THE STRÖMVIL SEVEN-COLOUR PHOTOMETRIC SYSTEM FOR GAIA: CLASSIFICATION OF PECULIAR STARS

V. Straižys[1], E. Høg[2], A.G. Davis Philip[3]

[1] Institute of Theoretical Physics and Astronomy, Goštauto 12, Vilnius 2600, Lithuania
[2] Copenhagen University Observatory, Juliane Maries Vej 30, 2100 Copenhagen Ø, Denmark
[3] Institute for Space Observations and Union College, Schenectady, NY 12308, U.S.A.

ABSTRACT

In our previous publications it was shown that the Strömvil seven-colour photometric system, when set up on a GAIA-type satellite, will be able to classify stars of all normal spectral classes down to 16 mag. In the present paper we demonstrate that the same system makes possible the photometric identification of a number of peculiar types of stars, including emission-line stars, metallic-line A and F stars, chemically peculiar B and A stars, metal-deficient F–G–K dwarfs (subdwarfs), metal-deficient G and K giants, blue horizontal-branch stars, white dwarfs and carbon-rich stars.

Key words: space photometry; stellar classification; GAIA satellite.

1. INTRODUCTION

Straižys, Crawford and Philip (1996) have shown that if the Strömgren four-colour system is supplemented by three passbands of the Vilnius system at 374, 516 and 656 nm, the combined Strömvil system becomes capable of classifying stars in spectral classes (or effective temperatures) and luminosities (or gravities) everywhere in the HR diagram, even when interstellar reddening is present. Setting up the Strömvil system on a GAIA-type satellite makes possible the classification of tens of millions stars down to 16 mag (Straižys & Høg 1995). Among them, up to 10 per cent of stars will be either metal-deficient or will have other peculiarities in their spectra. It is important to have a photometric method for identifying these peculiar stars and for estimating their matallicity or degree of peculiarity.

2. PHOTOMETRIC CLASSIFICATION IN THE VILNIUS SYSTEM

The possibility of identifying various types of peculiar stars has been demonstrated in the Vilnius photometric system. Most of them can be identified even in the presence of interstellar reddening. Such types of peculiar stars are: Be-type stars, Herbig Ae/Be stars, T Tauri-type stars, metal-deficient dwarfs (subdwarfs), subgiants and giants, carbon-rich stars (R, N, Ba and CH stars), horizontal-branch stars, white dwarfs and a number of unresolved binaries. The methods of identifying these stars and their calibration are described by one of the authors (Straižys 1992). Since all four passbands of the Strömgren system have their close analogs in the Vilnius system, the described classification properties are also valid for the Strömvil system. Since the amount of stars of different types, observed in this system, is not sufficient at the present time, we demonstrate here this possibility by exhibiting a set of diagrams of the Vilnius system designed for identification and classification of stars with different peculiarities.

In most cases, for the identification of peculiar stars we use the interstellar reddening-free Q-parameters. Here we exhibit only two-dimensional Q, Q or $Q, colour\ index$ diagrams, the Q-parameters being defined as follows:

$$Q(1,2,3,4) = (m_1 - m_2) - E_{12}/E_{34}(m_3 - m_4) \quad (1)$$

where m_1, m_2, m_3 and m_4 are magnitudes in four passbands and E_{12}/E_{34} are colour excess ratios. We use the designations of the passbands of the Vilnius and Strömvil systems listed in Tables 1 and 2. Q parameters are always expressed in magnitudes.

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

Name	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

Table 2. Mean wavelengths and half-widths (FWHM) of passbands of the Strömvil photometric system.

Name	u	P	v	b	Z	y	S
λ_0 [nm]	350	374	411	467	516	547	656
$\Delta\lambda$ [nm]	30	26	19	18	21	23	20

However, the identification of peculiar stars is much easier if we use three, four or five Qs, instead of two.

For the peculiarity estimation one can use different methods. One of them is the application of an analytical function containing the Q-parameters, which are most sensitive to a given type of peculiarity. The other method is the fitting of the Q-parameters of a star under investigation with Q-parameters of the peculiar standard stars. Here we limit ourselves by using only two-dimensional diagrams and bearing in mind that the addition of other Qs will do the job better.

2.1. F–G–K Subdwarfs

Figure 1 shows the diagram Q_{UXY}, Q_{UYV} which gives very good separation of F–G–K subdwarfs from the remaining types of stars. The diagram is calibrated in terms of effective temperature and metallicity. In the Strömvil system, the analogous diagram is Q_{uvb}, Q_{uby}.

