BE STARS IN THE AAVSO PHOTOELECTRIC PHOTOMETRY PROGRAM

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Presented at the 85th AAVSO Spring Meeting, April 13, 1996

Abstract

We present light curves, and an analysis of periodicity, for the three Be stars in the AAVSO Photoelectric Photometry Program for which there are adequate data. V2048 Ophiuchi was variable by 0.2 magnitude before JD 2447900, but has been constant, at minimum, since. V832 Cygni has varied quasi-cyclically by 0.1 magnitude over the period of observation. EW Lacertae showed a broad minimum, 0.2 magnitude deep. The spacing of the observations is not well suited for investigating the short-term variations of these stars.

1. Introduction

The AAVSO Photoelectric Photometry Program was established in 1982 (Percy 1984; Percy 1991), in order to obtain long term high-precision observations of stars with variations too small to be monitored by visual techniques. The original program included 51 semiregular red variables, six yellow supergiants (RV Tau and SRd types), five Be stars, and nine variables of other or unknown kinds. A few additional stars have subsequently been added, either by the coordinators of the program (John Percy and Janet Mattei) or at the request of other astronomers. Most of the stars are between magnitudes 4 and 7; Betelgeuse is a bright exception. They have amplitudes of a few tenths of a magnitude, time scales of weeks or months, and generally semiregular or irregular light curves. All are well suited for long term monitoring from small "backyard" observatories. The "typical" observer uses a Celestron-8 with a SSP-3 photometer.

The Be stars are hot stars (10,000 to 30,000 K) of luminosity classes III to V which have shown emission in at least one Balmer line on at least one occasion. The emission lines arise from hot gas in an equatorial disc around the star. As the definition suggests, the Be phenomenon is variable. The formation and dispersal of the disc leads to spectroscopic and photometric variations on time scales of weeks to years. There are also short term photometric and absorption line profile variations which are due to non-radial pulsation, or perhaps to rotation. A few Be stars such as KX And and CX Dra show variations due to orbital motion and/or mass transfer in a close binary system. The topic of Be and related stars is comprehensively reviewed in Balona *et al.* (1994). A combination of the stars' wind and rotation seems to be capable of producing the equatorial disc, but it is not clear what causes the disc to form in the first place, and whether there is any connection between the short term variability and the formation and dispersion of the disc. As we shall show in this paper, the long term variations in Be stars are well suited for observation by the AAVSO photoelectric photometry program.

The five Be stars in the AAVSO photoelectric photometry program are X Per, 27 (= EW) CMa, 66 (= V2048) Oph, 59 (= V832) Cyg, and EW Lac. The observations of X

Table 1. AAVSO program Be stars and their comparison stars.

Program Stars	*Comparison Stars*	*V*	*B*	*Spectrum*
V2048 Oph = 66 Oph = HR 6712	HR 6719	6.350	6.272	B3III
B2Ve	HR 6690	6.290	6.292	A0
V832 Cyg = 59 Cyg = HR 8047	HD 199311	6.690	6.769	A2V
B1IVe	HD 199479	6.847	6.806	B9V
EW Lac = HR 8731	HR 8805	5.685	6.118	F5V
B4e	HR 8800	6.66	6.61var	B2V

Per have already been published (Percy 1992); they followed the star from an "active" phase prior to 1989 into a prolonged phase in which the disc was absent and the star was at constant, minimum brightness. The observations of EW CMa are too sparse for detailed analysis; there are about 16 observations from 1983 to 1994, and they show a slow increase in V from magnitude 4.64 to 4.47 (assuming the comparison star HD 173411 to have V = 6.46). The observations of the other three stars are reported and discussed here.

2. Observations

The program stars and their comparison stars are shown in Table 1. The observations were corrected for differential extinction, and transformed to the standard UBV system using a standard computer program at AAVSO Headquarters. Observations were made in V only; the transformation uses the catalogue values of (B-V) for the stars, assuming these to be correct and constant. Using the catalogue values introduces a potential error of a few thousandths of a magnitude. The accuracy of the observations ranges from 0.009 to 0.015 magnitude, as determined from the autocorrelation diagram, and also from the scatter of the (check star - comparison star) magnitudes, though it is possible that at least one of the comparison stars is slightly variable, as described below. The observations have been deposited in the AAVSO archive of photoelectric data, and may be obtained from AAVSO Headquarters (25 Birch Street, Cambridge, MA 02138-1205, USA; e-mail aavso@aavso.org). Contributors to the photoelectric photometry database are shown in Table 2.

