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UBV PHOTOMETRY OF THE CEPHEID V367 SCUTI IN THE OPEN CLUSTER NGC 6649

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ABSTRACT

UBV photometry has been obtained for the Cepheid V367 Sct and for the cluster NGC 6649 in which it is located. The cluster is found to have $(m - M)_V = 15.4 \pm 0.2$ and suffers a reddening $E_{B-V}(B0) = 1.37$. For the Cepheid V367 Sct, $\langle V \rangle = 11.58$ and $\langle B \rangle - \langle V \rangle = 1.76$, so that $M_{\langle V \rangle} = -3.8 \pm 0.2$ and $\langle B \rangle_0 - \langle V \rangle_0 = 0.49$. A period of 5.255 ± 0.002 days is derived for V367 Sct. NGC 6649 also contains a nonvariable star in the Cepheid instability strip. Furthermore, the cluster appears to contain two red giants, one of which is a variable.

Subject headings: Cepheids and W Virginis stars — open clusters — stars, individual

I. INTRODUCTION

Cepheid variables that are located in open clusters provide a powerful tool for the calibration of the Cepheid period-luminosity relation. Previous data on five cluster Cepheids has been summarized by Kraft (1963). Subsequently The and Roslund (1963) suggested that the position of the variable star V367 Sct (which had been discovered by Roslund and Pretorius 1963) in the color-magnitude diagram of NGC 6649 indicated that it might be a cluster member. This conclusion was subsequently strengthened by Tammann (1969) who obtained more extensive observations of the variable.

NGC 6649 ($\alpha_{1950} = 18^h30^m.7$, $\delta_{1950} = -10°26'$) is a heavily reddened cluster that is situated at galactic coordinates $l = 21°.6$, $b = -0°.8$. The present paper presents new *UBV* photometry of both the cluster NGC 6649 and the Cepheid variable V367 Sct.

II. PHOTOELECTRIC OBSERVATIONS

a) *Observations of V367 Scuti*

New photoelectric observations of V367 Sct are listed in table 1. These observations were begun in 1972 using the 61-cm reflector of the University of Toronto on Las Campanas. More recently these data have been supplemented by observations with the 1.5-m and 1-m (Yale) reflectors on Cerro Tololo. The Tololo observations were all obtained with the same coldbox. All observations were made using the standard filters of the *UBV* system in front of a 1P21 photomultiplier that was refrigerated with dry ice. Transformations to the Johnson *UBV* system were made using the *E*-region standards of Cousins (1963, 1967) and Landolt (1973). The latter data were particularly valuable for the determination of the transformation equations for extremely red stars. Photon counting equipment was used for all observations. Each individual observation consisted of at least two integrations of 10 seconds each. Integrations were continued until between 3,000 and 10,000 counts above sky had been accumulated. Diaphragms of 7″ and 10″ diameter were used on the 1.5-m and 1.0-m telescopes respectively. A 14″ diaphragm was employed during the observations with the University of Toronto 61-cm reflector on Las Campanas. Additional details on observing procedures are given in Madore (1974).

The data on the variable V367 Sct are collected in table 1. In the table the data have been phased using a period of 5.2551 days. This period, which has an estimated uncertainty of 0.002 days, fits all of the observations except those of The and Roslund. The data possibly suggest a period change of ~1 percent between 1961 September and 1962 June. Over the most recent 800 cycles of variation, the period does not appear to have changed by more than 0.04 percent.

No evidence is found for the 6-day period reported by Kholopov and Efremov (1967). Tammann's 1969 period of 5.1182 days results from efforts to retain all of the data.

The *UBV* light curve of V367 Sct is plotted in figure 1.

The observations (except those of The and Roslund that were obtained in 1961 September) have been plotted and are seen to fit the adopted light curve reasonably well.

b) *Observations of Standard Stars*

The 1.5-m and 1.0-m reflectors of the Cerro Tololo Observatory were used to establish a sequence of 68 photoelectric standards in NGC 6649. Faint program

* Guest observer, 1974, Cerro Tololo Inter-American Observatory. CTIO is operated by AURA, Inc. under contract with the National Science Foundation of the USA.

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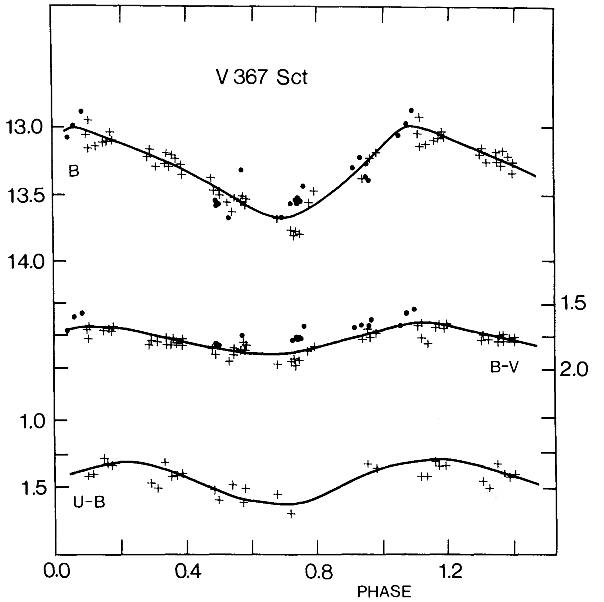

FIG. 1.—*UBV* light curve of V367 Sct. All previous observations (except those by The and Roslund in 1961) are shown as dots. New observations are plotted as crosses.

