

## 59 Cygni — photometric behaviour after the active period

*L. Iliev, B. Kovachev, N. Tomov*

Photometric behaviour of the Be shell star 59 Cyg is considered on the basis of more than 450 individual photoelectric measurements made from 1982 to 1985. Long-term variations in V band and B—V and U—B colour indices are revealed. Axial rotation is discussed as a possible reason for the short-time variations of the 59 Cyg brightness.

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*Address:* Department of Astronomy with National Astronomical Observatory, Bulgarian Academy of Sciences, 72 Lenin Blvd., 1784 Sofia, Bulgaria

### Introduction

The bright star 59 Cyg (HD200120, HR8047, V832 Cyg, MWC359; spectral type B1.5Ve;  $V\sin i=450$  km/s) has been studied spectroscopically relatively well. There are three periods in the history of the star based on observations in the visible region of the spectrum (D o a z a n, 1982):

1. A Be phase of decreasing intensity was observed in 1904, when the star was seen for the first time. A quasi-normal B phase was reached in 1917: the  $H_{\alpha}$  emission line even disappeared.

2. Since 1917 the star underwent gradual development from a quasi-normal B phase to a Be phase. The Balmer line emission increased again, reaching maxima in 1927 and 1936, respectively. This emission was exceedingly strong in the 1946-1948 period. The Paschen line emission was observed at some moments, too. A new development of the Balmer emission began in 1972 followed by a shell phase (D o a z a n et al., 1975). A strong emission phase was observed once more in 1973 followed by a second shell phase (B a r k e r, 1982). The second shell phase was transformed into a Be phase with decreasing intensity and its emission was the weakest in November 1977.

3. A new Be phase with V/R variations of the  $H_{\alpha}$  emission line developed after the end of 1977 (B a r k e r, 1982; D o a z a n, 1982). B a r k e r (1983) observes V/R variations which shows that the period may be either 28 or 14 days.

The ultraviolet spectral region of 59 Cyg has been relatively well studied. The observations of this spectral region were initiated in 1972 by means of the Copernicus and IUE satellites. Strong variability in the NV and CIV lines have been obser-

ved since 1978, interpreted as variability in the mass flux from the star (D o a z a n, 1980a, b; 1982). Strong changes in the ultraviolet spectrum were detected on the time scale of months, but they could be seen on the time scale of days, as well.

There has not been a detailed photometric study of the star 59 Cyg up to now. In this communication the photometric behaviour of the star is considered during the period of developing a Be phase on the basis of observations carried out at the National Astronomical Observatory from 1982 to 1985.

## Observations

The star 59 Cyg was included in the Be stars observational programme realized at the NAO. More than 450 photometric measurements have been made on 19 nights over the 1982-1985 period. The observations were performed by the photoelectric photometer attached to the 60 cm Cassegrain telescope of the National Astronomical Observatory, employing a photon-counting technique (P a n o v et al., 1982). All observations were in the three-colour UBV system. The star HD198639 was used for comparison and was checked out by means of HD199311 and HD199479 (Table 1). During the observations the comparison star has not exhibited changes greater than  $0^m,008$  in the V,  $0^m,004$  in the (B-V) and  $0^m,008$  in the (U-B). The observational time intervals on the different nights were up to  $5^h,5$ . The best time resolution was between 2 and 3 minutes. The observational data corrected for atmospheric extinction and transformed into a standard system are listed in Table 2.

Table 1

Star	V	B-V	U-B
HD 198639	$5^m,06$	$+0^m,20$	$+0^m,12$
HD 199311	6,68	$+0,05$	—
HD 199479	6,80	$-0,04$	—

## Results

The analysis of our observational data shows remarkable long-term variations in the brightness and colours of 59 Cyg. This is in good agreement with the conclusion of H a r m a n e c et al. (1979), that long-term brightness variations of Be stars have a larger amplitude than middle and short-term ones. Our observations reveal that the brightness of the star in V band has increased by about  $0^m,2$ . B-V and U-B colour indices have also increased in average with  $0^m,1$  over the period of observations (Fig. 1).

