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AC Vel, A TRIPLE SYSTEM. A CALL FOR OBSERVATIONS OF MINIMA AND SPECTRA

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AC Vel (SAO 238458, HD 93468, $(\alpha,\ \delta)_{2000} = 10^{\rm h}46^{\rm m}18\overset{\rm s}{.}40,\ -56°49'45\overset{''}{.}4$) is a binary consisting of two eclipsing early B type stars plus at least one more star. Complete light curves were obtained in the Strömgren *uvby* photometric system in 1982–1984. Additional times of minima have been observed between 1985 and 1997. Radial velocities have been measured by J. Andersen in 1984–86 and by P.F.L. Maxted in 1996 (both unpublished).

The photometric data provide a period P for the eclipses near 4.5622 days and indicate a circular orbit. The primary minimum has a depth of $0\overset{\rm m}{.}45$ in y, the secondary is $0\overset{\rm m}{.}40$ deep. Figure 1 shows the y light curve (Helt et al. 1998). From the spectroscopic and photometric analyses we obtain a preliminary value for the mass sum of $14 \pm 1.5 M_{\odot}$ and a mass ratio of 1.00 ± 0.05. Preliminary determination with the WINK code (Wood 1971, 1972, Vaz et al. 1995) of orbital inclination and radii indicates that the stars have evolved to the TAMS region. They should thus be useful for an empirical test of convection prescriptions. The presence of third light is indicated by the analysis. It amounts to 10–15% of the total light in y, enough to be obvious in the photometric solution but insignificant enough to make the lines of the third star inconspicuous in the spectra.

We soon noticed that the period of AC Vel is variable. This is not surprising since light time effect is to be expected in a system with a considerable amount of third light. Our observed times of minima are, however, insufficient for a full analysis of the O−C residuals from a linear ephemeris and we have so far restricted our modelling to circular orbits of the eclipsing pair around the centre of gravity of the system. The data indicate a period P' for this orbit of only 15–17 years.

The variability of AC Vel was discovered by Hertzsprung (1926) who obtained 520 photographic plates covering the region of η Car. The exact interval of time for the observations is not given by Hertzsprung but most of the observations must have been made during the first 6 months of 1924. His epoch corresponds to May 1924 and his period is half the true period, 2.28083 ± 0.00030 days. As the precise distribution of Hertzsprung's observations is unknown but the time interval short compared to the period P' we have simply used his epoch (HJD 2423934.011 $\pm$ 0.017) as the time of a secondary minimum.

Gaposchkin also studied AC Vel and noticed that the period was twice Hertzsprung's value (Gaposchkin 1946, 1953). His epoch and period (HJD 2429342.594, 4.5622426 days) are based on 990 photographic plates, partly Harvard Patrol plates that may date back at least as far as 1896, partly plates from the period 1938–1947. This wide time span turns out to be much larger than the period P'. For that reason we cannot use his ephemeris in our determination of the most likely P'.

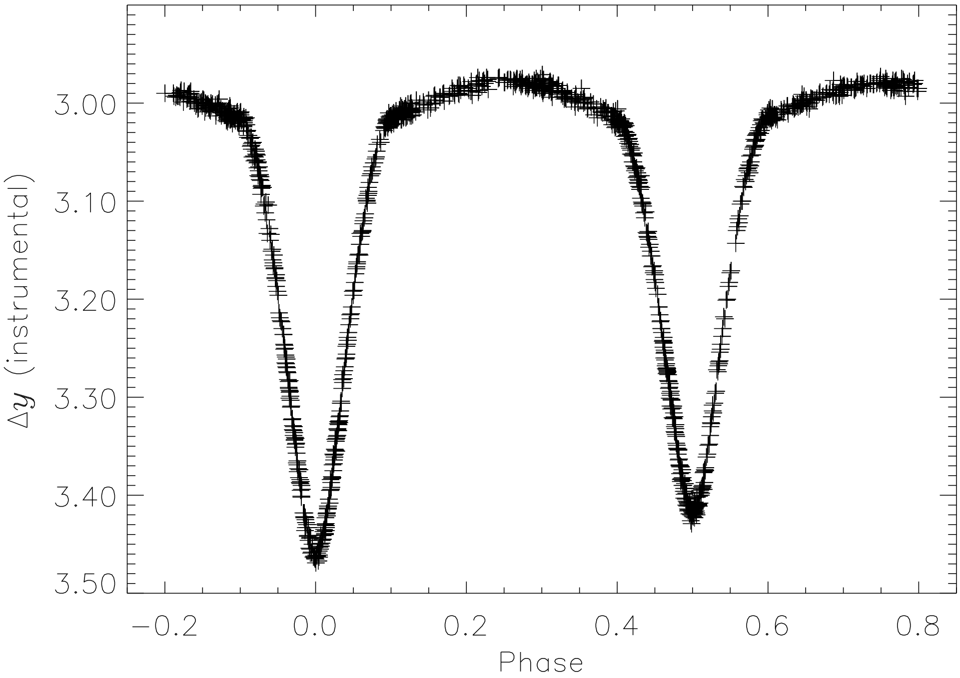

Figure 1. The differential y light curve: AC Vel – HR 4239AB

Our times of minima are given in Table 1. They were determined with the Kwee and van Woerden (1956) method even though there is a slight indication of asymmetry in the secondary minimum. For that reason we also provide the beginning and end of the time interval ΔT used for determination of the time of minimum. The O$-$C values are calculated as residuals from a linear ephemeris with period P_{true}, the true period for the orbital motion that causes the eclipses of stars A and B (value determined below). The large O$-$C values reflect the orbital motion of the AB pair around the common center of mass of AB and the third star.

