Edge-on LSB galaxies in the Sloan Digital Sky Survey & the red halo phenomenon

Brady Caldwell – masters thesis
Nils Bergvall - supervisor
1st line of evidence...

Halos around edge-on disk galaxies in the SDSS

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Zibetti et al. (2004) find...

...halos around 1047 SDSS stacked images...

...extremely red halos...

...consider bottom heavy IMF.

metal-poor ellipticals. $r - i$ is (at 2 $\sigma$) 0.2 mag redder than the reddest known stellar populations in globular clusters and elliptical galaxies and it is difficult to reconcile with any theoretical models, even allowing for ad hoc modified IMF’s dominated by low-mass stars and high metallicity.
MODELLING THE RED HALOS OF BLUE COMPACT GALAXIES

Abstract

Optical/near-IR broadband photometry of the halos of blue compact galaxies (BCGs) have revealed a very red spectral energy distribution, which cannot easily be reconciled with any normal, metal-poor stellar population. Here, three possible explanations for the red excess are explored: nebular emission, metal-rich stars and a stellar population with a very bottom-heavy initial mass function (IMF). We find, that nebular emission in BCG halos would produce very blue near-IR colours, and hence fails to explain the observed red excess. Although metal-rich stars may in principle explain the colours observed, the required stellar metallicity is very high (solar or higher), which would be a curious halo property given the low gas metallicity (~10% solar) of the central starburst in these objects. A stellar population with a low to intermediate metallicity and a very bottom-heavy IMF, does however adequately reproduce the observed BCG halo colours. A bottom-heavy IMF also proves successful in explaining a similar red excess observed in the halos of stacked edge-on disk galaxies from the Sloan Digital Sky Survey (SDSS). This may indicate that halos dominated by low-mass stars is a phenomenon common to galaxies of very different Hubble types.

Figure 9. Observed colours of BCG halos (crosses indicating 1σ error bars), compared to the predictions of PÉGASE.2 (lines) for stellar populations with a bottom heavy IMF \( \frac{dN}{dM} \propto M^{-\alpha} \) with \( \alpha = 4.50 \) for \( M = 0.08-120 M_\odot \) and the same star formation history as in Fig. 1. The different lines correspond to constant metallicities of \( Z = 0.0001 \) (thin dash-dotted), \( Z = 0.001 \) (thin dashed), \( Z = 0.004 \) (thin solid), \( Z = 0.008 \) (thick solid). With such an extreme IMF, stellar populations with low to intermediate metallicities (\( Z = 0.001-0.008 \)) give a reasonable fit.

Keywords: Galaxies: starburst – galaxies: evolution – galaxies: halos – galaxies: stellar content
Thesis objectives:

1. Select a “robust” sample of LSB galaxies from the SDSS.
2. Stack galaxies in the g, r & i bands
3. Search for halos around stacked image
4. If found, investigate properties of the halo
Leiden “Outer edges” galaxy workshop
**Previous stacking approaches:**

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<th>Reference</th>
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<td>Radio properties of quasars</td>
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<td>Detection of quasar hosts</td>
<td>SDSS</td>
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</table>
The Sloan 2.5m telescope at Apache Point Observatory, New Mexico, USA.
The 5 SDSS wave bands:

$u, g, r, i, z$

Fig. 4.—Preliminary 2.5 m telescope filter responses, in $u, g, r, i, z$. The upper curve in each case is the filter response including the quantum efficiency of the CCD and the reflectivity of the primary and secondary, ignoring the atmosphere, and the lower curve assumes an air mass of 1.3. Scattering within the thin chips affects the $r$ and $i$ bands; this has no effect on extended objects, and the corresponding response curve is given by the dashed line in these two cases.

Stoughton et al. 2002
SDSS footprint (DR3)

Northern Galactic cap
~10 000 deg²
1 000 000 spec. redshifts
$z \approx 0.1$
$\mu_{50,r} < 24.5$ mag arcsec$^{-2}$
$m_i < 17.7$ mag
Completed 2008 – DR8
A “mixed bag” of edge-on LSB galaxies

Different...

