Astron. Astrophys. Suppl. **29**, 327-332.

PHOTOELECTRIC OBSERVATIONS OF THE SHELL STAR o AND*

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Received August 19, 1976, revised March 18, 1977

Photoelectric observations of the shell star o And are given for the period ranging from October 1975 through January 1976. The relative light variations indicate a pseudoperiodicity of about $0^d.8$ which is hence similar to that of other shell stars. The eclipsing binary period proposed by Schmidt (1959) is not confirmed. The various possible hypotheses which may justify these light variations are taken into consideration and some clues of their being caused by shell activity are provided.

Key words: shell stars – photometry

1. INTRODUCTION

The star o And (HD 217675, spectral type B6) is a bright shell star whose nature is still the source of discussion. The various studies made of this star (the first of which date back to the dawn of the century) were for a very long time confined to spectroscopy alone. The first photoelectric measurements of any significance were taken by Gutnick (1941), who proposed a light period of $1^d.5765$. Those of Groeneweld (1944) were then to be followed in 1958 by the studies conducted by Archer (1958) who arrived at a pulsation of the same kind as that of RR Lyrae stars having a period of $0^d.788$. The first set of measurements of any accuracy was drawn up by Schmidt (1959) [a complete bibliography regarding this star for the previous period is included in that paper]. The latter concluded that o And is an eclipsing binary with a period of $1^d.5998398$. This hypothesis was then to be confirmed by Jackish (1963), but not by Detre (1969). Finally, Olsen (1972) also did not confirm the period proposed by Schmidt, but suggested a possible period of $1^d.0185$, stating at the same time that the evidence of the binary nature of o And was still very poor.

We observed the star from October 1975 through January 1976, obtaining measurements with the 40″ reflector of the Merate Observatory using an ice refrigerated Lallemand photomultiplier (19 stages) with S4 response and standard *UBV* filters. Use was also made of a Weitbrect-Gardiner amplifier with the integrating time set at 15 secs and a semi-automatic device for alternatively setting the variable and the comparison star.

It should be remembered that o And ejected a new shell in July 1975 (Koubsky 1975).

2. THE OBSERVATIONS

As a rule, six observations were performed of the variable in alternation with the comparison star for each of the *UBV* colours. These Δm magnitudes $(m_c - m_v)$ have been averaged to give normal points. The comparison star was 2 And (HD 217782, spectral type A2). Each measurement was adjusted to take into consideration the differential extinction using the coefficients determined, whenever possible, during the course of the same night or by means of average values. Tables 1, 2 and 3 show the *UBV* values of the normal points with observation times and standard errors σ. Figures 1 a and b show the trend followed by the normal points in colour B and the curves of the $(B-V)$ and $(U-B)$ colour indices. The bars represent the standard error. The values obtained during the last set of nights are not included in the said figures since only a small number of normal points could be determined for same as o And was too far from the meridian (the average values of same are shown in figures 2 a and b).

* This work has been partly supported by a contract of the Consiglio Nazionale delle Ricerche (CNR)

The constancy of 2 And has been previously verified by Walker (1958). We also ascertained same during nights J.D. 42689–692–700–711–712–714. The check star was HD 217811, spectral type B2. It may be concluded that the comparison star does not vary to an extent of greater than 0.01 mag.

By way of a general characteristic, the light curves show a very irregular tendency. For instance, the light curve of J.D. 42711 shows a significant decrease (of roughly 0.08 mag), whilst that of the night before is almost flat. The most notable variations in our set of measurements occurred at J.D. 42711 and namely $0^{m}.08$, $0^{m}.09$ and $0^{m}.12$ in V, B and U respectively. The $(B-V)$ colour index is fairly constant for all nights whilst the $(U-B)$ index in the case of some nights follows the trend of the B curves.

