Stellar populations in star forming galaxies in the Sloan Digital Sky Survey

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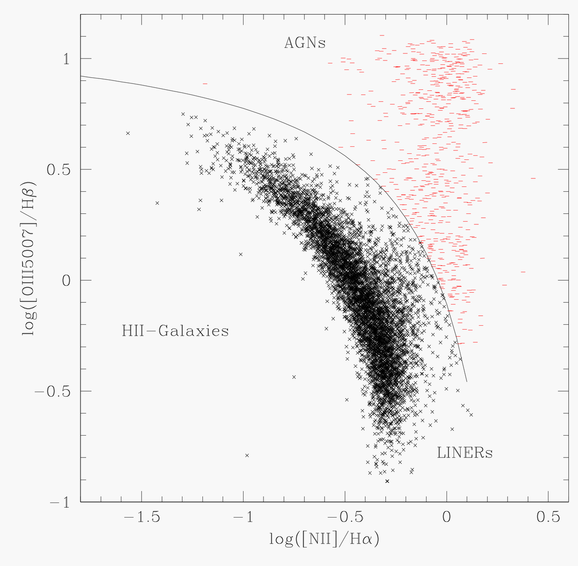
Introduction

Star forming galaxies are galaxies in a star formation phase, which results in strong emission lines in their spectra, particularly from hydrogen and helium, but also from heavier elements (Ne, N, O, Ar, S, etc). However, their spectra also show a continuum contribution, fainter than the emission lines, but clearly visible, which is attributed to stars. In Westera et al. (2004), we showed, analysing 6 spectral indices in a sample of $\sim$ 100 HII galaxy (a sub-class of star forming galaxies) spectra, that old stellar populations ($>$ 1 Gyr) constitute around 90 % or more of the stellar mass of these galaxies.

Nowadays, these results have been confirmed in several studies, i. e. those of the "SEAGal collaboration" (Cid Fernandes et al., 2007; Asari et al., 2007), and others. In these studies, and others, was also established the "downsizing" scenario, according to which high mass galaxies have a higher fraction of their gas transformed into stars and, therefore, have higher present-day (gas) metallicities than low mass galaxies.

In this work, we analyse by means of a population synthesis the stellar composition of a sample of over 6000 star forming galaxy spectra from the Sloan Digital Sky Survey (SDSS). The selected spectra have high signal-to-noise ratios and strong oxygen emission lines, permitting the determination of the gas metallicity.

Method

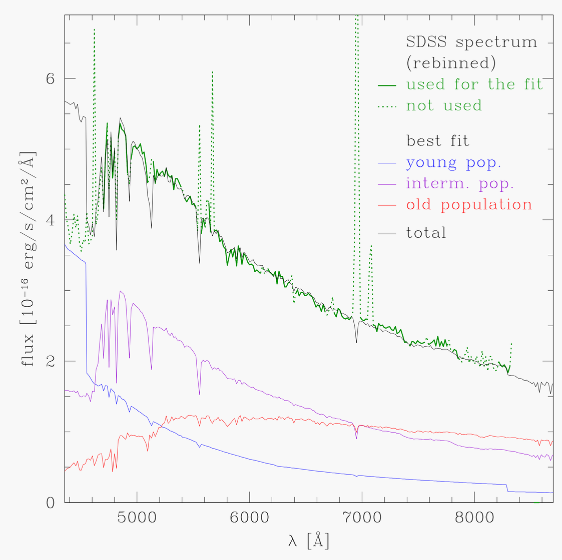


Separation of the galaxies of our sample from galaxies with AGNs.

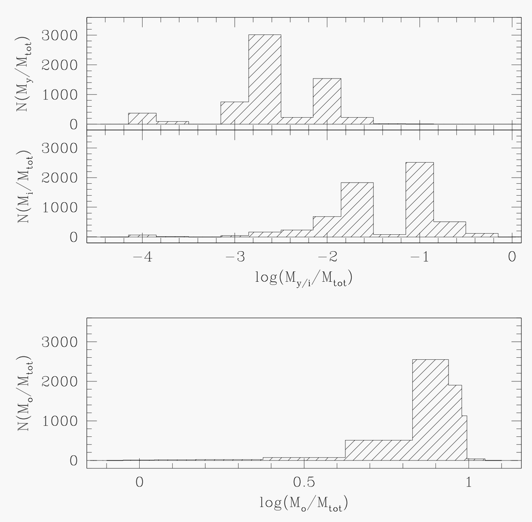
We separated the galaxies of our sample from galaxies with active galactic neuclei (AGNs) using the line excitation criterion by Kewley et al. (2001). As the emission line strengths given by the SDSS are of relatively low quality, we remeasured them by subtracting model spectra of the continuum contribution.

