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HOMOGENEOUS SOLUTION FOR SW LACERTAE

Kyungjoo Kim and Young Woon Kang
Daeyang Observatory, Department of Earth Science
Sejong University, Seoul, 133-747, Korea
email: kimkj@astro.sejong.ac.kr, kangyw@astro.sejong.ac.kr

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ABSTRACT

We have analyzed collected photoelectric light curves for light variations of SW Lac. The method of Fourier analysis was adopted to quantify the light variation from season to season. We found the linear relation between the Fourier coefficient, B_1 and the magnitude difference between two maxima. The total light of the system has been decreased as much as $0^m_{\cdot}04$ during approximately 20 years time interval. Photoelectric parameters including spot parameters for all light curves were obtained by the method of the Wilson and Devinney differential correction in order to secure the variations of parameters from season to season. SW Lac, not like RS CVn type stars, required to adjust all parameters as well as spot parameters for a reasonable fit to the observations of each epoch. A surface temperature of cooler star is one of the most sensitive parameters to affect a shape of light curve of SW Lac. We conclude that the shape of light curve of SW Lac varies even during one season as well as season to season. The light curve is mainly caused by inhomogeneous surface temperature due to strong chromospheric activity of the system.

1. INTRODUCTION

W Ursae Majoris type binaries have a long history for observation because of their short orbital period. The accumulated observations of the system have promoted to investigate the characteristics of W UMa system. W UMa type binaries are also well studied in theoretical view, but there are still many questions remained. Until 1970's a research on eclipsing binary stars concentrated to find a solution from the light curve and radial velocity curve. Then a reproduced theoretical light curve with solution is compared with observations. A deviation between model light curve and observation was used to be attributed to an observational error. Recently the observation quality is high enough so that the deviation is interpreted as proximate effects and/or intrinsic variation. It is generally accepted that several systems of W UMa type binaries show asymmetric light curves because of their intrinsic variation and such light curves change with time.

One of the systems is SW Lacerate. It has long been known for the period change and the variations in the shape of its light curve. Since discovery of the variability of SW Lac, numerous observations of this system have been published. Jeong *et al.* (1994) described an observational history of SW Lac in detail. Most investigators reported different shape of light curves and found a solution with different methods.

To define the variations which occur in the light curve, Bookmyer (1965) classified the observational data of 1960 and 1961 into five well-covered light curves. From her result there was no evidence of cycle to cycle variations, but magnitude of the variations between curves of two seasons was $0.^m06$. Bookmyer collected 6 other light curves in addition to her own 5 curves to prove an intrinsic variation.

Rucinski (1968) confirmed that the variations of shape could not be attributed to the differences in photometric systems from the result of his own observations. He noted the maximum following primary minimum was fainter than the maximum following secondary minimum in the 1965 light curve. Leung *et al.* (1984) made light curve in 1978 and found photometric solutions using the Wilson and Devinney model. In contrast with previous light curves, the 1978 light curve shows that the maximum following primary minimum was brighter than the maximum following secondary minimum. Niarchos (1987) calculated the absolute dimensions of SW Lac independently.

Jeong *et al.* (1994) presented observations made in 1988. They noted that one of the most interesting peculiarities of SW Lac was two different maxima shown on its light curve. Thus they classified all light curves into three groups according to the their maxima and designated the light at phase 0.25 as Max I and the light at phase 0.75 as Max II.

Rucinski *et al.* (1984), and Jeong *et al.* (1994) analyzed IUE observations of SW Lac. Jeong *et al.* (1994) analyzed the IUE low dispersion spectra to check the phase dependence of the chromospheric activity. They noted that the chromospheric activity confirmed by the intensity variation of Mg II emission line shown in IUE spectra was correlated with the light curve variation and depended on the orbital phase.

Each investigator found solutions of SW Lac to analyze the light curves with different method. In order to compare solutions reduced from the different shape of light curves, it is necessary to use homogeneous method for finding a solution. The purpose of this work is to analyze all published photoelectric light curves of SW Lac for homogeneous solution. In this paper we collected light curves from literatures. Fourier analysis was applied for light curve variations. Various solution sets have been determined from all collected light curves by the Wilson and Devinney method. Our results have been discussed with previous solutions.

2. COLLECTION OF LIGHT CURVES

The shape of light curve of SW Lac has been reported to be changed every season. We collected a total of 22 light curves (13 of V light curves, 9 of B light curves) observed between 1960 and 1988 to investigate light variations outside eclipse. During 28 years the orbital period of SW Lac has been changed so that the orbital phase of each observation has been calculated with various ephemerises. The information of the collected light curves is listed in Table 1. Fortunately all observations of SW Lac were made employing $BD + 37°4715$ as a comparison star. All light curves were published in the scale of magnitude difference between SW Lac and $BD + 37°4715$.

The magnitude differences of observations were normalized to zero at maximum light (phase 0.75) of 1961 light curve (Curve IV of Bookmyer) by applying appropriate adjustments. Conversions

Table 1. Collected photoelectric light curves of SW Lac.

