Long-term photometry of the symbiotic nova V1016 Cyg

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Abstract. Long-term $UBVR$ photoelectric photometry of the symbiotic nova V1016 Cyg performed from 1971 to 2000 is presented. The archive photographic plates were used to estimate the brightness of the object during the years 1895-1910 and 1937-1997. These data together with the post-outburst visual observations from international databases are discussed. The pre-outburst brightening in 1949, main nova-like outburst in 1964 and two small brightenings in 1980 and 1994 suggest a 5500-day periodicity of activity, interpreted as the orbital period of the binary. In 1971, during the brightness maximum of the symbiotic nova, the outbursting white dwarf mimicked a B6 supergiant.

Key words: stars – binaries – symbiotic – photometry – V1016 Cyg

1. Introduction

V1016 Cyg (MHα 328-116) is a member of the small subgroup of symbiotic stars, called symbiotic novae, also including V1329 Cyg and HM Sge, in which an outburst leads to a nebular spectrum (Mürset & Nussbaumer, 1994). Symbiotic novae are the wide interacting binaries where matter from a late-type giant is transferred onto the surface of the more compact companion. The nova-like optical outburst ($\Delta m \sim 5-7$ mag), lasting decades, is caused by a thermonuclear runaway on the surface of a wind accreting white dwarf after a critical amount of material has been accumulated (Mikolajewska & Kenyon, 1992). Most of the symbiotic novae, including V1016 Cyg, contain a Mira variable (Munari, 1997).

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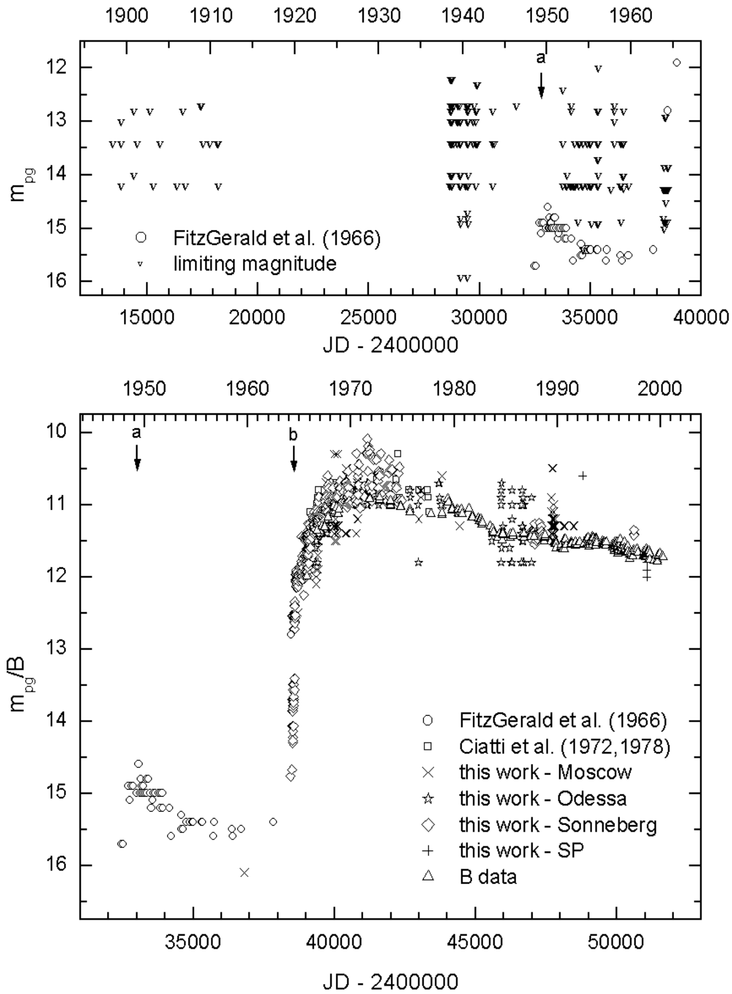

Figure 1. The limiting magnitude of the archive plates (top) and the historical m_{pg}/B-band light curve of V1016 Cyg (bottom). The pre-outburst brightening in 1949 and the main nova-like outburst in 1964 are marked by arrows (see Table 5).

V1016 Cyg underwent its nova-like outburst in 1964 (McCuskey, 1965). The pre-outburst photographic light curve was published by FitzGerald et al. (1966). The photographic magnitude of the star increased from $\sim$ 16 mag to $\sim$ 10.5 mag in 1971. Since then the brightness of the object has been slowly decreasing (Ciatti et al., 1972, 1978, 1979; Arkhipova, 1983).

V1016 Cyg was included in the international campaign of photoelectric observations of symbiotic stars (Hric et al. 1991, 1993, 1994, 1996; Skopal et al., 1995). Infrared photometry of the object has been published by Harvey (1974), Kenyon & Gallagher (1983), Lorenzetti et al. (1985), Taranova & Yudin (1986), Munari (1988), Ananth & Leahy (1993), Kamath & Ashok (1999) and Taranova & Schenavrin (2000). Munari (1988) determined the pulsation period of the Mira variable in the system to be 478 days. V1016 Cyg is classified as a D-type symbiotic star. The dust grains are present in the wind of the Mira. The infrared spectral distribution of V1016 Cyg represents a cool star with a blackbody temperature $T \sim 2800$ K and a dust envelope at a temperature $T \sim 600$ K (Taranova & Schenavrin, 2000). In 1983, the episodic formation of the dust in the system was detected (Taranova & Yudin, 1986).

The study of the symbiotic binary V1016 Cyg is negatively influenced by the fact that its orbital period is unknown. Taranova & Yudin (1983) used an increase of Balmer emission lines in combination with the appearance and disappearance of FeII lines and estimated an orbital period of about 20 years. Nussbaumer & Schmid (1988) proposed the orbital period of 9.5 years on the basis of the periodicity in the UV fluxes of OI and MgII lines. However they did not observe any two subsequent maxima or minima indicating that the phenomenon repeats with time. Munari (1988) analyzed IR observations taken over 2 decades and proposed a 6-year orbital period based on modelling of the dust obscuration episodes related to the passage of the Mira at the inferior conjuction in the system. Wallerstein (1988) suggested that the sharp FeII emission lines are formed in the chromosphere of the cool star and reflect the orbital motion. Their radial velocities between 1978-1985 limit any high inclination orbit to a period greater than 25 years or to a large eccentricity. Schild & Schmid (1996) concluded from analysis of spectropolarimetric data taken from 1991 – 1994, that the orbital period is about 80 ± 25 years. However, new observations in 1997 put this result into question (Schmid, 1998).

The aim of our paper is to present the UBV photometry of V1016 Cyg taken at the Crimean station of the Sternberg Astronomical Institute (1971- 1999), the $UBVR$ photometry obtained at the Skalnaté Pleso and Stará Lesná Observatories (1992-2000), the photographic magnitudes estimated from Moscow, Odessa, Sonneberg and Skalnaté Pleso archive plates taken during the years 1895-1910 and 1937-1997 and post-outburst visual estimates from international databases. Possible explanations of the brightness variations are discussed.

