MP PUPPIS: AN ECLIPSING BINARY WITH A 0.999-DAY PERIOD

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Abstract

Visual, photographic, and photoelectric observations reveal that MP Puppis is a beta Lyrae-type eclipsing binary with Min. I = 0.60 V, Min. II = 0.22 V. The period is very nearly equal to the sidereal day. Current light elements are:

$$\text{Min. I} = \text{JD (hel.) } 2449361.828 + 0.9989258 \text{ E}.$$

1. Introduction

The eclipsing variable MP Puppis (BD -12°2001) was discovered by Hoffmeister (1968), who reported two times when the star was faint on Sonneberg plates, with a variation of about 10–10.5 ptg. The star was neglected until Baldwin began visual monitoring as part of a project to determine periods for a number of unstudied eclipsing binaries and RR Lyr variables in Puppis. He made 69 estimates of MP Pup on 51 nights during the 1990–91 and 1991–92 seasons. During the first season, observations showed no variation greater than the expected scatter of visual estimates. A few days into the second season, MP Pup became fainter and remained so for several weeks. However, Baldwin soon noted that observations made very late each night showed the variable brighter than estimates made early in the evening. A period close to one day seemed likely.

Baldwin reported on MP Pup in a paper presented at the 81st Spring Meeting of the AAVSO, but only an abstract was published (Baldwin 1992). Combining his visual observations with the photographic minima reported by Hoffmeister, he found a period of 0.998982 day, just 2 minutes longer than the sidereal day. But because of the small range of variation and the limited precision of visual estimates, he could not dismiss the possibility of a period twice as long with primary and secondary eclipses of similar depth.

2. Photoelectric observations

At Baldwin's request, Kaiser began photoelectric observations of MP Pup in 1992, using a 35-cm Schmidt-Cassegrain telescope and Optec SSP-5 photometer. During the first season, he obtained observations on the rising branch of the primary eclipse on three nights, including both odd and even dates. Baldwin's preliminary period was confirmed and slightly improved by adjusting the period value to achieve alignment of the three

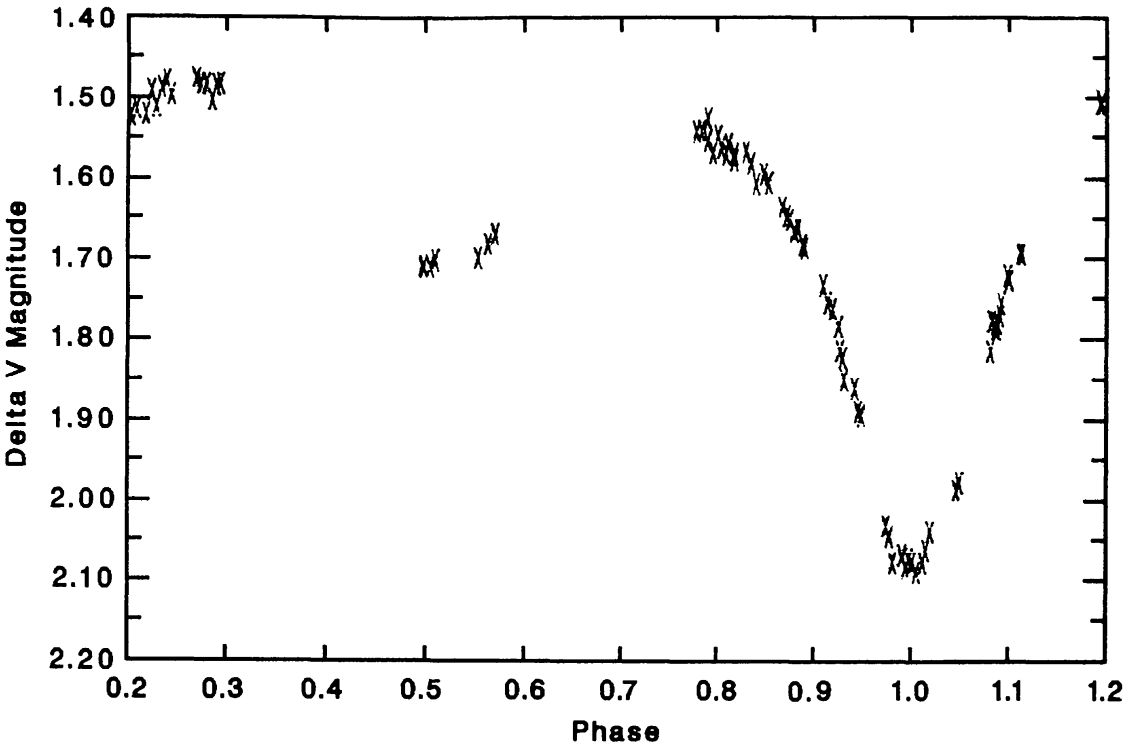

Figure 1. Photoelectric light curve of MP Puppis, 1992–1995, reduced to phase according to equation (1).

