CLASSIFICATION OF THE ENIGMATIC NANTUCKET VARIABLE XX SCT

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Abstract

The irregular variable XX Sct has been ascribed five different variability types since its discovery in 1924, from a Cepheid to a rapid irregular variable. Re-examination of nearly 1200 blue photographic plates of this star at the Maria Mitchell Observatory revealed strong irregular variability of up to 3 magnitudes on different time scales. Several possible periods have been found, none of which are particularly convincing. UBV photometry and a low-resolution optical spectrum are consistent with a reddened A star. We tentatively suggest that XX Sct is one of the class of young, intermediate mass Herbig Ae/Be stars known as UXors.

1. Introduction

XX Sct was discovered over 75 years ago, yet remains without a definitive classification. We began study of this star as a possible T Tauri candidate. After an examination of the most recent photographic plate data, we thought XX Sct appeared rather interesting and needed further classification.

A search of the literature reveals very little about XX Sct. The coordinates for XX Sct are RA $18^h 39^m 37^s$ and Dec -06° 42.9' 54.0" (Epoch J2000). The fourth edition of the *General Catalogue of Variable Stars* (GCVS) (Kholopov *et al.* 1987) classifies XX Sct as an IS variable: "rapid variations with no apparent connection to nebulosity." However, on many of the better plates in the Maria Mitchell Observatory (MMO) collection, there does appear to be some sort of nebulosity near XX Sct. The GCVS also gives $mpg_{max} = 13.2$ and $mpg_{min} = 15.2$. A literature search in the astronomical database SIMBAD reveals only three entries referring to XX Sct since the 1970's. The earliest (Hyland and Neugebauer 1970) mentions only that Nova Serpentis 1970's light curve is similar to that of XX Sct, but further exploration reveals they must be referring to a different star. The other two articles (Cieslinski *et al.* 1997, 1998) give colors: V = 13.17, U-B = 0.68, B-V = 0.79 and a low resolution

Table 1. Previous classifications of XX Sct.

Classification	*Source*
Cepheid	Cannon 1924
RR Lyrae	Harwood 1931
Irregular	Bakos 1950
RW Aurigae	Tsessevich 1973
R Coronae Borealis	Morgan 1978
Irregular	Kholopov 1987

optical spectrum, which the authors classify as SpT G0–G2 with Hα in emission. The authors were unable to further classify XX Sct, merely confirming its irregular variability. A more extensive search of the literature revealed that since its discovery in 1924 by Annie Jump Cannon, XX Sct has been classified at least six different times. These classifications are given in Table 1. Clearly, the confusion surrounding XX Sct makes it an evocative object to study.

2. Light curve analysis

The light curve of XX Sct shown in Figure 1 was made by eye estimates of nearly 1200 blue photographic plates over the 65-year period from 1926 to 1991. The eye estimates from 1926 to 1939 were done by N. S., while those done between 1940 and 1991 were done by J. B. This can cause only minor differences in magnitude ranges and step sizes. The error in these eye estimates is 0.1–0.2 magnitude, which is the limit of the human eye to see differences in brightness. There are gaps in the data of several years in which either no plates were taken at the MMO or else the Scutum cloud was

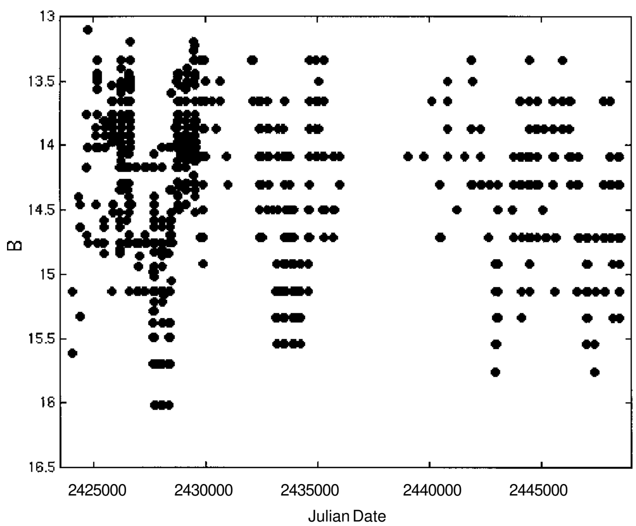

Figure 1. This light curve of XX Sct for 1926–1991 was made by eye estimates of nearly 1200 blue photographic plates from the Maria Mitchell Observatory over the 65-year period from 1926 to 1991.

