High Central Mass Density: Best Ticket to Cross the Blue to Red Bridge

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Two Main Take Aways

W.M. Keck Observatory

1) Best ticket for *massive, central, field* galaxies to cross the Bridge from Star Forming (SF) Blue to Quiescent Red galaxies is to reach a threshold (dependent on their galaxy-mass) in their central mass density:

Σ_{1kpc} = Stellar Mass within radius of 1Kpc

(~velocity dispersion σ ~ BH mass)

2) After normalizing for redshift evolution of SFR vs Mass (ΔSFR) & Σ_{1kpc} vs Mass ($\Delta\Sigma_{1kpc}$), the Bridge is a knee-shaped Universal Path in ΔSFR vs $\Delta\Sigma_{1kpc}$, whether compactifying crossings are slow strolls by bigger galaxies at lower z's or fast sprints by smaller ones at high redshifts

Overall flow of this talk

After establishing some very basic Terms and Definitions,

highlight our work regarding Σ_{1kpc} and transformation of massive galaxies from star forming to quiescence:

- **Cheung+12:** DEEP/AEGIS z ~ 0.5 – 0.8 sample discovers Σ_{1kpc} is tighter than Sersic n in correlation to red galaxies
- **Fang+13:** SDSS sample shows Σ_{1kpc} threshold for redness is mass dependent and necessary but not sufficient
- **Woo+15:** SDSS Σ_{1kpc} vs Mhalo shows Σ_{1kpc} varies quenched fraction while Mhalo varies mean sSFR
- **Barro+15:** CANDELS data confirms mass dependence of Σ_{1kpc} to distant galaxies & knee-shaped

DEFINITIONS/TERMS

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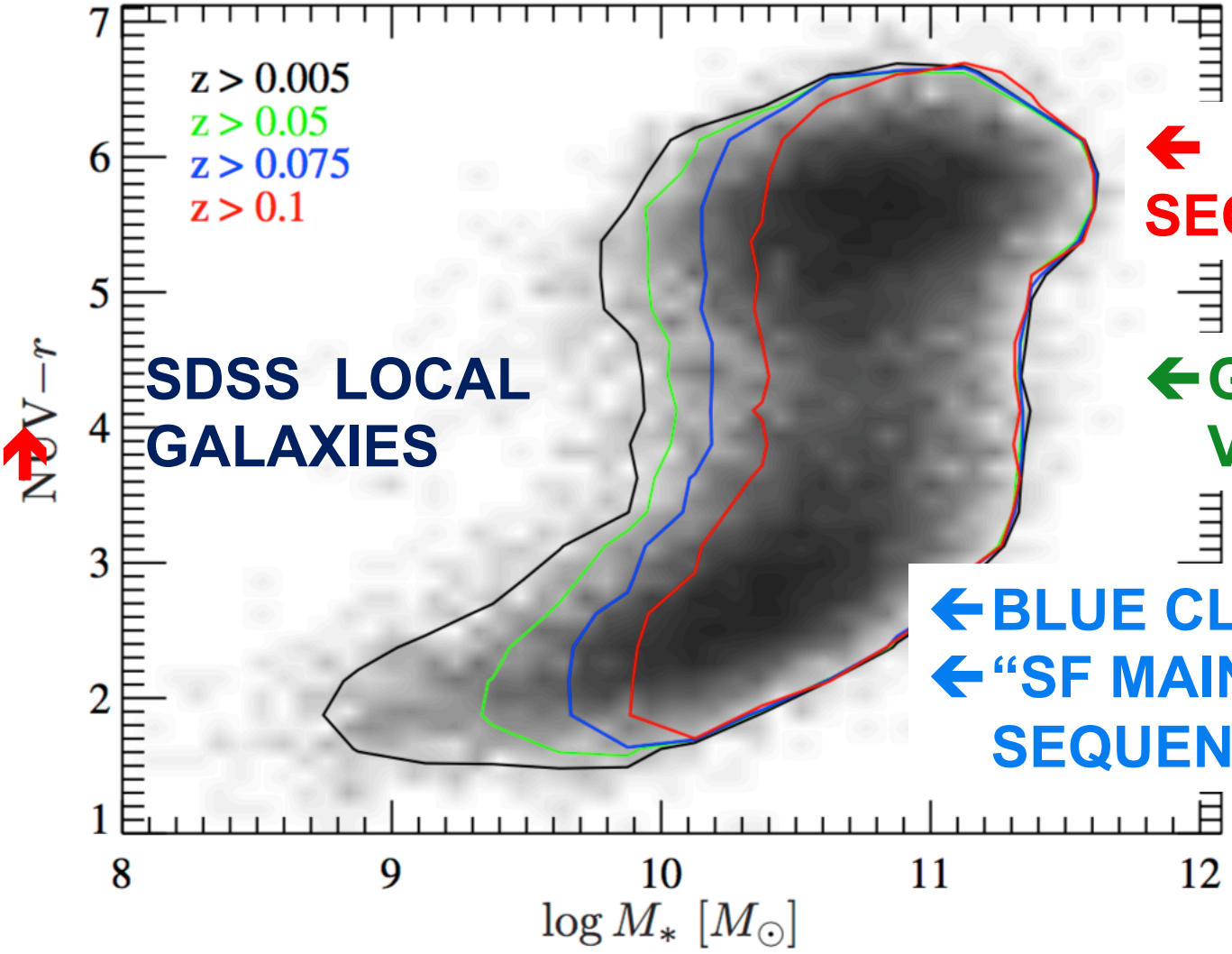
←BLUER COLOR REDDER →
←HIGHER Specific SFR LOWER



