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Pseudo bulges in galaxy groups: the role of environment in secular evolution

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ABSTRACT
We examine the dependence of the fraction of galaxies containing pseudo bulges on environment for a flux limited sample of ~5000 SDSS galaxies. We have separated bulges into classical and pseudo bulge categories based on their position on the Kormendy diagram. Pseudo bulges are thought to be formed by internal processes and are a result of secular evolution in galaxies. We attempt to understand the dependence of secular evolution on environment and morphology. Dividing our sample of disc+bulge galaxies based on group membership into three categories: central and satellite galaxies in groups and isolated field galaxies, we find that pseudo bulge fraction is almost equal for satellite and field galaxies. Fraction of pseudo bulge hosts in central galaxies is almost half of the fraction of pseudo bulges in satellite and field galaxies. This trend is also valid when only galaxies are considered only spirals or S0. Using the projected fifth nearest neighbour density as measure of local environment, we look for the dependence of pseudo bulge fraction on environmental density. Satellite and field galaxies show very weak or no dependence of pseudo bulge fraction on environment. However, fraction of pseudo bulges hosted by central galaxies decreases with increase in local environmental density. We do not find any dependence of pseudo bulge luminosity on environment. Our results suggest that the processes that differentiate the bulge types are a function of environment while processes responsible for the formation of pseudo bulges seem to be independent of environment.

Key words: galaxies: bulges – galaxies: evolution – galaxies: formation – galaxies:

- Цель: На примере галактик групп выяснить зависимость свойств балджей от плотности окружения.
- Материал: ~5000 галактик SDSS
- Два типа балджей (по положению на диаграмме Корменди). По индеку Серсика – ненадежно: index n and effective radius (r_e) have degenerate errors).
- Псевдобалджи: моложе звездное население, положе профиль дисперсии скоростей. Их происхождение иное. Возможны composite bulges.
- Три группы галактик: central, satellite, field.
- Массы звездного населения: модельные оценки из Kaufmann et al., 2003

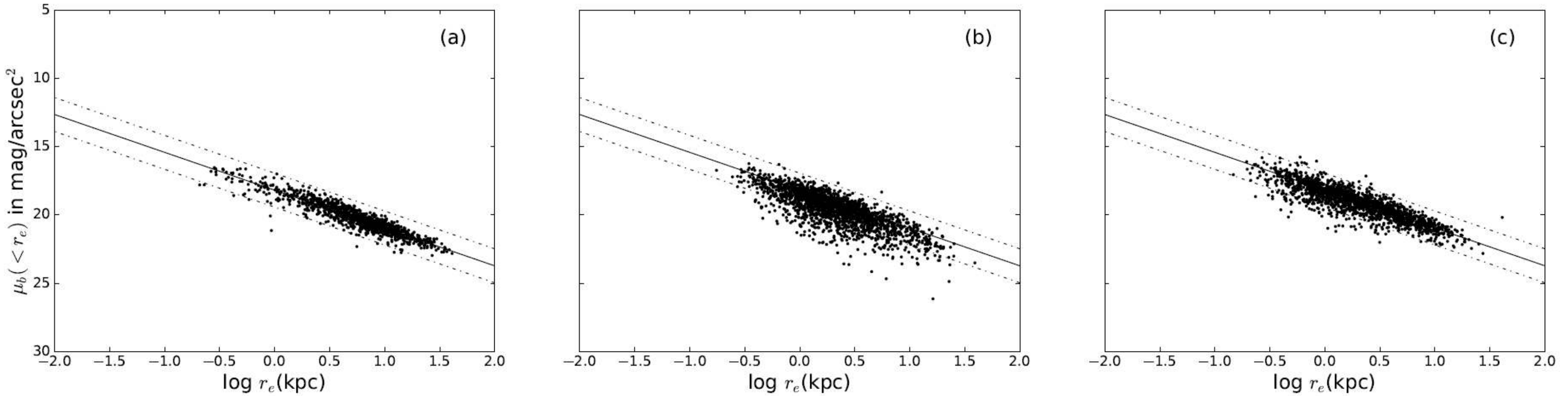


Figure 1. (a) Kormendy relation for elliptical galaxies. The solid line is best fit line to these ellipticals while the two dashed lines encl
3σ scatter from best fit; (b) bulges of spiral galaxies; (c) bulges of S0 galaxies in our sample

Any bulge that deviates more that three times the r.m.s. scatter from the best t relation for ellipticals is classied as pseudo bulge (Gadotti 2009).

