EFFECT for Windows

Description of software WinEFk by V.P.Goranskij. The software is written for OS Windows 95/NT/ 2000/XP/Vista/7 in Delphi computer language. Primordial Delphi text is presented free.

This is a sample of observational file. The ASCII coding in DOS/Windows format with a double symbol of line end CR+LF needed. The following line with column number explanation should not be included in the file.

JD-2400000	1	2	3	4	5	Remarks
51192.5794	15.974	15.175	0.000	0.000	0.000	v1 1999 Jan.13/14
51192.5848	16.013	15.200	0.000	0.000	0.000	v2 v79/v63/v64/v65/k
51193.6788	15.904	15.735	0.000	0.000	0.000	v14
51199.4981	15.484	15.497	0.000	0.000	0.000	v1 1999 Jan. 20/21
51199.5014	15.482	15.498	0.000	0.000	0.000	v2
51199.5967	15.59	15.720	0.000	0.000	0.000	v31
51199.6018	15.580	15.698	15.839	15.254	0.000	v35
51199.6541	15.780	15.792	15.937	15.427	16.581	v42
51199.6563	15.785	15.767	15.921	15.410	16.575	v43
51247.3886	15.803	15.320	15.741	15.806	16.48	v1 1999 Mar. 9/10
51247.3914	15.977	15.415	15.804	15.871	16.61	v2
51253.3860	15.814	15.909	15.788	15.869	16.56	v1 1999 Mar. 15/16
51253.3893	15.834	15.869	15.774	15.825	16.58	v2
51253.3920	15.795	15.930	15.687	15.853	16.47	v3
51253.5100	15.976	15.986	15.921	15.948	16.49	v40
51254.472	15.821	15.990	15.491	15.472	16.43	v1 1999 Mar 16/17
51254.478	15.826	15.921	15.535	15.459	16.69	v2
51255.5677	15.656	15.860	15.460	15.969	16.61	v57
51264.4144	15.703	15.624	15.886	15.181	16.58	v1 1999 Mar. 26/27
51264.4171	15.662	15.552	15.818	15.220	16.59	v2
51264.4196	15.746	15.636	15.886	15.298	16.69	v3
51274.3520	15.454	15.682	15.629	15.152	16.75	v3
51274.3716	15.489	0.000	15.409	15.085	0.00	v4
51274.3755	15.486	0.000	15.436	15.086	0.00	v5
51281.3365	15.840	15.866	15.795	15.648	16.512	v1 1999 Apr.12/13
51281.3387	15.806	15.870	15.790	15.614	15.661	v2
51583.4128	15.737	15.807	15.986	15.787	16.562	v08

If some observation does not exist in a column, it may be changed by "0" or "0.000". It is not allowed to use FORTRAN format zeros and numbers ended with a point, as "0." Column number may be arbitrary.

It is useful to have file named as "default.cfg" in the folder of the software with the following content. This is an example:

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d:\ss433\      -the folder of the file with observations;
*.*            -file name;
13.08211       -primary period;
50024.69       -initial date of the primary period;
162.15         -secondary period;
50000          -initial date of the secondary period;
8              -number of phase bins for the secondary period.
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One may input zeros instead of data in this file.

With the "default.cfg" file one may not seek the observation file in the folders when the software launches frequently. If the elements of star light curves are already known, it is not necessary to input them several times. The primary period and its initial date may be used to create the phased light curve automatically when the software is launched from the command line or the batch file.
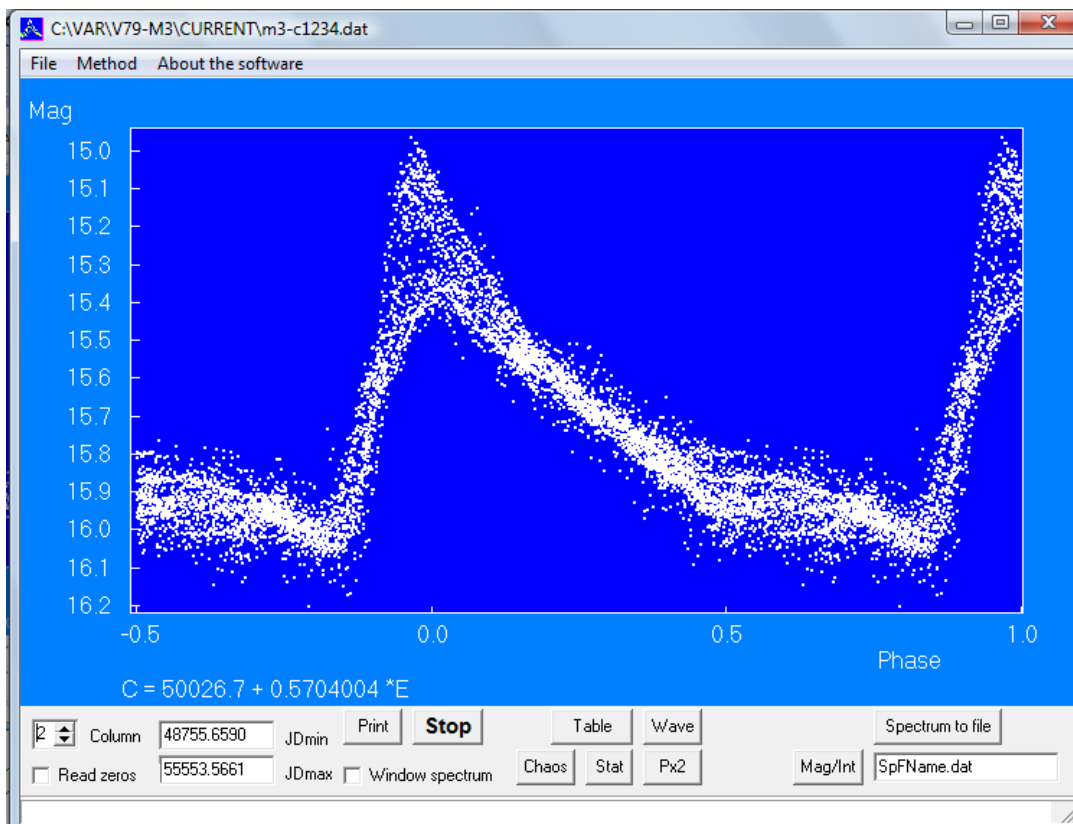

