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UBV OBSERVATIONS OF HELIUM STARS*

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UBV photoelectric observations of most of the known helium stars seem to indicate that at least some of these stars are variable at optical wavelengths with total amplitudes of $\sim 0^m1$.

Key words: helium star — variable star — photometry

I. Introduction

There exists a small group of hot blue stars whose spectra contain strong helium lines but no, or only very weak, hydrogen lines. These stars, the helium stars, have recently been reviewed by Dinger (1970), Landolt (1968), Hack (1967), Hill (1969*a*), and Faÿ, Honeycutt, and Warren (1973). Herbig (1967) and others have pointed out the importance of checking the helium stars for variability. Originally (Hill 1967) it was thought that helium stars were not variable, with the exception of the possibly related object MV Sagittarii (Hoffleit 1959). However, recent evidence (Landolt 1968; Hill 1969*b*) indicates possible variations of small amplitude and unknown time scale.

II. The Program

UBV photoelectric observations have been made of the helium stars BD +37°442, HD 264111, BD + 10°2179, HD 124448, BD +13°3224, HD 160641, and HD 168476 during the past five years with the 16- and 36-inch telescopes at the Cerro Tololo Inter-American Observatory and at the Kitt Peak National Observatory as part of larger observing programs (see annual reports of LSU Observatory in *Bull. Am. Astr. Soc.*). The observations were thoroughly tied into the *UBV* system (Johnson and Harris 1954) via utilization of some 20 standard stars each night. Standard observing and reduction procedures were followed (Landolt 1967). A more complete description of the manner in which the northern hemisphere data were handled may be found in Landolt (1973).

The magnitudes and color indices derived for the program stars in this investigation are given in Table I. The UT date code in the first column contains two digits each for the month, day, and year of the observation. The heliocentric Julian days in the second column are accurate to $\pm 0^d0005$.

The helium stars studied are all near tenth magnitude. Hence, the individual magnitudes and color indices should be accurately known. Study of Table I shows no gross changes in brightness or color for any of the stars. An attempt has been made to summarize in Table II the data presented in Table I. In Table II, the second, third, and fourth columns give the average magnitude and color index for each helium star studied. The fifth and sixth columns indicate the number of observations per star and the number of nights that each star was observed. The total range in V, $(B-V)$, and $(U-B)$ for each program star, taken directly from Table I, is given in the seventh, eighth, and ninth columns. The final three columns show the rms errors in magnitude and color indices for each helium star. All values pertaining to the star HD 160641 were calculated *without* the data of 032469 UT, for the observations for that date for this star are unreliable as indicated by the colons and footnotes in Table I.

Perusal of the summarized data in Table II, particularly the last three columns, indicates that the errors are higher than past experience would lead one to expect (Landolt 1967). This is particularly true if one compares the errors for

