LUMINOUS COMPACT BLUE GALAXIES IN THE ULTRA DEEP FIELD: DO THEY HAVE EXTENDED DISKS?

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Abstract We study the low-surface brightness structure of 30 Luminous Compact Blue Galaxies (LCBGs), mostly at $z \gtrsim 0.9$, in the HST/ACS Ultra Deep Field. Deep rest-frame B surface brightness profiles reveal extended, roughly exponential components, usually hosting centrally concentrated excess emission. The exponential components are relatively compact, with scale lengths $\alpha_E \sim 1 \ldots 2$ kpc, comparable to local small disks and dwarf galaxies. Large disks ($\alpha_E > 3$ kpc), possibly relating LCBGs to bulge formation in massive disks at $z = 0$, are rare. Our results indicate that most LCBGs require substantial disk growth to be progenitors of today's large disks.

Keywords: LCBGs, ACS, UDF, Structure, Evolution

1. Introduction

The rapid evolution of starbursting, Luminous Compact Blue Galaxies (LCBGs) from $z \sim 1$ to 0 (Phillips et al. 1997) feeds a controversial debate on their nature and their descendants in the local Universe (see also Bershady et al., this volume). The smallest LCBGs with low velocity dispersions have been suggested to fade into local low-mass ellipticals such as NGC 205, while larger LCBGs with broader linewidths were proposed to be related to local irregulars and starburst disk galaxies (Koo et al. 1995, Phillips et al. 1997, Guzmán et al. 1998). A different scenario attributes the small sizes, high surface brightnesses and narrow nebular emission line widths of distant LCBGs to the small extent and photometric dominance of a forming bulge in massive progenitors of normal disks (Hammer et al. 2001, Barton & van Zee 2001). We use the exceptionally deep images of the HST/ACS Ultra Deep Field (UDF) to address the presence of extended, possibly low surface brightness (LSB) disks in LCBGs at high redshifts, where cosmological surface brightness dimming usually hampers such studies.

2. Photometric structure of LCBGs

Sample: LCBGs were selected from the UDF SExtractor catalog (V1, Beckwith et al. 2004, in prep.), with rest-frame properties derived using robust literature redshifts (Noeske et al. 2005, in prep.) and the *DEEP2* K-correction code (Willmer et al. 2004). We assume $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_M = 0.3, \Omega_\Lambda = 0.7$. The adopted selection criteria (similar to Jangren et al. 2004: rest-frame $(B-V)_{\mathrm{Vega}} \le 0.6$, half-light radius $r_e \le 3.5\,\mathrm{kpc}$, average surface brightness within $r_e \le 21\,B\,\mathrm{mag\,arcsec^{-2}}$, $M_{B,\mathrm{Vega}} \le -18.5$) yield 30 LCBGs at redshifts $z = 0.2 \ldots 1.3$; two thirds of the sample are at $z > 0.9$.

Structure: extended components and central excesses Surface brightness profiles (SBPs) were derived from UDF/ACS B, V, i, z images (see methods in Papaderos et al. 2002, Noeske et al. 2003). These SBPs (Fig.1) show an approximately exponential component (EC) that is moderately extended (scale lengths $\alpha_E \gtrsim 1\,\mathrm{kpc}$). Most SBPs also display a central excess, superposed on the EC within $\lesssim 2-4\,\alpha_E$, confirming what earlier data (Guzmán et al. 1998) suggested. The ACS WFC PSF in red bands can mimick LSB components around compact objects. Using observed PSFs and convolved model galaxies, we confirmed that the ECs, and the central excess components are real (see Fig.1); only for few small, faint objects this structure remains insecure. The ECs were approximated by exponential fits to the outer SBPs, avoiding central excesses (thick lines in Fig.1). Resulting scale lengths α_E are shown in Fig.2, uncorrected for PSF effects. Arrows give typical corrections (see Fig.1).

