

Discovery of a New Deeply Eclipsing SU UMa-Type Dwarf Nova, IY UMa (= TmzV85)

Makoto UEMURA, Taichi KATO, Katsura MATSUMOTO

Department of Astronomy, Faculty of Science, Kyoto University, Sakyou-ku, Kyoto 606-8502

E-mail (MU): uemura@kusastro.kyoto-u.ac.jp

Kesao TAKAMIZAWA

Oohinata 65-1, Saku-machi, Nagano, 384-0502

Patrick SCHMEER

Bischmisheim, Am Probstbaum 10, 66132 Saarbrücken, Germany

Lasse Teist JENSEN

Center for Backyard Astrophysics (Denmark), Sndervej 38, DK-8350 Hundslund, Denmark

Tonny VANMUNSTER

Center for Backyard Astrophysics (Belgium), Walhostraat 1A, B-3401 Landen, Belgium

Rudolf NOVÁK

Nicholas Copernicus Observatory, Kraví hora 2, Brno 616 00, Czech Republic

Brian MARTIN

Center for Backyard Astrophysics (Alberta), The King's University College, 9125-50th Street,

Edmonton, Alberta, Canada

Jochen PIETZ

Rostocker Str. 62, 50374 Erftstadt, Germany

Denis BUCZYNSKI

Conder Brow Observatory, Littlefell Lane, Lancaster LA1 1XD England

Timo KINNUNEN

Sinirinnantie 16, SF-02660 Espoo, Finland

Marko MOILANEN, Arto OKSANEN

Nyrola Observatory, Jyväskylän Sirius ry, Kyllikinkatu 1, FIN-40100 Jyväskylä, Finland

Lewis M. COOK

Center for Backyard Astrophysics (California), 1730 Helix Ct. Concord, California 94518, USA

Tsutomu WATANABE

VSOLJ, 117 Shirao dormitory, 1414 Oonakazato, Shizuoka, 418-0044

Hiroyuki MAEHARA

VSOLJ, Namiki 1-13-4, Kawaguchi, Saitama, 332-0034

Hiroshi ITOH

VSOLJ, Nishiteragata-cho 1001-105, Hachioji, Tokyo, 192-0153

(Received 2000 February 23; accepted 2000 March 7)

Abstract

We discovered a new deeply eclipsing SU UMa-type dwarf nova, IY UMa, which experienced a super-outburst in 2000 January. Our monitoring revealed two distinct outbursts, which suggest a superoutburst interval of ~ 800 d, or its half, and an outburst amplitude of 5.4 mag. From time-series photometry during the superoutburst, we determined a superhump and orbital period of 0.07588 d and 0.0739132 d, respectively.

Key words: accretion disks — binaries: eclipsing — stars: cataclysmic variables — stars: individual (IY UMa)

1. Introduction

Dwarf novae are cataclysmic binary stars which exhibit repetitive outbursts of several magnitudes. They con-

tain a Roche-lobe-filling cool dwarf star that loses mass through the inner Lagrangian point, and a white-dwarf star accreting it (Warner 1995). The SU UMa stars form a sub-class of dwarf novae, showing two types of out-

burst, namely, a short “normal” outburst and a long “superoutburst”. According to theories for the superoutburst mechanism (e.g. Osaki 1996), after the accretion disk grows over a critical radius it becomes tidally unstable due to a gravitational interaction with the secondary. In this model the precession of an eccentric disk can explain the “superhump” modulation present in the superoutburst.

Eclipsing systems provide a unique opportunity to reconstruct the brightness distribution of an accretion disk from the observed integrated light (Horne 1985; Baptista, Steiner 1991, 1993). There are only five known SU UMa stars which exhibit deep eclipses, indicating occultation of the accretion disk and the white dwarf by the secondary star. Of these systems, HT Cas (Zhang et al. 1986), OY Car (Krzeminski, Vogt 1985), and Z Cha (Bailey 1979) have long been studied; these limited samples have historically provided almost all of our knowledge concerning the spatial structure and time-evolution of accretion disks in SU UMa stars. Although two more eclipsing SU UMa stars, DV UMa (Nogami et al., in preparation) and V2051 Oph (Kiyota, Kato 1998), have recently been discussed, the low frequency of superoutbursts and the small number of the known eclipsing systems still make it difficult to directly clarify the eccentric disk, itself, and its evolution with time by an observational approach.

In this letter we report on the discovery of a new deeply eclipsing northern SU UMa-type dwarf nova, IY UMa (= TmzV85), along with the results of our photometric monitoring and time-resolved photometry. A more detailed analysis of the eclipses, including the time-evolution of the accretion disk during this superoutburst and the subsequent rapid fading phase, will be presented in a separate paper.