In total, there are 161 observations of V2048 Oph, 71 observations of V832 Cyg, and 93 observations of EW Lac, covering the interval JD 2445570 to 2449700, approximately.

Table 2. Observers of AAVSO Be program stars.

Name	*No. of Observations*	*Name*	*No. of Observations*
W. Barksdale	3	H. Powell	6
J. Crast	17	M. Smith	12
F. Dempsey	21	L. Snyder	5
J. Isles	10	H. Sorensen	96
R. Johnsson	3	N. Stoikidis	15
G. Kohl	23	R. Thompson	53
H. Landis	14	D. Williams	3

3. Analysis

In this study, a simple inspection of the light curves provided most of the information on the stars' behavior. We also analyzed the data by two other methods: (a) Fourier analysis (Ferraz-Mello 1981, as implemented in a computer program kindly provided by Dr. E. P. Belserene), and (b) autocorrelation analysis (Percy *et al.* 1993). Because the data were generally obtained once a night, with the stars close to the meridian, these methods were not very effective, given that the periods of Be stars are in the range of 0.3 to 3 days. The longer-term variations (days and longer) also complicate the search for periods in the range of hours to days.

4. Results

The light curves shown in Figures 1–3 show the number and extent of the observations. The seasonal gaps are very obvious. The following notes deal with the individual stars. Since all observations are differential relative to comparison stars, the comments apply to the differential magnitudes.

4.1. V2048 Oph

Prior to JD 2447900, this star was active (Figure 1), with variations of up to 0.2 magnitude above the base level. Since then, the star has been in its "low state," indicating that the disc is now absent. There are no significant peaks in the power spectrum at periods of 0.2 to 2 days (but, as noted above, the data are not well suited to this form of analysis). The autocorrelation diagram rises very slowly between lag times of 0 to 5 days, indicating that there are no striking time scales in this range, and that the characteristic variations occur on longer time scales than this.

Peters (1994) has noted that the hydrogen emission in this star increased until 1990, and has subsequently decreased. This is consistent with our results, which suggest that the equatorial disc has dispersed in the last few years.

HR 6690, the check star for V2048 Oph, has an autocorrelation diagram which is flat (at 0.015 magnitude) at lag times of 0 to 5 days, which suggests that this is the characteristic accuracy of the observations, and that there are no significant time scales in the check or comparison stars in this range.

4.2. V832 Cyg

The light curve (Figure 2) shows slow variations during the interval of observation. The power spectrum shows no conspicuous peaks. The autocorrelation diagram is generally flat (at 0.01 magnitude) at lag times of 0 to 5 days; a shallow minimum at a period of about 2 days is not based on sufficient data to be significant.

HD 199479, the check star for V832 Cyg, has an autocorrelation diagram which is flat (at 0.01 magnitude) at lag times of 0 to 5 days, confirming that this is the characteristic accuracy of the observations, and that there are no significant time scales in the check or comparison stars in this range.

4.3. EW Lac

The light curve (Figure 3) shows a broad minimum lasting several years. The scatter (presumably reflecting the short term variations) seems to be greater in the first three years of the minimum, and much smaller in the last three years. There has been some suggestion that the amplitude of the short term variations in this star may be correlated with the long term variations, but the evidence is rather weak (Pavlovski and Ruzic 1991). In the power spectrum, no one period is conspicuous. The highest peaks are at 0.643 and 0.813 day (as compared with the previously-suspected short period of 0.72

day), but there are many other peaks almost as high. The autocorrelation diagram shows no conspicuous or significant minima. Hubert *et al.* (1987) have suggested that the appearance of the disc in this star is quasi-periodic, with a time scale of about seven years. This is not inconsistent with our results.

HR 8800, the check star for EW Lac, shows a scatter of about 0.013 magnitude. This star is a suspected ellipsoidal variable with a period of 3.3378 days and a peak-to-peak V amplitude of 0.02 magnitude (Sareyan *et al.* 1994). There is no significant peak in the power spectrum at this period, or any significant minimum in the autocorrelation diagram. This may be because the variations are below the noise level of our observations.

