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PHOTOMETRIC PERIOD VARIATION OF V1379 AQULAE

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Abstract. V1379 Aql is an eclipsing binary consisting an hot subdwarf (sdB) and K0 III/IV giant. The out of eclipse data of the system between 1988 and 2004 show that the giant component is a very active star and the dark and cool activity structures on the stellar surface like starspots dominate the total light of the system. The evalution of the activity structures manifest itself with seasonal light variation. Analysing the seasonal light curves that we separate to sixteen subsets, we found that the photometric period vary between $25^d.5$ to $26^d.5$. and we compared the photometric period variation with the mean brightness variation. We found that the photometric period of the system decrease, while the mean brightness increase. We suggest that the system should be at the end of the activity cycle because its photometric period in last years has nearly the same value with equatorial period.

Key words: stars: hot subdwarf, variable: general – stars: individual (V1379 Aql)

1. INTRODUCTION

V1379 Aql is a binary system composed of a red giant star (K0 III) 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 $0^m.2$ 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 the variation of about $0^m.12$ in U-B colour. 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 masses of two stars analysing the eclipse light curve, and refined the effective temperature and gravity of the hot companion and examined its evolutionary status. Hooten & Hall (1990) determined a photometric period about 26 days with a variation amplitude of $0^m.20$-$0^m.25$ in the V band. Robertson & Etzel (1993) obtained contemporaneous photometric and spectroscopic observations of the system in the 1990-93 seasons. Fekel et al. (1993) improved the orbital elements and the spectroscopic ephemeris from a new radial velocity curve. The analysis of the eclipse based on UV observations from IUE published by Jeffery & Simon (1997). UBV photometry and Hα spectroscopy of the system in 1995 presented and discussed by Frasca et al. (1998).

Cool spots are one of the signals of stellar activity. Unfortunately, it is impossible to resolve any stellar surface in enough detail to investigate individual small spots except on the Sun. Photometric observations are not suitable for that purpose. One useful application of photometry, however, is to detect active areas on the stars (Hall, 1991). Generally, to fit the observed light curves of active stars it is sufficent to suppose one or two major spotted areas on the stellar surfaces (Olah et al., 1991). Now, we will try to investigate the nature of these activity centers on the the stellar surface using the photometry of 16 years of the long period RS CVn type binary V1379 Aql, and to explain the long-term and short-term behaviour of the activity structures on the cool giant component of V1379 Aql which has a dominant effect on longer wavelengths. For this purpose, we collected the data from literature and our new observations, and we presented the description of data belongs to the years between 1988 and 2004 in section 2. In section 3, we analysed the light curve using the least squares method and searched the variation of the photometric period for each year. We discused the results in section 4.

2. THE OBSERVATIONS AND THE LIGHT CURVES

The observations of V1379 Aql are obtained with two telescopes at two observatories. The differential BV photometry of the system is 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 a 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 filter, respectively, are obtained during 1307 nights.

Since the mean magnitude and amplitude of the light curve vary with time, B and V data of V1379 Aql obtained between 1988 and 2004 are separated into 31 data sets. The data sets are listed in Table 1. In the columns of Table 1, the first to the last, respectively, are given the mean epoch, the observing time range (HJD-24 00000) and the number of average observing points in each data subset. B and V band photometry of the system obtained in the time interval containing the years of 1988-2004 are shown in Fig.1.

We show the light variation for each observing season in Fig. 2. As can be seen from Fig. 2. the shape of the light curves is quite different in all observational seasons. The scale of the axes in these figures are the same for each data set. The amplitudes, 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 are more complex in some years and it makes difficult to analyse, while they have a descriptive shape allowing the period analysis in some observing seasons.