It can be seen that there is a tendency towards variability in the brightness and colour indices of 59 Cyg during the observations in the course of some nights. The amplitude of these variations is largest in JD2445950 and reaches  $0^m,075$  in the V band (Fig. 2). The variations are in the time-scale from 7 to 12 hours. No periodicity was found by Deeming's method (D e e m i n g, 1975, 1978). A variability in a same time-scale was observed by T a r a s o v and S h t e r b a k o v (1983). They have found a period equal to 380 min for the V/R variations of the  $H_\alpha$  emission line. Giving the rapid rotation of the star:  $V \sin i = 450 \text{ km.s}^{-1}$  (B o y-

Table 2

JD <sub>hel</sub> 2440000+	V	B-V	U-B	JD <sub>hel</sub>	V	B-V	U-B
1	2	3	4	1	2	3	4
5241,2749	5 <sup>m</sup> 006	-0 <sup>m</sup> 211	-0 <sup>m</sup> 818	5538,4520	4 <sup>m</sup> 928	-0 <sup>m</sup> 097	-0 <sup>m</sup> 779
,2923	,008	,214	,812	,4546	,944	,106	,774
,3256	,016	,214	,822	,4570	,933	,106	,774
,3513	,013	,216	,818	,4597	,948	,106	,775
,3756	,005	,211	,802	,4626	,935	,108	,770
,4090	,006	,202	,828	,4660	,947	,112	,774
5536,3717	4,960	,112	,813	,4692	,947	,110	,776
,3873	,951	,116	,808	,4724	,931	,103	,768
,3898	,957	,098	,802	,4937	,945	,114	,777
,3932	,947	,111	,806	,5007	,946	,117	,773
,3965	,950	,106	,810	,5055	,929	,101	,770
,4047	,949	,110	,811	,5102	,932	,102	,763
,4101	,944	,111	,801	,5158	,933	,097	,763
,4226	,958	,103	,817	,5211	,940	,110	,764
,4269	,941	,104	,800	,5279	,952	,113	,779
,4290	,938	,111	,807	,5398	,948	,119	,770
,4339	,943	,110	,805	,5371	,950	,108	,764
,4363	,943	,105	,815	,5424	,950	,122	,762
,4388	,939	,113	,798	,5500	,959	,115	,764
,4466	,941	,113	,801	,5537	,950	,111	,767
,4491	,942	,105	,806	,5564	,953	,111	,782
,4516	,940	,109	,802	,5596	,949	,097	,766
,4538	,948	,119	,809	5540,3718	,950	,112	,810
,4600	,933	,103	,813	,3777	,933	,097	,806
,4627	,950	,119	,798	,3818	,936	,107	,800
,4651	,942	,110	,807	,3906	,940	,100	,805
,4679	,931	,108	,805	,3969	,936	,107	,817
,4703	,948	,116	,802	,4009	,934	,112	,817
,4741	,943	,108	,802	,4118	,928	,102	,818
,4766	,949	,104	,797	,4154	,946	,119	,806
,4790	,931	,102	,801	,4186	,941	,108	,798
,4845	,927	,116	,797	,5102	,943	,102	,794
,4867	,942	,101	,806	,5138	,954	,096	,796
,4895	,940	,113	,793	,5196	,935	,102	,799
,4923	,946	,110	,802	,5228	,945	,105	,796
,4971	,925	,103	,806	,5259	,945	,098	,800
,4999	,946	,107	,798	,5290	,937	,107	,794
5538,3706	,938	,102	,794	,5318	,932	,104	,798
,3802	,937	,107	,788	,5348	,950	,121	,789
,3872	,928	,100	,787	,5376	,942	,104	,792
,3903	,930	,111	,781	,5406	,950	,121	,797
,3931	,933	,084	,786	,5435	,933	,101	,798
,3986	,930	,103	,774	,5462	,953	,106	,791
,4014	,926	,097	,783	,5508	,967	,116	,795
,4035	,943	,115	,774	,5543	,942	,118	,799
,4063	,936	,104	,774	,5579	,946	,105	,819
,4090	,936	,102	,787	,5599	,953	,107	,812
,4111	,941	,108	,784	,5624	,945	,124	,806
,4153	,941	,118	,770	,5651	,952	,097	,923
,4181	,941	,108	,776	,5680	,937	,120	,798
,4290	,938	,118	,777	,5704	,938	,104	,816
,4317	,922	,096	,774	,5731	,932	,128	,812
,4348	,946	,110	,777	,5784	,934	,121	,821
,4371	,941	,114	,769	,5810	,935	,113	,820
,4395	,940	,096	,779	5839,5499	,859	,096	,765
,4422	,929	,098	,775	,5555	,843	,095	,763
,4444	,940	,106	,784	,5582	,839	,094	,771