2. Observations and data reduction

2.1. Photographic data

We measured almost 1200 photographic plates from Moscow (M), Odessa (O), Sonneberg (S) and Skalnaté Pleso (SP) archives taken from 1895 to 1997. Photographic magnitudes were estimated visually using the Nijland – Blazhko method and four comparison stars with reliable m_{pg}/B magnitudes (see Table 1).

Table 1. Comparison stars used for the photoelectric and photographic photometry

Photoelectric standards

HD	BD+	U	B	V	Sp. type	Note
188326	38°3801	8.69	8.34	7.56	G5	standard star (SP,SL)
226629	39°3960	10.13	10.08	9.52	G0	check star (SP,SL)
226775	39°3969	10.78	9.82	8.74	K0	check star (SP,SL)
226646	39°3961	10.73	10.50	10.16	A7	standard star (CS)
226756	39°3565	10.84	9.60	8.35	K0	check star (CS)

Photographic standards with new estimated magnitudes

Star	α (2000)	δ (2000)	U	B	V
GSC 3141-1503	$19^h\ 57^m\ 20^s$	39° 39′ 32″	11.07	10.80	10.50
GSC 3141-2675[1]	$19^h\ 57^m\ 31^s$	39° 39′ 19″		11.08	9.89
GSC 3141-2205[2]	$19^h\ 57^m\ 08^s$	39° 40′ 45″	11.56	11.32	11.18
GSC 3141-2817[3]	$19^h\ 56^m\ 33^s$	39° 39′ 26″		11.36	10.99
GSC 3141-1559	$19^h\ 56^m\ 14^s$	39° 19′ 03″	13.08	12.45	11.51
GSC 3141-0181	$19^h\ 57^m\ 10^s$	39° 50′ 39″	13.10	12.92	12.38
GSC 3141-0455	$19^h\ 57^m\ 14^s$	39° 56′ 00″		13.21	13.09
GSC 3141-0569	$19^h\ 57^m\ 17^s$	39° 47′ 22″		13.35	12.94
U1275_13058156[4]	$19^h\ 57^m\ 05^s$	39° 49′ 14″		14.27	13.77

Note: 1 – HD 226796, BD+39°3971, 2 – HD 226757, 3 – HD 226690, 4 – USNOA

Photographic standards

Star	α (2000)	δ (2000)	m_{pg}
GSC 3141-0839	$19^h\ 57^m\ 41^s$	39° 56′ 33″	11.7
USNOA U1275_13059970	$19^h\ 57^m\ 07^s$	39° 48′ 30″	15.4
USNOA U1275_13063808	$19^h\ 57^m\ 10^s$	39° 48′ 12″	15.6
USNOA U1275_13057066	$19^h\ 57^m\ 04^s$	39° 59′ 54″	16.6

The resulting photographic magnitudes of V1016 Cyg are given in Table 2. The number of plates n taken at the same observatory during a night is indicated. If $n > 1$, an average magnitude is yielded. Unsure values are designated by ":". The mean error of our estimates is about 0.3 mag. V1016 Cyg was visible only on 653 post-outburst plates. On the pre-outburst plates, taken using the 0.1 m and 0.16 m telescopes of the Moscow Observatory, the star was fainter than the limiting magnitude of a plate (Fig. 1, top). Post-outburst data were taken using the 0.4 m telescope of the Moscow Observatory and the two 0.15 m telescopes of the Odessa Observatory. All observations in Sonneberg were taken using a 6 cm telescope. A few observations were taken using the 0.3 m astrograph at the Skalnaté Pleso Observatory.

Because of different types of telescopes and plate sensibility (i.e., different λ_{eff}), the data exhibits relative shifts and large scatter. We took photoelectric B data (see Fig. 5) as a reference. We shifted the Moscow data by -0.6 mag,

Table 2. Photographic magnitudes of V1016 Cyg. JD = JD* + 2 400 000

JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.
36805	16.7	1	M	38697	12.6	2	S	39142	11.8	2	S
38348	14.3:	1	S	38709	12.7	2	S	39144	11.8:	1	S
38411	13.4:	1	S	38739	12.6	2	S	39146	12.0	2	S
38413	13.7:	1	S	38753	12.4	1	S	39185	11.6	1	S
38448	14.4:	1	S	38818	12.5	3	S	39205	11.5	2	S
38496	13.9:	2	S	38828	12.3	1	S	39206	11.7	2	S
38502	13.4	2	S	38831	12.4	1	S	39239	11.7	2	S
38504	13.4:	1	S	38832	12.6	1	S	39243	11.6	1	S
38505	13.4:	2	S	38833	11.7	2	S	39256	11.6	1	S
38521	13.6	4	S	38850	12.3	1	S	39262	11.7	3	S
38526	13.3	3	S	38853	12.4:	2	S	39264	11.6	1	S
38529	13.4	5	S	38854	12.5	1	S	39270	11.7	2	S
38530	13.4	4	S	38883	12.5	2	S	39286	11.6	3	S
38532	13.4	4	S	38884	12.2	1	S	39287	11.4	1	S
38549	13.4	6	S	38902	11.9:	1	S	39288	11.7	1	S
38550	13.4	3	S	38903	12.9	1	S	39289	11.8	1	S
38551	13.3	1	S	38932	12.5	2	S	39294	11.7	1	S
38554	13.4	1	S	38935	12.4	2	S	39298	11.7	1	S
38556	13.2	1	S	38936	12.6	1	S	39299	11.6	1	S
38556	13.3	1	S	38937	12.2	2	S	39317	11.6	1	S
38559	13.3	1	S	38940	12.6	1	S	39319	11.7	1	O
38561	13.2	1	S	38941	12.4:	2	S	39330	11.9	1	O
38583	13.3:	1	S	38974	11.9:	1	S	39330	11.7	1	S
38584	13.2	5	S	38977	12.3	2	S	39331	11.5	1	O
38585	13.2	3	S	38990	12.2:	1	S	39331	11.6	1	S
38587	13.2	6	S	38992	11.9	1	S	39347	11.6	1	S
38591	13.3:	1	S	38996	12.3	2	S	39349	11.6	1	S
38592	13.2	5	S	38998	12.1	1	S	39350	11.6	1	S
38592	13.0	1	S	39007	12.2	2	S	39351	12.5	3	M
38594	13.1	4	S	39021	12.3	2	S	39351	11.6	1	O
38613	12.9:	2	S	39023	12.6	1	S	39351	11.6	1	S
38614	12.6	1	S	39024	12.1	2	S	39352	12.1	5	M
38616	12.8:	2	S	39025	12.6	1	S	39352	11.6	1	S
38622	12.6	1	S	39026	12.0	2	S	39354	11.5	1	O
38623	12.6	1	S	39027	12.3	2	S	39354	11.6	2	S
38638	12.6	2	S	39028	12.0	3	S	39355	11.5	1	S
38640	12.7	1	S	39029	12.1	2	S	39360	11.9	1	O
38641	12.6	2	S	39034	12.1:	3	S	39363	12.1	1	M
38642	12.5	1	S	39038	11.9	1	S	39376	11.4	1	O
38650	12.5	3	S	39051	11.8	2	S	39378	11.6	1	S
38651	12.6	1	S	39052	11.8	1	S	39379	11.7	1	S
38652	12.4	1	S	39053	11.9	1	S	39380	11.5	1	S
38664	12.5	1	S	39054	11.9	4	S	39381	11.6	1	S
38667	12.6	1	S	39055	11.8	2	S	39384	11.6	1	O
38669	12.7	2	S	39056	11.9	2	S	39386	11.5	1	S
38670	12.5	1	S	39057	11.8	3	S	39388	11.6	1	S
38671	12.7	2	S	39058	11.9	3	S	39389	11.5	2	S
38673	12.6	1	S	39059	11.8	3	S	39390	11.5	2	S
38674	12.3:	1	S	39060	12.0	2	S	39391	11.7	1	S
38675	12.6	1	S	39063	12.4	1	S	39404	11.3	1	O
38680	12.5	2	S	39081	11.9	3	S	39404	11.4	1	S
38695	13.1	1	M	39087	12.3	1	S	39406	11.9	1	O
38696	13.1	1	M	39088	11.8	3	S	39406	11.7	1	S

