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Does the presence of cold dark matter can describe the high M/L ratios of UCDs?

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Abstract

Most of ultra-compact dwarf galaxies (UCDs) which have been studied in recent years are too distant to be spatially resolved, therefore their origins and structures is still ambiguous. The dynamical mass-to-light ratios of UCDs are on avarage about two times larger than those of gloubular clusters and therefor incompatible with stellar population synthesis (SPS) models. We assumed a two-compomnent mass model for UCDs: a Plummer sphere for stellar matter , and an NFW model for halo component. We calculeted the velocity dispersion profiles of UCDs and compared their mean values with the observational data available in the the literature. Almost 66% of modeled UCDs were in good agreement with the observations within the acceptable range of stellar mass-to-light ratios.

Ultra-compact dwarf galaxies (UCDs) were discovered in the Fornax galaxy cluster , for the first time, in the late 1990s [8] . These ultra faint objects with typical luminosities of $-13.5 < M_V < -11 mag$, half-light radii of $10 < r_h < 100pc$ and masses of $2 \times 10^6 < M < 10^8 M_\odot$ [11], are intermediate between typical globular star clusters(GCs) ($M_V \approx -8mag$) and normal dwarf galaxies ($M_V \approx -11$ to $-16mag$) .
Most ideas on the origin of UCDs could be devided into two parts, one suggests the GC origin [5] and the other believes in the galaxy origin for UCDs and discusses the "galaxy threshing" process as their formation scenario [2]. UCDs' dynamical M/L ratios are on average about twice as large as those of GCs with comparable metallicity, and tend to be larger than what one would expects for old stellar systems composed out of stars with standard mass functions.This might be as a result of: 1) overestimation of UCDs' virial massess due to loosing their virial equilibrium by tidal forces [6]; 2)having "top-heavy" [3] or "bottom-heavy" IMFs [12] ; 3)the presence of some dark matter (DM) in them [1].

In order to consider both possibilities of UCDs with and without dark matter, we first test all of them as they are just composed out of stars, then distribute some certain amount of dark (DM) among the stars of each UCD. Changing the total mass of a population of stars results in different velocity dispersions which are observationalliy available from the Doppler broadening of lines in the spectrum of the UCD.
With the asumption of a UCD as a nonrotating [7] and isotropic spherical systeme [9],with the velocity anisotropy parameter $\beta = 0$, its line of sight velocity dispersion (LOSVD) profile is obtained as :

$$\sigma^2_{LOS}(R) = \frac{2}{\sum(R)} \int_R^\infty \rho(r)\sigma^2(r) \frac{rdr}{\sqrt{r^2 - R^2}} \qquad (1)$$

where R and $\sum(R)$ are the projected radius and the surface mass density respectively [10].

In the first approach, we assumed that the UCDs are dark matter free objects. We considered the Plummer model for the stellar component of UCDs, which is the simplest plausible and self-consistent model for a star cluster . We modeled 21 UCDs (the six first

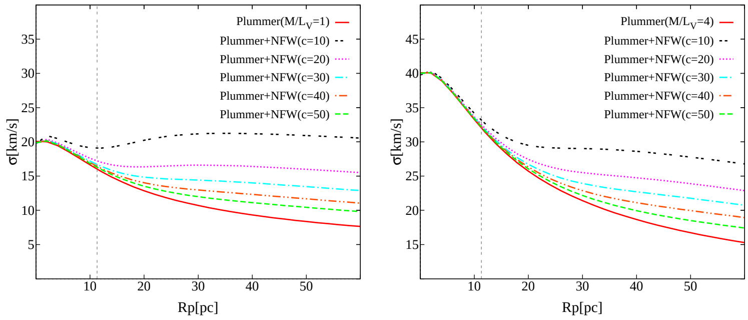

Figure 1: The LOSVD profiles of UCD1 with Plummer (for values of M_*/L ratios of 1 and 4) and NFW model (with c in the range of 10 to 50). The vertical dashed line is r_h of the UCD1. As the figure shows DM just affects the velocity of stars on the outskirt of the UCD. Although the situation is a bit different about the lower value of M_*/L ratio (the left pannel), according to the Fig. 3 the values of σ_g have not changed considerably.

UCDs' data are from [4], the five next from [9] and the ten last from [11]) as follows: After calculating each UCD's luminosity, L_V, using its absoloute magnitude, we iteratively chose γ_* from the range of 1 to 4 (acceptable for standard stellar populations) and calculated the total mass; $M_* = \gamma_* \times L_V$ and the Plummer mass density as a function of distance from the center. Finally we obtained the mean value of LOSVD among the UCD as well as its profile. As Fig. 3 (the upper panel) shows about seven UCDs need M_*/L_V ratios larger than 4 to be consistant with observations and four UCDs with the M_*/L ratios values of 4 are mariginally compatible with SPS models. The remaining ten need higher M_*/L_V ratios.