Table 1. Number of classical and pseudo bulges in spiral and S0 galaxies in our sample

Bulge type	Disc galaxies	S0	Spiral
All bulges	3758	1732	2026
Classical bulge	3327	1639	1688
Pseudo bulge	431	93	338
Pseudo bulge fraction(%)	11.47	5.37	16.68

Table 3. Number of classical and pseudo bulges in all disc galaxies classified as central, satellite and field galaxies.

Bulge type	Central	Satellite	Field
All bulges	1119	752	1770
Classical bulge	1058	657	1516
Pseudo bulge	61	95	254
Pseudo bulge fraction(%)	5.45	12.63	14.35
Median galaxy stellar mass ($\log M_{\odot}$)	10.865	10.624	10.627

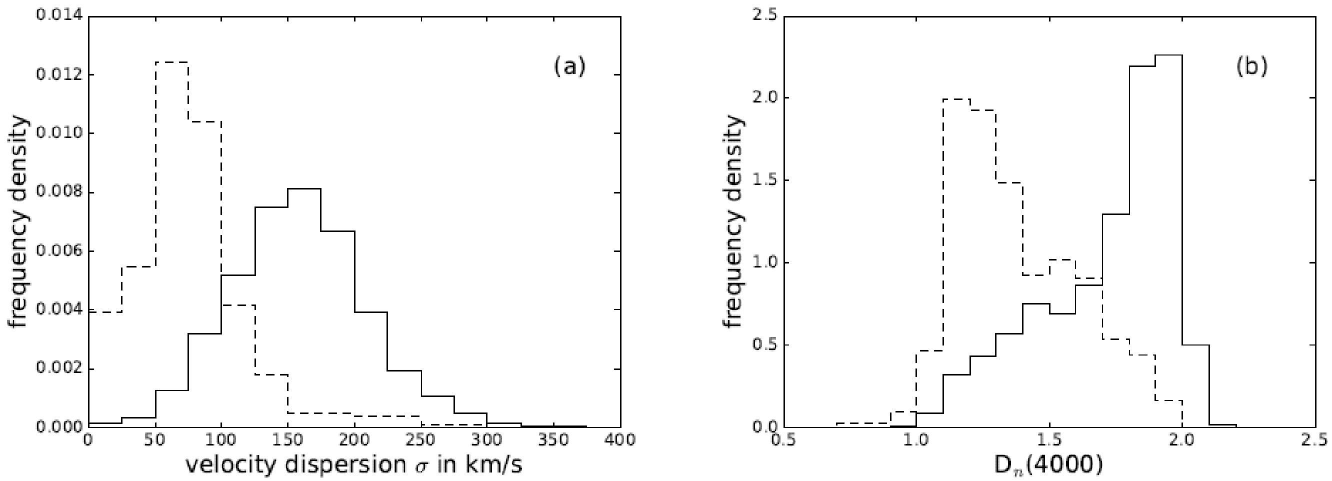


Figure 2. Distribution of (a) central velocity dispersion and (b) $D_n(4000)$ index for classical and pseudo bulges in our sample. Both distributions have been normalised by area. Solid and dashed lines denote classical and pseudo bulge host galaxies respectively.