2. Discovery and Observations

Takamizawa (1998) discovered a new variable star which had been brightening at a photographic magnitude of 13.0 on 1997 November 9.751 (UT) more fainter than 14.9 mag on November 1.753 (UT). He reported this star as TmzV85 to the Variable Star network (VSNET, <http://www.kusastro.kyoto-u.ac.jp/vsnet>) along with his comment that this is a potential dwarf nova based on the lack of detections on other films and the relatively blue color of the corresponding USNO star. Following this report, visual and CCD monitoring was conducted, yielding negative results until 2000 January 13.509, when Schmeer (2000) detected a second brightening at an unfiltered CCD magnitude of 14.0. We started CCD time-series observations, which immediately revealed the presence of superhumps and deep eclipses, establishing that TmzV85 is a new deeply eclipsing SU UMa-type dwarf nova (Uemura et al. 2000).

Fig. 1. CCD image of IY UMa observed at Iowa Robotic Observatory. The position of IY UMa is indicated. The differential photometry was performed with the comparison star C1, and its consistency was checked using stars C2 and C3. The left and right panels show IY UMa in quiescence (JD 2451552) and outburst (JD 2451556), respectively.

This object has subsequently been given the designation IY UMa (Samus 2000). This is the first case in which both superhumps and eclipses were discovered simultaneously. The position of IY UMa, derived by H. Yamaoka (in private communication), is R.A. = 10h 43m 56s.87, Decl. = +58° 07' 32".5 (equinox 2000.0). Figure 1 gives the finding chart of IY UMa.

A description of the equipment of CCD time-series photometry is given in table 1. After correcting for the standard de-biasing and flat fielding, we processed object frames with the PSF and aperture photometry packages. We performed differential photometry relative to the comparison star, C1, shown in figure 1, whose constancy was confirmed by check stars, C2 and C3.

3. Results

The first outburst occurred in 1997, which was recorded as two photographic magnitudes of 13.0 (November 9.751) and 13.4 (November 9.756); the second outburst was observed at 14.0 mag on 2000 January 13.509. The first outburst was most certainly also a superoutburst, because the observed maximum was brighter than that of the second outburst. This means the amplitude of a superoutburst of 5.4 mag, determined by the minimum magnitude of 18.4 (Henden 2000). No other outburst over 15.3 mag has been recorded since 1994 November 11 when K. Takamizawa took his oldest photographic image of the field of IY UMa, although this object has been relatively closely monitored, particularly since 1999. Because we cannot exclude the possibility of overlooking another superoutburst before 1999, we suggest the typical time interval between two subsequent superoutbursts, called “supercycle”, is ~ 800 d, or its half.

The light curve of the outburst in 2000 January is given in figure 2. The abscissa and ordinate denote time in heliocentric julian date and unfiltered CCD or visual magnitude, respectively. The points and their errorbars denote the nightly averaged outside-eclipse magnitudes of

Table 1. Equipment for time-series photometry.

Observer	Telescope	CCD	T_{exp} (s)
Kyoto team	25-cm SC	ST-7	30
L. T. Jensen	25-cm SC	ST-6	60
B. Martin	31-cm N	CB245	200
R. Novák	40-cm N	ST-7	50
D. Buczynski	33-cm N	SXL8	45
Nyrola team	40-cm SC	ST-7E	120/60
J. Pietz	20-cm SC	ST6-B	90/60
T. Vanmunster	35-cm SC	ST-7	60
L. Cook	44-cm N	CB245	16

SC = Schmidt-Cassegrain telescope

N = Newtonian telescope

CCD time-series photometry and their standard error, respectively. The open circles denote the magnitude by CCD monitorings. The last recorded magnitude before the outburst of 17.6 mag on January 8.463 and the discovery date of the outburst suggest that the duration of this superoutburst was between 12 and 18 days.

Figure 3 provides the light curve on HJD 2451561.9 – 2451562.7, representative of the intermediate stage of the superoutburst (upper panel) and HJD 2451567.1 – 2451567.9, representative of the advanced stage (lower panel), which clearly show the superhumps and the deep eclipses. The superhump amplitude of about 0.5 mag in the intermediate stage becomes smaller at the late stage, about 0.3 mag. On the other hand, the eclipses become deeper with time; the typical depth of the eclipse are about 1.3 mag in the upper panel and about 1.8 mag in the lower panel, which suggests that the brightness of the outer part of the disk gradually fades and/or the disk, itself, shrinks during the advanced stage. The profile of the eclipse is quite asymmetric, suggesting the presence of a strongly asymmetric disk.

We first determined the ephemeris of the eclipse center, T (in HJD):

$$T = 2451561.24546(\pm 0.00011) + 0.0739132(\pm 0.0000018) \times E,$$

where E is a cycle number. To determine the superhump period, we rejected observations within phase 0.10 of the eclipse center from all of the data obtained during the outburst (HJD 2451561.2098 – HJD 2451569.5865). After removing a linear trend of the decline, we performed a period analysis using the Phase Dispersion Minimization (PDM) method (Stellingwerf 1978), which indicates 0.07588 ± 0.0000113 d as the best estimated superhump period. The superhump excess, ε , defined by $\varepsilon = (P_{\text{sh}} - P_{\text{orb}})/P_{\text{orb}}$, where P_{orb} and P_{sh} denote the orbital and superhump period, respectively, is consequently calculated as 0.027.

