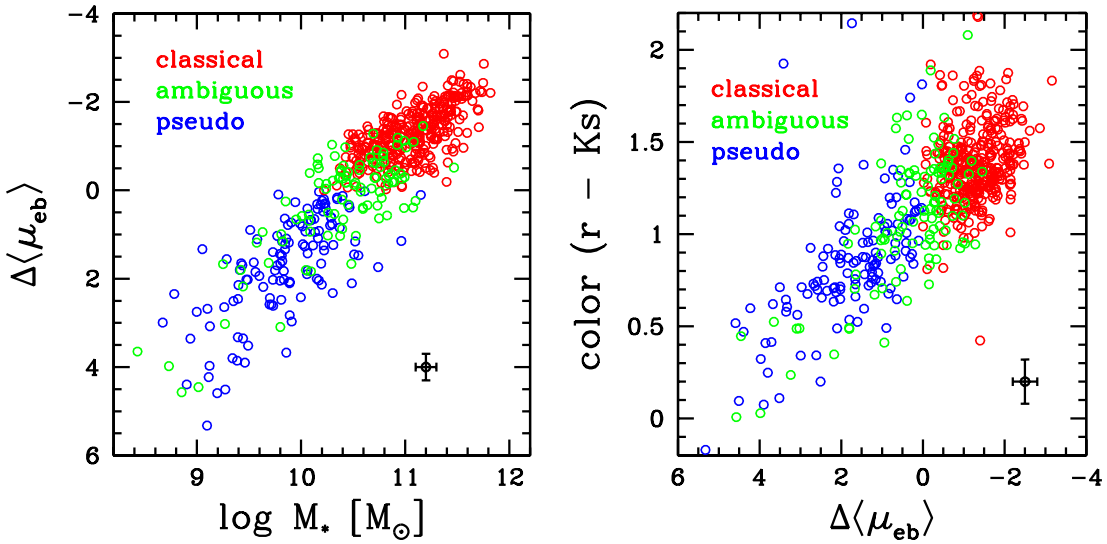
Correlation of bulge transformation in galaxies with decreasing stellar activity

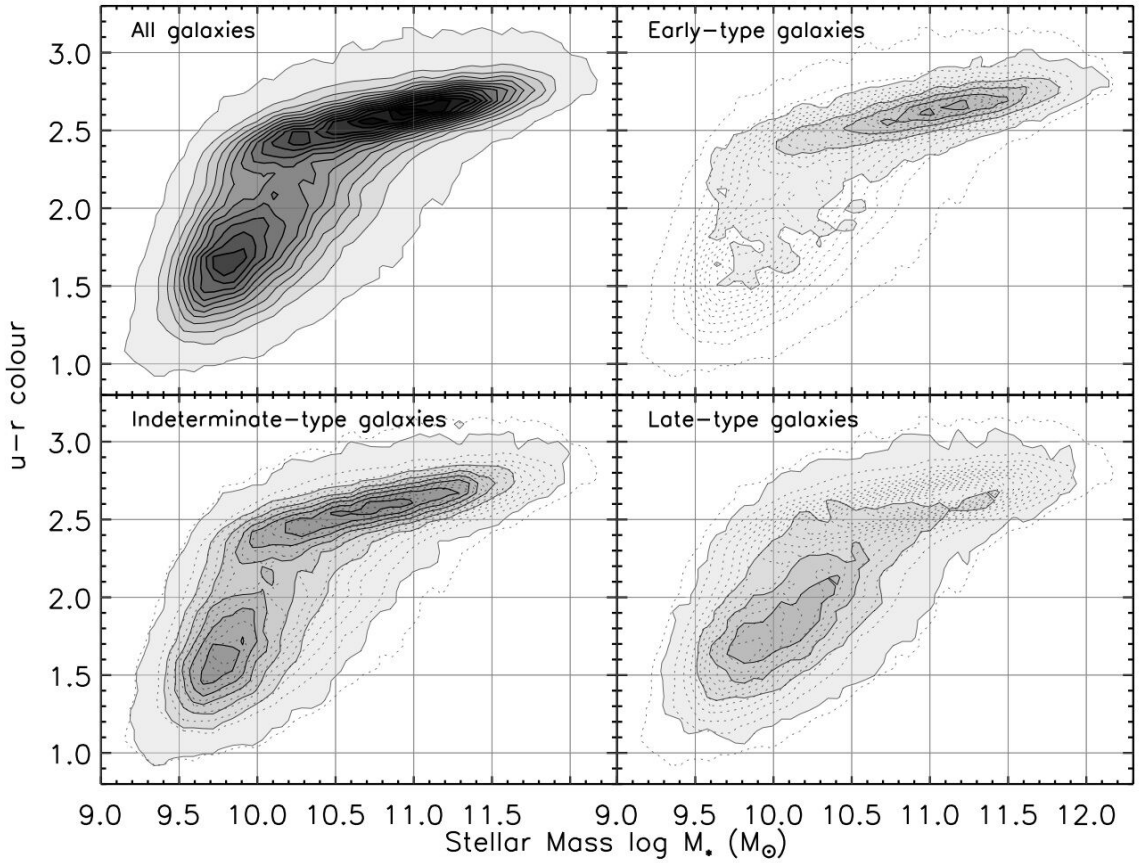
(Sachdeva S., Ho L., Li Y., Shankar F., 2020, ApJ, 899, 2)



