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CONSTRAINING GALAXY EVOLUTION WITH SCALING RELATIONS

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An ongoing study is presented in which a photometric non-linear Scaling Relation of Early-Type Galaxies (ETGs) is proposed to carry out a consistency test on cosmic and galaxy evolution.

The non-linear Scaling Relation (S-R) involving Surface Brightness (SB) and magnitude of ETGs shows a prominent turnover at $M_B \approx$ - 20.5. There is an open debate over the interpretation of the curved S-R (e.g. Graham 2013), although recent works (e.g. Trevisan et al. 2012) reinforce the idea of a dichotomy between the ellipticals at both sides of the S-R turnover. Independently of its interpretation, the present study proposes the use of the turnover as a *standard candle*.

The idea is to compare the same curved S-R for both a local and a moderate-redshift cluster. Once the position of their turnover points have been found two x-y offsets can be determined. After K-corrected, the magnitude-x-offset gives the distance modulus (DM), which allows to test the cosmological model in a DM vs. redshift diagram. On the y-axis, the SB-offset combines both the *Surface Brightness cosmological dimming* (Tolman Test) and the passive evolution of the galaxies. This is an observationally difficult test, but clean and free from assumptions, from a cosmological point of view. Despite the intrinsic interest of the cosmological tests, we can alternatively fix the cosmology model and focus our study on the systematic deviations introduced by the photometric evolution of the galaxies or the evolution of the Scaling Relation.

The original idea was proposed by Sandage & Perelmuter (1990), but only modern data make the test feasible. Our data source is the CLASH survey (Postman et al. 2012), which includes 25 clusters of galaxies, at $0.19 < z < 0.9$, observed with the Hubble Space Telescope (HST) in 16 bands from NUV to NIR. As a viability test, we have selected cluster MACSJ1149+22 at a redshift z=0.544 in the F775W band. Photometric redshifts are calculated for all the objects in the field and, through a sigma clipping cut, the probable cluster members are selected. A two-dimensional PSF-convolved photometric model fitting is applied to all the cluster members. Finally, both the observed and the residual images (observed - fitted model) are visually inspected to select only the ETGs.

Our local sample includes 10,000 galaxies, queried from the Sloan Digital Sky Survey (DR10) (Ahn et al. 2014), in the i-band, with the only condition of a Concentration Index > 2.6, to select ETGs. The turnover position (M_{abs} = -20.77 and $< \mu >_{eff}$ = 19.48 mag arcsec^{-2}) was measured in the curve joining the median values of 0.5 mag binning intervals. For the MACSJ1149+22 cluster, 180 objects were found, covering a six magnitude interval. A similar binning approach, albeit with a larger one-magnitude binning size, is followed to find the turnover position at m = 21.65 and $< \mu >_{eff}$ = 21.33 mag arcsec^{-2}.

Both the magnitude and the SB offsets match the expectations of the standard LCDM cosmology. On one side, the distance modulus, DM = 42.42, agrees with the predictions of the recent Planck-LCDM cosmology (Planck Collaboration. 2013). On the other side, the Surface Brightness offset, $\Delta < \mu >_{eff}$ = 1.85, matches the cosmological dimming predictions of an expanding universe $(1+z)^4$, instead of that of a non-expanding one (1+z). Although this test has confirmed the feasibility of the proposed approach, its results, based on a single measurement, are rather limited by the lack of a proper error determination. We are improving the study by extending our calculations to different photometric bands of the same cluster and to other clusters of the CLASH sample.

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