Connecting Black Hole Growth, Central Density and Galaxy Quenching

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with

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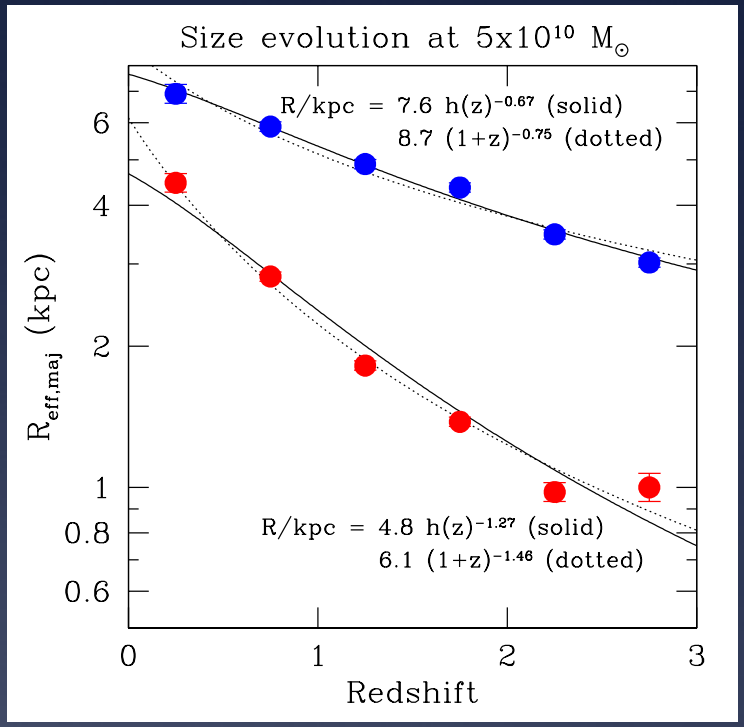
Rachel Somerville and the CANDELS Collaboration

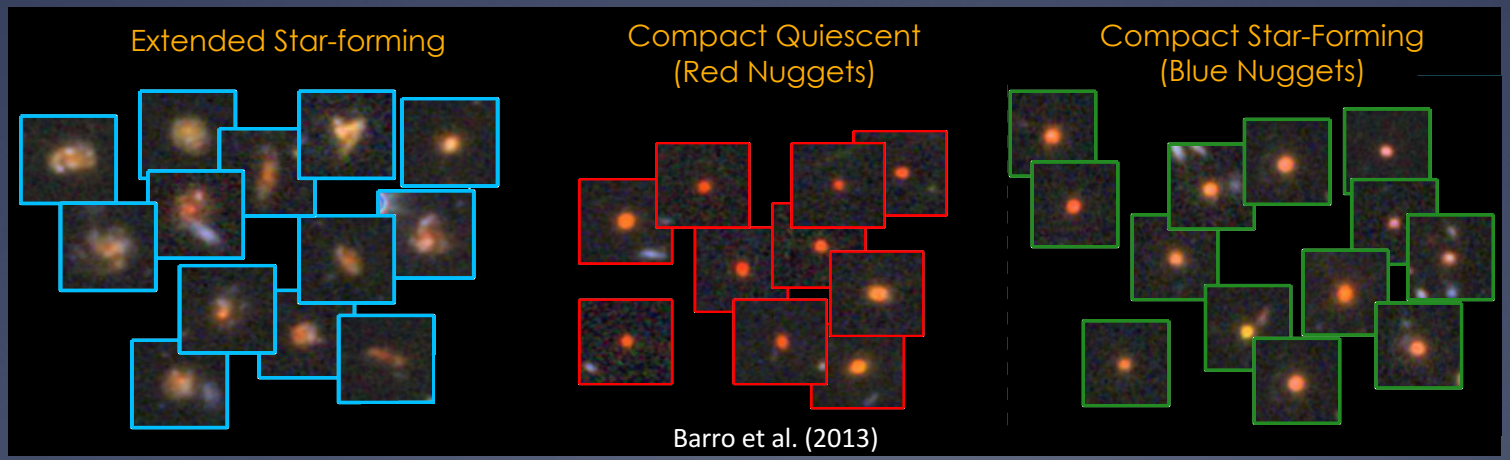
Are AGN Special? – Aug 2018

Compact Quiescent Galaxies

* Quenched galaxies at z~2 are substantially more compact than present day counterparts.
* Quenching pathway: galaxies need to shrink in size and reduce their star formation activity.
* Population of compact star forming progenitors (Blue Nuggets) identified in the CANDELS fields.