As regards the determination of the possible periodicity of the phenomenon, a first rough experiment was carried out to determine the minima and maxima of our measurements. The examined light curves allow determination of a minimum and a maximum only, which took place at J.D. 42714.30 and 42692.42 respectively. A second possible minimum took place at J.D. 42689.65. Taking into consideration all the other possible epochs which may be derived from the trend of the light curves, a possible period of $0^{d}.8$ may be determined. This value is substantially in agreement with the values determined for other shell stars (*e.g.* EW Lac, HD 183656, etc.). We then checked the periods proposed by Archer (1958), Schmidt (1959) and Olsen (1972), without however achieving any useful results. Similarly, no positive conclusions were reached with Lafter and Kinman's method (1965), considering the range of periods between $0^{d}.5$ and $2^{d}.5$ with a step of $0^{d}.0001$. A periodogram was then computed (according to Deeming 1975) between the frequencies of 0.0 and 2.5 cycles per day (c/d) with a step of 0.0025 c/d, using the B observations. This is shown in the top half of figure 3. In the lower half of the same figure there is the spectral window translated with its zero frequency under the highest periodogram peak (see Gray and Desikachary 1973). It is immediately apparent that (i) the highest peak is at 1.190 c/d (corresponding to a period of 0.84 days), (ii) the peaks immediately around same are not aliases of it and consequently the light curves are not strictly periodic, (iii) the peaks which lies at ± 1 c/d from same are aliases thereof.

For the purpose of determining, on the basis of our observations and of those previously made by others, a single period, other minima have been sought in literature: the only minima of any value to have been determined are three (see Schmidt 1959, Olsen 1972, Dworak 1976). Therefore the definition of a single period is not of any relevant significance.

Figure 2a indicates the averages of the normal points for each night in the B colour. The bars indicate in magnitude the range covered during the period of the observations. No bar points refer to the nights in which the observations were of short duration. A sudden decrease in the brightness of about 0.1 mag is to be seen in the figure. This decrease occurred between September 29th and November 10th. We wish, however, to add that such a fact may be the consequence of an observational effect. The unusually low average corresponding to the nights of J.D. 42727 and 42738 may be the result of the reduced number of measurements taken during the said nights. However, two facts exist which may be such as to support a physical hypothesis of the phenomenon: (a) the light curves related to the other nights never reach such low levels (also the two aforementioned minima are located at higher values), and (b) from figure 2a it is possible to derive some indications that the Δm values after J.D. 42727 would seem to return to the values of before J.D. 42714.

3. DISCUSSION

The photometric variations of Be stars have been justified in several ways:

1) the existence of a photospheric spot carried across the visible face by stellar rotation;
2) pulsation;
3) binarity;
4) shell variable absorption.

These are briefly discussed hereinbelow in connection with o And.

3.1. Spot Hypothesis

If we are to assume that o And has a projected rotational velocity of about 320 kms^{-1} (Slettebak 1966) and $R=7R_{\odot}$ (taking this star to be a B6 IV-V), we obtain a rotational period of about one day or even less which is comparable to the pseudo-period found.

However, such a spot should have a ray of about $0.25R_{*}$ if it is to justify the observed variations. Similar and higher dimensions are required for the same type of star as EW Lac (Lester, 1975).

Therefore, this theory does not look very attractive.

3.2. Pulsation Hypothesis

Some authors (Lester 1975, Fernie 1975) have supposed that the Be stars may be radial pulsating objects like β Cep stars. o And is completely out the instability strip of classic β Cep and has a decidedly higher rotational velocity. However, Eggen (1975) maintains that these characteristics of β Cep stars may be due to selection effects.

The light curve amplitude and colour variations of o And agree with the curves of β Cep, but the pseudo-period is appreciably longer than the one foreseen according to the $M_v - \log P$ equation with refers to same.

In conclusion, the pulsation constant Q, even when assuming the most favourable parameters for o And (corresponding to a B6 V star, see Allen 1973), proves to be equal to $0^d.29$, which value is very much greater than the value of the classic β Cep ($Q=0^d.037 \pm .004$, Watson 1972).

It would seem, in our opinion, that this theory is a highly questionable one.

3.3 Binary Hypothesis

According to Kriz and Harmanec (1975), the phenomenology of Be stars is produced by the evolution of a contact binary system. If this is so, since o And is a shell star and therefore seen almost equator-on, the probability of its being an eclipsing binary should be very high. On the contrary, our observations show no evidence of this nor do they confirm the periods proposed by Schmidt (1959) and Olsen (1972).

3.4. Shell Variable Absorption Hypothesis

With a view to explaining the phenomenology of the shell star Zeta Tauri, Nordh and Olofsson (1974) adopted a model which is in some respects also attractive for o And.

In such case, the light variations should be produced by some variation in the continuum absorption coefficient of the shell which should be optically thick in the Balmer continuum. Therefore such variation should be higher in the U band in comparison with the B and V bands.

