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Introduction

1.1 History

At the beginning of the twentieth century, the Milky Way Galaxy was believed to occupy more or less the whole Universe. It was not until the 1920's that the existence of galaxies external to the Milky Way was established. Pioneering efforts by astronomers such as Edwin Hubble proved that many of the nebulae objects observed at the time, were indeed galaxies outside our Milky Way. Many external galaxies were found and observed afterwards. In order to address them in a convenient and easy way, astronomers classified these objects according to their structures and shapes, or in short, morphology. The first classification scheme for galaxies was introduced by Hubble (1926) and has become known as Hubble tuning fork. This system, which is still in use today breaks galaxies into *elliptical*, *lenticular*, *spiral*, *irregular*. and each can be divided into subclasses based on the existence of extra features such as bars. The differences between various types, in fact, reflect the differences in their physical properties. Since then, astronomers have attempted to quantify the physical properties of galaxies in detail.

Spiral galaxies were found to have different stellar populations than ellipticals. The amount of gas and recent star formation of these galaxies are distinct from the ellipticals and they have bluer colors. The stellar populations of elliptical galaxies are old with redder colors and they tend to be more massive than the spirals (Kauffmann et al. 2003, Blanton et al. 2005). In general, observed quantities such as color, shape, luminosity, current star-formation rate, stellar and dynamical mass, circular velocity and velocity dispersion are the empirical properties for distinguishing galaxies and studying their underlying physics. (See more in review by Blanton & Moustakas 2009)

The diversity of galaxy populations observed in the present-day Universe raised questions about the origin of these differences. Astronomers strive to discover the story of formation and evolution of galaxies in theoretical and observational frameworks. The theoretical framework established in the 1960-70's (e.g., Eggen et al. 1962, Sandage et al. 1970, Press & Schechter 1974) describes the formation of galaxies from gravitational instability of density perturbations in the dark matter distribution and condensation of gas.

According to galaxy formation theory, as the dark matter halo collapses, shock heating will cause the gas within that halo to cool. The cooling will eliminate the pressure of the gas, however, in order to prevent the gas from ending up all at the center, some initial angular momentum of gas (acquired via tidal torques in the early Universe) is required. This helps to assemble the gas into a rotating disk (see e.g., Mo et al. 1998). However, different models can use different assumptions for density profiles of the dark matter halos and also for the initial dependence of the gas angular momentum on their dark matter halos. It is also not clear whether the gas angular momentum can change with time or how the star formation and feedback processes have an effect on changes of the structural properties of galaxies, such as their sizes.

There are mainly two different scenarios for the formation of bulges of late-type galaxies: One assumes that they are formed through merging and the other process is based on disk instabilities. The formation of the bulge through merging of two or more galaxies requires accretion of cold gas later on to form a disk around the bulge. Consequently, the bulge component can potentially have different stellar population properties in comparison to the disk. In the disk-instability scenario, the low angular momentum material near the center will finally transfer into the bulge. Nevertheless, many other assumptions need to be taken into account (e.g., feedback processes) for a full understanding of the formation and evolution of a typical late-type galaxy.

The formation of early-type galaxies is also not well understood. One scenario for the formation of these galaxies is from mergers of galaxies. Based on simulations, mergers of disk galaxies can reproduce similar properties of a typical elliptical galaxy (e.g., Hernquist 1992). Although this general model can predict simple properties of these galaxies, many properties still do not agree with the observations.

Therefore, direct observations are essential to test galaxy formation models. These observations should not only include complete samples of nearby galaxies, but also require large samples of galaxies at earlier stages of the Universe. As a result, identification of the first and most distant galaxies started to become more important by the mid-1970's and still continues today. The frontier of distant galaxies moved to redshifts of $z \sim 1 - 4$ in the 1990's corresponding to lookback times of $\sim 7 - 12$ Gyr. Thanks to deep and ultra deep observations during the last decade, the samples of high redshift galaxies have substantially increased and the limit is now pushed further to $z \sim 10$ (Bouwens et al. 2012).

