New Observations of AD Serpentis

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Abstract The little-studied star AD Ser has been investigated utilizing archival data as well as new CCD observations. AD Ser is found to be a semiregular variable with a V range of about 1.5 mag and a persistent, but likely somewhat variable, period of 90 d.

1. Introduction

Yerkes Observatory offers a number of activities for students with the goal of stimulating interest in science and engineering. Premier among these is the McQuown Scholars Program for high school students. Those named as McQuown Scholars assume leadership roles in the Yerkes educational program, helping to organize and run activities for younger students, while also selecting a project in computer science, engineering, or astronomy that allows an in-depth investigation of a topic that makes use of the resources of the observatory. One project area in astronomy is to investigate a poorly studied variable star, starting with Yerkes' collection of archival photographic plates. In brief, the selected star is identified and its variation followed on available plates. What is learned from the plate observations suggests additional data that would be useful, typically additional observations. The task is then to gather sufficient additional data, within the ever-present time and other constraints of student projects, for some new conclusions to be drawn about the star. The process demonstrates how a scientific study takes place. The goal is to produce a paper suitable for publication in a scientific journal, but this is not always achieved. This paper describes a study of the variable star AD Ser carried out as a McQuown Scholar project.

The Ross Variable Stars were discovered by F. Ross of Yerkes Observatory. Ross compared photographs he took in the 1920s and 1930s to plates that had been taken earlier by E. E. Barnard. He found 379 suspected variables. Most of these have been confirmed as variables, but many remain poorly studied. One of these is Ross 27 (Ross 1925), now known as AD Ser.

AD Ser is located at RA = 17 39 01.5, Dec = -15 07 16 (2000). The AAVSO International Database (AID) has only three old observations from the work of Ross (Kafka 2016); the AAVSO Photometric All-Sky Survey Data Release 9 (APASS; Henden *et al.* 2015) lists four observations. The star has been extensively observed by the All Sky Automated Survey (ASAS) monitoring program (Pojmański 1997). These indicated it is a semiregular variable with a V amplitude of 1.25 magnitudes and a period given as 92.70682 days. On the other hand, the *General Catalogue of Variable Stars* (GCVS; Samus *et al.* 2017) has AD Ser as a Mira with a period of 175.4 days and a photographic magnitude range of 13.5 to 16, with these values apparently from an unpublished manuscript.

The archival information on AD Ser is summarized in Table 1. The three ASAS values are from the ASAS web page (http://www.astrouw.edu.pl/asas/?page=catalogues) link to information in the ASAS variable star catalog (ACVS/variables), the link to the photometry (AASC/photometry), and our mean from the downloaded ASAS data. The inconsistencies in the published material for AD Ser indicate additional study of the star is warranted.

2. Observations

For our investigation three different sets of observations of AD Ser were collected. First, we made use of the V observations from the ASAS program. Second, we searched the Yerkes Observatory's archive for photographic plates showing the star's field. Finally, we obtained some CCD images of AD Ser using the Skynet System (Smith *et al.* 2016).

The ASAS is a program for monitoring the sky for variable stars and other objects. Over 1,300,000 stars brighter than V = 15 magnitude were observed. A catalogue of the observations is available online (http://www.astrouw.edu.pl/asas/?page=aasc), and AD Ser was found to be one of the stars listed. We downloaded the ASAS data, each observation having five magnitudes representing aperture photometry with different apertures (Pojmański *et al.* 2005). We adopted the MAG_0 values (2 pixel = 28.4 arcsec aperture, Pojmański 2002) as recommended.

Table 1. Information on AD Ser from various databases.

Data Source	*Number of Observations*	*Years*	*m(pg)*	*B*	*V*
GCVS		~1929	14.8[1]		
AID (AAVSO web page)	3	1908–1925		14.8:	13.9:
APASS (DR9)	4	2009–2013		14.629	12.726[2]
ASAS (ACVS/Variables)		2001–2009			13.52[3]
ASAS (AASC/Photometry)	15	2001–2009			13.396
ASAS (on-line data files)	335	2001–2009			13.263

1. Mean of listed photographic maximum and minimum.
2. The APASS coordinates are for AD Ser, but the V magnitude may refer to a star 4 seconds east that has V = 12.80 from ASAS.
3. The listed V(maximum) plus half the listed amplitude.

