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Photometric variability of 29 Cygni

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The λ Boötis-type star 29 Cygni has been found to be a pulsating variable, with a period of about 45 min and an amplitude of about $0^m.03$ in yellow light. This result confirms an earlier unpublished result by E. N. Walker, and suggests that the λ Boötis stars differ fundamentally from the Am and Ap stars, in which pulsation is rare and/or of very low amplitude. A comparison star, 28 Cygni (B3 Ve), has also been found to be variable on a time scale of several hours or more, with an amplitude of about $0^m.05$.

INTRODUCTION

THE bright star 29 Cygni (HD 192640, HR 7736, A2 V, $V = 4.94$) is one of a small group of stars called λ Boötis stars—stars characterized by low space velocities, early A spectra as judged from their hydrogen lines, weak metallic lines for their colors and (hydrogen line) spectral types, and moderately large rotational velocities. Recent studies of these stars have been made by Eggen (1967), Oke (1967), Sargent (1967), and Baschek and Searle (1969). Of the five stars which have been classified as λ Boötis stars, 29 Cygni is the reddest, and the only one which lies in the δ Scuti instability strip [see Baglin *et al.* (1973) for a discussion of the δ Scuti pulsating variable stars]. The colors of 29 Cygni are $B - V = 0.16$ and $U - B = 0.03$, and its absolute magnitude, as calculated from its known trigonometric parallax of $\pi = 0.033 \pm 0.006$, is $M_v = +2.53 \pm 0.40$. Baschek and Searle (1969) derive $\theta = 0.63$ and $\log g = 3.9$ from their observations.

Walker (1973) studied 29 Cygni extensively in 1971 and 1972 and suspected it to be variable in brightness with a period of about 45 min and an amplitude of $0^m.01$ to $0^m.04$. Winzer (1974) also studied 29 Cygni in 1971 and 1972, looking for light variations on a time scale of

TABLE I. 29 Cyg−28 Cyg: magnitude differences in yellow light.

$JD_{\odot}$ 2442931+	ΔV	$JD_{\odot}$ 2442933+	ΔV	$JD_{\odot}$ 2442968+	ΔV	$JD_{\odot}$ 2442968+	ΔV
0.7628	0.025	0.7736	0.027	0.6938	0.014	0.7729	0.050
0.7658	0.024	0.7764	0.012	0.6958	0.010	0.7757	0.048
0.7691	0.018	0.7806	−0.002	0.6986	0.005	0.7792	0.038
0.7713	0.016	0.7826	−0.005	0.7007	0.008	0.7813	0.033
0.7745	0.014	0.7882	0.002	0.7042	0.020	0.7840	0.028
0.7768	0.014	0.7910	0.018	0.7063	0.024	0.7861	0.026
0.7793	0.018	0.7944	0.029	0.7090	0.024	0.7896	0.028
0.7818	0.025	0.7979	0.027	0.7111	0.032	0.7917	0.034
0.7846	0.020	0.8007	0.022	0.7146	0.032	0.7951	0.034
0.7869	0.021	0.8035	0.018	0.7167	0.035	0.7972	0.040
0.7902	0.025	0.8069	0.014	0.7201	0.027	0.8007	0.047
0.7926	0.018	0.8097	0.010	0.7229	0.016	0.8028	0.046
0.7958	0.018	0.8132	0.005	0.7264	0.014	0.8063	0.051
0.7984	0.021	0.8160	0.007	0.7285	0.019	0.8083	0.055
0.8024	0.028	0.8194	0.008	0.7313	0.029	0.8111	0.057
0.8043	0.029	0.8222	0.020	0.7333	0.032	0.8132	0.062
0.8083	0.023	0.8257	0.020	0.7361	0.036	0.8167	0.057
0.8106	0.028	0.8285	0.016	0.7382	0.042	0.8188	0.053
0.8137	0.040	0.8319	0.009	0.7417	0.041	0.8222	0.055
0.8165	0.031	0.8340	0.015	0.7431	0.041	0.8243	0.051
0.8197	0.030	0.8382	0.005	0.7465	0.042	0.8285	0.044
0.8218	0.020	0.8410	0.005	0.7486	0.030	0.8306	0.041
0.8250	0.022	0.8451	0.005	0.7514	0.022	0.8333	0.046
0.8278	0.021	0.8479	0.006	0.7535	0.019	0.8361	0.052
0.8333	0.032	0.8514	−0.002	0.7563	0.020	0.8396	0.057
0.8354	0.041	0.8535	0.000	0.7583	0.022	0.8417	0.057
0.8389	0.048	0.8569	−0.001	0.7618	0.032	0.8451	0.066
0.8417	0.048	0.8590	0.001	0.7639	0.035	0.8479	0.062
0.8451	0.039			0.7674	0.047	0.8514	0.048
0.8472	0.027			0.7694	0.047	0.8535	0.051
0.8514	0.022						
0.8542	0.027						
0.8576	0.020						
0.8604	0.026						
0.8632	0.032						