We have attempted to find permitted values of P'. The shape of the orbit of the AB pair around the center of mass is unknown and may well be eccentric. As we have so far only ten times of minima not uniformly distributed in time we are unable to determine e and ω for an eccentric orbit, and we have assumed that the orbit is circular.

From Hertzsprung's minimum combined with our latest minimum we can restrict the permitted values for the true period P_{true} to small time intervals, each corresponding to a certain number of periods elapsed between the two minima. The one that gives the smallest values of O$-$C has $\Delta E = 5823$ and $P_{true} = 4.56221 \pm 0.00003$ days.

Another constraint can be placed on the true period by using Kepler's third law together with sensible guesses for the mass of the third star. For each guess of ΔE we can calculate an upper and a lower limit to the orbital velocity. It turns out that a consistent solution can be found only for $\Delta E = 5823$.

Table 1: Our observed times of minima

HJD – 2400000	E	ΔT	O−C
45371.8090 ± 14	−90.5	.75434–.86343	0.0027
45387.7738 ± 21	−87	.71538–.83251	−0.0003
45784.6771 ± 2	0	.51402–.84262	−0.0095
45816.6132 ± 5	7	.49101–.73870	−0.0089
46149.6467 ± 4	80	.51803–.78462	−0.0169
46831.6848 ± 4	229.5	.56176–.80963	−0.0297
50134.7860 ± 4	953.5	.67258–.89872	0.0293
50141.6311 ± 5	955	.52440–.73433	0.0311
50490.6382 ± 4	1031.5	.53565–.74610	0.0289
50499.7620 ± 4	1033.5	.62175–.89899	0.0282

The SBOP code (Etzel 1985) is then used to fit a circular orbit to the O−C values for a range of values of P_{true} around 4.56221. The formula used by SBOP is

$$\mathrm{O} - \mathrm{C} = a_{AB} \times \sin i \times \cos(2\pi(t-T)/P') + V_o \qquad (1)$$

where T is the time of maximum O−C, that is the time when the AB pair is farthest off. For each assumed value of P_{true} we thus find P', T, an amplitude $a_{AB} \times \sin i$ that represents the radius in light days of the AB pair's orbit around the center of mass times $\sin i$, and a zero point, V_o. This permits prediction of the observed period P_{app} for a given time interval. If Hertzsprung's point is given weight 0 and our ten points are weighted according to their Kwee and van Woerden (1956) standard errors we find minimum standard deviation for $P_{true} = 4.562232$. This value would imply that Hertzsprung's point is off by 0.15 days.

We have also determined the observed apparent period P_{app} for the time interval of light curve observations. For our 1983-84 data that cover all essential phases of the light curve we have used the Lafler–Kinman (1965) method (program kindly provided by L.P.R. Vaz) to find $P_{app} = 4.562118 \pm 0.000007$. The value for P_{true} that predicts this P_{app} is 4.562233 ± 0.000003.

Our *uvby* data predict $P_{true} = 4.562232$ which leads to $P' = 15.1$ years. If, however, we accept that Hertzsprung's data cannot be off by more than $2\,\sigma$ we must adopt $P_{true} \leq 4.562213$ and the corresponding value of $P' \geq 17.2$ years. The difference probably reflects that the ≈16 year orbit is eccentric while we have had to restrict our modelling to circular orbits.

Considering the fairly small value we find for P' it should be possible to determine the orbit of the eclipsing pair AB around the center of gravity of the system within a few years. On the other hand, it is important to observe the system each year. We therefore urge southern observers to put AC Vel on their observing list. Safe predictions of future times of minima can of course not be provided but our best prediction at present for minimum I, calculated with $P_{true} = 4.562213$ is

$$M = 2445784.6866 + 4.562213 \times E \qquad (2)$$

$$Min\ I = M + 0.0299\ \cos(2\pi(M - 2443908)/6295) \qquad (3)$$

This model is chosen such that it gives a 2σ deviation for Hertzsprung's epoch and still a reasonable fit to our observations. The O−C values in Table 1 were calculated from equation (2).

HD 92757 ($(\alpha,\ \delta)_{2000} = 10^{h}41^{m}26^{s}.36,\ -56^\circ04'06''.6$) and HD 92155 ($10^{h}37^{m}16^{s}.17,\ -53^\circ51'18''.6$) have been used as comparison stars and show no sign of variability. Any of them can be recommended as comparison star.

We also urge spectroscopists to put AC Vel on their observing list. The radial velocity for the center of gravity of the AB system is predicted from our simple, circular model to vary with an amplitude of 8–9 km/s, that is, a peak-to-peak variation of 16–18 km/s.

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