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Oxygen Abundances of Nearby Southern Dwarf Galaxies

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Abstract

Optical spectroscopy of H II regions in dwarf galaxies of the Centaurus A group, the Sculptor group, and from the field are presented. Oxygen abundances are derived using the direct method where [O III]λ4363 is detected; otherwise, abundances are derived with the bright-line method using the McGaugh and the Pilyugin calibrations. In the present sample, ESO358−G030 has the lowest oxygen abundance (12+log(O/H) = 7.32; $\simeq$ 4% solar), which is comparable to the value for the second most metal-poor galaxy known. Most galaxies have derived oxygen abundances in the range 5% to 16% of the solar value. Oxygen abundances for most of the dwarfs in the present sample are consistent with the metallicity-luminosity relationship defined by a control sample of dwarf irregulars with [O III]λ4363 abundances and well-measured distances. However, a number of dwarfs in the present sample exhibit lower baryonic gas fractions compared to dwarfs in the control sample at a given oxygen abundance.

1.1 Introduction

The environments surrounding and interactions between galaxies are important factors in galaxy evolution. For example, the dense intracluster medium in the Virgo Cluster is most likely to be responsible for stripping H I gas from spirals (e.g., [30]) and star-forming dwarf galaxies (e.g., [21]). However, as environments found in the field and within nearby groups are relatively sparse, studying dwarf galaxies within nearby groups can be used to disentangle the various effects acting on dwarf galaxies.

Following the conclusion of an all-sky survey for nearby dwarf and low-surface-brightness galaxies [11], we are carrying out a comprehensive program to study resolvable dwarf galaxies within 500 km s^{-1} to explore the properties of galaxies in various environments [6]. The program consists of ground-based imaging and spectroscopy, a 200-orbit HST/WFPC2 survey, and 21-cm follow-up studies. Ground-based imaging provides integrated colors, morphological classification, structural parameters, and star formation rates (e.g., [22]). The HST/WFPC2 photometry yields distances, and reveals the young and intermediate-age star formation history for over 150 galaxies, e.g., [3, 4, 5, 8, 9, 10, 12, 13, 14, 15, 16, 17]. These data allow us to explore the three-dimensional structure of nearby galaxy groups, and to recognize dwarf companions of specific massive galaxies in the groups.

Spectroscopic abundances in combination with distances, star formation histories, and star formation rates of dwarf galaxies in the field and in nearby groups can yield the most comprehensive picture of dwarf galaxy evolution ever obtained. Achievable with a large and statistically complete sample, our immediate goal is to correlate present-day oxygen abundances with distances and star formation histories in order to study how galaxy evolution depends upon group environment and intrinsic galaxy properties.

1.2 Spectroscopy and Oxygen Abundances

Long-slit emission-line spectroscopy of southern dwarf irregulars (dIs) were obtained with the 1.5-m telescope at CTIO (Fig. 1.1; [19]). The dIs were chosen from the Centaurus A (Cen A) group, the Sculptor (Scl) group, the Local Group, and the field. Total exposure times were between 1 to 3 hr for each galaxy. The direct method of obtaining oxygen abundances was used for any galaxy where [O III]λ4363 Å was detected (e.g., [2, 26]). Where [O III]λ4363 was absent, oxygen abundances were computed using the "bright-line" indicator, R_{23}, utilizing the [O II]λ3727 and [O III]$\lambda\lambda$ 4959,5007 emission lines [27]. However, models which produce a relationship between R_{23} and oxygen abundance show that there are two values of oxygen abundance at a given value of R_{23}. To break the degeneracy in the bright-line method, [N II]λ6584/[O II]λ3727 ratios were constructed to choose the appropriate oxygen abundance (e.g., [23, 24]). An alternative method recently proposed by Pilyugin [28] was also used to compute "bright-line" abundances.

1.3 Discussion

Table 1.1 lists the observed galaxies and their derived oxygen abundances. Lower limits to oxygen abundances obtained from upper limits of [O III]λ4363 intensities are consistent with abundances determined from the bright-line method. A majority of dwarfs listed have oxygen abundances in the range between 7.4 and 7.9, or about 5% to 16% of the solar value (12+log(O/H) = 8.69; [1]).

