The Astronomical Journal, 141:162 (4pp), 2011 May doi:10.1088/0004-6256/141/5/162
© 2011. The American Astronomical Society. All rights reserved. Printed in the U.S.A.

CORRELATION BETWEEN ENVIRONMENT AND GAS METALLICITY FOR STAR-FORMING GALAXIES IN THE MAIN GALAXY SAMPLE OF SDSS DR7

Xin-Fa Deng
School of Science, Nanchang University, Jiangxi 330031, China
Received 2010 September 1; accepted 2011 February 20; published 2011 April 5

ABSTRACT

Using two volume-limited samples of the Main Galaxy sample of the Sloan Digital Sky Survey Data Release 7 with luminosities of $-20.5 \leqslant M_r \leqslant -18.5$ and $-22.5 \leqslant M_r \leqslant -20.5$, respectively, I explore the correlation between environment and gas metallicity for star-forming galaxies. Overall, results indicate that galaxies in the lowest density regime preferentially have lower gas metallicity than galaxies in the densest regimes, and that the correlation between environment and gas metallicity is fundamental.

Key words: galaxies: fundamental parameters – galaxies: statistics

1. INTRODUCTION

The currently popular scenario of galaxy formation and evolution suggests that the environment of galaxies is a rather important factor which directly affects galaxy properties (Gunn & Gott 1972; Moore et al. 1998; Moss & Whittle 2000; Gnedin 2003). Thus, it is useful to study correlations between environment and various galaxy properties (e.g., Oemler 1974; Dressler 1980; Postman & Geller 1984; Dressler et al. 1997; Hashimoto & Oemler 1999; Fasano et al. 2000; Tran et al. 2001; Blanton et al. 2003, 2005; Goto et al. 2003; Helsdon & Ponman 2003; Hogg et al. 2003, 2004; Treu et al. 2003; Balogh et al. 2004a, 2004b; Kauffmann et al. 2004; Tanaka et al. 2004; Berlind et al. 2005; Blanton & Berlind 2007; Park et al. 2007; Schawinski et al. 2007; Thomas et al. 2010; Bamford et al. 2009; Deng et al. 2007a, 2007b, 2007c, 2007d, 2008a, 2008b, 2009a, 2009b, 2009c, 2009d, 2010; Deng & Zou 2009; Hughes & Cortese 2009; Skibba et al. 2009; Wolf et al. 2009). Typical correlations include those between environment and luminosity (Davis et al. 1988; Hamilton 1988; Park et al. 1994; Loveday et al. 1995; Norberg et al. 2001, 2002; Zehavi et al. 2002; Deng et al. 2007a, 2007c, 2008a, 2009c), environment and morphology (e.g., Dressler 1980; Postman & Geller 1984; Dressler et al. 1997; Hashimoto & Oemler 1999; Fasano et al. 2000; Tran et al. 2001; Goto et al. 2003; Helsdon & Ponman 2003; Treu et al. 2003; Deng et al. 2007b, 2007c, 2007d, 2008a, 2008b, 2009c), and environment and color (e.g.,Tanaka et al. 2004; Balogh et al. 2004b; Hogg et al. 2004; Deng et al. 2007b, 2007c, 2008a, 2008b, 2009c).

Metallicity is an important physical parameter of galaxies, which reflects the gas reprocessed by stars and any exchange of gas between the galaxy and its environment. Thus, it would be of great interest to investigate the correlation between environment and metallicity. For this purpose, in this study, I use the Main Galaxy sample of the final data release, the Sloan Digital Sky Survey Data Release 7 (SDSS DR7; Abazajian et al. 2009) and a relatively new and publicly available catalog of gas metallicity (Tremonti et al. 2004, see http://www.mpa-garching.mpg.de/SDSS/DR7/). The paper is organized as follows. In Section 2, I describe the data used. The correlation between environment and gas metallicity is discussed in Section 3. My main results and conclusions are summarized in Section 4.

In calculating the distance I used a cosmological model with a matter density of $\Omega_0 = 0.3$,cosmological constant of $\Omega_\Lambda = 0.7$, and Hubble constant of $H_0 = 100\,h\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ with $h = 0.7$.