2.2. G–K Metal-Deficient Giants

Figure 2 shows the diagram Q_{PYZ}, Q_{XYZ} which gives the best separation of G–K metal-deficient giants from the remaining stars. In a part of the same area the metal-deficient dwarfs (subdwarfs) are located. For their isolation, the Q_{UPY} and Q_{XZS} parameters are important. In the Strömvil system the analogous diagram is Q_{PbZ}, Q_{vbZ}.

2.3. Early-Type Stars of Different Peculiarities

Figure 3 shows the $Q_{XYV}, Y-V$ diagram with the Ap/Bp of different types and Am stars plotted. The solar chemical composition stars of luminosities V–IV–III form a belt between the two dashed lines. All stars outside this belt are identified as peculiar or metallic-line stars. Mild Ap/Bp and Am stars fall into the belt of normal stars. For their identification more photometric parameters should be used, especially Q_{UPY} and Q_{YZS}.

Helium-rich stars can be recognized in the Q_{XZV}, Q_{XYZ} diagram (not shown in this paper). Blue horizontal-branch stars can be identified in the $Q_{UXY}, Y-V$ diagram (or $Q_{uvb}, b-y$ in the Strömgren and Strömvil systems (Figure 4). The $(P-X)-(X-Y)$, $Y-V$ diagram (Figure 5) is good for separation of horizontal-branch stars of spectral classes from A to G.

2.4. Emission-Line Stars

It is very easy to identify Be-type stars because one of our passbands, S, is placed exactly on the Hα line. Figure 6 shows the Q_{XZS}, Q_{XYZ} diagram with the normal and emission B stars plotted. Extreme Be stars, such as γ Cas, ϕ Per or π Aqr deviate by about 0.4 mag from normal stars.

T Tauri-type stars and Herbig Ae/Be stars also contain Hα in emission and are well separated from the remaining stars in the Q_{UPY}, Q_{XZS} diagram (Figure 7).

2.5. White Dwarfs

White dwarfs of different types can be identified in the $Q_{UXY}, Y-V$ or $Q_{uvb}, b-y$ diagrams (Figure 4) and in other similar diagrams including the ultraviolet U and P passbands. DA-type white dwarfs can be separated from other WD types in the $U-Y, Y-V$ diagram (not shown here).

2.6. Carbon-Rich Stars

The most suitable diagram for identification of N-type carbon stars is Q_{XZS}, Q_{XYZ} (Figure 8). The cool carbon stars occupy in it an area where no other type of stars appear. For R-type stars, barium stars and CH-stars the best is the Q_{UPYV}, Q_{XZS} diagram (Figure 9).

3. CONCLUSIONS

The Vilnius and Strömvil seven-colour systems make possible the two-dimensional classification of solar chemical composition stars of all temperatures in terms of spectral classes and absolute magnitudes (or temperatures and gravities) in the presence of interstellar reddening. Also, these systems allow one to identify stars belonging to most types of peculiar stars, including metal-deficient dwarfs, subgiants and giants, emission-line stars, early-type stars of different chemical peculiarities, horizontal-branch stars, white dwarfs and carbon-rich stars. In most cases it is possible also to estimate the metallicity and the degree of peculiarity.

Consequently, both systems are equally capable to classify photometrically almost all stars in the general galactic field where stars of different temperatures, luminosities, metallicities, peculiarities and interstellar reddenings are mixed together. For this purpose, the accuracy of the measured colour indices must be of the order of 0.01 mag. The accuracy of the determined physical parameters differs in different ranges of temperatures and luminosities. The best expected accuracy is of the order of 1 subclass in spectral class, 0.3 mag in absolute magnitude, 0.15 dex in [Fe/H] ratio, 0.02 mag in colour excess and 20 per cent in distance.

