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STANDARD STARS FOR CCD PHOTOMETRY IN THE VILNIUS SYSTEM

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Abstract. The results of seven-color photometry of 73 stars of magnitudes 9–13 are given in 11 areas. The areas are of 10 × 10 arcmin size at low galactic latitudes in the transparent parts of the Milky Way in the constellations of Serpens, Aquila, Vulpecula, Lyra and Cygnus. These stars can be used as zero-point standards for future CCD photometry.

Key words: methods: observational – techniques: photometric – stars: standards (Vilnius photometric system)

1. INTRODUCTION

The main priority of the Vilnius seven-color photometric system, in comparison to other systems now in use, is its ability to determine temperatures, absolute magnitudes and interstellar reddenings for about 90–95 % of stars in the general galactic field. This was the reason why this photometric system has been proposed by Straižys and Philip (1994) for the investigation of stellar populations at low galactic latitudes. For this project, 25 areas of the Milky Way were selected near the galactic plane in the directions with relatively low interstellar reddening, trying to get more stars for their statistical investigations. In these areas of 20 × 20 arcmin size it is planned to obtain CCD photometry of stars down to 18th magnitude and to classify the stars in spectral and luminosity classes and maybe in metallicities.

For fixing the zero-point of magnitude scales in various filters, we need at least several standard stars in each field. The stars should be not very bright to be on the linear response of a CCD camera and not too faint to be measurable with sufficient accuracy on a 1 meter class telescope. The visual magnitude range, satisfying these requirements, is between 10 and 13 mag, bearing in mind that some of the standard stars in the ultraviolet will be fainter by 1–2 magnitudes.

2. OBSERVATIONS

In each field, intended for CCD photometry, we have chosen 5–10 stars in the mentioned magnitude range, most of them being within 5′ from the field center.

The photoelectric observations were made in 1994–1996 with the 1 meter Ritchey-Chretien telescope of the Institute of Theoretical Physics and Astronomy at the Maidanak mountain observatory (Uzbekistan). One of the standard sets of the Vilnius filters and a diaphragm of 16″ size were used. The magnitudes and color indices were reduced to the standard system by Nikonov's method as modified by Zdanavičius (1996). The stars HD 189796 (V = 7.82, G0 V) and HD 2666 (V = 7.60, F4 V) were used as the standard and the extinction stars. Each star in each filter was observed with an exposure giving the number of counts (after subtraction of the sky background) of the order of 10 000. Consequently, the resulting magnitudes and color indices must have accuracy of the order of 0.01 mag. In reality, this accuracy has not been always achieved, due to difficulty of measuring the sky background in the crowded Milky Way fields. Color equations for the transformation of instrumental magnitudes to the standard system were determined by observing 32 stars from the Cygnus Standard Region (Zdanavičius & Černienė 1985).

The first part of the work published here includes the measurement of standards in 11 areas in Serpens, Aquila, Vulpecula, Lyra and Cygnus. A list of the investigated areas is given in Table 1.

The V magnitudes and U–V, P–V, X–V, Y–V, Z–V and V–S color indices of the stars as well as the number of independent measurements n are listed in Table 2. The stars are identified in Figs. 1–11 which are plotted from the HST Guide Star Catalog by the program THESKY.

For all the observed stars we have determined spectral and luminosity classes using the method of comparison of 14 reddening-

Table 1. The areas with the standard stars measured.

Name of the area	Center RA (2000.0)	Center DEC (2000.0)	Number of stars	Observer
	h m	° ′		
Near GCl NGC 6535	18 01.3	–00 18	12	S.B.+K.Č.
Near GCl NGC 6760	19 12.2	+01 00	6	S.B.
Near OCl NGC 6791	19 21.2	+37 30	5	K.Č.
Near OCl NGC 6802	19 31.0	+20 18	7	S.B.
Near α Vul	19 35.0	+23 28	5	K.Č.
Near OCl NGC 6819	19 42.8	+40 00	5	K.Č.
Near GCl Pal 11	19 44.7	– 08 10	12	S.B.
In SA 64 (A)	19 58.6	+30 26	6	K.Č.
In SA 64 (B)	20 00.7	+30 24	5	K.Č.
Near 22 Vul	20 11.0	+23 54	5	K.Č.
In Veil Nebula	20 53.2	+31 33	5	K.Č.