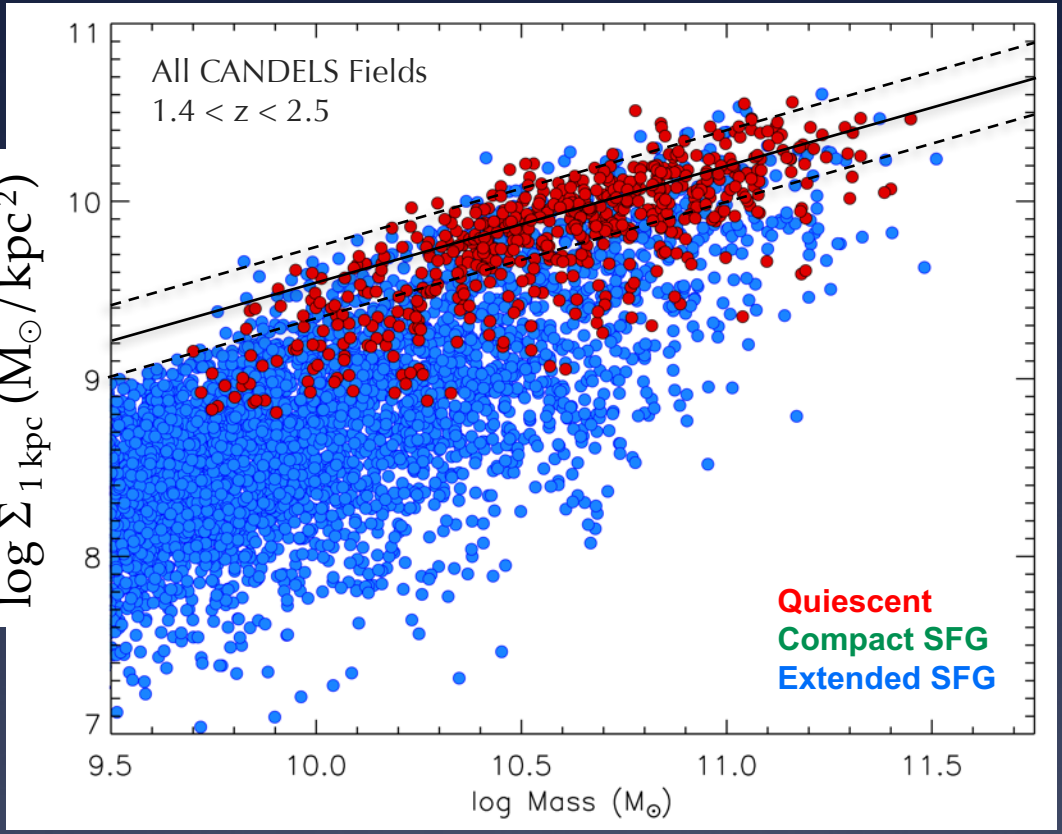


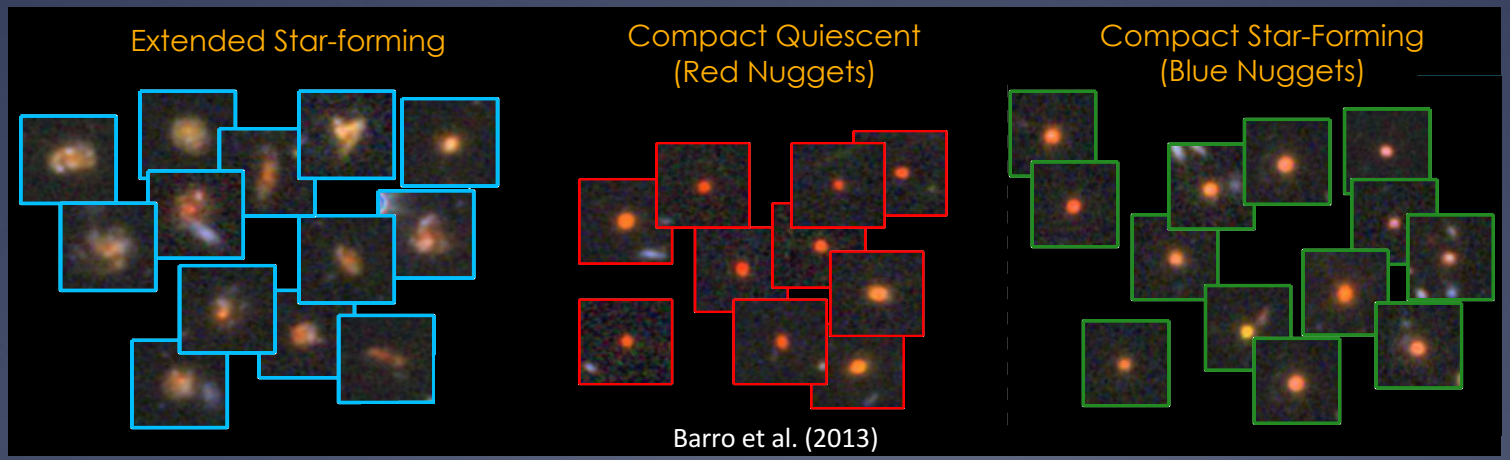
van der Wel et al. (2013)



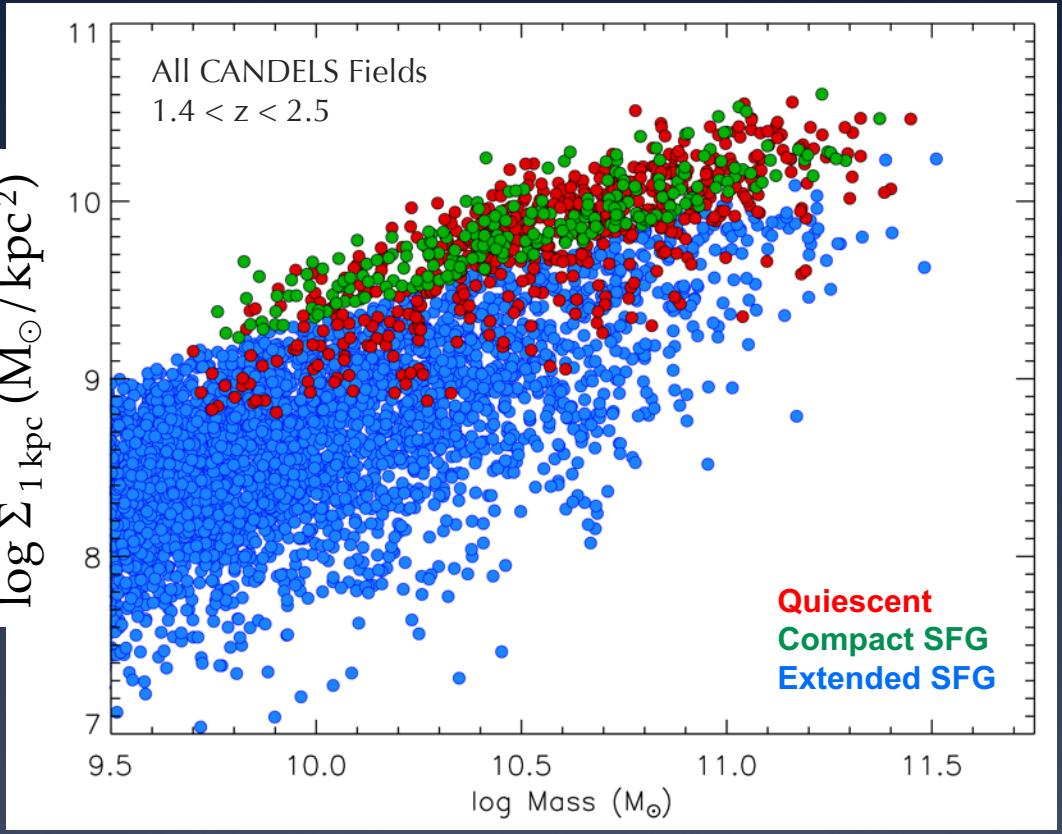
Barro et al. (2013)

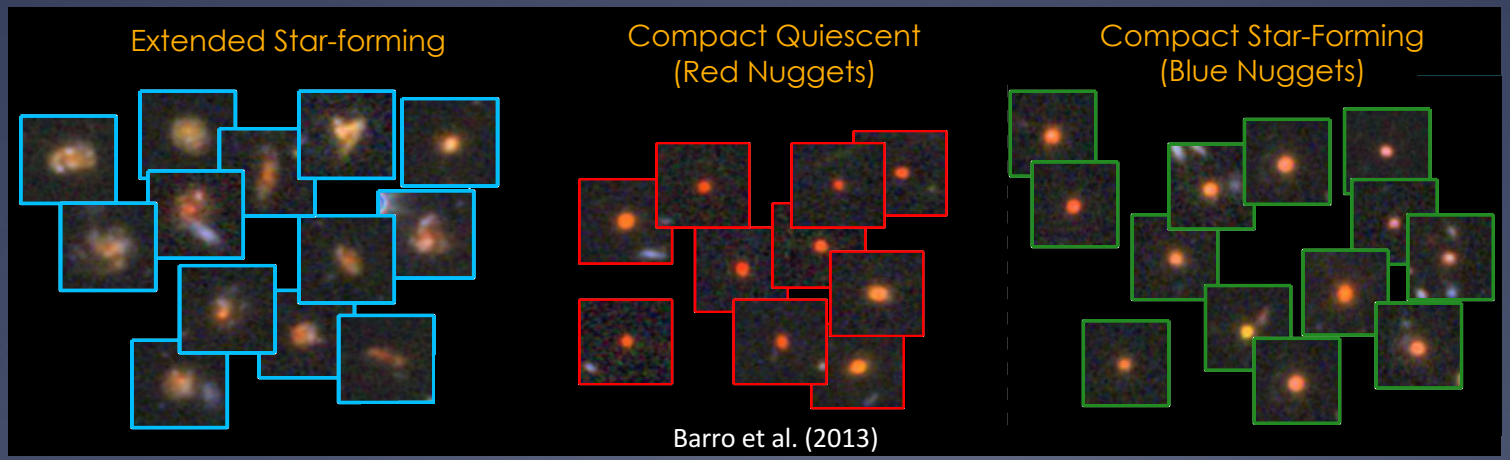
Finding Progenitors of Compact Quiescent Galaxies





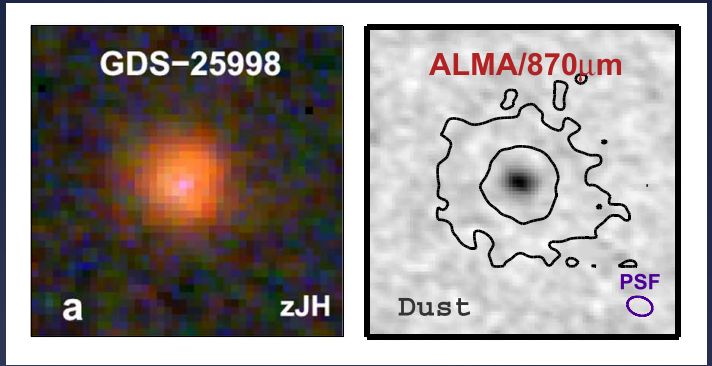
Finding Progenitors of Compact Quiescent Galaxies



