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NEW DOUBLE-LINED ECLIPSING BINARIES FOUND WITH RETICON, DIGICON, AND CCD DETECTORS

High resolution coudé spectrometric observations have been made during the past five years as part of a continuing program to determine accurate absolute properties of eclipsing binary stars. A previous progress report (Lacy and Evans 1979) discussed nine of the stars in this program (KP Aql, CW CMa, YZ Cas, V442 Cyg, TX Leo, FL Lyr, EE Peg, V906 Sco, and TX UMa) which were observed with a Reticon detector on the 2.7 m McDonald Observatory reflector. The completed analyses of the observations of CW CMa, YZ Cas, and EE Peg already have been published (Lacy 1982, 1981, and Lacy and Popper 1984). Observations of an additional 27 eclipsing binaries are discussed here. These observations were obtained with the coudé Reticon and Digicon detectors on the 2.7 m reflector at McDonald Observatory and the coudé CCD spectrograph of the 2.1 m reflector at Kitt Peak National Observatory. The binaries have been divided into two groups (double-lined systems and others) and are discussed in detail below:

Double-Lined Eclipsing Binaries

BW Aqr*	IT Cas*	V541 Cyg*	GG Ori*
HS Aur*	MU Cas*	V909 Cyg	IQ Per
BW Boo*	PV Cas	UZ Dra*	YY Sgr*
WW Cam*	V396 Cas*	FS Mon*	V907 Sco*
AY Cam	V459 Cas*	EW Ori*	RW UMa*
SW CMa*	WX Cep	FT Ori	BD +37°4713

Systems with an asterisk (*) either do not have a photoelectric light curve or need to have additional photometric coverage. Photoelectric observers are encouraged to observe these systems in at least two well-calibrated colors in order to make possible the most accurate determinations of absolute stellar properties.

Notes on the individual systems are listed below. The spectral types listed are generally as stated in the General Catalogue of Variable Stars (GCVS). For eccentric orbits the eccentricity is quoted in parentheses if known.

BW Aqr: Spectral type (Sp.) F7, orbital period P= 6.72 days, photographic magnitude (mag.) 10.2. My spectra are consistent with late F. Absorption lines of both components are of about equal strength. The lines are very crowded in the blue. Popper (1971, 1981a) has 5 plates. The existing photometry (Robinson and Kreiner 1970) shows deep, narrow eclipses, a displaced secondary eclipse, and possibly apsidal motion.

HS Aur: Sp. G8V (Popper 1983), P= 9.81 days, mag. 10.5. Lines of both components are of about equal strength. Popper (1983) has many plates. Unpublished photometry by Freuh and Turner shows narrow, deep eclipses. This is a very important system for filling in the gap in absolute data between the Sun and YY Gem.

BW Boo: Sp. A0, P= 3.33 days, mag. 7.0V. This is a large light-ratio system similar to YZ Cas. Lines of the primary are sharp and deep (Am?). Lines of the secondary are very shallow, mainly < 1% deep in the red (6400Å) region. A photoelectric light curve has been obtained by Kurpinska (1975). The single-lined orbit of Gorza and Heard (1971) showed a small eccentricity (0.14).

WW Cam: Sp. A?, P= 2.27 days, mag. 10.6. The stars have nearly equal line strength and moderately narrow lines. There are many nice lines in the blue (4500Å) region. The spectral type appears to be mid-A based on my 120Å wide coudé spectra. Photographic light curves (Huruhata and Gaposchkin 1940) show narrow, deep eclipses.

AY Cam: Sp. A5, P= 2.73 days, mag. 9.69V. The color index (B-V) of Tempesti (1969) corresponds to sp. F1 if there is no reddening. My spectra are consistent with late-A for the primary. The stars have a 2:1 line strength ratio and strong lines. Milano and Russo (1979) and Al-Naimiy (1977) have analyzed Tempesti's photoelectric light curve.

SW CMa: Sp. A8 + A8, P= 10.09 days, mag. 9.3. A poor spectroscopic orbit has been published by Struve (1945) who noted that it "did not represent the observations very satisfactorily." The secondary eclipse is displaced and the orbit is very eccentric (0.50). The lines are narrow, deep, and of nearly

equal strength on my spectra.

IT Cas: Sp. F6, P= 3.89 days, mag. 11.0. Narrow lines of nearly equal strength are shown in my spectra, which resemble those of BW Aqr. The secondary eclipse is slightly displaced, indicating eccentricity.

