АСТРОФИЗИКА

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INVESTIGATION OF THE CORRELATION BETWEEN MORPHOLOGY AND LUMINOSITY FOR TWO CLASSES OF MAIN GALAXIES

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Using an apparent-magnitude limited Main galaxy sample of the Sloan Digital Sky Survey Data Release 7(SDSS DR7), we investigate the correlation between morphologies and luminosity for the Main galaxy sample. Our Main galaxy sample is divided into two classes: Main galaxies only with TARGET_GALAXY flag (bestPrimtarget = 64), and ones also with other flags. It is found that for the second class Main galaxies, the early-type proportion monotonously increases with increasing luminosity nearly in the whole luminosity region. But for the first class Main galaxies, the early-type proportion increases with increasing luminosity only within certain luminosity region($-22.2 < M_r < -19.8$). In high luminosity region ($M_r < -22.2$), the early-type proportion of the first class Main galaxies even decreases dramatically with increasing luminosity. We also analyse the correlation between morphologies and luminosity of galaxies around the peak of the redshift distribution ($0.07 \le z \le 0.08$). In such a narrow redshift region, we still observe strong correlation between morphologies and luminosity, which shows that this correlation is fundamental.

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

1. *Introduction*. It has long been known that there are strong correlations among physical properties of galaxies. For example, the types of galaxies correlate with colors [1-3]. The study of Strateva et al. [3] indicated that the blue galaxies are indeed dominated by late types while the red galaxies are dominated by early types. Galaxy colors also depend strongly on luminosity, in the sense that more luminous galaxies are redder [4-20]. The correlation between morphological types and luminosity of galaxies is that high-luminosity galaxies are preferentially "early types" and that the late (early) type fraction decreases (increases) strongly with increasing luminosity [21-24].

As one of the most ambitious and influential surveys in the history of astronomy, the Sloan Digital Sky Survey (SDSS) undoubtedly provides a fairly perfect sample for the study of correlations among physical properties of galaxies.The SDSS galaxy data contains two interesting samples: the MAIN Galaxy sample [25] and the Luminous Red Galaxy (LRG) sample [26], which are selected by different algorithms. The Main Galaxy sample has a median redshift of 0.10 and few galaxies beyond $z = 0.25$, while the LRG sample is located at higher redshift and contains intrinsically red galaxies. Deng et al.

[27] investigated the correlations among color, morphologies and luminosity for the Luminous Red Galaxy (LRG) sample of the SDSS Data Release 5(Adelman-McCarthy et al. [28]), which contains cut I LRGs, cut II LRGs and Main galaxies that are also classified as LRGs. It was found that the morphologies of LRGs are tightly correlated with luminosity. But Deng et al. [27] showed this correlation is rather complicated. At low luminosity region $M_g > -22$, the proportion of early-type galaxies increases with increasing luminosity. At high luminosity region $M_g < -22$, early type fraction decreases strongly with increasing luminosity for cut I LRGs and Main galaxies-especially for Main galaxies, but early type fraction for cut II LRGs still increases strongly with increasing luminosity. Deng et al. [29] also found that the correlation between morphological types and luminosity of Main galaxies does not present single tendency: only within certain luminosity region, the early-type proportion increases with increasing luminosity. Within low luminosity region, it is almost constant except the u-band luminosity. For the u-band, this proportion even decreases with increasing luminosity in low luminosity region. Within very high luminosity region, the early-type proportion decreases with increasing luminosity-especially for the u-band luminosity, which is in qualitative agreement with results found by Blanton et al. [21]. Blanton et al. indicated that the reddest galaxies (according to the correlation between color and luminosity, these galaxies are also the most luminous galaxies) are in optical colors exponential galaxies (S'ersic index $n < 1.5$), not concentrated galaxies (S'ersic index $n > 3$).

The Main galaxies should be selected by "where (bestPrimtarget & 64) > 0 or (bestPrimtarget & 128) > 0 or (bestPrimtarget & 256) > 0", in which the most are with SDSS flag: bestPrimtarget & 64 > 0. In the final data release of SDSS; SDSS DR7(Abazajian et al. [30]), about 99.96% Main galaxies are with SDSS flag: bestPrimtarget & 64 > 0. Thus, when constructing the Main galaxy sample, Main galaxies with flag: bestPrimtarget & 128 > 0 or bestPrimtarget & 256 > 0 can be neglected. But Main galaxies with SDSS flag: bestPrimtarget & 64 > 0 also contain two classes: Main galaxies only with TARGET_GALAXY flag (bestPrimtarget = 64); ones also with other flags. We note that the Main galaxy sample of Deng et al. [29] only included the first class (bestPrimtarget = 64). Undoubtedly, such a study has major drawback. In this study, we use the Main galaxy sample with SDSS flag: bestPrimtarget & 64 > 0, divide this sample into two classes: Main galaxies only with TARGET_GALAXY flag (bestPrimtarget = 64); ones also with other flags, and respectively investigate the correlation between morphologies and luminosity for two classes of Mian galaxies.

