1974, *Astron. Astrophys. Suppl.* **13**, 81-90.

BD $-18°$ 3437, A NEW SHORT PERIOD ECLIPSING BINARY

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Received March 26, 1973

BD $-18°3437$ has been found to be a short period variable and from the nature of its light and colour variation we conclude that it is an eclipsing binary of W UMa type with depths of minima of $0^m.20$ and $0^m.18$ and a period of 0.3166386 days. After rectification the depths of the minima were found to be too shallow indicating that the light variation of this system is mainly due to the ellipticity and reflection effects. There are night to night variations in the light curves and the system became fainter by about $0^m.06$ in 1972 compared to 1971. These complications in the light curves may be associated with the intrinsic variation of one or both the components or they may be due to a change in the envelope surrounding the system.

Key words: Short-period eclipsing variable.

1. INTRODUCTION

The star BD $-18°3437$ (HD 110139, F8) was observed by us as a comparison star for photoelectric observations of the eclipsing binary system RV CrV. The plots of magnitude versus airmass for this star observed on two nights showed a periodic variation about the mean relation, indicating the possibility of a short period variation. Further observations of this star were made by us to test the suspected variability and it was found that BD $-18°3437$ undergoes light variations with two minima of nearly equal depth of roughly $0^m.20$ and $0^m.18$ in a period of about 6.5 hours. The possibility of this star being an intrinsic variable with a period of 3.25 hours was considered, but because of the difference in the shapes and depths of the two minima and due to the small amplitude of colour variation we feel that the new variable is an eclipsing binary of W UMa type.

2. OBSERVATIONS

The new variable has been observed by us through the standard U, B and V filters on 14 nights during 1971 and 1972, with a photoelectric photometer attached to the 1.2 m reflecting telescope of Rangapur Observatory. An unrefrigerated EMI 6256B photomultiplier tube was used as the detector, and the photocurrent was recorded by means of a GR 1230A dc-amplifier and a Honeywell Brown recorder. We have used BD $-17°3680$ and BD $-18°3438$ as the comparison and check stars respectively. The extinction coefficient for each filter was determined from the comparison star observations on each night and all the observations were corrected for atmospheric extinction. The data was then transformed to the UBV system by applying the transformation relations obtained from the observations of the standard stars.

The magnitude and colours of the comparison and check stars in the standard system observed on JD 2441429 are given in Table 1a. The magnitude differences ΔV, ΔB and ΔU between the comparison and check stars show considerable scatter particularly for 1971 observations. This scatter can probably be attributed

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to the poor observing conditions prevailing at the time of these observations, although the possibility of small variations in the light of the comparison or the check star cannot be totally ruled out. The mean values of ΔV, ΔB, and ΔU between the comparison and check stars are listed in table 1b along with the number of observations and the estimated probable error of a single observation. From this table it is apparent that there is no significant change in Δm (comparison – check) between 1971 and 1972.

The magnitude differences ΔV, ΔB and ΔU between the variable and BD $-17°3680$ are listed in table 2a, 2b and 2c respectively, along with the corresponding heliocentric Julian day of observation. Observations of the variable star made on the night of JD 2441034 have been excluded from these tables due to their consistently poor quality, although they have been used for estimating the time of minimum on that night.

3. PERIOD AND LIGHT CURVE

The times of minima were determined by the method of bisection from the plot of light curves for individual nights. No significant difference was found between the times of minima determined from the V, B and U light curves. The average values of times of minima determined from the V and B light curves are listed in table 3 along with the weights assigned to them. In this table the primary and secondary minima are identified by '*p*' and '*s*' respectively. As the secondary minima were found to occur halfway between the times of primary minima, a least squares solution of all the times of minima listed in table 3 was made and yield the following ephemeris:

$$T_{\min}\,(\text{Primary}) = \text{JD}_{\odot}\; \underset{\pm\ 5}{2441017.4557} + \underset{\pm\ 10}{0^{d}\!.3166386}\; \text{E}$$

The residuals $(O–C)$ between the observed and computed times of minima are given in the third column of table 3. A least squares solution of the times of maxima yielded a period of $0^{d}\!.3166372 \pm 0^{d}\!.0000028$, and the larger error of this result is attributed to the fact that the maxima following the secondary are not located halfway between the maxima following the primary minima and show a systematic trend in this respect. We have, therefore, adopted the period determined from the minima for further discussion.

