Baltic Astronomy, vol. 15, 199–205, 2006.

PHOTOMETRIC PERIOD VARIATION OF V 1379 AQL

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Received 2005 August 1

Abstract. V 1379 Aql is an eclipsing binary consisting a hot subdwarf (sdB) and a red giant star (K0 III/IV). According to the brightness variation outside of eclipses, the giant component is a chromospherically active star. The dark and cool active structures on this component and their evolution cause the variation of the total light of the system. Photometric observations spanning 16 years yield the variations of the photometric period and the mean brightness. There is a correlation between them. We suggest that the photometric period decreases as the latitude of the active region moves toward the equator.

Key words: stars: hot subdwarfs – stars: variables – stars: individual (V 1379 Aql)

1. INTRODUCTION

V 1379 Aql is a binary system composed of a red giant star (K0 III/IV) and a hot subdwarf star (sdB). The first indication of chromospheric activity on the giant star came from the detection of Ca II H&K emission by Bidelman & MacConnell (1973). Photometric variations with an amplitude of about $0\overset{m}{.}2$ were first observed by Henry et al. (1982). The presence of a hot companion was noticed by Fekel & Simon (1985) in ultraviolet IUE spectra. They suggested that the hot companion was a B subdwarf. Balona et al. (1987) discovered the eclipse of the subdwarf from a variation of about $0\overset{m}{.}12$ of the color index U–B. The system is asynchronous, the rotational period of 25.4 days found by Balona et al. (1987) and Lloyd et al. (1987) being longer than the orbital period of 20.7 days determined from radial velocity measurements by Balona (1987) and Fekel et al. (1993). Jeffery et al. (1992) determined the mass ratio from UV radial velocity measurements which, together with a light curve analysis, gave the masses. Hooten & Hall (1990) determined a photometric period of about 26 days with an amplitude of $0\overset{m}{.}20 - 0\overset{m}{.}25$ in the V passband. Fekel et al. (1993) improved the orbital elements and the spectroscopic ephemeris from a new radial velocity curve. Jeffery & Simon (1997) analyzed the UV eclipse. They defined the eclipse duration and the light curve profile. UBV photometry and Hα spectroscopy of the system in 1995 was presented and discussed by Frasca et al. (1998).

Starspots in a photosphere induce quasi-periodic brightness variations due to the star's axial rotation. Therefore, the modulation period marks the angular velocity of the mean latitude at which they are centered. By analogy with the solar case, the year-to-year variations of the rotational period can be attributed to the migration of stellar activity centers towards latitudes possessing different

Table 1. The subsets of V photometry of V 1379 Aql.

Datasets	Mean epoch	Time range	N_{obs}	Source
88A	1988.48	47276–47329	60	1
88B	1988.86	47415–47483	41	1
89A	1989.44	47615–47702	100	1
89B	1989.88	47779–47853	37	1
90A	1990.47	47987–48067	42	1
90B	1990.93	48185–48212	12	1
91A	1991.46	48354–48428	32	1
92A	1992.46	48702–48809	31	1
92B	1992.88	48874–48957	42	1
93A	1993.47	49081–49165	58	1
93B	1993.88	49236–49322	29	1
94A	1994.45	49428–49545	59	1
94B	1994.93	49643–49688	22	1
95A	1995.46	49791–49909	72	1
95B	1995.90	49982–50053	47	1
96A	1996.44	50160–50261	57	1
96B	1996.96	50392–50421	16	1
97A	1997.44	50515–50642	61	1
97B	1997.89	50713–50777	31	1
98A	1998.41	50881–50992	53	1
98B	1998.91	51089–51148	33	1
99A	1999.44	51257–51353	56	1
99B	1999.90	51447–51510	51	1
00A	2000.42	51615–51712	50	1
00B	2000.89	51805–51873	23	1
01A	2001.44	51979–52092	44	1
01B	2001.90	52181–52229	11	1
02A	2002.47	52354–52459	54	1
02B	2002.89	52535–52603	38	1-2
03A	2003.65	52809–52914	32	2
04A	2004.64	53177–53264	28	2

1. Henry (2002) **2.** This study

angular velocity. The long-term photometric monitoring of active stars provides a powerful tool to derive relevant parameters of stellar surface activity (Rodono et al. 2000; Messina & Guinan 2003). In this paper we investigate the presence of the photometric period variation and its connection with the mean brightness variation. The analysis of extended time-series of broad-band photometric observations of V 1379 Aql showed the existence of periodic variations of the seasonal mean brightness level and periodic variations of its photometric period. The second section of this paper contains B and V photometry obtained between 1998 and 2004 and the variations which appeared in the light (V) and color (B–V) curves. In the third section we present the seasonal rotational periods obtained by means of a periodogram analysis. The existence of the photometric period variation is discussed in Section 4.

