Are there any Young Galaxies in our local universe?

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Abstract.
We find no evidence for the presence of genuinely young galaxies in our Local universe. We argue that the metal deficiencies and the behavior of the N/O and C/O ratios meet several plausible explanations involving the primary and secondary nature of these elements and their dispersion and mixing by massive stars and intermediate mass stars. Colors are to be analysed using surface photometry and comparing several model scenario since an instant burst model unavoidably provides a lower limit to the age. Ultimately colour-magnitude diagram techniques will be the only direct test to be performed at least on a small number local starburst galaxies. Our present analysis provides important warning for assessing the true age of distant galaxies.

Keywords: young galaxies, local Universe, distant galaxies, metal abundances, colors

1. Introduction

It remains very important in the context of galaxy formation to establish beyond doubt whether or not galaxy formation is a continuous process so as to expect genuinely young galaxies to be observed in our Local Universe. This issue bears with some difficulties for many reasons, as for example the semantic aspect of what means “young”. Here we shall adopt the view that a young galaxy is a galaxy at its very first episode of star formation. Observationally the local dwarf starbursts discovered in the early 70s (Searle and Sargent, 1972) qualified for youth because they appeared to be metal deficient, gas-rich, have very blue colors, and for many of them, small amounts of dust. If such galaxies were young one should be able to detect the HI clouds out of which they are formed. The first survey by Lo and Sargent (1979) concluded for the absence of any excess of gas rich dwarfs and that no HI clouds without an optical counterpart had been found. At this moment, the HI mass function is still ill-defined (Martin Zwaan, 1998) but really constraining would be an accurate determination below, say, $10^7 M_\odot$. However the fact that galaxies contain young blue massive stars does not necessarily imply that they are young. In fact, most blue compact
dwarfs simply experience, at present, a burst of star formation which is, by no means, the first of the kind. With the advent of modern detectors more than 90% reveal an underlying old stellar population (Kunth and Östlin, 2000).

What about the rest? At this point we wish to argue that since most galaxies in the neighbourhood contain old stars, a genuinely young object would be a quite sensational discovery, and have more far-reaching implications than finding just another old galaxy. Therefore the burden of proof has to be carried by the youth hypothesis. It has to be shown beyond reasonable doubt (the limit set by existing technology) that an old population is absent, bearing in mind that it is much easier to detect young stellar populations than old ones. We shall examine how one could rely on metallicity determination and on colors to establish that a galaxy is young. Ultimately, colour-magnitude diagram (CMD) techniques will be the only direct test to be performed, keeping in mind however that it, up to now, has been applicable only to a very limited number of blue compact galaxies.

2. Metals

HII region abundance analysis can provide abundances of heavy elements such as O, C, and N that are of extreme importance in chemical evolution models. While metallicity is an important tool for studying how a galaxy chemically evolves, it is by no means straightforward to infer anything about the age (Kunth and Östlin, 2000). This issue has also been discussed by M. Edmunds in this conference.

Izotov and Thuan (1999), hereafter IT99, have observed a large set of blue compact galaxies among the most O/H deficient. They find positive correlations between C/O and N/O with O/H, but for $12+\log(O/H) \leq 7.6$, C/O and N/O remain constant and independent of O/H. Moreover, at these low oxygen abundances their N/O and C/O show almost no scatter, contrary to higher O/H. They conclude that galaxies with such low abundances are genuinely young (less than 40 Myr old), hence making their first generation of stars while all galaxies with $7.6 \leq 12+\log(O/H) \leq 8.2$ have ages significantly smaller than 1 Gyr. The basis of such a statement is that C, N and O should be produced by the ongoing burst as primary elements in galaxies with $12+\log(O/H) \leq 7.6$, meaning that this observed burst must be the first one. The absence of scatter is interpreted as evidence that intermediate mass stars (IMS) have not yet contributed to the N enrichment (because this would introduce time delays, hence a scatter). For galaxies with $12+\log(O/H) > 7.6$ N is secondary and N/O increases with time.
Admittedly the N/O diagram shows very little scatter at $12 + \log(O/H) \leq 7.6$, which is somewhat surprising from an observational point of view (N lines are in principle difficult to detect at such low abundances and there are many corrections involved in order to get both a correct O and N value). But even at face value the absence of a scatter does not necessarily have anything to do with youth.

Indeed chemical evolution models predict N/O to increase rapidly and level out around $\sim -1.5$ (e.g. Olofsson 1995). Subsequent starbursts will increase O/H and introduce wiggles (i.e. a scatter) in N/O since N production is delayed with respect to O. However, if star formation is continuous (at least prior to the present burst) no scatter in N/O is expected. The same is true if bursts are separated by long enough times that N can catch up with O (Pilyugin 1999). The selection criteria has, on purpose (since the common belief has been that a young galaxy should look similar to IZw18), picked out actively star forming galaxies, and will miss dormant post burst objects where N/O may have decreased. Connected to this is the question of the mixing timescale of fresh metals: If IT99 are correct (age less than 40 Myr and O/H a function of time), this must be close to instantaneous and similar to the timescale for massive star evolution. However the relative CNO yields are a sensitive function of mass, hence time, after the onset of the burst. Thus, if mixing is as fast as the youth scenario needs, we should expect to observe a scatter at low age, and IT99 do not. If the mixing timescale is longer, of the order of 100 Myr, the scatter could disappear before it becomes observable.

