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UBV photometry of the classical symbiotic star BF Cygni

B. F. YUDIN, E. A. KOLOTILOV, V. I. SHENAVRIN, A. A. TATARNIKOVA* and A. M. TATARNIKOV

Sternberg Astronomical Institute, Universitetskij Prospekt 13,
Moscow 119992, Russia

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We discuss the optical photometry of the classical symbiotic star BF Cyg obtained during the period 1978–2005 and analyse the eclipse of the active hot component in 1991.

Keywords: Photometry; Variable stars; BF Cygni

We present the results of the *UBV* photometric observations of the classical symbiotic star BF Cyg performed between 1978 and 2005. The observations were carried out with the 0.6 m reflector of the Sternberg Astronomical Institute Observatory in the Crimea. The standard star was HD183240 with the magnitudes $U = 7.84$, $B = 8.32$ and $V = 8.40$. The magnitude of the observational error did not exceed 0.03.

Table 1 presents the optical *UBV* observations of BF Cyg and figure 1 shows its U and V light curves and $U{-}B$ colour curve during both quiescent and active states of this binary system. The hot component of the BF Cyg underwent a great outburst in May 1989.

The ephemerides of Pucinskas [1] match quite well the U light curve during both the pre-outburst (1978–1989) and the post-outburst (1993–2005) quiescent epochs. The times of the minima in these periods coincide with the times of the spectroscopic conjunctions predicted by Fekel *et al.* [2]. However, the first minimum after the great outburst of BF Cyg in mid-1991 was 75 days late! This minimum was narrow and sharp and looked like the eclipse of the active hot component. If we include data from the work of Skopal *et al.* [3] (and references therein), we can determine the contact times more accurately, which allows us to verify the radii of the components (R_g is the radius of the cool giant and R_x is the radius of the eclipsed component), calculated earlier by Skopal *et al.* [3]. Our results are $R_g = 0.513A$ and $R_x \leq 0.024A$ for a circular orbit with $P_{orb} = 757.2$ days and the orbital

*Corresponding author. Email: aat@sai.msu.ru

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Table 1. Results of *UBV* observations of BF Cyg.

Julian date (2440000+)	*U*	*B*	*V*
3795	12.68	12.87	12.39
3835	12.82	13.12	12.44
4807	11.57	12.40	11.97
5124	11.90	12.74	11.92
5245	12.48	13.34	12.51
5518	11.04	12.23	11.69
5589	11.06	12.26	11.68
5837	11.66	12.57	12.08
5943	11.92	12.61	11.90
5961	12.08	12.69	12.17
6224	12.24	12.88	12.00
6225	12.24	13.10	12.36
6579	10.91	12.24	11.42
6580	10.73	11.95	11.34
6581	10.73	11.93	11.32
7046	10.73	11.38	10.68
7078	10.42	11.14	10.60
7123	10.88	11.55	10.88
7285	11.08	12.00	11.46
7345	11.21	12.16	11.65
7348	11.03	12.01	11.69
7415	11.02	11.91	11.41
7418	11.11	12.03	11.46
7702	10.55	11.29	10.62
7722	10.24	10.65	10.12
7734	9.97	10.42	9.98
7782	9.93	10.28	9.86
7791	9.94	10.30	9.88
7792	9.88	10.25	9.86
8020	9.73	10.15	9.76
8021	9.51	9.97	9.56
8053	9.59	10.08	9.74
8058	9.52	10.05	9.69
8064	9.44	10.03	9.61
8073	9.45	10.02	9.64
8093	9.36	10.05	9.69
8095	9.35	10.02	9.63
8104	9.44	10.12	9.75
8113	9.38	10.15	9.78
8115	9.32	10.11	9.77
8163	9.29	10.16	9.80
8352	10.52	10.75	10.32
8379	11.16	11.95	11.25
8388	11.00	11.95	11.34
8389	11.08	12.01	11.41
8392	11.30	12.20	11.63
8409	11.28	12.27	11.63
8410	11.31	12.20	11.65
8411	11.28	12.19	11.67
8421	11.44	12.30	11.80
8423	11.39	12.26	11.80
8424	11.40	12.24	11.79
8426	11.43	12.27	11.82
8437	11.46	12.27	11.78
8442	11.46	12.27	11.79
8451	11.53	12.30	11.80
8453	11.53	12.27	11.81