Table 2. (continued)

JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.
39407	11.5	1	O	39684	11.9	2	M	40033	11.7:	1	M
39407	11.6	1	S	39685	11.4	1	S	40033	11.4	1	S
39408	11.3	1	O	39701	11.4	1	S	40034	11.8:	1	M
39408	12.1	2	M	39704	11.3	4	M	40036	11.3:	1	M
39409	12.1	3	M	39705	11.8	2	M	40037	11.3:	1	M
39410	11.4	1	O	39708	11.8	5	M	40038	11.3	1	S
39410	12.1	5	M	39708	11.1	1	S	40040	11.1	1	S
39411	11.7	5	M	39709	11.9	4	M	40056	11.7	1	M
39412	12.0	5	M	39710	11.0	1	O	40059	11.1	1	O
39414	12.0	5	M	39711	11.9	3	M	40061	11.9	1	M
39414	11.4	2	S	39733	11.5	1	O	40062	11.0	1	O
39415	12.1	5	M	39734	11.1	1	O	40065	12.1	1	M
39416	12.0	5	M	39734	11.8	2	M	40066	11.4	1	S
39416	11.5	1	S	39735	11.9	3	M	40068	11.3	1	S
39418	12.0	5	M	39737	11.8	1	M	40095	11.2:	2	M
39419	12.1	2	M	39737	11.1	1	O	40097	11.9	1	M
39419	11.6	1	S	39739	11.4	1	S	40097	11.9:	1	M
39434	12.1	3	M	39739	11.8	2	M	40101	11.1	1	S
39435	12.1	2	M	39741	11.4	1	O	40117	11.1	1	O
39437	11.9	3	M	39742	11.8	3	M	40118	12.0	1	M
39439	11.6	1	S	39742	11.1	1	O	40121	11.1	1	O
39440	11.7	2	S	39743	11.3	1	O	40122	11.9:	1	M
39441	12.1	3	M	39744	11.1	1	O	40123	11.9	1	M
39443	11.4	3	S	39762	11.4	1	S	40125	11.3	1	S
39443	12.0	2	M	39765	10.7:	1	S	40145	11.4	1	S
39500	11.5	2	S	39769	11.7	1	M	40145	11.5:	1	M
39528	11.5	1	S	39777	10.9	1	S	40149	10.9	1	S
39534	11.6	1	S	39789	10.9	1	S	40150	11.3	1	S
39536	11.4	1	S	39801	11.4	1	S	40151	11.7	1	M
39594	11.4	2	S	39803	11.2	1	S	40152	11.6:	1	M
39598	11.4	1	S	39816	11.1	1	S	40153	11.3	1	S
39612	11.4	1	S	39827	11.2	1	S	40156	11.5:	1	M
39619	11.4	1	S	39852	11.5	1	S	40173	10.9	1	S
39621	11.6	1	S	39914	11.2	1	S	40201	11.0	1	S
39627	11.7	1	M	39919	11.1	1	S	40202	10.8	1	S
39628	11.9	1	M	39941	11.3	1	S	40205	10.9	1	S
39628	12.0	1	M	39943	11.0	2	S	40302	11.2	1	S
39646	11.5	1	S	39965	11.2	1	S	40321	11.0	1	S
39646	12.0	2	M	39966	11.4	1	S	40355	11.1	1	S
39647	12.0	2	M	39969	11.1	1	S	40368	11.6:	1	M
39649	11.5	1	S	39970	11.3	1	S	40382	11.2	1	S
39652	11.1	1	S	39971	11.9	1	M	40384	10.9	1	S
39653	11.9	2	M	39976	11.6	1	M	40387	11.8	2	M
39655	11.5	1	M	39981	11.4	1	S	40390	11.6:	1	M
39671	11.9	2	M	39994	12.0	2	M	40390	10.8	1	S
39671	11.4	1	S	39999	11.4	1	S	40393	12.0	1	M
39673	11.4	1	S	39999	11.9	2	M	40414	11.1	2	M
39675	11.9	2	M	40000	12.0	2	M	40415	11.4	1	S
39676	11.8	2	M	40004	12.0	2	M	40425	11.1	1	M
39677	11.6	2	M	40007	11.9	3	M	40425	10.8	1	S
39678	11.2	1	S	40008	11.4	1	S	40427	12.0	1	M
39681	11.3	1	S	40014	10.8	2	M	40441	10.9	1	S
39683	11.4	1	S	40025	11.4	1	S	40443	11.1	1	S

Table 2. (continued)

JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.
40447	11.1	1	S	40837	10.8	1	O	41561	10.9	1	S
40453	11.3	1	S	40837	11.1	1	S	41564	11.1	1	O
40470	11.0	1	S	40838	10.9	1	O	41568	11.1	1	O
40471	10.9	1	S	40853	11.0	1	O	41570	10.6	1	S
40472	11.2	1	S	40853	10.5	1	S	41592	10.6	1	S
40473	10.6	1	S	40858	10.9	1	S	41594	10.7	1	S
40475	11.4	1	S	40866	10.5	1	S	41596	10.7	1	S
40477	11.2	1	S	40881	11.0	1	O	41599	10.7	1	S
40479	11.0	1	O	40911	11.3	1	S	41600	11.2	1	S
40480	11.0	1	O	40915	11.4	1	S	41602	11.1	1	S
40483	11.1	1	S	41061	10.9	1	S	41647	10.3	1	S
40499	10.9	1	S	41071	11.1	1	S	41674	11.1	1	S
40501	11.2	1	S	41127	10.3	1	S	41799	11.3	1	S
40504	11.1	1	S	41150	10.8	1	O	41832	11.2	1	S
40505	11.0	1	O	41152	11.0	1	O	41859	11.2	1	S
40507	11.4	1	S	41158	10.9	1	O	41869	10.9	1	S
40509	11.0	1	O	41160	10.3	1	S	41894	11.0:	1	S
40532	11.2	1	S	41163	10.9	1	O	41918	10.9	1	S
40624	11.4:	1	S	41163	10.1	1	S	41922	10.6	1	S
40731	11.1	1	S	41164	11.1	1	O	41929	10.4	1	S
40745	11.1	1	S	41165	10.9	1	O	41931	10.9	1	S
40746	11.3	1	S	41179	10.6	1	S	41957	11.1	1	S
40769	11.8:	2	M	41180	11.0	1	O	41982	11.1	1	S
40774	11.4:	2	M	41181	10.2	1	S	41984	10.6	1	S
40774	11.4	1	S	41182	10.9	1	O	41987	10.9	1	S
40778	10.3	1	S	41185	11.1	1	O	42036	10.6	1	S
40779	11.5:	2	M	41186	10.8	1	O	42185	10.9	1	S
40793	11.0	1	O	41210	10.9	1	S	42194	10.9	1	S
40794	11.0	1	O	41216	10.9	1	S	42222	11.2	1	S
40797	11.1	1	O	41219	10.9	1	O	42276	10.6	1	S
40798	10.9	1	O	41240	10.2	1	S	42301	11.3	1	S
40800	11.4:	1	M	41244	10.3	1	S	42303	10.5	1	S
40801	11.1	1	O	41249	10.3	1	S	42395	11.3	1	S
40802	11.0	1	O	41276	11.3	1	S	42687	10.9	1	O
40803	11.4:	1	M	41300	11.0	1	S	42688	11.0	1	O
40806	11.5:	1	M	41322	10.4	1	S	42961	11.1	1	O
40806	11.1	1	O	41333	11.2	1	S	42982	11.9	1	O
40807	10.8	1	O	41335	10.9	1	S	42988	11.8:	1	M
40807	11.4:	1	M	41368	10.4	1	S	43049	11.4:	1	M
40808	10.9	1	O	41395	10.4	1	S	43050	11.4:	1	M
40809	10.9	1	O	41478	10.4	1	S	43063	11.4:	1	M
40810	11.4:	1	M	41512	10.9	1	O	43064	11.5:	1	M
40810	11.3:	1	M	41513	10.9	1	O	43065	11.4:	1	M
40823	11.8	1	M	41515	11.0	1	O	43066	11.4:	1	M
40824	10.7	1	S	41517	10.6	1	S	43072	11.4:	1	M
40827	11.4:	1	M	41537	10.8	1	O	43694	10.8	1	O
40827	11.0	1	O	41537	10.6	1	S	43717	10.8	1	O
40827	11.2	1	S	41543	10.9	1	O	43719	10.8	1	O
40828	10.9	1	O	41544	11.0	1	O	43729	11.0	1	O
40828	11.3	2	M	41545	11.0	1	O	43773	11.1	1	O
40829	10.9	1	O	41547	10.6	1	S	43806	11.6:	1	M
40831	10.6	1	S	41548	10.8	1	S	43806	11.5:	2	M
40834	11.6	2	M	41561	11.0	1	O	44436	11.9:	1	M

Table 2. (continued)

JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.	JD*	m_{pg}	n	Obs.
45581	11.6	1	O	46709	11.5	1	O	47737	11.1	1	M
45582	11.5	1	O	46710	11.1	1	O	47741	11.8	1	M
45583	11.6	1	O	46917	11.7	1	S	47745	11.8	1	M
45882	11.5	1	O	46977	11.6	1	S	47747	11.9	1	M
45902	11.9	1	O	46978	11.9	1	O	47747	11.8	1	M
45903	11.9	1	O	46979	11.0	1	O	47748	11.6	1	M
45907	11.0	1	O	46982	11.6	1	S	47749	12.1	1	M
45909	11.9	1	O	47028	11.6	1	S	47766	12.0	1	M
45911	10.9	1	O	47039	11.6	1	S	47767	11.7	1	M
45912	11.1	1	O	47070	11.6	1	S	47768	11.9	1	M
45914	10.8	1	O	47087	11.6	1	S	47773	12.1	1	M
45916	11.7	1	O	47087	11.6	1	S	47774	12.0	1	M
45941	11.5	1	O	47088	11.6	2	S	47776	11.9	1	M
45969	11.4	1	O	47094	11.8	1	S	47777	11.8	1	M
46203	11.7	1	O	47095	11.6	1	S	47778	12.0	1	M
46261	11.9	1	O	47139	11.7	1	S	47779	11.9	1	M
46263	11.9	1	O	47141	11.6	1	S	47789	11.9	1	M
46265	11.9	1	O	47152	11.7	2	S	47792	12.0	1	M
46271	11.9	1	O	47174	11.7	1	S	47793	11.9	1	M
46288	11.9	1	O	47264	11.5	2	S	47797	11.9	2	M
46289	10.9	1	O	47266	11.6	1	S	47798	11.9	1	M
46290	11.1	1	O	47325	11.6	1	S	47821	11.8	3	M
46291	11.1	1	O	47329	11.6	5	S	47825	11.9	1	M
46294	11.3	1	O	47331	11.5	2	S	47829	11.9	1	M
46618	11.1	1	O	47365	11.6	1	S	47830	11.9	1	M
46619	11.5	1	O	47366	11.6	1	S	47835	11.9	1	M
46620	11.9	1	O	47681	11.7	1	M	48119	11.9	1	M
46649	10.9	1	O	47681	11.5	1	M	48122	11.9	1	M
46652	11.6	1	O	47682	11.9	1	M	48124	11.9	1	M
46653	11.1	1	O	47683	11.9	7	M	48128	11.9	1	M
46654	11.5	1	O	47704	12.0	1	M	48132	11.9	1	M
46655	11.4	1	O	47705	11.9	1	M	48153	11.9	1	M
46656	10.9	1	O	47706	11.9	1	M	48453	11.9	1	M
46669	11.1	1	O	47707	11.5	2	M	48475	11.9	1	M
46671	11.1	1	O	47710	11.9	1	M	48484	11.9	1	M
46672	11.0	1	O	47711	12.0	1	M	48803	10.4	1	SP
46673	11.4	1	O	47716	12.0	1	M	48827	11.3	1	SP
46674	11.9	1	O	47717	12.0	1	M	48868	11.3	1	SP
46675	11.5	1	O	47718	12.1	1	M	48976	11.3	1	SP
46678	11.0	1	O	47724	11.9	1	M	50604	11.8	1	S
46680	11.6	1	O	47729	11.9	1	M	50607	11.8	1	S
46681	11.0	1	O	47730	11.1	1	M	50609	11.7	1	S
46682	11.1	1	O	47732	11.9	1	M	51079	11.7	2	SP
46683	11.5	1	O	47734	11.9	1	M	51080	11.6	1	SP
46702	11.9	1	O	47736	11.9	1	M	51080	11.7	1	SP

the Sonneberg data by -0.2 mag, the data from Odessa by -0.1 and data from the Skalnaté Pleso Observatory by +0.1 mag. All these data together with published m_{pg} observations (FitzGerald et al., 1966; Ciatti et al., 1972, 1978) were used to construct the historical m_{pg}/B light curve shown in Fig. 1 (bottom). FitzGerald's et al. (1966) photographic data were only published in graphical form. Therefore, we scanned their Fig. 3 and saved it as a bitmap picture. Then we carefully determined the pixel coordinates appropriate to the centres of symbols and transformed them to the Julian dates and magnitudes. The mean error of the determined magnitudes (0.05 mag) is smaller than the mean error (~ 0.2 mag) of FitzGerald's measurements.