TABLE 1

PHOTOELECTRIC OBSERVATIONS OF STAR V367SCT

JD(2430000.000+)	V	(B-V)	(U-B)	PHASE*
11762.910†	11.53	1.83		0.380
11763.863	11.70	1.81		0.562
11764.898	11.69	1.88		0.758
11765.891	11.46	1.78		0.947
11771.895	11.36	1.70		0.090
11772.883	11.42	1.81		0.278
11773.871	11.52	1.86		0.466
11921.602	11.71	1.83		0.578
11922.652	11.65	1.84		0.778
11923.648	11.45	1.75		0.987
11924.695	11.34	1.71		0.167
11925.633	11.49	1.82		0.345
11926.609	11.76	1.89		0.531
11927.609	11.86	1.94		0.721
11927.656	11.86	1.94		0.730
11928.672	11.61	1.80		0.923
11929.598	11.28	1.66		0.099
12213.605‡	11.40	1.71	1.30	0.144
12213.668	11.40	1.69	1.33	0.155
12213.758	11.40	1.69	1.34	0.172
12214.602	11.44	1.76	1.36	0.333
12214.695	11.44	1.77	1.41	0.351
12214.762	11.44	1.80	1.42	0.364
12214.844	11.50	1.78	1.40	0.379
12215.680	11.69	1.85	1.54	0.538
12215.766	11.71	1.86	1.56	0.554
12215.840	11.72	1.87	1.50	0.569
12216.625	11.82	1.99	1.62	0.718
12216.719	11.86	1.98	1.99	0.736
12218.625	11.39	1.78	1.41	0.099
12218.723	11.31	1.83	1.41	0.117
12219.609	11.39	1.78	1.46	0.286
12219.688	11.49	1.80	1.50	0.301
12220.617	11.59	1.89	1.51	0.478
12220.688	11.61	1.89	1.59	0.491
12220.824	11.67	1.90	1.57	0.517
12221.617	11.71	1.98	1.54	0.668

* For an adopted period of 5.2551 days.

† Observations obtained on Las Campanas.

‡ Observations obtained on Cerro Tololo.

stars were observed by blind offsets as determined from 200-inch plates. Sky readings were made in preselected star-free regions scattered throughout the cluster. The photoelectric sequence, which was established during eight moonless nights in 1974 June, extends to $V \approx 19.0$, $B \approx 20.0$, and $U \approx 18.5$.

Observations of individual photoelectric standards are listed in table 2. The total number of observations in each color is given in the fifth column of the table. Also given in this table are the photographic magnitudes of these standard stars obtained by reading the magnitudes of the stars back through the adopted calibration curves. In the table, numbers smaller than 200 are taken from the work of Cuffey (1940). An identification chart for the photoelectric standards and for the stars observed photographically is shown in figure 2.

c) *Photographic Photometry*

Four 10-minute *B*(103aO+GG13) and four 10-minute *V*(103aD+GG14) plates of the cluster NGC 6649 were obtained with the Hale 5-m reflector in 1973. These exposures were made with the Racine (1969) achromatic wedge in front of the Ross f/3.67 prime focus corrector. This wedge produces secondary images that are 5.00 mag fainter than their primaries. These secondary images made it possible to extend the calibration down to the plate limit in both colors. The plates were measured on the Cuffey-type iris photometer of the David Dunlap Observatory. The photographic and photoelectric observations of standard stars are compared in figure 3. The only systematic difference between the primary (*crosses*) and secondary (*dots*) images is that the secondaries may indicate slightly (0.02 mag) redder colors than do the primaries. The photographic photometry is summarized in table 3. A comparison between the present observations and those by The and Roslund (1963) is given in the Appendix.

d) *Spectroscopic Observations*

Spectra of the bright stars Cuffey nos. 9, 28, and 58 were obtained with the "toy" spectrograph and image intensifier attached to the 61-cm telescope of the University of Toronto on Las Campanas. This spectrograph gives a dispersion of 120 Å mm^{-1}. In the spectra of all three of these stars the hydrogen lines are partly filled in. This filling-in of the Balmer lines is more pronounced in star 9 (which is the brightest of the three stars studied spectroscopically) than it is in stars 28 and 58. A search of the emission-line catalog of Wackerling (1970) shows that star 9 had previously been identified as an emission-line star (I6-27) by Iriarte and Chavira (1955).

III. CLUSTER REDDENING AND DISTANCE

a) *Reddening Determination*

The color excesses of individual photoelectrically observed stars were determined by tracing them back

