β CANIS MAJORIS STARS IN THE (β, $[c_1]$) PLANE

R. R. SHOBBROOK
The University of Sydney, Sydney, Australia

Abstract. Recent publications have discussed the existence of stable *B* stars in the β CMa instability strip of the (β, Q) plane (Lesh and Aizenman, 1973) and the ($\log g$, θ_e) and (M_{bol}, $\log T_e$) planes (Watson, 1972). The new lists of Strömgren *uvby* β photometry published by Crawford *et al.* (1970, 1971a, 1971b) for most of the *B* stars in the ***Bright Star Catalogue*** suggested that one might determine quite precisely the proportion of stable *B* stars (that is, stars not known as β CMa variables) in a luminosity/colour plot in the form of the β index against $[c_1] = c_1 - 0.2\ (b-y)$.

The rectangle in Figure 1 shows the region of the (β, $[c_1]$) plane enclosing 22 of the 25 known β CMa stars. The variable lying in the top, left hand corner of the Figure is V 986 Oph, that just above the rectangle is τ^1 Lup (which has an uncertain β value) and that well below the rectangle is 53 Ari, probably with an incorrect β value. The dots in the figure are single early *B* stars brighter than $V = 5.0$, plotted to

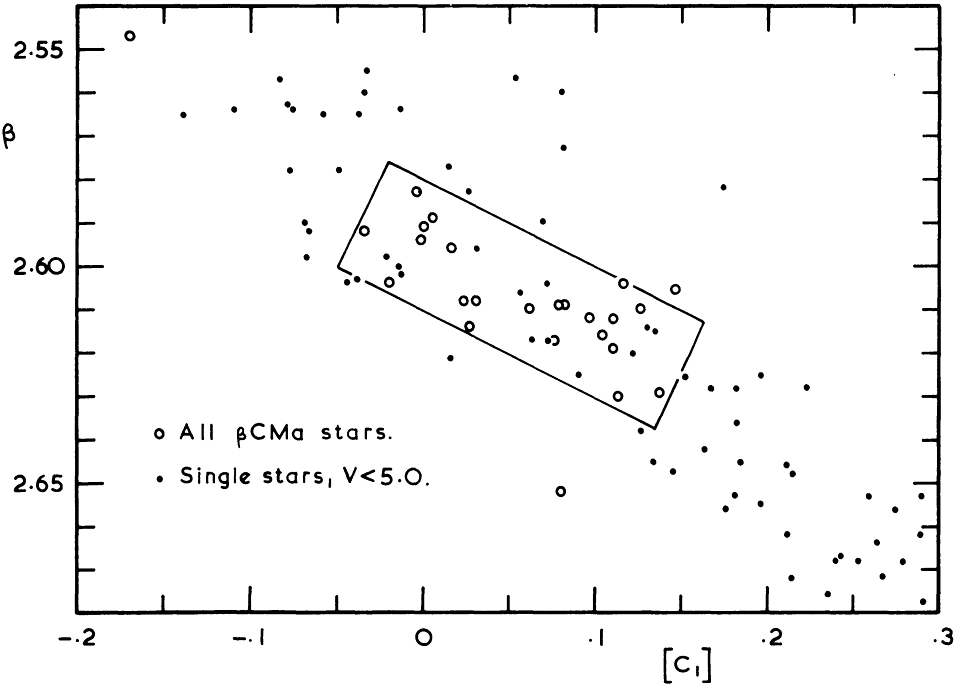

Fig. 1. A(β, $[c_1]$) plot of the known βCMa stars (open circles) with β and $[c_1]$ values corrected for effects of a companion when applicable, plus single B stars brighter than $V = 5.0$ (dots).

Ledoux et al. (eds.), Stellar Instability and Evolution, 69–71. *All Rights Reserved*

show the distribution of stars throughout the diagram; only 18 of the β CMa stars are brighter than $V=5.0$ and 13 of the 25 are double stars.