Normal light curves obtained by using the ephemeris given above are shown in figures 1 and 2 for 1971 and 1972, respectively. From a comparison of the two figures it is easily noticed that there is a systematic shift of about $0^{m}\!.06$ between the 1971 and 1972 light curves. This shift stands out clearly inspite of the fact that the observations of 1971 as well as those of 1972 have an internal scatter of the order of $0^{m}\!.04$. The possibility that this change in the light curves may be due to an increase in the brightness of the comparison star can be ruled out because, as noted earlier, the mean values of Δm (comparison-check) given in table 1b for 1971 and 1972 do not show much difference. We are therefore inclined to believe that the observed change in the light curves must be due to a decrease in the brightness of the eclipsing binary system itself. Additional evidence for the change being associated with the variable star is found from the fact that the decrease in the brightness is not the same at all phases of the light curve – indicating a variation in its shape. Further it is noted that for both the 1971 and 1972 data there are systematic shifts of the light curve and changes in its shape from night to night, which again leads us to believe that in this system some kind of intrinsic variation is superposed on the variation due to the eclipse.

The observed depths of the primary and secondary minima are listed in table 5a; we note that although the whole light curve is fainter in 1972 by $0^{m}\!.06$ relative to 1971 there is relatively small change in the depth of the two minima. Therefore, the observed changes in the light curve must be attributed to long period effects either due to intrinsic variation in one or both the components or due to a change in the envelope surrounding the whole binary system. Pronounced changes in the light curve have also been reported in several other binary systems (e.g. SW Lac, EM Cep, etc.) and have generally been attributed to mass transfer between the components.

4. RECTIFICATION

In view of the above complications we have not attempted to combine the 1971 and 1972 data and they were treated separately for analysing the light variations outside the eclipses. From a preliminary investigation the phase angle at the start of external tangency was estimated to be about 50°, and the light variations outside the eclipses defined by this limit were represented by a Fourier series including both the sine and cosine terms. Separate least squares solutions were made terminating the series at 2θ, 3θ and 4θ terms, but the coefficient of 3θ and 4θ terms were found to be negligible or comparable to their probable errors. Therefore, the light variation outside the eclipses was finally represented by

$$l = A_0 + A_1 \cos\theta + A_2 \cos 2\theta + B_1 \sin\theta + B_2 \sin 2\theta$$

The coefficients A_0, A_1, A_2, B_1, and B_2 determined from the least squares solution are listed in table 4 along with their probable errors. The values of these coefficients for different filters are consistent with each other, but significant changes are noticed in the values of A_1, B_1 and B_2 for 1971 and 1972 data. The perturbation terms which were negligible for 1971 data have become significant in 1972 observations, and the reflection coefficient A_1 has become less negative in 1972 compared to its value in 1971. The changes in the values of these coefficients again indicate the complex nature of the light variations in this system.

The rectification of the light curves in *V*, *B* and *U* was carried out using the method of Russell and Merrill (1952) after substracting out the sine terms which were treated as perturbations. The coefficients C_0 and C_2 needed for the rectification were estimated using the approximation $C_0 = 3C_2 = 0.090 \sin^2 \theta_e$, where we have used $\theta_e = 50°$. For the rectification of the phase for ellipticity the oblateness coefficient $z = 0.13$ has been used.

The depths of the primary and secondary minima in the rectified light curves are given in table 5b which should be compared with the unrectified depths given in table 5a. It is found that after the rectification the depths of both the primary and secondary minima are considerably reduced indicating that most of the light variation observed in this system is due to the ellipticity and reflection effects. In the rectified light curves the primary eclipse has smaller depth compared to the depth of the secondary minimum. Since the two minima in the observed light curves are of nearly equal depth we might consider the possibility that a mistake has been made in the identification of the primary minimum; but in that case the values of the reflection coefficient A_1 will become positive both for the 1971 and 1972 data and this would be in contradiction to the sign expected from the theory.

Owing to the very shallow depths of the eclipses left after rectification and due to the scatter in the observations introduced by the intrinsic variations present in the system, we have not carried out any solution for the orbital elements. We feel that for a better understanding of this system more thorough coverage of the light curves over long period will be needed to disentangle the nature of intrinsic variations present in the system. Spectroscopic observations of this system would be particularly useful to decide whether observed changes in the light curves are due to intrinsic variations in the components or whether they are related to the changes caused by a possible mass transfer between the components of the system.