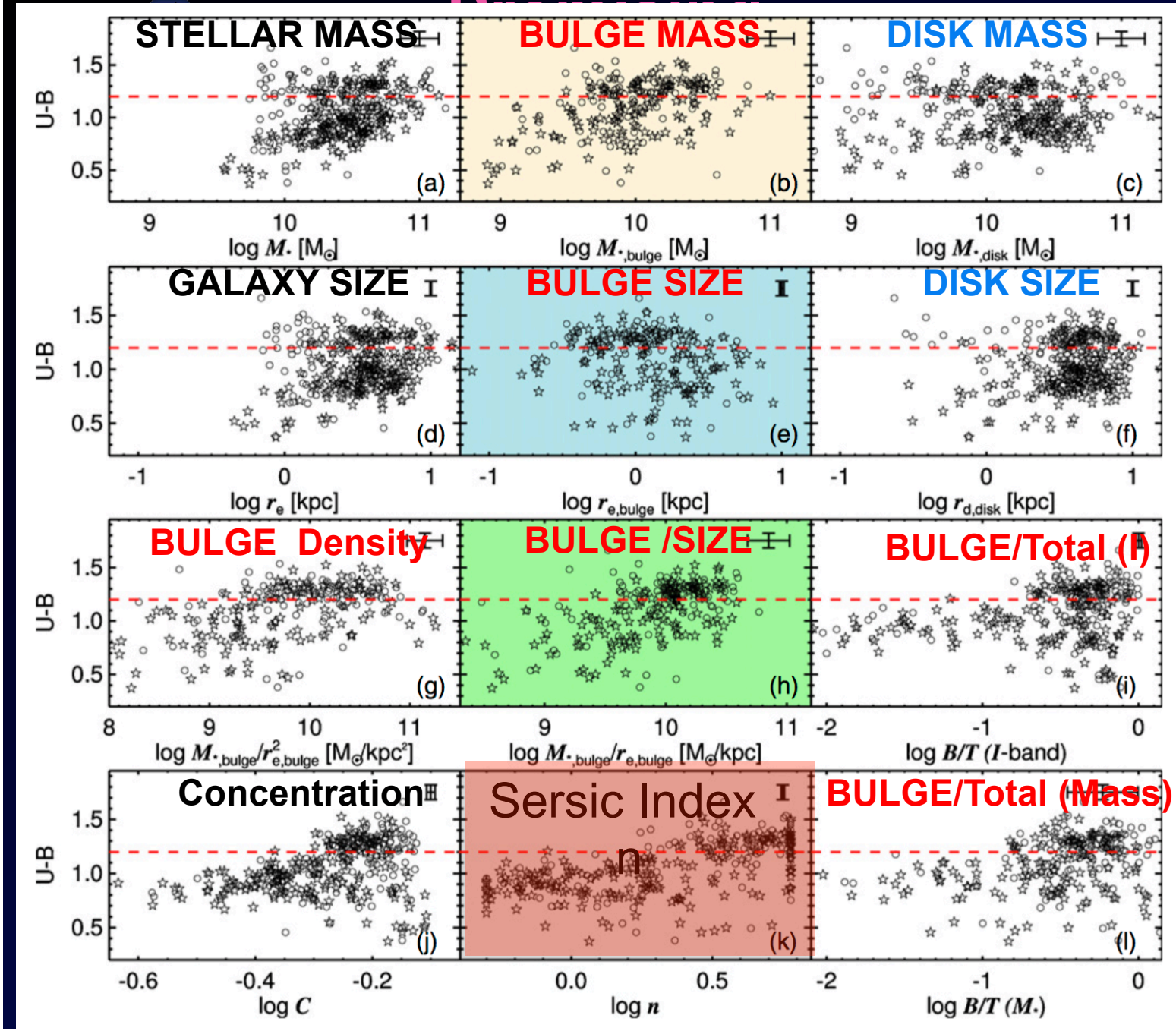
← RED SEQUENCE

←GREEN VALLEY

←BLUE CLOUD
←"SF MAIN SEQUENCE"

