*Baltic Astronomy, vol. 5, 197–206, 1996.*

# UBVR AND UPXYZVS SEQUENCES OF STANDARD STARS FOR THE MEGA PROGRAM FIELDS ALONG THE MAIN MERIDIAN OF THE GALAXY

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Received September 29, 1995.

**Abstract.** Within the framework of the MEGA program devoted to the study of the main meridional section of the Galaxy, photoelectric observations have been made in the Johnson *UBVR* and Vilnius *UPXYZVS* systems to obtain photometric sequences of standard stars in a number of proper motion fields, each of 1.4 square degree size, located approximately along the main galactic meridian.

The catalog of our *UBVR* observations includes a total of 1141 stars which provide sequences for 47 MEGA fields and for a few of other fields. Each of the sequences contains 15 to 28 stars almost uniformly distributed in the *V* magnitude range from 4.5 to 15.5 mag. The external rms errors of the observations are $\pm 0.014$ for the magnitude *V* and $\pm 0.026$, $\pm 0.012$ and $\pm 0.016$ for the color indices *U–B*, *B–V* and *V–R*, respectively. These standards will be used for the reduction of photographic magnitudes.

In the medium-band Vilnius system, the photoelectric sequences have been established for six MEGA fields near the galactic poles, each of which consists of about 50 standards in the magnitude range $8.5 < V < 13.5$ mag. The errors of the *UPXYZVS* magnitudes and color indices range from $\pm 0.008$ to $\pm 0.020$ mag, depending on the brightness of a star.

The possibility of making use of these standard sequences for CCD observations is discussed.

**Key words:** methods: observational – techniques: photometric (*UBVR* system, Vilnius system)

## 1. INTRODUCTION

In 1985 a group of astronomers of Kiev and Tartu observatories initiated a project of studying the main meridional section of the Galaxy (Einasto et al. 1985), which developed afterwards into the program called MEGA. This program concentrates on investigation of kinematic and physical properties of stellar populations by combining astrometric, photometric and spectral observations of stars in 64 selected fields located approximately along the main galactic meridian (for a more detailed description of the program, see Andruk et al. 1992, or the paper by Kharchenko & Schilbach 1996 in these proceedings).

The most extensive observational basis of the MEGA program is that composed of the absolute proper motions of stars measured in all of the program fields with respect to galaxies (Kharchenko 1983, Schilbach 1988). However, despite the very large amount of these astrometric data, there are only a few fields with deep photographic photometry on the Johnson $B, V$ system (Kharchenko et al. 1994) and no fields with CCD-based photometry, broadband or otherwise.

As a first step in an effort to improve this situation, we have established photoelectric sequences for most of the MEGA fields on the *UBVR* system and for six fields near the galactic poles on the Vilnius *UPXYZVS* system. The use of these sequences will be twofold: (a) for the reduction of photographic stellar magnitudes and (b) for future CCD observations.

The distribution of the MEGA fields containing the *UBVR* and Vilnius standards is shown in Fig. 1. For better visual perspective, we displayed the fields on the plane of the galactomeridional spherical coordinates $(\lambda, \theta)$, where the main galactic meridian is stretched out on the $\lambda$-axis with the starting point chosen at the galactic center and pointing the direction of increasing right ascension. Accordingly, the south and north galactic poles are located at the $(\lambda, \theta)$-coordinates $(90°, 0°)$ and $(270°, 0°)$, respectively. The fields are of $\sim 1.4$ square degree each and are distributed within 30° of the main meridional plane, with half of them being confined to within 10° of the meridian. There are more fields north of the galactic plane than south of it. The equatorial (1950), galactic $(l, b)$ and galactomeridional $(\lambda, \theta)$ coordinates of the field centers are given in Table 1, together with the numbers of standard stars observed on either the *UBVR* or Vilnius systems.

