Northwestern University

C I E R A

THE POPULATIONS OF STAR FORMING AND QUIESCENT GALAXIES IN LARGE-SCALE COSMOLOGICAL SIMULATIONS

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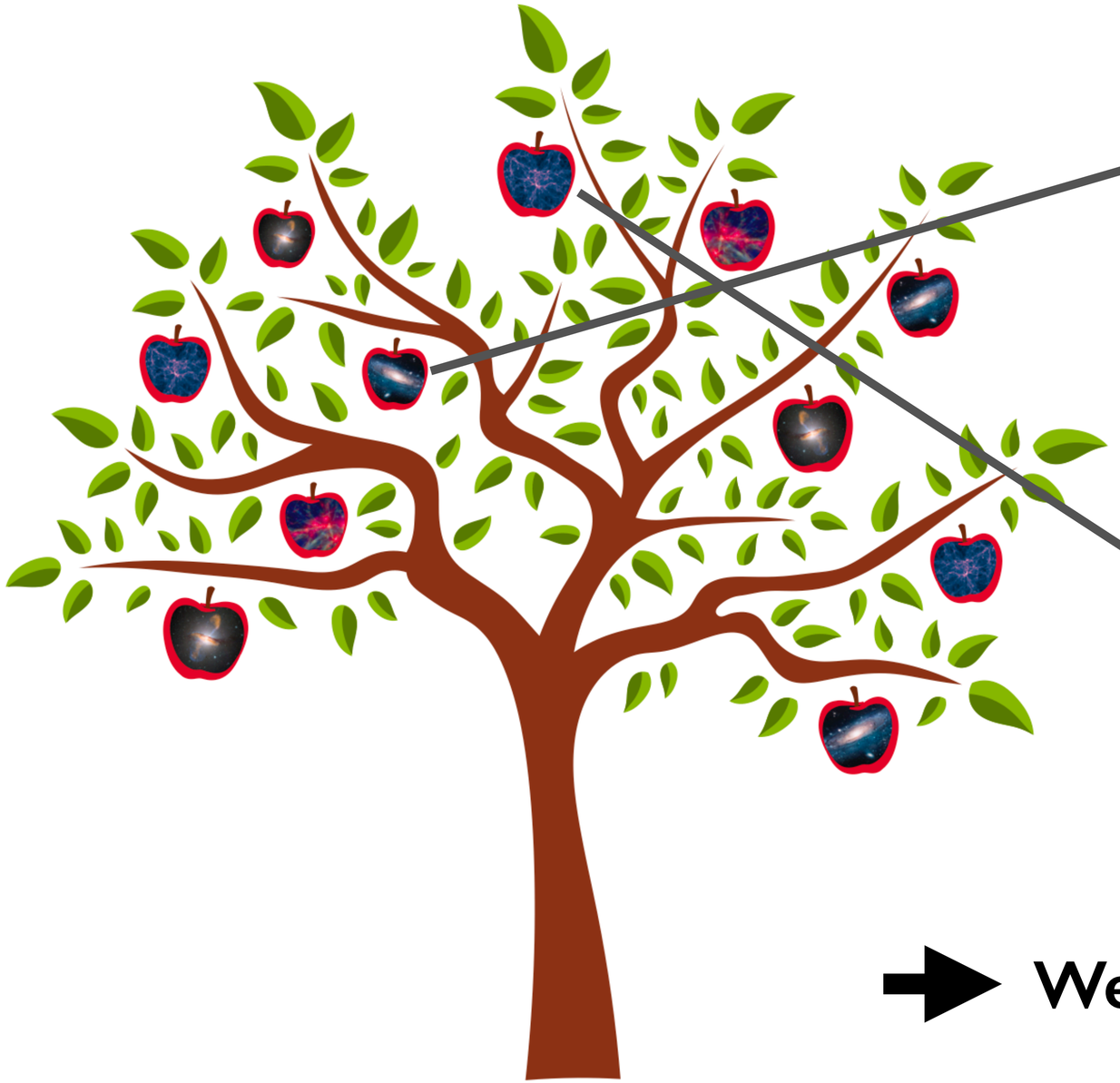
AND THE IQ-COLLABORATORY



Observationally, a dichotomy in galaxy colors, structure, environment, and other properties is observed to correlate with the presence or absence of star formation.