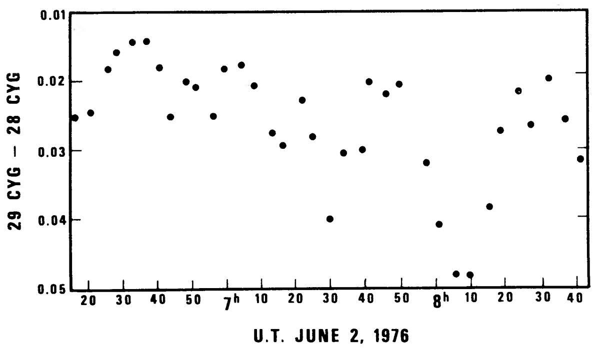

FIG. 1. Differential photometry of 29 Cygni, relative to 28 Cygni, in yellow light on 2 June 1976.

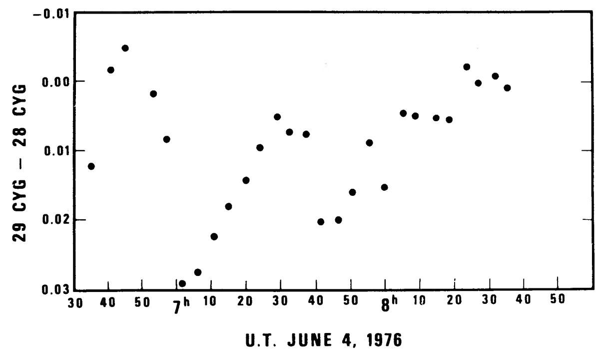

FIG. 2. Differential photometry of 29 Cygni, relative to 28 Cygni, in yellow light on 4 June 1976.

a day or more. He did not find any evidence of short-period light variability, but his observations do not rule out such variability, because of the way in which they were grouped and averaged.

In order to check on Walker's original result, we obtained photometric observations of 29 Cygni on several nights during June and July 1976.

I. OBSERVATIONS

Differential photometry of 29 Cygni was carried out using the 41-cm reflector mounted atop the McLennan Physical Laboratories on St. George campus of the University of Toronto. The photometer (Percy 1969) was used with a standard V filter. The observing sequence consisted of five 10-sec integrations on each of 29 Cyg–28 Cyg–29 Cyg–28 Cyg–sky. (Unfortunately, 28 Cygni appears to be slightly variable; 36 Cygni would have been a more suitable comparison star.) The sky brightness was subtracted from the means, and the difference was converted into a magnitude. These were then corrected for differential extinction where necessary. The corrected magnitude differences (29 Cyg–28 Cyg) are listed in Table I.

II. RESULTS

The light curves on the first two nights (Figs. 1 and 2) clearly show several phenomena: (a) a 45-min variability with an amplitude which itself appears to vary from $0\overset{m}{.}01$ to $0\overset{m}{.}03$, (b) scatter—mostly atmospheric—about this variation, and (c) a systematic variability on a time scale of several hours or more. Figure 3 shows the light curve of 29 Cygni on 9 July, the night when the observations covered the longest time span. In this case, the long-term variability has first been removed from the light curve. In Table II we list the values of ΔV (29 Cyg–28 Cyg), averaged over 45-min periods on 2 and 4 June and 9 July, and on three other nights which were unsuitable for studying the short-period variability of 29 Cygni. The data in Table II thus represent the long-term variability of (29 Cyg–28 Cyg).

