THE HIPPARCOS CALIBRATION OF ABSOLUTE MAGNITUDES IN THE VILNIUS PHOTOMETRIC SYSTEM

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ABSTRACT

Proposal No. 133 for the Hipparcos program contains a sample of 111 apparently bright stars of spectral classes F–G–K, different luminosity classes and metallicities. Stars of solar chemical composition, supplemented by stars with reliable ground-base parallaxes, Hyades cluster stars, etc. are used for the calibration of photometric criteria for two-dimensional classification of stars in the Vilnius photometric system in terms of M_V. New calibration provides a significant accuracy improvement in comparison to earlier calibrations.

Key words: multicolor photometry; photometric classification; absolute magnitudes.

1. INTRODUCTION

The seven-color photometric system, developed at the Vilnius Observatory, is being used already three decades for the photometric classification of stars. The system classifies stars of all MK types in spectral classes and absolute magnitudes in the presence of interstellar reddening. Also, it makes possible to identify photometrically the stars with different peculiarities in their spectra: emission-line stars (Be, Herbig Ae/Be, T Tauri-type, WR, etc.), chemically peculiar stars of A and B spectral types (Am, Ap, helium-rich, horizontal-branch stars), metal-deficient stars (subdwarfs, metal-deficient giants and subgiants), carbon-rich stars (carbon R and N stars, CH stars, barium stars), white dwarfs, many types of unresolved binaries. No other system currently in use, can do this type of job. The most recent description of the Vilnius photometric system is given by one of the authors (Straižys 1992a). The response functions of the system are shown in Figure 1.

A possibility to classify stars of all spectral types in the presence of interstellar reddening is especially important in photometric surveys, making possible the classification in three or more dimensions (temperature, luminosity, metallicity, peculiarity) of stars as faint as 20 mag with a 4 meter class telescope and a CCD camera (Straižys 1992b).

However, for a successful application of the Vilnius system for classification of stars, a careful its calibration in terms of temperatures and absolute magnitudes is essential. The Hipparcos parallaxes give a possibility to calibrate the classification parameters of the Vilnius system in absolute magnitudes.

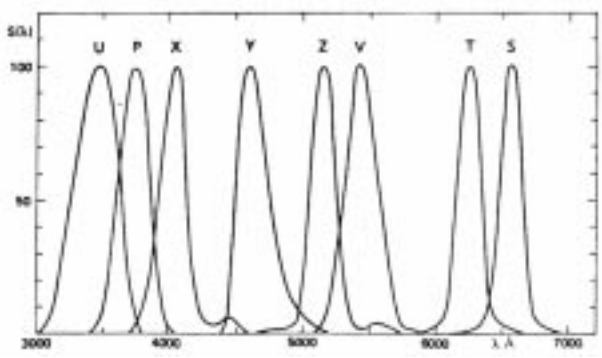

Figure 1. Response functions of the Vilnius photometric system.

Our proposal for the Hipparcos program contained a sample of 111 apparently bright stars of spectral classes F–G–K, different luminosities and metallicities and well studied by various astrophysical methods. These stars have been used by us as standards for three-dimensional quantitative spectral and photometric classification. The proposal has been made with the intention to use the Hipparcos trigonometric parallaxes for improving the calibration of our classification criteria in terms of absolute magnitudes.

2. A LIST OF THE STANDARD STARS

From the Hipparcos list we have selected 37 stars of spectral classes F5–K5 and luminosities V–II. This list was supplemented by:

(1) 21 G–K stars with the ground-based parallaxes $\pi > 0.04$ arcsec collected from the latest edition of the General Catalogue of Trigonometric Stellar Parallaxes (van Altena et al. 1995);

(2) 80 F5–K Hyades cluster stars calculating their

absolute magnitudes from the distance modulus $V - M_V = 3.30$ mag;

(3) 49 F5–K3 supergiants taking their absolute magnitudes from the MK versus M_V tabulation of Straižys & Kurilienė (1981).

