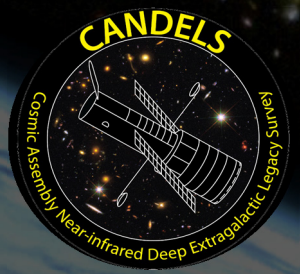
Bulge Growth and Quenching since z = 2.5 in CANDELS/3D-HST

Philipp Lang,
Stijn Wuyts, Rachel Somerville, Natascha Förster Schreiber, Reinhard Genzel

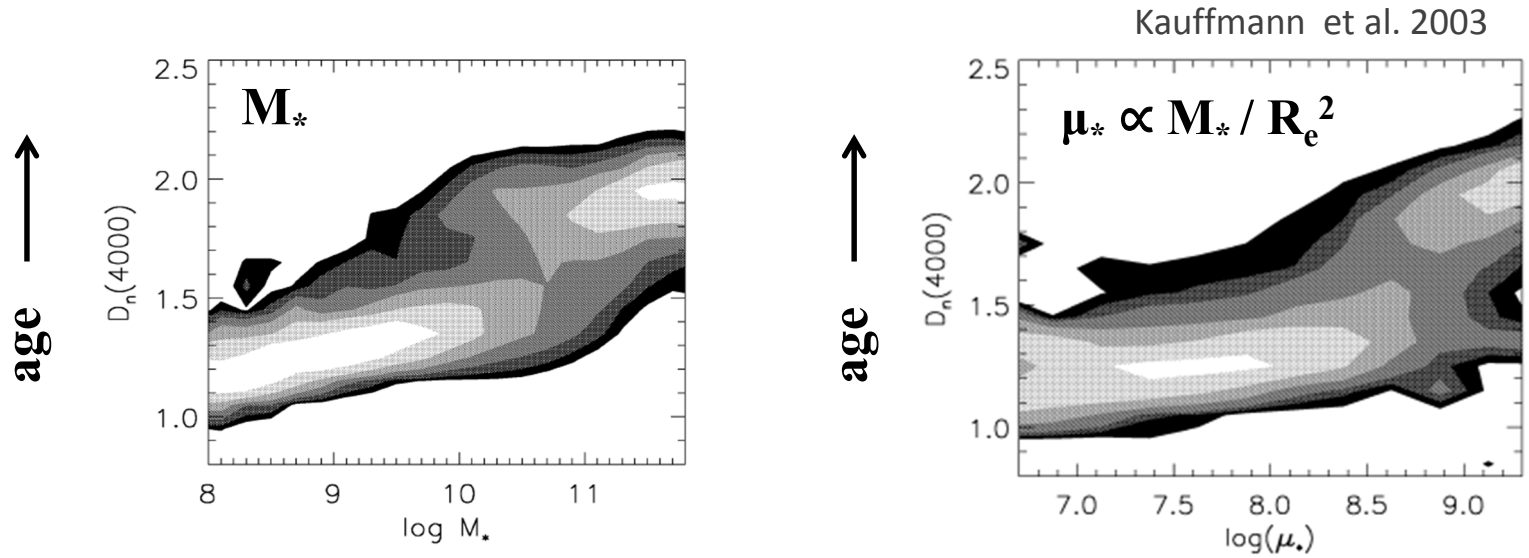
\+ **CANDELS/3D-HST** - Teams



Link between Structure and Quenching

Early work on SDSS: link between structure and age

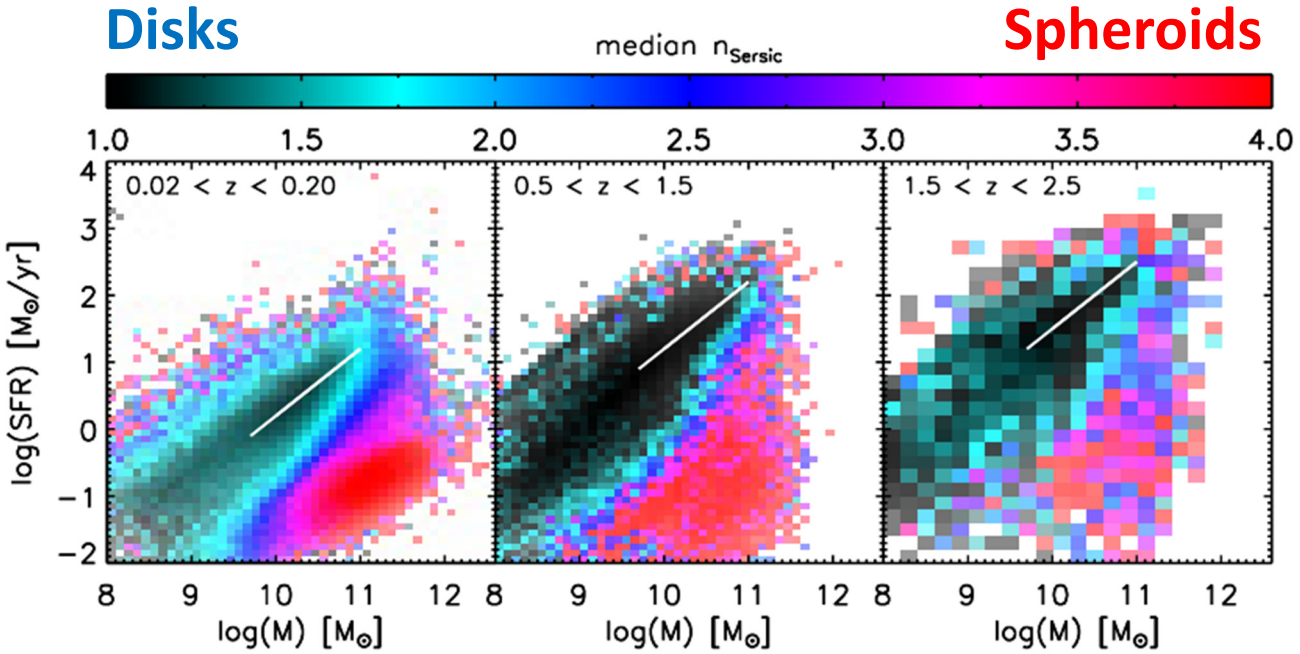
Kauffmann et al. 2003



- 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:
  $\mu_{*(1kpc)}$, **B/T**, n_{Sersic}

Link between Structure and Quenching

Existence of a Hubble sequence out to z ~ 2.5 with CANDELS



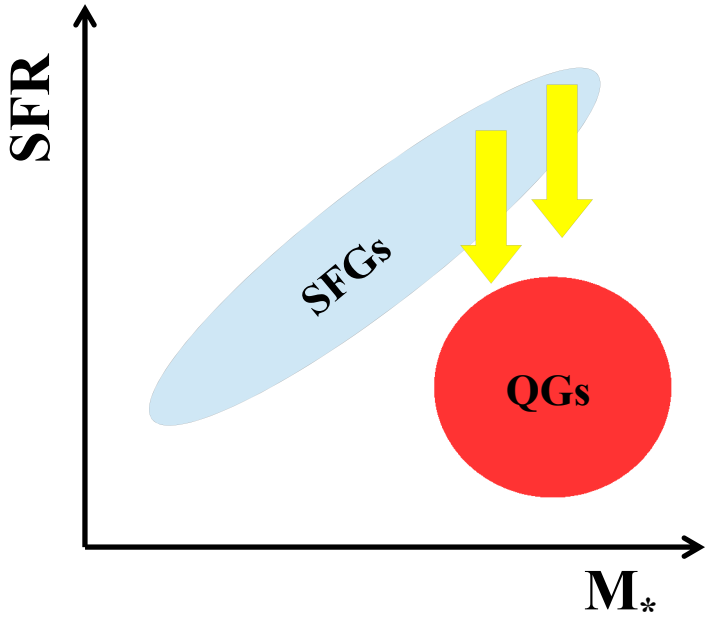
Wuyts et al. 2011

<u>but</u>:

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

See also: Bell+2004, Weiner+2005, Koo+2005, Franx+2008, Kriek+2009, Bell+2012,Wang+2012, Lee+2013, Cheung+2012, Bruce+2014

Link between Structure and Quenching



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)

What is the connection between bulges and quenching since z ~ 2.5 ?

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

The HST Dataset

CANDELS

(Cosmic Assembly Near Infrared Deep Extragalactic Legacy Survey)

HST imaging in 5 fields (800arcmin^2)

Imaging at 0.18" resolution

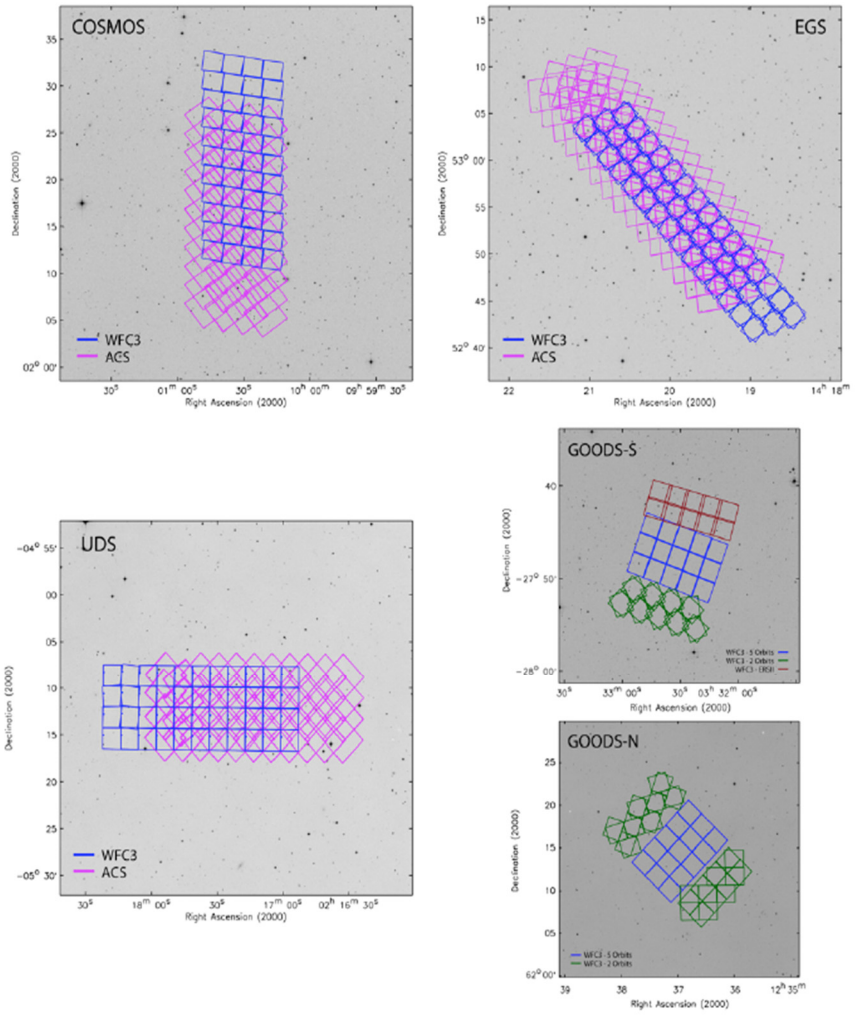
HST/ACS V_{606}, I_{814} (+ B_{435}, V_{775}, z_{850})
HST/WFC3 Y_{105}, J_{125}, H_{160}

