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Vilnius Photometry and Reddening of the Young Open Cluster NGC 6913

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Abstract 87 stars in the NGC 6913 field with both UBV and Vilnius photometry are selected to be the sample. The membership probability of the stars is greater than 50%. The correlation among Vilnius photometry, UBV photometry and reddening in the cluster is reviewed. It is found that the photometry in the Vilnius X, Y and Z bands can be used to make rough spectral classification. The values of $E(B-V)$ are well correlated with the Vilnius colors of $X-Y$, $Y-Z$, $Z-V$ and $V-S$ in NGC 6913. The ratio of $(V-S)/(Y-Z)$ of the MPCM (Most Possible Cluster Members) is a constant ($1.30 \sim \pm 0.06$), and has no effect on the values of $E(B-V)$, $(B-V)_0$ and V_0. Comparing with the observational data of all the stars of NGC 6913 region, we propose that the value of $(V-S)/(Y-Z)$ can probably be used to select the preliminary candidates of one open cluster. In addition, 12 variable stars are discovered in the NGC 6913 region, in which star #155 has a variation with an amplitude of 4.25 mag.

Key words: Galaxy: open clusters and associations – ISM: dust, extinction

1 INTRODUCTION

Young open clusters often have large and non-uniform extinction. In order to study intracluster extinction, we need a complete sample of cluster members, in which three groups of valuable data must be included, i.e., (i) reliable cluster membership; (ii) precise photometric data; (iii) accurate spectral classification.

The young open cluster NGC 6913 ($20^{\rm h}$ $23.9^{\rm m}$, +38.32 (2000)) lies in the Cygnus OB1 association. In 1973, based on relative proper motions, Sanders computed the probabilities of cluster membership for 228 stars in the field of NGC 6913 (Sanders 1973). He found that

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there are 105 stars with probabilities greater than 50% out of 228 field stars. Before the 1980s, all the stars in the cluster field had approximate values of visual magnitude, but only a small number of the stars had UBV photoelectric values available. The much more complete UBV photoelectric photometry was finished by Joshi et al. in 1983, using the 104-cm Sampurnanand reflector of the Uttar Pradesh State Observatory. The standard deviations of their observations are better than ± 0.025 mag in $(U-B)$, $(B-V)$ and V magnitudes (Joshi et al. 1983). From their photometric study, the distance modulus to the cluster is obtained to be 10.85, which corresponds to a cluster distance 1.5 kpc. And also it is found that the cluster stars have ages between 0.3 and 1.75 Myr with a few even younger than 0.3 Myr. That means NGC 6913 is a very young open cluster.

We have selected 100 stars which have membership probability greater than 50% in Sanders'star table of NGC 6913 as our sample to make MK classification by the means of spectroscopic observation (Wang & Hu 2000). In this paper, we will discuss the correlation among Vilnius photometry, UBV photometry and reddening inside the cluster.

2 OBSERVATIONAL DATA

The Vilnius photometric system has been described in detail by Straizys (Straizys 1973, 1992). Besides the V passband (the same to V in UBV system), there are six special Vilnius passbands which are called U, P, X, Y, Z and S passbands respectively. The corresponding mean wavelengths of the passbands are 345, 374, 405, 466, 516, 544 and 656 nm. There are 87 stars in NGC 6913 field with both UBV and Vilnius photometry. All the stars in the sample have membership probability greater than 50%. The data we used here are extracted from the database on open clusters developed by J.-C. Mermilliod (Mermilliod 1995).

MK spectral classification was obtained from the spectroscopic observations, which were carried out from Jun. 7 to Jun. 11 in 1994 with the 2.16 m telescope located in the Xinglong station of Beijing Astronomical Observatory. The UBV photometry is taken from Joshi et al. (1983). The Vilnius photometric data can be extracted from the database mentioned above in the CDS. And Table 1 shows the UBV color indices, values of reddening and the transformed indices from Vilnius photometry. We also present both V and Vilnius V(vilnius) magnitude in Table 1.

3 ANALYSIS AND DISCUSSION

3.1 Examination of Spectral Classification

The Vilnius photometric data for NGC 6913 can be used to examine the results of our spectral classification .

Figure 1 is the plot of $(Y-Z)$ versus $(X-Y)$. It can be used to divide stars into spectral groups (Straizys 1992). In this diagram, we mark the stars with different spectral type in different symbols ("plus" B type, "triangle" A–F type, "star" G type and "open circle" K type). The diagram is divided into a few zones corresponding to a few different spectral regions. Clearly, our spectral classification for most of the stars coincides with the $(Y-Z)$, $(X-Y)$ spectral classification. Only two G stars and a few B and $A-F$ stars locate out of "their zones". As far as the statistical meaning, the XYZ classification is roughly in agreement with the spectroscopic classification.

