PERIOD STUDY OF AX DRACONIS

R.K. SRIVASTAVA
Uttar Pradesh State Observatory, Manora Peak, Nainital, India

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Abstract. A new period (P = $0^d.5681643$) for AX Draconis, based on all available times of minima, has been given. O-C diagrams for the star, based on various periods, have been given. A sinusoidal variation is apparent in figures, which is suggestive of the possible presence of a third body, having a period of more than 80 years.

1. Introduction

The earliest observations of the eclipsing binary system AX Draconis (= AX Dra = BV 40) are attributed to the work of Kippenhahn (1955), who located the star and suspected its variability. Strohmeier and Knigge (1961) carried out photographic observations and presented a photographic light curve, and twelve times of minima. They suggested a period of $0^d.5681644$. Their light curve is suggestive of the fact that the system is of Algol-type.

Numbers of visual minima are given by BBSAG observers. First photoelectric epoch was presented by Faulkner (1986), who gave the period of the system as $0^d.5681616$. Later, Di-sheng *et al.* (1989) carried out photometry of AX Dra in detail and presented the photometric light curve, light elements, spectral types as F1 and K3, and gave a period of $0^d.56816240$. They suggested that the system is of β Lyr-type. None of the period studies given above are complete, and can not be supposed to be the last ventures.

TABLE I
Epochs and periods of AX Dra

Sl. No.	Author	Epoch and period	
1	Strohmeier and Knigge(1961)	J.D. 2426767.675	+ $0^d.5681644$ E
2	Brancewicz and Dworak(1980)	–	+ $0^d.568164$ E
3	Faulkner(1986)	J.D. 2446172.7202	+ $0^d.5681616$ E
4	Di-sheng *et al.*(1989)	J.D. 2446522.1423	+ $0^d.56816240$ E
5	Srivastava (present work, based on all available minima)	J.D. 2426767.659	+ $0^d.5681643$ E
6	Srivastava (present work, based on only pe minima)	J.D. 2446172.7202	+ $0^d.5681660$ E

2. Epoch, Period and New Period

Epochs and periods of AX Dra, determined by various authors, are given in Table I. The table shows some variation in the period of the system. Strohmeier and Knigge (1961) cosidered only 12 photographic minima and gave an epoch and a period. Faulkner (1986) considered only 7 minima including 1 photoelectric minimum, and 6 visual minima. Di-sheng *et al.* (1989) considered only 11 minima, including 3 photoelectric and 8 visual minima. All these investigators have not considered all the minima available in the literature at the time of their studies of the system AX Dra, as such their period studies were incomplete.

We have searched out the whole literature and, in all, 33 minima have been collected from the literature, out of which 15 are visual, 13 photographic and 5 photoelectric. All these minima are primary and no secondary minimum is available to us.

Using the initial epoch and period, a new period has been derived, based on all minima, from the method of least squares, which comes out to be $0\overset{d}{.}5681643$ ($\pm 0\overset{d}{.}0000001$). A photoelectric period has been derived, using only 5 photoelectric minima available to us, employing the photoelectric epoch, Pri. Min. = J.D. 2446172.7202, given by Faulkner (1986). The period comes out to be $0\overset{d}{.}5681660$ ($+0\overset{d}{.}0000001$).

3. O-C Diagrams and Period Variation

The period studies given by Strohmeier and Knigge (1961), Faulkner (1986) and Di-sheng *et al.* (1989) have been reviewed and found that these have been far from satisfactory, as being incomplete, not considering all times of minima available in the literature. All available times of minima, numbering 33, obtained in the time interval 1932 to 1986, have been listed in Table II. Four O-C diagrams (Figs. 1 to 4) have been drawn from the O-C values based on the following ephemerides:

1. Primary Minimum = J.D. 2426767.659+$0\overset{d}{.}5681644$ E, (Strohmeier and Knigge, (1961));
2. Primary Minimum = J.D. 2426767.659+$0\overset{d}{.}5681643$ E, (Srivastava, present work, based on all available times of minima);
3. Primary Minimum = J.D. 2426767.659+$0\overset{d}{.}56816240$ E, (Di-sheng *et al.*, 1989);
4. Primary Minimum = J.D. 2426767.659+$0\overset{d}{.}5681616$ E, (Faulkner, 1986, based on pe min only).

