PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
102: 646–648, June 1990

THE PHOTOMETRIC ELEMENTS OF XZ CANIS MINORIS

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Received 1990 January 26

ABSTRACT

We have analyzed the only published photoelectric observations of XZ CMi. Our solution does not show such large shoulder discrepancies as are associated with ellipsoid models, although some problems remain. We comment on the advisability of performing simultaneous multicolor solutions. The spectral type of the primary remains uncertain.

Key words: eclipsing binaries–Algol systems–orbital elements

1. Introduction

XZ Canis Minoris is an interesting binary because of the large fitting discrepancies it exhibits in primary eclipse. The system also is of interest because its period, $0^{d}.5788$, is within the range of W Ursae Majoris star periods, yet it has an Algol-type semidetached configuration. Since no solution based on a physical model exists, we wanted to see if a physical model would cure the fitting problems. No radial-velocity observations of this system have been made, but if such observations were to be made, an accurate photometric solution could be combined with the spectroscopic data (whether single or double lined). If the system is single lined the photometric mass ratio would be required to compute masses and absolute radii, and if double lined it would be interesting to compare the spectroscopic and photometric mass ratios. Wilson (1966) listed the early observational history.

Only one set of photoelectric light curves has been published (Wilson 1966). In searching for a Russell model solution, Wilson could not simultaneously satisfy both the depth relation and the shape of the primary eclipse without assuming an implausibly large amount of third light. Therefore, he gave only a cursory discussion of solution experiments and did not list a full set of elements. He concluded that the discrepancies were probably due to an inadequacy of the Russell model.

Mardirossian and Giuricin (1981, hereafter MG) analyzed Wilson's data using the WINK model of D. B. Wood (1971), which is an improvement on the Russell model but which also models the stars as ellipsoids. They assumed a primary-star temperature of 7200 K based on the F0 spectral type given by Kukarkin *et al.* (1969) and Flower's (1977) spectral-type calibration. They presented elements for solutions in each passband separately, which leads to the physically inconsistent situation of having two values for wavelength-independent parameters such as inclination, the sizes of the components, and the temperature of the secondary. Clearly, a simultaneous solution of the two light curves is statistically a more correct way to estimate the elements of the system (Wilson 1979; Van Hamme and Wilson 1984; Eichhorn 1990).

2. Solution

We analyzed yellow and blue data (Wilson 1966) with the model of Wilson and Devinney (1971) in mode 5, which constrains the secondary to fill its limiting lobe. We adjusted i (inclination), T_2 (mean temperature of the secondary), Ω_1 (surface potential of the primary), q (mass ratio of secondary to primary), and L_1 (relative monochromatic luminosity of the primary). The gravity-darkening exponent for the primary was set to 1.0, corresponding to the Von Zeipel law, and that of the secondary to 0.3 (Lucy 1967). The limb-darkening coefficients for the linear cosine law were estimated from the tables of Carbon and Gingerich (1969). Weighting of the observations was inversely proportional to the light level, based on an empirical estimate of the variation of scatter with light level. The relative weighting of the two curves was based on the probable errors of a single measurement given by Wilson (1966).

There is a disagreement on the spectral type of the

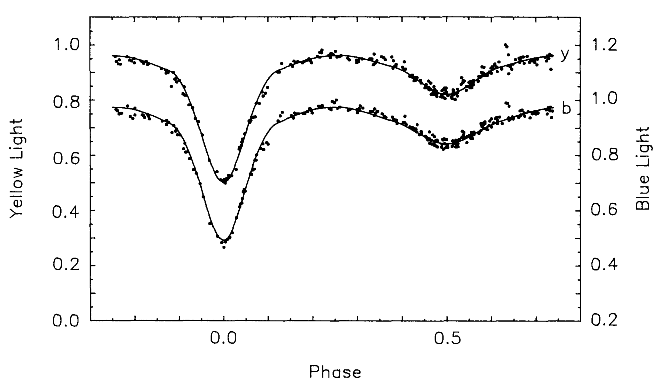

FIG. 1–Yellow and blue light curves for XZ CMi with the A5 simultaneous solutions.

primary. Kurkarkin *et al.* list the spectral type as F0, but Wilson (1966) estimated A5 from the color index. Estimates of spectral types from color measurements can be affected by interstellar reddening, but in this case the color of the star suggests a *higher* temperature than does the spectral type. Because of this uncertainty, we found solutions for both spectral types with T_1 = 7200 K and T_1 = 8200 K according to the spectral-type calibrations by Flower (1977).