Our paper is organized as follows. In section 2, we describe the data used. The correlation between morphologies and luminosity for the Main galaxy sample are discussed 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 $\Omega_\Lambda = 0.7$ and Hubble constant $H_0 = 100\,h$ km s^{-1} Mpc^{-1} with $h = 0.7$.

2. *Data*. Many of survey properties of the SDSS were discussed in detail in the Early Data Release paper (Stoughton et al. [31]). Galaxy spectroscopic targets were selected by two algorithms. The Main galaxy sample [25] comprises galaxies brighter than $r_{petro} < 17.77$ (r-band apparent Petrosian magnitude). The Luminous Red Galaxy (LRG) algorithm [26] selects galaxies to $r_{petro} < 19.5$ that are likely to be luminous early-types, based on the observed colors. In our work, the data were downloaded from the Catalog Archive Server of SDSS Data Release 7 (Abazajian et al. [30]) by the SDSS SQL Search (with SDSS flag: bestPrimtarget & 64 > 0) with high-confidence redshifts ($Z_{warning} \neq 16$ and $Z_{status} \neq 0$, 1 and redshift confidence level: $z_{conf} > 0.95$) (http://www.sdss.org/dr7/). From this sample, we select 565029 Main galaxies in the redshift region $0.02 \le z \le 0.2$, in which there are 479806 the first class Main galaxies (only with TARGET_GALAXY flag) and 85223 the second class ones (also with other flags). We note that 88.90% of the second class ones are Main galaxies which are also classified as LRGs.

3. *The correlation between morphological type and luminosity for the Main galaxy sample*. In this study, the absolute magnitude M_r is calculated from the r-band apparent Petrosian magnitude, using a polynomial fit formula (Park et al. [32]) for the mean K-correction (K-correcting to the $^{0.1}r$ band) (Blanton et al. [33]) within $0 < z < 0.3$:

$$K_{0.1r}(z) = 2.3537(z-0.1)^2 + 1.04423(z-0.1) - 2.5\log(1+0.1).$$

R_{50} and R_{90} are the radii enclosing 50% and 90% of the Petrosian flux, respectively. We use the concentration index $c_i = R_{90}/R_{50}$ to separate early-type ($c_i \ge 2.86$) galaxies from late-type ($c_i < 2.86$) galaxies (Shimasaku et al. [34], Nakamura et al. [35]). We note that some authors developed different methods or used other parameters, such as color, star formation rate indicators as the morphology classification tool (e.g., Shimasaku et al. [34]; Strateva et al. [3]; Abraham, van den Bergh & Nair [36]; Park & Choi [37]; Yamauchi et al. [38]; Sorrentino et al. [39]). Deng et al. [40] claimed that the concentration parameter is a good and simple morphological parameter.

Fig.1 shows the fraction of early-type galaxies in different luminosity bins for two classes of Main galaxies. As seen from this figure, the early-type proportion monotonously increases with increasing luminosity nearly in the whole luminosity region for the second class Main galaxies. But we still observe that for the first class Main galaxies (bestPrimtarget = 64), the early-type proportion increases with increasing luminosity only within certain luminosity region ($-22.2 < M_r < -19.8$). Deng et al. [41] found that the dependence of

luminosity on local environment is mainly due to the dependence of galaxy morphologies on local environment and the correlation between morphologies and luminosity. Galaxies with different morphologies show large variations of the galaxy correlation function, with late-type galaxies having considerably weaker clustering than early-type galaxies (Davis & Geller [42]; Loveday et al. [43], Norberg et al. [44]). Thus, we can explain results obtained by Norberg et al. [45] and Zehavi et al. [46]. They showed that the clustering amplitude of the correlation function increases slowly with absolute magnitude for fainter galaxies, but rises more strongly at higher luminosities.