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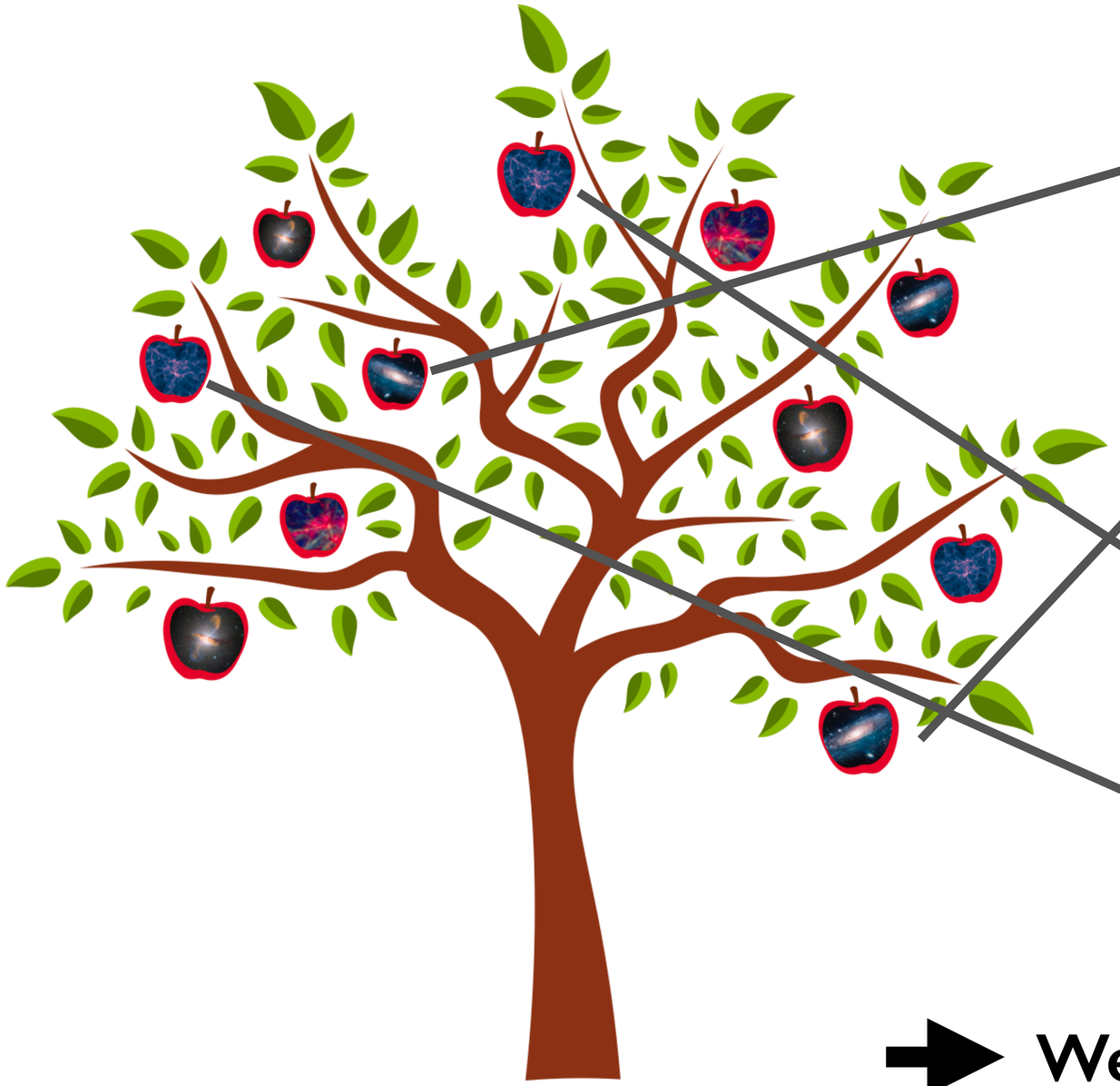
Theoretically, galaxies that decrease or stop star formation can be studied in detail, as well as their environment.

We need apples-to-apples comparisons

THE POPULATIONS OF STAR FORMING AND QUENCHED GALAXIES



Observationally, a dichotomy in galaxy colors, structure, environment, and other properties is observed to correlate with the presence or absence of star formation.

But there are many different observational tracers used, at high/low mass galaxies, green valley/"really" quiescent populations, high/low redshift

?

Theoretically, galaxies that decrease or stop star formation can be studied in detail, as well as their environment.

Different simulations with different underlying models, can produce "different" quiescent populations and quenching pathways.

?

We need apples-to-apples comparisons

Logo credits: Claire Dickey

the Isolated and Quiescent galaxies (IQ) - Collaboratory*

Simulators (sort-of): ***Tjitske Starkenburg (PI; Northwestern)****, Shy Genel (CCA) , Chris Hayward (CCA), Rachel Somerville (CCA), Ariyeh Maller (CUNY),* ***Ena Choi (KIAS),*** *Romeel Davé (ROE), Alyson Brooks (Rutgers), Mika Rafieferantsoa (UWC), Andrew Emerick (Carnegie), Daniel Angles-Alcazar (CCA/UConn), Greg Bryan (Columbia), Stephanie Tonnesen (CCA), Anna Wright (Rutgers)*

Observers (sort-of): ***Chang Hoon Hahn (Princeton),*** *Jeremy Tinker (NYU), John Moustakas (Sienna), Viraj Pandya (UCSC),* ***Claire Dickey (Yale),*** *Marla Geha (Yale), Kartheik Iyer (Dunlap), Nityasri Mandyam (NYU), Mary Putman (Columbia)*

iqcollaboratory.github.io

*Yes, it is a real word

Logo credits: Claire Dickey

the Isolated and Quiescent galaxies (IQ) - Collaboratory*

Observations: *SDSS volume limited sample (Tinker+2011), SDSS isolated dwarf galaxy sample (Geha+2012, Dickey+ in prep.), CANDELS (Iyer+2018,2019)*

Simulations: *Illustris (Vogelsberger+2014; Genel+2014), EAGLE (Schaye+2015; Crain+2015), MUFASA (Dave+2016), Santa Cruz semi-analytical model (Somerville+2015) , TNG100 (Pillepich+2018; Weinberger+2018), SIMBA (Dave+2019)*

