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CCD PHOTOMETRY OF THE M 67 CLUSTER IN THE VILNIUS PHOTOMETRIC SYSTEM

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Abstract. Seven-color CCD photometry in the Vilnius photometric system of 279 stars down to $V = 15$ mag in the open cluster M 67 area is obtained. 13 standard stars in the cluster are measured photoelectrically. Photometric spectral types have been determined for all the stars. The reddening of the cluster is found to be $E_{B-V} = 0.045$, the true distance modulus is 9.38 mag and the age is 4×10^9 years.

Key words: stars: fundamental parameters – clusters: individual: M 67

1. INTRODUCTION

The Vilnius photometric system, consisting of seven passbands with the mean wavelengths and halfwidths listed in Table 1, makes it possible to determine spectral classes (or temperatures), absolute magnitudes (or surface gravities), metallicities, interstellar reddening

Table 1. Mean wavelengths and half-widths of passbands of the Vilnius photometric system.

Passband	U	P	X	Y	Z	V	S
λ_0 (nm)	345	374	405	466	516	544	656
$\Delta\lambda$ (nm)	40	26	22	26	21	26	20

and peculiarity types for stars of all spectral types (Straižys 1977, 1992). This makes the system very useful for determining the physical parameters of stars which are too faint to be studied by spectroscopic methods. The system is especially effective when used with CCD detectors which combine a wide field, high sensitivity and photometric accuracy. The same properties characterize the Strömvil system (Straižys, Crawford & Philip 1996) which is combined from passbands of the Strömgren and the Vilnius systems.

The Vilnius photometric system was succesfully set up with a CCD detector for the first time in 1986 and 1987 on the 90 cm telescope of the Kitt Peak National Observatory (Boyle et al. 1990a,b, 1992; Smriglio et al. 1991). CCD frames in three fields near the globular clusters M 56 and M 71 were obtained with an RCA 316 × 508 chip with a field size of 5′ × 7′. Stars in these areas were classified photometrically down to 17 mag.

CCD arrays with 2048 × 2048 pixels offer the possibility of increasing considerably the field size and the number of stars observed. The CCD camera operating on the 1-meter Ritchey telescope of the Flagstaff Station of the US Naval Observatory has an especially large field: its 2048 × 2048 Tektronix chip gives a 23′ × 23′ area. We decided to test the possibility of using this camera for photometry of stars in the Vilnius system. For this, fields with different kinds of objects were selected, including some open and globular clusters. Since the observing time was limited, we were able to obtain only relatively short exposures for testing the method. Here we present the results of photometry in the M 67 field. Preliminary results of the investigation were presented at the IAU Symposium No. 167 at The Hague (Straižys et al. 1995).

M 67 is one of the best-studied open clusters of solar chemical composition. It was investigated in a number of photometric systems, including the *UBVRI* system and its parts (Johnson &

Sandage 1955, Eggen & Sandage 1964, Racine 1971, Sturch 1973, Schild 1983, 1985, Janes & Smith 1984, Frolov 1984, Taylor & Joner 1985, Joner & Taylor 1990, Gilliland et al. 1991, Chevalier & Ilovaisky 1991, Bhat et al. 1992, Montgomery et al. 1993, Anupama et al. 1994), the $uvby\beta$ system (Strom et al. 1971, Eggen 1983, Anthony-Twarog 1987, Nissen et al. 1987, Joner & Taylor 1997), the DDO system (Janes & Smith 1984), the Thuan and Gunn system (Jorgensen 1994), the Beijing system (Fan et al. 1996) and the *JHK* sytem (Houdashelt et al. 1992). So, this cluster is a good object for testing possibilities of any photometric system. In the case of the Vilnius system, the cluster is good as one of the cornerstones for the system calibration in ages and metallicities.

Among other tasks of this investigation the following may be mentioned: foundation of an area of photoelectric standards of different colors for future CCD photometry and testing of the wide-field CCD camera of the Flagstaff Observatory for precise stellar photometry.

2. OBSERVATIONS AND REDUCTIONS TO THE STANDARD SYSTEM

The cluster area was observed on three nights, February 18/19, 1993, December 3/4, 1994 and December 4/5, 1994, in all filters each night. The exposure durations were: 20 min for U and P, 5 min for X and V and 3 min for Y, Z and S. The filters were combined from two sets: a glass filter set of 80×80 mm size (filters U, P, Y and V) and an interference filter set of 60 mm diameter (filters X, Z and S). The glass filters covered the whole CCD area without vignetting ($23' \times 23'$ field). The interference filters gave an unvignetted field of $20'$ diameter. This field is shown in Fig. 1 on the cluster chart from Murray et al. (1965).

The standard routines of the IRAF software package were used in the reductions. For flatfielding, two skyflats in each filter were taken in evening and/or morning twilight on each night. Instrumental CCD magnitudes were obtained by using the aperture photometry routines in IRAF. Stars with oblong or double images were excluded from the analysis. A small nonlinearity of the CCD response was found and corrected for by using a linearization dataset provided by Luginbuhl (1998).

For transformation of the instrumental CCD magnitudes and color indices to the standard Vilnius system, we have used 13

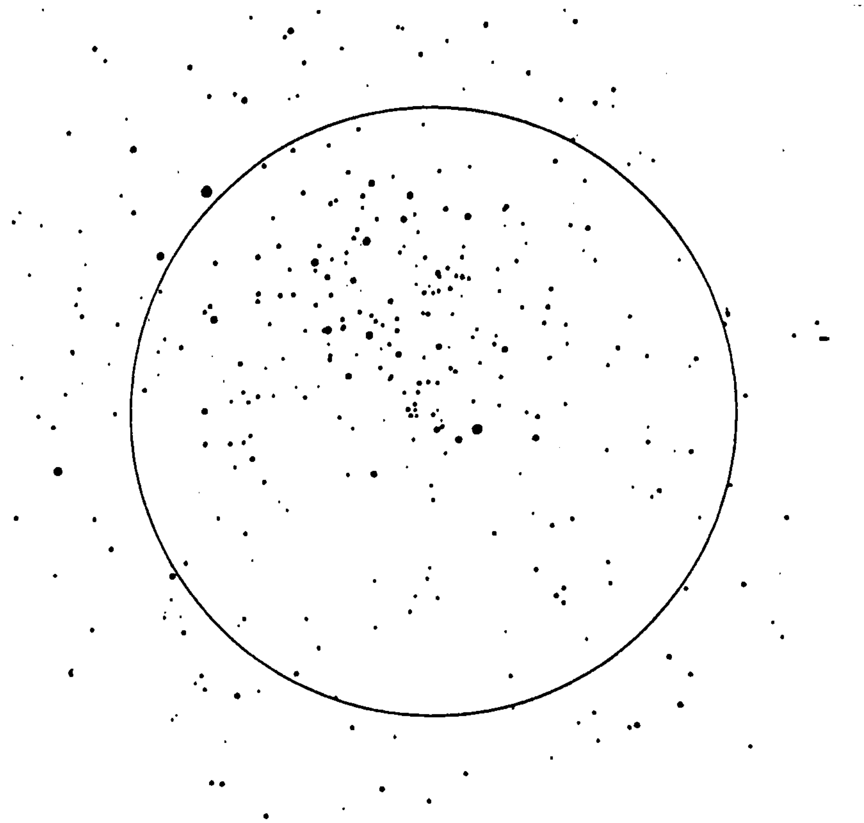

Fig. 1. The investigated area of M 67. The chart is from Murray et al. (1965).

standard stars in M 67 measured photoelectrically by one of us (J.S.) with the 1-meter telescope of the Institute of Theoretical Physics and Astronomy operating at the Maidanak Observatory in Uzbekistan. Table 2 gives the results of photometry for these stars. Some of them have been measured with the same telescope earlier by K. Černis (see Straižys & Kazlauskas 1993). In these cases Table 2 gives the weighted average values of color indices.

Our intention was to use all the stars of the "dipper asterism" proposed for CCD calibration purposes by Schild (1983, 1985). According to Schild, these stars are good for determining color equations between the instrumental and the standard color indices. We find, however, that the asterism contains only one blue star of spectral type B7 (a blue straggler) which is saturated in some of our

Table 2. Photoelectrically measured stars of M 67. *n* is the number of independent measurements. The second line for each star gives mean square errors.

