PERIOD STUDY OF AW UMA

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Abstract. A detailed period study of the eclipsing binary system AW UMa is presented. A new period ($P = 0^d.4387317$) is given. Period changes in different portions of the O–C diagram, based on new period, have been estimated. The total change in period (ΔP) ranges from 2.2×10^{-7} to 2.8×10^{-6} d, which is normal for AW UMa systems. Two distinct linear trends of period are visible in the O–C diagram. A third trend shows a new change in the period behaviour, which is yet to be confined.

1. Introduction

Paczyński (1963) discovered the variability of the eclipsing binary system AW UMa ($= BD + 30°2163$) and further details were published by Paczyński (1964), Kalish (1965), Eggen (1967), Dworak and Kurpinska (1975), Ferland and McMillan (1976), Hart *et al.* (1979), Mikolajewska and Mikolajewski (1980), Kurpinska-Winiarska (1980), Woodward *et al.* (1980), Hrivnak (1982), and Srivastava and Padalia (1986) studied the system further. Other details of history of AW UMa were given by Srivastava and Padalia (1986). In this communication, a detailed period study of AW UMa has been presented.

2. Epoch, Period, and New Period

Epochs and periods of AW UMa, presented by several authors, are given in Table I, wherein the change in the period of the system is evident.

In all, 55 minima have been collected from the literature. Fortunately, except two, all are photoelectric. Out of 55 minima 39 are primary and 16 are secondary.

Of the 55 minima, 4 minima (3 primary and 1 secondary) were left out in period discussion as they gave unusual values of O–C, completely different from the instant period trend, and are indicated by (?) mark, and are not plotted in the figures. Thus, only 51 minima have been chosen for the present study. From these a new period of AW UMa has been obtained employing the least-squares method. The new period comes out to be $0^d.4387317 \pm 0^d.0000002$.

3. O–C Diagrams and Period Changes

Al the available minima times, obtained in the interval 1963 to 1988, have been listed in Table II. Two O–C diagrams (Figures 1 and 2), based on the ephemeris:

$$\text{Primary Minimum} = \text{J.D. } 2438044.7808 + 0^d.438727E\,,$$

(cf. Hrivnak, 1982; Paczyński, 1964)

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TABLE I

Epochs and periods of AW UMa

Sl. No.	Author	Epoch and period
1,	Paczyński (1964)	J.D. 2438044.7812 + 0^d.438727
2.	Kalish (1965)	J.D. 2438044.7815 + 0^d.4387318
3.	Dworak and Kurpinska (1975)	J.D. 2438044.7812 + 0^d.43873235
4.	Ferland and McMillan (1976)	J.D. 2438044.7812 + 0^d.4387334
5.	Mikolajewska and Mikolajewski (1980)	J.D. 2444320.39578 + 0^d.43873234
6.	Kurpinska-Winiarska (1980)	J.D. 2441333.51870 + 0^d.43873231
7.	Woodward *et al.* (1980)	J.D. 2442150.4385 + 0^d.43873234
8.	McLean (1981)	– + 0^d.438732
9.	Hrivnak (1982)	J.D. 2438044.7808 + 0^d.43873382 – 1.60 × 10^{-10}
		J.D. 2438044.7814 + 0^d.43873231
		J.D. 2443576.7505 + 0^d.43872917
		J.D. 2443941.7717 + 0^d.43873212
10.	Anderson *et al.* (1983)	J.D. 2443980.337 + 0^d.438732
11.	Srivastava and Padalia (1986)	J.D. 2438044.7815 + 0^d.4387304
12.	Srivastava (present)	J.D. 2438044.7808 + 0^d.4387317

and

$$\text{Primary Minimum} = \text{J.D. } 2438044.7808 + 0^d.4387317E\,,$$

(cf. Hrivnak, 1982; the present)

respectively, are given.

Figure 1 shows an average period increase (marked by solid line with an arrow at one end) of nearly 6.3×10^{-3} s yr^{-1}, up to recent minimum, which is a very slow rate. Increasing and decreasing period trends are also apparent around this solid line.