5. Conclusions

The observations have clearly delineated the slow variations of these three Be stars in the program. They have not provided information on the short term (0.3 to 3 days) variations due to the spacing and limited precision of the data, and the irregular longer-term variations in the stars. We plan to add a few more Be stars to the photoelectric photometry program, in order to monitor the slow variations in selected stars, in a systematic way.

6. Acknowledgements

AD and DY were participants in the University of Toronto Mentorship Program, which enables outstanding senior high school students to work on research projects at the university. We thank the observers listed in Table 2 for their participation; Howard Landis for encouraging and assisting the observers and archiving the data; and AAVSO headquarters staff for their contributions. JRP thanks the Natural Sciences and Engineering Research Council of Canada for research support. AD was supported by a Canada Summer Career Placement award for part of his work on this project.

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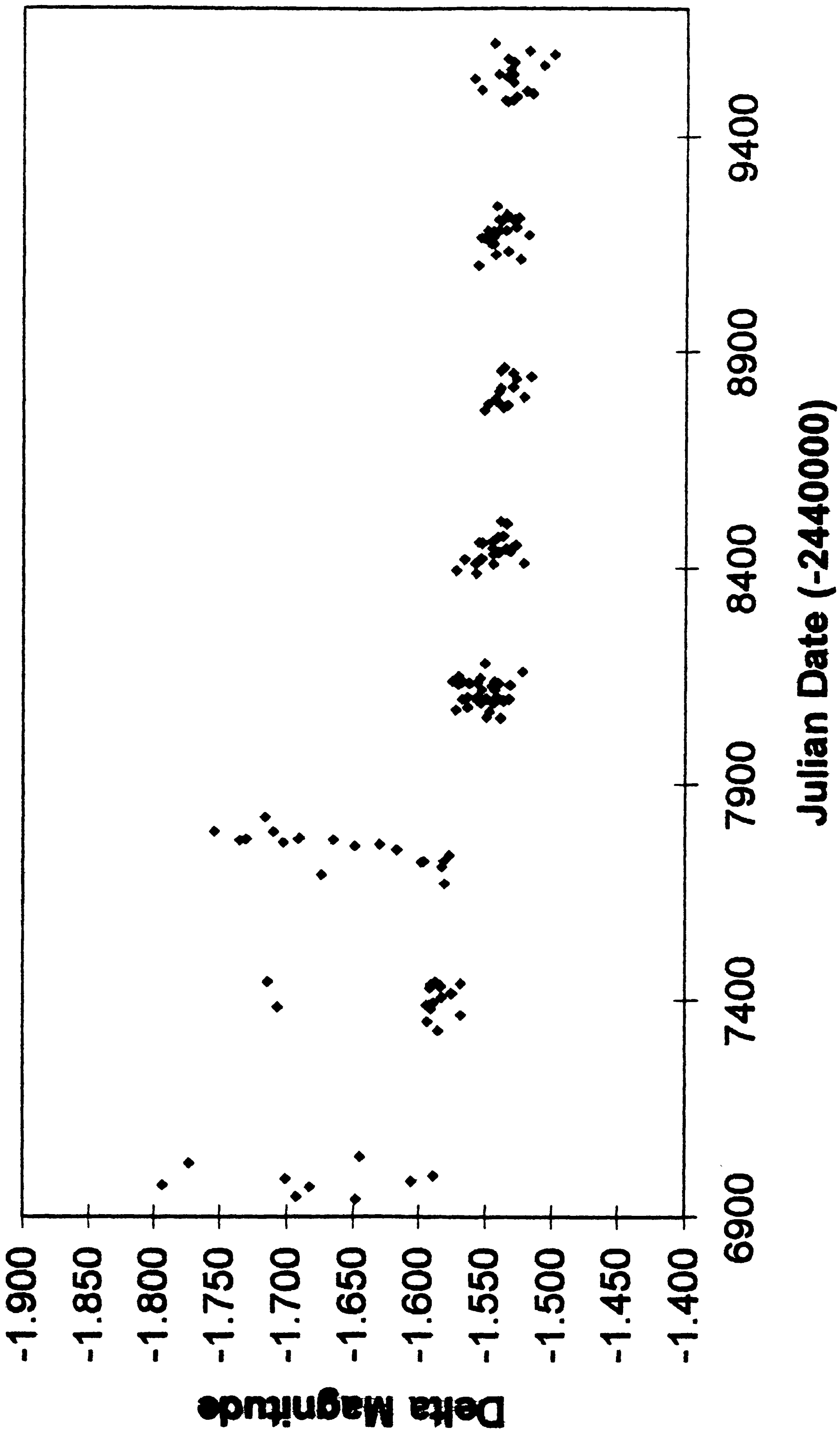

Figure 1. The AAVSO V light curve of V2048 Oph (66 Oph) relative to the comparison star HR 6719.