1.2 Galaxies at High Redshifts

Observations of galaxies at high redshifts reveal that their properties are very different compared to galaxies in the nearby Universe (e.g., Conselice & Arnold 2009, Ravindranath et al. 2006) and the Hubble sequence was not in place for most of the galaxies. Therefore, looking back to a time when galaxies are observed to have different physical properties is important for understanding galaxy evolution. This provides essential clues for interpreting how galaxies assembled their stellar masses and structures with time.

There have been several novel techniques developed for identifying galaxies at high redshifts (i.e., $z \gtrsim 1$) over the last two decades. These methods rely on particular features in galaxy spectral energy distributions. Multi-wavelength observations normally assist to find these features. Although these techniques have been efficient for detecting high-z galaxies, they are still suffering from incompleteness.

One of the first methods relies on the rest-frame UV color of galaxies. As the spectral energy distribution of distant galaxies is shifted to longer wavelengths, their rest-frame UV spectrum can be observed in optical filters. In addition, the flux short-ward of the Lyman limit is almost completely absorbed by neutral hydrogen in the intergalactic medium (IGM). The combination of these two phenomenon helped isolate UV-bright star-forming galaxies at $z \sim 3$ in the *UGR* color-color diagram. These galaxies are called Lyman Break Galaxies (LBGs) (Steidel et al. 1996). In order to detect galaxies at higher redshifts ($z \gtrsim 4$), this method was modified using redder sets of filters (e.g., Ouchi et al. 2004, Bouwens et al. 2007, 2011). Based on the rest-frame UV selection, star-forming galaxies at lower redshifts, $1.4 < z < 2.5$, are also selected (BM/BX galaxies: Adelberger et al. 2004, Steidel et al. 2004). Although this technique has been successful in detecting high redshift star forming galaxies, this method misses passive or dusty star-forming galaxies at these redshifts.

Using another spectral feature of galaxies in their optical rest-frame (Balmer/4000 Å break), another technique was developed to isolate galaxies with negligible levels of star formation at $z \gtrsim 2$ (Franx et al. 2003). This technique benefits from using the observed color of galaxies in the near infrared filters ($J_{Vega} - K_{Vega} > 2.3$). These galaxies which are called Distant Red Galaxies (DRGs) typically dominate the high stellar mass regime of galaxies at $z \sim 2$. The other method based on optical/near Infrared color is the so-called *BzK* method developed by Daddi et al. (2004). This technique can isolate star-forming and passive galaxies at $1.4 \lesssim z \lesssim 2.5$.

Sub-millimetre galaxies (SMGs) (Smail et al. 1997, Hughes et al. 1998) are systems at high redshift with a large amount of radiation in the far-IR due to their obscured star-formation or AGN activity. They are very massive and luminous. However, their link to galaxies in the local Universe is not yet understood. Another efficient method for identifying high-z galaxies is using narrowband filter to detect galaxies with large hydrogen Lyα emission-line equivalent widths. These galaxies are normally faint and their relation to the other populations of galaxies are yet to be well resolved.

Although the sample size of galaxies at high redshift is increasing they are still much smaller than surveys of the local Universe such as the Sloan Digital Sky Survey (SDSS). However, the properties of these high redshift galaxies provide important insight for understanding the formation and evolution of galaxies.

1.3 Scaling Relations

One of the key unsolved problems in astrophysics is to understand the formation and evolution of galaxies. There are many complementary approaches to study the evolution of galaxies and infer how distant galaxies are connected to galaxies in the present day Universe. These canonical ways are either focused on the evolution of the luminosity/mass functions of galaxies, the evolution of the star formation rate/stellar mass density, or the evolution of the observed scaling relations of galaxies. For instance, the luminosity function describes the number density of galaxies within a small luminosity range. This can constrain the overall abundances of galaxies at each epoch, therefore the evolution of the luminosity function with redshift provides essential information for understanding the evolution history of galaxies.

