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PHOTOELECTRIC PHOTOMETRY OF DELTA SCUTI STARS: HR 4715, HR 5329 AND HR 7331

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RESUMEN

Se presenta fotometría diferencial en el filtro *V* de Johnson, de las estrellas Delta Scuti HR 4715, HR 5329 y HR 7331.

ABSTRACT

Differential photometry in Johnson's *V* filter of the Delta Scuti stars HR 4715, HR 5329 and HR 7331 is presented.

Key words: **PHOTOMETRY – STARS-VARIABLES – STARS-δ SCUTI.**

I. INTRODUCTION

According to Breger's (1979) definition, the δ Scuti stars are short period variables located in the instability strip with spectral types between A2 and F5 and luminosity classes that vary between V and II. The possible relations between the δ Scuti and other short period variables located in the same region in the HR diagram have been pointed out by several authors. See for example Breger (1969), Eggen (1976) and Kurtz (1976).

The average period of δ Scuti stars is around $0^d.15$; current research is being carried out to find whether these periods are single or multiple. One group of astronomers believes that the multiplicity is merely the result of statistical fluctuations, while others think that the existence of multiple periods is real and related to radial or non-radial modes of oscillation in the outermost layers of this type of stars.

To determine the periods, the longest possible set of data is required. This is obtained by observing the star for the maximum possible number of consecutive nights since the credibility of the results, when compared with predictions from multiperiodic models, will depend strongly on the quality and the quantity of observational data available.

Since 1966 when HR 4715 (4 CVn) was established as a δ Scuti star, several authors have shown interest in it. A summary of the available literature about this star can be found in Warman *et al.* (1979).

HR 5329 (κ Boo A) is the brightest component of a

TABLE 1

GENERAL INFORMATION ABOUT STARS IN THIS PAPER

Star	HR	*V*	Sp	*B-V*	Type
4 CVn	4715	5.93	F3 IV	....	variable
BD - 43°2221	....	7.37	F2	....	standard
κ Boo A	5329	4.54	A8 IV	−0.20	variable
κ Boo B	5328	6.69	F2V	−0.39	standard
28 Aql	7331	5.34	F0	....	variable
31 Aql	7373	5.17	G8 IV	−0.78	standard
....	7389	5.72	F6 III	....	standard

