation of V_0 and A_v in the sense that the visual absorption is larger for stars of greater luminosity. This was interpreted by the tendency for more massive stars to be surrounded by denser, more massive remnants of their parent protostellar material. However, TS neglected the observational cutoff in magnitude which prevents one's detecting highly

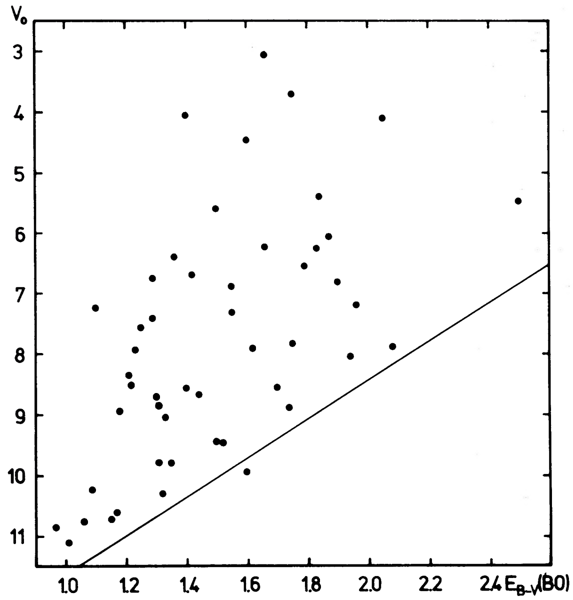

FIG. 7.—Intrinsic visual magnitude, V_0, versus reddening for the member stars in Table 1. The line drawn represents the observational cutoff caused by a plate limit of $V = 14.8$ from TS.

reddened stars of low intrinsic luminosity. In Figure 7 we have plotted our data from Table 1 in a similar way but *with* the cutoff line based on TS's limiting magnitude of $V = 14.8$. There is little if any evidence left for the trend claimed by TS. This agrees with the results of Bohannan (1975) and Moffat (1974), who recently reanalyzed the data for the clusters indicated by Reddish (1967) to show the strongest correlation of V_0 and A_v. This is also consistent with the theoretical work of Appenzeller and Tscharnuter (1973), who predict that massive stars will dissipate their protostellar envelopes quickly as they reach the main sequence.

V. THE SUPERGIANTS

Our spectral type for star 1 (CD $-33°12241$) is M0 Ia, based on 130 Å mm^{-1} blue plates, and agrees with the type M0: Ia of Imhoff and Keenan (1976) based on high-dispersion red plates. Its central location and reddening favor its membership in Tr 27.

This star's position in the color-magnitude diagram of Figure 6 indicates an absolute magnitude $M_v = -7.7$. The composite H-R diagram of Harris (1976*a*) for Group I clusters has no M supergiants; these are extremely rare in very young clusters. The composite H-R diagram of Harris for the next older age group, Group II (age between 0.6 and 1.6×10^7 years) shows M supergiants with a mean M_v of about -5.5, or more than 2 magnitudes less luminous than star 1, if it is a member of Tr 27. However, Stothers (1972*a*) obtains $M_v = -6.5 \pm 0.6$ (s.d.) for M Ia supergiants, all of them in OB associations. This value is consistent with the $M_v = -7.7$ we obtain for star 1 considering that (i) Imhoff and Keenan (1976) feel that star 1 could perhaps be classified slightly brighter than M0: Ia, and (ii) our value of $B - V$ for this star could be in error by ± 0.2 magnitudes, corresponding to about ± 0.7 magnitudes in V_0 and hence M_v. The photometry of such extremely red stars as no. 1 is uncertain on the *UBV* system owing to the lack of sufficiently reddened red standards.

