ON THE EVOLUTIONARY STATUS OF LOW-METALLICITY BLUE COMPACT GALAXIES

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ABSTRACT. A remarkably small scatter in the N/O ratios for the HII regions in low-metallicity blue compact galaxies (BCG) has been found recently by Izotov and Thuan. They have concluded that these galaxies are presently undergoing their first burst of star formation, and that nitrogen measured in these galaxies is produced by massive stars in the current star formation burst only. Here it has been tested whether this interpretation is compatible with other observational data and with the existing ideas on the chemical evolution of galaxies.

It has been found that the existence of systems (damped Lα absorbers) in which the N/Si ratios are lower than in low-metallicity BCGs and the chemical homogeneity of star-forming BCGs are in conflict with conclusion that the massive stars from current star formation event are responsible for the nitrogen abundance measured in low-metallicity BCGs. The low-metallicity BCGs seem to be systems with a small amount of old underlying stellar population over which the current star formation burst is superposed; only the stars from the previous star formation event(s) are responsible for the observed chemical composition in the giant HII regions in these galaxies.

Key words: Galaxies: irregular: evolution

1. Introduction

Assumption that BCGs can be young systems is widely discussed after it was initially suggested by Searle & Sargent (1972). In order to reproduce the observed properties of low-metallicity BCGs, only a few (in some cases only one or two) star formation bursts during their life are required (Tosi 1994). Papaderos et al (1998) have found that the spectrophotometric properties of SBS 0335-052, the second most metal-poor known BCD, can be accounted for by a stellar population not older than $\sim$ 100 Myr. The possibility of an underlying old stellar population with mass not exceeding $\sim$ 10 times that of young stellar population mass hawever cannot be definitely ruled out on the basis of the spectrophotometric properties. Then, in addition to the spectrophotometric properties, the element abundance ratios (in particular the N/O abundance ratios) are used in order to establish the evolutionary status of galaxies.

It is believed that both the massive and intermediate mass stars make contributions to the nitrogen production, but the mass range of the nitrogen-producing stars and the predicted amount of freshly produced nitrogen depend on poorly known parameters (Renzini and Voli, 1981; Marigo et al 1996; Marigo et al 1998; van den Hoek and Groenewegen 1997). The time variation of N/O ratio in the interstellar medium of the system after star formation burst has the characteristic feature. Since the bulk of oxygen is produced by short-living massive stars and part of nitrogen is produced by relatively long-living intermediate-mass stars, there is a temporary decrease of the N/O ratio after star formation event. The value of N/O decrease depends on the contribution of intermediate-mass stars to the nitrogen production and on the initial metallicity of gas where the star formation event takes place. The N/O ratio corresponding to the early stage (before ejecta of intermediate - mass stars) of the first star formation event is a lower limit for the global N/O ratios. The best way to find the lower limit of N/O ratio and hence the amount of nitrogen produced by massive stars would be an undisputable determination of the N/O ratios in galactic halo stars. Unfortunately, at the present state their N/O ratios cannot be determined with a precision better than a factor 2 or 3 (Carbon et al 1987).

Izotov and Thuan (Thuan et al 1995; Izotov and Thuan 1999) have found a remarkably small scatter ($\pm$ 0.02 *dex*) in the N/O ratios of the HII regions in low-metallicity (with 12+logO/H $\leq$ 7.6) BCGs. They concluded that these galaxies are presently undergoing their first burst of star formation, and that nitrogen in these galaxies is produced by massive stars only. (Strictly speaking, the constancy of N/O ratio during the early stage of the first star formation event will takes place if stellar nitrogen yields $Y_N(M_S)$ and oxygen yields $Y_O(M_S)$ are related by the following equation $Y_N(M_S) = const \times Y_O(M_S)$ for star of every mass M_S out of mass range $M_S \geq 10\ M_{\odot}$.) If low-metallicity BCGs galaxies are presently undergoing their first burst of star formation, the N/O ratio observed in these galaxies would be a lower limit for the global N/O ratios. This is in conflict with the fact that the nitrogen to α-element abundance ratios measured in some DLAs are well below than the value observed in low-metallicity BCGs (Lu et al 1998 and references therein). (Since oxygen abundance measurements are not available for DLAs, $[N/S]$ or $[N/Si]$ ratios are considered instead of $[N/O]$. This is justified by the fact that there is no reason to believe that the relative abundances of O, S and Si which are all produced in Type II supernovae are different from solar in DLAs.)