Table 2 (continued)

1	2	3	4	1	2	3	4
5839,5617	4 <sup>m</sup> 846	-0 <sup>m</sup> 100	-0 <sup>m</sup> 764	5857,5263	4 <sup>m</sup> 840	-0 <sup>m</sup> 044	-0 <sup>m</sup> 700
,5645	,842	,100	,773	,5277	,833	,025	,704
,5673	,837	,091	,768	,5297	,832	,032	,704
,5707	,827	,105	,773	,5318	,826	,022	,709
,5749	,833	,097	,779	,5339	,834	,018	,706
,5777	,829	,105	,777	5879,4496	,823	,036	,707
,5805	,819	,090	,779	,4530	,826	,046	,715
5840,5356	,836	,089	,743	,4551	,820	,053	,709
,5411	,846	,076	,756	,4579	,822	,062	,714
,5446	,844	,094	,743	,4628	,823	,053	,718
,5474	,838	,087	,755	,4954	,829	,053	,750
,5509	,849	,099	,763	,4975	,838	,047	,744
,5543	,841	,099	,767	,5025	,843	,056	,734
,5592	,843	,093	,776	,5122	,850	,060	,733
,5627	,840	,087	,762	,5143	,846	,058	,721
,5654	,854	,098	,774	,5164	,844	,071	,725
,5682	,852	,092	,777	,5178	,843	,052	,725
,5731	,845	,092	,764	,5213	,824	,052	,729
,5759	,837	,082	,779	,5233	,842	,053	,737
5845,5516	,845	,053	,708	,5254	,826	,051	,724
,5544	,848	,055	,718	,5268	,840	,054	,735
,5565	,844	,058	,710	,5289	,842	,066	,740
,5585	,841	,053	,716	,5310	,850	,045	,723
,5613	,842	,051	,716	5947,3365	,832	,073	,738
,5683	,850	,072	,706	,3413	,821	,068	,751
,5704	,842	,064	,714	,3448	,845	,075	,734
,5717	,844	,052	,713	,3476	,834	,074	,757
5846,5287	,838	,050	,708	,3510	,835	,065	,749
,5308	,843	,045	,717	,3615	,842	,062	,755
,5336	,839	,054	,719	,3649	,843	,073	,749
,5357	,850	,057	,720	,3677	,814	,058	,749
,5384	,840	,060	,708	,3705	,836	,075	,744
,5405	,844	,047	,714	,3733	,831	,068	,749
,5440	,841	,051	,720	,3760	,850	,072	,738
,5461	,834	,046	,720	,3788	,844	,070	,756
,5482	,832	,049	,728	,3899	,822	,082	,747
,5495	,839	,064	,717	,3927	,851	,068	,755
,5516	,832	,049	,718	,3955	,826	,067	,749
,5544	,842	,050	,725	,3983	,833	,074	,755
,5565	,837	,054	,719	,4010	,834	,070	,746
,5586	,838	,059	,734	,4045	,841	,062	,756
,5648	,830	,063	,724	,4121	,838	,076	,747
,5669	,829	,058	,725	,4156	,839	,071	,759
,5690	,842	,064	,733	,4267	,840	,065	,756
5857,4883	,831	,023	,701	,4295	,826	,077	,761
,4903	,840	,024	,694	,4323	,827	,067	,756
,4938	,842	,021	,694	,4358	,849	,070	,758
,4952	,836	,026	,700	,4385	,828	,071	,754
,4971	,845	,035	,701	,4420	,844	,077	,770
,4992	,836	,029	,698	,4448	,845	,080	,765
,5013	,836	,025	,708	,4483	,829	,076	,768
,5034	,843	,032	,694	,4510	,837	,074	,761
,5054	,838	,030	,698	,4538	,827	,083	,757
,5068	,832	,012	,705	5949,2868	,833	,095	,777
,5089	,841	,030	,698	,2923	,828	,088	,776
,5110	,829	,027	,704	,2958	,816	,093	,766
,5124	,822	,018	,697	,2986	,809	,086	,775
,5145	,833	,029	,707	,3014	,826	,096	,770
,5165	,838	,019	,706	,3069	,825	,084	,766
,5221	,837	,033	,698	,3152	,822	,094	,771
,5242	,829	,014	,704	,3180	,824	,103	,769