- Orientations
- Colours
- Inclinations
- Scales
- Backgrounds
**Total sample:**

**970 galaxies**

Selection criteria -

- Half light surface brightness $\mu_{50,g} < 23$ mag per arcsec$^2$
- Axial ratio $b/a < 0.25$ in $i$ band
- Colours $g-r : < 1.0$
- Semimajor axis $a > 10$ arcsec in $i$ band
- Culling-by-eye

**Subsamples:**

Selection criteria -

- Sample A: $g-r < 0.55$ (336 galaxies)
- Sample B: $0.55 < g-r < 0.75$ (318 galaxies)
- Sample C: $0.75 < g-r < 1.0$ (316 galaxies)
Sample properties
Metallicity
The image processing

Use the SDSS database to measure...

- Centers
- Position angles
- Disk exponential scale-lengths
- Extinction corrected magnitudes

Use SExtractor and MIDAS to...

- Mask
- Centre
- Rotate
- Rescale
- Stack
Example of a stacked image
Isophotes: 30, 29, 28, 26, 24 & 23 mag.

Isophotes: 30, 29, 28, 26, 24 & 23 mag.

Isophotes: 29.5, 28.5, 27.5, 25.5, 23.5 & 21.5 mag.

Isophotes: 29.5, 28.5, 27.5, 25.5, 23.5 & 21.5 mag.

150 pix = 10 $R_{\text{exp}}$

* g – stacked image

* r – stacked image

* i – stacked image

Isophotes: 30, 29, 28, 26, 24 & 22 mag.

Isophotes: 29.5, 28.5, 27.5, 25.5, 23.5 & 21.5 mag.
Wedge Profiles
(60° averages)
Total sample (970 LSBGs)
SBP plots

PSF:
Exponential wings contribute < 10%
at > 40 pixels:
g-band ~ 1%
r-band ~ 2%
i-band ~ 8%
Total sample

$g-r$ and $r-i$

colour profiles
Options:

PSF
Dust
Bulges
Thick disks
Background
Instrumental artifacts

... gravitational lensing?
$r-i$ colour map
**Red halo observations:**

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<tr>
<td>NGC 5907</td>
<td>Edge-on disk galaxy</td>
<td>Sacket et al. (1994)</td>
</tr>
<tr>
<td>Haro 11 (+ 9)</td>
<td>Blue Compact galaxy</td>
<td>Bergvall &amp; Östlin (2002)</td>
</tr>
<tr>
<td>z ( \sim 0.32 ) HUDF</td>
<td>Edge-on disk galaxy</td>
<td>Zibetti &amp; Ferguson (2004)</td>
</tr>
<tr>
<td>1047 stacked</td>
<td>HSB galaxies</td>
<td>Zibetti et al. (2004)</td>
</tr>
<tr>
<td>970 stacked</td>
<td>LSB galaxies</td>
<td>Caldwell &amp; Bergvall (2006)</td>
</tr>
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</table>

Haro 11 (courtesy G. Micheva)
Comparison with other results
Spectral evolutionary models

(Zackrisson et al. 2006)
Connections to our Galaxy...?

Our LSBG halos could be due to:
- large populations of M7-8 and L0-2 stars (West et al. 2005, Finlator et al. 2002), mixed with normal stellar populations
- 20000 late M and L type stars have been found in the MW (Burgasser et al. 2002)
Future studies:

* Postburst halos
* Elliptical halos
* Stacking Ellipticals
* Individual HSBG halos

BCG halo observations 14-17 May 2006
NOT, La Palma, The Canary Islands
Conclusions:

- Halos detected in stacked LSBG images in the g, r & i bands
- Halo flattening is $c/a \sim 0.6$
- Halo colours are: $g-r = 0.55 \pm 0.1$ ; $r-i = 0.85 \pm 0.1$
- Halo colours very red $\rightarrow$ high age and/or metal enrichment? $\rightarrow$ peculiar IMF?
- Results consistent with large fraction of LSBGs surrounded by luminous halos.
- Results possibly support scenario of halos being built up by infall of first generation stars.
- Future studies needed of individual nearby LSBGs & comparisons with other Hubble morphologies eg. Ellipticals.
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