INTERIM DISCUSSION OF THE ORBIT OF δ SAGITTAE

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ABSTRACT. New provisional orbital elements are derived for δ Sge and the next conjunction in 1990 should be observed. Probably no bodily eclipse of the B-star will be seen, but an atmosheric eclipse is expected. There are mass motions in the M-star's atmosphere.

Although δ Sagittae - α(1900) $19^h42^m.9$ δ(1900) + 18°17', M2 II + A0 V, V = 3.8 - has long been recognized as a binary of the ζ Aur type, that shows a composite spectrum, it has been neglected and good orbital elements have not yet been found. The period is still uncertain: the first value determined, 3988 days (Christie 1936), is too long. McLaughlin et al. (1952) proposed 3700 or 3725 days. Reimers and Schröder (1983), using some Victoria observations and seven previously unpublished high-dispersion Mount Wilson observations, obtained 3720 days. Judging by the agreement between those Mount Wilson velocities and early Lick observations (Campbell and Moore 1928), this value is nearly correct, although further refinement should be possible when the Victoria observations cover a whole cycle.

Batten and Fisher (1981) confirmed the suggestion by McLaughlin et al. that the A (or late B) star is eclipsed by the atmosphere of the M-giant. Absorption in the K line, barely visible in November 1979 was prominent in late April 1980, but had disappeared again by July 1980. Whether or not an actual eclipse by the body of the giant star takes place is still uncertain. The observations of 1979-80 suggest not; the next time to look is in 1990. For some decades, conjunction of the two components (large star in front) has been when δ Sge was unobservable: this should not be so in 1990.

Orbital elements derived by Reimers and Schröder predict conjunction for mid-May 1990. High-dispersion observations (2.4 Å mm^{-1}) since made at Victoria, however, depart from the velocity-curve computed by those investigators. Much of the deviation could be removed either by adjusting the period or by applying corrections to the Mount Wilson (and Lick) velocities with respect to those determined at Victoria. The Victoria observations also require a different value of e from that derived by Reimers and Schröder. The ascending branch of the velocity-curve has not yet been well observed,

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but the Victoria observations define it better than any others; it is steeper than previously supposed. Precise corrections are hard to derive because some individual observations in all series show large (usually negative) residuals, probably because the observed velocity contains an appreciable non-orbital component. I have subtracted 2.6 km s^{-1} from the Mount Wilson values and 1.2 km s^{-1} from the Lick, since it is most convenient to correct to Victoria. Better values will be obtainable when the Victoria observations cover more of the velocity-curve. With these corrections applied the Lick (1899-1907), Mount Wilson (late 1950s) and Victoria (1979-85) observations have been combined to make a new solution for orbital elements, which gives: P = 3720 d (assumed), T = 2444234 ± 18, $\omega = 268^\circ\!.0 \pm 2^\circ\!.5$, $e = 0.40 \pm 0.02$, $K = 8.3$ km $s^{-1} \pm 0.2$ km s^{-1}, $V_0 = +1.1$ km $s^{-1} \pm$ 0.1 km s^{-1}, $f(m) = 0.17 m_\odot \pm 0.01\ m_\odot$, $a \sin i = 3.9 \times 10^8$ km $\pm\ 0.1 \times 10^8$ km. These elements correspond to a conjunction in early January 1980 and predict the next one for mid-March 1990. January 1980 seems somewhat early, in view of the 1979-80 observations; probably these elements predict the earliest possible date for the 1990 conjunction. Intensive spectroscopic and photometric observations should be made late in the 1989 observing season.

Speckle-inteferometric observations of δ Sge have been published by McAlister and colleagues in several papers (e.g. McAlister et al. 1984). A few others have been published, but the homogeneity and quality of McAlister's, justify using them exclusively. These observations, which now cover about half the apparent orbit, do not suggest high inclination. One might estimate the major semi-axis of the true orbit as about 0″.05. For a mass-ratio of about 3:1 (Reimers and Schröder) and an orbital inclination of about 70° (since atmospheric eclipses do occur), the major semi-axis of the relative orbit is about 10.6 A.U. This leads to a parallax of just under 0″.005, or a distance of just over 200 parsecs - consistent with earlier estimates of 224 parsecs (Batten and Fisher 1981), 300 parsecs (Reimers and Kudritzki 1980) and 170 parsecs (Reimers and Schröder).