MU Cas: Sp. A0(GCVS), P= 3.86 days, mag. 10.5. The spectra show narrow lines of nearly equal strength. The He I line at 4471Å is much stronger than the 4481Å line of Mg II, and the spectral type therefore must be early B. The uvby indices of Hilditch and Hill (1975) imply a reddened B5 for the average spectral type. Romano (1958) has reported that the secondary eclipse is displaced, but this was not confirmed by Haussler (1973).

PV Cas: Sp. B6, P= 1.75 days, mag. 10.1. The spectra show broad lines of nearly equal strength. He I 4471 is barely visible, and the spectral type appears to be closer to B9 than B6 (GCVS). Popper (1971, 1978) has about two dozen spectrograms.

V396 Cas: Sp. late B, P= 11.13 days, mag. 9.9. The spectra show narrow lines with a line strength ratio of about 3:1. The spectral type appears to be close to A0 on my spectra.

V459 Cas: Sp. B9, P= 8.46 days, mag. 10.3. Moderately narrow lines of nearly equal line strength are shown.

WX Cep: Sp. A2 + A5, P= 3.38 days, mag. 9.3. The lines have approximately equal strength, but the primary's lines are slightly weaker and much narrower than the secondary's lines. According to Popper (1978) "Sahade and Cesco (1945) misinterpreted the appearance of the K-line, which is complex and not usable...Later than A2." Popper has many spectrograms. Ebbighausen et al. (1975) give a photometric orbit.

V541 Cyg: Sp. A0, P= 15.34 days, mag. 10.2. The lines are fairly narrow and of nearly equal strength. The orbit must be very eccentric since the primary and secondary eclipse durations differ by a factor of 2 and the secondary eclipse is displaced (Karpowicz 1961).

V909 Cyg: Sp. A0, P= 2.81 days, mag. 9.3. Lines of both components have nearly equal strength. Gulmen et al. (1982) have a photoelectric light curve in B, V.

UZ Dra: Sp. F8, P= 3.26 days, mag. 9.9. In the red region the lines are both narrow with a line strength ratio of about 2:1. The secondary lines are significantly narrower than those of the primary.

FS Mon: Sp. F2, P= 1.90 days, mag. 10.5. The lines are somewhat broad and

rather crowded in the blue. The line strength ratio is about 3:1.

EW Ori: Sp. G0, P= 6.94, mag. 10.4. The lines are sharp and of nearly equal line strength. Popper (1978) has 7 plates. Secondary eclipse is slightly displaced in an unpublished V, R lightcurve by Freuh. This is an important solar-type system.

FT Ori: Sp. A0 + A3, P= 3.15 days, mag. 9.0. The system shows fairly broad lines with the secondary lines somewhat weaker than the primary lines. The orbit is very eccentric (0.40). The lines are unblended only near phase 0.9, although near phase 0.2 they are only slightly blended. J. Tomkin has unpublished Digicon spectra and is collaborating with the author. Cristaldi (1970) has published a photometric orbit.

GG Ori: Sp. A2, P= 6.63 days, mag. 10.8. My spectra are consistent with an early A type. The lines are narrow and of nearly equal strength. The secondary eclipse is displaced (Kordylewski 1951), indicating an eccentric orbit. The eclipses are deep and narrow.

IQ Per: Sp. B7 + A2, P = 1.74 days, mag. 7.7. The lines are broad and the line strength ratio is about 4:1. The secondary component's Mg II 4481Å line is slightly blended with the wings of the very broad 4471Å He I line of the primary when the secondary line is displaced blueward. Young's (1975) estimate of K_2 is about 14% too small. The orbit is slightly eccentric (0.07). Hall et al. (1970) gives a photometric orbit.

YY Sgr: Sp. A0, P= 2.63 days, mag. 9.8. Both He I 4471Å and Mg II 4481Å are double and of comparable strength, implying a spectral type near B8. The He I components are always badly blended. The Mg II components are unblended and of nearly equal strength. The orbit is eccentric (0.16). Keller and Limber (1951) derive a photometric orbit.

V907 Sco: Sp. A0, P= 3.78 days, mag. 9.1. The spectra show nice sharp lines at 4481Å and 4550Å Fe II + Ti II, both components having nearly equal strength. Other lines are rather weak.

RW UMa: Sp. F9 + G9, P= 7.33 days, mag. 10.1. Lines of the secondary are broader than, and of comparable strength to, the primary. This is known to be an "RS CVn" type system. Provisional masses and radii have been given by Popper (1975, 1980).