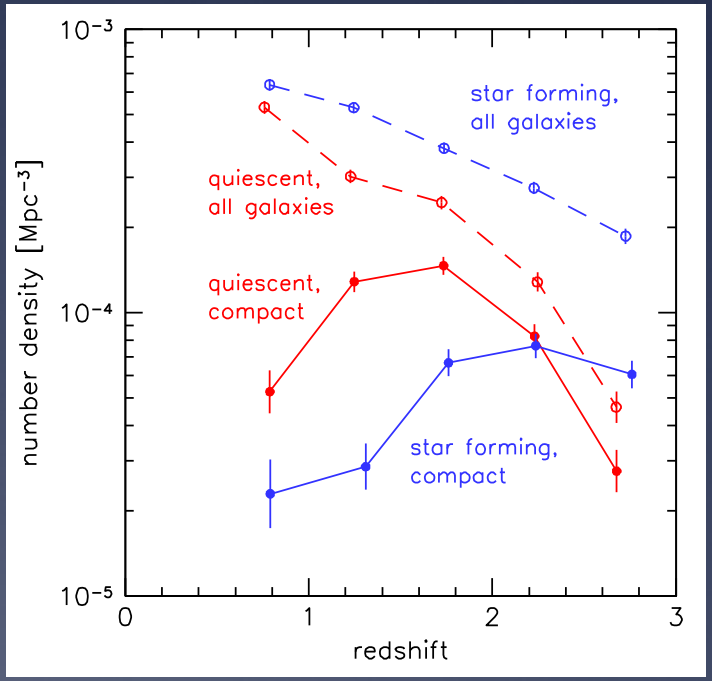


"Blue Nuggets" as a Transition Population

* Blue Nuggets: short lived phase of intense star formation (~1000 $M_\odot$/yr)
* Quenching timescale of ~500 Myr based on:
  * Short gas depletion timescales.
  * Number density evolution.
* Compact, star-forming galaxies are *direct* progenitors of red nuggets.
* Roughly 30% of stellar mass of red nuggets formed during this phase.

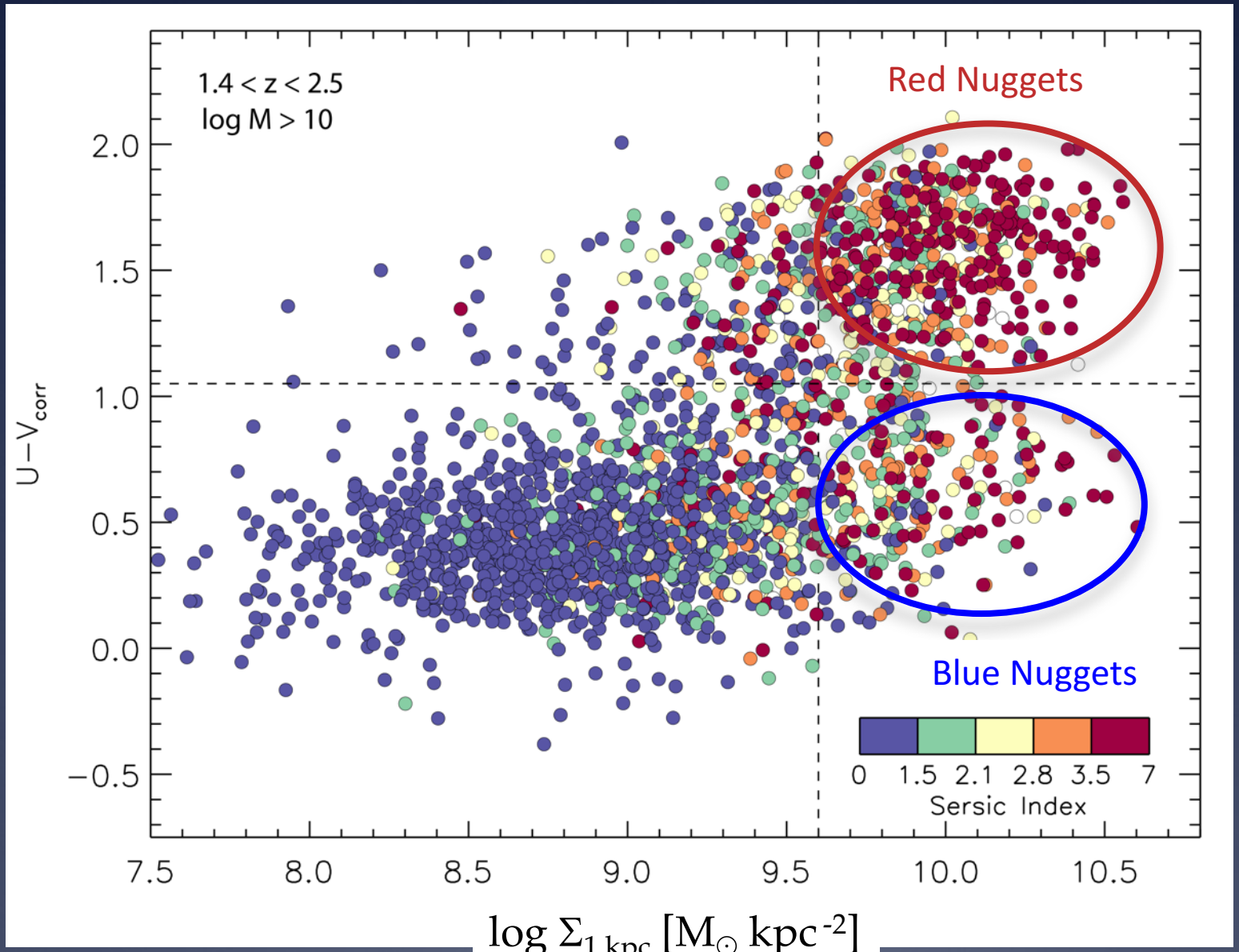


Barro et al. (2016)



van Dokkum et al. (2015)

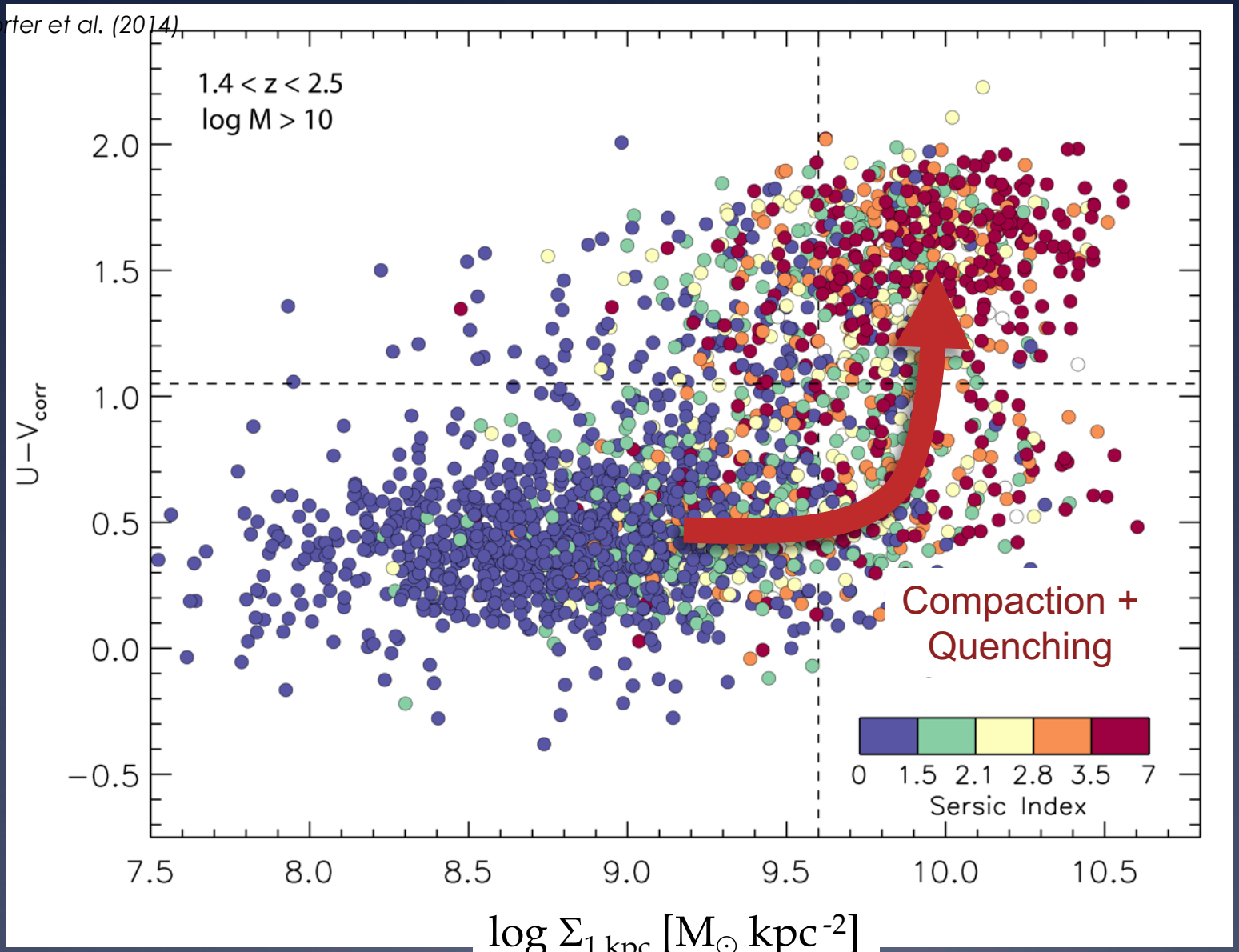
Blue Nuggets: Compact, Star-forming Galaxies