The final list of standard stars for the calibration is given in Table 1. The table contains the absolute magnitudes and four interstellar reddening-free photometric parameters of the Vilnius system:

$$Q_{UPY} = (U - P) - (E_{U-P}/E_{P-Y})(P - Y), \quad (1)$$

$$Q_{XYZ} = (X - Y) - (E_{X-Y}/E_{Y-Z})(Y - Z), \quad (2)$$

$$Q_{XYV} = (X - Y) - (E_{X-Y}/E_{Y-V})(Y - V), \quad (3)$$

$$Q_{XZS} = (X - Z) - (E_{X-Z}/E_{Z-S})(Z - S) \quad (4)$$

where U,P,X,Y,Z,V and S are the Vilnius magnitudes at 345, 374, 405, 466, 516, 544 and 656 nm and E/E are color excess ratios corresponding to various color indices. Color indices of the stars are taken from the General Photometric Catalogue of Stars Observed in the Vilnius System (Straižys & Kazlauskas (1993)). These Q-parameters form the diagrams Q_{UPY}, Q_{XYV}, Q_{UPY}, Q_{XZS} and Q_{XZS}, Q_{XYZ} which are the best for two-dimensional classification of F–G–K stars. Two of these diagrams with the preliminary calibration in spectral classes and absolute magnitudes are shown in Figures 2 and 3 (Straižys 1992a). Both these diagrams give the highest separation of luminosity sequences among all known photometric diagrams. This is due to very successful position of the Z passband which is centered on the broad and deep absorption feature at 516 nm which contains the Mg I triplet lines and the MgH molecular bands. This absorption feature in G–K–M type stars is especially sensitive to luminosity: it becomes deeper with decreasing luminosity.

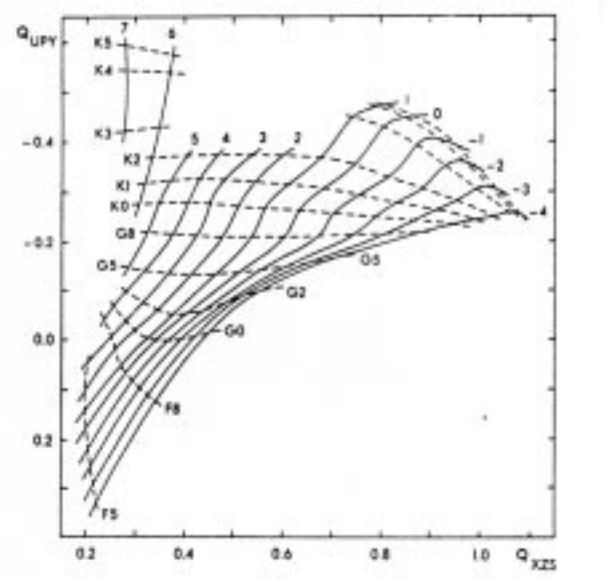

Figure 2. The reddening-free diagram Q_{UPY}, Q_{XZS} for two-dimensional classification of G–K stars in the Vilnius system with a preliminary calibration in terms of spectral classes and absolute magnitudes.

3. THE CALIBRATION

We have made the solution of the third order polynomials relating the absolute magnitudes with four Qs in different combinations and including or excluding luminosity III, II and I stars (giants and supergiants).

The best solutions including the luminosity V and IV stars only ($3.0 < M_V < 8.0$) are following:

$$\begin{aligned} M_V &= 0.6346 + 16.731Q_{XYZ} - 13.957Q^2_{XYZ} + \\ &\quad +4.401Q^3_{XYZ} - 11.078Q_{XZS} + \\ &\quad +30.773Q^2_{XZS} - 26.991Q^3_{XZS}, \end{aligned} \quad (5)$$

$$\begin{aligned} M_V &= 4.035 - 12.307Q_{UPY} - 9.301Q^2_{UPY} - \\ &\quad -0.956Q^3_{UPY} + 1.142Q_{XZS} - \\ &\quad -37.287Q^2_{XZS} + 71.240Q^3_{XZS}, \end{aligned} \quad (6)$$

These equations predict the absolute magnitudes within the standard deviation $\sigma = 0.277$ mag and 0.315 mag, respectively. Figures 4 and 5 show graphically the relation between the original and the calculated absolute magnitudes. Here we observe one of the best photometric predictions of absolute magnitudes among all photometric systems currently in use. Remember that this prediction does not depend on interstellar reddening! The Hipparcos field dwarfs and subgiants, the Hyades dwarfs and the field dwarfs with the surface-born parallaxes do not show any systematic effects.

