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Downsizing in HII galaxies

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Abstract. In this work we estimated the statistical age of a set of HII galaxies obtained from the Sloan Digital Sky Survey Data Release Three (SDSS DR3). Applying an inversion method to the observed distribution of an age sensitive parameter such as the equivalent width of (Hα), we estimate the age of the galaxies. We find strong dependence of the age with stellar luminosity, mass and metallicity with the youngest HII galaxies being those with the lowest mass and metallicity. These dependences found among HII galaxies indicate that "downsizing" extends to the low end of the mass distribution of galaxies.

Keywords. galaxies: evolution, formation, ISM: HII regions

1. Introduction

The cosmic history of star-formation can be studied in more than one way. Most commonly one uses the Universe as a time-machine and obtains the "Madau-Lilly Diagram" by observation and analysis of the Universe as a function of distance or look-back time. Alternatively using the "fossil" or "Astroarcheology" model, i.e. by analyzing the z $\sim$ 0 Universe as seen by (for example) the SDSS and, from the distributions of stars/galaxies of different ages, masses and metallicities, one can reconstruct the star formation (SF) history. Interestingly, both methods agree fairly well making their combination a very powerful approach to test models of galaxy formation and evolution.

An important aspect is the role galaxy mass plays in the evolution. We have known for many years that faint, low mass galaxies, on average, are bluer than high mass ones and have stronger SF. But according to the succesful hierarchical galaxy formation scenario, the low mass systems were the first ones to be assembled, and by subsequent clustering and merging of the low mass systemes, the high mass ones were formed (White & Rees 1978, White & Frenk 1991, Navarro, Frenk & White 1995:NFW). Interestingly recent observational work has provided firm support to the possibility that galaxy formation may proceed in a *downsizing* manner with the massive ellipticals forming earlier than the low mass ones (Cowie *et al.* 1996, Van Dokkum *et al.* 2004, Treu *et al.* 2005, Heavens *et al.* 2004: MOPED collaboration, Bouche & Lowenthal 2005, Juneau *et al.* 2005, Le Borgne *et al.* 2005, Shapley *et al.* 2005).

Bundy, Ellis & Conselice (2005) argue that downsizing also proceeds from early to late Hubble types.

Recently, the interest in this well established observational result has grown, and its implications have been more and more appreciated. In all environments, lower mass galaxies have a more recent star formation history. This implies that, on average, going to lower redshifts, the maximum luminosity/mass of galaxies with significant star formation activity progressively decreases. While the *downsizing* effect might suggest an anti-hierachical history for the star formation in galaxies, in fact this is not necessarily the case given that scenarios including a powerful nuclear AGN playing a central role in late stages of evolution of a massive galaxy, seem to naturally "explain" downsizing inside hierarchical galaxy formation.

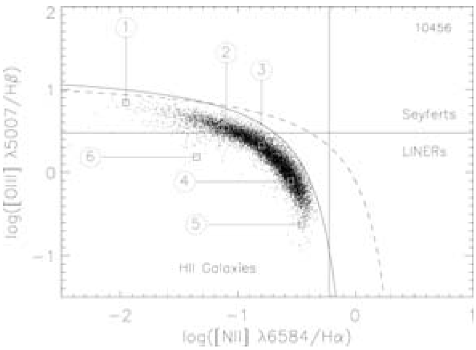

Figure 1. BPT diagnostic diagram for the sample of starforming galaxies.

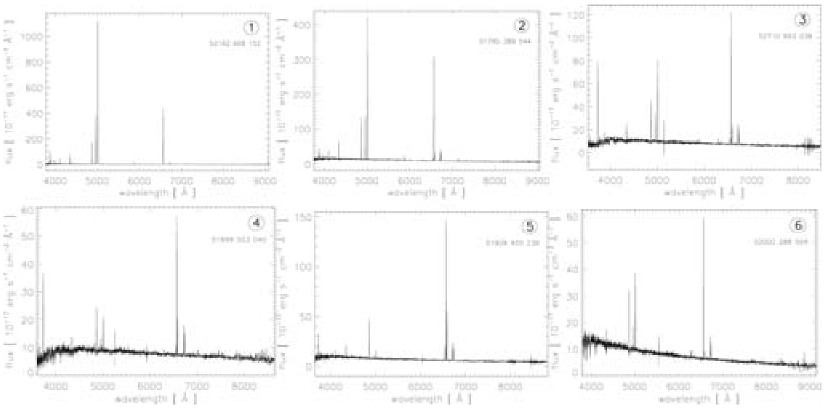

Figure 2. Spectra for selected objects (1-6) in figure 1.

It is therefore of great interest to determine whether downsizing is present also among low mass galaxies or only in the most massive ones, i.e. those capable of harbouring a powerful AGN.