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TABLE I

Magnitudes and Color Indices for Helium Stars

Date(UT)	JD⊙ 2400000+	V	B−V	U−B
	(a) BD +37° 442			
093068	40129.8565	10.01	-0.m27	-1.m16
102968	158.7804	9.98	-0.28	-1.19
090869	471.8956	10.00	-0.27	-1.16
112069	545.6343	10.02	-0.28	-1.18
020270	619.5985[a]	10.05	-0.31	-1.16
020370	620.6009	10.04	-0.28	-1.16
030870	653.5954	9.99	-0.28	-1.12
030870	653.5975	10.00	-0.27	-1.17
101070	869.8913	9.99	-0.28	-1.17
012771	40978.5933	10.025	-0.28	-1.15
062871	41130.9470	10.02	-0.26	-1.16
092371	217.8297	10.00	-0.28	-1.16
111471	269.6979	10.02	-0.28	-1.17
012070	41336.6174	10.00	-0.29	-1.15
a) high wind, seeing terrible, dust.				
	(b) HD 264111			
093068	40129.9888	9.63	+0.05	-0.72
102968	158.9018	9.66	0.04	-0.75
032469	304.6235	9.69	0.02	-0.73
041969	330.4862	9.66	0.03	-0.73
042169	332.4741	9.64	0.02	-0.71
112069	545.8922	9.65	0.04	-0.74
030870	653.6786	9.66	0.04	-0.71
040670	682.5025	9.66	0.02	-0.71
040670	682.5048	9.65	0.03	-0.71
011871	969.6275	9.66	0.02	-0.71
011971	970.6418	9.65	0.04	-0.70
012071	40971.5964	9.64	0.03	-0.69
111471	41269.8486	9.68	0.03	-0.75'
012072	336.8289	9.66	0.04	-0.72
051572	41452.4625	9.63	0.01	-0.69
	(c) BD +10° 2179			
051868	39994.6607	9.94	-0.m20	-0.m85
051968	995.6555	9.96	-0.18	-0.86
051968	995.6717	9.985	-0.18	-0.87
051968	995.6910	10.00	-0.17	-0.87
052068	996.6559	9.96	-0.17	-0.87
052068	996.6852	10.00	-0.18	-0.87
052068	996.7293	9.99	-0.14	-0.87
052268	39998.6648	9.99	-0.20	-0.86
102968	40159.0201	9.97	-0.18	-0.90
032469	304.7242	9.98	-0.20	-0.88
032469	304.7266	9.98	-0.19	-0.85
041869	329.5375	9.97	-0.20	-0.85
041969	330.5500	10.00	-0.19	-0.87
042169	332.5387	9.98	-0.19	-0.87
042269	333.5293	9.94	-0.18	-0.845
061469	386.6668	9.95	-0.18	-0.89
061569	387.6661	9.94	-0.16	-0.82
061569	387.6680	9.95	-0.18	-0.84
061869	390.6689	10.00	-0.21	-0.89
040670	682.5138	9.95	-0.21	-0.87
040670	682.5162	9.965	-0.20	-0.88
050870	714.6604	9.95	-0.18	-0.86
011871	969.8574	10.00	-0.20	-0.87
012071	40971.7823	9.95	-0.18	-0.845
050371	41074.6600	9.91	-0.16	-0.86
052071	091.5087	9.93	-0.16	-0.87
011872	334.9437	9.96	-0.18	-0.88
012072	336.9318	9.98	-0.19	-0.87
051572	41452.4813	9.99	-0.20	-0.84

TABLE I (*Continued*)

