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Research Note

Is SBS 0335-052 a young galaxy?

G. Östlin[1] and D. Kunth[2]

[1] Stockholm Observatory, 13336 Saltsjöbaden, Sweden
[2] Institut d'Astrophysique de Paris (IAP), 98 bis Boulevard Arago, 75014 Paris, France
e-mail: kunth@iap.fr

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Abstract. The metal-poor blue compact galaxy SBS 0335-052 has been put forward as a local primeval galaxy candidate, with a proposed age less than 10^8 years. If true, this would imply that galaxy formation was not confined to high red-shifts, but is still occurring in the local Universe, albeit at a slower rate. In this paper we show that some of the available data in the literature on SBS 0335-052 indicate an age significantly greater than 10^8 years. In view of this, the conclusion that SBS 0335-052 is a newly formed galaxy appears premature. We point out that single burst models in general give lower limits on age estimates, which should be borne in mind when assessing ages for distant galaxies.

Key words. galaxies: compact – galaxies: starburst – galaxies: formation – galaxies: evolution – galaxies: star clusters – galaxies: individual: SBS 0335-052

1. Introduction

The interest in blue compact galaxies (BCGs) was triggered by the work of Searle & Sargent (1972) who showed that two objects found by Zwicky, IZw18 and IIZw40, were metal-poor galaxies forming stars at very high rates as compared to their luminosity. IZw18 was later confirmed to have an oxygen abundance of $12 + \log(\mathrm{O/H}) = 7.2$, i.e. only two percent of the solar value (Alloin et al. 1978). Concentrated efforts to find more objects of this kind, resulted in numbers of fairly metal-poor emission line dwarf galaxies, but IZw18 long seemed to be in a league of its own. However, the entrance of SBS0335-052 from the second Byurukan survey (Markarian & Stepanian 1983) changed this situation: Izotov et al. (1990) reported a metallicity lower than that of IZw18 while subsequent high signal–to–noise spectra by Melnick et al. (1992) gave $12 + \log(\mathrm{O/H}) = 7.3$, in agreement with more recent determinations (e.g. Izotov & Thuan 1999).

One of the exciting features of the discovery of BCGs were that they might be genuinely young galaxies, presently forming their first generation of stars (Searle & Sargent 1972). Subsequent studies have shown that most of them do in fact contain older stars (see Kunth & Östlin 2000 for a review). However the most metal-poor galaxies, IZw18 and SBS0335-052, remained among a small number of galaxies where no evidence for an old underlying population was seen.

Izotov & Thuan (1999) made a study of CNO abundances in a large sample of metal-poor BCGs. For galaxies with $12 + \log(\mathrm{O/H}) \leq 7.6$, they found that C/O and N/O stayed at a constant level, with no detectable scatter. Their interpretation was that in these very metal-poor galaxies, the observed CNO abundances had been produced entirely by massive stars, and by consequence these galaxies must be younger than 40 Myrs. Although there are other possible interpretations for the C/O and N/O patterns (Henry et al. 2000; Kunth & Östlin 2000, 2001), this possibility deserves a serious consideration. Recently, studies of the colour–magnitude diagram (CMD) from data obtained with the Hubble Space Telescope (HST), have revealed ∼1 Gyr old stars in IZw18 (Aloisi et al. 1999; Östlin 2000), demonstrating that it is not a primeval galaxy. SBS0335-052 has, however, resisted the direct detection of an old stellar population. One reason is that its distance of around 50 Mpc (radial velocity $v = 4050\ \mathrm{km\,s^{-1}}$; $H_0 = 75\ \mathrm{km\,s^{-1}/Mpc}$) is too large for a CMD to be obtainable, even with the HST.