ACKNOWLEDGEMENT

We thank Mr. M. Syamasundara Reddy for his assistance during the observations, and one of us (M.P) would like to thank the University Grants Commission, New Delhi for providing the financial assistance during the tenure of this work.

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Table 1a Magnitude and colours of comparison and check stars

Star	BD.No.	V	B-V	U-B
Comparison	$-17^{\circ}3680$	8.78	+0.31	+0.04
Check	$-18^{\circ}3438$	9.60	+0.69	+0.34

Table 1b Magnitude difference (Check star – Comparison star)

Year	Δ V	n	p.e.	Δ B	n	p.e.	Δ U	n	p.e.
1971	0.828	10	± 0.017	1.182	10	± 0.022	1.484	7	± 0.017
1972	0.815	9	± 0.009	1.181	9	± 0.009	1.475	1	-

Table 2a *V* Observations of BD−18° 3437

Hel.J.D.	Δ V	Hel.J.D.	Δ V	Hel.J.D.	Δ V	Hel.J.D.	Δ V
2441000+		2441000+		2441000+		2441000+	
014.2504	+0.309	037.2469	+0.359	042.3820	+0.234	411.2629	+0.272
.2539	.311	.2646	.363	.4080	.251	.2677	.289
.2664	.361	.2688	.312	.4243	.294	.2754	.267
.2719	.382	.2893	.290	.4420	.340	.2806	.291
.2851	.404	.2926	.245			.2861	.281
.2886	.417	.2954	.235	044.1654	.277	.3443	.478
.3070	.367	.3200	.220	.1708	.297	.3491	.469
.3103	.354	.3207	.221	.1908	.349	.3580	.453
.3224	.314	.3214	.226	.1986	.389	.3637	.463
.3256	.309	.3416	.248	.2167	.388	.3720	.430
.3376	.285	.3447	.245	.2219	.388	.3774	.407
.3418	.286	.3711	.334	.2376	.337	.3817	.392
		.3752	.359	.2427	.331	.3862	.388
017.2640	.253	.4037	.396	.2585	.275	.3910	.370
.2854	.352	.4075	.385	.2632	.240	.3972	.337
.2903	.369	.4372	.293	.2821	.241	.4019	.345
.3044	.368			.2868	.233	.4080	.321
.3199	.326	040.2122	.312	.3062	.233	.4142	.291
.3394	.246	.2270	.326	.3108	.239	.4227	.287
.3791	.191	.2333	.368			.4319	.277
.3859	.219	.2397	.388	369.2871	.325		
.4053	.256	.2454	.409	.2963	.301	412.2699	.337
.4310	.355	.2517	.424	.3006	.290	.2744	.362
.4741	.389	.2571	.412	.3061	.274	.2787	.377
.4889	.313	.2645	.399	.3115	.278	.2862	.416
		.2661	.380	.3200	.271	.2904	.427
028.2628	.285	.2718	.380	.3269	.276	.2959	.437
.2840	.213	.2812	.364	.3351	.285	.3005	.449
.3017	.211	.2873	.339	.3413	.294	.3069	.451
.3264	.232	.2949	.307	.3470	.306	.3114	.446
.3531	.324	.3014	.299	.3536	.312	.3158	.441
.3799	.380	.3180	.265	.3618	.358	.3203	.429
.4024	.329	.3280	.251	.3677	.363	.3246	.404
.4271	.266	.3465	.217	.3735	.386	.3290	.383
.4417	.240	.3541	.226	.3792	.410	.3366	.369
		.3561	.227	.3860	.433	.3409	.342
029.2167	.268	.3621	.249	.3917	.435	.3455	.327
.2341	.250	.3711	.258	.3978	.445	.3509	.329
.2514	.200	.3777	.316	.4042	.443	.3566	.299
.2660	.211	.3874	.324	.4112	.428	.3614	.304
.2827	.246	.4055	.400	.4178	.409		
.2983	.292	.4248	.347	.4251	.377	429.3217	.277
.3139	.343	.4312	.366	.4314	.357	.3656	.366
.3295	.380			.4392	.332		
.3483	.343	041.2002	.386	.4472	.314	436.1940	.420
.3764	.250	.2186	.396	.4545	.304	.2003	.447
.3997	.223	.2993	.232	.4612	.286	.2064	.452
.4170	.226	.3097	.240	.4689	.283	.2255	.435
.4396	.274	.3189	.257	.4771	.272	.2311	.439
.4559	.329	.3277	.275	.4854	.281	.2382	.399
.4681	.371	.3378	.320	.4932	.303	.2433	.393
		.3491	.361	.5038	.324	.2502	.347
030.2407	.265	.3736	.363			.2562	.352
.2539	.311	.3949	.293	411.2159	.435	.2641	.337
.2629	.355	.4207	.228	.2209	.413	.2701	.318
				.2270	.384	.2768	.317
037.1996	.256	042.3305	.327	.2336	.382	.2820	.311
.2181	.295	.3479	.309	.2461	.311	.2998	.326
.2431	+0.357	.3583	+0.247	.2534	+0.298	.3065	+0.334

