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# ECLIPSES OF U GEMINORUM

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### ABSTRACT

Seven precise eclipse times for the cataclysmic variable star U Geminorum have been obtained during the 1974–1975 observing season. These, together with 65 others, have been used to reevaluate the eclipse parameters. We have, with some selection of the eclipses used, found a statistically significant slowdown of the binary system. Using previously published masses for the components of U Gem, we infer a mass transfer rate of  $8.1 \times 10^{-8} \, M_{\odot} \, \text{yr}^{-1}$  away from the primary. This direction of mass transfer is opposite to that required by current theoretical understanding of these systems.

Subject headings: stars: dwarf novae — stars: eclipsing binaries — stars: individual — stars: mass loss

### I. INTRODUCTION

The prototype dwarf nova, U Geminorum, is a typical eruptive binary. These are generally believed to consist of a red dwarf which is transferring matter onto a white dwarf companion. Some mass may be leaving the system. A detailed study of the binary period of such systems may be the only means of establishing the mass transfer rate. In a report on the slowdown rate of nine such systems, Pringle (1975) notes that spectroscopic observations for these objects are difficult to use in determining the rate of increase of the orbital period because of the breadth of the dominant spectral lines and because they come from the accretion disk around the white dwarf. U Geminorum was one of the nine systems examined by Pringle, and he found that evidence for orbital deceleration of that system is not strong. We have determined seven new eclipse times for U Geminorum and have repeated Pringle's analysis with some discrimination as to the selection of the published data. We find somewhat stronger formal evidence for a secular increase in orbital period that he published.

### II. OBSERVATIONS

As part of a program of studying the power spectra of rapid variations in compact blue objects, we have observed seven new eclipses of the U Gem system during the 1974–1975 observing season. These were all obtained at Kitt Peak National Observatory using the No. 1 and No. 2, 91 cm telescopes as indicated in Table 1. A dichroic beam-splitter fed light to two photomultipliers, an FW-129 and an FW-130, each of which was operated without additional bandpass filters. The dichroic beam-splitter splits roughly at  $\lambda 5500$ ; thus the signals are basically "blue" and "red," and the effective bandpasses are 1500–2000 Å

\* Visiting Astronomers, Kitt Peak National Observatory, which is operated by AURA, Inc., under contract with the NSF.

wide. A 15" diaphragm restricted sky background, and continuous offset guiding was used.

We recorded the photon rates using the University of Rochester data recording system (details of which are to be published elsewhere). This system is controlled by a master clock which can be set to  $\pm 1~\mu s$  UT. It can measure the photon counts at sampling rates between 1 ms and 10 s and record as many as three channels of information continuously on magnetic tape for extended periods. Throughout the present observations the recordings were made every second, and the times of the observations were known by comparison with WWV to within  $\pm 1$  s, which was satisfactory for present purposes. A limit of  $2^{16}$  counts per sampling time can be recorded, and this was well above our needs. Pulse pair resolution of the system is  $8 \times 10^{-8}$  s.

One of the eclipses is shown on Figure 1. Several features of the eclipse are relevant to the present discussion. The primary eclipse is asymmetric and flat-bottomed. It occurs during the descending portion of the shoulder in the light curve. Outside of the eclipse there is considerable flickering on time scales of the order of minutes. The degree of flickering is related to the eruptive activity of the U Gem system, being most prominent immediately after eruption. The asymmetric eclipse, believed to be the eclipse of a hot spot in the disk of material which is accreting around the white dwarf (Warner and Nather 1971; Smak 1971), is found to vary in width as a function of time since eruption (see, e.g., Krzemiński 1965). The phase of several possible estimates of the eclipse time, such as the moment of the middle of egress or the intersection of the eclipse bisector, varies markedly with the eruptive activity.

Krzemiński gives a definition for the time of eclipse minimum which is currently used and which he claims is independent of eruptive activity. He defines an eclipse bisector as the locus of points on the light curve which are at the same magnitude and average time of points on the ingress and egress. He then finds the time on