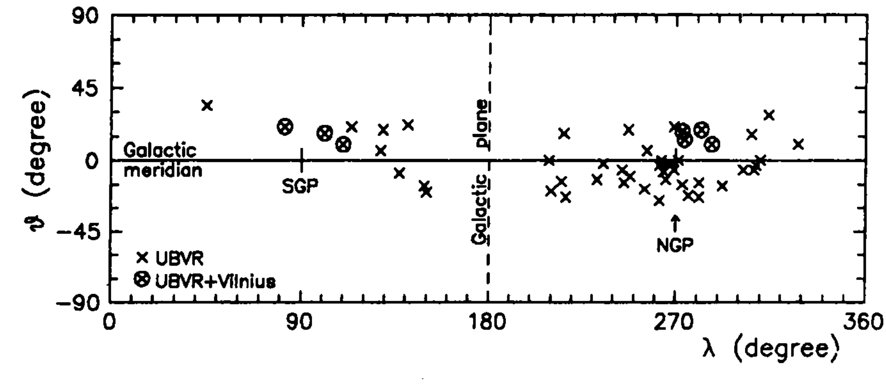


**Fig. 1.** Distribution of the MEGA fields along the main galactic meridian. The crosses denote fields with the *UBVR* sequences, and the circled crosses are fields with both the *UBVR* and *UPXYZVS* sequences.

## 2. UBVR OBSERVATIONS

Photoelectric *UBVR* observations of the MEGA fields were made in 1987–1991 (by V.A. and N.K.) from three observatories. Most of these observations, or more than 6100 measurements, were obtained with the 60 cm telescope at the Terskol Mountain Station (3100 m altitude) of the Ukrainian Academy of Sciences, situated in the North Caucasus. The remaining 1540 measurements of stars were performed with the 48 cm telescope of the Kiev University in Lesniki near Kiev and with the 60 cm telescope of the Kazan University in Zelenchuk (2300 m altitude), the North Caucasus. All observing runs included 105 nights, during which a total of 1141 stars within the $V$ magnitude interval 4.5 to 15.5 were measured in 47 MEGA fields, 4 fields near the North Galactic Pole and 10 fields in open clusters far outside the galactic meridian.

For the transformation of observations to the standard *UBVR* system, more than 300 standard stars were observed in SA 71 and SA 107, in the fields of several open clusters (Pleiades, Hyades, Praesepe, Coma Berenices, NGC 6633, NGC 2169 and $\chi$ Per) and the association Lac OB1 and also in vicinities of the MEGA fields. The magnitudes and colors for these standards were taken from the catalogs of Mendoza (1967), Blanco et al. (1968), Johnson et al. (1966) and Kazanasmas et al. (1981).

