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TWO UNITARY LIGHT CURVES OF AR LACERTAE IN 1984*

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ABSTRACT

Photoelectric observation in 1984 shows light variation outside eclipses. The effect of the changing ambient temperature on the light curves were studied. Difficulty of studying and unitary, or mean, light curve of AR Lac is stressed.

I. INTRODUCTION

The interesting RS Canum Venaticorum type eclipsing binary, AR Lacertae, has been observed photoelectrically by many investigators. Studies of its light curves are listed in Table I. With exception of the observation by Srivastava, all others were obtained with unrefrigerated photomultipliers. Because of the 1.98-day period, the star is a difficult system to observe for the coverage of complete light curves. At one observatory alone, a duration of four or more months was needed to obtain a full light curve that causes great changes of climate to give a big variation of ambient temperature at the time of observation. Therefore, it is extremely difficult to study the short-term burst-like light variations as well as the long-term wave-like distortions of its light curves. It is also hard to compare light curves using different comparison stars. During the 1980-81 and 1981-82 seasons, the U. S.-Korea cooperation of Fernbank, Kongju, Rosemary Hill, and Yonsei Observatory yielded interesting results showing light variations inside and outside the eclipses (Nha et al. 1985). However, the differential photometries were made in their respective instrumental system. The study of the merged observation cannot be made very precisely. In addition, Park and Chen (1989, hereafter called Paper 1) show the temperature dependence of differential photometry made at Kongju in 1984. This paper is a study of the effect of ambient temperature on the light curves of AR Lacertae which were obtained in the same 1984 season

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Table 1. Studies of Light Curves of AR Lac (Comparison stars, PM tubes)

Observer	Year	Observations	PM tude (uncooled)	Comparison	star
Kron	1938-40	*B* 1196	Potassium Hydride	HD 209932	A0
		IR 2757	?		
	1946-47	*B* 1052	1P21		
Wood	1938-49	*B* 143	1P21	HD 209813	K0
Chambliss	1972-74	*U* 653	EMI 6256 SA	HD 210731	F8
		B 676			
		V 679			
Hoffmann	1974	*V* 131	?	?	
Srivastava	1975-76	*U* 226	1P21	BD+44°.4044	A2
		B 236	refrigerated at −20°C	BD+44°.4044	
		V 233			
Nha and Kang	1976-77	*B* 55	1P21	BD+44°.4044	A2
		V 55			
	1977-78	*B* 608			
		V 608			
Kurtac *et al.*	1978-79	*B* & *V* 638	1P21, EMI 6256	HD 208728	K0
				SA°51476	
	1979-80	*B* & *V* 334		BD+45°.3741	
Nha *et al.*	1980-81	*B* 447	1P21	BD+44°.4044	A2
		V 467			
	1981-82	*B* 383			
		V 389			
E.−H. Lee	1982-83	*B* 589	1P21	BD+44°.4044	A2
		V 585			
Evren *et al.*	1982	*B* 305	EMI 9781A	HD 208728	K0
Ertan *et al.*	1980-81	439(1980) 341(1981)	EMI 9781A	HD 208728	K0
Caton	1979-80	1127(79-80)	EMI 6256S (refrigerated)	BD+47°.3711	G5
Rodono *et al.*	1981	three obs. combined	Cape system	HD 208728	

II. OBSERVATION AND DATA ANALYSIS

The observation was made at Kongju National Teachers College together with the comparison star BD+44°4044 and the check star BD+47°3711. The 16-inch reflecting telescope and the photometric equipment were described in Paper I. The uncooled phototube was used with the *B* and *V* filters. The data are referred to as the blue (B) and yellow (Y) observations. The differences in magnitude, Δm = (variable-star magnitude) − (comparison-star magnitude), are corrected for differential atmospheric extinction listed with the Heliocentric Julian days.

