BLUE LOW SURFACE–BRIGHTNESS GALAXIES

N. Bergvall
J. Rönnback
Astronomiska observatoriet
Box 515
S–751 20 Uppsala
Sweden

ABSTRACT: The first results from an analysis of CCD photometry of blue low surface–brightness galaxies are presented. The galaxies have a wide range of morphologies, luminosities and ages – all appear to be older than 2 Gyr. We also discuss the results from spectroscopy of ESO 146–G14, a large disk galaxy with low chemical abundances.

1. Introduction

Low surface–brightness galaxies (LSBGs) have come to be one of the more interesting topics in extragalactic astronomy today. Deep searches for LSBGs in clusters of galaxies [e.g. 1] have been initiated in an effort to track the faint tail of the luminosity function and to study the distribution and nature of the dark matter component of the universe. LSBGs also play an important role for the understanding of the chemical evolution of galaxies.

Different explanations for the low surface brightness have been suggested: a) The galaxies are faded remnants of starforming galaxies which have consumed the gas or lost it due to wind stripping b) The star formation rate is low because the surface gas density is close to the threshold for star formation [e.g. 2] c) The formation of the first stellar generation is just commencing – i.e. the galaxies are truly young. We wanted to investigate the last possibility, at the same time contributing to the understanding of the chemical evolution of galaxies in general.

It is obvious that the detection of young galaxies at low redshifts would have important consequences. It would give us a unique opportunity to investigate the conditions for galaxy formation, early stellar evolution and the primordial abundances in the interstellar gas. Galaxy formation theories predict [3] that star formation in protodisks occasionally may be delayed until present times if they are subject to slow contraction, thus maintaining the gas surface density below the critical threshold. A sudden very large increase in the star formation rate (SFR) can then be initiated [4] as the gas density increases due to contraction, gravitational interaction, accretion of gas or smaller galaxies. A galaxy fitting into this scenario could be the isolated HI cloud in Virgo [5], although the true age of the optical counterpart is still a matter of controversy. We recently started a pilot study of blue LSBGs (BLSBGs) in the optical and in the HI 21–cm line. Here we will discuss some of the first results from the optical study.

B. Barbuy and A. Renzini (eds.), The Stellar Populations of Galaxies, 211–214.

2. Observations

When selecting the galaxies of our sample [6] we searched the L–V ESO/Uppsala catalogue [7] for extremely blue galaxies, having $|B-R|<0^m.5$. This should guarantee a low age of the luminous stellar component and would definitely exclude normal LSB spirals and irregulars. To secure age homogeneity, we also demanded the gradient in B–R to be low. Finally, only galaxies with a surface magnitude $\mu(B,eff) > 23^m.5$ were accepted. This left us with about 60 candidates. We are aware that the uncertainties in the catalogued magnitudes and colours will have the consequence that some redder galaxies will be scattered into our sampling area. Only broadband CCD photometry can give us a definite indication as to whether these galaxies have extreme properties or not. So far, we have obtained b,V and "Gunn i" images at ESO and NOT and HI observations at Westerbork of about 50% of the sample. Spectra have been obtained of a few galaxies. The data will be used to study the stellar content and distribution, the chemical abundances, the fractional HI mass and the spatial distribution of the galaxies.

3. Results.

3.1 MORPHOLOGIES, SIZES AND LUMINOSITIES

Morphologically the sample is quite heterogeneous. Three main morphological types can be recognized – disks, irregular galaxies with prominent HII regions and amorphous galaxies. A small part of the sample seem to be nearby dwarfs.The disk galaxies often exhibit warped structures and no or inconspicuous bulges. In contrast to the irregulars, the amorphous galaxies, despite their blue colours, have a smooth appearance and do not seem to contain any bright HII regions.This could be due to a recent gas heating and expulsion by winds from massive stars. These are also the galaxies which tend to increase in number as one approaches the limiting surface magnitude of the ESO Schmidt plates. About a dozen measured velocities yield dimensions and luminosities in the ranges 10–50 kpc and $M_B = -15$ to -19 (H_0=50 kms^{-1}Mpc^{-1}).