Date(UT)	JD⊙ 2400000+	V	B−V	U−B
	(d) HD 124448			
041869	40329.5943	10.03	-0.09	-0.79
041969	330.5941	10.03	-0.10	-0.78
042169	332.6037	10.02	-0.10	-0.80
042369	334.7426	9.95	-0.08	-0.76
040670	682.7404	10.00	-0.07	-0.78
012071	971.7786	9.98	-0.10	-0.80
012071	40971.7807	9.97	-0.08	-0.80
052071	41091.5954	9.94	-0.08	-0.79
051572	41452.6259	10.01	-0.13	-0.78
	(e) BD +13° 3224			
051868	29974.8107	10.55	-0.m18	-0.m96
051868	994.8130	10.57	-0.20	-0.94
051968	995.7494	10.53	-0.19	-0.96
051968	995.7999	10.56	-0.17	-0.945
051968	995.8388	10.56	-0.17	-0.95
051968	995.9635	10.56	-0.19	-0.97
052068	996.7126	10.57	-0.16	-0.98
052068	996.7303	10.53	-0.17	-0.97
052068	996.8385	10.58	-0.20	-0.96
052168	997.7247	10.56	-0.17	-0.97
052168	997.7525	10.53	-0.165	-0.95
052168	997.7796	10.56	-0.19	-0.92
052168	997.8960	10.56	-0.19	-0.94
052268	39998.7815	10.52	-0.18	-9.98
093068	40129.6002	10.54	-0.18	-0.985
102968	158.5642	10.50	-0.12	-1.01
102968	158.5669	10.56	-0.17	-0.96
032469	304.9041	10.58	-0.20	-1.03
042369	334.8317	10.52	-0.17	-0.94
061469	386.7296	10.53	-0.17	-0.97
061569	387.6873	10.51	-0.16	-0.93
061869	390.6958	10.55	-0.17	-1.00
090869	471.6438	10.59	-0.18	-1.01
090869	471.6460	10.61	-0.19	-1.03
050870	714.8569	10.545	-0.19	-0.98
100670	40865.5965	10.53	-0.16	-0.91
052071	41091.7783	10.51	-0.18	-0.98
062871	130.7338	10.55	-0.19	-0.97
092571	219.6174	10.57	-0.16	-0.96
051572	41452.8168	10.55	-0.19	-0.95
	(f) HD 160641			
093068	40129.6059	9.86	+0.m15	-0.m87
093068	129.6086	9.86	0.15	-0.88
102968	158.5720	9.88	0.21	-0.88
102968	158.5741	9.88	0.20	-0.90
032469	304.9579[a]	10.08:	0.12:	-0.86:
042369	334.8360	9.87	0.16	-0.84
042469	335.8627	9.81	0.14	-0.82
061869	390.7270	9.87	0.13	-0.84
090868	471.6583	9.85	0.15	-0.86
040170	677.9108	9.78	0.18	-0.83
040470	680.8916	9.86	0.15	-0.84
050870	714.9096	9.86	0.15	-0.86
100670	40865.6021	9.82	0.17	-0.85
052071	41091.7825	9.79	0.15	-0.84
062871	130.7394	9.905	0.19	-0.84
092571	219.6159	9.87	0.18	-0.85
051472	451.6619[b]	9.82	0.15	-0.82
051472	41451.6718[b]	9.87	0.14	-0.82

a) extremely poor seeing at air mass 1.8.
b) possible cirrus

TABLE I (*Continued*)

Date(UT)	$JD_{\odot}$ 2400000+	V	$B-V$	$U-B$
	(g) HD 168476			
042369	40334.8389	9.25	+0.005	-0.66
042469	335.8586	9.25	-0.01	-0.66
040170	677.9054	9.30:	-0.01	-0.68
040470	40680.8864	9.27	+0.02	-0.70
052071	41091.8864	9.24	-0.01	-0.66
051572	41452.9151	9.25	-0.03	-0.67

these stars with those stars of comparable brightness which were observed on the same nights (Landolt 1973). From the available data in Table I, one can say that three objects, BD +37°442, HD 264111, and HD 168476, probably are not variable. However, there are only six observations for HD 168476. Although the color indices agree perfectly, and fortuitously, with Hill (1964), our V magnitudes differ by $0^m.11$, a factor of five, or so, larger than one would expect. Intercomparison of all of Hill's data and mine seems to indicate a slight secular brightening of HD 168476 over the past decade (Hill 1973). The data in Table III are unpublished results Hill (1973). These latter observations were all made with the Cape Observatory 40-inch reflector, and were tied into the *UBV* standards published by Cousins (1971).

Both the total range in V magnitude, the seventh column, and the larger-than-expected rms errors in the tenth column of Table II, would lead one to say that the four stars BD +10°2179, HD 124448, BD +13°3224, and HD 160641 are variable. Over the past five years, though, no drastic changes have been found.

What about short-term variations? It was possible to monitor HD 160641 for seven hours on 051572 UT at the no. 2 16-inch telescope on Cerro Tololo. The nearby star BD −17°4889 was used as a comparison star. Its magnitude and color indices are $V = 9.283 \pm 0^m.013$, $(B-V) = +0.257 \pm 0^m.013$, and $(U-B) = +0.159 \pm 0^m.012$ from 37 observations. The differential magnitude and color indices, in the sense variable *minus* comparison are given in Table IV. The heliocentric times again are known to $\pm 0^d.0005$.