Fig.1. The software window with the graph of phase-dependent light curve of the variable star V63 in the globular cluster M3.

Window interface of WinEFk software

The description of the main menu located in the upper left corner of the window.

"**File**" – input and output of files;

"**Open**" – open the file containing the observations. Before the opening the file one should set the column number using the ScrollBar "Column". If it is needed to input the data within the limited time interval of Julian Dates, two string editors "JDmin" and "JDmax" may be used.

"**Save parameters**"- keep the file, the folder name, and current elements of the light curve into the file "default.cfg".

"**Save as...**" – save into separated file the changed observational data which the computer memory contains.

"**Save condition**" – save current parameters and screen periodogram image after stop running to continue running in the next time.

"**Save extraction**" – save the extraction from observations by a phase interval of the known period in a separate file.

"**Exit**" – close the software.

"**Save statistics**" – output the statistical data obtained from the calculation of amplitude spectrum of a chaotic set into the file "stat.dat".

"**Mean light curve file**" – inputs the tables of mean light curves from a file into computer memory to compare the original observations with the model calculated as a sum of periodic components determined as a result of Fourier decomposition of the observational set. The procedure draws a simulated light curve computed as a sum of periodic components (not more then 20) over the time dependent light curve, and views the modeling representation of light curve fragments. Mean light curves file is forming automatically in the prewhitening procedures during Fourier decomposition of light curve into periodic components. The light elements and tables of smoothed mean light curves are accumulated in this file.

"**Method**" - selection of calculation method. This menu item is working after the input of observational data in the computer memory.

"**Light curve**" – drawing the light curve. The scale of the graph depends on the window size. The window size may be changed by dragging the right lower corner of the software window by mouse with its left button pressed.

"**For the primary period**" – drawing the light curve with the chosen light elements (period and initial date, see Fig.1). The light elements used for calculations are printed under the graph.

"**Light curves divided by secondary period phase bins**" – drawing the series of light curves calculated with the primary period for different phase intervals of a secondary period (the period of the modulation of the shape of primary wave), the curves being located in order of increasing the phase interval number of the secondary period. This method is applied to show the evolution of light curve with the changing phase of Blazhko effect (Fig. 2) or with the phase of a precession period (Fig. 3). In the lines of the dialog window, the following values should be put: the primary period and the extremum date (the date of maximum or minimum), the secondary period and the date of the extremum shape of its light curve (the

date of maximum or minimum amplitude), and number of phase bins (or intervals) to divide the secondary period.
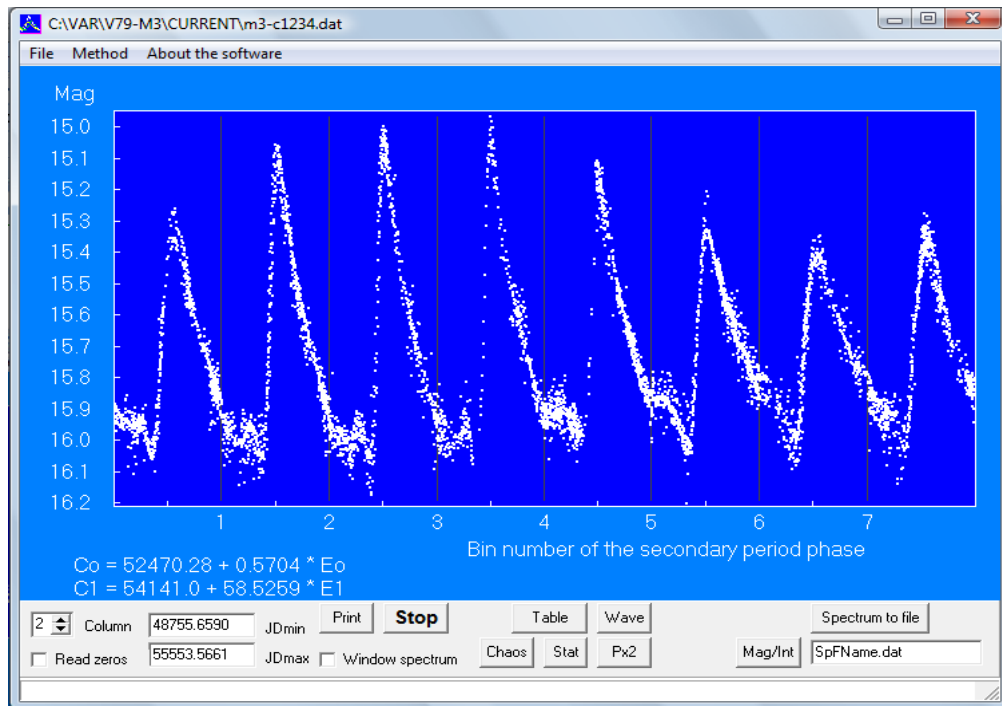