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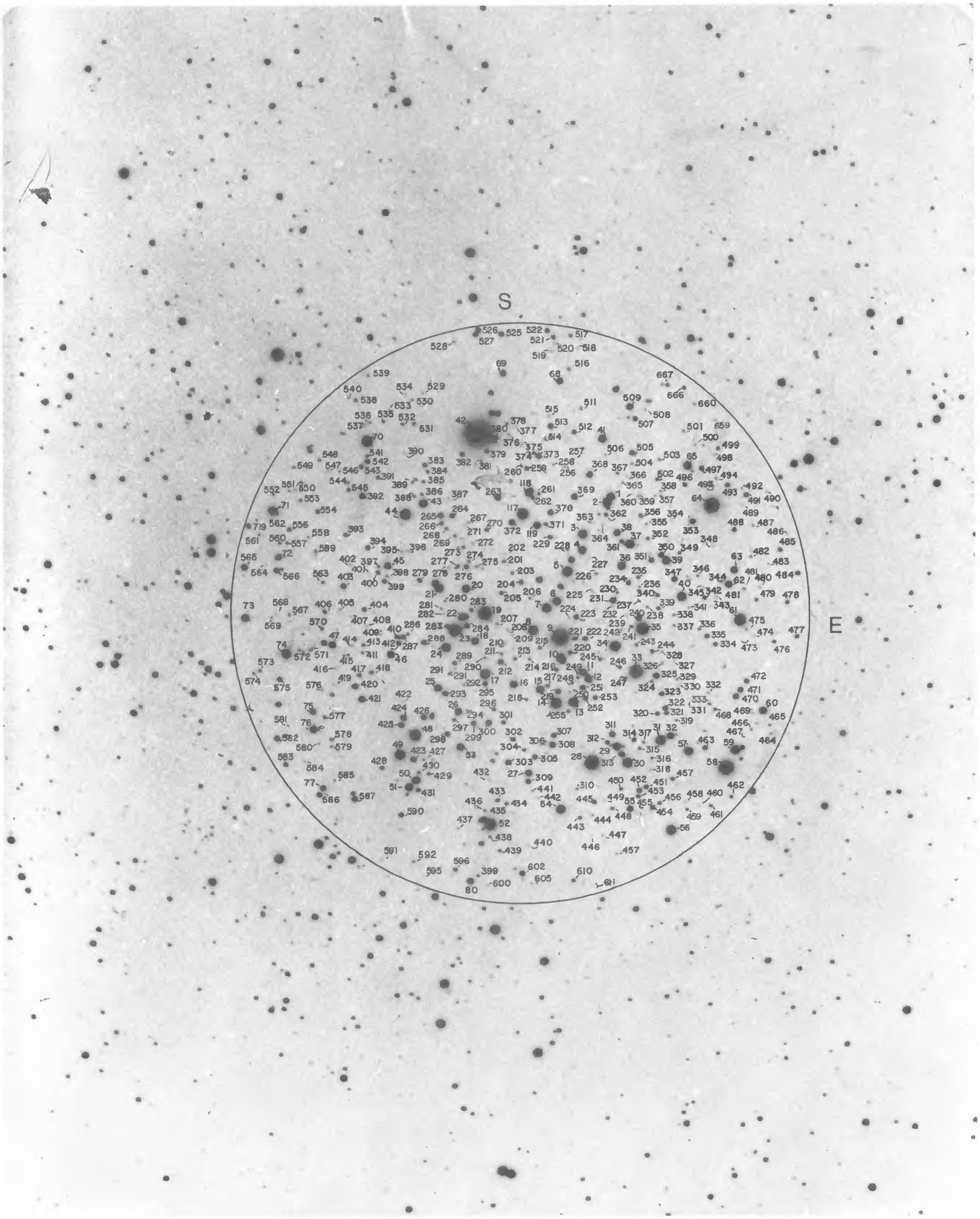

FIG. 2.—Identification chart for stars observed in the cluster NGC 6649. The circle has a radius of 2.′7. The Cepheid is star no. 64.

TABLE 2

PHOTOELECTRIC SEQUENCE IN NGC 6649

STAR	V	B-V	U-B	n	V_{pg}	$(B-V)_{pg}$	E(B-V)
3	14.58	1.24	0.66	4,4	14.53	1.26	1.34
4	15.08	1.31	0.71	3,3	15.00	1.33	1.43
5	14.03	1.27	0.96	3,3	14.02	1.23	1.28
6	15.10	1.19	0.46	2,2	14.93	1.31	1.35
7	14.55	1.23	0.53	3,3	14.49	1.26	1.38
8	14.08	1.26	0.53	4,4	14.11	1.12	1.42
9	11.77	1.30	0.08	9,7	11.79	1.30	em
13	14.00	1.33	0.59	2,2	13.96	1.38	1.48
14	13.45	1.34	0.77	1,1	13.46	1.39	1.43
15	14.95	1.33	0.86	2,1	14.98	1.37	1.39
17	14.10	1.26	0.51	2,2	14.03	1.26	1.42
18	15.10	1.32	0.72	3,2	15.04	1.38	1.43
19	12.11	1.78	1.43	14,14	12.08	1.75	evol
20	14.98	1.26	0.62	1,1	15.05	1.30	1.39
24	14.46	1.20	0.53	3,3	14.48	1.22	1.34
28	12.35	1.34	0.62	4,4	12.39	1.33	em
30	14.22	1.27	0.70	1,1	14.15	1.33	1.37
31	14.12	1.18	0.48	3,3	14.21	1.20	1.34
33	12.76	1.24	0.56	4,4	12.80	1.22	1.38
34	13.87	1.22	0.50	4,3	13.89	1.23	1.38
35	13.12	1.13	0.46	4,3	13.12	1.12	1.28
36	15.14	1.19	0.73	2,1	15.14	1.24	1.26
38	15.94	1.32	0.65	2,1	15.87	1.22	1.45
40	14.62	1.18	0.60	4,4	14.59	1.16	1.29
41	15.01	1.22	0.77	3,2	15.02	1.22	1.29
43	14.97	1.20	0.60	2,1	14.98	1.21	1.32
44	13.81	1.18	0.51	4,4	13.86	1.15	1.32
46	15.73	1.28	..	2,0	15.72	1.24	..
48	13.44	1.33	0.62	1,1	13.47	1.34	1.47
49	12.57	2.58	2.79	4,4	12.51	2.57	evol
53	15.33	1.35	0.85	3,2	15.29	1.51	1.42
54	14.28	1.34	0.71	2,2	14.28	1.40	1.45
55	16.07	1.35	0.85	1,1	16.10	1.34	1.42
56	13.90	1.32	0.62	4,4	13.93	1.33	1.46
57	14.76	1.23	0.49	4,3	14.72	1.26	1.38
58	12.20	1.32	0.82	4,4	12.29	1.29	em
60	15.42	1.19	0.64	4,1	15.49	1.21	1.29
61	13.49	1.19	0.52	4,4	13.54	1.20	1.33
63	15.59	1.27	0.72	2,1	15.60	1.26	1.36
70	13.92	1.13	0.41	4,4	13.92	1.06	1.29
84	15.68	1.39	..	1,0	15.64	1.46	..
117	12.07	2.75	3.28	4,4	variable		
119	15.53	1.30	0.57	1,1	15.56	1.30	1.45
204	17.43	1.46	..	2,0	17.51	1.61	..
206	18.75	1.81	..	1,0	18.91	1.87	..
212	16.76	1.44	..	1,0	16.83	1.37	..
215	17.86	1.39	..	1,0	17.83	1.95	..
222	17.24	1.49	..	1,0	17.22	1.33	..
243	18.42	1.79	..	2,0	18.43	1.72	..
245	18.18	1.71	..	1,0	18.15	1.68	..
264	16.85	1.66	..	1,0	16.84	1.65	..
289	17.55	1.44	..	1,0	17.72	1.46	..
290	18.75	1.75	..	1,0	18.73	1.77	..
299	17.08	1.41	..	1,0	17.14	1.50	..
300	15.99	1.41	..	1,0	16.01	1.41	..
323	17.22	1.46	..	1,0	17.29	1.30	..
348	19.12	1.82	..	1,0	18.92	1.85	..
353	16.48	1.26	..	2,0	16.53	1.23	..
368	16.15	1.23	..	1,0	16.26	1.21	..
369	16.11	1.24	0.88	2,1	16.17	1.21	1.33
391	18.00	1.53	..	1,0	18.04	1.64	..
392	16.35	1.20	0.89	1,1	16.37	1.22	1.21
496	17.70	1.57	..	1,0	17.67	1.58	..
502	17.56	1.94	..	1,0	17.60	2.29	..
532	16.50	2.78	..	1,0	16.39	3.45	..
600	16.20	1.37	1.39	2,1	16.21	1.33	1.26
601	16.80	1.36	..	2,0	16.83	1.33	..
602	16.10	1.34	1.10	1,1	16.15	1.30	1.36