free Q-parameters of a program star with those of about 8500 stars from the General Catalog of Stars Observed in the Vilnius System (Straižys & Kazlauskas 1993) with known MK types by the LYGINT program (Kazlauskas 1993). The spectral types obtained together with their accuracy estimation are given in the last two columns of Table 2. The accuracy is characterized by the standard deviation of Q-parameters of a program star in respect to a comparison star giving the best coincidence of 14 reddening-free Q-parameters. These standard deviations are stepped by 0.01 mag. The classification is the best when σ is 0.01–0.02 mag. For K- and M-type stars the values of σ up to 0.05 are acceptable. The larger values of σ mean uncertain classification. More explanations of the method can be found in Straižys et al. (1992).

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Table 2. Standard stars: magnitudes, color indices, photometric spectral types and their accuracy. For the stars marked by * see notes at the end of the Table.

Area and star No.	V	$U-V$	$P-V$	$X-V$	$Y-V$	$Z-V$	$V-S$	n	Sp.	σ
NGC 6535										
1.*	11.32	4.17	3.56	2.47	1.02	0.37	0.97	1	G9 III	0.03
2.*	14.40	-	2.45	1.72	0.78	0.34	0.62	2	G2 V	0.01
3.*	12.75	5.98	4.65:	3.31:	1.46	0.53	1.25	2	RGB, LPV?	-
4.*	13.51	-	-	2.66:	1.25:	0.45	1.05	3	RGB	-
5.*	12.82	3.06	2.33	1.39	0.65	0.25	0.51	3	A6 IV-V	0.02
6.	13.81	-	-	2.24	1.05	0.42	0.98	1	G2 IV-V	0.01
7.*	13.92	3.07:	2.41:	1.75	0.77	0.28	0.73	2	G0 III	0.02
8.	11.45	4.20	3.52	2.48	1.04	0.40	0.95	2	K0 III	0.01
9.*	11.93	3.97	3.35	2.32	0.98	0.38	0.90:	3	K1 III-IV	0.01
10.	12.29	-	-	2.89	1.18	0.49	1.06	2	K2 III	0.01
11.	12.01	-	-	3.30:	1.29	0.51	1.16	3	K2 III	0.02
NGC 6760										
1.	11.48	2.56	2.00	1.36	0.62	0.23	0.56	2	F5 V	0.01
2.	11.58:	-	-	3.78:	1.67	0.65	1.49	2	K2 III	0.01
3.	13.13	-	-	3.48:	1.41	0.62	1.28	3	K3 III	0.01
4.	12.44:	-	-	3.09:	1.73	0.46	1.77:	3	M III	0.07
5.	11.55	4.41	3.60	2.55	1.07	0.42	0.97	2	G2 I, G9 III	0.03
6.	12.97	-	-	3.16	1.80	0.52	1.71	3	M III	0.05
NGC 6791										
1.	9.76	2.31	1.69	0.91	0.37	0.14	0.36	3	A7-F0 IV-V	0.01
2.	11.22	2.39	1.84	1.20	0.52	0.20	0.49	3	F5 V	0.01
3.	11.17	2.18	1.59	0.77	0.30	0.10	0.25	3	A5 V	0.01
4.	9.95	2.23	1.60	0.81	0.33	0.12	0.31	3	A7 V	0.01
5.	10.12	5.69:	4.86	3.36	1.21	0.58	1.12	3	M0 III	0.02
NGC 6802										
1.	12.11	2.44	1.96	1.36	0.56	0.22	0.55	3	G1 V	0.01
2.	11.16	2.82	2.05	1.22	0.53	0.21	0.49	2	A7-9 V-III	0.02
3.	12.45	2.57	2.12	1.48	0.63	0.24	0.62	3	G2 V	0.01
4.	9.76	3.18	2.52	1.76	0.78	0.30	0.70	2	F9 V	0.02
5.	11.81	3.02	2.28	1.48	0.69	0.22	0.64	3	F0 IV	0.02
6.	12.36	2.57	2.03	1.52	0.84	0.30	0.66	4	B2 IV	0.01
7.	11.13	2.70	2.27	1.56	0.61	0.28	0.62	3	G8 V	0.02