light-curve segments.

Further photoelectric observations in 1993 recorded part of a shallower secondary minimum near phase 0.5 of the 0.999-day period, definitely eliminating the possibility that the period might be twice as long. Observations in 1994 covered the descending branch of the primary eclipse from near maximum to minimum, and observations in 1995 recorded the top of the maximum following primary eclipse.

The four seasons of photoelectric observations (Figure 1) established most of the important features of the light curve: the heights of the maxima, the depths of primary and secondary minima, and the overall shape of the light curve, which fits the beta Lyr type. Total system light is already decreasing shortly after quadrature (phase 0.75), leaving no room for an interval of constant light at maximum, and the decline steepens with phase toward primary minimum, so variation is continuous. The depth of secondary minimum is about one third that of the primary minimum. Max. I, following primary minimum, is about 0.4 magnitude brighter than Max. II.

The differential photoelectric observations indicate that MP Pup varies by 0.60 V from primary minimum to Max. I, and 0.22 V from Max. I to secondary minimum. Kaiser also measured the difference between his comparison star and HR 2897. Based on the magnitude and B-V index of HR 2897 in the *Bright Star Catalogue* (Hoffleit and Jaschek 1982), MP Pup varies from 9.49 to 10.09 V, with B-V = +0.26 near maximum. These results are preliminary and will be improved by future observations.

The most interesting feature of the photoelectric data appears at primary minimum. On the night when these observations were obtained, Kaiser was startled to see the photometer counts decline, reach a minimum value, and then remain steady at that value instead of increasing again. The minimum was essentially constant for the next 40 minutes, after which the star set behind a nearby roofline; the last data point, which appears to show the variable brightening again, may have been affected by a slightly occulted light path.

The interval of constant light could be significantly longer than 40 minutes, depending on the actual time of mid-eclipse on the night of these observations. Unfortunately, even though the eclipses occur only 1.5 minutes earlier each night, MP Pup itself sets 4 minutes earlier each night, so it was impossible to obtain any observations at later phases during the remainder of the 1994 season.

Observations of the ascending branch of primary eclipse from the 1992 season could help to delimit the duration of constant light at minimum if both seasons of data could be correctly phased and plotted on the same light curve. Alternatively, the time when constant light began (second contact) is known, so the total duration of constant light could be determined if we could accurately predict the time of mid-eclipse for that night. To achieve either of these solutions and to correctly piece together all four seasons of photoelectric measures in a reliable light curve, more accurate light elements were needed.

3. Photographic observations

As part of a parallel investigation of unstudied Puppis variables, including stars nominated by Baldwin, Williams studied MP Pup on about 200 Harvard patrol plates exposed with the small AC/AM cameras, dating from 1899 to 1917; 100 plates exposed with the larger RH/RB cameras, 1928–1951; and 30 Damon series plates, 1981–1989. MP Pup was usually overexposed on the RH/RB plates, so only a few reliable estimates were obtained from them.

While estimating MP Pup on the Harvard plates, Williams was not aware of the unusual period Baldwin found. But the distribution of magnitude estimates seemed odd. MP Pup remained near maximum for hundreds of days, then near minimum for several weeks, then returned to maximum for another several hundred days. After estimating the variable on the first 5,000-day span of the AC/AM plates, Williams plotted a light curve (Figure 2). This light curve resembles an eclipsing binary, but with substantial scatter at maximum and Algol-like minima at regular intervals of about 600 days. To confirm the apparent 600-day cycle, he examined plates for an additional 1000 days, and another cluster of faint observations recurred as expected.

