CEPHEID PERIOD CHANGES AND STELLAR EVOLUTION

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The question of whether or not the period changes observed in some classical cepheids are due to evolution across the HR diagram remains controversial. On the one hand, it is known that the stars are indeed evolving across the diagram and are therefore changing their radii and must therefore be changing their periods. On the other hand, only a fraction of cepheids appear to have period changes, and some of these seem to be in the form of sudden jumps. Is it then that the evolutionary changes are too small to be detected, and the observed changes due to something else? This note explores the question.

First we consider the period changes predicted by stellar evolution theory. Second, we shall compare these predictions to the observed changes. Finally, we discuss briefly the problems of sudden jumps and the small number of cepheids showing period changes.

For theory I have used the models of Becker, Iben, and Tuggle (1977: hereafter BIT). They show detailed evolutionary tracks on the theoretical HR diagram near the cepheid instability strip for 3, 5, 7, and 9 solar masses and a variety of chemical compositions. For each track I have read off the diagram the values of log L and log Te at each point where the track enters and leaves the instability strip. The corresponding fundamental period of pulsation was then calculated from equation (4) of Iben and Tuggle (1975), which gives P as a function of luminosity, temperature, and mass. Tables in BIT give the ages of the models located at the edges of the instability strip. Thus one obtains the change in period and age across the strip, and hence an average value of dP/dt at an average period.

An important point must be made here. The above data also give the time taken by a cepheid to cross the instability strip. These crossing times are very dependent on chemical composition and it is difficult to generalize from the rather coarse grid of models, but it is clear that no one particular crossing of the strip is completely dominant. It was long believed that virtually all cepheids are in their third crossing of the strip, based on the rapidity of other crossings. The BIT models, however, do not bear this out. Space precludes a full discussion, but as an example a 5 $M_\odot$ model of high helium content ($Y=.36$, $Z=.02$) spends 940 thousand years on the second crossing and 560

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thousand on the third crossing. The same mass with low helium (Y=.20, Z=.02) has second and third crossing times of 620 and 680 thousand years respectively. Similar trends are to be found at other masses. This may have serious implications for studies involving the 'effective' mass-luminosity law for cepheids. Its importance for this study is that we need not be deterred by finding a thorough mix of positive and negative period changes, because the probabilities of a cepheid being on its second or third crossing are similar and the second crossing will produce a negative period change while the third will show a positive change.

The calculated period changes (expressed in sec/yr) are shown in Figure 1 as a function of mean period. The numbers refer to the crossing, and one may note that even-numbers imply $\dot{P}<0$ while odd-numbers imply $\dot{P}>0$. They lie in a band shown roughly by the two slanted lines, the slope of which indicates that $\dot{P}$ increases as P^3. No segregation of the data by chemical composition is evident.

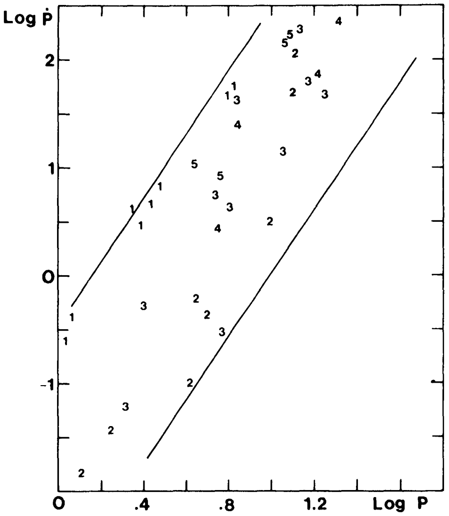

Fig. 1. Theoretically predicted rates of period change.

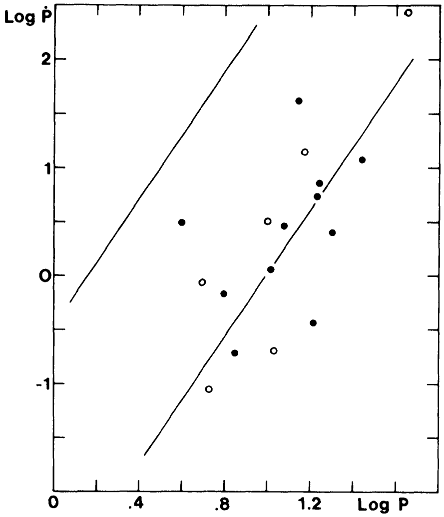

Fig. 2. Observed rates of period change.

I have made use of the extensive material of Szabados (1977, 1980, 1981) to compile the observed period changes shown in Table 1. This, of course, is seriously incomplete, including only those northern cepheids he happened to observe himself.

Table 1

Star	P	$\dot{P}$(sec/yr)	Star	P	$\dot{P}$(sec/yr)
α UMi	3.97	+3.2	SZ Cas	13.64	+46
V Lac	4.98	-0.85	RW Cas	14.79	-14
δ Cep	5.37	-0.089	X Cyg	16.39	+0.38
RS Cas	6.30	+0.67	CD Cyg	17.07	+5.5
η Aql	7.18	+0.19	SZ Aql	17.14	+7.4
SY Aur	10.14	+1.1	VX Cyg	20.13	+2.5
ζ Gem	10.15	-3.2	T Mon	27.03	+12
Z Lac	10.89	-0.20	SV Vul	45.0	-290
RY Cas	12.14	+2.8			

The observed values are shown plotted in Figure 2, with open circles representing negative changes, filled circles positive changes. The slanted lines come from Figure 1. As expected, no observed values lie near the upper line, which is mainly set by the very fast first crossings. Even so, the theoretical lower boundary is high - by about a factor of 5, in fact. Nevertheless, considering the many orders of magnitude over which these quantities could range, agreement is not unreasonable. The important conclusion, I think, is that the observed period changes are almost certainly due to evolution; otherwise where are the evolutionary changes, they being at least as large as any change observed?

Finally, the problems of sudden period jumps and the low percentage of cepheids showing period changes. The case of Polaris is illuminating; it has been quoted in the literature for many years as having shown a sudden period jump around 1927, yet a new, careful study (Arellano Ferro 1983) now shows that to have been simply a miscount of cycles. Polaris, it turns out, has historically always shown a smooth period increase. This is not to say that sudden jumps cannot occur, but I suspect their frequency is less than appears and perhaps inadequately substantiated.

Similarly, I believe we currently have only a poor idea of how many cepheids really show period changes. One is struck by the number of very well-known cepheids in Table 1, the implication being that if a star is studied long enough and often enough and carefully enough, a period change is revealed. Clearly, a detailed objective study of these problems would be worthwhile.

REFERENCES

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DISCUSSION

Tayler: Am I correct in thinking that you plotted the average theoretical $\dot{P}$ for each crossing? If so, since the actual $\dot{P}$ will vary between a small multiple of the average and zero, you must expect a larger spread below the theoretical value in log $\dot{P}$ than above it.

Fernie: Yes, it is the average P that is plotted. I agree the scatter would be larger below than above the lower theoretical envelope.