It is highly probable that the continuum absorption of the envelope of o And may vary on timescales of few hours since variations in the spectral lines of the same envelope on comparable timescales have been observed (Bolton and Gulliver 1976). Moreover, our observations show that during the same night, the $(U-B)$ index generally follows the trend of the B light curve while the $(B-V)$ index is fairly constant (see J.D. 42711 and 42714).

According to Beeckmans (1976), the variations in the continuum absorption should be produced by pulsations of the envelope. Said variations could also be produced by a shell structure having knots of higher density. Such a structure has been spectrographically observed by Hutchings *et al.* (1971) in some Be stars.

4. CONCLUSION

At this stage, it is not possible to take any conclusion as being final. These results seem to support the theory that the light variations are produced by shell activity, but the idea that more than one of the suggested hypotheses are working in o And, is not to be excluded.

It is our intention to continue with the photometric observations of o And throughout 1976 as well, in order to furnish a more reliable answer to the problem.

ACKNOWLEDGEMENTS

Our thanks go to Prof. L.E. Pasinetti and Prof. M. Fracassini for their valuable comments and to Dr. P. Conconi for his help with the reduction programming.

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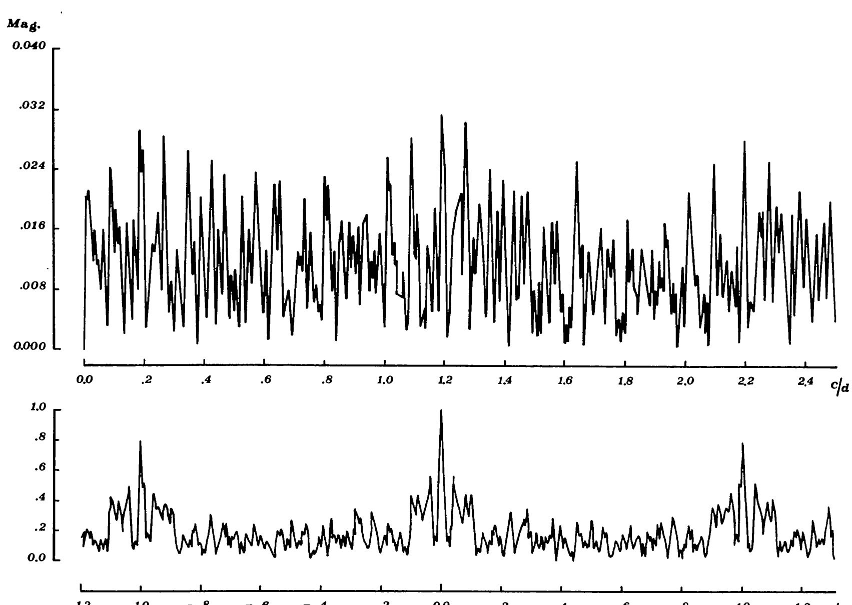

Figure 3 Top: periodogram of the *B* observations (in the ordinates there are the semiamplitudes expressed in magnitudes). Bottom: spectral window with the zero frequency translated under the highest periodogram peak (the maximum amplitude is normalized to one).

