Observational Study of Compact Groups of Galaxies(Abstracts of Doctoral Dissertations,Annual Report (form April 1998 to March 1999))

Observational Study of Compact Groups of Galaxies

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Compact Groups (CGs) of Galaxies are small, isolated and high surface density galaxy system. Many previous studies suggest that CGs represent sample for investigating the effects of a environment on the galaxy formation and on the galaxy evolution.

Chapter I Deep Optical Search for Common Optical Envelopes around Hickson Compact Groups of Galaxies We present results of optical (R and I bands) deep CCD imaging survey for a sample of 30 Hickson compact group of galaxies (HCGs). These data are used to investigate whether or not they have common optical envelopes (COE) which are considered to show strong evidence for the physical association of the member galaxies. We find that thirteen HCGs have the COE while fourteen HCGs have no COE above a surface brightness level of $\mu_R = 25$ mag. arcsec^{-2}. Our search was made for the HCGs whose R-band limiting surface brightness is below $\mu_R = 25.75$ mag. arcsec^{-2}. The remaining three HCGs are not studied because their CCD images were taken at shallower levels.

Since the presence of COE means that member galaxies in a group have already experienced many galaxy interactions (i.e., a part of stars associated with the galaxies have been striped out by the interactions), it is considered that the HCGs with COE are dynamically-bound, real compact groups of galaxies. We find that almost all the HCGs with COE also have extended soft X-ray halos. This strengthens that they are real compact groups. Therefore, we conclude that the finding COE provides a powerful tool to identify real compact groups.

For the HCGs with COE, we find a so-called fundamental plane, $\log L_{\rm B} = \log R^{0.83^{+0.16}_{-0.14}} + \log \sigma^{0.41^{+0.08}_{-0.07}} + 8.58^{+0.36}_{-0.43}$. This relation is different from that expected for a virialized system. The main reason for this difference is that the mass-to-luminosity ratio for the HCGs is proportional to the luminosity itself for the HCGs with COE; i.e., $M/L \propto L$. This relationship is also independently obtained by comparing the dynamical masses of the HCGs with their B luminosities.

We find that the relation between the dynamical mass-to-luminosity ratio and the size for the HCGs with COE is indistinguishable from that for elliptical galaxies studied by Bahcall, Lubin, & Dorman. This suggests strongly that the dark matter is associated mainly with galaxies even for the HCGs. This is understood reasonably if the dark matter of galaxies extends spatially up to $\sim$ 100 kpc, as suggested by Bahcall et al., because the typical size of HCGs is also $\sim$ 100 kpc. Comparing the dynamical masses with the luminous masses for the HCGs with COE, we find that the mass of the dark matter is up to $\sim$ ten times as high as the luminous mass. If the HCGs with COE will merge into one dynamical system, which is believed to be the natural

consequence such galaxy associations, they will evolve to giant field elliptical galaxies with dark matter extending up to $\sim$ 100 kpc.

Chapter II Deep Optical Imaging of a Compact Group of Galaxies, Seyfert's Sextet: Direct Evidence for the Dark Matter Associated with the Individual Galaxies
Recently, the X-ray satellite ROSAT has been used to investigate the dark matter content in a large number of groups of galaxies because the hot gas probed in the soft X-ray is generally believed to be gravitationally bound to the groups. Although the majority of groups of galaxies detected by ROSAT show round-shaped morphologies in the soft X-ray, some groups such as Seyfert's Sextet (SS) show irregular-shaped soft X-ray morphologies. In order to understand the origin of the irregular-shaped soft X-ray morphology of SS, we have obtained a deep R-band optical image of this group. Our image shows that a faint envelope down to a surface brightness $\mu_R \simeq 26$ mag. arcsec^{-2} surrounds the member galaxies. Comparing this optical faint envelope with the soft X-ray image, we find that both the images are remarkably similar in morphology. Since the optical faint envelope should be attributed to stars liberated from the member galaxies through historical tidal interactions, this similarity provides direct morphological evidence that the dark matter was originally associated with the individual galaxies and are now spreading out around the group.

Chapter III The Nuclear Activity of the Galaxies in the Hickson Compact Groups
In order to investigate the nuclear activity of galaxies resided in compact groups of galaxies, we present results of our optical spectroscopic program made at Okayama Astrophysical Observatory. We have performed optical spectroscopy of 69 galaxies which belong to 29 Hickson Compact Groups (HCGs) of Galaxies. Among them, three galaxies have discordant redshifts. Further, spectral quality is too poor to classify other three galaxies. Therefore, we describe our results for the remaining 63 galaxies.

Our main results are summarized below. (1) We have found in our sample; 31 AGN, 17 HII nuclei, and 15 normal galaxies which show no emission line. Adding the sample of Coziol et al. (13 AGNs, 6 HII nuclei, and 8 normal galaxies) to our sample, we obtain a large sample consists of 44 AGNs, 23 HII galaxies, and 23 normal galaxies (90 galaxies in total). We used this extended HCG sample for statistical analyses. (2) Comparing the frequency distributions of activity types between the HCGs and the field whose data are taken from Ho, Filippenko, & Sargent (387 field galaxies), we find that the frequency of HII galaxies in the HCGs is significantly less than that in the field. (3) However, our HCG sample contains more early-type galaxies than the field, the above difference may be due to this morphology bias because it is known that HII nuclei are rarer in early-type galaxies than in later ones. (4) Correcting this morphological bias to the HCG sample, we find that there is no statistically significant difference in the frequency of occurrence of emission-line galaxies between the HCGs and the field. This implies that the dense galaxy environment in the HCGs does not affect triggering both the nuclear activity and the nuclear starburst. We discuss some implications on the nuclear activity in the HCG galaxies.