PHOTOGRAPHIC STUDIES OF NEGLECTED VARIABLES, 1: TW, CG, DZ, AND NU PUPPIS

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Abstract

Light curves and new or improved periods are presented for the Algol-type eclipsing binaries TW and CG Puppis and the Mira stars DZ and NU Puppis. A new semiregular variable is also reported.

1. Introduction

In recent years I have been privileged to conduct several variable star investigations using the Harvard College Observatory plate collection. These visits to Cambridge, MA, are infrequent, expensive, and brief. So, to make each "observing run" as productive as possible, when I choose a particular variable for investigation, I check the *New Catalogue of Suspected Variable Stars* (NSV) and *General Catalogue of Variable Stars* (GCVS) (Kholopov *et al.* 1982; 1985) for other variables that appear to need more study and can be estimated on the same plates.

This paper presents results for four named but unstudied variables and a new semiregular variable in southern Puppis, and is the byproduct of an investigation of the eclipsing binary CF Puppis, which will be reported elsewhere. The Harvard plates are blue sensitive. The magnitudes of comparison stars near each variable were estimated using a graduated image scale calibrated by comparison to stars with photoelectric B magnitudes in the *Guide Star Photometric Catalog* field S205 (Lasker *et al.* 1988).

2. TW Puppis

TW Pup was discovered on Harvard plates by B. P. Gerasimovich (1927). He reported that it was an eclipsing binary, photographic range 11.8-12.8, but did not publish an initial epoch or a period. I estimated TW Pup on 404 plates of the AM, AX, RB, and Damon series, 1924-1953 and 1978-1988. The following light elements were determined by a least-squares solution of the 14 minima listed in Table 1:

$$\text{Min I}(\text{JD}_{\text{hel.}}) = \underset{\pm 0.009}{2426691.422} + \underset{\pm 0.000003}{2.894950}\,\text{E}. \qquad (1)$$

A minimum was defined as an observation of the variable within 0.5 magnitude of faintest light. O-C residuals from equation 1 are included in the table. A light curve based on this ephemeris is shown in Figure 1. The duration of primary minimum is about 0.12 P. The secondary minimum was not detected. The depth of primary eclipse, photographic range 11.7-14.2, is much greater than Gerasimovich reported, because none of the plates that he blinked caught TW Pup at full minimum. The period may be variable. The first 12 minima in Table 1, from the interval 1924-1953, yield a significantly shorter period of 2.894925 days. This remains uncertain, however, due to the small number of minima and the 25-year gap during which no plates are available.

Table 1. TW Puppis, epochs of minima, $JD_{hel.}$ 2400000+.

minima	*m(pg)*	*O-C*	*minima*	*m(pg)*	*O-C*
26691.460	<14.0	+0.038[d]	30269.604	14.1	+0.023[d]
26717.483	14.2	+0.006	30443.262	14.2	-0.016
28512.334	14.0	-0.012	32504.461	14.0	-0.021
28567.384	13.9	+0.034	32649.248	14.0	+0.018
28952.372	14.1	-0.044	33161.621	14.3	-0.015
29638.469	14.1	-0.013	46791.054	13.7	-0.008
30055.305	13.8	-0.049	47063.208	13.7	+0.021

3. CG Puppis

CG Pup was discovered on Sonneberg plates by Hoffmeister (1943). He reported that it was an Algol-type eclipsing binary, photographic range 10.2-13.0, with the following approximate light elements:

$$\text{Min I}(JD_{hel.}) = 2428493.53 + 1.04957\,E. \qquad (2)$$

I estimated CG Pup on 408 plates of the AM, AX, RB, and Damon series, 1924-1953 and 1978-1988. My light curve (Figure 2) shows a photographic range of 11.7-13.9. Hoffmeister's maximum is 1.5 magnitudes brighter than mine. However, his maximum photographic magnitude for the nearby eclipsing variable CF Pup, 9.4, is also more than 1 magnitude brighter than expected from the photoelectric V magnitude and F + K spectral types (Kviz and Rufener 1986). From this and my results for CG, DZ, and NU Pup, I believe that Hoffmeister's magnitudes in this field are systematically too bright.