F*	MMJ**	*V*	*U–V*	*P–V*	*X–V*	*Y–V*	*Z–V*	*V–S*	*n*
81	6481	10.001	1.289	0.926	0.371	0.161	0.063	0.128	6
		0.004	0.005	0.003	0.004	0.003	0.004	0.003	
102	5597	12.390	2.743	2.267	1.550	0.633	0.255	0.639	4
		0.004	0.020	0.008	0.016	0.006	0.009	0.007	
108	6482	9.733	4.788	4.108	2.780	0.987	0.458	0.938	4
		0.009	0.004	0.022	0.008	0.004	0.005	0.008	
111	5624	12.717	2.381	1.903	1.275	0.550	0.222	0.508	4
		0.009	0.012	0.005	0.005	0.009	0.014	0.010	
117	5643	12.609	2.790	2.338	1.619	0.665	0.249	0.664	4
		0.008	0.007	0.019	0.006	0.009	0.010	0.016	
124	5667	12.119	2.285	1.771	1.117	0.477	0.172	0.472	4
		0.015	0.011	0.009	0.007	0.010	0.008	0.003	
127	5675	12.756	2.354	1.881	1.272	0.542	0.211	0.528	4
		0.010	0.016	0.005	0.007	0.009	0.005	0.009	
128	5679	13.151	2.386	1.878	1.263	0.548	0.210	0.535	4
		0.008	0.017	0.035	0.011	0.015	0.015	0.009	
134	5699	12.252	2.388	1.921	1.289	0.534	0.210	0.535	3
		0.011	0.003	0.013	0.005	0.007	0.009	0.004	
135	6483	11.457	3.794	3.196	2.167	0.798	0.341	0.779	4
		0.011	0.012	0.012	0.008	0.010	0.008	0.007	
140	5716	13.182	2.387	1.918	1.314	0.539	0.211	0.528	5
		0.004	0.017	0.008	0.014	0.007	0.005	0.009	
149	5790	12.535	2.452	1.953	1.324	0.568	0.213	0.532	5
		0.011	0.012	0.007	0.019	0.009	0.011	0.012	
170	6499	9.682	4.661	3.991	2.728	0.974	0.443	0.919	5
		0.005	0.008	0.006	0.004	0.005	0.004	0.006	

* Fagerholm (1906)
** Montgomery, Marschall & Janes (1993)

Table 3. Color equations between the CCD and the standard systems.

Magnitude	*U*	*P*	*X*	*Y*	*Z*	*V*	*S*
b_i	0.078	−0.073	-0.097	0.054	0.036	0.004	0.090

CCD frames. The stars from Table 2 have been used for obtaining the coefficients a and b in equations of the following type:

$$m_{\rm st} - m_{\rm CCD} = a + b\,(Y - V)_{\rm st}\ . \qquad (1)$$

Values of the color coefficients b are given in Table 3. One can see that the color equations between the instrumental and the standard systems are small. It was shown by the method of synthetic photometry (Straižys et al. 1996) that color equations of the U–V and P–V color indices are slightly nonlinear for B–A main-sequence stars as well as for A–F supergiants. However, these types of stars are almost absent in the investigated area, so the linear color equations were applied.

3. RESULTS

Instrumental magnitudes from the three exposures were averaged and transformed to the standard system by Eqs. (1). Then the color indices U–V, P–V, X–V, Y–V, Z–V and V–S were formed for 279 stars down to $V = 15$ mag. Fig. 2 shows the standard deviations of magnitudes and colors of the stars from the average, as a function of magnitude V. Down to $V = 14$ mag, for all color indices the mean standard deviation of 188 stars is ≤ 0.02 mag. For fainter stars, the errors tend to increase. However, even at $V = 15$ mag, the mean standard deviation for the majority of stars is < 0.03 mag.

Table 4 gives the average values of magnitudes and color indices for stars brighter than $V = 15$ mag. All stars are listed by increasing right ascension for the epoch J2000.0. The identification numbers from Sanders (1977), Montgomery et al. (1993) and Fagerholm (1906) are given.

In Fig. 3 we compare our Y–V color indices with the b–y color indices from Strom et al. (1971), Anthony-Twarog (1987) and Nissen et al. (1987). Both indices are similar since the passbands of Y and b as well as of V and y are very close. In fact, in the combined Strömvil system these passbands are joined together (Straižys, Crawford & Philip 1996). Fig. 3 confirms a very small color equation of the relation between Y–V and b–y given by these authors. The mean standard deviation in Fig. 3 is about 0.02 mag, i.e. it is of the same order as the accuracy of our photometry. Systematic differences between different series of $uvby$ photometry are also seen.

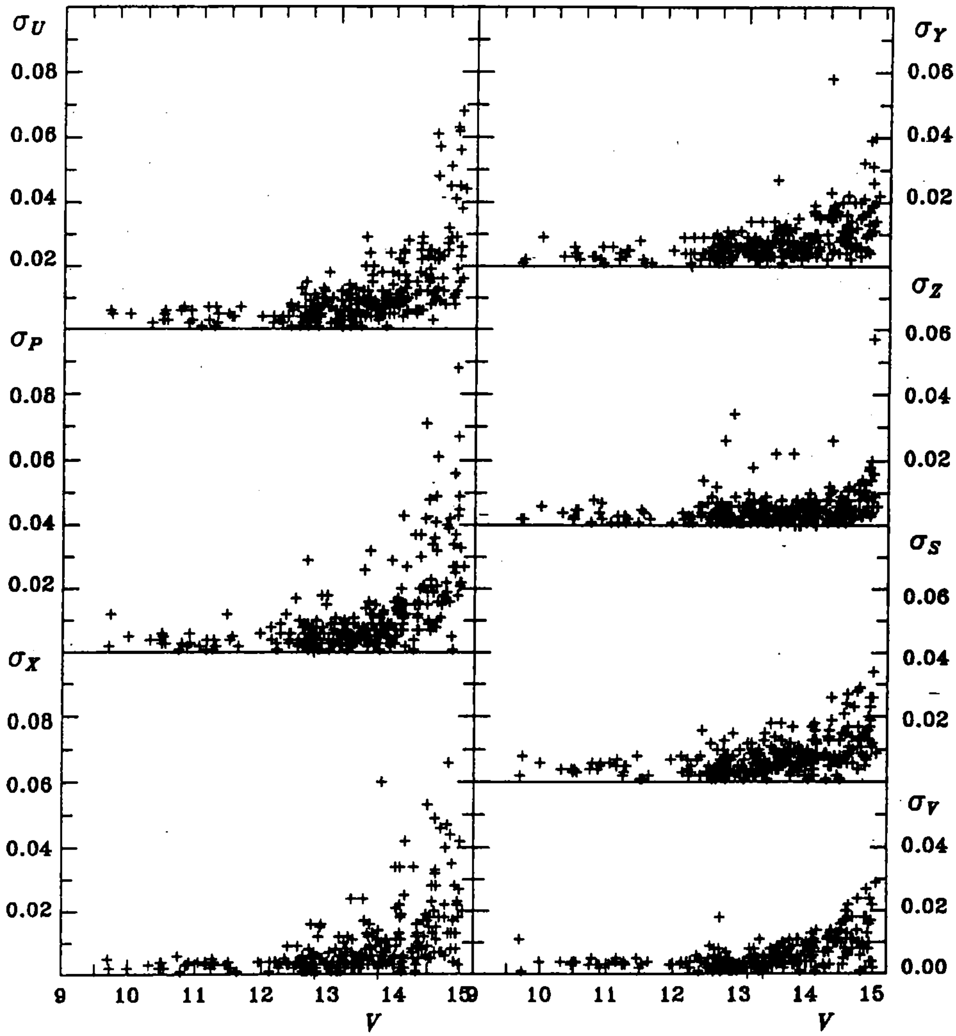

Fig. 2. Standard deviations of magnitudes averaged from three exposures.

4. CLASSIFICATION

For photometric classification of stars we have used the semi-automatic CLASS software (Vansevičius & Bridžius 1994) which gives the position of a program star in the "M_V versus spectral class" diagram by optimally matching color indices of a program star to color indices of standard cells reddened by different amounts using the standard interstellar reddening law. The CLASS program also gives interstellar reddening as the color excess E_{Y-V}. The results of the classification are given in the last column of Table 4. Instead of the absolute magnitude we give only the luminosity class, since the absolute magnitudes are obtained with the old calibration of the Vilnius system (Straižys et al. 1982). At present, a new calibration, based on the *Hipparcos* parallaxes, is under way.

Photometric spectral classes of 65 stars in Fig. 4 are intercompared with the spectroscopic spectral classes obtained by Burbidge & Burbidge (1959) and Allen & Strom (1995). For red giants and subgiants a good correspondence between the spectroscopic and photometric methods of classification is obtained: the differences do not exceed 4 spectral subclasses. However, for main-sequence stars a large scatter and a systematic shift is evident: in most cases Allen and Strom give earlier subclasses. This effect can be explained partly by possible systematic errors in the spectral classification since the above authors have used a non-traditional spectral range and criteria, different from those accepted for the MK classification system.

For determination of the approximate absolute magnitudes of the stars in the *Hipparcos* scale we have used the equations relating M_V with the reddening-free parameters of the Vilnius system, Q_{UPY}, Q_{XZS} and Q_{XYZ}, derived by Malyuto, Straižys and Kazlauskas (1997). These equations are valid only for the stars of luminosity classes V and IV and spectral classes G and K. We have used 128 stars of M 67 to obtain an average distance modulus of the cluster which was found to be $V{-}M_V = 9.38$ mag. The average color excess $E_{Y-V} = 0.035$ mag was obtained. This corresponds to $E_{B-V} = 0.045$ mag and $A_V = 0.14$ mag. This extinction originates in the galactic dust layer near its plane.