Table 2 (continued)

Area and star No.	V	U–V	P–V	X–V	Y–V	Z–V	V–S	n	Sp	σ
α Vul area										
1.	11.40	2.91:	2.10:	1.16:	0.60	0.22	0.48	2	A0 V-III	0.01
2.	10.31:	2.83:	2.18:	1.31:	0.56	0.23	0.56	3	F-G	
3.	9.42	3.86	3.22	2.21	0.88	0.36	0.81	3	G9 IV	0.01
4.	11.03	2.33:	1.76	1.03	0.46	0.17	0.40	3	A7 IV	0.02
5.	10.80	2.47	2.05	1.43	0.58	0.24	0.56	3	G4 V	0.01
NGC 6819										
1.	11.85	2.25	1.75	1.19	0.52	0.20	0.48	3	F6 V	0.01
2.	11.05	4.15	3.57	2.40	0.92	0.39	0.79	3	K1 III	0.03
3.	8.26	2.19	1.66	1.07	0.47	0.18	0.44	3	F5 V	0.01
4.	10.53	2.23	1.77	1.20	0.50	0.19	0.50	4	F8 V	0.01
5.	11.28	2.62	2.15	1.46	0.58	0.24	0.57	3	G1 V	0.01
Palomar 11										
1.	12.91	2.43:	1.93:	1.34	0.61	0.24	0.55	4	F8 V	0.01
2.	12.95	-	-	2.96:	1.10	0.51	1.01	3	K4 III	0.01
3.	13.17	2.63	2.07	1.46	0.64	0.25	0.58	3	F8 V	0.01
4.	11.78	2.65	2.08	1.43	0.63	0.23	0.61	3	F8 V	0.01
5.	12.98	2.56	2.06	1.46	0.63	0.25	0.62	3	F9 V	0.01
6.	10.50	5.36	4.58	3.14	1.17	0.55	1.11	3	K5 III	0.01
7.	11.86	2.68	2.00	1.25	0.55	0.20	0.53	4	F1 V	0.01
8.	12.06	3.18	2.60	1.81	0.78	0.30	0.76	3	G2 V	0.02
9.	12.78	3.83:	3.18	2.14	0.87	0.35	0.81	4	K0 IV	0.03
10.	11.61	2.51	1.97	1.31	0.61	0.23	0.56	4	F5 V	0.01
11.	11.36	2.59	1.89	1.06	0.45	0.19	0.37	3	A7 V	0.02
12.	12.19	2.50	1.89	1.23	0.58	0.21	0.52	3	F2 V	0.02
SA 64 A										
1.	12.36	-	-	3.28:	1.32	0.53	1.21	3	G8-K2 III	0.01
2.	10.08	2.20	1.58	0.76	0.29	0.10	0.25	3	A5 V	0.01
3.	11.92	2.30:	1.78	1.22	0.51	0.18	0.50	3	F5 V	0.01
4.	10.83	2.20	1.60	0.72	0.31	0.12	0.21	3	A1.5 V	0.01
5.	12.14	2.37	1.77	0.86	0.40	0.15	0.26	3	A1 V	0.02
6.	8.80	2.21	1.52	0.64	0.28	0.10	0.20	3	A1 V-III	0.01

Table 2 (continued)

