Time Series Analysis of Amateur Observations: Various Methods and Some Results

Ivan L. Andronov
Astronomical Observatory, Odessa State University, Ukraine (now Astronomical Observatory, Odessa National University, T. G. Shevchenko Park, Odessa 65014 Ukraine)

Present affiliation: Odessa National Maritime University, Mechnikova St. 34, Odessa 65029 Ukraine

Abstract Algorithms and programs are described which allow time series analysis of periodic, multi-periodic, quasi-periodic, and aperiodic signals of an arbitrary nature with equidistant and non-equidistant arguments. The methods are applied to the observations of semiregular, dwarf nova, eclipsing, and Mira-type stars.

1. Introduction

Variable stars exhibit a wide range of mechanisms and thus types of variability. To determine the model parameters, we have described programs which perform global smoothing; running (local) smoothing by using (weighted) spline, polynomial, and trigonometric fits; multi-frequency and multi-shift periodogram analysis; autocorrelation analysis which takes into account the influence of the finite length of the data and removal of arbitrary trends; parameter determination for "shot" and "red noise" models. The precise analytic expressions for the accuracy estimates are used to determine their numerical values. A brief description of the programs was presented by Andronov (1994a). A more extended review on the existing methods for the time series analysis of astronomical data can be found in Andronov (2005). The influence of the finite length of the data run on, and subtraction of the least-squares fit in general form from the autocorrelation function were discussed by Andronov (1994b).

2. Results and conclusions

By using these programs we have studied, e.g., the multi-periodicity of the semiregular variable RX Boo and of the cataclysmic variable TT Ari; the orientation changes of the white dwarf in the magnetic binaries AM Her and QQ Vul; the Blazhko effect in TT Cnc; and the presence of a third body in the eclipsing variable AK Her. Some dwarf nova stars show fast period changes from one value to another. These data were fitted by hyperbolic functions. Similar changes occurred in the semiregular variable AF Cyg. References to these studies may be found in Andronov (1994a).

An effective method of smoothing cyclic variations is the "running parabola" fit with an additional weight, proposed by Andronov (2005). The only free parameter is the filter half-width Δt. In Figure 1, the dependence on Δt is shown for the following parameters of the fit to AFOEV observations of the Mira-type star W And (Schweitzer 1993): estimates of the unit weight error σ_1 and σ_2; r.m.s. deviation of the smoothed values from the mean σ_C and from the fit σ_{O-C}; the estimates of the r.m.s. accuracy of the fit at the times of the observations $R\sigma_1$ and $R\sigma_2$; the proportionality coefficient $R = n_{eff}^{-1/2}$, where n_{eff} is the effective number of observations (cf. Foster 1996); and the "signal/noise" ratio $S / N = \sigma_C / R\sigma_1$. For W And, the optimal values are $S / N = 21$ (20–32 for other Mira-type stars), $\sigma_1 = 0^{m}.28$ ($0^{m}.15$–$0^{m}.27$), $R\sigma_1 = 0^{m}.09$($0^{m}.03$ – $0^{m}.06$).

It may be recommended to choose the optimal value of Δt which corresponds to the maximum value of S / N. This maximum occurs at $\Delta t = 0.545P$ for a harmonic signal with period P and added uncorrelated noise, and with a large number of data homogeneously distributed in the local interval. For real stars, this maximum is often shifted to $(0.25\ldots0.35)P$ because of the presence of harmonics in the main wave. The minimum of $R\sigma_1$ shifts from that value of Δt by not more than ~10%, which is not very crucial for the shape of the fit. The value of σ_1 for the optimal value of Δt is larger than its minimal value by 15%–20%, due to larger systematic deviations of the fit from the data.

References

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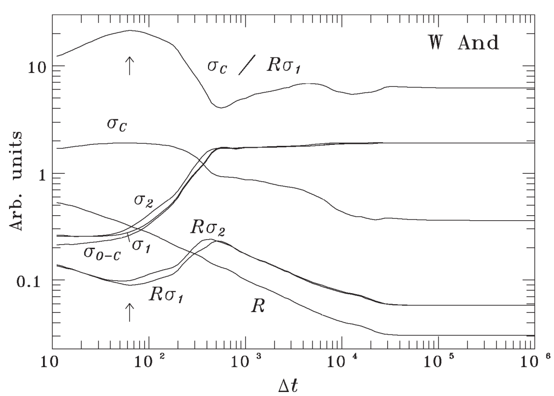

Figure 1. Dependence on Δt of the characteristics of the "running parabola" fit of W And. Vertical arrows mark the optimal value $\Delta t = 63^{d}$. The period is $P = 395^{d}.46$ (Andronov and Marsakova 2006).