

****FULL TITLE****
*ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION***
****NAMES OF EDITORS****

Frequency and Impact of Galaxy Mergers and Interactions over the last 7 Gyr

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Abstract. We explore the history and impact of galaxy mergers and interactions over $z \sim 0.24\text{--}0.80$, based on *HST* ACS, Combo-17, and Spitzer 24 μm data of ~ 4500 galaxies in the GEMS survey. Using visual and quantitative parameters, we identify galaxies with strong distortions indicative of recent strong interactions and mergers versus normal galaxies (E/S0, Sa, Sb-Sc, Sd/Irr). Our preliminary results are: (1) The observed fraction F of strongly disturbed systems among high mass ($M \geq 2.5 \times 10^{10} M_{\odot}$) galaxies is $\sim 9\%$ to 12% in every Gyr bin over $z \sim 0.24\text{--}0.80$. The corresponding merger rate is \sim a few $\times 10^{-4}$ galaxies $\text{Gyr}^{-1} \text{Mpc}^{-3}$. The fraction F shows fair agreement with the merger fraction of mass ratio $\geq 1:10$ predicted by several LCDM-based simulations. (2) For $M \geq 1.0 \times 10^9 M_{\odot}$ systems, the average SFR of strongly disturbed systems is only modestly enhanced with respect to normal galaxies. In fact, over $z \sim 0.24\text{--}0.8$, strongly disturbed systems only account for a small fraction ($< 30\%$) of the total SFR density. This suggests that the behaviour of the cosmic SFR density over $z \sim 0.24\text{--}0.80$ is predominantly shaped by normal galaxies.

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1. Introduction

Hierarchical Λ CDM (HLCDM) models provide a successful paradigm for the growth of dark matter on large scales, but predictions of how galaxies evolve depend on the baryonic merger history, star formation, feedback, and other aspects of the baryonic physics. In this paper, we provide empirical constraints on the frequency of mergers and interactions, and their impact on the star formation (SF) of galaxies over the last seven Gyr (Jogee et al. 2008).

Our sample consists of ~ 4500 galaxies with $R_{\text{Vega}} \leq 24$ over the redshift interval $z \sim 0.24\text{--}0.80$ (lookback $T_{\text{back}} \sim 3\text{--}7 \text{ Gyr}^1$), drawn from the Galaxy Evolution from Morphology and SEDS (GEMS; Rix et al. 2004) survey. We use *HST* ACS F606W (V) images from GEMS, accurate spectrophotometric redshifts [$\delta_z/(1+z) \sim 0.02$ down to $R_{\text{Vega}} = 24$] from COMBO-17 (Wolf et al. 2004), stellar masses based on COMBO-17 (Borch et al. 2006), and star formation rates (Bell et al. 2007) based on Combo-17 UV and Spitzer data.

2. Analysis and Preliminary Results

We visually classified galaxies in the F606W images into the following two main visual classes (VCs). (1) ‘Dist’: This VC contains strongly disturbed galaxies with *externally-triggered* distortions indicative of a recent strong tidal interaction or merger. The distortions include arcs, shells, ripples, tidal debris, warps, offset rings, extremely asymmetric light distributions, tidal tails, and multiple nuclei inside a common body. (2) ‘Normal’: This VC contains the remaining galaxies. It includes E/S0, Sa, and Sb-Sd galaxies with no significant *externally-triggered* distortions, and the class ‘Irr1’ of galaxies with *internally-triggered* asymmetries described below. Many non-interacting galaxies have some low level of small-scale asymmetry in their rest-frame V or B band light due to star-forming regions or due to the low ratio of rotational to random velocities in low mass systems (e.g., in local Im and Sm galaxies). These internally-triggered asymmetries differ in scale (few 100 pc vs several kpc) and morphology from the externally-triggered distortions listed in (1).

We also ran the CAS code (Conselice et al. 2000) on the the F606W images to derive asymmetry (A), and clumpiness (S) parameters. The CAS criterion ($A > 0.35$ and $A > S$) picks up only 37% to 58% of the strongly disturbed ‘Dist’ galaxies, as expected from simulations (Conselice 2006). However, it is also contaminated by a significant number of relatively normal galaxies.