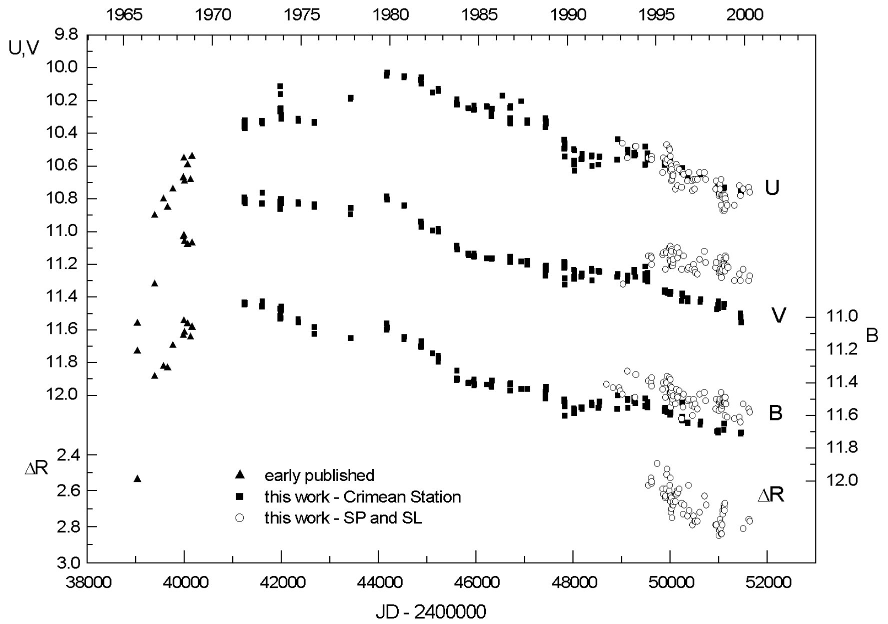

Figure 2. U, B, V and ΔR light curves of V1016 Cyg.

2.2. Photoelectric data

2.2.1. Crimean data

Photoelectric observations of V1016 Cyg were carried out at the Crimean station (CS) of the Sternberg Astronomical Institute from 1971 to 1999. The 0.6 m Cassegrain telescope equipped with a single-channel pulse-counting photoelectric photometer with EMI 6256 photomultiplier was employed. HD 226646 and HD 226756 served as the comparison and check star, respectively (see Table 1). The U, B, V filters and the instrumental photometric system is close to that of standard Johnson. In 1989 the photomultiplier was substituted by a new one of the serie EMI 9789 and the successive observations have shown the systematic differences ΔV = -0.02 mag, ΔB = -0.07 mag, ΔU = -0.17 mag. We reduced the new observations to the older system taking these differences into account. Moreover, the uncooled photometer showed the dependence of measured V magnitudes on the temperature: dV/dt = 0.0068 mag/deg and dV/dt = 0.0082 mag/deg for EMI 6256 and EMI 9789, respectively (Fig. 3).

Therefore, we reduced all V observations of V1016 Cyg to the same temperature t = +10 °C. The temperature coefficient in the B passband was zero for EMI 6256 and dB/dt = 0.002 mag/deg for EMI 9789. The same reduction procedure was applied to the photometry of the similar object HM Sge (Arkhipova

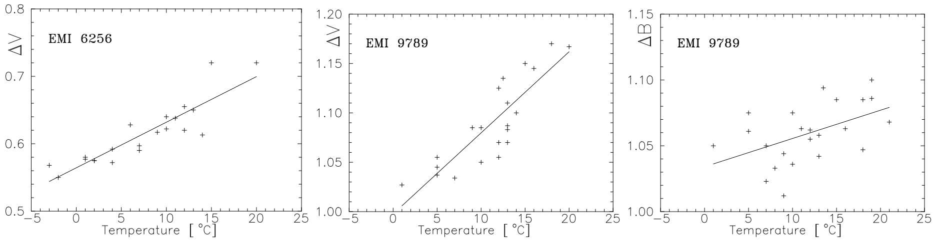

Figure 3. Dependence of the measured magnitudes on the temperature.

et al., 1994). The main cause of the temperature effect is the change of the transmission of the glass filter. The resulting CS instrumental magnitudes of V1016 Cyg are given in Table 3. Their mean errors do not exceed 0.01 mag.

2.2.2. Skalnaté Pleso and Stará Lesná data

The *UBVR* photoelectric photometry of V1016 Cyg was obtained at the Skalnaté Pleso (SP) and Stará Lesná (SL) Observatories in 1992 - 2000. In both cases a single-channel pulse-counting photoelectric photometer installed at the Cassegrain focus of the 0.6 m reflector was used. The SP observations were carried out through the standard *UBVR* filters using photomultiplier HAMAMATSU R 4457P sensitised in the *R* passband. Standard *UBV* filters were employed at SL using photomultiplier EMI 9789 QB. HD 188326 served as a comparison star, HD 226629 and HD 226775 as check stars (see Table 1). The comparison star was found to be stable within 0.01 mag in all passbands. Data reduction, atmospheric extinction correction and transformation to the international *UBV* system were carried out in the usual way. The *R* data are in the instrumental system. Part of the data have already been published by Hric et al. (1991, 1993, 1994, 1996) and Skopal et al. (1995). We have reanalysed these data in a homogeneous way. The resulting *UBV* and ΔR magnitudes, given in Table 4, are averages of all individual observations obtained during one night. The mean error of the average did not exceed 0.02 mag and 0.01 mag in the *U* and *BVR* passbands, respectively.

The *UBV* and ΔR light curves, compiled from early published data (Philip, 1968; FitzGerald & Houk, 1970) and our observations, are shown in Fig. 2. Due to the fact that the SP and SL data are given in the standard Johnson system, they were taken as a reference. The CS data were shifted by ΔB = -0.12 mag and ΔV = -0.22 mag with respect to the reference data (Fig. 5). The differences between the systems is caused by diversity in the spectral sensitivity of photomultipliers and the differences in transparency of the *B* and *V* filters used in both observatories. The strong [OIII] 4959Å and 5007Å emission lines near the edge of the *V* passband can be responsible for the shift, as in the case of nova V1974 Cyg (Chochol et al., 1993).