The differential V magnitudes for HD 160641 are plotted in Figure 1, as are the corresponding V magnitudes for the comparison star, BD −17°4889. The large scatter for the comparison star occurs because it was difficult to keep a star centered in the photometer diaphragm at the no. 2 16-inch telescope. The gaps in the data in Figure 1 at $JD_{\odot}2441452.70$ and $JD_{\odot}2441452.83$ occur at times when *UBV* standard stars were observed. Even though there is relatively large scatter in the data, a definite trend is evident in the differential V magnitude plot for HD 160641, in the sense that HD 160641 became brighter by $\sim 0^m.1$ during the seven hours of observation. An attempt to detect periodicity within the differential V magnitudes via the method of Lafler and Kinman (1965) failed.

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TABLE II

HELIUM STAR MAGNITUDES AND COLOR INDICES

Star	⟨V⟩	⟨B−V⟩	⟨U−B⟩	n	m	Total Range in V	Total Range in B−V	Total Range in U−B	RMS Error in V	RMS Error in B−V	RMS Error in U−B
+37°442	10.01	−0.m28	−1.m16	14	13	0.m06	0.m03	0.m07	±0.m020	±0.m011	±0.m016
HD264111	9.65	+0.03	−0.72	13	13	0.05	0.04	0.06	±0.015	±0.012	±0.020
+10°2179	9.97	−0.18	−0.86	27	21	0.09	0.07	0.08	±0.025	±0.016	±0.018
HD124448	9.99	−0.10	−0.79	8	7	0.09	0.05	0.04	±0.036	±0.018	±0.014
+13°3224	10.55	−0.18	−0.97	30	19	0.11	0.08	0.12	±0.025	±0.017	±0.029
HD160641	9.85	+0.16	−0.85	17	14	0.11	0.09	0.08	±0.033	±0.023	±0.022
HD168476	9.26	−0.01	−0.67	6	6	0.06	0.05	0.04	±0.022	±0.017	±0.016

TABLE III

UBV OBSERVATIONS OF SOUTHERN HELIUM STARS (HILL 1973)

Date	V	B−V	U−B
	(a) HD 124448		
1969 Apr. 14/15	9.98	−0.m08	−0.m80
1971 Jun. 24/25	9.97	−0.08	−0.82
	(b) HD 160641		
1969 Apr. 5/6	9.79	+0.15	−0.85
1969 Apr. 14/15	9.93	+0.16	−0.85
1971 Jun. 24/25	9.86	+0.16	−0.83
	(c) HD 168476		
1969 Apr. 5/6	9.32	−0.02	−0.70
1969 Apr. 14/15	9.28	−0.02	−0.73
1971 Jun. 24	9.29	−0.01	−0.70

TABLE IV

DIFFERENTIAL OBSERVATIONS OF HD 160641

JD⊙ 2441000+	ΔV	Δ(B−V)	Δ(U−B)
452.6343	+0.586	−0.098	−0.987
.6364	+0.614	−0.144	−0.987
.6421	+0.587	−0.110	−0.977
.6440	+0.580	−0.112	−0.954
.6479	+0.586	−0.104	−0.942
.6498	+0.560	−0.114	−0.926
.6538	+0.570	−0.104	−0.942
.6557	+0.556	−0.110	−0.944
.6594	+0.580	−0.155	−0.924
452.6613	+0.556	−0.110	−0.940

TABLE IV (*Continued*)

JD⊙ 2441000+	ΔV	Δ(B−V)	Δ(U−B)
452.6651	+0.560	−0.113	−0.936
.6670	+0.546	−0.092	−0.950
.6710	+0.583	−0.126	−0.949
.6735	+0.570	−0.130	−0.951
.6773	+0.580	−0.140	−0.962
.6791	+0.572	−0.126	−0.948
.6829	+0.604	−0.118	−0.984
.6848	+0.608	−0.150	−0.988
.7099	+0.588	−0.120	−0.972
.7118	+0.561	−0.107	−0.988
.7154	+0.532	−0.104	−0.962
.7173	+0.542	−0.124	−0.954
.7210	+0.534	−0.095	−0.985
.7230	+0.548	−0.115	−0.973
.7248	+0.540	−0.093	−0.973
.7285	+0.565	−0.094	−0.978
.7305	+0.522	−0.094	−0.958
.7325	+0.528	−0.090	−0.964
.7398	+0.550	−0.140	−0.940
.7417	+0.516	−0.108	−0.973
.7453	+0.544	−0.102	−0.968
.7473	+0.558	−0.122	−0.976
.7492	+0.529	−0.102	−0.976
.7531	+0.518	−0.115	−0.960
.7554	+0.501	−0.105	−0.976
.7595	+0.539	−0.136	−0.969
.7614	+0.530	−0.106	−1.002
.7652	+0.529	−0.114	−0.986
.7674	+0.502	−0.108	−0.969
452.7701	+0.516	−0.098	−0.993

