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THE LIGHT CURVES OF DELTA-SCUTI STARS HR 1170 AND HR 7563

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RESUMEN

Se presentan las curvas de luz de las estrellas variables tipo δ-Scuti HR 1170 y HR 7563. Asimismo, se presentan resultados preliminares de un estudio de sus períodos múltiples.

ABSTRACT

Light curves of δ-Scuti type stars HR 1170 and HR 7563 are presented. Also, preliminary results of a multiperiod analysis are mentioned.

Key words: SHORT PERIOD VARIABLES — δ-SCUTI STARS — LIGHT CURVES.

I. INTRODUCTION

Although many general features of δ-Scuti type stars are well known, there is still a great deal of uncertainty in the knowledge of their pulsation periods. This is due, largely, to the fact that a better period determination requires continuous observations of the same star for a considerable number of nights. This type of data is presently available only for very few δ-Scuti stars. Yet, a better knowledge of the periods can enhance our understanding of Period-Luminosity-Color relations as well as indicate wheter the amplitude and frequency variations are due to beats between two or more pulsating models present in the star, tidal distortion due to a close companion (Fitch 1967), or some other mechanism, such as non-radial pulsations.

In this paper we present the light curves of stars HR 1170 and HR 7563. These were obtained during eight nights of observation for the first star and ten for the second star. Also, a preliminary evaluation of the periods is given.

II. OBSERVATIONS

The observations were made at the National University of Mexico's Observatory at San Pedro Mártir, B. C., from September 28 through October 8, 1973. A 33-inch telescope was used with a dry-ice cooled 1P21 PMT. In order to obtain a larger number of measured points per period it was decided to make all the observations through one filter only. Johnson's V filter was chosen.

Because of the small magnitude variations to be measured, differential photometry techniques have to be applied (see, for example, Baglin *et al.* 1973). Two comparison stars (C1, C2) were chosen with the following characteristics:

i) Their spectral type placed them outside the instability strip (Breger 1970). This is done in order to try to ensure their constancy, since inside the instability strip their probability of being small amplitude variables can be as high as 30%.

ii) Their visual magnitudes were close to that of the program star. This avoids a possible syste-