Table 3. The U, B, V magnitudes (in the instrumental system) of V1016 Cyg obtained at the Crimea station of the Sternberg Astronomical Institute. JD = JD* + 2 400 000

JD*	U	B	V	JD*	U	B	V	JD*	U	B	V
41237	10.33	10.91	10.79	45844	10.24	11.40	11.13	48546	10.54	11.54	11.25
41238	10.36	10.92	10.81	45852	10.25	11.40	11.14	48548	10.54	11.52	11.24
41239	10.35	10.92	10.82	45964	10.26	11.39	11.15	48915	10.56	11.56	11.28
41240	10.34	10.92	10.81	45965	10.23	11.38	11.13	48929	10.44	11.48	11.26
41245	10.34	10.92	10.81	45967	10.24	11.42	11.15	49124	10.55	11.51	11.30
41246	10.32	10.91	10.82	45969	10.25	11.40	11.15	49131	10.50	11.50	11.27
41247	10.37	10.91	10.81	45975	10.26	11.41	11.15	49135	10.53	11.56	11.28
41252	10.36	10.91	10.83	46228	10.23	11.41	11.16	49269	10.52	11.51	11.25
41253	10.35	10.92	10.82	46232	10.24	11.41	11.16	49270	10.54	11.49	11.23
41596	10.32	10.93	10.83	46325	10.27	11.42	11.16	49286	10.53	11.53	11.28
41597	10.33	10.94	10.83	46328	10.29	11.41	11.16	49488	10.60	11.54	11.30
41604	10.34	10.93	10.83	46330	10.26	11.43	11.17	49490	10.48	11.50	11.21
41605	10.33	10.90	10.76	46332	10.25	11.39	11.16	49491	10.59	11.54	11.26
41973	10.11	10.95	10.86	46557	10.17	11.23	11.02	49533	10.54	11.55	11.27
41974	10.27	11.01	10.82	46706	10.24	11.41	11.15	49536	10.55	11.53	11.26
41975	10.25	10.99	10.85	46709	10.34	11.45	11.19	49539	10.53	11.54	11.25
41980	10.16	10.97	10.80	46710	10.31	11.45	11.17	49542	10.52	11.52	11.27
41982	10.26	11.00	10.82	46715	10.34	11.41	11.18	49544	10.55	11.55	11.30
41985	10.25	10.96	10.83	46717	10.23	11.40	11.16	49546	10.56	11.55	11.30
41991	10.29	10.96	10.82	46937	10.20	11.44	11.18	49885	10.55	11.56	11.36
41993	10.31	10.96	10.83	47062	10.34	11.44	11.18	49887	10.59	11.57	11.36
41997	10.29	10.94	10.80	47064	10.32	11.44	11.20	49892	10.58	11.56	11.37
42344	10.32	11.01	10.82	47436	10.31	11.47	11.21	49902	10.58	11.56	11.36
42345	10.31	11.02	10.82	47437	10.36	11.50	11.25	49950	10.57	11.58	11.37
42350	10.32	11.03	10.83	47439	10.31	11.46	11.27	49959	10.58	11.57	11.37
42679	10.33	11.06	10.85	47449	10.34	11.44	11.23	50003	10.56	11.60	11.38
42680	10.34	11.10	10.83	47450	10.33	11.42	11.21	50015	10.58	11.58	11.37
43423	10.19	11.13	10.89	47823	10.49	11.51	11.22	50247	10.62	11.63	11.42
43426	10.18	11.13	10.86	47826	10.44	11.50	11.19	50255	10.63	11.52	11.38
44162	10.05	11.04	10.79	47834	10.54	11.52	11.22	50256	10.64	11.61	11.38
44163	10.05	11.08	10.79	47835	10.46	11.53	11.20	50259	10.61	11.63	11.39
44175	10.03	11.06	10.81	47836	10.48	11.54	11.29	50366	10.67	11.64	11.43
44525	10.06	11.13	10.85	47837	10.47	11.54	11.19	50371	10.67	11.65	11.41
44526	10.05	11.12	10.84	47838	10.49	11.60	11.32	50624	10.65	11.65	11.43
44871	10.07	11.18	10.94	48026	10.50	11.56	11.23	50634	10.65	11.64	11.41
44876	10.07	11.18	10.94	48027	10.59	11.59	11.29	50966	10.74	11.70	11.48
44881	10.06	11.15	10.97	48028	10.57	11.56	11.28	50995	10.71	11.71	11.47
44882	10.10	11.18	10.95	48032	10.63	11.58	11.24	50997	10.74	11.70	11.45
45115	10.15	11.22	10.99	48035	10.51	11.56	11.24	50998	10.71	11.69	11.43
45226	10.13	11.24	10.98	48176	10.56	11.55	11.28	51111	10.74	11.69	11.46
45229	10.14	11.27	11.00	48188	10.56	11.55	11.26	51115	10.73	11.65	11.44
45234	10.14	11.25	11.00	48193	10.53	11.56	11.27	51453	10.76	11.71	11.50
45608	10.22	11.39	11.09	48387	10.54	11.52	11.23	51459	10.75	11.71	11.52
45614	10.22	11.37	11.09	48390	10.53	11.54	11.24	51470	10.76	11.70	11.56
45615	10.19	11.33	11.09	48400	10.60	11.54	11.30				
45619	10.23	11.38	11.11	48531	10.59	11.55	11.24				

2.3. Visual data

We also used visual estimates from the AAVSO (American Association of Variable Stars Observers), AFOEV (Association Française des Observateurs d'Etoiles Variables), VSOLJ (Variable Stars Observers League of Japan) and VSNET (Variable Stars Network) databases from 1967 to 2000. After removing the "unsure" (:) and "fainter than" (<) data, altogether 7734 visual estimates were used. Due to the large scatter of the original data, 10-day averages together

Table 4. The $U, B, V, \Delta R$ magnitudes of V1016 Cyg obtained at the Skalnaté Pleso and Stará Lesná (typed in *italics*) observatories. JD = JD* + 2 400 000