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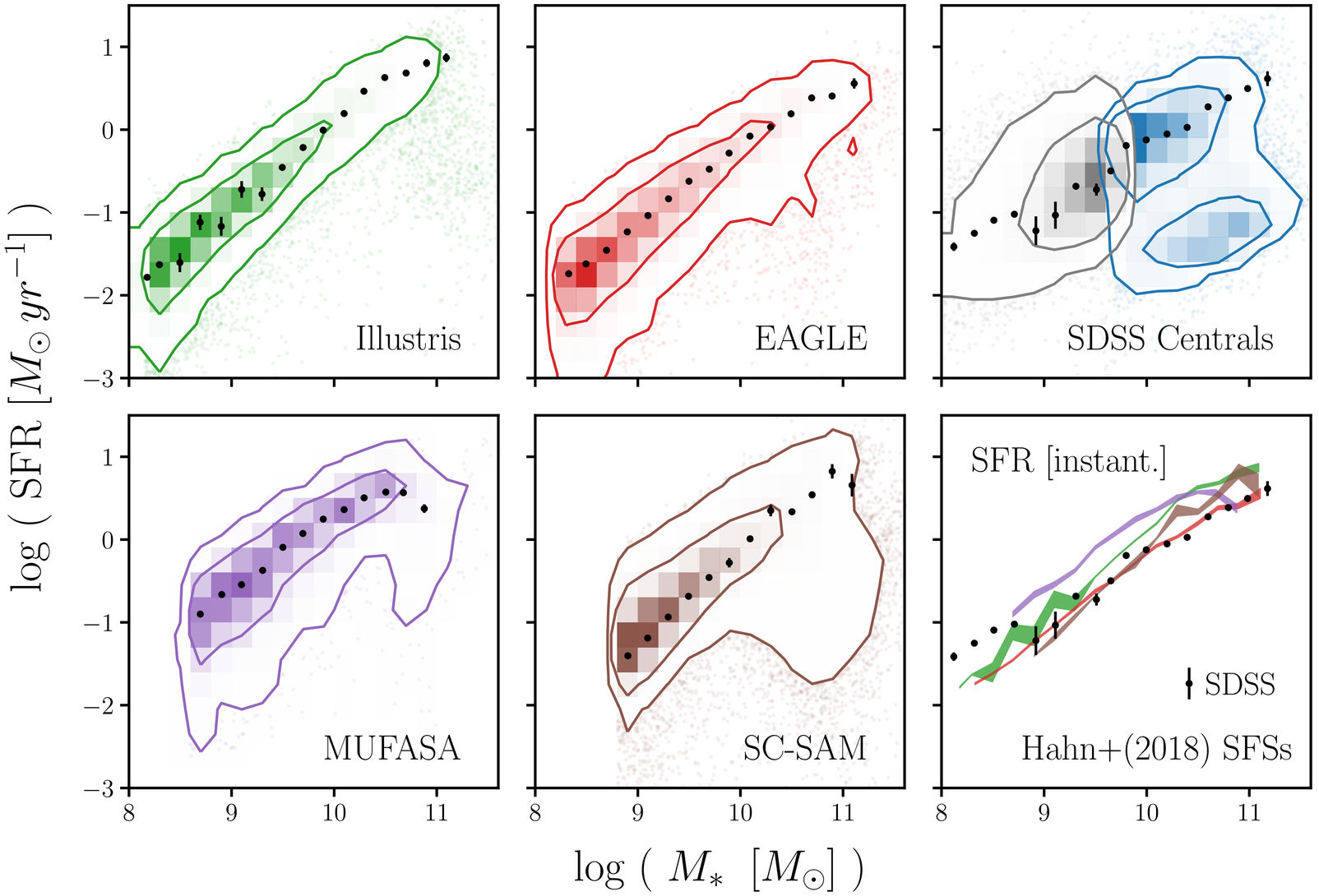
A LOOK AT DIFFERENT SIMULATIONS: THE STAR FORMATION SEQUENCE



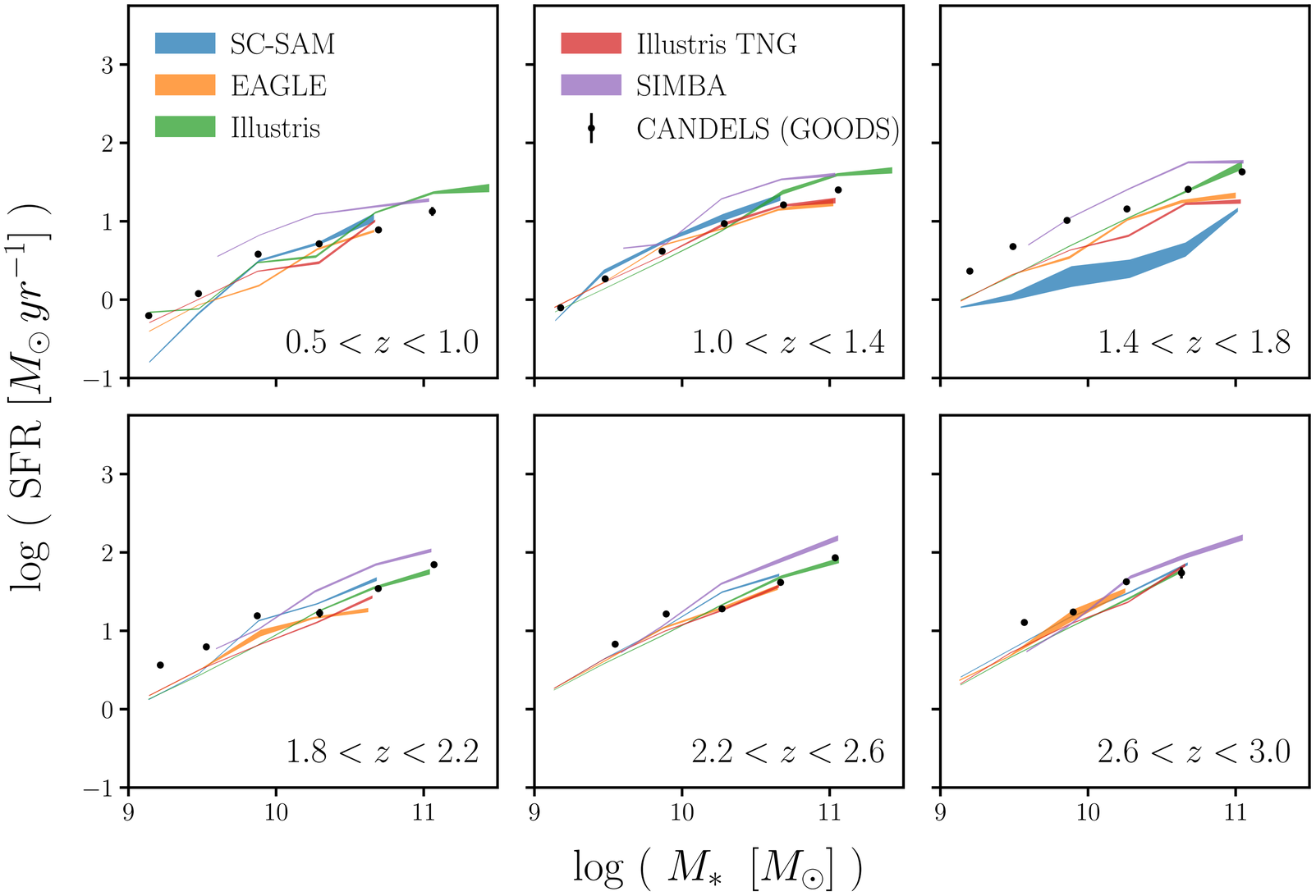
Very similar slope across all simulations, but also a factor of 5 (0.7 dex) discrepancy over the whole stellar mass range

this seems in some tension with earlier results (Genel+2014, Somerville & Dave 2014, Furlong+2015, Sparre+2015, Schaye+2015, Dave+2016, Bluck+2016, ...)