In a number of seminal papers, it has been shown that SBS0335-052 is perhaps the best remaining local candidate for a genuinely young galaxy: surface photometry does not reveal any red underlying population,

Send offprint requests to: G. Östlin,
e-mail: ostlin@astro.su.se

contrary to most other BCGs (Thuan et al. 1997; Papaderos at al. 1998). Near infrared photometry (Vanzi et al. 2000) does not reveal any evidence for the presence of an old stellar population. In addition, there are suggestions, although debatable, that the oxygen abundance in the neutral HI gas may be a factor of 100 lower than that seen in the HII gas (Thuan et al. 1997).

2. The case for an old population in SBS0335-052

On the other hand, there are other observations, available at hand, that point towards the possible existence of an older stellar population in SBS0335-052. The surface photometry by Lipovetsky et al. (1999) shows that the $R_C - I_C$ colour[1] becomes increasingly redder at larger radii. In the halo, at a radius of 10 arcsec, $R_C - I_C = 0.4$. This colour corresponds to an age of several Gyr for a single stellar population (SSP), when using a Bruzual & Charlot (2000) model for a metallicity of $Z = 0.0004$ ($\sim 2\%\ Z_\odot$) and a standard Salpeter (1955) IMF with a mass range 0.1 to 120 $M_\odot$. Assuming a non-zero internal reddening would decrease this value. For an internal extinction of $E(B-V) = 0.2$ the age would become 1.0 Gyr. On the other hand, a more extended star formation history for the underlying stellar population would require an even larger age. Using a single burst model (i.e. SSP) results in the lowest possible age, whereas more extended star formation histories give higher age estimates. On one extreme, assuming a constant past star formation rate (SFR) gives an age of 10 Gyr without extinction, and 3 Gyr for $E(B-V) = 0.2$. Other models (e.g. "PEGASE" by Fioc & Rocca-Volmerange 1999) give very similar results. Even the published $U-B$ colour profile by Papaderos et al. (1998) is consistent with an age considerably older than the claimed upper limit of 100 Myrs. The comparison of the observed colours in the outskirts of SBS 0335-052 with a set of model predictions is shown in Fig. 1.

A major concern with very active star-forming galaxies, like SBS0335-052, is the possibility of Lyman continuum photons leaking out from the central burst and ionising the halo, thereby contaminating the halo colours (Bergvall 1992). However, the contribution from ionised gas would be greater in the R_C filter than in the I_C filter (Papaderos et al. 1998; Kunth & Östlin 2001). Thus, contamination by ionised gas would not artificially mimic an old age, contrary to the case e.g. for $B-R_C$. The $U-B$ colours are little affected by gas, but get slightly bluer, if anything. Hence, we conclude that the available surface photometry is consistent with an age of several Gyr for this galaxy.

In their HST/WFPC2 images, Thuan et al. (1997) found several star clusters in the centre of SBS0335-052. More clusters were added from the reanalysis of the HST data by Papaderos et al. (1998). We have performed photometry of the star clusters in SBS0335-052, using

[1] Subscript "C" indicates the Kron-Cousins filter system.