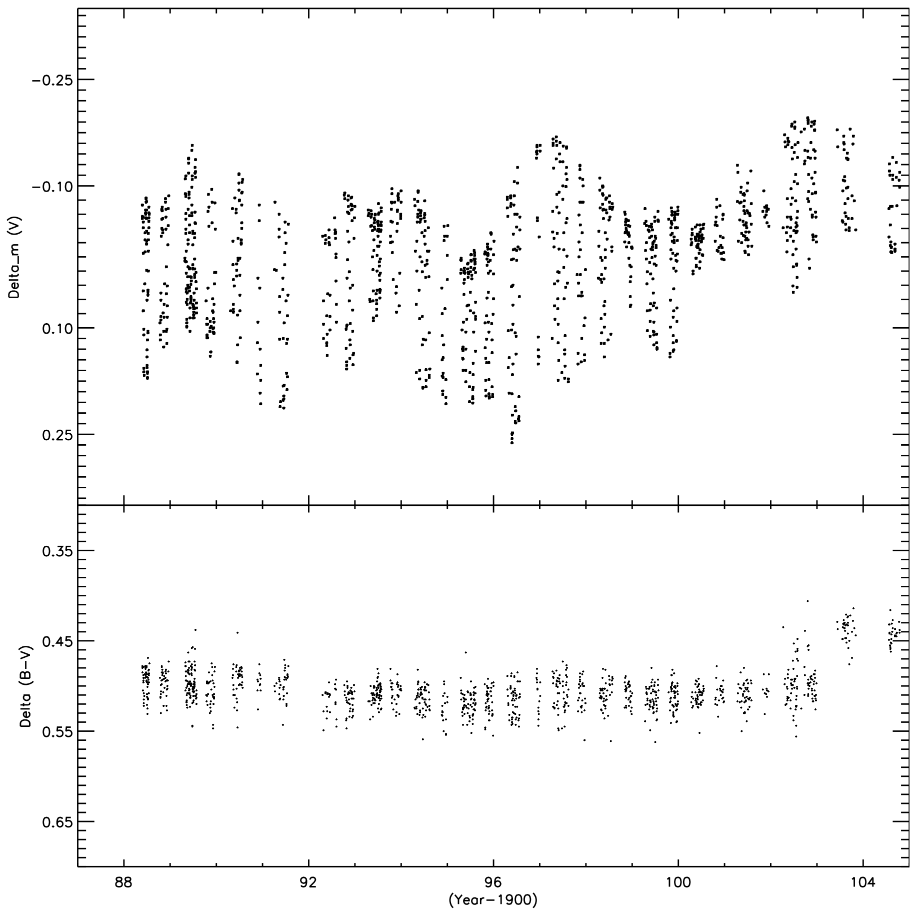

Fig. 1. The light (V) and color (B–V) variations of V 1379 Aql plotted against years.

2. OBSERVATIONS AND THE LIGHT CURVES

The observations of V 1379 Aql were obtained with two telescopes at two observatories. The differential BV photometry of the system was carried out between 1988 and 2002 with the Vanderbilt-Tennessee State 40 cm Automated Photoelectric Telescope (APT) and between 2002 and 2004 with the 48 cm Cassegrain telescope at Ege University Observatory. HD 185567 and HD 185587 were used as comparison and check stars, respectively. The comparison and check stars were found to be constant in brightness during the period of observations. All the differential magnitudes were corrected for the atmospheric extinction. Each observation was a mean of four or five measurements. A total of 1338 and 1364 average points in B and V filters, respectively, were obtained during 1307 nights.

