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A REVISED PERIOD FOR THE MIRA VARIABLE AW AURIGAE

TEMPLETON, M. R.

American Association of Variable Star Observers (AAVSO), 25 Birch Street, Cambridge, MA 02138, USA; email: aavso@aavso.org

AW Aurigae – α:5$^{\rm h}$40$^{\rm m}$00$^{\rm s}_{.}$7; δ:+28°42′49″.0 (J2000) – is listed in the GCVS as a Mira variable with a period of 695 days. The published period is one of the longest among the Miras, making AW Aurigae an object of some astrophysical interest. However, this period was considered preliminary by Kurochkin (1951), and the quoted $(O - C)$ values are very large. The star was among the 58 Mira variables studied by Whitney (1960) at the request of B.V. Kukarkin, to better determine their elements. Whitney did not revise the 695-day period for this star, though like Kurochkin he also noted very large residuals in his $(O-C)$ analysis. Although the star has been mentioned as part of several Mira population studies since then, no discussion or refinement of its period appears in the literature. As part of a larger project to study secular changes in Mira variable pulsations, I analyzed visual and CCD data from the American Association of Variable Star Observers (AAVSO) International Database (ID), along with Harvard College Observatory (HCO) photographic plate data for AW Aurigae, and compared the period determined using these data to the period given in the GCVS. I find that the period quoted in the GCVS is incorrect, and that the best-fitting period to the available data is 449.3 $\pm$ 0.7 days.

I used three separate data sets to determine the correct period: visual observations from the AAVSO ID (380 total observations, 148 positive observations), CCD V-band observations from the AAVSO ID (27 total observations, 24 positive), and blue-sensitive photographic plate observations from HCO (197 total observations, 46 positive). The visual observations span the longest period of time of the three data sets (JD 2439851 to 2452904; December 1967 to September 2003), and so were used for the Fourier analysis. I used the CLEANest program (Foster, 1996) to compute the Fourier transform shown in Figure 1. The strongest peak is centered on a period of 449.3 ± 0.7 days ($\nu = 2.225 \times 10^{-3}$ cyc/d). Although the data is noisy, the 449.3-day peak and its Fourier harmonic at 224.7 days are both stronger than any other peak in the spectrum. There is a weak signal at about 720 days, but given the noise level it may be spurious.

Based upon Fourier analysis of the visual data alone, the best ephemeris of AW Aurigae appears to be

$$\mathrm{Max} = \mathrm{JD}2445320 + 449.3 \cdot E. \qquad (1)$$

The post-1967 HCO plates agree with this ephemeris, as do the AAVSO V-band CCD observations. However, there is a significant phase shift between the maxima predicted by this ephemeris and the maxima obtained from the HCO photographic plate data from 1928 to 1952. Table 1 gives previously published dates of maximum for AW Aurigae as

Table 1: Dates of maxima of AW Aurigae. Dates taken from Kurochkin (1951) and Whitney (1960) are given without error bars. Dates derived from HCO plate data and AAVSO observations should be considered accurate to ±20 days.

JD Max	E	Source	JD Max	E	Source	JD Max	E	Source
2419447	−58	Kurochkin	2431540	−31	HCO	2445320	0	AAVSO
2424448	−47	Kurochkin	2432010	−30	HCO	2445790	1	AAVSO
2424857	−46	Kurochkin	2432440	−29	HCO	2446220	2	AAVSO
2425250	−45	HCO	2434712	−24	Whitney	2446670	3	AAVSO
2425700	−44	HCO	2435095	−23	Whitney	2447130	4	AAVSO
2426150	−43	HCO	2439920	−12	AAVSO	2447610	5	AAVSO
2426580	−42	HCO	2440360	−11	AAVSO	2448010	6	AAVSO
2427041	−41	Kurochkin	2440820	−10	AAVSO	2448470	7	AAVSO
2427490	−40	HCO	2441240	−9	AAVSO	2448900	8	AAVSO
2427960	−39	HCO	2441730	−8	AAVSO	2449370	9	AAVSO
2428380	−38	HCO	2442210	−7	AAVSO	2449850	10	AAVSO
2428820	−37	HCO	2442630	−6	AAVSO	2450270	11	AAVSO
2429283	−36	Kurochkin	2443090	−5	AAVSO	2450720	12	AAVSO
2429760	−35	HCO	2443540	−4	AAVSO	2451170	13	AAVSO
2430220	−34	HCO	2443960	−3	AAVSO	2451610	14	AAVSO
2430640	−33	HCO	2444450	−2	AAVSO	2452080	15	AAVSO
2431110	−32	HCO	2444900	−1	AAVSO	2452530	16	AAVSO