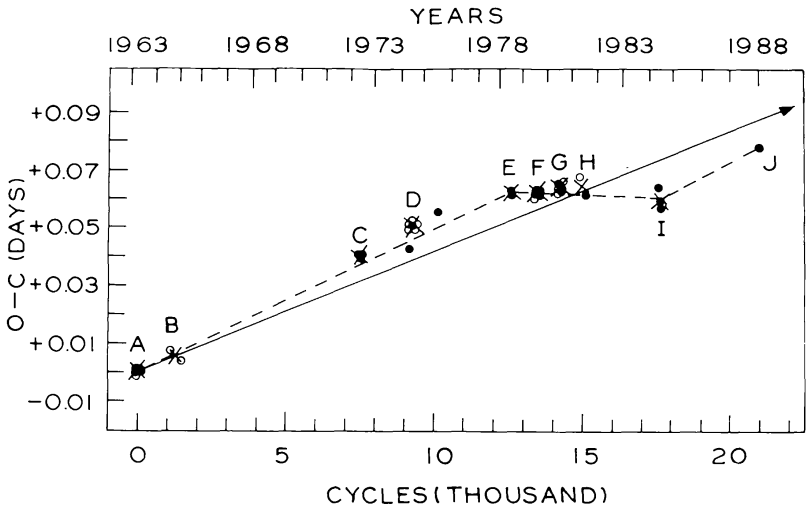

Fig. 1. O–C diagram based on $P = 0^d.438727$. Filled and open circles represent primary and secondary minima values, respectively, while the crosses indicate the mean values. The solid line, with an arrow at one end, represents the increasing tendency of period. Dashed lines represent increasing and decreasing tendencies of period changes.

TABLE II

Minima of AW UMa

J.D.$_\odot$	Min.	Based on $P = 0^d.438727$				Based on $P = 0^d.4387317$				Observer	Reference
		Cycle	Mean of cycles	O–C	Mean of O–C values	Cycle	Mean of cycles	O–C	Mean of O–C values		
2438044.7808	I	0		$0^d.0000$		0		$0^d.0000$		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2438044.7812	I	0		+0.0004		0		+0.0004		Ferland, G. J. and McMillan, R. S.	*IBVS* 1176, 1976
2438044.7812	I	0		+0.0004		0		+0.0004		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2438044.7814	I	0		+0.0006		0		+0.0006		cf. Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2438044.7815	I	0		+0.0007		0		+0.0007		cf. Kalish, M. S.	*PASP* **77**, 36, 1965
			12.3		$+0^d.0006$		12.3		$+0^d.0005$		
2438045.0020	II	0.5		+0.0018		0.5		+0.0018		Paczyński, B.	*AJ* **69**, 124, 1964
2438045.8785	II	2.5		+0.0008		2.5		+0.0008		Paczyński, B.	*AJ* **69**, 124, 1964
2438046.9740	I	5		−0.0004		5		−0.0005		Paczyński, B.	*AJ* **69**, 124, 1964
2438089.9707	I	103		+0.0010		103		+0.0005		Paczyński, B.	*AJ* **69**, 124, 1964
2438487.6825	II	1009.5		+0.0068		1009.5		+0.0023		Kalish, M. S.	*PASP* **77**, 36, 1976
			1025.5		+0.0052		1025.5		+0.0010		
2438501.7195	II	1041.5		+0.0035		1041.5		−0.0004		Kalish, M. S.	*PASP* **77**, 36, 1976
2441333.5178	I	7496		+0.0394		7496		+0.0042		Dworak, T. Z. and Kurpinska, M.	*AA*, **25**, 417, 1975
2441333.51870	I	7496	7498.3	+0.04030	+0.0400	7496	7498.3	+0.00508	0.0048	Kurpinska-Winiarska, M.	*IBVS* 1843, 1980

Table II (continued)