Year		No. of observations V	B	Reference
1960		815	696	Bookmyer (1965)
1961		816	687	Bookmyer (1965)
1962		314	296	Chou (1963)
1965		248		Rucinski (1968)
1966		167		Rucinski (1968)
1968		116		Semeniuk (1971)
1969		124		Semeniuk (1971)
1977		122	178	Faulkner & Bookmyer (1980)
1978		189	189	Leung *et al.* (1984)
1983	A(Aug.-Sep.)	317	320	Lafta & Grainger (1985)
	B(Sep.-Oct.)	352	352	Niarchos (1987)
1987		81	80	Han *et al.* (1988)
1988		148	149	Jeong *et al.* (1994)

from magnitude difference to intensity were then carried out. The magnitude differences at maximum light in V and B light curves were -0^m514 and -0^m735, respectively. The 1978 light curve of Leung *et al.* (1984) was not normalized because they published light curves in instrumental magnitude scale rather than magnitude difference.

3. VARIATIONS OUTSIDE ECLIPSE

The light variation during the outside-eclipse phases was represented by

$$l = A_0 + A_1 \cos\theta + A_2 \cos 2\theta + B_1 \sin\theta + B_2 \sin 2\theta, \quad (1)$$

where θ is the orbital phase. The phase range of the outside-eclipse for each light curve was determined by calculating the first contact degree using the following equation (Al-Naimy *et al.* 1989),

$$\theta = \sin^{-1}(r_1 + r_2\, cosec^2 i - \cot^2 i)^{1/2} \quad (2)$$

V light curves outside eclipse of SW Lac for 10 epochs are plotted in Figure 1. The values of the Fourier coefficients of equation (1) were determined by the method of least squares. Table 2 lists the values of Fourier coefficients and the magnitude difference of two maxima, Max(II-I), for each light curve. Because all observations employed the same comparison star, the variation of A_0 coefficient represents the variation of total light of SW Lac. As shown in Figure 2, it varies considerably from curve to curve, however the total light of the system has decreased. For the Fourier coefficients, A_1 and A_2 are known for reflection effect, and ellipticity and gravitation effect, respectively. The coefficient A_1 before 1969 shows positive while A_1 after 1969 is negative which agrees reflection theory. Thus we can infer the intrinsic variation of the system affects considerably its light curves