well as dates derived from the AAVSO and HCO data, and Figure 2 shows the resulting $(O-C)$ diagram. While the HCO and AAVSO visual data seem to be well-fit by a period of 449.3 days, the maxima derived from the 1928-1952 HCO plate data are offset in phase by nearly 150 days from the ephemeris given above.

The best-defined maximum of the HCO plate data lies at JD 2427490, and although we detected few maxima with the plate data, Kurochkin (1951) gives a date of maximum ($m = 12.3$) of JD 2427041 obtained by Shajn (1933). Assuming these two dates are actually maxima, then the period is 449 days, consistent with the 449.3-day period given the uncertainty of the maxima dates. Kurochkin lists another date of maximum of JD 2419447, and the time difference between these two maxima corresponds to 16.9 cycles of 449.3 days or exactly 17 cycles of 446.7 days, both results being reasonable given the measurement errors.

Figure 3 shows the AAVSO visual and V-band data and the 1928-1952 HCO photographic plate data folded with a period of 449.3 days. This folding period is an excellent fit to the data, though both the visual and plate data show significant scatter. All three data sets were folded with the GCVS period of 695 days, and the resulting folded light curves (not shown) were clearly incoherent. Therefore, it appears that the 449.3-day period matches all available data, with the only uncertainty being the reason for the discontinuity in $(O-C)$. There are only two data points in the 1952-1967 gap, published by Whitney (1960). The latter of these two points has a residual of around 100 days, much lower than the points preceeding it. While it suggests a possible trend downward in $(O-C)$, it may also be a random fluctuation. Analysis of other data archives besides the Harvard plate archives will be necessary to understand AW Aurigae's behavior during this time.

Though the revised period is likely the correct one, there is still substantial scatter in the $(O - C)$ residuals and in the folded visual light curve. In the case of the $(O - C)$ residuals, this may be due in large part to the scarcity of data and subsequent poor fitting of a mean curve to individual cycles. However, given the scatter in the folded visual data, it may also be due in part to intrinsic, cycle-to-cycle variations. Such behavior is observed in some other long-period Miras like Z Tau (Zijlstra & Bedding, 2003), and may indicate that AW Aurigae has a "meandering" period. Furthermore, the large jump in $(O - C)$ suggests that the star may not have maintained the 449.3-day period throughout the span of observations. Unfortunately, the data coverage is not sufficient to enable a more thorough analysis such as wavelet transformation, and it is difficult to more precisely determine the dates of maximum with the available data.

In summary, the period of the Mira variable AW Aurigae appears to be about 449.3 days, rather than the very long period of 695 days given in the GCVS. This period is still long relative to most Mira variables, but is not otherwise noteworthy. A discontinuity in the $(O - C)$ diagram suggests a possible temporary change in period or phase shift in pulsation, but both the 1967-2003 visual data and the 1928-1952 HCO plate data are both well-fit by a 449.3-day period. The $(O - C)$ residuals show some scatter, which could be attributed to poor determination of the dates of maxima or to real variations. The latter is observed in other Mira variables with similarly long periods, and better time-series coverage in future observations would be valuable in determining whether the period truly varies. Furthermore, the search for and analysis of archival data spanning the time between 1952 and 1967 will be necessary to understand the behavior of this star, and are encouraged.