Thus the question arises whether the constancy of the N/O ratios in low-metallicity BCGs and the scatter of the N/Si ratios in DLAs are compatible with each other and with the existing ideas on the chemical evolution of galaxies.

2. Possible interpretation of nitrogen abundances in BCGs and DLAs

Here we will demonstrate that the constancy of the N/O ratios in low-metallicity BCGs and the scatter of the N/Si ratios in DLAs can be reconciled under the assumptions that a significant part of nitrogen is produced by intermediate-mass stars, and the previous star formation events are responsible for heavy element abundances observed in the HII regions of the BCGs.

Assumption that previous star formation events are responsible for the observed heavy element abundances in BCGs is equivalent to say that the element abundances of HII regions in BCGs are not yet polluted by the stars of the present star formation event, and that their abundances reflect the average N/O in the galaxy, which results from cumulative previous star formation. Martin (1996) has found that the current event of star formation in the most metal-poor known blue compact galaxy I Zw 18 started 15-27 Myr ago. The duration of current star formation burst in another extremely metal-poor blue compact galaxy SBS 0335-052 (Papaderos et al 1998) is also in excess of the lifetime of the most massive stars. Therefore, a selection effect in favor of observations of young HII regions in which the massive stars had not yet have time to explode as supernovae cannot be reason why the HII regions are not observed as self-enriched. Massive stars in the current star formation burst have often had time to synthesize heavy elements and to eject them via stellar winds and supernova explosions into the surrounding interstellar gas. Kunth and Sargent (1986) suggest that the heavy elements produced by massive stars in the current star formation burst mix immediately into H II region, i.e. the giant H II regions are self-enriched. Given the time delay between the injection of nitrogen by intermediate-mass stars and that of oxygen by shorter lived massive stars (the time – delay hypothesis: Edmunds & Pagel 1978) and the hypothesis of self-enrichment of star formation regions (Kunth & Sargent 1986), models for the chemical evolution of dwarf galaxies predicting the large scatter in N/O at fixed O/H in low-metallicity dwarf galaxies have been constructed (Garnett 1990; Pilyugin 1992, 1993; Marconi et al 1994).

However, it is possible that the nucleosynthetic products of massive stars are in high stages of ionization and do not make appreciable contribution to the element abundance as derived from optical spectra (Kobulnicky and Skillman 1997; Kobulnicky 1999). Indeed, the oxygen abundance in SBS 0335-052 has been measured within the region of 3.6 kpc (Izotov et al 1997). There is a supershell of radius $\sim$ 380 pc. There is no significant difference in oxygen abundances inside and outside the supershell as it should be expected since $\sim$ 1500 supernovae are required to produce this supershell (Izotov et al 1997). Other star-forming galaxies, which are chemically homogeneous despite the presence of multiple massive star clusters, are reported by Kobulnicky and Skillman (1998). This can be considered as evidence that the nucleosynthetic products of massive stars in giant HII regions are hidden from optical spectroscopic searches because they are predominantly found in a hot, highly – ionized superbubble. It should be noted however that some fraction of supernova ejecta can mix with dense clouds changing their chemical composition. If such cloud survives and produces a subgroup of stars shortly, the star formation region will have sub-generations of stars with different chemical composition. This seems to be the case in the Orion star formation region (Cunha and Lambert 1994; Pilyugin and Edmunds 1996).

If the suggestion that the heavy elements ejected by massive stars are in hot superbubble for a some time and do not mix immediately into the giant HII region is correct, the time variation of the N/O ratio in the warm gas phase after star formation event does not agree with the time variation of the N/O ratio in the interstellar medium as a whole. Hot and warm gas phases have different chemical compositions. The chemical composition of warm gas within star formation region remains unaltered and is equal to the initial chemical composition of gas where the star formation event takes place. A temporary decrease of the N/O ratio takes place in cold gas phase after that the bubble disappeared and the nucleosynthetic products of massive stars mix with ambient interstellar medium.