Galaxies show great diversity in their physical parameters, such as luminosity, stellar mass, size and rotational velocity. Interestingly, galaxies obey well-defined scaling relations between some of these quantities. For instance, the relation between the luminosity and rotational velocity of spiral galaxies is know as a 'Tully-Fisher' relation (Tully & Fisher 1977) which basically defines a correlation between dynamical mass and the luminosity of galaxies. The relation between the velocity dispersion and luminosity of elliptical galaxies is known as a 'Faber-Jackson' relation (Faber & Jackson 1976) in which accordingly, elliptical galaxies with larger velocity dispersions are brighter.

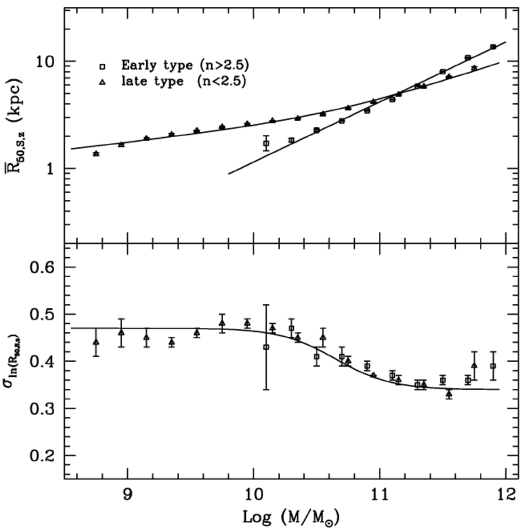

Figure 1.1 – The Stellar mass-size relation for late-type and early-type galaxies in the SDSS (top panel) and the size dispersion as a function of the stellar mass(bottom panel) from study by Shen et al. (2003)

It is essential to study the galaxy scaling relations over a wide range of redshifts. This can help to determine how galaxies move along these relations with time and accordingly, make it possible to test plausible model(s) for their evolution. In general, the slopes, zero points and scatters of these scaling relations at different epochs are fundamentally important to constrain models of galaxy formation.

However, there are some difficulties to obtain accurate measurements for some of the quantities used in these scaling relations. For instance, measuring the rotational velocity or velocity dispersion of the faint galaxies at high redshifts requires deep spectroscopic observations. Acquiring these quantities for a large sample of galaxies is a very time consuming process. Moreover, as the galaxies get fainter, the robustness of these measurements normally reduces. Therefore, constraining the correlations between some of these quantities becomes a difficult task for high redshift galaxies.

Among the scaling relations, the relation between the stellar mass and the size of galaxies has considerable importance. The size of galaxies can be measured using single-band imaging (photometry). The stellar mass of the galaxies can also be measured robustly, thanks to the multi-wavelength photometry and stellar population synthesis modelling. Therefore, there is less difficulties to estimate these properties for a larger sample of galaxies at high redshifts in comparison to some of the quantities mentioned above. In addition, the stellar mass and size of galaxies are two important ingredients for characterizing galaxies and have important physical meanings. Studying these quantities at different epochs will help investigate how the structures of the nearby galaxies have been

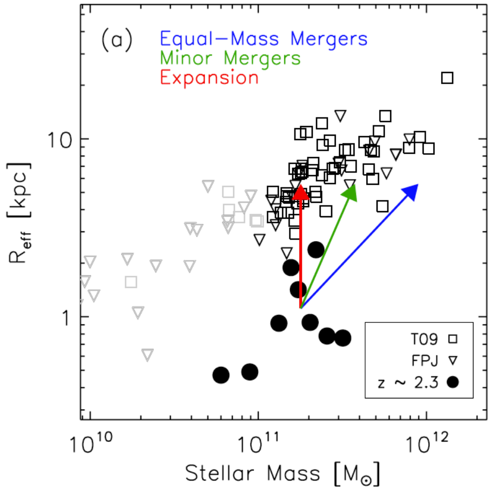

Figure 1.2 – The relative distributions of the stellar mass and size of quiescent galaxies at $z \sim 2$ and in the local Universe. The arrows show the predictions of evolution of sizes for each model with redshift. (Figure is taken From Bezanson et al. (2009).

formed and what were the properties of their progenitors at high redshifts. In brief, this can help to constrain evolutionary scenarios of galaxy formation and evolution.