J.D.$_{\odot}$	Min.	Based on $P = 0^{d}.438727$				Based on $P = 0^{d}.4387317$				Observer	Reference
		Cycle	Mean of cycles	O–C	Mean of O–C values	Cycle	Mean of cycles	O–C	Mean of O–C values		
2441336.5898	I	7503		$+0^{d}.0403$		7503		$+0^{d}.0051$		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442053.91	I	9138		+0.0419		9138		−0.0011		Ferland, G. J. and McMillan, R. S.	*IBVS* 1176, 1976
2442074.5380	I	9185		+0.0497		9185		+0.0065		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442091.4302	II	9223.5		+0.0509		9223.5		+0.0075		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442096.7808	I	9235		+0.0499		9235		+0.0064		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442107.4425	I	9260		+0.0497		9260		+0.0062		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442108.5393	II	9262.5		+0.0496		9262.5		+0.0061		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442134.4249	II	9321.5	9289.4	+0.0503	$+0^{d}.0494$	9321.5	9289.4	+0.0065	$+0^{d}.0057$	Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442140.3470	I	9335		+0.0497		9335		+0.0058		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442148.4648	II	9353.5		+0.0519		9353.5		+0.0070		Dworak, T. Z. and Kurpinska, M.	*AA* **25**, 417, 1975
2442150.4358	I	9358		+0.0504		9358		+0.0065		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2442151.7539	I	9361		+0.0497		9361		+0.0057		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980

Table II (continued)

J.D.$_\odot$	Min.	Based on $P = 0^d.438727$				Based on $P = 0^d.4387317$				Observer	Reference
		Cycle	Mean of cycles	O–C	Mean of O–C values	Cycle	Mean of cycles	O–C	Mean of O–C values		
2442152.8495	II	9363.5		$+0^d.0484$		9363.5		$+0^d.0044$		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2442153.7287	II	9365.5		+0.0505		9365.5		+0.0065		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2442461.5000	I	10067		+0.0545		10067		+0.0072		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2443576.7505	I	12609		+0.0610		12609		+0.0017		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
			12613.5		$+0^d.06182$		12613.5		$+0^d.00263$		
2443580.70074	I	12618		+0.06264		12618		+0.00355		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2443621.7220	I	12711		+0.2823(?)		12711		+0.2226(?)		Woodward, E. J., Koch, R. H., and Eisenhardt, P. R.	*AJ* **85**, 50, 1980
2443941.7714	I	13441		+0.0610		13441		+0.0022		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2443941.7717	I	13441		+0.0607		13441		+0.0019		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
243945.7190	I	13450		+0.0600		13450		+0.0068		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2443945.7220	I	13450		+0.0630		13450		−0.0002		Kurpinska-Winiarska, M.	*IBVS* 1843, 1980

Table II (continued)

J.D.$_{\odot}$	Min.	Based on $P = 0^{d}.438727$				Based on $P = 0^{d}.4387317$				Observer	Reference
		Cycle	Mean of cycles	O–C	Mean of O–C values	Cycle	Mean of cycles	O–C	Mean of O–C values		
2443948.79280	I	13457		$+0^{d}.06276$		13457		$-0^{d}.00049$		Hart, M. K., King, K., McNamara, B. R., Seaman, R. L., and Stoke, J.	*IBVS* 1701, 1979
2443948.7927	I	13457	13463.3	+0.0627	+0.0620	13457	13463.3	−0.0006	+0.0008	Hart, M. K., King, K., McNamara, B. R., Seaman, R. L., and Stoke, J.	*IBVS* 1701, 1979
2443954.7158	II	13470.5		+0.0629		13470.5		−0.0004		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2443966.3420	I	13497		+0.0629		13497		−0.0006		Istomin, L. F., Orlov, V. M., and Kulagin, V. V.	*IBVS* 1802, 1980
2443970.7281	I	13507		+0.0617		13507		−0.0018		Istomin, L. F., Orlov, V. M., and Kulagin, V. V.	*IBVS* 1802, 1980
2443980.337	I(Sp)	13529		+0.0186(?)		13529		−0.045(?)		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2443980.3370	I(Sp)	13529		+0.0186(?)		13529		−0.0450(?)		Anderson, L. A., Stanford, D., and Leininger, D.	*ApJ* **270**, 200, 1983
2444274.7702	I	14200		+0.0660		14200		−0.0007		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2444277.8396	I	14207		+0.0643		14207		−0.0025		Hrivnak, B. J.	*ApJ* **260**, 744, 1982

Table II (continued)