The binary phases were computed according to the light elements of Ertan et al. (1982).

$$\text{Hel. Min. I} = 2443672.0917 + 1^{d}.98318235E.$$

The light curves are shown in Fig. 1. The discontinuity at $0^{P}.2$ is evident. In Paper I, the differential photometry with an unrefrigerated phototube is shown to be subject to the temperature effect which depends on the ambient temperature, the photometric system, and the combination of the effective temperatures of the stars. A list of the change of the difference in magnitudes of two stars with the change in wavelength according to the blackbody radiation, $\delta m / \Delta \lambda$, is given in Table II. This indicates how different a comparison star would make in the differential photometry of AR Lacertae. In this analysis, the differential temperature correction applied to Δm is δm; hence the values of $\Delta m'$, normalized to the ambient temperature, T, of 10°C are given by:

a) Inside the primary eclipse,

$$\Delta m'_y = \Delta m_y + 0.001998\,(T-10)$$

and

$$\Delta m'_b = \Delta m_b + 0.001864\,(T-10);$$

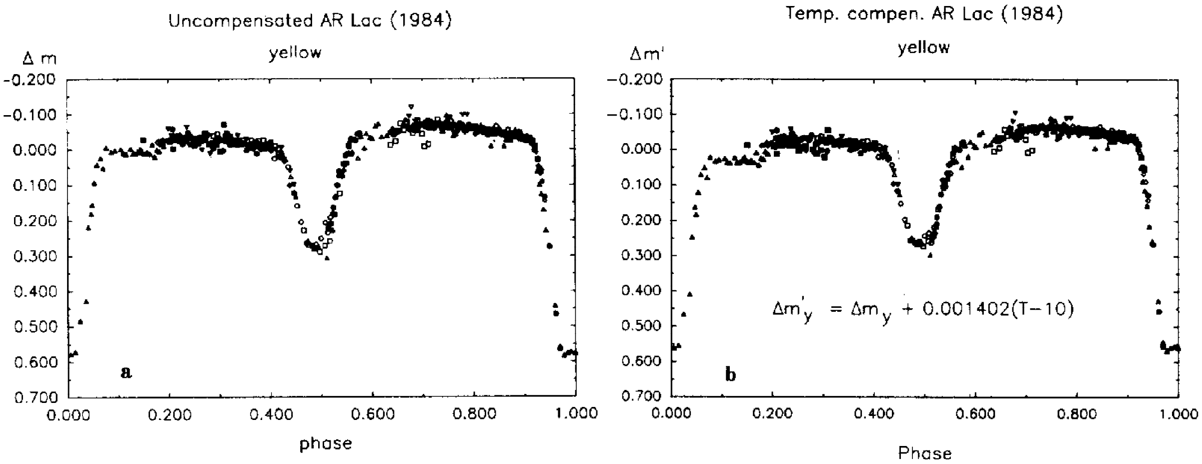

Fig. 1a. Yellow observations of AR Lac from summer(August) to winter(December) in 1984. The ambient temperature varied from 30°C in August to −10°C in December. The discontinuity of light1 level is $0^{m}.037$ at $0^{P}.175$. The shoulders of eclipses are evidently asymmetry.

Fig. 1b. Temperature compensated Yellow observations with the equation of $m'_y = m_y + 0.001402$ (T-10). The depth variation of $0^{m}.02$ of primary eclipse would be $0^{m}.03$ with the equation of $m'_y = m_y + 0.001998$ (T-10). The discontinuity at $0^{P}.175$ is increased by $0^{m}.012$. The asymmetry of secondary eclipse become symmetrical but the primary asymmetry become more asymmetrical.

Table 2. The change of the difference in magnitudes with the change in wavelength according to the black body radiation.

$\Delta\lambda$	λ_y	2.5 log I/Í			λ_b	2.5 log I/Í		
(Å)	(Å)	4700/9520	5500/9520	5600/9520	(Å)	4700/9520	5500/9520	5600/9520
0	5500	0.000000	0.000000	0.000000	4300	0.000000	0.000000	0.000000
1	5499	0.000520	0.000362	0.000353	4299	0.000885	0.000627	0.000601
2	5498	0.001047	0.000732	0.000706	4298	0.001771	0.001256	0.001197
3	5497	0.001571	0.001101	0.001054	4297	0.002651	0.001876	0.001793
4	5496	0.002100	0.001471	0.001411	4296	0.003538	0.002503	0.002394
5	5495	0.002623	0.001836	0.001762	4295	0.004427	0.003133	0.002995
6	5494	0.003142	0.002203	0.002110	4294	0.005310	0.003755	0.003588
7	5493	0.003669	0.002575	0.002465	4293	0.006196	0.004385	0.004194
8	5492	0.004194	0.002944	0.002813	4292	0.007088	0.005012	0.004795
9	5491	0.004721	0.003312	0.003169	4291	0.007973	0.005639	0.005393
10	5490	0.005248	0.003684	0.003524	4290	0.008860	0.006266	0.005991

