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A FOURIER SERIES METHOD FOR PLOTTING O-C GRAPHS

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Abstract

A Fourier series representation of a light curve permits the calculation of O-C values for individual observations.

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The Fourier Series method of O-C analysis starts with a knowledge of the basic shape of the star's light curve. With a good first approximation of the period, a model light curve (magnitude vs. phase) can be plotted for the star. Such a graph defines changes in magnitude quite well because many cycles are forced to overlap each other. In plotting this light curve it is preferable to choose a subset of the total observations that are relatively close together in time. This precaution eliminates any significant scatter along the abscissa due to the slightly incorrect period approximation. Also, there should be a sufficient number of observations in order to clearly define the curve.

After this light curve has been plotted, the scatter is reduced by condensing the observations into a well-defined shape. One method for obtaining a neat curve is to form running means, i.e., to designate each point in the original graph as the beginning of a set of points sequential in phase. The number of points in each set is arbitrary but was typically between five and seven in an application of this method to V Comae Berenices (Holliman 1986). A point is then plotted on the condensed graph at the average magnitude and average phase of all points in a given set. Thus, the number of sets is equal to the number of observations and each set produces one point on the condensed graph.

The next step is to express the light curve as a Fourier series. Integration is performed over one cycle of the condensed graph to find the Fourier series coefficients, by the formulae in Swartz (1973). My experience with V Com, an RR Lyrae star of subclass **ab**, showed that six to eight terms of the Fourier series typically represent the condensed graph most accurately. The sum of these terms provides an equation expressing magnitude as a function of phase.

Calculated phases for each observed magnitude are now found by plugging successive approximations of phase into the Fourier equation until it yields the observed magnitude. Since the light curve from which this Fourier series representation is derived need not have a peak at phase zero all phases plugged into the equation must have an offset constant applied to them. This constant effectively slides the graph of the Fourier equation along the abscicca so that its peak will occur at phase zero. The correction guarantees that the calculated phase of an observation at peak intensity will be zero, as defined by the adopted epoch and period.

For every magnitude other than maximum and minimum there will be two phases, one each on the ascending and descending branches of the light curve. To choose between them the computer analyzes the calculated phases of observations close together in time. The phase values which are most consistent with each other are then selected. Unfortunately, not every observed magnitude can produce a useful phase. The light curve for a type RRab variable, for example, usually levels out at the faintest magnitudes. As a result, the very faintest observations in the cycle suggest phase values too sensitive to changes in brightness, so they must have been removed from this analysis. For magnitudes that are retained, the weight of the derived phase can be made to depend on the slope of the light curve at that magnitude.

This procedure, which has been programmed in BASIC for an IBM PC, gives a value of C for each observation, namely the phase at which the observed magnitude is calculated to occur. O, the phase at which it was observed to occur, is found in the usual way by taking the fractional part of (JD-Epoch)/Period.

The procedure is automatic, but it is important for the user to verify graphically that the shape of the observed light curve closely matches the shape given by the sum of the terms of the Fourier series. Verifying the appropriateness of the two curves will assure the validity of this method.

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REFERENCES

Holliman, J. H. 1986b, **Journ. Amer. Assoc. Var. Star Obs.**, this issue.
Swartz, C. E. 1973, **Used Math**, Prentice-Hall, p. 195.

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UPDATED ELEMENTS FOR V COMAE BERENICES

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Abstract

Parabolic elements are determined for the RR Lyrae star, V Comae Berenices, implying that the period increases at a rate of 0.15 day per million years.

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Kholopov et al. (1985) listed elements for V Com which I adopted for plotting my light curves and O-C graph:

$$JD_{(max)} = 2440683.940 + 0.46914575\ E. \qquad (1)$$

The elements were updated by combining observations from Hoffmeister (1923), Kukarkin (1933), and the Harvard College Observatory plate collection with observations from plates taken more recently at the Maria Mitchell Observatory. 320 observations were of quality acceptable for this analysis.

To update the elements, I made an O-C graph by a method in which each point represents a single observation (Holliman 1986a). This was accomplished by first representing the light curve (magnitude vs. phase) by a Fourier series which peaks at phase zero. The equation is solved by successive approximations for the two possible phases corresponding to an individual observed magnitude. These represent the ascending and descending sides of the cycle. The computer selects one calculated phase for each observation creating the most self-consistent set of calculated phases possible for the O-C plot.

The resulting O-C diagram is shown in Figure 1 with a parabola fitted to the data by least squares. The new heliocentric elements are:

$$JD_{(max)} = \underset{\pm 0.002}{2430919.185} + \underset{\pm 0.00000007}{0.46914189}\ E + \underset{\pm 0.42 \times 10^{-11}}{9.64 \times 10^{-11}}\ E^2. \qquad (2)$$

This precision is possible because some observations are dated as far back as 1896 and because there are few gaps in the data. These elements imply a rate of change of period equal to 0.150 ± 0.006 day per million years.

More observations are needed to verify that the O-C graph continues to suggest a parabola. It has not been ruled out that V Com's period may have increased since the turn of the century and has recently leveled off.

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REFERENCES

Hoffmeister, C. 1923, **Astron. Nachr. 218**, 320.
Holliman, J. H. 1986a, **Journ. Amer. Assoc. Var. Star Obs.**, this issue.
Kholopov, P. N. et al. 1985, **General Catalogue of Variable Stars**, 4th edition, Moscow.
Kukarkin, B. W. 1933, **Russian Var. Stars 4**, 213.