Is the morphology telling us the truth about quenching?

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18 April 2019
Hubble sequence

Elliptical galaxies

S0
SB0
E0
E5

Spiral galaxies

Sa
Sb
Sc

S0
SB0
E0
E5

Stellar masses
Galaxy formation

Illustris simulation

Dark Matter Density  Gas  Stars
Galaxy - Star formation activity

conversion of gas into stars

Gas → ? → complex physics → stars
Galaxy - Star formation activity

not a chaotic process

Whitaker et al 2012
Quenching: fundamental question mark

(Madau & Dickinson 2014)
Galaxy - Star formation activity

(Barro et al. 2015)
Galaxy - Star formation activity

Introduction

**quenched galaxies**

(Barro et al. 2015)
Why galaxies stop forming stars? quenching mechanisms

The main source to produce stars is the gas content

Preventing cooling

Halo mass quenching
stops the accretion of new cold gas
(Birboim & Dekel 2003, Peng 2015)

Morphological quenching
The accretion of a central density stabilizes the gas in the disk
(Martig 2008)

Gas removal

Outflows of gas
AGN, supernovae
(Hopkins 2014, Cattaneo 2009)

Gravitational interactions
(ram pressure stripping, tidal interaction, etc)
(Gunn & Gott 1972, Nulsen 1982, Moore et al. 1996)
Bimodality of galaxy properties

(Schawinski et al., 2015)

star forming

quiescent

(Wuyts et al. 2011)

(van der Well 2014)
Stellar mass function for different morphologies

Huertas-Company et al. 2016
How galaxies evolve?

compaction
mergers
rejuvenation
disk instability
Galaxy properties

\[
\frac{B}{T} = \text{Bulge / Total}
\]

(Morselli et al. 2016)
Quenching ↔ Morphology


Bulge growth
Bulge-disk decomposition

1) Modeling the surface brightness profile

- **GalfitM**
  - (Häussler et al. 2013)
  - Galactic decomposition
  - $Mag(\lambda)$, $n(\lambda)$, $Re(\lambda)$, $q(\lambda)$

- **GOODS/CANDELS bands (400 - 1500 nm)**

2) Best model selection

- **CNN**
- 1 comp
- 2 comp

3) Spectral Energy Distribution

- Stellar masses
- rest-frame colors

(Dimauro 2018, Tucillo 2018)
Questions

Can we put constraints on bulge formation mechanisms?

Does the quenching imply a morphological transformation?
Questions

Can we put constraints on bulge formation mechanisms?

Does the quenching imply a morphological transformation?
Mass-size bulge and disc

Dimauro et al. 2019

\[
\log(M_{\star}[M_{\odot}])_{B,D} < z < 0.5
\]

\[
\log(M_{\star}[M_{\odot}])_{B,D} < z < 1.0
\]

\[
\log(M_{\star}[M_{\odot}])_{B,D} < z < 1.5
\]

\[
\log(M_{\star}[M_{\odot}])_{B,D} < z < 2.0
\]
Bulges and Disks in different morphologies

\[ M_D, > 10.3 M_\odot \]

\[ M_B, > 10.3 M_{\odot} \]

Dimauro et al. 2019
Bulges and Disks in different morphologies

Observed sizes are divided by the expected values from the best fit

Dimauro et al. 2019
Bulges and Disks in different morphologies

For the same disk mass higher B/T correspond to higher stellar mass, consequently higher halo mass and larger virial radii

Dimauro et al. 2019
Bulges and Disks in different morphologies

**BULGES**

\[ M_{B,*} > 10.3M_{\odot} \]

**DISKS**

\[ M_{D,*} > 10.3M_{\odot} \]

Bulges sizes in different morphologies are compatible confirmed by the K-S test

Dimauro et al. 2019
Bulges in different morphologies

BULGES

$\frac{R_e}{R_{e,fit,z}}$ BULGE

$M_*>10.3M_\odot$

Redshift

Dimauro et al. 2019
Bulges in different morphologies

Uuncertainties on the model

Dependence between size and B/T

Dimauro et al. 2019
Bulges in different morphologies

Dependence between size and B/T

Pearson coefficient:
- \( B/T - r_eB = 0.14 \)
- \( B/T - r_eD = 0.17 \)

NO correlation

Uncertainties on the model

Structural properties: formation mechanisms
Bulges in different morphologies

Uncertainties on the model
Dependence between size and B/T

Different formation mechanisms
- Merger
- Disk instability
- Wet Compaction

Dimauro et al. 2019
Bulges in different morphologies

Different evolution

Naked bulges galaxies experience more merger events

$M_{B,*} > 10.3M_{\odot}$
Questions

Can we put constraints on bulge formation mechanisms?