Log Stellar Mass →

Global Sersic Index is Most Promising

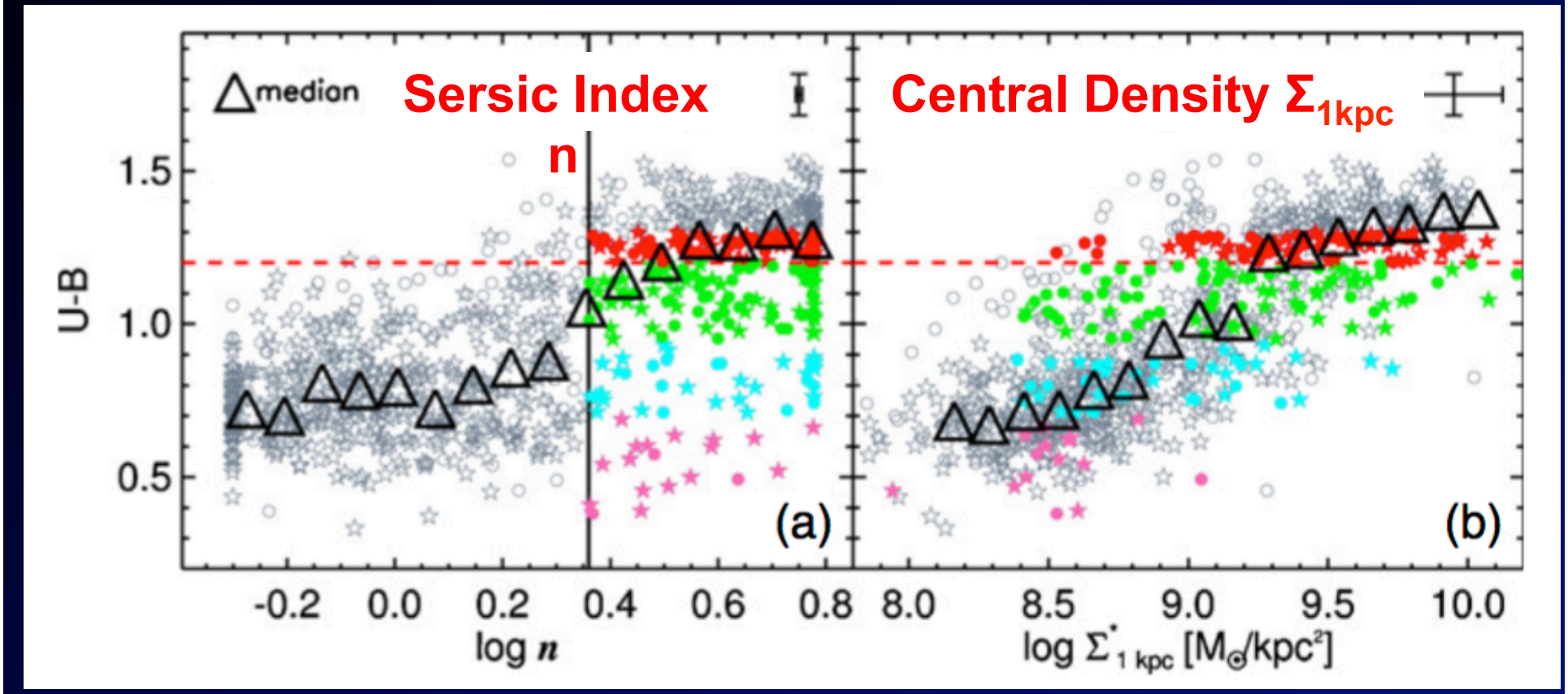


Edmond Cheung+12

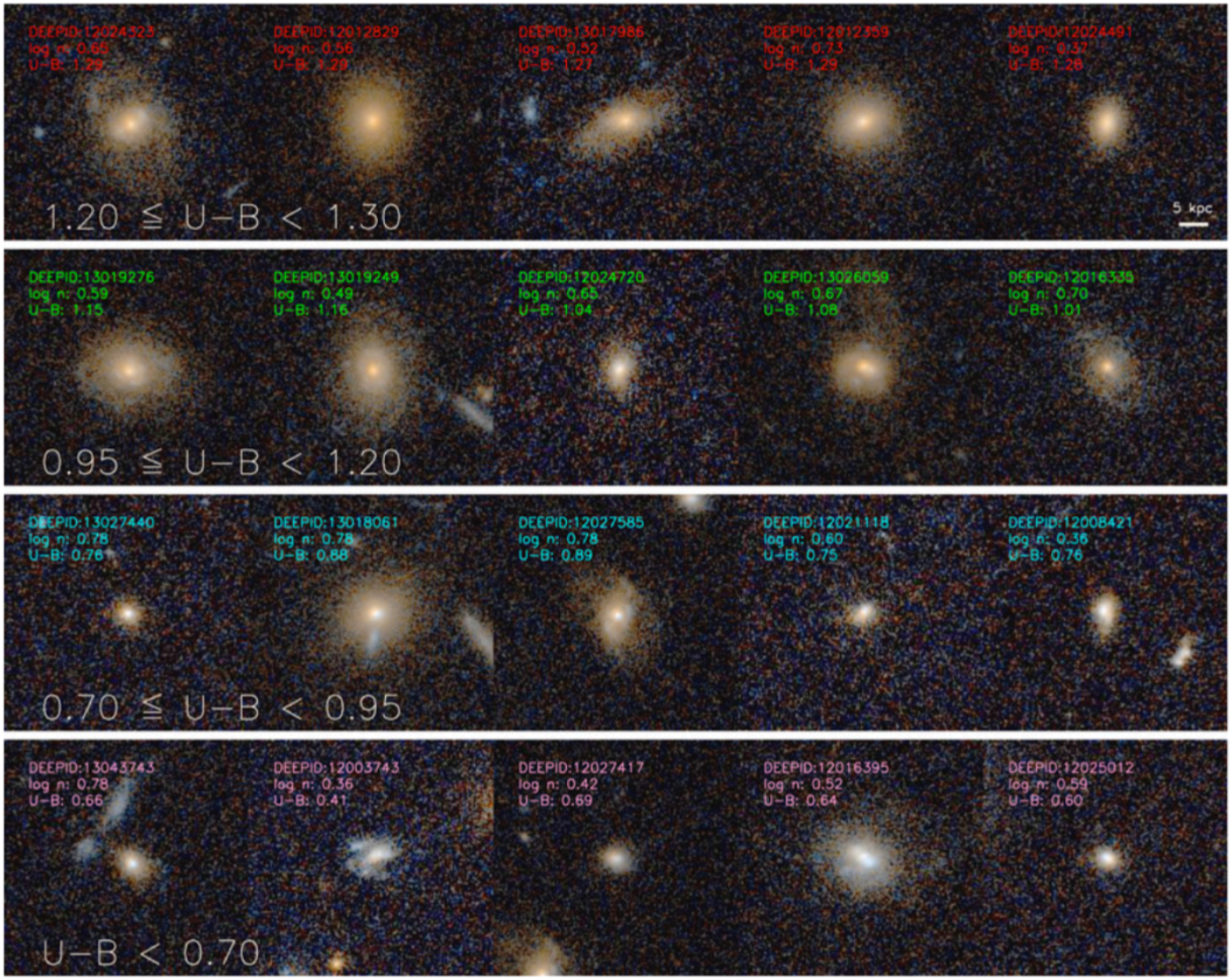
DEEP2 (z_s)
AEGIS
(HST)
z(s,p)~0.5-0.8
GIM2D:BDn
sSFR=U-B
M* via M/L
Non-Dusty:
(b/a > 0.55;
UVJ-Quies)

N ~1400

Σ_{1kpc} Cleaner than Sersic n for Discriminating Quiescent from Star Forming Galaxies

