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PERIOD VARIATION OF XX CYGNI REVISITED

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The light variation of XX Cygni (= HIP 98737, spectral type A5–F5, $\langle V \rangle = 11\overset{m}{.}7$, $P \approx 0\overset{d}{.}1349$, $\Delta V = 0\overset{m}{.}80$) was discovered by Ceraski (1904). While Shapley & Shapley (1915) referred to XX Cyg as "the shortest-period variable star known", McNamara & Feltz (1980) highlighted the importance of XX Cyg by noting the fact, that this star has longer period than any other high-velocity variables of this type. The single periodic nature of the star was recognized by Nijland (1923) and the follow-up studies regarding the description of the light variation concentrated on detecting small, secular changes of the light curve shape or the period. A full set of physical parameters was determined by Joner (1982). Szeidl & Mahdy (1981) published a very thorough period study concluding that the period of XX Cyg suffered a sudden change by $+87 \times 10^{-9}$ day ($\Delta P/P = 6 \times 10^{-7}$) in 1942 and was constant otherwise. Since then a few times of maxima have been published in almost every observing season, but there has been no paper dealing with the very recent behaviour of the period change. For this purpose, we made new CCD observations, collected all available epochs of maximum and analysed the resulting $O - C$ diagram.

Unfiltered CCD observations were carried out at University of Szeged on three subsequent nights (July 31–August 2, 2000). The applied instrument was the 0.28-m Schmidt–Cassegrain-type telescope located in the very center of the city of Szeged. The detector was an SBIG ST–9E CCD camera (512 × 512 pixels) giving an angular resolution of about $2''$/pixel. The exposure time was 20 seconds and the frames were obtained almost uninterruptedly enabling a very good phase coverage during every cycle.

The data were reduced with standard tasks in IRAF. We made aperture photometry with IRAF/DIGIPHOT. Two nearby stars were chosen as comparison and check stars (comp = GSC 3948-2542, $10\overset{m}{.}4$, check = GSC 3948-2105, $10\overset{m}{.}9$). Throughout the observations we did not find significant differential brightness variations larger than $0\overset{m}{.}015$ implying a photometric accuracy of the same order. A single-night light curve is shown in Fig. 1. The whole dataset contains 826 individual data points obtained on three nights. They are available upon request from the first author. All data were phased with the finally adopted ephemeris (see later) and the corresponding phase diagram is plotted in Fig. 2.

Five new times of maxima were determined from the individual cycles by fitting low-order (3–5) polynomials to the top part of the light curves. The estimated accuracy is about 0.0003 days. To construct the updated $O - C$ diagram, we collected all available data from the literature. Szeidl & Mahdy (1981) gave a full compilation until 1980,

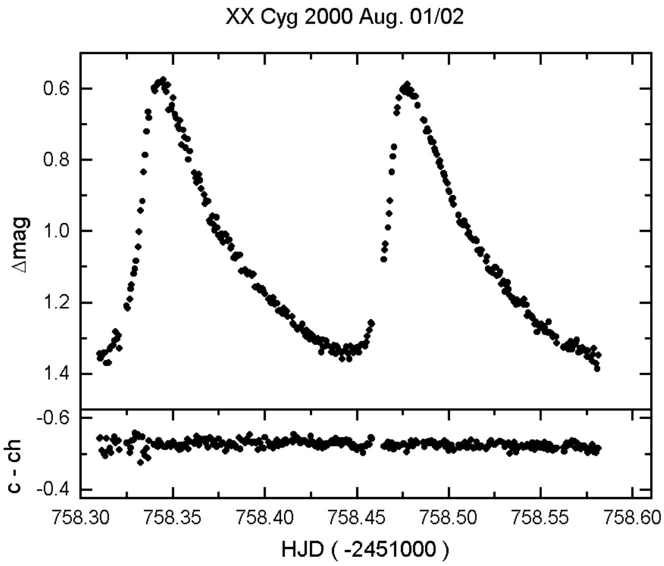

Figure 1. The unfiltered light curve of XX Cygni obtained on August 1, 2000

therefore, we had only to add new data published by Romano & Perissinotto (1982), Joner (1982), Sadun & Ressler (1986), Rodríguez et al. (1993), Kim & Joner (1994) and Agerer & Hübscher (2000). In cases when the authors listed only the photometric data, we determined the individual epochs of maximum with the same fitting procedure. We have to note that the typical light curve sampling is less dense than ours, therefore, some of the determined epochs are of lower quality.