5. COLOR-MAGNITUDE AND TWO-COLOR DIAGRAMS

Fig. 5 shows the V, $Y{-}V$ diagram for stars down to $V = 15$ mag. The cluster members are marked by dots and nonmembers by crosses. Cluster membership is taken from Girard et al. (1989). The Figure shows the zero-age main sequence from Kazlauskas (1998) adjusted to the true distance modulus $V{-}M_V = 9.38$ and color excess $E_{Y-V} = 0.035$, the values found in this paper. One can see that this diagram is not very different from the V, $B{-}V$ diagram of the *UBV*

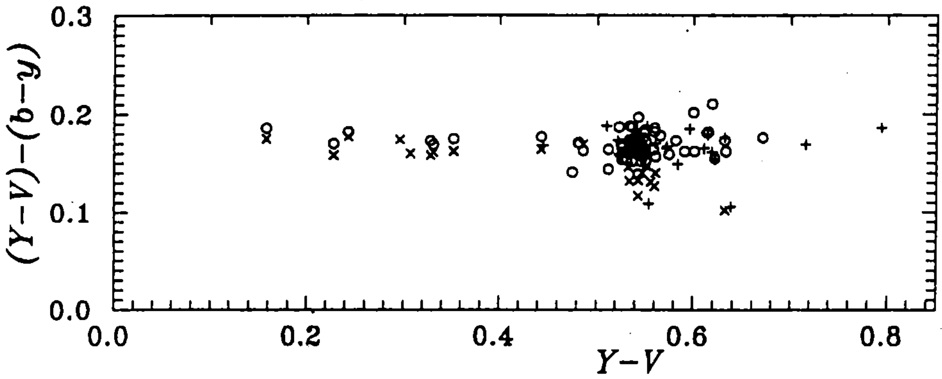

Fig. 3. Comparison of color indices $Y-V$ of this work and color indices $b-y$. Designations: × signs are for Strom et al. (1971), + signs are for Anthony-Twarog (1987) and o signs are for Nissen et al. (1987).

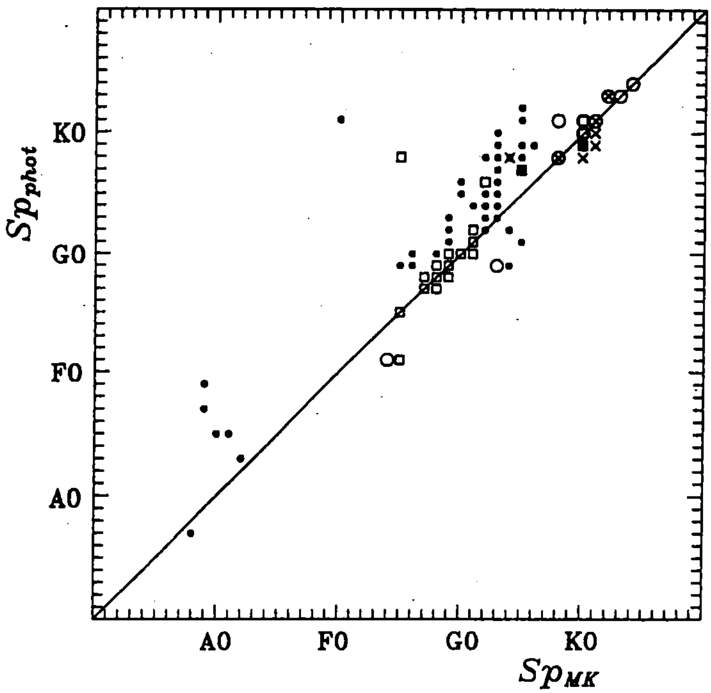

Fig. 4. Comparison of photometric spectral classes obtained in this work with spectral classes from Burbidge & Burbidge (1959), shown as circles, and Allen & Strom (1995), shown as squares for luminosity classes III and IV and as dots for luminosity class V.

Table 4. Magnitudes and color indices of M 67 stars. Designations: S – Sanders (1977) number, MMJ – Montgomery et al. (1993) number, F – Fagerholm (1906) number, * – non-members, B – spectroscopic binaries.

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
618	5061		8 50 36.6	+11 48 56	13.02	2.41	1.96	1.31	0.54	0.19	0.59	G0 V
616*	5064		8 50 36.8	+11 48 01	14.62	2.96	2.51	1.66	0.68	0.27	0.67	G8 V
603	5111		8 50 40.5	+11 42 12	14.02	2.40	1.98	1.32	0.56	0.19	0.56	G0 V
615	5118		8 50 40.8	+11 47 47	12.80	2.31	1.84	1.22	0.51	0.17	0.54	F7 V
607*	5124		8 50 41.5	+11 44 30	12.35	2.74	2.29	1.58	0.64	0.22	0.66	G4 V
608*	5152		8 50 43.9	+11 44 32	14.08	2.70	2.34	1.58	0.63	0.25	0.65	G6 V
791*	5174		8 50 45.8	+11 52 04	14.39	3.68	3.31	2.17	0.75	0.43	0.89	K3 V
745	5169		8 50 46.1	+11 43 09	13.08	2.36	1.91	1.30	0.54	0.19	0.55	F9 V
793*	5179		8 50 46.4	+11 52 17	14.99	2.81:	2.50	1.58	0.61	0.25	0.73	G6 V
800*	5184		8 50 46.8	+11 52 58	14.77	2.68	2.32	1.52	0.63	0.23	0.67	G6 V
744	5181		8 50 47.1	+11 42 55	14.11	2.41	2.02	1.37	0.57	0.21	0.57	G2 V
755	5189		8 50 47.6	+11 45 23	13.87	2.34	1.91	1.31	0.54	0.20	0.56	G0 V
751	5191		8 50 47.6	+11 44 52	12.68	2.27	1.79	1.19	0.50	0.17	0.51	F7 V
763	5196	15	8 50 47.6	+11 47 53	13.58	2.33	1.90	1.27	0.53	0.19	0.55	G0 V
777	5200		8 50 48.0	+11 49 42	14.49	2.59	2.16	1.44	0.60	0.23	0.61	G5 V
774	5228	20	8 50 49.9	+11 49 13	12.90	3.06	2.63	1.74	0.68	0.27	0.71	G8 V
765*	5239	23	8 50 51.7	+11 48 10	12.63	2.28	1.83	1.24	0.52	0.20	0.54	F7 V
753	5243		8 50 52.3	+11 45 04	14.57	2.60	2.15	1.48	0.62	0.27	0.56	G3 V
733	5249		8 50 53.0	+11 40 03	13.63	2.37	1.94	1.31	0.53	0.17	0.57	G0 V
760	5263	24	8 50 53.1	+11 47 34	13.27	2.38	1.93	1.32	0.54	0.21	0.58	G0 V
738*	5257		8 50 53.3	+11 41 44	13.67	2.41	1.97	1.33	0.57	0.20	0.59	F9 V
746	5261		8 50 53.3	+11 43 40	14.37	2.59	2.19	1.52	0.61	0.25	0.63	G5 V
750	5264	27	8 50 53.4	+11 44 35	13.59	2.48	2.08	1.42	0.57	0.22	0.59	G4 V
784	5283		8 50 54.7	+11 51 10	13.50	2.33	1.88	1.26	0.52	0.19	0.55	F9 V
799	5297		8 50 55.7	+11 52 56	15.00	2.72	2.39	1.46	0.61	0.23	0.64	G4 V
792	6477	30	8 50 55.7	+11 52 15	11.95	2.44	1.96	1.33	0.54	0.19	0.56	F9 V
803	5301		8 50 56.0	+11 53 52	13.61	2.36	1.89	1.25	0.52	0.18	0.55	F8 V
790*	5302		8 50 56.1	+11 51 56	14.63	2.80	2.44:	1.55	0.59	0.24	0.65	G7 V
788	5305		8 50 56.3	+11 51 30	14.08	2.41	1.98	1.37	0.55	0.21	0.58	G2 V
728	5294		8 50 56.5	+11 38 09	14.10	2.39	2.00	1.36	0.55	0.17	0.57	G2 V
779	5306		8 50 56.6	+11 49 55	14.63	2.64	2.21	1.52	0.60	0.25	0.62	G6 V
809	5314		8 50 57.6	+11 55 15	13.37	2.33	1.86	1.24	0.51	0.16	0.54	F7 V
794	5318	37	8 50 58.1	+11 52 23	12.86	3.36	2.87	1.89	0.73	0.29	0.75	K0 IV
741*	5313	39	8 50 58.4	+11 42 12	13.28	2.48	2.05	1.41	0.58	0.22	0.60	G2 V
766	5328	40	8 50 58.9	+11 48 20	13.75	2.38	1.93	1.31	0.55	0.21	0.56	G0 V
758	5334	43	8 50 59.2	+11 46 13	13.43	2.44	2.01	1.39	0.56	0.22	0.59	G2 V
748	5340		8 50 59.6	+11 44 08	14.61	2.90	2.53	1.73	0.65	0.28	0.68	K0 V
731	5335		8 50 59.7	+11 39 53	13.05	2.33	1.87	1.26	0.52	0.17	0.54	F9 V
729*	5336		8 50 59.7	+11 39 23	12.97	3.81	3.38	2.31	0.77	0.45	0.91	K4 V
785	5346		8 50 59.8	+11 51 13	14.79	2.66	2.28	1.45	0.63	0.26	0.65	F9 V