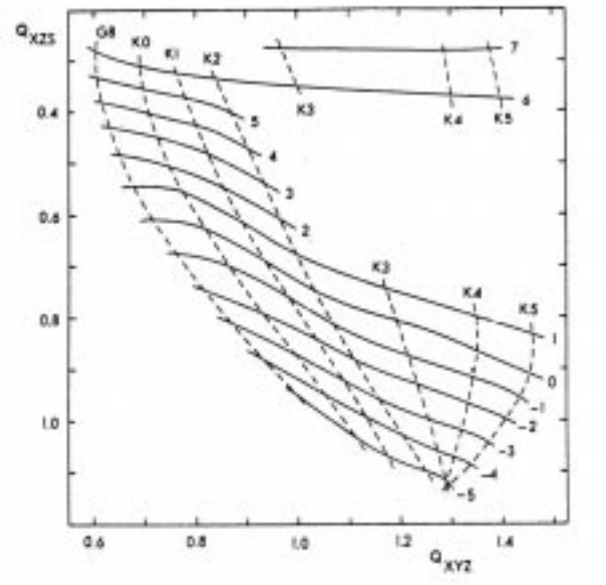

Figure 3. The reddening-free diagram Q_{XZS}, Q_{XYZ} for two-dimensional classification of G–K stars in the Vilnius system with a preliminary calibration in terms of spectral classes and absolute magnitudes.

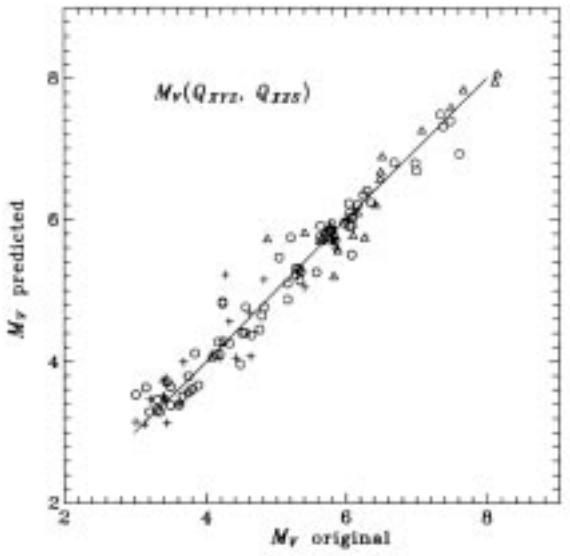

Figure 4. A comparison of the original and predicted absolute magnitudes determined by Equation (5). Crosses are the Hipparcos F5–K5 dwarfs and subgiants, circles are the Hyades dwarfs and triangles are the field K dwarfs with the ground based parallaxes.

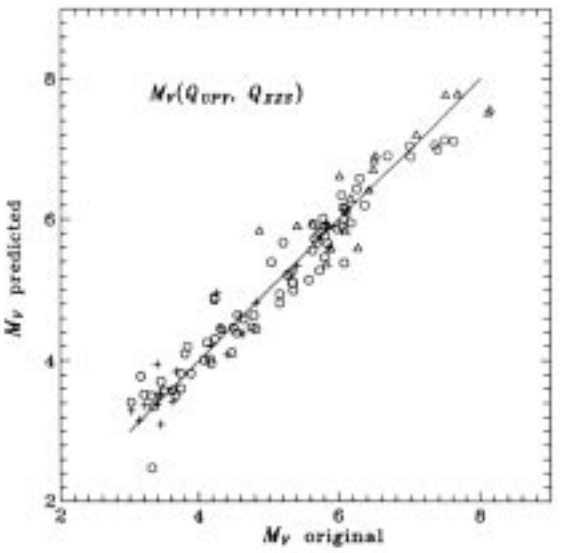

Figure 5. A comparison of the original and predicted absolute magnitudes determined by Equation (6). Symbols are the same as in Figure 4.

However, if the interval of absolute magnitudes is extended down to $M_V = -1$ mag, i.e. if the G–K giants are included, the prediction accuracy falls down to 0.82 mag for the Q_{XYZ} and Q_{XZS} parameters and 0.64 mag for the Q_{UPY} and Q_{XZS} parameters. In this case we observe a considerable scatter of the Hipparcos stars and a systematic displacement of the Hyades giants.

If we include also supergiants, the fitting accuracy becomes even lower. Probably, the dependence between M_V and Qs for giants and high luminosity stars has a different character and must be solved separately. For this, a larger number of stars with more accurate parallaxes are essential. This can be done by using G–K giants and supergiants in open star clusters with known distance moduli.

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