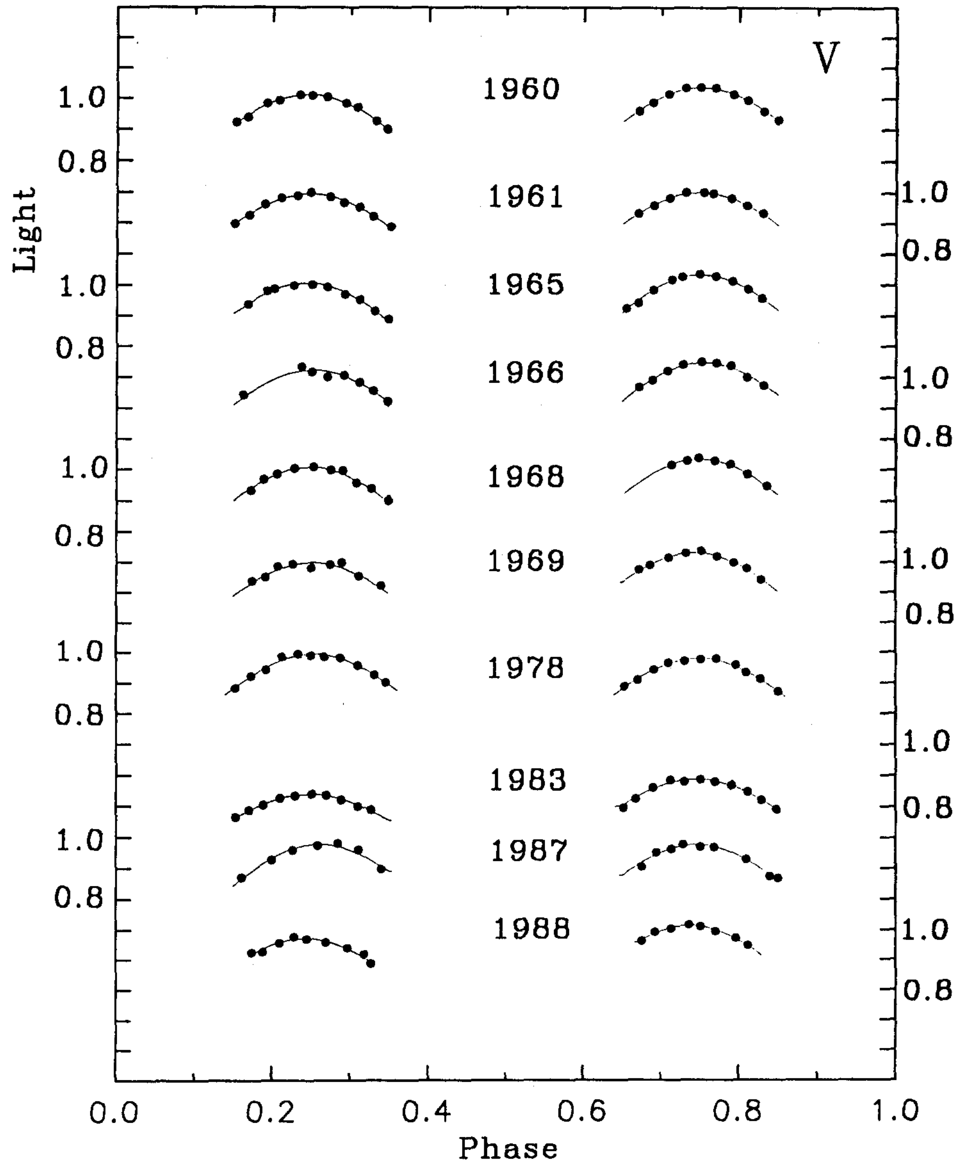

Figure 1. *V* light curves outside eclipse of SW Lac.

Table 2. Yearly variations of Fourier coefficients and Max (II-I).

Year	A_0	A_1	A_2	B_1	B_2	Max(II-I)
1960	0.868086	0.011466	-0.156484	-0.012541	0.004354	-0.04
1961	0.847554	0.003692	-0.150316	-0.003433	0.002932	0.00
1965	0.850673	0.014551	-0.168601	-0.013751	0.005830	-0.04
1966	0.873770	0.005638	-0.161713	-0.012239	-0.006006	-0.03
1968	0.858260	0.003750	-0.163178	-0.013042	0.001459	-0.03
1969	0.856579	-0.015963	-0.158107	-0.015460	0.006759	-0.05
1978	0.834533	-0.007835	-0.151774	0.007303	-0.001443	0.02
1983	0.739043	-0.003475	-0.124386	-0.024151	0.004580	-0.06
1987	0.817619	-0.028909	-0.160998	-0.000165	-0.007212	0.00
1988	0.832686	-0.011803	-0.158627	-0.020111	0.020001	-0.04

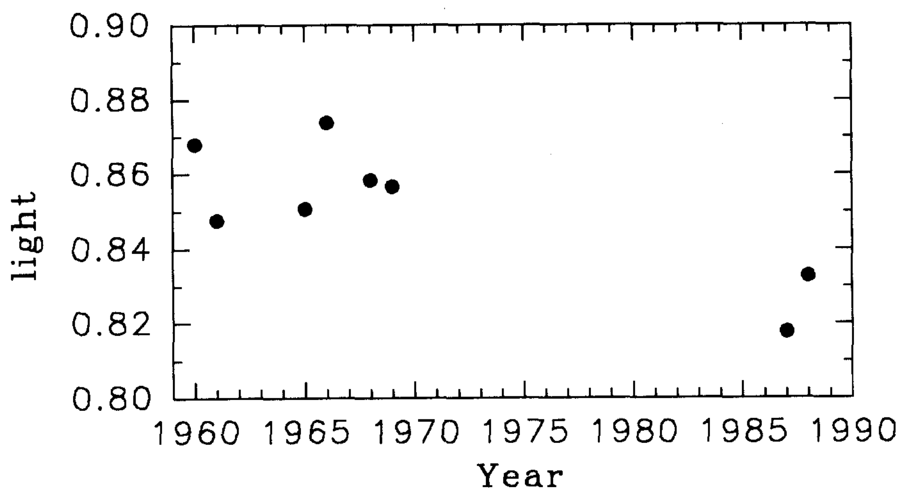

Figure 2. Variation of Fourier coefficient, $A_0(V)$ of SW Lac between 1960 and 1988.

before 1969. The B_1 and B_2 are physically unknown factors, so called intrinsic variations. The coefficient B_1 is as large as A_1 while B_2 is negligible.

4. LIGHT CURVE SOLUTION

The light curve solutions of SW Lac were published by Bookmyer (1965) with Russell & Merill's method, Binnendijk (1984) with his own method, Leung *et al.* (1984) and Jeong *et al.* (1994) with Wilson & Devinney's model, Lafta & Grainger (1985) and Niarchos (1987) with Kopal's method, respectively. Binnendijk (1984) and Eaton (1986) adopted a spot model to fit the asymmetrical light curves. It is not easy to compare the solutions determined by above investigators because they used different methods to find solutions.

In this paper we adopted the method of Wilson & Devinney differential correction to obtain photometric solutions. A total of 8 solution sets for 8 different epochs were derived. The solutions for four epochs were reduced from multi-color light curves. The parameters adjusted are: inclination, temperatures of both stars, albedo, gravitational darkening coefficient, limb darkening coefficient, potential, mass ratio, and spot parameters. We assume that spot activities cause the intrinsic variation because of chromospheric activity of SW Lac. Calculations were made in the WD mode 3 (a contact configuration). A combination of two or three parameters in a subset was adjusted rather than all of parameters together. The quality of a fit was quantified by calculating the sum of the squares of weighted residuals between the observations and computed values $(O - C)$.

