THE POPULATIONS OF STAR FORMING AND QUENCHED GALAXIES

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The goal:
Compare isolated and quenched galaxies between a large set of simulated and observational samples to learn about the quenching processes.

The problem:
How do we compare simulated and observed galaxies on equal footing?

What is quenching?
Quenched, quiescent, passive, gas-poor, gas-free, red and dead, red sequence, early type, evolved, ... 

Definitions based on: color-mass, color-color, SSFR cut, Dn4000, emission lines, distance from the galaxy star formation sequence (Fitted how?)
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THE IQ (ISOLATED AND QUENCHED GALAXIES) COLLABORATORY

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THE IQ (ISOLATED AND QUENCHED GALAXIES) COLLABORATORY

Compare isolated and quenched galaxies between simulated and observational samples to learn about the quenching processes

- Observations: SDSS volume limited sample (Tinker+2011), SDSS isolated dwarf galaxy sample (Geha+2012, Dickey+ in prep.)
- Simulations: Illustris (Vogelsberger+2014; Genel+2014), EAGLE (Schaye+2015; Crain+2015), MUFASA (Dave+2016), Santa Cruz semi-analytical model (Somerville+2015), High mass zoom simulations (Choi+2017), Low mass zoom simulations (Munshi+2017, Brooks+)
OTHER PROJECTS IN THE PIPELINE

QUENCHING AT HIGHER REDSHIFTS
Led by Ena Choi (Columbia)

GAS IN STAR-FORMING AND QUENCHED GALAXIES
Led by Andrew Emerick (Columbia)
WHAT IS QUENCHING?

- Find a way to fit the SFR-Mstar plane in a uniform way, and identify the populations of galaxies in that plane, without needing any cuts or additional preparation of any dataset.
- Build mock galaxy spectra for all simulated galaxies, also in a uniform way, and measure spectral lines, indices, bands, and derived parameters.
- Compare quenching (and therefore star formation) indicators.
There is a well defined SFMS over the full mass range for all simulations (see also Genel+2014, Somerville & Dave 2014, Furlong+2015, Sparre+2015, Schaye+2015, Dave+2016, Bluck+2016, ...)

Need to consider resolution effects (red lines: forming 1 star particle in 100 Myr)

Hahn, Starkenburg, and IQ-collaboratory in prep.
FITTING THE STAR FORMATION SEQUENCE

- Gaussian mixture model fit in (independent) bins of stellar mass -> flexible and data-driven
- 2-3 components per bin are the optimal solution almost everywhere

Hahn, Starkenburg, and IQ-collaboratory in prep.
There is a low-SFR component at almost all masses
There are sometimes transitioning, and sometimes high-SFR components

Hahn, Starkenburg, and IQ-collaboratory in prep.
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FITTING THE STAR FORMATION SEQUENCE

Very similar slope across all simulations, but also almost order of magnitude disagreement over the whole stellar mass range. This is in some disagreement with earlier results (Genel+2014, Somerville & Dave 2014, Furlong+2015, Sparre+2015, Schaye+2015, Dave+2016, Bluck+2016, ...)

Hahn, Starkenburg, and IQ-collaboratory in prep.
There is a low-SFR component at almost all masses
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Hahn, Starkenburg, and IQ-collaboratory in prep.
BUILDING MOCK GALAXY SPECTRA

- set assumptions such that all simulated galaxies are treated equally
Fitting the Star Formation Sequence

- SFR measurement based on Hα (top) or NUV (bottom) luminosity
- resolution effect are particularly strong for Hα (<10 Myr)

Starkenburg, Dickey, Hahn, and IQ-collaboratory in prep.
COMPARING QUIESCENT DEFINITIONS AND FRACTIONS

Illustris: SSFR cut defines less galaxies as quiescent than a dSFS cut
EAGLE: SSFR cut defines more galaxies as quiescent than a dSFS cut

- opposite trends due to different location of the Star Formation Sequence
- dependence on stellar mass, but this dependency also differs with simulation

Starkenburg, Hahn, and IQ-collaboratory in prep.
CONCLUSIONS

- The IQ (Isolated and Quenched galaxies) collaboratory aims to better understand and constrain the quenching processes. However, we first need to understand how to define quenching consistently between all simulations and observations.

- Gaussian Mixture Modeling is a flexible and data-driven approach to fit the SFMS. The amplitude of the SFMS differs by almost 1 dex between simulations. Consistent subpopulations are found for the hydro simulations, but differences with the SAM.

- We build mock galaxy spectra to compare “observations” for all galaxies, and remeasure spectral indices, lines, bands, and derived parameters. Different star formation and quenching indicators result in very different SFMS fits as well as quenched populations and fractions.
As is denoted in the caption of that figure “some of the modelers have applied a cut to select star forming galaxies, and some have not.”

We have already made the comparison a bit more equal by in all cases selecting as Star Forming sSFR > -11 Gyr^-1, and always showing the median.

The decision on how to plot the star formation sequence depends on the choices made in the simulations papers (taking the same selection if sSFR is show instead of SFR):

- Illustris: Genel+2014, Sparre+2015,
- EAGLE: Schaye+2015,
- the best match to the others for MUFASA (Dave+2016 show results for both the star-forming and all galaxies) and the SCSAM. Both MUFASA and the current version of the SCSAM were not in Fig. 5 of Somerville & Dave 2014.
Similar figures to the previous slide but now plotting medians for the same selection of galaxies for all simulations.