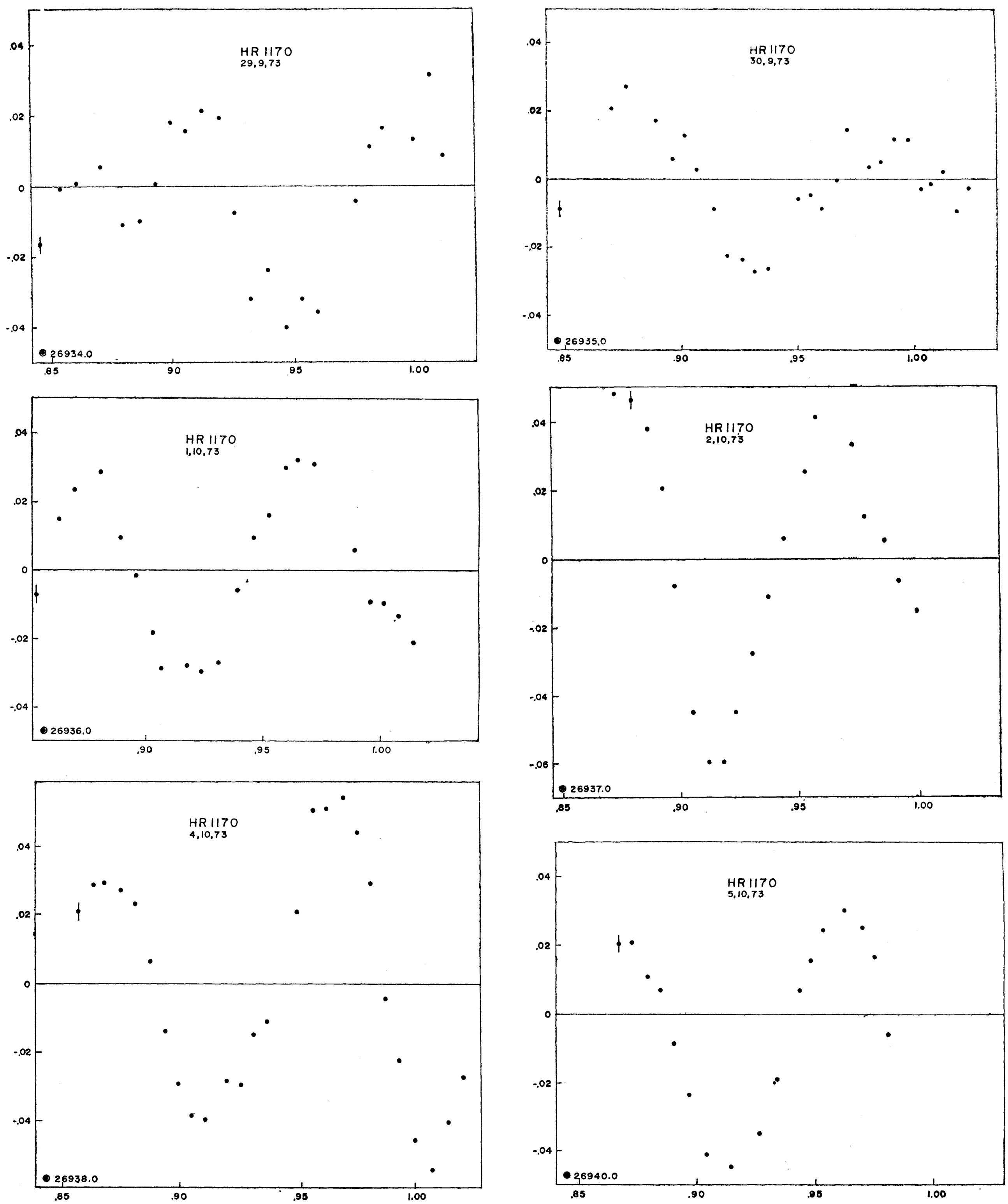

FIG. 1. Light Curves for HR 1170.

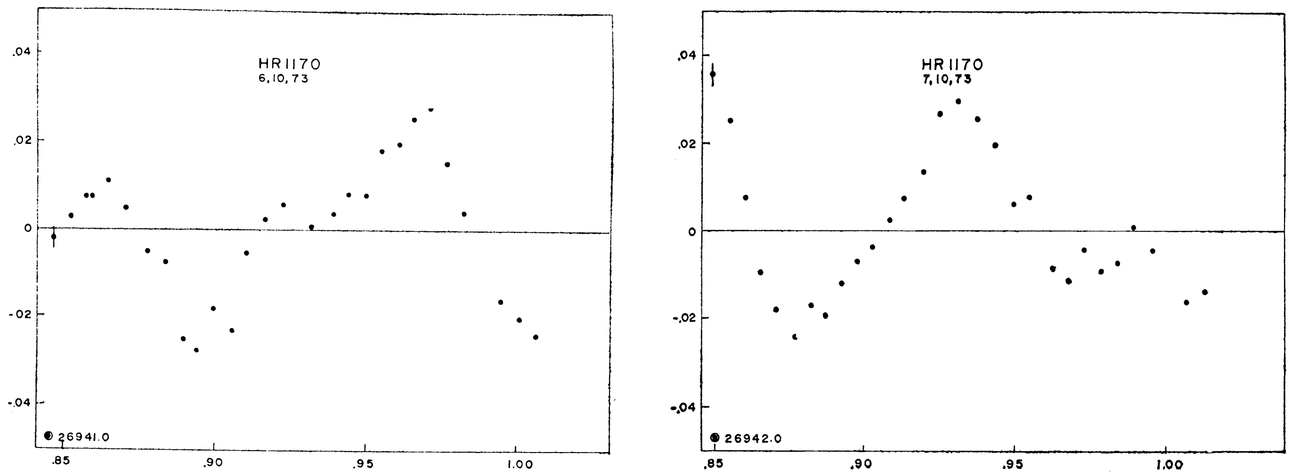

FIG. 1. Light Curves for HR 1170.

