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On the δ Scuti Period-Luminosity Relation

P-L relations for pulsating variables are of fundamental importance to astronomers. The existence of a tight correlation between a measurable parameter (period) and a relatively uncertain parameter (luminosity) is utilitarian as well as aesthetic. RR Lyr and Cepheid variables have been used to determine distances to globular clusters, the Galactic Centre, and Local Group members. The existence of δ Sct and the similar SX Phe variables in open clusters, globular clusters, and extragalactic systems then can provide independent estimates of distances to these systems.

The δ Sct pulsators seem to be more dynamically complex than other pulsators. This is manifested in P-L and P-L-C relations with relatively large dispersion which degrades their usefulness as potential distance indicators. Dworak & Zieba (1975) determined a P-L relation using 28 δ Sct stars with known parallax. They claimed that their stars fell into "two distinct groups" based on their absolute magnitude. The "bright" (or "ρ Puppis") and "faint" stars were distinguished based on absolute luminosity relative to a critical value of $M_V=1$. Leung (1970) and Eggen (1970) also made similar claims concerning two distinct luminosity groups though these were shown to be dubious by Breger (1979). The result of Dworak & Zieba's work was two P-L relations which, despite the division into brightness categories, showed considerable dispersion ($\sim$ 0.4 mag in V band).

Inclusion of a colour term reduces the dispersion in such relations for Cepheids. However, the observational P-L-C relation derived by Breger & Bregman (1975) still showed considerable uncertainty in M_V ($\pm$ 0.24 mag). An updated version by Breger (1979) had an estimated uncertainty of $\pm$ 0.31 mag in V band. Lopez de Coca *et al.* (1990, hereafter LRRG) used a large sample of δ Sct stars to derive a semi-empirical P-L-C relation. Though no formal estimate of the uncertainty is given, the dispersion of their Figure 1 appears to be $\sim$ 0.1 bolometric mag.

The above relations have not taken mode of pulsation into account. It is interesting to see what effect consideration of mode would have on a P-L

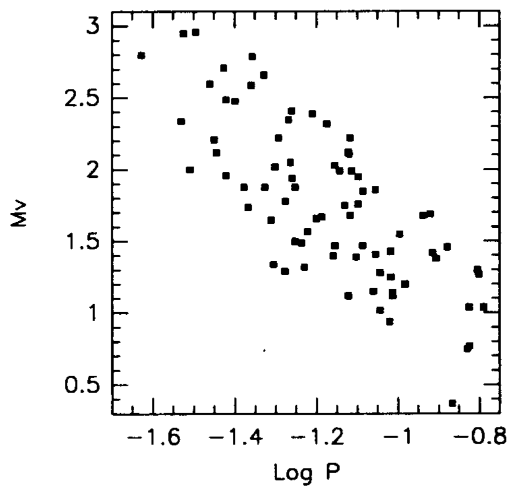

Figure 1

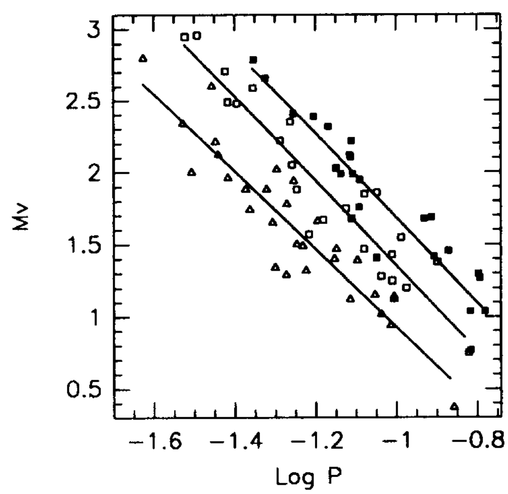

Figure 2

relation. In Figure 1, I have plotted M_V vs. Log P for the stars in LRRG's selected sample (their Table II). Clearly, there is a definite correlation, but the scatter is very large. In Figure 2, I have divided up the sample into fundamental mode pulsators (filled squares), first overtone pulsators (open squares), and second and third overtone pulsators (open triangles). The solid lines show least square fits to the three groups. The relations are given by the following formulae with rms dispersion (σ) and correlation coefficient (r) indicated:

Fundamental Mode: $M_V = -2.932 \times \log P - 1.247 (\sigma = \pm 0.036, r = 0.945)$
First Overtone: $M_V = -2.942 \times \log P - 1.588 (\sigma = \pm 0.038, r = 0.946)$
Second Overtone: $M_V = -2.698 \times \log P - 1.771 (\sigma = \pm 0.036, r = 0.924)$

At a given period, the higher order mode pulsators are brighter than lower order pulsators. Thus the division by Dworak and Zieba based on luminosity is somewhat unphysical. Rather, their separation reflects different modes of pulsation. The relations here show surprisingly small dispersion. However there are several caveats that one should be aware of: (1) The relation is only semi-empirical with M_v derived from $uvby\beta$ calibrations. (2) Some degree of circular reasoning has been invoked as for most of the points, LRRG derived a Q value from the relation given in Petersen and Jorgensen (1972). Here Q itself is dependent on M_V and log P in the same sense as in Figure 2 as well as the surface gravity, effective temperature, and appropriate bolometric corrections.

However, this semi-empirical relation provides a natural explanation for the effect seen by Dworak & Zieba. The relation also seems to indicate that the basic cycle count periods are meaningful; LRRG utilised a reduced period. Moreover, the relation should provide a framework for future work. After future, empirical calibration is undertaken, it seems that accurate luminosities could be determined with photometry in just one band if the photometry is such that it can give information on mode of pulsation. The inclusion of mode into the P-L relation has an analagous effect to including colour. Breger & Bregman found that for T_{eff}<7800 K, pulsation was in the fundamental mode while for hotter temperatures, the first overtone was prevalent. To investigate this, we again made use of the selected sample of LRRG. A t test reveals the difference in mean Q value between those stars hotter than 7800 K and cooler than 7800 K is significant at the 94% confidence level.

Future work should concentrate on calibrating such a relation. This will have to await more intensive ground base astrometry or the first results of the HIPPARCOS mission to provide trigonometric parallaxes. In addition, continued photometry may be required to provide reliable period estimates as well as empirical information on pulsational modes. In this way, recourse to theory is virtually eliminated. Additionally, it would be worthwhile to see if the SX Phe variables and dwarf Cepheids (if they are distinct from δ Sct variables) follow similar relations.

Jeremy R. King
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