OBSERVATIONS OF EVOLUTIONARY CHANGES IN THE PULSATION PERIOD OF CEPHEIDS

L. Szabados
Konkoly Observatory of the Hungarian Academy of Sciences
Budapest, P.O. Box 67
H - 1525 Hungary

In spite of the fact that Cepheid variables pulsate quite regularly their pulsation period remains constant only in the first approximation. The pulsation period is subject to variations because of stellar evolution. The calculations made by Hofmeister (1965) predicted that the evolutionary period changes of classical Cepheids should be observed on a time scale of several decades or longer. No detailed analysis of the observed period changes has been made since Hofmeister's fundamental theoretical work.

The available data concerning the period variations observed in classical Cepheids did, however, result in several useful pieces of information. Petit (1978) attempted to study the period changes of Cepheids on the basis of the remarks in the General Catalogue of Variable Stars (Kukarkin *et al.*, 1969-1970). One of the problems that was not solved, however, was that the use of inhomogeneous data resulted in less reliable statistics. Erleksova and Irkaev (1980) suspected that the observed progressive period changes were of evolutionary origin but they approximated the O-C diagrams by sections of straight lines instead of parabolas. Wayman (1981) estimated the period variations on the basis of independent determinations of period. Since the differences in the period much exceeded the theoretical period changes in several cases, he suggested that some causes of period change other than stellar evolution across the HR-diagram ought to be sought. The observed period variations of individual Cepheids do indicate, however, that the changes are mainly due to stellar evolution, at least in the case of the rapidly evolving long period Cepheids (see e.g. Fernie, 1979).

Extensive analysis of the O-C diagrams of Cepheids (Szabados, 1977, 1980, 1981 and 1983) made it possible to search for evolutionary period changes. The large frequency of parabolic O-C graphs (i.e. continuous period changes) serves as qualitative proof of its observability (see Figure 1). Parabolic O-C graphs occur more frequently with longer period classical Cepheids since the rate of evolution is faster for these stars. On the other hand, the numerical values of period changes as a function of the pulsation period also supports the assumption that stellar evolution can be caught by observations.

A brief summary of the theoretical and observed period changes

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Table I
Theoretical period variations due to stellar evolution (after Hofmeister, 1965)

Mass	Crossing	Average period	$\left[\frac{\Delta P}{P}\right]_{100}$
$5\mathfrak{M}_\odot$	1	$1^d.8$	+0.0014
	2	3.5	±0.00001
$9\mathfrak{M}_\odot$	1	12.4	+0.027
	2	22.4	-0.0054
	3	23.9	+0.0030
	4	27.0	-0.0079
	5	16.5	+0.024

Table II
Observed period changes

Average period	$\left[\frac{\lvert\Delta P\rvert}{P}\right]_{100}$
$4^d.2$	0.000035
6.0	0.000052
9.1	0.000068
16.0	0.00023
36.0	0.0049

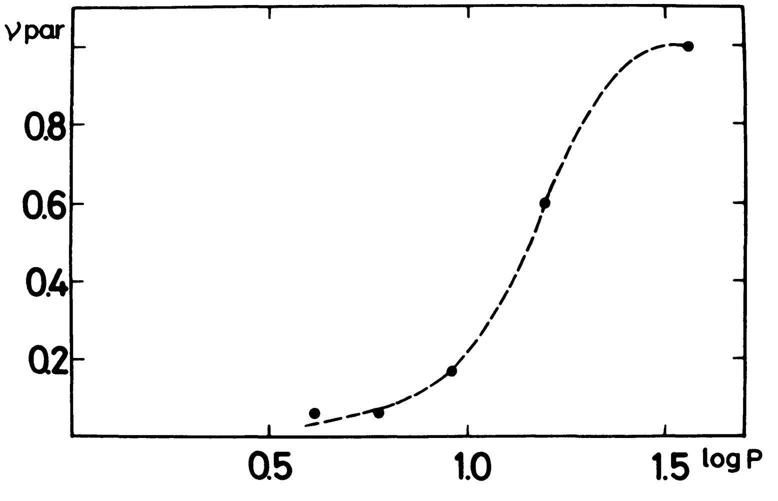

Figure 1. Relative frequency of parabolic O-C diagram vs. the logarithm of the period.

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is to be found in Tables I and II, respectively. In Table I the mass and crossing of different models as well as the average period and the predicted relative period variation within 100 years are indicated in the successive columns. Its observational counterpart in Table II gives the average period and the absolute value of the observed relative period variation within 100 years.

The agreement between the theoretical and the observed values is noteworthy especially in the case of longer period Cepheids. According to the O-C diagrams at an average period $P = 36^{d}.0$ the relative period change within 100 years is 0.0049 , while the theoretical value (averaged from the second, third and fourth crossings of a $9\,\mathfrak{M}_{\odot}$ Cepheid) is 0.0054 at an average period of $24^{d}.4$. (The first and fifth crossings have not been considered here since Cepheids have a much shorter pulsation period in these particular cases.)

The short period Population I Cepheids show a somewhat larger period variation than predicted by the stellar evolution. This may be caused by other kinds of period change for which the term 'period noise' is used. Since the shortest period Cepheids have the smallest evolutionary period changes this kind of variation may be commensurable with the period noise. In the case of the long period Cepheids the rate of period change caused by stellar evolution is far larger than the period noise, the latter kind of period change does not contribute significantly to the relative period variation within 100 years. The period noise, however, can be seen in the O-C diagrams of long period Cepheids, as well. It occurs as an irregular variation superimposed on the parabola.

Cepheid variables in the Magellanic Clouds seem to behave in a different way, viz. they are strongly affected by period noise, although parabolic O-C graphs also exist among the MC Cepheids (van Genderen, 1983). It is hoped that further O-C diagrams covering a longer time base will mitigate this difference.

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DISCUSSION

Burki: The O-C diagram is also very useful to detect cepheid binaries. How many new binaries did you find with our diagrams?

Szabados: The apparent period changes due to light-time effect were detected in five cases. Moreover, a stepwise O-C diagram ("rejumping" period) characterizes some of the binary cepheids.

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