(*continued*)

Table 1. Continued

Julian date (2440000+)	*U*	*B*	*V*
8455	11.50	12.27	11.77
8456	11.53	12.28	11.80
8461	11.51	12.23	11.82
8471	11.50	12.26	11.77
8476	11.52	12.28	11.76
8480	11.53	12.28	11.77
8490	11.47	12.15	11.62
8509	10.06	10.98	10.48
8522	10.09	11.17	10.61
8527	10.15	11.18	10.57
8528	10.06	11.15	10.55
8533	10.06	11.30	10.62
8541	10.10	11.36	10.72
8545	10.20	11.40	10.53
8564	10.26	11.40	10.79
8565	10.31	11.48	10.83
8572	10.28	11.45	10.83
8744	10.55	11.48	10.87
8747	10.47	11.47	10.88
8753	10.77	11.51	10.86
8767	10.77	11.47	10.80
8783	10.77	11.43	10.76
8807	10.67	11.44	10.82
8813	10.69	11.50	10.84
8832	10.78	11.47	10.83
8839	10.81	11.49	10.87
8856	10.75	11.09	10.63
8859	10.56	10.86	10.37
8864	10.51	10.99	10.44
8869	10.58	11.39	10.69
8880	10.76	11.69	11.06
8891	10.89	11.80	11.23
8896	10.94	11.89	11.32
8898	10.91	11.85	11.32
8901	10.79	11.82	11.33
8923	11.08	11.98	11.52
8928	11.21	12.11	11.64
8957	11.38	12.22	11.83
8960	11.46	12.27	11.83
9139	12.17	12.79	12.43
9140	12.19	12.82	12.41
9148	12.23	12.83	12.44
9178	12.21	12.78	12.34
9179	12.20	12.81	12.37
9181	12.18	12.80	12.34
9184	12.16	12.82	12.38
9185	12.10	12.82	12.33
9187	12.24	12.83	12.36
9190	12.18	12.80	12.37
9193	12.16	12.77	12.32
9194	12.21	12.79	12.34
9195	12.24	12.81	12.38
9196	12.27	12.85	12.35
9217	12.20	12.78	12.28
9223	12.17	12.76	12.22
9224	12.10	12.64	12.16
9235	12.09	12.76	12.22

(*continued*)

Table 1. Continued

Julian date (2440000+)	*U*	*B*	*V*
9236	12.10	12.77	12.27
9239	12.04	12.72	12.22
9245	12.23	12.74	12.20
9248	12.07	12.72	12.17
9252	12.09	12.71	12.15
9253	12.08	12.72	12.14
9254	12.10	12.73	12.17
9255	12.08	12.69	12.16
9275	12.12	12.71	12.12
9289	11.99	12.68	12.07
9292	12.01	12.71	12.06
9294	11.98	12.74	12.11
9316	11.82	12.64	12.06
9319	11.85	12.70	12.11
9320	11.80	12.66	12.06
9336	11.76	12.57	12.14
9341	11.74	12.56	12.00
9394	11.57	12.52	12.04
9469	11.28	12.25	11.79
9491	11.20	12.24	11.80
9495	11.25	12.22	11.79
9499	11.25	12.28	11.82
9529	11.25	12.28	11.82
9549	11.31	12.29	11.85
9583	11.47	12.24	11.77
9589	11.45	12.30	11.79
9598	11.55	12.34	11.76
9610	11.49	12.32	11.75
9617	11.50	12.36	11.79
9640	11.66	12.52	11.89
9647	11.67	12.46	11.89
9655	11.71	12.47	11.89
9672	11.84	12.58	12.06
9675	11.93	12.77	12.11
9703	12.03	12.80	12.07
9840	12.50	13.03	12.48
9855	12.64	13.13	12.54
9862	12.59	13.13	12.59
9867	12.56	13.13	12.64
9881	12.68	13.17	12.61
9882	12.66	13.15	12.53
9884	12.66	13.16	12.58
9885	12.65	13.17	12.62
9887	12.71	13.32	12.76
9897	12.75	13.35	12.77
9902	12.62	13.17	12.60
9903	12.64	13.20	12.60
9916	12.68	13.22	12.57
9917	12.61	13.18	12.58
9920	12.65	13.18	12.58
9921	12.60	13.16	12.53
9924	12.59	13.12	12.55
9925	12.60	13.12	12.53
9928	12.63	13.14	12.54
9929	12.64	13.18	12.55
9931	12.65	13.15	12.54
9935	12.72	13.26	12.55