Comparing the four O-C diagrams (Figs. 1 to 4), it is apparent that:

1. The period appears to be little over estimated in first O-C diagram (Fig. 1);
2. The period appears to be quite satisfactory as the O-C values balance them equally around O-C = $0\overset{d}{.}000$ in second O-C diagram (Fig. 2);
3. The period appears to be under estimated in third O-C diagram (Fig. 3);
4. The period appears to be under estimated in fourth O-C diagram (Fig. 4).

TABLE II

Minima of AX Dra

J.D.	Min.	Type of Observ.	Cycle	Mean of Cycles	Based on P=$0^d.5681644$ O-C(I)	Based on P=$0^d.5681644$ Mean of O-C(I) values	Based on P=$0^d.5681643$ O-C(II)	Based on P=$0^d.5681643$ Mean of O-C(II) values	Based on P=$0^d.56816240$ O-C(III)	Based on P=$0^d.56816240$ Mean of O-C(II) values	Based on P=$0^d.5681616$ O-C(IV)	Based on P=$0^d.5681616$ Mean of O-C(IV) values	Reference
2426767.659	I	pg	0		$0^d.000$		$0^d.000$		$0^d.000$		$0^d.000$		1
2426767.675	I	pg	0		+0.016		+0.016		+0.016		+0.016		2
				3		$+0^d.018$		$+0^d.018$		$+0^d.018$		$+0^d.018$	
2426770.519	I	pg	5		+0.019		+0.019		+0.019		+0.019		1
2427459.706	I	pg	1218		+0.023		+0.023		+0.025		+0.026		1
				1282		+0.026		+0.026		+0.028		+0.029	
2427532.437	I	pg	1346		+0.029		+0.029		+0.031		+0.032		1
2428957.385	I	pg	3854		+0.020		+0.021		+0.028		+0.031		1
2429024.452	I	pg	3972	3945	+0.044	+0.030	+0.044	+0.030	+0.052	+0.038	+0.055	+0.041	1
2429045.456	I	pg	4009		+0.026		+0.026		+0.034		+0.037		1
2436614.552	I	pg	17331		+0.036		+0.038		+0.070		+0.084		1
2437018.493	I	pg	18042		+0.012		+0.014		+0.048		+0.062		1
2437026.455	I	pg	18056	18113	+0.020	+0.017	+0.024	+0.020	+0.056	+0.053	+0.070	+0.068	1
2437315.635	I	pg	18565		+0.004		+0.006		+0.041		+0.056		1
2437319.622	I	pg	18572		+0.014		+0.016		+0.051		+0.066		1
2445061.390	I	v	32198		−0.026		−0.023		+0.038		+0.064		3
2445061.397	I	v	32198		−0.019		−0.016		+0.045		+0.071		4
2445061.404	I	v	32198		−0.012		−0.009		+0.052		+0.078		4
2445075.601	I	v	32223		−0.019		−0.016		+0.045		+0.071		5
2445104.571	I	v	32274		−0.026		−0.023		+0.039		+0.065		6
2445116.511	I	v	32295		−0.017		−0.014		+0.047		+0.073		7
2445120.486	I	v	32302		−0.019		−0.016		+0.045		+0.071		7
2445388.655	I	v	32774		−0.024		−0.021		+0.042		+0.068		7