Table 2b *B* Observations of BD−18° 3437

Hel.J.D.	Δ B	Hel.J.D.	Δ B	Hel.J.D.	Δ B	Hel.J.D.	Δ B
2441000+		2441000+		2441000+		2441000+	
014.2511	+0.526	037.2461	+0.631	042.3833	+0.397	411.2621	+0.515
.2533	.556	.2655	.598	.4087	.478	.2669	.516
.2676	.605	.2677	.602	.4253	.484	.2747	.490
.2709	.627	.2900	.488	.4427	.556	.2799	.526
.2858	.639	.2917	.503			.2849	.523
.2879	.652	.2962	.445	044.1661	.475	.3436	.678
.3077	.618	.3174	.433	.1701	.510	.3483	.708
.3098	.611	.3193	.429	.1933	.549	.3573	.712
.3231	.563	.3221	.462	.1977	.616	.3629	.721
.3251	.554	.3423	.468	.2171	.615	.3707	.691
.3381	.528	.3440	.464	.2212	.650	.3768	.645
.3408	.531	.3723	.534	.2382	.545	.3811	.627
		.3746	.553	.2420	.580	.3853	.621
017.2649	.508	.4046	.605	.2590	.464	.3905	.621
.2861	.603	.4068	.605	.2626	.473	.3961	.577
.2889	.616	.4381	.518	.2826	.455	.4008	.568
.3053	.606			.2861	.479	.4066	.550
.3206	.571	040.2131	.536	.3066	.453	.4127	.523
.3403	.492	.2277	.573	.3110	.472	.4210	.486
.3810	.433	.2338	.601			.4303	.506
.3848	.443	.2404	.625	369.2878	.553		
.4060	.499	.2461	.651	.2953	.528	412.2693	.596
.4324	.603	.2522	.657	.3004	.526	.2739	.600
.4748	.628	.2576	.627	.3054	.522	.2781	.620
.4896	.521	.2652	.608	.3108	.515	.2855	.652
		.2657	.590	.3180	.488	.2895	.656
028.2635	.531	.2725	.592	.3262	.524	.2948	.684
.2846	.458	.2817	.572	.3338	.508	.2996	.693
.3028	.452	.2878	.558	.3403	.538	.3059	.686
.3274	.476	.2958	.530	.3465	.542	.3103	.695
.3542	.557	.3026	.516	.3533	.556	.3146	.685
.3816	.613	.3187	.478	.3605	.587	.3194	.665
.4031	.555	.3279	.486	.3667	.612	.3237	.652
.4278	.486	.3472	.439	.3724	.634	.3282	.637
.4427	.479	.3547	.470	.3785	.663	.3355	.600
		.3555	.440	.3854	.688	.3401	.584
029.2181	.504	.3637	.436	.3910	.697	.3446	.567
.2351	.448	.3718	.465	.3969	.702	.3489	.556
.2521	.420	.3791	.532	.4036	.699	.3557	.528
.2670	.431	.3885	.536	.4108	.682	.3604	.531
.2837	.465	.4064	.635	.4170	.666		
.2990	.520	.4254	.578	.4243	.637	429.3227	.521
.3146	.596	.4319	.566	.4308	.615	.3664	.625
.3302	.621			.4387	.581		
.3490	.586	041.2011	.598	.4467	.556	436.1929	.659
.3778	.489	.2194	.619	.4539	.540	.1995	.701
.4004	.451	.3000	.446	.4601	.529	.2057	.707
.4188	.459	.3101	.461	.4677	.522	.2245	.691
.4403	.510	.3195	.469	.4746	.526	.2302	.667
.4570	.538	.3283	.503	.4844	.528	.2365	.672
.4691	.597	.3390	.542	.4924	.542	.2432	.649
		.3498	.577	.4989	.548	.2493	.633
030.2420	.502	.3743	.576			.2554	.595
.2546	.543	.3953	.510	411.2166	.660	.2624	.591
.2640	.586	.4213	.447	.2221	.652	.2693	.562
				.2283	.607	.2760	.560
037.2000	.491	042.3312	.568	.2368	.595	.2808	.563
.2186	.544	.3486	.532	.2474	.549	.2988	.579
.2438	+0.618	.3590	+0.489	.2525	+0.539	.3048	+0.566