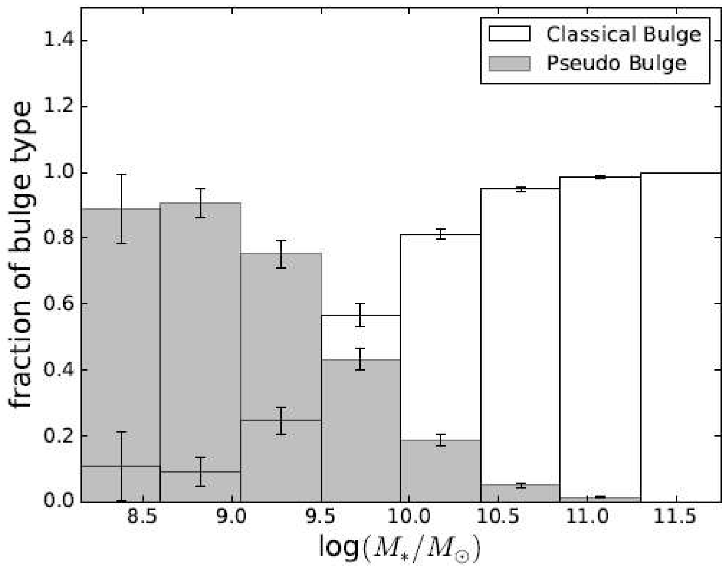
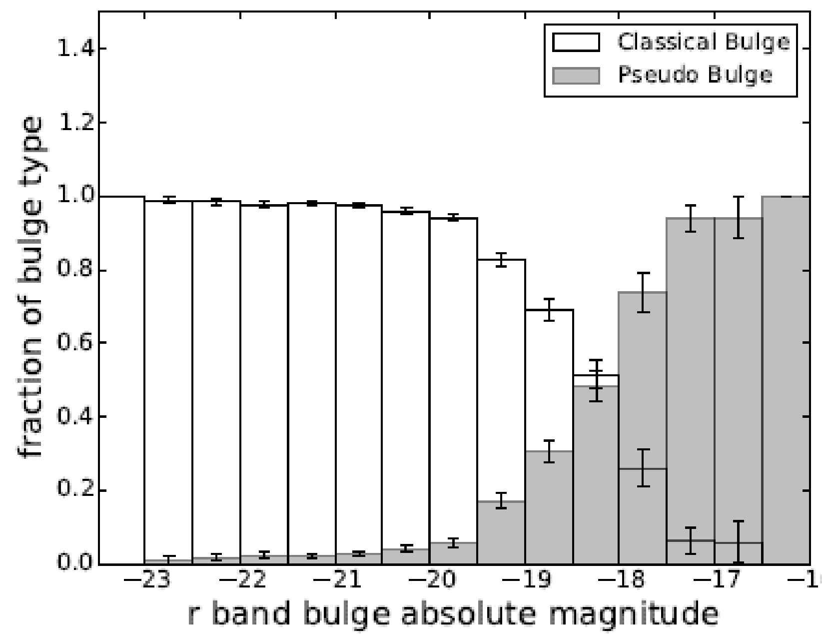


Figure 4. Dependence of classical/pseudo bulge fraction on host galaxy stellar mass. Grey shaded region denoting pseudo bulge is placed in front of the white region which denotes classical bulge. In the bins where pseudo bulge fraction dominates, classical bulge fraction is represented by the lower histogram



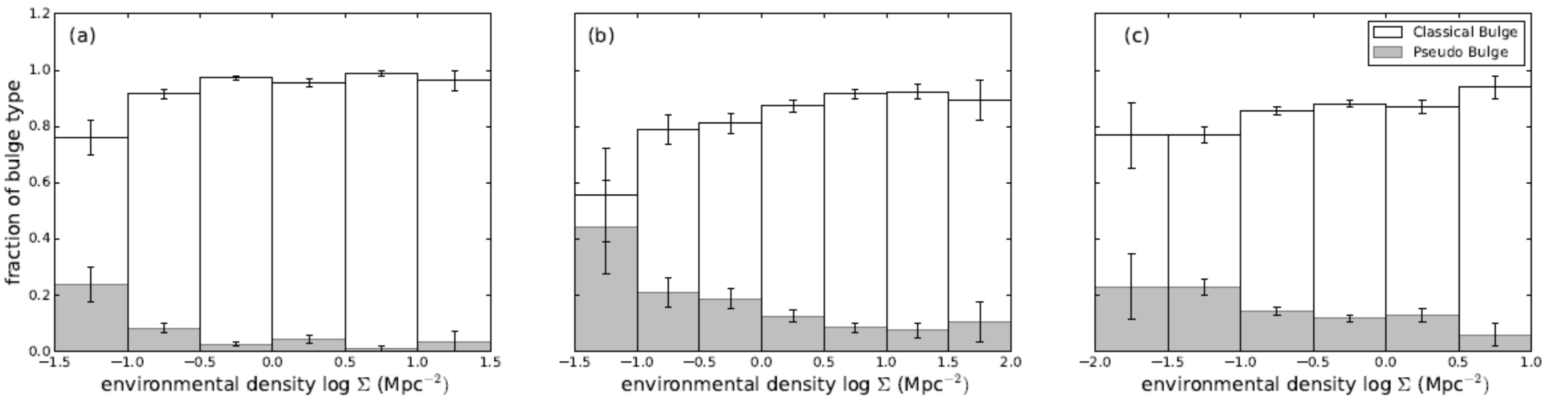


Figure 5. Dependence of fraction of bulge type as function of average environmental density for (a) central galaxies, (b) satellite galaxies and (c) field galaxies. The colour scheme is same as in Figure 4.