TABLE 2

PHOTOMETRY OF HR 5329 IN THE *V* FILTER

HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG
2443200.0 +									
		39.7714	-0.009	41.8568	-0.003	42.8845	0.000	46.8566	0.017
		39.7735	-0.010	41.8866	-0.008	42.8859	0.006	46.8587	0.015
37.7249	-0.002	39.7752	-0.011	41.8908	-0.008	42.8873	-0.011	46.8622	0.027
37.7284	-0.010	39.7777	-0.012	41.8957	0.001	42.8950	-0.015	46.8636	0.018
37.7305	-0.018	39.7801	-0.011	41.8978	0.001	42.8963	-0.012	46.8657	0.016
37.7347	-0.020	39.7822	-0.008	41.8998	-0.003	42.8998	-0.017	46.8677	0.013
37.7367	-0.016	39.7843	-0.006	41.9019	-0.002	42.9054	-0.026	46.8719	0.008
37.7395	-0.003	39.7860	-0.007	41.9040	0.004	42.9081	-0.025	46.8740	0.009
37.7437	-0.005	39.7881	-0.003	41.9061	0.002	42.9095	-0.017	46.8782	-0.004
37.7472	0.005	39.7905	0.002	41.9075	0.009	42.9109	-0.010	46.8851	-0.016
37.7499	0.014	39.7923	-0.000	41.9130	0.015	42.9123	-0.009	46.8879	-0.020
37.7541	0.010	39.7940	-0.003	41.9179	0.019	42.9137	-0.007	46.8907	-0.026
37.7597	-0.002	39.7961	-0.001	41.9228	0.020	42.9193	-0.003	46.8962	-0.022
37.7631	-0.004	39.7978	0.004	41.9262	0.019			46.8983	-0.019
37.7666	-0.006	39.7995	0.009	41.9283	0.017			46.9011	-0.017
37.7805	-0.010	39.8016	0.009	41.9339	0.016	43.7630	0.011	46.9032	-0.015
37.7902	-0.006	39.8034	0.007	41.9373	0.011	43.7678	0.015	46.9052	-0.010
37.7958	-0.001	39.8086	0.014	41.9415	-0.004	43.7699	0.021	46.9094	-0.010
		39.8124	0.013	41.9464	-0.003	43.7720	0.018	46.9143	-0.007
		39.8166	0.003	41.9484	-0.006	43.7762	0.023	46.9171	0.000
38.9263	-0.012	39.8190	-0.004			43.7810	0.031	46.9205	0.006
38.9277	-0.024	39.8211	-0.008			43.7831	0.031	46.9233	0.006
38.9284	-0.013	39.8228	-0.008	42.7276	-0.007	43.7859	0.033		
38.9298	-0.034	39.8242	-0.006	42.7297	-0.007	43.7914	0.028		
38.9319	-0.023	39.8259	-0.008	42.7331	-0.005	43.7942	0.022	47.7052	-0.011
38.9332	-0.035	39.8280	-0.012	42.7345	-0.005	43.7963	0.025	47.7073	-0.016
38.9402	-0.026	39.8298	-0.010	42.7429	-0.003	43.8012	0.018	47.7108	0.000
38.9437	-0.012	39.8315	-0.010	42.7463	-0.002	43.8026	0.016	47.7143	0.012
38.9451	-0.011	39.8336	-0.010	42.7526	-0.001	43.8095	0.000	47.7198	0.022
38.9471	-0.006	39.9034	-0.011	42.7595	-0.005	43.8130	0.001	47.7219	0.017
38.9506	-0.001	39.9051	-0.009	42.7630	-0.010	43.8171	-0.006	47.7254	0.001
38.9617	0.000	39.9068	-0.007	42.7693	-0.008	43.8206	-0.007	47.7288	-0.005
38.9652	-0.005	39.9086	-0.005	42.7706	-0.012	43.8248	-0.011	47.7309	-0.008
38.9666	-0.004	39.9103	-0.005	42.7804	-0.014	43.8269	-0.009	47.7344	-0.010
38.9673	-0.004	39.9141	-0.004	42.7818	-0.012	43.8296	-0.007	47.7365	-0.006
38.9701	-0.006	39.9179	-0.001	42.7894	-0.016	43.8317	-0.002	47.7386	0.000