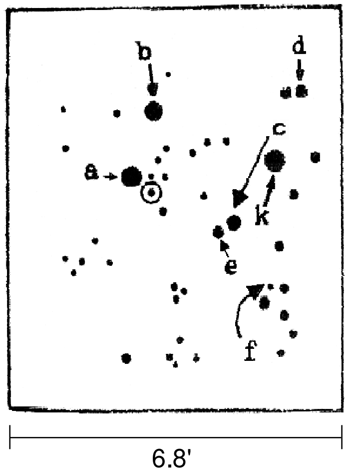

Table 2. Comparison stars for XX Sct.

Star	m_1	m_2
k	12.87	12.98
a	13.29	13.34
b	13.94	13.66
c	—	14.30
d	14.50	14.71
e	15.22	15.13

Figure 2. Finder chart for XX Sct from Tsessevich and Dragomiretskaya (1973). North is up; west is to the left.

not a focus of observations. The finder chart used is shown in Figure 2. Comparison stars used in the eye estimates were labeled a–e and k, and their magnitudes are given in Table 2. The magnitudes were given by Tsessevich and Dragomiretskaya (1973) (column 2) intially, and then revised using eye estimates by one of the authors (N. S.) (column 3) after determining that the previous magnitudes were uneven.

Over the 65-year baseline of observations, XX Sct varies from magnitude approximately 13.0 to 16.6 in the photographic B-band. These estimates surpass the values found in the literature at both the dim and bright ends of the scale. Overall, XX Sct shows irregular light variations that can range 3 magnitudes within one year. A drop of 0.4 magnitude in one night is common, though the rise back to the average magnitude usually takes longer than one night. In fact, XX Sct can stay at minimum light for more than one week at a time while showing variations of light within that minimum.

Table 3 is an analysis of each individual year in which more than 10 data points were obtained for XX Sct. The table displays the year of observation, the number of data points from that year, maximum magnitude, minimum magnitude, the average magnitude, magnitude range, the type of variations seen within one night with *t* given in days and Δm given in magnitudes, and the type of variations seen on a longer scale of 1–20 days. The average range in a given year was 1.32 magnitudes, while the largest and smallest ranges were 3.05 and 0.095 magnitudes, respectively. The maximum drop in brightness in one day is 1.85 magnitudes during 1934. For changes in magnitude within one night, the steepest is an 0.83 magnitude rise in 0.029 day in 1980.

2.1. Selected Years

The year 1936 (Figure 3) shows an example of an Algol-like minimum occurring at JD 2428336.732, with a drop of 1.52 magnitudes in 0.098 day. This year also shows nearly the full range of variation from magnitude 13.6 to 16.6.

In 1940 (Figure 4), XX Sct hovered near maximum light around magnitude 13.7 and made one steep drop of over 1.0 magnitude around JD 2429847. There are smaller variations within that 6-day minimum.

2.2. Average Magnitude

Within a single year, XX Sct can vary by as much as 3 magnitudes. Its average magnitude (Figure 5) also varies greatly from year to year, at times changing over 1.0

Table 3. Light curve characteristics of XX Sct.