Are LCBGs progenitors of small or large galaxies in the local Universe? Fig.2 shows that ECs of LCBGs are comparably small ($\alpha_E \sim 1 \ldots 2\,\mathrm{kpc}$) for a given luminosity, implying a compact, high surface brightness structure. The compact appearance of most LCBGs is thus only partly due to a central light excess. Large LSB disks ($\alpha_E \gtrsim 3\,\mathrm{kpc}$) that appear compact due to dominant central sources are rare (2/30 LCBGs, see UDF0900, Fig.2). More extended, faint LSB disks *below* the found *compact* ECs can be excluded down to low central surface brightnesses ($> 23\,B\,\mathrm{mag\ arcsec^{-2}}$) : at $z \sim 1$, rest-frame SBPs reach limits of 26.5 B mag arcsec^{-2} even for small galaxies (Fig.1, left). This constrains existing hypotheses on the nature of LCBGs at intermediate z:
(i) Assuming that the ECs do not undergo substantial size evolution (factor $\gtrsim$1.5) to $z = 0$, only few LCBGs may be forming bulges of local large disks. Most LCBGs will have an EC structure overlapping with local compact disks and various local dwarf galaxies, depending on the fading of the ECs to $z = 0$ (Fig.2), which may span $\sim 1 \ldots 6$ mag for various formation histories.
(ii) Central excesses may often be associated with star formation in LCBGs, as suggested by first rest-frame color estimates, and irregular morphology (see also Guzmán et al. 1998). Their relative extents in the ECs appear similar to that of star-forming components of local Blue Compact Galaxies (BCGs)