In the next step, using the NFW profile,we added DM to UCDs.The well-known NFW density profile for DM haloes represented by Navarro, Frank and white in 1996. We used some equations for NFW profile with single free concentration parameter,c. We changed c in the range of about 10 to 60, in order to test all possible haloes, although some may have almost illogical masses [10] , and added the resulting NFW mass dendity to the Plummer density and finally calculated global velocitiy dispersions as before (see Fig. 1). As Fig. 3 (bottom pannel) shows adding DM does not lead to a relative increase more than 10% in the value of the velocity dispersin of each UCD and the ten UCDs are still inconsistent with the obervations as before. Therefore, invoking the cold DM halos does not explain the high dynamical M/L ratios (analogous with velocity dispersions in our work) of UCDs.

As upper panel of Fig. 3 shows, Plummer model is able to explain the distribution of stars and their resulting relative velosities in 66% of UCDs in our sample and that they could be thought simply as star clusters, as Plummer (1911) fit the observations of GCs, or generally simple stellar populations as by [4], [9] and [11] mentioned.

About the remaining UCDs, adding DM does not improve the situation (see Fig. 3 lower panel and Fig. 2). Reviewing the literature one could find that there is not still a fully 100% acceptable reason for ruling out the existance of DM in UCDs. "However, DM can hardly be detected directly, such that observational efforts need to be directed towards verifying/ excluding alternative scenarios, such as a variation of the IMF in UCDs" [11] implied. The authors thank A. Hasani Zonoozi for her valuable comments.

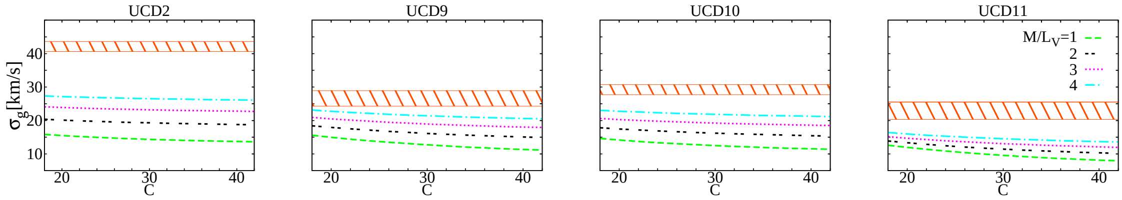

Figure 2: The global velocity dispersion versus concentration parameter,c, of NFW DM profile for a sub-sample of the modeled UCDs. As can be seen even by choosing the lower values of c, which are analogous to the higher halo masses, obtained velocities of some UCDs does not reach their observational values.

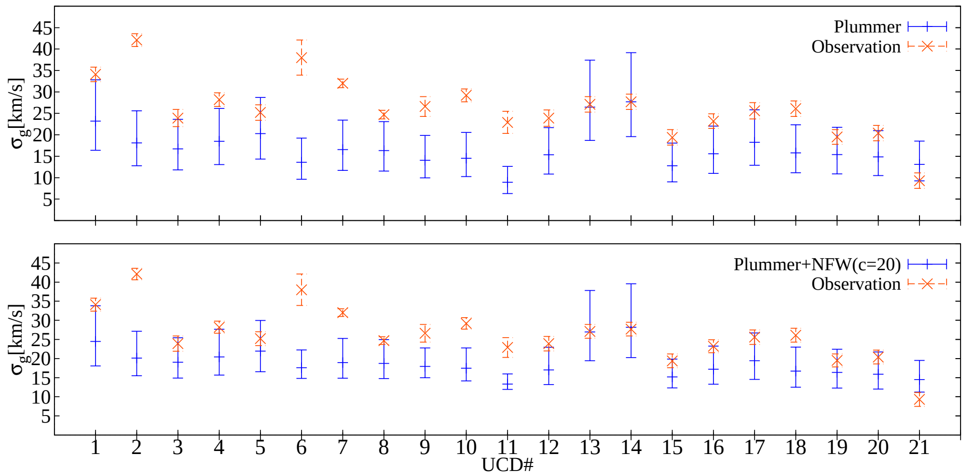

Figure 3: The LOSVDs of 21 UCDs with M_*/L_V ratios in the range of 1 to 4. Top panel shows the all modeled UCDs without DM (with Plummer model for the stellar component). Bottom panel: the velocities have increased after adding DM but it is not enough to make more UCDs to have volocities comparable with the observation.

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