Основные выводы

- Pseudo bulge fraction is almost equal for satellite and field galaxies. Fraction of pseudo bulge hosts in central galaxies is almost half of the fraction of pseudo bulges in satellite and field galaxies.
- Satellite and field galaxies show very weak or no dependence of pseudo bulge fraction on environment. However, fraction of pseudo bulges hosted by central galaxies decreases with increase in local environmental density.
- Our results suggest that the processes that differentiate the bulge types are a function of environment while processes responsible for the formation of pseudo bulges seem to be independent of environment.

THE NEAREST ULTRA DIFFUSE GALAXY: UGC2162

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ABSTRACT

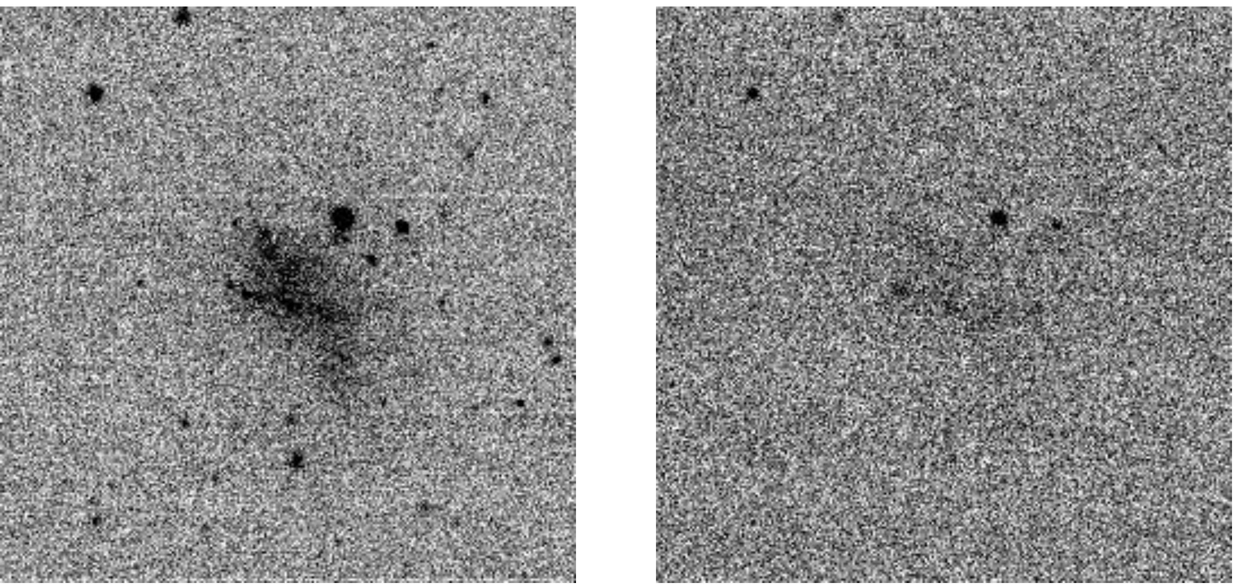
We describe the structural, stellar population and gas properties of the nearest Ultra Diffuse Galaxy (UDG) discovered so far: UGC2162 (z=0.00392; $R_{e,g}$=1.7($\pm$0.2) kpc; $\mu_g(0)$=24.4$\pm$0.1 mag/arcsec^2; g-i=0.33$\pm$0.02). This galaxy, located at a distance of 12.3($\pm$1.7) Mpc, is a member of the M77 group. UGC2162 has a stellar mass of $\sim2(^{+2}_{-1})\times10^7$ $M_\odot$ and is embedded within a cloud of HI gas $\sim$10 times more massive: $\sim1.9(\pm0.6)\times10^8$ $M_\odot$. Using the width of its HI line as a dynamical proxy, the enclosed mass within the inner R$\sim$5 kpc is $\sim4.6(\pm0.8)\times10^9$ $M_\odot$ (i.e. M/L$\sim$200). The estimated virial mass from the cumulative mass curve is $\sim8(\pm2)\times10^{10}$ $M_\odot$. Ultra deep imaging from the IAC Stripe82 Legacy Project show that the galaxy is irregular and has many star forming knots, with a gas-phase metallicity around 1/3 the solar value. Its estimated Star Formation Rate (SFR) is $\sim$0.01 $M_\odot$/yr. This SFR would double the stellar mass of the object in $\sim$2 Gyr. If the object were to stop forming stars at this moment, after a passive evolution, its surface brightness would become extremely faint: $\mu_g(0)\sim27$ mag/arcsec^2 and its size would remain large $R_{e,g}\sim$ 1.8 kpc. Such faintness would make it almost undetectable to most present-day surveys. This suggests that there could be an important population of $M_\star\sim10^7$ $M_\odot$ "dark galaxies" in rich environments (depleted of HI gas) waiting to be discovered by current and future ultra-deep surveys.