Area and star No.	V	$U-V$	$P-V$	$X-V$	$Y-V$	$Z-V$	$V-S$	n	Sp	σ
SA 64 B										
1.	10.09	1.70	1.36	1.06	0.59	0.24	0.48	3	O-B1	0.03
2.	11.20	2.36	1.77	1.00	0.41	0.16	0.38	3	F0 V	0.01
3.	13.29	2.80:	2.16:	1.41:	0.67:	0.24	0.51	2	F3 V	0.03
4.	11.16	2.12	1.51	0.66	0.27	0.11	0.17	3	A1 V	0.02
5.	10.93	1.74:	1.39	1.09:	0.62	0.24	0.50	3	B1-2	0.02
22 Vul area										
1.*	11.28	2.34	1.89	1.31	0.55	0.22	0.54	3	F9 V	0.01
2.	11.88	4.52:	3.84	2.68:	1.05	0.43	1.01	2	K0.5 III	0.02
3.	9.59	2.28	1.67	0.95	0.41	0.15	0.39	3	F0 IV	0.02
4.	11.72	2.55:	2.04:	1.39	0.56	0.21	0.59	3	G2 V	0.02
5.	10.99	2.24	1.66	0.93	0.39	0.14	0.32	3	A8 V	0.02
Veil Nebula										
1.	9.59	4.34	3.64:	2.49	0.92	0.39	0.88	3	K2 III	0.02
2.	10.23	2.19	1.66	1.06	0.46	0.18	0.43	3	F3 V	0.01
3.	10.87	4.11:	3.41:	2.32	0.86	0.36	0.83	3	K0 III	0.02
4.	11.45	-	4.25:	2.96	1.12	0.50	1.05	3	K3 III	0.02
5.	8.60	4.06	3.42	2.30	0.84	0.35	0.79	3	K0 III	0.01

* NGC 6535 BV observations by Liller (1980):
1 – Liller D ($V = 11.33$, $B-V = 1.28$, nonmember)
2 – Liller A ($V = 14.48$, $B-V = 0.85$, nonmember?)
3 – Liller 41 ($V = 12.83$, $B-V = 1.92$, member, LPV?)
4 – Liller 13 ($V = 13.51$, $B-V = 1.55$, member)
5 – Liller 83 ($V = 12.93$, $B-V = 0.56$, nonmember)
7 – Liller F ($V = 13.98$, $B-V = 0.92$, nonmember)
9 – Liller E ($V = 11.95$, $B-V = 1.22$, nonmember)

The stars designed by capital letters are measured photoelectrically and those designed by numerals are measured photographically.

Star No. 1 in the 22 Vul field: visual binary, both components measured together.

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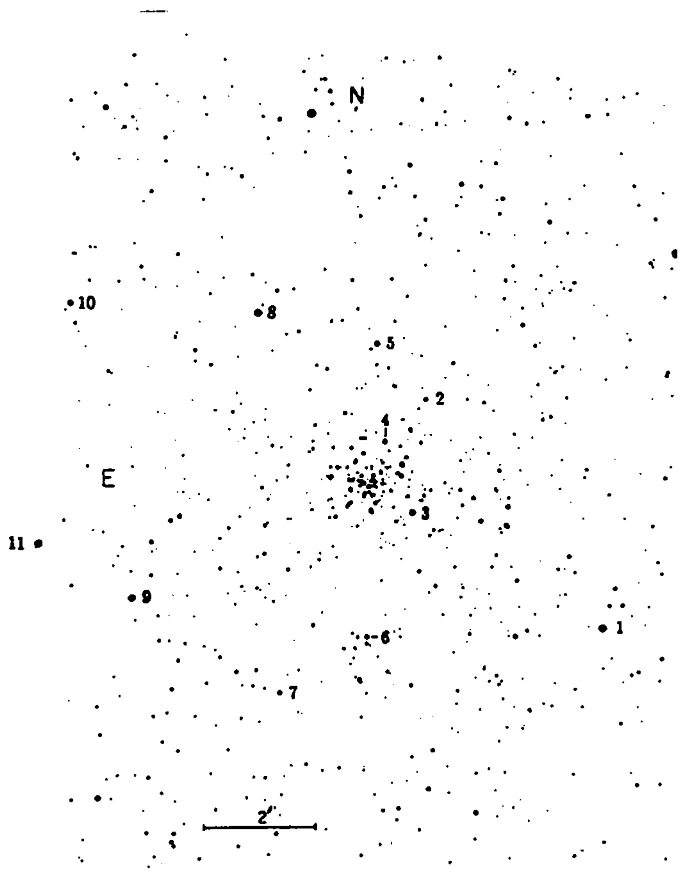

Fig. 1. Identification chart for the area around the globular cluster NGC 6535.