Table 1 The Observational Data of the Young Open Cluster NGC 6913

Star No.	V (vil)	V	$B-V$	U(vil) $-B$	$(B-V)_0$	$E(B-V)$	Star No.	V (vil)	V	$B-V$	U(vil) $-B$	$(B-V)_0$	$E(B-V)$
7	13.14	13.01	0.62	1.77	–0.30	1.14	131	13.13	13.17	0.62	1.77	0.39	0.19
9	13.33	13.39	0.74	2.70	0.05	0.66	133	12.90	12.90	0.76	1.93	–0.19	0.98
11	12.89	12.86	0.66	1.86	0.34	0.30	135	8.57	8.57	0.42	1.88	0.28	0.15
15	9.01	9.03	0.59	1.24	–0.32	0.93	136*	12.20	13.53	0.42	2.29	–0.18	1.26
17	13.28	13.38	0.52	2.03	0.09	0.48	139	9.36	9.35	0.77	1.51	–0.28	1.08
24	13.03	13.07	1.40	2.57	–0.25	1.64	141*	13.60	13.15	1.11	2.71	–0.02	1.08
26	10.40	10.33	0.41	1.42	–0.25	0.85	142	12.91	12.90	0.80	1.97	–0.19	1.03
28	13.02	12.97	2.07	2.94	1.16	0.69	143	11.93	11.88	1.14	2.04	–0.27	1.36
32	12.12	12.20	0.59	1.74	0.43	–0.02	144	13.49	13.50	0.92	2.19	0.54	0.14
33	13.23	13.28	0.71	2.32	–0.02	0.71	147	10.21	10.24	0.75	1.53	–0.30	1.00
36	13.42	13.41	0.74	2.63	0.05	0.69	148	11.86	11.80	0.45	1.75	0.21	0.25
37	10.68	10.62	1.75	3.39	1.01	0.56	149	8.91	8.93	0.76	1.48	–0.32	1.10
40*	13.09	13.60	0.98	2.31	0.23	0.57	151	12.54	12.49	1.29	2.26	–0.16	1.47
47	10.94	10.91	0.46	1.95	–0.10	0.52	152	12.54	12.54	0.78	1.81	–0.20	0.96
49	13.29	13.28	0.83	2.73	0.05	0.78	153	12.98	12.96	1.30	2.25	–0.14	1.46
51	13.57	13.59	0.60	1.77	0.60	0.04	155*	13.16	8.91	1.02	2.36	–0.14	0.92
52	13.32	13.40	0.61	2.21	–0.02	0.65	157	8.88	8.84	0.90	1.65	–0.23	1.15
54	13.21	13.25	0.86	2.66	0.20	0.58	159	8.96	8.89	0.83	1.55	–0.23	1.06
55	10.16	10.16	0.54	1.57	–0.25	0.80	166	13.69	13.67	0.85	2.46	–0.13	0.94
58	13.05	13.14	0.53	1.84	–0.30	0.81	167	11.82	11.84	1.11	2.55	0.86	0.20
61	11.87	11.96	0.58	1.88	0.23	0.29	168	13.32	13.20	1.85	3.36	0.86	0.81
64	13.18	13.03	0.69	1.91	–0.17	1.00	169	10.77	10.79	0.48	1.78	0.17	0.32
69	9.32	9.33	0.53	1.32	–0.24	0.78	171	12.41	12.35	0.50	1.84	0.17	0.35
71	12.74	12.77	0.61	1.98	–0.13	0.87	174	10.12	10.11	0.18	1.37	–0.19	0.37
73	12.06	12.09	0.49	1.73	–0.19	0.70	176	12.83	12.80	0.52	1.88	0.15	0.38
76	13.64	13.67	0.77	2.12	–0.07	0.87	179	13.95	13.84	1.05	2.45	1.29	–0.28
87	10.81	10.78	0.34	1.78	0.18	0.20	181	13.73	13.68	0.64	1.83	0.30	0.31
96	12.91	12.98	0.70	2.74	0.05	0.56	182	10.57	10.47	0.20	1.39	–0.14	0.32
98	11.45	11.40	0.54	1.88	0.28	0.27	184	12.67	12.63	1.02	2.13	–0.21	1.29
102	13.48	13.57	0.75	2.08	0.28	0.48	185	12.46	12.70	0.35	2.21	0.05	0.50
104	13.16	13.11	1.89	3.46	1.01	0.76	187	11.35	11.38	0.48	1.88	0.17	0.46
105	13.62	13.70	1.23	2.28	–0.20	0.97	191	13.28	13.32	0.63	1.95	0.23	0.33
107	12.63	12.64	0.40	2.10	0.05	0.39	192	11.74	11.53	1.19	2.07	–0.25	1.68
110	11.93	11.98	0.67	1.85	–0.15	0.82	199	12.78	12.77	0.70	1.93	0.43	0.33
115	13.16	13.19	0.72	1.91	–0.20	0.95	204	12.36	12.37	0.41	1.92	0.15	0.30
116	13.76	13.75	0.71	1.89	0.38	0.32	208	12.15	12.22	0.42	1.91	0.17	0.32
119*	12.76	13.50	1.04	2.73	0.20	0.82	209	12.04	12.08	0.32	2.17	0.05	0.38
120*	13.59	12.74	0.66	2.00	0.23	0.79	214	11.10	11.14	0.29	2.03	0.12	0.20
121	13.40	13.32	1.25	2.42	–0.19	1.58	216	12.25	12.33	0.68	1.96	0.43	0.23
123*	13.53	12.18	1.02	2.41	0.23	0.21	217	12.94	12.93	0.68	1.94	0.23	0.48
124	12.23	12.20	0.71	1.69	–0.21	0.93	219	11.96	11.90	1.62	2.46	–0.23	1.86
125	9.36	9.47	0.91	1.39	–0.30	1.17	221	12.36	12.42	0.60	2.15	0.02	0.62
126	12.18	12.22	0.78	1.86	–0.19	0.98	222	12.76	12.84	0.52	1.93	–0.10	0.55
130	12.10	12.07	0.89	1.88	–0.19	1.08							

The star numbers with "*" mean that the V magnitude of those stars have large difference between Joshi's and Vilnius'observations. U(vil) represents the Vilnius U passband.

