Deep multiband surface photometry on 45 star forming BCGs

Genoveva Micheva$^0$, Göran Östlin$^1$, Erik Zackrisson$^1$, Nils Bergvall$^2$

0 Subaru Telescope
1 Stockholm University
2 Uppsala University
Outline

- Blue compact galaxies? Why?
- Observations
- Low vs. High luminosity BCGs
  - Structural parameters
  - Asymmetry & concentration
- Conclusions
Blue Compact Galaxies (BCGs)

Metal-poor 10% $Z\odot$ to close to $Z\odot$

Gas-rich, $M_{\text{HI}} \sim 10^6$-$10^9 M\odot$

(short) Bursts of star formation in an underlying old “host” galaxy

SFR (Hα): 0.1-24 $M\odot$/yr

M/L: 0.1-0.8

Emission line (HII) galaxies

In some ways reminiscent of truly young galaxies at high $z$

Nearby $\Rightarrow$ surface photometry
Why study BCGs?

SF dwarfs most common type of galaxy in local Universe – difficult to study in large numbers

Starbursting dwarfs more exotic but easier to detect

At high z they contributed to reionization of Universe

Can't study dwarfs at high-z, must infer their properties from local analogs, i.e. either dwarfs, starbursting galaxies, or both (starbursting dwarfs ≈ BCGs)

Problem:

- There are no exact analogs

- None of these are homogeneous groups: significant differences in morphology, total luminosity, colors, gas and dust content, kinematics, chemical abundances, star formation rates, stellar populations, dark matter content.
Observations

17,446 raw images of 46 BCGs
6 years of observations (2001-2007)
NOT, NTT, VLT
Optical & NIR broadband
UBVRI HK
Southern & northern BCGs
High & low luminosity BCGs

Micheva et al (2013a,b)
Total B luminosity

On average burst contributes ~3 mag to total luminosity

On average the burst increases the luminosity by ~1 mag.
We go deeper

Cairos et al. 2001

Micheva et al. 2013a
- $\mu_0$ vs $h_r$
- $M_B^{\text{burst}}$ vs $M_b^{\text{host}}$
- Color coding: burst contribution
- Size coding: $h_r$
  - Extended $\rightarrow$ lower $\mu_0$
  - Extended $\rightarrow$ stronger burst
- Brightest host $\neq$ strongest burst
- Lines of constant burst contr.?
- \( \mu_0 \) vs \( h_r \)
- \( M_B^{\text{burst}} \) vs \( M_b^{\text{host}} \)
- Color coding: burst contribution
- Size coding: \( h_r \)

- No correlation \( h_r \) => \( \mu_0 \)
- Most are compact, low \( M_B \) but high \( \mu_0 \)
- Not SF dominated
$\mu_0$ vs $M_B^{\text{host}}$
$h_r$ vs $M_B^{\text{host}}$

$h_r$ & $\mu_0$ from $\mu_B = 24-26$ mag arcsec$^{-2}$
$\rightarrow$ consistent with BCD from the literature

$h_r$ & $\mu_0$ from $\mu_B = 26-28$ mag arcsec$^{-2}$
$\rightarrow$ consistent with dE, dl, and LSBG

dE, dl, BCDs from Papaderos et al. (2008); giant LSBGs from Sprayberry et al. (1995)
\[ \mu_0 \text{ vs } M^\text{host}_B \]

\[ h_r \text{ vs } M^\text{host}_B \]

\[ h_r \text{ & } \mu_0 \text{ from both} \]

\[ \mu_B = 24-26 \text{ mag arcsec}^{-2} \]

\[ \text{and } \mu_B = 26-28 \text{ mag arcsec}^{-2} \]

\[ \rightarrow \text{consistent with BCD from the literature} \]

dE, dl, BCDs from Papaderos et al. (2008)

giant LSBGs from Sprayberry et al. (1995)
Low vs High luminosity BCGs

- Behave in different ways
  1. Dynamically young luminous irregular galaxies
  2. Fainter objects, regular outer isophotes
  (Telles et al 1997)

- Different progenitors/evolution histories
Color coding: morphological class
Asymmetry

Morphology reveals dynamical history: mergers/interactions or lack thereof.

\[ \phi = 180 \]
What contributes to the asymmetry?

