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ON DELTA SCUTI STARS IN OPEN CLUSTERS

Summary

The observational correlations for Delta Scuti stars in clusters reported by Frolov and Irkaev (1982) between average period and cluster age, as well as average absolute magnitude and age, are examined. These correlations are shown to be a natural consequence of the systematically different color-magnitude diagrams for clusters of different ages, and the existence of a period-luminosity-color relation for Delta Scuti stars.

Over 200 Delta Scuti stars have been discovered so far. 29 variables are situated in open clusters. Frolov and Irkaev (1982) have examined these cluster variables and found impressive correlations. They write, "the greater the age, the longer the mean period of cluster variables and the higher their mean luminosity." They did not speculate on the possible reasons for the observed correlations. It would, of course, be exciting to discover that the particular radial or nonradial pulsation modes (and hence the period) chosen by a star would depend on the age of the star. However, a more mundane cause for the observed correlations might be the combination of main-sequence evolution with the known period-luminosity-color (PLC) relation for Delta Scuti stars.

We have reexamined the cluster data given by Frolov and Irkaev. Except for the star K573 in NGC 7789, our calculations give similar results. Cycle-count periods are from an updated collection by Breger and Stockenhuber (1983), and the cluster ages for the younger clusters were taken from Mermilliod (1981). Since the correlations of Delta Scuti star periods with other physical quantities usually involve log P, rather than P, we have averaged the log P values for each cluster.

The variable K573 = V521 Cas in NGC 7789 deserves some reexamination. The almost heroic search by Danziger (1971) for Delta Scuti variability among stars in the crowded field of NGC 7789 detected this one variable. Recent proper motions by McNamara and Solomon (1981) indicate a high probability of cluster membership of 96%.

Danziger conservatively deduced a period of about four hours from his 16 measurements of K573. The value of this cycle-count period must be regarded as quite uncertain. Since a "best" (though uncertain) value is required for statistical work, we have redetermined Danziger's period through a Fourier analysis. A best value of $0^{d}.147 \pm 0^{d}.037$ is found. Until more observation of this star become available, we recommend that the value of $0^{d}.15$ be adopted.

Frolov and Irkaev (1982) seem to have made an error in their absolute magnitude determination for K573, in that the correction for the substantial interstellar extinction seems to have been applied twice. With a reasonable reddening of $E(B-V) = 0^{m}.27$ and $(m-M) = 12^{m}.2$ (e.g. see Breger 1982) an absolute magnitude of $(M_V)_0 = 1^{m}.56$ is found. The effect of our correction is to reduce the steepness of the observed correlation between M_V and age.

The period-age and luminosity-age relations for the cluster variables are shown in Figure 1.

We first turn to the observed M_V-age relation. A good correlation can be seen in the lower part of Figure 1, though not quite as impressive as in Frolov and Irkaev. Is this correlation a specific property of Delta Scuti variables, or simply a reflection of different cluster H-R Diagrams? We note here that only one-third of the stars in the lower instability strip show detectable variability. For each cluster an average M_V value for all the stars inside the instability strip was calculated. Because of main-sequence evolution, these values change with cluster age. In NGC 7789, for example, only the edge of the turn-off point lies inside the instability strip. The results of the calculations are marked with the symbol "E" in Figure 1. The good agreement between the observations and the calculations suggests that the observed relation between average absolute magnitude and cluster age for Delta Scuti stars is simply a reflection of main-sequence evolution.

The existence of an evolutionary luminosity-age relation should result in a similar period-age relation because of the existence of a PLC relation for Delta Scuti stars. While the multiple periods present in many Delta Scuti stars have not yet been determined, average time scales of variation can be determined easily (cycle-count periods). For the stars with known values of the multiple periods, we substitute the value of the period with the largest associated amplitude. These cycle-count periods are correlated with the luminosity and color (Breger 1979, Halprin and Moon 1983). Field and cluster stars show no differences in this regard, and similar PLC relations are also found for individual radial modes.