Most of the discrepancy is purely due to using one and the same definition across all simulations.

Hahn, TKS & the IQ-collaboratory 2019

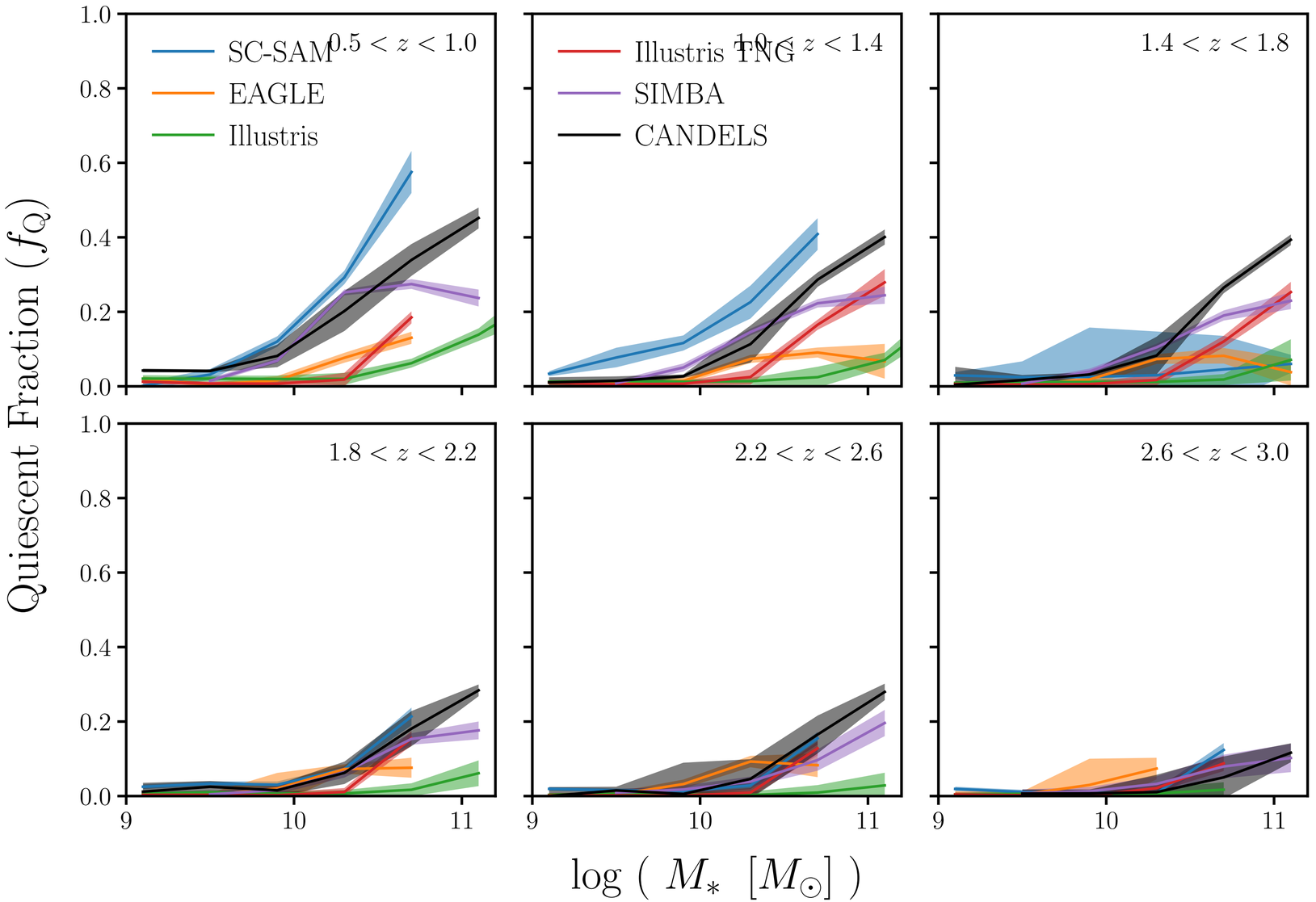
A LOOK AT DIFFERENT SIMULATIONS: THE HIGH-Z STAR FORMATION SEQUENCE



Very good agreement between simulations in particular at higher redshift, with overall good agreement with CANDELS data (Iyer+2018,2019)

Choi, TKS & the IQ-collaboratory in prep.