38.9714	-0.011	39.9204	-0.002	42.7929	-0.011	43.8366	0.000	47.7427	0.010
38.9756	-0.020	39.9232	-0.007	42.7963	-0.008	43.8387	-0.007	47.7455	0.011
38.9770	-0.024	39.9256	-0.013	42.7984	-0.006	43.8491	0.010	47.7476	0.005
38.9784	-0.026	39.9284	-0.014	42.8012	0.003	43.8526	0.002	47.7490	-0.003
38.9819	-0.030	39.9308	-0.012	42.8040	0.002	43.8539	0.005	47.7545	-0.004
38.9832	-0.026	39.9325	-0.011	42.7998	0.001	43.8567	0.006	47.7580	-0.002
38.9846	-0.025			42.8081	0.007	43.8616	-0.002	47.7594	0.000
38.9867	-0.022			42.8116	0.018	43.8637	0.002	47.7656	0.004
38.9888	-0.020	41.7561	-0.003	42.8144	0.022	43.8671	0.001	47.7670	0.001
38.9909	-0.013	41.7589	0.005	42.8158	0.029	43.8713	-0.009	47.7698	-0.005
38.9930	-0.017	41.7637	0.010	42.8179	0.031	43.8914	-0.015	47.7747	-0.008
38.9944	-0.002	41.7672	0.009	42.8206	0.033	43.8949	-0.018	47.7788	-0.006
38.9985	0.003	41.7734	0.023	42.8220	0.038	43.8984	-0.015	47.7823	-0.006
38.9992	-0.013	41.7776	0.025	42.8241	0.036	43.9012	-0.010	47.7837	-0.004
39.0027	0.002	41.7853	0.024	42.8255	0.035	43.9046	-0.007	47.7851	-0.003
		41.7873	0.016	42.8269	0.025	43.9095	-0.002	47.7913	0.006
		41.7894	0.014	42.8290	0.024	43.9130	-0.009	47.7948	0.007
39.7127	-0.008	41.7908	0.014	42.8311	0.011	43.9151	-0.004	47.8240	0.007
39.7155	-0.006	41.7971	0.005	42.8325	0.009	43.9171	-0.009	47.8309	-0.002
39.7179	-0.005	41.7984	0.002	42.8345	0.007	43.9234	-0.011	47.8330	-0.005
39.7197	-0.005	41.8068	-0.009	42.8373	0.005	43.9255	-0.014	47.8393	-0.008
39.7218	0.001	41.8089	-0.006	42.8394	0.003	43.9310	-0.015	47.8427	-0.006
39.7235	0.009	41.8116	-0.009	42.8408	-0.003	43.9387	-0.013	47.8490	-0.006
39.7256	0.019	41.8158	-0.007	42.8429	-0.006	43.9463	-0.011	47.8545	-0.002
39.7280	0.028	41.8221	-0.009	42.8450	-0.008	43.9512	-0.009	47.8559	-0.001
39.7298	0.028	41.8241	-0.008	42.8470	-0.005	43.9567	-0.010	47.8580	0.000
39.7315	0.025	41.8276	-0.008	42.8519	-0.001	43.9595	-0.009	47.8594	-0.006
39.7339	0.018	41.8318	-0.006	42.8575	0.002	43.9623	-0.004	47.8663	-0.009
39.7409	0.031	41.8339	-0.003	42.8595	0.007	43.9685	-0.005	47.8719	-0.006
39.7433	0.027	41.8359	0.000	42.8658	0.013	43.9713	0.000	47.8726	-0.009
39.7450	0.020	41.8380	0.003	42.8672	0.018	43.9734	0.000	47.8747	-0.001
39.7468	0.013	41.8422	0.004	42.8686	0.013			47.8768	0.005
39.7492	0.010	41.8436	0.006	42.8713	0.023			47.8802	0.010
39.7551	0.010	41.8471	0.007	42.8727	0.026	46.8476	0.005	47.8837	0.004
39.7607	-0.006	41.8491	0.011	42.8755	0.018	46.8490	0.004	47.8851	0.004
39.7634	-0.005	41.8505	0.011	42.8769	0.015	46.8511	0.003	47.8893	-0.006
39.7662	-0.011	41.8526	0.008	42.8811	0.010	46.8525	0.006	47.8927	-0.010
39.7686	-0.013	41.8540	0.001	42.8831	0.004	46.8546	0.010	0.0000	0.000