TABLE II *Continued*

J.D.	Min.	Type of Observ.	Cycle	Mean of Cycles	Based on P=$0^{d}.5681644$ O-C(I)	Mean of O-C(I) values	Based on P=$0^{d}.5681643$ O-C(II)	Mean of O-C(II) values	Based on P=$0^{d}.56816240$ O-C(III)	Mean of O-C(II) values	Based on P=$0^{d}.5681616$ O-C(IV)	Mean of O-C(IV) values	Reference
2445561.381	I	v	33078		$-0^{d}.020$		$-0^{d}.017$		$+0^{d}.046$		$+0^{d}.073$		8
2445615.345	I	v	33173		−0.032		−0.028		+0.035		+0.061		8
				33304		$-0^{d}.023$		$-0^{d}.020$		$+0^{d}.044$		$+0^{d}.070$	
2445635.238	I	v	33208		−0.024		−0.021		+0.042		+0.069		8
2445816.487	I	v	33527		−0.020		−0.016		+0.047		+0.074		8
2445936.367	I	v	33738		−0.023		−0.019		+0.045		+0.072		9
2446115.339	I	v	34053		−0.022		−0.018		+0.046		+0.073		10
2446145.445	I	v	34106		−0.029		−0.026		+0.039		+0.066		9
2446172.7201	I	pe	34154		−0.0258		−0.0224		+0.0425		+0.0701		11
2446172.7202	I	pe	34154		−0.0257		−0.0223		+0.0426		+0.0702		11
2446522.1401	I	pe	34769		−0.0269		−0.0234		+0.0427		+0.0705		12
2446522.1423	I	pe	34769		−0.0247		−0.0212		+0.0449		+0.0727		12
2446589.1878	I	pe	34887		−0.0226		−0.0191		+0.0472		+0.0751		12

(In deriving O-C(I), O-C(II), O-C(III) and O-C(IV) values, we have used E=2426767.659.)

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BAVM = Beobachtungsergebnisse der Berliner Arbeitgemeinschaft für Veränderliche Sterne, Mitteilungen,
BBS = Bedeckungs-Veränderlichen Beobachter der Schweizerischen Astronomische Gessellschaft, Bulletin, CAPP = Chinese Astronomy and Astrophysics,
PASP = Publication of the Astronomical Society of Pacific; PPEN = Publications of the University of Pennsylvania Astronomical Series;
VBAM = Veröffentlichungen der Remeis Sternwarte, Bamberg(Astronomische Institute der Universität Erlangen-Nürnberg).

