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XY BOOTIS – A W UMa-STAR WITH EXTREME RATE OF PERIOD CHANGE

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XY Boo (= BD+20°2874 = GSC 1466.0122 = HIP 67431 = FL 1632 = AN 21.1935 = P 3643; $\alpha = 13^{h}49^{m}11\overset{s}{.}6$, $\delta = +20°11'24\overset{''}{.}5$, J2000; V_{max} = 10.3 mag; Sp. F5V) was discovered as a variable star by Hoffmeister (1935). Tsesevich (1950, 1954) observed this star visually, classified it as an eclipsing binary of W UMa-type and determined the period of 0.31264 day. This period appeared to be discordant with the first photoelectric observations of XY Boo by Hinderer (1960). Therefore Wood (1965) reanalysed Hinderer's photoelectric data and found a new period of 0.37054 day. Binnendijk (1971) published six photoelectric minima timings of XY Boo and revealed remarkable increase in the period. This led him to the calculation of the new linear ephemeris

$$\text{Pri. Min.} = \text{HJD}2440389.7321 + 0\overset{d}{.}37055251 \times E \qquad (1)$$

valid after 1960. Winkler (1977) observed XY Boo photoelectrically in 1976 and derived three times of minimum light. He confirmed the long-term increase in orbital period of this binary system. He also analysed his own and Binnendijk's photoelectric data using the Wilson–Dewinney code to determine geometric parameters of XY Boo. The photometric mass ratio $q = 0.18$ calculated by Winkler was confirmed spectroscopically by McLean and Hilditch (1983) who obtained $q = 0.16$.

Awadalla and Yamasaki (1984) gave two photoelectric times of minima and confirmed the period increase reported by earlier authors. Since that time, more than twenty other photoelectric minima timings have been obtained by Zhang et al. (1991), Agerer (1993, 1994), Diethelm (1994) and Kleikamp (Agerer and Hübscher, 1996). However, no detailed period study of XY Boo has been published so far.

We performed our new CCD photometry of XY Boo during the night of May 8, 1998 at the Ondřejov Observatory, Czech Republic. A 65-cm telescope and the CCD camera SBIG ST-8 with standard R Cousins filter were used. Altogether 175 measurements in R have been obtained (Fig. 1).[†] The stars GSC 1466.0088 (V = 10.2 mag) and GSC 1466.0010 (V = 10.2 mag) on the same frame as the variable served as a comparison and check stars, respectively. These measurements yielded one moment of secondary minimum.

In addition, four new times of minimum light based on the Hipparcos photometric data were derived. They are included in Table 1 together with the given Hipparcos epoch and

[†]The table of observational data in ASCII format is available as the 4640-t2.txt file together with the electronic version of the Bulletin.

all other times of minimum of XY Boo available in the literature. A total of 43 moments of minimum spanning the interval 1944–1998 were incorporated in our analysis. Moments of minima denoted in Table 1 as Nos 14 and 15 were excluded due to large deviation. After calculating $O-C_1$ residuals with respect to the linear ephemeris (1) (see the fourth column in Table 1) it became evident that the period increase of XY Boo discovered by Binnendijk (1971) still continues. We found out that the description of the long-term course of O−C residuals by a parabola is well substantiated even if the period increase has not been strictly continual and a series of discrete period changes took place within the 54 year interval. Consequently, using the method of least squares we calculated the following light elements with a quadratic term

$$\begin{array}{c} \text{Pri. Min.} = \text{HJD}2440389.7345 + 0.3705526 \times E + 3.10 \times 10^{-10} \times E^2, \\ \pm 6 \qquad\qquad \pm 4 \qquad\qquad \pm 8 \end{array} \tag{2}$$

which can serve also for the prediction of future times of minima. The $O-C_2$ residuals calculated with respect to the quadratic elements are given in the fifth column of Table 1. The O−C residuals for 43 times of minimum with respect to the linear ephemeris (1) are shown in Figure 2. The non-linear fit corresponding to the elements (2) is plotted as a continuous curve.