Subject headings: galaxies: dwarf — galaxies: evolution — galaxies: structure

1. INTRODUCTION

In the last few years there has been a renewed interest on the study of extended low surface brightness galaxies (Impey et al. 1988; Bothun et al. 1991; Dalcanton et al. 1997; Caldwell 2006). The discovery of dozens of these objects in the Coma Cluster (coined UDGs by van Dokkum et al. 2015) has been followed by a large number of detections in other clusters (Koda et al. 2015; Mihos et al. 2015; Muñoz et al. 2015; van der Burg et al. 2016; Román & Trujillo 2016a), groups (Román & Trujillo 2016b; Smith Castelli et al. 2016; Merritt et al. 2016) and in the field (Martínez-Delgado et al. 2016). The low stellar mass (10^7-10^8 $M_\odot$) of these objects together with their large size (R_e >1.5 kpc) have opened a number of questions about the ultimate nature of these galaxies: are

are found in groups (e.g. Román & Trujillo 2016b). Are all these UDGs connected evolutively? Recently, Román & Trujillo (2016b) have suggested a scenario where all this diversity could be understood if UDG progenitors were born in the field, processed by groups and ended their lives inhabiting clusters. To answer all the above questions and shed more light on the nature of UDGs, it would be extremely useful to have the opportunity of probing in full detail the properties of a close (D<15 Mpc) UDG. This would give us the opportunity of exploring its individual stars. In particular, it would be extremely useful to have some information about the gas content of one of these galaxies. In this work, we present the serendipitous discovery of a very nearby UDG: the galaxy UGC2162. This galaxy is located in the M77 group (at only 12.3 Mpc distance from us) and has HI g u