It is noteworthy that the early-type fraction of the second class Main galaxies is much larger than that of the first class ones nearly in the whole luminosity region, which is due to the second class Main galaxies mostly being Main galaxies which are also classified as LRGs. Fig.2 shows the luminosity distributions for two classes of Main galaxies. We note that the second class Main galaxies are more luminous. If we realize that LRGs are likely to be luminous early-types, and that the second class Main galaxies mostly are LRGs, such results are not surprising.

The Main galaxy sample is an apparent-magnitude limited sample, in which fainter galaxies are progressively missed with increasing distance from the observer. In such a sample, the fraction of galaxies should increase strongly with increasing luminosity. But in Fig.2, we note that for the most luminous galaxies, the number of the first class galaxies decrease dramatically with increasing luminosity. As seen from Fig.1, nearly in the same luminosity region, the early-type proportion of galaxies decreases with increasing luminos-

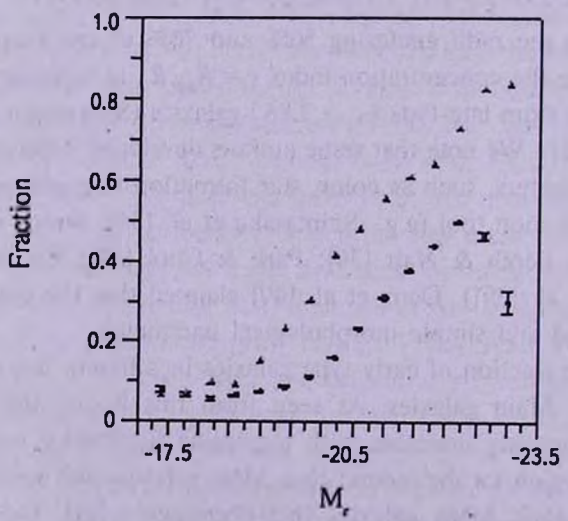

Fig.1 The fraction of early-type galaxies in different luminosity bins for two classes of Main galaxies: dots for the first class, triangles for the second class. The error bars are 1 sigma Poissonian errors for the first class.

ity. It is not clear whether such a result is due to selection effects.

As seen from Fig.7 of Deng et al. [47], the early-type proportion of galaxies

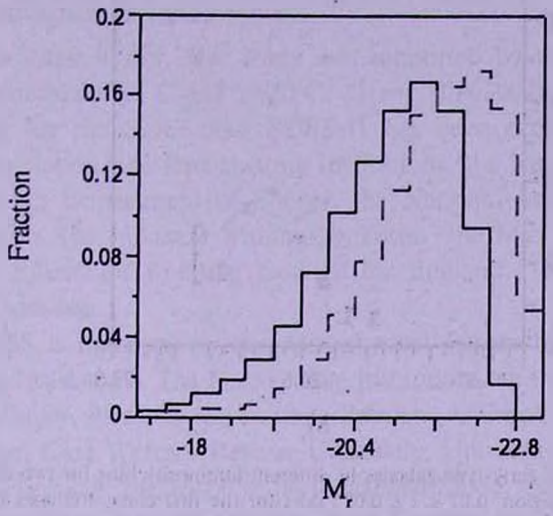

Fig.2 The luminosity distribution for two classes of Main galaxies: solid line for the first class, dashed line for the second class.

also apparently increases with redshift z. Thus, we must investigate which relation is fundamental between two correlations (the correlation between morphologies and luminosity and the one between morphologies and redshift z). Fig.3 shows the redshift distribution for two classes of Main galaxies. The peak of the redshift distribution is at about $z = 0.08$. Thus, we analyse the correlation between morphologies and luminosity of galaxies around the peak

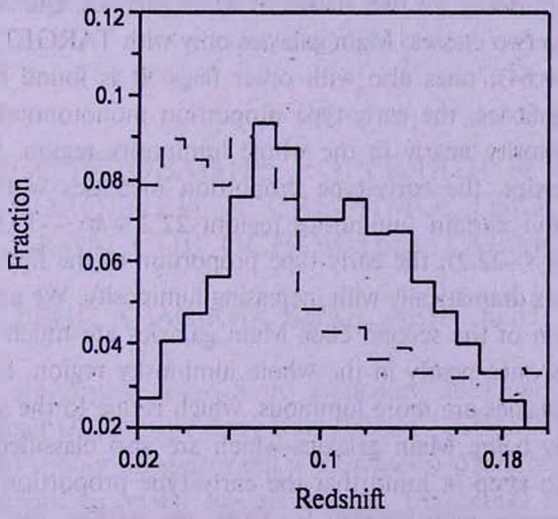

Fig.3 The redshift distribution for two classes of Main galaxies: solid line for the first class, dashed line for the second class.