J.D.$_{\odot}$	Min.	Based on $P = 0^d.438727$				Based on $P = 0^d.4387317$				Observer	Reference
		Cycle	Mean of cycles	O–C	Mean of O–C values	Cycle	Mean of cycles	O–C	Mean of O–C values		
2444283.7364	II	14220.5		$+0^d.0383$ (?)		14220.5		$-0^d.0286$ (?)		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2444292.5358	II	14240.5	14258.9	+0.0631	$+0^d.0643$	14240.5	14258.9	−0.0038	$-0^d.0027$	Kurpinska–Winiarska, M.	*IBVS* 1843, 1980
2444294.5093	I	14245		+0.0624		14245		−0.0046		Kurpinska–Winiarska, M.	*IBVS* 1843, 1980
2444320.39578	I	14304		+0.06397		14304		−0.00326		Mikolajewski, J. and Mikolajewska, M.	*IBVS* 1812, 1980
2444343.43098	II	14356.5		+0.06597		14356.5		−0.00151		Mikolajewski, J. and Mikolajewska, M.	*IBVS* 1812, 1980
2444608.8622	II	14961.5		+0.0674		14961.5		−0.0030		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
			15025.3		+0.0641		15025.3		−0.0066		
2444664.7933	I	15089		+0.0608		15089		−0.0101		Hrivnak, B. J.	*ApJ* **260**, 744, 1982
2445768.1950	I	17604		+0.0641		17604		−0.0186		Srivastava, R. K. and Padalia, T. D.	*ASS* **120**, 121, 1986
2445783.1060	I	17638		+0.0584		17638		−0.0245		Srivastava, R. K. and Padalia, T.D.	*ASS* **120**, 121, 1986
			17658.3		+0.0596		17658.3		−0.0234		
2445795.1712	II	17665		+0.0585		17665.5		−0.0245		Srivastava, R. K. and Padalia, T.D.	*ASS* **120**, 121, 1986
2445821.2742	I	17725		+0.0573		17725		−0.0260		Srivastava, R. K. and Padalia, T.D.	*ASS* **120**, 121, 1986
2447288.398	I	21069		+0.078		21069		−0.021		Diethelm, R.	*BBSAG* **88**, 6, 1988

? = These values are not plotted in Figures 1 and 2, since they appear to be unusually different than the instant period behaviour.

The O–C diagram (Figure 2) splits up into 9 portions (*AB*, *BC*, *CD*, *DE*, *EF*, *FG*, *GH*, *HI*, and *IJ*) between points *A* and *J*. This figure has been used for period discussion. The portion *AB* is sufficiently covered. Portion *BC* is scantily covered. Portion *CD* is also sufficiently covered. Portion *DE* again appears scantily covered, like *HI* and *IJ*. All other portions are well covered.

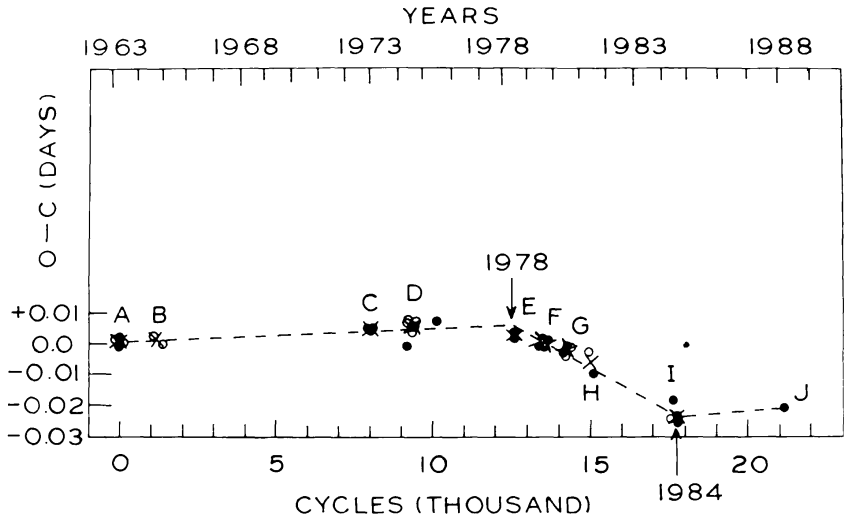

Fig. 2. O–C diagram based on $P = 0^d.4387317$. Filled and open circles represent primary and secondary minima values, respectively; while crosses indicate the mean values. Dashed lines represent the increasing and decreasing tendencies of period changes. Upward and downward arrows indicate the year of period changes.