Table 1

Hel.J.D. 2442...	ΔU	ε	Hel.J.D. 2442...	ΔU	ε	Hel.J.D. 2442...	ΔU	ε	Hel.J.D. 2442...	ΔU	ε	Hel.J.D. 2442...	ΔU	ε	Hel.J.D. 2442...	ΔU	ε
688.429	2.121	±.002	690.334	2.094	±.004	700.444	2.105	±.002	710.559	2.035	±.004	713.438	2.133	±.002	740.263	2.047	±.002
.447	2.132	.003	.350	2.097	.004	.475	2.103	.001	711.256	2.130	.001	.457	2.142	.002	.345	2.087	.002
.467	2.137	.003	692.292	2.098	.005	709.429	2.105	.002	.277	2.130	.004	.474	2.152	.002	.371	2.078	.004
.486	2.141	.003	.318	2.094	.002	.446	2.113	.001	.354	2.113	.002	.497	2.161	.003	.408	2.086	.002
.503	2.150	.002	.347	2.082	.002	.474	2.120	.003	.374	2.106	.002	727.414	1.951	.005	.436	2.079	.003
.523	2.095	.011	.367	2.077	.004	.494	2.124	.003	711.405	2.094	.003	.441	1.956	.004	.458	2.065	.004
.569	2.135	.004	.404	2.078	.004	.518	2.129	.002	.426	2.092	.002	.460	1.974	.003	752.400	2.023	.004
.599	2.157	.009	.425	2.063	.003	.528	2.122	.003	.455	2.072	.002	.483	1.973	.002	770.217	2.082	.005
689.409	2.103	.004	.455	2.061	.002	710.251	2.056	.005	.476	2.067	.003	.505	1.989	.001	.255	2.104	.005
.420	2.100	.002	.473	2.057	.002	.282	2.050	.003	.505	2.041	.003	.526	1.996	.002	776.210	2.009	.001
.449	2.089	.002	.490	2.063	.005	.325	2.069	.006	.527	2.025	.003	738.328	1.976	.003	.234	2.006	.002
.461	2.082	.001	.518	2.064	.001	.351	2.074	.002	.554	2.011	.002	.351	1.983	.005	780.220	2.111	.004
.483	2.072	.002	.573	2.071	.003	.375	2.077	.001	712.388	2.084	.003	.388	1.985	.004	781.235	2.093	.004
.496	2.068	.004	.594	2.054	.012	.419	2.085	.004	.404	2.077	.003	.411	1.989	.004	782.210	2.122	.002
.520	2.057	.003	693.500	2.103	.003	.437	2.069	.002	.428	2.072	.003	.438	1.999	.008	783.221	2.081	.001
.535	2.054	.005	.522	2.102	.008	.458	2.070	.003	.447	2.076	.004	.468	2.008	.003	784.250	2.086	.003
.572	2.034	.005	699.538	2.110	.004	.498	2.077	.004	.478	2.066	.003	739.217	2.067	.004	787.220	2.006	.003
.595	2.035	.007	700.387	2.124	.002	.507	2.069	.003	.496	2.067	.004	.248	2.072	.004	794.260	2.113	.003
.609	2.041	.003	.404	2.117	.001	.517	2.059	.004	.524	2.079	.004	.278	2.066	.003	800.236	2.160	.005
.632	2.030	.004	.427	2.108	.003	.539	2.051	.003	.544	2.079	.004	740.233	2.036	.003	804.249	2.094	.002

Table 2

Hel. J.D. 2442 ...	ΔB	ε	Hel. J.D. 2442 ...	ΔB	ε	Hel. J.D. 2442 ...	ΔB	ε	Hel. J.D. 2442 ...	ΔB	ε	Hel. J.D. 2442 ...	ΔB	ε	Hel. J.D. 2442 ...	ΔB	ε
688.434	1.577	±.001	690.324	1.542	±.005	700.500	1.552	±.003	711.382	1.558	±.002	714.304	1.608	±.002	740.273	1.526	±.001
.455	1.580	.002	.343	1.536	.002	709.417	1.569	.002	.413	1.554	.001	.326	1.609	.002	.354	1.541	.001
.473	1.586	.001	692.303	1.556	.004	.435	1.571	.003	.433	1.554	.002	.356	1.613	.003	.385	1.536	.003
.492	1.593	.002	.325	1.550	.004	.462	1.576	.001	.462	1.540	.002	.454	1.593	.002	.419	1.537	.003
.509	1.595	.001	.352	1.543	.002	.481	1.582	.002	.482	1.534	.004	.476	1.576	.003	.444	1.542	.002
.533	1.576	.006	.375	1.537	.001	.500	1.592	.001	.514	1.511	.001	.505	1.562	.002	.466	1.536	.002
.583	1.592	.002	.412	1.527	.003	.517	1.593	.002	.533	1.505	.003	.525	1.553	.003	752.411	1.482	.006
.608	1.604	.003	.431	1.535	.003	710.261	1.525	.006	.561	1.497	.003	.551	1.538	.004	770.225	1.546	.003
689.400	1.579	.003	.462	1.532	.003	.301	1.531	.003	712.394	1.526	.003	727.406	1.442	.002	.263	1.553	.002
.415	1.571	.003	.479	1.538	.003	.336	1.545	.002	.409	1.525	.002	.433	1.450	.004	776.220	1.476	.001
.443	1.563	.001	.506	1.541	.002	.360	1.544	.002	.435	1.528	.003	.454	1.463	.002	.242	1.475	.003
.455	1.560	.002	.522	1.550	.005	.387	1.544	.002	.454	1.523	.003	.476	1.467	.001	780.231	1.555	.003
.477	1.551	.002	.537	1.550	.002	.424	1.547	.004	.484	1.529	.003	.499	1.471	.002	.270	1.560	.002
.489	1.546	.002	.580	1.550	.003	.454	1.541	.003	.501	1.533	.002	.518	1.487	.003	781.216	1.557	.002
.513	1.535	.002	.599	1.563	.003	.466	1.542	.003	.531	1.543	.003	738.336	1.448	.003	782.218	1.535	.002
.529	1.528	.002	693.509	1.557	.003	.501	1.541	.001	.551	1.541	.004	.361	1.457	.002	783.207	1.535	.002
.562	1.523	.003	699.549	1.578	.005	.510	1.540	.003	713.445	1.578	.001	.397	1.464	.003	784.236	1.538	.003
.587	1.520	.003	700.393	1.580	.001	.526	1.539	.003	.463	1.593	.002	.424	1.472	.003	787.210	1.477	.002
.602	1.520	.002	.409	1.576	.001	.546	1.539	.003	.484	1.603	.002	.476	1.497	.004	.240	1.482	.002
.625	1.518	.003	.433	1.569	.001	711.241	1.584	.001	.502	1.611	.006	739.229	1.517	.003	794.240	1.544	.003
690.310	1.553	.005	.450	1.565	.003	.263	1.581	.002	714.238	1.598	.002	.259	1.526	.002	800.227	1.573	.004
.316	1.542	.005	.481	1.559	.003	.362	1.563	.002	.260	1.608	.003	740.245	1.510	.002	804.237	1.555	.002