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
806	5350	46	8 51 00.2	+11 54 32	12.74	2.93	2.45	1.65	0.65	0.24	0.66	G7 IV
802	5360		8 51 00.7	+11 53 12	14.76	2.65	2.21	1.45	0.60	0.22	0.63	G5 V
730*	5348		8 51 00.8	+11 39 38	12.60	2.81	2.41	1.57	0.61	0.22	0.62	G8 V
770	5357		8 51 00.8	+11 48 53	14.60	2.55	2.17	1.50	0.58	0.22	0.62	G5 V
781	5362	48	8 51 01.0	+11 50 11	12.72	2.75	2.28	1.54	0.62	0.25	0.65	G6 V
740	5354		8 51 01.3	+11 41 59	13.47	2.30	1.85	1.26	0.52	0.19	0.56	F9 V
761	5367	52	8 51 01.5	+11 47 50	13.48	2.40	1.96	1.34	0.55	0.22	0.56	G1 V
775	5371	51	8 51 01.5	+11 49 35	12.64	2.49	2.00	1.36	0.56	0.21	0.58	G0 V
754*	5372		8 51 02.0	+11 45 19	14.95	2.78	2.30:	1.59	0.59	0.23	0.70	G7 V
773	5377	62	8 51 02.1	+11 49 02	13.28	2.38	1.92	1.33	0.55	0.22	0.57	G0 V
787*	5387		8 51 02.7	+11 51 26	14.53	3.01:	2.59	1.73	0.69	0.29	0.71	G9 V
795	5391		8 51 03.0	+11 52 26	14.96	2.72	2.33:	1.57	0.63	0.26	0.65	G8 V
756	5388	54	8 51 03.2	+11 45 48	12.64	2.49	2.00	1.37	0.56	0.21	0.57	G0 V
752	6476	55	8 51 03.5	+11 45 03	11.29	2.32	1.69	0.92	0.35	0.14	0.34	A9 V
736	5389		8 51 03.6	+11 40 31	13.37	2.35	1.90	1.29	0.54	0.19	0.55	F9 V
742*	5393		8 51 03.9	+11 42 24	14.52	2.29	1.86	1.29	0.52	0.19	0.55	F9 V
789	5408		8 51 04.5	+11 51 46	14.01	2.51	2.09	1.44	0.58	0.25	0.62	G4 V
757	5405	61	8 51 04.8	+11 45 57	13.52	2.37	1.92	1.32	0.56	0.22	0.61	F9 V
796	5412		8 51 04.9	+11 52 26	13.81	2.35	1.92	1.30	0.54	0.21	0.56	G0 V
776	5413		8 51 05.2	+11 49 34	13.72	2.35	1.89	1.30	0.54	0.21	0.55	F9 V
747	5414	64	8 51 05.7	+11 43 47	14.03	2.58	2.16	1.50	0.60	0.23	0.61	G4 V
801	5424		8 51 05.8	+11 53 11	15.04	2.76	2.39	1.62	0.61	0.25	0.65	G9 V
783*	5422	63	8 51 05.9	+11 51 10	13.30	2.36	1.85	1.26	0.54	0.20	0.55	F6 V
1077B	5451		8 51 07.2	+11 53 02	12.55	2.49	2.00	1.38	0.58	0.23	0.62	F9 V
939	5434		8 51 07.4	+11 36 54	13.38	2.32	1.87	1.27	0.52	0.15	0.53	F8 V
2224	5454		8 51 07.5	+11 52 56	13.80	2.40	1.96	1.36	0.53	0.22	0.55	G1 V
1067	5455		8 51 07.5	+11 51 57	14.88	2.56	2.23	1.54	0.60	0.23	0.65	G5 V
1013*	6484	70	8 51 07.8	+11 48 09	11.53	2.16	1.66	1.06	0.44	0.17	0.44	F4 IV
942	5444		8 51 08.0	+11 38 26	14.44	2.45	2.06	1.41	0.55	0.18	0.61	G3 V
1047		71	8 51 08.4	+11 50 08	13.54	2.39	1.93	1.32	0.54	0.22	0.54	G0 V
1001		72	8 51 08.4	+11 47 12	12.39	3.47	2.98	1.98	0.75	0.32	0.75	K1 IV
1055	5471	73	8 51 08.5	+11 50 53	13.75	2.35	1.92	1.31	0.54	0.21	0.55	G0 V
990	5464	75	8 51 08.6	+11 46 12	13.40	2.33	1.88	1.29	0.53	0.22	0.53	F9 V
1022*	5474	76	8 51 08.9	+11 48 38	13.98	2.64	2.22	1.53	0.61	0.25	0.62	G6 V
1017	5478	77	8 51 09.2	+11 48 21	13.36	2.34	1.89	1.30	0.53	0.21	0.55	G0 V
961		79	8 51 09.5	+11 41 45	12.78	2.79	2.32	1.57	0.63	0.24	0.64	G6 V
991	5485		8 51 09.9	+11 46 17	14.53	2.57	2.08	1.46	0.59	0.25	0.61	G2 V
951	5489		8 51 10.7	+11 39 51	14.63	2.45	2.14	1.47	0.56	0.22	0.63	G4 V
1025	5508	80	8 51 11.6	+11 48 51	13.76	2.37	1.95	1.35	0.55	0.22	0.55	G1 V
977	6481	81	8 51 11.7	+11 45 22	9.99	1.29	0.95	0.38	0.16	0.06	0.13	B7 V

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
2213	5517		8 51 12.0	+11 48 27	14.85	2.59	2.28	1.53	0.55	0.24	0.64	G8 V
1021	5522	82	8 51 12.2	+11 48 35	13.88	2.36	1.94	1.34	0.54	0.22	0.55	G1 V
2222	5524		8 51 12.2	+11 50 33	14.81	2.78	2.30	1.62	0.59	0.23	0.66	G8 V
992	5520	83	8 51 12.3	+11 46 22	13.19	2.42	1.95	1.34	0.56	0.22	0.55	F9 V
1089	5532		8 51 12.3	+11 54 23	14.12	2.49	2.05	1.39	0.57	0.22	0.58	G2 V
1052	5534	85	8 51 12.6	+11 50 35	13.60	2.36	1.91	1.31	0.53	0.20	0.54	G0 V
1074	6492	84	8 51 12.7	+11 52 43	10.51	3.90	3.30	2.19	0.82	0.32	0.78	K1 III
1063	5542	86	8 51 13.3	+11 51 40	13.56	3.34	2.91	1.99	0.75	0.32	0.83	K1 V
1053B	5544	88	8 51 13.6	+11 50 38	12.20	2.57	2.11	1.44	0.60	0.23	0.59	G2 V
1061	5546	87	8 51 13.6	+11 51 19	13.56	2.31	1.87	1.28	0.53	0.21	0.51	F9 V
1043*	5547		8 51 13.7	+11 49 59	14.27	2.26	1.85	1.29	0.53	0.20	0.53	F8 V
958			8 51 14.3	+11 41 10	14.45	2.49	2.11	1.43	0.60	0.23	0.59	G3 V
2221	5559	89	8 51 14.4	+11 50 41	13.36	2.37	1.91	1.31	0.53	0.21	0.54	G0 V
1003	5562	91	8 51 14.7	+11 47 24	12.81	2.39	1.89	1.29	0.54	0.21	0.53	F8 V
1033	5567	93	8 51 15.0	+11 49 21	14.11	2.39	2.01	1.38	0.55	0.22	0.55	G2 V
1049	5573	94	8 51 15.3	+11 50 15	12.77	2.39	1.90	1.29	0.53	0.20	0.53	F8 V
1005	5571	95	8 51 15.4	+11 47 32	12.65	2.31	1.81	1.21	0.51	0.19	0.49	F7 V
1068	5578		8 51 15.4	+11 51 58	14.97	2.74	2.32	1.58	0.60	0.26	0.65	G8 V
1056	5580	96	8 51 15.6	+11 50 57	12.99	3.04	2.56	1.72	0.67	0.27	0.69	G9 V
1015*	5577	97	8 51 15.6	+11 48 16	14.33	2.17	1.75	1.22	0.55	0.21	0.53	F6 V
1076	5586	98	8 51 15.7	+11 52 59	12.79	2.39	1.89	1.28	0.53	0.19	0.53	F8 V
955			8 51 15.8	+11 40 31	14.77	2.63	2.13	1.49	0.60	0.22	0.64	G2 V
973	5583		8 51 16.3	+11 44 33	13.45	2.37	1.91	1.31	0.54	0.21	0.56	F9 V
1088	5601	99	8 51 16.5	+11 54 15	13.51	2.51	2.01	1.38	0.56	0.20	0.54	G0 III
2206	5591	102	8 51 16.7	+11 45 30	12.40	2.74	2.29	1.55	0.64	0.26	0.65	G6 V
981	5594		8 51 16.8	+11 45 42	14.16	2.61	2.22	1.47	0.62	0.26	0.62	G6 V
2220	5597	101	8 51 16.8	+11 50 39	13.11	2.40	1.93	1.30	0.52	0.20	0.56	G0 V
2219	5603	103	8 51 17.0	+11 50 10	13.15	2.37	1.90	1.29	0.52	0.20	0.51	G0 V
1054	6489	104	8 51 17.0	+11 50 47	11.14	3.83	3.26	2.17	0.81	0.34	0.78	K1 IV
1016	6486	105	8 51 17.1	+11 48 16	10.31	4.44	3.80	2.55	0.93	0.42	0.88	K3 III
963	5595		8 51 17.2	+11 42 37	14.53	2.56	2.11	1.48	0.57	0.23	0.64	G3 V
987	5608		8 51 17.3	+11 46 04	13.92	2.39	1.96	1.32	0.55	0.20	0.55	G0 V
998	5610	106	8 51 17.3	+11 47 01	13.07	2.36	1.87	1.28	0.53	0.21	0.52	F8 V
978		108	8 51 17.5	+11 45 23	9.73	4.80	4.11	2.78	0.99	0.46	0.95	K4 III
1046	5625	109	8 51 17.7	+11 50 06	13.49	2.35	1.88	1.28	0.52	0.20	0.53	F9 V
948*	5600	110	8 51 17.6	+11 39 36	13.54	2.40	1.97	1.33	0.54	0.19	0.55	G1 V
986B	5624	111	8 51 18.0	+11 45 55	12.72	2.38	1.90	1.28	0.54	0.21	0.53	F8 V
964	5622	112	8 51 18.1	+11 42 55	13.27	2.40	1.94	1.32	0.54	0.20	0.56	G0 V
1050	5639		8 51 18.2	+11 50 20	14.29	2.43	2.00	1.35	0.56	0.22	0.60	G1 V
967	5629	114	8 51 18.3	+11 43 25	13.40	2.36	1.90	1.29	0.54	0.21	0.54	F9 V