Sonali Sachdeva, Post Doctoral Fellow, KIAA-PKU

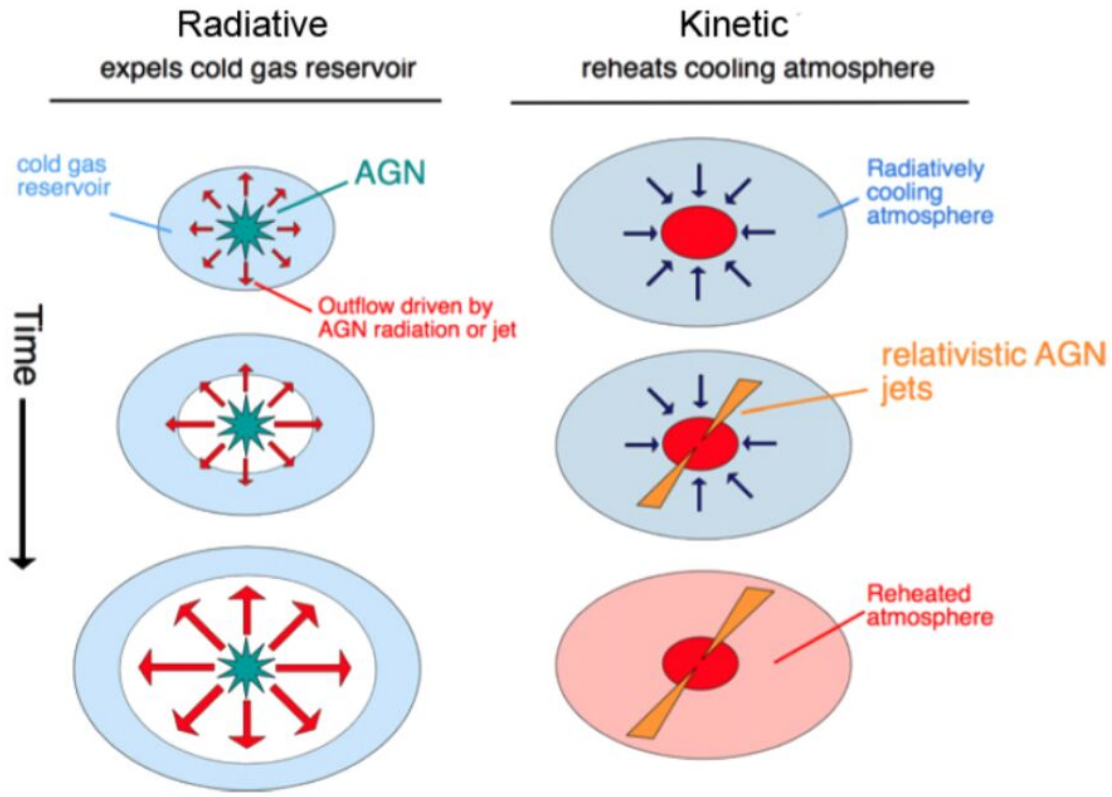
Epoch of Galaxy Quenching, KICC, 8-10 Sept 2020

Galaxy colour correlated with broad morphology



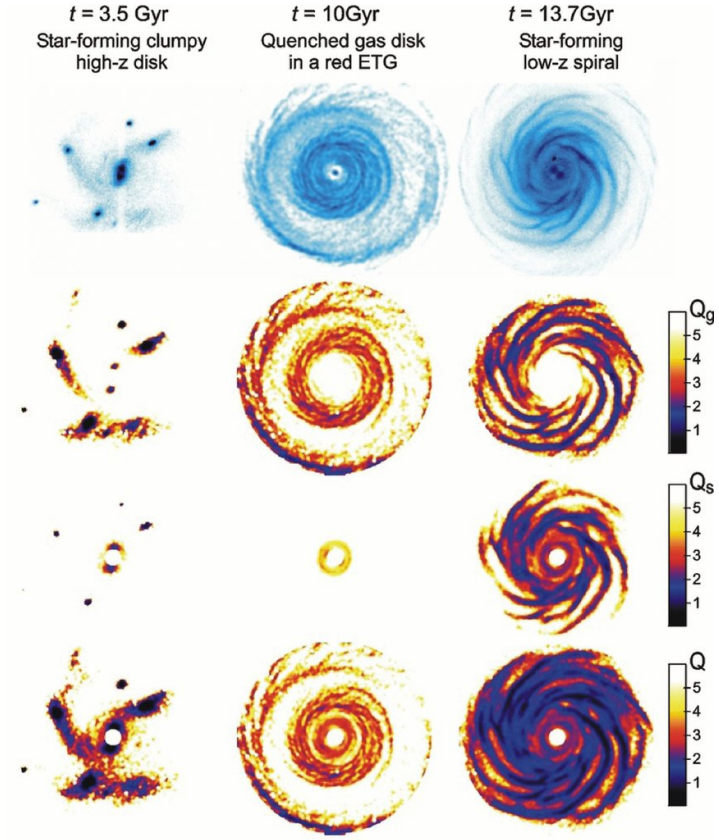
(Strateva+01,Brinchmann+04,Faber+07,Brammer+09,Taylor+15)

Reason : Stellar, AGN wind outflows & jets



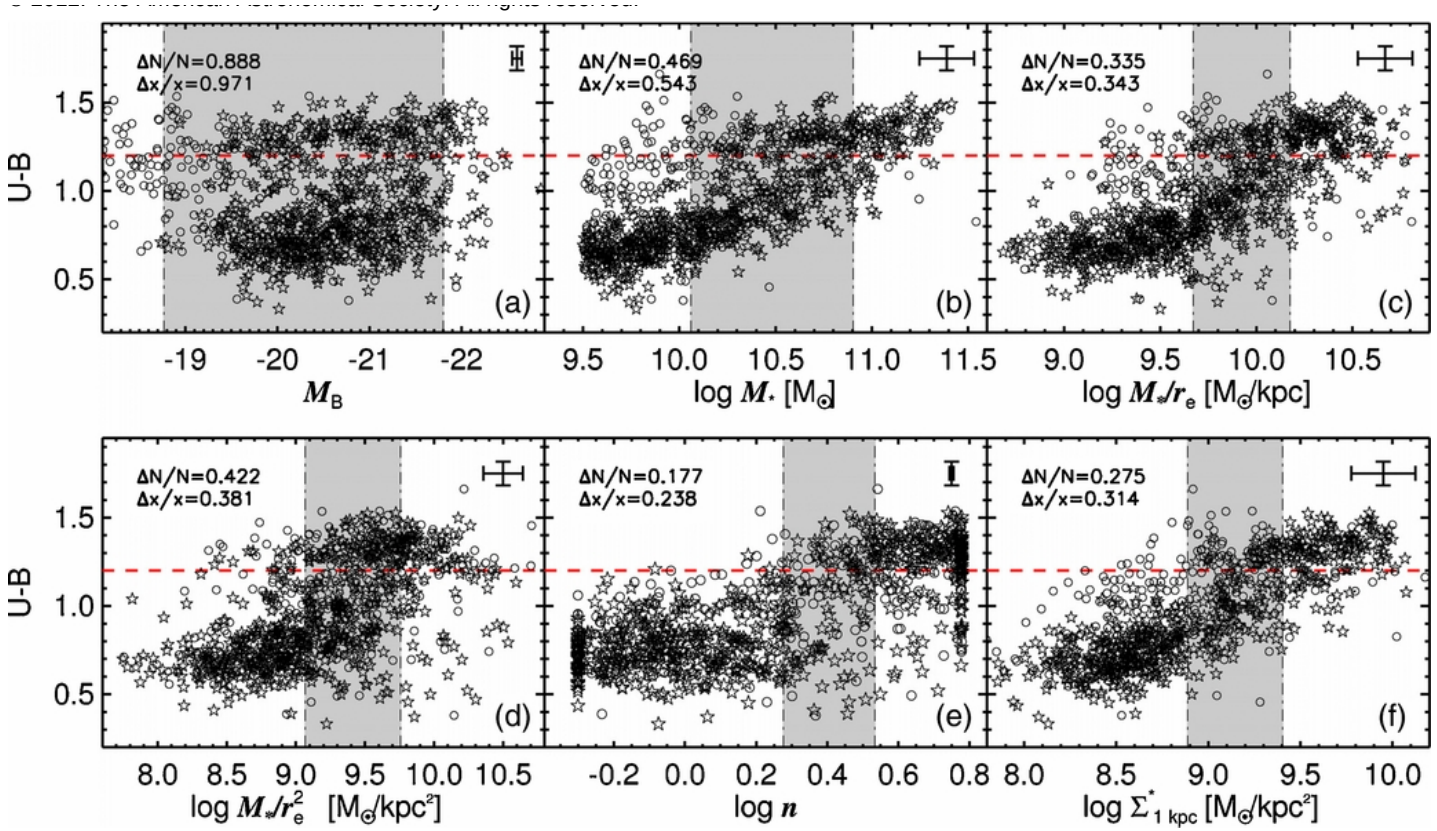
(Hopkins+06,Croton+06,Fabian12,Kormendy16,Cresci&Maiolino18)

Reason : Bulge stabilization & shock heating



(Kennicutt+89,Dekel+06,Martig+09,Peng+10,15,Genzel+13)

Most efficient predictor in structural parameters ?