The period has been constant. The following light elements were derived from Hoffmeister's minimum (equation 2) and the 8 faintest minima in Table 2:

$$\text{Min I}(JD_{hel.}) = \underset{\pm 0.004}{2428493.525} + \underset{\pm 0.0000003}{1.0495822}\,E. \qquad (3)$$

Table 2. CG Puppis, epochs of minima, $JD_{hel.}$ 2400000+.

minima	*m(pg)*	*O-C*	*minima*	*m(pg)*	*O-C*
26035.407	13.2	+0.004[d]	33377.229	13.4	-0.002d
29954.561	13.0	+0.018	34397.415	13.1	-0.010
30055.305	13.1	+0.002	44694.868	13.9	-0.008
31156.323	13.6	+0.008	44994.010	13.9	+0.003
31494.283	13.0	+0.002	45312.038	13.5	+0.008
31671.653	<13.3	-0.007	46116.008	13.8	-0.002
32031.659	<13.3	-0.007			

The O-C residuals from this ephemeris (Table 2) are extremely small for this kind of photographic observation. The duration of primary minimum is about 0.12 P. The secondary minimum was not detected. The light curve has a peculiar appearance, with all the observations fainter than photographic magnitude 13.0 falling in the same narrow phase interval. This might be due to the variability of a faint comparison star, or an adopted magnitude difference between the faintest comparison stars that is substantially larger than their true difference. With these possibilities in mind, I have included all the observations of CG Pup at magnitude 13.0 or fainter in the table. If possible, the critical plates will be re-examined at a future date.

4. DZ Puppis

DZ Pup was discovered at Sonneberg by Hoffmeister (1949). He reported that this variable is type M, with photographic range 11 - <13, but he did not determine the period. I estimated DZ Pup on 386 Harvard plates of the AM, RB, and Damon series, 1928-1953 and 1978-1988. The light curve for 1924-1950 shown in Figure 3 indicates that the photographic range of variation is 12.4 - 14.3. Since this is only 1.9 magnitudes, DZ Pup could be classed as type SRa rather than M. The period is variable. The following light elements were derived from the 16 maxima listed in Table 3 from the earlier interval JD 2424100-2433400:

$$JD_{max} = \underset{\pm 6.9}{2424159.6} + \underset{\pm 0.3}{229.8}\,E. \qquad (4)$$

The O-C residuals for the first 16 maxima in Table 3 are derived from equation 4. The seven maxima from the interval JD 2444700-2447300 indicate a slightly longer period, though of course the mean errors are greater because of the smaller number of maxima:

$$JD_{max} = \underset{\pm 13.9}{2444676.1} + \underset{\pm 2.0}{234.0}\,E. \qquad (5)$$

The O-C residuals of the last 7 maxima in Table 3 are derived from equation 5. Each ephemeris produces a significant reduction in the O-C residuals during the applicable time intervals, compared to residuals from the mean period for the entire span 1928-1988.

Table 3. DZ Puppis, epochs of maxima, JD 2400000+.

maxima	*m(pg)*	*O-C*	*maxima*	*m(pg)*	*O-C*
24170	12.7	+10 d	29911	12.6	+6 d
24414	12.6	+25	31951	12.7	-22
24826	12.6	-23	32421	12.6	-12
25534	12.7	-4	33377	12.6	+25
26006	12.6	+8	44700	12.8	+24
26456	12.6	-2	45362	12.8	-16
26673	12.4	-15	45827	13.0	-19
27125	12.6	-22	46078	13.0	-2
28080	12.7	+14	46536	12.9	-12
28994	12.5	+8	46796	12.9	+14
29215	12.4	0	47262	12.9	+12
29679	12.5	+4			