**Table 1.** The MEGA program fields with the photoelectric sequences

| Field | $\alpha$(1950) h m | $\delta$(1950) ° ′ | $l$ | $b$ | $\lambda$ | $\theta$ | $N_{st}$ | $N_{st}$ |
|---|---|---|---|---|---|---|---|---|
| | | | in degrees | | in degrees | | *UBVR* | Vilnius |
| 159 | 00 49.3 | −07 24 | 123 | −70 | 101 | +17 | 18 | 35 |
| 10 | 01 17.0 | +03 02 | 137 | −59 | 114 | +21 | 22 | |
| 161 | 01 34.3 | −07 42 | 154 | −68 | 110 | +10 | 21 | 55 |
| 17 | 02 05.6 | +10 46 | 152 | −48 | 129 | +19 | 18 | |
| 21 | 02 29.8 | +20 45 | 153 | −36 | 141 | +22 | 19 | |
| 23 | 02 38.9 | +00 20 | 171 | −52 | 128 | +6 | 17 | |
| 28 | 03 41.6 | −04 26 | 192 | −43 | 137 | −8 | 22 | |
| 30 | 04 39.2 | −02 14 | 99 | −30 | 149 | −16 | 22 | |
| 31 | 04 54.3 | −04 51 | 204 | −28 | 150 | −20 | 20 | |
| 39 | 07 55.5 | +40 07 | 180 | +29 | 209 | 0 | 20 | |
| 43 | 08 14.3 | +21 25 | 202 | +28 | 210 | −19 | 16 | |
| 42 | 08 15.9 | +57 58 | 160 | +34 | 216 | +17 | 21 | |
| 44 | 08 32.9 | +28 53 | 195 | +34 | 215 | −13 | 18 | |
| 46 | 08 46.2 | +19 14 | 207 | +34 | 217 | −23 | 17 | |
| 61 | 09 49.2 | +29 30 | 199 | +51 | 232 | −12 | 17 | |
| 64 | 10 09.9 | +39 01 | 183 | +55 | 235 | −2 | 18 | |
| 70 | 10 42.0 | +25 20 | 210 | +62 | 245 | −14 | 19 | |
| 74 | 10 49.3 | +33 19 | 193 | +64 | 244 | −6 | 15 | |
| 75 | 11 00.0 | +28 37 | 204 | +66 | 248 | −10 | 16 | |
| 77 | 11 14.7 | +18 30 | 230 | +67 | 255 | −18 | 20 | |
| 81 | 11 27.9 | +09 42 | 252 | +64 | 262 | −25 | 17 | |
| 84 | 11 52.7 | +55 59 | 139 | +60 | 247 | +19 | 17 | |
| 87 | 12 01.2 | +20 35 | 242 | +77 | 265 | −12 | 17 | |
| 89 | 12 07.5 | +39 54 | 155 | +75 | 256 | +6 | 17 | |
| NGP 4 | 12 09.0 | +29 00 | 200 | +81 | 262 | −3 | 11 | |
| NGP 3 | 12 12.6 | +24 00 | 233 | +81 | 264 | −7 | 15 | |
| 92 | 12 18.2 | +29 49 | 192 | +83 | 263 | −2 | 23 | |
| 94 | 12 18.7 | +05 46 | 283 | +67 | 276 | −22 | 21 | |
| 95 | 12 23.1 | +31 31 | 175 | +84 | 263 | 0 | 23 | |
| 96 | 12 24.7 | +13 17 | 280 | +75 | 273 | −15 | 28 | |
| NGP 2 | 12 29.4 | +27 18 | 213 | +86 | 267 | −2 | 18 | |
| 98 | 12 30.5 | +26 15 | 228 | +86 | 267 | −3 | 19 | |
| 99 | 12 33.6 | +02 15 | 294 | +65 | 281 | −23 | 23 | |
| NGP 1 | 12 34.2 | +23 20 | 263 | +85 | 269 | −5 | 23 | |
| 100 | 12 40.5 | +12 04 | 295 | +75 | 281 | −14 | 21 | |
| 102 | 12 48.7 | +26 18 | 299 | +89 | 271 | 0 | 19 | |
| 108 | 13 24.0 | +02 27 | 323 | +64 | 292 | −16 | 17 | |
| 110 | 13 30.0 | +47 30 | 104 | +68 | 269 | +21 | 15 | |
| 112 | 13 40.0 | +35 22 | 76 | +76 | 274 | +13 | 24 | 75 |
| 113 | 13 52.6 | +41 00 | 83 | +71 | 273 | +18 | 21 | 49 |
| 118 | 14 16.2 | +25 20 | 32 | +70 | 287 | +10 | 20 | |
| 119 | 14 18.8 | +36 53 | 65 | +69 | 282 | +19 | 17 | 53 |
| 120 | 14 17.2 | +03 58 | 349 | +59 | 302 | −6 | 23 | |

Table 1 (continued)

| Field | $\alpha(1950)$ h m | $\delta(1950)$ ° ′ | $l$ in degrees | $b$ | $\lambda$ in degrees | $\theta$ | $N_{st}$ *UBVR* | $N_{st}$ Vilnius |
|---|---|---|---|---|---|---|---|---|
| 121 | 14 36.9 | −00 02 | 351 | +52 | 307 | −6 | 17 | |
| 123 | 14 42.4 | +02 08 | 355 | +53 | 308 | −3 | 12 | |
| 124 | 14 59.0 | +01 49 | 359 | +50 | 310 | 0 | 24 | |
| 127 | 15 33.4 | +17 04 | 27 | +49 | 306 | +16 | 16 | |
| 130 | 16 19.0 | −01 34 | 12 | +32 | 328 | +10 | 17 | |
| 131 | 16 30.1 | +20 07 | 37 | +39 | 314 | +28 | 23 | |
| 201 | 21 17.0 | −09 00 | 43 | −37 | 45 | +34 | 28 | |
| 205 | 23 36.5 | −12 51 | 70 | −68 | 82 | +21 | 28 | 46 |