along reddening lines to the intrinsic color-color relation of Johnson (1963). The adopted reddening line (Sharpless 1963) had a slope

$$E_{U-B}/E_{B-V} = 0.72 + 0.05\,E_{B-V}\,. \quad (1)$$

The individual reddening values so derived are listed in the last column of table 2. No reddening values were determined for the emission-line stars 9, 28, and 58, or for the evolved stars 19 and 49. The remaining 39 stars give a mean reddening $\langle E_{B-V}\rangle = 1.37 \pm 0.01$, so that the visual absorption in front of the cluster amounts to more than 4 mag. The

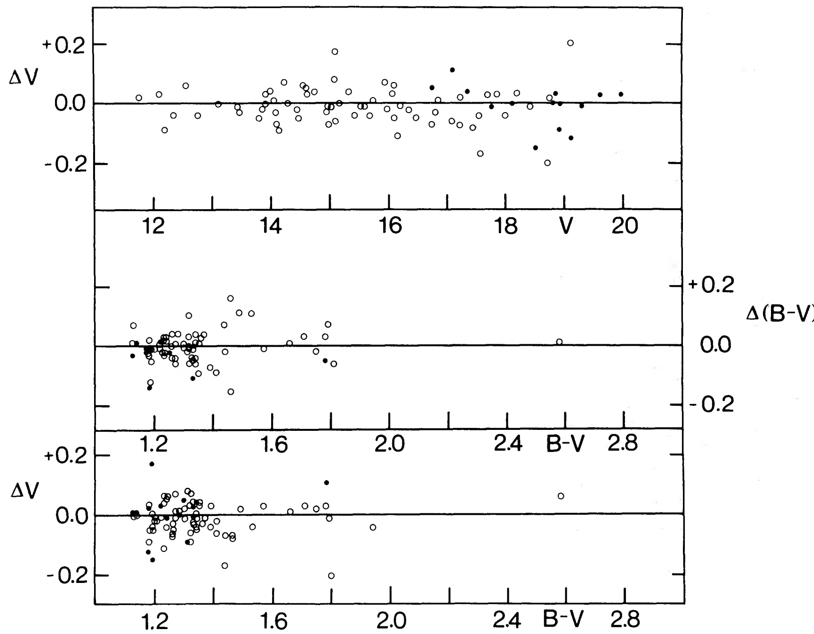

FIG. 3.—Comparison of photoelectric and photographic observations. Primary and secondary images are plotted as circles and as dots, respectively. Differences are in the sense photoelectric minus photographic.

standard deviation of individual reddening determinations about the mean amounts to 0.07 mag. The data may indicate a slight patchiness in the reddening across the face of the cluster. The six stars nearest to the Cepheid have $\langle E_{B-V} \rangle = 1.36 \pm 0.04$, which does not differ significantly from the mean reddening of the cluster. Furthermore, no significant difference is found between the reddening of evolved stars with $V < 14.5$ and unevolved stars with $V > 14.5$.

b) *The Distance to NGC* 6649

The cluster distance modulus was derived using the evolutionary deviation curve of Johnson (1960) and

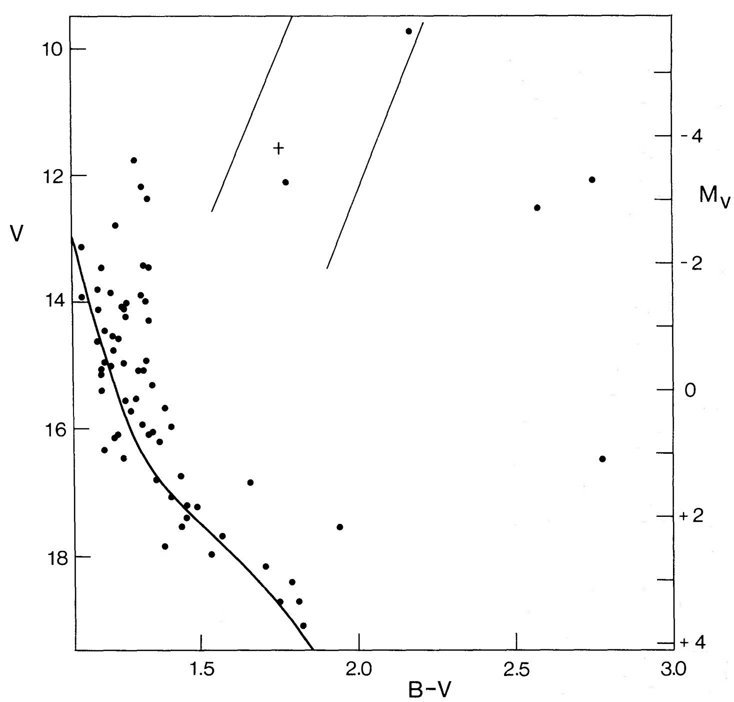

FIG. 4.—Cluster color-magnitude diagram for all photoelectrically observed stars. Also shown is the zero-age main sequence (Johnson 1963) and the location of the Cepheid instability strip according to Sandage and Tammann (1969). The Cepheid V367 Sct is marked as a cross.