5. NU Puppis

NU Pup was also discovered at Sonneberg by Hoffmeister (1949). He classified it as type M, with photographic range 12 - <13, but did not determine the period. I estimated NU Pup on 297 Harvard plates of the AM, RB, and Damon series, 1928-1953 and 1978-1988. The light curve for 1924-1945 shown in Figure 4 indicates that the photographic range is 12.7 - <15.3. The light curve also shows a substantial interval of constant light at minimum. This is the classic signature of an unresolved companion or nearby star of constant brightness, which is observed only when the variable is fainter. Inspection of the southern extension of the Palomar Sky Survey revealed a couple of 15th magnitude stars close to the variable's position. These stars can be detected on the best RB plates, and I conclude that I mistakenly estimated one of these stars when the variable was actually invisible.

The period is variable. The following light elements were derived from the first 10 maxima in Table 4:

$$JD_{max} = \underset{\pm 4.1}{2428490.4} + \underset{\pm 0.6}{304.8}\,E. \quad (6)$$

The O-C values for the first 11 maxima (Table 4) are derived from equation 6. An abrupt period decrease occurs between the tenth and eleventh maximum, followed by the long gap in the data. The following light elements represent the four recent maxima:

$$JD_{max} = \underset{\pm 8.8}{2445668.3} + \underset{\pm 2.4}{301.7}\,E. \quad (7)$$

The O-C residuals of the last four maxima are derived from equation 7.

Table 4. NU Puppis, epochs of maxima, JD 2400000+.

maxima	*m(pg)*	*O-C*	*maxima*	*m(pg)*	*O-C*
25734	12.7	-13^d	30623	12.9	-1^d
26045	12.7	-7	31523	13.1	-16
26365	12.6	+9	33290	12.8	-77
26659	12.8	-2	44165	12.9	+5
28189	12.8	+4	45073	12.9	+8
28486	12.9	-4	45647	13.1	-21
28822	13.1	+27	47185	12.9	+8
29714	12.8	+4			

6. A New Variable

While estimating NU Pup, I noticed that one of the comparison stars was sometimes brighter than a nearby field star and sometimes fainter. Since either star (or both) might be variable, I estimated both stars on 173 RB plates, JD 2425000-2433000. These observations are plotted in Figure 5, which shows that one star is constant at photographic magnitude 13.8 and the other is variable, ranging from photographic magnitude 13.6 to 14.4. The variable is located about 0.1 degree south of NU Pup at RA $06^h\,31^m\,18^s$, Dec. -43° 57.7' (1950). Figure 6 is a finding chart. A companion star about 1 magnitude fainter and at position angle 85° made estimates difficult because of image blending on lower-quality plates. The variations appear to be semiregular. A discrete Fourier transform analysis found a frequency peak equivalent to a period of 118 days.

7. Acknowledgements

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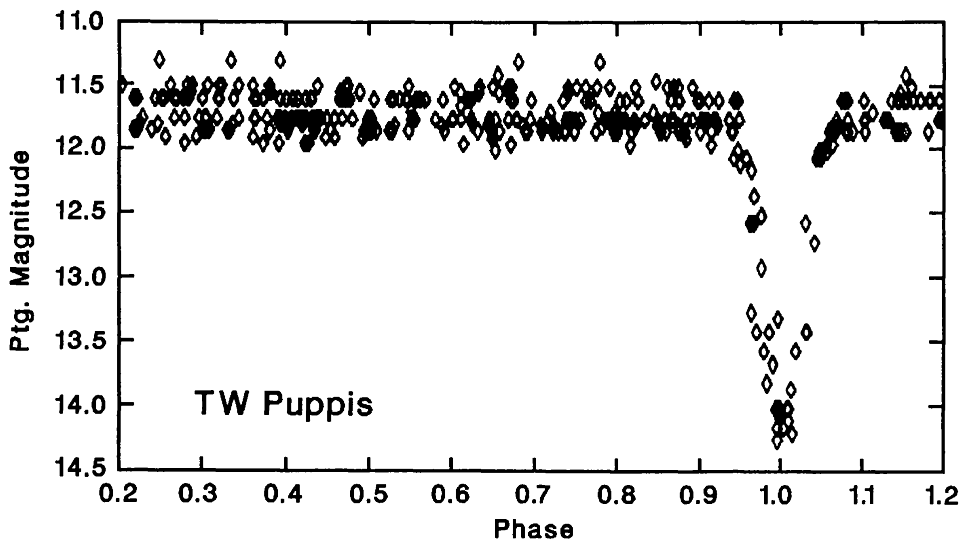