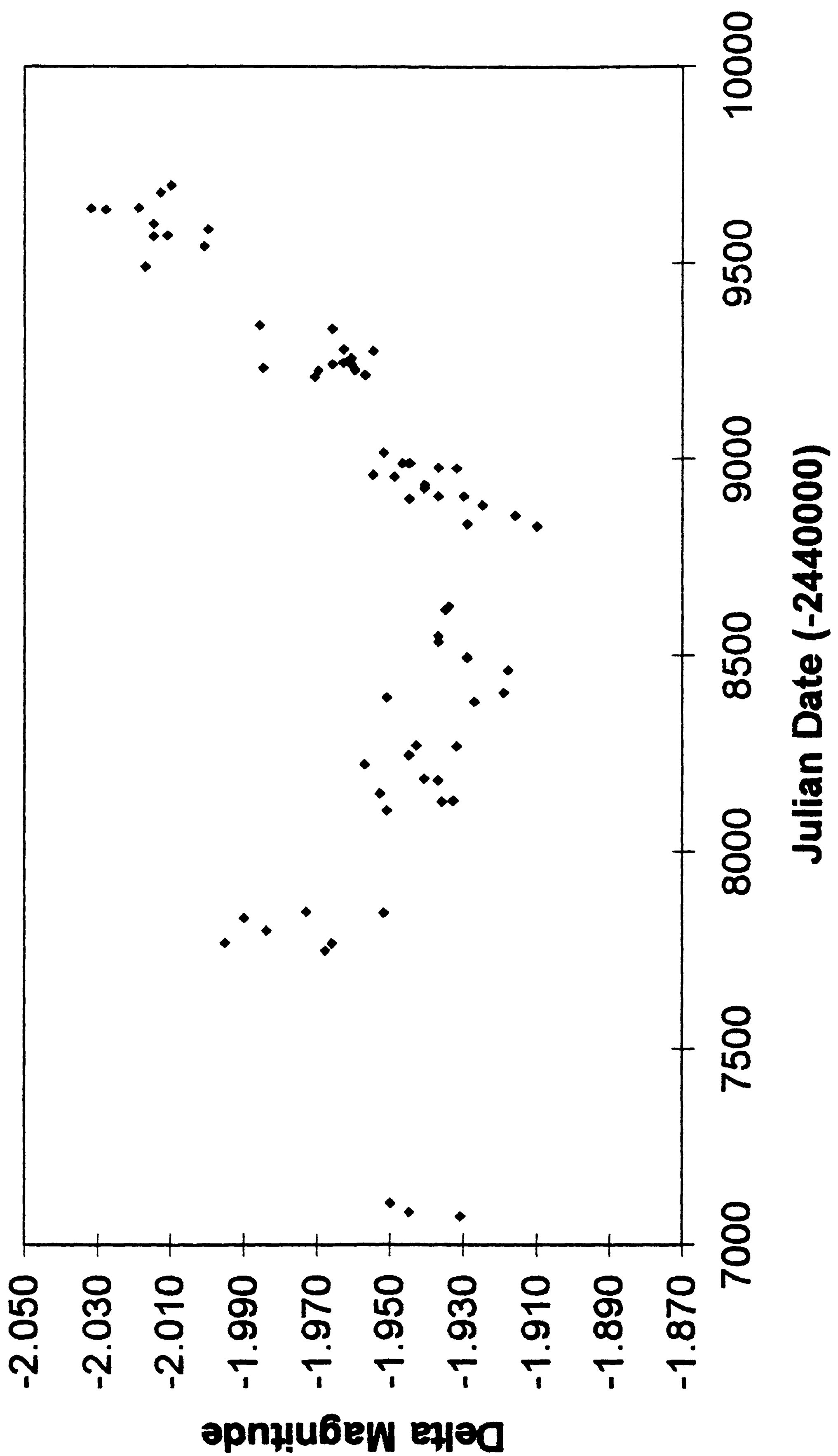

Figure 2. The AAVSO V light curve of V832 Cyg (59 Cyg) relative to the comparison star HR 199311.