+ 3D - HST

G141/G800 **grism - redshifts**

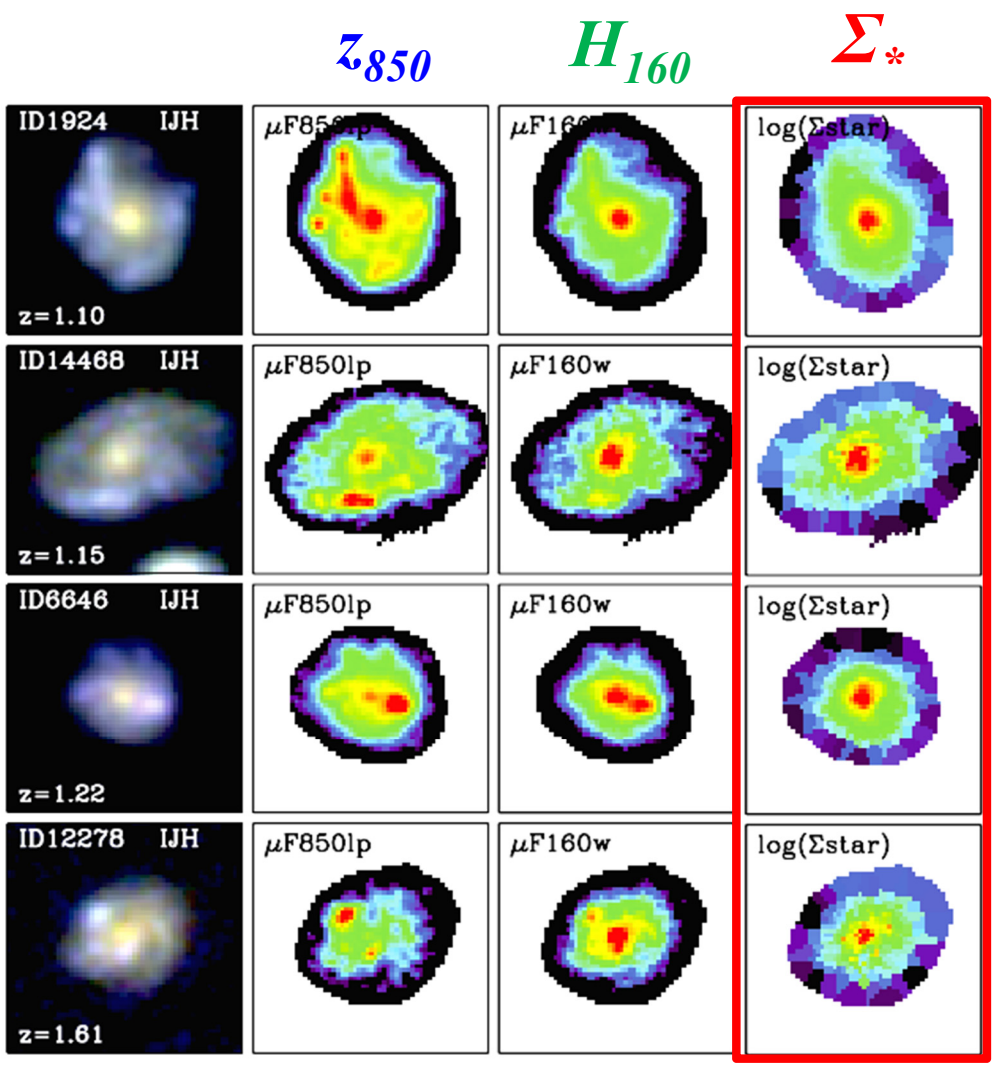
+ multi-wavelength ancillary data (UV – FIR)