Figure 1. TW Puppis, composite light curve phased according to equation 1.

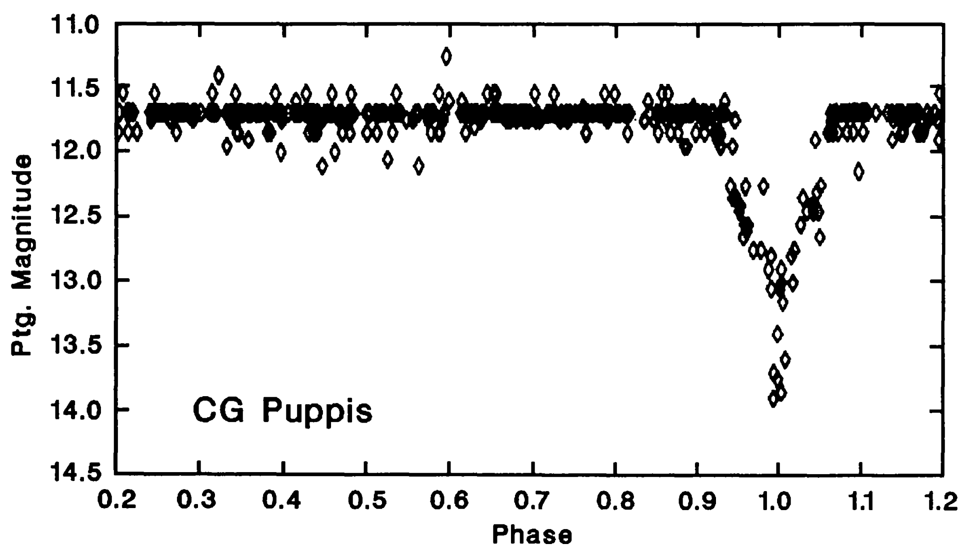

Figure 2. CG Puppis, composite light curve phased according to equation 3.