A LOOK AT DIFFERENT SIMULATIONS: THE HIGH-Z STAR FORMATION SEQUENCE



Very good agreement between simulations in particular at higher redshift, with overall good agreement with CANDELS data (Iyer+2018,2019)

Quiescent fractions based on distance from the star-forming sequence are quite different, and show different trends with stellar mass and with redshift

Choi, TKS & the IQ-collaboratory in prep.

comparing the **simulations** to **observation**
without forward modeling the measurements
is ***not*** an apples-to-apples comparison

M_*, SFR, *etc*
from simulations

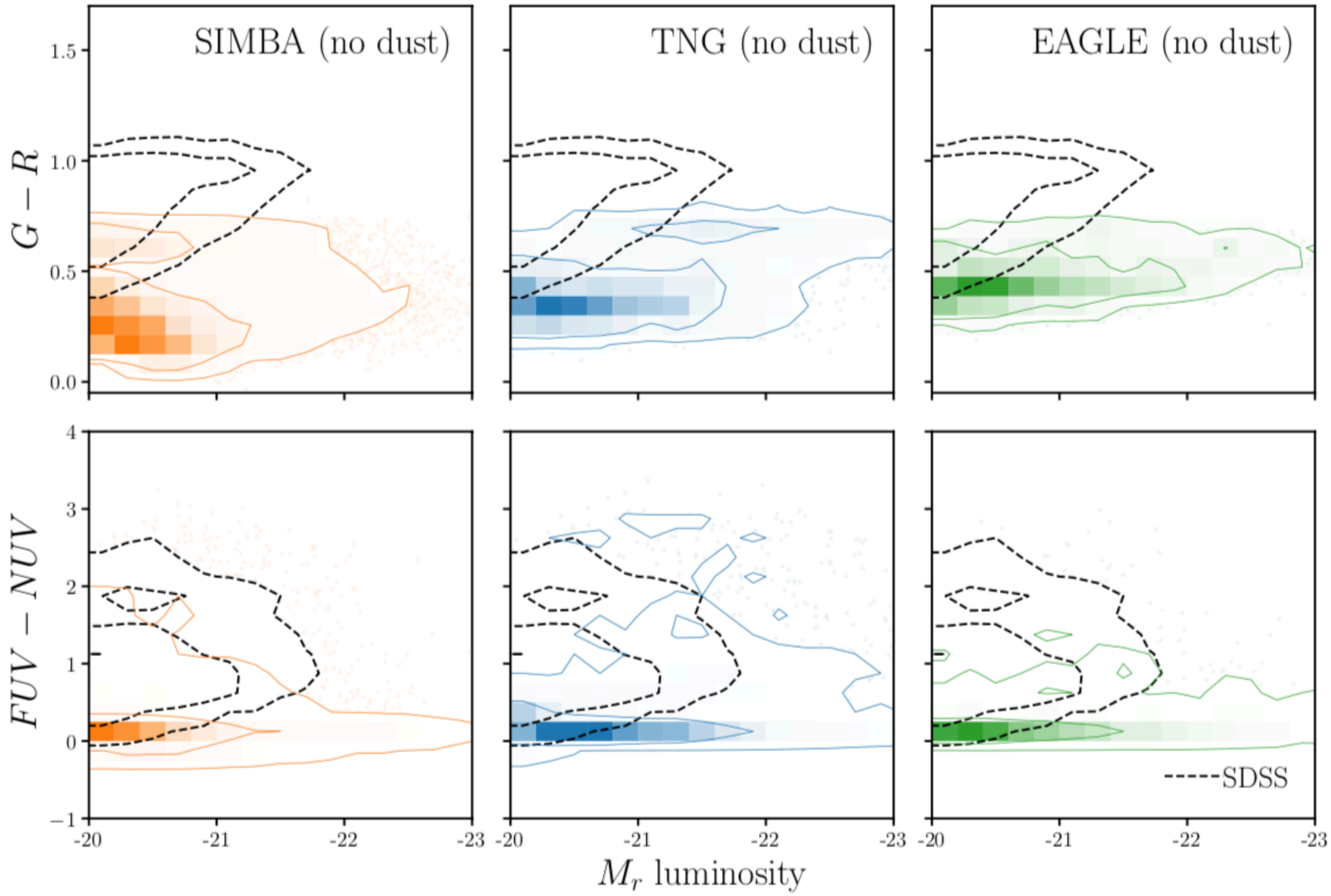
$\hat{M}_*$, $\widehat{\mathrm{SFR}}$, *etc* derived
from $H\alpha$, D_n4000, *etc*

Build Synthetic Galaxy Spectra and Photometry

- FSPS: Flexible Stellar Population Synthesis (Conroy+09, Conroy&Gunn2010, Conroy+2014)
- Use identical input from all simulations, and consistent assumptions
- Include noise and limits consistent with observational surveys to compare to
- Remeasure colors and spectral indices and compare one-to-one to observations

TKS & the IQ-collaboratory in prep.