Henry et al. (2000) and Edmunds (this conference) advocate that IMS can account for the bulk of primary N hence in this case we observe the average N/O obtained after burst completion. Timescale for complete dispersion and mixing needs to be larger than a Gyr (see also Piluygin 1999). The increase of N/O and C/O at higher metallicity can be explained by a metallicity dependent yield, perhaps with contributions from WR stars.

Another illustration that O/H in itself is by no means an indication of youth is that SBS 0335-052 (one of the most O/H deficient galaxies) has a similar O/H abundance in two knots that are completely unrelated causally (Lipovetsky et al., 1999). In IZw18 both H\textsc{i} and H\textsc{ii} metallicity is now known to be similar and show no gradient indicating that dispersion and mixing must have operated after one or several star formation episodes, excluding the possibility that the observed metals result from the present burst (van Zee et al., 1998; Legrand et al., 2000, Legrand, 2000). Finally we find it rather implausible that new SN-released metals could be incorporated into the ionised gas during the short lifetime of the burst. Rather they are more likely to remain...
for a long time in a hot phase before they cool down and mix (Pantelaki and Clayton, 1987; Tenorio-Tagle, 1996).

3. Colors

Several studies have attempted to reveal an old stellar population in the outskirts of blue compact starbursts using surface photometry. It is easy to show that in the red or near infrared, old stars should be easier to detect than in the blue, where massive stars dominate. Old stars have to dominate the young stellar population in order to produce an observable impact on the colours. When using optical bandpasses $\left(U, B, V, R\right)$ only, a single stellar population (SSP) of 1 Gyr must account for at least 90% of the mass to be detectable against a 10 Myr SSP\(^1\). Inclusion of near-IR passbands reduces this figure to $\sim 50\%$. For a 10 Gyr old SSP, these figures rise to $\sim 95\%$ and $\sim 75\%$ respectively. Observed colors have to be compared with predictions from spectral synthesis models. We emphasize here that many authors bias their discussion when using only one model scenario – presented to be the simplest – such as the instant burst model (= SSP). In fact this model will unavoidably provide a lower limit to the age as we show in Fig. Using only a SSP model to estimate the age is not only the “simplest” – it is also an oversimplification.

Another problem in interpreting colours is the possible contribution from ionised gas, both in the form of line- and continuous emission. Although some spectral synthesis models include gas emission, these assume that UV-photons are produced locally, whereas in the halo of a BCG, they are likely to leak out from the burst region. Gas emission makes some colours bluer (e.g. $V - I_c$), others redder (e.g. $B - R_c$), but the effect also depends on gas metallicity and the hardness of the ionising spectrum. By using combined colour indices, which tend to either increase or decrease the estimated ages, the problem can be circumvented somewhat. Using deep spectra helps to estimate the emission-line contribution along the slit (e.g. Papaderos et al. 1998), however this technique is limited if the relative contribution from ionised gas varies with position angle. Indeed, there are indications that dwarf galaxies have extended gas emission along the minor axes, in line with simple models of winds and outflows.

In Fig. 1 we compare published halo colours for two young galaxy candidates: Tololo 65 and SBS 0335-052 with the predictions from spectral synthesis models (PEGASE.2 by Fioc and Rocca-Volmerange,\(^1\) These estimates made use of the PEGASE.2 spectral synthesis code (Fioc and Rocca-Volmerange 1999).
Census on the existence of Young Galaxies...

Figure 1. The broadband colours in the haloes of Tololo 65 (left) and SBS 0335–052 (right) compared with the model predictions from PEGASE.2 for three different star formation histories. Additional used parameters: $Z = 0.004$ and standard Salpeter IMF with mass range 0.1 to $120 M_\odot$. The shaded region gives the quoted observational uncertainty. It is evident that the instant burst approximation gives a lower limit to the age. The best fit is produced assuming an exponentially decaying star formation rate (e-folding time 3 Gyr) which yields an age of several Gyr in both cases. The photometric data is from Papaderos et al. (1999) for Tololo 65 and from Fig. 5 in Papaderos et al. (1998) for SBS 0335-052.

1999). For Tololo 65 the agreement is good when comparing models with extended (i.e. not SSP) star formation history. For SBS 0335-052, $U - B$ gives a lower estimate, still the data can be fit with an age of several Gyr. There is nothing from the photometrical point of view that requires these galaxies to be young. Similarly, for IZw18, the surface photometry consistently gives a lower limit of 1 Gyr (Östlin, this conference) in agreement with the results from CMD analysis (Aloisi et al. 1999; Östlin 2000), although there may be a serious contribution from ionised gas in the halo (Izotov 2000, private correspondence).

4. Conclusion

No conclusive evidence remains that metallicity and colours are unambiguous tracers of youth in any galaxy of our local Universe. We have outlined the danger in oversimplifying the analysis of metal ratios and colour indices using only a SSP scenario. We conclude that care should be taken before assessing an age to distant galaxies. This show that
the only way out, in our local universe, is to study very nearby galaxies with CMD techniques.

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