Correlations Between Characteristics of Mean Light Curves of Long Period Variables

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Abstract The light curves of sixty-two Mira-type variables best covered by AAVSO observations made between 1974 and 1977 (AAVSO 1983) were approximated by a trigonometric polynomial fit with optimal values of the number of harmonics and of the period. Correlations between the pairs of twenty-five parameters are discussed.

1. Discussion

In *AAVSO Report 38* (1983) are published AAVSO observations of Mira-type stars over a 1,000-day period (JD 2442300–2443300, from 1974 to 1977). From the whole sample of stars we have chosen sixty-two of the best-observed objects and digitized the corresponding smoothed light curve to obtain the mean phase curve.

For this analysis we have used the program by Andronov (1994) which allows the use of a trigonometric polynomial fit. The preliminary value of the period was corrected by using the method of differential corrections for each order s of the trigonometric polynomial. Next, the r.m.s. residuals from the fit were analyzed using Fischer's criterion, and the value of s corresponding to the statistical significance of the last harmonic (≥ 0.99) was determined.

All computed parameters of light curves are subdivided into three groups: first, fundamental (period P, amplitude $\Delta\, m = m_{min} - m_{max}$, asymmetry $f = \phi_{max} - \phi_{min}$, degree of the trigonometric polynomial s); second, parameters of the extremal slope of the light curve; third, additional (parameters of harmonics).

The correlation table 25×25 was computed for these parameters. For sixty-one pairs the coefficient ρ exceeds 3σ. Eleven parameters correlate with f, nine correlate with Δm, and only eight correlate with P. It is interesting that the amplitude of the third harmonic (r_3) correlates with nine parameters, while the amplitude of the first

harmonic (r_1) correlates with only seven parameters. However, r_1 and r_2 correlate with Δm and f, and r_3 correlates only with Δm (concerning fundamental parameters). Coefficient $\rho\,(r_3 - \Delta m) = 0.79$ is larger than $\rho\,(r_2 - \Delta m) = 0.70$. An additional parameter $m_{is} = m_i P / (2\pi\Delta m)$ was introduced, where $m_i = t_i^{-1} = dm / dt$—the maximal slope of the incline, which is the ratio of the maximal slope to that obtained for a pure sinusoid of the same period P and amplitude Δm. It characterizes the slope of the phase curve scaled to the same amplitude for all stars. Contrary to the similar parameter of the descending branch m_d, it is correlated with nine parameters as shown in Table 1 (Figure 1, left).

Here r_k is an amplitude of the harmonic contribution, with a period P / k; ϕ_k is the phase of the maximum of this wave; and ϕ_m is the phase of maximum of the composite fit. Thus $\phi_3 - 3\phi_1$ is the phase of maximum of the second harmonic in respect to the main wave (Figure 1, right). The phase shifts and the ratio of the amplitudes are important in describing the light curves, as was initially noted by Kukarkin and Parenago (1937) for δ Cep—type stars, and is now widely used for comparison of observations with the numerical models of pulsation.

One or two stars stand out in several diagrams, among which are W And and χ Cyg, which have large amplitudes. The light curves (derived from *Report 38* light curves but not identical to them) and their error estimates are shown in Kudashkina (2003). For χ Cyg we found Δm = 8.99 mag. and P = 421.5d, compared to published values of Δm ~10 mag. and P ~408d. An examination of our light curve for W And (Δm = 11.08 mag., P = 399.2d, compared to published values of Δm ~7 mag., P ~ 396d) shows a lack of observations at minimum (for the relatively small time interval covering exactly 1,000 days, i.e., 2.5 cycles), and thus a very large error estimate of the minimum brightness. A real mean amplitude (which is variable, as in other Mira-type stars) may be estimated to be ~5 magnitudes from the AAVSO website (http://www.aavso.org) for all data. However, for uniformity of the data analysis, we have not used this value, mentioning an erroneously utstanding amplitude value from the trigonometric polynomial fit. This shows the importance of good coverage by observations of all phases of the light curve. However, these stars stay within the total picture for other parameters. X Oph stands out in diagrams $P - t_i$ and $\Delta m - t_i$. The light curve of this star is symmetric, the amplitude is very small $1^m.34$, and the time of the brightness change by 1^m is $t_i = 78^d$. Diagram $\Delta m - t_i$ shows two clusters of stars which cross at the point $\Delta m \approx = 5^m$, $t_i \approx 16^d$. There are more stars with long characteristic times t_i: X Cas (63^d), U Cyg (53^d), S Cep (55^d), V Aur (53^d). Note that many pairs of the characteristics are related, e.g., diagram $t_i - r_1$ resembles $t_i - \Delta m$, as the parameter r_1 correlates with the amplitude ($\rho\,(r_1, \Delta m) = 0.98$).

The results of the correlation analysis (i.e., both presence and absence of correlations) may be used to compare theoretical models of pulsation and to study evolutionary changes in stellar parameters.

References

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Table 1. Correlation of the slope of the phase curve, m_{is}, versus nine strongly correlated parameters.

m_{is}	P	m	f	Δm	r_1	$\phi_1 - \phi_m$	r_2	r_2 / r_1	$\phi_3 - 3\phi_1$
ρ	0.50	0.72	0.63	0.43	0.38	0.56	0.68	0.61	0.55
ρ / σ_ρ	4.4	8.1	6.3	3.7	3.2	4.7	6.4	5.3	3.4

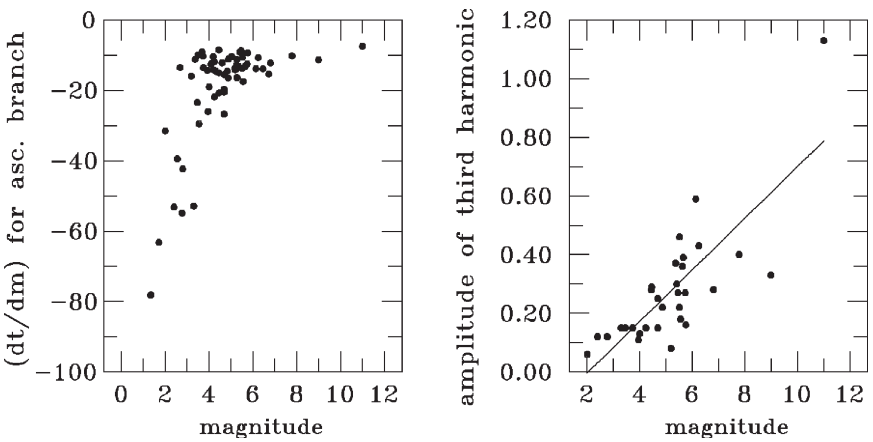

Figure 1. *Left:* the diagram *dt* / *dm* (for the ascending branch) vs. Δ*m*. *Right:* the diagram r_3 vs. Δ*m*.