2. DATA

Many of the survey properties of the SDSS were discussed in detail in the Early Data Release paper (Stoughton et al. 2002). Galaxy spectroscopic targets were selected by two algorithms. The Main Galaxy sample (Strauss et al. 2002) comprises galaxies brighter than $r_{\mathrm{petro}} < 17.77$ (r-band apparent Petrosian magnitude). The luminous red galaxy (LRG) algorithm (Eisenstein et al. 2001) selects galaxies to $r_{\mathrm{petro}} < 19.5$ which are likely to be luminous early types, based on the observed colors. I use the Main Galaxy sample (Strauss et al. 2002). In my work, the data were downloaded from the Catalog Archive Server of SDSS DR7 (Abazajian et al. 2009) by the SDSS SQL Search (with SDSS flag: bestPrimtarget&64 > 0) with high-confidence redshifts (Zwarning $\neq$ 16 and Zstatus $\neq$ 0,1 and redshift confidence level: zconf > 0.95) (http://www.sdss.org/dr7/).

In this study, I use two volume-limited galaxy samples constructed by Deng (2010). From the Main Galaxy sample of the SDSS DR7, Deng (2010) constructed two volume-limited samples above and below the value of M_r^*. The luminous volume-limited Main Galaxy sample contains 120,362 galaxies at $0.05 \leqslant z \leqslant 0.102$ with $-22.5 \leqslant M_r \leqslant -20.5$. The faint volume-limited sample includes 33,249 galaxies at $0.02 \leqslant z \leqslant 0.0436$ with $-20.5 \leqslant M_r \leqslant -18.5$.

Tremonti et al. (2004) derived oxygen abundances for 53,400 star-forming galaxies from the optical nebular emission lines. I obtained gas-phase metallicities from http://www.mpa-garching.mpg.de/SDSS/DR7/. The oxygen abundance estimates on this Web site are estimated using the Charlot & Longhetti (2001) model as discussed in Tremonti et al. (2004), and are only calculated for emission-line galaxies that they classified as "star forming." So, this work is limited to galaxies with ongoing star formation. In this study, the MEDIAN estimate is used. The luminous volume-limited Main Galaxy sample contains 17,946 star-forming galaxies with the oxygen abundance estimates, and the faint volume-limited Main Galaxy sample includes 18,443 star-forming galaxies. It has been known for a long time that the majority of the red population corresponds to passive objects, while the majority of the blue population corresponds to star-forming galaxies, and that red galaxies are more luminous. Deng et al. (2010) also noted that passive galaxies are more luminous, redder, highly

Table 1
Total Number of Galaxies and Number of Star-forming Galaxies with Oxygen Abundance Estimates for Two Subsamples at Both Extremes of Local Three-dimensional Density in Each Sample

Volume-limited Main Galaxy Sample	Subsamples	Total Galaxies	Number of Star-forming Galaxies
Luminous	Low density	6018	1329
	High density	6018	406
Faint	Low density	1662	1135
	High density	1662	435

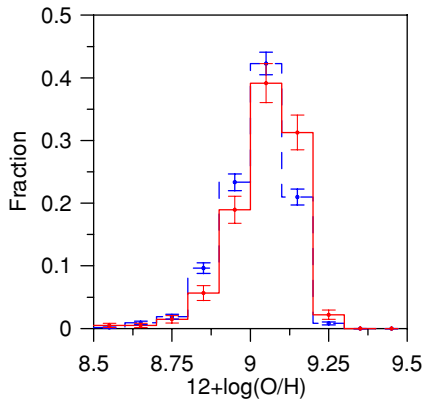

Figure 1. Gas metallicity distributions at both extremes of density for the luminous volume-limited Main Galaxy sample: the red solid line denotes the subsample at high density and the blue dashed line denotes the subsample at low density. The error bars are 1σ Poissonian errors.

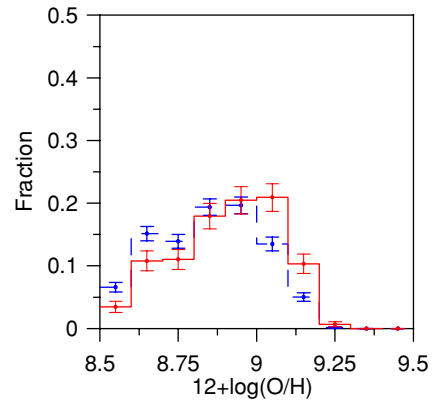

Figure 2. Gas metallicity distributions at both extremes of density for the faint volume-limited Main Galaxy sample: the red solid line denotes the subsample at high density and the blue dashed line denotes the subsample at low density. The error bars are 1σ Poissonian errors.

concentrated and preferentially "early type." Thus, it is not difficult to understand that the faint volume-limited Main Galaxy sample contains a higher proportion of star-forming galaxies.

