Elliptical Galaxies in Cosmological Context

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We present preliminary results from a project aimed at exploring elliptical galaxies in cosmological numerical simulations. Integrated properties of such systems were studied at redshift z=0 in order to establish the main astrophysical processes that determine their evolution. The ability of models to reproduce observational results will be also tested.

INTRODUCTION

Elliptical galaxies constitute the most numerous astrophysical systems in clusters and groups found in the local Universe. At present, there is not a unique scenario that explains, globally and in a consistent way, all the properties of these systems within the galaxy formation scenarios (e.g., Roediger et al. 2011, Sil'chenko et al, 2012, Janz et al. 2017).

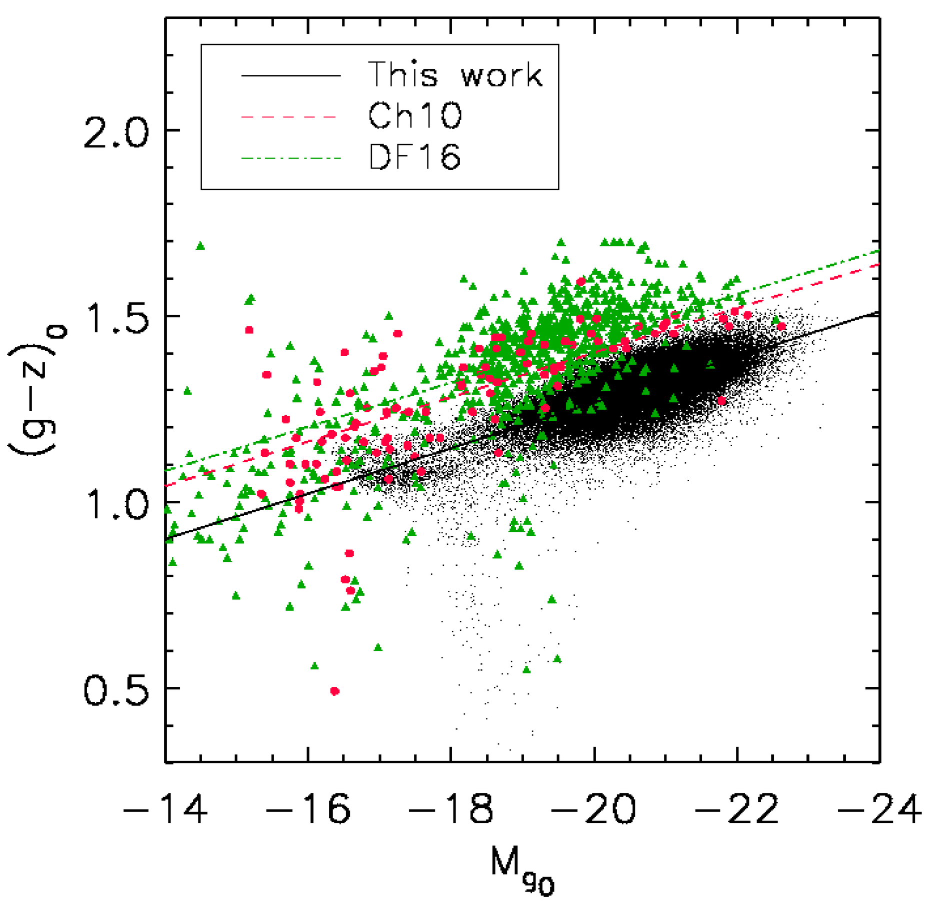
A current subject of study is the existence of dichotomies in the family of elliptical galaxies, such as fast and slow rotators, normal and dwarf elliptical galaxies, among others features (Kormendy et al. 2009, Cappellari 2016, Schombert 2016).

Here, we show preliminary results regarding a study of elliptical galaxies in cosmological context. Our work is mainly focused on the determination of **scaling relations for simulated elliptical galaxies** as function of their mass at redshift z=0. Also, some **comparisons between simulation and observations** are shown.