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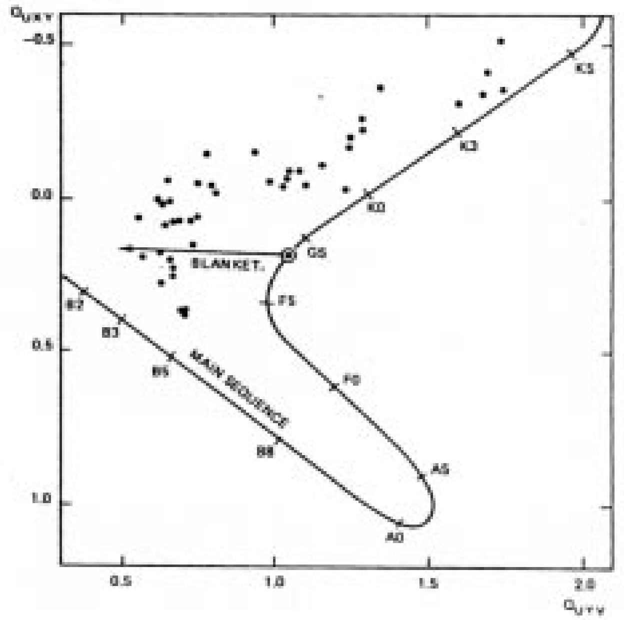

Figure 1. F–G–K subdwarfs in the Q_{UXY}, Q_{UYV} diagram. The deblanketing vector of the Sun is shown.

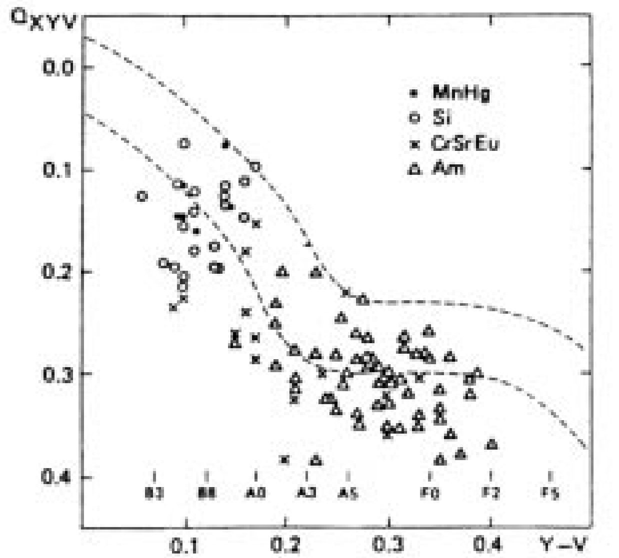

Figure 3. A–B chemically peculiar stars and A metallic-line stars in the $Q_{XYV}, Y-V$ diagram. The belt of normal stars of luminosities V–III is limited by two broken lines.

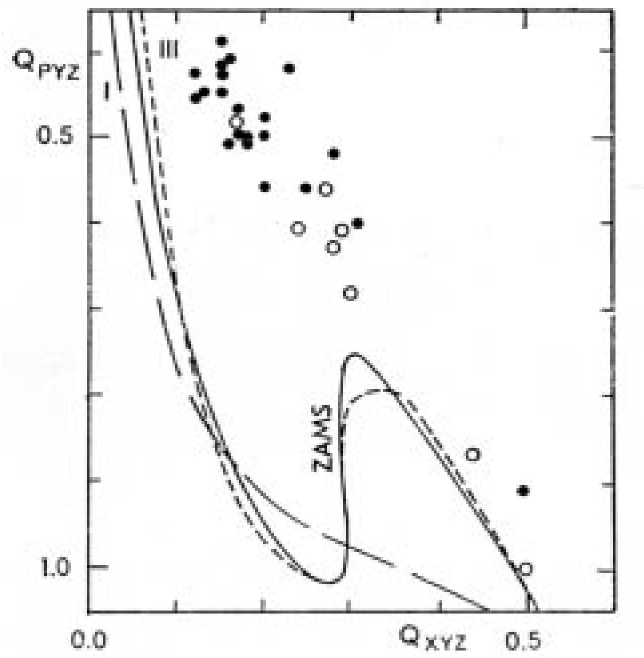

Figure 2. G–K metal-deficient giants (circles) and F–G subdwarfs (dots) in the Q_{PYZ}, Q_{XYZ} diagram. The lines of the zero-age main sequence (ZAMS), giants (III) and supergiants (I) are shown.

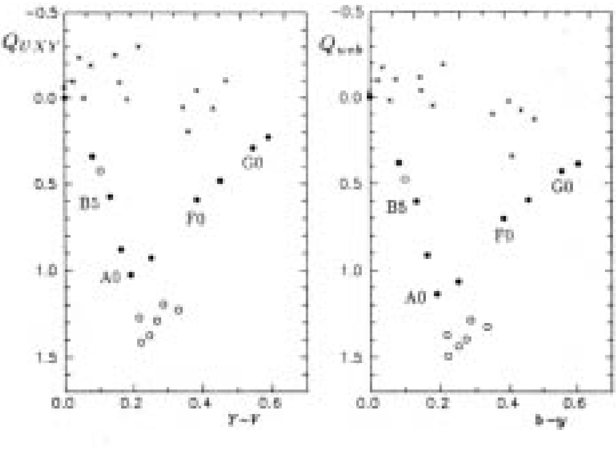

Figure 4. Blue horizontal-branch stars (circles) and white dwarfs (crosses) in the $Q_{UXY}, Y-V$ and $Q_{uvb}, b-y$ diagrams. Dots are the main sequence stars of spectral classes from B to G.

