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ON THE PERIODS OF THE DELTA SCUTI STAR HR 1170

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RESUMEN

Se presenta un análisis del contenido periódico de la estrella δ Scuti HR 1170. De los períodos deducidos, $0^d_.0994$ y $0^d_.0913$ para ésta y otras temporadas, se concluye que esta estrella varía en modos de pulsación no radiales.

ABSTRACT

Analysis of the periodic content of the δ Scuti star HR 1170 is carried out. From the periods found for this and other available data, $0^d_.0994$ and $0^d_.0913$, it is concluded that this star pulsates in non-radial modes.

Key words: **STARS-PULSATION – STARS-δ SCUTI – STARS-INDIVIDUAL.**

I. INTRODUCTION

The current thought on the driving mechanism of pulsation establishes that the main energy source is the internal energy of the mixture of gas and radiation in the ionization zones of the abundant elements, such as He and H. It is believed that this mechanism is present in Cepheids, RR Lyrae and δ Scuti stars so one could infer that these stars should oscillate in a simple radial mode (Petersen 1978) as the Cepheids. On the other hand, since the light curves of the δ Scuti stars show smaller amplitudes and very seldom a simple pattern, the presence of non-radial modes of pulsation in some δ Scuti stars should be expected, if one considers that the oscillations in a non-radial mode always result in amplitudes that are smaller than those corresponding to radial pulsations and that the beating of close frequencies produces light curves that are apparently more complex. Furthermore, according to Breger (1979) the observational evidence for the existence of non-radial modes rests on observed period ratios which cannot be fitted by radial modes as well as on identification with actual non-radial modes as in the well-known example of 1 Mon (Millis 1973; Shobbrook and Stobie 1974).

In a recent paper (Peña and Warman 1979, hereinafter PW) the δ Scuti stars HR 7331 = V1208 Aql and HR 1170 = V376 Per were studied in the search for their periodic content. In particular, for HR 1170 the photoelectric observational data analyzed by means of the multiple frequency fitting (MFF) method suggested the presence of two periods ($0^d_.0913$ and $0^d_.0994$) with a period ratio of $P_1/P_0 = 0.92$ that does not fit the radial pulsation scheme that has been developed by Petersen (1978) and Stellingwerf (1979) among others.

After analyzing all the data of HR 1170 known to us, we concluded that this star was indeed pulsating in a non-radial mode. Recently, we came upon more photoelectric data of this same star (Gupta 1977).

In this study, Gupta analyzed his data with that previously published (Breger 1969; Warman *et al.* 1974). The conclusion derived from his analysis differs from the one obtained in PW. By means of the O-C method, Gupta determined periods of $0^d_.098299$ and $0^d_.131192$ whose period ratio $P_1/P_0 = 0.75$ is in agreement with the radial pulsation scheme.

II. ANALYSIS

Since Gupta listed his observations, analysis of this data by the MFF was carried out along with a study of all the available data reported in PW with Gupta's reported frequencies. One of these, 10.173 c/d is quite similar (1.12% in percentual error) to the 10.0604 c/d derived in PW, but in the value of the other one rests the argument supporting the pulsational nature of the star.

First, due to the time spanned on Gupta's observational data (about 1 year) two sets were considered. The first one, observed in 1974, includes all but the last four nights; the second set, 1975, the last three nights. The night of HJD 402 was not considered because it is too

TABLE 1

STATISTICS FOR BOTH SETS OF FREQUENCIES

Season		10.0604 + 10.9529 (c/d)		7.6224 + 10.173 (c/d)	
		R^2	F	R^2	F
1977	(PW)	0.83	190	0.25	12
1973	(WMB)	0.85	185	0.07	3
1974	(Gupta)	0.63	50	0.17	6
1975	(Gupta)	0.67	78	0.58	54
1975	(Gupta)*	(0.74)	(109)	(0.65)	(73)

* Parameters were obtained w/o the tails from the first and last nights.

separated from each of the previously mentioned sets. Each season was treated independently along with the 1973 and the 1977 data as reported in Warman *et al.* (1974) and PW.

Table 1 shows the results of analysis of each season by means of the MFF (that sweeps each frequency keeping the others constant) and fitting the observational data by least squares to periodic terms. The statistical parameters considered were the correlation coefficient R^2, the F and Durbin Watson statistics and the mean

