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NEW CCD OBSERVATIONS OF UU SAGITTAE AND V477 LYRAE

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Eclipsing binary central stars of planetary nebulae form a rare class of variable stars which are key objects in determining absolute parameters of central compact systems through light curve modelling. There are only eight such objects listed in the latest catalogue of cataclysmic binaries, LMXBs and related objects (Ritter & Kolb 1998) and only two of them, UU Sge (central star of Abell 63) and V477 Lyr (Abell 46) have detailed analyses in the literature. Earlier photometric studies of these stars raised the possibility of period changes that can be attributed to either mass-losing processes or other kind of interaction between the components (UU Sge — Pollacco & Bell 1993, V477 Lyr — Pollacco & Bell 1994). The main aim of this note is to present new observations which reveal the recent behaviour of the orbital periods.

Unfiltered CCD photometry was carried out on 5 nights in August, 2000 at the Piszkéstető Station of the Konkoly Observatory. The main reason for doing unfiltered observations is the relative faintness of the observed stars ($V_{\max} = 14\overset{m}{.}7$ for UU Sge, $V_{\max} = 15\overset{m}{.}1$ for V477 Lyr). The applied instrument was the 60/90/180-cm Schmidt telescope equipped with a Photometrics AT200 CCD camera (1536 $\times$ 1024 pixels, KAF-1600 chip with UV-coating). The field of view is $29' \times 18'$ yielding an angular resolution of $1\overset{''}{.}1$/pixel. The exposure times varied from 60 sec to 180 sec depending on the actual weather conditions and target brightness. The image reduction performed with the standard tasks in IRAF included flat-fielding with a master frame formed from several individual exposures taken during the evening twilight. Differential aperture photometry was made with the IRAF/APPHOT package. In both cases we chose two nearby field stars at similar brightnesses as comparison and check stars. Their magnitude differences were used to estimate the photometric accuracy which is about $\pm$0.01–0.03 mag, the latter value being typical during the primary minima (e.g., UU Sge was only barely detectable in the primary minimum, see below). Individual data are available upon request from the first author.

UU Sagittae

This star was observed on all of the five nights (August 3/4, 4/5, 7/8, 8/9 and 9/10) by obtaining 174 individual CCD frames. There is an optical companion ($V = 15\overset{m}{.}87$) at a distance of $2\overset{''}{.}8$ toward PA 92° (Ciardullo et al. 1999) which strongly reduces the eclipse depth when including its contribution. Since our image scale ($1\overset{''}{.}1$/pixel) prevented an appropriate removing of the second light of optical companion, we applied an aperture photometry that included both stars. The reduced unfiltered eclipse depth was found to be $0\overset{\mathrm{m}}{.}9$. The light curve exhibits a strong reflection effect with an amplitude of $0\overset{\mathrm{m}}{.}3$ (Fig. 1, left panel).