(*continued*)

Table 1. Continued

Julian date (2440000+)	*U*	*B*	*V*
9936	12.64	13.08	12.49
9937	12.61	13.11	12.53
9938	12.61	13.19	12.57
9942	12.66	13.09	12.51
9943	12.66	13.20	12.53
9945	12.60	13.13	12.53
9970	12.62	13.19	12.43
9980	12.40	13.07	12.41
9981	12.48	12.98	12.32
9998	12.64	13.21	12.38
9999	12.55	13.16	12.40
10002	12.43	13.00	12.32
10003	12.44	13.02	12.36
10005	12.43	13.01	12.32
10009	12.39	12.99	12.31
10015	12.45	12.99	12.32
10061	12.26	12.90	12.24
10064	12.15	12.82	12.17
10069	12.10	12.82	12.18
10139	11.81	12.71	12.09
10197	11.53	12.53	11.96
10199	11.51	12.49	11.95
10222	11.43	12.44	11.87
10223	11.44	12.43	11.87
10231	11.41	12.40	11.84
10244	11.41	12.46	11.92
10258	11.40	12.42	11.90
10265	11.37	12.43	11.88
10269	11.37	12.43	11.85
10284	11.40	12.42	11.84
10299	11.44	12.50	11.92
10359	11.54	12.53	11.95
10362	11.57	12.55	12.02
10395	11.80	12.64	12.10
10403	11.76	12.63	12.06
10429	11.82	12.62	11.97
10509	12.01	12.82	12.16
10521	12.17	12.94	12.32
10579	12.56	13.16	12.53
10584	12.68	13.21	12.57
10601	12.72	13.24	12.69
10607	12.72	13.27	12.69
10624	12.75	13.24	12.66
10631	12.74	13.23	12.61
10647	12.71	13.21	12.62
10663	12.75	13.28	12.62
10669	12.86	13.30	12.63
10689	12.59	13.14	12.55
10695	12.63	13.15	12.55
10699	12.71	13.27	12.66
10705	12.60	13.23	12.59
10714	12.58	13.21	12.56
10748	12.44	13.14	12.47
10754	12.46	13.15	12.43
10758	12.50	13.10	12.39
10761	12.50	13.10	12.37
10818	12.33	13.00	12.23

(*continued*)

