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SPECTROPHOTOMETRIC CATALOGUE OF THE STERNBERG ASTRONOMICAL INSTITUTE: OBSERVATIONS AND ASTROPHYSICAL RESULTS

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Spectrophotometric observations of a large number of stars of different spectral types and luminosities were began at the Sternberg Astronomical Institute on the initiative of Professor D. Ya. Martynov. The spectrophotometric catalogue of the Sternberg Astronomical Institute was created on the basis of the observations at the Sternberg Institute Crimean Station and includes energy distribution data for 900 stars in the range 3200–7600Å and 250 stars in the range 6000–10 800Å with a 50Å step. These data were used for determination of physical parameters of atmospheres, comparison with theoretical model atmospheres and synthetic photometry.

KEY WORDS Spectrophotometry, catalogues, stars: general

1 OBSERVATIONS

About three decades ago when spectrophotometric observations of stars began at the Sternberg Institute Crimean Station energy distribution data were only available for a few bright stars.

So on the initiative of Professor D. Ya. Martynov, the director of the Sternberg Institute, spectrophotometric observations of a large number of stars of different spectral types and luminosities were produced in cooperation with the Alma-Ata Astrophysical Institute, Kazakhstan.

The registration of stellar spectra at the Sternberg Institute Crimean Station was done by means of two photoelectric spectrophotometers with concave gratings, installed using the scheme by Seya and Namioka at the 48 cm reflector, $F = 7.5$ m of the Sternberg Institute Crimean Station. Later this telescope was changed to a 60 cm Zeiss-2 reflector at $f = 2.4$ m. The first spectrophotometer enables the registration of stellar spectra in the range 3200–7600Å, the second one in the near-infrared range 6000–10 800Å.

Spectrophotometric data were obtained as a result of stellar spectra approximation by histograms with 50Å step boundaries (3200–3250, 3250–3300, etc.).

The stars of the observational programme were compared with the standard stars by means of the method of equal altitudes. Differential extinction was taken into account with the mean season spectral extinction coefficient. Each star of the catalogue was observed not less than three times on different nights. Most of the stars were observed four to seven times, so that the average number of observations for one star is equal to four.

2 STANDARD STARS

For effective realization of the method of equal altitudes it is necessary to use a few standards spread across the sky more or less uniformly.

Three sets of standards of different brightness were proposed. The first set includes eight stars of 0–2 mag: βAri, γOri, βTau, αLeo, ηUMa, αLyr, αAql and αPeg.

At first the spectral energy distribution of these stars was based on all the data published by different authors and the energy distribution of Vega, the main spectrophotometric standard was obtained also on the basis of several calibrations. Later special observations of standards were produced independently at two places: the Sternberg Institute Crimean Station and the Alma-Ata Astrophysical Institute. During the course of these observations each of seven standards was connected with Vega directly or using another standard star, compared with αLyr directly. For each standard energy distribution data obtained at two observatories were analysed and the mean values were obtained (Kharitonov and Glushneva, 1978). The next step was a reduction to the new scale of the Vega energy distribution, published by Hayes (1985). This reduction was done for all the stars of the catalogue.

Table 1 contains mean square errors of the standard star energy distribution data (%).

The very important characteristic of a spectrophotometric standard is the absence of brightness variations. Next. three independent investigations of the possible variability of eight stars used as spectrophotometric standards were produced.

(1) *WBVR* photometry during the Tien'-Shan' high-mountain expedition of the Sternberg Institute near Alma-Ata (altitude about 3000 m). For all the stars brightness variations are less than 0.01 mag (in the limits of 0.001–0.005 mag).

Table 1. Mean square errors for standards (%)

λ, Å	σ	λ, Å	σ
3200–3700	2.1	5000–6000	1.0
3300–3700	1.2	6000–7000	1.0
3700–4000	1.5	7000–7600	1.3
4000–5000	1.0		

(2) *UBV* photometry at the Crimean Station. Brightness variations less than 0.005 mag.

(3) *UBV* photometry at Mount Maydanak, Uzbekistan, altitude 3000 m, produced by Yu. Sperauskas (Vilnius University Observatory, Lithuania). Brightness variations of less than 0.005 mag during several hours or days, only for αAgl, long time variability $\sim$ 0.02 mag, were suspected (months).

The second set contains 11 more fainter stars up to 4 mag chosen from the catalogue of 238 secondary spectrophotometric standards (Glushneva *et al.*, 1992). This catalogue contains mean energy distribution data in the range 3200–7600Å for stars from the catalogue of the Sternberg Astronomical Institute (Moscow Catalogue) (Voloshina *et al.*, 1982) and Alma–Ata Astrophysical Institute (Alma–Ata catalogue) (Kharotonov *et al.*, 1988) with good agreement of data when the difference of monochromatic fluxes is less than 5% in the spectral range investigated.