3. ENVIRONMENTAL DEPENDENCE OF THE GAS METALLICITY IN TWO VOLUME-LIMITED SAMPLES

In this study, I compute the three-dimensional local galaxy density in a comoving sphere with a radius of the distance to the fifth nearest galaxy for each galaxy. Like Deng et al. (2008b), for each sample, I select about 5% of the galaxies (see Table 1), construct two subsamples at both extremes of density, and compare distributions of galaxy gas metallicity in the lowest density regime with those of galaxies in the densest regime.

Table 1 shows that the subsample at low density contains a higher proportion of star-forming galaxies, while the subsample at high density includes a lower proportion of star-forming galaxies. This is consistent with the conclusion obtained by other authors: dense environments contain a higher proportion of red, passive galaxies, while low-density environments contain more blue, star-forming galaxies (e.g., Dressler 1980; Poggianti et al. 1999; Lewis et al. 2002; Gómez et al. 2003).

Figure 1 shows the gas metallicity distributions at both extremes of density for the luminous volume-limited Main Galaxy sample. As seen from this figure, galaxies in the lowest density regime preferentially have lower gas metallicity than galaxies in the densest regimes. As seen from Figure 2, this trend is also seen for the faint volume-limited Main Galaxy sample.

Thomas et al. (2010) studied the environmental effect of stellar metallicity in SDSS early-type galaxies, and essentially found that there is no such effect. Deng et al. (2009a) investigated the dependence of luminosity and g–r color on environment for the early-type sample and the late-type sample, and found that at a given galaxy morphology, the environmental dependence of galaxy properties is greatly decreased. The study of Deng et al. (2009a) also showed that the environmental dependence of galaxy color in the early-type sample is much weaker than that in the late-type sample, which is consistent with the conclusion obtained by other authors (Park et al. 2007; Ball et al. 2008). Thus, it is not surprising that there is no environmental correlation between stellar metallicity and environment in SDSS early-type galaxies.

The error bars in histograms may change with binning sizes. However, the Kolmogorov–Smirnov (K-S) probability, which shows whether the two distributions are drawn from the same parent population, does not change with binning and is therefore robust, so I also perform a K-S test. The probability of the two distributions coming from the same parent distribution is 2.70×10^{-6} for the luminous volume-limited Main Galaxy sample and 3.18×10^{-8} for the faint volume-limited Main Galaxy sample, which is smaller than 0.05 (5% is the standard in a statistical analysis). This shows that a correlation between environment and gas metallicity does exist. As seen from Table 1 of Deng et al. (2009c), the K-S probability of g–r color and concentration index c_i is nearly 0, which shows that two distributions of g–r color and concentration index c_i at both extremes of density completely differ. Here, due to a certain K-S probability of gas metallicity, I conclude that the correlation between environment and gas metallicity is much weaker than that between environment and other galaxy properties.

It has been long known that a strong correlation between environment and galaxy luminosity exists (Davis et al. 1988; Hamilton 1988; Park et al. 1994; Loveday et al. 1995; Norberg et al. 2001, 2002; Zehavi et al. 2002; Deng et al. 2007a, 2007c, 2008a, 2009c). Due to a tight correlation between luminosity and gas metallicity (see Figure 4 of Tremonti et al. 2004), I need to distinguish between two simple scenarios: (1) the correlation between environment and gas metallicity is only due to the correlation between environment and galaxy luminosity

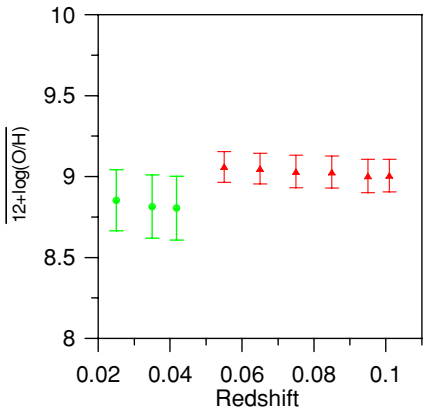

Figure 3. Mean metallicity as a function of redshift z for the luminous (red triangles) and faint (green dots) volume-limited samples. Error bars represent standard deviation in each redshift bin.