Table 2 (continued)

1	2	3	4	1	2	3	4
5949,3215	4 <sup>m</sup> 820	-0 <sup>m</sup> 093	-0 <sup>m</sup> 775	5950,4686	4 <sup>m</sup> 813	-0 <sup>m</sup> 108	-0 <sup>m</sup> 796
,3236	,822	,092	,773	,4714	,821	,101	,804
,3291	,819	,098	,767	,4770	,805	,083	,794
,3389	,813	,088	,777	,4881	,813	,100	,788
,3416	,818	,092	,787	,4909	,810	,091	,797
,3444	,823	,099	,787	,4943	,816	,100	,799
,3472	,820	,088	,777	,4974	,815	,116	,794
,3500	,820	,093	,781	,5002	,798	,107	,801
,3548	,818	,090	,776	,5057	,806	,106	,792
,3645	,823	,088	,782	,5182	,796	,097	,801
,3673	,815	,102	,777	,5217	,801	,092	,812
,3701	,826	,097	,783	,5252	,819	,116	,791
,3743	,815	,095	,783	,5293	,806	,118	,807
,3764	,819	,095	,786	,5342	,799	,104	,812
,3798	,825	,095	,787	,5474	,798	,100	,817
,3854	,818	,090	,784	,5516	,781	,092	,822
,4000	,808	,104	,787	,5543	,788	,079	,829
,4027	,828	,105	,789	,5578	,796	,093	,808
,4055	,816	,103	,794	,5634	,799	,107	,808
,4104	,815	,097	,782	5951,3036	,820	,088	,783
,4166	,819	,105	,787	,3113	,820	,820	,775
,4333	,817	,102	,771	,3141	,827	,092	,773
,4361	,811	,087	,788	,3168	,834	,101	,774
,4395	,815	,097	,780	,3196	,824	,090	,778
,4423	,821	,094	,781	,3245	,842	,083	,780
,4458	,804	,097	,771	,3314	,827	,086	,784
,4520	,811	,102	,776	,3342	,838	,102	,775
,4632	,814	,105	,787	,3363	,815	,095	,780
,4666	,819	,095	,796	,3391	,829	,105	,782
,4694	,811	,095	,793	,3418	,834	,094	,790
,4729	,815	,097	,791	,3467	,819	,096	,775
,4764	,804	,089	,796	3564	,819	,107	,784
,4791	,812	,097	,788	,3592	,820	,102	,794
,4819	,812	,099	,796	,3620	,826	,098	,789
5950,3395	,852	,100	,785	,3641	,811	,096	,792
,3492	,845	,098	,785	,3668	,824	,096	,791
,3520	,844	,097	,783	,3724	,823	,099	,780
,3548	,864	,098	,782	,3807	,834	,089	,789
,3575	,847	,093	,784	,3835	,824	,094	,782
,3631	,862	,098	,784	,3863	,826	,097	,795
,3700	,858	,116	,779	,3891	,820	,089	,782
,3728	,842	,101	,796	,3918	,825	,103	,782
,3763	,841	,101	,791	,3946	,823	,102	,790
,3791	,844	,114	,776	,4002	,812	,094	,789
,3853	,851	,096	,776	,4099	,818	,090	,779
,3936	,845	,106	,785	,4127	,815	,103	,781
,3964	,834	,112	,778	,4154	,826	,103	,781
,3992	,845	,103	,783	,4182	,816	,092	,792
,4027	,827	,105	,772	,4210	,805	,099	,787
,4055	,824	,085	,795	,4238	,834	,106	,782
,4110	,842	,103	,786	,4293	,814	,086	,787
,4242	,829	,096	,780	,4404	,820	,103	,789
,4277	,820	,099	,785	,4432	,804	,088	,786
,4305	,827	,099	,790	,4460	,817	,097	,784
,4332	,829	,119	,782	,4481	,816	,101	,785
,4360	,829	,093	,791	,4509	,817	,098	,793
,4423	,819	,092	,788	,4536	,823	,102	,803
,4561	,816	,102	,782	,4564	,806	,094	,784
,4589	,816	,102	,790	,4592	,816	,098	,792
,4617	,811	,110	,792	,4647	,816	,096	,790
,4652	,828	,108	,791	,4786	,814	,104	,791