Year	*Pts*	*Maximum*	*Minimum*	*Avg*	*Range*	$t<1$	Δm	$1<t<20$	Δm
1927	19	$13^{\mathrm{m}}.80$	$14^{\mathrm{m}}.75$	$13^{\mathrm{m}}.70$	$0^{\mathrm{m}}.95$	$0^{\mathrm{d}}.054$	$-0^{\mathrm{m}}.13$	13^{d}	$+1^{\mathrm{m}}.25$
1928	13	13.81	14.84	14.41	1.03	—	—	14	+0.94
1929	29	13.53	15.14	13.90	1.61	0.100	-0.44	1	-1.22
1930	64	13.34	14.84	14.10	1.50	0.058	-0.67	19	+1.41
1931	51	13.20	15.14	14.05	1.94	0.097	+0.63	2	-1.09
1932	57	14.17	15.13	14.74	0.96	0.063	+0.58	1	-0.96
1933	45	14.17	15.13	14.68	0.96	0.030	-0.96	8	-0.96
1934	60	14.07	16.02	15.00	1.95	0.058	+1.05	1	+1.85
1935	61	14.02	16.02	15.01	2.00	0.060	-1.27	7	-2.00
1936	39	13.60	16.65	15.02	3.05	0.098	-1.52	5	+1.27
1937	35	13.44	14.50	13.96	1.06	0.051	+0.73	3	+0.67
1938	28	13.40	14.46	13.89	1.06	0.083	+0.41	2	+0.81
1939	63	12.98	14.52	13.87	1.54	0.025	+0.65	6	+1.29
1940	78	13.34	14.92	13.84	1.58	0.069	+0.62	4	-1.37
1947	53	13.66	14.71	14.06	1.05	0.025	+0.43	19	+1.21
1948	46	13.66	14.50	14.08	0.84	0.035	-0.41	7	-0.84
1949	22	13.87	15.55	15.05	1.68	0.029	-0.42	2	+0.63
1950	43	13.66	15.55	14.84	1.89	0.050	-0.42	6	-1.25
1951	30	14.09	15.55	14.85	1.46	0.042	-0.42	18	+1.05
1952	21	14.92	15.55	15.28	0.63	0.019	-0.42	5	-0.63
1953	25	13.34	15.13	14.32	1.79	0.031	-0.42	6	-1.36
1954	13	13.34	14.09	13.84	0.75	0.035	-0.43	2	-0.75
1976	32	14.30	15.76	15.19	1.46	0.031	-0.21	3	-1.04
1978	11	14.09	14.71	14.54	0.62	0.025	-0.21	6	-0.62
1979	18	13.66	15.34	14.64	1.68	0.034	-0.62	12	+0.64
1980	27	13.34	15.13	14.38	1.79	0.029	+0.83	20	-1.79
1981	17	13.66	14.71	13.97	1.05	—	—	6	-1.05
1983	11	13.66	15.13	14.28	1.47	0.028	-0.21	2	-0.43
1985	14	13.66	14.30	14.02	0.64	0.099	+0.43	3	-0.64
1987	24	14.71	15.55	15.12	0.84	0.058	+0.42	7	+0.84
1990	10	13.66	15.34	14.46	1.68	0.074	-0.41	2	+1.05
1991	22	14.09	15.34	14.65	1.25	0.073	+0.62	20	-0.83

magnitude from one year to the next. For example, in 1936 XX Sct had an average magnitude of 15.02, then suddenly brightened in 1937 to an average magnitude of 13.96. However, even on a yearly scale, there is no pattern to this variability.

3. BVRI photometry

On September 10–11, 1999, the NURO (National Undergraduate Research Observatory, Flagstaff, AZ) 31-inch telescope was used (data were taken by Regina Jorgenson of the MMO and reduced by J. B.) with a TEK 512x512 back-illuminated, metachrome-coated CCD to obtain images of XX Sct in B, V, R, and I bands. The results of this photometry will be published in their complete form in a later paper; however, the main results are given here. Table 4 gives the magnitudes and color indices in BVRI we obtained for XX Sct as well as the UBV photometry already published (Cieslinski *et al.* 1997). At the time of our observations, XX Sct was over one magnitude dimmer than at the time of the previously published observations, yet well within the range of magnitudes seen on the photographic plates. There appears to be an infrared excess, given from the value R-I = +0.99. Figure 6 shows that this

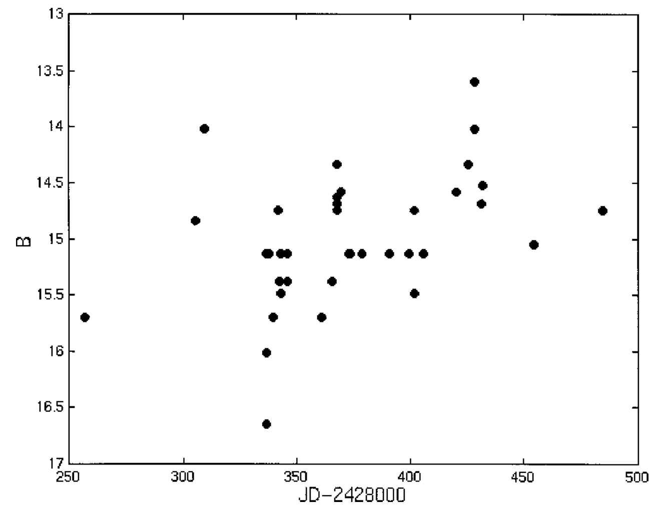

Figure 3. The year 1936 shows an example of an Algol-like minimum occurring at JD 2428336.732, with a drop of 1.52 magnitudes in 0.098 day. This year also shows nearly the full range of variation from magnitude 13.6 to 16.6.