We made, on the average, 19 observations per each standard star and four observations per program star. The observations were corrected for the atmospheric extinction and transformed to the standard *UBVR* system by the procedure described in detail by Andruk & Kharchenko (1996). The accuracy of the measurements varies with both the brightness and color of the stars. For stars brighter than $V$=13, the uncertainties remain below ± 0.02 mag, except for the $U$–$B$ index, the error of which is close to ± 0.03 mag. The catalog extends to $V$=15.5, and magnitude and error uncertainties appear to increase significantly dimward of the 13th magnitude, but this effect was entirely consistent with the photon statistics of the observations. The overall external error estimated by means of comparison of our *UBVR* data with those published in the literature (∼ 300 stars in common) are ± 0.014, ± 0.026, ± 0.012, and ± 0.016 for $V$, $U$–$B$, $B$–$V$ and $V$–$R$, respectively.

Table 1 gives the basic information on the MEGA fields observed in the *UBVR* system. For each field we list the name of the field according to the catalogs by Deutsch et al. (1955) and Fatchikhin & Latypov (1959), the equatorial (1950), galactic ($l, b$) and galactomeridional ($\lambda, \theta$) coordinates and the number of standard stars observed. Also given in the table are four fields near the North Galactic Pole (denoted by NGP), not yet included in the MEGA program, but for which our *UBVR* observations were also made. The number of stars measured per field range from 15 to 28, with an average number near 20. In an effort to use these observations for the establishing the photometric sequences, stars in each of the fields were purposively chosen to cover a wide range in $V$ and to lie

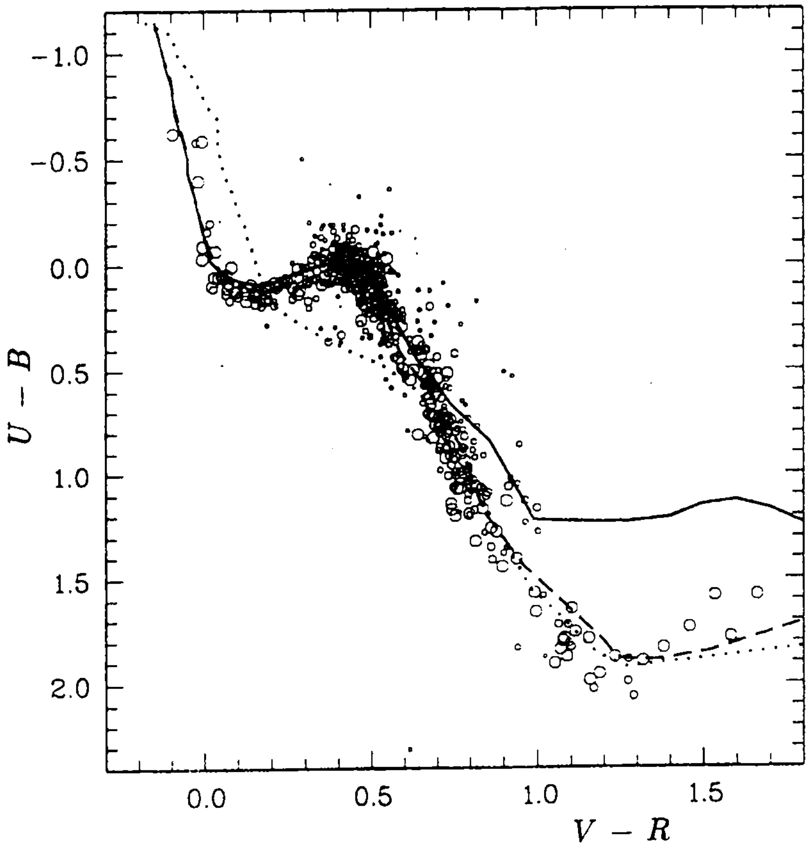


**Fig. 2.** *U–B*, *V–R* diagram for the *UBVR* standard stars in the MEGA fields. The size of the symbols is shown in proportion to the brightness of a star. The main sequence (solid line), giant (dashed line) and supergiant (dotted line) relationships for normal chemical composition stars are taken from Straižys (1977).