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
1034	5644	115	8 51 18.5	+11 49 22	12.63	2.48	1.99	1.36	0.56	0.22	0.56	G0 V
956*	5633		8 51 18.6	+11 40 37	14.03	2.28	1.85	1.26	0.52	0.18	0.54	F9 V
999B	5643	117	8 51 18.7	+11 47 03	12.62	2.79	2.33	1.61	0.67	0.28	0.67	G2 IV
1060	5651		8 51 18.7	+11 51 19	13.00	3.10	2.61	1.76	0.69	0.29	0.67	G9 IV
1093	5656		8 51 18.7	+11 55 50	14.09	2.42	1.98	1.33	0.55	0.20	0.57	G0 V
954	5640	122	8 51 19.0	+11 40 16	13.69	2.37	1.90	1.29	0.54	0.20	0.53	F9 V
1045B	5654	119	8 51 19.0	+11 50 06	12.53	2.40	1.92	1.32	0.55	0.21	0.55	F9 V
1009	5653	120	8 51 19.2	+11 47 55	13.67	2.30	1.87	1.29	0.54	0.21	0.55	F9 V
1035	5657		8 51 19.2	+11 49 25	13.84	2.37	1.92	1.32	0.54	0.21	0.55	G0 V
1070	5671	123	8 51 19.7	+11 52 11	13.87	2.40	1.96	1.36	0.57	0.23	0.57	G1 V
997	5667	124	8 51 19.9	+11 47 01	12.11	2.28	1.76	1.13	0.49	0.18	0.47	F5 V
1057	5683		8 51 20.0	+11 51 02	14.27	2.53	2.11	1.44	0.59	0.23	0.55	G3 V
995	5675	127	8 51 20.1	+11 46 42	12.76	2.36	1.87	1.27	0.54	0.20	0.53	F7 V
1051	5685	126	8 51 20.1	+11 50 24	13.93	2.36	1.92	1.33	0.55	0.21	0.54	G0 V
1075	5692		8 51 20.1	+11 52 48	13.83	2.38	1.91	1.31	0.54	0.20	0.53	F9 V
2205	5679	128	8 51 20.3	+11 45 53	13.16	2.36	1.89	1.27	0.54	0.21	0.53	F9 V
988	5687	129	8 51 20.5	+11 46 05	13.18	2.40	1.93	1.33	0.55	0.21	0.54	F9 V
2204	5688	130	8 51 20.5	+11 46 17	12.89	2.22	1.73	1.13	0.48	0.17	0.46	F6 V
950	5680		8 51 20.8	+11 39 40	13.65	2.42	1.95	1.33	0.53	0.19	0.55	G1 V
1082	6493	131	8 51 20.8	+11 53 26	11.15	2.30	1.74	1.05	0.44	0.16	0.43	F1 V
976	5695	132	8 51 20.8	+11 45 03	13.10	2.43	1.96	1.34	0.56	0.22	0.56	G0 V
984	5699	134	8 51 21.2	+11 45 53	12.26	2.40	1.92	1.31	0.54	0.21	0.54	F9 V
946*	5698		8 51 21.5	+11 39 09	13.61	2.20	1.73	1.14	0.49	0.16	0.50	F5 V
989		135	8 51 21.5	+11 46 07	11.45	3.81	3.25	2.15	0.81	0.34	0.77	K1 IV
1072B	6491	136	8 51 21.7	+11 52 38	11.27	2.56	2.02	1.36	0.57	0.21	0.56	F9 III
1064	5718		8 51 21.7	+11 51 42	14.01	2.52	2.07	1.43	0.59	0.26	0.57	G2 V
966	5704		8 51 21.8	+11 43 18	14.48	2.55	2.12	1.46	0.57	0.23	0.58	G4 V
994	5716	140	8 51 22.0	+11 46 41	13.19	2.36	1.90	1.31	0.54	0.21	0.54	F9 V
1062	5733		8 51 22.4	+11 51 30	13.26	2.39	1.91	1.30	0.54	0.20	0.53	F9 V
1010	6485	141	8 51 22.8	+11 48 02	10.47	3.92	3.33	2.21	0.84	0.34	0.77	K1 III
1024B	5739		8 51 22.9	+11 48 50	12.69	2.33	1.87	1.28	0.54	0.20	0.52	F8 V
1031	5741		8 51 22.9	+11 49 13	13.25	2.21	1.74	1.15	0.48	0.19	0.46	F7 V
1087	5753		8 51 23.1	+11 54 05	14.12	2.47	2.02	1.39	0.58	0.22	0.55	G1 V
947	5730		8 51 23.2	+11 39 15	14.91	2.77	2.27	1.59	0.59	0.23	0.64	G7 IV
1019	5748		8 51 23.2	+11 48 27	14.38	2.90	2.40	1.64	0.66	0.28	0.68	G6 V
1040B	6488	143	8 51 23.7	+11 49 50	11.48	3.13	2.62	1.77	0.69	0.27	0.70	G8 IV
945	5744		8 51 23.8	+11 38 52	14.50	2.54	2.08	1.46	0.55	0.20	0.59	G3 V
1018	5764	145	8 51 24.1	+11 48 22	12.80	2.37	1.90	1.31	0.55	0.21	0.52	F9 V
1004	5768		8 51 24.3	+11 47 29	14.94	2.72	2.24	1.47	0.64	0.23	0.62	G1 V
2216	5770		8 51 24.3	+11 49 51	14.98	2.80	2.38	1.61	0.60	0.28	0.67	G9 V