Table 2 (continued)

1	2	3	4	1	2	3	4
5951,4814	4 <sup>m</sup> 822	-0 <sup>m</sup> 098	-0 <sup>m</sup> 805	6224,5128	4 <sup>m</sup> 804	-0 <sup>m</sup> 085	-0 <sup>m</sup> ,747
,4842	,806	,099	,789	,5145	,813	,081	,749
,4877	,814	,100	,802	,5166	,803	,085	,748
,4904	,815	,108	,801	,5183	,804	,086	,746
,4932	,830	,114	,788	,5208	,820	,084	,748
,4994	,811	,112	,781	,5225	,806	,088	,749
,5125	,815	,098	,800	,5243	,801	,075	,754
,5153	,798	,098	,789	,5260	,808	,079	,743
,5195	,810	,094	,795	,5277	,800	,066	,739
,5223	,807	,095	,797	,5302	,816	,097	,740
,5250	,821	,125	,797	,5329	,807	,075	,748
,5278	,820	,124	,804	,5347	,801	,076	,745
,5334	,806	,116	,797	,5367	,807	,076	,749
5959,2990	,832	,091	,770	,5381	,813	,076	,746
,3074	,842	,084	,782	,5409	,808	,083	,746
,3103	,839	,068	,789	,5433	,806	,071	,746
,3135	,828	,100	,765	,5451	,804	,079	,739
,3165	,835	,096	,776	,5468	,812	,090	,740
,3194	,839	,112	,762	,5489	,808	,076	,744
,3226	,835	,117	,785	6243,5143	,802	,092	,736
,3288	,834	,088	,768	,5209	,808	,090	,738
,3389	,830	,108	,773	,5244	,810	,085	,740
,3418	,822	,089	,773	,5275	,803	,079	,736
,3444	,836	,101	,782	,5310	,805	,073	,744
,3473	,827	,108	,768	,5348	,810	,097	,735
,3501	,824	,097	,768	,5375	,808	,086	,738
,3553	,830	,096	,767	,5407	,814	,088	,739
,3648	,829	,115	,768	,5441	,813	,089	,739
,3675	,825	,088	,783	6274,4919	,813	,097	,757
,3704	,826	,107	,772	,4967	,819	,088	,754
,3732	,818	,093	,774	,5030	,820	,081	,763
,3799	,822	,085	,777	,5075	,818	,083	,759
,3869	,821	,121	,771	,5120	,821	,102	,762
,3910	,821	,114	,777	,5165	,822	,109	,764
,3937	,819	,097	,775	,5242	,822	,096	,766
,3965	,823	,110	,774	,5294	,817	,085	,763
,4019	,813	,088	,783	,5349	,821	,091	,767
,4197	,817	,106	,778	,5422	,824	,110	,757
,4224	,822	,099	,799	6277,4177	,814	,067	,746
,4250	,818	,108	,775	,4204	,804	,062	,746
,4276	,821	,127	,784	,4222	,809	,078	,728
,4305	,821	,124	,788	,4239	,805	,064	,736
,4332	,822	,103	,787	,4267	,833	,062	,739
,4385	,815	,094	,792	,4309	,808	,056	,725
,4492	,813	,111	,775	,4326	,803	,064	,736
,4523	,823	,095	,783	,4343	,813	,053	,734
,4552	,815	,120	,766	,4371	,796	,070	,776