3.2 Correlation Among Reddening, Spectral Type and Vilnius Photometric Colors

In order to obtain more information of the open cluster NGC 6913, Vilnius photometric data are used. Figures 2 and 3 present the relation among $E(B-V)$, $(B-V)_0$ and Vilnius photometric colors of the 24 most possible cluster members (MPCM) (Wang 1997). All of the stars have spectral type earlier than B7. We find that the values of $E(B-V)$ are well correlated with the colors of $X-Y$, $Y-Z$, $Z-V$ and $V-S$. Star #136 marked in the panels $(Y-Z)$ vs. $E(B-V)$ and $(V-S)$ vs. $E(B-V)$ has a large deviation, because its Joshi's V photometric magnitude is different from the Vilnius V photometric magnitude ($V_{\rm Joshi} = 13.53\,$mag, $V_{\rm Vilnius} = 12.20\,$mag). The other's V magnitude between the two photometric system is almost the same. By the way, the V photometric band in UBV system is nearly the same with Vilnius V band. There is no good correlation between $(B-V)_0$ and Vilnius' colors except for $(P-X)$. For stars with the same temperature but different luminosity , there are different values of Vilnius colors. However, for the color $P-X$ except for type I supergiants, the other type of stars have similar values (see Straizys' diagrams, 1992). So the color $P-X$ correlates well with $(B-V)_0$ in some range. The ratio among the Vilnius colors are calculated, we find that the ratio of $(V-S)/(Y-Z)$ of the MPCM is a constant (1.30 ± 0.06), and has no effect on the values of $E(B-V)$, $(B-V)_0$ and V_0. Figure 4 presents the three results, in which the values of $(V-S)/(Y-Z)$ are clearly well distributed along the line of $(V-S)/(Y-Z) = 1.30 \pm 0.06$.

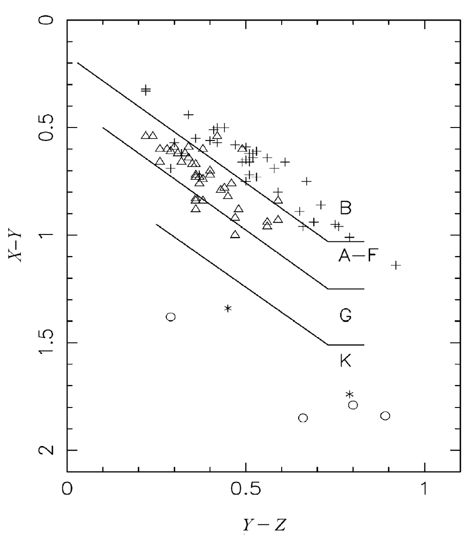

Fig. 1 The plot of $(Y-Z)$ versus $(X-Y)$. The stars with different spectral type are marked in different symbols ("plus" B type, "triangle" A-F type, "star" G type and "open circle" K type).

As a comparative sample, three sets of diagrams, similar to Figs. 2, 3 and 4 but for all the observed stars of NGC 6913 region, are shown in Figs. 5, 6 and 7 respectively. In Fig. 5, the correlation between $E(B-V)$ and $(Y-Z)$, $(Z-V)$ and $(V-S)$ has larger disperse than that in Fig. 2, especially for a few late type stars (e.g. #28(K2), 37(K0), 104(K0) and 168(G5)). It could be similarly explained as for #136 in Fig. 2. These stars could be variable stars.

As for Fig. 6, the appearance of all the panels is similar to that shown in Straizys' diagrams (Straizys 1992). As mentioned above, except for the color $P-X$, the values of the other Vilnius colors have effect on the stellar luminosity. So even though it is not linear between $(B-V)_0$ and $(P-X)$ in full range, it can still be separated into three ranges of $(B-V)_0$, each of them could be regarded as linearly correlated.

