

A Software System for Reduction and Visualization of Astronomical Photoelectric Data

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1 Introduction and methods

In spite of significant progress of the CCD photometry, the classic photoelectric photometry has place in the astronomical researches. The differential photometry is a good tool for studying of variable stars. Computers is used for directly accepting of photometric data, quickly processing and obtaining of the results. Computer graphic gives the possibility to see original photometric data as well as light curves, approximations, statistics and etc.

In this section we present a short description of observational methods with one channel photon counting photoelectric photometer. There are two types of observations. We define UBV-type observations, when one measures the variable, the comparison star and the sky background using U, B and V filters. Then the data are reduced to the standard UBV photometric system. The second type observations are long series of measurements of the variable or check star in an arbitrary fixed filter. Those series are interrupted for measuring of a comparison star and sky background. Then the magnitudes (with respect to the comparison star) in the instrumental system can be obtained in order to build the light curves of the variable and/or check stars. We will call these observations Light Curve (LC)-type observations.

Let us take the moments $t_1 < t_2$ and the average values v_1 and v_2 of the integrations of comparison star or the sky at these moments. Then at the time point t ($t_1 < t < t_2$) we will use three type of approximation for the integrations v at this point:

- mean value: $v = \frac{1}{2}(v_1 + v_2)$;
- nearest time point value: $v = \begin{cases} v_1, & \text{if } t < \frac{1}{2}(t_1 + t_2) \\ v_2, & \text{if } t \geq \frac{1}{2}(t_1 + t_2) \end{cases}$;
- linear approximation using two nearest time points: $v = \frac{t_2-t}{t_2-t_1}v_1 + \frac{t-t_1}{t_2-t_1}v_2$;
- parabolic approximation: $v = c_2t^2 + c_1t + c_0$, where the coefficients c_0, c_1 and c_2 are obtained from the method of least squares using all time points.

The following well-known algorithm is used to convert the original photometer data to the instrumental system data. The approximated values of the sky are subtracted from the average values of the comparison star. For UBV-type observations this procedure is also executed for the average values of the variable star for all filters. For LC-type observations the same procedure is applied for the measurements of the variable and of the check star (if it is observed). Then the formula

$$m = -2.5 \log\left(\frac{d}{d_s}\right)$$

converts the deflections to magnitudes, where d is the variable value at the moment t and d_s is the approximate value of the comparison star at t . The same formula is used for LC-type observations to calculate the magnitudes of the comparison star. Thus the measurements are converted to magnitudes in the instrumental system.

For UBV-type observations the following formulae (Hardie (1962) and Jerzykiewicz (1966)) are used to compute the magnitudes in the standard UBV-system:

$$\begin{aligned}\Delta V &= \Delta v - k_v \cdot \Delta X + \varepsilon \cdot \Delta(B - V) \\ \Delta(B - V) &= \mu \cdot \Delta(b - v) - \mu \cdot k'_{bv} \cdot \Delta X - \mu \cdot k''_{bv} \cdot \Delta(b - v) \cdot \bar{X} \\ \Delta(U - B) &= \psi \cdot \Delta(u - b) - \psi \cdot k'_{ub} \cdot \Delta X - \psi \cdot k''_{ub} \cdot \Delta(u - b) \cdot \bar{X}\end{aligned}$$

Here Δ denotes the difference between the variable and comparison stars values. \bar{X} is the average air mass for two stars. The air mass X for a star with right ascension α and declination δ , for sidereal time T and for an observatory with latitude φ is:

$$\begin{aligned}X &= \sec z - 0.0018167(\sec z - 1) - 0.002875(\sec z - 1) - 0.0008083(\sec z - 1), \\ \sec z &= (\sin \varphi \cdot \sin \delta + \cos \varphi \cdot \cos \delta \cdot \cos(T - \alpha))^{-1}.\end{aligned}$$

ΔX can be expressed by

$$\Delta X = (P \cdot \sin \bar{h} + Q \cdot \cos \bar{h} + R) \cdot \bar{X}^2, \text{ where}$$

$$P = \Delta \alpha \cdot \cos \varphi \cdot \cos \bar{\delta}, \quad Q = \Delta \delta \cdot \cos \varphi \cdot \sin \bar{\delta}, \quad R = -\Delta \delta \cdot \sin \varphi \cdot \cos \bar{\delta}.$$

$\Delta \alpha$ is the difference of the right ascensions and $\Delta \delta$ is the difference of the declinations of the variable and comparison stars. \bar{h} is the mean value of the hour angles for two stars.

The first-order extinction coefficients are denoted by k_v , k'_{bv} and k'_{ub} and the second-order (color-depending) coefficients — by k''_{bv} and k''_{ub} . ε , μ and ψ are transformation coefficients from the instrumental system to the standard UBV system.

2 Program system

An integrated software system for reduction of astronomical photoelectric data and visualization of light curves is created. It is written in Pascal language (Turbo-Pascal version 5.0) and works on IBM-PC/XT/AT computers. The system is controlled by menus. Fig. 1 presents the main menu.

UBV system		light Curve		Graphic
Load		New path		Status browse File
Approxim		Write level		Julian days
Quit		Help		

Fig. 1

The program system consists of four relatively independent parts:

- A file system
- UBV reduction system
- Light curve reduction system
- Light curve visualization system

The file system uses two file types of input photometric data. The software system [3] attached to the photoelectric photometer in Belogradchik observatory produces files of the first type. The second type files have a format suitable for manual (from the keyboard) input of photometric data. Also there are differences in the structure of the files containing UBV or LC type observations.

Also files with stars parameters are used — right ascensions and declinations of the stars and the magnitudes in standard UBV system of comparison stars. The file system uses a text file containing the transformation and extinction coefficients for a fixed observatory.

The UBV reduction system works with UBV-type observations and computes the magnitudes in the standard UBV system. If the file contains measurements of more than one comparison and variable stars, then the user can choose any pair (variable and comparison stars) for the calculation. Heliocentric Julian days can be calculated too. As a result a text file containing the magnitudes in the standard UBV-system is created.

The LC reduction system processes LC-type observations and produces files containing the instrumental values of light curves. There are possibilities to see data graphically at 3 points of the computational process:

- at the beginning (the input data)
- after sky subtraction
- after conversion to magnitudes (the output data)

Approximation functions can be displayed optionally too. Some statistic characteristics (mean value and dispersion) can be calculated and displayed numerically and graphically. As a result, a file containing the time and magnitude information for the variable, check and comparison stars will be created.

Light curve visualization system displays the reduced data (from light curve reduction system) graphically on the IBM computer screen. CGA, EGA and VGA graphic adapters are supported. The system gives the possibility for preparing the pictures containing light curves for printing on standard IBM or laser printers. The following design functions are available:

- vertical and horizontal scaling
- combining the variable, check and comparison stars graphics
- choosing types of connection the neighbour points
- writing a standard title and arbitrary texts and drawing polygons on the graphic
- saving the graphic screen on files
- saving and loading graphic configuration files

A picture, produced by the LC reduction system is given in Fig. 2.

Fig. 2

References

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