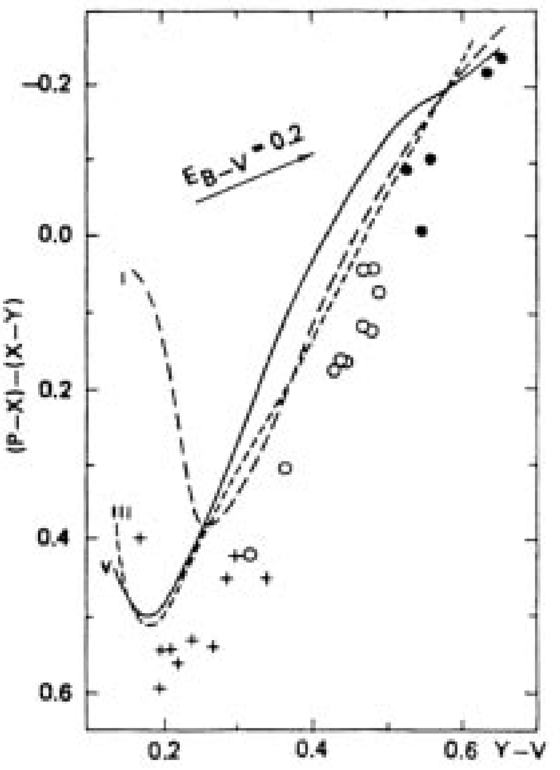

Figure 5. Horizontal-branch stars in the $(P-X)-(X-Y), Y-V$ diagram. Crosses are blue HB stars, circles are RR Lyrae type stars and dots are red HB stars. The lines of main sequence (V), giants (III) and supergiants (I) are shown.

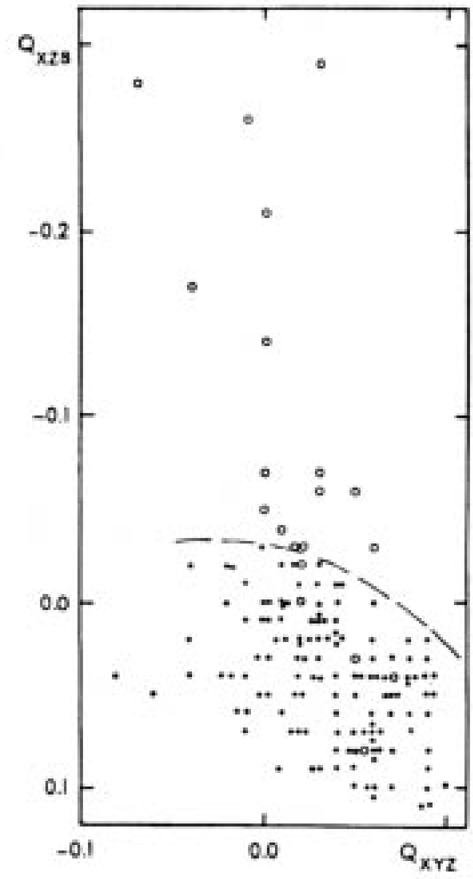

Figure 6. Be-type stars (circles) and normal B-type stars of luminosities V–III (dots) in the Q_{XZS}, Q_{XYZ} diagram. All stars above the broken line are Be-type stars.