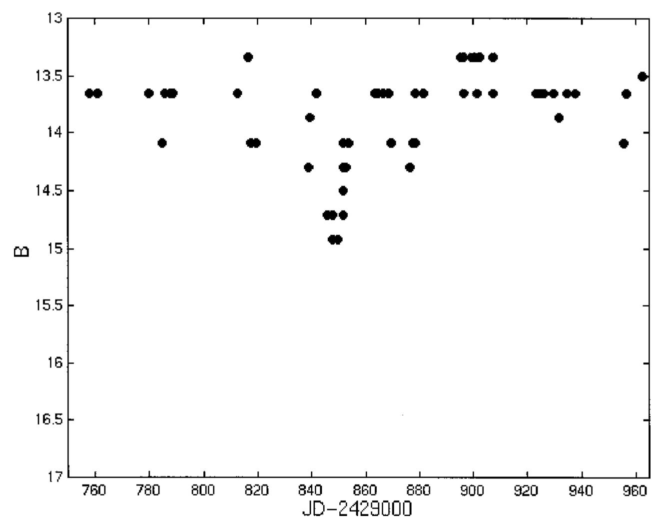

Figure 4. In 1940, XX Sct hovered near maximum light around magnitude 13.7 and made one steep drop of over 1.0 magnitude around JD 2429847. There are smaller variations within that 6-day minimum.

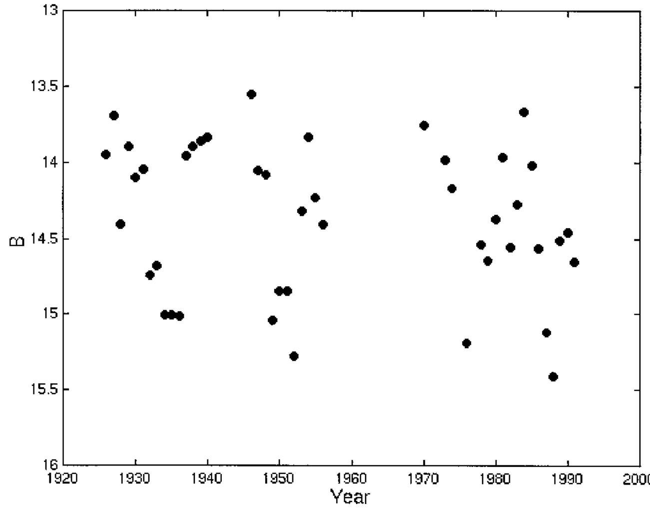

Figure 5. The average magnitude of XX Sct for each given year from 1926 to 1991 is shown in blue photographic magnitude vs time. The average magnitude varies from year to year by as much as one magnitude, but with no apparent pattern to this variability.

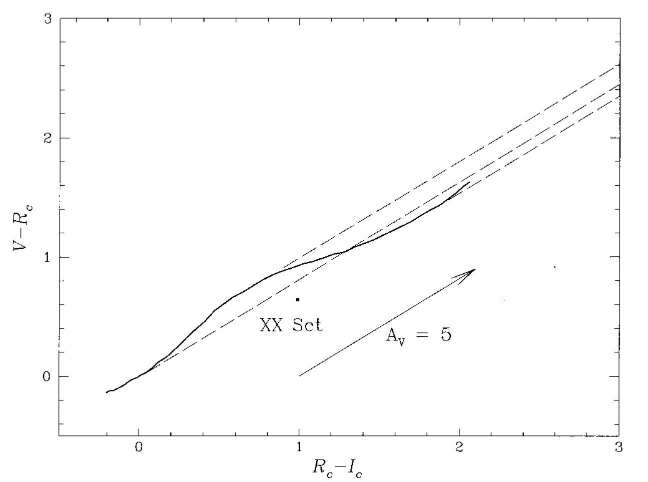

Figure 6. This two-color plot (V-R *vs* R-I with reddening vectors) shows XX Sct is well below the main sequence, even accounting for interstellar reddening. The infrared excess could be explained by a circumstellar disk. Main sequence VRI data taken from Straizys 1992. The dashed lines indicate the reddening vector for different positions on the main sequence.

Table 4. BVRI photometry of XX Sct.

Filter	m_{st}	*Cieslinski 1997*
U	—	14.64
B	15.05	13.96
V	14.13	13.17
R	13.49	—
I	12.50	—

Color Index	*Color*	*Cieslinski 1997*
U-B	—	+0.68
B-V	+0.97	+0.79
V-R	+0.64	—
R-I	+0.99	—

places XX Sct below the main sequence curve in such a way that even interstellar reddening would not return it to the main sequence. This infrared excess could be explained by a circumstellar disk surrounding a young star.

4. Conclusion

XX Sct shows irregular light variations of up to 3 magnitudes with Algol-type minima. BVRI photometry shows an infrared excess that could be indicative of a circumstellar disk. The nebulosity found in the region of XX Sct could indicate a star-forming region from which XX Sct may have only recently drifted away. These facts, combined with the Hα shown in emission, all make XX Sct a likely candidate for the class of young, intermediate-mass Herbig Ae/Be stars known as UXors.

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