Kocevski et al. (2017)

Compaction and Quenching

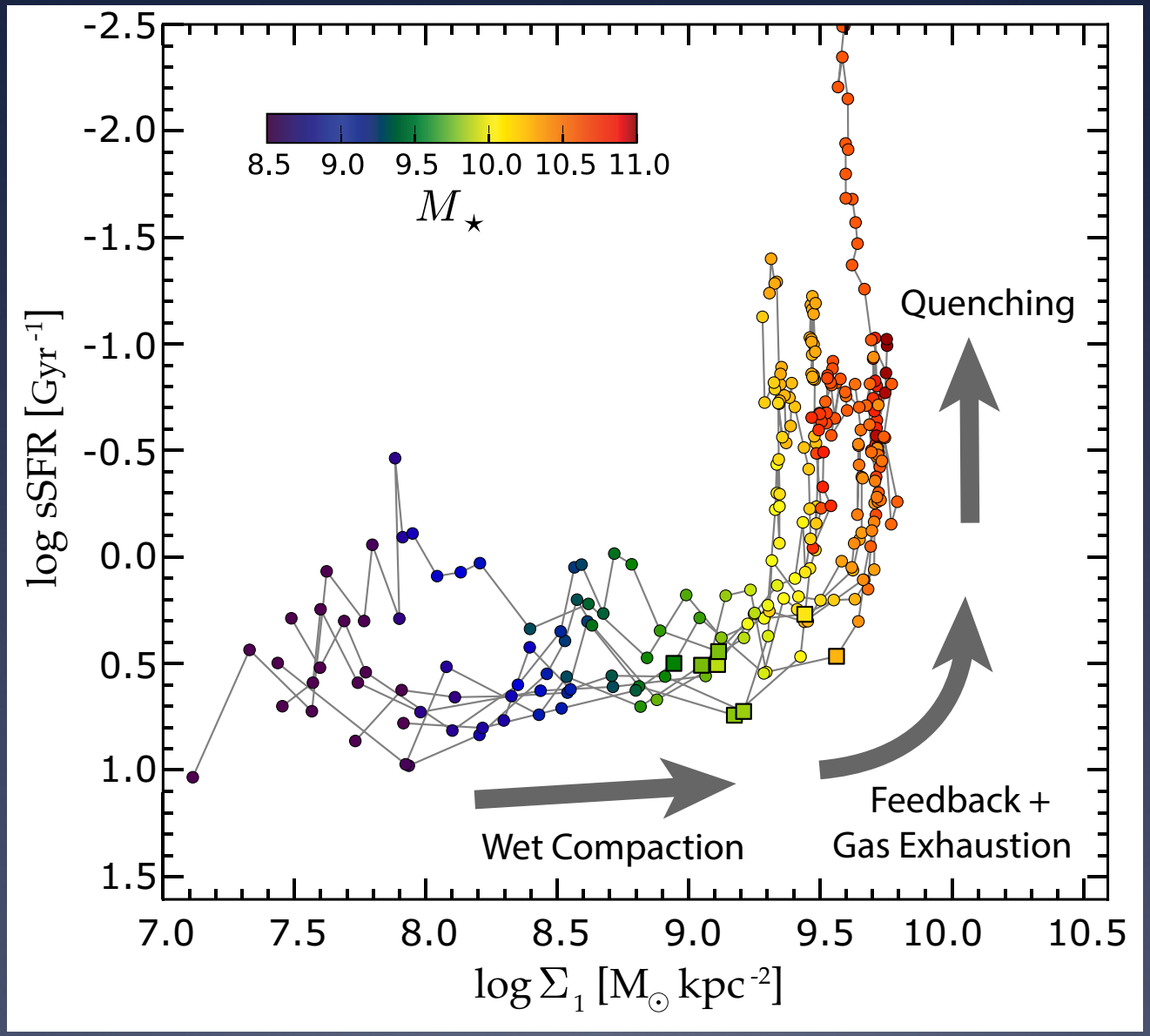
Porter et al. (2014)



Kocevski et al. (2017)