Since the mean magnitude and amplitude of the light curve vary with time, B and V data of V 1379 Aql obtained between 1988 and 2004 are separated into 31 subsets. The V-band datasets are listed in Table 1. The columns of Table 1 show

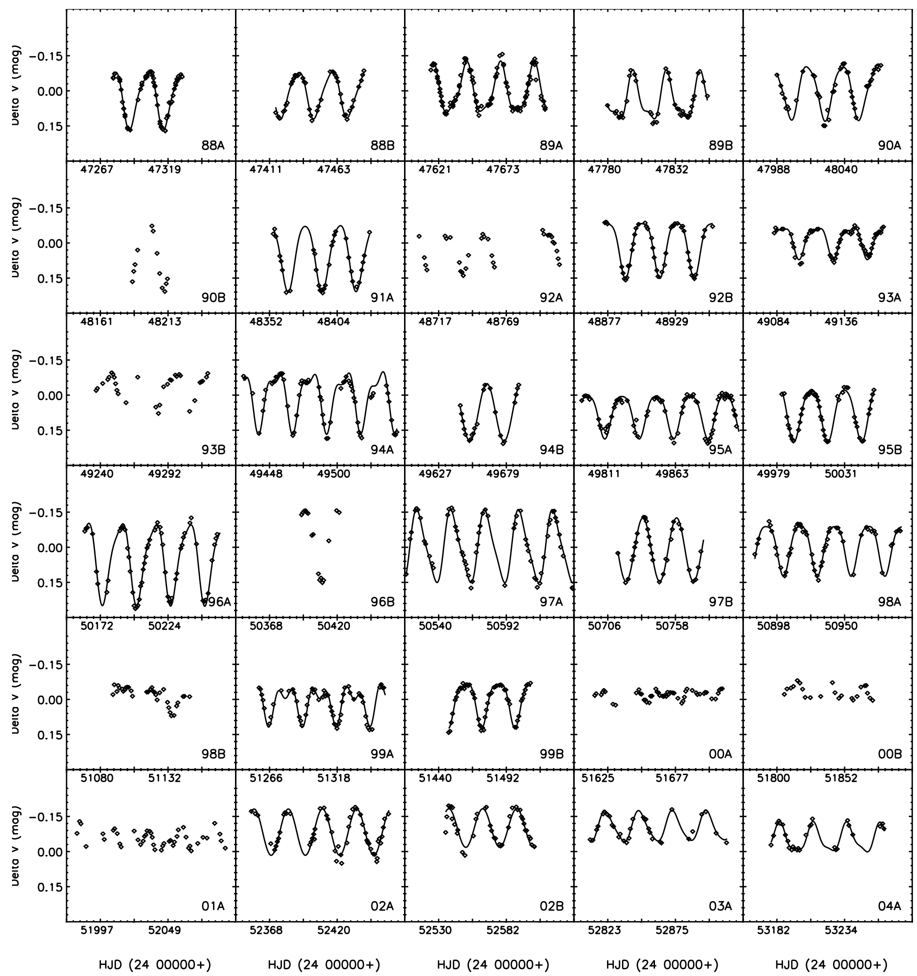

Fig. 2. The V light variation of V 1379 Aql for each year. The synthetic curves calculated by the periodogram analysis are also plotted. The observing seasons are listed in boxes at the top and left of the figure.

the data subsets, the mean epoch, the observing time range (HJD–24 00000) and the number of average observing points in each data subset. B and V photometry of the system obtained in 1988–2004 is shown in Figure 1.

We show the light variation for each observing season in Figure 2. As can be seen, the shape of the light curves is quite different in all observing seasons. The scales of the axes in this figure are the same for each data set. The amplitudes, as well as the minimum and maximum brightness vary during the years depending on the evolution of the activity structures on the cool component. The shape of the light curves is more complex in some years and therefore more difficult to analyze (e.g., 90B), while they have a descriptive shape allowing the period analysis in some observing seasons (e.g., 91A).