Imhoff and Keenan obtained a radial velocity of -11.4 ± 0.7 km s^{-1} for star 1 from two coudé spectrograms from the Palomar 5 m telescope. One of us (M. P. F.) has obtained one blue spectrogram for each of two blue members of Tr 27 using the image-tube spectrograph at 47 Å mm^{-1} on the KPNO 2.1 m telescope. Their radial velocities are -12 ± 5 (m.e.) km s^{-1} for LSS 4256 and -17 ± 3 (m.e.) km s^{-1} for LSS 4255. These velocities are in quite good agreement, again consistent with the view that star 1 is a member of Tr 27. The expected heliocentric radial velocity for Tr 27 resulting from differential circular galactic rotation, and assuming Oort's constant, $A = 15$ km s^{-1} kpc^{-1}, is -14 km s^{-1}. Since Tr 27 is located in a direction toward the galactic center where there is little spread of radial velocity with distance, only high-quality radial velocity measurements of the suggested members would provide a critical test of membership.

The yellow G0 Ia supergiant no. 102 (=HD 159378) lies about 7′ from the estimated cluster center (star 23). Its reddening favors membership in Tr 27, but at $M_v = -7.2$, it seems somewhat underluminous compared with the blue supergiants and star 1, CD $-33°12241$. Theoretical considerations (e.g., Stothers 1972*b*) indicate an essentially horizontal locus in the theoretical H-R diagram for the supergiants in a coeval cluster. Allowing for the bolometric corrections, we would then expect HD 159378 to be brighter in the color-magnitude diagram (Fig. 6) than the red and blue supergiants. If HD 159378 is a member of Tr 27, then we must consider it to be somewhat older than the other supergiants. It is not unusual (Harris 1976*b*) for evolved stars to be primarily in the outer regions and not in the core of galactic clusters (e.g., h and χ Persei and IC 2944). Also, there are some other stars (Nos. 30, 47, and 49) in Figure 6 which lie above the main sequence and would represent an older population of age 1.5×10^7 years, compared with the age of less than 0.6×10^7 years found above for the bluer members of Tr 27. If HD 159378 is a member, it lies at the blue, bright edge of the instability strip defined by Sandage and Tammann (1969), and is a possible Cepheid candidate with expected pulsation period of about 75 days. However, to our knowledge, the star is not listed anywhere as a Cepheid.

The remaining six supergiants (Nos. 2, 8, 23, 43, 46, 46a) range over the spectral types O9 to B9 and are all located in the central region of the cluster. The ratio of blue to red supergiants (6:1) is similar to that found by Stothers (1969) in the clusters NGC 3293 and NGC 4755 and in the association I Ori where the mean is 4.3:1. Besides each containing one red supergiant in the range M0–M2, these three objects and Tr 27 also have other characteristics in common: they all contain stars of very high luminosity, are void of stars earlier than O9, contain few yellow F, G, K supergiants, and have little dust in the cluster itself (only a probability for Tr 27). Stothers (1969) and Stothers and Chin (1969) explain the high ratio of blue to red supergiants by photoneutrino losses *after* core helium burning, causing acceleration of the evolution of massive red supergiants. However, it is still unclear whether core helium burning starts before the red supergiant stage is reached (Barbaro, Dallaporto, and Fabris 1969). If not, one may have to look for other processes to explain this large ratio of blue to red supergiants.

VI. CONCLUSIONS

We find Tr 27 to be a 6 million year old cluster containing eight supergiants (six blue, one yellow, and one red). At a distance from the Sun of 2.1 $\pm$ 0.2 kpc, Tr 27 is located in, or more likely behind, a region of highly variable extinction. Future observations would be worthwhile to obtain slit MK spectra of stars over a large range of reddening, both on and above the main sequence, in order to allow a better estimate of the ratio of total to selective extinction and to check the apparent deviation of the supergiant stars from the normal two-color reddening law. A photoelectric extension of the main sequence to fainter magnitude would also be valuable, as would a study of the apparent association of the 30 luminous stars around Tr 27. The reality of the cluster could be tested by high-quality radial-velocity observations.

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M. Pim FitzGerald and P. D. Jackson: Department of Physics, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

A. F. J. Moffat: Department de Physique, Université de Montréal, Montréal, Quebec H3C 3J7, Canada