Outskirts of Galaxy Clusters: Intense Life in the Suburbs
Proceedings IAU Colloquium No. 195, 2004
A. Diaferio, ed.

DOI: 10.1017/S174392130400095X

The environmental dependence of galaxy properties in the local universe: effects of local and global environment

M. Tanaka[1], T. Goto[1,2], S. Okamura[1], K. Shimasaku[1] and J. Brinkman[3]

[1]Department of Astronomy, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan email: tanaka@astron.s.u-tokyo.ac.jp

[2]Department of Physics and Astronomy, Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218-2686, USA

[3]Apache Point Observatory, P.O. Box 59, Sunspot, NM 88349, USA

Abstract. We investigate the environmental dependence of galaxy properties in the local universe based on the data of the Sloan Digital Sky Survey. We focus on how star formation and morphology of galaxies correlate with luminosity, local environment, and global environment. We find that galaxy properties abruptly change at a critical local density of $\log \Sigma_{\rm crit} \sim 0.4$ galaxies h_{75}^2 Mpc^{-2}. The 'break' at the critical density is found only for faint galaxies ($M_r^* + 1 < M_r < M_r^* + 2$). Bright galaxies ($M_r < M_r^* + 1$) show no break. That is, the star formation-density and the morphology-density relations depend on galaxy luminosity. Next, we focus on global environment, i.e., richness of galaxy groups and clusters. Most galaxies are not forming stars in groups as poor as $\sigma \sim 200$ km s^{-1}. This fact suggests that environmental mechanisms that are effective only in rich clusters, such as ram-pressure stripping of cold gas and harassment, have not played a major role in suppressing galaxy star formation. Our results may suggest that evolution of bright galaxies is not strongly related to galaxy systems such as groups and clusters. On the other hand, evolution of faint galaxies may have a close connection.

1. Introduction

It has been widely known that galaxy properties such as star formation and morphology depend on environment (e.g., Dressler 1980). However, it is still unknown how such dependences are established behind galaxy evolution. To further investigate the environmental dependences, we construct a volume-limited sample based on the data of the SDSS (York et al. 2000; Abazajian et al. 2003), and perform a detailed analysis of galaxy properties as a function of local environment and global environment. We define the volume-limited sample as $0.030 < z < 0.065$ and $M_r < M_r^* + 2$ $(= -19.4)$. In what follows, we refer to galaxies with $M_r < M_r^* + 1$ as *bright galaxies* and to those with $M_r^* + 1 < M_r < M_r^* + 2$ as *faint galaxies*. We assume a flat universe with $\Omega_M = 0.3,\ \Omega_\Lambda = 0.7$ and $H_0 = 75$ km s^{-1} Mpc^{-1}.

2. Dependence on local environment

We define local environment by projected local galaxy density which is measured from a projected distance to the 5^{th} nearest galaxy within a redshift sheet of ± 1000 km s^{-1} from the galaxy in question. We characterize star formation and morphology of galaxies by EW(Hα) and the bulge to total luminosity ratio (B/T). Figure 1 shows the star formation-density and the morphology-density relations. It can be observed that faint

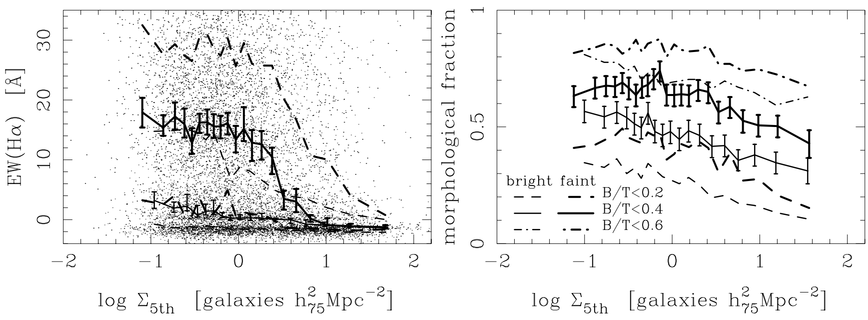

Figure 1. The thin and thick lines represent bright and faint galaxies, respectively. **Left:** EW(Hα) plotted against local density. The solid and dashed lines show the median and the quartiles (25% and 75%) of the distribution. The error bars show bootstrap 90% percentile intervals. **Right:** Morphological fractions ($B/T < 0.2,\ 0.4$, and 0.6) plotted against local density. The error bars are bootstrap 90% intervals.

galaxies show a 'break' at $\log \Sigma_{5\mathrm{th}} \sim 0.4$ galaxies h_{75}^2 Mpc^{-2} ($\Sigma_{5\mathrm{th}} \sim 2.5$). Below the break, star formation and morphology of faint galaxies do not depend on local density, and faint galaxies show more active star formation and later morphological types than bright galaxies. But, above the break, faint galaxies show weaker star formation and earlier morphological types. In contrast to faint galaxies, bright galaxies show no break, and their properties smoothly change with local density. It is interesting to note that the difference between the star formation activities of bright and faint galaxies becomes small above the break, but the difference in morphology is not strongly dependent on local density. This suggests that star formation and morphology are partly independent quantities.