The visual classification was performed by three classifiers to measure the dispersion. The largest uncertainties in the VCs are in the last bin ($z \sim 0.6$ to 0.8) due to surface brightness dimming and due to the rest frame wavelength (λ_{rest}) shifting to the violet/near-UV (3700 Å to 3290 Å). We addressed these by verifying that the VCs of most strongly disturbed and normal galaxies do not change when we repeat the classification in all 4 bins using the deep GOODS F850LP images, whose redder pivot wavelength (9103 Å), ensures that $\lambda_{\text{rest}} \geq 5000 \text{ \AA}$ in all bins. Further tests, including Monte Carlo simulations and comparisons with HUDF images are under way. We summarize our current results below:

¹We assume in this paper a flat cosmology with $\Omega_M = 1 - \Omega_\Lambda = 0.3$ and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

1. Fig. 1 shows the color-mass distribution of the sample. Out to $z \sim 0.8$, the req sequence is complete for high mass ($M \geq 2.5 \times 10^{10} M_{\odot}$; $N=804$) galaxies (Borch et al. 2006), while the blue cloud is complete for intermediate mass ($M \geq 1.0 \times 10^9 M_{\odot}$; $N=3864$) systems. The strongly disturbed (Dist) galaxies, coded as orange stars, lie on both the red sequence and blue cloud.

2. The observed fraction F of strongly disturbed systems among high mass ($M \geq 2.5 \times 10^{10} M_{\odot}$) galaxies is $\sim 8\%$ to 12% in each Gyr bin over $z \sim 0.24-0.80$ (Fig. 2). Similar results are reported by Lotz et al. (2008). The corresponding merger rate is \sim a few $\times 10^{-4}$ galaxies $\text{Gyr}^{-1} \text{Mpc}^{-3}$.

3. Fig. 2 compares the observed fraction F with the fraction of major mergers ($M1/M2 \geq 1:4$; dashed lines) and major+minor mergers ($M1/M2 \geq 1:10$; solid lines) predicted by LCDM-based semi-analytical (SA), N-body, and SPH simulations, namely Hopkins et al. (2008; red lines labeled ‘H’; SA), Somerville et al. (in prep.; blue lines labeled ‘S’; SA), Benson et al. (2005; pink lines labeled ‘B’; SA), and D’Onghia et al. (2008; labeled ‘D’; N-body). There is fair agreement between F and the predicted fraction of mergers with $M1/M2 \geq 1:10$.

4. Among $M \geq 1.0 \times 10^9 M_{\odot}$ systems over $z \sim 0.24-0.80$, the average SFR of strongly disturbed systems is only modestly enhanced with respect to normal galaxies over this redshift range (Fig. 3; see also Robaina et al. in prep.). This modest enhancement is consistent with a recent statistical studies of the SF efficiency from based on large sets of numerical simulations (di Matteo et al 2007). In fact, for this mass range, strongly disturbed systems only account for a small fraction ($< 30\%$) of the cosmic SFR density over $z \sim 0.24-0.80$ (Fig. 4). These results complement the findings that normal galaxies dominate the UV (Wolf et al. 2005) and IR (Bell et al. 2005) luminosity density at $z \sim 0.65-0.75$, and are in good agreement with the predictions by Hopkins et al. (2006). Our results suggest that the corresponding behaviour of the cosmic SFR density over $z \sim 0.24-0.80$ is predominantly shaped by normal galaxies.

Acknowledgments. S.J. acknowledge support from NSF grant AST 06-07748, NASA LTSA grant NAG5-13063, and HST G0-11082 from STScI