Table 2c *U* Observations of BD−18° 3437

Hel.J.D.	Δ U	Hel.J.D.	Δ U	Hel.J.D.	Δ U
2441000+		2441000+		2441000+	
014.2519	+0.474	029.2358	+0.425	037.4392	+0.535
.2586	.494	.2535	.383		
.2688	.571	.2684	.383	041.2029	.604
.2695	.568	.2844	.418	.2213	.622
.2865	.603	.3000	.483	.3012	.407
.2872	.599	.3153	.550	.3105	.396
.3087	.555	.3309	.585	.3202	.411
.3094	.555	.3497	.533	.3290	.475
.3237	.500	.3795	.455	.3400	.531
.3242	.500	.4014	.406	.3504	.557
.3390	.472	.4198	.426	.3750	.538
.3398	.479	.4414	.500	.3964	.472
		.4580	.548	.4218	.453
017.2657	.439	.4702	.585		
.2875	.542			042.3326	.556
.2882	.545	030.2435	.464	.3493	.507
.3060	.550	.2556	.529	.3597	.454
.3227	.498	.2650	.544	.3840	.357
.3412	.433	•		.4100	.479
.3817	.378	037.2007	.462	.4260	.464
.3824	.369	.2192	.453	.4437	.521
.4067	.468	.2443	.597		
.4338	.567	.2450	.628	044.1668	.505
.4755	.599	.2662	.570	.1693	.504
.4907	.490	.2669	.583	.1942	.556
		.2905	.467	.1970	.594
028.2642	.502	.2911	.484	.2181	.595
.2882	.418	.2968	.414	.2203	.608
.3038	.406	.3183	.411	.2392	.540
.3281	.416	.3186	.416	.2413	.531
.3549	.516	.3228	.421	.2597	.452
.3823	.568	.3428	.466	.2621	.443
.4042	.534	.3433	.481	.2833	.411
.4288	.459	.3725	.530	.2856	.420
.4441	.418	.3732	.512	.3073	.418
		.4048	.609	.3094	+0.419
029.2188	+0.477	.4055	+0.602		

Table 3 Times of Minima of BD−18° 3437

Hel.J.D. 2440000+	Eclipse	(O − C)	Weight
1014.288	p	− 0^{d}.001	2.0
1017.297	s	− 0.000	2.0
1017.458	p	+ 0.002	2.0
1028.378	s	− 0.002	2.0
1029.330	s	+ 0.000	2.0
1034.398	s	+ 0.002	0.3
1037.252	s	+ 0.006	1.5
1037.399	p	− 0.005	1.0
1040.251	p	− 0.003	1.5
1040.409	s	− 0.003	0.2
1041.361	s	− 0.001	1.0
1044.213	s	+ 0.001	1.2
1369.398	s	− 0.002	2.0
1412.305	p	− 0.001	2.0
1436.212	s	+ 0.002	0.5

Table 4 Fourier Coefficients of light variation outside the eclipses

Year	Filter	A_0	A_1	A_2	B_1	B_2
1971	V	+ 0.9415	- 0.0237	- 0.0611	- 0.0007	- 0.0039
		32	30	45	14	17
	B	+ 0.9337	- 0.0261	- 0.0614	- 0.0022	- 0.0072
		38	37	55	18	21
	U	+ 0.9131	- 0.0268	- 0.0889	+ 0.0061	- 0.0043
		56	56	82	29	33
1972	V	+ 0.9314	- 0.0104	- 0.0667	+ 0.0075	+ 0.0019
		41	35	53	15	22
	B	+ 0.9393	- 0.0016	- 0.0699	+ 0.0115	+ 0.0047
		62	50	77	21	33