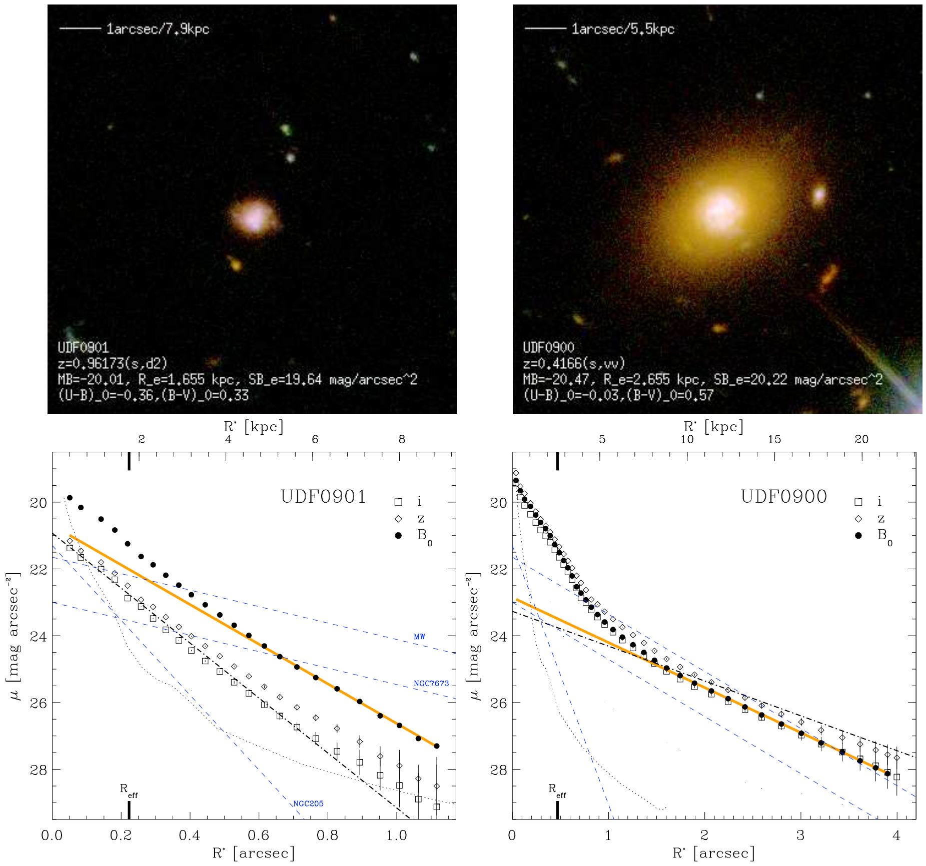

Figure 1. LCBGs with a compact (UDF0901, left) and an extended exponential component (UDF0900, right). **Surface brightness profiles:** observed ACS i and z data (AB mag) and rest-frame B band profile (B_0, Vega mag). **Local comparison objects:** dashed lines show a MW-like Freeman-disk ($\mu_{0,B} = 21.65$ mag arcsec^{-2}, $\alpha_E = 3.5$ kpc), the LSB disk in the local LCBG NGC 7673, and the exponential component of the dwarf elliptical NGC 205 (Choi et al. 2002). **PSF effects:** thick lines show fits to extended exponential components in the rest-frame B profiles, *uncorrected* for PSF effects. Dash-dotted lines show slopes of the extended component, *corrected* for PSF effects using GALFIT (Peng et al. 2002) decompositions in the z band. Uncorrected scale lengths are typically overestimated by $\lesssim 0.1$ dex, few by ~ 0.15 dex. The observed ACS z PSF (dotted line) shows that extended exponential components in both types of LCBGs cannot be PSF artifacts. **Three-color images** are derived from ACS B,V,i data; photometric data listed at the bottom are given in Vega mag.

within their stellar hosts (Papaderos et al. 1996). Nebular emission lines in LCBGs with compact ECs may therefore sample a comparable fraction of the HI velocity field as in local BCGs, and local correction factors (Pisano et al. 2001) could be applied. We note that central excesses in compact ECs might witness the formation of bulges or nuclei in local small disks or dEs.

(iii) The scarcity of large disks in distant LCBGs does not exclude that at least

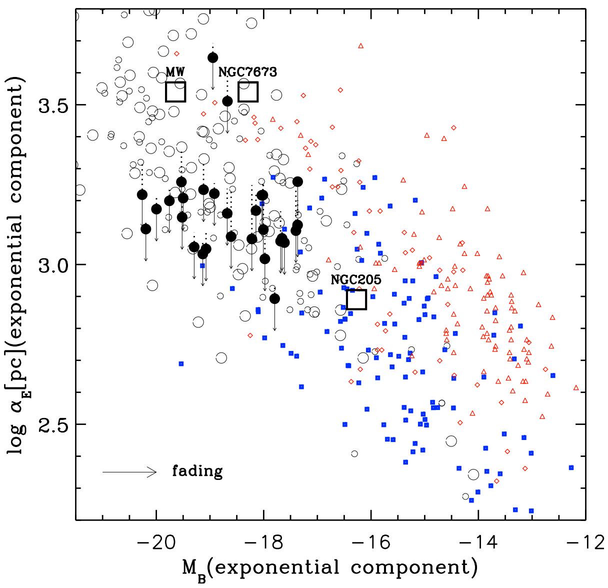

Figure 2 Scale lengths α_E vs. absolute B magnitudes of extended exponential components. **Filled dots:** LCBGs, this work; dotted lines: inclination corrections, to be applied if LCBGs are disks; arrows: typical corrections for PSF effects (not applied). **Open circles:** local disks (Tully et al. 1996 and Lu 1998). **Small symbols:** local dwarfs; squares: hosts of Blue Compact Galaxies (Gil de Paz et al. 2004); triangles: dEs (Binggeli & Cameron 1991); lozenges: dIs (Patterson & Thuan 1996). **Boxes:** Disks/exponentials in the Milky Way, NGC 7673 and NGC 205 (see Fig.1).

a fraction can evolve into massive disks in the local Universe. If compact ECs found in this work are stellar components forming in larger gaseous protogalaxies, then also extended star formation in such small ECs (see ii) will not sample the total velocity field well. The UDF images reveal no signs of star formation at large radii that would indicate large pre-existing disks. However, also if LCBGs are low-mass galaxies at higher z, substantial disk growth from accretion or merging might link them to more massive local galaxies.

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