EVOLUTION OF BRIGHTEST CLUSTER GALAXIES IN A HIERARCHICAL UNIVERSE

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BIG RED GALAXIES IN A YOUNG UNIVERSE

BCGs are very luminous in K, and very red

With BC03 modeling, they are also estimated to be the most massive galaxies we observe. They evolve in luminosity and colour like single stellar population models, with epoch of formation $z \sim 3-5$: passive evolution

Hierarchical semi-analytic models produce slower and more prolonged evolution, and lower masses at high redshift, OR: less luminous, bluer galaxies
IS THIS PROBLEM REAL?
Is there really something fundamentally wrong with the hierarchical clustering idea?

Galaxy formation models
- MASS
- SFR, age, Z
- LIGHT

Observations
- LIGHT
- MASS
- SFR, age, Z

Synthetic spectra associated to stellar mass at each timestep (intrinsic SFH)

SED fitting with template synthetic spectra + template SFH + K-corr + E-corr

STELLAR POPULATION MODELS + STAR FORMATION HISTORIES
Different evolutionary population synthesis mostly agree at low z
Until recently, other discrepancies with data made this effect negligible
DERIVED STELLAR MASS FUNCTION

Optical to mid-infrared data
Goods – Giavalisco et al. 2004
Musyc – Gawiser et al. 2006

Marchesini et al. 2009
STAR FORMATION HISTORIES

SFR (Mo/yr)

Redshift
MODELING BCGs

STAR-FORMATION HISTORIES
with a non-uniform time grid, in lookback time at every output redshift (every galaxy has the same age-grid), matching the age resolution of the SSP model (to capture younger stellar generations)

 STELLAR POPULATION MODEL
M05; see Tonini et al. 2009, 2010
with new dust model (E(B-V) proportional to SFR, calibrated with observations). No re-calibration of the semi-analytic model, no new physics!

OUTPUT
galaxy spectra: mock galaxy catalogues with apparent magnitudes tailored on each survey’s specifications (filters, errors, cuts...)

Theoretical Astrophysical Observatory (TAO)
http://tao.it.swin.edu.au/

Bernik, Tonini, Croton et al. in prep.
Croton et al. 2006, Croton et al. in prep.
Model BCGs are luminous enough! In fact, a little too much.
... so the hierarchical build-up of structures can assemble
enough mass to reproduce the luminosity evolution of BCGs.
Model BCGs match the observed colours. Their colour evolution is indistinguishable from that of single stellar populations of age > 10 Gyr...
STAR FORMATION RATE

Liu et al. 2012
Model BCGs grow a significant amount of mass down to $z=1$, mostly due to mergers (and some star formation). They are not single stellar populations. (see Lidman et al. 2012)
PASSIVE EVOLUTION IN THE HIERARCHICAL SENSE

Age of a galaxy: minimum age of certain fraction of its stars

1: model BCGs are old at z=0
2: BCGs age a lot since z=1, but so does the Universe, with the same speed
3: the SFRs are not large enough to offset this behaviour

The ageing of the BCG is dominated by its stellar populations getting older, regardless of where they formed and when they were accreted: **ageing of the merger tree**
CONCLUSIONS - part I

The model reproduces reasonably well the K-band luminosity evolution and the colour evolution of BCGs up to $z \sim 1.6$

The hierarchical mass assembly is fast enough to reproduce the K-band observations: model BCGs have enough mass

The K-band luminosity and colour evolution produced with the hierarchical star formation history of the SAM + M05 SP models is indistinguishable from that of a single stellar population + BC03

The physical properties of the galaxy and their evolution are completely different in the two scenarios. There is a degeneracy in the star-formation history – SP model combination, that is not broken by current observations. The evolution history of BCGs is currently inaccessible

Hierarchical model BCGs are “active” galaxies. However SFRs and assembly histories are such that the evolution is dominated by the ageing of the stars in the merger tree. We define such behaviour as passive evolution in the hierarchical sense.
THE FUTURE

TAO spectroscopy
mock galaxy catalogues with spectra: flexibility to be tailored to particular instruments and surveys

passive evolution and Dark Energy surveys
BOSS (SDSS-III) mock catalogues in search of passive evolution constrain the photometry of the passive population for selection criteria $\rightarrow$ large-scale structure growth with minimum biases

AGN feedback models
the high-mass end of the stellar mass function is obtained with ad-hoc parameters $\rightarrow$ $\rightarrow$ $\rightarrow$
physically motivated model for the cooling-heating cycle, to be ‘constrained’ by the star formation history