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NEW PHOTOELECTRIC OBSERVATIONS OF THE SHELL STAR o And*

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New photoelectric observations of the shell star o And for the years 1976–77 are reported. The light curves show a reduction in the range of luminous variations, a progressively bluer colour of the star and a return of its brightness at the values which preceded the reduction which took place between J.D. 42714–27.
These findings, related to a spectral analysis of the light curve of the 1976 data, seem to suggest a relation between photometric variability and shell activity, although no direct correlations were found with the spectrographic data published so far.
Key words: shell stars – photometry

1. THE OBSERVATIONS

The observations here recorded, which refer to the end of the years 1976–77, follow those made between October 1975 and January 1976 (Bossi *et al.* 1977, here referred to as Paper I), after o And had emitted a new shell in July 1975. The photoelectric equipment and also the comparison and check stars are the same as in Paper I and the method adopted for the observations and reductions is the same.

Tables 1, 2 and 3 show the U, B and V values of the normal points (average of six or more $\Delta m = (m_c - m_v)$ magnitudes). Figure 1 shows the light and colour curves for the nights when observations were made for some hours.

The most significant variation, concerning the light curves of Paper I, is the reduction of the mean range of variation. This fact is also evident from Figure 2a in which the bars represent the interval of magnitude covered during the period of observation. This figure shows another interesting fact: after the reduction in luminosity which took place between J.D. 42714–27, the luminosity of the star seems to have returned to the value prior to J.D. 42714, and moreover the value of B light relating to the end of the years 1976–77 are greater than those for 1975 (before the reduction). Simultaneously the colour indices $(U-B)$ and $(B-V)$ seem to denote a tendency for the light to become bluer. Both these facts should be interpreted as due to an increase in the thickness of the shell which occurred immediately after J.D. 42714 and to its subsequent rarefaction, which is still under way.

An analysis of the published spectrographic data, referring to this particular stage of the photometric behaviour of o And, offers no useful information: the supposed development of the main shell at the end of November 1975 has not been confirmed (Fracassini *et al.* 1977).

2. SPECTRAL ANALYSIS OF THE OBSERVATIONS

The spectrum of the 1976 observations (six nights) was calculated by means of the method proposed by Vanicek (1971). This method is a generalization of the traditional spectrum LS (see, for example, Lomb 1976).

The two spectra relating to the B and V observations were calculated separately. They are very similar. Figure 3a plots the mean spectrum with the frequencies (in cycles per day) as the abscissae and the percentage reduction of the variance as the ordinates.

It is not easy to interpret this spectrum, because it is a known fact that it is the convolution of the true spectrum and a spectral window (which depends upon pathology in the temporal distribution of the data; see Deeming 1975). This spectral window is plotted in Figure 3b, its ordinates are normalized by taking the value of the frequency zero as 100. Unfortunately, as the variance of the data is distributed in the direction

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of the lower frequencies, considerable interferences are produced in the spectrum between the aliases of the positive components of the frequency and the negative symmetrical components. In this way many peaks observed in the spectrum are produced and they can lead to the determination of incorrect periodicities. For example, the peak 0.319 c/d, which is the highest in the spectrum (reducing the variance by about 81%) is certainly due to these interferences. Great caution should therefore be exercised in attributing physical significance to many periods indicated in the literature on o And. As has been shown, this problem is related to the time distribution of the data, which is essentially a logistic problem, and which interests all Observers in more or less the same way.

Nonetheless it may be deduced from the spectrum that the phenomenon observed is not solely periodic. By adopting the method proposed by Vanicek (1971) for finding multiple frequencies, it is possible to find the parameters of three sinusoids which reproduce the observations inside the experimental errors. However this solution is not the only one: for instance, we have established four groups of three sinusoids which meet this criterion.

A few numerical experiments have shown that it is possible to represent the observations by means of a discrete autoregressive process of the second order, as follows:

$$\Delta m_{t_i} - \overline{\Delta m} = \alpha_1 \Delta m_{t_{i-1}} + \alpha_2 \Delta m_{t_{i-2}} + Z_i$$

here α_1 and α_2 are the parameters of the process, Z_i is a random gaussian series and t_i the time instants uniformely spaced. This representation has the advantage of requiring only three quantities (α_1, α_2 and noise variance) instead of the nine required by the three sinusoids.