The metallicity-luminosity relation is shown in Fig. 1.2 ([19, 20]). At a given luminosity, abundances for most of the galaxies in the southern sample are comparable to dIs in the control sample. However, NGC 5264 has a measured oxygen abundance about a factor of 2–3 higher than other dIs at comparable luminosities. This galaxy may be a low-luminosity or "dwarf" spiral, if a radial abundance gradient can be confirmed. ESO358−G060, a member of the Fornax Cluster (e.g., [29]), appears too luminous or too metal-poor compared to nearby dwarfs. This galaxy has the lowest abundance in the sample ($\simeq$ 4.2% solar), which is similar to the abundance for the second most metal-poor dwarf galaxy known, SBS 0335–052 (e.g., [7]).

The metallicity-gas fraction relation is shown in Fig. 1.3, where the baryonic gas fraction is written as $\mu = M_{\rm gas}/(M_{\rm gas}+M_*)$ [20]. Stellar masses for dIs in the southern sample are estimated using a mean $M_*/L_B = 0.9$, and gas masses are estimated assuming atomic hydrogen and helium [20]. Compared to the correlation seen for the control sample, a number of southern dIs appear to have similar gas fractions at a given abundance, but there are a few dwarfs with lower gas fractions. These dwarfs may have little gas, have strong bursts of star formation which bias B-band luminosities, and/or are evolving as "leaky boxes" with subsolar ($\sim$ 10%) oxygen yields. Some of the dwarf galaxies may be in close proximity with giants in their respective groups; see discussion in [19]. For additional comparison, the gas-rich dwarf DDO 154 is shown for M_*/L_B = 1.2 and 2.2 [18].

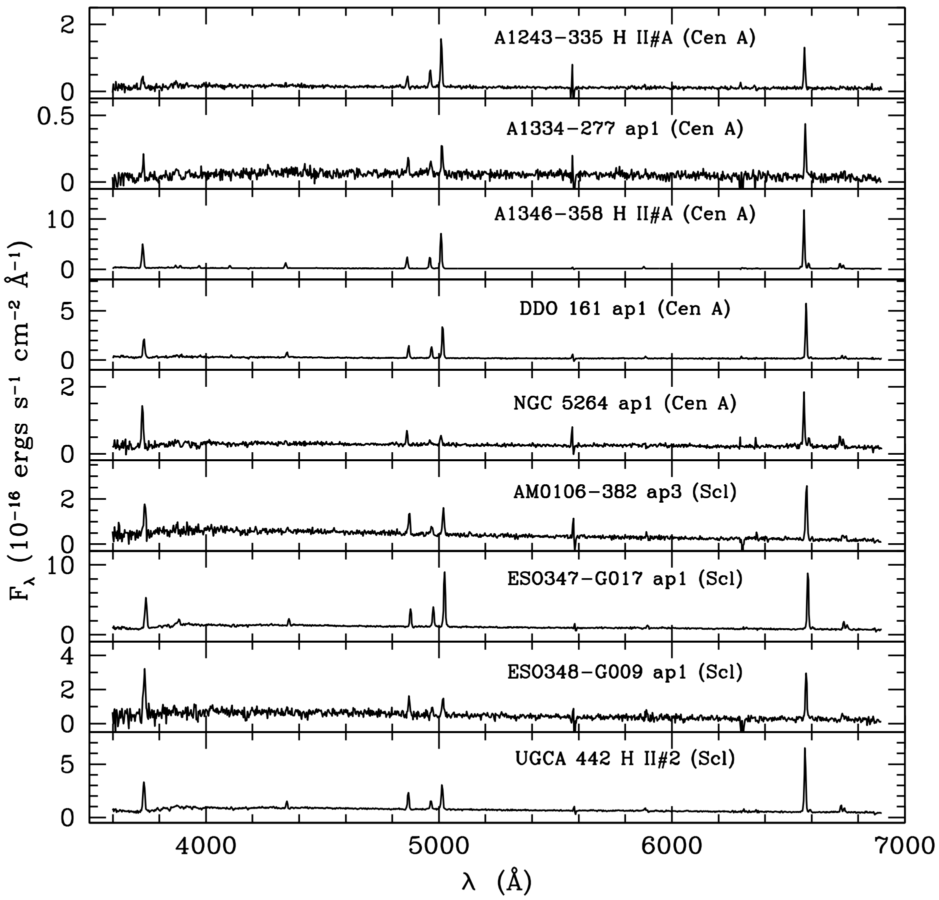

Fig. 1.1. Long-slit spectra of dwarf galaxies. Observed flux per unit wavelength is plotted against wavelength.