TABLE 3

PHOTOGRAPHIC PHOTOMETRY

NO.	V	B-V	NO.	V	B-V	NO.	V	B-V
1*	15.00	1.28	201	19.50	2.39	268*	18.35	1.77
2	14.35	1.27	203	18.54	1.81	269*	18.53	1.86
10*	14.13	1.27	207	18.67	1.84	270	17.68	1.59
11	15.19	1.33	208	19.32	1.86	271*	19.88	2.49
12*	15.14	1.24	209	19.41	2.05	272*	19.10	2.09
16	15.20	1.38	210	19.36	2.27	273	18.27	1.77
21*	14.63	1.31	213	19.36	2.16	274*	18.62	1.90
22*	15.32	1.36	214	18.79	2.03	275*	18.66	1.99
23	12.87	1.34	216*	17.59	1.63	276	17.30	1.40
25	15.31	1.28	217	17.98	1.66	277*	18.11	1.69
26	15.57	1.35	218	18.50	1.72	278*	19.02	1.82
27	15.78	1.40	219	16.53	1.31	279	17.57	1.51
29	14.89	1.40	220	17.45	1.64	280*	19.02	1.73
32	15.68	1.26	221*	17.46	1.63	281	19.08	1.93
37	14.49	1.22	224*	19.19	1.93	282*	18.98	2.06
39	15.00	1.34	225	19.39	1.90	284	16.54	1.34
45	15.68	1.19	226	19.52	1.99	285*	16.86	1.38
47	15.72	1.29	227	17.42	2.85	286	17.47	2.76
50	15.06	1.36	228*	18.85	1.90	287	16.89	1.39
51	15.00	1.35	229	17.33	1.49	288	16.77	1.30
52	13.15	1.37	230*	18.68	1.81	291*	18.54	1.94
59	14.32	1.25	231	16.14	1.23	292	18.91	1.97
62	15.74	1.20	232*	19.02	1.93	293	16.48	1.41
64	11.56	1.77	234	17.37	1.44	294*	19.07	2.95
65	14.95	1.29	235*	18.10	1.88	295	17.03	1.43
66*	16.79	1.63	236*	19.02	1.91	296	17.91	1.64
67	16.10	1.34	237	20.61	1.91	297	17.95	1.83
68	16.06	1.22	238*	17.69	3.00	298	17.08	1.41
69	16.18	1.25	239*	19.53	1.46	301	17.53	1.59
71	14.68	1.10	240*	16.32	1.40	302	17.42	1.42
72	16.24	1.18	242*	19.25	1.88	303	16.28	1.34
73*	15.31	1.34	246*	17.92	1.65	304	18.30	1.68
74	14.39	1.16	247	18.14	1.67	305	16.93	1.41
75	16.14	1.40	248	18.43	1.38	306*	19.06	1.85
76	15.12	1.42	249	18.43	1.81	307	17.14	1.36
77	16.28	1.33	250*	18.89	2.86	308	16.15	1.38
78*	15.22	1.38	251*	16.60	1.37	309	16.89	1.33
79	15.43	1.58	252	17.10	1.37	311	16.19	1.30
80	15.86	1.44	253	17.50	1.43	313	16.08	1.35
81*	13.99	1.44	255*	18.36	1.79	314	17.40	1.37
82*	16.30	1.98	256*	18.93	1.99	315	18.40	1.58
83*	15.04	1.33	257*	19.95	2.28	316*	18.95	1.65
85*	15.57	1.34	258*	19.38	2.06	317*	19.32	1.89
86	16.22	1.36	259	17.66	1.58	318*	17.86	3.29
87	15.94	1.35	260*	19.47	2.15	320	17.53	1.66
88	16.24	1.25	261*	16.74	3.01	321*	17.60	1.43
89*	15.38	1.26	262*	17.27	1.80	322*	16.68	1.38
90	13.93	1.16	263	16.19	1.34	324	18.58	1.72
92	15.15	1.30	265	16.42	1.26	325	16.22	1.21
93	15.29	1.33	266*	17.99	1.76	326	19.00	1.78
94	14.61	1.04	267*	19.06	1.94	327*	19.25	2.64
328	19.13	1.78	383	17.43	1.41	435	18.79	1.80
329	19.25	1.92	384*	18.09	1.75	436	19.36	1.84
330*	19.59	2.38	385*	18.07	1.92	437*	19.43	1.89
331*	20.12	2.44	387	19.67	2.44	438	18.72	1.78
332	19.34	1.95	388*	18.43	1.78	439	18.37	1.59
333	18.86	1.73	389*	17.54	2.89	440	19.59	2.22
334	17.56	1.39	390*	19.54	2.14	441*	18.92	2.32
335	17.33	1.36	393	17.78	1.59	442*	19.35	2.02
336	18.52	1.92	394	17.44	1.34	443	18.09	1.63
337*	18.85	1.92	395*	19.20	1.96	444	19.20	1.85
338*	18.57	1.82	396*	18.55	2.28	445	17.26	1.54
340	17.85	1.51	397*	18.71	1.77	446*	19.75	2.48
341	17.92	2.75	398*	18.89	1.96	447*	19.26	2.15
342	17.67	1.47	399	17.38	1.41	448	18.07	1.60
343*	19.46	2.05	400	17.24	1.85	449*	19.88	2.33
344*	18.17	2.04	401*	19.53	2.46	450	18.26	1.69
345*	19.44	1.76	402*	19.56	1.93	451	17.15	1.46
347	16.66	1.23	403	16.75	1.21	452	16.81	1.38
349*	18.56	1.85	404	17.67	1.45	453	17.59	1.46
350*	16.44	1.36	405*	19.56	2.10	454*	16.14	2.05
351	16.84	1.39	406	17.90	1.50	455*	19.05	3.32
352	18.11	1.65	407*	19.60	2.18	456	18.00	1.59
354*	19.59	2.32	408	19.60	2.14	457*	18.27	2.30
355*	19.49	1.34	409	18.84	2.09	458*	19.29	2.36

