Bulge Growth and Quenching since $z = 2.5$
in CANDELS/3D-HST

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+ CANDELS/3D-HST - Teams

Star formation across space and time, Nov 13$^{th}$ 2014

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Early work on SDSS: link between structure and age

- Connection of **stellar populations** with galaxy **morphology** has been shown using large samples locally (e.g. Kauffmann+2006, Schiminovich+2007, Bell2008, Fang+2013, Cheung+2013, Bluck+2014, Cibinel+2014)

- Tightest correlations with measures of the central mass concentration: 
  \[ \mu_* \propto M_* / R_e^2 \]

**Star formation across space and time, Nov 13th 2014**
Link between Structure and Quenching

Existence of a Hubble sequence out to $z \sim 2.5$ with CANDELS

- Disks
- Spheroids

**but:**
- measurements done so far in rest-frame optical
- samples don’t include fully available CANDELS dataset

What is the connection between bulges and quenching since $z \sim 2.5$?

→ Measurement of $B/T$, $M_{\text{Bulge}}$ needed for a large sample

Underlying physical processes?

- AGN feedback  
  (e.g. Hopkins+06, Bournaud+11)

- Morphological quenching  
  (e.g. Martig+2009, 2013, Genzel+2014)

- Halo mass quenching  
  (e.g. Dekel+03, Kereš+05)
CANDELS
(Cosmic Assembly Near Infrared Deep Extragalactic Legacy Survey)

HST imaging in 5 fields (800arcmin\(^2\))

Imaging at 0.18” resolution

HST/ACS \( V_{606}, I_{814} \) ( + \( B_{435}, V_{775}, z_{850} \) )
HST/WFC3 \( Y_{105}, J_{125}, H_{160} \)

\[ \rightarrow \text{SFR}_{\text{UV+IR}}, M_\star \]

\[ \text{Koekemoer+2011; Grogin+2011; van Dokkum+ 2011; Brammer+2012} \]

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Clumpy SFGs

Wuyts et al. 2012

Complete sample of ~ 7000 massive (M > 10^{10} M_\odot) galaxies at 0.5 < z < 2.5

Resolved SED modeling to recover mass distributions

2D Modeling

Sersic → N

Bulge + Disk → B/T
Higher B/T for SFGs compared to QGs

Increase of B/T along the MS up to 40%–50% $\rightarrow$ Significant bulge growth prior to quenching

No redshift evolution

P. Lang et al. 2014
Results on Galaxy Structure

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Results on Galaxy Structure

~ 600,000 Galaxies in SDSS

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“Bulge mass is king”

Bluck et al. 2014

- Rooted in Bolshoi DM simulation (Klypin+2008)
- Built-in recipes for gas-cooling, star formation, SN-feedback, merging, disk instabilities, black hole accretion, AGN feedback (Quasar + radio mode)

→ Good qualitative agreement with observations

P. Lang et al. 2014

- Rooted in Bolshoi DM simulation (Klypin+2008)
- Built-in recipes for gas-cooling, star formation, SN-feedback, merging, disk instabilities, black hole accretion, AGN feedback (Quasar + radio mode)

Bulge serves as closest observable proxy for the supermassive BH

P. Lang et al. 2014
Hints on underlying mechanisms at $z \sim 2.5$

Signatures of broad nuclear outflows

Signatures of morphological quenching

$Q = \frac{\sigma k}{\pi G \Sigma}$

Genzel+ 2014b, Förster Schreiber+2014b

Star formation across space and time, Nov 13th 2014

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Hints on underlying mechanisms at $z \sim 2.5$

Signatures of morphological quenching

$$Q = \frac{\sigma \kappa}{\pi G \Sigma}$$

Genzel+ 2014a
Summary

- Bulge growth along the MS prior or during quenching
  - Most massive SFGs have B/T up to 40–50%

- $M_{\text{Bulge}}$ correlates best with quiescence
  (See Bluck et al. 2014 for SDSS equivalent)

- Qualitative agreement with predictions from SAM
  - $F_{\text{quench}} - M_{\text{Bulge}}$ correlation consistent with AGN feedback, where $M_{\text{Bulge}}$ is a proxy for $M_{\text{BH}}$
  - But: room for additional quenching processes