Table 5a Observed depths of the minima

	Primary			Secondary		
Year	V	B	U	V	B	U
1971	0.19	0.20	0.22	0.16	0.19	0.19
1972	0.18	0.20	-	0.17	0.20	-

Table 5b Rectified depths of the minima

	Primary			Secondary		
Year	V	B	U	V	B	U
1971	0.015	0.015	0.00	0.040	0.060	0.01
1972	0.005	0.020	-	0.020	0.025	-

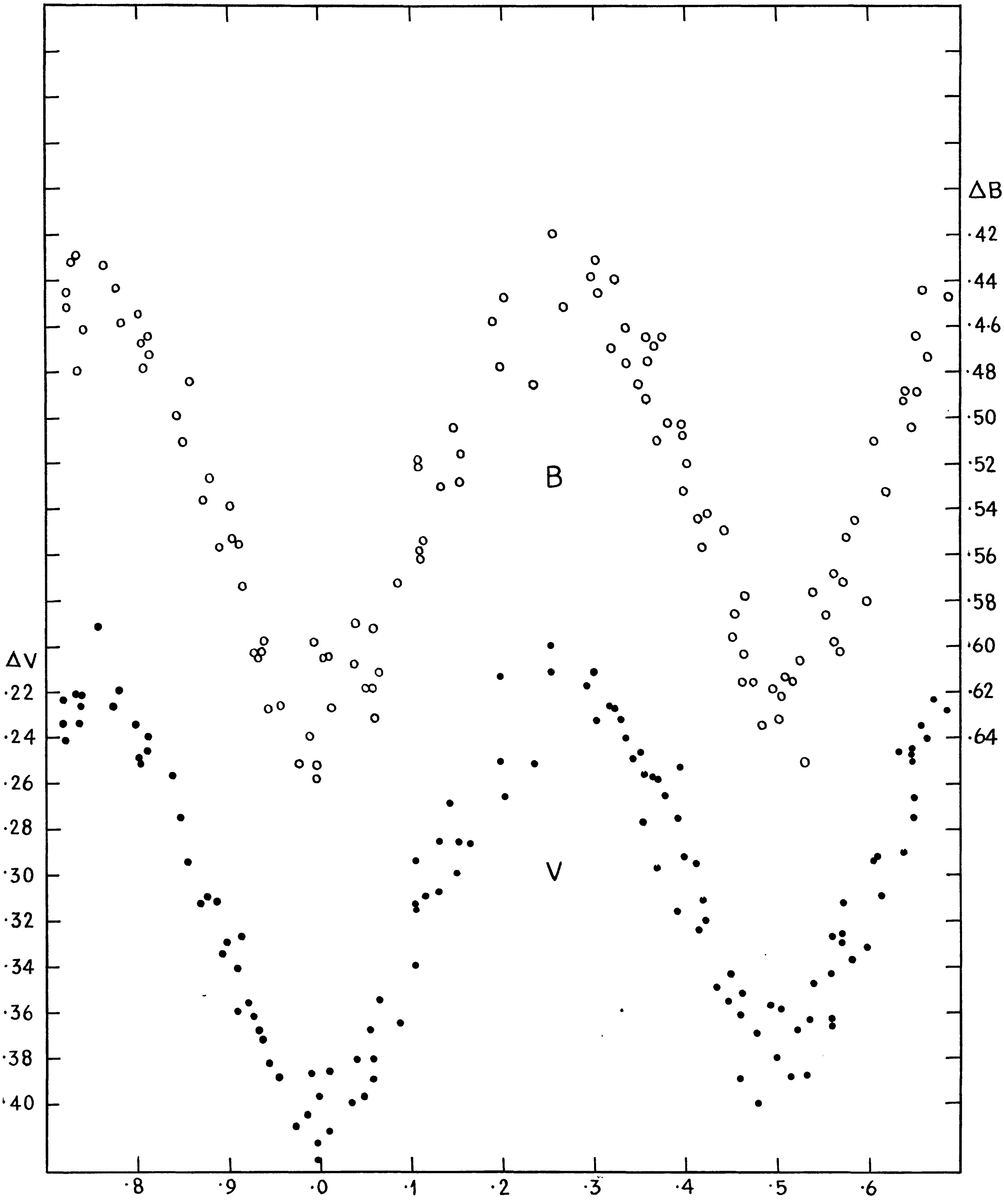

Figure 1 *B and V* light curves of BD−18° 3437 for 1971.

