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The (Anti-)Hierarchical Evolution of Disk Galaxies

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Abstract. Utilizing spatially resolved VLT/FORS spectroscopy and HST/-ACS imaging, we constructed a sample of over 200 field spiral galaxies at redshifts $0.1 < z < 1.0$. We find that the ratio between stellar and total mass remains roughly constant over the observed epochs, in compliance with the framework of hierarchical structure growth. However, the stellar mass–to–light ratios evolve more strongly in low–mass spirals than in high–mass spirals, indicating an anti-hierarchical evolution of their stellar populations (aka "down-sizing").

1. Introduction

Observations of the properties of distant galaxies at various cosmic epochs are a powerful tool to test the predictions of cosmological simulations in the framework of the hierarchical Cold Dark Matter paradigm. Combining high-resolution HST/ACS imaging and deep VLT/FORS spectroscopy and imaging, we have observed a sample of 202 disk galaxies at redshifts $0.1 < z < 1.0$ that represent a mean look-back time of ~ 5 Gyr. Such a data set allows - via a comparison to local reference samples - to study the evolution of fundamental parameters of galaxies, like luminosity, size, mass, M/L ratio etc., as a function of cosmic time. By applying models that fully account for observational effects like seeing and the influence of the slit width, we were able to extract spatially resolved rotation curves from the spectra and derive the galaxies' maximum rotation velocities as well as the total masses for 124 galaxies in our data set.

2. Main Results

In Böhm et al. (2004), we reported on an earlier stage of our survey and presented evidence for a slope change of the Tully–Fisher Relation (TFR) between $z \approx 0.5$ and the local universe, i.e. a mass-dependent luminosity evolution. Using the new, full sample of 124 galaxies, we found that this differential evolution could be attributed to the magnitude limit in our target selection, but *only* if the scatter of the TFR at $z \approx 0.5$ is more than a factor of three larger than in the local universe. Details on the analysis of the rotation curves and the Tully-Fisher Relation are presented in Böhm & Ziegler (2007).

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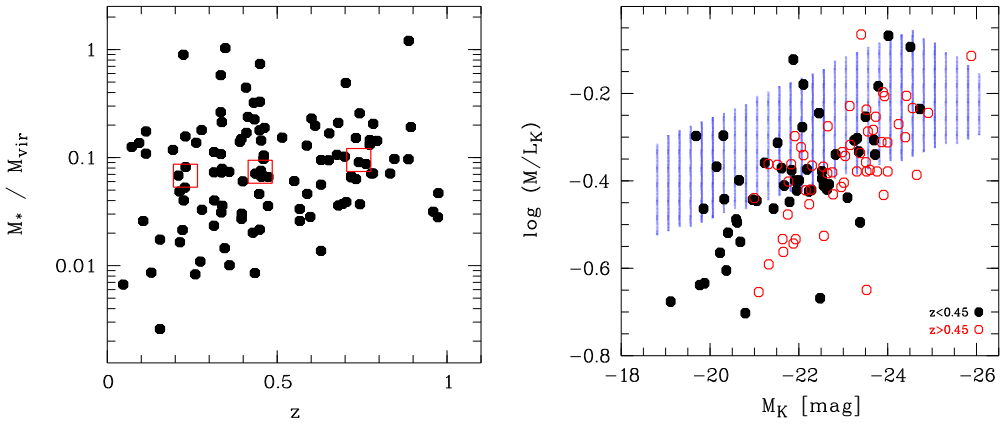

Figure 1. *left:* The observed stellar mass fraction is roughly constant at redshifts $0 < z < 1$ (squares give median values in three z-bins). *right:* Stellar mass-to-light ratios of our sample at $0.1 < z < 0.45$ (filled circles) and $0.45 < z < 1.0$ (open circles), compared to the parameter range covered by present-day spirals (shaded area) from Bell & de Jong (2001). The data indicate a stronger evolution in stellar M/L for low-luminosity disk galaxies.

The ratio between the stellar and total mass remains roughly constant between redshifts $z \approx 1$ and $z \approx 0$ (see left plot of Fig. 1), which could be understood in terms of smooth accretion of dark and baryonic matter over this epoch. If spiral galaxies already contained all their dark and baryonic matter at $z \approx 1$, the conversion of gas into stars via continuous star formation would lead to an increase of the stellar mass fraction $M_*/M_{\rm vir}$ towards lower redshifts, which is not observed. A similar result has been found by Conselice et al. (2005).

The stellar mass-to-light ratios evolve more strongly for low-luminosity spirals than for high-luminosity spirals (Fig. 1 right), yielding evidence for an anti-hierarchical evolution of the stellar populations (the "down-sizing" scenario). This interpretation gains further support from fits of single-zone models to the optical and NIR colors that indicate younger mean stellar ages in the distant low-mass spirals than in the high-mass spirals, see Ferreras et al. (2004). If the TFR slope remains constant between $z \approx 1$ and $z \approx 0$ then the down-sizing trend in stellar M/L would have to be counter-balanced by the evolution of other galaxy parameters like, e.g., gas mass fraction or disk size.

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