First, the parameters were adjusted without spot parameters. Because of asymmetrical light curves we could not reach a perfect fit. Thus the spot parameters were adjusted to fit the asymmetrical light curves. Description of spot model parameters can be found in Kang & Wilson (1989). For the spot parameters, we placed one near equatorial spot on the surface of the cooler component at a longitude estimated by inspection of the distorted light curve. Final photometric solutions are listed in Table 3. The light curves computed using final solutions are plotted with observations in Figure 3.

The orbital inclinations of SW Lac, computed by various investigators, do not coincide each other. Its values are distributed between 76° and 83°. For the 1961 epoch Bookmyer (1965) and Leung *et al.* (1984) found 75.°6 and 79.°3, respectively. Lafta & Grainger (1985) and Niarchos (1987) found 78.°8 and 80.°1 adopting the same method of Kopal for the 1983 epoch, repectively. In this paper, we found the inclination of 79.°8 from the 1966 epoch which shows most reasonable fit. The orbital inclination of 79.°8 has been fixed for other epochs. Previous solutions for SW Lac are listed in Table 4.

Each method is based on different model. For example, the Russell and Merrill's method gives spherical shape and the Wilson and Devinney's gives Roche geometry for star's size. Thus we could compare k, ratio of primary star's radius to secondary's. Bookmyer (1965), Leung *et al.* (1984), and this paper found k as 0.8, 0.94, and 0.95 for the 1961 epoch, respectively. For the 1983 epoch Lafta & Grainger (1985), Niarchos (1987), and this paper found k as 0.97, 0.94, and 0.95. Our k value is relatively constant for all epochs compared to other investigator's.

Temperature of stars could not be compared with results reduced by other methods. The relative V lights, $L_h/(L_h + L_c)$, are computed as 0.43, 0.51, and 0.50 for the 1961 V light curve, respectively, by Bookmyer (1965), Leung *et al.* (1984), and this paper. Lafta & Grainger (1985), and Niarchos (1987) found it as 0.29 for the 1983 V light curve using Kopal's method, while we found it as 0.52.

Considering above three parameters our values are more consistent and reliable compared to the results reduced by other methods.

5. DISCUSSION

The Fourier analysis of 16 light curves in B and V, observed between 1960 and 1988, confirmed previous classification of light curves of SW Lac which consists of 3 different groups. The 1961 and 1987 epochs show symmetric light curves, so called Group 2 defined by Jeong *et al.* (1994). The 1978 light curve belongs to Group 3 while other light curves belong to Group 1. We found the Fourier coefficient, B_1 could be used as an indicator of the light curve shape. The coefficients B_1 for the light curves of Group 1 which has Max II (0.75p) brighter than Max I (0.25p) are negative,

Table 3. Final photometric solutions of SW Lac.

	1960	1961	1965	1966
i		79.77±0.55		
q		1.1245±0.0125		
Pshift	0.9985±0.0003	0.9988±0.0001	0.9980±0.0003	0.0044±0.0002
T_h	5724±0.0009	5592±0.0004	5611±0.0010	5630
T_c	5680±0.0005	5475±0.0004	5578±0.0013	5461±0.0020
x_h=x_c(v)	0.851±0.049	0.700±0.080	0.738±0.088	0.771±0.078
x_h=x_c(b)	0.943±0.044	0.851±0.094		
g_h=g_c	0.494	0.333±0.133	0.494	0.494
A_h=A_c	0.540	0.482±0.394	0.540	0.540
$L_h/(L_h+L_c)$ v	0.4839±0.0211	0.4989±0.0100	0.4820±0.0324	0.5100±0.0518
b	0.4863±0.0244	0.5059±0.0122		
$\Omega_h=\Omega_c$	3.8037±0.0028	3.7940±0.0018	3.7646±0.0091	3.7964±0.0164
r_h(pole)	0.3640±0.0004	0.3653±0.0002	0.3691±0.0019	0.3649±0.0035
r_h(side)	0.3851±0.0004	0.3866±0.0003	0.3914±0.0015	0.3862±0.0045
r_h(back)	0.4270±0.0007	0.4295±0.0005	0.4371±0.0024	0.4288±0.0078
r_c(pole)	0.3835±0.0005	0.3847±0.0007	0.3885±0.0015	0.3844±0.0013
r_c(side)	0.4069±0.0007	0.4084±0.0009	0.4132±0.0021	0.4080±0.0018
r_c(back)	0.4470±0.0014	0.4494±0.0017	0.4567±0.0041	0.4487±0.0034

Table 3. (Continued)