Fig. 2. Identification chart for the area near the globular cluster NGC 6760. The vertical size of this and of all following charts is 13′.

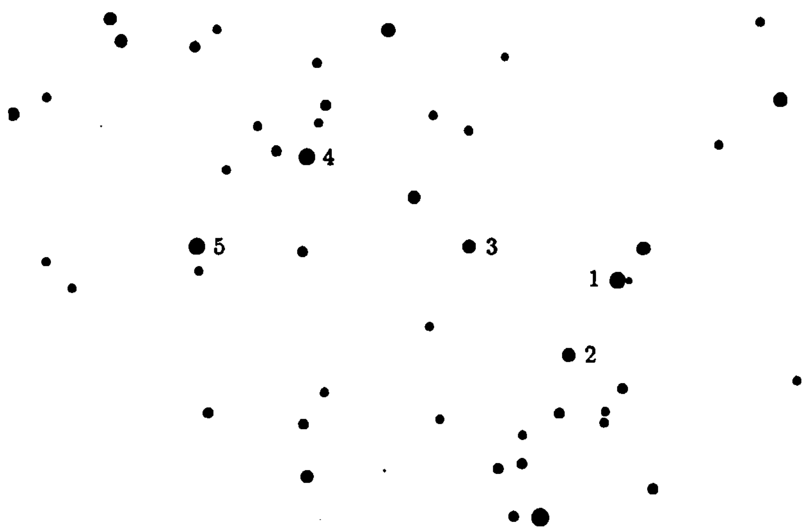

Fig. 3. Identification chart for the area near the open cluster NGC 6791.

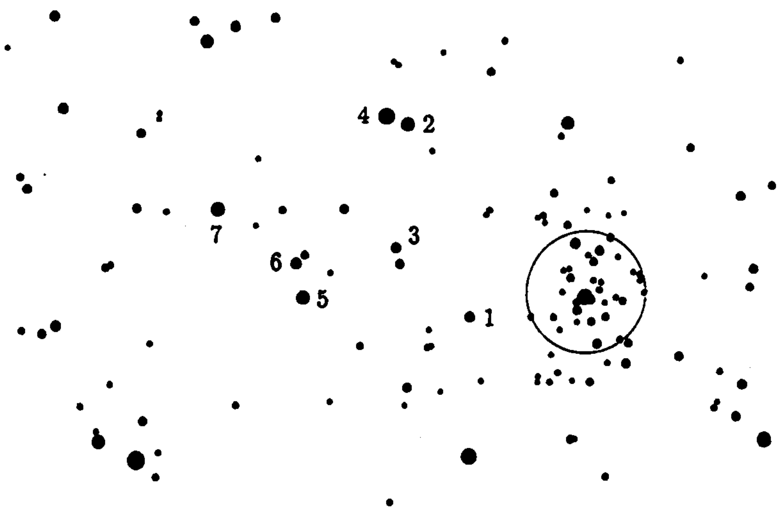

Fig. 4. Identification chart for the area near the open cluster NGC 6802.

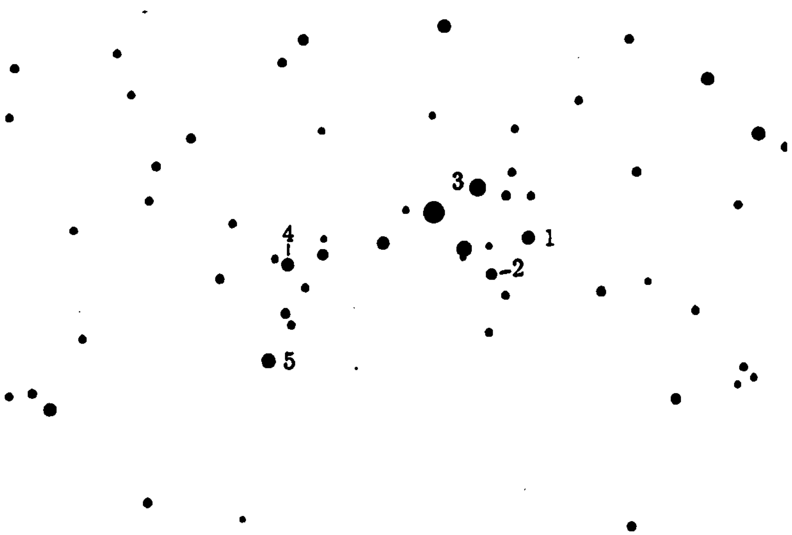

Fig. 5. Identification chart for the area near the star α Vul.