The O–C diagram (Figure 2) shows two distinct linear tendencies of the period, *AE* and *EI*. The period ($\Delta P/P$) was increasing in the portion *AE* at a constant linear rate of nearly 4.8×10^{-7} d, with a total period change $\Delta P = 2.1 \times 10^{-7}$ d. In portion *EI*, the period appears to be decreasing at a constant linear rate of nearly $\Delta P/P = 1.3 \times 10^{-5}$ d, with a total change in period $\Delta P = 5.8 \times 10^{-6}$ d. Portion *IJ* shows a slow tendency of period change (or of increase), possessing a $\Delta P/P = 5.9 \times 10^{-7}$ d, with a total period change (ΔP) of 2.6×10^{-7} d. Since at point *J*, only one minimum is available, hence, nothing can be said definitely about its significance. However, being a photoelectric observation at *J*, it shows a new period change.

The period changes in different portions of the O–C diagram (Figure 2) have been estimated on the assumption that period constantly behaves between different epochs of period change and $O-C(S) > 0^d.01$ are important for period study. The period changes (ΔP) in different portions of the O–C diagram range from 2.2×10^{-7} d to 2.8×10^{-6} d, the average (without considering the sign) being 1.1×10^{-6} d. From Table III, it is apparent that the order of period change (ΔP) is 10^{-6} to 10^{-7} d.

Kurpinska-Winiarska (1980) found a period decrease $\Delta P = 5.4 \times 10^{-6}$ d. Our results show that a period decrease ($\Delta P = 5.8 \times 10^{-6}$ d) has occurred around the year 1978. And, possibly, a new period increase is on the way whose occurrence is around 1984, which is yet to be confirmed. Our results do not suggest that O–C values of secondary

TABLE III

Changes in period of AW UMa

Portion	Interval of cycles	$\Delta P/P$	Total change in period ΔP (days)	Period trend
AB	$E = 12$ to $E = 1026$	4.93×10^{-7}	2.16×10^{-7}	*I*
BC	$E = 1026$ to $E = 7498$	5.87×10^{-7}	2.58×10^{-7}	*I*
CD	$E = 7498$ to $E = 9289$	5.03×10^{-7}	2.21×10^{-7}	*I*
DE	$E = 9289$ to $E = 12614$	9.32×10^{-7}	4.09×10^{-7}	*I*
EF	$E = 12614$ to $E = 12463$	2.12×10^{-6}	0.93×10^{-6}	*D*
FG	$E = 12463$ to $E = 14259$	4.40×10^{-6}	1.93×10^{-6}	*D*
GH	$E = 14259$ to $E = 15025$	5.09×10^{-6}	2.23×10^{-6}	*D*
HI	$E = 15025$ to $E = 17658$	6.38×10^{-6}	2.80×10^{-6}	*D*
IJ	$E = 17658$ to $E = 21069$	7.04×10^{-7}	3.09×10^{-7}	*I*
	Mean	2.54×10^{-6}	1.11×10^{-6}	
Linear trends *AE*, *EI*, and *IJ* are visible. Graphical values of the other of period change in these portions are given:				
AE	$E = 0$ to $E = 12500$	4.80×10^{-7}	2.11×10^{-7}	*I*
EI	$E = 12500$ to $E = 17700$	1.33×10^{-5}	5.84×10^{-6}	*D*
IJ[a]	$E = 17700$ to $E = 21069$	5.94×10^{-7}	2.60×10^{-7}	*I*

[a] Beginning of new period change.

minima are largely dispersed than the O–C values of primary minima as suggested by Kurpinska-Winiarska (1980). The period change (ΔP) in the portion *AE* is not strong (4.8×10^{-7} d) like in the portion *IJ*.

4. Summary

A detailed period study of AW UMa reveals that period changes (ΔP) of the order of 10^{-7} to 10^{-6} are present. Three linear trends of period changes are apparent, out of which two are definitive. The third trend indicates a new period change. In the first and third portions the changes in period are not appreciable, however, a change in period around the year 1978 is appreciable. Our results do not show more dispersion of O–C values of secondary minima than the primary ones.

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