	1968	1969	1978	1983
i		79.77±0.55		
q		1.1245±0.0125		
Pshift	0.9986±0.0003	0.9988±0.0005	0.9982±0.0003	0.9993±0.0005
T_h	5620	5596±0.0011	5630	5565
T_c	5383±0.0007	5317	5417±0.0009	5365±0.0012
x_h=x_c(v)	0.675±0.085	0.766	0.640±0.22	0.766
x_h=x_c(b)			0.772±0.21	0.889
g_h=g_c	0.494	0.494	0.494	0.494
A_h=A_c	0.540	0.540	0.540	0.540
$L_h/(L_h+L_c)$ v	0.5249±0.0208	0.5347±0.0267	0.5193±0.0074	0.5176±0.0128
b			0.5314±0.0081	0.5291±0.0161
$\Omega_h=\Omega_c$	3.7871±0.0039	3.7963±0.0044	3.8268±0.0075	3.8238±0.0057
r_h(pole)	0.3661±0.0005	0.3650±0.0006	0.3611±0.0009	0.3615±0.0007
r_h(side)	0.3878±0.0006	0.3863±0.0007	0.3814±0.0011	0.3819±0.0009
r_h(back)	0.4312±0.0010	0.4289±0.0011	0.4214±0.0018	0.4221±0.0014
r_c(pole)	0.3856±0.0012	0.3844±0.0026	0.3806±0.0010	0.3810±0.0014
r_c(side)	0.4095±0.0017	0.4080±0.0036	0.4032±0.0013	0.4037±0.0020
r_c(back)	0.4511±0.0032	0.4488±0.0067	0.4416±0.0024	0.4423±0.0036

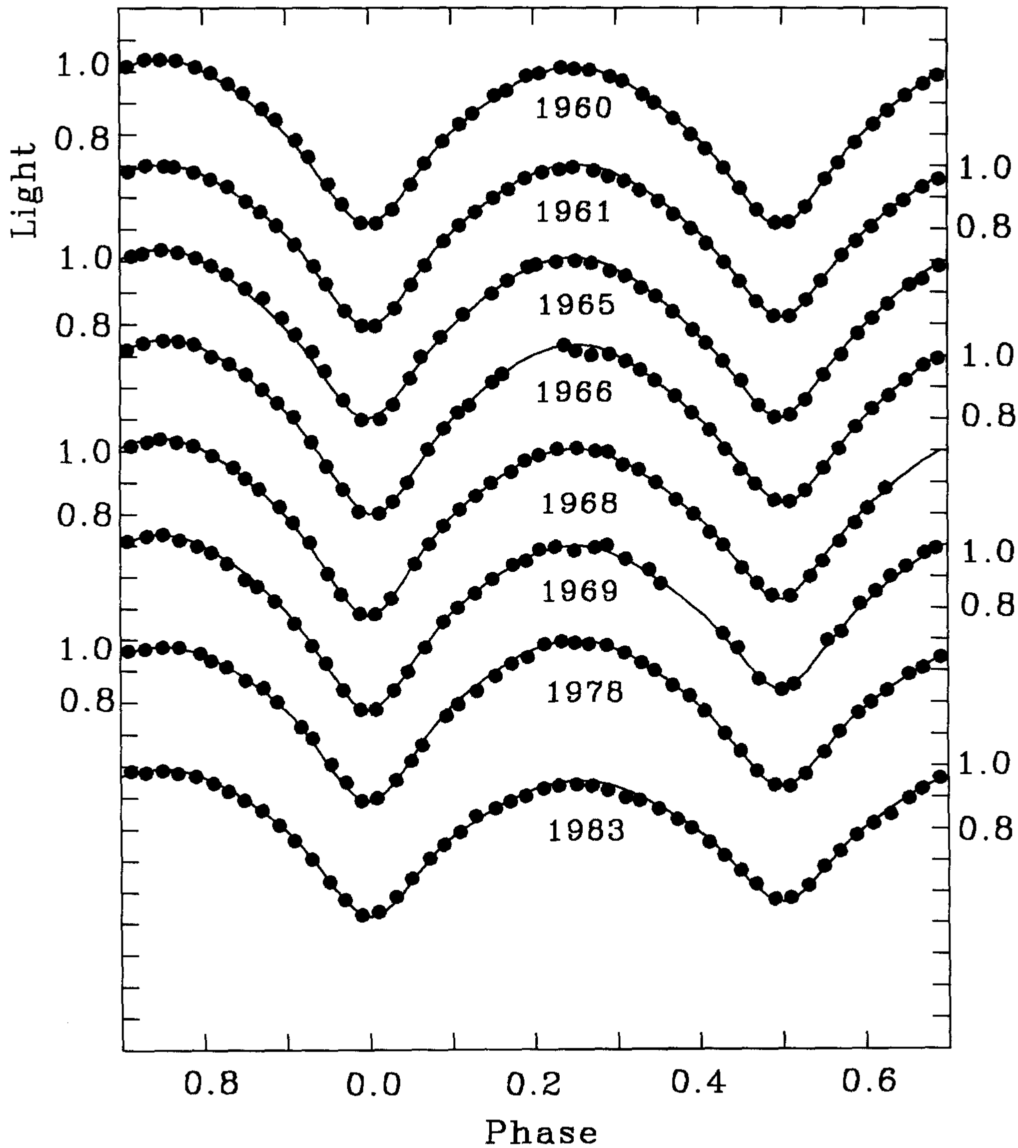

Figure 3. *V* light curves with computed light curves of SW Lac. Solid lines and dots represent computed light curves and observations, respectively.