TABLE 1
JOURNAL OF OBSERVATIONS

Color	HJD 2,440,000+	Cycle	O – C (day)	Eclipse Depth (mag)	Eclipse Width (day)
		Kitt Peak No. 1	91 cm Telescope		
Red	2365.9366	26721	+0.0068	0.69	0.0138
Blue	2365.9366	26721	+0.0068	0.68	0.0134
Red	2366.8210	26726	+0.0066	0.72	0.0136
Blue	2366.8208	26726	+0.0064	0.70	0.0141
Red	2367.8827	26732	+0.0069	0.84	0.0135
Blue	2367.8825	26732	+0.0067	0.79	0.0140
Red	2420.7775	27031	+0.0068	0.72	0.0104
Blue	2420.7774	27031	+0.0067	0.73	0.0106
		Kitt Peak No. 2.	91 cm Telescope		
Red	2476,6796	27347	+0.0066	0,55	0.0136
Blue	2476.6796	27347	+0.0066	0.54	0.0136
Red	2694.9820	28581	+0.0071	0.49	0.0101
Blue	2694.9821	28581	+0.0072	0.48	0.0101
Red	2696.9279	28592	+0.0071	0.53	0.0095
Blue	2696.9279	28592	+0.0071	0.51	0.0095

Note.—Table 1 gives the details of the observed eclipses reported in this work. In sequence the columns identify the color in which the eclipses were observed, the eclipse time, the cycle number, the difference between Krezmiński's (1965) elements and our observations, the depth and width of the eclipses.

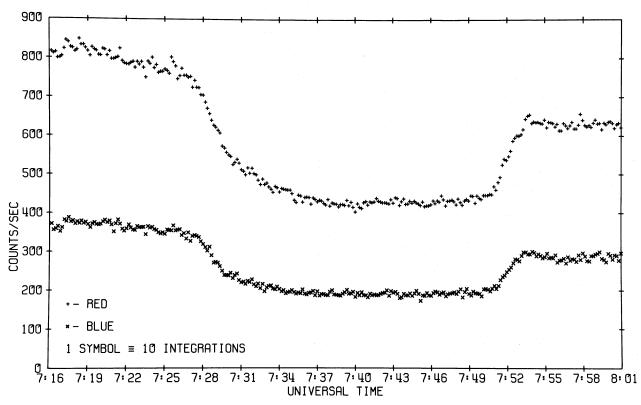


Fig. 1.—A typical eclipse of U Gem. This eclipse was recorded in two colors during our observing run of 1974 November 15. Note the asymmetry of the eclipse and the descending nature of the light curves outside the eclipse. Detailed examination of this and other light curves indicate considerable flickering outside of the eclipses and stability within counting statistics during the eclipse.

this bisector where the magnitude is halfway between that of the eclipse bottom and the estimated shoulder in the absence of the eclipse. This point is taken as the time of eclipse, but there is no dynamical reason to suppose it corresponds to any stable physical phase of the system. Depending as it does on the estimated light curve in the absence of eclipse, the precision with which the time of eclipse occurs must deteriorate with eruptive activity. This is perhaps doubly so as the depth of the eclipse has been estimated to be constant in intensity units (e.g., Krezmiński 1965) whereas the system gains as much as 5 mag during eruptions.

# III. ECLIPSE PARAMETERS

Krzemiński's (1965) eclipse elements, referred to the heliocenter, are

$$T_{\min} = \text{HJD } 2437638482704 + 0417690591E.$$

Pringle (1975) has reanalyzed the residuals for 97 published eclipses with respect to this ephemeris. He finds them to be well fitted by a linear relation and also finds that his best quadratic term has a 97.5 percent significance level. He correctly concludes that the evidence for an increase in period is weak.

We have analyzed our new data, together with the data reported by Pringle and seven other eclipses reported by Mumford (1970, 1975). However, Pringle has apparently used the same eclipses twice (or more) where they have been reported in more than one color. Instead, we have averaged such eclipse times. Also, we have discarded all eclipses known to occur within 5 days of an eruptive maximum since, from the above discussion, these must be regarded as of low weight. They apparently contribute excessively to the residuals discussed by Pringle (1975). In all, we include 72 separate eclipses. Table 2 presents our compilation of these eclipses, with the O – C residuals computed from Krzemiński's elements.

Two fits of the O-C residuals were made, one linear and one quadratic. The best linear fit was

$$HJD = 2437638^{\circ}82645 + 0^{\circ}17690617E \\ \pm 5 \qquad \pm 6$$

while the best quadratic fit was

HJD = 
$$2437638482685 + 0417690602E$$
  
 $\pm 3$   $\pm 2$   
 $+ 544 \times 10^{-12}E^{2}$ ,

where errors refer to the least significant digit and correspond to one standard deviation.