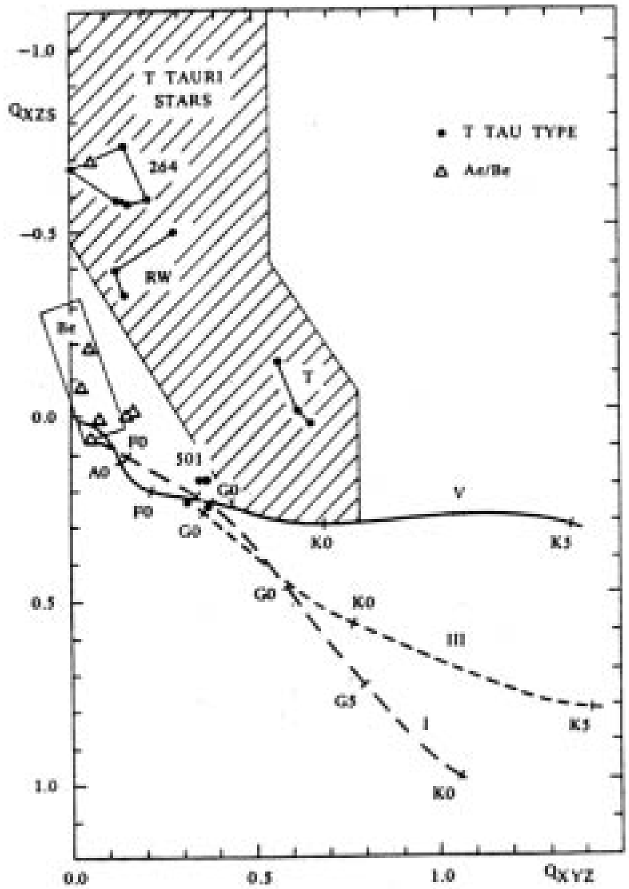

Figure 7. T Tauri-type stars and Herbig Ae/Be stars in the Q_{XZS}, Q_{XYZ} diagram. The domain of T Tauri stars is hatched. The domain of Be-type stars is shown by a rectangular. Lines of main sequence stars (V), giants (III) and supergiants (I) are shown.

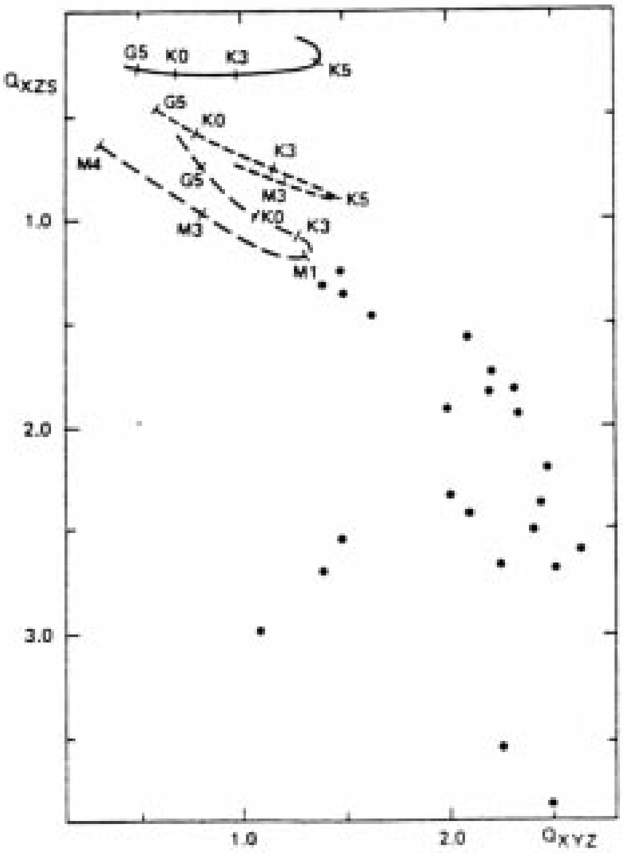

Figure 8. N-type carbon stars (dots) in the Q_{XZS}, Q_{XYZ} diagram. The solid line is the main sequence, the short-dashed line is the giant sequence and the long-dashed line is the supergiant sequence.

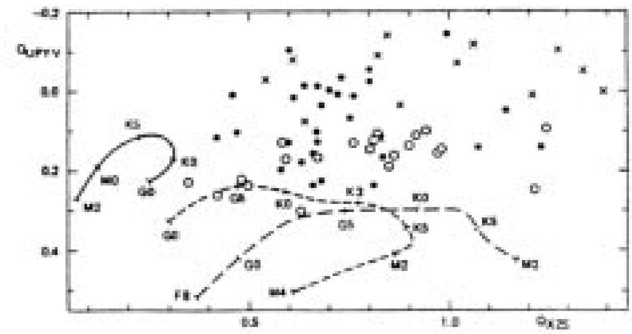

Figure 9. R-type stars (dots), barium stars (circles) and CH-type stars (crosses) in the Q_{UPYV}, Q_{XZS} diagram. Designations of lines are the same as in Figure 8.