We believe that this long-term variability is in 28 Cygni, for two reasons: (1) Winzer (1974) finds no long-term variability in 29 Cygni, using 36 Cygni as a comparison star and (2) 28 Cygni is a Be star (B3 Ve), and Be stars are known to show photometric variability on time scales of hours and days. The radial velocity of 28 Cygni is also variable. However, in order to confirm the variability of 28 Cygni, one of us (J.R.P.) obtained photometric observations of that star, relative to 36 Cygni, on two nights in October 1976 at Kitt Peak National Observatory. These observations showed that 28 Cygni is indeed variable: It brightened by $0\overset{m}{.}035$ in five hours on 8–9 October 1976, and faded by $0\overset{m}{.}020$ in three hours on 9–10 October 1976. The characteristic time scale of its variability is therefore at least 10 h.

The light curve in Fig. 3 shows that 29 Cygni is variable in light with a period of about 45 min and an amplitude which varies between about $0\overset{m}{.}015$ and $0\overset{m}{.}030$ in yellow light. Such variability is typical of δ Scuti pulsating variable stars, which are found in the same part of the Hertzsprung–Russell diagram as 29 Cygni.

TABLE II. 29 Cyg–28 Cyg: magnitude differences in yellow light, averaged over 45-min intervals.

JD	ΔV
2442931.7778	0.0198
2442931.8090	0.0264
2442931.8417	0.0308
2442932.7896	0.0122
2442932.8417	0.0005
2442933.7826	0.0137
2442933.8139	0.0141
2442933.8451	0.0043
2442963.7688	0.0545
2442963.8000	0.0429
2442964.7514	0.0400
2442968.7097	0.0211
2442968.7410	0.0298
2442968.7722	0.0368
2442968.8035	0.0470
2442968.8347	0.0530

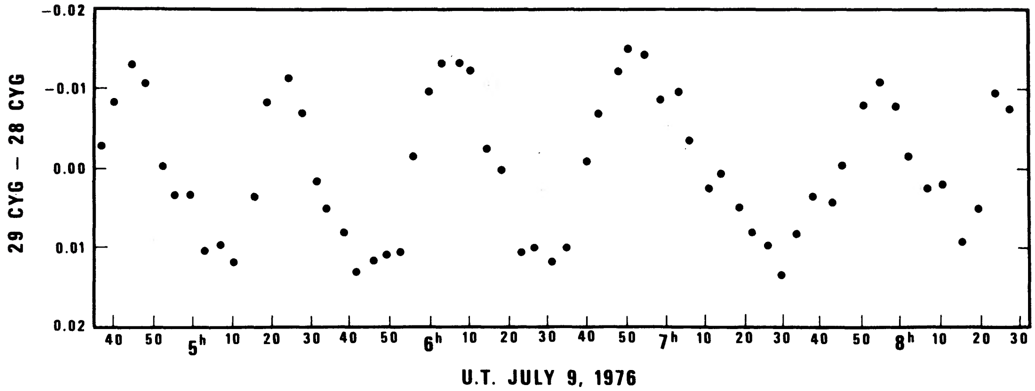

FIG. 3. Differential photometry of 29 Cygni, relative to 28 Cygni, in yellow light on 9 July 1976. The long-term variation of 28 Cygni has been removed, as described in the text.

III. DISCUSSION

Three groups of A-type stars show spectroscopic peculiarities: the λ Boötis stars, the metallic-line (Am) stars, and the peculiar (Ap) stars. The peculiarities of the Am and Ap stars are thought to be due to diffusive element separation; the cause of the λ Boötis phenomenon is not known.

In the Am stars, pulsation does not occur, even among stars lying in the δ Scuti instability strip (Breger 1970). In the Ap stars, pulsation is rare and/or of very small amplitude (Percy 1975). This exclusion between pulsation and spectroscopic peculiarity has been explained, at least for Am stars, by Pamjatnykh (1975) and Percy (1976). In δ Scuti stars, pulsation is driven by helium in the outer layers of the star; in Am stars, this helium has been removed, by diffusion, from these outer layers.

IV. CONCLUSION

We have shown that moderate-amplitude pulsation is found in 29 Cygni, the only λ Boötis star which lies in the δ Scuti instability strip. This suggests strongly (but does not prove) that a pulsation–λ Boötis exclusion does *not* exist and that the λ Boötis phenomenon is fundamentally different from the Am and Ap phenomenon. This suggestion cannot be investigated further until more λ Boötis stars are found in the δ Scuti instability strip.

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