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Observations of O VI Absorption from the Superbubbles of the Large Magellanic Cloud

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Abstract. We have presented the observations of O VI absorption at 1032 Å towards 22 sightlines in 10 superbubbles (SBs) of the Large Magellanic Cloud (LMC) using the data obtained from the *Far Ultraviolet Spectroscopic Explorer (FUSE)*. The estimated abundance of O VI in the SBs varies from a minimum of $(1.09 \pm 0.22)\times10^{14}$ atoms/cm^2 in SB N206 to a maximum of $(3.71\pm0.23)\times10^{14}$ atoms/cm^2 in SB N70. We find about a 46% excess in the abundance of O VI in the SBs compared to the non-SB lines of sight. Even inside a SB, O VI column density (N(O VI)) varies by about a factor of 2 to 2.5. These data are useful in understanding the nature of the hot gas in SBs.

Keywords. Galaxies: Magellanic Clouds, Ultraviolet: general, ISM: abundances

1. Introduction

SBs are cavities across the interstellar medium (ISM) created by cataclysmic processes such as strong stellar winds and supernova explosions associated with massive stars in an OB association. The swept up material by stellar winds and supernova remnants produce an outer dense shell with an interior filled by low-density hot gas. The gas at the center of the SB is bright in X-rays, the outer shell formed by dust and cool gas is observed in the infrared while the interface between the cool shell and the hot interior is seen in the ultraviolet (UV). O VI absorption lines at 1032 Å and 1037.6 Å are diagnostic of the energetic processes of the interface environments of the SBs which are produced by shock heating and are collisionally ionized. The LMC hosts more than 20 SBs which have been observed in X-rays and UV due to their proximity (∼50 kpc). *FUSE* has observed O VI doublet along many sightlines using early type stars as background objects. We have presented a study of O VI absorption at 1032 Å in the SBs of the LMC in order to assess the properties of intermediate environments in them.

2. Measurement of O VI Column Density

We selected high resolution *FUSE* spectra from the archival data which were observed in the SB lines of sight in the LMC and had well pronounced O VI profiles. We found 22 good O VI observations covering 10 SBs in the LMC. The stellar continuum of O VI profiles are of low order Legendre polynomials ($\leqslant 5$). The measurement of the optical depth of O VI and the equivalent width for the LMC component are done by the apparent optical depth method following the procedures of Savage & Sembach (1991), Sembach & Savage (1992) and Howk *et al.* (2002). The results are listed in Table 1. The 1σ error in the measurements were estimated from the fitting procedures using the uncertainties in the *FUSE* data. The Milky Way ($v \lesssim 150$ km/s) and LMC ($v \gtrsim 150$ km/s) absorption components are well resolved by *FUSE* for most of the sightlines. The average value of the equivalent width of O VI profiles of the SBs in the LMC comes out to be 214±19 mÅ.

Table 1. Details of O VI observations in the SBs of the LMC.