1.4 Upcoming Work

We have collected additional spectra for dwarfs from the following groups: Centaurus A, M 81, and M 101. Reductions and analyses are currently in progress, from which two additional papers are anticipated. The growing database of dwarf galaxies with oxygen abundances, distances, and star formation histories will be a powerful tool to examine galaxy evolution in the Local Volume.

References

[1] Allende Prieto, C., Lambert, D. L., & Asplund, M. 2001, ApJ, 556, L63
[2] Dinerstein, H. L. 1990, in The Interstellar Medium in Galaxies, ed. H. A. Thronson & J. M. Shull (Dordrecht: Kluwer), 257
[3] Dolphin, A. E. et al. 2001a, MNRAS, 324, 249
[4] Dolphin, A. E. et al. 2001b, ApJ, 550, 554

Table 1.1. *Oxygen abundances of dwarf galaxies in the present sample. The bright-line oxygen abundances for ESO347–G017, ESO348–G009, and UGCA 442 agree with the abundances recently published by Skillman et al. [25].*

Galaxy	Membership	Distance	12+log(O/H)		
			Direct	Bright-Line	
		(Mpc)	[O III]λ4363	McGaugh	Pilyugin
A1243–335 HII#A	Centaurus A	3.63	...	7.87	7.69
A1334–277	Centaurus A	4.61	...	7.45	7.34
A1346–358	Centaurus A	3.63	8.19 ± 0.06	8.26	8.22
DDO 161	Centaurus A	5.25	> 7.76	8.08	8.03
NGC 5264	Centaurus A	4.53	...	8.66	8.54
AM0106–382	Sculptor	3	...	7.58	7.56
ESO 347–G017	Sculptor	3	> 7.80	7.89	7.78
ESO 348–G009	Sculptor	3	...	7.89	8.07
UGCA 442 HII#2	Sculptor	4.27	> 7.48	7.81	7.88
A0355–465 HII#B	field	15.6	...	8.23	8.01
ESO 358–G060	Fornax Cluster	20.0	> 7.26	7.38	7.26
IC 1613 HII#13	Local Group	0.73	> 7.61	7.90	7.89
IC 1613 HII#37	Local Group	0.73	7.62 ± 0.05	7.88	7.71
IC 2032	Dorado	17.2	...	7.96	7.98
IC 5152 HII#A	field	2.07	7.92 ± 0.07	7.91	7.80
NGC 2915	field	3.78	...	8.21	8.35
NGC 3109 HII#6	Antlia-Sextans	1.33	...	7.57	7.55
Sag DIG HII#3	Local Group	1.11	...	7.73	7.73

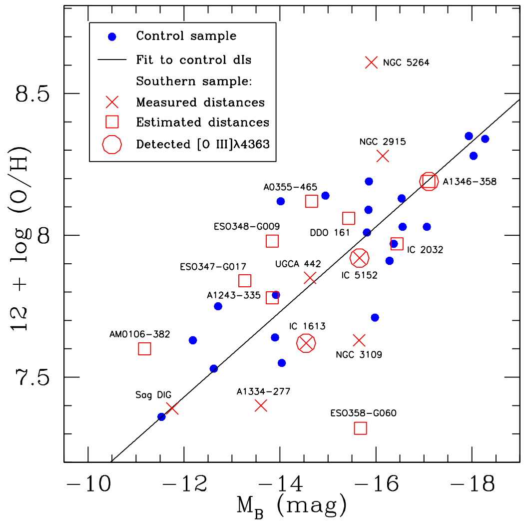

Fig. 1.2. Metallicity vs. luminosity diagram for dwarf irregulars (dIs). Filled circles mark the control sample of dIs and the solid line is a fit to these dIs [20]. For dIs in the present sample, crosses indicate galaxies with measured distances, and open squares indicate galaxies with estimated distances; also, open circles mark dIs with detected [O III]λ4363.

