COMPUTER PROGRAM "VARIABLE STARS CALCULATOR" (VSCALC)

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ABSTRACT. The freeware program is introduced, which allows to visualize data, to make periodogram analysis using the algorithm by Lafler and Kinman (1965), to make easier preparation of time series from visual and photographic observations, and to determine argument and signal value at extrema using polynomial fits. The program has been made under supervision of Prof. I.L.Andronov and both DOS and Windows versions are available from the site of the Ukrainian Asociation of Variable Star Observers *(http://uavso.pochta.ru)* and from the software servers *http://softbox.ru?a=21&i=4616* and *http://softodrom.ru/win/p4995.shtml*.

Key words: Stars: data reduction, periodogram analysis, extrema timings, photographic and visual observations.

The Program "Variable Stars Calculator" is intended for automatic processing of the observations of variable stars.

While working on photometric researches of symbiotic variable star BF Cygni and the Algol-type star TT Lyrae, I found that many calculations had to be executed by hand, so it took much time. To make such work easier, I made the computer program Variable Stars Calculator in the Object Pascal language.

Now a new updated version of this program with new possibilities has been written using the Borland Delphi. In this version, the interface of the program has 3 languages: Ukrainian, Russian and English. Its easy to add another language file.

Using this program, it is possible to convert brightness estimates obtained using the Niyland-Blazhko method into stellar magnitudes, to transform the numbers of plates of plates collection into Julian dates (if the database of plates collection exists), phases, to provide periodogram analysis, to determine extrema.

From the data files (*.dat), the program reads first 2 columns, which are usually Julian date and stellar magnitude. Obviously, these columns may represent argument and signal of any nature. There can be up to 1 million observations in a data file (Windows version). Adding of a new data in a file is executed by the command "Data>>Add". In the dialog (fig.1), the user should enter magnitudes of comparing stars (at the top) and then enter Julian dates and brightness estimates of the star. Click "Next" button until the end of observations, and after entering the last one, click "Finish". As a result there will be Julian dates (JD) and stellar magnitudes in a data file. User can also add comments to the field and change magnitudes of comparing stars when entering estimates. Also the user can add new data from a file. If exists the file, which contains JD and brightness estimates of star, the user can choose "Data>Add" from the "file" menu. The program will transform it automatically.

For translation of numbers of plates into JD, choose a menu item "Data>Convert numbers of plates into JD". The program finds number from data file in current database, gets needed JD and rewrites data file with JDs. As default, the program uses the file "7cam.dat" - the database of plate collection of the Astronomical Observatory of the Odessa National University (Pikhun and Yushchenko 2002). The user can change current database path in the "Options dialog". There is also an option "Full information in plate's Num > JD translating". If its on, the "renewed" data file will contain [JD], [stellar magnitude or estimates], [remark], [camera], [calendar date], else only 3 columns: [JD], [stellar magnitude or estimates], [remark].

Some variable stars change their magnitude so rapidly, that it is needed to calculate the correction. Earlier the astronomers used the heliocentric correction, but now the barycentric one is used as more exact. The barycentric correction may be computed using the formula by Soma et al. (1988). The user should enter the coordinates of the observed star. If the barycentric correction for current star was calculated early, the user can choose this star from the "hot stars" list; if not, the new star will be added to the list automatically. Using VSCalc, it is also possible to build the phase curve instead of the individual curves. The phase $E+\varphi=(t-T_0)/P$, where E is integer number of cy-

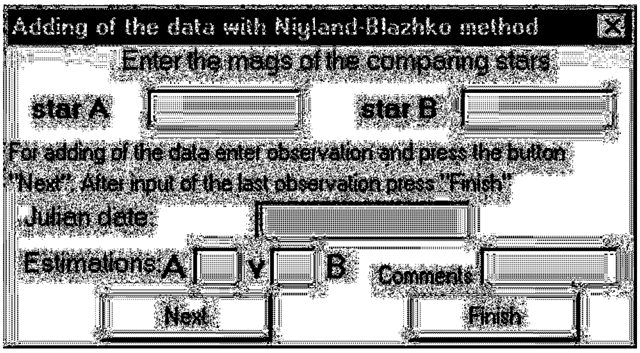

Figure 1. Program window for calculating magnitudes from visual estimates like *a3v4b* (see e.g. Tsessevich 1984).

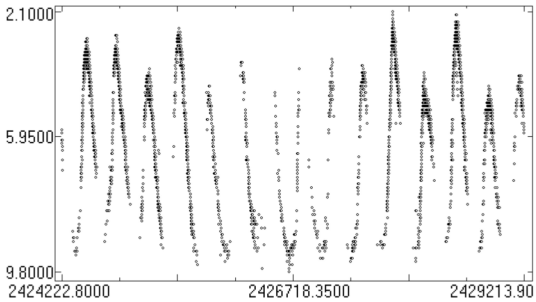

Figure 2. Part of the light curve of Mira (*o* Ceti) from the AFOEV and VSOLJ databases.