Table 4. Previously published parameters of SW Lac.

	Leung *et al.* (1984)			Jeong *et al.* (1994)		
	WD model			WD model		
	1953	1961	1978	1987	1988	1983
i	82.69	79.26	78.95	78.95	81.15	79.31
T_h	5630	5630	5630	5630	5630	5630
T_c	5477	5475	5416	5282	5305	5446
A_h=A_c	0.50	0.50	0.50	0.540		
g_h=g_c	0.50	0.50	0.50	0.494		
x_h=x_c(v)	0.65	0.65	0.65	0.766	0.166	0.700
x_h=x_c(b)	0.78	0.78	0.78	0.899	0.281	
				0.930	0.434	
$L_h/(L_h+L_c)$ v	0.4961	0.5059	0.5072	0.5475	0.5371	
b	0.5045	0.5130	0.5155	0.5672	0.5556	
u				0.5850	0.5721	
Ω_h=Ω_c	3.7889	3.8208	3.8510	3.7729	3.6859	3.7459
q	1.2158	1.1398	1.1370	1.1296	1.1701	1.1272
r_h(pole)	0.3768	0.3634	0.3593	0.3686	0.3854	0.3718
r_c(pole)	0.4088	0.3850	0.3806	0.3888	0.4111	0.3916
r_h(side)	0.4016	0.3837	0.3786	0.3909	0.4134	0.3950
r_c(side)	0.4373	0.4076	0.4021	0.4135	0.4426	0.4173
r_h(back)	0.4626	0.4267	0.4185	0.4366	0.4798	0.4432
r_c(back)	0.4915	0.4484	0.4402	0.4366	0.5023	0.4629

Table 4. (Continued)

Bookmyer (1965)		Lafta & Grainger (1985)			Eaton (1986)		Niarchos (1987)		
Russell-Merrill model		Kopal model					Kopal model		
	1961		1983			1983		1983	
			V	*B*		(IUE)		*V*	*B*
i	75.6	i	78.8	79.3	i	80.40	i	80.1	80.3
k	0.80	k	0.97	0.88	$A_h = A_c$	0.50	k	0.94	0.91
x	0.60	u	0.5	0.6	$g_h = g_c$	0.40	u	0.6	0.7
a_c	0.41	L_h	0.290	0.310	T_h	5430	L_h	0.292	0.312
b_c	0.35	L_c	0.710	0.690	X_V	0.63	L_c	0.708	0.688
a_h	0.33	r_c	0.376	0.361		1.05	r_h	0.362	0.355
b_h	0.28	r_h	0.389	0.410			r_c	0.384	0.392
$L_h(V)$	0.430								
$L_c(V)$	0.570								
$L_h(B)$	0.434								
$L_c(B)$	0.566								

while those for Group 3 which has Max II fainter than Max I are positive. The symmetrical light curves of the epochs 1961 and 1987 show that the coefficients are almost zero. The groups of light curves of SW Lac were classified by the location of maximum light outside eclipse. Thus a relation between the coefficient, B_1 and magnitude difference between two maxima was found as a linear relation like below;

$$B_1 = 0.41(MaxII - MaxI) - 0.033 \tag{3}$$

where B_1 is Fourier coefficient B_1, and (Max II - Max I) is magnitude difference between two maxima. The coefficients of B_1 are plotted against magnitude difference between two maxima in Figure 4.

The total light of SW Lac has been decreased according to Fourier coefficient A_0. The average of A_0 for whole epochs is 0.85. The average of early 1960's is 0.86 while that of late 1980's is 0.83. Therefore the total light has been decreased as much as $0.^m04$ during approximately 20 years time interval.

Photometric parameters for all light curves were obtained by the method of the Wilson & Devinney differential correction in order to secure variations of parameters from season to season. Most spotted stars, like RS CVn type binaries, show that the shape of light curve changes every season. In this case the fit reaches reasonably perfect by adjusting spot parameters only (Kang & Wilson 1989). However SW Lac requires to adjust all parameters as well as spot parameters for every epoch. The parameters adjusted have changed every season. Even orbital inclination and mass ratio of the system have also changed from season to season. Those parameters are not expected to change in short time interval for such systems. Thus we fixed both of inclination and mass ratio, and adjusted other parameters for all epochs again.