Compaction and Quenching

VELA Sims:
Zolotov+15,
Tacchella+16,
Dekel+17

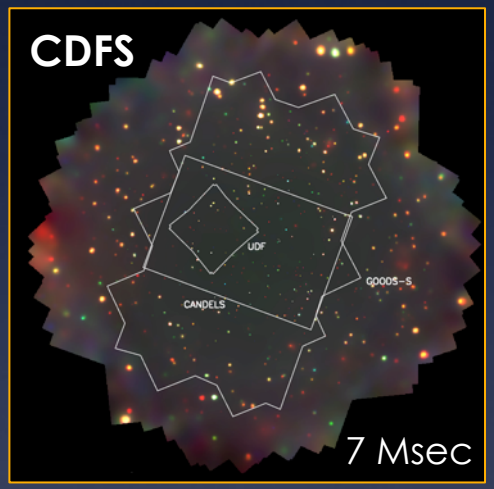


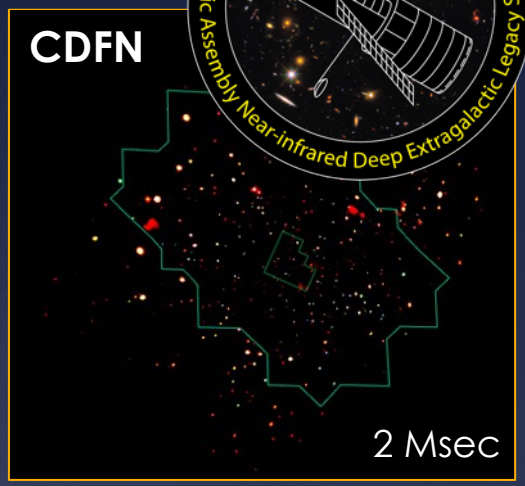
Red

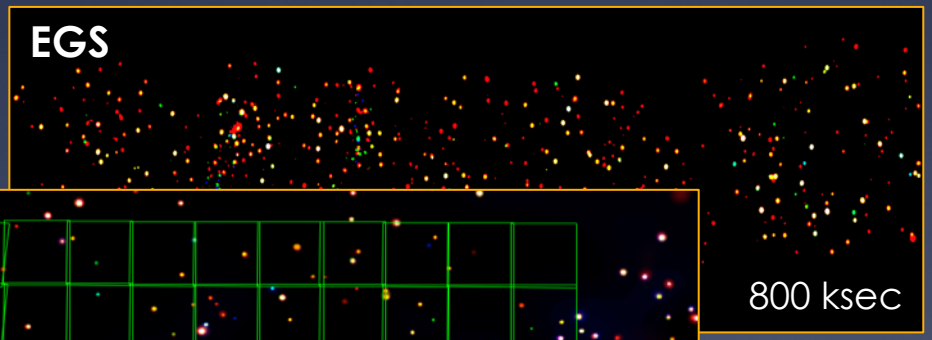
Blue

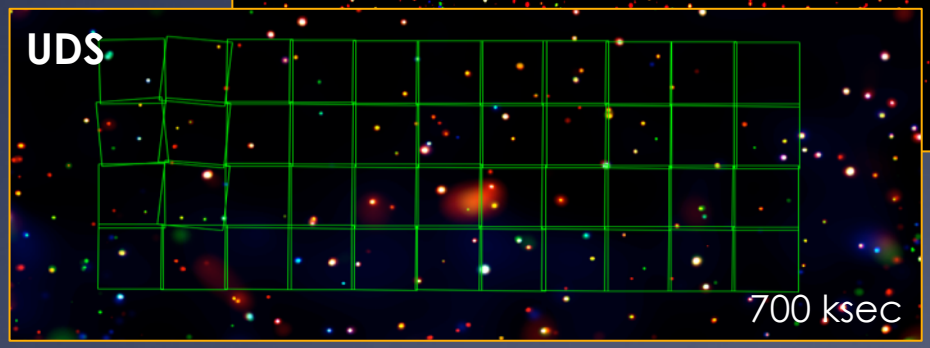
Kocevski et al. (2017)

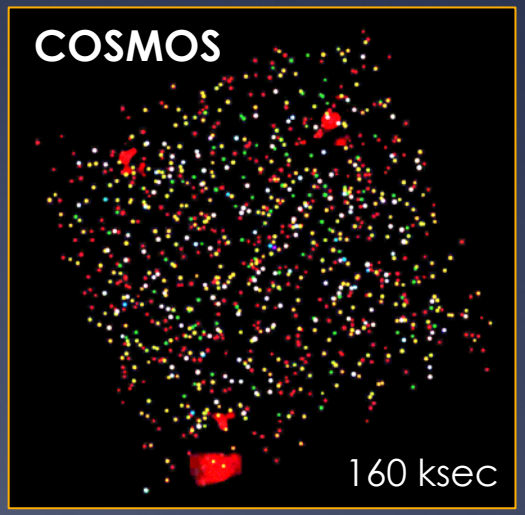
Identifying AGN in the CANDELS Fields





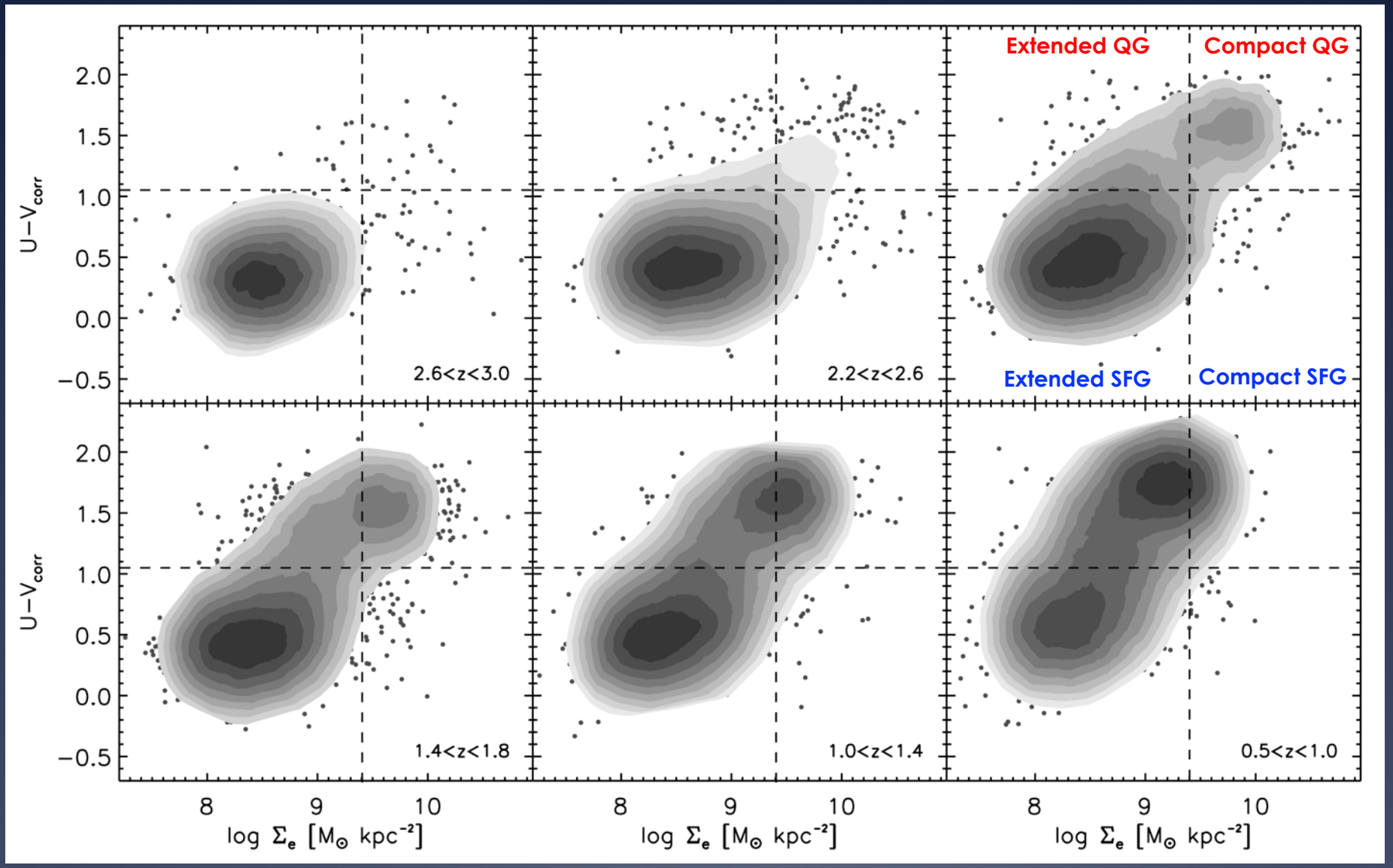






* Deep X-ray observations used to identify AGN in all five CANDELS fields – including newly available data in the UDS (Kocevski+2018)

AGN Activity in Blue Nuggets



Kocevski et al. (2017)