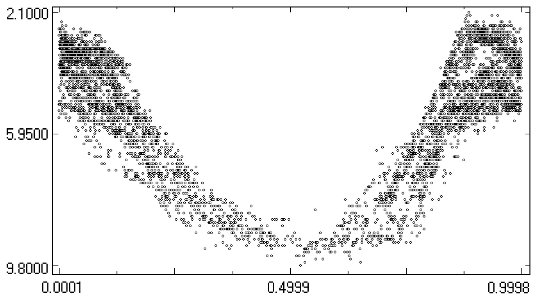

Figure 3. Phase curve of Mira for the period $333.^{m}6$.

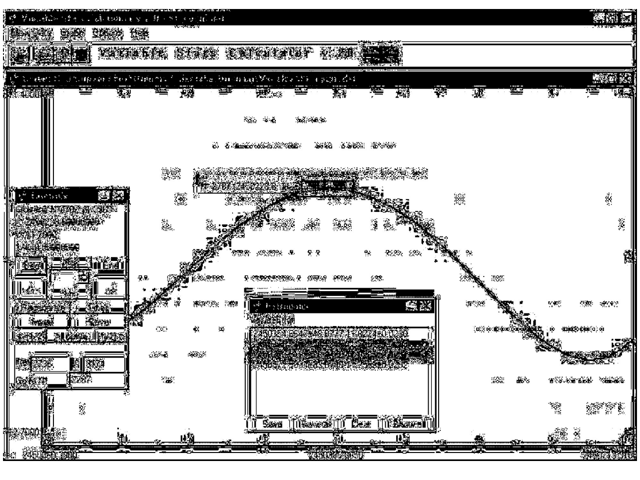

Figure 4. Program window for determination of extrema. Changing the degree of the polynomial cause change of the smoothing curve and the error box.

cle, starting from the initial epoch T_0; P is period. The phase $(0 \le \varphi < 1)$.

So, a phase is fractional part of ratio of range of JDs from the initial epoch to the current observation to the period. For calculations, it will be required to enter the output filename, epoch (or moment of extremum) and an adopted period of variable star. For illustration (Fig. 2), we have used the part of observations obtained by the members of AFOEV *(cdsweb.u-strasbg.fr/afoev)* and VSOLJ *(www.kusastro.kyoto-u.ac.jp)* and published at their Web sites. In Fig. 3, the output phase curve of *o* Ceti with period of 333.6 days is shown.

The periodogram analysis has been provided using the method originally proposed by Lafler and Kinman (1965) and improved by Kholopov (1970). Detailed description of the method and its basic modifications, and a comparison of their statistic properties are presented by Andronov and Chinarova (1997).

For each trial frequency f, the test-function $\Theta(f)$ is computed:

$$\Theta(f) = \frac{(m_1 - m_n)^2 + \sum_{i=2}^{N}(m_i - m_{i-1})^2}{\sum_{i=1}^{N}(m_i - \bar{m})^2} \qquad (1)$$

Here frequency, $f = 1/P$, P is trial period, i current number of obsevation, N number of observations, m_i element of array of stellar magnitudes sorted in ascending order of phases for the trial period, $\bar{m}$ mean stellar magnitude.

The value of the test-function should be at minimum if the trial frequency f is close to the true one, i.e. the less value of Θ is, the more probability is, that the period is correct. Periodograms are shown in Fig. 5,6.

For these calculations, the user can choose "Data>Period" menu item. Into the opened dialog box, it is necessary to enter the output file name, period range, i.e. minimal and maximal period, between which the program will calculate. This program needs the $\Delta\phi$ for calculate the step on frequency f: $\Delta f = \Delta\phi/(t_N - t_1)$. If $\Delta\phi$ is small, Δf will be small to. So, user can see more detailed periodogram, but it takes more time. 3 columns will be in the output file "file of periods": frequency, testfunction Θ and period.

At opening of data file, the window of the graph with the light curve from this file is automatically opened in the program. Opening the graph is possible also through the menu "Graph>Open". Together with the view window of the graph (see the fig. 4.), the "Panel of navigation" is opened. There are the buttons for moving between the observations (points): [Begin], [End], [<], [>], [Min], [Max], field for the input of step of moving between points. At moving a red cursor selects a current point, and on the top of the "Controls" panel, the information about it shown. The same takes place at pointing of mouse cursor on a point. The [Invert] button inverts the graph. [Regenerate] button recalculates graph from file. The [Lines] button connects/disconnects the points by lines. Clicking the [Save] button user can save the graph into image file (Windows Bitmap format, *.bmp). Following fields are intended to show graph from the number of observation from the field 1 to the number from the field 2. Showing the certain area of the light curve is possible by a mouse, pushing down mouse button on the first point (observation) and releasing on the end one. The button [All curve] shows all observations. If in the field N3 user enters the number of point, a red cursor will move to it and information about this observation will be represented.

