COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS
Number 1278

Konkoly Observatory
Budapest
1977 May 18

UBV PHOTOMETRY OF THE ECLIPSING BINARY SX AURIGAE

The variability of SX Aurigae (HD 33357) was discovered by Leavitt, and its period was first correctly determined by Hertzsprung. The first precise light curve of SX Aurigae was obtained by Oosterhoff (1933), who acquired 1191 photographic observations of the system. More recently Bondarenko (1974) obtained 215 photoelectric observations in blue light and 212 observations in yellow light.

This investigator began his observations of SX Aurigae in January, 1976. Using the 40-cm telescope no. 4 of Kitt Peak National Observatory, observations of this star were made in UBV. These observations were supplemented by later ones made with the 46-cm reflector of the Kutztown State College Observatory.Totals of 508 observations in V, 512 in B, and 481 in U have been obtained with coverage of all phases.

A new ephemeris for SX Aurigae has been obtained using all available photoelectric times of minimum light. In the least-squares solution all times were given equal weight. The times of minimum and their residuals are as follows:

JD Hel.	E	O-C	Ref.
2440162.3358	0	$-0^d.0004$	IBVS No.456
271.241	90	-0.0024	Bondarenko
289.396	105	+0.0014	IBVS No.456
491.478	272	+0.0001	"
683.277	430.5	+0.0015	Bondarenko
1677.3552	1252	-0.0009	IBVS No.937
1691.271	1263.5	-0.0010	"
1692.4819	1264.5	-0.0002	"
1763.275	1323	+0.0033	"
1769.3242	1328	+0.0021	"
1775.372	1333	-0.0005	"
1957.4886	1483.5	-0.0009	"

2132.3431	1628	-0.0030	IBVS No.1053
2403.4045	1852	+0.0006	"
2790.6298	2172	+0.0004	Chambliss
2793.6549	2174.5	+0.0003	"
3099.8040	2427.5	-0.0008	"
3113.7212	2439	+0.0005	"

The times previously published in the IBVS were obtained by Kizilirmak and Pohl from observations made at the Ege University Observatory in Izmir, Turkey. Two of the other times were obtained by myself using observations published by Bondarenko, while the last four were obtained from my own observations. The resultant ephemeris is:

$$\text{Min.I} = \text{JD}\ 2440162.3362 + 1^{d}\!.2100797 \cdot E.$$
$$\pm\ 5 \quad \pm\ 3\ \text{p.e.}$$

This period is almost identical to that originally published by Hertzsprung ($P=1^{d}\!.2100795$), and it differs only $0^{s}\!.2$ from that obtained by Oosterhoff. Thus it does not appear that the period of SX Aurigae has varied significantly over the past 50 years.

As a comparison the star HD 33411 was used, and for checks the stars HD 33324 and HD 33412 were observed. The magnitudes and colors which I determined for these stars are as follows:

HD 33411	V=8.182	B-V=+0.058	U-B=-0.595
HD 33324	8.284	+0.011	-0.292
HD 33412	8.528	+0.090	-0.268

The spectral types listed in the Henry Draper Catalogue for these stars are B8, B8 and B9, respectively, but the spectral type of HD 33411 is certainly much earlier than this. For SX Aurigae a spectral type of A3 is given, but Popper (1943) estimated the spectral types of both components as B3.5 on the basis of the strengths of their hydrogen and helium lines.

SX Aurigae is a Beta Lyrae-type eclipsing binary with continuous variation in its light curve at all phases. The eclipses are not complete. The following magnitudes as colors were obtained for this system.

max.	V=8.382	B-V=+0.015	U-B=-0.695
pri.	9.140	+0.022	-0.631
sec.	8.867	-0.004	-0.714

The corresponding depths of the eclipses are:

	V	B	U
pri.	$0^{m}\!.758$	$0^{m}\!.765$	$0^{m}\!.829$
sec.	0.485	0.466	0.447

Thus SX Aurigae follows the usual rule for eclipsing binaries, i.e., the system is reddest at primary minimum and bluest at secondary minimum. The change in color at secondary minimum is not so pronounced as Bondarenko indicates, however, and the asymmetry in the primary minimum reported by him also appears to be spurious, as the observations of this investigator as well as those of Oosterhoff do not indicate any significant asymmetries in the light curves of SX Aurigae.

The colors listed above for SX Aurigae indicate that the system is strongly reddened. The color excess E(B-V) is about $0^m.24$, while E(U-B) is about $0^m.17$. These results are to be expected, since SX Aurigae lies almost exactly on the galactic equator. Although Popper found that both components of SX Aurigae, a double-lined spectroscopic binary, had similar spectra, the difference in depths of the minima led him to assign spectral types of B2.5 and B5 to the respective components.

Least-squares solutions were made for the observations outside eclipses expressed as a Fourier series with terms through 20. Observations with phase angles between 40° and 140° and between 220° and 320° were used, and these were normalized to unity at maximum light. The coefficients which were obtained together with their probable errors are as follows:

	A_o	A_1	A_2	B_1	B_2
A)	+0.9188	-0.0074	-0.0838	-0.0048	-0.0027
	24	27	36	14	17
B)	+0.9051	-0.0439	-0.0865	+0.0136	+0.0244
	28	32	38	15	21
C)	+0.8919	-0.0492	-0.0956	+0.0118	+0.0213
	24	28	33	13	17
D)	+0.9034	-0.0176	-0.0963	-0.0007	-0.0013
	4	4	6	2	3
E)	+0.9072	-0.0181	-0.0923	-0.0012	-0.0018
	4	5	6	2	3
F)	+0.8980	-0.0249	-0.1001	-0.0008	-0.0016
	5	6	8	3	4

Notes: A: 24 photographic normal points of Oosterhoff, phases used are those given by him

B: 74 p.e.obs. of Bondarenko in yellow light, phases calculated with ephemeris given in this bulletin

C: 82 p.e.obs. of Bondarenko in blue light

D: 251 obs. of Chambliss in V

E: 253 obs. of Chambliss in B

F: 253 obs. of Chambliss in U

The coefficients obtained using the observations of this investigator are clearly more precise than are those of the earlier observers. Although the observations of Bondarenko indicate substantial values for the asymmetry coefficients, B_1 and B_2, my own observations do not support this.

The coefficient A_2 arises largely from the ellipticity effect, and the values listed above indicate that the components of SX Aurigae are significantly distorted from spherical shape. However, the values of A_2 are not as large as those normally encountered in W Ursae Majoris systems, which usually have A_2 coefficients in the range -0.11 to -0.15. The coefficient A_1 arises largely from the reflection effect, and in SX Aurigae this effect appears to be significant. In view of the fact that the two minima differ substantially in depth, this is to be expected.

Thus far two solutions for the photometric orbital elements of SX Aurigae have been published. These are by Oosterhoff and by Wyse (1934). Oosterhoff considered the two components to be spherical, but nearly in contact. Wyse indicated that this was unsatisfactory, but in the solutions which he obtained, the sums of the semimajor axes of the components, a_1+a_2, total about 0.87. For a system in which both components fill their Roche lobes, this sum should not exceed a value of about 0.77. This is the value which is often encountered with W Ursae Majoris stars, but in SX Aurigae the value of A_2 is somewhat less than that encountered in the W Ursae Majoris stars, and consequently we should expect the sum of the semimajor axes of the components also to be somewhat less. Thus a value of 0.87 for this sum in SX Aurigae is quite unrealistic.

This investigator is presently working on new solutions for the photometric orbital elements of SX Aurigae based on his own light curves.

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