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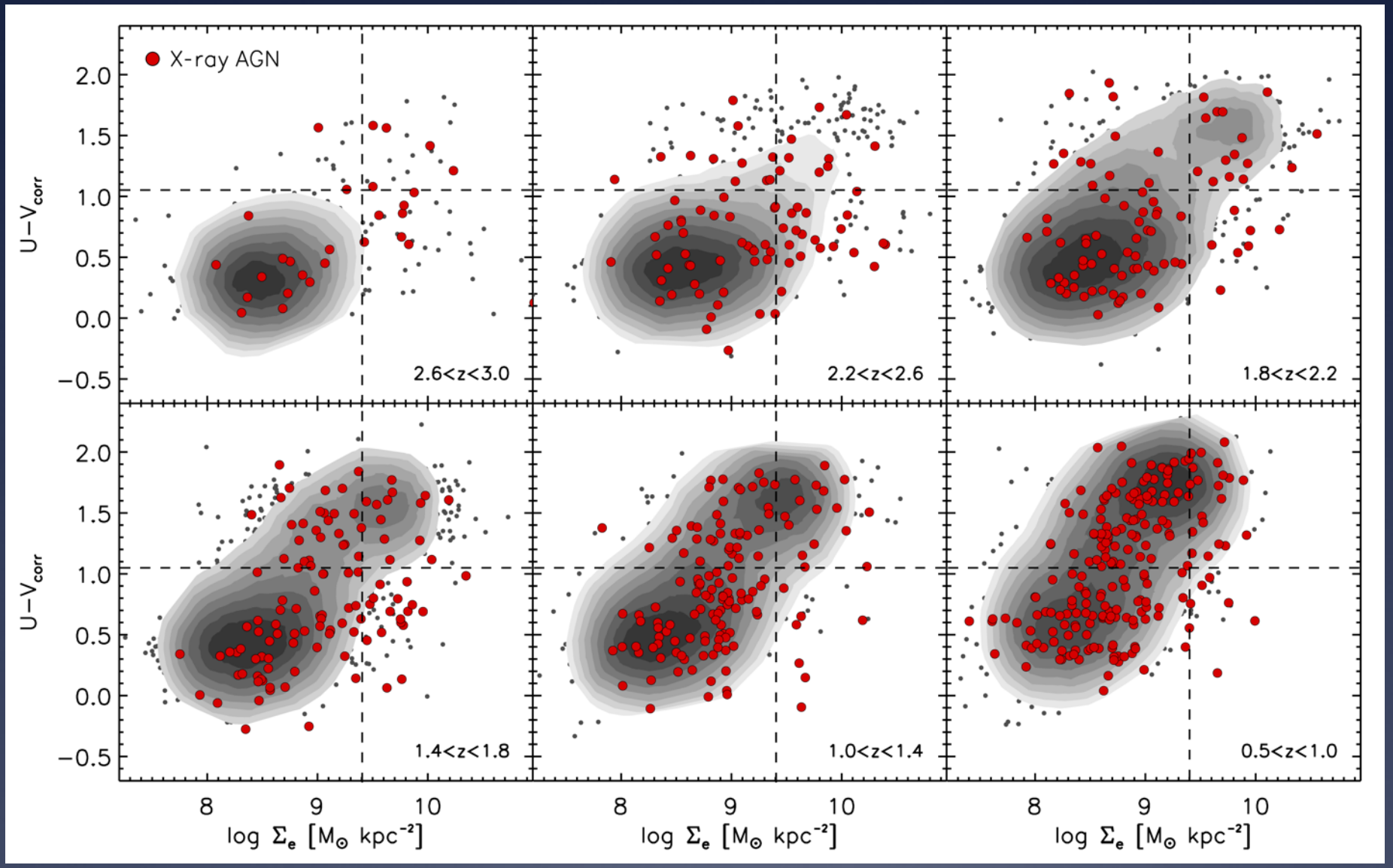
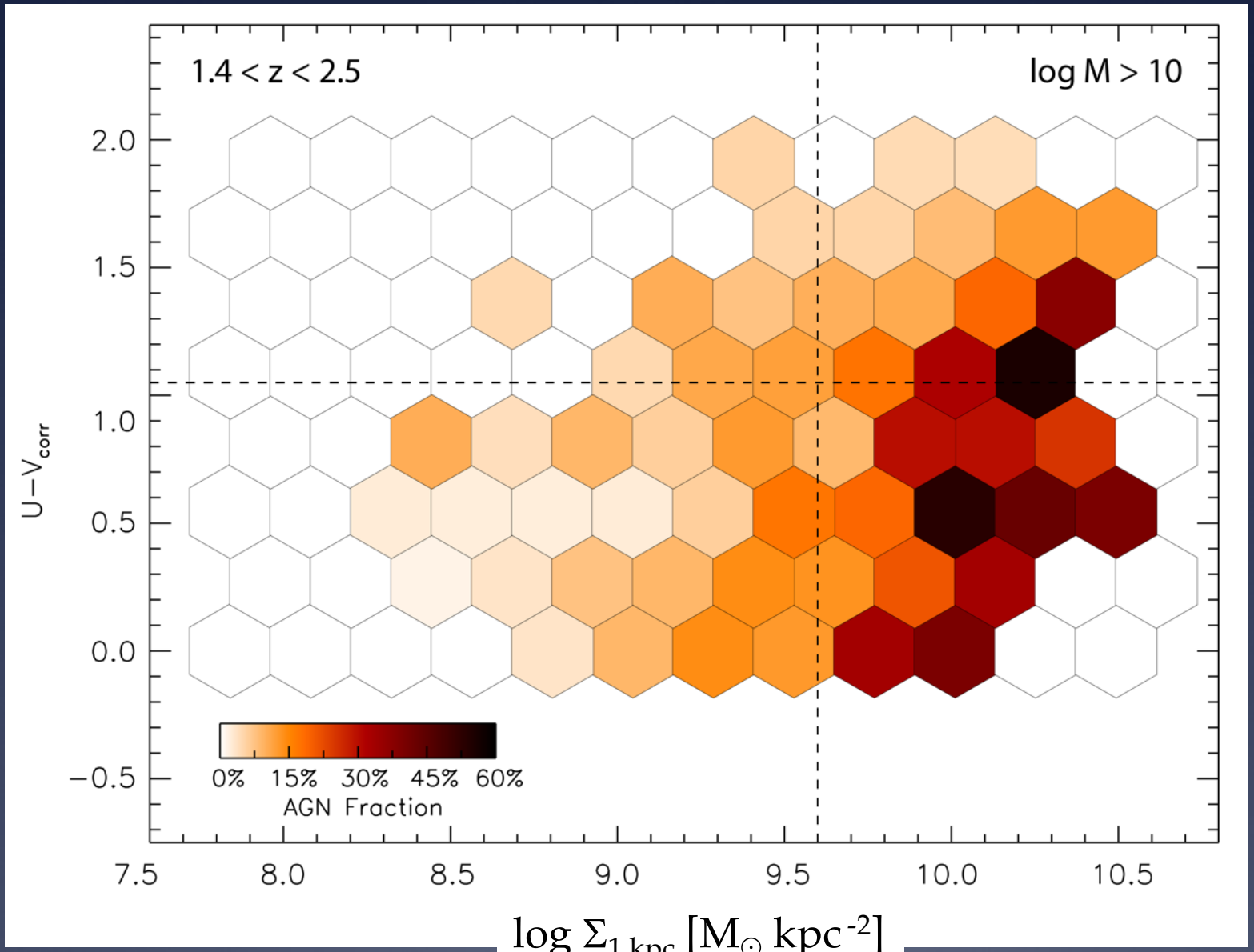


Kocevski et al. (2017)

