Detection of a Second Optical Component in the HI cloud associated with the Young Dwarf Galaxy SBS 0335–052: New Data from the 6–m Telescope.

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Abstract

The Blue Compact Dwarf (BCD) galaxy SBS 0335–052 is one of the most metal–deficient galaxies known and one of the best candidates for a young dwarf galaxy in the process of formation. A VLA HI map reveals an unusual structure: the neutral gas is distributed in a very extended disk, about 15 times larger than the Holmberg optical diameter of the BCG. There are two peaks of high density. The eastern peak is close to the position of SBS 0335–052 whereas the western HI peak is associated with a faint compact optical galaxy. A 6–m telescope spectrum of this object shows Hα, Hβ, and [OIII]λ5007 emission with a redshift close to that of SBS 0335–052. We suggest that it may be a young and chemically unevolved dwarf galaxy.

1 Introduction

The blue compact galaxy SBS 0335–052 was discovered by Izotov et al. (1990) as an extremely low metallicity galaxy, similar to I Zw 18. Its extremely low oxygen abundance [O/H]=7.26 has been confirmed by by Terlevich et al. (1992) who used this galaxy for a new estimate of the primordial helium abundance. An improved value of [O/H]=7.30 and an NTT Hα image was obtained by Melnick et al. (1992). They show that the object has a double nuclear structure with a separation between the two components of $\sim$1.0″. The fainter component has a higher abundance but it is still very metal poor, ([O/H]=7.64). The Hα image shows a complex structure with filaments and wisps; the hydrogen lines extend to about 6″ on either side of the nuclei.

Subsequent studies showed that SBS 0335–052 is an unusual HI gas–rich dwarf galaxy (Thuan et al. 1996a), with no indications of an old stellar population, either from high S/N MMT optical spectra (Izotov et al. 1996), or from V and I imaging with HST (Thuan et al. 1995). The images of SBS 0335–052 are generally reminiscent of I Zw 18 (Hunter and Thronson 1995). They show a large arc and several star–forming regions in the central part surrounded by extended low surface brightness emission of about 4 kpc in size, with systems of loops typical for supernova related phenomena in star–forming galaxies. The age

of these gas filaments is expected to be lower than the age of the current star–formation burst (several million years). Alternatively, the blue color of the extended halo could be due to stellar light, but in this case, the stellar age also has to be less than 100 million years.

The structure of the surrounding HI gas is especially interesting since it can indicate how primeval galaxies collapse and form their first stars. We used the VLA in the C and D configurations to map and study the velocity field of SBS 0335–052 in the 21–cm line. The observations were carried out in 1994–1995 for a total of 4.5 hours. The VLA data will be discussed in detail in a forthcoming paper by Thuan et al. (1996b).

2 Optical identification

When making the optical identifications we were guided by the integrated HI flux density map. The gas structure of this unique young dwarf galaxy is quite unusual. There are two prominent slightly resolved HI peaks located at roughly equal distance from the center of the HI cloud, separated by about 28 kpc. The location of the eastern peak is close to the position of SBS 0335–052.

In Fig.1 we show the identification map extracted from the Digital Sky Survey (DSS). There is a faint, very compact, slightly elongated galaxy at about $1.5'$ West of SBS 0335–052. The observational parameters for both eastern and western optical components are given in Table 1. The position of the W component is very close to the coordinates of the western HI peak and suggests that the two are physically associated. We estimate the integrated V luminosity of the W component to be roughly 19^m. Its size as measured by its FWHM is $2.8'' \times 2.2''$.

3 Spectroscopy

A spectrum of this western component (hereafter SBS 0335–052W) was obtained with the 6–m telescope on December 17, 1996. We used the spectrograph SP–124 at the Nasmyth–1 focus in combination with a new Tektronix 1024×1024 CCD detector provided by the Astronomical Institute at Potsdam (AIP) in the framework of a cooperative program between SAO and the AIP. Since the CCD detector had just been installed for a test run, the instrument was not optimized and the quality of the spectrum presented here is not representative of the system at its best. The weather conditions were not photometric with fairly poor seeing. A slit size of $35'' \times 2''$ was used. The observations were carried out in a MIDAS environment, with the use of the package NICE (Kniazev and Shergin 1995).

The spectrum covers the 4700÷7000 ÅÅ range with a resolution of 5.2 Å pxl^{-1}. Four 600 seconds exposures of variable quality were averaged with appropriate weights to obtain the final spectrum. The spectrophotometric standards Hiltner 600 and Feige 34 were used to correct the linearized spectrum for the spectral response of the total system. The reduction of the raw data was done in MIDAS with the package LONG, adapted for our instrument by A.Ugryumov.

The final spectrum is shown in Fig.2. Only three significant features are seen in the spectrum, Hα, Hβ and [OIII] 5007 Å. Their equivalent widths are respectively 332, 93 and 98 Å. A very faint feature is seen at the expected position of [OIII] 4959 Å with an EW of about 25 Å which is close to the expected value from the theoretical ratio of the two [OIII]

lines. There is no indication of either the [NII] or [SII] lines near Hα. For comparison we also obtained the spectrum of SBS 0335–052 in the same night with a total exposure time of 30 min. The spectra were taken with a position angle of –5° for the W component and of +10° for SBS 0335–052.

