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A full pipeline for modelling low surface brightness galaxies

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Abstract. Cosmological simulations are a powerful tool to test various cosmological and galaxy formation scenarios. The discovery of low surface brightness objects has been a challenge for both of these fields. Our work aims to create a fully reproducible pipeline to generate a realistic dark matter halo catalog with corresponding information on galaxy formation and evolution.

Keywords. methods: numerical, galaxies: evolution, cosmology: dark matter

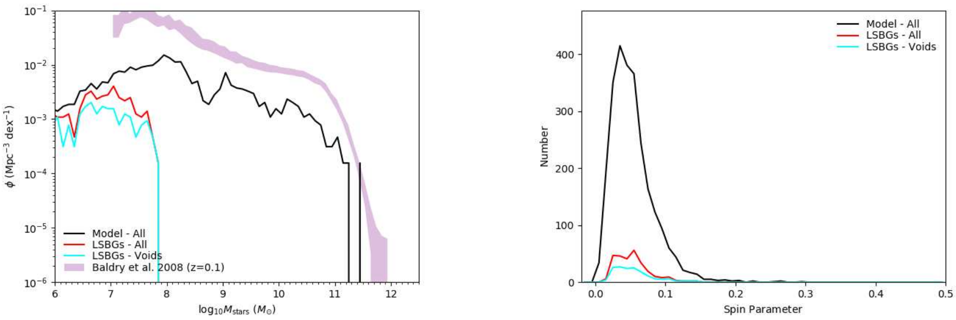
1. Introduction

Ever since their discovery (Sandage & Binggeli 1984; Bothun et al. 1987), the low surface brightness galaxies (LSBGs) were challenging to model theoretically. Recently van Dokkum et al. (2015)'s observations indicate LSBG can be of low mass but large size. The high abundance of these galaxies raises questions on the process regarding the formation scenarios. Moreover, LSBGs offer a unique chance to study galaxy evolution and dark matter.

2. Method

Our work aims to simulate a realistic galaxy population. To do this, we created a pipeline by using well established and tested codes. The initial position and velocity perturbations are generated with with MPGRAFIC (Prunet et al. 2008), which are evolved using RAMSES (Teyssier 2002). We analyse the structure of the dark matter (DM) distribution at successive time snapshots, finding DM halos with ROCKSTAR (Behroozi et al. 2013a) and voids with REVOLVER (Nadathur & Hotchkiss 2014). We use a semi-analytical model to simulate galaxies by following the DM halo merger history trees (Roukema et al. 1997), using CONSISTENT-TREES (Behroozi et al. 2013b). Semi-analytical star formation is implemented using SAGE (Croton et al. 2016). To estimate luminosities, we use stellar population synthesis models provided by PÉGASE (Fioc & Rocca-Volmerange 2019). We modified the output routine of SAGE in order to obtain the star formation rate, the infalling mass and the outflowing mass over several timesteps. Using this information as input for PÉGASE yields the brightness of a galaxy.

Our method provides a novel method of investigating galaxy formation and evolution, in the sense that we produce all the outputs on a single computer system and have full control over the pipeline (cf. Roukema et al. 1993, 1997). We have complete information on the temporal evolution of the simulation, galaxies and on the methods. We therefore are able to investigate the simulated galaxies of the full sample as deeply as required.



(a) The stellar mass functions of the full set of simulated galaxies and of the LSBG subset, compared to the observed stellar mass function. We reproduce the correct shape, but produce too few galaxies on all scales.

(b) The spin distribution of all galaxies compared to the spin distribution of LSBGs. In our simulation we do not reproduce a trend for LSBGs to have higher spins than typical galaxies.

Figure 1: Preliminary results.

3. Preliminary Results

Preliminary, highly tentative results of this project appear to be realistic. Figure 1a shows stellar mass functions of simulated LSBGs. The normalisation is low compared to the observations, but the shape looks reasonable, and the mass of simulated LSBGs is consistent with observational data (Prole et al. 2019) (fig. 8). One hypothesized scenario to form LSBGs is in high-spin dark-matter halos. Due to the high spin, the baryonic matter is spatially thinned, leading to a diffuse galaxy with low surface brightness. Our first results (Fig. 1b) do not seem to support this scenario, since our LSBGs seem to follow the general trend of the distribution of spins. For the future we plan to analyse LSBGs in our simulation over several timesteps. We want to investigate how their environment is affecting their evolution by comparing their quantities with other galaxies from our sample.

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