→ SFR_{UV+IR}, M_*



Koekemoer+2011; Grogin+2011; van Dokkum+ 2011; Brammer+2012

Clumpy SFGs



Wuyts et al. 2012

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

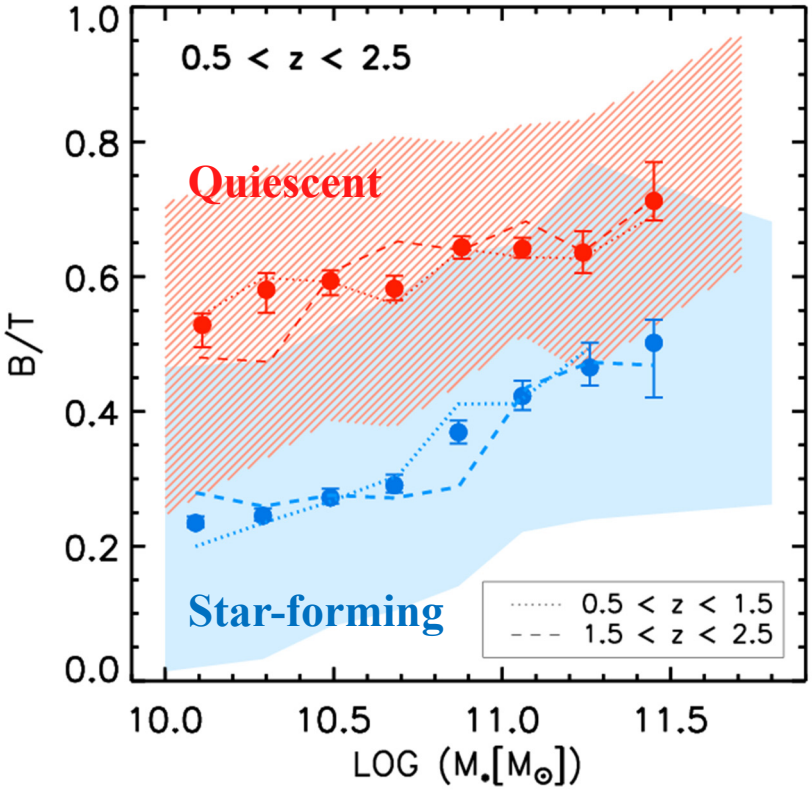
Resolved SED modeling to recover mass distributions

2D Modeling

Sersic ⟶ N

Bulge + Disk ⟶ B/T

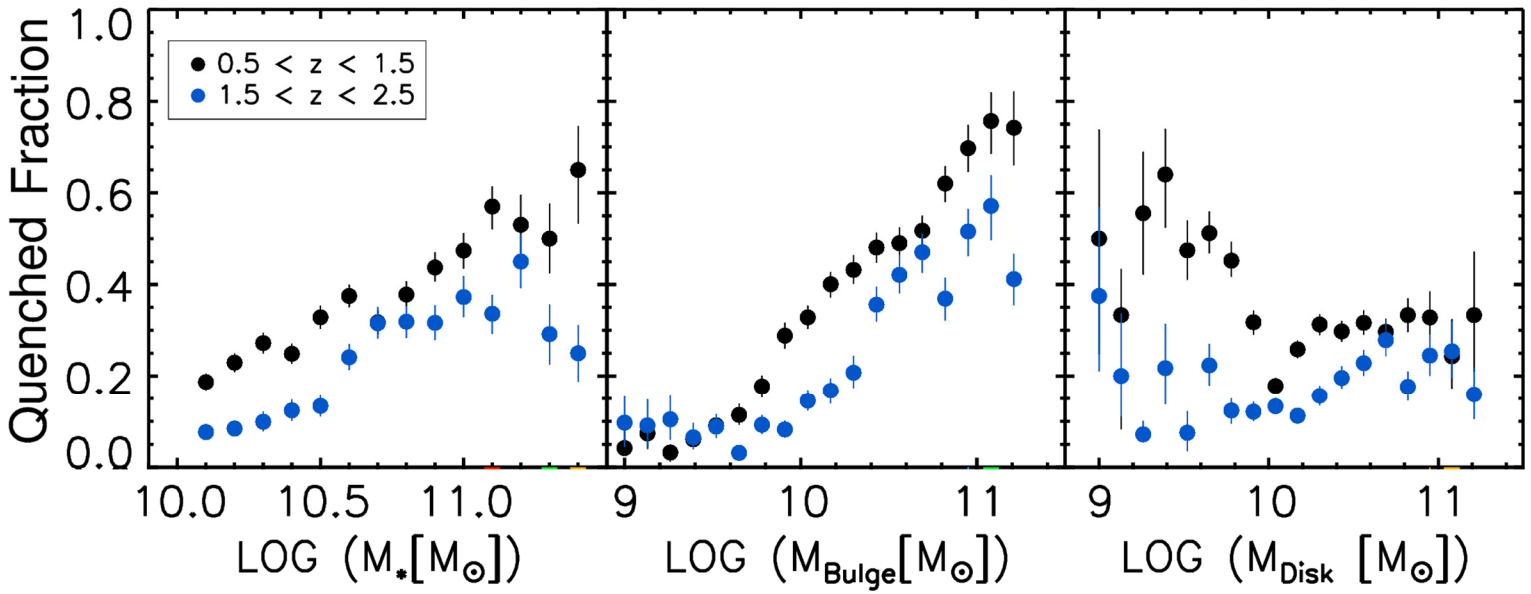
Results on Galaxy Structure



- Higher B/T for SFGs compared to QGs
- Increase of B/T along the MS up to **40%-50%** → Significant bulge growth prior to quenching
- No redshift evolution

