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Globular Clusters within Dark Matter Halos : Case Studies of 47 Tuc, NGC 1851 and M 15

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Abstract. Globular clusters (GCs) are known to have a very small amount of or no dark matter (DM). Even if GCs are formed in individual DM halos, they must have lost the majority of the DM through dynamical processes such as mass segregation or tidal stripping. Using Fokker-Planck (FP) calculations, we investigate the dynamical evolution of three Galactic GCs with an assumption that they were formed in mini DM halos. We trace the amount of DM of 47 Tuc, NGC 1851, and M 15, which are a 'disk/bulge' cluster, an 'old halo' cluster, and a 'young halo' cluster, respectively. We find that these three GCs must have initially had insignificant amounts of DM, less than 10 percent of the initial stellar mass of each cluster.

Keywords. stellar dynamics, methods: numerical, galaxy: globular clusters

1. GC formation within DM halo

Since Peebles & Dicke (1968) first proposed a primordial scenario of globular clusters (GCs) within individual dark matter (DM) halos, the existence of DM halo in GC formation has been debated. However, it was found that many Galactic GCs have tidal tails. Thus, numerical simulations showed that these tidal tails cannot be formed if DM halos envelop the GCs (Moore 1996). Meanwhile, several numerical simulations showed that even DM which once embedded the GCs can be tidally stripped away by Galactic tidal field or removed by mass segregation (Bromm & Clarke 2002; Mashchenko & Sills 2005; Baumgardt & Mieske 2008).

So far, numerical studies on the initial amount of DM in two GCs have been done. NGC 2419 could still have DM halo because it is less affected by Galactic tidal field due to the large Galactocentric radius. However, previous studies suggested that NGC 2419 unlikely had significant amount of DM (Baumgardt *et al.* 2009; Conroy *et al.* 2011). NGC 6397 is one of the typical Galactic GCs, and it might suffer significant mass segregation and tidal stripping, more than NGC 2419. However, the amount of the maximum initial DM of NGC 6397 is less than the initial stellar mass (Shin *et al.* 2013).

Although previous numerical studies found that two GCs did not show any evidence of significant amount of DM, further studies are still needed to see if there are any GC that have been formed with a significant amount of DM. Therefore we select three Galactic GCs (47 Tuc, NGC 1851 and M 15) which have different properties and origins. Then we find their initial amount of DM by comparing the results of Fokker-Planck (FP) calculation to the observational data (surface brightness and velocity dispersion).

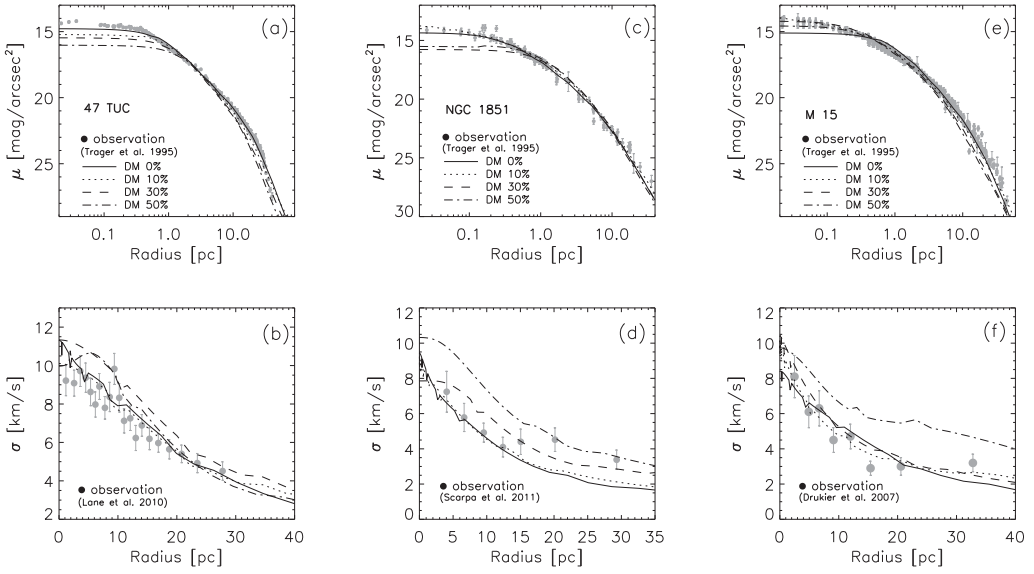

Figure 1. Surface brightness and velocity dispersion profiles of 47 Tuc, NGC 1851 and M 15. Grey dots are observational data (references are in each panel) and black lines are results of FP calculations which have different value of M_{DM}/M_{star}.

2. Initial amount of DM

We compare our FP results with the present-day observational data. We try hundreds of models which have different sets of initial conditions and find the best-fit model whose $M_{DM}/M_{star} = 0$ (no DM), 1, 3, and 5. Figure 1 shows the surface brightness (upper panel) and velocity dispersion profiles (lower panel) of three clusters. We find that 47 Tuc, NGC 1851 and M 15 have the best-fit model when M_{DM}/M_{star}=0 or 0.1 . When M_{DM}/M_{star} increases, the surface brightness profiles of models underestimate the central value while the velocity dispersion profiles overestimate the overall value.

47 Tuc and NGC 1851 are bulge/disk and old halo clusters which are believed to be native GCs. Otherwise, M 15 is a young halo cluster which might be accreted into the Galaxy. Therefore, if M 15 has lost the majority of DM in early phase of accretion, M 15 possibly had more DM mass initially.

We conclude that the three Galactic GCs, 47 Tuc, NGC 1851 and M 15 did not contain significant amount of DM regardless of their origins. Our result is similar to that of NGC 2419 and NGC 6397.

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