"TIME SERIES WORKSHOP" - OBSERVATIONS DATA PROCESSING TOOL

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ABSTRACT. The new tool for mathematical and visual processing of time series is represented. The program "Time Series WorkShop" (TSW) is specialized for processing visual observations of variable stars. An open structure of the allows to apply any old and new mathematical methods for searching any parameters of variability. The program also allows to visualize the time series and any calculation results (periodograms, histograms, light curves and their smoothing curves) in a camera–ready form. The following mathematical methods are realized: the periodogram analysis with "prewhitening", the method of "running parabolae", some methods of correction of observational series, including that taking into account the differences of the instrumental systems of individual observers. The possibility of exporting images into standard graphic formats and printing is specified. The program Time Series WorkShop has passed test trials at processing of visual observations of semiregular variable stars on the AFOEV and VSOLJ databases. TSW, like any other program product, will be developed by adding new mathematical methods and visualization improvement.

Key words: Time series analysis; Stars: semiregular, S Cam

Introduction.

The creation of the program "Time Series WorkShop" (TSW) is dictated by necessity to process large arrays of variable stars observations. "Time Series WorkShop" is oriented on mathematical and statistical handling of time series, and also, that on our sight is not less important, the high–quality graphic representation of outcomes. One of the tasks of TSW is the reduction of time expended on design of outcomes of evaluations. However, TSW is also a mathematical tool, in which the modern methods of searching parameters of variable stars oscillations are realized. The use of visual programming Borland DELPHI 3 in 32-bit operational system WINDOWS 95, and of the object-oriented programming language Object Pascal has allowed to obtain new possibilities in the field of time series processing.

The program contains algorithms of reading the data, including the special formats of the international databases of observations AFOEV and VSOLJ, which are accessible via Internet. The program automatically determines (by file extension) with what database it works, allows to merge databases in one and to save in a customary format - (columns XY) with the observer name indication. Unfortunately, VSOLJ database sometimes have error expressions (for example, a date 30.02.97), which are interpreted as a format read error and they cannot be used at processing.

"Time Series WorkShop" possibilities

Mathematical part of the TSW contains the following methods:

- Method of "running parabolae" (Andronov, 1997)
- Determination of the optimal value of filter half-width for the "running parabolae" method (Andronov, 1997).
- "O-C cutoff" correction observation data, based on "running parabolae" method;
- "Systematic differences of the instrumental systems of individual observers" correction,

based on "running parabolae" method (Chinarova, 1998)
- Periodogram analysis with precise period determination by using the method of differential corrections (Andronov, 1994).

Visualization part of the TSW:
- Light curve visualization.
- Periodogram building visualization.
- "Signal/noise" ratio building visualization.
- Several histogram visualization.

Additional functions of the TSW:
- Translation of the Julian date into the Gregorian date and backward.
- Reading data in the AFOEV and VSOLJ formats.
- Merge databases.
- Automatic sorting and filtering data files.

Smoothing by a method of " running parabolae "

The method of "running parabolae" was described by Andronov (1997). The program allows to compute a smoothing curve for processed series for a given filter half-width and filter type. There are four types of filter: 1, $(1-z^2)^2$, $1-|z|$, $\sin(2\pi z)/2\pi z$. Usually we apply the second type of filter.

Determination of the optimal value of filter half-width

For approximation by a method of "running parabolae" it is necessary to calculate an optimal half-width of a filter. In the TSW program is beinmg computed so-called "signal/noise" ratio (Andronov, 1997) or the ratio of mean-squared deviation of a smoothed value from the average to a mean accuracy of a smoothed value. The optimal half-width of a filter for approximation is determined as that corresponding to a maximum value of a "signal/noise" ratio. As the process of computation of "S/N" is rather long, the programm allows visual monitoring. Each computed value immediately is deduced on the graph. It is possible to obtain more precise value of a maximum by computing values in the vicinities of maximum with a smaller step. In a realization of a method there are following possibilities: to save outcomes in a file, to print the graph at any moment of evaluation process, to view and to continue the interrupted evaluations, to show progress of an evaluation by a visualization on the graph of each already computed point, to study in more detail any part of the graph chosen by the "mouse".