Figure 2. The software window showing the graph of the light curve of V63 in the globular cluster M3, a pulsating RR Lyr type variable star with the Blazhko effect (amplitude modulation). The evolution of the shape of the light curve is visible depending on the phase of 58.5 day period modulation.
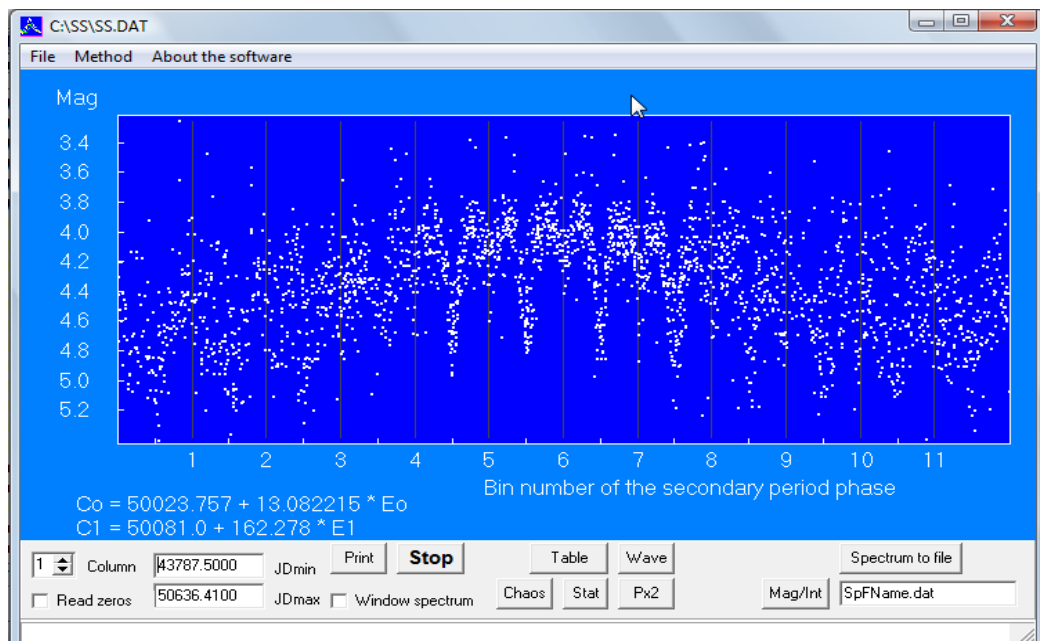

Figure 3. Graph of the orbital light curve of the astrophysical object SS433 divided by the phase of the secondary precession period 162.3 day. The Figure shows the evolution of the light curve shape with the phase of precession period.

"The secondary period phases are distinguished with different colors" - This menu item draws the light curve versus the phase of the primary period with the points colored depending on the phase of secondary period (Fig.4). The color scale is given to right.
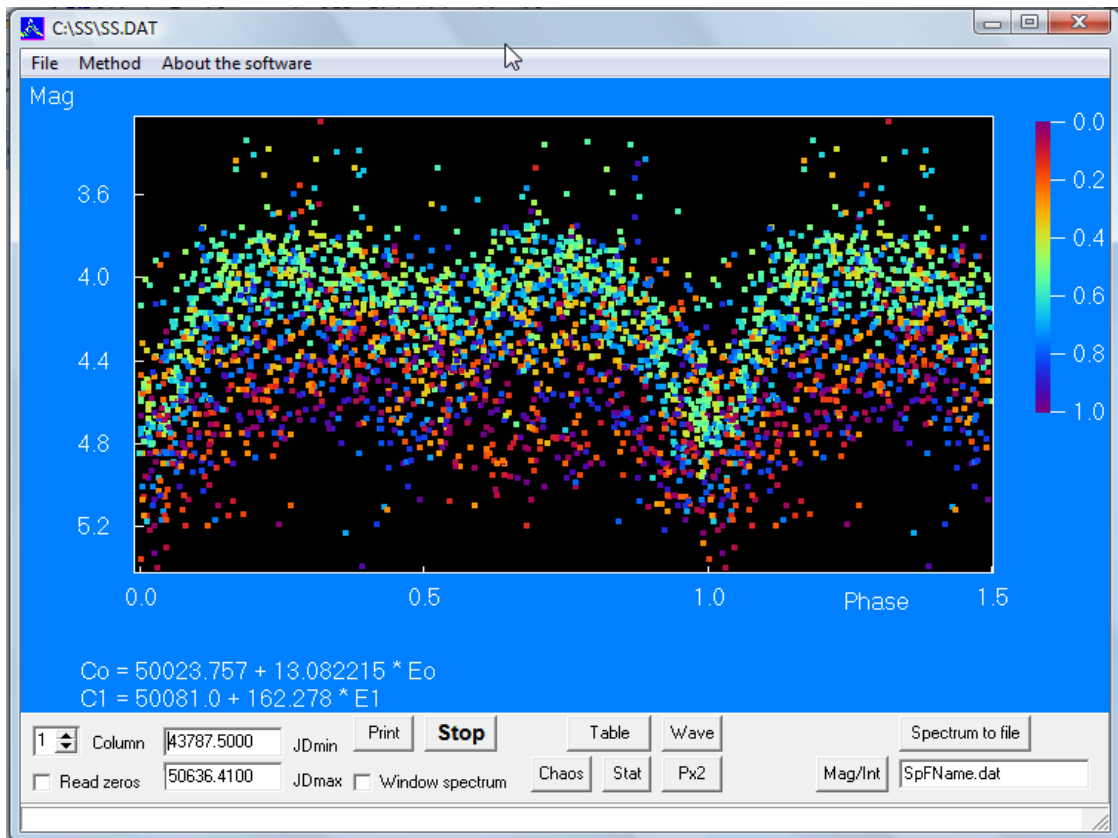