SBs	Size of SBs	*FUSE* Targets	RA (J2000) hr min sec	Dec (J2000) deg min sec	FWHM (mÅ)	Integration limit(km/s)	N(O VI)/ (10^{14} atoms/cm^2)
N11	$10'\times7'$	PGMW-3070	04 56 43.25	-66 25 02.0	132±23	180, 345	$1.27^{+0.43}_{-0.43}$
		LH103102	04 56 45.40	-66 24 45.9	132±23	180, 330	$1.46^{+0.10}_{-0.13}$
		LH91486	04 56 55.58	-66 28 58.0	266±29	175, 385	$2.96^{+0.68}_{-0.68}$
		PGMW-3223	04 57 00.80	-66 24 25.3	129±15	175, 315	$1.27^{+0.18}_{-0.18}$
N51	$12'\times10'$	Sk-67D106	05 26 15.20	-67 29 58.3	180±7	175, 345	$2.01^{+0.50}_{-0.53}$
		Sk-67D107	05 26 20.67	-67 29 55.4	254±10	160, 360	$2.85^{+0.27}_{-0.27}$
		Sk-67D111	05 26 47.95	-67 29 29.9	214±19	175, 365	$2.20^{+0.29}_{-0.24}$
N57	$12'\times7'$	Sk-67D166	05 31 44.31	-67 38 00.6	206±9	165, 390	$2.09^{+0.25}_{-0.20}$
N70	$8'\times7'$	SK-67D250	05 43 15.48	-67 51 09.6	316±33	165, 375	$3.71^{+0.23}_{-0.23}$
		D301-NW8	05 43 15.96	-67 49 51.0	228±30	175, 365	$2.60^{+0.09}_{-0.13}$
		D301-1005	05 43 08.30	-67 50 52.4	284±57	165, 385	$3.37^{+0.17}_{-0.22}$
N144	$13'\times12'$	HD36521	05 26 30.32	-68 50 25.4	126±9	175, 340	$1.18^{+0.28}_{-0.28}$
		Sk-68D80	05 26 30.43	-68 50 26.6	303±16	145, 335	$3.61^{+0.30}_{-0.26}$
N204	$14'\times13'$	Sk-70D91	05 27 33.74	-70 36 48.3	256±7	160, 365	$2.69^{+0.24}_{-0.17}$
N206	$9'\times15'$	BI184	05 30 30.60	-71 02 31.3	118±10	165, 330	$1.09^{+0.22}_{-0.22}$
		Sk-71D45	05 31 15.55	-71 04 08.9	194±9	160, 345	$1.80^{+0.24}_{-0.21}$
N154	$12'\times8'$	SK-69D191	05 34 19.39	-69 45 10.0	185±25	165, 340	$1.65^{+0.26}_{-0.23}$
N158	$8'\times7'$	HDE269927	05 38 58.25	-69 29 19.1	245±8	160, 320	$2.62^{+0.16}_{-0.21}$
30DOR C	$7'\times6'$	MK42	05 38 42.10	-69 05 54.7	228±24	160, 330	$2.60^{+0.46}_{-0.45}$
		SK-69D243	05 38 42.57	-69 06 03.2	307±15	150, 345	$3.63^{+0.40}_{-0.45}$
		30DOR-S-R136	05 38 51.70	-69 06 00.0	185±25	165, 320	$1.77^{+0.20}_{-0.24}$
		SK-69D246	05 38 53.50	-69 02 00.7	211±7	155, 325	$2.36^{+0.18}_{-0.14}$

3. Results and Discussions

N(O VI) of SBs varies from $(1.09\pm0.22)\times10^{14}$ to $(3.71\pm0.23)\times10^{14}$ atoms/cm^2. The mean N(O VI) for the SBs is found to be $(3.07\pm0.62)\times10^{14}$ atoms/cm^2 while the mean N(O VI) for the non-SBs lines of sight is $(2.10\pm0.50)\times10^{14}$ atoms/cm^2 (Pathak *et al.* 2011). Thus, the SBs in the LMC show an excess O VI abundance of about 46% in comparison to non-SB regions. Studies for SB N70 (Danforth *et al.* 2006) found similar results with 60% more O VI than the non-SB targets. Considering N(O VI) inside the individual SBs (e.g., N11 and 30 Dor C), a variation of about a factor of 2 to 2.5 in N(O VI) was obtained. The thermal conduction between the interior hot, X-ray producing gas and the cool, photoionized shell of SBs is found to be the most favourable mechanism for the production of O VI in the SBs (Danforth *et al.* 2006) as the thermal conduction models (Weaver *et al.* 1977 and Borkowski *et al.* 1990) have found N(O VI) $\approx$ few $\times\ 10^{13}$ atoms/cm^2, which is a close approximation of the observed N(O VI). O VI in the SBs does not show any correlation with the ISM morphologies such as Hα and X-ray surface brightnesses. The temperature estimated from the line width of O VI comes to be $\sim10^6$ K which represents slightly higher FWHM than expected for O VI absorption.

References

Borkowski, K. J., Balbus, S. A., & Fristrom, C. C. 1990, *ApJ*, 355, 501

Gaustad, J. E., McCullough, P. R., Rosing, W., & Van Buren, Dave 2001, *PASP*, 113, 1326

Danforth, C. W., Shull, J. M., Rosenberg, J. L., & Stocke, J. T. 2006,*ApJ*, 640, 716

Howk, J. C., Sembach, K. R., Savage, B. D., Massa, D., Friedman, S. D., & Fullerton, A. W. 2002, *ApJ*, 569, 214

Pathak, Amit, Pradhan, A. C. Murthy, Jayant, & Sujatha, N. V. 2011, *MNRAS*, 412, 1105

Savage, B. D. & Sembach, K. R. 1991, *ApJ*, 379, 245

Sembach, K. R. & Savage, B. D. 1992, *ApJS*, 83, 147

Weaver, R., McCray, R., Castor, J., Shapiro, P., & Moore, R. 1977, *ApJ*, 218,377

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