Table 3

Hel.J.D. 2442...	ΔV	ε	Hel.J.D. 2442...	ΔV	ε	Hel.J.D. 2442...	ΔV	ε	Hel.J.D. 2442...	ΔV	ε	Hel.J.D. 2442...	ΔV	ε	Hel.J.D. 2442...	ΔV	ε
688.440	1.422	±.001	692.587	1.418	±.002	710.398	1.405	±.006	711.567	1.370	±.002	714.510	1.425	±.002	740.427	1.381	±.003
.461	1.424	.003	.605	1.415	.003	.431	1.404	.003	712.399	1.396	.002	.531	1.427	.002	.451	1.387	.001
.479	1.431	.001	693.516	1.430	.004	.451	1.406	.002	.415	1.386	.003	.558	1.415	.003	752.424	1.331	.006
.497	1.443	.002	700.339	1.445	.001	.473	1.406	.002	.441	1.386	.002	727.422	1.303	.003	770.230	1.398	.001
.516	1.439	.003	.414	1.441	.002	.504	1.401	.002	.461	1.387	.003	.447	1.310	.003	.270	1.403	.002
.543	1.414	.006	.438	1.438	.001	.513	1.405	.002	.490	1.393	.004	.469	1.315	.005	776.227	1.329	.002
.555	1.407	.002	.458	1.431	.002	.533	1.406	.004	.509	1.394	.004	.512	1.341	.003	.249	1.328	.002
.592	1.442	.002	.487	1.426	.001	.553	1.403	.003	.537	1.401	.003	738.343	1.308	.004	780.241	1.401	.001
692.312	1.417	.001	709.423	1.432	.001	711.249	1.447	.001	.559	1.410	.004	.373	1.310	.002	.279	1.415	.005
.331	1.411	.001	.440	1.439	.002	.270	1.444	.002	713.451	1.454	.002	.405	1.326	.004	781.226	1.397	.002
.359	1.409	.002	.468	1.441	.004	.368	1.430	.001	.468	1.459	.002	.432	1.321	.004	782.229	1.380	.005
.385	1.401	.002	.487	1.450	.002	.389	1.427	.002	.490	1.471	.001	.487	1.343	.004	783.230	1.377	.001
.419	1.395	.002	.506	1.455	.002	.419	1.423	.002	714.244	1.475	.003	739.237	1.370	.002	784.222	1.370	.003
.438	1.397	.003	.522	1.452	.002	.440	1.416	.002	.274	1.466	.005	.269	1.371	.003	787.225	1.328	.002
.468	1.394	.001	710.372	1.382	.005	.469	1.399	.002	.311	1.476	.002	740.254	1.351	.003	.257	1.334	.002
.485	1.404	.002	.314	1.411	.004	.489	1.395	.001	.322	1.475	.003	.283	1.365	.002	794.218	1.399	.002
.512	1.407	.001	.344	1.407	.001	.521	1.380	.002	.460	1.456	.002	.362	1.385	.001	800.245	1.425	.004
.544	1.413	.003	.368	1.409	.004	.539	1.373	.003	.482	1.450	.003	740.394	1.380	.003	804.224	1.405	.002