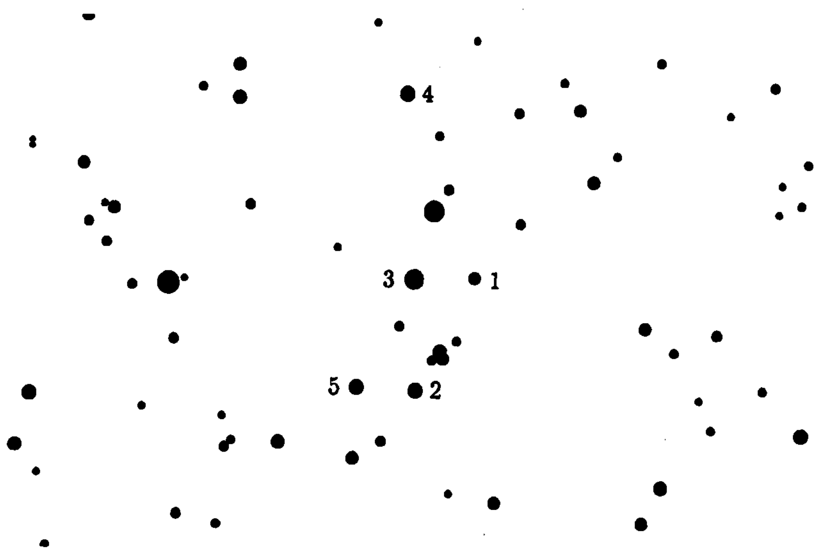

Fig. 6. Identification chart for the area near the open cluster NGC 6819.

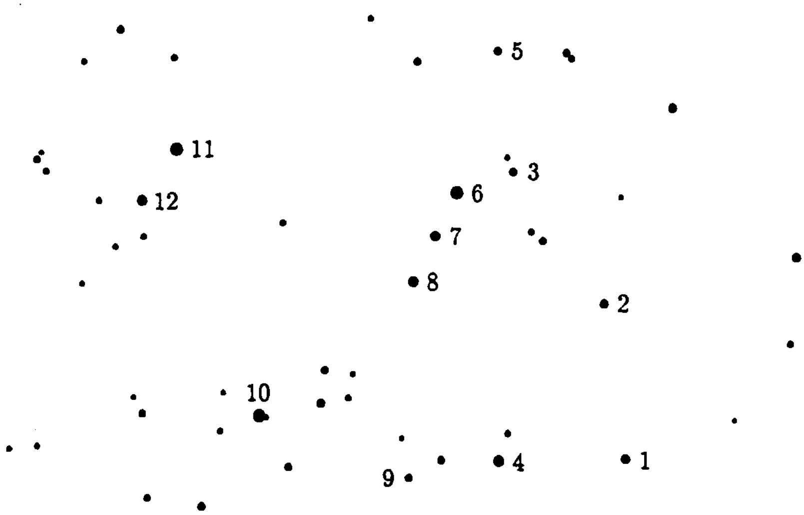

Fig. 7. Identification chart for the area near the globular cluster Pal 11.