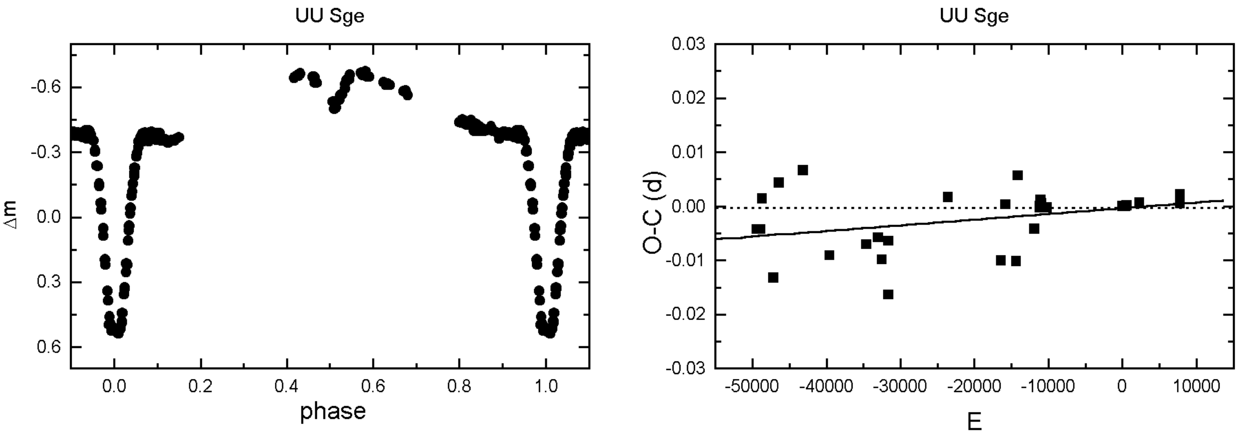

Figure 1. *Left*: the phase diagram of UU Sge with the adopted ephemeris. *Right*: The $O-C$ diagram of UU Sge. The solid line shows the linear fit, while the dotted line corresponds to the zero level.

We have tried to separate the effect of the optical companion by measuring its brightness relative to the chosen comparison stars during the primary minimum, when UU Sge has a minimal contribution. By choosing an aperture radius of 2 pixels we could exclude UU Sge's light and we calculated the unfiltered magnitude differences between the comparison stars and optical companion. This value was taken when correcting the combined differential magnitudes using larger aperture. After the second light removal we obtained a corrected light curve with an eclipse depth of 4.5 ± 0.3 mag which is close to the real value (Bell et al. 1994 reported $\Delta V = 4.05 \pm 0.06$ mag with the 4.2-m William Herschel Telescope). This correction illustrates the definite detection of UU Sge even in the primary minimum ($V_{\mathrm{min}} = 19.20 \pm 0.07$ mag, Bell et al. 1994). The scatter of the corrected light curve disabled the accurate eclipse timing. Fortunately, the primary minimum shows a quite symmetric light curve, thus the direct measurements could be used for determining epochs of minimum.

Three new times of minimum were obtained by determining the midpoints of several (2-3) chords taken a few tenth of a magnitude above the bottom part of the light curve (Table 1). The estimated timing accuracy is about 0.0005–0.0007 days (the first epoch has larger uncertainty because of the partial coverage). These times of minima were added to the published values collected by Pollacco & Bell (1993), while a further epoch was presented by Bell et al. (1994). The final sample contains 33 individual epochs which were used to calculate the $O-C$ diagram covering 76 years. The used ephemeris was the following (Pollacco & Bell 1993):

$$\mathrm{HJD(Min\ I)} = 2448133.40747 + 0.465069102 \times E.$$

Early data are photographic, thus their lower accuracy is the main reason for the considerable scatter of the first part of the diagram. The general appearance suggests a slightly larger, but most likely constant period which was determined by a least-squares linear fit of the $O-C$ values. The fitted slope is $(1.05 \pm 0.49) \times 10^{-7}$ resulting in a corrected period of 0.46506921(5) days. This is a little longer period than that of by Bell

Table 1: New times of minima (Hel. JD – 2400000). $O - C$ values were calculated with the ephemerides given in Pollaco & Bell (1993) — UU Sge, and Pollacco & Bell (1994) — V477 Lyr.

	Hel. JD	E	$O - C$
UU Sge	51760.4835:	7799	0.0021
	51761.4120	7801	0.0005
	51766.5285	7812	0.0012
V477 Lyr	51764.5163	7693	−0.0002
	51765.4605	7695	0.0005
	51766.4038	7697	0.0004

et al. (1994), however, the difference is very close to the detection limit. Therefore, we conclude, that our new ephemeris

$$\mathrm{HJD(Min\ I)} = 2451766.5285 + 0.46506921 \times E$$

is a marginally improved one allowing accurate phase predictions for the follow-up observations.

V477 Lyrae

V477 Lyrae ($V_{\rm max} = 15^{\rm m}\!.1$, $\Delta V = 1^{\rm m}\!.5$, $P = 0^{\rm d}\!.4717$) was observed on three subsequent nights (August 7/8, 8/9 and 9/10), thus only partial phase coverage could be obtained. Although V477 Lyr is similar to UU Sge, there are much less observations in the literature as for UU Sge. The most striking feature of the light curve is the strong reflection effect with an amplitude up to $0^{\rm m}\!.5$ (see left panel in Fig. 2). Pollacco & Bell (1994) presented the first full light-curve analysis for V477 Lyr concluding that Abell 46 may be an example of a 'lazy PN' (the central star is visually bright whilst the nebula itself has a low surface brightness), while the secondary component is oversized for its mass. There are 12 published epochs of minimum which were listed by Pollacco & Bell (1994). Since then there were no new observations on this star.