3. Dependence on global environment

Next, we focus on global environment, i.e., richness of galaxy systems. We identify galaxy groups and clusters via the friends-of-friends algorithm (Huchra & Geller 1982), and measure their velocity dispersions, which are used to characterize richness of galaxy systems. In Figure 2, we plot EW(Hα) against the velocity dispersion. Star formation of bright galaxies do not show any correlation with system richness, and most of the bright galaxies are not forming stars. As for faint galaxies, we find that the median star formation activity is extremely weak in $\sigma > 200$ km s^{-1} systems. It should be noted that the median star formation activity is weak even in systems as poor as $\sigma \sim 100$ km s^{-1} compared with that of field galaxies.

4. Discussion

There are several environmental mechanisms favored in the literature that are expected to transform galaxies into red early-type galaxies. Our finding in §3 suggests that environmental mechanisms that are effective only in rich systems, such as ram-pressure stripping of cold gas (Gunn & Gott 1972) and harassment (Moore et al. 1996), have not played a major role since the dominant galaxy population in poor systems cannot be fully explained by them. Galaxy-galaxy interactions (e.g., Mihos & Hernquist 1996) and strangulation (Larson, Tinsley & Caldwell 1980) are remained to be fascinating candidates since they are expected to be effective in poor systems and/or in the field.

Let us consider implications of our findings in §2. Since the critical density corresponds to *outskirts of galaxy systems* (e.g., Gómez et al. 2003), one possible interpretation of the

https://doi.org/10.1017/S174392130400095X Published online by Cambridge University Press

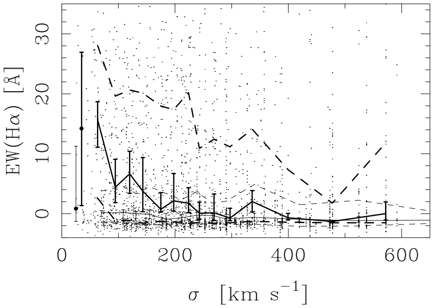

Figure 2. EW(Hα) plotted against velocity dispersion of galaxy systems. The leftmost points and the associated error bars show the median and the quartiles of the distribution of field galaxies. The meanings of the other lines are the same as of the left panel of Figure 1.

fact that faint galaxies show the break at the critical density is that faint galaxies are affected by galaxy systems. That is, evolution of faint galaxies may be closely related to galaxy systems. On the other hand, bright galaxies show no clear break at the critical density and their evolution may not have a strong connection with galaxy systems.

Acknowledgements

Funding for the creation and distribution of the SDSS Archive has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the U.S. Department of Energy, the Japanese Monbukagakusho, and the Max Planck Society. The SDSS Web site is http://www.sdss.org/.

The SDSS is managed by the Astrophysical Research Consortium (ARC) for the Participating Institutions. The Participating Institutions are The University of Chicago, Fermilab, the Institute for Advanced Study, the Japan Participation Group, The Johns Hopkins University, Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, University of Pittsburgh, Princeton University, the United States Naval Observatory, and the University of Washington.

References

Abazajian, K., et al., 2003, AJ, **126**, 2081
Dressler, A., 1980, ApJ, **236**, 351
Gómez, P. L., et al., 2003, ApJ, **584**, 210
Gunn, J. E. & Gott, J.R.III, 1972, ApJ, **176**, 1
Huchra, J. P. & Geller, M. J., 1982, ApJ, **257**, 423
Larson, R. B., Tinsley, B. M., & Caldwell, C. N., 1980, ApJ, **237**, 692
Mihos, J. C., & Hernquist, L., 1996, ApJ, **464**, 641
Moore, B., Katz, N., Lake, G., Dressler, A., & Oemler, A., 1996, Nature, **379**, 613
York, D. G., et al., 2000, AJ, **120**, 1579

https://doi.org/10.1017/S174392130400095X Published online by Cambridge University Press