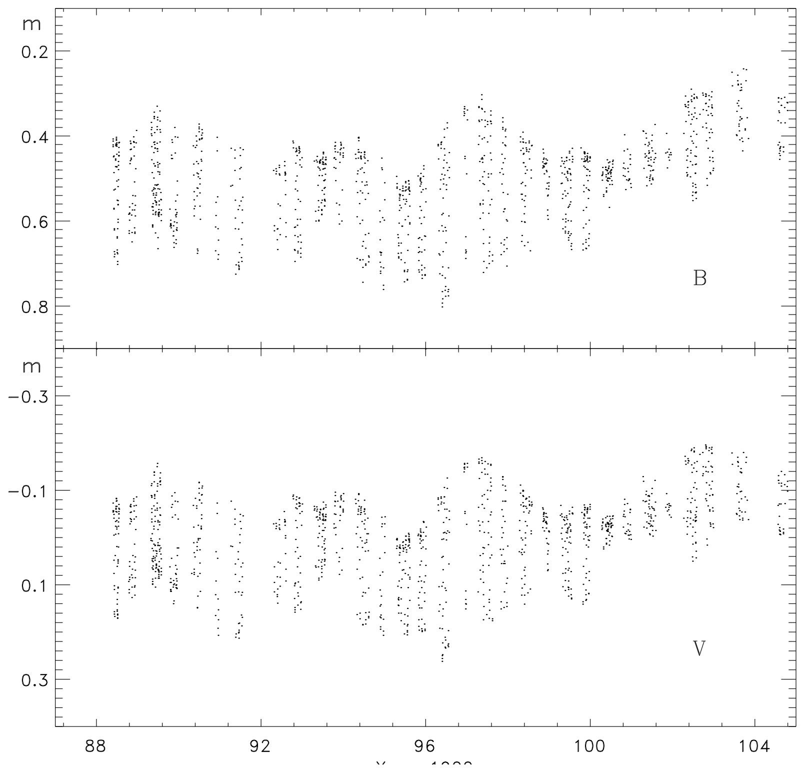

Fig. 1. The long-term light variation in B (top panel) and V (bottom panel) band of V1379 Aql.

3. PHOTOMETRIC PERIOD VARIATION

In this study we used the periodogram analysis (Scargle, 1982) to look for the period of the photometric rotational modulation and the stellar surface differential rotation. The data sets which are given in Table 1 have been analysed applying the PERIOD04 program (Lenz & Breger, 2005). The photometric period, the amplitude and the mean brightness of the light curves are calculated from each data set. Some data sets are represented with two frequencies while no periodicty is detected in some sets. The results are summarized in the Table 2.

In the columns of Table 2 are given, the averaged observing year (Year-1900) of each data set, the photometric periods (P) calculated from each data set, the amplitudes (A) of the light curves and the mean brigthness (ZP) of the light curves are given. The subscripts 1 and 2 show the results of analyse which the light curves are represented by only one and two frequencies, respectively. The agreement of the results of the period analyses with observing points are shown in Fig. 2. The variation of the photometric period and the mean brightness are shown in Fig. 3. The photometric period decrease, while the mean brightness increase from 1988 to 2004.

Table 1. The subsets of the V photometry of V1379 Aql.

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

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

Data Sets	Mean Epoch	P_1	σ	P_2	σ	A_1	σ	A_2	σ	ZP	N_{obs}
88A	88.48	26.12	0.04	26.13	0.08	0.118	0.002	0.026	0.002	0.030	0.002
88B	88.87	25.89	0.04	25.07	0.08	0.098	0.002	0.015	0.002	0.011	0.001
89A	89.45	26.12	0.04	25.61	0.08	0.102	0.003	0.026	0.002	0.000	0.002
89B	89.89	25.86	0.04	25.79	0.08	0.094	0.003	0.035	0.003	0.037	0.002
90A	90.47	26.41	0.04			0.114	0.004			-0.001	0.003
90B	90.93										
91A	91.46	26.40	0.04	25.58	0.08	0.140	0.004	0.018	0.003	0.051	0.003
92A	92.46			25.81	0.08			0.029	0.003	0.022	0.002
92B	92.89	26.51	0.04	26.29	0.08	0.117	0.002	0.027	0.002	0.008	0.001
93A	93.48	26.36	0.04	26.18	0.08	0.063	0.002	0.022	0.002	-0.014	0.002
93B	93.89			25.77	0.08			0.025	0.002	0.028	0.002
94A	94.46	26.38	0.04	26.08	0.08	0.111	0.004	0.048	0.004	0.010	0.003
94B	94.94	26.30	0.04			0.123	0.003			0.074	0.002
95A	95.47	26.44	0.04	26.48	0.08	0.091	0.002	0.018	0.003	0.079	0.002
95B	95.90	25.81	0.04	26.57	0.08	0.111	0.002	0.018	0.002	0.072	0.001
96A	96.44	26.17	0.04	26.30	0.08	0.166	0.003	0.038	0.003	0.052	0.002
96B	96.96										
97A	97.45	26.09	0.04	26.06	0.08	0.146	0.003	0.030	0.003	-0.001	0.002
97B	97.89	25.92	0.04			0.136	0.003			0.010	0.002
98A	98.41	26.03	0.04	25.91	0.08	0.106	0.002	0.022	0.002	-0.004	0.002
98B	98.92										
99A	99.44			26.15	0.08			0.045	0.003	0.012	0.002
99B	99.90	25.51	0.04	25.65	0.08	0.090	0.002	0.028	0.002	0.005	0.001
00A	100.43										
00B	100.90										
01A	101.44										
01B	101.90										
02A	102.48	26.30	0.04			0.099	0.004			-0.083	0.003
02B	102.89	26.06	0.04			0.082	0.005			-0.100	0.004
03A	103.66	25.70	0.04	26.22	0.08	0.063	0.003	0.011	0.003	-0.105	0.002
04A	104.64	26.10	0.04			0.059	0.002			-0.054	0.002

3. RESULTS

Measurements of stellar surface differantial rotation are currently obtained in different ways: from Doppler Imaging maps, by latitude-by-latitude cross-correlation analysis to pairs of surface images obtained several days apart (Vogt & Penrod 1983); from χ^2 landscape imaging methods (Collier Cameron et al. 2002; Donati et al., 2000); from line profile analysis (Reiners & Schmitt 2002); from stellar butterfly diagrams, that is from the season-to-season variations of the rotational period, as measured from spectro-photometric or broad-band photometric observations, correlated with the phase of the stellar activity cycle. By analogy with the solar case, such diagrams are interpretable in terms of migration of activity centers towards latitudes with different angular velocities.