The parameter  $\lambda$ , defined by Pringle (1975), has a value 81 with n=72. This parameter measures the confidence level at which one can exclude the null hypothesis that the quadratic term is zero. In this case the hypothesis can be ruled out at well beyond the 99.9 percent confidence limit. We conclude that the formal evidence for the slowdown of the U Gem

orbital system is very strong—being at the nine standard deviation level.

That this is at variance with Pringle's (1975) result is certainly due, in large part, to the fact that his residuals were dominated by the observations close to eruption and we have excluded those data. Our result assumes, of course, that the eclipse time is defined by a stable phase in the system. Only continued, careful observations over a period of years can clarify that question.

#### IV. CONCLUSIONS

If mass transfer is occurring with no loss from the system and if orbital angular momentum is conserved, then we can use equation (4.1) of Pringle (1975), which states that

$$-\dot{M}_2 = \dot{M}_1 = \frac{M_1 M_2}{3\tau_p (M_1 - M_2)},$$

where

$$\tau_p = P \frac{dP^{-1}}{dt} = \frac{P^2}{2\lambda_2},$$

where P is the binary period,  $M_1$  ( $M_2$ ) the mass of the white dwarf primary (red dwarf secondary), and  $\lambda_2$  is defined by

$$O-C=\alpha_2+\beta_2E+\lambda_2E^2.$$

Using the values  $M_1 = 0.65 M_{\odot}$ ,  $M_2 = 0.98 M_{\odot}$ , given by Warner (1973b), and our eclipse elements, we find

$$\dot{M}_1 \approx -8.1 \times 10^{-8} \, M_{\odot} \, \mathrm{yr}^{-1}$$
.

Current theoretical understanding of U Geminorum systems (Smak 1971; Warner and Nather 1971) demands that the mass exchange be from the secondary onto the white dwarf. To be consistent with such a constraint, our results require that the white dwarf has the larger mass. To resolve this difficulty, one may wish to discard all theories involving mass transfer onto the white dwarf, or one might question the assumptions giving rise to equation (4.1) of Pringle (1975). We prefer a third alternative, which is to question the values of the masses assigned to the U Gem system. Warner (1973b), in computing these masses, notes that U Gem is anomalous in two respects. Its period and mass ratio do not follow the well-defined relationship he finds for the other cataclysmic variables. Also, in all other systems he finds masses of the white dwarfs to be  $1 M_{\odot}$  or more. Improved determination of the masses is clearly needed.

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Note added in proof.—Robinson (Ap. J., 1976, 203, 485) has recently redetermined the masses of the U Gem system and finds  $M_1 = 0.92 M_{\odot}$  and  $M_2 = 053. M_{\odot}$ . This gives, according to the model above, mass transfer onto the white dwarf at a rate of  $5.25 \times 10^{-8} M_{\odot} \, \text{yr}^{-1}$ .

