RevMexAA (Serie de Conferencias), **40**, 84–85 (2011)

SEEDING THE LOCAL DISK GALAXY POPULATION

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RESUMEN

Mediante la técnica del empate de abundancias inferimos las relaciones locales masa estelar y bariónica-masa de halo ($M_{\rm s}$ & $M_{\rm b} - M_{\rm h}$) para galaxias centrales azules y rojas. La relación $M_{\rm b} - M_{\rm h}$ azul es sondeada a la luz de relaciones de escala observadas usando para esto modelos de galaxias de disco cargadas dentro de halos ΛCDM.

ABSTRACT

By means of the abundance matching technique we have inferred the local stellar & baryonic-halo mass ($M_{\rm s}$ & $M_{\rm b} - M$h) relations for central blue and red galaxies. Models of disk galaxies loaded inside Λ Cold Dark Matter (ΛCDM) halos are used to probe the obtained blue $M_{\rm b} - M_{\rm h}$ relation in the light of observed scaling relations.

Key Words: dark matter — galaxies: luminosity function, mass function — galaxies: spiral

1. INTRODUCTION

The connection between galaxy stellar ($M_{\rm s}$), baryonic ($M_{\rm b}$) and halo ($M_{\rm h}$) masses resumes key aspects of disk galaxy formation and evolution. The $M_{\rm s} - M_{\rm h}$ relation has been inferred recently for *all* galaxies by using direct and indirect methods (see e.g., More et al. 2011; Behroozi et al. 2010, and the references therein). One of them is the abundance matching formalism, based on the one-to-one monotonic relationship between the measured cumulative galaxy $M_{\rm s}$ function (GSMF) and the theoretical cumulative halo $M_{\rm h}$ function (HMF). We extend this formalism for estimating the $M_{\rm s} - M_{\rm h}$ (as well as the $M_{\rm b} - M_{\rm h}$) relations for blue (late-type) and red (early-type) *central* galaxies by separate (Rodríguez-Puebla et al. 2011). Then, models of disk galaxies loaded inside ΛCDM halos will be used to probe the obtained blue $M_{\rm b} - M_{\rm h}$ relation in the light of local observed scaling and dynamical relations.

2. THE HALOS AND THEIR GALAXIES

We use the blue and red GSMFs of central SDSS galaxies determined by Yang et al. (2009). The corresponding HMF to be matched with the blue GSMFs was obtained from the total ΛCDM (distinct) HMF but (i) by excluding those halos that suffered major mergers after $z = 0.8$ (theirs disks likely will be destroyed and not regenerated by $z \sim 0$), and (ii) by substracting the observed HMF of bounded groups with 3 or more members (late-type galaxies are rare as central objects in groups/clusters). For red galaxies, we take the complement of the obtained “blue” HMF to the total one.

The obtained $M_{\rm s} - M_{\rm h}$ relations and their 1σ uncertainty for central blue and red galaxies are plotted in Figure 1. We have found that these relations do not differ significantly from the one for “all” central galaxies. For $M_{\rm h} \gtrsim 10^{11.3}$, blue galaxies have slightly smaller stellar masses for a given $M_{\rm h}$ than red ones, the maximum difference in the means being a factor of 1.7. Previous inferences by using direct techniques (based on stacked weak-lensing and satellite-kinematics analysis) are also plotted in Figure 1; these techniques are yet very uncertain for low-mass galaxies. The dashed curves in Figure 1 are the averages of our inferred blue and red $M_{\rm b} - M_{\rm h}$ relations, where observational inferences of the gas content in blue and red galaxies were used in order to estimate the baryon mass functions from the corresponding GSMFs. The differences in $M_{\rm b} - M_{\rm h}$ between blue and red galaxies are now even less than in the stellar case. If galaxies would have a constant baryon fraction (e.g., equal to the universal one, f_U), then they would lie along the black dot-dashed lines in Figure 1. Astrophysical processes strongly bend the galaxy baryon fraction, $f_{\rm b} = M_{\rm b}/M_{\rm h}$, towards low and high masses, the peak of this fraction for blue and red galaxies being $f_{\rm b} = 0.028^{+0.018}_{-0.011}$ and $f_{\rm b} = 0.034^{+0.025}_{-0.014}$.

