АСТРОФИЗИКА

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ENVIRONMENTAL DEPENDENCE OF OTHER PROPERTIES OF MAIN GALAXIES AT FIXED LUMINOSITY

XIN-FA DENG, YONG XIN, CHENG-HONG LUO, PING WU

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Using three volume-limited samples of the Sloan Digital Sky Survey Data Release 6 (SDSS DR6), we have investigated how other properties of galaxies depend on the environment at fixed luminosity. At fixed luminosity, we still observe strong environmental dependence of $g-r$ color, concentration index and morphology of galaxies: red, highly concentrated and early type galaxies exist preferentially in the densest regions of the universe, while blue, lowly concentrated and late type galaxies are located preferentially in low density regions. This shows that luminosity is not fundamental in correlations between galaxy properties and the environment.

Key words: *galaxies:fundamental parameters - galaxies:statistics*

1. *Introduction.* In the past, correlations between galaxy properties and the environment were widely studied [1-33] to explore which parameter is fundamental in correlations between galaxy properties and the environment. For example, to disentangle the dependence of morphology and color on the environment, Skibba et al. [34] analysed the environmental dependence of galaxy color at fixed morphology and the environmental dependence of galaxy morphology at fixed color. It was found that at fixed morphology, galaxy colors are correlated with the environment, but the correlations between morphology and environment are extremely weak at fixed color. Thus, Skibba et al. [34] concluded that much of the morphology-density relation is due to the relation between color and density.

Luminosity is an important galaxy parameter. Naturally, we want to know whether luminosity is fundamental in correlations between galaxy properties and the environment. Deng et al. [26] analysed the dependence of luminosity and $g-r$ color on the environment at a given galaxy morphology and found that the local density dependence of luminosity in the early-type sample and the late-type sample is much weaker than that obtained in the volume-limited Main galaxy sample [24], which suggests that the dependence of luminosity on the local environment is mainly due to the dependence of galaxy morphologies on the local environment and the correlation between morphologies and luminosity. Deng et al. [22] also showed that at fixed color, the environmental dependence of galaxy luminosity is greatly decreased. These studies at least show that luminosity is not fundamental in correlations between galaxy properties and the environment. However, there are also some controversial results. Balogh et al. [13] showed that at fixed luminosity the mean color of blue galaxies or red galaxies is nearly independent of the environment. Blanton et al. [17] claimed that at fixed luminosity and color, density is not closely related to surface brightness or to sérsic index-measure of galaxy structure. When morphology and luminosity are fixed, Park et al. [29] also found that other physical properties, such as color, color-gradient, concentration, size, velocity dispersion and star formation rate, are nearly independent of the local density. These studies seemingly showed that luminosity possibely is a fundamental parameter in correlations between galaxy properties and the environment.

But it is noteworthy that the mean value of galaxy properties are insensitive to the environment [24]. Deng et al. [24] compared distributions of basic galaxy properties in the lowest density regime with those in the densest regime, and found that the subsample at low density has a higher proportion of faint, blue and late type galaxies and a lower proportion of luminous, red and early type galaxies than the subsample at high density, but there is no significant difference between the mean properties of two subsamples ($< 1\sigma$). Thus, we believe preferentially that the result of Balogh et al. [13] may be due to using a statistically incorrect method. Due to tight correlations between galaxy properties, when fixing two parameters, other parameters may be limited in a fairly small region, thus it is not surprising that there are no correlations between other parameters and the local density. May be, when exploring which parameter is fundamental in correlations between galaxy properties and the environment, we should only fix a parameter, not two ones. In this paper, we construct a series of volume-limited samples defined by absolute magnitude bins and redshift limits, use the method of Deng et al. [24] and investigate how other properties of galaxies depend on the environment at fixed luminosity.

Our paper is organized as follows. In section 2 we describe the data used. The dependence of other galaxy properties on the environment at fixed luminosity in section 3. Our main results and conclusions are summarized in section 4.