We determined the stellar compositions of these galaxies using evolutionary population synthesis - and spectral fitting methods, already used in Cuisinier et al. (2006) and Lisker et al. (2006). We decomposed the spectra into three single stellar populations (SSPs), a young one (aged less than 10 Myr), one of intermediate age (between 10 Myr and 1 Gyr), and an old one (older than 1 Gyr), of which we determined the (relative) masses, ages, and metallicities.

Results



Example of a spectral fit (51630-0266-054).

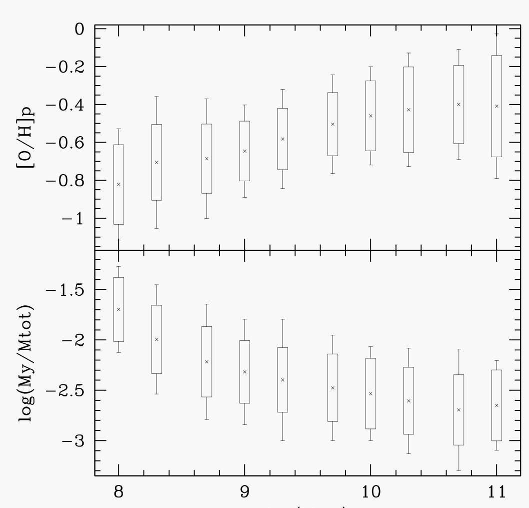

Mass fraction distribution of the three partial populations.

We confirm that most star forming galaxies, if not all, of our sample contain, apart from the presently forming young ($<$ 10 Myr) population, old ($>$ 1 Gyr) - and intermediate-age (between 10 Myr and 1 Gyr) populations, with the old population dominating the mass (but not the light), in general constituting over 90 % of the stellar mass, whereas the young population makes up for less than 1 % of the stellar mass, in spite of contributing a significant portion of the light.

The average metallicity of the gas, determined using the P method by Pilyugin (2001), and of the young - and intermediate populations is around -0.4, while the one of the old population lies close to -0.7. In a "closed box" context, the gas metallicity can be seen as a measure for the fraction of the gas that has been transformed into stars so far. In reality, the "closed box" hypothesis has to be verified. Various events can take place during the life of a galaxy, and for a realistic interpretation, interaction processes with the environment have to be taken into account. However, almost all possible processes involving gas exchange with the environment (inflows, outflows) lead to a decrease of the metallicity (Only outflows of low metallicity gas, which do not interrupt star formation, allow to increase the metallicity - but such outflows are usually not considered, as they do not correspond to identifiable physical processes).

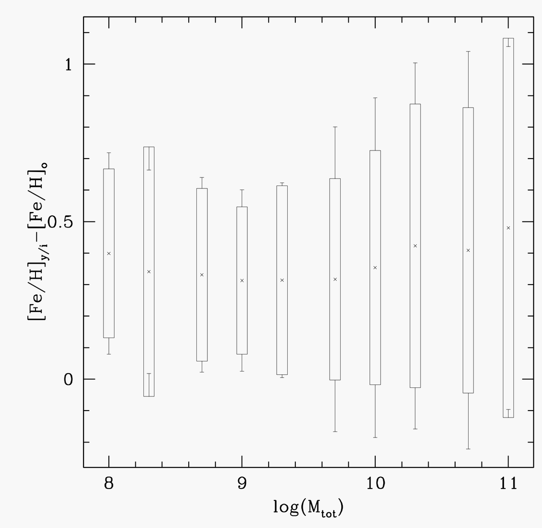
Galaxies that reach high metallicities are galaxies that have not been strongly disturbed by internal or external processes, and managed to transform a large fraction of their gas into stars. In our sample, those are the galaxies of high mass.

We also investigated the relation between the galaxy mass and the fraction of stars participating in the current starburst. Galaxies engaged in (relatively) important starbursts have low total masses and (gas) metallicities, which means that, so far, they have been relatively inefficient in transforming their gas into stars, in agreement with the "downsizing" scenario.

