

# Updating the Ephemerides of V1776 Cyg, QU Vul, and UX UMa

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Time-resolved Photometric observations of the eclipsing cataclysmic variables V1776 Cyg, QU Vul, and UX UMa have been used to update their orbital ephemerides. A total of four, five, & three eclipses were obtained for each system, respectively, resulting in the following ephemerides:

$$\begin{aligned} \text{V1776 Cyg: } T_{\text{mid-eclipse}} &= 2,446,716.6795(3) + 0.164738655(13)*E \\ \text{QU Vul: } T_{\text{mid-eclipse}} &= 2,449,514.8779(2) + 0.117647428(73)*E \\ \text{UX UMa: } T_{\text{mid-eclipse}} &= 2,440,978,9998(9) + 0.1966712961(32)*E \end{aligned}$$

## Introduction

Cataclysmic variables (e.g. novae, dwarf novae) are close binary star systems that consist of a cool, typically main sequence, secondary star that fills its Roche lobe and transfers material to a white dwarf companion. In most systems (i.e. those without a highly magnetic white dwarf), the transferred material forms an accretion disk before impacting the white dwarf. Gravitational potential energy liberated as the material spirals toward the white dwarf makes the disk typically the dominant source of light in the system. Accretion onto the white dwarf leads to the eruptive behavior that gives cataclysmic variables their name. Fluctuations of the mass accretion rate through the disk leads to dwarf nova eruptions, while runaway thermonuclear burning of accreted material on the white dwarf leads to nova eruptions. Systems with steady accretion but without recorded nova eruptions are classified as nova-like variables.

Eclipsing cataclysmic variables offer the opportunity to study the accretion disks in cataclysmic variables from analysis of their eclipse light curves. They also offer the opportunity to measure the orbital periods with great precision. In this paper, we have used eclipse timings of two nova-like variables, V1776 Cyg and UX UMa, and one classical nova, QU Vul (Nova Vulpecula 1984), to establish updated orbital ephemerides for these systems.

## Observations and Reduction

A summary of our times series observations of the systems V1776 Cyg, QU Vul and UX UMa are given in Tables 1, 2, and 3.

*Table 1. Observation Parameters of V1776 Cyg*

UT Date	Observatory	Filter	UT Time (start time)
July 16	Mt. Laguna	V band	6:27:00
July 17	Mt. Laguna	B band	6:28:00
July 18	Mt. Laguna	R band	6:16:30
Oct 27	Mt. Laguna	I band	1:57:30.3

*Table 2. Observation Parameters of QU Vul*

UT Date	Observatory	Filter	UT Time (start time)
Sept 2 2005	Mt. Laguna	V band	5:03:30
May 25 2006	Kitt Peak	V band	8:02:06
June 17 2006	Kitt Peak	B band	7:25:44
June 18 2006	Kitt Peak	I band	6:18:00
June 18 2006	Kitt Peak	B band	8:53:21

Table 3. Observation Parameters of UX UMa

UT Date 2005	Observatory	Filter	UT Time (start time)
July 16	Mt. Laguna	V band	4:18:00
July 17	Mt. Laguna	B band	4:20:00
July 18	Mt. Laguna	R band	4:14:19

A single eclipse was obtained for each night of observation. The data were debiased and flat-fielded using standard routines in the Image Reduction and Analysis Facility (IRAF). The magnitudes for the CVs and the comparison stars used in the calculation were determined using the IRAF APPHOT package. Using a Fortran code I generated the light curves for the systems. The observations from Kitt Peak Observatory had already been calibrated and the light curve's data points had already been generated.

### Analysis

With the light curves now generated we need to then establish the time of minimum for each eclipse. To do this we used a Fortran code that generated a best-fit parabola along the bottom half of the eclipse profile. The code then used this parabola to establish the UT time of minimum in hours. The UT time of minimum was then converted to Heliocentric Julian Day (HJD). The times of minimum obtained are listed in Tables 4, 5, and 6.

Table 4 Eclipse Parameters of V1776 Cyg

UT Date 2005	UT (hrs)	HJD(2,453,000.0)	O-C (x10 <sup>-3</sup> days)
July 16	7.873	567.8302	-0.759561
July 17	7.593	568.8186	-0.831540
July 18	7.370	569.8093	1.456480
Oct. 27	3.044	670.6281	0.144593

Table 5 Eclipse Parameters of QU Vul

UT Date	UT(hrs)	HJD(2,453,000.0)	O-C (x10 <sup>-3</sup> days)
Sept. 2 2005	5.897	615.7495	-0.101759
May 25 2006	8.513	880.8558	-0.028633
June 17 2006	9.045	903.8794	0.004354
June 18 2006	6.501	904.7735	-0.073588
June 18 2006	9.189	904.8855	0.191669

Table 6 Eclipse Parameters of UX UMa

UT Date 2005	UT (hrs)	HJD (2,453,000.0)	O-C (x10 <sup>-3</sup> days)
July 16	5.655	567.7338	1.064793
July 17	5.251	568.7169	0.828313
July 18	4.855	569.7004	0.901832

Our new eclipse timings were supplemented with the timings of Garnavich et al. 1990 (V1776 Cyg), Shafter et al. 1995 (QU Vul), Warner & Nather 1972, Kukarkin 1977, Rubenstein et al. 1991, Rutten et al. 1992, Kjurkchieva & Marchev 1994, Baptista et al. 1995, Knigge et al. 1998, and Bruch 2000 (UX UMa).