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
965	5769		8 51 24.6	+11 43 07	14.70	2.68	2.28	1.60	0.58	0.25	0.67	G8 V
1027	5781	147	8 51 24.9	+11 49 01	13.24	2.39	1.95	1.33	0.55	0.21	0.54	G0 V
1012	5777		8 51 24.8	+11 48 04	14.50	2.60	2.18	1.50	0.64	0.26	0.61	G4 V
982	5776		8 51 25.0	+11 45 43	14.11	2.40	1.98	1.35	0.53	0.21	0.54	G2 V
1014	5788		8 51 25.2	+11 48 14	14.15	2.63	2.20	1.51	0.63	0.25	0.62	G4 V
1007	5790	149	8 51 25.3	+11 47 35	12.54	2.43	1.95	1.32	0.55	0.21	0.54	F9 V
1073	5795	148	8 51 25.5	+11 52 39	13.24	2.44	1.95	1.32	0.55	0.20	0.54	F9 IV
1030	5803	150	8 51 25.9	+11 49 09	13.22	2.36	1.90	1.29	0.54	0.20	0.52	F9 V
1041	5807		8 51 26.0	+11 49 56	14.70	2.67	2.25	1.54	0.61	0.24	0.61	G7 V
1084	6494	151	8 51 26.2	+11 53 52	10.49	3.87	3.27	2.17	0.82	0.31	0.77	K0 III
944	5794		8 51 26.4	+11 38 37	13.64	2.38	1.91	1.30	0.53	0.17	0.53	F9 V
968	6479	153	8 51 26.4	+11 43 51	11.24	2.12	1.52	0.67	0.24	0.09	0.18	A3 V
953*	5797		8 51 26.5	+11 40 13	13.93	3.02	2.61	1.78	0.65	0.30	0.69	K1 V
1032	5813	152	8 51 26.5	+11 49 21	13.47	2.37	1.90	1.30	0.53	0.20	0.54	F9 V
1023*	6487	155	8 51 26.8	+11 48 41	10.49	2.36	1.91	1.30	0.55	0.20	0.54	F9 V
1066	6490	156	8 51 27.0	+11 51 53	10.91	2.09	1.47	0.62	0.23	0.08	0.17	A2 V
1006*	5820		8 51 27.2	+11 47 33	14.72	2.15	1.65	1.13	0.49	0.19	0.47	F6 V
1083	5825	157	8 51 27.4	+11 53 27	12.73	2.42	1.90	1.29	0.54	0.18	0.52	F7 IV
1078	5826		8 51 27.5	+11 53 03	14.15	2.50	2.05	1.40	0.56	0.21	0.55	G2 V
1065	5831		8 51 27.8	+11 51 46	14.62	2.66	2.33	1.54	0.63	0.28	0.67	G5 V
1048	5829		8 51 27.9	+11 50 12	14.38	2.56	2.13	1.46	0.58	0.23	0.61	G4 V
1092	5838	159	8 51 27.9	+11 55 41	13.28	2.44	1.99	1.34	0.55	0.19	0.55	G1 IV
1036	5833	161	8 51 28.1	+11 49 28	12.76	2.19	1.71	1.12	0.47	0.18	0.48	F5 V
996	5835		8 51 28.3	+11 46 50	14.92	2.99	2.70	1.85	0.74	0.37	0.71	K1 V
1071	5842	162	8 51 28.3	+11 52 18	12.79	2.40	1.89	1.27	0.53	0.19	0.53	F7 V
943	5828		8 51 28.6	+11 38 32	14.94	2.78	2.32	1.60	0.60	0.22	0.68	G7 V
1011	5844		8 51 28.7	+11 48 03	13.80	2.48	2.02	1.40	0.57	0.24	0.58	G1 V
1069	5853	163	8 51 28.8	+11 52 00	12.65	2.60	2.10	1.43	0.59	0.22	0.58	G1 IV
1297	5857		8 51 28.9	+11 52 13	14.96	2.82	2.41	1.57	0.56	0.25	0.69	K0 V
1279	6503	164	8 51 29.0	+11 50 33	10.54	3.96	3.36	2.23	0.84	0.34	0.79	K1 III
1231	5855	166	8 51 29.3	+11 45 28	12.92	3.25	2.77	1.86	0.71	0.29	0.72	K0 IV
1308	5864	165	8 51 29.4	+11 54 14	12.81	2.42	1.94	1.32	0.55	0.19	0.52	F9 V
2223	5871	168	8 51 29.8	+11 51 30	13.27	2.25	1.76	1.16	0.48	0.17	0.49	F6 V
1278	5869		8 51 29.9	+11 50 23	14.36	2.78	2.35	1.60	0.64	0.26	0.64	G8 V
1283	5873		8 51 29.9	+11 51 09	14.07	2.46	2.00	1.38	0.54	0.21	0.56	G2 V
1250	6499	170	8 51 29.9	+11 47 17	9.69	4.70	4.02	2.71	0.97	0.43	0.92	K3 III
1219	5863	171	8 51 30.1	+11 43 50	13.13	2.35	1.91	1.30	0.54	0.20	0.55	F9 V
1289	5879		8 51 30.3	+11 51 23	14.87	2.76	2.30	1.58	0.59	0.24	0.64	G8 V
2212	5884	174	8 51 30.5	+11 49 14	12.68	2.44	1.94	1.32	0.55	0.20	0.54	F9 V
1303	5903	175	8 51 31.2	+11 53 18	13.69	2.40	1.92	1.32	0.53	0.18	0.53	F9 V

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	$U-V$	$P-V$	$X-V$	$Y-V$	$Z-V$	$V-S$	Sp
1234B	5896	176	8 51 31.2	+11 45 51	12.62	2.34	1.89	1.28	0.54	0.20	0.53	F9 V
1294*	5910		8 51 31.5	+11 51 58	14.87	2.74	2.29	1.60	0.63	0.27	0.65	G6 V
1302	5926	177	8 51 31.9	+11 53 12	13.05	2.38	1.88	1.27	0.52	0.18	0.51	F8 V
1287	5917	178	8 51 31.9	+11 51 17	13.98	2.42	1.95	1.35	0.56	0.20	0.55	G0 V
1314	5932	179	8 51 32.0	+11 55 09	13.62	2.46	2.00	1.37	0.56	0.20	0.57	G0 V
1274	5925	180	8 51 32.1	+11 50 04	12.61	2.44	1.94	1.31	0.55	0.20	0.53	F9 V
1246	5922		8 51 32.4	+11 46 46	14.58	2.55	2.16	1.51	0.58	0.23	0.64	G5 V
2208	5927	181	8 51 32.4	+11 48 02	12.77	2.94	2.48	1.66	0.67	0.26	0.65	G8 V
2207	5929	182	8 51 32.4	+11 47 53	12.63	2.48	1.99	1.35	0.56	0.20	0.55	G0 V
1260	5937		8 51 32.5	+11 48 24	14.14	2.43	1.98	1.35	0.57	0.22	0.56	G0 V
1280	5940	184	8 51 32.5	+11 50 41	12.20	2.18	1.61	0.84	0.33	0.11	0.28	A7 V
1208			8 51 32.5	+11 42 06	14.56	2.86	2.41	1.69	0.66	0.27	0.65	G8 V
1263	6501	185	8 51 32.6	+11 48 52	11.04	2.28	1.63	0.80	0.31	0.11	0.25	A5 V
Y5	5951		8 51 33.2	+11 48 52	12.69	2.41	1.91	1.28	0.54	0.19	0.53	F8 V
1292	5961	187	8 51 33.6	+11 51 45	13.18	2.44	1.98	1.36	0.56	0.20	0.55	G0 V
1248	5963		8 51 34.1	+11 46 56	14.15	2.46	2.02	1.39	0.55	0.22	0.55	G2 V
1235	5964		8 51 34.2	+11 45 54	14.93	2.97:	2.66	1.83	0.64	0.35	0.73	K2 V
1281	5972	188	8 51 34.2	+11 50 55	13.67	2.31	1.84	1.24	0.51	0.19	0.52	F8 V
1271	5969	189	8 51 34.2	+11 49 44	12.83	2.33	1.83	1.23	0.51	0.18	0.50	F7 V
1284	6504	190	8 51 34.3	+11 51 11	10.90	2.29	1.62	0.83	0.33	0.10	0.28	A7 IV
1197	5959		8 51 34.4	+11 37 58	13.15	2.38	1.90	1.30	0.55	0.15	0.53	F7 V
1218	5966		8 51 34.5	+11 43 50	14.57	2.51	2.14	1.45	0.57	0.22	0.58	G5 V
1203	5981		8 51 35.5	+11 39 47	14.35	2.65	2.21	1.53	0.61	0.23	0.62	G4 V
1305	5997	193	8 51 35.8	+11 53 35	12.26	3.52	2.97	1.98	0.75	0.29	0.72	G9 III
1262	5992	194	8 51 35.8	+11 48 52	13.58	2.41	1.95	1.33	0.55	0.19	0.53	F9 V
1255	5995		8 51 36.0	+11 47 47	14.42	2.54	2.14	1.48	0.60	0.25	0.54	G4 V
1201	5989		8 51 36.1	+11 38 57	13.89	2.36	1.94	1.34	0.56	0.17	0.53	G0 V
1242	5993	195	8 51 37.0	+11 46 34	12.69	2.63	2.15	1.48	0.62	0.23	0.60	G1 V
1313	6019	199	8 51 37.1	+11 55 00	13.17	2.41	1.90	1.27	0.53	0.22	0.50	F9 IV
1247	6010	201	8 51 37.2	+11 46 56	13.98	2.45	1.98	1.39	0.57	0.23	0.55	G1 V
1275	6018	202	8 51 37.4	+11 50 06	12.57	2.45	1.94	1.32	0.54	0.18	0.53	F9 IV
1213	6031	208	8 51 38.7	+11 42 38	14.11	2.35	1.94	1.33	0.55	0.18	0.55	G0 V
1256	6039	209	8 51 39.0	+11 47 56	13.70	2.47	2.06	1.41	0.57	0.21	0.57	G2 V
1273	6047	210	8 51 39.2	+11 50 04	12.23	2.40	1.90	1.28	0.53	0.18	0.52	F8 V
1293	6050		8 51 39.4	+11 51 46	12.13	3.58	3.03	2.00	0.76	0.29	0.73	G8 III
1214*	6049		8 51 39.8	+11 42 56	14.34	2.45	1.99	1.38	0.58	0.20	0.59	G0 V
1300	6060	211	8 51 40.0	+11 52 44	13.76	2.41	1.92	1.33	0.54	0.18	0.51	F9 V
1244	6058	213	8 51 40.4	+11 46 38	13.81	2.38	1.92	1.33	0.55	0.19	0.53	G0 V
1265	6065	214	8 51 40.8	+11 49 06	13.77	2.36	1.91	1.32	0.54	0.19	0.52	G0 V
1310	6077	215	8 51 41.2	+11 54 29	12.76	2.41	1.87	1.27	0.53	0.22	0.49	F8 III

Table 4 (continued)