In calculating the distance we used a cosmological model with a matter density $\Omega_0 = 0.3$, cosmological constant $\Omega_\Lambda = 0.7$, Hubble's constant $H_0 = 70$ km s^{-1} Mpc^{-1}.

2. *Data*. Many of survey properties of the SDSS were discussed in detail in the Early Data Release paper (Stoughton et al. [35]). In this study we use the Main galaxy sample (Strauss et al. [36]) of the SDSS Data Release 6 (Adelman-McCarthy et al. [37]).

From the flux-limited Main galaxy sample in the redshift region

$0.02 \leq z \leq 0.2$, Deng et al. [38] constructed three volume-limited samples with different luminosity, labeled S1 to S3. The definitions for all samples are summarized in Table1. In this study, we still use these three volume-limited samples.

Table1

VOLUME-LIMITED SAMPLES

Name	Absolute Magnitude	Redshift	Number of galaxies
S1	$-19.5 > M_r > -20.5$	$0.02 < z < 0.0672$	43674
S2	$-20.5 > M_r > -21.5$	$0.02 < z < 0.1023$	89549
S3	$-21.5 > M_r > -22.5$	$0.02 < z < 0.1528$	87392

3. ***The dependence of other galaxy properties on the environment at fixed luminosity.*** In this paper we only measure the three-dimensional local density in a comoving sphere with a radius of the distance to the 5th nearest galaxy for each galaxy (e.g., Deng et al. [24,39]). Like Deng et al. [24] did, we arrange galaxies in a density order from the smallest to the largest, select about 5% galaxies and construct two subsamples at both extremes of density according to the density for each sample.

R_{50} and R_{90} are the radii enclosing 50% and 90% of the Petrosian flux, respectively. In this study, we use the concentration index $ci = R_{90}/R_{50}$ as a structural parameter. Fig.1-3 show the observed $g-r$ color and concentration index ci distributions at both extremes of density for S1-S3. Deng et al. [24] found that the subsample at low density has a higher proportion of faint, blue and late type galaxies and a lower proportion of luminous, red and early type galaxies than the subsample at high density. Deng et al. [25] also showed that

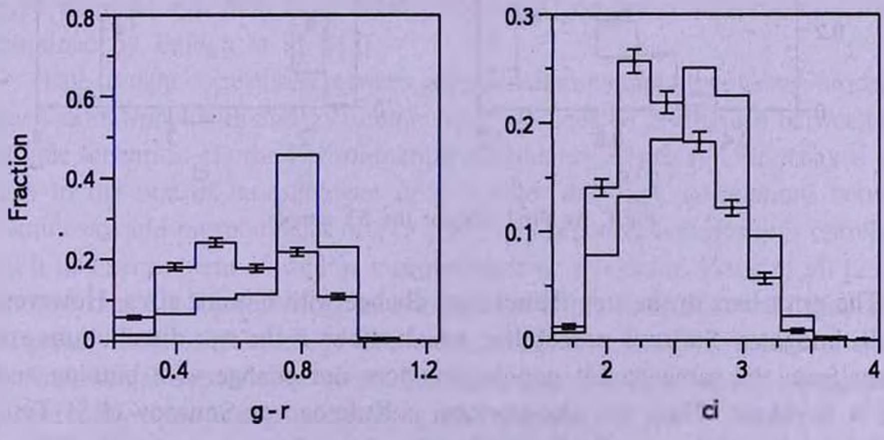

Fig.1. The $g-r$ color (left panel) and ci (right panel) distributions at both extremes of density for the S1 sample: red line for the subsample at low density, blue line for the subsample at high density. The error bars for the subsample at low density are 1σ Poissonian errors. Error bars for the subsample at high density are omitted for clarity.

luminous, red, highly concentrated and early type galaxies exist preferentially in the densest regions of the universe, while faint, blue, lowly concentrated and late type galaxies are located preferentially in low density regions. In Fig.1-3, we still observe fairly strong environmental dependence of $g-r$ color and concentration index of galaxies at fixed luminosity: red, highly concentrated galaxies exist preferentially in the densest regions of the universe, while blue, lowly concentrated galaxies are located preferentially in low density regions.