M_*, M_*/R^2_{eff} (Kauffmann+03,06), n_g, n_b (Driver+06,Bell+12)
σ_o (Wake+12,Bluck+16), Σ_1 (Cheung+12,Fang+13,Luo+20)

Same structural parameters to classify bulge-type

Bulges are complex!

Classical bulges: e.g. M81 [NASA]

Disk-like bulges (aka pseudo-bulges): e.g. NGC 6782 [NASA]

Box/Peanut bulges (aka pseudo-bulges): e.g. ESO 597-G 036 [NASA]

Classical bulges

- stick out of disk plane (not as flat as the disk)
- more or less sphroidal
- featureless: no spiral arms, bars, rings,…
- mostly old stars
- kinematically hot: dynamically supported by stellar velocity dispersions
- seem to be built mostly by mergers, fast bursts of star formation

Disk-like bulges(aka pseudo-bulges)

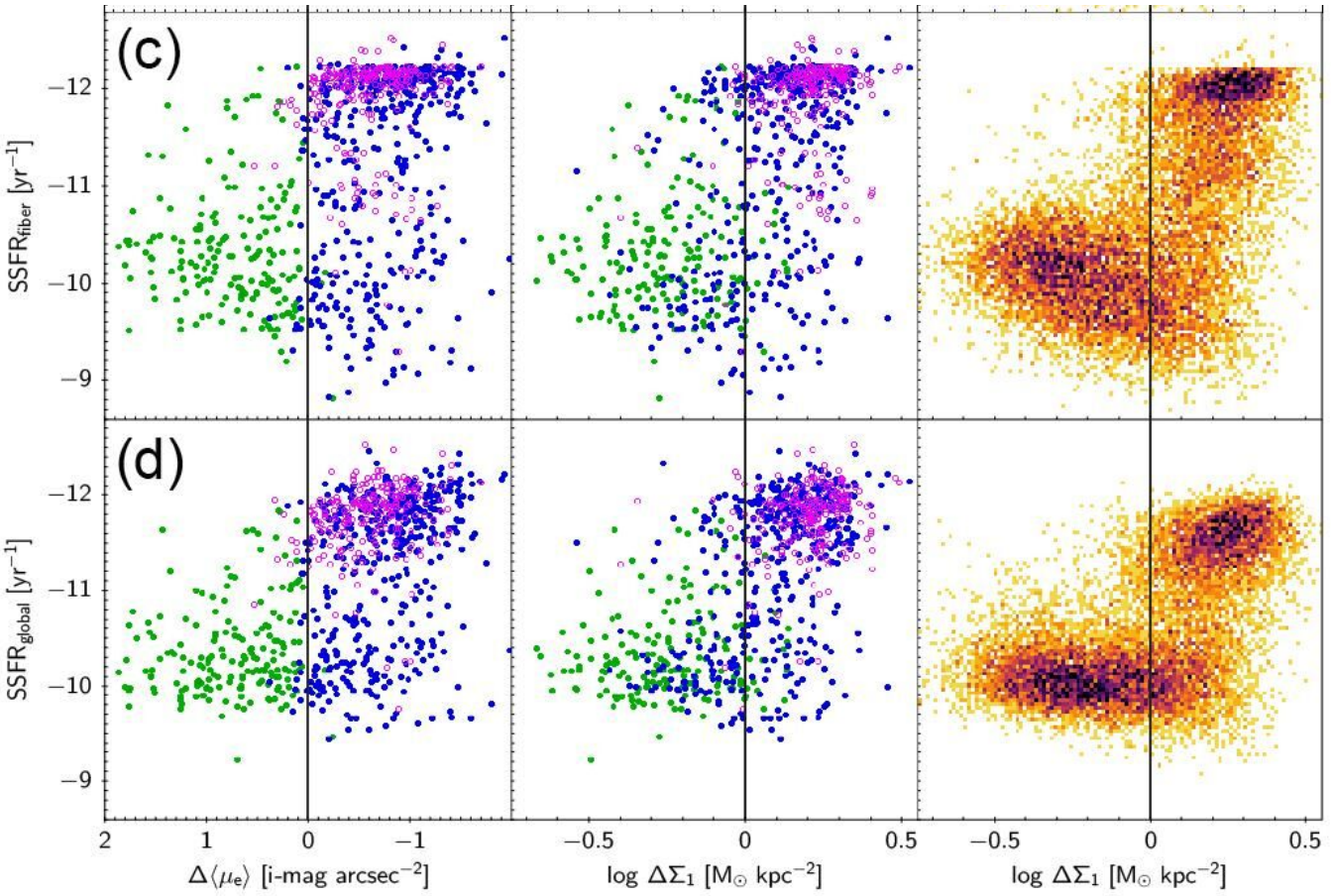
- as flat as the disk
- substructures: nuclear bars, spiral arms, rings,…
- young stellar populations or ongoing star formation
- kinematically cold: dynamically supported by rotation of its stars
- seem to be built mostly via disk instabilities: continuous, smooth process

Box/Peanut bulges(aka pseudo-bulges)

- stick out of the disk
- box or peanut-like morphology
- usually featureless
- usually does not show young stellar populations or star-forming regions
- kinematically cold: dynamically supported by rotation of its stars
- the inner parts of bars that grow vertically thick due to dynamical instabilities!