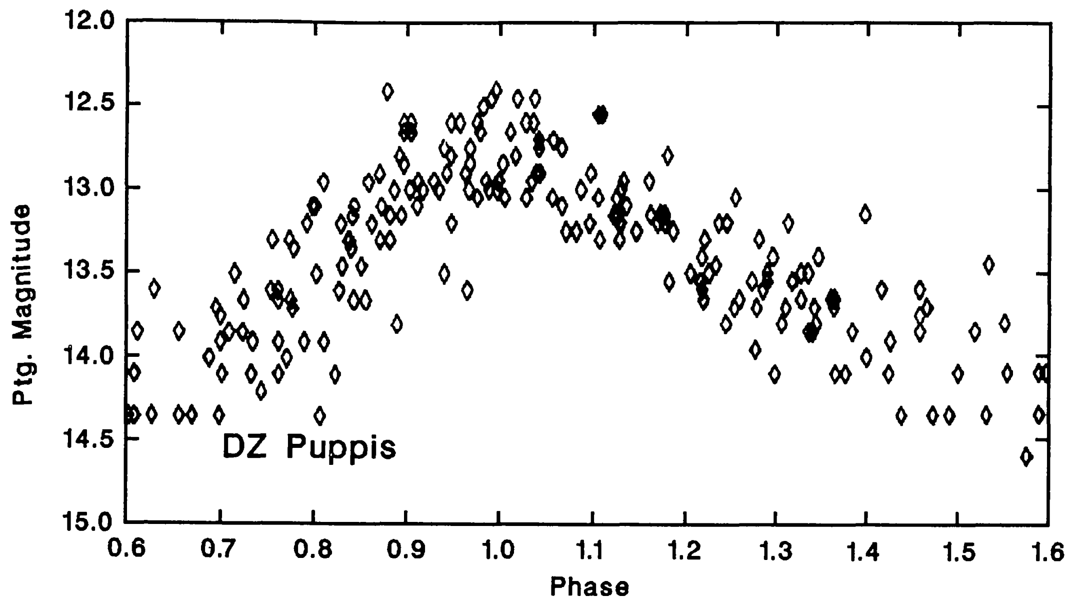

Figure 3. DZ Puppis, composite light curve of observations for JD 2424100-2433400, phased according to equation 4.

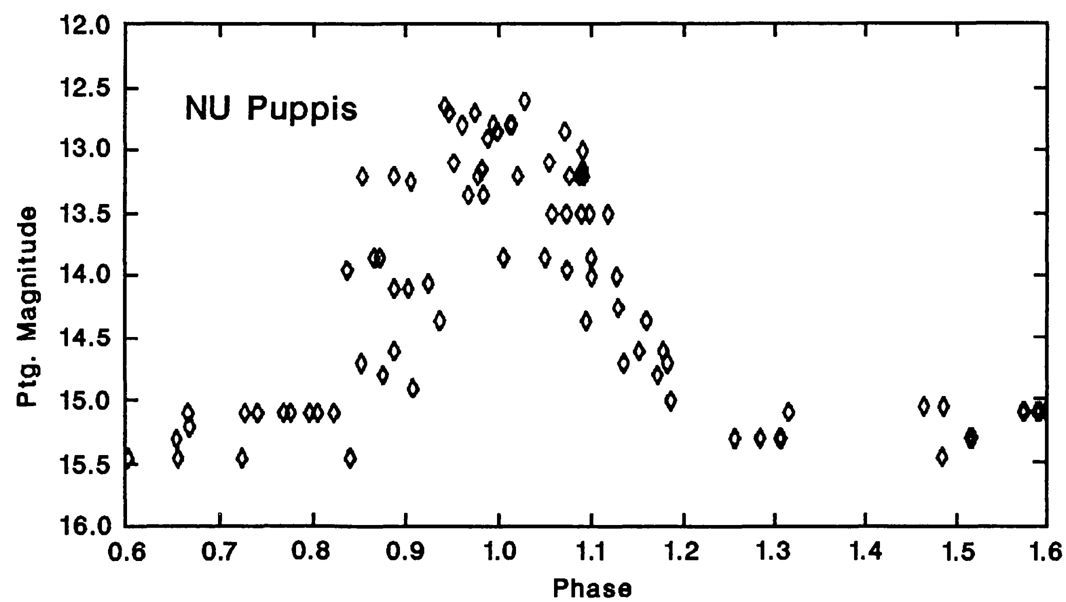

Figure 4. NU Puppis, composite light curve of observations for JD 2424100-2431600, phased according to equation 6.