JD*	U	B	V	ΔR	JD*	U	B	V	ΔR
48693	10.39	11.41	10.84	–	50393	10.64	11.50	11.22	2.71
48830	10.37	11.43	10.79	–	50455	10.69	11.54	11.23	–
48951	10.32	11.43	10.85	–	50466	10.75	11.60	11.23	2.79
48979	10.16	11.45	10.84	–	50483	10.68	11.50	11.20	2.74
49027	10.46	11.47	11.07	–	50512	10.74	11.55	11.23	2.77
49036	10.38	11.62	11.32	–	50519	10.68	11.53	11.25	2.77
49126	10.55	11.33	11.05	–	50563	10.68	11.56	11.26	2.77
49287	10.48	11.49	11.44	–	50611	10.64	11.47	11.17	2.72
49302	10.48	11.35	11.06	–	50709	10.64	11.46	11.12	2.63
49555	10.55	11.39	11.15	2.57	50742	10.68	11.51	11.19	2.68
49608	10.54	11.40	11.15	2.53	50944	10.74	11.56	11.22	2.79
49620	10.54	11.42	11.20	2.56	50958	10.69	11.50	11.19	2.79
49626	10.56	11.37	11.16	2.55	51008	10.77	11.57	11.26	2.85
49855	10.64	11.44	11.14	2.59	51016	10.78	11.51	11.25	2.82
49863	10.55	11.40	11.13	2.62	51026	10.77	11.52	11.24	–
49905	10.57	11.49	11.23	2.64	51035	10.71	11.51	11.16	2.76
49926	10.58	11.39	11.12	2.59	51038	10.74	11.50	11.23	2.81
49936	10.47	11.40	11.13	2.51	51054	10.78	11.54	11.27	2.84
49942	10.56	11.36	11.10	2.48	51056	10.68	11.46	11.24	2.78
49987	10.49	11.37	11.10	2.60	51061	10.84	11.56	11.28	2.84
49995	10.50	11.46	11.17	2.57	51079	10.79	11.54	11.23	2.79
50006	10.54	11.38	11.09	2.53	51090	10.87	11.50	11.20	2.71
50008	10.58	11.42	11.14	2.63	51091	10.78	11.53	11.20	2.73
50014	10.62	11.46	11.18	2.66	51108	10.78	11.53	11.18	2.69
50017	10.63	11.55	11.16	2.72	51110	10.78	11.50	11.17	2.68
50031	10.60	11.45	11.11	2.64	51118	10.80	11.52	11.20	2.69
50033	10.62	11.43	11.12	2.64	51120	10.87	11.52	11.21	2.71
50035	10.69	11.49	11.21	2.70	51130	10.78	11.52	11.16	2.67
50043	10.68	11.52	11.21	2.75	51137	10.86	11.60	11.24	2.67
50052	10.66	11.50	11.21	2.68	51142	10.80	11.49	11.15	2.63
50067	10.65	11.48	11.19	2.68	51159	10.83	11.53	11.16	2.61
50070	10.66	11.48	11.17	2.66	51177	10.84	11.61	11.21	2.64
50116	10.74	11.53	11.20	2.66	51197	–	–	11.22	2.59
50140	10.59	11.44	11.12	2.62	51202	–	–	11.26	2.67
50152	10.61	11.48	11.10	2.60	51323	10.84	11.62	11.30	2.81
50161	10.72	11.49	11.16	2.61	*51433*	*10.72*	*11.61*	*11.26*	–
50194	10.62	11.45	11.13	2.59	*51451*	*10.78*	*11.64*	*11.30*	–
50242	10.73	11.62	11.23	2.67	51511	10.74	11.53	11.23	2.81
50269	10.64	11.55	11.13	2.73	51627	10.73	11.56	11.30	2.76
50287	10.65	11.47	11.15	2.68	51644	10.76	11.58	11.27	2.77
50364	10.69	11.51	11.23	2.74					

with their running mean are presented in Fig. 4.

3. Analysis of the data

Prior to 1948, the star was fainter than 15.5 – 16 mag. During well documented pre-outburst brightening in 1948-52 (see Fig. 1), the brightness of the star fluctuated around 15 mag and then faded slowly to 15.6 mag in 1958. This brightening occurred $\sim 15 - 16$ years before the main nova-like outburst, which started in 1964. During the main outburst, the star brightened from $m_{pg} \sim 15.5$ in 1964 to $m_{pg} \sim 10.5$ mag in 1971. The rise was relatively fast. In 1964, a mean increase in brightness Δm_{pg} = - 0.02 mag/day can be estimated assuming a linear trend.

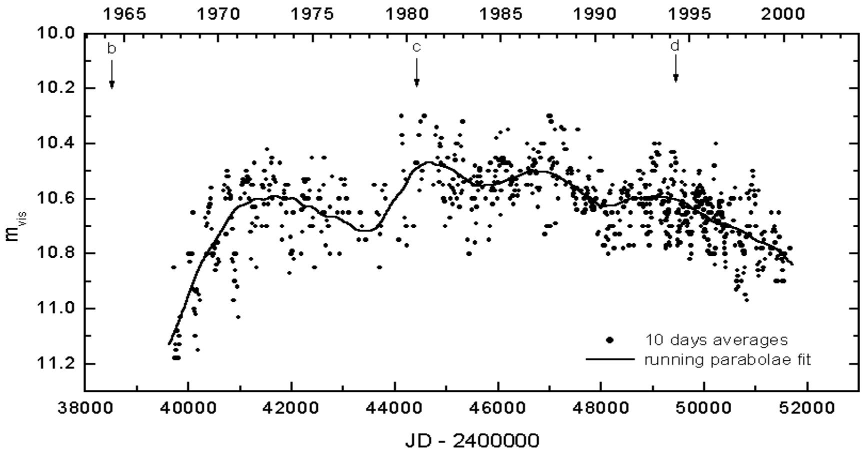

Figure 4. Visual light curve of V1016 Cyg. The star's brightenings in 1980 and 1994 as well as the main nova-like outburst in 1964 are marked by arrows (see Table 5).

Corrected post-outburst *UBV* light curves are shown in Fig. 5 (top). The brightness of V1016 Cyg in the *B* and *V* passbands reached a maximum in 1971, followed by almost linear brightness decrease with the rates:

$$\begin{aligned} B &= \underset{\pm 7}{10.81} + \underset{\pm 18}{7.58}\ 10^{-5}(JD - 2441000), \\ V &= \underset{\pm 5}{10.51} + \underset{\pm 12}{6.96}\ 10^{-5}(JD - 2441000). \end{aligned} \tag{1}$$

The nova reached a maximum brightness in the *U* passband in 1980. Simultaneously, the brightening in the *B* and *V* passbands was detected. The rate of the linear brightness decrease in the *U* passband was as follows:

$$U = \underset{\pm 1}{10.03} + \underset{\pm 2}{1.04}\ 10^{-4}(JD - 2444000) \tag{2}$$

The second brightening in *UBV* occurred in 1994. Both brightenings, designated by arrows in Fig. 5, were preceded by a decrease, observed in the visual light curve, too (see Fig. 4).

Long-term photometry of V1016 Cyg suggests a periodic variability of the activity of the system. The pre-outburst brightening in 1949 and the main outburst in 1964 are detected in photographic data, two other brightenings in 1980 and 1994 are best visible in the photoelectric *U* data. They are designated by arrows a, b, c and d in Figs. 1, 4 and 5. We accepted the time of the main outburst b as the moment when the brightness of the object due to the outburst

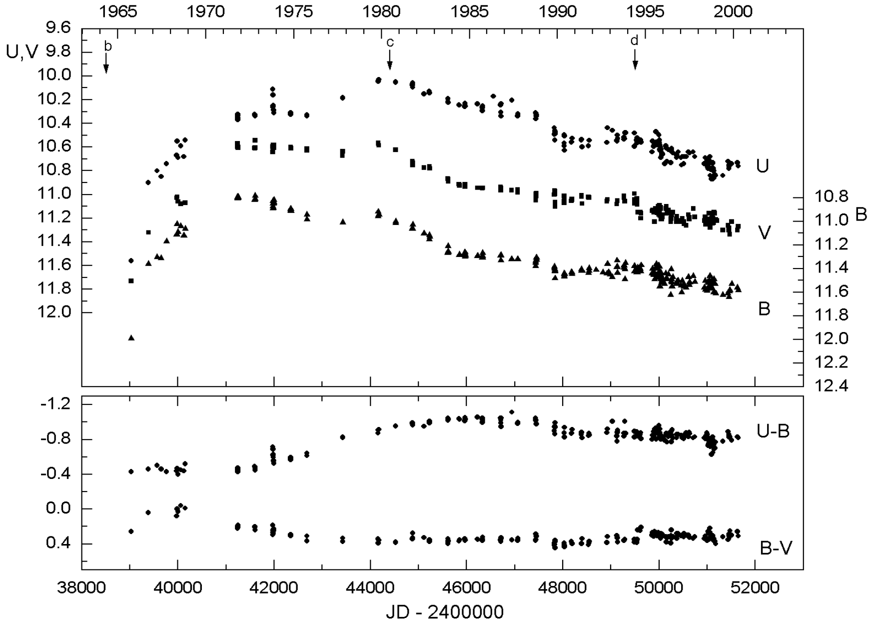

Figure 5. Corrected U, B, V light curves of V1016 Cyg and corresponding $U-B$ and $B-V$ colour indices. The star's brightenings in 1980 and 1994 as well as the main nova-like outburst in 1964 are marked by arrows (see Table 5).