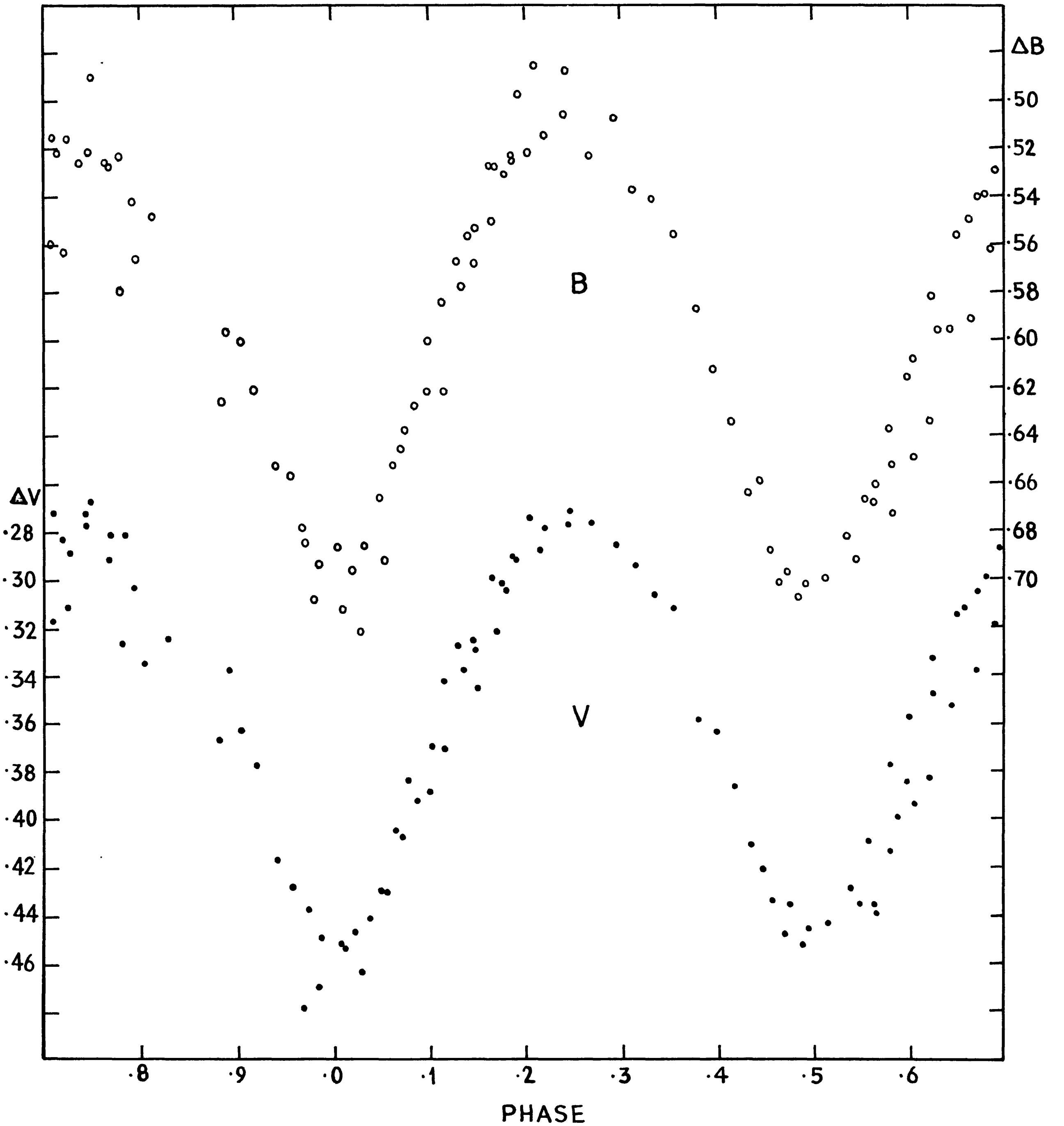

Figure 2 *B* and *V* light curves of BD−18° 3437 for 1972.