ARE THE CEPHEIDS IN CLUSTER NUCLEI A RARE BREED?

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As reviewed by Kholopov (1968), star counts for a variety of open clusters reveal the existence of low density coronal regions surrounding the nuclear concentrations of most star clusters. Such cluster coronae have diameters 2.5 to 5 times larger than the respective nuclear diameters for clusters which are poor to medium-rich in member stars, and have star densities only about 10% those observed in cluster nuclei. Cluster coronae therefore contain roughly 40% to 70% of the stars in an open cluster, and are subsequently a (or, more appropriately, the) major component of most star clusters.

The search for new calibrators for the Cepheid PL relation has yielded many Cepheids which qualify spatially as possible members of cluster coronae. The majority of these can be rejected as bona fide cluster members by such tests as star counts, age differences with respect to the turn-off point ages for the associated clusters, and derived luminosities greatly different from PL relation values when cluster membership is assumed. Specific examples are AB Cam and XZ CMa (cf. Tsarevsky et al. 1966), which fail as possible coronal members of the clusters Tombaugh 5 and Tombaugh 1, respectively, by location outside the cluster corona for AB Cam and by marked discrepancies in age and luminosity for XZ CMa (Turner 1983). Many Cepheids remain, however,

Table 1. Cepheids in Cluster Nuclei

Cepheid	P(days)	Cluster	Class
EV Sct	3.09	NGC 6664	III2m
V1726 Cyg	4.24	Anon	IV2p
CE Cas B	4.48	NGC 7790	II2m
CF Cas	4.88	NGC 7790	II2m
CE Cas A	5.14	NGC 7790	II2m
CV Mon	5.38	Anon	III2p
V367 Sct	6.29/4.38	NGC 6649	II2m
U Sgr	6.74	IC 4725	I2p
DL Cas	8.00	NGC 129	IV2p
S Nor	9.75	NGC 6087	I2p
CPD-53°7400p	11.29	NGC 6067	I2r
S Vul	68.5	Anon	III3m

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which do qualify as cluster coronal members from these tests, despite the lack of confirmation which might be possible from radial velocity and proper motion studies. A current listing of these objects and their parent clusters is provided here, along with a comparison of the properties of these clusters with those which contain Cepheids in their nuclear regions.

Table 1 is a summary of Cepheids seen projected against cluster nuclei for which the currently-available membership tests are consistent with cluster membership. The omission of a few notable calibrators such as CS Vel and TW Nor rests upon the results of a number of recent studies which suggest that they may not be cluster members. Table 1 contains 12 Cepheids in 10 different clusters, most of which are either poor or medium-rich in member stars. Trumpler types for these clusters are from the literature or from new classifications derived from photographs of the clusters. Since the clusters are mainly of poor to medium richness, the results given earlier for typical dimensions and star densities lead one to predict from simple geometry that between 21% and 39% (2 to 5) of the Cepheids in Table 1 are coronal members seen in projection against their cluster nuclei. Good candidates are V1726 Cyg and S Vul, which lie near the boundaries of their cluster nuclei, and one or more of the Cepheids seen projected against the nucleus of NGC 7790.

Table 2 is a list of coronal Cepheids for which the presently-available data are consistent with cluster membership, at least with regard to the tests mentioned earlier. The majority of these objects are established as cluster members by photometric studies alone, and a few additional objects such as TV CMa near NGC 2345 may be added later as studies of their possible cluster membership are completed. Two Cepheids, UY Per and RU Sct, are unusual in the sense that they lie roughly midway between two clusters of similar age and distance. Although Table 2 is

Table 2. Cepheids in Cluster Coronae

Cepheid	P(days)	Cluster	Class
SZ Tau	3.15	NGC 1647	II2m
BD Cas	3.65	Czernik 1	IV2m
HD 144972	3.79	NGC 6067	I2r
CG Cas	4.37	Berkeley 58	IV2p
UY Per	5.37 {	King 4 Czernik 8	III2p II3p
V Cen	5.49	NGC 5662	II3m
GH Car	5.73	Trumpler 18	III2p
R Cru	5.83	NGC 4349	II2r
BB Sgr	6.64	Collinder 394	IV2m
T Cru	6.73	NGC 4349	II2r
RU Sct	19.70 {	Trumpler 35 Dolidze 32	II2m I2p
WZ Sgr	21.85	Anon	IV2p

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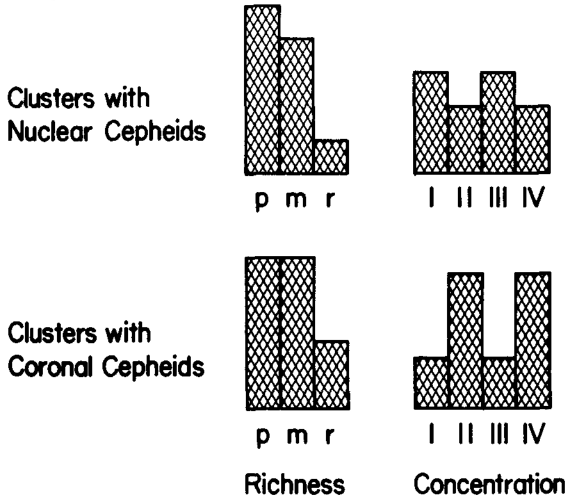
Figure 1.



probably incomplete, it already contains as many objects as Table 1. From the arguments presented earlier, it follows that coronal Cepheids must outnumber nuclear Cepheids by a factor of between 1.4 (14/10) and 2.4 (17/7). Coronal Cepheids are therefore probably about twice as abundant as nuclear Cepheids in this region of the Galaxy.

Fig. 1 shows the relative frequencies of the various concentration and richness classes found for clusters in Tables 1 & 2. There is no obvious preference of Cepheids for either very loose, class IV, or very compact, class I, clusters, although they are rare in rich clusters. This can be explained by cluster dynamics, since most star clusters will have undergone a large amount of disintegration through evaporation of member stars by the time they are old enough to produce Cepheids from the post-main-sequence evolution of intermediate mass stars.

It may also be possible to explain with similar arguments the apparent preference of Cepheids for cluster coronae. High density cluster nuclei are ideal sites for the formation, through frequent stellar encounters, of close binary systems in which the components are not sufficiently separated to permit either to evolve to the supergiant dimensions of typical Cepheids. Stone's (1980) H-R diagram for nuclear and coronal members of the cluster NGC 654 exhibits the expected effects of such dynamical evolution, namely larger scatter above the ZAMS for nuclear members than for coronal members. The nucleus of NGC 654 probably contains large numbers of unresolved binary systems with nearly equal components, in contrast to mostly single stars in the corona. If this is also true for the clusters in Tables 1 & 2, then conditions in their nuclei may hinder the natural evolution of intermediate mass stars to the Cepheid state. Lower density cluster coronae may therefore be the best sites to search for new calibrators for the Cepheid PL relation.

References.

Kholopov, P.N. (1968). Astron. Zh. 45, 786.
Stone, R.C. (1980). Publ. Astron. Soc. Pacific 92, 426.
Tsarevsky, G.S., Ureche, V. & Efremov, Y.N. (1966). Astron. Tsirk. 367.
Turner, D.G. (1983). J. Roy. Astron. Soc. Can. 77, 31.

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