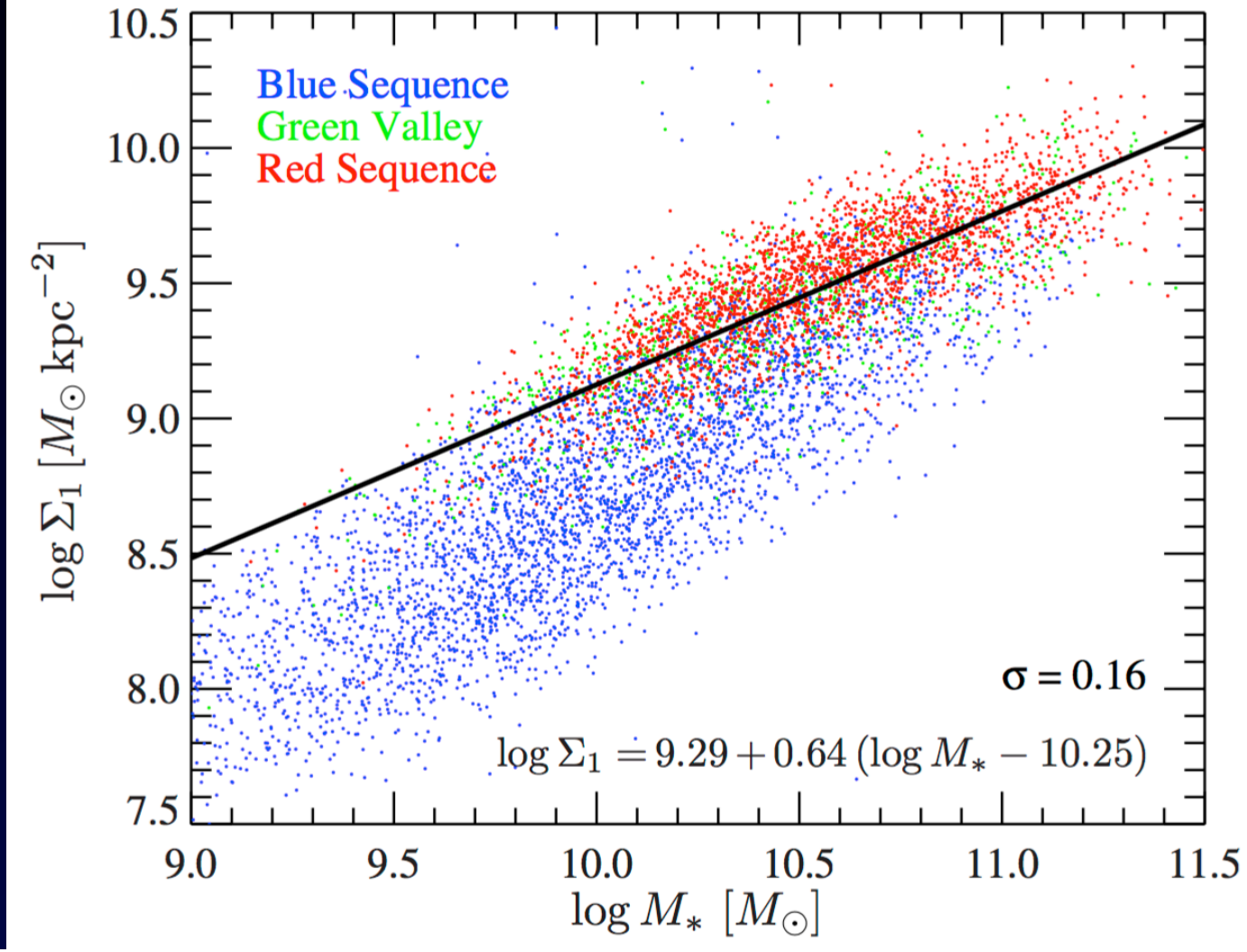


Images of Outliers in Sersic Index n vs U-B Figure



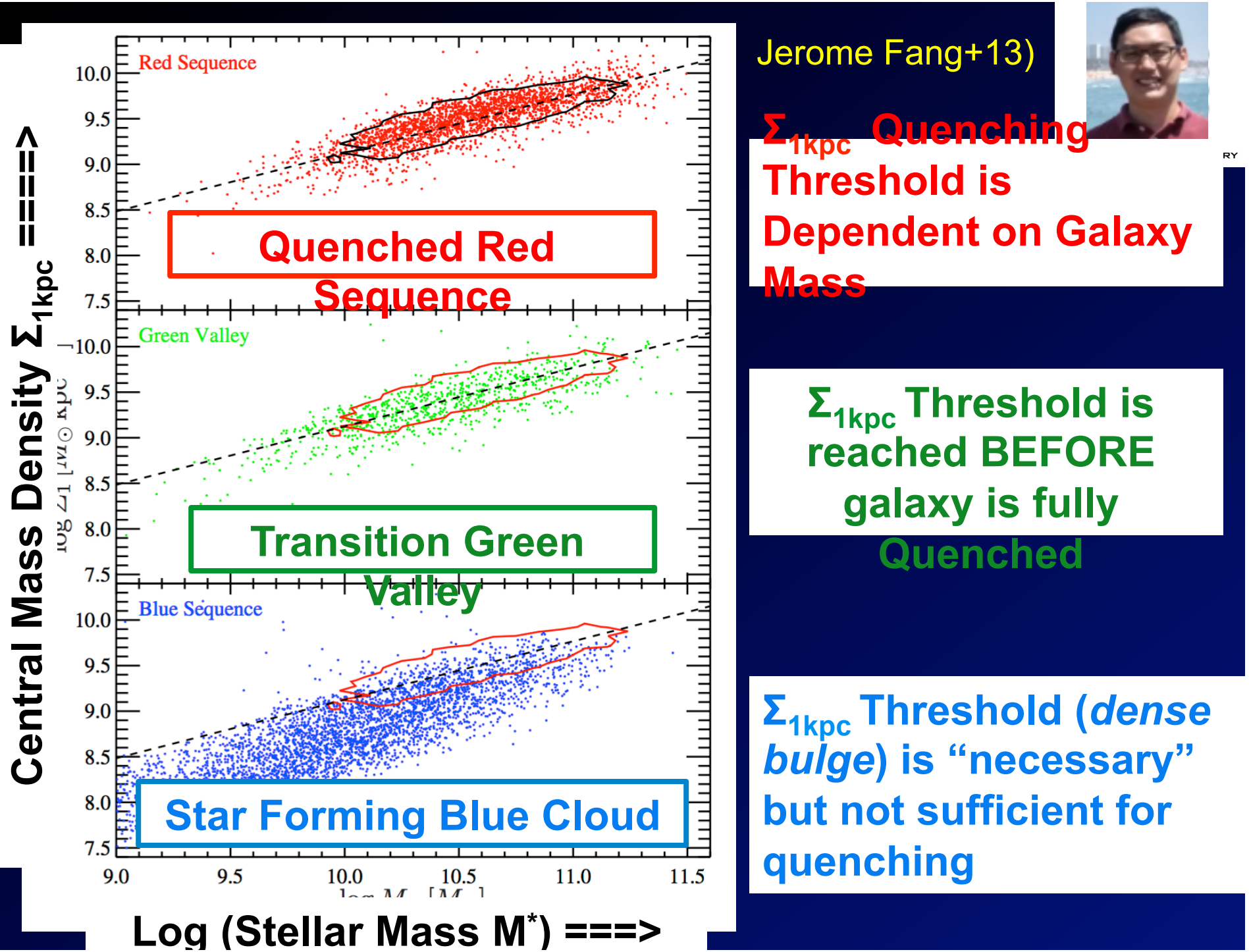
Σ_{1kpc} Quenching Threshold is Dependent on Galaxy Mass

(Jerome Fang+13)



SDSS &
GALEX
Non-dusty (b/a)
Central:Yang
+12
NUV-r(B,GV,Q)
M* via M/L

N ~ 2,350

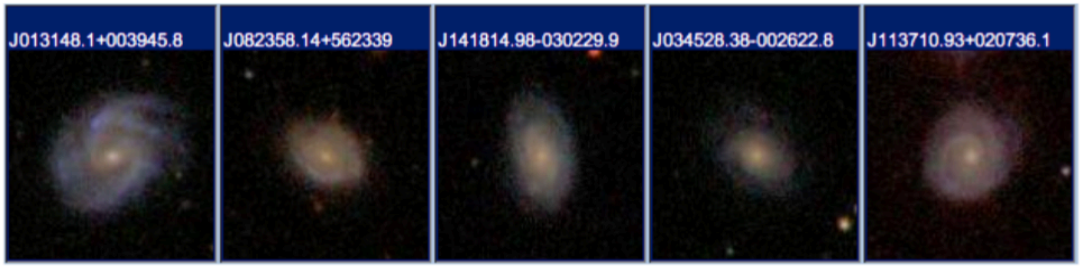

Jerome Fang+13)
Σ_{1kpc} Quenching Threshold is Dependent on Galaxy Mass
Σ_{1kpc} Threshold is reached BEFORE galaxy is fully Quenched
Σ_{1kpc} Threshold (*dense bulge*) is "necessary" but not sufficient for quenching
Central Mass Density Σ_{1kpc} ====>
Red Sequence
Quenched Red Sequence
Green Valley
Transition Green Valley
Blue Sequence
Star Forming Blue Cloud
Log (Stellar Mass M*) ===>
10.0
9.5
9.0
8.5
8.0
7.5
9.0
9.5
10.0
10.5
11.0
11.5

Montage of Same-Mass SDSS Images

(Fang+13)

$0.04 < z < 0.05$; $10.25 < \log M_* < 10.5$

Blue Sequence ($\log \Sigma_1 \sim 8.7$)



Blue Sequence ($\log \Sigma_1 \sim 9.4$)