TABLE 3—*Continued*

NO.	V	B-V	NO.	V	B-V	NO.	V	B-V
356	17.73	1.55	410	17.38	1.42	460*	19.58	2.77
357*	19.16	2.09	411*	18.70	1.71	461	16.66	3.12
358*	19.08	2.01	412	17.01	1.40	462	18.40	1.64
359*	18.99	1.99	413	18.27	1.74	463	17.25	1.33
360*	19.74	2.01	414*	19.68	2.43	464*	19.11	1.83
361*	17.54	1.48	415*	19.13	1.94	465	18.95	1.78
362	17.83	1.60	416*	19.44	2.17	466*	18.94	1.97
363*	19.77	2.29	417	17.85	1.55	467	19.44	1.20
364*	19.50	1.85	418	17.92	1.58	468	18.25	1.60
365*	19.59	1.36	419*	19.43	2.06	469*	19.39	2.09
366*	20.34	1.15	420	16.70	1.37	470	16.42	1.25
367*	18.47	1.92	421	15.97	1.43	471	16.98	1.28
370	16.62	1.26	422*	19.48	2.27	472	17.20	1.57
371	17.87	1.61	423	16.27	1.37	473*	19.09	3.04
372*	16.00	1.41	424	16.14	1.35	474*	19.42	1.97
373	16.44	1.22	425	16.67	1.33	475	19.03	1.81
374*	17.94	1.89	426	16.43	1.30	476	18.15	1.56
375*	19.33	1.93	427	19.03	1.79	477	17.73	1.48
376*	18.87	2.09	428	17.90	1.51	478	17.89	1.55
377*	19.42	2.18	429	18.36	1.69	480	19.29	1.88
378	18.47	1.98	430	18.68	1.68	481*	18.63	2.02
379	17.21	1.70	431	17.52	1.49	482	17.11	3.33
380*	14.73	1.51	432*	19.67	2.00	483*	19.48	2.29
381*	19.11	1.92	433	17.95	1.57	484	17.46	1.30
382	16.68	1.77	434	18.16	1.35	485	17.25	1.64
486*	19.38	2.11	538	17.79	1.67	589	18.23	2.07
487	19.04	1.89	539	19.11	1.86	590	17.32	1.44
488	17.09	1.77	540*	19.20	1.92	591*	18.74	3.49
489*	19.23	2.45	541	18.77	2.05	592*	17.70	2.93
490*	19.34	2.24	542*	17.09	1.50	593*	19.37	3.19
491	17.33	1.39	543*	17.80	1.49	594*	16.49	1.40
492*	19.33	2.13	544	18.52	1.78	595*	19.29	2.58
493	16.50	1.92	545	18.04	1.63	596*	17.80	1.53
494*	18.97	1.83	546	19.33	1.92	597	18.57	1.71
495	18.86	1.95	547*	19.59	2.02	598*	19.01	1.92
497	17.30	1.38	548	18.68	1.79	599*	18.32	2.04
498	19.21	1.95	549*	18.94	1.79			
499*	17.92	1.82	550	19.16	2.05			
500*	19.08	2.42	551*	19.56	1.32			
501*	18.81	1.97	552	19.13	1.78			
503*	18.69	1.96	553*	18.43	1.66			
504*	19.02	1.95	554	17.70	1.33			
505	16.70	1.67	556	17.76	1.62			
506	19.30	1.92	557*	18.60	1.75			
507*	17.21	1.51	558*	19.22	1.77			
508	19.27	2.49	559	18.61	1.72			
509	16.13	1.25	560*	18.83	1.73			
510	18.79	3.56	561*	18.85	1.69			
511	18.62	1.91	562*	18.05	2.54			
512	17.28	1.46	563*	18.39	2.10			
513	16.58	1.37	564	19.55	2.07			
514	18.70	1.91	565	16.06	1.33			
515*	19.12	2.07	567*	18.94	1.89			
516*	18.58	2.00	568*	19.26	3.47			
517	18.07	2.04	569*	19.37	1.86			
518	19.50	2.12	570*	18.60	1.69			
519*	19.40	2.14	571*	19.01	1.70			
520*	19.27	2.35	572*	19.07	1.78			
521	17.61	1.50	573	18.71	1.58			
522	16.81	1.82	574*	18.80	1.76			
523*	19.25	1.93	575*	19.27	2.19			
524	17.80	1.67	576*	19.20	1.83			
525*	17.17	1.22	577	18.28	1.71			
526	16.75	1.31	578	18.28	1.68			
527	16.95	1.22	579*	18.62	1.91			
528*	19.19	2.00	580*	19.41	2.05			
529*	19.11	2.45	581*	19.19	2.21			
530*	18.85	1.94	582	16.57	1.31			
531*	18.30	1.80	583	17.35	1.44			
533	19.49	2.65	584*	19.11	3.69			
534*	20.24	2.43	585*	19.04	2.26			
535*	18.92	1.12	586	16.67	1.32			
536*	18.99	1.91	587	16.38	1.36			
537*	19.38	2.11	588	18.04	1.63			

An asterisk (*) indicates that plate to plate errors exceeded 0.10 magnitudes.