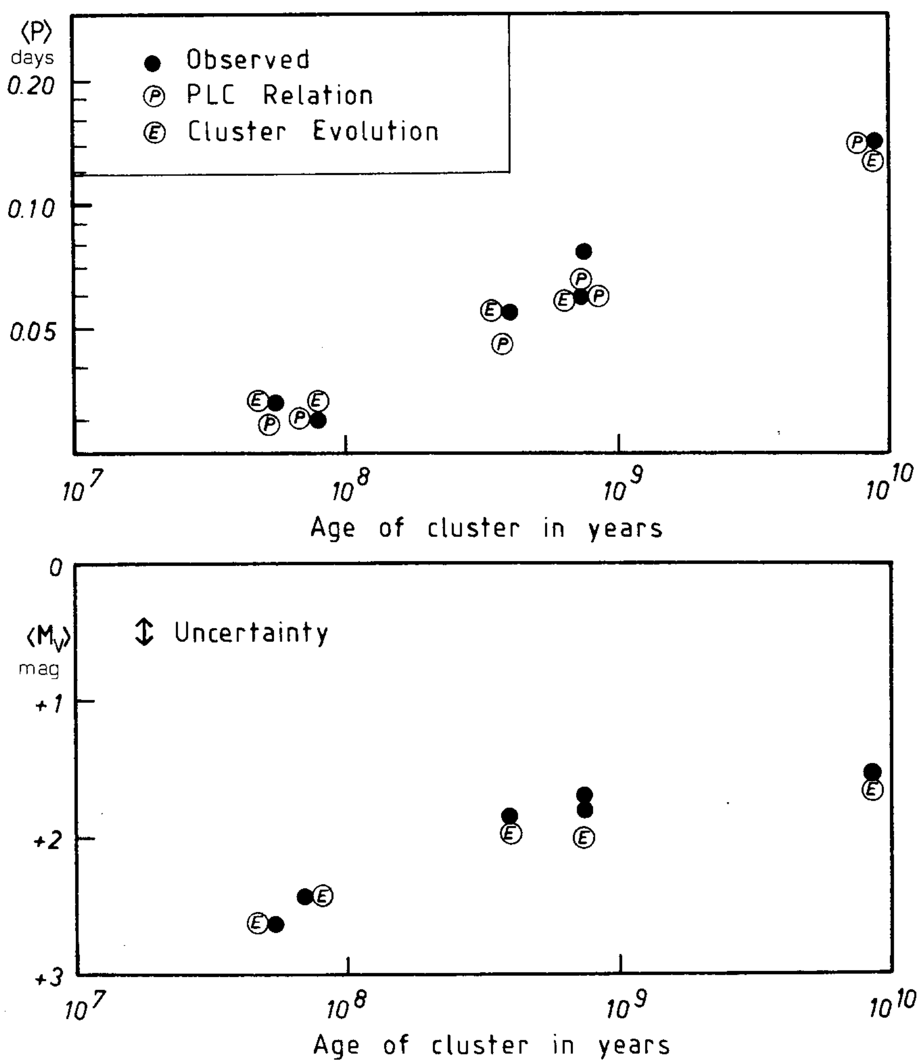

Fig. 1 – Correlations of average pulsation period and M_V with the age of the cluster. The diagrams show that the observed correlations can be explained by the period-luminosity-color relation and main-sequence evolution of the clusters.

To examine whether or not the evolution of cluster main sequences and the PLC can explain the observed period-age correlation, we have computed two average periods for each cluster. The first period (denoted by "P" in Figure 1) represents the calculated periods based on the actual colors and magnitudes of the variable stars. The second period (denoted by "E" in Figure 1) is the expected average period for the all the cluster stars (with or without detected pulsation) inside the instability strip.

The excellent agreement between the calculated and observed average periods indicates that the period-age relation is caused by stellar evolution and the PLC. There is so far no evidence that age and evolution affects Delta Scuti pulsation beyond fixing the initial stellar parameters such as mass, luminosity, and temperature. The only possible modification, which still needs to be explained, lies in the observed large pulsational amplitudes of some metal-poor, undermassive dwarfs such as SX Phe.

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