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MORPHOLOGICAL EVOLUTION OF CLUSTER GALAXIES

T. Okamoto[1] and M. Nagashima[2]

RESUMEN

Investigamos los efectos ambientales sobre la evolución morfológica de galaxias brillantes ($L > L_*$) en cúmulos, en un universo de materia oscura fría dominado por Λ, usando una combinación de simulaciones de N cuerpos y modelos semianalíticos. Normalizamos nuestros parámetros para reproducir las propiedades de las galaxias locales y luego estudiamos cómo la pérdida de masa por presión de encuentro (RPS) y los pequeños brotes estelares inducidos por una fusión pequeña afectan a la morfología de las galaxias en el cúmulo. Encontramos que la fracción morfólogica de galaxias con razones intermedias entre la luminosidad del bulbo y la total (B/Ts) no puede reproducirse, y que el efecto de la pérdida por RPS es despreciable, a menos que se considere el pequeño brote estelar.

ABSTRACT

We investigate environmental effects on morphology evolution of bright cluster galaxies ($L > L_*$) in a Λ-dominated cold dark matter universe using a combination of N-body simulations and semi-analytic (SA) model. We normalize our model parameters to reproduce the properties of local galaxies, and then we study how ram pressure stripping (RPS) and small starburst triggered by a minor merger (minor burst) affect the morphologies of cluster galaxies. We find that the morphological fraction of galaxies with intermediate bulge-to-total luminosity ratios (B/Ts) cannot be reproduced and the effect of the RPS is negligible unless we consider the minor burst.

Key Words: **GALAXIES: FORMATION — GALAXIES: EVOLUTION — GALAXIES: INTERACTIONS**

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1. INTRODUCTION

It has been found that galaxy morphology is a function of environment (Dressler 1980; Whitmore et al. 1993) and redshift (Dressler et al. 1997). Several mechanisms that may transform one morphological type into another have been proposed.

There are two mechanisms that have already been incorporated in SA work. One is the major mergers. N-body simulations confirmed that major mergers between disk galaxies produce galaxies resembling ellipticals as merger remnants (Barnes 1996). Another is the truncation of star formation through the removal of hot gas reservoir (Larson et al. 1980). In clusters, any hot diffuse material originally trapped in the potentials of the galactic halos becomes part of the ICM, and then the galaxy slowly exhausts its cold gas in a few gigayears. Although such processes are important ingredients in the success of SA models (e.g. Baugh et al. 1996; Kauffmann 1996), it has been suggested that S0 population in clusters cannot be understood only by these processes (Okamoto & Nagashima 2001; Diaferio et al. 2001).

In order to resolve this problem, we here consider two additional processes, minor burst and RPS of cold gas from a galactic disk. The former gradually develops a bulge to a disk-dominated galaxy (Walker et al. 1996) and the latter increases the B/T by the fading of the disk (Gunn & Gott 1972). Accordingly, it is expected that the number of galaxies with intermediate B/Ts is increased at the cluster center by these processes. Since we only discuss the bright galaxies here, we do not consider the galaxy harassment that is probably not important for the evolution of B/Ts of such bright galaxies (Moore et al. 1999).

2. RESULTS & DISCUSSION

To clarify the effect of the RPS and minor burst, we here examine 4 models. The model in which we do not consider either the RPS nor the minor burst is called the *standard* model, because this is the normal prescription in the SA models. The model with the RPS and the model with the minor burst are referred as the *RPS* model and the *minor burst* model, respectively. The last model has both the RPS and the minor burst and it dubbed the *minor burst + RPS* model.

We compare our simulated cluster at $z = 0.2$ to an observed sample that is constructed by superposing 7 low redshift CNOC1 (Yee et al. 1996) clusters ($0.18 < z < 0.3$). To compare our results with observations, we rescale our simulated cluster and the

[1]Dept. of Physics, U. Durham, UK.
[2]NAO, Japan

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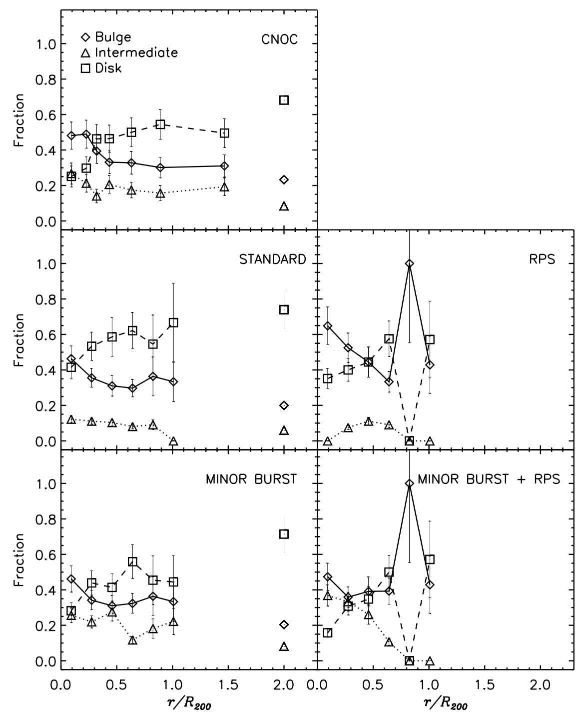

Fig. 1. The morphological fractions are plotted as a function of projected radius. The diamonds, triangles, and squares indicate the bulge-dominated, intermediate, and disk-dominated fractions, respectively. The symbols at $r/R_{200} = 2$ indicate the fractions in the field in each panel.

CNOC1 clusters by R_{200} which is the radius of the sphere centered on the cluster center and whose density is 200 times the critical density of the universe at a given redshift.

According to Diaferio et al. (2001), we classify the galaxies into three classes: a bulge-dominated class, a disk-dominated class, and an intermediate class based on their B/Ts. The observed data are taken from Diaferio et al. (2001) in which the galaxies with $M_R < -20.5$ are classified based on r-band B/T. We classify our model galaxies with $M_R < -20.5$ based on B-band B/T and choose the threshold values so that the morphological fractions in the field environment agree with the CNOC sample.

The morphological fractions are shown in Figure 1 as a function of projected cluster centric radius. By comparison of the CNOC sample with the standard model, it is confirmed that the intermediate fraction in the model is much smaller than the observed one, while the bulge-dominated fraction agrees with the observation. When we consider the RPS, although the bulge-dominated/disk-dominated fraction is increased/decreased, the intermediate fraction is still too small and it is even decreased at the center. It is because most of the disk-dominated galaxies are almost pure disk galaxies, and then the RPS simply darkens these galaxies rather than increasing their B/Ts. Furthermore, the intermediate galaxies with relatively large bulges change their morphology into bulge-dominated by RPS. The minor burst increases the intermediate fraction without changing the bulge-dominated fraction. As a result, this model reproduces the observation quite well. Now, disk-dominated galaxies tend to be non-pure disks. Consequently, RPS can change their B/Ts by fading of their disks, and then the intermediate fraction increases toward the center in the minor burst + RPS model.

In this paper, we show the importance of the minor burst in the morphology evolution and the RPS is not a negligible effect when the minor burst is considered.

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T. Okamoto: Physics Dept., Durham University , Durham DH1 3LE, UK (takashi.okamoto@durham.ac.uk).
M. Nagashima: National Astronomical Observatory, Mitaka, Tokyo 181-8588, Japan (masa@th.nao.ac.jp).