Abstract. We present first results of a study devoted to the analysis of the X-ray emission as tracer of activity and diagnostic tool for the structural properties of Blue Compact Dwarf Galaxies. The case of Henize 2-10 is being reviewed, and first trends are discussed.

1. Introduction

Blue Compact Dwarf Galaxies (BCDs) are metal poor ($Z \sim 1/10 Z_\odot$) and gas-rich extragalactic systems undergoing brief ($< 10^7$ yr) bursts of star formation, separated by long ($\sim 1$ Gyr) quiescent phases (see Thuan 1991 for a review). The detection of an extended and old low-surface-brightness (LSB) stellar component underlying the regions of active star formation in the majority of BCDs (Loose & Thuan 1986, Kunth et al. 1988) implies that such systems are old gas-rich dwarf galaxies undergoing recurrent activity phases. This faint, however dynamically important, mass constituent in BCDs, together with the H I-gas and Dark Matter, determines the gravitational potential within which starbursts occur. The physical origin of starbursts in the mostly isolated BCDs is not yet understood. Hypotheses put forward invoke a dynamical perturbation by a nearby H I-cloud (Taylor et al. 1994), interaction/merging with another dwarf galaxy (Comte et al. 1996), or inflow and collapse of their massive H I-halo onto the stellar LSB-component (Loose & Fricke 1981). The prime intrinsic properties of a BCD controlling the morphology, the spatial extent, and the strength of the burst are still a matter of debate. Among the hypotheses proposed are a massive, BCD-specific, Dark Matter halo dominating entirely the mass (Meurer et al. 1998). In another scenario the mass and the structural properties of the stellar LSB-component, i.e. the shape of the gravitational potential of the underlying old stellar population, are believed to regulate the global star-formation process (Papaderos et al. 1996).

A further issue is related to the evolutionary links between BCDs and other classes of galaxies such as dwarf irregulars dIs and dwarf ellipticals dEs. Papaderos et al. (1996) found that, at equal B-luminosity, the structural

properties of the underlying host galaxy of BCDs do systematically differ from dIs/dEs: at $M_B = -16$ mag the central surface brightness and the exponential scale length of the LSB-component of BCDs are by $\sim 1.5$ mag brighter and by factors $\sim 2$ smaller than dIs/dEs. This result, corroborated in the range of more luminous BCDs by Marlowe et al. (1997), implies that the commonly accepted evolutionary connection between BCDs and dIs cannot be maintained unless the LSB component of BCDs can undergo dynamical changes such as expansion and contraction on time scales of few $10^8$ yr (Papaderos et al. 1996).

Recent investigations (van Zee et al. 1998) reveal that BCDs show, unlike dIs, a compact and dense H I-distribution peaking typically very close to the intensity maximum of the starburst component (see also Taylor et al. 1994). Thus, if BCDs are dIs seen in active stages, the onset of a starburst must be accompanied by a large scale contraction of the massive gas-halo. Once a burst is initiated, star formation processes as well as the subsequent dynamical evolution of a BCD may sensitively depend on the formation circumstances of a hot (few $10^6$ K) gas phase, a process manifesting itself in the formation of bubbles expanding within the ambient cold gas medium (Marlowe et al. 1995, Heckman et al. 1995, Bomans et al. 1997). Although, in terms of its mass, this tenuous hot gas-phase may not be dynamically important, the pressure it exerts on the ambient cold H I-gas has obvious consequences. The gradual increase of the volume filling factor of the hot gas phase within the optical BCD, i.e. the replacement of the H I-gas by a warm/hot gas phase may lead to a flattening of the gravitational potential, thus initiating an adiabatic expansion of the stellar LSB-component.