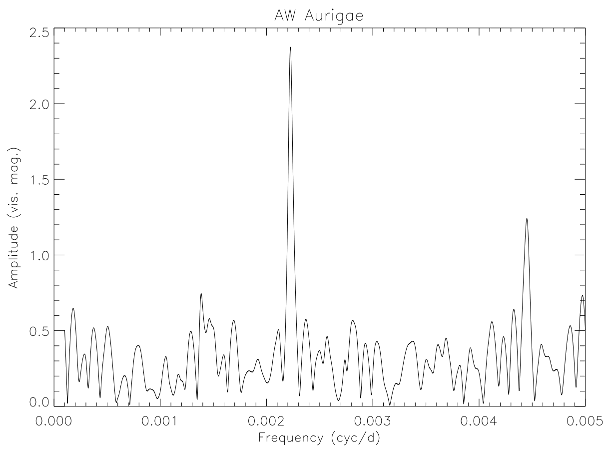

Figure 1. Fourier transform of AAVSO visual data for AW Aurigae. The strongest peak is centered on 449.3 days. The peak at 224.7 days (~ 0.00445 cyc/d) is the second Fourier harmonic of the main peak. There is a much weaker peak around 720 days, but this may be spurious.

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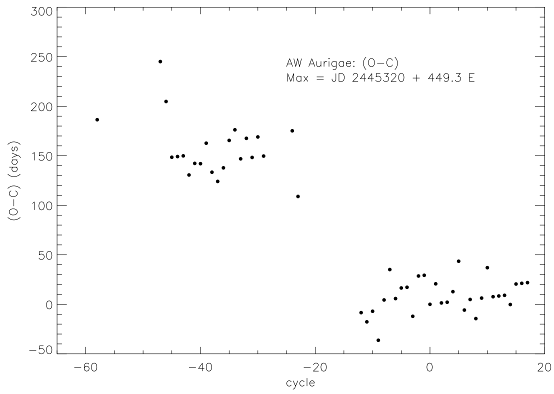

Figure 2. (O-C) diagram showing the dates of maximum derived from both the visual and HCO patrol plate data. There is a very large jump in (O-C) values between 1952 and 1967, suggesting either a temporary period change or a phase shift in the pulsations.

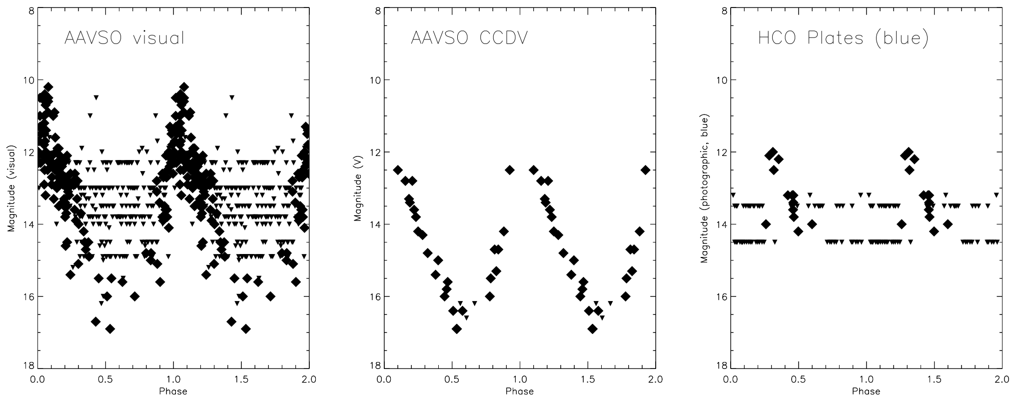

Figure 3. AAVSO visual data (left panel), AAVSO V-band CCD data (center panel), and HCO photographic plate data (right panel) of AW Aurigae, folded with a period of 449.3 days. The folding period is an excellent fit to the observations. Diamonds: positive observations; triangles: fainter-than observations.

References:

Foster, G., 1996, *AJ*, **112**, 1709
Kurochkin, N. E., 1951, *Perem. Zvezdy*, **8**, No. 5, 351
Shajn, P., 1933, *Perem. Zvezdy*, **4**, No. 4, 119
Whitney, B. S., 1960, *AJ*, **65**, 381
Zijlstra, A. A. & Bedding, T. R., 2003, *JAVSO*, **31**, 2