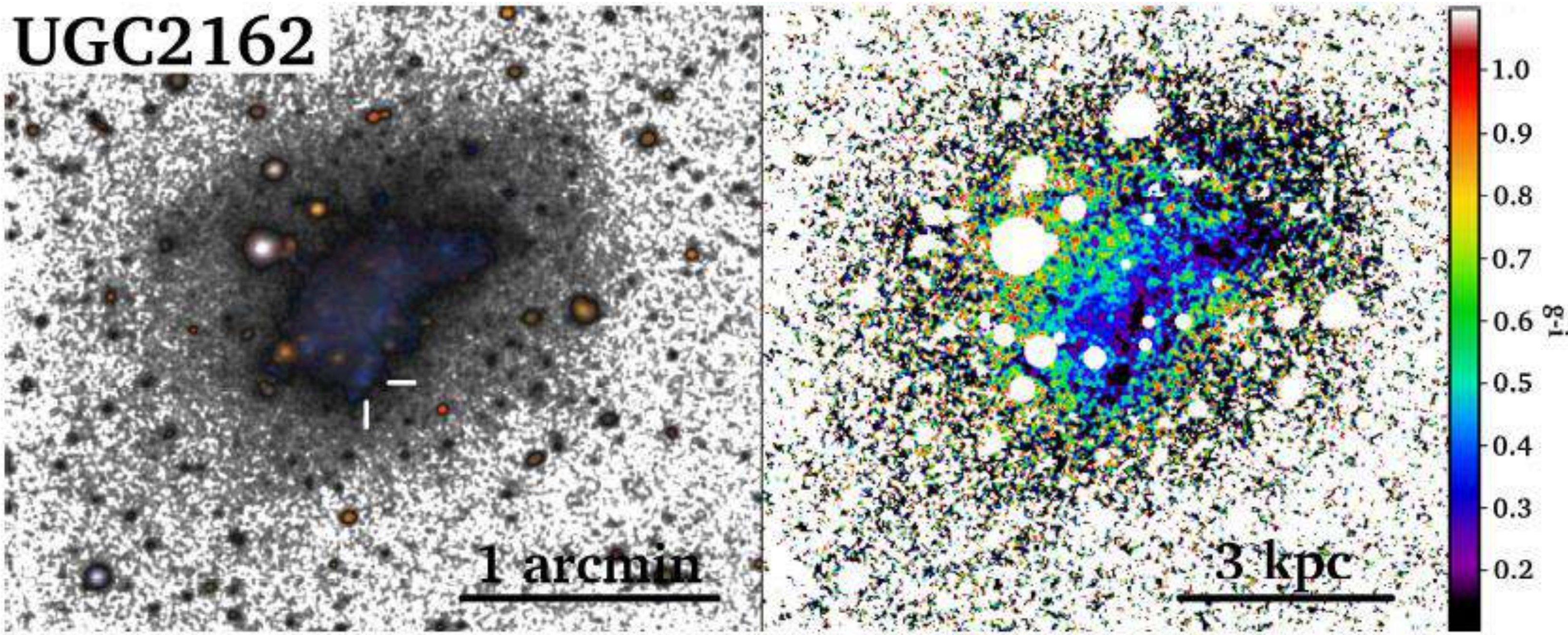


Figure 1. *Left Panel:* g,r,i *IAC Stripe82* composite image centered on UGC2162. The spatial location of the SDSS spectrum of this galaxy is indicated with white ticks. *Right Panel:* g-i color map of UGC2162. The central irregular region is located on top of a more rounded extended disk-like structure. The white circles are the masked regions used in this work.