Understanding the formation characteristics and evolution of this hot, X-ray emitting gas-phase in the course of a starburst is, therefore, a basic requirement for gaining insights into the dynamical evolution and the activity status of BCDs. In Sect. 2 we shall briefly introduce a further paradigm of the formation of a hot gas-phase in a BCD on the basis of X-ray and optical data and in Sect. 3 we discuss links between the structure of the stellar LSB-
Fig. 1. left: B-band exposure of Henize 2-10 (D=8.7 Mpc) obtained, as also the further optical data presented below, at the Danish 1.54m telescope at La Silla. Contours are shown at the intensities from 18 to 26 mag arcsec$^{-2}$ in steps of 0.5 mag. Either nucleus is separated by $\sim 9''$ (380 pc). The same diagram shows that for intensities $\gtrsim 23$ B mag arcsec$^{-2}$ the light is dominated by the smooth underlying LSB component. middle: Surface brightness profiles of Henize 2-10 in B and R. Note the exponential intensity decrease for radii $> 30''$. Profile decomposition into the exponential component (solid line) and the starburst-luminosity in excess of the LSB component (small circles) is shown for the B-band profile. The absolute B magnitudes of the underlying LSB component and of the starburst component within the 25 mag arcsec$^{-2}$ isophote amount to $-16.16$ mag and $-16.17$ mag, respectively, i.e. either component are nearly equally luminous. right: Radial B–R profile of Henize 2-10 derived by subtraction of the R-band profile from the B-band profile. The colour of the underlying LSB-component, $\sim 1.3$ mag, witnesses an older host galaxy underlying the regions of active star formation.

Fig. 2. left: ROSAT HRI exposure of Henize 2-10 overlaid to a H$\alpha$-map. The high surface brightness X-ray spot containing nearly half of the total flux appears to be slightly shifted with respect to the western, most luminous starburst knot. The positions of the starburst knots, of which the western one contributes $\sim 3/4$ of the total H$\alpha$-emission, are indicated by crosses. right: H$\alpha$-equivalent width $EW(H\alpha)$ map of the central region of Henize 2-10. The overlaid contours show the optical morphology in the B band and correspond to surface brightness levels from 17 to 20 B mag arcsec$^{-2}$ in steps of 0.5 mag. The dashed line indicates the orientation of the elongated $^{12}$CO component (Kobulnicki et al. 1995) protruding from the interface between either starburst knot to southeast.

component and the activity of a BCD as it imprints its integrated X-ray properties.

2. Henize 2-10

The morphological properties of this Wolf-Rayet galaxy have prompted different interpretations of its nature and of the origin of its starburst activity. In one of them Henize 2-10 is regarded a typical BCD (Corwin et al. 1993), similar to those discussed in Loose & Thuan (1986). On the other hand, the presence of two star-forming regions (Bergvall 1985, Johansson 1987) and the kinematics of its neutral and molecular gas (Kobulnicki et al. 1995) led to the hypothesis that Henize 2-10 is a system of two merg-
ing dwarf galaxies. Figure 1 shows that either starburst knot is embedded within a nearly circular stellar envelope dominating the light for $\gtrsim 23$ B mag arcsec$^{-2}$. The average B–R index of this LSB component of $\sim 1.3$ mag (Fig. 1,right) as well as its smooth morphology suggest an old, dynamically relaxed stellar population. Its intensity distribution can be approximated by an exponential fitting law with a central surface brightness $\mu_{B,0} = 21.35 \pm 0.02$ mag arcsec$^{-2}$ and a scale length $\alpha = 670 \pm 0.12$ pc, i.e. structural properties which are typical for BCDs (cf. Papaderos et al. 1996). This is also the case for the concentration index CI=0.88 which is close to the expected value for a host galaxy with the absolute luminosity of that of Henize 2-10. On the other hand, the disturbed B–R morphology (Fig. 3,left) and the evidence described above suggest that He 2-10 may be a dynamically perturbed BCD.

A thermal bremsstrahlung fit to the PSPC-spectrum of Henize 2-10 yields an average plasma temperature $kT = (0.49^{+0.29}_{-0.18}) \text{ keV}$ and an intrinsic $0.1–2.4 \text{ keV}$ luminosity of $\log(L_X) = (7.6^{+0.3}_{-0.3}) \times 10^{39} \text{ erg s}^{-1}$ in agreement with the value $\log(L_X/\text{erg s}^{-1}) = 40–41$ derived by Hensler et al. (1997) and Stevens & Strickland (1998). As HRI-maps reveal (Fig. 2, left) roughly one half of the X-ray emission is contributed by a compact high surface brightness source, being probably located slightly offset from the most luminous starburst knot, close to the region with low H I surface density discovered by Kobulnicky et al. (1995; cf. their Fig. 10). Given, however, the positional uncertainty of $\sim 6''$ in HRI-maps a further check is required. The remaining X-ray emission extends on scales comparable to those of the Hα-emission, the faint outskirt of the latter being visible out to $\sim 0.5$ (1.3 kpc) from the nuclear region.