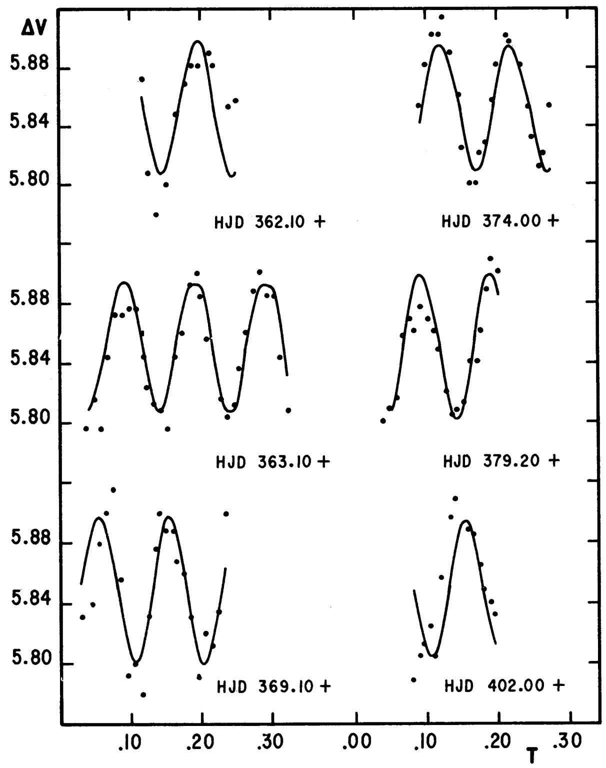

Fig. 1. Comparison between observations (dots) in 1974 (Gupta 1977) and the predicted variation (continuous line) for HR 1170. To convert time scale shown to conventional heliocentric Julian Days it is enough to add 2 442 000.00. *V* variation is in magnitudes.

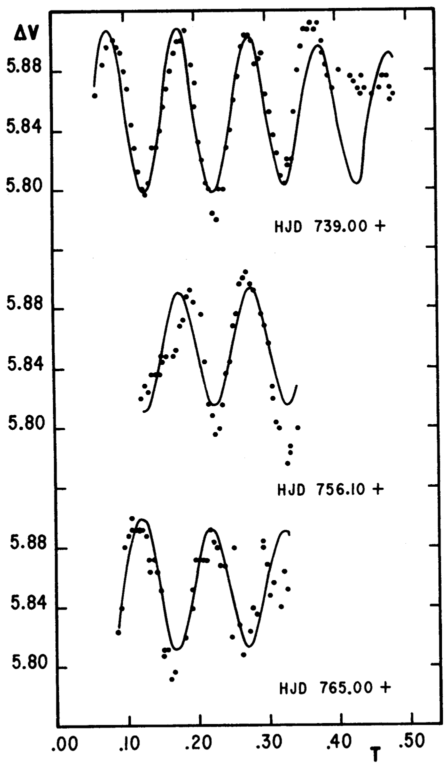

Fig. 2. Comparison between observations (dots) in 1975 (Gupta 1977) and the predicted variation (continuous line) for HR 1170. To convert time scale shown to conventional heliocentric Julian Days it is enough to add 2 442 000.00. *V* variation is in magnitudes.

square error. The table shows clearly that the set of frequencies proposed in PW give a much better fit than those proposed by Gupta.

Gupta's 1974 set of data was prewhitened with the 10.0604 c/d frequency and the residuals were analysed by a standard Fourier Transform and in the MFF method. The frequencies obtained from the Fourier analysis were 10.800 and 11.8080 c/d. Since these three nights are quite separated (24 days from the first to the last one) aliasing does present a problem. In this case, 11.8080 c/d can be shown to be an alias of 10.8000 c/d. When analyzed in the MFF this value converged to 10.9210 c/d, only 0.29% in the percentual error from the 10.9529 c/d found previously in PW (23 s difference).

The comparison between predictions and observations are shown in Figures 1 and 2. We must call attention to the poor agreement in the tails of the first and last nights on Figure 2. Coincidentally, these 3 nights were the only ones in the sample that were obtained with only one comparison star, so one should expect a larger error when subtracting the comparison from the variable star at larger hour angles. Statistical parameters obtained leaving out data from these tails are bracketed in Table 1, and show a much better fit. We notice that even with these (probably) poor data included, the fit obtained using PW frequencies is considerably better than the one obtained with Gupta's proposed values.

III. CONCLUSIONS

We feel that Gupta's observations, rather than contradict the non-radial pulsation in this star, support it. Given the amount and quality of the available data, we believe that the obtained difference (23 sec) in the values of the second frequency in PW and this paper reflects features of the data rather than a possible change in the pulsation of the star.

REFERENCES

Breger, M. 1969, *A.J.*, **74**, 166.
Breger, M. 1979, *Pub. A.S.P.*, **91**, 5.
Gupta, S.K. 1977, *Ap. and Space Sci.*, **48**, 199.
Millis, R.L. 1973, *Pub. A.S.P.*, **85**, 410.
Peña, J.H. and Warman, J. 1979, *A.J.*, **84**, 1046.
Petersen, J.O. 1978, *Astr. and Ap.*, **62**, 205.
Shobbrook, R.R. and Stobie, R.S. 1974, *M.N.R.A.S.*, **169**, 643.
Stellingwerf, R.F. 1979, *Ap. J.*, **227**, 935.
Warman, J., Malacara, Z., and Breger, M. 1974, *Rev. Mexicana Astron. Astrof.*, **1**, 143.

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