A MODERN VIEW OF THE DWARF NOVA Z CHAMAELEONTIS

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ABSTRACT. Some recent photometric and spectroscopic results for this "ultrashort" period system are summarized, and several straightforward consequences of these results for our understanding of the evolution of cataclysmic binaries are pointed out: The space motion of Z Cha is characteristic of the old disk population. The white dwarf cannot be composed primarily of He, unless it grew by accretion by at least 20%. The inferred masses of the component stars, combined with the usual gravitational quadrupole formula, probably do not suffice to explain the inferred rate of mass transfer, even in quiescence. The secondary star does not lie on the computed evolutionary tracks in the period - mass diagram of Paczynski and Sienkiewicz.

1. INTRODUCTION

Z Cha has been intensively studied over the years, due mainly to the nature of the eclipse. The double eclipse of the white dwarf primary star and of the bright spot allows the mass ratio and orbital inclination to be determined with precision. Measurement of the white dwarf ingress or egress duration, coupled with the assumption that the true radius of the white dwarf is being measured, allows the mass of the white dwarf to be inferred, and from it the other properties of the binary system. Since absolute photometry is available, the distance and luminosity can also be found.

The most recent photometric study of the eclipses of Z Cha is by Wood et al. (1986). This work makes use of a very well-defined average light curve obtained during a quiescent period in which the system properties (disc radius, etc.) were very stable. The inferred masses of the white dwarf primary and cool secondary stars are, respectively, 0.553 ± 0.012 and 0.082 ± 0.003 solar masses. The distance is 98 ± 16 pc. The single most critical assumption is that the luminous object in the center of the disc is the true photosphere of the white dwarf, rather than some more extended structure. In their prior similar study, Cook and Warner (1984) preferred to reject this interpretation rather than accept that the secondary star lies far from the main sequence. Wood

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et al. rely on the stability of the ingress/egress durations during 31 eclipses, and on the consistency of color temperature and brightness temperature measurements of the central object, in defense of their inferred masses and other properties.

It is possible to distinguish between the views of Cook and Warner on the one hand and Wood *et al.* on the other by measuring the orbital motion of the secondary star at near infrared wavelengths. Wade and Horne have completed such a study (to be presented in full elsewhere), using a CCD detector on the R-C spectrograph of the CTIO 4-m telescope. A comparison star was observed simultaneously on the long slit of the spectrograph, so that accurate corrections for variations in throughput or sky transparency could be made. The measured velocity semi-amplitude for the secondary star, from cross-correlation of the Na I infrared doublet, is $K = 410 \pm 8$ km/s, to which must be added a correction of -15 ± 5 km/s due to the uneven distribution of the Na I absorption lines over the surface of the star. The prediction of Wood *et al.* is $K = 374 \pm 3$ km/s, while that of Cook and Warner's preferred solution would be $K = 475$ to 500 km/s (for $M_2 = 0.17$ to 0.20 solar masses, and using the Wood value for the mass ratio). Each of these predictions, which are based ultimately on the Hamada-Salpeter relation between mass and radius for cold degenerate stars, should be increased by a few percent to account for the finite temperature of the white dwarf, and possibly also for a light-element envelope. Excellent agreement between predicted and observed values of K suggests that the properties of Z Cha as inferred by Wood *et al.* are very nearly correct. The heliocentric radial velocity of the binary center of mass is -60 km/s.

2. DISCUSSION

The systemic radial velocity of Z Cha, combined with the proper motion given in Kraft and Luyten (1965), results in a space motion of U = +51, V = +39, and W = +29 (km/s). Both its position in the U-V plane and the absolute value of W indicate that Z Cha belongs to the old disc population (e.g. Upgren 1978).

Core helium burning in single stars commences when the core mass reaches about 0.45 solar masses, regardless of the total mass of the star. Unless the white dwarf in Z Cha has accreted and retained about 0.1 solar masses of material from its companion since its own nuclear evolution was completed, it cannot be composed of helium.

The formula of Rappaport and Joss (1984) or a modified version of Patterson's (1984) formula can be used to predict the rate of mass transfer in Z Cha if gravitational radiation is the sole sink of orbital angular momentum. The estimates lie in the range log dM/dt = -11.05 to -10.75 (solar masses/yr), depending on the "stellar index". The rate of mass transfer into the bright spot *during quiescence* is log dM/dt = -10.43 ± 0.2 according to Wood *et al.* Thus there is (marginal) evidence in the case of Z Cha that gravitational radiation alone is not sufficient to drive the mass transfer, contrary to the usual model for ultrashort-period systems. The case is strengthened because the rate quoted by Wood *et al.* is likely to be a lower limit, in view

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of uncertainties in the bolometric correction. Also, during superoutbursts, and perhaps during normal outbursts, the rate of mass transfer from the secondary star is probably substantially higher.

If gravitational radiation were the sole driving force, Z Cha would be expected to lie on the evolutionary tracks calculated by, e.g., Paczynski and Sienkiewicz (1981; we use their results because they present a legible diagram in the observable quantities of orbital period and mass of the secondary star). In fact, Z Cha lies above the tracks in the P-M_2 plane. Whether this position is quantitatively consistent with the above-mentioned discrepancy between predicted and observed mass transfer rates, i.e. whether the higher rate of mass transfer drives the star from thermal equilibrium sooner, remains to be seen. An alternative explanation may be that the constitutive physics used to construct such tracks needs to be improved (see Paczynski and Sienkiewicz 1983 for a discussion of this point).

3. CONCLUSION

Z Cha continues its historical role of providing solid observational data from which we build our understanding of cataclysmic variable stars and their evolution.

REFERENCES

Wood, J., Horne, K., Berriman, G., Wade, R., O'Donoghue, D. & Warner, B., 1986. M.N.R.A.S. 219, 629.
Cook, M.C. & Warner, B., 1984. M.N.R.A.S. 207, 705.
Kraft, R.P. & Luyten, W.J., 1965. Ap.J. 142, 1041.
Paczynski, B. & Sienkiewicz, R., 1981. Ap.J. 248, L27.
______________________________, 1983. Ap.J. 268, 825.
Patterson, J., 1984. Ap.J.Suppl. 54, 443.
Rappaport, S. & Joss, P.C., 1984. Ap.J. 283, 232.
Upgren, A.R., 1978. A.J. 83, 626.

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