Nature or Nurture in Galaxy formation and evolution

Theoretical problems & Perspectives

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Solved questions?

➡️ Are there isolated galaxies? May be!
Robust definitions, criteria (Karachentseva, AMIGA..)

➡️ The Void Problem? Solved at zeroth order!
Environment is a secondary parameter (Tinker, Croton)
But expected dwarfs are not there (Koribalski)

➡️ Compact Groups: a real nurture effect!
CA? (Mamon), colors, SF, morphology (McConnachie),
AGN (Dultzin, Martinez)
..
➡️ Isolated early-type galaxies: Fossil Groups?
20% ETG in LDE (Forbes)
Remaining questions

➡️ Luminosity functions versus environment:
+ Low efficiency of SF: 6% of baryons in stars and visible gas

  Feedback from SF and AGN

➡️ Bimodality, and mass limit of $3 \times 10^{10} M_\odot$??
Variation of the limit with environment?
(radio mode, but less AGN in LDE)

➡️ Downsizing and environment
Obvious ways to quench SF: harassment strangulation..

➡️ Bulge-less galaxies? vs environment
Very large fraction of them in isolated galaxies
Problem for $\Lambda$CDM hierarchical scenario?
Mass & Light DF

$\Lambda$CDM SAM: Too many bright and too many faint galaxies

SF Feedback to fit faint end

Gas is heated in dwarfs, but falls in heavier haloes ➔ worsen the bright end problem

Somerville et al 2008

➔ Requires AGN feedback at the bright end
Luminosity function vs environment

Croton & Farrar 08

Luminosity function

Global halo mass function

Void halo mass function

Croton et al. (2005)

Red galaxies

Blue galaxies

Centrals only

Early-type

Late-type

Halo mass function

Halo mass function

All halos

Halo mass function

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LF and environment

Blue: under-dense
Red: over-dense

⇒ Nurture should act quite early
(or nature is important)

Ilbert et al 2006
Red sequence & Blue cloud

Color-Magnitude diagrams (CMD)
150 000 galaxies in the SDSS

- Parameter: essentially SFR
  But SFH, dust, age, metallicity..

- 2 different formation mechanisms
  Separating stellar mass $3 \times 10^{10} \text{Mo}$

Baldry et al 2004
Fraction in red sequence increases with mass and environment

Baldry et al 2006
SF History depends on surface density

LSB dwarfs               HSB high mass

Transition at $M_*=3 \times 10^{10}$ Mo, or $3 \times 10^{8}$ Mo/kpc$^2$
SFH depends more on surface density than on mass

There is a transition where the gas begins to outflow, at the $V_{SN}$ velocity $\sim 100$km/s

Kauffmann et al 2003
Origin of the bimodality

Above a certain mass ($3 \times 10^{11} M_\odot$), the gas is not accreted cold, but is heated in shocks and has no time to cool (or AGN feedback).

Dekel & Birnboim 2006
Keres et al 2005

Or above a certain surface density of stars ($3 \times 10^8 M_\odot/\text{kpc}^2$), the gas is quickly transformed into stars, and the time spent in the « blue » regime is short.
The bimodality as a function of $M$ (SAM)

- $M_r = -22.75$ ➔ Blue & bright
- $M_r = -21.25$ ➔ Not enough green
- $M_r = -19.75$ ➔ Not enough green
- $M_r = -18.25$ ➔ Red and faint

Excess of blue bright objects, and red faint satellites ➔ Gas accretion on the satellites?
The star formation history

Most massive elliptical galaxies have the shortest formation timescales

\[ M_{\text{star}} = 10^{12} \, M_{\text{sun}} \]

\[ M_{\text{star}} = 10^9 \, M_{\text{sun}} \]

De Lucia et al. 2006
Galaxy age vs environment

In clusters, massive ETG are older and more metallic
Mateus et al 2007
Galaxy metallicity vs environment

Mateus et al 2007
Hierarchical formation of BCG

*De Lucia & Blaizot 2007:*
- dry mergers since $z=1$
- 50% of stars formed at $z=5$
- mass assembling after $z=0.5$

\[ M_{\text{BCG}} = 60.56 \times 10^{10} \, h^{-1}M_\odot \]
\[ M_{\text{min}} = 1.0 \times 10^{10} \, h^{-1}M_\odot \]
\[ \text{type} = 0 \]
Problem of bulge-less galaxies

- Locally, about 2/3 or the bright spirals are bulgeless, or low-bulge

- Frequency of edge-on superthin galaxies (Kautsch et al 2006)
  1/3 of galaxies are completely bulgeless

- SDSS sample: 20% of bright spirals are bulgeless until z=0.03
  (Barazza et al 2008)

» In low-density environment (Karachentsev on Wednesday)

In $\Lambda$CDM, a B/T<0.2 galaxy requires no merger since 10 Gyr (z>2)
Predicted frequency: 15 times lower than observed
Comparison with predicted $B/T$

Semi-analytic models, with major mergers (mass ratio $<1/4$)

Weinzirl et al 2008
Cold accretion on galaxies

**Previous assumption:** shock heating to the Virial temperature

**But:** Cold gas falling along filaments, the fraction of cold gas being larger in low-mass haloes ($M_{CDM} < 3 \times 10^{11} M_\odot$)

Keres et al 2005
Relative role of gas accretion and mergers


Most of the starburst are due to smooth flows.

Inflow rates are sufficient to assemble galaxy mass (10-100 Mo/yr)
Galaxy aligned along a wall between voids

Talk of R. van de Weygaert, and winning poster!

Gas from the cosmic filaments flowing to the wall, and perpendicular to it

⇒ Formation of the gaseous polar disk

Up to 10 Mpc
Circles every 2 Mpc

Red, HI disk

Stanonik et al 2009
Perspectives

- Role of both Nature and Nurture?:
  - faster evolution and merging in dense regions, that will become clusters
  - when cluster is formed: strangulation, ram-pressure, harassment

- SF and AGN feedback to fit the L-function, and $f_{\text{bar}}$ in stars

- Downsizing partly due to environment, but models have
  - still too many bright blue objects at $z=0$
  - and too many red faint satellites

- May be gas accretion should not be stopped for these faint satellites
  - would enhance also the green valley