TABLE 2
ECLIPSES USED IN PRESENT ANALYSIS

2420.7775     27031     2     +0.0068     ABD       2476.6796     27347     2     +0.0066     ABD       2511.7073     27545     1     +0.0070     Md       2513.6535     27556     1     +0.0072     Md       2514.7151     27562     1     +0.0074     Md       2516.6610     27573     1     +0.0073     Md       2694.9821     28581     2     +0.0072     ABD	Average JD <sub>o</sub> (1)	Cycle (2)	No. of Obs. (3)	(O-C) (4)	Reference (5)
7639,8883 6 1 -0.0002 K 7691,7221 299 1 +0.0002 K 7691,7221 299 1 +0.0002 K 7791,7691,7231 299 1 +0.0002 K 7725,6878 491 1 0.0000 K 7725,6878 491 1 0.0000 K 7725,6878 492 1 +0.0002 K 7748,6858 621 1 +0.0002 K 7748,6858 621 1 -0.0003 K 7775,7084 672 1 +0.0006 K 7777,6979 785 1 -0.0003 K 7783,7123 819 1 -0.0003 K 7783,7123 819 1 -0.0001 K 7930,0140 1646 1 -0.0002 P 7930,0140 1646 1 -0.0002 P 7930,9793 125 4 -0.0004 P 7930,3793 125 4 -0.0004 P 8001,7995 2142 1 0.0000 P 8001,7995 2142 1 0.0000 P 8001,7995 2142 1 0.0000 P 8002,0172 2183 1 -0.0002 K 8030,8506 2216 1 +0.0001 K 8030,8506 2216 1 +0.0001 K 8031,0275 2217 1 +0.0001 K 8045,7103 2300 1 -0.0003 P 8056,8555 2363 3 -0.0001 P 8057,0323 2364 1 -0.0003 P 8057,0323 2364 1 -0.0003 P 8057,0323 2364 1 -0.0003 P 8057,0323 2364 1 -0.0000 P 8067,323 2364 1 -0.0000 P 8067,	2437638.8269				
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8087,8140					
8117.7117         2707         3         +0.0004         P           8345.9198         3997         1         -0.0002         Ma           8409.9601         4359         1         +0.0002         Ma           8410.8443         4364         1         -0.0001         Ma           8410.899         4370         1         0.0000         Ma           8430.8348         4477         1         0.0000         P           8493.6367         4832         1         +0.0003         Ma           8674.9658         5857         1         +0.0002         Ma           8674.9658         5857         1         +0.0003         Ma           9053.8987         7999         1         +0.0013         Ma           9054.9596         8005         1         +0.0013         Ma           9527.8330         10677         1         +0.0018         Ma           9527.8300         10678         1         +0.0019         Ma           9913.8392         12860         1         +0.0022         Ma           9913.8392         12860         1         +0.0032         Mb           0597.93666         16704					
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8493.6367       4832       1       +0.0003       Ma         8496.6440       4849       1       +0.0002       Ma         8674.9658       5857       1       +0.0008       Ma         8879.6464       7014       1       +0.0013       Ma         9053.8987       7999       1       +0.0003       Ma         9054.9596       8005       1       +0.0008       Ma         9211.6897       9004       1       +0.0019       Ma         9527.6533       10677       1       +0.0019       Ma         9527.8300       10678       1       +0.0017       Ma         9913.8392       12860       1       +0.0022       Ma         9919.9548       12894       1       +0.0030       Ma         2440593.8666       16704       1       +0.0032       Mb         0594.9279       16710       1       +0.0031       Mb         0597.9360       16727       1       +0.0038       Mb         0680.7279       17195       1       +0.0035       W         0680.7279       17195       1       +0.0037       W         1281.9543       20593       1	8411.9059				
8496.6440.       4849       1       +0.0002       Ma         8674.9658.       5857       1       +0.0008       Ma         8879.6464.       7014       1       +0.0013       Ma         9053.8987.       7999       1       +0.0013       Ma         9054.9596.       8005       1       +0.0008       Ma         9231.6897.       9004       1       +0.0018       Ma         9527.8533.       10677       1       +0.0019       Ma         9527.8300.       10678       1       +0.0017       Ma         9913.8392.       12860       1       +0.0022       Ma         2440593.8666.       16704       1       +0.0032       Mb         0594.9279.       16710       1       +0.0032       Mb         0597.9360.       16727       1       +0.0033       Mb         0680.7279.       17195       1       +0.0035       W         0976.6622.       17189       1       +0.0037       W         0976.6880.       18869       1       +0.0033       W         1281.9543.       20578       1       +0.0033       W         1296.8915.       20678					
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0594,9279         16710         1         +0.0031         Mb           0597,9360         16727         1         +0.0038         Mb           0679,6662         17189         1         +0.0035         W           0680,7279         17195         1         +0.0037         W           0976,8680         18869         1         +0.0033         W           1281,9543         20593         1         +0.0039         W           1296,8915         20678         1         +0.0041         W           1297,7760         20683         1         +0.0040         W           1356,6862         21016         1         +0.0046         W           1361,8161         21045         1         +0.0042         W           1368,7153         21084         1         +0.0045         W           1368,7153         21084         1         +0.0041         W           1978,8655         24533         1         +0.0047         W           1978,8655         24533         1         +0.0058         Mc           1980,9887         24545         1         +0.0061         Mc           1981,8731         24550	2440593.8666				
