CHAPTER 1

Introduction

Galaxy is a kind of hazily celestial object. It is a fundamental structure of the universe, containing 10^9 to 10^{13} $M_\odot$ of planets, stars, satellites, comets, meteorites, gas, dust and dark matter, gravitationally-bound together. Many galaxies built up from a simple structure of mainly main sequence stars and neutral gas, showing common features. On the other hand, some galaxies have complex structure. They built up from the different components, such as stars, ionized gas, dust, neutral and ionized molecular cloud, magnetic fields, or cosmic radiation. Typically, the brightest galaxy has the luminosity is about 10^{12} $L_\odot$, but most of them are much hazy. The luminosity of the smallest detected galaxy is about 10^5 $L_\odot$ (Karttunen et al., 2007). The galaxies do not have a sharp boundary. In addition, the area of galaxy edge composes of non-luminosity matter which increase the mass of the galaxies rapidly. The different galaxies and different parts of the galaxies have very different density of matter. So, the galaxy evolution may be the result of processes taking place on enormously different time and energy scales (Karttunen et al., 2007).

We live in the Milky Way Galaxy that is surrounded by billions of other galaxies spread throughout space. Many galaxies are isolated in space called field galaxies. Sometimes they combine into galaxy groups or galaxy clusters. For example, our Milky Way is one of two largest in about 40 galaxies in the Local Group. Galaxy groups have about 1.2 Mpc in radius and include at least a few tens galaxies. The groups with more than about 50 galaxy members are called galaxy clusters which have radius of about 2-5 Mpc. Our nearby irregular cluster is Virgo Cluster at distance of about 15 Mpc. The central region consists of early-type galaxies that is surrounded with the distribution of spiral galaxies. The Coma Cluster is the nearest regular cluster at distance of about 90 Mpc. The central pair of giant elliptical galaxies is encompassed by a system of early-type galaxies. If some galaxies, groups, or clusters of galaxies form a lager system with a radius of 5-10 Mpc approximately, they are called superclusters (Bennett et al., 2012; Karttunen et al., 2007). The different of environments between cluster galaxies and field galaxies can affect their evolution and physical properties. In particular, the galaxies in groups or clusters are possible to have galaxy-galaxy interaction or galaxy-cluster interaction, such as attraction, merging, and stripping. Those mechanisms were researched widely during recent decades.

Physical properties of galaxies were investigated and used to describe the nature of the galaxies. Star formation is an interesting properties for astronomers. Because it can be used to describe the galaxy evolution and correlated with various interactions that take place within the galaxies. Star formation of galaxies in low redshift galaxy groups and clusters have been extensively studied. There are many techniques for measurement of star formation activity, e.g. equivalent width of emission lines (e.g. Kennicutt and Kent, 1983; Young et al., 1996), far-infrared luminosity (e.g. Kennicutt et al., 1987), radio luminosity (e.g. Condon, 1992) or direct ultraviolet from massive stars (e.g. Bell and Kennicutt, 2001). The equivalent width of hydrogen alpha ($EW(\mathrm{H}\alpha)$) was used as an effective probe of star formation region (e.g. Kennicutt, 1983; Gavazzi et al., 2002; Thomas et al., 2008). The first astronomer who studied star formation properties in nearby cluster galaxies by using this method is Kennicutt (1983). The Hα emission is a result of the interaction between galaxy-galaxy and tidal interaction occurring within the galaxy groups as the trigger for the massive star formation (Boselli and Gavazzi, 2006). Young massive stars were detected by ultraviolet, Hα, and far-infrared fluxes. Because of extinction, fluxes in ultraviolet and Hα wavebands were detected at lower limit to star formation rate, while the far-infrared flux is only upper limit because a half of infrared luminosity comes from cirrus clouds (Elmegreen, 1998).

Gavazzi et al. (2006) presented the Hα observations of 273 late-type galaxies in the nearby rich clusters Virgo, Abell 1367, Cancer, Hercules and Coma. He informed that star formation rate in Virgo cluster increase from Sa to Scd, then decrease from Scd to Im. This conclusion interpreted that star formation rate are correlated with Hubble type, consistent with the result of Kennicutt (1998), which found that the early-type galaxies have lower $EW(\mathrm{H}\alpha)$ than late-type galaxies. Moreover, Koopmann et al. (2001) studied

63 bright spiral galaxies in the Virgo cluster and measured total Hα emission and light profiles of the galaxies by using narrow-band methods as well. When these late-type galaxies move closely together or fall into a group or cluster, gravitational potential of the galaxies can tidally interact on each other or interact on the entire group or cluster (Boselli and Gavazzi, 2006), resulting star formation rate more than early-type, which are redder gas-poor galaxies.

