THE ECLIPSING BINARIES IN NGC 5466 AND IMPLICATIONS FOR CLOSE BINARY EVOLUTION[1]

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ABSTRACT   The three eclipsing binaries among the blue stragglers of the globular cluster NGC 5466 have been modeled. Two of the systems are contact systems and the third is a short-period Algol system. The results indicate that the systems are well on their way to merger, but the implications for the origin of blue-stragglers are less clear.

INTRODUCTION

The rarity of binaries in globulars argues for a mechanism that evolves detached binaries into contact systems and ultimately into (spun-down) blue stragglers. The connection between W UMa stars and blue stragglers has been discussed in, *e.g.*, Leonard (1989), while angular momentum loss through magnetic field braking, the likely evolution mechanism, has been amply discussed (*e.g.* by Webbink 1976, Mochnacki 1981, Rahunen 1981). Mateo *et al.*'s (1990) discovery of three eclipsing systems in NGC 5466 provides an opportunity to study such systems at late stages of metamorphoses. Their CCD data of *NH19, 30*, and *31* (for *N*emec and *H*arris 1987) have been modeled with our improved Wilson-Devinney (*WD*) code (Milone *et al.* 1992) and an iterating *simplex*-enhanced version (*SWD*) (Kallrath *et al.* 1992) to shorten convergence time and to test model uniqueness.

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MODELING RESULTS

Modeling details are given by Kallrath *et al*. (1992); here we briefly summarize the results only.

The significance of *NH31* for binary star evolution is underscored by its period: at just over 0.5^d, it may be the shortest period Algol system detected to date. The first set of trials involved the case of a transit at primary minimum. Both detached and semi-detached solutions are viable. The semi-detached option is not viable in the occultation case. The residuals indicate the semi-detached transit case to be slightly preferred over other models; but the issue is moot: RV data especially are needed to decide the issue.

NH19 and *NH30* are contact systems with depth differences and O'Connell effects in the light curves; Milone *et al*. (1987, 1991) have demonstrated that spot modeling suffices as a treatment of the asymmetries. The systems are overcontact and very close to their outer Lagrangian surfaces. In *NH19*, $\iota \approx 74°$ indicates partial eclipses, so that the mass ratio cannot be considered secure until confirmed by spectroscopy, also required for T_1, M_1, and M_2. In *NH30*, a large uncertainty in q indicates that this parameter was not well determined and more data are needed here also. The optimized *DC* and simplex solutions differed slightly for this system, probably partially due to the condition that the minima of parameter space are relatively shallow. Fig. 1 shows system representations.
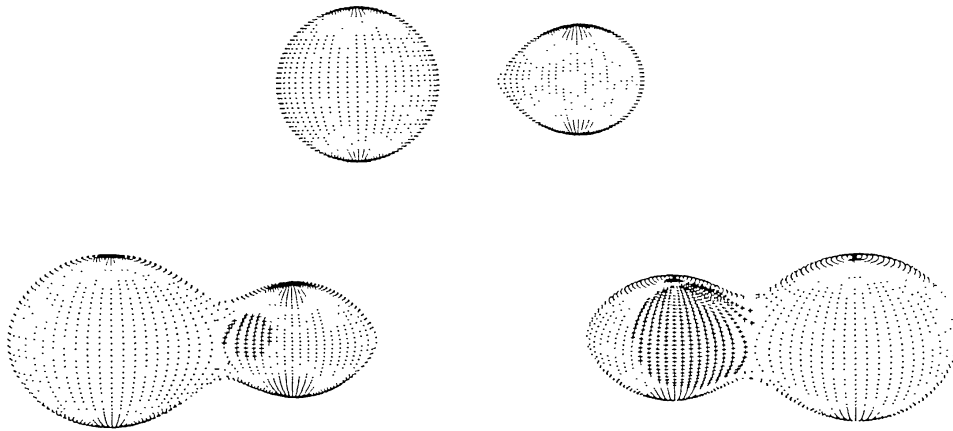

Fig. 1 Adopted models of *NH31*, (top), *NH30* (left), (both at ϕ = 0.25) and *NH19* (right) at 0.75^P, via *Binary Maker*, a software package produced and distributed by D.H. Bradstreet.