TABLE IV (*Continued*)

$JD_{\odot}$ 2441000+	ΔV	$\Delta(B-V)$	$\Delta(U-B)$
452.7740	+0.536	-0.102	-0.986
.7763	+0.498	-0.120	-0.966
.7784	+0.505	-0.120	-0.967
.7836	+0.535	-0.136	-0.990
.7858	+0.538	-0.152	-0.986
.7895	+0.532	-0.098	-0.990
.7916	+0.536	-0.126	-0.982
.7940	+0.548	-0.149	-0.968
.7980	+0.568	-0.148	-0.986
.8002	+0.551	-0.142	-1.000
.8050	+0.546	-0.126	-0.969
.8075	+0.518	-0.122	-0.992
.8095	+0.554	-0.130	-0.967
.8323	+0.532	-0.143	-0.966
.8344	+0.520	-0.131	-0.980
.8382	+0.519	-0.106	-1.004
.8401	+0.532	-0.140	-0.986
.8438	+0.512	-0.110	-0.999
.8458	+0.508	-0.102	-1.006
.8479	+0.476	-0.094	-0.983
.8516	+0.507	-0.112	-1.012
.8535	+0.517	-0.118	-1.014
.8555	+0.522	-0.134	-1.006
.8603	+0.520	-0.131	-0.992
.8624	+0.498	-0.123	-0.986
.8645	+0.504	-0.100	-0.985
.8686	+0.478	-0.081	-0.982
.8716	+0.497	-0.090	-0.984
.8759	+0.517	-0.126	-0.988
.8781	+0.504	-0.112	-0.978
.8803	+0.488	-0.101	-0.986
.8843	+0.533	-0.114	-0.976
.8864	+0.528	-0.124	-0.972
.8906	+0.565	-0.132	-0.970
.8925	+0.535	-0.132	-0.968
.8945	+0.527	-0.138	-0.966
.9005	+0.553	-0.146	-0.986
.9024	+0.545	-0.154	-0.966
.9072	+0.561	-0.128	-0.977
.9091	+0.538	-0.136	-0.973
452.9110	+0.514	-0.120	-0.976

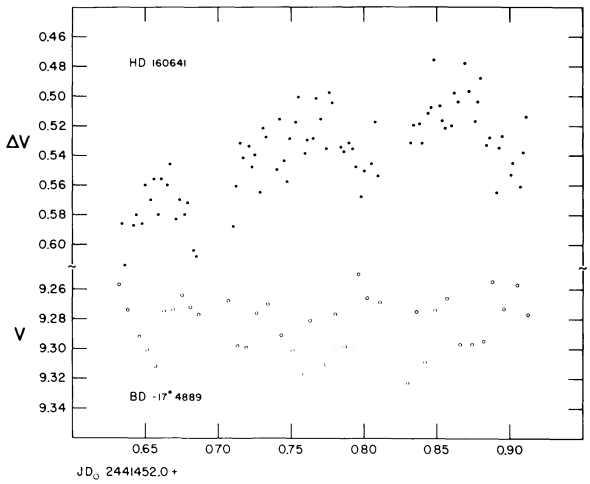

FIG. 1 — A plot of the differential V magnitude for HD 160641 and of the V magnitude for the comparison star BD −17° 4889 for a seven-hour observing run on 15 May 1972 UT.