and the luminosity–gas metallicity relationship and (2) the gas metallicity of a galaxy is correlated with its environment as well as with its luminosity. Deng et al. (2009c) showed that the galaxy luminosity strongly depends on local environments for the luminous volume-limited Main Galaxy sample, but this dependence is fairly weak for the faint volume-limited Main Galaxy sample. In this study, I note that the correlation between environment and gas metallicity for the faint volume-limited Main Galaxy sample is even stronger than that for the luminous volume-limited Main Galaxy sample, so the results of this work support the second scenario.

My concern is that the metallicity is redshift-dependent. Thus, different redshift distributions of two subsamples at both extremes of density lead to the difference in metallicity distributions at both extremes of density. I divide the whole redshift region of two volume-limited samples into redshift bins with width 0.01 (the last redshift bin is 0.100–0.102 for the luminous volume-limited Main Galaxy sample, and 0.04–0.0436 for the faint volume-limited Main Galaxy sample), and calculate the mean metallicity and standard deviation in each redshift bin. Figure 3 shows the mean metallicity as a function of redshift z for two volume-limited samples. I note that in two volume-limited samples, there is almost no redshift dependence in the metallicity. In the luminous volume-limited Main Galaxy sample, the largest difference of the mean metallicity in different redshift bins is 0.63%, while in the faint volume-limited Main Galaxy sample, it is only 0.54%.

4. SUMMARY

Using two volume-limited samples of the Main Galaxy sample of SDSS DR7 with luminosities of $-20.5 \leqslant M_r \leqslant -18.5$ and $-22.5 \leqslant M_r \leqslant -20.5$, respectively, I explore the correlation between environment and gas metallicity for star-forming galaxies. Like Deng et al. (2008b), I use the three-dimensional density estimator within the distance to the fifth nearest neighbor, construct two subsamples at both extremes of density, and perform comparative studies between them for each volume-limited sample. Overall, the results indicate that galaxies in the lowest density regime preferentially have lower gas metallicity than galaxies in the densest regimes, but the correlation between environment and gas metallicity is possibly due to the correlation between environment and galaxy luminosity and the luminosity–gas metallicity relationship. Further analysis shows, however, that the gas metallicity of a galaxy is actually correlated with its environment as well as with its luminosity.

Thomas et al. (2010) claimed that there is no environmental correlation between stellar metallicity and environment in SDSS early-type galaxies, which is not consistent with my conclusion. One possible explanation for this difference is that at a given galaxy morphology, the environmental dependence of galaxy properties is greatly decreased, especially for early-type galaxies. I am also concerned that the metallicity is redshift-dependent, which leads to the difference in metallicity distributions at both extremes of density. However, Figure 3 shows that in two volume-limited samples, there is almost no redshift dependence in the metallicity.

I thank the anonymous referee for many useful comments and suggestions. This study was supported by the National Natural Science Foundation of China (NSFC, grant 10863002).

Funding for the SDSS and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the US Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web site is http://www.sdss.org.

The SDSS is managed by the Astrophysical Research Consortium for the Participating Institutions. The Participating Institutions are the American Museum of Natural History, Astrophysical Institute Potsdam, University of Basel, University of Cambridge, Case Western Reserve University, University of Chicago, Drexel University, Fermilab, the Institute for Advanced Study, the Japan Participation Group, Johns Hopkins University, the Joint Institute for Nuclear Astrophysics, the Kavli Institute for Particle Astrophysics and Cosmology, the Korean Scientist Group, the Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max Planck Institute for Astronomy (MPIA), the Max Planck Institute for Astrophysics (MPA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the US Naval Observatory, and the University of Washington.