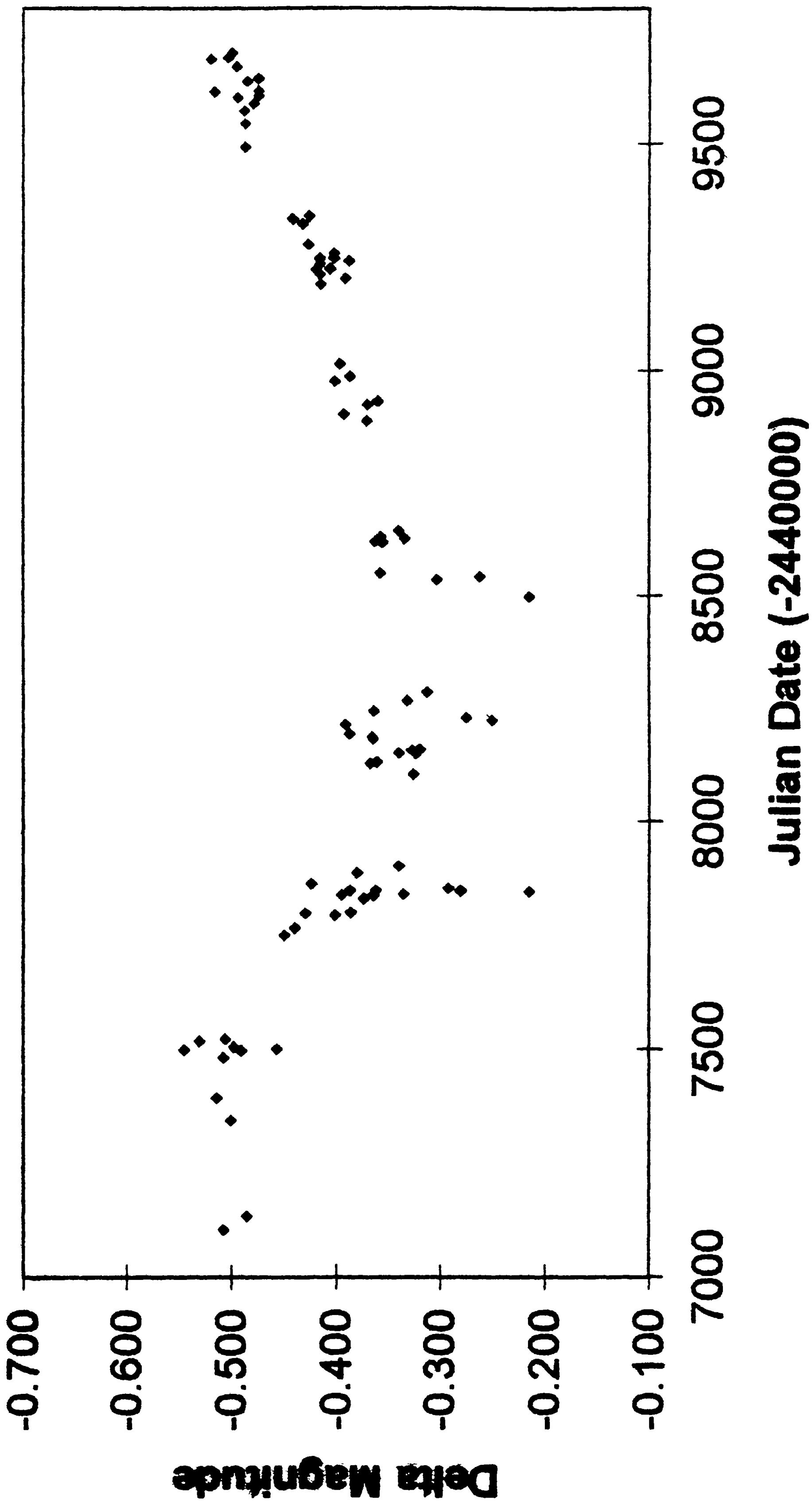

Figure 3. The AAVSO V light curve of EW Lac relative to the comparison star HR 8805.