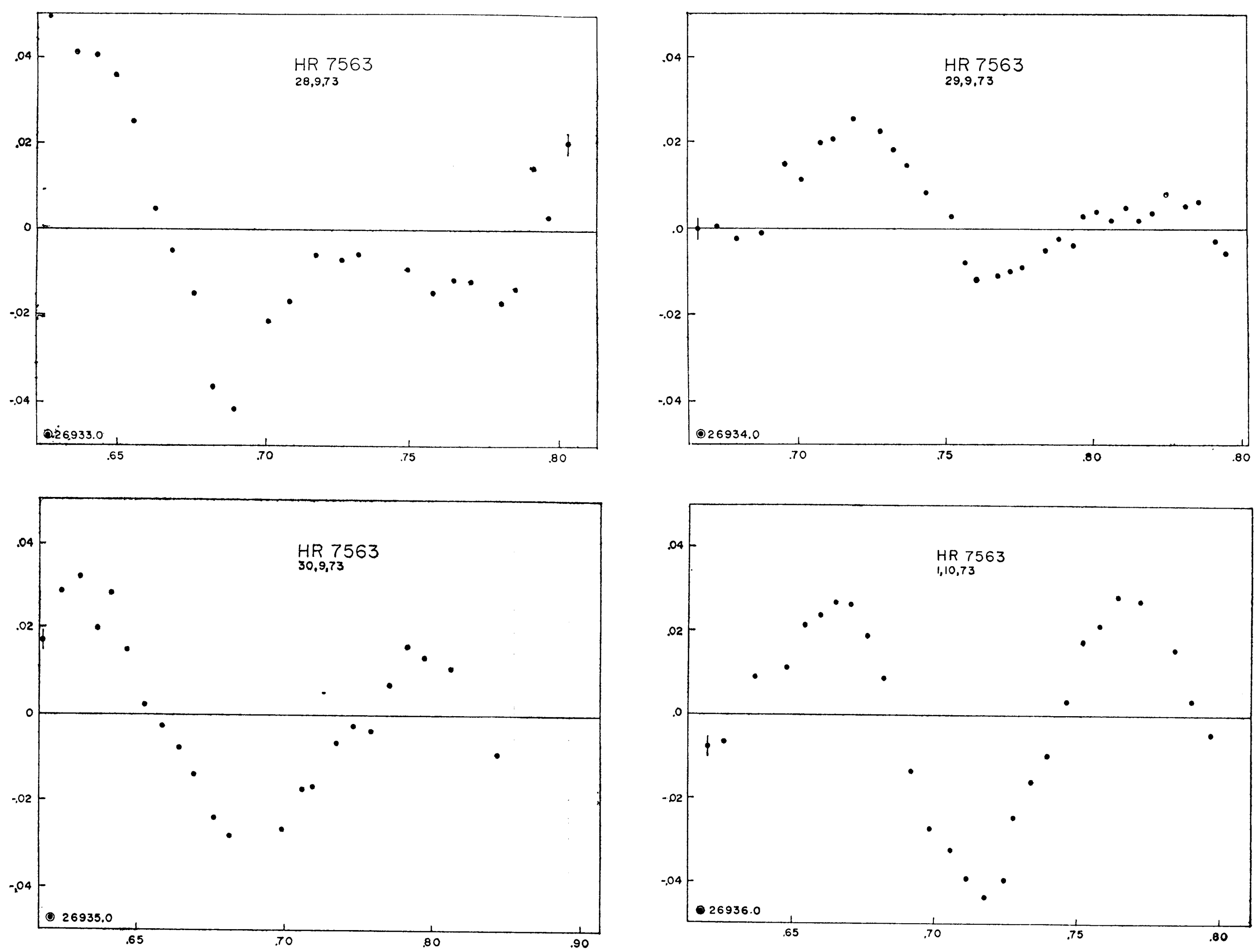

FIG. 2. Light Curves for HR 7563.

