THE BINARIES-IN-CLUSTERS PROGRAM IN THE AGE OF IMAGING

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The binaries-in-clusters program of the Rothney Astrophysical Observatory has targeted eclipsing binaries in galactic star clusters since 1975. The program uses a boot strap method: fundamental star data are obtained from light curve analysis and these data then elucidate the properties of the cluster environment, such as the distance, reddening, and, through isochrone fittings, information about the age and evolution of both binary components and the cluster as a whole. Here we discuss its current status and the increasingly important role of all-cluster direct and spectroscopic imaging.

It is now clear that the role played by binary stars is central to our understanding of clusters (cf. Hut et al. 1992). The evaporation of the high energy tail from a cluster leads to a more strongly bound core and to its eventual collapse, and stellar collisions provide the evaporants. Since binary star encounters are more probable than single star encounters by a factor of order a/R (where a and R are the semi-major axis and stellar radius, respectively), binaries are an important determinant of cluster evolution.

NGC 5466 is a low-density globular cluster, at least 48 stars of which are blue stragglers (Nemec & Harris 1987), which may be primordial objects since they are somewhat more centrally concentrated than subgiants. If the *BS*s are indeed merged binaries, were they formed through collisions or through magnetic braking? Masses are needed to decide the issue: are the components more massive than the turn-off mass or not? If the blue straggler masses are consistent with those expected from primordial binary evolution scenarios, probably they formed through magnetic braking, and the numbers of blue stragglers may be indicative of the primordial binary population. The existence of three short-period eclipsing systems among the BSs in this ancient ($\tau \sim 18$ Gy) cluster (Nemec & Harris 1987) offers strong support to the late evolution of such close binaries, either by merger through angular momentum loss or through repeated collisions in the cluster core, or both. Detailed analysis (Kallrath, Milone & Stagg 1992) of the Mateo et al. (1990) CCD BV light curves indicated a slight preference for a detached, transit solution over either semi-detached or detached, occultation solution for NH31; both NH19 and NH30 are overcontact A-type W UMa systems, very close to their outer lobes, with contact parameter, f ~ 0.94. In each case the primary star is *itself* a blue-straggler (Milone, Stagg & Kallrath 1992), requiring multiple mergers (Leonard & Linnell 1992) to sustain the merger scenario as the origin of the BSs. Yet, the cluster is so sparse and the velocity dispersion so low in the core that the average time between even wide collisions (10x orbital separation) is 10^{13} y

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(Mateo et al. 1990). Thus since the time scale for angular momentum loss to produce a merger is thought to be of order 10^8 - 10^9 y, it is difficult to see how this process could not have played a major role in the evolution of the binaries.

Two powerful techniques for determining ages are the fitting of isochrones to a cluster's CMD (a definitive test for which is the agreement with CMD stars of known masses) and comparing the *sizes* of evolved components with model predictions. These techniques were used to good effect in the Hyades and in NGC 752 by Schiller & Milone (1987, 1988). However, few binary systems in globular clusters are known to be eclipsing and only a handful (4) at this writing have been analyzed; three of these are the BS systems analyzed by us in NGC 4566. In deriving the fundamental parameters of those three systems, we assumed total masses of 1.2 $M_\odot$ but this assumption produces different distances for the systems; if we relax the mass constraint and require a common distance, the masses for NH30 and NH31, become very small. Substantial numbers of other types of variables are imaged along with the principal targets both in direct and in multi-object-spectrograph imaging. They provide independent assessments of cluster distance, alternatively permitting checks on their luminosity calibrations. For BL Boo, an anomalous cepheid (Zinn & King 1982) and several SX Phe stars, among the blue straggler population, and the RR Lyrae stars, Wesselink radii can be attempted. For δ *Scu* stars, we have improved the calculation of radius error (Wilson, Milone & Fry 1993), with a concomitant improved assessment of their luminosities. Finally, an RV study can establish limits to the variation in other BSs. We hope to carry out the RV work in the near future; in the meantime, we have extended and improved the photometry of this cluster and others. For M71, we have more than 100 CCD frames in each of BVR and I passbands, and have begun searching for variables in M2, M92, and Pal 1. IRAF and DAOPHOT have been used to reduce and analyze UBVI data obtained with the SDSU Mt. Laguna Obs. 1 m telescope equipped with a back-illumined, thin 800 x 800 chip. Averages of the brightest non-saturated, non-variable stars in the field define the 'comp' star for each frame. The uncertainty in each observation is ~ 0.05 for the faintest (NH30) and ~ 0.005 for the brightest variables. Images of M71 obtained from MLO and Apache Point Obs. (1.8 m telescope, HRI and GRIM cameras) in 1992 and 1993 are being currently reduced along with more recent BVRI NGC 5466 images. In the open clusters IC 1848, NGC 752, NGC 6791 and NGC 7209, we are concentrating on known variables: the Algol variables V497 and V498 Cas in IC 1848; the former-eclipsing system SS Lac in NGC 7209; and variable stars in NGC 7142.

We have obtained two nights of deep imaging data from MLO on the open cluster NGC 6791, one of the oldest open clusters. Reduction of these images is to be completed by mid-1994.

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