0597,9360         16727         1         +0.0038         Mb           0679,6662         17189         1         +0.0035         W           0680,7279         17195         1         +0.0037         W           0976,8680         18869         1         +0.0033         W           1281,9543         20593         1         +0.0039         W           1296,8915         20678         1         +0.0041         W           1297,7760         20683         1         +0.0040         W           1356,6862         21016         1         +0.0046         W           1361,8161         21045         1         +0.0042         W           1365,7083         21067         1         +0.0042         W           1368,7153         21084         1         +0.0041         W           1676,5322         22824         1         +0.0041         W           1676,5322         22824         1         +0.0047         W           1979,8655         24533         1         +0.0058         Mc           1979,9269         24539         1         +0.0057         Mc           1980,9887         24545	0594.9279				Mb
0679.6662         17189         1         +0.0035         W           0680.7279         17195         1         +0.0037         W           0976.8680         18869         1         +0.0033         W           1281.9543         20593         1         +0.0039         W           1296.8915         20678         1         +0.0041         W           1297.7760         20683         1         +0.0040         W           1356.6862         21016         1         +0.0046         W           1361.8161         21045         1         +0.0042         W           1368.7153         21084         1         +0.0045         W           1368.7153         21084         1         +0.0041         W           1676.5322         22824         1         +0.0041         W           1978.8655         24533         1         +0.0058         Mc           1979.9269         24539         1         +0.0058         Mc           1980.9887         24545         1         +0.0061         Mc           1981.8731         24550         1         +0.0061         Mc           2365.9366         26721	0597.9360	16727	1	+0.0038	Mb
0976.8680.         18869         1         +0.0033         W           1281.9543.         20593         1         +0.0039         W           1296.8915.         20678         1         +0.0041         W           1297.7760.         20683         1         +0.0040         W           1356.6862.         21016         1         +0.0046         W           1361.8161.         21045         1         +0.0042         W           1365.7083.         21067         1         +0.0045         W           1368.7153.         21084         1         +0.0041         W           1676.5322.         22824         1         +0.0041         W           1978.8655.         24533         1         +0.0058         Mc           1979.9269.         24539         1         +0.0057         Mc           1980.9887.         24545         1         +0.0061         Mc           1981.8731.         24550         1         +0.0060         Mc           2365.9366.         26721         2         +0.0068         ABD           2367.8826.         26732         2         +0.0068         ABD           2476.6796.	0679.6662	17189	1	+0.0035	$\mathbf{w}$
0976.8680.         18869         1         +0.0033         W           1281.9543.         20593         1         +0.0039         W           1296.8915.         20678         1         +0.0041         W           1297.7760.         20683         1         +0.0040         W           1356.6862.         21016         1         +0.0046         W           1361.8161.         21045         1         +0.0042         W           1365.7083.         21067         1         +0.0045         W           1368.7153.         21084         1         +0.0041         W           1676.5322.         22824         1         +0.0041         W           1978.8655.         24533         1         +0.0058         Mc           1979.9269.         24539         1         +0.0057         Mc           1980.9887.         24545         1         +0.0061         Mc           1981.8731.         24550         1         +0.0060         Mc           2365.9366.         26721         2         +0.0068         ABD           2367.8826.         26732         2         +0.0068         ABD           2476.6796.	0680.7279				
1296,8915       20678       1       +0.0041       W         1297,7760       20683       1       +0.0040       W         1356,6862       21016       1       +0.0046       W         1361,8161       21045       1       +0.0042       W         1365,7083       21067       1       +0.0045       W         1368,7153       21084       1       +0.0041       W         1676,5322       22824       1       +0.0047       W         1978,8655       24533       1       +0.0058       Mc         1979,9269       24539       1       +0.0057       Mc         1980,9887       24545       1       +0.0061       Mc         1981,8731       24550       1       +0.0060       Mc         2365,9366       26721       2       +0.0068       ABD         2367,8826       26732       2       +0.0068       ABD         2476,6796       27347       2       +0.0068       ABD         2511,7073       27545       1       +0.0070       Md         2513,6535       27556       1       +0.0072       Md         2514,7151       27562       1 <td>0976.8680</td> <td></td> <td>· <del>-</del></td> <td></td> <td></td>	0976.8680		· <del>-</del>		
1296,8915       20678       1       +0.0041       W         1297,7760       20683       1       +0.0040       W         1356,6862       21016       1       +0.0046       W         1361,8161       21045       1       +0.0042       W         1365,7083       21067       1       +0.0045       W         1368,7153       21084       1       +0.0041       W         1676,5322       22824       1       +0.0047       W         1978,8655       24533       1       +0.0058       Mc         1979,9269       24539       1       +0.0057       Mc         1980,9887       24545       1       +0.0061       Mc         1981,8731       24550       1       +0.0060       Mc         2365,9366       26721       2       +0.0068       ABD         2367,8826       26732       2       +0.0068       ABD         2476,6796       27347       2       +0.0068       ABD         2511,7073       27545       1       +0.0070       Md         2513,6535       27556       1       +0.0072       Md         2514,7151       27562       1 <td>1281.9543</td> <td></td> <td></td> <td></td> <td></td>	1281.9543				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1296.8915				