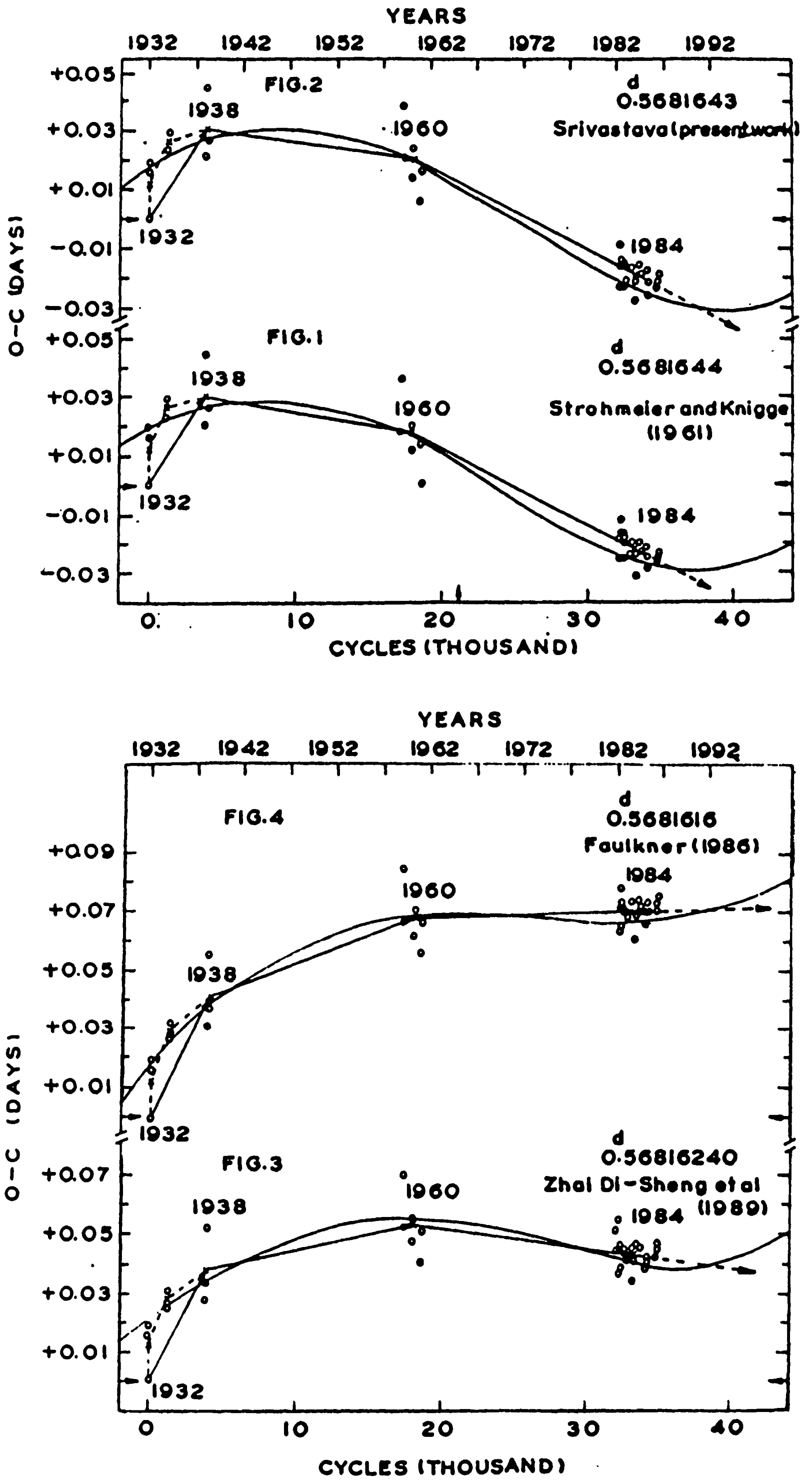

Fig. 1. O-C diagrams based on different periods. The horizontal arrows in the figures show the line of O-C = 0.^{d}000. The wavy curves in the figure show the sinusoidal variation. Other arrows show the future trend of O-C curves.

Thus, it is apparent that the period derived by us, $P = 0^{d}.5681643$ ($\pm 0^{d}.0000001$), based on all minima, is quite satisfactory, as O-C values vary almost equally around zero O-C line.

4. Sinusoidal Variation and Third Body

In all the O-C diagrams, a sinusoidal variation is apparent, which is suggestive of the presence of a third body. The time interval, spanning between 1947 to 1987 from maximum to minimum of sinusoidal curve, is slightly more than 40 years, and it is suggestive of a third body period of more than 80 years.

It is unfortunate that the times of secondary minima are not available in the literature, which could have revealed some more characteristics of the system such as apsidal motion and eccentricity etc.

5. Period Variation

The O-C values have been grouped as shown in Table II, and mean O-C values have been obtained to locate the average O-C pattern. The O-C diagram based on our present period ($0^{d}.5681643$) shows a range of O-C variation from $-0^{d}.028$ to $+0^{d}.044$, the total change being $0^{d}.072$, which is beyond the limits of normal errors incurred in minima of different type of observations. However, few visual minima have lesser and doubtful significance, as scanty observations are available.

The O-C diagrams clearly show change in period around the years 1938 and 1960. In addition, minor fluctuation is also seen around 1934. The quantitative analysis of the period is undesirable with the present sample of data, as the O-C diagrams are scantily covered with minima observations. The observations are populated between 1932 to 1938, around 1960, and between 1982 to 1986.

Di-sheng *et al.* (1989) suggested that the main star is more near to filling its Roche-lobe. The investigations of the system AX Dra by Brancewicz and Dworak (1980) suggest that AX Dra is nearly a contact system of β Lyr-type. Thus, the studies of Brancewicz and Dworak (1980), and Di-sheng *et al.* (1989) suggest that AX Dra is either a contact system or a near semi-detached system hence, the period variation is a possibility, and may be caused by mass transfer process between the components.

6. Summary

Present period study covers the observations of the time interval, 1932 to 1986, and surpasses all previous period studies, as it takes into account all the available times of minima. A sinusoidal variation is apparent in the O-C diagrams suggesting a third body with a period of more than 80 yrs. The period changes are also apparent around 1936 and 1960. These period variations are a possibility as the system is possibly a contact or a semi-detached system of β Lyr-type. For a better picture of the period variation present in the system, the times of secondary minima are badly needed.

References

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