Chemical Abundances in the Universe:
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Lookback time evolution of metals: discarding the closed box model

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Abstract. We have gathered a representative sample of 88 intermediate mass galaxies at z∼0.6 and have provided robust estimates of their gas phase metallicity based on the strong line method R23. We have found that these galaxies have undergone a strong evolution of their metal content during the last 8 Gyrs. We confirmed the shift about ∼0.3dex to lower abundance of the M-Z relation at z∼0.6 found by Liang *et al.* 2006. This result shows that the evolution of the gas phase is still active down to z=0.4 and that the close box model is not a valid scenario for local spiral progenitors.

1. Introduction

The evolution of the metal content of the gas in galaxies is a useful tool to disentangle between different scenarios of disk galaxy evolution. In particular the study of the stellar mass-metallicity relation (M-Z) can help to constrain the contribution of the several processes taking place during a galaxy lifetime : Star-formation history, outflow of gas by SN and stellar winds, and infall of gas by merger or secular accretion. There are several studies of the M-Z relation at different redshifts but the value evolution of the relation is still in debate. See e.g previous work: Local galaxies (Tremonti *et al.* (2004)), $0 < z < 1$ Savaglio *et al.* (2005), Rodrigues *et al.* (2008) and $z > 1$ Liu *et al.* (2008), Erb *et al.* (2006), Maier *et al.* (2006) and Maiolino *et al.* (2008).

2. Evolution of the metal content

We observed a representative and complete sample of 88 intermediate-mass galaxies ($M_{stel} > 10^{10}\,M_{\odot}$) from the CDFS with an average redshift of 0.7 (see complete description of the sample and the methodology used in Rodrigues *et al.* (2008)). We compared the metal abundance of 88 distant galaxies with those of local starburst from the SDSS (Tremonti *et al.* (2004)). We found that starburst and LIRGs at z∼0.7 are on average two times less metal rich than local galaxies at the same given mass. We have also reconstructed the chemical evolution over the last 8 Gyrs for intermediate-mass galaxies using 4 high-z samples from literature (1< z <1.5 Liu *et al.* (2008), $z \sim 2$ Shapley *et al.* (2004), z∼2 Erb *et al.* (2006), z∼3 Maiolino *et al.* (2008)) and two low-redshift sample from Lara-Lopez *et al.* (2009). In Fig. 1, we plotted the metallicity shift from the local relation of the 4-high-z samples and low-redshift sample as a function of lookback time. We found that the evolution of the metal content in galaxies from local Universe to a lookback time of ∼12 Gyr is linear.

We compared the observed chemical evolution of the gas with the one predicted by the closed box model. In such a model, the star formation is expected to be very intense at high redshift and then decreases exponentially with time. In fact, at high-z the star

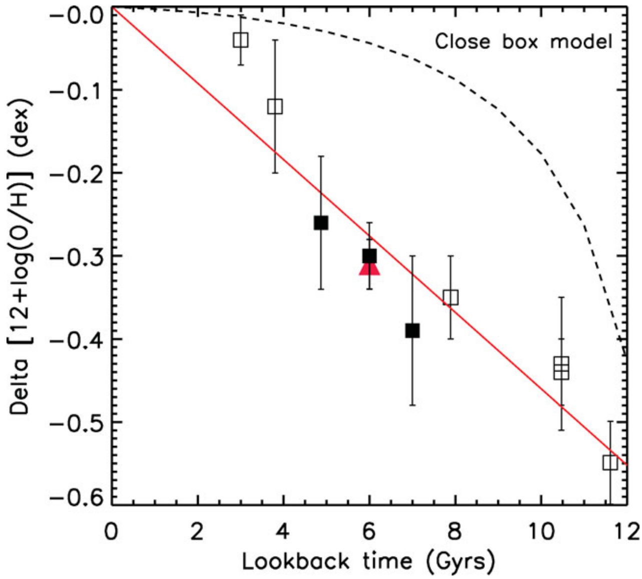

Figure 1. The metallicity shift from the local relation as function of the loockback time. The 4 high-z sample and the two low-redshift sample are plotted as black open squares, the 3 redfhift bins of the IMAGES sample as black square and the median of the 3 bins as red triangle. The evolution found by Savaglio *et al.* (2005) in the frame of a close box model is indicated with dashed line.

formation is fed by the large amount of gas available in galaxies. The production of metals at early epoch is then expected to be very high and the gas is rapidly enriched by metals. Due to the high initial star formation rate, the fraction of gas diminishes rapidly and the star formation rate decreases exponentially with time. The gas is then slowly enriched in metals at intermediate redshift. However, the current observation shows a strong evolution of the metal content from intermediate redshift to local Universe. This evolution is incompatible with the close box model in which galaxies evolve secularly. To explain the observed evolution an external supply of gas is required. The input of gas powers the star formation and dilutes metals at the same time. Combining our results with the reported evolution of the Tully-Fisher relation (Puech *et al.* (2008)), we do find that such metal content evolution requires that ∼30% of the stellar mass of local galaxies have been formed through an external supply of gas.

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