It is interesting to estimate the extent of this W component. The region which emits in Hα can be traced on our long–slit spectra over ∼13 pixels = 5.2″, the scale of the spectrum perpendicular to the dispersion direction being 0.4″ pxl^{-1}. This is about a factor of 3 less than the extent of Hα in SBS 0335–052 which covers about 40 pixels, as derived from the 6–m telescope spectra obtained under the same conditions.

4 Discussion

The heliocentric velocities of 3990 km s^{-1} for SBS 0335–052W, and 4110 km s^{-1} for SBS 0335–052 do not leave any doubt that both objects belong to one system. Both optical velocities coincide within the errors with the velocities of the HI gas (see Table 1). Thus in this unusual system we observe a pair of dwarf galaxies embedded within a massive and huge HI cloud. All the data indicate that in the eastern HI density peak the formation of the galaxy SBS 0335–052 started very recently. Its first massive stars were formed during the last several million years.

Table 1. Observed and derived parameters for the SBS 0335–052 system

Parameter	0335–052W	0335–052
$\alpha(1950.0)^a$	$03^h35^m09^s.57$	$03^h35^m15^s.15$
$\delta(1950.0)$	$-05°12'24''.0$	$-05°12'25''.9$
V (mag)	19	17
angular size $('')^b$	5.2	16
linear size (kpc)^c	1.3	4.1
V_{opt} (km s^{-1})	3990±40	4110±20
V_{HI} (km s^{-1})^d	4006± 5	4068± 5
F(Hα)×10^{-16} (erg s^{-1} cm^{-2})...	53±10	891±15

[a] The coordinates were obtained from the DSS using MIDAS.
[b] The Hα extension was used as the object's size.
[c] We adopted $H_\circ$=75 km s^{-1} Mpc $^{-1}$.
[d] HI parameters (Thuan et al. 1996b).

The absolute magnitude of the western component is $M_V \sim$ -14.5^m and its linear diameter is only about 1.3 kpc, taking the Hα extension as the size, which places it in the range of very small blue compact dwarf galaxies. Its emission line spectrum indicates that there is a current starburst in this galaxy as well. No strong low–excitation line is seen in the red part of the spectrum indicating, possibly, a high temperature and a low metal abundance. The strong [OIII] and Hβ lines seen do not contradict such a possibility. Our spectrum did not cover the region shortward of 4700 Å, so we have no information on the range of possible temperatures in the HII region. But if it turns out that its temperature is high then the low intensity of [OIII] 5007 Å relative to that of Hβ could be interpreted as an indication of a

very low abundance of oxygen. Clearly a high S/N spectrum of the western component is necessary to elucidate its oxygen abundance and evolutionary status.

There are two possible models to explain this system. Our preferred hypothesis which takes into account all available data, is that the eastern and western parts of SBS 0335–052 are two very young low metallicity objects embedded in one huge HI cloud having approximately the same young age. A second scenario describing the nature of this system is also possible, but seems to be not very probable. If the metallicity of the western component turns out to indicate that it is an older dwarf, we then witness an encounter of the dwarf with a pristine huge HI–cloud. In that case the tidal disturbance of this encounter has triggered the gas collapse in the eastern part of the HI cloud and the subsequent dwarf galaxy formation (SBS 0335–052 itself). Additional spectral observations and a detailed study of the HI kinematics of this unique system will be necessary to make a choice between these two models.

As for the possible tidal effect of another galaxy, indeed, such a galaxy, the Scd spiral NGC 1376, is located at an angular distance of about $9'$ to the West of the SBS 0335–052 system. Its velocity, determined from HI observations (Shostak 1975) is 4155 ± 5 km s^{-1}. The projected distance from the center of the SBS 0335–052 HI cloud is about 135 kpc. However the role of this galaxy is far from evident. If the radial velocities of SBS 0335–052 and NGC 1376 are due purely to Hubble flow, their relative distance is about 1500 kpc, and it would be hard to ascribe the very recent process of galaxy formation in the SBS 0335–052 system to an influence exerted by NGC 1376.

The only known BCD which is more metal–deficient than SBS 0335–052 is I Zw 18. It also has a double–component structure. But in I Zw 18, the two components embedded within an HI cloud are separated by only ~ 300 pc. This is very different from the situation in SBS 0335–052. The newly discovered western component lies at a projected distance of 28 kpc and without the VLA map (Thuan et al. 1996b), we could not have guessed that SBS 0335–052 and the its western component were parts of one and the same physical system, spanning a total size 64 kpc.

Better knowledge of the kinematics of the neutral and ionized gas in this key dwarf galaxy system in formation will allow us to shed some light on the processes occurring at the epoch of galaxy formation, and thus to predict better the properties of primeval galaxies.