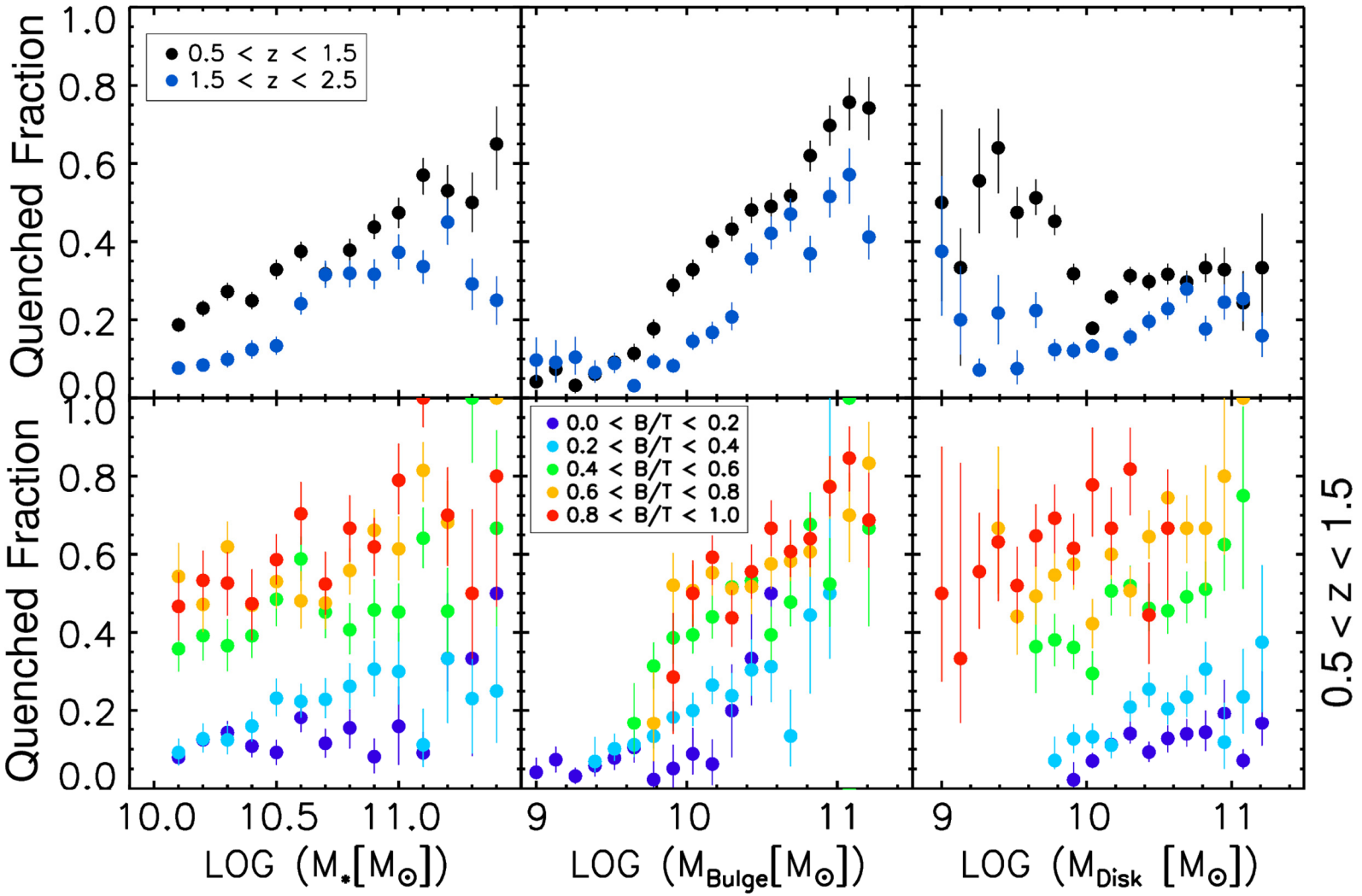
P. Lang et al. 2014

Results on Galaxy Structure



P. Lang et al. 2014

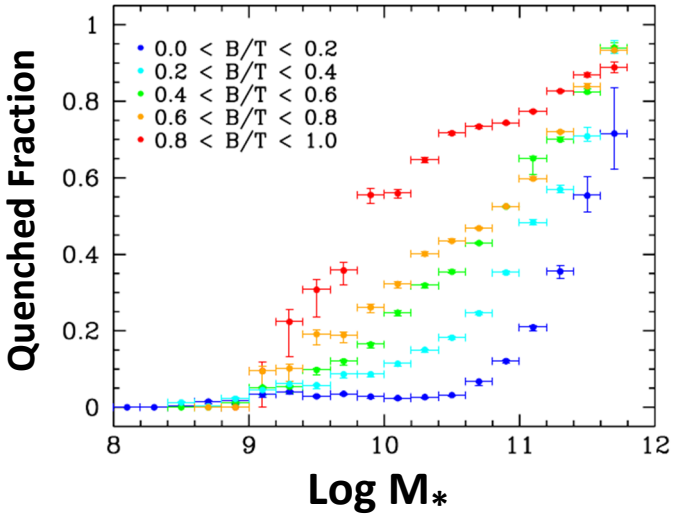
Results on Galaxy Structure

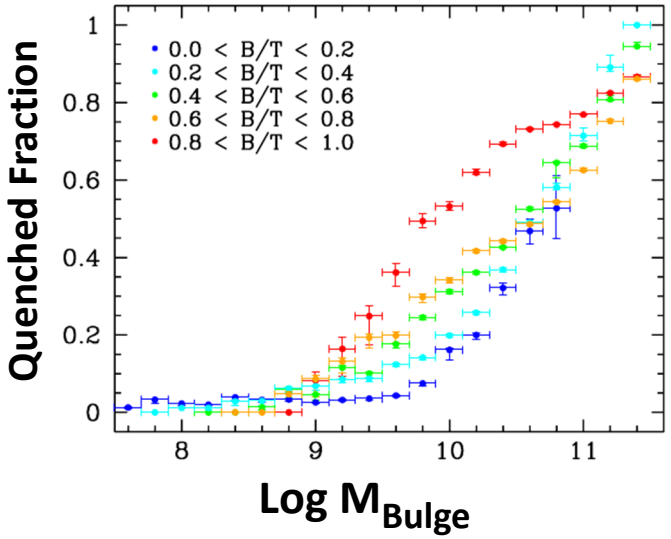