archuk and Kopilov, 1964) and assuming that  $R = 5,6R_{\odot}$  in stars of spectral type B1.5V (Allen, 1977), with  $\sin i \cong 1$ , we can explain the semiregular variations on the indicated time-scale with the appearance of active formations in the external layers of the stellar atmosphere. These formations can have a lifetime not greater than 1 to 3 cycles of star rotation.

There is a noticeable scattering of the points in the brightness and colour indices throughout the observations. This scattering is greater than the error of a single measurement and reaches  $0^m,03-0^m,04$ . We suppose that this is due to the variability on the time-scale from 10 to 20 minutes.

The solving of the problem of periodicity in long-term light and colour index variations, as well as the character of average and short-term variations requires new photometrical observations of 59 Cyg.

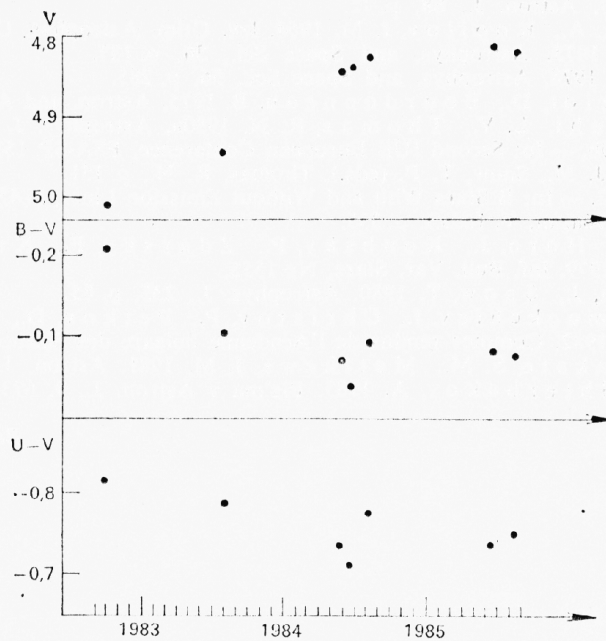


Fig. 1. V band magnitude and B—V and U—B colour indices averaged over months during the period of observations

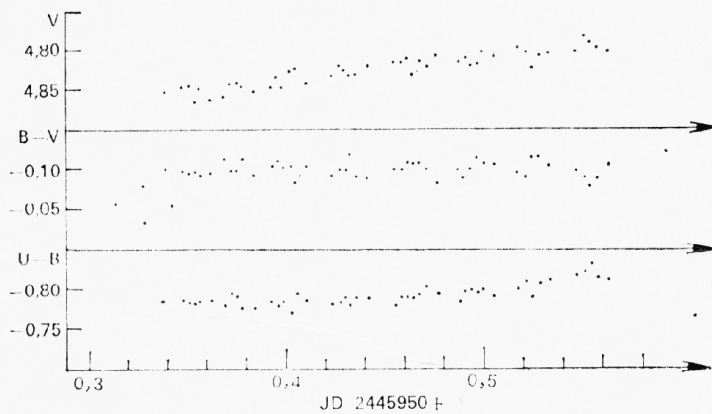


Fig. 2. Variations of the brightness in V band and colour indices in a single night

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