Table 1. Continued

Julian date (2440000+)	*U*	*B*	*V*
10873	11.96	12.83	12.17
10874	11.94	12.77	12.12
10957	11.39	12.42	11.81
10988	11.44	12.46	11.81
10997	11.53	12.51	11.90
11013	11.48	12.54	12.02
11018	11.50	12.57	12.07
11062	11.60	12.78	12.16
11063	11.61	12.59	12.00
11071	11.60	12.61	12.03
11082	11.62	12.64	12.11
11104	11.66	12.65	12.07
11161	11.88	12.75	12.15
11266	12.43	13.31	12.42
11276	12.42	13.13	12.43
11278	12.47	13.20	12.44
11285	12.44	13.15	12.44
11307	12.46	13.15	12.50
11308	12.33	12.99	12.33
11314	12.43	13.15	12.45
11320	12.45	13.15	12.43
11337	12.53	13.19	12.49
11346	12.57	13.25	12.60
11352	12.81	13.26	12.60
11367	12.91	13.35	12.67
11370	12.87	13.15	12.61
11374	12.81	13.31	12.63
11386	12.92	13.37	12.74
11387	13.02	13.47	12.76
11397	12.90	13.42	12.76
11404	12.87	13.38	12.73
11424	12.86	13.30	12.67
11426	12.83	13.36	12.73
11438	12.85	13.38	12.74
11448	12.92	13.41	12.75
11453	12.84	13.35	12.68
11493	12.66	13.21	12.64
11505	12.56	13.35	12.70
11549	12.44	13.36	12.69
11634	11.80	12.69	12.00
11669	11.69	12.58	11.97
11678	11.62	12.56	11.91
11719	11.49	12.51	11.94
11722	11.54	12.45	11.85
11752	11.51	12.53	11.98
11754	11.53	12.53	11.99
11776	11.51	12.55	12.02
11820	11.44	12.51	12.08
11866	11.57	12.55	11.99
11903	11.53	12.52	11.94
12047	12.40	13.11	12.42
12048	12.42	13.07	12.41
12106	12.79	13.33	12.70
12107	12.73	13.28	12.66
12115	12.69	13.28	12.56
12122	12.71	13.22	12.55
12132	12.84	13.40	12.78

(*continued*)

Table 1. Continued

Julian date (2440000+)	*U*	*B*	*V*
12134	12.82	13.39	12.75
12135	12.73	13.38	12.76
12138	12.88	13.41	12.79
12164	12.87	13.51	12.86
12168	12.89	13.42	12.79
12172	12.85	13.36	12.77
12191	12.95	13.48	12.83
12195	12.90	13.37	12.78
12197	12.88	13.33	12.73
12202	12.83	13.35	12.80
12211	12.90	13.48	12.83
12223	12.81	13.39	12.83
12250	12.64	13.27	12.63
12387	11.92	12.61	11.89
12396	11.86	12.75	12.02
12399	11.86	12.74	12.04
12406	11.80	12.70	12.00
12421	11.62	12.60	11.97
12439	11.63	12.64	11.99
12462	11.55	12.53	11.88
12488	11.52	12.54	11.96
12528	11.43	12.43	11.80
12587	11.34	12.41	11.87
12740	11.88	12.60	11.91
12752	11.97	12.68	11.99
12756	11.95	12.71	12.03
12775	12.02	12.77	11.98
12794	12.13	12.79	12.08
12818	12.30	12.97	12.26
12824	12.33	13.02	12.32
12843	12.51	13.11	12.37
12868	12.58	13.16	12.45
12890	12.71	13.35	12.70
12905	12.81	13.47	12.79
12915	12.96	13.76	12.99
12965	12.63	13.29	12.69
12967	12.70	13.31	12.70
12969	12.65	13.28	12.70
12974	12.55	13.20	12.57
12998	12.47	13.17	12.60
13003	12.45	13.04	12.48
13230	11.21	12.37	11.75
13235	11.16	12.32	11.77
13240	11.14	12.30	11.75

inclination $i = 90°$ (A is the separation between components). This estimate of the red giant's radius is in agreement with the conclusion of Yudin *et al.* [4] that the cool component of BF Cyg fills its Roche lobe. In this case the mass ratio $q = M_{\rm hot}/M_{\rm cool}$ must be near 0.25. Fekel *et al.* [2] used analyses of the radial velocities to derive the mass ratio for BF Cyg: $q = 0.21$–0.34. Our estimate of q is well inside this interval.

