COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS

Number 1347

Konkoly Observatory
Budapest
1977 October 10

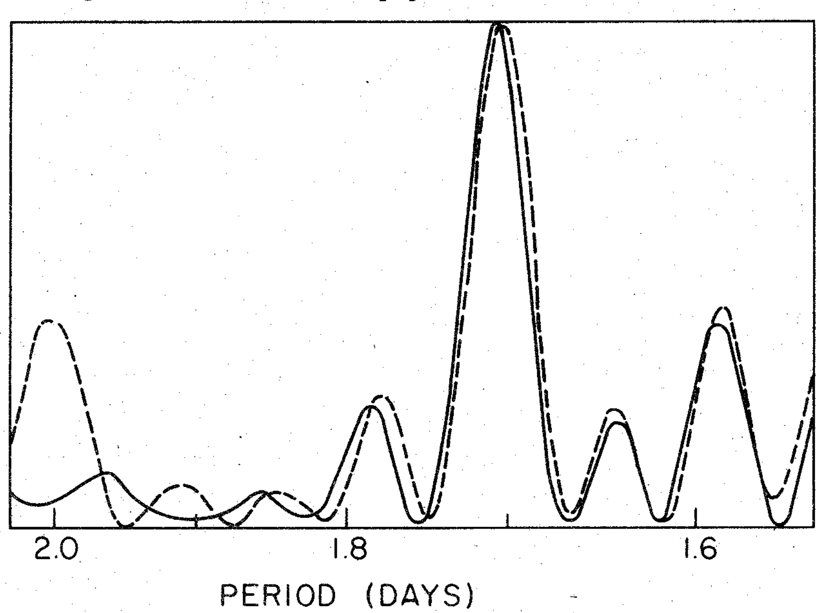
PRACTICAL FORMULAE TO SEARCH PERIODICITIES IN VARIABLE STARS

The distribution of the dates in the series of observations of variable stars are often very irregular. The spacing between consecutive dates may range from hours to weeks or even months. Such unlikeness forbids the use of classical methods to search periodicities, or, at least, makes its use very hazardous. Nevertheless, the use of the fast Fourier transform is almost generalized among astronomers under the pretext that the results obtained are fairly good. In fact we obtained some good results in the study of some BY Dra stars observed at the I.T.A. Astronomical Observatory before 1974. However this has not been always true and practical questions arose when comparing some completely different results obtained for HD 319139 using the fast Fourier transform or the Lafler-Kinman method. The light curve of BY Dra stars are characterized by small amplitude and great noise, and in 1975 we adopted a new technique to deal with series where the dates are arbitrarily spaced. This technique is a natural generalization of the fast Fourier transform and gives more accurate estimates.

In the figure, we show the periodogram obtained for 21 V-magnitudes of the star HD 319139 observed by C.A.O. Torres and I.C. Busko at Cerro Tololo in 1974 (solid line); we also compare it to the periodogram obtained with the classical fast Fourier transform (dashed line).

Recently, in a review paper presented in the Colloquium on Close Binary Stars held in Sao Paulo we have shown the way in which the technique may be generalized to more complex cases like those were the data consist of N pieces of continuous records or where the data have different precisions.

A typical example of problem involving unevenly spaced data of different precisions is the problem of the search of periodicities (and beats) in irregular, semi-regular or long-period variable stars. In this case the measurement I(ω) of the power spectrum at the trial frequency ω is given by the expressions in the next page.



$$x_j = 2\pi\omega t_j$$

$$a_o^{-2} = \Sigma\ w_j$$

$$a_1^{-2} = \Sigma\ w_j \cos^2 x_j - a_o^2 (\Sigma\ w_j \cos\ x_j)^2$$

$$a_2^{-2} = \Sigma\ w_j \sin^2 x_j - a_o^2 (\Sigma\ w_j \sin^2 x_j)^2 - a_1^2 (\Sigma\ w_j \cos\ x_j\ \sin\ x_j)^2$$
$$- a_o^4 a_1^2 (\Sigma\ w_j \cos\ x_j)^2 . (\Sigma\ w_j \sin\ x_j)^2$$
$$+ 2a_o^2 a_1^2 (\Sigma\ w_j \cos\ x_j) . (\Sigma\ w_j \sin\ x_j) . (\Sigma\ w_j \cos\ x_j\ \sin\ x_j)$$

$$c_1 = a_2\ \Sigma\ w_j f(t_j) \cos\ x_j$$

$$c_2 = a_2\ \Sigma\ w_j f(t_j) \sin\ x_j -$$
$$- a_1 a_2 c_1 (\Sigma\ w_j \cos\ x_j\ \sin\ x_j - a_o^2\ \Sigma\ w_j \cos\ x_j . \Sigma\ w_j \sin\ x_j)$$

$$I(\omega) = c_1^2 + c_2^2$$

In these formulae t_j are the observation dates and w_j the weights of the observations. The measures $f(t_j)$ are referred to their mean value, i.e., they are shifted in a way such that $\Sigma\ w_j f(t_j) = 0$. All other symbols are intrinsic quantities.

The light curves under study may be formed by several waves, not necessarily harmonic (as in Blazhko effect). In such cases, before searching for a secondary period, it is necessary to filter the time-series from the main wave. If ω_1 is the main frequency, the filtered time-series is given by

$$g(t_j) = f(t_j) - d(t_j)$$

where

$$d(t_j) = d_o + d_1 \cos x_j + d_2 \sin x_j$$

$$(x_j = 2\pi\omega t_j)$$

and

$$d_o = - a_o^2 (d_1 \Sigma w_j \cos x_j + d_2 \Sigma w_j \sin x_j)$$

$$d_1 = a_1 c_1 + a_2 a_1^2 c_2 (a_o^2 \Sigma w_j \cos x_j . \Sigma w_k \sin x_k - \Sigma w_j \cos x_j \sin x_j)$$

$$d_2 = a_2 c_2$$

The secondary frequencies are searched in the periodogram of the filtered series $g(t_j)$.

The epoch of the minimum in the main wave is one of the two roots of $tg\ x_o = d_2/d_1$.

S. FERRAZ-MELLO
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