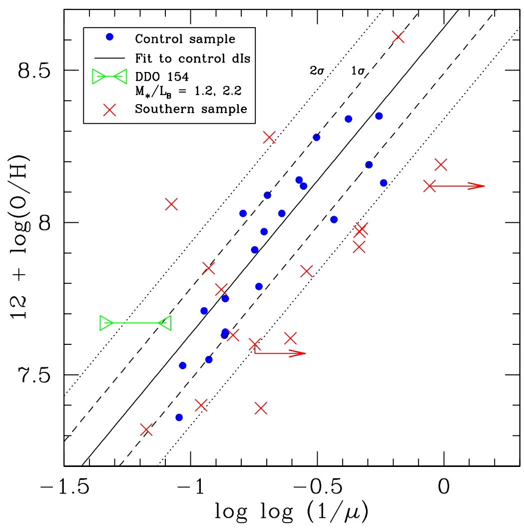

Fig. 1.3. Metallicity vs. gas fraction diagram for dwarf irregulars (dIs). Filled circles mark dIs in the control sample and the solid line is a fit to these galaxies [20]. One-sigma and two-sigma limits for the fit are indicated as dashed lines. Crosses mark dIs in the present sample. Open triangles connected by a solid horizontal line indicate the position of DDO 154 [18] with M_*/L_B equal to 1.2 and 2.2 (left and right, respectively).

[5] Dolphin, A. E. et al. 2003, AJ, 125, 1261
[6] Grebel, E. K. 2000, in Star Formation from the Small to the Large Scale, 33rd ESLAB Symp., ESA SP-445, ed. F. Favata, A. A. Kaas, & A. Wilson (Noordwijk: ESA), 87
[7] Izotov, Y. I., Lipovetsky, V. A., Chaffee, F. H., Foltz, C. B., Guseva, N. G., & Kniazev, A. Y. 1997, ApJ, 476, 698
[8] Karachentsev, I. D. et al. 1999, A&A, 352, 399
[9] Karachentsev, I. D. et al. 2000a, ApJ, 542, 128
[10] Karachentsev, I. D. et al. 2000b, A&A, 363, 117
[11] Karachentsev, I. D. et al. 2000c, A&AS, 145, 415
[12] Karachentsev, I. D. et al. 2001, A&A, 375, 359
[13] Karachentsev, I. D. et al. 2002a, A&A, 383, 125
[14] Karachentsev, I. D. et al. 2002b, A&A, 385, 21
[15] Karachentsev, I. D. et al. 2002c, A&A, 389, 812
[16] Karachentsev, I. D. et al. 2003a, A&A, 398, 467
[17] Karachentsev, I. D. et al. 2003b, A&A, 398, 479
[18] Kennicutt, R. C., & Skillman, E. D. 2001, AJ, 121, 1461
[19] Lee, H., Grebel, E. K., & Hodge, P. W. 2003a, A&A, 401, 141
[20] Lee, H., McCall, M. L., Kingsburgh, R. L., Ross, R., & Stevenson, C. C. 2003b, AJ, 125, 146
[21] Lee, H., McCall, M. L., & Richer, M. G. 2003c, AJ, 125, 2975
[22] Makarova, L. N., Karachentsev, I. D., Grebel, E. K., & Barsunova, O. Yu. 2002, A&A, 384, 72
[23] McGaugh, S. S. 1991, ApJ, 380, 140
[24] McGaugh, S. S. 1994, ApJ, 426, 135
[25] Skillman, E. D., Côté, S., & Miller, B. W. 2003, AJ, 125, 610
[26] Pagel, B. E. J. 1997, Nucleosynthesis & Chemical Evolution of Galaxies (Cambridge: Cambridge Univ. Press)
[27] Pagel, B. E. J., Edmunds, M. G., Blackwell, D. E., Chun, M. S., & Smith, G. 1979, MNRAS, 189, 95
[28] Pilyugin, L. S. 2000, A&A, 362, 325
[29] Schröder, A., Drinkwater, M. J., & Richter, O.-G. 2002, A&A, 376, 91
[30] Vollmer, B. 2003, A&A, 398, 525