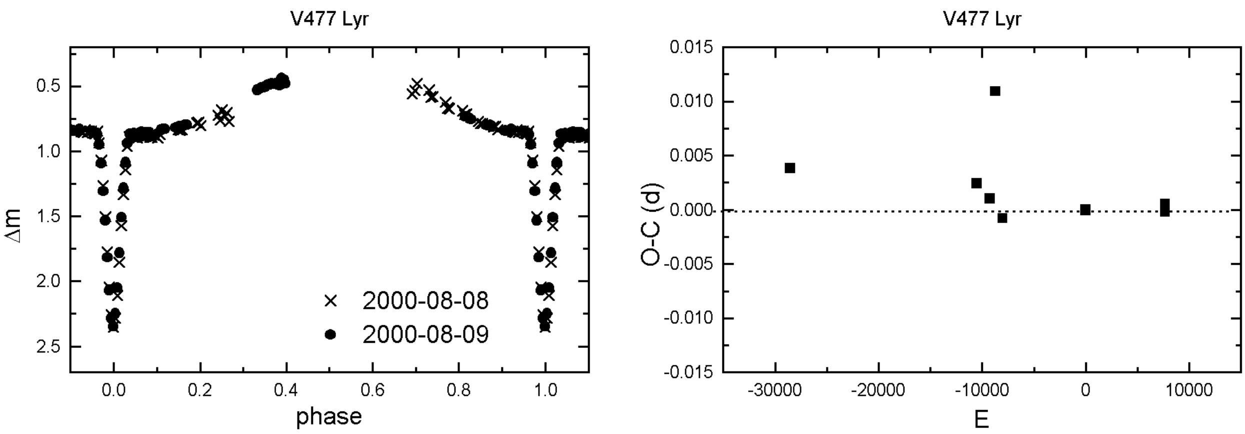

Figure 2. *Left*: the phase diagram of V477 Lyr with the adopted ephemeris. Data obtained on the first night were excluded because of larger scatter caused by the unfavorable weather conditions. *Right*: The $O - C$ diagram of V477 Lyr. Obviously inaccurate photographic data were exluded, while the dotted line corresponds to the zero level.

Our observations resulted in three new times of minima (Table 1) which were determined by fitting low-order polynomials to the lowest part of the individual light curves. Since the primary minimum is only partial, the timing is more accurate than in the case of UU Sge, with an estimated accuracy of 0.0003 days. The $O-C$ diagram was calculated with the ephemeris in Pollacco & Bell (1994):

$$\mathrm{HJD(Min\ I)} = 2448135.50446 + 0.47172909 \times E.$$

As can be seen in the right panel of Fig. 2, there is no significant variation in the $O-C$ diagram, which corresponds to a stable period over 40000 cycles (about 50 years). A formal linear fit gives a slope of $(-1.1 \pm 1.1) \times 10^{-7}$ suggesting a relative stability of the period $\Delta P/P \approx 1.1 \times 10^{-7}/0.4717 \approx 2 \times 10^{-7}$. Therefore, we conclude that no period change can be detected using the presently available data and follow-up observations can be planned with the cited ephemeris.

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References:

Bell, S.A., Pollacco, D.L., Hilditch, R.W., 1994, *MNRAS*, **270**, 449
Ciardullo, R., Bond, H.E., Sipior M.S. et al, 1999, *AJ*, **118**, 488
Pollacco, D.L., Bell, S.A., 1993, *MNRAS*, **262**, 377
Pollacco, D.L., Bell, S.A., 1994, *MNRAS*, **267**, 452
Ritter, H., Kolb, U., 1998, *A&AS*, **129**, 83