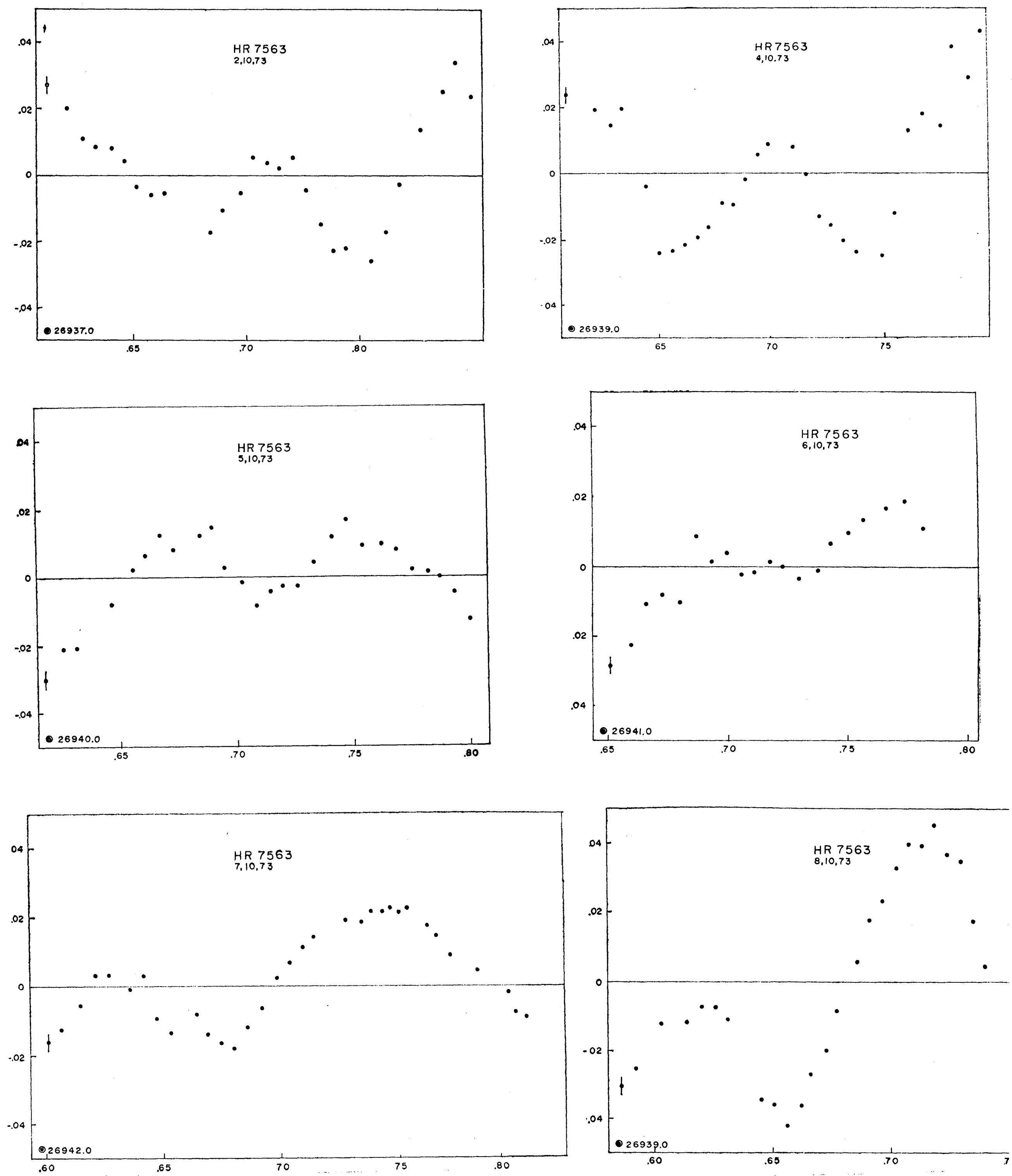

FIG. 2. Light Curves for HR 7563.

natic error arising from changing the amplifier etting when observing different stars.

iii) One of the constants was chosen with a arger right ascension than the program star and he other with a smaller. In this way one minimizes he effects o differential extinction.

iv) Of course, the comparison stars should be as close as possible to the program star. The larger he separation, the larger scatter is to be expected n the data, due to local inhomogeneities.

