The Formation of Bulges, Discs and Two Component Galaxies in the CANDELS Survey at $z < 3$

Berta Margalef Bentabol

Joint work with Christopher Conselice and the CANDELS Team

Discs in Galaxies

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Galaxies in the nearby universe can be distinguished between:

- Disc-dominated (e.g. spirals)
- Spheroid-dominated (e.g. ellipticals)
Introduction

Significant evolution in the fraction of galaxies of different morphologies.

Peculiar population is dominant at $z > 2$, with substantial spheroid population.

The combined fraction of spheroidal and disc galaxies is equal to that of the peculiar population at $z_{trans} \sim 1.86$
At $\sim 2.3$ disc-like galaxies are a factor of 2.6 smaller than present-day equal-mass galaxies.

- Spheroid-like galaxies at the same $z$ are 4.3 times smaller than present-day equal-mass elliptical galaxies.

- At $z > 2$ the results are compatible with both a leveling off or a mild evolution in size.
Introduction

Bruce et al. 2012

\[ z > 2 \]: Disc-dominated galaxies. Significant fraction of pure discs.

\[ z < 2 \]: Bulge-dominated galaxies. Pure bulges are rare.
The survey covers about $800 \ arcmin^2$.

It is divided into two parts:
- CANDELS/Deep Survey (GOODS-N and GOODS-S).
- CANDELS/Wide Survey (GOODS-S, EGS, COSMOS and UDS).

Two cameras of the Hubble Space Telescope:
- WFC3 (Near-Infrared).
- ACS (Visible-Light).
Our Sample

- **CANDELS/UDS**
- $H$-band
- Magnitude limit $\sim 27$

**About 1500 galaxies:**
- Redshift: $1 < z < 3$
- Mass: $\log \frac{M_*}{M_\odot} > 10$
Sérsic Profile
Surface brightness of galaxies can be described by a Sérsic profile:
\[ \Sigma(r) = \Sigma_e \exp \left[ -\kappa \left( \frac{r}{r_e} \right)^{1/n} - 1 \right] \]

Exponential profile
Discs are well described by an Exponential profile:
\[ \Sigma(r) = \Sigma_0 \exp \left( -\frac{r}{r_s} \right) \]

Two models for all our galaxies:
- Model 1: Sérsic profile.
- Model 2: Sérsic profile + Exponential profile.
Selecting a Model

1. Visual Inspection.

2. Residual Flux Fraction (RFF).

3. F-test.
Fraction of 2-component galaxies as a function of mass and redshift.
Number density of disc-like galaxies is the highest for all redshifts.

Rise of 2-component galaxies by a factor of 30.

$1 < z < 3$ is the epoch when 2-component galaxies form and dominate the abundance of massive galaxies.
Results. Mass Density

- Mass density of disc- and spheroid-like galaxies similar at all redshifts.
- Mass density of 2-component galaxies increases by a factor of 100.
- The most massive galaxies preferentially become the 2-component systems.
Results. Size Evolution

Disc-like galaxies

Spheroid-like galaxies

Discs of 2-comp. galaxies

Bulges of 2-comp. galaxies

B. Margalef Bentabol — Bulges, discs and 2-component galaxies at high redshift.
Flux ratio of disc to bulges does not evolve with redshift, but there is a change with size.
Multiwavelength Analysis

H, J, i, V bands + SED fittings = Masses and rest-frame colours

B. Margalef Bentabol — Bulges, discs and 2-component galaxies at high redshift.
Multiwavelength Analysis

1-component galaxies

|        | SF   | QS   |
|--------|------|------|
| $n < 2.5$ | 77%  | 33%  |
| $n > 2.5$ | 44%  | 66%  |

2-component galaxies

|        | SF   | QS   |
|--------|------|------|
| Discs  | 80%  | 20%  |
| Bulges | 77%  | 23%  |

SF bulges have lower Sérsic index than passive bulges.
We investigate the formation history of bulges and discs within massive galaxies in CANDELS/UDS. Two models for the surface brightness (Sérsic profile and Sérsic + Exponential profile. Three methods (visual classification, $R_{FF}$ and $F$-test) to decide which model is the best for each galaxy.

The fraction of 2-component galaxies increases with higher mass. There is also an evolution with redshift.

2-component systems form and dominate the abundance of massive galaxies at $1 < z < 3$.

The most massive galaxies preferentially become the 2-component galaxies.

Discs seem to grow later than bulges.
Thank you for your attention

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