Typically, blue stars are massive stars with high surface temperature that are formed not long ago. This is consistent with a lot of gas found in the late-type galaxies, particularly in the galactic disks (Pohlen et al., 2010; Boselli et al., 2002), which is the main raw material for star formation. Electrons of hydrogen atoms around the young massive stars are excited by ultraviolet emitted from the stars and transit from the ground state to the second excited state. After that they fall back into the first excited state and release the energy as the visible wavelength of Balmer series. In particular, the Hα is the strongest line of the series. Therefore, the young massive stars support mainly the Hα. The Hα emission line provides a closely instantaneous measure of the star formation rate, independent of the former star formation history (James et al., 2005). The measurement of $EW(H\alpha)$ could be a good indicator for star forming regions within galaxies (Fossati et al., 2013; Kennicutt, 1998). In addition, colors of galaxies also have correlated with the $EW(\mathrm{H}\alpha)$ (Kennicutt and Kent, 1983) and leading to explain the evolution of galaxy and star formation.

Measurement of the galaxy mass remained highly uncertain, because of the existence of the dark matter that cannot be measured. There are several methods to measure the galaxy mass. For example, we can determine the galaxy mass from the rotational curve of spiral galaxies. The rotation period is correlated with the galaxy mass as the Kepler's third law. In addition, a relationship between the maximum rotation velocity of a spiral galaxy and its luminosity known as Tully-Fisher relation. The relation contributes to the calculation of the galaxy mass, based on the relationship of the mass to light ratio. While, the mass of elliptical galaxies can be calculated by using the velocity dispersion with Virial theorem. Finally, the X-ray radiation in the halo of the elliptical galaxy can be used to obtain the galaxy mass. This method assumes that the hot gas was trapped by the gravitational force of the galaxy and cannot escape from the galaxy. So, we can analyze the escape velocity of the hot gas to calculate the galaxy mass (Carroll and Ostlie, 2014).

The difference of environment can affect the evolution of galaxies into various types. Generally, cluster galaxies are located in higher density environment with respect to field galaxies. The cluster galaxies have encountered more interactions among galaxies than the field galaxies. The physical processes which are believed to explain the interaction of galaxies in high density environments consist of the gravitational interactions, including all tidal interactions (galaxy-cluster, galaxy-galaxy and harassment) and the hydrodynamic interactions occurred between interstellar medium in galaxy and hot intergalactic medium (ram pressure stripping, viscous stripping and thermal evaporation) (Boselli and Gavazzi, 2006).

There are many astronomical researchers interested in factors that affect star formation rate in galaxies of groups. Boselli and Gavazzi (2006) studied the environmental effects on late-type galaxies in nearby clusters and found that the morphological segregation is the signature of the environmental dependence of the formation and evolution processes. Such as S0 galaxies in nearby clusters transform from spiral galaxies that have been disturbed by gravitational interactions. The simulation of Byrd and Valtonen (1990) show that tidal interaction generate enough gas flow from the disk into the circumnuclear regions. The efficiency of the interaction can be defined by perturbation parameters.

This thesis will measure fundamental physics properties of the sample galaxies in NGC 4213 Group that has an average recessional velocity of about 6,821 km s^{-1}. These include the magnitudes, colors, galaxy morphology in the Hubble and de Vaucouleurs system, and $EW(\mathrm{H}\alpha)$. The $EW(\mathrm{H}\alpha)$ is measured to study star formation in the sample galaxies. The correlations among the physical properties will be analyzed to understand the nature of the galaxies and the environmental effect on the star formation and evolution of the sample galaxies. Throughout the thesis, a Hubble constant $\mathrm{H}_0 = 67.8\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ (Planck Collaboration et al., 2014).

1.1 Research Objectives

1) To study the physical properties of sample galaxies in NGC 4213 Group, such as magnitudes, colors, galaxy morphology in the Hubble and de Vaucouleurs system, and the $EW(\text{H}\alpha)$.

2) To study the star formation of sample galaxies in NGC 4213 Group via measuring the $EW(\text{H}\alpha)$ (Gavazzi et al., 2006).

3) To study the effect on evolution of galaxies due to the environmental interactions around the galaxies within NGC 4213 Group (Boselli and Gavazzi, 2006; Kennicutt and Kent, 1983).

1.2 Research Plan and Scope

1) The imaging observations with broad-band filters (B, V and R_C) and narrow-band filters ([S II] and Red-continuum) for the sample galaxies in galaxy group NGC 4213, centered at the position of R.A. 12h 15m, Dec. $23^\circ\,57'$ will be taken from CCD imaging device model Apogee U42, connected to the 2.4-m reflecting telescope of Thai National Observatory, Chiang Mai.

2) Determine BVR_C magnitudes, colors, and classify morphological types for the sample galaxies.

3) Study star formation in galaxies via detection of the Hα emission in the term of equivalent width and analysis for interpretation of evolution of the sample galaxies.

1.3 Research Usefulness

1) Understanding about astronomical data and physical properties of sample galaxies in NGC 4213 Group. These include the magnitudes, colors, morphological types and the $EW(\text{H}\alpha)$.

2) Understanding the trend of star formation of sample galaxies in NGC 4213 Group via measuring the $EW(\text{H}\alpha)$, which is related to the type and trend of evolution of the galaxies.

3) Understanding the environmental effect on star formation and evolution of the sample galaxies in NGC 4213 Group.

4) The results in this research can be used to analyze the star formation rate and measure the mass of the sample galaxies in NGC 4213 Group.