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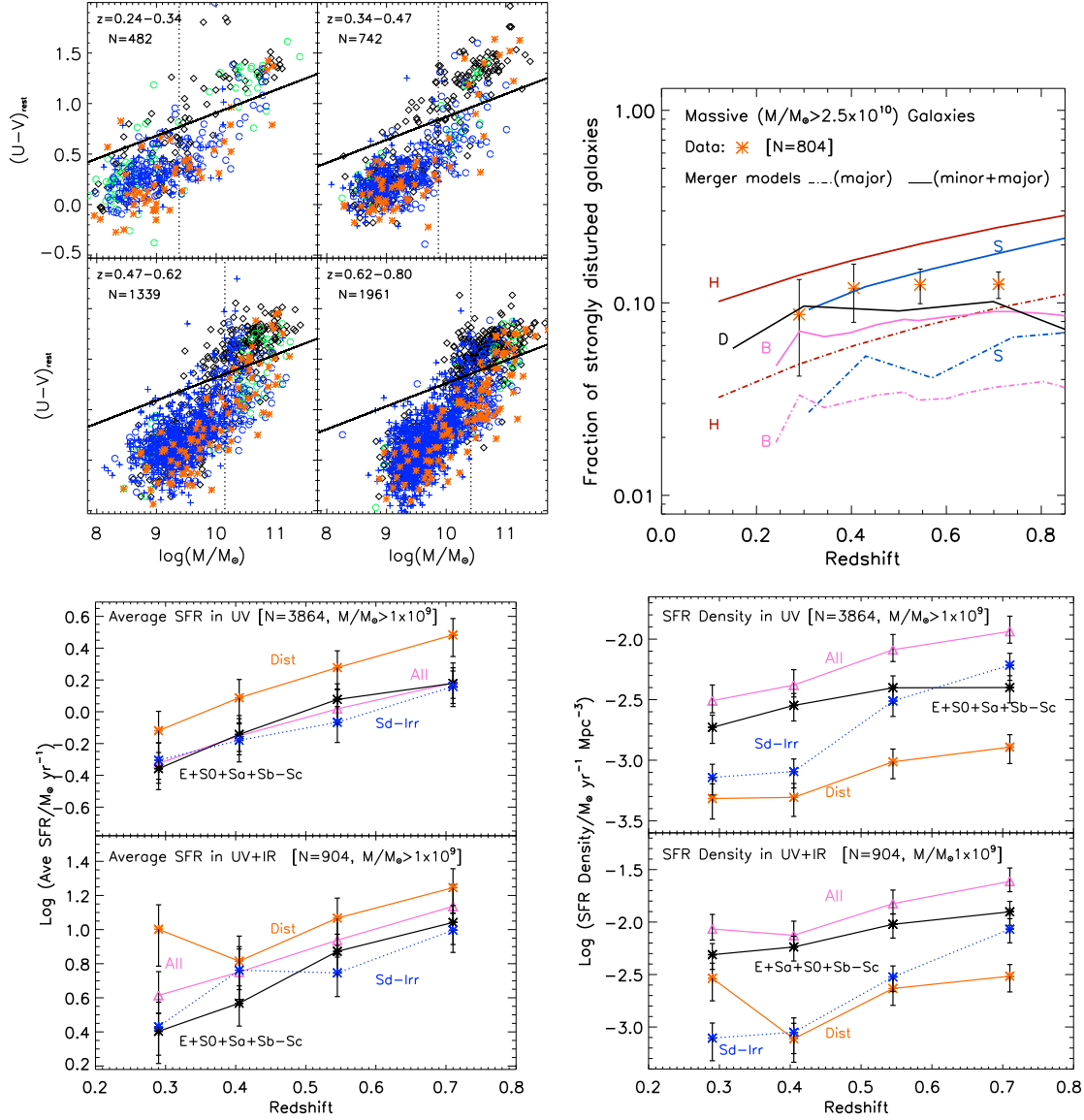


Fig. 1 (Top Left): The rest-frame $U - V$ color is plotted *vs* the stellar mass in four redshift bins, which span 1 Gyr each. The diagonal line marks the red sequence, and the vertical line denotes its mass completeness limit. Blue cloud galaxies are complete well below this mass. Strongly disturbed systems are coded as orange stars. **Fig. 2 (Top Right):** The observed fraction of strongly disturbed galaxies (orange stars) is compared to predictions from theoretical Λ CDM-based simulations. See text for details. **Fig. 3 (Lower Left):** The average SFR based on UV data and UV+IR data (for galaxies with a $24 \mu\text{m}$ detection) is plotted for strongly disturbed and normal galaxies. **Fig. 4 (Lower Right):** The contribution of strongly disturbed galaxies and normal galaxies to the cosmic SFR density out to $z \sim 0.80$ ($T_{\text{back}} \sim 7$ Gyr) is shown.