We used the method of multiple subsets (MMS, Wilson and Biermann 1976), where the adjusted parameters are broken up into subsets to alleviate correlation problems. In our solutions we adjusted i, T_2, and Ω_1 in one subset and q and L_1 in another. The program was iterated first using the corrections for one subset and then for the other until the corrections were an order of magnitude smaller than the probable errors. Table 1 shows the solutions for the two spectral types and Figure 1 shows a plot of Wilson's data and the computed curves for the A5 solution only, since the differences between the two solutions are not visible on a plot of this scale.

3. Discussion

Comparing Figure 1 with the Russell-model solution (Wilson 1966) it is apparent that the shoulder discrepancies are considerably smaller in our solution, even without the help of third light. Wilson (1966) originally speculated that the discrepancies were due to a departure from the Russell model and this does seem, at least partly, to be the case. In later runs we allowed the program to adjust third light, but the suggested corrections were always much smaller than the probable errors, so we conclude that any third light in XZ CMi is negligible.

A comparison of our F0 solution with that of MG shows

TABLE 1

XZ Canis Minoris solutions from Wilson observations

Parameter	T_1=8200 K	T_1=7200
i	77°.09 ± 0°.19 p.e.	77°.70 ± 0°.40 p.e.
g_1	1.0	1.0
g_2	0.3	0.3
A_1	1.0	1.0
A_2	0.5	0.5
T_2	4837 ± 1 K	4412 K ± 24 K
q	0.4385 ± 0.0086	0.418 ± 0.017
Ω_1	3.1887 ± 0.0245	3.1649 ± 0.0491
Ω_2	2.7556	2.7151
$L_1/(L_1+L_2)_y$	0.9154	0.9205
$L_1/(L_1+L_2)_b$	0.9456	0.9499
x_1 (yellow)	0.635	0.635
x_1 (blue)	0.760	0.760
x_2 (yellow)	0.746	0.746
x_2 (blue)	0.844	0.844
r_1 (pole)	0.3602 ± 0.0041	0.3608 ± 0.0065
r_1 (point)	0.3963 ± 0.0070	0.3957 ± 0.0103
r_1 (side)	0.3735 ± 0.0048	0.3740 ± 0.0075
r_1 (back)	0.3851 ± 0.0057	0.3851 ± 0.0086
r_2 (pole)	0.2896 ± 0.0015	0.2859 ± 0.0032
r_2 (point)	0.4161 ± 0.0020	0.4115 ± 0.0041
r_2 (side)	0.3020 ± 0.0016	0.2981 ± 0.0034
r_2 (back)	0.3346 ± 0.0016	0.3308 ± 0.0033
$\Sigma(W\ RES^2)$	0.0241	0.0259

several differences, most noticeably in the inclination and the temperature of the secondary star. MG estimated i to be $79^\circ.3 \pm 1^\circ.0$ while our solution yielded $77^\circ.7 \pm 0^\circ.4$. For T_2 MG obtained 4800 K–4900 K (they gave two different values of T_2 for the blue and yellow curves) while our solution resulted in $T_2 = 4412$ K $\pm$ 24 K. MG estimated the mass ratio to be 0.4, but no error estimates were given since q is not an adjustable parameter in the Wood model. We estimated $q = 0.418 \pm 0.017$ for the F0 solution and $q = 0.4385 \pm 0.0086$ for the A5 solution. All error estimates are probable errors.

We also ran the program in mode 2 (both components detached from their limiting lobes). The starting values for the parameters were those of the mode 5 solutions. The corrections were such that the secondary continued to fill its lobe while the primary remained detached, so it seems that XZ CMi is in an Algol-type semidetached configuration.

The ambiguity in the spectral type of the primary still exists. Our calculations indicate that the choice of A5 gives a marginally better solution, in terms of the residuals, but the difference is so small that one cannot rule out the other value. An accurate determination of the spectral type is still needed, as are radial-velocity observations.

4. Conclusions

Our solutions indicate that XZ CMi is a semidetached system, with partial eclipses, and the primary minimum is a transit. Problems in the shoulders of the primary eclipse still exist, and may be due to spots, but the uniqueness of a spotted solution could be suspect. Spectroscopic studies of this system as well as more accurate photoelectric observations would help resolve some of these problems.

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