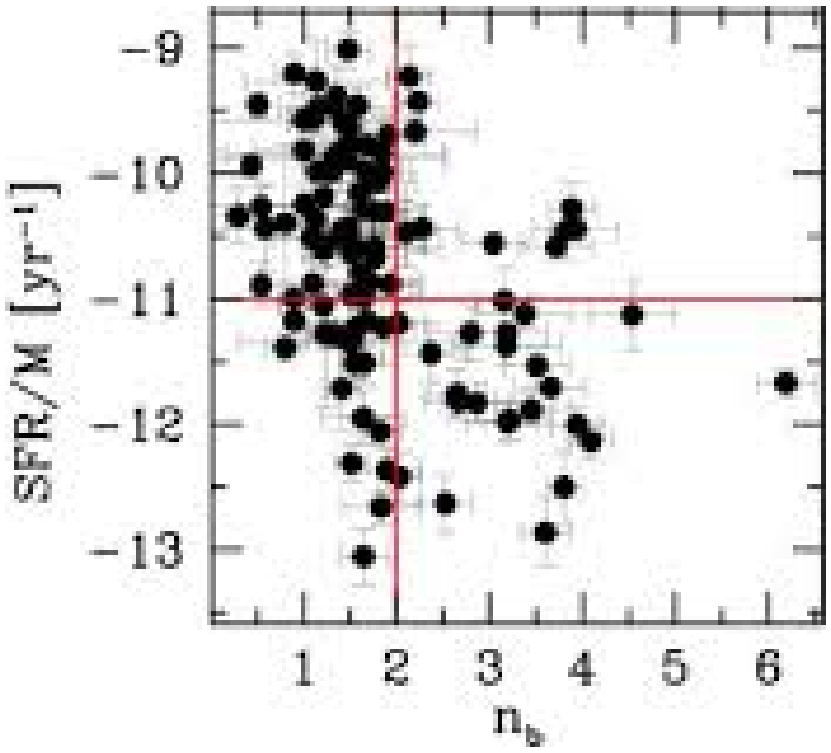
(Gouda,NOAO,13)

Contradictory assertion of bulge stellar activity !!



(Luo+20)

Contradictory assertion of bulge stellar activity !!



(Fisher+16)

Reason: Some bulges satisfy all criteria, others satisfy half
Classification subjective to criteria, contamination of both sets.

Improvement: Selection of pure sets, ambiguous kept separate

Improvements to extract a clearer picture

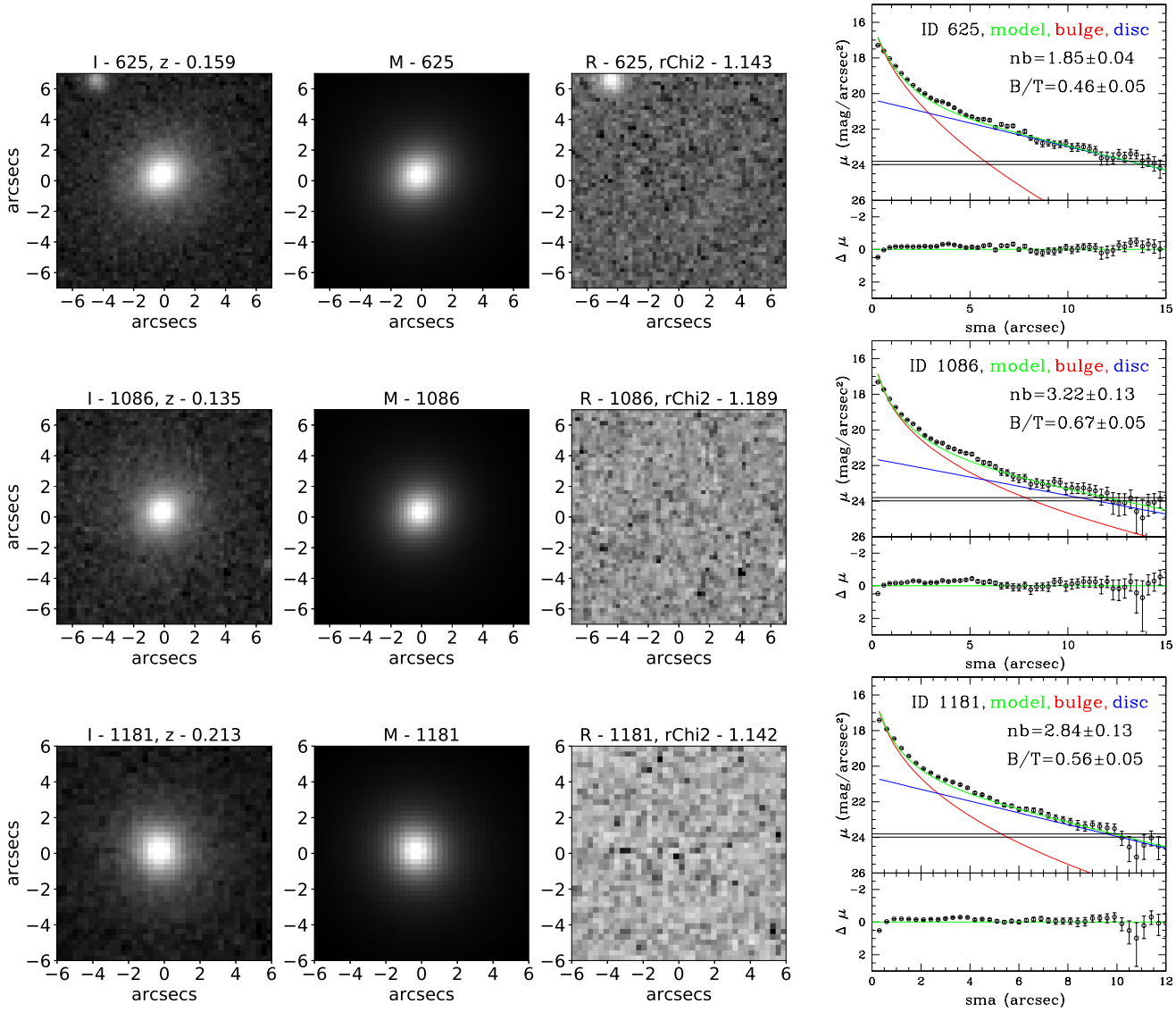
1) Selection of all local ($z < 0.3$) disc galaxies (total=1263)
Best coverage: Herschel imaging area of the Stripe82 region
Most reliable stellar parameters from GSWLC2 (Salim+16,18)
"True" IR flux: FIR (Herschel) + MIR (Wise), dust accounted.