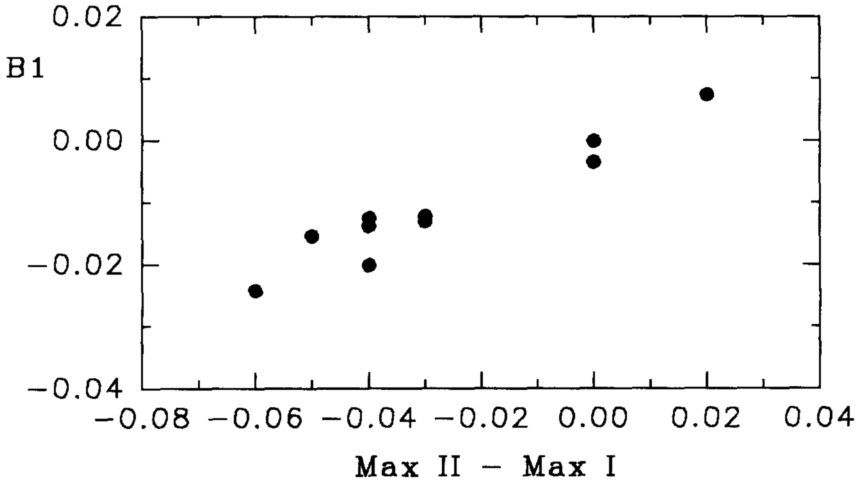

Figure 4. Variation of Fourier coefficient B_1 against Max (II-I).

Table 5. Mean value and standard deviations of parameters for SW Lac.

	Range	Mean value	S.D.
i	79.77		
q	1.1245		
PShift	0.9980 - 0.0040	0.9993	0.0021
T_h	5565 - 5724	5621	47.02
T_c	5317 - 5680	5460	119.40
$A_h=A_c$	0.482 - 0.540	0.533	0.020
$g_h=g_c$	0.333 - 0.494	0.474	0.056
$x_h=x_c$(v)	0.640 - 0.851	0.738	0.073
$x_h=x_c$(b)	0.772 - 0.943	0.864	0.072
$L_h/(L_h+L_c)$ v	0.4820 - 0.5347	0.5090	0.0178
b	0.4863 - 0.5314	0.5132	0.0213
$\Omega_h=\Omega_c$	3.7646 - 3.8268	3.7991	0.0199
r_h(pole)	0.3611 - 0.3691	0.3646	0.0025
r_c(pole)	0.3806 - 0.3885	0.3841	0.0056
r_h(side)	0.3814 - 0.3914	0.3858	0.0032
r_c(side)	0.4032 - 0.4132	0.4076	0.0032
r_h(back)	0.4214 - 0.4371	0.4283	0.0050
r_c(back)	0.4416 - 0.4567	0.4482	0.0048

In case of fixing two parameters, spot effect, potential, and temperatures of both stars became major contributors changing the shape of light curve from season to season. Those parameter variations for whole epochs are plotted in Figure 5 as well as whole parameters adjusted are listed in Table 5.

The spot effect was defined by Kang (1993) as a ratio of light loss due to spot to total light of the system. Thus symmetric light curve of the 1961 epoch, which does not need spot, has 0.0 spot effect. Mean spot effect for 7 epochs is approximate 0.19. The spot effects of the 1966, 1969, and 1983 epochs are larger than mean spot effect. However there is no periodicity during given time interval. The spot parameters are listed in Table 6.

The variation of potentials for whole epochs does not exceed 1% of their mean value. Thus the variation of radii of both stars is less than 1% of their mean value.

A surface temperature of star is one of the most sensitive parameters to affect a shape of light curve of eclipsing binary star. Mean temperatures of primary and secondary stars are $5621°K$ and $5460°K$, respectively. The amplitude of temperature variation for secondary star is much larger than that of primary star. Temperature of secondary star varies from $5317°K$ to $5680°K$, while that of primary star varies from $5565°K$ to $5724°K$. Therefore variation of secondary star's temperature is the most important contributor for changing light curve of SW Lac. The temperature variation can be explained by chromospheric activity on the cooler component which is one of the characteristics of RS Cvn type stars. The chromospheric activity of SW Lac has been confirmed by Jeong *et al.* (1994) who had analyzed the IUE spectra of SW Lac. Thus surface inhomogeneity for such late type stars is generally accepted as a result of strong chromospheric activity.

We conclude that the shape of light curve of SW Lac varies even during one season as well as season to season. The light curve is mainly caused by inhomogeneous surface temperature due to strong chromospheric activity of the system.