“Flocculent” component: due to star formation

“Dynamical” component: due to merger, tidal interaction

(Conselice et al. 2000)
Petrosian Asymmetry

Minimum, $\phi = 180$

- Radius $r(\eta[0.2])$
  - Small (~0.2) optical small NIR $A_p$ – nE BCGs
  - Small optical large NIR $A_p$ – iE BCGs
  - Large (~0.4) optical large NIR $A_p$ – iI BCGs
- Optical A dominated by star formation regions (a.k.a. "flocculent" component)

Sample 2
Identifying mergers

- B-V vs Petrosian A (R or I band)
- Fiducial color-asymmetry sequence (Conselice et al. 2000)
- Color coding: Petrosian A (blue)
- Size coding: $h_r$

SAMPLE 2
Identifying mergers

- B-V vs Petrosian A
- Fiducial color-asymmetry sequence (Conselice et al. 2000)
- Size coding: $h_r$
Identifying mergers
The dynamical component

- Starburst is in the way => mask it out
- $\mu_{\text{Opt}} \leq 25$ mag arcsec$^{-2}$ set to 25
- $\mu_{\text{NIR}} \leq 21$ mag arcsec$^{-2}$ set to 21
- Smoothed by 1x1 kpc
- Color coding: dynamical asymmetry
Asymmetry correlations

Sample 2

\[ A_H'(I) = 0.62 \times A_P - 0.003 \]

Normal galaxies:
\[ A'_G = 0.67 \times A_P + 0.01 \]
(Conselice 2003)

Dotted line: Conselice 2003 for normal galaxies

\[ A_{\text{dyn}} \] does not correlate with \[ A_P \]

\[ A_P \] – Petrosian asym.
\[ A'_P \] – Petrosian asym, filtered
\[ A_H \] – Holmberg asym
\[ A'_H \] – Holmberg asym, filtered
\[ A_{\text{dyn}} \] – Dynamical asym, filtered
Burst % vs $A_p$

Size coding: $h_r$

Black: $\mu_0$, $h_r$ consistent with giant LSBGs

Sample 1
Concentration

- \( R_{20} = 20\% \) of growth curve
- \( R_{80} = 80\% \) of growth curve

\[
C = 5 \log\left(\frac{r_{80}}{r_{20}}\right)
\]
Concentration vs Asymmetry

Normal galaxies from Conselice et al. 2000

BCGs/ELGs – large asymmetries, small concentration
Impossible to tell BCGs from ELGs
Conclusions

1. Low & high luminosity BCGs behave in distinctly different ways (structural parameters $\mu_B$, $h_r$, A, but not C)

3. Tentative link to giant LSBGs as hosts of high luminosity BCGs

4. Dynamical asymmetry component catches mergers more successfully in high luminosity BCGs

5. Change in optical/NIR asymmetry reflects morphological class

6. Optical Asym – an OK proxy for flocculent component; NIR Asym – good proxy for dynamical component
- $h_r$ vs $M_B$
- $\mu_0$ vs $M_B$
- $B-V$ vs $A_{dyn}$
- Burst % vs $A_{dyn}$
- Color coding: morphological class
Clumpiness

(references and further analyses)

normal+ULIRGs (Conselice 2003)
B-V vs. S

B-V = -0.88 ± 0.07 x S' + 0.85 ± 0.02 (Conselice 2003)

- Normal galaxies (Conselice 2003)
- BCGs (S1+S2)
Left: Yggdrasil spectral synthesis code (Zackrisson et al. 2011), with *Starburst99* Padova-AGB stellar population, z=0, instant burst, nebular emission with *Cloudy* (Ferland et al. 1998), spherical geometry, $Z_{\text{gas}} = Z_{\text{stars}}$, covering factor = 1 (no LyC leakage), standard Johnson/Cousins filters

Right: Pure stellar population, Marigo et al. 2008 tracks, Salpeter IMF, exponentially decaying SF rate of 1Gyr, z=0, standard Johnson/Cousins filters