The final sample including times of maxima from Szeidl & Mahdy (1981) contains 88 points. The $O-C$ values were calculated with the same formula as in Szeidl & Mahdy (1981): Hel. $\mathrm{JD}_{\mathrm{max}} = 2430671.1010 + 0.134865070 \times E$. Six discordant points which were obviously bad had to be rejected. The remaining 82 points were used to form yearly means of the cycle numbers and $O-C$ values. The resulting diagram is plotted in Fig. 3.

The two well-defined linear branches give further support to the main conclusion by Szeidl & Mahdy (1981) that the period of XX Cyg suffered a sudden change in 1942 and since then it has remained constant. The amount of period change is $(+92.8 \pm 9.8) \times 10^{-9}$ days, or $\Delta P/P = 6.9 \times 10^{-7}$. This is somewhat larger than the value determined by Szeidl & Mahdy (1981) — 87×10^{-9} days — that can be attributed to our longer dataset allowing higher accuracy. Our work extends the results of Szeidl & Mahdy (1981) by a further 20-year long period of time and thanks to the relatively large number of observations, we could determine a very accurate ephemeris for XX Cyg. By a least-squares linear fit of the second branch of the $O-C$ diagram, we obtained the following formula:

$$\text{Hel. JD}_{\mathrm{max}} = 2451757.3984 + 0.13486513(5) \times E.$$

The reason of the abrupt period change has remained essentially unknown since its detection. Recently, Breger & Pamyatnykh (1998) shortly discussed the observed period changes in SX Phe stars concluding that sudden jumps cannot be described in terms of long-term stellar evolution, but they are most likely in connection with nonlinear effects in pulsation. Similar conclusion was also reached by Rodríguez et al. (1995). Mixing events in the semiconvective zone or slight overshooting at the convective core edge predicted by

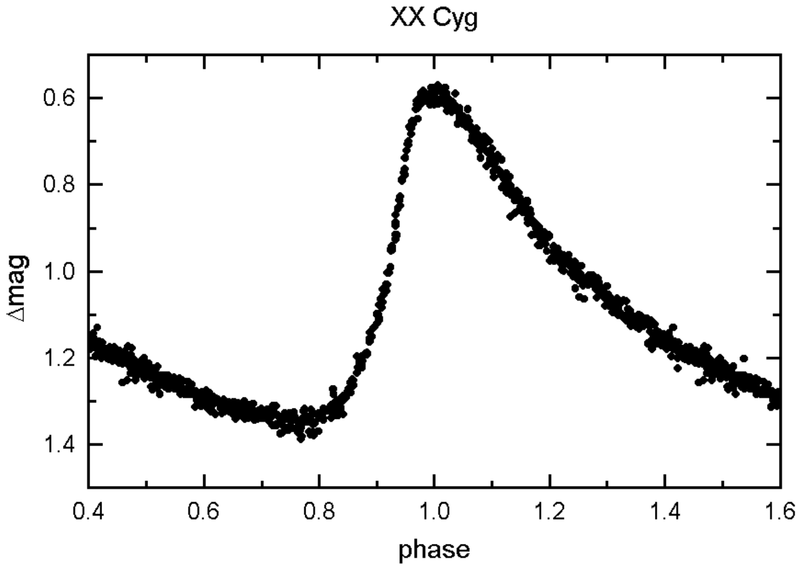

Figure 2. The phase diagram of all unfiltered observations calculated with the adopted ephemeris (E_0 = HJD 2451757.3984, $P = 0.134865123$ days)