Figure 4. Graph of the light curve of SS433 plotted versus phase of the orbital period. The observations in different phases of precession period are marked with different colors. The color scale is shown to right.

"**Dependent on time**" – drawing of an ordinary time-dependent light curve.

"**Lafler-Kinman**" – calculation of periodogram using known method of phase dispersion minimization [1]. The ordinate axis is 1/*theta*, *theta* being the normalized sum of squired magnitude differences between each two subsequent points of phased light curve calculated with a trial period. One should put in the lines of dialog window the maximum and the minimum periods of the search interval, and the maximum phase shift needed to estimate frequency step (this phase shift usually be accepted equal or less than 0.05 for pulsating variables, or equal or less than 0.005 for eclipsing variables).

"**Deeming**" - discrete Fourier transform for arbitrarily distributed time series [2]. The ordinate axis is a half-amplitude of harmonic component of light curve with a trial period (Fig. 5). Procedure calls the same dialog window.

"**Secondary period**" – calculation of periodogram with the method of phase dispersion minimization of the primary period light curve divided into phase bins of a trial secondary period [3]. This method of period search is a combination of methods by Lafler-Kinman [1] and Jurkevich [4]. The ordinate axis is the relation of *theta* parameters, that one of an ordinary phased curve, and the same phased curve divided
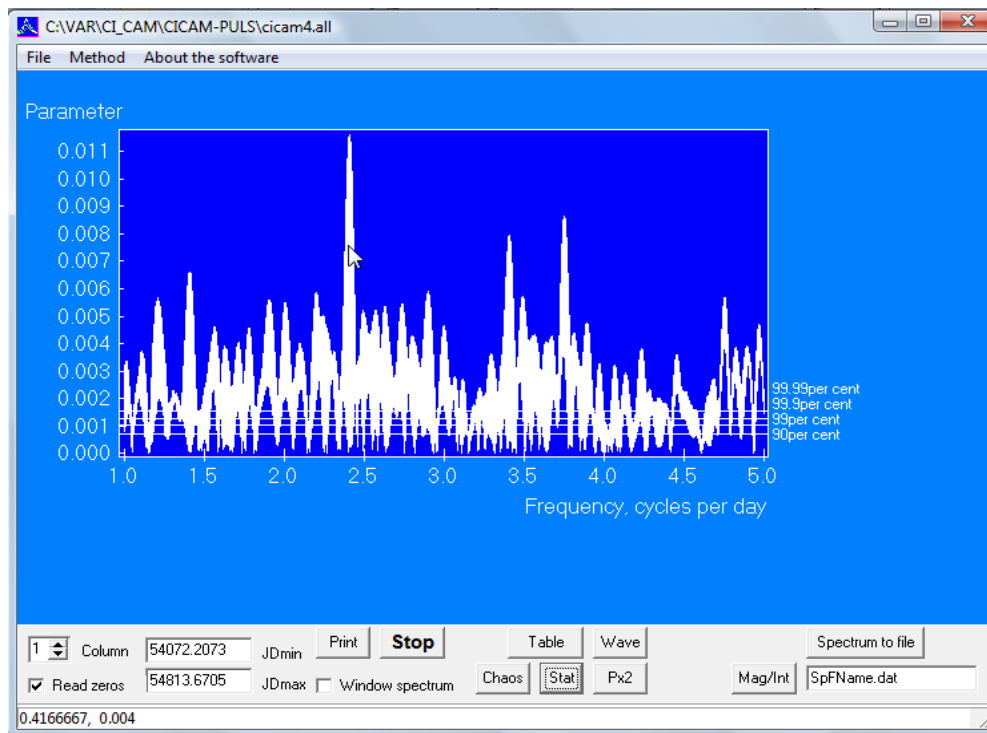
Figure 5. The amplitude spectrum of multiperiodic pulsating variable star CI Cam. The highest peak of the spectrum is indicated by mouse arrow, its aliases are visible to right and to left exactly at the distance +/-1.0. In the bottom StatusBar, the first number is a period value corresponding to the arrow location. The second high amplitude peak is related to the other pulsation wave which has also two aliases. The appearance of alias components of main peaks is concerned with the periodic discontinuity of observation times with the period of 1 day (because the observations were done only at night).

by phase bins of a trial secondary period (Fig. 6). The indication of true period is a peak in the periodogram, and a continuously varying shape of the main wave light curve with the phase of the secondary period. It is needed to put in the dialog window the primary period and the initial date for its extremum (maximum or minimum), a moment of light curve shape extremum, the maximum and the minimum of search interval for the trial secondary periods, the maximum phase shift for trial periods for calculation of frequency step (0.05), and number of bins to divide a trial period (minimum number is 4, normal 6-8).