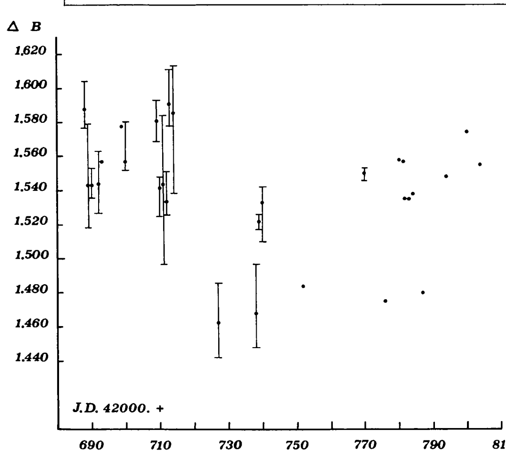

Figure 2a Average values of the *B* normal points for each night (see text for bars).

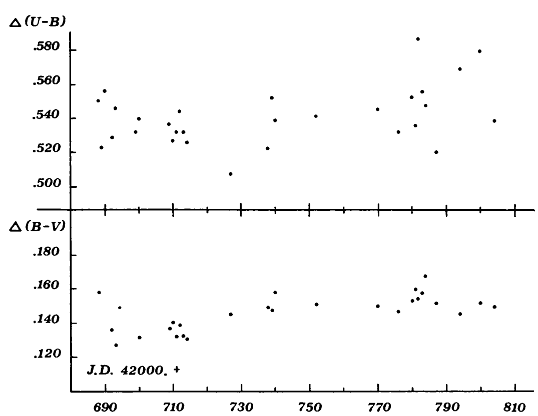

Figure 2b Average values of the colour indices for each night.

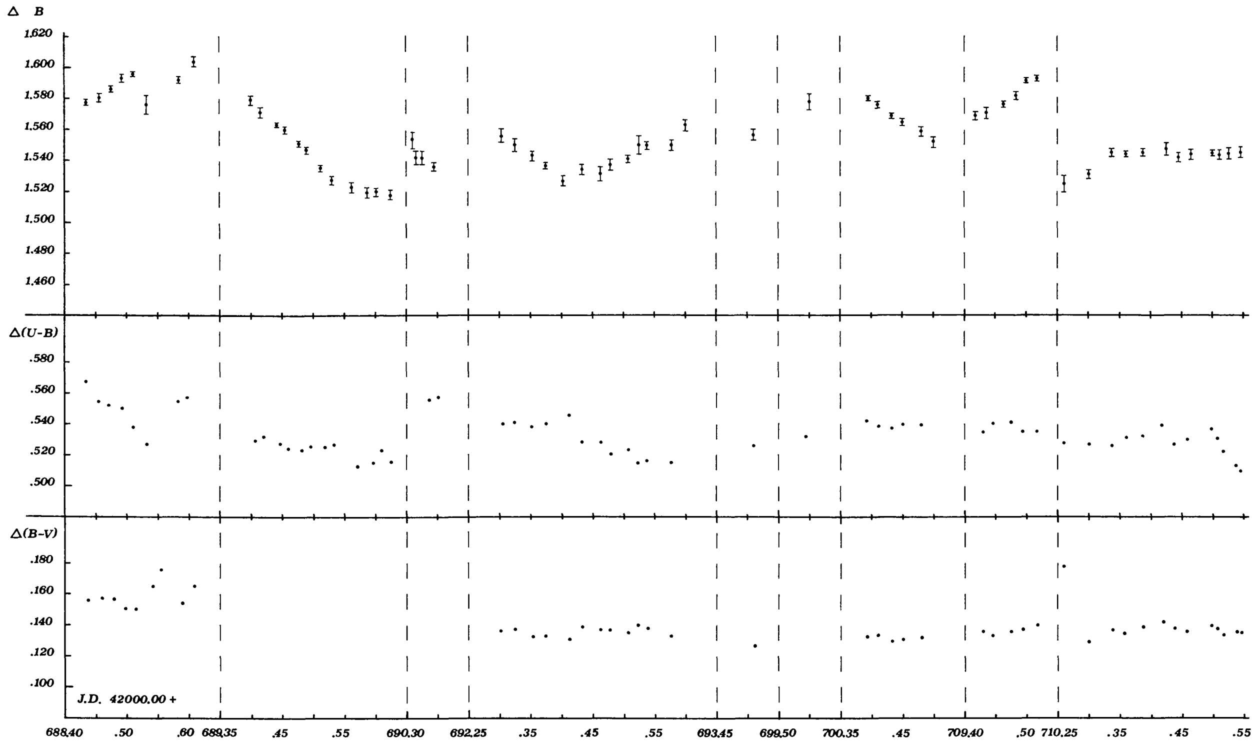
Figure 1a Light and colour curves of o And from J.D. 42688 to J.D. 42710.