The user can use range files. The range file should contain columns of such data: number1, [JD1], number2, [JD2]. To use range file click "Graph>Connect range file" or launch VSCalc with parameters "VSCalc.exe data_file range_file"
(e.g. "VSCalc.exe BF_Cygni.dat BF_Cygni.da!").

Finally 2 buttons appears at the bottom of the "Controls" panel and in the "Graph" menu. Clicking these buttons, the user can quickly move between the ranges from current window ("upper" or "lower" point). Moments of extrema of the signal are calculated automatically.

In this program, the calculation of moments of extrema is released by the method of least-squares approximation by a polynomial. The signal in the window is approximated by the formula:

$$m(t) = \sum_{\alpha=0}^{m} C_\alpha \cdot (t - \bar{t})^\alpha, \qquad (2)$$

where t is time (argument) in the accepted units, $\bar{t}$– the mean value for the interval of fitting, C_α are the coefficients. The moment of extremum is calculated by the relation $\frac{dm(t)}{dt} = 0$ by finding the root iteratively starting from the position of the extremum of parabola ($s = 2$). More details may be found in Andronov (1990).

In the program settings, there is an option, which determes, whether the most optimal degree of polynomial will automatically get out, or will be used the user degree entered in the field alongside. The polynomial, as well as the error box are shown in Fig. 4.

There are a lot of the additional options in the program: photometric database path, path to the external text editor; showing of "Controls" panel; changing of fonts of signatures of axes and more other ones.

Except for it, in the program there is a built-in calendar, which calculates JD on selected day; button 3 in toolbar ("Edit the file") calls a user-defined external text editor for the data file; call of the Windows calculator.

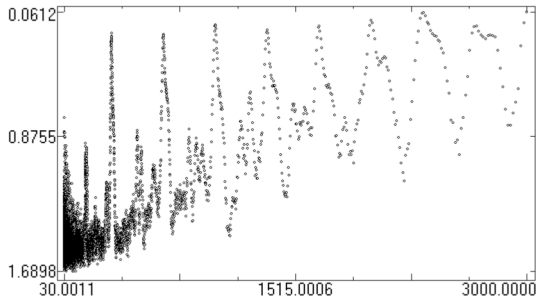

Figure 5. The periodogram for Mira as dependence of the test function $S(f)$ on trial period $P = 1/f$. Besides the peak corresponding to the true pulsational period P ($333.^{d}6$ for these data), one may see many peaks corresponding to multiple periods $P_j = jP$ (or frequencies $f_j = f_1/j$), where j is an integer. This is an effect of cycle-to-cycle changes of Mira, so longer "periods" take into account such changes. One may note that the width of the peaks is approximately proportional to the period's value.

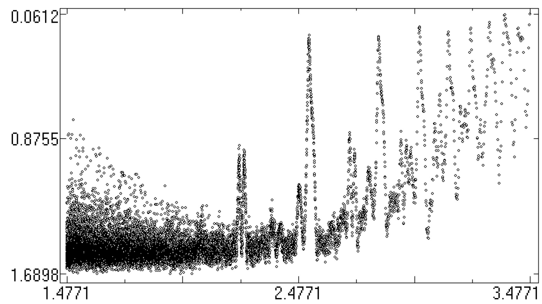

Figure 6. The periodogram for Mira as dependence of the test function $S(f)$ on logarithm of frequency $\lg f$. In such a presentation, the width of the peaks becomes nearly constant.

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References

Andronov I.L.: 1990, *Visual and Photographic Observations of Variable Stars,* Odessa Univ. Press
Andronov I.L.: 1994, *Odessa Astron.Publ.,* **7**, 49.
Andronov I.L.: 2001, *Odessa Astron.Publ.,* **14**, 255.
Andronov I.L.: 2003, *As.Soc.Pac. C.Ser.,* **292**, 391.
Andronov I.L., Chinarova L.L., 1997, *Kinematics and Physics of Space Bodies,* **13**, N6, 67.
Kholopov P.N.: 1970, *Trudy GAISh (Publ.Sternberg State Astron. Inst.Moscow),* **40**, 72.
Lafler J., Kinman T.D.: 1965, *Ap.J.Suppl.,* **11**, 216.
Pikhun A.I., Yushchenko A.V.: 2002, *I.B.V.S.,* **5215**.
Soma M., Hirayama Th., Kinoshita H.: 1988, *Celestial Mechanics,* **41**, 389.
Tsessevich V.P.: 1984, *What and How to Observe in the Sky,* 6^{th} Ed., Moscow, Nauka, 1984.