the zero-age main sequence of Johnson (1963). The distance moduli of the individual stars were obtained by applying the mean cluster reddening $E_{B-V} = 1.37$ and $E_{U-B} = 1.08$ to all photoelectrically observed stars. The data show that an acceptable fit to Johnson's evolutionary deviation curves for both $M_V(U - B)$ and $M_V(B - V)$ is provided by an apparent cluster distance modulus $(m - M)_V = 15.4 \pm 0.2$. The corresponding true distance modulus of NGC 6649 is $(m - M)_0 = 11.15 \pm 0.7$ if $R = A_V/E(B - V) = 3.1 \pm 0.5$. It should be emphasized that the uncertainty in the ratio of total to selective absorption (Martin 1971; Aannestad and Purcell 1973) contributes the major part of the quoted mean error in $(m - M)_0$.

c) The Cluster Color-Magnitude Diagram

The color-magnitude diagram for all photoelectrically observed stars is plotted in figure 4. Also plotted in the figure is the Johnson (1963) zero-age main sequence and the position of the Cepheid instability strip according to Sandage and Tammann (1969). The figure shows that the cluster contains a well developed main sequence that extends up to $V = 11.8$ ($M_V = -3.6$). In addition to the Cepheid V367 Sct (= Cuffey no. 64), the star Cuffey no. 19 ($V = 12.11$ $B - V = 1.78$, and $U - B = 1.43$) is located well within the instability strip. From its position star no. 19 would, if it is at the same distance as NGC 6649, be expected to have a period of ~4 days. With this in mind, the star was monitored on eight successive nights in 1974 in an attempt to detect any light variation. No variation greater than 0.06 mag in B was detected. Because of systematic color and magnitude differences (see Appendix), the difference between the earlier photometry of star no. 19 by The and Roslund (1963) and the present data are not considered to be conclusive evidence in favor of variability. On the basis of the present data alone, star no. 19 must therefore be regarded as a nonvariable. This suggests that this star may be similar to other nonvariable field supergiants which Fernie and Hube (1971) and Schmidt, Rosendhal, and Jewsbury (1974) have found within the boundaries of the Cepheid instability strip.

From their positions in the color-magnitude diagram, the red giants nos. 49 and 117 are also probable cluster members. The variability of star 117 was first noted by The and Roslund (1963) and was subsequently confirmed by Tammann (1969), who found relatively large short-term brightness variations but no evidence for periodicity. Star 42 is a binary in which the components are separated by only 4″. The primary images of the two components of this star overlap and could not be measured photographically. Their secondary images are, however, clearly separated. The secondary image of star 42b is clearly brighter than that of star 9, making star 42b the brightest member of the cluster. On a night of excellent seeing, a 5″ diaphragm was used on the

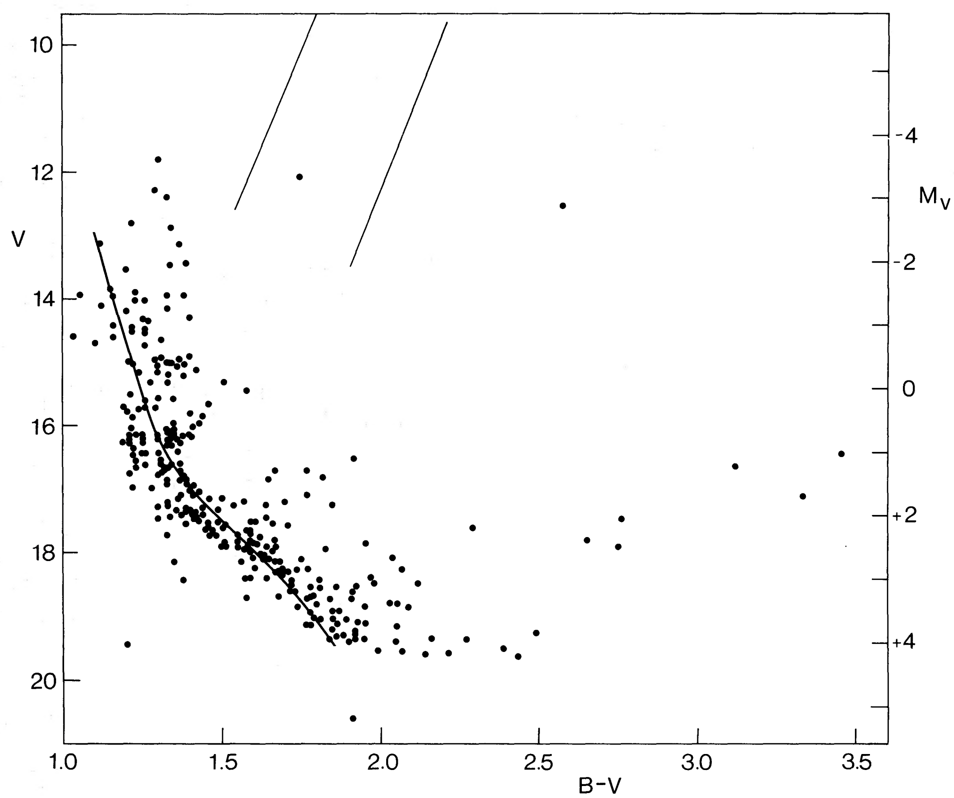

FIG. 5.—Cluster color-magnitude diagram for photographic observations

TABLE 4

PHOTOELECTRIC MEASUREMENTS OF THE TWO COMPONENTS OF THE BRIGHTEST STAR IN NGC 6649 = ADS 11441

Star	V	$B - V$	$U - B$
42a...........	9.74	2.17	2.12
42b...........	11.4	1.1	0.5

Cerro Tololo 1.5-m telescope to obtain separate photoelectric observations of both components of this star. These observations, which are of course quite uncertain, are listed in table 4. Figure 4 shows that star 42b is located close to the edge of the Cepheid instability strip.

A color-magnitude diagram for all photographically observed stars (see table 3) is shown in figure 5. This diagram strengthens and confirms the conclusions that have previously been obtained from the photoelectric data.

IV. CLUSTER LUMINOSITY FUNCTION

All uncrowded stars within a circle of radius 2:7 of the cluster center (see figure 2) were measured with the Cuffey-type iris photometer of the David Dunlap Observatory. The luminosity function of these stars is given in table 5 and shown in figure 6. The figure shows that the cluster luminosity function is still increasing at $V \simeq 19$ ($M_V \simeq +4$).