9520(°K): temperature of A2, comparison star.
5600(°K): temperature of G2, secondary eclipse.
5500(°K): termperature of G5, outside eclipse.
4700(°K): termperature of K0, primary eclipse.

b) Inside the secondary eclipse,

$$\Delta m'_y = \Delta m_y + 0.001335\ (T-10)$$

and

$$\Delta m'_b = \Delta m_b + 0.001254\ (T-10);$$

c) outside eclipses,

$$\Delta m'_y = \Delta m_y + 0.001402\ (T-10)$$

and

$$\Delta m'_b = \Delta m_b + 0.001311\ (T-10);$$

The light curves, corrected for differential temperature effect, with the coefficient of outside eclipses are shown in Fig. 2. While the general shapes of these curves do not change from the original one (Fig. 1). It is seen that for the blue observation, the primary eclipse is shallower, the secondary eclipse is more distorted, and the difference in brightness at the discontinuity is larger, and that for the yellow observation, both the primary and secondary eclipses are shallower and also a larger discontinuity at $0^P.2$ in Fig. 3 which is enlarged portions of light curves around the discontinuity. The amount of the light variation from temperature effect in primary eclipse is $0^m.05$ which could explain the depth variation of primary eclipse.

With the use of "tracing paper" means, the Δm-plot yieded times of minimum of the primary eclipse: Hel. J. D. 24456032.0681 for *B* and Hel.J. D. 24456032.0684 for *Y*. These values gave

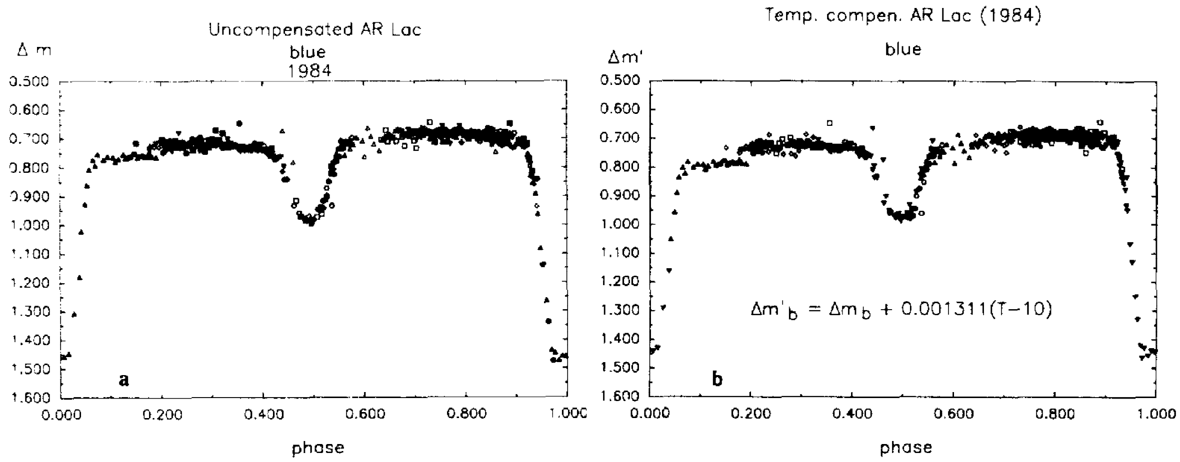

Fig. 2a. Blue observation of AR Lac from summer (August) to winter (December) in 1984. The ambient temperature ranges from 30°C in August to −10°C in December. The discontinuity of blue light level is $0^m.04$ at $0^P.175$. The asymmetry of eclipses is evident as the yellow.

Fig. 2b. Temperature compensated blue observations with the equation of $m'_B = m_B + 0.001311\ (T\text{-}10)$. The depth variation of $0^m.02$ in primary eclipse would be $0^m.028$ with the equation of $m'_B = m_B + 0.001864\ (T\text{-}10)$. The discontinuity at $0^P.175$ is increased by $0^m.013$. The asymmetry of eclipses change same as in yellow light curve.