3.2 COLOURS AND AGES

Relevant information about the initial mass function (IMF) and ages of the dominant stellar generations can be obtained from optical/infrared spectroscopy or from a combination of spectroscopy and broadband photometry. Since spectroscopy is very difficult to obtain for the majority of the objects we have to rely on information from the broadband CCD photometry. These data can be compared with predictions from spectral evolutionary models under different assumptions about the IMF and the temporal variation of the star formation rate (SFR).

Fig. 1 shows the colour properties of galaxies for which we have reliable photometry. The diagram also includes the predicted evolutionary tracks for two different star formation histories. We assumed a Salpeter mass function, a mass range $0.1<M<100\ M_\odot$ and a metallicity of 5% solar. Nebular emission was included. When we calculated the synthetic colours we took into account both the actual filter transmission profiles and the response curve of the CCD used for the observations. Therefore our b–V is about $0^m.1$ redder than the corresponding Johnson/Cousins B–V for our programme galaxies. If we keep this in mind we see that the mean B–V of our BLSBGs are about $0^m.1$ bluer than the bluest of the previous samples of LSB galaxies discussed in the literature [e.g. 8]. Still we note that none of the galaxies observed so far is extremely blue. As a whole, the sample does not agree with a young stellar population. Even if we account for a small amount of reddening, the stellar population appears to be > 2 Gyr old for the majority of the galaxies. Some exceptions may be found at the lower left envelope of the distribution. One of the galaxies in this region is ESO 146–G14, one of the few for which we have obtained a spectrum.

This large (≈30 kpc) disk galaxy has an unusually low oxygen abundance, about 4% of the solar value. With M_B=–17 it thus breaks the metallicity–luminosity relation [9] that holds for other low luminosity galaxies. The oxygen abundance, as derived from the empirical relations discussed by [10], is nearly constant across the disk, indicating strong mixing or infall of processed gas. The rotation curve shows signs of mass outflows from the star forming regions but this result probably needs to be checked [11] with spectroscopy at higher dispersion. The stellar absorption spectrum shows prominent Balmer lines across the galaxy, including the bulge. From model comparisons [12,13] we find that the colours (after extinction corrections), the spectrum and the low abundances are all consistent with an age of 4–6 Gyr, corresponding to z ≈ 0.4, assuming Ω=1 and a normal IMF.

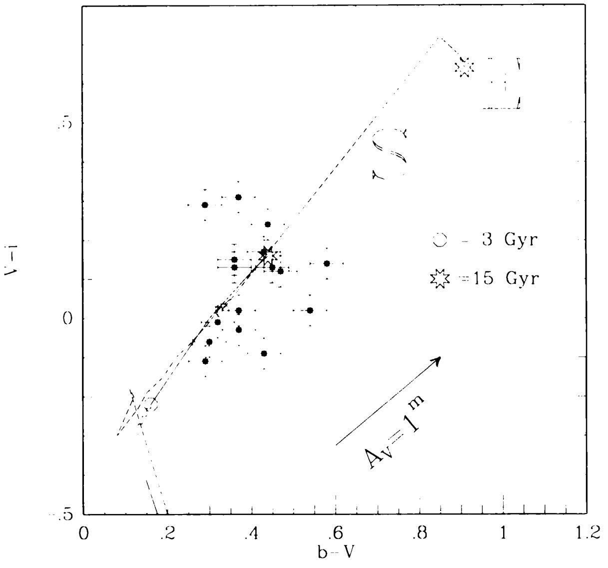

Figure 1. Colour–colour diagram of b–V versus V–i for BLSBGs. Also marked in the figure is the position of normal spiral galaxies (S) and elliptical galaxies (E). Evolutionary tracks up to an age of 15 Gyr are presented for a Salpeter mass function and two different star formation histories, constant SFR (—) and a short burst (– – –). The evolution up to 3 Gyr is from our models, assuming 5% solar metallicity. The later stages are from [14]. The reddening vector and the mean errors in the observations are indicated.