The stellar mass-size relation of galaxies in the present day Universe is pointed out first in Kauffmann et al. (2003) and well characterized by Shen et al. (2003), using large samples of galaxies in the Sloan Digital Sky Survey (SDSS). The top panel of Figure 1.1 shows the mass-size relation for late-type and early-type galaxies studied by Shen et al. (2003). The relation is shown to be different for late-type and early-type galaxies. The early-types have a steeper relation at high stellar mass. This reflects the different history of formation and the stellar mass assembly for each kind of galaxy. The size dispersions (bottom panel of Figure 1.1) also vary as a function of the stellar mass and the scatter decreases for massive galaxies.

Pioneering studies on the sizes of galaxies at higher redshifts were carried out in the 1990's (e.g., LBGs at $z \sim 3$ by Giavalisco et al. (1996) or Lilly et al. (1998) for galaxies up to $z \sim 1$.) However, the results of different studies were not in agreement due to difficulties in obtaining a large sample of galaxies at higher redshifts and the selection effects caused by surface brightness limits. However, the study of the size-luminosity relation of galaxies improved later, using deep ground and space based observations. These studies revealed that the sizes of galaxies at earlier time were smaller compare to galaxies in the local universe within a similar mass/luminosity range (e.g., Trujillo et al. 2006b, Zirm et al. 2007, van Dokkum et al. 2008). This means that sizes of massive galaxies within a given stellar mass should have been increased up to a factor of ~ 6 with time.

The process of size growth for galaxies can be different for each type and can vary at each epoch. Star-forming galaxies at high redshifts (e.g., at $z \sim 2$), have a larger fraction of gas per stellar mass compare to their counterparts at low redshifts (e.g., Erb et al. 2006). One plausible scenario for increasing sizes of these galaxies could be the accretion of gas into the disk (cold accretion) and converting that into stars (e.g., Law et al. 2012).

Observations have also illustrated that early-type galaxies at high redshifts are significantly smaller. There are two main questions about these galaxies; first is how these galaxies are formed at high redshift and second is to understand how they are connected to their low redshift analogs. The formation of these compact quiescent galaxies at high redshifts are yet to be understood. Nevertheless, there are several mechanisms proposed to explain the growth of these quiescent galaxies with time, such as major mergers, minor mergers or adiabatic expansion (e.g., Khochfar & Silk 2009, Naab et al. 2009, Bezanson et al. 2009, Fan et al. 2008). These mechanisms can change the stellar mass and profiles of galaxies in different way.

The observed stellar mass-size relation of these massive quiescent galaxies would help to constrain these models. Equal-mass merging of gas-poor systems (major mergers), could double sizes and stellar masses of these galaxies. Minor mergers, can increase the size of spheroids more significantly than the stellar masses, because this process nearly conserves the central densities and velocity dispersions. The puffing up scenario via adiabatic expansion, suggests the idea of expelling a large amount of material efficiently, through some sort of feedbacks (e.g., quasar feedback); however, in this process, the central density and velocity dispersion of a typical early-type galaxy will change. (see Figure 1.2 for more details). In general, comparing observed scaling relations at different redshifts (epochs) with results from simulations can help to verify different scenarios of galaxy formation and evolution.