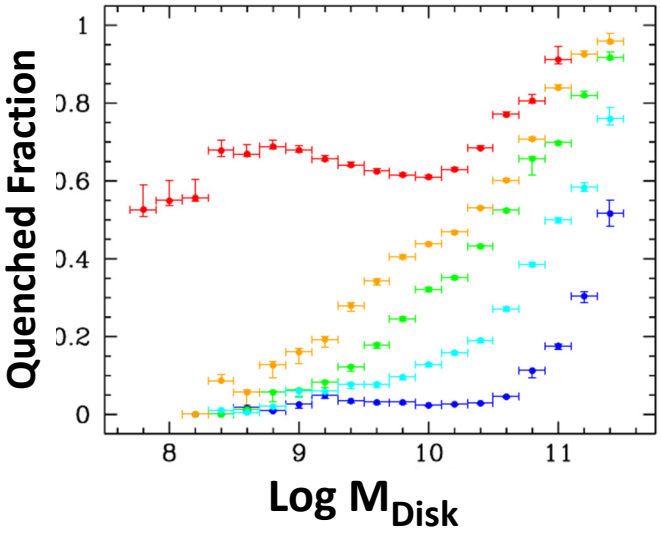
P. Lang et al. 2014

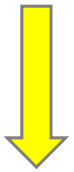
Results on Galaxy Structure

~ 600,000 Galaxies in SDSS









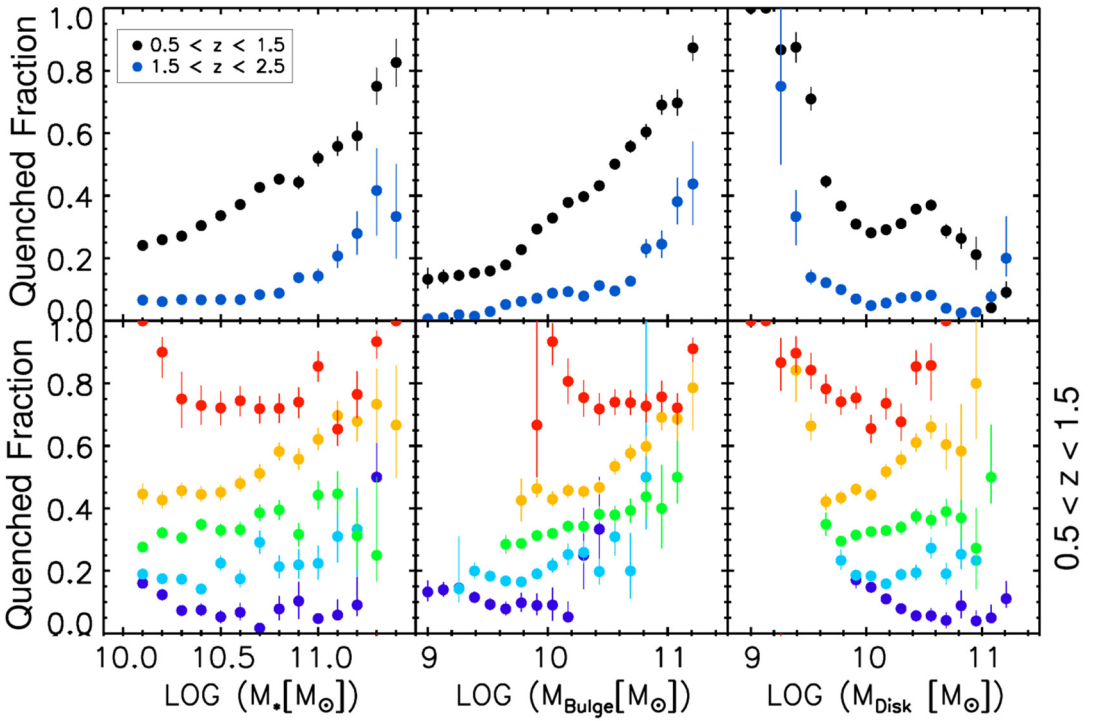
“Bulge mass is king”