TABLE 3

PHOTOMETRY OF HR 4715 IN THE *V* FILTER

HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG
2443200.0 +									
		38.7154	0.000	40.9028	0.010	42.6851	0.003	43.8367	-0.034
		38.7606	-0.002	40.9056	0.001	42.6872	0.003	43.8423	-0.039
37.7335	0.003.	38.7654	0.001	40.9105	0.003	42.6893	0.003	43.8492	-0.033
37.7377	0.010	38.7724	0.002	40.9160	-0.001	42.6909	0.010	43.8534	-0.011
37.7426	0.018	38.7765	0.007	40.9244	0.008	42.6947	0.013	43.8561	-0.006
37.7467	0.025	38.7814	0.006	40.9292	0.013	42.7193	0.021	43.8596	-0.009
37.7557	0.029	38.7849	0.013	40.9334	0.006	42.7226	0.019	43.8638	-0.002
37.7599	0.027	38.7897	0.010	40.9389	0.004	42.7243	0.020	43.8666	-0.007
37.7648	0.025	38.7932	0.007	40.9452	0.002	42.7259	0.012	43.8700	0.007
37.7689	0.026	38.7960	0.001			42.7272	0.006	43.8735	0.010
37.7745	0.021	38.7974	-0.006			42.7288	0.007	43.8770	0.014
37.7787	0.013	38.8161	-0.001	41.7139	0.019	42.7313	0.001	43.8805	0.001
37.7828	0.010	38.8231	0.004	41.7187	0.022	42.7347	0.000	43.8853	0.030
37.7863	0.009	38.8307	0.005	41.7222	0.022	42.7563	-0.008	43.8895	0.028
37.7912	-0.002	38.8349	0.001	41.7271	0.026	42.7580	-0.013	43.9027	0.030
37.7946	-0.005	38.8397	-0.005	41.7368	0.006	42.7601	-0.015	43.9075	0.049
37.7981	-0.008	38.8460	-0.007	41.7403	0.002	42.7613	-0.017	43.9207	0.054
37.8016	-0.016	38.8522	-0.004	41.7424	0.000	42.7634	-0.017	43.9256	0.056
37.8051	-0.017	38.8585	-0.003	41.7472	-0.016	42.7651	-0.018	43.9305	0.052
37.8120	-0.023	38.8626	-0.005	41.7507	-0.015	42.7680	-0.013		
37.8155	-0.023	38.8668	-0.009	41.7562	-0.023	42.7963	-0.022		
37.8189	-0.024	38.8758	-0.009	41.7597	-0.024	42.7980	-0.015	44.7221	0.009
37.8224	-0.030	38.8800	-0.007	41.7632	-0.021	42.8022	-0.018	44.7248	0.009
37.8266	-0.027	38.8869	-0.004	41.7681	-0.033	42.8034	-0.012	44.7269	0.012
37.8363	-0.029	38.8974	-0.001	41.7764	-0.042	42.8047	-0.008	44.7297	0.020
37.8412	-0.024	38.9015	0.006	41.7792	-0.041	42.8068	-0.013	44.7325	0.019
37.8453	-0.022	38.9057	0.006	41.7819	-0.039	42.8084	-0.012	44.7380	0.019
37.8502	-0.018	38.9106	0.007	41.7868	-0.031	42.8101	0.009	44.7408	0.024
37.8557	-0.010	38.9147	0.006	41.7896	-0.028	42.8122	0.005	44.7436	0.022
37.8606	-0.007	38.9182	0.009	41.7924	-0.025	42.8138	0.018	44.7464	0.024
37.8696	-0.004	38.9217	0.008	41.7951	-0.024	42.8393	0.028	44.7491	0.024
37.8738	-0.006	38.9251	0.004	41.8007	-0.023	42.8463	0.030	44.7547	0.023
37.8787	-0.001	38.9286	0.001	41.8056	-0.018	42.8480	0.025	44.7589	0.018
37.8821	0.003	38.9335	-0.001	41.8090	-0.013	42.8501	0.015	44.7623	0.015
37.8981	0.008	38.9494	-0.005	41.8201	-0.009	42.8522	0.012	44.7644	0.015
37.9044	0.006			41.8243	0.008	42.8543	0.004	44.7672	0.018
37.9064	0.004			41.8312	0.007	42.8559	0.000	44.7700	0.019
37.9092	0.006	40.8084	-0.019	41.8361	0.013	42.8588	-0.009	44.7728	0.013
37.9127	0.004	40.8125	-0.019	41.8410	0.017	42.8851	-0.019	44.7769	0.009
37.9196	0.005	40.8174	-0.024	41.8451	0.016	42.8888	-0.021	44.7804	-0.003
37.9301	0.004	40.8209	-0.023	41.8514	0.005	42.8947	-0.022	44.7825	-0.005
37.9342	0.005	40.8250	-0.024	41.8562	-0.001	42.8972	-0.022	44.7860	-0.005
37.9474	0.009	40.8299	-0.032	41.8611	-0.004			44.7894	-0.005
37.9509	0.011	40.8341	-0.030	41.8646	-0.003			44.7971	-0.014
37.9544	0.012	40.8369	-0.020	41.8681	-0.003	43.6916	0.031	44.8005	-0.022
37.9564	0.010	40.8389	-0.014	41.8924	0.007	43.6950	0.030	44.8089	-0.025
37.9620	0.007	40.8417	-0.017	41.8951	0.009	43.6978	0.014	44.8290	-0.018
37.9676	0.005	40.8445	-0.022	41.9000	0.008	43.7048	0.017	44.8339	-0.012
37.9717	0.001	40.8500	-0.016	41.9062	0.005	43.7082	0.012	44.8360	-0.013
37.9912	-0.005	40.8542	-0.011	41.9104	0.012	43.7096	0.013	44.8387	-0.010
37.9953	-0.006	40.8563	-0.005	41.9174	0.030	43.7173	0.003	44.8436	-0.009
37.9988	-0.010	40.8646	-0.005	41.9215	0.029	43.7221	-0.003	44.8533	-0.011
38.0030	-0.012	40.8681	0.006	41.9236	0.031	43.7277	-0.014	44.8554	-0.011
38.0064	-0.014	40.8702	0.016	41.9271	0.032	43.7478	-0.020	44.8575	-0.012
38.0106	-0.020	40.8730	0.024	41.9306	0.031	43.7735	-0.028	44.8637	-0.009
		40.8771	0.030	41.9382	0.024	43.7853	-0.017	44.8686	-0.011
		40.8834	0.021	41.9424	0.018	43.7895	-0.016	44.8735	-0.007
38.7342	-0.006	40.8875	0.020	41.9479	0.015	43.7923	-0.013	44.8769	-0.004
38.7363	-0.005	40.8931	0.028	41.9514	0.014	43.7999	0.005	44.8811	-0.001
38.7432	-0.006	40.8966	0.029			43.8166	-0.004	44.8839	-0.007
38.7488	-0.007	40.8994	0.025			43.8235	-0.023	44.8887	-0.003
38.7536	-0.005	40.9014	0.015	42.6830	-0.001	43.8270	-0.025	44.8915	0.002