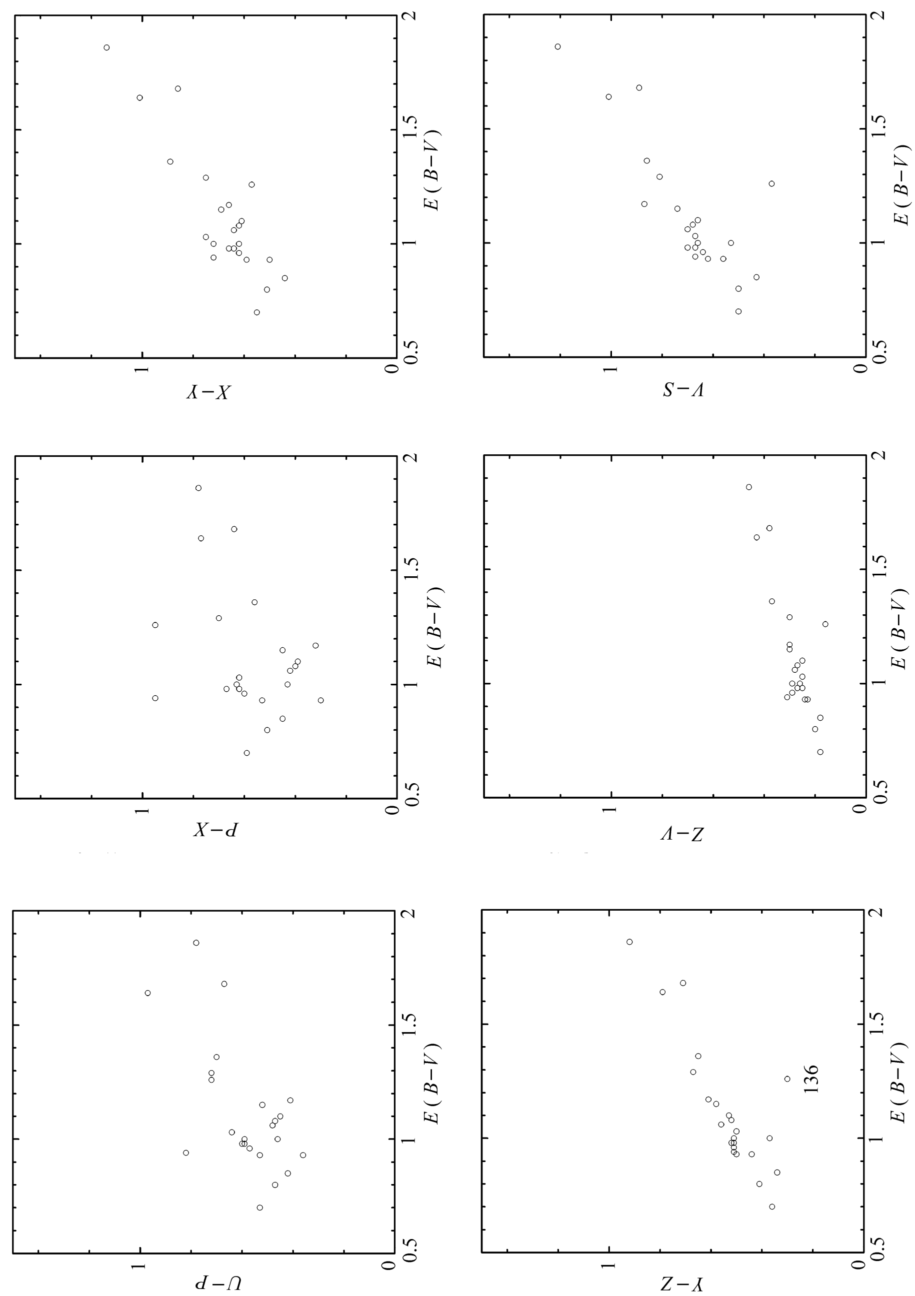

Fig. 2 The diagram of $E(B - V)$ versus Vilnius photometric colors of the 24 most possible cluster members.