compactly in the field (possibly within the field of view of a CCD camera). The entire catalog of the *UBVR* sequences, together with finding charts, may be found in the paper by Andruk et al. (1995).

Fig. 2 shows a *U–B* versus *V–R* two-color diagram for the *UBVR* standard stars. The features of the main sequence and giant sequence are well defined, though there is evidence for a color spread due to significant ultraviolet excesses of a few of the stars.

## 3. OBSERVATIONS IN THE VILNIUS SYSTEM

In the case of Vilnius photometry, the first priority was given to the MEGA fields located at high galactic latitudes. As a result, all stars brighter than $V$=13 and a number of fainter stars down to $V$=14 were measured in three fields near the North Galactic Pole (Nos. 112, 113 and 119) and in three fields near the South Galactic Pole (Nos. 159, 161 and 205).

The observations were obtained at the Maidanak Observatory (2600 m altitude) in Uzbekistan, Central Asia, during seven observing runs in 1983–1995 (by S.B.). The 1 m reflector of the Institute of Theoretical Physics and Astronomy (Vilnius, Lithuania) was used, equipped with a single-channel photometer with a multi-alkali photomultiplier and a standard set of the *UPXYZVS* filters.

As standards, we used the Cygnus Standard Region (CSR) and the North Celestial Pole Region stars from the lists of Zdanavičius & Černienė (1985) and Černis et al. (1989), respectively. Some of the program stars, measured with high precision in preceding observing runs, were treated as the fainter standards in the reductions of the magnitude $V$. The observational routine and data reduction followed normal procedures described in detail by Bartašiūtė (1994, 1996).

Many of the stars were repeatedly observed on several observing runs. Since no systematic differences appeared to be present between these runs of observations, the data on all 554 photoelectrically observed stars have been combined and included in the final catalog of observations (Bartašiūtė 1994, 1996) from which refined samples of stars have been isolated to form photoelectric sequences in each of the fields observed. We have admitted to these samples the stars with two or more observations. Also, we were careful to exclude from our refined samples the stars measured with lower accuracy. The established *UPXYZVS* sequences contain about 50 stars each (see the final column of Table 1) and extend from $V$=8.5 to 13.5. Each standard star was observed, on the average, three times, mostly in three different observing runs.

Standard errors in $V$ and color indices of the standard stars were estimated from repeated observations. For $V$, the typical uncertainty remains below $\pm\,0.015$ mag over the entire range of magnitudes, with a slight increase for the faintest stars due to photon statistics. For color indices, the standard errors show the same pattern, ranging typically from $\pm\,0.008$ mag at $V \approx 10$ to $\pm\,0.020$ mag at the faint end.