S	MMJ	F	α(2000) h m s	δ(2000) ° ′ ″	V	U–V	P–V	X–V	Y–V	Z–V	V–S	Sp
1223*	6068		8 51 41.2	+11 44 53	14.90	2.62	2.27	1.51	0.57	0.22	0.62	G8 V
1252	6073		8 51 41.5	+11 47 36	14.08	2.46	2.01	1.39	0.56	0.19	0.55	G2 V
1269	6080		8 51 41.9	+11 49 38	14.90	2.77	2.38	1.63	0.63	0.26	0.62	G9 V
1216B	6076	216	8 51 41.9	+11 43 38	12.69	2.37	1.88	1.27	0.53	0.18	0.52	F7 V
1288	6505	217	8 51 42.3	+11 51 23	11.26	3.84	3.24	2.15	0.81	0.31	0.75	G9 III
1277	6502	218	8 51 42.3	+11 50 08	11.63	3.74	3.17	2.10	0.79	0.30	0.75	K0 III
1272B	6089	219	8 51 42.4	+11 49 52	12.53	2.42	1.91	1.30	0.55	0.18	0.53	F7 V
1243*	6090	221	8 51 42.6	+11 46 37	12.39	2.24	1.78	1.26	0.55	0.18	0.54	F5 V
1221B	6497	224	8 51 43.5	+11 44 27	10.78	4.04	3.42	2.26	0.84	0.32	0.79	K1 III
1230	6103	225	8 51 43.7	+11 45 15	13.07	2.32	1.84	1.26	0.52	0.17	0.51	F8 V
1239	6107	226	8 52 43.9	+11 46 22	12.76	2.75	2.27	1.54	0.63	0.22	0.61	G4 V
1207	6108	228	8 51 44.6	+11 41 51	13.18	2.33	1.88	1.28	0.53	0.16	0.52	F8 V
1226	6112	229	8 51 44.7	+11 45 02	13.34	2.34	1.86	1.28	0.53	0.17	0.52	F7 V
1245	6114	227	8 51 44.7	+11 46 46	12.95	3.21	2.73	1.84	0.72	0.27	0.70	G9 IV
1202	6109		8 51 44.9	+11 38 59	13.51	2.36	1.89	1.30	0.53	0.15	0.52	F9 V
1254	6500	231	8 51 45.0	+11 47 46	11.50	3.72	3.16	2.10	0.79	0.30	0.76	K0 III
1200*	6119		8 51 45.7	+11 38 46	14.33	2.29	1.89	1.36	0.56	0.18	0.57	F8 V
1220	6125	233	8 51 45.9	+11 44 10	13.36	2.34	1.88	1.28	0.52	0.17	0.52	F9 V
1240	6134	235	8 51 46.4	+11 46 27	13.36	2.37	1.89	1.30	0.54	0.18	0.51	F8 V
1225*	6135		8 51 46.6	+11 44 59	12.85	2.17	1.70	1.15	0.50	0.15	0.49	F5 V
1222*	6142		8 51 47.4	+11 44 42	14.68	2.50	2.10	1.49	0.56	0.19	0.60	G3 V
1249	6144		8 51 47.4	+11 47 10	14.29	2.79	2.38	1.64	0.62	0.25	0.63	G9 V
1285B	6158	236	8 51 48.3	+11 51 12	12.49	2.55	2.06	1.41	0.58	0.19	0.55	G0 V
1211	6149	239	8 51 48.4	+11 42 23	14.01	2.37	1.95	1.36	0.53	0.17	0.54	G1 V
1267		238	8 51 48.6	+11 49 16	10.86	2.28	1.62	0.79	0.30	0.07	0.23	A5 V
1251	6160		8 51 48.6	+11 47 36	14.77	2.73	2.33	1.60	0.57	0.22	0.62	G8 V
1258			8 51 48.9	+11 48 03	14.47	2.52	2.08	1.46	0.56	0.18	0.57	G3 V
1270	6166	241	8 51 49.1	+11 49 44	12.67	2.42	1.92	1.31	0.54	0.17	0.52	F9 V
1204	6167		8 51 49.8	+11 39 59	14.60	2.88	2.54	1.71	0.63	0.23	0.67	G9 V
1268	6177	243	8 51 49.9	+11 49 32	12.60	2.43	1.94	1.32	0.55	0.16	0.52	F8 V
1237B	6498	244	8 51 50.2	+11 46 07	10.74	3.38	2.84	1.90	0.74	0.25	0.69	G8 III
1436*	6199		8 51 51.6	+11 44 51	14.82	3.27	2.75	1.94	0.65	0.31	0.73	K2 V
1428	6213	254	8 51 53.1	+11 40 54	13.31	2.38	1.93	1.32	0.54	0.18	0.50	G0 V
1456	6224	255	8 51 53.3	+11 48 21	12.70	2.38	1.88	1.28	0.52	0.15	0.51	F8 V
1457	6254	259	8 51 55.6	+11 48 39	13.87	2.55	2.13	1.48	0.57	0.18	0.56	G5 V
1463	6259	262	8 51 56.1	+11 50 15	12.89	3.44	2.93	1.94	0.73	0.36	0.67	K1 V
1453	6267	263	8 51 56.5	+11 48 13	13.92	2.42	1.97	1.37	0.54	0.16	0.51	G1 V
1449	6265		8 51 56.6	+11 47 25	14.33	2.50	2.08	1.44	0.56	0.19	0.52	G3 V
1447*	6293	265	8 51 58.5	+11 46 53	12.42	2.40	1.91	1.34	0.55	0.18	0.50	F9 V

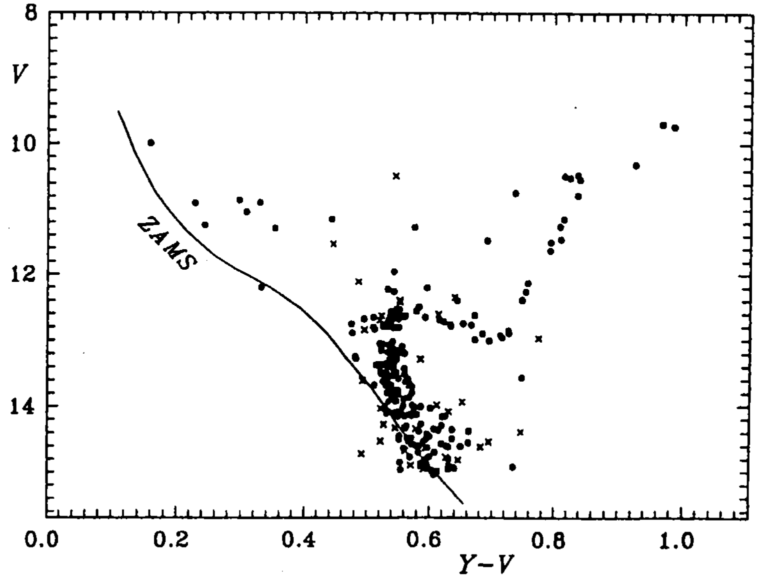

Fig. 5. Color-magnitude diagram of M 67 in the Vilnius system.

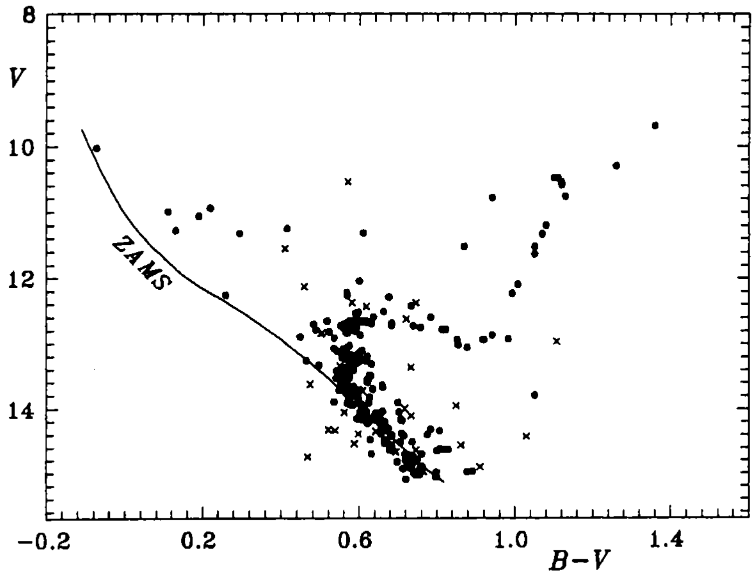

Fig. 6. Color-magnitude diagram of M 67 in the *BV* system for the same stars as in Fig. 5. The data are from Montgomery et al. (1993).

system which for the same stars is shown in Fig. 6, taking the V and B–V values from Montgomery et al. (1993).

Figs. 7–11 show five two-color diagrams of the Vilnius system on which color indices U–V, P–V, X–V, Z–V and V–S are plotted against the temperature-sensitive color index Y–V. The continuous and broken lines mark the intrinsic sequences of main-sequence stars and giants, respectively. Arrows are the interstellar reddening directions. The positions of sequences for M 67 are in agreement with the expected sequences of dwarfs and giants reddened by $E_{Y-V} = 0.035$ or $E_{B-V} = 0.045$.