Yerkes Observatory has the original plates taken by Ross on which he discovered AD Ser = Ross Variable 27. We were able to locate those plates and confirm the change in brightness he found. We also found fifty-eight additional plates showing the field of AD Ser. Forty of the plates reached deep enough to be useful. We made eye estimates of the variable's magnitude on these plates using the comparison sequence given in Table 2 where the adopted magnitudes are based on our CCD results and may have a significant zero point error. While our CCD measures are consistent differentially to a few hundredths of a magnitude, the published photographic B magnitudes needed to set the zero point are uncertain, with differences between different catalog values up to a magnitude. Each plate was estimated at least twice, and most more times, and the results averaged. Often there are two plates taken simultaneously with co-mounted 10-inch (10B) and 6-inch (6B) cameras. The contemporaneous results as well as the standard deviation of the magnitudes derived from the separate eye estimates indicate the typical error of a given magnitude is less than 0.20 magnitude, but the error depends significantly on how well the variable was exposed on the plate and may reach 0.30 magnitude in the worst cases. Our photographic plate results are given in Table 3. In those cases when the variable was not seen we determined "less than" measures based on the faintest comparison star visible.

Finally, we obtained CCD observations using the Skynet system (Smith *et al.* 2016) on ten nights from February to May 2016. We used a B filter to allow comparison with our plate results. We performed aperture photometry using the Skynet Afterglow program to obtain magnitudes relative to the same set of comparison stars used for the plates. The magnitudes of AD Ser from our CCD observations are given in Table 4.

3. Results

The ASAS data show a range of approximately 1.5 magnitudes from about 12.8 to 14.3 in the V band. A period search over the range 50 to 500 days was carried out using the VSTAR software available online from the AAVSO (Benn 2012). As shown in Figure 1 from VSTAR, the only periodicity showing power was centered on 90.23 days. The phased light curve for the ASAS data with this period is shown in Figure 2. The full-width at half maximum of the power spectrum peak is 3.0 days, indicating the derived period is uncertain by ± 1.5 days. Periods outside this range, including the 92.7-day period given by ASAS, gave significantly less smooth light curves. The GCVS 175.4-day period is close to an alias of 90.23 days.

The plate observations show a B range from about 14.0 to 16.5, consistent with the photographic range given in the GCVS. The light curve, which spans over 50 years, is shown in Figure 3. A period search on the photographic data yielded most power at 90.4 days.

Our CCD photometry, taken over two months, showed a rise in B from 14.8 to 14.4 over about 25 days followed by a slow decline. The light curve is consistent with the 90-day period but the variation over the 58-day span is less than seen in the other observation sets, as shown in Figure 4.

Table 2. Comparison stars and adopted magnitudes.

Identification	*R.A. (2000)* h m s	*Dec. (2000)* ° ′ ″	*B**
A = Nomad 0748-0430533	17 39 05.6	–15 07 20	13.85
B = Nomad 0748-0430001	17 38 58.4	–15 06 17	15.05
C = Nomad 0749-0430405	17 39 03.8	–15 08 30	15.96
D = Nomad 0748-0419986	17 38 58.7	–15 05 51	16.69

**From our CCD photometry with a B filter but not transformed to UBV system.*

Table 3. Magnitudes from photographic plates.