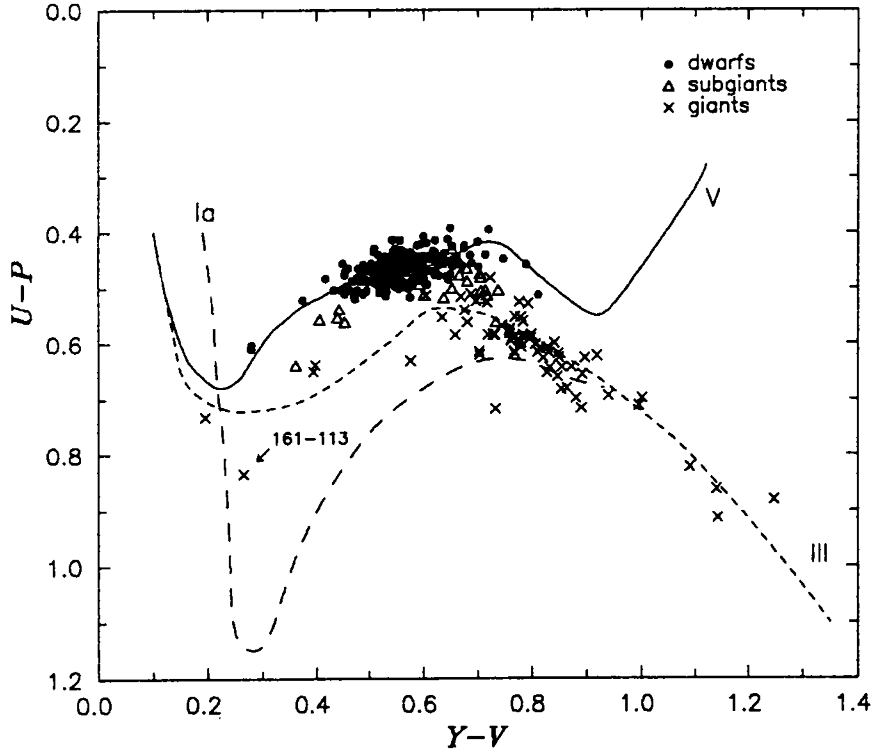


**Fig. 3.** *U–P*, *Y–V* diagram for the *UPXYZVS* standard stars in six MEGA fields near the galactic poles. The main sequence (solid line), giant (short-dashed line) and supergiant (long-dashed line) relationships for normal chemical composition stars are taken from Straižys et al. (1982). The star 116-113 is a probable blue horizontal branch star.

The lists of the *UPXYZVS* sequences and finding charts are not reproduced here in order to conserve space. The latter may be found in Bartašiūtė (1994, 1996).

In Fig. 3, we present the *U–P*, *Y–V* two-color diagram for the sample of standards in the Vilnius system. The stars have been assigned to dwarfs and giants by means of the three-dimensional photometric classification. Among the 313 standards plotted on the diagram, subdwarfs and metal-deficient giants ([Fe/H]<–0.5) constitute a fraction of ~20%. The star labelled by 116-113 in the field 161 near the South Galactic Pole has been classified as a probable blue horizontal branch star.

## 4. SUMMARY AND FUTURE WORK

We have established photoelectric sequences in the Johnson *UBVR* system for 47 MEGA fields and four NGP fields along the main galactic meridian, as well as photoelectric sequences in the Vilnius system for six MEGA fields near the galactic poles. Each of the *UBVR* sequences consists, on the average, of 20 standards in the magnitude range of $V$=4.5 to 15.5. In the case of the Vilnius photometry, the sequences span the magnitude range 8.5<$V$<13.5 and contain around 50 standards each.

These data will serve as an impetus for further study, including attempts to obtain deeper photometry in the MEGA fields. As a first step, this unusually large set of *UBVR* sequences will be used to calibrate the photographic data. Furthermore, our sequences can be used as standards for CCD photometry, as in each of the fields up to ten stars of 10 to 13 mag could be chosen to fall within the field of a CCD camera.

It should be emphasized that CCD photometry in the Vilnius system would be a very promising tool, especially if one is looking for determining the fundamental properties of the whole range of stellar populations in the Galaxy. Boyle et al. (1996), applying CCD Vilnius photometry to several fields in open clusters and dark clouds, have shown that the precision required by the Vilnius system is readily attainable down to $V$=17 with a 1 meter telescope. If applied to the MEGA fields, the CCD photometry would allow to reach three magnitudes below those achieved in our photoelectric survey (Bartašiūtė 1994, 1996) using a telescope of the same aperture. Therefore, any attempts to obtain CCD photometry in the MEGA fields should be appreciated.

Astronomers interested in the use of the sequences of the photoelectric standards presented here, may request copies of our data files by contacting us.

ACKNOWLEDGMENT. S.B. gratefully acknowledges travel support from the Lithuanian State Science and Studies Foundation under grant No. 95-191/2A.

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