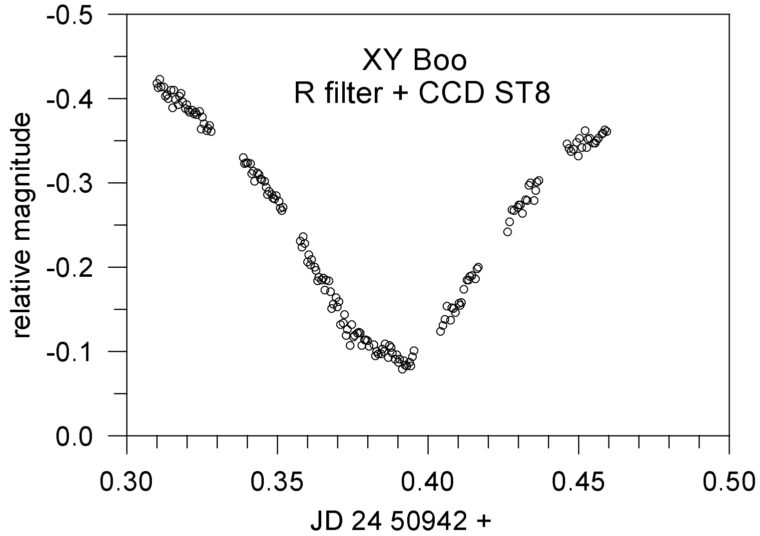

Figure 1. Differential R light curve of XY Boo obtained at JD 2450942.

The period increase by 6.2×10^{-10} day/cycle or 6.12×10^{-7} day/year or 5.3 seconds/century resulting from the elements (2) is extraordinarily large for a W UMa-star. The highest rates of similar long-term period increases in W UMa-stars previously known to us were 3.1 seconds/century in UZ Leo (see Hegedüs & Jäger 1992) and 2.7 seconds/century in V839 Oph (see Wolf et al. 1996). Because the long-term increase in orbital period is usually explained by mass transfer from the secondary to the primary component of given binary we calculated the value of this supposed mass transfer for XY Boo. Adopting the parameters given for this system by Maceroni and Van't Veer (1996) we obtained the value of 1.34×10^{-7} solar masses per year.

XY Boo, as noticed by Kaluzny (1985), has one of the shortest orbital periods for given spectral type (F5). In its position in the period-colour diagram one would expect an unevolved system with components having similar masses but XY Boo seems to be evolved