DISCUSSION

Our solutions differ slightly from the analyses given by Mateo *et al.* (1990): T_2 in the W UMa systems NH19 and NH30 are different from T_1 as suggested by the depth differences in the minima. Mateo *et al.*'s estimates of q (0.10 ± 0.04 and 0.14 ± 0.04 for *NH19* and *NH30*, respectively) were determined from statistical properties of population I field W UMa stars with relatively undistorted light curves and they assumed the radius of the inner contact surface as the radius of each component. Although the work reported here is not dependent on these assumptions, the models indicate that the components of *NH19* and *NH30* are very close to their outer Lagrangian surfaces, with contact parameters ~0.94 so that that mass loss can have occurred. The computed distances for the individual systems show small discrepancies ($\leq 2\sigma$), when compared to the distance derived by Nemec and Harris (1987). In particular, *NH30* may be a background system, since $(V-M_V)_c = 21.5 \pm 1.9$, compared to Nemec and Harris' (1987) value, 16.0; alternatively, the components may be undermassive.

The binaries are among the blue stragglers of the cluster. Mateo *et al.* argue that the merger mechanism should function only in relatively old clusters, where the turn-off mass is less than about 2 or 3 $M_\odot$, because, according to Iben and Tutukov (1984), this is the upper mass limit for strong magnetic fields which are needed to provide the magnetic braking mechanism for angular momentum loss. The presence of the O'Connell effect in two of the three systems studied here is supportive of that view, because surface brightness variation across the disk of a component due to stellar active regions is a possible mechanism for the O'Connell effect, which is seen in other A-type systems also.

Mateo *et al.* predict that between 3% and 15% of all population II blue stragglers should be *detectable* contact binaries. While the evolutionary merger process can yield blue straggler-like products, it is also true that mergers can be greatly aided if not accomplished through binary-binary collisions, especially in cluster cores. It is also probable that blue stragglers can be formed in still other ways (see Leonard 1989). It is interesting that in our preferred models, the hotter components themselves fall into the blue-straggler region of the CMD (see Fig. 2); therefore, the duplicity in itself cannot explain the blue-straggler condition.

REFERENCES

Eggen, O., and Iben. I. 1989, *AJ*. **97**, 431.

Iben, I., and Tutukov, 1984. *ApJ*. **284**, 719.

Kallrath, J., Milone, E.F., and Stagg, C.R. 1992, *ApJ*., *in press*.

Leonard, P.J.T. 1989, *AJ*. **98**, 217.

Mateo, M., Harris, H.C., Nemec, J., and Olszewski, E.W. 1990, *AJ*. **100**, 469.

Milone, E.F., Groisman, G., Fry, D.J.I.F., and Bradstreet, D.H. 1991, *ApJ*. **370**, 677.

Milone, E.F., Hrivnak, B,J, and Wilson, R.E. 1987, *ApJ*. **319**, 325.

Milone, E.F., Stagg, C.R., and Kurucz, R. 1992, *ApJ. Suppl.*, *in press*.

Mochnacki, S.W. 1981, *ApJ*. **245**, 650.

Nemec, J., and Harris, H.C. 1987, *ApJ*. **316**, 172.

Rahunen, T. 1982, *A&A*. **102**, 81.
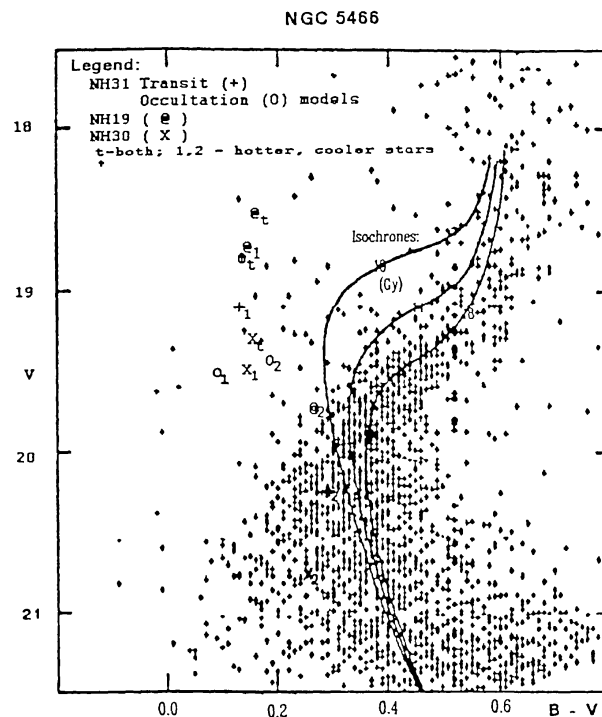
Webbink, R. 1976, *ApJ*. **209**, 829.

Fig. 2 The CMD of NGC 5466 (adapted from Nemec and Harris 1987). The more luminous components are themselves seen to lie in the blue-straggler region (upper left) of the cluster; also shown are their isochrones for ages of 10, 14, and 18 Gy.