REFERENCES

Abazajian, K., et al. 2009, ApJS, 182, 543
Ball, N. M., Loveday, J., & Brunner, R. J. 2008, MNRAS, 383, 907
Balogh, M. L., et al. 2004a, MNRAS, 348, 1355
Balogh, M. L., et al. 2004b, ApJ, 615, L101
Bamford, S. P., et al. 2009, MNRAS, 393, 1324
Berlind, A. A., et al. 2005, ApJ, 629, 625
Blanton, M. R., & Berlind, A. A. 2007, ApJ, 664, 791
Blanton, M. R., et al. 2003, ApJ, 594, 186
Blanton, M. R., et al. 2005, ApJ, 629, 143
Charlot, S., & Longhetti, M. 2001, MNRAS, 323, 887
Davis, M., et al. 1988, ApJ, 333, L9
Deng, X. F. 2010, ApJ, 721, 809
Deng, X. F., He, J. Z., & Jiang, P. 2007a, ApJ, 671, L101
Deng, X. F., He, J. Z., & Wen, X. Q. 2009a, ApJ, 693, L71
Deng, X. F., He, J. Z., & Wen, X. Q. 2009b, ApJ, 699, 948
Deng, X. F., He, J. Z., & Wen, X. Q. 2009c, MNRAS, 395, L90
Deng, X. F., He, J. Z., & Wu, P. 2008a, A&A, 484, 355
Deng, X. F., & Zou, S. Y. 2009, Astropart. Phys., 32, 129
Deng, X. F., et al. 2007b, Chin. J. Astron. Astrophys., 7, 639
Deng, X. F., et al. 2007c, A&A, 474, 783
Deng, X. F., et al. 2007d, Int. J. Mod. Phys. D, 16, 885
Deng, X. F., et al. 2008b, PASP, 120, 487
Deng, X. F., et al. 2009d, Astropart. Phys., 31, 255
Deng, X. F., et al. 2010, ApJ, 708, 101
Dressler, A. 1980, ApJ, 236, 351

Dressler, A., et al. 1997, ApJ, 490, 577
Eisenstein, D. J., et al. 2001, AJ, 122, 2267
Fasano, G., et al. 2000, ApJ, 542, 673
Gnedin, O. Y. 2003, ApJ, 589, 752
Gómez, P. L., et al. 2003, ApJ, 584, 210
Goto, T., et al. 2003, MNRAS, 346, 601
Gunn, J. E., & Gott, J. R. I. 1972, ApJ, 176, 1
Hamilton, A. J. S. 1988, ApJ, 331, L59
Hashimoto, Z., & Oemler, A. 1999, ApJ, 510, 609
Helsdon, S. F., & Ponman, T. J. 2003, MNRAS, 339, L29
Hogg, D. W., et al. 2003, ApJ, 585, L5
Hogg, D. W., et al. 2004, ApJ, 601, L29
Hughes, T. M., & Cortese, L. 2009, MNRAS, 396, L41
Kauffmann, G., et al. 2004, MNRAS, 353, 713
Lewis, I., et al. 2002, MNRAS, 334, 673
Loveday, J., Maddox, S. J., Efstathiou, G., & Peterson, B. A. 1995, ApJ, 442, 457
Moore, B., Lake, G., & Katz, N. 1998, ApJ, 495, 139
Moss, C., & Whittle, M. 2000, MNRAS, 317, 667
Norberg, P., et al. 2001, MNRAS, 328, 64
Norberg, P., et al. 2002, MNRAS, 332, 827
Oemler, A. 1974, ApJ, 194, 1
Park, C., Vogeley, M. S., Geller, M. J., & Huchra, J. P. 1994, ApJ, 431, 569
Park, C., et al. 2007, ApJ, 658, 898
Poggianti, B. M., et al. 1999, ApJ, 518, 576
Postman, M., & Geller, M. J. 1984, ApJ, 281, 95
Schawinski, K., et al. 2007, ApJS, 173, 512
Skibba, R. A., et al. 2009, MNRAS, 399, 966
Stoughton, C., et al. 2002, AJ, 123, 485
Strauss, M. A., et al. 2002, AJ, 124, 1810
Tanaka, M., et al. 2004, AJ, 128, 2677
Thomas, D., et al. 2010, MNRAS, 404, 1775
Tran, K. H., et al. 2001, ApJ, 549, 172
Tremonti, C. A., et al. 2004, ApJ, 613, 898
Treu, T., et al. 2003, ApJ, 591, 53
Wolf, C., et al. 2009, MNRAS, 393, 1302
Zehavi, I., et al. 2002, ApJ, 571, 172