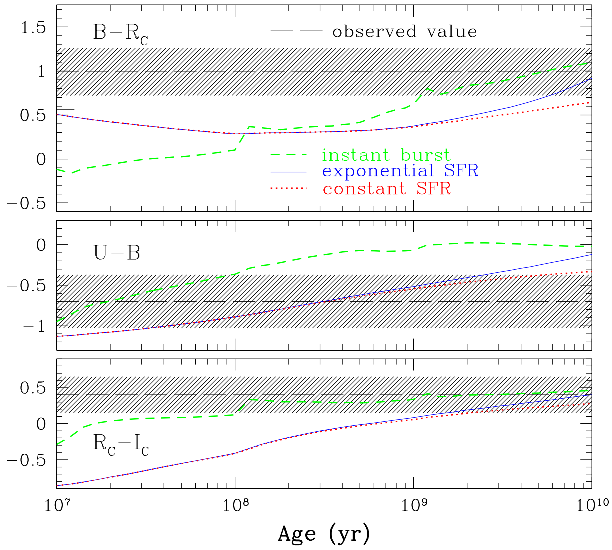

Fig. 1. Comparison of published halo colours in SBS0335-052 with those predicted by the PEGASE spectral synthesis models for three different star formation histories: instant burst, constant SFR, and exponentially declining SFR (e-folding time 3 Gyr). Additional used parameters: nebular emission included, metallicity of gas and stars: $Z = 0.0004$, and standard Salpeter (1955) IMF with a mass range 0.1 to 120 $M_\odot$. The long-dashed line gives the observed halo colours, and the shaded region represents 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 which yields an age of several Gyr. The photometric data has been taken from Fig. 5 in Papaderos et al. (1998) and from Lipovetsky et al. (1999)

the HST archive images in the F569W and F791W filters with "Vegamag" zero points. Comparing with the photometry reported by Papaderos et al. (1998), we find a good agreement. Papaderos et al. (1998) used a spectral synthesis model to constrain the ages of the star clusters to <100 Myr. However, as we demonstrate in Fig. 2, other spectral synthesis models give very different limits to the ages of the star clusters in SBS0335-052.

We have taken the system response curves for the F569W and F791W filters, the Vegamag zero points, and used the Bruzual & Charlot (2000) models as well as the PEGASE models (Fioc & Rocca-Volmerange 1999) to calculate the temporal evolution of the F569W–F791W colours for a single stellar population. We adopted a Salpeter (1955) IMF with a mass interval 0.1−120 $M_\odot$ and metallicity $Z = 0.0004$. The use of single burst models is well justified with stellar clusters since the stars in a stellar cluster have the same age. Moreover, diffuse ionised gas emission arising from leaking Lyman continuum photons is not a concern for stellar clusters since the background is subtracted. The evolution of colour with time is given in Fig. 2 and the model used by Papaderos et al. (1998) is shown for comparison. In Fig. 2 we have also added the predictions for the evolution of $V - I_C$, from the model by Kurth et al. (1999) with $Z = 0.0004$ and Salpeter IMF. In addition, we show the predictions from the

"Starburst99" model (Leitherer et al. 1999) for a metallicity $Z = 0.001$ and $0.1 - 120\ M_\odot$ Salpeter IMF. The latter model uses the Johnson I-band filter (I_J), and is scaled to $V - I_\mathrm{C}$ using the relation $V - I_\mathrm{J} = 1.30(V - I_\mathrm{C}) - 0.013$ (Withmore et al. 1993). Moreover, the "Starburst99" model does not include tracks for low mass stars, hence we only present results for ages less than 1 Gyr. As is evident from Fig. 2, the agreement between different models is reasonably good with the exception that for each age, the Papaderos et al. (1998) models give significantly redder colours, up to $\Delta_{V-I} = 0.5$. Such a difference may result in a difference in age of up to a factor of 100. In the top panel of Fig. 2 we show the difference between $V - I_\mathrm{C}$ and F569W–F791W as predicted by the Bruzual & Charlot (2000) model characterised above. Hence, the difference with respect to the Papaderos et al. (1998) models cannot be attributed to the possible use of different filter systems. The difference can neither be explained by different IMFs, giving only a minor effect on the colours for a SSP at ages greater than a few times 10 Myrs.

Empirical photometry for star clusters of varying age have been reported by Bica et al. (1990) using data for Galactic disc and LMC clusters. These clusters are much more metal-rich ($Z = 0.5$ to $1\ Z_\odot$) and the authors utilise the Johnson filter system, making a fair comparison difficult. We simply note that the Starburst99 and Bruzual & Charlot models with similar metallicity ($Z = 0.4$ to $1\ Z_\odot$) show a consistent behaviour. For ages in the interval 10^8 to 10^9 yr, the Papaderos et al. models are redder than the Bica et al. clusters despite a much lower metallicity and a "bluer" filter system. Old (>10 Gyr) globular clusters with $Z = 0.0004$ ([Fe/H] $= -1.7$) have colours $V - I_\mathrm{C} \approx 0.86$ (Kissler-Patig et al. 1998), corresponding to F569W–F791W ≈ 0.77 (see Fig. 2), in good agreement with the Bruzual & Charlot, PEGASE and Kurth et al. models.