Green Valley

Red Sequence

Blue SF usually have Low Central Density

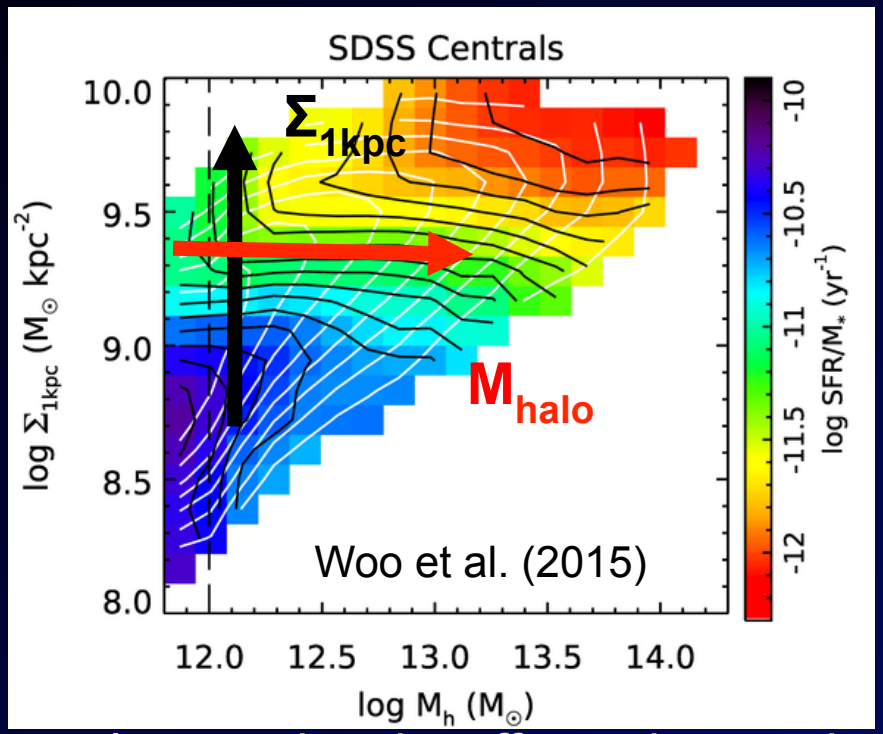
Blue SF may have High Central Density

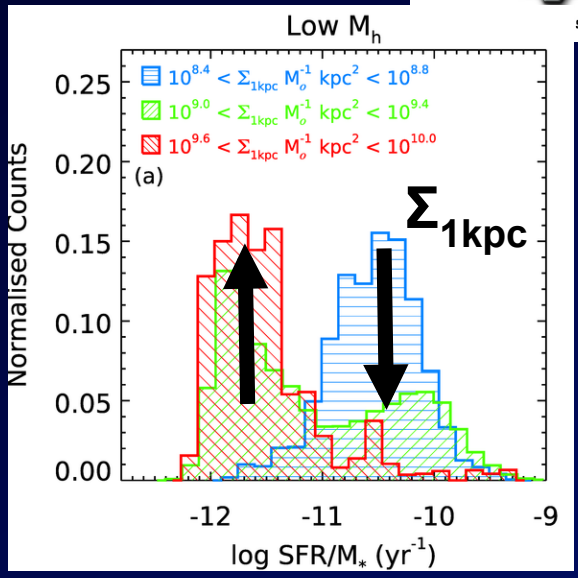
Green Valley have High Central Density

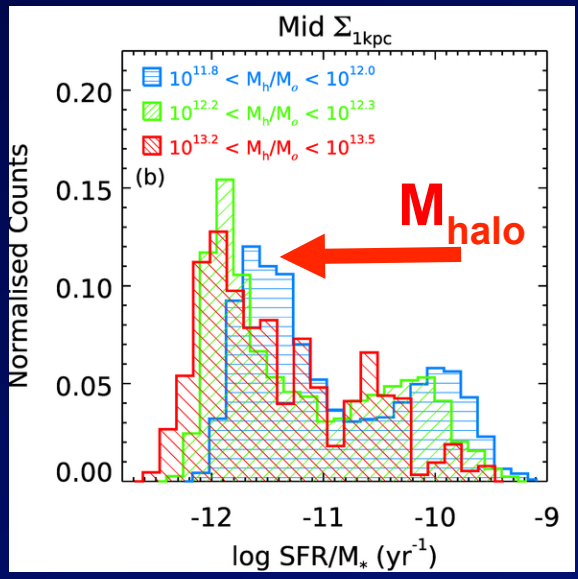
Red Quiescent have High Central Density

Central Mass Density vs Halo Mass

Joanna Woo et al. (2015)



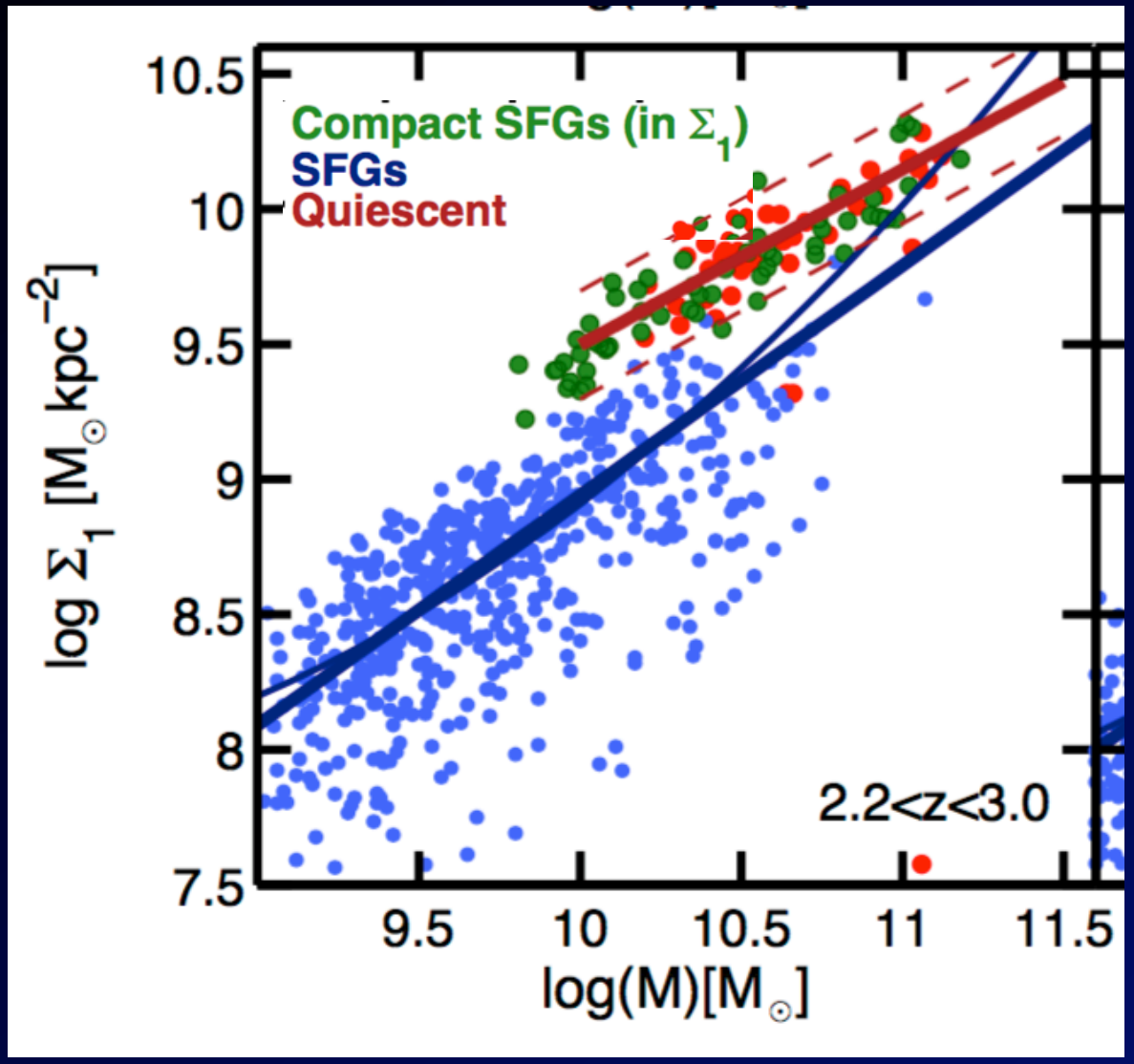




- * Central mass density affects the number ratio of the bimodality
- * Halo mass affects sSFR
- * 20% of quenched centrals in massive halos have low Σ_{1kpc}