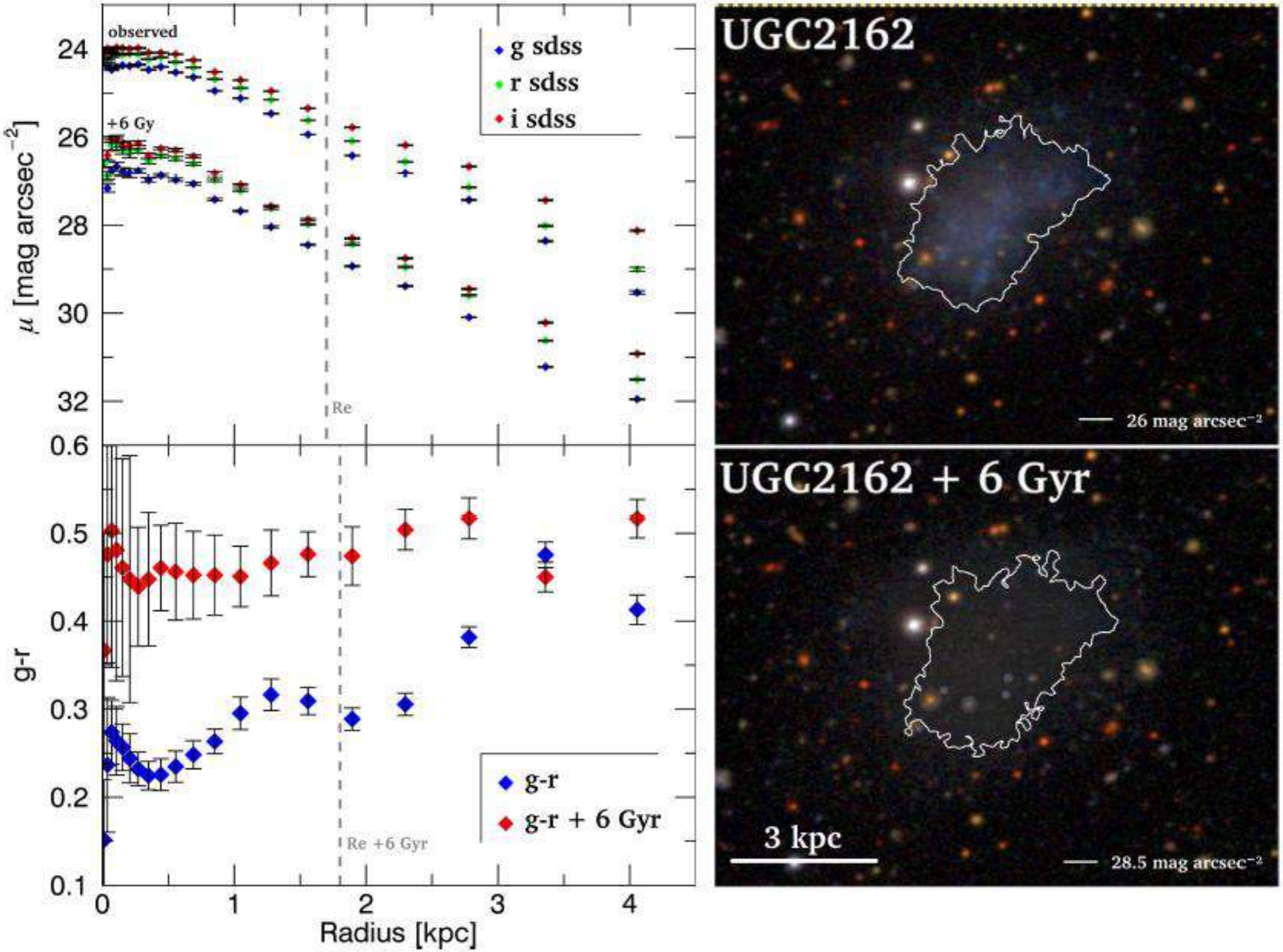


Figure 3. *Left column:* The g, r and i present-day surface brightness profiles of UGC2162 and their passive evolution after 6 Gyr. lower panel displays the g-r color radial profiles. After 6 Gyr of passive evolution the galaxy would get significantly dimmer, redder with a similar size. The vertical dashed lines show the position of the effective radius for the present-day UGC2162 and its potential fu evolution. *Right column:* A color composite of how UGC2162 looks today and how the galaxy would look like eventually in the fu (after 6 Gyr of passive evolution). The contours indicate the position of the (g band) 26 mag/arcsec^2 (upper panel) and 28.5 mag/arc

GALACTIC DARK MATTER HALOS AND GLOBULAR CLUSTER POPULATIONS. III: EXTENSION TO EXTREME ENVIRONMENTS

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ABSTRACT

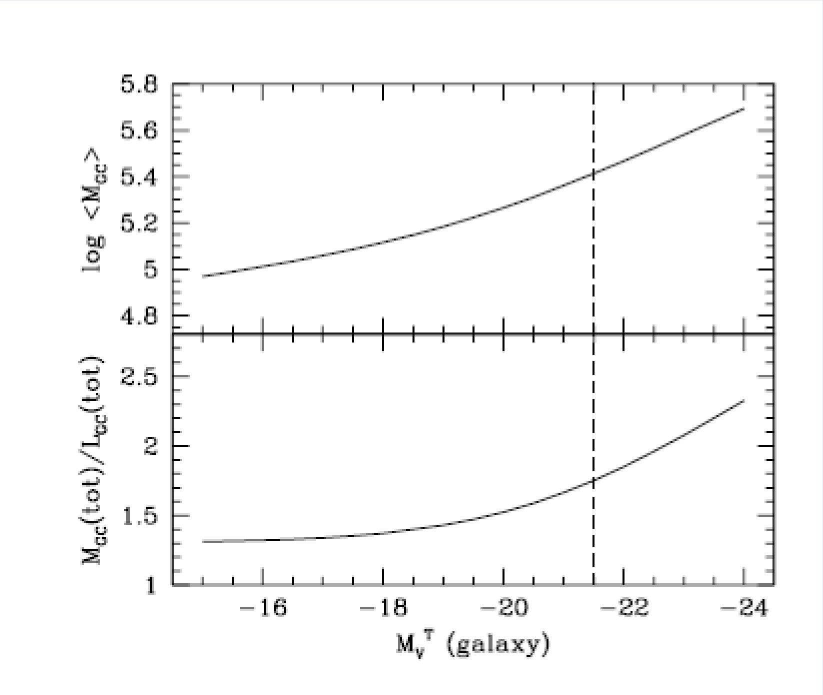
The total mass $M_{\rm GCS}$ in the globular cluster (GC) system of a galaxy is empirically a near-constant fraction of the total mass $M_h \equiv M_{bary} + M_{dark}$ of the galaxy, across a range of 10^5 in galaxy mass. This trend is radically unlike the strongly nonlinear behavior of total stellar mass $M_\star$ versus M_h. We discuss extensions of this trend to two more extreme situations: (a) entire clusters of galaxies, and (b) the Ultra-Diffuse Galaxies (UDGs) recently discovered in Coma and elsewhere. Our calibration of the ratio $\eta_M = M_{\rm GCS}/M_h$ from normal galaxies, accounting for new revisions in the adopted mass-to-light ratio for GCs, now gives $\eta_M = 2.9 \times 10^{-5}$ as the mean absolute mass fraction. We find that the same ratio appears valid for galaxy clusters and UDGs. Estimates of η_M in the four clusters we examine tend to be slightly higher than for individual galaxies, but more data and better constraints on the mean GC mass in such systems are needed to determine if this difference is significant. We use the constancy of η_M to estimate total masses for several individual cases; for example, the total mass of the Milky Way is calculated to be $M_h = 1.1 \times 10^{12} M_\odot$. Physical explanations for the uniformity of η_M are still descriptive, but point to a picture in which massive, dense star clusters in their formation stages were relatively immune to the feedback that more strongly influenced lower-density regions where most stars form.