In the three Crawford *et al.* lists, there is a total of 56 stars which lie in the rectangle ('instability strip') in Figure 1; these do not include stars classified as 'e' or 'p', since none of the β CMa stars is so classified. Both the β and $[c_1]$ values for double stars (including double β CMa stars) were corrected to the values for the primary by means of simple empirical relations. Where magnitude differences between components are not known, it was assumed that the secondary is 2–3 mag. fainter than the primary; the corrections are accurate to about 0.003 in β and 0.01 in $[c_1]$.

There are two items of information we can derive from this plot. Firstly, if we take into account that about 12 p.c. of early *B* stars are classified as 'e' or 'p', then a minimum of 37 ± 11 p.c. of the stars evolving through the instability strip (as defined by the rectangle) are β CMa variables. Secondly, the strip is not resolved by the observational data. This is inferred from the fact that the rms deviation of the β CMa stars in β about a line through the centre of the rectangle parallel to the long sides is ± 0.008, whereas the photometric errors in β are stated to be between 0.005 and 0.008. If we add to the latter values the errors in β determined for the primaries of double systems and the errors in $[c_1]$, we can see that the width of the rectangle is very largely due to the photometric errors. Similar conclusions are reached for the best available (β, Q), (M_v, Q) (Jones and Shobbrook, 1973), $(\log g, \theta_e)$ and $(M_{\text{bol}}, \log T_e)$ relations.

The most direct observational method of reducing the width of the instability strip significantly, so that there is a chance of resolving it in the 'luminosity' parameter, appears to be the reduction of observational errors in β. In principle, if errors in β can be reduced to 0.002 or 0.003, one might expect the width of the strip to decrease and the proportion of β CMa stars in it to increase. Moreover, if the 56 stars mentioned above are re-observed in β to this accuracy, we presumably obtain a short list of stars which may be undiscovered β CMa variables. However, although the currently known β CMa stars are highly concentrated to the rectangle in Figure 1, it will also be important to check for β CMa-type variability amonst the stars in the top left of the diagram (towards V986 Oph) and also in the bottom right amongst the *B*2.5 and *B*3 subgiants and giants.

References

Crawford, D. L., Barnes, J. V., and Golson, J. C.: 1970, *Astron. J.* **75**, 624.
Crawford, D. L., Barnes, J. V., and Golson, J. C.: 1971a, *Astron. J.* **76**, 621.
Crawford, D. L., Barnes, J. V., and Golson, J. C.: 1971b, *Astron. J.* **76**, 1058.
Jones, D. H. P. and Shobbrook, R. R.: 1973, *Monthly Not. Roy. Astron. Soc.* **166**, 649.
Lesh, J. R. and Aizenman, M. L.: 1973, *Astron. Astrophys.* **22**, 229.
Watson, R. D.: 1972, *Astrophys. J. Suppl.* **24**, 167.

DISCUSSION

Graham: Is there any chance that some of your stars have hydrogen line emission? It is what one would suspect.

Shobbrook: The spectra do not show emission.

Irwin: What is your purpose in observing β more thoroughly? Is it to reduce the thickness of the instability box?

Shobbrook: I think that careful observations on a few stars will eliminate up to 3/4 of the stars from this box.

Rodgers: Do the $(P\sqrt{\varrho})$ values from your observations differ significantly from those found by Watson?

Shobbrook: The calculated periods for β Cen, λ Sco, κ Sco and α Vir differed by 0.1 in $\log P$ from the observed values but there's nothing systematic, nor any difference for narrow or broad line stars.

Breger: Watson also calculated a box in M_v. Does it have the same width as yours?

Shobbrook: His box in M_v is about the same size as the one I found. The $\log g$ is a bit difficult because there's a lot of colour dependence.

Lesh: The stars which lie outside the β Cephei box in your diagram should not cause too much concern. V986 Oph is a very bright star, but it may not be a β Cephei star. As I recall, there is no radial velocity curve for it. As for 53 Ari, recent observations have shown it to be constant in light. But I am puzzled as to the location of τ Lup in your diagram. Crawford's published value of β is >2.7 for this star. Do you have a more recent value?

Shobbrook: Moreno in his Sco-Cen association study gives a value of 2.605.