Table 1: The times of minimum of XY Boo

No.	JD hel 2400000+	Epoch	$O-C_1$ [days]	$O-C_2$ [days]	Method Filter	Reference
1	31215.386	−24759.0	0.164	−0.027	v	Tsesevich, 1957
2	35622.4578	−12865.5	0.0690	0.0165	e	Hinderer, 1960
3	35627.4596	−12852.0	0.0684	0.0159	e	Hinderer, 1960
4	39950.8121	−1184.5	−0.0006	−0.0033	e	Binnendijk, 1971
5	39951.9243	−1181.5	−0.0000	−0.0027	e	Binnendijk, 1971
6	39953.7763	−1176.5	−0.0008	−0.0035	e	Binnendijk, 1971
7	39953.9626	−1176.0	0.0003	−0.0025	e	Binnendijk, 1971
8	40298.9470	−245.0	0.0003	−0.0021	e	Binnendijk, 1971
9	40389.7319	0.0	−0.0002	−0.0026	e	Binnendijk, 1971
10	42183.400	4840.5	0.009	−0.002	e	Pohl & Kizilirmak, 1975
11	42569.7091	5883.0	0.0166	0.0029	e	Winkler, 1977
12	42577.6745	5904.5	0.0151	0.0014	e	Winkler, 1977
13	42582.6769	5918.0	0.0150	0.0013	e	Winkler, 1977
14	44691.386	11608.5	0.095	0.050	e	Diethelm, 1981a
15	44716.390	11676.0	0.087	0.041	e	Diethelm, 1981b
16	45131.3793	12796.0	0.0573	0.0030	e	Awadalla & Yamasaki, 1984
17	45132.3056	12798.5	0.0572	0.0029	e	Awadalla & Yamasaki, 1984
18	46903.4115	17578.0	0.1074	0.0076	e	Diethelm, 1987
19	47288.4252	18617.0	0.1170	0.0055	e	Diethelm, 1988
20	48132.2036	20894.0	0.1478	0.0081	e H	this paper, Hip.
21	48132.3941	20894.5	0.1525	0.0129	e H	this paper, Hip.
22	48334.3320	21439.5	0.1394	−0.0075	e V	Zhang et al., 1991
23	48334.3319	21439.5	0.1393	−0.0076	e B	Zhang et al., 1991
24	48335.2623	21442.0	0.1433	−0.0036	e V	Zhang et al., 1991
25	48335.2624	21442.0	0.1434	−0.0035	e B	Zhang et al., 1991
26	48336.3700	21445.0	0.1393	−0.0076	e V	Zhang et al., 1991
27	48336.3704	21445.0	0.1397	−0.0072	e B	Zhang et al., 1991
28	48363.2365	21517.5	0.1408	−0.0071	e V	Zhang et al., 1991
29	48363.2360	21517.5	0.1403	−0.0076	e B	Zhang et al., 1991
30	48364.1655	21520.0	0.1434	−0.0045	e V	Zhang et al., 1991
31	48364.1660	21520.0	0.1439	−0.0040	e B	Zhang et al., 1991
32	48500.1730	21887.0	0.1581	0.0052	e H	Hipparcos epoch
33	48774.3912	22627.0	0.1673	0.0041	e H	this paper, Hip.
34	48774.5807	22627.5	0.1720	0.0088	e H	this paper, Hip.
35	49130.5078	23588.0	0.1831	0.0061	e B	Agerer, 1993
36	49130.5078	23588.0	0.1831	0.0061	e V	Agerer, 1993
37	49154.4059	23652.5	0.1806	0.0026	e V	Agerer, 1994
38	49154.4091	23652.5	0.1838	0.0058	e B	Agerer, 1994
39	49166.4481	23685.0	0.1798	0.0014	e V	Agerer, 1994
40	49166.4499	23685.0	0.1816	0.0032	e B	Agerer, 1994
41	49504.4082	24597.0	0.1960	0.0038	e B	Agerer, 1994
42	49504.4096	24597.0	0.1974	0.0052	e V	Agerer, 1994
43	49511.4497	24616.0	0.1970	0.0046	e B	Diethelm, 1994
44	49859.4101	25555.0	0.2086	0.0015	CCD	Agerer & Hübscher, 1996
45	50942.3992	28477.5	0.2580	0.0016	CCD R	this paper

Note: in the 6th column “v” means visual, “e” photoelectric observation.

and the mass ratio of its components is approximately 6:1. This makes the explanation of evolution of this system difficult. Further observations are needed to decide about the true nature of period changes as well as evolutionary status of this interesting system.

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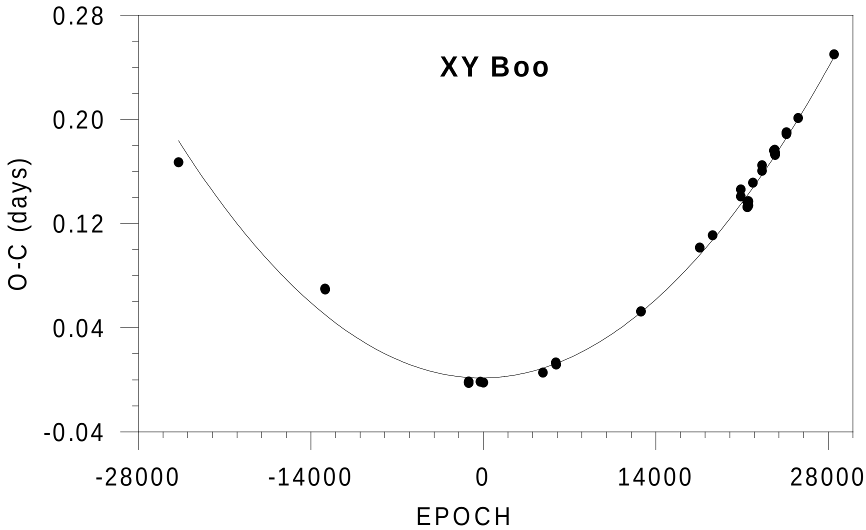

Figure 2. O−C diagram of XY Boo.

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