V. DISCUSSION

The observational parameters derived from the photoelectric photometry of V367 Sct are listed in table 6. Finally, table 7 summarizes available data on all Cepheids that are currently known to be

TABLE 5

LUMINOSITY FUNCTION OF NGC 6649*

	N(V)
11.5 < V < 12.5	1
12.5 < V < 13.5	2
13.5 < V < 14.5	7
14.5 < V < 15.5	23
15.5 < V < 16.5	40
16.5 < V < 17.5	67
17.5 < V < 18.5	80
18.5 < V < 19.5	131
19.5 < V < 20.5	39†

* Data refer to a circle of radius 2.'7 centered on the cluster.

† Data incomplete.

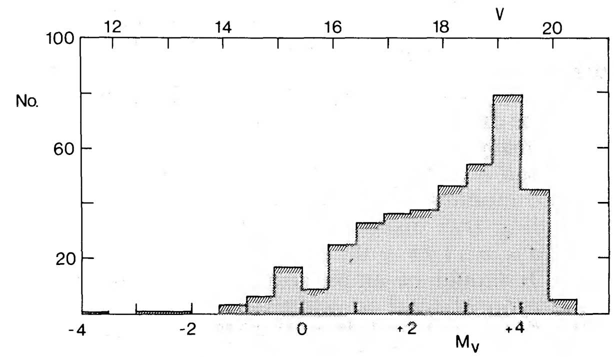

FIG. 6.—Luminosity function for the region within 2:7 of the cluster center.

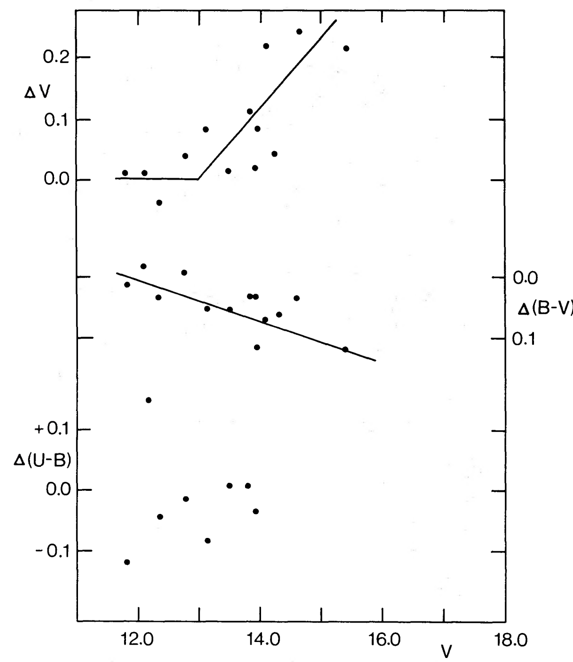

FIG. 7.—Comparison between the present photoelectric observations and those of The and Roslund (1963). Differences are in the sense Tololo minus Bosscha.

TABLE 6

SUMMARY OF DATA ON V 367 SCT

P(days) = 5.2551 ± 0.002	$M_{<V>}$ = -3.82±0.2
$(m-M)_V$ = 15.4±0.2	V_{ampl} = 0.54
	B_{ampl} = 0.76
< V > = 11.58	U_{ampl} = 1.13
< B > - < V > = 1.76	< B-V > = 1.81
$<B>_o - <V>_o$ = 0.49	$<B-V>_o$ = 0.54
< U > - < B > = 1.47	< U-B > = 1.44
$<U>_o - <B>_o$ = 0.31	$<U-B>_o$ = 0.28
$<B-V>_{mag}$ = 1.81	$<U-B>_{mag}$ = 1.45
$<B-V>_{o,mag}$ = 0.54	$<U-B>_{o,mag}$ = 0.29

TABLE 7

INTRINSIC PROPERTIES OF CEPHEIDS IN GALACTIC CLUSTERS*

Cepheid	Cluster	Period	$M^{obs}_{\langle V\rangle}$	$M^{calc}_{\langle V\rangle}$	$\langle B\rangle_0 - \langle V\rangle_0$
EV Sct	NGC 6664	$3^d.09$	-2.62	-2.70	0.57
CEb Cas	NGC 7790	4.48	-3.20	-3.28	0.56
CF Cas	NGC 7790	4.87	-3.08	-3.15	0.66
CEa Cas	NGC 7790	5.14	-3.28	-3.28	0.64
V 367 Sct	NGC 6649	5.26	-3.82	-3.69	0.49
U Sgr	M25	6.74	-3.92	-3.91	0.55
DL Cas	NGC 129	8.00	-3.84	-3.80	0.70
S Nor	NGC 6087	9.75	-4.03	-4.01	0.73

* Data, except those for V 367 Sct are from Sandage and Tammann (1969).

situated in open clusters. The values of $M\langle_V\rangle^{calc}$ in the table were obtained from eq. (19) of Sandage and Tammann (1969). The agreement between the observed values of the Cepheid absolute magnitudes and those calculated from the period-luminosity-color relation of Sandage and Tammann is seen to be excellent. From the data in the table, the mean difference $M\langle_V\rangle^{obs} - M\langle_V\rangle^{calc}$ is found to be 0.00 ± 0.04 mag. It should perhaps be emphasized that the revision of the distance modulus of the Hyades recently suggested by van Altena (1974) will decrease both the $M\langle_V\rangle^{obs}$ values of all cluster Cepheids *and* the $M\langle_V\rangle^{calc}$ values predicted by the Cepheid period-luminosity-color relation by $\sim$0.2 mag.

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APPENDIX

COMPARISON WITH THE AND ROSLUND

Thirteen of the stars studied photoelectrically by The and Roslund (1963) were also observed in the present program. A comparison between these observations is shown in figure 7. The figure shows that significant systematic differences between our observations and those of The and Roslund occur below $V \sim 13$.

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