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The evolution of the mass-metallicity relation up to z≈0.9 from the VIMOS/VLT Deep Survey

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Abstract. We present the first results derived from the spectrophotometric properties of the Vimos VLT Deep Survey (VVDS) first epoch data. We have measured the spectral features (emission/absorption lines, 4000Å break) of a sample a ≈ 8000 galaxies taken from the VVDS deep 02h and CDFS fields using the platefit_VVDS pipeline. We first selected a sub-sample of star-forming galaxies, which were distinguished from narrow-line AGNs by standard and blue diagnostic diagrams. Then the gas-phase oxygen abundances have been derived by fitting all available emission lines towards photo-ionization models. Finally the masses have been derived by fitting all photometric points together with significant spectral features to a library of stellar population models with complex star formation histories. The mass-metallicity relation that we find at low redshifts is in good agreement with previsous studies performed in the local Universe. We find moreover a significant evolution of the mass-metallicity relation with the redshift, the galaxies having on average less metals at a given mass when the redshift increases. We also find a flattening of the mass-metallicity relation up to $z \sim 1$.

Keywords. Keyword1, keyword2, keyword3, etc.

1. Conclusion

We have derived stellar masses and metallicities of VVDS galaxies up to $z = 0.9$ and studied the evolution of the median mass-metallicity relation in three redshift bins. We have found a flattening of the mass-metallicity relation at $z \sim 1$ which is explained in the open-to-close box model. Our results for the high-mass end of the mass-metallicity relation are in very good agreement with previous studies either at $z \sim 1$ or at $z \sim 2$, showing that the metallicity of these galaxies would have double in ≈ 8.6 Gyr. For intermediate mass galaxies, we have found a smaller evolution from $z = 1$ to $z = 0$ than from $z = 2$ to $z = 1$, comparing our results both to local and high redshifts studies. This can be explained by the downsizing effect which tells us that these galaxies reach a maximum in their star formation activity between $z = 1$ and $z = 2$.

The study of the evolution of the mass-metallicity relation can be improved in two ways: first by going deeper in stellar mass at intermediate redshifts ($z < 1$), second by observing in infrared galaxies at higher redshifts ($z > 1$) in order to estimate their metallicities.

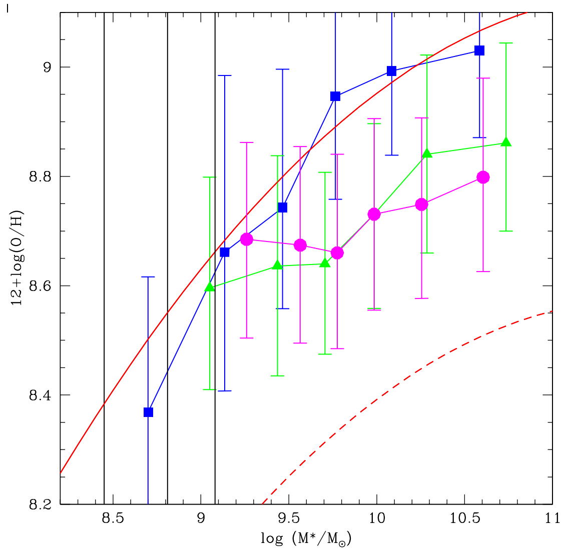

Figure 1. Evolution of the mass-metallicity relation. This plot presents the relation between gas-phase metallicity ans stellar mass for VVDS galaxies as a function of redshift. Each point is calculated as the running median of the metallicity of the galaxies in the sample along the stellar mass axis. The uncertainty of the median is also plotted. The squares, the triangles and the dots stands respectivily for the $0.0 < z < 0.5$, $0.5 < z < 0.7$ and $0.7 < z < 0.9$ redshift ranges. The curves shows the Tremonti *et al.* (2004) and Erb *et al.* (2006) results respectively as solid and dashed lines. The vertical lines show the three limiting masses of the subsamples.

Appendix A. Discussion

We evaluate the shape of the mass-metallicity relation in each redshift range by calculating a running median of the metallicity along the stellar mass axis. This approach is justified by the low uncertainties of the stellar masses (~ 0.1 dex) compared to the metallicities (~ 0.2 dex). Moreover, it allows us to compare our results to previous studies (Tremonti *et al.*, 2004; Erb *et al.*, 2006) which use the same method.