Close examination of the observations suggested that the true period was probably not 600 days because there were a few brighter observations within the clumps of faint observations. Suspecting a severe sidereal-day aliasing problem, Williams tested the simplest explanation suggested by inspection of Figure 2, that the period of MP Pup is almost equal to one sidereal day and the clumps of minima appearing at 600-day intervals reveal that the period is either 1 + 1/600 sidereal day or 1 - 1/600 sidereal day. When the observations were phased to each of these periods, the first possibility produced a satisfactory light curve.

4. Period analysis

Our photographic and visual observations provide a temporal baseline of 95 years (more than 34,000 orbital cycles). Table 1 includes 28 times when MP Pup was estimated to be at minimum on the Harvard plates, plus Hoffmeister's two minima from Sonneberg plates and 5 times of Baldwin's faintest visual estimates.

A least-squares solution of the 35 times of minima in Table 1 yields the following light elements:

$$\begin{aligned} \text{Min. I} = \text{JD(hel.) } & 2449361.828 + 0.9989258\ E \\ & \pm 0.009 \quad \pm 0.0000004 \end{aligned} \qquad (1)$$

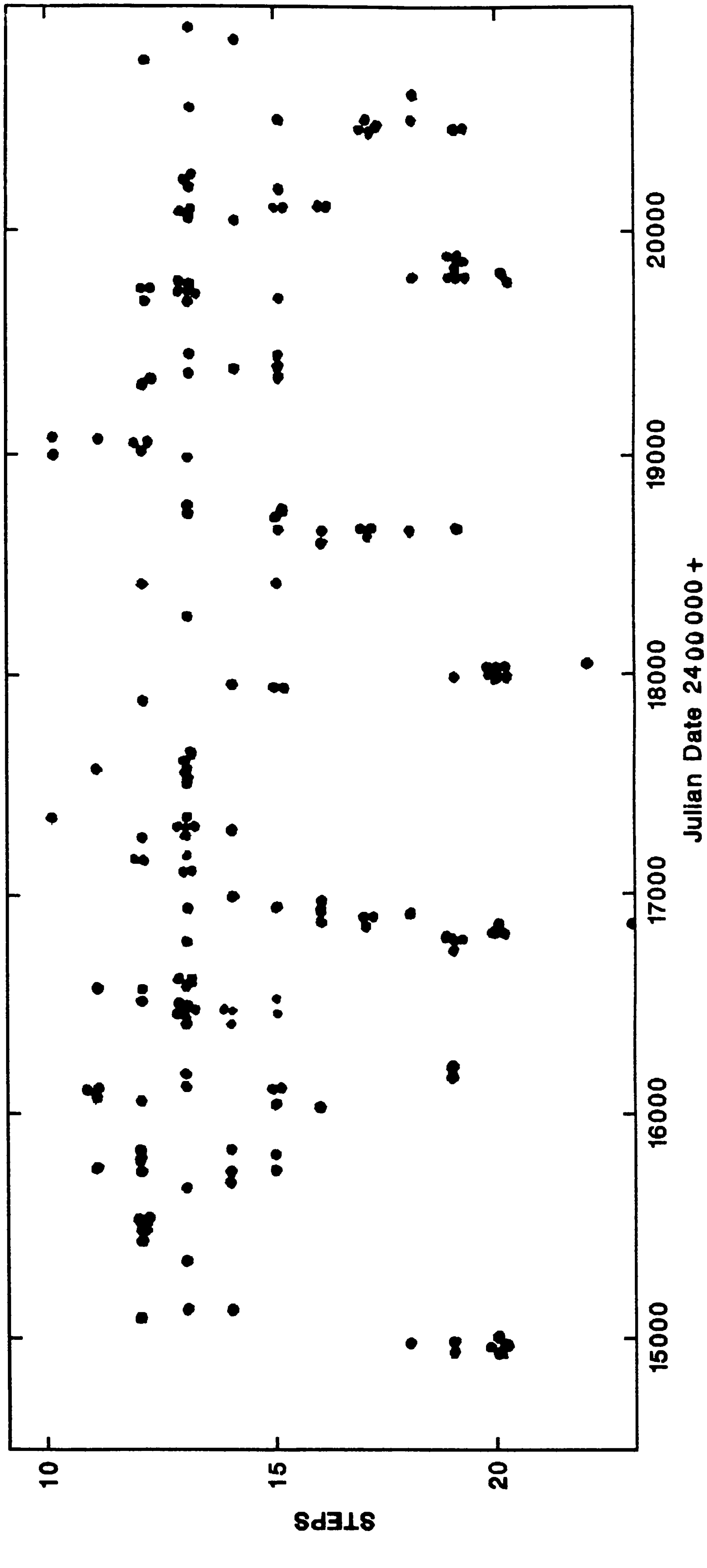

Figure 2. Synoptic light curve of MP Puppis from estimates on Harvard patrol plates, 1899–1925. The magnitude scale is in step units equal to about 0.08 magnitude per step.