References

1. Davies, J.I., Phillipps, S., Disney, M.J. (1989) Mon. Not. R. Astr. Soc. 244, 385

2. van der Hulst, J.M., Skillman, E.D., Kennicutt, R.C., Bothun, G.D. (1987) Astr. Astrophys 177, 63

3. Silk, J., Szalay, A.S. (1987) Astrophys J. 323, L107

4. Struck–Marcell, C., Scalo, J.M. (1987) Astrophys. J. Suppl. Ser. 64, 39

5. Salzer, J., Alighieri, S., Matteucchi, F., Giovanelli, R., Haynes, M.P. (1991) Astron. J. 101, 1258

6. Bergvall, N., Rönnback, J. (1990) Proc. Nordic Baltic Meeting, ed. C–I. Lagerkvist, D. Kiselman, M. Lindgren, Uppsala, 71

7. Lauberts, A., Valentijn, E.A. (1989) "The Surface Photometry Catalogue of The ESO/Uppsala Galaxies", European Southern Observatory, Munich

8. Schombert, J.M., Bothun, G.D., Impey, C.D., Mundy, L.G. (1990) Astron. J. 100, 1523

9. Skillman, E.D., Kennicutt, R.C., Hodge, P.W. (1989) Astrophys. J. 347, 875
10. Skillman, E.D. (1989) Astrophys. J. 347, 883
11. Schweizer, F. private communication
12. Bergvall, N. (1991) in preparation
13. Olofsson, K. (1991) private communication
14. Arimoto, N., Yoshii, Y. (1986) Astron. Astrophys. 164, 260

Discussion:

H. Ferguson: Your velocity diagram for ESO 146–G14 showed no sign of coherent rotation. Is this unusual for a disk of its scale length?

Bergvall: Since the spectra are of low dispersion, our data for the stellar absorption features are afflicted with rather large uncertainties and do not exclude a rotation of the order of 200 kms^{-1}.

G. Hensler: 2 comments: Firstly, Theis, Burkert and Hensler (1991, subm. to Astron. Astrophys.) demonstrate by means of chemo–dynamical evolutionary models of galaxies that all cosmological 1σ and 3σ density fluctuations with masses of 10^9 to $10^{12}\,M_\odot$ are evolving into the $\bar{\rho}$–M (mean density–mass) region where dwarf and giant spheroidal systems are located from observations. Exceptionally, only galaxies that start with $10^{11}\,M_\odot$ from 1σ fluctuations are not able to collapse thermally but are self–regulated by their star formation, i.e. stars produce hot gas that prevents the collapse and controls by this the subsequent star formation and the cooling timescale determines the galactic evolution. Such a galaxy remains at approximately $\bar{\rho} \approx 10^{-3}\,M_\odot pc^{-3}$ and looses mass continuously. Secondly, these low surface–brightness galaxies would be disrupted in clusters of galaxies due to encounters and are, therefore, observationally found only in the field.

Bergvall: Our data indicate that the BLSBGs indeed tend to avoid regions of high galaxy density.

J. Frogel (Question to Bergvall and Tosi): Can there be an evolutionary link between the dIrr and blue low surface–brightness galaxies?

M. Tosi: Yes, in my opinion these galaxies may well be related to the irregulars of our sample. Clearly our selection of only galaxies in the Local Group prevents any suggestion about clustering.

Bergvall: Our sample seems to contain galaxies of widely different sizes and luminosities, some of which I am sure are related to dIrrs. The difference lies in the surface brightness, reflecting either different ages or different SFR.

H. Dottori: Have you determined the equivalent width of the H lines in ESO 146–G14?

Bergvall: The W(Hα) in emission is between 10 and 350 Ångström. If you refer to the absorption lines we find that W(Hδ) is 5–8 Å in all parts of the galaxy. For a stellar population with an exponentially fading star formation rate, the measured equivalent widths of the absorption lines, in conjunction with the measured W(Hα) in emission, imply an intermediate age.