The Hα-equivalent width map of the central region of Henize 2-10 (Fig. 2, right) suggests a kinematically perturbed ISM on kpc-scales with two marked supershells expanding from either starburst knot roughly perpendicular to the plane of the CO-complex. The cavity delineated by the eastern supershell coincides with an extended blue region with an average B–R index $\lesssim 0.67$ mag. This feature being centered $\sim 3''$ northeast from the eastern starburst knot does not seem to be associated with any conspicuous local enhancement of the stellar background (cf. Sauvage et al. 1997, Beck et al. 1997). An analysis in progress (Papaderos et al. 1998a) focusses on the nature of the eastern shell, in particular the question of whether it may be driven by a mixture of warm and hot X-ray emitting gas inflating its interior. The measured B–R index is consis-
tent with the values between 0.48 and 1.1 mag predicted by Krüger (1992) for a photoionized gaseous continuum with metallicities of $1/20 Z_\odot$ and $Z_\odot$, respectively. These results show that Henize 2-10 is a well suited laboratory for studying the interplay between the cold, warm and hot gas phase of a BCD in the course of a violent starburst. A continued investigation of this system, in particular with the help of spatially resolved X-ray maps, is apparently of great interest.

3. On the effect of the LSB-component

The X-ray emission as a consequence of the starburst phenomenon, in particular the X-ray to B-luminosity ratio $\log(L_X/L_B)$, may hold important information on the activity status of starburst galaxies (cf. Fricke & Papaderos, these proceedings). A preliminary analysis of ROSAT-detected BCDs (Papaderos et al. 1998b) indicates that among them the more metal-rich objects follow, similar to colliding starburst galaxies, a trend of increasing $\log(L_X/L_B)$ with increasing $\log(L_{\text{FIR}}/L_B)$-ratio. Thus, in certain evolutionary stages the $\log(L_X/L_B)$-ratio may be regarded a measure of the burst strength. This, however, may not be the case in a late starburst age, when most of the X-ray emitting gas formed in a BCD inflates the galactic halo where, through adiabatic expansion, it may obtain spectral properties and a surface brightness comparable to those of the diffuse X-ray background. NGC 1705 (Hensler et al. 1998, cf. their Figs. 1&2) may be considered an example of this later starburst phase.

Next we shall comment on one of the questions posed in Sect. 1: how the structural properties of the underlying stellar component in a BCD may influence the starburst phenomenon. In Fig. 4 (top) the $\log(L_X/L_B)$-ratio for a sample of BCDs is compared with the exponential scale length $\alpha$ of their LSB component. In the lower diagram $\log(L_X/L_B)$ is correlated with the ratio of the central luminosity density of the LSB component of BCDs with that of dIs, $l_0_{\text{BCD}}/l_0_{\text{dI}}$. Both diagrams show a trend for increasing $\log(L_X/L_B)$-ratio with decreasing $\alpha$ and increasing $l_0_{\text{BCD}}/l_0_{\text{dI}}$. From the latter trends and Fig. 8 in Papaderos et al. (1996) follows that the most compact and most mass-poor BCDs show the highest $\log(L_X/L_B)$-ratio. Stevens & Strickland (1998) remarked that a sudden increase in the $\log(L_X/L_B)$-ratio is to be expected in an instantaneous burst with age $> 3$ Myr. By contrast, enduring star-formation is not expected to lead to such a strong increase in $\log(L_X/L_B)$. Combining all latter lines of evidence with the $\log(L_X/L_B)$-$\log(L_{\text{FIR}}/L_B)$-trend the present results may be interpreted as follows: bursts igniting in compact and less-massive BCDs are more violent than in the more massive ones, in the sense that they must be shorter and characterized by a higher burst parameter.

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