Table 1. Times of minima for MP Puppis.

HJD 2400000+		E	O-C	HJD 2400000+		E	O-C
14949.885	H	-34449	+0.051	19844.534	H	-29549	-0.036
14956.829	H	-34442	+0.003	19863.534	H	-29530	-0.016
14968.810	H	-34430	-0.003	19893.518	H	-29500	0.000
14993.774	H	-34405	-0.013	27017.891	H	-22368	+0.035
16815.818	H	-32581	-0.009	29267.451	H	-20116	+0.014
16825.786	H	-32571	-0.030	29300.381	H	-20083	-0.021
16871.754	H	-32525	-0.013	29385.270	H	-19998	-0.040
17994.591	H	-31401	+0.031	29965.620	S	-19417	-0.066
18000.577	H	-31395	+0.024	31090.470	S	-18291	-0.007
18006.576	H	-31389	+0.029	44750.800	H	-4616	+0.013
18010.546	H	-31385	+0.004	46506.938	H	-2858	+0.040
18022.531	H	-31373	+0.001	46535.857	H	-2829	-0.010
18026.532	H	-31369	+0.007	48673.558	B	-689	-0.010
18040.510	H	-31355	0.000	48682.569	B	-680	+0.010
19798.653	H	-29595	+0.033	48690.556	B	-672	+0.006
19804.632	H	-29589	+0.019	49361.845	B	0	+0.017
19811.612	H	-29582	+0.006	49362.805	B	1	-0.022
19834.533	H	-29559	-0.048				

H = Harvard plates, S = Sonneberg plates, B = Baldwin visual estimates.

The O-C residuals in Table 1 were calculated from equation (1). These elements predict primary mid-eclipse on the night of Kaiser's photoelectric observations of primary minimum at JD (hel.) 2449361.828, which is 0.021 day later than our estimated time of second contact. The interval from second to third contact would be twice as long, or about 60 minutes. More observations are needed to define this aspect of the light curve.

5. *Guide Star Catalog* observations

In an extraordinary astronomical coincidence, the primary minimum of MP Pup is recorded on the source plates of the *Guide Star Catalog* (GSC) (Lasker *et al.* 1988). This curious fact was discovered by Baldwin, who was installing the GSC CD-ROM when we were discussing our MP Pup observations. Out of curiosity, he called up MP Pup (GSC 5408:1227) and found that it had been measured on four plates. Table 2 presents the GSC data for MP Pup, with phases calculated from equation (1). All four observations fall within the interval of primary minimum, and the faintest observation falls almost exactly at mid-eclipse. The apparent photovisual range of MP Pup listed in Table 2 is greater than the photoelectric results reported in this paper due to variations in zero point and magnitude scale on the wide-angle Schmidt plates measured for the catalogue. The error range given in the GSC for the magnitudes in Table 2 is ±0.4.

Table 2. *Guide Star Catalog* observations of MP Pup = GSC 5408:1227

JD 2400000+	V	Phase
44669.916	9.94	0.043
45314.180	10.36	0.999
45341.084	10.14	0.932
45380.929	9.44	0.820

6. Conclusions

Our combined visual, photographic, and photoelectric observations show that MP Pup is a beta Lyr-type eclipsing binary varying from magnitude 9.49 to 10.09 V. The color index near maximum, +0.26 B-V, indicates an early spectral type. System light varies continuously with Min. I = 0.60 V, Min. II = 0.22 V. Max. I is brighter than Max. II, and there is an interval of constant light at minimum of about 60 minutes in duration. The period is 0.9989258 day and appears to have been constant during the 95-year span for which times of minima are available.

We plan to continue our investigation of MP Pup. It will be several years before all phases of the light curve can be observed from Indiana. We are grateful to Dr. Martha Hazen for use of the Harvard plate collection.

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