To calculate the autoregressive parameters, equally spaced data are required, thus α_1 and α_2 were determined for each of the three sinusoidal representations sampled with a step of 0.1 days (for the computing method see Jenkins *et al.* 1969). As these values were in close agreement one with another, their mean value was adopted as parameters of the process; so we have: $\alpha_1 = 1.6 \pm 0.1$, $\alpha_2 = -0.8 \pm 0.1$. The spectrum resulting from this process is that of band-limited noise with a peak at 0.8 c/d.

3. CONCLUSIONS

The photoelectric observations of o And in 1976–77 show: a) a reduction in the photometric activity of the star which was at its acme after the new emission of the shell; b) a return of the brightness and the colour of the star to the values prior to J.D. 42714. All these facts are probably produced by progressive rarefaction of the shell.

The spectral analysis of the 1976 data shows that the variability of the light within the space of one day is explained better with a stochastic model, and hence it is probably associated with the activity of the shell.

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Table 1

Hel.J.D. 2443..	ΔU	ε	Hel.J.D. 2443..	ΔU	ε	Hel.J.D. 2443..	ΔU	ε	Hel.J.D. 2443..	ΔU	ε	Hel.J.D. 2443..	ΔU	ε	Hel.J.D. 2443..	ΔU	ε
088.339	2.209	.002	116.408	2.208	.007	121.362	2.231	.003	124.399	2.231	.003	125.408	2.253	.006	126.319	2.186	.002
116.243	2.220	.003	.429	2.219	.005	.380	2.228	.002	.421	2.217	.006	.430	2.250	.006	.341	2.195	.003
.263	2.227	.003	.453	2.206	.003	124.219	2.253	.002	.448	2.207	.007	.452	2.236	.006	.363	2.188	.005
.284	2.223	.003	121.206	2.239	.003	.239	2.253	.003	125.229	2.257	.002	126.197	2.184	.004	.384	2.182	.004
.303	2.216	.006	.226	2.244	.001	.250	2.250	.004	.253	2.268	.002	.215	2.200	.005	.403	2.185	.004
.324	2.213	.002	.249	2.246	.002	.280	2.243	.004	.276	2.261	.004	.236	2.197	.002	.427	2.170	.003
.344	2.208	.002	.267	2.242	.001	.344	2.240	.004	.343	2.266	.003	.259	2.188	.003	494.248	2.243	.002
.369	2.202	.007	.321	2.241	.002	.362	2.246	.005	.363	2.262	.004	.281	2.189	.003	495.228	2.257	.001
.390	2.191	.004	.341	2.230	.003	.380	2.236	.005	.385	2.255	.004	.300	2.192	.003	497.224	2.247	.002

Table 2

Hel.J.D. 2443..	ΔB	ε	Hel.J.D. 2443..	ΔB	ε	Hel.J.D. 2443..	ΔB	ε	Hel.J.D. 2443..	ΔB	ε	Hel.J.D. 2443..	ΔB	ε	Hel.J.D. 2443..	ΔB	ε
088.348	1.641	.004	116.256	1.633	.001	121.233	1.648	.002	124.367	1.647	.004	125.437	1.669	.004	126.412	1.603	.002
.363	1.636	.004	.276	1.637	.001	.255	1.646	.002	.386	1.644	.002	.461	1.658	.005	.424	1.610	.004
.383	1.638	.004	.297	1.630	.003	.273	1.648	.001	.408	1.645	.003	126.203	1.603	.001	494.221	1.665	.001
.404	1.624	.003	.317	1.634	.002	.328	1.643	.002	.430	1.631	.006	.223	1.599	.005	.259	1.663	.003
.422	1.628	.003	.337	1.629	.002	.349	1.641	.002	.457	1.622	.007	.243	1.603	.003	495.209	1.683	.002
.433	1.614	.004	.362	1.639	.002	.368	1.641	.001	125.240	1.657	.002	.267	1.607	.004	.238	1.680	.001
.453	1.621	.004	.384	1.636	.002	.387	1.640	.002	.260	1.659	.002	.287	1.602	.001	.255	1.678	.002
.472	1.625	.004	.402	1.627	.004	124.228	1.647	.002	.284	1.662	.002	.306	1.602	.001	.403	1.656	.002
.492	1.618	.004	.422	1.636	.003	.246	1.653	.002	.350	1.662	.003	.327	1.598	.003	.421	1.659	.002
.513	1.611	.003	.447	1.639	.004	.267	1.655	.003	.370	1.656	.003	.349	1.593	.002	496.206	1.665	.002
.528	1.604	.004	.477	1.627	.005	.288	1.652	.004	.393	1.658	.005	.370	1.604	.001	497.202	1.663	.002
116.236	1.637	.001	121.213	1.641	.003	.350	1.654	.004	.416	1.661	.002	.390	1.611	.003	498.204	1.673	.002