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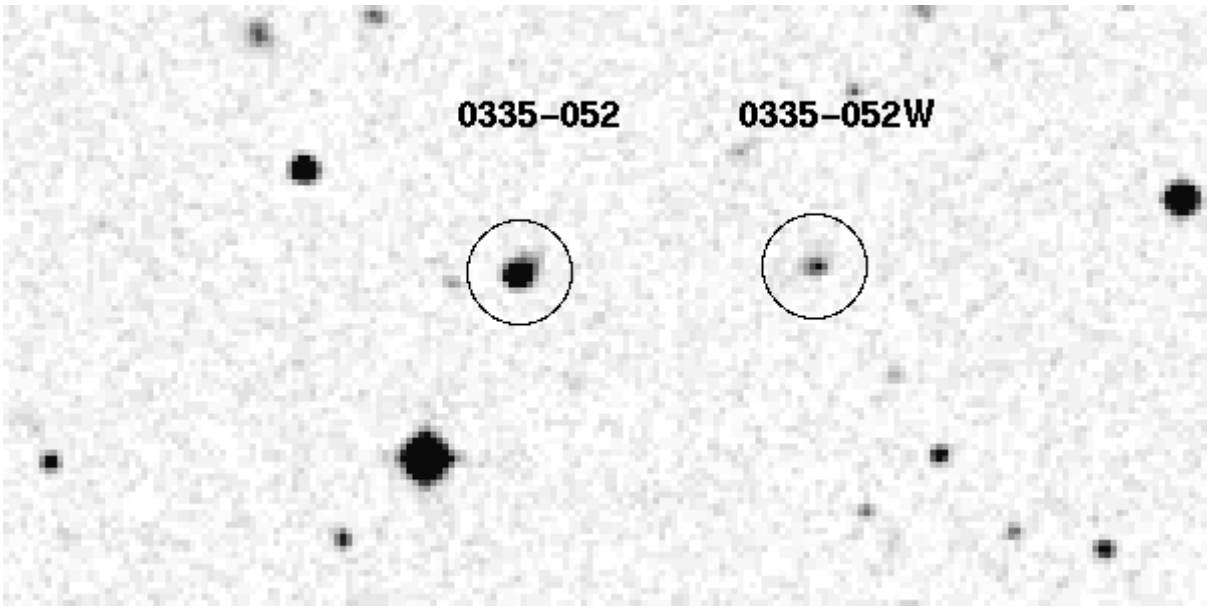

Figure 1: Identification chart from the DSS, 340″×170″ in size. SBS 0335–052 and the faint compact object 1.5′ to West are marked.

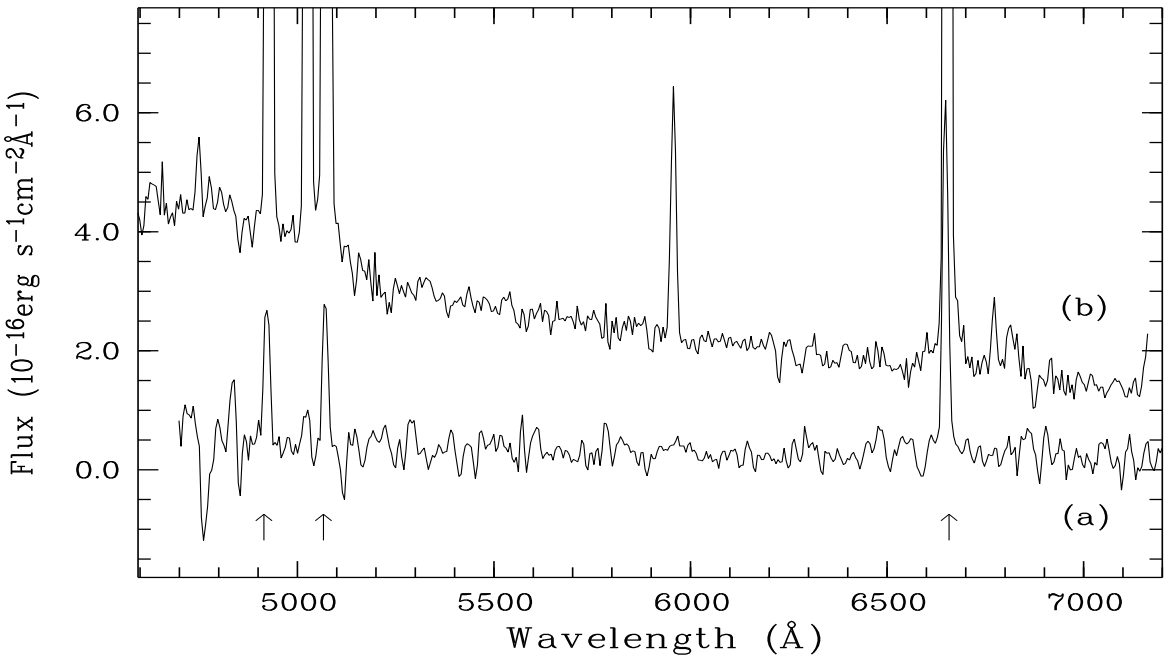

Figure 2: 6–m telescope spectra of SBS 0335–052W (a) and SBS 0335–052 (b); vertical arrows show the position of emission lines of Hβ, [OIII] 5007 Å, and Hα.