1.4 This Thesis

The uncertainties associated with the observed properties of galaxies can be further improved by additional observations using deeper data that covers larger area and well-defined complete samples. The multi-wavelength surveys are potent tools for these studies. Using the advantages of recent infrared galaxy surveys, with the aid of ancillary optical and near infrared data, make it possible for observers to study the properties of different kinds of galaxies at a wide range of redshifts and pushing the observational limits to the epoch of galaxy formation ($z \sim 10$).

This thesis focuses on assessing how the structural properties such as the sizes and the surface brightness profiles of galaxies change with time. In particular, we study the stellar mass-size relation of galaxies from $z = 7$ to $z = 0$, using recent deep observations in the near Infrared. Using deep optical and near-IR surveys, helped to characterize the spectral energy distributions (SEDs) of galaxies at a wide range of redshifts, especially at the peak of star-formation activity ($z \sim 2$). Studying galaxy properties and the scaling relations at different epochs can place important constrains on the underlying processes assumed for galaxy mass and structural assembly (e.g., accretion of gas onto galaxies or minor/major mergers), feedback effects.

Chapter 2: In this chapter, we present the first study of galaxy size evolution using a sample of objects with spectroscopic redshifts between $z \sim 0.5 - 3.5$ in the GOODS-North field. Most studies use photometric redshifts to measure the evolution of mass-size relations with time. Using spectroscopic samples can remove some biases based on photometric studies. We further investigate the half-light radii of different types of UV-bright star-forming galaxies at high redshifts; i.e., sizes of galaxies such as Lyman Break Galaxies, BM/BX galaxies and Lyman Break analog at $z \sim 1$ are measured. In addition, we compare the sizes of these galaxies with other types of star-forming galaxies, such as star-forming $BzKs$ and sub-millimeter galaxies (SMGs). The positions of these galaxies on the mass-size plane may provide clues about their relation to other galaxy populations.

Chapter 3: The newly installed Wide Field Camera 3 (WFC3) camera on the *Hubble Space Telescope* and the ultra-deep near-infrared imaging of the Hubble Ultra Deep Field (HUDF) helped to identify numerous candidates of Lyman Break Galaxies (LBGs) to the early stages of galaxy formation (e.g., out to $z \sim 8$). Many studies have focused on the evolution of the luminosity function, stellar mass and star-formation rates of the LBGs at these high redshifts (e.g., Bouwens et al. 2011, Gonzalez et al. 2011). However, the stellar mass-size relation of these galaxies at $z \gtrsim 4$ were not addressed in great detail. Therefore, in this chapter we take advantage of the ultra-deep WFC3/IR and IRAC observations in the HUDF and Early Release Science (ERS) field to study the stellar mass-size relation of LBGs out to the redshift of $z \sim 7$. At $z \gtrsim 4$, the rest-frame optical light shifts to mid-IR wavelengths, which is a problem in determining stellar masses. The Spitzer telescope provides very sensitive photometry at these wavelengths, but its large PSF can cause blending problems. However, robust techniques have been developed to deblend nearby objects and measure the stellar mass of high-z galaxies reliably (Labbé et al. 2006). In addition, we have used the profile fitting technique (assuming Sérsic models) to measure the sizes of these very high redshift galaxies, in a consistent way to the lower redshift analysis. Therefore, we study the stellar mass-size relation of galaxies up to $z \sim 7$.

Chapter 4: The stellar mass-size relation of galaxies in the present day Universe can be used as a baseline for inferring the rate of galaxies size evolution with time. Therefore, in this chapter we study the mass-size relation for a sample of galaxies at $z = 0.01 - 0.02$, dividing the sample based on different common methods of classifications. We also examined different methods of size measurements of galaxies, including single Sérsic fits, two-component Sérsic models and non-parametric method, in order to quantify the systematics associated in each method. Finally, to test the potential systematics of size measurements at high redshift, we further artificially redshifted our sample to z=1 and re-fit the galaxies using single Sérsic profile fitting.