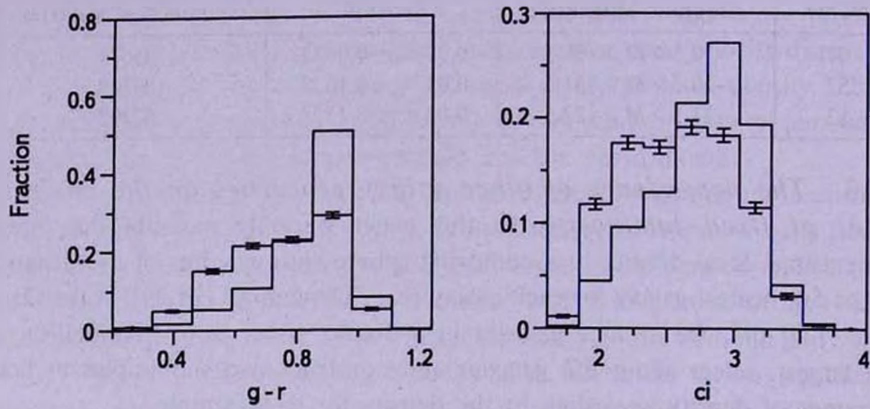

Fig.2. As Fig.1 but for the S2 sample.

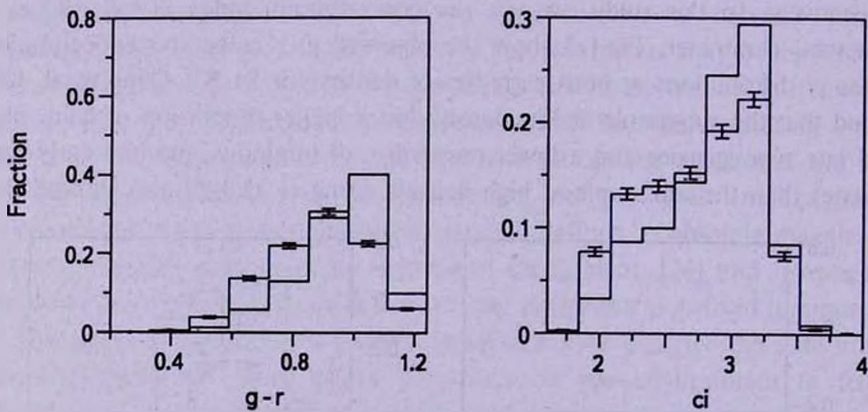

Fig.3. As Fig.1 but for the S3 sample.

The error bars in the step figures may change with binning sizes. However, the Kolmogorov-Smirnov probability, which shows if the two distributions are drawn from the same parent population, does not change with binning and thus it is robust. Thus, we also perform a Kolmogorov-Smirnov (KS) Test. The probability of the two distributions coming from the same parent distribution is listed in Table 2. The KS Test is in good agreement with the conclusion obtained by the step figures. As seen from this table, in three volume-limited samples with different luminosity, KS probabilities of $g-r$ color and concentration index ci nearly is 0, which shows that in three volume-limited samples with different luminosity, two distributions of $g-r$ color and concentration index ci at both extremes of density completely differ. This further shows that strong environmental dependence of $g-r$ color and concentration index of galaxies at fixed luminosity.

Table 2

KS PROBABILITIES OF $g-r$ COLOR AND CONCENTRATION INDEX ci THAT TWO SUBSAMPLES AT BOTH EXTREMES OF DENSITY ARE DRAWN FROM THE SAME DISTRIBUTION

The sample	$P(g-r$ color)	$P(ci)$
S1	0	0
S2	0	0
S3	0	5.49e-42

In this paper we use the concentration index $ci = R_{90}/R_{50}$ to separate early-type ($ci \geq 2.86$) galaxies from late-type ($ci < 2.86$) galaxies [40,41]. Many different parameters, such as color, star formation rate and concentration index, ever were used as the morphology classification tool (e.g., [40,31,42-45]. As indicated as Deng et al. [26], the concentration parameter is a good and simple morphological parameter. We compute the early-type fraction of two subsamples at both extremes of density for each sample: for the S1 sample 15.2% at low density and 28.1% at high density; for the S2 sample 28.8% at low density and 44.6% at high density; for the S3 sample 45.7% at low density and 59.2% at high density. In all samples we find the expected trend of increasing early type fraction with increasing density, which is consistent with the conclusion obtained by Balogh et al. [13].