The conjunction at which the B star is behind is so close to periastron that the separation of the two stars can be taken as $a(1-e) = 6.4$ A.U. The condition for an eclipse is that the radius of the M star R_M should be greater than or equal to 6.4 cosi, or 2.16 A.U. (for i = 70°), or 450 $R_\odot$. Reimers and Schröder estimate that $\log L_M/L_\odot = 3.44$ and assume T_e(M star) = 3600°. If T_e(Sun) is 5770°, we can deduce $R_M = 135 R_\odot$. Thus, actual eclipses of the B star are unlikely.

The influence of the secondary spectrum is obvious in the combined light, but that spectrum is not easily measured. Balmer lines such as Hδ and H8 are too blended with M-type lines to be accurately measured. Reimers and Kudritzki found the early-type spectrum to be dominant in the far UV, but Reimers and Schröder, who classified it as B9, found the line profiles too distorted by emission for accurate measurement. We hope to measure the early-type component by the same method we adopted for the composite spectrum of 93 Leonis (Batten et al. 1983).

Occasional large residuals from the velocity-curve have already been noted. Large mass motions are to be expected in the extended atmosphere of the M-type star. Reimers and Schröder presented evidence, from IUE observations, for mass loss of about $10^{-8} M_{\odot}$ yr^{-1}. Reimers and Kudritzki also pointed to evidence of a circumstellar disk around the B star. Most of the residuals are negative - as one would expect if we are observing radial outflow from the giant star - but recent observations in the summer of 1985 show positive residuals. These residuals set a limit to the accuracy with which the orbital elements, including the period, can be known.

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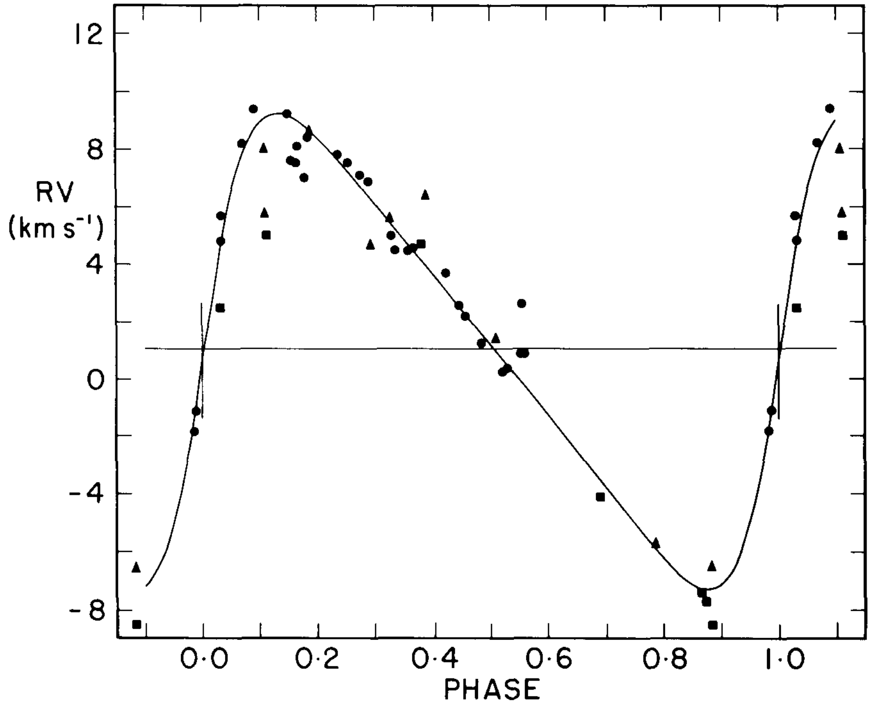

Figure 1. The velocity curve of δ Sge. Dots - Victoria; Triangles - Lick; squares - Mount Wilson. Phase from periastron.

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