Furthermore, this catalogue also contains near-infrared (6300–10 800Å) energy distribution data for 99 stars, obtained at the Sternberg Institute Crimean Station. This provides a homogeneous spectrophotometric data set for a rather wide range from 3200 to 10 800Å which may be used for total flux determination.

The 11*B–A* stars proposed as spectrophotometric standards are not members of the General Catalogue of Variable Srars, the Catalogue of the Suspected Variables or Name lists 67–70. For these stars energy distribution data in the range 3200–10 800Å are available (Glushneva *et al.*, 1992).

The third set includes *A–G* stars of 7–8 mag. Energy distribution data in the range 3400–7600Å for 75 stars are being obtained at the Crimean Station of the Sternberg Institute. The important part of the work on spectrophotometric standards creation is *UBV* photometry of these stars to search for possible brightness variations. No variations exceeding the inner accuracy of photometric observations were found and this enables us to use these stars of 7–8 mag as spectrophotometric standards.

3 PHYSICAL PARAMETERS OF ATMOSPHERES AND COMPARISON WITH THEORETICAL MODELS

Energy distribution data of the Moscow Catalogue were used for determination of physical parameters of stellar atmospheres.

Total fluxes were obtained for 125 *A–G* main-sequence stars combining Moscow Catalogue ground-based data in the range 3200–10 800Å with space spectrophotometric measurements and infrared photometry. By means of infrared flux method effective temperatures and angular diameters were determined. These parameters were used for determination of gravities and luminosities (Glushneva, 1985; 1989a,b). It was shown that effective temperatures obtained on the basis of photometry in the K band (2.2 μm) are the closest to those determined by means of the direct interferometric measurements of angular diameters (Glushneva, 1985).

Monochromatic fluxes of B–F main-sequence stars of the Moscow Catalogue were compared with theoretical model atmospheres of Kurucz (1979).

Satisfactory agreement was found between the observed energy distribution and models for B and A stars in the ultraviolet and visible ranges, however in the near-infrared (8000–10 800Å) observed monochromatic fluxes for A stars are 5–8% more than theoretical ones (Glushneva, 1990).

For F stars in the ultraviolet at $\lambda < 3700$Å discrepancies between observations and models were found: observed monochromatic fluxes are less than theoretical ones (Glushneva, 1989b).

4 "NORMAL" ENERGY DISTRIBUTION FOR A STARS

The catalogue of 238 secondary spectrophotometric standards was used for determination of the "normal" energy distribution data for main-sequence stars of all the subtypes of spectral class A. These data are free from interstellar reddening and are normalized to the monochromatic flux at 5575Å (Glushneva, 1992).

Comparison of the energy distribution of Vega, the main spectrophotometric standard, with the mean for stars A0V shows that in the ultraviolet range at $\lambda <$ 3600Å monochromatic fluxes of Vega are 6–10% less than the mean for A0V-type stars (Glushneva, 1996).

5 SYNTHETIC PHOTOMETRY

One of the important applications of spectrophotometric data is synthetic photometry. Photometric colour indices may be calculated on the basis of the energy distribution using response curves of different photometric bands and comparison with observed colour indices.

Synthetic photometry may be successfully used for calibration of photometric systems and also for a comparison of spectrophotometric and photometric observational data obtained independently.

Synthetic B–V colour indices in the *WBVR* system (Kornilov *et al.*, 1991) calculated for two sets of spectrophotometric standards: 11 stars of 3–4 mag and 60 stars of 7–8 mag, were compared with the observed colour indices.

This comparison demonstrates good agreement between synthetic and observed colour indices.

The mean value of the difference of these colour indices does not exceed 0.01 mag for the first set of standards and 0.016 mag for the second set. However, for all 16 stars of the second set for which *WBVR* photometric observations are available (the rest 44 stars are fainter than 7.2 mag, the limit of brightness for stars of *WBVR* catalogue) there is a systematic difference between synthetic and observed colour indices.

For individual stars all the differences are small, but negativa. This may be connected with the calibration of Vega used (Glushneva, 1996).

Synthetic $W-B$ and $B-V$ indices in the $WBVR$ photometric system were calculated for 22 G0–G8 stars and compared with the observed ones (Glushneva, 1994). The colour indices of the Sun in the same system were obtained from most reliable series of spectrophotometric measurements (Kharotonov *et al.*, 1994). Comparison of observed colour indices of solartype stars with synthetic colour indices of the Sun showed that $(W-B)_{\odot}$ corresponds to the mean value of this colour index for stars of spectral type G1.5. This conclusion is also confirmed by direct comparison of energy distributions of stars and the Sun in the range 3200–5500Å.

However, $(B-V)_{\odot}$ corresponds to the mean value of this colour index for G3–G5 stars.

These results may be important in the discussion as to whether the Sun is fully normal or a "slightly peculiar" star.

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