Table 1 shows the HR numbers, spectral type and visual magnitudes of both the program and comparison stars observed during the season. A hird star (59 Psc = HR 214) was observed in the same season and has been reported separately not to be variable during the time of observation, (Breger and Warman 1973).

TABLE 1

PROGRAM AND COMPARISON STARS OBSERVED

H R	Type	Visual mag.	Sp. Type	No. of observed nights
1170	program	5.85	F0	8
982	comparison	5.46	B8V	"
1207	comparison	5.35	B6V	"
7563	program	6.29	F0III	10
7545	comparison	5.91	A0	"
7783	comparison	5.94	G5V	"

The program and comparison stars were measured in the sequence C1, V, C2 for up to 5½ hours each night. Each measurement consisted of six ten second integrations on the star and one ten second integration on the sky, which was substracted from the average of the star integratioss. The interval separating succesive measurements of the program was about 10 min. When the equipment and the atmospheric conditions are stable enough, one can measure instead the sequence C1, V, C2, V, C1..., which gives a larger number of measured points per period of variability, at the expense of reference comparison points.

The data were corrected for extinction by taking an average extinction coefficient for the season ($k_V = 0.13$). Due to the small differences in air masses, an improbably large error of 0.1 in k_V would produce an error in the differential magnitudes of less than 0.001 mag. No attempt was made to reduce the measurements to the standard UBV system.

Table 2 (for 1170) and Table 3 (for 7536) show the reduced data. The numbers were obtained by choosing one of the comparison stars, interpolating its measurements to the time of the program star measurements and substracting the magnitudes. Afterwards, an average ΔV was substracted in order to obtain a zero base line. The presence of the second comparison star (of course, first and second comparison stars are interchangeable without altering the results) is extremely important and serves a number of purposes. The comparison between the two constant stars (i) indicates the behaviour of the equipment and atmospheric conditions and determines the corrections to be applied on account of these effects. (ii) Determines the precision of the measurements. We obtained the precision per single point to be associated with the program star measurements by plotting the difference in magnitude of the comparison stars versus time (C1-C2 vs. T) and computing the standard deviation.

For convenience in the computations, we have worked with the time expressed in heliocentric time starting from the Fundamental Epoch (January 0, 1900, at 12:00 ET). To convert the times shown in Tables 2, 3 and Figures 1, 2 to the conventional Julian Dates, it is enough to add 2415020.0, that is, the Julian Date of the Fundamental Epoch. Summarizing, the data shown are obtained from

$\Delta V(\text{shown}) = V(\text{program}) - V(\text{comparison, interpolated}) - \Delta V,$

$\text{J. D. (shown)} = \text{J. D.} - 2415020.0.$

The average precision per single point is 0.0025 mag. This is an average over all the observed nights.

III. PERIODS

Both HR 1170 and HR 7563 were identified as δ-Scuti type stars by Breger (1969). One night of observation on HR 1170 and four on HR 7563 gave, respectively, periods of 0.091 and 0.100 days, with mean amplitudes of variation of 0.08 and 0.05 ma. Valtier (1972), redetermined the periods by means of a least square fitting to a trigonometric

TABLE 2

LIGHT CURVES FOR HR 1170

29,9,73

J.D.$_\odot$	ΔV
26934.8799	-0.011
.8861	-0.009
.8931	0.001
.8993	0.018
.9118	0.022
.9194	0.020
.9257	-0.007
.9319	-0.032
.9389	-0.024
.9472	-0.040
.9535	-0.032
.9590	-0.035
.9757	-0.004
.9813	0.011
.9875	0.017
.9931	0.052
26935.0063	0.032
.0118	0.009