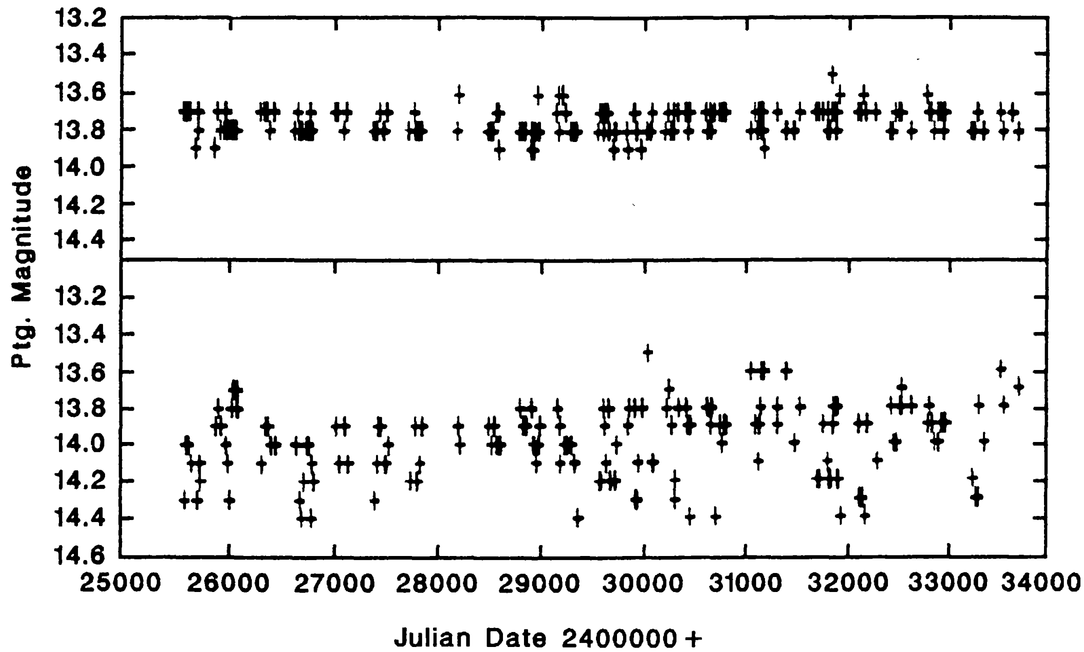

Figure 5. Upper panel, observations of the non-variable suspect; lower panel, observations of the new variable in the field NU Pup.

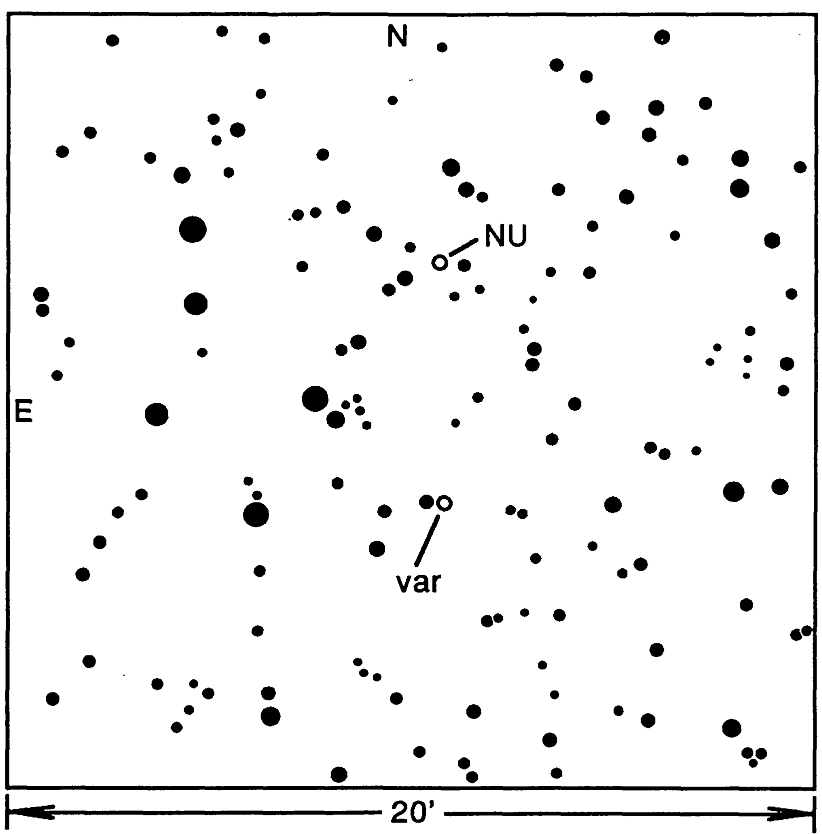

Figure 6. Finding chart for new variable in field of NU Puppis, based on red images. The faintest stars are about 16th magnitude.