binary system with a separation of 12 arcsec. This introduces difficulties in the observations since it requires an excellent seeing and a telescope of moderate size in order to isolate the light of the secondary star. Fortunately κ Boo B is two magnitudes fainter than HR 5329 and has a spectral type quite similar to its companion, a fact that allows us to use it as a standard. Millis (1967), Desikachary *et al.* (1971) and Elliott (1974) have report-

TABLE 4

PHOTOMETRY OF HR 7331 IN THE *V* FILTER

HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG	HEL JD	D MAG
2443300.0 +									
		9.8653	0.016	10.7790	0.005	10.8811	-0.013	11.7310	-0.008
		9.8708	0.019	10.7832	0.006	10.8844	-0.013	11.7360	-0.004
9.7645	0.010	9.8770	0.016	10.7861	0.010	10.8886	-0.011	11.7406	-0.011
9.7687	0.010	9.8833	0.023	10.7903	0.011	10.8944	-0.009	11.7456	-0.015
9.7737	-0.003	9.8887	0.022	10.7940	0.008	10.8999	-0.006	11.7489	-0.013
9.7778	-0.007	9.8928	0.017	10.7969	0.008	10.9049	-0.002	11.7631	-0.012
9.7824	-0.018	9.8970	0.010	10.8011	0.006	10.9124	-0.001	11.7664	-0.015
9.7883	-0.017	9.9062	0.011	10.8053	0.007	10.9178	-0.002	11.7706	-0.012
9.7937	-0.027	9.9112	0.007	10.8082	0.008	10.9219	0.003	11.7748	-0.013
9.7987	-0.020	9.9153	0.001	10.8111	0.008	10.9269	0.006	11.7777	-0.003
9.8041	-0.024	9.9195	0.001	10.8174	0.004	10.9319	0.008	11.7819	-0.009
9.8112	-0.021	9.9237	-0.006	10.8199	0.001	10.9361	0.009	11.7852	-0.007
9.8166	-0.018			10.8240	0.009	10.9403	0.006	11.7885	0.001
9.8208	-0.015			10.8290	0.005	10.9469	0.012	11.7969	0.011
9.8262	-0.014	10.7319	-0.008	10.8340	-0.005	10.9511	0.009	11.8027	0.013
9.8303	-0.012	10.7361	-0.002	10.8403	-0.002	10.9561	0.011	11.8081	0.021
9.8345	-0.013	10.7415	-0.004	10.8465	-0.005	10.9590	0.011	11.8123	0.019
9.8416	0.001	10.7469	0.004	10.8511	-0.010	10.9615	0.007	11.8164	0.022
9.8449	0.004	10.7511	-0.001	10.8569	-0.012	10.9653	0.002	11.8206	0.022
9.8491	0.003	10.7611	0.005	10.8615	-0.014	10.9686	-0.009	11.8319	0.020
9.8528	0.013	10.7657	0.006	10.8699	-0.015	10.9719	-0.000		
9.8570	0.012	10.7715	0.003	10.8736	-0.013				
9.8612	0.018	10.7753	0.003	10.8778	-0.010				