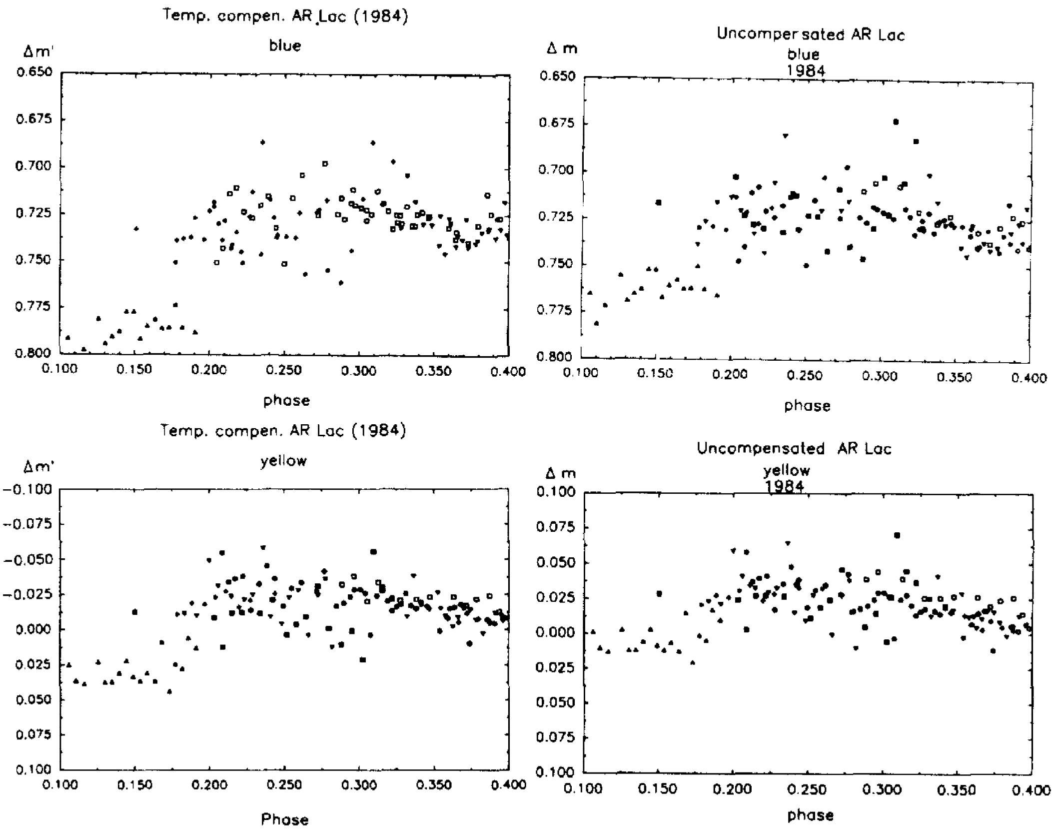

Fig. 3. Upper graphs are the original light curves, around the phase of $0^P.175$. The lower graphs show the temperature compensated discontinuity of light curves around $0^P.175$ which are bigger than the original observations. They imply time dependent variations as well as phase dependent variation of light curves.

the O-C values of 0.0106 and 0.0103 according to the light element of Ertan et al.(1982), On the other hand, the times of minimum of the primary minimum from the $\Delta m'$-plot are Hel. J. D. 24456032.0701 and Hel. J. D. 24456032.0706, and the corresponding O-C values are 0.0086 and 0.0081.

The jump at discontinuity of the light curve at $0^{P}.175$ is about $0^{m}.040$ for m_b, $0^{m}.037$ for m_y, while in Fig.'2 they are $0^{m}.053$ and $0^{m}.049$ for m_b' and m_y' respectively. Thus an increase in brightness of $0^{m}.05$ in *B* and $0^{m}.04$ in *Y* occurred between August 18/19 and September 21/22 in 1984.

III. DISCUSSION AND CONCLUSION

The behavior of the observed variation, the so-called wave-like distortion, of the light curves of AR Lacertae is not well understood. This makes the detailed analysis of the light curves, even the unitary ones, difficult. On top of it, there is the temperature effect on the differential photometry as shown in this paper. Thus a study of any combination of observations by different investigators using different comparison stars and different instrumental systems, in particular with unrefrigerated phototube, cannot produce too precise a result. Regardless, Rodono et al. (1986) made a study of the spot model for AR Lac based on observations, reduced to standard *UBV* system, mainly from Catania and Tokyo Observatories, and observations, in the instrumental system, of Ertan et al. (1982) at Ege Observatory. For an analysis of the non-eclipsing light variation through many cycles of the binary orbital motion, a statistical study of the chronical data will shed some light on the behavior of this interesting close binary.

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