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CORE RADIUS-MASS EVOLUTION OF GLOBULAR CLUSTERS

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RESUMEN

Algunas de las características dinámicas de los cúmulos globulares parecen ser el resultado de los efectos producidos durante la época de su formación, tanto para la tasa de estrellas binarias primordiales como para la formación y destrucción de las mismas. Incluso una segregación en la masa y una evaporación del cúmulo producida por la población de estrellas binarias es posible. Las variaciones observadas en el radio del núcleo de los cúmulos viejos y de edad intermedia, observados en la Gran Nube de Magallanes, podría generarse por estos dos efectos. Algunos resultados preliminares se presentan en esta contribución.

ABSTRACT

Some dynamical features of present day globular clusters seem to be the result of the effects produced at the epoch of formation, both by the rate of primordial binary stars and the formation and destruction of new ones. Even a mass segregation and a cluster evaporation driven by the population of binary stars are possible. The spread in the core radius among intermediate age and old stars clusters, observed e.g. in the LMC, could be generated by these two effects. In this contribution some preliminary results are shown.

Key Words: **GLOBULAR CLUSTERS — DYNAMICS: BINARY INTERACTION — MASS-RADIUS: EVOLUTION**

1. BINARY INTERACTIONS

Binary stars in globular clusters may have a primordial origin, or being the result of cluster dynamics (e.g. Tholine 2002). Binaries dynamically generated can be the output of three body encounters –where energy is preserved– because a third star can carry away the neccesary kinetic energy to leave the two others bound. Otherwise it can be dissipative if two stars happen to pass within a few stellar radii of one other. Such non primordial systems are likely to be found primarily in evolved globular cluster cores, both because of the mass segregation and because the high frequency of collisions.

On the other hand, very few is known about the mass and energy distribution of primordial binaries, in fact, until quite recently, it was beleived that Globular clusters (GCs) were born with few, if any, binary systems, so binaries had to form dynamically. At the present time, however, there is increasing evidence that many GCs contain binary fractions in the 3-30% range, and it seems reasonable to suppose that all GCs were born containing significant numbers (>10%) of primordial binaries (e.g. de la Fuente 1995; Nakasato, Mori & Nomoto 2002). Thus, dynamical interactions between hard primordial binaries and other single stars or binaries are thought to be the primary energy generation mechanism responsible for maintaining the GC in quasi-thermal equilibrium, supporting a core collapse for a time much longer than the two-body relaxation timescale (McMillan, Hut & Makino 1991; Gao, Goodman, Cohn & Murphy 1991).

Fregeau, Gurkan, Joshi & Rasio (2003) and Rasio, Pfahl & Rappaport (2000) have shown that strong dynamical interactions involving binaries might explain the large number of exotic objects found in dense star clusters. For instance, exchange interactions between hard primordial binaries and neutron stars produce pulsars. On the other hand, resonant interactions of primordial binaries result in increased collision rates for main-sequence stars in GC. A direct observational evidence for stellar collisions and mergers of main-sequence stars in globular clusters comes from the detection of large numbers of bright blue stragglers concentrated in the dense cluster cores (Bellazini, Fusi Pecci, Messineo, et al. 2002; Ferraro, D'Amico, Posseti et al. 2001). Moreover, Gebhardt, Rich & Ho (2002) and Portegeis Zwart & McMillan (2002) proposed that multiple mergers of main-sequence stars and runaway collisions in young star clusters could lead to the formation of a massive central black hole.

Numerical simulations, already have demonstrated how important are primordial binaries; e.g. if present at more than the 5% level, rapidly segregate to the cluster core, dominating the core mass and the cluster evolution (Heggie & Aarseth 1992).

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Even for a small initial population of hard binaries of $\approx 1-2\%$, can give rise to a core binary fraction in the 10-20% range within a half-mass relaxation time. Subsequently, binaries control the cluster dynamics until they are all destroyed by interactions with other binaries, or evaporated out of the cluster after a triple or four-body encounters. So, binary stars determine the core radius and mass evolution of globular clusters. The observed core radius-age relation in the globular cluster (see Figure 1), could in principle be explained in terms of the primordial fraction of binaries. We are interested in knowing whether this relation can be extended to the mass evolution of the globular clusters.

2. MAIN GOAL

We have used and adapted the NBODY4 Aarseth's code to perform numerical simulations in order to explore the results of the interaction of binary systems with a single or another binary star. As we are interested also in the evolution of mass of the Globular cluster, we have explored the results for different IMF, and initial number of primordial binaries.

We then need to implement the cross section for collisions, which is taken according to Heggie (1975) as $\sigma_{bs} = \pi b_{max}^2$ for binary-single star interaction. For a binary of mass m_b and a single star of mass m, we have

$$b_{max}^2 = r_{min}^2(1 + 2G(m + m_b)/w^2 r_{min}),$$

where $r_{min} = 3.5a$, and a is the binary semi-major axis, w is the relative velocity at infinity.

For binary-binary star interactions (each one with a binding energy ϵ_i) we adopted the analytic fit employed by Fregeau et al. (2003);

$$\sigma_{bb} \simeq 16.6(ln(\frac{29\epsilon_2}{mw^2+0.04\epsilon_2}))^{2/3}\frac{Gma_2}{w^2},$$

3. PRELIMINARY RESULTS

— A large fraction of primordial binaries produces significant core radius expansion.

— The results are very sensitive to the binary spatial distribution.

— Contrary to Wilkinson, Hurley, MacKey et al. (2003) we have detected a dependence of the previous results, on the Initial Mass Function adopted. We need further explore the results of using the Salpeter, Taff, Miller & Scalo, Kroupta and Scalo IMFs.

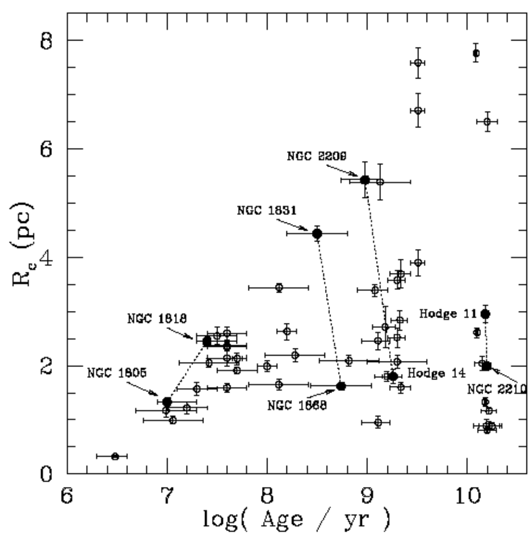

Fig. 1. Core radii R_c as a function of age of LMC clusters. The clusters in the GO7307 HST sample are identified by its name (data taken from Mackey & Gilmore 2003), and dotted lines match pairs as in Wilkinson et al. 2003.

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