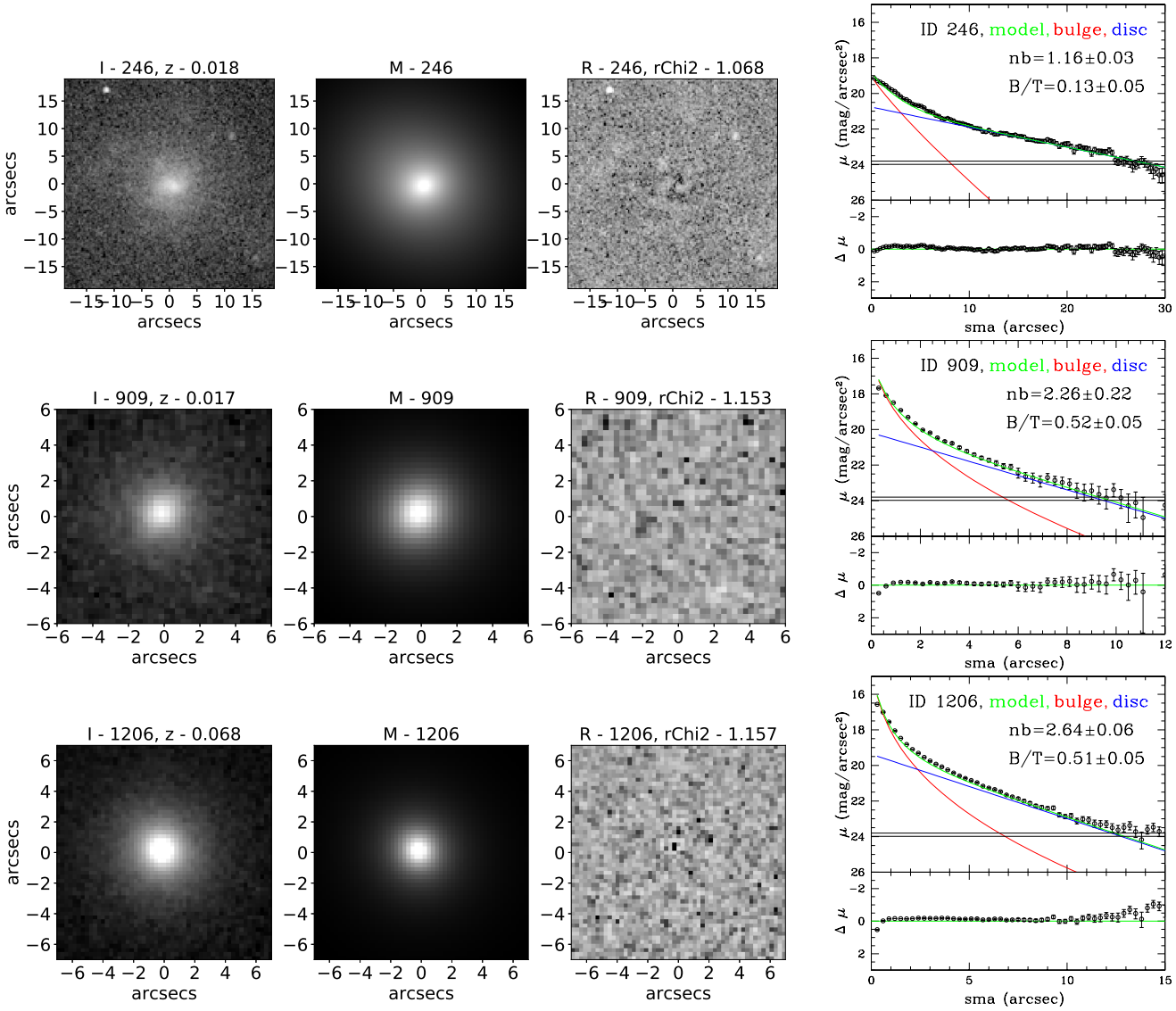
2) **Decomposition**: using K_s band images from VICS82 survey
VISTA+CFHT, 0.3"/pixel, 21.4 mag deep (Geach+17)
Best tracer of actual mass distribution (Bundy+06,Bluck+19)
Least dust affected, all middle & old age stars accounted.

3) Full range of structural parameters, multiple techniques
Parametric: 1D profile (*ellipse*) & 2D image fitting (*Galfit*)
Non-parametric: Concentration, Asymmetry (Conselice03)
Existing optical parameters for full sample from Bottrell+19.

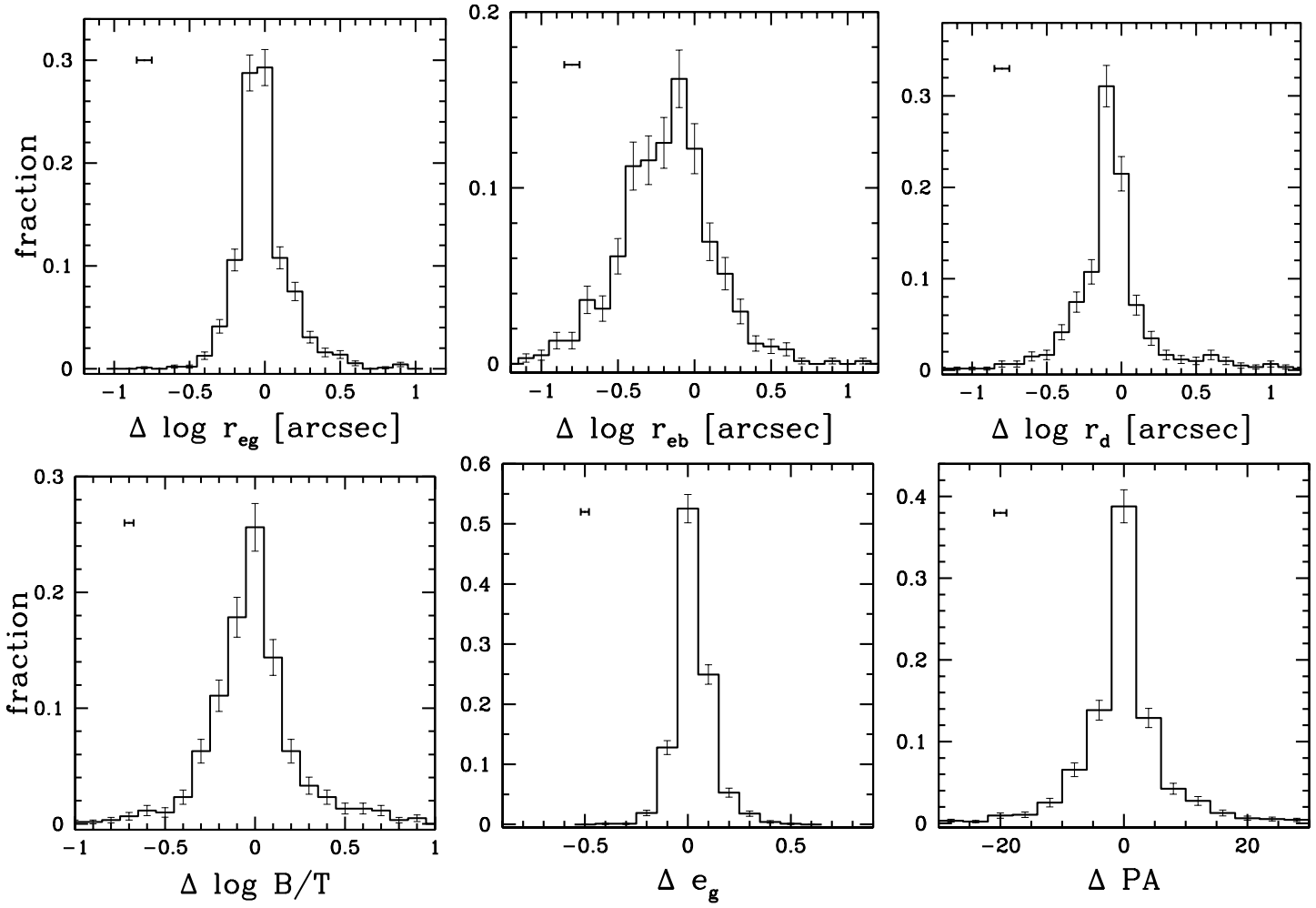
4) Multiple stringent criteria applied to determine bulge type
Separation of ambiguous bulge discs to prevent contamination
Consistency with kinematics & fundamental relations.