Filtration of data and correction for an individual system of the observer

In the TSW some methods of a correction of data are represented.
A "manual correction" - possibility of deleting "visually bad" points manually. Thus the light curve usualy becomes more suitable both for visual and mathematical processing. To check the process it is possible to look through a histogram of distribution of signal values.
"$O-C$ Cut off" correction of data using a method of "running parabolae". The essence of such correction consists of the following: the deviations of the observed values of a signal "O" from the smoothed "C" are calculated, the histogram of distribution of "$O-C$" is shown. Then a conventional maximum value Δm of "$O-C$" is chosen, and the data with larger deviations are deleted.
Systematic differences of the instrumental systems of individual observers are determined by averaging "$O-C$" for each author. For a reduction, these mean shifts are deleted from the original observations, if the ratio of mean value of "$O-C$" for the given author to the standard error of it is larger than 3 (3σ criterion). The individual observations are removed, if $|(O-C)-\langle O-C\rangle| > \Delta m$. The updated series can again be smoothed by the method of "running parabolae" and used for the time series analysis.

Computation of periodograms and "prewhitening"

The periodogram analysis is realized by using the least-squares algorithm described by Andronov (1994) used in his Fortran code FOUR-1. The test-function is determined as $S(f) = \sigma_C^2/\sigma_O^2 = 1 - \sigma_{O-C}^2/\sigma_O^2$. Here σ_O- is a mean-squared deviation of observations "O" from mean. The index "C" corresponds to calculated values and "$O - C$" to the deviations of observed values from the calculated ones.

The initial frequency is offered automatically with possibility of consequent editing at a value of $f_{begin} = 1/(t_n - t_1)$. The frequency step is shown for information, and varies at any modification of a number of frequencies (Points Count) or of a phase step $\Delta\phi$ in corresponding windows. Thus $\Delta f = \Delta\phi/(t_n - t_1)$.

Usually the number of trial frequencies is about 4000-8000. Also it is possible to process the periodogram analysis with a "prewhitening" - subtraction of the best harmonic fit from the data, recomputation of the perodogram for the residuals, subtraction of a new best fit sine etc (see Wehlau and Leung (1964) for details). In this case one should to set the desired number of "prewhitening" cycles. It is possible to monitor the process of an evaluation and construction of a periodogram immediately. Thus it is possible (without interrupting the process) to view interesting sites of a periodogram and make any conclusions, "zoom in" and "zoom out" the graph. After evaluations it is possible to save picture of a periodogram in a graphic format Windows BitMap (bmp), Windows MetaFile (wmf) or Enhanced MetaFile (emf) and print. Example of the periodogram is shown in Fig.1.