A linear least squares fit of the combined times of minimum yielded the following ephemerides:

$$\text{V1776 Cyg: } T_{\text{mid-eclipse}} = 2,446,716.6795(3) + 0.164738655(13)*E$$

$$\text{QU Vul: } T_{\text{mid-eclipse}} = 2,449,514.8779(2) + 0.117647428(73)*E$$

$$\text{UX UMa: } T_{\text{mid-eclipse}} = 2,440,978,9998(9) + 0.1966712961(32)*E$$

We increased the precision of the orbital periods of V1776 Cyg and QU Vul by a decimal place. UX UMa's period changed very slightly due to the fact that it has a large number of timings and is very precise as it is. With the new ephemerides we constructed the O-C values and are given in Tables 4-6 and shown in Figures 1, 2, and 3. The open circles in V1776 Cyg and UX UMa correspond to HJD times not used in the calculation of the ephemeris. The open circle in V1776 was an observation that used spectrographic analysis (Shafter et al. 1983) whose timing was not initially known to be part of an eclipse. Later research (Garnavich et al. 1990) confirmed that the spectral changes seen in that observation were due to an eclipse within a minute of the predicted eclipse minimum. The open circles in UX UMa (Kukarkin 1977) refer to an averaging over several observations to reduce the effective uncertainty in timings that are predominantly either visual or photographic (Rubenstein et al. 1991). Therefore not being single observations we did not include them in the calculation of the ephemeris.

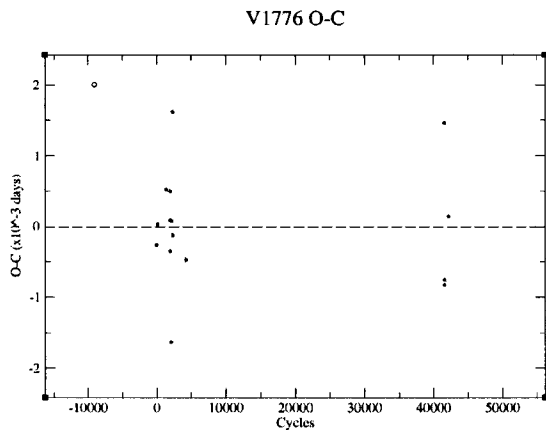


Fig. 1: O-C Diagram of V1776 Cyg

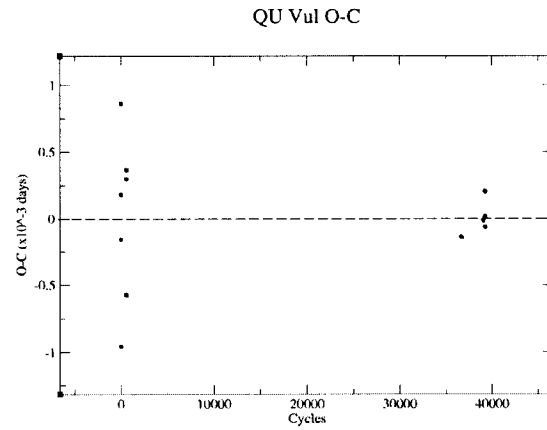


Figure 3: O-C Diagram of QU Vul

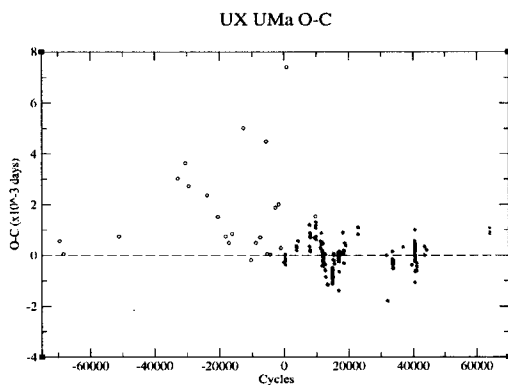


Figure 4: O-C Diagram of UX UMa

## Conclusion

Observations of these eclipses yielded more precise timings of the orbital period of these systems. This was evident in the systems V1776 Cyg and QU Vul. It is useful to have an accurate ephemeris in order to facilitate future studies of these systems. Of the three systems studied, QU Vul is of particular interest being a neon nova (Gehrz et al. 1985). Past observations recorded that the previous ephemeris of QU Vul was off by more than 5 minutes. We hope to have decreased this O-C value significantly so that the improved ephemeris of this system will help facilitate future studies aimed at measuring the white-dwarf's mass in this system.

## Acknowledgements

I would like to thank my advisor Allen Shafter for his invaluable help on this project. I like to also thank Jahrese Reed who worked with me during the three week period Allen was gone. I also give

thanks to the SDSU faculty part of the REU program for their extreme effort in making this program a success. Thank you.

**References:**

- Baptista, R., Horne, K., Hilditch, R.W., Mason, K.O., & Drew, J.E. 1995, ApJ, 448, 395.  
Bruch, A. 2000, A&A, 359, 998  
Garnavich, P.M., Szkody, P., Mateo, M., Fenswog, L., Booth, J., Goodrich, B., Miller, R.H., Carini, M.T., & Wilson, J.W. 1990, ApJ, 365, 696  
Gehrz, R.D., Grasdalen, G.L., & Hackwell, J.A. 1985, ApJ, 298, L47  
Kjurkchieva, D.P. & Marchev, D.V. 1994, IBVS, 4122, 1  
Knigge, C., Long, K.S., Wade, R.A., Baptista, R., Horne, K., Hubeny, I., & Rutten, R.M. 1998, ApJ, 499, 414  
Kukarkin, B.V. 1977, MNRAS, 180, 5  
Rubenstein, E.P., Patterson, J., & Africano, J.L. 1991, PASP, 103, 1258  
Rutten, R.M., Paradijs, J.V., & Tinbergen J. 1992, A&A, 260, 213  
Shafter, A.W., Misselt, K.A., Szkody, P., & Politano, M. 1995, ApJ, 448, 33  
Warner, B. & Nather, E. 1972, MNRAS, 159, 429