Bulges show weak dependence with the morphology of the host galaxies

Hint of possible different assembly history
Questions

Can we put constraints on bulge formation mechanisms?

Does the quenching imply a morphological transformation?
Structural properties: Main Sequence

Galaxy - Main SF sequence

Dimauro et al. 2019b in prep
Galaxy - Main SF sequence

Star forming galaxies are disk dominated

Dimauro et al. 2019b in prep
Galaxy - Main SF sequence

Bulges form in the Main Sequence

Structural properties: Main Sequence

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Bulges and Disks in SF or Q host galaxies

Structural properties: morphological transformation

- $M_{D,*} > 10.3 M_\odot$
- $M_{B,*} > 10.3 M_{\odot}$
Bulges and Disks in SF or Q host galaxies

**DISKS**

- $M_{D,\ast} > 10.3 M_\odot$

**BULGES**

- $M_{B,\ast} > 10.3 M_\odot$

Dimauro et al. 2019
Bulges and Disks in SF or Q host galaxies

Structural properties: morphological transformation

$M_{D,\ast} > 10.3 M_{\odot}$

$R_{e}/R_{\text{fit},z}$ DISCS

$R_{e}/R_{\text{fit},z}$ BULGES

$M_{B,\ast} > 10.3 M_{\odot}$

Dimauro et al. 2019

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19 October 2017
Bulges in SF or Q host galaxies

$R_{e}/R_{fit,z}$ BULGE

$log(M_B) > 10.3 M_*$

Redshift

Quiescent
Star-Forming

Systematics from the fit?
Bulges in SF or Q host galaxies

Systematics from the fit?

Mass distribution?

Structural properties: morphological transformation
Bulges in SF or Q host galaxies

Systematics from the fit?

Mass distribution?

Additional accretion of mass to the central region

\( \frac{R_e}{R_{fit,z\text{ BULGE}}} \) vs. Redshift

\[ \log(M_B) > 10.3M_\odot \]
Bulges in SF or Q host galaxies

Systematics from the fit?

Mass distribution?

Additional accretion of mass to the central region

Progenitor bias?

$L_{\text{BULGE}} > 10.3 M_*$

Quiescent

Star-Forming

(Lilly & Carollo 2016)
Sersic index progressively increases through cosmic time, no significant difference detected between the two populations of bulges.

Bulges in star forming galaxies are more elongated.

Dimauro et al. 2019
Questions

Does the quenching imply a morphological transformation?

Bulges in star forming systems are larger (~20%) than those in quiescent systems -> compaction or progenitor bias?

Disk structure is similar in star forming and quiescent galaxies -> disks are weekly affected by the quenching process, that it’s mostly affecting the central part of the galaxy
Colors of bulges and disks

Quiescent

Star forming

Dimauro et al. 2019b in prep
Disks are blue in star forming systems and red in quiescent ones  
Bulges are always redder than disks  
Bulges are more dusty in star forming systems than those in quiescent ones

Dimauro et al. 2019b in prep
Future projects

- Extend the analysis on other datasets -> larger wavelength coverage (Dimauro et al 2019b in prep)

- Larger sample -> automatic modeling (Tucillo et al 2018, 2019 in prep)

- Compare results with numerical simulations

- Study the effect of dense environments on bulge and disk properties
Conclusions

Part 1: catalog

• We built a catalog for ~17,300 galaxies, using 7/4 bands, released to the community http://lerma.obspm.fr/huertas/form_CANDELS

• It is the largest catalog of bulge and disk properties available today

• We introduced a novel selection algorithm

Part 2: Properties of bulges

Can we put constraints on bulge formation mechanisms?

• Bulge sizes are similar over a wide range of $B/T$ (0.2$<B/T<0.8$)

• Pure bulges ($B/T>0.8$) are 20% larger than bulges embedded in disks

• Possible different assembly histories

Does the quenching imply a morphological transformation?

• Bulges in star forming systems are larger (~20%) than those in quiescent systems

• Compaction or progenitor bias
Thank you very much!