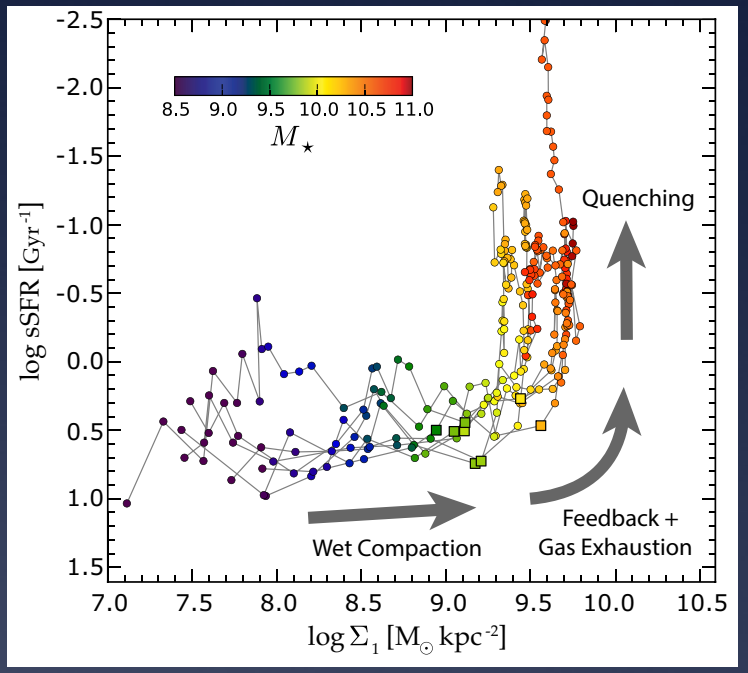
AGN Fraction vs Core Density

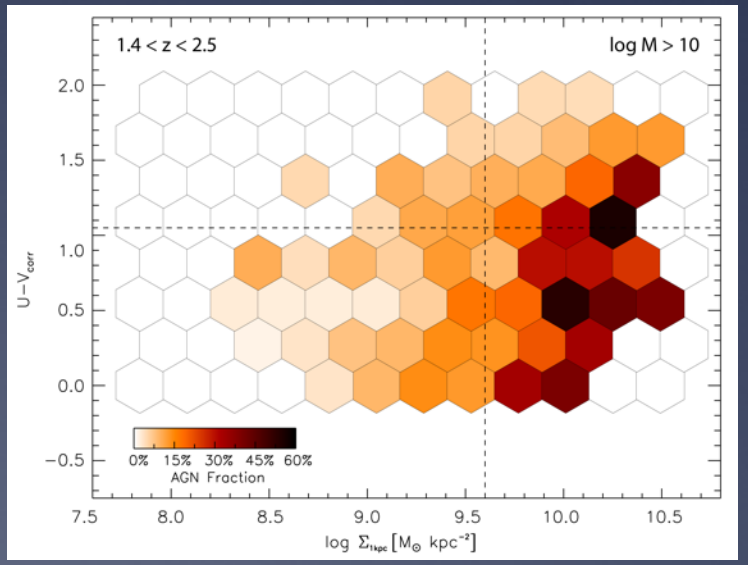


Kocevski et al. (2017)

Results & Implications

- Compaction results an increase in duty cycle/accretion efficiency.
- Volume-limited sample in GDS gives an AGN fraction of 55.9%. Implies AGN duty cycle of 280 Myr.
- Roughly 31% of SMBH mass accreted during blue nugget phase.
  - Matches stellar mass build up, maintaining SMBH-host correlations.
- Hints at possible role of AGN feedback in the quenching process.
- Are AGN Special?





Faber Energy Quota Quenching Model

* Quenching as a competition between cumulative AGN energy output and the thermal energy quota of halo gas.

QUENCHING AS A CONTEST BETWEEN GALAXY HALOS AND THEIR CENTRAL BLACK HOLES

ZHU CHEN[1], S. M. FABER[2], DAVID C. KOO[2], JOEL R. PRIMACK[3], AVISHAI DEKEL[4], RACHEL S. SOMERVILLE[5], ALDO RODRÍGUEZ-PUEBLA[6], YICHENG GUO[7], GUILLERMO BARRO[8], DALE D. KOCEVSKI[9], JEROME J. FANG[10], HENRY C. FERGUSON[11], MARC HUERTAS-COMPANY[12], LIN LIN[13], YIFEI LUO[14], ZHIJIAN LUO[1], VIRAJ PANDYA[2], CHENGGANG SHU[1], HASSEN M. YESUF[2],... OTHER AUTHORS TBD

Chen et al. (2017)

Faber Energy Quota Quenching Model

- Quenching as a competition between cumulative AGN energy output and the thermal energy quota of halo gas.
- Key Model Assumptions:
  - Black Hole mass scales with central density:

$$\Sigma_{(1\mathrm{kpc})} \propto M_{\mathrm{BH}}^{0.57}$$

Fang+2013, Kormendy & Ho 2013

$$E_{\mathrm{BH}} \propto M_{\mathrm{BH}} c^2 \propto \Sigma_{(1\mathrm{kpc})}^{1.76} c^2$$

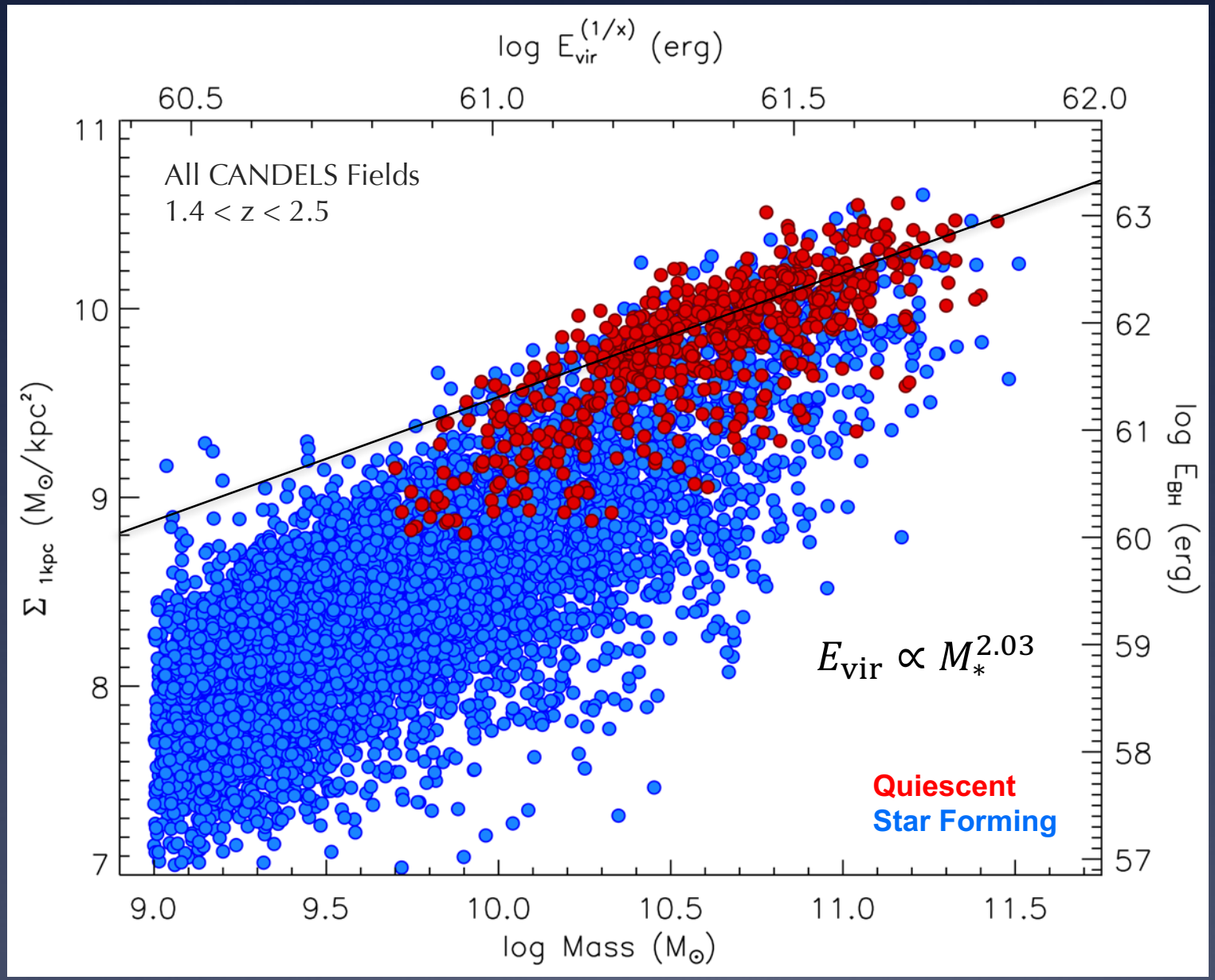
  - Halo mass and energy content tied to observable stellar mass:

$$M_* \propto M_{\mathrm{vir}}^{1.75}$$

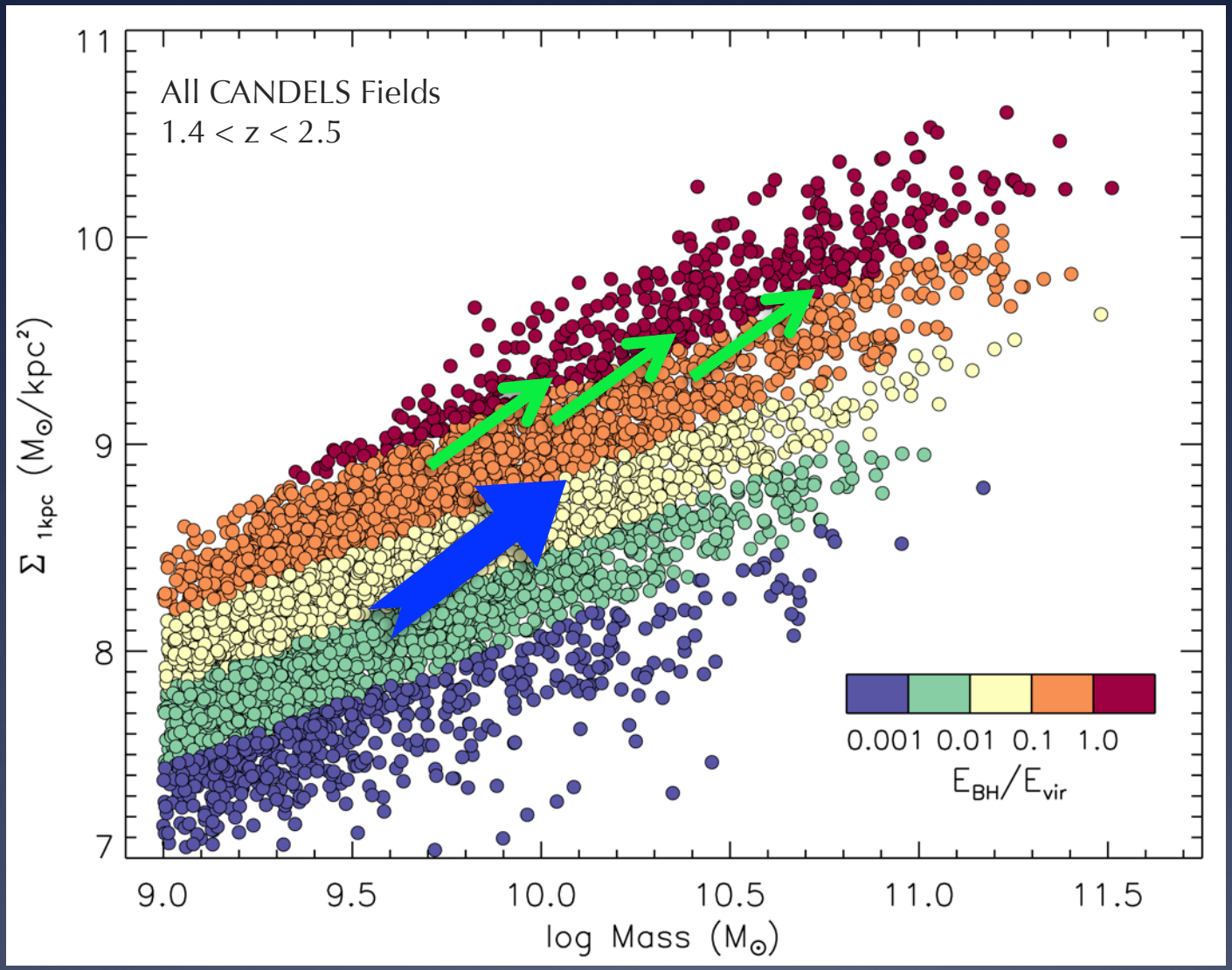
Rodríguez-Puebla+2017

$$E_{\mathrm{vir}} \propto M_{\mathrm{vir}}^{x} \propto M_*^{x/1.75}$$

  - Quenching occurs when $E_{\mathrm{BH}} > E_{\mathrm{vir}}$

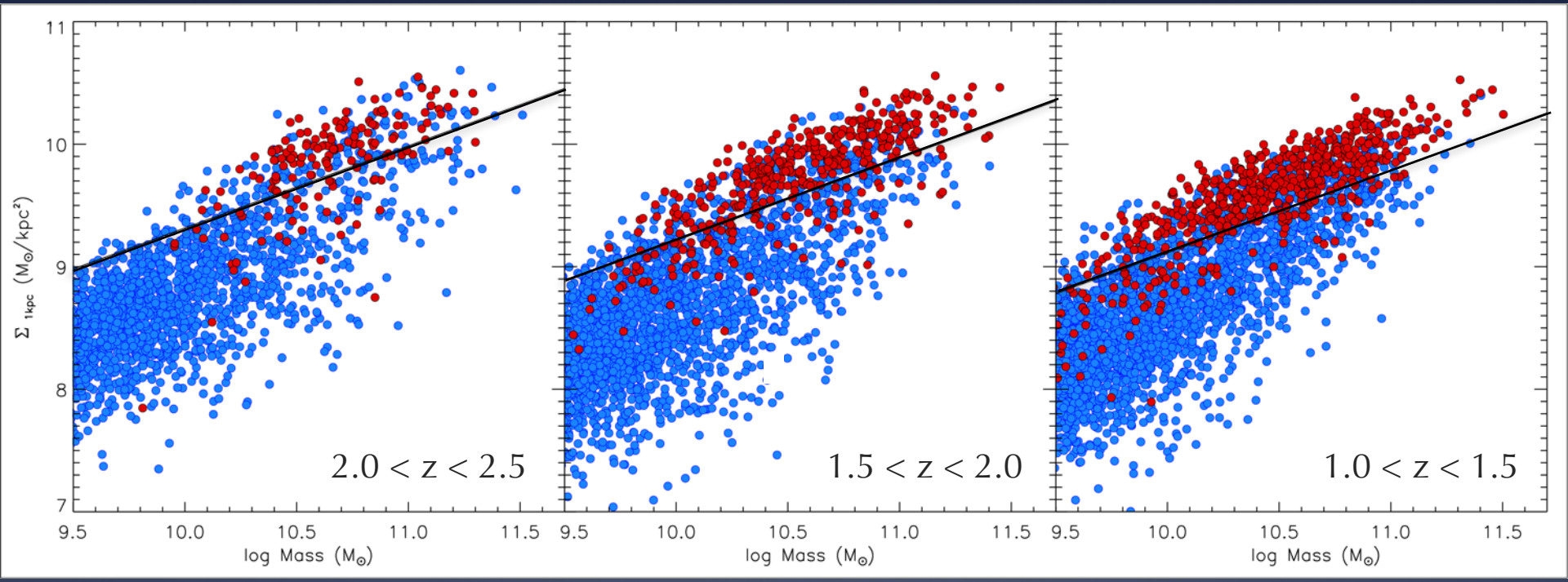

log $E_{vir}^{(1/x)}$ (erg)
60.5
61.0
61.5
62.0
All CANDELS Fields
1.4 < z < 2.5
Σ_{1kpc} ($M_\odot$/kpc^2)
11
10
9
8
7
log E_{BH} (erg)
63
62
61
60
59
58
57
$E_{vir} \propto M_*^{2.03}$
Quiescent
Star Forming
9.0
9.5
10.0
10.5
11.0
11.5
log Mass ($M_\odot$)

Energy Ratio & the Quenching Threshold



Build-up of Quiescent Galaxies Over Time

All CANDELS Fields
$1.4 < z < 3.0$



Summary

- At log M > 10, large fraction (39%) of compact, star forming galaxies host an X-ray luminous AGN at z~2.
- First generation of quenched galaxies emerged directly following a phase of rapid Black Hole growth.
- Halo Energy Quota model: AGN not special, but cumulative feedback plays key role in quenching.
- Halos build galaxies, which build black holes, which quench halos.
- Chen et al (2018, in prep).