5) Identification of single structural indicator to determine
bulge type as well as the level of stellar activity in galaxies.

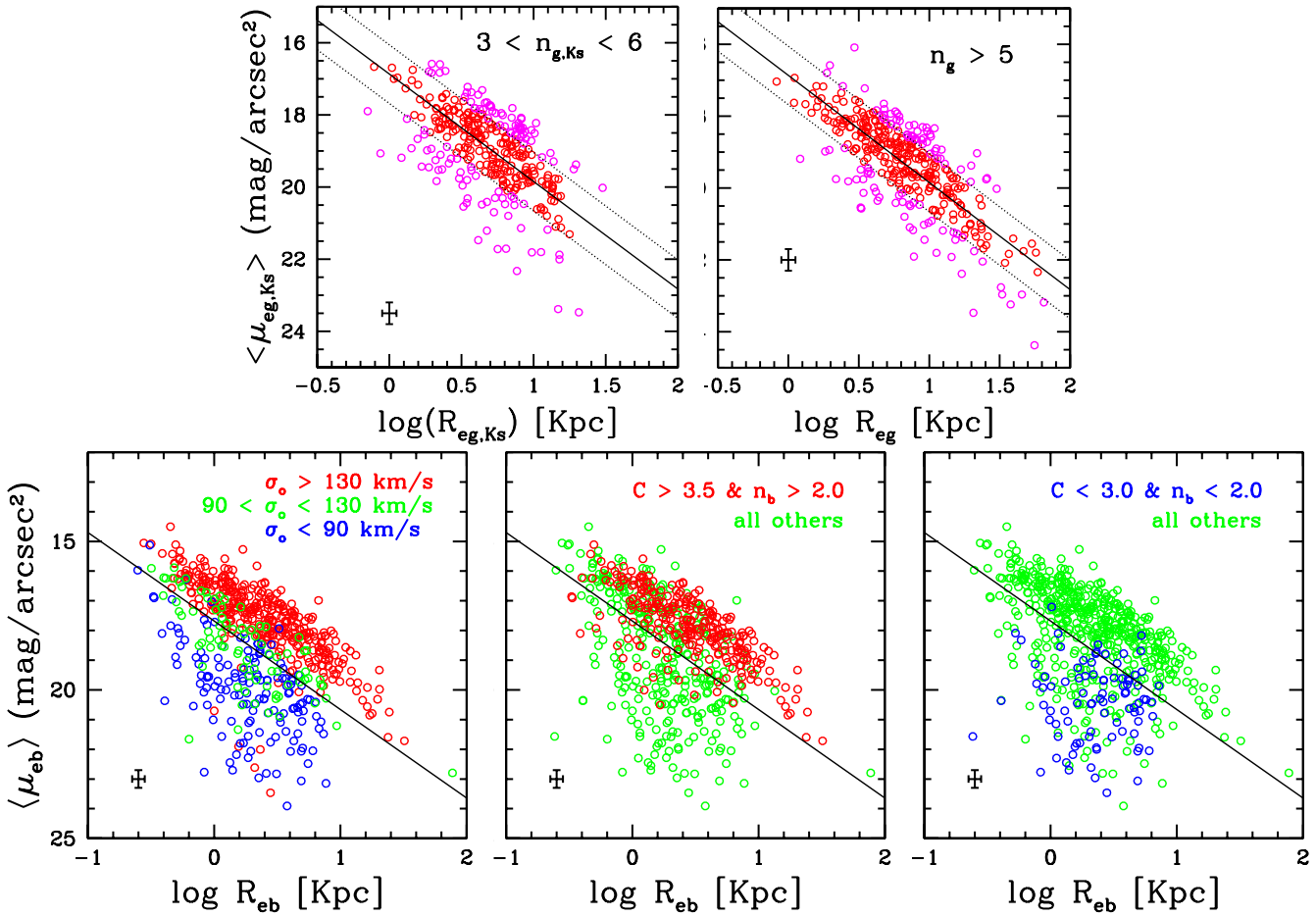

I - 625, z - 0.159
M - 625
R - 625, rChi2 - 1.143
I - 1086, z - 0.135
M - 1086
R - 1086, rChi2 - 1.189
I - 1181, z - 0.213
M - 1181
R - 1181, rChi2 - 1.142
arcsecs
ID 625, model, bulge, disc
nb=1.85±0.04
B/T=0.46±0.05
ID 1086, model, bulge, disc
nb=3.22±0.13
B/T=0.67±0.05
ID 1181, model, bulge, disc
nb=2.84±0.13
B/T=0.56±0.05
μ (mag/arcsec²)
Δ μ
sma (arcsec)


I - 246, z - 0.018
M - 246
R - 246, rChi2 - 1.068
I - 909, z - 0.017
M - 909
R - 909, rChi2 - 1.153
I - 1206, z - 0.068
M - 1206
R - 1206, rChi2 - 1.157
arcsecs
ID 246, model, bulge, disc
nb=1.16±0.03
B/T=0.13±0.05
ID 909, model, bulge, disc
nb=2.26±0.22
B/T=0.52±0.05
ID 1206, model, bulge, disc
nb=2.64±0.06
B/T=0.51±0.05
μ (mag/arcsec²)
Δ μ
sma (arcsec)