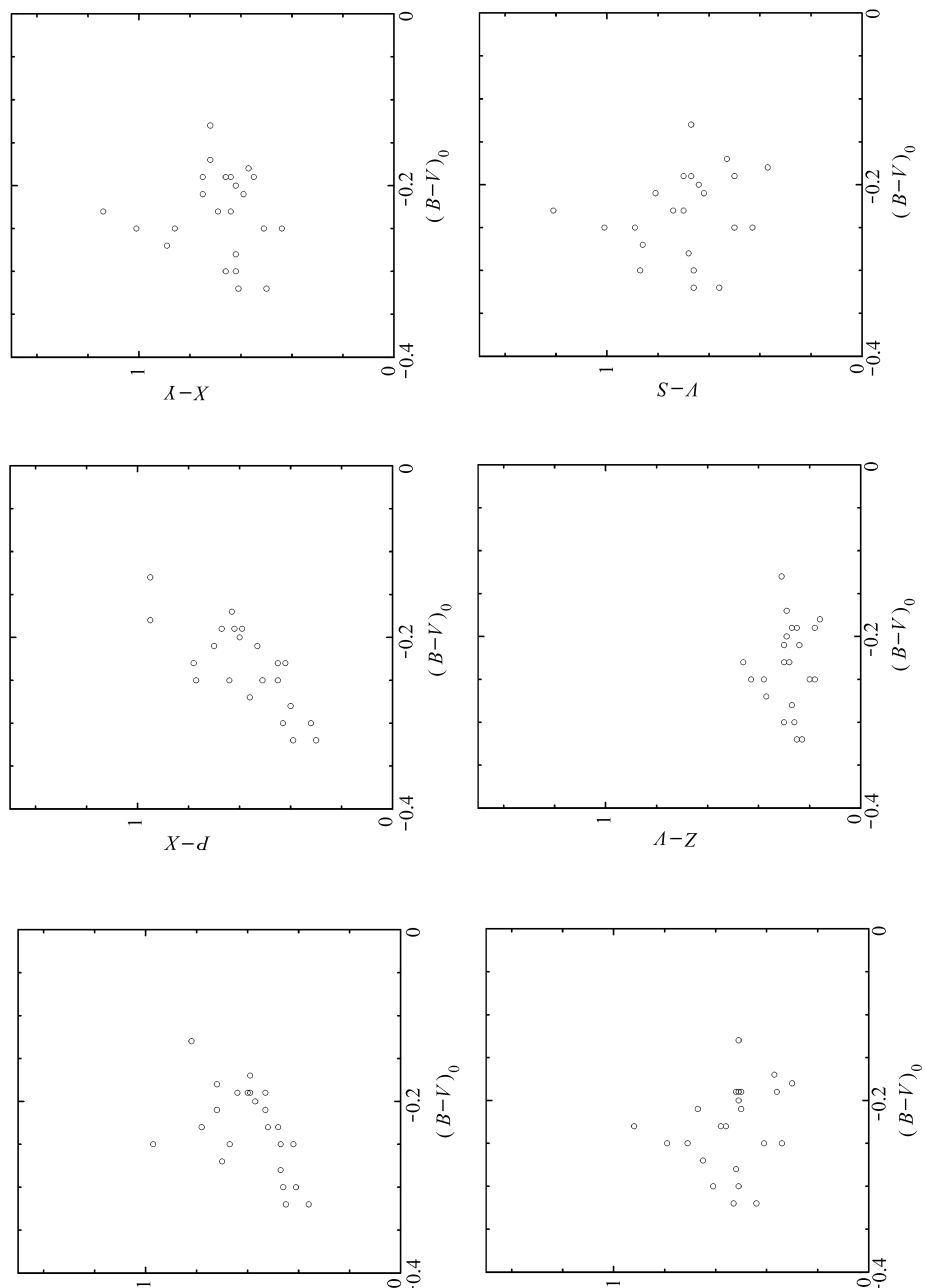

Fig. 3 The diagram of $(B-V)_0$ versus Vilnius photometric colors of the 24 most possible cluster members.

