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The Binary Fraction of NGC 6397

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Abstract. The binary fraction, η, of a globular cluster (GC) is a key parameter in determining its dynamical evolution, as well as its content of rare stars, such as cataclysmic variables and blue stragglers. The precise value of η for a GC was historically difficult to constrain due to an inability to obtain reliable photometry for faint objects in dense stellar fields. However, today, the HST allows us to image the main sequence of the nearest GCs to their terminations. Using HST observations we constrain η for NGC 6397. While the necessary computing power is now available to realistically simulate entire GCs, large discrepancies in the assumed primordial binary fraction, η_{p}, of GCs still exist. Estimates range from 5% (Hurley *et al.* 2007) to 100% (Ivanova *et al.* 2005). The N-body models of Hurley *et al.* (2007) suggest that η beyond the half-mass radius remains close to η_{p}, while cluster evolution can increase the value in the core. We find η for NGC 6397 is $15.2 \pm 0.8\%$ in a field centered on the core, and $1.1 \pm 0.3\%$ in a field beyond the half mass radius. These findings suggests $\eta_{\mathrm{p}} \sim 1\%$.

Keywords. binaries: general, globular clusters: individual (NGC 6397)

Observations: The data used in this project were obtained in 2005 by Richer *et al.* when 126 orbits were dedicated to imaging one ACS WFC field 5' South-East of the cluster core. WFPC2 parallels were obtained in the cluster core (Richer *et al.* 2006). The CMDs of the two fields are shown in Figs. 1C and 1D. Archival images (covering 60% of the ACS field and 80% of the WFPC field) were used to determine proper motions, shown in Figs. 1A and 1B.

The model: From isochrones (Dotter *et al.* 2006), and an empirically derived mass function and model for the photometric error, a model of the single-star sequence, $\mathrm{F_s}$, was constructed (Fig. 1G). The only further assumption required to simulate the binary sequence, $\mathrm{F_b}$ (shown in Fig. 1H), is the distribution of mass ratios, q. We experimented with two distributions of q's: 1) a flat distribution, and 2) 55% of the binaries with a flat distribution, and 45% of the binaries with a twin (q$\geqslant$0.95) secondary (as suggested by Pinsonneault & Stanek 2006). The derived binary fraction was relatively insensitive to the assumed distribution of q. For a given η, $\mathrm{F_s}$ and $\mathrm{F_b}$ are added to make a cluster model in the following manner: $\mathrm{F}(\eta) = (1-\eta)\mathrm{F_s} + \eta\mathrm{F_b}$.

Results: For a given magnitude, m, and colour, c, the number of observed stars, n, and the value of the model, F, is determined. The probability, P, of observing n stars, is given by a Poisson distribution: $P\,(c, m|n) = F(c, m)^n e^{F(c,m)}/n!$. Following Romani & Weinberg (1991), the likelihood of the data given the model is the product of every bin: $L(\eta) = \prod_{i=1}^{N} P(c_i, m_i|n)$. The likelihood is calculated for all η, and the most probable, η_0, is determined. The allowed region (1-σ) is determined where $log\,[L(\eta)/L(\eta_0)] \geqslant -0.5$. Shown in Figs. 1E and 1F are the probability distributions for η in both the ACS field and the WFPC2 field. The allowed region is shown with hatching. The derived η in both fields is low: $15.2 \pm 0.8\%$ in the WFPC2 field and $1.1 \pm 0.3\%$ in the ACS field.

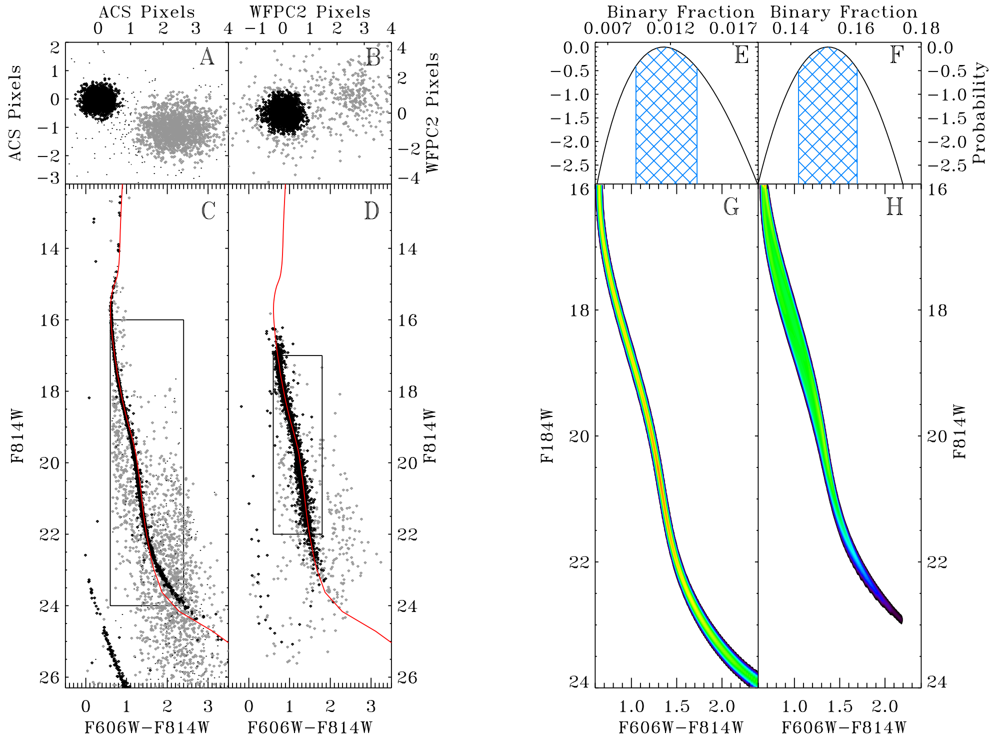

Figure 1. Panels A and B: The proper motions for the ACS and WFPC2 fields respectively, with cluster stars in black and field stars in gray. **Panels C and D:** The CMDs for the ACS and WFPC2 fields respectively. Again, stars with cluster proper motion are in black, while the field is in gray. Overlaid is the isochrone by Dotter *et al.* (2006). The color-magnitude space used for this study is shown with a box. **Panels E and F:** The derived binary fraction for the ACS and WFPC2 fields respectively. The 1-σ allowed region is designated with hatching. **Panels G and H:** The simulated probability for $\eta = 0$ and $\eta = 1$ for the ACS field respectively.

Conclusion: This work presents a very precise determination of η for a GC. Hurley *et al.* (2007) has shown that as a cluster evolves dynamically, η increases in the core while outside the half-mass radius it remains roughly constant. In this context, our results suggest that $\eta_{\rm p} \sim 1$–2% – significantly lower than typically assumed for N-body models.

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