Bluck et al. 2014

Observations vs. SAM

Predictions from SAM
(Somerville et al. 2008,2012
+ Porter 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

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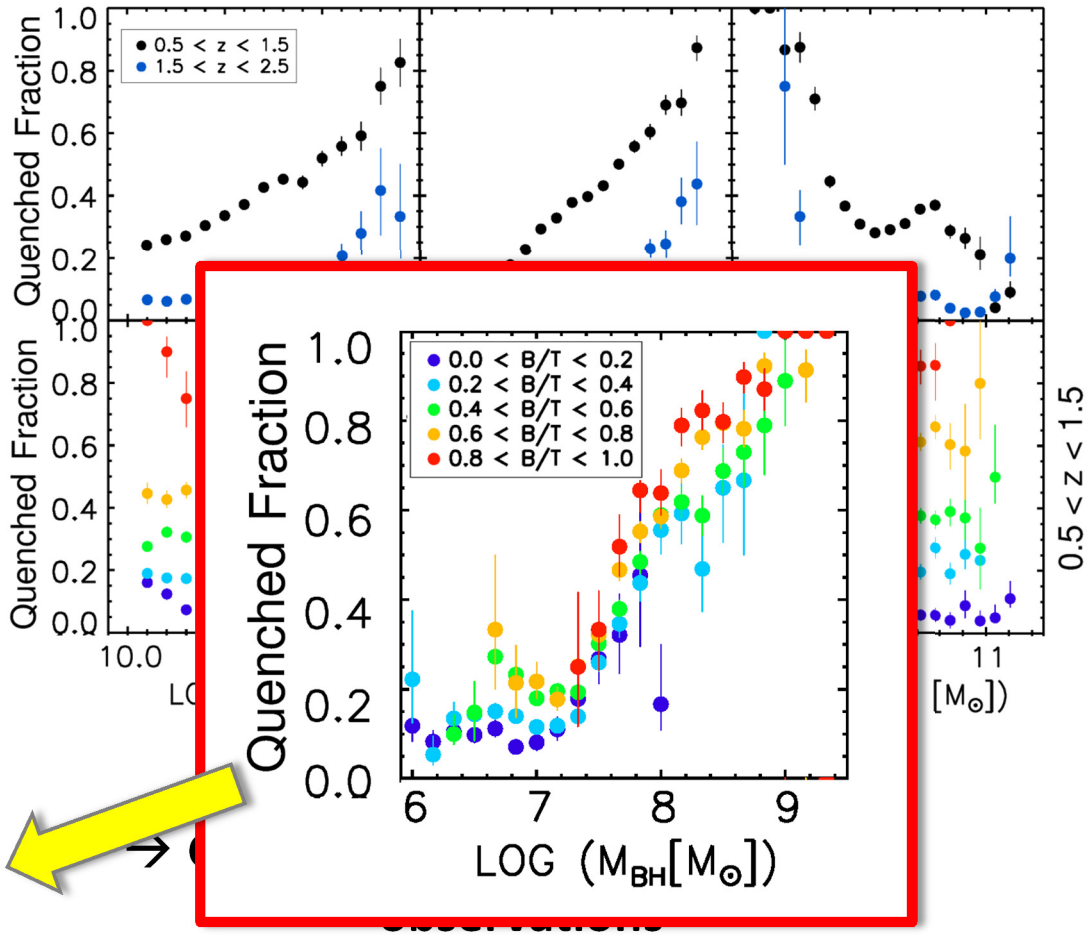
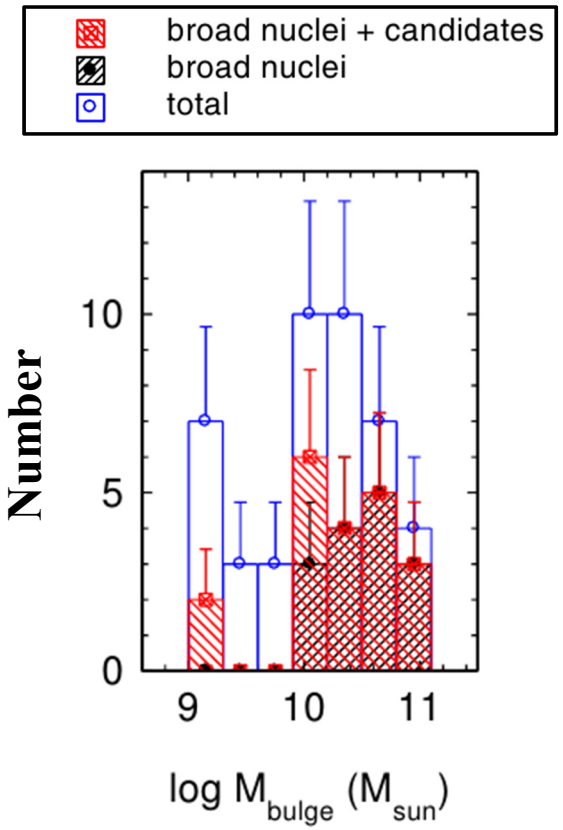