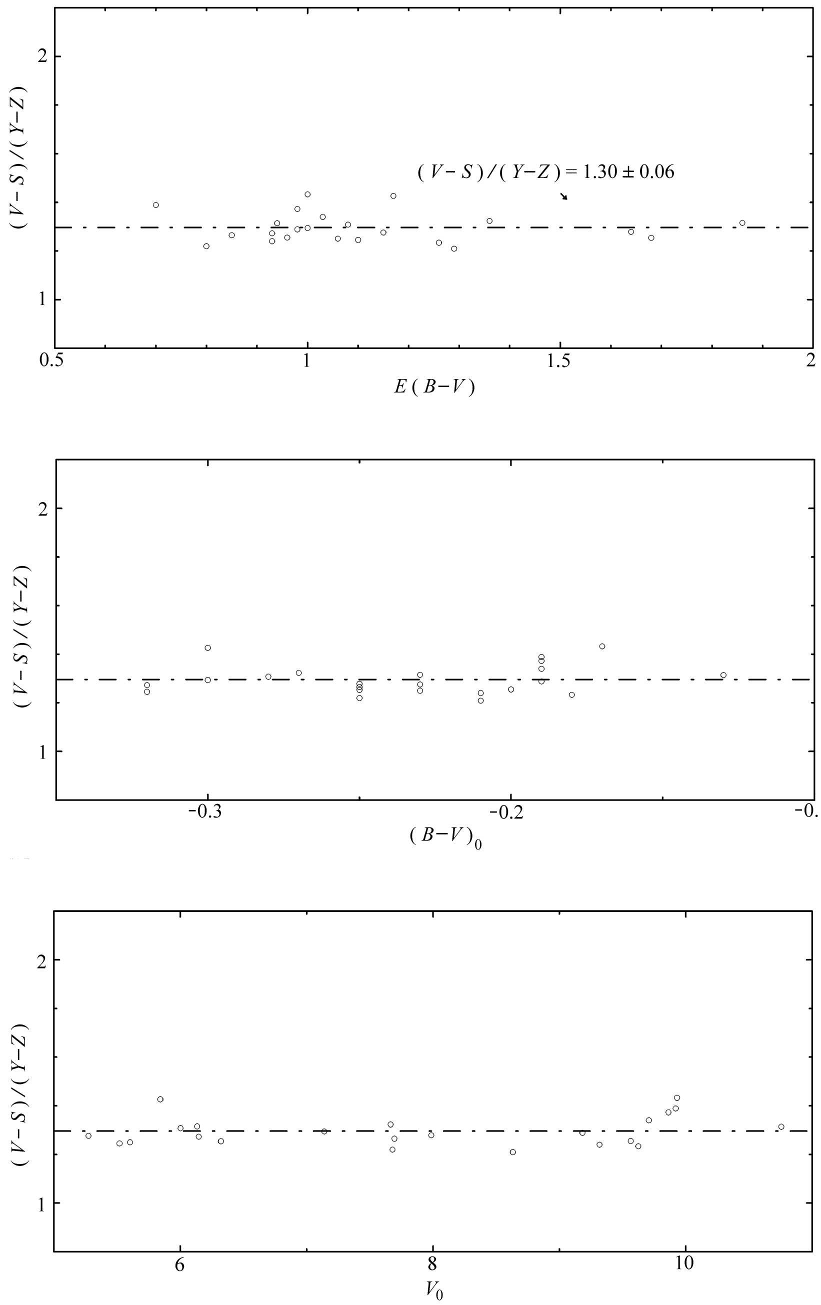

Fig. 4 The plot of $E(B-V)$, $(B-V)_0$ and V_0 versus $(V-S)/(Y-Z)$ (for MPCM), in which the values of $(V-S)/(Y-Z)$ are clearly well distributed along the line of $(V-S)/(Y-Z) = 1.30 \pm 0.06$.

By comparing Fig. 7 with Fig. 4, it is distinct that the disperse in Fig. 7 is much larger than that in Fig. 4. In the top panel of Fig. 7, the stars with the values of $E(B-V) > 1.0$ are well distributed along the line of $(V-S)/(Y-Z) = 1.30$, which are mainly MPCM. A similar

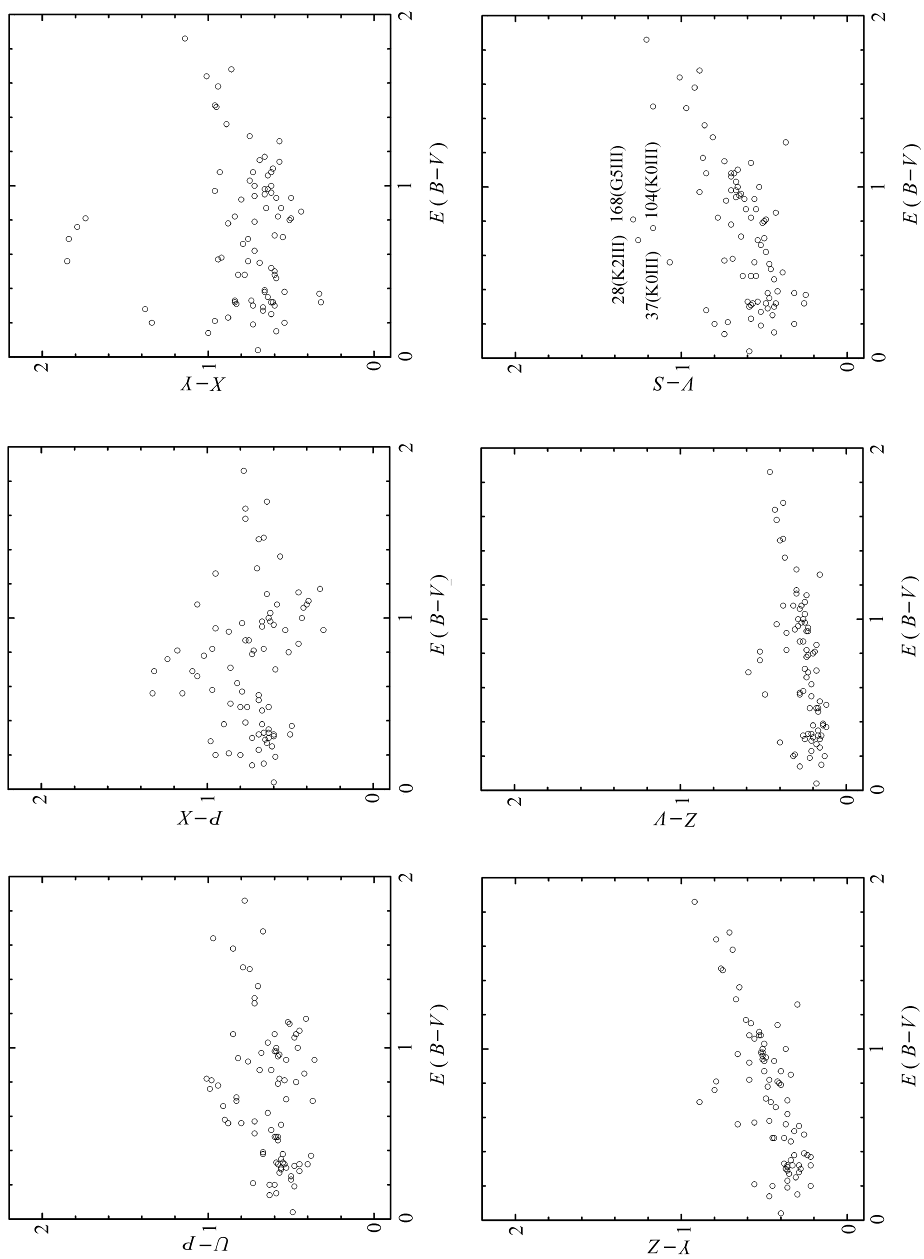

Fig. 5 The diagram of $E(B-V)$ versus Vilnius photometric colors for all the observed stars.

tendency appears in the bottom panel of Fig. 7. The most luminous stars, which are mainly MPCM, locate very close to the line of $(V-S)/(Y-Z) = 1.30$. And the distribution of stars in the middle panel of Fig. 7 appears to be in random, which could mean that the ratio of two Vilnius colors $(V-S)/(Y-Z)$ has no effect on the stellar temperature.