FORWARD MODELING: A DUST EMPIRICAL MODEL



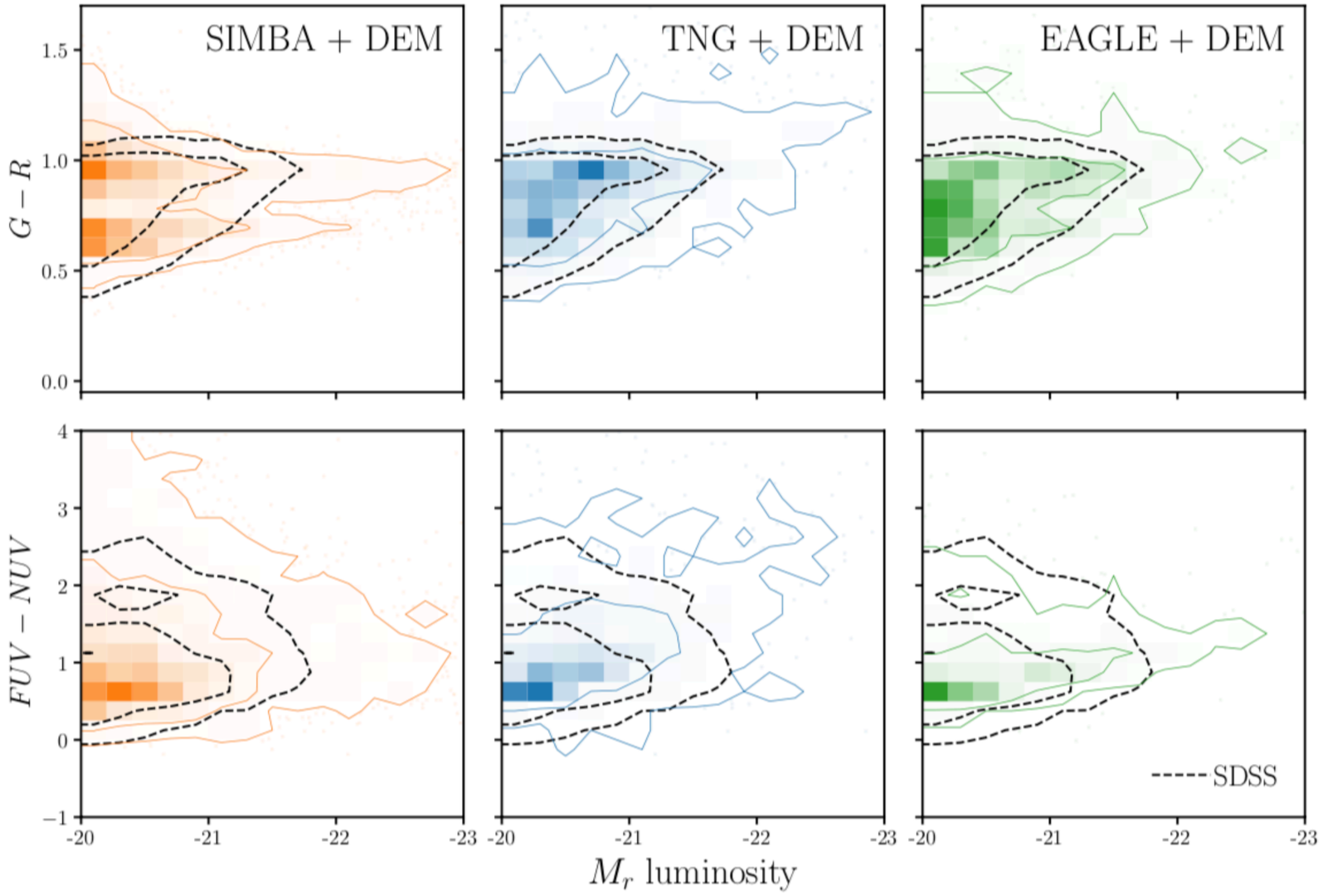
Dust is crucial but very challenging.

(Jonsson+2006, Rocha+2008, Baes+2011, Natale+2015, Hayward+2015, Hou+2017, Rodriguex-Gomez+2019, Nelson+2019, Trayford+2020, Salim+2020, Narayanan+2020, Baes+2020, and more)

We use color-magnitude diagrams to infer an empirical dust model, and then can learn the required dust-gas-metallicity relations required in the simulations by the inferred model.

Hahn, TKS & the IQ-collaboratory in prep.

FORWARD MODELING: A DUST EMPIRICAL MODEL



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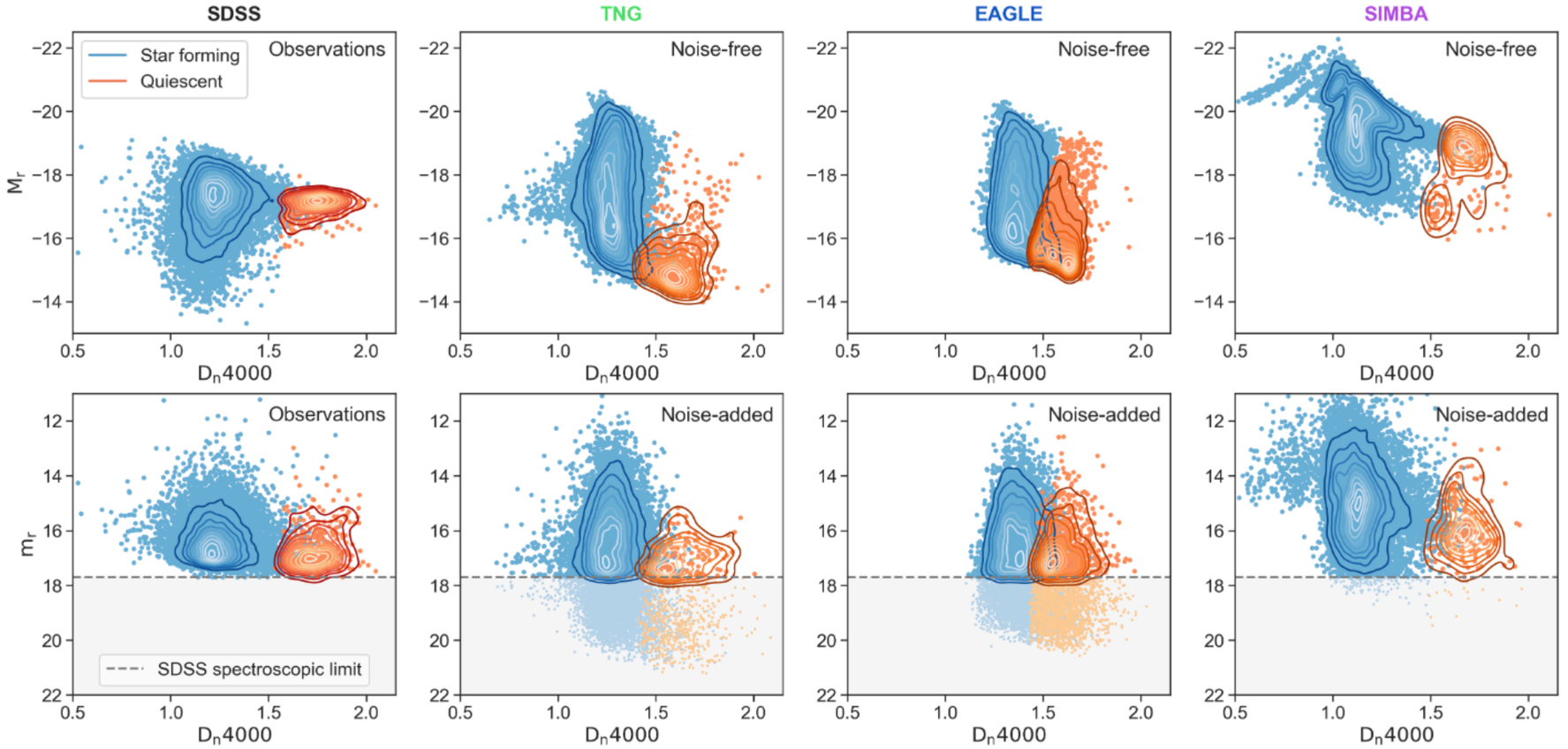
COMPARING TO OBSERVATIONS: THE LOW-MASS QUIESCENT FRACTION