6. ISOCHRONES AND AGE

Fig. 12 exhibits the $M_V, (Y\text{-}V)_0$ diagram of the cluster overlapped by isochrones from Bressan & Tautvaišienė (1996) for $Z = 0.02$ and 3, 4 and 5 billion years. The absolute magnitudes plotted here for M 67 stars are based on the distance modulus V–$M_V = 9.38$ corresponding to a distance of 750 pc. The 4.0 Gyr isochrone fits best the observations for the main-sequence stars, subgiants and giants. So, we obtain the same age as most other recent investigations in other photometric systems (see Montgomery et al. 1993).

7. CONCLUSION

CCD photometry of the cluster M 67 in the Vilnius system shows that, even with short exposures of the order of 15 min for ultraviolet filters and 3–5 min for other filters, useful photometric results can be obtained. Several hours of CCD observations replace tens of nights of usual photoelectric photometry. The results obtained for M 67 combined with the future CCD photometry of other open and globular clusters will form a database for the calibration of two-color and reddening-free diagrams of the Vilnius system in terms of metallicities and ages. A set of standard stars with magnitudes and colors measured photoelectrically in the Vilnius system is created in the cluster. This set can be used in future for tie in of CCD observations in other areas. It is concluded that the Flagstaff CCD camera used in this investigation is not sufficiently good for precise 1 % stellar photometry due to non-linear response.

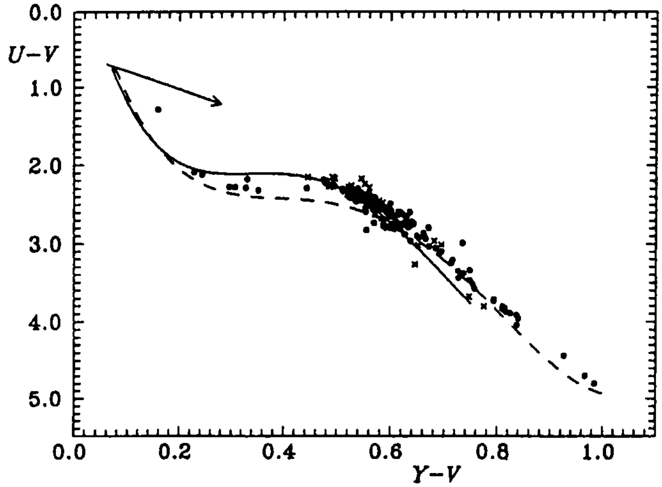

Fig. 7. Two-color diagram $U-V$ versus $Y-V$ of the Vilnius system. Dots are cluster members, crosses are non-members. The continuous line is the intrinsic main sequence and the broken line is the intrinsic line of giants. The arrow indicates the interstellar reddening direction. Its length is $E_{Y-V} = 0.2$.

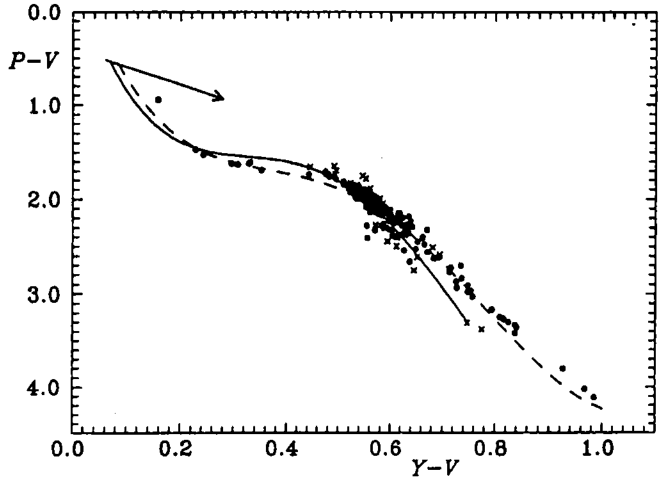

Fig. 8. Two-color diagram $P-V$ versus $Y-V$ of the Vilnius system. Designations are the same as in Fig. 7.

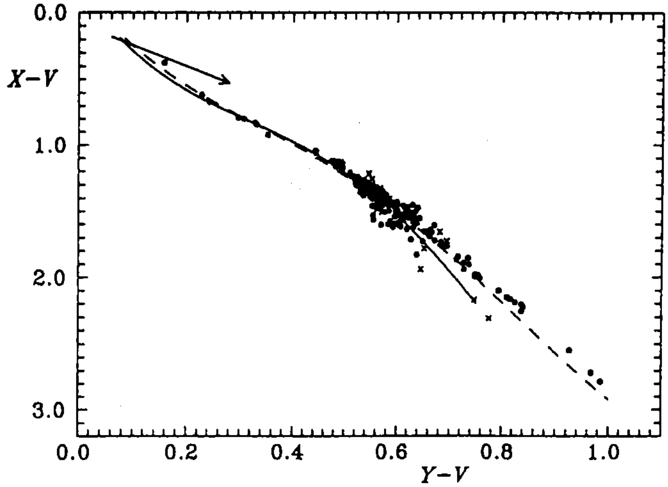

Fig. 9. Two-color diagram $X-V$ versus $Y-V$ of the Vilnius system. Designations are the same as in Fig. 7.

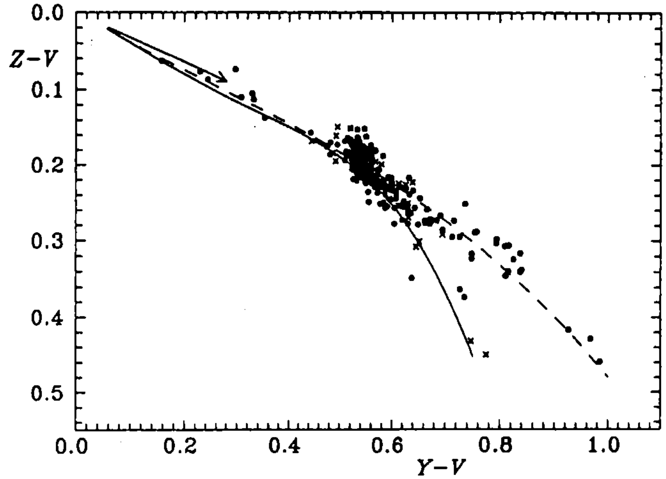

Fig. 10. Two-color diagram $Z-V$ versus $Y-V$ of the Vilnius system. Designations are the same as in Fig. 7.

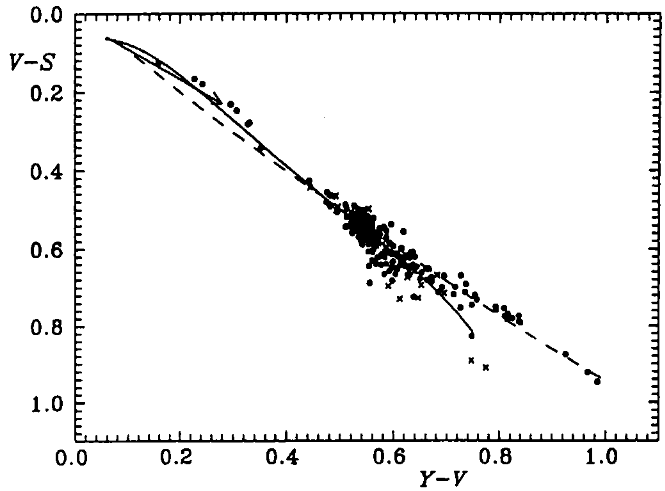

Fig. 11. Two-color diagram *V–S* versus *Y–V* of the Vilnius system. Designations are the same as in Fig. 7.

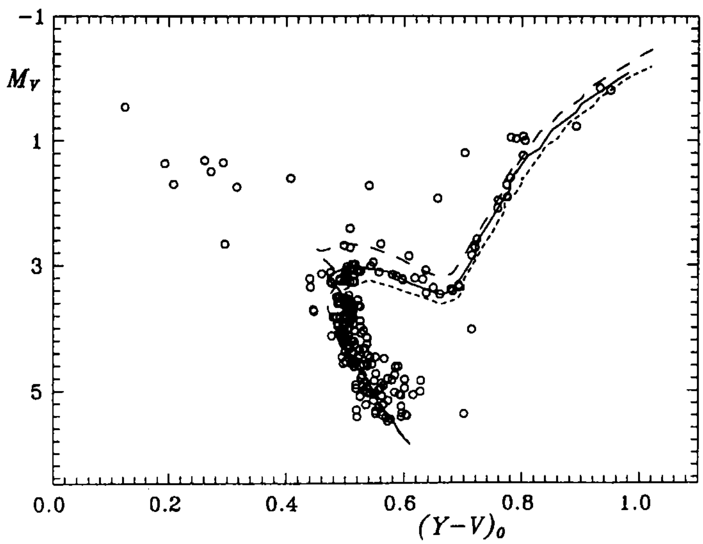

Fig. 12. HR diagram of the M 67 cluster with isochrones for ages of 3, 4 and 5 billion years (long-dashed, continuous and short-dashed lines, respectively). Only cluster members are plotted.

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