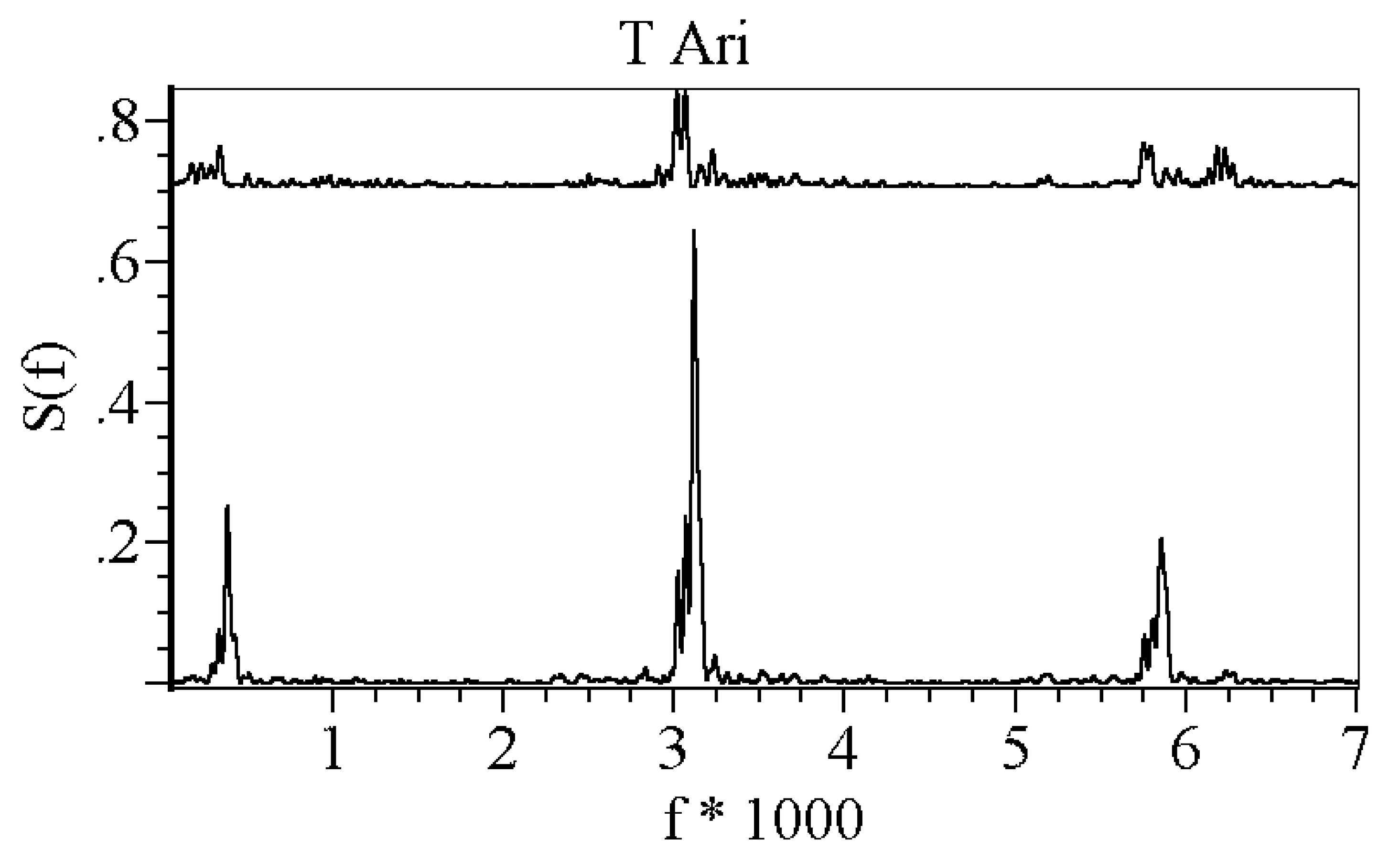

Fig.1. The periodogram representation in the TSW for original and "prewhitened" data.

Preparation of the light curves for visualization

The main function of the TSW is the automatic visualization of the light curve of variable star. The default type is shown in fig.2. Picture may be printed in any printer resolution or may be saved in a Windows BitMap (bmp) format.

The program allows to set up parameters of visualization: division of a light curve into parts of a total number determined by user. This possibility is intended for more detailed visual representation of a light curve. Also may be set the distance between the graphs (in mag), depth of a colour gamma, vertical (m) and horizontal (JD) axes of the graph. Set up is possible for titles of axes with a choice of the necessary font and its size, choice of a number of markers on axes, their fonts and sizes, automatic or manual breakdown of axes, and also a mantissa of markers. The program has a system of reports generated after calculation of all basic operations. The report can be viewed and saved in a file. Besides, TSW has auxiliary functions, for example, a translation of Julian date into Gregorian date and backward.

For a development of the program that fact was taken into account, that it should be simple and convenient in use and thus to make evaluations fastest. Besides the user should have a possibility to inspect the process and, if it is necessary, to interrupt evaluations without losing anything from already made. Therefore, the possibility of interruption of the process at any time is stipulated. Each realized method of evaluations has a "set up" window for setting parameters of the process.

The program "Time Series WorkShop" was tested at processing of observations of semiregular variable stars from the AFOEV and VSOLJ databases. The program is ready for use now and will be improved.