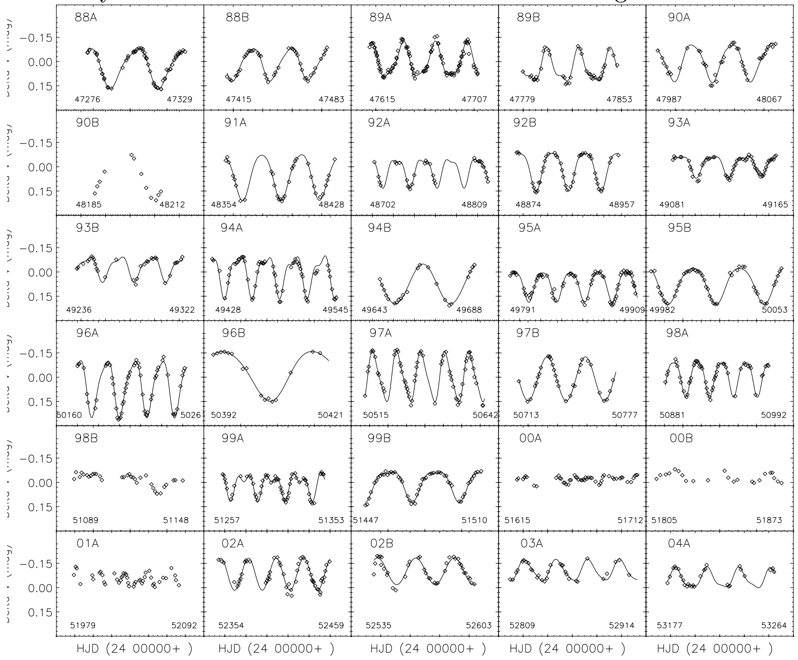

Fig. 2. The V light variation of V1379 Aql for each year. The synthetic curves calculated by the periodogram analysis are plotted, also. The observing seasons are shown with set names at the top and left of each boxes in figure.

In this paper, we present photometric data of V1379 Aql spreading to the interval of 16 years and we show the results of the times series analyse. Fig. 2. shows that the light curve shapes change for each year. The light curves have symmetric or asymmetric shape which refers to one or two activity structures like starspot or spot grouppes, respectively, in some years, but sometimes we can directly see the effect of two spot grouppes in the light curves which have two minima (eg. sets 94A, 99A). When the data are plotted versus the years, it can be seen V1379 Aql has the long term variation, but it is very early to say whether it has the periodicity or not. It is seen from Table 2 that the photometric period vary between $25^d.5$ to $26^d.5$. We compared the photometric period variation with the mean brightness variation in Fig. 3. In this figure it can be seen that the photometric period tends to decrease during 16 years, and at the same time interval the mean brightness increase about $0^m.2$. We suggest that the decreasing photometric period show that the activity structures move toward the equator due to the differential rotation of the stellar surface. V1379 Aql have a rotational period of $25^d.5$ (Balona et al., 1987). Then it should be close to the end of the activity cycle because it has the minimum photometric period values in last years. The slope of the mean brightness variation support this conclusion: the decreasing effect of the cool and dark activity structures on the stellar surface should be caused the increase of the mean brightness.

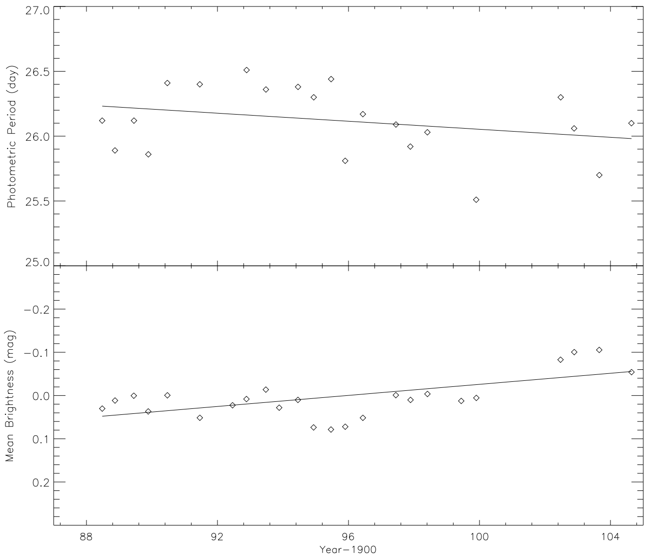

Fig. 3. The variation of the photometric period and the mean brightness.

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