1361.8161       21045       1       +0.0042       W         1365.7083       21067       1       +0.0045       W         1368.7153       21084       1       +0.0041       W         1676.5322       22824       1       +0.0047       W         1978.8655       24533       1       +0.0058       Mc         1979.9269       24539       1       +0.0057       Mc         1980.9887       24545       1       +0.0061       Mc         1981.8731       24550       1       +0.0060       Mc         2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2476.6796       27347       2       +0.0068       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2514.7051       28581       2       +0.0072       ABD	1297.7760				
1365.7083         21067         1         +0.0045         W           1368.7153         21084         1         +0.0041         W           1676.5322         22824         1         +0.0047         W           1978.8655         24533         1         +0.0058         Mc           1979.9269         24539         1         +0.0057         Mc           1980.9887         24545         1         +0.0061         Mc           1981.8731         24550         1         +0.0060         Mc           2365.9366         26721         2         +0.0068         ABD           2367.8826         26732         2         +0.0065         ABD           2476.6796         27347         2         +0.0068         ABD           2476.6796         27347         2         +0.0066         ABD           2511.7073         27545         1         +0.0070         Md           2513.6535         27556         1         +0.0072         Md           2514.7151         27562         1         +0.0074         Md           2514.7951         28581         2         +0.0072         ABD	1356.6862		-		
1368.7153       21084       1       +0.0041       W         1676.5322       22824       1       +0.0047       W         1978.8655       24533       1       +0.0058       Mc         1979.9269       24539       1       +0.0057       Mc         1980.9887       24545       1       +0.0061       Mc         1981.8731       24550       1       +0.0060       Mc         2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2476.6796       27347       2       +0.0068       ABD         2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2514.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD	1361.8161				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1365.7083			+0.0045	
1978.8655       24533       1       +0.0058       Mc         1979.9269       24539       1       +0.0057       Mc         1980.9887       24545       1       +0.0061       Mc         1981.8731       24550       1       +0.0060       Mc         2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2420.7775       27031       2       +0.0068       ABD         2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD			-	+ 0.0041	
1979,9269       24539       1       +0.0057       Mc         1980,9887       24545       1       +0.0061       Mc         1981,8731       24550       1       +0.0060       Mc         2365,9366       26721       2       +0.0068       ABD         2366,8209       26726       2       +0.0065       ABD         2367,8826       26732       2       +0.0068       ABD         2420,7775       27031       2       +0.0068       ABD         2476,6796       27347       2       +0.0066       ABD         2511,7073       27545       1       +0.0070       Md         2513,6535       27556       1       +0.0072       Md         2514,7151       27562       1       +0.0074       Md         2516,6610       27573       1       +0.0073       Md         2694,9821       28581       2       +0.0072       ABD					
1980.9887       24545       1       +0.0061       Mc         1981.8731       24550       1       +0.0060       Mc         2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2470.775       27031       2       +0.0068       ABD         2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD	1970.0033				
1981.8731       24550       1       +0.0060       Mc         2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD					
2365.9366       26721       2       +0.0068       ABD         2366.8209       26726       2       +0.0065       ABD         2367.8826       26732       2       +0.0068       ABD         2420.7775       27031       2       +0.0068       ABD         2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$					
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			ž		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2367.8826		5		ABD
2476.6796       27347       2       +0.0066       ABD         2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD	2420.7775		<b>5</b>		ABD
2511.7073       27545       1       +0.0070       Md         2513.6535       27556       1       +0.0072       Md         2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD	2476.6796		$\bar{z}$		ABD
2513.6535     27556     1     +0.0072     Md       2514.7151     27562     1     +0.0074     Md       2516.6610     27573     1     +0.0073     Md       2694.9821     28581     2     +0.0072     ABD		27545			
2514.7151       27562       1       +0.0074       Md         2516.6610       27573       1       +0.0073       Md         2694.9821       28581       2       +0.0072       ABD	2513.6535				
2516.6610	2514.7151				
2694.9821 28581 2 +0.0072 ABD	2516.6610				
2696 9279 28592 2 ±0 0071 ARD	2694.9821				ABD
	2696.9279	28592	$ar{2}$	+0.0071	ABD

Note.—Table 2 gives the details of eclipses used in the present analysis. Column (1) is the Heliocentric Julian Date of the eclipse, column (2) the cycle number, column (3) gives the number of observations of that eclipse, column (4) is the observed minus calculated time of eclipse according to the elements of Krzemiński (1965) and column (6) denotes the source of the observed times.

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