Two calculation modes were provided. (1) The main mode where the secondary period is divided by bins and the dispersion of light curves minimizes inside an each bin. This mode works without a special mention. (2) The mode when the primary period is divided by bins, and the dispersion of the secondary wave minimizes inside an each bin. This mode is useful if it is needed to study some subtypes of cataclysmic variables or to improve the primary period if secondary one is known. Minimum number of bins to be used is equal to 4. This number of bins may be used in the case of a few observations, and then the accurate date of extremum light curve shape should be set. The optimal number of bins is of $6 - 8$.

"**Continue**" – Continue running after a brake, if previous condition is saved in a file. But to continue the running, the observations should be put in computer memory beforehand.
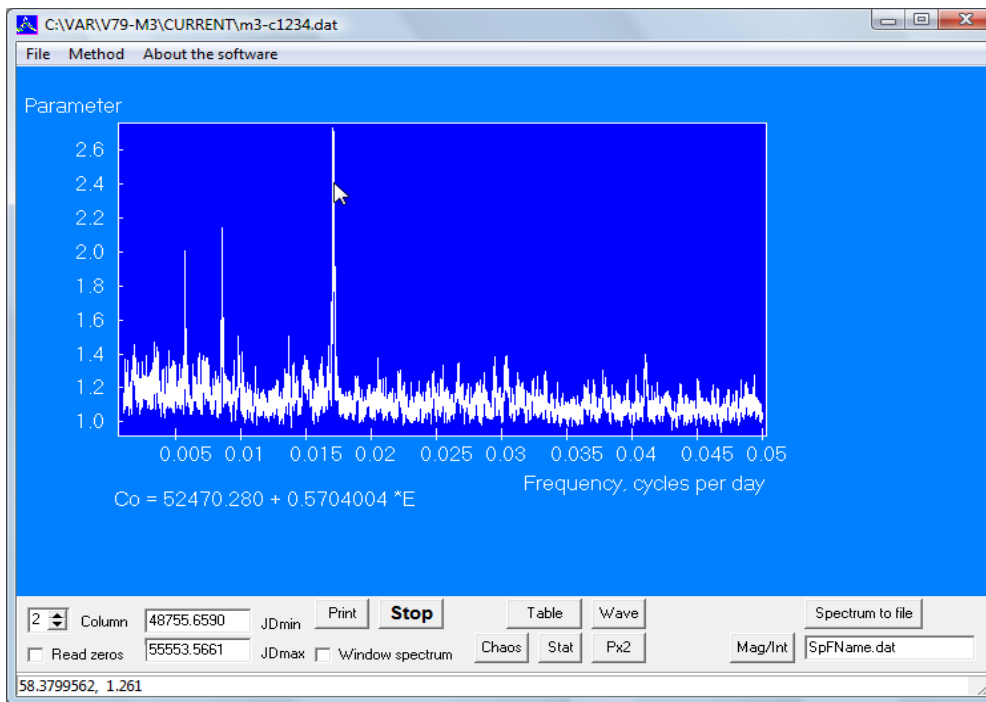
Figure 6. The software window with the periodogram for V63 in the globular cluster M3, an RR Lyr type variable with the Blazhko effect. The periodogram is a result of the search for amplitude modulation period. The highest peak marked by an arrow corresponds to modulation period 58.5259 day. The second high peak to the left corresponds to double value of this period.

"**About the software**". Here, the short description of the purposes and the basic capabilities of the software is printed.

Control panel.

The panel is located in the bottom of the software window. This is the description if buttons and editors of the control panel from left to right.

Figure 7. Control panel and StatusBar output string (bottom). All the buttons are shown including invisible ones which appear in the course of calculations.

"**Column**" – ScrollBar to select the column with the observational data for calculations. If not checked, the data from the first column will be put in the computer memory. The number of the column should be set before the data input.

"**Read zeros**" - CheckBox (the choice element which sets to read or not to read zeros in the column). In the observational file, zero means the absence of an observation. If not checked, zeros and corresponding Julian Dates will not be read. But in some cases when the observations are given in the form of magnitude differences Delta(Mag), the zeros in the tables may be significant values. In such a case one should mark this element by mouse click, and then a sign 'v' appears in the CheckBox.

"**JDmax**", "**JDmin**" – These are the editors to input the time moments of beginning and end of the time interval of data which should be read from the observational file. If the editor strings are empty then all the data from the chosen column will be read. The time moments should be set before the data input. After the data input from the observation file, the real extremum time moments appear in the editor windows.

"**Print**" – this is a button for graphical output of the software window into the file of Windows Bitmap (BMP) format. This file appears in the window of the graphical editor MSPaint. Then the graph may be edited for printer or for use in a scientific article, or transformed in other format.

"**Window spectrum**" – the choice element to calculate the frequency spectrum of time distribution (window spectrum) in the discrete Fourier transform. Click this CheckBox by left button of the mouse to calculate the window spectrum.

"**Stop**" – this is a button for stop running. Used when the result of calculation is yet obtained. When the calculation is brought to stop, the parameters of current condition may be saved ('File' – 'Save condition'), and then after data input, the running may be continued ('Method' – 'Continue').