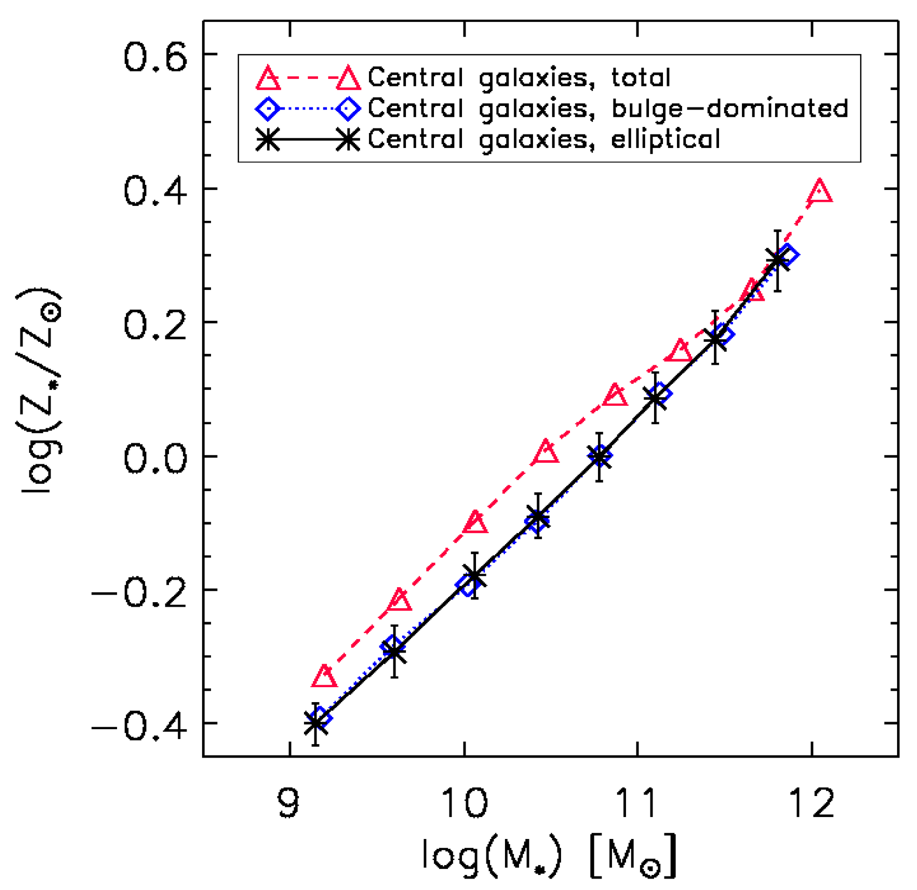
SIMULATED GALAXIES

Samples of simulated elliptical galaxies were extracted from catalogues generated by the application of a semi-analytical model over the **Millennium simulation** (Springel et al. 2015). We focused on the catalogues corresponding to the **semi-analytical model** of Henriques et al. (2015), which includes astrophysical prescriptions over a number of processes, such as gas cooling, star formation, supernovae and active galactic nuclei feedback, and interactions and fusions between galactic systems. The Millennium simulation used here was updated to the first data of PLANCK Collaboration (2014): **Ω_Λ=0.685, Ω_m=0.315, Ω_b=0.049 and h=0.673.** The **simulated volume** is a cubic box of side 714 Mpc, and the **mass resolution** is around **9×10^9 $M_\odot$**.

This work is focused on the study of **central galaxies** of dark matter haloes with more than **90% of their stellar mass in the bulge**. In order to obtain a simulated sample consistent with observations, we selected galaxies with a **cold-gas mass fraction** (with respect to stellar mass plus cold gas mass) **lower than 0.1**, and with star formation rate (**SFR**) lower than **1 $M_\odot$/yr**. Galaxies with these criteria are defined here as simulated elliptical galaxies.