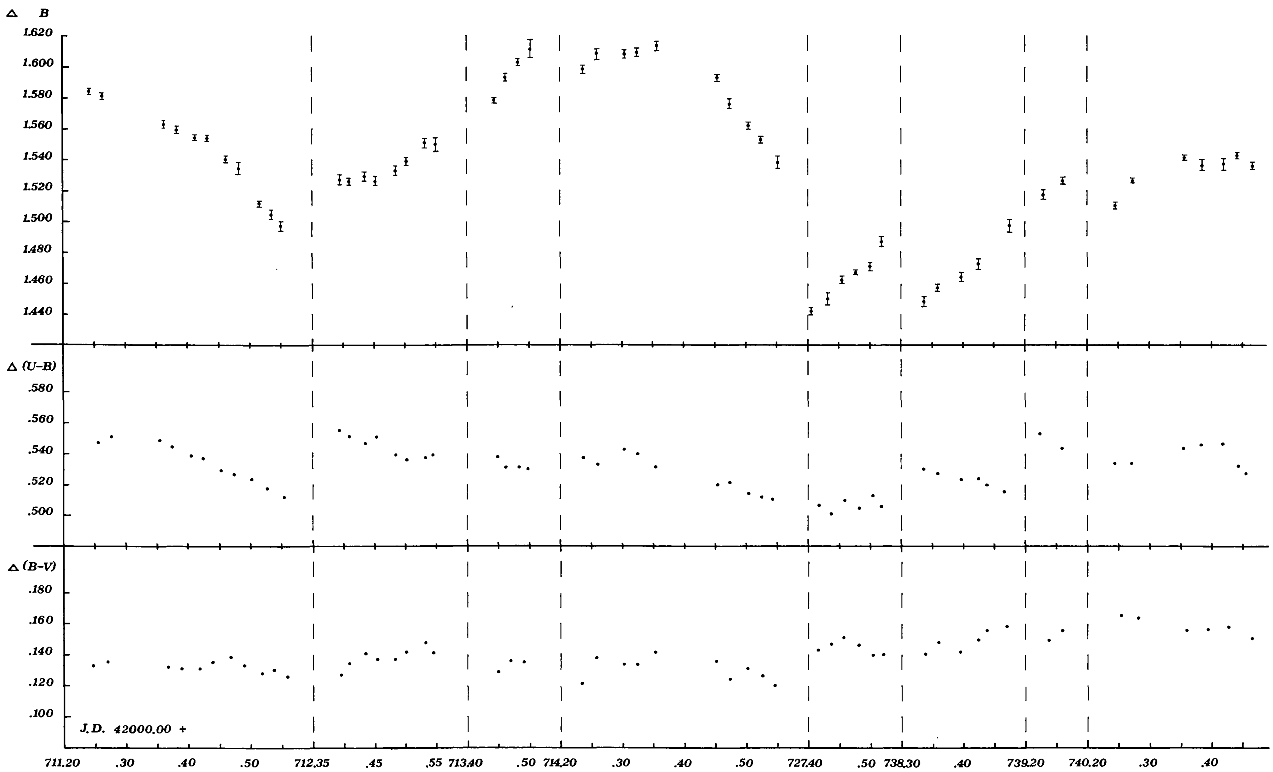
Figure 1b Light and colour curves of o And from J.D. 42711 to J.D. 42740.