With this behaviour of the N/O ratio, the nitrogen abundances measured in BCGs and DLAs can be interpreted in the following way (Pilyugin 1999). The low-metallicity BCGs are systems with a small amount of old underlying stellar population over which the current star formation burst is superposed; only the stars from the previous star formation event(s) are responsible for the observed chemical composition in the giant HII regions in these galaxies. In other words, the abundances mesured in giant HII regions in BCGs reflect the average N/O in the galaxy, which results from cumulative previous star formation. The DLA observations sample the general ISM at random times along random lines of sight and may or may not see a region where a star formation event occured in a recent past. The DLAs with low nitrogen to α-element ratios correspond to systems probed less than around 1 Gyr after the last local star formation event, but after a time sufficient for disappearance of the superbubble and mixing of the freshly produced heavy elements in the interstellar medium. Conversely, the DLAs with nitrogen to α-element ratios close to that in low-metallicity BCGs correspond to systems in which the time interval after last star formation event is sufficiently large for intermediate-mass stars to have substantially enhanced the nitrogen to α-element abundance ratios.

3. Conclusions

It has been found that the existence of systems (damped Lα absorbers) in which the N/Si ratios are lower than in low-metallicity BCGs and the chemical homogeneity of star-forming BCGs are in conflict with conclusion that the massive stars from current star formation event are responsible for the nitrogen abundance measured in low-metallicity BCGs.

The low-metallicity BCGs seem to be systems with a small amount of old underlying stellar population over which the current star formation burst is superposed; only the stars from the previous star formation event(s) are responsible for the observed chemical composition in the giant HII regions in these galaxies.

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References

Carbon D.F., Barbuy B., Kraft R.P., Friel E.D., Suntzeff N.B.: 1987, *P.A.S.P.*, **99**, 335
Cunha K., Lambert D.L.: 1994, *Ap.J.*, **426**, 170
Edmunds M.G., Pagel B.E.J.: 1978, *M.N.R.A.S.*, **185**, 77p
Garnett D.R.: 1990, *Ap.J.*, **363**, 142
Izotov Y.I., Lipovetsky V.A., Chaffee F.H., Foltz C.B., Guseva N.G., Kniazev A.Y.: 1997, *Ap.J.*, **476**, 698
Izotov Y.I., Thuan T.X.: 1999, *Ap.J.*, **511**, 639
Kobulnicky H.A.: 1999, *astro-ph* 9901260
Kobulnicky H.A., Skillman E.D.: 1997, *Ap.J.*, **489**, 636
Kobulnicky H.A., Skillman E.D.: 1998, *Ap.J.*, **497**, 601
Kunth D., Sargent W.L.W.: 1986, *Ap.J.*, **300**, 496
Lu L., Sargent W.L.W., Barlow T.A.: 1998, *Ap.J.*, **115**, 55
Marconi G., Matteucci F., Tosi M.: 1994, *M.N.R.A.S.*, **270**, 35
Marigo P., Bressan A., Chiosi C.: 1996, *As.Ap.*, **313**, 545
Marigo P., Bressan A., Chiosi C.: 1998, *As.Ap.*, **331**, 564
Martin C.L.: 1996, *Ap.J.*, **465**, 680
Papaderos P., Izotov Y.I., Fricke K.J., Thuan T.X., Guseva N.G.: 1998, *As.Ap.*, **338**, 43
Pilyugin L.S.: 1992, *As.Ap.*, **260**, 58
Pilyugin L.S.: 1993, *As.Ap.*, **277**, 42
Pilyugin L.S.: 1999, *As.Ap.*, **346**, 428
Pilyugin L.S., Edmunds M.G.: 1996, *As.Ap.*, **313**, 792
Renzini A., Voli M.: 1981, *As.Ap.*, **94**, 175
Searle L., Sargent W.L.W.: 1972, *Ap.J.*, **173**, 25
Thuan T.X., Izotov Y.I., Lipovetsky V.A.: 1995, *Ap.J.*, **445**, 108
Tosi M.: 1994, in *Dwarf Galaxies*, Eds. Meylan G., Prugniel P., (Garching: Europen Southern Observatory), p. 465
van den Hoek L.B., Groenewegen M.A.T.: 1997, *As.Ap.S.S.*, **123**, 305