30,9,73

J.D.$_\odot$	ΔV
26935.8479	-0.009
.9701	0.020
.8764	0.027
.8889	0.017
.9014	0.013
.9069	0.002
.9139	-0.009
.9194	-0.023
.9264	-0.024
.9319	-0.028
.9375	-0.027
.9500	-0.006
.9556	-0.006
.9604	-0.009
.9667	-0.000
.9722	0.014
.9799	0.003
.9910	0.011
.9965	0.011
26936.0014	-0.004
.0063	-0.002
.0118	0.002
.0174	-0.010
.0236	-0.004

1,10,73

J.D.$_\odot$	ΔV
26936.8528	-0.007
.8625	0.015
.8688	0.024
.8806	0.028
.8889	0.010
.8958	-0.002
.9021	-0.018
.9097	-0.029
.9174	-0.028
.9229	-0.030
.9299	-0.027
.9389	-0.006
.9451	0.009
.9521	0.016
.9583	0.030
.9646	0.032
.9715	0.031
.9889	0.006
.9958	-0.009
26937.0014	-0.009
.0069	-0.013
.0132	-0.021

2,10,73

J.D.$_\odot$	ΔV
26937.8722	0.049
.8792	0.046
.8861	0.038
.8924	0.020
.8979	-0.007
.9049	-0.045
.9118	-0.060
.9181	-0.060
.9236	-0.045
.9306	-0.028
.9375	-0.011
.9438	0.006
.9535	0.025
.9576	0.041
.9729	0.033
.9778	0.012
.9868	0.005
.9931	-0.007
26938.0000	-0.015

4,10,73

J.D.$_\odot$	ΔV
26938.8563	0.021
.8625	0.029
.8681	0.029
.8743	0.027
.8806	0.023
.8875	0.006
.8938	-0.014
.8993	-0.029
.9049	-0.039
.9104	-0.040
.9194	-0.028
.9257	-0.030
.9313	-0.014
.9368	-0.010
.9424	0.013
.9486	0.021
.9563	0.051
.9625	0.051
.9688	0.055
.9750	0.044
.9806	0.029
.9875	-0.004
.9931	-0.022
26939.0000	-0.046
.0069	-0.054
.0139	-0.040
.0201	-0.027

5,10,73

J.D.$_\odot$	ΔV
26940.8674	0.020
.8729	0.020
.8792	0.010
.8840	0.006
.8903	-0.009
.8965	-0.024
.9042	-0.042
.9153	-0.045
.9271	-0.036
.9340	-0.020
.9438	0.006
.9486	0.015
.9542	0.024
.9632	0.030
.9701	0.025
.9757	0.015
.9813	-0.007

6,10,73

J.D.$_\odot$	ΔV
26941.8458	-0.002
.8521	0.003
.8569	0.007
.8639	0.011
.8701	0.004
.8778	-0.005
.8840	-0.008
.8889	-0.025
.8938	-0.028
.8993	-0.018
.9056	-0.023
.9104	-0.006
.9167	0.002
.9222	0.006
.9326	0.000
.9389	0.004
.9438	0.008
.9549	0.018
.9604	0.019
.9653	0.025
.9708	0.028
.9764	0.015
.9819	0.004
.9944	-0.016
26942.0014	-0.020
.0063	-0.024

7,10,73

J.D.$_\odot$	ΔV
26942.8493	0.035
.8549	0.025
.8597	0.007
.8646	-0.010
.8701	-0.019
.8764	-0.025
.8819	-0.018
.8868	-0.019
.8924	-0.013
.8972	-0.008
.9021	-0.004
.9076	0.002
.9125	0.007
.9188	0.014
.9243	0.026
.9299	0.029
.9368	0.025
.9431	0.020
.9486	0.006
.9542	0.007
.9618	-0.009
.9674	-0.012
.9722	-0.005
.9778	-0.010
.9889	0.001
.9944	-0.005
26943.0063	-0.017
.0118	-0.014

