Chemical Abundances in the Universe: Connecting First Stars to Planets
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Superbubble H II regions: how self-enriched should they be?

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Abstract. I modeled the pollution of low metallicity ($Z = 0.001$) superbubble H II regions with the ejecta from single stellar populations of $10^4 - 10^6$ M$_\odot$ in mass. I found that the He, C, N, and O abundance enhancements in the H II regions, due to pollution with the enriched winds from Wolf-Rayet stars, are insignificant at 5 Myr. The few localized metal enhancements observed so far in resolved extragalactic H II regions are not associated with superbubbles and remain to be modeled in detail.

Keywords. ISM: abundances, ISM: bubbles, ISM: evolution, H II regions

1. Introduction

A superbubble is the shell of gas produced when the winds and supernovae (SNe) of massive stars in a cluster sweep up the ISM. Some superbubbles contain H II regions. I took advantage of the relatively simple geometry of superbubble H II regions in order to estimate how self-enriched they should be. Here, self-enrichment is the pollution of H II regions with ejecta from embedded massive stars, on spatial scales of a few $10 - 100$ pc, and on time scales of a few Myr.

If self-enrichment is significant, then 1) it could explain the lack of galaxies more metal poor than I Zw 18; 2) it could explain why some H II galaxies with Wolf-Rayet (WR) star signatures show N and He enhancements; 3) if star formation is triggered by the evolution of a previous generation of stars, then it could occur in a chemically enriched environment; and 4) H II regions do not reflect the composition of the gas out of which their ionizing stars form, nor the composition of galaxies at large. Most giant H II regions do not show clear signs of self-enrichment but some do (e.g., Kobulnicky & Skillman 1996; López-Sánchez *et al.* 2007).

2. Model

The central star cluster is point-like. The H II region is a spherical shell of constant density and inner radius $r_1 \propto (L \times t^3/n_0)^{1/5}$, as given by the standard superbubble model of Mac Low, M.-M. & McCray, R. (1988), where L is the mechanical luminosity of the stellar winds and supernovae, t is the age, and n_0 is the density of the ambient undisturbed ISM. At 5 Myr, I uniformly polluted the volume of radius r_2, where r_2 is the distance from the cluster to the outer edge of the H II region, with the cumulative mass ejected up to age $t = 5$ Myr, by single stellar populations of masses 10^4, 10^5, or 10^6 M$_\odot$. Note that chemical yields from supernovae were not included in the calculation because they are highly uncertain for the most massive stars. The stellar mass loss rate peaks at ∼4 Myr, during the stellar WR phase. At 5 Myr, the enriched WR star ejecta has had enough time to reach the H II region. I studied self-enrichment up to 5 Myr because at $t > 5\,\mathrm{Myr}$ three problems arise: 1) the ionizing luminosity from the stars is insufficient to produce a fully ionized H II region, 2) the radius of the H II region becomes comparable with the thickness of the Galactic disk, and the equilibrium time scale of the H II becomes greater than 1 Myr. The stellar radiative, mechanical, and chemical feedbacks used as input to the models are from STARBURST99 (Leitherer *et al.* 1999; Vázquez & Leitherer 2005) and are based on the 1994 Geneva non-rotating high-mass loss stellar evolutionary tracks.

3. Results

Columns 1 − 5 of Table 1 give: cluster mass, adopted ISM density, H II region inner radius, and predicted H II region C and O enhancements due to self-enrichment (with respect to the initial ISM values 12+log(C/H) = 7.22 and 12+log(O/H) = 7.53), respectively. The maximum enhancements occur for $M_\star = 10^6\,\mathrm{M}_\odot$ and $n_0 = 100\,\mathrm{cm}^{-3}$. They would be unobservable considering the typical uncertainties in the chemical abundance determinations of giant H II regions. The predicted He and N enhancements are even smaller and are not shown.

Table 1. Predictions of the extent of self-enrichment in C and O at 5 Myr.

$M_\star$ $\mathrm{M}_\odot$	n_0 cm^{-3}	r_1 pc	Δlog(C/H)	Δlog(O/H)
10^4	1	153	0.014	0.017
10^4	100	61	0.017	0.021
10^5	1	243	0.016	0.019
10^5	100	97	0.017	0.021
10^6	1	385	0.017	0.020
10^6	100	153	0.017	0.021

4. Conclusion

At 5 Myr, my self-enrichment scenario produces insignificant ($\leqslant 0.02\,\mathrm{dex}$) enhancements in He, C, N, and O, in superbubble H II regions with an initial metallicity of $Z = 0.001$. The few enhancements detected so far are associated with younger H II regions at higher subsolar metallicities. In Wofford (2009), a detailed study of self-enrichment in oxygen based on the model presented here can be found.

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Bacham Reddy during his talk.

Carlos Allende Prieto during his talk.