Table 5. Stages of activity of V1016 Cyg.

	Year	JD	Type of activity	$O-C$[1]
a	1949	2433070±160	flare	-27
b	1964	2438527± 19	main outburst	-80
c	1980	2444360±280	flare	244
d	1994	2449490±105	flare	-136

[1] - according to the ephemeris (3)

reached the value $(m_{pg,max} - m_{pg,min})/2$. The times of the brightness maxima a, c, d and the time of the main outburst b (see Table 5) were used to find the ephemeris of activity:

$$JD = \underset{\pm 250}{2427590} + \underset{\pm 90}{5510} \times E. \tag{3}$$

The behaviour of the $U-B$ and $B-V$ colour indices is shown in Fig. 5 (bottom). The $B-V$ colour index increased from ~ 0 in 1966 to ~ 0.3 mag in 1977. Thereafter, the $B-V$ index has been almost constant. On the other

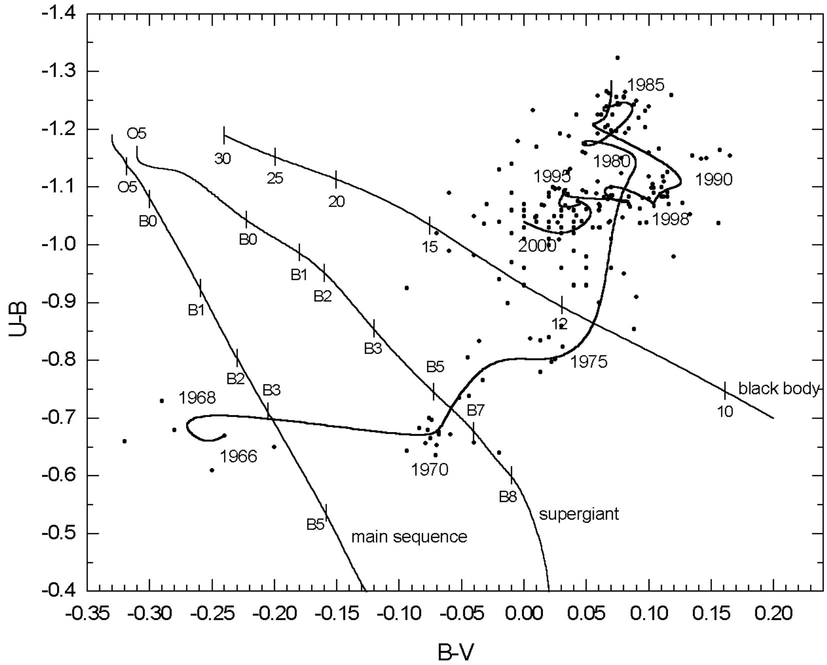

Figure 6. The two-colour diagram for dereddened indices with the main-sequence, supergiant and blackbody sequences and the evolutionary track for V1016 Cyg. The temperatures are given in 10^3 K.

hand, the $U-B$ colour index decreased from -0.4 mag in 1965 to -1.2 mag in 1985. Thereafter, a slow increase of the index to the present value $\sim$ -0.9 mag has been observed.

In Fig. 6 we present the two-colour diagram of V1016 Cyg using the dereddened $U-B$ and $B-V$ colour indices as well as the main-sequence, supergiant and blackbody sequences (Lang, 1992; Flower, 1996). The colour indices of V1016 Cyg were dereddened using the colour correction $E(B-V) = 0.28$ adopted from Nussbaumer & Schild (1981). Corresponding $E(U-B) = 0.21$ correction was calculated by applying the relation $E(U-B)/E(B-V) = 0.75+0.05\times E(B-V)$ published by Allen (1976). The evolutionary track of V1016 Cyg, caused by the outburst, was constructed using the 100-day averages and the cubic spline.

4. Discussion

Symbiotic nova V1016 Cyg is a wide orbit binary consisting of a pulsating Mira and a white dwarf that after prolonged accretion from the wind of the companion underwent a thermonuclear outburst. The outburst of V1016 Cyg led to a nebular spectrum, where the high temperature outbursting star acted as radiative ionization source for the surrounding nebula. The evolution of radiation temperature and luminosity of the outbursting star was studied by Mürset & Nussbaumer (1994). They showed that V1016 Cyg reached the maximum temperature 150 000 K in 1984. This is in agreement with the behaviour of the $U-B$ index (see Fig. 5), mainly controlled by the change of the temperature of the hot component. The evolutionary track of V1016 Cyg in two colour diagram after the outburst in 1964 (see Fig. 6) is the result of the time-dependent variations in the light contributions from the hot component as well as recombination radiation and emission line spectrum of the nebula. The outbursting white dwarf mimicked a B6 supergiant around the maximum of brightness of the nova in the B and V bands in 1971.

If we interpret the 5500-day periodicity of activity as an orbital period, we can explain the brightness increases (flares) by the enhanced mass transfer at the periastron of the eccentric orbit, which can also trigger the main outburst in the system. It is of interest to note that the brightness maxima in 1980 and 1994 occurred after the well detected brightness decreases in 1976 and 1992 as possible signatures of an enhanced mass transfer from the cool to the hot component. A similar effect was detected in a very slow classical nova V723 Cas (Chochol & Pribulla, 1998). The long-term infrared photometry performed by Taranova & Schenavrin (2000) clearly shows the increase of J and H brightness in 1992, suggesting the mass transfer burst in periastron, leading to the flare in 1994.

The wave-like variations on the decline from the main outburst with the amplitude decreasing from U to V (see Fig. 5) can also be influenced by the position of the stars in the orbit as seen from the Earth and the precessing accretion disk around the hot white dwarf formed by the wind from the Mira in V1016 Cyg. The 3D numerical simulation of the wind accretion by a compact companion demonstrated the formation of a dense accretion disk in the orbital plane (Theuns & Jorissen, 1993). Corradi et al. (1999) found evidence of a precessing accretion disk in the similar object HM Sge.

The 15-years orbital period of V1016 Cyg is also supported by variations of the UV emission line fluxes in the spectra taken by the IUE and HST satellites, which exhibit a wave with maximum in 1981 and minimum in 1988 (Parimucha, 2000).

Taranova & Yudin (1986) detected in the IR photometry a dust formation episode in 1983, which occurred after the maximum brightness of the system in the U passband in 1980. The brightness dip is well visible also in the visual data (see Fig. 4). This effect could be caused by the dust formation in the ejecta as in the classical novae (Bode, 1995).

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