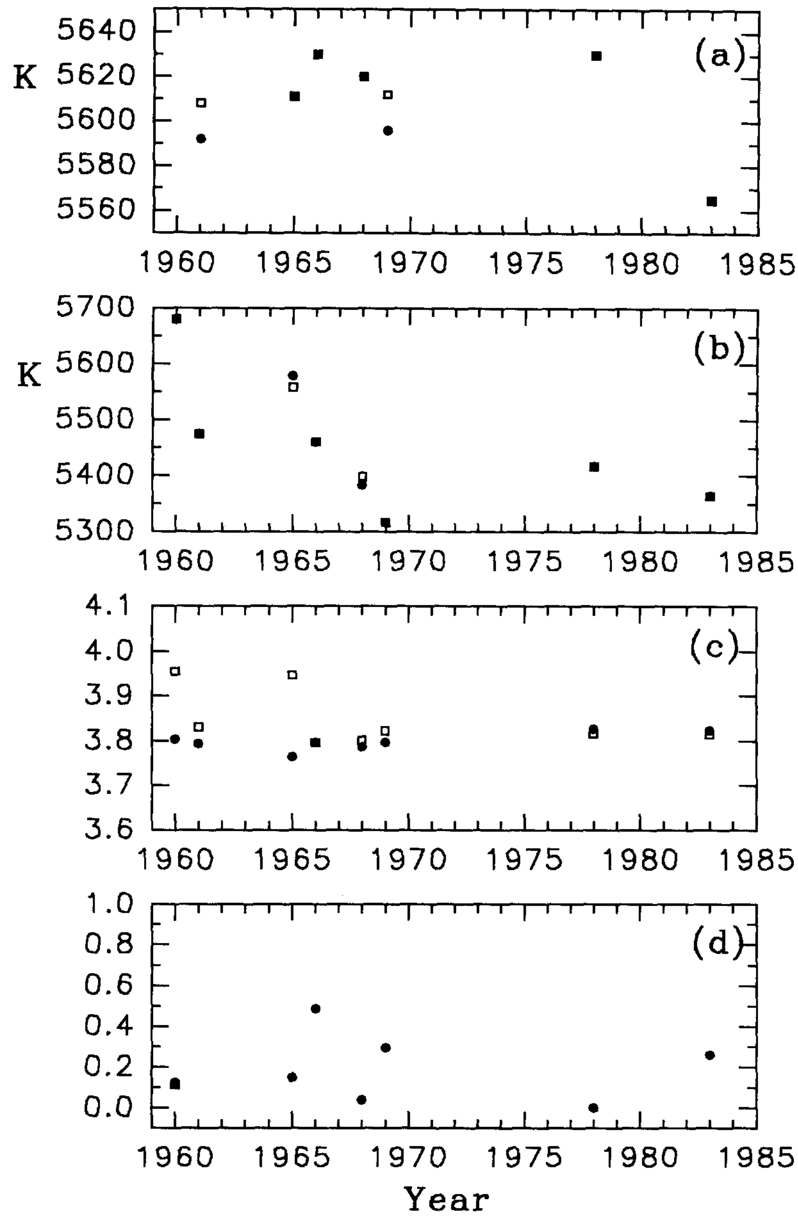

Figure 5. Variations for (a) temperature of primary, (b) temperature of secondary, (c) potential, and (d) spot effect. Open square and filled circle represent values obtained before and after inclination and mass ratio are fixed, respectively.

Table 6. Spot parameters of SW Lac.

Epoch	1960	1965	1966	1968	1969	1978	1983
Co-latitude	70	70	70	70	70	70	70
Longitude	289.94 ±3.77	288.32 ±5.64	339.03 ±4.21	280.72 ±4.44	274.19 ±11.76	77.56 ±5.29	260.63 ±3.50
Radius	16.65 ±3.83	17.20 ±0.59	17.44 ±8.02	23.51 ±12.45	18.77 ±17.53	3.38 ±0.48	22.59 ±0.54
Temp. Factor	0.854 ±0.08	0.850	0.800 ±0.18	0.907 ±0.12	0.830 ±0.57	0.850	0.850

REFERENCE

Al-Naimy, H. M. K., Jabbar, S. R., Flayen, H. A. & Al-Razzaa, J. M. 1989, Ap&SS, 151, 279
Binnendijk, L. 1984, PASP, 96, 646
Bookmyer, B. B. 1965, AJ, 70, 415
Chou, K. C. 1963, AJ, 68, 342
Eaton, J. A. 1986, A&A, 36, 79
Faulkner, D. R. & Bookmyer, B. B. 1980, PASP, 92, 92
Han, W. Y., Kim, K. M., Kim, C. H., Lee, W. B. & Kim, T. H. 1988, JA&SS, 5, 73
Jeong, J. H., Kang, Y. W., Lee, W. B. & Sung, E. C. 1994, ApJ, 421, 779
Kang, Y. W. 1993, Astronomical Society of the Pacific Conference Series, Vol.38, 371
Kang, Y. W. & Wilson, R. E. 1989, AJ, 97, 848
Lafta, S. J. & Grainger, J. F. 1985, Ap&SS, 114, 23
Leung, K. C., Zhai, D. & Zhaung, R. 1984, PASP, 96, 634
Niarchos, P. G. 1987, A&AS, 67, 365
Rucinski, S. M. 1968, A&A, 18, 49
Rucinski, S. M., Brunt, C. C. & Pringle, J. E. 1984, MNRAS, 208, 309
Semeniuk, I. 1971, A&A, 21, 49