Table 3

Hel.J.D. 2443..	ΔV	ε	Hel.J.D. 2443..	ΔV	ε	Hel.J.D. 2443..	ΔV	ε	Hel.J.D. 2443..	ΔV	ε	Hel.J.D. 2443..	ΔV	ε	Hel.J.D. 2443..	ΔV	ε
083.355	1.472	.002	116.250	1.462	.002	121.220	1.474	.002	124.356	1.477	.002	125.400	1.497	.004	126.356	1.432	.001
.373	1.476	.004	.270	1.463	.001	.231	1.475	.002	.374	1.486	.002	.422	1.499	.004	.376	1.449	.004
.394	1.458	.002	.290	1.460	.002	.261	1.479	.001	.393	1.489	.004	.445	1.481	.004	.397	1.446	.002
.414	1.468	.004	.310	1.460	.002	.314	1.474	.002	.414	1.482	.002	.468	1.491	.006	.420	1.446	.001
.430	1.462	.002	.330	1.462	.002	.334	1.474	.002	.438	1.481	.002	126.209	1.435	.002	494.233	1.494	.002
.445	1.466	.002	.356	1.463	.002	.355	1.478	.002	.465	1.473	.008	.230	1.439	.001	495.217	1.509	.002
.461	1.456	.002	.376	1.464	.004	.374	1.471	.001	125.246	1.486	.002	.251	1.438	.002	.247	1.506	.001
.482	1.448	.004	.396	1.468	.004	124.233	1.483	.002	.267	1.495	.002	.275	1.438	.001	.412	1.496	.002
.504	1.462	.003	.415	1.468	.003	.253	1.481	.003	.290	1.491	.003	.293	1.432	.003	496.223	1.487	.001
.521	1.461	.003	.437	1.454	.009	.274	1.483	.004	.356	1.488	.003	.313	1.437	.001	497.213	1.491	.001
.536	1.448	.002	.467	1.459	.006	.294	1.485	.003	.377	1.498	.003	.334	1.434	.003	498.222	1.497	.002
116.227	1.470	.002															