"**Chaos**" – This button is used to prepare a chaotic (mixed) file to estimate significance levels of peaks in the Deeming amplitude spectrum. One may click this button any times and mix the observation series as much as one wants. In the each mixing act, the time moments of observations stay in its order, but magnitudes change their places accidentally with other time moments (Terebizh method [5]). The property of the chaotic set is the following: it has the same window spectrum as the original set, and the same magnitude distribution. The amplitude spectrum of a chaotic set should be calculated in the largest possible range of frequencies. The results of calculation are the cumulative distribution function for amplitudes, and the estimates of the amplitude levels which have frequency of presence in the chaotic series be equal to 90, 99, 99.9 and 99.99 per cent. These results may be saved in the "stat.dat" file using menu items: 'File' – 'Save statistics' for the further applications.

After finish of the amplitude spectrum calculation, the following numbers appear in the StatusBar output string in the bottom of the software window: N – the number of tests (trial light curves with arbitrary periods checked by the software) and Sigma – the dispersion of the chaotic amplitude spectrum (one may consider significant the peaks of the original set with the amplitudes larger than 3*Sigma).

"**Stat**" – the button. If the chaotic set is studied beforehand, one may show the results of statistical investigation from 'stat.dat' file in the amplitude spectrum of original observation set as the significance levels of 90, 99, 99.9 and 99.99 per cent. To do this, we should click the 'Stat' button and launch running by Deming method.

"**Table**" – this button puts out the table of 20 best values of period, and corresponding peak parameters and frequencies. To create the light curve with one of these periods, it is enough to click a line in the table.

"**Wave**" – this button may be used to build the mean average light curve when phased light curve is present in the window. The elements are shown under the light curve graph. Method of moving averages applied to calculate the mean light curve. The mean light curve graph may be used to smooth the light curve by hand, and then to delete smoothed periodic light curve from the original set (prewhitening procedure). In the graph of mean light curve, the errors of average points are also drawn. Smoothing the mean light curve sections may be done with drugging of pieces of a blue broken line by left button of mouse (MouseDrag procedure).

Smoothed mean light curves and their light elements are collected in a special file. Using the collection of mean light curves, one may fit real observations by model calculated as a sum of mean light curves of extracted waves, and then estimate the quality of the model representation.

"**Prewhitening**" – this button appears in the control panel if the mean light curve is present in the software window. Click to this button calls the dialog window "Moving average method calculation" where one may put the number of light curve in a file (1, if not changed), the number of mean points (phase interval to average), the value of phase interval to average, the file name where mean light curves are collected, and the file name for residuals after the wave subtraction. If the CheckBox 'Check to be not saved' is not checked the residual file receives the name printed in the editor window (lower editor line).

After clicking "OK" button, the set of residuals stays in the computer's memory which contains the residuals for the following wave subtraction, and in the screen graph, the residuals stay to be plotted versus the phase of subtracted wave (this is done to control the quality of wave subtraction. Procedures of prewhitening are the part of Fourier decomposition into periodic components.

"**Px2**" – creates the light curve with the double period relative to that one shown in the graph. This button is assigned to study the orbital light curve of the stars with the effect of ellipsoidal components because the frequency analysis gives only period of single wave (half of orbital period). If click is repeated, the light curve with the previous light elements is created.

"**Mag/Int**" – this button is previewed to switch between magnitude scale (Mag) and flux or intensity scale (Int) in all graphs of light curves. Stellar magnitudes decrease when brightness increases, and then the scale of magnitudes is directed downwards. Otherwise, the flux or the intensity scale is directed upwards. If not clicked, the software works in the magnitude scale.

"**Spectrum to file**" – the button to download the amplitude spectrum in a file, the name of this file is written in the editor line below. One may written another name in the line. One should take into account that the files of amplitude spectra may be very large.

"**All**" – this button appears in the control panel only when a fragment of the light curve is extracted. It is previewed to return to all observational data in the same graph.

Capability of program analysis

Method of graphical fragment extraction is realized with an OS Windows procedure MouseDrag. One may extract a single point to get information on the corresponding observation, and a group or a great number of points to save a part of observations in a separate file as a table.

The procedure works as follows: first, click a left mouse button after pointing its arrow on the upper left part of a fragment, then drag the arrow of mouse to the lower right part of the fragment not releasing its button, and finally release a button. When the mouse arrow moves, the white rectangle appears, so that the extracted fragment becomes limited by sides of this rectangle. When the mouse button released, the procedure executes.

The software window and all the graphs (excluding amplitude spectra or periodograms) change their scale and dimensions if drag the right corner of the software window.

"Light curve" – "For the primary period"

When the cursor (mouse arrow) moves inside the graph field, the graphical co-ordinates (phase and magnitude) of the cursor are reflecting in the StatusBar output string in the bottom of software window.

One may extract single points or groups of points in the graph of the light curve using left mouse button and MouseDrag procedure. Then the information window appears with the selected observation and question "Delete ?" If the button "Yes" will be clicked, the observation will be removed, and the light curve will be rebuild without the deleted observation. This procedure works only in the mode for the light curve of the primary period.

The extraction of observation in the plane Magnitude – Phase may be done with the same MouseDrag method using the left mouse button and the simultaneously pressed keyboard key "Ctrl". One can release a key "Ctrl" only after the left mouse button is released. The extracted points are marked by red color. Then the extraction may be saved in a separate file. To save extraction in a file go to menu items "File" – "Save extraction" and fill the lines of file output dialog window. If some file with the given name exists in the folder, the request appears to change the name.