TABLE 3

LIGHT CURVES OF HR 7563

28,9,73

J.D.$_\odot$	ΔV
26933.6271	0.050
.6368	0.041
.6430	0.041
.6493	0.036
.6555	0.025
.6625	0.005
.6687	-0.005
.6757	-0.016
.6826	-0.036
.6896	-0.042
.7014	-0.023
.7076	-0.017
.7180	-0.006
.7264	-0.007
.7319	-0.006
.7486	-0.010
.7569	-0.015
.7632	-0.012
.7701	-0.012
.7805	-0.017
.7847	-0.014
.7910	0.015
.7965	0.003
.8028	0.021

29,9,73

J.D.$_\odot$	ΔV
26934.6159	0.000
.6229	0.000
.6298	-0.003
.6375	-0.001
.6451	0.016
.6513	0.013
.6576	0.021
.6625	0.021
.6696	0.026
.6777	0.023
.6826	0.018
.6868	0.015
.6902	0.017
.6937	0.008
.6979	0.011
.7020	0.003
.7062	-0.008
.7104	-0.012
.7180	-0.012
.7222	-0.010
.7263	-0.009
.7340	-0.005
.7388	-0.003
.7437	-0.004
.7472	0.004
.7520	0.004
.7562	0.002
.7611	0.005
.7659	0.002
.7708	0.004
.7756	0.009
.7819	0.005
.7861	0.006
.7916	-0.003
.7951	-0.006

30,9,73

J.D.$_\odot$	ΔV
26935.6180	0.017
.6243	0.028
.6305	0.032
.6361	0.020
.6410	0.028
.6465	0.015
.6528	0.003
.6583	-0.003
.6639	-0.008
.6694	-0.014
.6757	-0.025
.6812	-0.028
.6993	-0.027
.7055	-0.017
.7097	-0.017
.7174	-0.006
.7236	-0.003
.7299	-0.004
.7361	0.012
.7417	0.016
.7479	0.014
.7569	0.011
.7736	-0.009

1,10,73

J.D.$_\odot$	ΔV
26936.6201	-0.008
.6557	-0.006
.6368	0.009
.6479	0.012
.6542	0.022
.6597	0.024
.6653	0.027
.6708	0.027
.6764	0.019
.6819	0.009
.6917	-0.014
.6986	-0.027
.7049	-0.033
.7111	-0.040
.7174	-0.044
.7229	-0.040
.7278	-0.025
.7340	-0.017
.7396	-0.010
.7465	0.003
.7521	0.017
.7583	0.022
.7646	0.028
.7722	0.027
.7778	0.016
.7902	0.003
.7972	-0.005

2,10,73

J.D.$_\odot$	ΔV
26937.6118	0.027
.6208	0.021
.6285	0.011
.6333	0.009
.6403	0.008
.6458	0.004
.6514	-0.004
.6576	-0.006
.6639	-0.006
.6840	-0.013
.6889	-0.011
.6972	0.006
.7028	0.006
.7092	0.004
.7146	0.002
.7208	0.005
.7264	-0.005
.7326	-0.015
.7382	-0.023
.7437	-0.023
.7555	-0.027
.7618	-0.017
.7674	-0.004
.7771	0.014
.7868	0.025
.7924	0.034
.7986	0.024

4,10,73

J.D.$_\odot$	ΔV
26939.6083	0.024
.6208	0.019
.6277	0.017
.6333	0.195
.6437	-0.004
.6493	-0.025
.6555	-0.024
.6611	-0.022
.6667	-0.020
.6715	-0.017
.6778	-0.009
.6826	-0.010
.6882	-0.002
.6937	0.006
.6986	0.009
.7097	0.008
.7153	-0.000
.7208	-0.014
.7264	-0.016
.7319	-0.021
.7375	-0.025
.7486	-0.026
.7549	-0.012
.7604	0.013
.7667	0.018
.7743	0.014
.7799	0.039
.7868	0.029
.7923	0.044