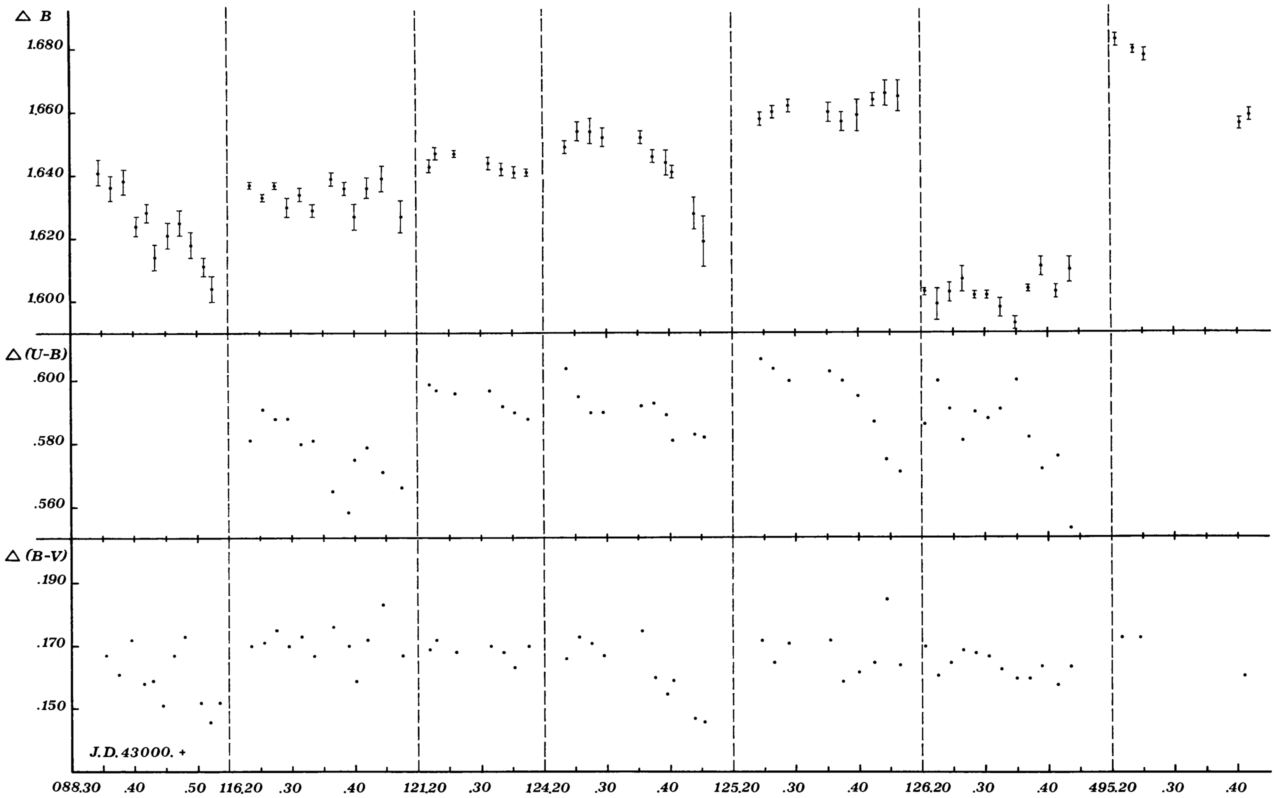

Figure 1 Light and colour curves of o And; observations concerning the end of the years 1976–77.

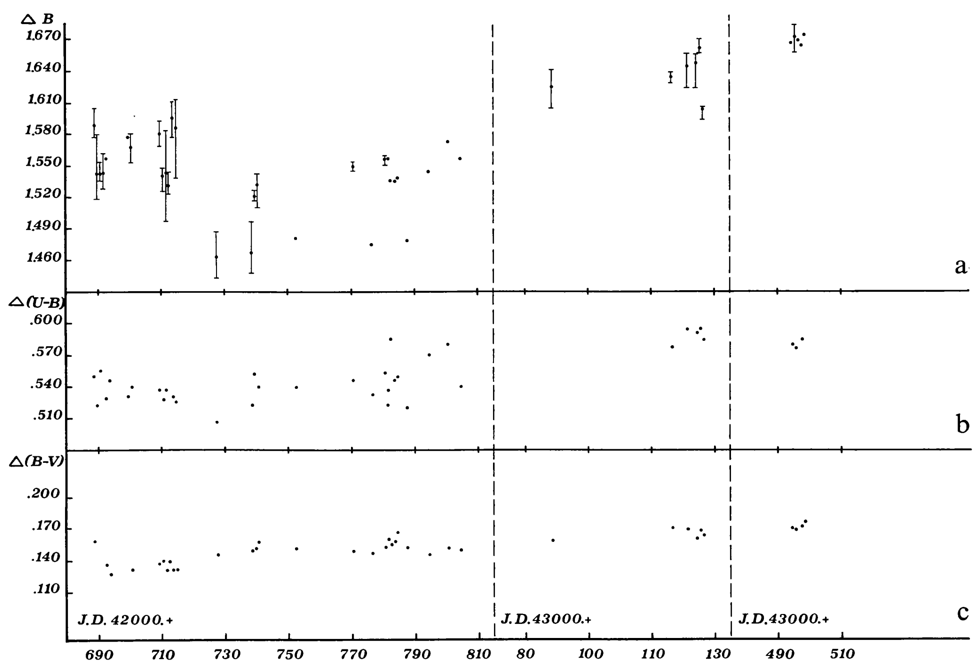

Figure 2a, b, c Average values of the B, $(U-B)$ and $(B-V)$ normal points for each night and for the three observational seasons (1975–76, 1976, 1977).