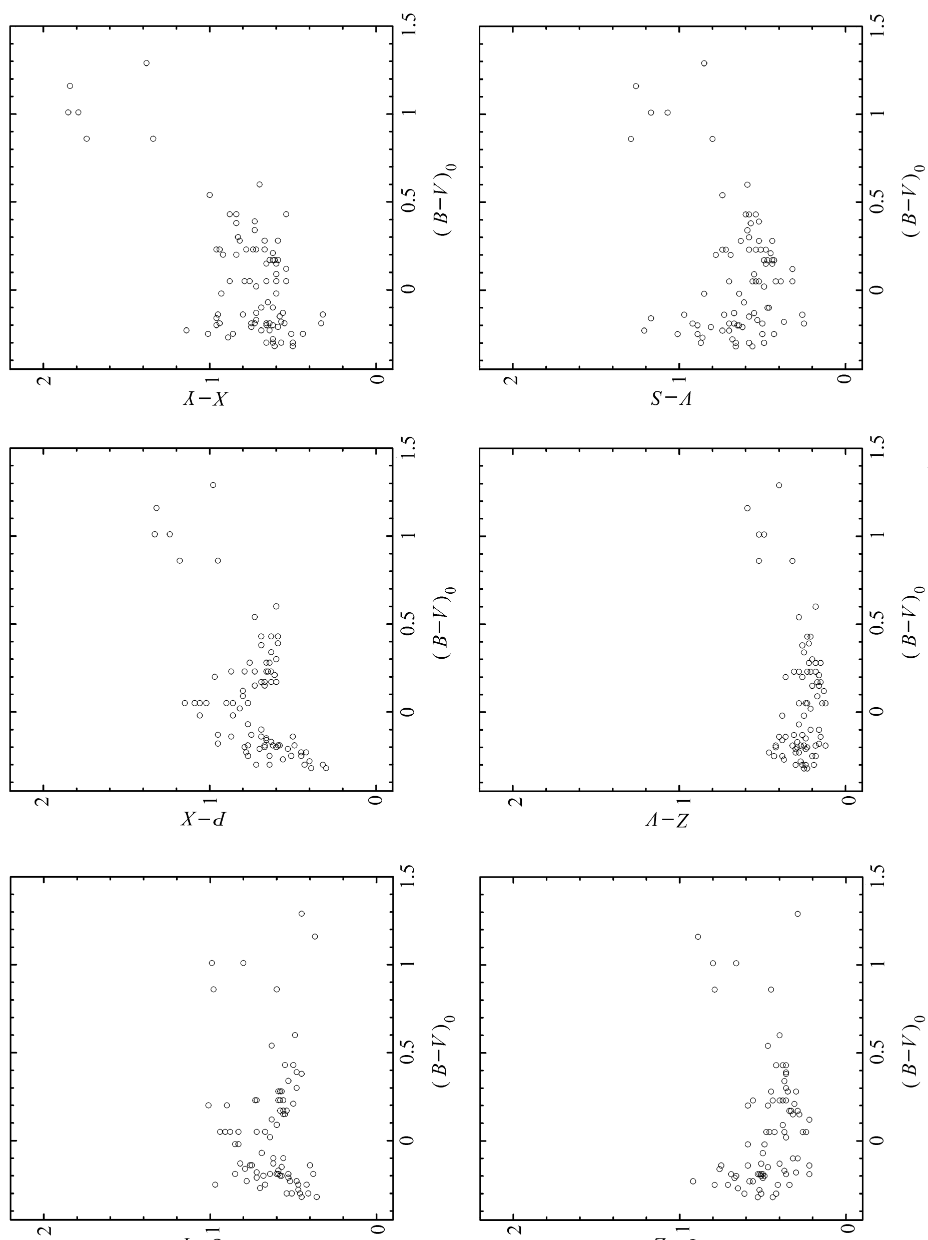

Fig. 6 The diagram of $(B-V)_0$ versus Vilnius photometric colors for all the observed stars.