Mass-Dependent Σ_{1kpc} Threshold Seen to High Redshifts z ~ 3

Guillermo Barro+15



CANDELS: GOODS-S
Photo-z from EAZY
Stellar Masses: FAST
SFR: UV + IR
Sizes, n, etc.: GALFIT
Quiescent: 0.7dex < SF-MS

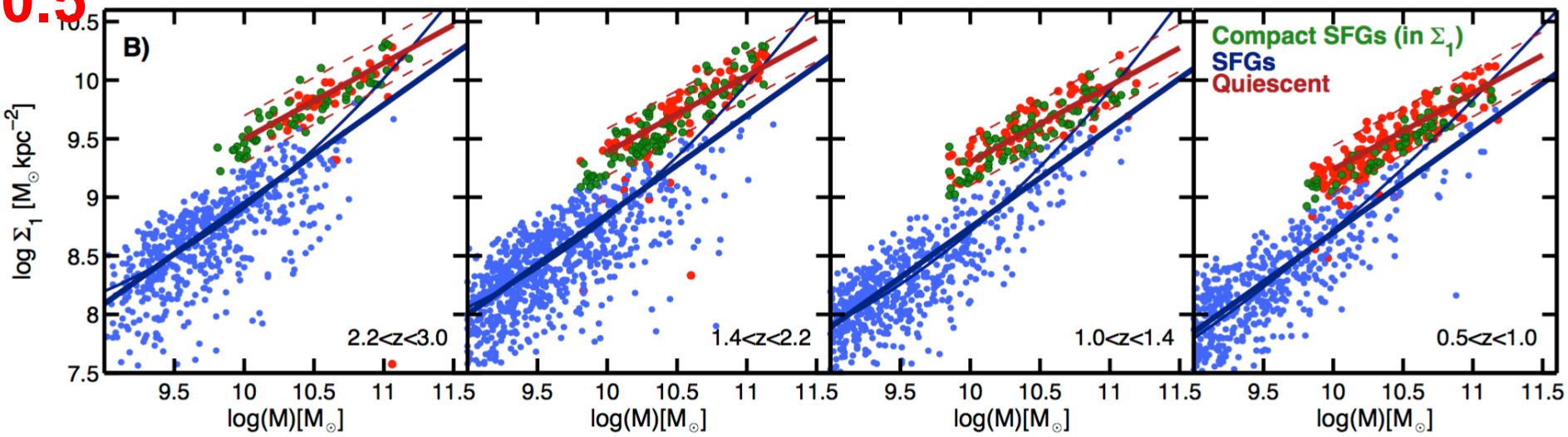
and intermediate redshifts.

Note only slight drops of mean Σ_{1kpc} vs Mass with time (dispersion ~ constant).

Can measure deviations from the RED LINE as $\Delta\Sigma_{1kpc}$

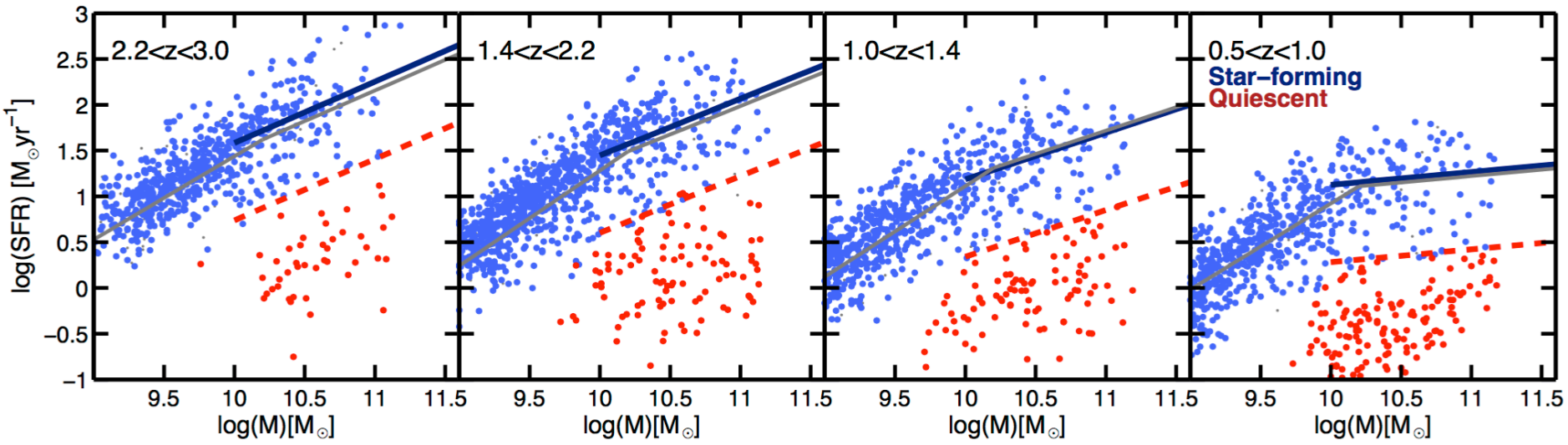
Guillermo Barro+15

z = 3.0 --- 2.2 2.2 --- 1.4 1.4 --- 1.0 1.0 --- 0.5



And the DARK LINE defining the SFR vs M* relation as △SFR.

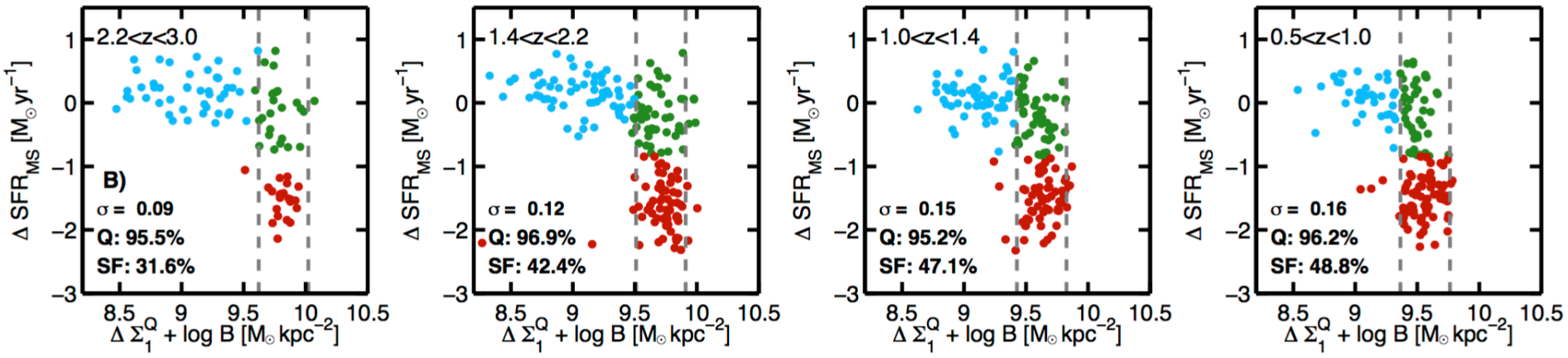
Guillermo Barro+15



ΔSFR and $\Delta\Sigma_{1kpc}$ can be used to make new plots. VOILA! We see nearly identical knee-shaped paths at all redshifts.

