RECENT WORK ON BEAT CEPHEIDS AT MOUNT STROMLO OBSERVATORY

S. L. Barrell, B. C. Cogan, D. J. Faulkner
Mount Stromlo and Siding Spring Observatories,
Australian National University, Canberra.
and R. R. Shobbrook
School of Physics, University of Sydney, Sydney.

Beat Cepheids continue to pose a number of unanswered questions concerning the behaviour of stars near the short-period end of the Cepheid instability strip; in particular, why is it that such a high proportion of stars with fundamental period $\lesssim$ 5 days exhibit simultaneous pulsation in both the fundamental and first-overtone radial modes, and why is it that these stars exhibit such a narrow range of period ratio ($P_1/P_0 \simeq 0.71$)? A programme of observation and Fourier analysis of beat Cepheids is presently being undertaken at Mount Stromlo and Siding Spring in an effort to understand these phenomena.

There is now evidence that, for the two best observed stars of this class - U TrA and TU Cas, both the period and the relative mode amplitudes are slowly changing with time. U TrA was observed in detail during the years 1953-59 by Oosterhoff (1957) and Jansen (1962), and a new series of 481 five colour observations of this star was obtained by Faulkner and Shobbrook (1979) in 1977. Using $E = \Sigma(\text{Amp} \times \text{Freq})^2$ summed over all the Fourier terms for a given mode as a measure of the pulsational energy associated with that mode,we can use this 20 year timebase to calculate the change in relative mode energy. For U TrA the energy of the overtone is increasing (see Table I). Similarly we can compare the fundamental period derived for these 20 years with an earlier period estimate of Oosterhoff (1957) to obtain the rate of frequency change shown.

For TU Cas there are 1194 photoelectric measures published in substantial sets, covering the years 1954-78 (Worley and Eggen 1957; Cocito and Masani 1960; Vasiljanovskaja 1966; Gieseking and Radeke 1978; Niva and Schmidt 1979). These have been Fourier analyzed by Faulkner and Cogan (1979) yielding the results for period and amplitude change shown in Table I. It will be seen that the changes for TU Cas are in the opposite sense to those for U TrA and are appreciably more rapid. The frequency changes may be compared with those predicted by evolutionary theory for a 5 $M_\odot$ star - ~+4 x 10^{-10} d^{-2} for the blueward and ~-2 x 10^{-9} d^{-2} for the subsequent redward evolution.

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 483–485.

https://doi.org/10.1017/S1539299600004317 Published online by Cambridge University Press

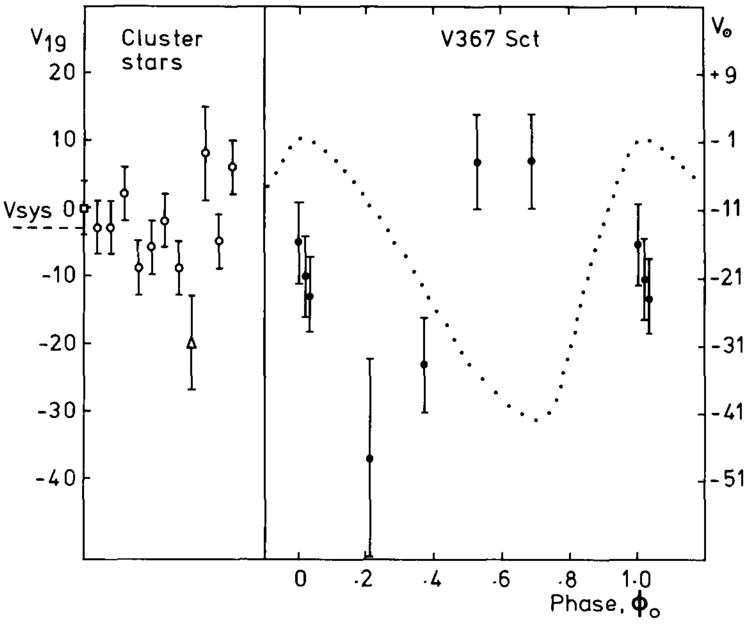

Figure 1 Radial velocities of NGC 6649 cluster stars and V367 Sct with respect to star 19 (left hand ordinate) and with heliocentric corrections (right hand ordinate). Cluster stars are shown by open circles with an open square for star 19 and open triangle for star 56, a possible non-member.

The various velocities of V367 Sct, dots, are plotted against fundamental phase and a schematic scaled light curve is superimposed

$$(V_{SYS})_{\odot} = -14 \text{ km sec}^{-1} .$$

Table I
Frequency and Mode Energy Changes in Beat Cepheids

Star	df_0/dt (d^{-2})	$\Delta(E_1/E_0)$ (over 20 yr)
U TrA	$+(1.8 \pm 3) \times 10^{-10}$	$+0.10 \pm 0.02$
TU Cas	$-(2.6 \pm 0.5) \times 10^{-9}$	-0.49 ± 0.04

V367 Sct is a key object among the beat Cepheids, being a probable member of the cluster NGC 6649. Its beat character is now well substantiated (Madore, Stobie and van den Bergh 1978), and confirmation of its cluster membership would provide valuable information concerning its reddening and luminosity. The positional, PLC, and C-M array data all support membership, although Flower (1978) has claimed that this would imply an abnormal time spread of star formation within the cluster. Recently Barrell (1979) has obtained radial velocity measurements for this Cepheid and for 12 cluster stars, which are summarized in Figure 1. Clearly the Cepheid velocity is very close to the systemic cluster velocity, which provides another piece of supporting evidence for membership. This implies that this beat Cepheid obeys the same PLC relationship as do normal Cepheids of the same fundamental period, indicating that their multi-mode character is not due to their being in some unexplained evolutionary state.

At first sight this result, coupled with that for period and mode energy changes, might appear to indicate that the double-mode behaviour is due to "mode-switching" as the star's evolution carries it across a boundary between regions of fundamental and first overtone instability. This explanation can hardly be correct, however, since the proportion of stars with $2d < P_0 < 4d$ exhibiting beat behaviour is ~20% (Stobie 1977) which is far too large to be consistent with mode-switching over a time scale of ~100 yr. Possibly the amplitude changes are due to some form of mode interaction in which energy is transferred back and forth between the modes.

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