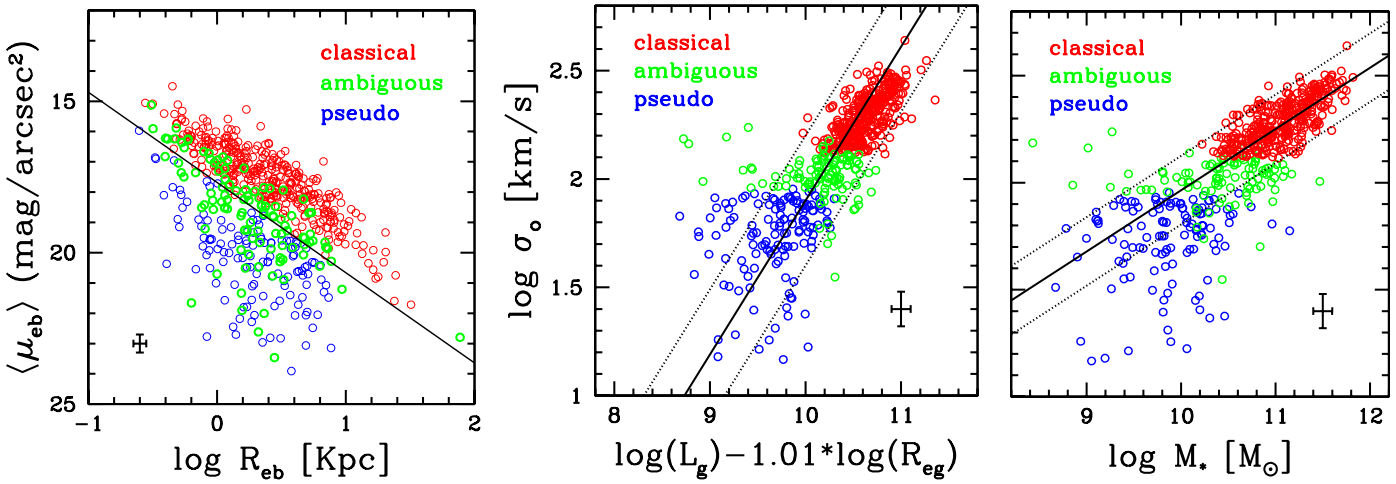
Consistency with r-band parameters (Bottrell+19)



Boundary containing ellipticals - separating bulges



Selection & placement of indubitable bulge types

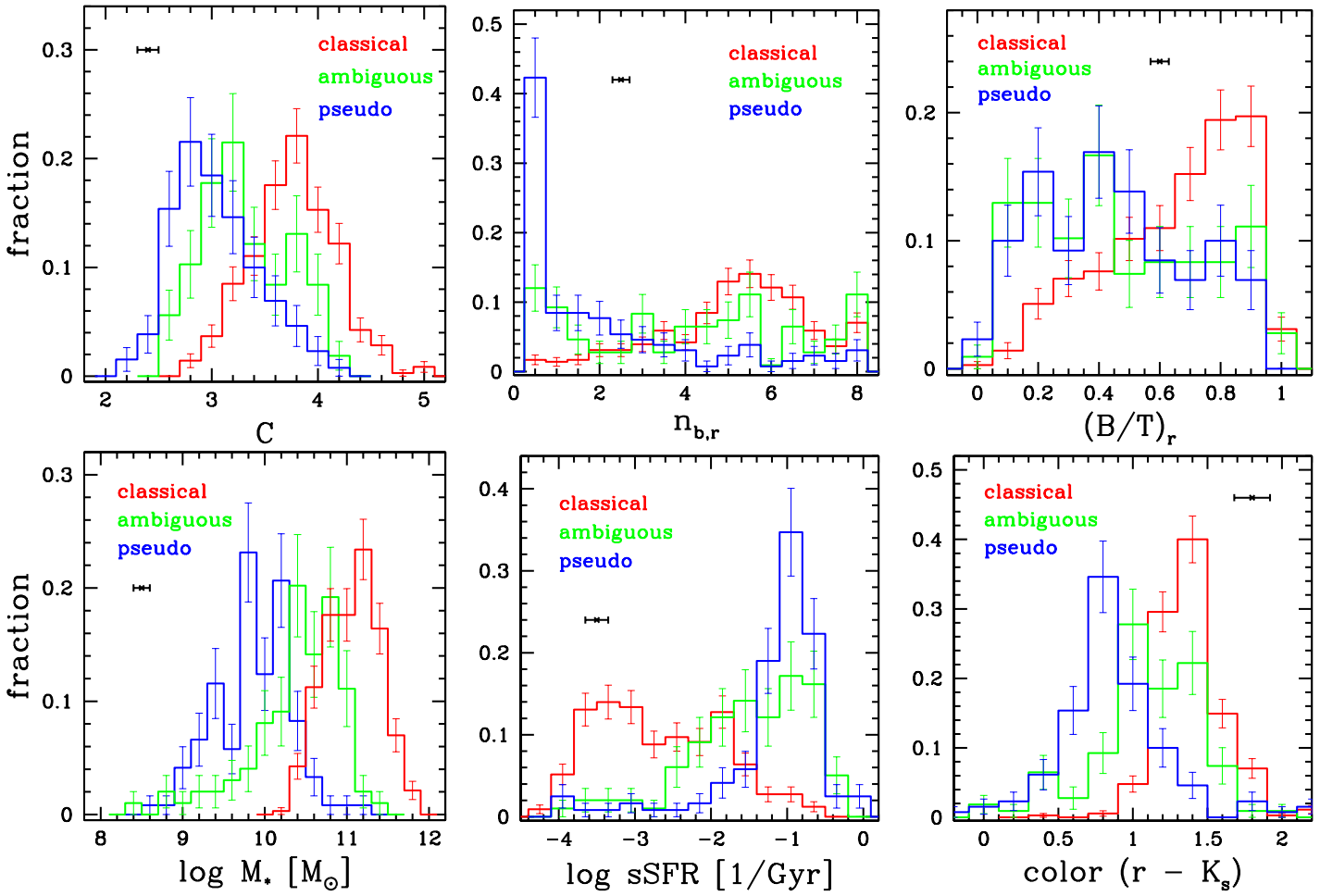


Classical bulges: follow KR & $\sigma_o > 130$ km/s
Pseudo bulges: outlier KR & $\sigma_o < 90$ km/s
Ambiguous bulges: $< 20\%$ of total, unclassifiable