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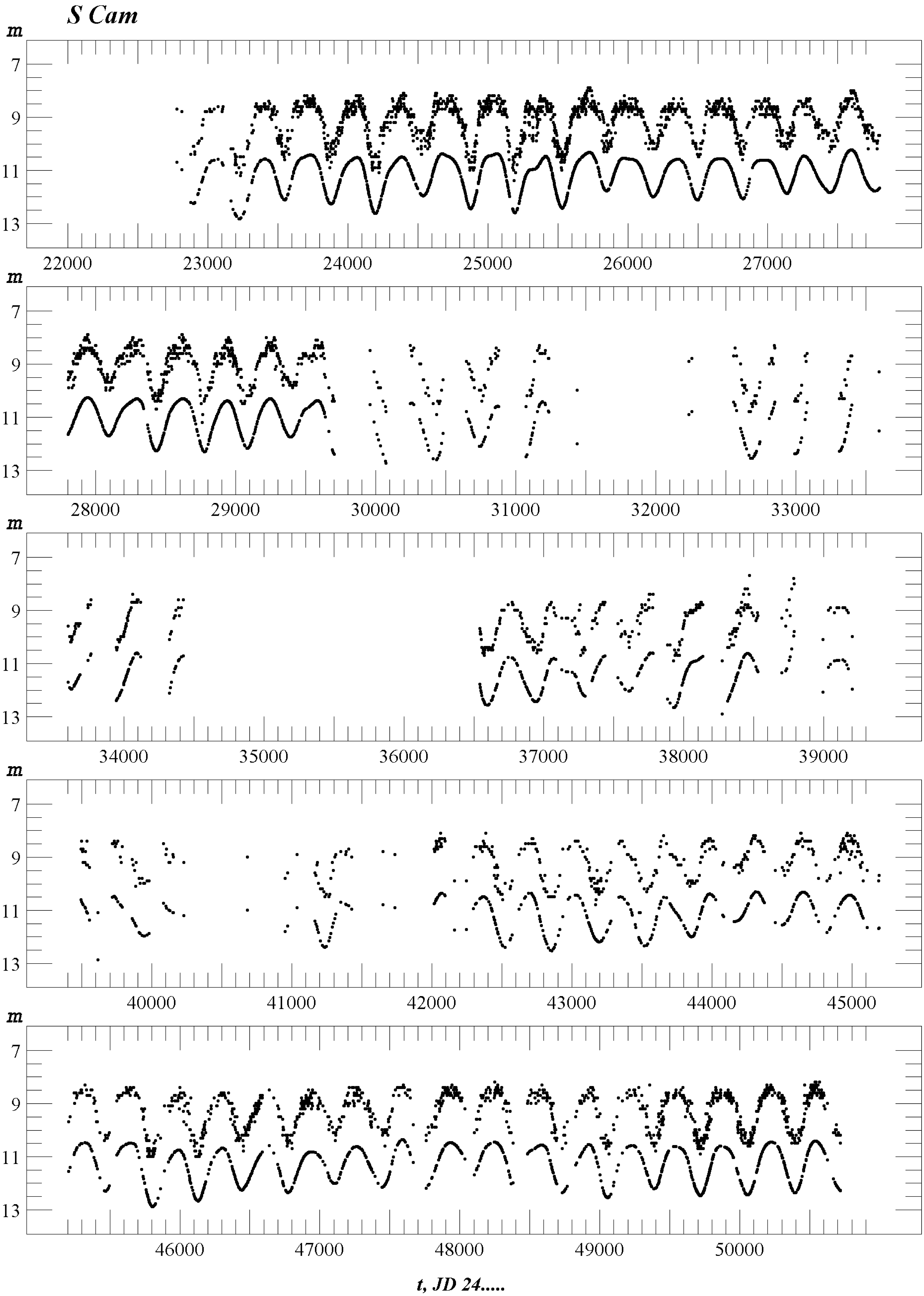

Fig.2. The light curve representation in the TSW. *Up:* original data, *bottom* "running parabolae" fit with an optimal value of the filter half-width Δt. The data are used from the AFOEV (*ftp://cdsarc.u-strasbg.fr/pub/afoev*) and VSOLJ (*www.kusastro.kyoto-u.ac.jp*) databases.