BD + 37°4713 = SAO 072799: Sp. A0, P= 7.35, mag. 8.0. One component has much broader lines than the other. The secondary eclipse is slightly displaced (Fernandes and Frank 1981), so the orbit is eccentric.

Other Eclipsing Binaries

QX Cas: Sp. B1, P= 6.00, mag. 10.3. No sign of a secondary spectrum can be detected in Digicon scans at phases 0.05, 0.10, 0.19, 0.27, 0.36, or 0.56. Sandage and Tammann (1969) give photometric data.

V380 Cyg: Sp. B1.5III, P= 12.43 days, mag. 5.7. The primary's lines are very broad and deep. Very weak (<1%) features possibly due to the secondary are seen near the 4481 Mg II line of the primary in three Reticon spectra with signal-to-noise ratio greater than 500. The possible secondary features are probably too weak to detect photographically. They are always somewhat blended with the strong primary line, even near quadrature phases. These observations reinforce Popper's (1981b) conclusion that Batten's (1962) orbit for the secondary must be considered unreliable.

VV Ori: Sp. B1, P= 1.49 days, mag. 5.3. The spectra are similar to those of V380 Cyg (above) except the lines of VV Ori are even broader and the secondary is somewhat stronger. The He I lines are always blended. The secondary 4481Å Mg II line is not detectable with certainty in spectra with signal-to-noise ratio of 500. These observations reinforce Popper's (1981) and Andersen's (1976) conclusions that Duerbeck's (1975, 1976) orbit for the secondary must be considered unreliable.

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References:

Al-Naimiy, H.M. 1977, Ap.Sp.Sci., 46, 261.
Andersen, J. 1976, Astr. Ap., 47, 467.
Batten, A.H. 1962, Pub. Dom. Ap. Obs. Victoria, 12, 91.
Cristaldi, S. 1970, Astr. Ap., 5, 228.
Duerbeck, H. W. 1975, Astr. Ap., 22, 19.
Ebbighausen, E.G., Penegor, G., and Straton, P. 1975, Pub. A.S.P., 87, 795.

Fernandes, M., and Frank, P. 1981, I.B.V.S., No. 2053.
Gorza, W.L., and Heard, J.F. 1971, Pub. David Dunlap Obs., 3, 99.
Gulmen, O., Gudur, N., and Sezer, C. 1982, I.B.V.S., No. 2245.
Hall, D.S., Gertken, R.H., and Burke, E.W. 1970, Pub. A.S.P., 82, 1077.
Haussler, G. 1973, I.B.V.S., No. 755.
Hilditch, R.W., and Hill, G. 1975, Mem. R.A.S., 79, 101.
Huruhata, M., and Gaposchkin, S. 1940, Bul. Harvard Col. Ob., No. 914.
Karpowicz, M. 1961, Acta Astr., 11, 51.
Keller, G., and Limber, D.N. 1951, Ap.J., 113, 637.
Kordylewski, K. 1951, Acta Astr., 4, 134.
Kurpinska, M. 1975, I.B.V.S., No. 1007.
Lacy, C.H. 1981, Ap.J., 251, 591.
Lacy, C.H. 1982, Ap.J., 261, 612.
Lacy, C.H., and Evans, D.S. 1979, I.B.V.S., No. 1704.
Lacy, C.H., and Popper, D.M. 1984, Ap.J., 281, in press.
Milano, L., and Russo, G. 1979, I.B.V.S., No. 1613.
Popper, D.M. 1971, Bul. A.A.S., 3, 48.
Popper, D.M. 1975, I.B.V.S., No. 1083.
Popper, D.M. 1978, private communication.
Popper, D.M. 1980, Ann. Rev. Astr. Ap., 18, 115.
Popper, D.M. 1981a, private communication.
Popper, D.M. 1981b, Ap.J. Suppl., 47, 339.
Popper, D.M. 1983, private communication.
Robinson, L.J., and Kreiner, J.M. 1970, Acta Astr., 20, 19.
Romano, G. 1958, Mem. Soc. Astr. Italiana, 29, 465.
Sahade, J., and Cesco, C.U. 1945, Ap.J., 102, 128.
Sandage, A., and Tammann, G.A. 1969, Ap.J., 157, 683.
Struve, O. 1945, Ap.J., 102, 74.
Tempesti, P. 1969, Mem. Soc. Astr. Italiana, 40, 345.
Young, A. 1975, Pub. A.S.P., 87, 717.