"Asymptotic Parabolic" Fit for Light Curves

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Abstract A method is proposed for local approximation of light curves with nearly linear ascending and descending branches connected by relatively short phases of maximum or minimum.

1. Discussion

Light curves of many pulsating stars and the minima of eclipsing variables may be satisfactorily explained by mathematical approximation as well as by the "O–C" diagrams of such stars whose periods abruptly change from one value to another.

Andronov and Shakun (1990) have used hyperbolic functions to study abrupt "switches" of the outburst cycle length of some dwarf novae between two preferred values. Marsakova and Andronov (1996) proposed to use a more simple function which consists of two asymptotic lines connected with a parabola, so the function and its first derivative are continuous even at the "border points" T_1 and T_2. The free parameters are the slopes of the asymptotes, the value at their crossing, and the arguments of the "border points." Assuming that the arguments of the data are $t_1 ... t_n$ and $T_1 \le T_2$, one may obtain for this "asymptotic parabola" (AP) fit different functions: AP ($t_1 < T_1 < T_2 < t_n$); single line ($T_2 \le t_1$ or $T_1 \ge t_n$); broken line ($t_1 < T_1 = T_2 < t_n$); ordinary parabola ($T_1 \le t_1 < t_n \le T_2$). A program has been developed which allows the determination of T_1 and T_2 by using a method of differential corrections after their initial values are estimated by minimizing the r.m.s. deviation σ_{O-C} of the residuals from the fit on a grid. The practical difficulty solved by this program is that it takes into account the variety of types of functions mentioned above which affect the equations for differential corrections.

Figure 1 illustrates part of the light curve of W Lyr from the AFOEV database (Schweitzer 1993) and various fits for these 210 observations with m model parameters, i.e., the trigonometric polynomial (TP) of the first ($m = 3, 4$) and second

(m = 5, 6) order, with best fit period obtained for this individual data set (m = 4, 6) (Andronov 1994) and for the fixed value P = 197.15 days (m = 3, 5); the ordinary polynomial of the order 2 (m = 3) which coincides with the cubic spline with m = 3 and with the AP with $T_1 \leq t_1$, $T_2 \geq t_n$. However, the AP fit corresponds to m = 5 unknowns, thus from the statistical point of view, this fit must be compared to the ordinary and trigonometric polynomials and with the cubic spline of the same value of m. The "running parabola" fit (Andronov 1997) was computed using the best-fit value Δt = 56 days.

Our experience shows that the AP fit corresponds to better mean accuracy for the moment of extremum, but worse mean accuracy for the corresponding magnitude than that of other methods. Obviously, these values differ from those corresponding to this sample minimum. Thus this method is preferable for analyzing the period variations and parameters of the individual cycles.

2. Addendum, 2006

This method has been effectively used to determine characteristics of 173 semiregular variables (Chinarova and Andronov 2000), 71 Mira-type stars (Marsakova and Andronov 1998, 2000, 2006), intermediate (Andronov *et al.* 2005) and asynchronous (Andronov *et al.* 2006) polars, and other stars from the visual, photographic (mainly Odessa 7-camera astrograph), and CCD observations. Various methods of determination of extrema were comparatively reviewed by Andronov (2005).

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Table 1. Various fits for one of the extrema of W Lyr. See Figure 1 caption for details.

Line	T_e *JD 2400000+*	$\sigma[T_e]$	m_e	$\sigma[m_e]$	σ_{O-C}	*Fit*
0 S	47774.33	0.71	11.464	0.035	0.254	Polynomial $m = 5$
0 L	47744.00	0.71	10.892	0.047	0.432	Parabola $m = 4$
1 S	47776.61	1.32	11.572	0.036	0.247	Run. parab. $\Delta t = 56^{d}$
1 L	47773.60	0.90	11.460	0.035	0.265	Cubic spline $m = 5$
2 S	47777.80	1.55	11.660	0.036	0.208	T.P. $m = 6$, $P = 175^{d}.2$
2 L	47777.12	0.55	11.629	0.032	0.210	T.P. $m = 5$, $P = 197^{d}.15$
3 S	47770.23	0.52	11.573	0.043	0.295	T.P. $m = 4$, $P = 162^{d}.8$
2 L	47768.98	0.50	11.421	0.040	0.324	T.P. $m = 3$, $P = 197^{d}.15$
4 S	47663.13	0.69	11.933	0.027	0.634	T.P. for all data $m = 8$
4 L	47781.43	0.66	12.033	0.060	0.232	Broken line $m = 3$
AP	47777.94	0.62	11.653	0.081	0.212	Asymp. Par. $m = 5$

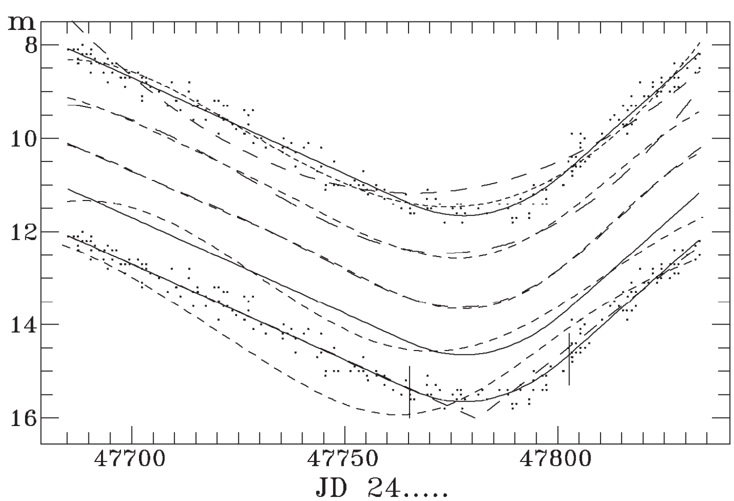

Figure 1. Various fits for one of the extrema of W Lyr (refer to Table 1). Solid line: the AP fit which coincides with the lines 1 L, 2 L, and 2 S. The solid lines correspond to the shift in magnitudes with respect to the observations (dots) and to the type of dashed line ("L" = long; "S" = short). Vertical bars mark the T_1 and T_2 positions of the switches of the parabola to the asymptotic lines.