Fig. 2. Superoutburst light curve of IY UMa. The outburst duration and the decline rate are typical for SU UMa stars. The long tail after the outburst is characteristic for this outburst of IY UMa.

4. Discussion and Summary

We have derived some of the physical parameters of the newly discovered SU UMa-type dwarf nova with a deep eclipse, IY UMa, and summarize them in table 2 along with those of the other eclipsing SU UMa stars. As shown in this table, the orbital period of IY UMa is quite similar to those of Z Cha and HT Cas. Because the normal outburst of IY UMa has historically not been detected, continuous observations are essential to determine the frequency of a normal outburst and the part of accretion disk where the disk-instability begins.

IY UMa is potentially the most valuable northern SU UMa-type dwarf nova with deep eclipses, the bright quiescence magnitude, and relatively frequent superoutbursts compared to HT Cas, which has not been observed to undergo a superoutburst since 1985. The star thus provides a unique opportunity for SUBARU telescope to study the structure of accretion disks of SU UMa-type dwarf novae in quiescence through eclipse-timing spectroscopic observations.

We are pleased to acknowledge comments by D. Nogami, which lead to several improvements in this paper. This research has been supported in part by a Grant-in-Aid for Scientific Research (10740095) of the Japanese Ministry of Education, Science, Sports, and Culture. KM has been financially supported as a Research Fellow for Young Scientists by the Japan Society for the Promotion of Science. PS's observations were made with the Iowa Robotic Observatory, and he wishes to thank Robert Mutel and his students.

Fig. 3. Eclipses and superhumps. Upper panel: the light curve on HJD 2451561 (intermediate phase in superoutburst). Lower panel: on HJD 2451567 (late phase in superoutburst). The eclipses become deeper with time.

Table 2. Physical parameters of the known eclipsing SU UMa stars.

Object Name	V_{quies}	V_{super}	T_{super}	P_{orb}	P_{sh}
Z Cha	15.3	11.9	287	0.074499	0.07740
OY Car	15.3	11.4	318	0.063121	0.064544
V2051 Oph	15.0	11.7*	430*	0.062428	0.06423 [†]
HT Cas	16.4	11.9 [‡]		0.073647	0.076077
DV UMa	18.6	14.0*	970*	0.08587 [§]	0.08867 [§]
IY UMa	18.4*	13.0	400 or 800	0.073913	0.07588

V_{quies} : magnitude at quiescence, V_{super} : maximum magnitude during superoutburst,

T_{super} : supercycle, P_{orb} : orbital period, and P_{sh} : superhump period.

Data without symbols from Ritter and Kolb (1998)

* from VSNET data, [†] IBVS 4644, [‡] IAU Circ. 4027, [§] Uemura et al. 2000 in preparation

References

- Bailey J. 1979, MNRAS 188, 681
Baptista R., Steiner J. E. 1991, A&A 249, 284
Baptista R., Steiner J. E. 1993, A&A 277, 331
Downes R. A., Mateo M., Szkody P., Jenner D. C., Margon B. 1986, ApJ 301, 240
Henden A. 2000, vsnet-alert circulation 4060
(<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/vsnet-alert/msg04060.html>)
Horne K. 1985, MNRAS 213, 129
Kiyota S., Kato T. 1998, Inf. Bull. Variable Stars 4644
Krzeminski W., Vogt N. 1985 A&A 144, 124
Mattei J. A., Kinnunen T., Hurst G. 1985 IAUC 4027
Mennickent R. E., Matsumoto K., Arenas J. 1999, A&A 348, 466
Osaki Y. 1995, PASJ 47, 47
Osaki Y. 1996, PASP 108, 39
Patterson J. 1998, PASP 110, 1132
Ritter H., Kolb U. 1998, A&AS 129, 83
Samus N. N. 2000, IAU Circ. 7353
Schmeer P. 2000, vsnet-alert circulation 4027
(<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/vsnet-alert/msg04027.html>)
Stellingwerf R. F. 1978, ApJ 224, 953
Takamizawa K. 1998, vsnet-obs circulation 18078
(<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/obs18000/msg00078.html>)
Uemura M., Kato T., Novák R., Jensen L. T., Takamizawa K., Schmeer P., Yamaoka H., Henden A. 2000, IAU Circ. 7349
Warner B. 1995, Cataclysmic Variable Stars, p126–215 (Cambridge Univ. Press, Cambridge)
Vanmunster T. 2000, in preparation
Zhang E. H., Robinson E. L., Nather R. E. 1986, ApJ 305, 740