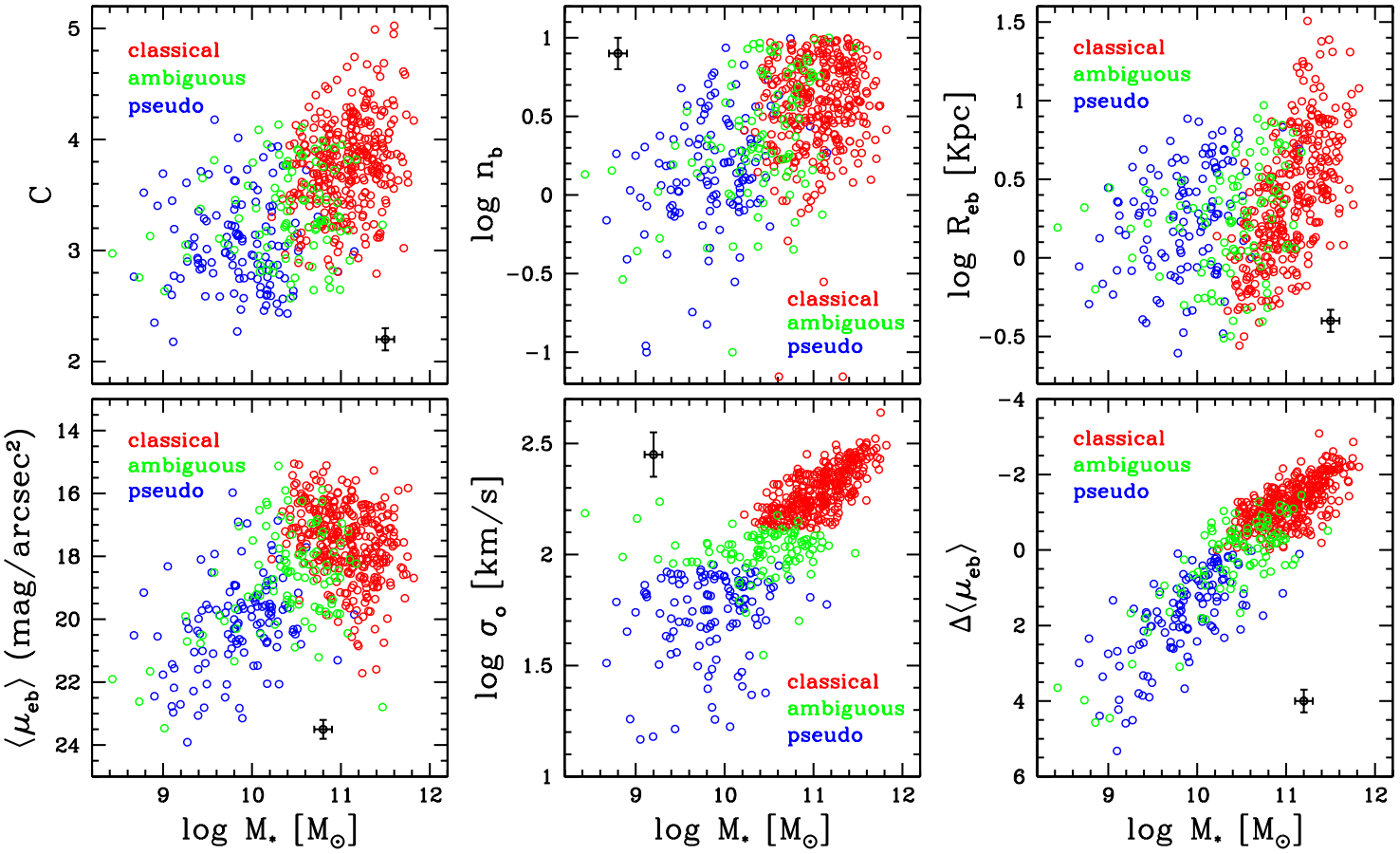
Fundamental plane: vandenBosch16, all BH-host galaxies
(all galaxies should follow since Ks traces total stellar mass)

Faber Jackson plane: Gallazi+16,Cortese+14,AquinoOrtiz+18
(Classical bulge discs best adherents of early type galaxies)

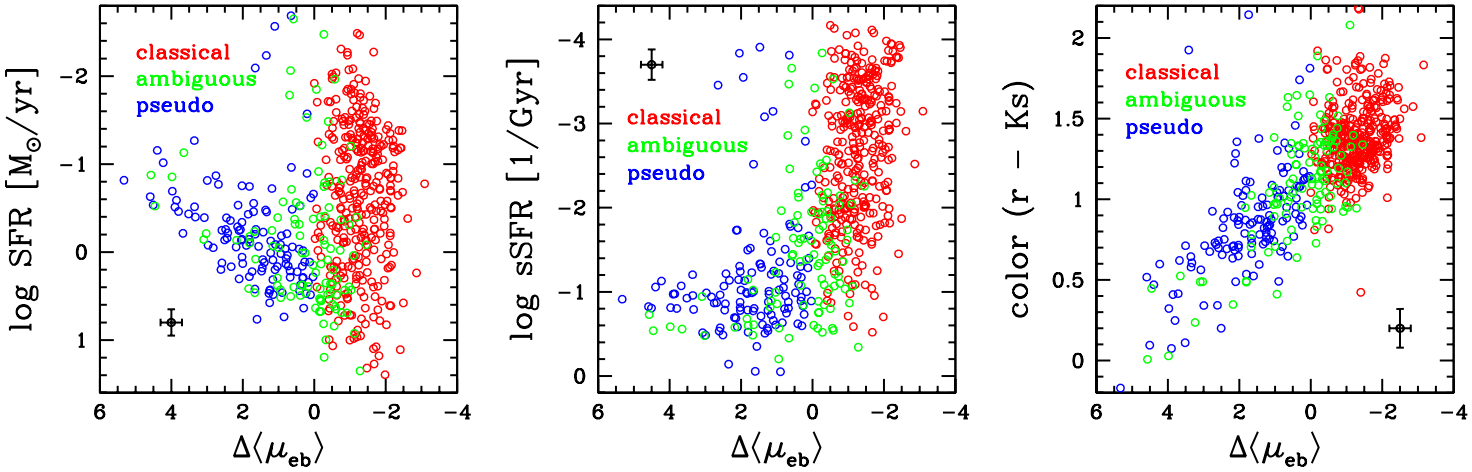
Distinctions in structural & stellar distributions



Single structural parameter : quenching predictor



$\Delta\langle\mu_{eb}\rangle$ - colour correlation & the green valley !!



Pattern change: Elbow (SFR,sSFR) to straight-line $(r - K_s)$
Elbow-like correlations also observed by others (Luo+20)
SFR/sSFR of ABDs & PBDs similar; ABDs redder than PBDs

One option: SFRs over-estimated for ABDs (Salim+16,18)
Second option: Composite population & / or dust-ridden
Composite: between starforming (PBD) & quenched (CBD)
Dust-ridden: difficulty in identification of bulge type.

ABDs: Placement & properties consistent with GV observations.

Major findings Sachdeva+20,ApJ & future steps

1) $\Delta\langle\mu_{eb}\rangle$ better correlated with colour than other indicators
Inner stellar mass surface density regulates stellar activity

2) More elliptical or virialized is the system, more passive it is
All (>90%) pure pseudo-bulge disc galaxies are blue & active
All (>90%) pure classical-bulge disc galaxies are red & passive

3) $\Delta\langle\mu_{eb}\rangle$ reflects kinematics, correlated with central VD (σ_o)
Both morphological stability & SMBH mass gauged with σ_o

4) C & n_b are better predictors than B/T of bulge-type & color
Thus, dominance or mass of the bulge is not the driving factor

5) Structural & stellar constraints on green valley population
Better understanding of their fraction, properties & time-scale

6) Upcoming: application to all (∼16000) sources in Stripe 82
MANGA (Sánchez+16) & SAMI (Scott+18) Galaxy Surveys
M_*, SFR, gas, dust density, kinematic maps & environment
Multi-component, multi-wavelength structural decomposition
Merely correlative or causative role of structure in quenching?