The Evolution of Disk Galaxies Since z=1

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\textbf{Abstract.} Based on VLT/FORS spectroscopy and HST/ACS imaging, we have constructed a sample of $\sim 200$ field spiral galaxies that cover redshifts up to $z \approx 1$. Such a large data set allows to study the evolution of fundamental galaxy parameters like luminosity, size, mass, mass-to-light ratio etc. as a function of cosmic time and in various mass regimes. Several of our findings — like the time-independent fraction of stellar-to-total mass — are in compliance with a hierarchical structure growth. However, the stellar population properties of intermediate-redshift disks favour a down-sizing scenario in the sense that the average stellar ages in high-mass spirals are older than in low-mass spirals.

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 $\sim 5$ 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 \textit{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 3 larger than in the local universe (for details, please see Böhm & Ziegler 2006).

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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), implying the accretion of dark (and probably baryonic) matter. *right:* Stellar mass-to-light ratios of our distant 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 $M/L$ for low-luminosity galaxies.

The fraction 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 $M_\ast/M_{\text{vir}}$ 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: we find that the mean model stellar ages of the distant low-mass spirals are younger than those of the distant high-mass spirals, see [Ferreras et al. (2004)]. This mass-dependency of the stellar ages has to be counter-balanced by the evolution of other galaxy parameters to explain the little evolution observed in the de-biased TFR slope.

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