Subject headings: galaxies: formation — galaxies: star clusters — globular clusters: general

- Массу гало обычно связывают с массой звездного населения.
- Georgiev et al 2010: $\eta_M = M_{GCS}/M_h$ для индивидуальных галактик – величина постоянная.

$$M_{GCS} = \int \left(\frac{M}{L}\right) L\, n(L)\, dL$$

Идея:
Проверить соотношение $\eta_M = M_{GCS} / M_h$ для двух крайних случаев:
для богатых скоплений с известным числом GCs в межгалактическом пространстве,
и для UDGs.



- В работе считается, что средняя масса GCs меняется со светимостью галактики из-за роста индивидуальных M/L шаровых скоплений в галактиках с большим числом скоплений,

following empirical evidence from recent literature (e.g. Rejkuba et al. 2007; Kruijssen 2008; Kruijssen & Mieske 2009; Strader et al. 2011).

{Масса гало – через $M_h – L_K$.}

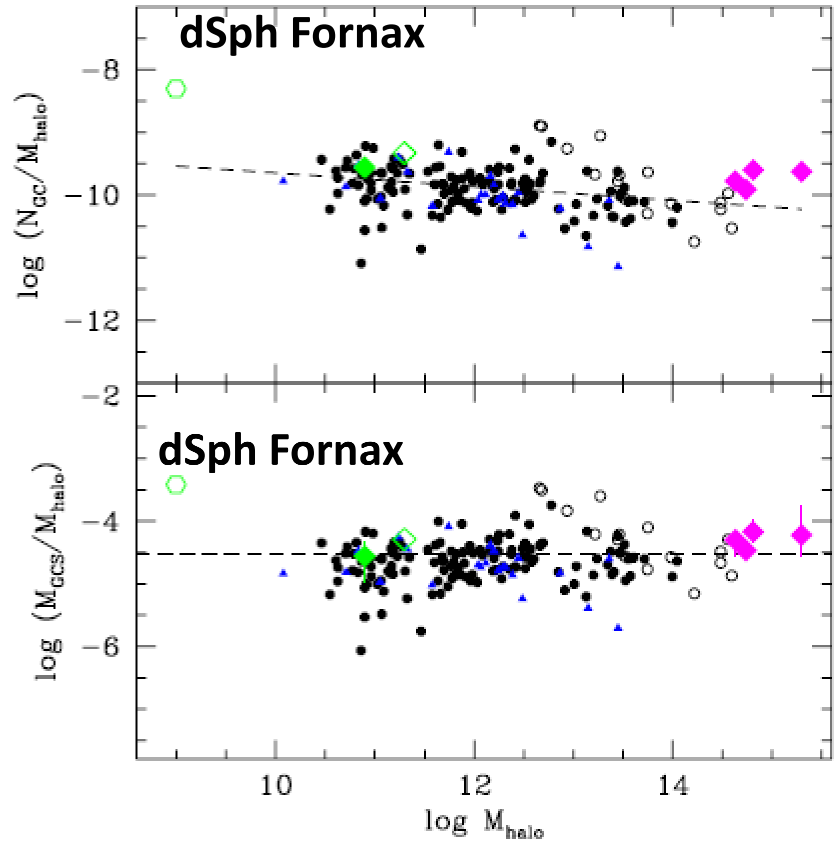


Figure 2. *Upper panel:* Log of the ratio $\eta_N = N_{GC}/M_h$, plotted versus total galaxy mass M_h. *Solid dots:* E/S0 galaxies. *Open circles:* BCGs. *Blue triangles:* S/Irr galaxies. *Magenta diamonds:* The four clusters of galaxies discussed in the text. *Green diamonds:* The ultra-diffuse galaxies. The open diamond for Dragonfly 44 in the Coma cluster is very uncertain (see text). *Green hexagon:* the Fornax dSph satellite of the Milky Way. The dashed line is the least-squares fit defined in the text. *Lower panel:* Log of the mass ratio $\eta_M = M_{GCS}/M_h$ versus M_h; symbols are the same as in the upper panel. The dashed line is the mean value $\langle \log \eta_M \rangle = -4.54$.

Основной вывод

- Учет систематического изменения M/L шаровых скоплений с ростом массы скоплений приводит к постоянству отношения массы скоплений к полной массе системы (~$3 \cdot 10^{-5}$) – от UDG- галактик до скоплений в целом.