5,10,73

J.D.$_\odot$	ΔV
26940.6174	-0.031
.6250	-0.022
.6305	-0.021
.6458	-0.006
.6549	0.002
.6604	0.006
.6667	0.012
.6732	0.008
.6778	0.000
.6840	0.012
.6889	0.015
.6944	0.003
.7021	-0.002
.7076	-0.009
.7139	-0.005
.7194	-0.003
.7257	-0.003
.7326	0.005
.7403	0.012
.7465	0.017
.7535	0.009

TABLE 3 (CONTINUED)

.7618	0.010
.7680	0.008
.7750	0.002
.7812	0.002
.7868	0.000
.7930	-0.005
.7993	-0.013

6,10,73	
J.D.⊙	ΔV
26941.6514	-0.028
.6597	-0.023
.6660	-0.010
.6722	-0.008
.6806	-0.010
.6868	0,009
.6931	0.002
.6993	0.004
.7056	-0.002
.7111	-0.001
.7174	0.002
.7229	0.000
.7299	-0.003
.7375	-0.001
.7431	0.007
.7500	0.010
.7563	0.014
.7660	0.017
.7736	0.019
.7813	0.011

7,10,73	
J.D.⊙	ΔV
26942.6007	-0.016
.6062	-0.013
.6146	-0.006
.6208	0.003
.6264	0.003
.6354	-0.001
.6410	0.003
.6472	-0.010
.6529	-0.014
.6639	-0.009
6687	-0.014
.6743	-0.017
.6799	-0.018
.6854	-0.012
.6917	-0.007
.6979	0.003
.7035	0.007
.7090	0.011
.7139	0.014
.7271	0.018
.7340	0.018
.7382	0.022
.7465	0.022
.7500	0.023
.7535	0.021
.7576	0.023
.7618	0.017
.7653	0.015
.7715	0.009
.7826	0.005
.7951	-0.002
.7986	-0.008
.8028	-0.009

8,10,73	
J.D.⊙	ΔV
26943.6035	-0.031
.6097	-0.026
.6201	-0.013
.6312	-0.012
.6375	-0.008
.6430	-0.008
.6486	-0.011
.6625	-0.035
.6680	-0.036
.6736	-0.042
.6792	-0.036
.6833	-0.027
.6896	-0.020
.6944	-0.009
.7028	0.006
.7083	0.017
.7139	0.023
.7201	0.033
.7250	0.040
.7305	0.039
.7361	0.045
.7417	0.036
.7472	0.035
.7521	0.017
.7576	0.004

polynomial, obtaining periods of 0.095 days for HR 1170 and 0.100 for HR 7563, with mean respective amplitudes of 0.082 and 0.035.

As was pointed out by Valtier (ibid) and Fitch (ibid), the period determination of short period variables involves a number of difficulties. We have started an extended study of this problem and the results will be reported in the future. However, *preliminary* results, using a "best-fit method" (analogous to Valtier's), indicate the presence of two periods for HR 1170, of 0.097 and 0.067 days. For HR 7563, we have obtained three periods; 0.181, 0.106 and 0.077 days. The precision of this method is 5%. Application of the Fourier transform method to the data seems to support these results. Of course, a more complete study is necessary to confirm the preliminary figures. This work is now in progress.

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REFERENCES

Baglin, A., Breger, M., Chevalier, C., Hauck, B., le Contel, J. M., Sareyan, J. P., and Valtier, J. C. 1973, *Astron. & Astrophys.*, **23,** 221.
Breger, M. 1969, *Astron. J.*, **74,** 166.
Breger, M. 1970, *Astrophys. J.*, **162,** 597.
Breger, M. and Warman, J. 1974, *Konkoly Obs. Bull.* 837.
Fitch, W. S. 1970, *Astrophys. J.*, **161,** 669.
Valtier, J. C. 1972, *Astron. & Astrophys.*, **16,** 38.