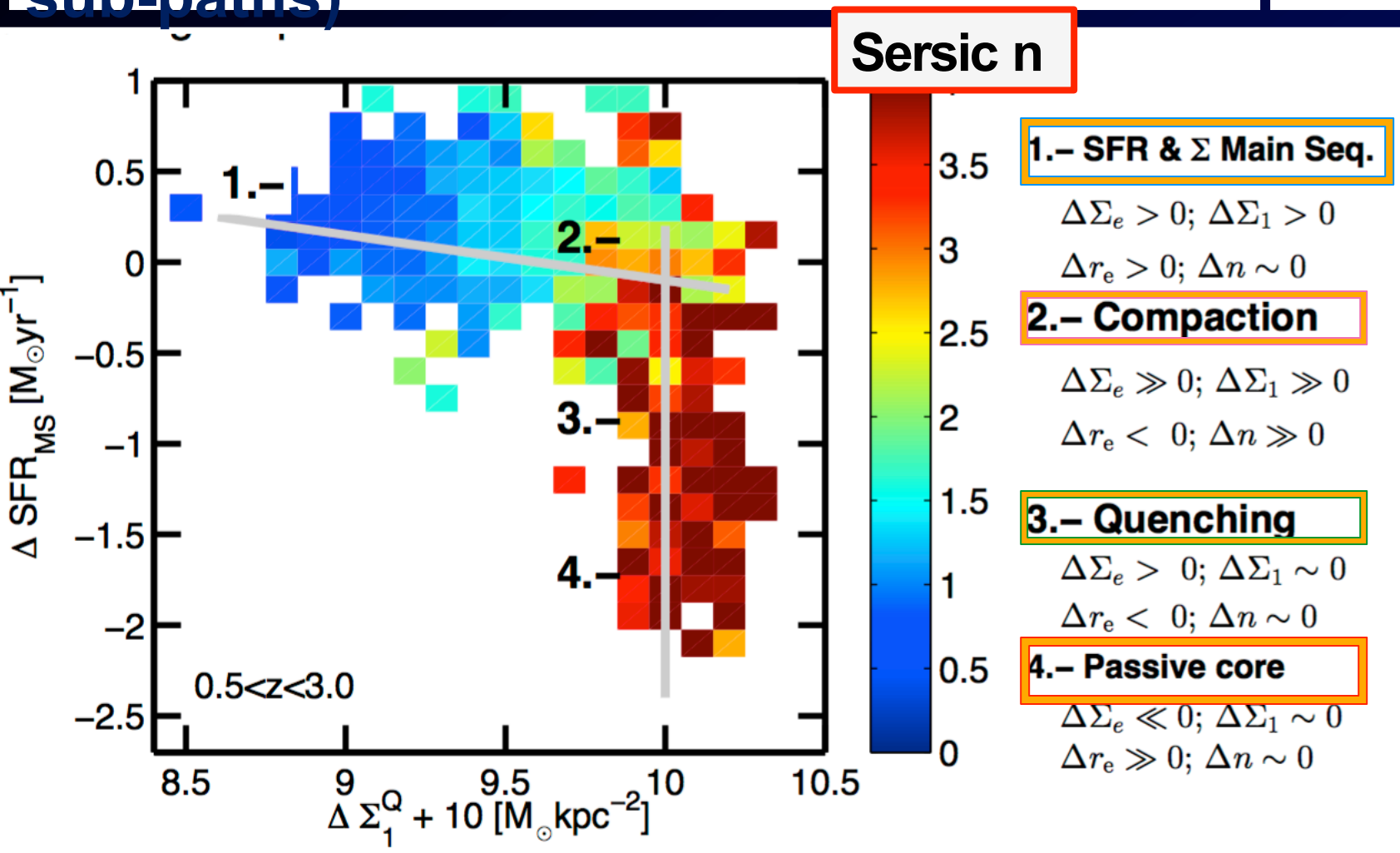
Guillermo Barro+15

Compact SFGs (in Σ_1)
SFGs
Quiescent



Mushed together, we discover our knee-shaped Universal Path that is the Bridge between Star Forming (SF) Blue to Quiescent Red galaxies (Note 4 main sub-paths)

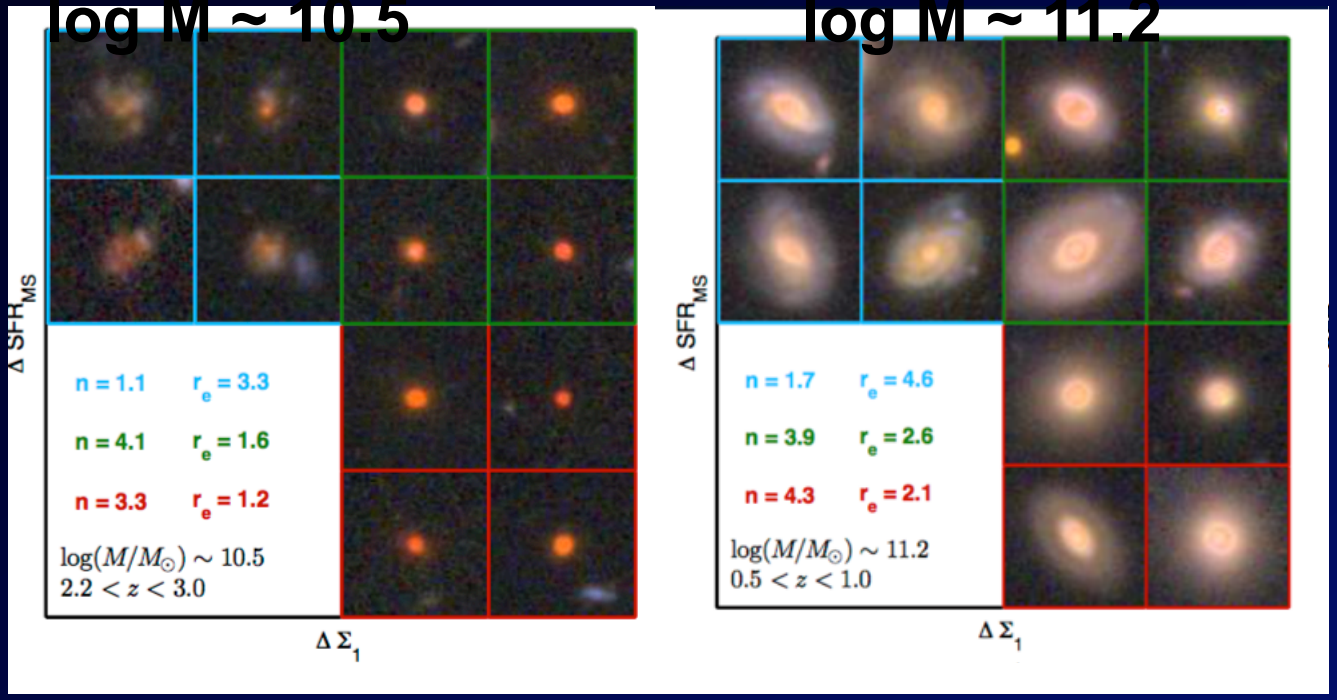
Barro+15



While the path is universal, in general, smaller galaxies sprint across quickly at high redshifts; larger galaxies stroll across leisurely at low redshifts.