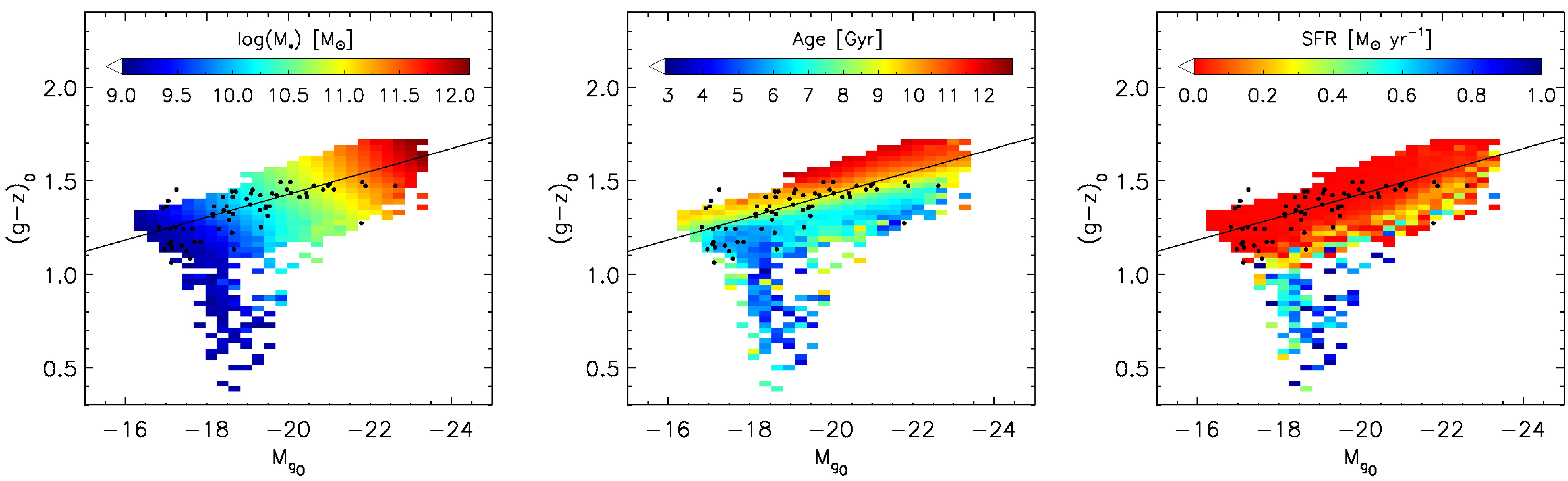


Color-magnitude diagram for our sample of simulated elliptical galaxies (black dots), and observations from Chen et al. (2010; red circles) and Dabringhausen & Fellhauer (2015; green triangles). Linear regressions were applied to the color-magnitude relations for simulated and observed samples by using the least squares fitting technique. The three samples show similar slopes, but with an offset in color between simulations and observations, being the simulated relation bluer than observations. This offset could be due to different definitions in the zero points of the magnitudes associated to each sample. It could be also driven by some model prescriptions, as we will analyse in a future work.



Simulated stellar mass-stellar metallicity relation. The relation for elliptical galaxies follows a similar trend to that predicted for bulge-dominated galaxies, which suggests that cold gas fraction and star formation rate don't affect this relation. For low-mass galaxies, stellar metallicity increases with stellar mass, which is consistent with observational and theoretical works (e.g., Estrada-Carpenter et al. 2017; De Rossi et al. 2017). However, the simulated relation does not flatten at high masses, in disagreement with observations (e.g. Gallazzi et al. 2005).

SIMULATED COLOR-MAGNITUD DIAGRAM AS FUNCTION OF STELLAR PROPERTIES



Color-magnitude diagrams for simulated elliptical galaxies and their dependence on stellar mass (left), stellar age (center) and star formation rate (right). The simulated diagrams were shifted towards redder colors in order to obtain the best fitting with observations of Chen et al. (2010). These observations are shown with black circles, and the black solid line depicts the results from a linear regression to the data. Elliptical galaxies become brighter and redder as stellar mass increases; galaxies at the low-mass end are the bluest. Due to the stellar mass-stellar metallicity relation, a similar trend is found in the diagram when studying the dependence on stellar metallicity. With respect to stellar age, the oldest simulated elliptical galaxies are the reddest, and the simulated color-magnitude relation is traced and delimited by the oldest systems. Also, the simulated color-magnitude relation seems to be defined by elliptical galaxies with negligible star formation, and elliptical galaxies that exhibit star formation are the bluest.

Summary and future work

- A sample of simulated elliptical galaxies was selected using observed properties (cold gas fraction and star formation rate). Those galaxies follow scaling relations that agree with observed trends.
- Simulated and observed color-magnitude relations show similar trends, but with differences in the zero points of colors. When correcting those offsets, simulations reproduce reasonably the observations.
- The simulated color-magnitude relation is traced and delimited mainly by elliptical galaxies with negligible star formation, which are the oldest galaxies at given stellar mass.
- In a future work, star formation histories of simulated elliptical galaxies and evolution of scaling relations with the redshift will be studied. Also, an exhaustive comparison with observed samples of elliptical galaxies will be carried out.

For more details about this work, see also Zenocratti et al. (2018)

REFERENCES

- *Chen C.-W., Côté P., West A. A., Peng E. W., Ferrarese L., 2010, ApJS, 191, 1*
- *Dabringhausen J., Fellhauer M., 2016, MNRAS, 460, 4492*
- *Cappellari M., 2016, ARA&A, 54, 597*
- *De Rossi M. E., Bower R. G., Font A. S., Schaye J., Theuns T., 2017, MNRAS, 472, 3354*
- *Estrada-Carpenter V., et al., 2017, in American Astronomical Society Meeting Abstracts #229*
- *Gallazzi A., Charlot S., Brinchmann J., White S. D. M., Tremonti C. A., 2005, MNRAS, 362, 41*
- *Henriques B. M. B., White S. D. M., Thomas P. A., Angulo R., Guo Q., Lemson G., Springel V., Overzier R., 2015, MNRAS, 451, 2663*
- *Janz, J., Penny S. J., Graham A. W., Forbes D. A., Davies, R. L., 2017, MNRAS, 468, 2850*
- *Kormendy J., Fisher D. B., Cornell M. E., Bender R., 2009, ApJS, 182, 216*
- *Roediger J. C., Courteau S., MacArthur L. A., McDonald M., 2011, MNRAS, 416, 1996*
- *Sil'chenko O. K., Proshina I. S., Shulga A. P., Koposov S. E., 2012, MNRAS, 427, 790*
- *Schombert J. M., 2016, AJ, 152, 214*
- *Springel V., et al., 2005, Nature, 435, 629*
- *Zahid H. J., Dima G. I., Kudritzki R. P., Kewley L. J., Geller M. J., Hwang H. S., Silverman J. D., Kashino D., 2014, ApJ, 791, 130*
- *Zenocratti L. J., De Rossi M. E., Smith Castelli A. V., Faifer F. R., 2018, BAAA, 60, in press*

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