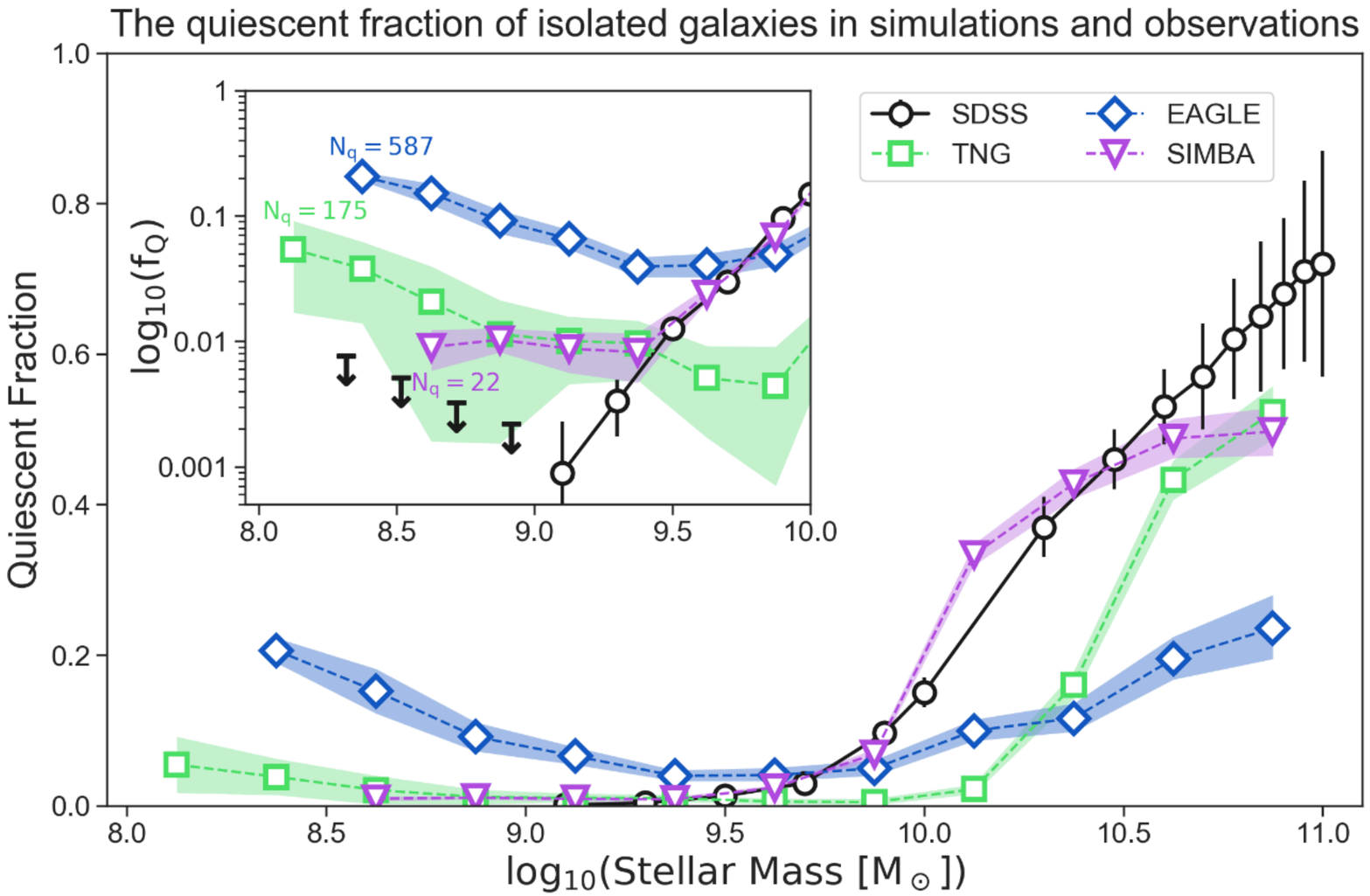


We build full synthetic SDSS spectra, including finite signal-to-noise, incompleteness, and limited position and velocity information.

We follow Geha+2012 in in selecting low-mass quiescent galaxies based on Dn4000 and HaEW, and compare.

Dickey, TKS & the IQ-collaboratory in prep.