Table 1: Times of maxima of XX Cyg (HJD – 2400000). References: (1) Romano & Perissinotto (1982), (2) Joner (1982), (3) Sadun & Ressler (1986), (4) Rodríguez et al. (1993), (5) Kim & Joner (1994), (6) Agerer & Hübscher (2000). Cycle numbers and $O-C$ values were calculated with the ephemeris of Szeidl & Mahdy (1981)

Hel. JD	E	$O-C$	Ref.	Hel. JD	E	$O-C$	Ref.
38939.4210	61308	0.0123	(1)	46631.7142	118345	0.0065	(5)
38961.3960	61471	0.0043	(1)	46951.6171	120717	0.0094	(4)
40124.3460	70094	0.0128	(1)	46999.4899	121072	0.0051	(4)
40152.2470	70301	−0.0033	(1)	46999.6249	121073	0.0053	(4)
44437.8645	102078	0.0069	(2)	47001.5153	121087	0.0076	(4)
44440.8298	102100	0.0052	(2)	47001.6508	121088	0.0082	(4)
44456.7445	102218	0.0058	(2)	47004.4814	121109	0.0066	(4)
44461.7353	102255	0.0066	(2)	47360.7955	123751	0.0072	(5)
44461.8705	102256	0.0069	(2)	47361.7374	123758	0.0051	(5)
44513.6594	102640	0.0076	(2)	50674.4279	148321	0.0049	(6)
45901.6893	112932	0.0062	(3)	50677.3965	148343	0.0064	(6)
45906.6798	112969	0.0067	(3)	50677.5315	148344	0.0066	(6)
45928.6638	113132	0.0077	(3)	51305.4641	153000	0.0074	(6)
45941.7467	113229	0.0087	(5)	51757.3984	156351	0.0088	this paper
45945.7926	113259	0.0086	(5)	51757.5342	156352	0.0098	this paper
46581.8129	117975	0.0053	(5)	51758.3432	156358	0.0096	this paper
46583.8378	117990	0.0072	(5)	51758.4773	156359	0.0088	this paper
46627.5333	118314	0.0064	(4)	51759.4214	156366	0.0089	this paper

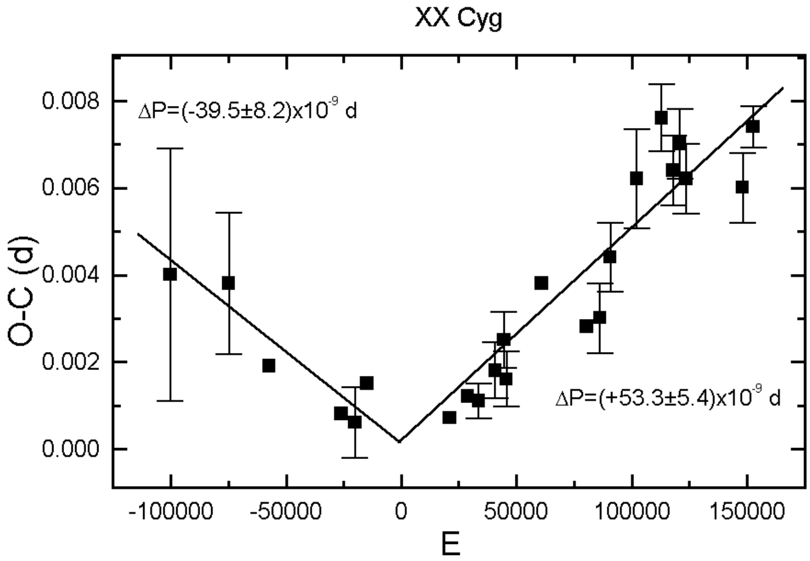

Figure 3. The mean $O - C$ diagram of XX Cyg

Sweigart & Renzini (1979) are the most widely accepted theoretical explanations. Follow-up observations are crucial to monitor the constancy of the period and to detect further possible sudden change(s).

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