Figure 1 shows the results for each subsample defined above. We see that our nearest to local estimate (redshift range $0.0 < z < 0.5$) is in good agreement with SDSS data. In the $0.5 < z < 0.7$ redshift range, we see a clear flattening of the mass-metallicity relation, mainly driven by a stronger evolution of its high-mass end. The $0.7 < z < 0.9$ redshift range shows a similar trend.

The flattening of the mass-metallicity relation can be understood in a sample open-to-close box model: low stellar mass galaxies would evolve more like an open-box model with a very low effective yield, while high stellar mass galaxies would evolve more like a close-box model with an effective yield close to the true yield value. In the open-to-close box model, the higher is the stellar mass the stronger is the evolution of the metallicity each time the galaxy is forming stars (i.e. each time its stellar mass increases).

The open-to-close box model assumes an increase of the effective yield with stellar mass. The flattening of the mass-metallicity relation is thus an evidence of the hierarchical mass assembly as the gravitational potential of the galaxies does not remain constant during the star formation process.

We calculate that galaxies at 10.5 logarithm of solar masses show a decrease of 0.26 dex in metallicity up to $z \approx 0.8$. We thus find that the metallicity doubles in 8.54 Gyr, which result is in very good agreement with both Lamareille *et al.* (2006b) and Erb *et al.*

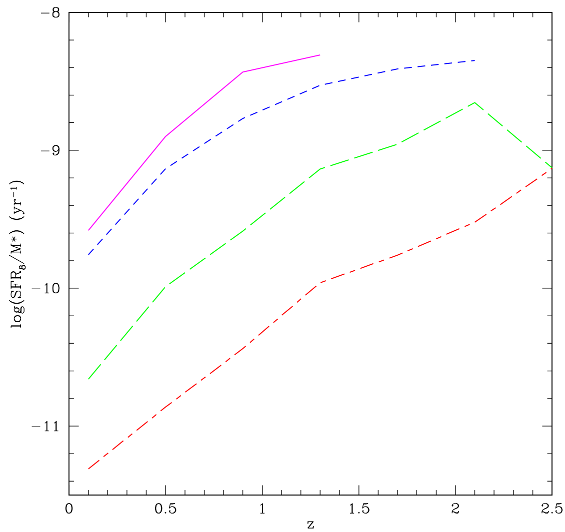

Figure 2. The downsizing effect seen from the VVDS. This plot shows the mean specific star formation rates (in logarithm per year) of VVDS galaxies as a function of redshift in four stellar mass ranges (in logarithm of solar masses): $8 < \log(M_\star) < 9$ (solid line), $9 < \log(M_\star) < 10$ (short-dashed line), $10 < \log(M_\star) < 11$ (long-dashed line) and $11 < \log(M_\star) < 12$ (short-dashed long-dashed line). The specific star formation rates have been derived from SED fitting with the same method as for stellar masses described above.

(2006) who found that the metallicity doubles in 8.87 Gyr and 8.95 Gyr respectively. For galaxies at 9.5 logarithm of solar masses, the decrease is only of 0.15 dex, The metallicity of these galaxies doubles in 10.15 Gyr, whereas lower mass galaxies show higher specific star formation rates.

It is interesting to note that the flattening effect we have found around $z \sim 1$ is stronger than the one noticed by Erb *et al.* (2006) at $z \sim 2$, who found a similar slope than in local universe. What process can explain a re-steppening of the mass-metallicity relation in the $1 < z < 2$ redshift range? The downsizing effect may be an answer. Indeed, we know that the more massive are the galaxies, the quicker their star formation activity rises to a maximum at higher redshifts. As shown in figure 2, galaxies at 9.5 logarithm of solar masses reach a maximum around $z \sim 1.5$, the ones at 10.5 logarithm of solar masses around $z \sim 2$. This effect can explain why the firsts would have produced more metals from $z = 2$ to $z = 1$ than from $z = 1$ to $z = 0$, while the seconds stay at a constant rate.

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