Chapter 5: It has been shown by many studies that the majority of galaxies follow a color-morphology relation up to high redshifts. In the other words, the morphological transformation and cessation of star-formation could be correlated. However, presence of a population of red or passive spiral galaxies (with a lack of ongoing star-formation) which was first noticed by van den Bergh (1976) and Couch et al. (1998) appears to break this relation. In this chapter we carefully selected face-on disk dominated spiral galaxies (at $z \sim 0$) from the Galaxy Zoo morphological catalogue (visually selected) to construct a sample of truly passive disk galaxies. We attempt to investigate various physical processes that shut down the star-formation of these red passive spiral galaxies while retaining their spiral morphology. We study the dust properties and stellar populations of these galaxies in comparison with blue face-on spiral galaxies. In addition we also examined the environmental properties of these galaxies and looked for AGN activity. We have also tried to compare the fraction of objects with specific morphological features (such as bars) between red and blue face-on spirals.

1.5 Conclusion and Outlook

We provide some constraints on the galaxy formation and evolution models and also the methods of measuring structural properties of galaxies at different redshifts. Our results confirm previous studies of the mass-size relation at high redshift based on photometric redshifts, and we showed that galaxies of similar mass were generally smaller in the past. We also show that the stellar mass-size relation of Lyman-break galaxies persists, at least to $z \sim 5$. We find that the best fitting size evolution for galaxies with stellar masses of $\log(M_*/M_\odot) \sim 10.$ evolves as $(1 + z)^{-1.20\pm0.11}$. This evolution is very similar for the galaxies with lower stellar masses of $\log(M_*/M_\odot) \sim 9$. This results is in agreement with simple theoretical galaxy formation models at high redshifts.

We compared the sizes of UV-bright galaxies and Sub-mm galaxies and we found that the median effective radius of the Sub-mm galaxies are consistent with the BM/BX galaxies within the same stellar masses. We also confirmed that the star-forming galaxies (at $z \sim 1-3$) are significantly larger than quiescent galaxies at the same mass and redshift by 0.45 ± 0.09 dex. We also confirmed the tight correlation between color and stellar mass surface density of galaxies at high redshifts using our sample of galaxies with secure redshifts. This demonstrate that galaxies with higher specific star-formation rates have larger effective radii than the ones with lower specific star-formation rates.

A larger sample of galaxies with deeper observations at their rest-frame optical for galaxies at $z \gtrsim 3$ is required to robustly constrain many other properties of these galaxies. It would also be interesting to understand the role of environment and intergalactic medium in shaping the morphologies or structural properties of galaxies. Comparing the stellar mass/star-formation rate profiles of galaxies at different environment can provide more clues on the galaxy evolution scenarios. Using larger spectroscopic samples of galaxies at high redshifts will also help to constrain the galaxies evolution models.

We showed that the stellar-mass size relation of both nearby late-type and early-type galaxies are steeper at high masses ($\sim 3-4 \times 10^{10} M_\odot$) and flatten at low stellar masses. This relation is not sensitive to the precise definition of the sample classification based on color, Sérsic index, morphology and specific star formation rate, with the exception of blue galaxies which follow a somewhat higher and steeper relation.

In this thesis we also investigated the systematics of different methods of size measurements for galaxies at low and high redshift. We show that nearby early-type galaxies with stellar masses $> 2 \times 10^{10} M_{\odot}$ are not well fit with single Sérsic profiles. The non-parametric methods and two component fits give less biased measurements for the sizes of these well-resolved galaxies. However, single Sérsic fit provide robust size estimates for galaxies at high redshifts.

The results from studying face-on red spiral galaxies showed that these galaxies indeed have older stellar populations and they do not have large amount of dusts. Although the findings show that these galaxies are common around or just inside the infalling regions of clusters, however, the environment alone cannot turn these galaxies red. Their AGN luminosity is also not enough for the difference between them and blue spirals. The fraction of red spiral galaxies with bar features is larger than blue ones and hence this suggests that the cessation of star-formation is strongly correlated with the bar instabilities in spiral galaxies.

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