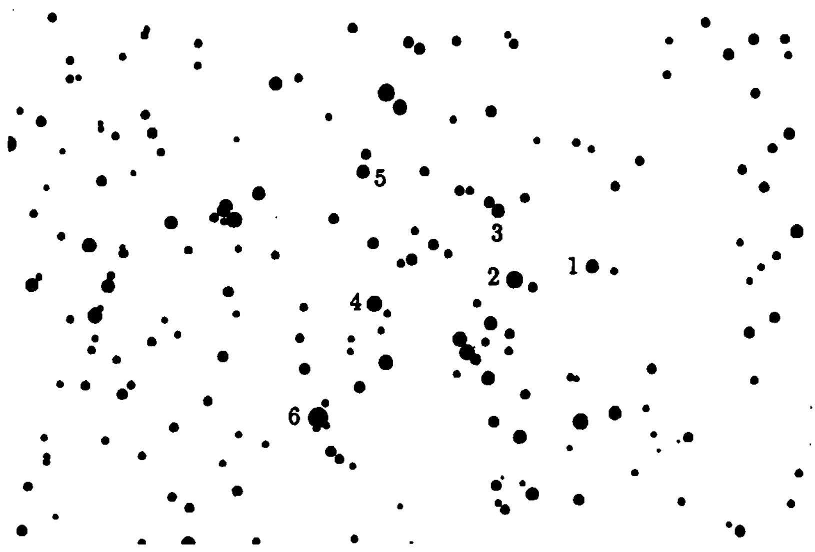

Fig. 8. Identification chart for the area A in SA 64.

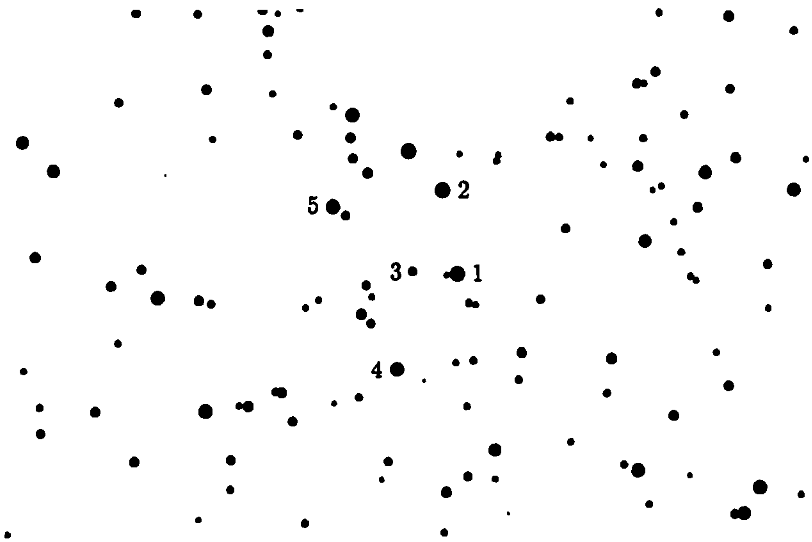

Fig. 9. Identification chart for the area B in SA 64.

Fig. 10. Identification chart for the area near the star 22 Vul.

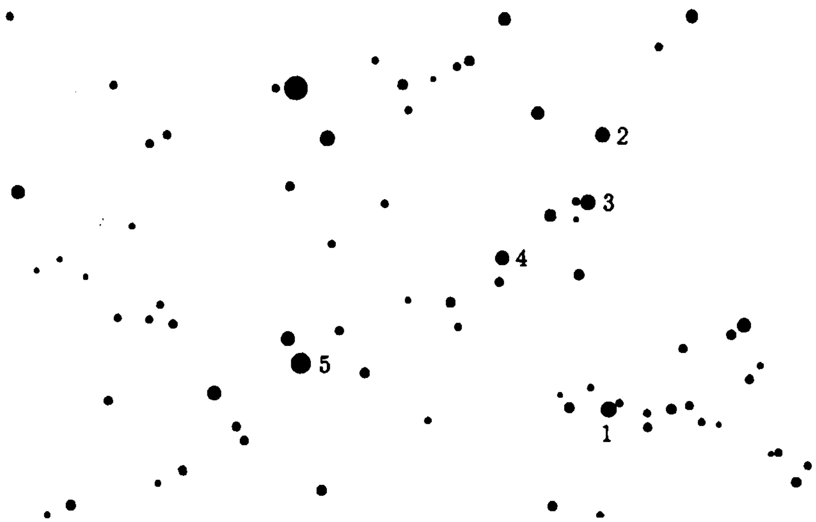

Fig. 11. Identification chart for the area inside the Veil Nebula.