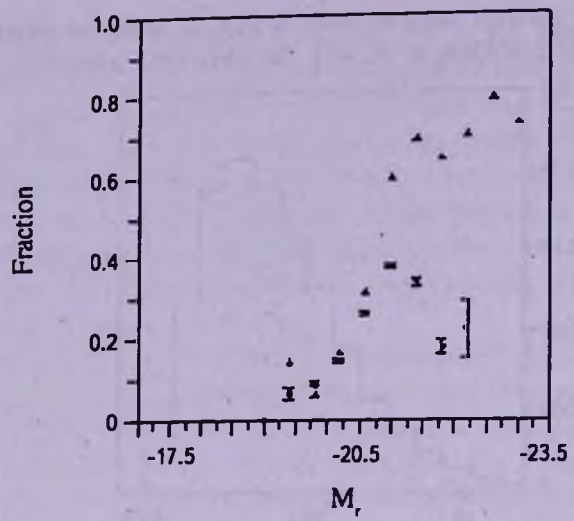

Fig.4 The fraction of early-type galaxies in different luminosity bins for two classes of Main galaxies in the redshift region $0.07 \le z \le 0.08$: dots for the first class, triangles for the second class. The error bars are 1 sigma Poissonian errors for the first class.

($0.07 \le z \le 0.08$). As seen from Fig.4, in such a narrow redshift region, the correlation between morphologies and luminosity still is rather significant, which shows that this correlation is fundamental.

4. *Summary*. It is widely accepted that high-luminosity galaxies are preferentially "early types", while faint galaxies are preferentially "late types". But we believe that the correlation between morphologies and luminosity should be rather complicated. In this work, we focus on the correlation between morphologies and luminosity for two classes of Main galaxies. Our Main galaxy sample is divided into two classes: Main galaxies only with TARGET_GALAXY flag (bestPrimtarget = 64); ones also with other flags. It is found that for the second class Main galaxies, the early-type proportion monotonously increases with increasing luminosity nearly in the whole luminosity region. But for the first class Main galaxies, the early-type proportion increases with increasing luminosity only within certain luminosity region($-22.2 < M_r < -19.8$). In high luminosity region ($M_r < -22.2$), the early-type proportion of the first class Main galaxies even decreases dramatically with increasing luminosity. We also note that the early-type fraction of the second class Main galaxies are much larger than that of the first class ones nearly in the whole luminosity region, and that the second class Main galaxies are more luminous, which is due to the second class Main galaxies mostly being Main galaxies which are also classified as LRGs.

It is important to keep in mind that the early-type proportion of galaxies also apparently increases with redshift z. Thus, we analyse the correlation between morphologies and luminosity of galaxies around the peak of the

redshift distribution ($0.07 \leq z \leq 0.08$). In such a narrow redshift region, we still observe strong correlation between morphologies and luminosity, which shows that this correlation is fundamental.

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ИССЛЕДОВАНИЕ КОРРЕЛЯЦИИ МЕЖДУ МОРФОЛОГИЕЙ И СВЕТИМОСТЬЮ ДЛЯ ДВУХ КЛАССОВ ОСНОВНЫХ ГАЛАКТИК

ХИН-ФА ДЕНГ, ХИАО-ХИА КИАН, ЧЕНГ-ХОНГ ЛУО, ПИНГ ВУ

Используя ограниченный по видимым звездным величинам обзор галактик Sloan Digital Sky Survey Data Release 7 (SDSSDR7), мы исследовали корреляцию между морфологией и светимостью для галактик обзора. Наш обзор галактик разделен на два класса. Основные галактики только с TARGET_GALAXY flag (bestPrimtarget = 64) и еще другие с другим флагом.

Найдено, что для второго класса галактик пропорция ранних типов монотонно растет с ростом светимости почти во всем диапазоне светимости. Однако для первого класса галактик, пропорция ранних типов растет с ростом светимости ($-22.2 < M_r < -19.8$). В области высокой светимости ($M_r < -22.2$) пропорция раннего типа галактик даже драматически убывает с ростом светимости. Мы также анализировали корреляцию между морфологией и светимостью галактик вокруг пика распределения красных смещений ($0.07 \le z \le 0.08$). В такой узкой области красных смещений мы все еще наблюдаем сильную корреляцию между морфологией и светимостью, показывая, что эта корреляция является фундаментальной.

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

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