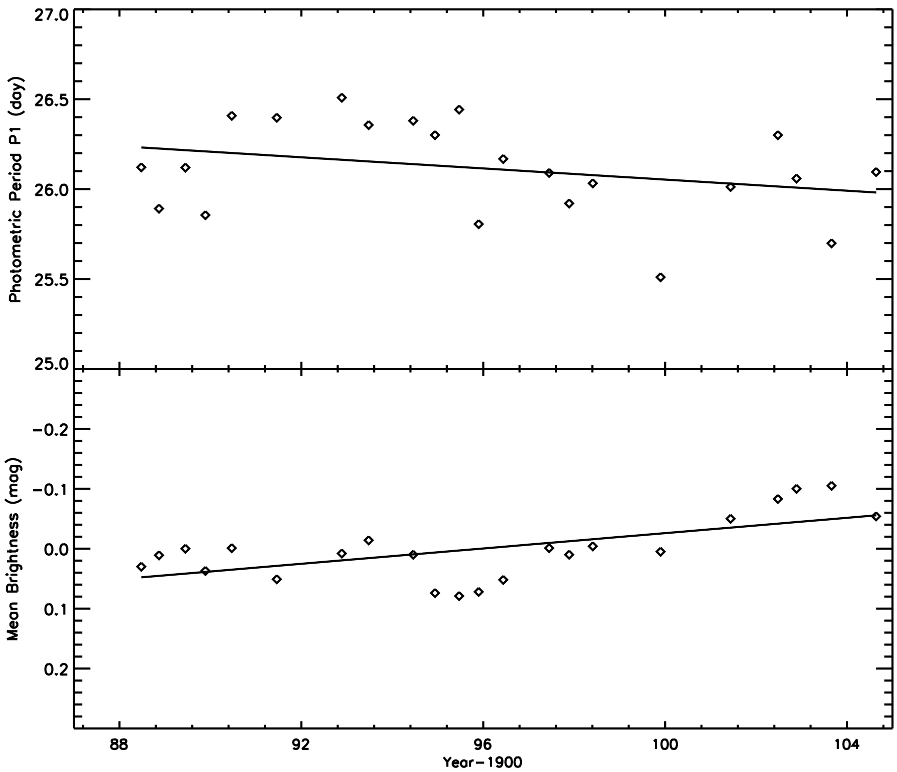

Fig. 3. Variations of the fundamental photometric period (P_1) and the mean brightness.

3. PHOTOMETRIC PERIOD VARIATION

In this study we used a periodogram analysis (Scargle 1982) to look for the period of the photometric rotational modulation and the stellar surface differential rotation. The datasets given in Table 1 have been analyzed by applying the program PERIOD04 (Lenz & Breger 2005). The photometric period, the amplitude and the mean brightness of the light variations are calculated from each dataset. A search for secondary periodicities was also performed by filtering the primary frequency modulation from the data and recomputing the periodogram for the residual data. The periodogram analysis detected the presence of a secondary rotation period in several datasets. The two rotational periods are believed to be due to the presence of two long-lived active regions at different latitudes having different angular velocities due to differential rotation (Messina & Guinan 2003). No periodicity was detected in some sets. The lack of periodicity was presumed to be caused by a rather uniform longitudinal distribution of spot centers that could not produce a rotational modulation.

The results are listed in Table 2. In it we give datasets and the mean epochs (year–1900) to which the photometric periods refer, the photometric periods (P_1, P_2) and their uncertainty, the amplitudes of the sinusoids resulting from the periodogram analysis (A_1, A_2) and the mean brightnesses (ZP) of the light curves. The agreement of the sinusoids obtained from the periodogram analysis with the

Table 2. The results of the photometric period analysis for V datasets.