Plate No.	*Date*	*Julian Date*	*B**	*Note*
6B-12	1899-06-07	2414813.708	14.8	
10B-90	1904-07-12	2416674.731	14.3	
6B-90	1904-07-12	2416674.731	14.1	
10B-99	1904-07-31	2416693.635	14.2	
6B-99	1904-07-31	2416693.635	14.3	
10B-100	1904-08-02	2416695.7	14.4	
6B-100	1904-08-02	2416695.7	14.3	
10B-194	1905-05-08	2416974.908	14.8	
10B-224	1905-06-20	2417017.717	15.2	
6B-224	1905-06-20	2417017.717	<15.05	Variable fainter than Star B
3B-224	1905-06-20	2417017.717	<15.05	Variable fainter than Star B
10B-255	1905-07-25	2417052.764	14.6	
6B-255	1905-07-25	2417052.764	14.5	
10B-457	1908-06-29	2418122.720	14.2	
6B-457	1908-06-29	2418122.720	14.1	
10B-689	1911-05-01	2419158.816	16.4	
6B-689	1911-05-01	2419158.816	16.7	
6B-810	1912-08-11	2419626.619	<13.85	Variable fainter than Star A
10B-979	1915-07-05	2420684.697	15.4	
6B-979	1915-07-05	2420684.697	15.0	
10B-1340	1919-03-02	2422020.930	14.9	
6B-1340	1919-03-02	2422020.930	14.6	
10B-1345	1919-03-27	2422045.887	<15.05	Variable fainter than Star B
6B-1345	1919-03-27	2422045.887	15.6	
10B-1355	1919-05-09	2422088.852	15.0	
6B-1355	1919-05-09	2422088.852	14.8	
10R-44	1925-06-19	2424320.766	16.0	
6R-44	1925-06-19	2424320.766	16.1	
10R-229	1927-04-28	2424998.869	15.8	
6R-229	1927-04-28	2424998.869	15.7	
5R-927	1931-06-11	2426504.750	16.7	
5R-1125	1933-06-21	2427244.805	13.9	
CR-1125	1933-06-21	2427244.805	14.1	
5R-1126	1933-06-22	2427245.792	13.7	
CR-1126	1933-06-22	2427245.792	14.1	
IL-RF-512	1941-05-24	2430138.808	<15.05	Variable fainter than Star B
IL-RF-518	1941-05-25	2430139.803	<13.85	Variable fainter than Star A
IL-RF-558	1941-06-25	2430170.738	14.5	
IL-RF-573	1941-07-17	2430192.668	<13.85	Variable fainter than Star A
Cook 1-103	1950-09-10	2433527.649	16.5	

**Based on our adopted magnitudes in Table 2 and not strictly on the UBV system.*

No mean period was found that fits all the data well, likely reflecting changes in period and light curve shape from cycle to cycle or over time. From many trials, the 90.23-day period seemed the best, and the phased light curve using it is shown in Figure 4. The plate observations are plotted as open circles and our CCD observations as dots. The phases of maximum from ASAS data and the GCVS are shown as filled and open arrows, respectively, plotted at magnitude 13.0. As an example of the incongruency in the data, modifying the period to align the plate

Table 4. CCD observations of AD Ser.

2016 date	*Julian Date*	*Exposure (seconds)*	*B* (magnitude)*
February 23	2457441.826	10	14.82
February 23	2457441.826	20	14.76
February 23	2457441.827	40	14.87
February 27	2457445.823	30	14.74
February 27	2457445.824	60	14.77
February 27	2457445.825	120	14.75
March 17	2457464.752	90	14.40
March 17	2457464.757	90	14.40
March 21	2457468.733	90	14.36
March 21	2457468.734	90	14.41
March 22	2457469.729	90	14.52
March 22	2457469.730	90	14.47
March 30	2457469.710	90	14.51
March 30	2457469.711	90	14.51
April 2	2457480.701	90	14.47
April 2	2457480.702	90	14.43
April 6	2457484.892	90	14.49
April 6	2457484.893	90	14.44
April 7	2457485.825	90	14.43
April 7	2457485.826	90	14.41
April 21	2457499.863	90	14.52
April 21	2457499.865	90	14.53

**Based on our adopted magnitudes in Table 2 and not strictly on the UBV system.*

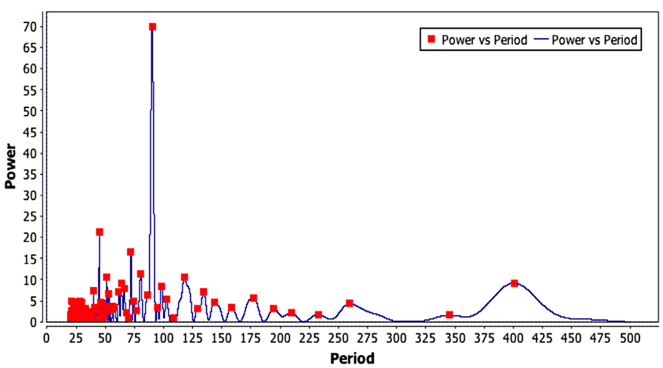

Figure 1. The power spectrum produced by VSTAR from a search on the ASAS data set for periodicities in the range 20 to 500 days. The only period with significant power is 90.23 days.