It is possible to enlarge a fragment in the light curve using the same MouseDrag method by the same left button mouse and simultaneously pressed keyboard key "Shift". The new button "All" appears in the control panel. This procedure may be used to view small details of a light curve, eclipses, for example. The software returns from a fragment to a full-size phase light curve if the button "All" pressed.
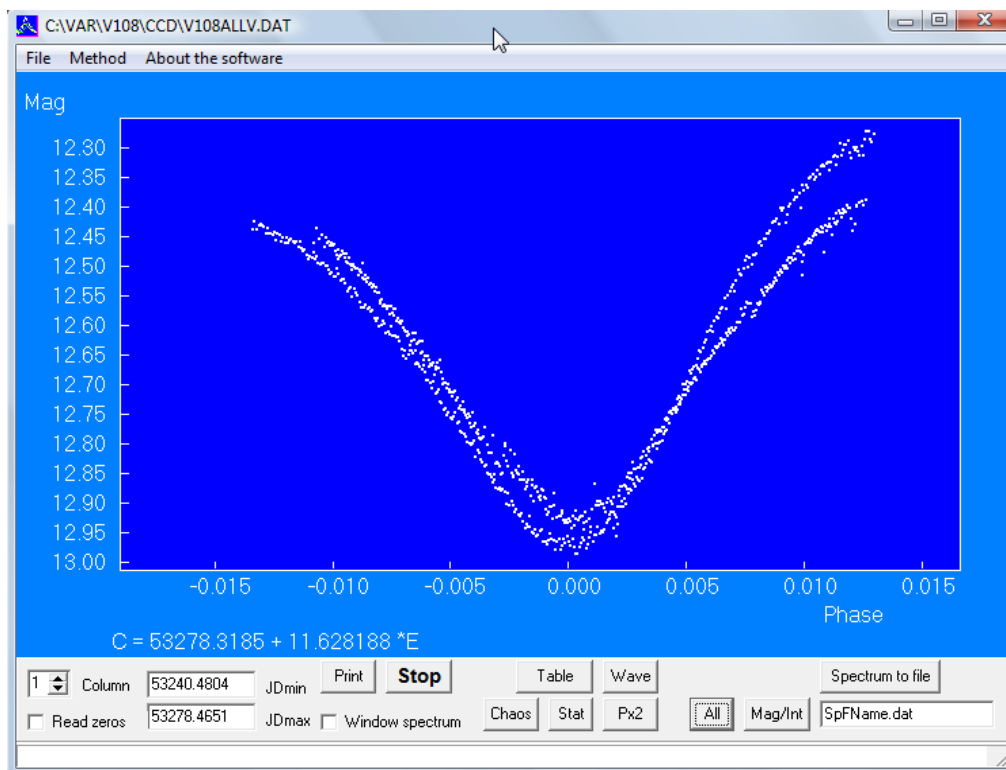

Figure 8. Fragment of the orbital light curve of eclipsing variable star GSC 4232.2830, the eclipse phases extracted.

In the extracted fragment, the possibility reserved to identify the points and to remove some points. The transition to full-size light curve size is realized by pressing "All" point.

"Light curve" – "Dependent on time"

In this mode, one may enlarge extracted fragment of the light curve using the procedure MouseDrag. Then a new button "All" appears in the control panel. This procedure is usually applied to view small fragments of light curves in the larger scale. One may enlarge scale of the fragment even greater if repeat the procedure, or return to full-size light curve graph if the button 'All' pressed.

There is a possibility to take values of Julian Date and magnitude from the cursor position. The cursor counts appear in the StatusBar output line at the bottom of software window.

There is a possibility to determine the accurate time location of eclipse minimum by method of combination of light curve with the same but mirror-reflected relative a vertical axis light curve. Such a location of this axis when the ascending and descending branches are coincided with their reflected parts may be considered as an accurate date of minimum. This position of the vertical axis is printed in the StatusBar output line as a Julian Date value.
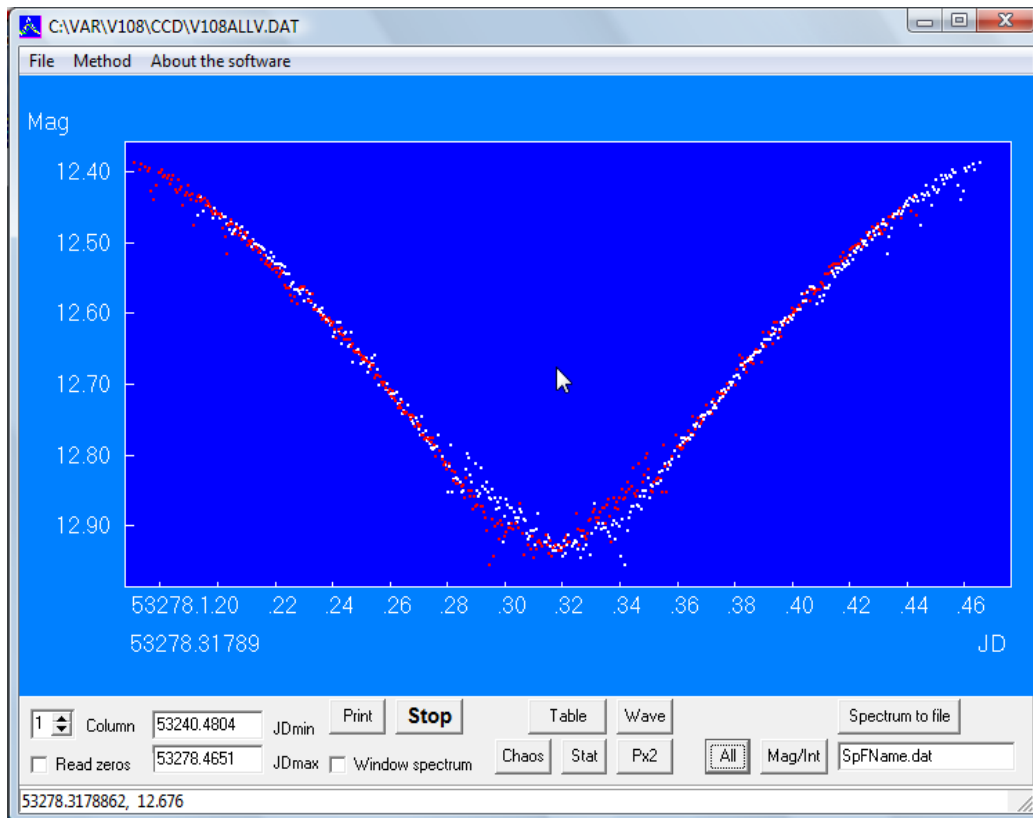