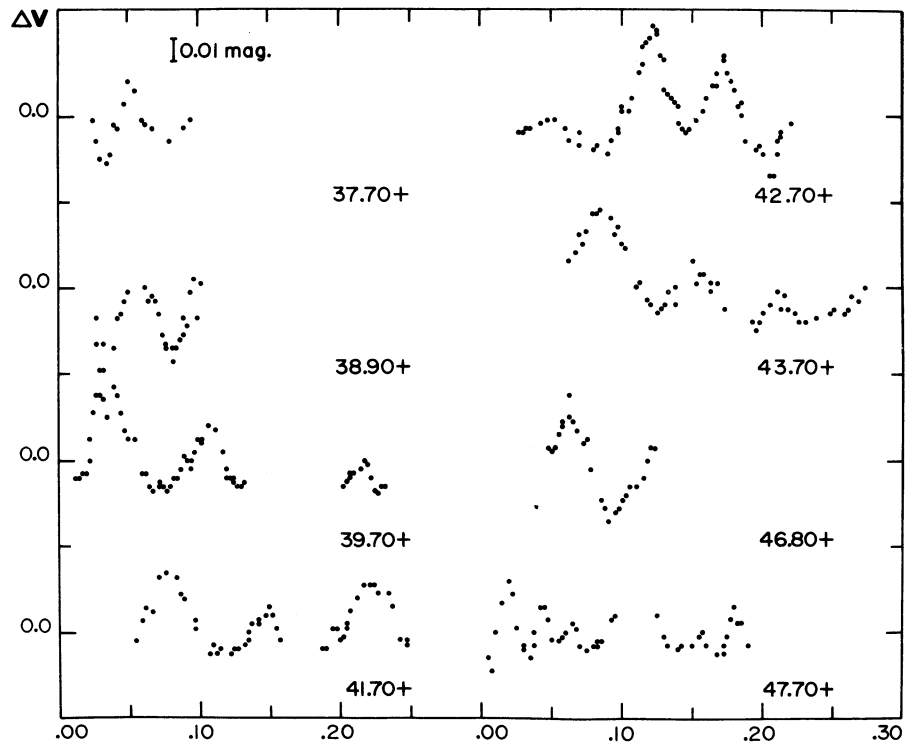

Fig. 1. Light curves of HR 5329.

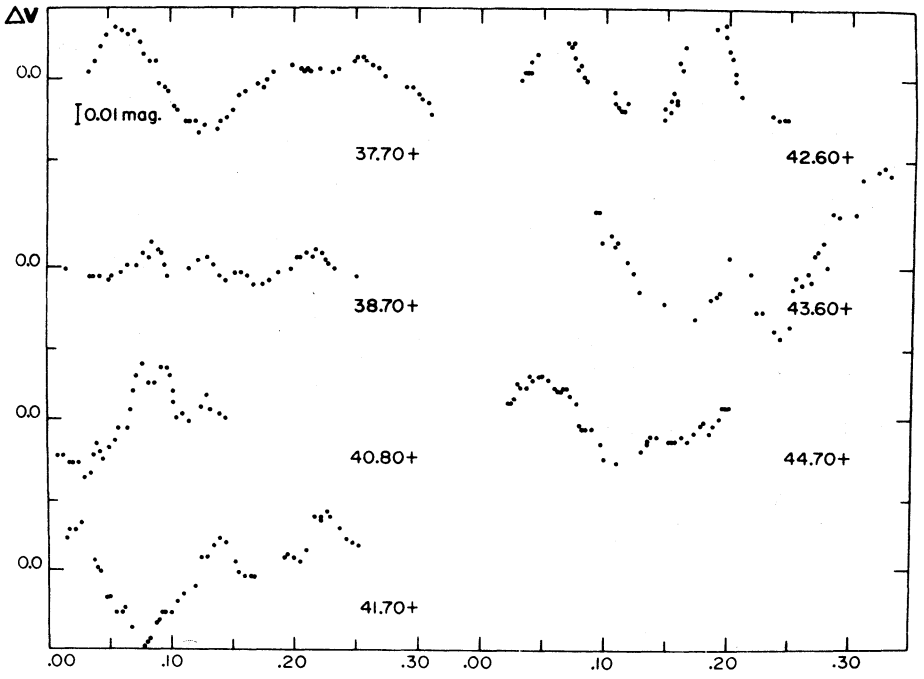

Fig. 2. Light curves of HR 4715.

ed observations and data related to the periods of κ Boo A.