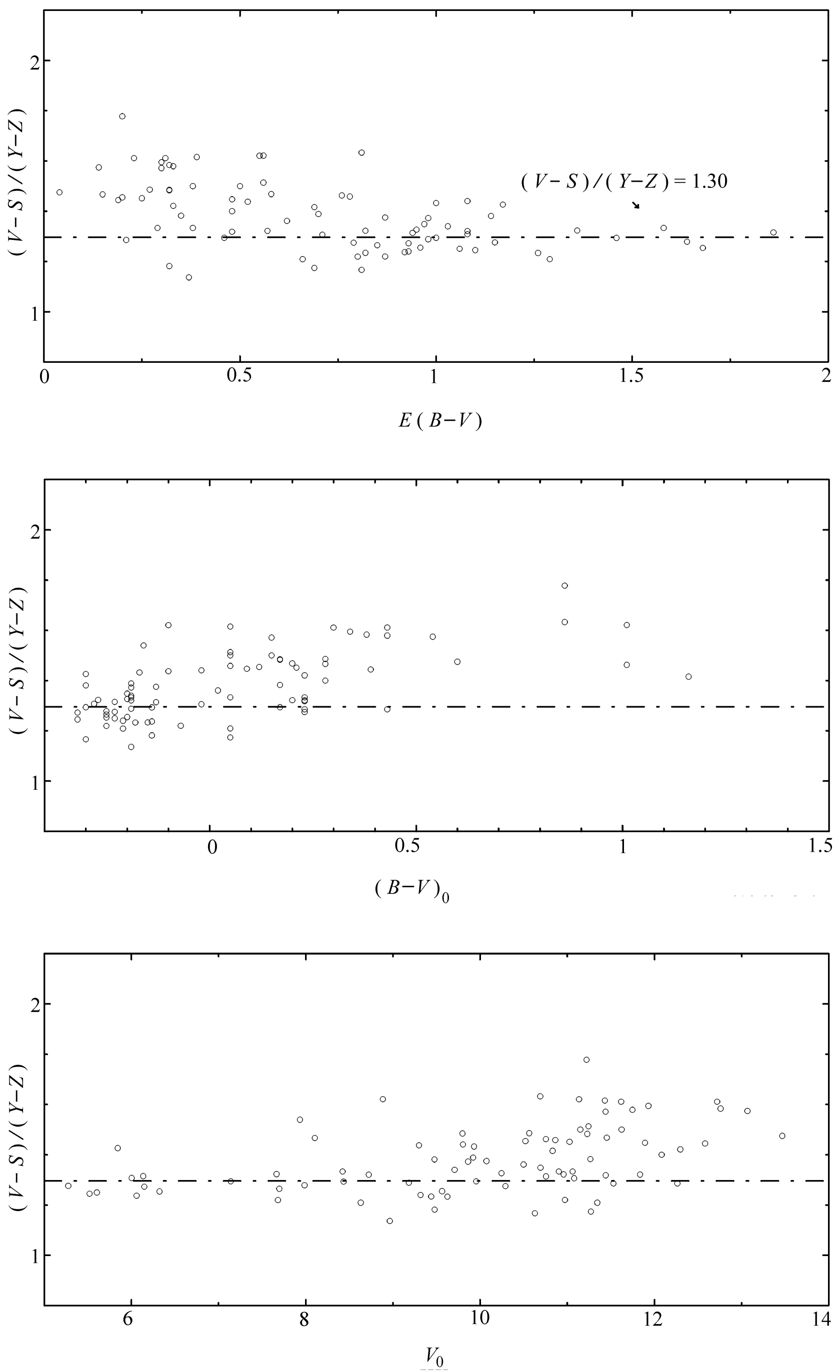

Fig. 7 The plot of $E(B-V)$, $(B-V)_0$ and V_0 versus $(V-S)/(Y-Z)$ (for all the observed stars).

In summary, the ratio of $(V-S)/(Y-Z)$ could reflect some common nature of one open cluster. Those real cluster members could have the same value of $(V-S)/(Y-Z)$, which could be varied with different cluster. In other words, the value of the ratio is constant for the stars in one open cluster, and could be different in the other clusters. This value can probably be used to select the preliminary candidates of an open cluster. Certainly, this must be examined in other open clusters in the future.

3.3 The Newly Discovered Variable Stars

Comparing with Joshi's photometry, we find that most of the stars (86%) in Vilnius V band photometry have nearly the same values (i.e., 75 stars: ≤ 0.1 mag, and 52 stars of them: ≤ 0.05 mag). 12 stars out of the total 87 stars have distinct variation (greater than 0.10 magnitude difference between two times of photometry). A few stars have more than 0.4 magnitude difference between two times of photometry in the V band, which are #40, 119, 120, 123, 136, 141 and 155, corresponding to Vilnius V magnitude 13.09, 12.76, 13.59, 13.53, 12.20 13.60 and 13.16 respectively. Most of them are A type stars, the other two are B type stars. Especially, there is a remarkable variation for the B type star #155, which varied from 8.91 mag. in Joshi's photometry to 13.16 mag. in Vilnius' photometry! If no identification mistake is made, it should be a very interesting variable star.

4 SUMMARY

We have selected 87 stars of NGC 6913 which have membership probability greater than 50% as our sample and discussed the correlation among Vilnius photometry, UBV photometry and reddening in the cluster. We find that the Vilnius X, Y and Z bands photometry can be used to make rough spectral classification. The values of $E(B-V)$ are well correlated with the Vilnius colors of $X-Y$, $Y-Z$, $Z-V$ and $V-S$ in NGC 6913. The ratio of $(V-S)/(Y-Z)$ of the MPCM is a constant (1.30 ± 0.06), and has no effect on the values of $E(B-V)$, $(B-V)_0$ and V_0. By comparing with the observation data of all the stars in NGC 6913 region observed by us, it is suggested indicated that the value of $(V-S)/(Y-Z)$ can probably be used to select the preliminary candidates of one open cluster. In addition, 12 variable stars are discovered in the NGC 6913 region, among which the star #155 has the variation of 4.25 magnitude. It is a very interesting star and worth observing further.

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