Due to tight correlations between galaxy luminosity and other galaxy properties such as morphologies and $g-r$ color, here, we need to distinguish between two simple scenarios: (1) the environmental dependence of galaxy luminosity is only due to the one of morphologies or $g-r$ color and tight correlations between luminosity and morphologies or $g-r$ color; or (2) galaxy luminosity is correlated with its environment as well as morphologies or $g-r$ color. Deng et al. [26,27] showed that when morphology or color are fixed, the environmental dependence of galaxy luminosity is greatly decreased, while in this study we observe strong environmental dependence of morphologies and $g-r$ color at fixed luminosity. Apparently, these results support the first scenario.

Between the sample fainter than M_r^* (S1) and ones brighter than M_r^* (S2 and S3), we do not observe significant statistical difference, which is consistent with the conclusion obtained by Deng et al. [46]. Deng et al. [46]

constructed two volume-limited samples above and below the value of M_r^*, and found that the galaxy luminosity strongly depend on local environment only for galaxies brighter than M_r^*, but this dependence is very weak for galaxies fainter than M_r^*. Deng et al. [46] also noted that $g-r$ color, concentration index ci and galaxy morphologies strongly depend on local environment for all galaxies with different luminosities. This shows that M_r^* is an characteristic parameter only for the environmental dependence of galaxy luminosity.

In Fig.1-3 we also note that more luminous galaxies are redder, highly concentrated and preferentially " early type", which is in qualitative agreement with previous work [6,32].

4. *Summary*. Using three volume-limited samples with luminosity bins $-19.5 > M_r > -20.5$, $-20.5 > M_r > -21.5$, $-21.5 > M_r > -22.5$, we have investigated how other properties of galaxies depend on the environment at fixed luminosity. For each sample, we measure the local three-dimensional galaxy density in a comoving sphere with a radius of the distance to the 5th nearest galaxy for each galaxy, select about 5% galaxies and construct two subsamples at both extremes of density. It is found that at fixed luminosity, red, highly concentrated and early type galaxies exist preferentially in the densest regions of the universe, while blue, lowly concentrated and late type galaxies are located preferentially in low density regions. We note that such a trend exists in all samples. This shows that luminosity is not fundamental in correlations between galaxy properties and the environment. In addition, our study further shows that more luminous galaxies are redder, highly concentrated and preferentially "early type".

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School of Science, Nanchang University, Jiangxi,
China, e-mail: xinfadeng@yahoo.com.cn

ЗАВИСИМОСТЬ ОТ ОКРУЖЕНИЯ РАЗНЫХ ОСОБЕННОСТЕЙ ГАЛАКТИК ПРИ ФИКСИРОВАННОЙ СВЕТИМОСТИ

ХИН-ФА ДЕНГ, ИОНГ ХИН, ЧЕНГ-ХОНГ ЛУО, ПИНГ ВУ

Используя три пространственно ограниченных обзора Sloan Digital Sky Survey Data Release 6 (SDSS DR 6), мы исследовали вопрос о том, как разные особенности галактик зависят от окружения при фиксированной светимости. При фиксированной светимости мы наблюдаем сильную зависимость от окружения показателя цвета $g-r$, индекса концентрации и морфологии галактик: красные, сильно концентрированные и раннего типа галактики в основном находятся в плотных областях Вселенной, между тем голубые, менее концентрированные и позднего типа галактики предпочитают находиться в областях низкой плотности. Это показывает, что светимость не является фундаментальным параметром в зависимостях между особенностями галактик и их окружением.

Ключевые слова: *галактики:фундаментальные параметры - галактики: статистика*

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