Bulge serves as closest observable proxy for the supermassive BH

P. Lang et al. 2014

Hints on underlying mechanisms at z ~ 2.5

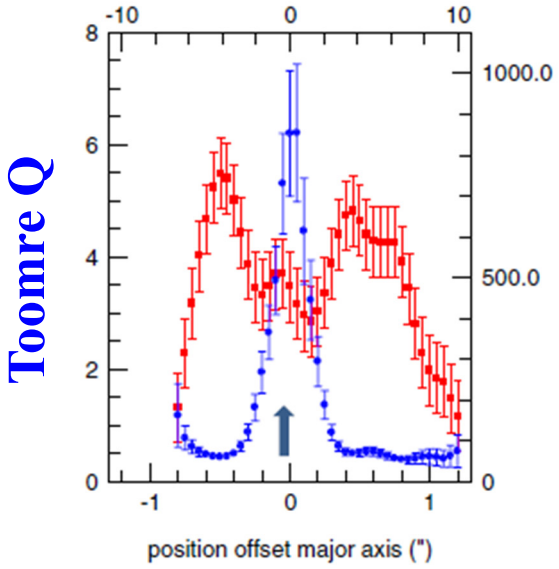
Signatures of broad nuclear outflows

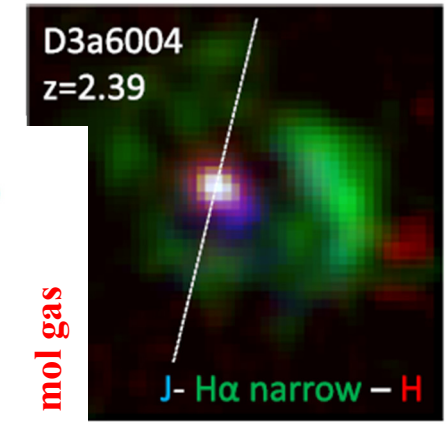


Genzel+ 2014b, Förster Schreiber+2014b

Signatures of morphological quenching

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





Genzel+ 2014a

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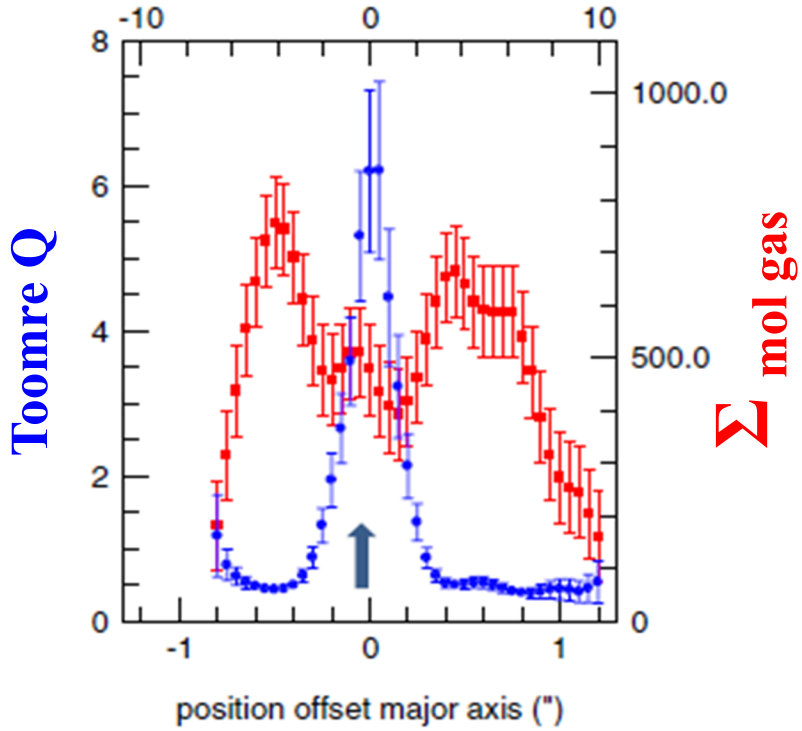

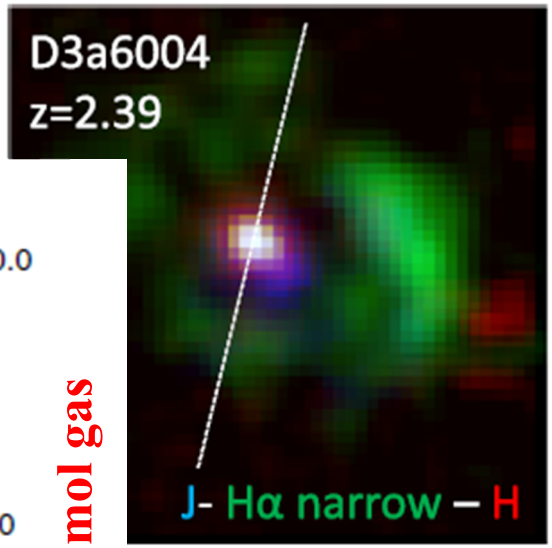

Genzel+ 2014a

Summary

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

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

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