Guillermo Barro+15

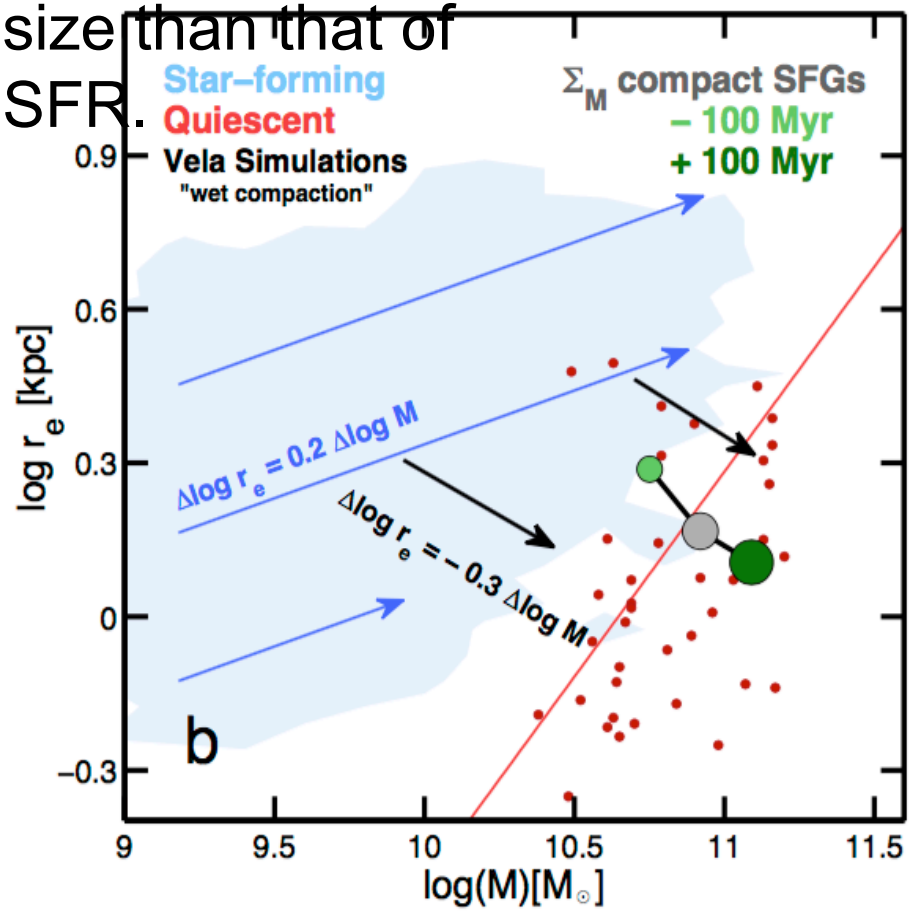
High z ~ 2.2 to 3.0 **Low z ~ 0.5 to 1.0**

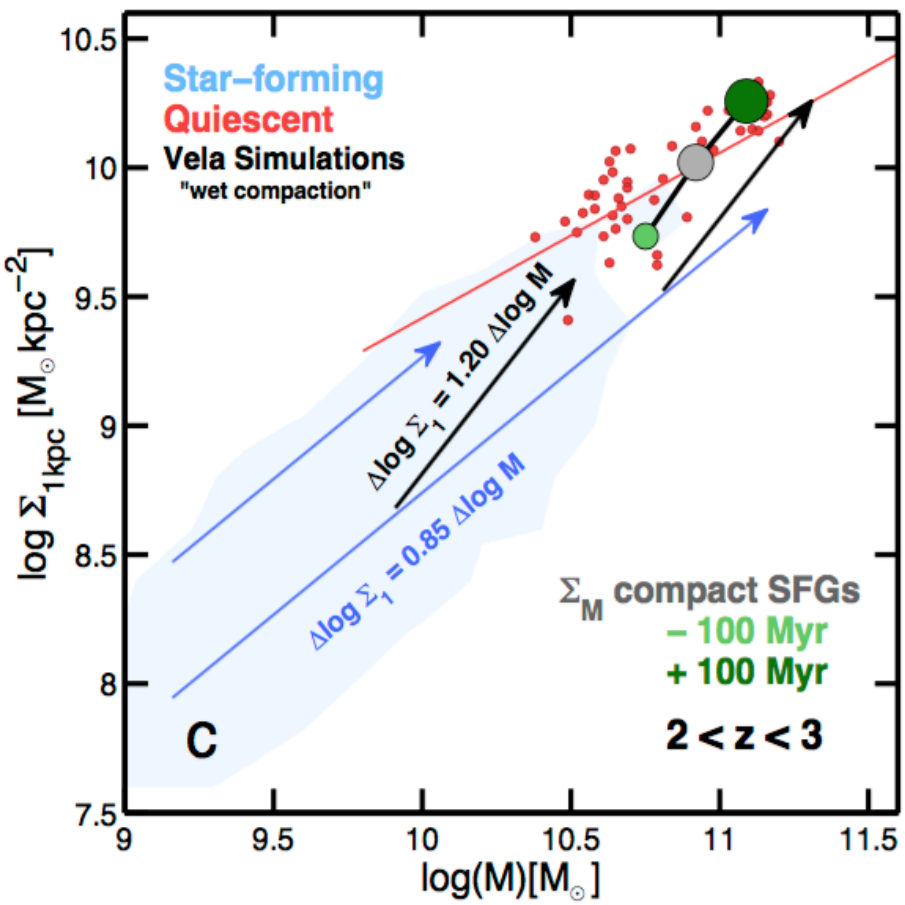


ALMA dust maps of 6 $Z \sim 2.5$ massive, dusty, compact galx. HST stellar masses are 40% larger in size than that of SFR.

ALMA Shows High Central SFR: Supports Compaction Simulations

Barro+16





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Comment & Implication

1) Our Σ_{1kpc} results are quite robust: directly supported by recent high-z studies of Whitaker +16 and with local studies originally by Wake +12 & now Teeimoorinia+16 using central velocity dispersions or that of Bluck+14 for masses of BH (derived from velocity dispersions).
2) Quenching is likely a two part process involving both central "quenching" mechanisms of cold gas removal (AGN, starburst feedback, bulge stabilization of gas) and by outer halo/environment gas heating or removal.

PLENTY of ISSUES LEFT!

W.M. Keck Observatory

Role of AGN and Star Formation Feedback

Role of Morphological Quenching (Martig+09)

Role of Rejuvenation of Quiescent Galaxies and minor

Behavior of Smaller Mass and Satellite Galaxies & additional quenching mechanisms (ram pressure stripping, harassment, tidal stripping, strangulation)

Role of Environment