COMPARING TO OBSERVATIONS: THE LOW-MASS QUIESCENT FRACTION



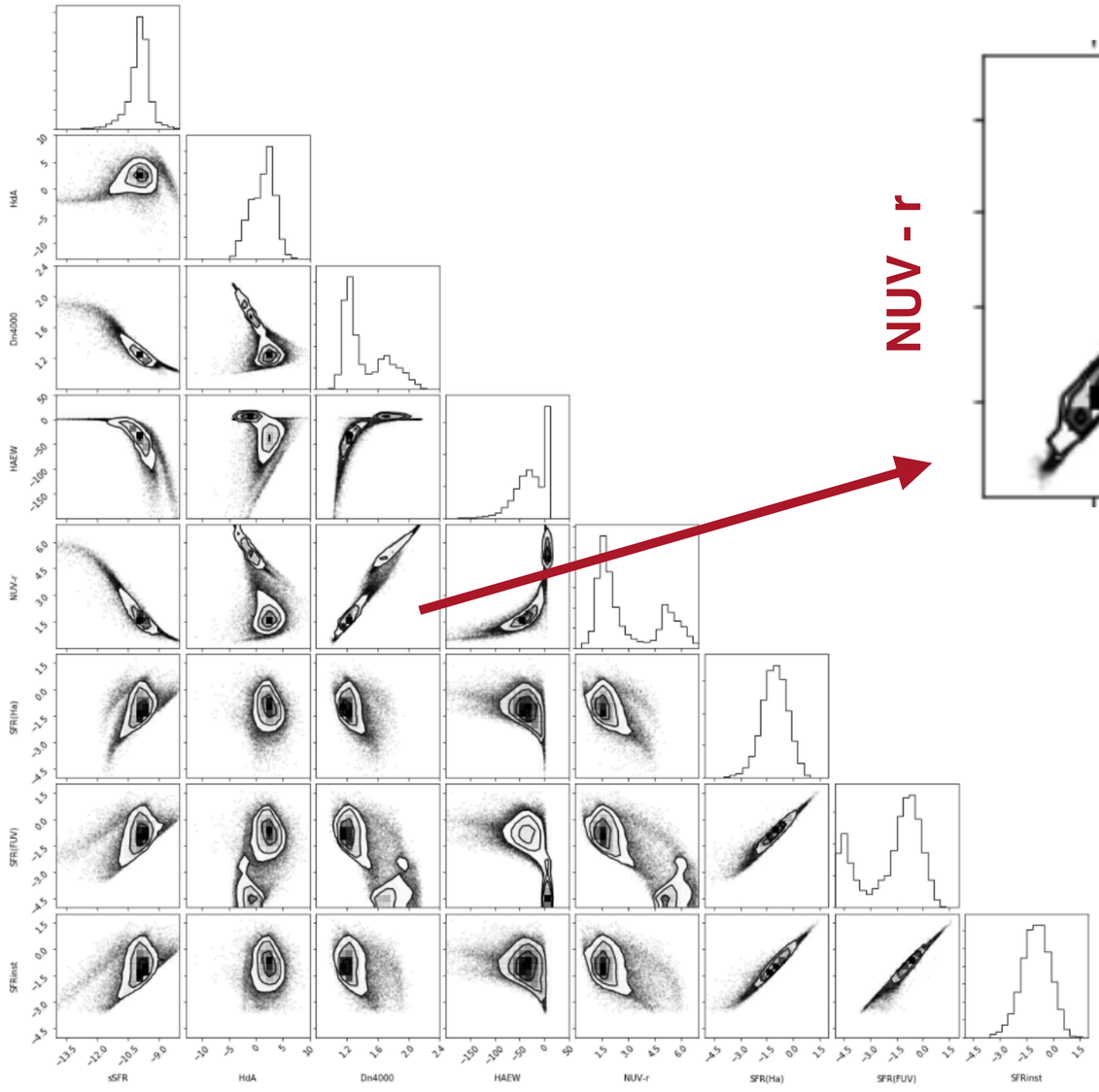
We follow Geha+2012 (*black*) in in selecting low-mass quiescent galaxies based on Dn4000 and HaEW, and compare.

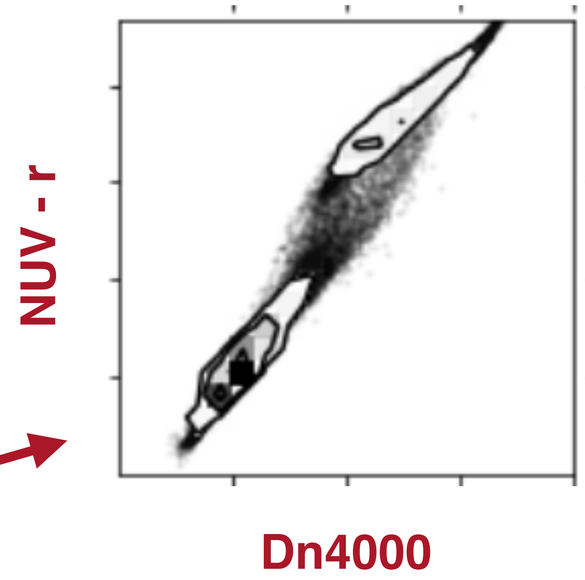
All simulations have too many low-mass quiescent galaxies, but in varying numbers. Resolution effects are important, but appear not to be the full story.

See also Trayford+2015,2017; Donnari+2019, 2020a,b

Dickey, TKS & the IQ-collaboratory in prep.
On arXiv next week

TRACING QUIESCENCE: COMPARING SF AND Q INDICATORS





Now we have this amazing space to explore:

Multi-dimensional in tracers, in theoretical models, in galaxies masses and other properties, in dust models, ….

TKS & the IQ-collaboratory in prep.

CONCLUSIONS

- The **IQ** (Isolated and Quiescent galaxies) **collaboratory** aims to better understand and constrain the quenching processes. However, we first need to do **apples-to-apples** comparisons between simulations and observations and define quiescence consistently.
- At z=0 the star-forming sequence is comparable between simulations but shows a factor 5 discrepancy in normalization *(Hahn+2019)*. At higher redshifts the star-forming sequence in simulations seems to agree much better, and agree with observations. Quiescent fractions however, are diverse *(Choi+in prep.)*.
- We build synthetic galaxy spectra to compare "observations" for all galaxies, and remeasure spectral indices, lines, bands, and derived parameters. **Dust** modeling is **crucial** and different dust models can change results for different simulations *(Starkenburg+in prep.)*. We are inferring a **dust empirical model** *(Hahn+in prep.)*.
- When fully forward modeling the SDSS spectroscopic survey, low-mass galaxy quiescent fractions in simulations tend to be higher than observed (Geha+2012). Differences between simulations may be connected to diverse star formation histories *(Dickey+in prep.)*.