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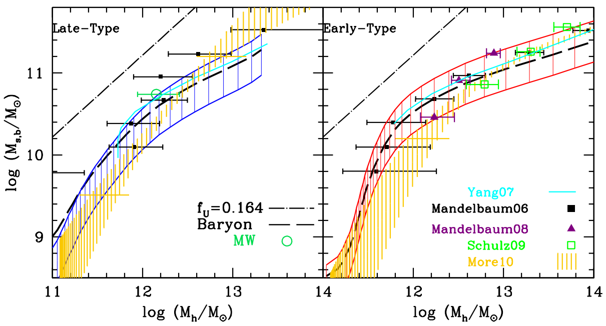

Fig. 1. The $\pm 1\sigma$ interval of the determined $M_{\rm s} - M_{\rm h}$ relations for blue (left panel, blue curves connected by vertical) and red (right panel, red curves connected by vertical lines) galaxies. Thick dashed lines are the means of the corresponding blue and red $M_{\rm b} - M_{\rm h}$ relations. Symbols with error bars correspond to weak lensing inferences, while the orange dashed regions are from satellite kinematics inferences.

3. THE SCALING LAWS OF DISK GALAXIES

According to our semi-empirical determination, blue galaxies have very low ($\ll f_U$) and strongly dependent on mass (bell-shaped function) baryon fractions. *Are consistent these fractions (given by the blue $f_{\rm b} - M_{\rm h}$ relation) with the structural and dynamical scaling laws of disk galaxies?* Following Mo et al. (1998) and Dutton et al. (2007), we implemented a model in which an exponential baryonic disk of mass $M_{\rm b} = f_{\rm b} M_{\rm h}$ is self-consistently loaded (gravitational drag is taken into account) in a dark matter halo with a NFW mass density profile characterized by the concentration parameter c and the spin parameter λ_h. A simple disk instability criterion is applied to estimate $M_{\rm s}$. The distributions of c and λ_h as a function of $M_{\rm h}$ are taken from results of cosmological simulations. For $f_{\rm b}(M_{\rm h})$ and its scatter, we use our semi-empirical inference.

The population of $z = 0$ disk galaxies generated with our model is in excellent agreement with the slope, zero-point, and intrinsic scatter of the observed stellar Tully-Fisher relation (upper panel of Figure 2). This relation is indeed very robust to changes in $f_{\rm b}$ (and λ_h, Firmani & Avila-Reese 2000; Dutton et al. 2007); our bell-shaped $f_{\rm b}(M_{\rm h})$ function just produces a slight bend at the faint end. Instead, the radius-$M_{\rm s}$ relation is much more sensitive to $f_{\rm b}(M_{\rm h})$: our peculiar $f_{\rm b}(M_{\rm h})$ produces a strong bend of this relation at low and high masses (Figure2, middle panel). The results plotted here are in fact by using a disk spin parameter $\lambda_d < \lambda_h$ and decreasing with $M_{\rm h}$ according to a law given by semi-empirical determinations (Berta et al. 2008);

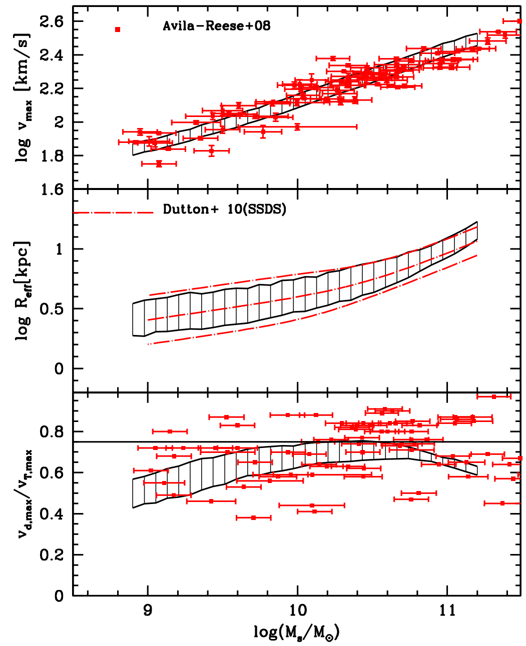

Fig. 2. Predicted dependences of $V_{\rm max}$, $R_{\rm eff}$, and the $V_{\rm d}$-to-$V_{\rm tot}$ ratio at 2.2 $R_{\rm d}$ on $M_{\rm s}$ by using the $f_{\rm b}(M_{\rm h})$ function inferred here for blue galaxies (the 1σ of the population distributions is plotted, vertical lines regions). The observational data are from Avila-Reese et al. (2008) and Dutton et al. (2011).

otherwise the radii are on average larger than observations, specially at high masses. The low values and peculiar dependence of $f_{\rm b}$ on $M_{\rm h}$ produce in average (sub-maximum) low disk-to-total circular velocity ratios at 2.2 $R_{\rm d}$, that even decreases with mass for large masses (bottom panel of Figure 2). This result seems to be at odds with observational determinations, though more accurate determinations are required before claiming for a potential inconsistency of the ΛCMD-based models.

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