Figure 9. Measuring of the accurate date of eclipse center in the light curve of GSC 4232.2380 by matching the prime and the mirror light curves to find a symmetry center. Red points are the light curve reflected relative to the vertical axis marked by an arrow. The accurate location of symmetry axis is given below the graph.

This procedure is working in a following way. First, it is needed to select comfortable scale of the graph using MouseDrag method (press the left mouse button, move the mouse in such a way to cover a fragment by a white rectangle, and release the button of mouse). Then pressing the keyboard key "Shift" and not releasing this key click to the mead-eclipse by mouse arrow with pressing the left button of the mouse. As a result, the mirror-reflected light curve will be drawn in the graph with red points, and a time moment corresponding to reflection axis will be printed under the graph. If a white light curve, and red mirror-reflected light curve differ more than point dispersion, this operation should be repeated shifting the arrow in such a direction to minimize the inconsistency between red and white curves.

Exit from this procedure is realized by simple pressing of left mouse button without pressing "Shift" key and with an arrow in the field of the graph.

"Method" – "Lafler - Kinman", "Deeming" and "Secondary period"

When the arrow of the mouse moves in the field of periodogram, *the period* and the parameter values are reflected in the StatusBar output (whereas the periodograms are plotted versus *the frequency*). This gives

possibility to estimate the periods of several peaks of the periodogram with pointing them by mouse arrow. One can pick out the separate fragment of the periodogram to recalculate it with the larger scale.

References

1.Lafler J., Kinman T.D. *Astrophys. Journal, Supplement* 11, 216L (1965).

2.Deeming T.J. *Astrophys. and Space Science* **36**, 173 (1975).

3.Goranskij V.P. *Variable Stars, Supplement* (Rus.) **2**, 323 (1976).

4.Jurkevich I*., Astrophys. and Space Science* **13**, 154 (1971).

5.Terebizh V.Yu.. *Analysis of Time Series in Astrophysics*. (Rus.) Science. Moscow (1992).

Vitaly Goranskij, SAI, Moscow University, the researcher

Improvement on 2011 January 10: launch from command line or from batch-file.

In the command line first, a total name of executed (.exe) file (with the folder name) goes, then a total name of the observation file, then may be written (or not) three options: digits and letters.

The first option is necessarily the digit one of 1, 2, …9 that means the number of the column in the file of observations to input the data. The second option is a letter that means the type of the light curve which should be demonstrated on the window of the software: t – dependent on time (Julian Date); d or l – dependent on phase calculated with the elements given in the 3-rd and 4-th lines of the "default.cfg" file. The third option is the label "r". It means that the observations from data file taken on the last night in the phased light curve will be marked with the red color. Absence of this option, or other digit or letter in the place of this option means that nothing will be marked. This option is needed to control the star behavior in the course of on-line reduction of the observation.

These are the examples of commands with options.

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat

or

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 1

or

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 1 t

- gives the same result: the launch of the software from command line showing the light curve dependent on time with the data taken from the 1-st column of file "c:\ss433.ptm\current\all433c.dat".

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 2

or

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 2 t

- gives the same result demonstrating the time-dependent light curve using the data taken from the 2-nd column of file "c:\ss433.ptm\current\all433c.dat".

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 4 d

or

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 4 l

- gives the same result: the launch of the software from command line demonstrating phase-dependent light curve with the data taken from the 4-th column of the file "c:\ss433.ptm\current\all433c.dat". The elements (period and initial date) of the phased light curve are taken from the 3-rd and 4-th lines of the file default.cfg located in the same directory as the software "winefk.exe".

c:\ef\winefk.exe c:\ss433.ptm\current\all433c.dat 2 d r

- this command leads to a launch of the software from the command line with the demonstration of the phase-dependent light curve from the 2-nd column of the file "c:\ss433.ptm\current\all433c.dat". The elements (period and initial date) of the phased light curve are taken from the 3-rd and 4-th lines of the file "default.cfg" located in the same directory as the software "winefk.exe". At the same time, the observations obtained with the telescope in the last night (in the time range of 0.5 day before the last observation in the file) will be drawn with red color.

If such a command is written in a batch file (with the extension ".bat") and the label with the reference on this file is placed on the desktop of computer then all these actions will be done by single click on the label.