CONFRONTING HIERARCHICAL CLUSTERING MODELS WITH OBSERVATIONS OF GALAXY PAIRS

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Abstract. We investigate the star formation activity in galaxy pairs in chemical hydrodynamical simulations consistent with a Λ-CDM scenario. A statistical analysis of the effects of galaxy interactions on the star formation activity as a function of orbital parameters shows that close encounters \( (r < 30 \, \text{kpc} \, h^{-1}) \) can be effectively correlated with an enhancement of star formation activity with respect to galaxies without a close companion. Our results suggest that the stability properties of systems are also relevant in this process. We found that the passive star forming galaxies pairs tend to have deeper potential wells, older stellar populations, and less leftover gas than active star forming ones. In order to assess the effects that projection and interlopers could introduce in observational samples, we have also constructed and analysed projected simulated catalogs of galaxy pairs. In good agreement with observations, our results show a threshold \( (r_p < 25 \, \text{kpc} \, h^{-1}) \) for interactions to enhance the star formation activity with respect to galaxies without a close companion. Finally, analysing the environmental effect, we detect the expected SFR-local density relation for both pairs and isolated galaxy samples, although the density dependence is stronger for galaxies in pairs suggesting a relevant role for interactions in driving this relation.

1 Introduction

Observations show that mergers and interactions can induce star formation (SF) activity in galaxies (e.g. Larson and Tinsley 1978). Barton et al. (2000) and Lambas et al. (2003, LTAC03) analysed a sample of pair galaxies in the field finding a clear correlation between the proximity in projected distance and radial velocity of two galaxies and their SF activity. Recently, Alonso et al. (2004) claimed that the mechanism for triggering SF in interactions seems to be weakly dependent on environment, finding that even in cluster environment, the relation between proximity and SF activity has very similar characteristics to the one measured in the field. On the other hand, numerical simulations of pre-prepared mergers showed that interactions between axisymmetrical systems without bulges might induce gas inflows to the central region of the systems, triggering starburst episodes (Mihos and Hernquist 1996). Results from the study of the effects of mergers in the SF history of galactic objects in cosmological hydrodynamical simulations (Tissera et al. 2002), indicate that, during some mergers events, gaseous disks could experience two starbursts depending on the characteristic of the potential well. Other authors showed that orbital parameters of the encounter can also play a role in the triggering of SF activity (e.g. Barnes & Hernquist 1996).

Undoubtedly, galaxy-galaxy interactions are a key process in the regulation of star formation activity and if the Universe is consistent with a hierarchical scenario, then it is of utmost importance to understand the detailed characteristics, effects and efficiency of the action of this physical process on the life of galaxies. In this work we focus on a statistical analysis of galaxy pairs in a hierarchical scenario with the aim at confronting this scenario with recent observational results of galaxy pairs. Details can be found in Pérerez et al. (2005).

2 Results and Conclusions

We analyzed a 10 Mpc \( h^{-1} \) cubic volume of a Λ-CDM Universe \( (\Lambda = 0.7, \Omega = 0.3, H = 100h \, \text{km} \, \text{s}^{-1} \, \text{Mpc}^{-1} \) with \( h = 0.7 \) \) run with the chemical cosmological GADGET-2 (Scannapieco et al. 2005). The chemical GADGET-2 uses a SF algorithm based on the Schmidt law (Navarro & White 1994), but transforming gas into stars in a stochastic way. It also includes chemical evolution by describing the enrichment of the interstellar medium by SNII and SNIa. After identifying the bounded systems in the simulations and imposing a minimum stellar mass of \( 8 \times 10^9 M_\odot h^{-1} \), we constructed a tridimensional simulated galaxy catalog (3D-GP) selecting pairs according to a distance criterium. Analysing the dependence of the SF activity on the proximity to a near companion, we found a sharp increase of the SF in galaxies within \( r < 100 \, \text{kpc} \, h^{-1} \), which defines a suitable threshold to select pairs from the 3D distribution. We also build a projected galaxy pair (2D-GP) catalog by projecting the total 3D galaxy distribution onto random directions and then, selecting 2D pairs according to the observational criteria of Lambas et al. (2003). Hence, the 2D-GP catalog is formed by those systems with relative projected
separation \( r_p < 100 \text{ kpc} \) and radial velocity \( \Delta cz < 350 \text{ km s}^{-1} \). In order to provide a suitable comparison to underpin the effects of interactions, we constructed galaxy control samples for pair catalogs defined by galaxies without a close companion within the corresponding thresholds. For each simulated galaxy, we estimated the stellar birthrate parameter \( b \), defined as the present level of SF activity of a galaxy normalized to its mean past SF rate.

The analysis of the SF activity for galaxies in the 3D-GP catalog as a function of their orbital parameters shows that proximity can be statistically related to an increase of SF activity, at higher levels than those measured for galactic systems without a close companion, if systems are closer than \( \approx 30 \pm 10 \text{ kpc} \). On the other hand, we find a very weak indication for encounters with low relative velocities to be related with an enhancement of SF activity. Interestingly, we also detect that the triggering of SF by tidal interactions can be statistically related to the stability of the systems and the gas reservoir. In fact, we found that \( \approx 56\% \) of galaxies in close pairs \( (r < 30 \text{ kpc}) \) are forming stars at lower level than the average of the control sample. Part of these systems have experienced recent star formation activity and the rest shows deeper potential well and are gas poorer than galaxies in pairs with strong SF activity.

Results from the 2D-GP catalog show the same global trends detected in the 3D-GP sample. The enhancement threshold in projected distance drops with respect to that found in 3D to \( \sim 25 \pm 5 \text{ kpc} \) which is in good agreement with observational results (LTAG03). This shrinking in the threshold is produced by both geometrical projection effects and interlopers (spurious pairs). In order to separate these both effects, we have removed spurious pairs from the 2D-GP sample by checking their 3D relative separations. Consistently with previous works (Alonso et al. 2004; Mammon et al. 1997), we found that \( 30\% \) of the pairs in 2D-GP sample are spurious. This percentage reduces to \( 19\% \) for 2D close pairs \( (r_p < 25 \text{ kpc}) \).

On the other hand, we analysed the dependence of the SF on environment by calculating the projected local density parameter: \( \Sigma = 6/(\pi d_6^2) \), being \( d_6 \) the projected distance to the \( 6^{th} \) neighbor brighter than \( M_r = -20.5 \). Globally, the SF activity in pairs seem to depend weakly on environment. However, the fraction of star forming pairs is higher in low density regions.

Summing up, from the 3D-simulated galaxy pair catalog, we found that galaxy-galaxy interactions can be correlated with an enhancement of SF activity at higher levels than those measured for galactic systems without a close companion. We also found that the internal dynamical stability of galactic systems plays an important role as it can be deduced from the presence of an anticorrelation signal between the deepness of the potential well and the star formation activity. From the analysis of the projected galaxy pair catalog we estimated similar dependence to those observed in recent observational works. The fraction of spurious pairs is found to be higher for larger galaxy pair separations and to increase with local density. However, the trends estimated from the projected catalog are in good agreement to those calculated from the tridimensional one. We also found that the star formation activity in galaxies in pairs is weakly dependent on the cosmology and local environment, although the fraction of strong star forming galaxies in pairs increases with decreasing density in agreement with observations.

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