The first observations of HR 7331 (28 Aql) were carried out by Breger (1969) who established it as a δ Scuti variable. Later, Breger, Hutchins and Kuhi (1976) reported simultaneous observations both by photometry and spectroscopy. More recently Peña and Warman (1979) have reported their observations and definite conclusions on the multiperiodicity and the non-radial nature of the pulsations of this star. The data reported in this paper were employed in their analysis.

II. OBSERVATIONS

The observations were carried out using the 33 and 60 inch telescopes at the Observatorio Astronómico Nacional, Baja California, México. Two dry-ice cooled photocells 1P21 were employed along with Johnson's *V* filter. The criteria followed to choose the standard stars have been described elsewhere (Warman *et al.* 1974). The characteristics of both the variable and the standard stars can be found in Table 1. The reported photometric values are the difference (in magnitudes) of the variable star and the standard star interpolated to the time of the observation of the program star. Afterwards, an average ΔV was subtracted in order to obtain a zero base line.

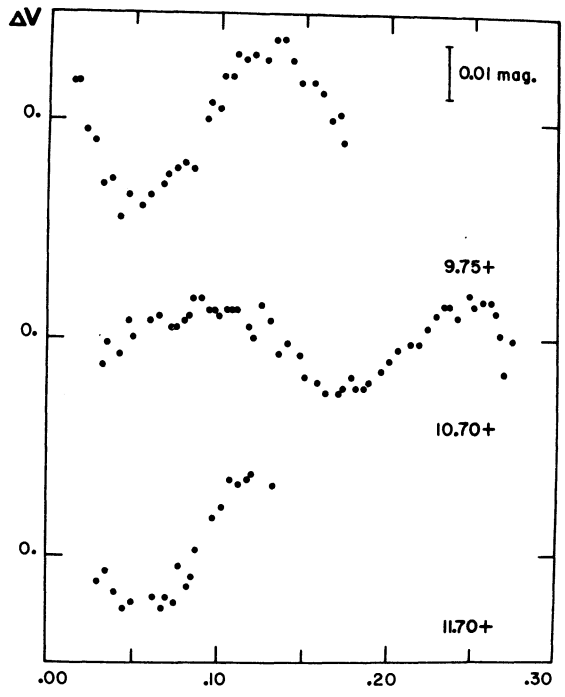

Fig. 3. Light curves of HR 7331.

III. RESULTS

Table 2 presents the observed photometry of HR 5329. Observations carried out during eight nights are reported. The corresponding light curves are plotted in Figure 1. The vertical axis shows the brightness variation ΔV in magnitudes while time is shown in the horizontal axis. Units are heliocentric Julian Days. Each point represents the average of at least four ten-second integrations. The standard deviation is, in all cases, less than 0.005 magnitudes. Time accuracy is better than $0^d.001$.

Table 3 shows the observations of HR 4715 and Figure 2 shows its light curve. For this star seven nights are reported.

Finally, the results of three nights of observations of HR 7331 are given in Table 4. The corresponding light curves are those of Figure 3.

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REFERENCES

Breger, M. 1969, *Ap. J. Suppl.*, **19**, 99.
Breger, M. 1979, *Pub. A.S.P.*, **91**, 5.
Breger, M., Hutchins, J., and Kuhi, L.V. 1976, *Ap. J.*, **210**, 163.
Desikachary, K., Parthasarathy, M., and Kameswara Rao, N. 1971, *Pub. A.S.P.*, **83**, 832.
Eggen, O.J. 1976, *Pub. A.S.P.*, **88**, 402.
Elliott, J.E. 1974, *A.J.*, **79**, 1082.
Kurtz, D.W. 1976, *Ap. J. Suppl.*, **32**, 651.
Millis, R.L. 1967, unpublished Ph. D. dissertation, University of Wisconsin.
Peña, J.H., and Warman, J. 1979, *A.J.*, **84**, 1046.
Warman, J., Malacara, Z., and Breger, M. 1974, *Rev. Mexicana Astron. Astrof.*, **1**, 143.
Warman, J., Peña, J.H., and Arellano-Ferro, A. 1979, *A.J.*, **84**, 109.

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