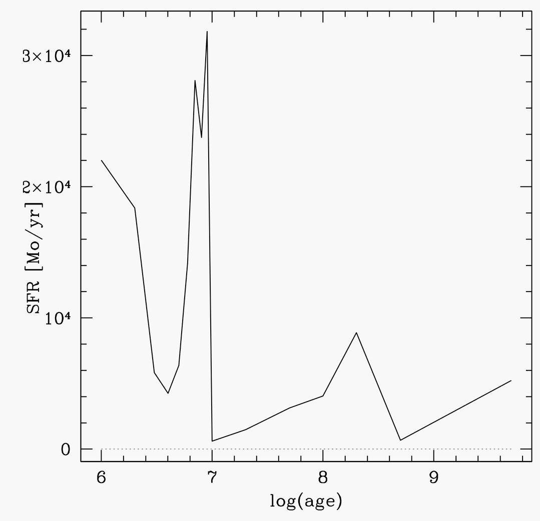


Gas metallicity and mass fraction of the young population in function of the total (stellar) mass.

The fact, that the metal enrichment since the formation of the old population, quantified by the metallicity difference between the young and the old populations $[Fe/H]_{y/i} - [Fe/H]_o$, does not depend on the galaxy mass suggests, that the enrichment mechanism are the same for low- and high-mass galaxies. Another noteworthy point is that, though the difference in metallicity $[Fe/H]_{y/i} - [Fe/H]_o$ does not vary with the galaxy mass, its dispersion increases with galactic mass. This indicates that, although the enrichment processes do not vary with galactic mass, high mass galaxies have a more complex chemical (and certainly assembly) history.


Metallicity difference between the young - and the old populations in function of the total (stellar) mass.

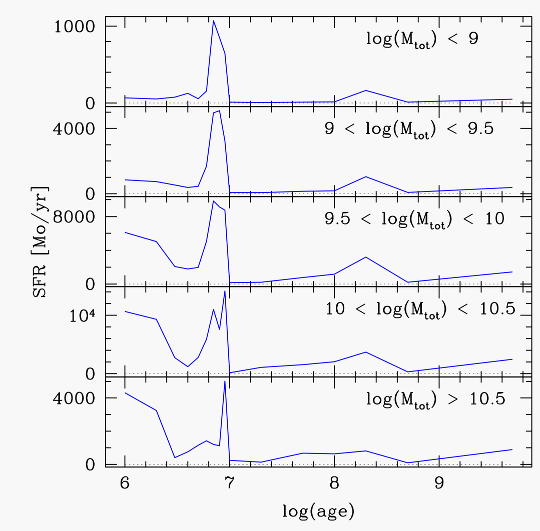
We investigated the "global" star formation rate (SFR), that is, summed up over all galaxies of our sample. It is of the order of 10000 $M_\odot$/yr and shows various peaks. The fact that these peaks appear at the borders between the age ranges of the three partial populations suggests they could be artifacts of the spectral fitting process.



Global star formation rate of the full sample.

To verify if the peaks are real, we performed the best fitting algorithm on synthetical spectra from simulations representing galaxies with different SFR histories. We used exponential SFRs with different decreasing time scales, a constant SFR, exponentially increasing SFRs, and "bursty" SFRs (made up of isolated star formation events). We find that the "global" SFR of our sample is consistent with the one of a model galaxy with a constant SFR. We conclude that in these galaxies, and in galaxies in general, star formation happens on an approximately constant level on long timescales, in spite of its bursty nature on short timescales.

We also investigated the dependence of the star formation history on the galaxy mass. For this purpose, we subdivided the "global" SFR in bins of galaxy mass. We find that, in high mass galaxies, the relative SFR in the remote past ($>$ 1 Gyr) was higher than in low mass galaxies. At the same time, the ages of the intermediate aged - and, particularly, the young populations decrease when the total (stellar) mass increases and, therefore, the mass fractions of the respective populations decrease. These results, too, are consistent with the "downsizing" scenario.



The global SFR subdivided by total (stellar) galaxy mass.

Conclusions

This leads to the conclusion that star forming galaxies are, in fact, old objects caught in a star formation phase, and that their star formation, and the one of galaxies in general, in spite of occurring in bursts, happens on an approximately constant level on longer timescales. We found indications that the gas recycling mechanisms are similar in low - and in high mass galaxies, as well as in galaxies with low - and high present-day metallicities, whereas the chemical - and assembly history might be more complicated in high mass galaxies. We also confirm a "downsizing" scenario for the galaxies of our sample.

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