The fact that the minimum in mid-1991 was 75 days later than predicted, according to ephemerides of Pucinskas [1], has no clear explanation. In some symbiotic stars (CI Cyg and Z And), during great outbursts, sharp and deep minima were also observed. In such cases,

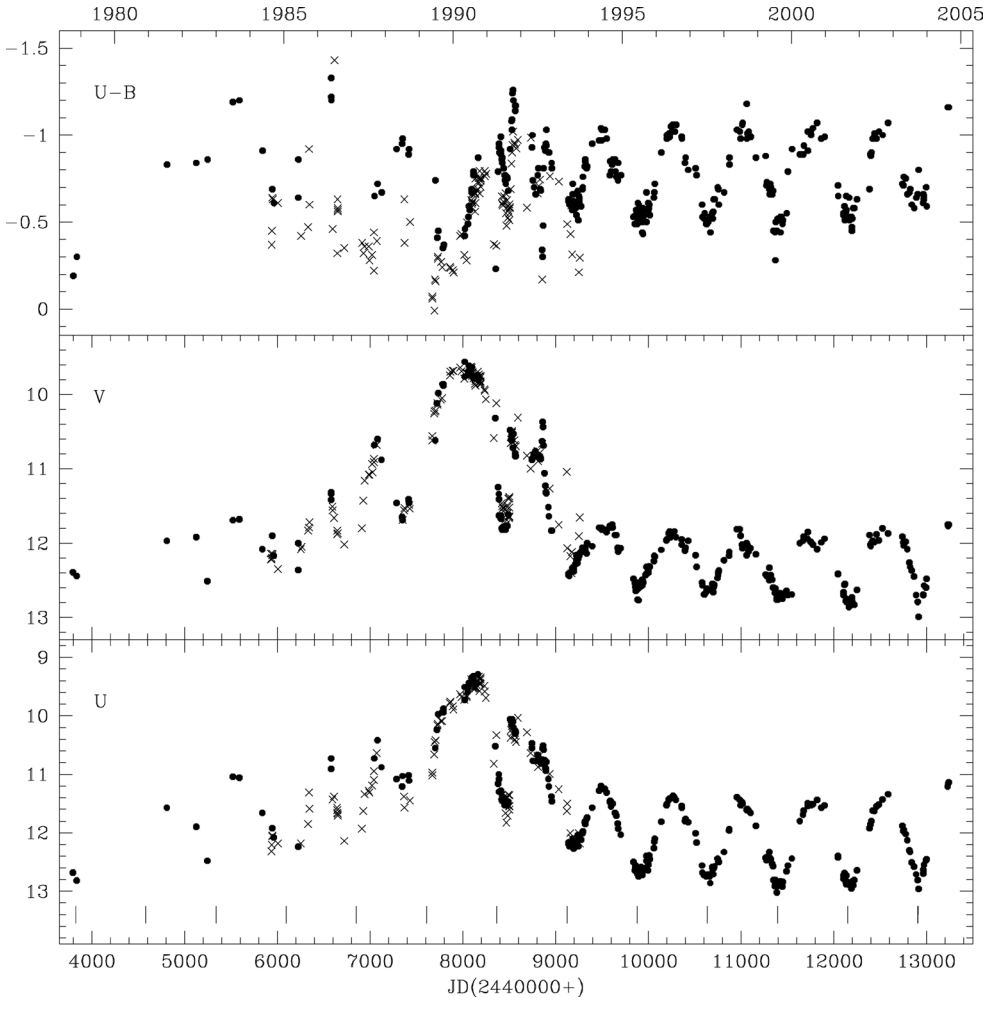

Figure 1. U, V and $U-B$ light curves of BF Cyg (JD, Julian date). The estimates of the magnitudes of U, B and V, which are taken from the work of Skopal *et al.* [3] (and references therein) are indicated by crosses; the full circles are our data. The vertical bars at the bottom of the U light curve indicate the dates of spectroscopic conjunctions calculated from the ephemerides of Fekel *et al.* [2].

not only were the shapes of the light curves changed, but also so were the ephemerides (see [5] and references therein). This is one of the unresolved problems connected with classical symbiotic stars.

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