Formation of Elliptical Galaxies and Metal Enrichment by Pregalactic Outflows

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Supernova (SN)-driven pregalactic outflows may be an efficient mechanism for distributing the product of stellar nucleosynthesis over large cosmological volumes prior to the reionization epoch. Here we present results from three-dimensional numerical simulations of the dynamics of SN-driven bubbles as they propagate through and escape the grasp of subgalactic halos with masses $M = 10^8\,h^{-1}\,M_\odot$ at redshift $z = 9$. Halos in this mass range are characterized by very short dynamical timescales (and even shorter gas cooling times) and may therefore form stars in a rapid but intense burst before SN 'feedback' quenches further star formation. The hydrodynamic simulations use a nested grid method to follow the evolution of explosive multi-SN events operating on the characteristic timescale of a few $\times 10^7$ yr, the lifetime of massive stars. The results confirm that, if the star formation efficiency of subgalactic halos is $\lesssim 10\%$, a significant fraction of the halo gas will be lifted out of the potential well ('blow-away'), shock the intergalactic medium, and pollute it with metal-enriched material. The volume filling factor of the ejecta is of order unity. Depending on the stellar distribution, we find that less than 30% of the available SN energy gets converted into kinetic energy of the blown away material, the remainder being radiated away. It appears that mechanical feedback is less efficient than expected from simple energetic arguments, as off-nuclear SN explosions drive inward-propagating shocks that tend to collect and pile up cold gas in the central regions of the host halo. Low-mass galaxies at early epochs may survive multiple SN events and continue forming stars.

Reference: Mori, M., Ferrara, A. and Madau, P., in press (astro-ph/0106107)

Figure 1: Snapshots of the logarithmic number density and temperature.