To investigate the downsizing among low mass galaxies we have used a sample of nearby HII Galaxies (HIIG). HIIG are low mass systems undergoing an intense period of star formation activity. In this work we have estimated a statistical age for a set of HIIG obtained form the Sloan Digital Sky Survey Data Release Three (SDSS DR3). The inversion method from Terlevich *et al.* (2004) was applied to the sample to estimate the age distribution of the galaxies.

2. Data Selection

The data was selected from the local (INAOE) copy of the SDSS DR3 spectroscopic survey with about 10^5 spectra. The first criterion to select the HII galaxies from the DR3 was to reject those objects with the $H\alpha$ equivalent width $EW(H\alpha) < 10$ Å, leaving only emission line galaxies. A redshift value larger than 10^{-3} was imposed to reject galactic peculiar objects. The sample quality was further improved by imposing high signal to noise limits to the different lines used in the analysis as shown in figure 1.

A velocity dispersion limit $\sigma_{H\alpha}$ was imposed to segregate massive galaxies (see figure 3), and the Kewley *et al.* (2001) limit was applied to exclude Seyfert, LINERs and transition objects. The final sample of bonafide HIIG comprised 10456 objects.

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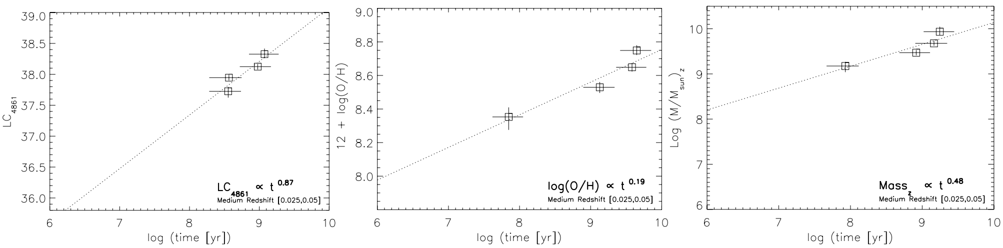

Figure 3. Inversion results by continuum luminosity at $\lambda 4861$ Å, by abundance and by mass (estimated from the z' band).

3. Ages

The age estimates for the HIIG selection are based on the statistical method developed by Terlevich *et al.* (2004). This method requires the studied parameter distribution to be monotonical in time with Poisson distribution of events, which is the case for the EW(Hα) emission in HIIG.

We confirm the findings of Terlevich *et al.* (2004) in that the history of star formation in HIIG is almost identical to the prediction of a continuous SF model but in this case with a sample $\sim$25 times larger. This strongly supports the idea that in HII galaxies the emission lines are produced in the present burst while the stellar continuum contains all the history of star formation, so a parameter such as the $EW(H\alpha)$ carries information about the whole history of star formation. A more detailed description is presented in a forthcoming paper (López, Terlevich & Terlevich, in preparation).

4. HIIG Evolution

To study the possible luminosity, mass and metallicity dependence of the SF evolution in HIIG the inversion method was applied to a narrow HIIG redshift sub-sample ranked by continuum luminosity, abundance and galaxy mass.

4.1. *Continuum luminosity vs age*

The continuum luminosity of a coeval integrated population has two main contributors, the stars at the turn-off and at the top of the giant branch. There is also a contribution from the ionized gas continuum emission but even for HIIG this is very small and can be disregarded for all but the most extreme systems, i.e. those with EW($H\beta$) > 200Å. The selection of the luminosity band defines the relative weights of the two main components that represent mainly the young (turn-off) and old (giant branch) stars. Here we have selected the luminosity value at $\lambda 4861$ Å(L_{C4861}) that is more dependent on the intermediate age population.

Results from the inversion taking 4 bins in L_{c4861} are in the left panel of figure 3.The results can be approximated by a power law in the form $L_{c4861} \propto t^{0.87}$.

This indicates that the star content in galaxies increases as a function of time. It also shows that there is a population of old stars formed a long time ago.

4.2. *Abundances vs age*

Abundances for the HIIG set were calculated using the N2 indicator (Denicoló, Terlevich & Terlevich 2002). Its advantages over other indicators are that it is calibrated over a large range of metallicities and that it is single valued. As can be seen in the central panel of figure 3, older HIIG are more metal rich than younger ones.

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4.3. *Mass vs age*

The galaxy mass was estimated from the z' band which is less affected by extinction and by the massive stellar population of the present burst giving a better estimate of the total stellar mass than that derived from L_C. The mass was apperture corrected according to Graham *et al.* (2005).

The results are shown in the right hand panel of figure 3, also for four different mass ranges. From here we see that the objects with larger mass are older and thus should be assembled before the low mass ones. This can be expressed in functional form as $M \propto t^{0.48}$.

5. Conclusions

We found strong trends relating the age of HII galaxies with their continuum luminosity, mass and metallicity. The relations indicate that the lowest mass systems tend to be younger and less metallic than the more massive ones on line with the results found for more massive systems. Therefore downsizing is present even among the lowest mass galaxies. Given this conclusion, scenarios involving a central AGN as the feedback source for the quenching of star formation may be excluded.

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