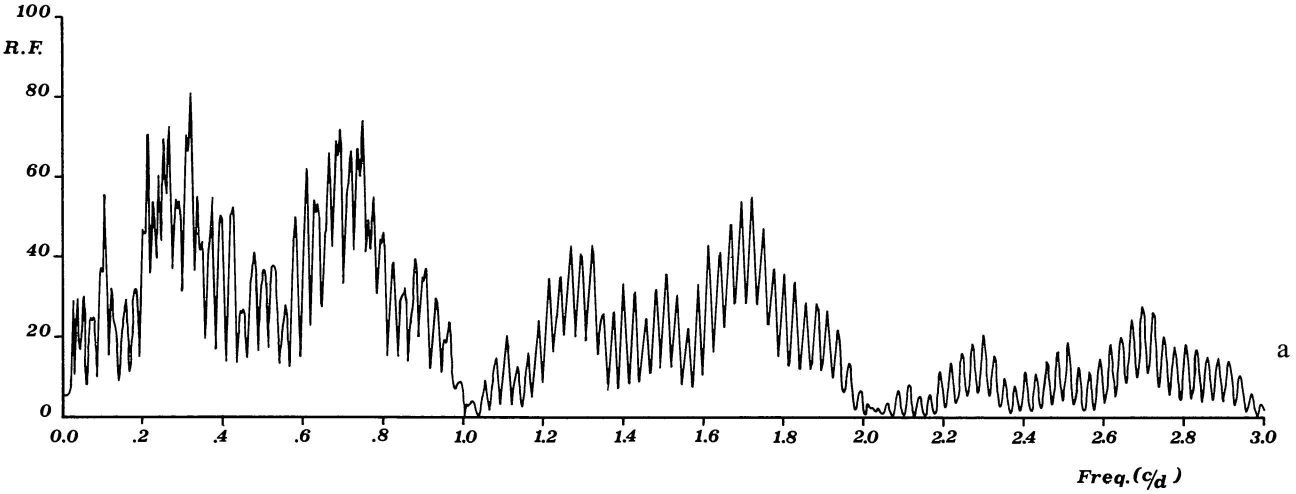

Figure 3a Power spectrum of the observations regarding the six nights of 1976.

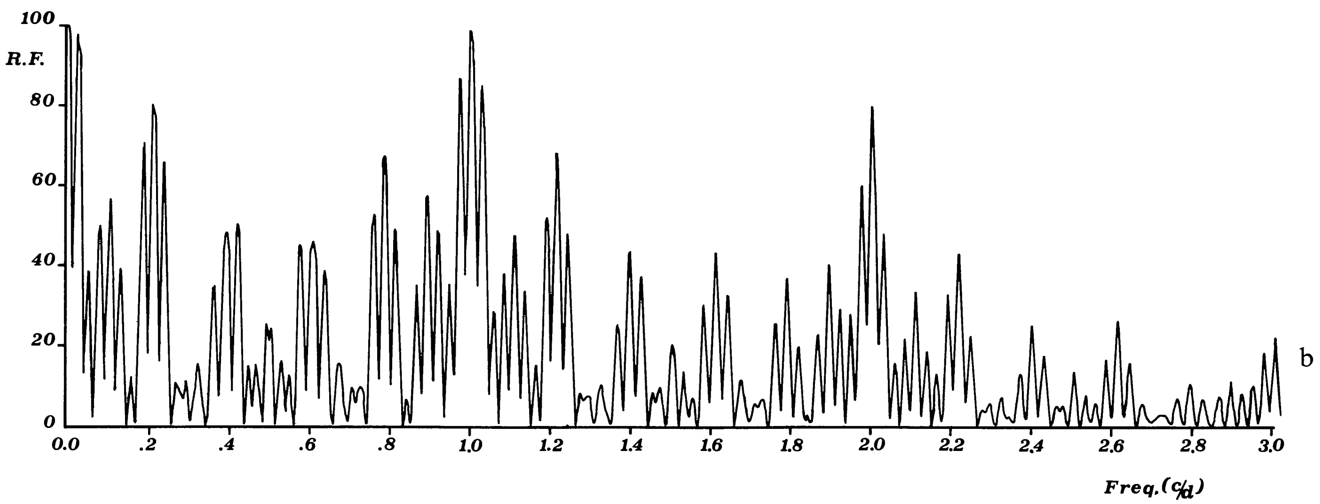

Figure 3b Spectral window.