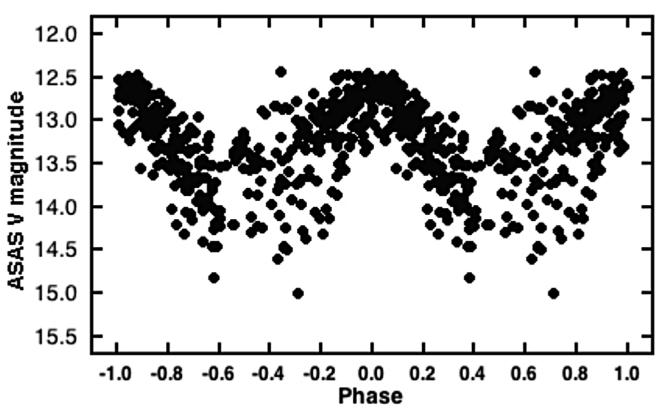

Figure 2. The phased light curve of ASAS data for AD Ser using the elements JD (Maximum) = 2452704.848 + 90.23 E.

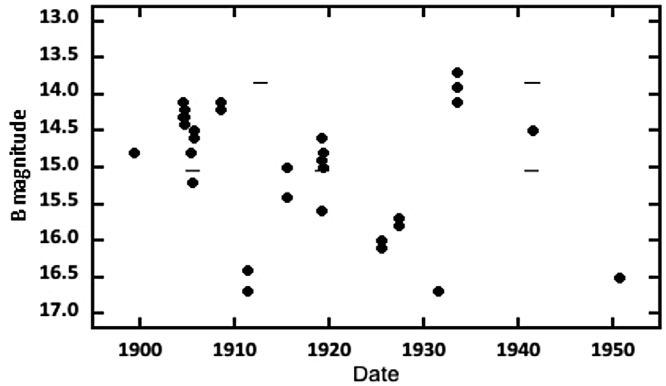

Figure 3. The light curve from magnitude estimates of AD Ser on photographic plates. Dots are observed magnitudes. Lines indicate the faintest magnitude seen in those cases where one or more comparison stars were visible but not the variable.

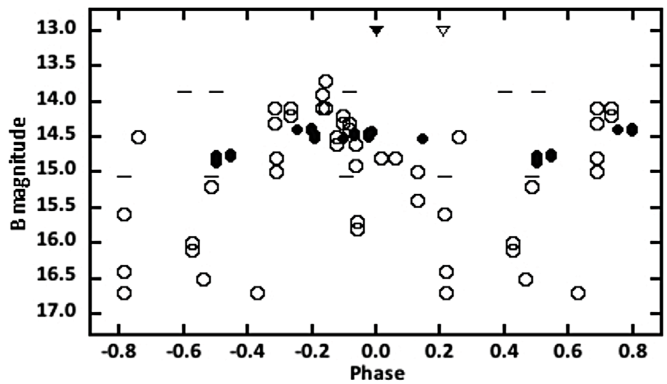

Figure 4. A phased light curve using the same ephemeris as in Figure 2. Plate observations are shown as open circles and CCD observations as dots. The phases of maximum from the ASAS data and from the GCVS are indicated by the filled and open arrows, respectively, at B = 13.0.

and ASAS maxima in Figure 4 leaves the CCD data—which seem to cover a maximum—shifted to the minima of the other observation sets.

4. Conclusions

Our results indicate that AD Ser should be classified as a semiregular variable, not a Mira, based on the GCVS variable type definitions (http://www.sai.msu.su/gcvs/gcvs/vartype.htm). We find variation amplitudes of about 1.5 magnitudes in V and ~2.5 magnitudes in B and a persistent, but likely somewhat variable, period of 90.23 days. A more systematic CCD study would be worthwhile.

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