Data Sets	Mean Epoch	P_1 (day)	σ	P_2 (day)	σ	A_1 (mag)	σ	A_2 (mag)	σ	ZP (mag)	σ
88A	1988.48	26.1214	0.0002	26.1293	0.0007	0.236	0.002	0.052	0.002	0.030	0.002
88B	1988.87	25.8916	0.0002	25.0722	0.0011	0.195	0.002	0.031	0.002	0.011	0.001
89A	1989.45	26.1197	0.0001	25.6051	0.0005	0.204	0.003	0.053	0.002	0.000	0.002
89B	1989.89	25.8555	0.0002	25.7881	0.0006	0.187	0.003	0.071	0.003	0.037	0.002
90A	1990.47	26.4082	0.0002			0.227	0.004			-0.001	0.003
90B	1990.93										
91A	1991.46	26.3973	0.0001	25.5825	0.0014	0.281	0.004	0.036	0.003	0.051	0.003
92A	1992.46										
92B	1992.89	26.5087	0.0001	26.2948	0.0004	0.233	0.002	0.053	0.002	0.008	0.001
93A	1993.48	26.3565	0.0002	26.1758	0.0006	0.126	0.002	0.045	0.002	-0.014	0.002
93B	1993.89										
94A	1994.46	26.3804	0.0002	26.0821	0.0004	0.223	0.004	0.096	0.004	0.010	0.003
94B	1994.94	26.3007	0.0003			0.246	0.003			0.074	0.002
95A	1995.47	26.4427	0.0001	26.4814	0.0006	0.182	0.002	0.036	0.003	0.079	0.002
95B	1995.90	25.8054	0.0001	26.5692	0.0009	0.223	0.002	0.037	0.002	0.072	0.001
96A	1996.44	26.1680	0.0001	26.2992	0.0005	0.332	0.003	0.076	0.003	0.052	0.002
96B	1996.96										
97A	1997.45	26.0902	0.0000	26.0591	0.0004	0.292	0.003	0.060	0.003	-0.001	0.002
97B	1997.89	25.9204	0.0002			0.271	0.003			0.010	0.002
98A	1998.41	26.0323	0.0001	25.9106	0.0006	0.212	0.002	0.043	0.002	-0.004	0.002
98B	1998.92										
99A	1999.44										
99B	1999.90	25.5102	0.0002	25.6521	0.0006	0.181	0.002	0.057	0.002	0.005	0.001
00A	2000.43										
00B	2000.90										
01A	2001.44	26.0124	0.0004	26.4932	0.0004	0.065	0.003	0.066	0.003	-0.050	0.002
01B	2001.90										
02A	2002.48	26.3002	0.0002			0.198	0.004			-0.083	0.003
02B	2002.89	26.0589	0.0005			0.165	0.005			-0.100	0.004
03A	2003.66	25.6987	0.0003	26.2197	0.0015	0.126	0.003	0.021	0.003	-0.105	0.002
04A	2004.64	26.0954	0.0003			0.117	0.002			-0.054	0.002

observed data are shown in Figure 2. The connection between the fundamental photometric period (P_1) and the mean brightness is shown in Figure 3. In 1988–2004 the mean brightness of the system increases when the photometric period decreases.

4. RESULTS

Measurements of stellar surface differential rotation are obtained in different ways. One of these is Fourier analysis of broad-band photometric data. In this paper, using 16 years of continuous V-band data of V 1379 Aql, we found a photometric period variation consistent with a solar-type differential rotation. As seen in Fig. 2, the shape of light curve varies for each dataset. The continual redistribution of spots as a result of stellar differential rotation accounts for much of the changing shape and amplitude of the light curve on rotational timescales. The observed asymmetries in the light curve clearly demonstrate that spot groups are present at multiple longitudes. As seen in Fig. 3, the photometric period (P_1) of the system varies between 26.5 and 25.5 days. We suggest that the latitude of spot activity center moves toward the equator, i.e., toward faster rotating latitudes during an activity cycle, producing a decrease in the photometric period. V 1379 Aql displays a solar-like behavior. As the active regions reach the equator, the activity cycle ends. The spots start to decay, and the system becomes brighter. The mean period of the system was reduced by ~ 0.25 d in 16 years, but the mean light brightened by about $0\overset{m}{.}2$ in the same time interval. We consider that the evolution of the active regions affected the variations of the photometric period and the mean brightness. There is an interesting correlation between them. Photometric observations of V 1379 Aql are continuing.

ACKNOWLEDGMENTS. This research was mostly based on observations obtained using the Vanderbilt-Tennessee State Automated Photoelectric Telescope. We would like to thank Dr. G. W. Henry for sending his unpublished photometric data. We are grateful to Dr. S. Jeffery for useful discussions and the referee for comments that improved the paper. One author (E. Sipahi) sends special thanks to Erol Turan for financial support.

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