Hence we conclude that the star clusters could be considerably older than suggested by Papaderos et al. (1998). Objects with $V - I \sim 0.4$ to 0.8, which, from the Papaderos et al. (1998) models are younger than 100 Myr, may in fact be older than 1 Gyr. We stress that we do not claim any particular age for these clusters since their internal reddening is unknown. We simply point out that they *may* be significantly older than previously reported.

A further problem with the youth hypothesis is that SBS0335-052 has a companion with similar metallicity: $12 + \log(\mathrm{O/H}) = 7.2$ (Lipovetsky et al. 1999). According to Izotov & Thuan (1999) this would imply that both galaxies are not more than a few 10 Myrs old, and hence have formed in synchronisation. The projected distance between the two galaxies is 22 kpc (Pustilnik et al. 2000), corresponding to a sound crossing time of more than 1 Gyr. Also the time scale for tidal triggering of star formation is much longer than 10 Myr. Thus the coordinated onset of the first star formation epoch in both galaxies, required by the youth hypothesis, would have to be a pure coincidence.

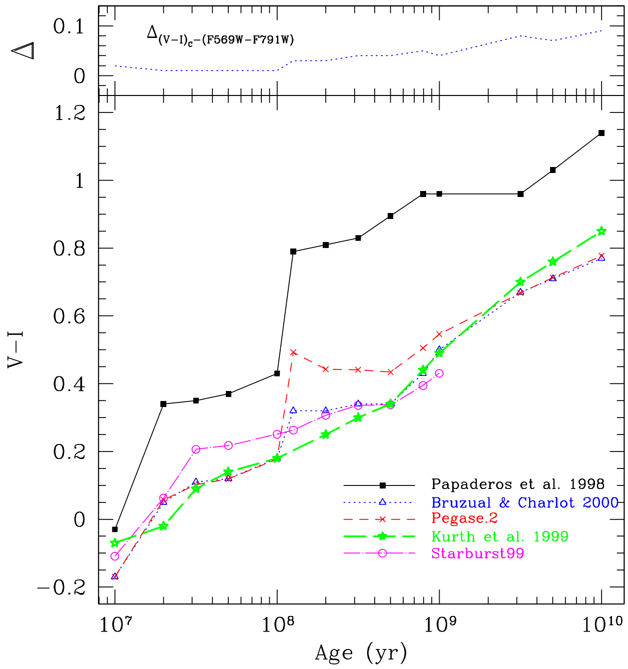

Fig. 2. Comparison of the predicted colour evolution for five different spectral synthesis models. All models assume a single short burst, Salpeter IMF and low metallicity. The different models use slightly different filter systems. The top panel shows the difference between the standard Kron-Cousins $V - I$ colour and the HST F569W-F791W colour systems. For more details, see text

3. Conclusions

Although we do not attempt to set any precise age limits on the stellar population in SBS0335-052, we claim that a young age cannot yet be concluded, leaving ample room for higher age interpretation. This galaxy still remains one of the best local young galaxy candidates, but there is nothing from the available photometric data, nor from chemistry, that *requires* this galaxy to be young (see also Kunth & Östlin 2001). Finding genuinely young galaxies at the present epoch would have more far reaching implications than finding just another old galaxy. The burden of proof has therefore to rest on the young galaxy hypothesis. It has to be shown beyond reasonable doubt that a galaxy does not contain an old population, the limit being set by the existing technology, before it can be considered young. In our view, SBS0335-052 does not yet fulfill these criteria. Our word of caution also naturally applies to any attempt to derive the age of high red-shift galaxies from colour indices using single burst models.

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